Geoarchaeological Study on Rock Art Sites, With Special Emphasis on Gabel-El-Silsilah and Wadi Hammamat

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Abstract

This paper describes the main types of deterioration observed in rock art sites in Egypt. The damage is due to structural and environmental factors. Owing to increasing damage from environmental factors on rock art sites, it seems necessary to discuss some action for the introduction of conservation in Egypt. The chemical and mineralogical composition and the structural and physical characteristics of the rock art are given. The various kinds of damage on the monuments, both natural and anthropogenic, are characterized. The main purpose of this investigation is to study effect of weathering on the chemical and mineralogical composition of rock art. Investigations method revealed the mineralogical, petrographic, physical and mechanical properties and the durability of these sites. These investigations based on various analytical techniques, including optical and electron microscopy; x-ray dispersive analysis. A strategy for making better conservation plans for rock art sites was suggested.

Introduction :

Rock art represents some of the outstanding cultural properties in the world, but it is also among the most vulnerable to destruction. This unique Art is commonly subjecting to deterioration due to several natural factors, which are hard to control, because it can not be isolated from the rock mass. It is especially vulnerable to damage by man-made deterioration. Moreover art rock seems particular to invite vandalism by visitors who wish to leave a personal record on the rock. The successful protection of rock art sites requires an ability to design comprehensive management policies that promote public appreciation of the value of the sites. Hence, intervention on the rock surface is only one element in a broad range of options for long-term management and monitoring.

Stones and carvings are usually damaged, and this action is considered to be common to these findings. A part of this damage is caused mainly by human actions as well as the other environmental stresses, Air temperature action in the surface, mineral transformations, biological decomposition (Principally by mosses and lichens), structural damage and others.

Materials & Techniques :

The present study tries to describe the state of the rock art sites in Egypt such as the prehistoric paintings at Kurkur Oasis and rock carvings in Aswan. Siani and the Red Sea. As well as, it tries to provide an addition to the preceding researches. The problems concerning the conservation and evaluation of stone structures are examined carefully. There are some suggestions that call for successive improvements of the actual state of carvings in rocks. This comes to light through systematic field surveys of ancient sites, by the researcher. Egypt, as a great place of history, has a lot of ancient archaeological sites that are rich with inscriptions. The most Egyptian art rock carvings are inscribed in granite, sandstone, metagreywacke, breccia, and limestone. The oldest inscriptions in Egypt date back to 15,000 B.C. They are mainly belonging to the pre-historical, Pharaonic, Roman ages Pl. (1). As a result of the tremendous environmental forces, erosion, extremes of temperature, and the action of wind with rain and flood as in the Red Sea, the damage is confined to the stone relief, and the color of rocks seriously change in an obvious way. The mineral grains vary from very small to very large ones, almost with varying porosity. The mixtures that are not in harmony are common and this always leads to special problems. In general, it is clear that the concentrations of quartz and feldspar are very high. These different kinds of rock have a texture that gives the stone particular properties. The rock carvings have been done mainly on polished surfaces, which are often very smooth, but they have deep cracks. In other cases some carvings have been done directly on the bedrock.

The investigations based on various analytical techniques, including morphological, petrographical and mineralogical characteristics. The optical study was carried on thin sections by means of polarizing light microscope and scanning electron microscope. on external deteriorated surfaces. Samples taken from damage surfaces collected from rock art sites have been examined by x-ray Flourescence and Energy Dispersive x-ray analysis.

The evaluation of the structural condition of rock art sites in Egypt was made by systematic structural survey of these sites for careful description of factors which may affect the stability conditions of rock art.

Results & Discussion :

The present study will discuss the carvings in each archaeological sites. The carvings techniques of the rock art in Egypt can be classified into different groups according to the nature of carvings and the degree of damage. Also, the durability cases can be also described in detail as follows :

(a) Carvings and painting direct in bedrock (Pl. 1).
(b) Carved stones of granite or other igneous rock species (Pl. 2).
(c) Carved stones of sandstone and limestone (Pl. 3).
(d) Carved stones of meta sediments e.g. metagreywake (Fig. 3, 4).

Rock carvings are constantly exposed to what is known as the natural decomposition, wind, rain, salt, temperature stresses, flood plain, mineral transformations, biological decomposition and other environmental factors. So, the selection of the products and materials has been governed by current knowledge in the field of preservation and restoration yet, it is clear that great part of these efforts do not meet the requirements.

Cement products, with different additive react in a way that damages the stone. For example cement with thermosetting resins move in away that differs from that in stone leading to enclose moisture. Another modern problem is vandalism. Graffiti are spreading like an epidemic, as also is the interest among amateur researchers in taking casts of the carved surfaces (Anderson, 1986). Faulty restoration and wrong treatment as well as the wrong methods of cleaning and inappropriate paint, for touching up figures and text can in the long run lead to increased damage.

(a) Carvings in the Bedrock :

These carvings suffer severely three types of weathering. The first is the physical weathering in which temperature, stress, frost damage, and wind action play the major role in their deterioration. The second type is the chemical weathering through which the feldspar minerals transform into clay minerals. Water that penetrates through the rock cracks is prerequisite for the chemical process. This in the long run, leads to leaching out of material with new weathering factors in consequence. The third is the biological attack such as plants, algae and lichens, which lead slowly to the destruction of minerals. Besides contributing to the change in the moisture content, the plants produce some organic acids, which dissolve certain minerals. They also have the ability to grow into cavities and causes cracking as well as they lift small parts of the stone by swelling. (Pl. 1, Figs. 3, 4) show examples of carvings directly in bed rock.

(b) Carvings in Granite and Other Igneous Species :

The ancient Egyptians carved a lot of rock inscriptions on granite such as those, which are on the island of Siheyl. They are about 200 rock inscriptions on granite.

A few kilometers from Aswan, there is the first cataract of the Nile. Travelers, soldiers, traders, all left traces of their passage in the dozens and dozens of graffiti which cover the black granite on Siheyl. The inscriptions on the island range from the 5th dynasty to the Ptolemaic period as in (Pl. 1, Figs. 3, 4).

The most important carving is the "stele of famine" of the Ptolemaic period in the second cataract region, and during the international Rescue campaign process at Abu Simbel (Philae and other sites), many rock inscriptions were recovered. They were moved from Philae to Igilkia to be re-erected (Soderbergh, 1989). One of those rock carvings is the rock carving of cattle (Pl. 1, Fig. 1).

In Sinai where the ancient mines of the Wadi Maghara were the first top exploited, there is the earliest rock inscriptions and relief dating back to Zonakht Djoser and Sekhemkhet (Baines & Malek, 1980) so, the earliest Egyptian inscription in Sinai is the rock carving of King Sekhemkhet (Pl. 1, Fig. 2).

Obelisks are considered one of the rock art types that are associated with heroic deeds during the different dynasties of ancient Egypt. Records were inscribed on their granite surface as hieroglyphs in their vertical rows about 1.5 inches deep (Pl. 2, Fig. 1). The history of these obelisks started as the time of Queen Hatchepsut of the 18th dynasty, her brother Thotmos III who had the center rows erased later Hatchepsut's name inscribed. Ramses II added the outer two rows on each face with his own name and his achievements. This present work tries to identify the durability that affects the granite obelisks in Egypt. So, it is clear that these obelisks suffer from chemical weathering. These obelisks suffer from physical and chemical weathering. The color of granite was changed to pale rose or gray while biotite was altered to pale yellowish brown (Pl. 2, Fig. 2). The surface layer was cracked and Flakes into Falls (Pl. 2, Fig. 2).

Barton (1916) observed a maximum disintegration rate of 1 cm in 2,000 years near the ground in Upper Egypt near the temples of Aswan, this is 0.005 mm per year. Knetsch (1960) pointed out that the continuously changing volume of magnesium and Sodium sulfate may cause bursting and Falking as a result of changing atmospheric conditions that alternately produce hydration and dehydration of the salts. Voute (1963) also described the damage to the granite of Aswan to soluble salts. The change of temperature in Egypt especially in the southern places affects these granite obelisks very much in a way that leads to a disintegration of grain inter growth forces and separation of some of these grains (Helmi, 1985).

The most important deterioration phenomena in granite are the exfoliation patterns. Granite crusts resulted from that exfoliation is friable when it is thin, while thick crusts is quite hard. Owing to the tremendous environmental factors by physical and chemical weathering (Pl. 2, Figs. 2, 3, 4).

Petrographic and Scanning Electron Microscope Studies :

The petrographic examination shows that granite consists essentially of quartz, feldspars, biotite with some secondary minerals such as hornblende, and iron oxides. As well as the formation of clay minerals as a result of feldspars and plagioclase. Gypsum is also found as an alteration product of granite, its formation is explained by the presence of Ca-ions from weathering of plagioclases.

K-feldspars are seen to be highly weathered to clay minerals (pl. 3, Fig.2), chlorite, iron oxides and very fine grained silica. These products occur in the form of silty and clayed materials and give rise to the dusty and cloudy appearance of the field Feldspars minerals along cleavage planes and fractures or in the form of patches (Pl. 3, Fig. 1). Cleavage planes and fractures of biotite and hornblende are filled and coated with these materials and appear as black color. Biotite weathering along cleavage plane gives rise to a parallel shape (Pl. 3, Fig. 1). Some hornblende and biotite crystals show the zonal structure where the internal core is more decomposed than the external periphery of the crystal. The decomposition of biotite and hornblende into iron oxides and hydroxides exceeds the individual minerals gives rise to the pigmentation of nearby minerals (Pl. 3, Fig. 3), as feldspars and quartz. These fractures inside the minerals act as channels through which the weathering products migrate and fill them with yellow limonite, red geothite and other silty materials.

Scanning electron microscope studies of granite samples have reveal a net of inter, intra and trans-granular fractures which may be taken as an index of the heavy deterioration of stone (Pl. 3, Figs. 5, 6). The internal kaolinizations of feldspars which lead to sericite formed product (Pl. 3, Fig. 5). Also, micropores and cracks obvious in a feldspar grain. SEM micrographs shows a long fissures inside the internal structure of stone (Pl. 3, Fig. 6). SEM reveals the expansion of biotite which partial alteration to biotite which leads the disintegration of stone. SEM (Pl. 3, Fig. 4) have revealed the formation of salts such as gypsum during the weathering of plagioclase. Traces of gypsum precipitate as rosette needles or fibrous crystals.

Energy dispersive analysis reveals that all deteriorated samples contain much lower amounts of silica. EDX shows high content of So_3

and CaO which is mainly due to the presence of gypsum in all granite samples. High chlorine which present in the studied samples is due to Halite.

(c) Carvings in Sandstone :

There are lots of inscriptions existing on the Nubian sandstone in the Kurkur Talh and in Al-Ewienaat oasis in the western desert. These inscriptions represent animal shapes such as lions, deers and giraffes, which belong to the prehistoric age (Pl. 4, Fig. 2).

In the second cataract area, in Aswan a group of blocks had been situated in new places at the time of the Nubian movements' rescue. These stones were cut off and moved to Aswan area to be conserved which represent a prehistoric rock carvings that have an elephant shape with later graffiti and hieroglyphic texts and (Pl. 4, Fig. 1), represents a rock carving from Gabel Suleiman. This inscription shows many events such as the slain enemies and the victory of King Djer (1st dynasty). In addition, and at Gabel El-Silsilah, some 40 km north of Aswan there are a lot of quarries that have been exploited by the Ancient Egyptians. Also, there are many rock inscriptions that date back to the 18th Dynasty until the Greco-Roman period.

In these sites, the sandstone are exposed to suffer from the physical weathering which affect the carvings of the surface. These sites are situated in desert places, therefore they are vulnerable to face the wide range of temperature. The rock carvings are affected badly in the sense that the high temperature draws the moisture out of the pores towards the surface and then the water would evaporate resulting in leaving salts on the surface. These salts play a dominant role in the disruption of its mineral constituents and the collapse of its physical structure. Moreover, the wind action may enhance this process where the wind temperature is in contact with the surface of the sandstone, which have different temperatures which affects the rock surface and many cause fracturing.

The atmospheric temperature and relative humidity with their diurnal and seasonal variations are considered as the principle causes of the physiochemical deterioration of the sites.

The petrographical examination of the deteriorated samples shows a highly degraded structure which is the cause of deterioration, (Pl. 4, Fig. 3). The weathering products of iron oxides may also occur as patches or disseminated within the matrix (Pl. 4, Fig. 4). The grains of sandstone are not intergrown but cemented by argilaceous matrix which give a stone a weak geotechnical properties (Pl. 4, Fig. 5). The scanning electron micrographs show the collapse of the internal structure of sandstone (Pl. 4, Fig. 6, 7). Also there are different cavities and cracks are present in these samples (Pl. 4, Fig. 6). SEM micrographs revealed also micropores inside the clay minerals and seriously deteriorated by lost their cohesion due to water interaction leading to the disintegration of sandstone (Pl. 4, Fig. 6). As a result, many new cavities originated inside the stone. SEM investigations show that the heavy concentration of crystalline salts mainly halite and gypsum inside the pores of the stone leading to spalling of sandstone (Pl. 4, Fig. 7).

1. Rock Art of Gabel El-Silsilah :

Gabel El-Silsilah is situated some 65 km north of Aswan The ancient name of the place, Kheny (or Khenu) at Gabel El-Silsilah steep sandstone cliffs play their role in narrowing the stream of the river Nile and forming a natural barrier to river traffic. (Baines and Malek, 1980). The local sandstone at Gabel El-Silsilah is characterized by fine quality. This sandstone could be shipped easily from the quarries on the river sides (Pl. 5, Fig. 3). These two factors brought the whole area into focus during the 18 Dynasty when sandstone became the common building material. The local quarries in this area, particularly on the east bank, were exploited from the 18 Dynasty until the Greco-Roman period (Pl. 5, Fig. 4).

On the western bank there exists the Great Spoes of Haremhab which is in fact a rock cut chapel. The chapel was originally dedicated by seven deities who were represented as statues seated in the niche at the back of the sanctuary (Pl. 5, Fig. 1). Among these statues one can find the local crocodile god Sobek and King Haremhab. South the Great spoes, there exist a lot of rock-cut shrines (chambers). These chambers function as memorials built in honor of soldiers who died in wars and were built by kings, (Pl. 5, Fig. 2). (Sethos I, Ramses II,

traces of decoration remain (Pl. 7, Fig. 2). Local erosion caused by the mechanical effect of water flow during the flood of the Nile river which covers this path and flows along the cliff. A detachment of façades caused by water erosion.

Rock art site consist mostly of quartz, arenite with feldspars and different cementing materials which affected by physical weathering causing fracturing of these mineral. The wind action on the surface of the sandstone affect the rock surface deformation and cause fracturing of the rocks (Pl. 7, Figs. 3, 4). Water weathering also affects the rock art. The surface water fill the intergrain pores may inter the small fractures within the grains, by thermal changes, it expands and causes the formation of new fracture which leads to the breakdown of quartz grains, especially the rain water. Water's flood before 1965 also acts upon cracks and fractures affecting the cementing material which leading to the weakness, fracturing of sandstone. The variations of air temperature and relative humidity, the salts show modifications in their crystalline structure (Pl. 6, Figs. 2, 3). Also, the dissolved salt when it reaches the surface, the water evaporated remaining the salt to crystallizes causing exfoliation and spalling of sandstone.

The sandstone samples suffer alteration and disintegration. Apparent alteration in color, loosening of friable sand grains and cementing materials. Salt weathering leads to spalling and cracking of sandstone. The petrographic studies reveal that Gabel El-Silsilah sandstones are characterized by a very broad variety of grain sizes (Pl. 8, Fig. 1). Cement are occasionally occurred as argilaceous, ferruginous or siliceous cements binding quartz grains. The plagioclases have been transformed extensively into small flakes of sericite. Feldspars alters to clay minerals (Pl. 8, Fig. 3). The destruction of quartz grains are also observed in thin section (Pl. 8, Fig. 3). Hematite and magnetite have changed into iron hydrate (Pl. 8, Fig. 4). The samples examined by scanning electron microscope show the physio-chemical changes in the rocks of this site. The collapse of internal structure of stone, destruction of quartz grains (Pl. 8, Fig. 5). A disintegration of the cement is cracking and fissures inside the internal structure of stone, (Pl. 8, Fig. 6). SEM studies have revealed micropores inside the clay minerals (Pl. 8, Fig. 7).

SEM (Pl. 8, Fig. 8) shows the fluffy and acicular salts presenting in the sandstone sample which cause severe damage to the physical structure of sandstone and the disintegration of mineral constituents. SEM reveals that sodium chloride, magnesium sulphates and sodium carbonate are the crystalline salts presenting within the pores of stone (Pl. 8, Fig. 9). On the other hand, cracks and fissures develop parallel to the exposed stone. The structural interlocking of sandstone grains (Pl. 8, Fig. 2) reveal a weak geotechnical properties of sandstone. The clay minerals found in all samples are highly deteriorated and distributed in the decayed layer of stone.

Energy dispersive analysis, EDX, of deteriorated samples reveals a high content of Na_2O and Cl. EDX of high alumina may be due to the clay minerals formed during weathering. The highest content of CaO is due to gypsum. Also So_3 presents which mainly due to sulphate minerals.

(d) Carved Stones of Metasediments (Rock Art of Wadi Hammamat) :

This case study deals with the art rock in Wadi-Hammamat and identify the decay factors that effect the inscriptions and stones in this area. It also deals with the following points :

a) Archaeological Aspects of the Site :

El-Hammamat Valley is in admist the road that joins the Nile Valley with the Red Sea coast from Qift to Quseir. The ancient Egyptians used this road since the oldest times in order to cross to the Red Sea coast or to reach it in order to cut out slate and basalt stones from which different utensils are made for ornamentation, amulets, statues, sarcophagus and sacrifice. All the missions and campaigns which came to this Valley left their inscriptions which record the time of their arrival and the purpose of their coming. The inscriptions record history in El-Hammamat Valley from the fourth dynasty till the fourth year in the reign of the Roman Caesar Tsar Maximums in (238).

In addition, there are some inscriptions, representing some animals and birds dating probably, back to prehistoric times. El-Hammamat valley was a road which led to Gasus valley, a port on the Red Sea coast, which was used during the Middle Kingdom. Inscription of Ramses II carved directly in greywacke (Pl. 1, Fig. 3). Also, there is a text that dates back to Amenemhat III (Pl. 1, Fig. 4). Also, there was a text that dates back to king Seb Hebt Ra Mentuhotep (the eleventh dynasty) recording the resumption of navigation in the Red Sea and Re-opening of El-Hammamat road. Also, there is a text dating back to king Mentuhotep the IV left by one of the campaigns recording the date of the second year of his rule (Moniet, 1912). This campaign came to cut out stones for a royal sarcophague and its lid. In addition, there is a text recording the arrival of a mission dating back to the 38th year in the rule of Snosirt I consisting of more than 17000 men who cut quarried out masses of stones for 60 statues for the Sphinx and other 150 statues (Goyon, 1957). One of the important documents found in the region of King Siti I, a papyrus paper kept in Toreino Museum and on which it is shown the oldest geographical picture in the world. In this papyrus paper, some mineral areas of gold were painted pictured in the region of El-Fawakhir, which lies at the end of El-Hammamat Valley. Also mountains and ways which lead to the mines and mineral areas are shown in this papyrus paper. There is along text of rock carvings in El-Hammamat valley which dates back to the third year in king Ramses IV period of rule recording 8000 men cutting out stones for buildings of his own. In the first year, he sent the high priest of Mont to this place and also sent in the second year to the same place some officials to estimate the necessary requirements for the process of cutting and to make a realistic planning. This shows that the tasks of quarries were going on according to a well-planned program. After the studies had been completed, he delegated, in the third year, the mission with the required numbers of men (Goyon, 1957).

b) Geological Aspects :

The Hammamat group includes a thick sequence of unmetamorphosed, clastic, immature to submature, coarse-medium-and fine-grained sediments of molasse facies (Akaad and Nowier, 1969-1980). Many models have been suggested for the origin, age, situation and conditions of sedimentation of the Hammamat sediment.

Akaad (1957) mentioned that the Igla formation which forms the base of the Hammamat sediments represent the clastic sediments formed by the erosion of moderately high relief volcanic rocks and pyroclastics. Akaad and El-Ramly (1958) stated that the Igla formation was derived from Dokhan Volcanic which appear to be rich in iron. The complete decomposition of these rocks produced the hematite that is now present in hematite-stained siltstone. Akaad and Nowier (1969) attributed the vertical variation in grain size to the variation in relief accompanying the organic movements. Samuel (1978) mentioned that the Igla formation which represents the base of the Hammamt sediments were deposited in local fresh water basins filling the low relief area after transportation by water, Grothaus et al., (1979) stated that the Hammamat group was formed by alluvial fan braided stream systems and include conglomerates, pebbly sandstone and siltstones. Moreover, the paleocurrents indicate that these rock were formed in an intermontane basin and they added that the variation in grain size is due to lateral variation. Soliman (1987) remarked that the Hammamt group at the type locality was subjected to a very low-grade regional metamorphism corresponding to the prehnite-pumpellite-quartz facies. El-Gaby (1983) and El-Gaby et al., (1984, 1988) believe that Dokhan volcanic and the Hammamat sediments are penecontemporaneous. The age of Hammamat clastic sediments is Late-Precambrain bracketed by 616 + 9 Ma (age of Dokhan volcanics at W. Soliman area) and 519 + 11 Ma (age of the intrusive Um Had Younger granite) Ries et al., 1983).

The Hammamat sediments at the type locality (W. Hammamat) can be treated as two different metamorphic zones, viz., chlorite and biotite zones. The rocks constituting the chlorite zone are more abundant than those representing the biotic zone are. Accordingly, the petrographic description of the hammamat sediments will be treated as follows :

I. Chlorite Zone :

In the chlorite zone, the Hammamat sediments are characterized by the presence of chlorite, sercite, muscovite, calcite and minor epidote. The clastic nature and the primary sedimentary structure such as ripple marks, laminations, graded bedding and rain drop prints are still preserved. Therefore, the rocks, include the following :

a) Laminated hematite-siltstones :

These rocks are red to purple in color, thinly laminated and characterized by poorly graded bedding and slumping structures. They are composed mainly of alternating silty and clay laminae, up to 3.8 mm and 1.8 mm, respectively. The silty laminae are composed of quartz, feldspar and subordiante reworked clay fragments in silty clay matrix composed of quartz, feldspar, chlorite, sericite, calcite and epidote (Pl. 9, Fig. 1). On the other hand, the clay laminae are dense turbid and comprise sericite, iron oxides, chlorite and minor quartz and feldspar clastic grains.

b) Greywakes :

These rocks are grayish green in color. They are composed mainly of clastic, quartz, feldspars (plagioclase) of sand-size grains and lithic fragments, embedded in a matrix of fine-grained sand-size, composed mainly of quartz, feldspar, iron-reworked mudstone fragments, graphic granites (Pl. 9, Fig. 2) and andesites.

c) Calcareous greywackes :

These rocks are similar petrographically to the previously mentioned greywackes, but differ in the presence of the calcareous ground mass.

d) Coarse lithic arenites :

These rocks are greyish green to green color and show incipient foliation. They are composed chiefly of lithic fragments, quartz, and plagioclase grains, embedded in a matrix of medium-grained sand-size lithic fragments quartz, plagioclase, chlorite, sercite, epidote, and iron oxides. The lithic fragments comprise mudstones, slates, andesites and hematite-stained siltstone.

e) Foliated greywacke :

These rocks are green in color and foliated. They are composed mainly of lithic fragment, quartz and plagioclase clastic grains, muscovite, chlorite, epidote and iron oxides. The foliation is due to the parallel alignment of the lithic fragments, quartz plagioclase, muscovite and chlorite. The lithic fragments comprise hematite-stained silstone, andesites, granite, arenite, serpentinites, andesite tuffs and slate. These fragments are commonly oriented with their longer axes parallel to the foliation, while in a few samples, the fragments are randomly oriented.

Chlorite and muscovite exhibit bending flakes that are warped around the lithic fragments, which display the foliation quartz commonly shows wavy extinction it is fractured and forms lensoidal crystals that are commonly oriented parallel to the foliation. The fractures in quartz crystals are frequently filled with finely and crushed quartz, muscovite chlorite and sometimes calcite. Plagioclase is saussuritized and forms lensolidal crystals that conform with the foliation (Pl. 9, Fig. 4) and are dissected by microfaults twining lamellae.

II. Biotite Zone :

In this zone, the metamorphosed Hammamat sediments are characterized by the appearance of small biotite flakes, chlorite, muscovite and epidote. However, the clastic nature and crude primary sedimentary structure are still preserved. These rocks include the following rock varieties :

a) Hematite-stained arenites :

These rocks are greyish purple in color and massive. They are composed mainly of subangular quartz and feldspar clastic grains of sand-size and also lithic fragments, set in a silt-size matrix composed of muscovite, chlorite, biotite and epidote. The lithic fragments comprise siltstones charged with iron oxides particles mudstones, andesites, granites and slates. Muscovite occurs as scaly aggregates and small flakes, up to 1.8 mm long and commonly replacing the feldspar clastic grains. Chlorite commonly forms dense paste and small flakes, up to 1.2 mm long replacing chlorite and enclosing irregular patches from the latter. It is brown in color and strongly pleochroic from pale yellow to dark brown.

b) Hematite-stained pebbly arenites :

These rocks are petrographically similar to the previously mentioned hematite-stained arenites, but differ in containing noticeable amounts of pebbles which are composed of siltstone, andesites, hematite-stained siltstone and quartz clastic grains (Pl. 9, Fig. 3).

c) Hematite-stained siltstones :

These rocks resembles the hematite-stained arenites but differ in containing clastic grains of silt-size. Therefore, the term hematite-stained siltstone is used herein. The foliated varieties for the previously described rocks are recorded and petrographically similar to them, but they differ in the presence of foliation. From the previously mentioned petrographic description of the studied Hammamat sediments at W. Hammamat, it can be concluded that these sediments are metamorphosed under the greenschist facies.

Geomorphological & Environmental Phenomena :

The Red Sea Hills region of Egypt can be geomorphologically and geologically divided into three units : (1) The flat coastal plain with mainly Quaternary deposits, (2) The mountain chain of the Red Sea hills rising up to 1978 m a.s.l, which belongs mainly to the juvenile Pan-African basement and (3) The intercontinental plateau built up of crystalline Precambrian basement covered by sedimentary sequence. Several wadis and Furrows dissect the middle part (the mountain chain). Only few wadis have regular annual floods. which reach the Red Sea in the east or to the Hill in the West. Wadi Hammamat dissects the target area. The climate is arid in the study area with two major wind-directions are predominate. From October to May the wind blows from northeast, with occasional winter - rains between November and January. The studied area was subjected to heavy rains in 1925, 1960, 1979, 1987, 1991, 1994 and 1996 with an average amount of rain fall 40 – 300 10^6 mm^3, over the area. From June to September the main wind direction is form Southwest causing scarce summer-rains. This alternation between arid climate and rainy climate increase the role of the physical weathering and translocation processes of the rock art site.

Deterioration Phenomena :

The structural analysis of Hammamat site makes its possible to define the shape and size of the potentially unstable stones. The site is affected by a series of joint with clear signs of sliding movements, cracking and collapse of the mineral constituents of stones. The joint is effected by water percolation, with two very negative results; a progressive decrease of the shear strength along the joint surface and very dangerous consequences to the inscribed surfaces. A mechanical damage of inscriptions due to fall of rock slopes as result of vertical joint with small displacement (Pl. 10, Fig. 4). Also, the mechanical damage in the bed rocks art of inscription of Ramses II, due to the combination of bedding planes and different composition of various beds as well as the effect of joints (Pl. 10, Fig. 1). The vertical and inclined joints appeared in eroded surfaces. The differential movements of blocks are due to minor displacements occurred on joint planes and dislocate the beding surface (Pl. 12, Fig. 3). It is worth mentioning that the fall down of the stone blocks leads to the damage of inscriptions of Ramses IV carved on fine greywacke (Pl. 12, Fig. 2). The intersection of two namely vertical joint planes perpendicular to stratification and lithological variation in the greywacke bed helped the differential weathering to proceed (Pl. 12, Fig. 1). Also, (Pl. 13 Fig. 2) show the detachment and deterioration of rock art due to the intersection of three joints planes. The predominately three sets of joints, was observed in (Pl. 13, Fig. 2). Their intersection leads to the block appearance of the outcrop. The geotechnical collapse could cause the blocks to fall down. In same cases the nearly vertical cracks and joint planes showing minor displacements on block dislocation (Pl. 10, Fig. 2). Cracks and fissures causing damage of rock art due to rock lamination preserved in the lower parts. In the middle, dislocations along vertical joints are still active due to loading (Pl. 11, Fig. 4). In addition, the minor fault leads to the surficial disintegration and structural damage of inscription of Amenemhat III (Pl. 11, Fig. 2). The mechanical damage in the rock art of Ramses II (Pl. 11, Fig. 1) due to the combination of bedding planes and different composition of various beds along the joint surface. Insolation weathering as result of difference in temperature causing the fracturing of the minerals. The wind action may enhance this process and effect the rock surface and may cause fracturing. Joint surfaces and block edges are slightly rounded by the action of wind abrasion (Pl. 12, Fig. 4). Physical weathering causes deterioration and cracking in the rock face. This may be due to thermal variation and lithological heterogeneity (Pl. 10, Fig. 1). Water weathering also affects the rocks percolation of surface water leads to the changes of the color of the stones due to mineral transformation. Chemical weathering leads to fracturing of Hammamat stone by dissolution of calcite nodules (Pl. 10, Fig. 3) (Pl. 11, Fig. 3). Lithological heterogeneity and the presence of carbonate nodules cause chemical weathering act by surface water diagonal cracks between vertical joints which can lead to block separation (Pl. 10, Fig. 3). Irregular cracks with the changes in the color of rock art are due the physio-chemical weathering around the inscription of Xerxes I (Pl. 13, Fig. 1). The following physical characteristics were determined for Hammamt stone according to ISRM, 1981, standards tests :

Table (1) : Physical Characteristics of Hammamat Stones.

Type of stone	Bulck density gm/cm^3	Specific gravity	Compressive strength kg/cm^2	Tensile strength Kg/cm^2
metagreywacke	2.92	2.58	≥ 800	112
metasiltstone	2.80	2.40	1200	175

The Hammamat greywacke mainly consists of chlorite, epodite, quartz (Pl. 14, Fig. 1). In addition there are rock fragments of various kinds. The mechanical weathering displays a great role in the target area. However, the great differences between changes of temperature in summer and winter as well as between night and day. This role becomes more effective in this area, i.e. subjected to play phased deformation started with major folding, thrusting with transport direction towards the west for the hanging wall, left-lateral strike slip faults and normal faults. This play phase deformation could be seen mesoscopically as a pressure solution on the micro-fracture and joints. microscopically, the comparable study between less affected samples and the weathered samples indicate that the plagioclase crystal of the rock fragments cut almost exactly at right-angles to the x-crystallographic axis. On these micro-fractures the plagioclase was transformed to epidote, muscovite and serciite (Pl. 9. Fig. 4, 8). Most of the cleavage in studied thin sections was filled with calcite. The calcite was kinked and it shows high-strained field (Pl. 9, Fig. 1). The chlorite is the most predominant as alteration product of maffic minerals especially on the cleavage and microfractures. Also there is a serious deformation in fine grained matrix (Pl. 9, Fig. 5). Alteration starts with the deformation in fine grained matrix, fracturing and disintegration can be observed. The plagioclase show alteration on the minor cracks (Pl.

9, Fig. 8). All deteriorated samples show the deformed plagioclase. The lensoidal quartz aggregates indicates strong deformation (Pl. 9, Fig. 6). Also, there is a slightly deformed quartz imbedded in fine-grained matrix (Pl. 9, Fig. 4). The analysis of SEM images obtained from scanning electron microscope shows the destruction of mineral constituents of greywacke due to the physical weathering (Pl. 14, Fig. 1). SEM have revealed that quartz, plagioclase, feldspars and calcite are the mineral constituents of greywacke (Pl. 14, Fig. 8). The collapse of internal structure of stone with the deformation of quartz grains (Pl. 15, Fig. 4). (Pl. 15, Fig. 2) show the presence of clay mineral inside the stone. Cracks and fractures are found in the internal structure of stone (Pl. 14, Fig. 2). SEM results show the collapse of quartz and calcite mineral (Pl. 15, Fig. 2), and the destruction of quarts grains (Pl. 14, Fig. 3) and (Pl. 14, Fig. 1).

Physical deterioration in the mineral constituents of stone with different fractures inside the stone (Pl. 15, Fig. 4). Micrograph (Pl. 15, Figs. 7, 9) show the alteration of feldspars to clay minerals due to chemical changes. The leaching of calcite in a large extent of alterations as a function of the deterioration of greywacke. Micrograph (Pl. 15, Fig. 6) show the destroying of calcite crystals in different forms. The partial alteratons in feldspars minerals are also observed (Pl. 14, Fig. 9) (Pl. 15, Fig. 8). SEM provided that clay minerals are found in all samples.

The chemical analysis for nine samples from the unmetamorphosed greywacke of Hammamt sediments were selected for chemical analysis. The obtained data show that the analysed sediments are characterized by higher K_2O, Sio_2. P_2O_2 and lower Fe, Mgo, CaO and MnO. Al_2O_3 content generally varies within rather narrow limits in the analysed rocks. It is apparent from the data that the Na_2O content is variable in the analysed rocks. Since Na_2O is essentially high but shows wide variation. The rather high silica content and the presence of variable alumina indicate the presence of appreciable amounts of detrital quartz and clay minerals. This confirmed that the shelf sediments are normally mature sediments which are rich in clay minerals; they are frequently agree with microscopic investigations which shows that they are composed of ill-sorted greywackes and siltstone. Si the latter are sometimes calcareous.

Table (2) : Analysis of Greywacke Using X-ray Flourescence.

Samp. / Oxides.	1	2	3	4	5	6	7	8	9
SiO_2	65.00	69.00	64.38	68.75	56.75	53.75	53.25	51.12	64.08
TiO_2	0.68	0.52	0.84	0.33	1.14	1.70	0.83	0.31	0.75
Al_2O_3	13.80	13.33	13.55	15.48	13.48	13.82	15.33	12.30	14.82
FeO*	6.60	5.14	4.45	2.97	8.91	9.65	8.91	9.65	6.60
MgO	5.15	2.06	4.12	2.06	5.16	5.16	6.19	12.37	3.09
CaO	4.70	5.17	2.86	4.30	10.04	12.91	10.04	10.04	6.17
Ma_2O	2.66	3.50	0.91	4.77	3.66	1.66	2.96	1.88	3.63
K_2O	0.95	0.90	4.13	1.19	0.15	0.09	0.27	0.22	0.49
MnO	0.04	0.04	0.06	0.02	0.16	0.21	0.19	0.17	0.05
P_2O_5	0.13	0.17	0.10	0.17	0.095	0.087	0.065	0.065	0.10

Energy dispersive analysis show a loss of silica. High concentrations may be from ferromagnisum minerals. EDX analyses reveals significant quantities of silica with accessory aluminum, potassium, magnesium, calcium and sodium. This suggests that quartz, clay minerals, feldspars predominates. the loss ignition of calcium are due to the leaching of calcite.

Recommendations and Suggestions for Conservation :

The present study shows that the rock movements are as a result of outside forces, in some monumental areas, which differ according to the nature of these forces. Therefore, the researcher recommends the following categories :

1) Carrying out a comprehensive survey for the rock inscriptions in the different areas of Egypt.

2) Studying the factors of decay and the conservation problems of the art rock sites.

3) Studying the possibility of preserving first the most important parts of the rocks in situ.

4) Setting a scientific plan to restore the most mportant parts which have inscriptions that are threatened by different deterioration factors

and carrying out the necessary process of restoration conservation and after recording them scientifically as well as monumentally. This project is considered to be an important national one for showing some parts as being apart of preserving these inscriptions in safe (especially those inscriptions that exist in Al-Ewienaat oasis, the Western desert and the eastern one as what has been done for the Nubian Monuments Rescue.

5) Since there are still some cracks a d joints that make the process of restoration difficult, there should be a work plan to keep these inscriptions by cutting them off and by moving them to the national museums.

6) Again, the researcher recommends the use of suitable mortar that fits in with the rock nature, which has inscriptions.

It is important to ahve a cleaning product that does not lead to the damage of the stone. In addition, the mechanical cleaving should be done in away that makes no loss of material. Therefore, it is not easy task to get the most suitable cleaning product.

Again, the choice of the cleaning time during the year is very important. The cleaning must be so thorough the stone and loses nothing. One must remember that every procedure is in itself often a threat to the monument. The main point in cleaning is to choose an agent that provides protection. The researcher recommends not to use the methyl cellulose and methyl chloride as they will deteriorate carvings. Ammonia too, must be used with great caution owing to its great proneness to reaction.

Damage often caused by a kind of decohesion between mineral grains, sp itting in the surface and using unstable repair material.

Using polyester, cement and iron accelerates the problem of damage. The acrylic resin could be used to fasten and fix the small portions and Flakes. The large cavities must be injected with suitable acrylic resin such as paraloid B72.

More recently solutions of aliphatic epoxy resins have been applied to stone consolidation. Epoxy resin is available commercially as a 25% solution in a mixture of isopropanol and toluene. It was tested in laboratory and it proved to be success with Lazzarini, L 1993. In 1995, the researcher applied this product to Egyptian granite samples taken from the temple of Karnak and it gave good results.

References :

Akaad, M.K. (1957). Petrography structures and time relation of the Igla Formation, Egypt. J. Geol., I, 93-102.

Akaad, M.K. and El-Ramly, M.F. (1958). Seven new occurrence of Igla Formation in the Eastern Desert of Egypt. Geol. Survey. Egypt, Paper 3.

Akaad, M.K. and Nowier, A.M. (1969). Lithost atigraphy of the Hammamat Um-Seleimat district, Eastern Desert of Egypt. Nature, Lond., 223, 284-285.

Akaad, M.K. and Nowier, A.M. (1980). Geology and Lithostratigraphy of the Arabian Desert orogenic belt of Egypt between lat. 25 and 26 N. In : S.A. Tohoun (ed.), Evolution and Mineralization of the Arabian-Nubian shield, inst. Aool. Geol., King Abdulaziz Univ. Jeddah, Bull. 3, Pergamon press, Oxford, pp. 127-134.

Andersson, T. (1986). Preservation and Restoration of Rock carvings and Rune stone; Case studies in the conservation of stone and wall paintings, Bologno Congress, pp. 122-126.

Baines, J. and Malek, J. (1980). Atlas of Ancient Egypt, pp. 75-76.

Barton. D.C., (1916). The disintegration of granite in Egypt; Jour. Geol., v. 24 p. 382-393.

Caminos, R.A. and James, T.G. (1963). Gebel Es-Silsilah. London.

Clark, S. and Engelbach (1930). Ancient Egyptian Masonry, London.

El-Gaby, S. (1983). Architecture of the Egyptian basement complex. Proc. Fifth Intern. Conf. Basement Tectonics, Cairo (in press).

El-Gaby, S., El-Nady, O. and Khudeir, A.A. (1984). Tectonic evolution of the basement complex in the central Eastern Desert of Egypt. Geol. Rdsch., 37, 1019-1036.

El-Gaby, S., List, F.F. and Tehrani, R. (1988). Geology, evolution and metallogenesis of the Pan-African belt of Northeast Africa and adjacent areas. Earth evolution Sciences, Vieweg. Wiesbaden. pp. 17-68.

Georges G. (1957). Nouvelles Inscriptions Rupestees du Wadi Hammamat.

Goyat et Montet (1912). Hammamat, les Inscriptions Hieroglyphiques du Quadi Hammamat.

Grothaus, B., Eppler, D. and Ehrlich, R. (1979). Depositional environment and structural implication of the Hammamat Formation, Egypt, Ann. Geol. Surv. Egypt, 564-590.

Helemi, F.M. (1985). Deterioration of some Granite in Egypt, Vth inter. Cong. on Deterioration and Conservation of stone, Lousanne, pp. 421-426.

ISRM (1981). Rock Characterization Testing and Monitoring. ISRM Suggested Methods. Pergamon Press.

Knetsch, G. (1960). Arid weathering with special reference to both natural and artificial walls in Egypt : Zeitschr. f. Geomorphologie, Supplement Band I, Morphologie des. Versants, p. 190-205.

Lazzarini, L. (1993). The deterioration and treatment of Granitic columns, second course on stone material in monuments : Diagnosis and conservation, Crete, pp. 160-168.

Lucas, A. and Harris, J. (1962). Ancient Egyptian Materials and Industries, 4th ed. London.

Ries. A.C., Shackleton, R.M. Graham, RH. and Fitches, W.R. (1983). Pan-African structures, ophiolites and melange in the Eastern Desert of Egypt : at traverse at N.J. Geol. Soc. 26. London, 140 : 75-95; London.

Samuel, M.D. (1977). Lithological and sedimentological studies on the Red Beds of Wadi Igla, Easter, Desert, Egypt. Bull. Nat. Res. Center, 2, 287-297.

Soderberg, (1989). Abu Simbel (Philae and Other Sites), The International Rescue Campaign.

Voüt, G. (1963). Some geological aspects of the conservation project for the Philae temples in the Aswan area : Geol. Rundschau, V. 52/2, p. 665-675.

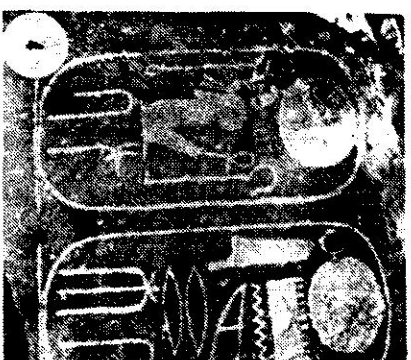
Pl. 1

Fig. (1) : Rock carving of cattle in Granite, Aswan.

Fig. (2) : A Relief of King Sekhemkhet in Wadi Maghara which is considered the earliest Egyptian inscriptions in Sinai.

Fig. (3) : Shows a text dates back to Amenemhat III carved in Greywacke.

Fig. (4) : Shows inscription of Ramses II carved directly in metasediments.



Pl. 2

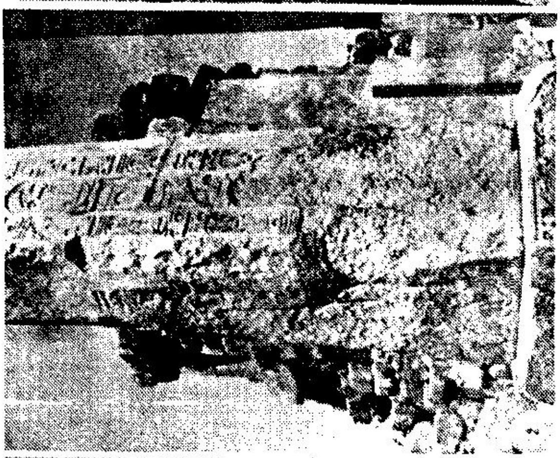
Fig. (1) : **Hatchepsut obslisk with inscriptions carved on Granitic stone, Karnak Temple.**

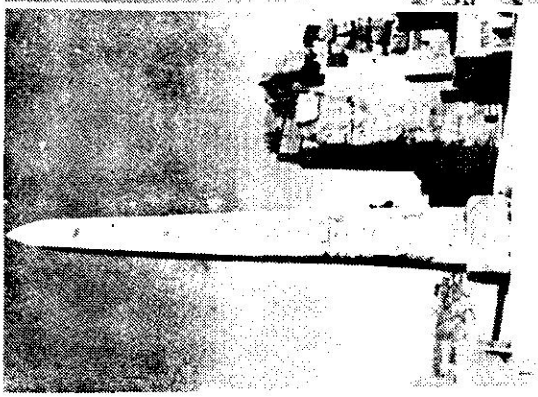
Fig. (2) : **Surficial exfoliation presenting in Hatshpsut Granitic obelisks at Karnak Temple.**

Fig. (3) : **Stele of famine carved in Granitic stone, Siheyl island, in Aswan.**

Fig. (4) : **Rock carving in Granite showing flaking of surface layer, Siheyl island, in Aswan.**

Fig. (5) : **Graffiti in Granitic stone showing the flaking of surface layer.**





Pl. 3

Fig. (1) : Biotite with brown color partly transformed to Chlorite.

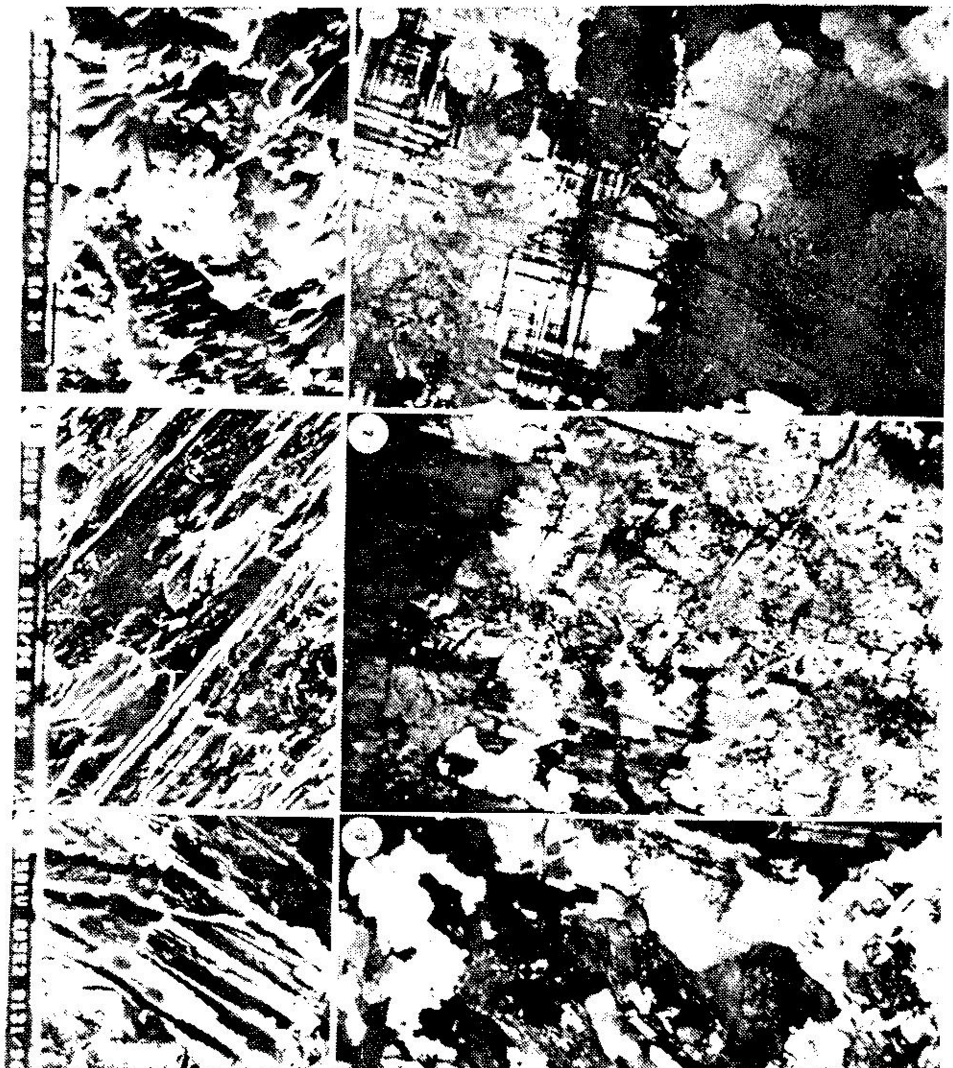
Fig. (2) : Orthoclase and Plagioclase transformed into Clay minerals.

Fig. (3) : Shows the decomposition of Biotite and Hornblende into Iron oxides and Hydroxides which gives rise to Pigmentation of nearby minerals.

Fig. (4) : Deformation of the most mineral constituents with Gypsum.

Fig. (5) : Shows chemical changes in feldspars and a serious cracking in the mineral constituents of Granite.

Fig. (6) : Microcracks inside the mineral constituents of the stone due to physiochemical deterioration.



Pl. 4

Fig. (1) : Shows a rock carving from Gabel Suleiman, Aswan.

Fig. (2) : Prehistoric inscription carved in Nubian Sandstone, Kurkur Talh, also it shows deterioration caused by physiochemical factors.

Fig. (3) : Shows a highly degraded structure of sandstone.

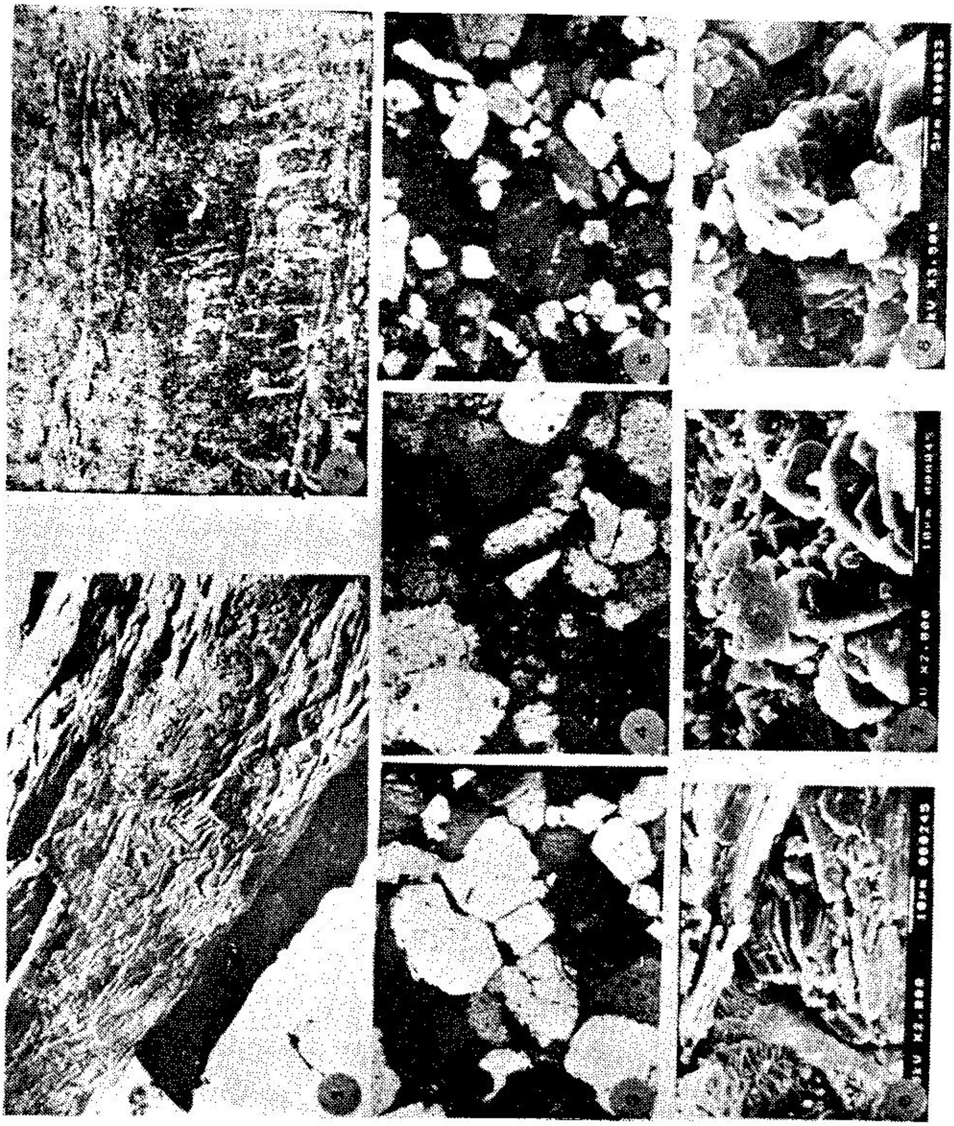
Fig. (4) : Shows the weathering products of Iron Oxides.

Fig. (5) : The grains of sandstone are not intergrown but Cemented by Argilaceous Matrix.

Fig. (6) : Shows microporse inside the Clay minerals of sandstone.

Fig. (7) : Shows the collapse of the internal structure of sandstone.

Fig. (8) : Shows the heavy concentration of Halite and Gypsum.



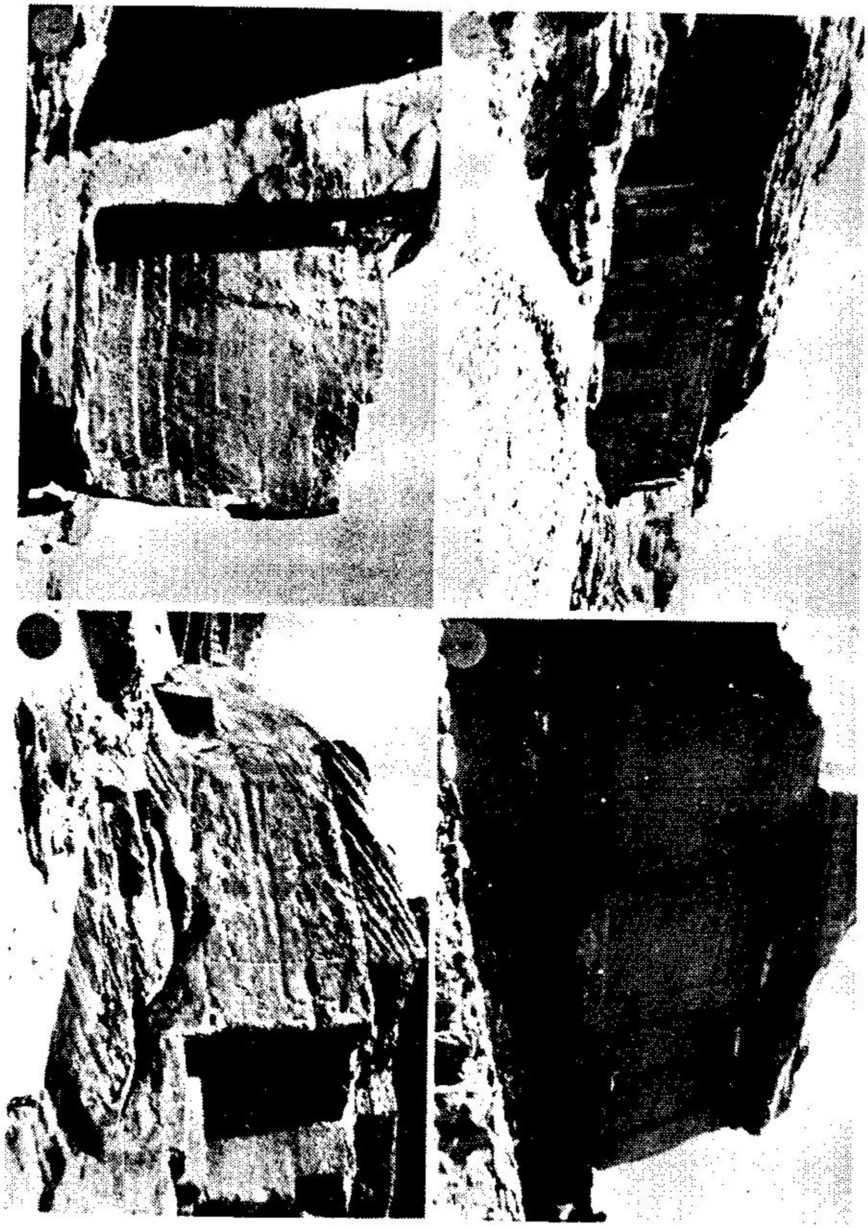
Pl. 5

Fig. (1) : Shows the facade of rock-cut chapel of Haremhab.

Fig. (2) : Shows two rock-cut shrines with two isncriptions, the first for Ramses II and the Second for Shashan I, XXII Dynasty.

Fig. (3) : Shows the ancient quarring method of sandstone in Gabel El-Silsilah that applied in Pharonic times.

Fig. (4) : Shows the inscription of quarrying signs from 18th and 19th Dynasties.

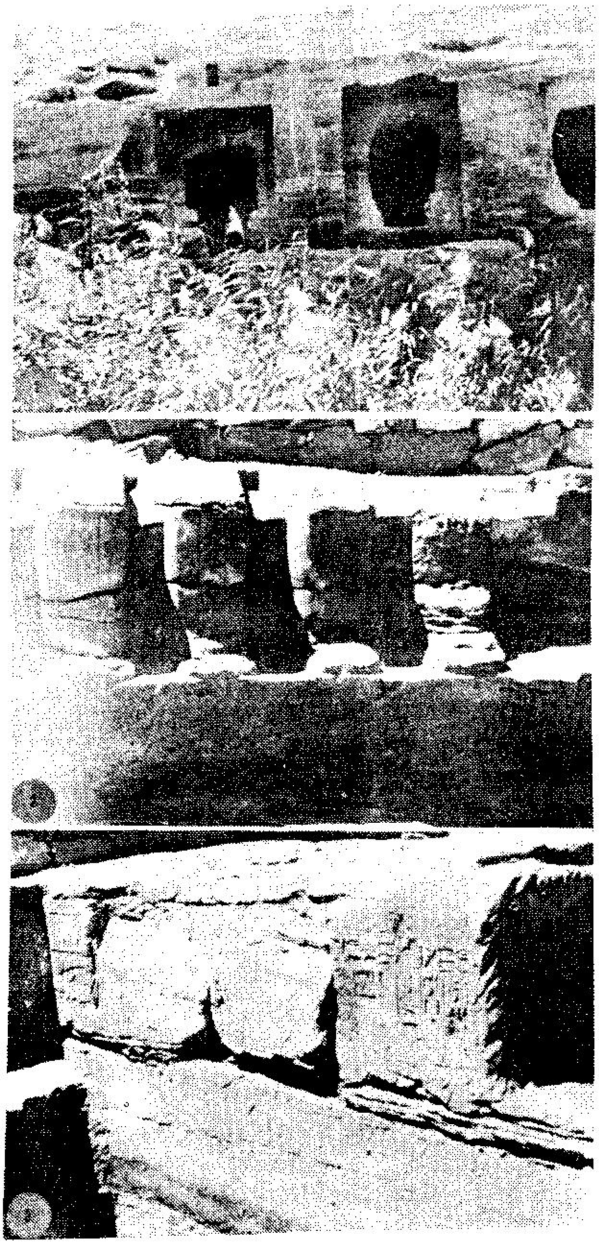


Pl. 6

Fig. (1) : The deterioration of stone of different chapels due to the effect of moisture which led to the dissolution of some mineral constituents such as Ferric oxides and Clay minerals with the destruction of chapel facades.

Fig. (2) : The lower parts seriously deteriorated by the accomulation of micro-organisms with salt efflorescences. Also badly preserved statues can be observed.

Fig. (3) : The deterioration of the mineral constituents of stone due to the effect of the Physio-Chemical Factors.



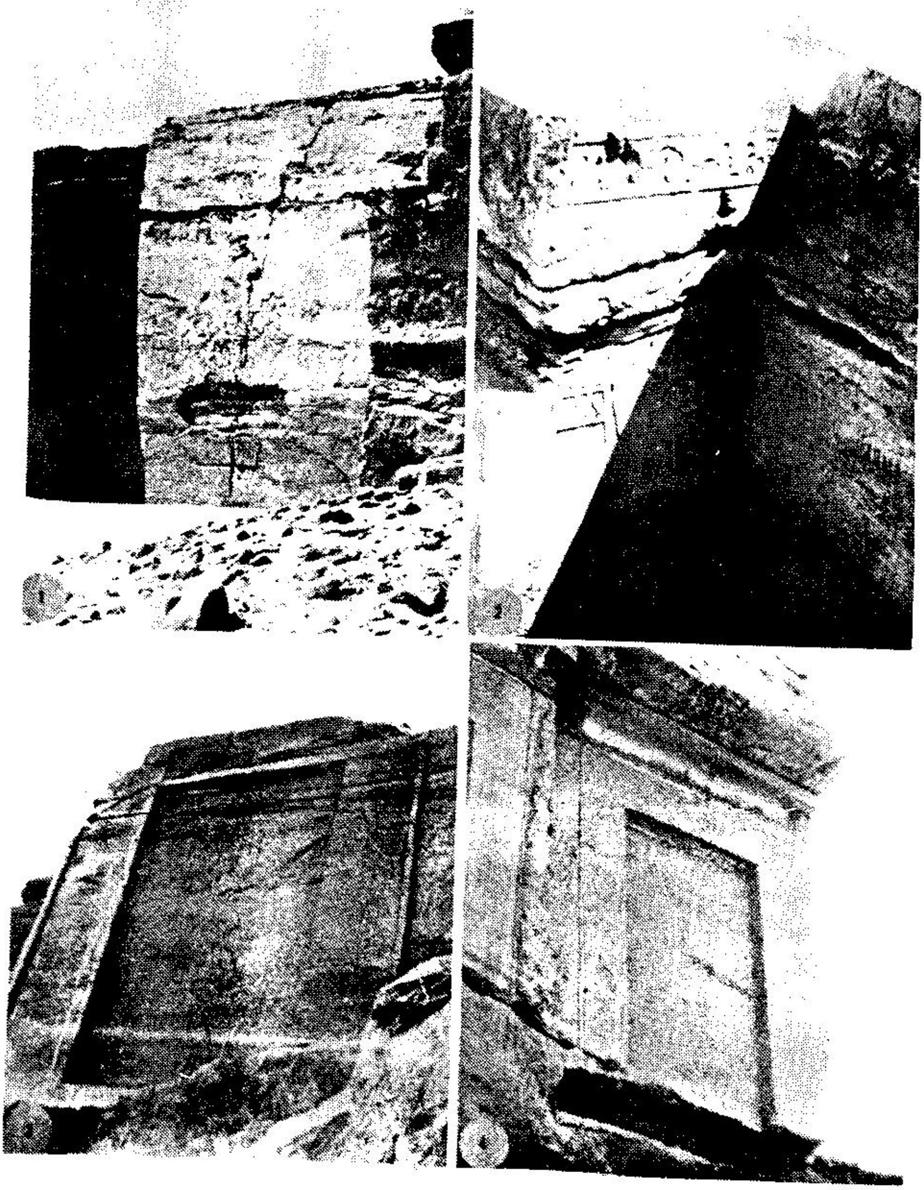
Pl. 7

Fig. (1) : Shows blistering of surface of stone due to chemical weathering.

Fig. (2) : Shows the serious effects of physio-chemical reaction in rock-cut chapel which resulting in a serious cracking of stones.

Fig. (3) : Shows the cracks in the Upper Parts of the Shrine and blistering of surface of stone as a result of weathering process, eastern bank of Nile, Silsilah.

Fig. (4) : Shows a aerious Damaging cracks in the bottom of Shashank Rock-cut Chapel as result of weathering effect.



Pl. 8

Fig. (1) : Shows a very broad variety of grain size.

Fig. (2) : Shows the Plagioclase which has been transformed into Clay minerals.

Fig. (3) : Shows the destruction of Quartz grains.

Fig. (4) : Shows the changes of Iron oxides to hydrated Iron.

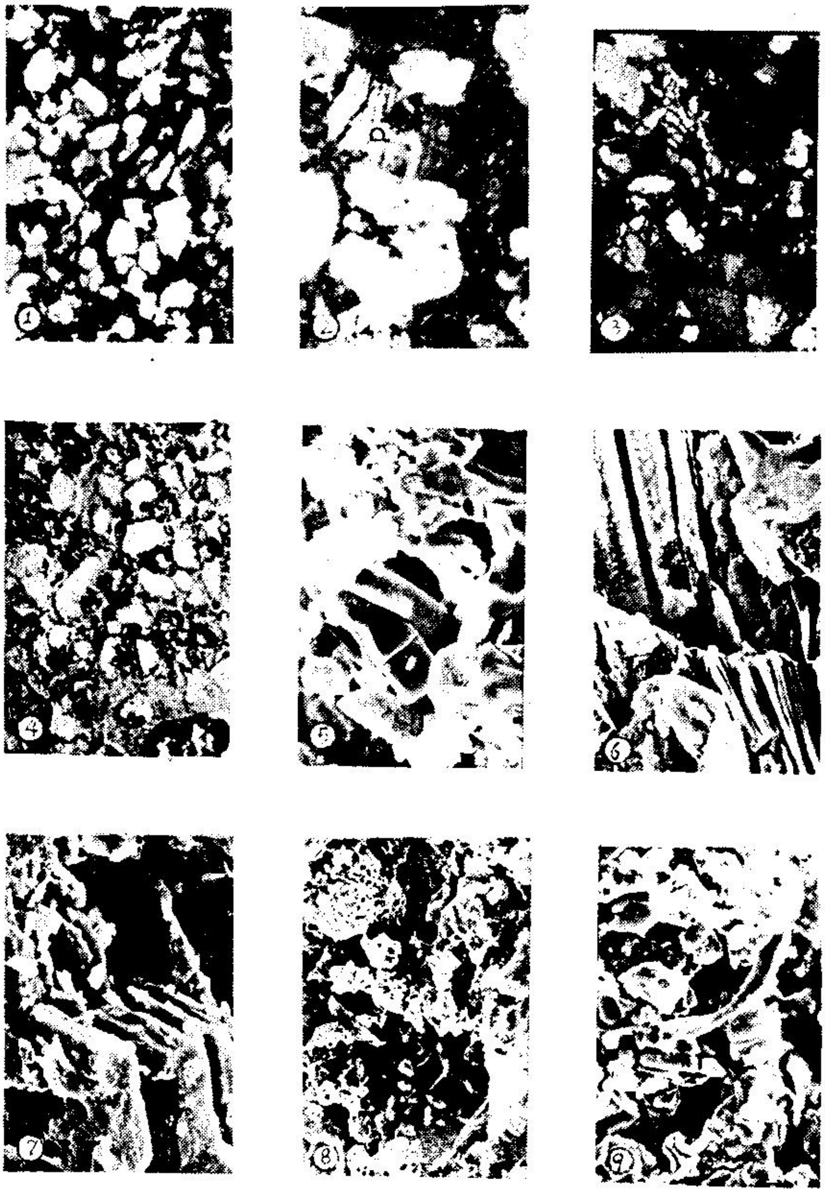
Fig. (5) : Shows the collapse of internal structure of stone.

Fig. (6) : Shows cracks and fissures inside the tnternal structure of stone.

Fig. (7) : Shows the microcracks inside the Clay minerals.

Fig. (8) : Shows the Fluffy and a cicular Salts.

Fig. (9) : Shows Halite and Gypsum crystals inside the Sandstone.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Pl. 9

Fig. (1) : Lapis Basanites with chlorite, epediote, Calcite, Feldspars and Iron Oxides.

Fig. (2) : Lithic Greywacke consists mainly of lithic fragment. Quartz and Feldspars crystals in fine frained matrix.

Fig. (3) : Andesite pebble in pebbly greywacke.

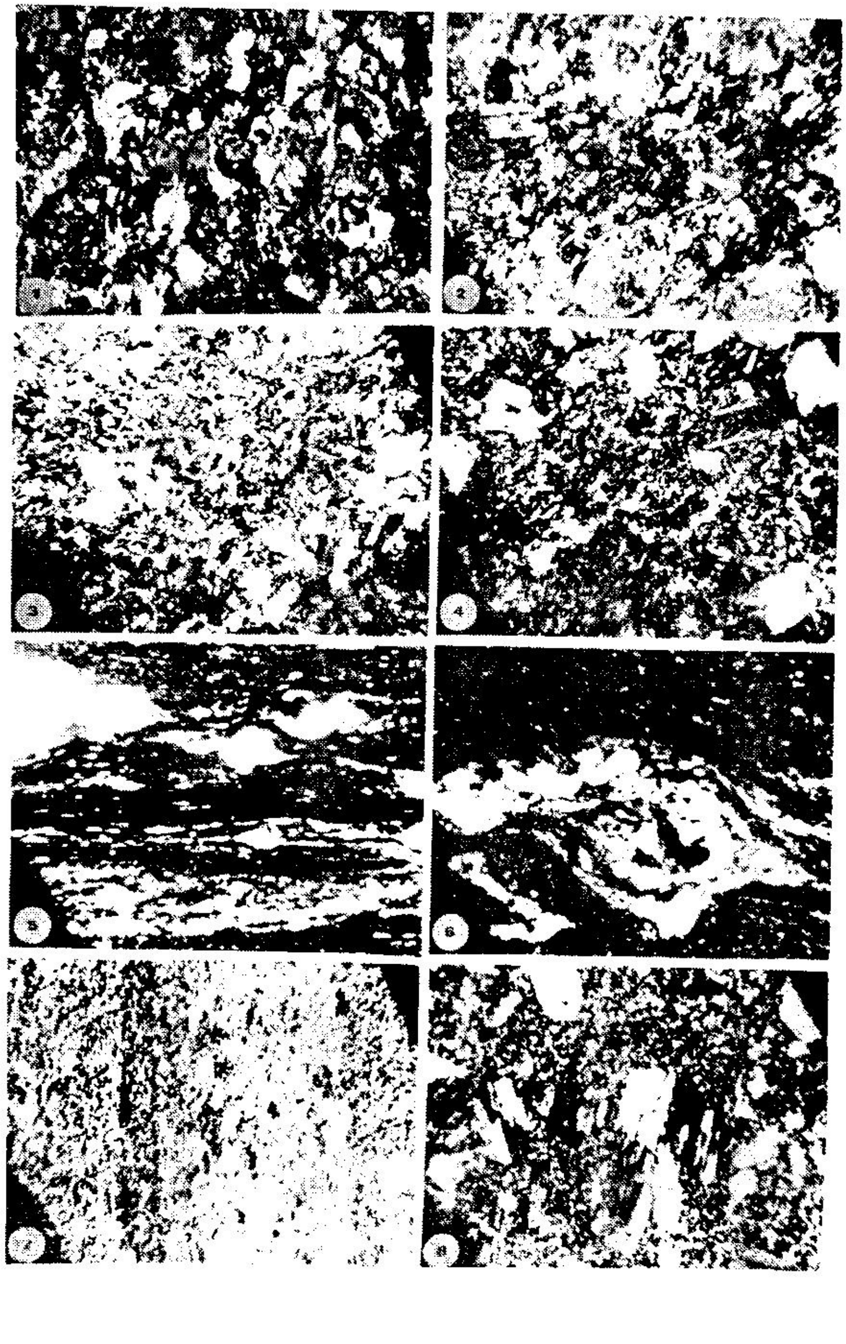
Fig. (4) : Feldspathic Greywacke. The Plagioclase phenocrystals and slightly deformed, to clay mineral; Quartz Imbedded in fine-grained of the same composition.

Fig. (5) : Serious deformation in fine grained matrix interclate between Greywacke and Siltstone.

Fig. (6) : Lensoidal Quartz aggregates indicates serious deformation after deposition.

Fig. (7) : Interclation between Greywacke, coarse, light and Siltstone (dark, fine grained).

Fig. (8) : Deformed Plagioclase in fine-grained matrix. The Plagioclase seriously altered to Clay minerals.



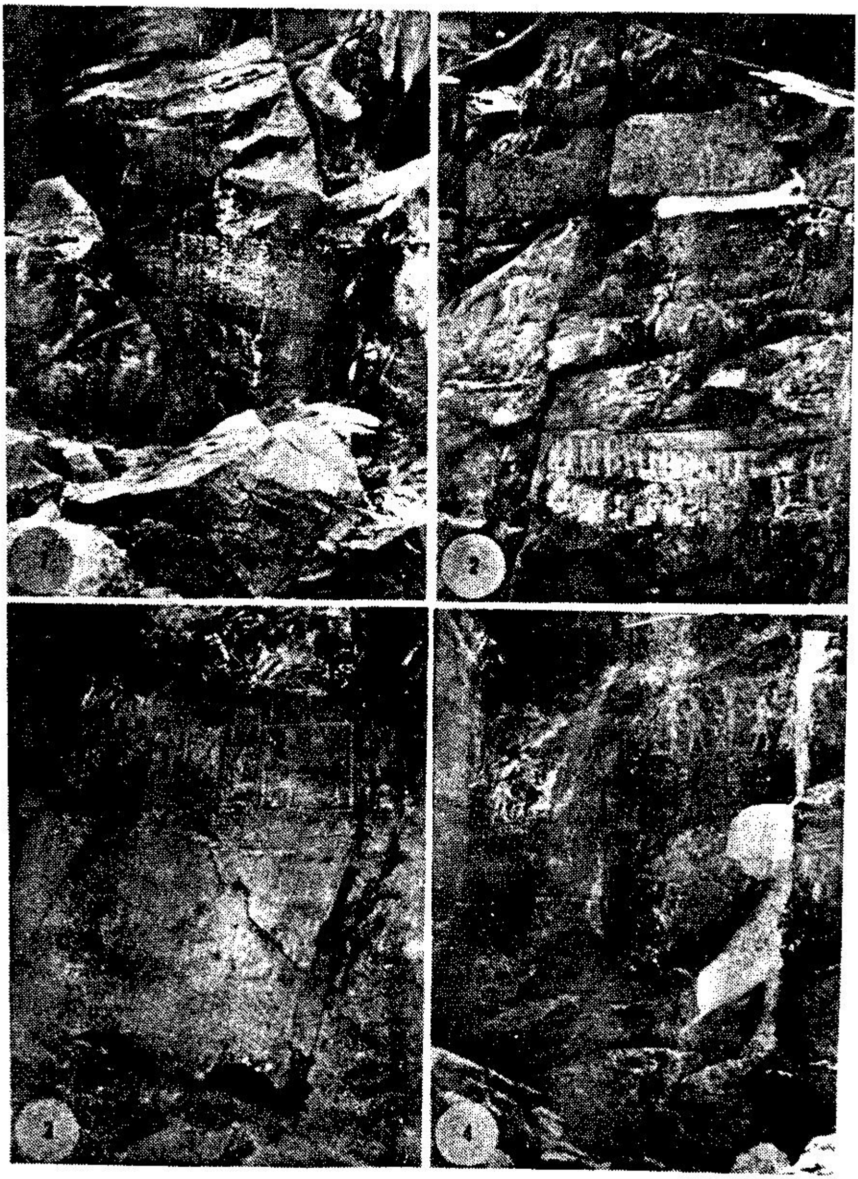
Pl. 10

Fig. (1) : **Physical weathering deterioration and cracking in the rock face may be due to thermal variations and lithologic heterogenity of the rock.**

Fig. (2) : **Nearly vertical Cracks and joint planes showing minor displacement and block dislocation.**

Fig. (3) : **Chemical weathering of inscriptions due to lithologic heterogenity and presence of Carbonate nodules caused by chemical effect. Diagonal Cracks between vertical joints which can lead to block separation.**

Fig. (4) : **Mechanical damage of inscription due to the fall of rock slaps as result of vertical joint with small displacement.**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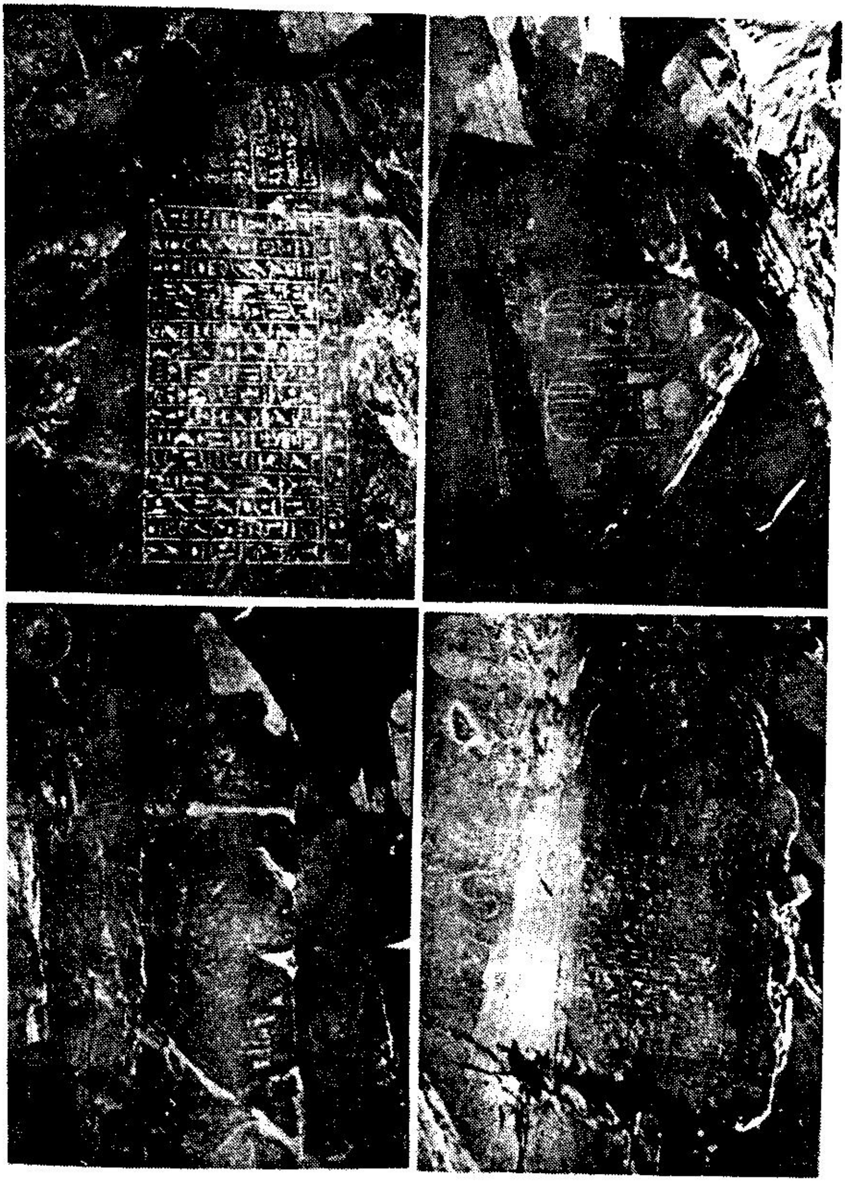
Pl. 11

Fig. (1) : **Mechanical damage in the bed rock art of Ramses II inscription due to combination of bedding planes and different composition of various beds as well as the effect of joints and the chemical weathering as result of leaching of Carbonate nodules.**

Fig. (2) : **Surficial disintegration and structural damage due to minor faults around the inscription of Amenmahat III.**

Fig. (3) : **Physio-chemical deterioration of the eroded surface. Also fracturing of rock is accentrated by dissolution of Calcite nodules.**

Fig. (4) : **Cracks, fissures causing damage of rock art due to rock lamination preserved in the lower parts, In the middle, dislocations along vertical joints are still active due to loading.**



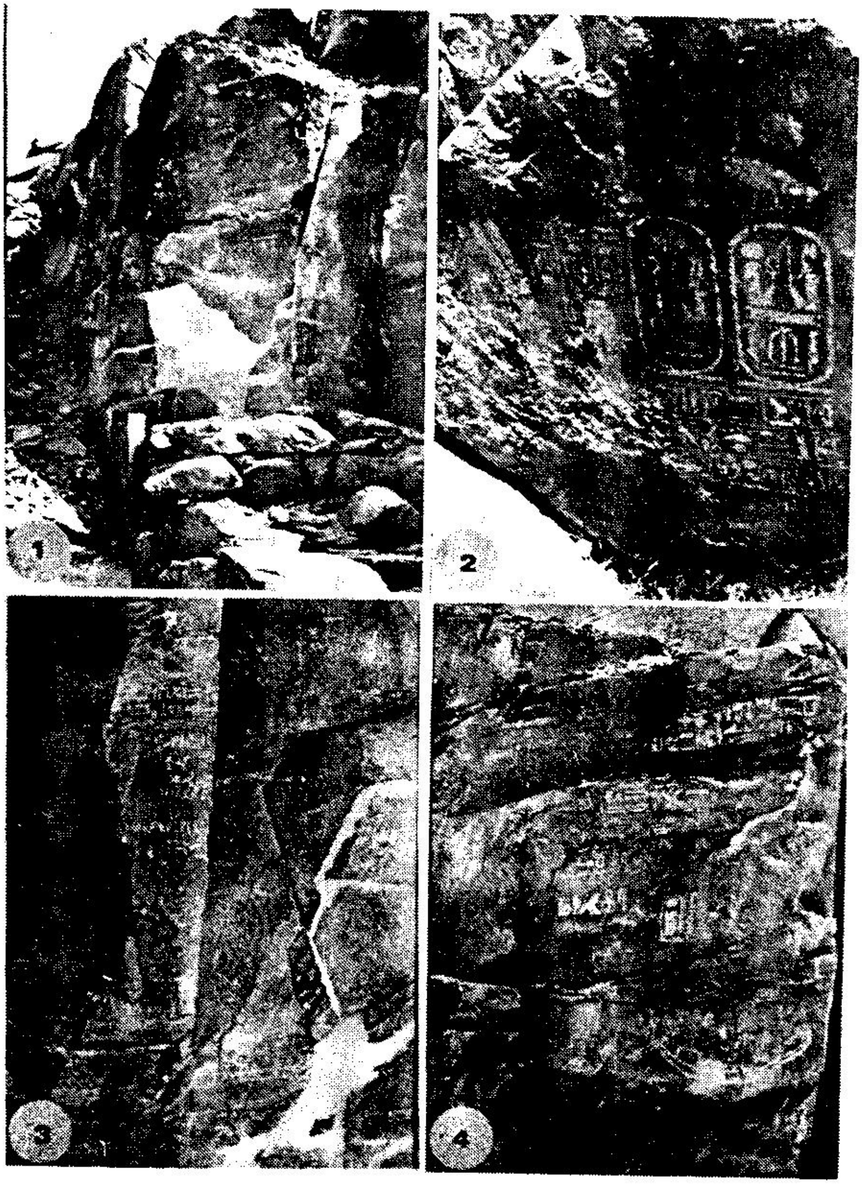
Pl. 12

Fig. (1) : Detachment of rock art due to the intersection of two nearly joint planes perpendicular to stratification. Lithologic variation in the Greywacke bed helped the differential weathering to produced.

Fig. (2) : A detail of inscriptions of Ramses IV on Greywacke show scratches due to the fall down on the stone blocks.

Fig. (3) : Differential movements of the blocks are due to minor displacements occurred on joint Planes and dislocate the bedding surfaces.

Fig. (4) : Mechanical weathering acts on joint surfaces and the rock edges are slightly rounded by the action of wind abrasion.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Pl. 13

Fig. (1) : Irregular cracks with changes in the color of rock art in the inscriptions of Xerxes I, 27th Dyn. This changes are due to the physiochemical weathering.

Fig. (2) : Predominately three sets of joints. This intersection leads to the blocks appearance of the out-crops. This geotechnical collapse could cause the fallen of the blocks which have the inscription of Pepi VI.

Fig. (3) : Detachment and deterioration of inscriptions of Pepi VI due to the intersection of three joints planes and the cracks were filled with Portland Cement which has lost its cohesion with the stone and fallen off.

Pl. 14

Fig. (1) : disintegration of mineral constituents of Greywackė stone due to physical weathering.

Fig. (2) : Occurrence of Clay minerals.

Fig. (3) : Destruction of Quartz grains, cracks are also observed.

Fig. (4) : Collapse of the internal structure of stone.

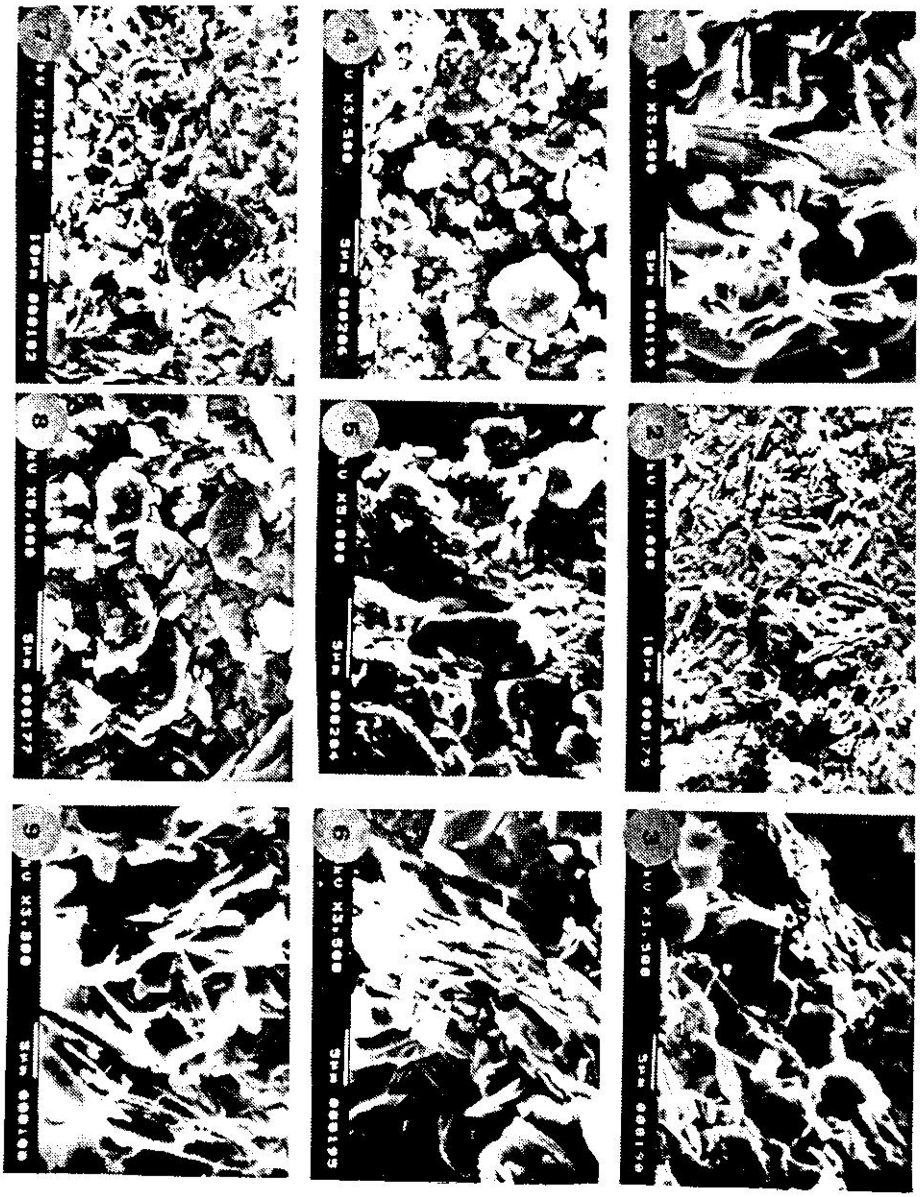
Fig. (5) : Physical deterioration and destroying of Feldspars.

Fig. (6) : The collapse of the internal structure of stone.

Fig. (7) : Alteration of Feldspars which changed into Clay minerals due to the chemical weathering.

Fig. (8) : Occurrence of calcite, plagioclase, Feldspars and Quartz minerals in the Greywacke.

Fig. (9) : Partial alteration of Feldspars which changed into Clay minerals.



Pl. 15

Fig. (1) : Destroying of Quartz grains.

Fig. (2) : Collapse of Quartz and Calcite minerals.

Fig. (3) : Deterioration of Hammamat stone due to the collapse of Quartz and Calcite minerals.

Fig. (4) : Cracks and fissures in the internal structure of Hammamat stone due to physical weathing.

Fig. (5) : Destruction of Quartz grains and the collapse of the internal structure of the stone.

Fig. (6) : Destruction of calcite minerals. Also Calcite crystals in different forms.

Fig. (7) : Occurrence of clay minerals and Quartz.

Fig. (8) : Partial alterations in Feldspars minerals with the destruction of clay minerals.

Fig. (9) : The collapse of the internal structure of stone with traces of clay minerals