العنوان:	Study Of the Deterioration Features Of the Umm Ubayda-Temple in Siwa Oasis - Egypt
المصدر:	مجلة كلية الآثار
الناشر:	جامعة جنوب الوادي - كلية الآثار بقنا
المؤلف الرئيسي:	Abd El Tawab, Nabil A.
المجلد/العدد:	ع3
محكمة:	نعم
التاريخ الميلادي:	2008
الشهر:	يوليو
الصفحات:	125 - 151
رقم MD:	933560
نوع المحتوى:	بحوث ومقالات
قواعد المعلومات:	HumanIndex
مواضيع:	الآثار التاريخية، التراث المعمارى، معبد أم عبيدة، واحة سيوة، مصر
رابط:	http://search.mandumah.com/Record/933560

STUDY OF THE DETERIORATION FEATURES OF THE UMM UBAYDA TEMPLE IN SIWA OASIS - EGYPT

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Journal of Faculty of Archaeology (Qena)

Abstract :

Siwa oasis is located in the extreme western part of the Egyptian western desert. There are several archaeological sites in the oasis , one of them is Umm Ubayda temple at Aghormi hill . it has a lot of deterioration features such as cracks , salts efflorescence , etc....

Field inspection and lab analysis, Indicate that geological features , environmental conditions , the type of rocks and man made deterioration play an important role on the destruction of the temple . X-ray diffraction [XRD] , thermal analyses [DTA & TGA] were carried out for stone samples taken from the Umm Ubayda temple and Aghormi hill. Also Petrographical examination by polarizing microscope [PLM] , and scanning electron microscope [SEM] attached with EDX diagnosis were determined . Physical and mechanical properties were detected .

The data showed that the stone of the temple consists of mainly biomicrite calcite , Sodium chloride , anhediral Quartz , and traces of Gypsum and Iron oxide.. XRD and thermal analyses {DTA & TGA} showed that the limestone contains clay minerals which consists of Xonotlite , Sillmanite , Halloysite , kaolinite and Smectite which make basic problems due to swelling and shrinkage of clay minerals which resumed from absorption and loss of water from agriculture land and a number of its fresh water springs running beside the temple. The problem is more complicated by the presence of Sodium chloride .

1. introduction .

Umm Ubayda temple is situated at Aghormi hill at the ancient city Aghurmi at the city of Siwa the capital of Siwa oasis , Western desert in Egypt . Siwa oasis which is located between the Qattara Depression and the Egyptian Sand Sea in the Libyan Desert, nearly 50 km (30 mi) east of the Libyan border, and 560 km (348 mil) from Cairo. About 80 km (50 miles) in length and 20 km (12 mi) wide , This is the most distant Egyptian oasis from the Nile Valley , Siwa Depression lies as much as 60 meters (192 feet) below sea level, but its average depth is 18 meters below sea level. . The temple was built during the 26th dynasty by the command of King Nectanebo 2 in the 4th century BCE , this temple flourished well during the Greek and Roman periods , it was built over the northern edge of Aghormi hill which consists of two distinct beds-an upper limestone bed and a lower shale one . It would have been standing if it hadn't been for an Ottoman general who blew it up in 1896 to get building materials .The temple is in an even worse condition. Just a piece of a wall still standing , Fortunately some fine wall-paintings on the western side of the wall have survived Which contain sacred scene , hieroglyphic text divided into three row of goddess .From this scene a group of persons accomplish liturgy (opening mouth) . This wall painting was threatened by slope instability and had many cracks . The aim of this study is to mend the main deterioration phenomenon of this temple and try to solve this problem .

Fig. 1 : Show the slope instability of the Umm Ubayda temple

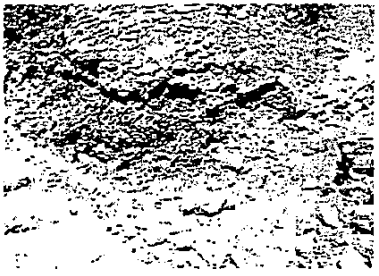


Fig.2 shows the edge of Aghormi hill, which consists of two distinct beds-an upper limestone bed and a lower shale one.

2- Analysis and diagnosis :

Several samples have been taken from Umm Ubayda temple and Aghormi hill , These samples have been investigated by Several analytical techniques in order to highlight the main physico-chemical properties of limestone and characteristics mineralogical of stone . The samples were examined by means of , X-ray diffraction analysis XRD (Philips X-ray diffractomer type Pw/ 1840, 20kv ,40mA) were used for identification of the main crystalline species . The morphological, and elemental characterization of the selected samples were examined under polarizing microscope . The quantification of clay minerals were performed by thermal analysis (DTA- TGA) , detector type DTA- 60H and TGA- 60H , atmosphere :Nitrogen , gas flow: 20ml/min , Pan name: Alumina , temp. Rate [^{5}C/min] 10^5 up to 1000^5 with α-Al_2O_3 as a reference material , sample weight : 1.812[mg]. The temperature , weight , change in wt., and the thermal behavior of each minerals were recorded on the chart . The surfaces of the deteriorated layers were also observed by means of a scanning electron microscope linked with a dispersive

energy microanalyzer (SEM-EDX) . The Physical and mechanical properties of the limestone were detected .

3- Results :

3-1. Petrographic characteristics of Aghormi limestone .

the limestone is red to reddish brown , soft , marly, and highly porous . Petrographical information evidenced by means of observation on thin section ,the polarized light (PLL) and crossed nicols (CN) showed that the limestone texture varies from place to place of extraction , it consists essentially of calcite crystals which occurs as fine to medium - grained , anhedral interlocked crystals with amount of fossil shells and fossil fragment embedded in a micrite matrix . the fossil shell takes six chamber forming . The rock contains *Malluska* which is represented by *Pelecypoda* and *Gastropoda* indicating that the rock was deposited in shallow marine environment .

Fossils and fossiliferous fragments are replaced in some parts by spary calcite crystals . Dolomite crystals are also noticed in some parts which are noticed in some parts which are characterized by their ramps forming .

Numerous grains of Quartz are found , occurring as subrounded to angular grains , it takes a Smokey shape because of its admixture by clay minerals . Slide showed the intrusions of Gypsum.

It was also found that there are clay mineral as Chlorite and serpentine. these were studied by (DTA,DGA) , therefore subject to swelling in the presence of water .

Iron oxides as opaque minerals and shapeless aggregates of ferric nature are also observed

. Impregnating Iron oxide substances are probably responsible for the reddish color of the limestone .There are irregular intercalation of clay minerals and Halite (NaCl) which was dissolved at the time of preparing the thin section which led to a lot of cavities in all slides .

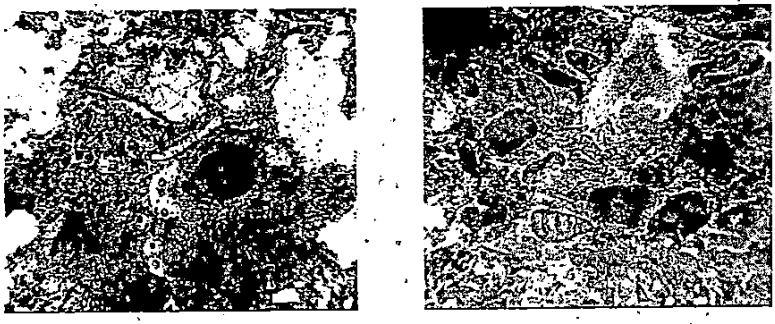


Fig. 3.4 : Polarizing microscopy view of Umm Ubayda limestone samples shows the mineralogical composition of limestone from Umm Ubayda temple Calcite , Dolomite , clay minerals , iron oxide

Fig. 5 : Thin section micrograph shows microcrackes and Iron oxide

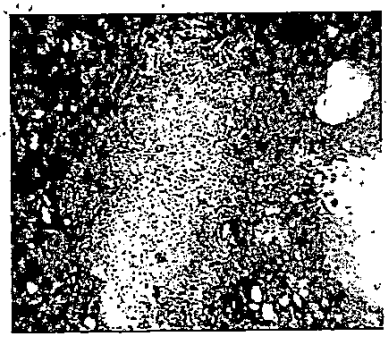


Fig. 6 : Polarizing microscopy show sub rounded to angular Smokey Quartz

Fig.7:Polarizing microscopy show clay minerals & fossil shell .

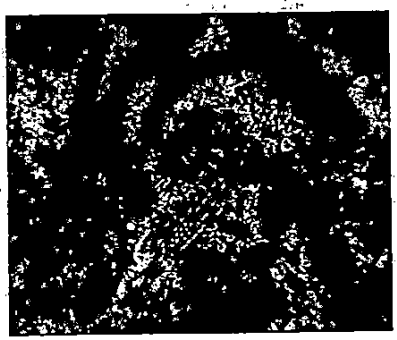


Fig.8:Polarizing microscopy show Gypsum with clay minerals & iron oxide

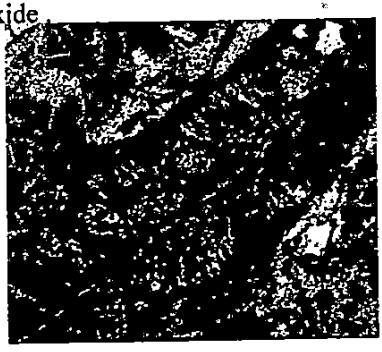


Fig.9: Polarizing microscopy show *Malluska* which is represented by *Pelecypoda* and *Gastropoda* .

Fig.10 : Polarizing microscopy show fossil shell takes six chamber. forming

3-2-X-ray differaction (XRD) .

XRD analysis indicate that Calcite ($CaCO_3$) the main mineral component with a smaller quantity of Halite (NaCl) . Dolomite {CaMg $(CO_3)2$} ,Quartz (SiO_2) and less frequently of mixture clay minerals , Gypsum ($CaSO_4.2H_2O$) ,Albite ($NaAlSi_3O_8$) , Iron oxide (Hematite Fe_2O_3) are represented with appreciable amount .

Clay fraction of Aghormi hill showed that it is composed of a mixture of Xonatite ($Ca_6Si_6O_{17}(OH)2$) , Halloysite ($Al_4Si_4(OH)_8O_{10}.4H_2O$) ,Sillmanite($Al_2SiO_5$) , Kaolinite($Al_4[Si_4O_{10}](OH)8$) and addition of Quartz , Halite and gypsum .

Table No. (1) show the principle minerals constituents of the limestone samples.

SAMPLES	SAMPLE A	SAMPLE B	SAMPLE C	SAMPLE D
Calcite	71.22	72.81	52.32	54.88
Halite	24.35	4.12	23.81	20.41
Gypsum	-------	-------	4.50	-------
Quartz	-------	-------	15.22	-------
Hematite	-------	3.87	-------	-------
Mon.	-------	2.54	-------	9.39
Dolomite	-------	16.4	3.43	-------
Albite	4.41	-------	-------	-------

Mon: Montmorillonite.
Kao:Kaolinite
Xon: Xonatite
Q: Quartz
Hal::' Halloysite
Sil: Sillmanite

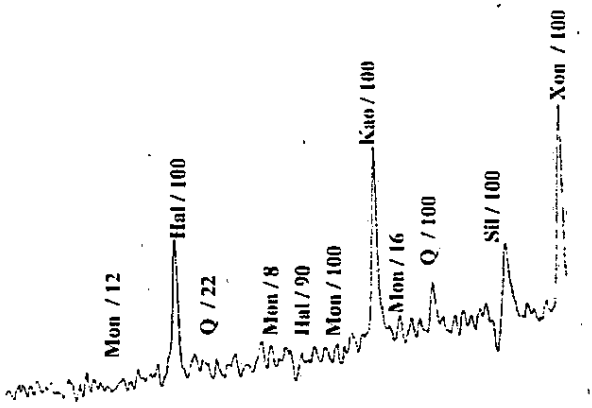
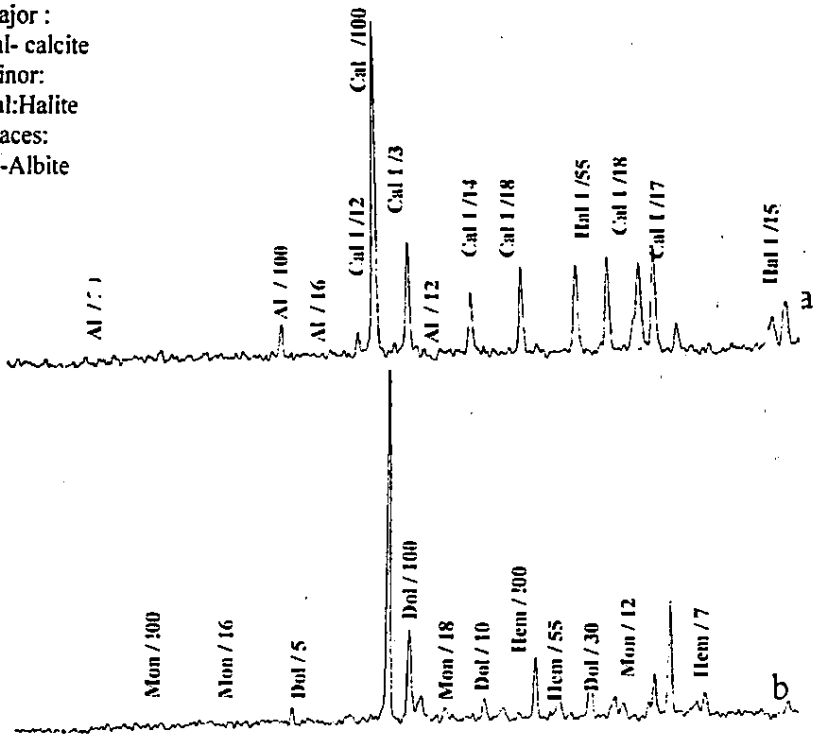


Fig. 11 X-ray diffraction pattern of clay fraction at Umm Ubayda temple .

Major :
Cal- calcite
Minor:
Hal:Halite
Traces:
Al-Albite



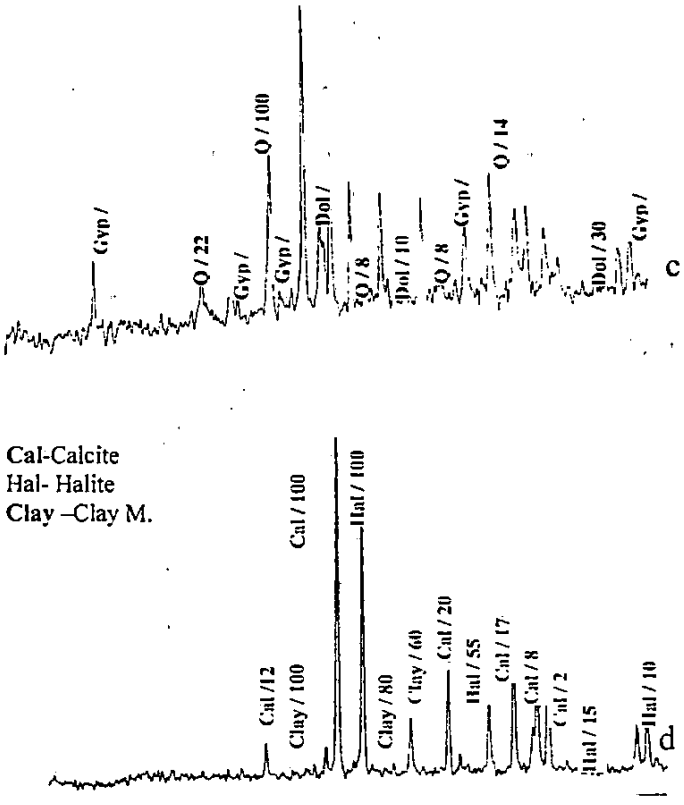
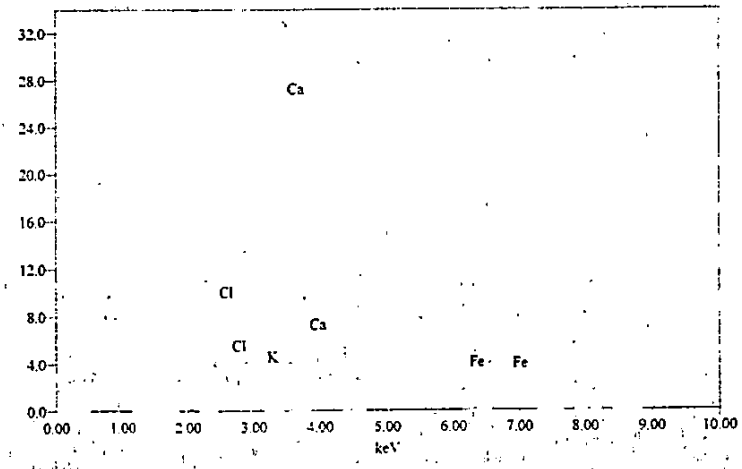
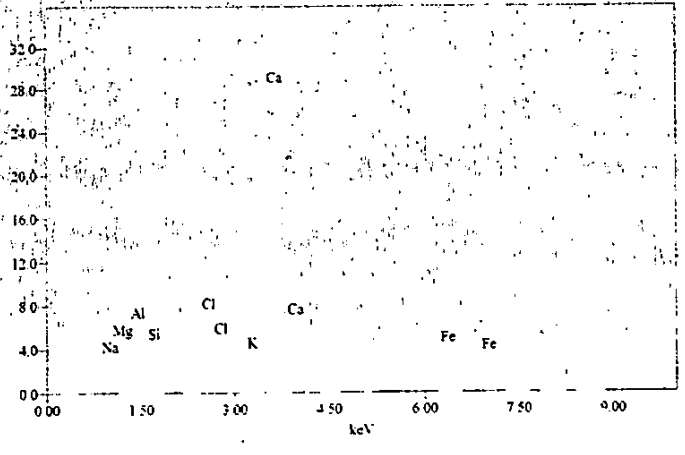


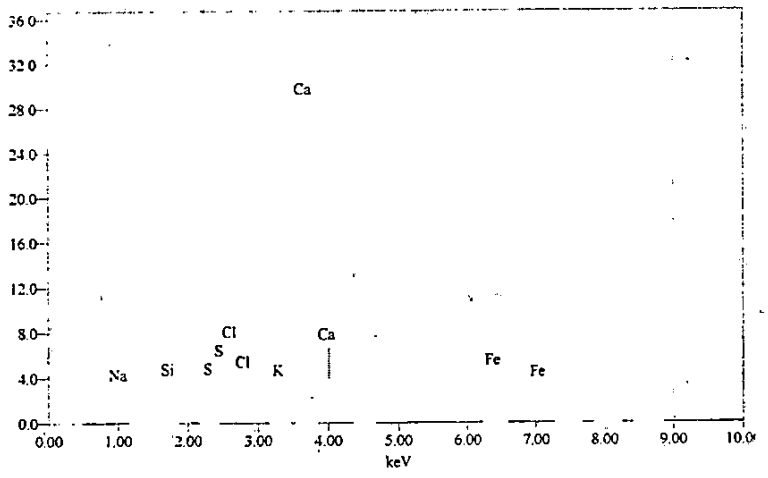
Fig. 12 a,b,c,d show X-ray diffraction patterns of Limestone samples at Umm Ubayda temple ; Major, Calcite - Minor : Dolomite, Quartz, , Halite , Gypsum, Traces : Albite ,Hematite, Clay mineral.

3-3.X-ray fluorescence analysis :

X-ray fluorescence detects a higher Ca , Cl, Al, Si, Na, and traces of Fe, S, K which showed the presence of Calcite , Halite, Xonatite , Montmorillonite and traces of Dolomite, Gypsum and Kaolinite.(tab.1 & fig.13 G1,G2,G3,G4) .







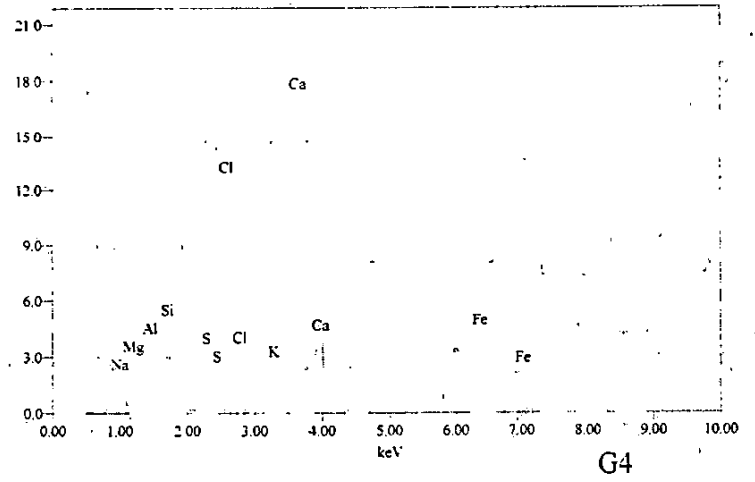


Fig.13 (G1,G2,G3,G4) shows X-ray fluorescence patterns of the stone and clay fraction of Aghormi hill and Umm Ubayda temple .

Table No.1 Shows elements of the minerals e stone and clay fraction .

ELEMENT CO. %	SAMPLES NO.			
	G1	G2	G3	G4
Ca %	86.472	80.540	86.292	58.850
Na %	1.0710	1.5399	1.0369	4.1161
Si %	------	4.9578	1.7266	4.2852
Cl %	10.134	6.5733	6.4561	21.284
K %	1.6729	0.9709	0.9194	2.6655
S %	0.2941	-----	0.4852	1.5421
Fe %	0.3557	1.9128	3.0833	4.8234
Mg %	----	2.0533	-----	1.4080
Al %	-----	1.4511	-----	1.0247
Total	99.8000	99.9999	100.010	99.9999

3-4. Thermal analysis DTA and TGA

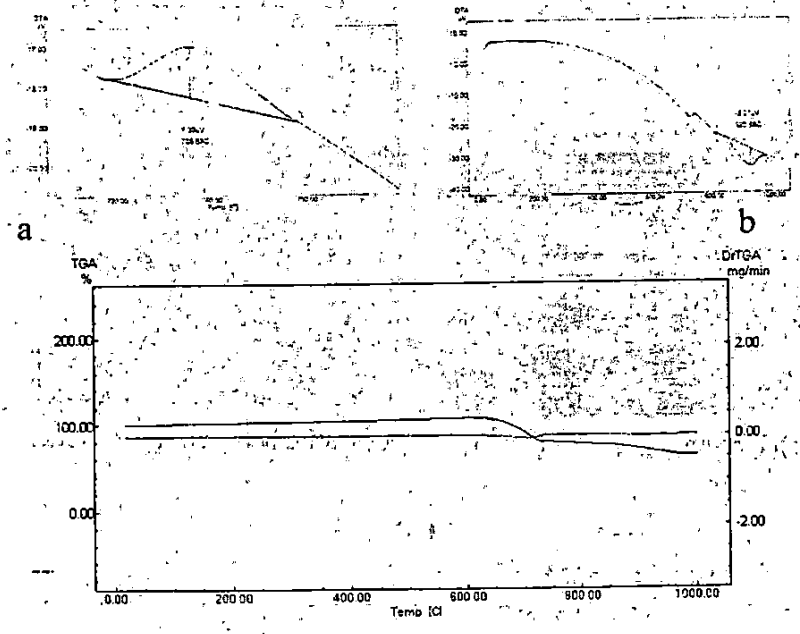
The DTA - TGA data shown the clay fraction of Aghormi hill consists of Smectite , Halloysite , Xonatlite , Sillimanite , Kaolinite ,Calcite , Quartz . The total loss in weight due to heating is 14.74% . Smectite exhibits three peaks on DTA curve , the first is a large endothermic peak at temperature 100-110°C due to the enter layer water of Smectite was lost ,the 2^{nd} is endothermic at temperature 500°C due to rapid loss of (OH) water, the 3^{rd} peak is exothermic at temperature

870-900°C due to decomposition of the structure .

Hallosyite , Kaolinite exhibit two peaks , the first one is a medium endothermic peak at 525°C due to loss of hydroxyl group and the 2nd is a very small exothermic reaction at temp.915°C due to the Structural Change of the Mineral .

Calcite gives medium endothermic peak at temperature 762°C , Gypsum gives a double endothermic peak , the 1st Small endothermic peak at 108°C due to a loss of 1.5 molecules of water to give Hemi-hydrate , the 2nd at temperature 182°C related to loss ½ molecules of water to give anhydrate .

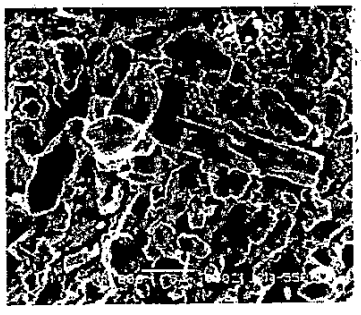
Quartz exhibits a small peak at temperature 675°C due to transformation of α-Quartz to ß- Quartz , Smectite gaves endothermic peak at temperature 684°C related to a loss of hydroxyl group (OH) , Halloysite exhibits endothermic peak at temperature 700°C related to a loss of hydroxyl group (OH) as shown in fig.15a,b,c,d .



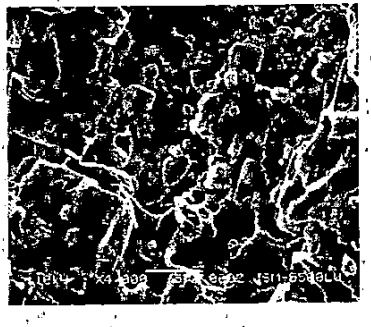
3-5.Optical and electron microscope observation .

Fig.15 shows thermal analysis(DTA,TGA) charts of clay fraction of Aghormi hill

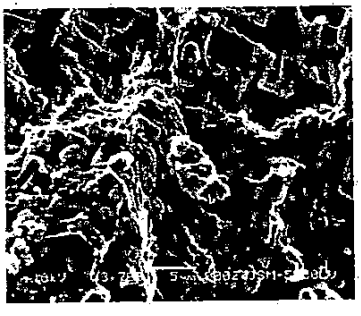
The Scanning electron microscope micrograph showed that the main mineral constituents of Aghormi hill and Umm Ubayda temple are calcite cemented with clay minerals . results of SEM revealed the presence of Halite which is accumulated in glassy shape , destroy of calcite grains , Gypsum crystals , Observation by SEM also show droplets of halite mixed with clay minerals crystals , spherical particles of fossils . fig. 16



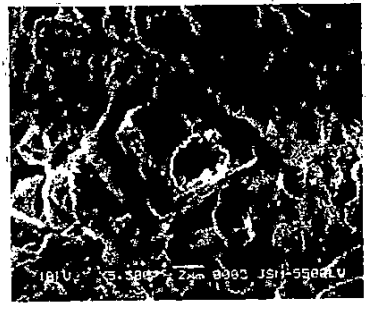
a) clay minerals &, salts



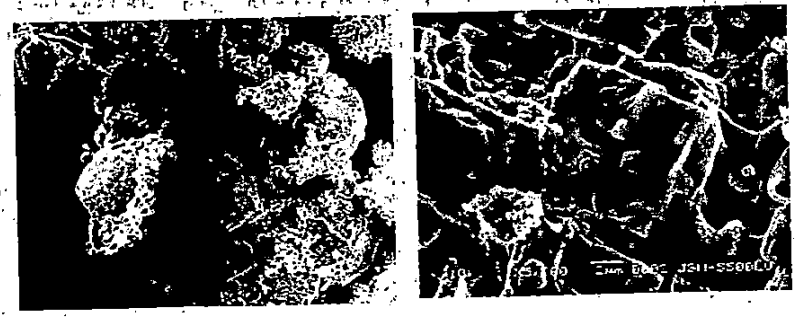
b) destroyed of calcite grains.



c)Gypsum with clay minerals.



d) Halite between fine Calcite.



e) quartz grains with Gypsum .

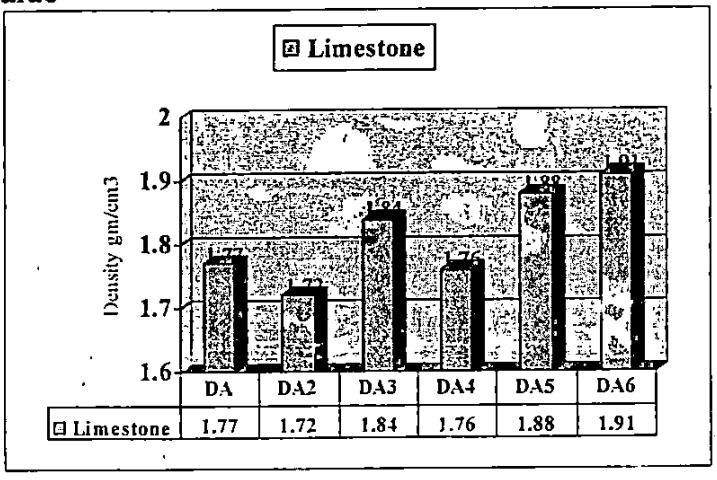
f)calcite was cased by clay minerals & salts .

Fig.16 Scanning electron micrograph (SEM)of Umm Ubayda limestone and Aghormi hill showing the presence of clay minerals , destroyed of calcite grains due to growth of crystalline salts mainly sodium chloride and calcium sulphate , quartz grains with clay minerals

3-6. Physical and Mechanical properties tests :

Bulk density , water absorption , porosity and compressive strength were determined according to ASTM . The sample sizes used in the study were 5×5×5cm cubes . The samples were dried at oven , where temperature average was 105°C .The results showed (fig .17-18) all samples which were collected from Aghormi hill and Umm Ubayda temple have quite similar physical properties .The bulk density is between 1.7 and 1.9 g/cm^3 .The water absorption is between 2.45-3.20 % , and the porosity is between 5.9-7.20 % .

The results obtained from mechanical test (compressive strength) summarized in (fig. 20) : There is significant change of compressive strength for the wet samples , that gave a decrease in the compressive value



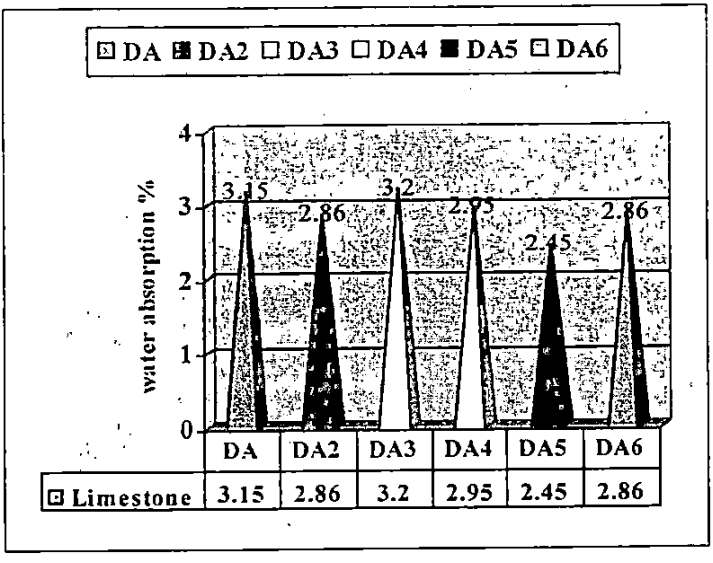


Fig.18 Shows water absorption measuring for limestone samples from Umm Ubayda temple .

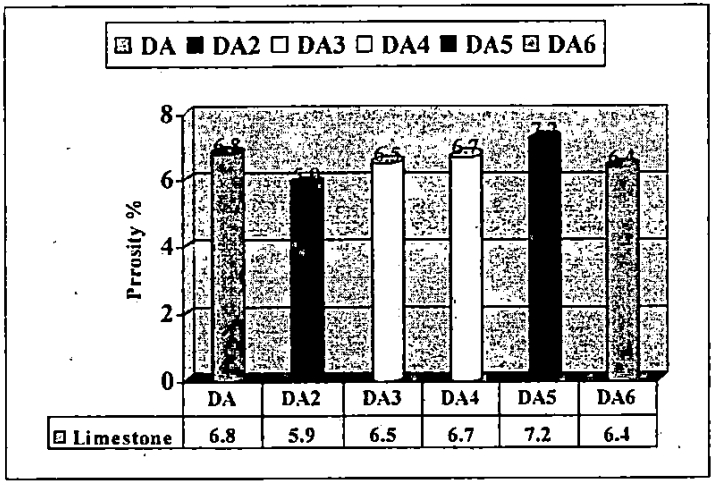


Fig.19 Shows porosity measuring for limestone samples from Umm Ubayda temple. .

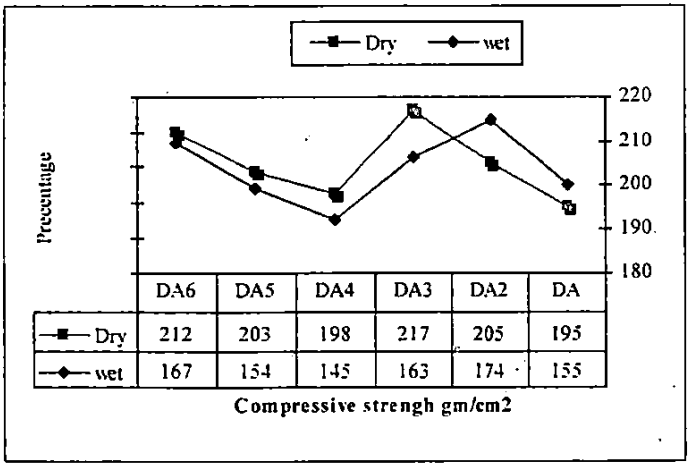


Fig.20 Shows compressive strength (wet and dry) for limestone samples from Umm Ubayda temple. .

4- Discussion :

From the field inspection and laboratory analysis, it is clear that the weathering process is the most affecting agent in the stones of Umm Ubayda temple .

The Siwa region is exposed to semi arid climate. Short, rainy winter period Siwa does not receive much rain (fig.20),hot and dry summer period with significant diurnal variations of air temperature and air humidity are characteristic(fig.22) . The microclimatic studies have confirmed high temperature variations at the surface of the monuments with significant heating and cooling rates . Wind storms are frequently (In 1928, a major storms which resulted in the local inhabitants abandoning their ancient town). Atmospheric of Siwa predominate at weathering process affecting the Siwa monuments.

The result of X-Ray diffraction, X-Ray florescence , Polarizing light microscope and SEM indicated that presence of Halite in the stone of Umm Ubayda . This salts are characteristic with continuous crystallization mechanism as a result to the number of its fresh water springs run into salt water lakes, making the water mostly useless , Some of the lakes are so salty and the salt crystals are visible in the water* . Water together with salts rise up to the higher levels and evaporate through the stone pores , the cyclic variations of air temperature and relative humidity surrounding the temple lead to soluble salts appeared on the surface of the relief . It is clear that correlations between stone decay and combined water and salt effect can be postulated . The surface of stone relief was cracked , peels off and gradually the stone losses its mechanical

* The salty soil of the Oasis is called karshif in Arabic(Vivian, 2000))

strength , relief disintegrated into powder , this leads to the corrosion of the stone ,leaching of binder of the mortar , damaging of the wall and threatens the whole complex of building . In this case the pressure of the chemical materials of the pore fluid to avoid deterioration caused by action of water and salts and decrease the stone durability .So different water-repellent consolidants were determined , After treatment with Wacker OH100 , Tegovakon V (Ethyl silicate), Paraloid 66 (Acrylic resin) , it is found that Tegovakon V shows perfect penetration, The network structure of consolidant can be seen dispersed between the grains and made a thickness coating to the calcite grains , salts grains were observed above this coating .

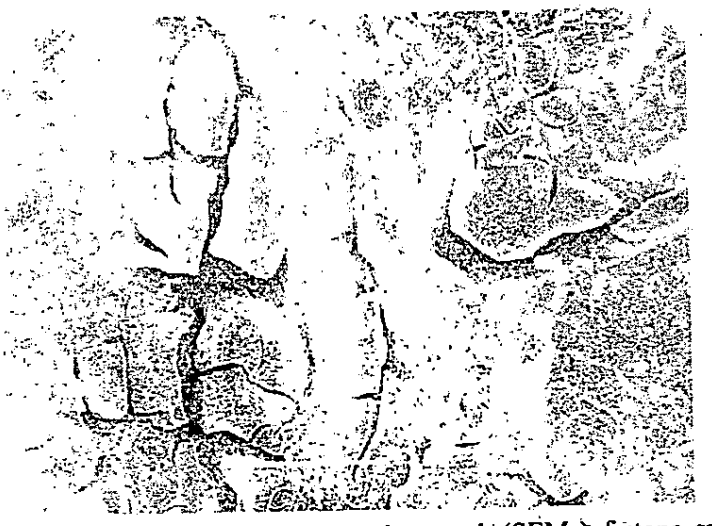


Fig No. 23 Scanning electron micrograph (SEM)of stone sample which was treated with Wacker OH100 shows sporadic network of the polymer.

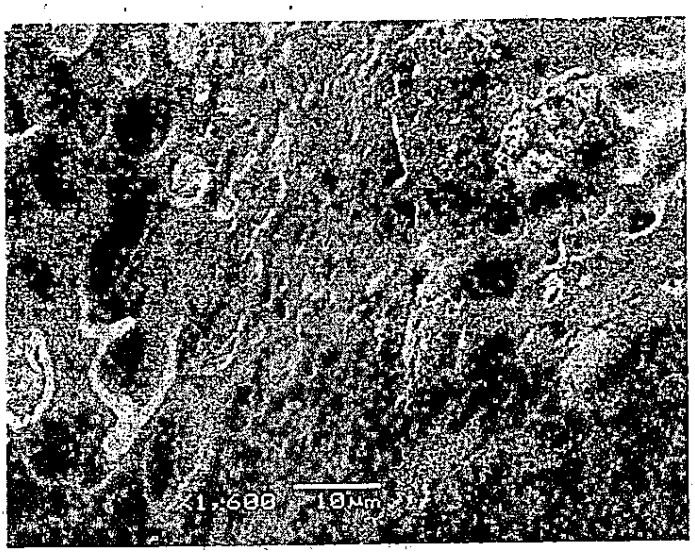


Fig No.24 Scanning electron micrograph (SEM)of stone sample was treated with Acryloid 66 shows a good penetration of the polymer .

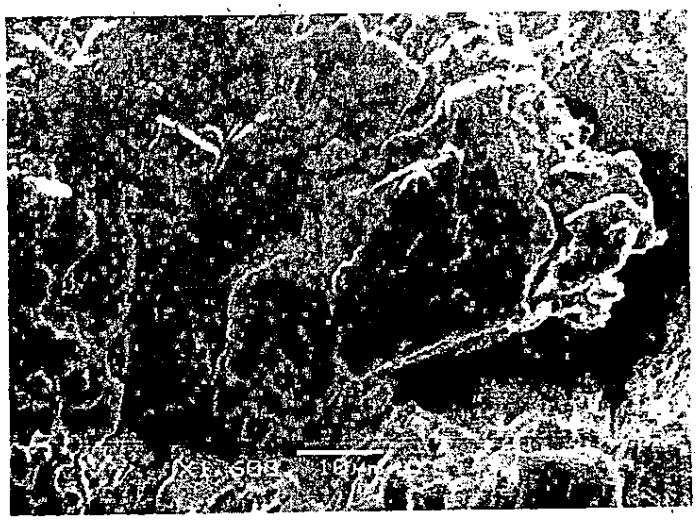


Fig No. 25. Scanning electron micrograph (SEM)of stone sample was treated with Tegovakon V shows perfect penetration, thickness coating to the calcite grains with polymer.

Growth of microorganisms on the surface and inside the limestone add more deterioration features at the Umm Ubayda temple because when the fungi and bacteria cells penetrated to the mineral matrix and crystals of stone , they produce an organic and inorganic acids like nitrous , nitric and sulphoric acid which reacts with the calcium carbonate of stone and gives rise to Gypsum ($CaSO_4.2H_2O$) Fig No. 26 .

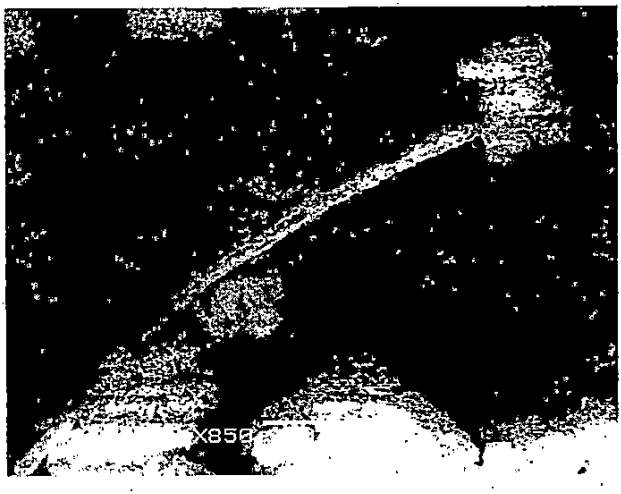


Fig No. 26 Scanning electron micrograph (SEM)shows the microorganisms groth inside the limestone sample which was taken from Umm Ubayda temple

It is postulated that geological aspects play an important role in the extent of damage. Umm Ubayda temple was built over the northern edge of Aghormi hill, which consists of two distinct beds-an upper limestone bed which exist on isolated middle miocene and a lower is shale . The shale is considered as a high expanded bed and weak in its bearing capacity, because of clay content (mainly, Kaolinite ($Al_4Si_4(OH)_8O_{10}.4H_2O$) Halloysite($Al_4Si_4(OH)_8O_{10}.4H_2O$),Smectite

($Al_4Si_8O_{20}(OH)_4.^nH2O$)*,Sillmanite and traces of Montmorillonite).The swelling of shale due to the ground water spring underneath. Consequently, the upper limestone bed suffered from map cracking associated with rock falls due to the differential settlement of the swelled lower shale one. The temple was threatened by slope instability and had experienced many cracks . The problem is more complicated by the existence of Gypsum minerals. It is produced by the reaction between the SO_4^{2-} ions present in the acid deposition and the calcium carbonate ($CaCO_3$) present in limestone or perhaps it is a natural mineral in the stone and shell .Transformation of Gypsum to anhydrate by heating in Summer causes a great change in the volume of the crystal structure unit. This will be additive factor to the swelling character of clay minerals leading to flacing , disintegration of stone . In this case the remedial measures suggested to overcome the stability problems on Umm Ubayda temple are grouting or construction of retaining walls . Ibrahim H. A. M. & Samh G. E.2006 . To stabilize and reduce the swelling capacity of clay we can use styrene and $Ca(OH_2)$ minimize sufficiently the swelling of Umm Ubayda temple stones (Helmi,F., M., 2000) . We can use the mortar which consists of 660gm of hydraulic conglomerate C30 ,2000gr crushed local stone (free of salts) ,500gm water for the restoration and filling the cracks and gaps, (Meli,C.,B.,P., and others 2000) . (Balleste P. and Marmol , I . , 2007) recommended that we can use aggregate with limestone obtained as a by-product from waste of the mussel cannery industry. The CaCO3 aggregate consists mainly of elongated

* Member of Montmorillonite group (tri-octahedral) ,it is swelling clay minerals in that it can take up water between its structural layers

prismatic particles less than 4 μm long rather than of the rounded particles of smaller size (2–6 μm) obtained with quarry limestone this mortar displays a significant resistance to salt crystallization .

6-Conclusion :

The major problem to be investigated is that crystallization of salts and swelling capacity of clay minerals are existed as interlaminates clay at Aghormi hill. The limestone which had been used at Umm Ubayda temple is a much higher clay minerals and halite and fall of cracks and gaps . The geological features of Siwa Oasis (the rock with clay minerals , atmospheric aspects , saline water) has a big role in the deterioration of Umm Ubayda temple , A number of its fresh water springs run into salt water lakes, making the water mostly useless which are rich in by capillary risen and make a deterioration features . Petrographic investigation showed a large amount of fossil shells and fossil fragments cemented by carbonated materials which declare that the marine had covered the earth of old Siwa oasis .

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