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EFFECTIVE ROLES OF SOME DETERIORATION AGENTS AFFECTING EDFU ROYAL BIRTH HOUSE "MAMMISI"

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Abstract

This paper is the first part of a study about a birth house located in Edfu temple. It studies the deterioration phenomena that has affected the stone surfaces, and the ideal methods and materials, which have been used for conserving and restoring stone surfaces. In this article, three of the main deterioration factors which have affected the monument under study are identified. Furthermore, field observations are conducted to achieve a weathering graphical profile and deterioration patterns. In addition, different investigating techniques are used for studying aggressive influences affecting the stone surfaces to evaluate their weathering state and defining their different chemical characteristics and physio-mechanical properties. These techniques are EDS, SEM, and XRD, in addition to different scientific computer programs. Our findings have proved that the main factors of deterioration affecting the monument are mainly three factors. They are alternative effects of air temperature and relative humidity, Man made damages and bird effects. The study shows that the main elemental composition consists of Al, K, Ca, Na, S, Cl and Mg; these elements are present in different structures such as Quartz, Mica, Plagioclase and Calcite as main minerals. Hematite and Goethite as cement materials. Finally Halite, Sylvite, Niter, Nitrate and Kaolinite as a salt and weathering products. Moreover, SEM morphological investigations have proved that the grains of the investigated samples are characterized by the presence of severe abrasive in Qz grains, and the spreading of soiling particles and salt layers. In addition, etching of the cement materials because of hydrolysis process. Moreover, the presence of weakness and brittleness of stone core and some pits on the stone surface are observed.

Keywords: *Mammisi; Deterioration patterns; Weathering graphical profile; EDS; SEM; XRD*.

Introduction

Sandstone was used as a building material at most of the historical structures for long periods in Egypt; it was used in most of Pharaonic monuments in Upper Egypt [1]. Also, it was used in some buildings belonging to Islamic period [2], in addition to its uses in Greco Roman time [3]. In Egypt, deterioration cycles especially in sensitive arid areas are more common factors. It has been found that the repeated drying and wetting cycles, or regular moisture in closed spaces (like tombs) have been linked to stone weathering [4]. Many of the monumental sandstones in Egypt have suffered serious damage due to natural weathering [5] through several extrinsic and intrinsic deterioration factors [6-7]. *Edfu Mammisi* is suffering from serious deterioration factors through different related forms resulted from the alternative cycles between air temperature and relative humidity up and down [8-9], in addition to the effects of

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other environmental factors [10-11]. Moreover, some of these forms could be owed to manmade damages [12] and the effects of pigeons and other bird species [13-14].

Archaeological history of Edfu birth house

According to *E. Daumas* [15], Mammisi of Edfu birth house (Fig. 1a) is a modern creation by J.F. Champollion; it is derived from Coptic "ma n mise/misi", where ma = *place*, n = *of* and mise/misi = *to bear*. Therefore the complete meaning is "*place of giving birth*". The ancient Egyptian designation was pr-mst, “*house of birth*”; this name refers to the key theological topic of the decoration of the Mammisi, which centers around the birth of the divine child of the triad of the main temple [16]. These houses were added as subsidiary buildings to a number of the late period temples for a period of more than 500 years and they had several names; Dendara, Armant, Edfu, Kom Ombo and Philae [17]. Mammisi of Edfu "*Harsomtus*" (Fig. 1b) is located in the southwest side of the great space in front of the temple's pylon. The major part of this building belongs to King Ptolemy IX (*Lathyros*) except the last internal room which is called in several sources as sanctuary that dates back to the reign of Ptolemy VIII (*Euergetes*) [18]. This major part was built of Nubia sandstone that is characterized by the presence of sand and clastic sediments and generally differs from the igneous rocks and other crystalline rocks in possessing a framework of grains [19]. This paper presents the status quo of the stone deterioration features of an Egyptian archaeological site in aired climate (*Edfu Birth Houses*). Also, it presents different investigation results of collected stone samples and deterioration products both in situ and in laboratories.

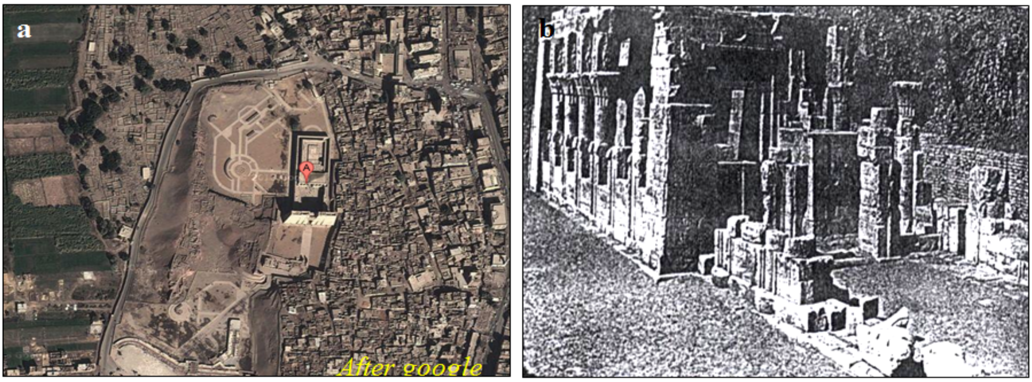

Fig. 1. Showing localition map of the Edfu temple in Upper Egypt (a) and the royal birth house "*Mammisi"* in Edfu (b)

Deterioration problems affecting Edfu Birth House

Deterioration of the monumental stone is a combined process caused by physical, chemical and biological factors. For instance, the relative importance of each factor varies according to topoclimatic environmental conditions and petrographic properties [20-21]. Sandstone deterioration is a complex process which depends on the type of bonding and the grains micro-structural aggregation, in addition to bonding phases (type and kind of cement materials) [20]. Sandstone is composed of quartz, feldspar, silicates, mica, hornblende, and clay minerals that are cemented by siliceous, carboneous, argillaceous or ferruginous materials [22-23]. These materials affect the longevity or durability of one sandstone type over another [24-25]. Sandstones that contain silica are quite hard, strong and decay resistant, whereas those which contain calcite resemble limestone in their susceptibility to acid damage. Furthermore, the type containing clay absorbs water and deteriorates more easily [26]. Regarding the type containing iron oxide, (*our case study*) it is mostly much softer, partially infilling with open porosity and has a color which varies between pale cream to light tan or yellowish to rusty coloration produced by Biotite alteration [27-28]. This type of cement material leads to the enhancing of sandstone deterioration through the effects of capillary action [29-31]. From a specialized point of view, it is affirmed that the most effective factors that lead to accurate deterioration symptoms on Edfu Mammisi are *AT and RH alternative cycles*, *human activities* and *bird effects*.

AT and RH alternative cycles

Air temperature and relative humidity are two of the main elements of the climatic conditions. According to [32] city of Edfu is located on the Northern part of Aswan governorate, 120km far, and on the Western part of Edfu town, on the border between the cultivated land and the old town. Our field studies attest that the study area rises on the South part of the Nile valley coming from Aswan to Qena, 1200m far from the Nile and it is characterized by the prevailing of Mediterranean climate. In our case study, as well the air temperature (AT) and relative humidity (RH) represent a severe deterioration factor especially through their alternative cycles (*drying - wetting actions/shrinkage contraction actions*) [11, 33-36]. These cycles finally led to many deterioration features such as scaling, flaking and salt crystallization. According to EMO [37] seasonal mean temperatures and RH for the years 1960-2000 are given in table 1.

Table 1. Average of AT ^oC and RH % from (1960-2000)

Metrological Measurement	**Season**											
	Winter			*Spring*			*Summer*			*Autumn*		
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
AT (^oC)	17.3	15.6	17.6	21.8	27.0	30.7	30.3	34.9	33.2	31.5	28.2	21.9
RH (%)	40	39	30	22	18	15	15	18	20	22	25	35

Man made damages

Few papers have addressed the relationship between the human activities and building stone damages, these activities that play important roles both in direct and indirect deterioration phenomenon. According to [38-41] these activities are scribed to several factors which are attributed to *agricultural activities*, *looting*, *theft* and *vandalism*, in addition to the *wrong conservation processes* (*improper techniques and unsuitable materials*). Through field studies it could be noticed that harmful human activities or man made damages affecting Edfu Mammisi are attributed essentially to vandalism caused by surfaces destruction. Moreover, there are wrong conservation processes which created several deterioration features such as black hard crusts and some friable unsuitable layers. Finally, there are other minor effects resulted from the effect of condensation and graffiti.

Bird effects

Bird effects represent one of the most severe factors that have affected archaeological buildings through the three main deterioration mechanisms "*chemical*, *physical* and *biological*" [42-44]. In this case study, widespread families of these birds are recorded, they are; *strunus valgaris* [7], *columbia livia, pass domesticus, streptobelia senegalesis egyptice* [13-45] and *taphozous nudiventrus nudiventrus* [14]. They play a major role in the deterioration processes, mechanically by some scratching and scraping forms. Chemically and biologically; they create some acidic central points and chemical damage trough the deposition of guano [46].

Experimental

Our field observations have proved that there are different weathering forms and related products affecting the stone surface inside the building. The intensity of these forms is mainly due to the location of the affected area (*sheltered or not sheltered*). These products are caused by three main mechanisms. They are; expansion and contraction cycles by AT & RH, sever human effects, in addition to the influences of the birds. All of these mechanisms have led to the presence of some deterioration patterns affecting the building materials, which could be summarized as following:

a) Presence of some stress and strains on the stone surface and within its structure, particularly in micro zone.

b) Growing of some salt species by alternative cycles of wetting and drying as well as hydration and crystallization process.

c) Etching of minerals edges' and dissolving its cement materials (Iron oxide) led to the stone bleeding and create some (red/brown, sometimes black) hard crust containing some friable unsuitable layers.

d) Surface oxidation, expansion and contraction, weakness and embrittlement of stone surfaces are caused by the effects of salt crystallization.

e) Degradation features attributed to human effects through intended damages by damaging the stone surfaces or by using some types of old treatments (*poly venial acetate with high concentration, gypsum, black cement and un-galvanized steel*).

f) Decaying and decomposing some stone features and their mineralogical contents are caused by the effects of bird's by mechanical actions (*scratching and scraping*) and chemical actions (*acidic central points*), these features are shown in Figure 2.

Fig. 2. Showing some *deterioration patterns* affected sandstone of Edfu Mammisi

Weathering graphical profile and deterioration patterns

The representation of weathering forms on the archaeological materials by drawing a graphical profile is an important target. This target presents the relationship between the material microstructure, its durability, their physical-mechanical properties and their decaying process. Weathering graphical profile designed by a computer program (Fig. 3), was performed to imitate the deterioration features affecting the building and to evaluate the relations between dominated factors and weathering products, finally, to choose the suitable conservation action that should be applied.

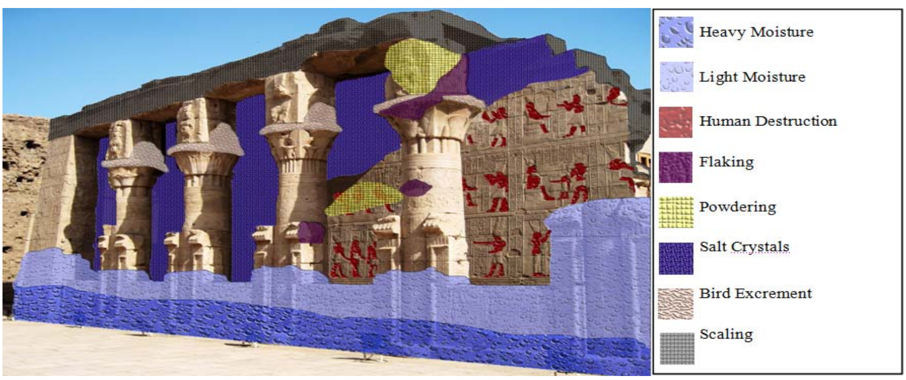

Fig. 3. Showing the front view of Edfu Mammisi after signing *weathering graphical profile*

Sampling and analytical procedures

Some sandstone samples have been collected from the building under study. They have been prepared to be a target for elemental and mineralogical investigations in addition to physio-mechanical characterizations. For chemical, elemental and morphological studies, the collected samples are firstly coated with carbon to make them conducting and to facilitate elemental analysis of features identified morphologically. Secondly, they are examined and analyzed by an energy dispersive X-ray analyzer *EDS INCA300* fitted with a *LEO1450VP* scanning electron microscope (EDS-SEM). In addition, X-ray diffraction (XRD) is used for characterizing the mineralogical studies of the samples and insoluble residue through performed *Shimadzu Lab X, XRD 6000 X-Ray Diffractometer*. Moreover, Leica *Polarizing Microscope* at 50-200x magnification is used for observing different petrographic features, granulometric distributions, structural, textural and optical properties of the samples prepared in thin sections. Within the same context, some hard samples have been cut according to ASTM [47] and prepared in cubes (30×30×30mm) for physical-mechanical studies. They have been smoothed perfectly by carborandum abrasive paper "no 120", washed with de-ionized water and dried in electronic oven in "40^oC for 48h" [48]. Finally, their different physical-mechanical properties (*dry density, total porosity, water absorption coefficient and uniaxial compressive strength*) were measured.

Results

Chemical characteristics

The findings of EDS resulted data have proved that the samples are composed essentially from *Si* as a main element of quartz grains and *Fe* a main element of hematite cement materials. Furthermore, these elemental ratios are affected gradually according to their places and direction. In addition other elements are present *Al, K, Ca, Na, S, Cl* and *Mg* as surface contamination components or weathering products, these data are listed in Table 2. SEM morphological investigations have proved that the grains are characterized by presence of severe abrasive in quartz grains, and spreading of soiling particles and salt layers. In addition, etching of the cement materials is observed as a result of hydrolysis process. Moreover, presence of weakness and brittleness of stone core and some pits on the stone surface can be seen (Fig. 4).

Table 2. Elemental ratios of analyzed stone samples by EDS

Cat.	Samp.	Analytical Results									
		Si	Al	Fe	K	Ca	Na	S	Cl	Mg	Sum
	1	91.59	3.58	--	--	0.4	--	--	4.4	--	**99.97**
First	2	79.6	--	--	2.6	10.1	--	--	7.7	--	**100.00**
	3	77.3	10.5	5.9	0.3	3.48	2.5	--	--	--	**99.98**
	4	55.4	5.6	18.2	4.3	8.3	--	--	8.2	--	**100.00**
Second	5	54.3	36.3	--	0.9	0.3	4.3	--	0.1	3.8	**100.00**
	6	52.3	--	4	3.9	6.3	4.5	3.4	25.6	--	**100.00**
	7	10.2	28.6	--	11.5	0.3	6.2	--	42.3	0.9	**100.00**
Tiered	8	3.05	2.6	--	28.6	8.3	8.4	0.32	45.1	3.62	**100.00**
	9	7.6	12.5	--	8.4	10.6	8.94	0.5	47.5	3.96	**100.00**

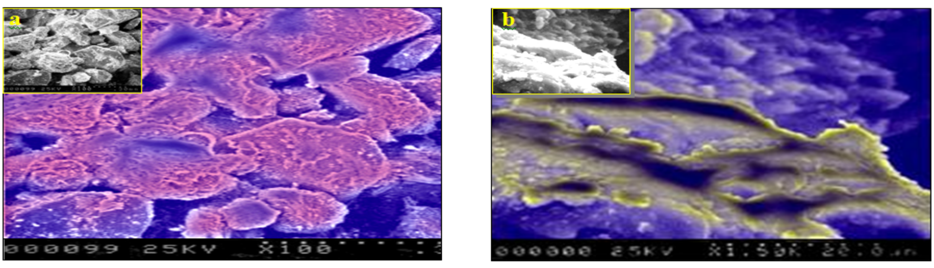

Fig. 4. Fracture quartz and plagioclase feldspar grains (*light red*) cemented by iron oxide (*blue*) and covered by clay minerals (*grey*) (a) and layer of iron oxide mixed with kaolinite or ferruginous clays (*yellow*) covered quartz grains (*light blue*) as a weathering products (b)

Mineralogical characteristics

XRD investigations attest that the samples can be divided qualitatively into three main categories; they are *None-affected samples*, *deteriorated fragile samples and fractured surfaces & weathering products*). Also, it can be divided semi-quantitatively into *Major materials, Minor materials and Traces*, all of these data are listed in Table 3. PM petrological studies have proved that the samples showing fine to medium grain size, with typical presence of relatively common iron oxide (*black*) as a cement material. Furthermore, the presence of very fine grained of clay minerals partially infilling the stone pores; these petrographic features can be shown in Figure 5. On the other hand, the granulometric distribution studies attested that the investigated samples are divided into two main categories; the 1st one contains none affected grains (*angular and sub-angular*) and the 2nd is related to deteriorated affected grains (*rounded and sub-rounded*) as listed in Table 4.

Table 3. Mineralogical composition of analyzed stone samples by XRD

	Detected minerals	**Samples**								
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
Main component	**Quartz** (SiO_2)	A	A	A	A	A	A	A	A	A
	Mica (Hydro Silicate. Al. K. Mg. Fe)	B	--	A	--	--	--	--	--	--
	Plagioclase (Silicate. Al. Ca. Na)	--	--	B	--	--	--	--	--	--
	Calcite ($CaCO_3$)	B	--	A	--	--	--	--	--	--
	Hematite (Fe_2O_3)	C	B	C	--	B	B	--	--	B
	Goethite ($\alpha FeOOH$)	C	B	C	--	--	--	B	B	
Weathering products	**Halite** (NaCl)	B	A	--	B	A	A	B	--	A
	Sylvite (KCl)	--	A	--	A	A	B	A	A	A
	Niter (KNO_3)	--	B	--	--	B	B	--	--	--
	Nitrate (NO_3^-)	--	--	--	--	B		--	--	--
	Kaolinite ($Al_4(Si_4.O_{10})(OH)_8$)	--	--	B	--	--	--	B	B	--

A = *Major minerals* **B** = *Minor minerals* **C** = *Traces* **--** = *Undetectable*

None-affected (samples 1–3) *Deteriorated, fragile samples* (samples 4–6) *Fractured surfaces and weathering products* (samples 7–9)

Table 4. Granulometric distributions of grains defined by PLM

Description Results	Angular and sub-angular grains	Rounded and sub-rounded grains
Grain No. per cm^2	~ 619	~ 265
Percentage **%**	70	30
Minimum measurement **µ**	7.1×7.3	3.7 × 4.8
Maximum measurement **µ**	8.6×8.4	8.2×5.1
Qz content **%**	55.2	10.6
Feldspars content **%**	1.2	1.1
Other minerals content **%**	19.8	12.1

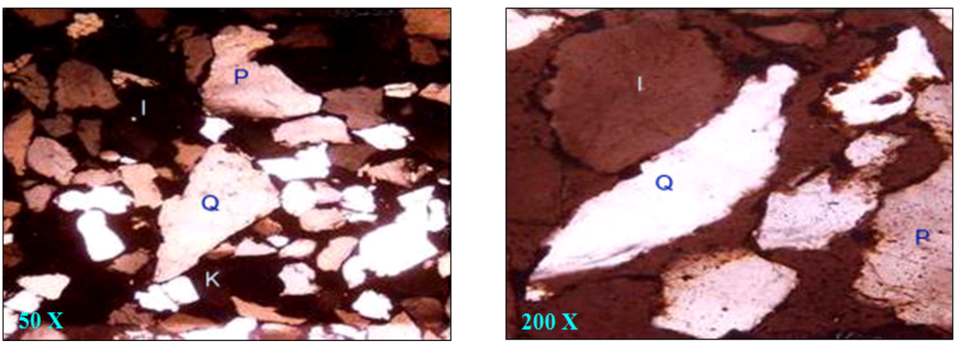

Fig. 5. Showing sandstone samples (**Q**) medium to coarse quartz grains "*white*", (**P**) coarse plagioclase "*light pink*", (**I**) common iron oxide "*dark brown*" and (**K**) very fine grained clay minerals partially infilling porosity "*earthy dark red*".

Physico-Mechanical properties

Different petro-physical measurements have proved that the examined samples are characterized by minor variations between them. In addition they ascertain that the samples are affected by different deterioration factors, these measurements are listed in Table 5.

Table 5. Physico-mechanical properties measurements of reference stone samples

Properties	Results of Measurements		
	Maximum	*Minimum*	*Average*
Dry density "γ_d" g/cm^3	1.90	1.73	**1.80**
Porosity "**η**" %	34.80	29.10	**32.20**
Water absorption "**WA**" %	12.30	10.00	**11.44**
Uniaxial compressive strength "**UCS**" MPa	14.82.	7.86	**12.74**

All experiments are a average of (30) samples

Discussion

The decay processes of natural rocks are well known to architects through many centuries [49]. Through close examination of many studies, it can be said that the recent trends in weathering researches emphasize the importance of clear and precise up of micron-scale processes to link the monumental stone deterioration and rock art conservation [42, 50-54]. These studies have separated weathering influences into two distinctive categories; the 1st category resulted from the effects of intrinsic characteristics of the stone itself (lithologic, constituents and fractures) [49]. The 2nd category is affected by external influences or extrinsic effects (environment, climate, human contact) [4]. Through explaining deterioration patterns (Fig. 2) and weathering map (Fig. 3) it can be mentioned that this work has been crucial in our understanding of some environmental influences on stone decay mechanisms in Edfu royal birth house "Mammisi". These influences contain AT & RH as elements of climatic conditions and man made damages, in addition to aggressive effects of birds, which led to the presence of some dangerous deterioration problems. These problems that affect both chemical characteristics and physio-mechanical properties of stone and led to the presence of negative features, deterioration and degradation forms and different weathering products.

Regarding the climatic conditions dominating in the study area; they lead to different deterioration symptoms through three deterioration mechanisms. The 1st mechanism (*unique effects of RH*), is a key factor of many deterioration processes affecting porous sandstones [33, 56]. This is related to the physical changes in the stone appearances due to water saturation. These changes which create slight darkening on the stone surface are characterized by the presence of few varnished appearances in random areas. These areas seem to be more compact than the other parts of the surface as argued previously by *K. Beck* and *M. Al-Mukhtar* [57]. They are attributed to the presence of high RH content and stone intrinsic materials and mostly characterized by the presence of black crusts mainly consist of calcite and quartz derived from the stone matrix with minor contents of clays, plagioclase and other potash feldspars (mica and microcline) [58]. Furthermore, decreasing of surface roughness in specific areas and occurring of blackish or colored heterogeneously layers cover the monumental surface due to the biological effects as previously noted [59]. Finally, dissolving the salt content both under the ground surfaces and within the stone structures which can be absorbed through capillary rising causing several deterioration forms even when it is mild [60]

The 2nd mechanism (*effects of AT only*), is due to the effects of expansion or shrinkage of construction components caused by thermal processes. This mechanism is depending essentially on linear thermal expansion coefficients of materials which equal 10×10^{-6}/°C in sandstone [35]. This means that this material will expand/shrink by 10 units in 1000000 when subjected to a temperature change of 1°C, or a movement of 200 units per 1000000 for a temperature change of 20°C. According to the dominated temperature values, it may or may not cause enough or complete stress to affect the rock and cause full mechanical weathering as mentioned by [34, 61-62]. Also, it can be noticed that the mentioned aggressive mechanisms resulted by the increasing of temperature degrees especially in summer lead to the occurrence of internal strains especially with the combination of other effects (visible waveband radiation and Infra-red radiation) as reported previously by some authors in similar cases [63-64]. Then, these mechanisms create permanent changes in physical or chemical properties of stone along time, such as weakness and embrittlement at low temperature and accelerated oxidation at high temperature degrees [65]. In addition, the occurrence of some severe stresses, resulted by alternative thermal expansion and contraction actions, appear when changes of size are restrained and strains are imposed on jointing materials [66-68]. Moreover, they may establish and enhance the development of microorganisms [69-70].

The 3rd mechanism is related to the (*alternative effects between AT & RH*) that occur when warm air is cooled or when cold air is heated. It is the most dangerous one; it is created due to the alternative drying (*by heating*) and wetting (*by cooling*) cycles. These cycles represent a micro-scale of climatic condition that affect archaeological building materials, which ranges from a few tens of meters (*for instance, one side of a building to another*) down to sub millimeter scale (*in the pores and mineral boundaries of the rock*) [71-74]. The direct result of this mechanism leads to the salt weathering through the growth of some salt species and weathering products listed in tab (3). These salt spices contain two main categories; they are chlorides and nitrates. Chlorides, include halite and sylvite, it originates from the groundwater and land components through salt-loaded rising damp [1, 75-76]. *Halite* (NaCl) is commonly found in building materials and in the other construction elements, which it can lead in special circumstances to durability problems through severe mechanism [72, 77]. Its crystals can grow inside fractures, on one hand as perfect, smooth-faced cubic crystals mainly as efflorescence at low RH (35 per cent). On the other hand, it tends to grow as waxy, micrometer-sized aggregates filling the stone pores at high value of RH (<60 per cent) [78-79]. Moreover, *Sylvite* (KCl) can lead to enlarging the micro fissures and internal cracks after penetrating within inter-granular spaces of stone pores, in addition to the enhancement of the production of some species of Streptomyces [80]. Nitrates which includes KNO_3 and *nitrate ion* (NO_3^-) are created through the decomposition of organic matters from the ecosystems by high cells numbers of the nitrifying bacteria [23, 81-82], or that present in cultivated lands around the study area. These salts and their related negative/positive actions are synergistic mortal enemies of masonry structures that lead to a multitude of alteration processes [76, 83-84]. These salts are owed to crystallization-dissolution cycles or to hydric and hygric dilation-contraction of materials. In addition they can finally damage porous building materials, especially with presence of other deteriorating factors in surrounded environment such as biological colonization or freezing thaw cycles [85-86].

Regarding weathering products; it can be concluded that the presence of Calcite ($CaCO_3$) in our findings is due to significant calcium loading suction gradient between mortar and stone blocks. It can be subsequently mobilized by percolating moisture to penetrate deeper into the blocks through the balance between the dryness and wetness cycles of the stone as attested by Smith, et al. in their case study [87]. Within the same context, the presence of minor quantities of Kaolinite ($Al_4(Si_4O_{10})(OH)_8$) as microscopic clays within the stone pores owes to on one hand, the susceptibility of sandstone to expansion and contraction through wetting and drying cycles which can break the microscopic silica bonds in the stone structure [88]. On the other hand, this is caused by the enhancement of feldspar alteration through effects of capillary action as demonstrated by magnetic susceptibility studies by some authors [29-30]. The brown color affecting clay mineral may be due to the presence of kaolinite in plate-like particles [23] and to the occurring of iron in the kaolinite structure through groundwater providing or by some iron-bearing minerals in the sandstone itself [89]. Moreover, the accumulation of red/brown matrix minerals as trace weathering products on the stone surface is attributed to the great ability of iron oxide *Hematite* (Fe_2O_3) and hydroxide *Goethite* ($FeO(OH)$) for chemical deterioration than quartz [28]. This mechanism that creates serious weathering products is composed of kaolinite as an essential matter, pigmented by hematite and/or goethite [11]. Finally, the lack of peaks of iron compounds detected in the XRD patterns implies that most of these peaks are in amorphous state such as goethite [90].

The different damages created by human activities presented in Figures 2 and 3, explain that most of them are due to vandalism and wrong conservation processes. These damages are considered some of the most critical concerns for professional archaeologists that lead to destruction of cultural resources [91]. In ancient Egypt, vandalism is a widespread phenomenon affecting many archaeological sites. It is essentially ascribed to some religious belief [92-93], or political ideologies [94]. Furthermore, wrong conservation plays an important role in the deterioration processes attributed to using some types of unsuitable treatments in the rebuilding, particularly nearby foundations with PVA emulsion, gypsum, black cement, and un-galvanized steel as previously argued by some researchers [95-98]. Within the same context, it can be claimed that these processes led to the enhancement of other deteriorations to appear, and so removing many of the ornamental features which are existing on stone surfaces [12, 95]. The proportion of this removal depends on the perdition and the intensity of these factors, in addition to the presence of other deterioration factors [95, 99]. Moreover, the presence of salt damages and the crystallization of some salt species (*Halite*, *Sylvite*, *Niter* and *Nitrate*) affected the rock surfaces, are essentially due to rising of salty water level in the surrounding area [9, 100]. These processes are mostly created through severe alternative hydration and crystallization cycles or through wetting and drying mechanisms, as attested by many specialists [43, 101-102]. As well as the effects of condensation which is owed to the improper tour visits through raising the moisture contents especially within the closed rooms, this symptom had led to the increasing of water vapor average in the building approximately 20-25mm/tourist [103]. Finally, it could be claimed that graffiti is due essentially to the absence of historical and archaeological consciousness.

Regarding the birds effects; the deterioration resulted from them has a clear and direct relation with environmental conditions of the ambient as previously described by *T. Warscheid et al.* [104]. The results of our field observations (Figs. 2 and 3), have proved that birds lead to severe mechanical, chemical and biological effects. Mechanically, by scratching and scraping the stone surfaces with their hoofs or through rubbing their bodies on the walls especially in sheltered areas [105]. Chemically, the deteriorations caused by birds were enhanced and transformed directly on one hand, into full disintegration and decomposition features that affected the stone surfaces. On the other hand, they are transformed into acidic central points that mostly contain *acetic, formic* and *nitric acids* especially by the presence of water sources in high values of RH or even drizzle [106]. These acidic points can be produced and enhanced more and more with the presence of some bacterial and microscopic fungi species [107-108]. In addition, the birds complicated relations with chemical composition of building materials are considered as one of the main sources of bird nourishment such as salts and organic remains [109]. Biologically, the birds lead to unsightliness chemical effects of historical buildings through their acids released from their excrement which can cause irreversible damage to building surfaces [46, 110]. Furthermore, another type of deterioration is created by leaving some organic deposits on stone surface creating high nitrogen levels, then nitric acid; also encourage many species of fungi and different lichenin species to develop [35, 111-112].

Concerning the laboratories analytical results and morphological studies, as it can be seen in table 2, the investigated samples are classified into three categories according to the aggressiveness of the weathering effects. The 1st category contains *semi-weathered* samples, where the main components of sandstone are Si (82.84%), Al (3.58%), Ca (5.2%), Mg (0.6%) and Fe (1.96%) in a grand total of 94.18% and the weathering products Na (0.83%), Cl (4.03%), K (0.96%) and S (0.0%) with about 5.82%. The 2nd category contains *weathered* samples; in this category the analytical ratios of chemical constituents are varied partially due to the effects of multi deterioration factors dominating the study area, where sandstone main components are Si (54.06%), Al (13.96%), Ca (4.96%), Mg (1.26%) and Fe (7.4%), these are decreased and recorded 81.64%. The weathering products Na (2.93%), Cl (11.26%), K (3.03%) and S (1.13%) are increased, recorded as 18.35%. Finally, the 3rd category contains *Fully-weathered* samples; its chemical components are completely different due to the synergetic deterioration factors affecting the building materials, where, the main components of sandstone Si (6.53%), Al (14.56%), Ca (6.4%), Mg (2.82%) and Fe (0.0%) are low and recorded as 30.31%. On the other hand, weathering products Na (7.84%), Cl (44.96%), K (16.6%) and S (0.27%) are enhanced and recorded as 69.67%. According to the clinical history of this stone type [100], it can be decided that this category was highly affected by many deterioration agents either pre or post-emplacement. These effects are most clearly seen through some chemical alterations as previously attested by several specialists in similar cases [113-117]. In Figure 4, proves that Qz grains transforms into a ball of hardened sand due to the effect of deterioration mechanisms as argued before by Cull [118]. Moreover, the spreading of soiling [119] and salt layers [120] are mainly due to the alternative cycles of crystallization and hydration. In addition, the presence of cement materials, etching, brittleness symptoms, and some pits resulted through a hydrolysis process. All of these results completely cope with the others proved by Friolo, et al. in their case especially in the elemental peaks intensities that are responsible for weathering products Al, Na, Cl, K and S [89].

Within the same context the data of mineralogical characteristics presented in Table 3 indicate that the sample compositions are matching with the SEM-EDX results. The stone major components are quartz (SiO_2), hematite (Fe_2O_3), goethite (α-FeOOH) and calcite ($CaCO_3$) [121]. These components have been affected by deterioration processes and they decreased consequently as major minerals from the 1st category to the 3rd. Qz grains were highly affected by weathering mechanisms that decrease its percentage to 65.8% compared to the ideal one ranging from 81.3% to 86.5%. Conversely, the weathering products include halite (NaCl), sylvite (KCl), niter (KNO_3) and nitrate (NO_3^-) these have increased from nothing to major or at least minor minerals recorded as 34.2%. Moreover, the presence of other matrix minerals in the samples kaolinite ($Al_4(Si_4O_{10})(OH)_8$), mica (hydro silicate with Al, K, Mg and Fe) and plagioclase (silicate with Al, Ca and Na) led to the creation of a high open porosity infilled by iron oxides, carbonate and clay minerals. The same results were confirmed by petrographic investigations (Fig. 5), where, it can be seen that the samples generally have a high quartz content and an open pore structure with a very low content of clay minerals. These minerals are characterized by the presence of typical well angular and sub-angular grains, in addition to the presence of some rounded grains [122]. Thin coating of iron oxide composes the essential framework of the grains giving the reddish color to the stone as referred by *S.A. El-Sherbiny* and *S.K. Amin* [123]. The presence of other minerals with low percent such as potash feldspar indicates that their occurrence is due to the geological structures characterized sandstone quarries [124]. The presence of kaolinite in fractured surfaces and weathering products with more than 20% is attributed to the alternative beds of clays and Nubian sandstone characterized by stone quarries in Upper Egypt [125]. Furthermore, the data presented in Table 4 show that the samples have grain sizes ranging from fine to coarse as previously mentioned by other scientists [124, 126-127]. These grains are devised into two types; the first one contains angular and sub-angular grain shape; they are estimated by 70%, its main diameters vary form 7.1×7.3μ as a min and ø - 8.6×8.4μ as a max ø. The second type includes rounded and sub-rounded grains which are estimated by 30%; their diameters are varied between 3.7 × 4.8μ as a min ø - 8.2×5.1μ as a max ø. The texture of second type resulted by contained natural weathering cycles that affected angular and sub-angular as previously discussed by *D. Dragovich* and *G. Susino* [128].

Regarding physical-mechanical properties of the stone, it can be argued that these properties are more or less liable to a decay process and estimating the weathering state of the building under study [120, 129-131]. The findings of these studies, Table 5, indicate that these properties are highly affected by different weathering agents. These agents include rock fabric of the stone, chemical and mineralogical characteristics, digenetic changes, as well as the dominated environmental factors [132-134]. It can be concluded that the *density values* vary between 1.895g/cm^3 as a max. recording and 1.731g/cm^3 as a min. recording, compared with the fresh samples of the same stone types that vary between 2.65 to 2.67g/cm^3 [135]. These differences are mostly due to the effects of weathering factors dominating the area, or can be related to the mineralogical composition, porosity and pore-size. This may be explained through noticing that the stone which has a lower open porosity has a highest bulk density and vice versa. In addition, the stone that has a heavy or compacted mineral content has a highest bulk density and vice versa, as noted by in a similar case [21]. Furthermore, this highest bulk density value is also correlated with large amounts of non-carbonate minerals, especially ferrous and argillaceous cements [21, 136]. Porosity is estimated typically at 29-35%, and generally open or locally unfilled by iron oxides mixed with clay minerals. This range is in accordance with the previously measurements made [124], where it ranges in the fresh samples between 13.6% and 30.73%. From a scientific point of view increasing of porosity index both in minimum and maximum values may be attributed to the effects of various digenetic, physical, chemical and mechanical processes [137]. They are also probably caused by the apparition of micro fissures, increasing pores specific surface or to the increasing of mean pore diameter [138]. The influence of different weathering sources as salts, leaching, dissolution, erosion etc., lead to the changing of the stone porosity through time, especially in the subsurface layer [139]. Specifically, porosity is related to the weathering agents workability through flowing of the solutions and remaining moisture in such a way that finally produces a negative influences on stone durability [140-141]. On the other hand, pore structure is an effective parameter that enhances the negative role of crystallization process within the stone materials. This process is depending on the energy differences between the crystals, pores and the pore diameter [77], where, narrow pores attract a higher moisture than wide pores [142]. Furthermore, it should be noticed that both porosity and pore structure are linked parameters and they are mostly responsible for the enhancement of different deterioration mechanisms particularly salt crystallization [143]. Moreover, the effect of thermal expansion affects quartz grains [144] that finally lead to the development of internal fissures and micro fissures especially at high temperatures generated from a grain to another [64]. Water absorption is one of the most important hygroscopic properties of building materials [145-147]. This index may be attributed to both high number and noticeable size of micro pores that have radius more than 2μ, which play an important role in the deterioration processes. This role takes place in two ways: the 1st generates the highest affected capillary forces [148], and 2nd facilitates the damaging actions of other deterioration agents, especially accumulating more salt species within the stone pores. Both of them lead to even more serious decay [6, 149]. Capillary absorption coefficient is one of the most dangerous factors that affects stone durability, especially when the cause of damage is salt crystallization [141]. It is very much linked to other parameters as pore structure, pore geometry and the fluidity. The results of laboratory measurements listed in Table 5 proved that the stone samples are characterized by a higher mean of water absorption capacity of 11.44%, which may be owed to two essential factors: primary is the direct factor, it is attributed to the presences of sufficient quantities of clay minerals that absorb different ions from different water sources [150] and secondary, is due to the increasing porosity in kaolinite and the degraded feldspars relatively to that in un-weathered sandstone [151]. This increase which strongly influences the deterioration of the sandstone is due to the swelling/expansion property [152].

Mechanical properties of archaeological stones which are affected by weathering have been rarely studied compared with chemical and physical ones [153-157]. These properties are negatively affected by weathering factors [158-159]. It is well known that the decreasing of mechanical properties in decayed stones is mostly due to many deterioration factors particularly the negative intrinsic effects as grains types and cement materials [160]. In addition, they may be due to several extrinsic factors as thermal expansion, moistures and salt crystallization [101, 161]. UCS measurements prove that the average of the investigated samples is 12.74MPa and the highest measurement is 14.82MPa, lowest 7.86MPa, compared to the ideal compressive strength value estimated by 17.5MPa. From this point of view, it can be decided that this low value is attributed to three factors; the 1st one is the presence of fine to medium clay grains composed of kaolinite pigmented by iron oxides. The 2nd is the effects of water infiltrations which has a negative influence on the overall resistance of the stone, or it is caused by salt crystallization mechanisms [141, 162]. The 3rd factor is related to the negative resistance that could be owed to the alternative effects of moisture and temperature changes, which undoubtedly cause disruption within the pore structure [21]. Finally, investigations of historic buildings are essential tasks which can be achieved to correlate their reduction strength and appearance changes due to different reasons, either extrinsic factors (environmental impacts, man made damages and biological factors) or intrinsic ones (mineralogical phase changes, improper designs).

Conclusions

Mammisi of Edfu is located in the South-West side in front of the temple's pylon and it is built of Nubia sandstone. The building was exposed to some effective factors that led to accurate deterioration mechanisms on its stone structure. These factors are the alternative cycles between AT & RH, human activities and bird effects. These mechanisms have led to the creation of some aggressive deterioration symptoms such as the presence of some stress and strains, growing of some salt species, etching of minerals edges and dissolving its cement materials. In addition some colored hard crusts have appeared friable, unsuitable layers, oxidation, expansion and contraction, weakness and embrittlement of stone surfaces. Furthermore, decaying and decomposing of stone features and their mineralogical contents. This experimental study attests that the deterioration features are divided into three categories; there are none-affected areas, deteriorated and fragile areas, and finally fractured surfaces and weathering areas. All of these areas contain their distinguishing products that vary among major and minor traces. Within the same context, it can be argued that all factors and ambient conditions dominating the study area, in addition to related physical-mechanical properties, are the key factor of many deterioration processes affecting porous sandstones in the selected monument. Finally, further study is required to enhance a scientific plan for treating and consolidating the affected stone of this monument, taking into consideration the suitable materials and application processes.

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