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THE ENVIRONMENTAL FACTORS AFFECTING THE ARCHAEOLOGICAL BUILDINGS IN EGYPT "*III DETERIORATION BY SEVERE SEISMIC HAZARDS*"

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Abstract:
This paper is a diagnostic study and it is the 3rd in a series of scientific articles which investigate the environmental factors that affect the archaeological buildings all over the country (Egypt). It explores the Nektenebo II temple in Bahbit El-Hagar, which is one of the most significant archeological sites in Pharaonic Egypt. It is particularly selected to assess and evaluate the deterioration conditions, which affect its components. The temple has an aggressive harmful deteriorated appearance because of severe seismic actions, especially earthquakes and unstable lands. Thus, the site is investigated via close inspection and a complimentary survey (CICS) to check the decay conditions that resulted from the severe effects of seismic actions. Moreover, it investigates some samples collected from the aforementioned monumental site using certain techniques, such as PM, SEM-EDX and XRD, in addition to define the effective physio-mechanical properties to identify the deterioration products caused by secondary environmental factors. The results asserted that the deteriorated appearances that dominate the study area are mechanical destruction (cracks and micro fissures) as well as other deterioration symptoms, such as salt crystallization, soiling and crusting, as well as crumbling and scaling.

1. Introduction

Ancient masonry structures in the Mediterranean basin countries are at risk due to dynamic actions, especially earthquakes and the presence of various ancient monuments. In Egypt, many monumental sites and stone buildings have several extrinsic and intrinsic factors that negatively affect the deterioration processes [1-4]. Such factors include temperature variation [5, 6], relative humidity [7], wind erosion [8], air pollution [9-11] and sismic actions [12]. All these factors caused great harmful appearance because of chemical, physical and biological mechanisms [13,14]. Earthquakes and/or ground shaking are considered among the typical geodynamic phenomena of hazardous nature that have affected nature, life and man-made structures. These actions have greatly influenced multiple regions characterized by seismic activities throughout the world [15]. From a diagnostic point of view, earthquakes substantially affect durability of historic buildings because they suddenly occur, particularly in seismic areas [16]. Furthermore, they cause immense damage to the three dimensions of cultural properties and historic buildings [17]. This damage depends on the amplitude and the duration of shaking during the dynamic movements, the structure's design, the materials used and the structural behavior of the building itself [18,19]. It involves several types of cracking, crushing, bending failure, loss of integrity, collapse of parametric and structural walls or complete collapse of the building [20,21]. In this paper, the temple of *Nektenebo II in Bahbit El-Hagar*, which is one of the most significant archeological sites in Pharaonic Egypt, is selected to evaluate its deterioration conditions that resulted from severe seismic actions.

1.1. *History of Nektenebo II temple in Bahbit El-Hagar*

Nektenebo II temple is located in the middle of the Nile Delta, about 8.5 Km., fig. (1-a) from Samannoud town "the ancient capital of Nome XII of Lower Egypt" in (31° 02′ N, 31° 17′ E) [22-25]. The temple is located in the modern village of Behbit el-Hagar, which is known in hieroglyphic as (*tb-nṯr*), fig. (1-b). This village is one of the most well-known ancient towns belonging to the 12th region in Lower Egypt [23, 26]. According to Favard-Meeks [27], the temple and its architectural features, fig. (1-c) are very important Egyptian archaeological sites that were investigated by De bois Ayme and Jollois during the French expedition in chapter 25, volume 5 of *Déscription del' Egypte*. They drew different maps for the temple site and its surrounding area as well as defined its boundaries by 362 m. long and 241 m. wide. Moreover, they stated the presence of some architectural remains, whose measurements are 18-20 m. high and 9-10 m. thick, in addition to 4 open areas from the west side, 1 from the southern and the other from the northern side.

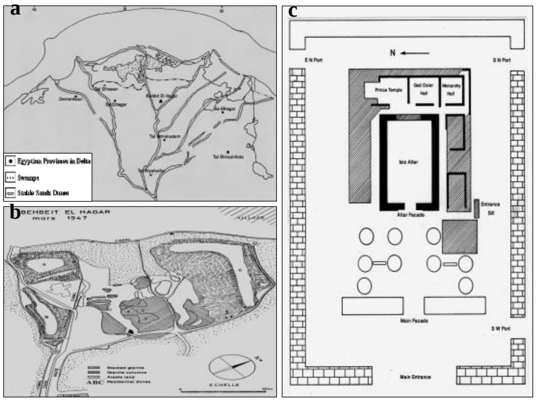


Figure (1) Shows **a**. map of Behbit el-Hagar in El-Gharbia governorate, **b**. map of *Nektenebo II temple* area, **c**. features of *Nektenebo II* temple

1.2. *Pathology and geotechnical features of building material*

The temple is built from red coarse grained granite belonging to Aswan quarries characterized by normally pinkish color with abundant pink porphyroblasts [28]. Geologically, this type belongs to (*Precambrian formation*) and it is one of the three main types of the Egyptian bedrocks [29] belonging to the two fundamentally different tectonic provinces, i.e. the *Arabian Nubian Shield* in the east and the *Saharan Metacraton* in the west [30,31], fig. (2). It is characterizes by the presence of small feldspars, quartz and dark ferromagnesians, and small crystals of apatite [32]. In addition, it is hard and compact with dense cores grain and color varies between gray to pink according to its essential mafic contents, such as, microcline, orthoclase biotite, and plagioclase. Moreover, there exist some accessory minerals, such as zircon [33]. Morphologically, this type of stone was highly affected by alteration and decomposition processes due to many decaying factors and poor condition in the study area [28]. Geotechnically, four of the main physio-mechanical properties were assessed using 5 samples for each test. El-Gohary [34] reports that they are density (**γ_d**), porosity (**η**), water absorption (**WA**) and compressive strength (**UCS**). The results proved that the main average of (γ_d) = 2.71 g/cm^3, (**η**) = 0.81 %, (WA) = 0.079 % and (UCS) = 104.3 MPa, respectively, as argued previously by Wahab, et al [35].

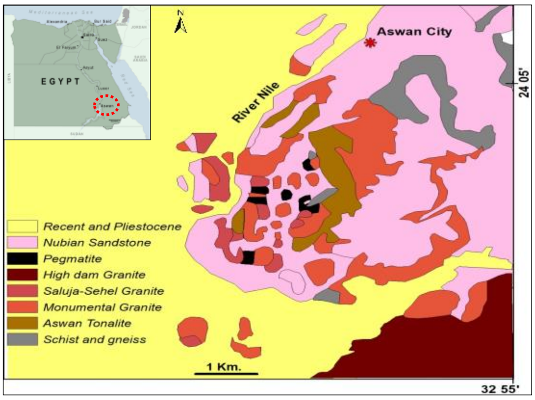


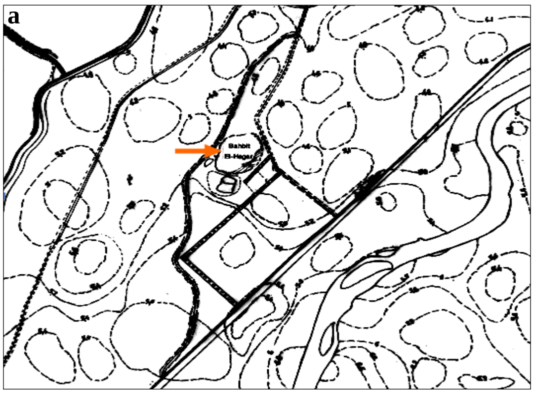
Figure (2) Showing map of granite quarries used in the study area belonging to *Precambrian formation* (*modified after Dixon & Golombek 1988*)

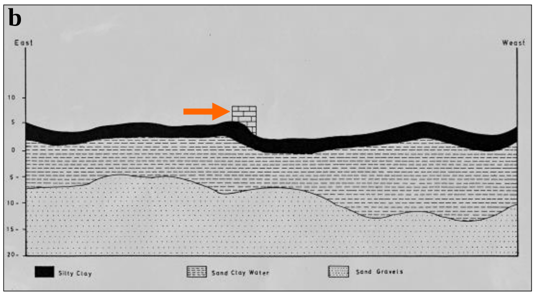
1.3. *Environmental situation in the study area*

The environmental situation of the archaeological areas should be considered when addressing the effects of different deterioration factors [36,37]. The temple site presents intensive weathering indicated by the presence of several weathering forms as will be mentioned in macro and micro deterioration processes section. From this point of view, the environmental context in the area should be divided into (2) essential parts, as follows:

1.3.1. Topographic features affected the study area

Nektenebo II temple, fig. (3-a) was built on the part of the existing Nile Delta, which is essentially composed of sand and gravels covered by layers of clay. These layers were formed through the last 7000-8000 years by Nile floods [38]. For defining these features, topographical survey was conducted using digital Theodolite to find out the specific topographical contour map and land levels of the area. It proves that it is characterized by several structural units and features, as follows: Presence of some lower sites below the surrounded cultivated lands at about 1.42 m., some canals and ditches that serve cultivated lands in this area that lead to leakage of the domestic waste water and its aggressive salts under the temple, as well as high quantities of clay assessed by 15-20 m. and bordered by a hill composed from sand and gravels, fig. (3-b, c).





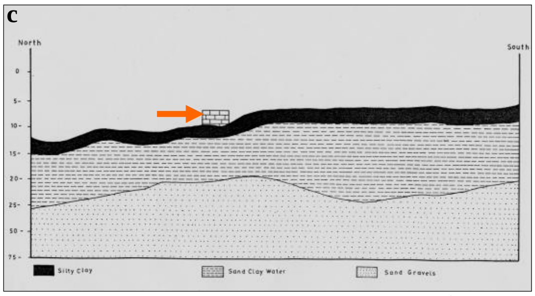


Figure (3) Shows **a**. topographical map of temple area, (*After, El-Gohary, 1996*), **b**. west east direction **c**. north south direction of lithographic section of temple

1.3.2. Geological framework of the study area

Nile Valley is characterized by three geomorphological units: ***)** the young alluvial plain, ***)** older alluvial plains, ***)** the limestone plateau. Pleistocene sediments are surrounded on both sides of the modern floodplain and form elevated terraces with elevations ranging from 25 and 100 m. Geologically, the area is mostly covered by sedimentary rocks from Quaternary period, fig. (4). According to Saʿīd [39] and Abotalib and Mohamed [40], the deposits of this period are of fluvial origin and include Pleistocene sediments and Holocene Nile silt. The Pleistocene sediments are composed of sand and gravel intercalated with clay lenses and have variable thicknesses. The study area is covered by Holocene Nile silt and clay deposits, which vary in thickness from 0 to 20 m. According to El-Gamili and Shaaban [41] and El-Gohary [36], the lithographic sections under the temple and its surround area are characterized by the following layers

- ***)** Superficial layer of ground with unique thickness. It extends from east to west, varies between 1-2 m. with average 1.4 m., and is composed essentially from mud, muddy silt and silt.
- ***)** Layer with thickness ranging between 4.5-14 m. It is essentially composed of the same silty material that filled the ancient Nile branches.
- ***)** Layer differs from the previous because it is characterized by greatness of its grains, especially towards the bottom

direction which was thought to have composed the ground water table in this area.

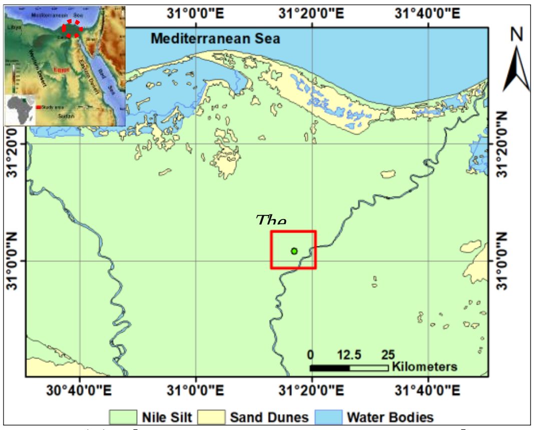


Figure (4) Shows geological map of the study area

2. Seismic Hazards Affected Nektenebo II Temple

The Mediterranean area is well known for its archaeological richness as well as frequent earthquakes. Many recent studies in the region are the result of collaborative work of archaeologists, seismologists, geophysicists and engineers [42]. These studies focus on finding the archaeological, geological and geomorphological evidences to identify whether or not an earthquake caused the destruction of the archaeological sites [43,44]. In this regard, these studies should contain two main branches of earthquakes effects: *Macro* zoning and *Micro* zoning.

2.1. *Seismic hazards affecting Egyptian land (Macro zoning)*

Seismically, Egypt is located in a continental fracture system (*Hellenic arc*) at the convergence boundary of two big lithospheric plates (*Eurasia & Africa*) [45]. In addition, it is affected by the opening of the Red Sea (*Mid Oceanic System*) and its two branches (*Gulf of Suez and Gulf of Aqaba*). Accordingly, it is claimed that although destructive earthquakes occurred infrequently, the grave consequences cannot be ignored. Furthermore, the geomorphological features and soil composition of Egypt, as a part of the Mediterranean area, had been influenced by the properties of the Nile Delta and its moisten land, which had seven major tributaries that formed the eastern and western boundaries of the delta area during Pharaonic times [46,47].

2.2. *Seismic hazards affecting* the temple area *(Micro zoning)*

In spite of the general recording of different ancient Egyptians earthquakes (*nwr-tꜣ*) as major deterioration factors, several sites and monuments were exposed to disastrous seismic events that occurred in Pharaonic times [48]. More than half of these earthquakes affecting Egyptian structures in the Nile Delta originated from epicenters outside Egypt [49]. These earthquakes are generally considered large magnitude earthquakes in the *Hellenic Arc*, *Red Sea* and *Dead Sea* systems [50-52]. They include Hellenic Arc earthquake in 365 July which affected al-Manzala, and east of the Delta between Damietta and Port Said. In addition to the 951 September earthquake that negatively affected local zones in this area. Other earthquakes, such as the earthquake dated August 1303, destroyed some areas in the Delta and several sites. The major one that occurred in October 1856 led to substantial damage through tumbling down old walls in this area, especially in Tanta and Damanhur near *Behbit*. The 1863 earthquake is considered a destructive one due to its great effects, the Red Sea earthquakes affected many recorded ancient places in Egypt, and the 1969 earthquake caused some typical damages in Kafr al-Shaikh, al-Gira, Damietta and Dakahliyya in the northeast of the Delta beside the area under study. Investigation of the detailed seismic analyses of the site is an important procedure to analyze the area of study in order to perform the so-called micro-zoning [53]. Micro-zoning is a process that evaluates seismic input in the selected area, which is characterized by specific geological, geomorphological and geotechnical characteristics. This process was conducted to explain the seismic actions that affected the temple area. The study output proves that the study area was affected by numerous severe earthquakes, especially in the middle ages and in modern times [54,55].

According to both Favard-Meeks [23] and Bataille [56], a typical and strong earthquake occurred in 27 BC., and caused heavy damages in many Pharaonic sites, such as *Behbit el-Hagar* temple. It caused a full collapse of the temple architectural features. The huge pile of fallen blocks does not show heaps of debris or other traces of quarrying activity, but the temple seems to have collapsed on itself. Furthermore, two main earthquakes affected the temple: The first occurred after the 2nd century BC, and the second took place during the early 19th century in 1897. Severe destruction mechanisms that affected the temple are due to unstable and damping land as a minor deterioration effects. These effects led to some severe deterioration mechanisms as ground motion, faulting, landslides, cliff collapse, mass-wasting movements and liquefaction [57]. All of these varied actions caused collapse and complete destruction of the whole building structures under its own weight and using its location later as a quarry by the local inhabitants as mentioned by [25,58].

3. Materials and Methods

According to some authors [59-61]; these scientific experiments aim to assess the geo-engineering problems that affected the temple architectural units, the actual conditions dominated in the temple area as well as the different architectural characteristics of the temple and its surrounding area. In the present section, some in-situ investigations were carried out in and around the temple using CICS technique (*close inspection and complimentary survey*) as well as some handy and electronic measurements. These procedures employ micro-zoning process to evaluate seismic input in the selected area. Moreover, some laboratory investigations were conducted to evaluate the deterioration state of the temple stone blocks. Petrographic description was conducted using *Leica DLMSP* polarizing microscope to define the mineralogical composition of stone samples through the recognition of their optical characteristics. *EDAX-Oxford* unit equipped with *JSM 5300* Scanning Electronic Mic*roscope* was performed to define the elemental composition and its different ratios as well as the morphological characteristics of stones. The mineralogical composition of some crushed stone samples was determined using XRD unit model *Philips PW 1840 (CuKα/Ni) diffractometer*. Finally, some effective physio-mechanical properties of deteriorated granite samples (*density*, *porosity*, *water absorption* & *compressive strength*) were defined to evaluate their influence by the weathering processes. The purpose of these investigations is to evaluate deterioration forms and their weathering products resulting from the effects of the dominating environmental factors.

4. Results

The results of the study demonstrate some critical aspects concerning archaeological constructions, in general, and our case study, in particular. These aspects are concluded, as follows:

4.1. *Macro and micro deterioration processes affecting the temple*

Using (**CICS**) showed that both macro and micro deterioration factors led to total disintegration of the monumental buildings and their different architectural components [62,63]. Seismic actions, as macro agents, are the most destructive factors affecting the archaeological buildings [42]. Weathering as micro agents may also cause a rapid change in the initial petro-physical properties of rocks and so limit their durability index [64]. Our case study was highly affected by both *micro* and *macro* deterioration factors along time. It is still exposed to other harmful forces, especially the ones related to theft and vandalism [36]. The results of field site observations demonstrate the following: Direct effects of seismic actions, such as ground motion, faulting, collapsing and complete destruction of the whole structural elements, especially some columns, entrances and thresholds, fig. (5-a); sliding and overlapping of granite rock blocks and detachment of some layers (scaling and flaking forms), fig. (5-b); indirect effects such as crystallizing of some salt species owing to water evaporation process, fig. (5-c); mechanical destruction due to the alternative cycles of freezing and thawing (*frost actions*), fig. (5-d); presence of some biological and microbiological colonization that creates a suitable environment for lichens and wild bees, fig. (5-e) and growth of some species of higher plants (*barssica nigra, chene podium, cylindrica imperata and savada monica*) that cause some mechanical deterioration forms due to plant growth (*aggressive cracks and micro fissures*). Also, there are effects of chemical deterioration forms through sap roots (colored crusts on stone surfaces), fig. (5-f) .

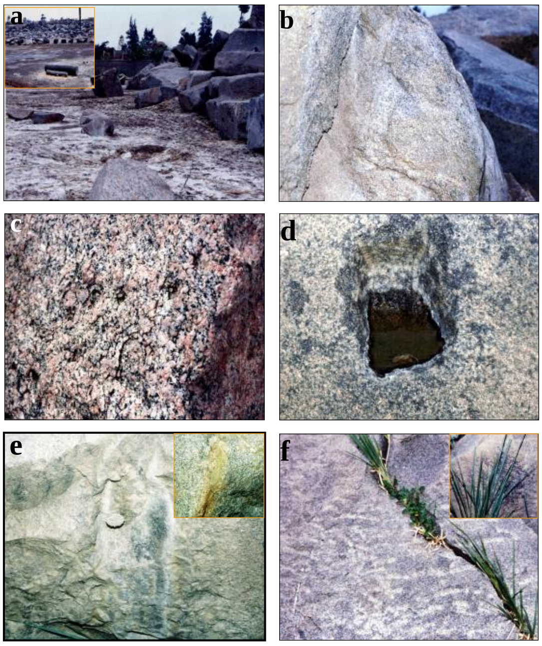


Figure (5) Shows different deterioration forms dominated in the temple of Nektenebo II in Behbit el-Hagar

4.2. *Petrographic results by PM*

The investigation results assert that the essential components of the samples are *Plagioclase, Orthoclase, Quartz, Biotite* and *Zircon.* In addition, there exist some degraded minerals, such as *Chlorite* (green color), as well as other minor minerals, such as *Kaolinite* (gray color), *Epidote* (pale greenish-yellow), *Zoisite* (blue color), and *Saussurite* (light red color) which resulted from weathering processes affecting the main components of the temple stone blocks, figs. (6-a, b, c, d).

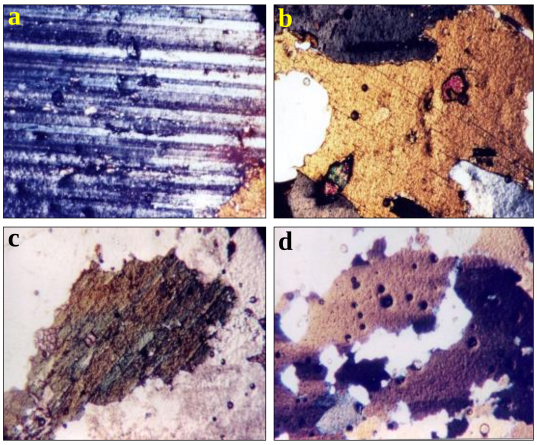


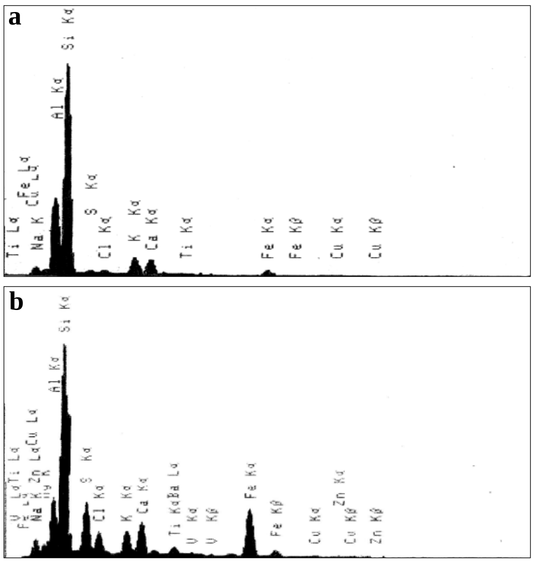
Figure (6) Shows different petrographic features characterize the studied samples in the temple of Nektenebo II - (all 60-X)

4.3. *EDX-SEM results*

The investigations have shown that the samples are composed of several elements which are listed in tab. (1) & figs. (7-a, b). Within the same context, SEM remarks indicate that they are characterized by obvious disintegration and decomposition in mica cheets. In addition to brittleness and weakness appearance, the elemental charts and SEM photomicrographs are shown in figs. (7-c, d).

Table (1) The elemental ratios average of investigated granite samples

Samples	Elemental composition							
	Si	*Al*	*Fe*	*K*	*Ca*	*Na*	*S*	*Cl*
S-1	67.25	11.16	09.44	05.16	04.63	02.36	-	-
S-2	54.80	07.55	05.16	08.60	06.28	02.32	03.59	11.70



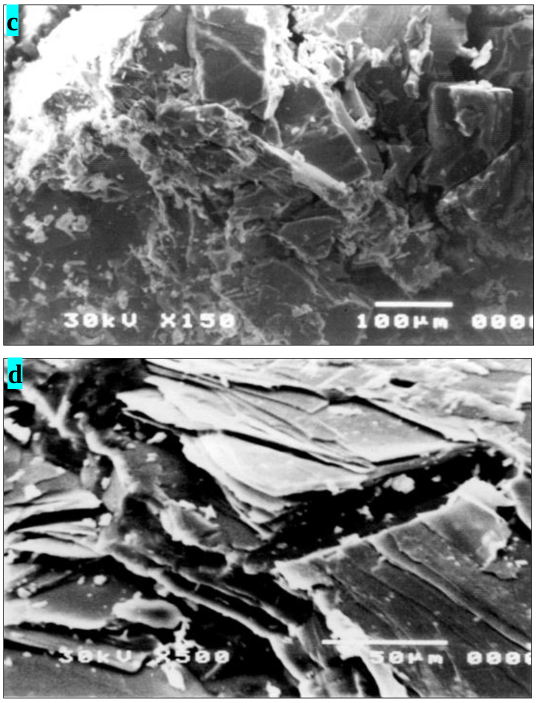


Figure (7) Shows **a**, **b** EDX charts and **c**, **d** SEM photomicrographs of investigated samples in the temple of Nektenebo II

4.4. *XRD results*

XRD results show that the main components of the investigated samples are Biotite [$K(MgFe)_2AlSi_2O_{10}(OH)_2$], Albite [$NaAl\,Si_3O_8$], Mica [$KAl_2(AlSi_2O_{10})(OH)_2$] and Orthoclase [$KAlSi_3O_8$] as major minerals; QZ [SiO_2] and Microcline [$KAlSi_3O_8$] as minor minerals and traces of Zircon [$Zr(SiO_4)$], as shown in figs. (8-a, b).

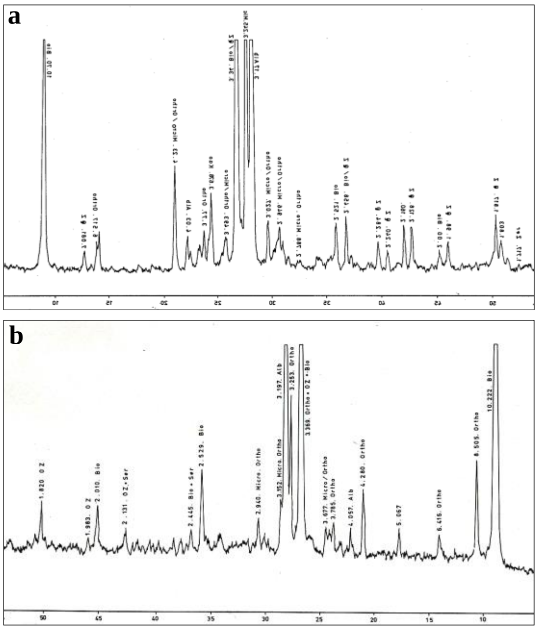


Figure (8) Showing XRD patterns of investigated samples in the temple of Nektenebo II

4.5. *Physio-mechanical properties results*

The geotechnical study of deteriorated granite (5 samples) adapted for evaluating the same physio-mechanical properties of the original mentioned above proved that all of these properties were negatively affected by weathering processes. Where, density (γ_d) = 2.58 g/cm^3, porosity (η) = 4.98 %, water absorption (WA) = 2.36 % and uniaxial compressive strength (UCS) = 76.08 MPa respectively. These results are shown in figs. (9-a, b, c, d).

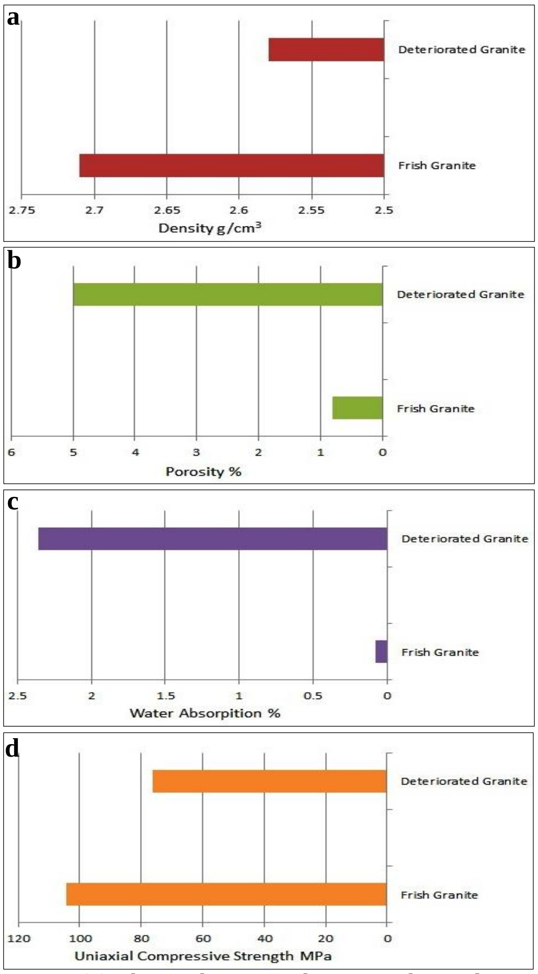


Figure (9) Shows the main physio-mechanical properties of fresh and deteriorated granite samples

5. Discussion

The analysis of ancient monuments poses serious challenges due to complexity of their geometry, variability of their materials properties [65], their building techniques as well as lack of knowledge on the existing damage that resulted from different earthquakes [66]. It is well known that the large scales which were carried out to detect and quantify the deterioration mechanisms on the temple blocks proved that these blocks were highly affected through aggressive environmental conditions as attested previously by many authors [67-70] in similar cases. From this point of view, it could be asserted that there are two essential categories of environmental conditions that affected the temple: *seismic actions* which are the major reason for the temple collapse and some *ambient deterioration factors* which are the secondary cause of the temple deterioration. *Seismically*, due to the heterogeneity of masonry structure materials, the generalization of their degradation is impossible because their properties and behavior greatly change [71], particularly under different actions [72]. Hence, the historical investigations help characterize and analyze the origin of the structure and its vicissitudes, in particular. Based on the available data collected by means of field assessment, it is asserted that the temple was highly affected by the two main earthquakes, which led to severe structural deterioration forms, especially with the presence of abundant ability of weathering out depending on stone structures. Moreover, the amount of damage depends on various factors: the size of earthquake, distance from the epicenter, terrain, structural design of buildings and the ground hydrogeological conditions, …etc. as argued previously by Sawires et al. [73]. The first earthquake probably took place around the year 27 BC at latitude 29.3, longitude 26, with magnitude 5.6 and intensity VII. According to Dowrick et al. [74], it is classified as a very strong earthquake which had approximate acceleration = 100 cm/s^2 which is equal to 6.1 degree on Richter Scale, and it mostly led to some initial deterioration mechanisms in the study area, such as ground motion and faulting. *Ground motion* is an action based on amplitudes as well as frequency content of both local and distant seismic sources in addition to local soil conditions [75]. Also, it depends on other important factors: strength and deformability characteristics of the materials, interaction between the local soil and the structure [76], dynamic properties of the structure, damping capacity dominating the area due to the weakness of the properties of soil mechanics, as well as the presence of some channels and passages connected with two of the historical Nile branches (*Phatmetic Mouth & Sebennytic Mouth*) under the temple area, fig. (1-a) [36]. *Faulting* is one of the six major effects caused by the earthquakes that lead to direct damages. According to Noller [77] and Marco [78], it is a process that defines the deformation of archaeological buildings as well as damage and dislocation affecting archaeological structures as previously affirmed by Lambers et al. [79] and Premo [80]. In this regard, the active faulting process was an important mechanism that affected the damage of temple area due to the 27 BC earthquake and facilitated the destruction of the whole building structure. The second earthquake, which precisely occurred on 11 July 1879 at latitude 29, longitude 33 with magnitude 5.1 and intensity VI, was classified as a strong one due to its damage resulting from overturning and falling stone blocks. It had approximate acceleration = 50 cm/s^2 equal 5.4 degree on Richter Scale. It also led to the severe and the definitive degradation forms, such as collapsing, sliding and detachment of the temple architectural features. Collapse of a building, as a whole, cannot be conventionally defined as *collapse of a single element* because each element may have a different role in the resistance of the whole structure [81]. According to Augusti and Ciampoli [82] as well as Arıoglu and Acun [83], several collapsing mechanisms of each macro-element in addition to the collapse factors should be investigated to evaluate their deterioration levels. In this regard, conducted in-situ tests provide some information about the *collapsing* state of the temple which briefly contains some structural features of the temples (*façade, nave walls, arches and lintels*) [36]. Augusti &

Ciampoli [82] also reported this in their case study. However, it is noticeable that these features had been affected without micro fracturing (*topple off.*) due to a predominant period of ground motion and the structure dimensions [84]. Both of these two variables significantly affected the case study, particularly during the second earthquake that was characterized by low frequency, the response and the possibility of collapse with low frequency earthquakes [85]. Within the same context, the most common features are cut-off the temple corners, displaced columns and broken stone elements [86]. *Sliding and overlapping of granite rock blocks*, fig. (5-b) are other dangerous deterioration forms that resulted from high-frequency earthquakes. On one hand, sliding of the collapsed elements is close to the upper part of the structure [85]. In our case, structural sliding is one of the main deterioration forms that affected the temple's structural elements (*columns and lintels*). In this regard, it occurs when the intensity of motion owing to violent shakings becomes significantly great, as had been the case during the second earthquake as affirmed by Omori [87]. On the other hand, overlapping is a degradation form which is mostly caused by distribution of spectral accelerations [88]. In the study area, due to the presence of notable alluvium thickness, this form was noticeable and enormously affected the stone blocks. These effects that led finally to splitting cracks appeared especially along the overlapping length [89]. *Detachment of some layers (scaling and flaking forms)* represent serious deterioration forms [90] that affected the stone blocks of the temples. Scaling is a physical weathering form resulting from chemical transformations and salt crystallization [91], in addition to some anthropogenic activities [61]. Flaking is a small stratum or a flat thin layer that has become detached from a larger piece or mass. In our case, it is another severe form that affected the temple blocks. It was created through volume increasing which was caused by a hydration process of salts [92,93]. As previously explained by Lagomarsino [94], the two earthquakes led to the full collapsing of the whole temple architectural features based on damaging grade estimated by (5-6 degrees). Thus, it is assumed that the increase of damping maximized the random lengths of cracks throughout a material which leads to random distribution of the critical shear stress [95]. Regarding the secondary reasons for the temple deterioration, it is affirmed that they include the following ambient factors: Salt crystallization which is a fundamental and practical interest in porous media. Practically, the temple granitic blocks have severe damage due to salt crystallization process. The existing types are varying between sulphates and nitrates [36]. In this regard, sulphates are due to acid rains in ambient air that characterizes this area, where nitrates are due to the water table that characterizes the cultivated area beside the temple. Both types have led to the creation of some destroying features that finally affected the stone strength as shown in fig. (5-c). Freezin/ thawing is one of the harshest deterioration agents affecting the building under study. These processes as well as wetness were identified as the major risk factors for the sudden degradation of the stone and archaeological buildings [64,96]. They led to a complicated phenomenon as shown in Fig$_s$. (5-d, e, f). This phenomenon could affect the stones even when no salt is present, where salt cannot be incorporated into the ice crystal and the unfrozen brine becomes increasingly concentrated [97]. Biological and microbiological colonizations that resulted from the accumulation of sap roots and other organic matters on the stone surfaces led to the effacement of stone carvings as well as aggressive cracking that resulted from the mechanical effects of plant growing [98-100]. Moreover, it is noticeable that the presence of wild bee nests and lichen colored films are due to the effects of pollutants, gaseous deposits and iron, carbon or non carbon accumulations, particularly with the presence of Continuous sources of polluted ground water. *Petrographically*, the data collected through investigations using this technique, fig. (6-a, b, c, d) proves that the main components of granite samples are plagioclase and orthoclase, which belong to the feldspars group. They are the most important minerals in igneous rocks [101, 102]. Quartz grain containing wavy extinction that resulted from sub-grains forming in response to strain, biotite with good basal cleavage and pleochroic haloes surrounding. Zircon inclusion were highly affected through different aggressive alteration mechanisms and created different degradation forms. Geologically, the partial degradation and alteration of mineral from brown biotite into green chlorite are attributed to weathering processes affecting feldspars. Chlorite is a secondary mineral characterized by fairly robust to weathering into clay minerals [103,104]. In addition, the presence of kaolinite, which is a clay mineral, is essentially due to the alteration processes affecting feldspars, feldspathoids and other silicates [105,106]. Epidote may be associated with hydrothermal alteration, weathering, diuretic alteration of orthoclase and plagioclase [107,108]. Also, it may be formed from the breakdown of chlorite or saussuritization of plagioclase. *Zoisite* may be produced from the breakdown of calcium plagioclase through hydrothermal alteration. Saussurite is a weathering product attributed to the alteration of Ca-plagioclase [109,110]. *Chemically*, EDX data, fig. (7-a & b) asserted that the primary elemental components of the granite sample are (Si, Al, Fe and K), which vary between 76.11 and 93.01 %, in addition to the elements of weathering products (Ca, Na, S and Cl) that vary between 6.99 and 23.89 %). These products came from the dominated deterioration factors in the study area, such as groundwater, rain waters, aggressive atmospheric pollutants as well as freezing and thawing phases [36]. Such factors lead to the chemical corrosion and decomposition of stone materials [111-114]. *Morphologically*, SEM observations, fig. (7-c & d) illustrate that the deterioration forms affected the stone blocks due to the severe effects of alternative cycles between heat and cold as well as the other mechanical weathering actions attributed to wind erosion. Moreover, the most noticeable deterioration forms indicate that the stone body was highly affected by the chemical aggressive actions of groundwater as well as other actions of acid rainfall [115]. Organic substances between the stones cracks resulted from the effects of biological and microbiological factors [116]. *Mineralogically*, XRD results, fig. (8-a, b) affirm that the investigated samples contain the main components of Egyptian granite which is characterized by normally pinkish color with abundant pink porphyroblasts, small feldspar crystals, quartz and dark ferromagnesians, and small crystals of apatite [117]. Moreover, the resulted data confirmed that the final stage of weathering effects lead to some products particularly, kaolinite according to the following formulas [28].

$$2)\ \underset{\text{Orthoclase}}{2KAlSi_3O_8} + \underset{\text{Water}}{3H_2O} + \underset{\text{Carbon Dioxide}}{2CO_2} \longrightarrow \underset{\text{Kaolinite}}{Al_2Si_2O_5(OH)_4} + \underset{\text{Silicic acid}}{H_4SiO_4} + \underset{\text{Potassium bicarbonate}}{2KHCO_3}$$

$$1)\ \underset{\text{Albite}}{2NaAlSi_3O_8} + \underset{\text{Water}}{3H_2O} + \underset{\text{Carbon Dioxide}}{2CO_2} \longrightarrow \underset{\text{Kaolinite}}{Al_2Si_2O_5(OH)_4} + \underset{\text{Silicic acid}}{H_4SiO_4} + \underset{\text{Sodium bicarbonate}}{2Na\,HCO_3}$$

The results reveal that the environmental parameters extensively affect the decaying rate of archaeological buildings and their different components that can reduce the age of these buildings. Also, it is premature to recommend the application of a surfactant as a protective treatment for the temple stone blocks to reduce the effects of these parameters. On the other hand, a pioneer architectural conservation project should be considered to reconstruct the temple. This may be realized through true real interaction and coordination among different national and international authorities. *Physically*, in spite of the Egyptian granite is characterized by its stable performance, in our case it was affected by the different deterioration and weathering factors and their related mechanisms, especially the synergetic effects of natural alterative cycles, i.e. heating/cooling and freezing/ thawing. The resulted data of physio-mechanical properties of deteriorated samples proved that they were highly affected by environmental situation dominated in the study area, particularly after the effects of macro and micro seismic hazards affected previously the study area. From specialized point of view, it could be asserted that the measured effective physio-mechanical parameters were negatively changed as shown in, fig. (9). Where, (γ_d) was decreased 5.8%, (**η**) increased 99.8 %, (**WA**) increased 99.9 % and finally (UCS) decreased 27.1 %. Reality, the negative changes in of these measurements affected rock body inherently have attributed essentially to the flaws or the presence of small cracks, in addition to the relative orientations between major flaws and loading directions as argued previously by Fookes et al. [118] and Keunbo et al [119] in their studies. Furthermore, it may be resulted due to the alternative cycles of frosting and desolation actions [120], or to the weakening of the bonding strength at rocks interface that influences the lifespan of rocks [121]. At the end it could be asserted that all factors mentioned above led to the aggressive deterioration forms in damaged blocks that need urgent conservation and rehabilitation processes to alive the temple under the study.

6. Conclusion

The present paper addressed the effect of two effective deterioration factors (i.e. earthquakes and unstable lands) that lead to complete destruction of archaeological sites. The results demonstrated that the temple area composed essentially from sand and gravels covered by layers of clay accumulated over the last 7000-8000 years by Nile floods. The topographical survey of the study area asserted that it is characterized by several structures. Furthermore, the lithographic sections in surrounded area are characterized by unique thick layers through the eastern/western direction and composed essentially of the ancient silty material which comes from the Nile branches characterized by large grains, especially towards the bottom direction, which is thought to compose the ground water in this zone. Moreover, the dominating deterioration symptoms vary between the temple structure destruction, sliding and overlapping of rock blocks, in addition to the mechanical destructions due to the effects of earthquakes, alternative cycles of rain water through frosting and desolation actions. In addition, there are some falling down parts, some scale layers, aggressive cracks and micro fissures and detachment of small thin stone elements in flaking pattern. In addition, presence of some colored crusts resulted from biological and microbiological colonizations and wiled bees. All of these features and weathering products could be used to develop appropriate methodologies for cleaning the granite blocks and suggesting appropriate surface treatments for practical usage. These procedures should be focused on different chemical and petrophysical properties, such as pore structural changes related to the progress of degradation, and using pore structural measurements to assess and predict the effectiveness of the selected appropriate treatment materials used for this purpose. This paper showed the importance of developing appropriate action plans, materials and techniques that evaluate the state of deterioration and help map the risks of damage. Hence, further investigations are needed for an accurate qualification and quantification of the site deterioration. Also, more reliable and effective structural conservation plan should be developed to preserve the site and reconstruct the temple. This plan is based on different steps of structural conservation according to two main processes: The first is the reconstruction of the main temple building and the second is foundation strengthening and the third wall grouting.

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