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ARCHAEOMETRIC STUDY OF THE MEMORIAL STONE ENTRANCE OF KING RAMSES III IN HELIOPOLIS TEMPLE, CAIRO, EGYPT

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Abstract:

The Heliopolis temple is considered one of the most important temples of ancient Egypt, as it was built at the beginning of the dynastic era and continued until the Greco-Roman era, moreover every Egyptian king during that period was keen to establish his own part inside this temple dedicated to the worship of the sun god Ra, Unfortunately, most of the features of this temple have disappeared for urban sprawl.One of the most important remaining parts of Heliopolis Temple is the remains of the stone entrance gate of King Ramses III, which was discovered by Professor Dr. Abdel Aziz Saleh during excavations at Cairo University in 1974. The site of the Heliopolis Temple is one of the most important archaeological sites that tell us an important part of the history of modern state. The site contains valuable and unique stone monuments such as a stone statue in the shape of the Sphinx and a number of unique stone pieces such as a stone pillar, two limestone cornices, and others pieces that are considered the architectural elements of the gate, and the site was called (Abo Alhol) due to the presence of a statue of the Sphinx. This study aims to determine the actual state of the remains of the stone pieces of King Ramses III's Gate as a starting point for developing a plan to restore and rebuild this gate. In addition to some examinations and analyses that were achieved through field studies such as visual examination, recording field observations, monitoring the climatic elements at the site. Furthermore, determining the nature of the soil and its relationship to the remains of the archaeological temple. Upon closer investigation with a polarizing and digital microscope, two types of limestone are discovered, Wacke stone is the first kind, mudstone is the second, and the Halite salt crystals appear on the sample surfaces. SEM investigation were used to determine the grain morphology and surface damage aspects. To identify the crystalline mineral components, calcite, quartz, gypsum, and halite, XRD analysis had been performed. The study concluded that the remains of the archaeological site were damaged as a consequence of direct contact with the soil and the saline environment. The analyses showed that the remains of the stone gate stones consist of calcite and a small percentage of gypsum and halite salts. The limestone was classified according to the petrographic study into three types: Fossiliferous limestone, packed biomicrite, and sparse biomicrite.

1. Introduction

Heliopolis is considered one of the oldest cities in ancient Egypt and has been inhabited by ancient Egyptians since the pre-dynastic era. The city has greatly expanded under rule of the ancient Egyptian kingdom, passing through the Middle Kingdom and the modern state [1], the temple of the city of Heliopolis was dedicated to the worship of the sun god (Ra), as the temple was a major religious center in ancient Egypt. Unfortunately, the temple has been destroyed at the present time as a consequence of several reasons, including destructive weathering factors, which led to the destruction of large parts of the temple [2], as well as the reuse of the destroyed parts of the temple and their use as building elements in Cairo buildings in the Middle Ages [3]. When comparing the era of the modern state and what remains of it now, we find that the temple has shrunk in size to less than half due to urban sprawl from all sides. The site of the Great Sphinx (the gate of King Ramses III) is considered one of the most important remaining parts of the temple in Heliopolis.

1.1. *Sphinx site (Gate of king Ramses III)*

The site of the Great Sphinx is located at Al-Mataria district of Arab Al-Hisn, which is located in the northeastern part of Cairo Governorate, fig. (1). It is about 20 km from downtown Cairo, and this site is one of the discoveries of Prof. Dr. Abdel Aziz Saleh in the excavations of Cairo University in 1974. This site is considered one of the most important archaeological sites that tell us an important part of the history of the new kingdom, fig. (2) [4]. There is nothing left of this gate unless some of architectural elements, such as a stone pillar, a statue of the Sphinx and two cornices remain.

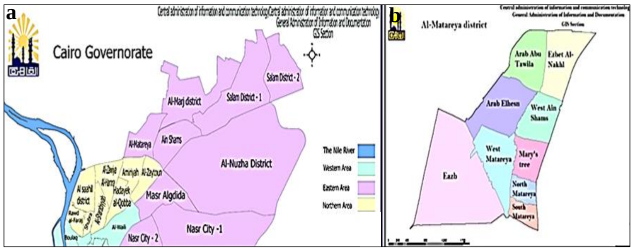


Figure (1) **a.** the neighborhoods of Cairo Governorate, **b.** the geographical planning of Al-Mataria districts (*After: http://cairo.gov.eg/ar/Maps/PublishingImages*)

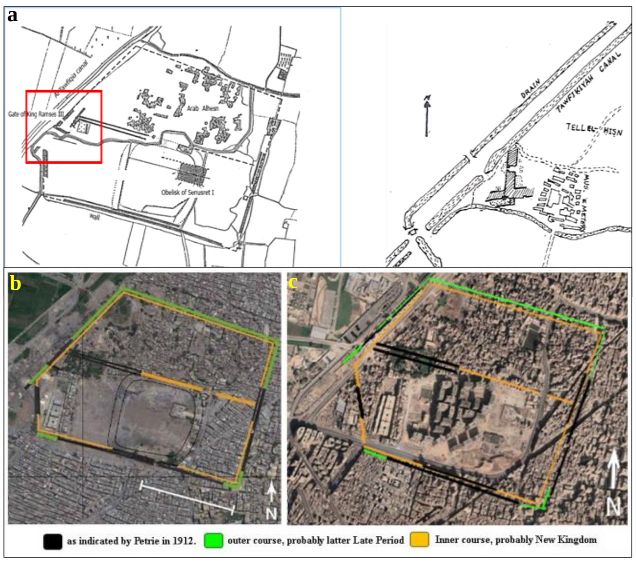


Figure (2) **a.** the location of the entrance of King Ramses III, quoting (*After: Saleh, 1983*) [5], **b.** the expansions of the Heliopolis temple until the late period, (*After: Dietrich Raue, 2014*) [4], **c.** the outer borders of the archaeological site in Al-Mataria (*After: Google earth, 2020*)

This site contains valuable and unique stone monuments such as a Sphinx statue in and several unique stone artifacts such as a stone pillar, two limestone cornices, and other important artifacts [5]. These antiquities suffer from the circle of damage around them from soil, moisture, pollution and human damage, fig. (3) [6].

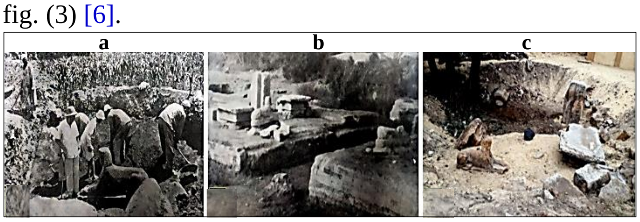


Figure (3) **a.** the site during the discovery, **b.** the site after its detection citing (*After: Saleh, 1983*), **c.** the archaeological site 2022.

1.2. *The first artifact*

Description: A stone pillar carved of limestone (part of the gate of King Ramses III), King Ramses III appears in an official form and presents offerings to the gods. His head is topped by a sun disk, as a symbol of protection [7], and on the other side are hieroglyphic writings bearing the royal titles, fig. (4). Dimensions: 180 cm in length, 85 cm in width, and 55 cm in thickness. Through visual examination, it was noticed that the stone pillar is in a poor state of preservation, as it shows manifestations of crusting and separation of the surface layers as a result of subsurface salt crystallization, especially in the lower parts, which almost completely fell, which led to obliteration and loss of the inscriptions on it. A deterioration map was drawn to identify the main damage aspects of the artifact [6].

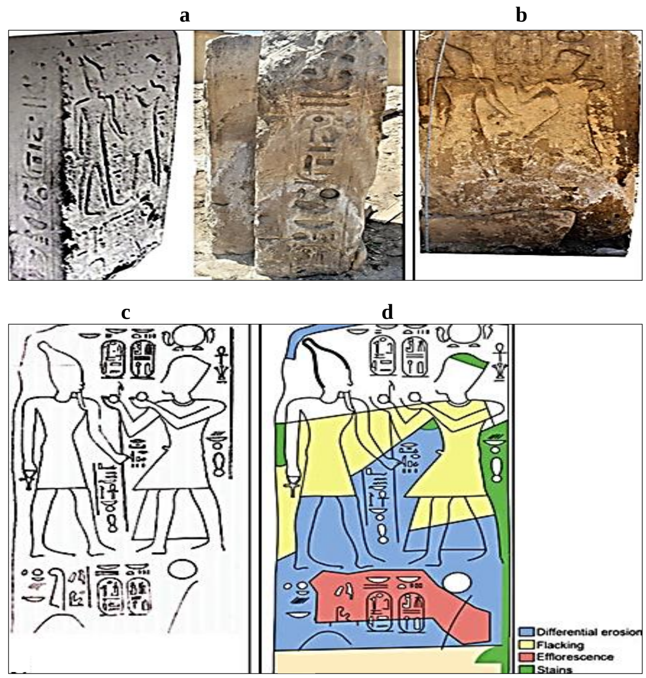


Figure (4) **a.** stone pillar at the time of discovery in 1974, **b.** the pillar condition in 2022, **c.** details of the pillar inscriptions, quoting Saleh, A., 1983, **d.** deterioration map of the current actual condition of the pillar, 2022.

1.3. *The second artifact*

Description: A limestone cornice with a special inscription bearing the name of King Ramses III inside a royal cartouche, in addition to some plant decorations, fig. (5). Dimensions: the length of the cornice surface is 220 cm, its width is 160 cm, and its height is 90 cm. Through a visual examination of the cornice, it was found that this artifact suffers from many manifestations of damage, including the presence of remnants of soot as a result of the site's exposure to fire, which led to obliteration of some inscriptions. It was also noted the existence of gaps and voids in the upper area of the cornice, a phenomenon known as tafoni appearance, *Tafoni or honeycomb is a weathering phenomenon found in diverse environments throughout the world. It occurs on limestone, sandstone, and other rock types in natural outcrops, Honeycomb weathering is a term used to describe numerous small pits no more than a few centimeters wide and deep, separated by the intricate network of narrow walls and resembling a honeycomb* [8]. The cornice was found in an up-side-down position adjacent to the soil [4], which explains the occurrence of the phenomenon of tafoni and crusting of the surface of the cornice [9].

The architectural style of the cornice is called the cavetto [10], and it is an architectural form that has a regular shape that represents part of a concave circle. The cavetto style was used widely in the field of architecture and decorative arts in many previous civilizations, and this style was famous in ancient Egyptian architecture, so that it was known in the name of the Egyptian cornice, as we find it in most of the capitals of the ancient Egyptian columns, which were known as Papyrus crowns [11].

a

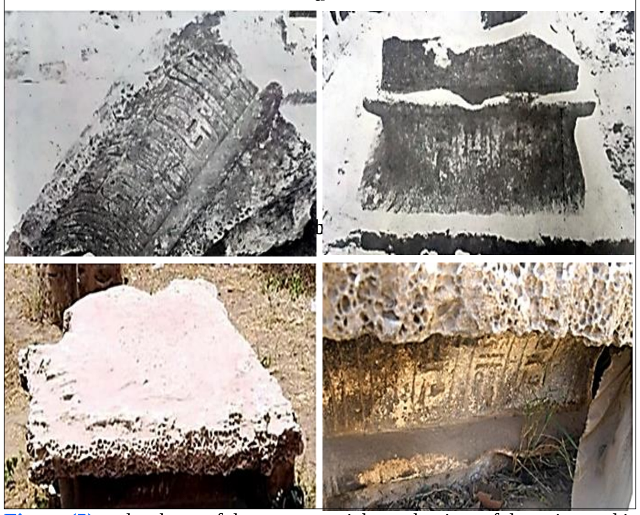


Figure (5) **a.** the shape of the stone corniche at the time of detection and it appears in an up side down position, **b.** the shape of the stone corniche, 2022. Tafoni or honeycomb aspects are shown at the top of the stone corniche.

1.4. *The third artifact*

Description: a statue of Sphinx, which has a human head and a lion's body, where the ancient Egyptians used to place statues of the Sphinx on both sides of the roads and gates leading to the temples, in the belief that the Sphinx's body is a symbol of the power and wisdom of the king [12]. Dimensions: 170 cm long, 93 cm high at the head area, and the width 50 cm, through a visual examination of the Sphinx, it was noted that this statue suffers from the tafoni apperance as well it also notice the loss of the right foot of the statue, in addition to vertical separations in the head area, fig. (6) [6]. By studying the stone artifacts that found at the site, it can make an imaginary drawing of the shape of king Ramesses III's gate, fig. (7) [13]. In order to determine the actual state of the stone monuments at the site, it was necessary to study the climatic conditions [14] dominated in Cairo governorate, in order to study the nigative impact of the environment on the antiquities and to explain the damage aspects [15], tab. (1) & fig (8)

a b c

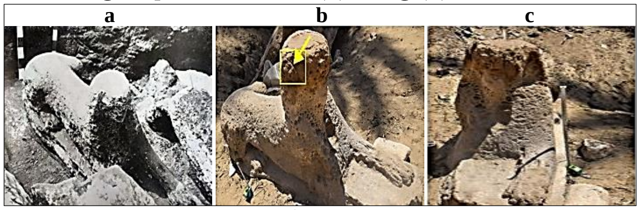


Figure (6) **a.** sphinx at the time of discovery in 1974, **b.** and **c.** the Sphinx and the areas of detachments in the head, in addition to the missing foot.

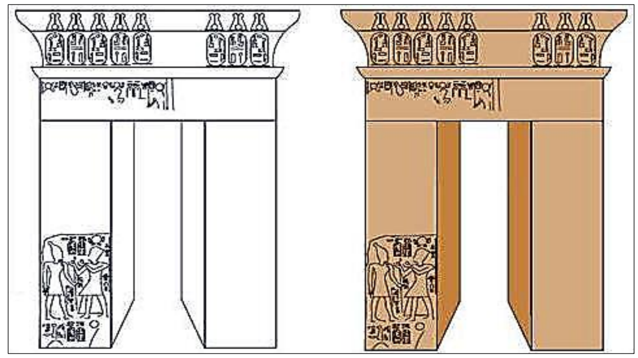


Figure (7) the use of the most important artifacts found in the site to create an imaginary form of the gate of King Ramses III using the AutoCad program [16].

Table (1) the environmental conditions of Cairo governorate in 2022. [17]

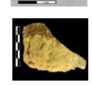
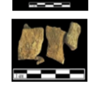
Month	Temperature F°	SUN hours / day	HUM days	Wind speed Mph	Rainfall Inches
January	51:67	10.5	0.00	08.2	0.100
February	52:69	11.1	0.00	08.6	0.100
march	56:75	12.0	0.00	09.1	0.200
April	61:83	12.9	0.00	09.6	0.100
may	67:90	13.7	0.40	09.9	0.000
June	72:95	14.1	5.50	10.0	0.000
July	75:95	13.9	16.4	09.2	0.000
August	75:95	13.2	19.4	08.8	0.000
September	73:92	12.3	11.7	08.9	0.000
October	67:86	11.4	4.40	08.6	0.100
November	60:77	10.6	0.50	08.1	0.200
December	53:69	10.2	0.00	08.0	0.200

2. Material and Methods

2.1. *Material*

To determine the actual condition of the stone monuments located at the sphinx site (Abo Alhol), some scientific methods were used to examine and analysis the samples collected from the site. A letter code has been given for each sample as follows: (**P**) = Pillar, (**C-a**) = first cornich, (**S**) = Sphinx, (**C-b**) = second cornich, (**SS**) = non carving stone in the site (stone building of the gate). Table (2) shows the places where samples were taken and described.

Table (2) the sample description

Sample code	Description	Weight/gm	Place	Photo
P1	The sample is crumbled into a powder and the residue is separated into small layers	00.96	from the bottom of the stone pillar	
P2	The surface is damaged, yellow in color	00.50	back of the stone pillar	
C-a	Some little piece	00.25	Cornice 1 surface	
S	Some little pieces	04.82	head of the Sphinx	
C-b	The sample is crumbled into a powder and the residue is separated into small layers	20.00	Cornice 2 surface	
SS	irregularly shaped part, surface is damaged, yellow in color	56.00	Stone gate	

2.2. *Methods*

VehoVMS-004 DELUXE smart-eye USB digital microscope model at various magnifications, was used to examine the outer surface of the samples and identify different damage aspects resulted from different weathering processes. *Olympus BX50 polarizing microscope* and the carbonate classification suggested according to Dunham (1962) [18] was addapted to investigate the petrographic features of limestone samples. These samples were firstly subjected to sawing with a diamond saw and mounted on a glass slide (standard thin section) and examined using a polarizing microscope. XRD technique is used to determine the mineralogical composation of the investigated limestone, the limestone sample were prepared by fine grounding to 20 μM using Herzog (Herzog co. Germany) grinder to minimize the effect of absorption and extinction of the X-ray beam. Rectangular type sample holder was used to pack about 0.2 gm of the examined sample. The sample holder is then fed into the *PAN – Analytical X pert pro MPD PW 3050/60 X-ray diffractometer*; provided with a proportional digital counter and Nickel – filtered CU-Ka Radiation at 40 KV and 30 mA and scanned over an interval of 5 – 502 theta at a scanning speed of 5/min. The obtained XRD patterns were converted to a series of lattice spacing (A). and identified by computer software X pert High score using ASTM cards of international Center of Diffraction Data (ICDD 2006).

3. Results

3.1 *Digital microscope*

DM result of the examined stone pieces at the site (the pillar, the cornice, and the Sphinx) showed that the appearance of salt crystals charactrized by scattering on the samples surfaces. Presence of surface erosion affected the three samples, in add-ition to presence of loose surface deposits, fig. (8) [19].

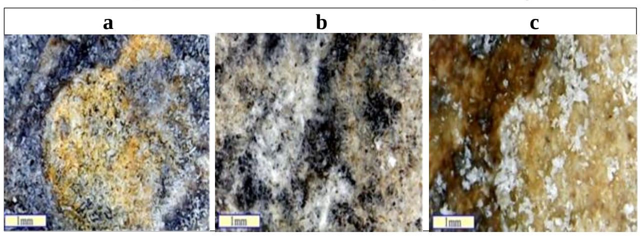


Figure (8) **a.** the stone pillar, shows a large percentage of salt crystals, on the left, the separated stone form in horizontal layers, on the right, there is surface erosion and a black sediments layer, and the stone appears in a yellowish color**, b.** the stone cornices, showing surface erosion and a large percentage of surface voids beside salt crystals, **c.** the Sphinx, on the left appears salt crystals and a yellowish-brown surface layer of a consolidant (most likely the remains of a previous consolidation process since the period of discovery in 1981), and on the right is a thick layer of cry-stallized salts.

3.2 *Petrographical microscope*

Petrographically, two types of limestone were identified within the monument body. The first type is wacke stone, fig. (10) with remains of shells, foraminiferal and bioclastic fragments in micritic matrix and with presence of subangular quartz grains, fig. (10-a) representing sample P1 and S (which side of monument). Foraminiferal cavities are filled with sparry calcite, while the walls are heavily micritized, fig. (10-b). These types of limestone are subjected to aggrading type of neomorphism, where the micrite in skeletal shells is replaced by mico-sparite giving rise to larger calcite crystals in finer matrix. The second type is mudstone, fig. (10-c) with some voids that are filled with sparry calcite and with remains of foraminiferal of globular form with its cavities filled with blocky calcite representing sample C-b [20].

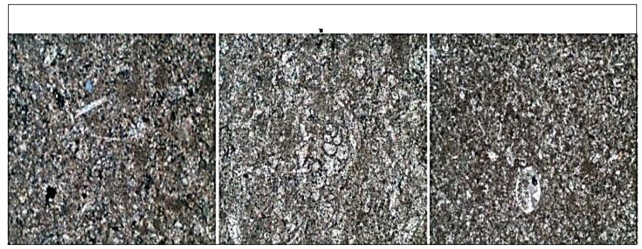


Figure (10) **a.** skeletal constituents in micritic matrix (sample B-1), CN, 100-X, **a.** foraminifera chambers are filled with sparry calcite (sample S), CN, 100-X**, a.** globular foraminifera remain filled with blocky calcite (sample C-b), CN, 40-X

3.3 *XRD result*

These result, 6 stone samples were analysisd using the X-ray diffraction method to determine the crystalline mineral components, through the analysis, the following result was revealed in tab (3).

Table (3) XRD result

Sample	Minerals	Chemical formula	Percentage %	Reference code
P1	Calcite	$CaCO_3$	96	01-086-2334
	Quartz	SiO_2	4	01-085-0798
P2	Calcite	$CaCO_3$	88	01-086-2334
	Gypsum	$CaSO_4\ (H_2O)_2$	9	01-074-1433
	Halite	NaCl	3	01-071-3741
C-a	Calcite	$CaCO_3$	100	01-086-2334
S	Calcite	$CaCO_3$	87	01-086-2334
	Gypsum	$CaSO_4\ (H_2O)_2$	13	01-074-1433
C-b	Calcite	$CaCO_3$	100	01-086-2334
SS	Calcite	$CaCO_3$	92	01-086-2334
	Gypsum	$CaSO_4(H_2O)_2$	8	01-074-1433

3.4 *SEM result*

SEM result, the three samples (**a**, the pillar, **b**, the cornice, and **c**, the Sphinx) were examined using a scanning electron microscope, which showed the surface erosion in the three samples, in addition to the presence of a percentage of salt crystals between the voids and tracess of clay sheets, fig. (11).

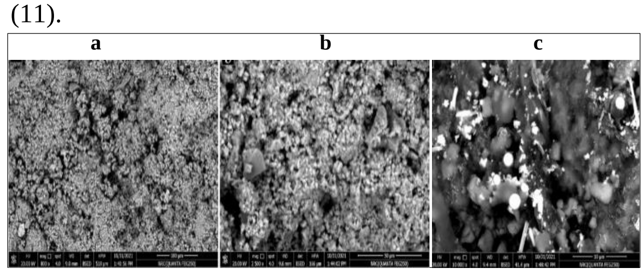


Figure (11) **a.** & **b.** the surface erosion in the three samples, in addition to the presence of a percentage of salt crystals and clay sheets between the voids, **c.** a close up of c sample.

4. Discussion

The site of the Great Sphinx at Arab Al-Hisn, is considered one of the most important archaeological sites that tell us an important information of the history of the new kingdom [3], but unfortunately there is nothing left of this site unless some of architectural elements, such as a stone pillar, a statue of the Sphinx and two cornices remain [5]. These antiquities suffer from the circle of damage around them such as soil, moisture, pollution and human damage. The most noted deterioration aspects is the existence of gaps and voids in the upper area of the stone artifacts, a phenomenon known as tafoni appearance, which is caused by the geological defects in the composition of the stone and weathering factors, it was noted that this statue of Sphinx suffers from the tafoni apperance as well it also notice the loss of the right foot of the statue [21,22], in addition to vertical separations in the head area. This can be explained as a result of the statue being buried for a long time in poor preservation conditions. By studying the climatic elements prevailing in the Arab Al-Hisn site, the following can be observed:The average temperature ranges from 63-82 F°, with the highest temperature in July and August being 95 F°, equivalent to 35 C°, and the lowest temperature in January being 51 Fahrenheit, equivalent to 10.56 C°. As for the site being exposed to the number of hours of sunshine, the site achieved an average of 12.1 hours. This percentage is considered high, and this explains the decay and fading of the layers of colors on the stone pieces such as the stone cornice [23,24]. As for humidity and rainfall, the site achieved low rates of 4.85 hum/day and 0.075 inches. Therefore, thinking about the direct source of moisture for the stone monuments on the site will be the soil and the ground water it contains. As for the wind speed, it achieved an average of 8.9 Mph, which is an average rate that cannot cause damage due to the phenomenon of wind erosion [18]. *USB microscope* examined three stone pieces at the site (the pillar, the cornice, and the Sphinx) the result shows appearance of salt crystals scattered on the surface of the three samples, erosion on the surface of the three samples and the presence of loose surface deposits. *Petrographic study* for the Arab Al-Hisn site shows two two types of limestone were identified. The first type is wackestone, the second type is carbonate mudstone. Wackestone is defined as a mud-supported carbonate rock that contains greater than 10% grains. Most recently, this definition has been clarified as *a carbonate-dominated rock in which the carbonate mud (<63 μm) component supports a fabric comprising 10% or more very fine-sand grade (63 μm) or larger grains but where less than 10% of the rock is formed of grains larger than sand grade (>2 mm)*. Carbonate mudstone**,** in the Dunham classification system of limestones [18], a mudstone is defined as a mud-supported carbonate rock that contains less than 10% grains. Most recently, this definition has been clarified as *a matrix-supported carbonate-dominated rock composed of more than 90% carbonate mud (<63 μm) component*. By identifying the two types of limestone at the site and the presence of a percentage of clay minerals (hygroscopic material), it is possible to explain the existing of damage aspects, such as the tafoni phenomenon and surface damage such as separation, cracking, and the presence of salt crystals. Through analysis by X-ray diffraction of the six stone samples [25,26], it is clear that the main component of these samples is calcite $CaCO_3$, followed by gy-psum $CaSO_4(H_2O)_2$ then halite NaCl, The presence of both gypsum and halite can be explained as an aspect of damage in the form of salts [27]. SEM examination showed surface damage, the percentage of voids, and the spread of salt crystals of halite and gypsum, in addition to the presence of sheets of clay minerals. Therefore, it is recommended to use one of the salt inhibition techniques to protect the stone monuments at the Arab Al-Hosn site from the damaging effects of salts, especially gypsum and halite salts [20,28,29].

5. Conclusion

The site of the Sphinx has important artistic, historical and archaeological value because it is an original part of the Heliopolis temple and must be preserved. The artifacts on the site are made of limestone and extracted from excavations, so they must be handled with care and appropriate restoration materials must be chosen for their condition. Restoration and conservation operations must include getting rid of dissolved salts and cosolidating the surface of the artifacts at the site. The limestone of the memorial stone entrance of King Ramses III in Heliopolis temple at Arab Al-Hisn site shows two two types of limestone were identified. The first type is wackestone, the second type is carbonate mudstone and mostly cutted from Helwan area quarry south of Mokattam, it is suffers from separations, fine scales and microcracks as a result of the crystallization of dissolved salts and tafoni phenomenon. Therefore, the treatment and conservation program must include getting rid of dissolved salts, reducing the percentage of subsurface water, by drying its sources, and finding a site around the monument that preserves it from various infringements. If there are cases of reconstraction the Memorial stone entrance of King Ramses III stones must be brought from Helwan area quarry south of Mokattam. Therefor the site of Sphinx needs for more studies to choose suitable matrial to consolidate this artifacts, such as polymers and nano material to preserve this mounments in the futuer.

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