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An applied analytical study of restoration of Qan-Amun tomb in the archaeological site of Al-Meskhouta in Ismailia

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Abstract:

Al-Meskhouta is the city of Peratum or house of Atum (the sun god) and it was also known as Bitum, and as Tkw beside the Greek name Heroonpolis. It is located in Abu-sweir city about 15 km away from the current city of Ismailia within the range of the valley in which the current Suez Canal was digged, which is known as Wadi Al-Tumailat.

The history of the city goes back to the dynastic era, when peratum was the capital of the eighth district of Lower Egypt in ancient Egypt. Qen-Amun tomb was discovered in 2010 by an Egyptian archaeological mission at Tell Roud Iskandar in Al-Maskhouta. It was found that the limestone gable roof had been broken or removed in the middle, meaning that the tomb had been stormed in the ancient time and its contents had been looted.

This research deals with the manifestations of damage and collapse that tomb of Qen-Amun suffers from, including the burial soil and other phenomena was caused by weathering and various environmental factors after the discovery. But the human factor is the main factor causing the various manifestations of damage and collapse. This research deals also with documentations, analysis and examinations of the current situation of the tomb and the most important conservation and restoration works that took place on the tomb building.

Keywords: Bitum– Limestone – Mortars– Documentation– Analysis-Characterization – Application – Restoration- Discussion

Introduction

Damage of the monuments depends on the environmental conditions surrounding them, in addition to the conditions of their formation, their geological origins, their basic properties, such as mineral and tissue composition, and the shape and distribution of pores. The damage mechanism depends on the physical, mechanical and chemical properties of the metals of the building materials.

The mechanical and physical weathering processes are mainly involved in the deterioration and destruction of the components of stones even without any chemical effect, but their relationship with chemical weathering is a close relationship that exhausts the forces of the stone to the extent of the mechanical stresses to a degree Sufficient to cause the complete destruction of the stones of the ancient building. In the case of Qen-Amun tomb the vibrations generated by means of transports, especially heavy transport, as well as railway trains, are series effective vibrations, specially that the railway road to the north, about 20 meters away, and the Cairo-Ismailia Agricultural highway about 400 meters to the south.

The foregoing factors caused many aspects of damage in the tomb. Hence, this research dealt with the full documentation of the archaeological and architectural documentations of the tomb in addition to the decay phenomena that it is suffering from. The current conditions of the limestone and mortars used in the tomb building was documented using scanning electron microscope imaging (SEM) and analyzed using X-ray diffraction (XRD). Photography was also conducted using different cameras for the stages of restoration and conservation.

The research also dealt with the most important conclusions learned from the analytical and characterization study, as well as the interventions that were tacked place in terms of restoration and conservation to benefit from that study in any work that might be carried out on monuments and archaeological buildings similar to the case of the tomb of Qen-Amun.

Al-Maskhuta means a statue in the colloquial Egyptian and it was launched by the locals when they noticed the large number of archaeological finds in the area, and therefore the ancient city of Bitum was called Tel Al-Maskhuta. This archaeological city turned into two sites after the opening of the Ismailia Canal as it is showed in the photo No (1). These two

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sites can be called the southern hill of Al-Maskhouta, and the other is the northern hill al-Maskhouta, and the latter is called Roud Iskandar, where the cemetery of the ancient city is located. Qen-Amun tomb was discovered as a part of a group of mud-brick tombs with different shapes and sizes excavation.

Documentation Study

1- History of the Eastern Delta and Bitum (Al-Maskhutah)

Bitum was a semi-desert area as the settlement center of a strong garrison, a fortress, and a military point from which armies departed to Sinai and the eastern borders [(1)].

The history of the city dates back to the dynastic era, where Bitum was the capital of the eighth province of Lower Egypt in ancient Egypt and a religious center for the worship of the god Atum (the sun god). Matters in the area given the strategic importance of the city's location as an entrance and crossing point for the military forces to and from Sinai and the countries of the East. Interest in this region has begun from a military point of view, in addition to its religious and commercial importance, and this is evidenced by more than the important discovery announced by the Egyptian-Italian mission in 2017, which is about the walls of military forts With a width of 12 meters, it dates back to the era of Ramesses III.

When the region rose to the epicenter of the events after the settlement of the Hyksos in Avaris, which is the Egyptian city (ḥ.t wʕr.t) Hat and Irat, which was then known in Greek: αυαριϛ, Auaris [(2)]. It was located near the current Tell al-Dabaa in Sharkia Governorate, northeast of the Nile Delta. Where the delta was deposited and moved with the river, its location on the desert side of the commercial centers in the Nile Delta made it a major administrative capital for the Hyksos and other merchants [(3)].

At the end of the Eighteenth Dynasty, the Hittite power threatened the Egyptians. Seti I was able to seize Kadesh and erect stele on the shores of Orento, the upper part of which was found. And Ramesses II received reports from his messengers warning him that there is one king who threatens his sovereignty. For this reason, Ramesses II decided to build a seat of government far from the borders, where he could be safe, gather and train his archers and knights, and to facilitate communication and access to the Mediterranean, the Red Sea and the southern countries. To the east of the ancient city of Avaris begins the land of Goshen, which was attributed by the Hyksos kings [(4)].

It was necessary to create a new city in the middle of the desert and ruins. Engineers, builders, and stone masons were present in their shops, but small jobs such as making bricks and dragging stones needed labors that might not be available, and then it was Hebrews and their presence [(5)].

As mentioned in the Torah, a text says, "With humiliation and humiliation, we built Bitum and Per-Ramesses." It is the city of the god Atum, which is considered one of the most important ancient cities that played an important role across the different historical eras since the middle Pharaonic state, and its importance increased in the new kingdom and stated in the lists of the late era)) where it was the capital of the eighth district of Lower Egypt, its name was mentioned in the list of King Senusret I, as Ramesses II took care of it and made it a fortified city as it is located at the eastern entrance to Egypt, so forts and castles were built in it to protect Egypt from Asian infiltration, and the name of the city was found engraved on the statue of Atakh Nebnefer (the military commander in the days of Osorken II) [(4)].

2- Archaeological documentation of Tell Al-Maskhuta

Al-Maskhuta is located in Al-Mukfar 7, Plot No.28 of the district of the city of Abu-sweir at the center of Ismailia Governorate [(6)].

Many archaeologists have taken care of it, such as Nafil 1884 AD, Petri 1904 AD, and Shafiq Farid 1960 AD, where excavations revealed many antiquities, as previously explained, including two granite statues of Ramses II between Ra and Atum, a temple of the god Atum in the southwestern side, a basalt sarcophagus on a base of limestone, and a statue of Ramses between Atum, Khepri, and another between Hoor Akhti and Khebri and a large group of stores. Traces of the late era were also found, such as a statue of King Pasmatik II of black granite, and a black granite lid in the form of a mummy with an inscription in the name of (wag hur bar Nsut), meaning the head of the palace. Royal as well as the ruins of King Nkutanbo [(1)]. Site area was About 82 acres, this area has now shrunk due to human encroachments, which caused the detachment of large areas of the ancient hill.

3- Archaeological documentation of Qen-Amun tomb

The tomb was discovered in 2010 by an Egyptian antiquities mission affiliated with the Supreme Council of Antiquities, as part of comprehensive excavations for the Roud Iskandar site in Al-Maskhouta. The tomb dates back to the 19th Dynasty and it was built of limestone rectangular blocks. It has a gabled roof made of stone blocks with inscriptions belong to the owner of the tomb. Inside the tomb a huge limestone sarcophagus of the owner was found, and his name is "Qen-Amun" who was responsible for the royal records from the 19th Dynasty. The sarcophagus was inscribed from the inside and outside. The name

of the wife of the owner "Isis" was mentioned on the walls of the tomb and she was the singer of the god Atum temple. The tomb is engraved with recessed carvings of various scenes of religious and funerary scenes. The most important of these scenes is the scene of the trial of the dead, "Chapter 125 of the Book of the Dead" and the scene of the mourners (wails) for the dead man and the scene of the cow (the goddess Hathor) in the form of a cow emerging from the delta forests. There are also the scenes of the four sons of Horus, the titles of the deceased, the jobs he held, and the inscriptions show that he had an important role in the state and that he was responsible for the royal records.
The discovery of the tomb took several stages, as the rubble was removed from the roof then its sides. So that the stone tomb was surrounded on all sides by walls of mud bricks and the ceiling was also covered with mud bricks. So it is believed that the mud bricks buildings which surrounded the stone tomb has some structural function, but it had another purpose, which is to mislead the thieves from infiltrating the tomb and stealing its contents, although this did not prevent the tomb from storming.


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(5)

So it was found upon revealing that the mud brick ceiling had been removed from it in part and the stone gable roof had been broken in the middle, meaning that the tomb had been raided in the past and its contents were looted.

After removing the rubble, sand and dust around and inside the tomb so revealing the mud brick and stone elements of the tomb (photo no.4) It was found that the builder used the sarcophagus as a fulcrum for the stone gable ceiling to ease the load of the stone blocks of the roof of the tomb by building two rows of stones as columns resting on the sarcophagus lid as in (photo No. 5)

4- Architectural documentation of the tomb

The tomb takes a rectangular shape. The northern and southern walls reaching 400 cm length and a height of 150 cm. but the eastern and western walls 260 cm length and a height of 250 cm. and thickness 25 cm).

The stone gable ceiling measuring 150 cm long x 30 cm thick x 33 cm wide that represents the roof of the tomb.

The stone sarcophagus of the tomb has a lid in the shape of a human being, where there is a face of the owner of the tomb and the body takes the Osiris position and contains inscriptions in deep relief.

The length of the sarcophagus is 257 cm, width 110 cm, height 53 cm, increasing in the face area to 64 cm, as well as in the foot area up to 82 cm. As for the coffin itself, it has the same dimensions as the coffin, and its height increases to 100 cm.

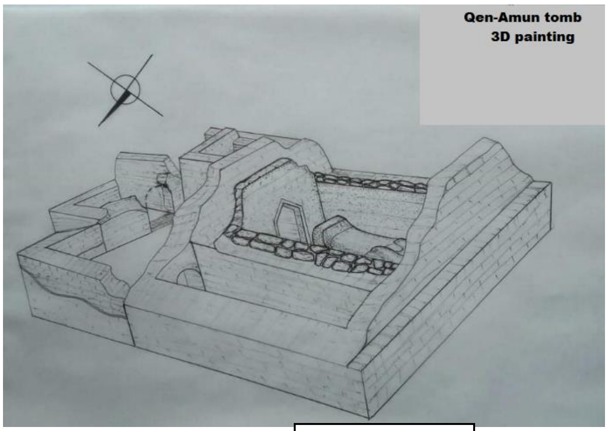
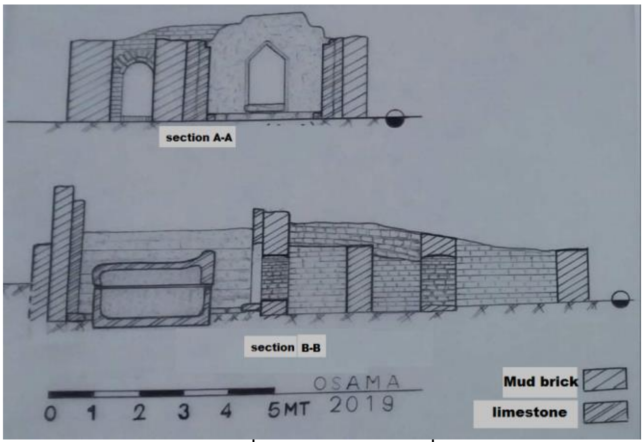


Fig No 1



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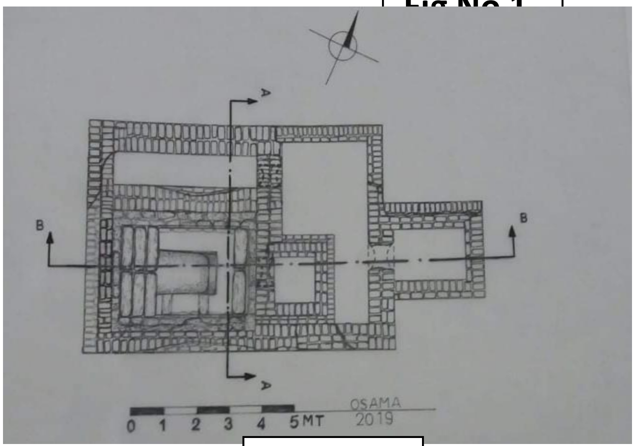

Fig No 3

5- Deterioration phenomena in the tomb of Qen-Amun

The tomb of Qen-Amun suffers from many manifestations of damage and collapse, including what we found out since the first discovery of the tomb. The factors of deterioration included what were caused by weathering and various environmental factors after the discovery, but the human factor is considered the main factor causing the damage and various collapses. Especially because of the events that followed January 25, 2011 AD and so on. It was from the storming of some thugs into the tomb and causing some deliberate destruction of the various elements of it which caused a decision by the Supreme Council of Antiquities to bury the tomb again in order to preserve it in the graveyard. Characterization, documentation and analytical studies have proven that the monument suffers from severe damage as a result of the various damage factors that were presented.

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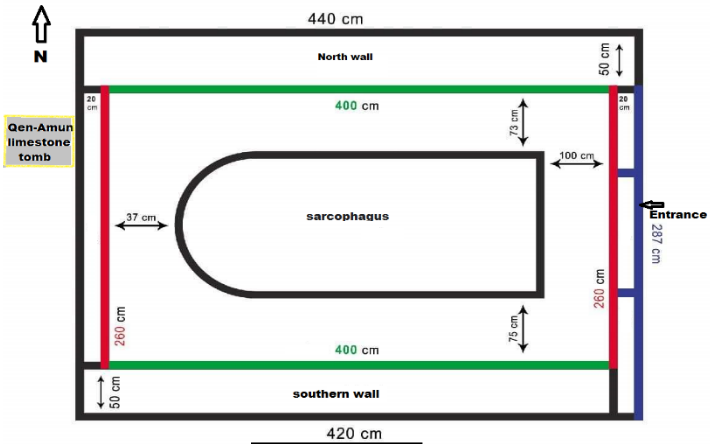

Fig No 4

The displacement of some stone slabs in the walls from the level, as well as the presence of human damage represented in the tampering and deliberate destruction of the tomb building and the sarcophagus as a result of the various encroachments that were previously mentioned. Documentation of the manifestations of damage will be dealt with using scales of stone deterioration in the following steps:

5-1- Non-visible deterioration:

There are very accurate manifestations of **Nano scale damage,** which are less than (mm), i.e. invisible, such as a change in the components and characteristics of the stone, or in its strength and durability. These manifestations are confirmed by physical and mechanical studies, as well as the tests that was conducted on the stone material as it is noticed in results of (XRD) analysis. This is what was shown by the studies of the stone and mortars samples of the tomb of Qen-Amun (XRD) which showed that the archaeological building was affected by damage factors over thousands of years, and the weakness of its elements.

5-2- Visible deterioration

Visible damage is divided into:

- **Micro scale manifestations of damage** from mm to cm of discoloration mass loss, micro-morphology, and this appears in the tomb through Examination by means of laboratory investigation, as shown by the results of imaging and examination by scanning electron microscope of limestone samples from the tomb, as well as, through accurate imaging as it was in documented photos.

- **Medium damage manifestations**, and their sizes are visible in the Micro-scale archaeological stones from mm to cm. These manifestations of damage appear in the tomb of Qen-Amun in the form of severe fragmentation, simple cracking, and some forms of loss of cohesion. They were detected through imaging in its various forms of the elements of the archaeological tomb. This was also

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documented by drawing a map of damage manifestations, as in figures (5, 6) and signs of damage manifestations, as in these figures.

- **Manifestations of significant damage**, including damage to an element or elements of the building, which affects the stability and balance of the building. There are clear cases of that such as large cracks and collapses in all their forms, and this was examined by means of examination in the site. So tests of the extent of its activity were made. As it was done using the bulging method in examining the activity of the cracks of the eastern wall and the northern wall in the tomb of Qen-Amun. Paintings of cracks and collapses were also made, as well as the displacement of some stone slabs.

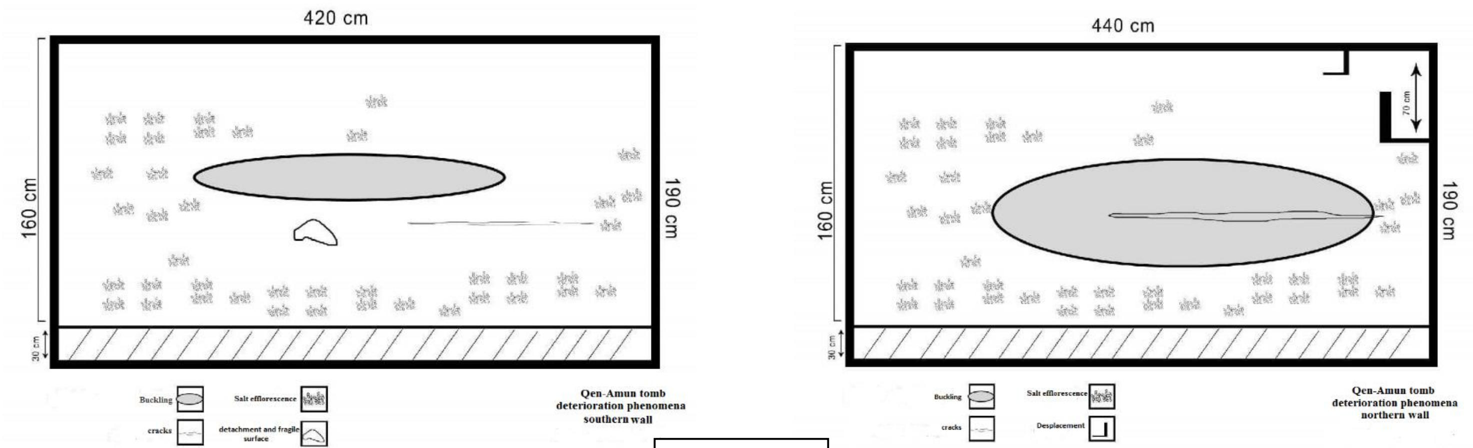

Fig No 5

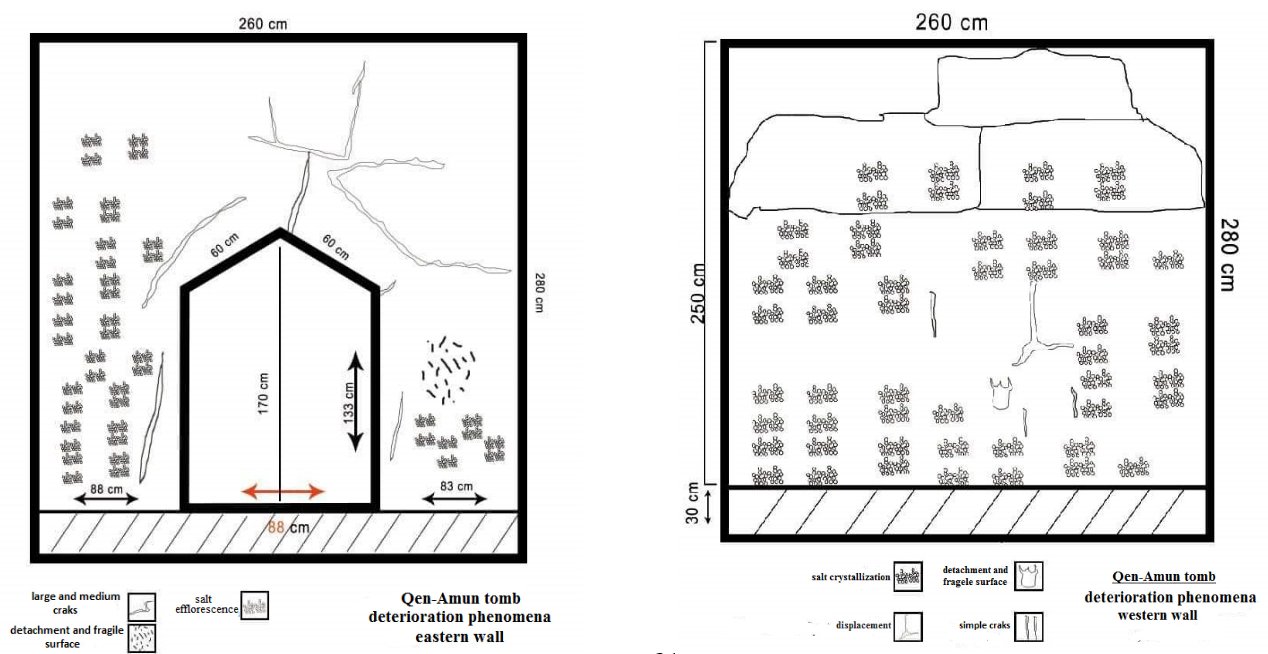

Fig No 6

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Analytical and examination study

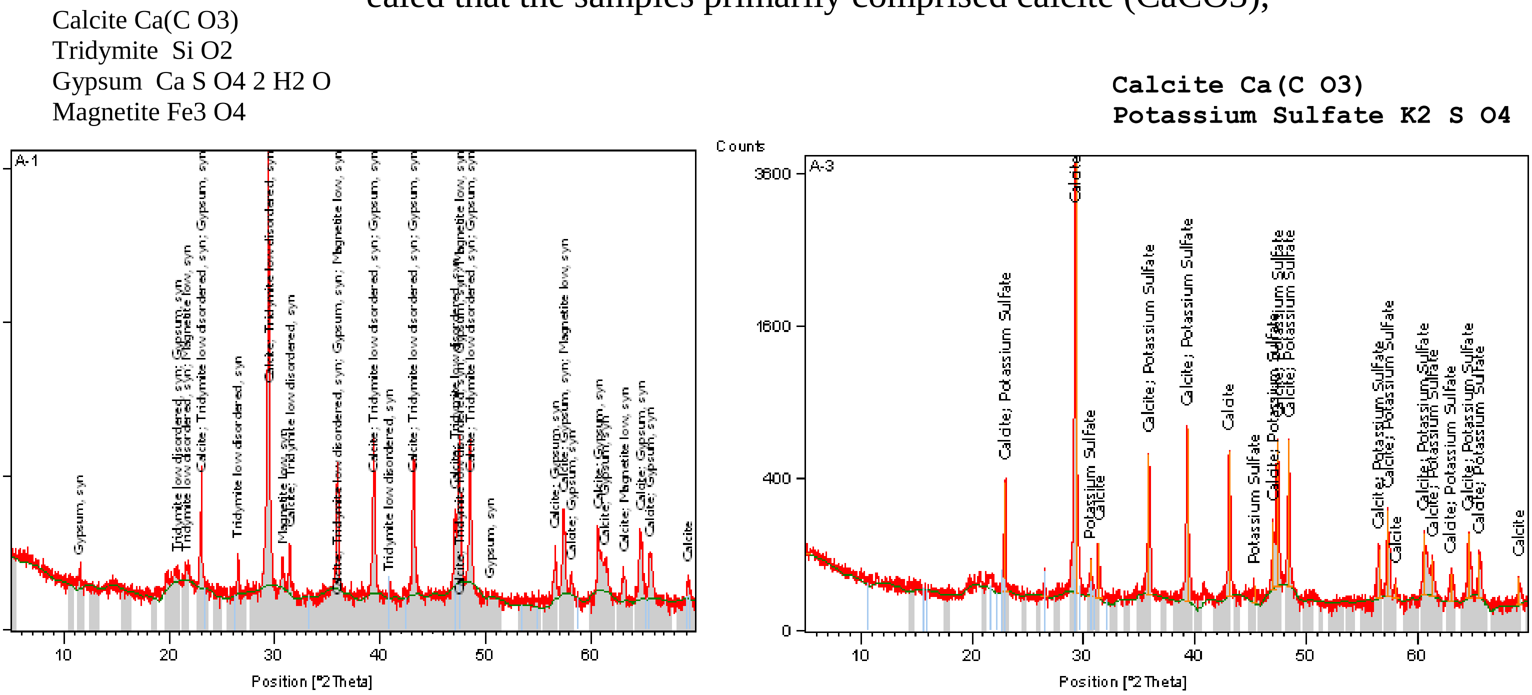
Materials and Methods

1- Samples of limestone were taken from the tomb, specifically from areas that were directly exposed to the effects of burial conditions and meteorological factors. Salt efflorescence was collected using a brush. The gathered samples underwent analysis and examination to distinguish various forms of weathering. The analysis primarily relied on non-destructive techniques such as:

2- X-ray diffraction (XRD):

Limestone analysis:

The XRD analysis conducted on the examined limestone samples (Fig. A1 and A3) revealed that the samples primarily comprised calcite (CaCO3),



potassium sulfate (K2SO4), quartz (SiO2), gypsum (CaSO4.2H2O), and magnetite (Fe3O4), as shown in Figure 7.

Fig No 7

Mortars analysis:

The XRD analysis conducted on the examined mortar samples (Fig. B1, B3, and C2) revealed that the samples primarily consisted of gypsum (CaSO4.2H2O), calcite (CaCO3), quartz (SiO2), and zinc sulfide (ZnS), as depicted in Figures 8 and 9.

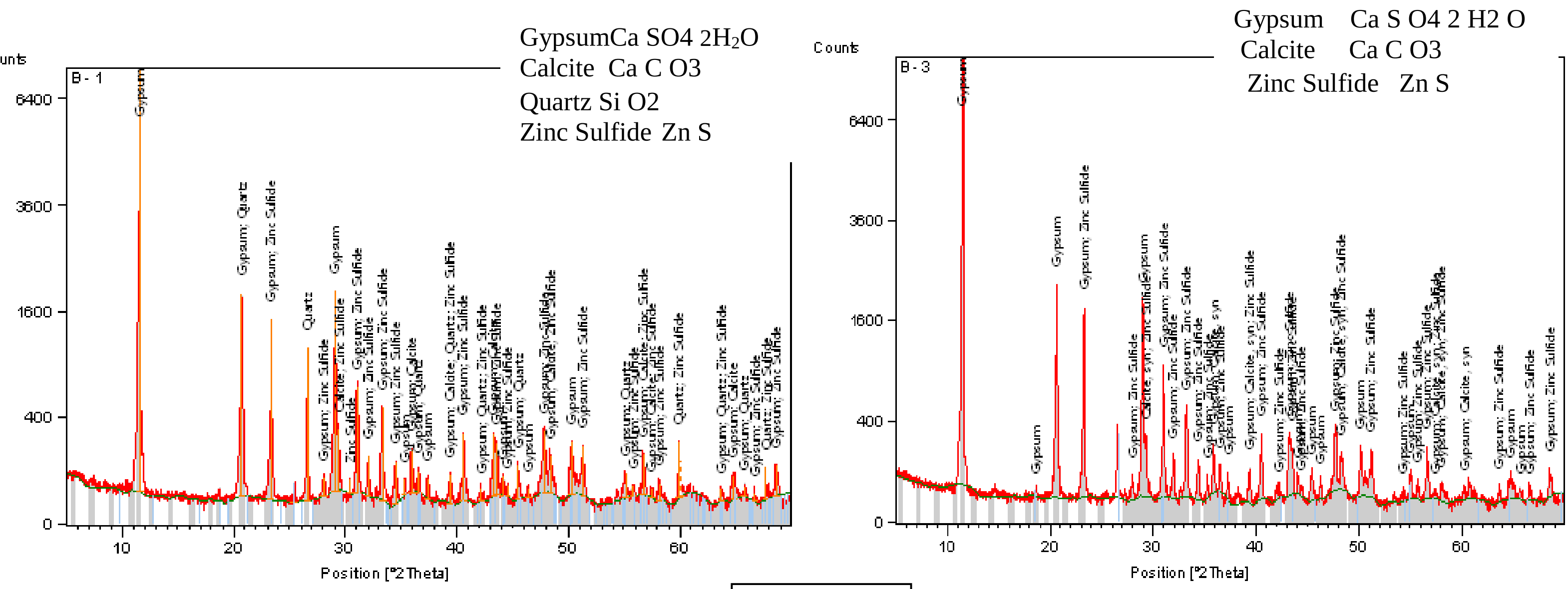


Fig No 8

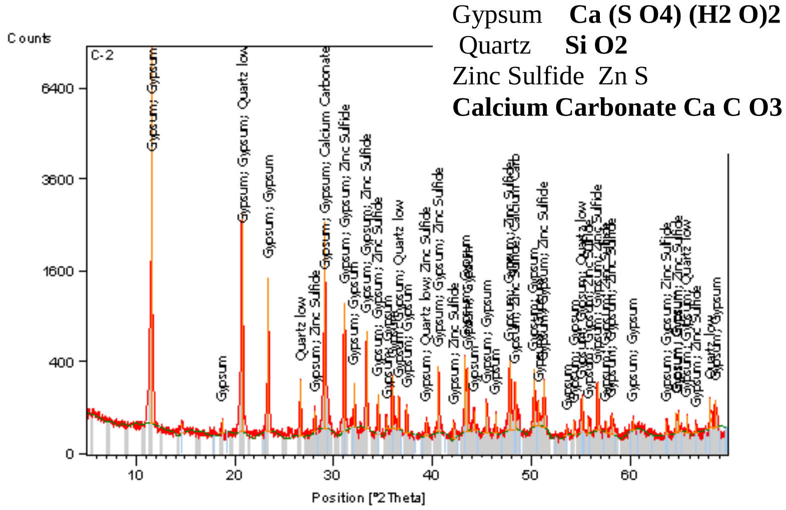


Fig No 9

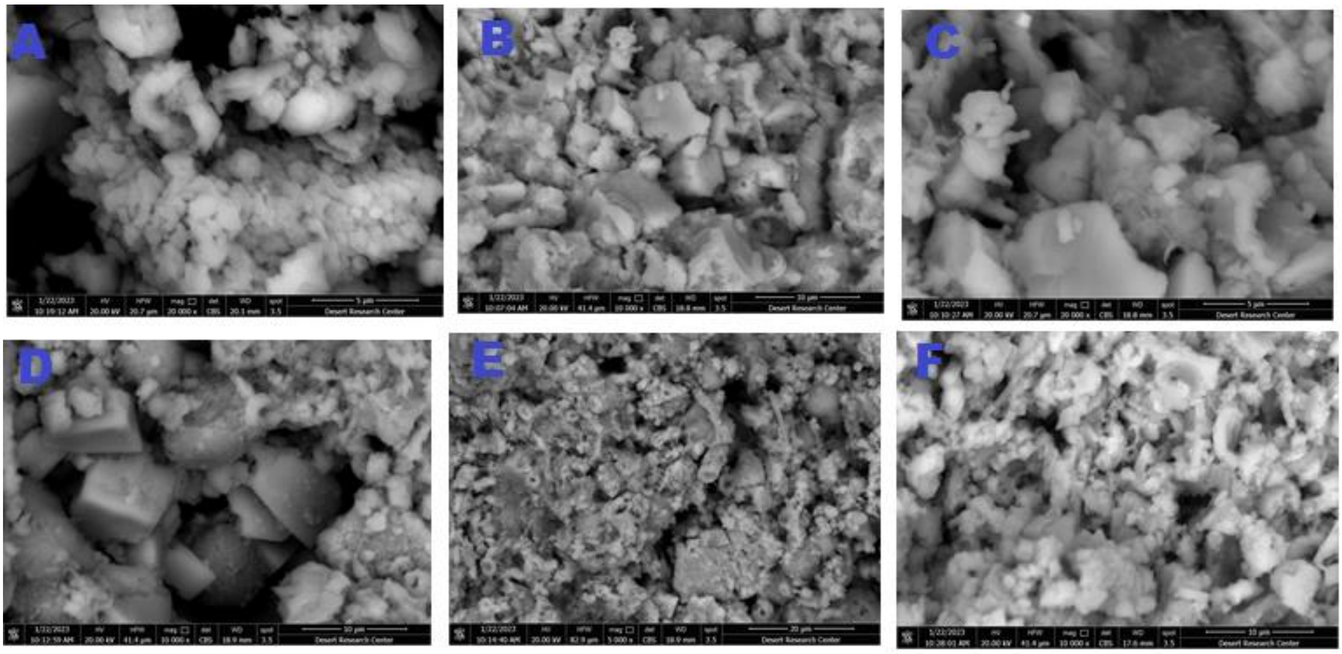


Fig No 10

2-SEM photomicrographs

The findings from the scanning electron microscope characterization confirm that the primary cause of significant deterioration in the rock is the high presence of soluble salts. Additionally, the results demonstrate a wide array of deterioration features, as depicted in Figure 5. These features include disintegration between calcite crystals, dissolution of calcite crystals, loss of binding materials between grains due to the crystallization of salts, the presence of small fissures and cracks, localized cavities, and the existence of clay minerals alongside the calcite grains. Furthermore, the results indicate that the gypsum content in the samples is a result of the transformation of calcite into gypsum.
Figure 10 showcases SEM micrographs of deteriorated stone within the tomb of Qen-Amun, highlighting various observations:
A) The presence of cracks and scales separating from the rock due to the pressure exerted by gypsum and potassium sulfate salts.
B) Different salt crystals, including potassium sulfate salts and gypsum.
C) Sulfate salts leading to the loss of cohesion between grains, as well as the destruction and dissolution of calcite crystals.
D) Sulfate salts affecting both calcite crystals and causing their destruction and dissolution.
E) The growth of gypsum and potassium sulfate salts on calcite cleavage planes, with accompanying fossils found beside noticeable cracks.
F) The occurrence of rock separation and cracks attributed to the influence of gypsum and potassium sulfate salts.

Restoration and conservation of the tomb of Qen-Amun

1- Preliminary interventions and preventive conservation

The initial restoration and conservation steps for the stone elements of the tomb started from the early stages of the excavation, and those steps were as follows:

- **Crucifixion and warding off risks**

It was necessary to take quick procedures to prevent danger and risks for the ceiling, the sarcophagus, and the entrance. Strong wooden crucifixes were made in the same shape as the gabled ceiling, and they were installed on wooden pillars as shown in the pictures (No 7, 8). Then the two rows of stone pillars were gradually dismantled, so thus the load was transferred from the sarcophagus lid to the wooden crucifixes gradually. This process was the first step in preventing structural risks.

A wooden solid ceiling was also made for the entrance of the tomb, which is located in the eastern wall, and it is also aesthetically shaped as in the pictures (No 9, 10) and preserved the entrance from collapse, especially since the eastern wall which suffers from many forms of cracks.

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- **Removing the rubble behind the eastern wall**

Soil pressure especially behind the eastern wall and the entrance was a severe horizontal pressure (literal load) on this wall. Therefore, raising this rubble was one of the most important steps to prevent the danger that was made to the architectural elements in the tomb and reduce the side loads from on walls of the tomb.

- **Installing a protective Shelter**

The protective Shelter is considered one of the most important necessary and preliminary procedures that must be taken in such a case as that of the Qen-Amun tomb, to protect the elements of the tomb from weather conditions and various weathering factors such as heat, rain and humidity. With following the necessary ventilation specifications in order to maintain a suitable air environment for preservation and conservation. The pictures illustrate the work of the tomb Shelter protection umbrella that was installed.

2- Sustainable restoration and conservation

2-1- Cleaning and salt reduction

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(12)

(13

Cleaning and reduction salts are important and difficult stages of treating monuments, especially in buildings that suffer from deterioration and neglect in uninhabited desert areas such as Al-Maskhuta cemetery. Salts and dirt were found on all the stone walls, and therefore we find that this process needs a lot of patience and concentration. The following methods were used in cleaning and salt reduction:

- **Mechanical cleaning:**

Mechanical cleaning using fine tools and brushes is used in removing salts and dirt from ancient surfaces. At this stage, brushes and tools of various sizes, shapes, and different heads are used to help with accuracy and skill in applying this technique. The result of this work is usually the removal of the largest amount of plankton and calcified salts, as in Picture No (13), where large quantities of salt calcifications were removed before moving on to other stages of cleaning and salt removal, which usually takes place after mechanical work. Stone cleaning can be to the advantage of a surface by displaying the true color of previously obscured and by revealing the quality of the carved detail [(7)].

- **Cleaning by vacuum cleaner and air pumping devices:**

There are many air pumping and vacuum devices that are used in cleaning dust and salts on ancient surfaces. They usually not only remove plankton that are not attached to the surface with strong bonds, but also help conservators for cleaning works to get rid of those plankton that may lead to the formation of stronger bonds to the surfaces when using the Chemical solutions, and this is what was done in the tomb of Qen-Amun.

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- **Chemical cleaning and salt reduction**

Various chemical techniques are employed for the removal of salts and calcified dirt from ancient surfaces, with the choice of cleaning method being contingent upon the condition of the monumental surface (8). When mechanical cleaning proves insufficient, chemical cleaning (wet cleaning) is implemented. Ingrained dirt, unsightly patchiness, and encrusted deposits of Potassium Sulfate (K_2SO_4) and Zinc Sulfide (ZnS) were addressed using three poultices.

The first poultice consisted of absorbent materials saturated with a mixture of 10% sodium thiosulphate ($Na_2S_2O_3·5H_2O$) and 5% ammonium carbonate, combined with distilled water. Subsequently, a rinse of distilled water and ethyl alcohol was applied to the treated areas to eliminate ammonium sulfate, which is highly soluble in water.

The second poultice utilized the sodium salt of ethylenediaminetetraacetic acid, commonly referred to as EDTA, as the active ingredient. This poultice was particularly suitable for gypsum crusts because EDTA forms a stable complex with Ca^{2+} ions, effectively transforming gypsum into soluble sodium sulfate (Na_2SO_4), which is then mobilized into the poultice and extracted from the stone (8).

The third poultice consisted of sepiolite clay, to which carboxymethyl cellulose (CMC) dissolved in hot water was added in a ratio of 4 parts clay to 1 part CMC. This poultice was applied to walls with robust stones. Prior to the application of the sepiolite clay poultice, Japanese paper chips were spread over the stone's surface to facilitate the removal of the poultice without contaminating the archaeological surface once it dried. Conservators often favor this poultice, which incorporates sepiolite clay, for desalination purposes, as it aids in drawing out soluble salts. It is also utilized as a cleaning method on substrates like limestone that respond well to water-based cleaning (9).

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Consolidation:

Consolidation is a comprehensive treatment method aimed at re-establishing the cohesion among particles of deteriorated stone (10). Due to the combined effects of chemical and mechanical weathering, the stone loses its cohesion, as evidenced by SEM analysis, necessitating treatment to restore its integrity. After the completion of fundamental restoration tasks such as cleaning and salt reduction, the limestone surface is treated with Nano SiO_2 + Nano $Ca(OH)_2$ (core shell).
The Nano SiO_2 + Nano $Ca(OH)_2$ (core shell) based impregnates are considered superior to other Nano materials commonly used in conservation. This is because they possess excellent ability to treat limestone, being composed of the same natural constituents found in limestone. Additionally, as Nano materials, they have a good capacity to penetrate into the pores of limestone. Kumar and Pilz (11) have also noted the success of Consolidation materials depends on their ability to penetrate inside the pores, as well as the symmetry of their distribution within the pores. The degree of penetration and distribution symmetry inside the pores primarily relies on the viscosity of the material, which, in turn, depends on its concentration (12).

Paraloid B-72 was utilized to enhance the physio-mechanical properties of the stone. This hydrophobic product was applied to the dry stone surface using brushes.

Discussion:

The analytical data obtained from previous analysis and diagnostic methods have provided valuable insights into the harmful factors that have impacted the limestone tomb and resulted in deterioration. SEM photomicrographs revealed disintegration between calcite crystals and loss of binding materials between grains due to the crystallization of salts. Decayed samples displayed etching features in certain calcite grains, indicating micro-dissolution processes associated with chemical weathering. Carbonate cement dissolution and subsequent calcite recrystallization were also observed. Potassium sulfate crystals were found, and SEM observations further revealed destroyed calcite grains and droplets of Zinc Sulfide mixed with clay mineral crystals. White crusts containing gypsum were detected beneath the surface, suggesting precipitation occurs during the formation of these crusts after gypsum dissolution.

Mineralogical analysis using XRD of the limestone samples indicated that the salt layers primarily consisted of Zinc Sulfide and sulfate phases (gypsum, Potassium sulfate). The presence of Zinc Sulfide and Potassium sulfate salts can be attributed to the Ismailia Canal and cultivated land. Gypsum was likely formed through the reaction between SO42- ions present in acid deposition and the calcium carbonate (CaCO3) in limestone. It may also occur naturally as a mineral within the stone, commonly found in the form of dehydrated sulfate (CaSO4·2H2O) gypsum in the Qen-Amun tomb limestone. Atmospheric pollution is a significant source of sulfate. The transformation of gypsum to anhydrite due to heating in summer causes a substantial volume change in the crystal structure, resulting in numerous cracks and microcracks within the blocks. Sulfates, therefore, constitute the most common damaging salts. The presence of iron and quartz, attributed to clay minerals, further complicates the issue. SEM images documented these findings. Traces of iron oxide were also identified in the samples, and the fracturing observed in samples exposed to salt baths could be attributed to the presence of Fe ions. The alternating cycles of hydration and crystallization, caused by exposure to oxygen and moisture in the open environment, lead to the conversion of Fe ions into hydrous iron oxide, which has a significantly higher volume compared to the parent iron. This volumetric increase generates substantial pressure in confined spaces, leading to the fracturing of the stone [14].

The restoration and conservation work carried out on the Qen-Amun tomb includes cleaning (both mechanical and chemical), desalination, and consolidation. There is also a proposal to relocate the tomb to the Ismailia museum as an important step in its preservation.

Conclusions

Based on the study conducted, the following conclusions can be drawn: The location of the tomb in agricultural land near the Ismailia Canal has significantly contributed to its deterioration. Factors such as water irrigation, salts, sudden changes in temperature and moisture, as well as human damage including unauthorized access and vibrations from nearby railway and highway, have adversely affected the architectural elements of the tomb.

The composition analysis of the limestone revealed the presence of calcite, dolomite, and quartz. The abundance of these minerals can be attributed to the direct effects of salts crystallization, rising damp, irrigation water, relative humidity, and vibrations from the railway and highway. These factors have led to various forms of deterioration, primarily related to drying conditions. One notable

consequence is the growth of salt crystals within the stone pores, which can cause it to disintegrate.
XRD analysis indicated a weakness in the limestone due to deterioration factors such as the interference of potassium sulfate and gypsum between grains, as well as the presence of Zinc Sulfide salt in the mortars. Similar results were obtained from the analysis of multiple limestone and salt samples, confirming the presence of the same salts.
The restoration and conservation work for the stone tomb encompass various measures, including mechanical and chemical cleaning, desalination, consolidation, restoration processes, and a proposal to relocate the tomb to the Ismailia museum.
In summary, the study underscores the significant impact of environmental and human factors on the deterioration of the tomb's architectural elements. The analysis of the limestone and salt samples provides valuable insights into the specific salts present and their effects on the stone. The proposed restoration plan aims to address these issues and ensure the long-term preservation of the tomb, including its potential relocation to a museum setting.

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