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A PROPOSAL FOR PREVENTIVE CONSERVATION AND ACHIEVING SUSTAINABILITY OF THE KHAFRE'S VALLEY TEMPLE IN EGYPT

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***Abstract**:*
*Preventive conservation of archaeological buildings is one of the most important procedures that helps to preserve the sustainability of these buildings and transfers them to future generations with all their characteristics and values. The importance of this procedure increases with the increase in the building's value and uniqueness especially its archaeological value and historical depth. Therefore, the study came up with a proposal for the preventive conservation of the Valley Temple of King Khafre that is located in the Giza plateau. The temple receives visitors daily, but it suffers from a set of structural and architectural problems which threaten its sustainability and negatively affect its presentation. Therefore, the study aims to monitor risks and develop a proposal for preventive conservation through: **a.** a proposal for interventional conservation to get rid of the main problems **b.** developing a proposal to avoid future problems and **c.** suggesting ways to better present the temple. The study suggested a preventive conservation proposal for the temple, which includes urgent restoration work to keep the temple from collapsing or losing some granite blocks, roofing the temple as a preventive measure that contributes to reducing the effect of deterioration factors in its environment, as well as a way to better present it by simulating its original architecture where the temple had a roof. In addition to a proposal to use some modern techniques to display models of the King Khafre's statues inside the temple, with the possibility of employing these techniques to clarify some of the ancient Egyptian rituals that were performed in the temple.*

1. Introduction

Archaeological buildings always have different values that necessitate the intervention with conservation works [1]. There are two types of conservation: **a)** preventive conservation that means dealing with the environment surrounding the monument (environment, humidity, temperature, and lighting), **b)** interventional conservation (restoration) or emergency conservation that means adding materials for treatment or removing deterioration to protect the monument [2]. As stated in the Athens Charter [3], one of the most important principles in restoration is the adoption of a system of follow-up and periodic conservation to ensure the maintenance of the building and avoid risks, and that restoration work is an inevitable necessity to protect against damage. *Preventive conservation* means the precautionary measures that are taken in order to prevent or limit the deterioration that occurs on the archaeological building, whether at the present time or in the future, as well as predicting the occurrence of damage or the time of its occurrence and taking the necessary measures to prevent it or reduce it as much as possible. It is also intended to carry out works that would prevent danger from buildings and their elements. Therefore, preventive conservation focuses on monitoring work and regular follow-up for each element of the building at suitable time periods with the aim of early detection of any defect or damage that may arise in the future [4]. There are a number of preventive conservation methods including: the use of reversible restoration and conservation materials, extensive study before restoration works and sufficient knowledge of the properties and effect of the restoration materials and techniques, interfering with minimal conservation work to preserve the archaeological building [5], the use of alternative roofs to receive loads instead of the archaeological roofs, the use of mechanical ventilation methods or chemical means to get rid of high temperature and pollution, and the use of some materials that absorb excess moisture from inside buildings [6].The importance of preventive conservation, periodic follow-up and continuous evaluation increases when dealing with ancient archaeological buildings, as it is when dealing with the Khafre's Valley temple. This temple is of great importance, which makes it the focus of attention and receives visitors daily. From the field visits, it is clear that the temple suffers from many structural and architectural problems that affect it negatively and threaten its sustainability. Therefore, the study aims to monitor its risks and develop a proposal for preventive conservation.

2. Practical Development

2.1. *Archaeological and architectural description of the temple*

Auguste Mariette discovered this temple in 1853 AD [7], it is a part of the funerary group of King Khafre of the 4th dynasty, fig. (1). The temple has been impressive since its discovery due to its very good condition. The building measures 45×46 m and its height is 13 m. Limestone was used as a main building material in the temple while it was cased inside and outside with carved stones of the polished granite, fig. (2) [8]. The four outer walls were built inclined according to the style prevailing at that time. It has granite pillars and architraves with an Egyptian alabaster floor. This building has two entrances on the eastern facade, and these two entrances lead to short passages that lead to a long portico in whose floor there is a deep pit that contained a diorite statue of Khafre [9]. The references mentioned that sunlight used to enter the temple through inclined openings at the top of the walls and other openings in the flat granite roof, but these openings cannot be inferred now because of the complete loss of the original roof of the temple and the falling of most of the upper parts of the granite walls. The interior of the valley temple, fig. (3 & 4) consists of a vestibule and a T-shaped hall with sixteen granite pillars. The T-shaped hall contains twenty-three bases carved into the floor next to the walls of the temple. These bases were the place of the granite statues of King Khafre (Only one statue and a few small statues remained preserved in the Egyptian Museum) [10]. The valley temple was combines the benefits of two buildings as it was for purification and mummification. It is assumed that the mummification was carried out in a temporary place built above the roof. After purification and wrapping the body in wraps, it was taken to the T-hall (where the twenty-three statues were located) to perform the third ceremony that takes place in the valley building (opening the mouth) [9].

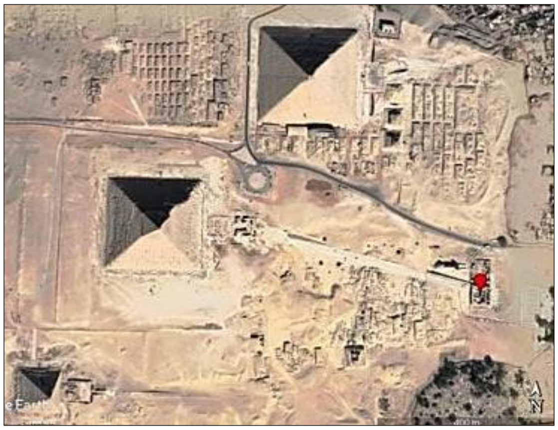

Figure (1) Shows general view of the valley temple in the urbanization of the three Giza pyramids (*After: Google Earth, 2022*)

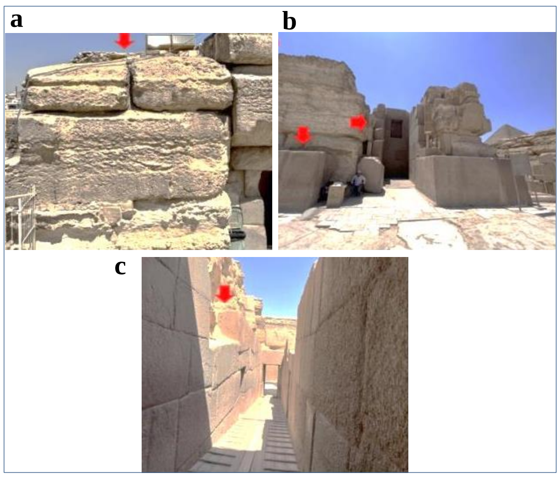

Figure (2) Shows **a.** the walls of the temple that were built of local limestone, **b.** outer and **c.** inner casing with granite blocks

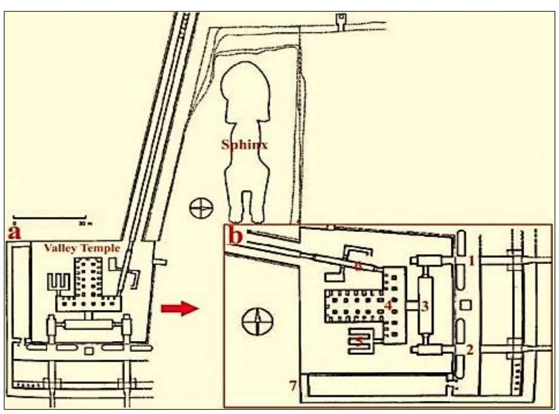

Figure (3) Shows **a.** plan of the valley temple and sphinx (*After: Hamilton, 2021*), **b.** detail of the temple's parts; 1 & 2. entrances, 3. vestibule, 4. chamber of sixteen pillars, 5. storage chambers, 6. the causeway, 7. temple's enclosure wall.

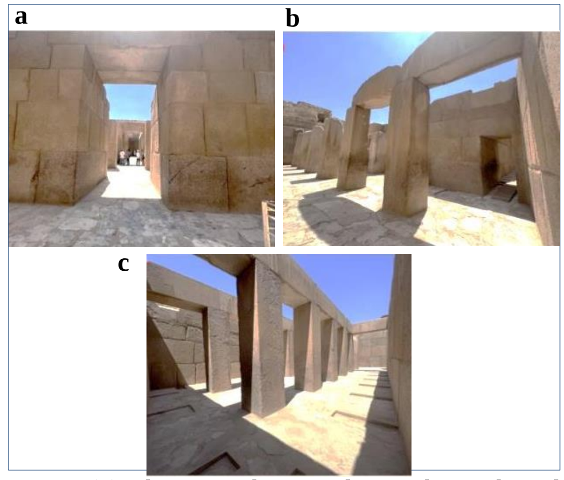

Figure (4) Shows **a.** the corridor to the T-shaped hall, **b.** the complete loss of the original roof of the temple, **c.** sixteen granite pillars and twenty-three bases carved into the alabaster floor

2.2. *Monitoring risks that threaten the temple's sustainability*

Proposal for preventive conservation of archaeological buildings include monitoring the most important deterioration aspects and determining their different factors [11], then developing a plan for restoration to get rid of the damaging effect, and developing a proposal for preventive conservation to avoid any problems that may negatively affect the temple in the future. The most important damage aspects in the Khafre's valley temple are:

2.2.1. Variation in the mineral composition of granite rock

The variation in the physicochemical composition of the granite minerals is one of the most important and most dangerous internal damage factors for this type of stone. It is known that every mineral differs from the other in terms of its physical and chemical composition. Therefore, when these minerals are exposed to any affecting factors, each of them has a different interaction and these results in mechanical stresses inside the stone that eventually leads to cracking and sometimes separation. This is what actually happened to the Temple Valley Stones, fig. (5) [12].

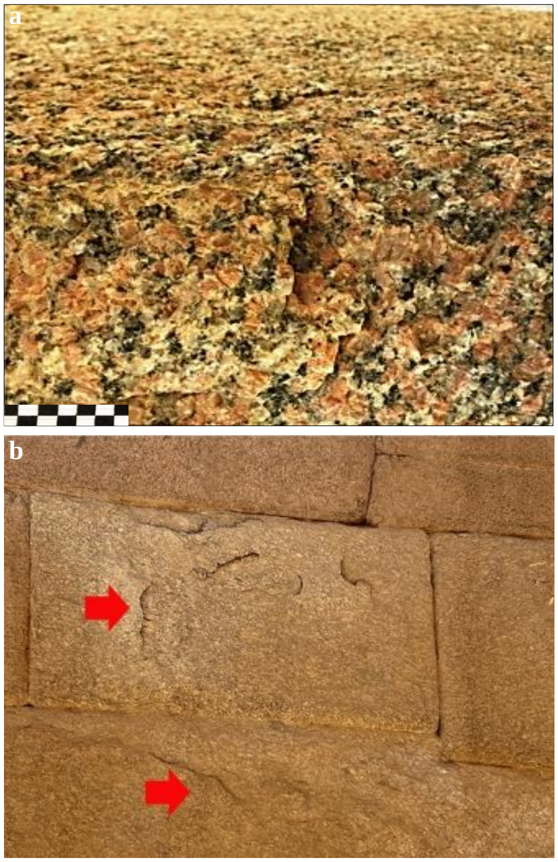

Figure (5) Shows **a.** the different minerals that make up granite **b.** separation in layers due to the variation in the physicochemical composition of the granite minerals

2.2.2. Moisture effect

Moisture played an important role in the damage to stones in the temple due to its large presence in the surrounding environment. There are many and different sources of moisture: **a)** *external sources*; rainwater, condensed water and water vapour **b)** *internal sources*: groundwater, salts that have the ability to absorb large amounts of water known by hygroscopic salts and microorganisms that migrated from the moisten soil. In addition to the direct role of moisture in the deterioration processes, it plays the role of a catalyst and an activator for most other deterioration factors [13,14].

2.2.3. Salts effect

Salts are one of the most important and most dangerous deterioration factors. There are many sources for salts: **a)** stones have different proportions of salts in their natural components, **b)** groundwater dissolves soil salts and carries them through cracks caused by weathering factors, **c)** the penetration of water from the drainage nets because the temple is located near Nazlet El Simman area. The problem of this area lies in its high population density and the deterioration of its sewage networks resulting in sewage leakage that has a negative impact on the archaeological buildings in the Giza plateau [15,16]. Given the location of the valley temple on the lower edge of the plateau, it is the most archaeological building affected by the water leaking from this area.

From examinations and analysis that were carried out on the temple stones, it was found that halite salt (NaCl) is a water-soluble salt that represents a deterioration factor and negatively affects the building materials [8].

2.2.4. Air temperature variation effect

Variation in temperatures in the Giza plateau region, whether daily or seasonal, helps in the damage to non-porous stones such as granite. The effect of variation in temperatures on granite depends on the duration of the sun's brightness, the large difference between day and night temperatures and their role in the expansion and contraction processes of mineral component [17,18]. As a result of the multiplicity and different minerals of granite, each mineral has a different rate of expansion and contraction than others, and has different colour according to its exposer to direct temperatures and according to its thermal conductivity where the dark mineral components in granite are characterized by absorbing the largest amount of temperatures [19]. Giza plateau has a desert climate [20]. The variation in temperature vary by 15.8 °C, with the lowest average temperature reaching 13.4 °C in January and the highest one reaching 29.2 °C in August. There is virtually no rainfall all year long in Giza. The annual rainfall is

18 mm/0.7 inch. The month with the highest relative humidity is December (55.29 %), while the month with the lowest one is May (36.44 %) [21].

2.2.5. Man-made deterioration

Man-made deterioration is represented in the lack of awareness of the value of the archaeological buildings or as a result of the old unsuitable restoration work by using inappropriate materials in the restoration operations and the ignorance of the nature of the restoration materials [22].

2.3. *Preventive conservation requirements for preserving the temple*

The proposed preventive conservation plan to preserve the valley temple is based on the following: **a)** Getting rid of the main problems that have been detected and threatened the temple's sustainability, **b)** Developing a proposal to avoid future problems negatively affecting the temple, **c)** Suggesting ways to better present the temple based on the use of modern technologies.

2.3.1. Getting rid of the main problems that threaten the temple's sustainability

2.3.1.1. *Structural restoration works*

The temple shows some structural deterioration phenomena such as the complete loss of the ceiling, the appearance of cracks, and the lintels' damage as a result of the use of iron in the reinforcement with a heterogeneous restoration work using Portland cement with granite. As a result, temporary reinforcement of the lintels is proposed removing old and unsuitable restoration work (iron bars, completion mortars with Portland cement) and carrying out shores with wooden or metal structures. Taking into account, all the shores are structurally effective the stability of the soil under the building with the use of light and non-solid materials such as sponge or plastic strips at the points where the shores meet with the building [23]. This is followed by monitoring and treatment of cracks. The used methods to treat cracks are many and varied according to the size and depth of the crack. There are cracks of medium permeability and depth that appear at the meeting of the lintels with the walls and medium cracks are present in the lintels themselves that represent a structural danger by causing the collapse of the lintel and micro cracks resulting from the discrepancy in the properties of the materials used in restoration from the original building materials. Stitching by stainless steel beams can be used for medium cracks [24] while stitching by regular blocks of granite can be used for the cracks resulted at the joints between the stones to cut the path of those joints. The tiny cracks are considered ineffective structurally, and this is mainly caused by the discrepancy in the properties between restoration and original building materials. Accordingly, completion with unsuitable mortars will be removed then the dust and suspended materials will be thoroughly cleaned using compressed air. After that, the surface is wetted with water and completed with the same type of stone that will be mixed with a suitable bonding agent for good bonding with the original surrounding building material [25].

2.3.1.2. *Architectural restoration works*

It is necessary to complete the largely dilapidated parts and the parts that have been removed as inappropriate completion works. Completion is based on the use of the same type of the original stones or stones with similar characteristics taking into account cleaning and restoring surfaces before the completion process, In addition to studying the techniques of providing lighting and displaying elements that better present temple to visitors [24].

2.3.1.3. *Fine restoration works*

It includes all works related to filling cracks and gaps, injecting cracks, fixing surface crusts, treating wall reliefs, decorations and ornaments, cleaning and fixing colours, assembling and strengthening stone blocks, and extracting salts. It is suggested using the manual cleaning very carefully with brushes of different types and sizes. This is followed by the extraction of salts from the walls of the temple [26]. Previous examinations and analyses have proven that the salts negatively affecting the temple are halite salt, which is a type of soluble salt in water, and it is found as a natural impurity in Egyptian soil [27]. Bader study [8] suggested the use of poultices to extract those salts, whether natural materials, such as some clay minerals, including *Atabolite*, *Sepiolite* and *Bentonite*, or industrial materials such as paper tissue, cellulose powder which are prepared by mixing with de-ionized water. The basic structure of some temple walls needs consolidation, so it is suggested that we use consolidation materials that meet the necessary conditions in terms of application and penetration, and not to produce any acids or salts. These materials do not chemically react with the building material and they have good aging properties [8, 28]. As for floors, it's recommended to clean the dilapidated alabaster floors as follows: first, mechanically removing fine dust with smooth brushes in order not to scratch the weak surface, second, wetting soil crusts with distilled water and removing them with scalpels and the remains of crusts will be removed with ethyl alcohol and cleaned with distilled water to remove the solvent' remains [29]. The consolidation process for alabaster floors is necessary; Taking into account studying the effect of temperature and exposure to direct sun on the chosen consolidation material, As well as a study of its effect by friction as a result of the presence of alabaster on the temple floor, and alternative floors can be used as one of the preventive conservation measures to ensure the preservation of the floor's temple.

2.3.2. Developing a proposal to avoid future problems negatively affecting the temple

The roof of the valley temple is considered one of the most damaged structural elements as there are no remains left of it. Lack of a ceiling makes the temple more affected by the influence of weather factors such as rainwater, the effect of direct sunlight, and the temperature variation. In the Old Kingdom most of the temples' roofs were flat; this is due to the dry climate where there are little rains. Flat roofs led to their use in some of the cult rituals. The valley temple roof was sloping as water was led from the roof to ramps that led to flat collective channels then drained to waterspouts [30]. To reduce the current damage and as a preventive conservation measure to avoid future problems that arising from the site of the temple in its open desert environment, it is proposed to re-roof the temple. There are many ways to roof archaeological buildings such as: **a)** Using glass to let in natural light. **b)** Constructing a shelter of steel and may be designed in the same style as the original. **c)** Using girders in combination with glass. The external main walls of the temple can be used to load the proposed roof instead of the internal granite columns and lintels, and it is suggested that the roof be of stainless steel frames (similar in their colour to the surrounding rock) whose spaces are filled with glass with taking into account the frame is set inside to preserve the outer historical view [31]. The used glass shall be treated to reduce greenhouse gas emissions, and shall be designed insulating to prevent leakage of heat and reflecting the sun's rays allowing only the amount that is not harmful to the building to pass through, fig. (6). A specialized study can be conducted to compare the use of clear glass with the previously mentioned specifications, and the use of opaque glass as it will mimic the opacity of the original ceiling. Strudwick [10] mentioned that the ceiling was of granite and the fall of the sun's rays was indirectly on the interior statues as it was fallen from openings in the ceiling then reflected on the floors that were covered with alabaster.

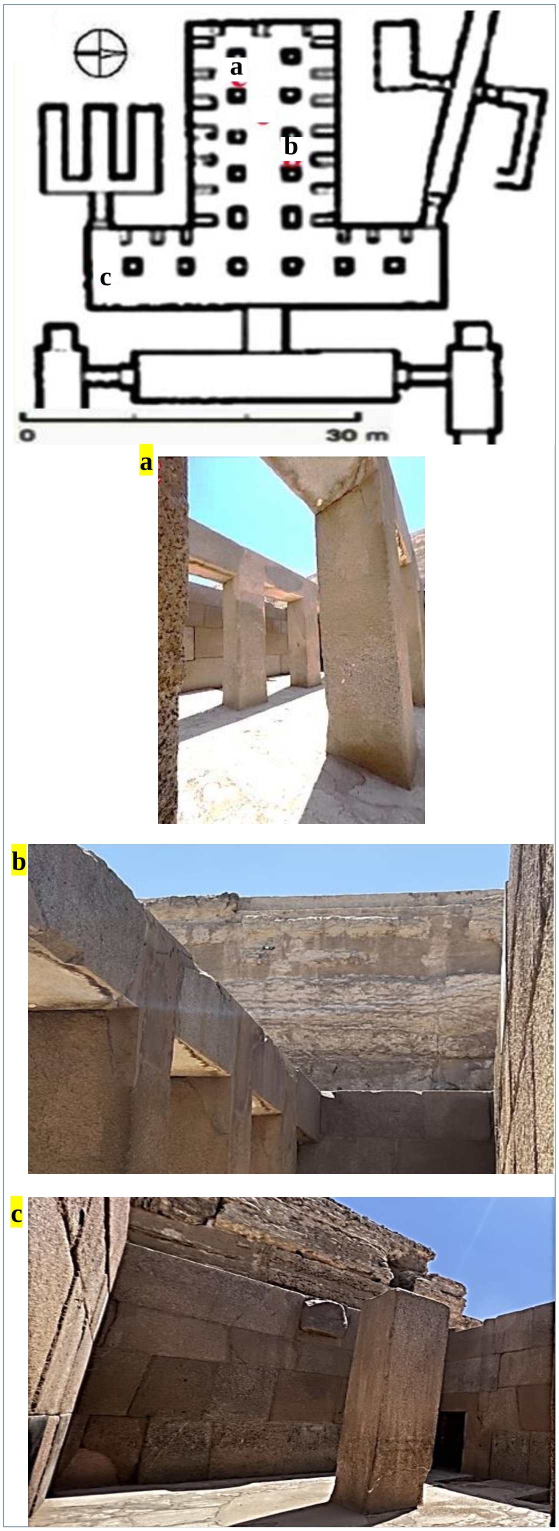

Figure (6) Shows locations of the taken photos on the plan; detachment of the surface layers, chromatic asymmetry and the appearance of dark spots as a general appearance of granite blocks

2.3.3. The better suggestions to present the temple

Better suggestions to present the temple based on the use of modern technologies. The roof of the building was used for mummification, so modern displays (multi-dimensional) can be used in the short passage to display information about mummification and the characteristics of the hall above the ceiling that was designed for this in the temple in addition to displaying information about the ritual of the mouth opening that was performed in the T-shaped hall. It also suggested the use of holographic display (virtual three-dimensional image) to display models of the statues of the king in their specific bases on the floor of the temple and inside the deep pit at the short passage where visitors are confused about the main reason or purpose of these places, fig. (6). Also copies of the king's statues may be placed in these spaces that mimic the original.

3. Results

Detailed study was conducted to assess the condition of the Khafre's valley temple and propose a plan for *preventive conservation*, and the results of the study were as follows:

1st highlighting the value of the temple and clarified its importance, its architectural ele-ments and its building material.

2nd monitoring the risks that threatening the sustainability of the temple represented by: **a)** *variation in the mineral composition of granite rock*, **b)** *Moisture effect*, **c)** *Salts effect*, **d)** *Air temperature variation*, **e)** *Human damage*. In light of all of the previous, the granite in the temple is subjected to many stresses, which in turn led to many reactions represented in disintegration, cracking and peeling [32].

3rd proposing a preventive conservation plan includes: **a)** *proposal to solve the structural, architectural and fine problems, which negatively affect the sustainability of the temple elements and its building materials*. **b)** *proposal to reduce the fut-*

ure problems of the temple. **c)** *proposal to better present the temple to visitors*.

4. Discussion

As illustrated in fig. (1), the value of the temple is evident in its location within the urbanization of the three pyramids and its relationship to the Khafre's pyramid and the Sphinx statue. Over time, the effect of a new area in the urbanization of the temple appeared. This area is Nazlet El-Simman that negatively affects the temple due to its population density and random planning. Figure (2) showed the variety between main building and casing materials in the temple, where limestone was used as the main building material, while granite blocks formed the inner casing material that define its spaces, its structural system as columns carrying lintels on which the roof was supported (as indicated in historical studies). In view of the archaeological and architectural value of the temple, the study focused on monitoring the risks, which are clear once the temple is visited and visually examined. These risks are represented in the loss of the temple roof, the collapse of some parts of the lintels and columns, and the separation of some surface layers in the granite casing [33]. Monitoring the risks that threatening the sustainability of the temple represented by: **1)** variation in the mineral composition of granite rock: caused mechanical stresses inside the stone that eventually lead to cracking and separation as illustrated in fig. (5), the resulting cracks also act as channels for water, which accelerates the rates of damage resulting from the physical and chemical weathering processes [34]. **2)** effect of moisture; the increase in the percentage of moisture greatly affected the damage to granite, as it worked in the presence of carbon dioxide CO_2 to transform feldspar which is one of the most important components of granite, such as (*orthoclase*, *microclean* and *albite*) found in granite to secondary clay minerals such as kaolinite which is easy to disintegrate and dissolve [14,35].

$$3KAlSi_3O_8 \ (\textit{K. feldspar}) + 2H^{++} \ 12H_2O = 2K^+ + 6Si(OH)_4 + KAlSi_3O_{10}(OH)_2 \ (\textit{Illite})$$

$$2KAlSi_3O_{10}(OH)_2 \ (\textit{Illite}) + 3H_2O + 2H^+ = 2K^+ + 3Al_2Si_2O_5(OH)4 \ (\textit{Kaolinite})$$

3) effect of salts; the salts caused damage to the granite stone due to its interaction with moisture. Dissolution of salts in the water leads to the formation of brines (salt solutions) that move inside the cracks. When the temperature rises and the water evaporates, the salt crystallizes under or on the surfaces [36] through internal pressure and leads to the loss of the strength ability of the granite. After a sufficient rate of wet and dry cycles, the surface of the stone loses its parts in the form of powder, fig. (7-a) [37]. **4)** variation of air temperature; the continuous change in the air temperature average affected the architectural elements [38] represented in the granite columns, which lead to the separation between lintels and supports, the presence of fine cracks in some parts, in addition to the exfoliation of the surface layers in the form of scales like fish scales [39]. **5)** man-made deterioration; its effect in the Valley temple was shown as follows: **a-** the use of metal bars, fig. (7-b) in the architectural restoration and the resulting rust problems affecting mineral components. Iron rusts formed due to a change in the surrounding environmental conditions, and by increasing their volume, they create internal pressures that lead to separations in stones and sometimes cause stone bleeding [40]. The rust also leads to changing the components of the stones through the migration of rust compounds through its pores. **b-** The use of Portland cement, fig. (7-c) is considered one of the human damage resulted from old unsuitable restoration work as its danger lies in the penetration of its salts then the problems that result from its recrystallization. Examples of such salts are sodium hydroxide, calcium hydroxide, sodium sulfate, sodium silicate and calcium sulfate. Cement contains 12% of fully or partially water-soluble salts whose solutions pass into pores with the processes of evaporation and drought local pressures accompanying crystal growth occur between and on the surfaces of the stones leading to the fragmentation of their surfaces. **c-** Not determining the layout of the site or determining a protection zone [41], threaten with the loss of the outer granite casing that collapsed and scattered surrounding the temple due to the effect of earthquakes, fig. (7-d). [42] **d-** The failure to preserve the details of the stone blocks specially in the completion process of lintels, fig. (7-e) that illustrate the structural system of the building. It's noted that most restoration works are structural restoration at the lintels and columns and show the weakness of these places, fig. (7-f:i). **e-** There is no regulation of the number of visitors inside the temple. The effect of visitors inside the archaeological buildings varies between: mechanical (scratch, and abrasion), physical–chemical (writings, thro-wing wastes, and vandalism) and biological deterioration (pollution) [43] Proposing a plan for preventive conservation includes: **1)** proposal to solve the structural, architectural and fine problems, which negatively affect the sustainability of the elements of the temple and its building materials. **2)** proposal to reduce the future problems of the temple. This proposal was based on the idea of roofing the temple depending on the following: **a-** The idea of roofing helps to reduce the impact of external deterioration factors because most of the temple's problems result mainly from its open environment. **b-** The roofing proposal has been applied with different mechanisms in many open sites to control the impact of the surrounding environment, such as excavation sites and to shade the ruins of buildings. It has proven effective on these sites. **c-** Simulating the original design of the temple during its construction period, as it was covered with a flat roof. **d-** The possibility of roofing with many modern methods and mechanisms that provide light and thermal control and compatibility in colour and texture with the general design and used building materials. **e-** The possibility of loading the proposed roof on the external building of the temple and reducing the impact of any loads resulting from the new roof on the temple's inner granite lintels and columns. The study suggested the use of glass for the possibility of controlling its colour and degree of opacity and its emission of CO_2, but there are still limits to this proposal that depend on the fact that the temple is one of the ancient buildings, which were classified by the Madrid conference [44] as a dead monument, with which interference with it is minimal. Therefore, the study of the roofing proposal depends on being one of the preventive conservation measures that guarantee the sustainability of the temple, and to prove the effectiveness of the proposal or not, this study should be followed by a study that includes modelling the temple and studying the effect of the proposed roof, its design alternatives and the nature of its material. **3)** Proposal to better present the temple to visitors, because the archaeological site management plans are not limited to restoration and conservation work, but also are concerned with display and presentation methods for visitors to highlight the values of the building and get the most of their visit.

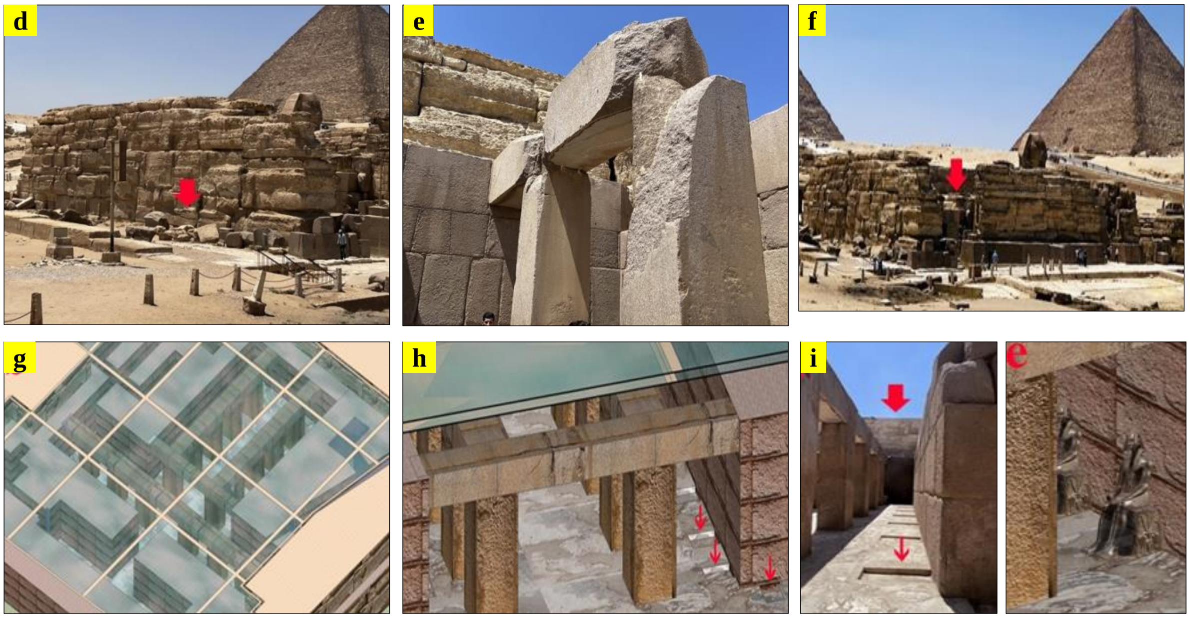

Figure (7) Shows **a.** exfoliation of the surface layers in the form of scales, **b.** separations resulting from the use of metal bars, **c.** separations resulting from the use of Portland cement, **d.** the danger of losing outer granite casing, **e.** the necessity of reinforcing lintels and insuring their stability, **f.** structural restoration of weakened at the lintels and columns, **f.** external limestone blocks proposed to receive the proposed roof loads; the arrow indicates the height of the internal granite casing, **g.** imagine the proposed ceiling, **h.** the temple after the roofing and the necessity of using modern techniques to display models of statues in their bases, **i.** external blocks and statue bases, **e.** models of the statues of in their places.

5. Conclusions

The study discusses some preventive conservation measures to preserve the Khafre's valley temple which is one of the most important archaeological buildings on the Giza plateau because of it is a unique model of valley temples and the using of huge carefully formed granite blocks. The study monitored the problems facing the temple and its deterioration factors. The seriousness of these problems lies in the fact that the temple suffers from structural problems that may affect the sustainability of its architectural details. There are also some problems related to carrying out some inappropriate restoration work that need to be removed and problems caused by not rationing the number of visitors and determining a protection zone for the temple. It also monitored that there is a problem of the better presenting the temple to visitors through modern display techniques. Accordingly, the study suggested a preventive conservation proposal for the temple, which includes: ***a.*** *urgent restoration work to keep the temple from collapsing or losing some granite blocks,* ***b.*** *roofing the temple as a preventive measure that contributes to reducing the effect of deterioration factors in its environment, as well as a way to better present it by simulating its original architecture where the temple had a roof. It's suggested that the proposed roof loads could be transferred to the external walls of limestone due to the loss of many of the columns ends and lintels that were carrying the original roof. In addition to a proposal to use some modern techniques to display models of the King Khafre statues inside the temple, with the possibility of employing these techniques to clarify some of the ancient Egyptian rituals that were performed in the temple.*

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