The Effect of Weathering Processes on the Rocks of the Pyramids of Dahshur, South of Giza, Egypt: A Geoarchaeological Study

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Abstract: In Egypt, the Pyramids of Dahshur are located approximately 20 km south of the Giza pyramids' plateau. The Dahshur area's geological setting conforms to standard geological formations. Research on the rocks of the pyramids holds significant scientific and practical importance, given that various environmental pollutants expose these coarse-grained rocks to weathering processes, which in turn impact people's health. The Dahshur area consists of The Bent Pyramid and The Red Pyramid. These pyramids are among the earliest and most important in Egypt's history. The current study conducts a geological and geoarchaeological in situ examination of the rocks (main chamber lining blocks) of the Dahshur Pyramids, with the aim of investigating the weathering features caused by rocks undergoing weathering processes. The current study provides a firsthand account of the rocks' behavior as experienced by the ancient Egyptian masons during their partial cutting for pyramid construction. They handled these rocks with utmost systematic and meticulous care to ascertain their future behavior, which is a crucial testament to the pharaonic civilization in Egypt, depending upon field observation.

Keywords: Dahshur Pyramids; The Red Pyramid; The Bent Pyramid; Giza; Egypt.

1. INTRODUCTION

The pyramids of Egypt have attracted the attention of scientists, researchers, and Egyptologists for many decades. The pyramids belong to the group of ancient world wonders. The period 4,600–3,800 years before present (BP) saw the construction of these solid rock structures. These gigantic stone-built structures are meaningless without an understanding of the type of rock that was used in their construction. Researchers have extensively studied the rock-cut features of the inner walls of the burial chambers in Saqqara and Giza, but their study of the pyramids in Dahshur, south of Giza, has been less extensive. The aim of this research study is to provide new techniques and recommendations to improve the condition of the rocks of the Bent and the Red Pyramids of Dahshur, Egypt.

Wind abrasion, water erosion, and the growth of microorganisms have all contributed to environmental degradation of the Dahshur pyramids over the long period since their construction. This research demonstrates new geoarchaeological details on the degradation processes caused by the long-term effects of the endemic conditions. The present research aims to investigate the effect of weathering processes on the rocks of the Dahshur pyramids south of Giza, Egypt, and provide solutions and suggestions for the restoration and preservation of these stones (Fahmy et al., 2022).

1.1. BACKGROUND

Egypt's history is one of the finest archaeological wonders, showing the world's unique aspects of human progress. The Pyramids of El-Dahshur are one of Egypt's most precious historical sites, dating back to Pharaoh Senefru's rule. The northern pyramid, also known as the Red Pyramid, is the largest among the south pyramids. We're currently cutting limestone for experiments. Stone is extensively abundant in all parts of Egypt and occurs in different geographic shapes. Calcite, quartz, and mica traces make up the limestone specimens under investigation. Furthermore, one can recognize color differences among limestone rocks, ranging from gray to white cream. In daylight, one can see the brown rock areas, which symbolize the alteration phenomenon resulting from natural weathering. With modern surface treatment technologies, we should study and partially treat the significant deterioration in the pyramid's limestone rocks. This chapter aims to provide comprehensive insights into the various types of altered limestone trees in the Dahshur Pyramids through a comprehensive range of rapid weathering processes

1.2. HISTORY OF THE DAHSHUR PYRAMIDS

The Dahshur pyramids are among the greatest archaeological sites in Egypt. The Dahshur pyramids, located south of Cairo and not far from the pyramids of Giza and Saqqara, are the country's most ancient and best-preserved local stone structures. They are remarkable, bright remnants of daily life from more than four millennia ago. They are descendants of the kings of the 4th dynasty, which is considered the golden age of Egyptian architectural achievement. Considering the entire building complex, they are excellent examples of the ancient world's use of geometry (Alexanian et al., 2015).

Architects built the pyramids with a more rigorous architectural style, excellent geometrical outlooks, and superior observation points in mind. About a millennium later, with the advent of new state miracles, the pyramids evolved into the temples of the emerging cosmology. They made enormous efforts to preserve these temple sites. One millennium after the pyramids, researchers reported more than two hundred hieroglyphic inscriptions narrating the Pharaohs' and kings' histories, religions, and daily lives. Debate still surrounds the origins of Egyptian hieroglyphs, one of the earliest forms of written communication. It is believed that the use of simple hieroglyphic pictographs, monuments of history and pride, came first. However, these texts had already evolved into elaborate and complex structures by the time of their excavation.

Today, the Dahshur pyramids stand as the surface remnant of a vast archaeological landscape, serving as both a temple and a quarry for numerous other pyramids. The Dahshur pyramids are arched ancient repos and hover-domed brilliants, reflecting the upper parts of the fine Meagner River and its bright environment. Being contemporaneous to degrees in the changes of ocean level, sun-utilized era, Julian calendars, angles of the pyramids, and mastaba nilometer, they are outcomes of a Great Drive. We are hoping that a decade of rebending, heart-shaped serial frontier great arched earth equatorial domed couplings are on exploration near the first pyramids (Fig. 1).

Fig.1: General view of The Bent Pyramid

From a scientific perspective, it is crucial to investigate the factors that lead to the deterioration of the stone layers of the pyramids in order to achieve the goal of preserving a significant portion of the pyramids. Geological interactions or chemistry govern the deterioration of the rock's main components, which results in low stability and physical properties of the involved rock layers around the pyramids. The weathering processes primarily lead to physical weathering and color changes on the pyramids' facade, especially when reconstruction covers large surfaces with white plaster. Furthermore, this process has consumed large steel supports, which were set inside the pyramids' inner walls for construction and the addition of new entities. The knowledge limits of the damaged mechanism of the limestone effect under cutting-free experiments, as well as stability, need to be determined (Yu et al. 2020).

1.3. LOCATION

The Dahshur area is undoubtedly one of the main sites of Egyptian civilization from both a historical and architectural point of view. Dahshur is an ancient Egyptian pyramid complex and necropolis that shares the same name as the nearby village of Manshiyyat Dahshur, near Badrashin town, Giza Governorate. Its coordinates are 29°48′23″N and 31°12′29″E (Fig.2).

Dahshur, a UNESCO World Heritage Site, is located at the edge of the cultivated plain on the Western Desert plateau. It forms the pyramid fields of the ancient capital city of Memphis, along with the pyramid complexes at Saqqara, Abu sir, and Giza to the north. It is most famous for several pyramids, mainly Snefru's Bent Pyramid and the Red Pyramid, which are among the oldest, largest, and best preserved in Egypt, built from 2613 to 2589 BC.

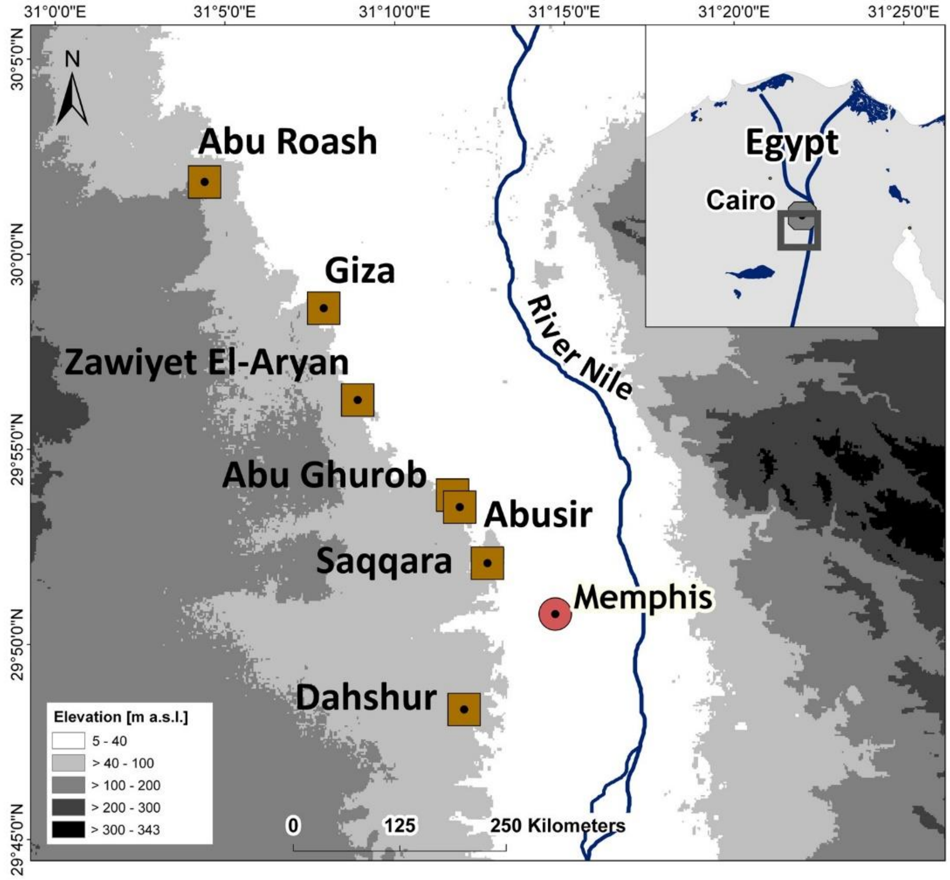

Fig.2: Location map (map source: Shuttle Radar Topography Mission, http://edc.usgs.gov/srtm/

1.4. OBJECTIVES

The study specifically set out to achieve the following goals: The study aimed to investigate the nature and composition of the core and facing masonry of the Bent Pyramid and The Red Pyramid (Snefru) at the Dahshur site.

a) Identify their mineralogical and petrographic characteristics, as well as their physical-mechanical properties.

b) To ascertain the materials utilized and identify any missing facing stones,

c) Researchers studied the weathering processes, including cracks, deposits, and scabs that impacted the rocks of the two buildings.

d) Identifying the reasons for their implementation, analyzing them to understand the mechanisms underlying these changes, and pinpointing their origin.

e) Highlighting all the paleo-erosional surfaces on the hillsides of the two pyramids, which have undergone one or more alterations to shape the slopes of the two monuments

f) Determine the level of conservation, paying particular attention to any differences between the black and red buildings' structures.

Some of the methods we used to study the rocks of the Pyramids were petrophysical and chemical analysis, fine and very fine petrostructural observation, and digital encoding in stereomicroscopy, SEM-EDS, and optical petrography, in that order. The presence of ash and scoria in the core of the two pyramids' black/red masonry determines their colors. The study reveals three key findings: a) the existence of slope-building processes; b) the conservation status of the two pyramids; and c) the color and its logical correlation with the mortar.

1.5. METHODOLOGY

The current investigation used several complementary approaches to develop a comprehensive understanding of the weathering processes on the rocks of the pyramids. First, we conducted geological mapping, petrographic, and geochemical investigations of the pyramid's rocks to understand their relationship to the surrounding stones at Dahshur. We also focused on enhancing our understanding of the selected construction materials, their provenance and their quality. The results of these tests provide valuable insights into the mechanical and physical characteristics of the construction rocks, their geochemical and mineralogical properties, and the location of their layers. We used geo-archaeological methodology to observe and accurately record the karstic features in the rocks of the pyramid plateau, walking in an east-west direction to inspect the ruins. We utilized geoarchaeological strategies to understand both natural and anthropogenic weathering phenomena, particularly those associated with unroofed sites. We carefully identified and scientifically investigated the existence of modern weathering features on the southern rock surface of the pyramids. We enhanced the survey process by using geophysical and remote sensing techniques. We used a 3D model of the area around the pyramids and a sedimentological and stratigraphic approach to analyze survey data, which provided us with useful details about the types of deposits made and their locations (Fig.3).

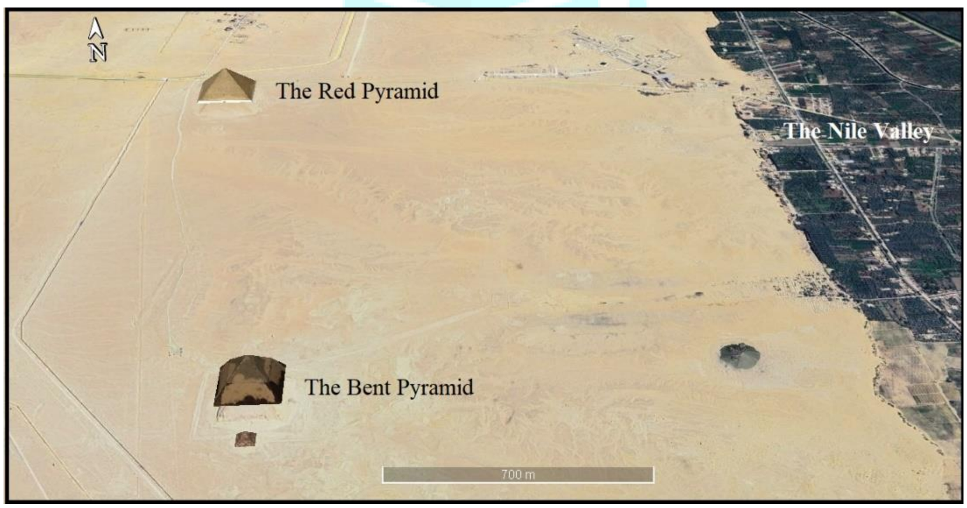

Fig.3: Oblique view of the pyramids of Dahshur area (Source: www.googleearth.com)

2. RESULTS AND DISSECTIONS

2.1. STUDY AREA

The present study focuses on the Pyramids of Dahshur, a geoarchaeological approach located 40 km south of Cairo in Egypt. The area lies in the geomorphological basin of the Nile, which is rich in minerals, particularly calcite, dolomite, and gypsum. Scholars extensively study the weathering and deterioration of stone in monuments, as it plays a crucial role in determining the geometries and stability of various structures.

The Pyramids of Dahshur are considered to be among the most ancient stone monuments situated in the Nile, south of Giza, Egypt. Researchers study the geomorphology and mineralogy of these pyramids, which primarily consist of dolomitic limestone. Despite numerous investigations using geoarchaeological methods to understand rock weathering, there aren't many comparable studies focusing on Dahshur's pyramid's geoarchaeology.

We studied the Dahshur pyramids using weathering processes and geoarchaeological approaches to understand the quarry sites, transportation, and quarrying methods in the ancient world, as well as the high scientific proficiency and technological advancement of ancient mankind. Dahshur pyramids are low-fumed pyramids built by ancient kings Snofru of Egypt's fourth dynasty around 2600 BC, spectacularly deformed, attacked by quarrying, and blasted. We need to study them to understand geoarchaeological processes, their nature, the effects of weathering and quarrying methods, and the restoration of meteorite rocks and fossils.

2.2. GEOLOGICAL CONTEXT OF THE PYRAMIDS OF DAHSHUR

The Pyramids of Dahshur are located in a vast area of quaternary deposits, where extensive tilling and leveling have eliminated all elevation differences. It is considered an isolated geomorphic feature, with the surrounding area of deflated materials averaging a total relief of 20 m up and down. Researchers have only studied the southern section of the Giza pyramid necropolis in the context of ancient quarrying and the Pyramid of Amenemhat I. Amenemhat I utilized the rich bedrock in the area as a platform for the construction of his monumental pyramid.

The local Mudlike Lower Bedrock Limestone (MLBL), with clear siltstone extrusions and thin intercalated sandy layers, served as the building material for the southern pyramid, also known as the Blunted Pyramid. The pyramid's western south edge, which later served as a limestone block quarry, outlines the three layers. Calcite from the El Sheikh gems now covers the blunted pyramid. The the building platform is considered the geological formation of the underlying area. The bedrock in the northeastern part of the quarry consists of active limestone layers from the El-Asl Formation and El-Ghazalat Member, known as Mudlike Bedrock Limestone (MBL), along with bedrocks of Urgonian origin. This area features a long depression adorned with granite leanings and inscriptions from the Khufu pyramid construction. The southern pyramid was primarily constructed using limestone from the Lower Member of the Sudr Formation. The Softstone Formation consists primarily of side-bedded limestones with interbeds of calcareous marl and marl. Limestones and marls, rich in fossils, comprise the Upper Cretaceous Sudan Member. The Galala Member of the Upper Cretaceous, located near Limestone, is characterized by its yellow to light brown color, high hardness, thin to thick bedded texture, medium-grained granular texture, and clotted structure (El Ayyat, 2021) (Fig.4).

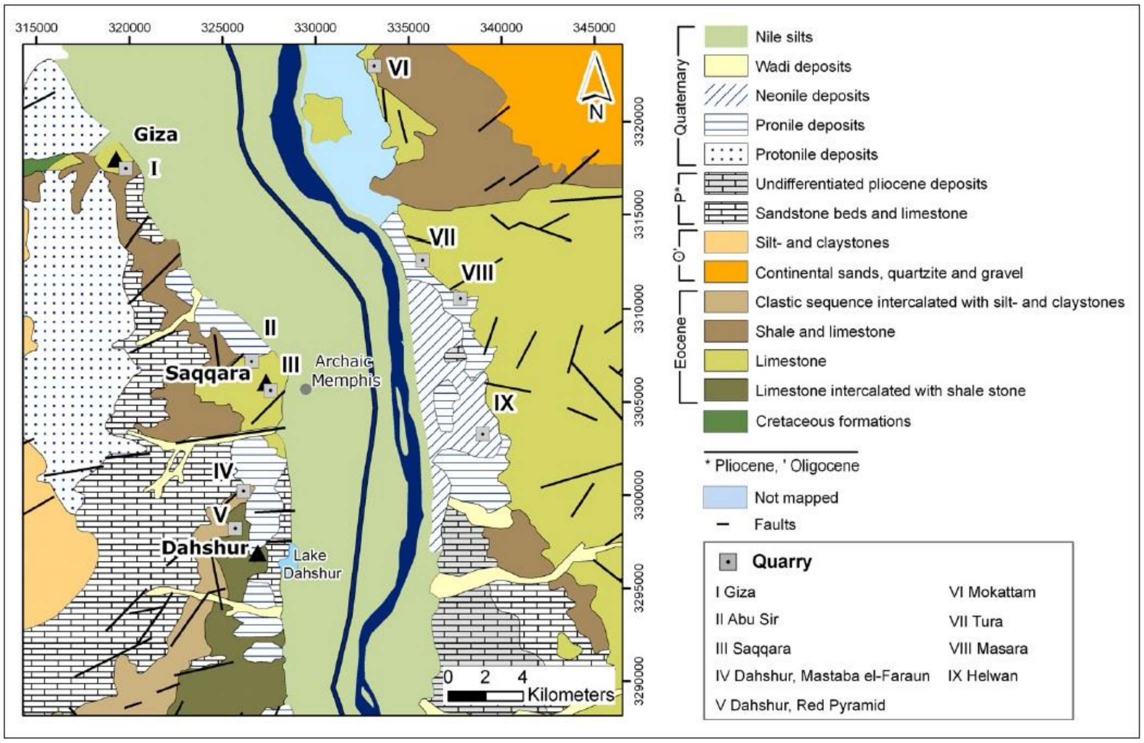

Fig.4: Geological map of the study area (Source: Conico Cora, Geological Map of Egypt 1:500,000, Sheet NH 36 SW, Beni Suef)

2.3. OVERVIEW OF THE GEOLOGICAL FORMATION

The geology of the area of the Pyramids of Dahshur represents the sediments of the Middle Eocene succession, and according to the classification of the Egyptian Geological Survey, these strata form the sequence No. 31. Geological formations provide information about the natural processes that occurred earlier in the area. The Pyramids of Dahshur show a sedimentary sequence that is about 2,600 meters thick and made up of many lithological units. Various types of rocks compose the succession. Lacustrine environments are fluvial and shallow. Continental clastic facies, primarily sandstones and shales, make up the majority of the sequence (Aigner, 1983).

The pyramid's lower wall features ornaments of these lithology types. The mentioned facies are juicy in figure and colorful, with dark to light colors of ferruginous staining representing strong weathering and shale depositional environments. The clastic linens consist of medium calcite veins; some of them are discontinuous, large, and closely spaced, whereas other linens are thin and straight or wavy and connected to the previous rock weathering processes. The sideways, standing geological masses consist of constructive (small), medium, and large calcite veins, and the main vein linens on the central wall of the pyramid move from the east direction to the westward. Deterioration also ornaments the rock walls with vertical fractures (Ghoneim et al., 2024).

2.4. TYPES OF ROCKS USED IN CONSTRUCTION

Although the core of each of the pyramids at Dahshur was built from limestone from quarries in the immediate vicinity, the thick casings of the Pink Pyramid, the Red Pyramid, and many other ancient Egyptian structures were constructed using limestone from Tura, near Cairo. The minerals calcite and/or aragonite, composed of calcium, carbon, and oxygen, almost entirely comprise the pale buff-colored Tura limestones. The sea makes calcite/aragonite from the remains of plants and animals, occasionally mixing it with impurities. Banding is by far the commonest texture, comprising bands of different thickness between 0.2 mm and 6 mm in thickness. Thick bands are the most important, followed by medium and thin bands.

Banded limestones have both hard and soft bands. This type of texture is distinct from other textures due to the alternating properties of firm and soft bands, which result in rocks with weak mechanical properties. These rocks may have resistant rigid bands in shallow water or smaller pore spaces, but they can also have harder bands of consolidation water flow and large pore spaces in between. The limitations and continuity of limestone bodies influenced the built structures of the Old Kingdom and Middle Kingdom (c. 2613–1759 B.C.) (Fahmy et al., 2022).

2.5. WEATHERING PROCESSES AND MECHANISMS

The Giza and Dahshur pyramids are located in the northeastern part of the Western Desert, south of Cairo, Egypt. Calcareous and argillaceous sedimentary rocks of the Eocene age primarily construct the Giza pyramids. The Mokattam Formation's argillaceous limestone primarily constructs the Pyramids of Dahshur. Chemical, physical, and biological processes act in different degrees of intensity, depending on many factors. The pyramids' rocks may decay and disintegrate differently due to their contributions.

The surface's corrosion often reveals weathering. Ion surface migration and salt crystallization, which intensify in saline and arid environments like the pyramid construction site, may also lead to the rock's disintegration. Except for landslides, which salt crystallization exacerbates by increasing detachment, the other three processes may not occur at the same pace as salt crystallization. These processes may impact certain rock characteristics, particularly in situ, but it's important to distinguish their patterns (Badawy, 2021).

Many forms of weathering exist in nature, including most notably physical, chemical, and biological processes. All of these processes could have some effect on monument sites. Concerning the Egyptian pyramids, several working hypotheses considered some agents that might have an impact. In some tombs, squeezing the stone blocks together could cause friction between them. Then, a resistive force will build up on the blocks' interfaces, represented by frictional resistance. This can also be a reason for the maximum amplified separation around the tips (crown) and in the joints near the tips in agreement with the tension crack release by our result, since strong resistive forces will build up in that location.

The hydraulic movement of salt solution throughout the pores of the pyramid's materials adds another resistive force. Such a resistive force will increase the differential pressure. Consequently, the joints will record an outward force acting on the stones within the block's interfaces. Furthermore, there is significant fracture saturation, particularly in the initial 3 meters surrounding the pyramid base. Therefore, the damage zone will expand to the confined stress, and the resultant outward force will swamp the weak pressure within the monuments (Hussein & Abd El-Rahman, 2020) (Fig.5 & 6).

Fig.5: Effect of weathering process on the stones of The Bent Pyramid (a: The effect of weathering processes on the breakdown of rock masses in the northwestern corner of the pyramid; b: The effect of chemical weathering processes by water vapor on one of the rock masses on the northern side of the pyramid; c: The effect of weathering processes on the collapse of the northwest corner of the pyramid; d: The effect of weathering processes on the breakdown of the lower part of the stones of the pyramid)

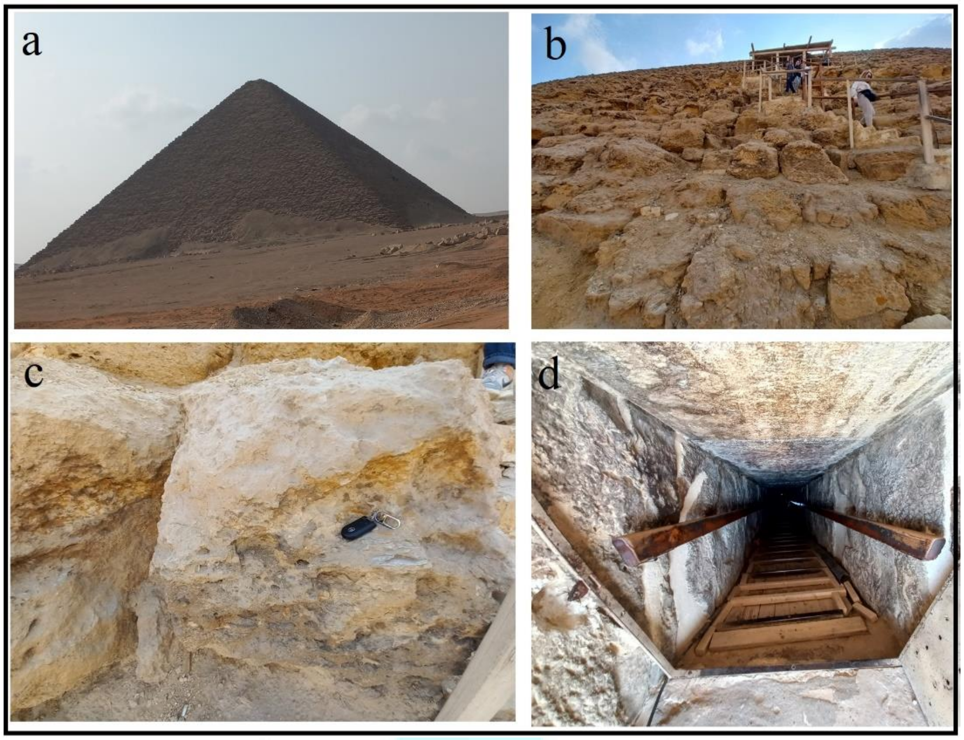

Fig.6: Effect of weathering process on the stones of The Red Pyramid (a: General view of The Red Pyramid; b: The effect of chemical weathering processes on the entrance to the Red Pyramid on the northern side of the pyramid at a height of 28 meters above the ground; c: Effects of chemical weathering on one of the blocks on the northern side of the pyramid; d: Effects of chemical weathering by atmospheric agents and visitors on the roof of the main corridor of the pyramid)

2.5.1. PHYSICAL WEATHERING

The main building material of the Dahshur pyramids, especially the royal burial chamber, was granite. Three minerals, quartz (30%), plagioclase (in this case, Labradorite) (60–70%), and potassium feldspar (5–10), grow on top of each other to form this stone, making it highly susceptible to weathering. The latter consists primarily of small, white, irregularly dispersed phenocrystals. Most of our thin sections exhibit granite's characteristic features, such as its hypidiomorphic-crystalline texture and intense recrystallization of its original texture in compacted and fine-grained areas. The formation of feldspar, a plutonic process, or the pressing of the deposited rock, a metamorphic process, likely initiated the pressure solution process that caused quartz and plagioclase to refract.

The pyramid stone could have experienced three main types of physical weathering: mechanical breakdowns caused by trees growing between the stones or natural irruptive crystallization of salts; wind sandblasting; and erosion, which causes loose stone to build up and move slowly downhill. As for the soiling mechanisms, two of the most likely ones that have had time to happen on the pyramids are the adhesion of sediment grains (such as silt, clay, or even sand) to the rock surface or else subaerial or at least anoxic biofilm growth. However, the latter is challenging to recognize and study in the absence of molecular/structural biomarkers. Understanding those processes is crucial to assessing their contribution to the actual weathering of the pyramids (Heizer, 1973).

2.5.2. CHEMICAL WEATHERING

La Moreaux and Tanner (2000) stated that weathering may occur through a variety of mechanisms, including physical, chemical, and biological actions. The factors controlling the rate of chemical weathering are the same as those that control the rate of physical weathering: crystalline structure, mineralogy, the presence or absence of cracks and fractures, and the presence of catalysts that might affect the rate of reactions due to their mineral structure. Weathering processes acting on rocks can remove or add natural cementing agents or compaction materials, weaken cementing agents so that the rock unravels or becomes uncemented, or weaken the remaining strength of a rock (Krklec et al., 2021).

Each of these processes works together to help disintegrate rock and reduce its strength as a foundation or construction material. Chemical weathering occurs when the chemical composition of rock materials reacts with weathering agents such as water, oxygen, acids, and CO2-associated bases. Of course, these agents' status should be source dominant rather than sink (Stephens & Aharon 2011a). Chemical weathering is the process of reactions and transformations that reflect the mineral compositions and changes of rock materials on contact with the environment around them. There is often a conversion of primary minerals to secondary minerals. Clay minerals, secondary iron oxides, and hydroxides are some common chemical weathering products. Human activities can influence or generate chemical processes, in addition to their occurrence in natural settings.

Nature may initiate chemical degradation, and human actions only stress or accelerate it. Several minerals in the pyramid's parent rocks contain at least Fe, Al, and some Si, such as ortsteinized and/or kaolinitized biotite and microcline. These parent rocks' weathering processes should result in soils rich in these minerals, which, conversely, should contain a low percentage of calcite. At this site, there is detrital calcite, indicating that it is probably better protected by calcium-rich microaggregates. It may have also formed slowly in leftover soil because there haven't been many freeze-thaw cycles in this area, which can break down softer minerals like calcite (Hack, 2020).

2.5.3. BIOLOGICAL WEATHERING

Living organisms can be beneficial rock architects and 'engineers' because they may have physical, chemical, or biological activity that exerts a negative influence on the rocks. The present study demonstrates that the lithobionts, e.g., algae, lichens, cyanobacteria, and fungi, could contribute to additional weathering. Some of the lithobiont groups mentioned above secrete biogenic oxalates, which could damage the rocks of the Dahshur Pyramids.

Biological activity has a well-documented ability to alter the physical appearance of materials used for ancient structures within and around selected sites of ancient architectural complexes. Researchers have conducted numerous biological activity-based studies on the two pyramids, including the Red Pyramid, the Bent and Meidum pyramids, as well as the Dashur pyramids, to determine whether the black layer on the Red Pyramid's polished facing is a result of biological activity. The present study examined the biological and micro-physical changes in the core stones of the Bent and Red Pyramids due to natural forces such as self-cleaning and the impact of dry air on fungal growth. Also, the most common weathered rocks of the studied pyramids were the Nubian sandstone, the nummulitic limestone, the qrei limestone, and the basalt. As a result, we investigated the influence of the relevant strains extracted from the pyramid core stones on the chosen ancient Egyptian rock specimens. Based on the previously published investigations, it is believed that the biological separation of rock materials over and/or in the surrounding area of the pyramid complexes is a significant factor that could lead to the destruction of the pyramid material(s) (Heizer, 1973).

2.6. THE IMPACT OF WEATHERING PROCESSES ON THE ROCKS OF THE PYRAMIDS

This article examines the effects of weathering processes on the rocks of the Dahshur Pyramids, located south of Giza in Egypt. The purpose of the present study is to assess the general state of these rocks by investigating their weathering features, the agents of their weathering processes, and the rate of their erosion. Climate change is believed to have caused the unusual weather patterns of the last century, along with faster aeolian transport and deposition, microbiological activity, and accidents. These threats have caused significant change, particularly on the western side. As a result, more field evidence supports the hypotheses about these parts' potential inherent fragility. This lets us make a planning guide for any reinforcement interventions aimed at restoring valuable masonry and revealing its many hidden treasures. On the west side of Dahshur, which encompasses the Red Bent and the southern and northern Pyramids, we have identified the primary weathering phenomena as the oxidation of ferrous minerals and the dehydration of the rock's gypsum. This process results in an efflorescent crust of dihydrated calcium and sodium sulfates, with only a small percentage of free water submerged in their volumetric proportion. At the moment, the main geomechanical surface pressure is generated by salt crystallization reactions. This pressure is concentrated on the south faces of the two pyramids, particularly the compact limestone. Weathering is a general term that describes the alteration or breakdown of exposed rocks. It is often a mix of physical (or mechanical), chemical, and biological processes. Weathering processes can affect the strength, structure, texture, and other important properties of rocks, thus damaging the rocks, in particular the structural rocks such as those of the Pyramids of Egypt.

2.7. IMPLICATIONS FOR CONSERVATION AND PRESERVATION

The field investigations' findings indicate that the rocks in the three pyramids have distinct lithotheques. Each lithotheque is composed of two rocks. The first rock has a homogeneous, medium- to coarse-grained texture. The second rock is more diverse, with two main layers and two to three smaller ones inside. These layers consist of a variety of deeply buried wind-eroding channels filled with colluvial sediment.

Based on our observations, we have identified the following stages that cause solid weathering: The stone undergoes atmospheric weathering up to the base of the weathering rind; there is a phase of a deeper wind-erosional channel just below the already-eroded surface, which is covered by a white crust; subadominal weathering occurs with the formation of an alfisol; and more atmospheric weathering occurs.

Theoretical considerations and analyses of the meteorological data show the omnipotence and intensity of the Aeolian phases, especially during the Late Old Kingdom, the reign of King SenWesret III, when the annual average of the maximum wind speeds reaches a value of 26 m/s. This has dramatic consequences on the appearance of the landscape and plays a determinant role for the architecture of the South Dahshur complex (Alexanian et al., 2015).

Understanding this complex's weathering processes is critical for both local conservation strategies and global cultural property preservation at World Heritage sites. The global challenge of preserving cultural heritage has significantly escalated in recent decades due to global change. To find methods for preserving all kinds of cultural heritage in the future, it is essential to provide a scientific understanding of the geomorphic processes that threaten remains.

Archaeologists can better survey, protect, and preserve the cultural treasures of the south Giza-Egyptian plateau by understanding how the three pyramids of South Dahshur have weathered over time. This is because the pyramids are located near smaller cult and pyramid queens from the 4th Dynasty (around 2550 B.C.) and the 13th Dynasty (1773–1650 B.C.) (Harrell and Brown, 1995).

2.8. CHALLENGES IN PRESERVING WEATHERED STRUCTURES

Preserving weathered structures, such as the pyramids, in various environments around the world is important for historical, architectural, and engineering reasons. The agenda for preserving and perpetuating cultural assets for current and future generations includes the implementation of innovative preservation and conservation strategies. Without a deep understanding of how rocks weather and a close study of weathered rocks on both small and large scales, it is impossible to find the damaged areas and describe their conditions, let alone suggest ways to keep building stones safe, strengthen them, and preserve them. Because stones are complex, weathering processes and regimes vary; there are no recipes.

In the lab, one can study mechanics, hydraulics, chemicals, minerals, crystallography, and geophysics, as well as test conservation treatments that account for all the important details and complexity of the lithotypes. We can also delve into the study of efflorescence and precipitated salts, the functioning of frost, the processes of sedimentation and erosion, the disintegration of structural blocks and internal cavities, and the extraction of water from the interior mass.

Preserving weathered structures in various environments and climatic conditions is an important topic in different parts of the world. The issue with studying the weathering effect lies in the absence of observations regarding the weathering processes and their impact on the building stones used in various conditions and climates. Many cities older than 5000 years have soft stones in different climates and conditions, and they are dissolving simply without the help of different factors. Researchers have identified and measured the factors influencing the weathering process, developed equations and computer models, and conducted laboratory tests to account for the material and process in the field (Monnier and Puchkov, 2018).

3. CONCLUSION

The goal of this study was to provide detailed insights into the effects of the various weathering processes on the different rock types of the main buildings of one of the world's most famous archaeological sites, the Pyramids of Dahshur, south of Giza. The analyses show that nearly all weathering processes occur, causing deterioration, and that the petrophysical properties are responsible for the form and impact of the weathering agents identified. To ensure their preservation, the study identified the most suitable rock types for each part of the buildings.

The long-term fluctuations between relatively high and low subsurface water table levels seem to control almost all the features currently present on the gneiss and granite stones of the internal corridors of the pyramids, the western walls of the Bent Pyramid, and the northwestern external enclosure for the Bent Pyramid. Salt weathering is the primary exogenic form that affects these stone surfaces. Curved layers and lotus-shaped disintegration indicate that the salt primarily originates from the local and regional rock and soil environments. Studies are underway to identify the former integrity of the surfaces, as seen in the quarry. Geoarchaeological studies on monumental structures' weathering provide a solid foundation for future research. Further areas of research could include construction methods, subsoil conditions, rock surface texture, mortar acidity, roof construction, and a more detailed investigation of the cause of salt formation. Of course, these findings also open up the possibility of investigating various historic and modern settlements in the Delta, as well as the desert and monasteries elsewhere in Egypt.

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