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The Geomorphological Hazards in the Archaeological Area West of Qena Bend

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Abstract: This Study deals with the main geomorphic hazards in the eastern side of Tiba plateau and the narrow, dissected flood plain of the western sides of Luxor. The area under investigation comprises the more important Antiquities in Egypt as a whole. The sites of pharhonic Archaeological area are subjected to various kinds of geomorphic and environmental hazards such as land slides, salt weathering, torrential floods and subsidence as a result of subterranean water processes. Results on the petographic of sandstones and their state of weathering damage on the Archaeological area are presented. Deterioration of temple of Luxor is observed in various forms of groundwater which delivering salts into the monuments' foundations evaporate leaving salts behind. Pressure developed during crystallization and hydration of residual salts within the foundations is suggested as the most likely cause for deterioration. The viable and safe mitigation of the deterioration problem requires an understanding of the hydrostratigraphy of the Luxor area.

Keywords: Geomorphology, Geology, Climatology, Hydrology, Hazards.Archaeology.

INTRODUCTION

The area lies on the western side of the Nile valley opposite to the City of Luxor Fig. (1).between Latitudes 25° 40` to 25° 47` North and Latitudes 32° 27` to 32° 45` East. The hill in the area is filled with the tombs of the Kings, the Nobles and common people. These have been carved into the solid limestone rock of Tiba plateau Fig. (2) to preserve the bodies until the day of resurrection.

Two branches of desert valleys crossing an escarpment in western Thebes Fig. (3) are named the Valley of the Kings. A western branch of the Valley of the Kings, presently called the Valley of the Apes (in Arabian: Wadi el-Gurud, Biban el-Gurud). Their tombs were hewn in a bed-rock. Eastern part of the valley, from Arabian - Biban el-Muluk (Gates of Kings), was used as a burial site for kings of Dynasties XVIII, XIX, XX as well as for other royal family members. There are 62 numbered tombs in the East and West Valleys, plus another 20 unfinished pits and shafts designated A-T.

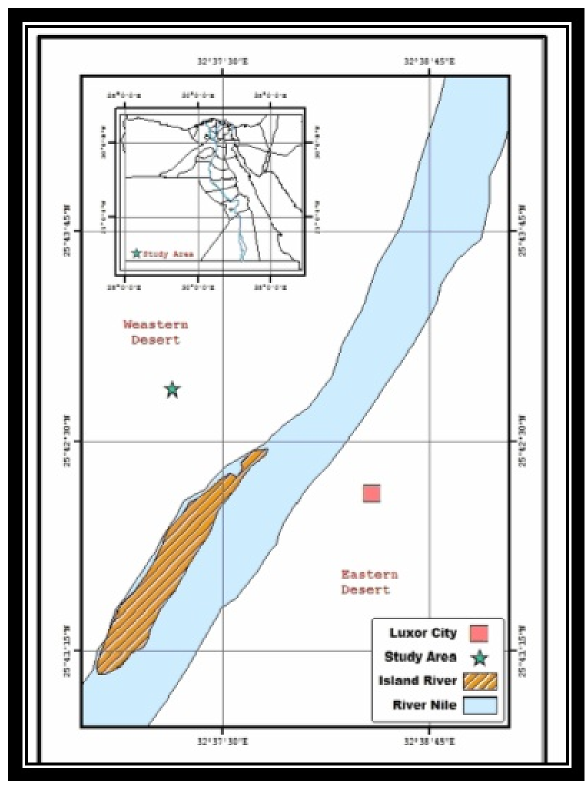

Fig. 1: Location map of the study area.

The aims of the study
This study aims to the following:

- Reveal the Geomorphic aspects in this important area, and the main geomorphic hazards on the archaeological sits.
- The effectiveness of the geomorphic hazards on the Archaeological sites.
- It also tries to definite the effective ways to face these hazards from a geomorphologic point of view, and how to protect the Temples and Tombs from hazards

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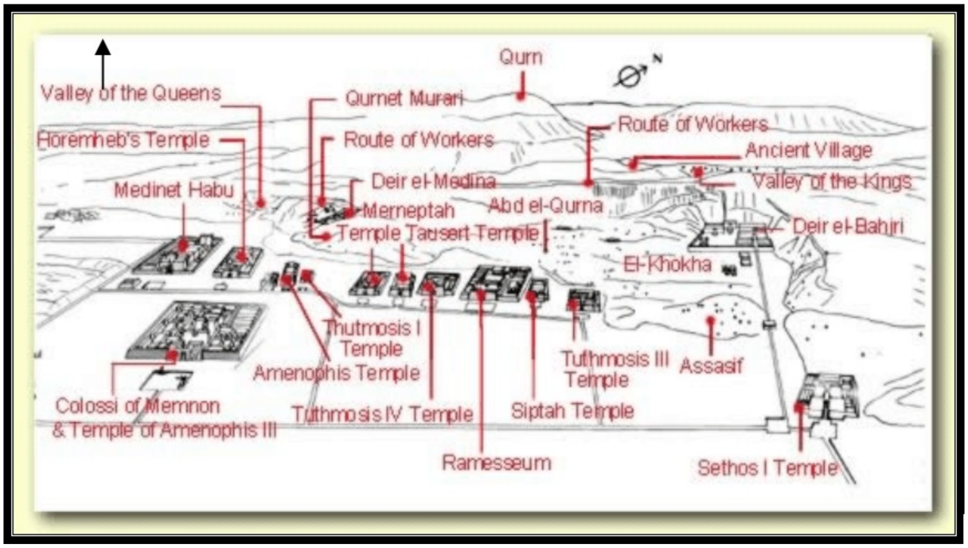

Fig. 2: Temples and Tombs in the study area. (Internet page 1).

Fig. 3: Valleys crossing an escarpment in western thebes. (Internet page 1).

The main topics of the study:

- The Geographical setting of the Study Area (Climate condition, the geological aspects, The Geomorphological Aspects).
- The Effects of the Geomorphic Processes and Forms on the Archaeological Sites.
- Conservation procedures.
- Conclusions.
- Recommendations.

The Geographical setting of the Study Area:

Climate condition: The climate of this area is an arid and does not receive enough rain through the year. In fact the intermittent rainfall in spring and winter causes torrential floods. The climates of the area –as a part of Upper Egypt –is characterized by large annual ranges of temperature, summer is likely to be abnormally hot and winter abnormally cool or cold. Air temperature rises in the study area most of the year, the monthly average of air temperature ranges between 14 ºC and 32.6 ºC with annual average of 24.8 ºC, The most important climatic features; evaporation, evapotranspiration and dew consideration are effected by relative humidity which increase in winter time The monthly average of relative humidity is 35.4 % and the ranging between 22.0 and 53,0 %.The monthly average of wind speed is 7.2km/hr ranging between 9.2 km/hr and 5.5 km/hr. Rain fall is rare and occurs randomly. In addition The monthly

Table 1: .Monthly average of (Air temperature, relative humidity, Wind speed. Precipitation) at Luxor the period(1960-1990)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Min	Max	Ave
Air temp c	14	16	20.2	30.2	30	32,4	32.6	32.5	30	25.4	20.3	15	14	32.6	24.8
relative humidity %	52	42	34	26	22	23	26	27	32	40	47	22	22	53	35.4
Wind speed Km/hr	6.8	7.2	9	9.2	8.5	7.7	7.4	6.8	6..2	5..5	5..9	5..5	5..5	9..2	7..2
Precipitation mm	0.1	0,2	Trace	Trace	0.3	0	0	Trace	Trace	Trace	Trace	0,5	0	0,3	0.1
Evaporation mm	4.7	6,2	9	12.5	10.1	16.3	15.7	15.4	12.9	9.6	6..5	5	4.7	16.3	10.3

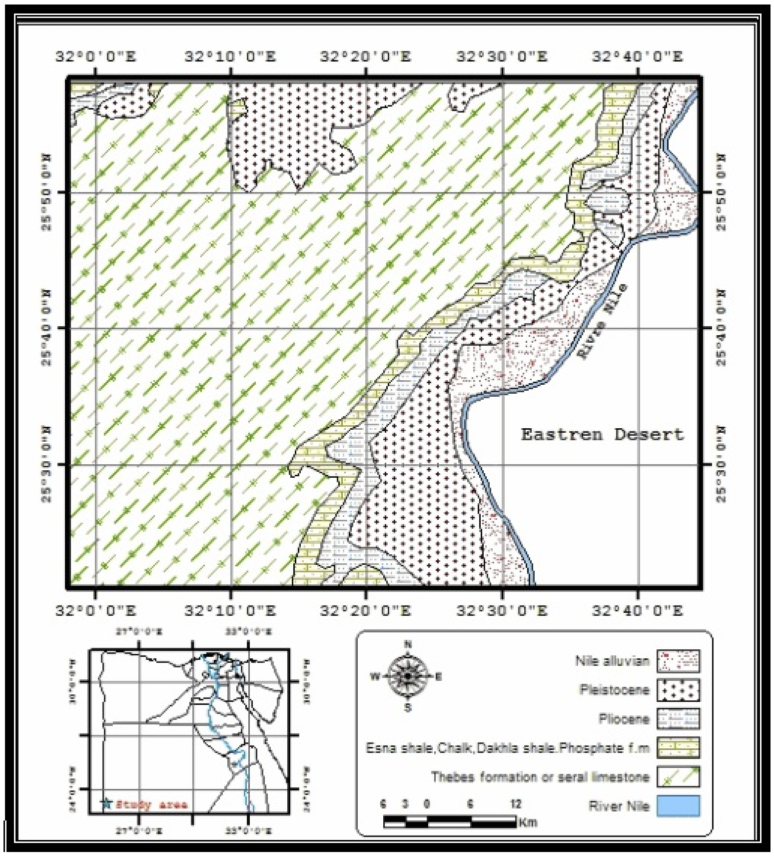

Fig. 4: Geological map of the study area. (After, El Hosary[5])

average of rain fall ranges between 0.0 and 0,3 mm Table (1). Evaporation is a function of the air temperature, air humidity, and wind velocity.It affects both the surface and groundwater, particularly when the level of groundwater is close to the surface.the monthly average of evaporation varies between 4.7 mm and 16.3 mm.

The geological aspects: Understanding the geology of the West Bank is an important aspect of understanding the original decisions for tomb location, as well as their modern conservation.

Giovanni Belzoni[2] appears to have been the first European to describe the basic geology and topography of the Valley of the Kings. He pointed out the drainage patterns which led to the positioning of some Tombs. However, more recent work has established three groups of Tombs that seem to be related geologically and hydrology. They are also closely related to the three Egyptian dynasties that utilized the Valley of the King's as their necropolis. For example, Tombs that date from the early to the mid 18th Dynasty[3] were usually quarried from the limestone clefts, and often, as in the case of the Tomb of Tuthmosis III[4], beneath ancient waterfalls. After the burial took place, the entrances were walled over with stone and then plastered. Later, when flood waters poured into the Valley, they were buried beneath massive amounts of debris. The main formations in the study area are sedimentary rocks and recent surface deposits. This formation ranges in age from the upper Cretaceous to Holocene: the main structures are represented in some fault lines[5] fig. (4).

Fig. 5: Rock layer.

That alternate between dense limestone and softer layers of Marl-a stone containing calcium carbon mixed with clay. Marls are easily moulded and thus form sloping mounds of debris. By contrast, the limestone layers are more resistant and form sheer vertical faces (fig. 5). Overall the limestone strata of the Serai Formation total 290 m in thickness, rising to the left and above the Hatshepsut Temple. This natural pyramid may have inspired the Egyptian kings to select this site for their Tombs.

Stratigraphy: The Stratigraphy of the area has been well studied by Said[6], and Fronobarger[7]. Fig. (6) illustrates the important formation that outcrop in the study area include the following: Paleocene Tarawan Formation; It consists of marl to chalky limestone, very

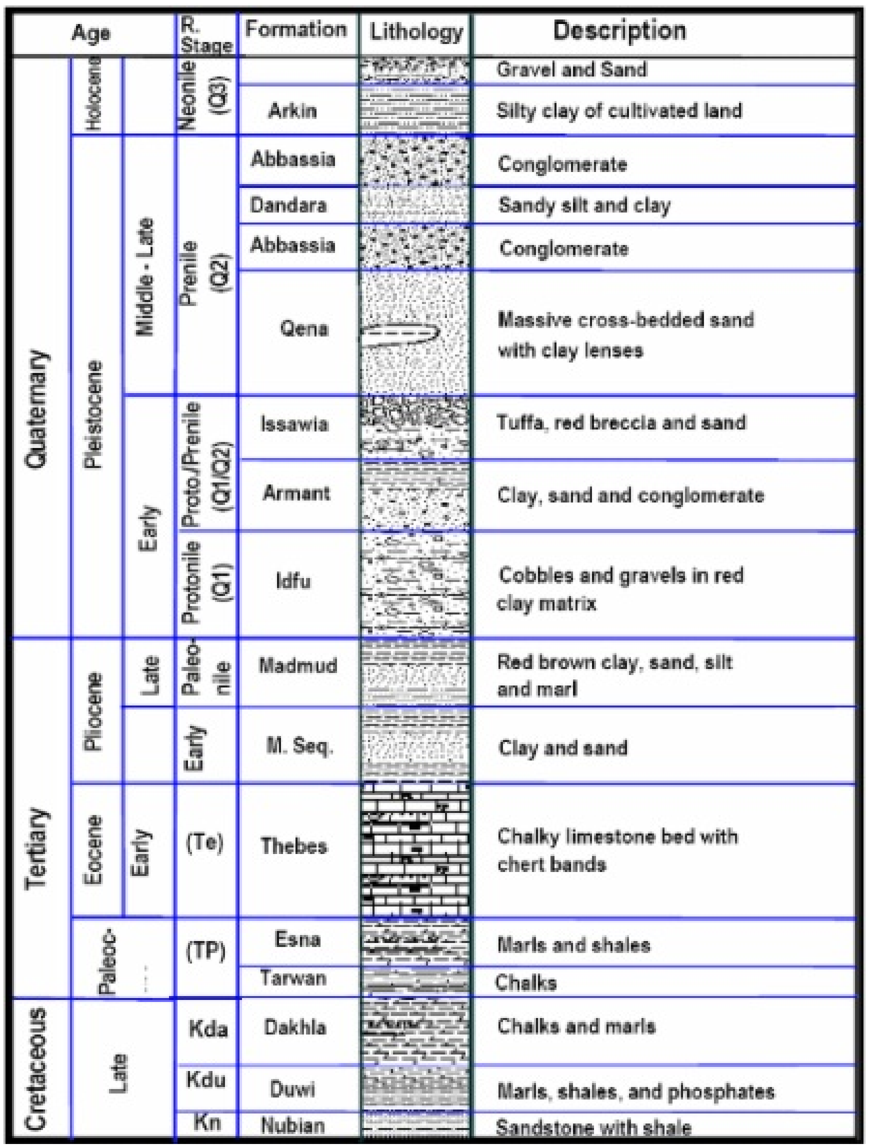

Fig. 6: Composite stratigraphic column, Luxor study area. (After, Youssef[9]).

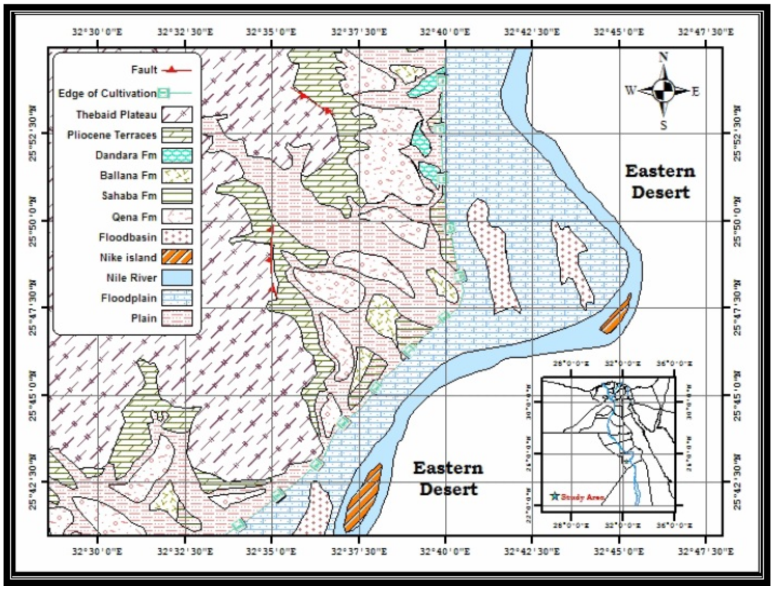

Fig. 7: Geomorphological map of the study area. (El-Hosary[5]).

Fig. 8: The hills are located on the surface of the study area.

fine grained and well lithified and joined. Esna Formation; Overlying the Tarawan Formation is an extensive out crop of the Esna Formation that occurs at the base of cliffs adjacent to Deir El Bahari and continuing along the escarpment lower the south ward: the thickness of this formation according to Said[8] is about 47 m, thinly laminated and friable gray shell.Thebes Formation ; Most of Tombs in the study area are excavated in this formation which consists of solid brown limestone with thickness of more than 300 m.It consists of 3 members in the Gebel Gurnah type locality behind the Temples at Deir El Bahary, the lower member is 133 m thin alternating beds of limestone, containing chert nodules.The middle member consists of bedded limestone.the upper member 30 m thick is a hash layer.Conglomerate ;It is composed of angular and sub angular boulders and cobbles of limestone derived from Thebes limestone as a result of erosion.it is easily weathered as it is poorly lithifed.

These conglomerate layers probably are a result of floods of Wad's such as Wadi El Molouq and Wadi EL Sheikh Abd el Qurna which flows off the scarps into the margins of paleo Nile floor plain[8].

The Geomorphological Aspects: The area can be subdivided into geomorphic units as follow fig. (7).

Theban Hills Unit: The hills are located on the surface of Thebe plateau, fig. (8) They consist of rugged, limestone which has been deeply dissected by dry Wad's, such as in the site of Sheikh Abd El Qurna, they reach a maximum height of 450 m.

The relief ratio of the area as a whole is about 400 m.The surface of this hilly area slopes from west to east toward the flood plain (fig. 8)

It is dissected by more than 25 Wadies. Most of these Wadies flow eastward such as El Qurna, El Molouk (Kings),El Beiria etc.

The river course: At Luxor, the river suffers an acute bend, Qena bend which is the major loop of the Nile in its Egyptian course. This bend marks the transitions from a relatively narrow valley in the south to a wider valley in the north. Fig. (9)

The alluvial plains: The alluvial plans of the Nile are restricted to the Nile valley area differentiated into the young and old alluvial plains.The young alluvial plains

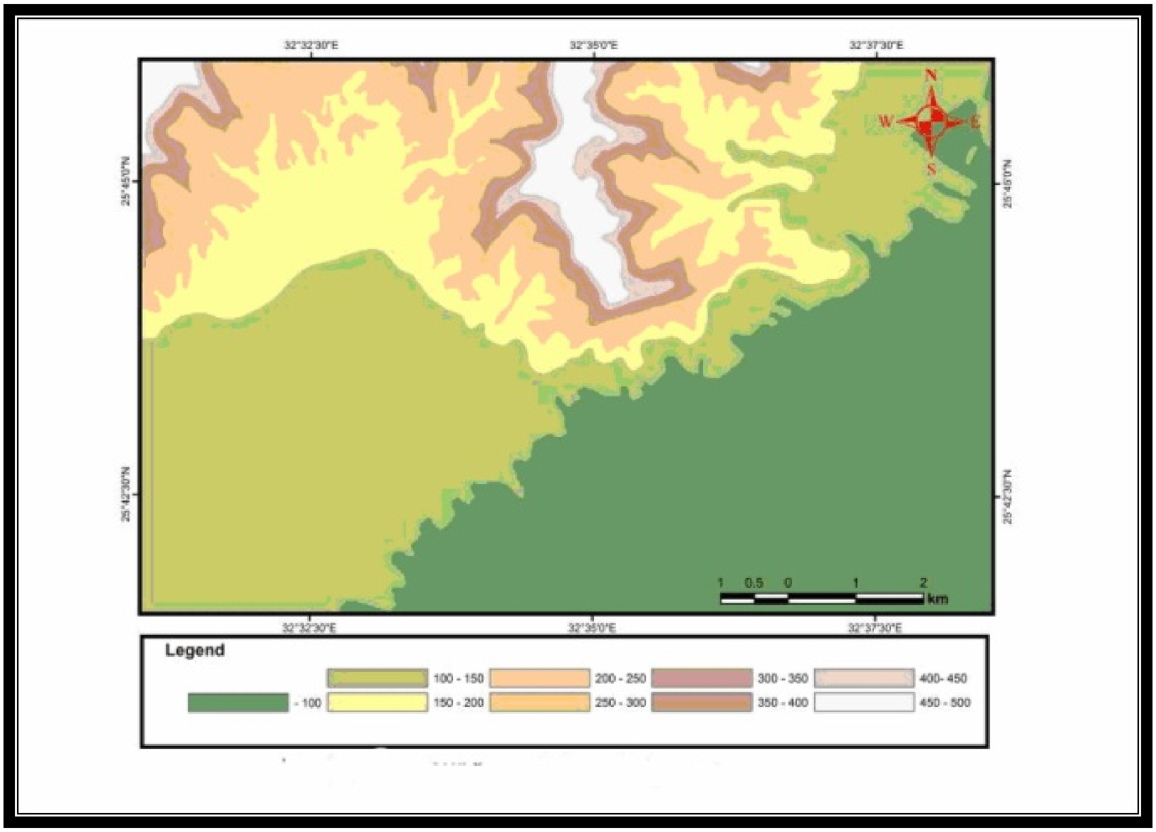

Fig. 9: Topography of study area.

comprise the cultivated lands bordering the river channel on the East of the study area. The young alluvial plains are almost flat and slope from south to north (about +90 m at Aswan).there is also a certain amount of slope in the direction of the river stream. The surface of such plain is underlain by silt deposits possibly belonging to Neolithic times. The old alluvial plains of the Nile are located between the cultivated lands and edges of the bordering limestone plateaus. They are represented by a series of terraces with different altitudes and overlying each other[10].

The terraces were formed as a result of aggradations and degradation of the Nile valley relative to the eustatic changes of the ultimate base level of the Mediterranean [11]

The calcareous structural plateau: The western structural plateau is lower in elevation than the Eastern structural plateau of the Nile and its surface is less regular. It rises about +400 m near to Aswan and +200 m close to Assiut. The escarpment is dissected by wadies that drain into the Nile(12)

The structural plains: The structural plains, known as the Nubian Plains are regionally extensive in the southern part of Egypt. The surface of these plains is generally weathered and enplaned, about numerous scattered hills forming erosion relics of the more resistant sandstone. Several Wad's occasionally cross the surface of he plain and commonly filled with shifting sands

The desert hydrographic basin: The surface of the plateaus is dissected by dry drainage lines (Wadi) which are directed towards the Nile channel. Occasionally, flooding of these Wadis's cause significant damage downstream.

The Effects of the Geomorphic Processes and Forms on the Archaeological Sites: There are many works carried out in different places of Upper Egypt dealing with deterioration of archaeological sites in the Nile Valley such as works of SWECO[13],Abd El Hady[14] and Ismaeil[15]; The Temples, the tombs of valley of Kings and Queens are located adjacent to the drainage basins outlets which will affect the tombs directly once the runoff reaches the basin outlet. Tombs of Queens and Temple of Medinet Habu is located at the outlet of the drainage. The water level in the river Nile fluctuates by about 6 m over the course of the year from high flood to low water. Fields were inundated for 40 to 60 days during the flood season, then the water is drained into the river, carrying with it excess salts Attia[16]. Today, the higher water level in the river interferes with the gravity draining of irrigation water. This problem is exacerbated by the fact that more water in now being applied to the fields under the practice of perennial irrigation than when basin irrigation was employed and the fact that agricultural drainage and domestic sewer systems in Luxor are generally inadequate.

The inevitable consequence is that the ground water is becoming saturated with increasingly salt water. The sandstone temples are being gravely affected by water that is being drawn up into their columns and walls. Along with the water dissolved salts are carried from the soil into the stone. When the water evaporates from the surface of the stone, salts remain behind then recrystallize on or just below the surface.

The biggest threat, of course, is flood water penetration by flash flooding, as illustrated by the dramatic and tragic events during the fall of 1994.[17] Incidents of heavy rains in the Theban mountains are not unusual and have been noted from ancient times.7 There are several eyewitness accounts of flooding during the last two centuries, Howard Carter having witnessed probably the hitherto last major flood event during 1918. Several tombs in the Valley of the Kings are completely choked or contain chambers that are thoroughly encumbered with the debris of flooding.
According to the historical records, the various forms of flooding and runoff hazards caused by overland flow and channel flow can be summarized as follows:

sediment erosion: The sediment erosion involves mechanical abrasion whereby coarse and angular fragments of hard rock are released. Rolled and dragged along the channel floor. The hydraulic power exerted by rapid flow led to the fragmentation of bedrock in the channels. This process is obviously seen along the channel and low lands.

Sediment transportation: This process includes the downstream movement of the eroded sediment on the form of dragging jumping of practical and suspension of particles.in addition salts were also transported by solution.

Sediment deposition: The loss of energy of running water at the exit of the considered basins giving rise to deposition of transported material, this process was obviously noticed in the study area where a layer of transported sediments fully covered the cultivated lands at mouth of basins.

Groundwater: Since the construction of High Dam

Fig. 10: The effects of ground water in the Temple of memnon.

regulating the river discharges downstream of Luxor,the water level in the study area is generally lower than the ground water heads all the year except in reaches located up stream of the main barrages.this Leeds to seepage of ground water to River Nile.

The increase in ground water head after building High Dam is a result of increase in surface water delivering and applied irrigation water due to the lack of a suitable drainage network.

As a result the water table has built up continuously causing drainage problems, the groundwater monthly fluctuation with an increasing trend contributed to some rock degree in the present deterioration of the archaeological sites Archeological Authority(18) cleared that the Temple of Memnon is suffering from ground water Fig. (10).

Aeolian Erosion: High winds are not uncommon in the Theban Mountains, and on more than one occasion I have been able to examine clean Valley tombs in their aftermath and found significant quantities of wind-blown sand, dust and tourist litter. Many of the tombs of the 19th and 20th Dynasties with their large openings guarded by grated doors are susceptible to this sort of abrasive erosion and such should be considered in future preservation schemes.

Humidity: The desert climate is characterized by extensive temperature changes where it varies remarkably between days and nights. The high temperature of the day is able to draw the moist out of pores towards the surface; this water evaporates resulting in a concentration of water soluble salts on the surface of the stone.

Capillarity: pores and cracks. Extremely fine pores (capillaries, as fine as a hair, order of magnitude 0.1-1 micron) and cracks (micro cracks) such water inside them (capillary suction) If the surface happens to be wet, water molecules are actually able to climb the walls of fine pores and cracks overcoming the force of gravity (capillary rise)[19]

Most of the pharhonic monuments are damaged in the zone close to the ground surface due to the action of capillary water. The continuous migration of the water takes place due to evaporation into two ways:

- The dissolving of salts reduces the strength of stone material as the cementing agent is partly removed.
- the more spectacular damage takes place at the surface where the dissolved salts recrystallize and the expansion causes deterioration

The capillary rise in soils increases with decreasing grain size. Extensive rise can thus occur in homogeneous fine-grained soil deposits such as silt and clay.

Salt in soil material: Since the climate in the Nile valley in Upper Egypt is characterized by low precipitation and high evaporation during the major part of the year, the capillary zone normally reaches the ground surface and continuous transport of salt takes place in an upward direction. The result of this is a concentration of salt in the upper soil strata.

Movement of water and salt can also occur in rock strata located above the capillary zone.the surface layer of the rock can take up water from the humidity of the air.variation in humidity and air temperature cause the moist zone to move into the rock or retreat toward the surface. The result of this concentration of the salt which is dissolved in the evaporation of water, the volume increases as compared to fluid phase; the result of this expansion can crush the stone matrix and the rock surface deteriorates.

Conservation procedures: Conservation of archaeological sites is a complicated process due to the many factors that should be considered in any conservation project. According to the result of this study and other works, the main sources and causes of deterioration of archaeological sites in the study area are the groundwater rise, capillary effects, salt content in groundwater and rock material, urbanization and agricultural activities.

Lowering groundwater table: It is important to establish the seasonal variation of groundwater levels in several locations within or adjacent to pharhonic monuments. This can be achieved by different, relatively simple methods such as installing a nest of pyrometers extended to a certain depth below the groundwater table or using other modern instruments.

Groundwater table in the study area can be lowered through the following procedures:

- Pumping groundwater: By installing of a pumping system, water level can be controlled and kept below a chosen area. Normally this will not require continuous pumping, as the groundwater level will be drawn to a certain level and then be allowed to fluctuate as controlled by intermittent pumping.
- Decreasing capillary effects: If the capillary zone can be lowered at some depth below the ground surface, visible deterioration can be prevented.lowering of capillary zone can be achieved by ;lowering groundwater level and by using gravel filter

Reduction of salt concentration: The removal of salt from stone or plaster may sometimes require that the walls be repeatedly wetted for a number of days and then covered with a poultice of absorbent clay or diatomaceous earth for at least a month.as the walls dry out, the salts will be transferred into the poultice.it may be necessary to repeat the process a number of times to obtain any worthwhile reduction in the salt content (12).

Conservation of stone and rock: The conservation of stone and rock by cleaning; aimed at the removal of salts.

Reducing effects of agriculture: Agricultural activities and irrigation are the main sources of rising of water table. The effects of irrigation and agricultural activities can be reduced by:

- Excluding areas bordering the archaeological sites from agricultural activities.the areas to be excluded depends on the degree of deterioration and situation of groundwater condition in the area under investigation.
- Changing the irrigation methods where the present irrigation method in the study area is the basin irrigation which leads to increasing the water table.
- Using efficient drainage network in the study area will help reduce the water table to a certain level.

Reducing urbanization effects: Urbanization in the study area is a major factor of deterioration of archaeological sites; that includes the building of random houses which are adjacent to the different archaeological sites in the study area Fig. (11). The absence of managed septic tanks and cesspools can cause major damaging effects in the study area where seepage from the septic tanks is a major deteriorating factor as the contained waste water is normally of bad quality that could enhance the corrosion processes and precipitation of salts in the infected foundation.

Solving the problems of deterioration arising from urbanization can be achieved through the following procedures:

- Introducing a waste water treatment system in the affected areas to prevent the seepage of sewage and waste water to the archaeological buildings
- Relocating of adjacent houses to another site, where houses are in direct contact with temples constituting a dangerous source of deterioration in the study area.
- Monitoring these water treatment systems periodically to completely prevent any seepage that could damage the foundation

Conclusions: The area of study includes many Archaeological sites such as Temple of Memnon and the famous Tombs such as Tombs of Valley of Kings and Valley of Queens.

The area of study is dominated by sedimentary rocks belonging to Upper Cretaceous. The main Geomorphologic units are River s course, the alluvia plains, the structural plateaus, the structural plains, and the desert hydrographic basins.

Many cavities and cracks are developed inside the stones.Gypsum and halite are crystallized within the pores of stones resulting from the salt attack developing different micro-cracks in the surface of sand stone leading to deterioration and damage of stones.Climate is a reliable factor in weathering processes.

Recommendations: The following recommendations should be taken into consideration to protect the archaeological sites from deterioration and future damage:

- Flood management should be done in the study area to avoid flooding and runoff hazards.
- Groundwater management should be taken into consideration to avoid rising groundwater levels in and around the archaeological sites.
- New irrigation methods should be applied in the study area to avoid rising groundwater levels, the cultivated areas around the archaeological sites should be replanted to avoid the effects of ground seepages from the irrigation lands.
- The houses that are in contact with the archaeological sites should be re-located in other places far enough to avoid the effects of random housing and seepage tanks and other domestic sources of groundwater.
- Monitoring groundwater levels and deterioration processes in and around the archaeological sites should be achieved periodically to solve any deterioration problem in the appropriate time before initiating further damages.

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