Contributions To The Geneses Of Continental Waters In North Western Egyptian Sahara Using Landsat Images

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Abstract - The present observation at northern Western Desert of Egypt is a downward migration of water in the lakes whilst the water increases in the springs. This paper delineate the geneses and behavior of the ground water in this region. Geomorphological landforms were interpreted from integrating geological data with visual analyses of Landsat TM images and the spatially variable reliefs from the DEM as well as field verifications. The Ed Defa limestone plateau retreated to the north as a result of E-W faults with southern 300 m downthrow followed by extensive weathering and karst phases. Ground water developed in mature horizontal subsurface canyon fluvial model. The collected water by this model supported the sandstone aquifer under Siwa and Qattara depressions, consequently the springs evolved in E-W depression. Besides to the karst water in lakes depression, Quaternary aquifer formed inside thick deposits by quick runoff across the plateau cliff but subjected to evaporation. [Nature and Science 2010;8(11):35-43]. (ISSN: 1545-0740).

Key words; depression, springs, lake and fault

1- Introduction

The Western Desert can be considered Egypt's land of promise. However, its development must be based on a deep understanding of the dry and harsh desert climate, the strong winds that result in sand and dune movement, and the non-replenishable groundwater Resources[4]. The northern Western Desert limestone plateau had been interrupted by depressions and lowering below sea level, hence springs and natural lakes appeared. The question is how the lakes and springs formed and why there is some downward migration of lakes water table while the water increase in springs.

The complex development history of springs and lakes initiative with emphasis to its origin modeling is the aim of this article. Structural and geomorphological process integrated in this study to monitor the springs and lakes configuration in the northern Western Desert, where settlements and ecotourism activities depend on.

2- Methodology

The lithological units and structural lineaments were extracted from the available geological maps [2 and 15] and Landsat TM images (Fig.1) with field verifications. The geomorphological units were interpreted from integrating geological data with visual analyses of Landsat TM images and the spatially variable reliefs from the DEM and slope map with field work. The landforms of the study area were initially defined according to their genesis (i.e. coastal, fluvial, aeolian, etc). The broad water fossils including fluvial and lacustrine deposits as well as sand dunes were traced from the satellite images with field verifications. The Tertiary-Quaternary tectonics control on different landforms was implied given the influence of structural lineaments on recent springs and lakes configuration. Additionally, the E-W structural trends have thrown down forming ellipsoidal grab-shape. Consequently, the hydro-climatic changes during and after the Holocene pluvial cycles crystallized as fluvial terraces and playa deposits were deposited. Moreover, the impact of changing hydro-climatic conditions in this region was also determined. Overall, the morph-tectonic and karst developments will be used to interpretation the potential groundwater resources.

3- Remote Sensing Applications In The Study Area

The principal component PC (bands 7, 4, 2) are used for the lithologic discrimination and edge enhancement of different rock units in the area. And suitable for visual interpretation of the various structure, and geomorphic features, where they show brightness, fair drainage pattern. In false color composite images, the limestone appeared in greenish blue, sandstone in yellowish brown, while shale in pale grey color. Landsat ETM Image for the area shows the road to springs and natural lakes (Fig.1). Digital elevation model (3D DEM, Fig.3) prepared from Landsat ETM image and topographic maps to understand the relation of the springs and lakes to its surroundings (Fig. 2). This gives clues to some aspects of the processes involved the abundant of springs in Siwa depression whilst there is desertification in lakes depression.

Field work and remote sensing techniques elucidated that Siwa depression is a closed tectonic basin bounded by limestone plateau in the north, in the west and south by Great Sand Sea and in the east by uplifted hill, therefore the inadequate drainage creates several problem in Siwa. In addition, the agriculture sewage water formed wide salt lakes around Siwa (Fig.1), mixed with fresh water and rise the water table in Siwa closed depression and produced geoenvironmental problem. This sewage water should be extracted outside the depression may be by pumping and the water spillway outside the basin and/or may use the retreated cycle technique. The problem can be explained in Figure 3 (3D DEM s) illustrate; (**a**) the topography of the area nearly at sea level without water appearance (b) minimum water appeared at the more lower topography (c) stage of water spread around Siwa, it is the present position. (d) maximum water appearance at the topography of the area in future (nearly at sea level) it shows the predicted risk on the oases.

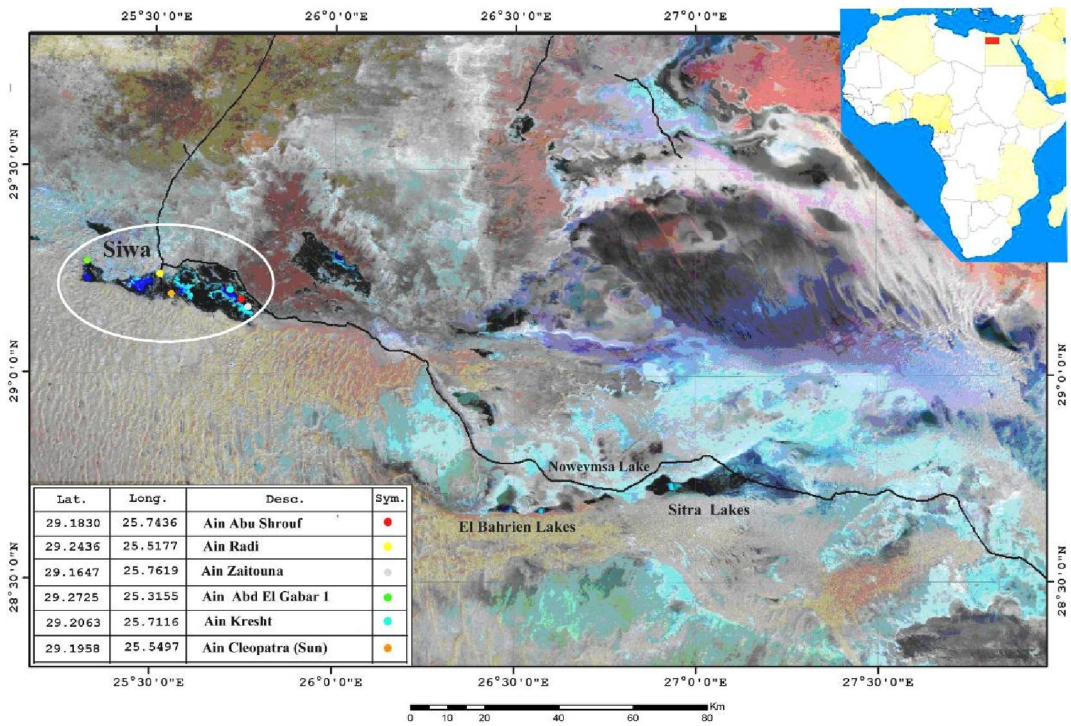


Figure 1, Landsat ETM image shows springs and natural lakes and the road

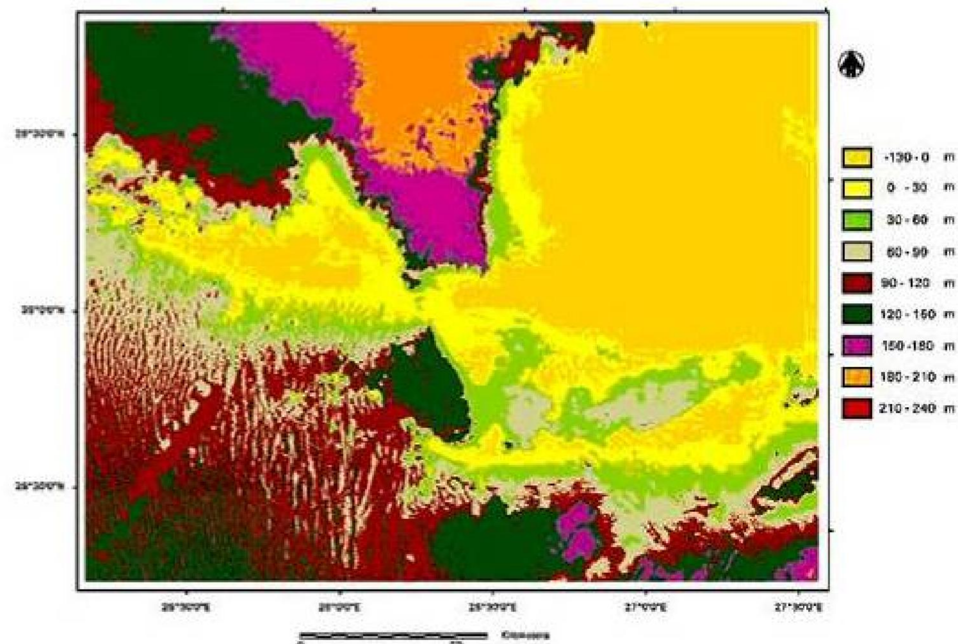


Figure 2. Digital elevation model of Siwa Oasis.

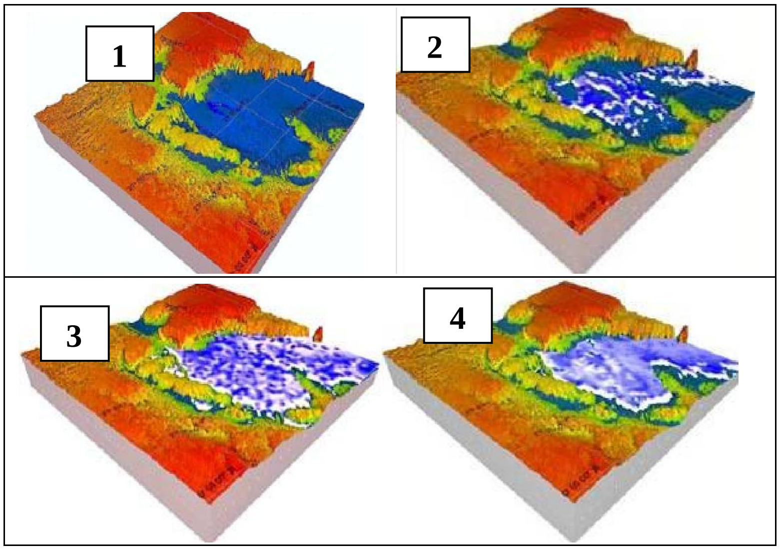


Figure 3. Three dimension (3D) model for Siwa area, (1) the area without water appearance (2) minimum water appearance at lower topography (3) proposed stage water appearance is the present day of water bodies. (4) maximum water appearance risk at Siwa.

4- Geology And Structure

According to geological maps [2 and 15], the exposed Middle and Upper Miocene carbonate rocks are widespread north of Siwa and Qattara depressions while the EOCENE carbonate rocks are exposed to the south of the lakes (Fig.4). The two horizontal sedimentary sequences are separated by E-W structural plain. Middle Eocene Hamra Formation (F.) composed of white to grayish white limestone, including intraformational conglomerates and sand beds intercalations. Upper Eocene, Qasr El Sagha F composed of clay-stone and shale with sandstone interbeds and fossiliferous limestone. Middle Miocene, Mamoura F composed of interbedded fossiliferous shale, gypsiferous claystone, sandstone and limestone, equivalent to the top part of Moghra F. Moghra F composed of continental to shallow marine silciclastic sequence including shale, siltstone and white sandy carbonate beds, with abundant silicified wood. Upper Miocene**,** Marmarica Formation composed of grayish white calcarenites with few shale interactions, followed upwards by white limestone rich in fossils (Fig.4). Pleistocene sheet of reworked limestone, sandstone and chert gravels covered wide parts to the north of Siwa. Holocene fine to medium grained quartz sand arranged in longitudinal and barchan dunes. Flat to slightly undulated sand sheet (northern part of the Great Sand Sea). Sabkha sediments composed of silt, sand and clay intercalated with evaporites.

The present area is extensively affected by structural movement from the Miocene age to recent. Series of faults are obvious at the field forming the E-W oriented incised depression. A lineament map had been interpreted from Landsat ETM images together with field verifications and plotted on the geological map (Fig.4). Three major E-W fault-scarps formed southern down throws are from north to south; 200m, 100m and 200m. These down throws cannot be accomplished by one rapid and continuous movement, but it is the outcome of numbers of successive movements during a comparatively brief period of geological time. Right lateral E-W and ENE-WSW faults predominant in the central and southern parts of the area while the northern part is predominated by NE-SW and NW-SE faults. In addition, the impact of the structural movement appeared in the following features: i- in highly dissection in Ed Defa plateau, ii- inliers landform and major scarps north of the depression. iii- the E-W depressions (Fig.5) which followed by water agent in karst activities. The lakes are arranged in E-W line inside the northern part of this depression in the same extension, and the springs in Siwa are located in E-W ellipsoidal depression (Fig.1 & 4) we may can call regional sinkhole.

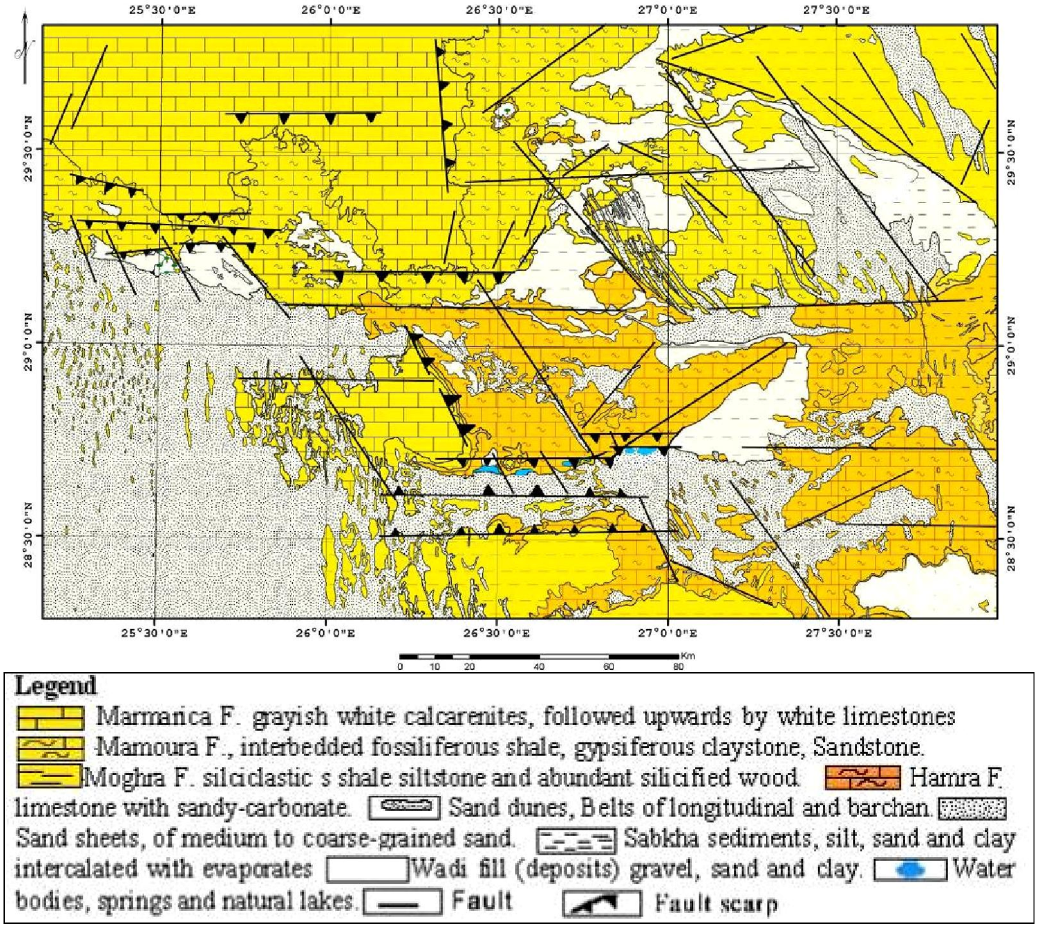


Figure 4, Geological map of the study area illustrates the structural elements.

5- Geomorphological Features

Paleokarst cycles in Western Desert led to the continuous lowering of the landscape. Connected or disconnected solution dolines and variety of karren features dominate theMiocene carbonate cap.These karst features are often associated with "terra rossa'" rich in rhizoiiths [3 and 4].

Karstified dissected Ed Defa limestone plateau (350 m asl) widely extended from the Mediterranean coast to north of Siwa Oasis (Fig. 5). The upper surface of Ed Defa plateau is covered by duricrust surface. It subjected to deep major fault series and retreated to the north and left behined outliers such as Gabal El Bahrien , mesas and butte are located north of El Bahrien lakes. Major and minor fault-scarps and ridges (Fig.6). The karst processes for the long time produced caves, depression in carbonates and caves in chalk that capped by dolometic limestone (Fig.9).

Lacustrine landforms, wet playa sediments exposed in central and southern parts of the area, it composed of silt, sands and clay intercalated with thin evaporate beds. In the eastern side of the area, the dry playa sediments are higher topography than the wet playa in the center. Dry playa sediments composed of salts, silt, clay, and rare carbonates. Erosional fluvial landforms, Eroded undulated plain partially covered with thin gravel sheet include reworked limestone, sandstone and chert gravels formed by flow water as an erosion agent in the northern part of the area. Longitudinal and barchan dunes as well as sand sheets are restricted in a lower topographic area between two E-W major faults around the lakes. Great Sand Sea flat to slightly undulated sand sheets extended southward from the southewest Siwa to the Egypt-Sudan border, composed of quartz medium to coarse-grained.

The springs (Ain s) of Siwa lie in an structural controlled ellipsoidal depression in altitude 100 m below sea level with E-W length and covered by playa deposits referring to old lake during the rain periods in Holocene. This depression divided into blocks by NW-SE faults and surrounded by Quaternary deposits. There are more than 55 Ain in Siwa depression have wonderful bubbles race through the clear hard the pleasure of swimming (Fig.1), which travelers can bathe but 10 Ain are famous, not only for the pleasure of swimming in their bubbling waters (Fig.7), but for the history (Alexander the Great& Herodotus) The bubbles in many springs rising to tickle toes, belly, and nose on their way to the surface. Baharaine Lake, Sitra Lake, Bir Sitra Lake and Noweymsa Lake are tectonically controlled by E-W depressions separated from each others by NW-SE highs blocks in low land. The lakes exhibit semi-circular to longitudinal shape surrounded by minor bedded scarps of limestone (Fig.8).These continental lakes are full of saline to fairly saline water surrounded by wet sabkhas of salts and sandy-clay, followed outward by dray areas below sea level. Wali, [16] postulated that Sitra Lake area occupies 2000 km. It is divided into 5 sedimentary zones–permanently wet–temporarily (partially) dry temporarily (partially) wet -and permanently dry.

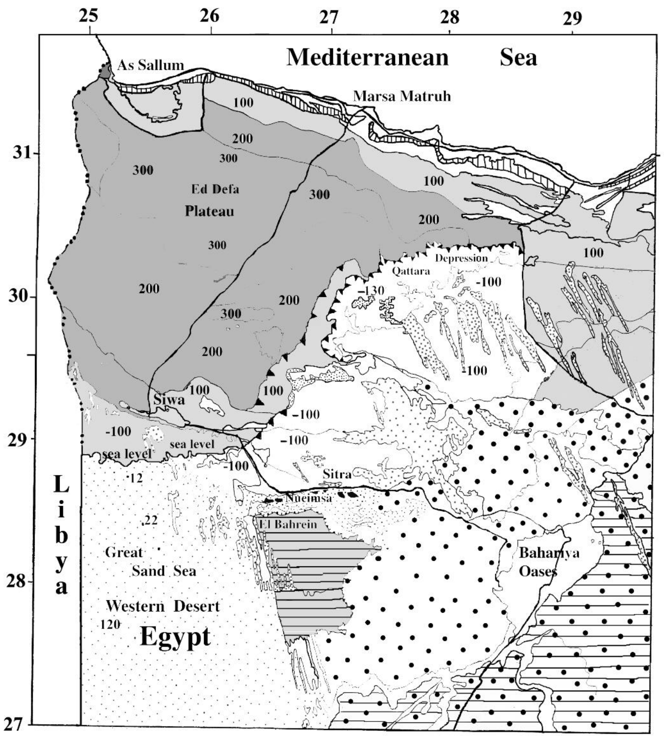
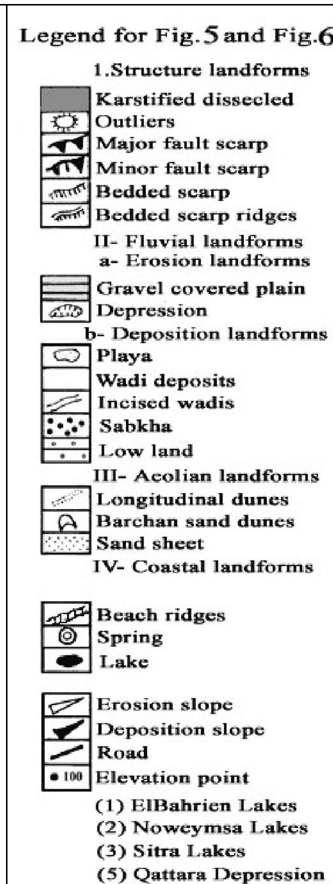


Fig. 5, Geomorphological map of the northern part of Western Desert,Egypt interpreted fromTM images and topographic maps



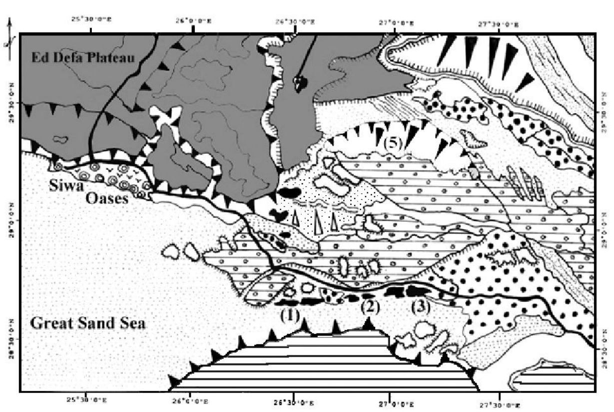


Fig. 6. Geomorphological map prepared in the field for the study area

6. Discussion

Climate change during Quaternary recounts the environmental history of the area. The playa at Hatiet Umm El-Hityus in Siwa Oasis filled around 8500BP and was a locus of cultural activity during the Early Neolithic [17]. The Early Holocene was characterized by the advent of water conditions across much of Egypt and northern Sudan [6]. While [10] postulated that during the Late Pleistocene, most of Egypt and northern Sudan was internally drained and run-off accumulated within disjunctive internal drainage divides and deflation hollows. Early

Holocene playa are abundant around the springs and lakes evidence on the rising water tables were sufficient to support the lakes and give clues to Holocene water which is a main agent in karst at the present area. In studying the influence of oscillating climates on scarp retreat, [11] stated that the rotating slump blocks below Black Mesa, Vermillion and Echo Cliffs of Arizona subsided blocks below the scarp of New Mexico's Chuska Mountains, and both types of detachment in Nubian sandstones in the central Sahara, all strongly eroded and without recent counterparts, to conclude that substrate erosion and caprock collapse were much more active in a past period of greater precipitation, presumably in the Late Pleistocene. The current search in Siwa area ensure the conclusion of [11] and the study of limestone scarp forms in Morocco, Algeria and Tunisia,[14]concluded that previously active cliff recession and seepage- related cavernous weathering are now stagnant with inactive cliff faces.

The investigated area lies at the boundary between the Stable Shelf and Unstable Shelf postulated by[12] while [9] drew this boundary at the southern part of the present area. The major structural elements in the Stable Shelf and Unstable Shelf are northwest and northeast trends. The interaction of these trends was responsible for the generation of the frequent east-west faults. E-W regional faults are observed in the field. And [8] drew flexure zones in north Egypt, the study area lies at the path of this flexure zones. For these reasons, the current search document present area lies in site of E-W mobility zone. Moreover, the target area lies between the Neogene stratigraphic sequence (clastic, evaporates and carbonate rocks) and Paleogene stratigraphic sequence (sandstone, and clay), it means that this area subjected to deep seated E-W fault zone forming E-W depression between the Neogene and Paleogene. Hence, the continental water in the present area had been collected in E-W structural depression.

In Ed Defa plateau, the karst are best developed in relatively massive uniform mechanically strong and impermeable limestone. Chalk, for instance, is too porous and mechanically weak for karst development. Rates of Ed Defa Scarp retreat is relatively high due to; (i) the number of E-W faults, post Miocene (ii) climate and (iii) the sedimentary succession of hard and soft alternating bedding (Fig.9). Extensive karst processes developed in interbedding of shale, marl and chalk and limestone below the hard limestone as a canyons erosion model. [1] stated that in Siwa Oases, the deep waters are frequently similar to those from the other Western Desert oases, but the shallow wells and springs are typically of all MgCl water type and there salinities range from 2000 to 8000 mg/I. It has been suggested that the Western Desert hydraulic system is in equilibrium with recharge occurring in the Tebesti-Ennedi area of the northwest Chad. While [7] postulated that Western Desert underground waters originated locally during the last pluvial. We tend to favor the second explanation on the basis of the low salinity of the Western Desert underground waters because of Siwa springs are far from the Mediterranean Sea (about 320 km) and separated from the south by major deep E-W faults and by other structural movements and blocks, and thick plateau traced by E-W faults also present in south of Western Desert. Several deep wells (100 - 200 m) had been drilled adjacent to springs (such as Ain Abo Shroof, Ain Zaytona and Ain Qurashet). This drilling decreases the water strong flow around some springs which is a problem for the farmers. Other wells reach to Cretaceous sandstone aquifer. This canyon water model support and recharged the Cretaceous sandstone aquifer under Siwa.

Baharaine Lakes, Sitra Lakes, and Noweamsa Lakes are arranged also in an E-W structural line in tectonic depressions (Fig.1 and Fig. 8). They are isolated from each others by NW-SE blocks. These continental lakes full of saline to fairly saline water and each lake is ellipsoidal water body with E-W longer axis confined to gathered water setting on silciclastic sequence. The observed evaporites and playa sediments in dry rings at the outer parts of the Lakes delineate the position of the former periphery of the older lakes configuration. Therefore the lakes suffer from decrease water supply and increase salinity. The lakes periphery formerly was most probably at the topographic zone sea level while now it is at -20m. The sand dunes migrated across the dried up areas west of the lakes in E-W depression as a corridor coming from Great Sand Sea. Great Sand Sea south west Siwa counted by [13] in the Sahara ergs larger than 12 000 km² as active statues sand in north Africa. [5] stated that water table phreatic gypsum cementation in the sands dunes field in New Mexico, which has acted as a basal limit to aeolian deflation and created extensive planar surfaces. Gypsum cementation zones around the lakes are adjacent to sand dunes, this indicate that the presence of these lakes close to water table in the present area and coincide with [5] observations in New Mexico.


Figure7.Photographs show, Ain Cleopatra (Cleopatra's Bath, left),Ain Abo Shroof (right)

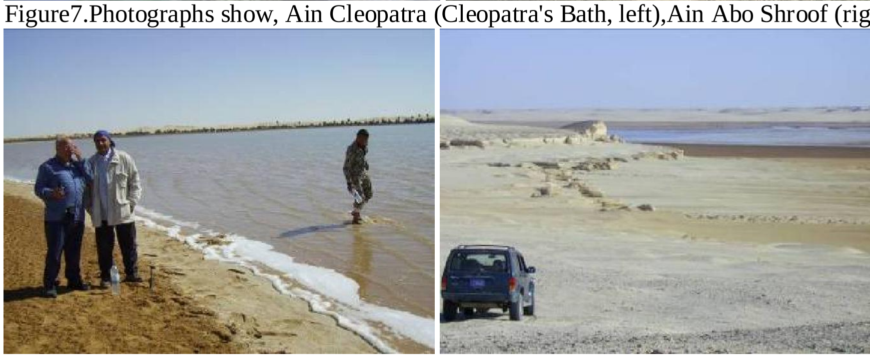


Figure 8. Photographs, show EL-Bahrien Lakes (left), and Sitra Lakes (right).

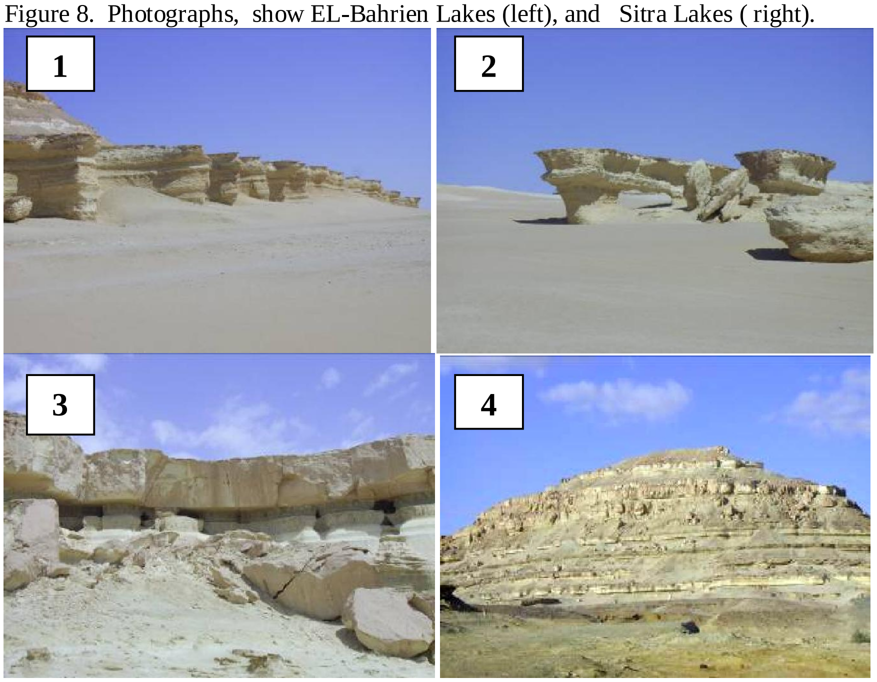


Figure 9. Photographs show; 1,scarp retreat east Siwa. 2, mesa and butte west Siwa. 3, karst caves north Siwa. 4,cliffs and gentle slopes caused by erosion of differential horizontal sedimentary layers

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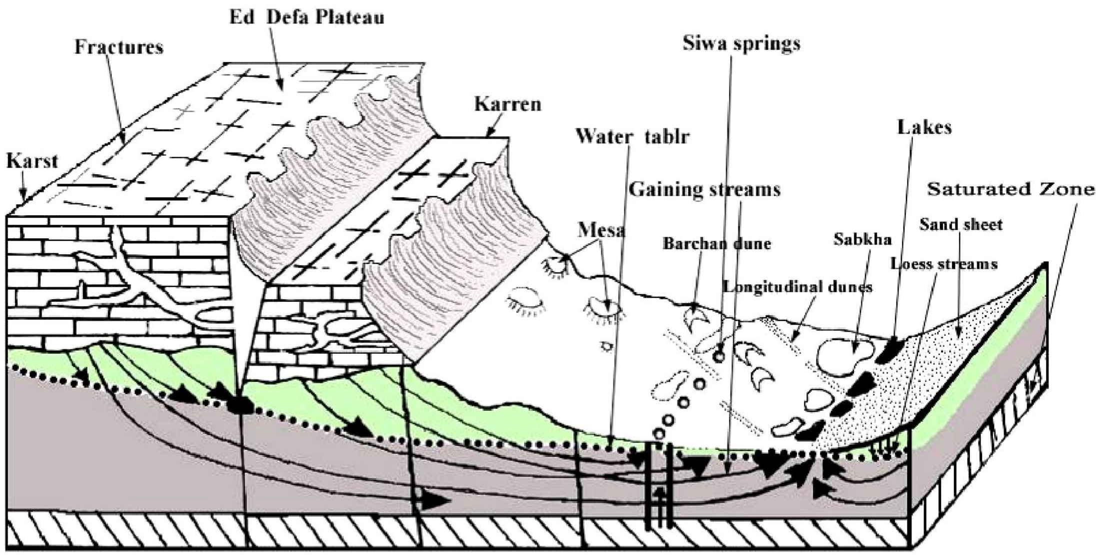
Overall, the history of the continental water imitation in the preset area can be summarized. Firstly, the Miocene plateau subjected to major deep E-W faults series with southern downthrow forming steep scarp series of 200m, 100m and 200m forming depression in E-W trend. This depression is the site of trapping the water through geologic periods. The plateau retreated in phases by Karst processes yielded; caves, mesas and putt in mature karst in the remnant of the plateau (Fig.9). Water flow in wet periods infiltrated and migrates through the rock fractures and go down in lower E-W canyon that exposed to the south of the plateau. This situation have to be active for long time, therefore, the surface of the springs and natural lakes in Siwa area present below the sea level (-100m). And continuous recharge water in canyon erosion model in limestone and in interbedding of shale, marl and chalk and limestone below the hard limestone (Fig.10). As a results of the last stages of weathering in lower topography area, the water appears as springs. Whilst the water in lakes decrease due to wide depressed plain, high temperature, high evaporation and high infiltration into superficial sediments in wet land around the lakes. Movement of ground water beneath a sloping water table in uniformly permeable rock. Near the surface the ground water tends to flow parallel to sloping water table. Water moved along the fractures and bedding planes in Ed Defa limestone, dissolving to form caves and old karst valley below the water level. Then water collected by gaining stream support the springs while losing streams contribute to the ground water in dry sand sheet around the lakes. Wind deflation modified the karstified plateau surface, anyway, the wind action and aeolian deflation at /and around the springs and lakes are limited by the water-table depth.

The proposed fluvial model landscape for the formation of underground water occurred in north-western Egypt is of horizontal bedded to gently dipping Tertiary limestone plateau structural plain canyon erosion model subjected to breaks of slopes in the down throw zone (Fig.10).



Figur .10. Schematic diagram illustrates the proposed fluvial canyon model landscape of natural water generation in the north Western Egyptian Sahara.

7- Environmental And Ecosystem Implication

Regard to long history and several ancient temples can seen in Siwa depression north Western Egyptian Sahara, the underground and surface waters were life grant for agriculture. Siwa has been called ‘Santarieh’, the Oasis of Jupiter-Amun, field of palm trees known to have been inhabited in Neolithic times. ‘Alexander the Great’, like ‘Perseus’ and ‘Hercules’ before him made a long exhausting to consult the famous ‘Orcale’ of ‘Amun’. The current search interpreted the following environmental and ecosystem implications; 1-Siwa depression is a closed basin surrounded by uplifted land, therefore the inadequate drainage creates several problems. People have limited agriculture, growing olive and dates. The agriculture sewage water formed wide salt lakes around Siwa causing ecosystem disturbance. In last decades, there is no place for the water to go. The sewage water may mixed with fresh water and rise the water table in Siwa. This sewage water need to extracted outside the depression may be by pump and rising water outside the basin or may use the retreated cycle technology. The lakes are salty that is difficult fishing industry causing agriculture growing not wide of crops. 2- Herein problem in Siwa, the salt comes in huge chunks ,like salt licks, it helps strengthen the walls, but is unhealthy, leading to rheumatism, and melts in the rain making the houses potential risk. 3- The bubbles race through the clear hard pleasure of swimming in more than 77 springs (Ain) in Siwa which travelers can bathe while 8 Ain are famous, not only for swimming in their bubbling waters (slightly saline-sulphate water), but for the history, such as Alexander the Great, Herodotus and events that have taken place around them. Water pumped, flooded around several springs and flow up during the farmer plow land for agriculture. Farmers consider it as a problem but it only need management. These are indications that water recharge more than the water discharge and people should be utilize from these observations. 4- The downward water level in the Baharaine Lakes, Sitra Lakes, and Nowama Lakes, disturbed the old ecosystem around the lakes that was comprise birds, plants and tam animals replaced now by raven animals. Also, Palm and natural vegetations are subjected to stiffen because of salinity increase. Sand encouragement the area cause natural hazards from sand/dust storms coming from the Great Sand Sea. While natural caves around the lakes were used formerly as houses and tomb in rain periods, for these reasons, ecotourism site cab impaired in the future. It have to found how utilize from these water both in Quaternary and in lower aquifers. 5-The interpreted canyon fluvial model in limestone aquifer below Quaternary deposits can support people with water requirements in this Sahara sector of Egypt, therefore the people can drill water wells in lower topographic areas outside the lakes in limestone aquifer. 6- In Quaternary aquifer, thick wet sabkhas and thick wide playa around the lakes, but the water discharge rate consider more than recharge rate, while people can dig shallow water wells. In the future the lakes may will disappear and the landscape change. Another different solve that people can groove and clean the lakes borders and not dig wells around the lakes to save the natural environment and ecosystem and ecotourism sites in the area.

8- Conclusion

The proposed fluvial model landscape for the formation of underground water occurred in north Western Desert is of horizontal bedded to gently dipping sedimentary structural plain canyons erosion model. Hence the water gathered and exposed in E-W depression forming many springs and lakes. This canyon fluvial model supported and recharged the Cretaceous Nubia sandstone aquifer under depressions where other springs evolved. Besides to the canyon karst water in altitudes below zero level, the Quaternary aquifer formed inside thick deposits in lakes depression by quick runoff across the plateau cliff. In the Baharaine Lakes, Sitra Lakes, and Noweamsa Lakes, the recharged water from gaining streams in this canyon model is not enough to equal the discharge water due to many functions including; parts of waters infiltrated and absorbed by the underlined Moghra Formation(clastic sediments), fracture, evaporation and loss streams in the surrounded sands. Consequently, the water decrease in lakes and salinity increase.

References

[1] Chandler M.E.J.(1984) Some upper Cretaceous and Eocene fruits from Egypt. Bull.Brit. Mus. Nate. Hist. 2 (4): pp 147-187.

[2] CONOCO Coral, and Egyptian General Petroleum Company, 1987. Geological map of Egypt scale 1:5,00,000, Cairo, Egypt.

[3] El Aref. M.M (2000) Paleokarst Surfaces and Karst Morphology of the Western Desert of Egypt, History and Economic Potentialities The International Conference on flic Western Desert - January 17-20, 211(11- 4).

[4] EL-Baz F (2000) Potential of Economic Development in the Western Desert of Egypt The International Conference on the Western Desert - January 17-21) Cairo Egypt, 200I.

[5] Fryberger S.G., Schenk, C.J. and Krystinik, L.F., (1988) Stokes surfaces and the effect of nearsurface groundwater-table on Aeolian deposition. Sedimentology, 35:pp 21-41.

[6] Haynes Jr .C.V. (2001) Geochronology and climate of the Pleistocene Holocene transition in the Darb el Arba in desert Eastern Sahara . Georchacology 16, pp 119 – 142

[7] Higazy, R.A. and Shata, A. (1960) Remarks on the age and origin of groundwater in the Western Desert with special reference to el Kharga oasis: Ext. Du. Bull. De La Soc.Geor. D, Egypt,Tome XXXIII, pp 177-186.

[8] Kerdany, M.T.and Cherif,O.H., (1990) The Mesozoic in Egypt. (from Said ed,1990). The Geology of Egypt. Balkema Rotterdam Brookfield. pp 407-438..

[9] Meshref W (1990) Tectonic framwoek of Egypt. (from Said ed,1990). The Geology of Egypt. Balkema Rotterdam Brookfield pp 113-155.

[10] Nicoll K.(2004) Recent environmental change and prehistoric human activity in Egypt and north Sudan. Quaternary Science Reviews, Elsevier. 23 (2004), pp 561-580,

[11] Oberlander Th. M. (1997) Slope and pediment systems from David, S. G. Thomas, (ed). Arid zone geomorphology. Second Edition John Willy and Sons New York. pp147.

[12] Said R, 1962. The Geology of Egypt. Elsevier, pp 377.

[13] Show P. A. (1997) Geomorphology of Africa and Europe. from Thomas, D.S. G. (ed). Arid zone geomorphology. Second Edition John Willy and Sons New York. p 474.

[14] Smith, BJ(1978)The origin and geomorphic implications of cliff foot recesses and tafoni on limestone hamadas in the northwest Sahara. Zeitschrift fur Geomorphologie, Supplement band, 22: pp21-43.

[15] UNESCO office Cairo, (2006). Geological map of north Western Desert Egypt scale 1:000,000, Cairo, Egypt, project for capacity building.

[16] Wali,I. A. MA.; Morsy , MA. and Afifi, SY. (2001) Sitra Lake a recent continental saline lake and its developing stages sedimentological and petrographical approach , western desert Egypt Annal of Geological Survey of Egypt Vol. XXIII-Part I, .pp 45-62

[17] Wendorf,F.A. Hassan F.A. (1980) Holocene ecology and prehistory in the Egyptian Sahara. In: Williams M.A.J and Faure H. (ed s). The Sahara and the Nile-Quaternary Environment and Prehistoric Occupation in northern Africa. Balkema Rotterdam, pp.407-419.

13-6-2010