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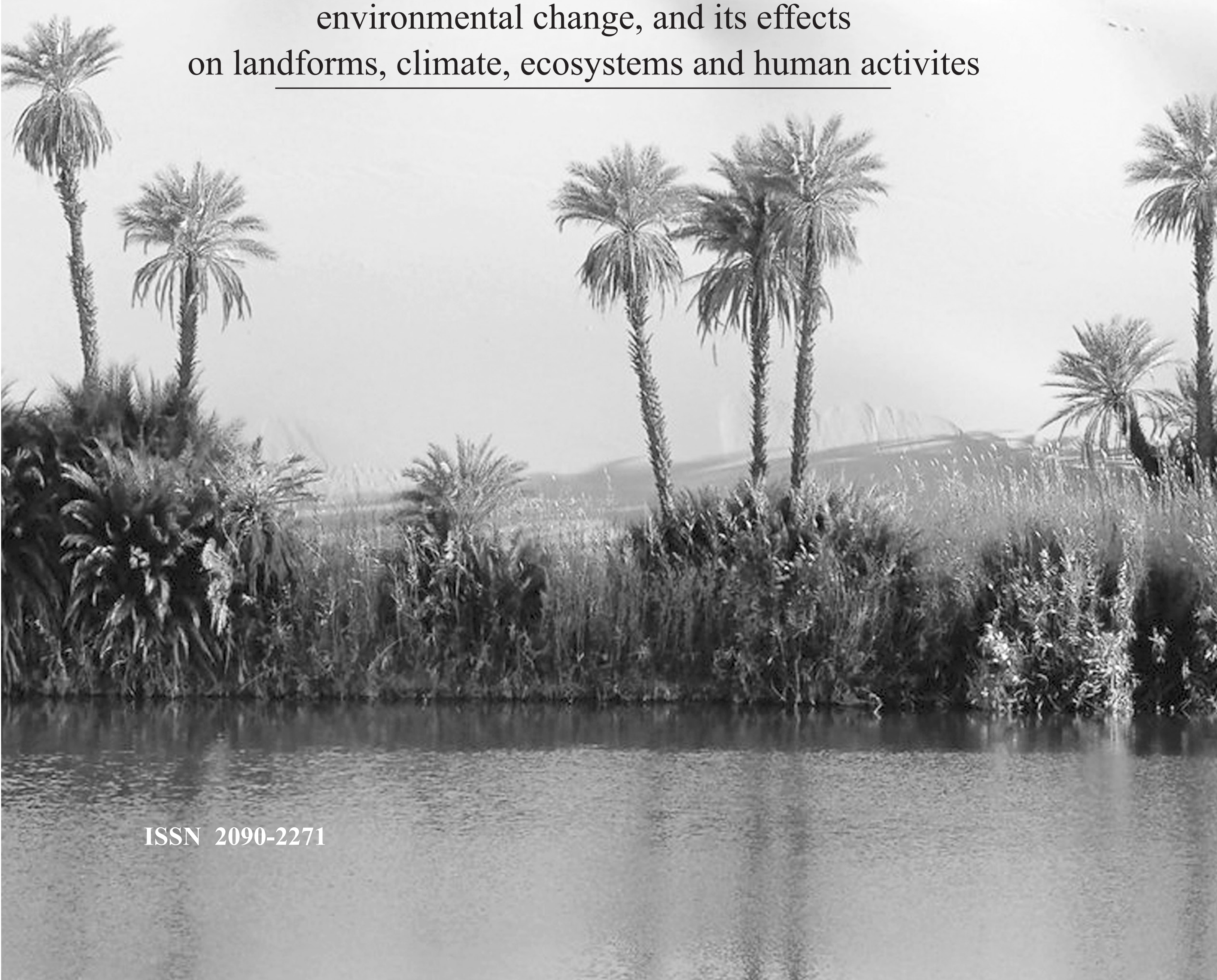
EJEC

The Egyptian Journal of Environmental Change

An international journal devoted to environmental change, and its effects on landforms, climate, ecosystems and human activites



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Geomorphology of the Al-Umrani paleo-karst cave (southeastern Egypt): its morphological determinants and links to the Nile Quaternary terraces.

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GEOMORPHOLOGY OF THE AL-UMRANI PALEO-KARST CAVE (SOUTHEASTERN EGYPT): ITS MORPHOLOGICAL DETERMINANTS AND LINKS TO THE NILE QUATERNARY TERRACES.

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Abstract:

This work presents – for the first time- the geomorphological characteristics of a recently explored karst cave (Al-Umrani karst cave) in eastern Egypt, allowing for better understanding of paleoclimate of Egypt in particular and the Sahara in general. This study provided a detailed geomorphological map and topographic profiles for the cave, which is located 12 km from the eastern bank of the Nile. With a total area of 61 m2, the cave extends over only 32 m, with a breadth of about 17 m and a depth of 15 m from the entrance to the deepest point. Al-Umrani Cave is a classic karst cave created by groundwater near the western edge of the Eocene limestone of the Northern Plateau of the Eastern Desert. The cave was formed in a shallow marine limestone hill (Mokattam Group, Samalout Formation) of the Middle Eocene. Inside the cave several paleo-karst features were recognized such as stalactites, columns, and few stalagmites. These geomorphological features indicate that the area was a relatively humid tropical environment during the karistirization activities up to the Quaternary. The cave led to the opening of an entranceway to multi-stages steeply passage to the major double karst chambers, it is formed along a fault line through the limestone hill. In this study, we also assessed effects of the Quaternary fluvial terraces of Wadi Al-Amrani on the cave morphology. This assessment was made based on extensive field work, combined with employing geomorphic mapping, digital elevation model (DEM) analysis, hydro-morphological analysis of Wadi Al-Umrani basin and its network, and detailed surveying of the interior cave using a laser Total Station, in addition to a laboratory analysis of stalactites samples and 14C dating.

Key words:

Al-Umrani paleo-cave, Wadi Al-Umrani, paleo-karst cave, paleo-karst, the Quaternary, Assiut, Egypt.

1. INTRODUCTION

The study of paleo-karst caves in the current deserts can be used as an indicator for more understanding of ancient events and environmental conditions in the past especially the Quaternary climate changes, during humid and dry phases, and the fluctuation of groundwater level.

Few paleo-karst caves have been discovered in Egypt, but most of the published studies on two caves only have them; Djara Cave which is located in the Western Desert between the Farfara Oasis and the Nile Valley in the city of Assiut (Kuper, R., 1996; Claben et al., 2001; Brook et al., 2002; Riemer, H., 2003; Kindermann, K., 2003, Kindermann, K., 2004, Kindermann, K., 2006, Kindermann et al., 2006, Kindermann, K., & Bubenzer, O., 2007) and the Cave of Wadi Sennur, which is located in the Eastern Desert, south of Beni Suef City (Gunay et al. 1997; Dabous and Osmond 2000; Amin and Eissa 2008; Amin et al. 2008; Sallam et al., 2019).

In the literature, there exist many studies that dealt with the relationship between karst caves and eustatic river terraces and knickpoints migration in different geographical regions.

Some of these studies have been concerned with the effects of base-level lowering on karst evolution and cave development, (e.g. Warwick 1960; Droppa 1966; Smart 1986; Palmer 1989; Chédeville et al., 2015; Nehme et al., 2016; Harmand et al., 2017; Bella et al., 2019; Nehme et al.,2020). These studies relied mainly on extensive field study and geomorphic mapping, lab. analysis of stalactites samples profiles analysis and 14C dating, and hydro-morphological analysis.

The Al-Umrani Cave was discovered by the local people while searching for Alabaster quarries some years ago. The cave is one of the representative examples of paleo-karst caves in Egypt, as the water percolates downwards, excess calcium carbonates are deposited on the roof and floor of the cave forming spectacular stalactites and stalagmites of various forms. Some deposits of the terra Rossa were recognized in the cave's floor, as well as some sinkholes. The cave was formed by paleo-karstic solution inside a limestone hill surrounded by the network of the semi-arid Wadi Al Amrani; which drains into the Nile north of the city of Dairut. The Wadi Al-Umrani was affected by the Quaternary climate changes, and five fluvial terraces were effects on the morphology of the cave.

This study aims to (1) define the geomorphological characteristics of the Wadi Al-Umrani, constructing a geomorphic map and topographic profiles for the cave and the Wadi's basin; (2) assess the effect of the Quaternary fluvial evolution of Wadi Al-Amrani on the cave morphology; and (3) define the links between karst action and fluvial activity during the humid periods of the Quaternary. The main innovative aspect of this study is that it addresses – for the first time- the geomorphological characteristics of this recently explored karst cave in Egypt.

2. Materials and methods

2.1. Study area:

Al-Umrani karst Cave is located east of the Dairut City, Assiut Governorate, Upper Egypt, near the northern borders of Assiut Governorate. It is situated at the latitude of 27° 33″56.5 ′ N and longitude of 30° 57″45.4 ′ E, around 12 km far from the eastern bank of the Nile. (Fig.1). Climate is arid with very low rainfall intensity and a high evaporation rate (average 14.3 mm / day); average annual rainfall is 7 mm and is mostly limited in November and December. The warmest month is June, with an average high-temperature of 37.1°C, while the coldest months is January with an average low temperature of 21.3°C (Fig.2).

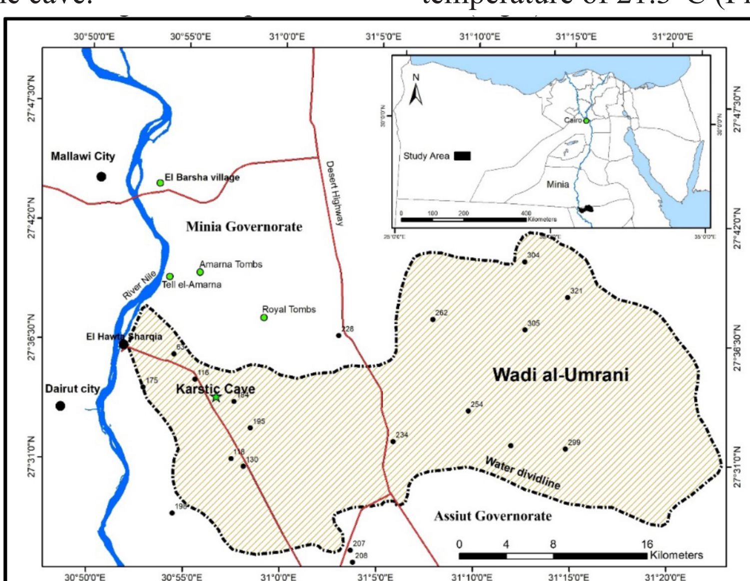


Fig.1: Location of the study area.

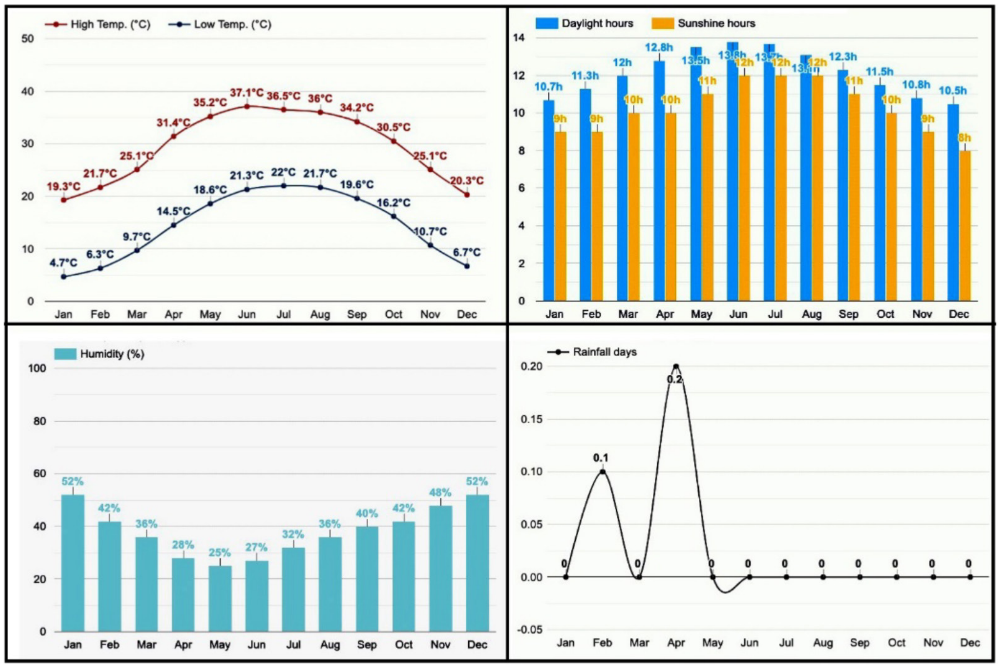


Fig.2: Climatic conditions at Assiut city between 1990-2019

Data source: Egyptian General Authority of Meteorology

2.2. Geological and geomorphological settings

The Assiut area is mainly formed of sedimentary sequence from Late Cretaceous up to the recent time. The total thickness of this succession is approximately 1500m, on average (Ibrahim et al. 1995). The study area is located as a part of the stable shelf of Egypt between Nubian massif in the south of Egypt and the unstable shelf in the north, (Youssef, 2003). The sedimentary sequence in the Assiut area deposited on the pre-Cambrian basement (Fig.3). The area is affected by several structural features, especially faults and folds in the Eocene limestone, according to (Osman 1980). The studied area located in northern portion of Assiut Governorate, which affected by intense joint systems and fractures in addition to faults trending N35°W, N-S, N77°E (Figs.3 & 4).

The faults have an important role in the formation of both the paleo-karst cave and directions of the wadi’s drainage network, as well as recharge mechanisms to groundwater aquifers in Assiut area, especially the Eocene aquifer (Youssef 2003). As illustrated in Figs.3,4 and 5, **major fault systems can be identified in the study domain following directions:**

- N 30-35 W trend: This type of fault is related to the Gulf of Suez trend (Pelusic trend). Most of the faults are normal, gravity, strike, and longitudinal types.
- N 35-55 W trend: This trend is parallel to the Gulf of Suez. Most of these types of faults are normal, the downthrown is toward the north and northeast.
- N 40-45 E trend: This type of fault is the minimum trend, which is related to the Gulf of Aqaba system. Some measured faults have an N 35 W and extend for more than 10 km length.

Faults system in the study area follows several trends, with gulf –parallel faulting dominant. Conjugate normal faulting caused by arching during uplift is the latest faulting effect. It affected the direction of most parts of the wadi's drainage network, especially toward the northwestern direction. Several ages of joint and fault development are apparent from an examination of cross-cutting relationships in the rocks, (Youssef 2003).

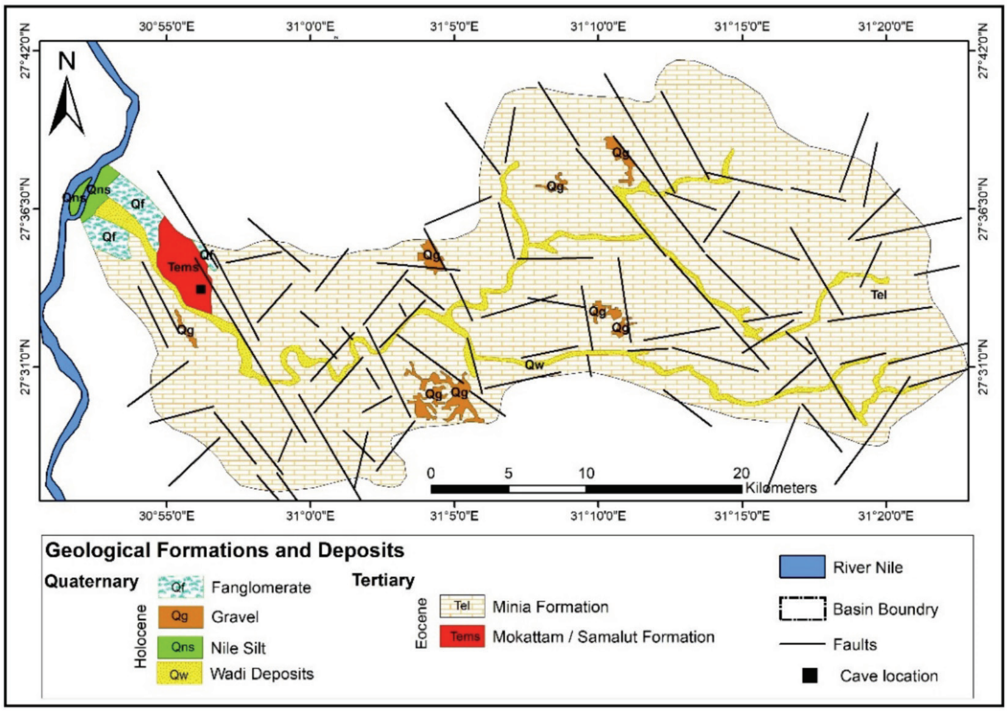


Fig.3: Geological map of the study area

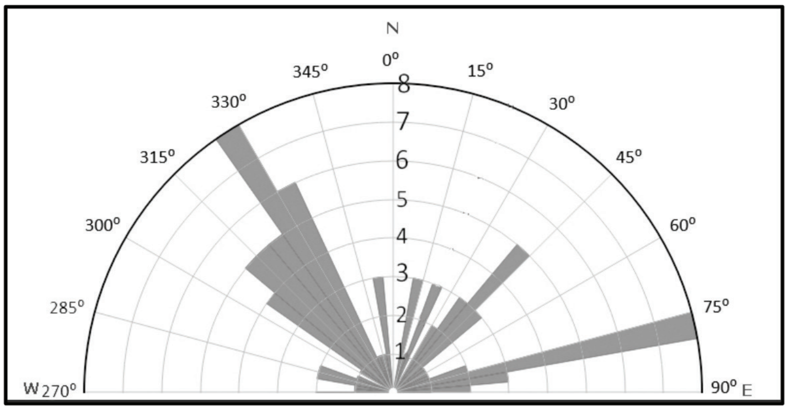


Fig.4: Orientation rose diagram of 91 faults
(depends upon EGPC, 1987 geological map NG36NW Assiut)

Fig.5: A) Major NW/SE fault on the land surface above the cave. B) The effect of the same of fault on the cave floor as a fracture with 80-110 cm. depth and 20-30 cm. breadth.

The major landforms in the northern part of Assiut Governorate are the following:

The limestone plateau contains some paleo-karst landforms such as caves, caverns, sinkholes, valleys, and residual isolated hills and domes in addition to micro-features like karren and rills (Merghany 2018). Hamada at semi-flat interior plains covered with stones, gravels or boulders, they are often located in areas where the wind can remove the sand to leave larger deposits on the land surface. Sand sheets and sand accumulation including different types of sand dunes and nebaks. The Semi-dry wadis that cut the escarpment of the limestone plateau and flow towards the Nile River, and Wadi Al-Umrani is one of them (Fig.6). The old and young floodplains of the Nile River including the cultivated lands and reclaimed land near the plateau escarpment. The Quaternary Nile Valley terraces, relative elevations were measured to the modern Nile floodplain their elevations are + 50 to 55m, + 48m, + 42m gravels, + 32m and + 24m gravels (Hansen and Butzer 1966).

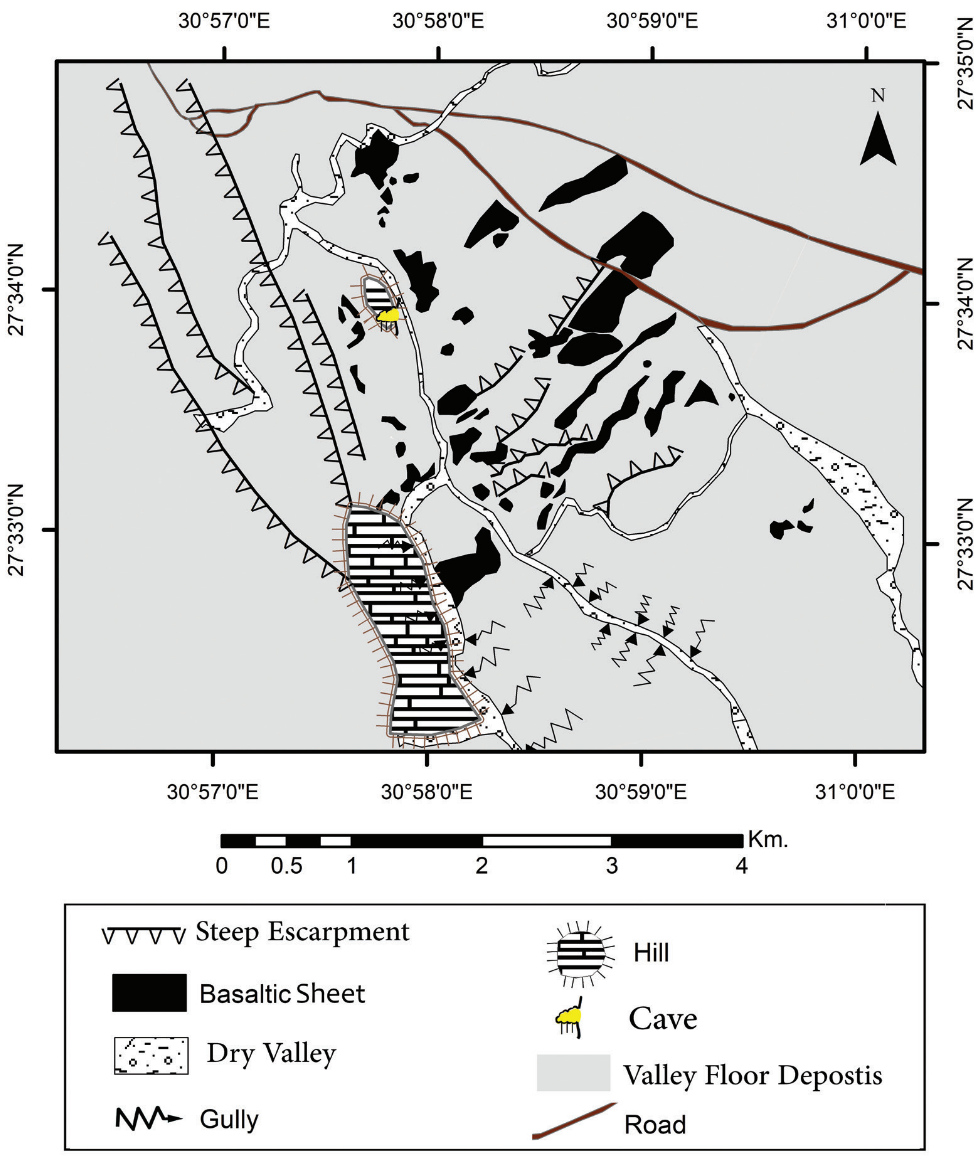


Fig.6: Simplified geomorphological map for the surrounded area of the Al-Umrani karst Cave
(depending upon field observation and interpretation of Sentinel 2, May, 2020, resolution 10m)

The methods of this work depend upon extensive field study and geomorphic mapping, lab. analysis of stalactites samples profiles analysis and 14C dating, hydro-morphological analysis of Wadi Al-Umrani basin and its drainage network and detailed surveying of the interior cave using a laser Total Station [1] for and also for the terraces for Wadi Al-Umrani, 1720 surveying points were measured for interior the cave, plus more than 420 measured points for the wadi terraces profile

2.3. Methods

- Field study of both the cave system and Wadi Al-Umrani Quaternary terraces, including surveying the interior cave by using Laser Total Station (Fig.7).

- Geomorphological mapping for interior the cave by using the official UIS cave symbol list (Hauselman, 2002), depending upon field observation, measurement and surveying.

- One stalactite sample was collected from the western chamber for dating its layers and used it to make a cross profile and 14C dating the morphometric parameters of the basin and drainage network of Wadi Al-Umrani have been studied in order to characterize and estimate their hydrological characteristics using geological, drainage network, and spectral resolution data.

3. RESULTS AND DISCUTION

3.1. The cave characteristics and morphology

The cave was dug inside an elongated limestone hill, about 38 m. above the wadi channels surrounding it. The cave is about 32 m long, its breadth about 17 m, its depth is about 15 m from the entrance to the deepest point and with total area about 61 m2. It is a classic paleo-karst cave created by groundwater percolating near the western edge of the Eocene limestone of the Northern Plateau of the Eastern Desert.

The steeply narrow entrance of the cave was formed by a vertical fault and it is a rectangular shape with dimensions of about 2.8 × 1.7 m., and the narrow entrance begins with a rugged path that descends with four vertical edges or stairs ranging in height between 1.4 -2 m (Fig.7: a & b). The passage is covered with rock blocks collapsing from the ceiling of the cave, and the orientation of the main passage is consistent with the fault line, it extends for a distance of 12 m., it lead to vertical passage through a narrow into two karst chambers (eastern and western chambers), with a height ranges between 1-1.5 m and spread inside both chamber's karst features such as stalactites with lengths ranging from a few centimeters to 1 m. and limited length stalagmites not exceeding 30 cm, curtains and some Karst columns of

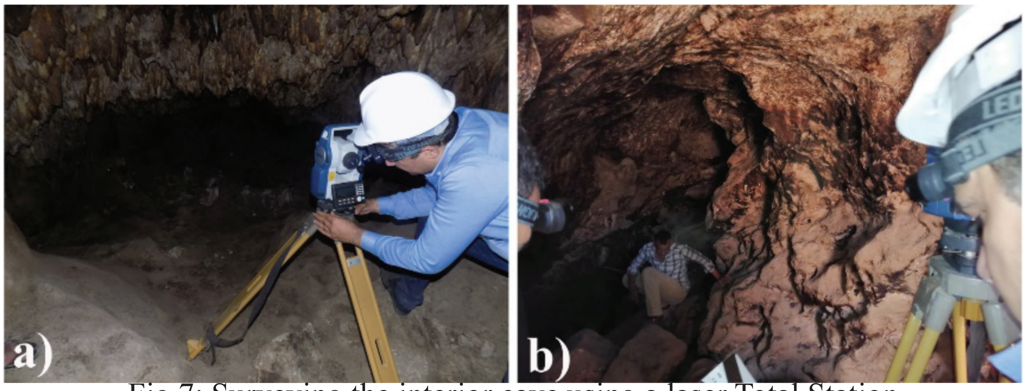


Fig.7: Surveying the interior cave using a laser Total Station

[1] Field observation and mapping on November,2019 and Surveying on 1st & 24 of May 2020 by Sokkia CX 107 Total Station, horizontal resolution 2mm and vertical resolution for distances without Prizm 3mm, with dark guide light, it surveyed and analyzed by E. El Bardan

varying diameters, curtains, and flowstone (Fig. 8:e,f,g& h).

The floor of the cave chambers is covered with sediments of varying diameters such as blocks, boulders, pebbles, and sand mixed with the remains of the bats in red color and bad smell. The southern cave room ends with a vertical fissure, with its extension consistent with the rift, its depth is about a meter, with a width of about 23 cm (Fig.8 h, 9 and 11).

Fig.8: a) & b): The cave entrance, photo direction toward NW,
c) & d): The steeply passage of the cave, Different types of karst features inside the cave: e) Stalactites and columns,
f) Stalagmites, g) flowstone and h) General view of the eastern chamber

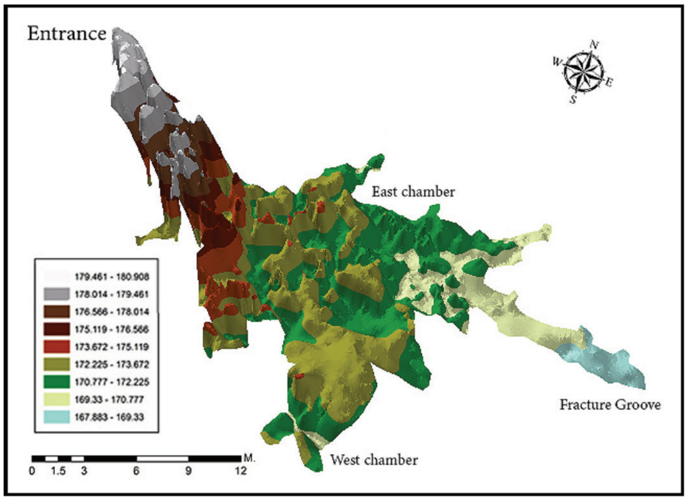


Fig.9: 3D map of the Al-Umrani karst Cave
(A,B,C,D,E,F and G: location of surveying profiles: Fig.4-depends upon field survey inside the cave by using Laser total station of 1720 measured points)

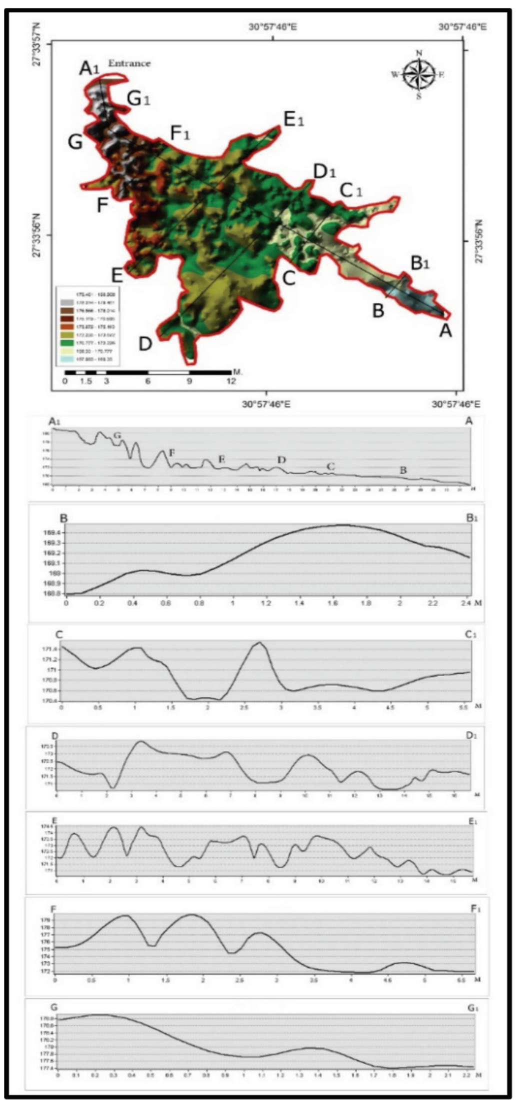


Fig. 10: General morphology of Al-Umrani karst Cave and interior topographic profiles
(depends upon field survey inside the cave by using Laser total station of 1720 measured points)

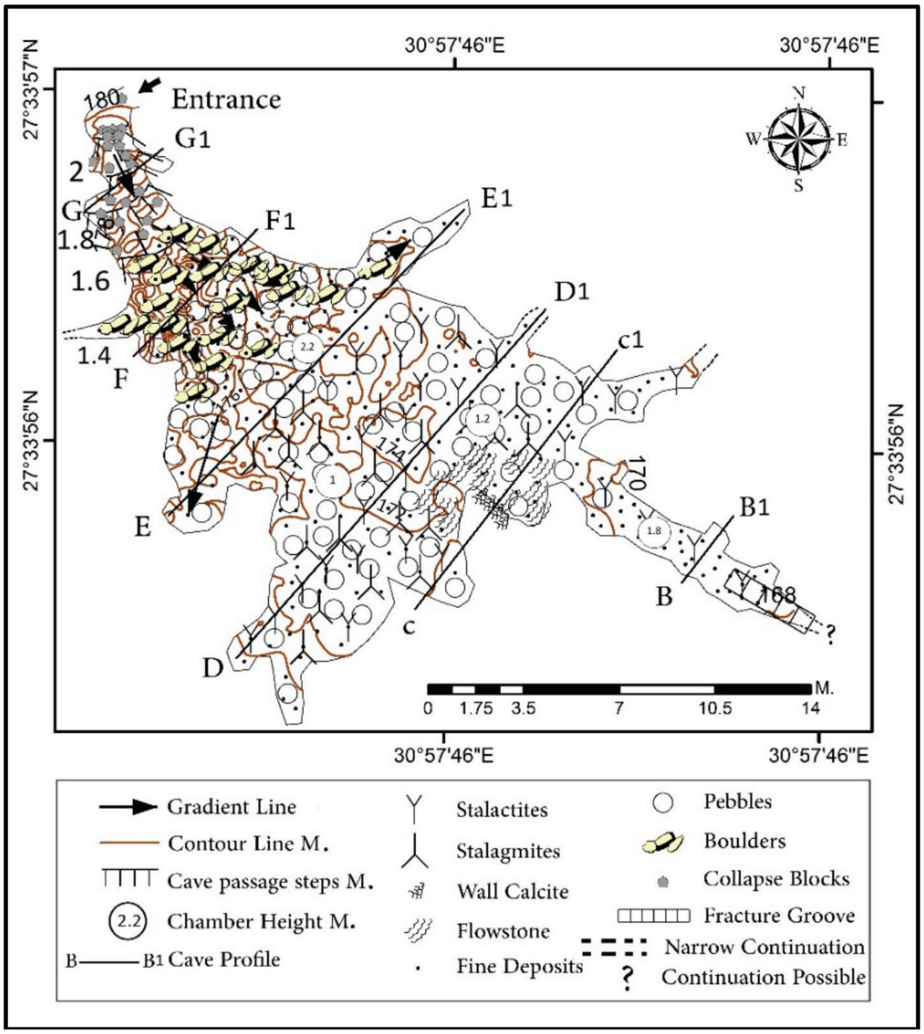


Fig.11: Geomorphological map of the cave

Source: Field observation and measurement by using the cave surveying as a base map

3.2. Stalactites profiles

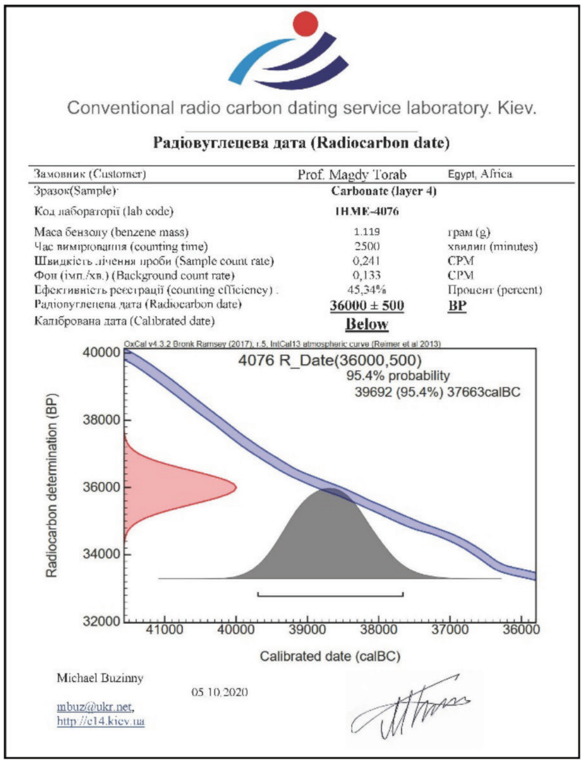
One stalactite sample was collected from the western chamber for dating its layers and used it to make a cross profile to determine its formation stages throw the humid periods before the current drought. The cross profile of the sample shows that; the stalactite formed five calcites white color layers; these five layers can be used as an indicator to expose the cave to five phases of rainy periods for Karstization active before the current drought (Fig.12).

If there is any interaction between the stalactite and ancient (fossil) carbon from the surrounding rocks, then the age of the Dissolved Inorganic Carbonate in the water coming through the rocks and precipitating onto the surfaces of the stalactites could be biased in the older direction. How much the age is biased will depend on how much DIC from the surrounding karstic rocks is picked up by the rain water that is percolating down into the cave to form the new stalactite surface structures.

^{14}C dating of two outer layers of stalactite sample collected from the west chamber of the cave, show that the ages of these layers going back 30250±500 and 36000±500 years BP[2], essentially creating the ultimate calibration curve for the dating technique (Fig.12&13).

[2] Conventional radio carbon dating service laboratory, Kiev, Ukraine, on 5/10/2020.

Fig.12: Cross profile of stalactite sample collected from the west chamber of the cave



Conventional radio carbon dating service laboratory. Kiev.

Радіовуглецева дата (Radiocarbon date)

Замовник (Customer)	Prof. Magdy Torab	Egypt, Africa
Зразок(Sample):	**Carbonate (layer 4)**	
Код лабораторії (lab code)	**IHME-4076**	
Маса бензолу (benzene mass)	1.119	грам (g)
Час вимірювання (counting time)	2500	хвилин (minutes)
Швидкість лічення проби (Sample count rate)	0,241	CPM
Фон (імп./хв.) (Background count rate)	0,133	CPM
Ефективність реєстрації (counting efficiency) :	45,34%	Процент (percent)
Радіовуглецева дата (Radiocarbon date)	**36000 ± 500**	**BP**
Калібрована дата (Calibrated date)	**Below**	

Michael Buzinny

05.10.2020

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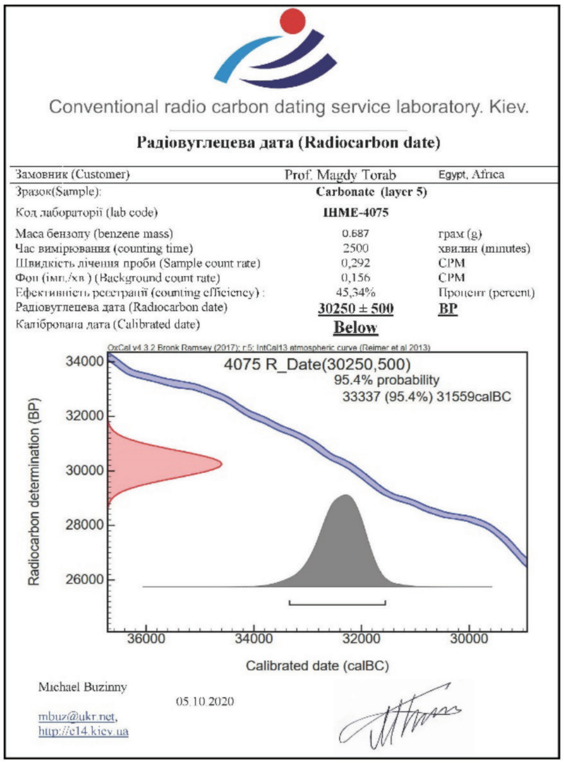

Conventional radio carbon dating service laboratory. Kiev.

Радіовуглецева дата (Radiocarbon date)

Замовник (Customer)	Prof. Magdy Torab	Egypt, Africa
Зразок(Sample):	**Carbonate (layer 5)**	
Код лабораторії (lab code)	**IHME-4075**	
Маса бензолу (benzene mass)	0.687	грам (g)
Час вимірювання (counting time)	2500	хвилин (minutes)
Швидкість лічення проби (Sample count rate)	0,292	CPM
Фон (імп./хв.) (Background count rate)	0,156	CPM
Ефективність реєстрації (counting efficiency) :	45,34%	Процент (percent)
Радіовуглецева дата (Radiocarbon date)	**30250 ± 500**	**BP**
Калібрована дата (Calibrated date)	**Below**	

Michael Buzinny

05.10.2020

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http://c14.kiev.ua

Fig.13: Radiocarbon dating of two outer layers of stalactite sample collected from the west chamber of the cave

3.3. Morphology of Wadi Al-Umrani

The limestone plateau of the Eastern Desert of Egypt is severely interrupted by a large number of wadis, these wadis are divided into two systems separated by water divider line that passes through the peaks of the Res Sea mountain, the first system head east to the Red Sea and the second system head west to flow into the Nile through old and young alluvial plain. Generally, the drainage system characterized by the presence of short wadis and small catchment area, Wadi Al-Umrani one of them.

The morphometric parameters of the basin and drainage network of Wadi Al-Umrani have been studied in order to characterize and estimate their hydrological characteristics using geological, drainage network, and spectral resolution data (SENTAL-2) (Tab.1), to realize the morphometric aspects of the basin and its drainage network to define its dimensional, basin shape, relief morphometric features and network density.

The results show that; the basin area of Wadi Al-Umrani about 783 km2, and the basin length is about 43 km, and its width is 18 km. The highest point in the basin is 382 m. and it flows into the Nile at a level of 25 m. Form factor, elongation ratio, and circulatory ratio are computed for the basin shape, the results show that the basin is nearby elongated shape (Re= 0.86) as a result of the basin affected the fault lines.

The relief ratio (**Rh**) of Wadi Al-Umrani is not more than 7 m/km, it indicates that the basin relief is not roughness, it means that the water load slowly flows from the wadi's upper streams towards its mouth. The basin slope is also simple and does not exceed 8.3 m/km, which indicates the weakening effect of erosion factors on the basin morphology (Tab.1).

Table 1: Morphometric parameters of Wadi Al-Umrani basin and its drainage network [3]

Morphometric Parameters	Definition/ formula	Data of Wadi Al-Umrani	References
Basin parameters			
Basin length (**Lb**)	Basin measurement	43 km	Horton (1945)
Basin width (**Wb**)		18 km	
Basin area (**A**)		783 km^2	
Basin perimeter (**P**)		149 km	
Drainage texture (**Rt**)	Rt = Σ Nu/p	1.76 stream/km	
Elongation ratio (**Re**)	Re = Dc/Ld Where: Dd= diameter of the same perimeter circle (km)	0.86	Schumm (1956)
Circularity ratio (**Rc**)	Rc = A/(p2/4π) Where: p= perimeter (km); A= area of the basin (km2)	0.44	Strahler (1964)
Form factor (**Ff**)	Ff = Au/Lb^2	0.30	Horton (1932)
Relief ration (**Rh**)	Rh = Hb/Lb Where: Hb= Basin relief (m)& Lb= Maximum basin length	7 m/km	Schumm (1956)
Basin slope (**S**)	S = H/L; Where: H = Basin relief (m), L= horizontal distance (m)	8.3 m/km	Rai et al. (2011)
Drainage network parameters			
Stream order (**U**)	Hierarchical rank	5	Strahler (1964)
Stream numbers (**Nu**)		263	
Total stream length (**Lu**)	Total network length (km)	597.82	
Mean stream length (**Lsm**)	Lsm = Lu/Nu (km)	2.27	
Drainage density (**Dd**)	Dd = Σ Lu/Au	0.76 km/km^2	Horton (1945)
Stream frequency (**Fs**)	Fs = Σ Nu/Au	0.45 stream/km^2	

The total number of wadi's streams (**Nu**) is the maximum number in the fifth order, the drainage network of Wadi Al-Umrani is not high density (**Dd**) (0.76 km/km^2) and its stream frequency (**Fs**)= 0.45 stream/km^2,, it means that the wadi was unable to erode a dense network of watercourses in the limestone plateau (Fig.14). The drainage systems depended on the following factors; the geological lithology, structure, tectonic activity of the region and amount of rainfall and other climate conditions and hydrological processes before the recent drought, as a result of climate change.

[3] By using ARC MAP,10.8 software and Sental2 for spatial and spectral resolution data (12 bands, resolution 10-60 m.)

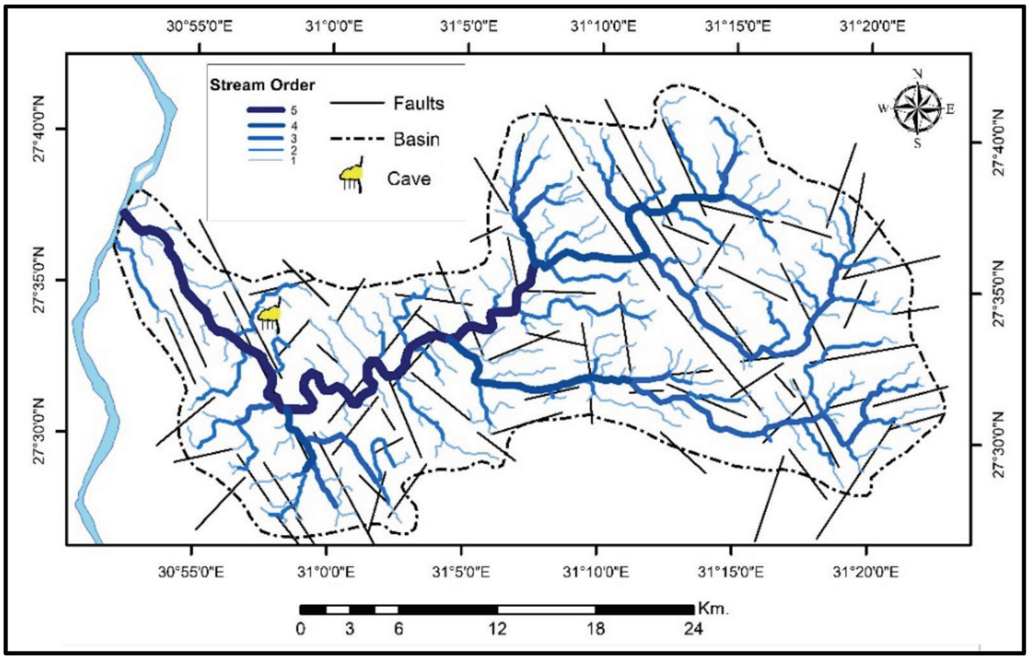

Fig14: Drainage network and faults of Wadi Al-Umrani

3.4. Terraces of Wadi Al-Umrani

Interpretation of satellite image[4] and field work in some parts of the wadi's streams, show that there are five pair fluvial terraces on both sides of the valley, the height of the terraces from the bottom of the wadi are as follows: 2.75, 9.2, 13.7, 17, and 24.5 m (Fig.15).

The remains of the terraces can be found clearly on the convex banks of the meanders, or on the both sides of the strait parts of the wadi channels on the same heights as measured from the bottom of the stream. They are mostly seen as some separated terraces, but the complete sequence of the terraces can be found in a few parts. Unconformity terraces may be erosive, forming a low gradient layer in the bedrock, covered by a thin layer of gravel, or may represent the upper altitude of the aggradations prior to the subsequent down-cutting of the plane of the previous floodplains. The pairs of fluvial terraces can be used as an indicator of The Quaternary climate change and its effect on lowering the general base level and fluctuations in rainfall.

[4] Est, Digital Globe, GeoEye, Earthstar Geographics USDA, USGS, AeroGrid, IGN, May 2020

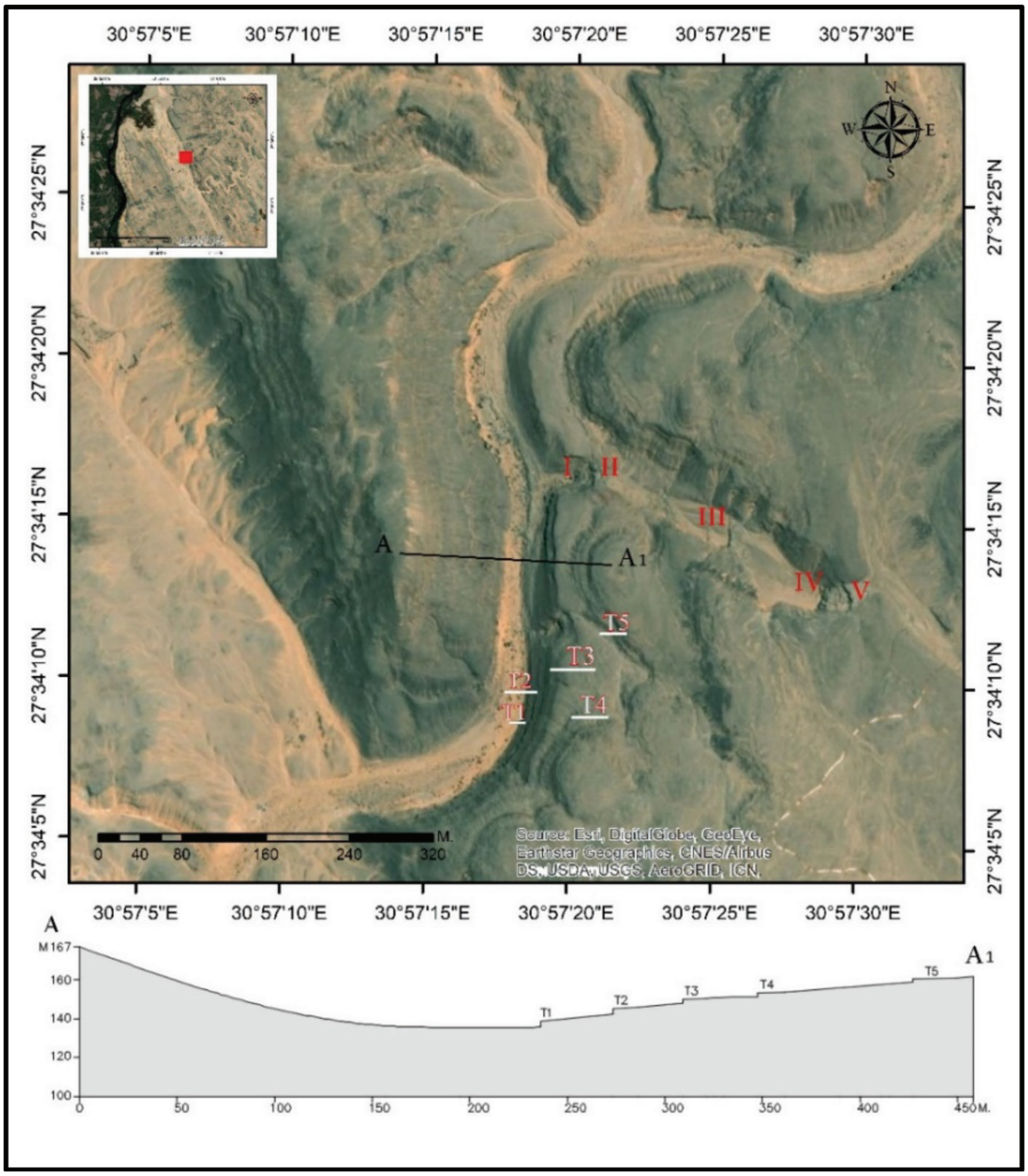

Fig.15: a) Wadi Al-Umrani's terraces (White color) and knickpoints (Red color)

Source: Est, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGrid, IGN, May 2020.b) Cross topographic profile for the wadi's terraces by using Total Station surveying.

Correlation between the levels of the interior cave steps, and the terraces of both wadi Al-Umrani and the Nile River

Table 2: The levels of the interior cave steps, and the terraces of both of Wadi Al-Umrani and the Nile river in the study area (m)

Level #	The cave steps	The wadi terraces		The Nile river terraces	
	Lower from the cave entrance	Sea level	Height from the wadi bottom	Height from the modern Nile floodplain	Sea level
Data source	Field surveying by using Total station			(Hansen and Butzer 1966)	Topographic map & field measure by GPS
1	2	178	2.75	24	65
2	1.8	176.2	9.2	32	73
3	1.6	174.6	13.7	42	83
4	1.4	173.2	17	48	89
5	1.0 (fracture groove)	172.2	24.5	50 -55	91- 96

A correlation could be identified between the levels of the interior cave steps, and the terraces of both of Wadi Al-Umrani and the Nile river in Upper Egypt (m), as some Pleistocene Nile terraces were studied at heights of 50-55, 48, 42, 32, and 24 m. above the present-day floodplain, fossils and human artifacts were found in all of these terraces (Hansen and Butzer 1966). These correlation can be used as indicator of the Quaternary climate change.

4. CONCLUSION

The study presented a geomorphological description of the Al-Umrani karst Cave, depend upon field surveying of the interior cave and geomorphic mapping, lab. analysis of a stalactites sample profiles analysis, hydro-morphological analysis of Wadi Al-Umrani basin and its drainage network. The study showed that the cave was affected by a fault line in the NW / SE direction, and the faults also affected the directing of the drainage networks of the Al-Umrani Wadi as well.

The study concluded that there is a correlation relationship between five levels of the interior cave steps (including the fifth step of the fracture groove of the deepest point inside the cave), and five terraces of both wadi Al-Umrani and the Quaternary Nile River, in addition to the stalactite cross section is formed of five calcite white color layers; this indicates that the cave has experienced five rainy periods before the current drought.

The final result can be used as evidence that both the cave and the wadi were affected by the climatic changes that occurred in the Quaternary, but the study requires a future research stage for dating the ages of karstic stalactites and stalagmites of the cave, as well as the wadi's terraces and compare its results with the ages of the Nile River Quaternary terraces.

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