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Karst's caves characteristics in Daryanah area, Al Jabal Al Akhdar, NE Libya.

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Highlights

- **Karst caves are small caves, formed along bedding planes of secondary and endogenic origin.**
- **Caves formed and developed according to simple model with limited recharging points.**
- **Caves initiated and developed in phreatic and vadose zones respectively.**
- **Stalactites are still active and growing.**

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ABSTRACT

The genesis and development of karst caves in the Daryanah area have been detected through the study of cave chambers, passages and different types of cave deposits. It has been proved that caves were initiated and developed in the phreatic and vadose zone respectively. The studied caves are classified as small carbonate caves, formed along bedding planes of endogenic origin and developed according to simple model of limited recharging points.

1. Introduction

Al Jabal Al Akhdar is a large broad anticlinorium trending NE-SW in the NE corner of Libya. The rocks exposed are limestone with minor dolomite and marl of age ranging from Late Cretaceous to Miocene. Karst characteristics of the Al Jabal Al Akhdar is barely studied, and in particular, karst caves. Some of these studies includes Ashahomi (2008), Faraj, et.al (2014), El-Amawy, *et al.* (2010).

Cave definition varies according to the aims and interest of the study. Bretz (1965) defined *cave* as a natural roofed cavity in the rock, which allowed human penetration for an appreciable distance. However, White (1984) define *cave* as natural cavity in a rock which acts as a conduit for water flow between input points, such as stream sinks, and output points, as springs or seeps.

Caves are useful indicators for the tectonic, eustatic sea level and climatic changes. Gilli (2015) discussed in details these applications and claimed that caves are sites of minerals, hydrothermal and geothermal resources, as well as providing paleo-environmental indicators and a record for the pervious geodesy and rock deformation, they are also a manifest of paleontology, archaeology, and biology of an area, and in addition caves are tourist attractive sites.

The first requirement for cave formation and development is pure massive limestones, which is well-bedded or compact and possess well-defined joints and fractures along which water can penetrate and circulate through the rocks. The second requirement is a climate with an adequate rainfall. The third is the presence of high relief topography.

2. Location of the study area

The Daryanah area is located in the NW region of Al Jabal Al Akhdar, and situated about 45 km to the NE of Benghazi and marked by top right intersection point of (32^0 24' 00'' N and 20^0 33' 00''E) and bottom left point (32^0 15' 00'' N and 20^0 17' 00'' E). The area is accessible through the Benghazi – Tukrah dual carriageway and then through the Daryanah - Alwattayat blacktop (Fig. 1). The investigated caves are located at Wadi Asoukunyah, Wadi Belgares, and Wadi Ashalani (Fig .2)

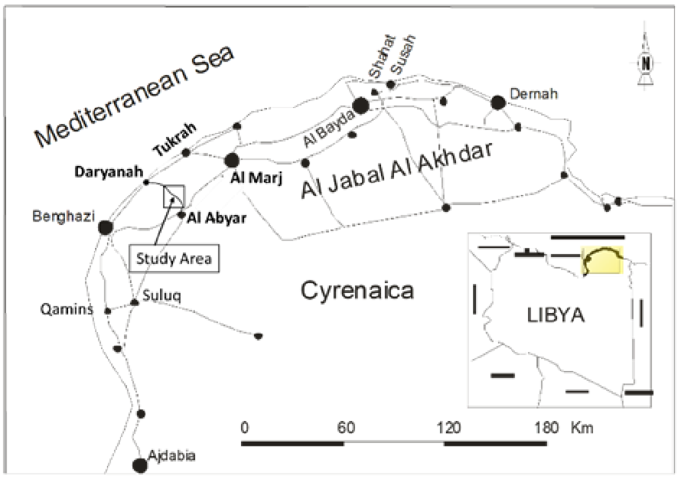

Fig. 1. Location of the study area

3. Aims of the study

The aim is to describe caves geomorphic characteristics in order to interpret their formation and development history

4. Geology of the area

Paleogene-Neogene formations exposed in the Daryanah area (Fig. 2) are the Darnah formation, which consists of nummulitic limestones and the Shahat Marl and algal limestone members of Al Bayda Formation. The Al Abraq Formation composed of crystalline limestones and skeletal limestone of calcarenitic texture and the Al

Faidiydah formation consists of fossiliferous marl and marly limestones. The Benghazi Formation consists of fossiliferous limestones and the Wadi Al Qattarah formation, which composed of oolitic limestone. The total thickness of the exposed section is about 100 meters.

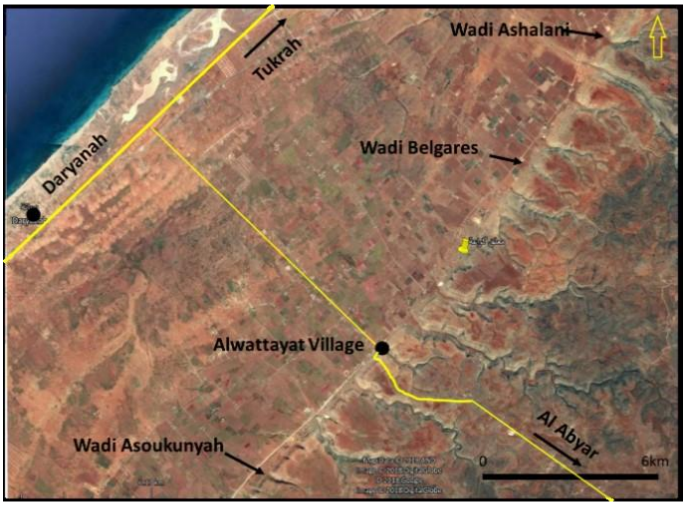

Fig. 2. Location of investigateed caves

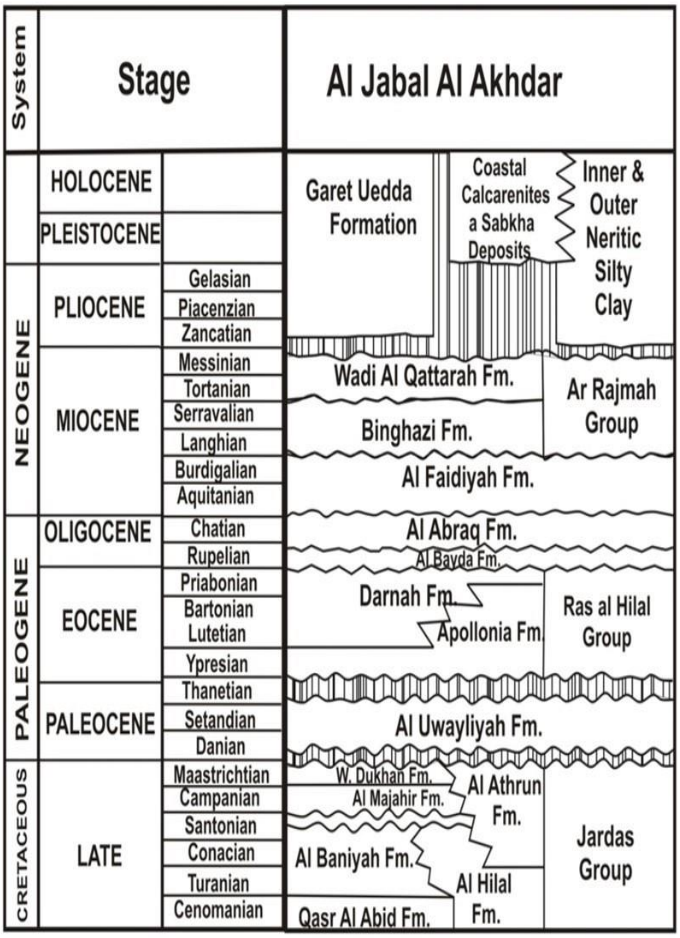

Fig. 3. Stratigraphy of Al Jabal Al Akhdar, (after El Hawat and Abdosamad 2004)

Details on the stratigraphy of area may be encountered in Klen (1974), Rohlich (1974) and in the field guide notes of El Hawat and Shelamani (1993), Elwerfalii, *et al*. (2000), El Hawat and Abdulsamad (2004) and El Hawa and Pawellk (2005). However, recent studies based on nannofossils, foraminifera and isotopes have shown age discrepancy of some of the rock unites, this includes the works of "El Mehaghag and Ashahomi (2002); El Mehaghag and Ashahomi (2003); Muftah and Bukhary (2013); Shaltami, *et al.* (2017) and Shaltami, *et al.* (2018 a, b and c)". However, additional investigations are required to verify and to resolve this inconsistency.

Rohlich (1978 and 1980) described the tectonic evolution of Al Jabla Al Akhdar in a sequence of cycles of sedimentation interrupted by compressional uplifts associated with normal and reverse faults. These cycles started in Late Cretaceous and terminated at the end of Late Miocene time. The Tertiary being tectonically active as compared to Upper Cretaceous section.

Anketell (1996) in his tectonic analysis of the northern Libyan basins, he postulated that the Cyrenaica platform (south of Al Jabal Al Akhdar) was formed within a splay wedge, and Al Jabal Al Akhdar inversion anticlinorium represents dextral contraction duplex bounded by north Cyrenaica fault zone (NCFZ), Cyrenaica fault zone (CFZ) and south Cyrenaica dextral wrench fault systems (SCFZ), (Fig. 3).

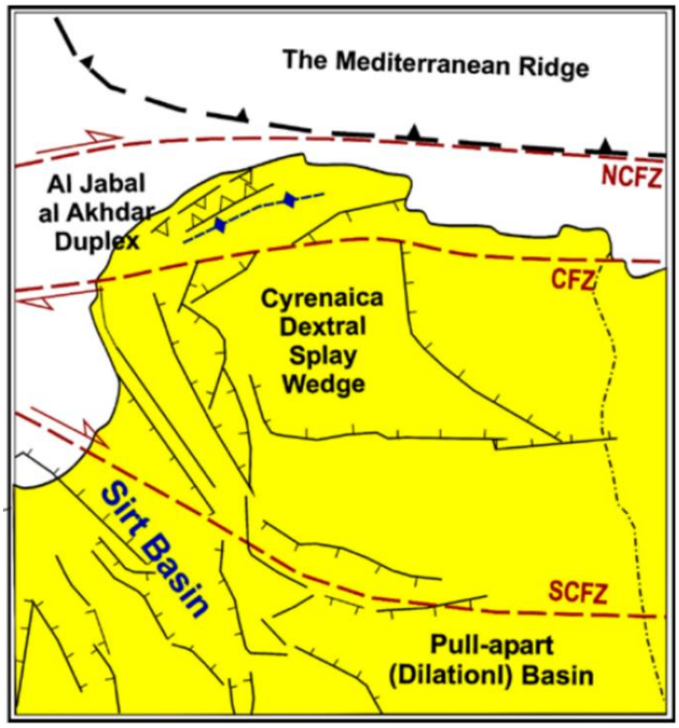

Fig. 4. Tectonic Elements of Cyrenaica Region, (After Anketell, 1996)

Detailed structural analyses of Ras Al Hilal- Al Athrun area by El Amawy *et al.* (2011) who indicating that structural inversion during Late Cretaceous–Miocene times in response to a right lateral compressional shear. The deformation within this system revealed three phases of consistent ductile and brittle structures conformable with three main tectonic stages during Late Cretaceous, Eocene, and Oligo-Miocene times

5. Cave formation and development

The formation and development of caves are influenced by many factors, which discussed by Sweeting (1972) and in length by Gillieson (1998). The most important are: lithological characters of the limestones, caves frequently originate at the contact of relatively impure limestone beds with pure beds. The structure of the limestones, such as the dip of bedding, joints and faults. The type and amount of water flow through the passages, whether the flow is forced or free (i.e. phreatic or vadose) and cave deposits. Other factors such as regional physiography of the area, history of the cave development and past climatic variations may also play a role in cave formation and development. These factors are reflected in the shape of the chambers, passages and features engraved on the roof and ceiling of these passages and chambers.

Many attempts to classify caves have been proposed, such that of Dwerryhouse (1907); Davis (1932); Bretz (1942); Swinnerton

(1932); Rhoad and Sinacori (1942); Bogli (1980) and Ewers and Quinian (1981). An overview of classifications that are based on the formation due to type of water flow, (*i.e*. water-table, phreatic or vadose) presented by Sweeting (1972) and summarized by Huggett (2011).

Vadose caves are those developed in the vadose zone (above the water table) by downward moving of vadose water. *Phreatic caves* are those developed by deep flow paths in zone of saturation. *Water table* caves are those formed at or just below water table. However many observations indicating that caverns formed in the phreatic zone below the water table and later evolved in vadose zone, Sweeting (1972) and Huggett (2011).

Bogli (1980) claimed that caves might be classified in three categories; according to: - (i) its mode of genesis (primary or secondary), (ii) its size and (iii) its lithology. Ewers and Quinian (1981) proposed a model for cave development in low dip strata.

6. Evidences of phreatic zone in chambers and passages

1) Cave passages and chambers with circular, elliptical and laminar profile indicating phreatic or forced flow as this shape offers the least resistance to the infiltrating water. Since the flow is under considerable hydrostatic pressure the passage is symmetrical and convex, (Fig. 5, 6 and 7).

2) Joint determined wall and ceiling cavities are narrow vertical slots dissolved out along joints cut in the ceiling of the caves and extending several meters up into the roof. (Fig. 6).

3) Circular ceiling cavities are cone-shaped channels, which penetrate the roof of caves. They narrow upward and the wall of the channel is spirally engraved.

4) Sponge network (honeycomb) Cave wall and ceiling have a complicated pattern of minor cavities a few cm to 50 cm depth. They are formed by differential solution (Fig. 8).

Fig. 5. Elliptical shape passages formed along bedding plane in Wadi Asoukunyah cave.

Fig. 6. Jointed roof in Wadi Belgares Cave and lower elliptical shape passages formed along bedding plane

Fig. 7. Elliptical shape passage along bedding plane with corroded base, Wadi Asoukunyah cave

Fig. 8. Honeycomb pattern in Wadi Belgares Cave

7. Evidence of vadose zone in chamber and passage

When the water level is lowered so that air enters the cave passage and the flow is no longer confined, the passage shape begins to change. The original elliptical passage formed along bedding planes is deepened by normal stream erosion as well as by corrosion. Passages formed along the bedding planes become much more rounded and rectangular (Fig. 9). Passages formed along joints and fractures become triangular shape (Fig. 10).

Fig. 9. Corroded base of (horizontal) passages in Wadi Ashalani Cave.

Fig. 10. Vertical corroded passage formed along joints in Wadi Ashalani Cave

8. Caves deposits

Cave deposits are the main features indicating that the caves were developed in the vadose zones; they are divided into two main types. The first is allochthonous, these are mud, silt, sand and gravel deposits, which have been brought into the cave by phreatic or vadose water. The second is autochthonous, these are deposits resulting from the solution of limestone and its subsequent re-deposition within the cave (Sweeting, 1972). Cave deposits are classified according to their mode of formation into: (1) Dripping water deposits, which include stalactite, stalagmite and column. (2) Seepage water deposits, helictite. (3) Running water deposits and (4) Cave breakdown

a) Dripping Water Deposits

1. Stalactite

As water drop enter cave and CO_2 lost, calcite deposits as thin ring, and as more drops emerge, the stalactites grow. Stalactites can grow in different forms such as; conical, straw, curtain shapes and tabular (Figs. 11, 12, and 13).

Fig. 11. Conical Stalactite in Wadi Asoukunyah cave. Note water drops indicating that the stalactites are still growing.

Fig. 12. Straw Stalactite Wadi Asoukunyah cave

Fig. 13. Curtain Stalactite formed by flow of water drops over inclined roof, Wadi Asoukunyah cave

2. Stalagmite

They are variable in shape and are deposited on the floor of the cave, this variation result from the heights that the water drops have to fall. Uniform sizes of stalagmite indicating uniform rate of growth and the dull color indicating hot climate or shutoff of water supply (Fig. 14).

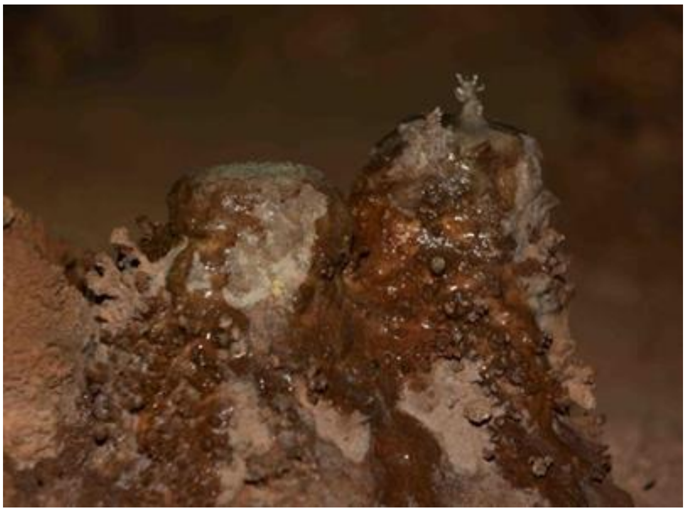

Fig. 14. Stalagmite in Wadi Asoukunyah

3. Column:

They are formed by welding of stalactite and stalagmite (Fig. 15). Amalgamation of group of columns form deposits known as travertine, (Fig. 16). In the study area dripping stone are of small size

Fig. 15. Column

Fig. 16. Mass of Travertine deposit formed by welding of group of columns

b) Seepage Water Deposits

1. Helictites

These are irregular stalactites usually small and twisting. They are several centimeters in length and about one centimeter in diameter. They formed due to very slow seeping water issuing from very minute opening under hydrostatic pressure. They produce beautiful ornamentations to cave wall. The observed helictite in the studied caves are very small less than 3 centimeters long (Fig. 17).

Fig. 17. Helictite (arrowed)

c) Running water

1. Flowstone

These deposits formed by flowing of water down the walls or over the floors of the caves, it composed of calcite sheets with smooth surface. They are crystalline, hard, and thinly laminated and may display banded colors due to contamination (Fig. 18).

Fig. 18. Flow stone

d) Cave Breakdown

The heaps of debris and limestone blocks which cover many caves floor, indicating periods of collapsing in cave history. They are also indicating that the breakdown of cave walls and ceiling is an important way of caves enlargement. The possible two reasons for cave breakdown are; (i) the chemical effect (i.e. solution) and (ii) the mechanical reason due to: - (a) loss of pressure and (b) frost action. The breakdown have been classified based on size of fallen rock fragments into:-

1) Block Breakdown: failure of roughly rectangular blocks, which are common in very thickly bedded limestone with widely spaced joints, (Fig. 19), they reach up to 1.5 meter across.

2) Plate Breakdown: These are thin plates of limestone one meter across and about ten centimeters thick (Fig. 20).
3) Chips Breakdown: Small fragments of few centimeters cross. These pieces are flat brittle and minute layer of rock scales cover the floor of caves formed due to frost action. (Fig. 21).

Fig. 19. Block Breakdown in Wadi Asoukunyah Cave

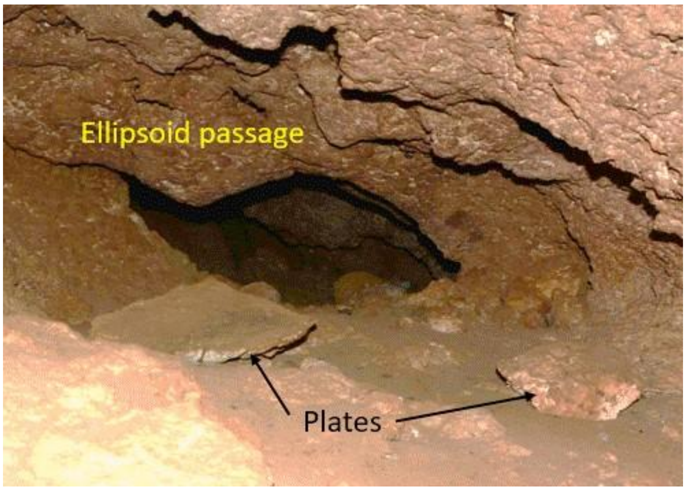

Fig. 20. Plate Breakdown in Wadi Asoukunyah Cave

Fig. 21. Chips Breakdown in Wadi Asoukunyah Cave

9. Cave description

1) Wadi Asoukunyah cave

Fig. 22. The entrance of Wadi Asoukunyah Cave

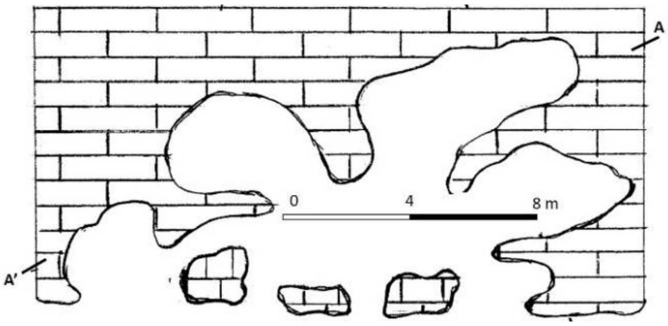

Fig. 23. Plan view of Wadi Asoukunyah Cave

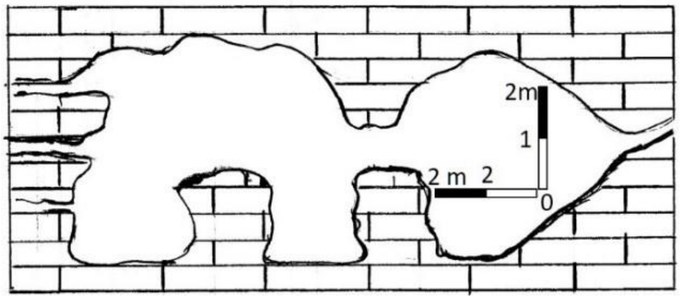

Fig. 24. Cross Section A-A'

The Wadi Asoukunyah cave is about 6 km south of Alwayttayat villages on the southern flanks of the Wadi Asoukunyah. It is situated at the intersection of the Latitude 32^0 15 40.78" N and Longitude 20^0 24' 01.01" E, at elevation 190 m.a.s.l. The beds of Benghazi formation that enclosed the Wadi Asoukunyah cave are thick to very thickly and well jointed. The cave entrance is marked by blocks of variable sizes (Fig. 22).

The cave has elliptical shape with wide passages and low height roof. The cave is about 15 m wide, 6 m deep and about 4 m height. It consists of a main wide hall with three small chambers. The champers are separated by irregular walls, which are covered by flowstone (Fig. 23 and 24).

Cross section (Fig. 24) showing that the main hall and the champers are elliptical in shape, and the walls of the cave contain many ellipsoid and laminar horizontal passages and conduits which indicating that these chambers, passages and conduits formed along the bedding planes. Some of these passages and conduits show corroded and deepened base in response to free flowing streams in the vadose zone. The texture of rock led to formation of small, irregular and random solution caverns, which may be seen in the wall of the cave.

The Wadi Asoukunyah cave encompasses different types of cave deposits, it includes: straw, conical and curtain stalactites, helictite, and columns. These deposits are mostly small in size range from few millimeters for the helictite to few centimeters up to 9 centimeters long for the dripping stones. These deposits are still active as water still emerges from the stalactites (Figs 11 to 18).

The floor of the cave is covered with thick layer of terra rosa mixed with rock fragments range from few centimeters to about one meter, these rock debris formed by breakdown of roof and wall of the cave.

2. Wadi Belgares cave

Fig. 25. Entrance of Wadi Belgares Cave

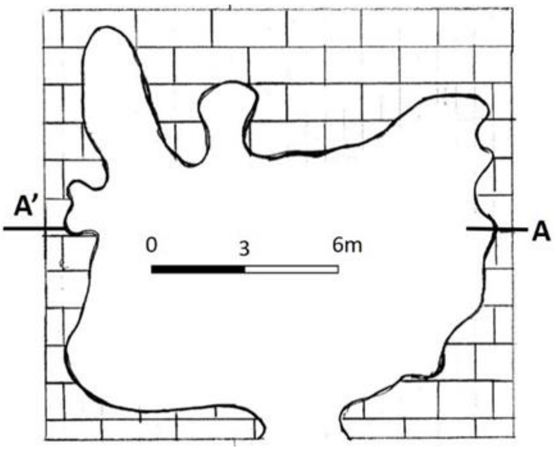

Fig. 26. Plane view of Wadi Belgares Cave

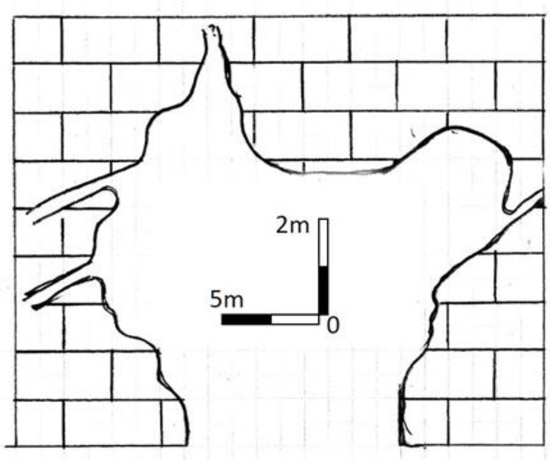

Fig. 27. Cross section A – A'

The cave is located about 8 km to the north of the village of Alwattayat. On the southern flanks of the Wadi Belgares. It is situated at the intersection of the Latitude 32^0 21' 38.9"N and the Longitude 20^0 29' 51.85" E, at 157 m.a.s.l. The caves penetrated the Nummulitic limestone of Darnah Formation. The beds are well jointed and are very thick up to 3 m thick.

The cave consists of one main chamber with high roof marked with widened joints and two small chambers of regular shapes, which may indicate human intervening. The main chamber is 12 meters wide, 8.5 m deep 11m high (Figs. 25, 26 and 27). The widening ceiling joints and the wide horizontal bedding planes, in addition to honeycomb sculpture in the walls are indicating formation in the phreatic zone. It seems that joints may have played a role in the formation of the cave; this may be indicated by the inclined entrance of the cave (Fig. 25). Corroded base of horizontal conduits and joint controlled passages are suggesting development in the vadose zone. Cave deposits in Wadi Belgarse are limited and only represented by only small curtain stalactites and rock debris of variable size.

3) Wadi Ashalani cave

Fig. 28. Wadi Ashalani Cave

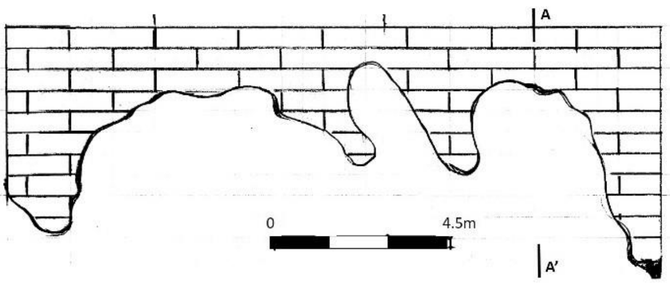

Fig. 29. Plane view of Wadi Ashalani Cave

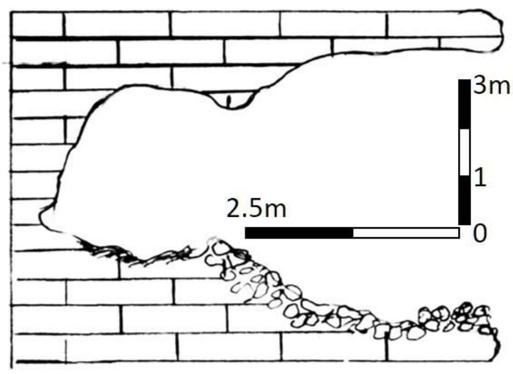

Fig. 30. Cross section A-A'

The cave is located about 13 km to the north of Alwattayat village on the northern side of Wadi Ashalani, at the intersection of the latitude 32^0 24' 07.1" N and the longitude 20^0 32' 0.15 E, with an elevation 230 m.a.s.l. The caves penetrated the Nummulitic limestone of Darnah Formation. The beds are well jointed and are very thick reaches up to 3 m thick.

The cave is made up of one main wide room with three small cavities open into the main room (Figs. 28, 29 and 30). The room is 14 m wide 5 m deep and 6 m high. The cross section showing the ellipsoidal shape chambers with low arched roof and corroded base. The cave lacking any obvious features of stalactite and stalagmite, although honeycomb features are observed in the cave, the floor of the cave is covered with rocks fragments of different sizes.

10. Discussion and interpretation

The origin and development of the karst caves in the Daryanah area has been interpreted by studying the cave features. The ellipsoidal and laminar horizontal passages and conduits indicating that these chambers, passages and conduits formed along the bedding planes in the phreatic zone. The honeycomb and widened ceiling joints may also suggesting saturated zone.

The reported cave deposits include dripping stone (stalactites, stalagmites and columns), helictite and rock debris formed due to breakdown of roof and wall, in addition to passages with corroded base all are evidences of development in vadose zone.

The studied caves are classified as small carbonate caves, formed along bedding planes of secondary and endogenic origin according to Bogli (1980) classification. The simple shape of the chambers and their occurrence in the same level in gently dipping beds with wide spaced joints suggesting that these caves formed and developed according to simple model with limited recharging points proposed by Ewers and Quinian (1982).

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