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ROUEISS CAVE: POTENTIAL SIMILARITIES WITH AFQA CAVE

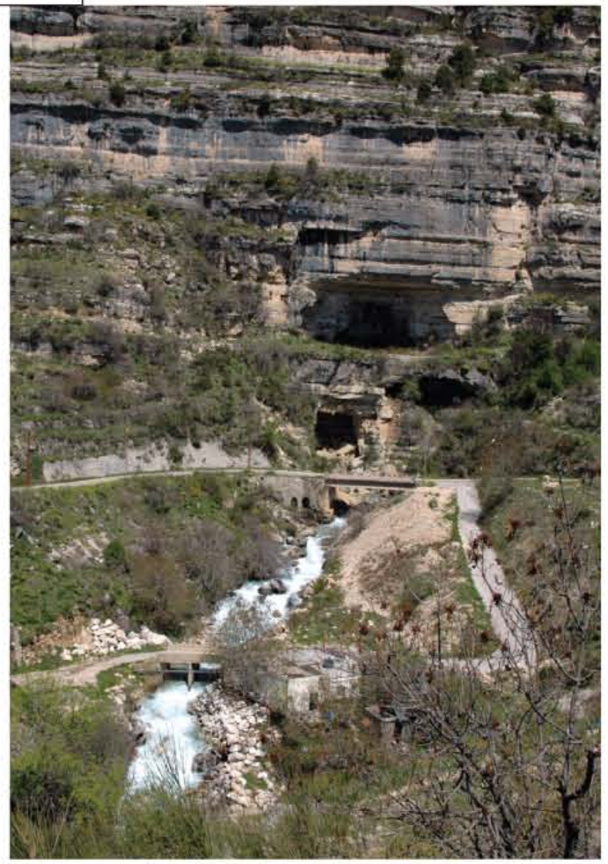


Fig. 1
The entrance of Roueiss cave in April 2009.
(photo by Issam Bou Jaoude)

ان ينابيع أفقا والرويس يغزيان نهر أبراهيم ويتدفقان من فم مغاور أفقا والرويس. ان تشابه وفوارق خصائص تكوين هاتين المغارتين من النواحي الجيولوجية والهدروجيولوجية والجيومورفولوجية والسبيلوجينيسية تزويدونا بمعلومات عن كيفية تكوين هاتين المغارتين وتعطينا أيضاحات عن كيفية تكوين بعض المغاور الشبيهة لهاتين المغارتين في لبنان.

La rivière du Nahr Ibrahim est principalement alimentée par les sources de Afqa et Roueiss, jaillissant des grottes portant le même nom. L'étude de la géologie, la spéléogenèse, la géomorphologie et l'hydrogéologie de ces réseaux souterrains révèle des similarités et différences intéressantes à noter pour la compréhension de leur développement et fournit des explications probables sur le développement de grottes similaires au Liban.

NAME OF CAVE	ROUEISS CAVE	AFQA CAVE
DEVELOPMENT	5411m	5260m
FORMATION	Upper Albian, Hammana Formation	Upper Albian, Hammana Formation
LEVELS INSIDE CAVE	3 Levels Three fully developed levels	3 Levels One fully developed level
DISCHARGE OF SPRING	0.75 m^3/sec	1.5 m^3/sec
SIZE AND TYPE OF ENTRANCE	Two natural bridges with large collapsed blocks	Large collapse entrance measuring 50mx30m
CAVE PASSAGE SHAPES	10 types	9 types
UNDERGROUND RIVER	Located in the lower levels issuing from inbetween rocks with no clear river flowing	Located throughout the year from a large tunnel passage
TYPE OF CAVE	Fissure network cave	Fissure network cave
LOCATION OF CAVE WITH RESPECT TO MAJOR FAULT	North of the fault (on the lowered block)	South of the fault (on the lowered block)
WATER RESEVOIR AQUIFER	Sannine Formation, C4	Sannine Formation, C4
WATER BARRIER FORMATION	Hammana Formation	Hammana Formation
FRACTURE ANALYSIS	Set 1 ENE-WSW Set 2 WNW-ESE	Set 1 ENE-WSW Set 2 NW-SE
BEDDING DIRECTION (Sannine Formation)	North of major fault 15° to 35° SE South of major fault 15° to 20° NNE	North of major fault 5° SE South of major fault 15° to 20° NNW

Table 1
Similarities and differences between Afqa cave and Roueiss cave

Two major springs which are 6 km apart (as the crow flies), Afqa and Roueiss, are the primary sources of Nahr Ibrahim River. These two springs issue from the same named caves respectively. Those caves have developed in the Upper Albian aged rocks (Hammana Formation), and both of their springs are fed primarily from the Cenomanian aquifer (Sannine Formation). In addition to that they both have similar cave passage shapes, they are of similar size, and they both have similar structural control on their cave development. However, Roueiss cave has developed on the northern block of a major fault while the Afqa is on the southern block of a similar fault.

The similarities and differences between these two cave systems based on their geology, speleogenesis, geomorphology and hydrogeology is interesting as it gives insight on how those caves have developed and provides a possible explanation on how similar caves have developed in Lebanon. This paper will introduce the issues surrounding the development of Roueiss cave and try to compare those elements with its counter-part Afqa cave.

Introduction

Roueiss cave is the second longest horizontal cave in Lebanon, measuring 5460m in cave development. It is located in central Mount Lebanon between the villages of Kartaba and Aaqoura. The Lambert coordinates for the entrance of Roueiss cave are x=167,000m and y=240,940m, with an elevation of 1300m (asl). It lies approximately 6km (as the crow flies) from the third longest horizontal cave in Lebanon, Afqa cave which has a development of 5260m (Table 1).

A perennial spring, Roueiss spring, issues from the cave but does not issue from the cave's two entrances directly (Fig. 1); it flows from the lower levels of the cave through collapse boulders. During winter, the water floods the cave and issues from a higher location close to the lower entrance of the cave. The average rate of the spring according to Edgell (1997) is 0.5m^3/s - 1m^3/s. A spring with similar characteristics issues from Afqa cave, however, contrary to Roueiss spring it issues from the mouth of the cave and during flooding condition water emerges from the lower levels. The location of the springs during flooding and dry season and the difference in development of levels in the two caves might indicate that Rouiess cave could be more developed than the Afqa cave.

Roueiss cave, similar to its counterpart, is made up of three separate levels. But in Roueiss cave the three levels are fully developed while in Afqa cave only one level is (Table 1). The Ground level, which is effectively rectangular in shape, consists of fissure passages, keyhole passages, mazes, and large rooms. The Lower level is a set of grid-like labyrinths set in a rough rectangular pattern. The Upper level is a long, large L-shaped tunnel which includes the Dream Theatre the largest chamber in the cave measuring approximately 50m by 50m.

Hydro-Stratigraphy

The area around Roueiss cave contains rocks that span nearly the entire sequence of the Cretaceous period from the Chouf Sandstone formation until the Sannine Formation (Fig. 2). There are also some Quaternary deposits in the region as well as a large alluvial fan located approximately 500m NW of the cave.

Similar to Afqa cave, Roueiss cave lies in the upper Hammana Formation (Albian epoch) in a sequence of interbeds of limestone and marl beds of varied thicknesses. Overlying the Hammana Formation are rocks of the Sannine Formation. Nearly 400 vertical meters of Sannine formation limestone lie above the Roueiss cave. This can be considered the source rock of Roueiss spring while the Upper Hammana can be considered the discharge rocks whose lower volcanic beds act as a barrier to water flow.

The percentage of infiltration of precipitation into the Sannine Formation is approximately 60%, average rainfall in the area is around 1200mm/year (Atlas Climatique, 1977) and an average discharge from the cave is 0.75m^3/s (Edgell, 1997). Taking these measurements into consideration a rough estimate of the catchment area was calculated and found to be 33km^2. Afqa cave's catchment area is 66 km^2 based on a spring average discharge of 1.5m^3/s (Edgell, 1997). Considering this we can deduce that in the 1970's the discharge out of Afqa cave is double that of Roueiss cave.

Structural Geology

Much like Afqa cave the area around Mgharet Roueiss cave is highly faulted and has undergone a great deal of deformation.

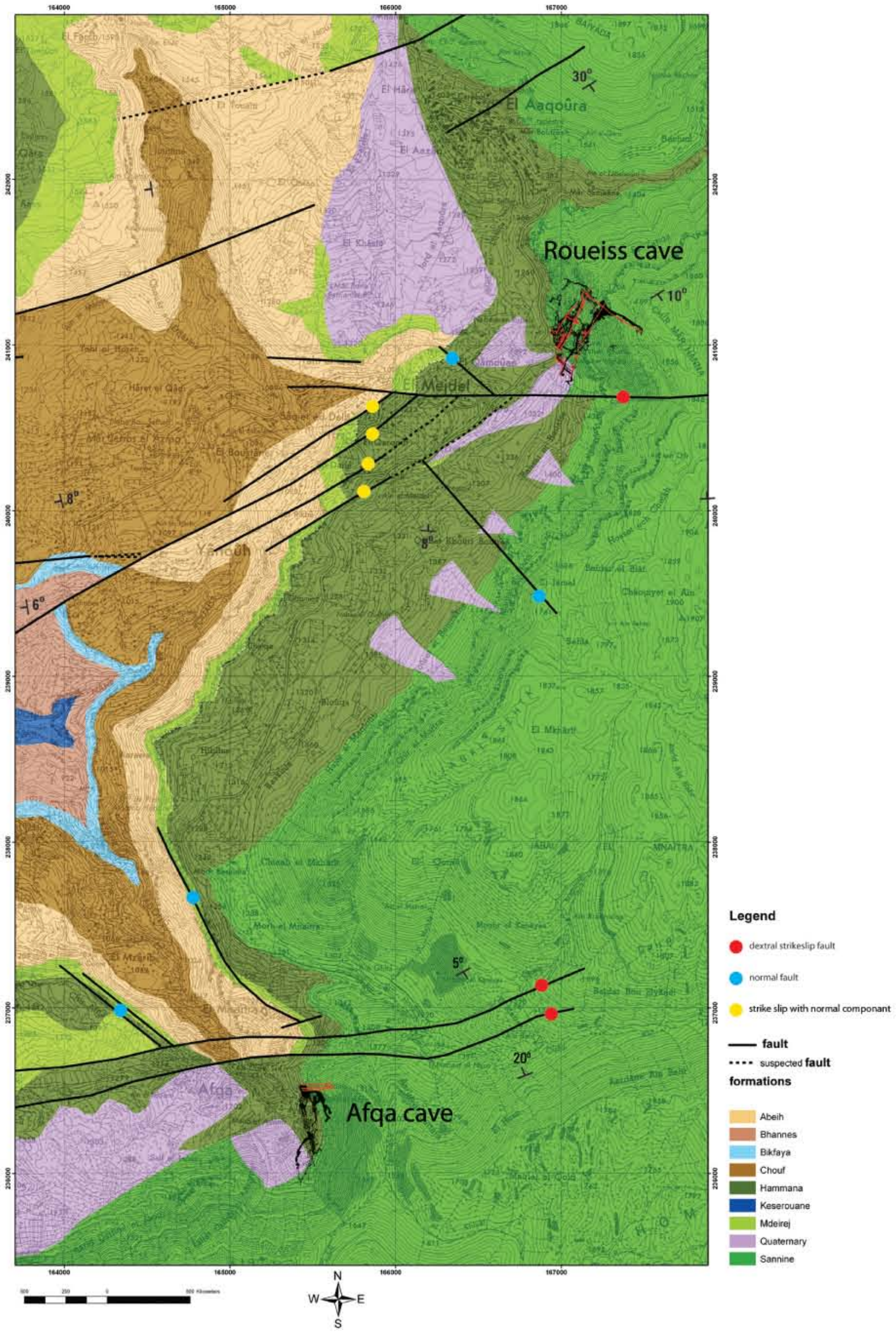
Faults

The major fault in the Roueiss cave area is an E-W trending dextral strike-slip fault (with a normal dip-slip component), passing approximately 250m south of the cave. The orientation and inclination of this fault is 260/70º with a vertical displacement of about 70m and a horizontal displacement of nearly 330m. Lineations on this fault were measured and found to have a pitch of 12° E. The major fault in the Afqa cave area has a similar structural imprint but it passes north of the cave. Both caves have developed on the lowered faulted block. For Rouiess cave it is the northern block and for Afqa cave it is the southern block (Fig. 2).

Secondary synthetic strike-slip faults trending NE-SW were identified. Also secondary normal faults trending NW-SE and NE-SW are present. The vertical displacement of these faults range from 2m to 20m.

There are six major faults (Fig. 3) observed inside Roueiss cave. Three were located in the Upper Level passage with orientations trending NE (with slickenlines pitching 15º East). One fault passes through the Big Room and has a trend of NW. Another lies in the Large Tunnel of the Lower level trending also NE.

Fig. 2
Geological map of the Afqa-Aaqoura area showing both Roueiss cave and Afqa cave.



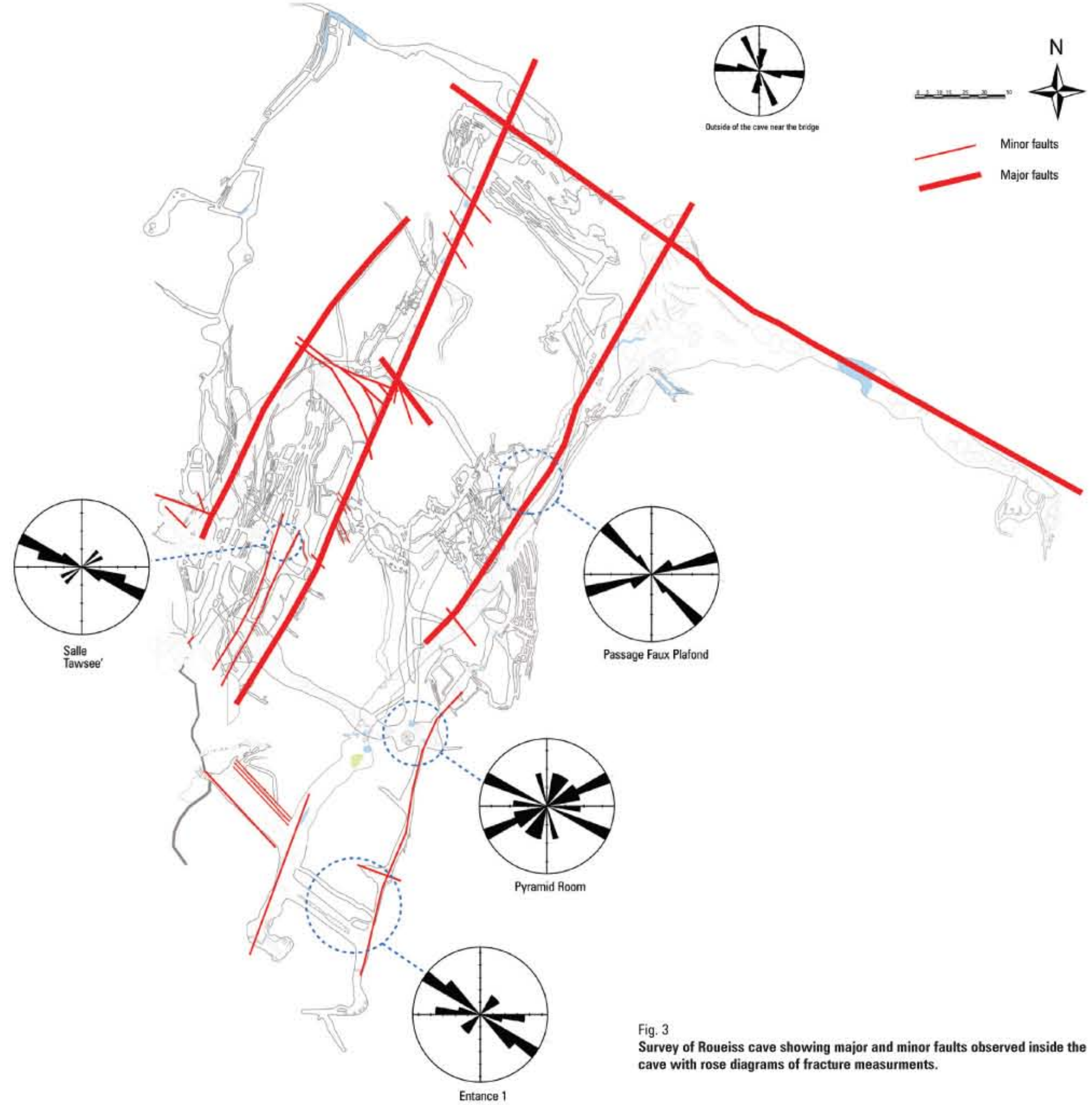


Fig. 3
Survey of Roueiss cave showing major and minor faults observed inside the cave with rose diagrams of fracture measurments.

Bedding

The area around Roueiss cave can be split into two regions. The first is the block south of the E-W fault with a general bedding inclination ranging from 15° to 20° NNE. The second region lies north of the NNE-WSW fault. The bedding in this area ranges from 15° to 35° NNW.

Beds in the Afqa cave area are also different between the northern and southern blocks for the northern block 5° SE and in the southern block 10° to 20° NNW.

Joints and Fractures

Five locations were chosen for fracture analyses. A total of 63 discontinuities were measured inside and outside of the cave. Rose diagrams were constructed for each location (Fig. 3). The general orientations of these sets were found to be WNW-ESE and SW-NE.

- In Salle Tawsee (in the Lower level), 8 discontinuities were measured. The dominant orientations were WNW-ESE and to a lesser degree NE-SW.
- In the Faux Plafond Gallery, 9 discontinuities were measured. The dominant orientations were NW-SE and to a lesser degree WSW-ENE.
- In the Pyramid Room, 11 discontinuities were measured. The dominant orientations were NW-SE and WSW-ENE.
- In the area near the Entrance One, 11 discontinuities were measured. The dominant orientations were NW-SE, and to a lesser degree E-W and NE-SW.
- In the area outside, west of the cave (next to the bridge), 24 discontinuities were measured. Three different directions for the discontinuities were measured, two for joints, ENE-WSW and NNW- SSE, and one for veins, NW-SE.

These joints can be considered as secondary conjugate sets for the major strike-slip fault.

It is clear from the rose diagrams that the fracturing correlates well with the directions of the faults observed inside the cave as well as the general orientation of the tunnels. Similarly the major passages in Afqa cave are developed along the major fracture directions which are NNW-SSE.

Passage Morphology

Fissure, tubular, keyhole passages, lenticular tubes, shafts and large collapse rooms were identified inside Roueiss cave

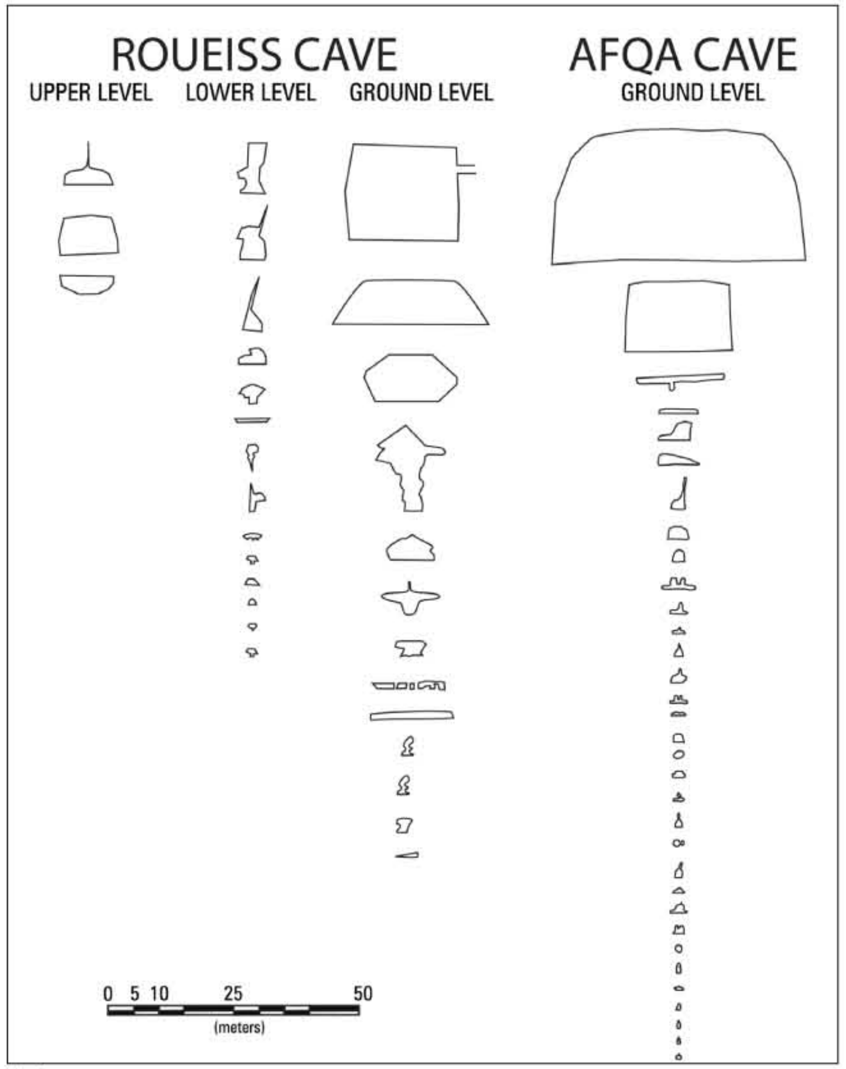


Fig. 4
Roueiss cave passage morphology with comparison to the Afqa cave counter parts.

(Fig. 4). In high water flow during winter the lower levels become inaccessible due to flooding. This all supports the notion that the cave is still very active in its lower passages, and the upper level has become a fossil gallery.

Ten different passage shapes were observed inside Roueiss cave. Although the sizes of each passage differed, the actual shapes of the openings were similar (and were consequently placed into one category). The different sizes of the passages have a direct relationship with the level they are located on. The Upper level contains some of the largest passages while the Lower level contains some of the tightest. The Ground level has varied sized passages. This might be due to the lithological nature in which each passage has developed. The larger upper rooms are developed in thick massive limestone of the Sannine Formation. While the smaller tighter formation of lower level passages are developed in the upper Hammana thin limestone beds. Afqa cave has nine different shapes of cave passages which are similarly controlled by lithology and structural geology.

Large rooms in Roueiss cave appear to be formed at the intersections of faults with collapse being the main process enlarging the volume along with solution action. For these rooms to have become as big as they are means that a substantial stream used to run through these rooms to remove debris and to enlarge them. This appears to ascertain that water level has dropped over time, from water eroding and forming the Upper level, to the current water flow at the Lower level since the big tunnels are located in the Upper levels and hence the oldest and largest.

Small scale speleogens solution features were found in most passages. Scallops, flutes, rills, spongework, solution pockets and potholes were seen in various sizes throughout most of the Roueiss cave.

The cave is not overtly well endowed with speleothems. It has its fair share of the traditional concretions including stalagmites, columns, stalactites, flowstone, rimstone dams and there is nothing extraordinary about these calcification features. This might be due to the large volume of fast moving water that has flowed through this cave. Afqa cave also has a lack of

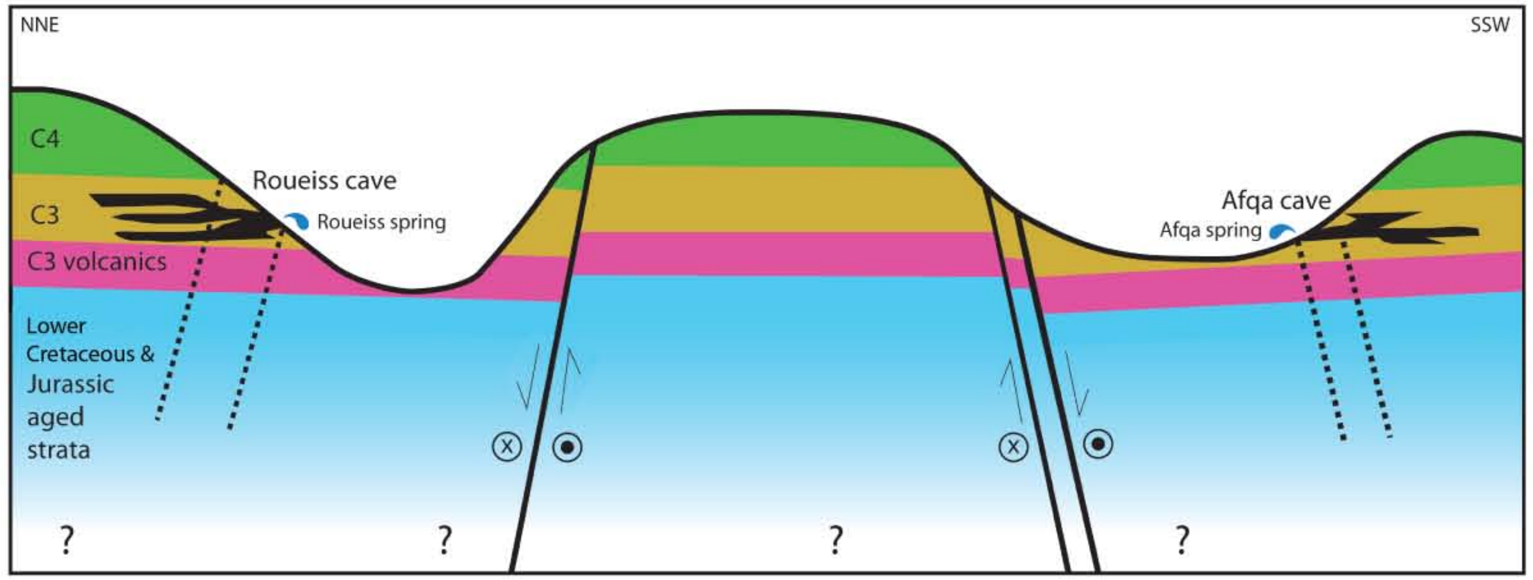


Fig.5
A schematic cross-section showing the geology in Roueiss cave and Afqa cave area.

speleothems inside it. Much like Roueiss cave it has the standard common speleothems of stalactites, stalagmites and flowstone with no large-scale special deposits.

Discussion

The second and third longest caves in Lebanon are 6km apart. Both feed the waters of Nahr Ibrahim and both have imprints of the local tectonic activities on their formation and development.

Similar to Afqa cave, Roueiss cave is a structurally controlled cave. They were developed on the lowered blocks (Fig. 5) of an EW strike-slip fault with normal dip-slip componant. The caves follow two general fracture sets in the area which in turn follow the orientations of secondary faults in the region. Essentially Roueiss cave is a fissure network cave with the underlying layer of impermeable rock (Hammana Volcanics Formation) acting as the lower boundary of the cave much like Afqa cave. Both caves are also formed on the structurally lowered block as a result of water damming (Karanouh & Bou Jaoude, 2007). There is also a clear alignment of cave passages with local discontinuities in both caves and this can be observed in the cave, on the rose diagrams and on the geological map. There is also an alignment between the faults in the cave and the secondary ones observed outside.

Considering Afqa cave and Roueiss cave as having been formed essentially by the same processes (water banking on faults with water flow along bedding planes) we can also suppose, with the three levels in Roueiss cave being well developed while only one well developed level in Afqa cave, that Roueiss cave has been developing longer than Afqa cave. The systematic regional lowering of the water-table over time has formed the different levels, with the passage sizes affected by the different flow rates of the underground water as well as lithology it passes through.

An interesting observation is that in Afqa cave the perennial spring flows above the flooding springs and in Roueiss cave the perennial spring flows below the flooding springs. This indicates that Roueiss cave is possibly more developed than Afqa cave.

The Upper passages in Roueiss cave are now fossil galleries. The Ground level is effectively a potential fossil gallery although during flooding water still does pass through it and the range of small and large passages is a testimony to this interplay of water flow, lithology and structure. The Lower level is the youngest level and it is still enlarging its current small passages, but the extent of enlargement is restricted by the bedding thickness.

The comparison made, showing a noticeable correlation between these two caves, allows further understanding of the development of the Lebanese caves. Although the Afqa and Roueiss caves are in different stages of development they draw a picture, albeit a vague one, on the events that led to their development.

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