AL HAJAR

Issued by Geological Society of Oman

24th edition | June 2018

Oman Mountains

Between Water Resources and Caves Discoveries

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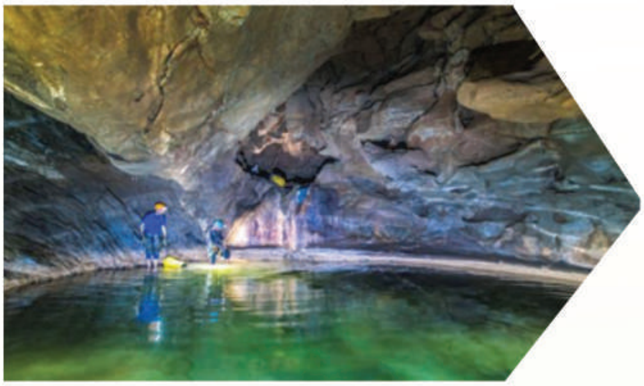

Editorial Board

President's Address

Dr. Ibrahim Al Isamili

GSO President

Dear GSO Members,

The society had many successful events run by our dedicated members in 2017. These included the geo-challengers Universities' competition, Geo-kids fun and learning event, workshop for Al Amal School for the Deaf, and supported event on earth geo-history by SQU geo-group. Additionally, GSO formed a mining sub-committee to follow and support the active mining sector and to participate in shaping the mining strategy. Furthermore, a student chapter is put with proper focal points to ensure efficient support to and participation of our young students. For 2018, a full calendar of talks and trips awaits us. Thanks to those who volunteered to lead and to those who helped presenting and organizing.

The society has grown in members and has also demands from different institutes to offer support and participation. To do this efficiently, 2017 was marked with a lot of work to ensure proper update of our database and processes to serve our members better. So, kindly make sure you regularly update your details by either responding to our emails on this regard or by taking the initiative and communicating directly with us via our phone or email address. Also, always ensure that your membership is renewed annually. This helps us organizing all GSO activities and events more efficiently.

Finally, we urge you to participate in GSO activities. You can volunteer by giving a talk, run a trip or assist organizing educational activities. As our AGM is coming soon and we are looking forward to seeing you all.

I close by offering many thanks to the dedicated work of the committee, our many active members and continuing supporters.

Yours truly,

Dr. Ibrahim Al Isamili,

GSO President

Editor's Note

Dr. Aisha Al Hajri
GSO Editor

Dear readers,

Welcome to the 24th edition of Al Hajar. In this edition, we provide you with a very interesting and comprehensive information about the newly discovered caves in the area between Jebel Saih Hatat and Al Jebel Al Abyadh. You will also find a summary about the field trip organized by GSO to explore the geology of Jebel Madar in Ad Dakhiliyah Governorate. The Hajar Mountains Range (HMR) plays a major control in the distribution of underground waters and many geological structures in northern Oman and in this edition, we are shading a light on this topic. The discovery of unique trace fossils, known as Nereites ichnofacies in the deep sea, Late Triassic-aged turbidite sediments, Wadi Hibi, has recently occurred. You will find all details about some of these fossils in this edition. Finally, the GSO would like to thank CGG Services (Oman) for sponsoring this edition of Al Hajar Magazine.

We hope you have a joyful reading.

Dr. Aisha Al Hajri,
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New Caves Discoveries

in the area between Jebel Saih Hatat and Al Jebel Al Abyadh

Written by: Simon Cahill and Mohammed Al Kindi

Introduction

The Eastern Al Hajar Mountains are characterized by two main mountain massifs, known as the Saih Hatat Mountain and Al Jebel Al Abyadh. The Saih Hatat structure is a large deeply eroded anticline, 80km x 50km elongated in the NW-SE direction. It extends from the wilayats of Al Seeb and Muscat in the northwest to the wilayats of the Dima Wa Tayyin and Qurayat in the southeast, for about 80km. The Al Jebel Al Abyadh extends from Qurayat and Dima Wa Tayyin and plunges to the ground close to the Wilayat of Sur, with a total NW-SE length of approximately 70km. The bordering cliffs of the Saih Hatat Mountain is mainly composed of Late Palaeozoic and Mesozoic grey carbonates, while Al Jebel Al Abyad is primarily composed of yellow Tertiary limestone sequences. The two mountain chains converge in the area SE of Wadi Daiqa, and outcrops of both groups of rocks can be seen around some villages in this area (Figure 1), e.g. Hail Al Hareem Village.

Enthusiastic cave explorers have investigated and surveyed new caves in the area, one of which could be the deepest cave in Oman. This article documents the preliminarily surveying results and the history of exploring these caves. The article sheds light on the possibility of finding more cave channels and chambers in the area, and the relationship between the location of these caves and the main geological structural features.

Figure 1: Outcrops of both grey Mesozoic carbonates (the Saih Hatat Massif) and yellow Tertiary carbonates (Al Jebel Al Abyadh Mountain) in the area close to the Hail Al Hareem Village. Field of view is about 400m.

Figure 2: The location of the Hail Al Hareem Village in a bowl filled by quaternary deposits at the south-eastern end of the Saih Hatat Massif (UTM 40Q 686017mE, 2548870mN), about 1070m above sea level. The field of view of the picture is to the west. Climbing the mountain on the northern side of the village opens a spectacular window overlooking the dam and extensive lake of Wadi Daiqa. The area receives higher rainfall compared to other places in Oman, hence promoting the development of caves in the surrounding carbonate rocks.

Geology of the area

The carbonate rocks of Al Jebel Abyadh contain a number of large caves (e.g. the Majlis Al Jin Cave and the 7th Hole Cave, locally known as Maqandli and Aqabat Khishl, respectively). Since their deposition about 50 million years ago, in the Early Cenozoic, these carbonates have not been metamorphosed or significantly cemented. They also contain significant nodular features and large porous spaces, and have wide and open fracture corridors that are closely spaced. Together, these factors promote the formations of large karst features that get connected to form cave chambers and underground water channels.

In contrast, the Permian and Mesozoic grey carbonates of the Saih Hatat, deposited in the period between about 260 million years and 90 million years ago, are significantly cemented and metamorphosed, due to the considerable alteration they experienced during the subduction of the continental edge in the Late Cretaceous. The porosity of their matrix is probably less than 10% in general, based on outcrop analysis of the same rock units in other places in Oman such as in the Al Jebel Al Akhdar and the Salakh Arch. Although their matrix porosity and permeability is low, these grey carbonates are significantly structured due to the long tectonic history of the area. Large faults and fracture pathways promote the formation of cavities, particularly in the areas where many faults and fracture sets intersect.

Caves provide very important windows to the geological, hydrological, archaeological and climatic history of the earth. They have been for long considered as the archives of the past. The carbonate units of the Al Hajar Mountains and the Dhofar Mountains offer large numbers of a world-class set of amazing caves to explore and study. Many of these have been discovered and surveyed, but many are still to be found. For many adventurers, the exploration of caves and their speleological features is a challenge and life-time experience that requires driving long distances and consuming efforts.

Recently, several small caves were discovered in the Jebel Al Akhdar region and published in this magazine. Since the 1980's large caves such as the Majlis al Jinn (Khoshilat Maqandeli), the Selmah Plateau system, Al Hoota Cave (Kahf Al Hoti) and the sinkholes of Dohfar have been discovered and documented. Today we can add another large significant cave and two smaller ones to the list of wonders in Oman. These caves are known as: Al Khishil Cave, Al Naqqah Cave and Al Fiqu Cave.

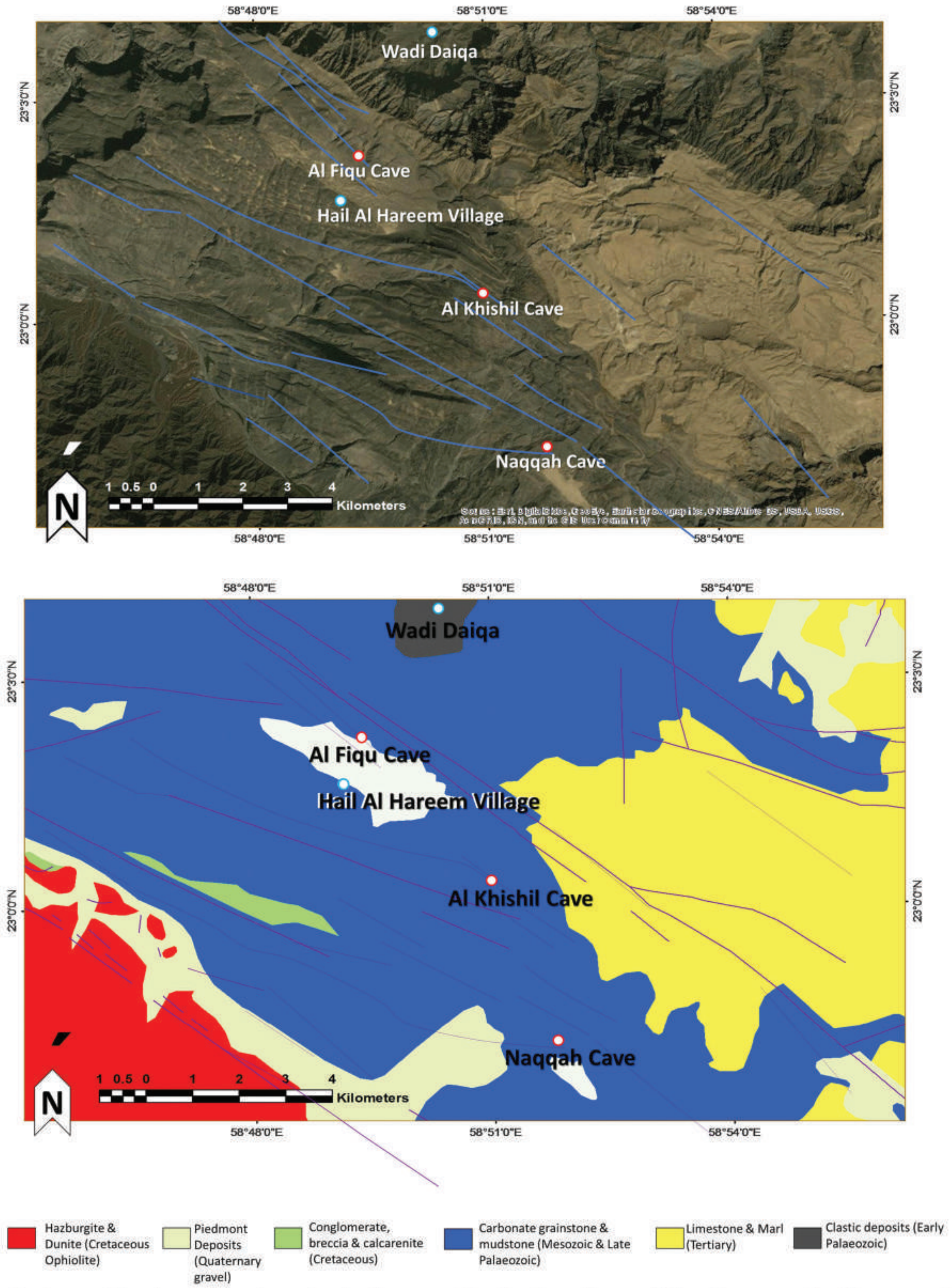

Figure 3: A satellite image and geological map with the locations of the three newly discovered caves. The purple lineaments in the geological map are major faults. The entrances to the new caves are located at the intersections zones of faults, where the water circulation and hence the dissolution of carbonates is intensified, promoting the formation of karsts, caves and underground water channels. The underground pathways of these caves are controlled by the subsurface continuity and orientation of these faults and fractures.

Discovering and exploring caves

Who should claim to be the one who discovered a cave is an interesting topic that could be debated for hours. The caves have been around for hundreds of thousands or even millions of years. Humans have been present in Oman for more than 100 000 years, so in the year 2017AD it seems a bit strange to be the one claiming to have "discovered a cave". However, pinpointing when a cave was first explored can be a simpler task especially when the cave is deep and technically challenging to enter. If a challenging cave has been entered before, there are normally signs such as stone steps, wooden pegs, artefacts or remains and in modern times metal climbing aids such as pitons or bolts.

In the case of the three caves recently explored, all three were certainly known to and have been named by the local inhabitants. Villagers from Hail Al Hareem say the biggest cave, Al Khishil Cave, was visited by Westerners in a helicopter many years ago. This report ties in with the 1980's explorations undertaken by Don Davison and Cheryl Jones in conjunction with the Oman Public Authority for Electricity and Water. Cheryl has confirmed they would have likely been the Western visitors, but they did not enter the cave. It, therefore, appears that the cave had not been entered and explored prior to 2015. In 2011, Tim Harrison, a keen hiker and photographer, visited the area and took a photograph of the entrance of Al Khishil Cave. For the Naqqah Cave, no signs of previous entry have been seen in the cave and the local villagers never reported any cave explorers visiting the cave before. The Naqqah Cave requires hiking for about 30 minutes to reach its entrance and the area is quite frequently visited by the villagers.

Al Khishil Cave

Al Khishil Cave is massive and at about 7km driving distance from the Hail Al Hareem Village, along the graded road to the Al Kfof village at the Selmah Plateau (Figure 4). Simon Cahill, a British caver, accidently came across a photograph posted online by Tim Harrison of a cave on the Fida Dank Road. Simon contacted Tim via Panoramio, the photograph sharing website, to ask about the photograph. Tim replied saying the cave was not deep, but referring to the photo he took in 2011, Tim said he had an image of another cave entrance near Hail Al Hareem that may be more interesting. Tim had not entered this cave as it required climbing equipment and technical expertise, but he thought it was a deep cave. In the summer of 2015, Tim sent Simon the location for what has become known as Al Khishal Cave. In December 2015, Simon spent a few days caving on the Selmah Plateau with some friends. After the Selmeh trip, Simon and Blair Hoover, a caver from the USA, stopped off to have a look at the cave Tim had referred to. Simon and Blair rigged ropes from natural anchors and descended to a depth of around 40m. The cave obviously went down a long way, but without proper bolting equipment Simon and Blair returned to the surface to plan further exploration.

In January 2016, Canadian caver Christopher Pike joined Simon and Blair to explore the cave further. The initial pit, with a drop of around 130m, was bolted with several re-belays and deviations. Pike took the lead on bolting and reached the base of the pit in a few hours. The walls of the pit had been polished by water to a fine smooth finish. It became clear nobody had been down there before; it was not possible to descend to the bottom without placing mechanical anchors. Beyond the main pit, the cave plunged again and quickly became varied and technically challenging. A climb slightly up through a hole lead to a larger more open maze of tunnels, then within a short distance a technically difficult climb was encountered, followed by a tricky traverse.

The cave opens into a decorated chamber Blair named The Art Gallery. A tunnel just about head height and two meters wide leads out from The Art Gallery. The tunnel twists and turns and finally arrives at a wide passage with a very low roof requiring a crawl / squeeze through a gap no more than 40cm high; 10cm of water and 30cm air gap. Pike hummed the theme tune to the to the film Mission Impossible and the crawl section was aptly named "Mission Impossible". The cave narrows, but the roof rises allowing a more comfortable crawl on your knees rather than the previous squeeze on your stomach. Another tunnel with difficult climbs continues, but the team had already explored several hundred meters of cave, with Blair taking survey notes along the way. This was enough for one day. It was 6:35pm and time to turn around. The cave was proving to be very interesting, challenging and potentially dangerous. The nature of the cave constantly changes from tight low passages to open chambers. Mission Impossible is an early and dangerous sump; just a small amount of flood water can close off the way through or rather the way back! Later explorations have been stopped at this point as the cave has been flooded to the roof.

Figure 4: The entrance of the Al Khishil Cave. The cave is located along the graded road from Hail Al Hareem to Al Kfof in the Selmah Plateau.

Survey and mapping

There have been several expeditions to the cave since 2015 to push on further and conduct surveying missions. The cave continues to be challenging. There is a lot of climbing with and without ropes.

The cave is humid for the most part but can also be cold after swimming through the numerous lakes and pools. Pike summed the cave up by saying; "the cave is the most technically challenging in Oman by far and took a lot of rigging and sorting out direction as the cave splits multiple times. This cave is quite full on and the effort to keep the drill dry is unexpectedly hard. At the 60-minute mark there is another point that could easily sump out, but a mild duck dive to swim under formations can be done to get through. Later is a tight squeeze descent, then finally the passage continues through one of the most decorated sections of the cave.

Toufic Abou Nader, a caver from Lebanon who in 2016 descended Krubera Cave, the deepest cave in the World; pushed the cave further and reached what appears to be the end. It is difficult to know the exact depth and length of the cave until the survey is finished. What we do know is that the cave is long and deep and a very significant discovery for Oman.

Surveying and mapping the cave has proved to be a real challenge both in the planning and preparation stages and while descending in the cave. Blair initially took the lead on mapping; a brave commitment as this was by far the biggest mapping project she had ever taken on. The first initial survey was done with a Disto measuring device specially adapted for use in caves. However, it was very difficult; the custom-built circuit board burnt out and was destroyed. Blair persevered for many months using more traditional survey methods, going back to a standard Disto unit for distance and inclination readings and using a traditional compass for direction. Using these simple equipments, Blair surveyed about 500m of passages. Unfortunately, the data did not make a lot of sense when analyzed, because the compass readings seemed off. Possibly the metal on Blair's harness affected the reading or the amount of iron in the rock had an effect.

Figure 5: Various speleological deposits in Al khishil Cave. Field of view on the top photograph is about 15m.

Hergen Meyer, a caver from Germany with an interest in all things techni cal,stepped in to help. Hergen crunched the data from several of Blair's surveys and came up with a center line plot covering around 60 survey points for 300 horizontal meters and a depth of 160m. Paul Emous, a caver and professional photographer from the Netherlands, had for some time been building and developing a 3D scanner that could be used to map caves. Paul's development had been on hold due to other commitments and another company (Scanse Sweep) bought a similar scanner to market this year. Paul bought one of their units in October and was keen to test it. Simon Cahill, Paul Emous, Herg en Meyer and Mikolaj Zielinski, a caver from Poland, planned an expedition to photograph the cave and to try to continue the survey from Blair's furthest point. With a new adapted Disto, the Scanse Sweep scanner and cameras the team was well equipped. The expedition was a huge success and exceeded all expectations. Arriving at Hail Al Hareem on the 30th of October 2017, the team chose to photograph and scan Al Fiqu Cave. The aim for the day was to test equipment and hopefully get some usable data and pictures. The next day's main aim was to take photographs in Al Khishil Cave. The secondary aim was to pick up from where Blair had left off on the survey. In one regard this made sense, but on the other it seemed a good idea to start from the entrance; finally, a decision was made, and the survey began from the entrance. The team worked hard to take delicate and heavy equipment through the cave. The result after a strenuous and exhausting eighteen hours underground was a center line survey from the Entrance to the Fork (Figure 6), a set of incredible photographs and 3D scans carried out at the Entrance, the Art Gallery and the Fork (Figure 8). The 1.3km of passage surveyed, approximately one third of the cave, from the Entrance to the Fork gives some indication of the complexity of the cave. It will take many expeditions and dozens of hours underground, probably years to produce a fully detailed map.

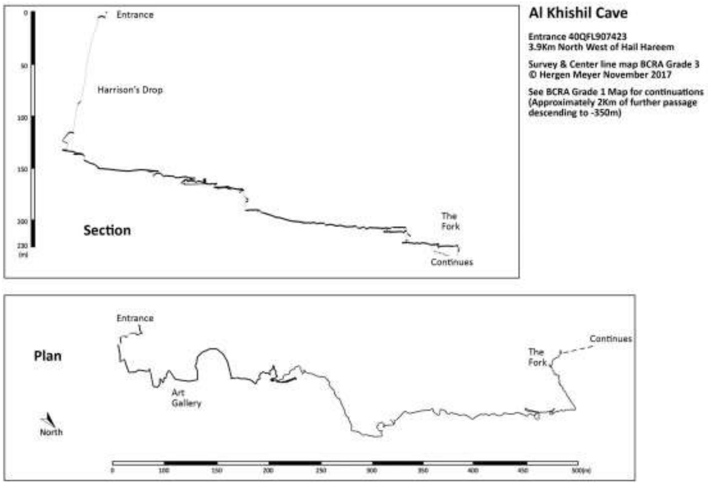

Figure 6: Centre line survey; plan and section of Al Khishil Cave. about 15m.

Beyond the Fork

Toufic Abou Nader has described the cave and provided a sketched map for the continuations beyond the Fork.

Toufic says "I believe the right Fork was the first to be formed; it is very dry and old. Blair also commented that this section looks very old and her way was obstructed by fragile formations. It is thought the right Fork is likely blocked, but there are still possibilities to explore. Toufic continues: "to descend through the left Fork there is a need to crawl backwards and squeeze through a hole dropping around five meters onto a steeply inclined slab. A further drop, again five meters leads to a crystal clear lake. However, an easier option discovered on later expeditions is to backtrack twenty meters from the Fork and descend about seven meters through an alternative drop. This drop avoids the tight squeeze hole and lands you directly on the inclined slab above the Crystal Lake".

Figure 7: One of the many lakes & pools in Al Khishil Cave.

The temperature at this level gets slightly cooler and less humid. The cave also changes drastically. The speleothems are wet and active. Flowstone has formed into draperies (curtain like formations). Rimstone dams have formed cascading gour basins full of clear water. Young and some older stalactites and stalagmites up to a meter long extend from the floor and ceiling. Soda straws are active and dripping water. Helictite, a wispy hair-like fragile speleothem appears as if grown in zero gravity. Frostwork, a delicate needle-like growth of calcite, is present and the trained eye will find cave pearls. Beyond the Crystal Lake, the passage to the bottom of the cave is inclined and has a further four vertical drops ranging from five to fifteen meters giving a further elevation loss of around 150m.

After the Crystal Lake, a boulder section for one hundred meters leads to a ten-meter drop. From this drop, a meander connects to a small room containing the gour basins. A small stream on the left runs towards the end of the cave; sometimes it is visible and sometimes it disappears between the rocks. The room connects to a crawl section before opening to a large room (100m wide and 50m high). The floor of the room is covered with very slippery boulders. The room narrows and the roof drops to form another crawl passage for approximately fifty meters leading to the next vertical drop. This drop leads to another meander that connects to the final vertical pitch. A chamber opens up to a large room similar in size to the pervious room. This room appears not to have any passages leading out. But it leads to small pond with a solid rock bottom; a feature known as a "Cave Table". Water must drain here somewhere, but it is not obvious where, maybe through a number of small cracks. An altimeter reading of 1120m was taken, suggesting the cave is about 330m deep and possibly up to 3km long.

Al Khishil Cave is important in terms of size and diversity. Future exploration should try to get more surveyors into the deeper parts of Al Khishil Cave.

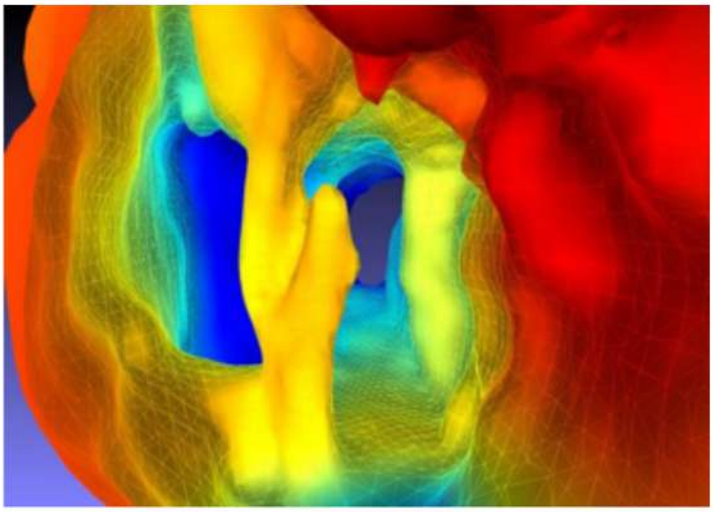

Figure 8: 3D Scan of the Fork, made with Scans Sweep 3D Scanner. Width is about 4m.

Al Naqqah Cave

While exploring the area around the Hail Al Hareen Village,the local people in the village (Kahmis Al Handhali and Mahmoud Al Handhali) guided 6 Omani cavers to the entrance of Al Naqqah Cave. The cave is known as a landmark in the area, where many shepherds take their goats.

To reach the cave entrance, one needs to hike for about half an hour, along well-established hiking routes. The cave's relatively-accessible entrance ends with a pitch of 25m vertical depth (P3 in Figure 4) that apparently has not been abseiled before. The cave continues for about 40m, before getting to a number of ditches and cracks, some of which are decorated by different speleothems. P4 is relatively difficult to get through as it requires significant squeezing while attempting to abseil. The cave gets more humid and muddy beyond P4. A simple sketch of the cave was done during the visit on the 22nd of September, 2017 (Figure 9). Further mapping and exploring needs to be done to find other routes and possible extensions.

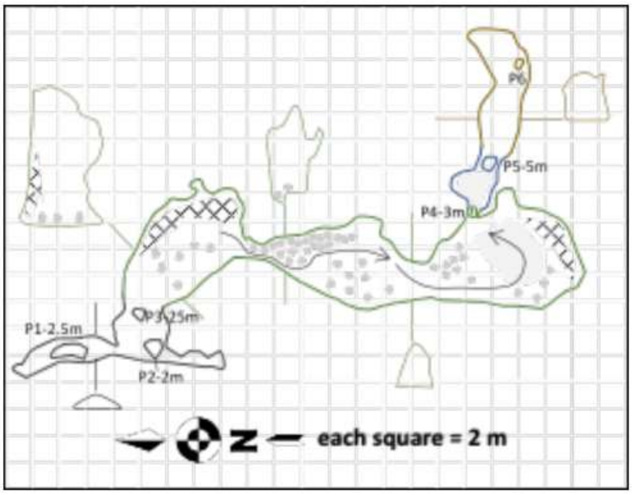

Figure 9: Rough and preliminary sketch of Al Naqqah cave, with a map view and cross sections, showing the different parts of the cave, made during the first scouting trip in the cave.

Figure 10: The surface entrance, main pitch (pitch 3) and some stalactites in the Al Naqqah Cave.

Al Fiqu Cave

The Al Fiqu Cave is located about half a kilometre on the north-eastern side of Hail Al Hareem Village. This cave is important for its impressive flowstone decorations. This cave, at 47m depth, is small compared to other caves in the area, but is technically challenging to enter due to a lack of stable rocks around the entrance. The speleothems extend from just below the surface to the cave floor (150m) in huge flowing formations.

Figure 11: The surface entrance and some beautiful decorations in the Al Fiqu Cave.

Naming the caves

The naming of important geological features is a controversial topic. In a discussion with Mohammed Al Kindi and Simon Cahill, Mikolaj Zielinski said that it is important that correct names are researched and used. The highest mountain on Earth was named Everest in honor of the British surveyor George Everest. Africa's largest lake was named Victoria after England's Queen Victoria. Yet to the local people the highest mountain on Earth already had names; Tibetans call it Chomolungma and the Nepalese call it Sagarmatha. Africa's largest lake was called Nam Lolwe or Nalubaale I in local languages. With the ease of travel today, communication and information databases, there is no excuse for not doing the necessary research and finding correct names. Simon Cahill said "the first person to allegedly discover or explore an important geological feature should not feel they have the right to name it freely as they wish. It is for this reason the names used above should be the ones the caves are known by.

Contributors to the work

Exploring caves takes a huge commitment by many people. A large technical and potentially dangerous cave such as Al Khishil Cave makes the task even more challenging. Exploration and documentation requires fit strong teams with a wide range of skills, knowledge and specialist equipment. More than 20 people have been involved in the exploration to date.

Special acknowledgment goes to; Tim Harrison for posting the photograph that lead to the exploration. Simon Cahill for research and leading the initial exploration teams, Blair Hoover for being there all the way through and supporting in every possible way, Christopher Pike for taking the lead on bolting the entrance pitch, Alan Goddard (Australia) & Rayan (Lebanon) for being strong members of the early push and rigging teams, Toufic Nader for pushing beyond what anyone else has been able to do so far and reaching the bottom of the cave, Hergan Meyer for going out his way to crunch Blair's data and then join the team to get a centre line survey in one day, Paul Emous for taking photographs & scans in an extremely challenging environment, Mikolaj Zielinski for making himself available for almost every trip and hauling bags of kit when the old guys got tired.

Hassan Ibrahim Almaeeni (United Arab Emirates) for being a strong push team member and communicating with the local villagers to locate Al Fiqu Cave, Mohammed Al Kindi for consultation with the local population, leading the first exploration team to Al Naqqaah Cave and providing background geological information.

Those cavers not mentioned know who you are and you are thanked for your time and participation. The cavers who contributed to the exploration of the Al Naqqah Cave are Nabil Al Zakwani, Nasser Al Riyami, Nabil Al Saqri, Khalifa Al Jamoudi and Hamad Al Zakwani. A special thank you goes to the local residents for their kindness and for guiding us to two of the caves. The villagers have been welcoming and helpful and shown an interest in the exploration.

Main photographs: Paul Emous (Al Khishil Cave), Toufic Abou Nader (Formation close ups) and Mohammed Al Kindi (Al Naqqah Cave and regional photographs)

The Al-Hajar Mountain Range

Influences and Sustains Oman's Water Resources

Written by: Dr. Othman Abdalla, Earth Sciences Department, SQU

The Sultanate of Oman is characterized by a fascinating mountain range: Al Hajar that extends for about 700 km from Musandam Peninsula in the north to Ras Al Hadd in Al Sharqiyah Governorate in the southeast. Wadi Samail divides the Al Hajar Mountain range into two main sections: Al Hajar Al Gharbi (western Hajar) and Al Hajar Ash Sharqi (eastern Hajar). This mountain range, driven by its natural diversity, has always attracted the attention of geologists, environmentalists, biologists among others for exploration and scientific investigations. It has also played a major role in Oman's water resources, which will be explored and presented in this paper.

The highly elevated Al Hajar Mountain Range (HMR) separates a narrow low-lying coastal strip of the Batinah from the desert plain of Oman's interior; thus, forming a remarkable water divide. The crest of the mountain range divides surface water to flow along wadis into either the Batinah plain to the north or the desert to the south. In the subsurface, groundwater also mimics the flow pattern of the surface water and discharges either into the sea or evaporates in the desert, forming sabkha and/or shallow water table.

The mountain range consists of different rock types, but the most important ones from the hydrogeological perspective are the ophiolites and the carbonates of the Hajar Super Group (HSG).

• Precipitation

In Oman, the main moisture sources are either from the south (Indian Ocean and the Arabian Sea) or from the north (North Atlantic or the Mediterranean Sea). This is confirmed by the isotopic characteristics of these two sources (Abdalla et al. 2016). The Al Hajar Mountain Range (HMR) drives the mechanism of precipitation in north Oman. As soon as the vapor carrying winds, from either the north or the south, reach the HMR it will rise up because of the elevated mountain's topography. As temperature drops with elevation, the dew point at which the vapor condenses, will be reached and rain will start to fall. Therefore, the HMR marks the area of the anomalous rainfall in Oman, and hence represents the main source for groundwater recharge.

• Groundwater recharge and age

The natural recharge to groundwater basin is fundamental to sustain water resources, form hydraulic gradient and drive the dynamics of groundwater. Many arid areas with a present hydraulic gradient may have developed such gradient in ancient time due to recharge that took place during pluvial periods. Such groundwater is fossil and its extensive exploitation endangers the resources. Oman's groundwater shows variation in age from modern to old, as indicated by groundwater dating. The carbon-14 dating method reveals groundwater age exceeding 30,000 years (i.e. formed during Pleistocene Epoch) in some areas in the interior of Oman, such as "Fahud and Qurn Alalam. However, tritium and helium dating indicate younger groundwater around the HMR, thus assuring its role as a source of modern recharge. The age of Omani groundwater ranges from old to modern (30000 years to recent), depending on the depth and location with reference to HMR. Older groundwater is found in the low-lying desert areas that were covered with lakes a few thousands years ago. Recent groundwater modeling conducted for Wadi Al-Faraa in the Batinah region (Amerjeed, 2017) has shown that recharge flux from the upper catchment (highland) to the coastal zone is a major contributor (12 MCM/yr) to the groundwater resources of the Batinah. The subsurface lateral flow from the HMR through its fracture systems is the primary source of recharge to the coastal plain that relatively sustains the hydrological system and contributes to agricultural stability.

How the HMR affects the groundwater chemistry?

It is well observed that the dissolved ions in Oman's groundwater resources tend to increase progressively as one goes away from the mountains. The recharge induced by the mountains brings fresher water resources to the groundwater system and establishes a hydraulic gradient that drives the groundwater flow into the plain basinal areas. As its flow is naturally slow, groundwater remains in contact with the hosting rocks for prolonged periods, leading to minerals dissolution and consequently increasing salinity along groundwater flow path. Therefore, groundwater in Oman shows an increasing salinity from the mountains into the desert plain areas. The salinity of groundwater reaches higher level in the interior that deems these resources unsuitable for all kinds of water use. Abdalla et al (2016) used geochemical and isotopic tools to understand the geochemical evolution of groundwater in the ophiolite and HSG aquifers of the HMR. They found that the groundwater in the HSG aquifer is highly affected by carbonate minerals dissolution, whereas the dissolution of Mg-bearing silicate minerals in the ophiolite groundwater highly controls groundwater geochemistry. Mixing of the HSG and ophiolite groundwaters is indicated as groundwater evolves from Ca to Mg dominant in the ophiolite aquifer associated with slight increase in the pH that enhances the dissolution of Mg-bearing minerals (brucite and serpentine).

• Karstification in the HMR and the Offshore Springs Discharge

Karstification is a geological process that is observed in carbonate rocks when they get in contact with water. The groundwater circulation in the carbonate rocks will lead to dissolution of the carbonate minerals, namely calcite and dolomite, to release carbon dioxide and form holes and cavities in the carbonate rocks. A prolonged contact of water with these rocks will eventually lead to the formation of caves, conduits and sinkholes that enhance secondary porosity of aquifers and thus groundwater storage and transmissivity. These conduits control groundwater flow and occurrence.

The HMR is famous of these karstification structures (e.g. Bimmah sinkhole, plate 1)

Plate 1: Bimmah Sinkhole: shows the dissolution of carbonate rocks to form the hole and accumulation of the water within the hole.

especially in the Eastern Al Hajar Mountains that is located between Quriyat and Sur. In that region, fresh groundwater discharges into the ocean to form offshore springs that enhance marine biodiversity and ecology. In addition, natural springs discharge along the slopes of the HMR due to karstification also enhances the ecological system at the terrestrial side and provides local water supply. The Dayqah Dam demonstrates the importance of the HMR in supplying freshwater. The springs discharge from the carbonate rocks of the eastern HMR is impound and collected via the dam to yield a major water reservoir (Plate 2).

Plate 2: Dayqah Dam is constructed with the eastern HMR surrounded by carbonate rocks. The phot shows the reservoir of the dam filled with freshwater.

The karstification of carbonate rocks due to groundwater circulation in the HMR also form fascinating caves such as Al Hoota Cave that attracts tourism. These caves, conduits and holes are the main receptors of rainfall in the elevated mountains and therefore enhance recharge and play a major role in connecting carbonate rocks with neighboring ophiolites and tertiary rocks.

• Aflaj and Springs

The aflaj (plural of falaj which means channel to convey water) is an ancient technique used to deliver water to different areas. The Omanis have invented a pioneer system to manage and share the water resources of aflaj. We think of aflaj (Dawoodi aflaj) as a horizontal well that intercepts groundwater along mountains' slopes and uses gravity for water transport. Without the mountain slope of the HMR, the establishment of the widely spread Dawoodi aflaj (Plate 3) around the mountain range would not have been possible.

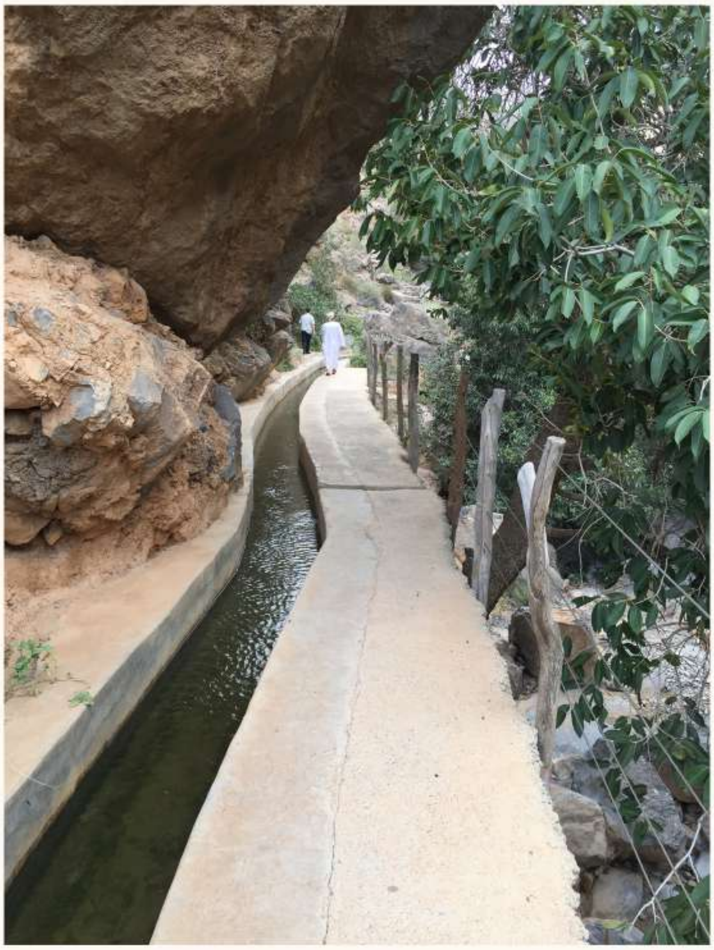

Plate 3: The falaj of Misfat Al-Abreen flowing along the western HMR.

In addition, the springs that form along bedding planes, fractures, faults and karstification conduits provide an optimum environment for natural spring formation that are also used by the Omanis to construct aflaj (Ain aflaj). Such aflaj and springs are well observed along the contacts between the HSG and ophiolites and along the fractures and faulting zones.

• Al Hajar mountains and surface water dams

The relatively high precipitation / low evaporation in the HMR, rock terrains and narrow grooves and wadis formed in the plateau of the HMR furnish suitable environment to construct relatively smaller surface water dams as opposed to the low-lying plains of the Batinah and Oman's dessert where precipitation is minimum, evaporation is high and soil is permeable. Although these dams are small, they were able to contribute significantly to the agricultural demand and partially cover the domestic needs. Many locals also use drums and underground reservoirs to collect rainwater from the gutters at edge of the roofs, which are connected by pipes or hoses (Al-Amri and Abdalla 2014).

• Blue Pools in the HMR

Groundwater circulates and presents in the ophiolites, especially the mantle sequence, tends to have elevated pH (the negative logarithm of ion hydrogen concentration) that in most cases exceeds nine and sometimes reaches thirteen. Under subsurface condition, when no adequate oxygen is available, such groundwater will contain dissolved calcium. The outflow of such groundwater in the form of springs via fractures, faults and bedding planes will expose it to oxygen and atmospheric carbon dioxide. The exchange with atmospheric oxygen will lower the pH of the water, whereas the exchange with the atmospheric carbon diox ide followed by a reaction with the dissolved calcium will lead to the deposition of the mineral calcite under the low pH. The collection of these waters in pools will accumulate relatively thicker calcite deposits at the bottom of the pool. Such calcite deposits will reflect the sunlight falling on water to form a distinctive blue color; hence, the name blue pools is driven. The blue pools are found close to the foothills of the HMR and they are popular touristic destinations and may offer natural medicinal treatment.

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A New Fossil Site of Highly Diverse Ichno-fauna in the Deep-Sea Deposits of Hamra Duru Group in Wadi Hibi, North Oman

Mohammed Al Kindi, Majid Al Miqbali and Yousuf Al Sinani

Trace fossils are important geological indicators of the environment and depositional setting. They have often been used to indicate the depth of sea water in which they were formed. This is because of their sensitivity to water depth, temperature, water energy, salinity and sedimentary setting. In general, vertical traces of organisms form in shallow seas and horizontal ones develop in deep seas. The study of trace fossils is known as ichnology and a certain assemblage of trace fossils is known as ichnofacies or ichnofauna. For example, Skolithus ichnofacies normally indicate shallow seas and tidal flats, whereas Cruziana traces are most likely produced in mid to distal sea shelves.

Nereites ichnofacies represent a group of trace fossils that mostly form in deep-sea sedimentary fans along the base of slope of turbidity systems. They are thought to be a product of grazing trails of possibly worms that live in deep seas and abyssal zones. Different forms of Nereites ichnofacies are identified, and many still need better classifications (Wetzel et al., 2007; and Monaco, 2008). One of the well-known components of the Nereites ichnofacies are the graphoglyptids, which form complex ornate forms of mostly horizontal, meandering and net-shaped tunnels used for dwelling and to trap food. Their complexity and diversity apparently increased significantly from the Triassic to Cretaceous times. During the Late Cretaceous time, graphoglyptids became suddenly highly diversified.

The deep-sea sediments of Oman contain exceptionally-rich and highly-diverse graphoglyptids trace fossils in the Late Triassic-aged turbidite sediments. These sediments were emplaced on North Oman during Late Cretaceous, together with the Ophiolite sequences. At least 15 types of graphoglyptids traces have been identified in few locations on the southern and northern sides of the Al Hajar Mountains (Wetzel et al., 2007), in places like Wadi Hibi, Wadi Sal and Al Jil (Figure 1). Two types of these graphoglyptids exhibit new features, different from previously described graphoglyptids, and hence form two new ichnogenera of graphoglyptids. Together these fossils form important assemblages from the Triassic Period, and have significantly helped to understand the diversity and climate conditions during this time period.

Figure 1: Locations of Wadi Sal, Al Jil and Wadi Hibi.

Recently, a new location of Nereites ichnofacies fossils has been found by Majid Al Miqbali in the deep-sea deposits of the lower part of the Mesozoic Hamrat Duru Group along Wadi Hibi (Figure 2). Majid is a geography teacher in Wadi Hibi. He is very passionate in finding unique geological features and fossils. While hiking in his hometown, Majid found a fossil site with very diverse trace fossils, including mostly graphoglyptid trace fossils and depositional casts by turbidites. Mohammed Al Kindi and Yousuf Al Sinani later visited the area with Majid to find and report these fossils. Most of these fossils have been identified before, but some may be new.


Figure 2: The location of the fossils' site in Wadi Hibi.

The deposits are mainly composed of well-bedded radiolarian chert, green shale and fine grained calcarenite deposits, alternating in beds of about 2cm to 15cm thickness (Figure 3).

Figure 3: The lower part of the Mesozoic Hamra Duru Group is mainly composed of alternating layers of radiolarian chert, green shale and fine grained calcarenite deposits.

The sequence is full of turbiditic scour marks and cross-lamination, most likely belonging to the upper member of the Matabat Formation; this part is also known as the Al Ayn Formation in some publications, which probably represents the Late Triassic to Early Jurassic part of the Hamra Duru Group. The diversity of deep-sea ichnofacies from Oman during the Early Mesozoic (Late Triassic) (Figures 4, 5 and 6) was probably supported by the position of Oman during that time, which was near the equator. Wadi Hibi also includes spectacular exposures of the upper extrusive crustal part of the Ophiolite sequence, including andesitic pillow lava and sheeted sills and dykes that are often capped by recent alluvium deposits (Figure 7).

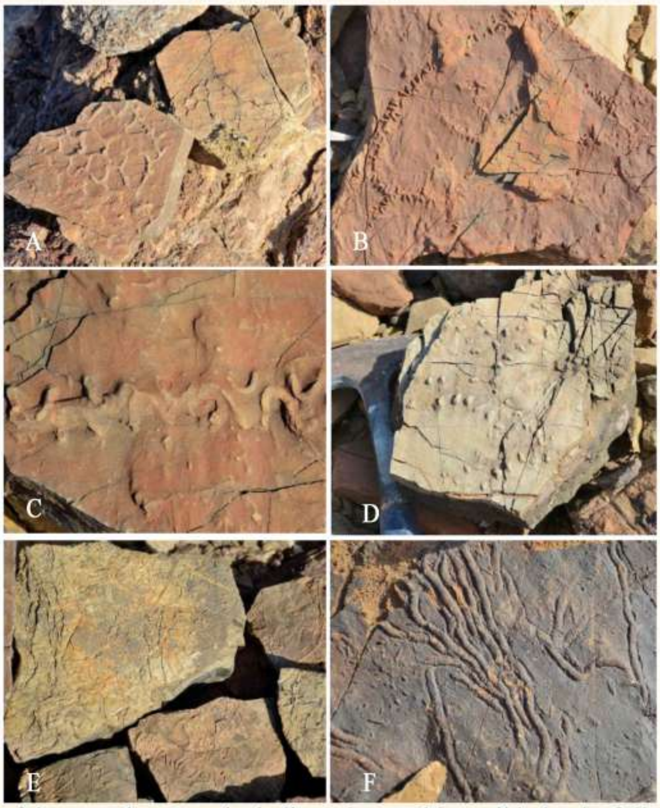

Figure 4: Various types of deep-sea burrows, including what could possibly be the following types: Paleodictyon (A), Desmograpton (B and C), Saerichnites (D), Gordia (E) and Imponoglyphus (F). The length of each burrow trace is from 5cm to 15cm.

Figure 5: Examples of deep-sea burrows we could not identify

Figure 6: Majid Al Miqbali examining one of the trace fossils in Wadi Hibi (type is not identified).

Figure 7: Spectacular pillow lavas outcrop could be seen in Wadi Hibi.

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GSO field trip summary: Facies and Fault geometries in Jebel Madar

By: Najat Al Fudhaili

On the 3rd of March, 2017, the Geological Society of Oman organized a field trip to its members to Jebel Madar led by: Dr. Mohammed Al Kindi & Dr. Ibrahim Al Ismaili. The main objective of this field trip was to recognize different facies as well as looking at the distribution of some geological geometries which are mainly fractures patterns within the lower parts of the Shuaiba and the Natih formations in Jebel Madar, in the Adam Foothills of Northern Oman, which is located in the south of the Samail Ophiolite complex, (Fig. 1). The mountain is approximately 140 km south of Muscat, where the neighboring village is Sinaw. Four stops were visited in the area.

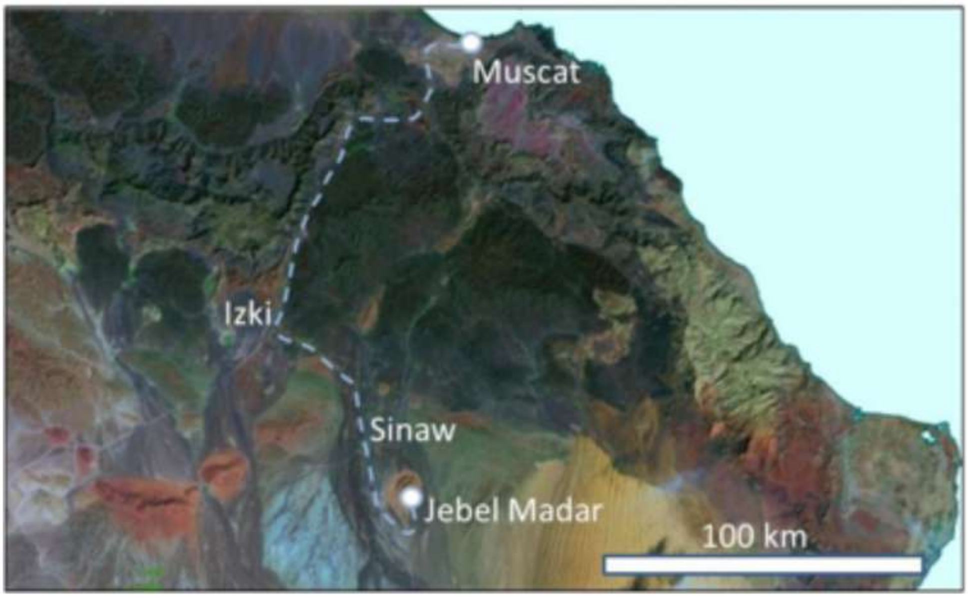


Figure1: Road map to Jebel Madar (Source: Al Kindi and Al Ismaili, 2017)

General Information

Many of prolific reservoirs in the Middle East are made of the Late Cretaceous carbonates. The Cretaceous Carbonates in the stratigraphic column of Oman are made of the Kahmah, Wasia and Aruma groups (Blake, 2017), and there are Sets of smaller subgroups (i.e. formations) within these three main groups (Fig2), in Jebel Madar, Natih and Shuaiba formations were our aimed rocks to examine. These two formations are considered as the most important carbonate reservoirs in the northern part of Oman's petroleum fields.

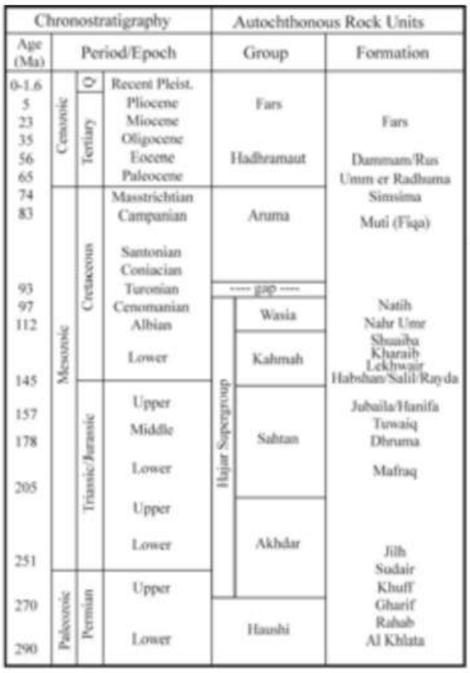


Figure 2: Stratigraphic column of Oman Mountains. Ages based on Remane at al. (2002). Modified after Glennie (1995).

Shuaiba Formation:

Deposited within the inner platform and intra-shelf basin environments and it is made of aggradational to progradational facies (Homewood et al., 2008). This formation is mainly marked by massively-bedded peloidal packstones and bioturbated bioclastic that mostly rich in Rudists, (Blake, 2017).

Natih Formation:

Made up of interfingering carbonate platform and intra-shelf basin deposits. The facies are aggradational, and the formation contains internal progradational facies, which were deposited in the intrashelf basins, (Blake, 2017). It is divided to seven members (i.e. Natih Members A-G) and in Jabal Madar the Natih E forms a big cliffs and a significant fault was visible where at stop 1.

Data and discussion

Stop 1 (Geological setting and tectonic evolution):

Discussion started with talking about the main structural elements of the northern part of Oman, focusing on the paleo-salt Basins; the Ghaba Salt Basin and Fahud Salt Basin with Makarim High in between. The Ghaba Salt Basin is unique, because the salt within, and because of its viscous characteristics, has been compressed and deformed significantly to move upwards to form salt intrusions (i.e. diapers), resulted in the formation of more salt-related basins and domal structures (i.e. mountains).

Jebel Madar is a unique example, because it was formed by salt movement but the salt does not appear on the surface, which means that the whole amount of salt that comes from the subsurface didn't reach the surface during the salt dome formation, but the faults geometries on Jebel Madar are indicative of salt movement related faults.

Stop 2 (Shuaiba Formation rock facies and fractures geometries):

Discussion at this stop was focused on the importance of the facies distribution, the fractures patterns and the properties of the reservoir in Shuaiba Formation. During the Shuaiba Formation deposition, the area went through a set of changes, including variation in sea level that led to the occurrence of different organisms that were later preserved as fossils. An example of these fossils is Rudist. The Rudist-rich Rudstones (i.e. carbonate rocks that are rich of fossils that are more than 2mm in size which were preserved in the rock after they grew mostly vertically in the marine environment) (Fig.3) are common in Shuaiba Formation and these rocks form good reservoir for hydrocarbons and water, because they tend to have good permeability and the porosity.

Figure 3: Rudstones in Shuaiba Formation

The fractures are closely spaced in the outcrop, forming what is known as fractures corridors, and the can be seen through the cliffs of Jebel Madar, (Fig.4). These corridors are also common in the subsurface and they can be defined from wireline logs as small zone that cut through the whole log from the top to the base during the drilling. The rudstones facies seems to control the distribution of the fractures and faults (i.e. fractures along which rocks are displaced). In fact, these fractures and faults were fast paths for the fluids in the reservoir to migrate and knowing the precise place of these fractures will allow the dynamic reservoir simulation to give consistent outcomes.

Figure 4: Two fracture corridors, spacing is about 50m, at top Shuaiba. (Source: Al Kindi and Al Ismaili, 2017)

Figure 5: Overview of the Natih, Nahr Umr, and Shuaiba formations in one of the locations in Jebel Madar. (Source: Al Kindi and Al Ismaili, 2017)

Sur Chert

These sedimentary rocks are composed of chert layers and were deposited in deep ocean.They were buckled into wonderful zigzag folds.

Photo by: Husam Salim Al Rawahi

صخور الصوان في صور

ترسبت هذه الصخور الرسوبية المكونة من صخور الصوان في أعماق المحيطات، ثم تجمعت لتشكل هذه التعرجات والانحناءات الرائعة.

بعدسة : حسام سالم الرواحي

شكل ٣: فلج مسفاة العبريين في الجانب الغربي من سلسلة جبال الحجر

المراجع:

Abdalla، O.، Abri، R.A.، Semhi، K.، Hosni، T.A.، Amerjeed، M.، Clark، I.، 2016. Groundwater Recharge to Ophiolite Aquifer in North Oman: Constrained by Stable Isotopes and Geochemistry. Environmental Earth Sciences، 75 (15). DOI: 10.1007/s12665-016-5887-8

Al-Amri، S. and Abdalla، O.، 2014. Innovative Rainwater Harvesting in Arid Areas: Jabal Al Akhdar Region. International Seminar on the Use of Unconventional Water in Urban Water Management، February 2014، Muscat، Sultanate of Oman.

Aamerjeed، M.، 2017. Groundwater Flow Modeling with Emphasis on Recharge Estimation in Hardrock-alluvium Al-Fara Catchment، Oman: Comparison of WTF، CMB and Modeling Methods. PhD thesis، Sultan Qaboos University، Oman.

شكل ٢: سد وادي ضيقة في الجانب الشرقي من سلسلة جبال الحجر محاط بالصخور الكلسية وممتلئ بالمياه

الأفلاج والينابيع:

يعد نظام الأفلاج من الأنظمة القديمة المستخدمة في سلطنة عمان لتوصيل المياه الجوفية إلى المناطق المختلفة. حيث ابتكر العمانيون أنواع مختلفة من الأفلاج ومن ضمنها الأفلاج الداؤودية والتي هي عبارة عن آبار أفقية يتم بناءها على منحدرات الجبال بحيث تقطع مجرى المياه الجوفية وتعتمد على قوة الجاذبية الأرضية في دفع المياه وتوجيه حركتها في قنوات الأفلاج. أما بالنسبة للينابيع، فيتحكم في جريانها توزيع الطبقات الصخرية والصدوع وتشكيلات الكارست. كما يقوم العمانيون بإنشاء بعض الأفلاج على مقربة من الينابيع، في المناطق التي تكثر فيها الصدوع والشقوق بين صخور الأفيوليت ومجموعة صخور الحجر الكلسية الضخمة، والتي تعرف بأفلاج العين.

جبال الحجر ومياه السدود:

يهيئ التوزيع الجغرافي لسلسلة جبال الحجر في شمال عمان، حيث تكثر نسبة الأمطار وتتوزع مجاري الوديان الضيقة، الظروف الملائمة لإنشاء السدود المائية مقارنة بالمناطق الساحلية المنبسطة في الباطنة والمناطق الصحراوية والتي تعاني من نسب تبخير للمياه بشكل كبير بالإضافة لقلة هطول الأمطار. وبالرغم من صغر حجم هذه السدود، إلا أنها تساهم بشكل كبير في تلبية احتياجات قطاع الزراعة كما أنها تغطي بشكل جزئي احتياجات الاستخدامات المنزلية (شكل ٢).

الأحواض الزرقاء في سلسلة جبال الحجر:

تتميز المياه الجوفية الموجودة في صخور الأفيوليت، خاصة المياه الموجودة في طبقة صخور القشرة الداخلية (Mantle)، بارتفاع نسبة القلوية والتي تتجاوز ٩ في مقياس pH. تساهم هذه المياه في باطن الأرض ومع عدم توافر الأوكسجين في إذابة معدن الكالسيوم. عند صعود هذه المياه إلى سطح الأرض عن طريق الصدوع والشقوق وطبقات الصخور على شكل ينابيع، تتفاعل مع الأوكسجين وثاني أكسيد الكربون الموجودين في الهواء مما يؤدي إلى ارتفاع حامضية المياه وترسيب معدن الكالسيت في أحواض. تنعكس أشعة الشمس الساقطة على سطح الماء وبعد ارتطامها بسطوح معدن الكالسيت لتشكل ألوان زرقاء مميزة وتسمى الأحواض الحاوية لها بالأحواض الزرقاء. تتواجد هذه الأحواض على مقربة من سفوح سلسلة جبال الحجر وتعد مزارا سياحيا مشهورا بالإضافة لإمكانية استخدامها في العلاج الطبيعي.

في دراسة أجراها د. عثمان عبدالله ومجموعة من الباحثين في عام ٢٠١٦، لمحاولة فهم تطور التركيب الجيوكيميائي للمياه الجوفية في صخور الأفيوليت ومجموعة صخور الحجر الكلسية الضخمة التي تشكل سلسلة جبال حجر عمان، أظهرت الدراسة أن المياه الجوفية في مجموعة صخور الحجر الكلسية الضخمة تتميز بوجود كميات كبيرة من المعادن المذابة الغنية بالكالسيوم. في المقابل، فإن المياه الجوفية في صخور الأفيوليت تحتوي بشكل كبير على معادن السيلكا الغنية بعنصر الماغنيسيوم. في المناطق التي يختلط فيها هذين النوعين من المياه الجوفية، يتدرج تركيز كلا من عنصري الكالسيوم والماغنيسيوم مما يؤثر على مدى حامضية الوسط، وبالتالي على معدل الإذابة لبعض المعادن مثل معدني السربنتين (Serpantine) والبروسايت (Brucite) الذين يكثر تواجدهما في صخور الأفيوليت.

تشكيلات الكارست في سلسلة جبال الحجر وتفريغ الينابيع في المصبات البحرية:

تنشأ تشكيلات الكارست (karstification) نتيجة إذابة معادن الكالسيت والدولومايت في الصخور الكلسية عن طريق تفاعلها مع المياه الجوفية. ينتج عن هذا التفاعل إطلاق غاز ثاني أكسيد الكربون وتكوين فجوات وفتحات في الصخور الكلسية والتي بدورها تتحول إلى كهوف كبيرة وقنوات مع استمرار عمليات الإذابة. تشتهر سلسلة جبال الحجر بوجود العديد من تشكيلات الكارست، خاصة في الجانب الشرقي بين صور وقريات ومثال ذلك هوية نجم (شكل ١). في هذه المنطقة تصب المياه الجوفية بعد خروجها من الجبال الكلسية عن طريق تشكيلات الكارست في مياه البحر على شكل ينابيع تسهم في تنوع الحياة البحرية البيولوجية والبيئية. كما أن جزء من هذه الينابيع يصب في أسفل منحدرات سلسلة جبال الحجر في الأراضي المنبسطة موفرا مصدر مياه للسكان المحليين. مثال على ذلك مياه الينابيع التي يتم تجميعها في الجانب الشرقي من سلسلة جبال الحجر عن طريق سد وادي ضيقة (شكل ٢). ويعد كهف الهوتة الذي يستقطب العديد من السياح في محافظة الداخلية مثال آخر على تشكيلات الكارست.

شكل ١: ذوبان الصخور الكلسية بفعل المياه الجوفية لتكون الحفرة المعروفة ب «هوية نجم».

سلسلة جبال الحجر وتأثيرها على موارد المياه في سلطنة عمان

كتبه: د. عثمان عبدالله، قسم علوم الأرض، جامعة السلطان قابوس

تتميز سلطنة عمان بوجود سلسلة جبال الحجر العجيبة والتي تمتد لمسافة ٧٠٠ كم من شبه جزيرة مسندم في شمال عمان إلى رأس الحد في محافظة الشرقية في الجزء الجنوبي الغربي من السلطنة.

تنقسم سلسلة جبال حجر عمان إلى قسمين على جانبي وادي سمائل: سلسلة جبال الحجر الشرقي وسلسلة جبال الحجر الغربي. وتتميز كلتا السلسلتين بتنوع طبيعي شكل عامل جذب للدارسين في مجالات الجيولوجيا وعلوم البيئة والأحياء ومحبي الاستكشاف للقيام بالدراسات العلمية. كما تؤثر هذه السلاسل بشكل أساسي في توفر وتوزيع موارد المياه في السلطنة.

تفصل سلسلة جبال حجر عمان بإرتفاعاتها الشاهقة خط الباطنة الساحلي الضيق في الشمال عن الصحراء الممتدة داخل عمان وهي بذلك تشكل فاصلا طبيعيا يؤثر في توزيع المياه السطحية في كلا الجانبين. بالمثل يتبع توزيع المياه الجوفية على جانبي سلسلة جبال الحجر توزيع المياه السطحية. فقسم منها يصب في مياه البحر وقسم منها يصب في الأحواض الصحراوية ويتبخر مع مرور الزمن مؤديا إلى تكون سبخات أو مياه جوفية ضحلة العمق. تتألف سلسلة جبال حجر عمان من أنواع مختلفة من الصخور، غير أن صخور الأفيوليت ومجموعة صخور الحجر الكلسية الضخمة تعتبر من أهم أنواع الصخور لما لها من تأثير على الغلاف المائي في المنطقة.

الأمطار:

تظهر الدراسة القائمة على العناصر المشعة المستقرة (Stable isotopes) التي أجراها د. عثمان عبدالله ومجموعة من الباحثين في عام ٢٠١٦، أن كلا من المحيط الهندي وبحر العرب في الجنوب والمحيط الأطلسي والبحر الأبيض المتوسط في الشمال يعتبران من أهم مصادر الرطوبة التي تسهم في نزول الأمطار في سلطنة عمان خلال العام. وتتحكم سلسلة جبال حجر عمان في تشكل السحب في شمال عمان، حيث تتكثف السحب حول هذه الجبال على ارتفاعات عالية وفي درجات حرارة منخفضة مؤدية إلى نزول الأمطار وتجمع المياة الجوفية.

المياة الجوفية وأعمارها الجيولوجية:

تعتبر التغذية الطبيعية لأحواض المياه الجوفية عملية أساسية للحفاظ على موارد المياه، شريطة أن يتوفر الإنحدار المناسب الذي يساعد على حركة المياه من الأماكن المرتفعة إلى المناطق المنخفضة. وقد يختلف معدل الإنحدار بمرور الزمن خلال الفترات الماطرة المختلفة. ويمكن الاستدلال على هذا الاختلاف في معدل الانحدار بواسطة حساب العمر الجيولوجي للمياه الجوفية التي ترسبت بفعل تساقط الأمطار في فترات زمنية مختلفة باستخدام عنصر الكربون-١٤ المشع (C١٤). حيث أثبتت الدراسات أن عمر المياه الجوفية في بعض المناطق في عمان مثل فهود وقرن علم يتعدى ٣٠٠٠٠ سنة. بالمقابل فإن بعض المناطق حول سلسلة جبال الحجر تحتوي على مياه جوفية ذات عمر جيولوجي أقل بكثير كما تشير الدراسات القائمة على كلا من عنصري التريتيوم والهيليوم. على هذا فإن عمر المياه الجوفية يختلف على حسب عمقها وبعدها عن سلساة جبال الحجر. وتشير الدراسات إلى أن المياه الجوفية في المناطق الصحراوية البعيدة عن جبال الحجر هي الأقدم عمرا.

وقد وضحت دراسة دكتوراه أجريت في عام ٢٠١٧ في جامعة السلطان قابوس، أن مياه الأمطار التي تتغلغل خلال الصدوع والشقوق في سلسلة جبال الحجر تسهم في زيادة المياه الجوفية على سواحل الباطنة بمعدل ١٢ مليون متر مكعب في السنة، مسهمة بذلك في توفير الاستقرار لقطاع الزراعة.

كيف تؤثر سلسلة جبال الحجر على التركيب الكيميائي للمياه الجوفية؟

تعد حركة المياه الجوفية عبر الصخور من المناطق الشديدة الانحدار إلى المناطق المنبسطة حركة بطيئة نسبيا، تكون الصخور خلالها في تفاعل مستمر مع المياه. ينتج عن هذا التفاعل إذابة للمعادن المختلفة في الصخور وزيادة نسبة ملوحة المياه الجوفية كلما زادت المسافة بعيدا عن قمم الجبال بتأثير انحدار هذه الجبال حتى تصبح هذه المياه غير قابلة للاستخدام، خاصة في المناطق المنبسطة داخل عمان.

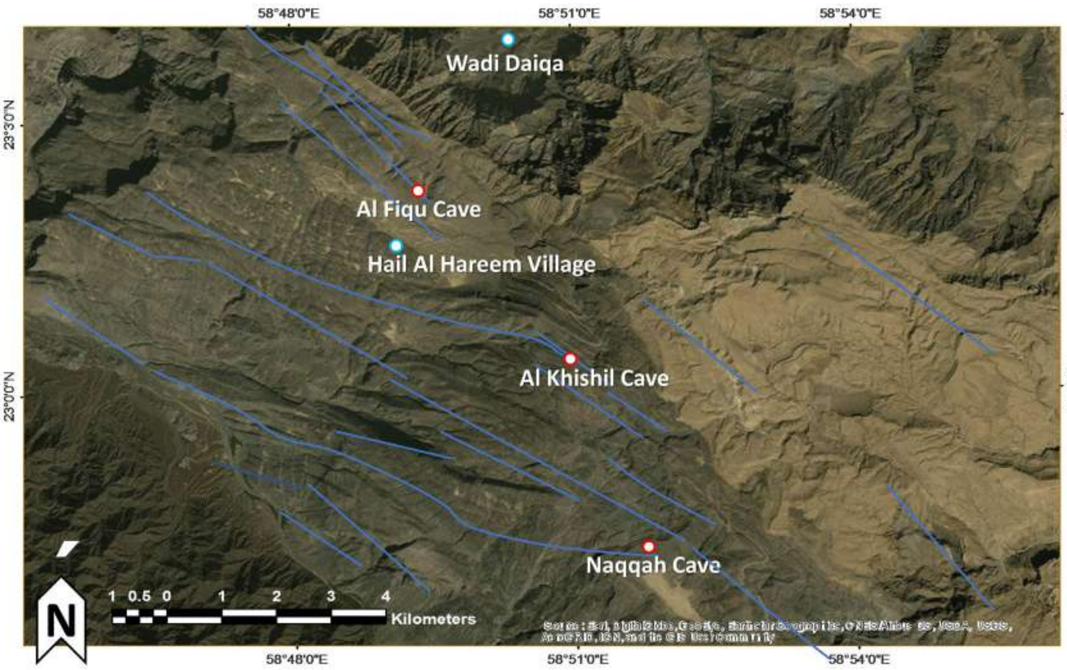
ويعـد كهـف النقـاح معلـما معروفـا لـدى أهـل القـرى المجـاورة، لكـن أحـدا لم ينـزل إلى باطنـه مـن قبـل فيـما يبـدو. والوصـول إلى الكهـوف يتطلـب المـشي لمسـافة نصـف سـاعة تقريبـا مـن الشـارع الـترابي للوصـول إلى فتحتـه العلويـة، وفتحتـه العلويـة تنتهـي بمنحـدر عمـودي عمقـه ٢٥ مـترا، ويمتـد الكهـف لعـشرات الأمتـار داخـل الجبـل. وبـه مجموعـة مـن التشـكيلات الجميلـة، قبـل أن ينتهـي بمجموعـة مـن الشـقوق والخنـادق والـبرك المائيـة الصغـيرة (شـكل ٤).

شكل ٤: مدخل كهف النقاح وبعض المعالم داخل الكهف مثل تراكيب النوازل

أمـا كهـف الفقـع فهـو يقـع عـلى بعـد حـوالي نصـف كيلومـتر عـلى الجانـب الشـمالي الشرقـي مـن قريـة حيـل الحريـم، في أعـلى الجبـال الجنوبيـة المحيطـة بـوادي ضيقـة. ويبلـغ عمـق الكهـف نحـو ٤٧ مـترا ويتطلـب النـزول العمـودي بالحبـال، علـما بـأن سـطحه لا يوجـد بـه أماكـن مناسـبة لربـط الحبـال أو صخـور قويـة ومتماسـكة لثقبهـا، مـما يتطلـب جهـدا فنيـا مضاعفـا لتأمـين الحبـال قبـل النـزول إلى الكهـف. ولا يحتـوي الكهـف عمومـا عـلى امتـدادات شاسـعة في داخلـه لكـن جدرانـه تـزدان بمجموعـة مـن الترسـبات الكهفيـة الجميلـة (شـكل ٥).

شكل ٥: مدخل كهف الفقع وبعض التراكيب الجيولوجية العجيبة داخل الكهف

وتعد هذه الاكتشافات في مجملها دليلا على احتمالية وجود مجموعة من الكهوف الكثيرة التي لم تكتشف حتى الآن سواءً في محيط جبال الحجر الشرقي أو غيرها من جبال عمان، علما بأن الفريق العماني لاستكشاف الكهوف مرتبط بوزارة السياحة والجمعية الجيولوجية العمانية.



شكل ٢: خارطة توضح موقع الكهوف الثلاثة المكتشفة: كهف الخشيل (KhishilAl Cave) وكهف النقاح (Naqqah Cave) وكهف الفقع (FiquAl Cave)

شكل ٣: إحدى البحيرات الجميلة داخل كهف الخشيل

اكتشاف كهوف جديدة

بين جبل سيح حطاط والجبل الأبيض

كتبه: د. محمد الكندي

تتميز جبال الحجر الشرقي بسلسلتين جبليتين رئيسيتين، هما جبل سيح حطاط وما يعرف بالجبل الأبيض. ويمثل جبل سيح حطاط خط متعرج كبير متآكل من الداخل بعمق بسبب عوامل التعرية والعوامل التكتونية، ويمتد هذا الجبل لمسافة ٨٠ كم × ٥٠ كم، من ولايتي السيب ومسقط في الشمال الغربي إلى ولايتي دماء والطائيين وقريات في الجنوب الشرقي. في حين يمتد الجبل الأبيض من قريات ودماء والطائيين وينتهي بالقرب من ولاية صور، لمسافة يبلغ طولها الإجمالي نحو ٧٠ كيلومترا. تتكون المنحدرات المتاخمة لجبال سيح حطاط بشكل رئيسي من كربونات رمادية تعود لحقبتي الحياة القديمة والمتوسطة، في حين يتكون الجبل الأبيض أساسا من تسلسل الصخور الجيرية الصفراء التي تعود للعصر الثالث. تتلاقى السلسلتان الجبليتان بالقرب من وادي ضيقة، ويمكن رؤية النتوءات من كلتى المجموعتين من الصخور حول بعض القرى في هذه المنطقة (الشكل ١)، على سبيل المثال قرية حائل الحريم.

في الأشهر الأخيرة، قام مجموعة من مستكشفي الكهوف باستكشاف مجموعة من الكهوف الجديدة في المنطقة ومسحها، ويمكن أن يكون أحدها أعمق كهف معروف في عمان، وتوثق هذه المقالة نتائج المسح الأولية وتاريخ استكشاف هذه الكهوف. ويسلط المقال الضوء على إمكانية إيجاد المزيد من القنوات الكهفية والأغوار في المنطقة، والعلاقة بين موقع هذه الكهوف والخصائص الجيولوجية الرئيسية.

شكل ١: جبال كربونات رمادية اللون تعود للعصر المتوسط في سلسلة جبال سيح حطاط وجبال العصر الثلاثي الجيرية الصفراء اللون في الجبل الأبيض بالقرب من قرية حائل الحريم. القياس العرضي للمنظر في الصورة ٤٠٠ م تقريبا

قام مجموعة من المستكشفين والسكان المحليين بالتنسيق مع الفريق العماني لاستكشاف الكهوف بسبر أغوار مجموعة من الكهوف التي لم تكتشف بعد في محيط قرية حيل الحريم بولاية دماء والطائيين. وأسفرت هذه الجهود عن استكشاف ثلاثة كهوف جديدة ومسحها. وأطلق على هذه الكهوف أسماء كهف الخشيل وكهف النقاح وكهف الفقع (شكل ٢)، وهي جميعها أسماء محلية يستخدمها أهل القرى المجاورة لوصف هذه الفتحات الجبلية العميقة التي لم يتم النزول إليها من قبل.

وقد يكون كهف الخشيل أعمق كهف مكتشف في عمان حتى الآن، إذ يتوقع أن يزيد عمقه عن ٤٠٠م تحت سطح الأرض. هذا الكهف الضخم يقع على بعد نحو ٧ كم من قرية حيل الحريم، على طول الطريق المؤدي إلى ما يعرف بالجبل الأبيض، وهو يحتوي على مجموعة من البرك المائية الصافية والتشكيلات الكهفية الرائعة (شكل ٣). إلا أن النزول إليه واستكشافه يعد مغامرة خطرة وتحتاج إلى حذر شديد؛ نظرا لتعدد المنحدرات العمودية فيه ووجود أرضية زلقة في كثير من أجزاءه. وتعد الفتحة الأولى في الكهف أعمق جزء منه إذ يصل عمقها إلى نحو ١٤٠ مترا، تعقبها بعد ذلك عدة فتحات متتابعة يتراوح عمقها بين ٣٠ مترا وعدة أمتار.

كلمة المحررة

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أعزاءنا القراء،

مرحبا بكم في العدد الرابع والعشرين من مجلة الحجر. في هذا العدد، ستجدون معلومات شيقة ومفصلة عن الكهوف الجديدة المكتشفة في المنطقة مابين جبل سيح حطاط والجبل الأبيض. تلعب سلسلة جبال الحجر دورا مهما في توزيع المياة الجوفية والعديد من التراكيب الجيولوجية المهمة في شمال عمان، ونحن في هذا العدد نسلط الضوء على أهمية هذه الجبال. كما يحتوي العدد على ملخص علمي عن الرحلة الجيولوجية الميدانية التي نظمتها الجمعية لأعضائها إلى جبل مدر في محافظة الداخلية والحفريات الجديدة المكتشفة في وادي حيبي في صحار. هذين المقالين متوفرين باللغة الإنجليزية فقط؛ لما يحويانه من معلومات علمية دقيقة مختصة بدارسي علوم الجيولوجيا. أخيرا تتقدم الجمعية الجيولوجية العمانية لشركة سي جي جي عمان(CGG) ؛ لدعمها المادي لهذا العدد من مجلة الحجر.

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رئيس الجمعية الجيولوجية العُمانية

الأفاضل أعضاء الجمعية الجيولوجية العمانية،

كان للجمعية العديد من الفعاليات الناجحة التي أدارها أعضاؤنا المتفانون هذا العام (٢٠١٧). تضمنت هذه الفعاليات برنامج «المُتَحدِّين الجيولوجيين» لطلاب الجامعات، و فعالية «جيوكيدز» لطلاب المدارس، ومشغل تعليمي لطلاب مدرسة الأمل للصم، و دعم فعالية عن التاريخ الجيولوجي بمسقط جراند مول قدمته مجموعة علوم الأرض في جامعة السلطان قابوس. وبالإضافة إلى ذلك، شكلت الجمعية لجنة فرعية للتعدين لمتابعة ودعم قطاع التعدين النشط والمشاركة في صياغة استراتيجية التعدين. وعلاوة على ذلك، تم تأسيس فرع طلابي من الإدارة معني بضمان الدعم الفعال لطلابنا الشباب ومشاركتهم. وبالنسبة لعام ٢٠١٨ ينتظرنا جدول كامل من المحاضرات والرحلات جاء بفضل أولئك الذين تطوعوا للقيادة ولمن ساعدوا في التنظيم.

لقد شهدت الجمعية نموا في عدد أعضائها وزادت كذلك دعوات الدعم والمشاركة من الجهات المختلفة بالبلد. للسماح لنا للقيام بدورنا بكفاءة، تم التركيز في عام ٢٠١٧ على مراجعة طريقة العمل والتحديث لقاعدة البيانات لدينا؛ للسماح لنا لخدمتكم بشكل أفضل. وندعوكم أعضائنا للتأكد من تحديث التفاصيل الخاصة بكم عن طريق الرد على البريد الإلكتروني المرسل بهذا الصدد أو عن طريق أخذ زمام المبادرة والتواصل مباشرة معنا عبر الهاتف أو البريد الإلكتروني. كما نرجو أيضا التأكد دائما من تجديد عضويتكم سنويا فهذا يساعدنا على الاستمرار في خدمتكم وفي استمرارية كفاءة الجمعية.

وأخيرا، نحثكم على المشاركة في أنشطتنا من خلال المبادرة لتقديم محاضرات أو قيادة رحلات جيولوجية أو المساعدة في إدارة أنشطتنا. ونطالبكم بالسعي لحضور الاجتماع السنوي العام للجمعية الذي نعتزم إقامته في القريب حيث نثمن هذا الحضور لما له من أهمية من تأكيد لاهتمامكم بالجمعية ولما له من أهمية مع الجهات الرسمية لتأكيد مشاركتكم في قرارات الجمعية.

في النهاية أتقدم بالشكر الجزيل للعمل المتفاني لفريق إدارة الجمعية ولجميع الأعضاء النشطين وللداعمين للجمعية.

مخلصكم،

د. إبراهيم الإسماعيلي،
رئيس الجمعية الجيولوجية العمانية

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تنبيه

الحجر

تصدر عن : الجمعية الجيولوجية العُمانية

العدد ٢٤ | يونيو ٢٠١٨

جبال عُمان

بين مصادر المياة

واكتشافات الكهوف