PRELIMINARY SURVEY FOR CAVES SUITABLE FOR TOURISM IN THE KINGDOM OF SAUDI ARABIA: AS SULB PLATEAU

KAHF AL RUTUWBAH AND B32 CAVE

By

John J. Pint, Mahmoud A. Al-Shanti, Abdulrahman J. Al-Juaid, and Saeed A. Al-Amoudi

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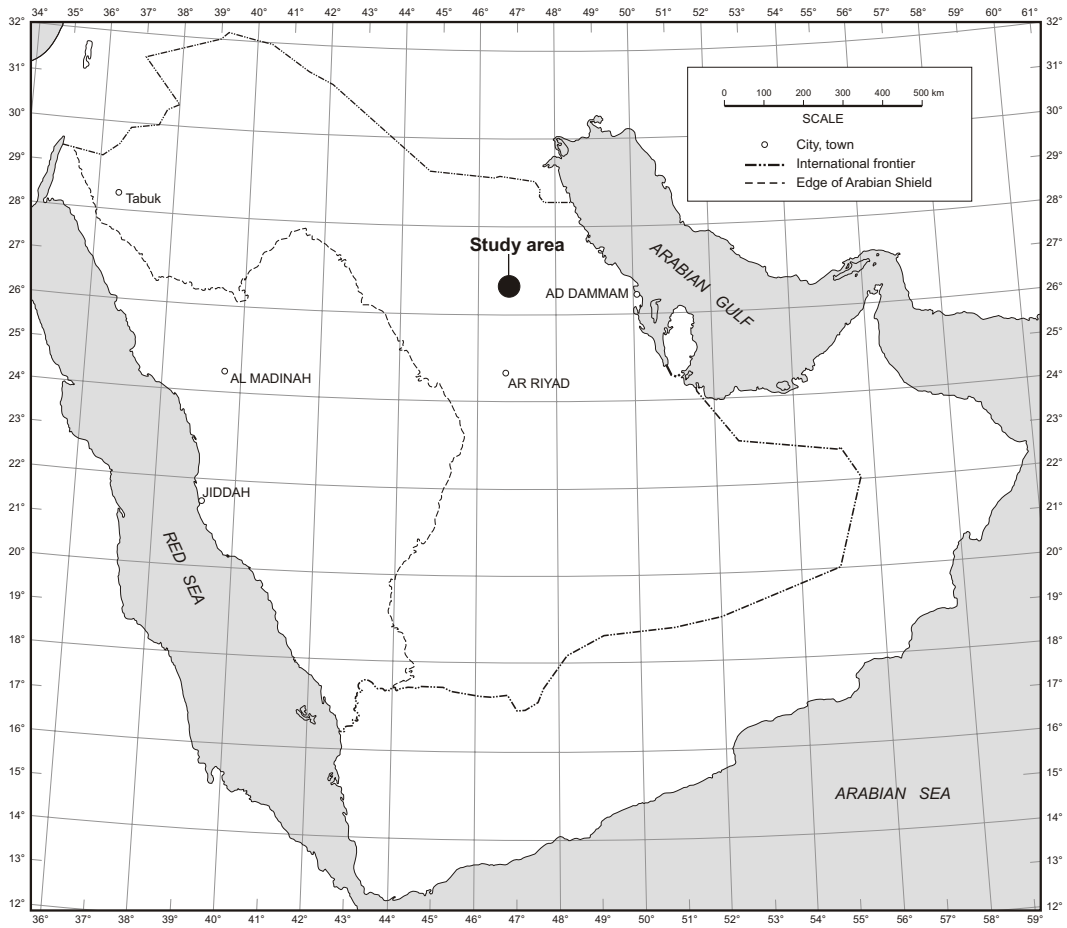

Index map of the Arabian Peninsula

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Saudi Geological Survey
Post Office Box 54141, Jeddah 21514
Tel. (966-2) 619-5000

Saudi Geological Survey-Riyadh Office
Post Office Box 9655, Riyadh 11402
Tel. (966-1) 476-5000

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PRELIMINARY SURVEY FOR CAVES SUITABLE FOR TOURISM IN THE KINGDOM OF SAUDI ARABIA: AS SULB PLATEAU

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ABSTRACT

The development of some Saudi Arabian caves into tourist sites (show caves) would permit Saudi and other visitors to learn first-hand about a little-known part of the Kingdom natural heritage and would facilitate cave access for scientists of many disciplines. This report studies two caves with touristic potential situated in the As Sulb Plateau, approximately 200 km NNE of Riyadh, Kingdom of Saudi Arabia, at the contact between Miocene calcareous clastic rocks and the Paleocene-Early Eocene Umm er Radhuma formation. Kahf al Rutuwbah, also known as Gecko Cave, is 203 m long with passage and room widths varying from 50 cm to 17 m and the cave height ranging from 66 cm to 4.97, but usually under 1.5 m. The temperature 28 m inside the cave is 25°C and humidity is 66 percent. At a distance of 115 m from the entrance, the temperature drops to 21°C and the humidity rises to 97 percent. The floor of the cave is mostly covered with loose quartz sand introduced from the surface. The walls and ceilings exhibit white or iron-stained stalactites, soda straws, draperies, cauliflower structures and flowstone. White, powdery gypsum deposits and flaky calcite lace were also observed. Because of the abundance of touristically attractive formations and the apparent lack of dangerous features, a 113 m section of this cave was judged to have good potential for adventure tourism, that is, suitable for people willing and able to crawl on soft sand under low ceilings. The farthest part of the cave was deemed unsuitable for tourism due to its high humidity.

A section of B32 cave was also surveyed, described and evaluated for its touristic potential. This cave was named and explored by Austrian and KFUPM speleologists in the 1980s and photographs were published showing aesthetically pleasing speleothems. The portion of the cave surveyed by SGS is 92 m long with passage and room widths varying from 1 m to 10.3 m and the cave height ranging from 70 cm to 5.4 m, requiring little crawling and minimal climbing. The temperature is 21°C with a humidity of 70 percent. The floor is mostly covered with breakdown in the form of brittle, haphazardly piled slabs of limestone up to 5 m in length. Some parts of the cave have stalactites, stalagmites and draperies from 5 to 70 cm long. Helictites are also found. Because the heaped-up breakdown can easily fracture under human weight, plunging a visitor into openings below, the surveyed passages of this cave were judged unsuitable for tourism.

مسح أولى للكهوف المناسبة لأغراض السياحة في المملكة العربية السعودية مثل كهف هضبة الصلب وكهف الرطوبة وكهف بي ٣٢ .

إعداد : جون بنت – محمود شنطي – عبدالرحمن الجعيد – سعيد العامودي

خلاصة

أن تطوير بعض الكهوف في المملكة العربية السعودية لتصبح مواقع سياحية يتيح للزائرين السعوديين وغيرهم فرصة التعرف أولاً بأول على الجزء اليسير المكتشف من إرثهم الطبيعي ، وقد يساعد ذلك على تسهيل دخول العلماء إلى تلك الكهوف لمعرفة مختلف المجالات البحثية المتعلقة بها . يتطرق هذا التقرير إلى كهفين لهما احتمالات سياحية ، يقع أحدهما في هضبة الصلب وعلى بعد نحو ٢٠٠كلم شمال الشمال الشرقي لمدينة الرياض ويقع على خط التماس بين الصخور الكلسية الفتاتية من العصر البليوسيني إلى الايوسيني المتقدم . والكهف الثاني هو كهف الرطوبة (ويعرف كذلك بكهف جيكو) ويبلغ طوله ٢٠٣ متراً وبه ممرات وغرف يتراوح عرض كل منها ما بين ٥٠سم و١٧ متراً ويتراوح ارتفاع الكهف ما بين ٦٦ سم إلى ٤,٩٧متراً ولكن معظمه يقع على ارتفاع متر ونصف . وتبلغ درجة الحرارة في مساحة ٢٨متراً داخل الكهف ٢٥°م ونسبة الرطوبة ٦٦%. وعلى بعد ١١٥ متراً من المداخل تنخفض درجة الحرارة إلى ٢١°م وترتفع نسبة الرطوبة إلى ٩٧% وتغطي رمال الكوارتز السائبة أرضية الكهف وهى رمال تساقطت من سطح الكهف . وتظهر على جدران وسقوف الكهف مجموعة من الهوابط الحديدية الصدئة وأنابيب من الصودا وتكوينات غطائية شفافة وتراكيب قرنبيطية الشكل واحجار انسيابية . وقد شوهدت كذلك رواسب من مسحوق الجبس الأبيض الناعم وشريط قشري من الكالسيت . ولأن هنالك العديد من التكوينات الجاذبة سياحياً، ولعدم وجود مظاهر تدعو للخطر ، فقد تم التأكد من جزء طولة ١١٣ متراً من الكهف وثبت أنه جيد للأغراض السياحية التي يحركها دافع المغامرة وشغف المعرفة وهو مناسب للسياح الراغبين والقادرين على الزحف على رمل ناعم تحت سقوف منخفضة .

وقد اعتبر الجزء النائي من الكهف غير ملائم أو مناسب للسياحة لارتفاع نسبة رطوبته .

وقد تم كذلك مسح جزء من كهف " بي ٣٢ " وتم تصنيفه وتقييمه كمصدر سياحي ، وقد تم اختيار الاسم لهذا الكهف بعد أن اكتشفه جيولوجي نمساوي وعلماء كهوف من جامعة الملك فهد للبترول والمعادن في عقد الثمانينات وقد تم نشر صور توضح أشكالا جمالية مبهجة من التكوينات الكهفية ، ويبلغ طول الجزء الذي قامت هيئة المساحة الجيولوجية السعودية بمسحه ٩٢متراً ويتراوح عرض ممراته وحجراته ما بين متر واحد إلى ١٠,٣متراً، ويتراوح ارتفاع الكهف ما بين ٧٠سم إلى ٥,٤متراً. ويحتاج هذا الارتفاع إلى الزحف الخفيف والتسلق البسيط لبلوغه ، وتصل درجة الحرارة داخل الكهف إلى ٢١°م ونسبة الرطوبة إلى ٧٠% ، وتغطى أرضية الكهف أحجار جيرية متساقطة وشرائح هشة (قصيفة) تكونت بشكل عشوائي ويبلغ طولها نحو ٥ أمتار. وتوجد في بعض أجزاء الكهف هوابط وصواعد وتكوينات ساترة يبلغ طولها نحو ٧٠سم ، وتوجد كذلك رواسب كلسية متدلية. ولأن الرواسب الأرضية على سطح الكهف يمكن أن تتهشم بسهولة من جراء السير عليها بالأقدام نتيجة لثقل الوزن البشري ، مما قد يسبب الانزلاق أو السقوط ، فإن الممرات التي تم مسحها في هذا الكهف تعتبر غير مناسبة للسياحة .

INTRODUCTION

A large number of caves are located on the Summan Plateau with a particularly heavy concentration in the karst of the As Sulb. For example, Stewart Edgell reports that an area of 500 square kms was studied by a joint team from King Fahd University of Petroleum and Minerals and the Austrian Academy of Sciences and was found to contain 58 cavities, most of them leading to sub horizontal cave systems (Edgell, 1990). The general public, however, is not aware that so many caves are found beneath this part of the desert and even local people are generally unfamiliar with the interior of these desert caves. This is partly due to the dangers involved in cave exploration and the need for technical expertise required for getting in and out of them safely. The development of selected caves into tourist sites would permit Saudis to become familiar with an important part of their natural heritage and provide easy access to caves for scientists of all disciplines.

The Saudi Geological Survey is conducting a reconnaissance of caves in Phanerozoic rocks for various purposes, including recreation by the general public (tourism) and educating the public about the environment (Saudi Geological Survey, 2001). This report presents two that which were investigated as possible candidates for such touristic development, with comments on their suitability.

The authors believe that a cave suitable for general tourism ought to contain an abundance of speleothems which visitors of all sorts would find beautiful and/or interesting. Underground rooms of an impressive size might also be considered a plus. For adventure tourism, a physically challenging, but not unduly dangerous underground environment might be sought. For ecotourism and educational tourism, scientifically or historically significant features such as ancient earthquake damage, active (still growing) speleothems or grooves from use as a water well might be deemed desirable.

Aspects which might make a cave unsuitable for development include instability of the ceiling, walls, entrance shaft and speleothems, as well as the instability of cave breakdown (rock fallen from the ceiling), which visitors might have to pass over or around, the presence of female phlebotomine sandflies, which can infect people with leishmaniasis, the presence of bat guano, which could harbor Histoplasma capsulatum spores, which can cause histoplasmosis, the presence of dried fox dung, which could contain the tapeworm Echinococcus multilocularis, and pockets of carbon dioxide that can cause asphyxiation.

Some caves may be considered unsuitable because delicate speleothems would be easily reachable by visitors. Accidental damage to unique Saudi speleothems has already occurred, for example the destruction of “The Rope” stalagmite in Mossy Cave. In other places, the presence of visitors in large numbers could endanger archeological or paleontological sites or the roosts of bats or rock doves. Even their guano should not be disturbed, as it may contain spores or pollen providing records regarding flora and fauna in ancient times. Other caves may be negatively affected by the humidity generated by visitors’ breath or the heat produced by their bodies. Another factor to be considered is the ease or difficulty involved in removing the deposits of lint which eventually build up on speleothems in tourist caves.

Before caves can be selected for development into touristic sites, they must be mapped. This is not only important for a thorough knowledge of the cave itself, but also vital for purposes of Cave Search or Rescue in the event that a tourist somehow becomes lost or injured in a remote part of the cave. A geological description of the cave should also be produced, including measurements of temperature and humidity, so the impact that touristic development might have on the cave environment can be estimated. Such descriptions, together with cave maps, may indicate areas of the cave that pose dangers to visitors, and which would require modifications, construction of walkways or ramparts, etc. On the other hand, the map and description may indicate areas where visitors would pose dangers to cave formations or indeed to the cave itself.

This document is a preliminary report which may aid in the selection of caves for touristic purposes. A subsequent, more detailed study, will then be required of any cave chosen for development to assure that the cave will not suffer from such development and that visitors will not be placed in danger.

GEOLOGY OF THE AS SULB PLATEAU

The caves studied in this report are situated approximately 200 km NNE of Riyadh (fig. 1) in the As Sulb Plateau, which is part of the Summan, a bedrock plateau stretching east and west from the Dahna to the Gulf and north and south from the border of Kuwait to well inside the Rub al Khali. The As Sulb region is approximately located between latitude 25°19'N to 26°41'N and longitude 47°15'E to 48°30'E. and geologically encompasses the Umm er Radhuma Formation (Paleocene-Early Eocene) and a younger, unnamed Miocene-Pliocene unit of calcareous clastic rocks (Schyfsma, 1978). The Umm er Radhuma formation is composed of light-colored, fine-grained and arenitic limestones as well as dolomites containing chert. Benischke and others (1997) reports that lithologic, sedimentologic and thin-section investigations show a strongly recrystallized texture, dolomitization and partly complete decalcification within the marl-like layers of this formation, favoring the possibilities of karstification or erosion. The two caves reported on lie partly in the Umm er Radhuma Formation and partly in the Miocene clastic sediments, which consist of calcareous sandstone and marl, and limestone (fig. 2). Because these sediments are well cemented by calcium carbonate, they lend themselves to the development of caves.

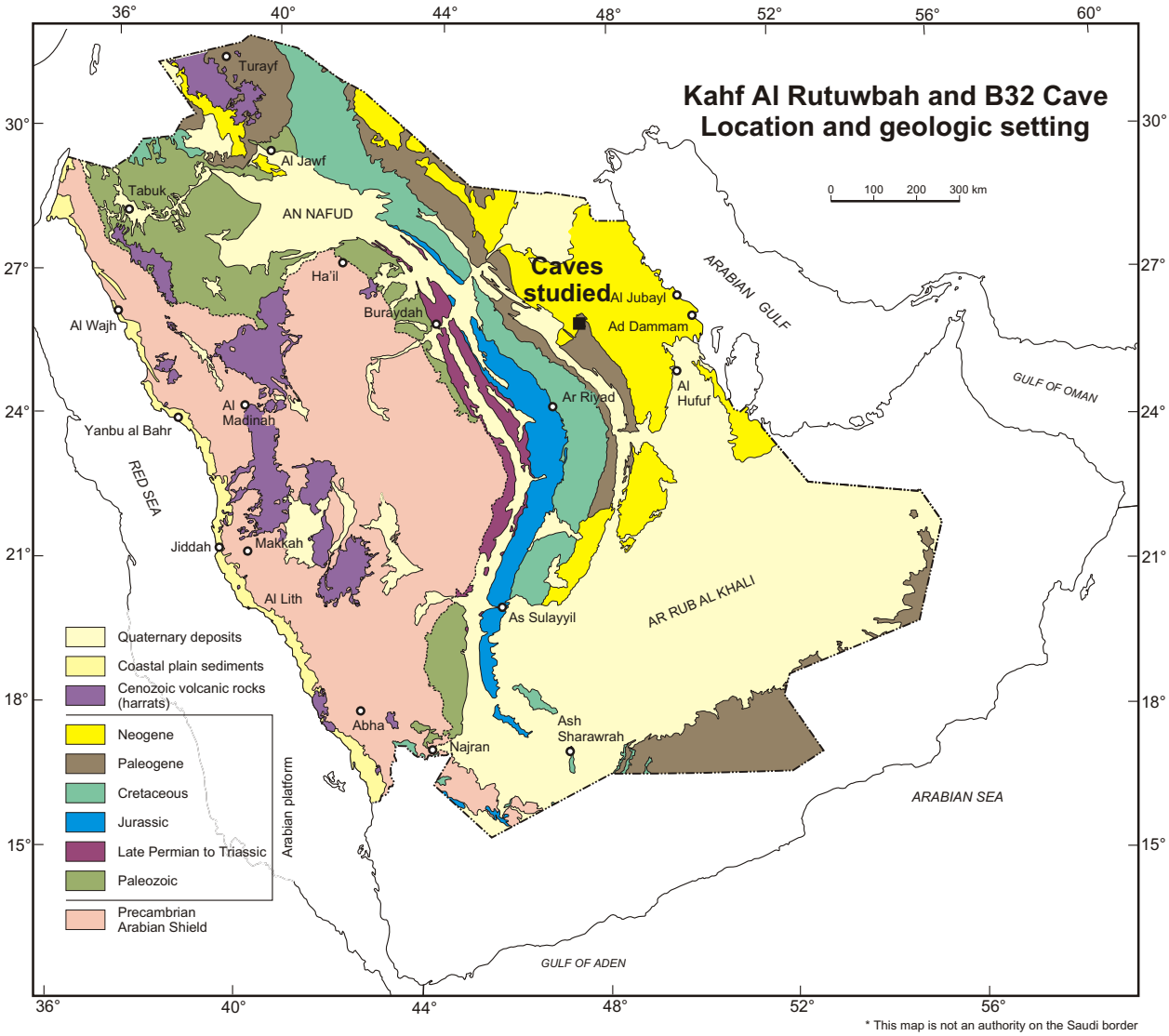
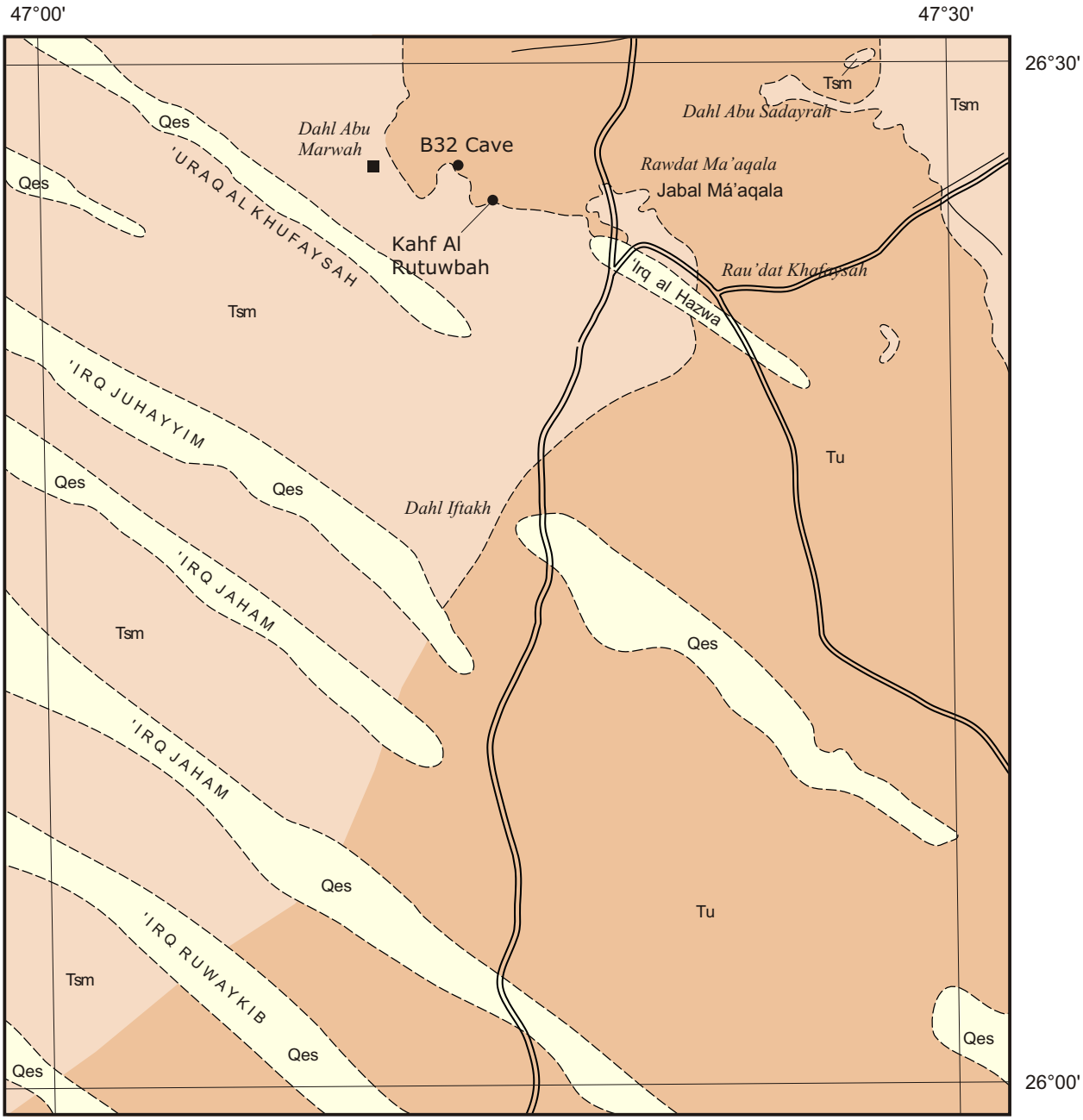


Figure 1. Kahf al Rutuwbah and B32 Cave – Location and geologic setting.



GEOLOGIC EXPLANATION

SEDIMENTARY ROCKS

Qes — **Eolian sand**

Sandstone, marl, and limestone

Tsm — *White and pink marly sandstone, sandy marly, and sandy limestone; locally cherty; contains nonmarine invertebrates. In places Hadrukh formation. In As Summan area Tsm discontinuously overlies Umm er Radhuma formation,* Tsm / Tu

Tu — **Umm er Radhuma formation**

Cream, tan, and gray limestone, dolomitic limestone, and dolomite

Primary tracks

Figure 2. Detailed view of cave locations and geologic setting.

Several hundred cave entrances dot the As Sulb Plateau but relatively few have been catalogued or investigated in a systematic manner. Nonetheless, four types of caves appear to be present:

- Vertical pits or shafts developed wholly or partly within the Umm er Radhuma formation. An example is Dahl al Hashami, 14.67 meters deep, long used as a water well as evidenced by deep rope marks at the entrance and on rock protrusions inside (Peters and others, 1990). So far, no caves of this sort are reported to contain speleothems.
- Horizontal maze systems ten to fifteen meters deep, developed in the Miocene clastic sedimentary formation. Such systems sometimes contain speleothems. An example is Dahl Sultan (Pint and Peters, 1985), which has several kilometers of passages lying fifteen meters below the surface. Stalactites, stalagmites, gypsum flowers, helictites, curtains and hollow "birds' nests" can be found in Dahl Sultan.
- Collapse structures in both the Umm er Radhuma and Miocene formations. Examples are Dahl Abu Marwah (Felber, 1978) and Dahl Abu Jirfan (Benischke and others, 1991) where palm and other trees have taken root on the floor of the structure.
- Sand-filled caves. These caves, or at least their entrances, have been filled by aeolian or water movement of sand from the Dahna desert. An example is Dahl Iftakh, many of whose features, described by Benischke and others (1991) are now covered by sand. Another example is The Foxhole, described by Peters and others (1990). This cave, a pit 7.5 meters deep with a 20-meter-long horizontal passage averaging 1.5 meters high is now completely buried in sand.

KAHF AL RUTUWBAH

Geological Description of the Cave

The latitude and longitude of Kahf al Rutuwbah (also known as Gecko Cave) are given in Pint, J., (2001). The cave is shown in figure 3 and encompasses 200 m of surveyed passages. The entrance (fig. 4) is a depression in the Miocene clastic sedimentary formation. The depth of this depression is 4.75 m, the length is 11 m and the maximum width is also 11 m. The margins are highly weathered, exhibiting gently sloping, crumbling sides. At the lowest point in the depression is an opening 60 cm high and 2 m wide, beyond which is a horizontal passage15 m long with an average height of 60 cm and an average width of 2.5 m.

The floor of this entrance passage is covered with sharp, broken pieces of marly limestone less than 10 cm long. The walls and ceiling are mottled limestone rock, the dissolution of which by rain and running water, created the15m-long crawlway.

The crawlway opens at station zero (fig. 5) into a room averaging 1.2 m high (fig. 6). Stalactites appear on the ceiling from 20-40 cm long (fig. 7) with a few as long as 60c m. Figure 8 shows one of these longer stalactites as well as one of five geckos (Ptyodactylus hasselquistii) observed in this same room on Jan 25, 2001, which gave the name of the cave. Geckos were not observed in the cave during the survey and geological description of the cave on May 19 and 20, 2002). The ceiling and side walls of this room are fractured. Mud, introduced by water from the surface, fills these fractures and locally plasters the side walls, sometimes reaching as much as 1.8 m above the floor in the highest part of the room. This is inferred to indicate the level of standing water in the cave at some point in the past. The floor of this room is of inequigranular limestone with a mosaic texture, which appears to belong to the Umm er Radhuma formation.

Eleven meters west of station 1, on the NW wall, there is a broken stalagmite which was cemented to the wall by mud. The position of the broken piece shows that it was impacted by the force of water moving into the cave from the SE, through the entrance. This water may have contained gravel, helping to produce such an effect. Figure 9 shows the NW wall, which was eroded and smoothed due to the

force of the water, and figure 10 shows the broken stalagmite. South of this stalagmite is another broken stalagmite, the upper portion of which appears to have been removed by the force of water.

On the ceiling and side walls of this room, patches of secondary gypsum are present where water seeps through the fractures (fig. 11). The gypsum is white, soft and powdery. White, rippling flowstone occurs on the W wall (fig. 12). Interaction between the limestone walls and ceiling and water resulted in the development of spots and nodules in the limestone, an example of which is shown in figure 13.

Between stations 2 and 3, blocks of breakdown are found on the floor, fallen from the ceiling.

A maximum-minimum thermometer showed that the temperature of this room varied between 23 and 25 degrees C. on May 19 and 20, 2002. The humidity in this room on these two days was observed to be 66 percent, using a Springfield relative humidity meter.

Station 3 is at a very narrow entrance to a second room. A flaky calcite lace can be seen on the walls and ceiling of this room, caused by dissolution of a secondary gypsum (fig. 14). Nine meters south of station 3 there is marly, chalky limestone filling the fractures in the ceiling and side walls. Stalagmites and stalactites are found on or hanging from shelves on the SE wall (fig. 15) and stalactites are hanging from the ceiling at Station 4 (fig. 16).

To the NW of Station 4 lies the Coral Room, so called because of the ceiling formations resembling the mouths of sharks. Here are found stalactites and stalagmites of various sizes, up to 50 cm in length. Some of these are small stalactites 2-20 cmslong built up within and beneath ceiling cracks that funnel water from the surface (fig. 17). Flowstone is also found on the walls. The Coral Room has holes in the ceiling from whose edges water once dripped, producing cauliflower formations such as those shown in figure 18. The concentration of stalactites and stalagmites in this room, caused by dripping through fractures, may indicate that surface water collects above this point.

Loose quartz sand (introduced from the surface) covers the floor of the cave from Station 3 to Station 9. A low crawlway, 40 to 50 cm high, is encountered between Stations 5 and 6 (fig. 19). At Station 6 there are stalactites 1-3 cm in width and 3 to 15 cms long (fig. 20). The mottled limestone in this area sparkles, caused by the reflection of light on calcite faces.

At Station 8, what appears to be the larva of a beetle, approximately 1.5 cm long, was found on the sand floor. It was observed diving into the sand and resurfacing, perhaps because it was disturbed by the observers' lights (fig. 21).

At Station 9, the mottled limestone is observed as well as stalactites with red stains due to iron oxide (fig. 22). Beyond this station lies a large room 85 m long, branching NW and SE (see cave map). The temperature in this room was 21°C with 97 percent humidity. The high humidity causes condensation on the stalactites as well as dripping. This room, named the Steam Room, contains stalactites ranging in size from ten centimeters to 1.5 m. In addition, stalagmites were observed growing on mud (fig. 23).

Three beds were observed in the walls of this room, comprising, from bottom to top, 2 meters of spotted variegated, gray and white limestone; 40 cm brown mudstone; and 6.5 m gray to white argillaceous limestone with secondary gypsum and nodules of brown, very fine-grained limestone. The mudstone appears to be absorbent to moisture, and, because of the high humidity, pieces flake off. As shown in the cross section (fig. 24), neither bottom of the lower bed nor top of the upper bed are exposed at this point in the cave system. Figure 25 shows that the limestone in this room was eroded and also shows new secondary gypsum on the right side of the photograph. Figure 26 shows the secondary gypsum on the ceiling (white areas).

Comments on Suitability for Tourism

Our study of Kahf al Rutuwbah indicates that a large part of the cave (from the entrance to station 9) has potential as a site for ecotourism and adventure tourism.

This cave can be entered without the use of ropes or ladders. With the help of knee pads, agile visitors can pass through the stony entrance crawlway (15 m long, 60 cm high, 2.5 m wide).

The part of the cave between the entrance and station 9 has many displays of clean, often multicolored stalactites and stalagmites, including soda straws. The Sharks Mouth speleothem-lined ceiling holes are unusual and impressive. Although much crawling is required, the soft, sandy floor adds an aesthetically pleasing aspect to this physical activity (figs. 15, 18, 27, 28, 29). The temperature and humidity between stations 0 and 9 are not uncomfortable and air circulation in this area is good.

Bats, rock doves or their guano have not been observed in this cave. The geckos that are sometimes found in the cave are harmless to human beings and eat the sandflies which otherwise might present a problem. No sign of wolves, foxes or hyenas has been found.

Because the speleothems in this cave are all within reach of visitors, it is recommended only for small groups of adults who have been instructed in cave conservation and in techniques for avoiding accidental breakage of formations.

The area west of station 9, referred to as the Steam Room on the map, has impressive flowstone displays (fig. 30) but is excessively humid, with poor air circulation and large blocks of breakdown that make walking dangerous. This area might be considered off limits to most visitors.

B32 CAVE

Geological Description of the Cave

The latitude and longitude of B32 Cave are given in Pint, J., (2001). The cave is shown in figure 31 and encompasses 95 m of surveyed passages. However, unexplored passages to the west and references to this cave in Verkarstung und Grundwasser im As Summan Plateau (Saudi Arabien) (Hötzl et al, 1993, p. 101) suggest that the cave is much longer. This cave was named and explored in the 1980s by researchers from the Austrian Academy of Sciences and King Fahd University of Petroleum and Minerals, Dhahran, KSA but no map or geological description was published. However, photographs taken in the cave and sent to the SGS Cave Unit by R. Benishchke of the Austrian Academy of Sciences show speleothems which could be of interest to the general public for their aesthetic value. These photographs are included in the Stacey-International/SGS publication Desert Caves of Saudi Arabia (Pint, 2002).

The entrance (fig. 32) is a depression in the Miocene clastic sedimentary formation of the As Sulb Plateau. The depth of this depression is 6 m, the length is 8.5 m and the approximate width is 5 m. A passage 1 m wide, 70 cm high and 4 m long lies at the lowest point of the depression and leads into the cave (fig. 33). This passage is in sandy limestone that was affected by water and dissolution and contains many fractures and cavities. It also contains micrite.

A sample of the sandy limestone in this cave was taken from the wall at station 1. It contains carbonate, quartz, and chlorite or clay minerals. The carbonate is fine-to very fine-and the quartz is fine-grained and irregular in shape. Colorless chlorite or clay minerals appear in fibrous aggregates. On the ceiling and side wall near station 1, cavities and clear spots can be observed in the limestone (fig. 34).

The first room of this cave is 12 meters long and has an average width of five meters. The ceiling is 5.3 m above the floor and is approximately two meters below the ground surface. Fragments and blocks of material fallen from the ceiling are found on the floor of this room and are common throughout the cave, sometimes reaching sizes of 4 to 5 m in length (fig. 35). This rock is brittle and easily broken, and care is needed when traversing the cave. The first room, furthermore, contains debris and trash washed in from the surface as well as a small number of bones.

Readings on a maximum-minimum thermometer showed that the temperature of this room remained at a constant 21°C on May 21, 2002. The humidity in this room on the same day was determined to be 70 percent, using a Springfield relative humidity meter.

A passage at the north end of the first room leads to the second room. It is easy to climb into this passage, which is 1.5 m above the floor level and 2 m wide. Near station 2, protrusions are present on both sides of the passage, which, like many of the rock surfaces in this cave, are eroded and coated in patchy secondary gypsum (fig. 36).

The room north of station 2 is accessed by descending 1.5 m. Quartz sand, introduced from the surface, covers the floor at the south end of this room. The east wall of the room (fig. 37) has many sharp erosional protrusions and the west wall (fig. 38) is soft, smooth and chalky and tinted green and red. It appears that water flowing through this room preferentially eroded the west wall, but left the east wall unaffected apart from a green-red tinting caused by staining (fig. 39). Mud and sand also appear in the cavities of this wall.

At the north end of this room a 1.5 m climb leads to a second elevated passage, which, between stations 5 and 6, contains sharp limestone protrusions, suggesting the absence of a rapid flow of water through this area.

The room north of station 7 is 9 by 5 m across and 3.8 m high and contains, at the north end, a pure white, apparently recent stalactite, 14 cm long and a stalagmite 5 cm high, located beneath a dripping fracture in the ceiling. A lot of breakdown is found in this room, making walking tedious because great care must be taken not to break the fallen rock.

At station 8, a 1.5 m climb leads to a passage 1 m wide that gives access to the most northerly room explored. This is a chamber 10 m wide and 29 m long with a height of 5 m. Openings and fractures are present in the ceiling, related to extensive breakdown that covers the entire floor of the room. Some of these fallen blocks are as long as 6 m.

Patches of gypsum occur on the walls of this room together with brown and green coloring caused by staining.

Small stalactites 5-10 cms long are seen on the ceiling at the SW end of the room. In the NW half of the room, larger stalactites and stalagmites are abundant, some as long as 70 cm. Draperies and helictites (fig. 40) are also found. The breakdown and speleothems suggest that a large amount of water entered this room from the surface via fissures.

Comments on Suitability for Tourism

Although this cave contains various speleothems of aesthetic merit, the nature of the accumulated breakdown on the cave floor presents a serious safety hazard. For this reason, the portion of the cave surveyed by SGS is not recommended for visits by the general public.

The speleothems in this cave include stalactites, stalagmites, draperies and helictites (figs. 41 and 42) Other features that might make the cave a candidate for tourism include the walk-in entrance and the apparent absence of bats, owls, foxes, rock doves, or sand flies. In addition, climbing the low walls separating the rooms would provide a reasonable challenge for adventure tourists. Finally, the temperature and humidity of the cave are within acceptable norms.

The friability of the breakdown, however, poses far too great a danger for visitors. Large slabs of flat rock were observed to break when stood upon by a member of the survey team, plunging the surveyor into hollow spaces below where delicately balanced rocks could collapse over him or where limbs could easily be broken. These dangerous breakdown piles are found in all the rooms where speleothems can be found (fig. 43).

CONCLUSIONS AND RECOMMENDATIONS

Kahf al Rutuwbah should be included in a list of caves suitable for ecotourism and adventure tourism. Should this cave be chosen for such projects, an in-depth study of the cave should be undertaken, including a study of its biology, to determine the possible ecological impact of tourism upon organisms in the cave, speleothems in the cave and upon the cave itself. If negative impact can be avoided, a tourist pathway should be mapped out and off-limit areas delineated.

The parts of B32 Cave surveyed by SGS should not be included in a list of caves suitable for any form of tourism, due to the safety hazard posed by the brittle nature of the large slabs of breakdown covering most of the floor. However, openings that might lead to other passages in this cave should be investigated to determine whether safer conditions predominate in other parts of the cave, warranting further mapping and geological studies.

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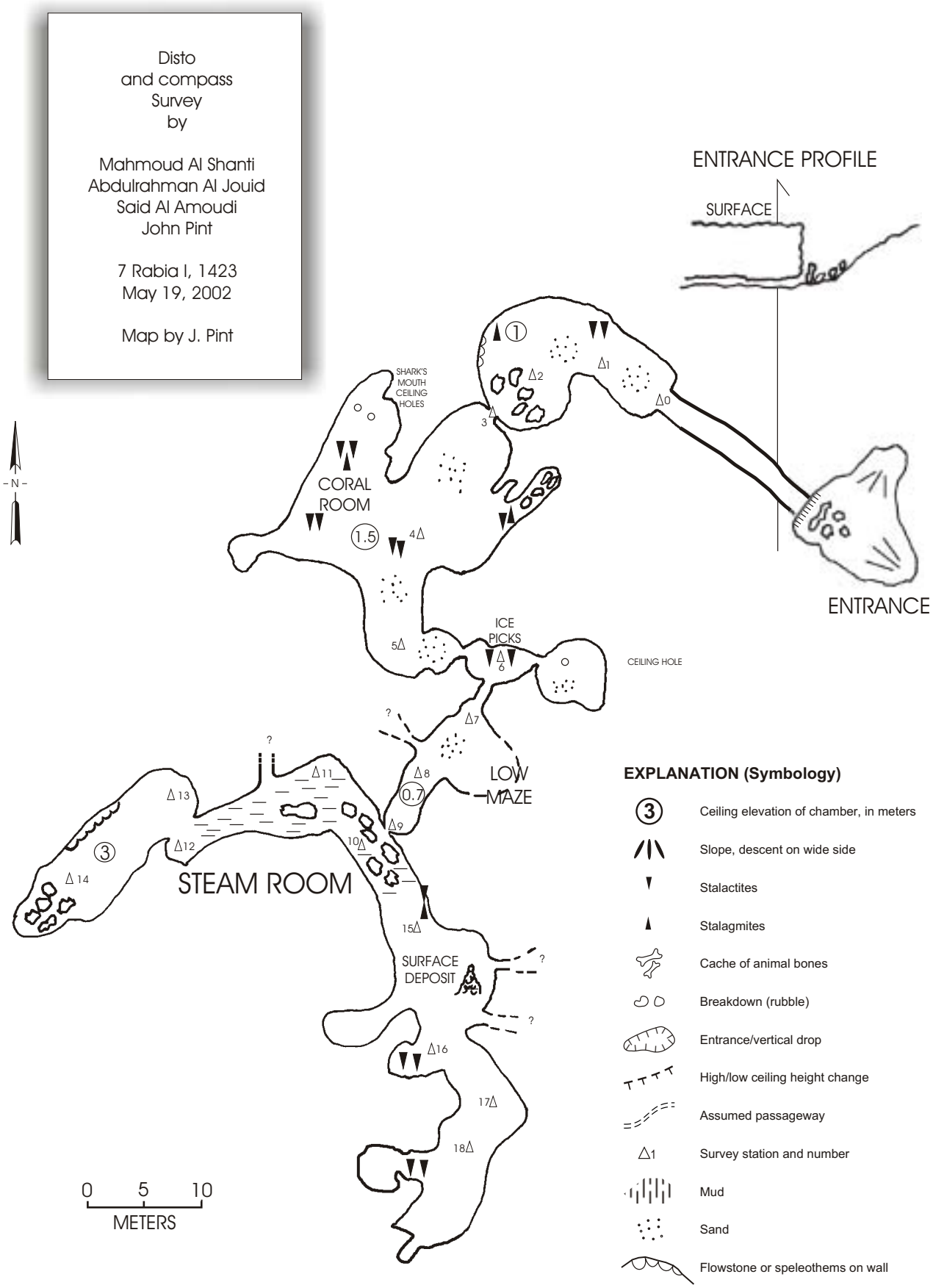

Figure 3. Map of Kahf al Rutuwbah.

Figure 4. The entrance to Kahf al Rutuwbah lies at the bottom of a depression 11 meters long and 4.75 m deep.

Figure 5. Exiting the low, 15-meter-long crawlway that leads from the entrance of the cave to the first room.

Figure 6. First room of Kahf al Rutuwbah showing low ceiling near station 1.

Figure 7. Stalactites 20 to 30 cm long, found near station 1.

Figure 8. A gecko (Ptyodactylus hasselquistii) on one of the longest stalactites found in the first room.

Figure 9. Section of wall NW of station 1, eroded by force of moving water.

Figure 10. Stalagmite on wall NW of station 1, impacted by moving water, broken and recemented by mud.

Figure 11. Soft, powdery, secondary gypsum on ceiling.

Figure 12. Calcite flowstone on wall west of station 2.

Figure 13. Nodules on ceiling above station 2, exposed due to weathering.

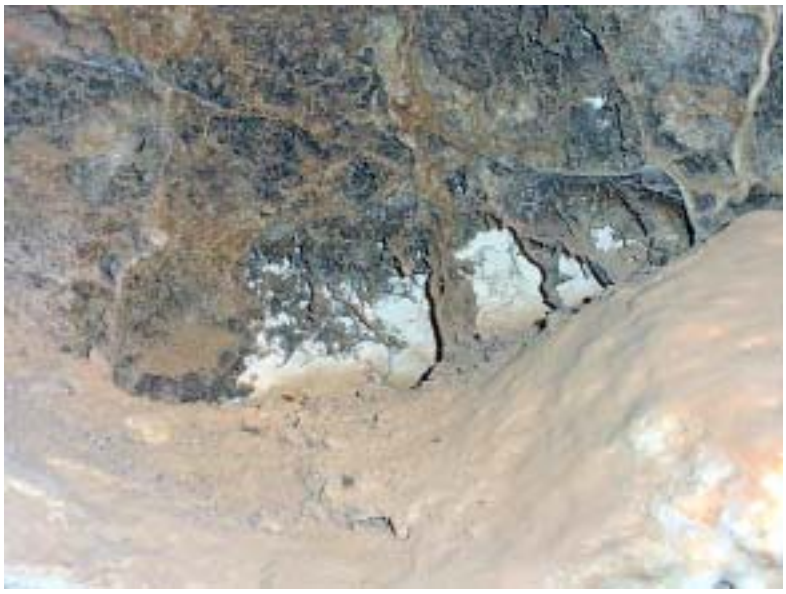

Figure 14. Flaky calcite lace between stations 3 and 4, remaining after weathering of gypsum.

Figure 15. Alcove E of station 4. Several strata can be seen, as well as stalactites and stalagmites on the shelves.

Figure 16. Different sizes and thicknesses of stalactites are seen at station 4.

Figure 17. Stalactites suspended beneath ceiling cracks in Coral Room. Varying shapes are due to arrival of surface water from different directions.

Figure 18. Cauliflower formations ringing the edge of Shark's Mouth ceiling hole in the Coral Room.

Figure 19. Low crawlway between stations 5 and 6.

Figure 20. Stalactites at station 6 are of various shapes due to water coming from more than one direction.

Figure 21. Larva of a beetle, approximately 1.5 cm long, found at station 8.

Figure 22. Iron oxide stains on stalactites and draperies at station 9.

Figure 23. Stalactites of varying shapes as well as stalagmites growing on the mud, all located in the Steam Room.

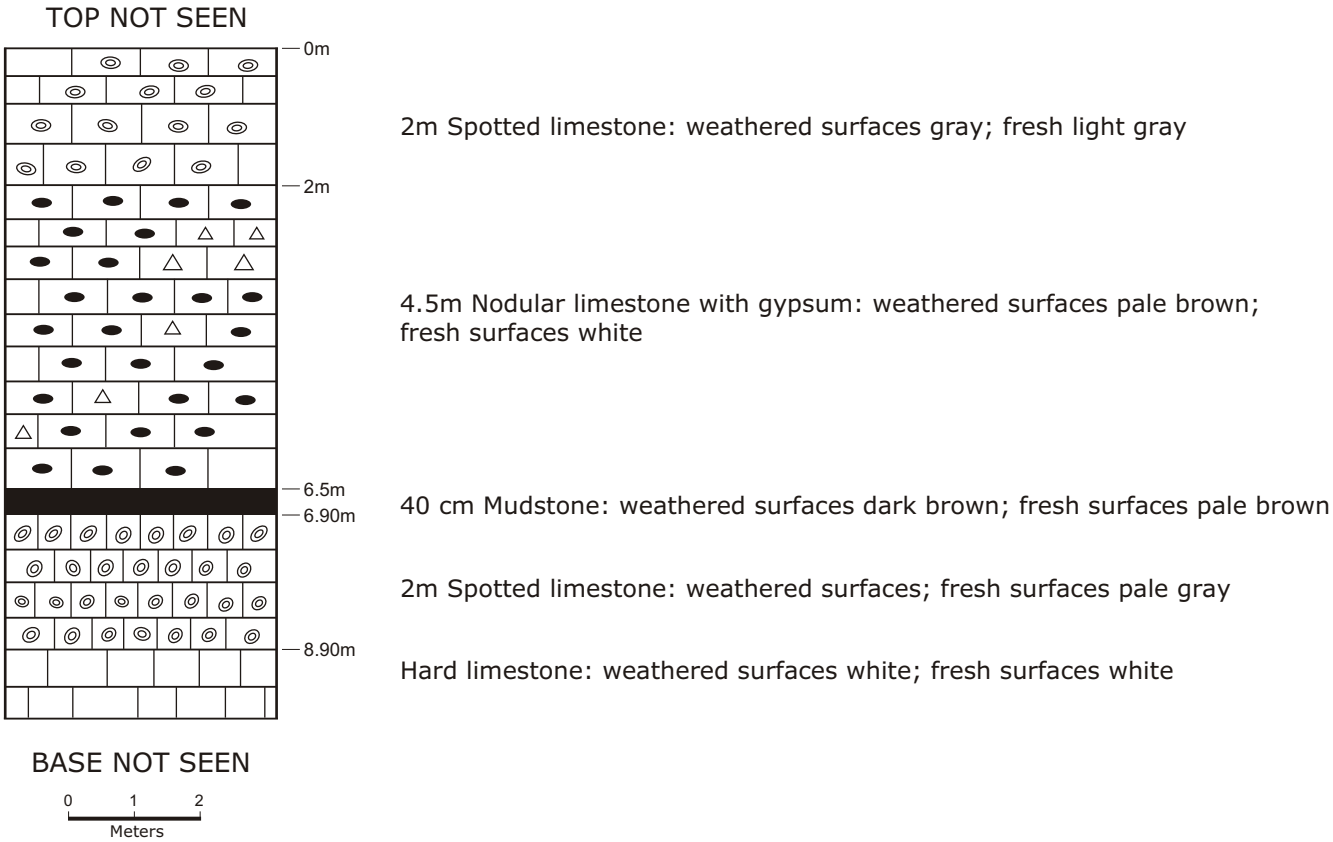

Figure 24. Cross Section - Part of the Umm Er Radhuma formation at the location of the Steam Room in Rutuwbah Cave.

Figure 25. Eroded limestone on the ceiling of the Steam Room. Condensation of water is seen, due to 97 percent humidity.

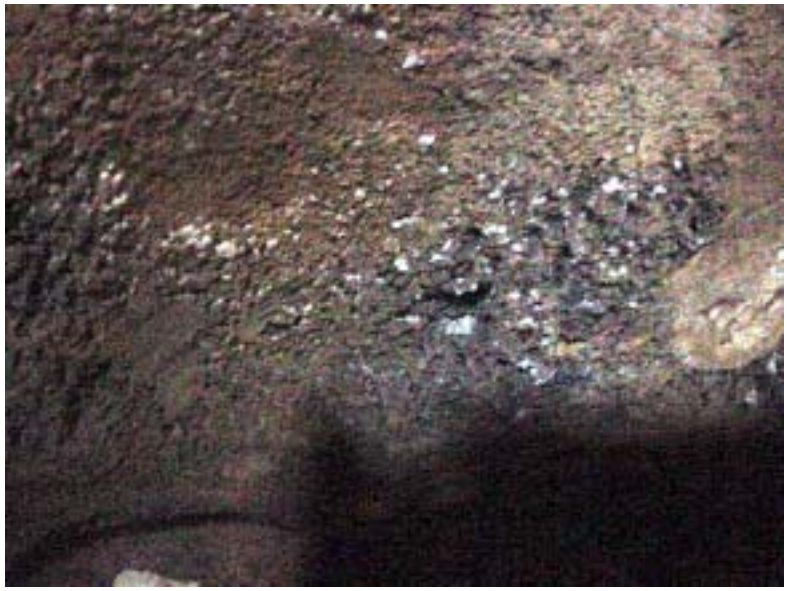

Figure 26. The white spots are secondary gypsum on the weathered ceiling of the Steam Room.

Figure 27. Stalactites are found in many nooks and crannies of the cave, right from the first room.

Figure 28. Although the ceiling is low, the Coral Room has a soft, sandy floor and is richly decorated.

Figure 29. One of the many multi-colored, translucent stalactites found in Gecko/Rutuwbah Cave.

Figure 30. A beautiful display of flowstone, draperies and stalactites in the Steam Room.

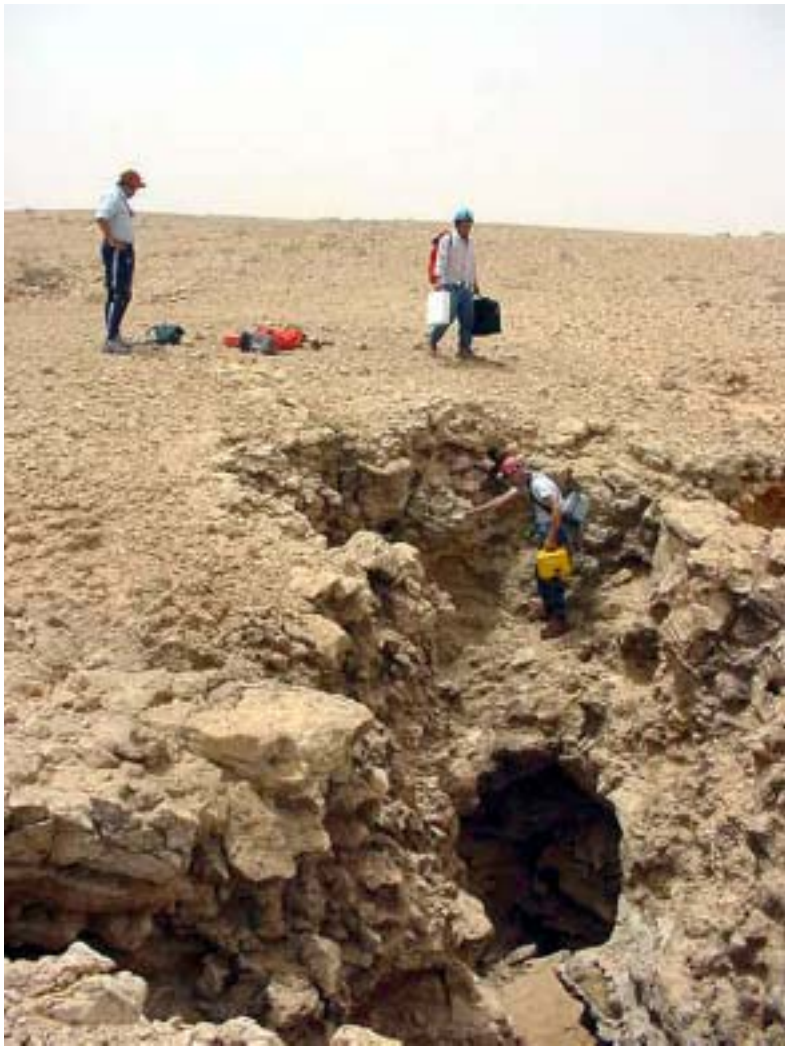

Figure 32. A 6m-deep depression in the Miocene clastic sedimentary formation of the As Sulb Plateau leads to the entrance, on the left, of B32 Cave.

Figure 31. Map of B32 Cave.

Figure 33. Four-meter-long entrance passage seen from inside, at station 0. This passage is 70 cm high. A first-aid kit can be seen on the floor.

Figure 34. Nodules on the ceiling near station 1. These remained after gypsum was eroded.

Figure 35. Brittle slabs of fallen rock, up to 5 m long, are seen on the floor of the first room, between stations 1 and 2.

Figure 36. Protrusions near station 2, caused by erosion due to the force of moving water. White gypsum patches can be seen.

Figure 37. The east wall between stations 3 and 4. Sharp erosional protrusions are present because they were not affected by water rushing through the room (contrast fig. 28).

Figure 38. The west wall between stations 3 and 4. A soft, smooth chalky surface is observed, with mud and sand appearing in small cavities. This wall was smoothed by the pressure of moving water.

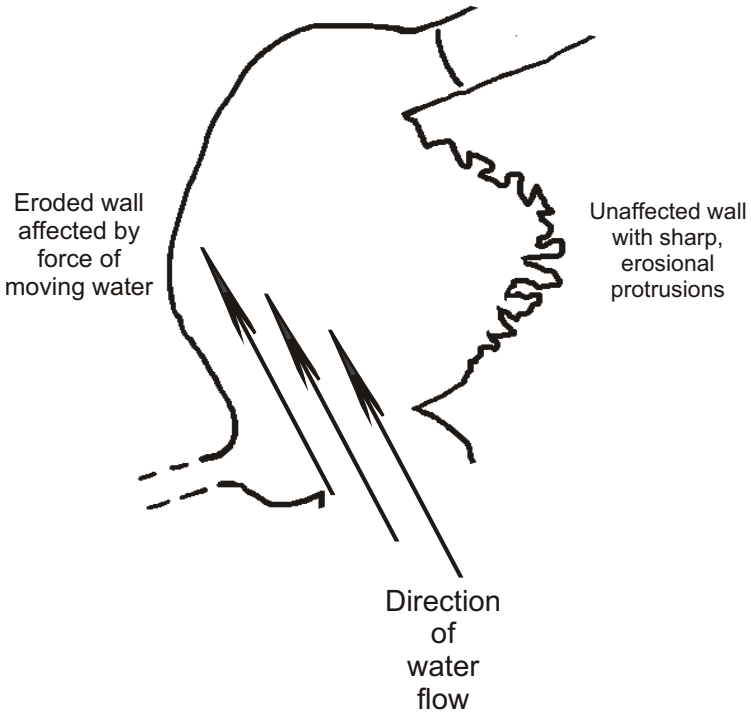

Figure 39. Diagram showing the likely movement of water flowing through the cave between stations 3 and 4, resulting in the contrasting surfaces of the east and west walls.

Figure 40. Vertical stalactites and eccentric helictites are found in many parts of the room between stations 9 and 11.

Figure 41. Large displays of stalactites, stalagmites, helictites and draperies decorate parts of B32 Cave.

Figure 42. Viewing displays like this one often require climbing to the top of unstable heaps of breakdown.

Figure 43. Breakdown in the form of brittle slabs of limestone predominates throughout the surveyed portion of the cave, greatly reducing its potentiality for tourism.