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Karst in Northeastern Saudi Arabia

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ABSTRACT. Exposed carbonate strata of the Paleogene Umm er Radhuma Formation (UER) are karstified in northeastern Saudi Arabia. Detailed studies around Ma'aqala, 280 km west of Dhahran, have been conducted by a joint team from King Fahd University of Petroleum and Minerals and the Austrian Academy of Sciences. An area of 500 km^2 containing 58 dahls or dolines has been mapped. These are mostly vertical sinkholes, 10 to 30 m deep, leading to subhorizontal cave systems. In the subsurface, all caves examined in the UER limestones are dry and were developed long ago, as the present ground water table is at depths of 130 to 210 m. Karstification was possibly initiated during Middle to Late Eocene and Oligocene, when the UER may have been exposed to weathering, although most karstification is Quaternary. Miocene calcareous sandy sediments were disconformably deposited on the eroded UER limestones. Later erosion removed these Neogene strata over the very gentle Ma'aqala Arch and UER limestones were predominantly karstified during Quaternary pluvial phases. Well-developed karst features are unusual in hyperarid areas. Here, they are primarily relict features. Typical karst features found near Ma'aqala include karren, sinkholes, dolines, uvalas, poljes, blind valleys, vertical and horizontal caves, stalactites and stalagmites. Caves are structurally controlled by major vertical joint trends of N30° E, N40° W, a less well-developed trend of N75° E, and minor N–S and E–W joints, as shown very clearly by the UPM Cave and Dahl Abu Hashemi, 4 and 8 km NNE of Shawyah, respectively. Stratigraphic control of cave development is seen in the UPM Cave with three levels of galleries caused by more soluble calcareous strata. The longest cave mapped in the UER is 1.1 km.

Dolines are also found in adjacent Neogene calcareous sandy strata, *e.g.*, Dahl Aba Jirfan. Some of these dolines contain locally used perched water.

Introduction

The solutional landforms of limestone regions are known by the German word *karst*, derived from the Slovenian term *kars* and of Sanskrit origin. The classical area for karst lies in Yugoslavian province of Slovenia (Sweeting 1973).

Solution features have long been known to exist in carbonate and evaporite formations of northeastern Saudi Arabia (Felber *et al.* 1978, Pint and Peters 1985). A good example is Dahl Hit, which occurs some 35 km southeast of Riyadh where the soluble anhydrite of the uppermost Jurassic Hith Formation has been dissolved into a prominent sinkhole. The most widespread occurrence of these sinkholes, or dahls, is in the Umm er Radhuma Formation limestones, which crop out extensively from the Saudi-Iraq border along the Interior Homocline (Fig. 1) to the latitude of Al Layla (approx. 22° 20'N). These sinkholes, or dahls, are well-known by the bedouins and the major ones are named and represented on the 1:500,000 geographic and geologic maps of the Kingdom (Bramkamp and Ramirez 1958) and, in considerably greater detail, on the 1:50,000 topographic maps prepared by the Ministry of Petroleum and Minerals Resources (1982).

It is only in recent years that it has been realized that these sinkholes are quite unusual in the hyperarid area of northeastern Saudi Arabia, where karstification has continued through the dry intervals of the Quaternary and is probably still continuing to a limited extent. Together with many other solution features, such as poljes, uvalas, dolines, ponor and karren, the sinkholes are part of a set of geomorphological features known as karst, which are formed by solution in carbonate and evaporite rocks. Clearly, these karst features, in a presently quite arid area bordering the Dahna, were mainly formed in pluvial phases of the

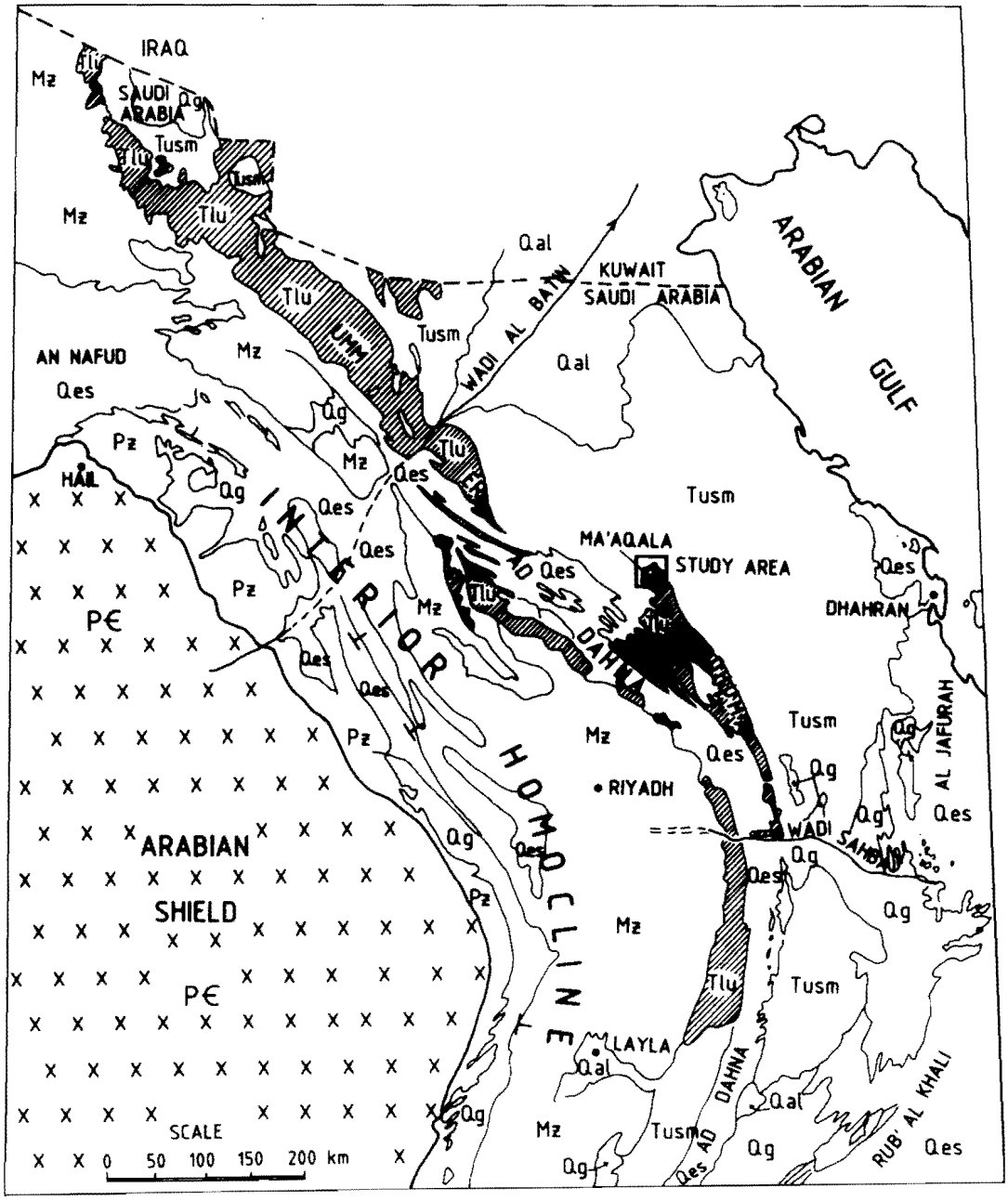

FIG. 1. Umm er Radhuma limestone outcrops along the Interior Homocline of northeastern Saudi Arabia.

Pleistocene, when the rainfall was much greater (Hötzl and Zötl 1976) and when the ground water table was at a much higher level. Karstification continued above the regional ground water table to a lesser extent, when stalactites and stalagmites were formed.

An outcrop area of the Umm er Radhuma Formation of the Paleocene-Early Eocene age, covering about 500 km^2 around Ma'aqala, some 280 km west of Dhahran, was selected for a detailed joint study of karst phenomena by scientists from King Fahd University of Petroleum and Minerals and from the Austrian Academy of Sciences, largely because of the numerous sinkholes and caves in this area of well-exposed outcrops of this formation. This lithostratigraphic unit consists of some 250 m of limestone and dolomitic limestone, with some marl interbeds and calcareous shales towards the base. Due to its relatively pure carbonate lithology, prominent jointing

and widespread exposure, the Umm er Radhuma Formation is the most widely karstified rock-unit in Saudi Arabia.

In this paper, the author will only discuss karst in the relatively small area between Ma'aqala, Shawyah and Al 'Aytaliyah.

Karst Geomorphology in Northeastern Saudi Arabia

In the Summan Plateau of northeastern Saudi Arabia, a large area of Lower Tertiary limestones crops out, bordered by the Upper Cretaceous Aruma Formation on the southwest and by Neogene calcareous sandstone, sandy limestone and marl towards the northeast. The Lower Tertiary limestones of the Umm er Radhuma Formation are especially well-exposed in an area of about 500 km^2 around the town of Ma'aqala with a generally low dip from 1/2° to 1° in a northeast direction. They form a northward prolongation of Lower Tertiray outcrops, due to the very gently north plunging Ma'aqala Arch (Edgell 1987a). The sands of the Dahna ('Urayq al Khufaysah, 'Urayq ad Duhul and 'Irq al Hizwah) lie to the south, and Upper Tertiary (Miocene) calcareous sandstones, marls and thin-bedded limestones lie on the east and west flanks of the Ma'aqala Arch, as well as on its northern plunge (Fig. 2). Gentle folding of the competent Umm er Radhuma limestones on the Ma'aqala anticline has caused a network of vertical and horizontal diaclases, which has favoured the development of karst features.

Karstification is well-developed in the exposed Umm er Radhuma Formation due to its favourable carbonate lithology, consisting of thick-bedded calcarenitic and slightly dolomitic, non-porous limestones, minor dolomite and some marl interbeds. The outcrops of this formation are also strongly jointed along north-northeast, northwest and nearly east-west trends, with minor northerly and northeasterly joint sets (Fig. 3). Combined with the dominantly limestone lithology, the well-developed jointing has permitted the formation of numerous karst features.

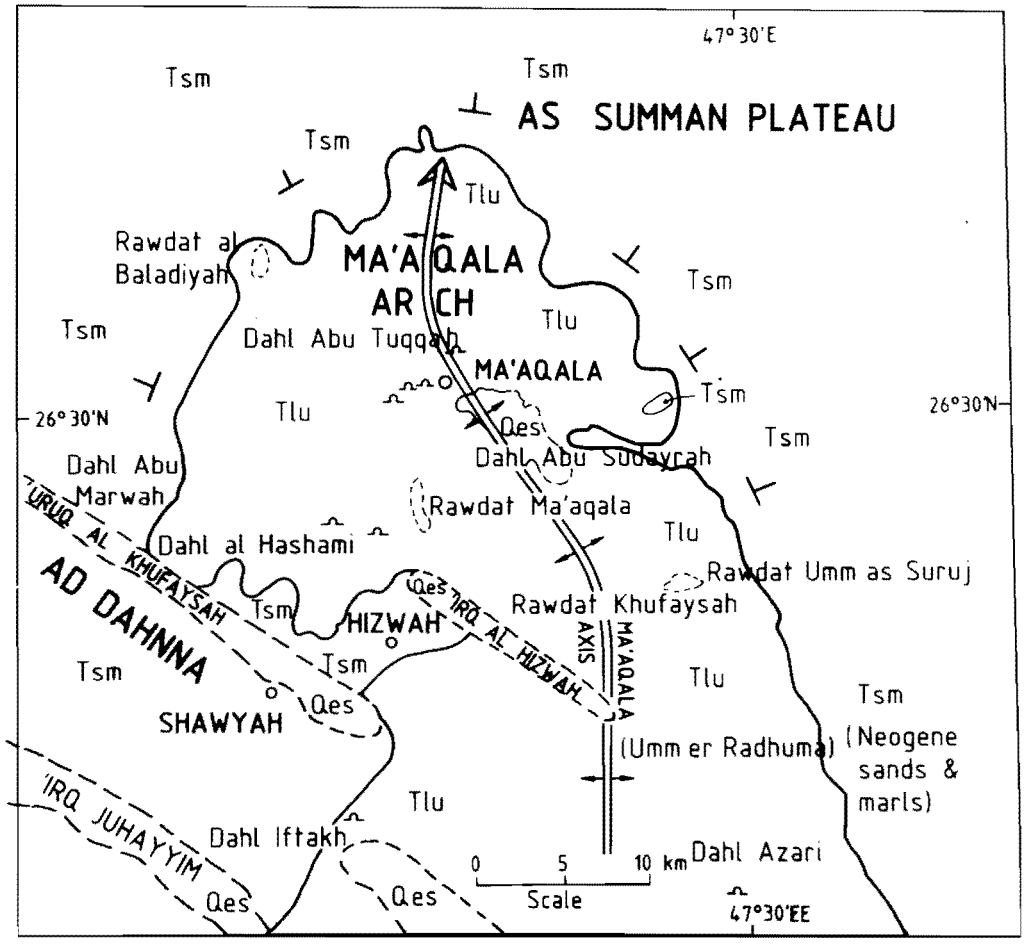

FIG. 2. The Ma'aqala arch, with exposed Umm er Radhuma limestones plunging gently northward beneath, and flanked by, Upper Tertiary sands and marls.

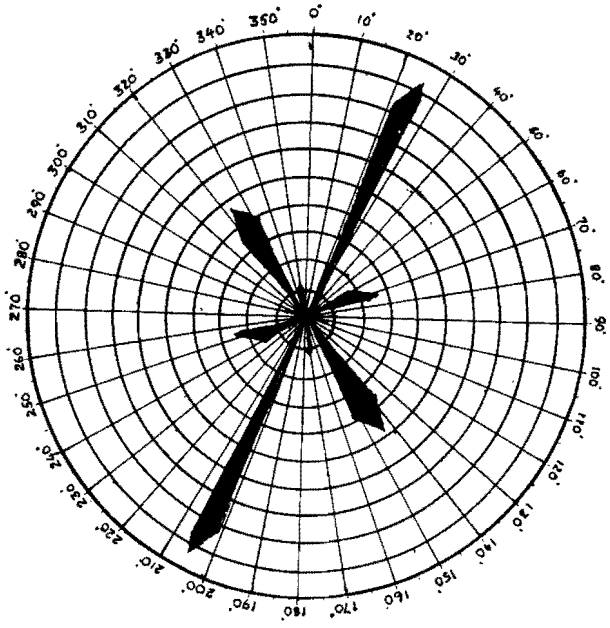

FIG. 3. Major joint trends in the Umm er Radhuma Formation limestones of the Ma'aqala area (shown by Rose Diagram).

FIG. 4. Numerous poljes seen as dark areas on a Landsat TM image of the Ma'aqala area.

The exposures of the Umm er Radhuma limestones in the Ma'aqala area mostly form bare karst, or holokarst, with many similarities to the Mediterranean Dinaric karst. In some shallow depressions (rawdat), such as Rawdat Khufaysah, shallow clay-sand sediment covers the Umm er Radhuma limestones, so that these areas can be considered covered karst. These alluvial depressions in the Lower Tertiary limestones of the Ma'aqala area are clearly seen on an enlarged satellite image of the studied area and represent poorly developed poljes (Fig. 4). The longitudinal sand dunes of the Dahna blanket the Umm er Radhuma just north of Shawyah, forming a type of covered karst. Neogene strata rest unconformably on the Paleogene Umm er Radhuma on the flanks and plunge of the Ma'aqala Arch, so that the old karst landscape, possibly initiated during the Middle to Late Eocene and Oligocene, may be obscured completely to form buried karst, although there is no evidence of buried karst features in many V-holes and structure holes drilled in the area by Saudi Aramco.

Small scale karst features seen include subparallel channels up to 2 cm deep, which are known as rillenkarren (Bögli 1980, White 1988), formed on inclined surfaces of purer limestones by solution caused by small amounts of precipitation, including dew condensation in humid weather (Fig. 5).

FIG. 5. Rillenkarren solution channels, formed on inclined surfaces of purer limestones in the exposed Umm er Radhuma Formation.

In some places, very small meandering runnels are formed on low sloping limestone surfaces, being only a few millimeters deep, probably as a result of the low annual precipitation. These may be referred to as mini-meanderkarren.

Solution along mainly vertical joints in the Lower Tertiary limestones causes the frequent development of kluftkarren, which are clefts from a few centimeters to several meters wide (Fig. 6). In horizontal plan, these are seen as grikes separated by small, ridge-like clints (Jennings 1971, 1985).

more conspicuous and of much larger diameter in the Ma'aqala area, in keeping with karst of the hot arid extreme (Ford and Williams 1989). They are caused by collapse of the roofs of enlarged caverns, resulting in a jumbled pile of broken limestone blocks at the bottom of the doline. Alluvial dolines are not readily seen, but are believed to exist in the limestones underlying the alluvial-filled depressions, or rawdat. Clearly, water does not accumulate in these enclosed alluvial depressions, such as Rawdat Ma'aqala (Fig. 8), and the dried clay-sand alluvium forms desiccation cracks in the summer, so that sand can be seen to run endlessly into

FIG. 6. Kluftkarren developed as clefts by solution along vertical joints in Lower Tertiary limestone.

Among the larger scale karst features, those most commonly encountered are dolines, which form the numerous dahls in the Ma'aqala area, such as Dahl al Hashemi, Dahl Abu Sudayrah and Dahl Abu Tuqqah, plus a great many others which are unnamed. These dolines are of at least three distinct kinds, namely solution dolines, collapse dolines and alluvial dolines (Williams 1969).

Solution dolines are due to dissolution of limestones along intersecting joints so as to form sub-vertical shafts (Fig. 7) and are the most frequent type encountered. Collapse dolines are also quite common being

the polygonal cracks. Failure to accumulate water and loss of sand, down cracks in the alluvium, both imply dolines in the underlying limestones of these alluvial depressions. Dolines developed in the Umm er Radhuma limestones of the Ma'aqala area are usually only 10 to 30 m deep (maximum 42 m) and have a diameter of a few meters to some 40 m. Dahl Abu Marwah is one of the larger diameter collapse dolines (Fig. 9).

Some of the narrow vertical shafts, which are less than a few meters in diameter, are better referred to as sinkholes, swallow holes or ponor (Sweeting 1973),

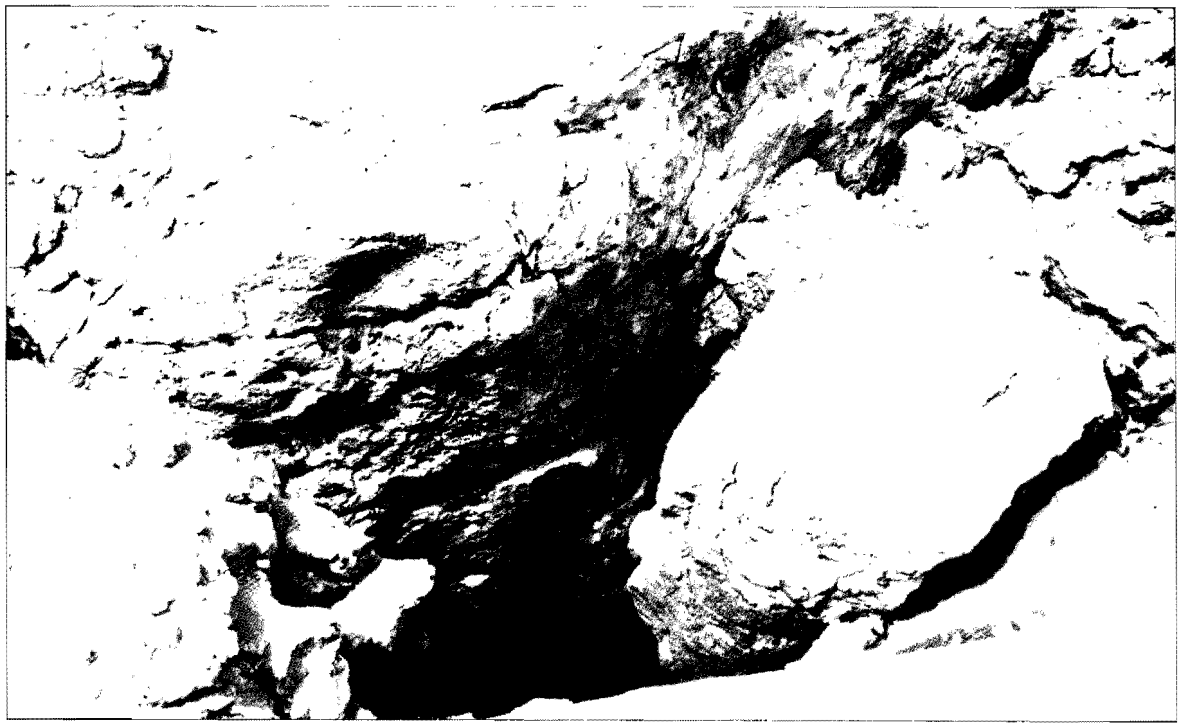

FIG. 7. Solution doline due to dissolving of Umm er Radhuma limestones along vertical joints; about 12 km west of Ma'aqala.

FIG. 8. Open cracks in alluvial fill of Rawdat Ma'aqala underlain by dolines; 7 km SSW of Ma'aqala

and are quite frequent in an area about 4 to 10 km north-northwest of Shawyah (Fig. 10). Some of them are bottle-shaped and open downwards from a very narrow entrance.

Where several dolines have coalesced, a moderately large, compound depression may form with a diameter of 100 m or more. These are uvalas and the rarity of these features in the Ma'aqala area suggests that the

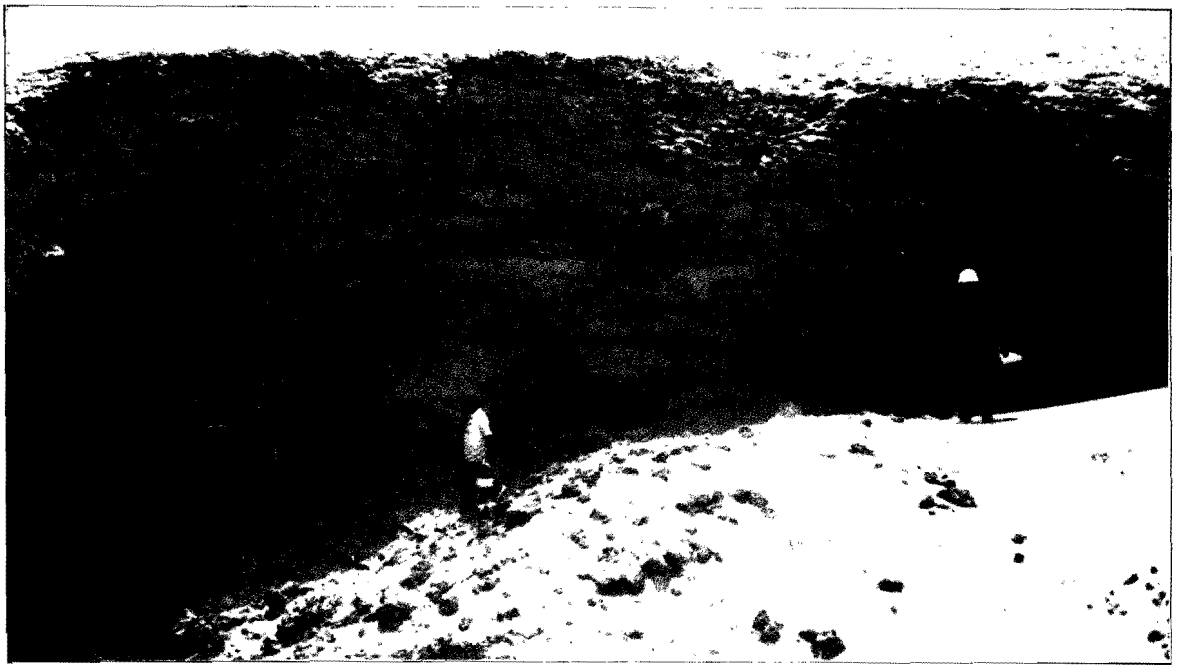

FIG. 9. Collapse doline of Dahl Abu Marwah, caused by collapse of the roof of an enlarged cavern, some 8.8 km NWW of Shawyah.

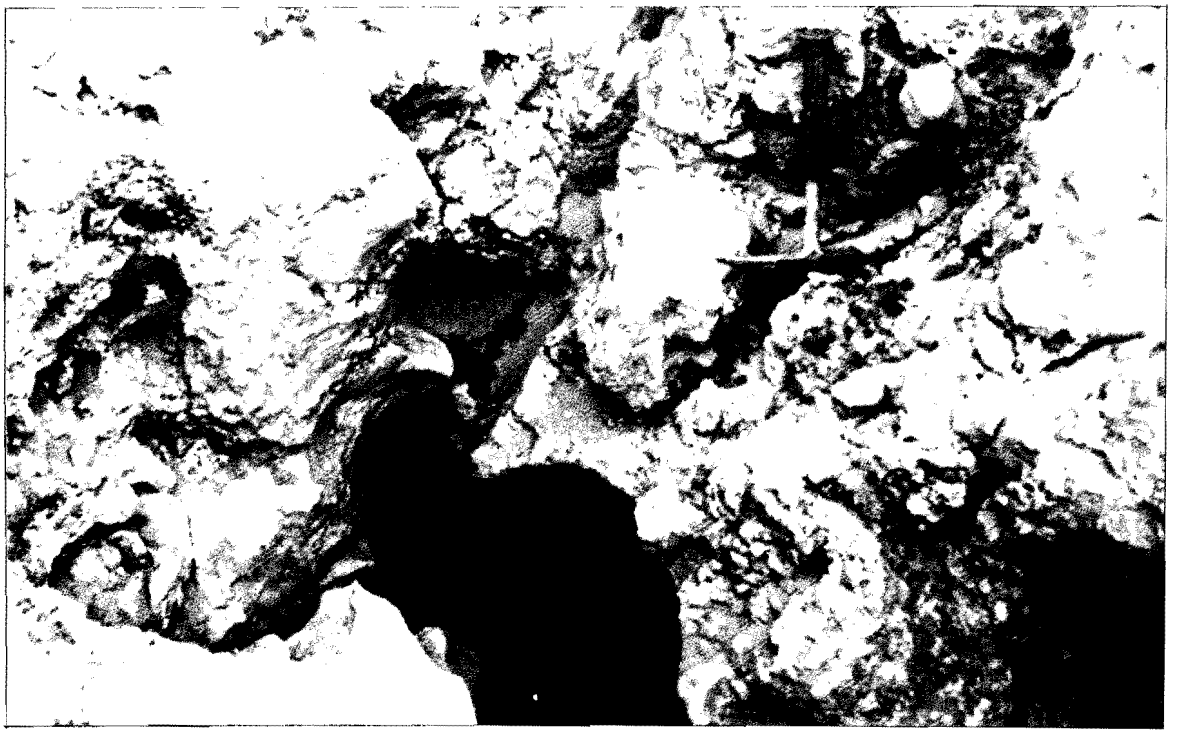

FIG. 10. Sinkhole, or ponor, with narrow vertical shaft; about 10 km NW of Shawyah.

karst cycle on the exposed Umm er Radhuma surface has not progressed past an early stage; another indication of the absence of significant karstification in Eocene and Oligocene.

Poljes are large, flat-floored, enclosed basins several square kilometers in area (Ford and Williams 1989), which are drained by underground channels. They are quite common in the Umm er Radhuma limestones of northeastern Saudi Arabia and are seen in the Ma'aqala area as numerous, subcircular to irregularly oval, alluvium-filled depressions, generally less than 1 km long, and exceptionally up to 2 km long. They appear on enlarged Landsat Thematic Mapper imagery as dark patches and many show a clear orientation along major trends. A good example is seen about 3½ km south southwest of Ma'aqala with a sandy alluvial floor and several sinkholes draining it on the northern side. It is very probable that some of the larger depressions, or rawdat, such as Rawdat Ma'aqala and Rawdat Umm es Suruj, are also poljes and they certainly have internal drainage and alluvial fill, while several residual hills, or hums, of Umm er Radhuma limestone poke out through the alluvium of these larger poljes (Fig. 11). Since they occur in an arid region, these poljes do not have the same landscape appearence as seen in the higher rainfall karst areas of Europe, but they are undoubtedly poljes, formed in Arabia during more pluvial periods and probably slightly enlarged by periodic rainfall even during present arid conditions.

Subsurface Karstification

Many of the sinkholes and dolines in the Umm er Radhuma limestones lead into extensive and quite complicated cave systems, first described by Pint and Peters (1985) and later, in more detail, by Benischke *et al.* (1987). Caves up to 1.1 km long have been mapped (Benischke *et al.* 1987), although most can be followed for only a few hundred meters. These caves are generally entered by shafts, or dolines, and are usually from 10 to 30 m below ground surface. They have obviously developed into cave passages by solution along open joints and bedding planes under lower vadose conditions related to base level drainage. This implies that the ground water table was once quite near the surface, whereas it now lies a depths of 130 to 210 m below the ground surface.

The cave galleries are often at several levels and appear to have selected more soluble strata as the ground water table lowered, probably during the Early and Middle Quaternary. This is clearly shown in the so-called UPM Cave (Lat. 26° 24′ 08.40″ N; Long. 47° 15′ 53.40″ E).

All the caves examined in the Umm er Radhuma limestones of the Ma'aqala area are now dry and abandoned, except for a few small pools trapped during years with heavy winter rains. Precipitation records show that every 10 or 15 years, there is unusually heavy and intense rainfall during short periods of winter and spring, when considerable amounts of

FIG. 11. A hum, or residual limestone hill, in the large polje-type depression of Rawdat Ma'aqala.

water enter the old dry karst system.

Otherwise, the features developed in the caves of northeastern Saudi Arabia are those typical of cave systems everywhere. There are stalactites and stalagmites within the caves, as well as sinter shawls, and potholes in the floor of the cave passages. There are evidently fewer speleothems here than found in caves in areas of higher rainfall. After the initial cave shaft, most caves consist of several passages running in different directions, of branching passages which, on closer examination, show a systematic relation to the major joint trends of the region and to selective stratigraphic horizons (Edgell 1987b).

Stratigraphic Control of Karst Development

The most obvious stratigraphic control of karst development is the occurrence of the thick, tabular, dense, partly non-porous limestone body of the Umm er Radhuma Formation. Adjacent formations, such as the underlying, intercalated calcareous sandstones, marls and sandy limestone of the Neogene, do not show karstification to anywhere near the same extent as the Umm er Radhuma limestones. These Paleocene-Lower Eocene limestones may also have been exposed during the Middle to Late Eocene and Oligocene, before the Neogene clastics were deposited. The Pre-Neogene unconformity may have allowed some initial karstification of the Umm er Radhuma Formation, although many drill holes in the Ma'aqala area fail to show any paleosol horizon or lost circulation at this unconformity.

Cave galleries have developed at several different levels in many cases, due to the more favourable solubility of certain strata and the gradual drop in the ground water table. This is clearly seen in the UPM Cave (Fig. 12), where stacked galleries are developed at about 7, 17 and 23 m below ground surface (Benischke *et al.* 1987). Detailed examination of the lithologic sequences in several caves by Irtem and Ahmed (1987) shows that chalky marl layers seem to have been preferentially dissolved, rather than the slightly dolomitized limestones.

Structural Control of Karst Development

The influence of the regional stress field on the brittle and thick-bedded limestones of the Umm er Radhuma Formation has created well-developed joint sets which have a clear effect on the direction and development of both surface and subsurface karstification (Edgell 1987b). Together with favourable carbonate lithology, a low regional ground water table and previous pluvial intervals, the influence of well-developed, near vertical joints has played a major role in karst development in northeastern Saudi Arabia.

In areas where the Umm er Radhuma carbonates are well exposed near some dahls, or just west of Ma'aqala, there is a surface pattern of clints and grikes which reflects the major joint trends.

These major joint trends are clearly shown on Landsat Thematic Mapper images of the Ma'aqala area by the alignment of successive poljes (Fig. 13). Large Format Camera images of the area also show prominent jointing along a major trend about N 30° E. A second major joint set trends N 40° W, with a third joint set trending N 75° E. Less important joints trend almost north-south and east-west.

Since these joints, seen in outcrop and in caves, are almost vertical and expanded by solution, they provide major avenues for access of surface water to karstify the Umm er Radhuma limestones in the sub-

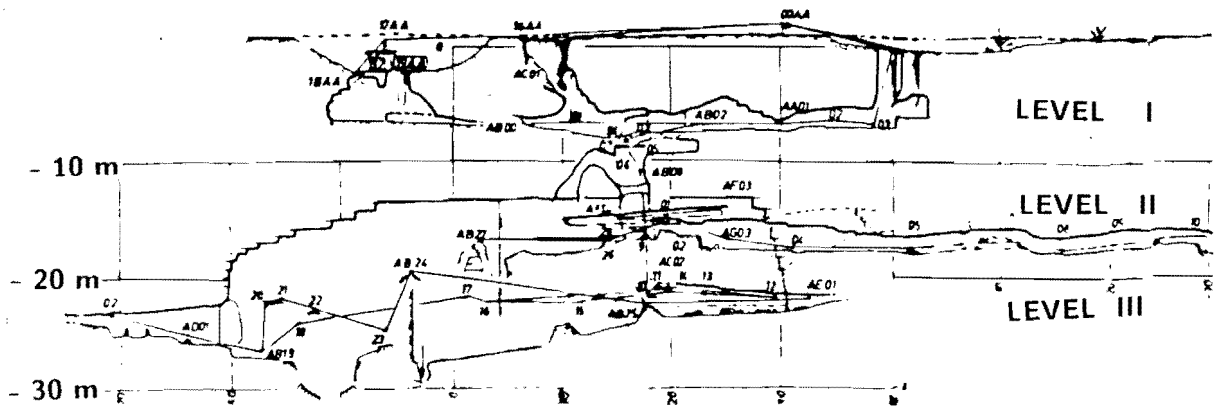

FIG. 12. Longitudinal cross section of the UPM cave, showing successively abandoned galleries. (Benischke *et al.* 1987)

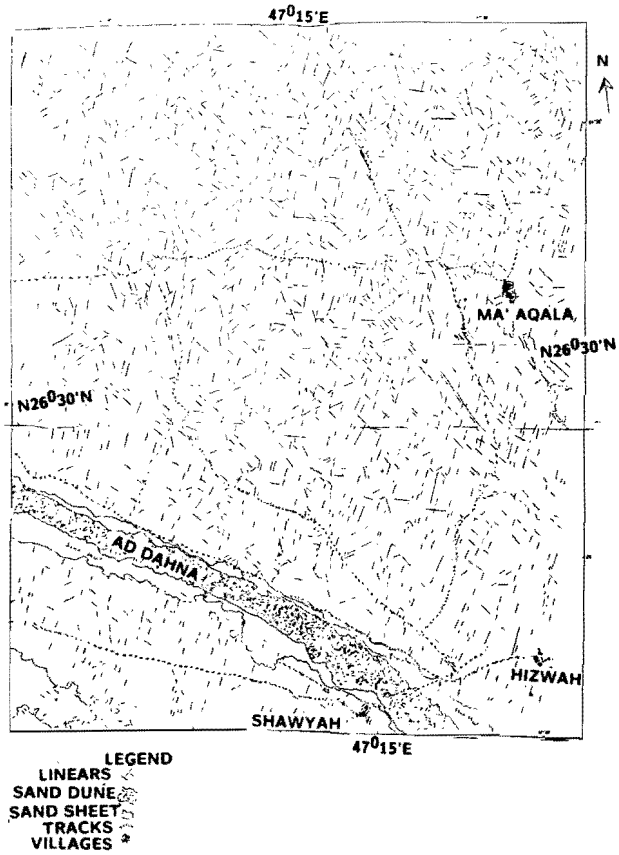

FIG. 13. Major joint trends and alignment of poljes in the Ma'aqala area, as seen on Landsat TM imagery.

surface. Where major joints belonging to different joints sets intersect, solution often favours the development of sinkholes, or larger collapse and solution dolines.

The influence of fractures on jointing is very clearly seen in the subsurface in the UPM Cave, whose main gallery has a length of 668 m and follows a zig-zag path. This long cave passage proceeds downdip towards the north, probably in response to an old base level, but, in detail, it alternates between the predominant N 30° E joint trend and the other major joint trend of N 37° W. The UPM Cave represents a classical case of structural control of cavern development by major joint systems and by bedding plane diaclases (Fig. 14).

Evolution of Karst in Northeastern Saudi Arabia

There are several stages in the development of karst in northeastern Saudi Arabia, as seen by the example of karstification of the Umm er Radhuma limestones.

These shallow water, marine limestones accumulated during the Paleocene and Early Eocene over most of the Arabian Shelf. At the end of the Early Eocene there was possibly a widespread regression, since the anhydritic Rus Formation, as well as the Dammam Formation, are missing from most of the Summan Plateau. Alternatively, the Rus and Dammam Formations may have been removed by erosion prior to deposition of the Neogene sediments. The Umm er Radhuma limestones may have been exposed to weathering during the Middle and Late Eocene, and the Oligocene. During this interval of approximately 26 million years, the Umm er Radhuma carbonates may possibly have undergone initial karstification. Their upper suface is now weathered so that a brown, ferruginous, chert duricrust has formed. This duricrust can still be seen on many parts of the Umm er

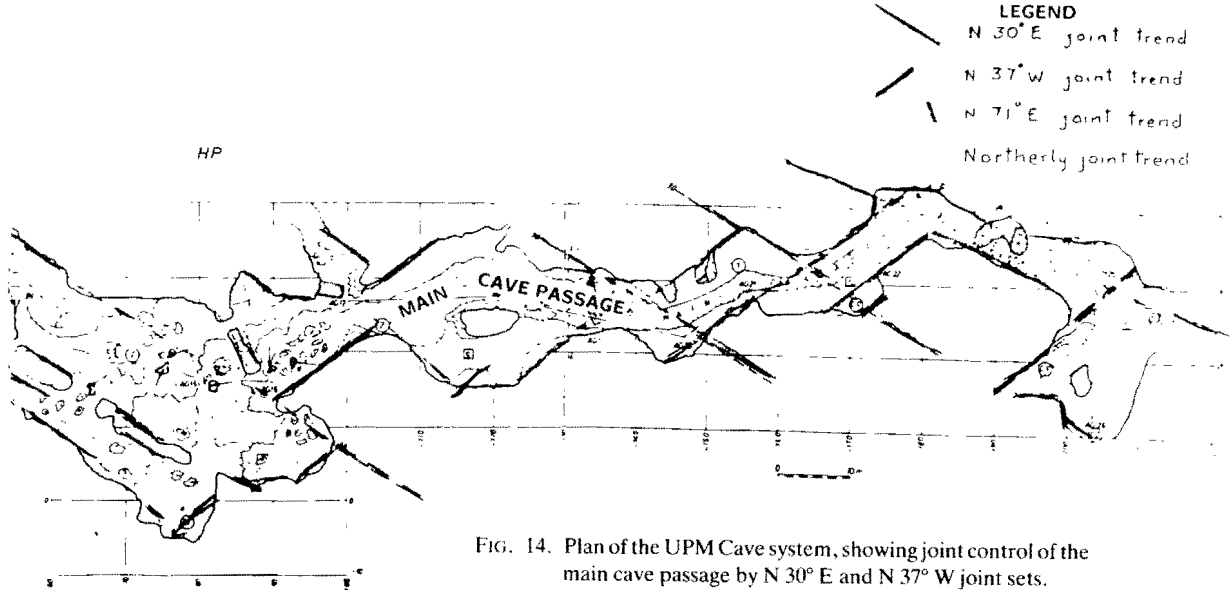

FIG. 14. Plan of the UPM Cave system, showing joint control of the main cave passage by N 30° E and N 37° W joint sets.

Radhuma surface, particularly towards the flanks of the Ma'aqala Arch where there has been least erosion (Fig. 15). The reasons why the Umm er Radhuma limestones were not more karstified during Middle Eocene to Oligocene times may be due to their low relief, with the sea only about 10 km to the northeast, or because they were once covered by later Eocene sediments.

south central part of the Ma'aqala Arch, the upwarped Umm er Radhuma was also slightly eroded, so that its protective duricrust coating was removed. As a result, the most frequent caves have been found in this south-central area between Ma'aqala and Shawyah.

In the Middle Pleistocene, arid conditions began and continued until the present, with a few minor plu-

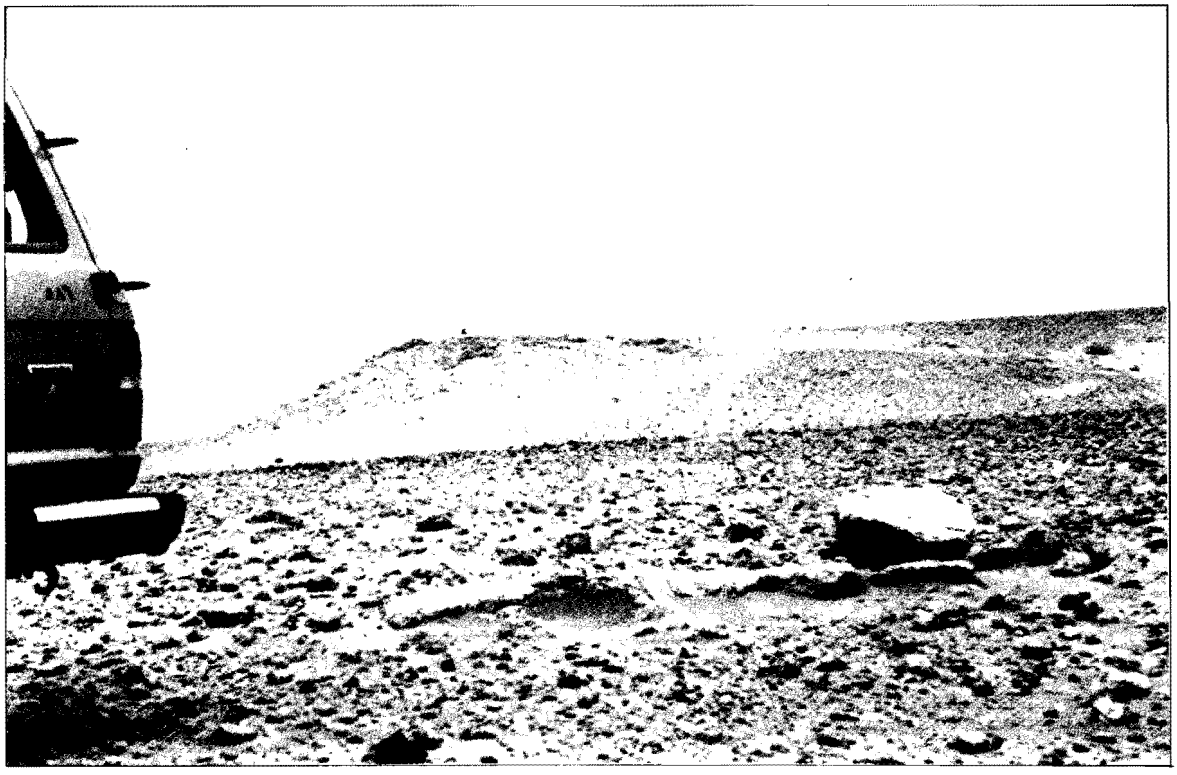

FIG. 15. Duricrust of brown, ferruginous chert on the uppermost surface of the Umm er Radhuma Formation; 12 km ESE of Ma'aqala.

In the Early Miocene, the eroded surface of the Umm er Radhuma was buried beneath up to 250 m of transgressive marls, thinly-bedded sandy limestones and calcareous sandstones of Late Tertiary age.

Renewed structural uplift along the north-trending Ma'aqala Axis occurred during the Pliocene and the overlying Neogene sediments were eroded. By the end of Pliocene, the Umm er Radhuma Formation itself was exposed to erosion along the northerly trending axis of the Ma'aqala Arch.

During the Early and Middle Pleistocene, from approximately 1.6 million to 700,000 years ago, a warm pluvial period prevailed as indicated by oxygen isotope ratios. It was probably during this time that the greatest amount of karstification of the Umm er Radhuma limestones took place with poljes, dolines and sinkholes (or ponor) being widely formed. In the

vial exceptions, such as in the Late Pleistocene from 17,000 to 36,000 years BP and in the 'Neolithic Wet Phase' from 6,000 to 10,000 years BP, when it was more rainy and additional karstification took place. In Saudi Arabia, cold intervals of the Quaternary coincide with pluvial phases and warm intervals with arid phases as at present.

During the last 6,000 years, all of northeastern Saudi Arabia has been hyperarid and the caves and dahls in the Umm er Radhuma limestones have mostly remained dry, while the ground water table has fallen progressively. High intensity rain occurs very rarely. In this hyperarid interval, which continues to the present day (Hötzl and Zötl 1976), the main influences have been eolian with the formation of longitudinal sand dunes ('uruq) of the Dahna, as well as thin sand sheets over parts of the Umm er Radhuma Formation.

Karstification and Paleoclimate

The most significant evidence of the age of most of the karstification in the Summan Plateau of northeastern Saudi Arabia is provided by radioactive isotope datings carried out recently on cave stalactites, stalagmites and sinter drapery. These datings based on Carbon 14 (^{14}C) and Uranium/Thorium (U/Th) were carried out by W. Rauert *et al.* (1988).

Amongst the ^{14}C datings of cave materials, the majority exceeded 40,000 years, and, thus, could not be determined because of the short half-life to this isotope.

Some sinter on a bat specimen was dated by ^{14}C as 1740 ± 140 years old. This corresponds to the moister period when Thaj (or Phigea), Gerrha and Qaryat al Fau all flourished and the radiocarbon date fits well with the ancient historical record. Anything dated younger than this was either camel bone of antelope horn (from 810-955 years BP) and already indicative of a desert climate.

Dating of bat guano at 7090 ± 75 years ago (Rauert *et al.* 1988) is significant, since bats no longer inhabit these dry caves as the area is now too arid. Also, a sinter tube was dated at 9400 ± 300 years BP. It is important that these two datings fall in the pluvial 'Neolithic Wet Phase' from 6,000 to 10,000 years ago.

The next group of ^{14}C dates are those made on stalactites and range from 29,000 (± 2200) to 36,600 (± 1500) years ago. This was a major wet phase in Saudi Arabia, corresponding to the last glacial maximum (Würm Glaciation in Europe), and evidently sufficient water seeped into the caves to form stalactites; a process which is not taking place today.

There is one definite U/Th age date, of 72,000 (± 1700) BP., on sinter drapery from one of the caves. It also indicates a moister phase in Arabia and falls within an early phase of the Würm Glacial (Nilsson 1983, and Martinson *et al.* 1987).

The most important fact is that most U/Th isotope datings on cave stalactites are greater than 270,000 to 350,000 years BP. Thus, the major karstification and cave formation in the Summan Plateau of northeastern Saudi Arabia is quite old and took place in Early and Middle Pleistocene. Additional karstification took place in the Late Pleistocene (17,000-36,000 years BP) and in the Early Holocene. From the observation of stalactites cemented into the land surface near Dahl Abu Marwah, it is clear that there have been repeated cycles of karstification (Felber *et al.* 1978).

It is not considered likely that the major cave systems, dolines and poljes date back to the Middle Eocene to Oligocene. If this were the case, then the poljes and rawdah type depressions would have to contain remnant Neogene sediments.

Acknowledgement

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ظاهرة التكهف في شمال شرق المملكة العربية السعودية

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المستخلص . تعرضت الطبقات الجيرية البليوجينية لتكوين أم الرضومة لعملية التكهف في شمال شرق المملكة العربية السعودية . وقد قام فريق مكون من جامعة الملك فهد للبترول والمعادن والأكاديمية النمساوية للعلوم بإجراء الدراسات التفصيلية حول منطقة معاقلا والتي تقع غرب مدينة الظهران وعلى بعد ٢٨٠ كم منها . وقد أعدت الخرائط لمنطقة تبلغ مساحتها ٥٠٠ كم وتحتوى على ٥٨ دَحلاً أو دولينًا ، وغالبا ما تكون تلك الدحول عبارة عن حفر وعائية رأسية يبلغ عمقها من ١٠ إلى ٣٠ مترًا تتشعب داخل الأرض إلى كهوف . وتشير الدراسة إلى أن الطبقات الجيرية لتكوينات أم الرضومة داخل الكهوف كانت جافةً وقد تكونت منذ زمن بعيد ، حيث إن منسوب المياه الجوفية الحالي يقع على عمق يتراوح ما بين ١٣٠ و ٢١٠ متر . ويحتمل بدء عملية التكهف خلال منتصف أو آخر الإيوسين والأوليجوسين حيث تعرض تكوين أم الرضومة للتعرية ، على الرغم من أن معظم التكهف حدث بالعصر الرباعي . وقد وجدت الرواسب الجيرية الرملية لعصر الميوسين غير متوافقة فـ ـ طبقات أم الرضومة الجيرية المتأكلة . وقد تسببت عوامل التعرية ، فيما بعد ، في تعرية طبقة النيوجين من منـ ـمة التحدب الخفيف لمعاقلا حيث سادت ظاهرة التكهف في الطبقات الجيرية لتكوينات أم الرضومة وذلك خلال الفترات الممطرة من العصر الرباعي . ونادرًا ما توجد ظاهرة التكهف بشكلها الأمثل في المناطق القاحلة .

وتـوجد بمنطقة معاقلا الآن بقايا ظاهرة التكهف . كما يقع بجوار معاقلا ملامح نموذجية لظاهرة التكهف تشتمل على الكارن والحفر الوعائية الرأسية والدوليـنات واليوفالات والبولجات والأودية العمياء والكهوف الرأسية والأفقية والصواعد والهوابط . ويحكم الكهوف وجود تراكيب بنائية عبارة عن شقوق أساسية رأسية تتجه ٣٠° شمال شرق ، ٤٠° شمال غرب . كما توجد شقوق أخرى رأسية أقل حدة تتجه ٧٥° شمال شرق ، وشقوق أخرى ثانوية تتجه شمال - جنوب وشرق - غرب ، ويتضح ذلك بجلاء في كهف UPM وكهف أبوهاشم اللذين يقعان على بعد ٤ و ٨ كم شمال وشمال شرق شاوية ، على الترتيب .

ويتضح أيضًا التحكم الطباقي في تطور الكهوف في كهف UPM ، وذلك بوجود ثلاثة مستويات من الممرات نتيجة لوجود طبقات جيرية سهلة الذوبان ؛ أطول كهف تم رصده بلغ طوله ١,١ كم .

وقد وُجدت الدوليـنات في الطبقات الجيرية الرملية المجاورة ، مثل دحل أبو جِرْفان . بعض هذه الدوليـنات يحتوى على ماء محلية محصورة أمكن استخدامها .