

Solutional Landforms of Gabal Al-Qaraha, The Oasis of Al-Hasa, Saudi Arabia.

by

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ABSTRACT

Jabal Al-Qarah is one of the small outlier hills at the Oasis of Al-Hasa, lying at about 10km ENE of Al-Hafuf Town. The solutional forms of Al-Qarah hill discussed in this paper are as follows :-

1. A calcareous duricrust which covers the top and some of the slopes of the hill.
2. Rock Pillars which are long columns of white lime-stone.
3. Huge crevasses which are wide erosional openings along vertical joints.
4. Narrow, sinuous caves inside the hill.
5. Pedestal rocks with mushroom-like shape.

Evidences collected from the field suggest that these characteristic solutional forms of Jabal Al-Qarah were developed under a variety of climates by the process of solution, and that their development was controlled by high rock solubility, horizontal beds of varying lithologies, and pronounced vertical joints.

1 - INTRODUCTION

In the large desert area of Saudi Arabia which is a part of vast low-latitude arid belt, there are many landforms of varying kinds . Some forms, like the great sand accumulations of the Rub Al-Khali are being formed by one relatively simple geomorphic agent which is wind action under the present arid conditions. Other forms, like those of the Higaz and Asir rugged mountains were developed by a combination of tectonic and gradational processes. Still other forms such as many of those of the Eastern Province were formed by several processes. Of these latter forms are the unique solutional forms of Jabal Al-Qarah.

The present study of Jabal Al-Qarah solutional landforms is based on a field study carried out in March 1972. The conclusion drawn from this field study is that the landforms of the hill evolved under specific structural and climatic conditions. Therefore, this paper is an attempt to describe these characteristic solutional forms and to explain their mode of development. Before discussing that, it helps to consider briefly the physical and geological setting of Jabal Al-Qarah area.

II - THE PHYSICAL AND GEOLOGICAL SETTING OF JABAL AL - QARAH AREA

1. The Physical Setting :

Jabal Al - Qarah is a small erosional outlier hill, being detached from the nearby Shedqum Plateau (Naa'lat Shedqum), and lying about 10 km ENE of Al Hofuf Town, the administrative capital of Al-Hasa Oasis (Fig. 1). The hill has a maximum length of about 2 km, and a maximum breadth of about 1 km. It rises 210 metres above sea level, and about 100 metres above the surrounding plain. Well-defined stream channels are absent over the top of the hill because rainfall sinks quickly into the underlying permeable rocks. Although it is the smallest prominent outlier hill in the area, Jabal Al - Qarah is the only hill which exhibits the solutional forms discussed in this paper. Other forms present in the plain area which extends from Naa'lat Shedqum to the coast of the Gulf of Bahrain are sabkhas, sand accumulations, and lowlying scarps.

Present climatic conditions of Al - Hasa region characterised by high summer temperatures which frequently reach 40°-50°C, and cool temperate short winters with temperature rarely descending below 5°C. The region receives about 100mm. of rain from November to May as few sudden heavy showers. From late August through October, warm, moist, southeast winds from the Gulf blow across the land raising the humidity to high levels. These climatic conditions undoubtedly play a role in the development of some of the solutional forms of Jabal Al - Qarah.

2. The Geological Setting :

Jabal Al-Qarah is underlain by flat-lying sedimentary rocks. They consist of beds of white limestone, green marl, clay and sandy limestone. The white limestone which caps the hill is partially covered with a surficial calcareous duricrust. According to Powers & others (1966, p. D 97), these beds are known collectively as the Hofuf Formations after the town of Al-Hofuf, and they belong either to late Miocene or Pliocene age.

Field observations revealed four characteristics for these sedimentary rocks that have affected its weathering and erosion, and have controlled the shape and arrangements of Jabal Al-Qarah forms. They are as follows :-

- a. Most of the beds are calcareous and at least partially soluble. This has been a major factor in the development of the solutional forms of the hill.
- b. The beds are all horizontal, and of varying lithologies. Consequently, they tend to weather and dissolve at different rates.
- c. The beds are transected by huge vertical joints which dissect the rocks from top to base into huge blocks. There are two main sets of joints which meet at right - angles. The first set of joints strike northeast, while the second set strike northwest. This characteristic controlled the shape of some forms of Jabal Al - Qarah.
- d. The presence of a duricrust on the tops of the hill and the isolated forms like the rock pillars. This crust was an excellent correlative evidence in the study of the landforms of the hill.

III - SOLUTIONAL LANDFORMS OF THE HILL

Although Jabal Al-Qarah is a small outlier hill, any geomorphologist visiting it, can easily detect that this hill exhibits numerous features especially the solutional ones. The characteristic solutional forms of the hill are as follows :-

1. A calcareous duricrust.
2. Rock Pillars.
3. Huge crevasses and caves.
4. Pedestal rocks.

1. The Calcareous Duricrust:

A grey to buff calcareous duricrust is a conspicuous feature of Jabal Al - Qarah. Although partly eroded, it still caps the hill and clings to some steep bedrock slopes (plate 1). It also caps the isolated rock pillars and pedestals, indicating that these forms are younger than the crust. Its thickness is generally less than 1 metre, but formerly it must have been thicker and perhaps more evenly distributed. In spite of that, the crust has effectively sealed the top surface of the hill and protected it from erosion.

A close examination of the duricrust revealed that it is composed of thin calcareous layers. In this characteristic, it resembles the lamina of the tufa deposits of the Kharga Depression (Embabi, 1967, p.49), suggesting a similar mode of development, i.e. by slow sheet flow of water under alternate wetting and drying conditions.

These characteristics of the calcareous duricrust leads to the following conclusions :

- a. The climate prevailing at the time of formation was wetter than it is now. This conclusion is in accordance with the results of former studies on similar

calcareous duricrusts in other parts of tropical deserts (Cook & Warren, 1973,p.116).

b. The crust was - probably - formed during times of semiaridity of the Pleistocene when rainy seasons alternated with dry ones.

c. The crust is older than some other solutional forms of Jabal Al - Qarah, since it still crowns them.

2. Rock Pillars :

A - Form: Rock Pillars - the second most common surface feature of Jabal Al-Qarah - are long columns of white limestone (plate II, a). They are of different sizes, some of them are long (10-15 metres) and thin (50-100 cm in diameter), while some others are short (3-5 metres), and broad (100-200 cm in diameter). In the meantime, some rock pillars are isolated columns and are widely-spaced, while some others are clustered and closely-spaced (plate II, b). This feature indicates that rock pillars are at different stages of development.

In detail, a well-developed rock pillar can be divided into three sections from top to bottom as follows (plate III, a):

a. The top is composed of a thin calcareous (20-50 cm) duricrust crown. This indicates, as mentioned above, that rock pillars are younger than the duricrust which protects their tops.

b. The trunk which is the body of the pillar has smooth walls. On many wall surfaces, thin scales are peeling away (plate II, a) due to present-day weathering. This peeling gave the pillar's trunk the cylindrical shape.

c. An undermined honeycombed, short (30-50 cm) base which is full of surficial bores (plate III, b). Examination of a honeycombed base in the field showed that it is composed of the same type of limestone as the pillar's trunk. It is concluded from field observations that undermining and formation of honeycombs at the base of rock pillars is due to the concentration of chemical action of water. Water resulting from the condensation of atmospheric moisture or from rain droplets might glide along the walls of the columns and settle down at their bases.

B - Stages of development : Field evidences indicate that rock pillars are developed under the effect of weathering and chemical action of water along the joints which characterise the bedrock in the following manner :

a. Stage 1 : The formation of a duricrust on the undulating top of the hill (Fig. 2)

b. Stage 2 : Dissection of the duricrust and widening of joints by the chemical action of rain water. Rain falling on the top of the hill sinks quickly into the permeable rocks along the sides of the joints dissolving a calcareous layer and

leading to the widening of joints. This process resulted in the development of high closely-spaced blocks of rocks capped with a layer of duricrust and separated by very wide crevasses (Fig. 2). This might have happened during late Pleistocene when pluvial climates dominated Eastern Arabia (Chapman, 1971, p. 2725, Table 1).

c. Stage 3 : The formation of rock Pillars through the thinning of the isolated blocks of rock under the effect of the same processes prevalent in stage 2 with the aid of weathering processes, but under a decreasing rainfall condition (Fig. 2). This might have happened in Holocene, i.e. since the beginning of the present-day arid conditions.

3. Huge Crevasses and Caves

Crevasses and caves are two ubiquitous features of Jabal Al - Qarah. The crevasses are huge openings (20 Metres or more high and 2 Metres or more wide) which penetrate into the rocks in cases as much as 50 Metres or more. Some crevasses have smooth walls, while some others have irregular sides (plate IV, a & b). This is mainly due to differences in bedrock succession at different localities.

Field observations indicate that these huge crevasses are erosional openings formed by the chemical action of water gliding along the vertical walls of the joints which characterise the Hofuf formation. But the question which arises at this point is whether these crevasses were formed under the present arid climatic conditions or under a former water climate. One can judge from the dimensions of the crevasses that they were developed primarily under a former wetter climate. This might be late Pleistocene, i.e. contemporaneous to stage 2 of development of rock pillars. In the meantime, one can notice in the field that present chemical decomposition (especially during the rainy season) is still making noticeable progress in widening the crevasses. This means that the crevasses are still growing under the present arid conditions, but at quite a slow rate.

Caves are the second feature which developed at Jabal Al - Qarah in association with the crevasses, since some of them open at each other. This form was first reported by Cheesman (1925, p.122) to be one of the fascinating features of Jabal Al-Qarah, but no morphological observations or studies were made on this form. However, the present study revealed some significant characteristics of these caves. Firstly, the caves are narrow, sinuous paths inside the hill, and many of them have relatively wide entrances at the base of the hill (plate V, a). These relatively wide entrances open into small rooms which were probably suitable for the residence of former settlers in the area, since walls of bricks and red pottery sherds were found at some cave entrances (plate V, b). This finding is in accordance with the result of former investigations which found ruin fields in

various parts of Al - Hasa region (Cornwell,1946. p. 31).

Secondly, the floor of an investigated cave is littered with fallen rock blocks of various sizes. Some of the large ones are hung in the narrow section of the cave roof. No stalactite or stalagmite or wide rooms were observed inside the cave. This might indicate that conditions (climatic and / or rock structure were not suitable for the formation of these features inside the caves. The walls of the cave are coated with rock meal, and in some places rock scales are peeling away.

The presence of wider and larger caves than the investigated one is still a matter which needs future study. However, the wide entrances of some caves can be an indication to their presence. But one might expect that any cave system in this hill will be quite small in comparison with the famous cave system in the karst regions of the world. This is because of the following two facts :

- a. The dimensions of the hills are quite small, therefore any cave system resulting from the solution of some of the limestone beds will be small.
- b. The climatic conditions, especially rainfall, prevailing in the past when these caves started to develop, or the present arid conditions are not ideal for the formation of wider caves.

The question which arises at the end of this discussion is about the age of these caves. The most probable age is late Pleistocene when the climate was wetter than that of the present time. This was the time at which the rock pillars and the huge crevasses started to develop. At that time, the infiltrated water along the side of the joints dissolved the limestone bed at the base of the hill forming the caves.

5 - Pedestal Rocks :

Pedestal rocks are mushroom - like, base supporting columns. Mushroom rocks of Jabal Al - Qarah like many others which developed in various parts of the world are micro - features since their height varies between 2 and 4 metres, and the diameter of the upper broad unit ranges 1 and 2 metres. These rocks are composed of two units, the first is lower neck - like unit, while the second is an upper broad crown - like unit with rounded to subrounded sides (plate VI, a & b). The tops of the pedestals are covered with a calcareous duricrust similar to that one covering the tops of the rock pillars.

Pedestals are found to develop along a constant horizon at the foot - slopes of Jabal Al - Qarah (plate VI, a). This is due to the effect of the varying lithology of the bedrock on the formation of pedestals, since the upper broad unit coincides with the outcrops of a relatively thick limestone bed, while the neck - like lower unit coincides with the exposure of two thin beds of marl and chalk. If this indicates the role of rock structure in pedestal development at the slopes of Jabal Al - Qarah, what is the role of the denudational processes in their development?

Previous studies on this form attribute its formation to wind etching which occurs close to ground level (Strahler, 1969, p. 550 & Twidale, 1968, p.228). This interpretation cannot be accepted as explaining the development of pedestals Jabal Al - Qarah for the following reasons :

- a. Pedestal rocks are undermined at the lower part from all sides forming the neck - like unit. This neck - like lower unit cannot be developed by wind abrasion because wind etching of small rock mass rising above the surrounding surface may cut away at the base of the windward face and of the two sides of the rock mass but cannot cut away at the base of the leeward side.
- b. No evidence of wind erosion were seen at Jabal Al - Qarah.
- c. Pedestals were seen developing at other localities where no evidence of wind erosion was found, like that one which was observed at the slopes of a small granitic hill lying at the margins of Asir Mountains at about 60 km south of the Holy City of Makkah (plate VI,c).

The above - mentioned characteristics of Jabal Al - Qarah pedestals suggest that they were originally small jointed rock masses of varying lithologies, then they developed into pedestals under the effect of chemical weathering. But due to lithological differences, chemical action was more pronounced at the base than at the upper part of the rock block. This differential weathering leads to the regress of the lower part from all sides and the development of the neck - like unit.

VI - CONCLUSIONS

The discussion of the characteristics of the solutional forms of Jabal Al - Qarah and their mode of development revealed the following findings :-

1. They are all micro - forms.
2. Their development was controlled by bedrock structure, especially high rock solubility and huge joints.
3. Although they all are developed under wetter climatic conditions, some of them are still developing at a lower rate under the present arid climate.
4. Except for the calcareous duricrust which is the oldest form (Mid - Pleistocene), other solutional forms probably belong to the same age, i.e. late Pleistocene.

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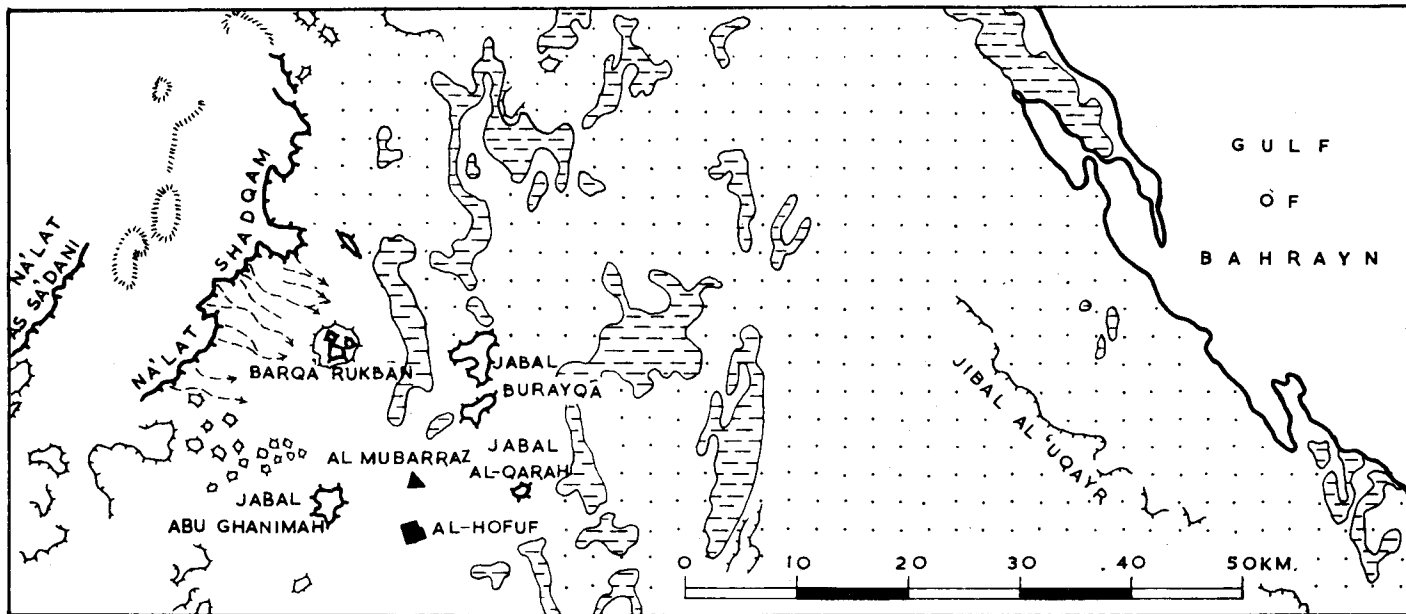
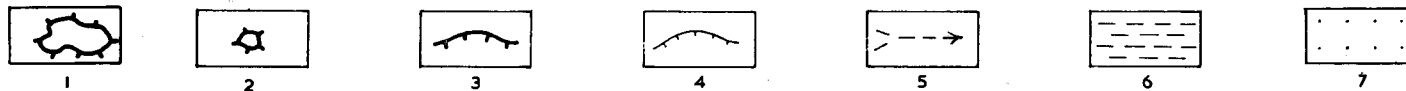


FIG.1, LANDFORMS OF AL-HASA REGION.



1-MESA. 2-OUTLIER HILL. 3-MAIN SCARP. 4-SECONDARY SCARP. 5-DRAINAGE LINES. 6-SABKHAH. 7-SAND SHEET.
 [COMPILED FROM : GEOGRAPHIC MAP OF THE WESTERN PERSIAN GULF QUADRANGLE, KINGDOM OF SAUDI ARABIA, MAP I - 208 B, PUBL. BY THE U.S. GEOL. SURVEY, 1958]

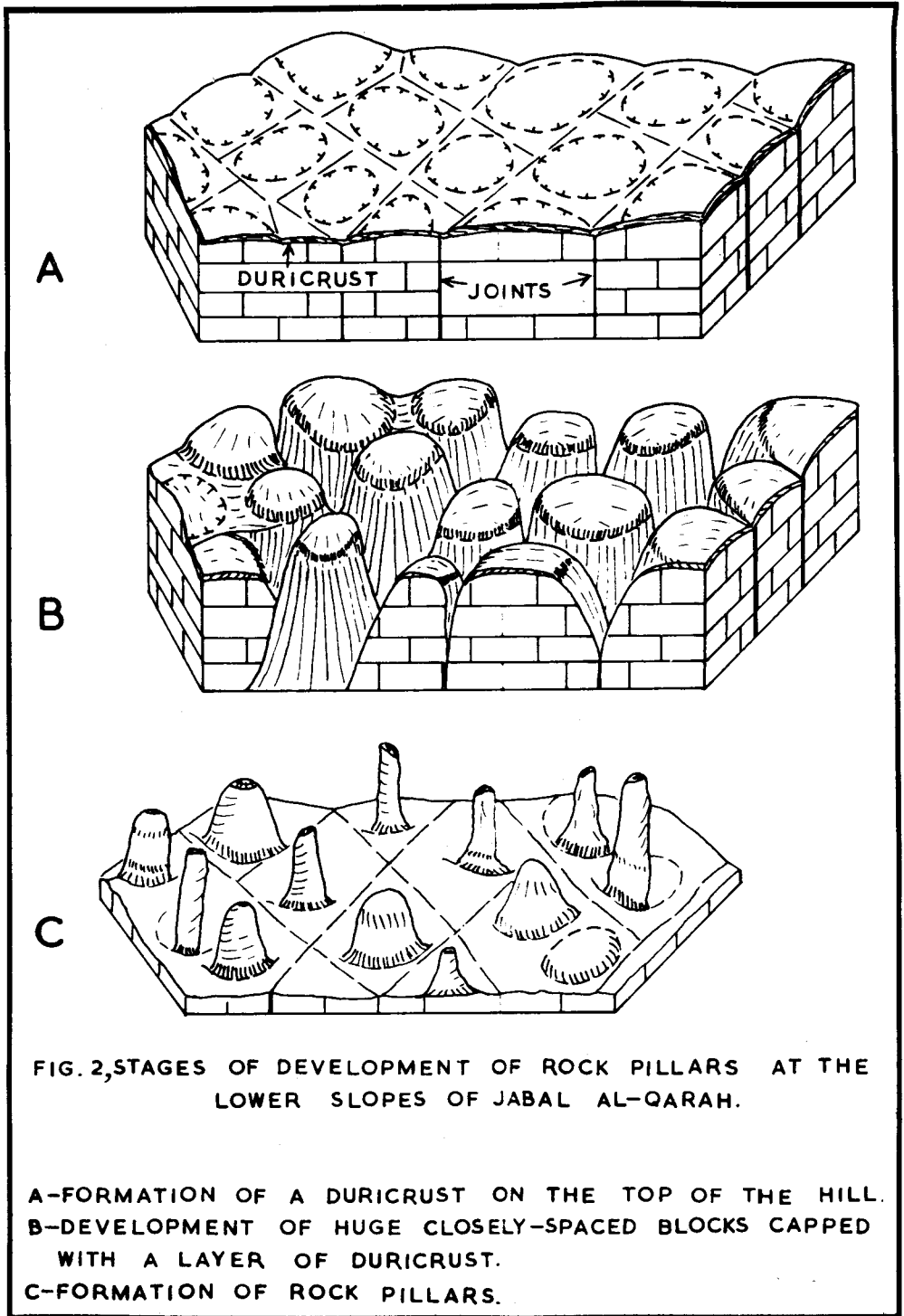


FIG. 2, STAGES OF DEVELOPMENT OF ROCK PILLARS AT THE LOWER SLOPES OF JABAL AL-QARAH.

A-FORMATION OF A DURICRUST ON THE TOP OF THE HILL.
 B-DEVELOPMENT OF HUGE CLOSELY-SPACED BLOCKS CAPPED WITH A LAYER OF DURICRUST.
 C-FORMATION OF ROCK PILLARS.

Plate I



The calcareous duricrust covering the top and slopes of Jabal Al - Qarah.

Plate II



a - Two rock pillars with a duricrust cap and rock scales off their trunks.

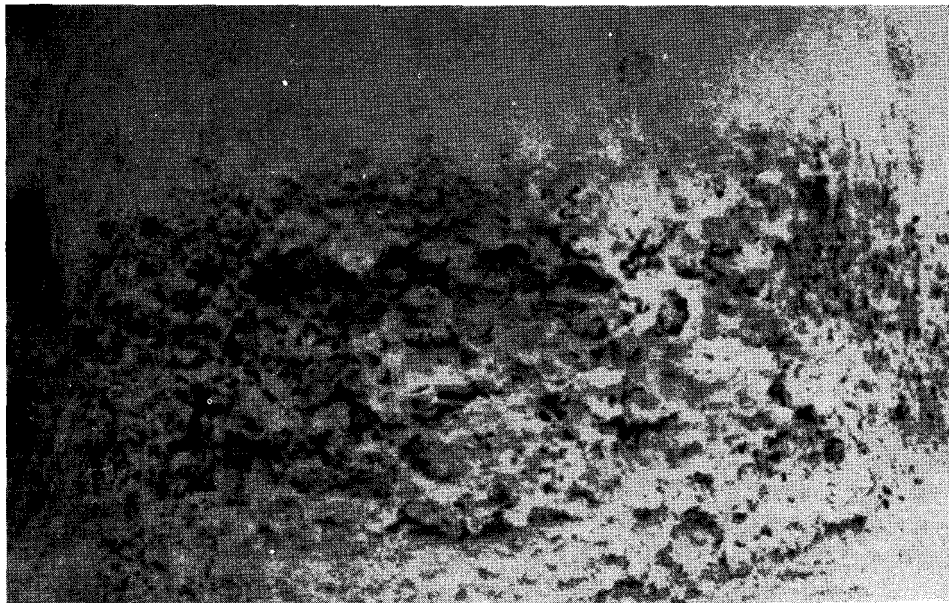


b - Rock pillars at various stages of development.

Plate III



a - An isolated rock pillar exhibiting the three component units : the duricrust crown, the main trunk, and the undermined honeycombed base.



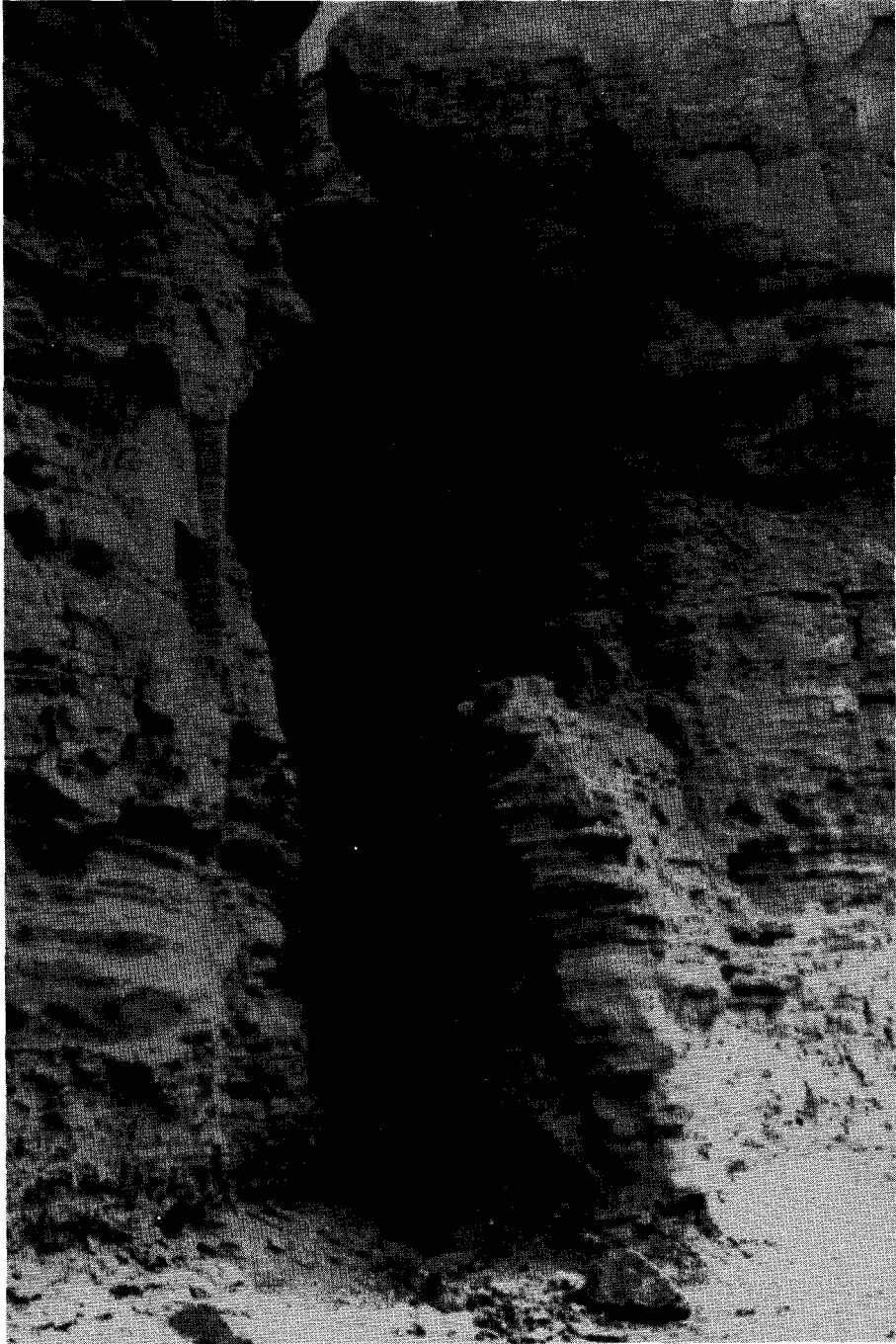
b - The honeycomb of a rock pillar base.

Plate **IV**



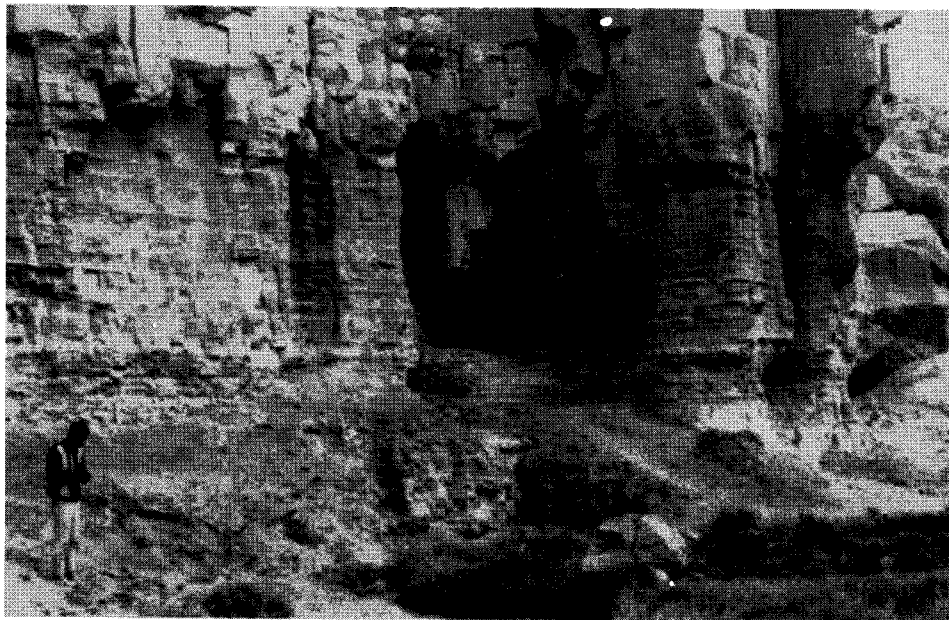
a - A huge crevasse with smooth walls.

— Plate **IV** —



b - Another crevasse with irregular walls.

Plate V

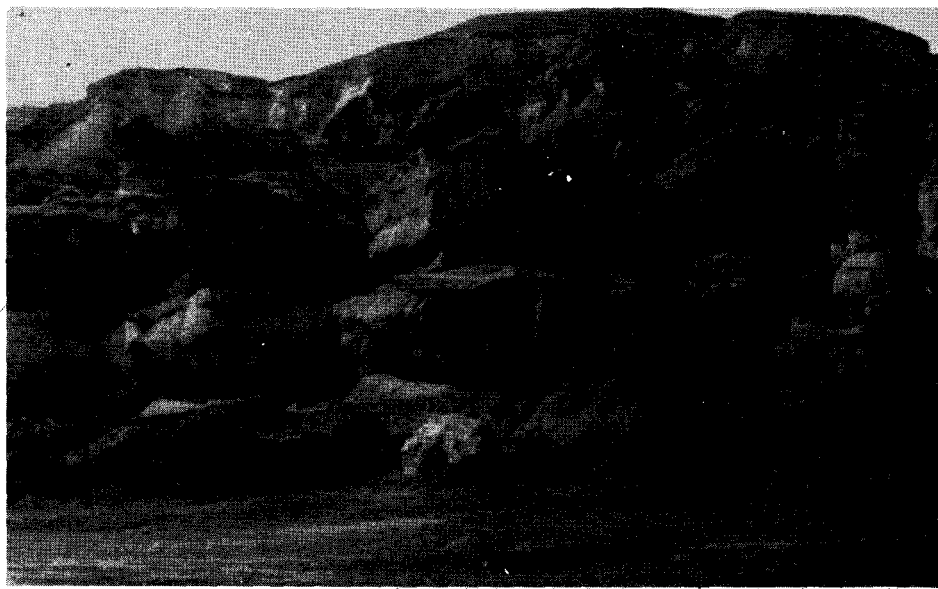


a - Entrance of a cave at the footslopes of Jabal Al - Qarah.

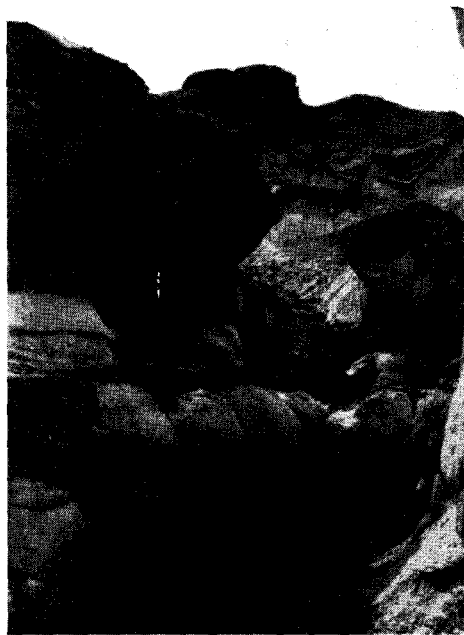


b - An ancient wall of bricks at the entrance of another cave at Jabal Al - Qarah.

Plate VI



a - Pedestal rocks developing at a constant horizon at the footslopes of Jabal Al - Qarah.



b - Two pedestals capped with a calcareous duricrust (note the varying lithologies of bedrock).



c - A granitic pedestal developed at the slopes of a small hill in Asir Mountains.