

GEOMORPHOLOGY OF TAFONI CAVES IN DAHAB AREA SOUTH TO SINAI PENINSULA MOHAMED EL SHARKAWY

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Abstract:

“Tafoni” refers to small size caves that have resulted from weathering. They generally occur in rough granular rocks, sandstone, and limestone. The paper in hand intends to investigate the origins and development of Tafoni caves in granular rocks in the Dahab area.

Results indicated that the dominant climatic conditions in the study area contribute largely to the generation and development of Tafoni caves. A combination of both high temperatures and prevailing winds have had the largest impacts on the development of Tafoni caves by promoting weathering processes and transferring weathering residuals. The structure of the area itself plays a significant role as well. In turn, it was found that Tafni caves play a crucial role in changing the topography of the study area, as such caves themselves also contribute to the development of slopes.

Key words: Tafoni caves, Dahab, weathering.

1. Introduction:

‘Tafoni’ refers to small size caves formed by the effects of weathering. They generally occur in rough granular rocks, sand- and limestone. Tafoni caves are circularly shaped holes, that are hollow with smooth concave internal walls. The dimensions of these caves range between decimeters to more than a meter in some cases (Torab, 1996, p. 153).

Generally speaking, Tafoni caves develop as a result of weathering processes, which accelerate due to high temperatures. Therefore, this phenomenon is found to be

wide-spread in those areas that are characterized by wide seasonal and daily temperature range. In addition, strong wind plays an equally important role in the development of Tafoni caves as it removes and transfers residues from holes under weathering processes. Similarly, Geologic structure plays a significant role in the development of Tafoni caves as it identifies the type of rocks involved and consequently the amount of resistance to weathering processes.

Finally, it can be argued that the main factors underlying the development of Tafoni caves are scale of seasonal temperatures, dominant winds, and geologic structure of the area in question.

In spite of the importance of Tafoni caves, which are wide-spread in most granular rocks in both the Eastern desert and the Southern parts of the Sinai Peninsula, the phenomenon was not adequately considered in Egyptian geomorphologic studies. Accordingly, this paper aims to investigate the origins and development of granular-rocks Tafoni-caves in Dahab area, where, as it happens, various types of Tafoni caves are quite prevalent (Picture 1).



Picture (1): Different forms of Tafoni caves in the study area

2. Study area:

The study area; Dahab, is located in the Southern part of the Sinai Peninsula at the Western coast of Aqaba Gulf in the lower parts of Wadi Om Shouki. The area extends between $28^{\circ} 30' 30''$ and $28^{\circ} 35' 30''$ North, and $34^{\circ} 22' 30''$ and $34^{\circ} 27' 15''$ East, covering a total area of 9.6 km², which represents about 27.9% of the Wadi Om Shouki catchment area (Figures 1 & 2).

From a geologic point of view, The study area is dominant by base rocks with vertical Dikes extending from Eastern North to Western South, the same direction of Aqaba Gulf. Dahab area consists mainly of igneous and metamorphic rocks, which seem to be one geomorphological unit as they are interfering in a complicated manner. The different types of granular rocks are widely-spread in the study area which Tafoni caves are wide-spread.



Figure (1): Location of the Study area

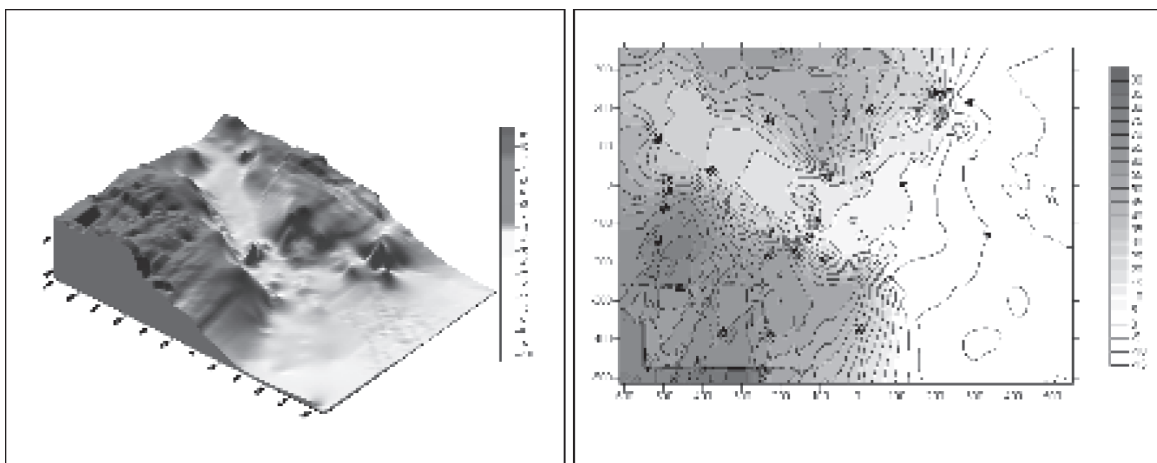


Figure (2): Contour map and 3D Surface of the study area
Source: Field survey of the study area using Total station

Concerning the geologic structure, the study area, as most parts of Southern parts of Sinai Peninsula, experienced a wide range of faults which lead to numerous Joints. Within the study area alone, about 124 Faults & Joints were recorded, variable in their length and direction, with a total length of 156 km and a structural density of 4.53 km/km².

Based on the nearest meteorological station to the study area in Sharm El Sheikh, the average maximum temperature in the study area is recorded in July (36.7° C), the average minimum temperature is recorded in January (15.8° C). This means that the temperature varies widely between summer and winter with a range of about 20.9° C. Such widely varied temperatures in different seasons have a considerable impact in accelerating weathering process (Meteorological Authority, 2006).

Meanwhile, the precipitation in the study area is mainly associated with thunder storms, which occur mostly in autumn and winter seasons. Such storms cause high rains, that lead usually to floods.

The relative humidity in the study area ranges between 54% in January and 37% in June. This means that the study area is characterized by obvious aridity as the average relative humidity is less than 50% (44.8%) (Meteorological Authority, 2006).

3. Field work:

The research is based on an empirical work and a field survey in Dahab area. The field survey was conducted through a field trip to the study area for five days, during which, the dimensions of about 86 Tafoni caves were measured. Moreover, during the field survey, six samples of sediments were collected; three samples collected from inside parts of Tafoni caves and three from outlets of caves.

4. Results and discussion

4.1 Morphometric analysis of Tafoni Caves

Tafon caves in the study area vary in their dimensions, shapes and slopes. The main morphometric characteristics of the Tafoni-caves sample, in the study area, were investigated (Table I).

According to their shapes, Tafoni caves in the study area can be subdivided into four main categories including:

- Elliptical shape: This category of Tafoni caves found to be dominant in the study area representing about 8.37% of the total number of Tafoni caves sample in the study area (Figure 3). The distribution of such type of caves in the study area was usually associated with Faults & Joints, where the dimensions and extension of the caves are determined mainly by the size of these Faults & Joints, which were the main case underlying generating Tafoni caves. This type of caves were generally shallow (have low depth) compared to other categories of Tafoni caves with different shapes (Picture 2).

Table (I): Dimensions and slopes of Tafoni caves sample in the study area

Variable	Dimensions (Meter)			Slope (°)
	Depth (meter)	Width	Height	
Maximum	3	1.20	2.50	65
Minimum	0.15	0.09	0.06	2
Average	0.73	0.54	0.61	16.86
Variance	0.30	0.10	0.21	149.96

Source: Based on the sample collected during the field study.

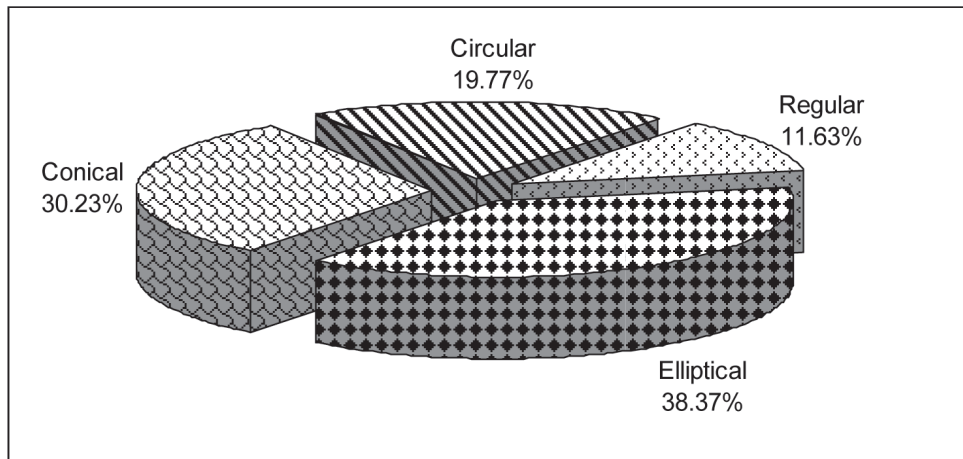
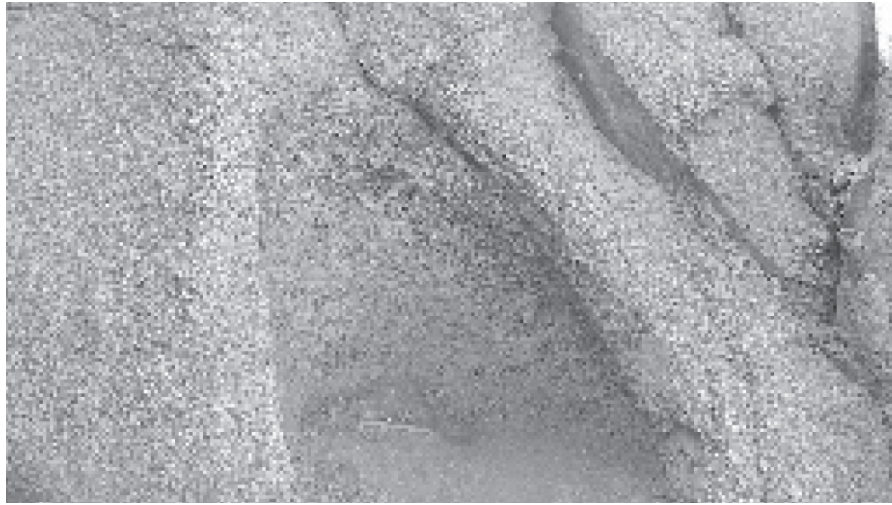


Figure (3): The relative distribution of various shapes of Tafoni caves
 Source: Based on the sample collected during the field study.



Picture (2): Elliprical shape of Tafoni caves

- Conical shape: This category of caves, which has a bill-shape mouth, represents about 30.23% of the total number of Tafoni caves in the study area. The caves of this category have generally high depth compared to other categories of caves, ranging between 1,2 and 3 meters (Picture 3).



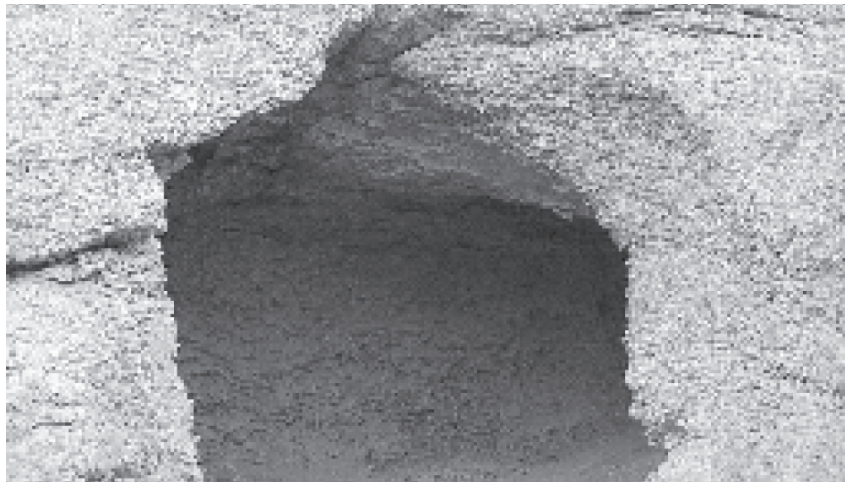
Picture (3): Conical shape of Tafoni caves

- Circular shape: This category, which represents about 19.77% of the total number of caves, is considered the preliminary shape from which Tafoni caves develop according to different geologic circumstances prevailing in the area. As most of these caves are premature, they have low depth ranging between 0.15-0.90 meter (Picture 4).



Picture (4): Circular shape of Tafoni caves

- Regular shape: This category of caves refers to those caves that have regular geometric shapes such as rectangle or square...etc. Although the regularity of shape is not common in such natural phenomena, it was found that about 11.63% of Tafoni caves in the study area have regular shapes. This is mainly due to the location of these caves, which develop above a set of perpendicular Faults & Joints leading to the regular geometric forms of the mouths of these caves (Picture 5).



Picture (5): Regular shape of Tafone caves

4. 2 Sediments analysis

The analysis of the surface sediments in Tafone caves aims at identifying the sources of these sediments and main factors contributing to their transference. It was found that fine sediments such as clay, as well as fine and medium silt, are dominant in Tafone caves representing about 48.22% of the total sample collected from their insides. Meanwhile, the coarse sediments such as gravel and medium sands represented 16.66% of the total sample (Table II) (Figure 4).

Table (II): Mechanical analysis of Tafone sediments in the study area

Sampling No.	Gravel	Medium sand	Fine sand	Very fine sand	Course silt	Medium silt	Fine silt and clay
Inside	1	6.33	11.44	10.52	13.43	8.01	24.81
	2	7.14	11.88	11.34	16.22	8.63	18.32
	3	5.05	8.14	9.63	14.92	12.65	15.78
	Average	6.17	10.49	10.5	14.86	9.76	19.64
Around the outlets	4	17.08	20.9	14.76	16.11	10.23	11.12
	5	12.44	37.39	11.7	9.6	9.12	12.45
	6	14.87	25.65	17.46	11.66	9.65	11.31
	Average	14.8	27.97	14.64	12.46	9.67	11.63

Source: Laboratorial analysis of the sample collected during in the field study.

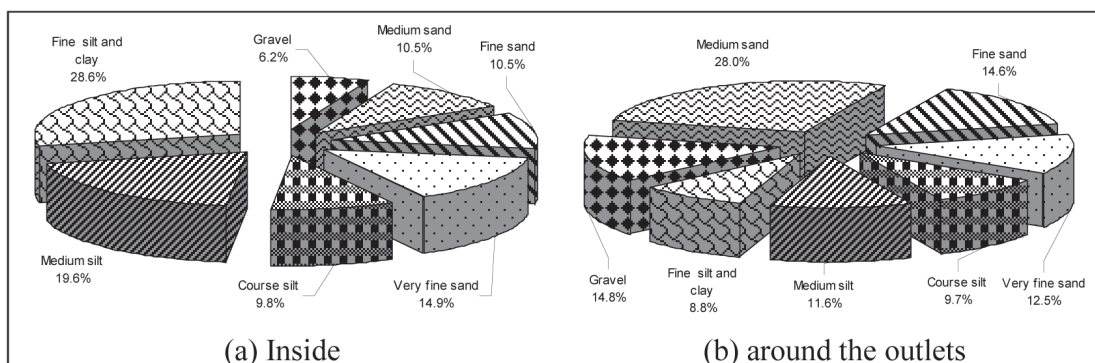


Figure (4): Type of sediments inside and around the outlets of Tafone Caves

Source: sample collected during the field study

By contrast, the coarse sediments such as gravel and medium sand were found to be dominant in the outlets sample as they represented about 42.77% of the total sample, while the fine sediments (clay, fine silt and medium silt) represented about 20.46%. Such variations of type of sediments inside and outside Tafoni caves can be attributed to the processes that are responsible for generating these sediments. The sediments inside Tafoni caves were found to be generally fine as they are results of a chemical process, which usually results in fine residuals. Meanwhile, the dominance of coarse sediments around outlets of Tafoni caves is due to the impact of erosive and mechanical weathering processes, which usually result in coarse sediments.

4.3 Relationship between Tafoni caves and Faults & Joints

To examine the impact of geologic structure in generating Tafoni caves in the study area, the direction of Tafoni axis were compared to the direction of the Faults & Joints in the area. It was found that major proportion of Faults & Joints and Tafoni caves in the study area had a direction Eastern North/Southern West¹ with a percentages of 37.1% and 39.54% of the total number of sample for each of them, respectively. Meanwhile, about 30.65% of Faults & Joints and 29.07% of Tafoni caves extend from Western North to Eastern South. This is followed by the direction of East/West, as 16.93% of Faults & Joints and 19.76% of Tafoni caves extended from East to West. Finally, minor part of the Faults & Joints and Tafoni caves extend from North to South with percentages of 15.32% and 11.63% of the total number of each of them, respectively (Figure 5).

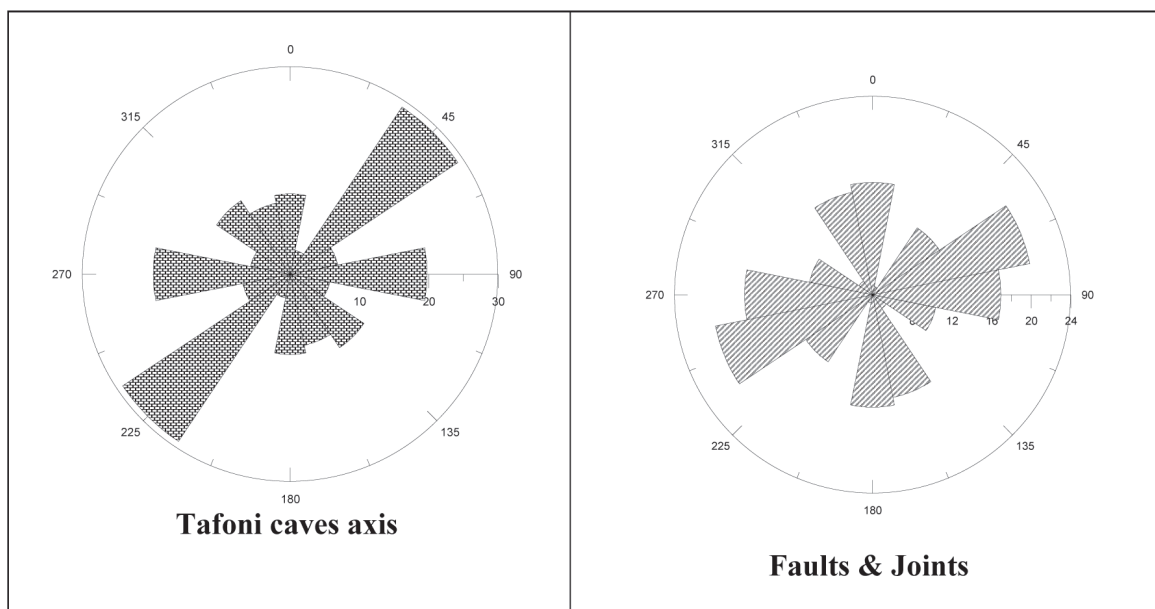


Figure (5): Direction of Faults & Joints and Tafoni caves axis in the study area
Source: Based on the sample collected during the field study.

Generally, it was noticed that both of Tafoni axis and Faults & Joints directions are highly associated. Such an association testifies to the significant role of geologic structure in generating and developing Tafoni caves in the study area (Picture 6).

¹ The same direction of Aqaba Gulf.



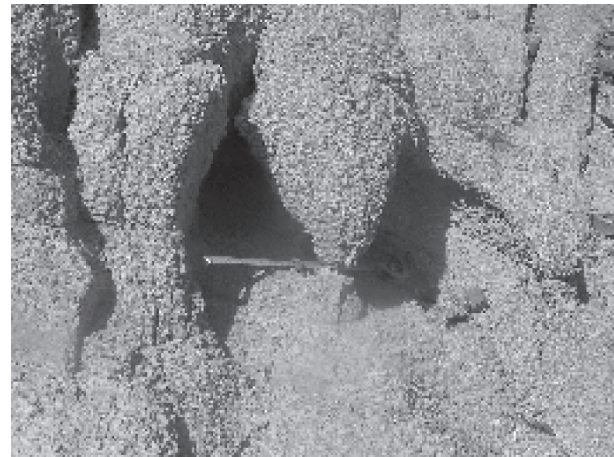
Picture (6): development of Tafoni caves alongside the Faults & Joints

4.4 The development of Tafoni caves

It was noticed that Tafoni caves in the study area develop and become wider and deeper through merging with one another (Picture 7). According to Walton (1976), the main factor that leads usually to deepen and widen Tafoni caves is represented in the active chemical weathering process. The inside parts of these caves are inherently set aside in shadow away from the sun rays, so that these caves often retain a degree of moisture, which, in turn, helps in activating chemical weathering processes.

The activity of chemical weathering processes produces embryo or seed holes, which grow up inside the initial Tafoni cave. With the development of these seed holes, merging among them usually follows, which, in turn, leads to deepening and widening of the initial Tafoni case. This is often associated with action of aerial erosive factors, which transfer sediments and weathering residuals form Tafoni caves. It should be noted that the slope of a Tafoni cave plays a crucial role in accelerating the transferring processes (Picture 8).

Moreover, it was noticed that the continued processes of Tafoni caves development contribute to the reshaping of the slopes in the study area. This was emphasized by



Picture (7): Merging of Tafoni Caves to each other



Picture (8): Seed holes inside one of Tafoni caves

high percentage of concave slopes at the expense of the convex slopes in the lower part of Wadi Om Shouki, where the coefficient shapes of slopes at both the right-hand and left-hand sides were 0.88 and 0.47, respectively. This indicates that the slopes in the study area are mature or full-fledged from geomorphologic perspective, particularly the right-hand side slopes. Such maturity of slopes is considerably due to the development of Tafoni caves, which are widespread in the study area. The development of these caves means the widening and consequently the eventual merging of these caves, generating even larger holes and caves. The ceiling of these large caves and holes erelong collapse in the form of falling blocks (Picture 9).



5. Conclusion

This study of Tafoni caves in the lower part of Wadi Om Shouki, which involved investigating a sample of 86 caves in granular rocks, shows how significant the role of climatic conditions is in the generation and development of Tafoni caves. In this respect, it was obvious the role of high temperature range, prevailing in the study area, in accelerating weathering processes. Also, dominant wind plays a crucial role in development of Tafoni caves as it transfers the sediments and weathering residuals, which lead to exposure of the surface of the caves and consequently be subject to further weathering process and erosion factors.

Also, the role of weathering activities, particularly, chemical weathering, was emphasized by the type of sediments involved. In this respect, it was found that major proportions of sediments inside Tafoni caves were fine sediments. The dominance of fine sediments inside Tafoni caves testifies both to the activity of chemical weathering and, subsequently, to their significance in the development of Tafoni caves. Meanwhile, the majority of sediments outside Tafoni caves were found to be coarse sediments, which represent residuals of erosive factors and mechanical weathering.

Similarly, the geologic structure has a significant impact on Tafoni caves in the study area. In this respect, it was found that the directions of Tafoni caves were highly associated with the directions of Faults & Joints which have mostly Eastern North/Western South direction.

The shapes of Tafoni caves was found to be varied

widely, for instance, four main categories of shapes were recognized. These are elliptical, conical, circular and regular.

On the other hand, it was also found that Tafoni caves themselves play a significant role in the development of slopes in the study area, which are generally mature or full-fledged from a geomorphologic perspective.

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