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Qarārāt of the Sarīr Al Qattūsah, central Libya

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Abstract

Qarārāt are endoreic depressions forming in arid to semiarid climate by two alternating processes: preparation stage and removal of the material. They are situated on an oligo-miocene (?) paleopediplain, in the vicinity of two escarpments. The closer qarārāt lie to the escarpment, the greater is their depth. The evolution model is based on an effect of fluctuating piezometric level, with slow and gradual lowering reflecting regional aridization and extensive younger (mio-pliocene) pedimentation . Subrosion of evaporitic material and intrastratal/interstratal dissolution of carbonates resulted from slow regional groundwater flow through porous media of poorly to medium lithified sediments, northward to northwestward. These processes could contribute to the formation of an initial surface depression in the place where qarārāt deepened.

Résumé

Les qarārāt (au singulier: qarārat) sont des dépressions endoréiques à flancs abrupts, profondes de 35 à 95 m, qui se sont formées, sous climat aride à semi-aride, par alternance de deux processus: stade de préparation et enlèvement de matériaux. Elles sont situées sur une pédiplaine oligo-miocène (?), au voisinage de deux escarpements. Plus les qarārāt sont proches d'un escarpement, plus elles sont profondes. Leur modèle d'évolution repose sur des fluctuations du niveau de la nappe aquifère, baissant lentement et progressivement au fur et à mesure que le climat régional devenait plus sec, et sur une vaste pédimentation ultérieure (mio-pliocène). La dissolution d'évaporites et d'horizons carbonatés a été provoquée par un lent écoulement d'eau souterraine, vers le nord ou vers le nord-est, dans des roches poreuses appartenant à des sédiments peu ou moyennement lapidifiés et le long de lignes de fractures. Cela contribua à faire apparaître en surface des dépressions que divers processus géomorphologiques mécaniques approfondirent ensuite en qarārāt.

I. Introduction

Endoreic depressions are typical geomorphological features of arid and semiarid climate. In Libya, they are known as *qarārāt* (singular *qarārat*) developed as polygenetic and polycyclic forms on paleo-pediments, e. g. in Wādī Khunayir (Woller, 1984), Wādī as Shātī (Seidl & Röhlich, 1984), or on flat desert of Sarīr al Qattūsah, all in the Fazzān (central Libya). Endoreic depressions selectively reworked on fold structures are known from Adrar - Tassili region in Algeria. Depressions of the *daia*-type originated from karstification on Hamada du Guir and in Ouargly region in Algeria. The pseudocrater depression of Al Umchaimin occurs in the western desert of Iraq, where endoreic depressions are generally known as *gaara* (Mitchell, 1958).

The most typical qarārāt are four depressions on the Al Fuqahā map-sheet (27° to 28° E, 15° to 16° 30' N, Fig. 1): Al Fuqahā (el Fogha), Al Hīrah (el Heira), Shakk (Sceccar) and Bin al Qāsim (Belgasem, el Agaab, Bilgāsim; older names in brackets after Klitzsch, 1974). They represent very expressive forms of the landscape, which were connected to numerous relief-forming processes, sometimes very speculative (e. g. impact crater, gas eruption, etc.).

Age			Formation	Member	Qarārat			
					F	H	S	Q
Tertiary	Eoc.	Ypr.	Bishímah	Rawághah				
				Wádí Zákim				
				Khaiyr				
	Paleocene	Thanet	Shurfah	'Ammúr				
				Qaltah				
				Bú Ra's				
		M	Zimám	Hád				
		D		Upper Tár				
M	K_2	M		Bin 'Affín				

Table 1. Stratigraphic position of qarārāt

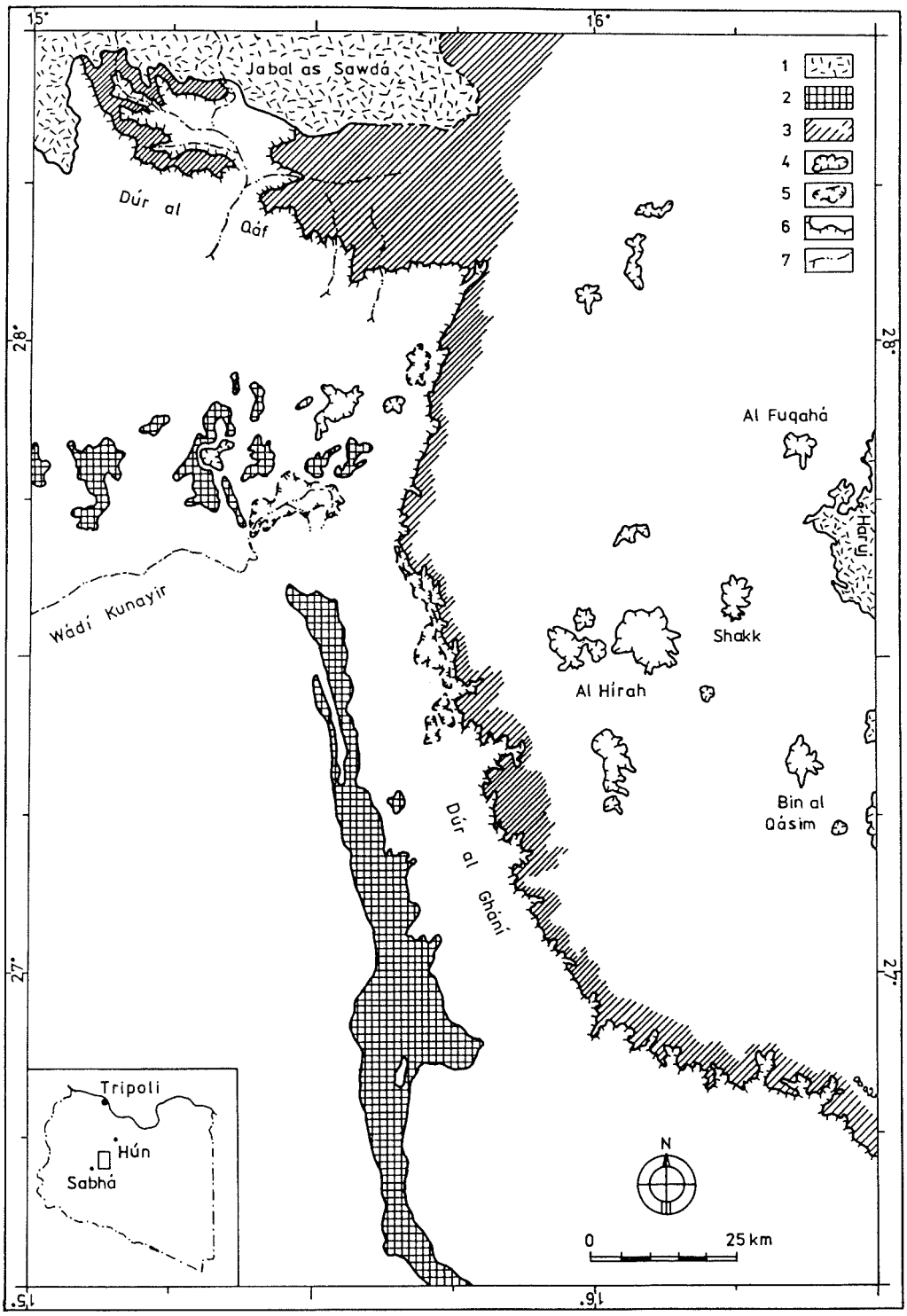

Figure 1 : Position of qarārāt in the large-scale geomorphologic situation of the region between volcanic mountains of Jabal as Sawdā and Jabal Haruj al Assuad
1 - volcanic rocks 2 - Al Mahrūqah Formation 3 - hamada on Hād Member 4 - qarārat 5 - deflation trough 6 - escarpment 7 - wadi

II. Geological position

All four qarārāt occur in identical geological position (Fig. 2 and Tabl. 1) .

They are developed in marine cretaceous to lower eocene platform sediments belonging to the western margin of the Sirte Basin. Wādī Zākim Member is composed of dolostones, often silicified. Khayir Member consists of dolomitic marl to clayey dolostone, poorly lithified, often with gypsum. 'Ammūr Member is built of dense limestones to dolostones with marly intercalations. Qaltah Member is represented mostly by dolomitic marls and clays, often with gypsum, sometimes with halite. Important is an interbed of massive dolomitic limestone to calcarenite. Bū Ra's Member contains marls to clayey dolostones with a bed of hard sandy dolostone to sandstones at the top. Hād and Upper Tār Members are composed dominantly of hard resistant dolostones and dolomitic limestones. The upper part of Bin 'Affīn Member (Maastrichtian), exposed in Q. Al Hīrah only , is a poorly lithified complex of siltstones to sandstones. From the morphological point of view, important relief-forming members are as follows: Wādī Zākim (dolostone), 'Ammūr (limestone to dolostone), Bū Ra's (sandy dolostone at top) and Hād with Upper Tār (dolostone to limestone).

III. Structural position

Qarārāt are situated in a very flat position. FÜRST (1965) and KLITZSCH (1974) supposed that the structural position is dominant in their origin. FÜRST (1965) expected that qarārāt are developed in cores of very flat domes with limb dips less than 1°. KLITZSCH (1974), on the contrary, assumed that Q. Shakk and Bin al Qāsim, and probably also other ones are situated in centres of very shallow structurally controlled depressions. To prove or invalidate both theories, a set of detailed survey measurements were carried out. The strata dip around qarārāt reaches 5 to 20', max. 1°13' in Q. Al Fuqahā; in many points no dip was detected.

The strike of dip is highly variable, therefore no dome or depression can be proved. Tectonic lines, supposedly controlling qarārāt (FÜRST, 1965), were detected on air photos only in Q. Al Fuqahā and classified in the field as fractures without any movement. No faults have been detected in the vicinity of other qarārāt.

IV. Morphology

Morphometric data are summarized in Table 2. The depth of qarārāt varies from 35 m (Q. Bin al Qāsim) up to 95 m (Q. Al Hīrah). The orientation of longer axes follows, more or less, the N-S trend, except Al Fuqahā. The latter is based on the resistant basal bed of Wādī Zākim Member, while other ones on soft Khayir Member. This fact, together with W-E trending fractures, affected the W-E trend longer axis and the higher rate of elongation. The shape of this qarārat is therefore very close to endoreic depressions originating on the contact of two lithologically different rocks.

Qarárat	Longer axis		Shorter axis		Ratio of longer to shorter axis	Depth (m)
	Dir.	Length (km)	Dir.	Length (km)		
Al Hírah	NNW-SSE	11.2	WSW-ENE	10.0	1.1 : 1	95
Shakk	NNW-SSE	5.8	WSW-ENE	4.4	1.3 : 1	68
Al Fuqahá	W-E	4.8	N-S	2.8	1.7 : 1	55
al Qásim	N-S	6.0	W-E	4.8	1.3 : 1	35

Table 2. Morphometric characteristics of qarārāt

The place in which qarārāt started to cut down is not distinct in soft Khayir Member. The topmost part of the qarārāt gently inclines towards the centre and is marked by a net of small wadis and run-off forms, often dendritic. Therefore, each qarārat is encircled by a belt of gentle sloping surface; the vertical and horizontal dimensions of this belt are defined by the thickness of soft Khayir Member. From the centre to the margins, this belt is substituted by a hanging pediment developed on top of massive carbonates of 'Ammūr Member.

The most expressive morphological step is developed on carbonates of 'Ammūr Member (Fig. 1). The upper edge of the step represents the marginal line of the qarārat. Other structural terraces are originating on limestone layer in Qaltah Member, on top bed of Bū Ra's Member, and in Q. Al Hīrah also on Hād and Upper Tār Members. There several structural steps are based on dolostone and limestone bedding.

The quaternary cover is developed in the lowest point of the qarārāt. It is composed mostly of clayey-silty material with sandy admixture, locally with interbeds of evaporites. Sediments are impermeable, constituting conditions for accumulation of intermittent lakes during rainy seasons. Numerous recent wadis empty into the centre of the qarārāt, originating flat alluvial cones overlapping fine sabkha-like sediments. Accumulations of eolian sands are concentrated at western and northwestern-northern foothills of the qarārāt. An extensive sand dune in Q. Al Hīrah occurs in the western or northwestern direction, climbing up the 95 m high slope. The accumulation of eolian sands is controlled by present wind directions blowing from south in winter and from east in summer.

Steps (structural terraces) in qarārāt are situated eccentrically owing to the outer margin, i. e. they are shifted somewhat to NW-NNW and correspond to sand accumulations in the lowest qarārat point. The original

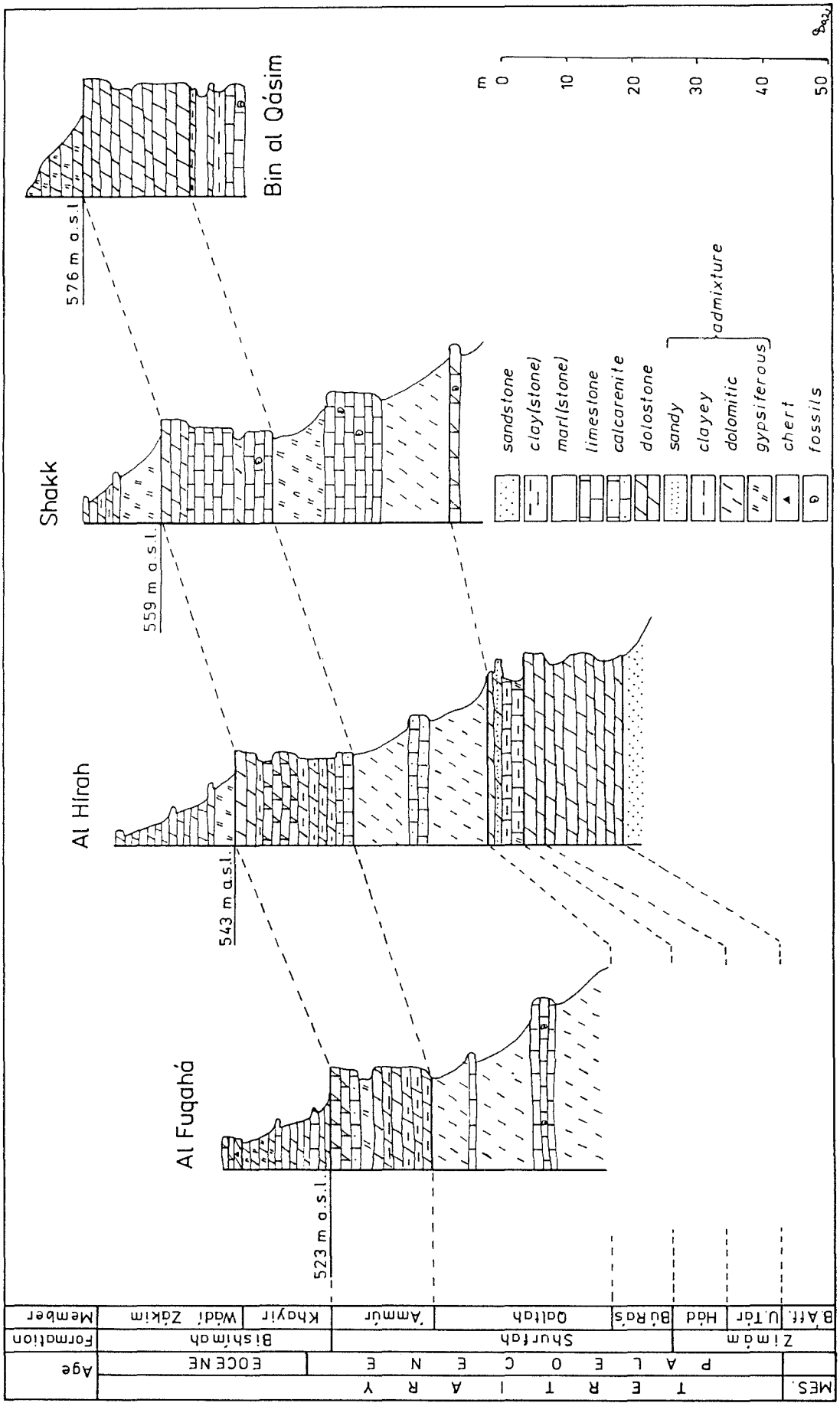

Figure 2 : Geological sketch map and cross-section of Qarārat Shakk
1 - Proluvial deposits 2 - Sabkha deposits 3 - Khayir Member 4 - 'Ammūr Member 5 - Qaltah Member 6 -Bū Ra's Member

shape of the qarārāt is disturbed by young processes of backward erosion mostly on southern to eastern side. Here, the hanging pediment with the greatest width is developed on Khayir Member. The disturbance of the original qarārat contour and the eccentric structure indicate increased erosion during storm precipitation and outwash into the qarārat, directed from SE generally. This fact corresponds with the general inclination of the sculptured surface in the region west of Jabal Haruj al Assuad, reaching 20 to 40' northwestward.

V. GEOMORPHOLOGICAL POSITION

Qarārāt are situated in the flat surface of the Sarīr al Qatūsah between the escarpments of Dūr al Ghānī and Dūr al Qāf on the west, and the volcanic mountain of Jabal Haruj al Assuad on the east, in the altitudes of 545 to 580 m a. s. l. (Fig. 1). Sarīr al Qattūsah is a very flat sculptured paleorelief (pediplain) gently dipping to the northwest from about 600 m a. s. l. south of Jabal Haruj al Assuad to about 500 m a. s. l. near Jabal as Sawdā (another volcanic mountain) in the north-northwest. The pediplain is older than 2. 0 ± 0. 2 Ma, dated after the earliest basal flow of the Jabal Haruj Volcanic Province (ADE HALL *& al.*, 1974, 1975) which rests on gently sculptured relief on paleocene-eocene rocks. In the present time, the pediplain terminates on both escarpments. Originally, it had a larger extent, terminating on the regional geological elevation of the Qarqaf Uplift (WSW-ENE).

The origin and the evolution of both escarpments, i. e. Dūr al Ghānī (N-S in general) and Dūr al Qāf (W-E), are connected with a complex and polygenetic development of the extensive W-E oriented paleodepression of present Wādī Kunayir, at the contact of horizontal Messāk Formation (Nubian-facies clastics of jurassic to lower cretaceous age) and inclined paleozoic clastics on the north. the original depression developed as erosional downcut before the maastrichtian transgression. After a regression, during the Oligocene, an intensive planation took part. Relief at about 500 m a. s. l. originated.

The evolution of the region corresponded to the geomorphological evolution of a broader region between the Tassili (deeply in the south) and Qarqaf Uplifts after the Messinian, in more arid climate. Here, in the place of the recent Awbāri depression, very extensive endoreic depressions started to develop due to water table lowering and climate aridization; pediplanation was a typical process. Depressions following the regional geological trends, i. e. Qarqaf (WSW-ENE) and Haruj Uplifts (NNW-SSE), started to develop. A system of shallow depressions developed at their foothills in distinctive periods as winnowed deflation troughs.

During the Mio-Pliocene, these depressions served as the depocentre for sandy carbonates with conglomerates at their base, i. e. the so-called Maharūqah Formation defined by SEIDL and RÖHLICH (1984; Fig. 1). Carbonate deposition was polycyclic, with numerous breaks in which hardening and formation of calcretes occur in semiarid climate. The base of carbonates lies at 450 to 470 m a. s. l. marking position of escarpments.

Later slope retreat was uneven. The retreat of Dūr al Qāf to the north was somewhat accelerated and supported by backward erosion of numerous wadis (Fig. 3) from Jabal as Sawdā richer in precipitation. The origin of both escarpments distinctly separated sculptured paleorelief on the north and the east (oligo-miocene in age) from younger set of pediments in front of them.

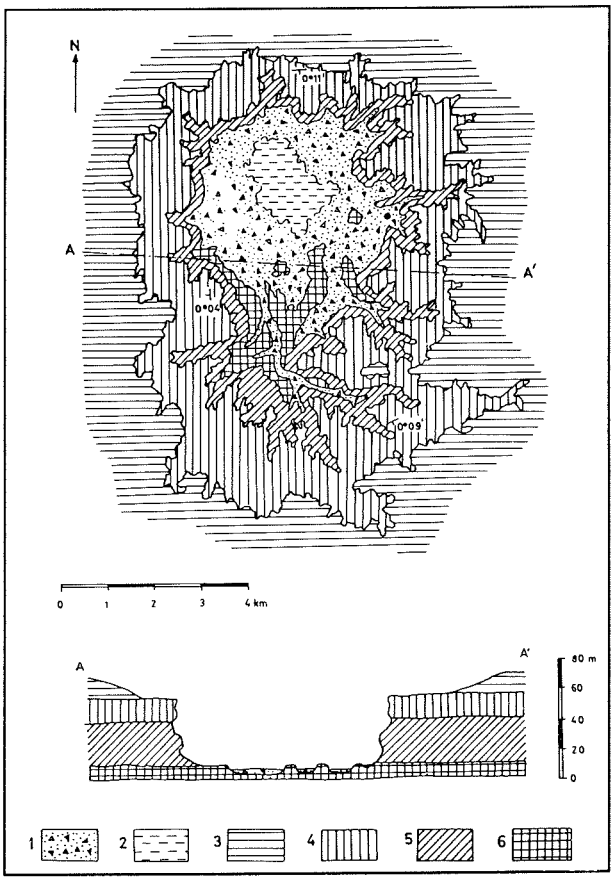

Figure 3 : Schematic lithologic columns through qarārāt

VI. Evolution of qarārāt

Qarārāt are developed, as stated above, on sculptured paleorelief of supposedly oligo-miocene age. The closer is their position to the Dūr al Ghānī escarpment, the greater is their depth, in general, proving the close relationship between slope retreat of escarpments and deepening of qarārāt, and decreasing water table. Some shallow qarārāt are developed also in front of escarpments, e. g. on silurian Tanzuft Formation (claystones) in Wādī Khunayir (Fig. 1) or on pediments in maastrichtian Bin 'Affīn Member.

The origin and development of qarārāt is conditioned by a set of processes cumulated in two alternating stages: (1) preparation stage and (2) removal of material. The origin is based on following factors:

(1) semiarid to arid climate with alternation of drier and more humid periods,

(2) hardening and calcrete formation on gently undulating surface with shallow depressions and impermeable bottom enabling accumulation of precipitation,

(3) complex of mechanic and namely chemical processes changing material brought into depressions to particles removable by wind,

(4) eolian transport of prepared material when intermittent lake is dry,

(5) gradual regional lowering of piezometric level (water table) due to morphological evolution and gradual climate aridization. Some processes should repeat themselves several times. The evolution of qarārāt cannot be described as a continuous process. The intensity of effect of individual factors was affected by paleoclimatic conditions and different lithological characters of rocks exposed on the surface.

The evolution model is generally based on fluctuations of the piezometric level and its slow and gradual lowering, depending on geomorphological evolution of large depressions of the Ar Ramlat az Zallāf in the north of the Murzuq Basin (Awbāri depression). Oscillating water table resulted in different processes in different rocks. No effect can be traced in marls and clays, more or less impermeable. Nevertheless, when evaporite admixture to intercalations are present, their subsurface dissolution and removal (subrosion) can be assumed, e. g. in Khayir or Qaltah Members. Slow regional groundwater flow through carbonates, even often dolomitic, sometimes with admixture of evaporites, was connected with intrastratal solution of calcitic and evaporitic constituents in relatively porous medium lithified rocks. Interconnected vug porosity appeared in places. It can be supposed that the regional groundwater flow was directed northward along the dip of the sculptured paleopediplain surface and transversally or oblique by to escarpment edges, i. e. northwestward in general. The subrosion and the intrastratal karstification represent an important part of the preparation stage. It cannot be excluded that sinks of the surface, above dissolved evaporites and weakened carbonates, resulted in the formation of shallow surface depressions, the most important feature for the establishment of qarārāt at this stage.

Mineralized karst water perhaps appeared at escarpment foothills in a set of springs feeding the mio-pliocene Al Mahrūqah depocentre. The appearance of karst groundwater on the surface is proved since carbonate tufa sheets had formed deposits in the Ma'zūl Ninah Formation (Oligocene to Oligo-Miocene) in the Hūn Graben north of Jabal as Sawdā, but here in different geological position aligned with deep faults (Al Washkah map-sheet, Woller, 1978, and Zallah map-sheet, Veselý, 1985).

Shallow surface depressions with intermittent lakes were substantial for the preparation of rocks and sediments to be later removed by deflation. Alternating processes of deposition (out-washes), hardening and crustification occurred in highly aggressive (mostly alkaline) environment. Precipitates were destructed by changing humidity and thermal conditions, dissolved and precipitated over again, sometimes in powdery calcretes and gypcretes easily removed by wind. The slow, oscillating and continuous lowering of the piezometric level allowed the deepening of shallow depressions. The deepening accelerated in slightly resistant rocks, to decelerate in more resistant, mostly carbonate formations. When the process was slower, chemical processes appeared to be more important in the preparation stage. Water should appear in present bottoms as compared with fissure springs discharging at the Q. Al Fuqāha in the recent time. Springs feed a sabkha lake in the centre of the qarārat when precipitation of a salt-gypsum crust on easily disintegrable fine-grained material occurs. Fine mudstone originates in aggressive sabkha environment, by disintegration and decomposition of rock fallen from walls and from sediment brought by floods. Relics of solutional-erosional caves were detected in a limestone bed in Qaltah Member, above the recent sabkha. This means that a part of precipitation or spring waters can sink into subsurface, removing a part of dissolved material out of qarārāt. The retardation of deepening is marked on resistant horizons by diminution of qarārat diameter, structural terrace steps and nearly vertical walls.

The most intensive processes modelling qarārāt, in the

recent time, are run-off and eolian erosion. Traces of eolian erosion connected with the transport of sand material from depressions are distinct on qarārat walls, forming typical yardangs. Tafoni and other weathering forms are also common.

VII. Conclusions

Qarārāt are endoreic depressions with steep to vertical slopes, more or less oval and kettle-shaped. In the Sarīr al Qattūsah, central Libya, their width reaches 4.8 to 11.2 km along longer axes (N-S to NNW-SSE, W-E) and 2.8 to 10.0 km along the shorter ones (W-E to WSW-ENE, N-S). Their depth varies between 35 and 95 m depending on the proximity to the Dūr al Ghānī escarpment. The closer is the position to the escarpment, the deeper is the qarārat. Qarārāt are situated on a slightly undulated sculptured paleosurface (paleopediplain) of supposedly oligo-miocene age, at 540 to 580 m a.s.l. The origin of a qarārat is influenced by two alternating processes: (1) preparation stage and (2) removal of material. The evolution model is based on fluctuations of piezometric level and the slow gradual deepening connected with the slope retreat of escarpments in aridized climatic conditions since the Miocene (Messinian ?). The initial impulse for the origin of a qarārat is the presence of a shallow depression. This stage can be connected with subrosion of evaporitic interbeds and intrastratal / interstratal karstification of carbonates by slow groundwater flow through poorly to medium lithified rocks. The regional groundwater flow followed porosity, eventually also fractures and the northward dip of the paleopediplain . When the initial depression existed, alteration by changing humidity and thermal conditions could proceed to full deflation activity. Qarārāt are polygenetic geomorphological forms originated by a combination of many chemical and mechanical relief-forming agents, including karstification.

VIII. Acknowledgements

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IX. References

ADE HALL, J.M., *et al.*, 1974. Geophysical studies of North African Cenozoic volcanic areas. I. Harūj Assuad, Libya. *Can. J. Earth Sc.*, 11: 998-1006.

ADE HALL, J.M., *et al.*, 1975. Geophysical studies of North Africa Cenozoic volcanic areas. II. Jebel Soda, Libya. *Can. J. Earth Sc.*, 12: 1264-1271.

FÜRST, M., 1965. Hammada-Serir-Erg, eine morphogenetische Analyse des nordöstlichen Fezzan (Libyen). *Z. Geomorph.*, 9, 4: 385-421.

KLITZSCH, E., 1974. Bau und Genese der Gararets und Alter des Grossreliefs in Nordostfezzan (Südlibyen). *Z. Geomorph.*, 18, 1: 99-116.

MITCHELL, R., 1958. The Al Umchaimin crater, western Iraq. *Geogr. J.*, 124, 4: 578-580.

SEIDL, K. & RÖHLICH, P., 1984. *Geological Map of Libya, 1 : 250 000. Sheet Sabhā NG 33-2. Explanatory Booklet.* Ind. Res. Centre, Tripoli: 138 p.

VESELY, J., 1985. *Geological Map of Libya, 1 : 250 000. Sheet Zallah NH 33-16. Explanatory Booklet.* Ind. Res. Centre, Tripoli: 136 p.

WOLLER, F., 1978. *Geological Map of Libya, 1 : 250 000. Sheet Al Washkah NH 33-15. Explanatory Booklet.* Ind.Res.Centre, Tripoli: 140 p.

WOLLER, F., 1984. *Geological Map of Libya, 1 : 250 000. Sheet Al Fuqahā NG 33-3. Explanatory Booklet.* Ind. Res. Centre, Tripoli: 140 p.

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