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Lime and Gypsum Accumulation as Important Parameters in the Classification of the Soils of Sahl Baraka, Farafra Oasis

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HUNDRED soil profiles were selected to cover the present geomorphic units and represent the main morphological variations in the soils of the studied area. Based on the climatological conditions, morphological description, physical and chemical analyses, the investigated soils could be classified as the following : Psamments; *Typic Torripsamments* (15 profiles), *Typic Quartzipsamments* (3 profiles); Calcids; *Typic Haplocalcids* (15 profiles), *Lithic Haplocalcids* (8 profiles); Salids; *Gypsic Haplosalids* (7 profiles), *Calcic Haplosaldids* (6 profiles), *Calcic Haplosalids + Gypsic horizon* (15 profiles), *Gypsic Aquisalids and Calcic Aquisalids* (5 profiles) and Gypsids; *Typic Calcigypsids* (22 profiles), *Typic Haplogypsids* (4 profiles).

The only prominent features of development of this virgin area are the accumulation and formation of calcium carbonate and gypsum precipitations in soil layers of various profiles. According to the accumulation and formation shape of calcium carbonate in these soils they could be classified into six classes. Meanwhile, the soil under investigation can be grouped into four categories according to gypsum content.

Keywords: Calcium carbonate content, Farafra oasis, Gypsum, Soil survey & Classification.

The principle problem facing Egypt at the present time is the slow expansion of cultivated land area compared to the very rapid increase of human population. The large depressions where the ground is close to the water table include the five major oases of the western desert namely; Siwa, Bahariya, Farafra, Dakhla, Kharga plus the Fayoum which is the closest to the Nile Valley. Recently, Farafra, Dakhla and Kharga have been joined into one province called the New Valley Governorate and ambitious plans have been laid down to increase the water supply and improve the agriculture of the whole area. Farafra depression, from the geographical point of view, lies in the western desert 300 km west of Assiut city. It has an irregularly triangular shape with the apex to the north; its breadth increases as one goes south. Mohamed (1995) pointed out that Farafra Oasis and surrounding areas present extensive development of duricusts and karst products and the main source of silica is clay mineral diagnosis which

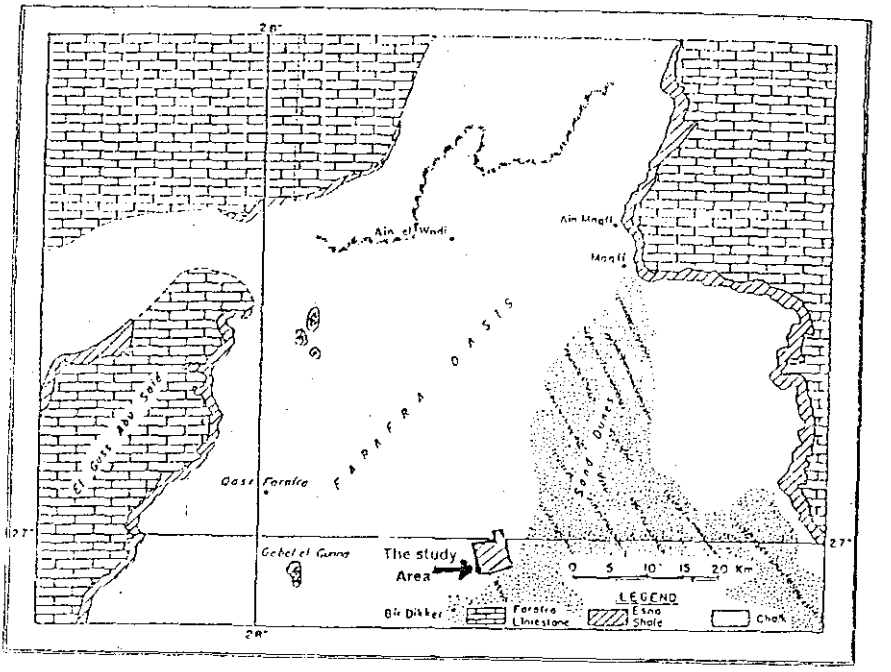
ascending translocation is considered. Draz-My (1997) studied seven areas of Egypt affected by shifting sand were categorized for sand and encroachment control. Categorization was based on the evaluation of the area of dune extent, grain size characteristics of the aeolian deposits, climate, movement of sand grains and intensity of the agriculture activity. The results showed that the areas of agricultural potential located within the southern portion of the western sand dunes belts (El-Farafra, El-Charge, El-Dakhla and El-Uweinat) require rapid action for sand encroachment control. Beshay and Sallam (1994) mentioned that the characteristics of different sand fractions formed in aeolian, alluvial and lacustrine sedimentation environments in Farafra depression, Egypt was investigated. Soils formed in the aeolian environment have uniform materials throughout but soils formed under the alluvial and lacustrine environments showed heterogeneity of parent material with depth (Asma, 1995). For the granulometric studies, conducted on 180 samples of aeolian sand deposits in northeast of Sinai and El-Farafra depression, the samples were sorted and skewed towards a coarse admixture.

In arid soils, gypsum is precipitated as a result of over-saturation of the soil solution, crystallizing mainly as lenticular crystals (ranging from silt size to a few centimeters in diameter) in pores. Accretion of growing crystals gives rise to coherent granular masses-petro-gypsic with anhedral to subhedral equigranular fabric (Barzanji and Stoops, 1974). Fibrous gypsum has been reported in few cases in Aridisols as reported by Labib (1970).

The aim of the current investigation is to assess lime and gypsum accumulation as important parameters in the survey and classification of virgin area in "Sahl Baraka", Farafra Oasis, New-Valley as one of the promising cultivated land.

Material and Methods

The studied area "Sahl Baraka" belongs to Farafra city (27° 03` 55``N & 27° 58` 13``E), Map 1 shows the geology of Farafra oasis and the location of the investigated area. A semi-detailed survey for 10000 feddan in "Sahl Baraka" area by 100 soil profiles according to the morphological observations of the soils and its sites as well as the main points of the borders of the investigated area (A, B... H) have been conducted by Global Position System (GPS) as laid out on Map 2. A profile has been dug in each site to a depth of about 150 cm or to the present of hard layers or the parent rock. Profile description included observations on land surface, depth of the solum, identification of horizons and boundaries, soil texture, structure, consistency, pedo-formations of lime, gypsum, iron and manganese compounds. A number of 209 soil samples of the various layers have been collected for laboratory analyses.



Map 1. Geology of Farafra Oasis and location of investigated area.

Grain size distribution and texture classes of samples according to Soil Conservation Service (1984). Soil chemical analyses as pH, EC, soluble cations and anions, gypsum and total calcium carbonate contents were estimated according to Black *et al.* (1982). Classification of the soil profiles according to USDA (1999).

Results and Discussion

The study area is located in the southern part of Farafra depression at a distance of 43 km east south of Farafra city, between latitudes (A) 27 ° 01` 40`` to (E) 26 ° 56` 35`` N and longitudes (F) 28 ° 13` 21`` to (D) 28 ° 18` 07`` E (Map 2).

The investigated area lies within the extremely arid belt, having long hot summer and short warm winter, where the mean monthly minimum temperature values range widely from 5 to 22°C in winter while the mean maximum values range from 20 to 38°C at summer. No precipitation at all is recorded at any time within the year.

Soils of the study area are developed during pluvial times and preserve the present desert condition, therefore, these soils display different depositional environments; mostly of aeolian, alluvial and lacustrine nature.

Water available for irrigation is provided from one single source, the underground reservoir. The chemical analysis of water sample shows that this underground water has a very good quality (EC = 0.17 dS/m and pH 6.6) which can be used for all agricultural purposes and domestic use.

According to the meteorological data of the study area, the morphological soil description in the field and physico-chemical analysis of soil samples from various layers in the 100 profiles and applying the most recent and well established as well as widely accepted system of classification (USDA, 1999). The soils of the investigated area can be grouped as indicated in Table 1.

Meanwhile Map 2 shows the location of the main soil sub-orders of the project area.

In general, topography of the landscape is almost flat to gently undulating with level to very gently sloping, deflated or denuded surface. The soil surface is therefore covered with drift sand or varnished gravels, or both. The effective depth of soils varies widely from very shallow to very deep and coincides well with the depth at which cemented or compacted subsurface layers or hard rock layers are present. The soil texture throughout the entire depth of soil profiles is variable according to the sediments origin, *i.e.*, lacustrine, alluvial and aeoline sand deposits, and ranges widely from coarse and moderately coarse to moderately fine texture. The soil structure is single grain or massive for the coarse to moderately coarse textured layers while being blocky or platy for fine to moderately fine textured ones. Gravels are only observed in few layers.

Gypsum and calcium carbonate contents and their formation

The data in Tables 2 and 3 show that gypsum and calcium carbonate contents in percent vary widely from null to 30.1% and from 2.2 to 86.8 %, respectively. With respect to gypsum content the surveyed soils can be grouped into four categories as follows:

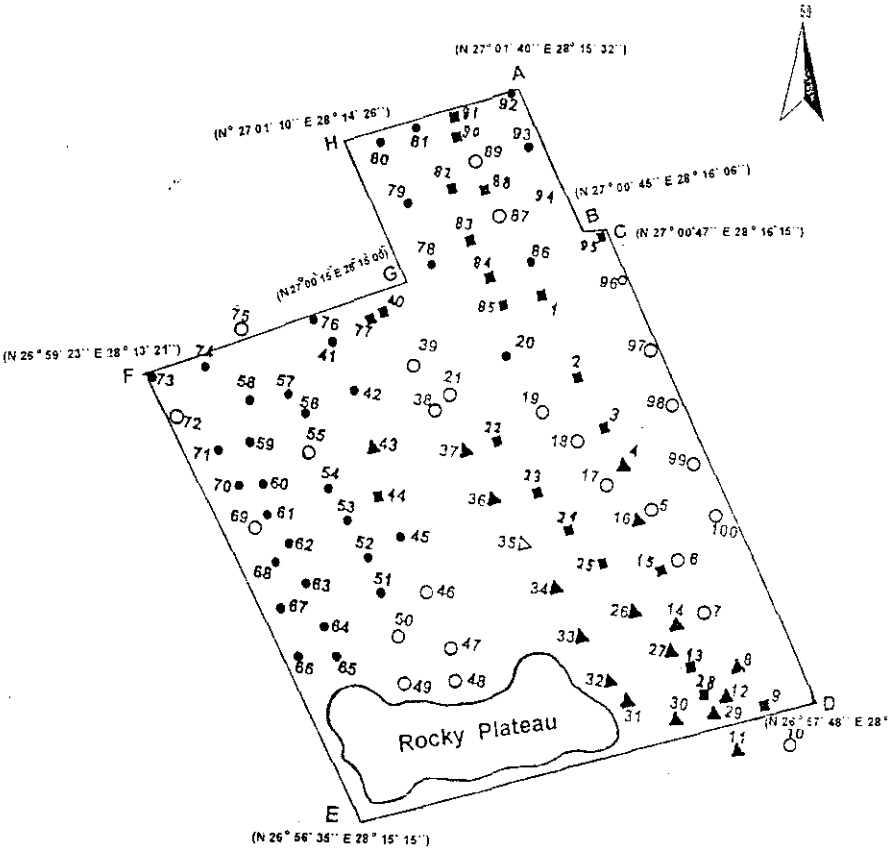
1) Soils with low gypsum content <7%. 2) moderate gypsum content 7–15 % in one or more of the horizon. 3) high gypsum content 15–30%. 4) soils with abundant gypsum content >30 %. In this respect , Labib *et al.* (1986) and El-Taweel (1982), classified gypsum content in some soils of Egypt to three groups 5%, 5 – 10% and 10–20%, respectively. In general, gypsum accumulation within the profile reflects to great extent, its mode of formation and the physical – chemical prevailing conditions.

With regard to values of gypsum content (Table 2) and detailed profile description in the field and some physical and chemical analyses in laboratory, it appears that gypsum accumulation in the profiles under consideration are found in the following forms:

TABLE 1. Classification of the investigated soils.

Soil suborder	Characteristics	*Profiles No.*	Classification (Sub-group)
Psamments	Profiles are deep > 150 cm, naturally well drained, non-saline EC < 2 dS/m, gypsum accumulation is very limited <10%, $CaCO_3$ ranges between 5-10%.	4,8,11,12,14,16, 26,31,32,33,34,3 5,36,37,43	*Typic Torrip samments*
	The deep profiles are homogeneous till 150 cm depth. These soils are characterized by bright yellowish brown colour (10YR 7/6). The coarse sandy texture has more than 95% quartz and other resistant minerals. Free of soluble salts and gypsum, $CaCO_3$ is less than 5%.	27,29,30.	*Typic Quartzipsamments*
Calcids	Calcic horizon in one or more layers of the profiles, $CaCO_3$ is more than 15%. The windblown sand covers many areas as thin 1-5 cm, drainage condition range from perfect to moderately.	1,2,3,9,13,15,22, 23,24,25,28,40, 44,77,85	*Typic Haplocalcids*
	These soils have shallow profiles < 50 cm, usually rocky area. The calcareous rock mostly limestone is hard penetrating for sampling. These areas are not suitable for cultivation activities.	82,83,84,88,90,9 1,94,95.	*Lithic Haplocalcids*
Salids	These soils are saline EC > 6.0* dS/m which satisfy the requirement of salic horizon. Gypsum accumulation occurs in most of the layers and cementing soil particles forming aggregates or hard layers. The texture is clayey particularly in sub-layer and presence portions of calcareous stones and lime.	56,57,58,63,64,6 6,86.	*Gypsic Haplosalids*
	Accumulation of soluble salts in one or more of layers, EC > 6.0dS/m. The dominant soluble salts are $NaCl>CaCl_2>Na_2SO_4>MgCl_2>KCL$. Most of these soils has high $CaCO_3$ > 15%.	20,54,62,65, 67,73.	*Calcic Haplosalids*
	Similar characteristics as above (salic and calcic horizons) beside gypsic horizon.	42,52,53,59,60,6 1,68,70,71,76,78, 79,80,81,92.	*Calcic Haplosalids* + *Gypsic horizon*
	These profiles are wet soils in the field, have accumulation of salts besides calcic or gypsic horizons. Redoximorphic features are very clear. Fine texture of profiles from silty loam to clay.	41,45,51,74,93.	*Gypsic Aquisalids & Calcic Aquisalids*
Gypsids	Most of these soil profiles have coarse texture allover the profile. These soils are characterized by high gypsum content > 10% in one or more layers. Also $CaCO_3$ content is more than > 15%.	5,6,10,18,19,21, 38,39,46,47,50,5 5,69,72,75,87,89, 96,97,98,99,100	*Typic Calcigypsids*
	These soils have coarse texture, structure-less, single grains, well drained, non-saline. $CaCO_3$ content is > 15% and gypsum content > 10%.	7,17,48,49.	*Typic Haplogypsids*

* 6.0 dS/m in soil: water extract



Map 2.The Main soils sub-orders of the studied area.

▲ Psamments soils • Salids soils
! Calcids soils OGypsids soils

1- Un-crystallized in some layers. This form can be accumulated from sudden evaporation saline water in micro-pores.
2- Crystals of gypsum, when the content of calcium carbonate is high, many crystals of gypsum under such conditions are cemented together or cemented with fine crystals of calcite.
3- Many needles of anhydrous gypsum noticed in the subsurface and deep layers, single small needle–like crystals mostly cemented forming large nodules.

4- Sali–gypsic nodules, this form was easily distinguished in field as small stones, mostly extend to form continuous gypsic horizon.
5- Iron–gypsum compound nodules were observed in some profiles, where fluctuation of saline water table lead to oxidation– reduction processes and flocculation of amorphous compounds of iron and manganese.

TABLE 2. Calcium carbonate and gypsum contents in the Gypsic profiles.

Profile No	Depth cm	$CaCO_3$ %	Gypsum %	Profile No	Depth cm	$CaCO_3$ %	Gypsum %	Profile No	Depth cm	$CaCO_3$ %	Gypsum %
Typic Calcigypsids				46	0-15	15.2	---	97	0-40	35.6	---
5	0-10	21.7	---		15-180	17.4	20.5		40-150	21.7	12.5
	10-40	19.5	10.3	47	0-50	19.5	---		+150	65.1	14.3
	40-150	2.2	11.5		50-150	15.2	15.7	98	0-25	13.0	14.6
6	0-20	21.7	---		0-25	2.2	---		25-100	28.2	16.2
	20-50	23.9	9.8	50	25-160	4.3	8.7	99	0-35	17.4	---
	50-150	17.4	12.0		+160	21.7	12.5		35-100	16.0	---
10	0-40	21.7	9.5	69	0-100	21.7	33.4		+100	10.6	24.5
	40-70	10.9	11.1	72	0-50	21.7	---	100	0-25	15.4	---
	70-150	15.2	---		50-100	15.2	11.4		25-75	17.9	25.5
18	0-20	17.4	---		100-160	28.2	13.5		75-150	21.7	27.8
	20-75	21.7	12.1	75	0-80	19.5	---	Typic Haplogypsids			
	75-150	19.5	13.5		+80	34.7	12.5	7	0-35	13.0	---
19	0-50	26.0	10.5	87	0-40	21.7	---		35-70	2.2	9.8
	50-120	15.2	15.2		40-120	10.9	14.7		70-180	10.9	12.3
21	0-30	15.2	----	89	0-30	32.6	---	17	0-20	2.2	9.6
	30-55	17.4	10.5		30-80	21.7	13.4		20-120	2.2	10.1
	55-150	32.2	11.2	93	0-60	30.4	13.5	48	0-50	8.7	----
38	0-25	23.9	---		60-150	26.0	24.5		50-150	10.9	12.3
	25-150	2.2	11.4	96	0-50	13.0	---	49	0-50	10.9	---
39	0-20	8.2	----		50-120	15.2	11.5		50-150	13.0	10.9
	20-50	10.9	12.4		120-150	34.7	12.1				

TABLE 3. Calcium carbonate and gypsum contents in the Calcids profiles.

Profile No	Depth Cm	$CaCO_3$ %	Gypsum %	Profile No	Depth cm	$CaCO_3$ %	Gypsum %	Profile No	Depth cm	$CaCO_3$ %	Gypsum %
Typic Haplocalcids				15	80-110	19.5	---	77	30-140	13.0	6.3
1	0-60	21.7	---		110-150	15.2	---		+ 140	34.7	7.1
	60-120	43.4	---	22	0-150	23.9	---	85	0-30	28.2	---
2	0-70	21.7	---	23	0-150	15.2	---		30-100	2.2	---
	70-90	10.9	5.7	24	0-60	17.4	---	*Lithic Haplocalcids*			
	90-150	6.5	6.4		60-70	21.7	8.7	82	0-40	52.1	---
3	0-30	28.2	6.3		70-150	23.9	9.3		+ 40	43.4	---
	30-50	10.9	29.3	25	0-65	21.7	---	83	0-25	73.8	8.5
	50-150	15.2	30.1		65-150	2.2	10.5	84	0-30	32.6	---
9	0-30	19.5	5.7	28	0-25	13.0	---	88	0-20	65.1	19.5
	30-120	15.2	6.4		25-150	21.7	---	90	0-10	67.3	---
13	0-60	15.2	---	40	0-40	2.2	---	91	0-20	54.3	---
	60-120	19.5	---		40-150	17.4	8.8	94	0-20	32.6	29.2
15	0-55	19.5	---	44	0-160	15.2	---	95	0-15	21.7	---
	55-80	21.7	6.4	77	0-30	17.4	---		15-40	15.2	12.5

It is noteworthy to mention that the accumulation of gypsum in surface layer of soil (Table 2) could be mixed or over lined by accumulation zone of salts. These features have direct effect on percolating water, which accumulate above these layers with low permeability, where salts precipitation occurs in most cases. Then water table rises and evaporates leaving the salts on the soil surface consequently inhibit plant growth.

In general, many factors are expected to control the gypsum crystallization in the studied soils, namely: high salinity of soils being rich in sulfate ions; high content of carbonate; fluctuation of the saline ground water and high temperature and evaporation rates (Beshay, 2001; Boyadgiev & Verheye, 1996; Poch *et al.*, 1996 and Labib *et al.*, 1986).

The accumulation of pedogenic calcite is a common feature in the soil profiles of this arid area (Table 3). The various climatic conditions have resulted in a variety of forms and content of calcite precipitated at various depths in the soil profiles. Some profiles in this group are characterized by the presence of gypsum in concretions combined with lime accumulations, which could possibly occur in separate formation and is normally found below the lime accumulation zone. From several macro forms of pedogenic carbonate in the studied profiles two types are observed namely; 1) rounded to sub-rounded calcite concretions of small to medium size (0.5–1.0 cm) and 2) angular to sub angular lime concretions about (2.5 cm). The changes from a soft diffuse nodule to hard is due to churning or desiccation and these conditions are concordant with climate of Farafra oasis. Total carbonates content are generally high and either accumulates on the subsurface layer or increases with depth these soils can be grouped in six classes according to FAO (1973) depend on $CaCO_3$ content as follows:

1 – Non or almost non–calcareous soils, $CaCO_3$ content <5% .
2 – Slightly calcareous soils, $CaCO_3$ content 5–15% .
3 – Moderately calcareous, $CaCO_3$ content 15–35% .
4 – Calcareous soils (strong), $CaCO_3$ content 35 –55% .
5 – Very calcareous soils (very strong), $CaCO_3$ content 55–75% .
6 – Extremely calcareous soils, $CaCO_3$ >75% .

Pal *et al.* (2001) mentioned that in semi–arid climate remover of Ca^{++} ions from the soil solution occurs by precipitating carbonate and also causes the ESP and sodium adsorption ratio to increase with the depth. In general the accumulation of calcium carbonate in the soils depend on the position of the area, evaporation rates and the depth of percolating rainwater.

The presence of carbonate hard pans caused the presence of shallow soils in the northeastern part (small quadrate, ~ 10% of the total area) *(Typic- Lithic Haplocalcids).* In addition, they are located in the southeastern corner of the studied area which consists of a rocky plateau (calcareous shale deposits) and represent ~ 15% of the total investigated area.

Conclusions

From the field observations and semi detailed survey as well as laboratory analysis for some soil parameters, the classification until the subgroup level could be obtained. It is clear that most of the area located in the eastern part and the middle of the land (more than 75% of the investigated area) which are included in the sub-order of Psamments (*Torripsamments and Quartzipsamments)* are characterized by a deep profile, sandy texture, non saline and, free or slightly $CaCO_3$ & gypsum contents. These soils can be easily cultivated if enough available water can be amended. The saline soils including *Gypsic – Calcic-Haplosalids and Gypsic- Calcic- Aquisalids*, and the accumulation of $CaCO_3$ & gypsum occurs in most of the layers and cementing soil particles forming aggregates or hard layers. The texture of these soils is clayey particularly in sub-surface layers. However, good production is expected under favorable management practices. The calcareous soils *(Typic Haplocalids and Gypsic Haplocalcids)* require careful selection of crops and amendment of nutrients through fertilization program.

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تجمعات الجير والجبس كمحددات هامة فى تقسيم أراضى سهل بركه – واحة الفرافره

منير مراد وهبه ، جميل وهيب عجيب ، إبراهيم سعيد رحيم وفكرى عوض مسعد
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يهدف البحث الى حصر وتصنيف وتقسيم اراضى سهل بركـــه ــ واحة الفرافره ــ الوادى الجديد اعتمادا على دراسة الصفات المورفولوجيه للاراضى حقليا ومعمليا وربطـــها بظروف التكوين وذلك لمحاولة تصنيف هذه الاراضى بصوره اكثر دقه . وقد تم التركيز على التكوينات الجبسيه والكلسية باعتبارهما من العوامل الأكثر فاعليه لاستغلال هذه الاراضى زراعيا .

ولتحقيق هذا الهدف تم حفر ١٠٠ قطـاع أرضى يغطى مساحة ١٠٠٠٠ فدان وتم وصفهم مورفولوجيا كما تم تقدير الصفات الكيميائية معمليا ، وبناء على النتائج تم تقسيم الاراضى الى أربع مجموعات رئيسيه هى :
Psamments (١٨ قطاع) ، Calcids (٢٣ قطاع) ، Salids (٣٣ قطاع) ، Gypsids (٢٦ قطاع)، كما تمت دراسة تفصيلية لأشكال وكميات الجبس وكربونات الكالسيوم بكل طبقه من القطاع الأرضي ، حيث تم تصنيف أشكال الجبس مورفولوجيا الى خمسة أقسام (بللوريه ــ غير بللوريه ــ ابريه ــ بقع أملاح جبسيه ــ بقع جبسيه مع حديد) . كما تم تقسيم محتوى الجبس الى أربعة درجات (٪٧< ، ٧–١٥٪ ، ١٥–٣٠٪ ، ٣٠٪<) اما بالنسبة للتكوينات الكلسية فقد تم وصفها مورفولوجيا من صغيره الى متوسطة الحجم ذات بقع متحجرة تأخذ زوايا فى شكلها والبعض الأخر ملتحم مع الحديد او مغطى لها كما تم تقسيم كميه كربونات الكالسيوم الى سته أقسام .