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# Microfeatures and Distribution of Calcium Carbonate in Some Calcareous Soils of Egypt

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THE AIM of this work is to deal with macro and micromorphology of the forms and distribution of calcium carbonate accumulation in some calcareous soils of Egypt. Four calcareous soil profiles from El-Fayoum, Maryut, Burg El-Arab and El-Arish valley have been chosen to study the distribution of $CaCO_3$ in different fractions and their pedogenic accumulation in different shape , size , colour and nature. Concerning the distribution of calcium carbonate in different soil fractions, it is found in clay textured soils most of the $CaCO_3$ is usually found in the silt and clay fractions, whereas in the clay loam textured soils, the calcium carbonate content was rather regularly distributed over the clay, silt and sand fractions. While the sandy clay loam and sandy textured soils have the majority of calcium carbonate in the sand fraction. On the other hand, most of the active $CaCO_3$ content was within the clay fraction. The microscope investigation of thin sections show many shapes and different formations of carbonates. The nucleic carbonate nodules are dominant as secondary formation in the alluvial soils of Fayoum. While in the lacustrine deposits of Maryut grain carbonate cutans are the distinct phenomena. In the profile of Burg El-Arab, many calcified shells and oolitic sands are the main components of the calcareous materials in the soil mass. Many forms of calcite have been observed in the soil of Al-Arish valley as coarse and fine mineral grains and nodules in different shapes.

**Keywords:** Active $CaCO_3$, Nucleic carbonate, Oolitic, Lacustrine.

The accumulation of pedogenic calcite is a common feature in the soils of the arid and semi-arid regions . The various climatic conditions have resulted in a variety of forms of calcite precipitated at various depths in the different soil types , as may be observed partly in the field , and more completely under the microscope. In this point, Pal *et al.* (2001) stated that the semiarid climate removes $Ca^{2+}$ ions from the soil solution by precipitating carbonate, and also causes the ESP and sodium absorption ratio to increase with depth. Sehgal and Stoops (1972) reported that calcite formations in soils may be of two possible origins namely "primary" that is inherited from the parent rock and "secondary" that is developed or formed in the soil itself. On a landscape basis, carbonate occurs mainly in $C_{ca}$ horizons in mid and upper slope soils as a result of moisture movement and ground water flux (Wang and Anderson, 2000). Magaritiz and Amiel (1980) studied the calcium carbonate origin in some calcareous soils in the Jordan Valley, they demonstrated that the pedogenic carbonate constitutes about 50 % of total carbonates in the soil and the highest pedogenic carbonate concentration occur in the finer fractions. In this point, Wider and Yaalon ( 1974 ) concluded that the size and growth of calcite are controlled by the texture of the soil matrix. Massoud (1972) reported that $CaCO_3$ was found in various size fraction depending on the soil forming factors mainly parent material and climate. Abdel-Aal *et al.* (1990) and Wahba (1998) found that carbonate in Burg-El-Arab soil concentrated in coarse fractions. Generally, the size of calcium carbonate crystals is related to the dominant size fraction of soil particles (Abdou *el al.*, 1984 ).

Therefore the knowledge of carbonate fabrics (*e.g.* the carbonate being finely dispersed, or accumulated in nodules etc.) in soils are of very great importance for understanding genesis and several soil chemical reactions. Khadr *et al.* (1997) studied the micropedological characteristics in a toposequence of the soils of Fayoum, Egypt. They showed that typic Calcitorrerts contain micro crystalline calcite embedded in the soil matrix. Dasog *et al.* (1991) found that in semi-arid Boreal clays masepic fabric was evident from the surface down to lower solum, whereas in sub humid soils it was confined to lower solum. Shell fragments found in Vertisols suggest a marshy or lacustrine conditions in the early stage of Vertisols development of the pedon sites in India ( Wright,1990).

The aim of this current work is to study the distribution of total and active calcium carbonate in different soil fractions which varies in texture and genesis. Also, the forms and fabrics of carbonate accumulation have been investigated on the thin sections for selected samples from the soils under investigation applying the polarizing microscope

## Material and Methods

Four profiles were selected to represent calcareous soils in Egypt. They are located in Tamia-El-Fayoum , Maryut , Burg El-Arab and El-Arish valley. Field description of the studied profiles were recorded according to the FAO Guidelines (1990) and classified according to Soil Survey Staff (1999). Soil samples were air dried and passed through a 2-mm sieve . The soil samples were analysed for particle size distribution, pH, total soluble salts , total calcium carbonate, organic matter content and amorphous iron and manganese extracted by dithionite citrate bicarbonate (DCB ) buffer solution (Black *et al.*, 1982), active calcium carbonate according to Yaalon (1957). Micromorphological study:thin sections were prepared according to the general procedure elaborated by Stoops ( 1976 ) , using a mixture of plastic material diluted by styrene and accelerated by catalizer. The thin sections were examined by polarized microscope (Zeiss) and described according to terminology developed by Bullock *et al.* (1984).

## Results and Discssion

The main morphological features of the studied profiles are shown in Table 1. Results of the mechanical composition profiles given in Table 2 reveal that textural classes vary between clay, sandy clay loam, clay loam to sand. Data in Table 3 indicate that total calcium carbonate in the studied profiles varies from 11.1 to 46.70%. The total carbonate is generally high and it either accumulates on the subsurface layer as in profile no. (3) or increases with depth as in profiles no. (1,2,4). These soils could be classified under the subgroups level as follows; profile (1) Typic Torriorthents, profiles (2,3,4) are Typic Haplocalcids.

TABLE 1. Main morphological features of the different layers of the studied profiles.

| Prof. N°. | Location. | Topography | Land Use. | Parent Material | Drainage | Depth cm. | Hor. | Colour moist | Colour Dry | Texture | Structure | Consistence sticky | Consistence plastic | Soil Reaction | Boundary |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tamia El Fayoum | F | Cotton | Alluvial deposits | W | 0-15 | Ap | Brownish black 10YR 2/2 | Grayish yellow brown 10YR 6/2 | C | Ma | ST | PL | SL | DS |
| | | | | | | 15-50 | Ap/C1 | Brownish black 10YR 3/1 | Brownish gray 10YR 4/1 | C | Ma | VST | VPL | MO | DS |
| | | | | | | 50-100 | C2 | Dark brown 10YR 3/3 | Dull yellowish brown 10YR 4/3 | C | Ma | VST | VPL | MO | — |
| 2 | Maryut | A | Clover | Calcareous deposits | W | 0-20 | ApCa | Bright yellowish brown 10YR6/6 | Yellow orange 10YR8/6 | S.C.L | AS | ST | PL | ST | DS |
| | | | | | | 20-60 | Ap/$C_1$ Ca | yellowish brown 10YR5/6 | Bright yellowish brown10YR7/6 | C.L | SB | ST | PL | ST | DS |
| | | | | | | 60-100 | $C_2$Ca | Yellowish brown 10YR5/8 | Bright yellowish brown 10YR6/8 | C.L | SB | ST | PL | ST | — |
| 3 | Burg El-Arab | A | Maize | Calcareous deposits | W | 0-20 | ApCa | Bright yellowish brown 10YR7/6 | yellow orange 10YR7/8 | S.C.L | AS | ST | PL | ST | DS |
| | | | | | | 20-50 | $C_1$Ca | Bright yellowish brown 10YR6/6 | yellow orange 10YR8/6 | S.C.L | AS | ST | PL | ST | DS |
| | | | | | | 50-100 | $C_2$Ca | Grayish yellow brown 10YR6/2 | dull yellow orange 10YR7/2 | C.L | SB | ST | PL | ST | — |
| 4 | El-Arish valley | G | U | Calcareous deposits | E | 0-20 | $CK_1$ | Light yellow orange 10YR8/3 | Yellow orange 10YR8/6 | S | SG | NST | NPL | EX | AS |
| | | | | | | 20-100 | CK2 | Light yellow orange 10YR8/4 | Yellow orange 10YR8/8 | S | SG | NST | NPL | EX | — |

Topography: F: Flate; A: Almost flat; G: gently undulating; Land use: U: Uncultivated; Drainge: W: Well drained; E: Excessively drained; Texture: C: Clay; S.C.L. sandy clay loam; C. L: Clay loam; S: Sand; Structure: Ma: massive; AS: Angular and Sub-angular blocky; SB: Sub-angular block; SG: Single grain; Consistence: ST: Sticky; VST: Very sticky; NST: Non sticky; PL: Plastic; VPL: Very plastic; NPL: Non plastic; Soil reaction: SL: Slightly calcareous; Mo: Moderately calcareous; ST: Strongly calcareous; EX: Extremely calcareous; Boundary: DS: Diffuse boundary; AS: Abrupt smooth.

**TABLE 2. Texture analysis and some chemical characteristics of the studied profiles.**

| Profile No. | Depth cm. | Hor. | pH 1:2.5 | EC ds/m | O.M % | $Fe_2O_3$ ppm | Particle size distribution | | | | Texture class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | C.S% 2000-200u | F.S% 200 20u | Silt % 20-2u | Clay % <2u | |
| (1) El-Fayoum | 0-15 | Ap | 8.1 | 1.3 | 1.23 | 7220 | 13.26 | 27.10 | 11.27 | 48.37 | Clay |
| | 15-50 | Ap/cl | 8.2 | 1.7 | 1.11 | 7080 | 12.33 | 23.67 | 21.72 | 42.28 | Clay |
| | 50-100 | C | 8.2 | 1.8 | 1.00 | 7480 | 5.70 | 20.29 | 23.49 | 50.52 | Clay |
| (2) Maryut | 0-20 | Apca | 8.2 | 0.56 | 0.88 | 2405 | 2.9 | 45.1 | 19.7 | 32.3 | S.C.L |
| | 20-60 | Ap/cl ca | 8.5 | 0.50 | 0.65 | 2770 | 2.2 | 31.1 | 30.2 | 36.5 | C.L |
| | 60-100 | C2ca | 8.4 | 0.39 | 0.50 | 2500 | 1.5 | 35.5 | 29.9 | 33.1 | C.L |
| (3) Burg El-Arab | 0-20 | Apca | 8.3 | 1.39 | 0.75 | 2115 | 4.30 | 50.10 | 21.70 | 23.9 | S.C.L |
| | 20-50 | C1ca | 8.0 | 1.45 | 0.66 | 2202 | 3.70 | 41.50 | 26.10 | 28.7 | S.C.L |
| | 50-100 | C2ca | 7.98 | 1.51 | 0.45 | 2280 | 3.30 | 27.40 | 33.60 | 35.7 | C.L |
| (4) El-Arish Valley | 0-20 | Ck1 | 8.5 | 0.15 | 0.34 | 1451 | 33.30 | 45.70 | 8.10 | 12.90 | Sand |
| | 20-80 | Ck2 | 8.6 | 0.21 | 0.4 | 1500 | 29.10 | 47.90 | 9.50 | 13.50 | Sand |

**TABLE 3. Distribution of total and active carbonate contents in the different fractions**

| Location | Depth cm. | Total carbonate in total mass of soil % | $CaCO_3$ fractions % of total $CaCO_3$ | | | | Active carbonate in total mass of soil % | Active $CaCO_3$ fractions %of total $CaCO_3$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | coarse sand | Fine sand | silt | Clay | | coarse sand | Fine sand | silt | clay |
| Tamia El-Fayoum | 0-15 | 11.10 | 10.50 | 18.80 | 30.30 | 40.40 | 9.7 | 4.12 | 10.32 | 14.43 | 71.13 |
| | 15-50 | 12.50 | 11.40 | 20.30 | 24.90 | 43.40 | 9.1 | 3.30 | 10.99 | 23.08 | 62.64 |
| | 50-100 | 13.09 | 17.80 | 19.10 | 22.30 | 40.80 | 10.2 | 1.96 | 11.76 | 18.63 | 67.65 |
| Maryut | 0-20 | 25.70 | 3.11 | 6.48 | 8.95 | 26.46 | 11.9 | 1.26 | 21.01 | 30.35 | 47.48 |
| | 20-60 | 28.70 | 1.75 | 31.01 | 32.40 | 34.84 | 12.7 | 0.79 | 14.57 | 39.92 | 44.72 |
| | 60-100 | 31.40 | 0.96 | 35.37 | 31.19 | 32.48 | 13.3 | 0.75 | 19.55 | 33.08 | 46.62 |
| Burg El-Arab | 0-20 | 34.30 | 8.25 | 47.52 | 25.89 | 18.34 | 12.5 | 2.4 | 18.40 | 32.80 | 46.40 |
| | 20-50 | 41.42 | 6.04 | 59.63 | 16.37 | 17.96 | 14.4 | 2.78 | 15.97 | 34.03 | 47.22 |
| | 50-100 | 39.94 | 2.50 | 30.05 | 32.55 | 34.90 | 15.5 | 1.93 | 9.68 | 37.29 | 51.10 |
| El-Arish valley | 0-20 | 44.50 | 36.40 | 43.60 | 7.87 | 12.13 | 4.4 | 6.80 | 20.45 | 34.11 | 38.64 |
| | 20-80 | 46.70 | 38.12 | 42.18 | 8.35 | 11.35 | 5.1 | 5.88 | 21.57 | 33.33 | 39.22 |

The distribution of total carbonate among the particle size fractions are summarised in Table 3 and Fig. 1. According to soil texture, the profiles under consideration can be grouped into 3 groups:

Group 1 : clay

Group 2 : clay loam

Group 3 : sandy clay loam and sand.

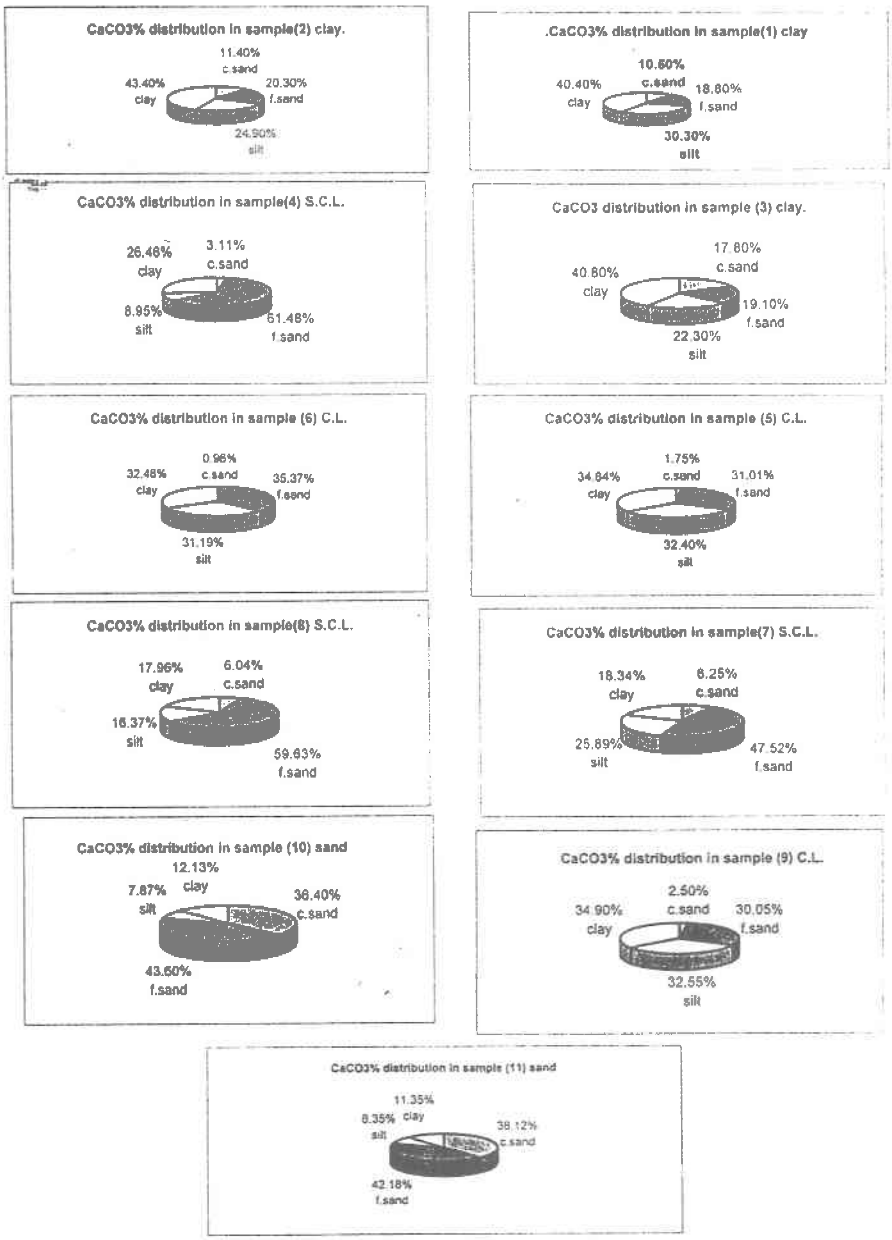


**Fig. 1. Calcium carbonate distribution % for the sampled soils.**

*For the group (1)* : The majority of calcium carbonate content in this soil was within the clay fraction. These results are in agreement with, Bui *et al.* (1990), and Sobecki and Wilding (1983). In the same respect, the predominance of clay and silt size carbonate is indicative of pedogenic secondary carbonates . Negm *et al.* (1990) added that the high content of $CaCO_3$ in the clay fraction can be attributed to the transportation and sedimentation processes of these soils in aqueous medium. On the other hand, when calcium carbonate found in clay or silt size it will be more effective on crust formation in calcareous soil.

*For the group (2)* : In clay loam soils (profiles 2 and 3; at a depth of 20-100 cm), the calcium carbonate content was rather regularly distributed over the clay , silt and sand fractions. Wider and Yaalon (1974) referred that the size and growth of calcite are controlled by thc texturc of the soil matrix.

*For the group (3)* : In sandy clay loam and sandy texture (Burg El-Arab and El-Arish), the majority of the calcium carbonate was within the sand fraction (2-0.05mm). These results coincide with Harga and El-Shazly(1982) and Rabie *et al.* (1993), who concluded that the main origin of these soils are the oolitic sand minerals.

*Active calcium carbonate*

In Table 3, it is apparent that the active carbonate content in the different fractions follows the order clay > silt > sand for all samples, the majority of calcium carbonate within the clay fraction. These results indicate that the clay and silt fractions are the main factors controlling the active carbonate content.

*Micromorphological characteristics of the profiles*

It is very important in dealing with calcareous soil to recognize the form (shape, size and distribution) of carbonate particles, as total percentage of carbonates can be inadequate guide , i.e two types of soils may have distinctly different properties although they contain the same quantity of calcium carbonate when calcium or magnesium carbonates are present in soil as fine crystallites in the plasma resulting in a compact porphyroskelic groundmass fabric, they may have different chemical and physical processes in the soils.The systematic microscopic description of soil thin sections are cited in Table 4 .

TABLE 4. The micromorphological features of the studied profiles.

| Profile No. | Ground mass | | | | Voids | Pedofeatures. |
|---|---|---|---|---|---|---|
| | Coarse materials | Fine materials | Organic matter | C/F related distribution | | |
| Tamia El-Fayoum 20-50cm (clay) | Few large grains in the surface and subsurface layers, the whole profile contains few fine grains, quartz, feldspars, mica some opaque and other translucent minerals. | Clay medium and fine silt mixed with O.M. and iron oxides, crystic plasmic, fabric is dominants, some parts show the speckled and moasic speckled b-fabric. | Organic matter is composed of some plant rests of brown color in different decom-positions stages. | porphyric and the b-fabric is speckled in the surface layer. | In the surface layers some large chambers and many large meta-vughs. | Some large and small diffuse irregular nodules rich in calcareous materials. Few small nodules of pure calcium carbonate crystallites, and many small completely rounded concretions of iron complexes are observed in this layer and few diffused neoferrans around some channels and planes. |
| Maryut 20-50cm (clay loam) | Grains are mostly sub-angular calcite crystalis of silt to fine and size associated with quartz and other mineral crystals. | The fine material is composed mainly of micro- calcium carbonate particles, it is rich in carbonate and iron compounds. | In the sub-surface layers there are a few organic materials in different stages of decomposition. | Many chitionic locally gefuric and enaulic. | The voids are mainly of simple and compound packing voids. Ortho-meta-vughs in the samples which have coarse texture are also observed. | The cutanic feature observed in calcareous soils are cutans, organic cutans and iron-manganese cutans with grains calcium carbonate. |
| Burg EL-Arab 20-50cm (sandy clay loam) | Meso and macro grains are dominant moderately sorted, different shapes ;dominant quartz, feldspars, calcite, and heavy minerals. | Yellowish brown to dark brown , mainly clay and silt sized minerals mixed with amorphous compound of Fe and Mn. | Few dark punctuation. | enaulic, chitionic besides close and open poryphyric. | The dominant voids are compound packing voids, irregular inter-connected different size vughs. | Many large fragments of long shape striated completely calcified shells, some have dark brown color, and some iron nodules. |
| El-Arish Valley 20-50cm (Sand) | Single and compound mineral grains, dominantly quartz, poly-crystalline quartz and calcite. | The fine material is composed mainly inherited calcareous nodules which show distinct internal fabric. | None | mainly gefuric and chitionic. | Simple and compound packing voids. | Various shapes and species of shells partly or completely calcified, have coarse sand size and many micro crystalline calcite nodules and small orthic ferrogenous nodules. |

*Tamia, El-Fayoum (clay texture)*

Few small nodules of pure calcium carbonate crystallites are observed, photo (1), these nodules according to internal fabrics are nucleic and aggregate of external morphology. C/F related distribution is porphyric which associates with the textural clay. On Nile alluvial soils the presence of $CaCO_3$ of secondary formation accumulations at the soil surface due to water evaporation and the subsequent transformation of soluble $Ca(HCO_3)_2$ into $CaCO_3$. The high amount of lime nodules is noticed in the alluvial soils, particularly in soil affected by fluctuating water table associated mostly with inadequate drainage conditions.

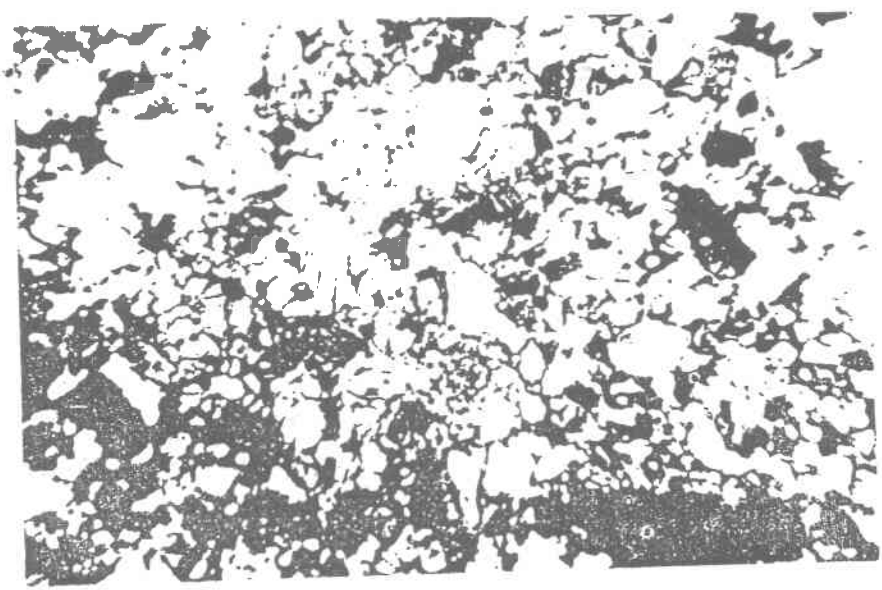

**Photo 1. El-Fayoum, large and small diffuse irregular calcareous nodules. Profile (1). 15-50cm. 80x.**

*Maryut (clay loam texture)*

It is noticed that the fine material is composed mainly of micro-calcium carbonate particles, and the grain cutanic features are common. The calcite nodules are irregularly distributed through out the profile, as a result of the less amounts of percolating rain water, and the high rate of evaporation in such arid climatic conditions, in same cases these calcareous complex nodules are enriched with iron and manganese compounds (photo 2). With regard to the fine material, it is composed mainly of micro calcium carbonate particles and the grains (coarse materials) are mostly sub-angular calcite crystals of silt to fine sand size associated with quartz. These findings coincide with Wang and Andreson (2000) they found that in the Cca horizons, carbonate in clay and fine silt fractions is mostly calcite. Calcitic coatings on the surfaces of both silt and sand particles forming the oolitic sands.

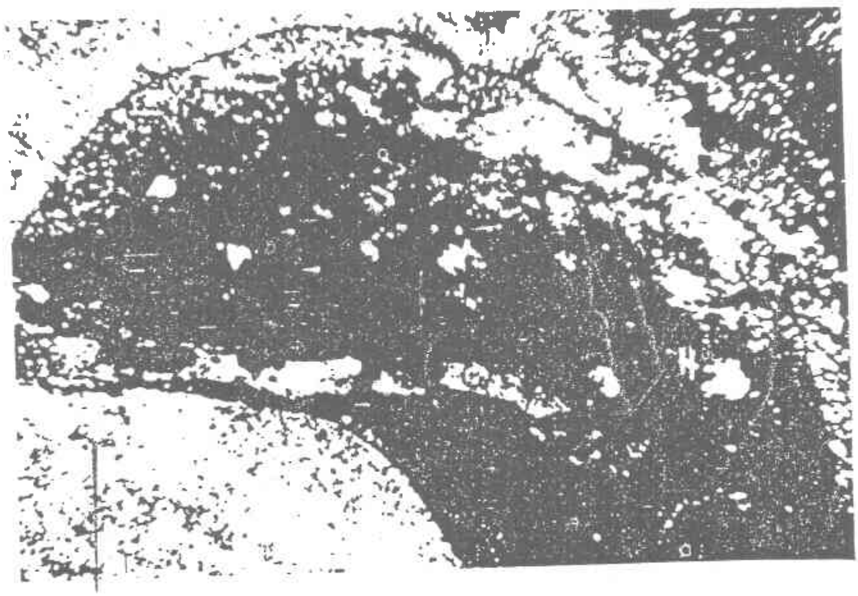

**Photo 2. Maryut, complex nodules of calcium carbonate and amorphous iron compounds. Profile (2) 20-60cm. 50x**

*Burg El-Arab (sandy clay loam texture)*

From the pedofeatures many large fragments of long shape striated completely or partly calcified shells (photo 3). The high proportion of the calcified shells and oolitic sands, relatively stable, form an essential part of the soil mass and regarded in such marine or lacustrine sediments as skeleton grains. These shells exhibit very dense internal fabric which is reflected on their hardness. It is evident that the North Western Coast was covered for a certain period by seawater. In such conditions saturated suspension of soluble calcium bicarbonate are crystalized and deposited by abrupt evaporation consequently fine crystallites are formed in between the relative large shells and oolitic sands acting as strong linkage. The chemical weathering is mainly responsible for the formation of these soils.

**Photo 3. Burg-El-Arab, Surface layer, striated shells, partly calcified. Profil (3). 20-50cm. 50x.**

*El-Arish valley (sandy texture)*

The pedofeatures in this profile have various shapes and species of shells partly or completely calcified (photo 4), have coarse sand size and many micro crystalline calcite nodules. The rounded shape of calcite nodules with sharp boundary may be transported with alluvial sediments, by wind. Generally, geomorpholgy of El-Arish valley consists of three conspicuous parent material is mostly dominated by calcareous sediments which derived from Pliocene and Miocene limestone. Due to the prevailing arid envirornmental conditions in this region, physical weathering seems to dominate and to act on the redeposit sediments.

The pattern of carbonate distribution in the different soil fractions can be explained as follows : in coarse textured soil , the calcite crystals can be precipitated and grow in the wide vughs. In clayey textured soil the pores and vughs are mainly of fine-size, the calcite crystals can not reach coarse size and remain in fine fractions.

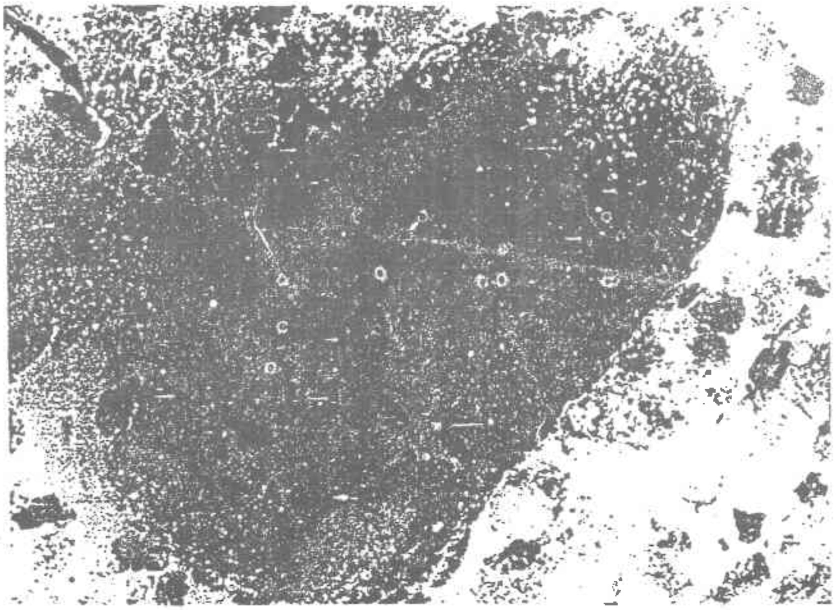

**Photo 4. El-Arish valley, Shell fragment completely calcified. Profile (4) 20-80cm. 50x.**

## Conclusion

The active $CaCO_3$ associated with clay textured soil (as in the alluvial sediments of Fayoum) characterised by porphyric related distribution mostly form nodulic pedofeatures as a result of fluctuation of water table saturated with Ca $(HCO_3)_2$. While in the lacustrine sediments (as in Maryut profile) $CaCO_3$ is precipitated from the saline sea water as small crystallites of calcite either forming the fine material in the ground mass or as cutanic features around quartz or feldspars grains which is well known as oolitic sand. However in the sandy calcareous soils particularly in the marine and lacustrine deposits the calcified shells are forming a considerable proportion of the coarse component as sand fractions while the active calcium carbonate are relatively very limited.

The calcareous pedofeatures as small nodules or oolitic sands can be transported by wind and deposited in another region as in El-Arish valley, causing an increase in the total calcium carbonate content but not in the active fraction.

Therefore, the total carbonate content is not the only effective parameter in the soil but the proportion of the active $CaCO_3$ which influence the pedofeatures and consequently the physicochemical and hydrological reactions.

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# دراسات مورفولوجيه على كربونات الكالسيوم وتوزيعها فى بعض الاراضى الجيرية المصرية

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*قسم الأراضى واستغلال المياه - المركز القومى للبحوث - القاهرة - مصر.*

يهدف هذا البحث إلى الدراسة المورفولوجية والكيميائية لكربونات الكالسيوم وربط المظاهر البيدولوجيه بقوام التربة وقد تم دراسة اربعه قطاعات ممثله من الفيوم - مريوط - برج العرب - وادى العريش ويتراوح نسبة كربونات الكالسيوم بها من ١١,١ الى ٤٦,٧٪. ويتضح من النتائج أن كربونات الكالسيوم النشطة المصاحبة للقوام الطيني الممثل فى قطاع الفيوم فنجد معظم توزيع كربونات الكالسيوم في شكل nodules وهذا نتيجة لتردد الماء الأرضى المشبع ببيكربونات الكالسيوم، بينما الترسيبات البحيريه الممثلة فى قطاع مريوط نجد أن كربونات الكالسيوم، المترسبة من ماء البحر المالح تتكون على هيئة بللورات صغيره من الكالسيت فى الجزء الناعم من ال groundmass أو على هيئة غلاف cutanic features حول الكوارتز والفلسبارات التى تعرف بـــ oolitic sand . ومن الملاحظ أن الأراضى الجيريه الرملية وعلى الاخص الترسيبات البحريه والبحيريه تكون الاصداف الكلسية متكونة بنسبه ملحوظة فى الجزء الخشن" الرمل" بينما تكون كربونات الكالسيوم النشطة نسبيا محدوده جدا. ومن المظاهر البيدولوجيه للاراضى الجيرية مثل التجمعات الصغيرةnodules أو oolitic sand التى ممكن ان تنتقل بواسطه الرياح وتترسب فى مكان آخر وهذا ماحدث فى وادى العريش مسببا ذلك زيادة فى نسبة كربونات الكالسيوم الكلية فقط دون حدوث زيادة فى نسبه كربونات الكالسيوم النشطة.

ولذلك محتوى كربونات الكالسيوم الكلى ليس هو المقياس الأمثل للاراضى بينما محتوى كربونات الكالسيوم النشط الذى يعكس المظاهر البيد ولوجيه وبالتالى الخواص الفيزيوكيميائية والهيدرولوجيه للأراضى التى يتحدد على أسسها برامج خدمه الأرض والنبات.