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# Carbonate Metabolism as an Internal Soil Building Process in Gharian Area, Libya, with Special Reference to Loesslike Deposits

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## ABSTRACT

Gharian area is covered partly by Quaternary deposits. According to Gray (6), it is Loess deposit. The morphological and pedochemical properties of this material are illustrated and compared with the glacial Loess from middle Europe. The differences are mainly in particle size distribution and also in the lime content of each size fraction.

The dominant size fraction in glacial Loess is the coarse silt in contrast to fine sand in the material under study. The maximum lime content accompanies the dominant size fraction in Loess, but it does not in Gharian material. The fine silt in Loess material is 5 times higher than that in Gharian, which indicates a different weathering pattern of the original materials.

Soil formation on Loesslike sediment has been shown in Wadi el-Quasim and Gharian profiles. The latter is relatively well differentiated in IA and IIB horizons. Clay formation and clay displacement is discussed in relation to the other pedogenic processes, and the possibility of pseudo-profile habits has been shown.

The status of available phosphorus is discussed from two aspects; as indication for the weathering of the lithogenic factor and as indication for phosphorus fertilization requirement.

## INTRODUCTION

Calcium-Carbonate household in Calcareous soil is an important pedogenic process, which stands in good relationship to the different soil classification systems. The relationships between the lime content and the different soil properties are, in general, well studied and are illustrated in many soil textbooks.

From a pedogenic point of view, the lime content in soil profile is an important property, that reflects the stage of soil development and the ecological circumstances of the location. There are two possibilities for the presence of lime in soil matrix; *primary* when soil material is derived from the weathering residues of calcareous rocks formed in situ or transported, and *secondary* when the calcification process occurs through high water table, lateral water movement in soil, run off, solifluction, blowing of carbonate dust and

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other processes of cumulization. It is not always easy to recognize the primary lime as lithogenic property and the secondary lime as pedogenic property.

From a chemical point of view, the calcium or (-magnesium) carbonate is important for soil chemical properties and soil as a medium for plant growth. The availability of many plant-nutrients like phosphorus and others is affected directly or indirectly by lime content. (3). The effect of lime depends not only on the content, but also on its size distribution in the soil matrix.

The lime problem in the soil of Gharian province in relation to these aspects, specially to calcification, decalcification processes, its relation to other pedogenic processes and the availability of phosphorus is illustrated.

## METHODS

Twenty gram of sample was dispersed in 0.001 N NaOH in order to prevent $CaCO_3$ solubility and shaked overnight (11). The different size fractions were collected by sieving, sedimentation and centrifugation (11,7,13). The lime content is determined by a calcimeter in each fraction and calculated from the $CO_2$ as $CaCO_3$ (2).

In order to have an exact figure about the particle size distribution, a parallel experiment was done after destroying the $CaCO_3$ in samples, and a percentage of fractions was calculated on a base of lime free samples. The lime cementation effect practised on sand, silt and clay fractions could be detected.

Measurement of pH was done in 1/2.5 distilled water by pH-meter; available phosphorus is determined in sodium bicarbonate extract (14); available potassium is determined by ammonium acetate extraction (5). Colour is determined according to Munsell chart.

## MATERIALS

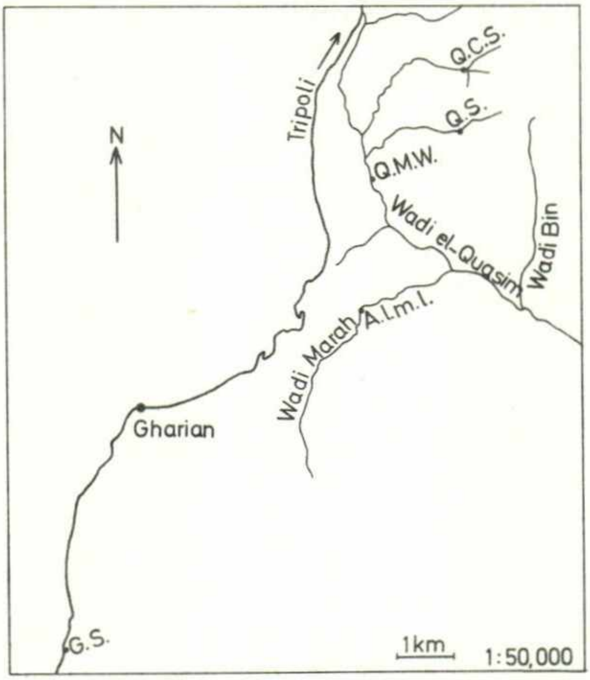
Samples are collected as following:

A. Wadi el-Quasim.

1. Soil profile:
   Location: the first east-side valley 10 Kms to the N.E. of Gharian. Soil development is recent. The profile is derived from homogeneous parent material with slightly columnar structure, slightly hard and contains lime mycelia. Two samples were taken according to slight differentiation in colour and root distribution, which is more intensive in the surface soil.
   surface sample: (0–60 cm), colour is 7.5 YR 6/6 (dry) and

   7.5 YR 5/8 (moist).

   subsurface sample: (60–120 cm), 7.5 YR 6/6 (dry) and 7.5 YR 5/6 (moist).
2. Main Valley Watercourse:
   Location: Main valley.
   The deposition reaches approximately 15 m depth on lime stone bed rock. The sample was taken from about 12 m depth, it has hard consistency, 7.5 YR 5/6 (dry) and 5 YR 4/8 (moist) colours. Columnar structure and lime mycelia are recognisable.
3. Cultivated surface soil:
   Location: Middle side valley.
   It has slightly hard consistency, 7.5 YR 6/6 (dry) and 7.5 YR 5/6 (moist) colours.
4. Alluvial locally mixed layer of 30 cm thickness between the wind blown material.
   Location: first side valley nearest Gharian.



Map shows the location of samples.

B. Gharian soil profile.

Location: 5 Kms south Gharian on the main road.

The whole profile contains lime fragments.

A-horizon (0–30 cm) is distinguished by its light brown colour, 7.5 YR 5/4 (dry) and 7.5 YR 4/4 (moist), and intensive fine vertical root distribution from the underlying horizon (30–70 cm) with strong brown to yellowish red colour: 7.5 YR 5/8 (dry) and 5 YR 4/8 (moist), slightly columnar structure, and hard lime concretions.

The parent material of all samples is mostly aeolian deposit (partly locally transported), cut by streams, specially in Wadi el-Quasim and standing in vertical walls, which is typical for Loess material. Undulating relief is typical for the whole Gharian area.

See the map for site locations.

## RESULTS AND DISCUSSION

The particle size distribution before and after destruction of lime, and lime fractionisation data, of the selected samples are shown in Tables 1 and 2.

The materials show more or less homogeneous particle size distribution of a dominant size fraction from 63 – 125 $\mu$ which is not accompanied by a maximum of lime content (compare Tables 1 and 2).

As the material of Wadi el-Quasim shows typical morphological feature of Loess[1,2] (reddish yellow calcareous deposits with vertical walls), a comparison with well studied Loess from middle Europe (11) is undertaken.

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[1] "Loess is unstratified, homogenous, porous, calcarous silt; it is yellowish or buff, tending to split along vertical points; maintains steep faces, and ordinarily contains concretions and snails shells." Russel cited by Joffe page 268(8).

[2] C. Gray 1971 reported on Loess presence in Gharian Area (6).

Table 1 Particle size distribution of Wadi el-Quasim and Gharian soil Profiles based on:
note 1 = lime free material
note 2 = total material

| Sample | depth cm | note | Particle size Ø from … to … in micron % | | | | |
|---|---|---|---|---|---|---|---|
| | | | <2 | 2–20 | 20–63 | 63–125 | 125–2000 |
| Q.S. Surface | 0–60 | 1 | 11.2 | 2.6 | 18.6 | 67.4 | 0.2 |
| | | 2 | 5.6 | 8.1 | 20.8 | 63.7 | 1.8 |
| Q.S. Sub-surface | 60–120 | 1 | 11.3 | 2.3 | 18.9 | 67.3 | 0.2 |
| | | 2 | 5.3 | 9.0 | 18.0 | 63.3 | 4.4 |
| Q.M.W. | 1,200 | 1 | 12.4 | 3.0 | 17.9 | 66.5 | 0.2 |
| | | 2 | 5.1 | 9.4 | 18.4 | 62.2 | 4.9 |
| Q.C.S. | 0–30 | 1 | 13.0 | 2.6 | 17.6 | 66.4 | 0.4 |
| | | 2 | 4.6 | 8.6 | 18.3 | 64.7 | 3.8 |
| G.A-horizon | 0–30 | 1 | 9.6 | 5.0 | 18.9 | 66.2 | 0.3 |
| | | 2 | 6.6 | 9.6 | 20.7 | 57.0 | 6.1 |
| G.B-horizon | 30–70 | 1 | 18.8 | 3.4 | 17.8 | 60.0 | 0.0 |
| | | 2 | 7.1 | 12.3 | 20.5 | 57.5 | 2.6 |

Q.S. surface: Surface soil from the first side valley North East of Gharian of Wadi el-Quasim
Q.M.W.: Main valley watercourse of Wadi el-Quasim
Q.C.S.: Cultivated surface soil from the middle side valley in Wadi el-Quasim
G.: Gharian soil profile.

Table 2 Lime distribution percentage based on total soil material (including lime) and available phosphorus determined in 0.5 M Na $HCO_3$-extract in Wadi el-Quasim and Gharian soil materials.

| Sample | depth cm | pH | Lime percentage based on total soil in size fractions in microns. | | | | | | Available phosphorus ppm |
|---|---|---|---|---|---|---|---|---|---|
| | | | <2 | 2–20 | 20–63 | 63–125 | 125–2000 | $\Sigma$ | |
| Q.S. Surface | 0–60 | 8.5 | 2.62 | 3.75 | 4.5 | 3.31 | 0.57 | 14.75 | nig. |
| Q.S. Subsurface | 60–120 | 8.5 | 3.0 | 4.52 | 3.78 | 3.35 | 1.22 | 15.87 | nig. |
| Q.M.W. | 1,200 | 8.9 | 1.03 | 2.36 | 1.38 | 0.75 | 1.18 | 6.7 | 2.75 |
| Q.C.S. | 0–30 | 8.5 | 2.51 | 4.15 | 4.11 | 3.56 | 2.26 | 16.6 | nig. |
| G.A-horizon | 0–30 | 8.5 | 2.15 | 3.96 | 2.87 | 1.71 | 4.36 | 15.05 | 4.75 |
| G.B-horizon | 30–70 | 8.3 | 1.86 | 3.79 | 2.71 | 1.09 | 1.34 | 10.76 | 2.5 |

Q.S. surface: Surface soil from the first side valley North East of Gharian of Wadi el-Quasim.
Q.S. Subsurface soil from the first side valley North East of Gharian of Wadi el-Quasim.
Q.M.W.: Main valley watercourse of Wadi el-Quasim.
Q.C.S.: Cultivated surface soil from the middle side valley in Wadi el-Quasim.
G.: Gharian soil profile.

As shown in Fig. 1 the maximum of the particle size distribution of European Loess, lies in the silt fraction 20–63 $\mu$ (graph A) and is accompanied by a maximum in the lime (graph B). The second difference in both particle size distribution is the fine silt content, which is much higher in the European Loess (compare graphs A and C). This fact reflects a different pattern of original weathered material before the transportation process. The relatively high lime content in clay and fine silt fractions in Wadi-el Quasim indicates more or less, that these fractions may have been blown as stable cemented components formed by cementation of clay colloids in particles of fine silt or by cementation of clay particles on the surface of silt particles. Consequently the lime in 'Loesslike' material is mostly primary (See graphs C, D and E).

According to the morphological study in the field, the pedogenical processes in the 'Loesslike' material in Wadi el-Quasim are weak.

Lime content distribution in the size fractions shows a different pattern in Wadi el-Quasim from Loess (Table 2). We have here carbonate mobilization and redistribution of lime in the soil matrix. According to Rhodenburg and Meyer (11), under good natural drainage and deep water table, the redistribution of lime tends mostly to increase its reprecipitation in the fine size fractions. It is difficult to recognize exactly the primary lime content in the Loesslike material. I looked in the field for signs of the solubility of lime and infiltration being impeded through clay substratum. Such profiles could not be found.

Q.S. surface and subsurface and Q.C.S. give representative lime distribution in particle size fractions of loesslike material, which show more or less lime maxima in silt fraction. It was expected that the maxima may be in the fine sand, as it is the dominant size fraction (Table 2). Here it is not the case; the fine sand contains only lime ranging from 3.31%–3.56%. The original lime content of fine sand and total material was perhaps higher because of the presence of eroded material in Quasim area, which indicates climatic changes towards more humidity after or during the disposition of the wind blown

Fig. 1. *Above*: The particle size distribution histographs based on lime free material of North hessen European Loess (left, Rhodenburg and Meyer) and for Loesslike material of Wadi-el-Quasim (right). *Middle*: Particle size distribution histograph of the Loesslike material based on total material. *Below*: Lime distribution histographs of same samples.

material. The alluvial locally mixed layer found in the studied area, between the deposit, only contains 42.5% fine sand (against about 64% in other samples) plus 5% rounded lime concretion >2 mm in diameter, which is a result of the erosion phase.

Through this fact the primary lime content should be higher than the recently obtained one. The lime supply from the dissolved 'calcium and magnesium hydrogen carbonate' from the surrounding lime stone and delomites in Gabal Nefusa, regarding the deep water table and the good natural drainage of the aeolain material, may play a small role.

Actually the lime content in fractions < 125 μ undergo decalcification and lime redistribution process at the same time but not to an equal extent. The lime content of fine sand may undergo this process intensively more than the finer fractions. This is according to the relatively rapid water infiltration through the coarse drainage pores of the dominant fine sand (13). A good example of this phenomenon is offered by the low lime content (only 0.75 %) of fine sand fraction obtained from the main valley (see Table 2 under Q.M.W.). This sample is close to the bottom at about 12 m depth, and its low total lime content (6.7 %) expresses more intensive decalcification resulting from water flooding in the main valley.

The lime of > 125 μ size is secondary formed (reprecipitation) at the expense of partly decalcificated lime of other smaller fractions. This lime of size > 125 μ in Quasim Soil Surface-horizon is 0.57 % and comes to 2.5 times greater than that in the underlying layer (Table 2). It ranges in other samples between 1.18 %–2.26 %. Rohdenburg and Meyer (11) showed, by studying loess stratigraphy in middle Europe, the formation of secondary carbonate particles of the coarse size > 63 μ during the soil formation.

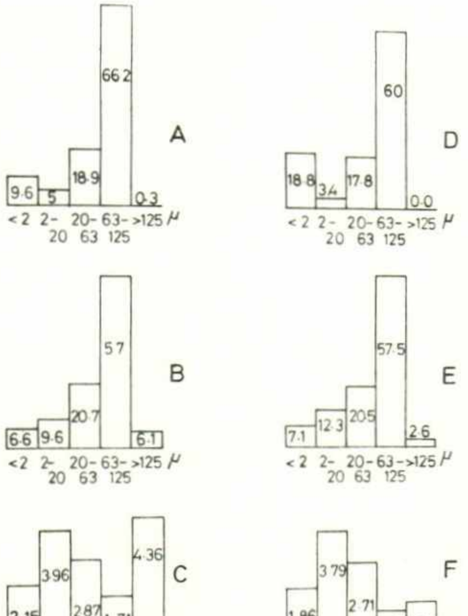

Fig. 2. *Above*: Particle size distribution histographs of Gharian Soil profile based on lime free material (A-hor., left, B-hor., right).
*Middle*: Particle size distribution histographs of same samples based on total material.
*Below*: Lime distribution histographs of the same samples.

The Gharian soil profile is selected for relatively developed and representative soil formation on such material. The whole profile contains lime stone fragments, which indicate that the parent material is locally transported and expressing admixture of the aeolain and at least about 5 % collovial material.

The lime distribution (Fig. 2 graphs C and F) in the size fractions of both soil horizons is approximately identical in fractions $< 63\ \mu$, although the total lime content in A-horizon (see also Table 2), is one and a half times greater than that in B-horizon. The maximum of lime lies in both horizons in 2–20 $\mu$ size as a result of the lime redistribution process (compare also with the lime distribution in Q.M.W.).

The difference in the total lime content in both horizons is more or less reflected through the high lime content of sand fraction $> 125\ \mu$ of A-horizon (Fig. 2 graph C), which is formed as a result of secondary calcification within the coarse pores of the soil matrix. This process can be attributed to the leaching away of dissolved carbonate from the included lime fragments and lime particles, which may be impeded to some extent by the high clay content of B-horizon. Therefore, the lime may reprecipitate in coarse fraction size in A-horizon material. The rain fall of 326.2 mm (average over 32 years for Gharian) (1) allows for the decalcification process to some extent. The profile shows twice more clay content in B-horizon than in A-horizon (Fig. 2 graphs A and D). Clay cutans of chocolate colour is observed on the column of the B-horizon. The question rises, how this clay originated from A-horizon is not clear, because clay leaching supposes a prior dispersion of colloids of A-horizon. According to Scheffer and Meyer (12), clay leaching in original loess soil presupposes lime leaching; consequently the first process can not be realized under the high total lime content. The higher content of lime in A-horizon and the absence of particle size fraction $> 125\ \mu$ in B-horizon leaves the question also open (see Tables 1 and 2). It is possible, that we have here a 'Pseudo-profile' originated from heterogeneous parent material. That means there is a 'fossil soil' having clay formation and clay leaching during at least the pluvial-time or even older, followed by an erosion phase which may produce a 'truncated profile'. Such a case is realizable under Gabal Nefusa topography. A new local deposition with, perhaps higher total lime content, takes place, from which the A-horizon may have been developed. Locally transportation of already pedogenetically weathered material is also possible. Arguments for this interpretation can be offered, by the higher lime content of A-horizon and its clay content of 9.6 %, which is not much less than that of the aeolain deposits; another one is the presence of lime mycelia on the clay cutans of B-horizon, which indicates a secondary calcification process of B-horizon. Further work may reveal the participation of other arguments for understanding this pedegenic problem.

Values of available phosphorus determined by $NaHCO_3$ extraction and pH are shown in Table 2. The pH of soil ranges between 8.3 and 8.5, which indicates that soil is fully base saturated because free $CaCO_3$ is present in the system (4). The pH value of Q.M.W. is 8.9, the EC is checked ($< 3$ mmhos at 25°), which indicates a high amount of $CO_3^-$ in the soil solution (10). According to Olsen (9), $NaHCO_3$ solution at pH 8.5 not only extracts some phosphate from Calcium phosphate but the $HCO_3^-$, $CO_3^=$ and $OH^-$ present in sodium bicarbonate solution replaces the phosphate ions present on the surface of soil particles. The extracted phosphorus stays in good correlation with the expected yield response. The results show negligible values for wadi el Quasim soil except Q-main watercourse (2.75 ppm of soil). This value compared with that of B-horizon in Gharian profile (2.5 ppm) can be attributed to similar phosphorus status of both weathered material with low lime content. This is in contrast to the negligible amounts of P-extracted in other relatively less weathered soil of wadi-el-Quasim with higher lime content. The value of 4.75 ppm phosphorus, of Gharian A-horizon can be attributed to the habits of the parent material from which A-horizon may have been developed in the pseudoprofile. (This is yet another argument for the above mentioned earlier interpretation). According to Black (2), the relation between the P-soluble in all extracts and the expected yield response to applied fertilizers (all values are smaller than 5 ppm of soil), is positive.

Additional Contribution: The available potassium data shows high values for all analysed samples. It ranges from 720 to 1750 ppm of soil. It is interesting in that the available K in Q.S. surface is higher than that of the underlying horizon. This indicates probably more weathering of minerals supplying potassium in surface soil. The higher available potassium value of B-horizon in Gharian profile (1,750 ppm) is attributed to its higher clay content than that in A-horizon (1,425 ppm). According to the evaluation of (5), all samples are rich in potassium and potassium fertilizers are now not necessary in Gharian area.

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