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QUANTIFYING DEVELOPMENT OF SOME EGYPTIAN SOILS FROM MICROMORPHOLOGICAL FEATURES AND MICROMORPHOMETRIC ANALYSIS

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ABSTRACT

The computation of micromorphological index is a recent approach to quantifying soil development from micromorphological features and micromorphometric analysis, where, few studies were conducted on this approach. In the current study, five soil profiles with different mode of formation were selected i.e., sandy, alluvial, calcareous, lacustrine and delta fringes to identify and quantifying the micromorphological features, using micromorphometric analysis and determine the soil development using micromorphological index on the basis of micromorphological features and micromorphometric data. The micromorphological index was helpful for quantitative determination of soil development of the studied soils especially alluvial and lacustrine ones. The index value is less than expected for calcareous soil. The micromorphological index can be equally useful for soils developed under different factors of soil formation. But, quantification of the micromorphological properties used for calculating the micromorphological index needs specific modification for particular situations.

Keywords: Micromorphological index, Soil development, Micromorphometeric analysis.

INTRODUCTION

Soils of different ages and degree of development will display their properties in different ways. Thus, the study of how the properties of soils vary with degree of development is of great interest and may offer useful information regarding to their genesis (Dorronsor and Alonso, 1994). On the macro-morphological level, several authors have stressed the considerable difficulty in evaluating the degree of soil development due to the enormous amount of data about different soil properties that such studies usually generate. To overcome this problem, quantitative indices have been developed; using a single value to evaluate the degree of evolution among different soils, and could also be applied to the different horizons of a single soil (Buntley and Westin, 1965; Walker and Green, 1976; Bilzi and Ciolkosz, 1977; Harden. 1982; Harden and Taylor 1983; Birkeland, 1984 a and b; Busacca 1987 and Lin *et al.*, 1999). These indices were calculated by determining the intensity of the change occurring between the properties of the horizons and those of the original material.

On the micro-morphological level, generally, soil micromorphology has great value for soil science; it is concerned with the description, interpretation and, to an increasing extent, the measurement of components, features and fabrics in soils at a microscopic level (Bullock et al, 1985). Recently, many authors confirmed that micromorphology will continue to serve the development of soil science in the future (Stoops, 2002 and Kapur *et al.*, 2004). Comparative studies of different profiles or within the same profile are often limited by the fact the quantitative estimates, of the observed micromorphometry as a solution (Eswaran, 1968, Bullock et al, 1985 and Acott et al, 1997 and VandenBygaart et al, 2000). Micromorphometry has enriched soil science by a new research method and series of new quantitative determinable soil properties. Among these are: the aggregate content on a morphometrical basis, the aggregate size relation, the aggregate type relation, the pore content; size and distribution, and finally the quantitative values of the homogeneity or heterogeneity of the structure of a soil (Kubiena, 1964). Over the last few years, micromorphometry as area-counting and description have been combined in about twenty studies (e.g., Macphail and Cruise 1996). Such area counts can be extremely accurate, achieving as little as a 0-5% difference when compared to image analysis (Macphail and Cruise 1996; Acott *et al.* 1997). Micromorphometric studies of Egyptian soils are very limited. All of these studies concentrated on the quantifying the micro-structure features and measurements of voids (Labib and Sys,1970, Ramadan, 1987, El-Maddah, 1988, El-Hussieny et al, 1990, El-Zahaby et al, 1990 and Moustafa, 1993).

The micromorphological soil development index is a recent approach to determine soil development and few studies were conducted on this approach. All these studies are concluded that the micromorphological index can be equally useful for soils developed under different factors of soil formation. But, quantification of the micromorphological properties used for calculating the micromorphological index needs specific modification for particular situations (Alonso et al; 1994, Dorronsoro, 1994, Alonso and Dorronsoro; 1996, Ortiz et al; 2000, Ortiz et al; 2002, and Mccarthy, 2003).

The current study aimed at identifying the micromorphological features of some Egyptian soils with different origin and mode of formation; quantifying the micromorphological features using micromorphometric analysis; and determine the degree of soil development using micromorphological index on the basis of micromorphological features and micromorphometric data.

MATERIALS AND METHODS

Soil sampling and laboratory analysis:

Five soil profiles were selected to represents some Egyptian soils of different origin and degree of developments as follows:

Profile 1: Representing soils of recent Aeolian deposits and classified as *Typic Torripsamments* (Nubaseed farm, North Tahrir)

Profile 2: Representing soils of Pleistocene calcareous deposits and classified as *Petronodic Haplocalcids* (Besar village, west of km. 63 Alex-Cairo desert road)

Profile 3: Representing soils of old Alluvial deposits and classified as *Typic Haplotorrets* (Itay El-Barod, Behera Governorate)

Profile 4: Representing soils of Lacustrine deposits and classified as *Aquic Torrifluvents* (South Idko lake, Behera Governorate)

Profile 5: Representing soils of intermixed deposits of western delta fringes and classified as *Gypsic Aquisalids* (Abu El-Matamer, Behera Governorate)

Profiles were described macromorphologically and undisturbed soil samples were collected to studying micromorphological characteristics. Thin sections were prepared according to the procedure described by Milner (1962), studied and photographed with Zeiss G41-500/I-e polarizing microscope. Terminology used for micromorphological features was according to Brewer (1964) and Bullock *et al.* (1985). The percentage of different micromorphological features were determined by area counting method for each thin section as described by Eswaran, (1968) and Moustafa (1993).

Calculation of micromorphological indices:

Using the schemes developed by Dorronsoro (1994), the micromorphological index was calculated from the magnitude change of the micromorphological features in horizons with respect to their parent material (Table 1).

Nine micromorphological properties were used to calculate the micromorphological index:

1) microstructure (type, grade, void types and abundance of voids),
2) fine material (color and abundance of particles smaller than 0.01 mm),
3) groundmass birefringence (fabric type and proportion of sepic domains),
4) organic matter (degree of alteration, abundance and excrement pedofeatures),
5) hydromorphic features (types and proportions),
6) carbonates (type, thickness and abundance)
7) illuvial clay pedofeatures (texture, degree of orientation, lamination, deformation and compound layering),
8) prevalence of illuvial clay features (thickness and abundance), and
9) mineral alterations (quartz and feldspar content).

The micromorphological index was calculated by the following steps:

1. Description and quantification of selected micromorphological features in parent material and soils.
2. Assessment of the magnitude of difference in micromorphological features (between horizons) and parent material
3. Normalization of each property from 0 to 1. The normal values were obtained by dividing the value calculated for each feature by the maximum value attainable if evolution were allowed to proceed to its endpoint. These steps were used to calculate the micromorphological index for each property and horizon. The resulting values were be used to get either specific indices for each individual property, or a general index for all properties.
4. The micromorphological indices for each property and soil were obtained by multiplying the normalized value of each property by horizon thickness, and by adding the products for each horizon in a given soil.
5. The general micromorphological index for a given horizon was obtained by adding the micromorphological indices for each property and horizon and by dividing the sum by the number of properties being considered.
6. The general micromorphological index for a given soil was acquired by multiplying each micromorphological index for all properties of a horizon by horizon thickness, and adding then the resultant products of all horizons.

Table 1: Evaluation scales for micromorphlogical properties (After Dorronsoro, 1994)

1- Microstructure

Type

0	Apedal: single grains, compact grains with vesicles.
10	Apedal: bridge grains, pellicular grains, with micro-aggregates and channels.
20	Apedal: vughy, spongy, channel, chamber, vesicular, fissure, crack, massive.
30	Pedal: platy.
40	Pedal: granular, crumb.
50	Pedal: blocky, prismatic

Grade of pedality		Voids types		Proportions*	
0	Apedal	0	Simple packing	5	1-5%
10	Weakly developed	5	Compound packing	10	5-15%
30	Moderately developed	10	Channels, chambers, vesicles	20	15-30%
50	Strongly developed	20	Vughs, planes	30	>30%

2- Fine material (10 µm)

Colors		Proportions*			
0	Gray	10	1-5%	60	40-50%
5	Brown	20	5-10%	70	50-60%
10	Yellow	30	10-20%	80	60-70%
20	Orange	40	20-30%	90	70-80%
40	Red	50	30-40	100	80-90%
				110	>90%

3- Groundmass birefringence

Birefringence		Proportions*of sepic domains	
0	Undifferentiated	10	1-5%
10	Stipple speckled, crystallitic	20	5-15%
20	Mosaic speckled, mono-striated	30	15-30%
30	Grano-, poro-, parallel-striated	40	30-50%
40	Reticulate-, cross-, circular-, crescent-striated	50	50-70%
50	Strait	60	>70%

4- Organic materials

Degree of alteration		Proportions*		Excrements	
5	Weak	10	1-5%	10	<1%
10	Moderate	20	5-15%	20	1-10%
30	Strong	30	15-30%	30	>10%
		40	>30%		

5-Hydromorphic features

Types

5	Nodules and coatings of Fe/Mn, weakly impregnated
10	Nodules and coatings of Fe/Mn, strongly impregnated
20	Depletion mottles
30	Depletion matrices

Proportions*

Nodules and coatings		Depletion domains	
5	<1%	10	1-5%
10	1-15%	20	15-30%
20	15-30%	30	30-50%
30	30-60%	40	>50%
40	>60%		

Table 1: Cont'd

6- Carbonates

Types and size

10	Fine nodules and coatings (<500µm)
20	Coarse nodules and coatings (>500µm)
40	Massive (<2mm)

Proportions %*

5	<1%	40	30-50%
10	1-5%	50	50-70%
20	5-15%	60	>70%
30	15-30%		

7- Features of alluvial clay

Interference colors

10	Interference color <1^{st}. order red
20	Interference color = 1^{st}. order red
30	Interference color > 1^{st}. order red

Features

10	Limpid clay
20	Disturbed
30	Laminated
40	disintegrated
50	Compound layer

8- Prevalence of illuvial clay

Proportions*

5	<0.5%	40	10-20%
10	0.5-2%	50	20-40%
20	2-5%	60	40-60%
30	5-10%		

Thickness

10	Fine (<50µm)
30	Medium (50-200µm)
50	Coarse (>200µm)

9- Mineral alteration

Proportions*of quartz

5	1-5%
10	5-10%
20	10-20%
30	20-30%
40	>30%

Proportions*of feldspars

5	1-5%
10	5-10%
20	10-20%
30	20-30%
40	>30

Proportions*: % in soil horizons - % in parent materials

RESULTS AND DISCUSSION

Micromorphological features

Micromorphological characteristics of the studied soil thin sections are presented in table 2, Data revealed that: Skeleton grains were observed in most horizons as few coarse to many fine quartz grains (Photos 1,2&3), few to common fine feldspars and few heavy minerals especially opaque. In addition, lacustrine soil (P.4) was characterized by occurrence of shells fragment. Presence of shells, which usually grow in shallow waters, prove the lacustrine origin of the parent material (El-Hussieny, 1990a).

Plasmic fabric is not detected in the sandy soil (P.1) due to the complete absence of plasma (Photo 1). While, the lacustrine, delta fringes and surface horizon of the calcareous soils have sil-skelsepic plasmic fabric. Such plasma separations could be attributed to swelling pressure where skeleton grains present a solid surface against which pressure can be exerted (Brewer, 1964 and El-Hussieny, 1990b). However, vo-skelsepic was observed throughout the subsurface horizons of calcareous soil. Alluvial soil (P.3) has argill-vo-skel-masepic plasmic fabric due to argillic plasma separations associated with voids, skeleton grains and within the matrix. Plasma separations appeared in such soils owing to swelling on wetting and shrinking on drying of the smectite clay minerals and may be formed in the surface horizon due to the management processes (Brewer, 1964 and El-Hussieny, 1985).The plasma-skeleton fabric is granular in the sandy soil. While, it is porphyroskelic in all other studied soil thins. Nearly all types of voids are observed, especially channels (Photo. 4), orthovughs (Photo. 3) and planes. Formation of channels was explained by the activity of funa and decay of plant roots (VandenBygaart et al, 2000). Orthovughs may be formed by adhesion of plasma particles to each others and to the coarse skeleton grains, or by differential weathering of skeleton grains and comlpete removal of weathering products (Brewer, 1964). In addition, orthovughs in calcareous soil may be formed due to the volatization of CO_2 during the precipitation of $CaCO_3$ as pedological features. Planes are originated through shrinking and swelling during wetting and drying of soil material (Brewer, 1964 and El-Hussieny, 1985). While, sandy soil has simple packing voids due to the dominant of skeleton grains and completely absence of plasma.

Pedological features varied between studied soil samples. Sandy soil samples were characterized by few fine carbonate nodules. Calcareous soil samples are dominated by carbonate nodules, gypsum crystals, sesquans and mangans (Photos 2 and 3). Formation and development of carbonate nodules were governed by dissolution, migration and re-precipitation of carbonates. Since present climate in the studied zone is too arid to encourage decalcification-calcification process, the formation of carbonate nodules is related to the past paleo-pluvial period (Moustafa, 1987 and El-Hussieny and Moustafa, 1990). Gypsum crystals are only found in the lower horizons and may be formed through the physico-chemical process, which is defined as the marine cycle of gypsum formation (Moustafa, 1987 and El-Hussieny and Moustafa, 1990). The dominant features in alluvial soil are argillans, and organans, (Photos 4 and 5). Argillans referred to a downward migration of plasma under cultivated conditions. Organans are directly resulted from strong decomposition of roots within channels. The formation of ferromanganese nodules are explained by the richness of Nile alluvial deposits in both iron and manganese (Ghanem et al, 1971 and El-Gala and Hendawy 1972). Soils in such area are exposed to alternate reducing and oxidizing conditions and assist the formation of ferromanganese nodules. This type of nodules is also formed at the ground water table as a result of the upward movement of reduced iron and manganese (Rowell, 1981). The lacustrine and delta fringes soils were characterized by many soulans, sesquans, mangans, and coarse gypsum crystals, and ferromanganese nodules, (Photos 6, 7 and 8). Soulans indicated an upward movement of soil solution which encourages by the high and saline ground water, strong capillarity and arid conditions (Photo 7). Sesquans were more abundant in the glayed horizons where osidation takes place on drying. Gypsum crystals were noticed as vughy crystallaria and intercalary crystals. Vughy crystallaria were undoubtedly formed due to crystallization from solution within voids, while intercalary crystals were probably formed due to the normal growth of large crystals on the expense of smaller ones (El-Hussieny, 1990b and Mourad, 1990). Ferromanganese nodules dominated in the glayed horizons while carbonate was found in the shelly layer as a result of the strong decomposition of shells.

It is worthy to note that pedality, alluvial soil and surface horizons of calcareous, lacustrine and delta fringes have well developed peds (Photo 4). Peds are coarse, strongly accordant and separated by planes and channels.

Table 2: Main micromprphological features of the studied soil profiles

P.	Depth, Cm	Skeleton grains	Plasmic fabric & Plasma-skeleton fabric	voids	Pedological features	Pedality
1	0-30	Dominant rounded quartz, common shells fragments and few feldspars.	Granular.	Simple packing.	Few fine yellowish carbonate nodules.	Apedal soil material.
	30-70	Dominant rounded quartz, common shells fragments and few feldspars.	Granular.	Simple packing.	Few fine yellowish carbonate nodules	Apedal soil material.
	70-120	Dominant rounded quartz, common shells fragments and few feldspars.	Granular.	Simple packing.	Few fine yellowish carbonate nodules	Apedal soil material.
2	0-20	Dominant rounded to sub-rounded quartz, few heavy minerals and rare plant roots.	Sil-skelsepic & Porphyroskelic.	Channels and orthovughs.	Common fine brown carbonate nodules, few fine black ferromanganese nodules.	Pedal soil material.
	20-50	Dominant rounded to sub-rounded quartz.	Vo-skelsepic & Porphyroskelic.	Orthovughs.	Many medium brown carbonate nodules, many fine dark ferromanganese nodules and common sesquans and mangans.	Apedal soil material.
	50-80	Dominant rounded to sub-rounded quartz.	Vo-skelsepic & Porphyroskelic.	Orthovughs.	Many medium pale brown carbonate nodules, many fine dark ferromanganese nodules and common sesquans and mangans.	Apedal soil material.
	80-115	Common sub-rounded quartz and opaques	Silasepic & Porphyroskelic.	Planes and orthovughs.	Dominant coarse gypsum crystals, common fine brown carbonate nodules and common sesquans and mangans.	Apedal soil material.
3	0-30	Many angular quartz, many feldspars and common heavy minerals.	Argill-vo-skel-masepic & Porphyroskelic.	Channels and orthovughs	Few fine dark ferromanganese nodules and common organans.	Pedal, well defined blocky peds isolated by channels.
	30-70	Common angular quartz, many feldspars and common heavy minerals.	Argill-vo-skel-masepic & Porphyroskelic.	Channels and planes.	Few fine dark ferromanganese nodules and dominant argillans.	Pedal, well defined blocky peds isolated by channels.
	70-120	Many angular quartz, many feldspars and common heavy minerals.	Argill-vo-skel-masepic & Porphyroskelic.	Channels and planes.	Few fine dark ferromanganese nodules and dominant argillans.	Well defined blocky peds isolated by channels.
4	0-35	Many fine angular quartz, few feldspars and dominant shells fragments.	Sil-skelsepic & Porphyroskelic.	Orthovughs and channels.	Few very fine dark ferromanganese nodules and few organans and soulans.	Pedal soil material
	35-65	Many fine angular quartz, few feldspars and abundant shells fragments.	Sil-skelsepic & Porphyroskelic.	Orthovughs and channels.	Few very fine dark ferromanganese nodules and few organans and soulans.	Pedal soil material
	65-90	Dominant angular quartz, common feldspars and heavy minerals.	Sil-skelsepic & Porphyroskelic.	Orthovughs and channels.	Common medium dark ferromanganese concretions, many coarse gypsum crystals and few mangans and soulans.	Apedal soil material.
5	0-20	Many medium sub-rounded quartz, common feldspars and plant roots.	Sil-skelsepic & Porphyroskelic.	Channels and orthovughs.	Few organans and soulans.	Pedal soil material, isolated by channels.
	20-40	Many medium sub-rounded quartz, few feldspars and common heavy minerals.	Sil-skelsepic & Porphyroskelic.	Orthovughs and channels.	Common fine gypsum crystals and few mangans and sesquans.	Apedal soil material.
	40-55	Many medium sub-rounded quartz, few feldspars and common heavy minerals.	Sil-skelsepic & Porphyroskelic.	Orthovughs and channels.	Many fine gypsum crystals and few mangans and sesquans.	Apedal soil material.
	55-80	Many medium sub-rounded quartz, few feldspars and common heavy minerals.	Sil-skelsepic & Porphyroskelic.	Orthovughs.	Dominant fine gypsum crystals and few mangans and sesquans.	Apedal soil material

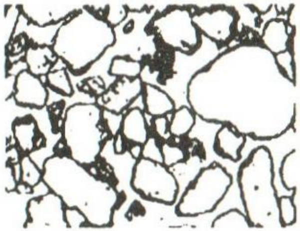

Photo (1): (P1, 0-30cm), Single grains and simple packing voids (P.L. 40X)*

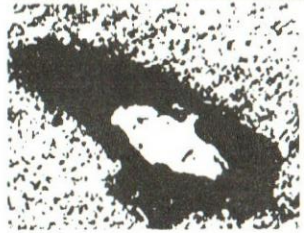

Photo (2): (P2, 50-85cm) Sesquans or mangans on the wall of voids (X.N. 40X)**

Photo (3): (P2, 25-50cm) Apedal s-matrix, siltic plasma and orthovughs voids (X.N. 40X)

Photo (4): (P3, 30-70cm) Well defined blocky peds isolated by channels and argillans on the wall of voids (X.N. 40X)

Photo (5): (P3, 30-70) Dark argill-ferromanganese nodules (X.N. 80X)

Photo (6): (P4, 65-90cm) Coarse gypsum crystals (X.N. 40X)

Phot (7): (P4, 65-90cm) fine gypsum crystals and soulans on the wall of orthovughs (X.N. 40X)

Photo (8): (P5, 20-40 cm) Mixed clay and silt plasma and oriented gypsum crystals (X.N. 40X)

*(P.L.): Plain Light. **(X.N.): Crossed nicoles. (40X and 80X): Magnification power

The shape and arrangement of peds are controlled by uniformity of the parent materials, uniformity and rate of drying, and percentage and type of clay, humic acids, iron oxides and exchangeable cations (Sleeman, 1963; Brewer, 1964 and El-Hussieny, 1990a), but attributed subsurface horizons are apedal. Lack of peds might be regards to the silitic and heterogeneous nature of plasma in which uniform patteren of fine cracks and surfaces of weakness can not develop (El-Hussieny, 1990b). Sandy soil (P.1) is apedal due to complete absence of plasma.

With the exception of sandy soil (P.1) as young soil, the other studied soil profiles are reached to primary micro-structure which includes plasmic fabric, plasma skeleton fabric, voids, and two types of pedological features. At this level of micro-structure, the soils could be considered highly developed from micro-structure point of view. This equality in qualitative and descriptive degree of development pushes off to find another technique to distinguishing and differentiating between such cases.

Micromorphometric Analysis

Results of the quantitative micromorphometric analysis are given in Table 3. It is showing that sandy soil, sub-surface horizons of the calcareous soil, lacustrines soil and delta fringes soil are apedal due to the absence of peds.

Table 3: Quantitative distribution of fabric elements and units in the studied soil profiles

Profile no.	Depth, cm	Pd.	Fabric elements, %			Pedological features, %		
			Pl.	Sk.Gr.	V.	Gl.	Cu.	Cr.
1	0-30	0.00	0.00	75.18	23.55	1.27	0.00	0.00
	30-70	0.00	0.00	74.53	21.95	3.52	0.00	0.00
	70-120	0.00	0.00	77.08	20.84	2.08	0.00	0.00
2	0-20	79.24	19.53	46.00	20.76	8.51	5.20	0.00
	20-50	0.00	16.46	34.61	18.25	19.16	11.52	0.00
	50-80	0.00	25.01	25.17	13.01	21.73	13.00	2.08
	80-115	0.00	18.91	28.84	13.23	18.67	9.11	11.24
3	0-30	81.12	48.15	26.81	18.88	2.08	4.08	0.00
	30-70	81.05	58.09	8.85	18.95	2.00	12.11	0.00
	70-120	78.29	53.21	16.74	15.71	4.11	10.23	0.00
4	0-35	72.18	38.25	31.57	27.82	1.18	1.18	0.00
	35-65	74.25	38.73	28.15	25.75	3.17	4.20	0.00
	65-90	0.00	24.44	30.15	23.98	6.21	6.11	9.11
5	0-20	66.91	31.09	33.85	33.09	0.00	1.97	0.00
	20-40	0.00	32.15	35.00	26.40	1.07	2.23	3.15
	40-55	0.00	27.09	37.11	23.60	2.08	3.01	7.11
	55-80	0.00	25.19	38.92	21.95	2.00	2.97	8.97

Pd.: Peds   Pl.: Plasma   GL.: Glaebules   Cu.: Cutans
Cr.: Crystallaria   Sk.Gr.: Skeleton Grains   V.: Voids

Peds present in alluvial soil and surface horizons of calcareous and delta fringes, and ranged between 72.18 and 81.18%. With regard to fabric elements, plasma completely absent from sandy soil and reached to the maximum in sub-surface horizon of the alluvial soil (58.09%) due to the downward migration of fine plasma under cultivated conditions as suspension and controlled by void nature, type of clay mineralogy and length of cultivation period (Bryant and Davidson, 1996 and Kozlovskii *et al.*, 2001). Generally, Skeleton grains decreased with depth in all studied soil profiles. Skeleton grains are the dominant fabric elements in the sandy soil and ranged between 67.08 and 75.18%, while the lowest value is detected in deep horizons of the alluvial soil (8.85%) due to the dominant fine plasma. Voids decreased with depth in all studied soil profiles, due to the compaction and alternative swelling and shrinking of soils (Stoops *et al*, 1988, Moustafa, 1993 and Marsili *et al*, 1998). Concerning pedological features, Glabules are detected in all studied soil samples and increased with depth. They reached to the maximum value in the subsurface horizons of calcareous soil and ranged between 19.16 and 21.73%. Cutans present in all studied soil thin sections except sandy soil (P.1) and attain to maximum values in subsurface horizons of calcareous and alluvial soils. Crystallaria present only in sub-surface horizons of delta fringes soil and deep horizons of lacustrine and calcareous soils, and varied between 9.11 and 11.24%. In addition, some micromorphological features are quantified in all studied horizons and parent material (Table 4). Based on this data and micromorphological description, the proportions and rating values of these features are calculated and presented in Table 5.

Micromorphological index for each property

Micromorphological indices for the quantifying the degree of soil development are established on the basis of micromorphological properties.

Data in Table 6 reveal that, the index of microstructure reached to the maximum value (0.867) in the surface and subsurface horizons of the alluvial soil and surface horizon of lacustrine soil due to high development of pedality and voids, while, the minimum values are detected in all horizons of the sandy soil (0.033). Fine material index increased in subsurface horizons due to migration of fine fraction under water percolation. It reached to the maximum value in the deepest horizons of the calcareous soil as 0.467 and subsurface horizon of alluvial soil as 0.433, while. In lacustrine and delta fringes soils have regular distribution with depth. On the other hand, sandy soil which has coarse texture and the index of their fine material is zero. It is clear that, fine texture soil has high value of microstructure and fine material indices than coarse texture soil. Groundmass birefringence reached to the maximum value as 0.818 in alluvial and lacustrine soils due to the dominance of fine clay plasma. Generally, the organic matter index tended to decrease with depth. The high value of this index is detected in alluvial and lacustrine soils due to agriculture practices and addition of organic manure. The high index of organic matter in delta fringes soil might be due to high salinity which controls the decomposition process. Hydromorphic indices varied between the studied soils, alluvial, lacustrine and delta fringes soils have the highest value (0.500) in the deepest horizons due to the effect of high water table. While, sandy soil has the minimum value due to the absence of such feature. As expected, carbonate indices are high in calcareous soil and increased with depth to maximum value (0.700), while it is zero or very low in other soils due to the absence of carbonate formations.

Table 4: Quantitative of some micromorphological features and their proportions with parent material.

Profiles	P.1				P.2					P.3				P.4				P.5				
Horizons	A_w	C_{f1}	C_{f2}	C_{f3}	A_g	B_{ca1}	B_{ca2}	C_{ca}	C	A_g	B_t	B_t/C_g	C	A_g	B_t	B_t/C_g	C	A_g	B_{sa1}	B_{sa2}	B_{sa}/C_g	C
Micro-features																						
Voids %	23.55	21.95	20.84	18.75	20.76	18.25	13.01	13.23	3.11	18.88	18.95	15.71	10.20	27.82	25.75	23.98	20.15	33.09	26.40	23.60	21.95	18.01
Proportion %	4.80	3.20	2.09	-	17.65	15.64	9.90	10.12	-	8.68	8.75	5.51	-	7.67	5.60	3.83	-	15.08	8.39	5.59	3.94	-
Rating value	5	5	5	-	20	20	10	10	-	10	10	10	-	10	10	5	-	20	10	10	5	-
Fine material %	0.00	0.00	0.00	0.00	19.53	16.46	25.01	18.91	66.20	48.15	58.09	53.21	16.10	38.25	38.73	24.44	11.24	31.09	32.15	27.09	23.19	14.21
Proportion %	0.00	0.00	0.00	-	46.67	49.74	41.19	47.29	-	32.05	41.99	37.11	-	27.01	27.49	13.20	-	16.88	17.94	12.88	10.98	-
Rating value	0	0	0	-	60	60	60	60	-	50	60	50	-	40	40	30	-	30	30	30	30	-
Plasma separation %	0.00	0.00	0.00	0.00	0.00	6.50	6.30	0.00	0.00	41.50	48.62	46.10	8.50	31.20	30.0	10.50	0.00	25.60	18.25	16.10	8.53	0.00
Proportion %	0.00	0.00	0.00	-	0.00	6.50	6.30	0.00	-	33.00	40.12	37.60	-	31.20	30.0	10.50	-	23.60	18.25	16.10	8.53	-
Rating value	0	0	0	-	0	20	20	0	-	40	40	40	-	40	40	20	-	30	30	30	20	-
Organic matter %	1.00	0.00	0.00	0.00	1.50	1.00	1.00	0.00	0.00	6.50	5.29	1.16	0.00	8.15	3.90	1.00	0.00	10.52	6.21	3.50	1.00	0.00
Proportion %	1.00	0.00	0.00	-	1.50	1.00	1.00	0.00	-	6.50	5.29	1.16	-	8.15	3.90	1.00	-	10.52	6.21	3.50	1.00	-
Rating value	10	0	0	-	10	10	10	0	-	20	20	10	-	20	10	10	-	20	20	10	10	-
Hydromorphic features %	0.20	0.35	0.00	0.00	1.50	2.36	3.21	3.83	0.00	5.08	14.00	14.00	1.00	2.10	6.50	11.05	1.15	1.00	2.52	4.38	4.12	0.00
Proportion %	0.20	0.35	0.00	-	1.50	2.36	3.21	3.83	-	4.08	13.00	13.00	-	0.95	5.35	9.90	-	1.00	2.52	4.38	4.12	-
Rating value	5	5	0	-	10	10	10	10	-	10	10	10	-	5	10	10	-	10	10	10	10	-
Carbonates %	1.07	3.20	2.08	0.00	11.00	25.80	31.00	26.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Proportion %	1.07	3.20	2.08	-	11.00	25.80	31.00	26.50	-	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Rating value	10	10	10	-	20	30	40	30	-	0	0	0	-	0	0	0	0	0	0	0	0	-
Illuvial clay %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.90	11.60	0.00	0.00	14.80	10.90	0.00	0.00	6.52	11.24	9.25	0.00
Proportion %	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-	0.00	18.90	11.60	-	0.00	14.80	10.90	-	0.00	6.52	11.24	9.25	-
Rating value	0	0	0	-	0	0	0	0	-	0	40	30	-	0	40	30	-	0	30	40	30	-
Quartz alteration %	73.20	71.90	76.80	78.80	44.20	31.80	21.40	22.40	20.00	20.81	5.18	10.30	41.50	26.15	22.10	24.89	63.20	28.90	33.15	34.11	36.12	45.51
Proportion %	5.60	6.90	2.00	-	24.20	11.80	1.40	2.40	-	20.69	36.32	31.12	-	37.05	41.10	38.31	-	16.61	12.36	11.40	9.39	-
Rating value	10	10	5	-	30	20	5	5	-	30	40	40	-	40	40	40	-	20	20	20	10	-
Feldspars alteration %	1.50	1.30	1.80	2.00	2.80	1.90	1.97	2.13	8.51	3.85	4.21	4.67	14.80	1.18	2.57	3.14	6.53	2.18	2.16	3.11	2.15	11.53
Proportion %	0.50	0.70	0.20	-	6.01	6.61	6.54	6.38	-	10.95	10.59	10.13	-	5.35	3.96	3.39	-	9.35	9.37	8.42	9.38	-
Rating value	0	0	0	-	10	10	10	10	-	20	20	20	-	10	5	5	-	10	10	10	10	-

Table 5: worksheet steps followed to calculate the micromorpholgical indices for the studied soil thin sections.

Profile	P.1			P.2				P.3			P.4			P.5				Top value
Horizon	A_w	C_{11}	C_{12}	A_p	B_{ca1}	B_{ca2}	C_{cacs}	A_p	B_t	B_t/C_g	A_p	B_t	B_t/C_g	A_p	B_{ss1}	B_{ss2}	B_{ss}/C_g	
Basal depth (cm)	30	70	120	20	50	80	115	30	70	120	35	65	90	20	40	55	80	
Horizon thickness (cm)	30	40	50	20	30	30	35	30	40	50	35	30	25	20	20	15	25	
Quantified properties 1- Microstructure	(5)	(5)	(5)	(110)	(60)	(50)	(50)	(130)	(130)	(100)	(130)	(100)	(35)	(120)	(40)	(40)	(35)	150
Type	0	0	0	50	20	20	20	50	50	40	50	50	20	50	20	20	20	
Pedality grade	0	0	0	30	0	0	0	50	50	30	50	30	0	30	0	0	0	
Void types	0	0	0	10	20	20	20	20	20	20	20	10	10	20	10	10	10	
Void proportions	5	5	5	20	20	10	10	10	10	10	10	10	5	20	10	10	5	
2- Fine material	(0)	(0)	(0)	(65)	(65)	(70)	(70)	(55)	(65)	(55)	(45)	(45)	(35)	(35)	(35)	(35)	(35)	150
Colors	0	0	0	5	5	10	10	5	5	5	5	5	5	5	5	5	5	
Proportions	0	0	0	60	60	60	60	50	60	50	40	40	30	30	30	30	30	
3- Groundmass Birefringence	(0)	(0)	(0)	(0)	(30)	(30)	(0)	(90)	(90)	(80)	(90)	(90)	(40)	(60)	(70)	(60)	(40)	110
Birefringence fabric	0	0	0	0	10	10	0	50	50	40	50	50	20	30	40	30	20	
Proportions of sepic domaind	0	0	0	0	20	20	0	40	40	40	40	40	20	30	30	30	20	
4- Organic materials	(15)	(5)	(0)	(20)	(20)	(20)	(0)	(50)	(50)	(30)	(60)	(50)	(15)	(40)	(50)	(40)	(40)	100
Degree of alteration	5	5	0	10	10	10	0	10	30	20	30	30	5	10	30	30	30	
Proportions	10	0	0	10	10	10	0	20	20	10	20	10	10	20	20	10	10	
Excrements	0	0	0	0	0	0	0	20	0	0	10	10	0	10	0	0	0	
5- Hydromorphic features	(10)	(10)	(0)	(20)	(20)	(20)	(20)	(15)	(20)	(40)	(10)	(20)	(40)	(20)	(30)	(40)	(40)	80
Types	5	5	0	10	10	10	10	5	10	30	5	10	30	10	20	30	30	
Proportions (nodules & cutans)	5	5	0	10	10	10	10	10	10	10	5	10	10	10	10	10	10	
6- Carbonates	(20)	(20)	(20)	(30)	(50)	(60)	(70)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	100
Types and size	10	10	10	10	20	20	40	0	0	0	0	0	0	0	0	0	0	
Proportions	10	10	10	20	30	40	30	0	0	0	0	0	0	0	0	0	0	
7- Features of illuvial clay	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(80)	(50)	(0)	(60)	(30)	(0)	(30)	(30)	(20)	120
Degree of orientation	0	0	0	0	0	0	0	0	30	30	0	30	20	0	10	10	10	
Features	0	0	0	0	0	0	0	0	50	20	0	30	10	0	20	20	10	
8- Prevalence illuvial clay	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(70)	(40)	(0)	(70)	(40)	(0)	(40)	(50)	(40)	120
Proportions	0	0	0	0	0	0	0	0	40	30	0	40	30	0	30	40	30	
Thickness	0	0	0	0	0	0	0	0	30	10	0	30	10	0	10	10	10	
9- Mineral alteration	(10)	(10)	(5)	(40)	(30)	(15)	(15)	(50)	(60)	(60)	(50)	(50)	(45)	(30)	(30)	(30)	(20)	80
Proportions of quartz	10	10	5	30	20	5	5	30	40	40	40	40	40	20	20	20	10	
Proportions of feldspars	0	0	0	10	10	10	10	20	20	20	10	10	5	10	10	10	10	

Table 6: Micromorpholgical indices and general micromorphological index for the studied soil thin sections.

Profile	P.1			Av. soil	P.2				Av. soil	P.3			Av. soil	P.4			Av. soil	P.5				Av. soil
Horizon	A_p	C_{11}	C_{12}		A_p	B_{ca1}	B_{ca2}	C_{cs}		A_p	B_k	B_k/C_g		Ap	Bk	Cg		A_p	B_{sa1}	B_{sa2}	B_{sa}/C_g	
Basal depth (cm)	30	70	120		20	50	80	115		30	70	120		35	65	90		20	40	55	80	
Horizon thickness (cm)	30	40	50		20	30	30	35		30	40	50		35	30	25		20	20	15	25	
Micromorpholgical indices																						
1- Microstructure	0.033	0.033	0.033	3.96	0.733	0.400	0.333	0.333	48.31	0.867	0.867	0.667	94.04	0.867	0.667	0.233	56.18	0.800	0.267	0.267	0.233	31.17
2- Fine material	0.000	0.000	0.000	0.00	0.433	0.433	0.467	0.467	52.01	0.367	0.433	0.367	46.68	0.300	0.300	0.233	25.33	0.233	0.233	0.233	0.233	18.64
3- Groundmass	0.000	0.000	0.000	0.00	0.000	0.273	0.233	0.000	16.38	0.818	0.818	0.727	93.61	0.818	0.818	0.364	62.27	0.545	0.636	0.545	0.364	40.90
Birefringence	0.150	0.050	0.000	6.50	0.200	0.200	0.200	0.000	16.00	0.500	0.500	0.300	50.00	0.600	0.500	0.150	39.75	0.400	0.500	0.400	0.400	34.00
4- Organic materials	0.125	0.125	0.000	8.75	0.250	0.250	0.250	0.250	28.75	0.188	0.250	0.500	40.64	0.125	0.250	0.500	24.38	0.250	0.375	0.500	0.500	25.38
5- Hydromorphic features	0.200	0.200	0.200	24.00	0.300	0.500	0.600	0.700	63.50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000	0.00
6- Carbonates	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000	0.00	0.000	0.667	0.417	47.53	0.000	0.500	0.250	20.00	0.000	0.250	0.250	0.167	14.18
7- Features of illuvial clay	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000	0.00	0.000	0.583	0.333	39.97	0.000	0.583	0.333	24.15	0.000	0.333	0.417	0.333	21.24
8- Prevalence illuvial clay	0.125	0.125	0.063	11.90	0.500	0.375	0.188	0.188	33.47	0.625	0.750	0.750	86.25	0.625	0.625	0.563	54.70	0.375	0.375	0.375	0.250	26.88
9- Mineral alteration																						
General micromorphological index	0.070	0.059	0.033	6.12	0.268	0.270	0.257	0.215	28.71	0.374	0.541	0.451	55.41	0.371	0.471	0.292	34.09	0.289	0.330	0.332	0.276	23.60

The indices for alluvial clay and its prevalence increased with depth in most of sub-surface horizons of fluvial soils (P.3,4&5). A possible explanation for this finding is the increased stability of illuvial features given the lack of disturbance of the deeper layers by surface events (Dorronsoro, 1994). The index of minerals alteration seems to be high in alluvial and lacustrine soil and ranged between 0.625 and 0.750 and might be explained by the active weathering processes in these fluvial deposits.

General micromorphological index for each horizon

The calculation and distribution of general micromorphological index for each horizon with depth are presented in Table 6. Recent sandy soil (P.1) consistently yielded values below 0.1 in all horizons due to their deprived of micro-features and degree of development. The calcareous soil (P.2) has values ranged between 0.215 and 0.270 with regular decrease with depth, while old alluvial soil (P.3) has values ranged between 0.374 and 0.541 and reached to the maximum in the subsurface horizon. Lacustrine and delta fringes soils have the same previous trend with values varied between 0.292 to 0.471 and 0.276 to 0.332, respectively. The distribution of general micromorphological index is showing no clear relation with depth in younger sandy soils, whereas in older soils, maximum values are obtained in sub-surface horizons of alluvial and lacustrine soils. The increasing of micromorphological index of both soils seems related to the long time cultivation activity and the activity of soil processes in the fluvial environment. Also, the index is increased in subsurface horizon of calcareous soil, but the value is less than expected from this type of old formed soil. This could be explained by the micromorphological properties used for calculating the micromorphological index were not sufficient for determining the degree of development in calcareous soils and needs specific modification to be capable to evaluate the evolution of such soils.

Average soil micromorphology index

The average values of this index possibly will be helpful to differentiate between the studied soils, which have the same degree of development from descriptive micromorphological point of view. Average soil micromorphology index is used as indicator to soil development and showed that old alluvial soil is more developed than other soils. It is reached to the maximum value of 55.41, while the sandy soil has the minimum value as 6.12. The lacustrine soil has value as 34.09 and the delta fringes soil has value as 23.60. The low value of delta fringes soil may be explained by multi-depositional environment and lack of genetic relations with parent material, while, the calcareous soil has micromorphological index as 28.71 and it looks less than expected for this type of soil. This might be due to Dorronsoro method of evaluation which concerned with the features of fluvial deposits, the nature of the uncultivated soil and the weakness of soil forming processes under dry climate.

CONCLUSION

The micromorphological index was found to be effective for quantitative determination of soil development of some Egyptian soils especially fluvial ones. The index value is less than expected for calcareous soil. This micromorphological index could be equally useful for soils developed under different factors of soil formation. But, quantification of the micromorphological properties used for calculating the micromorphological index needs specific modification and would require improvements for application in a wider range of soils. This type of studies could help in recognition of the main occurred pedogenic processes and features and lead to more understanding of genesis and development of these Egyptian soils.

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التقدير الكمى لتطور بعض قطاعات الأراضي المصرية باستخدام الخصائص الميكرومورفولوجية و القياسات الميكرومورفومترية

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يعتبر التقدير الكمى لتطور الأراضى باستخدام الخصائص الميكرومورفولوجية و القياسات الميكرومورفومترية من الأساليب الكمية الجديدة و التى تعطى للدراسات الميكرومورفولوجية بُعداً جديداً. هذا و قد اُستحدث دليل الميكرومورفولوجي Micromorphological Index بواسطة Dorronsoro, 1994 لتقدير درجة تطور الأراضى علي اسس الدراسة الميكرومورفولوجية. و تعتبر الدراسة الحالية أحد المحاولات لاستخدام و تطبيق هذا الدليل علي الأراضى المصرية. تم أختيار عدد ٥ قطاعات تربة ذات ظروف نشأة متباينة و مع افتراض تباينها في درجة التطور؛ و تمثل هذه الترب كل من الترسيبات الرملية و الاراضى الجيرية و الترسيبات النيلية القديمة و الترسيبات البحيرية و الهوامش الدلتاوية. و تم اعداد الشرائح الرقيقة Thin sections لكل من افاق هذه القطاعات و مواد الاصل التي ترتكز عليها هذه القطاعات؛ وقد وجدت الدراسة أنه من وجهة النظر الميكرومورفولوجية الوصفية ان قطاع التربة الرملية ضعيف التطور بينما بقية القطاعات لها نفس درجة التطور حيث وصلت الى مستوى Primary structure و هو أعلى مستويات تطور البناء من الناحية الميكرومورفولوجية. و قد أكد ذلك مدى أهمية استخدام التقدير الكمى لدليل الميكرومورفولوجي للتمييز بينهم Quantitative Micromorphological Index و الذى أوضح أن قطاع الترسيبات النيلية القديمة هو الأكثر تطوراً و له دليل ميكرومورفولوجي ٥٥,٤١ و يليه قطاع الترسيات البحيرية ٣٤,٠٩ وقطاع الأراضى الجيرية ٢٨,٧١ و قطاع الهوامش الدلتاوية ٢٣,٦٠ و اقلهم تطوراً قطاع الترسيبات الرملية ٦,١٢ . و توضح الدراسة مدى الحاجة الى اجراء المزيد من الدراسات باستخدام هذا الدليل وتطويره و اضافة بعض الخصائص اليه ليتناسب مع كافة انواع الاراضى و خاصة تحت الظروف المصرية.