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Characterization of Sarir Sahara Soils in the Libyan Jamahiriya*

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ABSTRACT

A study of the major soil series in the Sarir area, southeast of the Libyan Jamahiriya, disclosed a number of: (a) morphological features reflecting a minimum of pedogenic processes (aeolian as well as alluviation activities), (b) chemical data characterizing non-saline, alkali soil conditions (with possible lithological discontinuities), and (c) mineralogical structures exhibiting domination of the clay fraction by expansible 2:1-layer silicates.

Fibrous clays of the attapulgite (palygorskite) form appear to be present in these soils, but the evidence obtained is yet to be confirmed.

INTRODUCTION

The Sarir area, Southeast of Libya, extends from 24° to 30° N. latitude, and from 19° to 25° E. longitude. According to Pomeryal (13), Sanford (16), and others the geology of this area could be briefly summarized as follows: (a) Holocene to oligocene consisting of an 800 ft-thick upper zone of unconsolidated, slightly feldspathic sand followed by a 1000 ft-thick middle zone of gray green-to-red brown shale and claystone with fine-to-coarse grained of dolomite and sandstone; (b) Middle Eocene containing nummulitic limestone and marl; (c) Paleocene including evaporite mixtures, shale, and anhydrite.

Three major soil series were named in this area by Tempten Klen Pack* in1973–1974:

1. Faregh Series (after one of the oldest valley passes).
2. Sarir Series.
3. Kufra Series (after Kufra oasis).

Subsequently, more detailed studies (made by the Agriculture Studies and Consultation Office** in 1975–1976) made it possible to subdivide these series into phases based on the following factors of soil management: (a) profile depth; (b) hardpans; (c) degree of erosion, and (d) percent of gravel in profile. Accordingly, eight, seven, and five soil phases were recognized for the respective three series.

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* 'Reconnaissance soil studies of Sarir Agriculture Project', Reports submitted to the Agriculture Council the Libyan Jamahiriya.

** Three reports submitted to the Agriculture Development Council.

In view of the fact that these soils are planned for intensive, irrigated cropping, their properties should be well characterized in order to anticipate future problems. These properties are reported here for the first two series, those for Kufra series having already been published (Abdelgawad *et al.*, (1)).

Emphasis is placed upon the question of attapulgite presence in these soils since the foregoing geological features are typical for its occurrence [Muir, (11); Barshad and Gold, (3); Kerr, (9); Rogers *et al.*, (15); Elgabaly, (16); Lee *et al.*, (10)].

MATERIALS AND DMETHODS

The study area, covering 32000 hectares, is located between 20° 30′–28° 0′ latitude and 21° 30′–22° 30′ longitude. Following an extensive morphological survey of the area, soil samples were collected from a large number of profiles, dried, and sieved through 2 mm sieves. The following analyses were carried out according to Dewis and Freites (5):

— Particle size	: hydrometer method
— $CaCO_3$	: calcimeter method
— Soluble components (determined in the saturation extract):	
— pH	: Beckman pH meter
— EC_e	: Conductivity bridge
— Cl^-	: Titration with .02 N $Hg(NO_3)_2$ + .05 N HNO_3
— $SO_4^=$	: Precipitation with $BaCl_2$
— $CO_3^=$ and HCO_3^-	: Titration with .02 N HCl (Potentiometric)
— Ca^{++} and Mg^{++}	: Titration with EDTA
— Na^+ and K^+	: Flame photometer
— Cation exchange capacity (CEC)	: saturation with sodium acetate
— Exchangeable cations	: leaching with 1 N ammonium acetate

X-ray diffraction analyses were performed according to Jackson (8) on the clay fraction ($< 2\mu$) as separated by sedimentation and prepared as oriented aggregates carefully deposited on glass slides. Using a Krestalloflex instrument with copper radiation ($K\alpha$, 1.5417 A°), diffractograms were obtained for clay samples treated with one of the following treatments: (1) K saturation, air dry; (2) K saturation, heated to 600°C; (3) Mg saturation, air dry; (4) Mg saturation, glycerol solvation;

RESULTS AND DISCUSSION

The results appearing in Tables 1 and 2 were obtained for two profiles that are typical of the examined two series. Certain common features reflecting participation of both aeolian and alluviation processes in the course of formation of these soils follow.

One feature is the lack of profile development (absence of horizon differentiation) and appearance of a more or less uniform sandy solum. Tough not shown with the data at hand, the percentage of both silt and clay fractions increases in certain cases (especially in Faregh series) with depth leading to a silty-sand texture. The soil structure in general is of the single-grain type with numerous medium-to-large pores and exhibits loose-to-friable consistency. Consequently the soil profile slides down easily but compaction increases with depth.

Another characteristic feature is the presence of concretions of various kinds and sizes, notable of which are lime concretions (strong effervescence with HCl) and

Table 1 Analyses of Faregh soil series.

Depth (cm)	Horizon	Mechanical analysis (%)			Gravel[a] (%)	$CaCO_3$ (%)	Texture	Colour	
		Sand	Silt	Clay					
0–25	C_1	98.0	1.8	0.2	2.61	0.98	Sandy	Yellowish brown	10 YR 5/5 dry 10 YR 5/8 moist
25–60	C_2	95.8	1.8	2.4	1.22	1.07	Sandy	Light yellowish brown	10 YR 6/4 moist
60–150	C_3	98.4	1.0	0.6	13.29	1.18	Sandy	Brownish yellow	10 YR 6/8 dry and moist

[a]Soil surface is covered with brown gravel 5–30 mm in diameter. Rounded, brownish pebbles also exist.

Depth (cm)	pH	ECe (m.mhoes/ cm/25°C)	Soluble cations and anions (meq/liter)								CEC (meq 100/ gr)	Exchangeable cation (meq/100 gram)			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	$CO_3^=$	$SO_4^=$	Cl^-		Ca^{++}	Mg^{++}	Na^{+}	K^{+}
0–25	8.8	0.254	1.2	0.3	3.12	0.3	3.6	0.3	1.1	1.14	1.43	0.75	0.15	0.25	0.39
25–60	8.5	1.53	2.4	1.2	8.4	0.81	3.8	0.2	2.9	6.1	2.33	1.40	0.10	0.32	0.48
60–150	8.0	2.9	6.4	2.6	16.28	0.55	4.4	—	8.2	12.8	1.86	0.65	0.15	0.26	0.42

Depth (cm)	Minerals identified in the clay fraction
0–25	Montmorillonite, mica, attapulgite, kaolinite, interstratified minerals.
25–60	Minerals above plus quartz and feldspars.
60–150	Minerals in the overlying two layers.

Table 2 Analyses of Sarir soil series.

Depth (cm)	Horizon	Mechanical analysis (%) Sand	Silt	Clay	Gravel[a] (%)	$CaCO_3$ (%)	Texture	Colour
0–8	C_1	95.4	4.0	0.6	1.67	4.38	Sandy	Brownish yellow 10 YR 6/8 moist
8–26	C_2	97.2	0.6	2.2	5.80	0.26	Sandy	Light brownish gray 2.5 Y 6/2 dry and moist
26–72	IIC_3	97.2	2.0	0.8	8.51	0.35	Sandy	Light brownish gray 2.5 Y 6/2 dry and moist
72–150	IIC_4	95.0	2.0	3.0	5.0	1.53	Sandy	Light brownish gray 2.5 Y 6/2 dry and moist

[a]In certain cases the surface is covered with rounded dark gray gravel 2–20 mm in diameter, sometimes covered with recent wind-blown deposits.

Depth (cm)	pH	ECe (m.mhoes/ cm/25°C)	Soluble cations and anions (meq/liter) Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3^-	$CO_3^=$	$SO_4^=$	Cl^-	CEC (meq/100 gr)	Exchangeable cations (meq/100 gr) Ca^{++}	Mg^{++}	Na^+	K^+
0–8	8.9	0.6	1.0	1.0	2.79	0.3	1.3	—	2.0	1.7	1.9	0.97	0.21	0.51	0.22
8–26	9.0	3.0	1.0	1.5	25.0	2.1	1.4	—	7.0	21.0	2.9	0.97	0.21	0.51	0.23
26–72	8.0	24.6	96.0	42.0	152.0	7.14	0.6	—	96.0	203.0	2.9	0.82	0.24	0.46	0.20
72–150	7.3	23.5	60.0	52.0	120.0	7.95	1.0	—	60.2	180.0	1.75	1.04	0.1	0.2	0.41

Depth (cm)	Minerals identified in the clay fraction
o–8	Montmarillonite, randomly interstratified micas and montmorillonites, kaolinite, quarts,
0–8	associated mica and attapulgite.
8–26	Minerals above expect for possible separation of mica and attapulgite.
26–72	Minerals in the overlying two layers.
72–150	Minerals in the uppermost two layers.

agglomerations of sand particles cemented together with lime, gypsum, or iron oxides Occasionally, these cementations are sufficiently extensive as to lead (particularly) in Sarir series) to formation of isolated hard layers at various depths. Thus, while good drainage may be expected as a rule it might pose some problems in such places.

A third feature is the almost non-existence of organic matter in these soils. It is reasonable, therefore, to assume that the clay fraction is mostly responsible for the manifested exchange properties. Tables 1 and 2 show that the CEC values are low. Matching these values with the corresponding clay percentages, it is inferred that the clays in these soils are predominantly expanding 2:1 layer silicates (Evidently, a meager quantity of organic matter appears to be present in the top layer of Sarir profile).

Considering the low EC_e values in the furrow-slice layer (25 cm) the soils are classified as non-saline and it might be concluded that salinity problems are not likely to appear. While this could be completely true for Faregh series, care must be taken to exclude sensitive crops from Sarir series. Moreover, in view of the high content of salt in the subsoil of Sarir series the use of deep-rooted crops is not to be recommended therein. It is to be noted in this context that the salt distribution in Sarir series (Table 2) is not concordant with that commonly found in the soils of arid regions where the salts are usually accumulated at the surface and decrease gradually with depth. With due account for the other data obtained, the accumulation of salt in Sarir subsoil appears to be a lithological discontinuity. By definition, the soils may also be classified as sodic (as could be varified by calculating exchangeable sodium percentages). It is doubtful, however, that they will develop the well known characteristics of sodic soils by virtue of their low clay contents. The soils are also alkaline as indicated both by their pH values and by their contents of soluble carbonates and bicarbonates. This calls for due precautions as to quality of irrigation water to be employed.

Following are the interpretation of X-ray diffractograms (Figs. 1 and 2) leading to indentification of the minerals listed in Tables 1 and 2. Certain groups of minerals were identified in such a straight forward manner as the preclude conjecture, viz,

— Micaceous-type minerals from the peak at 10.04 A° and those in the range 4.92–4.95 A° (second-order diffractions).

— Montmorillonitic-type minerals from the peaks produced with Mg-saturated specimens both in the range 14–15 A° (air dried) and at 17.6 A° (solvated).

— Kaolinitic-type minerals from their characteristic peak range (7.0–7.15 A°) and its second-order analogue (3.53–3.54 A°), both disappearing upon heating to 600° C.

— Feldspars from the diffraction peaks displayed in the area of (3.12–3.2 A°). Judging from the two respective ranges (3.12–3.23 A°) and (3.21–3.28 A°) given by Jackson (8) for plagioclase feldspars and potassium feldspars, it might be reasonable to state that the feldspars in these soils are predominantly plagioclases.

Inferences with respect to the remaining groups are not without some degree of speculation:

1. Quartz was deduced from either 4.26 A° or 4.21 A° peak in conjection with diffractions in the range of 3.30–3.35 A° taking account of the reported values of 4.21 A° [Jackson, (18)] and 4.26 A°, 3.34 A° [Rich and Kunze (14)] for these fairly strong pairs. Consequently, the intense peak 4.27 A°, in Figure 2b was presumed to be due to quartz although reports to the contrary exist (Lee, (9) in which the symmetrical pattern of the peak at 4.27 A° was assigned to attapulgite.

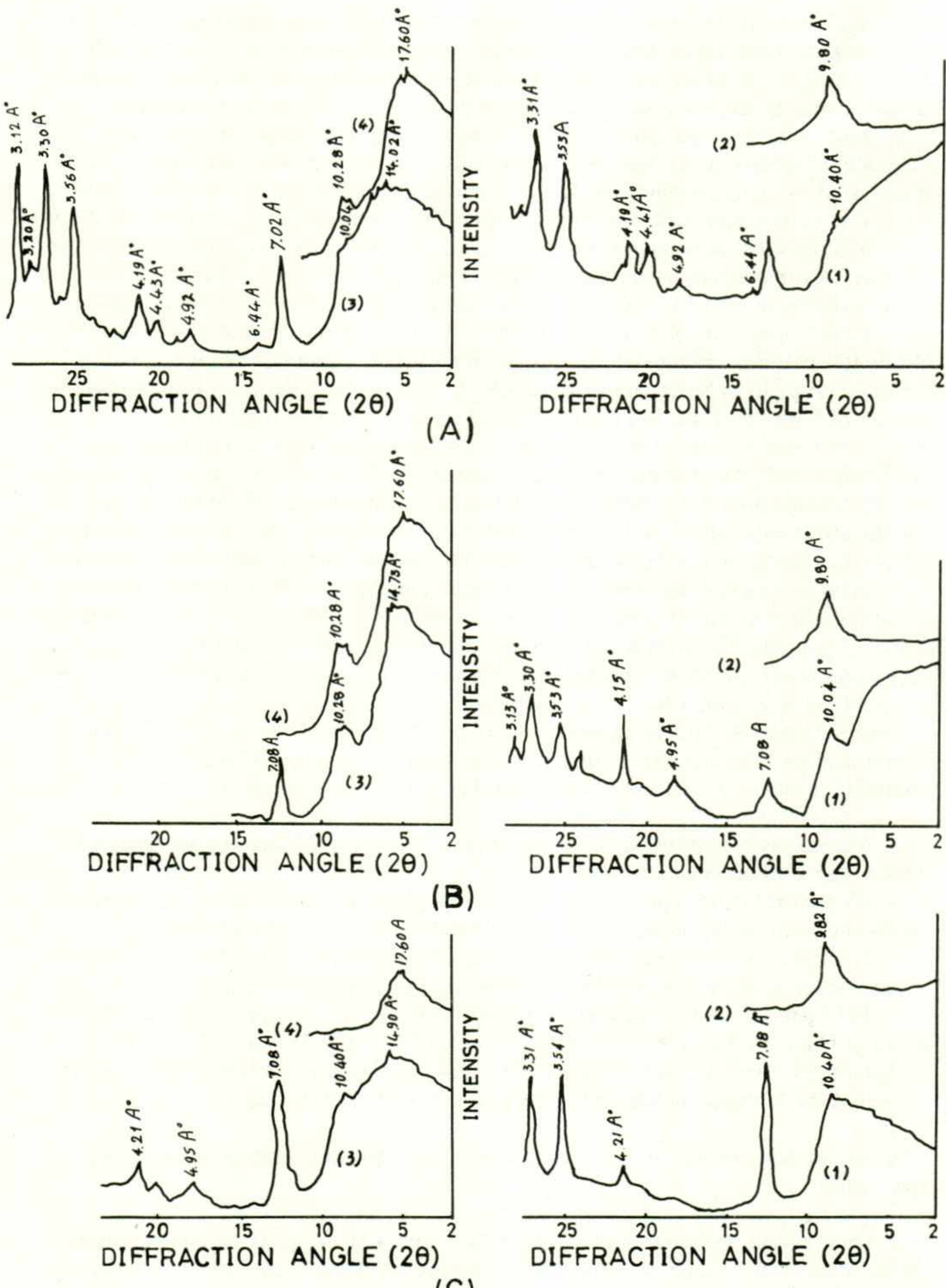

Fig. 1. X-ray diffractograms for the less than 2μ fraction of the three layers of Faregh Series.

A = from 5–25 cm layer
B = from 25–60 cm layer
C = from 60–150 cm layer

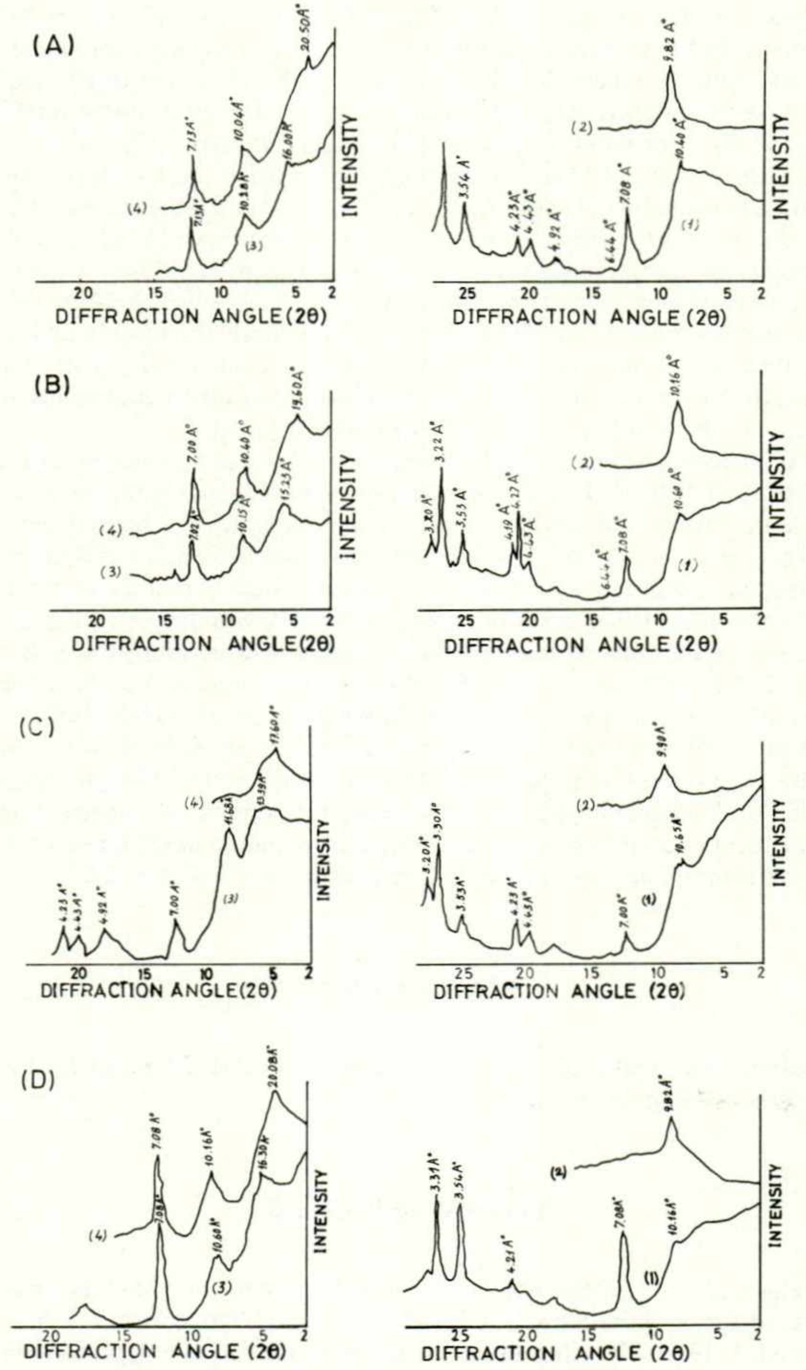

Fig. 2. X-ray diffractograms for the less than 2μ fraction of the four layers of Sarir Series.

A = from 0–8 cm depth
B = from 8–26 cm depth
C = from 26–72 cm depth
D = from 72–150 cm depth

2. Interstratification in general is deduced from low-angle diffractions. While this diffraction is diffuse in Faregh profile, a specific case of mixing is provided by Sarir profile. Referring to Figure 2A for example, both the 16 A° (air-dried) and 20.5 A° (solvated) peaks obtained with Mg-saturated samples are indicative of random interstratification involving montmorillonite [Schmehl and Jackson, (17)]. Upon potassium saturation a peak at 10.4 A° (with its associated higher order counterparts) was produced along with a low intensity spacing in the range of 12–13 A°. Whereas the latter peak is possibly due to montmorillonite [Barshad, (12), Jackson, (8); Nelson and Nettleton, (12)] a clue to the former peak is furnished by heating to 600° C. This treatment yielded a diffraction maximum at 9.82 A°, a characteristic of a relatively uniform dehydrated 2:1 layer silicates that are free of chlorite. The 10.4 A° peak, therefore, could well result from combination of illite, montmorillonite and vermiculite (contracted). It may then be concluded that interstratification here involves random mixtures of montmorillonite and mica, with the possibility of vermiculite being included.

3. Attapulgite is known to give diffraction of very strong intensity in the region 10.20–10.50 A°]Rich and Kunze, (14)]. The spacings obtained in this range might not be sufficiently strong and could well be due to interstratified materials. Besides, the controversial peak at 4.27 A° (Fig. 2C) has been alluded to earlier in connection with quartz. Inspite of these limitations there is reason to believe that the mineral exists in these soils. Considering a number of reports [Grim, (7); Brindley (4); Rich and Kunze, (14); Lee *et al.*, (10)] the weak band at 6.44 A° in addition to certain rather intense bands at 4.49, 4.43, 4.41, 4.19, 4.18, 4.15, and 3.20 A° could be indicative in this regard. Since these conditions are satisfied, to a greater or lesser extent, in the attached diffractograms the implication of attapulgite in the principal spacing at 10.40 A° is substantiated. Should this be the case, then the 10.28 A° spacing in Figure 2A might well be due to association of this mineral with mica. While these results merely suggest presence of attapulgite, confirmation is best obtained through revelation of the fibrous habits of its crystals. An electron microscopic study is in progress towards this end.

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خواص تربة السرير الصحراوية فى الجماهيرية العربية الليبية الشعبية الاشتراكية

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المستخلـــــص

فى هذا البحث تم دراسة وحدات التربة الرئيسية فى منطقة السرير ودرست خواصها المعدنية والكيميائية والمرفولوجية ۰ ولقد دلت النتائج بأن هذه التربة تكونت بواسطة عوامل الرياح والمياه وأن التربة هى قلوية غير ملحية ۰

ومعادن التربة فى حبيبات الطين هى معادن أولية مثل الكوارتز والفلدسبار وكذلك المعادن الاخرى مثل الميكا والاليات والمنتومر ليننايت والمعادن الخطيطية مثل معن الباليو كرسكايت ۰۰ ومما تجدر الاشارة به بأن هذه التربة خالية من المعادن التى تحتوى على العناصر النادرة اللازمة لنمو المحاصيل الزراعية ۰