World Journal of Environmental Pollution 2 (1): 01-09, 2012
ISSN 2222-1360

DOI: 10.5829/idosi.wjep.2012.2.1.1101

Mineralogical and Geochemical Characterization of Soils in East Rosetta, Egypt

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Abstract: Seventeen soil samples were collected from East Rosetta area. Based on particle size distribution, the studied samples are classified as sandy, loamy sand, sandy loam, clay loam and sandy clay loam. The studied samples were mineralogically and geochemically studied to identify their mineral compositions and chemical characteristics. In addition, uranium and thorium were determined to evaluate their radioactive behavior. Mineralogically, the heavy mineral fractions of the studied samples contain monazite, zircon, rutile, magnetite, ilmenite, garnet and green silicates (pyroxenes and amphiboles). Geochemically, based on CaO-Na_2O-K_2O and (Fe_2O_3 + MgO), Na_2O and K_2O ternary relationships, most of the studied samples are classified as greywacke with small contribution from arkose composition. Comparing the major oxides and trace elements distribution, the studied sandy and loamy sand samples exhibit high SiO_2 and low MgO compared with sandy loam samples which exhibit high K_2O and Na_2O but depleted in CaO. Sandy clay loam and clay loam samples exhibit high content of Al_2O_3 and Fe_2O_3 but depleted in K_2O and P_2O_5 compared to sandy facies.

Key words: East Rosetta %Minerals % Heavy metals % Fractions % Radioactivity

INTRODUCTION

The beach area of Rosetta includes most of the economic minerals reserves in the Egyptian black sands due to its relatively great extension and high grade especially on both sides of the Rosetta distributary mouth [1]. Rosetta black sands are considered as the most important economic mineral resources in Egypt that include ilmenite, magnetite, garnet, zircon, rutile and monazite. These deposits occur as beach sediments and coastal sand dunes.

Ammar *et al.* [2] divided Rosetta beach area into 5 zones. These five distinct zones were characterized by relatively high radioactivity. They stated that, the radioactivity and hence the concentration of the two radioactive minerals, zircon and monazite decreased in general as the distance from Rosetta estuary increased, either eastward or westward. Moustafa *et al.* [3] concerned with the different mineralogical features of the Egyptian beach mineral deposits. Huge sand deposits occur in front of the Nile Delta as submerged bars and shoals, considerd as possible source of economic minerals.

The aim of this work is to study the mineralogical and geochemical characterization in the soils of East Rosetta area, River Nile, Egypt. Additionally, this work includes evaluation of the radioactivity content of the studied soils.

MATERIALS AND METHODS

Soil Sampling: Seventeen surface soil samples (0-25 cm) were collected from East Rosetta Estuary, Egypt between longitudes 30° 22' - 30° 26' East and latitudes 31° 25' - 31° 28' North (Fig. 1).

Soil Analysis: The collected soil samples were air dried and sieved to pass through a 2mm sieve. Soil particles size distribution was performed according to the pipette method as descried by Dewis and Feritas [4]. Soil pH and electrical conductivity were determined in a soil to water suspension ratio of 1:2.5 [5]. Organic matter content (O.M) was determined according to Walkley and Black method and total carbonates were determined using Collins calcimeter and calculated as $CaCO_3$ [4]. Cation exchange capacity (CEC) was determined by Na-acetate at pH 7 [6].

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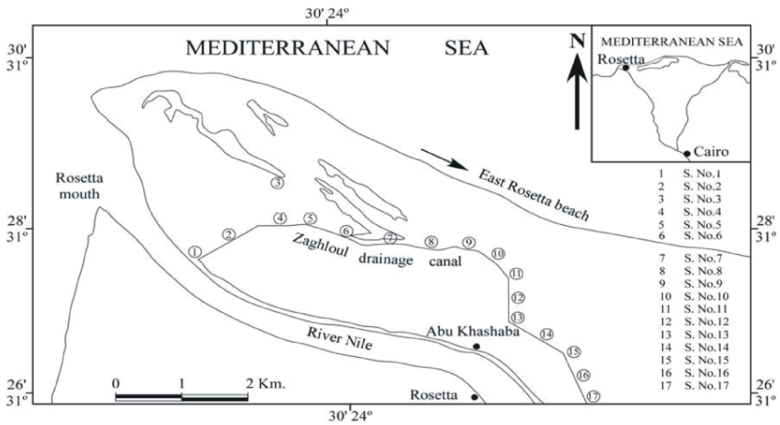

Fig. 1: The location of the studied soil samples

Mineralogical Analysis

Clay Mineral Identification: Bulk soil samples and oriented clay fractions were analyzed using X-ray diffraction technique using PHILIPS PW 3710/31 diffractmeter. The criteria used for clay mineral identification are those mentioned by Wilson [7].

Heavy Liquid Minerals Identification: Five selected soil samples were chosen for heavy liquid separation. Clay fraction was removed using sementation and decantation method. The cleaned samples were subjected to heavy liquid separation using bromoform (sp. gr. 2.88) which separate the light minerals, mainly of quartz and feldspars from the heavy ones.

Geochemical Analysis

Major Oxides and Trace Elements: The studied soil samples were chemically analyzed for their major oxides following the method of Shapiro and Bannock [8]. The trace elements were analyzed using XRF technique (PHILIPS X' Unique-II spectrometer). CaO-Na_2O-K_2O ternary diagram [9] was used for classification of the studied samples. In addition, another ternary relationship between (Fe_2O_3 + MgO), Na_2O and K_2O was used [10].

Uranium and Thorium Analysis: Uranium and thorium were determined using a multichannel analysis of γ- ray detector (gamma ray spectrometer technique).

RESULTS AND DISCUSSION

Physico-Chemical Characteristics of the Studied Soil Samples: Data presented in Table 1 indicate that the soil samples show relatively variation in its texture class: sandy, loamy sand, sandy loam, sandy clay loam and clay loam. pH values range between 7.53 to 8.86. The tested soil samples have slight salinity; the EC values were between 0.45 to 2.6 dS/m. The $CaCO_3$ contents ranged between 0.72 to 3.31 %. CEC values ranged between 1.76 and 5.84 Cmolkg^{-1} for coarse texture studied soils and between 7.56 and 19.34 Cmolkg^{-1} for medium textured ones.

Mineralogical Investigations

Bulk Samples Analyses: Analysis of the bulk soil samples led to identify the essential minerals in the studied samples. X-ray diffraction data of some selected soil samples from the studied area are listed in Table 2 and presented in Fig. 2. The obtained data indicate that quartz and albite minerals are present in all the studied soil samples. Feldspar are present in samples No. 1, 2, 5, 6 and 7 and amphibole in samples No.6, 7, 11, 12 and 16. Calcite is present in sample No. 17, halite in sample No. 2 and mica in sample No. 7.

It was realized that the presence of quartz mineral in all the studied samples reflect the sandy facies. The presence of calcite in sample No. 17 reflect the calcerous nature of this facies while the presence of halite in sample No. 2 indicate the saliferous behaviour of this facies. It is interesting to note that some clay minerals (kaolinite and montmorillonite) were also detected in the bulk samples (Table 2 and Fig. 2).

Clay Fractions Analyses: X-ray Diffraction analysis of the clay fractions (<2μ) for representative soil samples is shown in Table 3 and presented in Fig. 3. The data indicate that the clay fraction of the studied sandy clay loam and clay loam soils (S. No. 1 and 17) contains montmorillonite, kaolinite and illite whereas the clay fraction of sandy loam and sandy soils (S. No. 3 and 7) contains only montmorillonite and kaolinite.

Table 1: General characteristics of the studied samples

S.N	Particle Size Distribution ---------- Sand %	Silt %	Clay %	Texture Class	EC (ds/m)	PH (1:2.5)	$CaCO_3$ -----------%	O.M ---------	CEC Cmolkg^{-1}
1	46.90	25.11	27.99	Sandy clay loam	1.26	8.07	0.83	0.89	12.70
2	62.55	17.52	19.93	Sandy loam	2.10	7.53	1.14	0.80	7.56
3	75.15	12.40	12.45	Sandy loam	1.60	8.21	2.38	0.30	6.83
4	89.10	5.30	5.60	Loamy sand	2.60	7.94	1.45	0.54	4.69
5	85.85	7.20	6.95	Loamy sand	0.88	8.41	1.34	0.39	3.58
6	91.85	4.56	3.59	Sand	0.67	7.40	1.86	0.61	3.88
7	87.95	6.54	5.51	Sand	1.68	8.86	3.00	0.55	3.86
8	87.40	7.10	5.50	Sand	1.50	8.72	2.38	0.50	3.00
9	90.80	5.21	3.99	Sand	0.45	8.40	1.03	0.72	3.44
10	91.40	4.51	4.09	Sand	1.03	7.72	0.72	0.59	3.23
11	85.00	6.80	8.20	Loamy sand	0.70	8.28	0.72	0.57	5.24
12	81.50	8.90	9.60	Loamy sand	0.85	8.01	2.28	0.52	5.84
13	66.10	16.40	17.50	Sandy loam	1.35	7.96	2.07	0.67	7.09
14	82.70	8.74	8.56	Loamy sand	0.85	8.52	1.76	0.44	5.16
15	82.45	8.51	9.04	Loamy sand	1.43	7.85	3.31	0.03	4.58
16	94.55	3.21	2.24	Sand	0.53	7.91	0.31	0.32	1.76
17	31.05	34.60	34.35	clay loam	0.70	8.05	3.00	1.09	19.34

Table 2: Minerals detected in the studied bulk soil samples

S.N	Quartz	Albite	Feldspar	Amphibole	Calcite	Halite	Mica	Mont.	Kaol.
1	*		*					*	*
2	*		*			*		*	
3	*								
4	*	*							
5	*	*	*	*					
6	*	*	*	*					
7	*	*	*	*			*		
8	*	*						*	
9	*	*						*	
10	*	*							
11	*			*					
12	*			*				*	
13	*	*							
14	*	*						*	
15	*	*						*	
16	*	*		*					
17	*	*			*			*	

Table 3: Clay minerals composition of the clay fraction (<2μ)

S.N	Texture	Mont.	Kaol.	Illite
1	S.C.L.	*	*	*
3	S. L.	*	*	
7	S.	*	*	
17	C.L	*	*	*

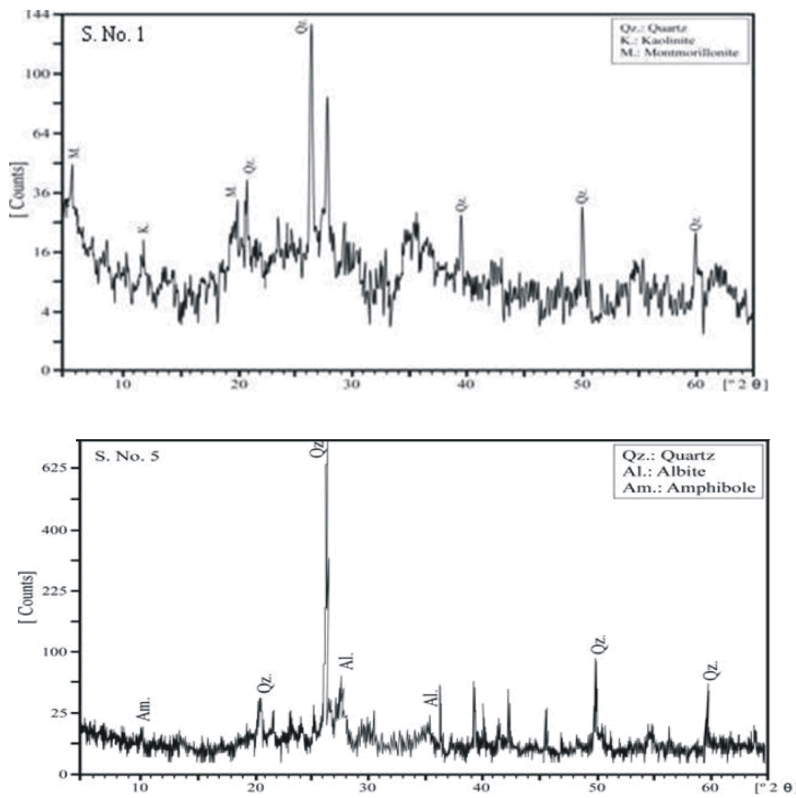

Fig. 2: X-ray diffraction patterns of selected bulk soil samples

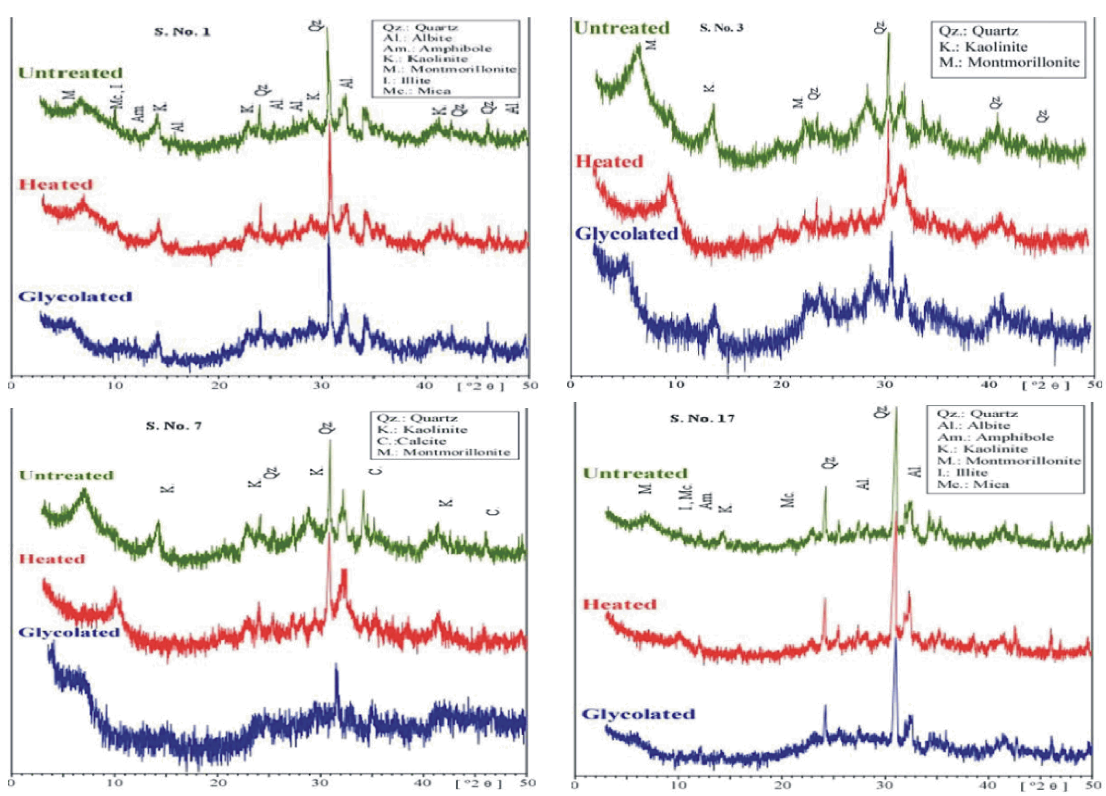

Fig. 3: X-Ray diffraction patterns of some studied clay fractions (>2µ)

Table 4: Percentages of some heavy minerals in selected soil samples

S. No.	Total	Amphiboles	Pyroxenes	Ilmenite	Magnetite	Garnet	Zircon	Rutile	Monazite
1	12	5	3	2.1	1.1	0.2	0.3	0.2	0.1
3	9.05	4	2	1.9	0.8	0.1	0.1	0.1	0.05
7	7.45	3.5	1.4	1.7	0.7	0.09	0.05	-	0.05
17	0.78	0.4	0.1	0.13	0.1	0.05	-	-	-

-not present

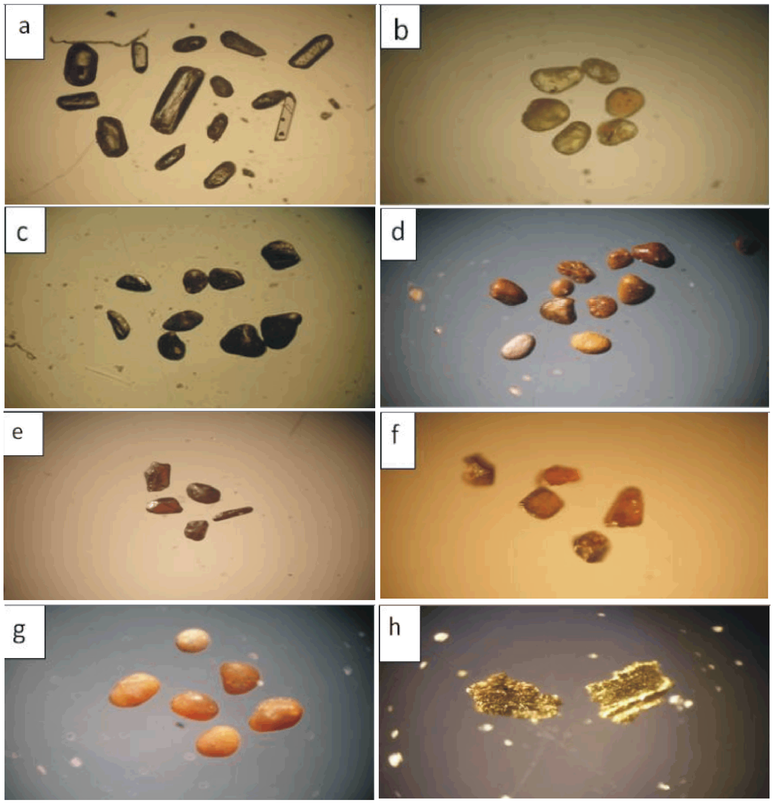

Fig. 4: Plates showing (a: Zircon- b: Monazite- c: Ilminite- d: Leucoxene- e: Rutile-f: Sphene- g: Garnet- h: Gold), X 20

Heavy Liquid Minerals Identification: The heavy bromoform fraction in selected studied soil samples ranged from 0.78 % to 12 % with an average 7.32 %. The minerals encountured in descending order of abundance are amphiboles, pyroxenes, ilmenite, magnetite, garnet, zircon, rutile, monazite, sphene and gold (Table 4). The distribution of the haevy minerals show that amphiboles range from 0.4 % to 5 % with an average 3.23 %, pyroxenes ranges from 0.1 % to 3 %, ilmenite ranges from 0.13 % to 2.1 %, magnetite ranges from 0.1 % to 1.1 %, garnet ranges from 0.05 % to 0.2%, zircon ranges from 0.05 % to 0.3 %, rutile ranges from 0.1% to 0.2 %, monazite ranges from 0.05 % to 0.1%. Sphene and gold found in low proportion. Generally, our results are in good agreement with findings of Dewedar [11] and El Hadary [12].

In the Following, a Breif Description for Each Mineral.

Zircon [Zr (SIO_4)]: It occurs as euhedral to subhedral pale yellow crystals mostly prismatic of good adamantine luster. Some of the prismatic zircon grains are characterized by bipyramidal terminations (Fig. 4a). The oval, needle, spherical and broken crystals are also observed.

Monazite [(Ce, La, Nd, Th) PO_4]: Monazite present as euhederal and someimes subhederal, yellow to reddish brown colours, rounded to subrounded crystals (egg-shaped) with resinous luster (Fig. 4b).

Ilminite ($FeTiO_3$): It presents as angular to subrounded in shape exhibiting smooth or pitted surface with metallic luster (Fig. 4c). Some few grains exhibit rhombohedral forms and iron-black to brownish black colours (Fig. 4.d). Leucoxenation appears on the ilmenite grain surfaces and show different colours as well as their changes in

Table 5: Chemical analysis of the studied soil samples

S.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Major oxides (%)																	
SiO_2	49.28	46.94	68.97	72.88	67.19	70.19	68.69	69.76	76.80	77.39	72.50	68.50	68.50	73.24	71.06	77.04	56.00
Al_2O_3	14.98	16.68	8.78	6.38	13.99	9.48	6.99	8.37	6.50	8.57	7.01	9.21	10.14	10.30	10.05	7.04	15.24
Fe_2O_3	8.02	8.31	6.07	6.87	5.91	5.88	4.87	6.07	5.99	5.96	7.21	8.79	6.87	5.43	7.56	6.79	9.00
CaO	4.28	4.29	4.38	4.49	5.00	3.68	9.53	5.33	4.07	0.97	4.00	6.15	3.00	4.01	4.00	3.64	5.53
MgO	5.44	2.28	1.28	2.46	1.01	3.33	0.18	1.92	0.30	1.61	3.41	0.91	2.52	1.11	1.41	1.92	2.02
Na_2O	1.48	2.99	1.28	1.48	1.40	1.54	1.66	1.34	1.50	1.40	1.47	1.49	1.23	1.50	1.26	1.11	1.40
K_2O	1.18	2.34	1.08	1.28	1.20	1.36	1.43	1.15	1.29	1.20	1.26	1.28	1.05	1.28	1.10	0.95	1.20
P_2O_5	0.48	0.29	0.19	0.37	0.28	0.26	0.14	0.27	0.22	0.20	0.22	0.25	0.29	0.25	0.20	0.19	0.18
Others	15.2	16	7.9	3.7	4.1	4.2	6.6	5.7	3.4	2.6	2.9	3.3	6.4	2.9	3.2	1.5	9.5
Trace elements (ppm)																	
Zr	481	346	500	684	439	718	471	662	811	390	448	280	401	400	340	296	431
Ba	673	359	252	574	607	478	514	564	557	300	585	204	546	207	235	622	697
Sr	295	260	324	415	347	299	332	304	379	287	270	342	279	290	320	439	339
V	371	112	202	206	193	214	192	194	249	160	250	200	225	198	140	137	322
Cr	114	94	92	117	109	117	103	114	125	94	99	102	88	84	93	71	98
Rb	77	75	59	56	60	75	75	65	70	70	63	61	59	55	61	70	69
Y	30	30	30	30	39	29	25	25	30	26	30	20	30	28	26	26	30
Nb	29	29	26	25	21	17	17	24	23	20	28	26	24	25	20	28	29
Ga	28	28	25	15	22	17	12	19	17	29	24	24	28	20	20	15	28
Radioactives elements (ppm)																	
eU	5	4	4	5	5	3	2	2	3	2	3	4	2	3	4	3	3
eTh	6	6	4	5	4	3	2	6	4	5	6	5	4	4	3	6	5

magnetic susceptibities. Leucoxene grains indicate advanced degree of ilmenite alterations.

Rutile: It occurs as subhedral to anhedral prismatic, tabular and elongated crystals of yellowish red, brown to black colours with adamantine luster (Fig. 4e). Frequently, fragmental and irrigular crystals are present. They are commonly subangular to rounded with adamantine luster and roughly pitted surfaces.

Sphene (Ca Ti [SiO_4] (O,OH,F)): Sphene exhibits prismatic, tabular and platy crystals. The colour of sphene ranges from yellowish brown to brown colours. it is translucent mineral crystals with resinous luster (Fig. 4f). Garnet ($Mg_3Al_2Si_3O_{12}$): Garnet crystals are observed as angular to subrounded of rosy-pink and Reddish- pink subordinate associated by some brownish yellow and colourless (Fig. 4g). Some grains are cloudy due to staining or inclusions. Some grain sufaces show little pitting, grooves and cavities.

Gold (Au): Most of gold mineral crystals in the studied samples of East Rosetta area are golden yellow colour, flattened and ductile grains with aplate-like shape and abrilliant metallic lustr (Fig. 4h). Some irrrgular grains also noticed.

Geochemical Characterization: The analyzed major oxides, trace elements and uranium and thorium are shown in Table 5. The presence of the SiO_2 and Al_2O_3 oxides in all the studied samples reflect the presence of quartz and/or kaolinite. The presence of kaolinite clay mineral is confirmed by the high K_2O contents in some samples (2, 6 and 7). The high CaO contents in samples (7, 12 and 17) confirm the presence of calcite, while the high contents of Na_2O may indicate the presence of NaCl and/or feldspars. The high Fe_2O_3 in some samples (1, 2, 12 and 17) indicate the presence of hematite. The P_2O_5 contents in some samples (1 and 4) may indicate the presence of the apatite minerals.

Concerning the data of trace elements, the concentration of Nb, Y and Zr may be controlled by the presence of quartz content (sample No.1). The high Sr content (samples No.4 and 16) may mainly be controlled by the high CaO contents (calcite). Vanadium concentrations reached up to 371 and 322 ppm in some samples (No. 1 and 17) when comparing with international value of sandstone. The high V contents in these samples may indicate their loamy facies which mainly controlled by the presence of clay components.

From the data presented in Fig. 5 for major oxides and Fig. 6 for trace elements, it could be concluded the following results:

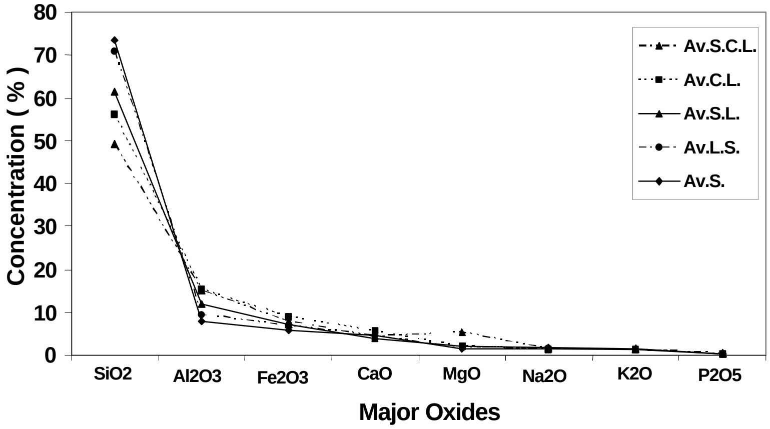

Fig. 5: Major oxides distribution in the studied soil samples

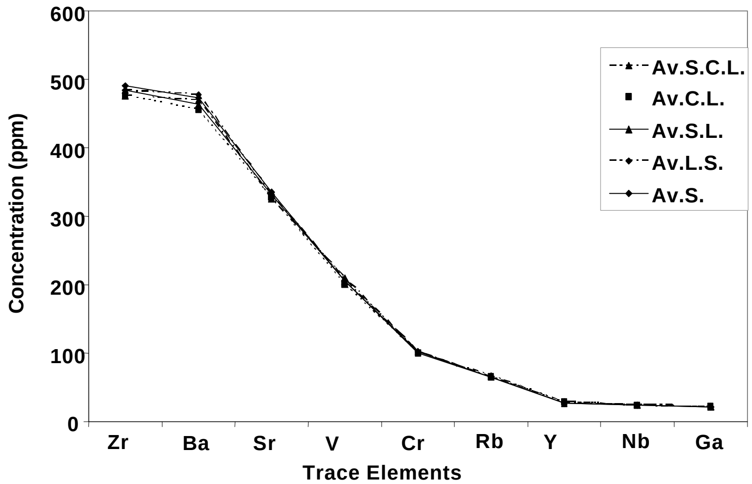

Fig. 6: Trace elements distribution in the studied soil samples

- Sandy soil samples (No. 6, 7, 8, 9, 10 and 16) exhibit enrichment in SiO_2, Sr, Zr and Ba elements while they are depleted in Al_2O_3, MgO and Fe_2O_3 oxides and Nb and Ga compared to sandy clay loam samples.
- Loamy sand samples (No.4,5,11,12,14 and 15) exhibit enrichment in SiO_2, P_2O_5 and CaO oxide and Ba, V and Zr elements while they are depleted in MgO oxide and Ga and Nb elements compared to clay loam and sandy loam facies.
- Sandy loam samples (No.2, 3 and 13) exhibit enrichment in Na_2O and K_2O oxides and Ba, V and Zr elements while they are depleted in CaO oxides and Ga, Nb and Cr elements compared to sandy clay loam samples.
- Sandy clay loam samples (S.No. 1) exhibit enrichment in Al_2O_3, Fe_2O_3, MgO and P_2O_5 oxides and Cr, Zr, Ba, V and Sr elements and they are depleted in K_2O oxides and Ga, Nb and Y elements compared to sandy samples.
- Clay loam samples (S.No. 17) exhibit enrichment in Fe_2O_3, Al_2O_3 and CaO oxides and Zr, Ba and Sr elements but they are depleted in P_2O_5 oxides and Ga and Nb elements compared to sandy facies.

Uranium and thorium occur naturally in low concentrations in the studied soil samples. The data presented in Table 5 show that U concentrations in the studied soil samples range between 2 and 5 ppm with an average of 3.4 ppm. Th contents range between 2 and 6 ppm with an average of 4.6 ppm.

Geochemical Classification of the Studied Samples: Using CaO-Na_2O-K_2O ternary diagram for classification of the studied soil samples, (Fig. 7a) indicate that most of the sandy samples (No. 6, 7, 9 and 16), loamy sand samples (No. 4, 11 and 14) and sandy clay loam sample (No. 1) are plotted in the greywacke field while loamy samples (No. 5 and 12) and clay loam sample (No. 17) are plotted in

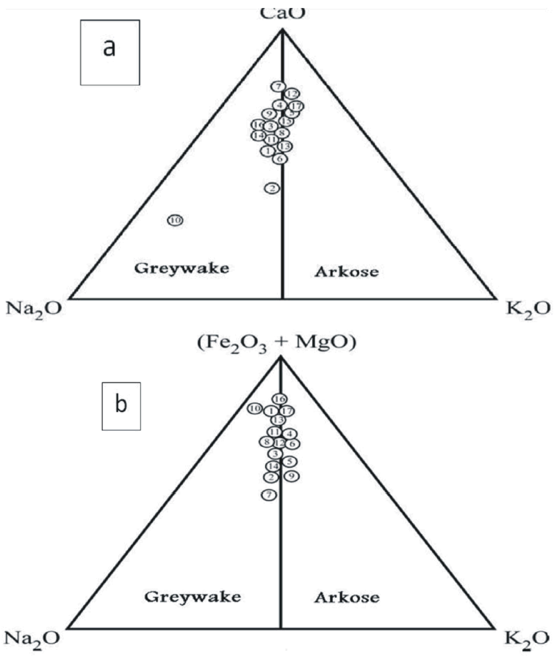

Fig. 7: Ternary classification diagram (a: after Pittijohn *et al.* 1972) and (b: after Blatt *et al.* 1980)

Arkose field. The other soil samples are plotted in the middle between greywacke field and Arkose field. It is realized that most of the studied samples are plotted near CaO apex indicating their enrichment by CaO. In addition, using the ternary relationship between (Fe_2O_3 + MgO), Na_2O and K_2O for classification of the studied soil samples (Fig. 7 b) indicate that most of the sandy soil samples (No. 7, 8 and 10) and sandy clay loam sample (No. 1) are plotted in the greywacke field and clay loam sample (No. 17) are plotted in Arkose field while loamy sand facies (No. 4, 5, 11 and 14) distributed equally between greywacke and Arkose field. It is clear that most of the studied soil samples are plotted near (Fe_2O_3 + MgO) apex indicating their enrichment by Fe_2O_3 and MgO.

CONCLUSION

Lithologically, the studied samples can be classified into sand, loamy sand, sandy loam, clay loam and sandy clay loam based on particles size distribution of soils. Mineralogically, the studied samples indicate the presence of quartz in all samples as well as calcite, gypsum and hematite. XRD for the separated clay minerals indicate that the types of the clays are kaolinite, illite and montmorillonite. Geochemically, the analysis of the major oxides confirm the mineralogical constituents of the studied samples. The trace elements: Nb was controlled by quartz content whereas Zn and Co were controlled by the presence of iron. Also, the high Cr, Zn, Cu, Y, V, Ga, Co, Zr, Nb and Rb contents were mainly controlled by the presence of clay components.

The CaO-Na_2O-K_2O ternary diagram and ternary relationship between (Fe_2O_3 + MgO), Na_2O and K_2O indicate that most of the sandy samples are classified as greywacke field while loamy sand facies are classified as Arkose field.

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