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## MINERALOGICAL AND GEOCHEMICAL CHARACTERIZATION OF SOILS IN EAST ROSETTA, EGYPT

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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 behaviour.

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<sub>2</sub>O-K<sub>2</sub>O and (Fe<sub>2</sub>O<sub>3</sub> + MgO), Na<sub>2</sub>O and K<sub>2</sub>O 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<sub>2</sub> and low MgO compared with sandy loam samples which exhibit high K<sub>2</sub>O and Na<sub>2</sub>O but depleted in CaO. Sandy clay loam and clay loam samples exhibit high content of Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> but depleted in K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> compared to sandy facies.

### 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 (Dabbour, 1995). 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. (1983) 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. (2000) 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, considered 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

#### A. 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 (Figure 1).

#### B. Soil analysis

The collected soil samples were air dried and sieved to pass through a 2 mm sieve. Soil particles size distribution was performed according to the pipette method as described by Dewis and Feritas (1970). Soil pH and electrical conductivity were determined in a soil to water suspension ratio of 1:2.5 (Cottenie *et al.*, 1982). 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<sub>3</sub> (Dewis and Feritas, 1970). Cation exchange capacity (CEC) was determined by Na-acetate at pH 7 (Jackson, 1967).

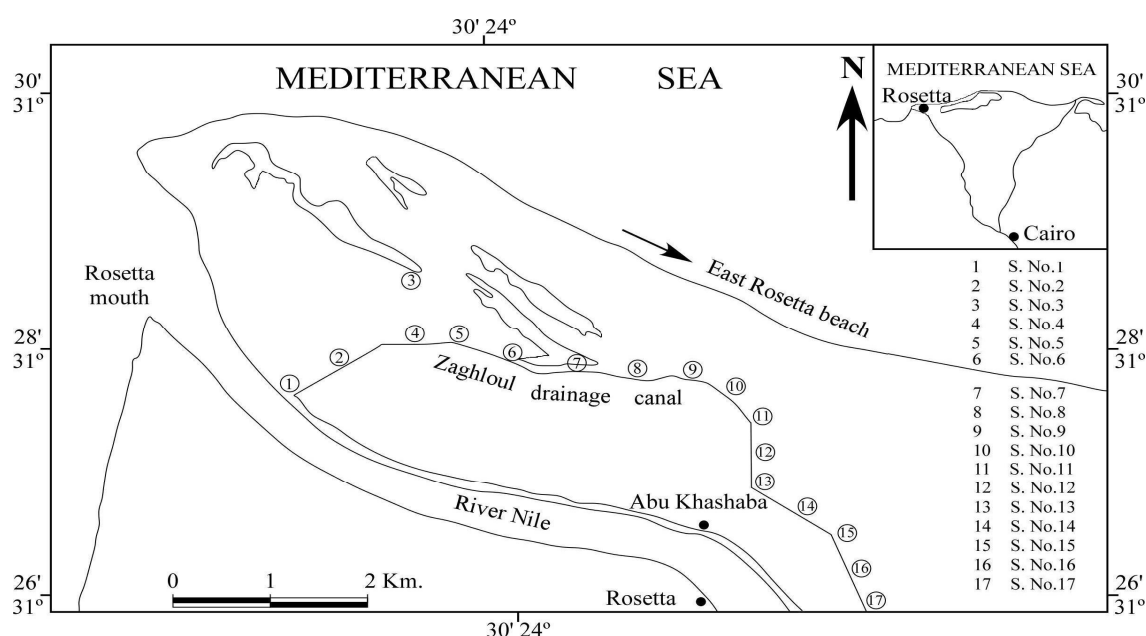


Fig. 1. The location of the studied soil samples

## C. Mineralogical analysis

### 1. Clay mineral identification

Bulk soil samples and oriented clay fractions were analyzed using X-ray diffraction technique using PHILIPS PW 3710/31 diffractometer. The criteria used for clay mineral identification are those mentioned by Wilson (1987).

### 2. Heavy liquid minerals identification

Five selected soil samples were chosen for heavy liquid separation. Clay fraction was removed using sedimentation 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.

## D. Geochemical analysis

### 1. Major oxides and trace elements

The studied soil samples were chemically analyzed for their major oxides following the method of Shapiro and Bannock (1962). The trace elements were analyzed using XRF technique (PHILIPS X' Unique-II spectrometer). CaO-Na<sub>2</sub>O-K<sub>2</sub>O ternary diagram (Pittijohn *et al.*, 1972) was used for classification of the studied samples. In addition, another ternary relationship between (Fe<sub>2</sub>O<sub>3</sub> + MgO), Na<sub>2</sub>O and K<sub>2</sub>O was

used (Blatt *et al.*, 1980).

### 2. Uranium and thorium analysis

Uranium and thorium were determined using a multichannel analysis of  $\gamma$ - ray detector (gamma ray spectrometer technique).

## RESULTS AND DISCUSSION

### 1. 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<sub>3</sub> contents ranged between 0.72 to 3.31 %. CEC values ranged between 1.76 and 5.84 Cmol<sup>-1</sup> for coarse texture studied soils and between 7.56 and 19.34 Cmol<sup>-1</sup> for medium textured ones.

### 2. Mineralogical investigations

#### a. 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. Feldspars 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 reflects the sandy facies. The presence of calcite in sample No. 17 reflects the calcareous nature of this facies while the presence of halite in sample No. 2 indicates 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).

**Table 1**

General characteristics of the studied samples

| S.N | Particle Size Distribution |           |           |                 | EC<br>(ds/m) | PH<br>(1:2.5) | CaCO <sub>3</sub> | O.M  | CEC<br>Cmolk <sup>-1</sup> |
|-----|----------------------------|-----------|-----------|-----------------|--------------|---------------|-------------------|------|----------------------------|
|     | Sand<br>%                  | Silt<br>% | Clay<br>% | Texture Class   |              |               | %                 |      |                            |
| 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  | *      | *      |          |           | *       |        |      | *     |       |

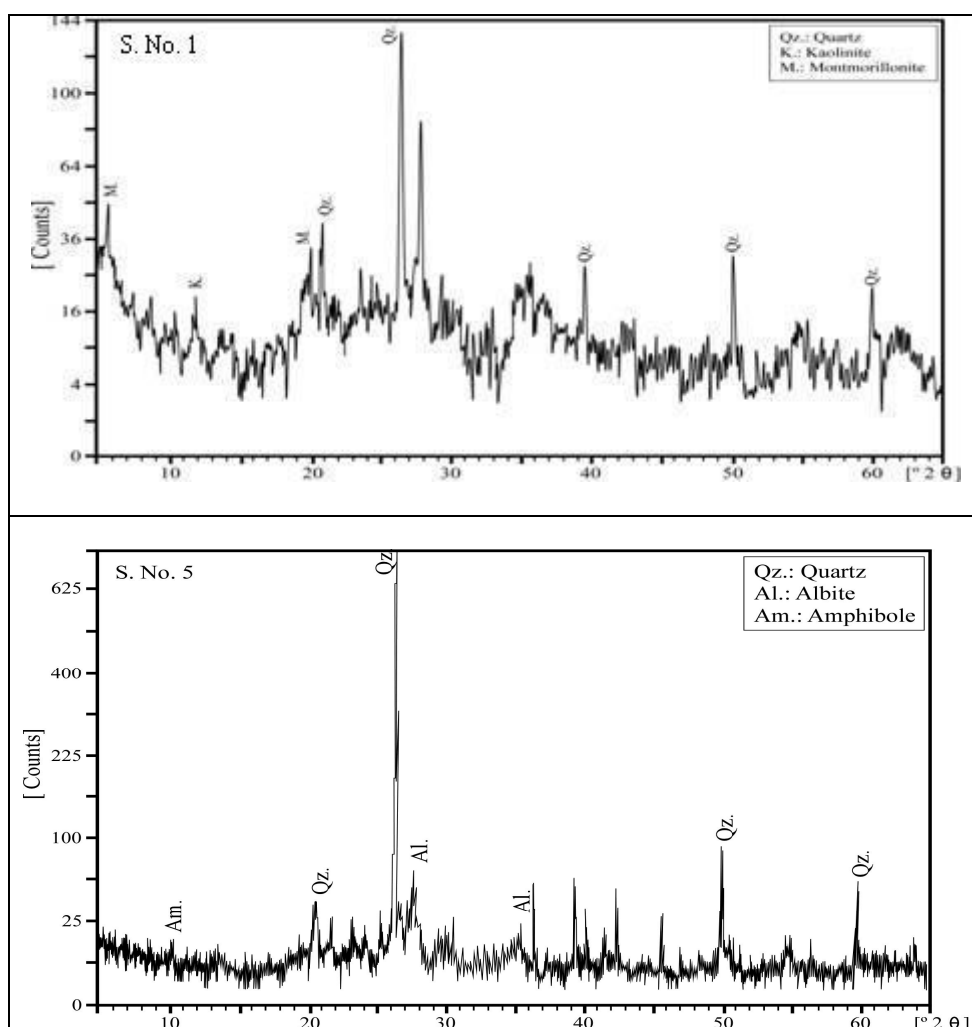


Fig. 2. X-ray diffraction patterns of selected bulk soil samples

### b. Clay fractions analyses

X-ray Diffraction analysis of the clay fractions ( $<2\mu$ ) for representative soil samples is shown in Table (3) and presented in Fig. (3). The data indicate that the studied sandy loam and

sandy facies (S. No. 3 and 7) contain montmorillonite, kaolinite and illite whereas the sandy clay loam facies (S. No. 1) contain kaolinite and montmorillonite, while clay loam facies (S. No. 17) contain kaolinite.

Table 3

Clay minerals composition of the clay fraction ( $<2\mu$ )

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

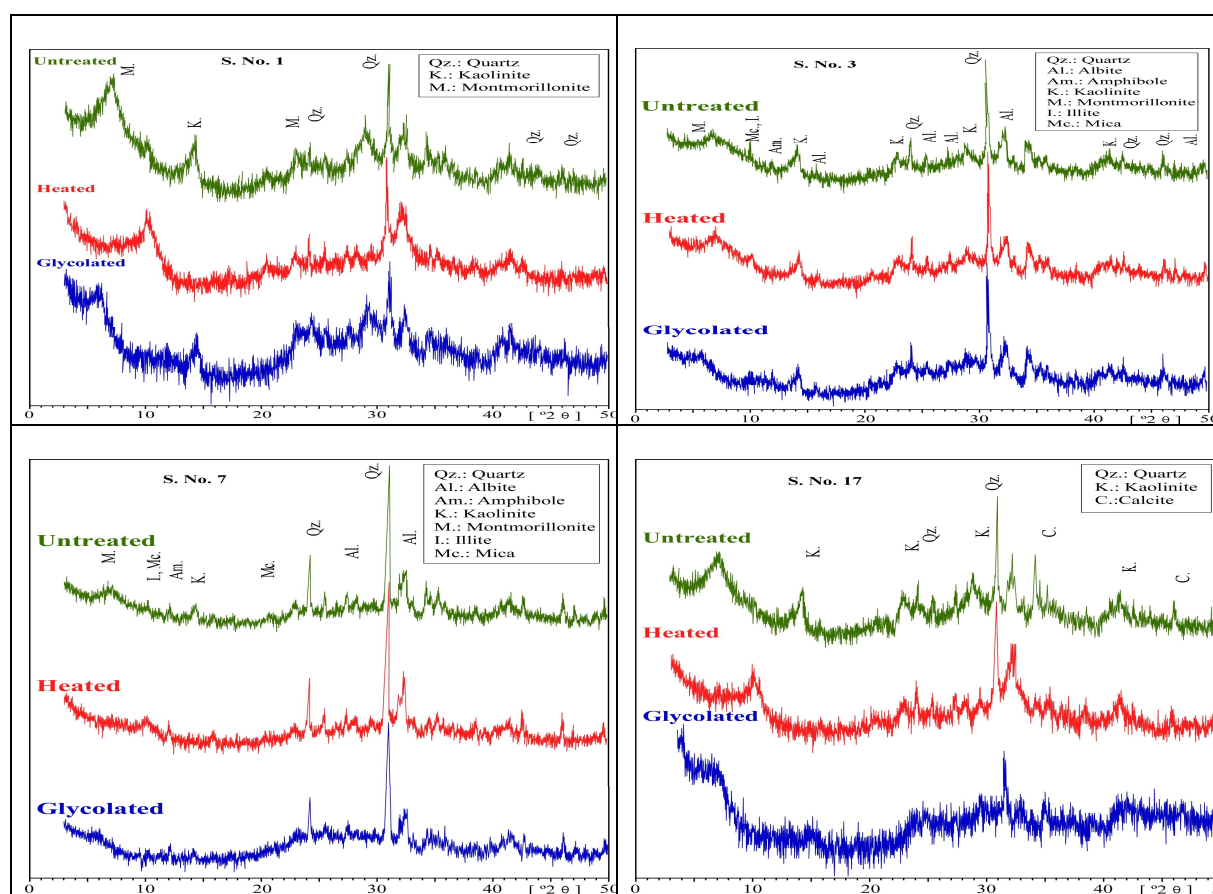


Fig. 3. X-Ray diffraction patterns of some studied clay fractions ( $< 2\mu$ )

### c. 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 encountered in descending order of abundance are amphiboles, pyroxenes, ilmenite, magnetite, garnet, zircon, rutile, monazite, sphene and gold (Table 4). The distribution of the heavy minerals shows that amphiboles range from 0.4 % to 5 % with an

average 3.23 %, pyroxenes range 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 (1998) and El Hadary (1988).

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

In the following, a brief description for each mineral.

**Zircon [ $\text{Zr} (\text{SiO}_4)$ ]:** It occurs as euhedral to subhedral pale yellow crystals mostly prismatic 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)  $\text{PO}_4$ ]:** Monazite presents as euhedral and sometimes subhedral, yellow to reddish brown colours, rounded to subrounded crystals (egg-shaped) with resinous luster (Fig. 4b).

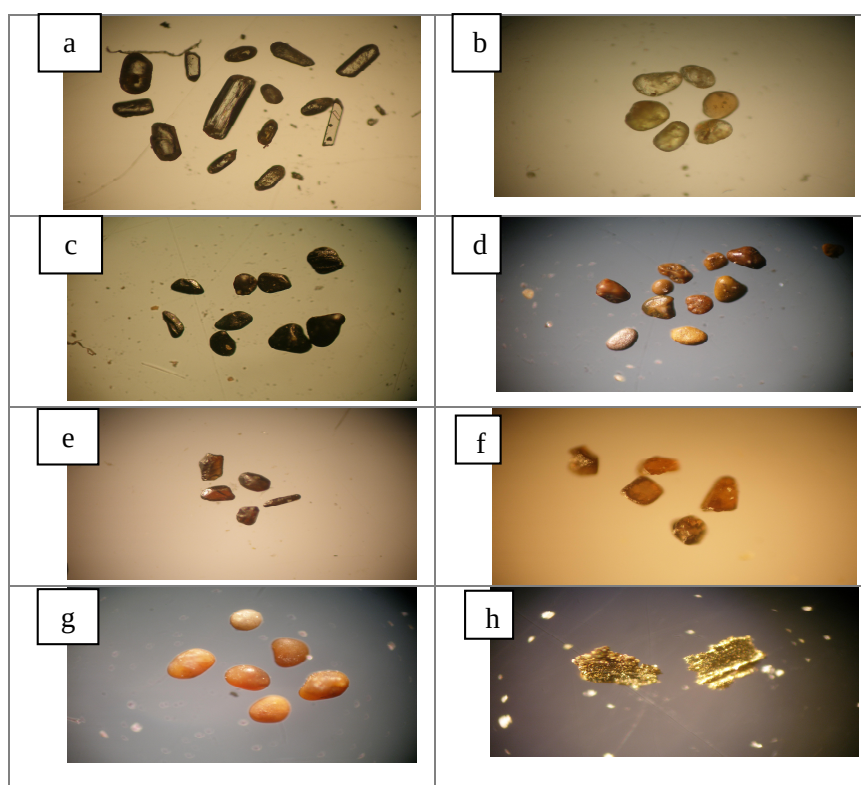
**Ilmenite ( $\text{FeTiO}_3$ ):** It presents as angular to subrounded in shape exhibiting smooth or pitted surface with metallic luster (Fig. 4c). Some few grains exhibit rhombohedral forms and iron-black to brownish black colours (Fig. 4d). Leucoxenation appears on the ilmenite grain surfaces and shows different colours as well as their changes in magnetic susceptibilities. 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 irregular crystals are present. They are commonly subangular to rounded with adamantine luster and roughly pitted surfaces.

**Sphene ( $\text{Ca Ti} [\text{SiO}_4] (\text{O}, \text{OH}, \text{F})$ ):** 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. 4.f).

**Garnet ( $\text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ ):** Garnet crystals are observed as angular to subrounded of rosy-pink and Reddish-pink subordinate associated by some brownish yellow and colourless (Fig. 4.g). Some grains are cloudy due to staining or inclusions. Some grain surfaces 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 a plate-like shape and a brilliant metallic luster (Fig. 4h). Some irregular grains also noticed.



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

### 3. Geochemical characterization

The analyzed major oxides, trace elements and uranium and thorium are shown in Table 5. The presence of the  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  oxides in all the studied samples reflects the presence of quartz and/or kaolinite. The presence of kaolinite clay mineral is confirmed by the high  $\text{K}_2\text{O}$  contents in some samples (2, 6 and 7). The high  $\text{CaO}$  contents in samples (7, 12 and 17) confirm the presence of calcite, while the high contents of  $\text{Na}_2\text{O}$  may indicate the presence of  $\text{NaCl}$  and/or feldspars. The high  $\text{Fe}_2\text{O}_3$  in some samples (1, 2, 12 and 17) indicates the presence of hematite. The  $\text{P}_2\text{O}_5$  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  $\text{CaO}$  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 are 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:

1. Sandy soil samples (No. 6, 7, 8, 9, 10 and 16) exhibit enrichment in  $\text{SiO}_2$ , Sr, Zr and Ba elements while they are depleted in  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$  and  $\text{Fe}_2\text{O}_3$  oxides and Nb and Ga compared to sandy clay loam samples.
2. Loamy sand samples (No.4,5,11,12,14 and 15) exhibit enrichment in  $\text{SiO}_2$ ,  $\text{P}_2\text{O}_5$  and  $\text{CaO}$  oxide and Ba, V and Zr elements while they are depleted in  $\text{MgO}$  oxide and Ga and Nb elements compared to clay loam and sandy loam facies.
3. Sandy loam samples (No.2, 3 and 13) exhibit enrichment in  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  oxides and Ba, V and Zr elements while they are depleted in  $\text{CaO}$  oxides and Ga, Nb and Cr elements compared to sandy clay loam samples.
4. Sandy clay loam samples (S.No. 1) exhibit enrichment in  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MgO}$  and  $\text{P}_2\text{O}_5$  oxides and Cr, Zr, Ba, V and Sr elements and they are depleted in  $\text{K}_2\text{O}$  oxides and Ga, Nb and Y elements compared to sandy samples.
5. Clay loam samples (S.No. 17) exhibit enrichment

in  $\text{Fe}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$  and  $\text{CaO}$  oxides and Zr, Ba and Sr elements but they are depleted in  $\text{P}_2\text{O}_5$  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 (2-5) ppm with an average of 3.4 ppm. Th contents range between (2-6) ppm with an average of 4.6 ppm.

### Geochemical classification of the studied samples

Using  $\text{CaO}$ - $\text{Na}_2\text{O}$ - $\text{K}_2\text{O}$  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 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  $\text{CaO}$  apex indicating their enrichment by  $\text{CaO}$ . In addition, using the ternary relationship between  $(\text{Fe}_2\text{O}_3 + \text{MgO})$ ,  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  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  $(\text{Fe}_2\text{O}_3 + \text{MgO})$  apex indicating their enrichment by  $\text{Fe}_2\text{O}_3$  and  $\text{MgO}$ .

### 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

**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 (%)                   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| <b>SiO<sub>2</sub></b>             | 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 |
| <b>Al<sub>2</sub>O<sub>3</sub></b> | 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 |
| <b>Fe<sub>2</sub>O<sub>3</sub></b> | 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  |
| <b>CaO</b>                         | 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  |
| <b>MgO</b>                         | 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  |
| <b>Na<sub>2</sub>O</b>             | 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  |
| <b>K<sub>2</sub>O</b>              | 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  |
| <b>P<sub>2</sub>O<sub>5</sub></b>  | 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  |
| Trace elements (ppm)               |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| <b>Cr</b>                          | 114   | 4     | 2     | 117   | 109   | 117   | 103   | 114   | 125   | 4     | 99    | 2     | 88    | 4     | 3     | 71    | 98    |
| <b>V</b>                           | 371   | u.d   | u.d   | 206   | 193   | 214   | 192   | 194   | 249   | u.d   | 250   | u.d   | 225   | u.d   | u.d   | 137   | 322   |
| <b>Zr</b>                          | 481   | u.d   | u.d   | 684   | 439   | 718   | 471   | 662   | 811   | u.d   | 448   | u.d   | 401   | u.d   | u.d   | 296   | 431   |
| <b>Rb</b>                          | 77    | u.d   | u.d   | 56    | 60    | 45    | 50    | 51    | 55    | u.d   | 63    | u.d   | 59    | u.d   | u.d   | 52    | 69    |
| <b>Ga</b>                          | 31    | 2     | 2     | 15    | 22    | 17    | 12    | 19    | 17    | 2     | 24    | 4     | 28    | 2     | 2     | 15    | 36    |
| <b>Ba</b>                          | 673   | 359   | 252   | 574   | 607   | 478   | 514   | 564   | 557   | 300   | 585   | 204   | 546   | 207   | 235   | 622   | 697   |
| <b>Y</b>                           | 56    | u.d   | u.d   | 40    | 39    | 20    | 33    | 32    | 35    | u.d   | 36    | u.d   | 35    | u.d   | u.d   | 33    | 54    |
| <b>Sr</b>                          | 295   | 2     | 2     | 415   | 347   | 299   | 332   | 304   | 379   | 2     | 270   | 2     | 279   | 2     | 2     | 439   | 339   |
| <b>Nb</b>                          | 44    | u.d   | u.d   | 25    | 21    | 17    | 17    | 24    | 23    | u.d   | 28    | u.d   | 24    | u.d   | u.d   | 22    | 31    |
| Radioactives elements (ppm)        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| <b>eU</b>                          | 5     | 4     | 4     | 5     | 5     | 3     | 2     | 2     | 3     | 2     | 3     | 4     | 2     | 3     | 4     | 3     | 3     |
| <b>eTh</b>                         | 6     | 6     | 4     | 5     | 4     | 3     | 2     | 6     | 4     | 5     | 6     | 5     | 4     | 4     | 3     | 6     | 5     |

Note : (u.d .) Under detection limit which estimated at 2 ppm for Ga and Sr and 5 ppm for other measured trace elements.



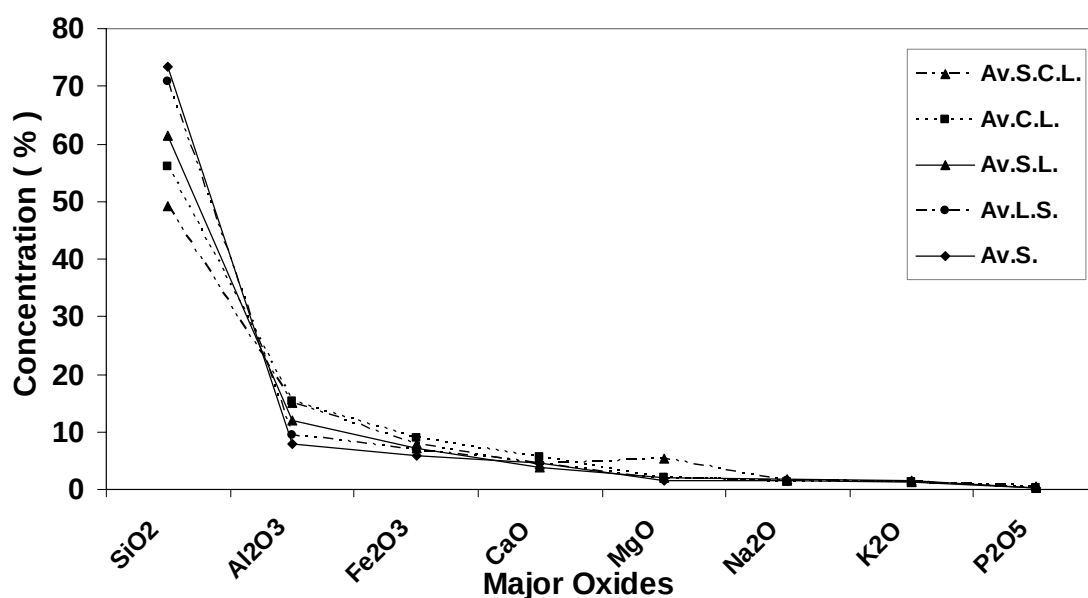


Fig. 5. Major oxides distribution in the studied soil samples

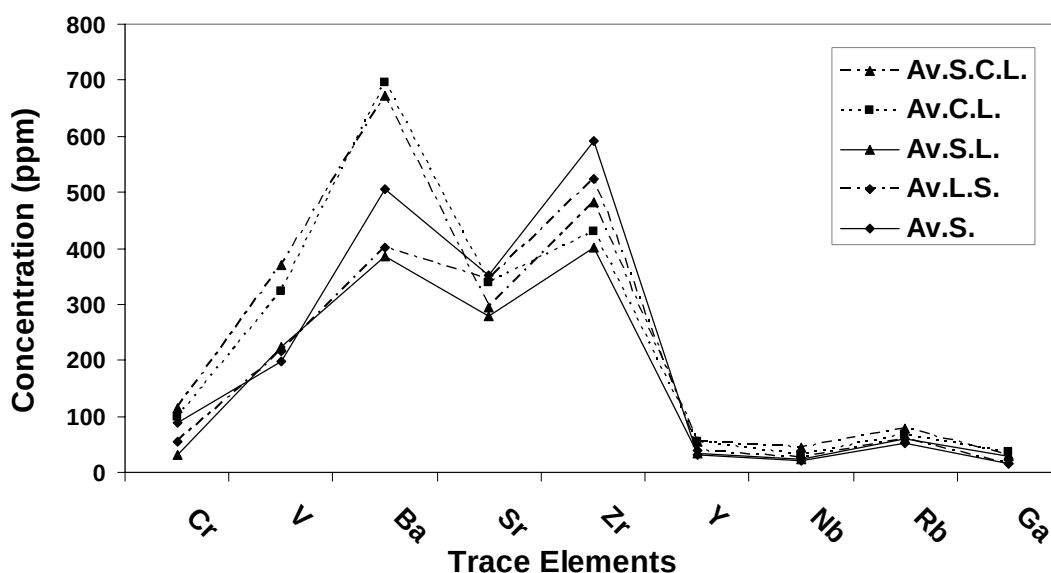


Fig. 6. Trace elements distribution in the studied soil samples

montmorillonite. Geochemically, the analysis of the major oxides confirms 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<sub>2</sub>O-K<sub>2</sub>O ternary diagram and ternary relationship between (Fe<sub>2</sub>O<sub>3</sub> + MgO), Na<sub>2</sub>O and K<sub>2</sub>O indicate that most of the sandy samples are classified as greywacke field while loamy sand facies are classified as Arkose field.

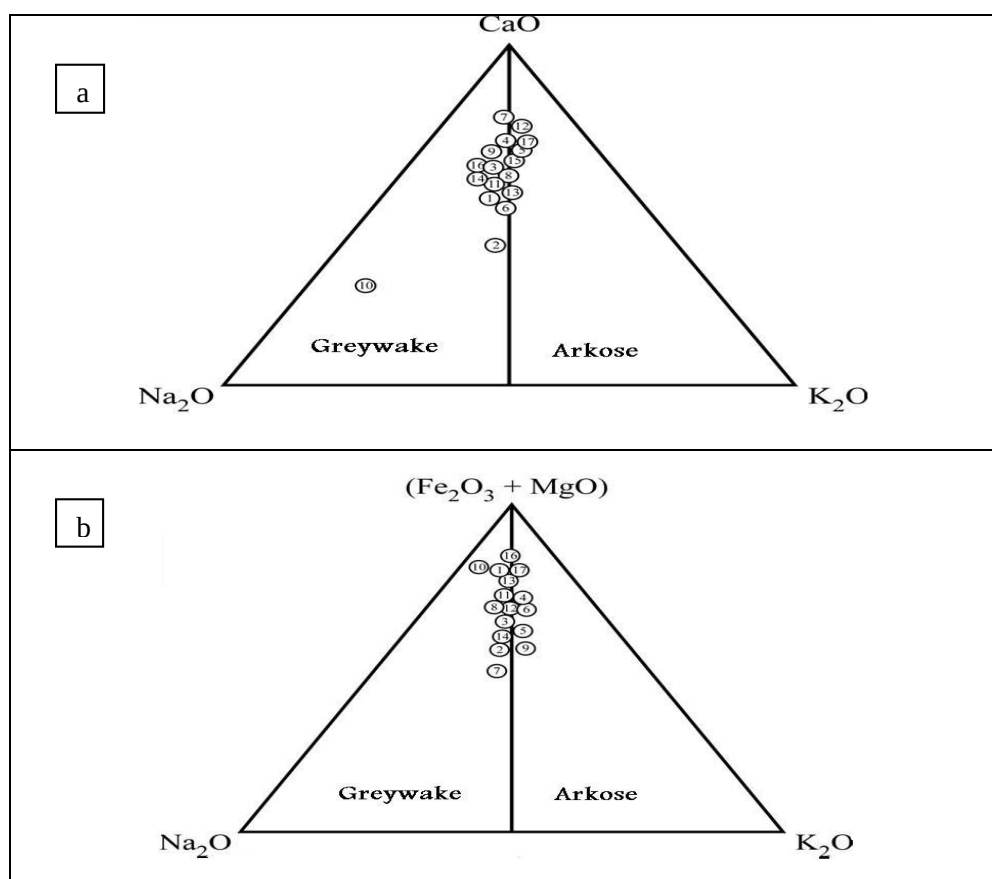


Fig. 7. Ternary classification diagram (a: after Pittijohn et al., 1972) and (b: after Blatt et al., 1980)

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