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MINERALOGY OF THE SUBSURFACE SEDIMENTS AT ROSETTA AND DAMIETTA PROMONTORIES, EGYPT

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ABSTRACT

The mineralogy of the sandy and muddy units of the subsurface sediments of Rosetta and Damietta promontories is investigated. Heavy minerals of the sandy units are dominated by opaques. Several non-opaque unstable, metastable and ultrastable minerals are also recorded. Based on the relative frequencies of amphiboles, pyroxenes and epidotes, the studied sediments are believed to have been deposited in Holocene time. X-ray diffraction analysis of the clay fraction of samples of the mud unit indicates the presence of montmorillonite and kaolinite with lesser amount of illite. Their presence in the same proportions throughout the whole mud unit indicates the same source and environmental (fluviomarine) condition for its formation.

INTRODUCTION

Relatively few studies have been done on the mineralogy of the subsurface sediments along the Nile delta coast. Anwar and El-Bouseily (1970 a & b) carried out subsurface studies on the black sand deposits at Rosetta mouth to evaluate their economic value . Frihy (1975) discussed the distribution of heavy minerals in the subsurface deposits near Idku Lake. Anwar et al. (1983) recorded five subsurface sedimentary units at Rosetta and Damietta promontories. These, starting from top, are: fine & very fine sand, silty sand-muddy sand, mud deposits, muddy peat deposits and medium sand. The object of the present paper is to study the heavy mineral constituents of the sandy units in order to get any possible environmental relation between mineral stability and these units. Besides, a trial was made to determine the relative age of the studied succession. Environmental interpretation of clay mineral contents of the muddy samples is also discussed.

SAMPLING AND PROCEDURES

The present investigation is carried out on the sandy and mud units of 13 shallow boreholes (up to 30 m depth) at Rosetta and Damietta promontories (Fig. 1). The lithology of boreholes succession is shown in figs. 2 & 3. A total of 142 samples representing the sand (fine & very fine sand and medium sand), and silty sand-muddy sand deposits are selected for heavy mineral study. The heavy mineral analysis was carried out on 2.5 - 4.0 ϕ fraction, where heavy minerals are concentrated, using bromoform

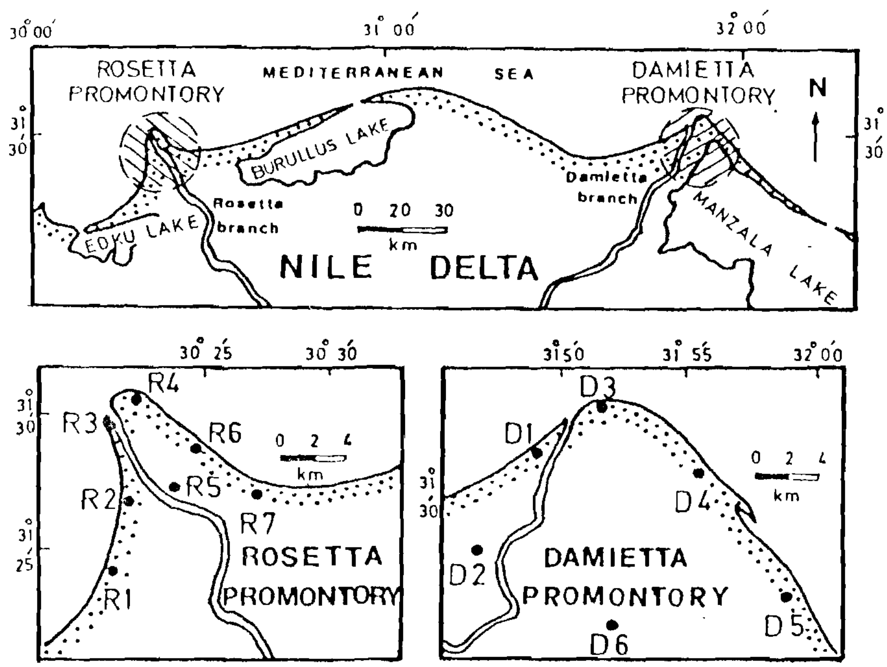

Fig. 1. Area of study and locations of boreholes on Rosetta and Damietta promontories.

(sp. gr. 2.85) as a separating medium. Light and heavy fractions were separately mounted in balsam and mineral constituents were counted under the microscope. X-ray diffraction analysis was made for 21 representative mud samples. The analysis was performed on clay fraction separated by the sedimentation procedure mentioned in Krumbein and Pettijohn (1938). Oriented preparations on glass slides were made, all allowing the clay water suspension to dry at room temperature. Three diffraction patterns were obtained for each sample as follows:

- Untreated, i.e., air dry samples without any treatment.
- Heated, i.e., the samples were heated to 550°C.
- Glycolated, i.e., the samples were saturated with ethylene glycol vapour.

The prepared slides were run on a PW 1130 Philips X-ray diffractometer . The patterns were run with Ni-filter, Cu K radiation (λ = 1.5418 A° at 50 Kv, 30 mA potential). Chart speed is 20 mm per minute.

Mineralogy of Sandy Units:

The light fraction of all the studied samples is generally made up mainly of quartz with minor amount of feldspar and microfaunal tests. The heavy mineral suite separated from these samples arranged in a decreasing order

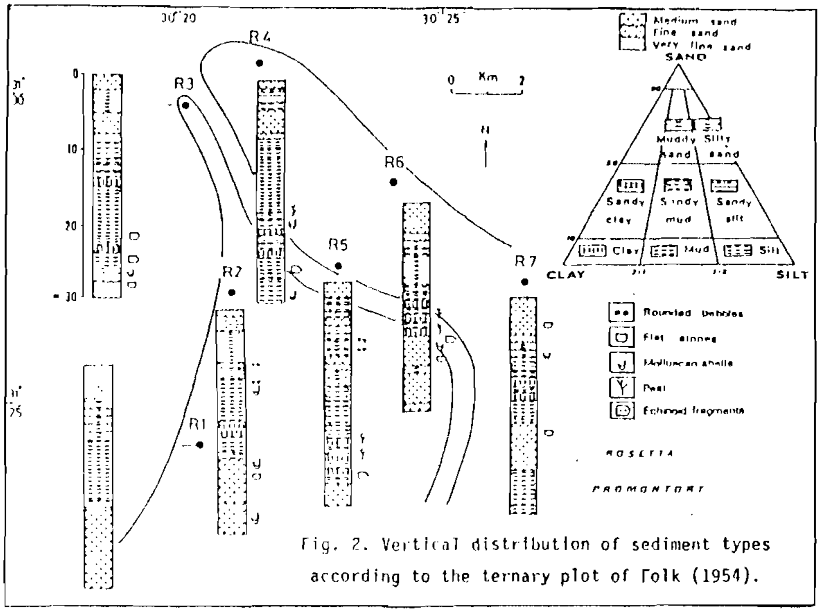

Fig. 2. Vertical distribution of sediment types according to the ternary plot of Folk (1954).

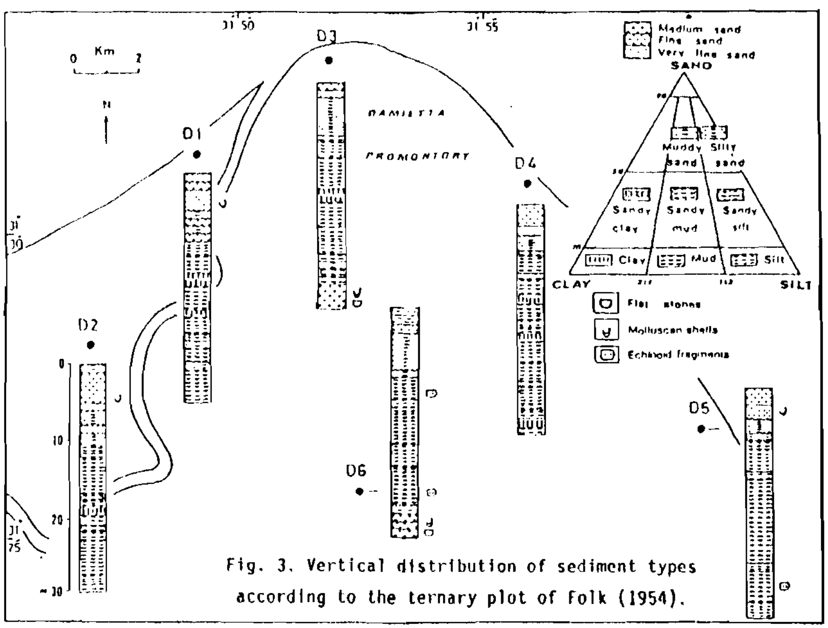

Fig. 3. Vertical distribution of sediment types according to the ternary plot of Folk (1954).

includes the following minerals: opaques, pyroxene, amphibole, garnet, epidote, staurolite, zircon, rutile, tourmaline, biotite, monazite, kyanite, andalusite and sillimanite.

Many authors made attempts to group the heavy minerals according to their stability. Folk (1974) grouped the heavy minerals in terms of opaques, micas, ultrastable (zircon, tourmaline and rutile) and metastable (garnet, epidote,apatite and kyanite). He considered the amphibole and pyroxene as unstable. Friis (1974) considered pyroxene and amphibole as extremely unstable while epidote and garnet are unstable. El-Sayed (1977) evaluated the Holocene/Pre-Holocene boundary layer on the basis of heavy minerals stability in the core samples of the inner transition zone off the island of Sylt, Germany. The studied heavy minerals are grouped as follows: opaques, unstable (amphibole and pyroxene), metastable (garnet, epidote, apatite and kyanite) and ultrastable (zircon, rutile and tourmaline). All other heavy minerals (staurolite, biotite, monazite, andalusite and sillimanite) are considered as one group.

Distribution of heavy minerals: (Figs. 4 and 5)

Opaques: The observed opaque minerals are magnetite, hematite, ilmenite and limonite. Most of the grains are subrounded to rounded with lesser amount of angular grains. The opaques are recorded in all the studied samples in both Rosetta and Damietta boreholes. They show a random vertical variation with slight higher concentration in the medium sand unit.

Unstable minerals: Pyroxenes are represented mainly by augite of greenish yellow to brownish varieties. The rhombic members are enstatite and hypersthene. Pyroxene grains range from rounded to irregular. Amphiboles are second in abundance after pyroxenes. They are represented by hornblende, actinolite and tremolite of prismatic and subrounded forms. Pyroxenes and amphiboles are recorded in all the studied samples and show similar vertical distribution, where they generally show gradual decrease in abundance with depth.

Metastable minerals: Members of this group, arranged in a decreasing order are: garnet, epidotes, apatite and kyanite. Garnet and epidotes are recorded in all the studied medium sand samples, while the others are recorded in some of the studied sandy samples. Garnet grains are angular, subangular of pink, rose and colourless varieties. Epidotes are represented by rounded to subrounded grains of pistachite, clinozoisite and rarely zoisite. In general, the frequency percent of metastable minerals, represented mainly by garnet and epidotes, show a downward increase, where they attain their maximum values in the medium sand unit of both localities.

Ultrastable minerals: These include zircon, rutile and tourmaline and are found as a minor association in some of the studied samples. Zircon is found as colourless small prismatic, bipyramidal or broken grains with rounded edges in some of them. Rutile is present as small dark reddish brown and yellowish prismatic grains showing fair rounding edges. Tourmaline displays different pleochroic colours; grey, brown, pink and black in prismatic oval and rounded grains.

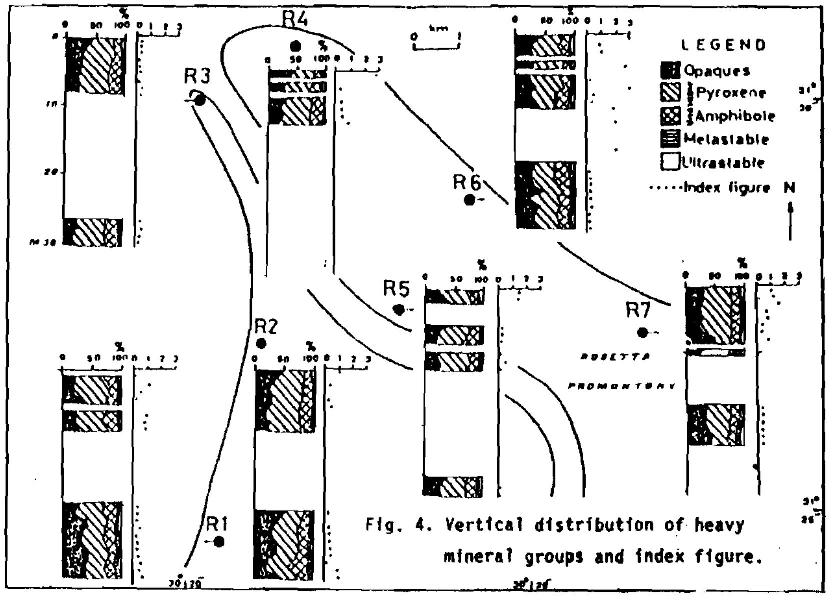

Fig. 4. Vertical distribution of heavy mineral groups and index figure.

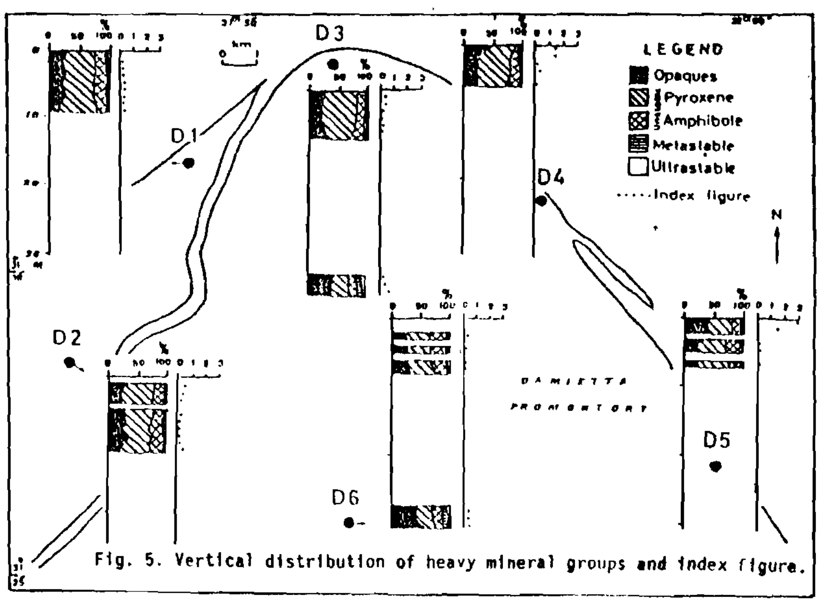

Fig. 5. Vertical distribution of heavy mineral groups and index figure.

Biotite, monazite, staurolite, sillimanite and andalusite are rarely and habhazardly recorded in the studied samples. The slight differences in the frequency of occurrence of the main heavy mineral species in the different lithological units are shown in Fig. 6. Unstable minerals (pyroxenes and amphiboles) show slight decrease while opaques, garnet and epidotes show slight increase in the medium sand samples.

The concentration of heavy minerals is expressed by the index figure ratio, i.e., weight of heavy minerals/weight of light minerals. The vertical distributions of idex figure (Figs. 4 and 5) in Rosetta and Damietta boreholes show clearly high concentration of heavy minerals in the upper portion of the boreholes.

The studied samples are plotted on the pyroxene, amphibole and epidote ternary diagram (Fig.7). The plots lie on the pyroxene-amphibole boundary and occupy an area more closer to the pyroxene end member. Comparison with age boundaries of Shukri and Azer (1952) indicates that all the studied samples lie outside the Paleolithic time zones; i.e., have been possibly deposited in Holocene.

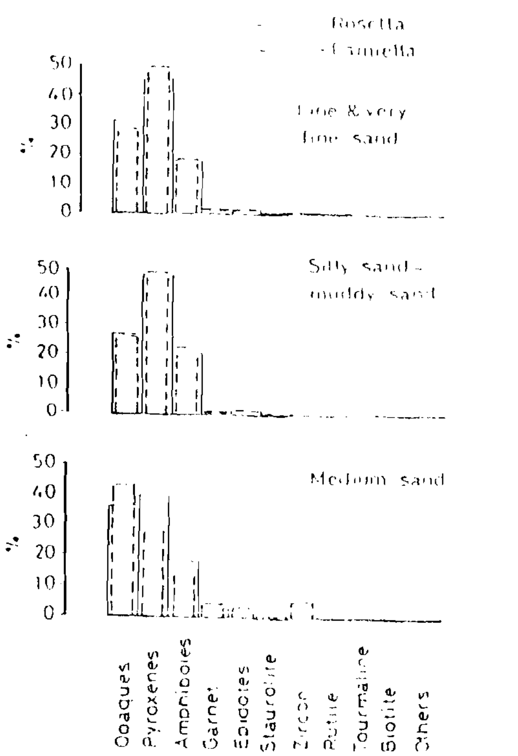

Fig. 6. Average histograms of heavy mineral frequencies in the different lithologic units.

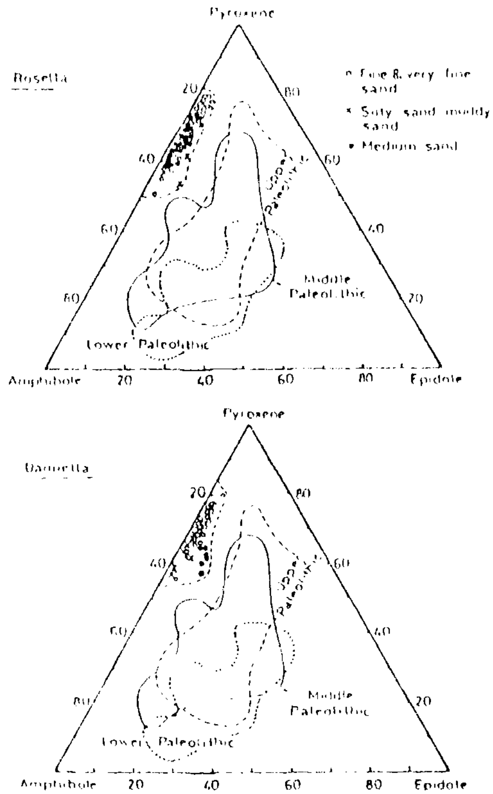

Fig. 7. Pyroxene-amphibole-epidote ternary plot, boundaries after Shukri and Azer (1952).

Mineralogy of Mud Unit

X-ray diffraction analysis was carried out for the identification of clay minerals. The identification was based on the scheme proposed by Warshaw and Roy (1961), Smith (1967), Grim (1968) and Barry (1972). Representative X-ray diffraction patterns are shown in Fig. 8. All the untreated samples gave a peak between 14-15 A°, when treated with ethylene glycol, the peak expands to near 17 A°. However, on heating to 550°C, both peaks retreat to the illite spacing at about 10.0 A°. Kaolinite is recognized in all the studied samples by its well defined first and second order basal reflections (or peaks) at about 7 A° & 3.7 A°, respectively. These peaks are recorded in both untreated and glycolated samples. Heating to 550°C causes complete destruction of the two peaks. A peak with d-spacing at about 10 A° has been noticed in the untreated, glycolated and more exaggerated in the heated samples. This peak is characteristic of illite (Fig. 8). Quartz was the only prominent non-clay mineral observed in all the studied samples. Its peak has been noticed as shown in Fig. 8 at about 3.6 A° reflection.

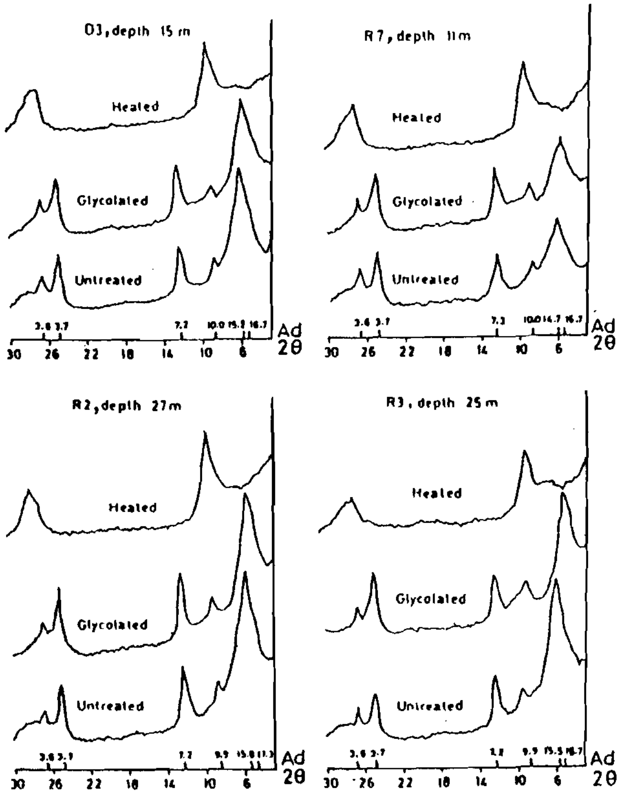

Fig. 8. X-ray diffraction patterns of selected mud samples.

Generally, the semi-quantitative approximation based on peak heights suggests that the mud samples consist mainly of montmorillonite, kaolinite and lesser amounts of illite and quartz. The relative abundance of clay minerals in each sample was estimated using the height of peaks. Keller (1946, 1953 & 1956) related the modification or development of clay minerals to a "set of physicochemical conditions " which occur during processes of deposition and diagenesis rather than to a specified environment, i.e. "non-marine" or "marine". Keller (1956 & 1970) has summarized the environmental conditions common to the genesis of montmorillonite, kaolinite and illite groups of minerals. He stated that montmorillonite requires alkaline condition in stagnant water; i.e., perhaps in marine conditions where poor leaching and Mg^{2+} and Ca^{2+} and iron ions were present . He also indicated that illite resembles montmorillonite, being produced from volcanic or igneous materials, where the solutions were basic with moderate leaching and with retention of metallic ions particularly potassium and calcium. Glass (1958), Pryor and Glass (1961) and Weaver (1960 & 1961) have generally considered that kaolinite is dominant in fluviatile environment. They also indicate that illite and montmorillonite are most abundant in marine sediments. Venkatarathnam and Ryan (1971) have reported clay minerals Nile assemblage with high kaolinite amount in the surface sediments of the Nile cone in the Eastern Mediterranean . Hegab (1974) showed that montmorillonite with lesser amounts of well-ordered kaolinite and minor illite are the main constituents of the terraces east of the Nile delta. Illite, montmorillonite and kaolinite were also recorded by Hamama (1978) in the bottom sediments (about 6 m depth) off Ras El-Barr to Port Said. Gindy and Samuel (1982) showed that montmorillonite still dominated the clay fraction of the Nile sediments contributing the majority of clays to Egypt which was suffering from dry conditions since Late Eocene. Its amount is increasing slightly at the expense of minor detrital illite and chlorite. The depositional processes and climate might have a role in determining the character of the recorded clay mineral asseblage. So, the clay minerals of the mud deposits were carried by the River Nile to the Mediterranean Sea and deposited under fluviomarine conditions. These clay minerals were originally derived from the Nile drained volcanic rocks (Abyssinian Plateau) and metamorphic and igneous rocks (Central African Complex).

CONCLUSION

The light fraction of the subsurface sandy units of Rosetta and Damietta promontories is generally made up mainly of quartz with minor amounts of feldspars and microfaunal tests. The heavy minerals recorded in these units include opaques, unstable minerals (amphibole and pyroxene), metastable minerals (garnet, epidote, apatite and kyanite), ultrastable minerals (zircon, rutile and tourmaline) and minor amounts of staurolite, biotite, monazite, andalusite and sillimanite. The study showed slight differences in the frequency of occurrence of some mineral species in the different lithological units. The unstable minerals showed slight decrease while opaques, garnet and epidotes showed slight increase in the lowermost medium sand samples.

X-ray diffraction analysis showed that the mud samples consist mainly of montmorillonite, kaolinite and lesser amount of illite. These minerals indicate that the mud deposits were carried by the River Nile to the Mediterranean Sea and deposited under fluviomarine conditions.

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