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Mineralogy, chemistry and radioactivity of the heavy minerals in the black sands, along the northern coast of Egypt

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ABSTRACT

Three hundreds and six black sand samples have been collected from the beach areas along the northern coast of Egypt, parallel and perpendicular to the shoreline. The mineralogy and chemistry of the economic heavy minerals were studied. The grain size distribution of the studied economic minerals shows a unimodal class that mostly in the very fine sand size. The microscopic investigation indicates that the study area is enriched with six economic heavy minerals. These are ilmenite, magnetite, garnet, zircon, rutile and monazite; in addition to leucoxene, arranged in decreasing order of their abundance. The studied black sands suggest a reserve of 329, 183, 24, 21, 7, 1 and 14 thousand tons of ilmenite, magnetite, garnet, zircon, rutile, monazite and leucoxene, respectively. The spherical magnetite grains are higher in Fe_2O_3 than those of euhedral shaped grains. Ilmenite grains display sub-rounded to euhedral shapes. The altered ilmenite grains have higher TiO_2 and lower Fe_2O_3 in comparison with the euhedral fresh ones. Garnet occurs as angular (49%), sub-spherical (45%), spherical (5%) and euhedral grains (1%). Garnet grains containing mineral inclusions represent 10% of their concentrate. The euhedral garnet grains have Al, Fe, Mn, Mg and Ca that arranged in decreasing order of their abundance. The magnetic zircon fraction obtained from their bulk concentrate is particularly rich in colored grains (70%). Their common colors are red and brown with some malacons. The reddish-brown color of zircon may be due to iron oxide stains. Some magnetic zircon grains are enriched in Hf and REEs contents. Rutile grains are sub-to well rounded (70%), and rich in TiO_2. Monazite is enriched in Ce, La, Nd, Th and U. Detectable inclusions of gold, copper, lead, galena, cinnabar, platinum group elements (PGE_S) and silver are recorded in cassiterite.

The radiometric measurements revealed that the black sands of the western zone (4 km^2) have high values of specific activity, absorbed and effective doses. This is attributed to the high contents of radioactive monazite and zircon. On the other hand, the black sands in the eastern (3 km^2) and middle (3 km^2) zones have moderate and low radioactivity values due to their lower contents of radioactive zircon. Therefore, the black sands of the western zone are not recommended for use in building constructions, because the inhabitants will receive relatively high radioactive doses. Similarly, the black sands of the middle and eastern zones are also not suitable for building construction purpose unless the radioactive minerals are removed.

1. Introduction

The Egyptian black sand placer deposits are discontinuously distributed along the Mediterranean Sea coast. They extend between Abu Qir to the west and Rafah to the east (about 700 km long and ~20 m depth) and well developed in the beach areas of Rosetta, Damietta, north Sinai and the coastal sand dunes of the El-Burullus-Baltim area (El-Askary and Frihy, 1986; El-Hadary, 1998; Hegazy and Emam, 2011). The direction of the long shore current, size and specific gravity of minerals play a fundamental role in the distribution and concentration of heavy minerals along the Mediterranean Sea coast (El-Askary and Frihy, 1986). Actually, the black sand deposits consider one of the most important mineral resources in

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Egypt. These deposits contain strategic and economic heavy minerals, which are needed either for the nuclear industry or other metallurgical and engineering industries.

The Egyptian black sands along the Mediterranean Sea coast are known for their enhanced natural radiation environment, due to the presence of radiogenic heavy minerals such as monazite, radioactive zircon, thorite and uranothorite. The radioactivity of the Egyptian black sands was studied previously by many workers (Gindy, 1961; Meleik et al., 1978; Dabbour et al., 1988; Moustafa et al., 2000; El-Kammar et al., 2010; Abdel-Karim et al., 2010; El-Gamal and Saleh, 2012; Abdel-Karim, and El-Shafey, 2012). Moustafa (2007b) stated that "highly radioactive grains were detected inside cassiterite concentrate". They are most probably composed of thorian-uraninite and urano-thorianite individual grains. In thorian uraninite, uranium is present in the U^{6+} oxidation state while in urano-thorianite U is present as U^{4+}.

The main part of the Egyptian beach minerals derive from basement rocks of the upper reaches of the Nile River and its main tributaries as, Blue Nile (60%), Atbara River (Ethiopian highland, 26%) and White Nile (Equatorial plateau, 14%) (Wassef, 1964). El-Kammar et al. (2010) studied the geochemical characteristics of the heavy minerals of Rosetta black sand and suggested that the coarse grained zircon minerals were probably derived from the crust and highly fractioned pegmatite from the eastern central African. Also, the fine-grained zircon was probably derived from the mantle and Ethiopian plateau of basaltic nature. On the other hand, the monazite was probably derived from granite and pegmatite of the White Nile provenance. The garnet originated from metamorphic rocks (two mica schist) source of the White Nile provenance (El-Kammar et al., 2010). The magnetite and ilmenite originated from basaltic rocks of Blue Nile provenance. While the Rutile originated from mafic intrusive igneous rocks of Blue Nile provenance. El-Kammar et al. (2010) also concluded that the cassiterite minerals originated from Muscovite-granitic source of White Nile provenance.

Recently, Nuclear Materials Authority (NMA) was constructed a semi-industrial plan for the exploitation of the black sands at Rosetta town and Abu-Khashabah village (east of Rosetta). For the completion and continuation of this plan to extract the economic minerals on industrial scale, the present work aims to study the mineralogical and geochemical characterization of the economic heavy minerals in the black sands along the northern coast of Egypt. Additionally, this work includes evaluation of the radioactivity content of the studied black sands.

2. Study area

The study area lies on the Mediterranean Sea coast, about 8 Km east of Rosetta distributary mouth, north-west of El- Burullus lake between longitudes 30° 25′ 48″–30° 33′ 00″ E and latitudes 31° 26′ 42″–31° 27′ 18″ N (Fig. 1). The coastal plain of this area is nearly rectangular in shape, 10 Km long parallel to the shoreline and 2 Km width nearly perpendicular to the shoreline (Fig. 1). El-Sahel (coastal) drain which runs parallel to the shoreline divided this coastal plain area into northern and southern sectors. The northern sector bounded by the Mediterranean Sea in the north and by El-Sahel drain in the south. It is characterized by relatively highly concentrated black sand especially in the near shore area. The southern sector is the subject of the present work, bounded by El-Sahel drain in the north and by the international highway in the south. It is characterized by diluted homogenous sediments, rich in clay and organic matter.

3. Sampling and methodology

The study area is 10 Km long parallel to the shoreline and 1 Km width nearly perpendicular to the shoreline. Three hundred and six samples were collected from the coastal plain area to a depth of 1 m at the intersection of a grid pattern 200 m × 200 m nearly parallel and perpendicular to the shoreline. Totally 306 samples were collected along 6 profiles (A, B, C, D, E, F), each profile comprise 51 samples taken from west to east and parallel to the shoreline (Fig. 1).

Each representative sample was weighed and slowly poured inside a calibrated cylinder and compacted very well by shaking to be analogous to the field deposit. The weight of the sand was divided by its volume to obtain the apparent specific gravity (Table 1). Grain-size analysis was carried out in a Ro-Tap sieve shaker using American Society for Testing and Material (ASTM) sieves ranging from +1 ϕ to 4.25 ϕ at 0.50 ϕ intervals for 20 min (Table 2). Cumulative curves were constructed to calculate the statistical grain-size parameters (mean grain size, sorting, skewness and kurtosis values) by applying the equations of Folk and Ward (1957); (Table 3). Modal mineralogical determinations were carried out by counting 300 grains per thin sections. The point counts were done using both Gazzi-Dickinson (Gazzi, 1966; Dickinson, 1970) and standard methods. The major six economic heavy minerals (magnetite, ilmenite, zircon, rutile, garnet and monazite), leucoxene, and remaining economic minerals were

Fig. 1. Satellite map showing location of field samples.