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DISTRIBUTION AND PROPERTIES OF PLACER ILMENITE IN DAMIETTA — PORT SAID BEACH SANDS, EGYPT

S. N. WASSEF* and N. S. HAMMOUD*

ABSTRACT

This work deals with a comprehensive study of ilmenite distribution in the sands of Damietta-Port Said beach which is a part of the African Coast on Mediterranean Sea. This area extends for about 36 km to the east of Damietta Nile branch estuary, and of about 11 km^2.

The sands come out of the estuary and subjected to northwesterly winds, and a current parallel to the beach line from west to east. These conditions cause the accumulation of heavy minerals bearing ilmenite on the eastern side of Damietta estuary.

Systematic withdrawal of 116 auger samples distributed regularly on the beach stretch have been analyzed for ilmenite. The tenor of ilmenite was found to vary between 5.82% and 15.328% and concentrates in three main locations. The upper meter showed a reserve of about 1.23 million dry tons of ilmenite.

Ilmenite is characterized by the presence of hematite, rutile, magnetite as exsolutions and decomposition into different alteration products is recorded.

The presence of ilmenite besides zircon and rutile is suggesting the Precambrian and basic plutonic rocks provenances drained by the highlands of the River Nile in Africa. The high chromium content in ilmenite relates its origin to the basaltic rocks in Ethiopia, Sudan and Upper Egypt.

INTRODUCTION

The ilmenite content was estimated in 116 auger samples in the area between Damietta and Port Said beach sands *(Fig. 1)*. This area extends for about 36 km east of Damietta mouth eastwards to Port Said, and represents about 11 km^2. This area is the second important one after east Rosetta. The heavy minerals come down the River Nile and passed through Damietta mouth to the outlet in Mediterranean Sea. Because of the long shore currents which forms the horizontal component of the waves initiated by the prevailing north-westerly winds, the sediments travel eastwards to deposit on the area between Damietta mouth and Port Said on the beach stretch.

HILMY (1951) divided the coast of Egypt arbitrarily into three parts based mainly on the general difference in topography and lithology. These parts are: (1) Western part west of Rosetta, (2) Middle part between Rosetta and Damietta, and (3) Eastern part east of Damietta. This study revealed that these beach sands are mostly derived from the Ethiopian volcanic highland with minor addition from Sudan and Upper Egypt. The minerals are reported to occur in fresh state and to have a medium size ranging from 0.25 to 0.63 mm in diameter, and well sorted (So=1.1—1.56), and well rounded. Also HILMY (1951) stated his belief that these sands represent waterborne sediments transported mechanically by the River Nile.

* Nuclear Materials Corporation, Cairo, Egypt

Damietta beach is characterized by relative unstability of sedimentation conditions due to the subjection of different climatic conditions and frequent high tide periods.

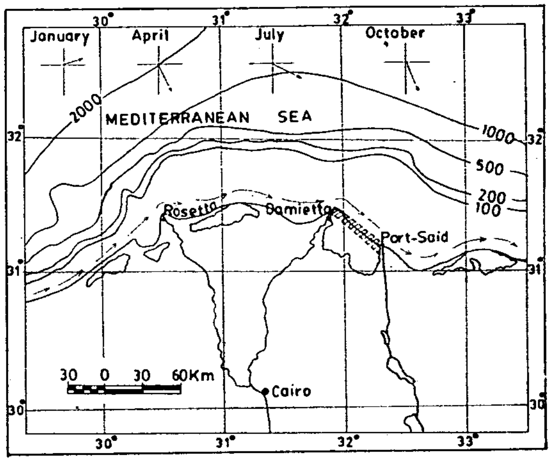

Fig. 1. Location map showing the depth contours, the direction of water current and the prevailing wind in Damietta

It is known that there have been old branches of the Nile between Damietta and Port Said (BALL, 1942). According to HERODOTUS map, 450 B.C. *(Fig. 2)* these branches were called; Mendesian mouth which was 13 km to the south-east of the actual Damietta mouth, and Saitic mouth which was 10 km to the west-north of Port Said. These old branches may be responsible for the present crenulations of the beach as a result of their openings into the Mediterranean Sea (WASSEF, 1964). The Bucolic mouth was mostly in the same site of the actual Damietta mouth. The Pelusiac mouth was mostly east of Port Said by not less than of 20 km.

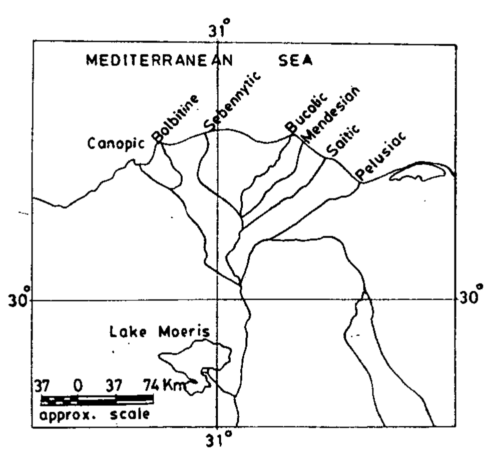

Fig. 2. Map showing the extinct Nile branches between Damietta and Port Said, after HERODOTUS 450 B. C. (BALL, 1942)

El-Shazly (1966) estimated the reserve of the economic minerals on the beach from Abu Quir to Port Said. This study showed the presence of 6.922.300 t of total economic minerals in the upper meter.

Meleik *et al.* (1978) compared the aerial and ground radiometric surveys. The result obtained by different methods particularly aeroradiometry distinguished six zones of rich minerals content, either directly on the beach or inland. Three of these zones can be related to the former branches of the River Nile, the Bucolic, Mendesian and Saitic branches mentioned by Ball (1942). The study revealed that there is a general direct correlation between aerial data and that from ground radiometry and zircon and monazite contents.

The mineralogy as well as the petrography of ilmenite is studied by: Basta (1953, 1959*a*, 1959*b*, 1960), Rittman and Nakhla (1958), El-Goresy (1962), El-Hinnawi (1964), Boctor (1966), Hammoud (1966).

Morphology of the area

The beach of Damietta is sufficiently narrow in order to permit the high tide sea water to drop in Lake Manzalah especially in winter and stormy conditions. The crop of the heavy minerals is denser in Damietta than in Rosetta due to the higher deposition rate in winter and flood time. The reworking process of these crops by sea water takes place in summer and a wave-cut ridge appears close to the berm (Wassef, 1964, 1973).

The building of the coast takes place by accretion in longitudinal portions each of which is being formed by an off-shore submarine spit or bar. The alluvial advance of the coast is attributed to the fact that spits were built infront of the shore, separated from it by swales which filled up and formed a part of the solid land. The long shore current is responsible for the distribution of the materials along the foreshore area. The sediments of the bars are gently well sorted and if black sand placers are found they are always only on the seaward side of the bar. This is supported by the presence of numerous elongated islands in Lake Manzalah running parallel to the sea coast. Thus the Damietta beach is actually a compound bar that have grown seawards by building of secondary bars and the silting of the lagoons trapped behind (Said, 1958).

The pattern of Damietta beach is gentle slope, flat, smooth and regular. The effect of the gentle slope is to absorb nearly all the energy approaching from offshore, so there are no strong waves acting on the beach except when abnormal stormy conditions are present. No rock structures are present on Damietta-Port Said beach, therefore all the deposits present are maintained by water, not including disintigrated grains of rocks as a result of wave action. It was found that from the shore to about 60 km in sea water the depth of the shelf ranged between 0 and 100 m *(Fig. 1)*.

There are no sand dunes in this area, except some spots of wind-blown quartz sand not more than 20 cm thick overlying the shore sand. The nature of the waves acting on the beach along the year in the normal climatic conditions is low amplitude waves (low crest), or gentle waves because the subsurface topography is gentle and simple. The prevailing wind to Damietta beach is in NW-SE direction with a small angle to the east at months from April to December *(Fig. 1)*. Thus causes the waves created to strike the beach obliquely at the same angle as the prevailing wind. In July the angle of wind changes to a more westerly direction, hence the angle of striking of the waves is changed, and a drift of deposit to the east takes place.

The mechanical analysis of the beach sands of Damietta showed an average median diameter equals 0.114 mm which is finer than those of Rosetta sands which equals 0.163 mm. The sorting coefficients in both areas are the same and equal 1.27.

METHODS APPLIED

Field sampling method

The samples were collected in sequence along the beach line every 400 m using the auger drill representing the upper one meter. In the wide locations another sample is collected towards the mainland perpendicular to the beach line and separates 200 m from the first sample. Since Damietta beach is a narrow stretch no more than three samples in the column all over the area. The first sample was collected always within the berm close to the beach line. The auger sampler is hummered twice per one sample.

Laboratory work

1. The dry original sample is quartered carefully down to about 75 gm.
2. The sample is then washed to remove the clay by decantation. The organic matter is removed by addition of few cc. of conc. hydrogen peroxide with hot water. After about half an hour, the sample is washed by distilled water and dried in an oven at about 60 °C until complete dryness.
3. The clean sample is divided into two halves, one for the mechanical analysis and the other one for the mineral separation.
4. Magnetite is removed simply by using a small natural magnet according to the method explained by RITTMAN (1957) and NAKHLA (1958).
5. Frantz isodynamic separator is used for magnetic fractionation of the magnetite-free samples. This separator is used twice, once to concentrate the magnetic heavy minerals in the magnetic fraction, and the other one to separate ilmenite from this fraction.

For the concentration of the heavy minerals, the working conditions were 20° side slope, current of 1.5 amp., and tilt 3°. This magnetic fraction contains nearly all the economic minerals and green silicates, while the non-magnetic fraction contains mainly quartz and the non-magnetic zircon and some rutile.

The working conditions of the separator are changed to perform a suitable field for ilmenite separation from the previous magnetic fraction. The tilt is changed into 4°, the current into 0.3 amp., and the slope is maintained with 20°, with moderate vibration rate. In these conditions the magnetic fraction obtained is very rich in ilmenite which represents about 98% of the total ilmenite present in the sample. The exact percentage of ilmenite is defined by checking the fraction under the microscope by using the grain counting technique (WASSEF, 1981).

The ilmenite is the most major one among the economic minerals of the black sands. The rest of minerals are; magnetite, hematite, monazite, zircon, rutile, and garnet. Ilmenite and magnetite are of $FeO—Fe_2O_3—TiO_2$ system.

RESULTS

Ilmenite distribution

The distribution of ilmenite in East Damietta area *(Fig. 3)* concentrates in three main locations, A, B, and C. The area A is the most rich location in ilmenite, and the concentration is declined eastwards in locations B and C.

The modal class of ilmenite is ranged between 6 and 8% which reached a frequency of 56.05% of the total distribution *(Fig. 4)*. The average value of ilmenite ($\bar{X}$) showed an order of 8.277%. The minimum percentage is 5.852%, and the maximum reached 15.328%.

The calculation of ilmenite reserve revealed the presence of about 1.23 millions dry tons as a proven reserve in the upper meter. If the continuation of the heavy minerals is until 20 m depth, and if the upper meter unit is repeated, a probable reserve of order 24.6 millions dry tons can be considered.

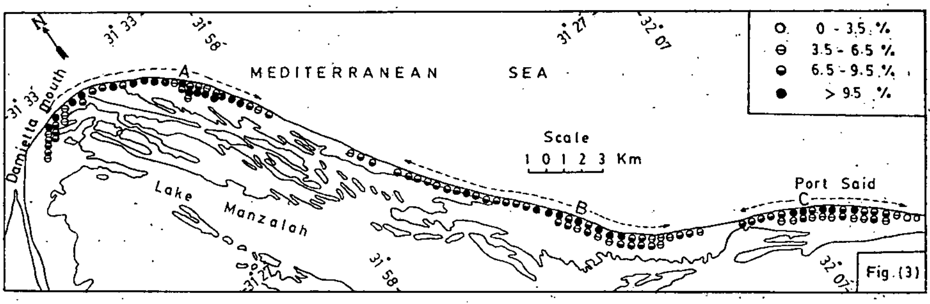

Fig. 3. Distribution of ilmenite along Damietta beach

Properties of ilmenite

Ilmenite is mostly black with bluish or violet tint. Some altered grains are dull black. Most of ilmenite grains are irregular in shape; angular to subangular and some grains are rounded. The ilmenite grains show the L/B (Length—Breadth) ratio between 2:1, among them the majority have L/B ratio between 1:1 and 2:1 (MIKHAIL, 1971). Twinning is a common feature, twin lamellae exist in one or two directions parallel to *(10$\bar{1}$1)* planes of ilmenite.

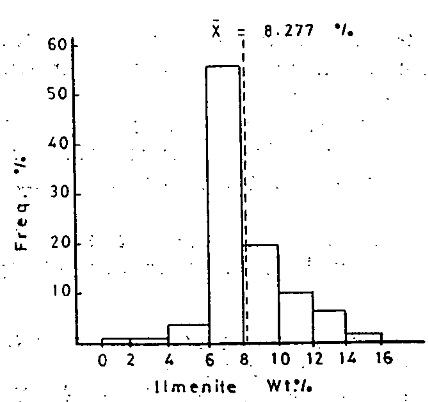

Fig. 4. Statistical distribution of ilmenite

Exsolutions

A- Hematite

At high temperature ilmenite and hematite form a continuous solid solution series. On moderately slow cooling unmixing takes place into two solid solutions, ferri-ilmenite and titanhematite. However BASTA (1953, 1959*b*) found that at normal temperature ferri-ilmenite with 18% Fe_2O_3 and titanhematite with 10% TiO_2 in solid solution exist in nature.

B- Rutile

There is limited solid solution between rutile and ilmenite which does not exceed 6% TiO_2 at about 1050 °C. The exsolution of rutile in ilmenite is not common in comparison with those of titanhematite and is found as fine lamellae in six directions parallel to $(hh\bar{2}hl)$ directions of ilmenite (BASTA, 1959*b*).

C- Magnetite

RAMDOHR (1955, 1956) explained that at high temperature there is a limited solid solution between magnetite and ilmenite, possibly not more than 5—10% of Fe_3O_4.

In some twinned ilmenite grains, few relatively coarse tabular lamellae or fine grains of magnetite are developed inside the twin lamellae (BOCTOR, 1966).

Ilmenite is occasionaly decomposed to different alteration products of variable composition. Two types of alteration are recorded: high temperature alteration represented by rutile-hematite and rutile-magnetite intergrowth, and low temperature alteration represented by rutile-anatase intergrowths (BOCTOR, 1966).

BAILEY *et al.* (1956) explained that the alteration of ilmenite takes place in 3 stages:

1. Ilmenite is partially altered to greyish amorphous phase.
2. Complete alteration of ilmenite to this phase forming an amorphous iron-titanium oxides as an end product.
3. Development of leucoxene on the expense of this amorphous material.

The composition of this leucoxene was questionable and described by many authors as follows:

1. Oriented aggregates of finely crystalline rutile or brookite (BAILEY *et al.*, 1956).
2. Amorphous iron-titanium oxide as crystalline mixture of anatase, brookite, sphene and rutile (ALLEN, 1956).
3. Rutile with subordinate anatase (BAILEY and CAMERON, 1957).
4. A mixture of hematite, pseudobrookite and rutile in an average molar ratio of approximately 1:5:7 as in the brown leucoxene from Quilon (KARKHANAVALA *et al.*, 1959).
5. Development of leucoxene on the expense of amorphous iron-titanium oxide. The leucoxene results in higher titanium content together with high oxidation of iron (HAMMOUD, 1966).

The ilmenite can be recovered in the isodynamic separator as maximum at 0.3 amp., 4° tilt, and 20° as side slope (WASSEF, 1981).

The chemical difference between the strongly and weak magnetic ilmenite showed that the strongly one contains 46.32% TiO_2, 0.34% Cr_2O_3, and 0.12% V_2O_5.

The weak magnetic ilmenite contains 47.52% TiO_2, 0.12% Cr_2O_3, and 0.05% V_2O_5. The chemical composition of highly purified dry ilmenite sample analyzed chemically and by *X*-ray fluorescence spectroscopy was found to be composed of as follows: 18.63% Fe_2O_3, 31.18% FeO, 46.24% TiO_2, 1.35% MnO, 0.64% MgO, 0.87% Al_2O_3, 0.28% Cr_2O_3, 0.14% V_2O_5, 0.12% CaO, 0.32% SiO_2, 0.04% P_2O_5, 0.03% S and traces of Nb, Co, Ni, Zn, Mo and Zr (HAMMOUD, 1966, 1975).

CONCLUSIONS

Ilmenite showed the presence of considerable reserve reaches 1.23 millions dry tons. The presence of ilmenite besides zircon and rutile is suggesting the Precambrian and basic plutonic rocks provenances drained by highlands of the River Nile in Africa. The high chromium content in ilmenite relates its origin to the basaltic rocks in Ethiopia, Sudan and Upper Egypt.

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