CORRELATION OF MINERALOGICAL AND PHYSICAL PROPERTIES OF SOME ECONOMIC BLACK SAND MINERALS FROM ROSETTA AND DAMIETTA WITH THEIR ELECTRICAL SEPARATION AND CONCENTRATION

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INTRODUCTION

The Egyptian beach black sands cover a wide area and occur along the present shores of the Mideterranean from Port Said to Abu Qir east of Alexandria. These large deposits of black sands contain stratigic and economic minerals which are suitable for profitable industrial exploitation and they contain raw materials for atomic energy and others for engineering and metallurgical industries. These values of heavy economic minerals are widely distributed in the beach sands, sand dunes and sand bars along our northern beaches. El Shazly (1964) estimated the reserves of economic minerals on the beaches from Abu Qir to Port Said as 30,802,300 tons in the top meter and 616,046,000 tons in the top twenty meters. The Egyptian beach deposits are unique concerning the quantities and tenors of its valuable heavy economic and strategic minerals. They contain great reserves of monazite, zircon, ilmenite, rutile and magnetite.

For the present study, we have chosen ilmenite and zircon; the former is an important conducting mineral and the latter is a non conducting mineral of particular economic importance.

The role of high tension electrostatic separation processes in the recovery of high grade ilmenite and zircon concentrates is essential and even decisive. Hence the behaviour of the Egyptian beach ilmenite and zircon in the high tension electrostatic separator (Carpco model HP 167) has been investigated. Very clean samples of Egyptian beach Ilmenite (+ 99%) and zircon (+ 99%) were prepared by wet tabling and magnetic separation only. This study of individual pure minerals is a necessity to guide any further studies to define the optimum conditions of electrical separation when utilised for solving different problems of producing marketable grades of these two important Egyptian beach minerals and to help a successful separation of impurities of these two minerals deteriorating the grades of other beach minerals concentrates.

The effects of some important conditions as speed of rotor (r.p.m.), voltage, temperature of sand, polarity of charged electrodes and their orientation relative to each other and to the carrier rotor, position of the feeding point and diameter of aluminium and copper electrostatic electrodes were investigated. Trials for theoretical explanation of the quantified results were tried based mainly on the concepts of Δt (prereversal time lag) introduced by Mora (1962), the phenomena of frictional charging, the effect of temperature on the electrical properties of minerals and the specific mineralogical nature of the Egyptian beach ilmenite and zircon.

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darker colour, a lower reflectivity, and a reddish brown internal reflection if compared to normal ilmenite.

Structure and chemical composition.

Deer (1966) indicated that ilmenite is a titanate of ferrous iron (Fe^{+2} Ti^{+2} O_3) rather than a double oxide of ferric iron and titanium (Fe^{+3} Ti^{+3} O_3). Its structure is somewhat similiar to that of hematite but with some distortion in the oxygen layers. Along the direction of the triad axis, pairs of Ti ions alternate with pairs of Fe^{+2} ions, thus each cation layer is a mixture of Fe^{+2} and Ti. In the series Fe Ti O_3 - Fe_2O_3 there is a steady decrease in the rhombohedral cell edge from ilmenite to hematite. With introduction of considerable manganese, the cell dimensions increase appreciably. The formula of ilmenite may be fully expressed as (Fe, Mg, Mn) Ti O_3 with only a limited amount of Mg and Mn. Hammoud (1966) carried out an x-ray spectrographic analysis for a pure sample of ilmenite. The elements: Fe Ti (+ Mn, Cr, Ca, Mg) - V, Nb, Co, Cu Ni, Zn were recorded. It was also found that there is a relation between the magnetic susceptibility of ilmenite i- Rutile - Hematite:

Ilmenite decomposes to rutile - hematite intergrowths on heating to high temperature. This change was noticed to be gradual in some cases, resulting in the primary stage of slightly altered grains an oriented lamellae of rutile in hematite accompanied by rutile spindles showing more or less the **same** orientation. In more advanced stages of alteration, the rutile becomes well defined having a definite orientation in the hematite. When complete alteration takes place, the ilmenite is totally decomposed to oriented intergrowths of rutile in hematite. Ramdohr (1940 - 1955) explained the effect of temperature on ilmenite by the following equation:

$$2\ Fe\ Ti\ O_3 + O \xrightarrow{heat} Fe_2O_3 + 2\ Ti\ O_2$$

He stated that at high temperatures ($\geqslant$ 1110°C.) pseudobrookite is developed at the expense of such rutile - hematite intergrowths. He also indicated that the granularity and the clearance of the orientation of the rutile - hematite intergrowths is influenced by its temperature of formation.

intergrowths of rutile - anatase, greyish white in colour, with a yellowish white internal reflection and having a microporous structure. This alteration process was suggested to proceed through three stages (Baily et al 1956):

- Incipient stage:

  Starts with the leucoxenation of the surface followed by the appearance of elongated stringers or round patches of a material with reflectivity near or slightly lower than rutile.

- Amorphous iron titanium oxide stage:

  The altered areas become elongated and merge into one another. The end product is essentially an amorphous iron-titanium oxide.

- Leucoxene stage:

  Development of leucoxene at the expense of amorphous iron - titanium oxide. The leucoxene developed at this stage has a seemingly crystalline appearance. The alteration of ilmenite into leucoxene results in a higher titanium content with a higher oxidation of iron and a decrease in the magnetic susceptibility.

- Bailey et al (1956) considered it as oriented aggregates of finely crystalline rutile or brookite.

- Bailey and Cameron (1957) suggested it to be rutile with subordinate anatase.

- Karkhanavala et al (1959) considered it a mixture of hematite, pseudobrookite and rutile in an average molar ratio of approximately 1 : 5 : 7 as in the brown leucoxene from Quillon.

- Flinter (1960) attributed the presence of pseudobrookite in the brown leucoxene from Quillon to its occurence as a primary mineral in the source area.

- Bolfa et al (1961) found that the composition of the altered ilmenites from the rocks and sands of Madagascar closely approaches the molecular constitution of arizonite (Fe_2O_3. 3 Ti O_2).

- Deer (1966) stated that arizonite is probably a mixture of minerals including hematite, pseudobrookite and rutile and sometimes also contained anatase.

2- Solid solution:-

A second factor affecting the chemical composition of ilmenite is the presence of intricate intergrowths of solid solutions and exsolutions between ilmenite - hematite rutile - magnetite.

a- Hematite exsolution:

At high temperature, ilmenite and hematite form a continuous solid socution series. On moderately slow cooling unmixing takes place into two solid solutions, ferriilmenite and titanhematite. The ilmenite - hematite intergrowth account for the relative increase in the percentage of iron oxides. According to Deer (1966), it has been found experimentally that at 1050°C a complete solubility exists between ilmenite and hematite, but at lower temperatures, there is an increasingly larger missibility gap extending from approximately 33 to 67 mol % at 950°C. According to Edwards (1947) the end product of unmixing is an ilmenite with 6% Fe_2O_3 and titanhematite with 10% TiO_2 in solid solution. However Basta (1953, 1959 b) found that ii- Titanhematite with ferriilmenite exsolutions:-

This type is less common than the above discussed type. According to El Hennawi, it constitutes 6.9 % of the Egyptian beach ilmenite. Occasionally fine needles of rutile are observed (Boctor 1966). Edwards (1947) believed that the rutile lamellae are an earlier generation than the ferriilmenite exsolution bodies. Ramdohr (1955) considered them intermediate between the first and second generation of ferriilmenite exsolutions. However Basta (1959) thinks that the unmixing of the ilmenite hematite solid solution to ferriilmenite and titanhematite starts before the separation of the excess of $Ti\ O_2$ as rutile. According to Ramdohr (1956), the formation of rutile exsolutions is a result of partial oxidation (under high oxidation potential) of the $Fe\ TiO_3$ in a mixed crystal lying near the $Fe_2O_3 - Fe\ TiO_3$ Join, on the $Ti\ O_2$ side of the system $Fe\ O - Fe_2O_3 - Ti\ O_2$ to hematite and rutile according to the following equation:

$$2\ Fe\ TiO_3 + O \longrightarrow Fe_2O_3 + 2\ Ti\ O_2$$

The resulting rutile is then dissolved at sufficient temperature (very roughly $\geq$ 350°C.) in the $Fe\ TiO_3$ -

[illegible] solid solution [illegible]
later unmixing of the rutile in solid solution takes place.

b- Rutile exsolutions:

Exsolution of rutile in ilmenite is far less common than those of titanhematite. Basta (1959 b) indicated that there is a limited solid solution between rutile and ilmenite which does not exceed 6 % $Ti\ O_2$ at about 1050°C.

c- Magnetite exsolutions:

According to Basta (1953 - 1960), a limited solid solution between magnetite and ilmenite and it is possibly in the range of 3 - 4 % at 1050°C. with temperature fall, the magnetite is exsolved as fine needles parallel to (0001) planes of ilmenite. Boctor (1966) indicated that such intergrowths are rare in the ilmenite of Rosetta and Damietta black sands. He also noticed that in some twinned ilmenite grains few relatively coarse tabular lamellae or fine grains of magnetite are developed inside the twin lamellae. According to Ramdohr (1956), the loosening of the ilmenite lattice due to twinning facilitates the absorption and migration of the hematite exsolutions later reduced to magnetite.

5- Atomic substitution:

According to Hammoud (1966), the manganese content in the Egyptian beach ilmenite ranges from 1.2 to 1.8 % Mn O. This can be explained by the fact that the elements Ca, Mg, Ni, Cu, Co and Mn. can substitute for the Fe^{+2} ion in ilmenite. According to Goldschmidt (1954) Cr^{+3} and V^{+5} may replace 2 Ti^{+4}. Hammoud (1966) stated that the vanadium content in the Egyptian beach ilmenite is ranging from 0.05 to 0.12 % V_2O_5 and also it contains chromium ranging from 0.10 to 0.38 % $Cr_2\,O_3$.

Mass Magnetic Susceptibility:-

Ilmenite was found to cover a wide range of magnetic susceptibility. It was recovered within 3,000 - 7,000 Oersted ranges with maximum attractability at 4,000 - 6,000 Oersted. Hammoud (1966) found that Egyptian ilmenite develops an increase in magnetic susceptibility after roasting. This begins to take place at 300°C. and is pronounced in material heated to 450°C. A sample of the roasted (420 - 450°C.) magnetised ilmenite was fractionated magnetically by hand magnet. The strongly magnetic fraction