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Investigation on Mineralogical and Chemical Characterization of Ilmenite Deposits of Northern Keral Coast, India

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Abstract: Surface samples have been collected from Kerala coast, Valapatanam-Azhikode deposit of northern Kerala coast. The average heavy minerals percentage shows 30.32 %. The heavy mineral assemblage of samples from area showed an appreciable percentage of opaque followed by sillimanite and zircon. The chemical analysis carried out for the present investigation, is detailed as Ferrian ilmenite. X-ray diffraction analysis of ilmenite shows characteristic peaks of ilmenite and some altered phases of hematite mineral. Micro-morphological studies of Ilmenite were carried out using SEM.

Key words: Heavy minerals % Non magnetic minerals % Iso dynamic separator % Ilmenite characterization % XRD % SEM % Kerala coast

INTRODUCTION

Heavy minerals such as ilmenite, monazite, zircon, sillimanite and garnets are important economic resources as they are useful in many industries for various applications. The known deposits of heavy minerals in India are at Chavara(Kerala), Ratanagiri (Maharastra), Manavalakurichi (Tamil Nadu) and Gajram(Orissa). The placer deposits are considered economically viable deposits because of profitability and easy mineablity. Better profit and development of cost-effective indigenous technology both in mining and processing are the main factors for its increasing importance over the years [1]. The alteration process gives rise to distinct phases, i.e., a parent or resistate phase and the newly formed or neo formed authigenic phase distributed in an orderly or disorderly manner along with the resistate [2]. Economical heavy minerals in the coastal zone have created much interest for exploration and exploitation in many parts of the world [3-6].

In India, a two stage model for pseudo-rutile formation from the ilmenites of Manavalakurichi region has been reported [7] and the alteration of ilmenites from the river Valliyar and Manavalakurichi beach has been outlined [8]. Along the Ratnagiri coast, the provenance of offshore ilmenite placers, based on geochemical studies has been dealt in detail [9, 10]. From South India, a detailed account of alteration characteristics of ilmenites has been enunciated [11-14]. In view of the above detailed investigations of heavy minerals were undertaken in the Northern Kerala coast. The present study deals with the detailed mineralogical and characterization studies of samples from the North Kerala coast.

MATERIALS AND METHODS

Some of the heavy mineral concentrations like at Valapatanam-Azhikode, are found to extend southwards from the mouth of major rivers [15]. This may be due to the combined sorting action of the high-energy waves and long shore currents during monsoon period. The coastal land consists of crystalline rocks of Archaen age, sediments of tertiary age and laterite capping on crystalline and sediments of sub-recent to recent age. The crystallines include charnockites and Khondalites, granite gneisses and granites traversed by basic rocks. Charnockite is wide spread in the hill ranges of Western Ghats. Hornblende and biotite gneiss occur locally and are derived by retrograde metamorphism and migmatisation of biotite gneiss.

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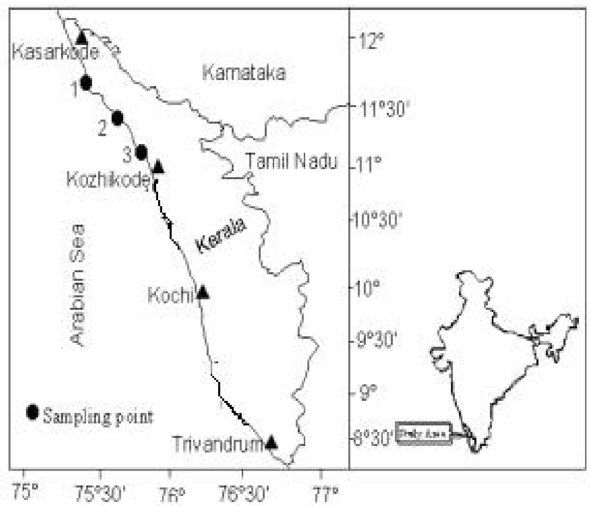


Fig. 1: Location map and sampling station

Khondalitic rocks are exposed in the south Kerala and Palghat districts. Quartz and pegmatite veins are intrusive into charnockites and schists. Dolerite, basalt and gabbro cut across the crystalline rocks variegated sandstones and clays of Miocene age with lignite grains overline the compact sands and clays with shell fragments. Laterite is the product of residual chemical weathering of the crystalline rocks and tertiary sediments and forms flat-topped hills and ridges between the foothills of the western ghat and the Arabian Sea.

Heavy minerals in fractions of sands were separated using bromoform following the procedure mentioned in [16] and the count percentage of heavy minerals from selected samples was calculated. The heavy fractions were mounted on slides (~250 grains) and counted under polarized light using a Leitz orthoplan microscope by the line counting method [17]. Using a horseshoe hand magnet, magnetic minerals were removed from the separated heavy mineral fractions and their weight percentages were estimated. Further, the samples were subjected to magnetic separation using Frantz isodynamic separator to separate magnetic and non-magnetic fractions. A forward slope of 15° and a slide tilt of 12° at 0.5 Amp and 0.4 Amp were used to separate non-magnetic, magnetic and ilmenite fractions respectively. For XRD analysis, the ilmenite grains were powdered and the powdered samples were run from 10° to 60°22, using a Phillips X' Pert X-ray diffractometer. SEM studies using Jeol-JSM 5600 LV microscope on ilmenite samples were also carried out to understand mineral alteration and micro morphology. Powdered ilmenite is brought into solution by fusion with $KHSO_4$ and dissolution in hot dilute H_2SO_4. Titanium is determined by reducing titanium IV to titanium III using aluminum metal and titrating with standard ferric ammonium sulphate [18-19]. The total iron is estimated by stannous chloride reduction-$K_2Cr_2O_7$ titration method. The content of FeO in the ilmenite is analysed by treating the powdered ilmenite with HF-H_2SO_4 mixture and titrating with Standard $K_2Cr_2O_7$ [20].

RESULTS AND DISCUSSION

Heavy Minerals: Weight percentage of heavy minerals varies from 21.74 to 36.88 % (av. (30.32 %); samples 1-3 register a significant enrichment of heavy minerals (Table 1).

The heavy mineral assemblages of the study region is generally represented by the predominant minerals like opaque, zircon, silimenite, garnet, pyroxene and amphibole minerals on the basis of the nature, colour, typical digenetic activities.

The mineralogical analyses of heavy minerals obtained from the study area are summarized in Table 2. The dominant heavy minerals in the beach sand samples in the northern sectors are opaques (magnetite and ilmenite), sillimanite and rutile. The samples also contain lower concentrations of zircon, starolite, garnet, amphibole, chlorite and Kyanite. There are a number of other heavy minerals which occur in very small amounts.

Table 1: Heavy mineral weight percentage

Sample No	Heavy mineral %
1	21.74
2	32.35
3	36.88
Avg	30.32

Table 2: Distribution of heavy minerals (%)

SI.No	Heavy Minerals	1	2	3
1	Amphibole	2.23	3.29	5.05
2	Chlorite	0.89	1.87	0.84
3	Epidote	1.77	-	1.59
4	Garnet	1.34	1.88	1.24
5	Kyanite	1.79	0.94	2.63
6	Opaque	73.13	69.50	69.67
7	Pyroxene	-	-	0.79
8	Rutile	7.12	10.34	8.44
9	Sillimanite	9.26	10.66	10.59
10	Starolite	1.96	1.05	4.56
11	Tourmaline	1.60	1.57	2.49
12	Zircon	4.42	3.73	2.38
13	Others	5.16	4.91	3.46

Table 3: The relative weight of the mineral

Sample No	Wt. %of Ilmenite	Wt. % of Garnet
1	1.05	1.01
2	1.49	0.36
3	1.04	0.29

Table 4: Chemical analysis and alteration stages of ilmenite

Sample No	FeO	Fe_2O_3	Total Iron	TiO_2	Ti/Ti+Fe	Alteration stage
1	30.48	20.46	38.00	43.42	0.41	Ferrian Ilmenite
2	17.07	20.96	27.93	41.00	0.47	Ferrian Ilmenite
3	18.97	26.19	33.07	40.92	0.43	Ferrian Ilmenite

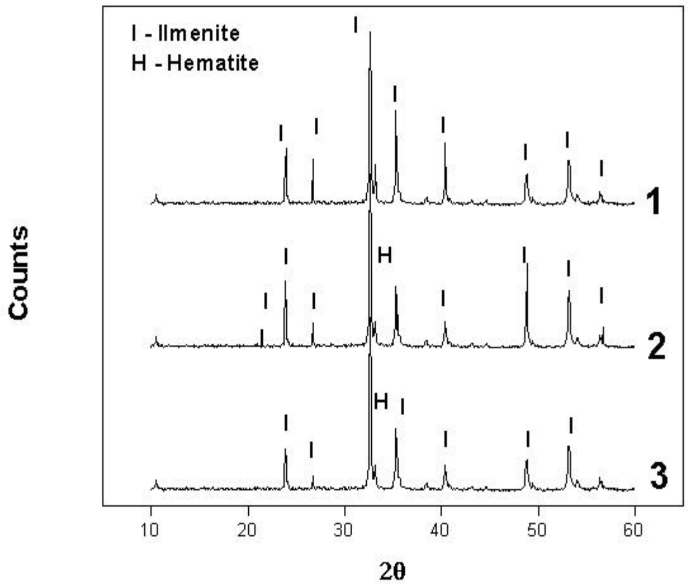


Fig. 2: X-Ray diffractrograms of representative ilmenite from northern sector

Non-magnetite Minerals: The non-magnetite Minerals are subjected to iso-dynamic separation. Initially the samples were fed into the separator maintained at a magnetic field of 0.5A.It was observed that under the above amperage, both garnet and ilmenite separated to gether. The magnetic fraction separated at 0.5A was further fed into the separator maintained at a field of 0.4A for further separation of ilmenite from garnet.

The relative weight of the mineral phases separated in the above separator is given below.

Characterization of Ilmenite in Kerala Coast: The TiO_2 content of the ilmenite of northern deposit is 41.78 %. The FeO content are 22.17%. Northern area shows 22.54% of Fe_2O_3. (Table 4). Even though Brazilian ilmenite is more weathered than the Indian ilmenite, its TiO_2 content is low due to lesser removal of ferric oxide by leaching [15].

The TiO_2 content of the ilmenite separated from the samples of the study area varies from 40.92 to 43.42 % where as the iron content varies from 27.93 to 38 %.

Some of the samples from the study area have TiO_2 and iron content far away from the theoretical ilmenite composition.

The chemistry of iron and titanium in the ilmenite mineral structure is the most evident and direct indicator of the stage of alteration undergone. While the oxidation stage of iron is defined by the ferrous-ferric conversion, as the first stage of alteration, the latter process is the function of the leaching of iron from the mineral structure and the corresponding enrichment of titanium. Thus the study of major elements of ilmenite have implications on the quality of ilmenite ore.

Different elemental ratios have been proposed to delineate the weathering mechanisms in ilmenite. Forst *et al.* [21] has classified ilmenite alteration into four stages based on the Ti/(Ti+Fe) ratios. The terminology of those stages in the order of increasing stage of alteration is as follows. The Ti/ (Ti+Fe) values for different stages of alteration are Ferrian Ilmenite' (<0.5),'Hydrated Ilmenite' (0.5-0.6), 'Pseudorutile' (0.6-0.7) and 'Leucoxene' (>0.7). This system of classification has been used in this work for chemical characterization of ilmenite based on the major element chemistry. The chemical analysis carried out for the present investigation, is detailed in Table 4.

X-ray Diffraction Analysis: X-ray diffraction pattern of ilmenite of the northern sector shows the presence of ilmenite and hematite phases (Fig 2).

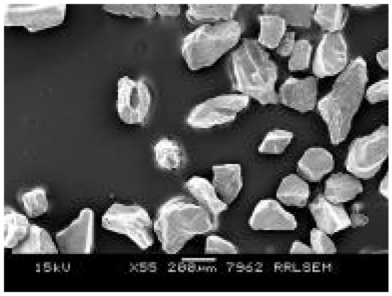


Fig (a) Angular to sub rounded ilmenite

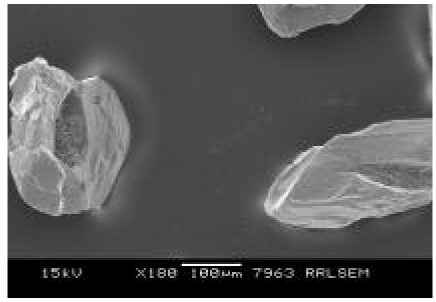
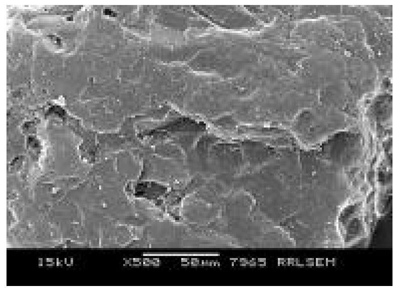


Fig (b)Micro cavity in ilmenite



(c) Altered surface of to Ilmenite grains

Fig. 3: SEM photo of ilmenite from northern sector

Scanning Electron Microscopic Investigations: Micro morphological studies of ilmenite from the northern sector (Fig. 3 a to c) using SEM reveal different features. Kringsley and Doornkamp (1973) [22] used the surface textures of quartz grains in order to achieve and understand the post depositional or digenetic history of the sediments. The relatively limited alteration of ilmenite in the study area is attributed to its occurrence in active, high energy depositional environment, where only the non stable minerals remain preferred and the almost entire absence of digenetic process.

These features are described by mechanical and chemical processes. Shape of ilmenite grain from the northern sector is angular to sub rounded (Fig.3a) which indicates that the grains would have been the product of disintegration of the parent rock and later transported and deposited in the area. Micro cavity and altered surface of ilmenite (Fig. 3 b, c) are due to mechanical and chemical processes. High-energy conditions and the aquatic transport system have given rise to cavities and alteration.

CONCLUSION

The heavy mineral distributions in the northern sector bring out a characteristic variation. Assemblage studies also show characteristic variation in the northern sector. Higher weight percentage of opaque is recorded in northern area. The chemical analysis of fractionated samples of northern areas indicates that the composition of the mineral varies with in the deposit along the length. It is also observed that the ilmenite samples of northern area contain more than 40% of TiO_2 content. Wet chemical studies reveal that the samples from the northern sector are less altered ilmenite samples. X-ray diffraction pattern shows some altered phases of mineral ilmenite and hematite. SEM studies also exemplify very low alteration of ilmenite in the study area.

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