Studies on Beach Placers of Kerala Coast

P. Bhattacharyya, B. Nayak, R. Singh & S.C. Maulik
National Metallurgical Laboratory, Jamshedpur, India

Abstract

In the present paper, studies carried out on beach placer samples of Kerala coast in general and contributions of NML and its current activities in particular on beach sands of Kerala have been discussed. While earlier beneficiation study at NML was on purification of zircon, present study, under network project, consist of characterization of samples from different areas to identify prospective area that will be taken up for development of process technology. Characterisation studies involve size and chemical analyses, sink and float studies, optical microscopy and scanning electron microscopy. Samples from four different areas (Valarpattanam Azhikod (VA), Chavakkad Ponnani (CP), Neendakara Kayamkulam (NK) and Warkala coast) were studied. It has been found that while heavy mineral concentration at NK and Warkala coast is quite high, the same at CP is rather low in comparison and at VA it's not significant.

1. Introduction

India, endowed with a coastline of over 6000 km, hosts some of the largest and richest shoreline placers. Extensive beach placer deposits are located along the coastal lines of the eastern and the western parts of India. Out of total world deposit of about 2500 million tons, India has a share of about 270 million tons i.e., about 10-11% of world reserve. The distribution of the individual minerals viz., ilmenite, rutile, garnet, sillimenite, zircon, monazite etc. in the deposit varies from place to place according to the natural process of formation and the proveniance of the deposit and accordingly determines its economic value. The state of Kerala is by far the best in India, in terms of titanium mineral placer resources - especially of ilmenite, with over 60% of contained TiO2 in the world's leading ilmenite deposit at Chavara - 127 million tonnes of total heavy minerals of which ilmenite accounts for 79.45 million tonnes.

In India major beach sand deposits are found in the states of Tamilnadu, Kerala, Orissa and Andhra Pradesh. Ilmenite-rich major beach and dune sand deposits occur in the coastal stretches of Kerala (Chavara), Tamilnadu (Manavalakurichi, Midalam, Vayakallur), Andhra Pradesh (Kakinada, Pentakota, Bhimunipatnam, Konada Kandivalasa-Mukumpeta-Bendicreek-Donkuru), Orissa (Sanaeka-sangi-Gopalpur, Chatrapur, Bajarkot, Satpara and Puri) and Maharashtra (Kalbadevi, Newre and Malgund). Rich concentration of almandine-rich garnet (upto 31% in the raw sand) is observed in the 68 km beach stretch of Navaladi-Periathalai, South of Tiruchendur in Tamilnadu. The red Teri inland sands occurring in the coastal plains of southern Tamilnadu contain HMs upto 10% and occupy vast tracts with large tonnage of heavy minerals. The Indian ilmenites commonly contain 50 to 65% TiO2 and are suitable for various process-technologies. Zircon, monazite and sillimanite are ubiquitous in both the beach and inland red Teri sands and constitute potential co-products. The Indian resources of placer minerals are : 348 million tonnes (Mt) of ilmenite, 107 Mt of garnet, 21 Mt of zircon, 18 Mt of rutile, 8 Mt of monazite and 130 Mt of sillimanite. Indian resources constitute about 35% of world resources of ilmenite, 10% of rutile, 14% of zircon and 71.4% of monazite. India meets about 10% of the world requirement of garnet. This unique status is largely due to the exploratory efforts of the Atomic Minerals Directorate for Exploration and Research (AMD) of the Department of Atomic Energy, Government of India since 1950's [1].

Manavalakurachi of Tamilnadu, Chavara in Kerala, Bhimlipatnam in Andhra Pradesh and Chatrapur in Orissa, Indian Rare Earths Ltd., a Govt. of India undertaking functioning under the Department of Atomic Energy, is actively engaged in beach sand mining and processing in India. Kerala Minerals and Metals Ltd. (KMML), an undertaking of Kerala State Government, is also engaged in beach sand industry in a small way in the state of Kerala [2]. R&D studies, carried out to recover values from placer deposits of different coasts of India at CSIR Laboratories viz., National Metallurgical Laboratory (NML), Jamshedpur, Regional Research Laboratory, Bhubaneswar etc., since 1953, have also been reported [3]. NML had earlier carried out R&D study on sample from Kerala coast and has been involved presently in characterization and beneficiation studies on beach placers from Kerala-Karnataka coast under CSIR networking programme during Tenth Five Year Plan. It is time to set up downstream industries for better utilisation of and much higher returns from these placer minerals instead of exporting them in raw form. This calls for development of suitable technology towards exploitation of unexplored deposits for effective utilisation of yet-to-be explored placer deposits leading to conservation of national resources and boost to national economy.

2. Beach Placer Deposits of Kerala

Beach placer deposits are characterised by diverse nature, mineral assemblage, concentration and tonnage. The variations are attributable to the geologic, geomorphic, climate, tectonic, structural, biotic and hydrodynamic regimes. The state of Kerala is by far the best in India, in terms of titanium mineral placer resources - especially of ilmenite, with over 60% of contained TiO2 in the world's leading ilmenite deposit at Chavara - 127 million tonnes of total heavy minerals of which ilmenite accounts for 79.45 million tonnes. Concept of mineralogical provinces-classification, based on heavy mineral constituents, can be applied for Kerala deposits. Beach placers of Kerala coast contain 7-64% THM (Total Heavy Mineral) in it. The southern Kerala forms ilmenite-sillimanite province containing essentially of these minerals with zircon whereas the northern Kerala is pyriboles-ilmenite province of essentially pyriboles and seconded by ilmenite. Charnockites and khondalites contribute for ilmenite-sillimanite province whereas hornblende-biotite gneisses and retrograded rocks for pyriboles-ilmenite province. The geomorphic features of the south Kerala are excellent favouring the formations of placers and the localisation is mainly by long-shore drifts.

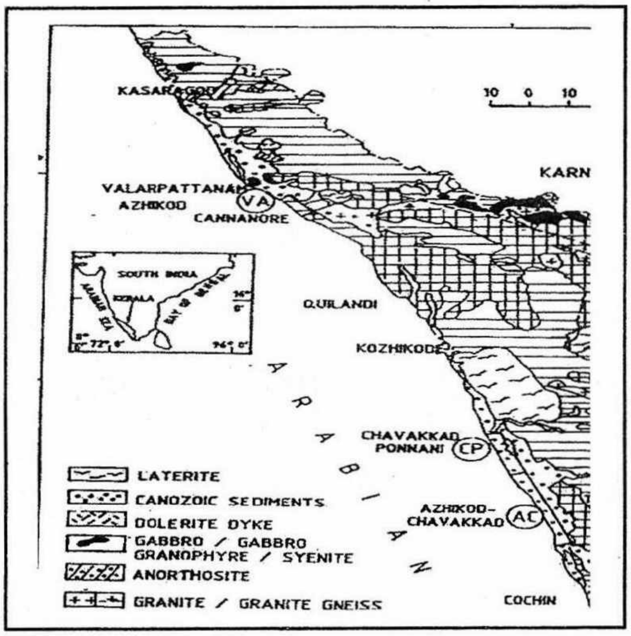


Figure 1: Geological map showing explored beach placer deposits of Kerala

In addition to the major deposit of Chavara, many other deposits/occurrences have been identified by the exploration work of AMD. Geological map showing explored beach placer deposits/occurrences of Kerala is presented in Figure 1. The deposits/occurrences to the south and in the northern contiguity of Chavara, are ilmenite-rich with prevalent leucoxenisation. Viable mineralisation is recorded in lake bed sediments and also in sea bed sediments off the Chavara coast. The deposits/occurrences in the northern Kerala at Azhikode-Chavakkad, Chavakkad-Ponnani and Valarpattnam-Azhikode are pyribole-predominant, ilmenite-depleted and, hence, not of economic interest concurrently [4].

3. Contribution of the National Metallurgical Laboratory, Jamshedpur

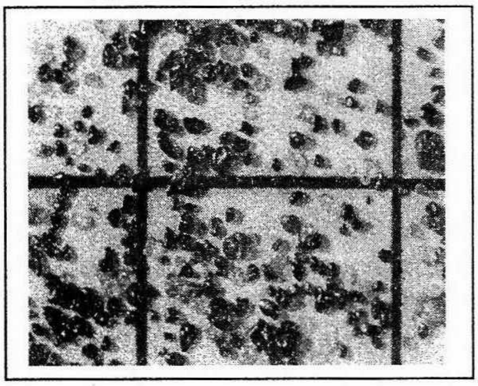
A number of studies carried out at National Metallurgical Laboratory, Jamshedpur, since 1953, to recover titanium zirconium bearing minerals along with other products from beach sands of Kerala, Gujarat, Maharashtra and Tamilnadu. For processing of beach placers, several equipment viz., spiral, table, hydrocyclone, high and low intensity magnetic separators, high tension separator and flotation cell etc. were used after careful study of the minerals and impurities present in the particular sample [5].

Recently, under network project, a grab sample of beach sand was collected from the beach of Warkala in the Kerala coast. It has been found that more than 90% material were in the size range of -20+100 mesh. It was interesting to note that while 0.1% were above 10 mesh, only 0.04% were found to be below 200 mesh. One representative fraction was subjected to float and sink test. From the beach sand of Warkala Coast, Kerala, the heavies were separated by using bromoform (density: 2.82). The bromoform float consists of gangues that are mainly quartz with minor feldspar and shell fragments. In general the average size of the float/gangue minerals is higher (~

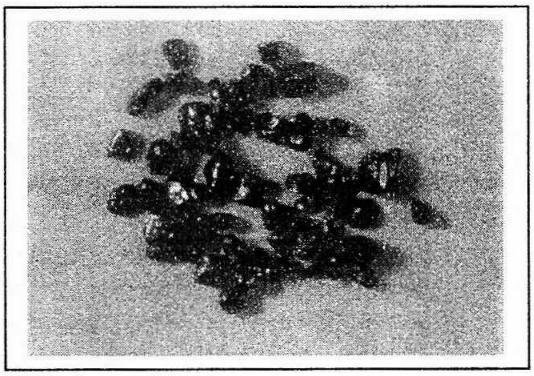
600 μm) than that of the heavies (~ 250 μm). The proportion of heavies was 54.6% by weight. The heavies that are identified are mainly ilmenite, sillimanite, garnet, zircon, iron oxide, apatite and monazite. Ilmenite is the dominating phase, sub-rounded in nature and has a moderate grain size. Though other phases have suffered rounding, the angularity is more prominent in the garnets. The quantitative modal distribution of different minerals in the Warkala sample is given below.

Mineral	Ilm.	Sill.	Gar.	Zir.	Mon.	Iron oxide	Apatite
Modal %	78.6	10.1	2.1	2.4	3.4	2.1	1.3

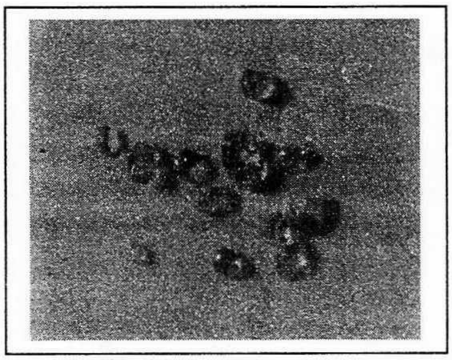
Some of the heavy minerals are shown in photos (1-3).



Ph. 1 Heavy mineral containing ilimenite, gamet,zircon and monzite



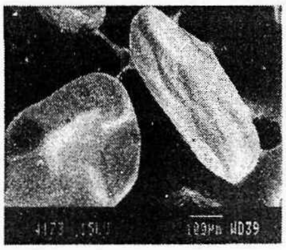
Ph.2:Separated fractions of ilimenite



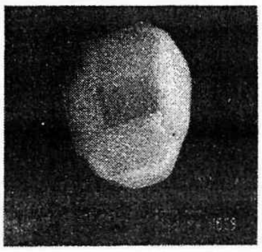
Ph.3.: Separated fractions of Zircon

Examination under stereomicroscope reveals that all Ilmenite grains are not in purer form. Some of them contain impurities inherited from the parent rock. These are inter-grown with other gangue minerals and some retain the relics of originally associated minerals (mainly silicate) which are seen as brown coatings/scales. Both types, the pure and impure ilmenites have been studied under scanning electron microscope (SEM) and have been analysed with EDAX. The results show that the purer variety contains Fe and Ti around 35 and 57 atomic percent with minor impurity of alumina. The gangue mineral that occurs as scales with the impure variety of ilmenite has also been analysed. This gangue mineral is a Fe-Mg-Al silicate and has also suffered some alteration. The atomic percentages of Fe, Mg, Al and Si in this phase are 40.2, 3.2, 20.9 and 21.5 respectively. It also reveals about 10 atomic % of Ti. However, the real composition may have lesser Fe and Ti and higher Mg, Al and Si. This is because of the thinness of the mineral and therefore, some of the signals of Fe and Ti may have been captured from the host ilmenite.

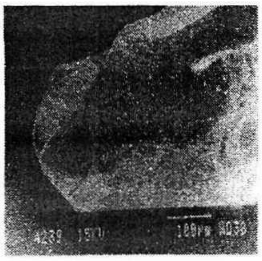
On the Warkala sample, Scanning Electron Microscopic (SEM) studies were undertaken along with in-situ micro-chemical analysis of individual mineral phases by EDAX. In addition, similar studies have been undertaken on garnet, sillimanite and zircon. The SEM photomicrographs of Ilmenite, garnet and zircon are presented in photos (4-6). Compositionally the garnets are found to be iron rich and belong to the almandine variety.



Ph. 4: Secondary Electron Image(SEI) of two Ilmenite grains. One is elongated and the other is sub-rounded



Ph. 5: SEI of a zircon crystal that shows original faces of the crystal.



Ph.6: SEI of a garnet grain showing fracture Surfaces and differential weathering.

Studies with three samples, received from three different localities of Kerala Coast viz., Valarpattanam Azhikod (VA), Chavakkad Ponnani (CP) and Neendakara Kayamkulam (NK), as shown in figure 1, were also carried out. The VA, CP and NK had 15, 21 and 14 sub-samples respectively. The sub-samples in each category were mixed and the composite samples were prepared. All the three samples have been subjected to heavy liquid separation. The NK-sample is exceptionally rich with the heavy minerals. The total heavies account for 86.1 % by weight. The lighter fraction mainly consists of quartz while the heavy fraction consists of ilmenite, sillimanite, garnet, zircon and monazite. While ilmenite dominates the scene, the concentration of zircon and monazite is very low. Chemical analysis and size analysis of NK sample are given Tables (1 and 2). While NK sample was found to contain 42.53% TiO_2 in it, CP and VA were found

Table 1: Size Analysis of composite NK-sample

Sieve Fraction	Wt. %	Cum. Wt.%
+10	1.3	1.3
-10 +14	0.4	1.7
-14 +20	0.7	2.4
-20 +28	1.3	3.7
-28 +35	2.9	6.6
-35 +48	8.5	15.1
-48 +60	17.1	32.2
-60 +100	53.9	86.1
-100 +150	12.4	98.5
-150 +200	1.3	99.8
-200	0.2	100

Table-2: Chemical composition of composite NK-sample

Constituent	Weight %
TiO_2	42.53
FeO	5.37
Fe(t)	15.86
Al_2O_3	5.08
SiO_2	20.40
ZrO_2	5.45
P_2O_5	0.43
Ca	0.28
Mg	0.37
Mn	0.18
Na_2O	0.11
K_2O	0.02
LOI	1.35

to contain only 2.63% and 1.43% TiO_2 respectively. It was also found that total heavies in CP and VA were 25.2% and 14% respectively. Beneficiation studies with CP sample is in progress. Chemical analysis and size analysis of VA sample are given Tables (3 and 4).

Table 3: Size Analysis of composite VA sample

Sieve Fraction	Wt. %	Cum. Wt.%
+10	0.2	0.2
-10 +14	0.3	0.5
-14 +20	0.4	0.9
-20 +28	0.9	1.8
-28 +35	5.2	7.0
-35 +48	14.8	21.8
-48 +60	15.9	37.7
-60 +100	42.8	80.5
-100 +150	16.3	96.8
-150 +200	2.4	99.2
-200	0.8	100

Table-4: Chemical composition of composite VA sample

Constituent	Weight %
TiO_2	1.43
FeO	3.65
Fe(t)	4.38
Al_2O_3	4.86
SiO_2	78.86
ZrO_2	0.09
P_2O_5	0.13
Ca	2.26
Mg	0.86
Mn	0.05
Na_2O	1.0
K_2O	0.6
LOI	2.44

NML has been actively involved in the CSIR network project, under Fourth Five Year Plan, on Capacity Building for Coastal Placer Mining since its inception during 2002, as one of the members under taskforce Mineral Processing and value addition. Though samples from Kerala-Karnataka coast, are to be studied under network project, NML is well equipped with facilities and expertise, both at bench and pilot scale level to take up any assignment on treatment of beach placers.

4. Discussions

It has already been mentioned that IREL is actively engaged in beach sand mining and processing at Chavara, Kerala. KMML is also engaged in beach sand industry in a small way in the state of Kerala. Over the years, the quality of beach washings has come down drastically. The limited availability of these seasonal accruals has forced IREL to depend on the inland beach deposits as the primary source of feed material. The inland deposits have a complex mineral assemblage compared to the beach washings. The heavy minerals are finer in size. The major

gangue mineral quartz is of wider size range and the content of fine quartz is relatively higher in the inland deposits [6]. Most mineral processing treatment including gravity separation, magnetic separation, electrostatic separation, flotation has a limiting minimum particle size beyond which the separation is not effective. The inherent difficulty in recovering very fine particles is to be properly addressed and it is expected that the new ideas and improved technology will enable the mineral engineers and allied technologists in meeting the challenges.

Proposed studies, under CSIR network project, on Kerala-Karnataka beach placers of yet to be explored deposits are expected to be very useful for Central/State Govt. as well as Small Mines Owners for future consideration. If suitable technology could be developed to recover valuable minerals from unexplored deposits even private owners could be interested to set up industries to their benefit.

5. Conclusion

- Huge reserves of valuable heavy minerals in beach placers along coastal lines of India should be utilised to the best possible advantage of the nation.
- Small Miners should encourage R&D studies, to develop process technology by the National Laboratories having capabilities for the same, to their advantage and ultimate benefit.
- Close interaction between associated industries and R&D laboratories to be established for implementation of the technology.

6. Acknowledgement

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7. References

1. M.A. Ali, S.Krishnan and D.C.Banerjee : Beach and Inland Heavy Mineral Sand Investigations and Deposits in India - An Overview, Exploration and Research for Atomic Minerals (Special issue on Beach and Inland Heavy Minerals Sand Deposits of India), Vol.13, 2001.
2. A.S.Siddique, A.K.Mohapatra and J.V.Rao : Separation of Beach Sand Minerals, Processing of Fines (2), NML Publication, Eds. P.K.Bhattacharyya, Ratnakar Singh and N.G.Goswami, pp.114-126, 2000.
3. Peravadhanulu, P.D. Prasada Rao, G.P. Mathur & V.A. Altekar : Beneficiation of Beach Sands, Monograph on Ores and Minerals of India, NML Publication, Vol.II, pp.272-275.
4. S.Krishnan, G.Viswanathan and K.Balachandran : Heavy Mineral Sand Deposits of Kerala, Exploration, Exploration and Research for Atomic Minerals
5. (Special issue on Beach and Inland Heavy Minerals Sand Deposits of India), Vol.13, 2001.
6. P. Bhattacharyya, R. Singh and J.P. Srivastava : Recovery of values from Indian Beach Placer Deposits, Sustainable Development of Costal Placer Minerals, Proceedings of Nat. Sem. (PLACER-2004), Eds: V.J. Loveson and D.D. Misra, pp-151-169, 2004.
7. N.R.Nair and T.K.Mukherjee : Various aspects of fines in separation and processing of beach sand minerals in India, Processing of Fines (2), NML Publication, Eds. P.K.Bhattacharyya, Ratnakar Singh and N.G.Goswami, pp.93-99, 2000.