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Studies on Medium Grade Ilmenite-Depleted Beach Placer Deposit of Chavakkad Ponnani Coast, Kerala

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Abstract

In the present paper, characterization, beneficiation and further value addition studies carried out with samples collected from unexploited Chavakkad Ponnani (CP) area of Kerala coast have been reported. Characterisation studies involve size and chemical analyses, sink and float studies and optical microscopy. Total 21 samples were collected from 18 km. stretch of CP area at almost 1 km. apart. While sink and float studies and optical microscopy were carried on with all individual samples, detail characterization and beneficiation studies were undertaken with two composite samples - one prepared from all 21 samples and the second from few selected samples. Pre-concentration followed by high tension separation and magnetic separation yielded product containing more than 95% THM with around 90% recovery. Further value addition studies with generated ilmenite concentrate was found to produce synthetic rutile, through reduction followed by oxidation and leaching, containing more than 94% TiO_2.

INTRODUCTION

India, endowed with a coastline of over 6000 km, hosts some of the largest and richest shoreline placers. 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. A combination of favourable factors like the hinterland geology, coastal geomorphology, sub-tropical to tropical climate and intricate network of drainage, aided by wind and coastal processes like waves and currents, have influenced the formation of beach and adjoining dune sands. 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 TiO_2 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. 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. The geomorphic features of the south Kerala are excellent favouring the formations of placers and the localisation is mainly by long-shore drifts. 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 and ilmenite-depleted (Krishnan et al. 2001). These are low/medium grade deposits containing 12-25% THM.

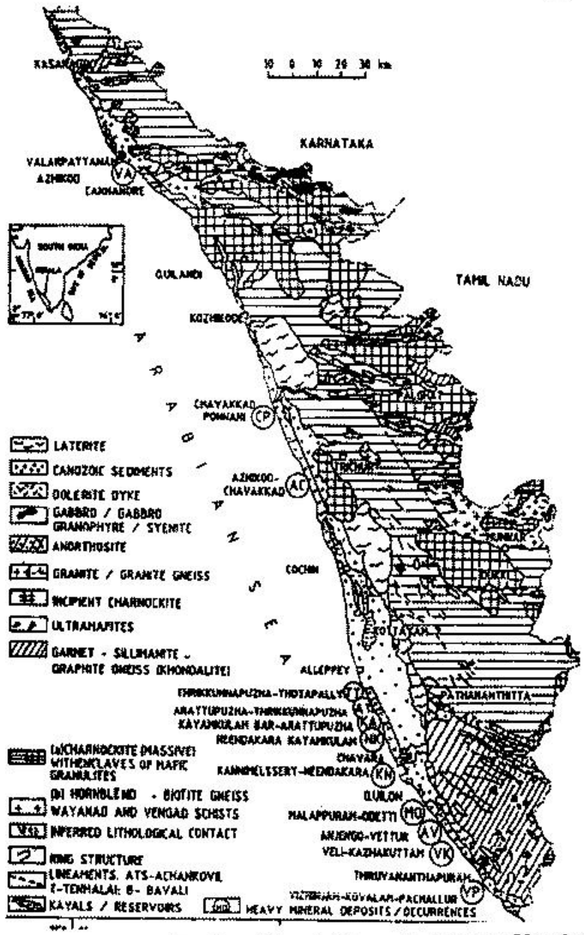

Fig. 1: Geological Map Showing Explored Beach Placer Deposits of Kerala [2]

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 (Manavalakurachi of Tamilnadu, Chavara in Kerala, Bhimlipatnam in Andhra Pradesh and Chatrapur in Orissa). 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 (Ali et al. 2001). R&D studies, carried out to recover values from placer deposits of different coasts of India at CSIR Laboratories viz., National Metallurgical Laboratory, Jamshedpur, Regional Research Laboratory, Bhubaneswar etc., since 1953, have also been reported (Peravadhanulu 1979).

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. 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 (Siddique et al. 2000). 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 (Nair and Mukherjee 2000).

Under Tenth Five Year Plan, Council of Scientific and Industrial Research (CSIR) has identified few prospective areas to be taken up as networking programme involving its constituent laboratories and, in some cases, other non-CSIR organisations to achieve best possible results towards utilisation of national resources. One of such programmes is on "Capacity Building for Coastal Placer Mining" having participation from different CSIR and non-CSIR institutions. Under this network programme, five different sub-tasks were identified to explore different new approaches. Use of GPR for mapping subsurface sand was one of such attempts (Loveson et al. 2005). National Metallurgical Laboratory (NML), Jamshedpur has been actively involved in this CSIR network project, since its inception during 2002, as one of the members under sub-task 4: Mineral Processing and Value Addition Technology. The main objective of this sub-task is to develop appropriate process technology to every categorized deposit of India. Many CSIR and non-CSIR organisations are involved under this sub-task. Characterisation and bench scale beneficiation studies on beach placer of Kerala-Karnataka coast are to be carried out by NML, Jamshedpur. Other coastal placer will be studied by other participating institutes. (Bhattacharyya et al. 2004). Proposed studies under network project on Kerala-Karnataka beach placers of yet to be exploited 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 unexploited deposits even private owners could be interested to set up industries to their benefit. 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 for effective utilisation of yet-to-be exploited placer deposits leading to conservation of national resources and boost to national economy (Bhattacharyya et al. 2005 a & b).

SAMPLE

Total 21 sub-samples, each weighing about 10 kg., were collected from 18 km. stretch of CP area at almost 1 km. apart. Sub-samples were collected by CESS-Thiruvanantapuram and sent to NML. The composite CP sample has been prepared by mixing the individual samples. It was noticed that there were distinct areas of low grade, medium grade and high grade beach placers. To initiate bench scale beneficiation studies with CP sample, the sub-samples, 21 nos., were mixed at same proportions and one composite sample (CP1) was prepared. Another composite sample (CP2) was also prepared mixing few sub-samples of selective high grade areas.

CHARACTERISATION STUDIES

The characters of individual sub-samples are quite different from each other. The colour and morphology (roundness) of the grains in a particular sample is also different. Photos (1-4), under zoom stereo microscope X 25, show some of the different varieties (according to colour) of sub-samples collected. Quartz for example is transparent in one sample (Ph.-1) and is slight brownish in (Ph.-2) while it is reddish brown in (Ph-3). The dominance of quartz in these samples also determines the overall colour of the sample (whitish, brownish white or reddish brown). The brownish colouration is a supergene phenomenon due to contamination of ferruginous solutions. The angularity and roundness of these grains also vary in individual sample. Some samples are dominantly black in colour (Ph.-4). This is because of the predominance of ilmenite that counts even more than 70% in these samples. In certain samples, the black minerals are only pyriboles and there is hardly any ilmenite, while in other cases the blacks are mostly ilmenite. Similarly, the incidence of zircon and sillimanite are quite high in some samples compared to the others. All these observations indicate different sources (provenance and original host rock) from which the minerals have originated and have been transported to varied distances.

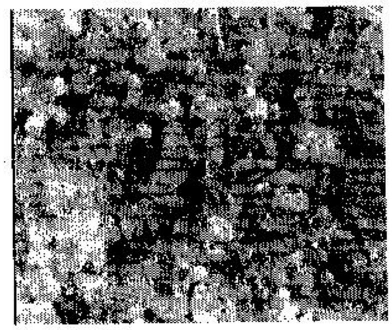

Photo-1: As-received white looking CP sub-sample Under zoom stereo microscope X 25

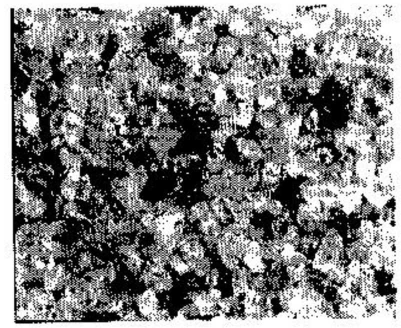

Photo-2: As-received brownish white CP sub-sample Under zoom stereo microscope X 25

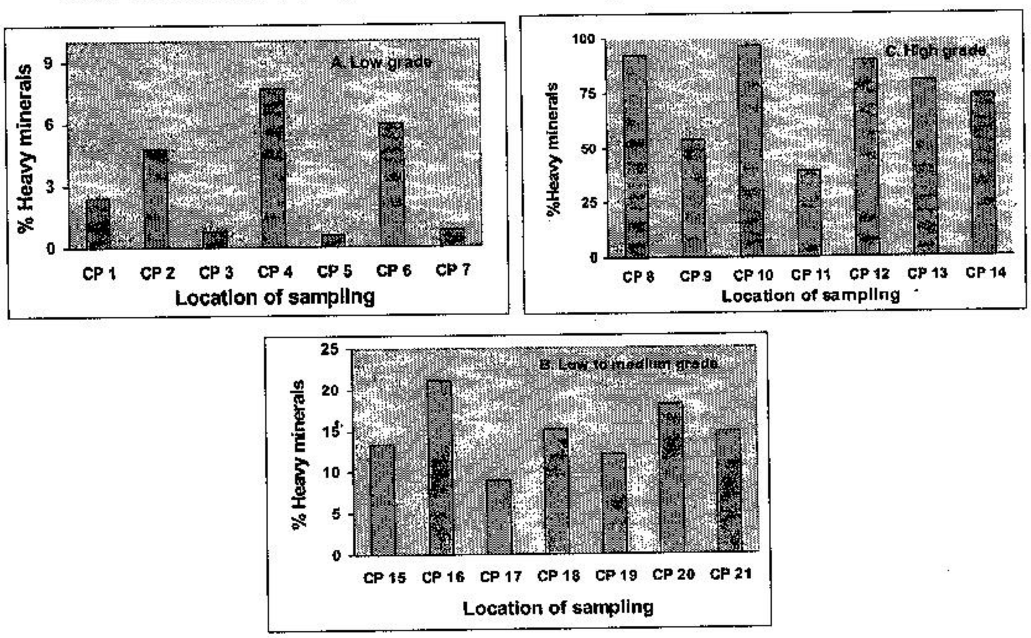

Fig. 2: Heavy Mineral Distribution at Different Sample Collection Locations of CP (Sample Nos. are According to Grouping of Grades Not Along Coast Line)

Total heavy mineral (THM) content of each sub-sample was obtained and plotted as (%THM) in fig.2. While sink and float studies and optical microscopy were carried on with all individual samples, detail characterization and beneficiation studies were undertaken firstly with one composite sample prepared from all 21 samples and then with another composite sample prepared from high grade samples. While TMH content in the first composite (CP1), mixing 21 sub-samples, was found to be 25.24%, the same in the second composite (CP2), mixing high grade samples, was obtained as 77.6%. Size and chemical analyses of CP1 and CP2 composites are given in Tables (1-4). Modal distributions of minerals in CP1 & CP2 are given in Table 5.

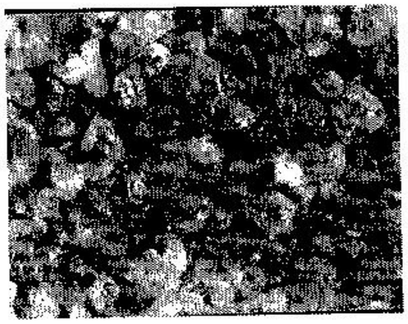

Photo-3: As-received reddish brown CP sub-sample Under zoom stereo microscope X 25

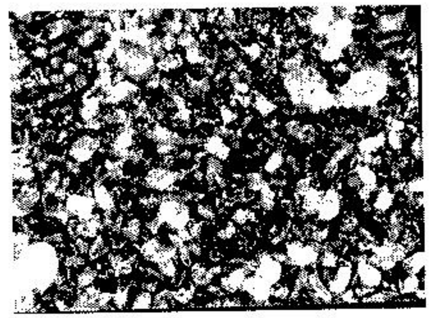

Photo-4: As-received black looking CP sub-sample Under zoom stereo microscope X 25

Table 1: Size Analysis of CP1 Composite

Size (#)	Weight %
-10 +14	0.7
-14 +20	2.9
-20 +28	6.6
-28 +35	15.3
-35 +48	21.1
-48 +160	20.8
-60 +100	25.0
-100 +150	5.5
-150 +200	0.7
-200	0.4
Total	100.0

Table 2 : Chemical Composition of CP1 Composite

Constituent	Weight %
TiO_2	2.63
FeO	5.48
Fe(t)	6.35
Al_2O_3	8.87
SiO_2	68.39
ZrO_2	0.28
P_2O_5	0.19
Ca	2.08
Mg	0.70
Mn	0.09
Na_2O	2.21
K_2O	1.73
LOI	0.58

Table 3: Size Analysis of CP2 Composite

Size (#)	Weight %
-10 +14	0.3
-14 +20	0.8
-20 +28	2.0
-28 +35	5.5
-35 +48	15.2
-48 +60	18.4
-60 +100	46.9
-100 +150	9.2
-150 +200	1.5
-200	0.2
Total	100.0

Table 4 : Chemical Composition of CP2 Composite

Constituent	Weight %
TiO_2	36.38
FeO	3.91
Fe_2O_3	15.67
Al_2O_3	7.20
SiO_2	25.07
ZrO_2	6.73.
P_2O_5	1.32
CaO	nf
MgO	1.68
Na_2O	0.26
K_2O	0.90
LOI	0.8

Table 5: Modal Distribution of Minerals in CP1 & CP2

Mineral	Modal% CP1 (%THM-25.24)	Modal% CP2 (%THM-77.6)
Ilmenite	34.2	49.59
Rutile	Trace	1.89
Hematite	1.0	0.27
Pyriboles & Tourmaline	41.6	13.51
Garnet	5.7	1.90
Sillimanite	7.9	22.84
Zircon	3.8	4.73
Monazite	Trace	2.16
Miscellaneous	4.3	3.25

BENIFICIATION STUDIES

As pre-concentration studies, CP1 composite was subjected to gravity separation. It was found that heavy fraction containing more than 99% heavy minerals could be produced but it was decided to restrict loss of values in the lighter fraction. Accordingly gravity method continued to produce bulk material for carrying on downstream operations (high tension separation, magnetic separation, electrostatic separation etc.) towards separation of valuable minerals. Lighter fraction (48.8% of CP1 composite) was found to contain <5% heavy minerals in it. Results are given in Table 6. Heavy fraction (33% of CP1 composite) was containing over 60% TMH. Some more heavy minerals could be recovered from the middling (18.2%) which will be re-circulated in the circuit. Then the heavy fraction was subjected to high tension separation followed by magnetic separation of conducting fraction. Results are given in Tables 7-8.

Table 6: Results of Pre-Concentration Study with CP1

Product	Wt.%	%THM	% Dist. (THM)
Heavy	33.0	60.7	82.8
Middling	18.2	25.6	8.6
Light	48.8	4.3	8.6
Head	100.0	24.3	100.0

Table 7: Results of High Tension Separation with CP1

Product	Wt.%	%THM	%Dist. (THM)
Cond. 1	27.5	98.0	45.1
Cond. 2	0.9	78.7	1.2
Middling	16.3	55.4	15.1
Non-cond.	55.3	41.8	38.6
Head	100.0	59.8	100.0

Table 8: Results of Magnetic Separation with CP1

Product	Wt.%	%THM	% Dist. (THM)
Mag. 1	90.7	99.0	91.5
Mag. 2	4.9	98.1	4.9
Non-mag.	4.4	81.2	3.6
Head	100.0	98.2	100.0

From Table 8, one finds that more than 95% magnetics (Mag. 1 + Mag. 2) contains nearly 99% THM which is expected to be mainly ilmenite. While middling fraction of high tension separation will again be re-circulated in the circuit, Non-cond. fraction of Table 7 and Non-mag. fraction of Table 8 will be the feed to another circuit to recover other heavy minerals like garnet, zircon, sillimanite etc.

Second composite sample (CP2), prepared from high grade sub-samples, was also subjected to the same beneficiation route and the results are given in tables (9-11). Composite CP2 is of much better quality than that of CP1 as far as TiO_2 content is concerned (Tables 2 & 4). Tables (9-11) confirm better recovery of good quality ilmenite from CP2. Photos (5-6) show ilmenite concentrate obtained from CP1 and CP2 respectively.

Photo 5: Ilmenite concentrate obtained from CP1

Photo 6: Ilmenite concentrate obtained from CP2

Table 9: Results of Pre-Concentration Study CP2

Product	Wt.%	%THM	%Dist. (THM)
Heavy	73.7	91.1	86.4
Middling	7.9	79.1	8.1
Light	18.4	23.2	5.5
Head	100.0	77.7	100.0

Table 10: Results of High Tension Separation CP2

Product	Wt.%	%THM	%Dist. (THM)
Cond. 1	51.16	98.41	54.74
Cond. 2	17.48	92.46	17.57
Middling	2.80	85.29	2.59
Non-cond.	28.56	80.81	25.1
Head	100.0	91.97	100.0

Table 11: Results of Magnetic Separation CP2

Product	Wt.%	%THM	% Dist. (THM)
Mag. 1	84.7	99.76	85.0
Mag. 2	10.2	99.51	10.2
Non-mag.	5.1	93.89	4.8
Head	100.0	99.44	100.0

VALUE ADDITION

Ilmenite concentrates generated from CP1 and CP2 were subjected to beneficiation studies using a new process developed and patented by RRL, Trivandrum.

The process involves essentially the following steps:

1. Carbothermic reduction of ilmenite to convert the iron oxide to metallic iron.
2. Catalytic conversion of the metallic iron to solid iron oxide which can be easily separated from the aqueous medium.
3. Rutilation of the product at higher temperature which is essentially an oxidation step
4. Dilute HCl leaching of the rutileted product.

Reduced ilmenite after removal of coal ash etc. is subjected to catalytic rusting where all the metallic iron is converted iron oxide. The rusted product is subjected to rutilation which is essentially oxidation at higher temperature is subjected to diluted leaching at slightly elevated temperature to yield synthetic rutile. The product synthetic rutile obtained contained more than 94% TiO_2 in it.

Samples of ilmenite concentrates CP1 and CP2 can be easily converted to be synthetic rutile and is comparable with standard ilmenite samples. It lies between the rich Quilon ilmenite and the Manavalakuri ilmenite.

CONCLUSION

From the above study it can be concluded that good quality ilmenite, which in turn easily be converted to synthetic rutile, can be recovered from beach placers of unexploited CP area. Keeping in view the future global need for titanium, present study has immense importance towards conservation of national resources and boost to national economy.

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