Characterization of Srikurmum and Navaladi Beach Placer Minerals

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Abstract

Two different beach placer samples from Srikurmum of Andhra Pradesh and Navaladi of Tamilnadu were collected and characterized in terms of their total heavy mineral content by heavy media as well as magnetic separation studies. Navaladi beach placer sample contains higher amounts of total heavy minerals than that of the Srikurmum beach. Mineralogical analysis on both the samples revealed high amounts of garnet and minor quantities of ilmenite. The particle size of garnet is coarser than that of ilmenite. EPMA results indicated that garnet is of almandine variety. The Eastern Ghats metamorphic belt, covering both the areas, is considered to be the source of these beach placer minerals.

1. Introduction

India is endowed with a coastline of over 6000 kilometers along the eastern and western sea boards, covering Gujarat, Maharastra, Goa, Karnataka, Kerala states on the west coast while Tamilnadu, Pondicherry, Andhra Pradesh, Orissa and West Bengal on the east coast. India is blessed with large reserves of strategic and economically important heavy minerals such as ilmenite, rutile, zircon, monazite, garnet and sillimanite along these eastern and western coastal states. Out of these six heavy beach placer minerals, the first four are prescribed as atomic minerals. Depending upon its main end uses these six different minerals are classified into titanium bearing minerals (ilmenite, rutile), abrasive (garnet), refractory (sillimanite) and nuclear (monazite and zircon) minerals. However, the workable deposits are located only around Chatrapur (Orissa); between Vizag-Srikakulam (Andhra Pradesh); between Tiruchendur and Kanykumari (Tamilnadu) on the east coast and near Chavara (Kerala) on the west coast. These placer deposits are unique due to (i) an assemblage of four to six minerals (or better termed as multi mineral deposits) in different proportions in different areas (ii) completely liberated unlike other ores (iii) heavy minerals with varying magnetic susceptibility and conductivity lend themselves for less expensive physical beneficiation methods in natural state itself (iv) naturally ground and need no grinding and (v) easy mining as these are not compacted, consolidated and cemented. The formation, identification, exploration and exploitation of these heavy mineral deposits are complex than that meets the eyes at the first sight for which one needs detail characterisation studies especially the heavy mineral content.

2. Materials And Methods

2.1 Srikurmum coast: The coastal stretch between the Nagavalli and Vamsadhara rivers in the Srikakulam district, Andhra Pradesh which is referred as the Srikurmum coast, extends over 22 kilometers in length (Fig.1) with and average width of about 700m [1]. The general trend of the Srikurmum coast is N 45° E - S 45° W with rock exposures right at the coast. Srikurmum area follows prominent lineaments trending NNW-SSE. The river Vamsadhra joins the Bay of Bengal near kalingapatnam and Nagvalli at Mopasbandar in Srikakulam district. These two small traveled rivers, originating from the Eastern Ghats terrain, and a creek (Lppi Gedda) supply the bulk of the sediments from the hinder land area [2].

2.2 Navaladi coast: Situated 17 kilometers north of Kudamkulam, the deposit extends N65°E – S65°W over a coastal length of 10 kilometers and with a width of 50 to 200 meters [3]. The Eastern Ghats metamorphic belt (Fig.2), covering both the above areas, forms the prominent hills along the east coast of India, underlain by various rock types metamorphosed to granulite facies, is considered to be the source of these beach placer minerals [4].

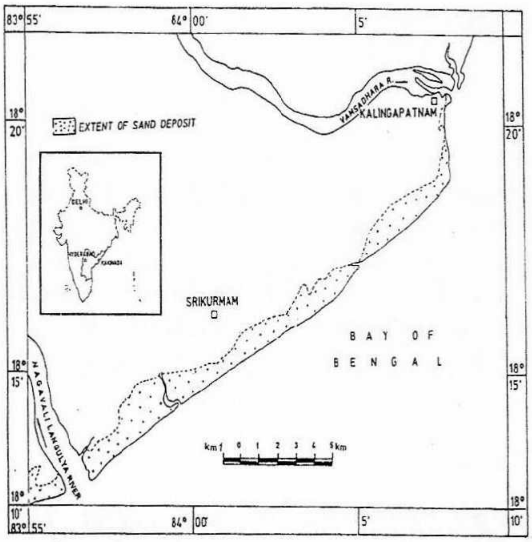

Fig.1: Mineral sand deposit of Srikurmum coast, A.P. (after Ali et al., 2001)

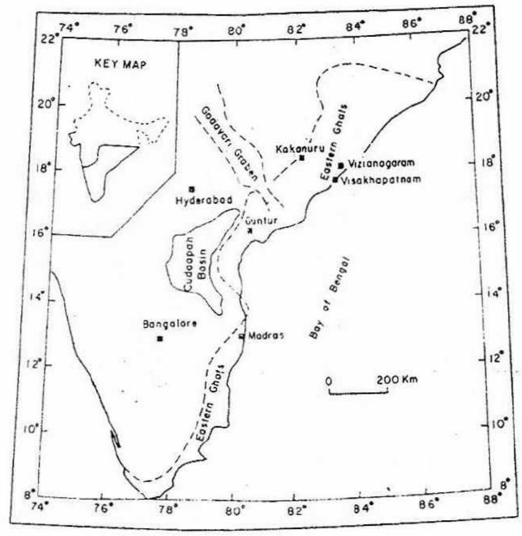

Fig.2: Map of India showing the extent of Eastern Ghats granulite belt (Kamineni et al., 1991).

Around 150 kilograms of the beach placer sample was drawn from Srikurmum as well as Navaladi area for their characterization studies. Both the samples were processed for estimation of total heavy mineral (THM) content using Bromoform ($CHBr_3$; specific gravity 2.89) as a media for separation of heavier fractions from the lighter ones. Further the sample was subjected to magnetic separation (using Permroll of 20,000 Gauss) for obtaining magnetic and non-magnetic fractions. The bulk sample was classified using ASTM sieves. After sieving each sieve fraction was again subjected to magnetic and heavy media separation. Petromineralogical studies were carried out, by stereomicroscopy as well as LEITZ Orthoplan optical microscope, to decipher the heavy mineral content. Some of the heavy minerals were analysed with the help of a JEOL EPMA Super Probe JXA – 8600 model, with an accelerating voltage of 15 kV and a specimen current of $2x10^{-8}$ A and using SPI mineral standards. Particle size analysis was carried out using a laser diffraction particle size analyzer (CILAS 1180, France) and also by standard sieves.

3. Results and Discussion

3.1 Classification: Sieve analysis of the Srikurmum ROM sample indicates that most of the material is distributed between –420 to 105 microns while Navaladi ROM sample distributed between –600 to 105 microns.

3.2 Magnetic separation: Magnetic separation studies of the ROM sample of Srikurmum, have shown 26.76% of magnetic minerals (Table 1) while the magnetic separation of the individual sieve fractions have indicated 27.50% of total magnetic minerals (Table 2). The magnetic separation of the sieve shows that the magnetic minerals are enriched slowly from coarse to fine (-600 microns to –105 microns). Similarly magnetic separation studies of the ROM sample of Navaladi area have indicated 33.22% of magnetic minerals (Table 1) while the magnetic separation of the individual sieve fractions indicated 33.15% of total magnetic minerals (Table 5).

Table 1: Magnetic and heavy media separation of ROM sample of Srikurmum and Navaladi

Area	Magnetic separation		Heavy media separation	
	Magnetic %	Non-magnetic %	Heavy %	Light %
Navaladi	33.22	66.78	34.20	65.80
Srikurmum	26.76	73.24	29.96	70.04

3.3 Heavy media separation: Heavy media separation studies of the ROM sample from Srikurmum have indicated that the sample contains around 29.96% of total heavy minerals (Table 1). However, slightly higher percentage (32.95%) of heavy minerals was obtained by the heavy media separation studies of the individual sieve fractions (Table 2). Similar phenomena were observed in case of Navaladi (Table 1 and 3). The higher amount of heavy minerals in due to the sillimanite and zircon content, which are not reported in the magnetic fractions due to their non-magnetic nature.

Table 2: Distribution of minerals in various sieve fractions of Srikurmum beach placer sample

Size distribution of the ROM sample		Distribution of magnetic and non-magnetic minerals in sieve fractions		Distribution of heavy and light minerals in sieve fractions	
Sieves (μ)	% Distribution	Mag. %	Non-Mag %	Heavies %	Lights %
+1700	0.12	Magnetic separation was not carried out as the sample fraction was very less (0.71%).		Heavy media separation was not carried out as the sample faction was very less (0.71%).	
-1700+850	0.06				
-850+600	0.53				
-600+420	2.84	0.470	2.585	0.75	4.11
-420+300	25.59	2.350	23.267	1.78	38.93
-300+210	31.64	3.760	27.027	1.66	10.25
-210+150	21.68	6.816	15.511	7.48	8.65
-150+105	11.97	8.461	3.995	13.29	4.78
-105	5.57	5.640	0.118	7.99	0.33
Total	100.00	27.497	72.503	32.95	67.05

Table 3: Distribution of minerals in various sieve fractions of Navaladi placer sample

Size distribution of the ROM sample		Distribution of magnetic and non-magnetic minerals in sieve fractions		Distribution of heavy and light minerals in sieve fractions	
Sieves (μ)	% Distribution	Mag %	Non-Mag %	Heavies %	Lights %
+1700	0.06	Not done		Not done	
-1700+850	0.60	0.03	0.52	0.13	3.05
-850+600	5.00	0.62	3.64	1.97	11.67
-600+420	10.95	2.63	7.98	3.74	11.80
-420+300	39.21	9.35	28.81	3.29	9.77
-300+210	24.56	9.00	18.07	6.03	9.49
-210+150	14.34	7.78	6.33	10.23	10.97
-150+105	4.31	3.07	1.27	9.28	3.34
-105	0.97	0.67	0.23	1.96	3.28
Total	100.00	33.15	66.85	36.63	63.37

3.4 Characterisation: The sand, from the above two beaches, comprises gravel, silty sand and medium to coarse sand followed by fine sand. The heavy minerals that are economically important associated with these beach placer sands are ilmenite, and garnet in substantial quantities and sillimanite and zircon as traces. The non-economical minerals are quartz, feldspar, hypersthene, diopside, augite, sphene, hornblende and tourmaline. Ilmenite occurs mostly as subrounded to subangular grains with moderate relief, marked by numerous surface pits. Micromorphological features noticed on the ilmenite grains include mainly itch features and signs of mechanical impact. Leucoxene and anatase occur as patches along margins, fractures and within ilmenite due to alteration. In rare instances, ilmenite was seen completely altered to anatase/leucoxene. The garnet occurs as angular to subangular grain occasionally subrounded grains and is characterized by conchoidal fracture. Common appearance of sillimanite is in the form of prismatic crystals sometimes as needle shaped crystals. Magnetic as well heavy media separated heavy fractions were characterized microscopically, for both Srikurmum as well as Navaladi samples, for their mineral distribution and presented in the Tables 4a and 4b and Table 5 respectively. In both the samples, it was observed that the ilmenite content increases while garnet content decreases with fineness (Figs.3-4).

Table 4a: Mineralogy of magnetic portion of Srikurmum beach placer

Sieve classified fractions	Minerals of the magnetic fractions		
	Garnet %	Ilmenite %	*Others %
-600+420 μ	90.98	4.77	4.25
-420+300 μ	91.76	5.26	2.98
-300+210 μ	90.22	7.75	2.03
-210+150 μ	87.54	10.65	1.81
-150+105 μ	72.70	26.12	1.18
-105 μ	53.37	46.10	0.53

**Others = unliberated opaques associated with garnet and other silicates like quartz, feldspar and sillimanite*

Table 4b: Mineralogy of the heavy fraction of Srikurmum beach placer

Sieve classified fractions	Minerals of the heavy fractions				
	Garnet %	Sillimanite %	Zircon %	Ilmenite %	Others %
-600+420 μ	77.20	10.13	1.17	6.51	4.99
-420+300 μ	78.15	10.43	0.56	7.49	3.37
-300+210 μ	80.56	9.02	0.60	8.42	1.40
-210+150 μ	78.56	10.57	0.47	9.37	1.03
-150+105 μ	65.67	8.25	0.62	24.54	0.92
-105 μ	40.33	7.87	0.89	49.78	1.13

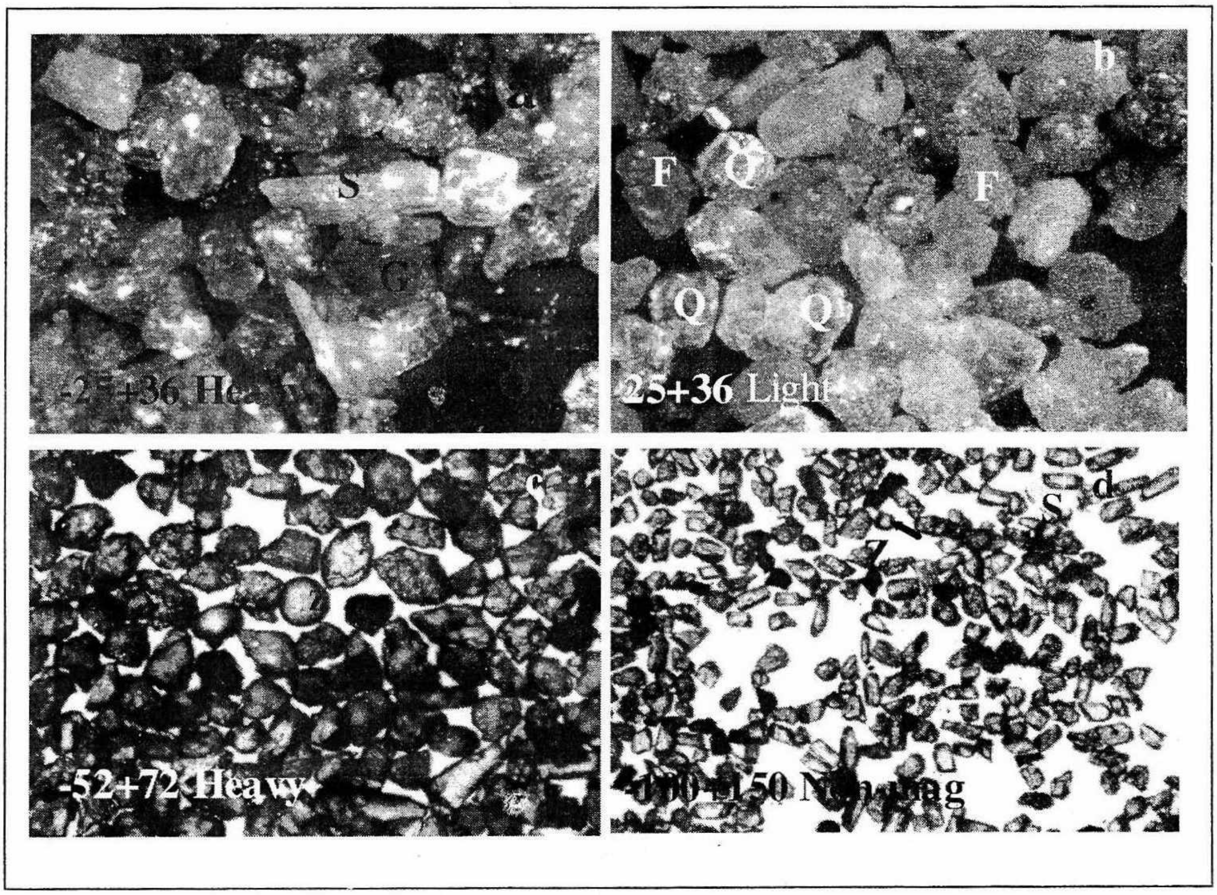

Fig.3: Srikurmum beach placers. (a) Distribution of heavy minerals in the heavy fraction Garnet (G), Sillimanite (S) and opaques (O); (b) Distribution of heavy minerals in the light fraction feldspar (f) and quartz (Q); (c) Distribution of heavy minerals in the heavy fraction Zircon (Z) grains (d) Distribution of heavy minerals in the non-magnetic fraction.

Table 5: Distribution of minerals in the Navaladi beach placer sample

Sample ID		Garnet %	Ilmenite %	Others %
ROM sample		22.3	11.8	65.9
Magnetic separation of classified fractions				
ROM	Magnetic	62.5	28.4	9.1
	Non-magnetic	0.6	1.2	98.2
-850+600 μ	Magnetic	82.3	0.7	17
	Non-magnetic	-	-	100
-600+420 μ	Magnetic	91.8	0.9	7.3
	Non-magnetic	0.5	-	99.5
-420+300 μ	Magnetic	83.9	6.0	10.1
	Non-magnetic	0.4	-	99.6
-300+210 μ	magnetic	79.6	11.6	8.8
	Non-magnetic	0.4	-	99.6
-210+150 μ	Magnetic	69.4	21.8	8.8
	Non-magnetic	0.5	1.9	97.6
-150+105 μ	Magnetic	46.9	41.1	12.0
	Non-magnetic	1.5	6.0	92.5
-105 μ	Magnetic	47.9	42.8	9.3
	Non-magnetic	1.6	6.5	91.9
Heavy media separation of classified fractions				
-850+600 μ	Heavy	87.5	0.6	11.8
	Light	-	-	100
-600+420 μ	Heavy	94.5	0.9	4.6
	Light	0.4	-	00.6
-420+300 μ	Heavy	84.6	4.5	10.9
	Light	0.5	0.02	99.3
-300+210 μ	Heavy	63.3	10.3	26.4
	Light	0.4	-	99.6
-210+150 μ	Heavy	65.2	20.8	14.0
	Light	0.5	0.5	99.0
-150+105 μ	Heavy	41.7	45.2	13.1
	Light	-	-	100
-105 μ	Heavy	25.5	60.7	13.8
	Light	-	-	100

Table 6: EPMA data of Srikurmum placer minerals (wt%)

	Garnet	**Garnet**	**Ilmenite**	**Sillimanite**
SiO_2	39.187	40.388	-----	37.454
Al_2O_3	18.884	12.372	0.651	61.832
FeO	3.880	15.582	48.404	0.194
MgO	-----	8.940	1.213	-----
MnO	1.961	0.211	1.002	-----
CaO	33.351	11.288	0.003	-----
K_2O	-----	1.733	-----	-----
Na_2O	-----	1.900	-----	0.044
TiO_2	0.104	2.644	49.151	0.025
Cr_2O_3	-----	0.146	0.066	0.214
ZnO	-----	0.028	0.118	0.018

------ = *not detected*

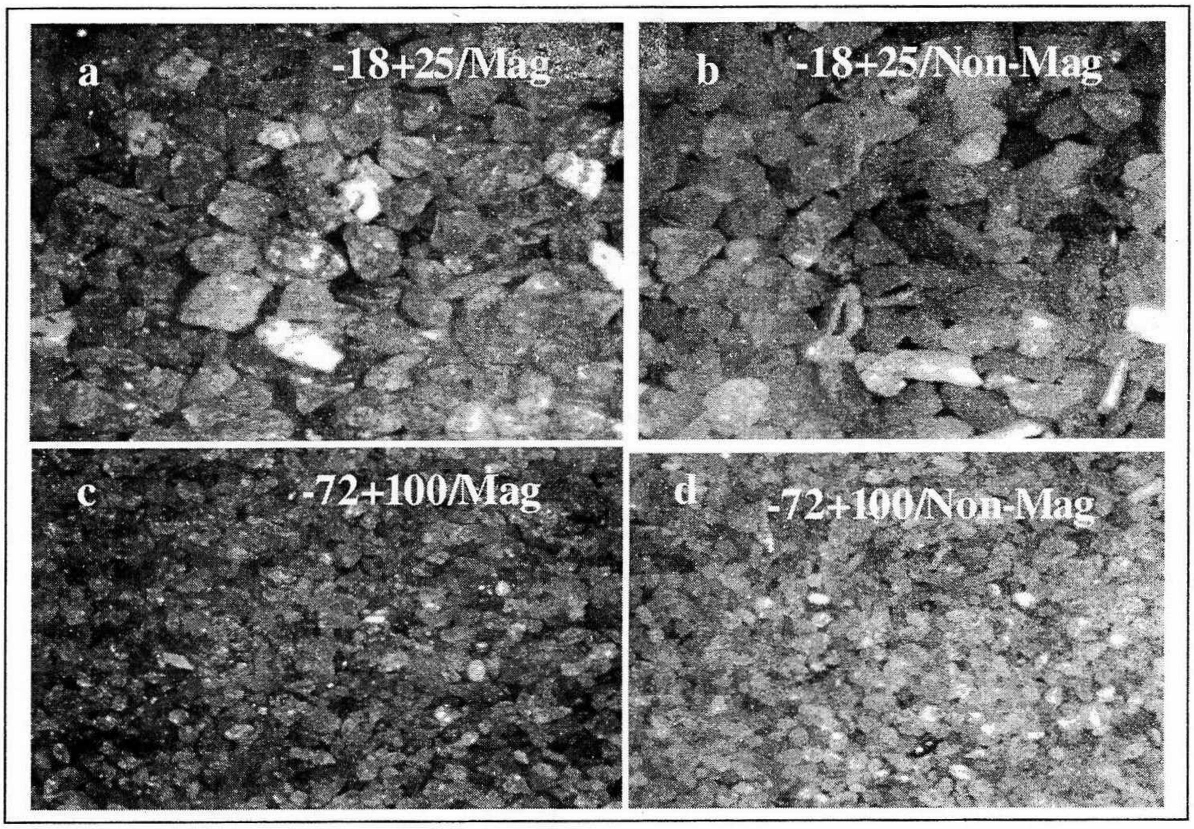

Fig.4: Distribution of ilmenite with reference to the fineness of the material of Navaladi sample (black grains are ilmenite)

3.5 Electron probe microanalysis: Ilmenite is the dominant member of the heavy mineral assemblage and as such declares the commercial prospect of any beach placer deposit because of wide variety of end uses. Some of the heavy minerals were analysed by Electron Probe Micro-analyser (Table 6 and Table 7) to decipher their mineral chemistry. The ilmenite from Srikurmum area contains 48.404% FeO and 49.151% TiO_2 with minor amounts of MgO and MnO while chromium, aluminium, calcium and zinc in traces. The ilmenite from Navaladi area contains 45.218% FeO and 51.624% TiO_2 with minor amounts of MgO and MnO while chromium, aluminium, calcium and zinc in traces. Magnesium and manganese in ilmenite are due to substitution for Fe^{2+}. The presence of significant amounts of magnesium and manganese indicates that the ilmenite of both the areas constitute a solid solution series with geikielite and pyrophanite respectively. As a result of this solid solution, the TiO_2 content of these ilmenites is lower than the ideal value (52.65%).

Table 7: EPMA data of Navaladi placer sample (wt%)

	Garnet	Garnet	Garnet	Garnet	Ilmenite
SiO_2	39.454	38.468	38.115	38.783	-----
Al_2O_3	20.677	20.621	20.647	19.831	0.614
FeO	29.578	33.056	30.540	29.969	45.218
MgO	7.605	4.357	6.017	6.943	1.862
MnO	0.357	1.011	0.622	0.514	0.801
CaO	0.811	1.287	1.840	1.474	0.391
Na_2O	0.047	-----	-----	-----	0.049
TiO_2	0.052	0.064	0.049	0.066	51.624
Cr_2O_3	0.031	0.087	0.132	0.127	0.162
ZnO	0.122	0.049	-----	0.038	0.026
V_2O_5	-----	-----	-----	-----	0.280

------ = *not detected*

3.6 Particle size distribution: Particle size distribution of the ROM sample as well as magnetic and non-magnetic products, from Srikurmum area, (Fig.5) clearly shows that the magnetic fraction is higher in particle size than that of the non-magnetic portion. Particle size distribution of the ROM sample as well as magnetic and non-magnetic products, from Navaladi area, (Fig.6) also shows a similar trend.

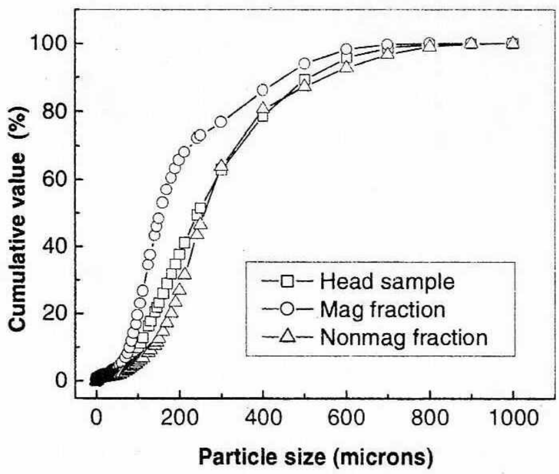

Fig.5: Particle size distribution of the Srikurmum ROM sample along with its magnetic as well as non-magnetic fraction

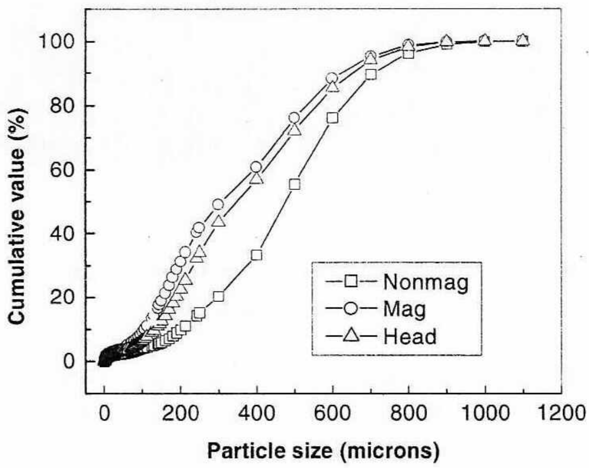

Fig.6: Particle size analysis of Navaladi ROM sample along with magnetic and non-magnetic fractions

4. Conclusions

The following conclusions are drawn from the preliminary characterisation study on these beach placer minerals

1. Both Srikurmum and Navaladi placer samples indicated presence of garnet and ilmenite as economically exploitable heavy minerals.

2. The Srikurmum and Navaladi beach placers mostly contain high amounts garnet and minor amount of ilmenite with traces of sillimanite and zircon. The garnet and ilmenite (which are magnetic) show higher particle size range than that of the non-magnetic products. Among garnet and ilmenite the particle size of garnet is coarser than that of the ilmenite.

3. Navaladi beach placers contain higher amounts of total heavy minerals than the Srikurmum beach placer minerals.

4. The presence of significant amounts of magnesium and manganese in ilmenite indicates that the ilmenite of both the areas constitute a solid solution series with geikielite and pyrophanite respectively. As a result of this solid solution, the TiO_2 content of these ilmenites is lower than the ideal value (52.65%).

5. The Eastern Ghats metamorphic belt, covering both the above areas, forms the prominent hills along the east coast of India, underlain by various rock types metamorphosed to granulite facies, is considered to be the source of these beach placer minerals.

5. Acknowledgements

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