Geochemistry and Ore Mineralogy of Ilmenite from Beach Placers of the Visakhapatnam-Bhimunipatnam Deposit, Andhra Pradesh

M. JAGANNADHA RAO, J. VENKATA RAMANA, R. VENUGOPAL* and M. CHANDRA RAO
Department of Geology, Andhra University, Visakhapatnam - 530 003
*Department of Mineral Engineering, Indian School of Mines, Dhanbad - 826 004

Abstract: Ilmenite from the beach and dune environments of the Visakhapatnam-Bhimunipatnam placer sand deposit has less TiO_2 and more total iron contents, as compared to its stoichiometric composition. Its trace elemental concentrations indicate its basic parentage. It has exsolution features and four types of intergrowths, viz. ilmenite-hematite, hematite-ilmenite, graphic intergrowth and ilmenite-rutile. Hematite phase in ilmenite incorporate excess iron in the structure of ilmenite. Based on the geochemical and ore mineralogical aspects, ilmenite of present study area is more suitable for pigment-manufacturing than to synthetic rutile preparation.

Keywords: Ilmenite, Beach placers, Mineragraphy, Geochemistry, Visakhapatnam coast, Andhra Pradesh.

Introduction

Occurrence of ilmenite in notable concentration in placer sands along the East Coast has initiated vigorous exploratory and exploitation programmes by various organisations. Demand for ilmenite and its value-added products has increased many fold, and India, with an estimated total reserves of 278 million tons (Mukherjee, 1998), including Andhra Pradesh's 103.05 million tonnes (Ravi et al. 2001) is comfortably placed. The Visakhapatnam-Bhimunipatnam coastal sand deposit in Andhra Pradesh is one of the promising deposits on the East Coast of India (Fig.1). The deposit was initially explored and delineated by the Atomic Minerals Division (Rao et al. 1989). Some work on mineralogical and textural aspects of this deposit was carried out earlier (Rao et al. 1983; Jagannadha Rao, 1985; Sastry et al.1987). Recent work by Ravi et al (2001) on this deposit indicates a total heavy mineral reserve of 4.40 million tonnes contained in 23.10 million tonnes of raw sand. However, baseline data pertaining to industrial utility of ilmenite like its geochemistry are scanty. This note presents geochemical and ore mineralogical aspects of ilmenite of this deposit and their possible bearing on processing and value-addition.

Methodology

From the beach and dune parts of Visakhapatnam-Bhimunipatnam sand deposit, representative bulk samples each of about 30 to 50 kg were collected at seven locations (Fig.1). Each sample was reduced to required quantity by standard sample reduction techniques. The heavy minerals were concentrated by Bromoform (sp.gr 2.87) and the magnetite was separated by hand magnet. The magnetite-free samples were then run through the isodynamic separator set at $\cong$ 0.25amp to separate ilmenite and the separation was repeated several times to ensure high purity of ilmenite. The purity was checked under a binocular microscope, and 99% pure samples were analyzed by Atomic Absorption Spectrophotometer of Perkin Elmer make, model 2380.

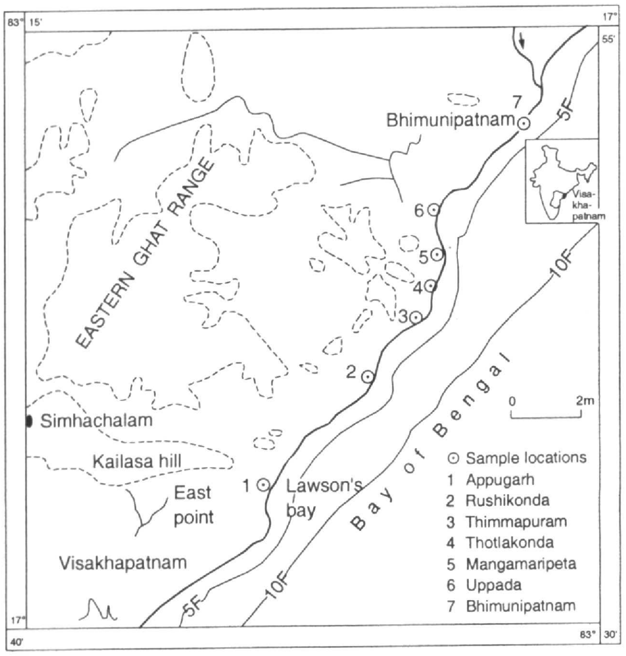

Fig.1. Location map of the sand samples collected from the Visakhapatnam-Bhimunipatnam coastal mineral sand deposit, Andhra Pradesh.

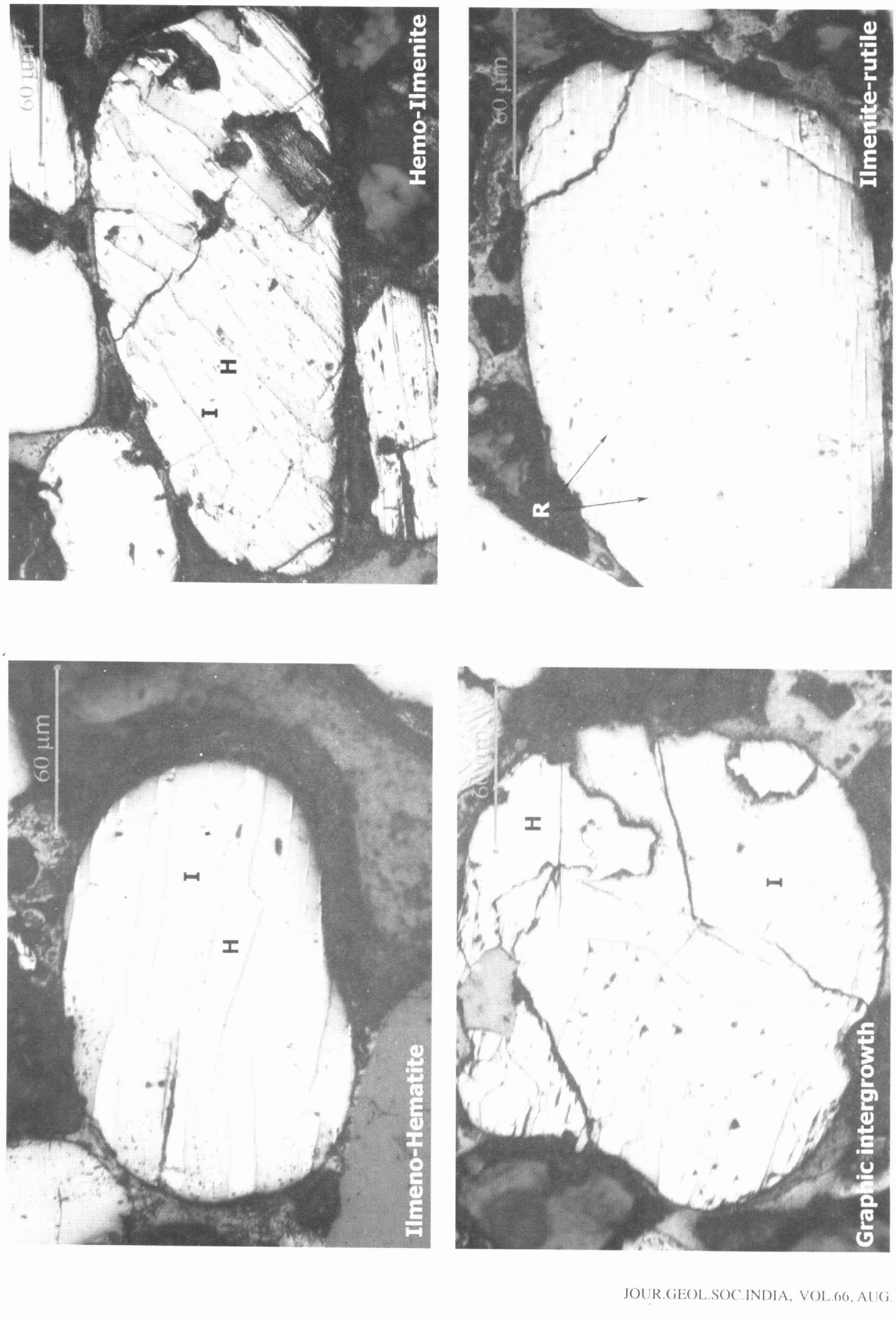

Fig.2. Ilmenite grain morphology with exsolved phases of ore minerals. Ilmenite (I), Hematite (H), Rutile (R).

Table 1. Chemical analysis of Ilmenites (major radicals in wt% and trace elements in ppm) from the Visakhapatnam-Bhimunipatnam Coastal sand deposit, Andhra Pradesh

Sample Location	TiO_2	SiO_2	Al_2O_3	Total Iron	MgO	Cr	Mn	V	Co	Ni	Zn	Cu
1. Appugarh(B)	47.42	0.22	0.40	49.54	0.42	990	1120	600	90	44	103	8
2. Rushikonda (B)	47.36	0.24	0.41	49.95	0.40	1016	1020	720	110	36	188	16
3. Rushikonda (D)	50.30	0.29	0.54	46.90	0.30	910	1615	159	160	66	99	9
4. Thimmapuram(B)	48.18	0.50	0.28	49.29	0.20	416	1724	805	38	90	122	18
5. Thimmapuram(D)	49.66	0.22	0.50	46.23	0.26	844	1652	201	123	90	101	8
6. Thotlakonda (B)	50.50	0.80	0.30	46.34	0.32	444	1518	800	57	38	166	8
7. Mangamaripet (B)	48.12	0.18	0.52	49.26	0.26	1520	8100	512	120	62	124	4
8. Uppada (B)	51.09	0.50	0.30	46.20	0.25	334	2020	714	88	22	106	12
9. Uppada (D)	51.90	0.30	0.60	46.10	0.38	1110	1818	188	150	54	112	6
10. Uppada (D)	52.30	0.44	0.32	44.10	0.18	212	1808	716	10	62	206	20
11. Bhimunipatnam (B)	50.05	0.11	0.19	47.28	0.65	504	1520	616	68	41	172	10
Average	49.71	0.34	0.39	47.38	0.02	754	1628	584	92	55	136	10
12. 84/1943-5	51.25	ND	ND	43.79	ND	621	2107	872	194	84	232	ND
13. 84/1946-6	56.25	ND	ND	37.50	ND	773	2057	791	178	93	197	ND
14. 84/1946-17	50.00	ND	ND	45.08	ND	513	2210	661	93	78	179	ND
15. 84/1946-19	53.13	ND	ND	42.55	ND	583	2218	811	153	94	208	ND
16. 91/2536-1	51.25	ND	ND	40.64	ND	724	2189	875	153	82	223	ND
17. 91/2536-18	53.13	ND	ND	41.47	ND	740	2344	849	123	87	235	ND
18. 84/KB/B-1	54.38	ND	ND	40.95	ND	508	2228	738	114	86	207	ND
19. Q	60.00	0.90	1.10	35.20	0.60	416	3080	420	ND	ND	ND	ND
20. MK	55.00	0.90	0.80	39.80	1.00	256	3080	1232	ND	ND	ND	ND
21. OR	50.20	0.80	0.60	46.90	0.65	160	4235	672	ND	ND	ND	ND

Samples 1-11 Present study (Analyst M.Jagannadha Rao) B-Beach,D-Dune., ND-Not Determined; Sample 12-18 Ratnagiri (Sukumaran and Nambiar, 1994); Samples 19-21 Chatrapur (Mukherjee,1998)

Polished sections, mounted in araldite medium, were studied under Leica DMLP microscope for their ore mineralogical aspects.

Results

The TiO_2 content of ilmenite in the beach samples varies from 47.36% to 51.09%, whereas that in dune sands it is marginally higher (49.66% to 52.30%, Table 1) and the average of the deposit (49.71%) is significantly lower than the theoretical ilmenite of 52.75% (Deer et al. 1965). Possible reason for relatively higher TiO_2 and lower Fe contents in dune samples, compared to that from beach, could possibly be due to the continuous wave action on the latter, which resulted in the removal of more TiO_2. The average total iron content of the ilmenite of the deposit is 47.38% with beach samples recording a range of 46.20% to 49.95% and dune samples 44.10% to 46.90%. The data, thus, demonstrate that the ilmenite of this deposit records higher total iron and lower TiO_2 contents, as compared to the composition of ilmenites from the published data. For instance, the Chatrapur ilmenite has TiO_2 in the range of 50.2% to 60.00% and total iron in the range of 35.20% to 46.90% (Mukherjee, 1998) and that from the Ratnagiri coast of Maharashtra has 50% to 56.25% TiO_2 (Sukumaran and Nambiar, 1994) and less total iron than the ilmenites of study area. The SiO_2 content (0.11% to 0.80%) is significantly less than that reported from Chatrapur (Mukherjee, 1998). Similar observations were made regarding the concentration of Al_2O_3 as well. However, the MgO%, which is in the range of 0.18% to 0.65%, is comparable to that of Chatrapur ilmenites (Mukherjee,1998). The higher abundance of Mn and its positive relationship with higher Fe values points out a possible geochemical affinity. In general, the Mn concentrations are comparable to Ratnagiri (Sukumaran and Nambiar, 1994) and Chatrapur (Mukherjee, 1998) ilmenites. The trace elemental concentrations of Cr and V are comparable with ilmenites of Chatrapur (Mukherjee, 1998). Another striking observation is the trace elements of basic affinity such as Cr, Co, Ni and V have higher abundances and are comparable to that of Ratnagiri, which has an established basaltic parentage (Sukumaran and Nambiar, 1994). This feature suggests the possible derivation of these ilmenites from basic lithologies like pyroxene granulites and basic charnockites of the hinterland. The low Si and Al values of ilmenite of the present study further supports this observation.

Ore Mineralogy: Earlier study by Jagannadha Rao (1985) on the ore mineralogy of Bhimunipatnam deposit indicated that the ilmenite shows high variability in terms of grain size, texture, pattern of exsolutions, composition of exsolved minerals etc. In general, the ilmenite is granular or perfectly rounded to irregular. Its grain size varies from 60 to 80 microns and it is abundant in finer sizes. It shows lamellae of hematite that is white, greenish white, feebly pleochroic and anisotropic. Coarse ilmenite exhibits extensive exsolution features of hematite within ilmenite or vice versa. The exsolved phase is mainly hematite and depending upon the dominance of a given mineral phase in the grain, this can be called either as hemo-ilmenite (hematite matrix) or ilmeno-hematite (ilmenite matrix) (Fig.2). The presence of notable content of hematite in the ilmenite explains the higher total iron content in the analysed ilmenite. The lamellae of hematite are spindle shaped, discs of different sizes, besides tabular form. Some ilmenite grains show very fine needle-shaped (hair like) exsolution and are microcrystalline in nature. These ore mineralogical aspects indicate that the exsolution feature of ilmenite under study has resemblance to that from Cox Bazar (Sam Suddin Ahmed et al. 1992). Ore microscopic study of ilmenites reveals wide variety of exsolution features with the exsolved phases. Four different types of intergrowths are distinguished; these are: (1) Ilmeno-hematite, (2) hemo-ilmenite, (3) graphitic intergrowth of ilmenite and hematite and (4) Ilmeno-rutile. The most common of these are exsolutions of ilmeno-hematite and hemo-ilmenite. Number of grains showing simultaneous crystallization of ilmenite and hematite resulting, in graphitic texture were also observed. The occurrence of wide variety of exsolutions in ilmenite suggests their derivation from more than one source or more than one paragenetic sequence. The finer ilmenite is in general devoid of exsolution. The exsolution features of different forms will make up the exsolved phase up to 50-55% of some of the grains. The occurrence of extensive exsolutions in beach sand and rather scanty exsolutions in dune sands corroborates high TiO_2 and low total iron in ilmenite of dune sands, as compared to that of beach sands. However, further detailed mineralogical work is needed for establishing the role of ore mineralogy on the chemistry of ilmenites and also the influence of these intergrowths on the physical and chemical processing of these ilmenites.

Discussion

The exsolution of ilmenite has a considerable economic implication in processing and ore reserve estimation. This is because that the estimated TiO_2 values and, hence reserves, may be higher than the actual ones. This is an important aspect to be considered, especially when TiO_2 recoveries are estimated. Similarly, the higher total iron content may result excess iron as tailings in chloride route of synthetic rutile preparation. This excess iron is environmentally unwanted and consumes more acid in the process, which may have economic implications. The geochemical data indicate that the ilmenite of the study deposit is suitable for pigment manufacturing rather than for synthetic rutile preparation. The ore mineralogical work on ilmenite has indicated variability in grain morphology within the deposit, and two or three genetic affinities.

Acknowledgements: The authors are thankful to Department of Ocean Development-Ocean Science Technology cell, Tanjavur, for the financial assistance in the form of a Research project.

References

DEER, W. A., HOWIE, R.A. and ZUSSMAN, J. (1965) An Introduction to Rock-Forming Minerals, ELBS and Longman.

JAGANNADHA RAO, M. (1985) Origin of recent sediments along Visakhapatnam-Bhimunipatnam Coast. Unpublished Ph.D. Thesis, Andhra University, Visakhapatnam.

MUKHERJEE, T.K. (1998) Metals materials and processes. Meshap Science Publishers, Mumbai, India, pp.85-98.

RAO, G.D.,SETTY, B.K. and RAMINAIDU, CH. (1989) Exploration and research for Atomic minerals. Expl. Res. At. Min., v.2, pp.247-254.

RAO, T.R., RAO, N.R. and RAMA RAJU, M.V. (1983) Ilmenite of black sand deposits of Visakhapatnam – Bhimunipatnam beach, East coast of India. Indian Jour. Mar. Sci., v.12, pp.220-222.

RAVI, G.S., GAJAPATHI RAO and YUNGANDHARA RAO, A. (2001) Coastal heavy mineral sand deposits of Andhra Pradesh. Expl. Res. At. Min., v.13, pp.53-85.

SAMSUDDIN AHMED, TARAKNATH PAL and SACHINATH MITRA (1992), Ilmenites from Cox's Bazar Beach sands, Bangladesh: Their intergrowths. Jour. Geol. Soc. India, v.40, pp.29-41.

SASTRY, A.V.R., SWAMY, A.S.R and VASUDEV, K. (1987) Heavy minerals of beach sands along Visakhapatnam-Bhimunipatnam, Eastcoast of India. Indian Jour. Mar. Sci., v.16, pp.39-42.

SUKUMARAN, P.V. and NAMBIAR, A.R. (1994) Geochemistry of Ilmenites from Ratnagiri Coast, Maharastra. Curr. Sci., v.67, no.2, pp.105-106.

(Received: 23 December 2004; Revised form accepted: 10 March 2005)