

HEAVY MINERAL DISTRIBUTION IN THE SURFICIAL SEDIMENTS FROM THE EASTERN CONTINENTAL MARGIN OF INDIA AND THEIR IMPLICATIONS ON PALAEOENVIRONMENT

P.G. MISLANKAR AND A.R. GUJAR
National Institute of Oceanography, Dona Paula Goa 403004

ABSTRACT

Heavy mineral distribution from the surficial sediments of the Eastern Continental Margin of India, between Machilipatnam and Gopalpur shows that their concentration ranges from 0.4 to 13.9%. Heavy minerals such as opaques, (ilmenite, magnetite and titanite), garnet, sillimanite, hornblende, hypersthene, tourmaline, zircon, monazite, biotite, kyanite and staurolite are present in variable proportions. Hydraulic fractionation (size, shape, density) and selective chemical decomposition of unstable minerals are attributed to for variations within the heavy minerals. Reworking of heavy minerals during the Holocene transgression resulted in concentration of heavy minerals with high density, more stability and equant morphology along the submerged shorelines. These heavy minerals are believed to have been derived from two different provenances.

INTRODUCTION

The beach placer deposits largely comprising of minerals such as opaques (ilmenite and magnetite) sillimanite, zircon, garnet monazite etc. have been reported from the coastal belts of Maharashtra, Kerala, Tamil Nadu, Andhra Pradesh and Orissa (Gujar *et al* 1988). The offshore extension of these heavy minerals have also has been reported (Siddiquie *et al*, 1982, Senthial *et al*, 1992 and Sengupta *et al*, 1992). However most of these studies were restricted on their distribution and economic aspect. But no emphasis was made on the palaeoenvironmental setting of the region. In view of the above, it is intended to study the distribution of heavy minerals from the eastern continental margin of India between Gopalpur and Machilipatnam and their implication on the prevalent environmental condition during their formation. It is also further envisaged to delineate precisely the provenances of the heavy minerals.

METHODS

The present study is based on analysis of 40 surficial sediment samples collected during the 76 and 77 cruise of R.V. *Gaveshani* (Fig 1) in the Bay of Bengal, in a depth range of 20-200 m during 1980. These samples were washed at 230 mesh sieve to estimate coarse and fine fraction and treated with 10% HCl and carbonate percentage is determined and tabulated. The insoluble residue thus obtained was used for heavy mineral analysis. Heavy mineral separation of three fractions [medium sand

(500-250 μ m)] fine sand [250-125 μ m], very fine sand [125-63 μ m], was carried out using the bromoform (sp. gr. 2.89), and weight percentage is calculated. Selected heavy mineral samples were taken for determination of number percentage. The magnetite were separated using hand magnet and ilmenite by isodynamic separator following Hutchinson (1974) and these separated fraction were subjected to X-ray diffraction on PHILIPS (Pw 1840) for their confirmation.

RESULTS AND DISCUSSIONS

The sediments are composed of varying amount of silt and clay. The clay percentage ranges from 1.30% to a maximum of 97.70%. The carbonate content ranges between 2.60 % to 98.80 % in coarse fraction which tend to increase with increasing depth. (Table 1). The texture of innershelf (30-50 m) sediments are mostly silty clay except in the region of Bahuda river mouth at Kalingapatnam wherein it is silty sand. On the outershelf sediments are carbonate rich. Silty sands are confined to the river mouths where these are partially covered by modern clays.

The heavy minerals content varies from 0.4 to 15.0% by weight (Table 1). The distribution close to the coast shows increase in the heavy mineral content (maximum 15.0%), in the areas off the mouths of river Godavari, Vamsadhara, Bahuda and Rushikulya. On the contrary low heavy mineral content (< 4.5 %) is observed in the areas between Godavari and Vamsadhara river mouths (Fig. 2).

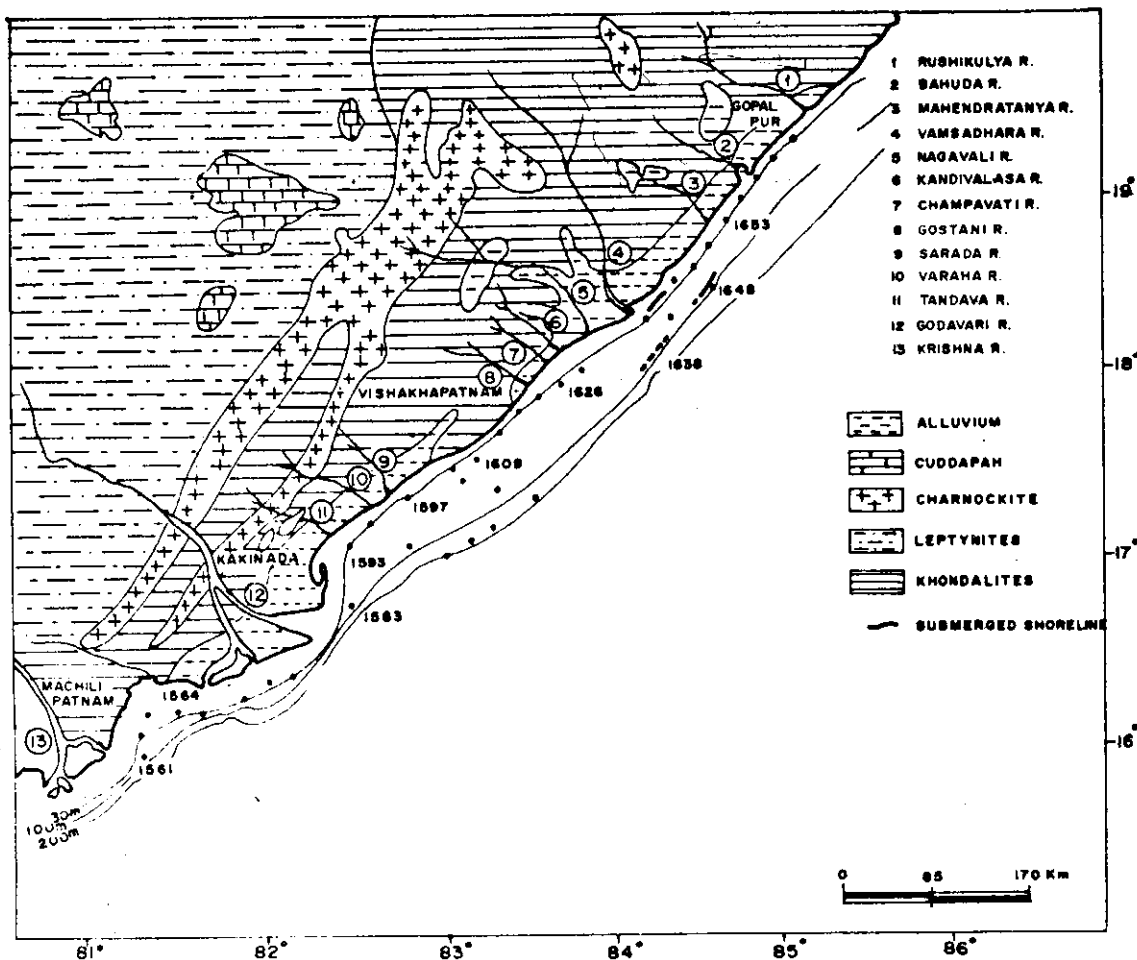


Fig. 1: Location of sample stations, general geology of the hinterland, river drainage and positions of patches of submerged shoreline. (Geology adapted after Radhakrishna Murthy *et al.*, 1991)

TABLE 1: PERCENTAGE OF COARSE, FINE FRACTIONS, CARBONATES AND HEAVY MINERALS

Stn No.	Coarse %	Fine %	Carbonate% in coarse fraction	Heavy %	Stn No.	Coarse %	Fine %	Carbonate% in coarse fraction	Heavy %
1561	0.30	99.70	32.50	NA	1615	26.54	73.46	81.5	0.85
1562	0.70	99.30	41.10	NA	1618	73.7	26.3	4.3	2.96
1563	2.96	97.02	20.40	0.50	1619	98.7	1.3	2.6	3.12
1564	2.36	97.64	32.00	15.0	1625	38.7	61.3	15.2	4.5
1568	0.75	99.25	74.0	NA	1626	13.8	86.2	17.3	2.14
1571	13.1	86.9	52.4	13.05	1631	4.15	95.85	27.9	0.72
1575	0.74	99.26	32.3	9.09	1638	72.7	33.3	85.4	7.5
1576	3.9	96.1	37.8	8.5	1640	47.5	52.5	9.7	8.9
1583	38.2	61.8	95.0	10.0	1641	42.8	57.2	14.3	8.95
1590	21.3	78.7	86.1	2.86	1642	60.0	40.0	35.10	4.81
1593	99.3	0.7	5.1	1.7	1646	50.2	49.80	16.80	7.85
1594	97.7	2.3	3.2	1.26	1647	98.2	1.80	5.20	7.15
1597	67.84	32.16	7.10	4.07	1648	82.4	17.6	18.4	4.31
1600	58.50	41.50	97.2	2.9	1652	92.36	7.64	20.2	5.4
1601	60.55	39.45	97.2	NA	1653	74.5	25.5	27.4	4.0
1605	60.45	39.45	98.8	NA	1660	57.05	42.95	59.60	4.11
1608	34.5	65.5	8.3	0.4	1661	72.3	27.7	9.1	6.2
1609	11.2	88.8	16.7	0.9	1669	25.6	74.4	8.9	6.2
1611	54.6	45.4	70.5	2.55	1671	22.85	77.15	82.0	1.0
1613	57.9	42.1	97.25	0.9					

In the further offshore, the distribution is patchy.

The heavy mineral suite is essentially composed of opaques, (ilmenite, magnetite and titanite) garnet, sillimanite, hornblende, hypersthene, tourmaline, zircon, monazite, biotite, kyanite, andalusite, staurolite and epidote (Table 2). While the light mineral fraction is represented by quartz and feldspar, quartz grains shows the staining of iron oxide (Table 4). The heavy minerals and quartz grains are subangular to subrounded to rounded in nature. Garnet, sillimanite, hornblende and staurolite are characteristic of medium sands, however they do occur in fine and very fine sands. The high content of these species occurs on the shelf off river Sarada and Vamsadhara around 20 m depth. Zircon is present in all the samples with maximum abundance (4.80%) in the north of Godavari river mouth, in contrast this mineral is in less abundance in the region between Nagavelli and Vamsadhara river mouths. In the rest of the area the content varies between 2.1 and 4.1%. Rutile occurs almost throughout the shelf region with a minimal concentration of 0.5 % off river Vamsadhara and maximum concentration of 3.2 % off Visakhapatnam. In the area north of Vamsadhara its concentration ranges between 0.36 and 2.0 %. The concentration of mineral tourmaline ranges between 0.10% to 2.06% and is present throughout the area except off Godavari and Vamsadhara river mouths. The mineral epidote (0.66- 1.60 %) is distributed almost evenly from Krishna river mouth to Nagavelli river mouth but north of Nagavelli river mouth it is conspicuously absent. The other minerals like kyanite, andalusite, biotite are rare and have sporadic occurrences and do not show any specific trend. Based on the observed heavy mineral assemblage in the sediments, two major provenances could be delineated. These are 1) between Rushikulya and Sarada river mouths and 2) between Sarada and Krishna river mouths.

The area north of Sarada river is dominated by opaques (ilmenite and magnetite), garnet and sillimanite with less concentrations of pyroxenes and amphiboles, whereas the other region displays abundance of opaques (ilmenite and magnetite), pyroxenes with subordinate quantities of garnet, sillimanite, kyanite and zircon.

The area north of river Sarada is drained by many rivers and ephemeral streams (Fig.1). The major geological formation of the drainage basins of these rivers comprised of Eastern Ghat group of rocks (Khondalites and Charnokites) of the Archaean age (Rao *et al.* 1980) which forms the main source rocks for the heavy mineral

suite in the area (Table 3, Fig. 1). The area south of river Sarada is drained by two major rivers Godavari and Krishna. A major part of the drainage in the upper reaches of Godavari and Krishna is covered by Deccan Trap and crystalline rocks of Archaean age and in the lower reaches by Gondwana and Eastern Ghat Super group (Mohapotra *et al.*, 1992). These rocks form the source rocks for the heavy minerals of this area (Table 3). The mineralogy of the studied area shows analogy with that of onshore (beach, backshore, dried up river channel in the hinterland) and offshore (innershelf) sediments (Rao *et al.*, 1982, Rao *et al.*, 1992, Narasaya *et al.*, 1989, Sengupta *et al.*, 1989 and Sastri *et al.*, 1987). The observed near uniformity in the heavy mineralogy is suggestive of its derivation from common source rocks. Thus the variation of the northern and southern area in the heavy mineral assemblage under study appears to be provenance induced resulted from the sediment dispersal from two different source areas as indicated above. However, the observed variability in the heavy mineral assemblage may also be attributed to the sedimentary processes operated during and after their deposition. In order to understand the effect of the source and the sedimentary processes as a control of heavy mineral variability, individual heavy mineral which reflect difference in grain shape, density and selective chemical decomposition and heavy mineral ratios were used following Flores and Shideler (1978).

These heavy mineral ratios (Table 4) suggest the effect of hydraulic fractionation by density as indicated by large variation in opaque/non-opaque ratios further suggesting probable prolonged reworking during Holocene transgression. This reworking was regionally effective in selective sorting. The more equant (garnet, epidote) and heavier minerals (opaque) had higher probability of being selected for permanent deposition during reworking.

The significant compositional differences resulting from selective decomposition of heavy minerals as indicated by higher variation in the values of stability index (Table 4) reflects differential weathering conditions. The areas from where higher values of stability index are observed coincide with the areas of reported submerged shorelines. These patchy submerged shorelines are reported by Banerjee and Sengupta (1992) along ± 30 m and ± 100 m isobaths. The similarity in the heavy mineral assemblage of these submerged shoreline and river sediments further suggest that these rivers were supplying the sediments to the submerged shoreline when it was a part of the beach during its formation. This is also

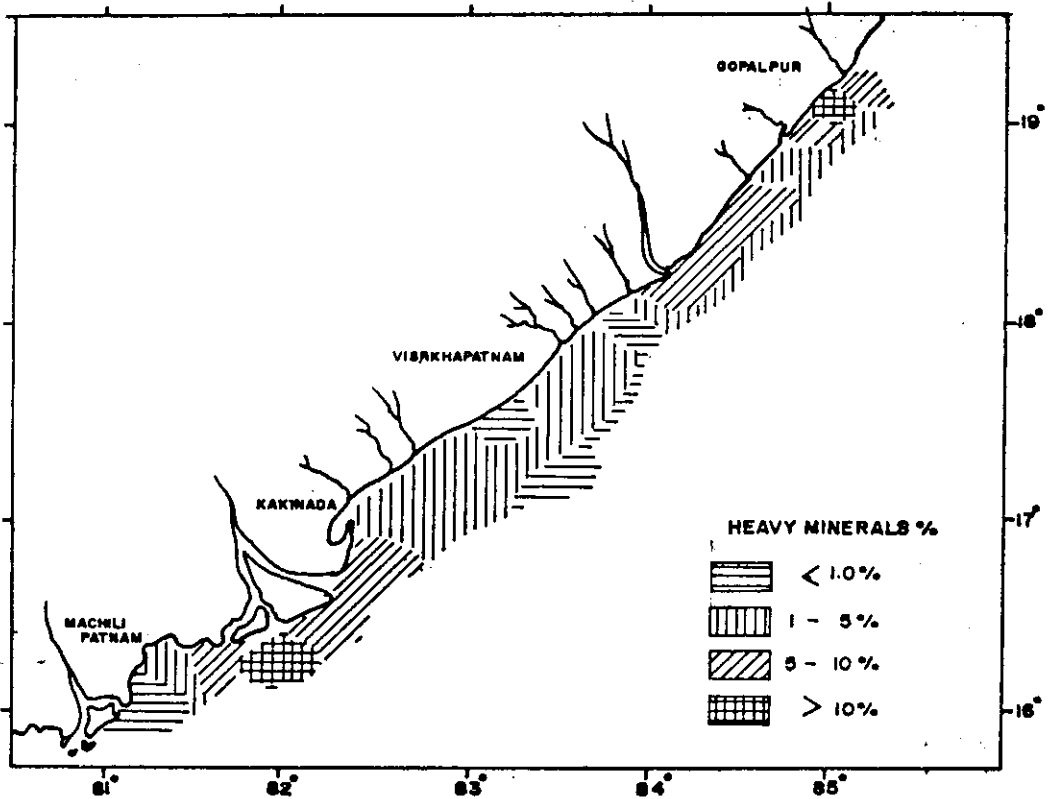


Fig 2 : Distribution of total heavy minerals

TABLE 2: AVERAGE NO. PERCENTAGE OF DIFFERENT MINERALS

STATIONS	1564	1583	1593	1597	1609	1619	1626	1638	1641	1648	1653
OPAQUE	52.3	46.75	49.56	37.95	40.6	27.46	33.5	50.96	36.93	33	42.64
GARNET	15.23	47.1	19.78	36	22.4	29.3	9.8	28.74	43.4	39.54	22.96
SILLIMANTITE	13	1.3	9.54	11.3	15.1	28.7	49.5	13.78	15.04	21.19	18.34
HORNBLLENDE	0.95	1.9	7.81	3.8	5.7	4.23	2.3	0.75	0.42	0.8	3.25
HYPERSTHENE	1.5	0.32	1.3	0.66	0	2	0	0	0.2	0.5	0.65
TOURMALINE	0	0	2.06	1.3	1.54	0.6	0	0	0.1	0.3	1.13
ZIRCON	2	0	4.8	0	3.06	3.1	2.1	4.1	1.91	0.9	3.7
RUTILE	2	0.65	1.04	1.3	3.6	2.9	2.06	1.57	1.2	0.5	0.9
MONAZITE	0	0.32	0	0.93	0	0	0	0	0.36	0.3	1.4
BIOTITE	10	0	0	0	10	0	1.35	0	0	0	1.58
KYANITE	0	0	0	1	0.5	0	0	0	0	0	0
ANDALUSITE	0	0	0	0	0	0	0	0	0	0	0.46
STAUROLITE	0	0.65	2.7	0.66	0	1.13	0	0.23	0	0	0
EPIDOTE	1	1	1.3	0.66	1.03	1.6	0	0	0	0	3

TABLE 3: DRAINAGE, GEOLOGY OF CATCHMENT AREA & CHARACTERISTIC HEAVY MINERALS

RIVER	LENGTH (Km)	CATCHMENT (Sq Km)	GEOLOGY OF DRAINAGE AREA	CHARACTERISTIC HEAVY MINERALS OF DRAINAGE
RUSHIKULYA	146	7753	khondalite, charnockite	gt, sill, zir, hyp, mt, ilm
BAHUDA*			khondalite, charnockite	do
MAHENDRATANYA*			do	do
VAMSADHARA	221	10830	do	gt, sill, hyp, mt, ilm
NAGAVALI	217	9140	do	hyp, gt, sill, zir
KANDIVALASA*			do	
CHAMPAVATI*			khondalite	
GOSTANI*			do	
SARADA	104	2725	charnockite, khondalite	gt, sill, hyp, zir
VARSHA*			do	
TANDAV*			do	
GODAVARI	1465	312812	basalt, sandstone, shale, khondalite, charnockite, leptynite	ilm, mt, gt, sill, hyp, zir, rutile, tourmaline
KRISHNA	1400	8948	basalt, gneiss, quartzite, phyllite, shale, sandstone	ilm, mt, gt, sill, hyp, andalusite, staurolite, zir, tourmaline

* Minor rivers; gt= garnet, sill= sillimanite, zir =zircon, hyp=hypersthene, mt= magnetite, ilm= ilmenite,

Sources :- K.L. Rao (1979) and A.R. Rao et al. (1980)

TABLE 4: AVERAGE VALUES OF SELECTED HEAVY MINERL RATIOS & PERCENTAGE OF IRON STAINED QUARTZ GRAINS

STATION	O/NO	ZTR/PH	E/PHT	IRON STAINED QUARTZ	CLEAR QUARTZ
1564	1.09	0.2	0.4	41.8	58.2
1583	0.86	0.34	0.5	41.6	58.4
1593	1.00	1.01	0.1	55	45
1597	0.6	1.73	0.12	49.6	50.4
1609	0.66	1.42	0.14	39.75	60.25
1619	0.43	1.32	0.33	43	57
1626	0.5	1.67	-	-	-
1638	1.0	7.52	-	-	-
1641	0.56	7.6	-	40.2	59.8
1648	0.5	2.1	-	20	80
1653	0.72	5.27	1.68	49	51

O/NO = opaque/ non opaque; ZTR/PH = (zircon+tourmaline+rutile) / (pyroxene + hornblende)

E/PHT = epidote/ (pyroxene + hornblende + tourmaline)

supplemented by the presence palaeobathymetric features like palaeo depression and paleaolinear highs (Venkateshwarlu *et al*, 1989) parallel to the coast in northern area.

The slow rise of sea levels during Holocene period provides greater opportunity for the reworking of heavy minerals at the submerged shoreline, thus increasing the

were present during Holocene lower stand (Rao and Vijayakumar 1990) as a result of which the more stable minerals were preserved and the unstable minerals were weathered to fine size and finally removed. Similarly the observed higher values of opaque to non opaque ratio and rounding of the grains in this area as indicated above suggest prolonged reworking during the lower stand of sealevel. Thus these high concentration zones of heavies in the areas of submerged shoreline represent relict heavy mineral beach zone formed during low stand of sealevel and subsequently escaped transportation towards the shore as the sealevel rose.

CONCLUSIONS:

1. Heavy mineral distribution in the sediments of continental margin in the studied area between Gopalpur and Machilipatnam shows regional and local variabilities produced due to the combined effect of provenance and processes like sediment dispersion by rivers.
2. Selective chemical decomposition and hydraulic fractionation (shape & density) associated with reworking during Holocene transgression have shown the effectiveness in the preferential concentration, of heavy minerals, with high density, more stability and equant morphology along the submerged shores.

ACKNOWLEDGEMENTS

Authors thank Dr. E. Desa, Director, National Institute of Oceanography, for permission to publish this paper and Mr. R. R. Nair, Deputy Director, for encouragement and critically going through the paper.

REFERENCES

Banerjee, A and Sengupta, R., 1992: Evidences of low stands on the continental shelf of East coast of India. Recent Geoscientific studies in the Bay of Bengal and Andaman sea, sp. Pub. 29, 163-170.

Flores, R.M. and Shideler, G.L., 1978: Factor controlling heavy mineral variation on the south Texas outer continental shelf gulf of Mexico. Jour. Sed. Petrol. 48(i), 269-280.

Gujar, A.R., Nagender Nath, B. and Banerjee, R., Marine Minerals: 1988, The Indian Prospective. Marine Mining, 7, 317-350.

Hutchison, C.S., 1974 Laboratory Handbook of Petrographic Techniques. Wiley Interscience Publication, New York.

Mohapatra, G.P., Rao, B.R. and Biswas, N.K. 1992: Morphology and surfacial sediment of the Eastern Continental Shelf off Peninsula India. Rec. Geoscientific stud. in the Bay of Bengal & Andaman Sea, 29, 229-243.

Narasayya, B.L., Rao, B.L., Kalidas, J. Rao, R.B.S. Khan, M.I.A., Shankar, J. Hari Prasad, M., Maharana, C.R. and Mitra, P.K. 1989: Heavy mineral dispersion pattern of Godavari river of Bay of Bengal. Geol. Surv. India, Rec. 122, Pt.2, 175p.

Radhakrishna Murthy I.V., B. Polinaidu and A.T. Rao 1991: Magnetic anomalies and basement structure around Vizianagram, Andhra Pradesh. J.Geol. Soc. India, 37, 272-286.

Rao, A.T., Acharyulu, K.V.S. and Rao, K.S: 1980: Aplite vein from charnockite pegmatite of Visakhapatnam, Andhra Pradesh. J. Geol. Soc. India, 21, 204-205.

Rao, B. R., Rao, R. B. S., Mohapatra, G. P., Reddy, D.R.S., Vijaykumar, P. Jairam, M.S. Hariprasad, M. and Misra, U.S. 1989: Kalingapatnam Placer mineral project: Bay of Bengal. Geol. Surv. India. Rec. 122, Pt.2, 175p.

Rao, B. R., Mohapatra, G. P., Vaz, G. G., Reddy, D.R.S., Hariprasad, M., Misra, U.S., Raju, D.C.L. and Shankar, J. 1992: inner-shelf placer sands of North Andhra Coast. Geol. Surv. India, Newsletter, VIII-1, 11-12.

Rao, R.T., Rao, Ch.S. and Rao, K.S. 1982 : Textural analysis and mineralogy of the black sand deposits: Visakhapatnam - Bhimuniapatnam coast, Andhra Pradesh, India. Geol. Soc. India, 23, 284-289.

Rao, K.L. 1979: India's water wealth, its assessment and uses and projections. Orient Longman, N.Delhi, 234p.

Rao, P.V. and Vijay Kumar, B. 1990: Quartz and felspar distribution in continental shelf sediments of East coast of India. Ind. Jour. Marin. Sci., 19, 191-195.

- Sastry, A.V.R., Swamy, A.S.R. and Vasudev, K. 1987: Heavy mineral of beach sands along Visakhapatnam - Bhimunipatnam. *Ind. Jour. marin. Sci.*, 16(1), 339 - 342.
- Sengupta, R., Khalil, S.M., Rakshit, S., Deb Roy, D.K., Sinha, J.K., Mitra, S.K., Majumdar, S., Raghav, S. and Bhattacharya, S. 1992: Multiminerals placers in the inner-shelf of Orissa. *Recent Geoscientific Studies in the Bay of Bengal and the Andaman Sea. Geol. Surv. Ind. Sp. Pub.*, 29, 135 - 143.
- Sengupta, R., Khalil, S.M., Bhattacharya, S., Deb Roy, D.K., Venkatesh, B.R., Balasubramaniam, K. and Majumdar, S. 1989: Exploration for evolution of placer mineral in territorial water of Gopalpur, Orissa. *Geol. Surv. Ind. Rec.*, 122 (pt. 2), 175p.
- Senthippan, M., Michael, G.P., Charlu, T.K., Jayakumar, R., Abdulla, N.M., Kumaran, K., Unnikrishnan, E. and Bhat, K.K. 1992: *Geol. Surv. Ind. Newsletter*, VIII - 1, 1-4.
- Siddiquie, H.N., Rajamanickam, G.V., Gujar, A.R. and Ramana, M.V. 1982: Geological and Geophysical exploration for offshore ilmenite placer of the Konkan coast, Maharashtra, India. *Proc. 14th Offshore Technology Conference*, 749 - 755.
- Venkateshwarlu, P.D., Chatterjee, S., Sengupta, B.J., Brahmam, C.V. and Khar, Y.C. 1989: Shallow seismic investigation for the placer. *Ind. Jour. Marin. Sci.*, 18, 134 - 138.

Manuscript received: June 22, 1995

Revised manuscript received: June 19, 1996