

Heavy minerals of modern and relict sediments of the Nizampatnam bay, east coast of India

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Heavy minerals of the beach, sand-spit and palaeostrandline sediments of Nizampatnam bay are dominated by opaques, amphibiles and pyroxenes (70% of the total). Garnet, epidote and monazite are present in significant quantities (20%), whereas rutile, zircon and tourmaline are in appreciable amounts. Multiple regression analysis indicates that heavy mineral variations in each sedimentary environment have been significantly influenced by hydraulic fractionation by size, shape, density and by a selective chemical decomposition of unstable heavy minerals. A comparison of heavy mineral suites of the modern and relict sediments, derived from a common provenance, also shows mineral variations resulting from factors other than provenance.

Occurrence of heavy minerals in the beach and continental shelf sediments along the east coast of India has been reported¹⁻⁴. Most of the previous studies attempted to explain the origin of heavy mineral concentration. Presently, heavy mineral assemblages of beach, sand-spit and palaeostrandline of Nizampatnam bay environments have been studied. Attempts are also made to determine the variations attributable to depositional processes as opposed to variations induced by provenance. Further, the variability of heavy minerals from modern environments is compared with that of palaeostrandline to assess differences between modern and relict assemblages originating from a common source.

Materials and Methods

Nizampatnam bay (area = 1825 km²) has a shoreline of about 122 km between Kottapatnam in the SW to False Divi point in the NE (Fig.1). Krishna river (basin area = 258948 km²) is the principal source of sediments for the bay. Smaller rivers like the Gundlakamma, Romperu and Upputeru also provide detritus to the bay. Drainage basin characteristics of these rivers are presented in Fig.2. Bottom topography of the bay is rather smooth and generally slopes towards the open sea (Fig.1). Three prominent sand-spits occur in the north eastern part (near Kottapatnam).

Sediment samples from the beach (10) and sand-spit (10) were collected by pushing down a PVC tube (60 mm diam), whereas the LaFond-Dietz

snapper and Peterson grab were used to collect bottom sediment samples (23) from palaeostrandline deposits (Fig.1) during Jan. - Feb. 1987. Samples, after removal of organic matter and salt, were sieved to obtain two size fractions viz. coarse and fine fractions. Heavy minerals were separated using bromoform (sp gr 2.89). About 300 to 600 grains per slide were counted per sample and the number counts for each minerals were obtained which were converted into weight percentages by following the method of young⁵. The mineral variability was determined by multiple regression⁶.

The shape fractionation index⁷ is expressed as ratio of bladed elongate minerals [eg. pyroxenes hornblende (amphiboles), tourmaline, zircon and rutile] to equant minerals (eg. garnet and epidote). The ratio used in this study is [(pyroxene + hornblende + tourmaline)/(garnet + epidote) PHT/GE]. Hydraulic fractionation by density is expressed by the ratio of opaques (av. sp gr = 4.7) to non-opaques (av. sp gr = 3.7). In addition to these ratios, percentages of individual translucent heavy minerals were used to facilitate interpretations. Role of selective chemical decomposition in heavy mineral variations is inferred from a stability index [zircon + tourmaline + rutile/pyroxenes + hornblende (ZTR/PH)].

Results

Average weight percentages of heavy minerals of coarse and fine fractions of the beach (NE, SW regions), sand-spit and palaeostrandline of the

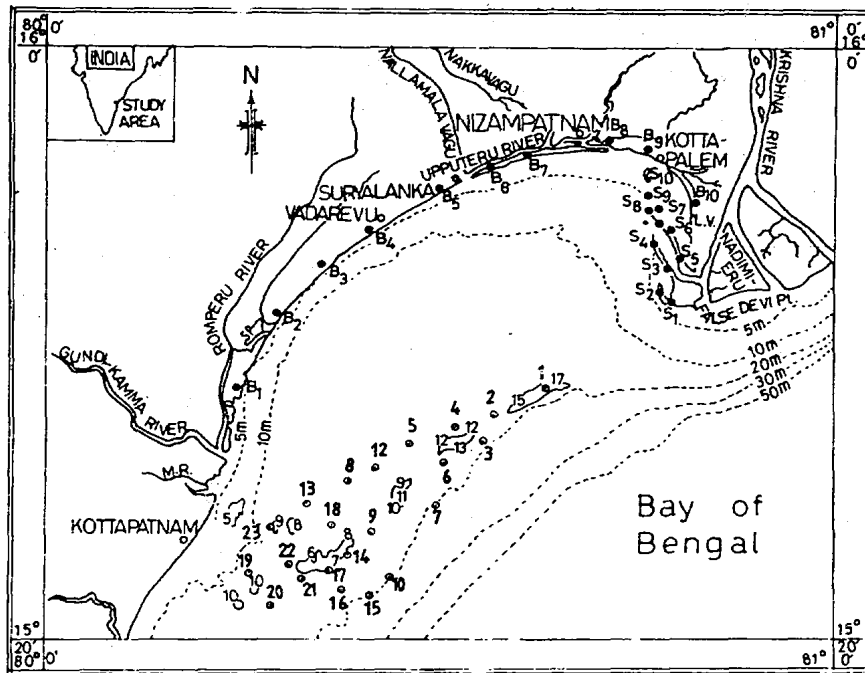


Fig. 1—Study area and sample location

Nizampatnam bay are given in Table 1. The results of multiple regression analysis are depicted in Figs 3-5 and Table 2. Both fractions consist of significant amounts of heavies and it is more in the fine fraction. Further, in the beach heavy mineral content of the FF are very high (40%) along the NE. The heavy minerals are dominated by opaques (ilmenite, magnetite and hematite = 30-40%), followed by amphiboles (hornblende), pyroxenes (hypersthene and diopside = 15-20% each), garnet and epidote (5-10%), rutile, zircon, tourmaline and monazite are also in significant quantities (3 to 5%). The heavy mineral assemblage is suggestive of its derivation from a common source comprising Deccan traps and the high grade metamorphic rock formations (Fig.2).

Opaques are more in the sand-spit and palaeostrandline sediments. Contents of amphiboles and pyroxenes are high in beach and decreases in sand-spit and palaeostrandline. Garnet, epidote, zircon and rutile are more in the CF and show a uniform concentration in the environments examined. Tourmaline and Kyanite are present in lesser quantities in spit and palaeostrandline. Sillimanite content is more in palaeostrandline and chlorite is absent. Mica is higher in sand-spit and palaeostrandline. Monazite concentration increases in FF of the beach and spit sands, but falls in palaeostrandline.

Fine fraction shows higher shape index in all the three environments. It is high in beach sands and

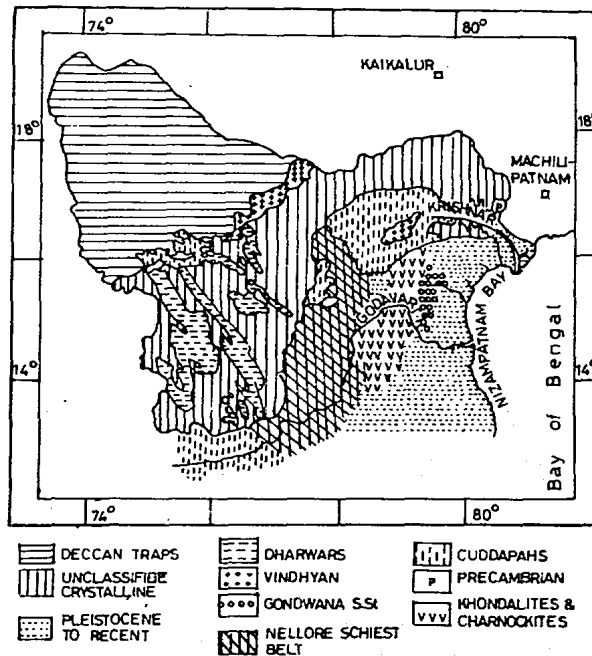


Fig. 2—Geology of the drainage basins of the Krishna and Gundlakamma rivers

uniform in spit and palaeostrandline. Density index is inversely related to shape index in the 3 environments. Stability index is relatively low in spit sediments. Coarse fraction has high stability index compared to the FF. The heavies in the palaeostrandline sediments are characterized by high multiple correlation, in

Table 1—Average content (in %) of heavy minerals in coarse and fine fraction of beach (NE and SW region) sand-spit and palaeostrandline, sediments off Nizampatnam

Environment Bulk (samples analysed)	Bulk (%)	Percentage																
		Op	Am	Py	Ga	Ep	Ru	Zr	Tou	Ky	Sil	Stau	Mi	Chl	Mon	SI	DI	StI
BEACH : NE region																		
CF (5)	7.89	33.38	19.04	17.13	7.26	8.64	2.13	3.83	2.87	0.83	0.69	0.98	0.53	0.17	1.79	2.83	0.51	0.24
FF (5)	40.45	32.68	19.43	20.19	3.97	6.58	1.93	4.08	3.52	0.70	0.41	0.68	0.44	0.11	4.93	4.66	0.48	0.24
SW region																		
CF (5)	3.56	27.65	17.33	15.78	8.54	8.22	2.36	3.94	2.76	0.99	0.82	0.85	0.74	0.43	2.82	2.51	0.42	0.27
FF (5)	18.33	37.46	17.73	28.64	5.18	8.23	1.26	1.79	2.36	0.85	0.52	0.84	0.65	0.50	3.10	3.11	0.60	0.14
SAND-SPIT																		
CF (10)	3.92	40.55	14.49	15.03	7.27	8.17	2.81	1.90	0.88	1.38	0.45	1.10	1.66	2.23	3.96	2.27	0.66	0.18
FF (10)	17.31	43.05	14.35	13.96	5.28	7.75	1.33	2.23	0.89	2.06	0.40	1.31	1.16	0.25	5.95	2.51	0.75	0.15
PALAEOSTRANDLINE																		
CF (23)	9.07	39.18	13.99	14.34	8.29	8.11	2.88	3.58	2.29	1.19	2.22	1.55	0.99	—	2.03	2.26	0.63	0.30
FF (23)	19.71	41.56	15.25	13.97	6.70	7.56	2.31	2.84	2.18	1.29	1.56	1.02	0.76	—	1.62	2.55	0.72	0.25
CF = coarse fraction, FF = fine fraction, Op = opaques, Am = amphiboles, Py = pyroxenes, Ga = garnet, Ep = epidote, Ru = rutile, Zr = zircon, Tou = tourmaline, Ky = kyanite, Sil = sillimanite, Stau = staurolite, Mi = mica, Chl = chlorite, Mon = monazite, SI = shape index, DI = density index. St I = stability index.																		

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Table 2—Analysis of variance for the regression of the beach, sand-spit and Nizampatnam Bay

Source	DF	Sum of squares	Mean squares	'F' statistics	Multiple correlation	Significance level
Beach						
C	9	3328.97	382.38	0.700	0.81	*5.12
F	9	3291.11	352.95	0.927	0.84	**10.56
Spit						
C	9	4254.66	778.50	0.054	0.36	*5.12
F	9	3481.63	384.91	0.977	0.86	**10.56
Bay						
C	22	1040.62	83.36	7.924	0.95	*4.30
F	22	946.11	79.12	46.038	0.99	**7.95

C = coarse, F = fine, *P < .05 designated, **P < .01 designated

comparison with beach. Though, 'F' statistics for palaeostrandline sediments indicates a significant difference than that of the beach and sand-spit, there is no significant difference between the beach and sand-spit (Table 2).

Discussion

Heavy mineral variations recorded in the beach, sand-spit and palaeostrandline (PSL) sediments seem to be related to regional hydrodynamic processes. The hydrodynamic features are different in the beach (high energy with continuous waves and currents), sand-spit (dumped with little reworking) and palaeostrandline (relict sediments). Heavy minerals in these environments show more or less similar assemblages except for the differences in frequency of occurrence. Chowdhari and Grewel⁸ have considered size, shape and density to explain the

variations in the frequency distribution of heavy minerals. In the present study, since heavy minerals were studied in two size grades, differences in shape and density are utilised to explain the variations in the frequency distribution of heavy minerals.

Sorting processes in this region may also increase the concentration of heavy minerals by selectively removing the coarse grains towards offshore leaving a fine-grained placers. All the minerals form a pattern of increasing efficiency of concentration within the placer with an increase in grain density and decrease in mean grain size. Sorting processes and selective grain transport played a prominent role in the concentration of heavy minerals in the Oregon beaches^{9,10}. Winnowing processes effecting the concentration of heavy minerals in the beach are regarded as largely the function of wave energy and grain size. During monsoon period, the nearshore

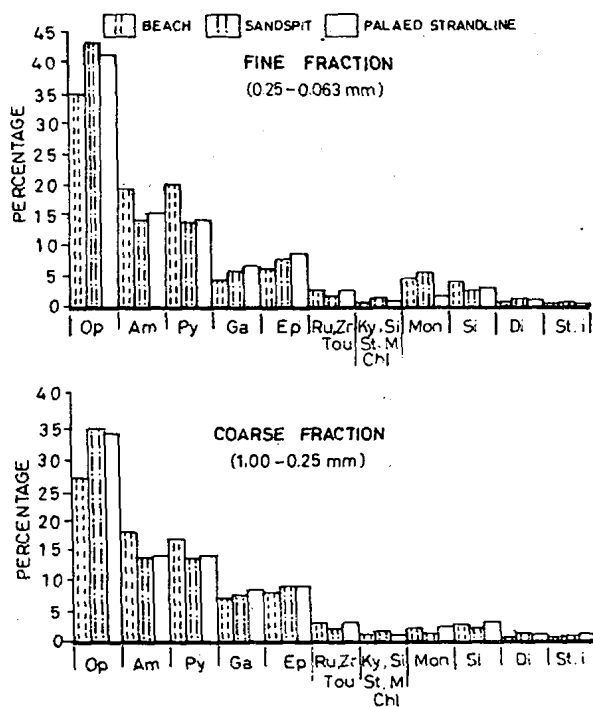


Fig. 3—Mean ($\bar{X}$) of the heavy minerals (CF, FF) from Beach, sand-spit and palaeostrandline sediments (OP = opaques, Am = amphiboles, Py = pyroxenes, Ga = garnet, Ep = epidote, Ru = rutile, Zr = zircon, Tou = tourmaline, Ky = kyanite, Si = sillimanite, St = stanrolite, M = mica, Chl = chlorite, Mon = monozite, SI = shape index, DI = density index, St. I = stability index)

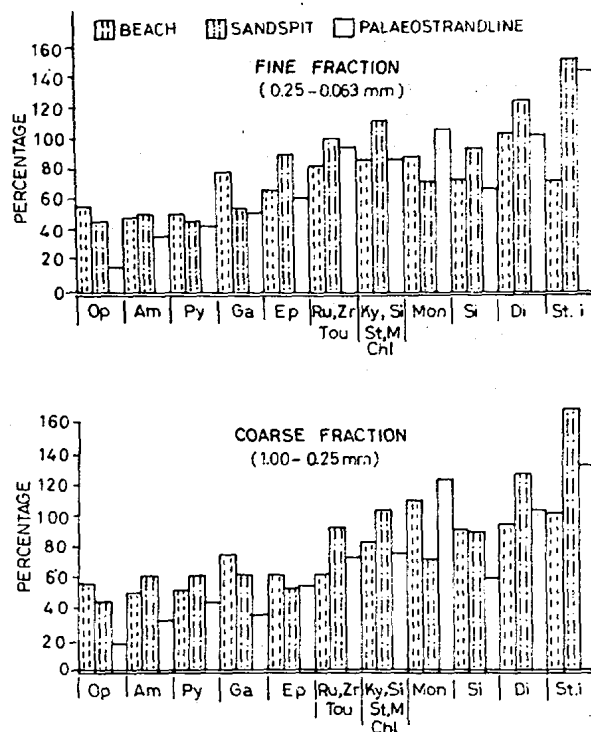


Fig. 5—Co-variance of heavy minerals from beach, sand-spit and palaeostrandline sediments (OP = opaques, Am = amphiboles, Py = pyroxenes, Ga = garnet, Ep = epidote, Ru = rutile, Zr = zircon, Tou = tourmaline, Ky = kyanite, Si = sillimanite, St = stanrolite, M = mica, Chl = chlorite, Mon = monozite, SI = shape index, DI = density index, St. I = stability index)

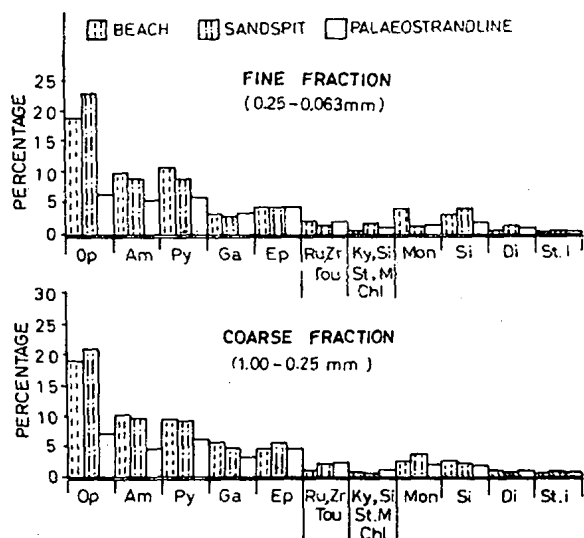


Fig. 4—Standard deviation (σ) of heavy minerals from Beach, sand-spit and palaeostrandline sediments (OP = opaques, Am = amphiboles, Py = pyroxenes, Ga = garnet, Ep = epidote, Ru = rutile, Zr = zircon, Tou = tourmaline, Ky = kyanite, Si = sillimanite, St = stanrolite, M = mica, Chl = chlorite, Mon = monozite, SI = shape index, DI = density index, St. I = stability index)

currents are directed towards north¹¹ with an estimated speed of 1 km.h^{-1} . Due to intense wave action in the beach, finer and lighter grains are either removed to the inner shelf or to the backshore. On the other hand wind transports the lighter sand landwards to form dunes. A cumulative effect of these two processes is the enrichment of heavies in the beach relative to the other environments⁴. Constant washing of sediments in the backshore could lead to the heavy mineral concentrations in the beaches¹².

Higher heavy mineral contents, in the samples of NE beach, than in the SW part (Table 1) indicate the heavy mineral source from the Krishna river. The rich placers on the beach and sandspits to the south of the Krishna river mouth are attributed to the divergence of currents at the mouth of the river. Rao¹ has reported the concentration of heavy minerals accumulated by this processes in beaches and adjacent river mouths along the east coast of India.

The heavy minerals of the palaeostrandline are similar to these reported for the Krishna river sands¹³. As the sea level rose, the heavy mineral concentration on former beaches tended to follow the

landward moving shore zone. The slow rise of sea level¹⁴ during the past 8000 y BP is the opportunity to abide the reworked minerals at the ancient beaches is certainly greater than for modern beaches. Pujos *et al.*¹⁵ from their studies of French Guiana continental shelf reported that the shoreline was close to -25 m around 8000 y BP, which supplements the present interpretation. Heavy mineral distribution of the modern and ancient environments were induced both by selective chemical decomposition and hydraulic fractionation.

The enrichment of opaques, garnet, epidote and zircon, the depletion of amphiboles and pyroxenes in coarse fraction and the absence of chlorite in the relict sands of palaeostrandline sediments may have resulted as below. The fine grained, bladed heavy minerals were differentially winnowed, thus leaving a lag of coarse grained, higher density, generally equant heavy minerals. Alternately, the inverse relationship of amphiboles (hornblende) and garnet could reflect a greater degree of *in situ* selective decomposition of relatively unstable hornblende in the relict suite. The highly significant 'F' statistic of the PSL sediments, at $P < .05$ and $P < .01$ level indicates the function of reworking and poorly sorted nature. The beach and spit sediments are less significant due to their well sorted nature. The fine fraction of spit sands have higher multiple correlation than that of the other fractions. It may probably be

due to the fact that there is more accumulation of heavies in the fines.

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