

HEAVY MINERAL OCCURRENCE OFF HAZIRA, WEST COAST OF INDIA

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ABSTRACT

The occurrences of heavy mineral placers on the west coast of India are well known from Konkan and Malabar coast. However, a geological and geophysical investigation (including echosounding and side scan sonar profiles and 7 samples) off Hazira, Gujarat coast, have indicated appreciable concentration of heavy mineral placers in the intertidal zone. The mineral suite is mainly composed of opaques (ilmenite and magnetite), pyroxenes (augite and diopside) and amphibole (hornblende) with minor percentages of sphene, zircon, staurolite, kyanite, tourmaline etc. indicating mixed igneous and metamorphic source. The grain size studies indicate positive correlation between concentration of heavies and high sorting values, as well as concentration of heavies and the areas having geomorphic features like mega ripples. The transportation history has indicated the effect of high energy hydrodynamic regime prevailing in the area.

INTRODUCTION

Occurrences of heavy mineral bearing beach sands along the western coast of India are reported from many localities, prominently from Kerala and Maharashtra. These sands commonly contain minerals like ilmenite, magnetite, monazite, zircon, garnet etc. Of these, heavy mineral placers along the Kerala coast are well known and best studied (Jacob 1956; Mallick *et al* 1987). The accumulation of these minerals along the beaches of Konkan, Maharashtra was studied by Roy (1958) and Mane and Gawade (1974).

The offshore extension of these heavy mineral beach occurrences was established by Siddiquie *et al* (1979, 1982), along the Konkan coast. However, all these studies were generally confined to small isolated areas. Wagle *et al* (1989), on the basis of aerial photo-interpretation technique, identified zones of black sand occurrences on the beaches for entire Maharashtra coast (from Bassein to Vengurla). Similar occurrences has been reported from the intervening areas other than the southern Kerala and central Maharashtra (Kumar 1977, 1980;

Kidwai, 1971; Kidwai and Wagle, 1975 and Mislankar, 1988). All these studies have established the presence of heavy mineral beach sands from Bassein (north of Bombay) to Cape Comorin.

However, it is interesting to note that from north of Bassein, especially around Gulf of Khambhat, except irregular patchy occurrence around north eastern part of Piram island (Sakhawala and Shringarpure 1988) no heavy mineral occurrence has been reported which is somewhat intriguing. The nearshore area north of Bassein perhaps was not studied in details because in this area sediment budget is high due to its proximity to deltas of large rivers like Narmada, Tapi, Mahi and Sabarmati in prevailing very high energy environment.

While carrying out high resolution geophysical survey for an offshore engineering project off Hazira (near Surat), at the mouth of Gulf of Khambhat, seven surface sediment samples were collected along a track, mainly to confirm the marine geophysical data. However, visual inspection, being black in colour necessitated detailed investigation. When checked for

heavy mineral content, they were found to contain appreciable proportion of the same. In the present paper the black sand occurrence off Hazira has been discussed in detail and an attempt has been made to describe their mode of deposition, mineralogy, probable origin and its correlation with geomorphic features present

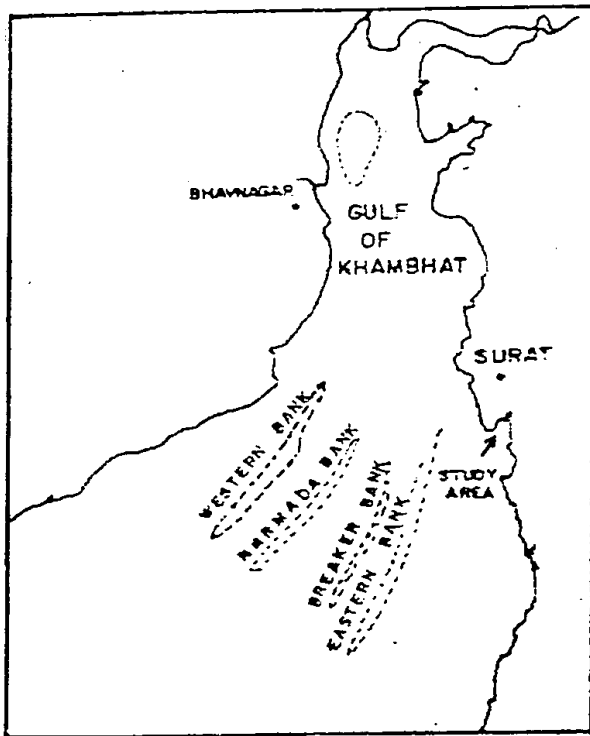


Fig. 1 Location of the study area in the Gulf of Khambhat, India.

in the area. It is presumed that though the number of samples analysed are less, they are representative of the area as they were taken from a single transect perpendicular to shoreline. Being preliminary study, the paper is expected to provide baseline data for intensive and systematic study.

ENVIRONMENT

Physiography: The area (Fig. 1) is on the western flank of the Gulf of Khambhat and has a complex hydrodynamic regime. The study area is at the confluence of rivers Tapi (length

724 km, Catchment area 64,750 sq. km., average annual runoff 8634 million cu.m.) and Mindhola (a small estuarine tributary).

The tides in the area are semidiurnal and of the order of 7 m, while current velocity is of the order of 55-115 cm sec⁻¹ in NNW-SSE direction (Swamy *et al* 1982). Significant wave height is 2.84 m in the area (P Chandramohan. Pers. comm.). The study area becomes interesting mainly due to high tidal range as most part of it is about 3.5 m above chart datum and gets submerged during high tide twice a day. The sediments in the study area are, therefore, constantly influenced by flood and ebb tides as well as river flows from different directions.

Geology: The alluvial plains cover to great extent the coastal zone of Surat and Broach districts. The Cambay trough runs nearly N - S and is bounded by faults on its eastern and western sides. The Deccan Traps are exposed on both the sides of the trough. The traps are covered by a full succession of Tertiary, specially near Surat- Broach which are capped by laterites. Mesozoic and Archaean rocks are also exposed in the hinterland areas through which the Tapi as well as the other smaller rivers flow contributing sediments to the study area (Wadia 1966; Krishnan 1968 and Gadekar 1986).

METHODS

High resolution marine geological and geophysical surveys were carried out using a small (12 m length) boat. Bathymetry of the area was obtained by dual frequency Atlas Deso 10 echosounder (frequency 210 and 30 KHz). As the echosounder continuously records the profile of the seabed, the presence of various geomorphic features can also be identified from the same.

Side scan sonar system (EG & G model 259-4) provided plan view of the seafloor in the form of the tonal variations similar to aerial photography and helped in identifying the morphologi-

cal and lithological variations. Positions during the survey were obtained by a shore based radio electronic position fixing Miniranger MRS III system which has an accuracy of ± 3 m.

Seabed samples (Fig. 2) were collected using a Van Veen grab (area 0.04 sq.m.). All the samples were analysed for the heavy mineral study.

The sand samples were washed to remove salt and dried. A representative portion (about 40 gms) of the sample was taken for dry sieving through a set of A.S.T.M. sieves at half phi interval for granulometric studies.

For heavy mineral studies, another set of samples (about 10 to 12 gm) was taken. The samples were treated with hydrogen peroxide

and 10% hydrochloric acid to remove organic matter and carbonate content respectively followed by dry sieving. Three size fractions, greater than 0.25 mm (fraction A), 0.125 - 0.25 mm (fraction B) and 0.062-0.125 mm (fraction C) were separated.

Heavy mineral separation was carried out using tetrabromoethane ($C_2H_2Br_4$, Sp. gr. 2.96) and the percentage of heavy minerals in respective fractions were calculated. Highly magnetic minerals like magnetite were separated by bar hand magnet and their percentage were calculated. Only two (0.125 - 0.25 mm and 0.062-0.125 mm) heavy fractions (free from magnetite) were mounted on slides and about 300 to 400 grains on each slide were counted under a petrological microscope and the number per-

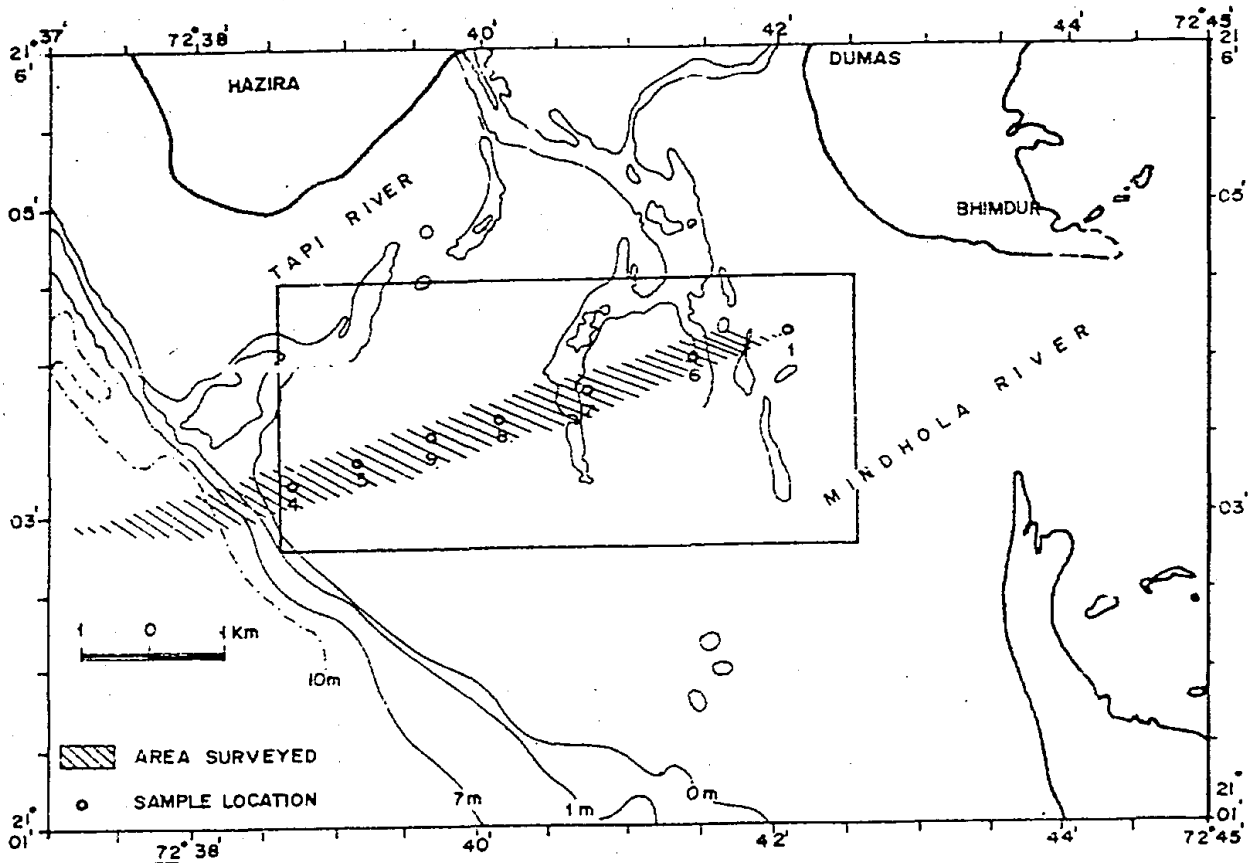


Fig. 2 Map showing the area surveyed and locations of the samples collected. Inset covers the area shown in Fig.6

centage of individual minerals were computed. Some bulk heavy mineral fractions were powdered for X-Ray analysis, for confirming the identification.

The size parameters such as mean grain size (Mz ϕ), sorting (6x), skewness (SK) and kurtosis (K) etc. were obtained by following graphic methods of Folk and Ward (1957) (Table 1).

TABLE 1

TEXTURAL PARAMETERS OF SEDIMENTS OFF HAZIRA

Sample No	Depth in m	Mean Size Mz ϕ	Standar Deviation ('6 ₁)	Skewness (Sk.)	Kurtosis (Kg)
H 1	- 3.5	2.57	0.34	- 0.4	0.93
H 6	1.4	1.46	0.56	- 0.39	0.82
H 7	- 1.2	1.28	0.82	- 0.37	1.04
H 9	- 2.0	1.48	0.95	- 0.14	0.89
H 5	- 1.9	0.71	1.13	- 0.04	0.83
H 4	0.0	1.85	0.93	- 0.04	0.93

Negative depth indicate height above mean sealevel, which gets submerged in prevailing tide range of about 7 m .

RESULTS AND DISCUSSION

The mean grain size varies from 0.71 to 2.57 ϕ (coarse to fine sand). The standard deviation values vary between 0.38 to 1.13 ϕ showing a general trend from well sorted at eastern end to poorly sorted at western end. This correlates well with grain size. The eastern most point at shore is at high tide level and the sediments here are under prolonged winnowing action of waves, whereas at the westernmost end, sediments are at mid-tide level and are not subjected to so much wave action (Chaudhri *et al* 1981). The skewness values vary from -0.04 to -0.39 showing negatively skewed sediments flanked by nearly symmetrically skewed sediments. The negative skewness indicates strong winnowing action and can be correlated with high energy environment (Daune 1964). The kurtosis values vary from 0.82 to 1.04 where majority of samples show platykurtic nature except samples from extreme ends which are mesokurtic.

The heavy mineral concentration in the sediment varies in different size fractions (fraction A: 1.48- 22.15%, B: 1.88- 72.32 % and

C: 0.01 - 12.61 % ; Table 2 and Fig.3). This variation shows that except in sample no. 1, in other samples the heavies are concentrated more in fractions A and B (medium to fine sand). More or less similar trend is observed for magnetite also. But in sample no. H- 1 relatively high concentration of heavy and magnetite is noted in fraction C (very fine sand). This would be probably related to the location of the sample no. 1 which is situated at higher elevation

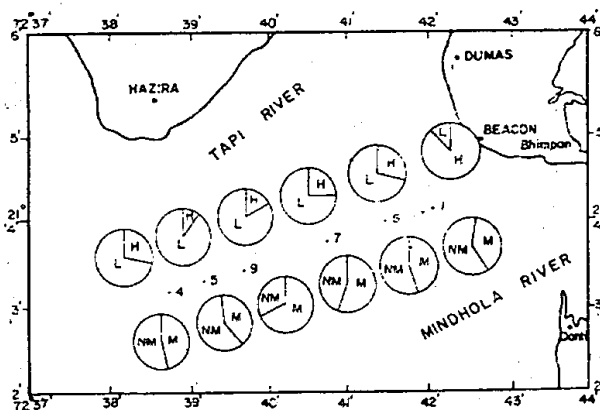


Fig. 3 Distribution of heavy (H) and light (L) minerals and magnetic (M) and non-magnetic (NM) fractions within heavy minerals. (Location of the samples collected given numerically)

TABLE 2

PERCENTAGE OF HEAVY MINERALS, MAGNETITE AND ASSOCIATED GEOMORPHIC FEATURES

HEAVY MINERALS					MAGNETIC MINERALS				
Sample No.	Bulk Sample	A	B	C	Bulk Sample	A	B	C	Geomorphic feature
H 1	85.8	1.73	84.20	14.06	33.56	0.26	85.15	14.58	Enriched by mega ripples
H 6	28.48	76.45	23.55	0.07	14.14	81.11	18.88	0.70	Transition of mega ripple and sand sheet (within channel)
H 7	22.32	60.08	39.03	0.88	11.89	68.85	30.33	0.12	Near Cchannel
H 9	16.011	54.42	41.50	4.08	8.38	62.33	35.06	2.60	Sand
H 5	8.75	86.30	13.69	0.96	3.8	93.75	6.25	-	Sand
H 4	38.0	22.14	70.71	7.50	13.56	27.81	63.15	5.02	Near to mega-ripple.

Size fractions : A - + 0.25, B - 0.125 - 0.25, and C 0064 - 0.125 mm

than that of others, being above mean sea-level at -3.5 m. In such situation, it is expected that the sediments will be dumped by plunging wave during high tide, which are latter subjected to winnowing action, due to which lights are removed (Komar and Wang 1984). Strong winnowing action in the study area is reflected by negative skewness in all samples which decreases from very negatively skewed at near shore end to gradually symmetrically skewed towards offshore. This phenomena could be affecting the relative concentration of heavies in finer fractions. The relative increase of heavies in fraction C of station no. H- 4, which is westward also supports this.

The opaque heavies, other than magnetite, are mainly ilmenite and ilmeno-rutile. Fig. 4 shows X-ray diffraction pattern for 2 samples. Station no. H-1 shows ilmenite (2.75 A°), ilmeno-rutile (3.24 A°), augite (2.99 A°), ulvo spinel (2.57 A°), epidote (2.90 A°) and topaz (2.94, 3.2 A°); whereas station H-7 sample shows hypersthene (3.18 A°) along with trevorite (2.52 A°, a magnetite series mineral). The other major heavy minerals present are pyroxenes (mainly augite and diopside: 12.8-87%) and amphibole (green and brown hornblende, 0.3-2.7%). The minor heavy minerals are sphene, zircon, staurolite, kyanite, tourmaline etc. (Table 3).

Opaques commonly occur as irregular, angular to subangular grains though subrounded to well rounded grains are also present. Augite is brownish to dark brown whereas diopside is colourless to pale green. Most of the grains are short prismatic crystals but some grains show rounded edges. Epidotes are subangular and are present in all samples. Bluish green hornblende show platy nature, whereas hypersthene grains are irregular in form with characteristics pink pleochroism. Zircon is elongated and euhedral whereas monazite is well rounded with light yellow colour. Tourmaline is dark brown, dichroic and with rounded ends but rectangular grains of tourmaline are also noticed in sample no. 4. Biotite, found in station H- 6, is brown in colour with rounded edges.

The results obtained from the study area show that the high percentage of heavies at station no. 1 (84.2%) are associated with high sorting values (0.34%) and least concentration of heavy mineral at station no. 5 (13.7%) is where the sediments are poorly sorted (1.13%). This indicates that in the study area the concentration of heavies is controlled by sorting process (Komar and Wang 1984).

The sonographs collected from the area clearly reveal the presence of bedforms like

TABLE 3
THE PERCENTAGE DISTRIBUTION OF HEAVY MINERALS OTHER THAN MAGNETITE
IN DIFFERENT SIZE FRACTION

Sample	Size fraction	Opq	Aug	Hyp	G.Hb	B.Hb	Epd	Rut	Gar	Sph	Zir	Mon	Sir	Kyt	Tor	Bit
H-1	A	37.7	55.9	2.0	0.4	0.6	0.7	0.7	0.7	0.3	-	-	0.7	-	-	-
	B	83.4	12.8	0.2	-	0.4	0.4	0.4	0.4	0.2	0.4	1.3	-	0.2	-	-
	Avg	60.0	33.5	1.1	0.2	0.5	0.5	0.5	0.5	0.25	0.2	0.6	0.3	0.1	-	-
H-4	A	21.6	69.3	1.2	2.6	1.3	1.7	0.9	0.4	0.5	-	-	-	-	0.5	-
	B	34.7	58.5	1.0	1.0	1.4	1.9	-	0.5	0.5	-	-	-	-	0.5	-
	Avg	28.2	64.0	1.1	1.8	1.3	1.8	0.4	0.4	0.2	-	-	-	0.2	0.4	-
H-5	A	17.9	74.5	0.7	0.7	1.3	2.7	2.0	-	-	-	-	-	-	0.7	-
	B	55.5	73.0	-	2.0	1.7	2.9	2.5	0.4	0.4	-	-	0.4	-	-	-
	Avg	36.7	53.7	0.3	1.8	1.5	2.8	2.2	0.2	0.2	-	-	0.2	-	-	-
H-6	A	14.2	77.0	0.6	1.2	3.1	3.7	-	-	-	-	-	-	-	-	-
	B	53.5	36.0	-	1.2	1.8	2.4	4.2	-	-	-	-	-	-	0.5	0.5
	Avg	33.8	56.5	0.3	1.2	2.4	3.0	2.1	-	-	-	-	-	-	0.2	0.2
H-7	A	8.5	81.4	-	0.7	4.2	1.4	3.5	-	-	-	-	-	-	-	-
	B	35.3	61.4	0.6	0.3	1.2	0.6	0.3	-	0.3	-	-	-	-	-	-
	Avg	21.9	71.4	0.3	0.5	2.7	1.0	1.9	-	0.1	-	-	-	-	-	-
H-9	A	19.8	76.5	0.3	1.8	0.7	0.3	-	0.3	-	-	-	-	-	-	-
	B	8.2	87.0	-	1.0	1.0	2.6	-	-	-	-	-	-	-	-	-
	Avg	14.0	81.7	0.2	1.4	0.8	1.4	-	0.1	-	-	-	-	-	-	-

Size fraction = A-0.125' mm, B-0.062 0.125-0.25 mm Avg = Average Opq = Opques, Aug = Augite, Hyp = Hypersthene, G. Hb= Gren hornblende, B. Hb=Brown hornblende, Epd=Epidote, Rut=Rutile, Gar=Garnet, Sph=Sphene, Zirc=Zircon, Mon=Monazite, Sir=Staurolite, Kyt=Kyanite, Tor= Tourmaline and Bit=Biotite.

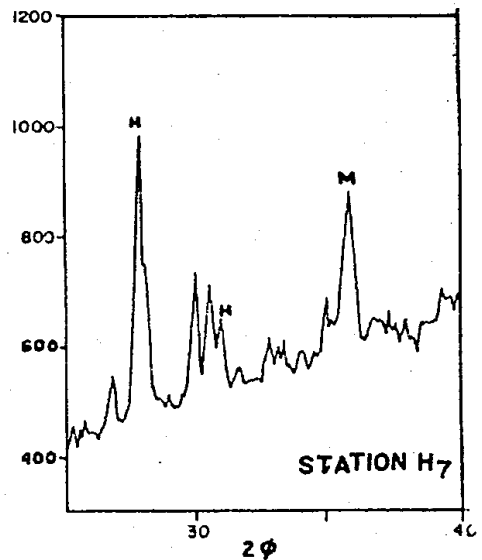
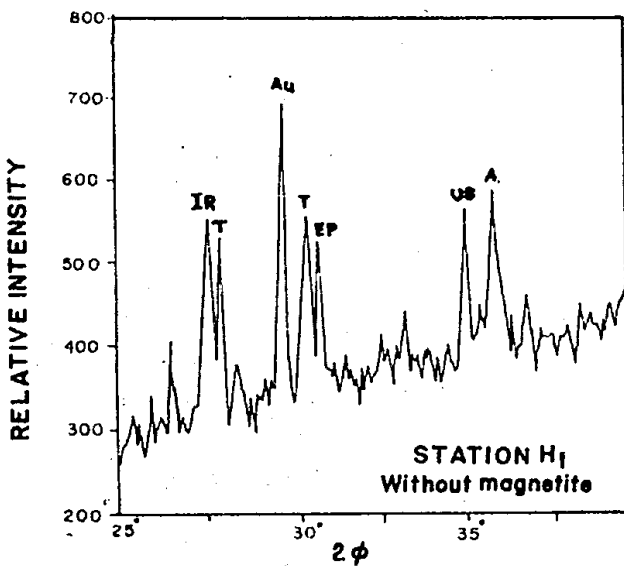
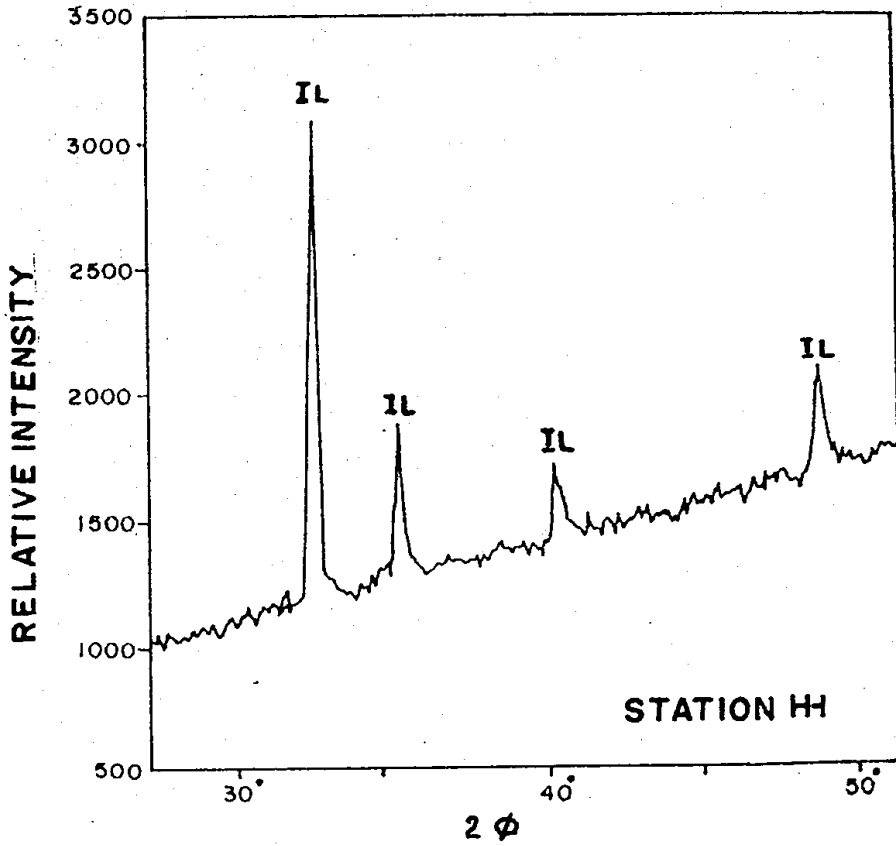


Fig. 4 X-ray diffraction patterns of the selected heavy mineral fractions. (IL - Ilmenite, IR - Ilmeno-rutile, T-Topaz, Au-Auguite, Ep-Epidote, us-ulvo spinel, H-Hypersthene and M-Magnetite).

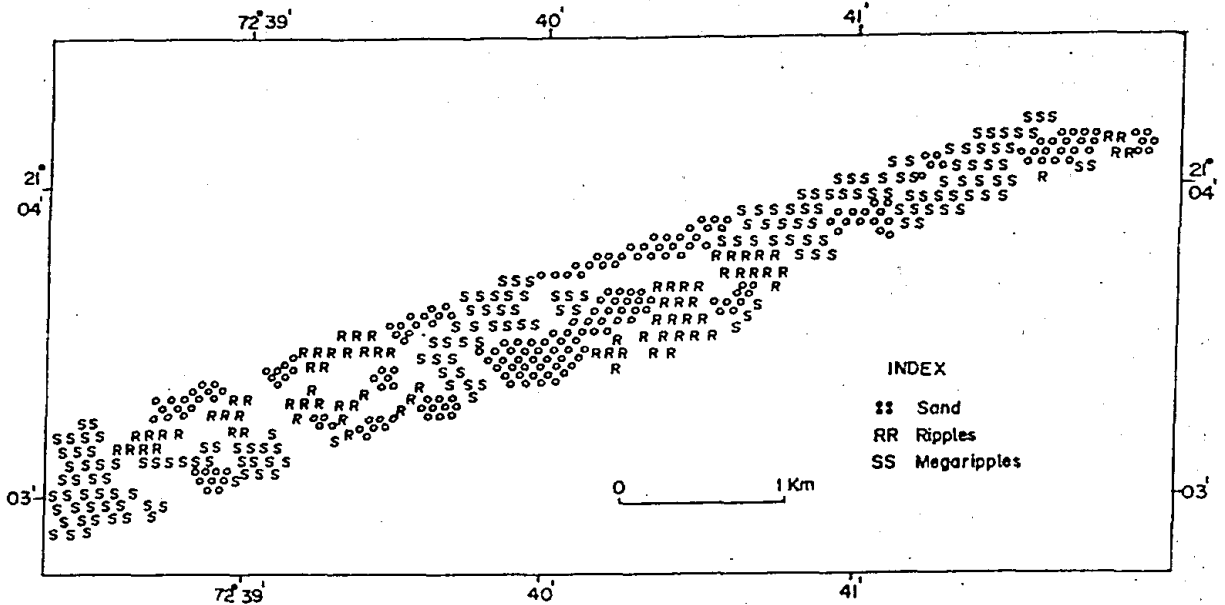


Fig. 6 Distribution of geomorphic features in the study area. (Location of the map shown in Fig. 2)

ripples and sandwaves besides sand ribbons. The ripple marks, as observed from the sonographs (Fig. 5) can broadly be divided into two categories: i) megaripples having wavelength generally more than 5 m and ii) ripples having average wavelength upto 2 m. The distribution of these bedforms is shown in Fig. 6. The orientation of these ripple marks in the eastern part is NW-SE which changes to NE-SW in western side. The ripple marks are believed to be oriented transverse to current direction. These bedforms presumably occurs due to complex hydrodynamic regime prevailing in the area supported by abundant sediment load brought by the rivers. A close relationship is observed between high concentration of heavies and occurrence of megaripples. (Table 2), which can be explained based on the fact that megaripples occurs with finer sands (Middleton and Southard 1977). The presence of bedforms like sandwaves, sand-ribbons, sand ripples etc. which can easily be identified by side scan sonar, itself is indication of presence of sand. The side scan sonar

profiling in the heavy mineral exploration can be used advantageously to demarcate the occurrence of sand.

CONCLUSIONS

1. Placer sands with appreciable concentrations of minerals like ilmenite and magnetite are noted in the intertidal zone of study area; mineral assemblage is indicative of mixed igneous and metamorphic source and minerals show polycyclic nature. The concentration pattern reveals the effect of high energy hydrodynamic regime.

2. A technique of mapping the seafloor by side scan sonar can be very useful in the mineral exploration in delineating the sandrich zone and associated geomorphic features which can be further checked for its heavy mineral content.

3. A detailed survey of the adjoining area including the upstreams of Tapi and Mindhola river can be useful in delineating the prospective

area and can also provide useful information on related topics like sediment transport, deposition pattern etc.

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