

## Shoreline Configurations Control on the Concentration of Nearshore Heavy Minerals: A Case Study from Konkan-Maharashtra, Central West Coast of India.

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### ABSTRACT

The geological and geophysical exploration in the nearshore areas between 3 and 19 m water depth, in four bays viz., Wada-Vetye, Ambolgarh, Rajapur and Vijaydurg along the Konkan coast - central west coast of India (16°42' and 16°33' N Lat. and 73°14' and 73°20' E long.) has revealed the presence of heavy mineral concentrations rich in ilmenite and magnetite in the surficial sediments. The heavy mineral concentration reaches upto 80% (average 30.0%) in the study area, with the highest concentration in Ambolgarh bay, (6.9 to 80% on an average to 40.86%) and lowest in the Wada-Vetye bay (0.6 to 54% on an average to 17.71%). Intermediate concentration in the range of 5.38 to 76.22% (average 36.87%) and 4.3 to 65.9% (average 28.47%) are found in Rajapur and Vijaydurg bays respectively.

The variations in the distribution pattern of heavy minerals varies from bay to bay is attributed to the influence of coastline configuration and its morphological features. The Ambolgarh bay which has the highest concentration is arcuate with gentle gradient. NE-SW orientation appears to be more suitable for the accumulation of more heavy minerals. Wada-Vetye bay with steep gradient almost oriented in N-S direction and causes minimal interception of the sediment movement resulting poor accumulation of heavy minerals. The E-W oriented Rajapur bay, with moderate to gentle gradient shows moderate to high concentration of heavy mineral mainly due to the partial wave convergence around Musakazi promontory in the northern part. In the Vijayadurg Bay, with NNE-SSW orientation and moderate to gentle gradient, has fair concentrations of heavy mineral are due to its arcuate shape, disposition in the updrift side of wave converging point and accretion.

**Key Words :** Shoreline Configuration, Heavy Mineral, West Coast, India.

### INTRODUCTION

The occurrence of heavy mineral placers in the nearshore areas along the Konkan coast, Maharashtra is known since long (Siddiquie and Rajamanickam, 1979; Siddiquie et al. 1982 and Wagle et al, 1989). These placer deposits are enriched in ilmenite and magnetite along with granitic and metamorphic index heavy minerals like zircon, tourmaline, kyanite, staurolite etc. Though the source rocks, climate, assemblage of heavy minerals and oceanographic conditions are more or less same throughout the area, the heavy mineral concentration patterns vary from bay to bay, suggesting the influence of other factors for the concentrations of these placer sands.

In the present paper the patterns of offshore heavy mineral concentration in the surficial sediments of four bays viz. Wada-Vetye, Ambolgarh, Rajapur and Vijaydurg are studied with reference to the prevailing oceanographic conditions, and role of morphogenetic factors such as shoreline configuration, disposition of rivers/streams and other associated geomorphological features of the areas. The area under study lies between the latitude

16°42' and 16°33'N and longitude 73°14' and 73°20'E stretching from Wada-Vetye bay in the north to Vijaydurg bay in the south with intermediate Ambolgarh and Rajapur bays. The coastline is submergent type, it is very irregularly indented and is drained principally by two major rivers viz., Vaghotan and Kodavil along with two small streams (Fig.1). The coast is characterised by the presence of wave cut terraces, headlands, stacks, tombolas, tidal flat, cliffs, etc. (Fig.2). All the four bays under study widely vary in their shapes, coastal outlines, river sources, position of promontories and their alignment with wind direction (Table 1). The northern most cliff point of Wada-Vetye bay is comprised of boulders, whereas the southern most is found to be of a straight and narrow beach with coarse sands. The Ambolgarh bay is arcuate to semi-arcuate in shape. The Rajapur bay has a small pocket beach behind the promontory. The southernmost Vijaydurg bay is arcuate to semi-arcuate in shape. The Vaghotan river debouches into Vijaydurg bay whereas Kodavil river into Rajapur bay and only 2 small streams enters Vijaydurg and Wada-Vetye bay.

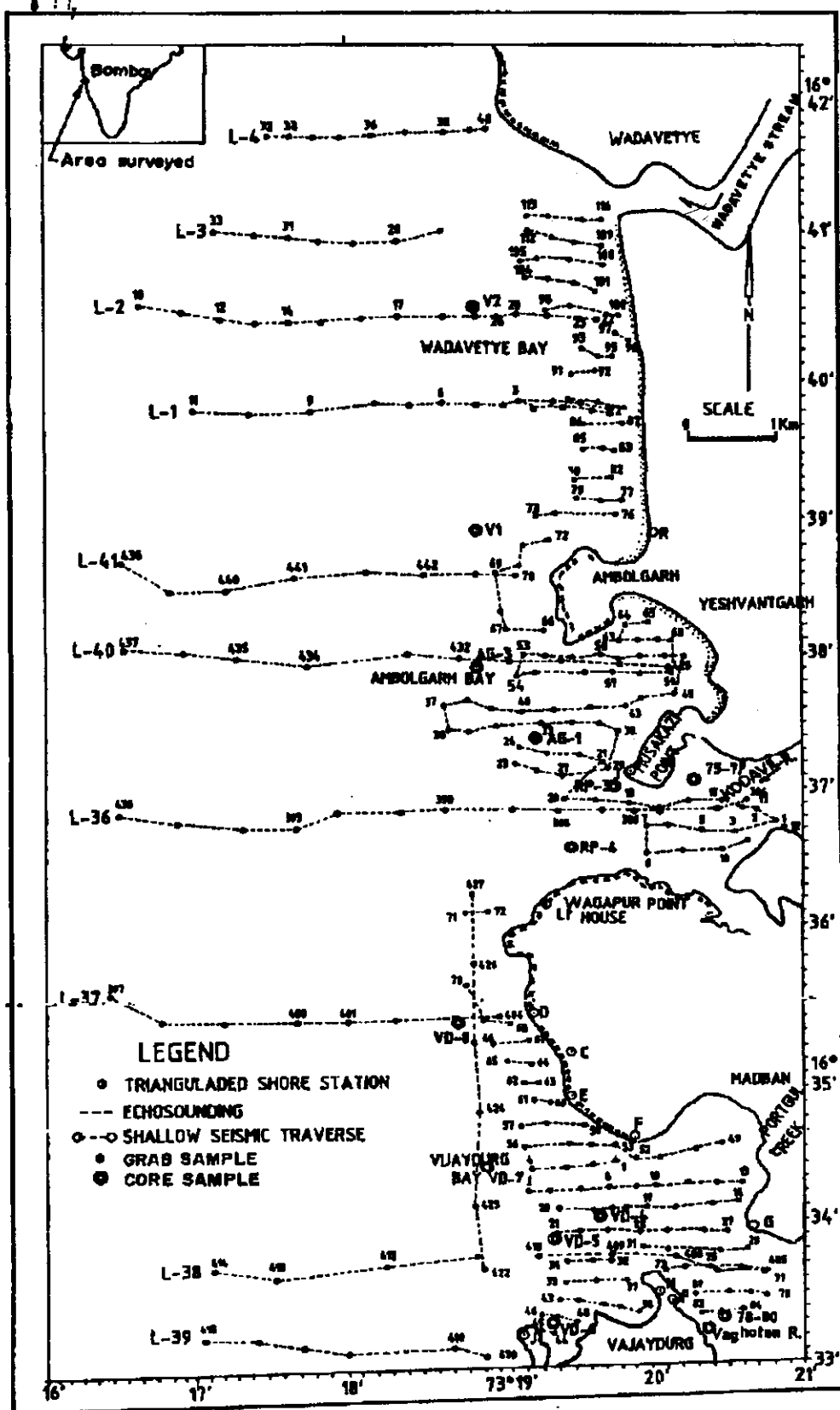


Fig.1 Location of Study Area and Positions of Survey Track

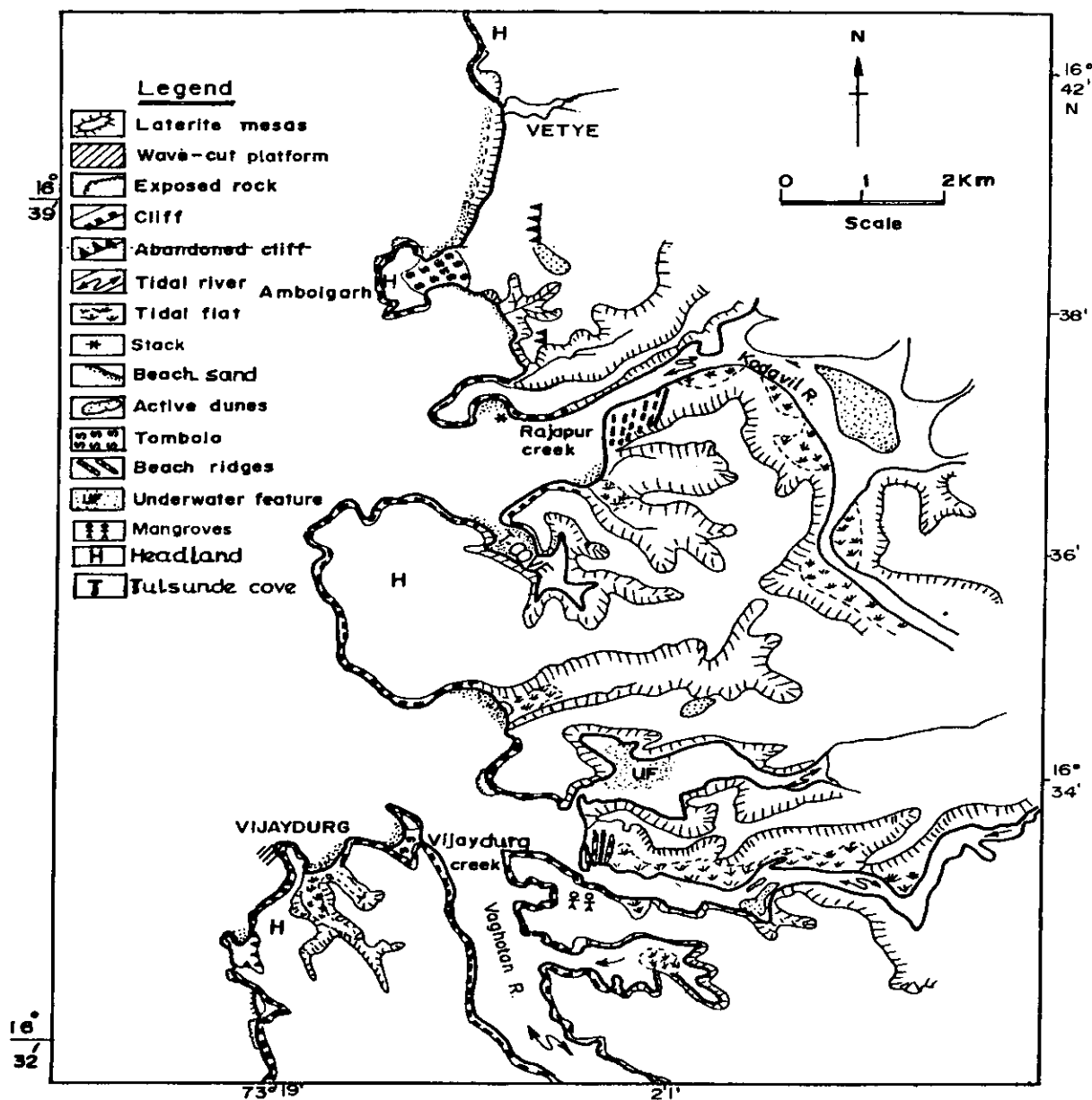


Fig.2 Geomorphological Features of the Area

The wave refraction patterns of SW, W, WSW and WNW directions for 6, 8, 10 and 12 seconds period confirms the existence of high energy and low energy centres induced by the convergence and divergence of waves especially opposite to promontories and in the bays, respectively (Fig.3 & Table 2).

#### METHODS

The area was surveyed at a close spacing of 250 m for sampling and about 1000 m for seismic, using Atlas Deso 10 dual frequency

echosounder to know water depth and EG&G Sparker for knowing sub-surface sediment thickness. The sediment samples were collected using Van Veen grab (0.04 sq.m.) and Piston gravity and gravity corer. The positions were fixed using Mini Ranger MRS III system. The analysis of sediments for grain size parameters, heavy mineral separation, identification and sedimentation rates were carried out using standard techniques (Hutchison, 1974; Krishnaswami and Sarin, 1976). A total 225 sediment samples (210 grab & 15 cores) were collected, out of which 150 samples (146 grabs & 4 cores) were analysed.

RESULTS AND DISCUSSIONS

Table 1 Characteristic Features of the Bays

Bays	Vijaydurg	Rajapur	Ambolgarh	Wada-Vetye
Location	16°36'32"N 16°33'00"N 73°19'00"E 73°20'43"E	16°37'00"N 16°36'22"N 73°19'00"E 73°21'00"E	16°38'46"N 16°37'00"N 73°19'00"E 73°20'00"E	16°42'00"N 16°38'46"N 73°19'00"E 73°20'00"E
Total area covered km <sup>2</sup>	22.86	04.62	05.80	23.43
Shape	Arcuate	Arcuate pocket	Arcuate to semi-arcuate	Straight
Coastline Configuration	NNE-SSW	E-W	NE-SW	N-S
Promontories in N and S	N.Wagapur S.Vijaydurg	Musakazi pt. Wagapur	Musakazi pt.	Ambolgarh
River source and stream	Vaghotan R. Stream in South	Kodavil R.	----	Stream in the north
Nature of bouldary & beach	Sandy		Sandy	Sandy coarse sand
Wind	Semi closed	Semi closed	Closed and	Open and exposed
Common Features :	Water depth : 2-19 m Climate : humid tropical Rainfall : 2500-3000 mm Tidal range : 0.5-2.0 m Predominant wave directions : W, SW, WNW, WSW			

Table 2 Energy Conditions Prevailing in the Study Area in Different Wave Directions and Periods

Directions Period in Seconds	W				WNW				SW				WSW			
	6	8	10	12	6	8	10	12	6	8	10	12	6	8	10	12
Area	D	D	I	D	C	C	D	I	C	C	C	C	C	D	D	C
Wada-Vetye North	D	C	I	D	D	D	C	D	D	D	D	D	D	D	D	D
Wada-Vetye	D	C	I	D	D	D	C	D	D	D	D	D	D	D	D	D
Ambolgarh Promontory	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	D
Ambolgarh	D	D	C	D	D	C	D	C	D	D	D	D	D	D	C	D
Rajapur	D	D	C	C	D	D	D	D	D	D	D	D	D	D	D	C
Vijaydurg Promontory	C	C	D	D	C	C	C	C	C	C	D	C	C	C	D	C
Vijaydurg bay	D	D	D	C	D	D	D	D	D	D	D	D	D	D	C	D
Vijaydurg point	C	C	C	C	C	C	C	I	C	C	C	C	C	C	C	C

D = Divergence; C = Convergence; I = Inept.Condition

The water depths in the studied area range between 3 m to 19 m. The sediments upto 10-11 m depth are sandy with gradients ranging between 1:6 to 1:330. Beyond 11 m water depth, acoustically transparent clay overlaps the sandy sediments. The gradients are ranging from 1:135 to 1:720. Among the four bays the Wada-Vetye bay has coarser sediments and very steep gradients (1:6 to 1:90), while other bays remain to be gently sloping with fine sediments. The sediments in these bays consist of sand, silt, clay and silty clay with variable proportions of quartz (transparent and iron stained), feldspar, calcareous material and heavy minerals. The grain size analysis of sediments shows the overlapping of different environments and presence of sediments from two environments ancient/relict and Recent (Gujar, 1996).

The heavy mineral concentration in the sediments ranges upto 80% (average 30%). The highest concentration of 6.9-80.0%, (average 40.86%), is in the Ambolgarh bay. While the lowest concentration of 0.65% to 54% (average 17.71%) is in Wada-Vetye bay. The intermediate concentrations in the range of 5.3%-76.2% (average 36.8%) and 4.3%-65.9% (average 28.4%) are in the Rajapur and Vijaydurg bays, respectively. The heavy minerals suite is composed mainly of ilmenite and magnetite and in minor amounts of zircon, tourmaline, kyanite, garnet, staurolite, etc.

The distribution of heavy minerals (Fig.4) shows different concentration zones from bay to bay. In the northern most Wada-Vetye bay two concentration zones in the range of 40-60% are noted. One of them is in the northern extreme and other just adjacent to Ambolgarh promontory in the south. Both the zones are located in the area of high energy and strong winnowing zone. In the rest of the bay, the overall poor concentration of heavy minerals is noted which is due to the presence of coarser nature of sediments. The updrift accretion, influenced by the Ambolgarh promontory appears to be responsible for the higher concentration of heavies in the zone adjacent to Ambolgarh promontory. The similar phenomenon of accretion on the updrift side and erosion on the downdrift side has been reported by many workers like Lemehaute and Brebner (1961). Subramanian and Mohan (1989), Raja Ganesh and Subramanian (1987), Angusamy (1995) and Kunte and Wagle (1993). The Ambolgarh bay, an arcuate bay shows overall high concentration of heavies (more than 60%). It is devoid of any river source and hence, the inland sediment supply is insignificant. However,

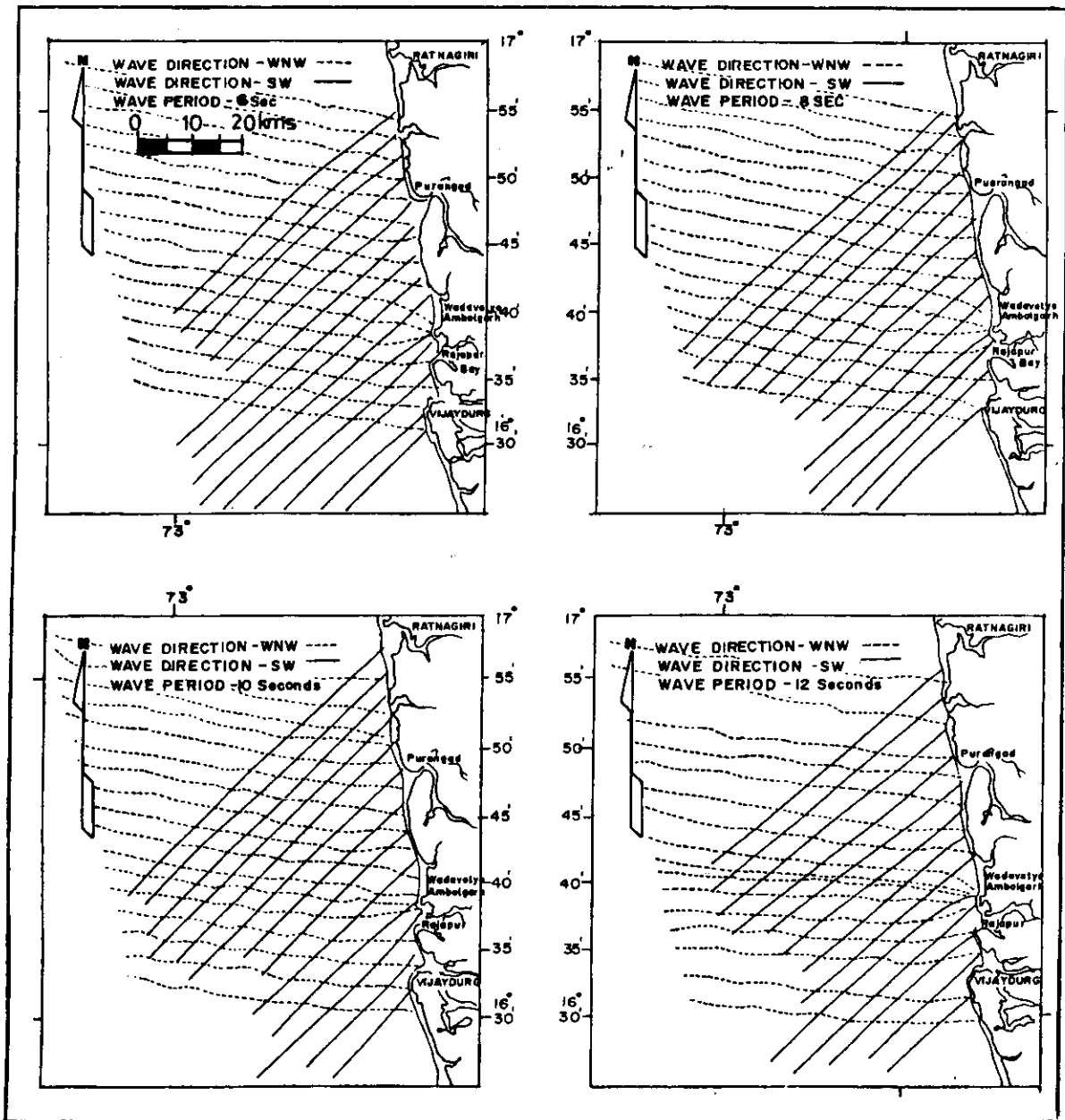


Fig.3a Wave Refraction Pattern

the sediments are rich in heavy minerals and probably are contributed by shoreward transport of sediment. The observed rates of sedimentation in these bays and off river mouths have indicated that the rivers and streams of this area (Vaghotan, Kodavil and Vetye stream) do not contribute the sand sized sediments significantly to the depositional basin (Gujar, 1996). These rivers appear to be contributing limited amount of sediments, which is supported by the presence of fresh olivines whereas most of the sediment supply is consisting of clay sized sediments, as evidenced by the presence of mud flats around Vijaydurg

and Rajapur bays. This is clear to conclude that the landward migration of offshore sediments are the main source of these placer rich sands. The observed trend of percentages of relative lower sp. gravity of minerals, sharp changes in the roundness and sphericity of ilmenite and magnetite grains also support the shoreward migration of offshore sediments. The higher concentration of heavies in the offshore may be due to the fine grained segregation and high order of mixing of two end populations which is confirmed from higher values of kurtosis (Gujar, 1996). A zone of poor concentration in the northern limit of bay, just in

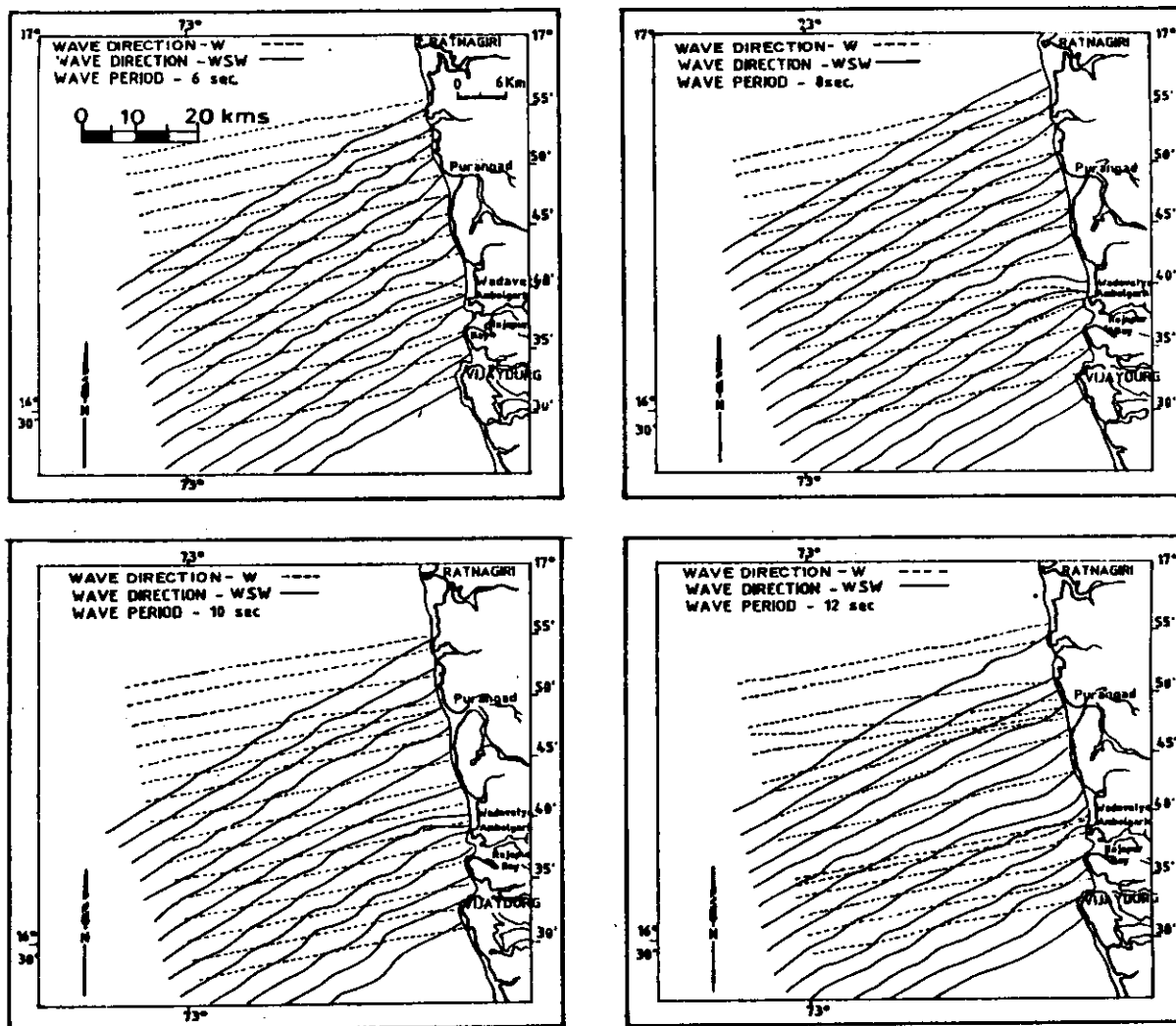


Fig.3b Wave Refraction Pattern

the vicinity of Ambolgarh promontory appears to be the result of down drift erosion where the finer sediments enriched in heavies are removed during the process of reworking.

In the Rajapur bay, the zone of higher concentration of heavy minerals is noted in the outer most part of the bay along the northern extreme (Fig.4). It can be attributed to the large amount of accretion.

In the Vijaydurg bay, heavy mineral percentage ranges between 4.3 - 65.9%, (average of 28.47%) with a patch of higher concentration off Waghapur point. The rest of the bay is in the divergent zones and shows better concentration of heavies.

It is evident that sediment budget, oceanographic conditions, nature of shoreline and nearshore zone are the main controlling factors for the distribution of heavy minerals (Sutherland, 1985). However, the maintenance of equilibrium between sediment supply and loss is also important (Zenkovitch, 1967). Significant concentrations of heavy minerals are observed along the coast where sediment budget is low (Sutherland, 1985 and 1987). In the study area river and streams contribute very limited supply of sediment and estuary development is also not noticed. Eventhough the oceanographic conditons are similar for all these four bays (wave direction period, etc.), the configuration of shoreline's physical setting differs from bay to bay (Table.1 Fig.1). When

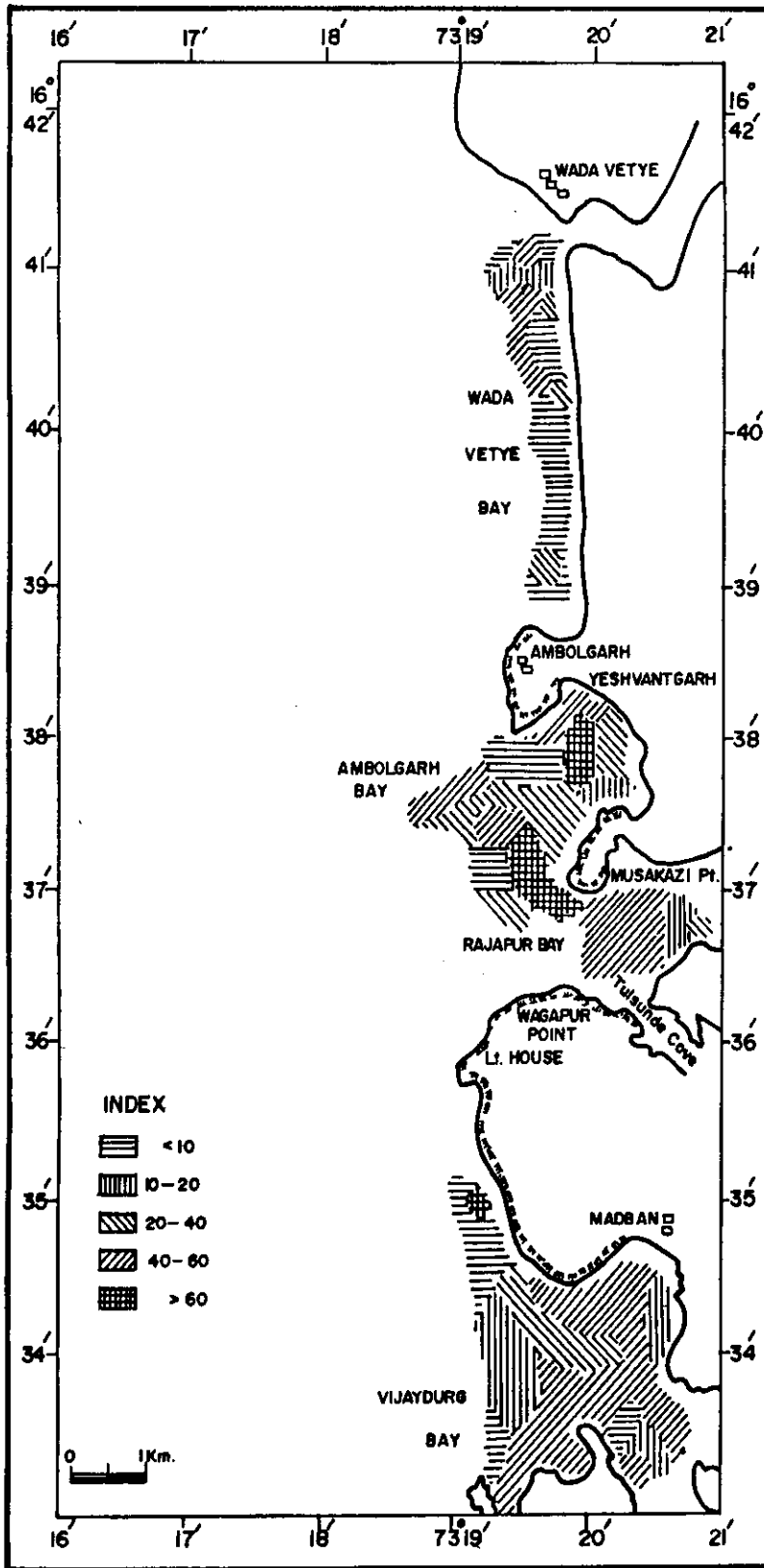


Fig.4 Distribution of Heavy Minerals in the Surficial Sediments of Study Area

such a coastline is subjected to wave attack, generation of different transport paths (circulation cells, littoral currents, etc.) is unavoidable. In the present case, the coastal configuration in the physical setting of Wada-Vetye bay is N-S, while Ambolgarh is in NE-SW, Rajapur in the E-W and Vijaydurg in the NNE-SSW. These coastal setting and observed concentrations of heavy minerals suggest that the NE-SW configuration is most favourable for the concentration of heavies by shoreward transportation of sediments by waves and depositing sediment lenses of different dimensions which further undergoes size sorting under the influence of swash, sorting due to differential environment and transport (Sligerland, 1984). The Ambolgarh and parts of Vijaydurg bay show such a configuration and have gentle gradients. On the other hand the coastline configuration from Ambolgarh (northern end) to Wada-Vetye almost follows N-S trend and have steep gradient. Such an alignment of coast line and gradients hardly help to intercept the sediment movement by littoral currents. So, accumulation of shoreward transported sediments by swell waves which is possible in Ambolgarh and parts of Vijaydurg bay due to its arcuate to semi-arcuate nature of the bay.

The Rajapur bay orienting almost E-W trend and part of the Kodavil rivermouth shows higher concentrations of heavy minerals. Such a concentration may be due to Musakazi point promontory which causes partial convergence and winnowing of lighter fractions, leading to enrichment of heavies. Similarly the southern portion of Vijaydurg bay shows relatively higher concentration of heavies

which is due to arcuate shape and protected nature of bay and its disposition in the updrift side of converging point (Vijaydurg Southern tip resulting into accretion).

Although the NE-SW configuration helps in the better concentration of heavy minerals, that is not the only factor responsible for governing the heavy mineral concentration. Otherwise good concentration should have been possible in the northern portion of Vijaydurg bay and southern tip of Wade-Vetye bay. But these portions are devoid of significant concentration of heavies. This is due to the strong converging currents (Fig.3, Table 2), which prevents the deposition of sediments. On the other hand the material brought to these zones gets winnowed and redeposited further south i.e. in the central portion of Vijaydurg and Ambolgarh bay respectively. This accounts for poor concentration of heavy minerals in these zones.

The shallow seismic studies of the area, along with ground truth information suggest that the area has witnessed the neotectonic activity, in the recent past (Gujar et al. 1986 and Gujar, 1996). The basement configuration shows two different blocks at different levels. Among these, the Wada-Vetye block is younger and elevated when compared to Ambolgarh whereas Rajapur and Vijaydurg blocks are also deep. Such variations in the relief of basement probably, affected the processes like transport, sorting and redistribution of sediments within the depositional basin, which ultimately resulted in differential enrichment of heavy minerals within the bays.

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