

MORPHOGENETIC CONTROLS ON THE DISTRIBUTION OF THE LITTORAL PLACERS ALONG CENTRAL WEST COAST OF INDIA

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ABSTRACT

Littoral placers of ilmenite and magnetite are known to occur along central west coast of India between 19°00' – 15°55' N latitude. The distribution of these beach placers and their landward extensions are observed to be governed by the coastal geomorphological features integrated with prevailing drainage system, sediment input, wave dynamics and sea-level changes.

The total heavy mineral concentration along the central west coast of India varies from 0.17 to 98.54 percent. A zone of higher concentration is confined to the central portion of the coastal segment between 17°59' and 16°30' N latitude. The coastline in this zone is of submergent type and bounded by plunging steep cliffs, arcuate to semi-arcuate bays with low gradients. The rivers are of moderate length with steep thalweg. These rivers are regulated by topography resulting in more fluvial erosion, however, overall sediment input is low due to the lithological variations along their courses. Headlands and plunging cliffs favour the sediment deposition by impeding the long shore drift and the sediments passing headlands enter the low energy zone leeward side and gets deposited in pocket beaches.

The area north of 17°59' and south of 16°30' N latitude shows poor concentrations of placer which may be attributed to contrasting physiography, drainage and variable sediment inputs. The northern areas has irregular emergent type of coastline with extensive mudflats and creeks. The rivers have long graded profiles showing control of tectonic lineaments and the total sediment input is high. Similarly, the southernmost area also has irregular narrow coastline. The drainage is shallow thereby causing decreasing erosion resulting in low sediment input. In view of the above it is envisaged that the morphogenetic control exists over the placer distribution in the littoral zone.

KEY WORDS

Morphogenetic, Littoral, placers, Heavy minerals, Revalanda, Deobag.

INTRODUCTION

The occurrence of littoral heavy mineral placers, commonly known as 'black sands' are known to occur along the central west coast of India, between 19°00' – 15°55'

N latitude (Fig. 1) (Patel, 1936, Roy, 1958 and Chari et.al; 1975 Wagle et. al.; 1989). These occurrences were mainly studied for their economic evaluation of ilmenite and hence could not explain the localization of placer concentration zone, which is confined

to the central portion of the coastal segment between 17°59' and 16°30' N latitude, although favourable conditions for the formation of placers appear to be existing through out the coast. According to Hails (1969) the placer formed in the littoral zone are the product of an interaction of variable complex factors, on a variety of scales, these factors are source rocks, external processes like weathering, erosion etc., acting up on them, (which are mainly climatically controlled), suitable drainage and wave climate, coastal geomorphological features, sea-level variations and tectonics.

The present paper examines these different factors and discusses their role in the development of littoral placer mineral concentrations along central west coast of India. The objective of such an approach is the generation of a model for placer development, which will be of use in orienting future exploration programmes.

Placer Distribution and Mineralogy

The placer rich sands in the study area (Fig. 1) occur as high grade dune and low grade beach deposits. The mineral composition of these placers mainly consists of opaques, augite, rutile, tourmaline, hornblende, hypersthene, enstatite, garnet, epidote, biotite, staurolite, kyanite, zircon, etc. in variable proportions. The light fraction is represented by quartz, feldspar and micas. The opaques include ilmenite and magnetite and their weathered derivatives. Ilmenite occurs as ilmeno-rutile or ilmeno-magnetite and magnetite as titano-magnetite. The total heavy mineral concentration varies from 0.17 to 98.54%. The areas of higher concentra-

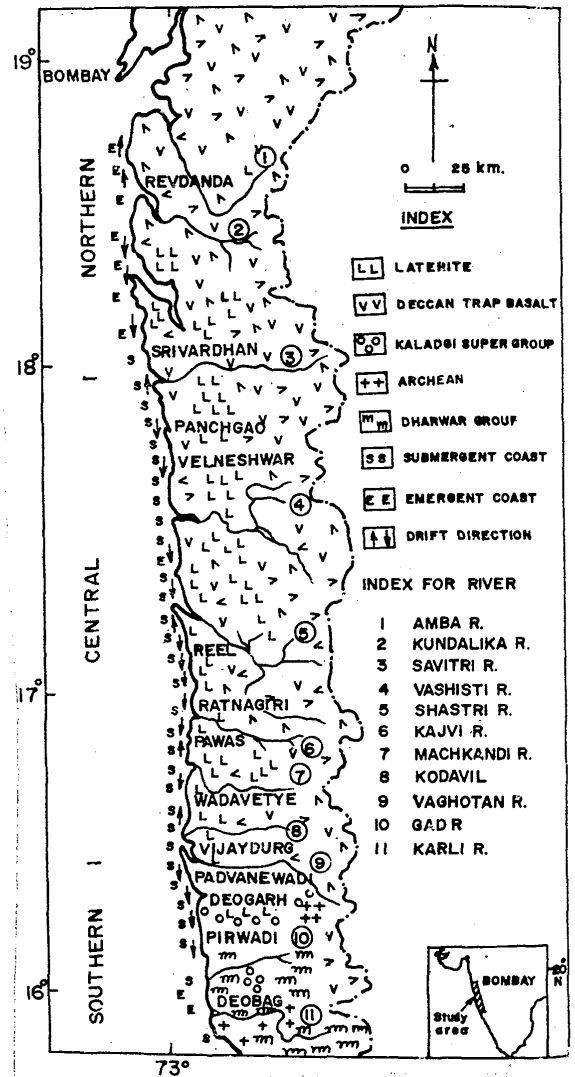


Fig. 1: Geology of the Hinterland, Drainage, areas of submergence & Emergence & Drift Direction.

TABLE 1

THE OCCURRENCE OF HEAVY MINERAL DEPOSITS AND RICH CONCENTRATIONS, THEIR MINERALOGY AND ASSOCIATED GEOMORPHIC FEATURES IN THE STUDY AREA (MODIFIED AFTER CHARI ET. AL., 1975, WAGLE ET. AL., 1989).

Occurrence	Grade	Mineralogy	Associated Geomorphic Features
A. Deposits			
Undi-Real-Varvade (17°12' - 17°14' N)	Medium Grade ilmenite with 20-50% TiO ₂	menite, magnetite, monite, rutile, zoisite, tourmaline	Arcuate-semi arcuate beach backed by dunes, sand bar at rivulet.
Tiware - Malgund (17°10' - 17°11' N)	Medium Grade Ilmenite with 36-50% TiO ₂	ilmenite, magnetite, rutile, limonite,	Straight beach, backed by dunes.
Never-Ohokmale-Vare (17°05' - 17°06' N)	Medium grade ilmenite with 19-52% TiO ₂	ilmenite, magnetite, tourmaline, zoisite	Arcuate beach backed by dunes.
Are-Kalbadevi (17°03' - 17°04' N)	Medium grade ilmenite with 20-40% TiO ₂	ilmenite, magnetite rutile, tourmaline, Hornblende	Arcuate-Semi arcuate beach backed by dunes, with sand bar in mouth of river and low laying Khajan lands.
Bhatye (16°58' N')	Medium grade ilmenite with 19-44% TiO ₂	ilmenite, magnetite, augite, rutile, tourmaline, zoisite	Kajvi river mouth with sand bar, semi-arcuate beach backed by dunes.
Purangad-Gaokhandi (16°48'30"N)	High grade ilmenite with 10-52%, TiO ₂	ilmenite, low magnetite augite, rutile etc.	Protected beach, Machkandi river with sand bar.
B. Rich Concentration			
Panchaagao- Velneshwar	Heavy minerals upto 32%	opaques upto 90% (ilmenite + magnetite) rutile, tourmaline, augite etc.	semi-arcuate beach, with river mouth.
Wada-Vetye	Heavy minerals upto 64%	opaques (ilmenite + magnetite): upto 97% augite, rutile, tourmaline, zircon, garnet.	Straight beach with bar at Vetye stream.
S. Vijaydurg	Heavy minerals upto 80%	opaques (ilmenite + magnetite) upto 92%, augite, hornblende, zircon, garnet, etc.	Arcuate beach with stream
Padvanewadi	Heavy minerals upto 52%	opaques (ilmenite + magnetite) upto 98%	Semi-arcuate beach backed by dunes.
Sarjekot (Malvan)	Heavy Minerals upto 68%.	opaques (ilmenite + magnetite upto 88%.	Concentrations limited to spit of Gad river.

tion are restricted to the central area between Panchgao in the North and Padvanewadi in the south (17°59' – 16°30' N latitude). The continuous stretch of these coastal deposits is broken by topographical features such as creeks and bluff jetting out into the sea. The economic beach deposits of ilmenite (TiO₂ content upto 52%) from north to south are located near the village of Undi, Reel, Varvade, Tivare, Malgund, Ganpatipule, Bhandarpule, Nevere, Dhokmale, Are, Kalbadevi, Ratnagiri, Pawas, Purangad and Gaokhandi and good concentrations of heavies are located at Panchgao-Velneshwar, Wada-Vetye, Vijaydurg Padvanewadi etc. but their grade and quantum is not yet assessed (Table 1).

Source rocks :

The geologic formations of the hinterland area includes those of Precambrian, Mesozoic and Quaternary age. (Fig. 1). The stratigraphic sequence, type of rock formation and their characteristic heavy minerals are indicated in Table 2. The majority of the hinterland area is covered by basaltic lava flows. The area south of Vijaydurg is covered by Precambrian formations (Anon, 1976). These formations have lateritic capping of variable thickness at different altitudes. The area between Panchgao and Padvanewadi (Central area) where concentrations of placers, rich in ilmenite and magnetite are observed more, the hinterland basaltic forma-

TABLE 2

STRATIGRAPHIC SEQUENCE AND THEIR ASSOCIATED CHARACTERISTIC MINERALS

Stratigraphic sequence	Type of rock	Characteristic minerals
Pleistocene to Sub-Recent	Laterite	Gibbsite, kaolinite, clachchite and ferruginous matter like hematite, goethite (after *3 & 4)
Upper-Cretaceous to Miocene		Deccan Trap (Basalt) labroderite, plagioclase augite, glass and opaqueslike ilmenite and magnetite.
Precambrian	Kaladgis	Clay, glass sand, foundary sand, tourmaline, zircon, rutile, staurolite, kyanite, sillimanite, epidote, hornblende, garnet, chlorite, ilmenite, magnetite and pyrite. (after *5)
	Archean and Dharwars (Phyllites, quartzites, schists, intruded by dolerite, gabbro, granite, pegmatite, aplites and quartz veins.)	Manganese and iron ore tourmaline staurolite garnet, sillimanite zircon chromite, quartz and feldspars (after *1 & *2)

* Adapted from 1. Chari et. al., 1973, 2. Kelkar 1956, 3. Anon 1976, 4. Sahasrabudhe and Deshmukh 1979, 5. Sarkar and Soman 1984.

TABLE 3

DETAILS OF RIVERS AND ASSOCIATED GEOMORPHIC FEATURES

River	Length (Km) and Orientation	Area (Km ²) of Drainage Basin	Associated Geomorphic Features
Amba	69 NW-SE	907	Estuarine mouth with a thick sediment accumulations at mouth.
Kundalika	69 NW-SE	778	Thick sediment accumulation a mouth.
Savitri	96 E-W	2299	Thick sediment at mouth hills on either side of mouth jetting out into sea.
Vashisti	86 E-W	2215	Thick sediment at mouth, thickness 8-26 m, silty sands in upstreams.
Shastri	72 NW-SE	2296	Sand bar at the mouth.
Kajvi	64 E-W	524	Sand bar at the mouth.
Machkandi	62 E-W	825	Sand bar at the mouth.
Kodavil	54 E-W	588	Sediment acumulation at mouth
Vaghotan	68 E-W	894	Sediment acumulation at mouth
Gad	74 E-W	973	Sand spit at mouth.
Karli	75 E-W	816	Sand spit at mouth.

tions have appreciable thickness of laterite, this laterite cover thins out towards north and towards south, it is sporadic and covers the rocks of Precambrian age. This suggests that Deccan trap basalt and laterite are the major contributors for these placers. Najafi et. al.; (1981), Krishnamurthy and Udas (1981) have noticed domination of titanomagnetites in Deccan basalts. Rajamanickam (1983), indicated the presence of fine grained titanomagnetite in the hinterland ferro basalts of this area. Gujar and Srinivas (1991) inferred that the process of lateritization of underlying Deccan basalts is responsible for the enrichment of titanium minerals and subsequent alteration of magnetite to goethite and hematite.

However, Deccan basalts and laterites alone cannot be a source rock for the observed mineral assemblage because the presence of transparent crystalline quartz grains, granitic suite of heavy minerals like tourmaline, zircon, and metamorphic index minerals like kyanite, staurolite, garnet etc. cannot be derived from Deccan basalts and laterites. Such a mineral assemblage is noticed in Kaladgi sandstones and gneissic basement of south Konkan by Kelkar, (1955), Sowani, (1961) and Sarkar and Soman (1984).

Climate, drainage and sediment budget

Humid climate is prevalent in this area and the areas of such climate are

characterised by perennial stream flows and ubiquitous vegetation cover, deep chemical weathering which is significant in detaching weathering resistant minerals from the source rocks (Sutherland, op. cit). Most of the humid tropical zones have experienced semi-arid conditions periodically during Quaternary, wherein such the fluvial activity was more efficient in eroding the source rocks and transporting the liberated heavy minerals to the site of accumulation. With the return of humid conditions the vegetation cover which reduced sediment supply and the reworking of material started (Sutherland, Op. cit.), such cycles of arid and humid phase have also been reported by Gujar and Guptha, (1993) from this area. Evidences of the effects of recycling are observed on stable minerals like zircon, tourmaline etc. Rounded to subrounded tourmaline in the northern area, zircon and garnet in central zone and angular zircon, tourmaline, kyanite in the southern zone indicate multi or poly cycle, single cyclone or direct deposition from source rocks.

The area is drained by 11 principal rivers, which originate in the western ghats (Table 3 Fig. 1). Apart from these main rivers there are about 36 minor rivers (not shown in map) and creeks which drain directly into the sea. The rivers which join the sea flow either in the east-west or south-east north-west direction. Lithological differences govern the longitudinal profile of the rivers and the erosion. The rivers in the central area are of medium length flowing in the east-west direction, showing control of topography and have steeper graded profiles (Dixit, 1975) with more fluvial erosion in the scarp zone probably due to higher gradients and greater

weathering ability of basalts. However, laterites are not affected by erosion and the overall sediment budget remains low in this area. The littoral concentrates of heavy mineral are best developed along coastal areas where sediment budget is low (Sutherland 1987). The rivers of northern area (north of 17°59' N latitude) and southern area (south of 16°30' N latitude) are long, show control of tectonic lineament and have long graded profiles in the northern zone. Due to less lateritic cover, the sediment budget here is high. However, since the river mouths in this area are occupied by creeks, the coarse sediment (sand/silt) derived from the weathering of basaltic hills and valley sides does not reach the sea and hence restrict the supply of heavy minerals to the coastal zone. In the southern zone most of the area is occupied by Kaladgi sandstones, quartzites and granites. The rivers though long and graded are shallow and hence they do not cause much erosion.

Wave Climate :

The wave climate does not change much along this area. The tidal range varies from 1 to 2m and the predominant wave direction is from southwest; west south west, west and westnorthwest (period ranging from 5-14 seconds) (Reddy 1976). The average breaking height of waves changes from season to season (0.3 m in winter and 2.2 m in monsoon). The waves break parallel to coast and the wave energy is high during monsoon. The longshore current directions are variable in the area. Their long transport paths get terminated in areas of accumulation like spit, depositional foreland shoals and projecting promontories. In the case of

open straight beaches the wave energy is high whereas in arcuate and semi-arcuate bays the energy is less. The longshore transport rates are variable from north to south. It is greater towards south than in the north (Chandramohan, et. al., 1989). The length of littoral transport zone, under uniform wave conditions is largely governed by coastal configuration. On such a coast with smooth outline the material can be transported for longer distance whereas on indented coastline the development of long transport paths individual sections with unique heavy mineral population is formed (Hallam 1964). Such heavy mineral aggregates in the individual sections are noticed in the same parts of central zone (Rajmanickam et. al., 1986).

Coastal Geomorphological Features :

The coast of the area under study is more or less straight and trends NNW-SSE. The coastline is a relatively narrow strip of land towards south, which widens towards north and consists of sandy beaches separated by rocky headlands, cliff, river mouths and broad estuaries (Wagle, 1990). On the basis of geomorphological features, the coastline is divided into three different zones (Dixit, 1976) (Fig. 1) these zones are.

(1) *Northern Zone :*

It is characterised by modified surfaces of plains of marine planation formed as a result of combination of both fluvial and marine activity dominating in succession. The zone is marked by tidal flats, creeks, straight sandy beaches backed by abandoned cliffs and littoral terraces, the headlands are eroded. Sukhtankar

(1989) classified this shoreline as emergent type, the low concentration of heavy minerals along this zone can be attributed to the presence of estuarine river mouths, which act as filters for entry of sediments (Kulm and Byrne, 1966). During the sea level rise, these estuaries act as sink for coastal zone. In addition due to progradation the placer deposited earlier are left backshore or are getting buried under incoming sediments.

(2) *Central Zone :*

It is hilly zone, which is fastly wearing out. This area is characterised by the process of recession at foot and sub-aerial wash at the top. The zone is marked by highly localised bay-head beaches, sand bars, plunging cliffs, abandoned cliffs, littoral terraces. Rivers here have deep indentation and are devoid of delta or flood plain. The shore features are related to wave action responsible for recession of cliff. Sukhtankar (1989) classified this shoreline as of submergent type. Along such a coastline the exchange of material from nearshore slope to beach keeps on replenishing the beach with sediments. In this process, the particles of higher settling velocities (heavies) accumulate and particles of lower settling velocities (lighter) get washed to lower zone of beach and then further offshore (Ainemer, 1989, Komar & Wang 1984). such a process helps to increase the concentration of heavies on these beaches.

(3) *Southern zone :*

This zone is represented by narrow coastal plains, associated with estuaries. In this area the notable heavy mineral concentration are only on spit, which is formed at the mouth of Gad river at Sarjekot near Malvan.

The sea level fluctuations (Wagle, 1990, Ramana et. al., 1990, Guzder, 1975, Sukhtankar and Pandiyan, 1990; Gujar et. al; unpublished data) also have contributed in the migration of sediments along this coastal strip at different times. Due to the slow rise of sea level during the last 5,000 years, the modern beaches had greater opportunity to receive minerals reworked from ancient beaches (Emery & Noakes, 1968). Such migrations resulted in repeated sorting of heavies during sea level changes at different stages and in turn have given rise to the concentration of more resistant minerals in the finer fraction.

Besides, sea level fluctuations the tectonics (Neo-tectonics ?) (Power, 1993, Sukhtankar, 1989) might have also influenced in changing coastal paleo-features either by restricting or enhancing the sediment supply as well as by changing the direction of oceanographic parameters (currents, etc.) to give rise to the present distribution.

CONCLUSIONS

The hinterland geological formations, along the narrow coastal plains, humid tropical climate resulting in deep chemical weathering, medium length east-west flowing riv-

ers with steeper graded profiles, overall low sediment budget, the prevalence of uniform wave conditions and moderate wave energy along the crenulated coastline have been essentially responsible for the accumulation of heavy mineral placers on the beaches of the central zone between 17°59' – 16°30' N latitude along central west coast of India.

The highly enriched concentrations are restricted to arcuate to semi-arcuate beaches bounded on both sides by promontories, and beaches located close to major streams with spits and bars which primarily control their development.

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