

Significance of heavy mineral ratios in some beach placers of Andhra Pradesh, East Coast of India

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Heavy minerals in Hamsaladivi–Manginipudi, Vasishta Godavari–Upputeru and Visakhapatnam–Bhimuni-patnam are characterized by magnetite-ilmenite-augite, ilmenite-magnetite-garnet-zircon and ilmenite-garnet-zircon-monazite suites. Heavy mineral variation in each region has been significantly influenced by hydraulic fractionation by size, density, shape and chemical decomposition of unstable minerals. The regional variability is largely induced by the respective provenance.

SEVERAL studies on the beach placer deposits of Andhra Pradesh coast made earlier¹⁻³ were related to the provenance, distribution and abundance of heavy minerals. An attempt has been made here to study the relative variation of heavy mineral suites in different regions on the basis of ratios and to ascertain the physical factors governing to affect such variation. The regions chosen for this purpose in the Andhra Pradesh Coast include: Hamsaladivi–Manginipudi (HM), Vasishta Godavari–Upputeru (VGU) and Visakhapatnam–Bhimuni-patnam (VB) (Figure 1). HM beach sands are derived

from the Krishna River, which drains the Deccan Traps, Crystalline Archaean rocks and Precambrian sediments. VGU beach sands are derived from Godavari River, which drains the Deccan Traps, Crystalline Archaean rocks, Khondalite group of rocks of Eastern Ghats and Gondwana sediments. VB beach sands are derived from the Eastern Ghats suite of rocks through numerous small rivers.

Top 12 cm beach/dune sand was sampled in December 1989 by driving a plastic tube of 5 cm diameter. Heavy mineral composition (wt%) of the 63 sieved fractions (2–3, 3–3.5, 3.5–4) of the 21 representative samples (5 beach, 2 dune samples from each region) chosen was determined following the techniques of Ramamohana Rao *et al.*². Average heavy mineral percentages and ratios were computed from each size fraction for each region (Tables 1–3).

HM beach placers are characterized by a magnetite-ilmenite-augite suite (Table 1). Magnetite is most abundant (43%) followed by ilmenite (26%) and augite (19%). Garnet, sillimanite, hornblende, chlorite and zircon are 1–2% each, biotite, monazite and kyanite are less than 1% each; tourmaline is in traces. VGU beach placers (Table 2) are characterized by an ilmenite-magnetite-garnet-zircon suite. Magnetite and ilmenite are in equal proportions (32–34%), garnet, zircon and augite are less than 10% each. Sillimanite and hornblende are about 2.5% each, chlorite, monazite and kyanite are about 1–2% and biotite, rutile and tourmaline are less than 1% each. An ilmenite-garnet-zircon-monazite suite characterizes VB beach placers (Table 3). Ilmenite is most abundant (>50%), followed by magnetite (13%), zircon (9%) and monazite (8%), garnet is up to 9%, hypersthene is about 1% and hornblende, chlorite, biotite, kyanite, rutile and tourmaline are less than 1% each. VB beach placers are coarse grained and HM beach placers are fine grained, while VGU placers are intermediate between the two in grain size⁴.

Hydraulic fractionation by density is expressed by the ratio of opaque (av. sp. gr. = 4.7) minerals to non-opaques (av. sp. gr. = 3.7), referred to as O/NO. The O/NO ratio as used by Flores and Shideler⁵ is not applicable to the study beaches for two reasons: (i) ilmenite is an opaque mineral and its sp. gr. (4.5) is low compared to magnetite (sp. gr. 5.16). Monazite is a non-opaque mineral and its sp. gr. (5.2) is high compared to other non-opaque minerals (sp. gr. <5.7). When these two minerals occur in substantial amounts as in the study areas, O/NO ratio does not reflect the true efficiency of the process of hydraulic fraction by density. Therefore, in the present study hydraulic fraction by density is expressed by the ratio of magnetite + monazite to ilmenite + non-opaque minus monazite (MMO/INO-Mo) and referred to as density index for convenience.

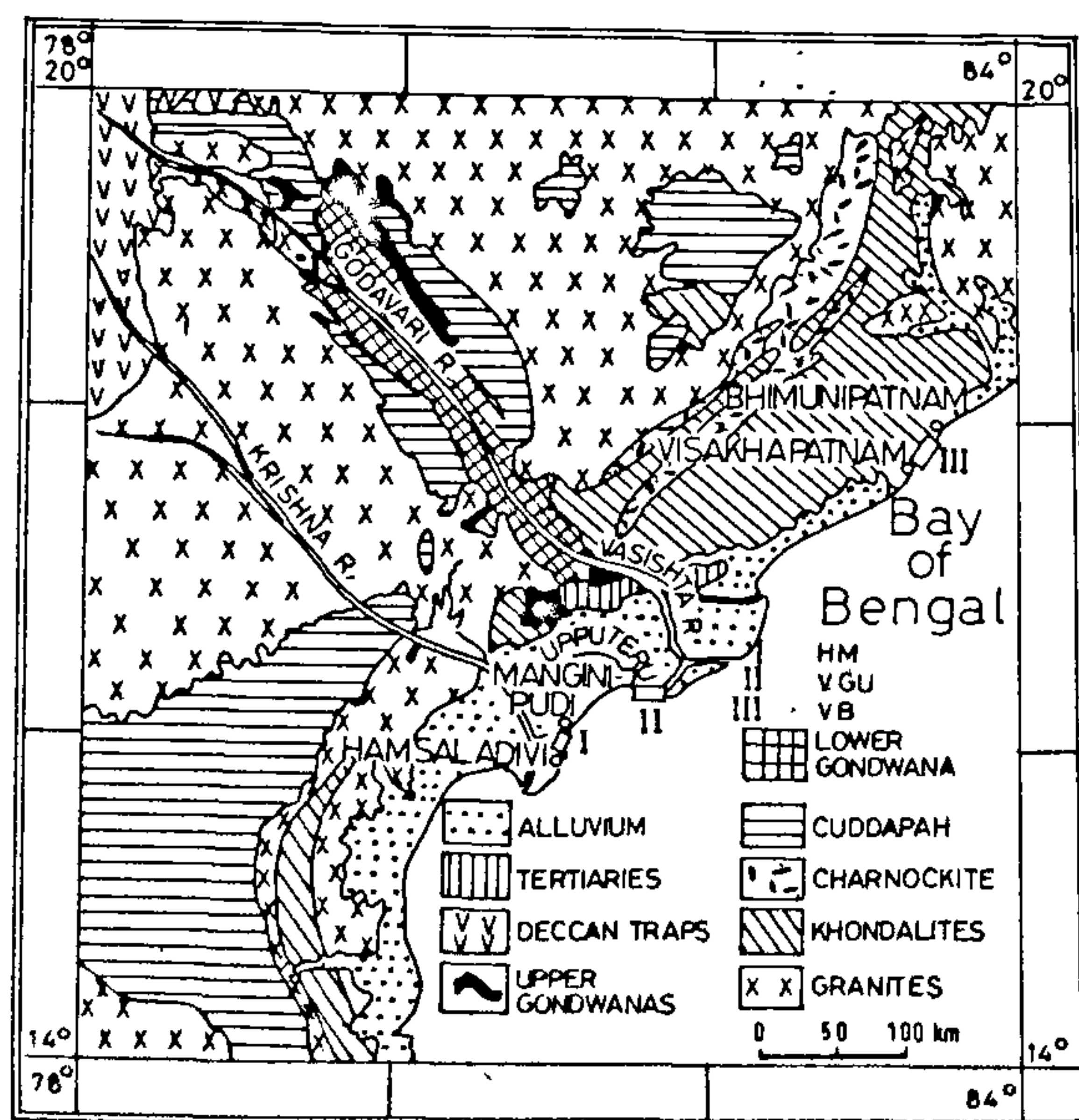


Figure 1. Location map of the study regions with general hinterland geology

Table 1. Average heavy mineral (wt%) in different size (Ø) fractions in Ham-saladivi-Manginipudi

| Mineral | Beach placers | | | Dunes | | |
|-------------|---------------|-------|-------|-------|-------|-------|
| | 2-3 | 3-3.5 | 3.5-4 | 2-3 | 3-3.5 | 3.5-4 |
| Magnetite | 38.02 | 44.24 | 49.77 | 39.90 | 42.85 | 46.43 |
| Ilmenite | 22.02 | 25.84 | 29.62 | 25.25 | 27.28 | 29.10 |
| Garnet | 4.11 | 1.92 | 0.57 | 4.68 | 0.85 | 0.93 |
| Sillimanite | 1.86 | 0.74 | 1.95 | 0.57 | 0.49 | 1.38 |
| Pyroxene | 24.43 | 21.59 | 11.59 | 22.64 | 23.27 | 13.13 |
| Hornblende | 1.99 | 1.16 | 0.63 | 1.84 | 1.59 | 1.55 |
| Chlorite | 3.06 | 1.58 | 0.22 | 2.34 | 2.37 | 0.71 |
| Biotite | 1.86 | 0.38 | 0.17 | 0.57 | 0.28 | 0.19 |
| Zircon | 1.27 | 1.57 | 4.20 | 0.90 | 0.58 | 5.76 |
| Monazite | 0.08 | 0.24 | 0.49 | 0.00 | 0.07 | 0.44 |
| Kyanite | 0.27 | 0.12 | 0.61 | 0.22 | 0.13 | 0.55 |
| Rutile | 0.00 | 0.00 | 0.00 | 0.12 | 0.03 | 0.00 |
| Tourmaline | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 |
| Others | 0.49 | 0.52 | 0.11 | 0.46 | 0.25 | 0.34 |
| MMo/INO-Mo | 0.62 | 0.80 | 1.01 | 0.67 | 0.75 | 0.87 |
| G/PHT | 0.16 | 0.08 | 0.05 | 0.19 | 0.03 | 0.06 |
| ZTR/PH | 0.05 | 0.07 | 0.25 | 0.06 | 0.02 | 0.39 |

M = Magnetite; Mo = Monazite, O = Opaques, NO = Non-opaques; I = Ilmenite; G = Garnet; P = Pyroxene; H = Hornblende; T = Tourmaline, Z = Zircon; R = Rutile.

Table 2. Average heavy mineral (wt%) in different size (Ø) fractions in Vasishta Godavari-Upputeru

| Mineral | Beach placers | | | Dunes | | |
|-------------|---------------|-------|-------|-------|-------|-------|
| | 2-3 | 3-3.5 | 3.5-4 | 2-3 | 3-3.5 | 3.5-4 |
| Magnetite | 31.02 | 35.14 | 38.21 | 20.87 | 23.10 | 29.10 |
| Ilmenite | 29.80 | 34.16 | 39.20 | 33.10 | 37.80 | 31.63 |
| Garnet | 20.58 | 7.36 | 1.57 | 6.49 | 1.77 | 2.85 |
| Sillimanite | 3.03 | 1.14 | 0.56 | 10.11 | 3.32 | 1.80 |
| Pyroxene | 6.25 | 5.68 | 1.55 | 12.29 | 17.42 | 23.96 |
| Hornblende | 2.68 | 0.83 | 0.20 | 7.90 | 5.32 | 3.97 |
| Chlorite | 2.05 | 1.50 | 0.08 | 0.69 | 7.85 | 3.54 |
| Biotite | 0.48 | 0.14 | 0.03 | 0.26 | 0.72 | 0.25 |
| Zircon | 1.04 | 10.76 | 14.42 | 0.54 | 1.03 | 0.97 |
| Monazite | 0.15 | 1.00 | 2.87 | 0.00 | 0.07 | 0.25 |
| Rutile | 0.00 | 0.33 | 0.15 | 0.00 | 0.00 | 0.00 |
| Kyanite | 0.82 | 1.14 | 0.56 | 3.60 | 0.76 | 0.71 |
| Tourmaline | 0.00 | 0.12 | 0.14 | 0.00 | 0.00 | 0.15 |
| Others | 1.75 | 0.42 | 0.38 | 4.12 | 0.84 | 0.35 |
| MMo/INO-Mo | 0.45 | 0.57 | 0.70 | 0.26 | 0.30 | 0.42 |
| G/PHT | 2.30 | 1.11 | 0.83 | 0.32 | 0.08 | 0.10 |
| ZTR/PH | 0.12 | 1.72 | 8.40 | 0.03 | 0.04 | 0.04 |

M = Magnetite; Mo = Monazite, O = Opaques; NO = Non-opaques; I = Ilmenite, G = Garnet, P = Pyroxene, H = Hornblende, T = Tourmaline, Z = Zircon, R = Rutile.

The density index is less than 1 in the beaches and dunes except in the HM beach placers where it is slightly more than 1. The index increases from coarse to fine fractions, i.e., with diminishing mean size. In a placer deposit hydraulic fraction of minerals by density is more effective in finer size grades. Density index is less in dunes compared to the adjacent beach placers but the index trend of increasing with diminishing mean size is similar in the beach and dune settings. Low index values in dunes indicate that eolian fractionation by density is a weak process compared to hydraulic

fractionation by density.

The high density index in HM and in finer size fractions reflects greater efficiency for hydraulic fractionation of magnetite due to its higher concentration. The intermediate density index values in VGU reveals equal amounts of magnetite and ilmenite. Although Deccan Traps are the major and common source for the magnetite in HM and VGU, the magnetite supplied from Deccan Trap provenance is considerably diluted by detrital minerals of different compositions contributed from other than Deccan Traps in Godavari river compared

Table 3. Average heavy mineral (wt%) in different size (φ) fractions in Visakhapatnam-Bhimunipatnam

| Mineral | Beach placers | | | Dunes | | |
|-------------|---------------|-------|-------|-------|-------|-------|
| | 2-3 | 3-3.5 | 3.5-4 | 2-3 | 3-3.5 | 3.5-4 |
| Magnetite | 12.54 | 14.60 | 17.60 | 7.10 | 7.20 | 11.35 |
| Ilmenite | 52.44 | 59.44 | 47.62 | 57.60 | 65.10 | 48.67 |
| Garnet | 18.35 | 3.69 | 0.60 | 19.47 | 6.27 | 8.26 |
| Sillimanite | 6.24 | 0.77 | 0.16 | 8.64 | 3.20 | 2.78 |
| Pyroxene | 1.38 | 0.23 | 0.16 | 0.24 | 3.59 | 2.77 |
| Hornblende | 0.00 | 0.10 | 0.28 | 0.12 | 0.74 | 0.15 |
| Chlorite | 0.30 | 0.11 | 0.00 | 0.21 | 0.62 | 0.39 |
| Biotite | 0.15 | 0.09 | 0.00 | 0.20 | 0.25 | 0.00 |
| Kyanite | 0.71 | 0.05 | 0.06 | 0.79 | 0.31 | 0.49 |
| Zircon | 0.96 | 11.94 | 17.26 | 0.17 | 5.10 | 12.39 |
| Monazite | 1.55 | 6.13 | 15.39 | 1.68 | 5.29 | 11.80 |
| Rutile | 1.25 | 1.43 | 0.12 | 0.62 | 0.85 | 0.72 |
| Tourmaline | 0.28 | 0.10 | 0.05 | 0.00 | 0.08 | 0.02 |
| Others | 3.82 | 1.30 | 0.73 | 3.18 | 0.69 | 0.21 |
| MMo/INO-Mo | 0.16 | 0.26 | 0.53 | 0.10 | 0.14 | 0.30 |
| G/PHT | 11.05 | 8.58 | 1.22 | 54.08 | 1.42 | 2.81 |
| ZTR/PH | 1.80 | 40.82 | 39.60 | 2.19 | 1.39 | 4.50 |

M = Magnetite; Mo = Monazite; O = Opaques; NO = Non-opaques; I = Ilmenite, G = Garnet; P = Pyroxene, H = Hornblende; T = Tourmaline, Z = Zircon; R = Rutile.

to Krishna.

The shape fractionation index is expressed here by the ratio of garnet to pyroxene + hornblende + tourmaline (G/PHT) since epidote is rare. G/PHT ratio is less than 0.2 in HM beach placers and dunes; ranges from 0.08 to 0.32 in dunes and 0.83 to 2.3 in beach placers in VGU and 1.42 to 54.08 in dunes and 1.22 to 11.05 in beach placers of VB (Tables 1-3). The ratio decreases from coarse to fine size fractions in both dunes and beach placers in the three regions. This trend shows that hydraulic fractionation of minerals by shape is more effective in coarser fractions of a given deposit. Between placers of varying mean grain size, shape fractionation is high in coarse-grained placers as in VB compared to fine grained deposit of HM. Shape fractionation is also achieved by eolian agency. The low shape index values in HM and VGU compared to VB suggest a garnet-deficient provenance. Further, pyroxene supplied originally in larger abundance from the source rocks. Because of its elongate shape, pyroxene is fractionated by size and retained in the beach placers as lag concentrates. The higher values of shape index in coarse fractions correspond to high percentage of garnet, suggesting that these (garnet) grains tend to be hydraulically equivalent to coarse grain sizes during reworking.

Stability index (zircon + tourmaline + rutile/pyroxene + hornblende = ZTR/PH) provides a measure of heavy mineral variations due to selective chemical decomposi-

tion⁵. Stability index is less than 0.4 in HM, 0.12-8.40 in beach and 0.03-0.04 in dune of VGU and 1.80-40.82 in beach and 1.39-4.50 in dunes of VB (Tables 1-3). The significant variations in the stability index are due to the change in weathering condition. Stability index increases from coarse to fine size fractions. In other words, stability index increases with diminishing mean grain size in a given deposit. Regionally it is not true as evidenced from the three study beaches. VB beach placers are coarser-grained but are composed of more stable minerals than the finer grained deposits of HM and VGU. Relative mineral stability is a character inherited from provenance. Thus, the Eastern Ghats provide mineral suites abundant in stable minerals in contrast to the Deccan Traps which provide mineral assemblages rich in unstable minerals.

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