

Provenance of heavy minerals with special reference to ilmenite of the Honnavar beach, central west coast of India

V. S. Hegde*, G. Shalini and
D. Gosavi Kanchanagouri

S.D.M. College of Engineering and Technology, Dharwad 580 002,
India

Heavy mineral assemblage and geochemistry of ilmenite from the Honnavar beach, Karnataka, central west coast of India have been studied to understand their provenance. The heavy mineral assemblage of ilmenite, magnetite, zircon, hornblende, epidote, sphene, kyanite, garnet and staurolite indicates its derivation from mixed sources of gneissic/granitic, basic and high-grade metamorphic rocks. Trace element content of ilmenite like Co, Cr, V and Ni suggests gneissic to basic provenance. The study indicated that the heavy mineral suite, characterizing the Precambrian gneissic, granitic and basic rocks, has been derived from the hinterland and the river Sharavati brings these minerals. The heavy minerals, characterizing high-grade metamorphic sources like garnet, kyanite and staurolite appear to be reworked and derived from the offshore/palaeo-beach and brought out by combined action of alongshore current from south and waves to the present beach.

Keywords: Beach sand, Honnavar, heavy mineral assemblage, ilmenite, provenance.

ILMENITE deposits are known from the Maharashtra and Kerala coasts, but little is known about deposits from the Karnataka coast, and in particular, their provenance, though ilmenite is a common heavy mineral in the beaches of northern Karnataka^{1,2}. The petrographic and chemical characteristics of ilmenites derived from different source rocks exhibit specific features, in particular the Mn/Mg ratio of ilmenite is an indicator of its source rocks³. However, Mn/Mg ratio is not always a reliable provenance-indicator, because in many cases the Mn content of ilmenite is leached out due to alteration process⁴. In the present study, provenance of heavy minerals from the beach sands of Honnavar is probed, based on field observations and laboratory studies such as mineral assemblage, petrography, including textural characters and mineral chemistry of ilmenite.

The study area lies between the Apsarakonda headland and the Pavinkurve beach, on either side of the Sharavati river mouth (Figure 1). A spit is growing across the river from south to north. Pockets of heavy mineral concentration occur in the beaches to the north and south of the

river mouth, and also close to the Apsarakonda headland, as alternate layers of black and light minerals (Figure 2).

Eight samples (about 1 kg each) were collected using a plastic tube of 8 cm diameter and driving it 10 cm deep into the foreshore of the study area. On the northern side of the river mouth, two samples were collected from a stretch of about 0.5 km. On the southern side of the river mouth, 3 samples were collected in a stretch of about 1.5 km close to the river mouth, and three more samples were drawn from the beach close to the Apsarakonda headland side in a stretch of 0.5 km length.

The samples were washed thoroughly, de-silted and oven-dried, and studied under binocular microscope to find the overall heavy mineral concentration and heavy mineral suite. Four samples (one from Pavinkurve, two from the beach to the south of the river mouth and another from the beach section close to the Apsarakonda headland) were selected for detailed investigations, and were subjected to sieve analysis for 15 min in ASTM sieves on a Ro Tap sieve shaker at 1/4 ϕ intervals. The fractions obtained from the sieve analysis were subjected to magnetic separation using a bar magnet, and the non-magnetic fractions were further subjected to heavy liquid separation (Bromoform sp. gr. 2.89 gm/cc), following standard procedure. Heavies obtained from the heavy liquid separation of the fractions were further subjected to isodynamic separation at 0.275 A for separation of ilmenite. The purity of the ilmenite separated was ensured to be more than 95% by

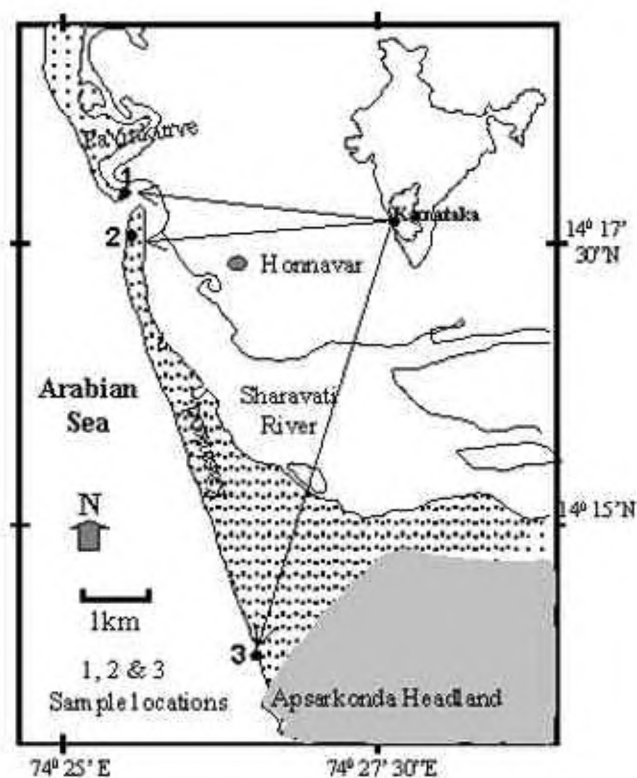


Figure 1. Location map of the study area, near Honnavar, Karnataka.

*For correspondence. (e-mail: vshegde2001@yahoo.com)

examining the fractions under binocular microscope. The ilmenite fractions were then split into two parts for further investigation. One part was used for petrographic study and the other part was powdered in an agate mortar and used for chemical analyses by ICP-MS for major and selected trace elements. Seventeen individual grains of ilmenite were analysed by an electron probe micro analyser (EPMA) under conditions of 15 keV and 40 nA.

The bulk sediments are bimodal to poly-modal (Figure 3), medium to fine-grained, moderately well-sorted (0.45–0.67) and negatively to symmetrically skewed. The heavy mineral concentration occurs mostly in two modes – one in 2ϕ (23–37%) and the other in 2.75ϕ (13–25%).

Microscopic observations reveal that magnetic heavy mineral fractions are dominated by ilmenite. Ilmenites are of two types. One type has rounded-off corners, is grey-white coloured, of high relief and shows variation in reflectivity. The poorly reflected parts of the grains could be due to minor alteration. The other type is relatively fresh, angular to sub-angular and grey in colour. Its associated

magnetite is also of the same size and shape, but exhibits alteration along the periphery.

Zircon, epidote, hornblende, augite, kyanite, staurolite and garnet represent the non-opaque minerals. Zircon is euhedral, indicating short-distance transportation. Hornblende is green to light yellow, while epidote is lemon yellow, augite is pale brown to black in colour and sphene is oval to rounded and sandy brown, showing mild alteration. Kyanite is fresh with two sets of well-developed cleavages and blue to light in colour, staurolite is golden yellow, and garnet is pink, well-rounded and shows high relief. Rutile is needle-shaped and elongated.

A comparison of chemical data of the study ilmenite on single grains from EPMA with that from ICP-MS on separated mineral fractions demonstrates relatively higher contents of SiO_2 , Na_2O and CaO in the latter (Table 1), which could be due to impurity of quartz and plagioclase in the latter. Ilmenite from the Honnavar beach is high in TiO_2 (50–56.33%), MnO (0.6–3.48%) and low in iron oxide (41–46.89%) contents (Table 1). Mn/Mg ratio varies from 6.53 to 178 and is comparable to that of the Gopalpur and Chatrapur deposits of Orissa. Highly different values of Mn/Mg ratio have been reported for the Chatrapur ilmenites^{5,6} (9.43 and 0.84), which are derived from migmatite and khondalite source. High manganese content in ilmenite of Honnavar beach sands implies that manganese is not leached away due to alteration process, whereas low content could be related to the presence of altered ilmenites in the beach sands. $\text{Ti}/(\text{Ti} + \text{Fe})$ has also been considered as an important parameter for estimation of alteration of ilmenite⁴. The common processes involved in the alteration of ilmenite are hydration and conversion of ilmenite into pseudorutile that has $\text{Ti}/(\text{Ti} + \text{Fe})$ ratio between 0.5 and 0.6. This is due to the leaching of iron. Although the observed ratio of $\text{Ti}/(\text{Ti} + \text{Fe})$ for ilmenite of the Honnavar beach (0.46–0.51) is low compared to that from Chavara, Manavalakurichi and Gopalpur, the negative trend between its TiO_2 and FeO , coupled with high TiO_2 content (up to 56%) that is more than the stoichiometric proportion (Table 1), corroborate that the beach sands consist of altered ilmenite.

Ni, Cr, V and Co contents are important in ilmenite chemistry, as abundance of these elements in ilmenite makes it unsuitable for pigment industry. The Cr, V and Ni content of the study ilmenite was 292–437, 247–350 and 23–24 ppm respectively, which is low compared to that of ilmenites from Ratnagiri coast, Maharashtra, derived from basaltic source⁷. Two grains of ilmenites, however, have shown higher content of Cr (1112 and 2472 ppm). During crystallization, these elements are preferentially incorporated in basic rocks and hence ilmenite in the basic rocks incorporates them more than those in acidic rocks. These characteristics are inherited in ilmenite and become a provenance indicator. Zr content ranges from 50 to 66 ppm. Ilmenites are characterized by low values of Zr/Cr (≤ 0.56), which is consistent with the



Figure 2. Field photograph of beach section of Honnavar (location 2) showing alternate light and heavy (black) minerals.

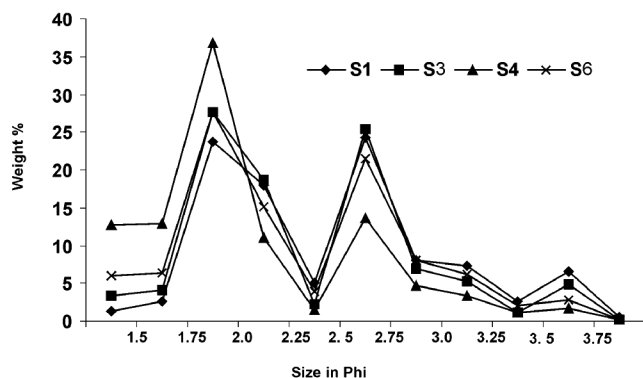


Figure 3. Frequency distribution of grain size of beach sand (bulk samples) of Honnavar showing bimodal to polymodal distribution during September 2003.

Table 1. Chemical composition of ilmenite from beach sands of Honnavar, Karnataka

Sl. no	TiO ₂	FeO	Al ₂ O ₃	MgO	MnO	SiO ₂	Na ₂ O	CaO	Total	Cr	Co	Ni	V	Zn	Zr	Ti/Ti+Fe	Mn/Mg	Zr/Cr
1	52.88	44.90		0.05	1.85	0.15	0.02	0.08	99.93	286						0.486	47.76	
2	54.25	44.57	0.08	0.10	0.84	0.10		0.03	99.98	2472						0.48	10.84	
3	54.27	44.54		0.06	1.26	0.07	0.07	0.05	100.32							0.48	27.11	
4	55.36	44.12	0.17	0.06	0.70	0.12	0.09	0.05	100.00	383						0.49	15.06	
5	54.57	43.54		0.10	2.45	0.08		0.02	100.76	321						0.49	31.30	
6	54.24	41.54		0.03	3.48	0.07	0.36	0.03	99.76	342						0.50	149.70	
7	54.28	45.22		0.02	1.02	0.09		0.01	100.60	219						0.48	65.84	
8	55.61	43.59		0.06	0.80	0.06		0.02	100.14							0.50	17.21	
9	54.19	45.18	0.02	0.20	1.14	0.12	0.07	0.05	100.97	123						0.49	7.36	
10	55.21	44.13		0.05	1.07	0.08		0.02	100.56	116						0.49	17.26	
11	53.97	45.48		0.34	0.46	0.07		0.01	100.33	121						0.48	1.74	
12	54.12	45.26		0.01	1.38	0.06		0.01	100.84							0.49	178.00	
13	55.13	44.25		0.17	0.86	0.08	0.08	0.03	100.60	397						0.49	6.53	
14	56.29	41.33	0.16	0.04	2.54	0.13	0.13	0.05	100.68	61						0.51	81.97	
15	54.55	45.11		0.04	0.38	0.07	0.03		100.18	280						0.48	12.26	
16	54.10	45.12		0.02	0.61	0.07	0.04	0.06	100.02							0.48	39.37	
17	56.33	40.68	0.23	0.15	1.46	0.12	0.10	0.07	99.16	321						0.52	12.56	
18	52.8	41.50		0.24	1.78	1.56	0.47	0.34	98.89	437	203	24	350	245	66	0.50	9.64	0.15
19	53.55	40.30		0.19	1.93	2.13	0.47	0.22	98.99	412	161	23	247	255	52	0.51	13.20	0.13
20	50.26	41.12		0.27	1.72	4.12	0.48	0.32	98.29	409	116	23	325	258	65	0.49	8.28	0.16
21	50.91	46.85		0.26	1.80	1.22	0.51	0.26	101.41	292		24	300	258	50	0.46	9.00	0.17
22	49.98	43.12			1.29					1112	31	19	110	279		0.47		
23	52.77	41.71			0.24											0.49		
24	49.71			0.32		0.34				734	92	55	584	136				

Sl. nos 1 to 17, Individual ilmenite grains from Honnavar beach sand analysed by EPMA; Sl. nos 18–21, 95% pure ilmenites analysed by ICP–MS; Sl. no. 22, Average of two samples from the Honnavar beach, Karnataka⁷; Sl. no. 23 Average of six samples from beach sands of Maharashtra⁷ and Sl. no. 24, Average of six samples from Vishakhapatnam–Bhimunipatnam beach⁸.

gneissic rocks of the catchments of the Sharavati river (V. S. Hegde, unpublished). However, Zn content in these ilmenites (245–255 ppm) is comparable to those from the Maharashtra coast⁷, and Vishakapatnam and Bhimunipatnam deposits, Andhra Pradesh⁸.

The low value of $Ti/(Ti + Fe)$, high Mn content and fresh grains of ilmenite suggest their recent contribution to placer deposits. As the Sharavati is a major river debauching into the Arabian Sea near Honnavar, it is probable that ilmenite is brought from the hinterland. Concentration of heavy minerals is found on either side of the river mouth during monsoon, and is relatively less abundant during other seasons. At Apsarakonda, there is a small ephemeral stream flowing and heavy mineral concentration is found on either side of the nalla mouth. These sedimentary processes indicate that they are derived from the hinterland and brought by the rivers.

Mineral assemblage of green hornblende, epidote, sphene, zircon, ilmenite and magnetite in the heavy mineral suite is indicative of granitic, gneissic and basic sources. However, presence of minerals like garnet, kyanite and staurolite suggests a high-grade metamorphic source, whereas altered-rounded ilmenite suggests reworked older ilmenite. The river Sharavati originated on the eastern face of the Western Ghats and has extended its catchments by river piracy⁹. Hitherto, it is not draining the high grade metamorphic terrain. Such a source can be envisaged in the far south (Kerala), where sediments derived from high-grade metamorphic terrain are plausible. Similar features are observed in heavy minerals of the Paraver and Varkala beaches of Kerala, where heavy minerals are derived from the Precambrian charnokite–khondalite rocks as well from Mio-Pliocene Varkala sediments¹⁰. Further, no relation between bed-load sediments by rivers and those found on the beach was observed. Similar features were also observed at Chavara and Manavalakuruchi¹¹.

Beach processes and variation in hydrodynamic conditions operating along the coast are considered to be important factors in beach placer formation^{12,13}. Medium-grained, well-sorted nature and negative skewness of the beach sands of Honnavar imply winnowing action of waves and removal of fines and lighter minerals leading to concentration of heavy minerals. Moderate to high-energy conditions of waves facilitate such a process. Influence of selective transport of lighter ones by long-shore current and winnowing action by waves in concentration of placer are reported for heavy minerals concentration of the Kerala coast¹¹. However, there is no such variation in the concentration of the heavy minerals along the Honnavar beach. The concentration of heavies is found to be associated with the erosional profile. This corroborates that concentration of heavies is the result of strong winnowing action of waves rather than selective transport by long-shore currents. Concentration of alternate layers of black and light minerals corresponds to deposition during different energy conditions. During high-energy conditions,

strong winnowing action of waves washes away the lighter ones, leaving behind the heavier, darker ones, on the beach. During low-energy conditions (fair weather season), the earlier removed light sands creep back onto the shore¹⁴ and are deposited on the heavier ones, resulting in alternate bands of dark and light sands (Figure 2).

In view of the presence of a number of headlands to the south and far north, and a number of rivers on both north as well south of the study area, uninterrupted alongshore drift is less likely. Therefore, transportation of such sediments by alongshore current to the beach from far south or north is a remote possibility. Hence, a preferred model that can explain their concentration is the offshore reservoir of sands. Presence of heavy minerals around –15 m depth off the coasts of Maharashtra¹⁵ and Kerala¹⁶ lends support to this interpretation. Presence of palaeo-beach off Mangalore¹⁷ and off Karwar¹⁸, and buried palaeo-channels off Honnavar¹⁹ suggest the possibility of the presence of palaeo-beach off this coast. During post-monsoon, there is net shoreward movement of materials along the west coast²⁰. Such a shoreward transport of materials is also reported for the Mangalore coast²¹. Therefore, it is probable that heavy minerals characteristic of high-grade metamorphic provenance might have been transported from south by strong northerly drift generated by the SW monsoon to buried palaeobeach off Honnavar during Holocene, when the sea was further west. Palaeo-geographic conditions would have facilitated uninterrupted movement of alongshore drift towards north. During sea-level rise, these palaeo-beaches could have been buried, and now, during shoreward movement of materials, these might have been transported towards the shore.

Thus, from the foregoing account it can be concluded that heavy minerals on the Honnavar beach have mixed mode of origin, viz. – one a contribution from hinterland brought by rivers presently draining the area and the other from palaeo-beach.

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Morphophenology and karyotype study of *Patidoi* (*Schumannianthus dichotomus* (Roxb.) Gagnep. synonym *Clinogyne dichotoma* Salisb.) – a traditional plant of Assam

Dhiren Chowdhury and Bolin Kr. Konwar*

Molecular Biology and Biotechnology Department, Tezpur University, Napam 784 028, India

***Patidoi* (*Schumannianthus dichotomus* (Roxb.) Gagnep. synonym *Clinogyne dichotoma* Salisb., family Marantaceae) is a perennial shrub. Leaves are petiolated, distichous and sheathing. Flowering occurs during May–June, with 9–18 panicles (inflorescence) in each culm. Anthesis begins around 3.30 h and continues up to 10.00 h. Ovary is villous and three-celled. Fruits are indehiscent, subglobose and take 25–35 days for maturity. Karyotypic study revealed that the species is diploid with $2n = 20$ (where $n = x = 10$). The total haploid genome length is 12.7 μm . The length of chromosome is found to vary from 0.8 to 2.2 μm , with predominance of meta-centric (M) and submetacentric (SM) behaviour.**

Keywords: *Clinogyne dichotoma*, diploid, karyotype, morphophenology, Sital pati.

THE genus *Schumannianthus* consists of two species in the Indo-Malayan region¹. *Patidoi* is a major component of the rural cottage industry of the Northeastern states. The bark of the matured culm is used as raw material for making ‘Pati or Sital pati’ (a type of decorated, durable and biodegradable mat) and many other domestic articles like handbag, hat, seat, hand-held fans, etc. The pith is used as raw material for preparing indigenous detergent solution, paper and in some cases as firewood in the countryside. Leaves and flowers are also used for cooking purposes. The plant is found to have wide adaptability under water-logged conditions². In the years to come, it could become an agriculturally important plant for the landless poor farmers of the region, provided effective agro-techniques are developed. In the last two to three decades, the population of this plant in its natural habitat has been decreasing at an alarming rate due to over-exploitation, destructive harvesting, large-scale deforestation and lack of awareness. Information on the plant with respect to its morphophenology is scanty. As far as karyotype is concerned, no reports were found elsewhere. Different authors studied karyotype of genera other than *Schumannianthus* (synonym *Clinogyne*) under the family Marantaceae and reported the chromosome numbers^{3–6}. However, the objectives of the present communication are to provide morphological and cytological data for future utilization of *Patidoi*.

*For correspondence. (e-mail: bkkn@tezu.ernet.in)