Discovery of heavy mineral-rich sand dunes along the Orissa–Bengal coast of India using remote sensing techniques

Remote sensing techniques from aerial and space-borne platforms are used to identify the earth's features by detecting the characteristic electromagnetic radiations that are reflected by the earth's surface. They can be applied to numerous fields such as geology and mineral exploration (through geomorphology, lithology and structure), soil mapping, agriculture, forestry, environmental studies, water resources, snow-melt studies, flood-inundation studies, land use–land cover studies, urban planning and wildlife management[1–5].

Heavy minerals, viz. ilmenite, rutile, zircon, monazite, etc. have specific gravity more than that of bromoform (2.89). They are highly resistant to the abrasive action of water. The Atomic Minerals Directorate for Exploration and Research (AMD) of the Department of Atomic Energy (DAE), Hyderabad, has been engaged in the exploration and evaluation of heavy mineral beach and inland placer deposits along the coastline of India during the past five decades[6], like those at Chavara (Kerala), Manavalakurichi (Tamil Nadu), Ratnagiri (Maharashtra), Kakinada (Andhra Pradesh) and Chattarpur (Orissa). These deposits have been identified through traditional methods of reconnaissance and detailed surveys. They are sampled in a grid pattern and the samples are processed and analysed in the laboratory at AMD. The laboratory methodology given elsewhere[7] was adopted in the present study together with remote sensing technique adopted to identify rich, heavy mineral-bearing sand bodies.

Palaeo-strand lines are the limits of the palaeo-sea (shoreline) that are represented by sand bodies consisting of shells and pebbles. These are several kilometres in length, 200–300 m in width and a few metres in amplitude. These are also called 'ancient beach ridge complexes'. The sands are the sediments that represent mechanically disintegrated hinterland rock types brought by the rivers into the sea. These are further sorted, concentrated and deposited along the coast by the waves and winds and thus these sediments (sands) may generally contain rich concentrations of heavy minerals[8].

Remote sensing studies were carried out using data from the space sensors, viz. Landsat MSS, TM; IRS-IC/ID LISS-III and IV that are available in different formats at different spectral and spatial

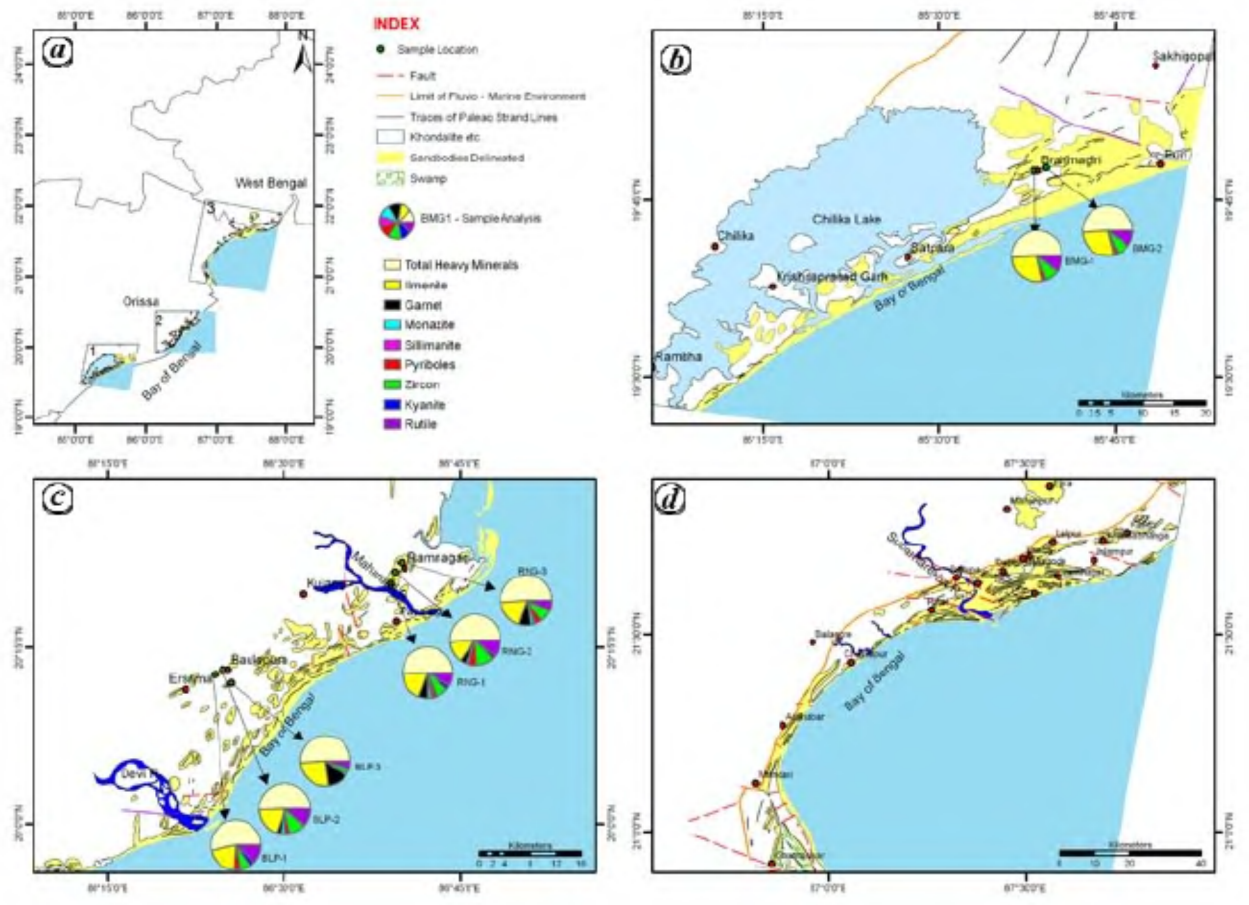

Figure 1. ***a***, Key map; ***b***, Brahmagiri–Puri sector; ***c***, Ersama–Ramnagar sector; ***d***, Ghanteswar–Balasore–Kanthi sector.

Table 1. Heavy-mineral analysis (in wt%) of sand samples along the Brahmagiri–Konark–Baulapura–Ramnagar tract, north Orissa coast

Sample no.	THM (%)	Ilmenite	Garnet	Monazite	Rutile	Zircon	Pyriboles	Kyanite	Sillimanite
BMG-1	16.04	8.55	0.10	0.06	3.22	2.80	0.78	0.08	–
BMG-2	14.63	7.91	0.040	0.30	2.92	2.31	0.55	–	–
KNK-1	3.48	0.99	–	0.17	0.70	0.56	0.40	0.44	–
KNK-2	19.26	8.13	2.18	–	3.53	2.27	1.82	1.02	–
BLP-1	8.45	3.26	0.11	0.14	1.92	1.06	0.62	0.52	0.034
BLP-2	17.72	6.67	0.82	1.01	3.99	3.51	0.898	–	0.41
BLP-3	81.36	41.3	20.76	2.57	7.77	5.73	–	0.56	–
RNG-1	15.00	5.4	1.62	0.67	2.54	2.38	0.67	0.75	0.412
RNG-2	7.12	1.86	0.48	0.215	1.53	1.54	0.67	0.25	0.145
RNG-3	4.66	1.695	0.68	0.25	0.57	0.76	0.34	–	0.129

BMG, Brahmagiri; KNK, Konark; BLP, Baulapura; RNG, Ramnagar; THM, Total heavy minerals.

Table 2. Potential heavy-mineral zones for ground follow-up

Area	Toposheet no.	Dimension of the heavy mineral zone	Trend of the palaeo-strandline	Distance from the coast (km)
Chandipur–Ranasahi–Inchuri–Aruhabar–Mandari	73 O/2 73 K/15	3 × 40 km	NNE–SSW	3–5
Retei backwater system, west of Subarnarekha river mouth	73 O/2	5 sq. km	ENE–WSW	4
Khalisabhanga–Kanthi tract	73 O/9	2 × 12 km	NE–SW	10
West of Lalpur	73 O/9 and 10	7 × 2 km	ENE–WSW	15–25
East of Mohanpur	73 O/5	8 × 9 km	Inland sand body	25
Egra	73 O/9	11 × 7	Inland sand body	25
Dehurda–Kasba–Mirgoda–Deula	73 O/6	40 sq. km	ENE–WSW	12

resolutions. Comparatively, the Landsat TM sensor had an improved spectral configuration that employs seven spectral bands – one each in the blue, green and red spectral regions (i.e. 0.45–0.52; 0.52-0.60 and 0.63–0.69 μm respectively), one in near infrared (0.76–0.90 μm), two in short-wave infrared (1.55–1.75 and 2.08–2.35 μm) and one in thermal infrared (10.4–12.5 μm) regions. The Landsat TM data with a combination of bands 3, 4 and 7 (red, near infrared and short-wave infrared spectral regions) have been found to be more informative for land–water boundary discrimination, soil moisture differences and band 3 highlights iron compounds (e.g. ilmenite) and iron oxide absorption features. This combination has been opted to map out the coastal geomorphic features and to identify sand bodies with heavy mineral concentration in the present study area[9].

Geomorphic interpretation of Landsat TM bands 3, 4 and 7 (B, G, R) over the area in parts of the east coast from Chilika Lake in Orissa to Kanthi in West Bengal, covering parts of Devi, Mahanadi and Subarnarekha deltaic regions, has been carried out (K. Jagannadha Rao, unpublished AMD report). The beach and inland placer-bearing geomorphic units, viz. palaeo-strand lines, inland sand dunes, spits and bars, which are favourable locales of heavy mineral concentration are delineated at Brahmagiri, Puri, Ersama, Baulapura, Kujang, Paradip, Ghanteswar, Chandipur, Digha and Khalisabhanga.

The palaeo-strandlines could be identified from the satellite images by their conspicuous linear/curvilinear and subparallel to parallel ridges with alternating swales. Palaeo-strandlines with high ridges and slopes, supporting vegetation and displaying slightly darker tones due to iron absorption in band 3, are interpreted to be rich in heavy minerals. Relatively lesser concentration of heavy minerals has been interpreted on the bright-toned, smooth, broad and low ridges/dunes of sand that supports scanty vegetation.

Ground checking of the sand bodies has confirmed the occurrence of heavy-mineral placer concentrations at the following locations: Brahmagiri, Sutana-Konark (Figure 1 *b*), Baulapura-Bhitar Andhari (NE of Ersama) and Ramnagar (Figure 1 *c*). All these heavy mineral-rich dunes are located 6–12 km inland from the coast and are sampled up to 1.5 m depth. These are identified as palaeo-strandlines in the Mahanadi–Devi–Subarnarekha delta.

The heavy-mineral analysis of these sand samples has revealed significant concentration of ilmenite, rutile and zircon in them (Table 1). The heavy minerals identified in all these areas are: ilmenite (1.0–41% by wt), rutile (0.57–7.77%), garnet (0.1–20.8%), zircon (0.56–5.73%) and monazite (0.14–2.57%). However, the samples of Brahmagiri, Sutana–Konark and Ramnagar show abundance of ilmenite–rutile–zircon–garnet mineral crops.

This study has opened up new areas far inland, i.e. 15–20 km from the coast for exploration of heavy minerals in the Orissa–Bengal coast of India. Sustained follow-up exploration by the Beach Sand and Off-shore Investigation Group of AMD for the past four years resulted in establishing the largest heavy mineral deposit so far along the east coast of India at Brahmagiri, Orissa.

Apart from this, several other areas along the north Orissa and West Bengal coast have also been identified as potential heavy-mineral zones for further ground follow-up. Dimensions of these are given in Table 2.

The remote sensing technique as a useful tool applied in mapping of coastal geomorphology, in general, and the heavy mineral-bearing sand bodies, in particular, has been demonstrated in this study. The present study guided the Beach Sand and Off-shore Investigation Group of AMD to locate heavy mineral-rich sands from Brahmagiri to Ramnagar along the Orissa coast. The study has also delineated several other sand bodies further north, from Ghanteswar in Orissa to Kanthi in West Bengal (Figure 1 *d*), which need future exploration.

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ACKNOWLEDGEMENTS. We thank the Director, AMD, Hyderabad for permission to publish this work and G. S. Ravi, R. D. Deshmukh of AMD, for fruitful discussions. We also thank the anonymous reviewer for valuable suggestions.

Received 30 July 2007; revised accepted 10 March 2008

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