

# NEARSHORE MAGNETIC ANOMALIES OF INNER SHELF OF BHIMUNIPATNAM-PUDIMADAKA, EAST COAST OF INDIA

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## ABSTRACT

Analysis of Marine Magnetic data of the nearshore marine environment between Bhimunipatnam and Pudimadaka on the east coast of India indicate charnockite intrusions in the innershelf in certain areas. From the analysis of magnetic data, the causative sources (intrusive bodies) are estimated to occur at depths varying between 80 and 200 m from the sea surface. In the Lawson's Bay the high-amplitude anomaly is attributed to basement uplift due to folding in granitic or gneissic rocks. Even though heavy mineral concentrations coincide with magnetic anomaly at certain places, a distinct correlation between heavy mineral percentage of the surface sediments and magnetic data is not always discernible.

## INTRODUCTION

Visakhapatnam shelf from Bhimunipatnam in the north to Pudimadaka in the south comprises of shallow water bays (Fig. 1) formed mainly due to the protruding hills of Eastern Ghat complex into the sea. Most of these bays, particularly beaches of Bhimunipatnam, Lawson's Bay and R. K. Beach are associated with patches of black sands. Some preliminary studies have been attempted during 1950-60 on these placer concentrations of black sands (Mahadevan and Rao 1953). Rao and Murthy (1980) and Rao *et al* (1985) attempted preliminary geophysical and geological investigations over the Visakhapatnam

shelf to identify zones of nearshore heavy mineral concentrations. Murthy *et al* (1987) analysed the magnetic anomalies in detail. Sastry *et al* (1987) reported the occurrence of high concentrations of magnetite and ilmenite in the fine to medium size beach sands extending from Bhimunipatnam to Visakhapatnam.

During 1985-88, the Regional Centre of National Institute of Oceanography at Visakhapatnam carried out systematic bathymetric and magnetic surveys over these shallow water bays in addition to nearshore surface sediment sampling in some of these areas. This paper presents the results of these studies and makes a correlative study of these

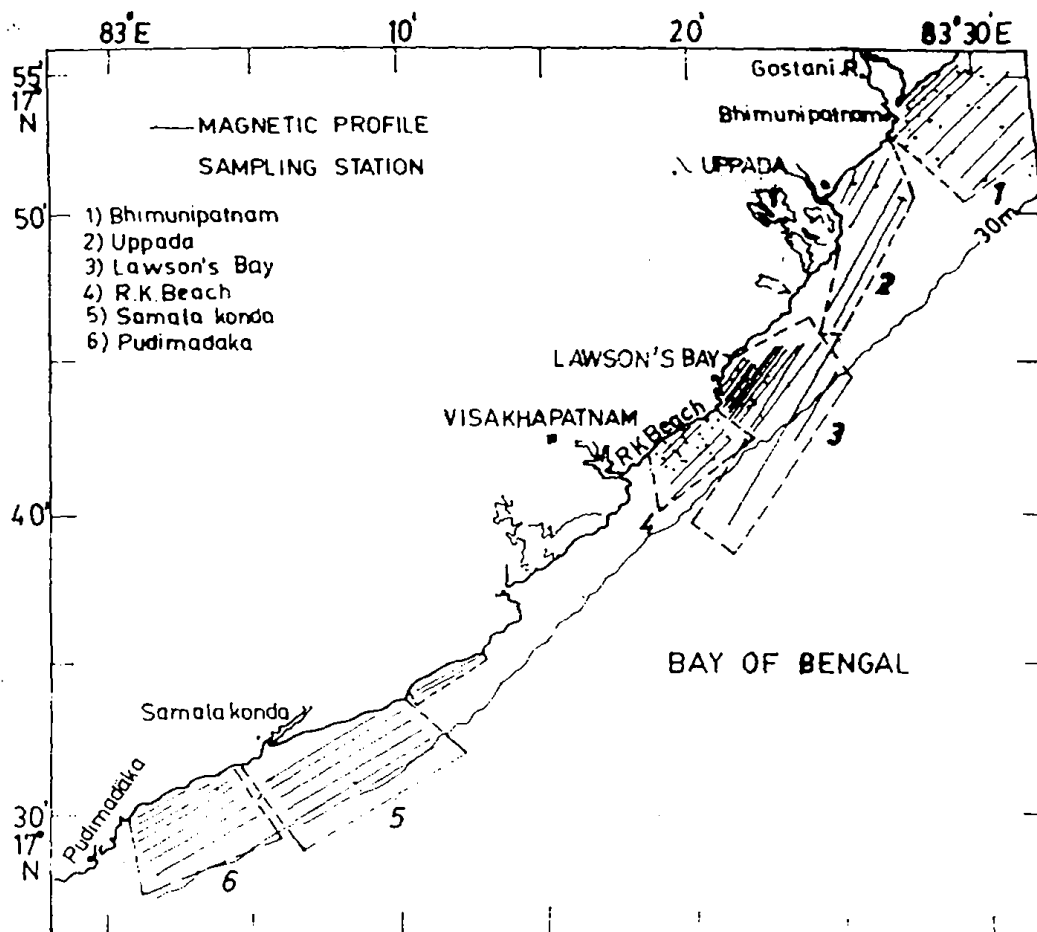


Fig. 1 : Location map of the Bhimuniapatnam—Pudimadaka shelf. (the numbers 1 to 6 correspond to the shallow water bays).

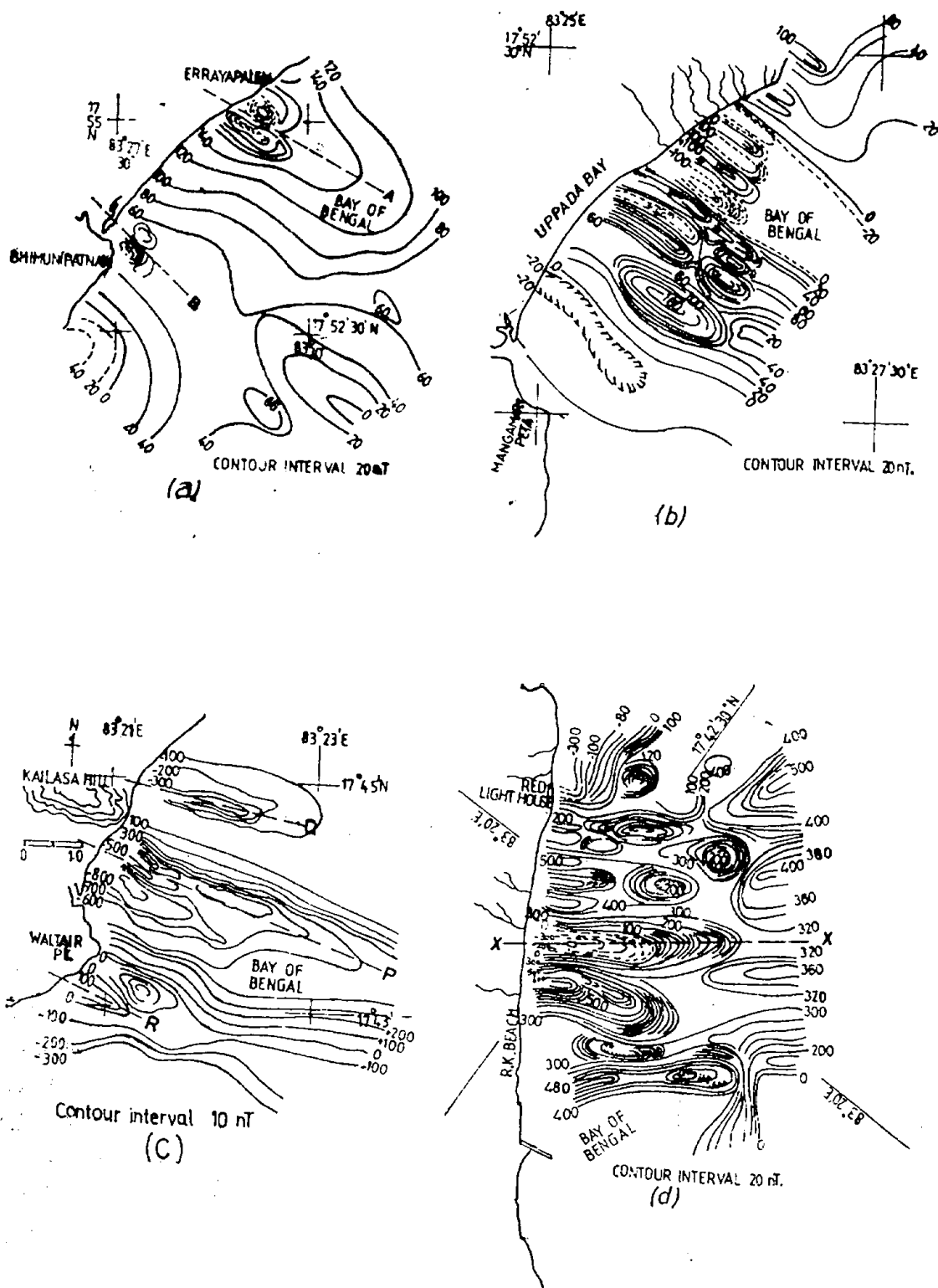
areas from Bhimuniapatnam in the north to Pudimadaka in the south.

### COASTAL GEOMORPHOLOGY

The area of study comprises mainly of Khondalite of Eastern Ghat complex generally trending in a NE-SW direction with some hills of Visakhapatnam coast protruding into the sea in E-W direction thereby forming shallow water bays in between them. Char-

nockite intrusions are reported at several places of the coast in an otherwise knondalite terrain (Rangachari 1952 Unpub. M Sc thesis, Srirama Das and Rao 1979, Bhaskara Rao and Vaidyanathan 1975) identified several faults and fracture lineaments from aerial photographs of Pudimadaka-Visakhapatnam coast.

The Bhimuniapatnam-Pudimadaka coast is also associated with several drainage channels that carry terrigenous sediments from coast



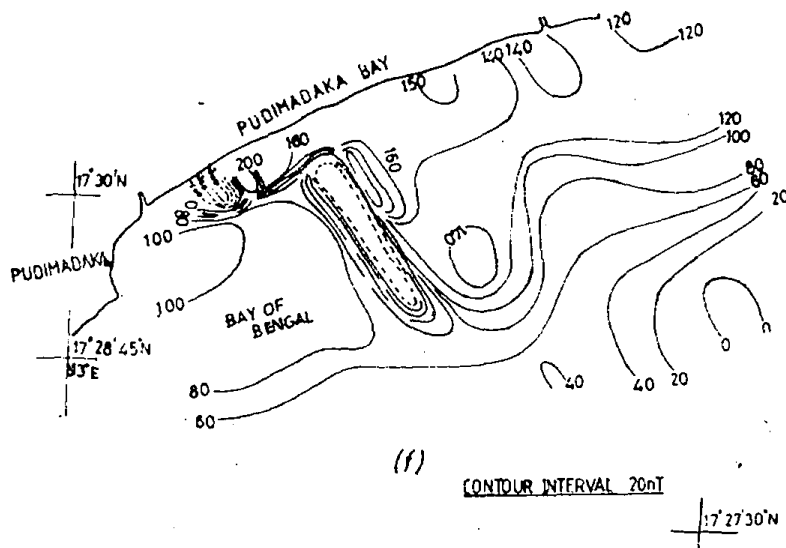
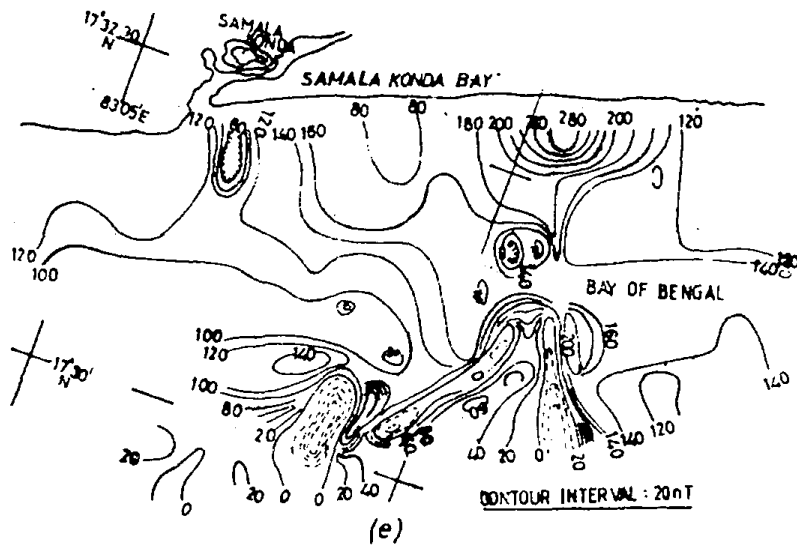


Fig. 2 : Total intensity magnetic anomaly contour maps : (a) Bhimunipatnam Bay (b) Uppada Bay (c) Lawson's Bay (d) R. K. Beach (e) Samalkonda Bay and (f) Pudimadaka Bay.

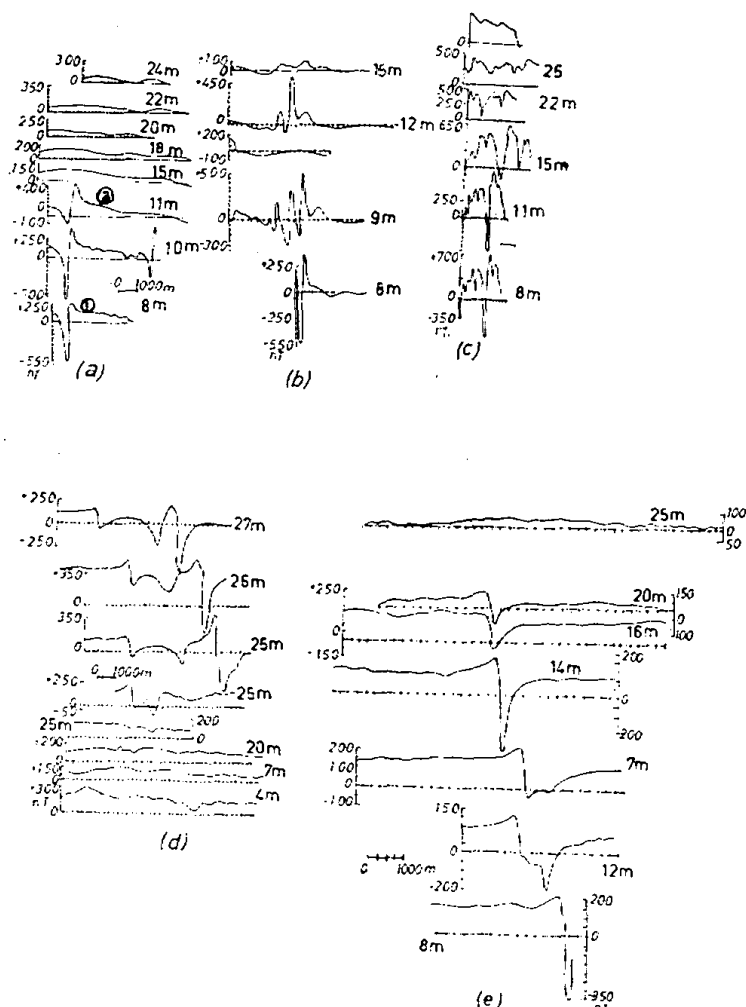


Fig. 3 : Stacked magnetic anomaly sections : (a) Bhimunipatnam Bay (b) Uppada Bay (c) R. K. Beach (d) Samalkonda Bay and (e) Pudimadaka Bay (Stacked sections for Lawson's Bay are shown in Fig. 4b).

to the inner shelf, the Gostani river at Bhimunipatnam being the major source for such terrigenous sediments.

## MATERIALS AND METHODS

Bathymetric and total field magnetic data along continuous tracks parallel to the coast

were collected in all the six shallow water regions of Bhimunipatnam-Pudimadaka (Fig. 1). Bathymetric data was collected using a Simrad EQ echosounder and are mostly smooth and featureless in these areas. Surface sediment samples were collected off Bhimunipatnam, Lawson's Bay and Ramakrishna Beach,

Magnetic data was collected both in analogue and digital form using a Barringer Proton Precession Magnetometer at 20 sec polarisation interval. The profiles are continued to nearly 30 m water depth in all these areas. The position fixing during the surveys was made by using three theodolites fixed at known locations on the coast. The raw magnetic data were corrected for the normal variation of the earth's magnetic field using IGRF coefficients for the epoch 1985 (Barracough 1985). The residual data was used to prepare isonanotesla maps for these areas (Fig. 2a to f) and also for stacked anomaly sections (Fig. 3a to e). Magnetic anomalies along these sections are analysed using conventional modelling as well as automated methods. Some representative magnetic sections and the derived models are shown in Fig. 4a, b & c for Bhimunipatnam and Lawson's Bay and the results are summarised in Tables 1 and 2 for these two bays.

Sediment samples from Bhimunipatnam Bay and Lawson's Bay to R. K. Beach, north of Visakhapatnam Port, are collected along vertical sections covering water depths from 5 to 20 m using a Vanveen Grab with a profile interval of nearly 500 m. The required amount of 50 gm of sediment sample was taken by coning and quartering method from each collection and subjected to thorough washing to remove the oxide coatings and chlorides following which the samples are oven-dried (Ingram 1971). The sieve analysis was carried out for the dried samples at 0.5 $\phi$  interval with

sieves starting from 18 mesh (1.0 mm) to 230 mesh (0.062 mm) using the rotary sieve shaker. The different size fractions were subjected to heavy mineral separation using bromoform of 2.89 specific gravity. The bulk heavy mineral concentrations were computed from the heavy mineral content of different size fractions. Heavy mineral distribution maps prepared for Bhimunipatnam and Lawson's Bay to R. K. Beach areas are shown in Figs. 5a & b.

Magnetic anomaly maps with the derived models, coastal geomorphology and the heavy mineral distribution maps have been used for a correlative study of these bays.

## RESULTS

### *Magnetic anomaly trends and modelling :*

The isonanotesla ( $\eta$  T) maps of the study area shows different amplitudes of magnetic anomalies (Fig. 2). The Bhimunipatnam area is characterised by two prominent anomaly trends marked A and B (Fig. 2a), the former a high gradient anomaly with an amplitude of 900  $\eta$  T confined between 5 and 28 m water depth off Errayapalem and the latter off Gostani river at 8 m water depth with an amplitude of 280  $\eta$  T. Stacked sections (Fig. 3a) indicate the former to be an asymmetric anomaly. Quantitative interpretation of the anomaly by different methods (Table 1) indicates a two-dimensional body at an average width and depth of about 100 m and 130 m respectively from the sea surface as the

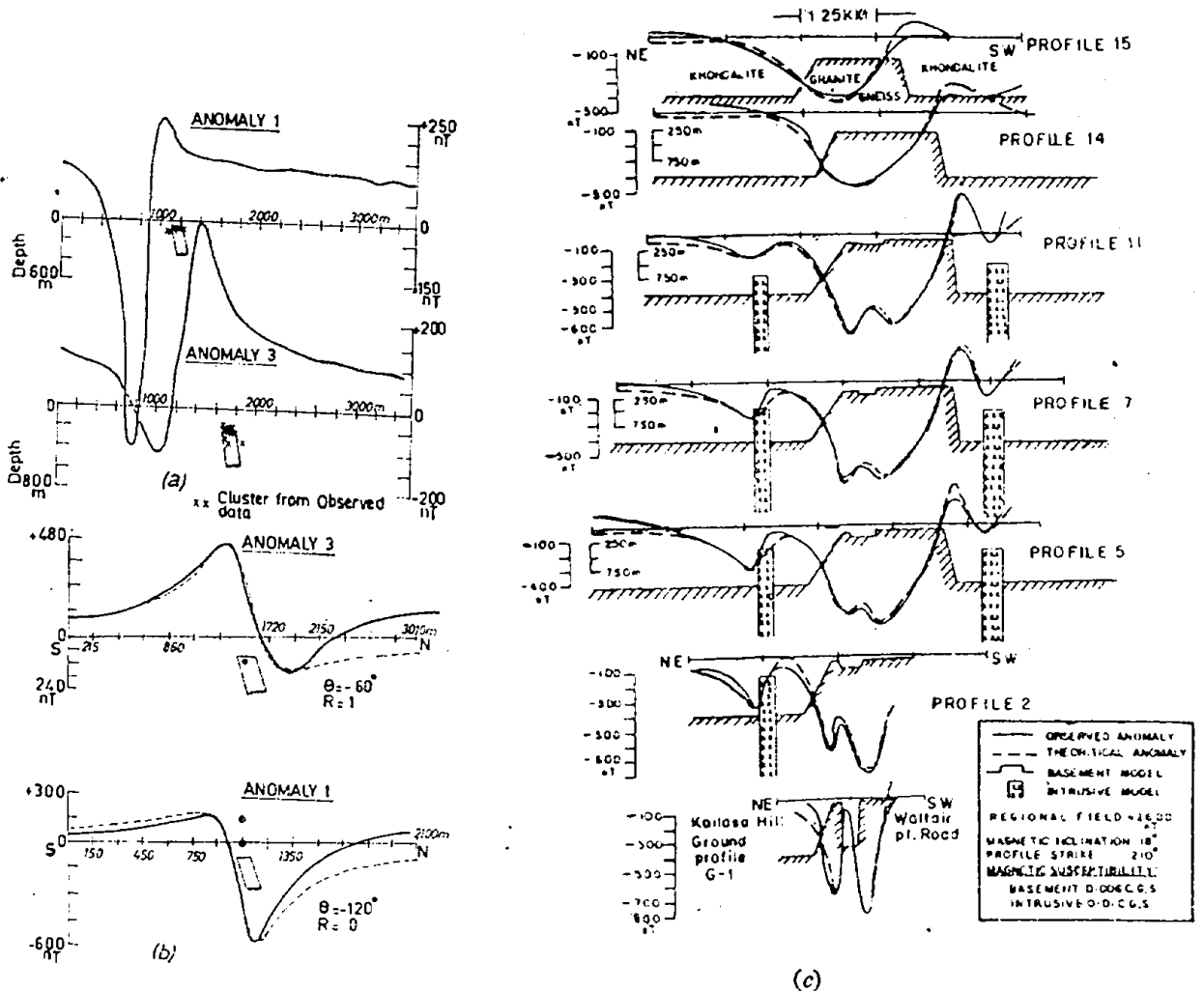


Fig. 4 : Modelling of marine magnetic anomalies : (a) Bhimunipatnam Bay using Ku and Sharp (1983) method; (b) Bhimunipatnam Bay using Parker Gay (1963) method; (c) Lawson's Bay using Talwani *et al.* (1964) method.

causative source for the anomaly 'A' (Fig. 4a) off Bhimunipatnam area. The high amplitude anomalies of the order of 200 to 300  $\eta$  T with a series of positive and negative peaks forming linear trends from coast to about 15m water depth are shown in Fig. 2b. The causative source of these anomalies derived by modelling are similar to that of the Bhimunipatnam area.

The isonanotesla map of the Lawson's bay area (Fig. 2c) shows three linear trends P, Q and R extending from coast to the sea. The major trend P with a broad anomaly of amplitude 400 to 900  $\eta$  T is extending to nearly 50 m water depth whereas short wave length anomaly trends Q and R on either side of P are confined to water depths of 20 m and have an amplitude of 100 to 200  $\eta$  T,

TABLE I : RESULTS OF MAGNETIC DATA ANALYSIS OFF BHIMUNIPATNAM  
ANOMIAY 1 (Fig. 3a)

Method	Depth to the top of the intrusive body in metres	Width of the body in metres
Gay (1963)	125	110
Nabhighian (1972)	80	—
Werner Deconvolution of Ku and Sharp (1983)	80	100
Straight slope method of Rao et al (1984)	75	—
Anomaly 3 (Fig. 3a)		
Gay (1963)	170	170
Koulomzine et al (1970)	180	120
Nabhighian (1972)	160	—
Werner Deconvolution of Ku and Sharp (1983)	200	120
Straight slope method of Rao et al (1984)	160	—

TABLE 2 : RESULTS OF MAGNETIC DATA ANALYSIS OFF LAWSON'S BAY  
ANOMALIES ALONG TRENDS, P, Q AND R  
(Fig. 2(b))

I Basement uplift (P)	II Intrusives (Q & R)	III Structural Low at Shallow depths
<i>(i) Intrusive Q on the north</i>		
Depth to base : 1.0 km		
Depth to top of uplift :	Depth to top : 300-450 m	Width : 250 m
Min 25 m	width : 250 m	
Max 375 m	Nature of material : Charnockite	Vertical throw : 875 m
Width of the uplift : 1.6 to 1.8 km	Mag. Susceptibility : .01 CGS	
<i>(ii) Intrusive R on the south</i>		
Vertical uplift : 750 m	Depth to top: 375-475 m	
Type of material : Granite/Gneissic	Width : 375 m	
Magnetic susceptibility : .006 CGS Units	Nature of material : Charnockite	
	Mag. Susceptibility : .01 CGS	



Detailed modelling of these anomalies (Fig. 4c and Table 2) indicates that the major trend 'P' is related to a basement uplift due to folding in the granitic/gneissic basement and the minor trends 'Q' and 'R' to charnockitic intrusions on either side of the uplift (Murthy *et al* 1987 a, b).

R. K. Beach area (Fig. 2d) is characterised by anomalies with multiple peaks from coast to about 12 m water depth and are having amplitudes of 500  $\eta$  T. A major lineation (marked X, Fig. 2d) with a negative peak of 580  $\eta$  T is prominent among these anomalies which extends to 2 km into the sea. The Samalkonda area is devoid of any anomalous trends from coast to the sea unlike the other areas of the study. However, at water depths of about 27 m, high amplitude magnetic anomalies of the order of 270 to 500  $\eta$  T are observed which appear to be confined to this depth and do not extend either coastward or seaward (Fig. 2c). The nature of these anomalies and their preliminary interpretation suggest some isolated object. Magnetic map of Pudimadaka area indicates a linear trend of a prominent negative anomaly with amplitude of the order of 500  $\eta$  T (Fig. 2f) extending to 2.5 km. The positive closure of this trend terminates at a distance of 1.25 km. High resolution seismic records at about 50 m water depth recorded parallel to the coast, indicate a buried channel off Pudimadaka (NIO unpublished report 1986), while Bhas-kara Rao and Vaidyanathan (1975) reported a palaeochannel on Pudimadaka coast. Hence

the linear magnetic anomalies over this channel may represent the extension of the coastal palaeochannel into the sea.

#### Heavy Minerals :

The surface sediment samples collected over some of these areas indicate enrichment of heavy mineral concentrations in the near-shore regions from 5 to 12 m depth and gradual seaward decrease thereafter. Heavy minerals of these areas comprise of magnetic and ilmenite as dominant minerals and zircon, rutile, garnet, monazite, kyanite, sillimanite, augite, hypersthene and hornblende as acces-

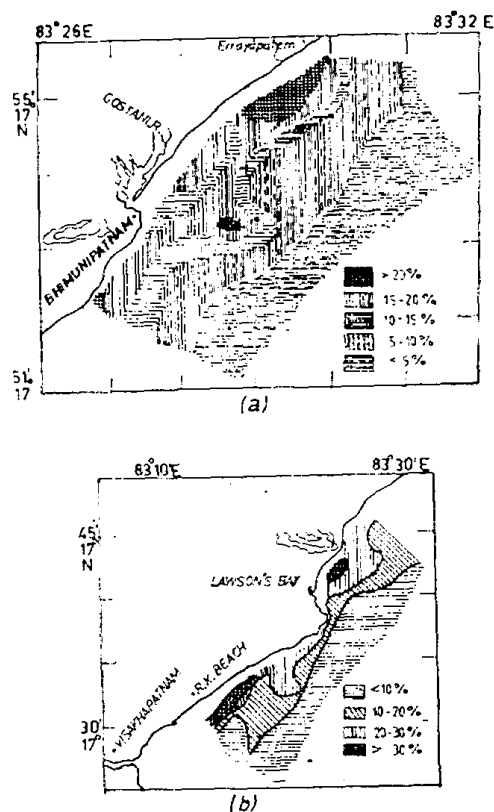


Fig. 5 : Heavy mineral distribution maps for (a) Bhimuniapatnam Bay and (b) Lawson's Bay.

sories. These heavy minerals are mostly associated with fine sandy sediments. Heavy mineral distribution map of Bhimunipatnam area (Fig. 5a) shows about 20% of heavy minerals at shallow depth of 5 to 12m and are well concentrated to more than 20% off Errayapalem. These are mainly derived from the hinterland due to weathering and erosion and got deposited in the beaches and inner shelf regions. Similar trend of seaward decrease in heavy mineral concentration is observed off Lawson's Bay to R. K. Beach area (Fig. 5b). However, at some places in the nearshore regions of 5 to 10 m depth the high concentrations of more than 30 percent are observed.

## DISCUSSION AND CONCLUSION

The magnetic data analysis off Bhimunipatnam and Uppada have indicated the existence of intrusive body at depths below the seabed of inner shelf and these can be attributed to the charnockite intrusive bodies. Off Errayapalem in the Bhimunipatnam area, the charnockitic intrusive body might be existing at the depths indicated by modelling and appears to be sloping seaward. The inland magnetic survey near the coast in the Gostani river basin in the same region carried out by Venkateswara Rao *et al* (1990) indicate the existence of a suite of parallel charnockitic intrusive bodies running approximately E-W at depth under the khondalitic and leptynitic cover. The two-dimensional body derived from the modelling of the anomalies in the

offshore regions of the same area might be the extension of the above E-W running charnockitic suite on the coast. The existence of such bodies at depths can be confirmed by the presence of charnockitic rocks on the coast as lenses and patches, exposed due to the tectonic activity and subsequent erosion of the overlying khondalitic and leptynitic formations (Venkateswara Rao *et al* 1990). Similarly the anomalies observed off Lawson's Bay and R. K. Beach areas might have been caused due to the charnockitic intrusive bodies existing below the inner shelf. However, the high amplitude anomaly of about 400 to 900  $\gamma$  T off Lawson's Bay is inferred by Murthy *et al* (1987) as basement uplift due to folding of the basement and the short wave length amplitude as charnockitic intrusive bodies. Rao *et al* (1985) have also correlated these high amplitude anomaly off Lawson's Bay to the structural lineament at 200 m depth below the seabed. Hence, the anomaly off Lawson's Bay can be attributed to the structural lineament in the basement. The anomalies off R. K. Beach can be interpreted to the seaward extension of charnockitic intrusion outcropped in beaches as lenticular lenses (Srirama Das and Rao 1979). Presence of leptynitic rock exposures in the very shallow regions off R. K. Beach also suggest the existence of charnockitic bodies because normally prominent zones of leptynites are often localised near the contact zones between the charnockitic and khondalite suites (Naraswamy 1975).

In the present work it is also observed that the low-amplitude nearshore magnetic anomalies are associated with the enrichment of heavy mineral sands. High heavy mineral concentrations of more than 20% are found in the nearshore magnetic anomalous areas off Errayapalem in Bhimunipatnam area, Lawson's Bay and R. K. Beach areas. However, off Gostani river, though the magnetic anomaly of 280  $\gamma$  T exists, encouraging heavy mineral sands are not noticed. Rao *et al* (1985) have correlated the nearshore anomalies off Lawson's Bay and R. K. Beach areas to the magnetite-dominated heavy mineral sands. Ramana (1988) has correlated the short wavelength magnetic anomalies to the magnetic mineral concentrations in the central west coast of India. In the present survey, though nearshore anomalies are associated with the high heavy mineral concentrated sands, definite trend is not observed throughout the study area. The magnetic anomaly with poor concentration of heavy minerals in the nearshore areas off Gostani river in the Bhimunipatnam area may be attributed to either the presence of charnockitic rock bodies beneath the seabed or the high concentration of heavy minerals in the subsurface layers. From the studies it is noticed that the surface heavy mineral concentrations alone are not always correlatable to magnetic anomaly. The nature of magnetic anomaly observed off Pudimadaka may be related to a buried channel (NIO Report 1988) which is also considered to be enriched with high heavy mineral concentrations.

The above correlative study using magnetic anomalies, coastal geomorphology and heavy mineral distribution indicates that in most cases the magnetic anomalies are caused due to the charnockitic intrusions though off Lawson's Bay the structural lineament is also reported to be causative source. Though the nearshore magnetic anomalies are well associated with the magnetite dominant heavy mineral sands, the perfect correlatable trend is not found throughout the surface sediments and hence the surface heavy mineral concentrations with magnetic anomalies are not always correlatable.

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