

# SURFICIAL MINERAL DEPOSITS OF THE CONTINENTAL SHELF OF INDIA

## LES RESSOURCES MINERALES SOUS-MARINES

### DU PLATEAU CONTINENTAL INDIEN

H.N. SIDDIQUIE, G.V. RAJAMANICKAM

National Institute of Oceanography,  
Donapaula, Goa, India.

The Indian National Institute of Oceanography has been carrying out a programme of exploration on the continental shelf and slope in India.

The occurrence of heavy mineral placers (monazite, zircon, ...) are already known from the various localities on the Indian coast and more particularly from the west coast (ilmenite off Ratnagiri). The biogenous deposits (calcareous sands and shells) are mined in the Gulf of Kutch and backwaters of Kerala. Other possibilities are in the Laccadives Islands.

Occurrences of phosphate, barium concretions, manganese encrustations have been recorded but appear to be not economic.

*L'Institut National Indien d'Océanographie a entrepris et poursuit la reconnaissance des potentialités minérales du vaste plateau continental de l'Inde (environ 1 million de km<sup>2</sup>).*

*L'auteur signale de nombreux indices de sables minéralisés (monazite, zircon, etc.), notamment sur la côte occidentale (ilmenite au large de Ratnagiri).*

*Un inventaire des dépôts de sables calcaires est donné, certains d'entre eux faisant l'objet d'exploitation (côte de l'état du Kerala, golfe de Kutch).*

*L'existence de concentrations de baryum, de croûtes de manganèse, etc., est également évoquée.*

### MAP SHOWING THE PRESENT STATUS OF EXPLORATION OF THE CONTINENTAL MARGIN OF INDIA

OUTER LIMIT OF THE CONTINENTAL SHELF  $\approx$  200 m  
OUTER LIMIT OF THE CONTINENTAL SLOPE  $\approx$  2000 m

EXPLORATION PROGRAMME

PROPOSED CRUISE TRACKS FOR REGIONAL  
EXPLORATION PROGRAMME

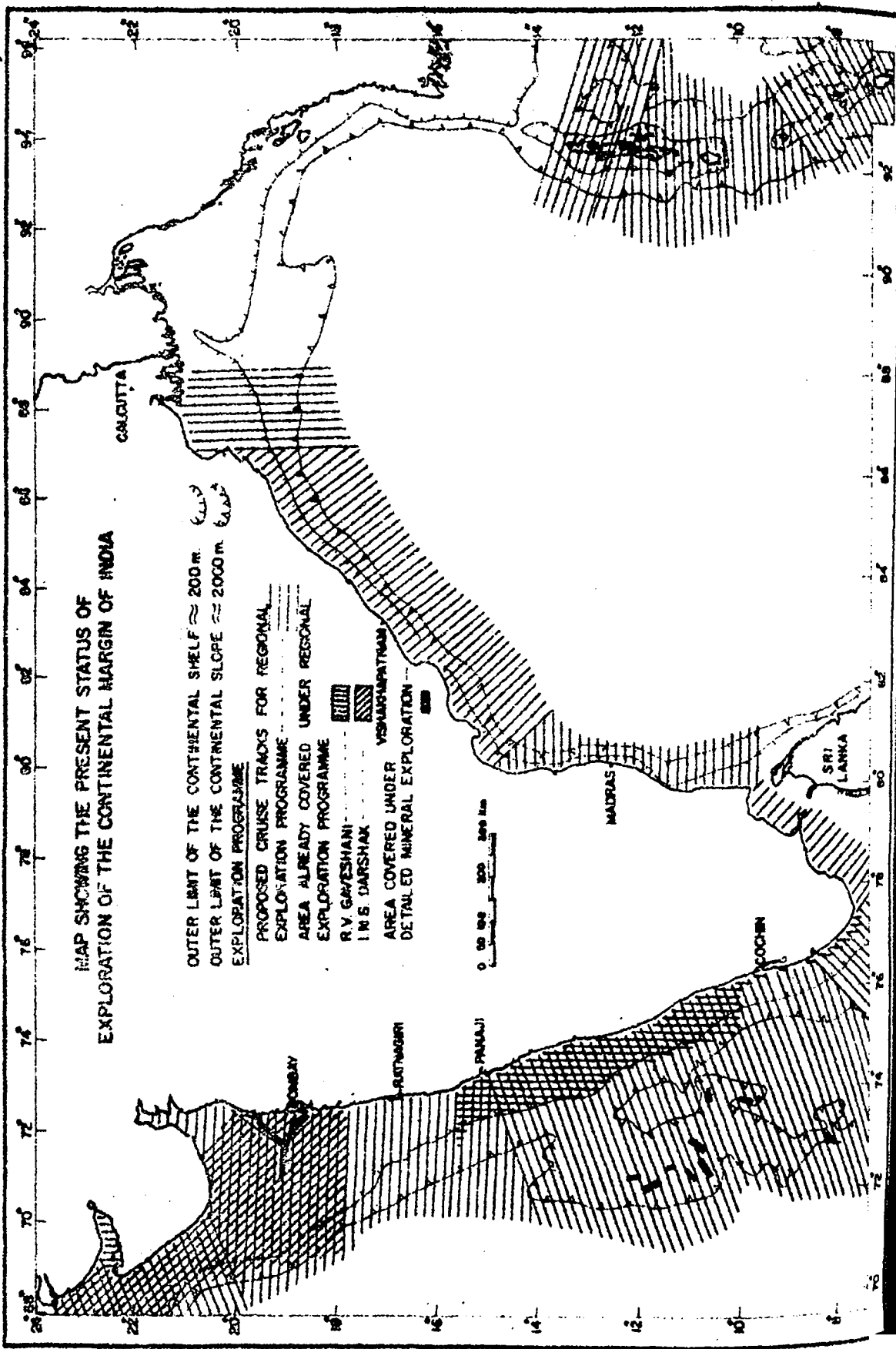
AREA ALREADY COVERED UNDER REGIONAL  
EXPLORATION PROGRAMME

R.V. GAYESHANI

I.N.S. DAKSHAK

AREA COVERED UNDER  
DETAILED MINERAL EXPLORATION

Y.S. SAMPATIRAM



## INTRODUCTION

The continental shelf and slope of India cover an area of about one million km<sup>2</sup>, which is about one third of the land area of the country. The shelf itself covers an area of about 450,000 km<sup>2</sup> and till recently very little was known about the geology, mineral and oil resources of this vast area. The discovery of large oil and gas deposits on the shelf off Bombay and availability of facilities particularly vessels for marine exploration and oceanographic research provided an impetus for work.

Previous Work : the mineral potential of the continental margin of India has been reviewed earlier by Chatterjee, Karanakaran and Siddiquie (1968) and subsequently briefly up-dated by Siddiquie (1975) in "Marine geology in India - a review". Prabhakar Rao (1968) described the sediments of nearshore region of Kerala which included a description of heavy mineral distribution in this region. Qasim and Nair (1977) reviewed the prospects of offshore mining in India.

Present Exploration Programme : the National Institute of Oceanography is now operating a programme for geological and geophysical exploration of the entire continental shelf and slope (fig. 1). The surveys are carried out mainly by the Institute's research vessel GAVESHANI (68 m long, 12 m broad and provision for 19 scientists). In addition, smaller vessels, mainly fishing trawlers are engaged at various localities on the coast to survey shallow areas. These smaller vessels have been utilised for the exploration of ilmenite deposits in the shallow offshore areas and calcareous sands in the lagoons of the Laccadive Islands. The exploration programme is based on an evaluation of the available data chiefly the Sediment Map of the Seas bordering India (Siddiquie, Shrivastava, Melik, Venkatesh and Ray, 1975). The distribution of different sediment types i.e., terrigenous, biogenous and chemogenous, their differentiation into recent and relict, identification of non-depositional environments and proximity to recent heavy mineral placers on beach are some of the factors used for evaluating the mineral potential of the area and assigning priorities for surveys of different regions. The programme envisages traversing the entire continental margin of India at tracks spaced at 20 km so that the spacing is sufficient for incorporation of basic geological data on the existing 1/2 000 000 maps of India. The programme involves traversing over 75,000 line km, collection of bottom samples from 5,000 stations and about 22 months ship time. The underway surveys include bathymetry, side scan sonar, shallow seismic and magnetics followed by sampling by grabs, corers and/or dredging at about 10 km or after the identification of suitable locations from examination of underway records. The data and samples thus collected are studied for the preparation of various geological, geophysical and tectonic maps and evaluating the mineral potential of the area. The follow up laboratory studies include sedimentology, geochemistry and micropaleontology. A reconnaissance of more than two third of the western shelf has been completed under this programme (fig. 1).

Fig. 2

MAP SHOWING THE TERRIGENOUS MINERAL OCCURRENCES ON THE CONTINENTAL MARGIN OF INDIA

OUTER LIMIT OF THE CONTINENTAL SHELF  $\approx 200m.$   
 OUTER LIMIT OF THE CONTINENTAL SLOPE  $\approx 2000m.$

BOTTOM SEDIMENTS

- SAND
  - RECENT
  - RELICT
- CARBONATE (Biogenous or Chemosynous)

MINERAL OCCURRENCES

- Undifferentiated
- Erinite
- Monazite
- Garnet
- Magnetite
- Olivine
- Pyroxene
- Amphibole
- Spinel
- Ilmenite
- Staurolite
- Monazite
- Garnet
- Magnetite
- Quartz
- Pyroxene
- Amphibole
- Spinel
- Ilmenite
- Staurolite
- Monazite
- Garnet
- Magnetite

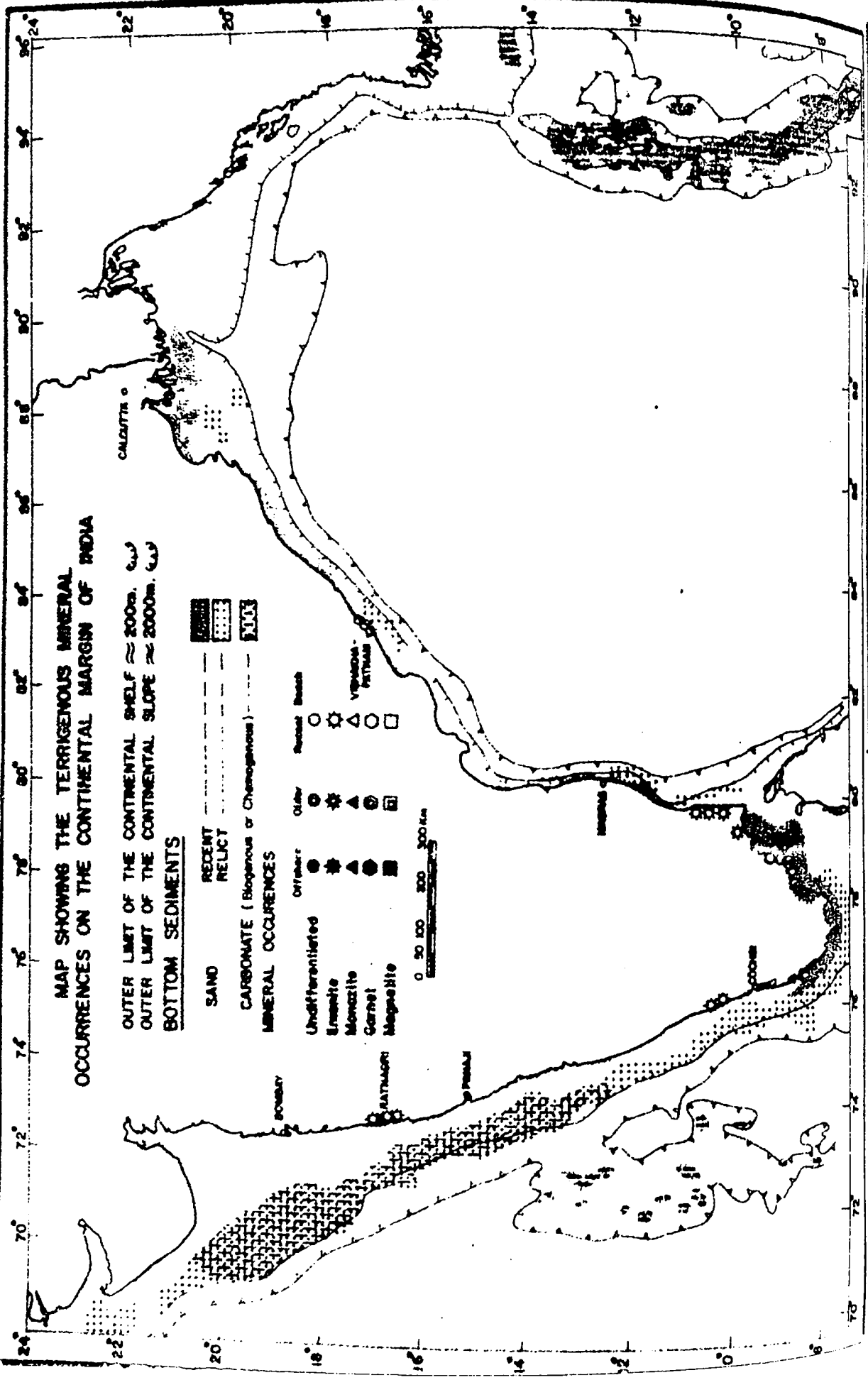
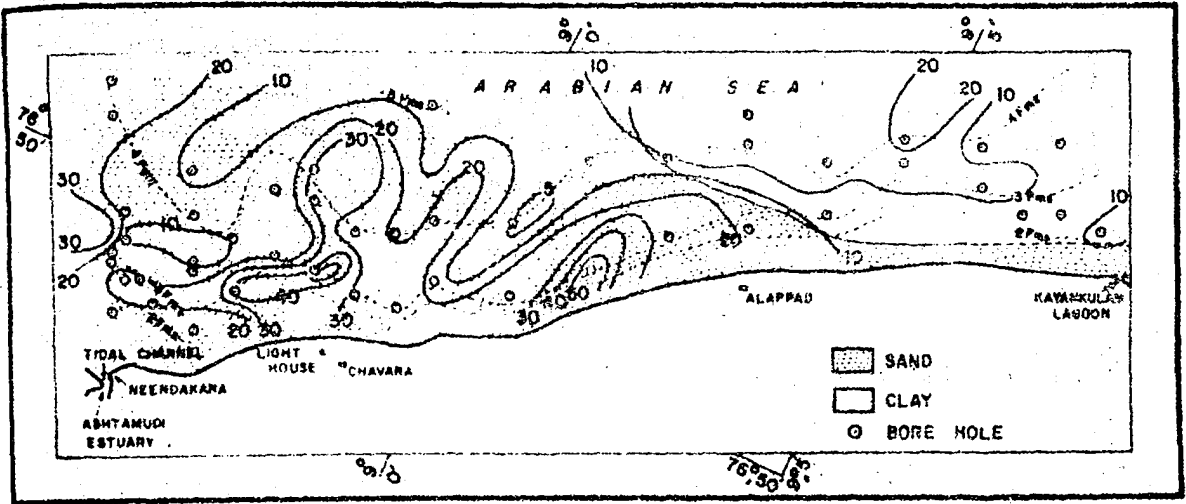
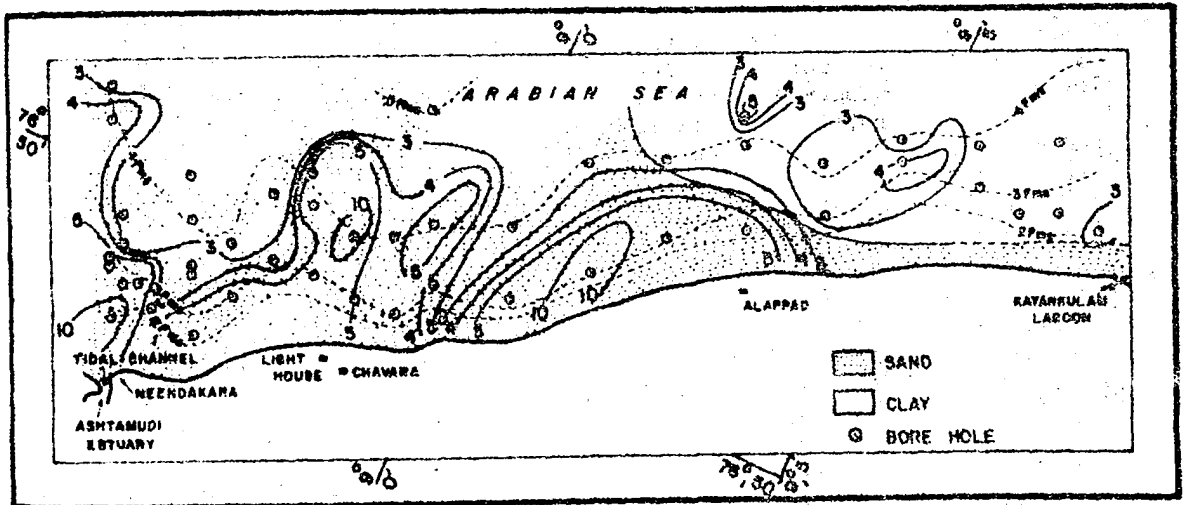


Fig. 3



1. Map showing the distribution of heavy minerals in the sediments of Neendakara-Kayankulam region (data replotted from Prabhakar Rao, 1968)



2. Map showing the distribution of ilmenite in the sediments of Neendakara-Kayankulam region (data replotted from Prabhakar Rao, 1968)

The present paper is largely based on the work carried out under this programme at the National Institute of Oceanography and from the published reports of other organizations in the country (Geological Survey of India and Department of Atomic Energy). The work is in the initial stages of the exploration programmes and the paper does not give the synthesis of results of a completed survey.

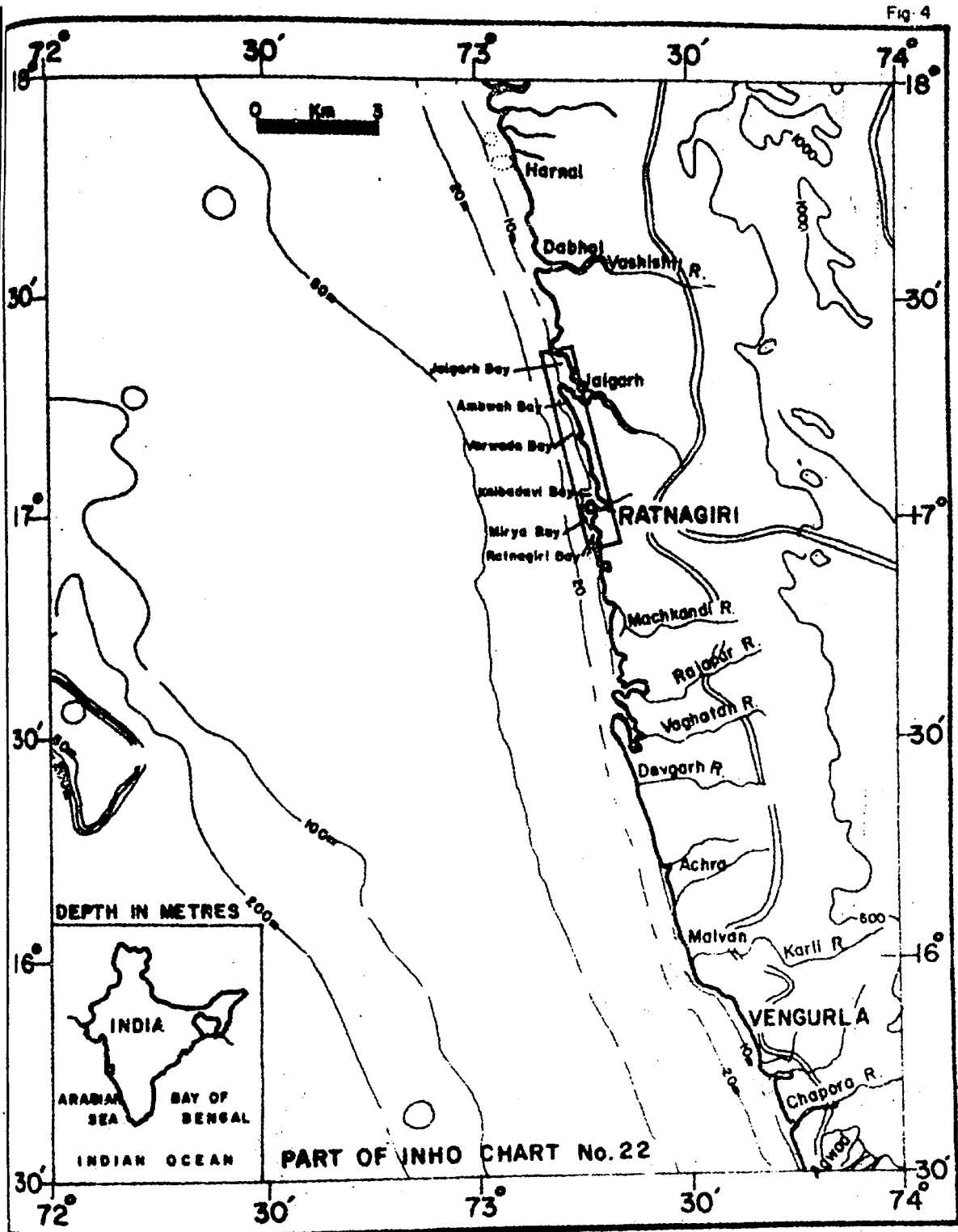
The surficial mineral deposits, as is customary, have been grouped into terrigenous, biogenous and chemogenous as described below.

## SURFICIAL MINERAL DEPOSITS

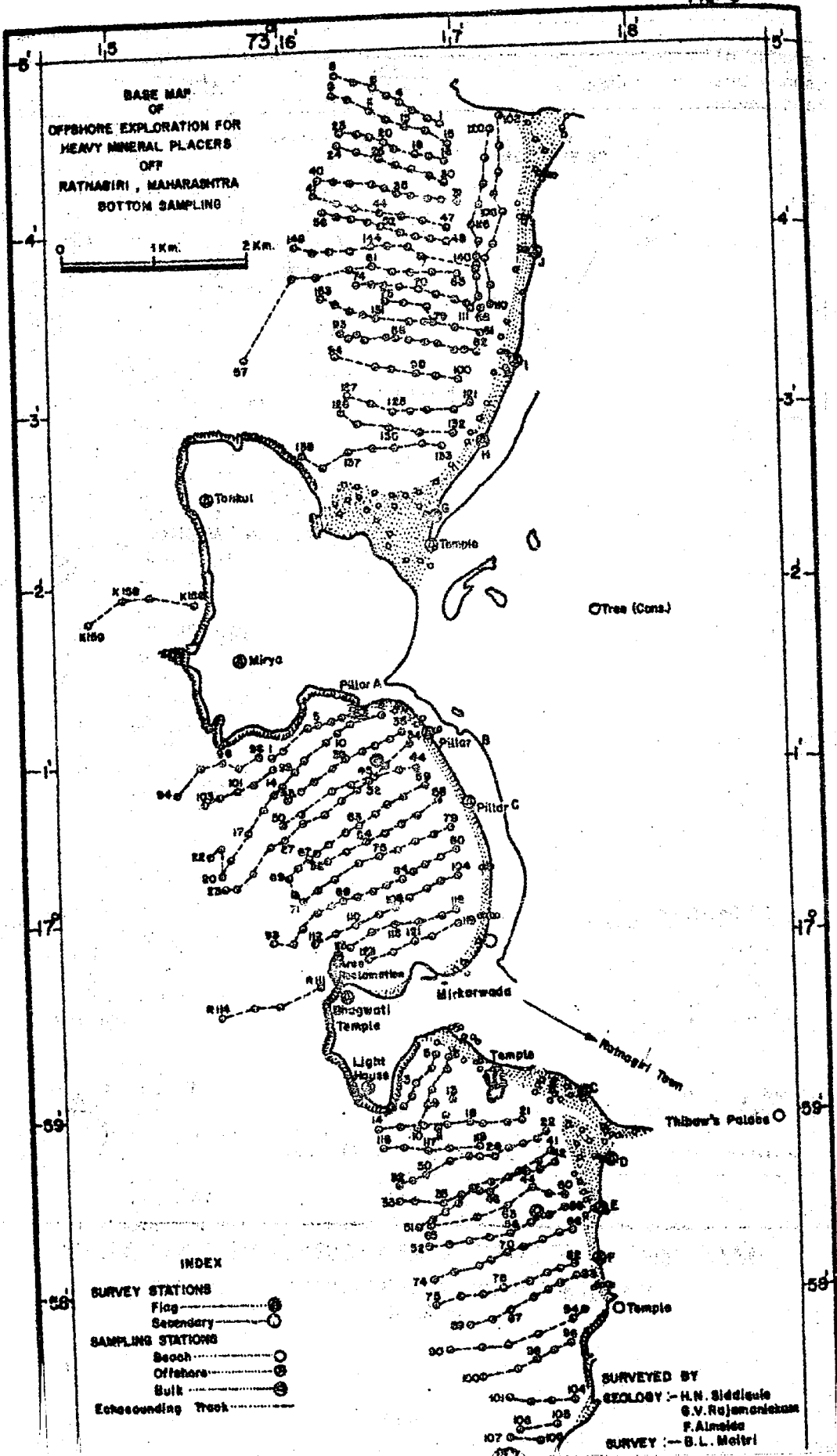
Terrigenous Deposits (fig. 2) : occurrences of heavy mineral concentrates usually known as "black sands" are reported from many localities of the Indian coast. These sands usually contain monazite, ilmenite, zircon and garnet, besides magnetite, sillimanite, kyanite in significant proportions for economic exploitation.

Of these, the occurrence of heavy mineral sands along the Kerala coast is best known (Tipper 1914 ; Brown and Dey 1955). The heavy mineral sands occur in an area extending from Quilon to Cape Comorin. The deposit is reported to contain 17 million tonnes of ilmenite, 1 million tonnes of rutile, 1.2 million tonnes of zircon and 0.2 million tonnes of monazite. Similar beach deposits with varying proportions of monazite, ilmenite, zircon and garnet have been described from the Retnagiri area. (KRISHANAN and ROY 1945 and ROY 1958) Tinnavelli, Ramnad and Tanjore districts, Tamil Nadu (JACOB 1956), Visakhapatnam, Yarada, Waltair, Bhimunipatnam areas of Andhra (Mahadevan and Sriramdas 1954 ; Mahadevan and Rao 1958 ; Mahadevan and Rao 1950) and the coastal areas of Orissa (Officers of GSI 1949). The total reserves of ilmenite are estimated to be 130 million tonnes, while the present production is 76,670 tonnes (Indian Bureau of Mines, 1974).

The extension of heavy mineral placers from the beach to offshore areas has been a subject of speculation till recently. Some of the richest placers deposit in India occur along the 25 km long stretch of the coast from Neendakara to Kayankulam. Prabhakar Rao (1968) explored the shallow offshore area in the vicinity of this coastal stretch to a depth of about 10 to 12 m. About 48 holes were drilled by a water jet from one meter to 6 m into the sea bed. The surveys indicated the occurrence of sand in the southern part, silty sand in the central part and sand, silt and clay in the northern part. The heavy minerals consisted of kyanite, sillimanite, zircon, garnet, ilmenite, leucoxene and rutile. The concentration of heavy minerals varied from 4 to 56 per cent. The highest concentration of heavy minerals occurred along the shore and in the southern part (fig. 3). According to Prabhakar Rao (1968) the maximum concentration of the heavy minerals in general is associated with the medium sand. It is found that the concentration of ilmenite varied



MAP SHOWING THE AREA SURVEYED IN DETAIL FOR OFFSHORE ILMENITE PLACERS



**BASE MAP OF  
OFFSHORE EXPLORATION FOR  
HEAVY MINERAL PLACERS  
OFF  
RATHNABIRI, MAHARASHTRA  
BOTTOM SAMPLING**

0 1 Km. 2 Km.

- INDEX**
- SURVEY STATIONS**
  - Flag ———— (●)
  - Secondary ———— (○)
  - SAMPLING STATIONS**
  - Beach ———— (○)
  - Offshore ———— (○)
  - Bulk ———— (○)
  - Echosounding Track ———— (—)

**SURVEYED BY**  
**GEOLOGY** — H.N. Siddique  
 G.V. Rajamohanam  
 F. Almeida  
**SURVEY** — B.L. Meitri

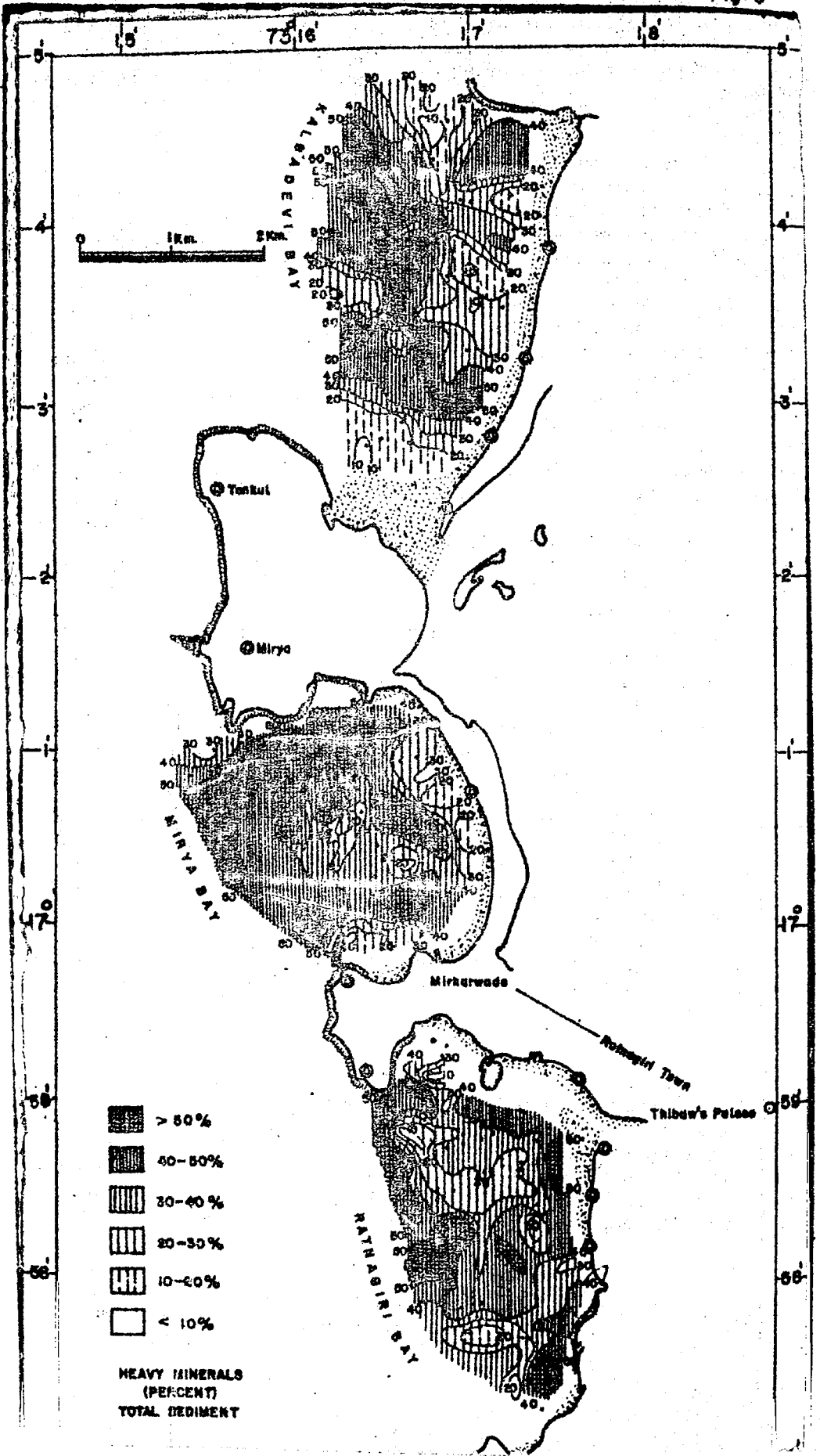


from 0.8 to 20 per cent. Prabhakar Rao (1968) indicated that the sediments have been derived from the areas immediately to the east. The season of greatest turbulence in the sea coincides with the season of annual precipitation. During this period, the rivers discharge large amount of sediments which is transported by shore currents along the sandy beaches, sorted and heavy minerals concentrated due to currents and waves.

The Konkan Coast especially the area extending from Dabhol (lat.  $17^{\circ}20'$ ) through Ratnagiri to Vengurla (lat.  $16^{\circ}$ ) a distance of about 200 km is marked by a number of projecting rocky promontories with intervening arcuate bays and estuaries. The occurrence of ilmenite placers on the beaches was reported by Krishnan and Roy (1945) and Roy (1958). The onshore placers on beaches contain 17 to 74 per cent ilmenite and the reserves have been estimated at about 4 million tonnes (Mane and Gawade 1974). The numerous small rivers discharging sediments on this coast drain the plateau and hills covered by Deccan traps in the east. The tidal range in the area is about 1-2 m. The area receives the rainfall of 2500-3000 mm and the period of maximum precipitation and sediment discharge coincide with maximum turbulence and wave activity in the sea. This facilitates the sorting and concentration of heavy minerals. According to Reddy (1976), off the Konkan coast, the wave period is usually 5 to 14 seconds and the predominant direction of waves is SW, WSW, W, WNW. The waves during the monsoon are from SW, WSW and W and the sediment movement is towards the north. The analyses of wave refraction indicates that there are several places where convergence and divergence of littoral currents take place. The sediment transport is usually directed into these bays. The National Institute of Oceanography is carrying out a survey of the Konkan offshore region to explore the extension of the beach placers to offshore areas (fig. 4). A preliminary examination of the terrain indicated that the sands are more or less confined to the beaches within arcuate bays and no sandy material is accumulated at the promontories. Based on this preliminary examination, a number of bays were surveyed i.e., Jaigad, Ambwah, Varvada, Kalvadevi, Mirya and Ratnagiri. The surveys were carried out on a scale of 1/10 000 and the positions were fixed by the usual methods of traversing the shore with theodolites to fix shore objects and the positions were determined by sextant angle of shore objects. A fishing trawler, 40 to 45 m length was utilised for the offshore surveys consisting of echosounding, magnetics and bottom sampling by grabs and snapper (fig. 5). In the first phase of the surveys the surficial distribution of the heavy minerals placers was proposed to be mapped to be followed by shallow seismic profiling and vibro-coring in selected areas in the second phase. The second phase of the surveys is expected to commence by the end of 1978.

In each bay the shore line was traversed for fixing shore markers and the distribution of placers was recorded. For the offshore surveys in the bays, the tracks were aligned at a spacing of about 100-200 m, perpendicular to the coast to obtain best possible coverage of topography. Echosounding and magnetic surveys were carried out along these tracks and sediment samples were collected at a spacing of about 50-100 m. The analyses of the samples indicated that sand covers the

Fig. 6



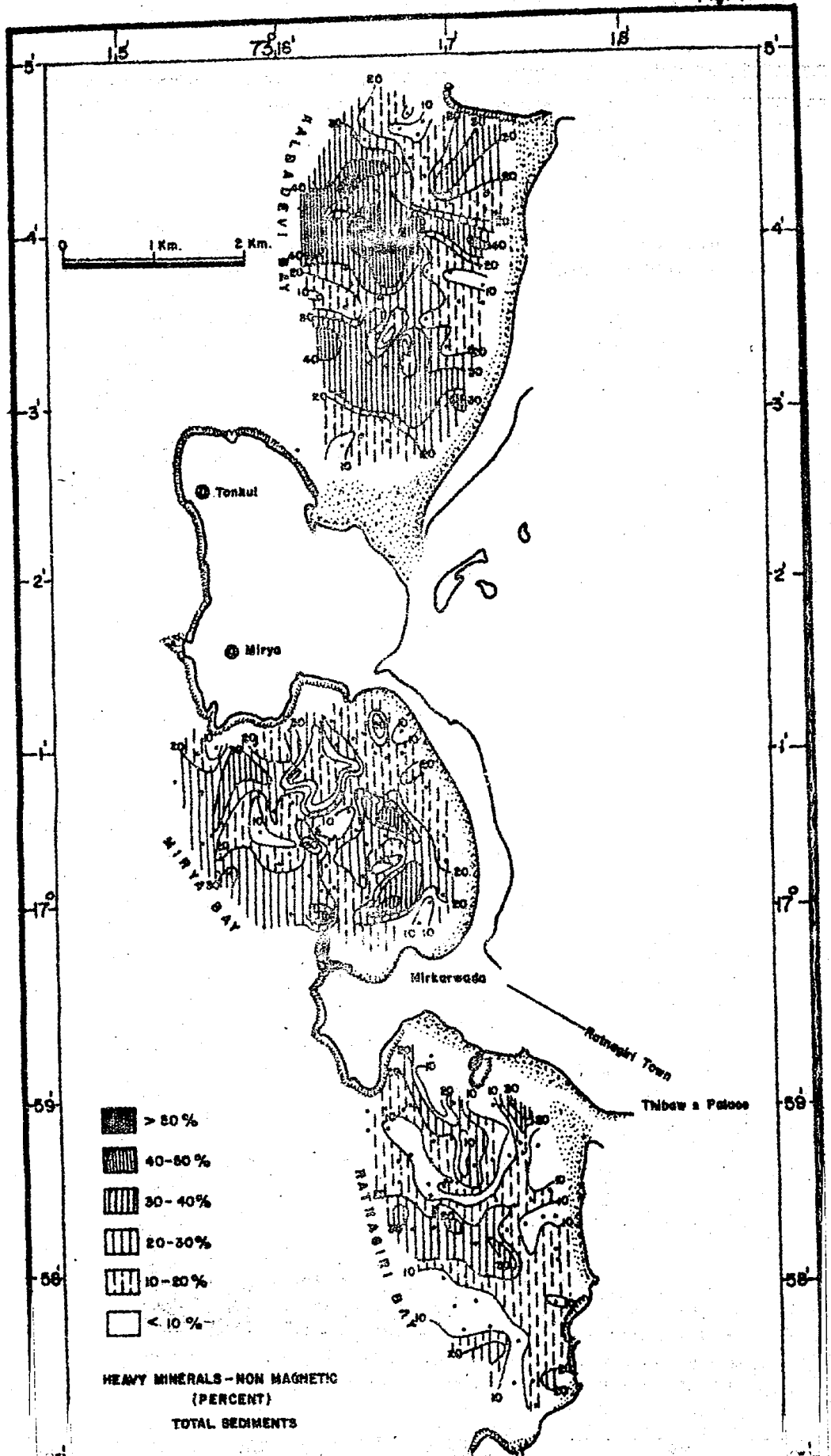
floor of the bays and extends to a distance of 2 to 5 km offshore to a depth of about 9 to 12 m. Beyond this distance, the sands are apparently overlain by recent clays which is confirmed by dual low frequency sounding in some of the areas.

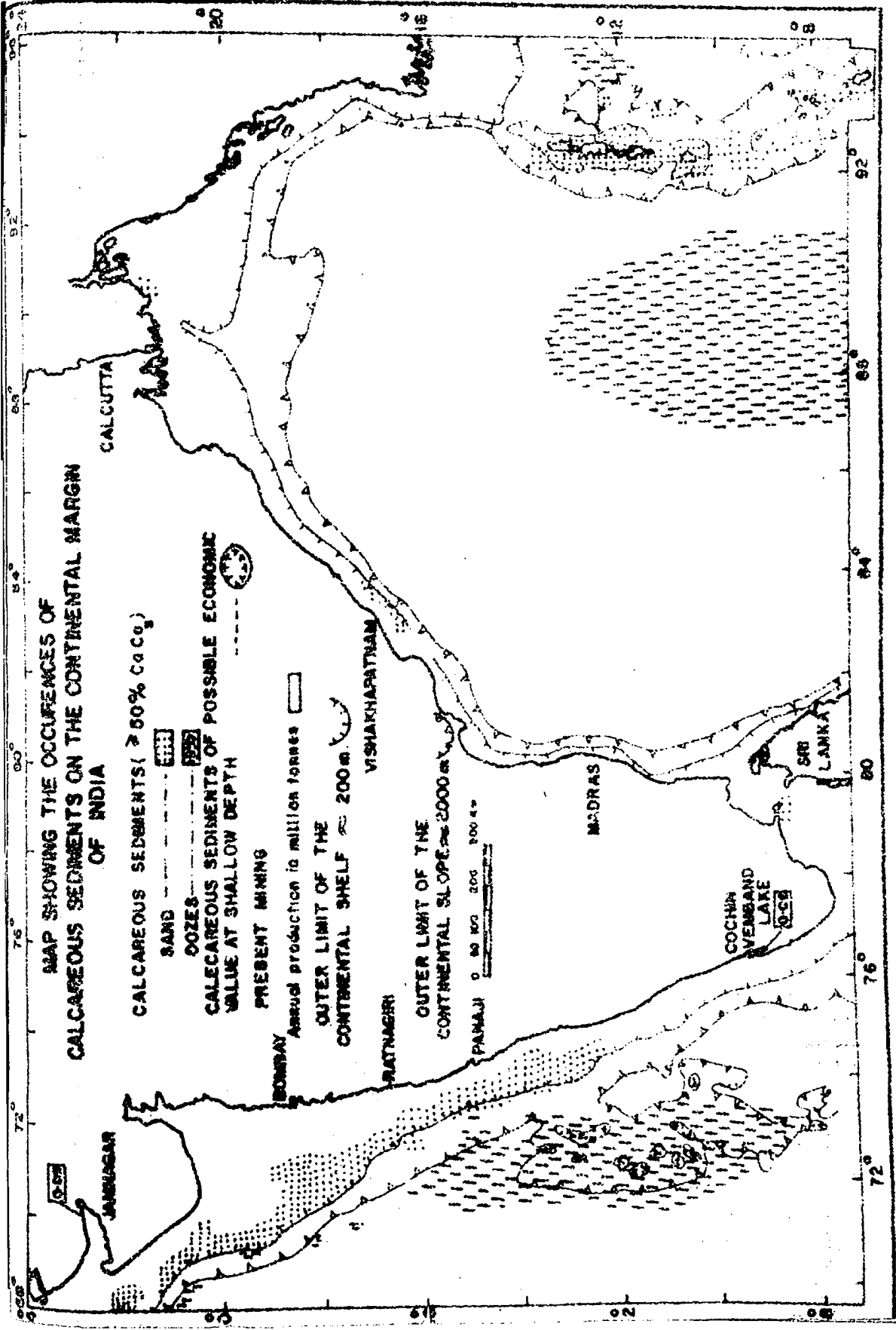
The analyses of the samples indicated that the sediments in the bays consist of silty sand to medium sand. The heavy mineral fraction in the different fractions of sediments samples was separated by bromoform and subsequently separated into magnetic and non-magnetic fractions over a cooks magnetic separator. The results of the analyses indicate that the heavy minerals vary from 7 to 81 per cent (fig. 6). The area covered by heavy mineral placers is about 23 km<sup>2</sup> in the bays surveyed so far. The heavy mineral suite consists of magnetite, ilmenite, hornblende, diopside and augite etc.. However, a very large proportion of the non-magnetic heavy minerals consist of limonite only. The ilmenite concentration on this basis is estimated to range from 1 to 55 per cent (fig. 7). In the absence of cores and the known vertical and horizontal variability of the heavy mineral placers, it is difficult to estimate the reserves at this stage. However, assuming the open space to have about 40 per cent and specific gravity of 4 with an average ilmenite content of 20 per cent, the probable reserves of ilmenite in the three bays would be of the order of 1.5 to 7 million tonnes. The total reserves considering the number of bays still to be surveyed will be many times more.

Further, exploration of offshore placers as started earlier in this paper will be guided on the proximity to onshore placers and an examination of relict sands on the middle and outer shelf. The present data indicate that for a considerable portion on the western shelf i.e., from the Gulf of Kutch to the vicinity of Mangalore (lat. 12-13°) the relict sands consist of oolites or biogenous material with a very insignificant terrigenous component. The relict sands in this entire belt, as also those west of Ratnagiri, do not appear to be promising for heavy mineral placers. The relict sands further south (off Kerala) are terrigenous, but these have not been explored in detail. Since these relict sands are in the vicinity of known extensive and rich onshore placers of ilmenite, monazite and garnet etc., these appear to be promising for further exploration. The extensive sand zone continues eastwards to the Gulf of Mannar and also appears promising for further exploration. The reported occurrences of heavy mineral concentrates on the east coast are not as extensive as on the west coast. The sands on the middle and outer shelf south of Madras are terrigenous and these may be relict and appear promising for further exploration. The relict sand off Visakhapatnam consists largely of oolite, and therefore, their potential for occurrence of placers is limited. However, the extensive terrigenous sands on the middle and inner eastern shelf need to be carefully examined before ruling out the possibility of heavy mineral placers.

Sand and gravel are increasingly being exploited from the continental shelves of some countries for construction work on land. Sand and gravel being a low cost material, their mining from offshore has to compete with onshore deposits. This is likely to be possible in such coastal areas which have large urban centres and intense building

Fig. 7





activity. Such a demand has not yet arisen in India but an analysis of the available data indicates that such calcareous deposits do not occur in the vicinity of Bombay while heavy populated areas of Kerala and the urban centres at Cochin, Madras, Visakhapatnam and Calcutta have extensive sand deposits in offshore areas which may be useful for future exploitation.

### Biogenous Deposits (fig. 8)

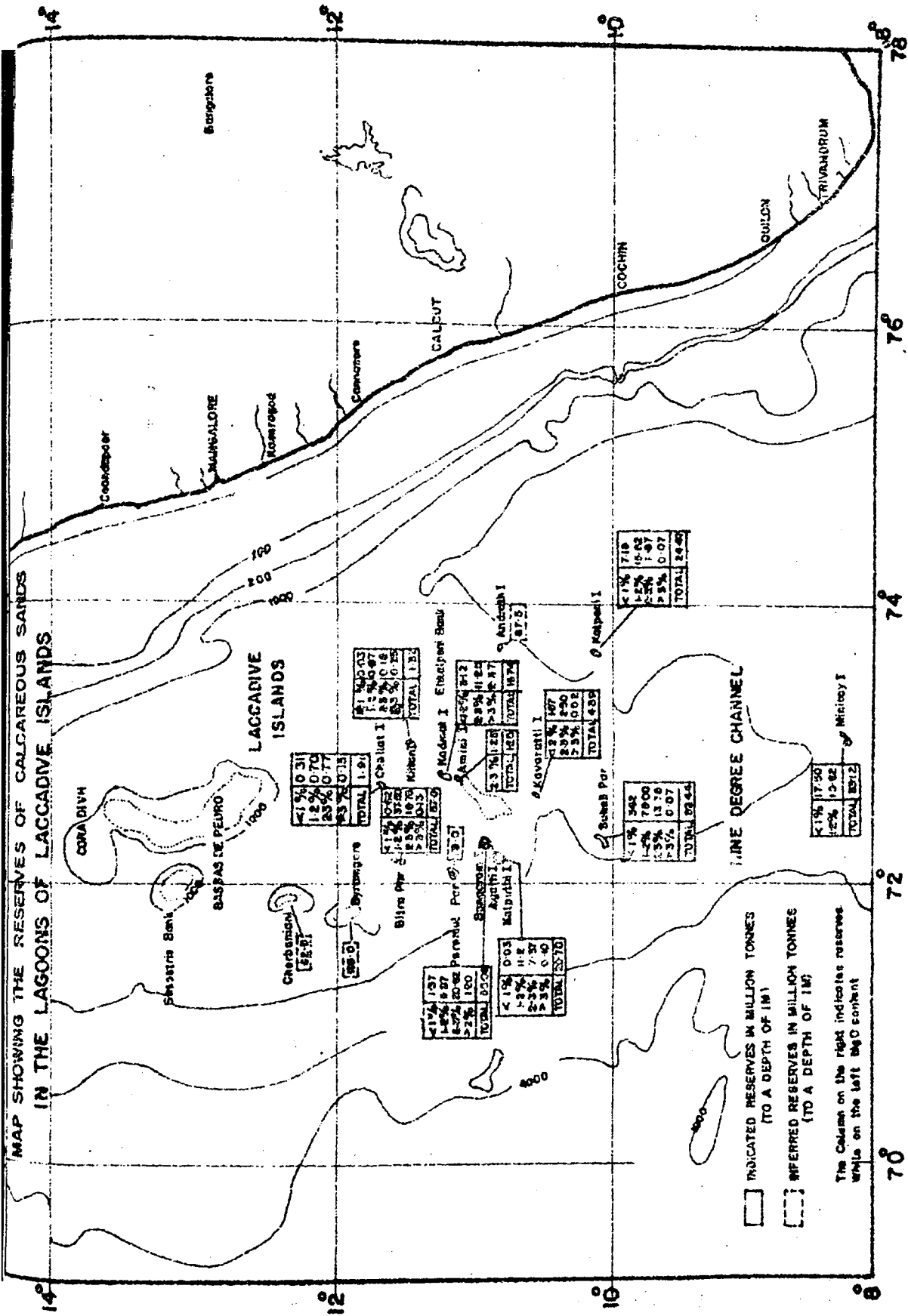
Deposits of shells, corals and calcareous sands occurring in the coastal areas have been utilised on a small scale from the early historical times for making lime used for local construction work. The exploitation of the deposits on a larger scale for industries of cement and chemicals is however comparatively recent.

The best known deposits are in the Gulf of Kutch and in the Vembanad Lake (backwaters) of Kerala. The present production from these two deposits is over a million tonnes. The shell deposits in the backwaters of Kerala consist of *Crassostrea malabarica*, *Crassostrea cucullata*, *Villorita cyprinoides*, *Mactra* sp. and *Meretrix* sp., the last three are predominant in the Vembanad lake while the first two dominate the estuaries. The reserves have been estimated to be 1.7 to 2.5 million tonnes in the Vembanad lake, 0.4 to 0.5 million tonnes in the Koderundi and about one million tonnes in the lower reaches of Pullet and Inthipalli rivers.

An examination of the bottom sediment map of the seas bordering India shows relict calcareous and biogenous sands on the middle and outer shelves (fig. 8). Those on the western shelf extend almost as a continuous wide strip from the Gulf of Kutch to the vicinity of Mangalore. On the eastern shelf, the relict sands are exposed in patches in a discontinuous belt, and of these, only the occurrence off Visakhapatnam consists of relict carbonate (oolitic and/or biogenous sands). The relict sands occur at a depth of more than 50 m and these are not likely to be of immediate economic interest on both the shelves. However, deposits of coral and shell sands occurring in relatively shallow areas both in the lagoons of the Laccadive Islands, of the Andaman Islands and in the Gulf of Manner and such straits appear to be promising.

The Laccadives consist of a group of coral atolls submerged reefs and banks. Siddiqui and Malik (1973) surveyed eleven of the lagoons in detail (1/20 000 and 1/10 000) and a reconnaissance of four submerged reefs and banks was carried out (fig. 9) over 1130 km of echosounding was carried out 1855 samples were collected from the lagoons and 546 from the offshore areas. From this, partial chemical analyses of 264 samples was carried out. These sands are of good quality and contain few silica, alumina and iron (table 1). MgO is the only impurity and it is interesting to note that the MgO content in the sands of some of the lagoons is related to the proximity to the reef (figs 10 and 11). The sands can be utilised for cement, lime, glass, paper and chemical industries. The surveys indicate the occurrence of 155 million tonnes of calcareous sands in the lagoons to a depth of about 1 metre.

MAP SHOWING THE RESERVES OF CALCAREOUS SANDS  
IN THE LAGOONS OF LACCADIVE ISLANDS.



41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

41%	0.31
1.8%	0.70
25%	0.77
TOTAL 1.81	

INDICATED RESERVES IN MILLION TONNES  
(TO A DEPTH OF 1M)

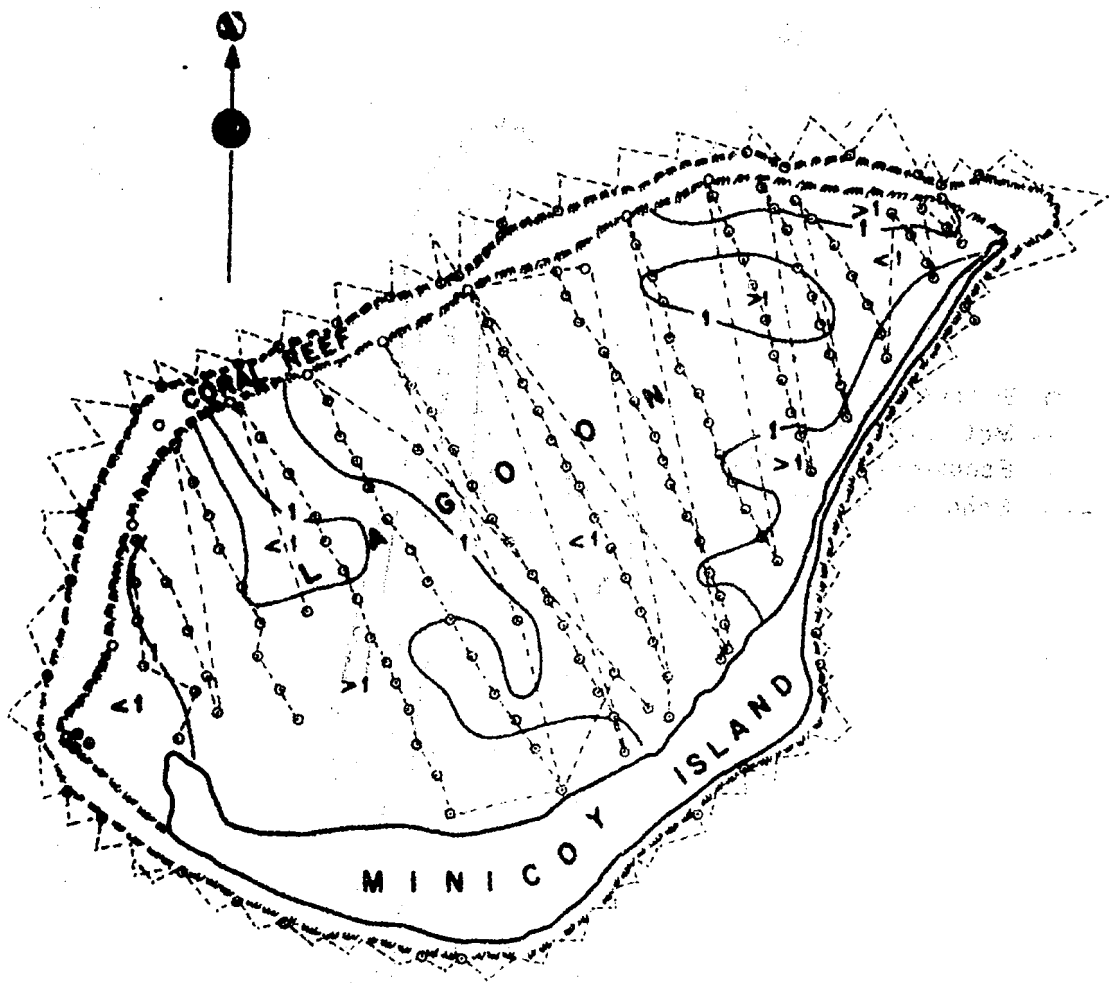
INFERRED RESERVES IN MILLION TONNES  
(TO A DEPTH OF 1M)

The Column on the right indicates reserves  
while on the left MgO content

TABLE 1 : CHEMICAL ANALYSES OF CALCAREOUS SANDS FROM THE LAGOONS IN LACCADIVE ISLANDS

LAGOON Average of number of analyses	CHETTIAT 4	KILTAN 4	KADMAT 4	AKINI 3	AGATTI 4	KAVARATTI 3	BANGARAM 9
SiO <sub>2</sub>	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	0.08
Al <sub>2</sub> O <sub>3</sub>	1.78	1.11	1.17	0.85	0.75	0.73	0.16
Fe <sub>2</sub> O <sub>3</sub>	0.13	0.25	0.16	0.05	0.12	0.08	0.19
TiO <sub>2</sub>	Tr.	Tr.	0.14	0.02	0.05	0.10	0.02
P <sub>2</sub> O <sub>5</sub>	0.05	0.05	0.12	0.11	0.04	0.06	0.04
CaO	50.14	50.19	49.25	49.41	49.51	49.43	51.47
MgO	0.86	0.73	2.47	2.48	2.30	2.23	1.25
Na <sub>2</sub> O	0.48	0.53	0.62	0.94	0.76	0.72	0.65
K <sub>2</sub> O	0.25	Tr.	Tr.	Tr.	Tr.	Tr.	0.15
SO <sub>3</sub>	0.23	0.62	0.37	0.39	1.39	1.41	0.20
Loss on Ignition	46.31	46.29	45.64	45.60	45.31	45.35	42.08



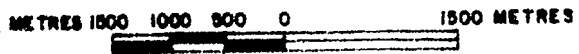


INDEX { ○ Sampling station. • Echosounding station.  
— MgO (percent) ---- Echosounding track.

MINICOY ISLAND, LACCADIVE ISLANDS  
A BASE MAP OF EXPLORATION IN THE LAGOON AND OFFSHORE AREA

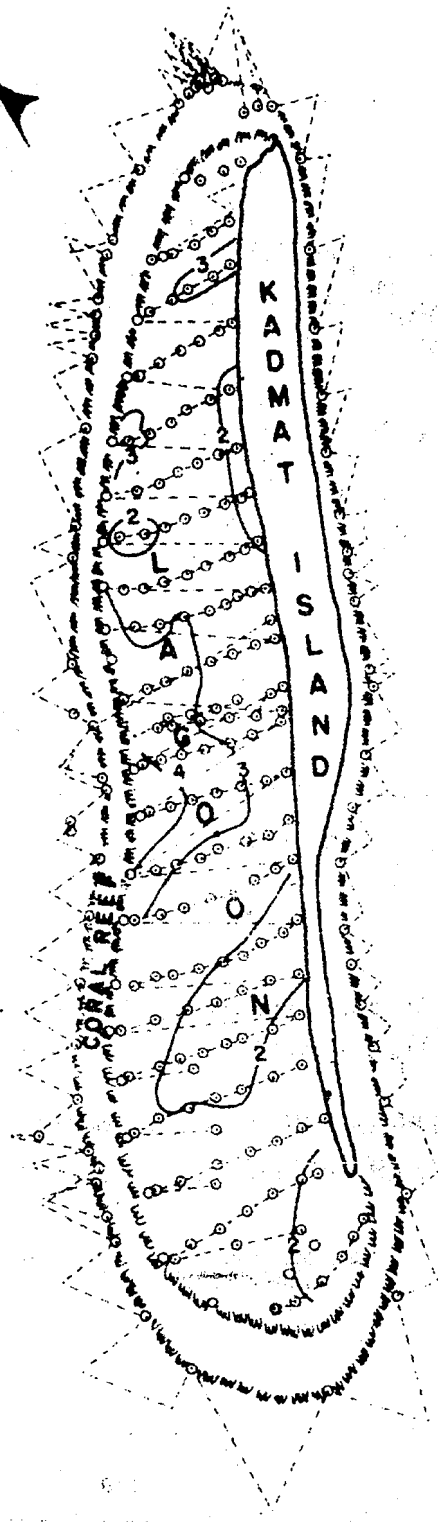
METRES 1000 500 0 1000 METRES

# KADMAT ISLAND, LACCADIVE ISLANDS A BASE MAP OF EXPLORATION IN THE LAGOON AND OFFSHORE AREA



## INDEX

- Sampling station.
- MgO (percent)
- Echosounding station.
- Echosounding track.



below the lagoon floor. The inferred reserves in some lagoons where no detailed surveys could be carried out are of the order of 423 million tonnes to a depth of 1 metre. The reserves at greater depth are expected to be many times more and the inferred reserves in the lagoons between 1-2 metre below the lagoon floor are about 712 million tonnes.

The western coast of India especially the Konkan, Karnataka and Kerala coasts do not have large limestone deposits, and therefore, the deposits in Laccadives are favourably situated for exploitation. The extensive mining of these deposits particularly those in the inhabited lagoons will need a careful study of the impact of the removal of the sand on the reef. In some of the lagoons the extraction of sands from the lagoons may be linked with the development of port facilities.

### Chemogenous deposits (fig. 12)

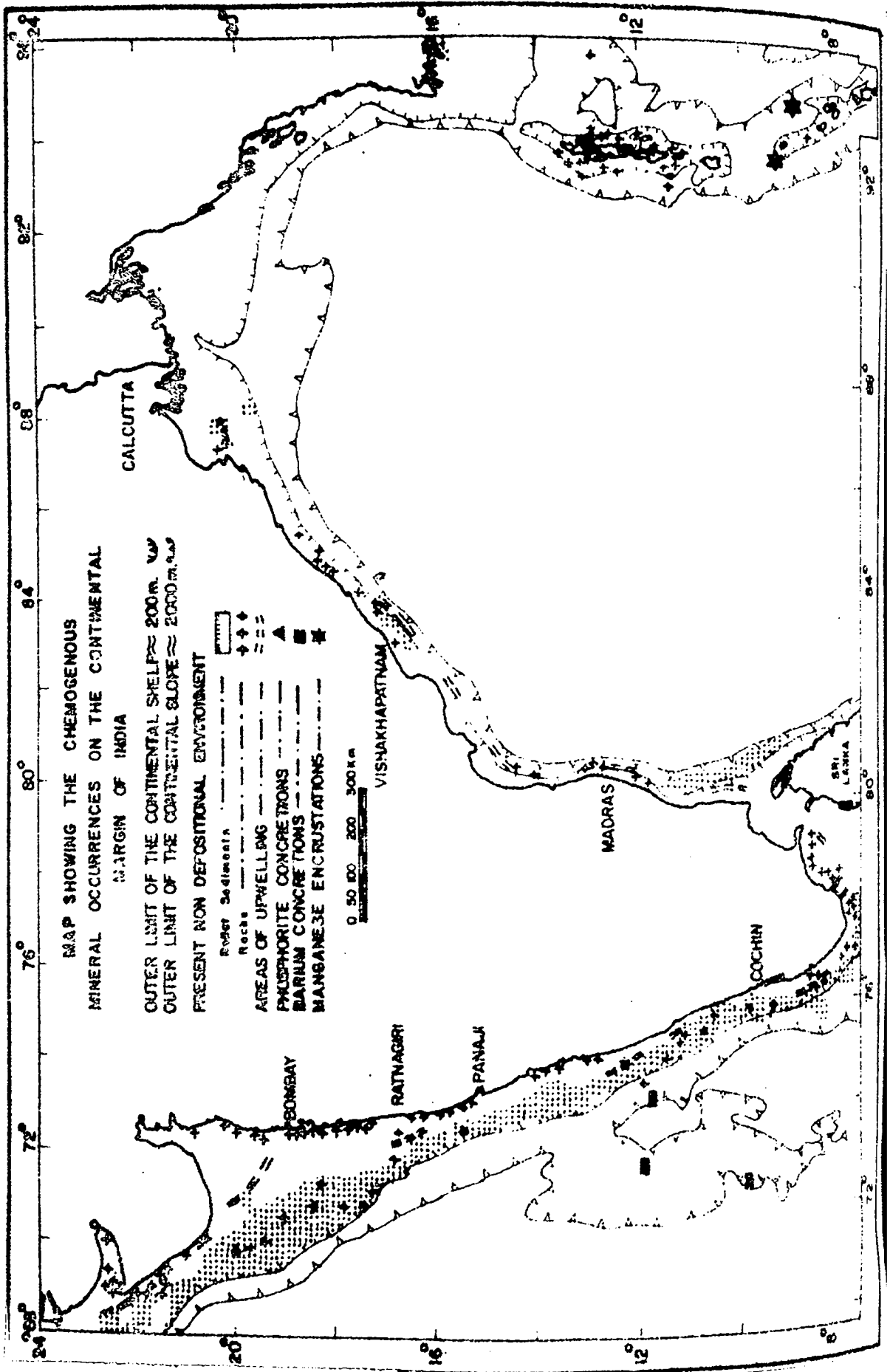
The chemogenous deposits reported from the ocean floor in the vicinity of the country are barium nodules described by JONES (1887 and 1900) and phosphate nodules described by TIPPER (1911) off North-Andamans.

At present there is little interest in the exploration for barium nodules because it is a low priced commodity. In the late 1960's a number of organizations carried out sampling for phosphorites on the continental shelf of the country, particularly in the vicinity of their reported occurrence off north-Andamans, but the results have not been encouraging. The occurrence of phosphorite in this area if any appears to be sporadic. The western shelf because of being an upwelling area with a low sedimentation and non-depositional environment i.e., large areas covered by relict coralline sands and extensive exposures of rocks, appears to be an area favourable for chemical precipitation especially for the formation of phosphorites. Extensive sampling so far carried out has indicated that the phosphate content of the sediments is low and ranges from 0.1 to 1.2 per cent (RAG et al. 1978). However, large areas on the slope will have to be explored in greater details before the formation of phosphate deposits in this area is completely ruled out. Encrustations of manganese on the rocks have been reported in some areas on the shelf and slope but these do not appear to be extensive and of immediate economic significance.

### CONCLUSIONS

The continental shelf and slope of India cover a large area (about one million km<sup>2</sup>), which is one-third of the land area of the country. Exploration of this vast territory has been commenced recently and preliminary results indicate that the area is promising for the occurrence of surficial mineral deposits.

Fig 12



The coast of India particularly, the western coast has very large and rich deposit of heavy mineral placers (monazite, ilmenite, zircon, garnet and magnetite etc.). Recent surveys have indicated that the deposits on the south west coast i.e., in the vicinity of Neendakara and Kayankulam and on the Konkan (Ratnagiri) coast extend to offshore areas also. Though the deposits in Konkan are localised to some bays but the concentration of heavy minerals is high and these appear to be promising for further exploration.

Deposits of calcareous sands and shells are being exploited on a large scale (annual production about one million tonnes) for cement manufacture from the Gulf of Kutch and backwaters of Kerala. The occurrences of calcareous deposits on the shelf particularly on the western shelf and in the vicinity of Andaman, Nicobar and Laccadive Island are well known. The deposits in the Laccadive Island are fairly large and of good quality and the indicated reserves are estimated at 288 million tonnes and the inferred reserved 1135 million tonnes.

The occurrences of phosphate, barium concretions and manganese concretions are known from some localities on the continental margin of India but these do not appear to be of economic significance. Though the continental shelf of India especially the western shelf has upwelling and non-depositional environment, the surveys so far carried out have indicated only a low phosphate concentration in the sediments.

#### ACKNOWLEDGEMENTS

The authors are grateful to Dr. S. Z. Qasim for critically going through the manuscript of the paper.

## REFERENCES

- BROWN J. COGGIN and DEY A.K. (1956) - India's mineral wealth, Oxford University Press, 761 p.
- CHATTERJI G. C., KARUNAKARAN C. and SIDDIQUI H.N. (1968) - Exploration for minerals on the continental margin of India. An appraisal of the existing data. *Bull. Natl. Inst. Sci., Ind.*, 38 : 552-562.
- Indian Bureau of mines (1974) - Indian minerals year book, 1970, government of India Press, New Delhi, 520 p.
- JACOB K. (1956) - Ilmenite and garnet sands of the Chowghat, West Coast, Tinnevely, Ramnad and Tanjore Coasts (East Coast) *Rec. Geol. Surv. Ind.*, 82, 567-602
- JONES E.J. (1887) - Natural history notes from H. M.'s IMS Investigator No. 5 : on some nodular stones obtained by trawling off Colombo in 675 fathoms of water. *J. Asiatic Soc. Beng.* 56, 209-212.
- JONES E.J. (1888) - Nodular stones obtained by trawling off Colombo *Rec. Geol. Surv. India*, 21, 35-37.
- KRISHNAN M.S. and ROY B.C. (1945) - *Indian Rec. Geol. Surv. India* 78, 1-32
- MAHADEVAN C. and RAO B.N. (1950) - Black sand concentrates of Vizagapatnam coast, *Curr. Sci.*, 19, 48-49.
- MAHADEVAN C. and SRIRAMDAS A. (1954) - Effects of high waves on the formation of coastal black sand deposits *Andhra Univ. Mem. Oceanog.*, 1, 57-62.
- MANE R.B. and GAWADE M.K. (1974) - *Unpub. Rep. Directorate of Geol. and Min.* Government of Maharashtra, Nagpur.
- Officers of the Geological Survey of India (1949) - The economic geology and mineral resources of Orissa, Orissa government Press, Cuttack, 131 p.
- QASIM S.Z. and NAIR R.R. (1977) - Prospects of Offshore mining in India *J. Mines Metals and Fuels*, Indian Mining annual review, 1977, 47-52.
- RAO Ch. M., MURTHY P.S.N., Victor RAJAMANICKAM, G. and PAROPKARI A.L. (1978) - Distribution of phosphate in the sediments of the northern half of the western continental shelf of India, *Indian J. Mar. Sci.*, ? (in press).
- RAO G. PRABHAKRA (1968) - Sediments of the nearshore region off Neendakara, Kayankulam coast and Ashtamudi and Vatia Estuaries, Kerala, India. *Bull. Nat. Inst. Sci. Ind.*, 38, 513-551.
- REDDY M.P.M. (1976) - Wave refraction in relation to sediment transport tendency along the west coast of India. *Indian J. Mar. Sci.* 5, 152-162.

ROY B.C. (1953) - Ilmenite sand along Malabar coast, Bombay. *Rec. Geol. Surv. India*, 27, 432-432.

TIPPER G.H. (1911) - The geological formations of Andamans with reference to Nicobars, *Mem. Geol. Surv. India*, 15.

TIPPER G.H. (1914) - The monazite sands of Travancore. *Rec. Geol. Surv. India*, 44, 186-195.

SIDDIQUIE H.N. (1972) - Marine geology in India. A review. *Geophys. Res. Rep.*, 10, 123-214.

SIDDIQUIE H.N. and MALLIK T.K. (1973) - The investigation of calcareous sand deposits in the lagoons of the Laccadive, unpub. *Rep. Geol. Surv. India*.

SIDDIQUIE H.N., SRIVASTAVA P.C., MALLIK T.K., RAY I. and VENKATESH K.V. (1975) - Bottom sediment map of the seas bordering India; published by geological survey of India, printed at the geological survey of India, Hyderabad.