Indian Journal of Marine Sciences
Vol. 7, June 1978, pp. 67-71

Distribution Patterns of Aluminium, Titanium, Manganese, Copper & Nickel in Sediments of the Northern Half of the Western Continental Shelf of India

P. S. N. MURTY, CH. M. RAO, A. L. PAROPKARI & R. S. TOPGI
National Institute of Oceanography, Dona Paula 403004, Goa

Received 24 *February* 1978; *revised received* 12 *April* 1978

Studies on the distribution patterns of various elements coupled with the distribution pattern of calcium carbonate have revealed that (i) along any given section across the shelf, relatively high concentrations of all the elements are associated with the terrigenous sediments than those with the relict sediments of the outer shelf, (ii) elements like titanium, manganese and copper exhibit regional differences from north to south and (iii) manganese, nickel and copper (on carbonate-free basis) tend to be enriched in clays and silty clays of the outer shelf region. While variations across the shelf are attributed to the association of elements with the terrigenous material to a large extent, variations along the shelf (from north to south) are attributed to the differences in the mineralogical composition of sediments. These studies have also revealed that the effect of Indus river system is profound on the shelf between Indus canyon and Gulf of Kutch, marginal between Gulf of Kutch and Gulf of Cambay and least in the rest of the region.

PARTITION patterns of iron in the surficial sediments of northern half of the western continental shelf of India have been reported[1]. In continuation, the overall distribution patterns of several other elements have been studied in these sediments and the results pertaining to aluminium, titanium, manganese, nickel and copper are presented in this paper. It may be mentioned here that except for brief investigations[2-7] there is practically no information on the distribution patterns of these elements from this part of the continental shelf. An attempt has also been made to demarcate the limit of influence of the Indus system on this shelf.

Fig. 1 shows the area from which the sea floor sediments were collected. In all about 90 stations were occupied for sampling during the INS *Darshak* cruises from December 1973 to May 1974 and they were distributed along 14 sections normal to the coast between Indus canyon in the north and Port Dabol in the south. Samples were collected using La Fond-Dietz snapper. Along most of the sections, samples were collected between 20 and 100 m water depths on the coastal and seaward sides respectively while along a few sections, sampling on the seaward side was extended up to 150-250 m water depth.

In the region under study, the continental shelf is characterized by certain well-defined features in regard to its bottom topography[8], sediment distribution and texture[9] and sediment chemistry[10-12].

Materials and Methods

Representative samples were obtained from the collections made at each station and suitable aliquots were digested with hydrofluoric and perchloric acids following the method of Chester and Hughes[13]. Aluminium, titanium and manganese were estimated colorimetrically, aluminium and titanium by the methods prescribed by Riley[14] and manganese by the method of Sandell[15]. Copper and nickel were determined on Hilger and Watts Atomspeck H 1550.

Results and Discussion

Distribution patterns obtained for the various elements along with the distribution of calcium carbonate[16] are shown in Fig. 2a-f.

The texture of sediments and depth of sampling leads to the following inferences in regard to the distribution patterns of calcium carbonate and other elements:

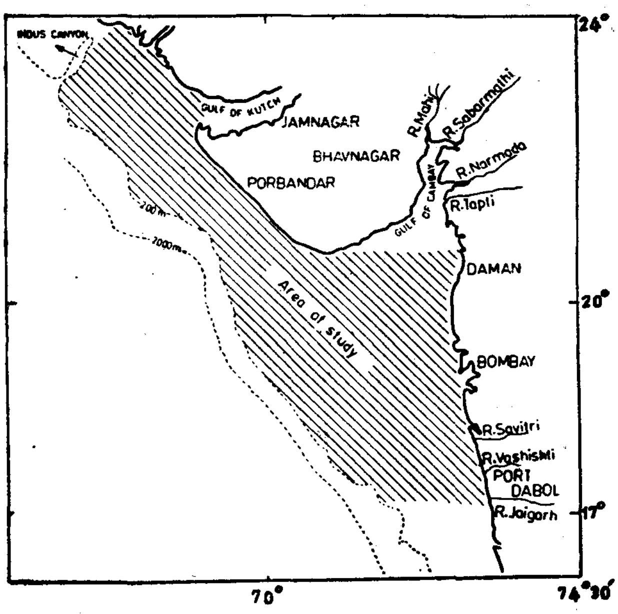

Fig. 1 — Study area

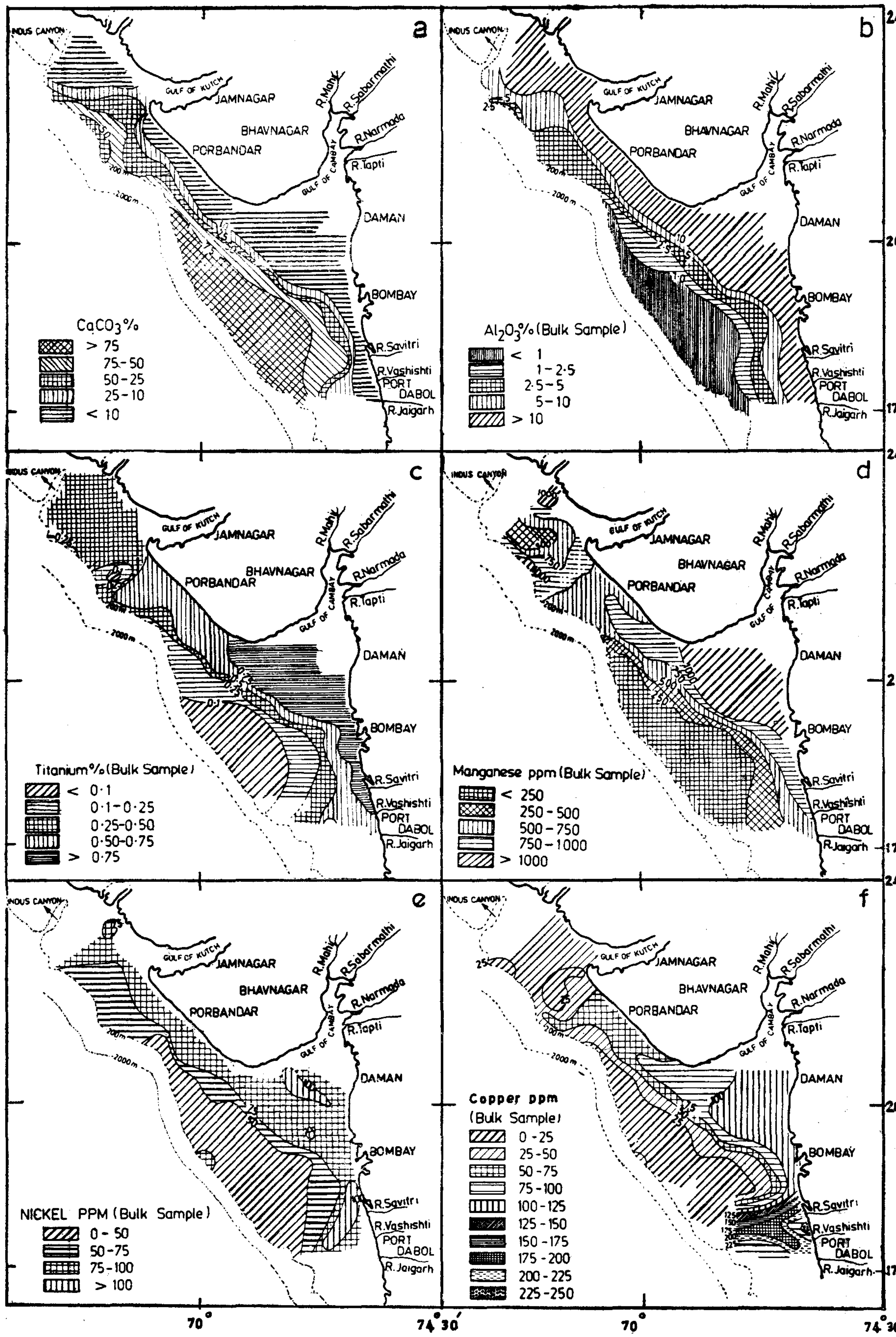

Fig. 2 — Distribution of calcium carbonate (a), aluminium (b), titanium (c), manganese (d), nickel (e) and copper (f)

The region under study can be divided into 5 zones on the basis of calcium carbonate (Fig. 2a). The 1st zone (<10%) occupies the entire shelf region between the Indus canyon and Gulf of Kutch, while in the shelf region between Gulf of Kutch and Port Dabol it extends from the coast up to 40-50 m water depth. Zones 2 and 3 (10-25 and 25-50%) which are also mostly associated with the fine-grained sediments are encountered in the shelf region between Port Dabol and Gulf of Kutch and not beyond. Zones 4 and 5 (50-75 and >75%) are mostly associated with coarse-grained sediments-silty sands/sands of the outer shelf region. Zone 4 is encountered between water depths 60 and 80 m approximately and is found to extend from Port Dabol in the south to Gulf of Kutch in the north. Zone 5 which is the outermost zone is encountered beyond 80 m water depth and is confined to the outer shelf region between Gulf of Cambay and Port Dabol.

Concentrations of the elements exhibit a decreasing trend away from the coast. This is conspicuous in the case of elements in the shelf region between the southern end of Gulf of Kutch and Port Dabol while it is not so conspicuous in the region further north in respect of certain elements such as titanium, manganese and copper.

Concentrations of the elements broadly follow the texture of the sediments. The higher ranges of concentrations of all the elements >10 and 5-10% for alumina; >0·75, 0·5-0·75 and 0·25-0·5% for titanium; >1000, 750-1000 and 500-750 ppm for manganese; >100, 75-100 and 50-75 ppm for nickel are associated with the fine-grained sediments while the lower ranges of concentrations are associated with the coarse-grained sediments. In the case of copper, while no doubt, the higher ranges of concentrations are associated with the fine-grained sediments in the shelf region between the southern end of Gulf of Kutch and Port Dabol, the fine-grained sediments in the shelf region further north form an exception by the lowest concentrations of copper associated with them at par with the outer shelf sediments in the south.

Even among the fine-grained sediments, the sediments in the shelf region between Gulf of Kutch and Indus canyon are characterized by lower concentrations of titanium and copper than the sediments of the shelf region south of Gulf of Kutch.

With a certain amount of overlapping here and there, the lowest ranges of the concentrations of all the elements are met with in the sediments of the outer shelf region between Gulf of Cambay and Port Dabol.

A comparative study of the distribution patterns of the elements under reference and the calcium carbonate shows that the higher ranges of concentrations of the elements are associated with the first 3 zones of calcium carbonate while the lower ranges of concentrations are associated with the last 2 zones of calcium carbonate. In order to understand whether the decreasing trend away from the coast exhibited by the elements is due to dilution by calcium carbonate or to some other reason, scatter plots have been drawn between the percentages of non-carbonate fractions and the concentrations of the elements (Fig. 3) for a few sections. Further, concentrations of the elements have also been recalculated on carbonate-free basis. The scatter plots broadly indicate a linear relationship between the parameters implying thereby that the concentrations of various elements are associated with the non-carbonate fractions of the sediments and the decreasing trend is due to the decreasing percentages of the non-carbonate fractions away from the coast. Elemental concentrations calculated on the carbonate-free basis have brought out the following features: (1) along any given section, the concentrations of each of the elements associated with the fine-grained sediments of the inner shelf region are more or less the same; (ii) concentrations of aluminium and titanium associated with the inner shelf sediments are higher than those associated with the outer shelf sediments; (iii) fine-grained sediments met with in certain regions of the outer shelf (between Gulf of Cambay and Indus canyon) tend to be enriched in manganese, nickel and copper; and (iv) differences between the sediments of the shelf region north of Gulf of Kutch and south of it, as stated above in regard to titanium and copper, are still maintained. In addition the concentrations of manganese in the inner shelf sediments of the region between Gulf of Kutch and Gulf of Cambay occupy an intermediate position between the concentrations of the shelf sediments north of Gulf of Kutch and the Gulf of Cambay region.

On the basis of heavy mineral assemblages, 4 distinct provinces have been recognized[17]. They are: (a) Indus province characterized by muscovite, biotite and chlorite, (b) offshore province characterized by clinopyroxenes, hornblende and some garnet, (c) Cambay province characterized by opaques, pyroxene, zircon and garnet, and (d) Bombay-Daman province characterized by epidote, monazite, pyroxene and some muscovite. Clay mineral assemblages also exhibit certain differences in the study area. In the areas south of Gulf of Kutch, the general order of concentration of clay minerals is montmorillonite (50-70%), illite (0-20%), chlorite (0-10%) and kaolinite (0-10%) whereas in the Gulf of Kutch region and north of it the general order of clay mineral concentration is illite (40-50%), montmorillonite (30-50%), chlorite (20-30%) and kaolinite (0-10%)[18]. It is seen that the shelf sediments exhibit regional differences mineralogically which could be related to the geology of the adjacent areas and the major river systems present in the area. The present chemical studies also indicate certain regional differences in regard to the distribution patterns of the elements along and across the shelf.

All clay minerals contain aluminium in their crystal lattices and much of the aluminium in deep sea sediments is located in these positions. Geochemically, aluminium is not a very active element in the sense that <1% is exchangeable and for this reason it is used as an index of the inorganic or argillaceous fraction of the sediments[19]. Viewed from this angle, distribution pattern of aluminium in the present study indicates that the fine-grained sediments of the inner shelf region with their high

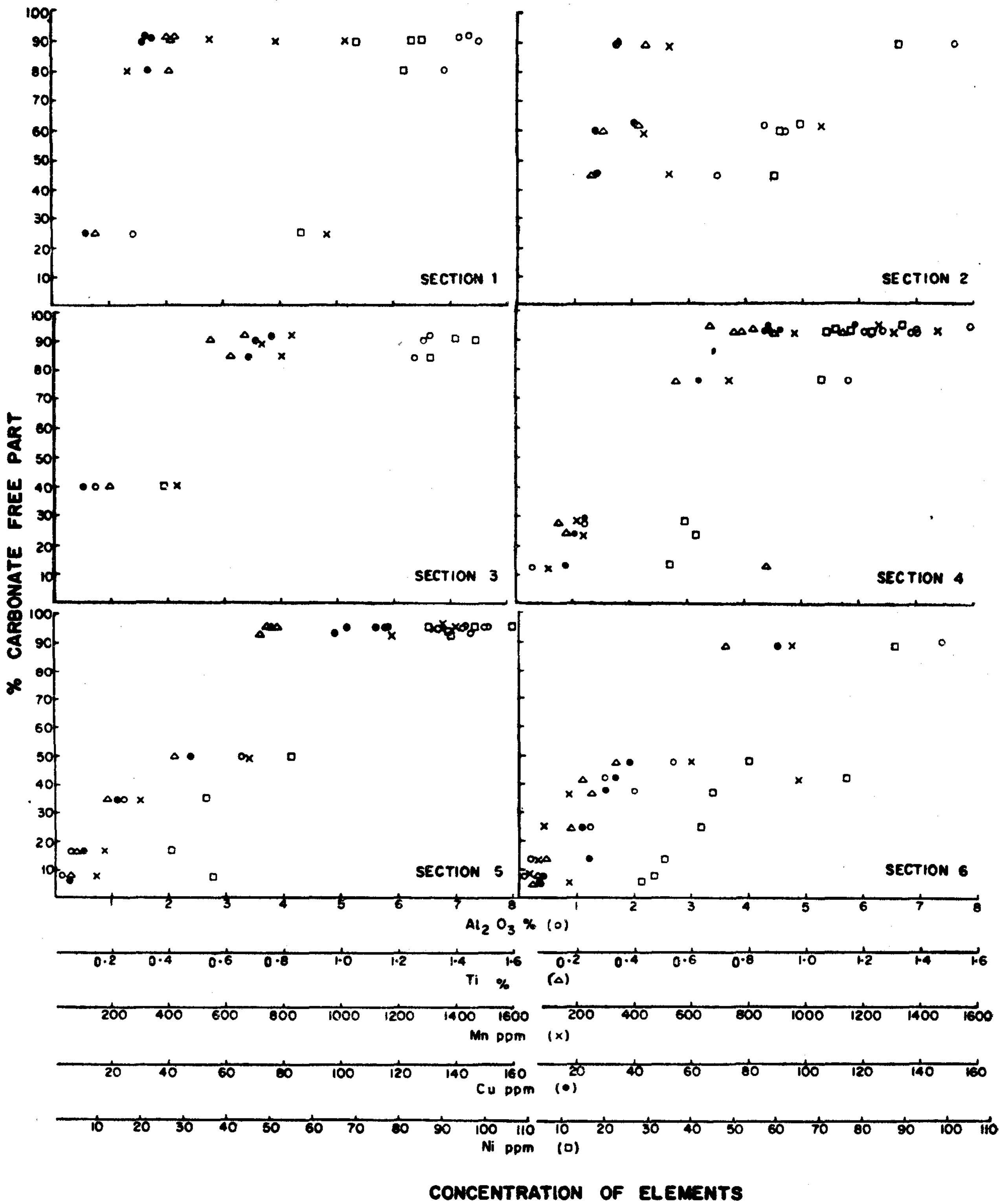

Fig. 3 — Relationship between percentage of non-carbonate fraction and concentrations of elements along different sections [Section 1, north of Gulf of Kutch; section 2, off Gulf of Kutch; section 3, between Gulf of Kutch and Gulf of Cambay; section 4, off Gulf of Cambay; and sections 5 and 6, south of Gulf of Cambay]

aluminium content are terrigenous in nature and their deposition is confined up to approximately 60-65 m water depth (between Daman and Port Dabol particularly). Lower concentrations associated with the relict sediments of the outer shelf region are due to the very low percentage of terrigenous material present in them. Thus, while the distribution pattern of aluminium across the shelf could be explained on the basis of its association with the inorganic fraction of the sediments, absence of any regional differences along the shelf from north to south especially among fine-grained sediments could be attributed to the presence of clay minerals and other aluminosilicate minerals in the whole inner shelf region in significant amounts. In the case of other elements, while their distribution patterns across the shelf indicate their association with the terrigenous material to a large extent (this is also supported by the partition studies[20]), the differences exhibited by them from north to south could be attributed to the differences in the mineralogy of the sediments. Higher concentrations of manganese, nickel and copper associated with the fine-grained sediments of the outer shelf region of certain areas such as between Gulf of Cambay and Indus canyon (on carbonate-free basis) appear to be due to the adsorption of these elements from sea water by the clays because of increasing duration of the clay mineral transport.

From the similarity found between the sediments of the Gulf of Kutch with those from the adjacent shelf region north of Gulf in their chemistry, Murty *et al.*[21] indicated that the sediments coming from the north are brought into the gulf and are not carried further south to a large extent. The intermediate values of titanium, manganese and copper met with in the sediments of the shelf region between Gulf of Kutch and Gulf of Cambay (on carbonate-free basis) appear to be the result of the intermingling of part of the sediments transported north from the Gulf of Cambay region and a portion of the sediments transported south from the Indus region. It is, therefore, tentatively suggested that while the effect of Indus is profound in the shelf region between Indus canyon and Gulf of Kutch, it appears to be marginal in the shelf region between Gulf of Kutch and Gulf of Cambay and least in the regions off Gulf of Cambay and further south which are dominated by river systems like the Narmada and the Tapti.

Acknowledgement

The authors are grateful to Dr S. Z. Qasim and Shri H. N. Siddiquie for their encouragement in the course of these studies. They are also grateful to the Captain and crew of INS *Darshak* for the facilities provided for the sample collection.

References

1. Rao, Ch. M., Rajamanickam, G. V., Murty, P. S. N. & Reddy, C. V. G., *Indian J. mar. Sci.*, **5** (1976), 44.
2. Gogate, S. S., Sastry, V. N., Krishnamurty, T. M. & Viswanathan, R., *Curr. Sci.*, **39** (1970), 71.
3. Murty, P. S. N., Rao, Ch. M. & Reddy, C. V. G., *Indian J. mar. Sci.*, **2** (1973), 6.
4. Murty, P. S. N., Rao, Ch. M. & Reddy, C. V. G., *Proc. Joint. Oceanogr. Assembly* (Tokyo 1970), 1971, 504.
5. Rao, Ch. M., Murty, P. S. N. & Reddy, C. V. G., *Indian J. Mar. Sci.*, **3** (1974), 12.
6. Von Marchig, V., *Meteor* (Forsch-Ergeb, Reiche, C. No. 11, Berlin, Stuttgart), 1972, 1.
7. Rao, Ch. M. & Setty, M. G. A. P., *J. geol. Soc. India*, **17** (1976), 62.
8. Siddiquie, H. N. & Rajamanickam, G. V., *Initial Report and Data file of INS Darshak Oceanographic Expedition* 1973-74. Ref. No. 71-1 (National Institute of Oceanography, Panaji), 1974.
9. Kidwai, R. M., personal communication.
10. Stewart, R. A., Pilkey, O. H. & Nelson, W. B., *Mar. Geol.*, **3** (1965), 411.
11. Von Stackelberg, U., *Meteor* (Forsch-Ergeb, Reiche, C. No. 9, Berlin, Stuttgart), 1972, 1.
12. Nair, R. R., *Proc. Indian Acad. Sci.*, **73** (1971), 148.
13. Chester, R. & Hughes, M. J., *Trans. Instn Min. Metal.*, **77** (1968), 37.
14. Riley, J. P., *Analyt. Chim. Acta*, **19** (1958), 413.
15. Sandell, E. B., in *Colorimetric determination of traces of metals* (Interscience, New York), 1959, 1032.
16. Rao, Ch. M., personal communication.
17. Mallik, T. K., Venkatesh, K. V., Sengupta, R., Rao, B. R. & Ramamurty, M., *Indian J. Earth Sci.*, **3** (1976), 178.
18. Goldberg, E. D. & Criffin, J. J., *Deep Sea Res.*, **17** (1970), 513.
19. Goldberg, E. D. & Arrhenius, G., *Geochim. cosmochim. Acta*, **13** (1958), 153.
20. Murty, P. S. N., Rao, Ch. M., Paropkari, A. L. & Topgi, R. S., unpublished data.
21. Murty, P. S. N., Paropkari, A. L., Rao, Ch. M. & Topgi, R. S., *Indian J. mar. Sci.*, (in press).