DISTRIBUTION OF TITANIUM IN THE SHELF SEDIMENTS ALONG THE WEST COAST OF INDIA

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The paper presents the results obtained on the titanium content of the shelf sediments along the five sections between Bombay and Alleppey, collected during the International Indian Ocean Expedition. The results pertain only to the surface sediments and the estimations are made on the total sample and silt-clay fraction.

The distribution shows marked variations with the geographical locations and the texture of the sediments. The titanium content is higher in the southern region. In all the sections, the innershelf sediments contain higher concentrations with a decreasing tendency towards the slope region indicating the dominance of lithogenous origin. It is generally seen that a major portion of titanium is concentrated in the silt-clay fraction of the sediments. However, along the Cochin and Alleppey sections, it is more associated with the sand fraction. The concentrations over the entire area range between 100 and 8500 ppm with maximum levels off Alleppey and minimum off Karwar. Analysis of covariance reveal that titanium is closely related with iron, and no correlation exists with organic carbon and calcium carbonate. The probable factors controlling the distribution of titanium in the sediments are discussed.

INTRODUCTION

Prior to the International Indian Ocean Expedition, knowledge on the distribution and chemical characteristics of the Indian Ocean sediments was meagre. During the International Indian Ocean Expedition period, as a part of the Indian Programme, it was possible to undertake such studies at this Institute, mainly over the shelf region along the Indian coast. The present study is a part of the investigations being carried out on the nature and chemical composition of the sediments. Titanium is one of the major constituents of the marine sediments having several origins. In view of the abundant occurrence of titanium in the igneous rocks and its close association with iron, the present study may throw some light on its nature and the probable factors controlling its distribution in the marine sediments along the coast.

METHOD

Sediment samples were collected on the 25th cruise of INS KISTNA (Indian Programme of International Indian Ocean Expedition), along the five sections, off

Bombay, Karwar, Mangalore, Cochin and Alleppey. The station locations are shown in Fig. 1. Samples were collected with Phleger type gravity corer and LaFond-Dietz snapper. Only surface sediments were analysed.

The estimations of titanium were made on both the bulk sample and silt-clay fraction utilising the reaction between hydrogen peroxide and the acidic titanium producing the yellow coloured peroxide titanium complex and the extinction is measured at 410 mμ (Sandell 1950). Measurements were made on Sp. 500 UNICAM Spectro-photometer. The concentrations reported here are not on carbonate free basis.

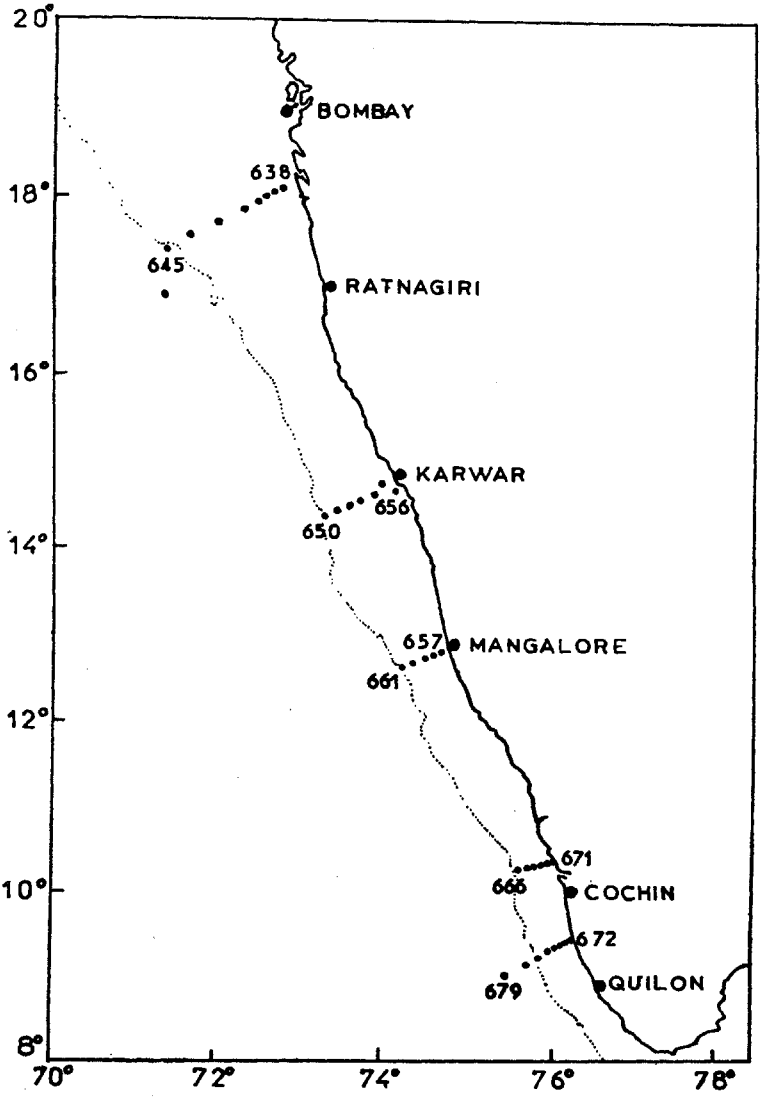

FIG. 1 Location of sampling stations

Results

Texturally the sediments show a well defined zonation. Generally the innershelf (upto 20 fms) consists of clayey silts or silty clays with a very low carbonate content and this is followed by a zone of silty or clayey sands seawards with high carbonate content (Nair and Pylee 1968). It may also be mentioned here that off Cochin and Alleppey, sand of detrital origin occurs in significant quantities in the innershelf sediments.

Table I presents the concentrations of titanium, iron, and calcium carbonate along with the sand-silt-clay percentages. The data reveal marked variations in the titanium content of the sediments with the location and texture. The general trend of distribution of titanium in the north-south direction shows an increase towards the southern region, except that of off Karwar wherein the titanium levels are the lowest. Generally, along all the sections titanium decreases towards the slope. The fall in the concentrations is sharp off Bombay and Karwar, from the innershelf followed by a progressive decrease towards the slope region, while in the southern sections the decrease is gradual. An examination of the titanium levels of the sediments in the bulk sample and with silt-clay fractions of the sediment indicate that in general a major portion of it is tied up with the silt-clay fraction; the maximum content of titanium is in the innershelf sediments having high percentage of silt. However, along the sections off Cochin and Alleppey it appears to be associated more with the sand fraction.

The correlation of titanium with other constituents like iron, organic carbon and calcium carbonate shows that the titanium in the sediments is associated with iron. Table II gives the correlation coefficients of titanium with iron for each section. No correlation is observed with organic carbon and calcium carbonate.

Discussion

The importance of titanium in the sediments as an index of sedimentation rates and in elucidating their genesis has been mentioned by several authors (Arhenius, Rjelberg and Libby 1951; Arhenius 1952; Goldberg 1954; Goldberg and Arhenius 1958). Titanium in the marine sediments may be of minerogenous (terrigenous and hydrogenous) and biogenous origin (Griel and Robinson 1952; Correns 1954; Goldberg 1954). The highly variable characteristics of the marine environment and the terrain along this coast, renders the present study to be of some use in assessing the general nature of the sediments.

The dominant influence of lithogenous material is evident in all the sections as is revealed by the high concentrations of titanium in the innershelf sediments mostly associated with the silt-clay fraction in the northern sections and, in southern sections, with both sand and silt. This tendency is in correspondence with the observation that the titanium is located mainly in the non-colloidal fraction (Correns 1937). Analysis of Deccan traps (basalts) by Washington (1922) shows that titanium is present in considerable amounts. The extensive occurence of basalts along the Bombay coast may account for the observed high titanium content in the region. The sharp fall in the concentration off Karwar suggests that the supply of titanium from the terrestrial source is not significant as the source rocks are away, and further,

the concentrations are lowered due to the high carbonate content of the sediment (Nair *et al.* 1968) by dilution. Off Mangalore the values again tend to increase rather sharply followed by a gradual increase further south. This trend in the

TABLE I

Concentrations of Titanium, Iron and Calcium carbonate in the sediment

Stn. No.	Depth (fms)	Sand-silt-clay %	Titanium (ppm)		Iron %	Calcium carbonate %	
			Total	Silt-clay	Silt-clay	Total	Silt-clay
638	13	4.0/30.0/66.0	2060	1790	3.65	10.0	2.5
639	17	49.0/31.0/20.0	2010	1505	2.50	46.5	41.5
640	19	26.6/ 8.6/64.0	650	490	2.30	45.0	35.0
641	19	1.0/10.0/89.0	370	930	4.50	42.0	22.5
642	26	1.9/34.3/63.8	940	1020	1.55	31.0	20.0
643	38	4.9/16.6/78.5	290	350	1.60	32.5	32.0
645	250	48.0/30.0/21.0	400	505	2.15	32.0	30.0
656	10	9.4/75.6/15.0	840	685	3.55	3.5	0.0
655	12	8.6/60.6/31.1	640	760	—	6.0	1.5
654	25	81.0/13.0/ 6.0	320	840	2.20	43.0	0.0
653	32	97.6/ 2.4/ 0.0	280	450	1.90	33.0	0.0
652	42	75.6/13.3/10.1	100	325	0.20	47.0	42.0
651	66	72.7/17.0/10.3	150	200	0.40	51.0	0.0
650	108	48.0/30.0/21.0	150	400	0.30	56.0	50.0
657	10	3.2/66.4/33.0	1225	515	3.65	7.0	4.0
658	17	7.6/80.1/12.3	1025	450	3.65	13.0	7.0
659	23	51.0/35.0/14.0	860	360	1.95	28.0	24.0
660	43	—	810	605	2.95	—	—
661	105	75.0/19.0/ 6.0	710	820	2.75	57.0	28.5
671	14	1.9/97.0/ 1.1	2200	255	5.10	2.0	0.0
670	13	99.0/ 1.0/ 0.0	1780	270	4.25	0.0	0.0
669	17	81.0/18.0/ 1.0	1500	300	4.30	10.0	17.0
668	23	63.3/22.5/14.2	1250	765	4.85	30.0	12.0
667	32	69.6/22.7/ 7.0	1290	675	3.90	21.5	19.0
666	43	70.0/20.0/10.0	930	540	3.60	23.0	3.8
672	10	14.2/42.0/42.6	5460	2910	2.40	1.5	0.0
673	9	3.6/60.4/35.6	3400	2700	3.40	2.0	2.0
674	20	62.0/20.0/18.0	3250	4580	4.15	19.0	0.0
675	27	89.0/10.0/ 1.0	3000	2170	2.10	16.2	16.0
676	29	96.4/ 4.0/ 4.0	8500	—	3.75	24.5	24.0
677	85	74.0/20.0/ 6.0	560	1880	3.20	31.5	24.0
678	250	52.0/47.0/ 1.0	580	1280	2.30	54.5	1.0
679	370	90.0/ 6.0/ 4.0	700	1155	1.25	59.5	31.5

southern sections may perhaps be due to the presence of important titanium bearing minerals like rutile, ilmenite derived from the coastal terrain.

From the foregoing it is evident that the titanium is largely incorporated in the innershelf sediments directly by the terrigenous material. However, a study of covariance with iron, shows that a part might have been fixed in the sediments indirectly (hydrogenous) in all the regions. El Wakeel and Riley (1961) and Revelle *et al.* (1955) showed a linear relationship between iron and titanium in marine sediments. Goldberg (1954) has postulated on the basis of covariance of iron and titanium in the manganese nodules that the titanium in the nodules has been scavenged from sea water by hydrous ferric oxide. Therefore the significantly high correlation coefficient of titanium with iron in the sections off Bombay, Karwar, Mangalore and Alleppey indicate that some of the titanium might have been fixed through hydrous ferric oxide. The insignificant correlation noticed off Cochin could be due to the presence of excess iron unbound with titanium, since these sediments contain the highest concentrations of iron (Table I).

Off Bombay the weathering of basalts bring part of the titanium into solution and the rest may be deposited as resistates like ilmenite and titanaugite, etc. Titanium in sea water is known to occur as titanate ion (Griel and Robinson 1952). Therefore, in the present instance the titanium in the waters might also get adsorbed by the positively charged colloid of hydrous ferric oxide in the form of anions as indicated by Goldberg (1954) and Revelle *et al.* (1955). Chester (1965) mentions that titanium is also known to migrate into the sediments by the neoformation of anatase. In view of this possibly a part of the titanium which may also go into solution as cations (Ti IV) by the weathering of traps gets readily hydrolysed and precipitated as anatase hydrous oxide. Off Karwar, due to lack of enough lithogenous supply of titanium, the major source appears to be the waters; the titanium in solution as titanate gets adsorbed by hydrous ferric oxide. In the southern sections the hydrogenous fixation of titanium may be of less significance in view of the major terrestrial contribution of titanium bearing minerals to the sediment. From the present studies it is not possible to indicate the relative proportions of titanium of hydrogenous and detrital origin. The maximum concentrations of titanium off Alleppey are due to the extensive occurrence of ilmenite sands and also to some extent by the presence of rutile in the terrigenous material.

TABLE II

r-values of titanium with iron

Section	Iron
Bombay	0.80
Karwar	0.72
Mangalore	0.83
Cochin	0.34
Alleppey	0.82

The general distribution patterns of titanium in the sediments away from the coast reveal certain interesting features. The titanium levels off Bombay and Karwar show a sharp fall around 15 fathoms while in the southern sections the fall is gradual. It is difficult to explain this sharp fall noticed in the northern sections. However, one reason could be that the present day supply of terrigenous material in the northern region is perhaps limited to the innershelf region and the other might be due to the presence of high calcium carbonate content of the outershelf sediments causing dilution and also inhibiting the effective incorporation of titanium into the sediments as suggested by Pierccuni (1951).

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