DISTRIBUTION OF ORGANIC MATTER IN THE MARINE SEDIMENTS OFF THE WEST COAST OF INDIA*

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Organic matter has been estimated in sediment samples collected from the continental shelf and slope regions along five sections normal to the coast off Bombay, Karwar, Mangalore, Cochin and Alleppey and its distribution studied. The study has revealed that the sediments in the inner shelf and the continental slope are characterized by a higher content of organic matter while the sediments in the region in between are relatively poor in their organic matter content. The regional distribution of organic matter has been discussed in relation to the texture of the sediments and their distribution as well as upwelling and other factors.

INTRODUCTION

Except for a few values reported by Wiseman and Bennette (1940) and the recent studies by Stewart *et al.* (1965) no information is available on the organic content of the recent marine sediments forming along the eastern margin of the Arabian Sea. It is, therefore, the object of this paper to give a short account of the distribution of organic matter in the shelf and slope sediments off the west coast of India between Bombay and Quilon.

MATERIALS AND METHODS

Samples of bottom sediments from the shelf and slope regions were collected along five sections normal to the coast between Bombay and Quilon (Fig. 1) using La Fond-Dietz snapper and a gravity corer during the 25th and 26th cruises of INS *Kistna* between 22nd March, 1965 and 1st April, 1965. In the region under study, the width of the shelf is about 90 miles in the north. It gradually narrows down to about 35 miles in the south. A number of small rivers join the sea at different places but their effect on the shelf may be very local. The samples collected represent essentially the top few inches of the deposit in the case of the snapper samples and the upper 12 to 28 inches in the case of the core samples.

For the estimation of organic matter sufficient quantity of the sample was taken and washed free of salts with distilled water. In the case of the

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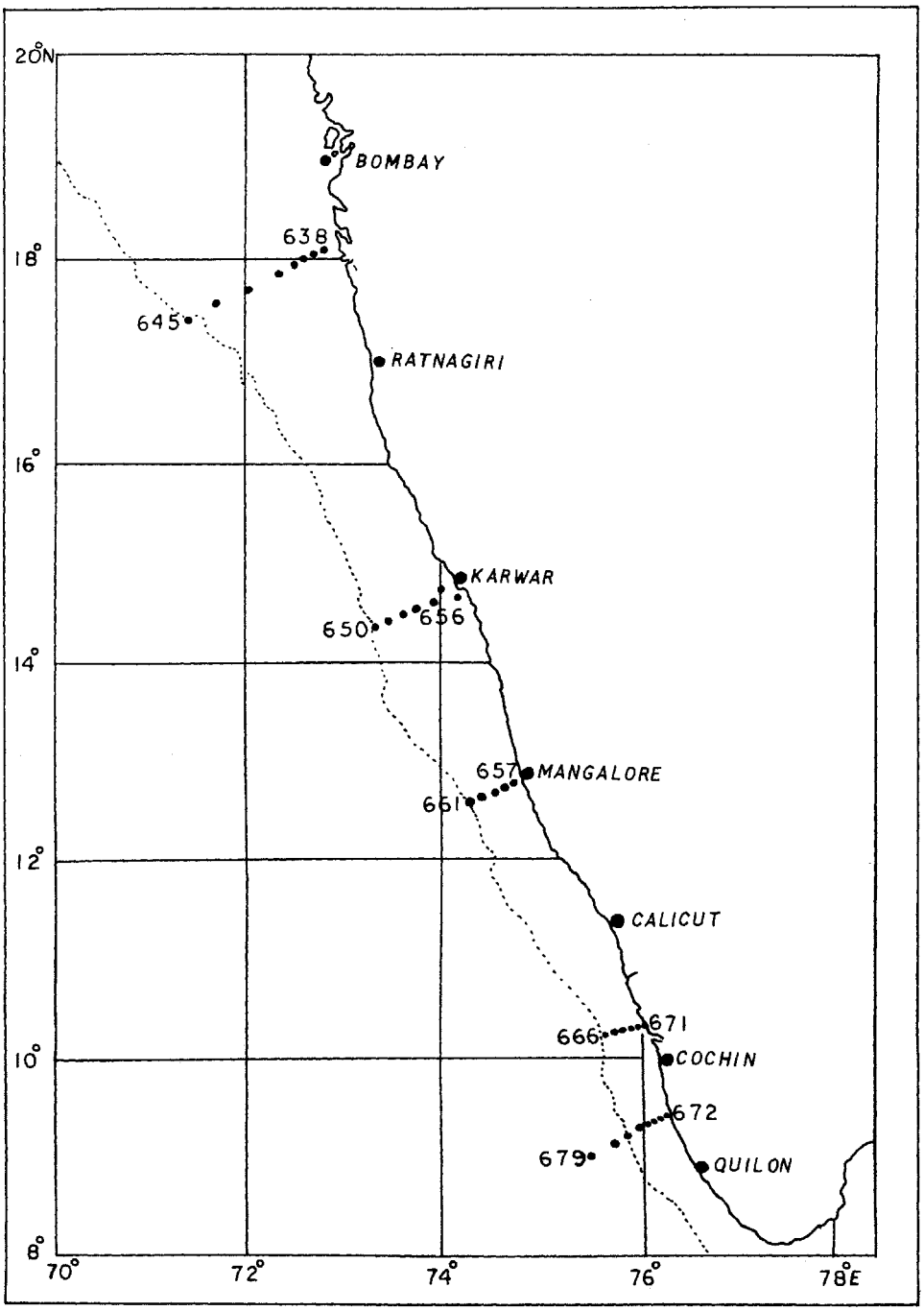

FIG. 1. Showing the locations of the sampling stations.

core samples, where the depthwise distribution of the organic content has been studied, each core was cut into 4″ long bits and washed free of salts for the determination of organic matter. The material was afterwards dried at 60 to 70 °C and then pulverized. In view of its highly complex chemical composition the organic matter in the marine sediments is determined indirectly, usually by multiplying by an appropriate factor, some property of the sediment that is related to the organic content such as the content of carbon, nitrogen, etc. In the present study organic carbon has been determined by the method of El Wakeel and Riley (1957) which consists of oxidizing the organic matter in the samples by a known quantity of chromic acid and determining the amount of acid consumed by titration against ferrous ammonium sulphate. The amount of organic matter is obtained by multiplying the organic carbon values by a factor 1·724 which is recommended by the soil chemists. This factor of 1·724 is used here as, according to Wiseman and Bennette (1940), 'the organic matter of marine muds collecting not far from land is undoubtedly partially of terrestrial origin and consequently the organic matter of these sediments is likely to have a ligno-protein with a high carbon content just as the soils'.

Results

Organic matter has been estimated in samples collected from 33 stations distributed over the five sections mentioned above. The results of the analysis are given in Table I. In view of the fact that physical characteristics such as the texture of sediment influence to some extent the accumulation of organic matter in the sediments, these characteristics have also been recorded to facilitate a better appraisal of the variations of the organic matter in the bottom sediments. Some of the salient features in the distribution of organic content of the sediments based on a study of these data are presented here.

1. On an average the organic matter constitutes about 2·55 per cent by dry weight which is just above the world average of 2·5 per cent for nearshore sediments (Trask 1939). The values, however, show a wide variation, ranging between 0·24 and 11·12 per cent.

2. The nearshore sediments and sediments on the slope have a high organic content while the sediments from the in between regions of the shelf are comparatively poor.

3. In regard to texture-organic content relationships, it is seen that invariably fine-grained sediments have a higher content of organic matter. Even within the fine-grained sediments, there is a lower percentage of organic matter in those samples collected from the shelf region off Bombay as compared to other areas.

Discussion

In a discussion of the factors responsible for the organic matter in the bottom sediments, Sverdrup *et al.* (1942) have indicated that an abundant

TABLE I

Serial No.	Station No.	Depth in fathoms	Type of sample	Sediment level in inches	Texture	% Organic matter
Off Bombay						
1	638	13	corer	0–4	Silty clay	1·92
				4–8	,,	1·94
				8–12	,,	1·73
2	639	17	snapper	0–4	Silty sand	0·24
3	640	19	corer	0–4	Sandy clay	0·89
				4–8	,,	1·43
				8–12	,,	1·07
4	641	19	,,	0–4	Silty clay	1·73
				4–8	,,	1·01
				8–12	,,	0·95
				12–16	,,	1·73
				16–20	,,	1·91
5	642	26	,,	0–4	,,	3·15
				4–8	,,	2·91
				8–12	,,	2·74
				12–16	,,	2·97
				16–20	,,	2·97
				20–24	,,	2·91
6	643	38	snapper	0–4	,,	0·89
7	645	250	corer	0–4	Clayey silt	11·12
				4–8	,,	9·52
				8–12	,,	7·79
				12–16	,,	9·12
				16–20	,,	7·61
				20–24	,,	7·67
Off Karwar						
8	656	10	,,	0–4	,,	3·81
				4–8	,,	2·50
				8–12	,,	4·45
				12–16	,,	4·39
				16–20	,,	3·86
				20–24	,,	3·76
				24–28	,,	3·31
9	655	12	,,	0–4	Silty clay	3·45
				4–8	,,	3·39
				8–12	,,	2·56
				12–16	,,	2·09
10	654	25	snapper	0–4	Silty sand	0·83
11	653	32	,,	0–4	,,	0·88
12	652	42	corer	0–4	,,	0·95
				4–8	,,	1·42
				8–12	,,	1·31
				12–16	,,	1·19
				16–20	,,	0·98
				20–24	,,	0·88
13	651	55	,,	0–4	,,	1·49
				4–8	,,	2·14
				8–12	,,	2·02
				12–16	,,	1·49
14	650	110	,,	0–4	Clayey sand	3·69
				4–8	,,	2·43
				8–12	,,	1·90
				12–16	,,	1·55
				16–20	,,	1·37
				20–24	,,	1·49
				24–28	,,	1·31

TABLE I—(*concld.*)

Serial No.	Station No.	Depth in fathoms	Type of sample	Sediment level in inches	Texture	% Organic matter
Off Mangalore						
15	657	10	corer	0–4	Clayey silt	3·93
				4–8	,,	4·70
				8–12	,,	3·75
				12–16	,,	4·04
16	658	17	,,	0–4	,,	4·40
				4–8	,,	3·33
				8–12	,,	3·83
				12–16	,,	3·33
				16–20	,,	1·96
				20–24	,,	1·96
17	659	23	,,	0–4	Silty sand	1·78
				4–8	,,	1·43
				8–12	,,	1·01
18	660	43	,,	0–4	Clayey sand	1·90
				4–8	,,	1·78
				8–12	,,	1·49
19	661	105	,,	0–4	Silty sand	3·15
				4–8	,,	2·65
				8–12	,,	2·83
Off Cochin						
20	671	13	snapper	0–4	Silty clay	3·80
21	670	14	,,	0–4	Silty sand	0·24
22	669	17	,,	0–4	,,	0·89
23	668	23	,,	0–4	,,	1·19
24	667	32	,,	0–4	,,	1·07
25	666	46	,,	0–4	Silty clay	1·71
Off Alleppey						
26	673	9	corer	0–4	Clayey silt	4·69
				4–8	,,	4·88
				8–12	,,	3·45
27	672	10	,,	0–4	Silty clay	4·52
				4–8	,,	3·35
				8–12	,,	3·45
28	674	20	,,	0–4	Silty sand	1·96
				4–8	,,	1·61
				8–12	,,	1·91
				12–16	,,	1·77
29	675	27	,,	0–4	,,	1·19
				4–8	,,	1·07
				8–12	,,	1·84
30	676	29	snapper	0–4	,,	1·31
31	677	85	,,	0–4	,,	2·44
32	678	250	corer	0–4	,,	5·34
				4–8	,,	4·94
				8–12	,,	2·91
33	679	370	,,	0–4	,,	5·04
				4–8	,,	5·17
				8–12	,,	3·86

supply of organic matter in the overlying column of water, a relatively rapid rate of accumulation of fine-grained inorganic matter and a low oxygen content of the waters immediately above the bottom sediments would favour high organic content in the bottom sediments. Deposits exceptionally rich in

organic matter are encountered in areas where the upwelling waters fertilize the surface layers of the open ocean (Kuenen 1950). While sufficient data have been accumulated to show the existence of seasonal upwelling in different areas along the west coast of India (Jayaraman and Gogate 1957; Banse 1959; Carruthers *et al.* 1959; Ramamritham and Jayaraman 1960; Varadachari and Sarma 1964; Gangadhara Reddy and Sankaranarayanan 1966), not much information is available in regard to actual estimates of organic production in different shelf areas along this coast. The inference that the coastal waters along the west coast are highly productive is derived from the data on the distribution of phytoplankton as well as fishery production in different areas and during different seasons (Subrahmanyan 1959; Gogate 1960; Sudarshan 1964; Ramamurthy 1965). The high organic content of the waters could, therefore, be explained on this basis.

An examination of the texture of the sediments shows that they exhibit a distinct zonation in regard to their distribution in that the inner shelf up to a depth of about 20 fathoms is composed of silty clays or clayey silts and this is followed by zone of silty or clayey sands in the outer shelf (approximately 20 fms to the edge of the shelf) and in the slope regions. This is particularly so in the region between Alleppey in the south and Karwar in the north. Off Bombay, however, the major part of the shelf bottom consists of fine-grained sediments. The fine-grained character of the sediments as well as high organic production in the overlying waters explain the high content of organic matter in the nearshore sediments. But the slope sediments also, though coarse grained, contain a high per cent of organic matter. Coarse fraction studies on the slope sediments have revealed the presence in abundance of the tests of Globigerina and Globorotalia which indicates the existence of conditions favourable for the deposition of material in suspension. Further, the presence of glauconite in the cavities of some of the tests of Foraminifera points to the existence of a reducing environment (Jun-Ichi Takahashi 1939). Thus the existence of favourable conditions for the deposition and preservation of organic matter either present in the overlying waters or supplied to the slope from the adjacent shelf by currents may account for the high organic content in these sediments. Hydrographic studies along the west coast of India also reveal low levels of oxygen in the waters in the slope region. The sediments in the middle and outer shelf regions are relatively poor in their organic matter content when compared with the sediments in the nearshore and slope regions. Perhaps the texture of the sediments in this region is favourable for the waters to permeate through them and destroy the organic matter, deposited in them, by oxidation.

The fine-grained sediments off the Bombay coast contain a lesser amount of organic matter when compared with the sediments of similar texture in other sections. The reason for this may have to be sought in the different

set of conditions obtaining off the Bombay coast. Any sediment that is supplied to the shelf is supplied during the south-west monsoon period. But the plankton bloom takes place only during the north-east monsoon period (Sudarshan 1964). Therefore the plankton debris settling to the bottom will not have enough masking cover of inorganic material and will have to remain exposed to the destructive actions of the bottom feeders and the bacteria till the next monsoon period. It is quite possible that under these conditions organic matter may not be preserved in these sediments to a higher degree.

The organic matter of the core samples does not show any systematic trend with depth. Although it is found to decrease with depth in some cases, in the majority of the cases there is a considerable degree of unsystematic variation. Correns (1937) working on 'Meteor samples' found similar trends of variations of organic carbon within the core. The organic content at any depth in a core sample is a function of several factors like the productivity of the region of sediment deposition, time of burial, rates of sedimentation and *in situ* biological and chemical activities. Present studies on the depthwise distribution of the organic matter reflects the existence of variable conditions along the shelf off the west coast of India through different periods.

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References

Banse, K. (1959). On upwelling and bottom-trawling off the south-west coast of India. *J Mar. biol. Ass. India*, **1**, 33–49.

Carruthers, J. N., Gogate, S. S., Naidu, T. R., and Leevatsu, T. (1959). Shoreward upslope of the layer of minimum oxygen off Bombay: Its influence on marine biology, especially fisheries. *Nature, Lond.*, **183**, 1084–1087.

Correns, C. W. (1937). Die sedimente des aquatorialen Atlantischen Ozeans. *Wiss. Ergebn dt. atlant. Exped. 'Meteor'*, **3**.

El Wakeel, S. K., and Riley, J. P. (1957). Determination of organic carbon in the marine muds. *J. Cons. perm. int. Explor. Mer.*, **22**.

Gangadhara Reddy, C. V., and Sankaranarayanan, V. N. (1966). Distribution of phosphates and silicates in the shelf waters of the Arabian Sea along the west coast of India. *Abstracts, 2nd Internat. Oceanog. Congr., Moscow*, 1966.

Gogate, S. S. (1960). 'Some aspects of the hydrobiology of the Bombay waters.' Thesis submitted to Bombay University (M.Sc.).

Jayaraman, R., and Gogate, S. S. (1957). Salinity and temperature variations in the surface waters of the Arabian Sea off the Bombay and Saurashtra coasts. *Proc. Ind. Acad. Sci.*, **45**, 151–164.

Jun-Ichi Takahashi (1939). 'Synopsis of Glauconitization.' *Soc. Econ. Paleon. and Mineral, Tulsa, Oklahoma*, 736 pp.

Kuenen, Ph. H. (1950). *Marine Geology.* John Wiley & Sons, New York, 551 pp.

Ramamritham, C. P., and Jayaraman, R. (1960). Hydrographical features of the continental shelf waters off Cochin. *J. Mar. biol. Ass. India*, 2, 199–207.

Ramamurthy, S. (1965). Studies on the plankton of the North Kanara coast in relation to the Pelagic fisheries. *J. Mar. biol. Ass. India*, 7, 129–149.

Stewart, Richard A., Pilkey, Orrin H., and Nelson, Bruce W. (1965). Sediments of the Northern Arabian Sea. *Marine Geol.*, 3, 411–427.

Subrahmanyan, R. (1959). Studies on the phytoplankton of the west coast of India. *Proc. Ind. Acad. Sci.*, 50.

Sudarshan, D. (1964). Observations on the plankton and trawler catches off Bombay. *J. Mar. biol. Ass. India*, 6, 222–225.

Sverdrup, H. U., Johnson, M. W., and Fleming, R. H. (1942). *The Oceans*—their physics, chemistry and general biology. Prentice Hall, New York, 1087 pp.

Trask, P. D. (1939). Organic content of recent marine sediments. *Soc. Econ. Paleon. and Mineral, Tulsa, Oklahoma*, 736 pp.

Varadachari, V. V. R., and Sarma, G. S. (1964). On the Vergence field in the north Indian Ocean. *Bull. National Geophysical Research Institute*, 2, 1–14.

Wiseman, J. D. H., and Bennette, H. (1940). Distribution of organic matter and nitrogen in the sediments from the Arabian Sea. *John Murray Expedition*, 3.