

Distribution of Organic Matter on the Continental Shelf off Bombay: A Terrigenous-Carbonate Depositional Environment

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Distribution of organic matter in the terrigenous facies and the carbonate facies on the continental shelf off Bombay has been found to be comparable. This distribution has been discussed in relation to the nature of the organic matter, texture of the sediment and the associated sedimentary processes prevailing on the continental shelf and slope.

A TERRIGENOUS-CARBONATE environment is described as being composed of sediments in part derived from land (terrigenous), usually river-borne and in part by carbonate sediments of organic and/or inorganic origin^{1,2}. The terrigenous-carbonate depositional environment may thus be considered as being intermediate between two members composed of purely terrigenous material and purely carbonate material. Purely terrigenous depositional environment would be expected on those shelves receiving large quantities of river-borne sediments as, for example, the eastern continental shelf of India, whereas pure carbonate sediments are usually found on shallow offshore banks such as the well-known Bahama Banks. Apparently, similar terrigenous-carbonate environments are, however, found to have important dissimilarities in their sedimentary facies. These dissimilarities result from variation in the physiography of the adjacent coastal rock formations, climate, bathymetry, hydrography and water chemistry. Two of the relatively better known areas of terrigenous-carbonate sediments are the Great Barrier Reef and the Florida-Bahamas that have been compared and contrasted by Maxwell and Swinchat².

Results and Discussion

The salient features used in the comparison of Great Barrier Reef and Florida-Bahamas with those of the continental shelf off Bombay are given in Table 1. In order to have a meaningful comparison, the sedimentary facies on the continental shelf off Bombay are described. The continental shelf off Bombay (Fig. 1) is about 280 km wide. It is characterized by a near shore zone (1 km wide) of detrital sands. This zone grades rather sharply into a silty clay/clayey silt facies extending to about 60 m depth (approx. 50 km wide) off Bombay and to a lesser depth (40 m) off the Gulf of Cambay. From 60 to 130 m (shelf break), the sediments are dominantly carbonate material composed of oolites, shell fragments and algal debris in various proportions. Coarse fraction ($>63 \mu$) on the outer shelf is between 38 and 92%. Outcrops of algal and oolitic limestone are present between depths of 90 and 180 m and have been inferred to give rise to the pinnacle and trough topography of the outer shelf³⁻⁶. Continental slope sediments are similar in feature to inner shelf silts and clays, with the difference that the continental slope clays are frequently calcareous. Gravity displacement (slumps and slides)

TABLE 1 — SALIENT FEATURES OF COMPARISON OF GREAT BARRIER REEF, CONTINENTAL SHELF OFF BOMBAY AND FLORIDA-BAHAMAS

	Great Barrier Reef	Continental shelf off Bombay	Florida-Bahamas
Depth (max.), ft	300	420	30
Tidal range (max.), ft	30	30	2-3
Circulation	Strong (tidal and wind)	Strong (tidal and wind)	Restricted (tidal only)
Temperature	Normal oceanic	Normal oceanic	Variable from oceanic average
Salinity	Short term and local effects of rainfall	Seasonal variation associated with monsoon	Max. 46‰
Sedimentary facies: 1.	Massive reef development	Highly restricted reef development	Poorly developed coral reef
2.	Skeletal grains with small amounts of lime mud	Skeletal grains with small amounts of lime mud on outer shelf	Coarse skeletal grains in thin fringe at bank margin
3.	Ooids and aggregate grains absent; fecal pellets in one areally restricted locality	Ooids and aggregate grains in abundance; fecal pellets present	Ooids, aggregate grains, fecal pellets, fine grained carbonate of mixed origin
4.	Coarse grained carbonates on or very near reefs	Coarse grained carbonates on outer shelf and shelf edge	Reef derived skeletal sands extend 3 miles into shallow back reef zone

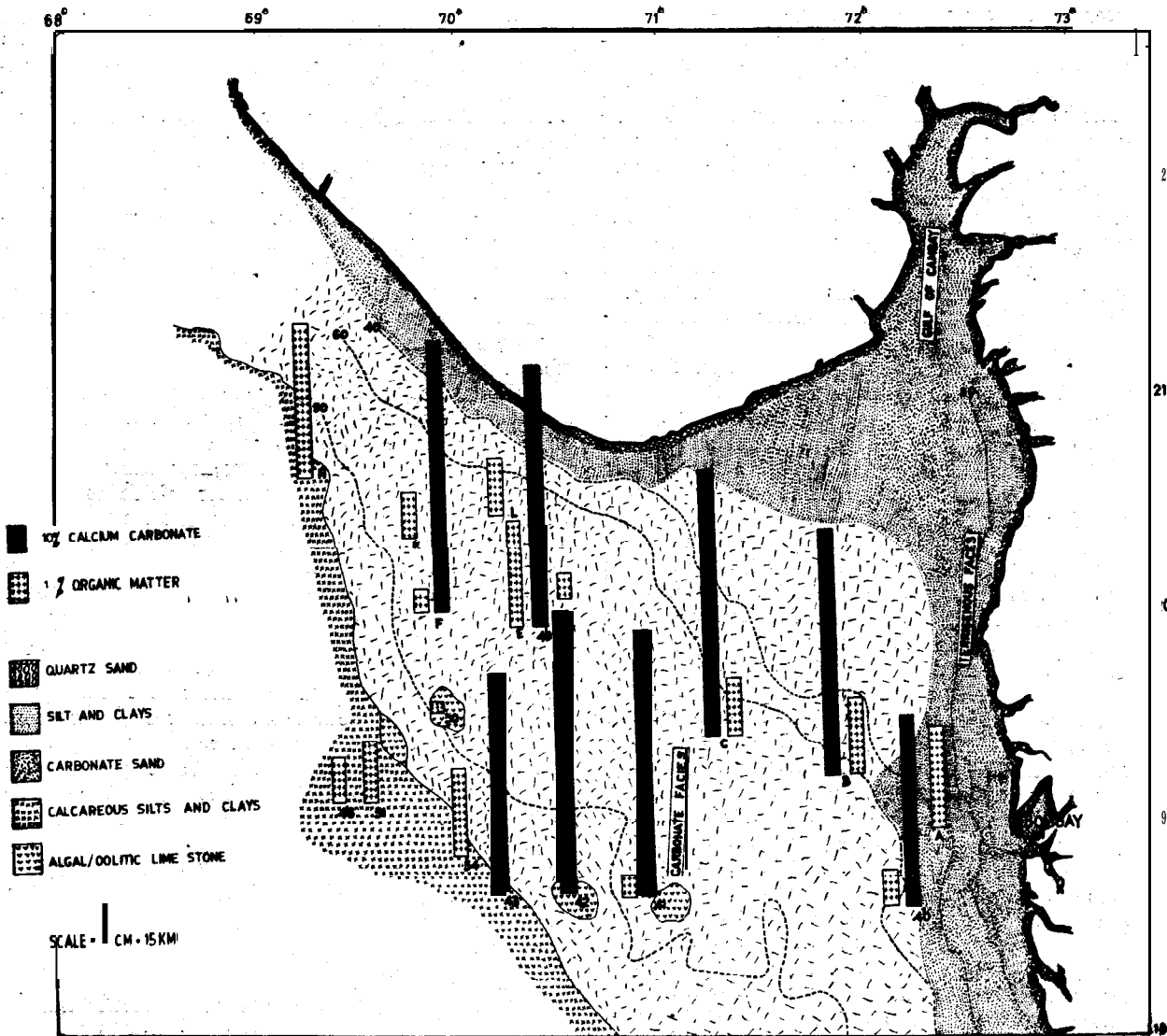


Fig. 1 → Generalized distribution of sediments, per cent calcium carbonate (ref. 15) and per cent organic matter on the continental shelf off Bombay [Contours in metres]

of sediments down the slope is indicated by cores which show alternating grey calcareous and olive-green muds.

From the above description of the sedimentary facies, particularly the carbonate components, one may conclude that the continental shelf off Bombay, represents an intermediate depositional environment between the Florida-Bahamas and the Great Barrier Reef. The distribution of organic matter in terrigenous-carbonate sediments which may be considered to be recent analogues of ancient limestone (dolomite) and shale sequences and which have acted as source and/or reservoir rocks has, therefore, direct bearing on the origin, migration and accumulation of oil. Sediments collected during the various cruises of INS *Dharshak* were analysed for organic matter by the method of E. Wakeel and Riley, and the results presented in Table 2.

Organic matter in recent sediments, has been extensively studied and reviewed^{8,9}. There appears to be no investigation specifically dealing with the distribution of organic matter in recent terrigenous-carbonate sediments. The content of organic matter in clays and silts ranges between 4 and 8%¹⁰

TABLE 2-i ORGANIC MATTER IN SEDIMENTS COLLECTED FROM DIFFERENT DEPTHS

Sample No.	Depth m	Organic matter %
A	49	3.64
B	77	2.70
C	82	2.05
D	85	4.52
E	86	3.37
F	86	0.79
K	333	5.51
L	80	1.58
40	82	2.09
41	62	1.43
46 (top)	87	0.23
	204	1.78
46 (bottom)	81	0.89
49	1486	0.44
54 (top)	312	3.13
54 (bottom)	800	3.33

whereas Hunt⁹ gives average value for recent clays as 1.5%. The value in carbonates given by the respective authors are 1.6 and 1.7% (average). Only a solitary value (3.6%) is available in this paper for the terrigenous silt-clay facies. Murthy *et al.*¹¹ report values for a section off Bombay as ranging from 0.24 to 3.15% (a.v. 1.93%) in the silt-clay facies. The carbonate facies is characterized by an equally wide spread of values (0.43-4.5%), the average (1.87%) being only slightly less than that of the silt-clay facies. The values in either of the facies is higher than the world averages cited by Hunt⁹.

The distribution of organic matter in a depositional environment may be explained in terms of its production, destruction and dilution in the environment. A marine depositional environment contains usually allochthonous organic matter transported to the site of deposition and autochthonous Organic matter which originates at the site of the deposition. Allochthonous material is usually contributed by river discharge from inland sources to the sea and consist of plant and animal remains. The principal source of organic matter in the marine environment is the autochthonous contribution by the phytoplankton and zooplankton living in the surface waters, algae and other bottom dwelling organisms¹². Rates of production of organic matter are usually higher in areas of upwelling with concurrent higher values resulting in the underlying sediments. Assuming similar rates of production of organic matter in the shelf waters off Bombay, slightly lower value in the carbonate facies as compared to the clay facies suggests that the destruction of organic matter in the carbonates is more rapid than in the muds. One of the factors favouring the accumulation and the preservation of organic matter in muds is the sediment size. Fine grained sediments have larger surface area and tend to adsorb due to the presence of clay minerals much greater organic matter than coarse sediments. Once associated with muds, the organic matter remains preserved due to high rates of sedimentation of the fine grained sediments in the near shore regions and the reducing conditions associated with such rapidly deposited muds.

The outer shelf carbonate sediments are generally coarser than the inner shelf silts and clays. Sand sized material in the form of oolites, shell fragments and rock debris form the dominant constituents. A significant difference in the behaviour of organic matter in carbonate and clay sediments is the effect of bacterial activity. Bacteria living on organic matter in carbonate muds from Florida and Cuba died out within the first 5 ft of sediment⁹. Clay muds from areas such as the Gulf of California and the Orinoco delta contained bacteria at a much greater depth. The decrease in bacteria is attributed to the reducing conditions and H₂S content which inhibits bacterial activity⁹. The iron associated with the clay sediment utilizes H₂S to form sulphides, whereas in carbonates devoid of iron, H₂S tends to accumulate. High value of organic matter in the slope sediments (max. 7.25%) may be attributed to its preservation under a reducing environment and in part by rapid deposition by slumping of sediments from the shelf edge.

An additional feature relevant to the distribution of organic matter in marine sediments is the difference in composition of the organic matter

in carbonates and clay sediments. The carbonates contain proteinaceous organic matter which is hydrolysed during diagenesis (cementation and recrystallization). The clays, on the other hand, contain humic and lignitic organic matter which survives compaction and diagenesis¹³.

Terrigenous sediments are fine grained, rapidly deposited and contain mainly the resistant lignite and humic organic matter. The fine grain size results in greater absorption and rapid deposition, and the associated reducing conditions aid the preservation of organic matter. Additional local factors such as the presence of low oxygen waters reaching the shelf as off Bombay¹⁴ may also be responsible for their preservation.

Carbonate sediments are generally coarse in grain size, have slower rates of deposition and contain dominantly proteinaceous organic matter. The slow rates of deposition result in greater destruction of the proteinaceous organic matter which is intrinsically more susceptible to destruction than humic and lignite organic matter. Carbonates, moreover, lose their water within a few feet of burial and undergo cementation and recrystallization. These processes are not conducive to the preservation of organic matter and may account for the slightly lower value of organic matter in the outer shelf sediments.

Highest value of organic matter is found associated with slope sediments and results from a combination of the presence of reducing conditions in the bottom waters and rapid deposition of sediments through slumps and slides down the continental slope.

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