

SURFICIAL SEDIMENTS OF THE CONTINENTAL SHELF OFF KARNATAKA *

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Abstract

The continental shelf in this area is about 80 km wide and the edge of the shelf varies between 90 and 120m water depth. Geologically modern fine-grained clastic sediments occur between the water depths of 15 to 50 m corresponding to a distance of about 40 km from the coast. Beyond 50 m to the shelf edge are calcareous sands. Non-carbonate components of these deep water sands are essentially quartz, many of which are heavily iron-stained and are attributed to the presence of rich iron formation on the land. The carbonate components in the outer shelf sediments are mainly foraminifers, pelecypods, gastropods, pteropods, and ooids, while ooids and pteropods are absent on the inner shelf. X-ray mineralogy of the silt fraction of the sediments shows the presence of quartz, calcite, aragonite and orthoclase as major minerals. Some of the sedimentary processes effecting the distribution of these sediments are discussed.

INTRODUCTION

The survey of the continental shelf off Karnataka was carried out by National Institute of Oceanography, Goa, as part of the geological and geophysical surveys of the entire western continental margin of India. These surveys are being carried out by R.V. *Gaveshani*, the research vessel of N.I.O. Some earlier work in this area was carried out on a reconnaissance basis during the International Indian Ocean Expedition by INS *Kistna*. So far sampling has been completed from the Indus Canyon in the north to Cochin in the south. The samples were collected at an interval of 10 km along transects which were 20 km apart. The sedimentological aspects of the surficial sediments of the continental shelf off Karnataka coast (Fig. 1) are discussed in this note.

PROCEDURES

Shipboard Procedures: On board the ship the surficial unconsolidated samples were collected by using a La Fond Dietz snapper (capacity 0.001 m³) and a Petterson grab (capacity 0.03 m³). Colour of the sediments were compared with the standard rock colour chart at the time of collection. Navigation during the cruises were based on (i) shore and radar fixes in the inshore areas and (ii) satellite navigation in the offshore areas. Echosounding was mainly carried out by Kelvin and Hughes MS-45 Echosounder having a range of 1,300 m and operating at a frequency of 45 kHz. Another echosounder, Simrad EQ, was also operated occasionally for cross checking of MS-45.

Laboratory Procedures: Weighed and salt-free samples were soaked overnight with the peptizer (Sodium hexametaphosphate) and afterward wet sieved through 230 mesh sieve (62.5 μ opening). The fraction coarser than 62.5 μ was dried and sieved. The fine fraction (< 62.5 μ) was diluted to 1,000 ml to obtain the size distribution of the fine fraction by using the pipetting procedure outlined by Folk (1961). The bulk analysis of sand fraction was carried out under the binocular microscope. The heavy and light minerals were separated with the help of Bromoform (sp. gr. 2.89) from the carbonate free fraction. The carbonate minerals were determined using a

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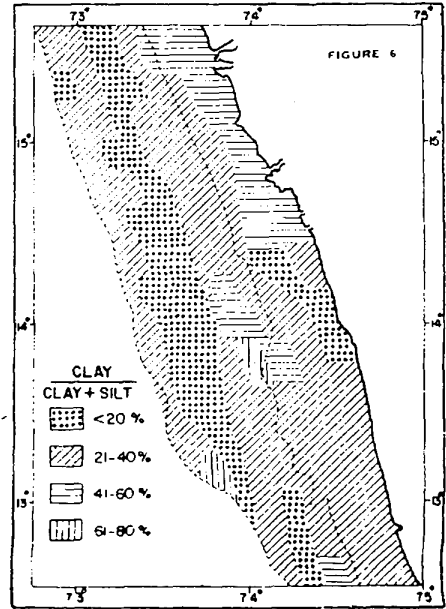
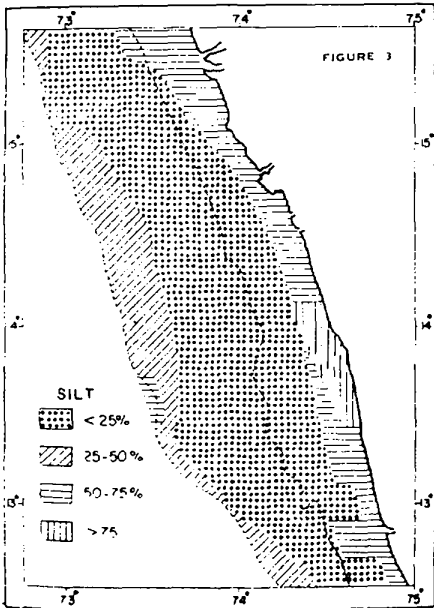
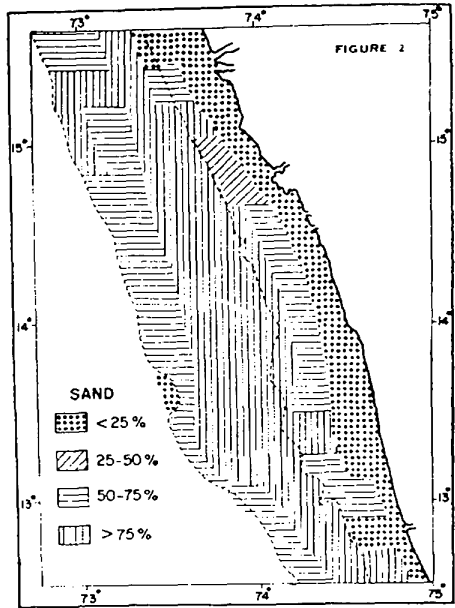
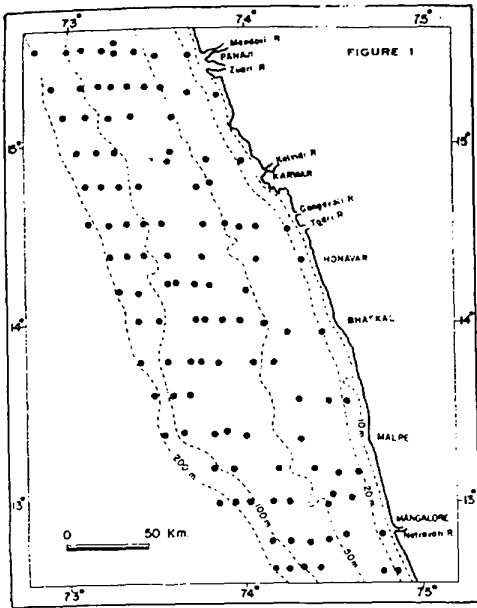


Figure 1. Sample location and general bathymetry.

Figure 2. Distribution of sand in the sediment.

Figure 3. Distribution of silt in the sediment.

Figure 6. Ratio percentage of clay to clay plus silt in the fine fraction of the sediments.

philips X-ray diffractometer (PW 1130). Peak heights of the aragonite and calcite were measured and their ratios calculated. The results are reported as variation in ratio rather than as absolute values.

GEOMORPHOLOGY AND GEOLOGY OF THE HINTERLAND

The Karnataka coast is bordered by the Western Ghats. Regarding the Ghats of this area Radhakrishna (1967) had noted that to the south of Goa the horizontally disposed Deccan Traps give place to the steeply dipping gneisses and schist. Moreover, in this section the Ghats lose their abrupt and precipitous character. The Ghat scarp swings back to the coast south of Honavar. The Ghat scarp recedes again east of Mangalore where the Netravati river has extended its valley by headward erosion. The coastal plain is narrow in this region varying from 25-75 km. The shoreline is characterised by sandy beaches with intermittent rocky headlands. Many short rivers flow across the coastal plain. They are Mandovi and Zuari in Goa, Kalinadi and Gangavali near Karwar, Tadri near Honavar and Netravati and Gurpur in Mangalore. Presumably each of these bring small quantity of suspended and bed loads. However, floods can transport relatively high sediment concentrations, but apparently little of these materials have reached even the inner shelf (Hashimi *et al.*, 1978). All of these rivers are estuarine in nature.

The following group of formations can be inferred on the land bordering the shelf off Karnataka from the geological map of Karnataka (Radhakrishna and Vasudev, 1977):

Chitradurga Group

Bababudan Group

Older Granite, Gneiss, Migmatite Complex (Peninsular gneiss)

Granulites

TOPOGRAPHY AND SEDIMENT OF THE SHELF

The continental shelf in the study area has an average width of 80 km and the depth of the shelf break varies between 90-120 m. The shelf is smooth and featureless upto a depth of 50 m, beyond which small scale (<5 m) prominances and undulations appear while the fall in the sea floor is sharp beyond the shelf edge. On the outer shelf off Malpe, Nair and Qasim (1978) reported a bank, named as Gaveshani Bank, with living hermatypic corals. The depth over the bank ranges from 38 to 60 m. This is the only known occurrence of living coral bank on the western continental margin of India.

On the shelf off Karnataka three most abundant sediment types are found viz. Clayey silt, silty sand and sand. The clayey silt forms a relatively narrow band confined to less than 50 m water depth and within a distance of 25 to 40 km from the coast. Between 50 and 100 m the sediments are sands. Off Goa and north of Mangalore these sands extend to 200 m. The silty sands do not show any relationship with water depth and are found from 40 to 200 m. In contrast to the generally uniform distribution of clayey silt present on the inner shelf, the inner shelf off Bhatkal has silt sized material (Nair *et al.*, 1978).

The size parameters were computed for each samples and it is found that the range of these on the inner shelf are: mean size 4.3 to 8.0 phi (Av. 6.67 phi), standard deviation 1.76 to 2.37 phi (Av. 2.07 phi), skewness +0.03 to +0.35 phi (Av. +0.2 phi) and kurtosis 0.54 to 1.5 phi (Av. 0.79 phi). The corresponding values for the outer shelf sediments are 0.49 to 7.34 phi (Av. 3.17 phi), 0.80 to 3.56 phi (Av. 2.09 phi), +0.30 to -0.48 phi (Av. +0.08 phi) and 0.59 to 2.0 phi (Av.

1.36 phi) and for the slope sediments the values are 2.01 to 6.59 phi (Av. 4.04 phi), 1.12 to 2.81 phi (Av. 2.01 phi), +0.55 to -0.34 phi (Av. +0.15 phi) and 0.53 to 2.81 phi (Av. 1.38 phi). The interrelations of these parameters were also examined and it is found that except for distinguishing the inner and outer shelves sediments no further separation of environment is possible (Hashimi *et al.*, 1978).

SAND FRACTION

The areal distribution of the sand fraction ($> 62.5 \mu$) in the study area is shown in Fig. 2. It ranges from 0.2 to 99 per cent.

Study of the sand fraction under the binocular microscope revealed that, in general, the inner shelf sediments are dominated by terrigenous material consisting of rock fragments and minerals (9 to 89%) with less skeletal material. The outer shelf and slope sediments consist of 15 to 100% of the skeletal components (pelecypods, gastropods, pteropods, foraminifers etc.), 0.35 to 30% of non-skeletal components (oooids, grapestones and pelletoids) and rock fragments and minerals (3 to 68%).

The skeletal components of the inner shelf and slope regions are dominantly benthic foraminifera, molluscs, and planktonic foraminifera respectively. On the outer shelf both types of foraminifers and molluscs are present.

Carbonate content

The amount of carbonate (determined by 10% HCl digestion) is low ($< 30\%$) in the inner shelf clayey silts, intermediate in the outer shelf sands (50 to 70%) and high ($> 90\%$) in the slope sediments. Exception to this distribution are the zone of 50 to 90% carbonate found on the middle and outer shelf off Bhatkal, and on the outer shelf off Mangalore. The carbonate content of the inner shelf and continental slope is due to the present biological productivity of the waters, whereas the carbonate content of the outer shelf is due to a combination of ancient (relict) and modern sedimentation processes.

Heavy Minerals

The heavy mineral study was only possible for the outer shelf sediments as the sand fraction in most of the inner shelf and slope samples were very small in quantity ($< 5\%$). The heavy mineral study of this area by Kidwai *et al.*, (1981) shows that the common heavy minerals are opaques, hornblende, epidote, garnet, sillimanite, hypersthene, and zircon with minor amount of andalusite, augite, monazite, muscovite and tremolite-actinolite. On the basis of their distribution pattern and assemblage four heavy mineral provinces were demarcated and it was concluded that the minerals are derived from mixed metamorphic terrain with a predominant contribution from metamorphic rocks.

Light Minerals

Among the samples containing the light minerals, quartz (56.9 to 97.24%), potash feldspar (0.24 to 8.0%), plagioclase (0.24 to 10%) are commonly present along with rock fragments (0 to 42.05%). In term of the percentage of Feldspar/(Quartz + Feldspar) most of the samples are orthoquartzitic (ratio = $< 5\%$) in nature. Only four samples - two off Karwar, one off Bhatkal and one off Malpe are subarkosic (ratio = 10 to 25%). This may be due to the occurrence of feldspar rich Peninsular gneisses on the land (Radhakrishna and Vasudev, 1977).

Iron-staining

The iron-stain on the quartz grains in the sand fractions were examined under the binocular microscope and their abundance was estimated. Generally the proportion of iron-stained quartz ranges from 5 to 20%. The area between Karwar and Bhatkal shows a zone of high percentage (>20% and may be due to the presence of extensive ferruginous laterite and iron rich coastal rocks in the area. The sediments on and seaward of the shelf edge have authigenic limonite as infilling (moulds) of foraminiferal and molluscan shells. The infilled shells are assumed to be recent because of their shining and unbroken appearance in contrast to the relict shells which have worn and dull lustre. Since the authigenic limonite is found in the recent shells the formation of limonite seems to be a modern feature. On the other hand, the iron-staining may be partly relict and partly modern because beach sands have iron-staining (Nair *et al.*, 1978).

SILT FRACTION

Next to the sand fraction the silt size dominates (1 to 70%) with an exception in the area off Bhatkal where the percentage reaches upto 92. On the average the mean size of the inner shelf and slope sediments fall in this size range. The general distribution of silt in the area is shown in Fig. 3. Size being beyond the optimum degree of recognition of the components the binocular microscopic study of this fraction was not taken up.

Mineralogy

X-ray analysis of 25 representative samples of the silt fraction from the study area was carried out by powder diffraction method. It is found that quartz, calcite, aragonite are the common major minerals with muscovite and chlorite as minor constituents. Besides these minerals, south of Karwar, potash feldspar also occurs which is in accordance of the same in the sand fraction.

Carbonate Mineralogy

The peak heights of aragonite and calcite from the diffractograms were measured and the ratios of aragonite to calcite were plotted against depth (Fig. 4). In

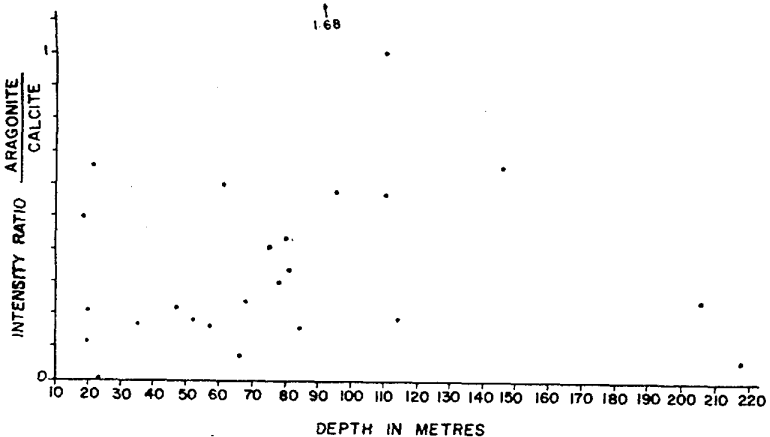


Figure 4. Variation of the ratio of Aragonite and calcite peak heights with water depth.

this fraction the abundance of aragonite and calcite shows a reverse pattern in comparison to the sand fraction (Nair and Hashimi, 1981). Here the ratio decreases for the inner shelf samples while increases comparatively for the outer shelf samples. The samples beyond 200 m water depth show again a decrease. The low values of the aragonite calcite ratios may be attributed to the lessening of the molluscan shells compared to the foraminiferal tests in this fraction.

SEDIMENTARY PROCESSES

The sedimentary processes taking place on the sea floor are the processes of erosion and deposition of the various types of sediments, rate of sedimentation, accumulation, topographic and hydraulic controls etc.

In order to understand these features three transects were selected - first one is from the northern part i.e., off Panaji, the second from the central part i.e., off Bhatkal and the third from the southern part i.e., off Mangalore. The schematic profiles were drawn for these three transects. These profiles, though not depicting the minor topographic changes along the transects, give the relationship with sample location and the water depth (Fig. 5).

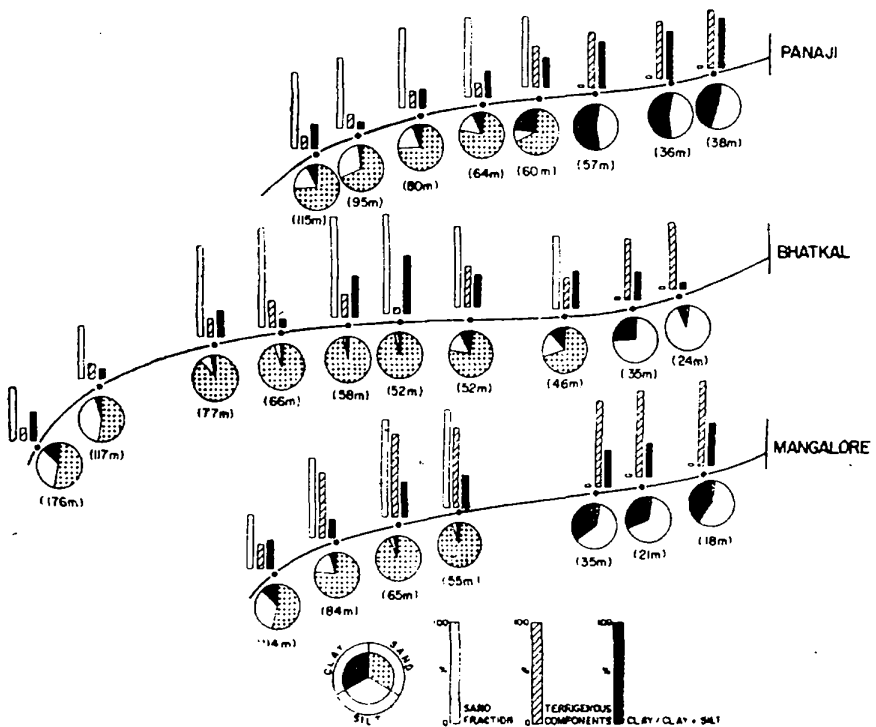


Figure 5. Variation of sediment characteristics along three profiles across the shelf. Numbers in brackets indicate water depth.

The high percentage of clay/(clay + silt) on the inner shelf may be due to the flocculation. During the monsoon the salinity of estuarine waters becomes as low as 2‰. These low salinity sediment-laden waters of the estuaries are discharged into the relatively higher salinity (~35‰) waters of the inner shelf. This mixing leads to flocculation resulting in the deposition of fine grained sediments. This type of deposition takes place within the 15 to 50 m water depths corresponding to the distance of about 40 km from the coast. The effect of this process can be seen in the schematic profiles (Fig. 5) for the particular transect and the area in general in Fig. 6. This type of near shore deposition of river discharged sediments is common on the other shelves also (e.g., Barreto *et al.*, 1975; Drake, 1961).

In the outer shelf sediments the percentage of clay/(clay + silt) decreases to 20 (Fig. 6). This may be due to the relict nature of the sediments and the absence of the conditions favourable for deposition. One exception to this distribution is off Bhatkal where zones of high clay/ (clay + silt) percentage (41 to 80%) are encountered. The cause of the high percentage at present is difficult to explain. However, one interesting observation is that during the dredging in this particular section we obtained stiff clay balls (diameter 10 cm) having fines up to 85%. Presence of silt (Fig. 3) in the near shore zone between Bhatkal and Malpe and the stiff clay balls away from this silt zone suggests that some local physical agencies (wave and currents) are responsible for the removal of clay from the near shore zone and depositing them seaward of silt zone.

The percentage of insoluble residue (Fig. 5) decreases towards the outer shelf giving support to the inferences that the modern terrigenous material is confined to the inner shelf.

Other processes that may be operating in the depositional environment and bringing about a redistribution of bottom sediments are bottom currents. These currents can be a combination of the tide and/or wave generated. No direct measurement of deep water bottom currents are available for this area in particular and the western continental shelf of India in general. Surface current velocities (from NHO Charts 215, 216, 217) during the monsoon range from 100 cm/sec to 150 cm/sec and are directed towards the southeast. It is probable that these currents play an important role in the sedimentary processes on the continental shelf.

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