

CLAY MINERAL DISTRIBUTION ON THE KERALA CONTINENTAL SHELF AND SLOPE

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Abstract

Seventy-five sediment samples collected from the Kerala continental shelf and slope during the 17th and 71st Cruises of *RV Gaveshani* were analysed by X-ray diffraction for clay mineral content. The distribution of total clay ($< 4\mu$ fraction) indicates low percentages ($< 10\%$) on the outer shelf and high percentages on the inner shelf (20 to 50%) and upper continental slope (11 to 47%). The clay minerals are composed of montmorillonite (smectite), kaolinite, illite and gibbsite and the non-clay minerals are quartz and feldspar. Kaolinite and gibbsite have low values on the outer shelf and high values on the inner shelf and slope, while illite increases in the offshore direction. However, montmorillonite behaves differently from others in having high values on the outer shelf and low values on the inner shelf and slope. These variations in the clay mineral distribution have been attributed to differences in the energy of the various environments and due to size segregation of the minerals.

INTRODUCTION

Clay minerals are the weathering products of a variety of rocks on the continent. These weathered products are transported from the land to the continental shelf by rivers and are deposited on the continental margin (shelf + slope) directly or via estuaries. The final clay mineral composition on the marginal sediments is the cumulative effect of weathering, transport history and the hydraulic regime of the shelf waters. Diagenetic processes have insignificant effect on clays in modern sediments. The amount and type of clay in the sediment also determines the fate of many trace and major elements present either naturally in the shelf waters or discharged as industrial effluent. This paper reports the clay mineral distribution on the continental shelf and slope of Kerala.

PHYSIOGRAPHIC SETTING

The coastal plain of the study area is covered by recent and sub-recent alluvial sediments in the north and, in the south near Quilon, Varkala beds (sandstone and limestone) are exposed as cliffs on the coast. A number of rivers such as Periyar, Ponnani, flow through the Precambrian formations in their upper reaches and recent alluvium in their lower reaches. Well developed system of barrier beaches and lagoons is present. The Vembanad lake and the Ashtamudi lake are the two most extensive lagoons present. 'Mud Banks' characterised by kaolinite-rich silty clay sediments are present in shallow waters close to the shore (Nair and Murty, 1968; Nair, 1976).

The continental shelf in this region has an average width of 45 km. The topography of the inner shelf is smooth, while on the outer shelf it is rugged, made up of ridges and depressions 6 m deep. The depth of the shelf break occurs between 80 to 110 m. An unusual valley-like feature parallel to the shelf edge is present south of Cochin (line-P) at a depth of 900 m. A 35 km wide terrace is observed at a depth of 330-400 m along the lines R and S off Quilon.

MATERIAL AND METHODS

75 grab samples collected during the 17th and 71st Cruises of *RV Gaveshani* on the continental shelf of Kerala between Cochin and Quilon were analysed for

the present study (Fig 1). These samples have a depth range of 17 to 1000m. Representative sub-samples of each grab sample were oven-dried at 60°C and standard methods of Folk (1968) were adopted to determine the percentage of sand, silt and clay.

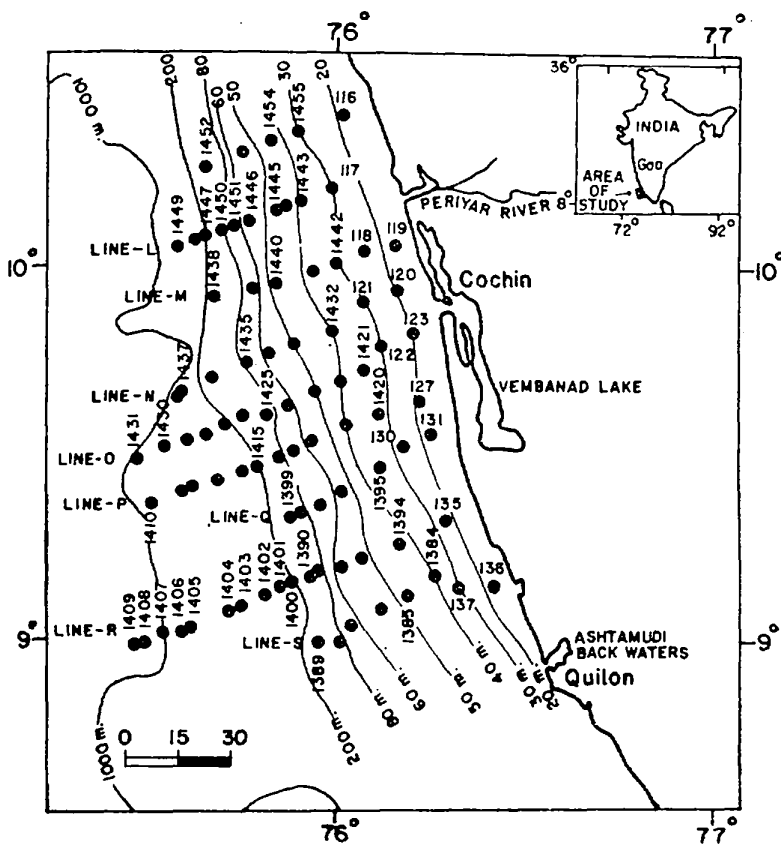


Figure 1. Sample location and bathymetry.

The fraction less than 2μ was used for the clay mineral study. It was made free of calcium carbonate and organic matter by treating with acetic acid and hydrogen peroxide respectively. Air-dried, oriented clay samples were prepared by pipetting on glass slides. These were scanned from 4 to 30° at $2^\circ 2\theta/\text{min}$ on a Philips X-ray diffractometer using nickel filtered $\text{Cu K}\alpha$ radiation. Standard tests were carried out for confirmation of montmorillonite by glycolation and chlorite/kaolinite by acid treatment in accordance with Carrol (1970). The relative proportion of clay minerals were determined by measuring the area of their principal reflections above the base line with polar planimeter thrice on each peak. The percentage of clay minerals were determined by the weighted peak area method of Biscaye (1965) using the multiplying factors 1, 2 and 4 for montmorillonite, kaolinite and illite respectively. It was found difficult to measure the area of the gibbsite

principal reflection (4.85 \AA), since it has the 4.46 \AA peak of illite at low angle side. Therefore, height of the peak was measured above the base line. Fig. 2 and Fig. 3 show the distribution of the three principal clay minerals.

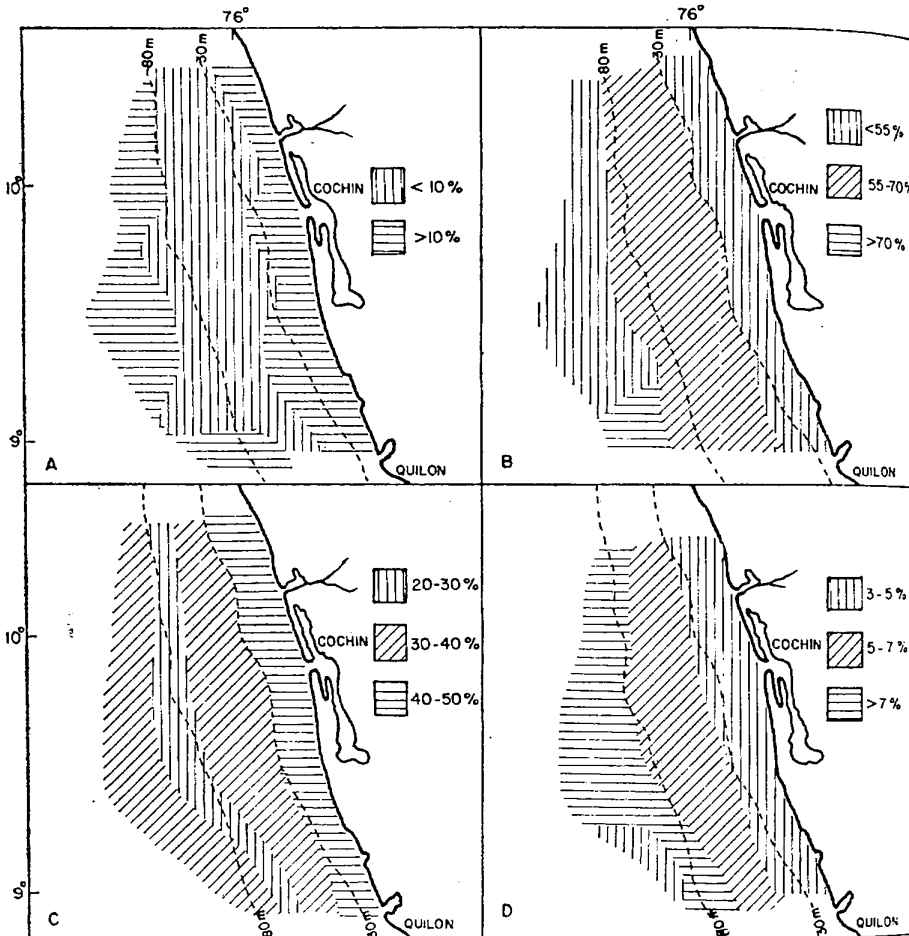


Figure 2.

Distribution of total clay percentage (A), montmorillonite (smectite) (B), kaolinite (C), illite (D).

RESULTS AND DISCUSSION

The areal distribution of the percentage of clay fraction ($< 4\mu$) is shown in Fig. 2A. It is high in the inner shelf (20 to 50%), low on the outer continental shelf ($< 10\%$) and high values (11-47%) occur again on the upper continental slope.

Clay minerals observed in the present samples are montmorillonite (smectite), kaolinite, illite and gibbsite. The non-clay minerals are quartz and feldspar. Montmorillonite is the most abundant clay mineral in all samples followed by

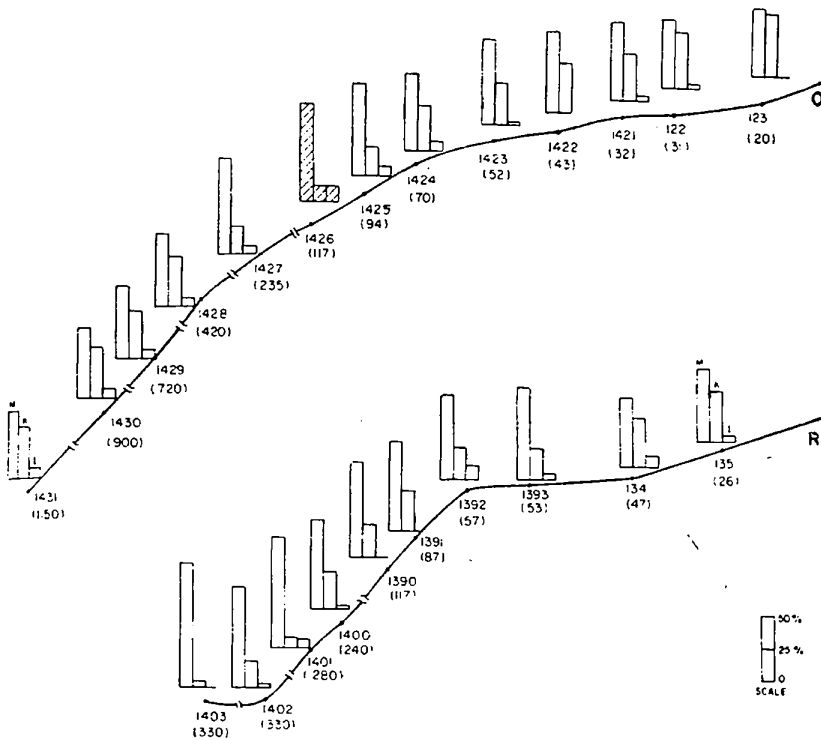


Figure 3. Distribution of montmorillonite (M), kaolinite (K), and illite (I) along two representative sections (Line O and R) across the continental shelf and slope. Number in brackets shows water depth in metres. Hatched histogram indicates clay mineral content of insoluble residue of dredged rock samples.

kaolinite, illite, and gibbsite. The relative percentage of montmorillonite is low in the inner continental shelf (about 30 m) and slope (greater than 100 m) samples but increases to high on the outer shelf region (30 to 100 m) Fig. 2B and Fig. 3. The small amount in the inner continental shelf sediments could be due to wave action in the shallow waters which selectively winnows the montmorillonite grains from the sediments. This is a consequence of the fact that the grain size of montmorillonite is smaller than kaolinite and illite, as demonstrated by the settling velocity study of the minerals by Whitehouse *et al* (1960). Therefore, montmorillonite tends to remain in suspension longer and the coarser fractions of the clay minerals settle to the bottom at a rate faster than the finer fractions and the final result is a size segregation (Gibbs, 1977). Montmorillonite thus tends to be carried further out to sea than the other clay minerals as observed, for example, by Van Anel and Postma (1954) in the Gulf of Paria, Porrenga (1966) in the Niger delta sediments and Gibbs (1977) in Amazon River/Atlantic Ocean.

An additional plausible reason for the anomalous increase on the outer shelf of montmorillonite could be that the south-west monsoon drift (Fig. 4) transports it from the north, which previous work (Nair *et al*, in Press) has shown to have the

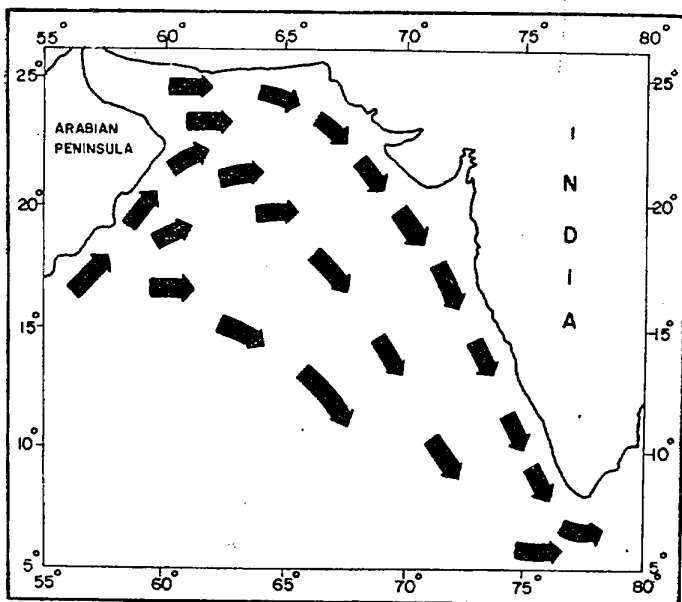


Figure 4. Generalised surface water circulation in Arabian Sea during southwest monsoon (May to September) according to Monatskarten für der Indischen Ozean, Deutsches Hydrographisches Institut (1960).

highest montmorillonite content. This conclusion is based on the fact that the principal basal reflection of montmorillonite has different 'd' spacing on the inner shelf and outer shelf. For example, the 'd' spacing of the inner shelf montmorillonite (unglycolated) is between 14.97 \AA ($5.9^{\circ}2\theta$) to 14.7 \AA ($6.0^{\circ}2\theta$), whereas those on the outer shelf have 'd' spacing 16.36 \AA ($5.4^{\circ}2\theta$) to 15.5 \AA ($5.7^{\circ}2\theta$). This implies that the montmorillonite on the outer shelf and slope in this region has a different origin. It is likely that the inner shelf montmorillonites are those derived from the weathering of the rocks on the Kerala hinterland, while those on the outer shelf and slope are derived from the north under the action of the southwest monsoon drift. In order to test this hypothesis, we have compared the 'd' spacing of the montmorillonite from the sediments of the continental shelf between Bombay and Ratnagiri, with those of the 'd' spacing of the montmorillonite from the outer shelf of Kerala. We find the 'd' spacings comparable. For example, the average value of ten samples between Bombay and Ratnagiri is 15.92 \AA ($5.54^{\circ}2\theta$), lending support to our contention that a part of the montmorillonite is derived from the north. The alternate explanation for the differences in the montmorillonite could be that they are due to diagenetic changes taking place after deposition. In this connection, the detailed review by Grim (1968, p. 535) on diagenetic processes emphasises the uncertainty of its happening in recent marine sediments. He concludes on the basis of the review of the work of numerous investigators on recent marine sediments that the clay mineral composition is more likely to reflect source area and climatic conditions than diagenetic change. Our results tend to

support the conclusion that the differences in the nature of the montmorillonite reflect derivation from different source areas.

The highest value of montmorillonite in the study area occurs on the continental slope south of Cochin (line R) where the total percentage of the clay is the least (1%). We are at present unable to provide a definite explanation for this high value, but suggest provisionally that they may be transported into this region from the Bay of Bengal, as suggested earlier by Kolla *et al* (1981).

Kaolinite shows a gradual offshore decrease, has the lowest abundance on the outer shelf (av. 34.4%) and shelf edge (av. 25.5%) and increases (av. 36.4%) on the upper continental slope (Fig. 2C and Fig. 3). Its distribution parallel to the coast shows it to be more abundant off the estuarine regions as compared to the non-estuarine regions i.e., on the shelf south of the Vembanad lake. This change in distribution reflects the fact that the lake receives the drainage of rivers whereas south of it rivers are few. Low kaolinite content on the outer shelf and high values near the coast and on the upper continental slope can be explained by the fact that kaolinite being a product of continental weathering, there arises a concentration gradient of the mineral near the coast due to deposition of terrigenous sediments. The concentration gradient results in the diffusion of sediments in the offshore direction but no deposition takes place on the outer shelf because of high energy condition prevailing there (surface waves, tidal currents and breaking internal waves). On the upper slope, however, low energy conditions are encountered and hence kaolinite accumulates (Fig. 3).

Illite content in most sections increases offshore (Fig. 2D). The outer shelf high may also have its source in the outcrops of aragonite cemented sandstones and limestones which from the x-ray analysis of their insoluble residue are seen to contain illite as well as other clay minerals. The proportion contributed by this source is not known. Illite content is high on the upper continental slope because of it being a region of low energy where illite can accumulate.

Gibbsite occurs as a minor clay mineral. It shows two maxima, one on the inner shelf (av. 11 units) and the other on the slope (av. 9 units) with low values (av. 7 units) on the outer shelf.

Gibbsite is a common product of laterites in humid tropical zones and thus has a continental origin along with kaolinite (Grim, 1968). Its origin has been discussed by Millot (1970) and its presence in the inner continental shelf sediments of the west coast of India is due to its derivation from the aluminous laterites and bauxites present on the coast. Gibbsite in these sediment samples is due to its occurrence in aluminous clays in the hinterland and below the lateritic cappings along the Kerala coast. The present study leads to the inference that, like other clay minerals, it is deposited in the inner shelf, by-passing the outer shelf and depositing on the slope.

The absence of feldspar in the estuarine region and its presence in the outer shelf and slope of the non-estuarine region is striking. The absence of feldspar on the shelf off the Vembanad lake is because this region consists of a fault trough which is filled with Tertiary and Quarternary and modern sediments (Varadarajan and Nair, 1978). Shelf sediments having their source in sedimentary rocks are feldspar poor whereas those off Quilon having a higher content of feldspar reflect their derivation from feldspar rich Precambrian granites and gneisses with relatively thin cover of sediments.

ACKNOWLEDGEMENTS

The authors are grateful to the Director, National Institute of Oceanography and Sri H. N. Siddiquie for their interest and encouragement.

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(Received: Sep. 4, 1982; Revised form accepted: Mar. 12, 1983)