

Letter Section

DISTRIBUTION AND DISPERSAL OF CLAY MINERALS ON THE WESTERN CONTINENTAL SHELF OF INDIA

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ABSTRACT

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Sediment samples distributed over a distance of 1700 km from the inner continental shelf of western India were analysed for their clay-mineral content by X-ray diffraction. The clay minerals present in the sediments, in order of abundance, are montmorillonite, kaolinite, illite, chlorite and gibbsite. Based on the abundance of montmorillonite and kaolinite, four clay-mineral provinces on the continental shelf have been demarcated. These are: (1) the montmorillonite-kaolinite-illite-chlorite province off the Gulf of Kutch; (2) the montmorillonite-rich zone off the Gulf of Cambay; (3) a transition zone on the central parts of the shelf; and (4) a relatively montmorillonite poor-gibbsite province on the southwestern part of the shelf. Source-rock influence on clay-mineral composition appears to be more important than physical transport — the southwest monsoon drift in the present case.

In the northwestern part of the study area, the high-velocity tidal streams of the macro-tidal Gulf of Kutch act as dynamic barriers to longshore sediment dispersal, leading to distinct clay-mineral assemblages on the shelf north and south of the gulf mouth.

INTRODUCTION

Common to some tropical continental shelves is the presence of a band of modern, terrigenous, fine-grained sediments in the shallow waters close to the coast, for example, northern Brazil (Baretto et al., 1975) and Western Indonesia (Emery, 1969). Products of intense chemical weathering, these sediments are transported by streams and rivers and are deposited by decrease in the competency of the transporting agent or by flocculation, or both, at varying distances from the shore. These fine-grained sediments are predominantly clays. The objective of the present paper is to determine the relative proportions of clay minerals in the inner continental shelf sediments of western India and to provide an explanation for their distribution.

Previous work by Goldberg and Griffin (1970) and Kolla et al. (1976) on the regional distribution of clay minerals in the northern Indian Ocean included a few widely spaced samples from the western continental margin of

India, but these samples are insufficient to delineate the clay-mineral distribution on the continental shelf. Likewise limited in scope is the clay-mineralogy study of the mudbanks of Kerala (Nair, 1976) reported in Nair and Murty (1968).

LABORATORY METHODS

The grab samples analysed were collected by R.V. "Gaveshani", the research vessel of National Institute of Oceanography, during the course of many surveys undertaken for the geological exploration of the western continental margin of India. For the purposes of the present study we selected samples distributed over the entire mud facies but with variable sample spacing. The samples from the northwest and southwest parts of the shelf were widely spaced, whereas those from the central portions of the shelf, where the onshore rocks change from basalts (Deccan Traps) to Precambrian granites, gneisses and schists (the transition zone), the sample spacing was closer (Fig. 1). This sampling pattern was adopted in order to evaluate if the onshore changes were reflected in the clay-mineral composition.

Calcium carbonate and organic matter were removed from the sediment by dilute acetic acid and hydrogen peroxide, respectively. Air-dried oriented samples (three for each sample) of the $< 2\text{-}\mu$ fraction were prepared by pipetting on glass slides. The slides were scanned from 4° to $30^\circ 2\theta$ at 2°min^{-1} , with slow scanning at 1° and 0.5° for selected reflections, on a Philips X-ray diffractometer using Ni-filtered $\text{Cu K}\alpha$ radiation, proportional counter and pulse-height analyser. Standard tests were carried out for confirmation of montmorillonite by glycolation and for chlorite by acid treatment (1N HCl at 80°C for one hour) (Carrol, 1970; Thorez, 1975). The relative proportions of the clay minerals were determined by measuring the area of their principal reflections, in many cases the average of replicate measurements, by a polar planimeter. The percentages of the major and minor clay minerals thus determined are shown in Fig. 2. The percentages of the major clay minerals were also determined by the weighted peak area method of Biscaye (1965). Duplicate analyses show that the results are accurate to within 10% for montmorillonite and about 5% for kaolinite. The lesser accuracy for montmorillonite results from the problem of drawing the base line. Ratios of the two major clay minerals which are quantitatively the most important, montmorillonite and kaolinite, are shown in Fig. 3.

RESULTS

The clay minerals present in the sediment samples are montmorillonite, kaolinite, illite, chlorite and gibbsite.

All identifications of the clay minerals are confined in this report to the group level of Brindley et al. (1968). Non-clay minerals are quartz and feldspar and they occur in minor quantities. In all the samples montmorillonite is

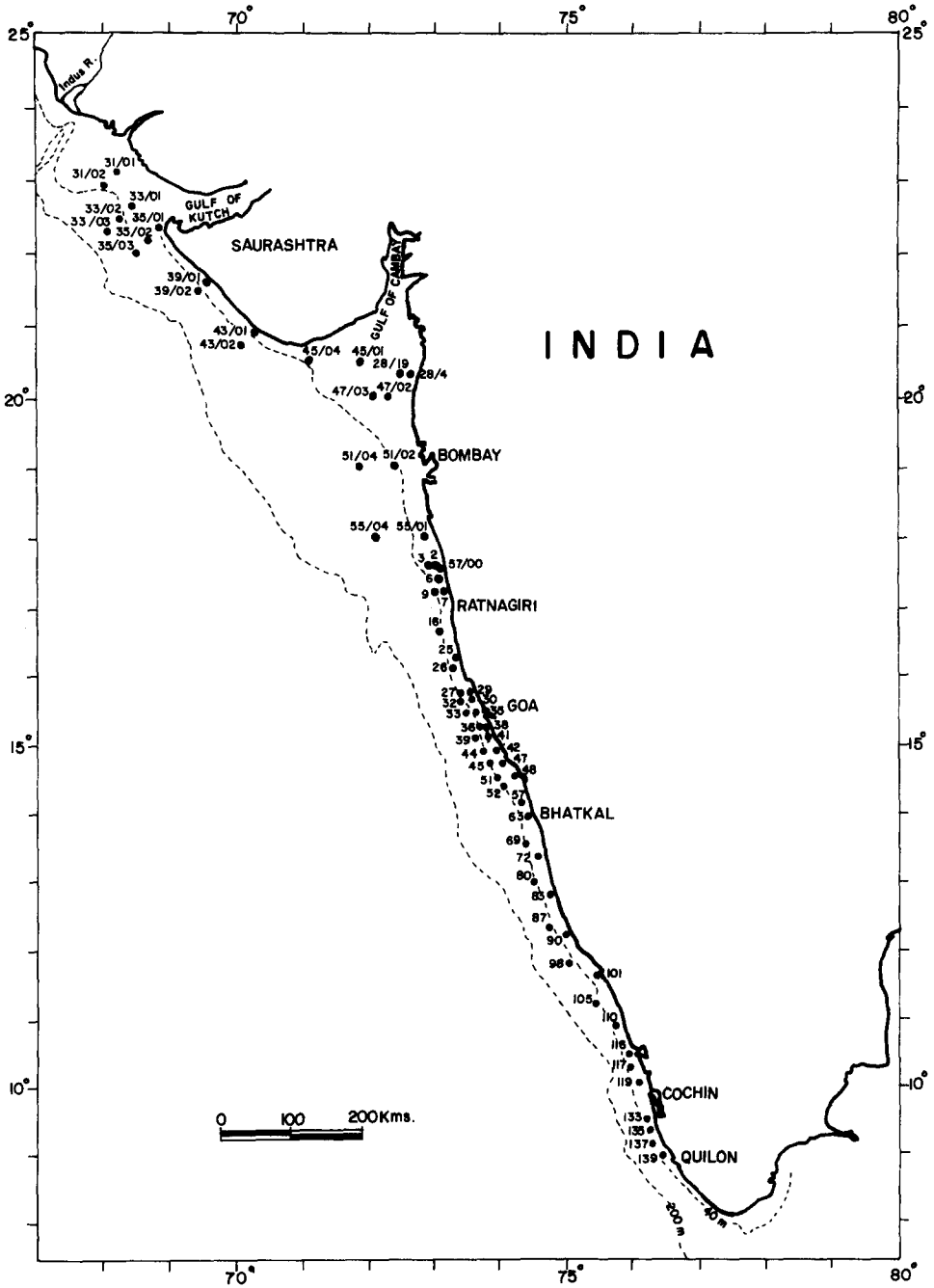


Fig. 1. Sample locations.

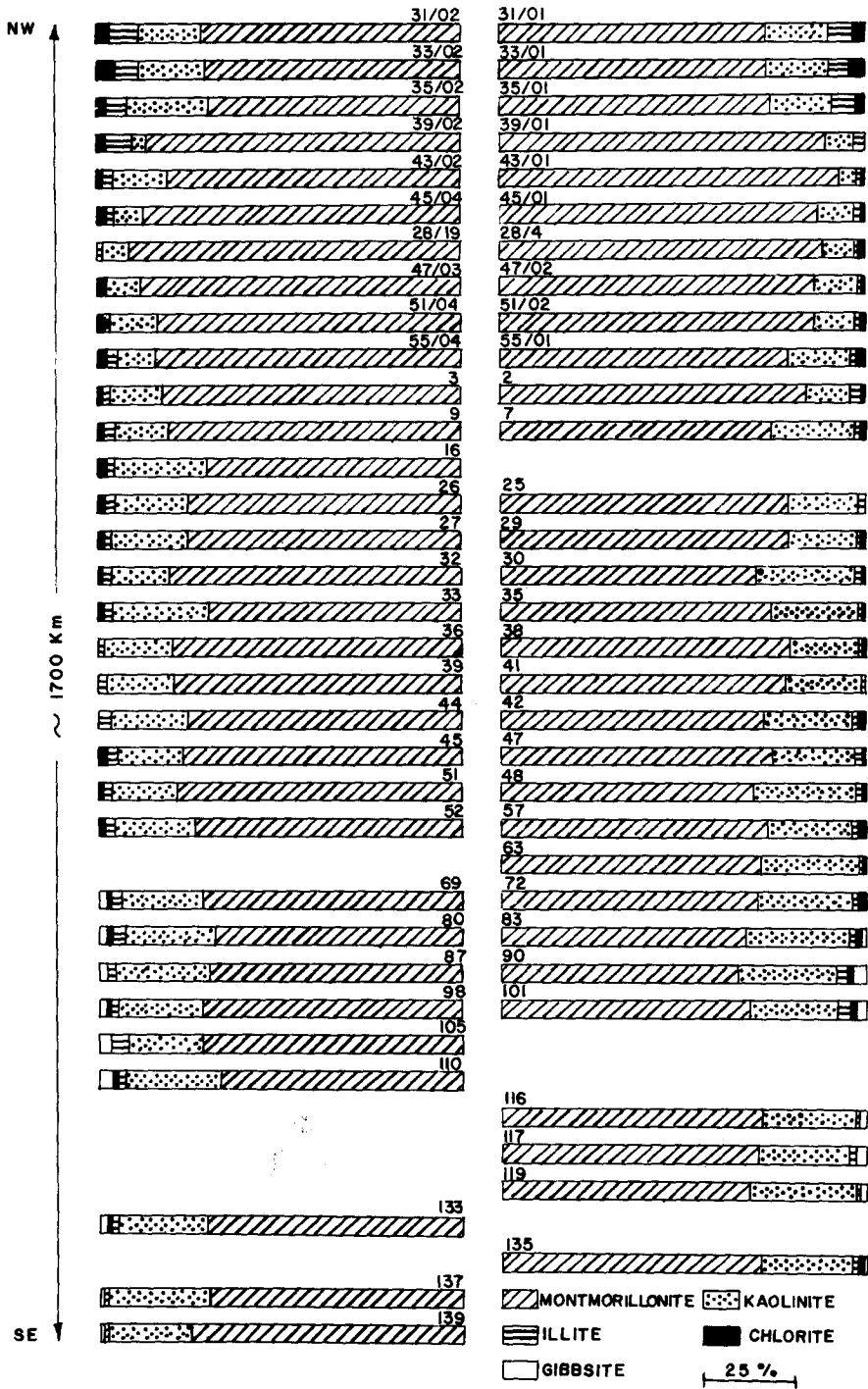


Fig. 2. Distribution of clay minerals over a length of 1700 km. Based on peak area percentages.

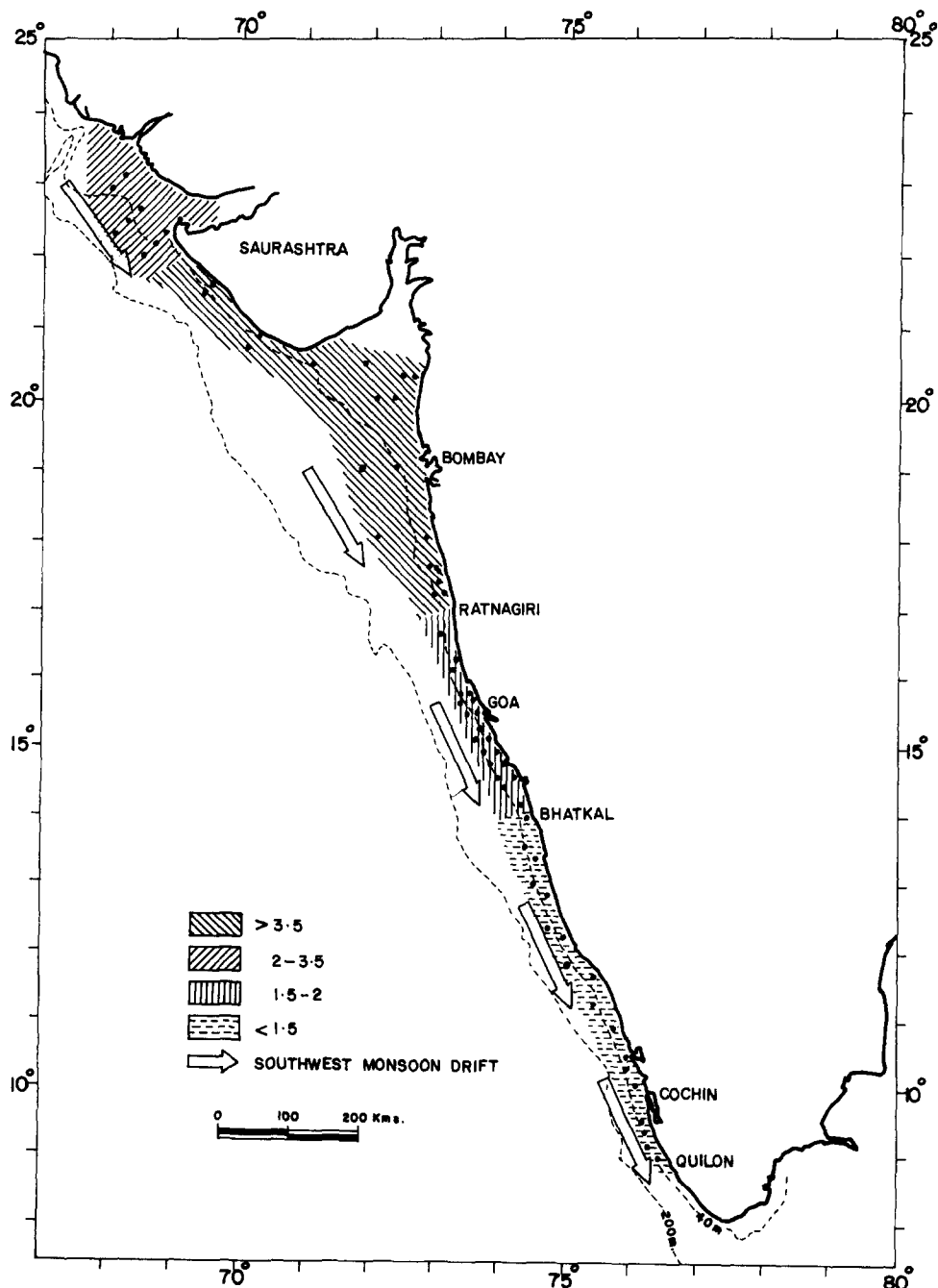


Fig. 3. Clay-mineral zonation based on ratio of montmorillonite to kaolinite. Based on weighted peak area percentages.

the most abundant clay mineral (Fig. 2), followed by poorly crystallised kaolinite and illite. Chlorite is most abundant in the region off the Gulf of Kutch while in the rest of the samples it is present only in trace quantities. Gibbsite, although present in all the samples, becomes quantitatively important only on the southwestern part of the shelf (samples 69–139 in Fig. 2) where it is present to the extent of 1–3%.

These results provide the means for distinguishing various clay-mineral zones on the inner continental shelf. These zones are shown in Fig. 3. Since the results of the clay-mineral analysis by X-ray diffraction methods are invariably semiquantitative, the boundaries shown on the map are to be considered as first-order approximations only. The zones identified are: (1) the montmorillonite-kaolinite-illite-chlorite zone of the Gulf of Kutch (M/K 2–3.5); (2) the montmorillonite rich zone (M/K > 3.5) between the Gulf of Cambay and Ratnagiri; (3) the transition zone (M/K 1.5–2) from Ratnagiri to Bhatkal; and (4) the montmorillonite poor-(M/K 1.5) gibbsite zone from Bhatkal to Quilon.

DISCUSSION

The montmorillonite-kaolinite-illite-chlorite zone off the Gulf of Kutch

This zone is distinguishable from the rest of the area by the presence of significant quantities of chlorite (2–4%) and also because of the high values of illite (6–9%). Chlorite, though considered uncommon in tropical marine sediments (Griffin et al., 1968) owes its presence in the present case due to the fact that the river Indus drains the cold high-altitude regions of the Himalayan mountains. These low-latitude chlorites, as pointed out by Griffin et al. (1968), do not show a sharp reflection. In this area chlorite also occurs in the sand fraction of the sediments (Nair et al., 1982). The rather abrupt decrease in the chlorite and illite contents south of the gulf mouth has been attributed (Nair et al., 1982) to the high-velocity tidal stream of the macro-tidal gulf which acts as a dynamic barrier preventing the Indus-borne sediments from being transported across the gulf mouth to the Saurashtra shelf.

The montmorillonite-rich zone off the Gulf of Cambay

This zone has a M/K ratio ranging from 3 to 10 (average 4.4). The highest values are found off the Saurashtra shelf—Gulf of Cambay region and decreases to the south towards Ratnagiri. The high montmorillonite values are a direct reflection of the fact that the onshore rocks in this region are composed of basalts. The two rivers Narmada and Tapti which flow into the Gulf of Cambay transport the weathering products of the Deccan Trap basalts to the inner shelf. The influence of these two rivers appears to be ineffective south of Ratnagiri, where the clay contribution is likely to be from the numerous small streams draining the Deccan basalts. Within this area (M/K > 3.5, Fig. 3),

the montmorillonite content does not show any regular variation with depth, therefore, differential settling does not seem to take place. It is, however, possible that the relatively limited differences in depth of the samples analysed here precludes the possibility of identifying the process of differential settling.

The transition zone

This zone is the onshore region where the coastal rocks change from principally basalts to dominantly Precambrian granites, gneisses and schists. The basic climatic regime over the region remains unchanged. The samples in this region were closely spaced in order to ascertain if the clay minerals also reflect a change corresponding to source lithologies. The M/K ratio in this area has an intermediate value of 1.6, with the higher values occurring at the northern part where the basalts are predominant. The ratios become progressively lower to the south where acid rocks increase in abundance. These results indicate clearly that the source rocks determine the clay-mineral composition of the inner continental sediments. This fact also leads to the conclusion that the processes of transportation and redistribution by the hydraulic regime (the southwest monsoon drift) of the shelf waters have minimal impact.

The montmorillonite-poor zone

The southwestern part of the shelf between Bhatkal and Quilon, has the lowest M/K ratio (average 1.3, Fig. 3). The montmorillonite content decreases from a maximum of 87% off the basaltic regions in the northwest to a maximum of 60% in this area where the coastal rocks are granites and gneisses. There is a corresponding increase of kaolinite to a maximum of 44% in this area. Kaolinite increases to 65% in the mud banks of Kerala (Nair and Murty, 1968) but these mud banks occur in waters generally less than 10 m deep and their high kaolinite content is doubtless due to the presence on the Kerala coast of extensive deposits of kaolin. The regional variations in the distribution of the principal clay-mineral types in the sediments of the continental shelf reflect the fact that kaolinites characterise stronger weathering in a well-drained acid environment, whereas montmorillonite results when the drainage is poor.

Another feature characteristic of this region is the presence of gibbsite, although in minor amounts (1–3%, Fig. 2). Gibbsite was identified by its principal reflection at $18.3^\circ 2\theta$. Gibbsite is a common product in the laterites and lateritic soils of the humid tropical zone. According to Millot (1970), it forms from a variety of rock types under different drainage and water-table conditions. Gibbsite forms either directly from the parent rock or indirectly from kaolinite by removal of silica and the extreme form of this desilicification results in bauxite. Bauxite deposits at high altitudes (1000–2000 m) occur on peninsular India on both basalts and acid rocks, and also as aluminous laterites on the coastal rocks of the central parts of the west coast of India,

particularly on the Karnataka coast (Krishnaswamy, 1972). In the present instance, gibbsite is more likely to be derived from the aluminous laterites on the coast rather than from the high-altitude bauxite of the peninsula because the rivers draining to the west coast, which are the principal transporting agents of sediments to the continental shelf, are generally less than 100 km long.

Dispersal patterns in the nearshore region are difficult to determine from the clay-mineral distribution in the present instance because the same mineral can result from a variety of rocks under different weathering conditions. For example, the coastal laterites contain both montmorillonite and kaolinite, but the former exceeds the latter. The bulk of the sediment input to the western shelf occurs during the southwest monsoon rainy season and dispersal takes place, in all probability, during the period when the clay minerals are still in suspension. Once the clay minerals are deposited on the seabed, their cohesive nature due to their fine grain size and high organic carbon content may prevent their erosion and transportation.

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