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Clay Minerals Distribution and their Association with Trace Elements, Calcium and Organic Matter in Inner shelf Sediments off Gangolli, West Coast of India

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ABSTRACT

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Inner shelf sediments off Gangolli, west coast of India, are mostly silty clays and clayey silts. Clay minerals present in order of decreasing abundance are montmorillonite, kaolinite-chlorite, illite and gibbsite. The relative abundance of kaolinite-chlorite and illite decreases seaward, whereas montmorillonite increases. Clay minerals do not show a distinct association with trace elements; this may be attributed to desorption mechanisms in the marine environment. Organic matter supports the formation of montmorillonite. The presence of calcium also favours the formation of montmorillonite but not that of kaolinite-chlorite and illite.

ADDITIONAL INDEX WORDS: *Clay minerals, trace elements, calcium and organic matter.*

INTRODUCTION

Fine-grained sediments, composed of silts and clays, are common on many tropical continental shelves. These sediments are products of weathering and are transported by rivers and accumulate at varying distances from the shore, depending on the transporting agent. Studies on clays have been carried out to interpret provenance and dispersal patterns of finer sediments (PORRENGA, 1966; SCAFE and KUNZE, 1971; SHAW, 1973). RATEEV *et al.* (1969) have studied the distribution of clay minerals in the world oceans and reported that kaolinite in marine sediments shows a latitudinal control. There is an "equatorial" type of distribution with the maximum content of kaolinite near the equator and a gradual decrease in content towards the poles. For example, gibbsite and montmorillonite have also an equatorial type of distribution, while chlorite and illite are bipolar and not equatorial.

GOLDBERG and GRIFFIN (1970) and KOLLA *et al.* (1976) have studied the regional distribution of clay minerals in the northern Indian ocean. Studies on clay minerals in the surficial sediments of Western continental shelf of India (NAIR *et al.*, 1982b) and of mud banks off Kerala (NAIR and MURTY, 1968; NAIR, 1976) have been carried out. PRITHVIRAJ and PRAKASH (1990) have investigated the geochemical association of clay minerals on the inner shelf of central Kerala, India. No such study with closely spaced samples has been made along the Karnataka coast.

In the present study, the relative abundance of clay mineral groups and their distribution in the inner shelf sediments off Gangolli, west coast of India, are analysed. An attempt is also made to understand the association of trace elements, calcium and organic matter with the clay minerals in this area.

METHODS

Fifteen grab samples of surficial sediment were collected at depths of 10, 20 and 30 meters. There is a 10 km-interval between sample stations along each track (Figure 1). The samples were washed free of salts; calcium carbonate and organic matter were removed by dilute acetic acid and hydrogen peroxide, respectively.

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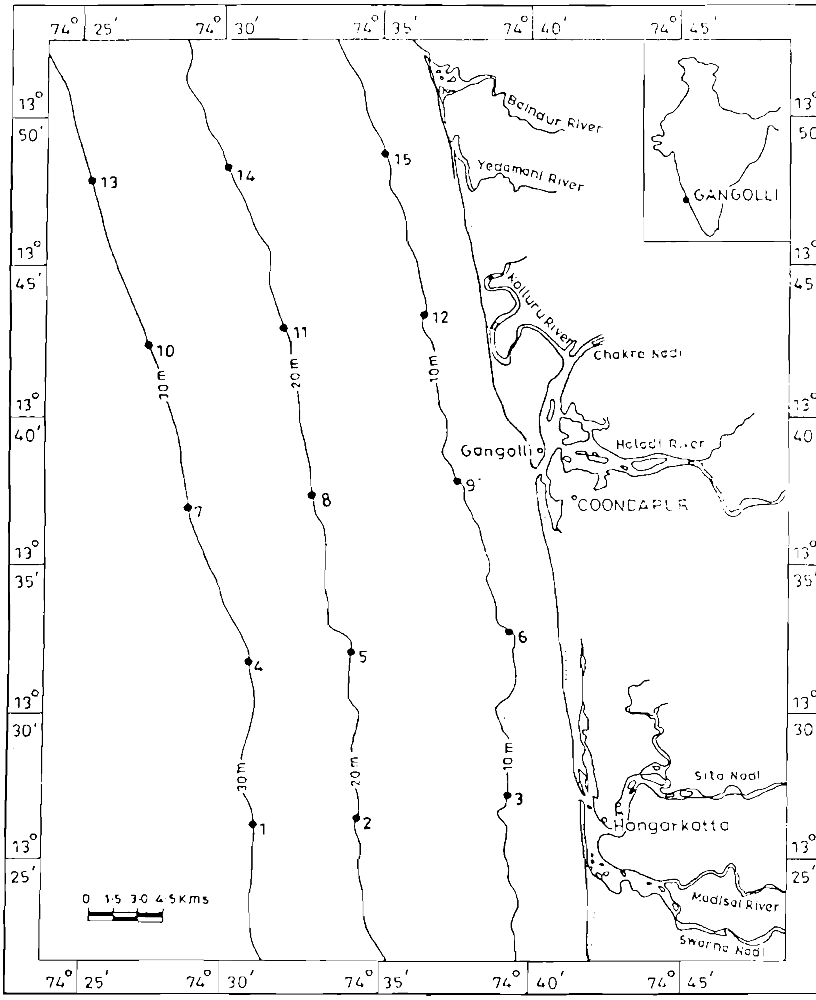

Figure 1. The sample locations and bathymetry off Gangolli.

Air dried oriented samples of the <2-μm fraction were prepared by the pipetting method. The prepared glass slides were scanned from 3° to 30° 2θ at 0.05°/sec using a Philips X-Ray diffractometer (PW 1840) using Ni-filtered Cu Kα radiations. A standard test was carried out for montmorillonite confirmation by glycolation. Kaolinite and chlorite were not differentiated in this study. The relative percentages of the clay minerals were determined semi-quantitatively following the Weighted Peak Area method of BISCAYE (1965). As the gibbsite is present in trace to minor quantity, relative percentages are calculated only for montmorillonite, kaolinite-chlorite and illite. The clay mineral data in conjunction with trace elements, organic matter and calcium were subjected to R-mode factor analysis to determine their relation.

RESULTS AND DISCUSSION

The inner shelf sediments off Gangolli are largely silty clay and clayey silt. The clay content increases in a seaward direction. The concentration of trace elements, calcium and organic matter in inner shelf sediments also increases seaward (PANDARINATH and NARAYANA, in press). The distribution and abundance of clay minerals and their association with trace elements, calcium and organic matter is of specific interest of this study.

In all the samples montmorillonite is the most abundant clay mineral; progressively lesser amounts of kaolinite-chlorite, illite and gibbsite are also present (Table 1). Non-clay mineral quartz also present in minor quantity. The relative abundance of montmorillonite in inner shelf sediments increases gradually offshore. This is because the mineral is derived from coastal aluminous laterites and, being small in size, it remains in suspension for longer time (WHITEHOUSE *et al.*, 1960). This, in turn, increases the likelihood of the mineral being dispersed toward deeper and more distal parts of the inner shelf (VAN ANDEL and POSTMA, 1954; PORRENGA, 1966).

In contrast to montmorillonite, the relative abundance of kaolinite-chlorite in the sediments of the study area indicates a landward increase (Figure 2). This is probably due to the effect of differential sorting of these minerals resulting from their different physical properties. The landward concentration of kaolinite-chlorite and good positive loading with Al in Factor-2 (Table 2) suggest that these minerals have a terrigenous origin. WHITEHOUSE *et al.* (1960) attributed a decreased content of kaolinite in a seaward direction partly as a function of their terrigenous origin and partly due to their higher settling velocity than montmorillonite. As the peak at 25Å is prominent and kaolinite-chlorite peak at 7Å is smooth, it can be said that chlorite abundance is negligible in the samples. Though chlorite is considered uncommon in tropical marine sediments (GRIFFIN *et al.*, 1968), it occurs in relatively very low percentages along the west coast of India (NAIR *et al.*, 1982b). In general, kaolinite is an important product of continental weathering under tropical conditions (*cf.* MILNE and EARLEY, 1958; GRIFFIN *et al.*, 1968).

The illite content in the sediments also increases landward. Further, its good positive loading with Al in Factor-2 (Table 2) also suggests a detrital origin. Gibbsite occurs as a minor clay mineral in the sediments of the study area. This mineral is a common product in laterites and lateritic soils of humid tropical zone. The formation of gibbsite is either by desilicification of kaolinite or by direct alteration of the parent rock (MILLOT, 1970). In the present study, it is likely that gibbsite is derived from aluminous laterites exposed along the coast. The distribution pattern of the clay minerals in the sediments of the study area is similar to the trend in nearshore sediments off central Kerala (PRITHVIRAJ and PRAKASH, 1990).

The increase in relative abundance of montmorillonite and decrease in illite content in deeper inner shelf sediments can be attributed to various factors. Montmorillonite may be derived from onshore basalt rocks (NAIR *et al.*, 1982b) and post-depositional alteration of illite to montmorillonite. It is viewed that the clay minerals may also be transported from the Indus fan by longshore currents. But the decrease in chlorite and illite contents in the inner shelf sediments south of the gulf of Kutch has been attributed (NAIR *et al.*, 1982a) to the high velocity tidal stream of the macrotidal gulf which acts as a dynamic barrier preventing the Indus-borne sediments from being transported across the gulf mouth to the southern shelf. Based on their studies, NAIR *et al.* (1982b) further stated that the process of transportation and redistribution by the hydraulic regime (the southwest monsoon longshore drift) of the shelf waters have minimal impact on the clay mineralogy of inner shelf sediments. Therefore, it appears that onshore lithology and post-depositional alteration of illite to montmorillonite are contributing factors for high values of montmorillonite in deeper parts of the inner shelf area. WEIR *et al.* (1975) also observed such post-depositional transformations in the sediments of the western Nile delta.

The post-depositional transformation of illite to montmorillonite takes place by alteration or mechanical illuviation, or both processes (HAMDI, 1977). Further, the mobilization of K-ions from illite may have been aided by organic acids released by the decomposition of organic matter (EL SABROUTI and SOKKARY, 1982). In the present investigation, this hypothesis is supported by the strong negative loadings of montmorillonite and organic matter and strong positive loading of illite in Factor-2 (Table 2). Except for this relation, the results of the factor analysis do not indicate strong relationship between organic matter and clay minerals.

The distribution of kaolinite and illite is rel-

Table 1: *Clay mineralogy and geochemistry of inner shelf sediments off Gangolli, West coast of India*

Sample Number	Montmor-illonite	Kaolinite-chlorite	Illite	Cu	Pb	Zn	Ni	Co	Mn	Cr	V	Fe	Al	Ti	O.M.	Ca
	(Relative percentages)			PPM								%				
1	57.68	33.71	8.61	37	9	56	71	21	355	185	114	5.95	7	0.48	5.26	6.15
2	56.14	35.54	8.32	31	7	42	62	21	330	161	102	5.19	7	0.66	4.83	5.82
3	54.20	36.77	9.03	30	10	46	63	17	226	165	94	5.21	8	0.64	3.62	5.24
4	68.42	27.25	4.33	29	6	42	54	21	300	140	72	4.80	4	0.55	8.45	6.40
5	58.68	34.00	7.32	21	3	27	62	15	316	108	82	3.66	5	0.49	3.45	6.00
6	53.51	39.03	7.46	18	2	30	41	15	296	109	75	2.97	6	0.33	3.90	5.24
7	59.00	35.54	5.46	34	11	43	65	18	310	156	100	5.95	7	0.56	5.28	5.18
8	52.56	37.18	10.26	40	7	56	82	20	358	189	115	5.98	8	0.39	5.00	4.90
9	50.74	39.64	9.62	44	9	63	89	25	384	209	143	6.47	8	0.42	4.52	3.20
10	55.21	35.77	9.02	40	7	62	80	23	360	194	135	5.84	6	0.43	5.17	6.40
11	54.05	36.26	9.69	25	5	42	47	18	320	136	103	4.12	6	0.49	4.65	6.62
12	52.29	37.22	10.49	32	9	63	65	21	342	163	130	5.09	8	0.46	5.14	5.60
13	55.26	36.16	8.58	47	2	61	86	20	386	187	118	6.17	8	0.24	5.34	6.30
14	53.40	37.66	8.94	39	2	61	71	18	310	166	102	5.48	7	0.23	4.62	4.40
15	50.14	40.02	9.84	35	4	54	61	19	360	137	96	4.36	6	0.38	4.28	5.80

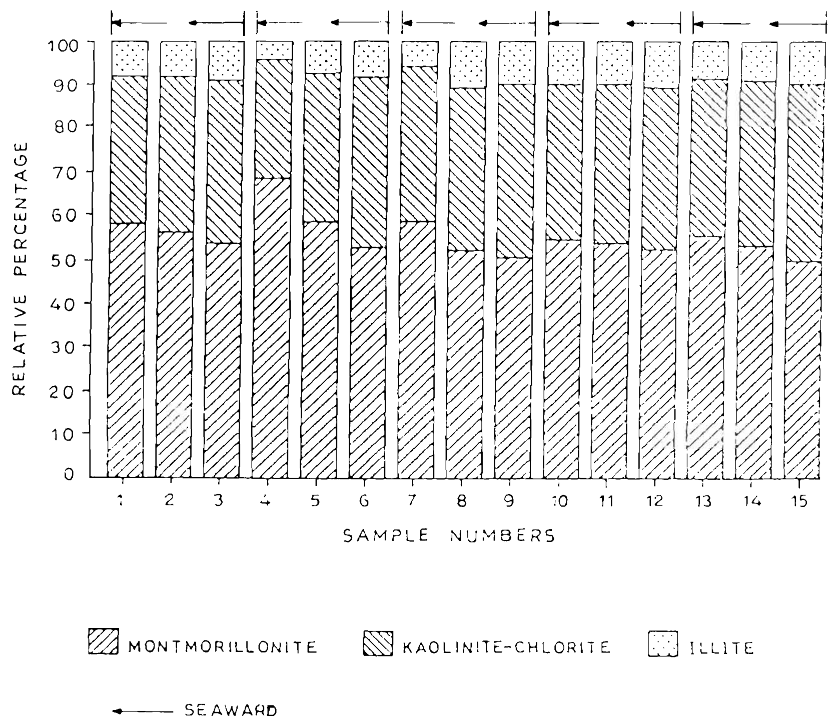

Figure 2. Bar graphs showing relative percentage of clays along 5 transects.

Table 2. *Varimax rotated R-mode factor loading matrix.*

Factor 1	Factor 2	Factor 3	Variable
− 0.0976	− 0.9527	0.1315	Montmorillonite
0.0495	0.9363	− 0.2111	Kaolinite-Chlorite
0.3140	0.7785	− 0.1763	Illite
0.9396	0.0989	− 0.1475	Cu
0.3667	0.0470	0.8810	Pb
0.8847	0.2355	− 0.1465	Zn
0.8859	0.1786	− 0.0770	Ni
0.8692	− 0.1139	0.1212	Co
0.6741	0.0497	− 0.5032	Mn
0.9472	0.1665	0.1561	Cr
0.8383	0.3933	0.0274	V
0.9277	0.0103	0.2366	Fe
0.5289	0.6699	0.2180	Al
− 0.2153	− 0.2304	0.8719	Ti
0.3411	− 0.8469	0.0340	Organic Matter
− 0.2533	− 0.5580	− 0.1491	Ca

atively higher on the inner parts of inner shelf. This could be attributed to the settling velocities of these minerals which tend to increase rapidly with a slight increase in salinity (WHITEHOUSE and JEFFERY, 1953). As the clay minerals enter the marine environment from the terrestrial fresh water condition, the settling velocities of kaolinite and illite are such that their deposition takes place at shallower depths, near the shore. This condition may help explain the concentration of kaolinite-chlorite and illite on the inner part of inner shelf sediments rather than further seaward of the study area.

Clay minerals are viewed as good carriers of trace elements since they absorb trace elements through cation exchange (GREENLAND and HAYES, 1978). But the nature of clays also plays a significant role in the absorption of trace elements (GRIM, 1968). In the present investigation, the results of the factor analysis do not show any relationship between trace elements and clay minerals (Table 2). The clay minerals in the sediments are mainly of detrital nature and the desorption of trace elements takes place from these detrital clay mineral surfaces on contact with sea water (MURTY *et al.*, 1973). This may be the reason for the absence of any obvious association between trace elements and clay minerals. Deprotonation of iron hydroxide surfaces of the clays by sodium chloride present in sea water creates an electrostatic repulsion between trace elements and the clay mineral surfaces, and this may be one of the explanations for the desorption mechanism (CHANDRASHEKARAM and USHAKUMARI, 1987).

We note strong negative loadings for montmorillonite and calcium, and positive loadings for kaolinite-chlorite and illite in Factor-2 (Table 2). This would suggest: (1) formation of montmorillonite in association with calcium, and (2) the possible role of calcium which tends to block the formation of kaolinite-chlorite and illite. The availability of Ca usually favours the formation of montmorillonite (DEER *et al.*, 1966) and tends to block the formation of kaolinite (MILLOT, 1942).

CONCLUSIONS

The clay minerals in the sediments off Gangolli, India, in the following order of decreasing abundance are: montmorillonite, kaolinite-chlorite, illite and gibbsite, and non-clay mineral quartz. The noticeable increase in montmorillonite content in a seaward direction toward deeper water can be attributed to its smaller size which results in suspension for longer periods and greater dispersal. The decrease in kaolinite-chlorite and illite towards offshore and their strong factor loadings with Al is interpreted as a function of their terrestrial origin. The absence of relationships between clay minerals and trace elements can be attributed to desorption mechanisms that take place as clays enter the marine environment. The abundance of organic matter and calcium supports the formation of montmorillonite, while calcium may block the formation of kaolinite-chlorite and illite.

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□ RÉSUMÉ □

Le plateau continental situé au large de Gangolli, sur la côte ouest de l'Inde est principalement composé d'argiles silteuses et de silts argileux. Les minéraux argileux présents sont, par ordre d'importance décroissante: montmorillonite, kaolinite-chlorite, illite et gibbsite. L'abondance relative de kaolinite-chlorite et d'illite décroit vers le large, tandis que la montmorillonite augmente. Les minéraux argileux ne présentment pas d'associations distinctes avec les éléments en trace. Ce fait peut être attribué au mécanisme de désorption dans les environments marins. La matière organique permet la formation de la montmorillonite. Le présence de calcium la favorise aussi, mais pas celle de la kaolinite-chhlorite, ni de l'illite.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

□ ZUSAMMENFASSUNG □

An der Westküste Indiens bestehen die inneren Schelfsedimente vor Gangolli hauptsächlich aus schluffigen Tonen und tonigen Schluffen. Die vorhandenen Tonminerale sind gemäβ der Häufigkeit ihres Auftretens: Montmorillonit, Kaolinit-Chlorit, Illit und Gibbsit. Die relative Hüfigkeit von Kaolinit-Chlorit und Illit nimmt meerwärts ab, während gleichzietig der Montmorillonitanteil zunimmt. Die Tonminerale zeigen keine Präferenz der Adsorption von Spurenelementen, was sich eventuell aus der Desorption im marinen Milieu erklärt. Das Vorhandensein von organischem Material unterstützt die Montmorillonitbildung. Auch die Anwesenheit von Kalzium begünstigt die Genese von Montmorillonit, nicht jedoch diejenige von Kaolinit-Chlorit oder Illit.—*Helmut Brückner, Geographisches Institut, Universität Düsseldorf, Universitätsstr. 1, D-4000 Düsseldorf 1, F.R.6*