Journal of Coastal Research	5	3	541-546	Charlottesville, Virginia	Summer 1989

Lack of Cross-shelf Transport of Sediments on the Western Margin of India: Evidence from Clay Mineralogy

V. Ramaswamy and R. R. Nair

National Institute of
Oceanography
Dona Paula, Goa—403 004
India

ABSTRACT

RAMASWAMY, V. and NAIR, R. R., 1989. Lack of cross-shelf transport of sediments on the western margin of India: evidence from clay mineralogy. *Journal of Coastal Research*, 5(3), 541-546. Charlottesville (Virginia), ISSN 0749-0208.

The distribution of clay minerals on the inner shelf, outer shelf and in a 6 month sediment trap on the western continental shelf of India has been studied. Marked compositional differences in the inner shelf clays (montomorillonite dominated) and the outer shelf clays (illite dominated) are noted. Inner shelf clay sources are the contemporary rivers draining the west coast of India while the outer shelf clays appear to have been derived from the Indus RIver. Though fine sediments have been transported long distances along the shelf, cross-shelf transport appears to be minimal. Confirmatory evidence of qualitative differences in outer and inner shelf clays is provided by sediment trap clay mineralogy on the outer shelf. Clay bound pollutant discharge is likely to be confined to the inner continental shelf.

ADDITIONAL INDEX WORDS: *Continental shelf, sediment trap, clay mineralogy, sediment transport.*

INTRODUCTION

Fine sediments can form appreciable deposits on continental shelves when the supply of sediments is more than the dispersal rate (McCAVE, 1972). Most of the suspended load is deposited in estuaries and near coastal areas due to rapid settling aided by flocculation and biological aggregation (DRAKE, 1976). The outer shelf of most continental shelves are devoid of fine sediments and are composed of relict sands deposited during lowered sea levels (EMERY, 1968). Circulation patterns on the inner shelves oppose the seaward transport of fine sediments and consequently mud delivered by major rivers may be moved alongshore and accreted to the coast (DRAKE, 1977). Internal waves impinging on the shelf edge may resuspend fine grained sediments from the sea floor to the bottom nepheloid layer, which may then be transported by the prevailing current direction (SOUTHARD and STANLEY 1976). Fine sediments can be transported long distances by the prevailing currents on continental shelves. Transport of sediments on the continental shelf can take place along shelf or across the shelf. The relative importance of these two processes has implications not only for sedimentary processes but also to the applied problem of pollutant retention within the shelf sediments and their disposal strategy. The purpose of this paper is to compare the clay mineralogy of the outer and inner shelf sediments as related to their source and dispersal.

88025 received 21 April 1988; accepted in revision 14 September 1988.

THE STUDY AREA

The western continental margin of India has been described by NAIR *et al.*, (1978, 1980). The width of the shelf is around 100–160 km in the northern part of the shelf and widens to a maximum of 300 km north of Bombay. Further south it narrows to about 45 km at 9°N. The shelf break is generally found at a depth of 130 m. The continental shelf has a nearshore mud belt but relict sands on the outer shelf. The west coast of India receives around 3000 mm of rain annually of which around 80% occur during the southwest monsoon period between June to October. The major rivers (Indus, Narmada and Tapti) join the Arabian Sea in the northern part of the shelf whereas the southern part receives sediments from relatively smaller rivers.

The clay minerals on the inner shelf are dominated by montomorillonite (60% to 80%) followed by illite, kaolinite and chlorite (NAIR *et al.*, 1982a). The Indus River does not contribute much sediment to the inner shelf because of the tidal barrier in the Gulf of Kutch (NAIR *et al.*, 1982b).

METHODS

Twenty two grab samples distributed along the length of the outer continental shelf and spaced at about 1° interval from 9°N to 22°N on the outer shelf of the west coast of India were analyzed for clay mineralogy for the present study, (Figure 1). The sample depth ranged from 70 to 100 meters. Clay mineral data from three sediment traps deployed on the outer shelf at a depth of 115 m between June to September (RAMASWAMY 1987) were also used for this study. In addition the data on clay mineralogy from 16 inner shelf samples (Figure 1) were taken from a previous study (NAIR *et al.*, 1980).

Three sediment traps on a taut subsurface mooring were deployed at a depth of 115 m on the central part of the shelf off Goa. The traps are a modification of those described by GARDNER (1977) having a diameter of 150 mm and a height of 450 mm. The traps are deployed at depths of 30, 70 and 103 m respectively, on 5th May 1985 prior to the onset of the monsoon. The traps were closed on 1st September, 1985 with the help of a timer.

For clay mineral analysis the samples were made free of organic matter by treatment with

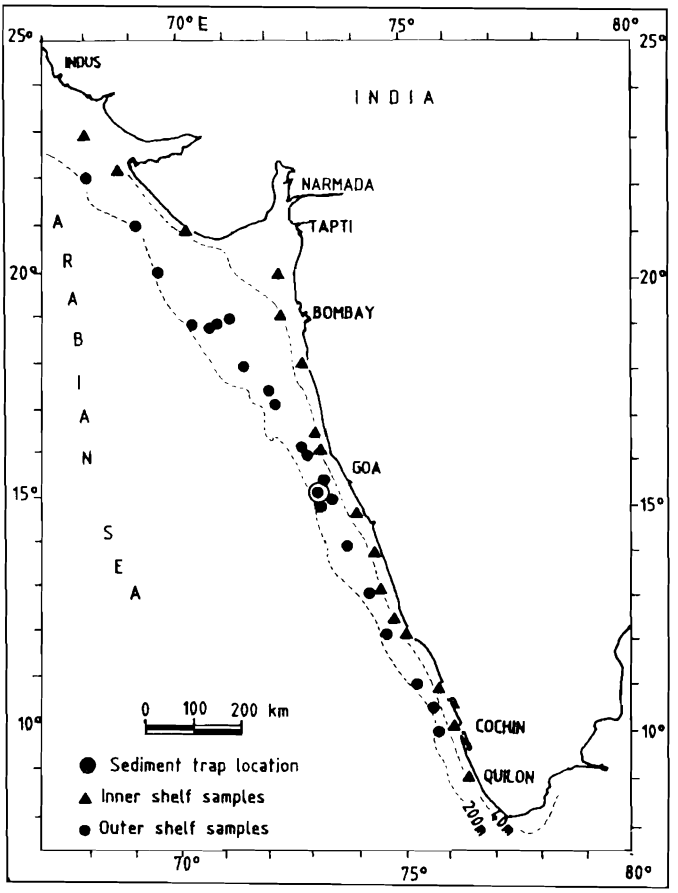

Figure 1. Figure showing sample and sediment trap locations on the western continental shelf of India.

30% hydrogen peroxide solution. Calcium carbonate was removed by treatment with dilute acetic acid. Air dried oriented clay samples were prepared by pipetting onto glass slides. These were scanned from 4° to 30° 2 θ at 2° 2 θ0/ min on a Philips X-ray diffractometer using nickel filtered Cu K_{α} radiation. The relative proportions of clay minerals were determined by measuring the area of their principal reflections above the base line. The clay mineral percentages were determined by following the weighted peak area method of BISCAYE (1965). The results obtained are semi-quantitative but are useful in determining the trend of clay mineral distribution.

RESULTS

The clay mineral percentages of the inner and outer shelf are shown in Figure 2. Montmorillonite is the most abundant mineral on the inner shelf followed by kaolinite, illite and chlorite whereas in the outer shelf sediments, illite is the major mineral followed by kaolinite and montmorillonite. Illite percentage decreases and kaolinite increases towards the southern part of the shelf. The principal source of illite in the Arabian Sea is the Indus river and consequently illite percentage decreases away from the source.

The total particle flux, $CaCO_3$, organic carbon percentage and clay mineral percentage of material collected in the sediment trap is given in Table 1 (RAMASWAMY, 1987). The total particle flux of the outer shelf off Goa is very low compared to other near coastal areas which range between 2 – 200 mg. $m^2.day^{-1}$ (LARRANCE *et al.*, 1979, LANDING AND FEELY, 1981). The total particle flux on the outer shelf is only marginally higher than those reported

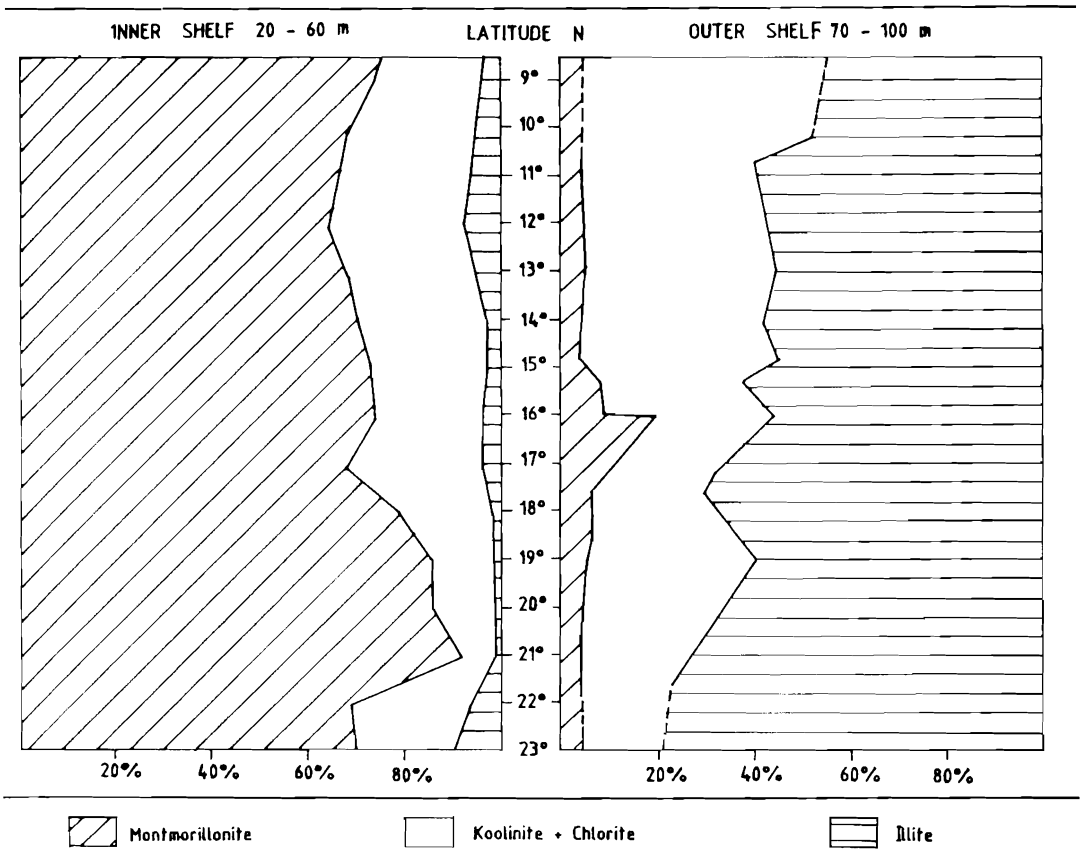

Figure 2. Clay mineral distribution on the inner and outer shelf on the western continental shelf of India.

Table 1. *Total particle flux and component flux to the outer shelf of the western continental shelf of India measured by sediment traps.*

Sediment trap No.	Depth in m	Total particle flux.mg.m.^{2} day^{-1}	CaCO %	Organic carbon %	Relative Clay mineral percentage I	K + C	M
S_1	30	400.1	66.4	6.4	56.8	39.5	3.7
S_2	70	178.0	44.4	10.96	60.5	35.8	3.7
S_3*	103	69.9	58.9	7.83	47.8	44.5	7.7

* The trap at 103 m failed to close and an unknown amount of sample was lost. I = Illite, K + C = Kaolinite + Chlorite, M = Montmorillonite

for the deep sea, 10 to 120 mg.m^2. day^{-1} (DEUSER, 1986). The high carbonate and low silicate percentage in the trap sample indicates a low terrigenous contribution to the outer shelf sediments.

The clay minerals present in the trap samples are similar to the bottom sediment clays in that area. The principal mineral is illite followed by kaolinite and montmorillonite (Table 1).

DISCUSSION

On the basis of clay mineral percentage, the western continental margin of India can be classified as (i) montmorillonite rich inner shelf clays and (ii) illite rich outer shelf sediments. The inner shelf sediments are mostly derived from the Narmada and Tapti Rivers and other seasonal rivers draining the west coast of India. During the southwest monsoon period there is a surface drift towards the south as a consequence of which the sediments are transported alongshore to the southern part of the shelf. PURNACHANDRA RAO *et al.*, (1983) reported montmorillonite on the southern part of the western continental shelf of Kerala (9° to 10° north) thought to have been derived from the Deccan traps 600 km to the north. Based on satellite photographs WAGLE (1985) reported a band of turbid water confined to the 20 m isobath but no cross shelf plumes were observed.

The outer shelf clay mineralogy can be explained only if we consider sources other than the rivers draining the west coast of India. Because of the fact that the relative proportion of the clay minerals are different on the inner and outer shelf their derivation from the inner shelf is marginal, if any. The other possible source is that these sediments may have been derived from the Indus river directly and transported southwards due to the action of the southwest monsoon drift (Figure 3).

Confirmatory evidence that the outer shelf clays are not derived from the inner shelf sediments is provided by sediment trap data. The illite rich clays present in these traps indicates that even during the peak of the monsoon the montmorillonite rich clays of the inner shelf do not reach the outer shelf in significant quantities.

CONCLUSIONS

(1) The continental shelf of the western margin of India has montmorillonite rich inner shelf and illite rich outer shelf sediments.

(2) Fine sediments are being transported more than 600 km alongshore towards the south but offshore transport appears to be minimal.

(3) Illite rich clays on the outer shelf are most probably derived from the Indus River and transported alongshore towards the south under the action of the south west monsoon drift.

(4) It is obvious from the data, that anthropogenically derived pollutants, most of which are associated with clay particles discharged from the coast, would tend to remain within the narrow confines of the inner continental shelf.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, NIO for permission to publish this paper. The senior author (V.R.) is thankful to the late Dr. H. N. Siddiquie, former Director, NIO, for encouragement and guidance especially in the sediment trap work.

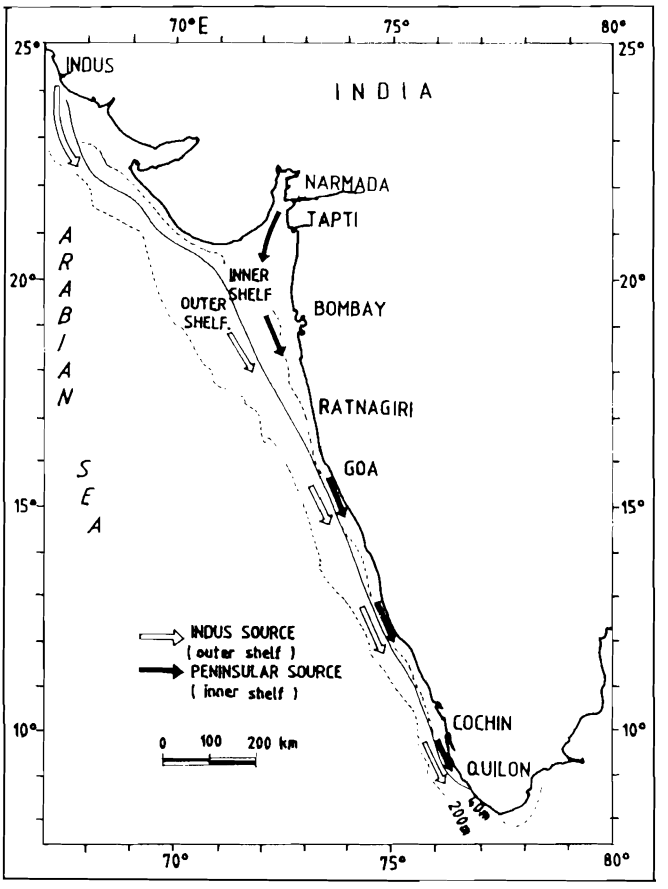

Figure 3. Map showing the major sources and dispersal of sediments on the western continental shelf of India. Arrows indicate the general direction of transport of fine grained sediment on the outer and inner shelf. The solid line indicates the approximate boundary between the inner and outer shelf.

LITERATURE CITED

BISCAYE, P. E., 1965. Mineralogy and sedimentation of recent deep-sea clays in the Atlantic ocean and adjacent seas and oceans. *Geological Society of America Bulletin*, 76, 803–832.

DEUSER, W. G., 1986. Seasonal and interannual variation in deep water particle fluxes in the Sargasso sea and their surface hydrography. *Deep-Sea Research*, 33, 225–246.

DRAKE, D. E., 1976. Suspended sediment transport and mud deposition on continental shelves. *In:* SWIFT, D. J. P. and STANLEY, D. J., (eds), *Marine sediment transport and environmental management.* New York: Wiley, pp. 127–158.

EMERY, K. O., 1968. Relict sediments on continental shelves of the world. *Bulletin of the American Association of Petroleum Geologist*, 52, 445–64.

GARDNER, W. D., 1977. Fluxes, dynamics and chemistry of particulates in the ocean. *Ph.D. Dissertation M.I.T./Woods Hole Oceanographic Institution*, Cambridge, Massachusetts, 405p.

LANDING, W. M. and FEELY R. A., 1981. The chemistry and vertical flux of particles in the Northeastern Gulf of Alaska. *Deep-Sea Research*, 28, 19–37.

LARRANCE, J. D., CHESTER, A. J. and MILBURN, H. B., 1979. A new sediment trap and particle flux measurements in Lower Cook Inlet Alaska. *Marine Science Communications*, 5 (4 & 5), 269–282.

McCAVE, I. N., 1972. Transport and escape of fine grained sediments from shelf areas. *In*: SWIFT, D. J. P.; DUANE, D. B. and PILKEY, O. H., (eds), *Shelf sediment Transport.* Stroudsburg, PA: Dodwen Hutchinson and Ross, pp. 225–248.

NAIR, R. R., HASHIMI, N. H., KIDWAI, R. M., GUPTHA, M. V. S., PAROPKARI, A. L., AMBRE, N. V., MURALINATH, A. S., MASCARENHAS, A., and D'COSTA, G. P., 1978. Topography and sediments of

the western continental shelf of India-Vengurla to Mangalore. *Indian Journal of Marine Sciences*, 7, 224–230.

NAIR, R. R. and HASHIMI, N. H., 1980. Holocene climate inferences from the sediments of the western Indian continental shelf. *Proceedings Indian Academy Sciences (Earth and Planetary Sciences)*, 89, 299–315.

NAIR, R. R., HASHIMI, N. H. and RAO, V. P., 1982a. Distribution and dispersal of clay minerals on the western continental shelf of India. *Marine Geology*, 50, MI-M9.

NAIR, R. R., HASHIMI, N. H., and RAO, V. P., 1982b. On the possibility of high velocity tidal streams as dynamic barriers to longshore sediment transport: evidence from the continental shelf off the Gulf of Kutch, India. *Marine Geology*, 47, 77–86.

PURNACHANDRA RAO, V., NAIR, R. R., and HASHIMI, N. H., 1983. Clay mineral distribution on the Kerala continental shelf and slope. *Journal of the Geological Society of India*, 24, 10, 540–546.

RAMASWAMY, V., 1987. Particle flux during the southwest monsoon on the western margin of India. *In*: DEGEN, E. T., IZDAR, E. and HONJO, S., (eds), *Particle Flux in the Oceans*. SCOPE/UNEP Sonderband. Heft 62. Mitteilungen ans dem Geologisch-Palaontologisches institut der Universitat Hamburg, pp. 233–242.

SOUTHARD, J. B. and STANLEY, D. J. 1976. Shelf break processes and sedimentation. *In*: STANLEY, D. J. and SWIFT, D J. P., (eds), *Marine Sediment Transport and Environmental Management*. New York: Wiley, pp. 351–378.

WAGLE, B. G., 1985. Distribution and dispersion of turbid waters on the continental shelf of India—An interpretation of LANDSAT images. *International Journal of Remote Sensing* 6, 1681–1684.

RESUMEN

Se ha estudiado la distrobución de arcillas minerales sobre la plataforma interior, exterior y en los sedimentos atrapados en los últimos seis meses en la plataforma continental oeste de La India. Se notó marcadas diferencias de composición en las arcillas de la plataforma interior (predominio de monmorillonita) y de las arcillas de la plataforma exterior (predominando Ilitas). Las fuentes de las arcillas de la plataforma interior son los desagües de los rios actuales de la costa oeste de La India, mientras las arcillas de la plataforma exterior parece que vienen del rio Indo.

Aunque los sedimentos finos han sido transportados largas distancias a lo largo de la plataforma, el transporte a través de la misma parece ser minimo. La evidencia que confirma las diferencias cualitativas entre las arcillas de la plataforma exterior e interior provienen de la mineralogia de los sedimentos de arcilla atrapados en la plataforma exterior.—*Department of Water Sciences, University of Cantabria, Santander, Spain.*

RÉSUMÉ

Etudie la distribution des minéraux argileux sur l'ensemble du plateau continental grâce à 6 mois de piégeage de sédiments. Les argiles du proche plateau continental (à dominance de montmorillonite) montrent des différences marquées de composition. Les sources argileuses y sont les rivières actuelles drainant la côte ouest de l'Inde, alors que les argiles de la partie externe du plateau continental semblent avoir dérivé depuis l'Indus. Bien que les sédiments fins aient été transportés sur de grandes distances le long du plateau continental, le transport transversal est minimal. La minéralogie des argiles piégées sur la partie externe du plateau continental confirme les différences qualitatives d'avec celles du proche plateau continental. La limite de la décharge de boues polluantes doit donc être limitée au proche plateau continental.—*Catherine Bressolier, Laboratoire de Géomorphologie EPHE, Montrouge, France.*

ZUSAMMENFASSUNG

Das Fehlen von Sedimenttransport über dem Schelf von Westindien: Ergebnis der Tonmineralogie.

Es wurde die Verteilung der Tonminerale auf dem inneren und äußeren Schelf sowie in einer 6-monatigen Sedimentfalle im Western von Indien untersucht. Markante Unterschiede in der Zusammensetzung der Tone vom inneren (überweigend Montmorillonite) und vom äußeren Schelf (vorwiegend Illit) wurde erkannt. Liefergebiete für den inneren Schelf sind die Flüsse, welche gegenwärtig die Westküsten Indiens entwässern, während die Minerals des äußern Schelfs vom Indus angeliefert zu sein scheinen. Obwohl Feinsedimente über lange Distanzen auf dem Schelf transportiert werden, erscheint der Transport quer zum Schelfverlauf minmal. Sichere Ergebnisse und qualitative Unterschiede zwischen den Tonmineralien vom inneren und äußeren Schelf wurden durch Sedimentfallen geliefert. Danach ist die Anlieferung von Verunreinigungen auf den inneren Schelf beschränkt.—*D. Kelletat, Essen.*