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CLAYS OF HUDSON RIVER

CLAY MINERALOGY OF THE HUDSON RIVER AND ESTUARY

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ABSTRACT

Bottom and suspended sediment samples from along the lower 120 km of the Hudson River estuary, U.S.A., were analyzed for their clay mineralogy. A uniform composition along the estuary was found for mica (65%±4), chlorite (24%±4), and kaolinite (10%±1). Only smectite exhibited a trend by its absence in the upper estuary above 60 km and being < 5% in the lower estuary. This uniform clay mineralogy (CM) is attributed to the strong tidal currents mixing the flocs with uniform CM along the estuary.

INTRODUCTION

Background on Clay Minerals Trends

The lateral variations of the clay minerals (cm) in bottom sediments extending seaward from river mouth has been discussed by Van Andel and Postma (1954), Porrenga (1966), Powers (1957), and Edzwald and O'Melia (1975). The studies by Griffin and Ingram (1955), Powers (1954), and Nelson (1960) postulated that diagenetic processes caused the clay mineral trends that were encountered in the coastal plain estuaries. Later, the work of Russell (1970) and Drever (1971) discounted the idea of diagenesis and showed that the clays were subjected to cation exchange reactions without changing the clay minerals themselves. Another potential source of clay mineral trends in an estuary or shelf is multiple inputs (ocean and river) of clay minerals was postulated by Postma (1967) and Meade (1972) as being caused by estuarine circulation which brought in different clay minerals landward from the ocean. This was followed by the work of Hathaway (1972) and Gibbs (1977) that suggested a primary particle size segregation with distance was causing a trend in the clay minerals on shelves. In addition, the process of differential coagulation was postulated as a mechanism causing trends in the clay mineralogy of bottom sediments of estuaries by Whitehouse et al. (1960), Edzwald and O'Melia (1975) and discussed by Gibbs (1977). The work of Allen (1991) on the Severn estuary showed fairly constant composition down the estuary and a dominant source of clays coming in from the river. The CM in the Fly River basin and delta was reviewed by Harris et al. (1993), but he didn't give detail CM trends. The work of Subramanian and Jha (1988) on the CM in the bed sediments of the Ganges showed no clear trends in the lower 125 km Hoogly River (part of the Ganges). In Europe the river/estuaries studies of Boldrin et al. (1988) on the Po and that of Gallene (1974) on the Loire are worth mentioning. In three estuaries in Georgia, U.S.A., Windom et al. (1971) found clay minerals coming in from both the ocean and rivers. An interesting study of 34 rivers around New Zealand (Churchman et al., 1988)

showed mica dominated along with smectite.

Background on Hudson River Estuary

Intrusion of sea water varies between 50 and 110 km (35 and 75 miles) from the ocean, and its location is dominated by freshwater discharge and secondarily affected by tidal phases (Abood, 1974; Posamentier and Raymont, 1979). Stratification decreases downstream from furthest intrusion, but vertical circulation is relatively low above The Battery (Posamentier & Raymont, 1979), except near shallow margins where mixing reduces stratification. Tidal power is greatest below Haverstraw Bay and stronger during flood than ebb (Abood, 1974; Panuzio, 1963). Surface currents reach 2 m/s (NOAA, tide tables, 1992). Pritchard et al. (1962) and Jay and Bowman (1975) conducted additional investigations of the physical structure and circulation in the lower Hudson. The existence of two turbidity maxima is perhaps distinctive of the Hudson. One maximum in Haverstraw Bay is related to the salt/fresh water interface. A second maximum near the George Washington Bridge appears to be caused by lateral circulation induced by hydrodynamic constriction.

Aims

The purpose of this paper is to present the results of the clay mineralogy of the Hudson River estuary and lower Hudson River and to postulate the role of flocs in the transport and deposition of clay minerals.

METHODS

The samples for this study were collected near the center along the length of the Hudson Estuary/River up to 120km from the ocean (Figure 1). The samples were collected from the bottom of estuary using a pipe dredge that sampled the surface 8 cm, with the exception of two filtered samples of flocculated suspended material. The samples were deflocculated by dialysis to remove sea water, treated with sodium hexametaphosphate and size segregated by standard centrifugal techniques (Jackson, 1956) to obtain the less than 2 micrometer fractions. These muds were then mounted on glass slides using the smear technique to produce oriented clays (Gibbs, 1965). The analysis was conducted on a Phillips X-ray diffraction unit using CuKα radiation (35 Kv and 20 Ma) with Ni filter with a Phillips monochrometer between 2-14° 2θ and 22-26° 2θ utilizing standard techniques (Gibbs, 1967) and the percentages determination followed the procedure of Biscaye (1965).

RESULTS

The trends of clay minerals up the estuary from the ocean are presented in Figure 2, and they show that the percent of mica, chlorite and kaolinite remains constant from the ocean to 120 km inland in the bottom sediments and that smectite is the only mineral (rather small in percentages, always less than 5%), that shows a minor trend from 0 to 60 km, whereas above 62 km from the ocean there is no smectite present in the bottom sediments.

DISCUSSION

These percentages of clay minerals are remarkably constant throughout the entire estuary of the Hudson River as well as 120 Km up the river. The sample at 120 Km from the ocean is in fresh water and would be before significant coagulation occurred. Most all of the other studies of estuaries, as discussed in the Introduction, showed some trends in the minerals changing along the length of the estuary. Allen's work (1991) in the Severn estuary showed similar results to this study, in having a nearly constant composition along the estuary. The Severn estuary, like the Hudson estuary, has high tidal currents.

In the case of the Hudson River, the input of suspended clay minerals comes in from the Hudson River. The clay minerals then coagulate forming flocs (coagulation observed by microscope) at about ½ ppt salinity. This coagulation occurs upstream of the salt water intrusion so its position would shift with river discharge between 50 and 1150 Km from the ocean. Once formed it is postulated that these flocs are carried back and forth by the strong tidal currents, to produce this uniform composition. In Figure 3 the photomicrograph of the flocs in suspension shows all the clays in flocs with clear water between them. The only trend found is for smectite where a small amount (2-5%) in the lower 60 km of the Hudson estuary from New York Harbor up into lower Haverstraw Bay. This smectite percent correlated with the trend in the salinity due to intrusion from the ocean. The smectite could be imported from the ocean -- but still in all, it is a very low amount.

In suspended samples from 18 and 78 Km in from the ocean the composition of the CM in the flocs in suspension has the same composition as the bottom mud beneath it and is the same for flocs from widely different locations (not shown on graph). These observations suggest that coagulation "freezes" the composition of the flocs and then the flocs are distributed along the estuary.

In the case of the Hudson River, it appears that differential flocculation does not have an effect. If it did, a change in the percent of mica and kaolinite as it coagulates above Peekskill would be observed because based on the work of Whitehouse et al. (1960) and Gibbs (1983) it would be expected that these clays would coagulate first at a couple ppt salinity. It has been shown that illite alone coagulates 2½ times as fast as kaolinite alone at the salinity of the first coagulation (Whitehouse et al., 1960; Edzwald et al., 1974; Gibbs, 1983). The differential coagulation studies on clay minerals mostly studied individual clays not natural mixtures with coatings and what probably is occuring is a mutual coagulation of these natural mixtures. Likewise, the primary particle size segregation doesn't seem to be prevalent as was proposed by Gibbs (1977). Gibbs' (1977) study of the Amazon River showed trends in clay minerals over 1400 km, whereas this study is less than 120 km and the distance may simply not be large enough to produce this trend. The complete lack of a trend would indicate that the flocs once formed in upper Hudson River estuary are then just being distributed along the entire length of the estuary with no segregation of the minerals by primary particle size. Or else the mica, kaolinite and chlorite have the same primary particle size distributions and therefore could not be size segregated. Smectites are usually the smallest particles relative to the other clays and therefore would be the easiest to size segregate -- but the Hudson River supplies none. There is a minor trend of smectites coming in from the ocean in the lower 60 km of the estuary. The work of Hathaway (1972) showed trace amounts of montmorillonite in these offshore areas, so the ocean would appear to be a significant source. There are, however, a number of other rivers and man-made sources which could cause this minor (<5%) trend.

This study shows that CM progressive change with distance in estuaries and off river mouths is not always to be expected. This has implications for (1) predicating sediment patterns of fine-grained sediments and (2) predicting sediment source in studies of ancient mud records. Just because no trend is found in ancient sediments does not rule out a estuary/river mouth environment. Since these clay minerals are the major toxic substance carriers in these environments, these findings are of interest to researchers involved in toxic transport and modelling. It should also indicate that coagulation as a mechanism controlling size and composition in geological and engineering studies should be studied and encouraged in future studies.

CONCLUSION

The Hudson River estuary exhibits a uniform clay mineral composition along the lower 120 km except for a minor (< 5%) amount of smectite toward the ocean. While many other estuaries show trends, in the case of the Hudson River estuary this lack of a trend is attributed to coagulated clays being homogenized along the estuary by high tidal currents.

FIGURE CAPTION

FIGURE 1. Area location map.

FIGURE 2. Clay mineral percent versus distance from ocean (km) for Chlorite (*), Kaolinite (□), Mica (+) and Smectite (■) in bottom sediments.

FIGURE 3. Photomicrograph of suspended floc from Hudson River Estuary. Bar is 100 μm long.

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Chlorite (*), Kaolinite (□), Mica (+), Smectite (■)

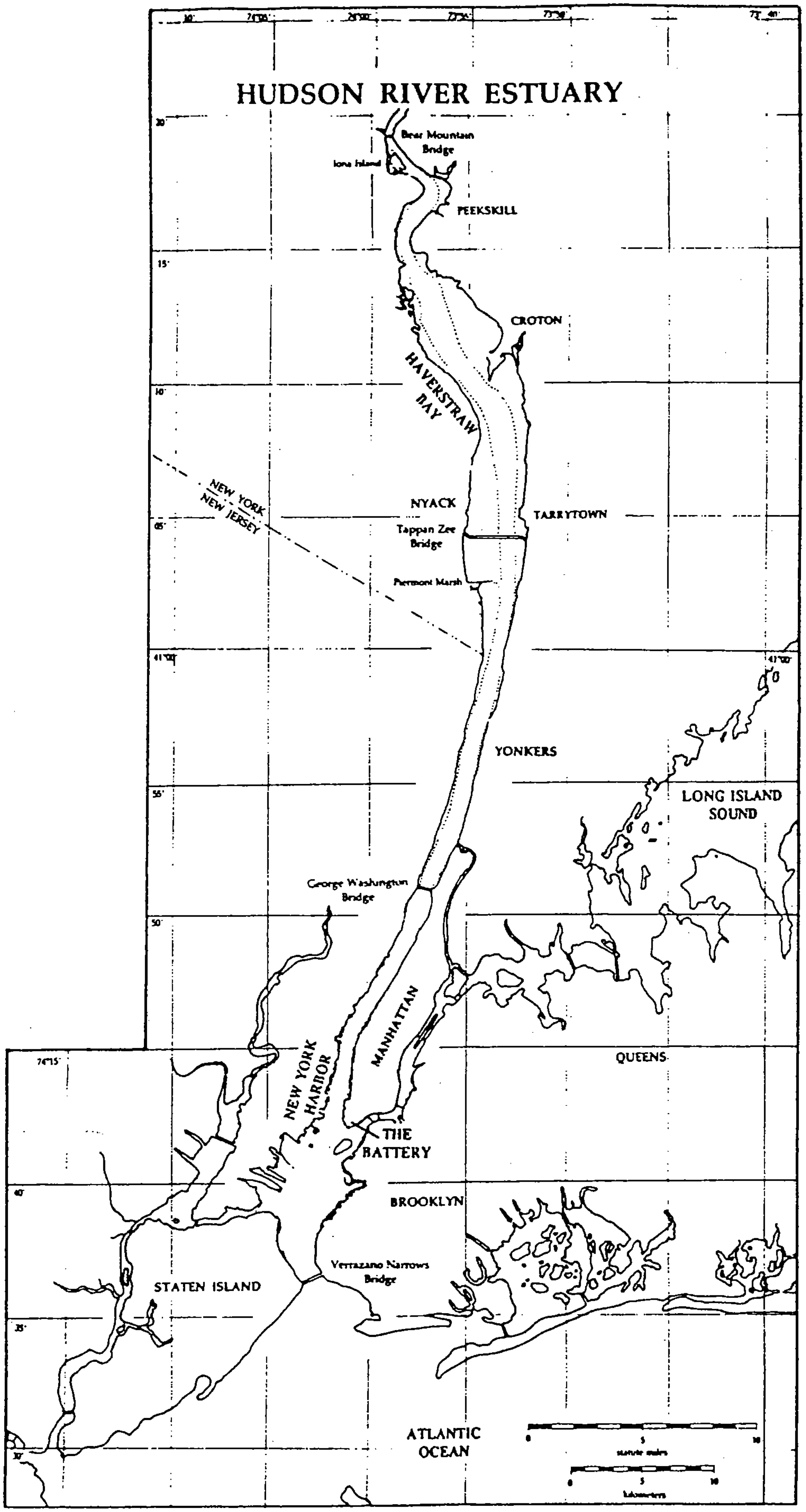
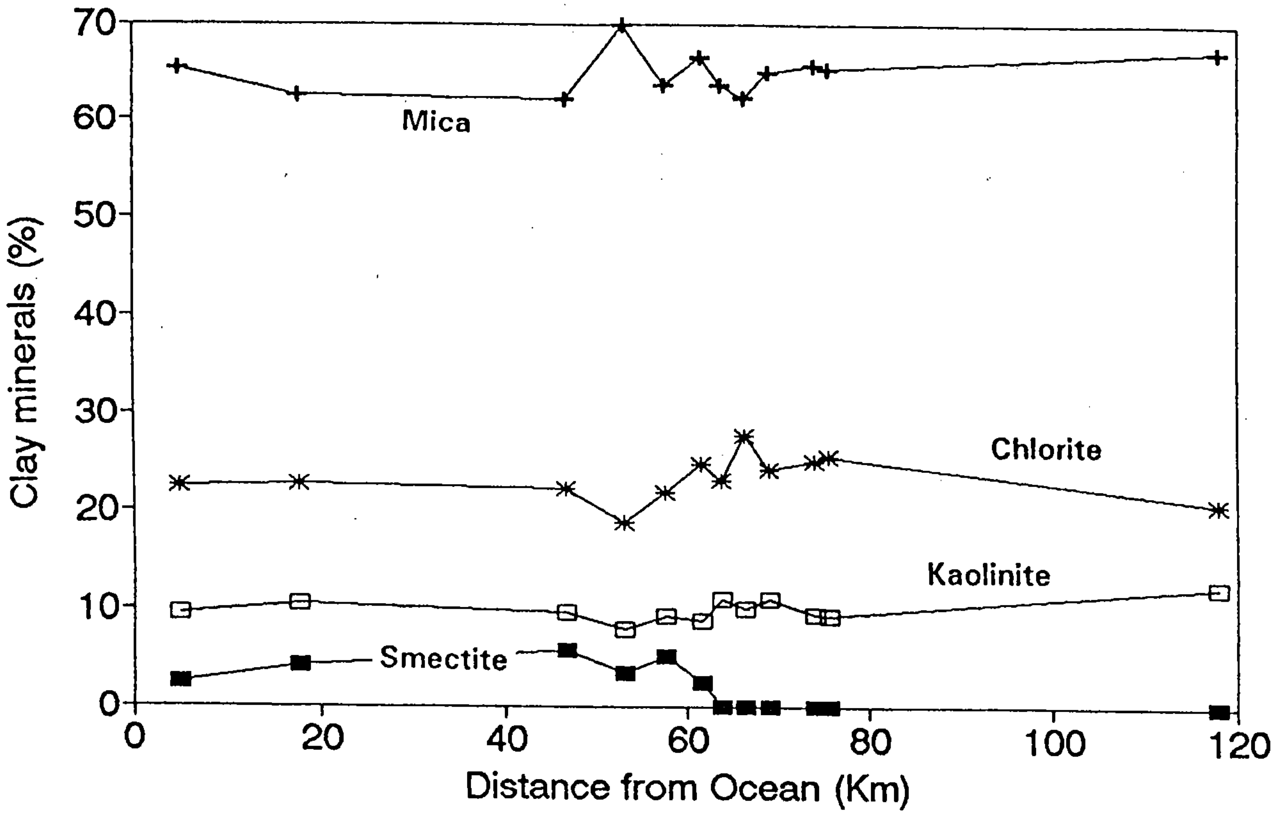
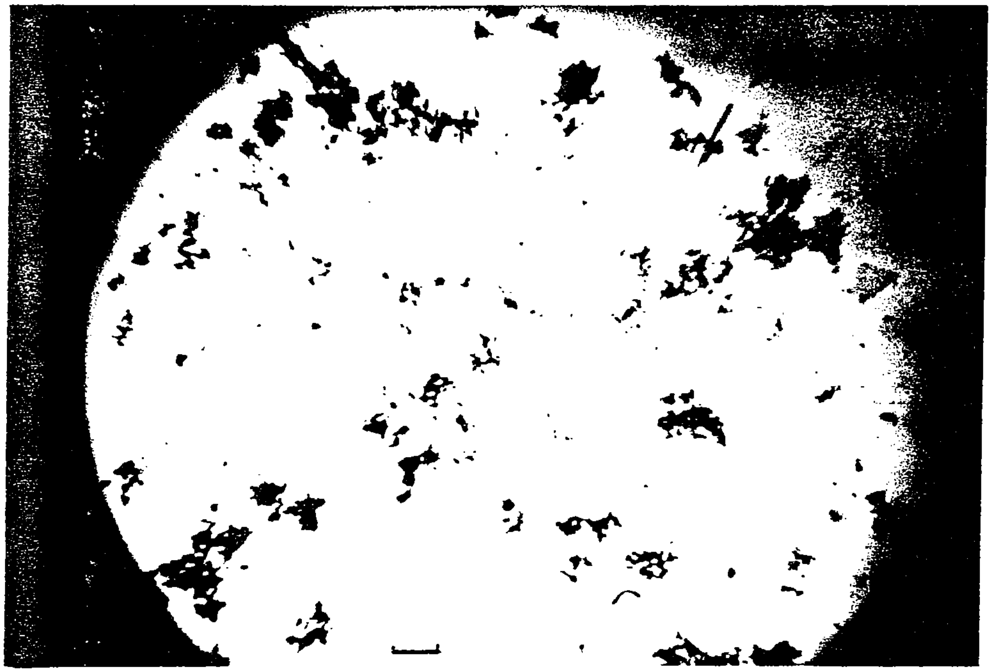

HUDSON RIVER ESTUARY
Bear Mountain Bridge
Iona Island
PEEKSKILL
CROTON
HAVERSTRAW BAY
NEW YORK
NEW JERSEY
NYACK
TARRYTOWN
Tappan Zee Bridge
Piermont Marsh
41°00'
YONKERS
LONG ISLAND SOUND
George Washington Bridge
MANHATTAN
NEW YORK HARBOR
QUEENS
THE BATTERY
BROOKLYN
STATEN ISLAND
Verrazano Narrows Bridge
ATLANTIC OCEAN
74°15'
20'
15'
10'
05'
55'
50'
40'
35'
30'
0
5
10
statute miles
kilometers

Fig 1



Clay minerals (%)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Distance from Ocean (Km)
Mica
Chlorite
Kaolinite
Smectite

2



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