PRELIMINARY RESEARCH ON THE CLAY MINERAL COMPOSITION OF SOME SEDIMENT SAMPLES IN THE ZAIRE ESTUARY AND FAN

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PRELIMINARY RESEARCH ON THE CLAY MINERAL COMPOSITION OF SOME SEDIMENT SAMPLES IN THE ZAIRE ESTUARY AND FAN

door

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INHOUD

SUMMARY

Samples from the top-layer of some selected trip-cores from the Zaire estuary and fan were analysed for their clay mineral composition. The main feature to be distinguished is a pronounced seaward decrease in the relative percentage of kaolinite and a simultaneous increase in smectite.

RÉSUMÉ

Des échantillons de la couche supérieure de quelques carottes courtes de l'estuaire et "fan" du Zaire ont été analysés pour leur composition en minéraux argileux. La caractéristique dominante, lorsqu'on s'éloigne de la côte, est le décroissement prononcé du pourcentage relatif en kaolinite et, simultanément, l'acroissement en smectite.

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1. INTRODUCTION

In order to examine the clay mineral composition of recent sediments from the Zaire estuary and fan (Figs 1 and 2) samples were taken from the top 4 cm of some selected trip-cores (Table I) collected during the May 1978 cruise (JANSEN *et al.*, 1983).

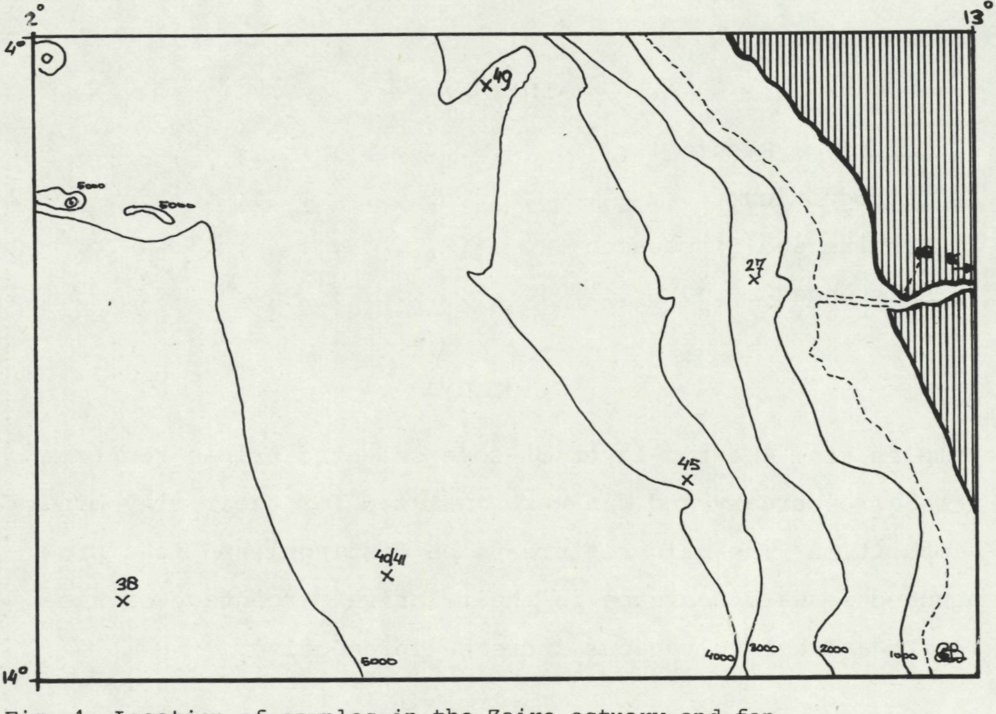

Fig. 1. Location of samples in the Zaire estuary and fan.

Analyses of the clay mineral composition were performed on the < 2 μm fraction with a Philips X-ray diffractometer, using Co $K_{d\ 1,2}$ radiation wavelength 1.7902 Å.

After separation of the < 2 μm fraction by centrifugation and subsequent coagulation as a Ca-clay no other pre-treatments, such as decalcification (DE LANGE, 1976) or iron extraction (MEHRA & JACKSON, 1960; HOLMGREN, 1967; DE LANGE, 1976), were applied to these samples. Removal of the organic material using the bromine method (VAN LANGEVELD, 1977; VAN LANGEVELD *et al.*, 1978) did not improve the diffraction pattern and this

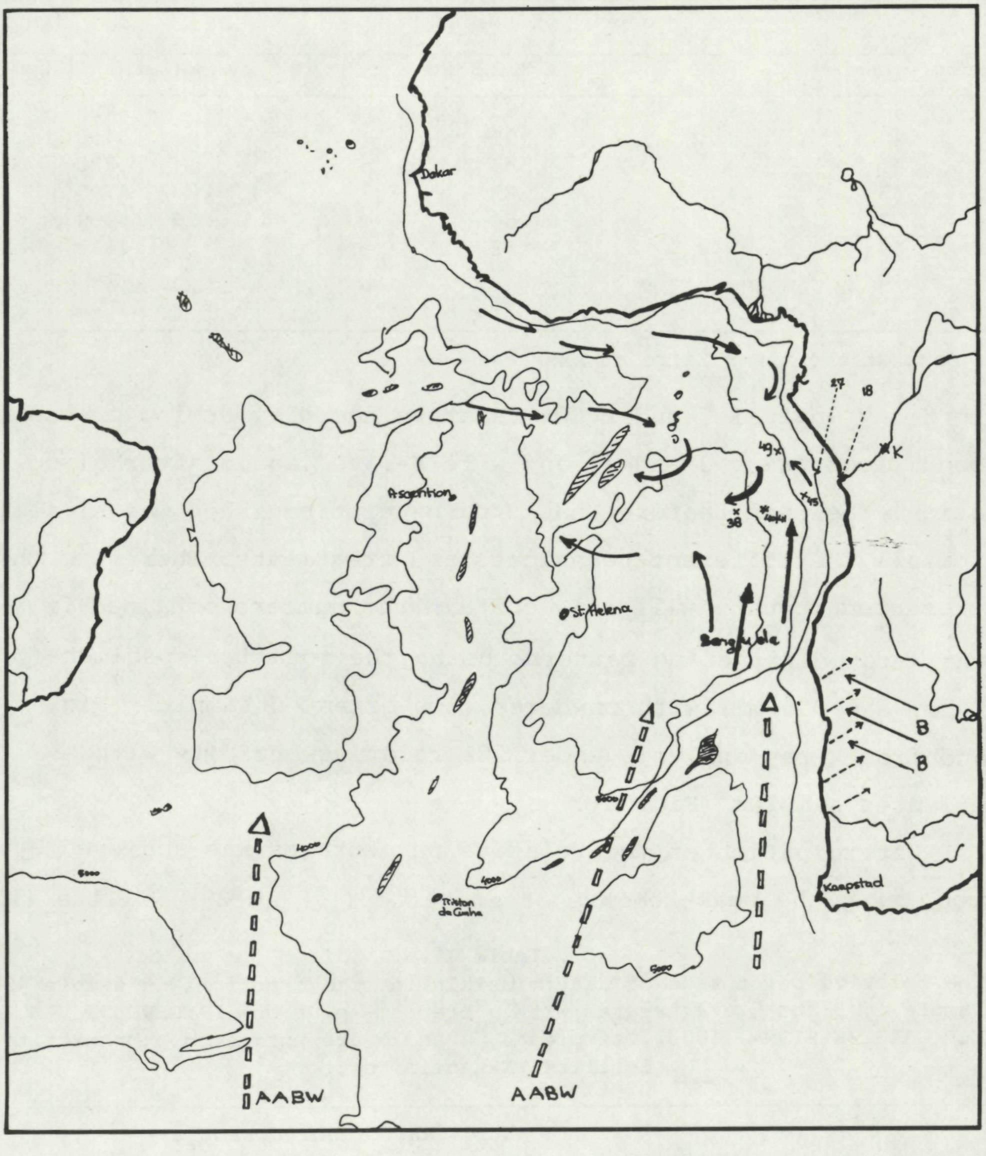

Fig. 2. South Atlantic Ocean; currents after GIRESSE (1978); AABW = Antarctic Bottom Water, B = Bergwinds (after BORNHOLD, 1973).

method was therefore only used in the test series on different grain sizes from one sample (Table II).

Powdered, oriented and non-oriented samples were subjected

Table I
Percentage of particles smaller than 2 μm, and the approximate water-depth, of the samples.

Sample number	*% < 2 μm*	*Waterdepth (m)*
38	85	1455
40	92	5450
41	83	4770
45	83	4790
27	56	4060
49	78	4330
18	73	-
K	26	*

* Bank of the river Zaire at Kinshasa

to X-ray analysis, under 50% relative humidity or low pressure conditions (Figs 3 and 4) and were X-rayed again after glycolation. The main feature that could be distinguished was similar for all the different techniques and treatments. Therefore the presented results will only contain the numbers obtained from the X-ray diffraction patterns using the rotating specimen (Ø 2 cm, d = 0.5 mm) with powdered, non-oriented samples (Fig. 5) and from X-ray analysis under 50% relative humidity with oriented samples (Fig. 6).

Determination of the relative percentages was achieved by comparing the peak-heights of smectite (17° as 2θ), illite (10°

Table II
The relative percentage of clay minerals in some fractions of sample 40. Sample 1, 3 and 5 are treated with a bromium-solution (LANGEVELD, VAN DER GAAST & EISMA, 1978), samples 2, 4 and 6 are untreated. (M=smectite; I=illite; K=kaolinite).

Sample number	*(50% RH, oriented samples)* Relative percentages of *M*	*I*	*K*	*Particle fraction*
40-1	45	12	43	< 2 μm
40-2	42	14	44	< 2 μm
40-3	33	8	59	< 1 μm
40-4	39	11	50	< 1 μm
40-5	46	7	54	< 0.5 μm
40-6	40	7	52	< 0.5 μm

Fig. 3. X-ray diffraction patterns of oriented samples, measured in a 50% relative humidity atmosphere.

Fig. 4. X-ray diffraction patterns of oriented samples at lower pressure (ca 5 mm Hg).

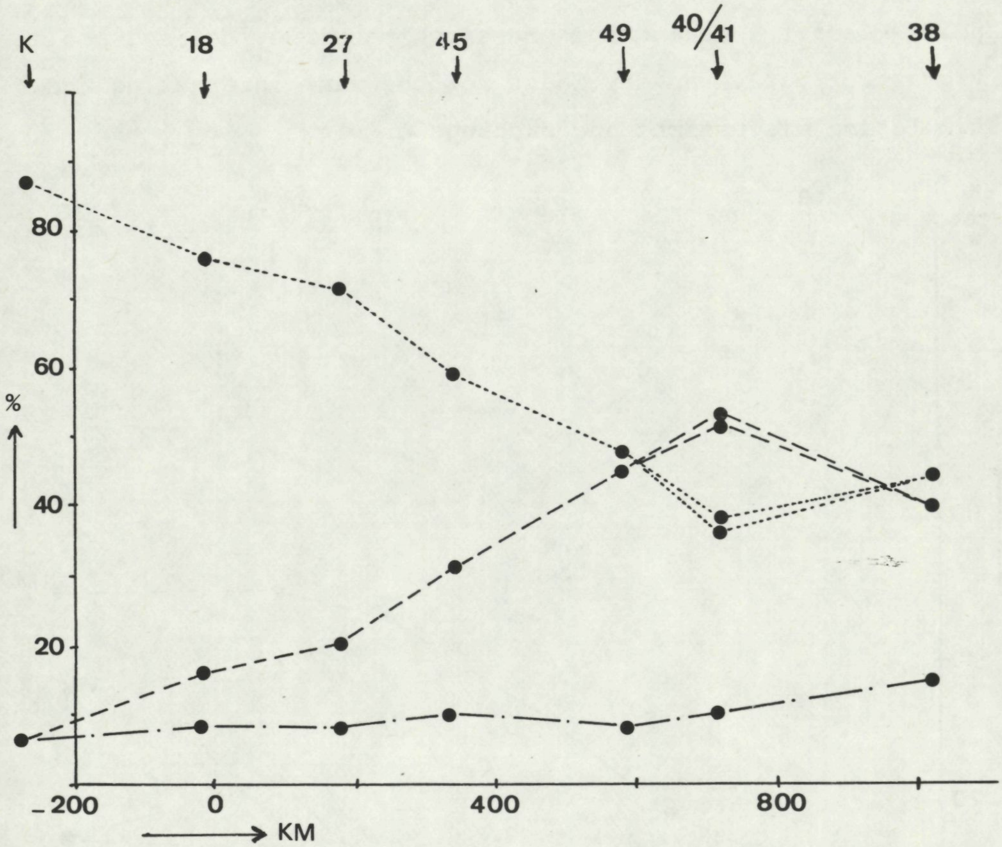

Fig. 5. The relation between the clay mineral composition and the distance from the coast. The relative clay mineral percentages were calculated from the X-ray diffraction patterns with the rotating specimen and powdered, non-oriented samples, and an atmosphere of 50% relative humidity.

as 2θ) and kaolinite (14^{o} as 2θ). The sum of the three clay minerals was taken as 100%. No corrections were made for the individual clay minerals, as done by others; the resulting relative percentages are nevertheless comparable for this region (GOLDBERG & GRIFFIN, 1964; BISCAYE, 1965; GRIFFIN *et al.*, 1968; RATEEV *et al.*, 1969; ROBERT, 1980). Chlorite could not be detected at 29.6^{o} (2θ) at $1/4^{o}$ min, with oriented untreated samples.

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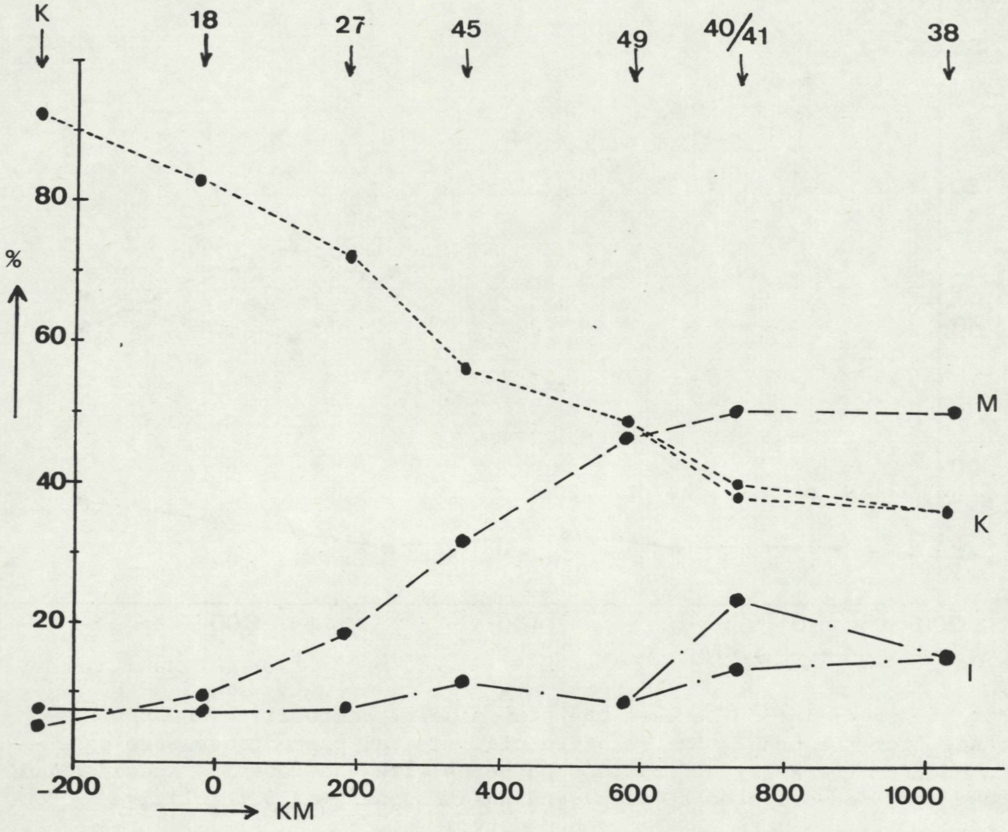

Fig. 6. The relation between the clay mineral composition and the distance from the coast. The relative clay mineral percentages were calculated from the X-ray diffraction patterns of oriented samples, with an atmospere of 50% relative humidity.

2. RESULTS AND DISCUSSION

In the relative clay mineral composition there is a pronounced decrease in the percentage of kaolinite with increasing distance from the coast (Figs 5 and 6) and a simultaneous increase in smectite. This phenomenon has already been observed by some investigators in other regions (POSTMA *et al.*, 1954; WHITEHOUSE *et al.*, 1960; BISCAYE, 1965; PORRENGA, 1967; CHAMLEY, 1979; GIBBS, 1967). This has been attributed to processes such as:

1) differential settling tendencies (POSTMA *et al.*, 1954; WHITEHOUSE *et al.*, 1960),

2) decreasing terrestrial influence (BISCAYE, 1965),

3) increasing "other source" material (CHAMLEY, 1967, 1971; HOFFERT, 1980).

It seems evident that the river Zaire, or more generally the African continent is the source of kaolinite (BORNHOLD, 1973; EISMA *et al.*, 1978) although authigenese or hydrothermal formation of kaolinite has been reported for some regions (ZEN, 1959; MULLER, 1961; SHAW, 1980; SHIEH & SUTER, 1979).

The occurrence of high relative percentages of kaolinite seems to be restricted mainly to the continental margin, due to the large settling velocity of this mineral (WHITEHOUSE *et al.*, 1960; PORRENGA, 1967). The relationship to the continents is clearly shown by a comparison of ocean sediments (GOLDBERG & GRIFFIN, 1964; BISCAYE, 1965; GRIFFIN *et al* , 1968; RATEEV *et al.*, 1969) and by the resemblance between the zonation of soils and climates on the continents and the ocean sediments (PÉDRO, 1968).

An indication for the authigenic formation of smectite in the sediments of the South Atlantic Ocean is the relative percentage of smectite in aeolian dust and surface ocean water. In the North Atlantic Ocean the concentrations of smectite in the aeolian dust/surface ocean water and the sediments show a good correlation. As the relative percentage of smectite in the sediments of the South Atlantic Ocean has doubled in comparison to the concentration in the aeolian dust/surface water, BEHAIRY *et al*. (1975) conclude that half of the smectite in the sediments of the South Atlantic Ocean must be authigenic.

Besides a terrestrial origin smectite can have various other sources, as mentioned by many authors:

Volcanic/hydrothermal origin.—High percentages of smectite in the sediment have been reported near areas with hydrothermal activity (HÉKINIAN & FEVRIER, 1979; KASTNER, 1981 and refs herein). Formation by alteration of volcanic material has been widely reported from many areas (KENNETH, 1981 and refs herein): Pacific Ocean (PETERSON et al., 1964; KASTNER, 1976, 1981; KURNOSOV et al., 1980); Mediterranean (GRIM & VERNET, 1961; CHAMLEY, 1967, 1971); Atlantic Ocean (ROBERT et al., 1979; ROBERT, 1980).

Possible volcanic areas that could contribute to our samples are the Cameroon Ridge, Mid Atlantic Ridge and Walvis Ridge. The Scotia Ridge being a source of smectite for the Argentine Basin (ZIMMERMAN, 1977) seems too far away to make any significant contribution to the Zaire region. Favourable currents do exist for the other ridges, like the Equatorial Counter Current and the Benguela Current; the influence of these currents on the Zaire region are dependant on amongst other things the presence of "glacials" and "non-glacials" (GIRESSE, 1978), the Equatorial Counter Current descending more to the south in interglacials, and the Benguela Current going far up north in glacials. As the warmer periods coincide with relatively larger concentrations of smectite in the sediment (GIRESSE, 1978; VAN DER GAAST (pers. comm.) one is tempted to look for the possible volcanic origin of smectite at the Cameroon Ridge. A present day southward flowing bottom current has also been mentioned by SHANNON (1970) in the eastern Angola Basin and postulated by SIESSER (1973, 1980) for the Miocene period.

Authigenese of smectite on silica.—It has been reported that smectite can form not only on volcanic material but also on diatom-frustules (CHAMLEY & MILLOT, 1972; VAN BENNEKOM & VAN DER GAAST, 1976; HOFFERT *et al.*, 1980). This way of formation of smectite could mean that there is a significant source of smectite in the oceans, since diatom-frustules are known to be present on a large scale in oceanic sediments. Unfortunately the frequency of occurrence and the velocity of formation are not yet known. Therefore the importance of this way of formation of smectite cannot be estimated quantitatively. However, since no striking differences have been observed between the clay mineral composition of silicious oozes and calcareous oozes, this formation method does not seem to be of major importance, unless other parameters are necessary as well. Newly formed smectite is generally highly ferrous and aluminous (PORRENGA, 1967; GIRESSE, 1975). The river Zaire is rather rich in "dissolved" (partly colloidal) iron (FIGUÈRES *et al.*, 1978) a fact that might promote the new formation of smectite in this region. In some of the cases where there is evidence for authigenese of smectite, there is also volcanic material at hand (CHAMLEY & MILLOT, 1972). CHAMLEY suggests that volcanic material is needed for the formation of smectite from the dissolution of diatoms.

Aeolian transport.—It is known that material from the Sahara is transported by wind to the ocean over many of the countries along the west coast of Africa, from Sierra Leone to Nigeria (BISCAYE, 1965; McMASTER *et al.*, 1977). Dust collected in the northern part of the South Atlantic Ocean contains a considerable amount of smectite (CHESTER *et al.*, 1972, 1974). Aeolian input from the southern part of Africa seems to be of no importance since no terrestrial material was found on the Walvis Ridge (ZIMMERMAN, 1977). Others claim it to be of importance (BORNHOLD, 1973; CHESTER *et al.*, 1972) especially for smectite and illite. Since no detailed dust collection has been made, especially during the Bergwinds, no approximation can be made of the importance of this possible source. In view of the relative concentrations of smectite and illite in the sediments in the eastern part of the South Atlantic Ocean, it seems reasonable to assume only there is only a very small influx into the Zaire region.

Bottom currents.—An input of material into the Angola Basin could perhaps occur via bottom currents. The northward flowing Antarctic Bottom water contains only minor amounts of clay minerals; contribution to the sediments of the Argentine Basin was considered minor or not present (ZIMMERMAN, 1977). Therefore no input into the Zaire region is to be expected from this current. The possible existence of southward flowing bottom currents as well as the northward flowing Benguela Current has already been mentioned.

Differential settling.—From one sample (40) three different particle sizes were examined for their clay mineral composition (Table II). No differential settling could be deduced, in accordance with the findings of VAN DER GAAST *et al.* (1983), who found no pronounced differences between the relative percentages of smectite and kaolinite, even in the low size ranges of some samples from the Zaire region.

In summary it can be concluded that all possible explanations for the seaward increase of smectite compared to kaolinite can be ruled out, or they are only of minor or unknown importance. The question of the origin of smectite in the Zaire region must therefore remain partly unanswered. If future research is done on the clay mineral composition of suspended matter in the South Atlantic Ocean, including depth differences (*cf.* McMASTER *et al.*, 1977), and this is combined with a detailed study of the stable isotope composition of smectite (SAVIN & EPSTEIN, 1970) and/or rare earth metals, like cerium (HOFFERT, 1980; DESPRAIRIES *et al.*, 1980; CHAMLEY *et al.*, 1981; PIPER, 1974; STEINBERG & COURTOIS, 1976) we might be more certain about the major paths and origin(s) of smectite.

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