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MINERALOGY OF THE CLAY COMPONENTS OF THE MFAMOSING LIMESTONE, SE NIGERIA

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ABSTRACT

Bulk clay mineralogical analyses were carried out on samples from the Mfamosing Limestone deposit. Results indicate the presence of Kaolinite (57%), illite (33%), Smectite (4%) and mixed layer clay types (10%). Kaolinite and smectite are restricted to the southern part of the study area, while illite occurs dominantly in the north. Mixed layer clays show no discernable trend. Factors identified to account for the occurrence of these clay types and their distribution include: the adjoining Oban Massif, the physiography of the area and climate. The clay mineral assemblages allowed for the evaluation of depositional paleoenvironment of the limestone unit.

KEY WORDS: Clay mineral types, kaolinite, illite, Mfamosing.

INTRODUCTION

The Mid-Albian Mfamosing Limestone is located within the Calabar Flank. The carbonate body is over 50m thick in the type section and 450m in the subsurface (Reijers and Petters, 1987). It is as such the thickest limestone section in Nigeria. The Mfamosing Limestone is arcuate shaped and rims the Precambrian Oban Basement Complex. The area under study is situated between longitude 8°02′ and 8°03′E and Latitude 5°10 and 5°50′N (Fig.1). Considerable amount of work has been carried out on this carbonate body. Most of the work is based on biostratigraphy (Dessauvagie, 1968, Fayose, 1978, Ramanathan and Kumaran, 1981), depositional environments (Reijers and Petters, 1987, Nair et al; 1982, Akpan, 1990, Essien, (1995), diagenesis (Oti and Koch, 1990) and Chemical analysis (Ekwueme, 1985).

Clay mineralogy studies have been used by several workers in paleogeographical and environmental studies (Keller, 1970, Adeleye, 1978, Braide, 1983 and Etu-Efeotor, 1984). The primary objective of this work is to extend our knowledge based on clay mineralogy of this carbonate body beyond the Mfamosing quarry type section, which hitherto has received considerable attention. Through extensive sampling of this limestone at Mfamosing (type section), Odukpani, Okoyong Usang Abasi, Ikot Okpora and Agoi Ibami (Fig. 1), it was possible to trace this carbonate buildup from the region south of the Oban Massif, northward along the perimeter of the Oban Massif where the Mfamosing Limestone becomes sandy on account of the admixture of basement derived siliciclastics.

The present study permits the determination of the clay mineralogical composition and distribution in this limestone body. It allows for the evaluation of factors that could influence clay mineral occurrence and distribution. Their depositional environmental implication has been assessed.

REGIONAL GEOLOGY AND STRATIGRAPHY

Structurally, the Calabar Flank is characterized by a system of NW-SE trending step fault system that resulted in the formation of a horst (Ituk high) and a graben (Ikang Trough) within the area (Fig. 1). Carbonate sedimentation took place in the horst while the graben was the site for clastic deposition. Sedimentation started in the Calabar Flank with the deposition of fluvio-deltaic clastics of probably Aptian age on the Precambrian crysalline basement complex, the Oban Massif. These sediments belong to the Awi Formation (Adeleye and Fayose, 1978).

The Mid-Albian first marine transgression into the Calabar Flank accounted for the deposition of platform carbonate of the Mfamosing Limestone. This limestone unit was deposited in a variety of depositional environments such as shelf marginal, protected bay/lagoonal and oolitic shoals (Essien, 1995).

The Ekenkpon shales (Cenomanian – Turonian), a dark grey, thick shale sequence with minor intercalation of marls, calcareous mudstone and oyster beds overlies the Mfamosing Limestone. This shale unit is in turn overlain by a thick marl unit, the New Netim Marl of Coniacian age (Petters et al, 1995)

This unit is unconformably overlain by a carbonaceous dark gray shale, the Nkporo Formation (Late Campanian-Maastrichian) (Reyment, 1965). The Nkporo shales cap the Cretaceous succession in the Calabar Flank. The shale unit is overlains by a pebbly sandstone unit of the Tertiary Benin Formation.

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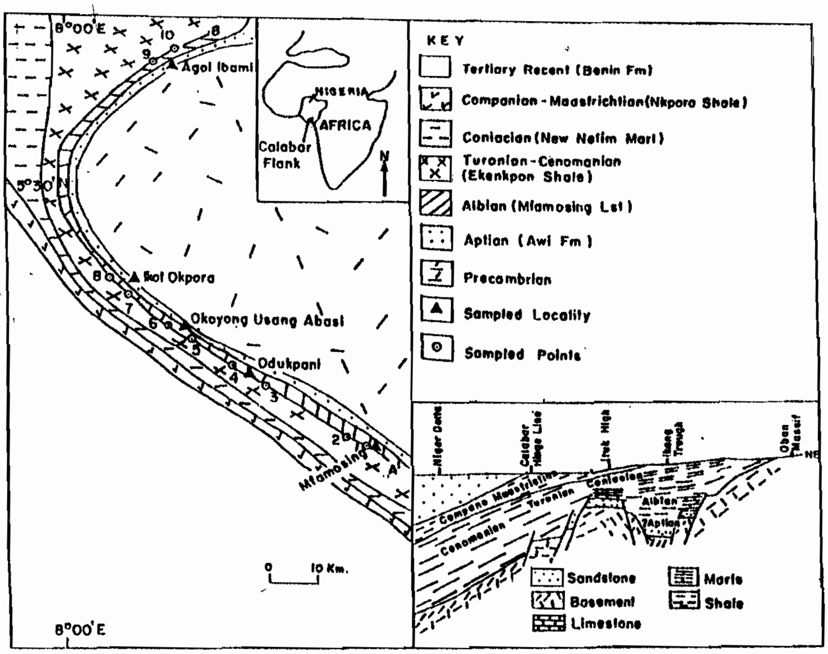

Fig. 1: Calabar Flank showing Sampled Localities and Points.

Inset: Structural elements and conceptual subsurface distribution of cretaceous sediments in the Calabar Flank.

MATERIALS AND METHODS

Insoluble residue from composite limestone samples were obtained by dissolving the carbonates with dilute HCl. In order to differentiate all the clay mineral phases, X-ray analyses were carried out on untreated samples, glycol-treated samples and samples heated to a temperature of 550°C.

Fig. 2.

The clay mineralogy analysis was carried out using a Philip X-ray diffractor (XRD) fitted with a X-ray generator – PW 1130/006 and goniometer – PW1050/2. Other components of the diffractor include N-1 filtered Cu-Kx radiation with setting of 40KV and 20mA. Scanning speed was 1°/min; paper speed 10mm/sec with a range, CPS $1 \times 10^{o3}4 \times 10^{-3}$. The analysis were carried out in the University of Turbengen, Germany.

CLAY MINERAL TYPES AND DISTRIBUTION

Interpretation of the clay mineral diffractograms indicate the presence of diverse clay mineral suites (Fig. 2). These are kaolinite, illite, smectite and mixed layer clays.

In the Mfamosing Limestone, kaolinite ranges from 0-85%, while illite varied between 5-90%. Smectite and mixed layer clays ranged from 0-30% and 5-25%, respectively (Table 1).

Volumetrically, kaolinite is the dominant clay mineral in the Mfamosing Limestone. It is about 53% by volume and is followed by illite which averages 33%. Smectite and mixed layer clays depicts average values pf 4% and 10%, respectively (Table 1).

This implies that areas of high kaolinite minerals

Table 1: Abundance of clay Minerals in the Mfamosing Limestone

S/N	Sample Code	Locality	Kaolinite (%)	Illite (%)	Smecite (%)	Mixed Layer (%)
1	MF 1	Mfamosing	60	5	30	5
2	MF 2	"	50	30	"	20
3	OD 1	Odukpani	60	30	5	5
4	OD 2	"	85	5	5	5
5	OUA 1	Okoyong Usang Abasi	50	40	-	10
6	OUA 2	"	60	20	-	20
7	OK 1	Ikot Okpora	80	10	-	10
8	OK 2	"	80	10	-	10
9	ABA 1	Agoi Ibami	5	90	-	10
10	ABA 2	"	-	90	-	5
	Average abundance of clay minerals in Mfamosing Limestone		53	33	4	10

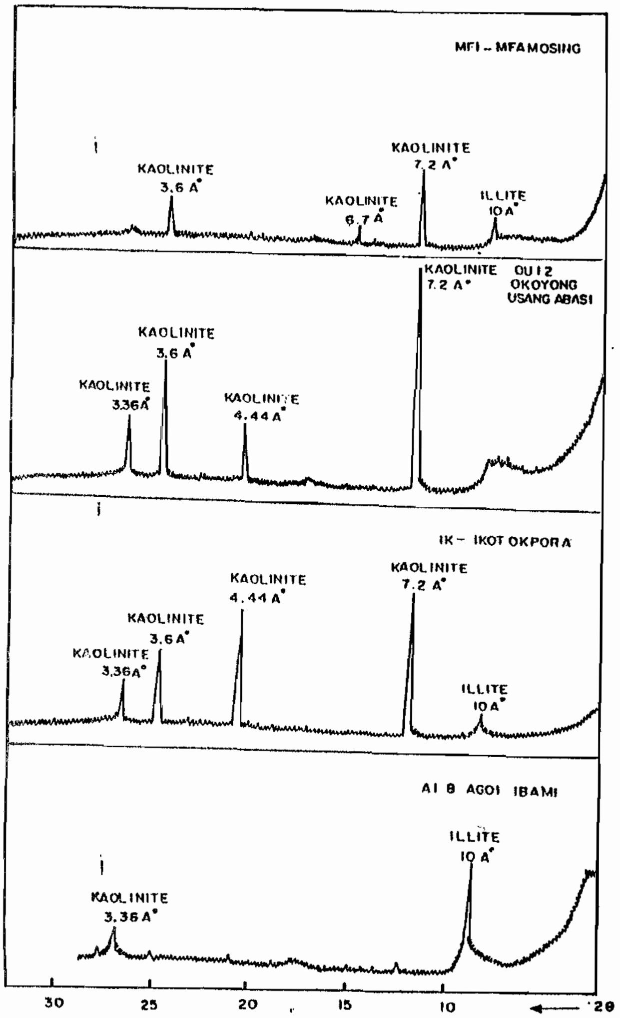

Fig. 2 : X-ray diffractograms of clay minerals in the Mfamosing Limestone at type section (Mfamosing), Okoyong Usang Abasi, Ikot Okpora and Agoi Ibami

are those of low illite and vice versa (Fig. 2). This study indicate that, kaolinite and illite have antipathetic relationship. It was also noticed that kaolinite is the dominant clay mineral in the southern part of the study area and diminishes northward. On the other hand, illite is the main clay mineral type in the north and reduces southwards. Smectite occurs only in the southern part of the studied area while the mixed layer clays show no discernable trend.

ENVIRONMENTAL SIGNIFICANCE

The Mfamosing Limestone rims the Precambrian Oban Massif. Chemical analyses by Ekwueme (1985) and Essien (1995) indicate very high degree of purity, reducing northwards with increase in clastic content. The clastics were derived mainly from the Oban Massif made up of predominantly phyllite, schist and gneiss (Ekwueme and Onyeagocha, 1986). Clastic influx inhibited carbonate deposition in the northern part of the studied area, whereas its effect was minimal in the south. Petrographic studies on this limestone indicate the presence of clay minerals as minute particles mixed with micrite and as cavity infilling in fossils/bioclastic fragments (Essien, 1995).

The antipathetic relationship between kaolinite and illite, the restriction of smectite to the southern part and the non-discernable pattern displayed by the mixed layer clay minerals in the Mfamosing Limestone could be attributed to several factors. These include the influence of the adjoining Oban Massif, the physiography of the area and climate.

The relatively high clastic content of the limestone in the northern part of the studied area (Agoi Ibami) suggests that the clay minerals are sourced mainly from the adjoining Oban Massif, whose rocks are rich in K-feldspar and micaceous minerals (Ekwueme and Onyegocha, 1986). Illite was originally proposed not as a specific clay mineral name but as a general term for clay mineral constituents of argiliaceous sediments belonging to the mica group (Grim, et al, 1937). The availability of potassium ion is known to be the most important ingredient in the formation of illite. In the northern part of the study area, the relative abundance of illite could be attributed principally to the abundance of k^+ ions derived from the Oban Massif. It diminishes southward where inputs from the Oban Massif is minimal.

The relief in the northern area under study especially around Agoi Ibami measures up to 90 meter above sea level whereas it is almost horizontal in the south. Though the difference in relief is not significant but it does play a significant role in determining the rate of retention of runoffs during rainfall. The horizontal to concave topography in the south allows for the accumulation and longer residence time for runoffs.

This ensures complete leaching and with the attendant cation removal enhances the formation of abundant kaolinite and reduction in illite. Kaolinite is known to form in an environment of strong leaching and removal of Ca^{2+}, Mg^{2+}, Na^+, K^+, K^+, Fe^+ and possibly SiO, and the addition of H^+ (Keller, 1970).

Smectite occurs only in the southern part of the area. This is attributed to the build up of high saturation level due to the accumulation of leachates as slope became horizontal or concave. Smectite is a product of incomplete leaching and represents the intermediate stage in the degradation of illite (Keller, 1970).

The absence of smectite in the northern part of the area is related to the availability of adequate amount and concentration of K^+ ions derived from the adjoining Oban Massif. K^+ ion when taken up by "true" smectite (Montmorillonite) in a single-stage cation exchange changes to illite (Keller, 1970). Thus, the absence of smectite in the northern part of the area could be due to illitization of smectite. Such illitization of smectite has been reported in the Eocene Wilcox Formation in the subsurface of the Gulf Coast (Burts, 1967).

Climate exerted some control on the clay mineral types and distribution in the Mfamosing Limestone. The area under investigation falls within the equatorial climate belt. The abundant rainfall which enhances leaching favoured the formation of kaolinite. This is probably responsible for the predominance of kaolinite over other clay mineral types in the studies area.

The clay mineral types and distribution in the Mfamosing Limestone were controlled by several variables. The physiography of the adjoining Oban Massif and the climatic conditions seem to have a dominating influence in determining the clay mineral assemblage and their distribution in the Mfamosing Limestone.

From the clay mineral distribution in the Mfamosing Limestone, information regarding the paleogeography and depositional environment of the limestone can be deduced. In making paleogeographic or paleoenvironmental deductions, comparison can be made with the known occurrences of clay mineral suites in Nigeria sedimentary basins where clay mineralogical data are available. Adeleye (1978), Braide (1983) and Etu-Efeotor (1981) observed the preponderance of kaolinite in the Niger Delta shales to be largely contributed from the Niger-Benue drainage system, which is located in the humid tropical environment. Smectite on the other hand is predominant in the shales of the Coniacian Sukuluye and Numanha Formation in the Upper Benue Trough which were deposited in warm, humid, quiet, coastal, stagnant, lagoonal paleoenvironment (Enu, 1980).

Similarly, the presence of smectite in the Mfamosing Limestone in southern localities suggests the existence of a protected bay/lagoonal paleoenvironment, while the abundance of illite is suggestive of clastic influx from basement into an open, coastal and shelf depositional environments, lagoons and poorly drained wasteland that fringed the Oban Massif in the north.

SUMMARY

Analysis of the clay components of the Mfamosing Limestone was carried out using an X-ray diffractometer (X-RD). Results reveal the dominance of kaolinite which is 53% by volume. Other clay types identified include illite (33%0, smectite (4%) and mixed-layer clays (10%).

Clay minerals distribution in the limestone shows an antipathetic relationship between kaolinite and illite. Kaolinite is dominant in the south and diminishes northwards while the reverse is the case with illite. Smectite is found only in the southern part of the area under investigation. The mixed-layer clay show no discenable trend.

The clay mineral types and distribution in the carbonate body are controlled by the physiography of the adjoining Oban Massif and climate. The occurrence of smectite in southern localities suggests lagoonal/protected bay paleoenvironments. On the other hand, the occurrence of illite is indicative of the existence of open coastal shelfs, lagoons and poorly drained waste lands in the northern part of the area under investigation.

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