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Paleoclimate Reconstruction during Mamu Formations (Cretaceous) Based on Clay Mineral Distribution in Northern Anambra Basin, Nigeria

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ABSTRACT

Paleoclimate was reconstructed by the clay mineral assemblage of clay units in Mamu formation of Northern Anambra Basin. Collected samples were prepared using standard clay mineral methodology. Their identification was made on X-ray diffractographs, the results show that the clay mineral is predominantly kaolinitic with a percentage abundance of about 28.75%, its variation style in different locations could be a marker of climate change from wet to dry which is supported by lithological changes. The high dominance of quartz with percentage abundance of 67% confirms the grittiness of the clay. Microcline constituents about 5- 10% confirming the clay as a product of weathering from granitic rock possible from the Precambrian basement rock units of Adamawa- Oban massif areas to the east of the Anambra Basin and the adjacent Abakaliki Anticlinorium.

With the absence of illite, Smectite, montmorillonite which are characteristics of dry and arid climate confirms a wet/tropical climate for the clay deposit in the Northern Anambra Basin and thus, the present results can be indicated as a possible procedure for ancient climate changes evaluation.

Key words: *Palaeoclimate, XRD, Northern Anambra Basin, Clay minerals.*

I. INTRODUCTION

Clay minerals are an important group of minerals because they are among the most common products of the chemical weathering, and thus are the main constituents of the fine-grained sedimentary rocks called mudrocks (including mudstones, claystones and shales) . In fact, clay minerals make up about 40% in sedimentary rocks. In addition, clay minerals are the main constituent of soils. Understanding of clay minerals is also important from an engineering point of view, as some minerals expand significantly when exposed to water.

Clay is formed either as a product of the chemical weathering of pre-existing granitic rocks and feldspar minerals, particularly in warm tropical and substropical regions of the world or as a result of the hydrothermal alteration of granitic rocks

Chemically, clays are hydrous aluminum silicates, ordinarily containing impurities, for example potassium, or iron, in small amounts, and are characterized by sheet silicate structures of composite layers staked along the c-axis (Grim, 1968). Clay has a wide variety of physical characteristics such as plasticity, shrinkage under firing and under firing, hardness, cohesion, and capacity of the surface to take decoration.

Clay minerals are commonly interested for industrial (Patchett, J., 1975, Carretero, M.I., 2002) and medical purposes due to chemical and physical properties (Carretero, M.I., 2002). Their application is numerous in literature which may be expressed as follows: diagenetic transformation and initiate of metamorphism (Boles, J.R., et al., 1979, Mittbq, R.E.A. et al., 2000, Chilingarian, G.U., 1981, Keller, W.D., 1963); paleosalinity and clay minerals (Hingston, F.G., 1964); geothermommeter and organic maturity indicator (Pallastro, R.M., 1993, Soleimani, B., 1999, Slatt, R.M., 2003); source rock and paleo-environment of sedimentary basin (Net, L.I., et al., 2002, Biscaye, P.E., 1965, Grim, R.E., 1968, Ingles-Ramos, M., Guerrero, R.E., 1995, Weaver, C.E., 1989, Keller, W.D., 1970) ; provenance and stratigraphy studies (Boggs, S.G., 1987, Cavanagh, A., 1997, Odin, G.S., Fullagar, P.D., 1988, Prothero, D.R. and Schwab, F., 1996); the nature and source of clay minerals (Ingram, R.L et al., 1959, Moll, W.F . Jr., 1979, Jeans, C.V. et al., 2000, Drits, V.A., 2003, Arslan, M. et al., 2006, Jeans, C.V 2006a, Jeans, C.V, 2006b, Jeans, C.V 2006c); Petroleum sources rock evaluation (Slatt, R.M., 2003, Pollastro, R.M., 1993, Soleimani, B., 1999, Eslinger, E. & Pevear, D., 1988, Kublicki, C., & Millot, G., 1963, Jeans, C.V 2000), effects on net porosity, fluid and hydrocarbon saturation (Aly, S.A., et al., 2003); the relation between gamma ray and clay minerals (Blum, P., et al., 1997, Meyer, B.L., & Nederlof, M.H., 1984, Hassan, M. A., et al., 1997, Jurado, M.J., 1997); Drilling problem (Mondshine, T.C., & Kercheville, J.D., 1996); impacts of sedimentary basin, provenance rock and tectonic factors (Ingles- Ramos, M., Guerrero, R.E., 1995, Net, L.I., et al., 2002, Schnyder, J., et al., 2006 & Mats, V.D., 2004) on the composition and frequency of clay minerals: the role on burial of atomic waste (Velde, B., 1981), and paleogeography and paleoclimate (Flores, R.M., et al., 1990, Van Valkenburg., S.G., et al., 1997 & Lindgreen, H., & Surlyk, F., 2000). The latest one has not applied yet in the Mamu Formation of Northern Anambra Basin, Nigeria.

In the present study, clay units of Cretaceous Formation (Mamu) are investigated to reconstruct paleoclimate during their deposition in Northern Anambra Basin, North Central Nigeria.

II. GEOLOGICAL DESCRIPTION

Clay mineral distribution was studied in major clay units with in the age of Cretaceous (Campanian- Maastrichtian) (Figure 1) in different geological situation, that occurred in the Northern Anambra Basin, North Central, Nigeria (Figure 2). This unit is described briefly.

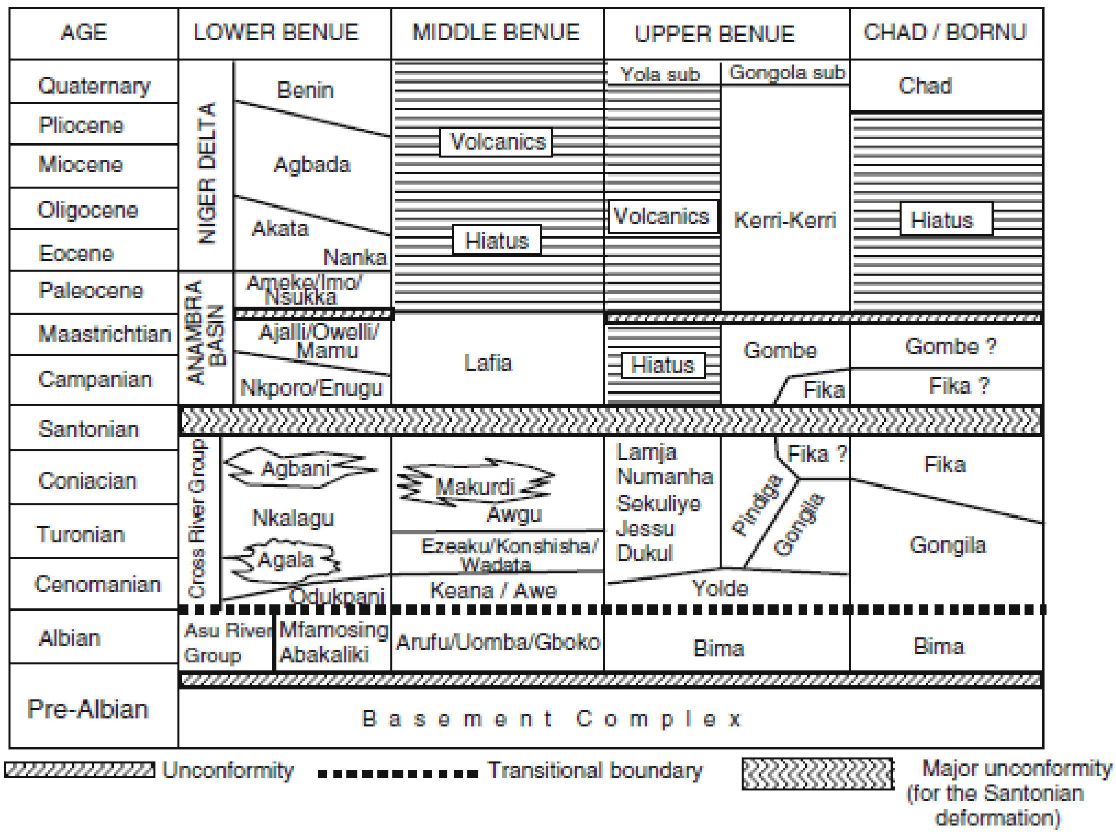

Fig. 1: Mesozoic-Cenozoic Stratigraphic correlation chart of the Benue Trough showing the Anambra Basin

Sedimentation in the Anambra Basin commenced with the Campanian-Maastrichtian marine and paralic shales of the Enugu and Nkporo Formations, overlain by the coal measures of the Mamu Formation. The fluviodeltaic sandstones of the Ajali and Owelli Formations lie on the Mamu Formation and constitute its lateral equivalents in most places. The coal-bearing Mamu Formation and the Ajali Sandstone accumulated during this epoch of overall regression of the Nkporo cycle. The Mamu Formation occurs as a narrow strip trending north–south from the Calabar Flank, swinging west around the Ankpa plateau and terminating at Idah near the River Niger. The Nsukka Formation and the Imo Shale mark the onset of another transgression in the Anambra Basin during the Paleocene. The shales contain significant amount of organic matter and may be a potential source for the hydrocarbons in the northern part of the Niger Delta (Reijers and Nwajide, 1998). In the Anambra Basin, they are only locally expected to reach maturity levels for hydrocarbon expulsion. The Eocene Nanka Sands mark the return to regressive conditions. The Nanka Formation offers an excellent opportunity to study tidal deposits. Well-exposed, strongly assymetrical sandwaves suggest the predominance of flood-tidal currents over weak ebbreverse currents. The presence of the latter are only suggested by the bundling of lamine separated from each other by mud drapes reflecting neap tides. A good outcrop of the Nanka Formation is the Umunya section, 18 km from the Niger Bridge at Onitsha on the Enugu – Onitsha Expressway.

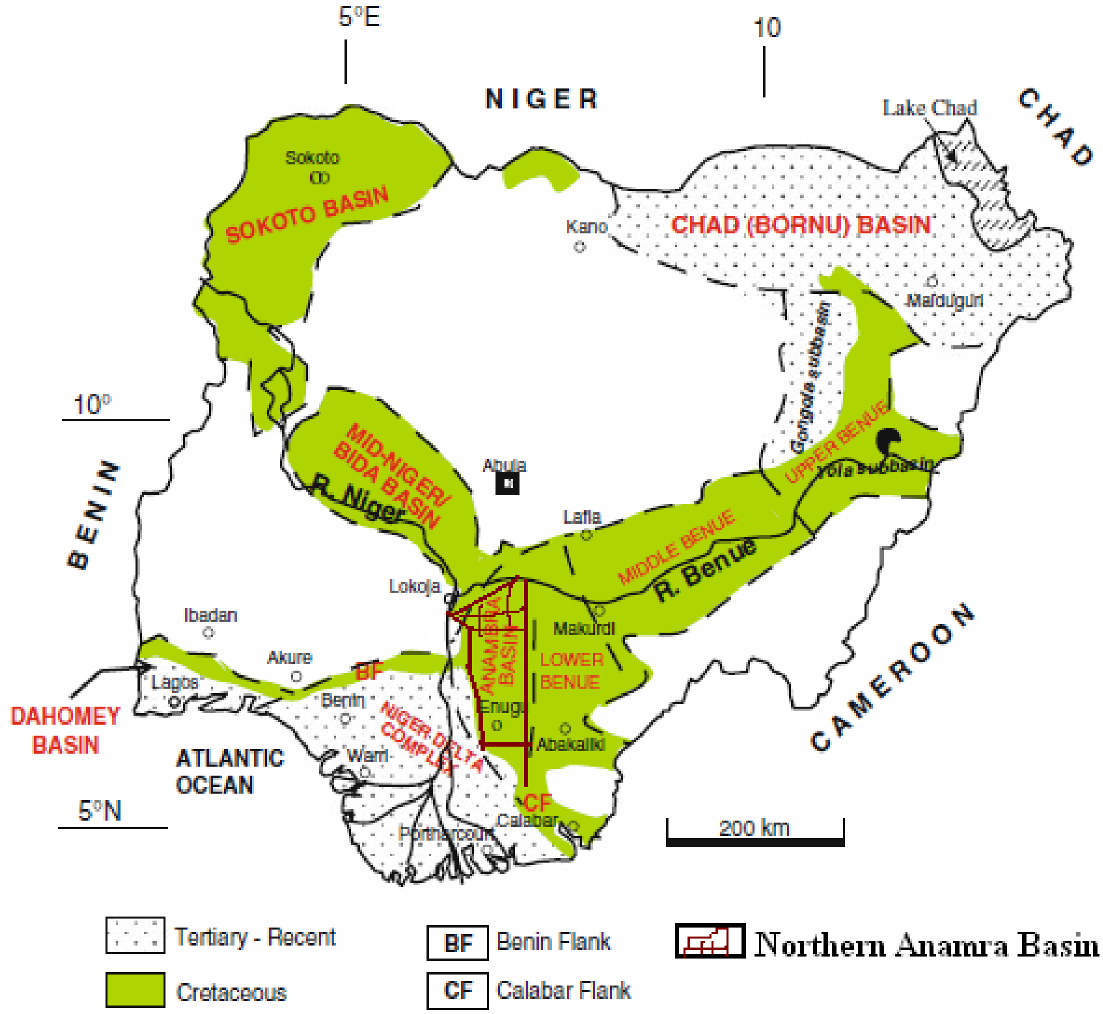

Fig. 2: The Location of the studied Basin (Modified after Ogbaje et al, 2009)

III. METHODOLOGY

A quantitative determination of the mineralogical property of the clay samples using X-ray diffraction were carried out at ACME laboratories, Vancouver, Canada.

To study clay mineral assemblage, the selected samples were subjected to different processes: grinding and homogenization (Moll, W.F., Jr., 2001). Grind the dried sample thoroughly with the mortar and pestle. The particles should be much finer than 0.062mm to avoid fractionation of the minerals. The finer the powder the greater the opportunity for obtaining an adequate number of particles with random orientation and less likely the surface roughness will reduce low-angle intensities. The powdered sample was weighed and tested using a PW 1840 automated powder diffraction equipped with a Cu –Kα radiation source, inbuilt standards, Peak/width and a detector. The diffraction pattern was obtained with the aid of a computer, while the 2ϴ, d- values and peak intensities yielded by the powder patterns were used to identify the minerals.

IV. RESULTS AND DISCUSSION

Clay minerals are used extensively in different aspects. The latest application is in the paleoclimate determination. Based on structural and chemical compositions, the clay mineral susceptibility does not vary as the clay mineral assemblage identified in the Northern Anambra Basin is only kaolinite which is formed under an environmental and chemical condition that will help us to interpret depositional/climate condition.

A sample of the results obtained from the X-ray diffraction analysis is presented in Figure 3. A summary of the XRD results of the mineralogical in table 1.

The XRD results of the mineralogical assemblages of the sample, the major minerals present have been indicated against the diagnostic peaks as shown in figure 3.

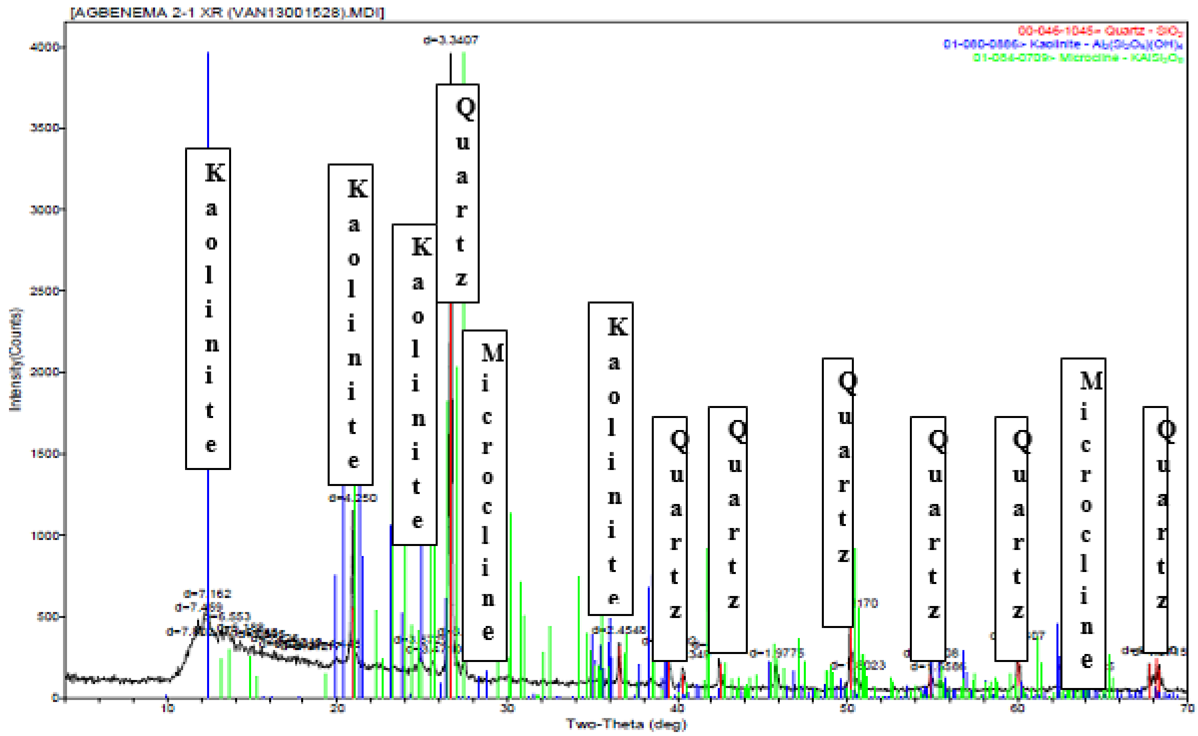

Fig.3: X –ray diffraction result of Agbenema clay deposit in Kogi State, Northern Anambra Basin

Table 1: Mineralogical composition (in percentages) of clay deposits from different locations in Kogi State, Northern Anambra Basin

Minerals %	Agbenema 2.1 XR	Aloji 1.1 XR	Ofe-jiji 1.1 XR	Udane B. 1.1
Kaolinite	30	35	25	25
Quartz	60	65	70	75
Microline	10	-	5	-

The results of the mineralogical composition of the clay show that the dominant minerals present are kaolinite and quartz, while microclines occur as traces. Of all the mineral presents, kaolinite covered a range of 25 – 35%, Quartz about 60 – 75% and microcline about 5-10%. However, result of the investigated clay deposits differ significantly from those of some well-known kaolin deposits in term of mineralogical compositions. The kaolinite content of Northern Anambra Basin (25-35%) is by far lower than that of Ibadan (91%), China clay (85%), Kaduna (96%), Oza-Nagogo (86%) and NAFCON recommended value (85%). Whereas the quartz content of Northern Anambra Basin clay (60-75%) is far higher than those of Ibadan (6%), Oza-Nagogo (14%), Kaduna (2%), China-clay (traces) and NAFCON recommended value (4%). The Microcline content of the Northern Anambra Basin constitutes about 5-10% which is not present in Ibadan, Kaduna, Oza-Ngogo, china-clay and NAFCON.

Paleoclimatic significance of minerals assemblage from Northern Anambra Basin

Clay minerals in sediments can be useful indicators of paleoclimatic conditions, particularly when the sedimentary basins are small. Our paleoclimatic reconstruction mainly uses the systematic data obtained from Northern Anambra clay mineral association. The mineralogy of the clay analyses were considered when interpreting the climatic changes around Northern Anambra Basin, in addition, the minor and major element concentrations were considered.

According to Churchman (2000), the two layer/three layer clay mineral ratio is mainly controlled climate. Therefore, it is easy to recognize between warm and humid conditions typical for kaolinite formation or dry seasons, specific for illite or smectite formation. Furthermore, the formation of kaolinite is favoured by an acidic conditions, and high leaching environments. Conversely, relatively low or no leaching environment and conditions under neutral to low alkaline pH favour the formation of montmorillonite and three-layer clay minerals.

The variation of kaolinite in the Northern Anambra Basin and absence of illite, smectite and montmorrilonite is interesting. It can be interpreted to be the result of climate changes /depositional condition (shallow water) erosional rate and the composition of the initial provenance rock. Field investigation supports the idea of the first suggestion thereby inferring wet/tropical climate for the clay deposition in Mamu Formation of the Northern Anambra Basin. Kaolinite is formed by weathering or hydrothermal alteration of aluminosilicate minerals. Thus, rocks rich in feldspar commonly weather to kaolinite, in order to form, ions like Na, K, Ca, Mg, and Fe must first be leached away by the weathering or alteration process. This leaching is favoured by acidic conditions (low pH). Granitic rocks, because they are rich in feldspar, are a common source of kaolinite and this is confirmed by the presence of microline (K-feldspar). Kaolinite, because it does not absorb water, does not expand when it comes in contact with water. Thus, kaolinite is the preferred type for ceramic industry.

The high dominance of quartz in the clay deposits explains its grittiness and also suggests the clay to be of residual origin.

V. CONCLUSION

The present study revealed that clay mineral distribution in different locations of the Northern Anambra Basin indicated individual trends. Kaolinite present in the Mamu Formation can be indicating climate regime changes from dry to wet and the absence of illite/smectite which is characterized by dry and terrestrial climate and montmorillonite characterized with non-marine/terrestrial condition confirms this. Thus, climate factor must be considered as possible factor in monitoring observed clay types in questionable points.

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