Geochemistry and Depositional Environment of Shale Deposit in Nanim Field Offshore Niger Delta, Nigeria

Eronini C. D[1], Richmond U. Ideozu[2], Fortune I. Chiazor[3]

[1, 2, 3]Department of Geology, University of Port Harcourt
Corresponding Author Email: *richmond.ideozu[at]uniport.edu.ng*

Abstract: ***In this study, shale deposits from offshore wells in Nanim Field, Niger Delta were evaluated geochemically to establish the paragenesis of the studied section and thereafter, determine the conditions that control the depositional environments in the area. Shale samples were grinded, pulverized and sieved with less than 75µm and analyzed using X-ray fluorescence (XRF) for elemental analysis and X-ray diffraction techniques (XRD) for mineralogical composition. The XRD for mineralogical analysis shows that the lower part of the section under study is characterized by quartz and kaolinite as the major crystalline minerals with trace of halloysite and minor quantities of other minerals. The XRF results reveal that SiO_2 and Al_2O_3 are the predominant major oxides in the analyzed samples. Silica enrichment is a measure of sandstone maturity, and is a reflection of the duration and intensity of weathering and destruction of other minerals during transportation. The presence of hematite in the basal part of the shale outcrop suggests oxidizing diagenetic environment of deposition. The A-K-F ternary plot of the depositional environment shows a gradual transition of the sediments of the basin from transitional to marine environment and the binary plot also shows that the samples support the non-marine boundary and marine zone, majorly falling within the transition zone. The Carbonaceous zone indicates elevated amounts of organic matter of floral or faunal origin, which are indicative of reducing conditions. The binary plot can also be used to determine depositional environments. The binary plot shows that the samples align with the non-marine boundary (Fluvial deltaic terrain) and marine zone i. e. the Transition-marine zone, which are also sedimentary terrains.***

Keywords: Geochemistry, Depositional environment, kaolinite and elemental analysis

1. Introduction

Geochemical characterization of clastic sedimentary rocks in contemporary times, have been an invaluable tool in studying the composition, tectonic setting and evolution of the continental crust, when the conventional petrographic methods are uncertain. Trace elements and rare earth elements are also valuable indicators of provenance, geological processes and tectonic setting due to their relatively low mobility and insolubility during sedimentary processes [McLennan, et al 1993]. Nonetheless, the chemical and mineralogical composition of sandstones and shale can be influenced by the source rock characteristics, weathering, sorting processes during transportation, sedimentation and diagenetic processes to an extent [Armstrong-Altrin, et al 2009].

This paper is aimed at investigating the bulk geochemical and mineralogical compositions of the shale deposits in Nanim Field, Off-shore Niger Delta, in order to determine the mineralogical and chemical composition of the studied section using the XRD and XRF techniques and thereafter, determine the conditions that control the depositional environments in the area.

Geology of the Niger Delta Basin

The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province as defined by Klett, *et al., (*1997). The Niger Delta Basin evolved from the separation of the African and South American continental plates.

Several researchers such as Grant (1971), Burke (1971) and Wright (1976) have attributed the origin of the Niger Delta Basin to the RRR (ridge-ridge-ridge) system. The failed arm of this RRR structure is the Anambra-Benue rift valley within which the oceanic crust was inactive. The rivers depositional centers moved seawards thus making the coastal plain deposits to become progressively younger in that direction. The tertiary deltaic complex is divided into three depositional lithofacies identified as the Akata Formation, Agbada Formation and Benin Formation respectively (Short and Stauble, 1967). Agbada Formation constitutes the main reservoir of hydrocarbon in the Niger Delta.

Location of the Study Area

The study area is Nanim Field (pseudo name of the original field) is located Offshore Niger Delta. This field is in the Niger Delta Basin within the Gulf of Guinea on the West Coast of Africa. See Figure 1

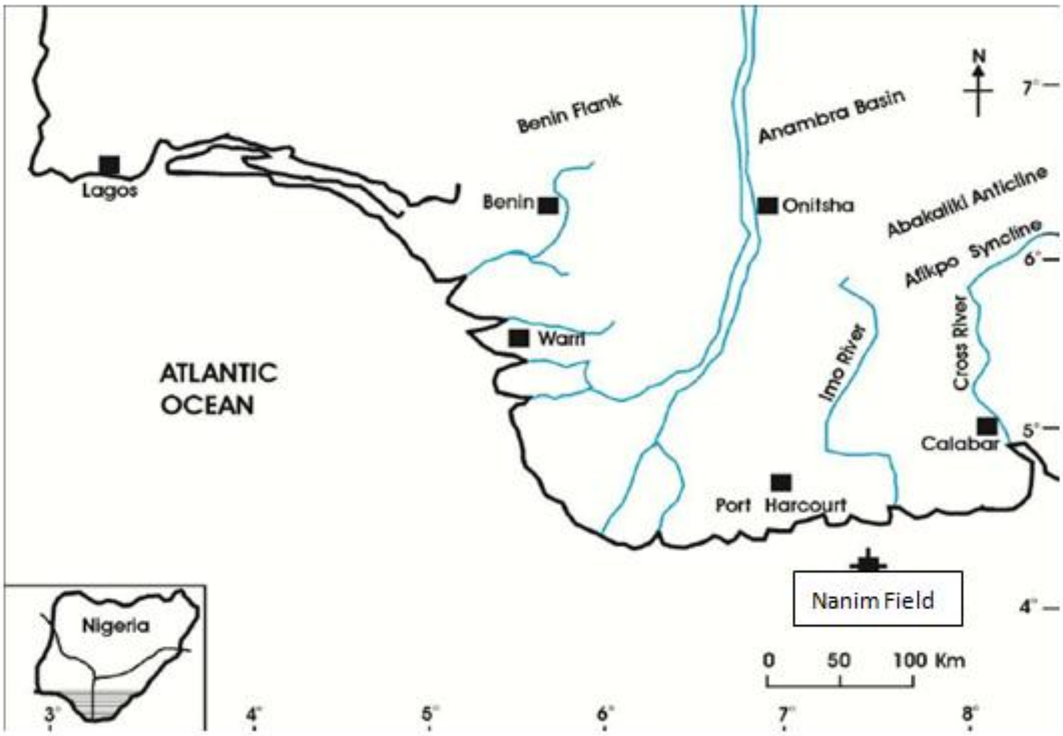


Figure 1: Location of the Study Area

2. Materials and Methods

Nine Shale samples were collected at an interval of 10 metres from the off-shore well. All the shale samples were immediately stored in zip lock polyethylene bag and preserved at room temperature. The samples were dried at 60ºC, crushed to fine powder and homogenized in an agate ball mill. The pulverized shale samples were analyzed at the Nigerian Geological research laboratory (NGRL), Kaduna using an Empyrean diffractometer with a copper anode material manufactured by panalytical with X-ray diffraction [XRD] for mineralogical composition and X-ray fluorescence [XRF] techniques elemental composition.

3. Results and Discussions

The geochemical results from the X-ray fluorescence (X-RF) technique for the major element concentrations of the selected samples is given in Table 1. The major oxides (wt. %) varies widely, the range and average values of major elemental oxides are as follows: SiO_2 (49.06-41.8, average 45.5), CaO (9.5-5.42, average 6.66), MgO (2.96-1.01, average 2.48), SO_3 (0.96-0.06, average 0.57), BaO (0.4-0.09, average 0.27), K_2O (2.1-1.44), average 1.84), Na_2O (3.73-2.42, average 2.79), TiO_2

Table 1: Major Chemical Element.

OXIDES	A1	A2	A3	A4	A5	46	47	B1
SIO2	42.9	45.4	46.8	42.6	41.8	48.6	49.06	46.90
AL2O3	12.34	15.8	15.1	17.4	15.5	15.6	15.3	13.90
SO3	0.31	0.06	0.52	0.96	0.78	0.55	0.54	0.82
TIO2	0.28	0.53	0.51	0.74	0.73	0.37	0.34	0.71
K2O	2.0	1.44	1.92	1.44	1.75	2.1	2.05	2.01
NA2O	3.73	2.91	2.86	2.42	2.81	2.48	2.49	2.99
Fe2O3	5.75	5.61	5.51	4.62	6.88	5.11	3.20	4.92
MnO	0.09	0.07	0.05	0.06	0.04	0.08	0.07	0.07
MgO	2.4	2.71	2.81	2.37	2.85	1.01	2.96	2.73
CaO	9.5	6.8	5.6	5.42	6.84	5.52	6.48	7.11
P2O5	0.13	0.11	0.08	0.07	0.09	0.05	0.06	0.04
BaO	0.4	0.13	0.09	0.26	0.18	0.4	0.39	0.3
Cl	5.37	3.96	3.57	2.80	3.12	3.08	3.14	4.28
LOI	14.79	13.97	14.57	18.84	16.63	14.95	13.91	13.42
ppm								
V	12	21	25	110	11	16	14	16
Cr	21	62	75	22	28	25	11	6 bb
Ni	23	39	161	160	171	181	141	142
Cu	12	34	58	25	28	20	52	22
Zn	201	38	205	140	150	120	99	271
Ga	9	11	17	16	13	13	-	-
As	6	3	7	-	-	4	7	5

Sr	75	72	124	290	290	300	230	240
Zr	133	104	76	230	180	170	122	310
Y	6	4	2	-	-	-	-	-
Br	22	14	3	11	16	12	11	14
In	6	4	8	4	4	4	-	5
Ce	10	16	9	10	13	6	13	10
Re	8	3	19	3	3	4	24	2
Pb	12	12	27	12	10	11	28	31
Eu	12	11	18	10	9	9	9	10

The Shale samples are made up of Quartz, Calcite, Kaolinite, Hatite and Ilmenite. (0.74-0.28, average 0.53), MnO (0.09-0.04, average 0.06), P_2O_5 (0.13-0.04, average 0.07), Fe_2O_3 (6.88-3.20, average 5.2), Al_2O_3 (17.4-12.34, average 13.16) and Lol (18.84-13.42, average 15.13).

The geochemical results also show that the average value of silica is far higher than the average values of the rest oxides. Silica enrichment is a measure of sandstone maturity, and is a reflection of the duration and intensity of weathering and destruction of other minerals during transportation. The lower part of the shale has a dominance of quartz and kaolinite as the crystalline minerals with traces of halloysite. Similarly, the presence of hematite in the basal part of the shale outcrop suggests oxidizing diagenetic environment of deposition. The A-K-F ternary plot (Fig.2) of the depositional environment shows a gradual transition of the sediments of the basin from transitional to marine environment and the binary plot (Fig.3) shows that the samples support the non-marine boundary and marine zone

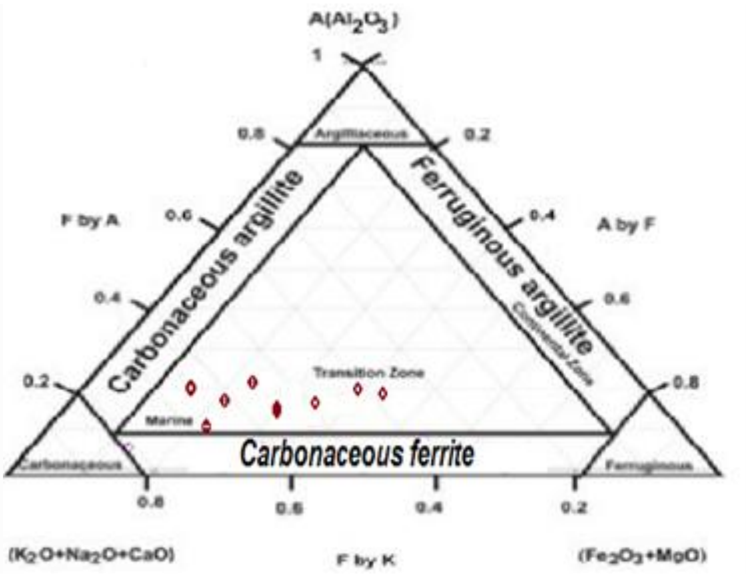


Figure 2: A-K-F plots for sediments from Nanim field

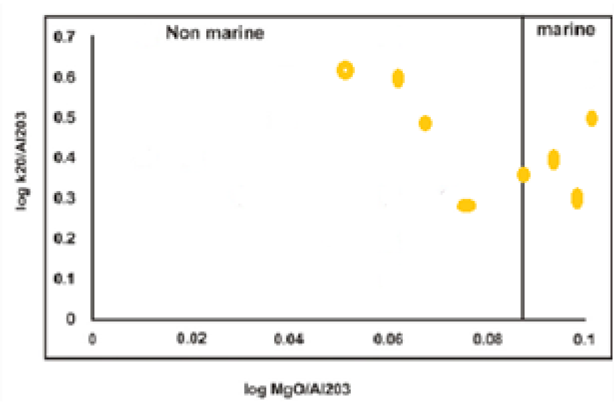
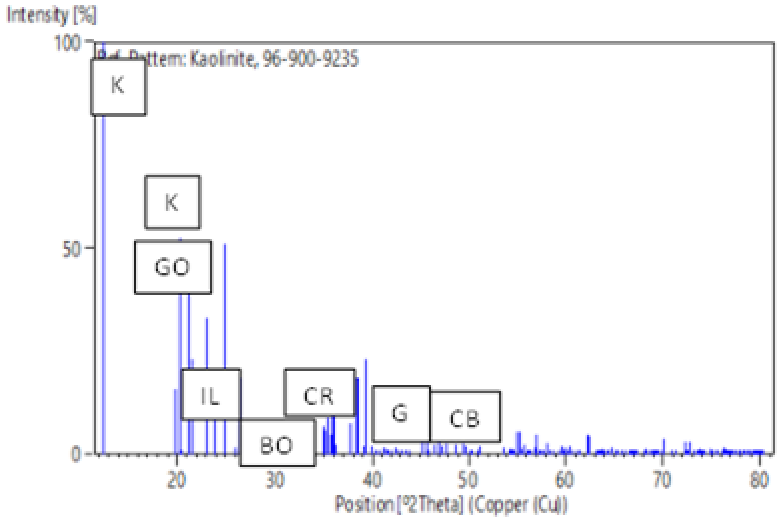


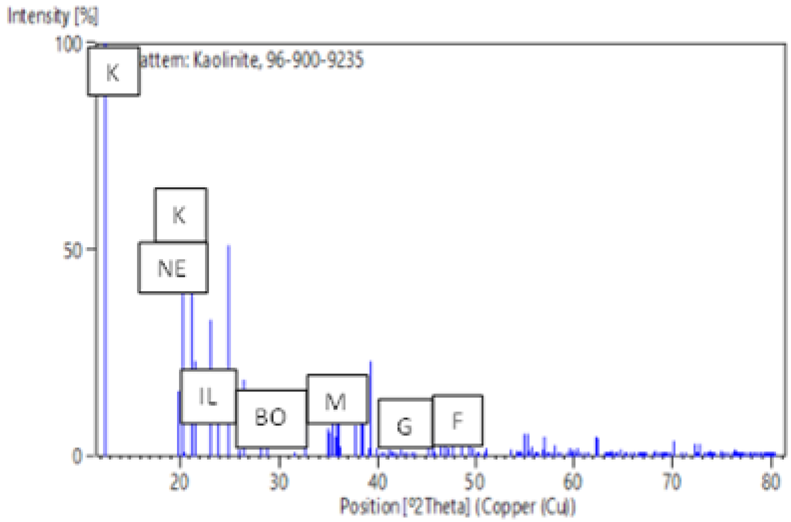
Figure 3: Binary plot showing log K2O/Al2O3 Vs log MgO/Al2O3

The XRD patterns of all whole-rock samples (Figs.4 and 5), which were obtained following the method of Brown and Brindley (1984), indicate the predominating presence of kaolinite peaks; accessory minerals included microcline, quartz. Iron mineral peak was observed in all the samples, indicating their incorporation in the clay minerals



K=Kaolinite, GO=Goethite, IL=Ilmanite, BO=Boehmite, CR=Corundum, G=Graphite, CB=Cristobalite.

Figure 4: XRD pattern for Sample 7, showing Kaolinite with high peaks



K=Kaolinite, NE=Nepheline, IL=Ilmanite, BO=Boehmite, M=Magnetite, G=Graphite, F=Fluorite

Figure 5: XRD pattern for Sample 8, showing Kaolinite with high peaks

Kaolinite is formed by weathering or hydrothermal alteration of aluminosilicate minerals, thus, rocks rich in feldspar commonly weather to kaolinite. They are indicators for its detrital origin in continental sediments (Kassim, 2006).

Furthermore, Weaver (1960) stated that kaolinite is dominant in sediments of fluviatile environments. Kaolinite is known to be concentrated in many near-shore sediments and to decrease in abundance with distance from the shoreline as other clay minerals increase (Parham, 1966). Robert et al, (1994) reported that increased kaolinite contents in marine sediments resulted either from increased runoff, which could be caused by sea level falls, or from increased rainfall. Berner et al (1996) in their study established that kaolinite is formed under a good drainage system where the water travel-distance was much greater, less rapid flushing of sediments and less removal of silica. Hematite is the oxidation products of weathering of ferrous minerals and constitutes a major source of detrital iron in sediments.

Depositional Environments

Ternary plots of England and Jørgensen (1973) proposed that certain classification of soil samples may be employed to ascertain the depositional environment of the sediments of the basin. This employs the chemical classification on the basis of AKF [Al_2O_3-(K_2O+Na_2O+CaO)-(Fe_2O_3+MgO)] contents. The samples were plotted on the ternary diagram of the AKF plots which reveals whether the sediments are deposited in continental, transition and/or marine zone. The results show a gradual transition of the sediments of the basin from continental to marine environment, majorly falling within the transition zone as indicated in figure 2. Ternary plots of Englund and Jorgensen (1973) proposed that certain classification of soil samples may be employed to ascertain the depositional environment of the sediments of the basin. This employs the chemical classification on the basis of AKF [Al2O3-(K2O+Na2O+CaO)-(Fe2O3+MgO)] contents. The samples were plotted on the ternary diagram of the AKF plots which reveals whether the sediments are deposited in continental, transition and/or marine zone. The results show a gradual transition of the sediments of the basin from Transition to marine environment, majorly falling within the transition zone. The Carbonaceous zone indicates elevated amounts of organic matter of floral or faunal origin, which are indicative of reducing conditions. The binary plot can also be used to determine depositional environments. The binary plot shows that the samples align with the non-marine boundary (Fluvial deltaic terrain) and marine zone i. e. the Transition-marine zone, which are also sedimentary

4. Conclusion

Based on the geochemical analysis for the Nanim field in the Niger Delta, Nigeria, the following conclusions may be drawn:

1) The basal part of the shale is characterized by quartz and kaolinite as the major crystalline minerals with traces of halloysite. Similarly, the presence of hematite in the basal part of the shale outcrop suggests oxidizing diagenetic environment of deposition.
2) The AKF plots show a gradual transition of the sediments of the basin from transitional to marine environment.
3) The binary plot shows that the samples align with the non-marine boundary and marine zone i. e. the Transition-marine zones, which are also sedimentary terrains.

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