

MINERALOGY AND GEOCHEMISTRY ASSESSMENT OF THE CRETACEOUS SEDIMENTS IN KANADI-1 WELLS, BORNUN BASIN FORMATION, NORTH-EASTERN NIGERIA

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ABSTRACT

Mineralogical and Geochemical prospect were used to evaluate the Cretaceous and Tertiary sediments in the Bornu Basin of northeastern Nigeria, particularly those found in Kanadi-1 Wells, seeks to gain insight into their origins and how they were deposited. The Bima Sandstone Formation, the sandy-shale Gongila Formation, and the clayey-shaley Fika Formation, are mainly composed of around 35-58% quartz and up to 50% kaolinitic clay. Notably, the quantity of quartz decreases steadily across the stratigraphic sequence. The base of the Bima Sandstone Formation is characterized by its abundance of arkosic characteristics, consisting of 25% albite feldspars. The sandy layers in the Bornu Basin formation (Bima and Fika) are particularly distinguished by containing 15-25% barite. The $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios, ranging from 5 to 6, indicate that the sediments are mostly sandy, while the $(\text{NaO} + \text{K}_2\text{O})/(\text{MgO} + \text{CaO})$ ratios of 1 to 2 in the Bima and Gongila Formations show their calcareous nature. Significant increase of barite in both Bima, Gongila, and lower parts of the Fika Formations shows there is presence of 2-3% SO_3 . These sediments are believed to have originated in environments resembling shallow, tropical conditions. The mineralogical and geochemical features of Cretaceous and Tertiary sediments in the Bornu Basin suggest promising opportunities for exploration. Further research in hydrocarbon, mineral resources, and paleoenvironmental reconstruction can maximize their potential.

Keywords: Geochemistry, Mineralogy, Kanadi-1 Wells, Bornu Basin Formation, Nigeria.

I. INTRODUCTION

The Bornu Basin, situated in Nigeria's south-west, covers 2,335,000 square kilometers and consists mainly of flat land. Nonetheless, there is a significant sand ridge known as the Bama-Maiduguri Ridge Complex, which stretches for 160 kilometers in a direction from northwest to southeast. The ridge originates in Dar-el-Jimeil in Cameroon, passes through Bama and Maiduguri, and then diminishes at Magumeri. The Bama-Maiduguri Ridge Complex represents the highest layer of the Chad Formation during the Pliocene-Pleistocene period, indicating the previous shoreline of Mega Lake Chad's third lake advance approximately 7,500 years ago [1]. The peak consists mainly of sandy boulders, along with spots of

silt, mud, and clay-like rocks. This research is focused on the claystones and mudstones in the eastern part of the ridge, which were deposited from Mega Lake Chad. Siliciclastic rocks show slight changes in their source, surroundings, and processes post-deposition, which can be observed in their chemical composition as well as in the presence of heavy minerals and clays. Geochemical characteristics are impacted by factors such as original material, erosion, mechanical separation, and diagenesis. Mudstones, which are sedimentary rocks, most accurately depict the usual makeup of the Earth's crust in a specific region, offering important details on the local geology, formation, erosion trends, and sediment recycling [2]. The Kandi-1 wells provide a thorough insight into previous depositional settings through its

stratigraphic record. The mineralogical and geochemical features aid in identifying sediment origins and formation settings, differentiating between various rock strata and offering information on historical environmental conditions. The well also evaluates the effects of weathering and paleo-redox conditions, giving a more thorough insight into the sedimentary environment [3].

The aim of the paper is to analyze the mineralogical and geochemical properties of Cretaceous and Tertiary sediments from the Bornu Basin in northeastern Nigeria, focusing on understanding the composition and variations within the sediments encountered in Kanadi-1 Wells.

1.1 Study Objectives

1. To analyze the mineral makeup of Cretaceous and Tertiary sediments in the Bornu Basin, with specific attention to detecting and measuring

important minerals like quartz, kaolinite, albite, and barite.

2. To examine the geochemical properties of the sediments, including major oxide and trace element concentrations, to understand their chemical composition and variation across different formations.
3. To assess the distribution and variations in quartz and kaolinite content across the stratigraphic sequence, with particular attention to changes in mineral composition from the basal to upper formations.
4. To deduce the depositional environments of the sediments based on their mineralogical and geochemical signatures, with a focus on identifying whether they were formed in shallow, tropical-like conditions.
5. To analyze the ratios of major oxides (such as $\text{SiO}_2/\text{Al}_2\text{O}_3$ and $(\text{Na}_2\text{O}+\text{K}_2\text{O})/(\text{MgO}+\text{CaO})$) and the presence of barite and albite to infer the influence of calcareous and terrigenous processes on sediment formation.

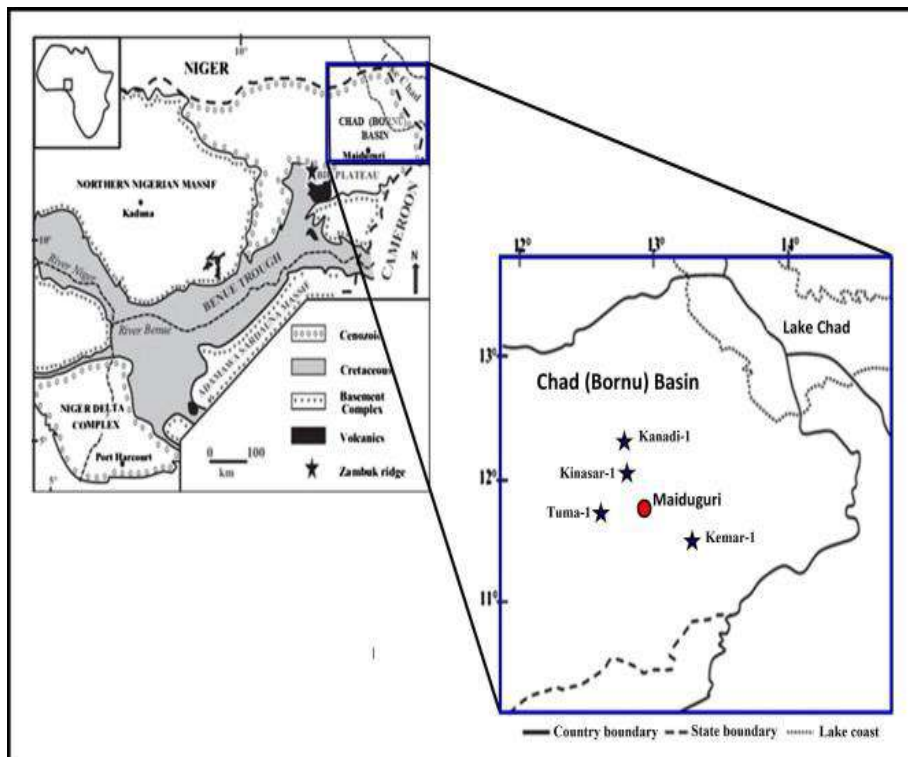


Figure 1. Geological of Bornu Basun Showing the studied exploratory well: Kanadi-1

III. RESULTS AND DISCUSSION

3.1 Lithostratigraphy

The Kanadi-1 well in Kanadi, close to Gajigana, holds a mixture of both marine and continental sediments including Bima Sandstone, Gongila Formation, Fika Shale, Kerri-Kerri Formation, and Chad Formation. The Kerri-Kerri Formation is uncommon in the western section of the basin [7]. Proposed are new hypo-lecto and neo-stratotypes for Gongila, Fika Shale, and Chad Formations. X-ray diffraction analysis shows that kaolinite is present as a clay mineral, as well as quartz, albite, barite, magnetite, zircon, and anatase.

In the XRF analysis, the focus was on determining SiO₂ and Al₂O₃ content. Five grams of pulverized sample were placed into the X-Ray chamber of a Pan Analytical XRF machine. The machine, calibrated for accurate measurement, provided results in weight percentage oxide (wt% oxide) displayed on the connected computer's result window. Additionally, the loss on ignition (LOI) was assessed using a Carbolite furnace. For this, one gram of sieved clay samples was placed in crucibles and heated in the furnace at 1000°C for approximately one and a half hours. After cooling, the samples were reweighed to calculate the LOI.

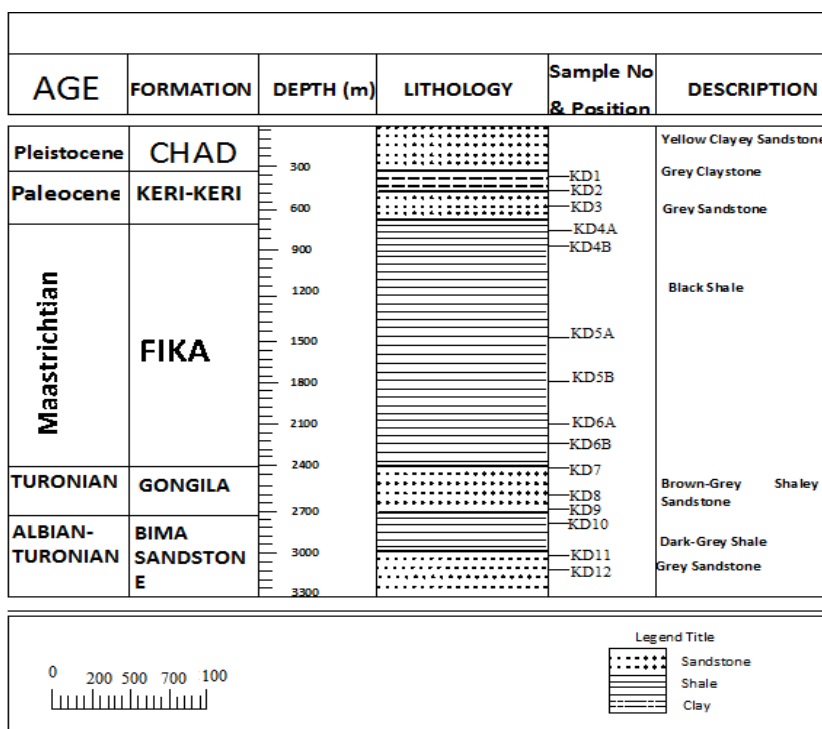


Figure 3. Lithostratigraphic of Kanadi-1 showing the sample depths

3.2 Mineralogy

The analysis of minerals showed that there was a significant variation in the amount of quartz in the different samples, ranging from 30 wt% at KD2 to 50 wt% at KD12, with an average of 44 wt% for the overall study area (Table 1). Kaolinite had a low of 25 wt% at KD8 and a high of 50 wt% at KD2, averaging 27.5 wt% overall. Anatase was specifically located in

KD8 at a concentration of 8.00 wt%, whereas zircon was solely found in KD4 at a concentration of 5.00 wt% [8]. Barite levels varied from 15.00 wt% at KD6 to 25.00 wt% at KD12 according to Table 2. Albite was not found in most samples, except for KD10, in which it was observed at a significant 25 wt%.

3.3 Geochemistry

The sandstones from the Kerri-Kerri, Fika, Gongila, and Bima formations were analyzed geochemically, revealing a SiO₂ content ranging from 60.20 wt% to 77.60 wt%, with mean value of 68.90 wt% (Table 1). The weight percentage of Al₂O₃ ranges from 12.00 wt% to 18.24 wt%, with mean of 15.12 wt%. The CaO content varies between 0.76 wt% and 2.60 wt%, averaging at 1.68 wt% [8]. The levels of Na₂O range from 0.001 wt% to 1.60 wt%, with an average of 0.80 wt%, while K₂O concentrations vary from 0.001 wt%

to 1.32 wt%, averaging 0.66 wt%. The range of Fe₂O₃ content is from 2.03 wt% to 12.20 wt%, with a mean of 7.10 wt%. Smaller quantities of MgO and MnO are found; MgO varies from 0.045 wt% to 1.00 wt%, averaging 0.52 wt%, while MnO ranges from 0.001 wt% to 0.25 wt%, with an average of 0.13 wt%. TiO₂ is present in small quantities, varying from 1.38 wt% to 2.18 wt%, and has an average of 1.78 wt%. The Loss on Ignition (LOI) ranges from 1.01 wt% to 5.10 wt%, averaging 3.1 wt%.

Table 1. Selected sediments of Bornu Basin; Kanadi-1 well

| Sample | Depth(m) | Formation | Lithostratigraphic Description |
|--------|-----------|----------------|--------------------------------|
| KD 2 | 400-650 | Keri Keri | Grey claystone |
| KD 4 | 700-1500 | Fika | Black shale |
| KD 6 | 2000-2325 | Fika | Black shale |
| KD 8 | 2625-2700 | Gongila | Brown-greyshaley sandstone |
| KD 10 | 2775-3000 | Bima Sandstone | Dark grey shale |
| KD 12 | 3150-3400 | Bima Sandstone | Grey sandstone |

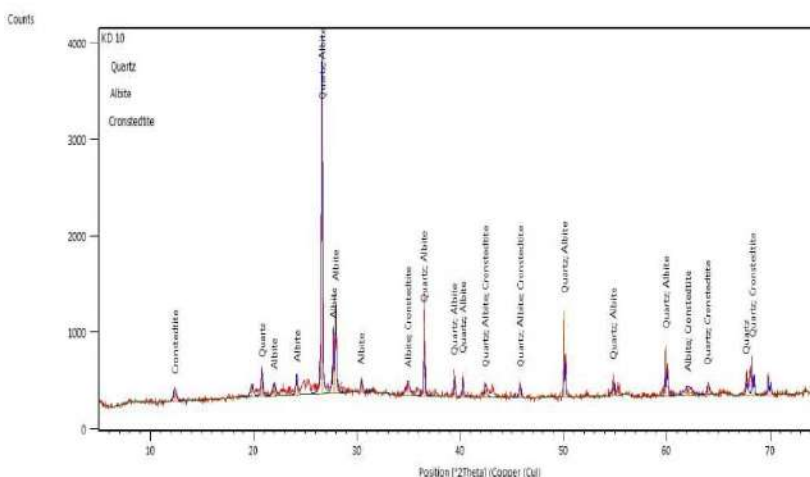


Figure 4a. XRD Diffractographs of Sandstones of Kanadi-1 Well

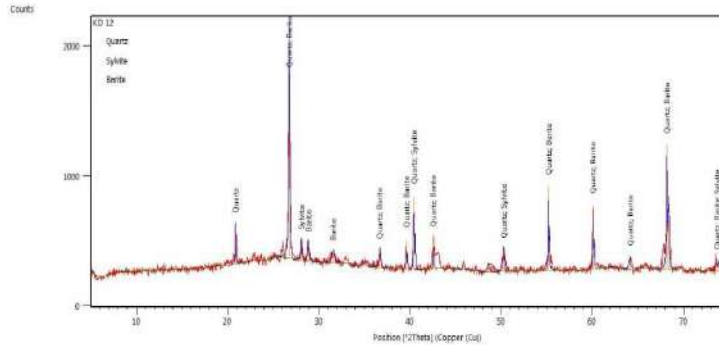


Figure 4e. XRD Diffractograms of Sandstones of Kanadi-1 Well

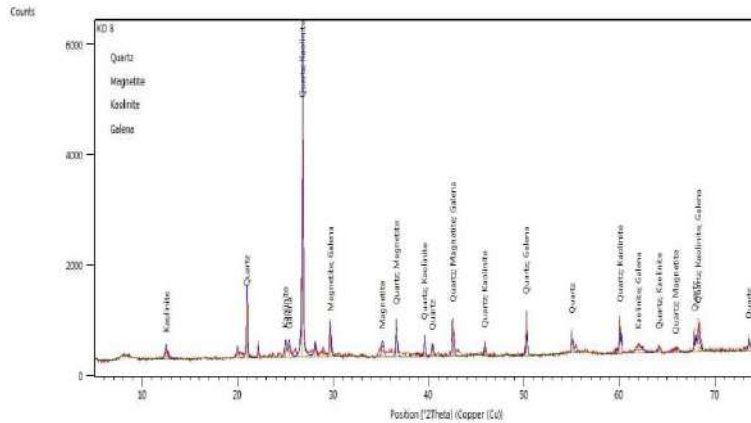


Figure 4f. XRD Diffractograms of Sandstones of Kanadi-1 Well

Table 2. Mineralogical composition of Bornu Basin Sediments Kanadi-1 Well

| S/N | KD 2 | KD 4 | KD 6 | KD 8 | KD 10 | KD 12 |
|-----------|------|------|------|------|-------|-------|
| Quartz | 30 | 35 | 52 | 50 | 56 | 58 |
| Kaolinite | 50 | 44 | — | 25 | — | — |
| Anatase | — | 8 | — | — | — | — |
| Zircon | — | 5 | — | — | — | — |
| Barite | — | — | 15 | — | — | 25 |
| Magnetite | — | — | 5 | 10 | — | — |
| Albite | — | — | — | — | 25 | — |

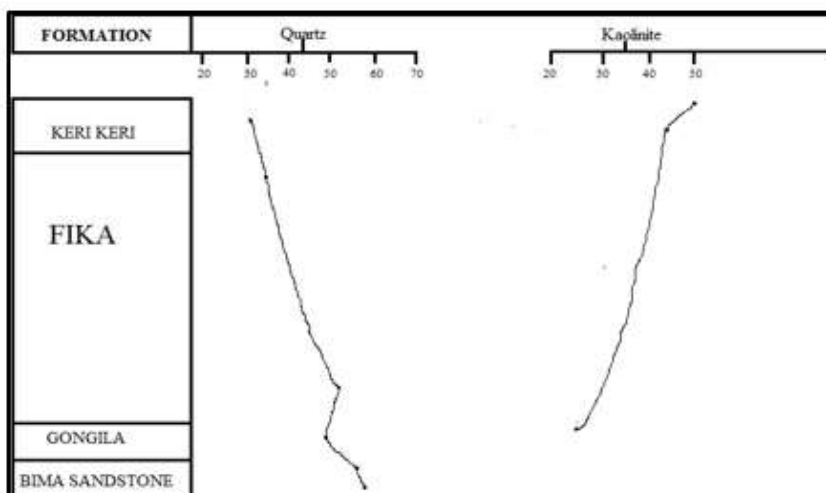


Figure 5. Log of mineral for Kanadi-1 well formation interpretation

Table 3. Geochemical composition of major Oxides (in %) of Bornu Basin Sediments; Kanadi-1 well

| Sample No | KD 2 | KD 4 A | KD 5 | KD 6 | KD 8 | KD 10 | KD11 |
|--------------------------------|-----------|--------|--------|-------|---------|----------------|----------------|
| Formation | Keri Keri | Fika | Fika | Fika | Gongila | Bima Sandstone | Bima Sandstone |
| SiO ₂ | 77.60 | 76.10 | 67.40 | 60.20 | 67.70 | 67.20 | 67.30 |
| TiO ₂ | 2.18 | 1.80 | 1.87 | 2.07 | 1.53 | 1.72 | 1.38 |
| Al ₂ O ₃ | 13.00 | 13.64 | 14.30 | 18.24 | 13.30 | 13.02 | 12.00 |
| Fe ₂ O ₃ | 3.41 | 2.35 | 4.38 | 12.20 | 4.80 | 3.74 | 2.03 |
| MgO | 0.045 | 0.88 | 0.40 | 1.00 | 0.53 | 0.84 | 0.76 |
| CaO | 0.88 | 1.70 | 0.84 | 2.60 | 0.76 | 1.60 | 1.08 |
| Na ₂ O | <0.001 | 0.63 | 1.00 | 1.04 | 1.60 | 1.40 | 0.84 |
| K ₂ O | <0.001 | 0.50 | 1.60 | 1.06 | 1.00 | 1.32 | 0.76 |
| MnO | <0.001 | 0.12 | <0.001 | 0.075 | 0.25 | 0.13 | 0.11 |
| SO ₃ | Nd | Nd | Nd | 3.20 | 2.10 | 2.00 | 3.10 |
| L.I.O | 1.01 | 1.20 | 2.50 | 5.10 | 2.30 | 3.76 | 2.72 |

Nd: Not detected

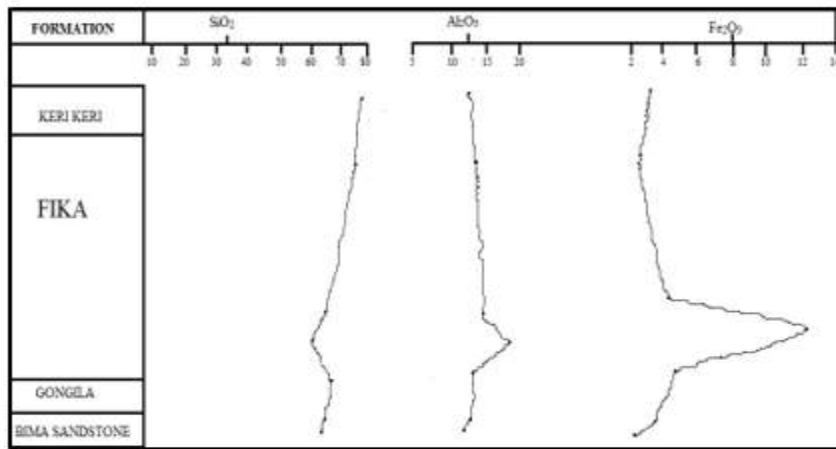


Figure 6. Log of major elements for Kanadi-1 well formation interpretation

IV. CONCLUSION

The classification of the Cretaceous sediments from the Kanadi-1 well relied on the proportions of key oxide groups such as silica, alumina, alkali oxides, iron oxide, and magnesia. The sediments contain a high amount of authigenic albite, indicating they may have formed through the alteration of volcanic ash or weathering of basic rocks. Albite is detected in both the Fika and Gongila formations. The analysis of X-ray diffraction on the sediments from the Kanadi-1 well showed that quartz is the main component with kaolinite coming next. Quartz and kaolinite are found in all the formations. The substantial occurrence of barite and albite suggests a significant terrigenous impact, indicating a nearby origin for the Cretaceous sediments.

The mineralogical and geochemical characteristics of the Cretaceous and Tertiary sediments in the Bornu Basin reveal significant potential for future exploration and exploitation. By conducting further detailed studies in hydrocarbon, mineral resources, and paleoenvironmental reconstruction, the full potential of these sediments can be realized,

contributing to the economic and environmental sustainability of the region.

REFERENCES

- [1] Bamidele, S.O., Ekundayo, J.A., & Peter., S.O. Palynostratigraphy of Late Cretaceous subsurface sediment of southern Bornu Basin, Nigeria: Implications for depositional environments and palaeoclimatic predictions., *Journal of African Earth Sciences*,212(2024)105192.,<https://doi.org/10.1016/j.jafrearsci.2024.105192>.
- [2] Ekwok, S.E., Achadu, O.M., Akpan, A.E., Eldosouky, A.M., Ufuafuonye, C.H., Abdelrahman, K., & Gómez-Ortiz, D. Depth Estimation of Sedimentary Sections and Basement Rocks in the Bornu Basin, Northeast Nigeria Using High-Resolution Airborne Magnetic Data. *Minerals*,12 (2022) 285. <https://doi.org/10.3390/min12030285>.
- [3] Solomon, O.O., John, A.A., & Peter, S.O. Distribution of sedimentary formations in the Bornu Basin, Nigeria, *Petroleum Exploration and Development*,42(2015)674-682. [https://doi.org/10.1016/S1876-3804\(15\)30062-8](https://doi.org/10.1016/S1876-3804(15)30062-8).
- [4] Akpunonu, E., Okafor, O., Okeke, S., Oboh, G., Omeokachie, A., & Chekwube, D. Integration of

Sequence Stratigraphy, Facies, and Geotemperature Analyses in the Study of Hydrocarbon Prospectivity of Bornu Basin in Northeastern Nigeria.(2023)343–346. doi. 10.1007/978-3-031-43218-7_80

[5] Guiraud., M. Tectono-Sedimentary Framework of the Early Cretaceous continental Bima Formation (Upper Benue Trough, NE Nigeria). *Journal of African Earth Science* 10(1990)341–353.

[6] Ilozobhie, A., & Obi., D. Geostatistical analysis of porosity distribution from well log data, in part of Bornu Basin, North-eastern part, Nigeria Using Kriging and Co-Kriging methods. *Advances in Applied Science Research* 6(2019)83–95..

[7] Yusuf, A., Adam, E.D., Uko, C.O., Ofoegbu, O.S., & Ayanninuola. Petrophysical Characteristics of Bornu-Chad Basin Using Well Logs Data. *Geosciences Research Journal (GSRJ)*,1(2023) 47-72.

[8] Obaje N.G., Wehner, H., Scheeder, G., Abubakar, M.B., & Jauro, A. Hydrocarbon prospectivity of Nigeria's inland basins: from the viewpoint of organic geochemistry and petrology. *AAPG Bull* 87(2024) 325-353.