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MINERALOGY AND GEOCHEMISTRY ASSESSMENT OF THE CRETACEOUS SEDIMENTS IN KANADI-1 WELLS, BORNU 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 SiO_2/Al_2O_3 ratios, ranging from 5 to 6, indicate that the sediments are mostly sandy, while the $(NaO+K_2O)/(MgO+CaO)$ 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 SiO_2/Al_2O_3 and $(Na_2O+K_2O)/(MgO+CaO)$) and the presence of barite and albite to infer the influence of calcareous and terrigenous processes on sediment formation.

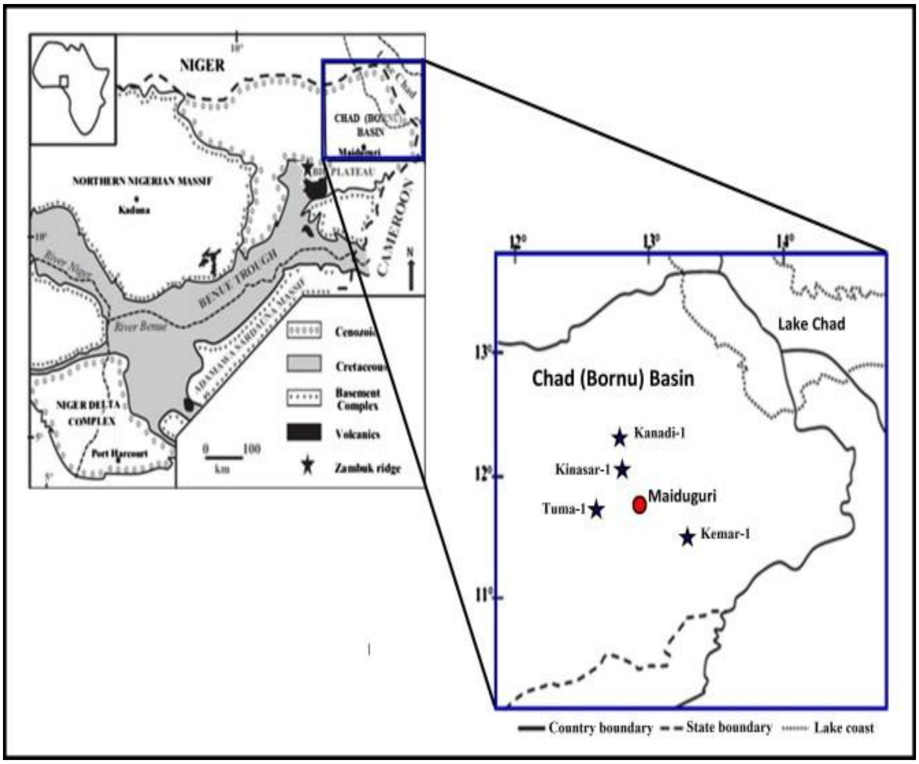

Figure 1. Geological of Bornu Basun Showing the studied exploratory well: Kanadi-1

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1.2 Stratigraphic Setting

The deposition of sediments in one of the basins in Nigeria (Bornu Basin) started during the era called (Albian era) with the Bima Sandstone, a continental formation of feldspathic sandstone lacking fossils [4]. Sitting above the Precambrian Basement Complex, it mainly consists of sandstone and some shale layers [5]. The Gongila Formation marks the start of marine transgression, with calcareous shales and sandstones [6]. In the Maastrichtian period, the Fika Shale, known for its blue-black color and ammonite fossils, formed [6]. The Gombe Sandstone, containing various rock types, was deposited above the Fika Shale [6]. The Kerri-Kerri Formation from the Paleocene period is the only evidence of Tertiary sedimentation, followed by the Chad Formation in the Pleistocene and potentially Pliocene. Volcanic events have been ongoing in the southern and central regions of the Basin since the end of the Tertiary period.

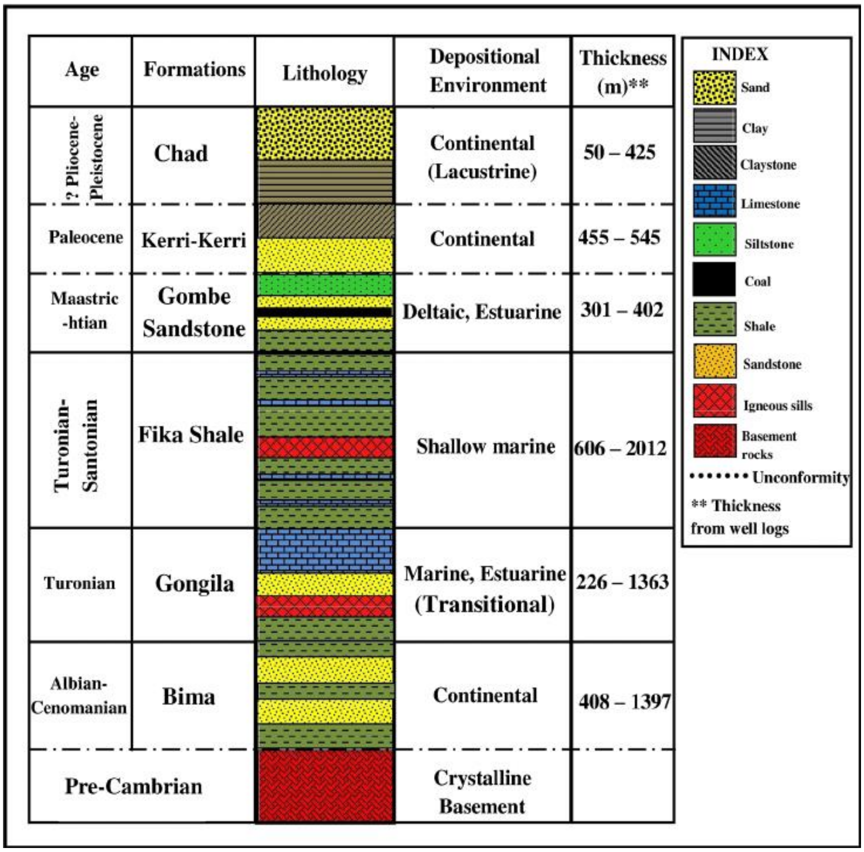

Figure 2. Bornu Basin Regional Stratigraphy

II. MATERIAL AND METHOD

Major and trace element analyses for clay samples were performed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) and X-Ray Fluorescence (XRF). For ICP-OES (Optima 2000DV), elements such as K, Al, Ca, Mg, Fe, Mn, Ti, and P were analyzed. The process began with ashing the samples, followed by digestion of 0.2 grams of the ash with concentrated nitric acid (HNO_3) and hydrochloric acid (HCl). The resulting solution was then introduced into the ICP-OES, where it was nebulized into an aerosol which was used to determine the elements and their concentrations.

In the XRF analysis, the focus was on determining SiO_2 and Al_2O_3 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.

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.

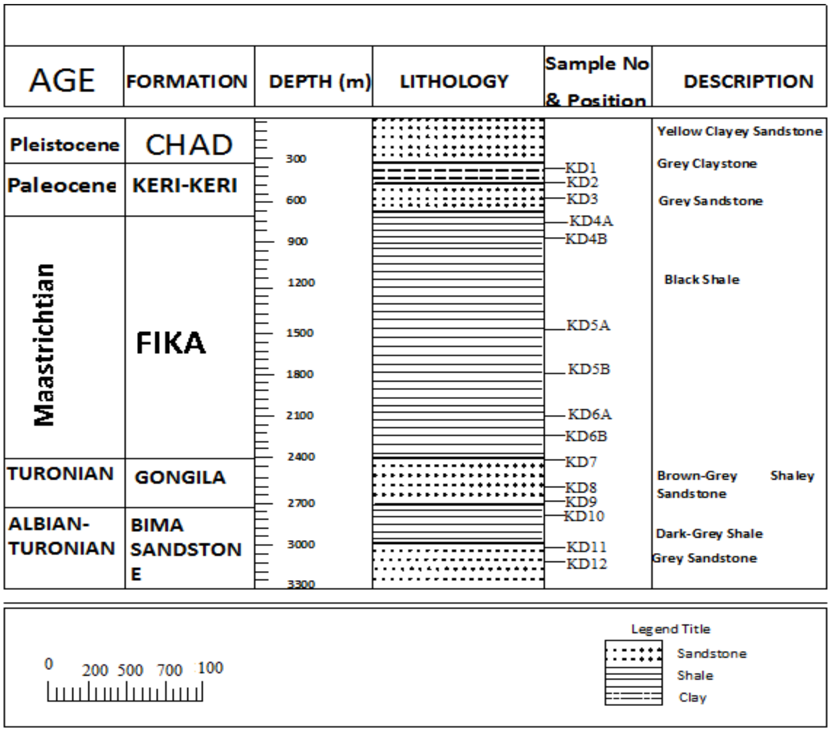

Figure 3. Lithostratigraphic of Kanadi-1 showing the sample depths

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 SiO_2 content ranging from 60.20 wt% to 77.60 wt%, with mean value of 68.90 wt% (Table 1). The weight percentage of Al_2O_3 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 Na_2O 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

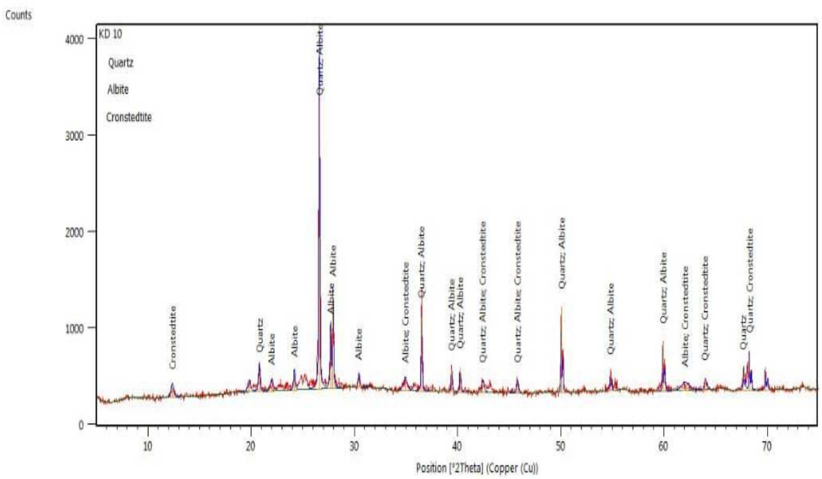

Figure 4a. XRD Diffractographs of Sandstones of Kanadi-1 Well

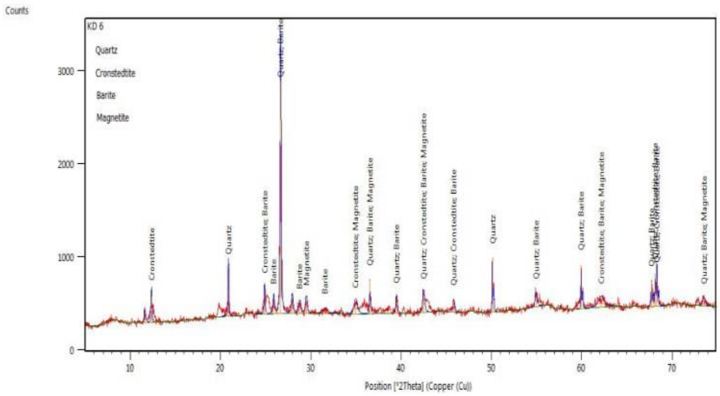

Figure 4b. XRD Diffractographs of Sandstones of Kanadi-1 Well

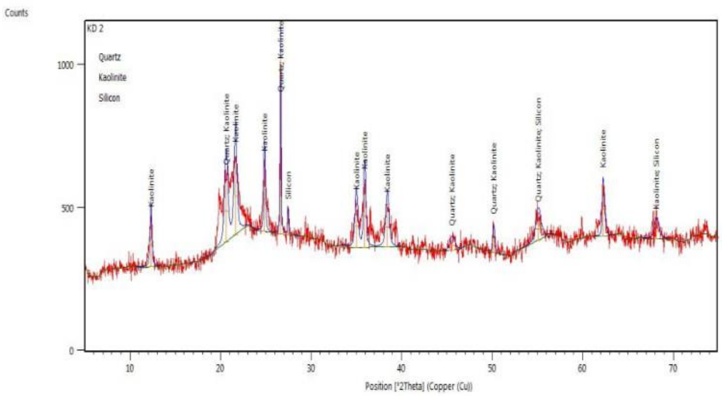

Figure 4c. XRD Diffractographs of Sandstones of Kanadi-1 Well

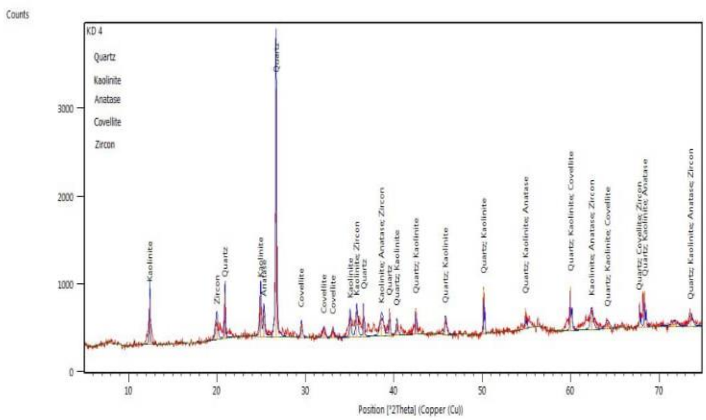

Figure 4d. XRD Diffractographs of Sandstones of Kanadi-1 Well

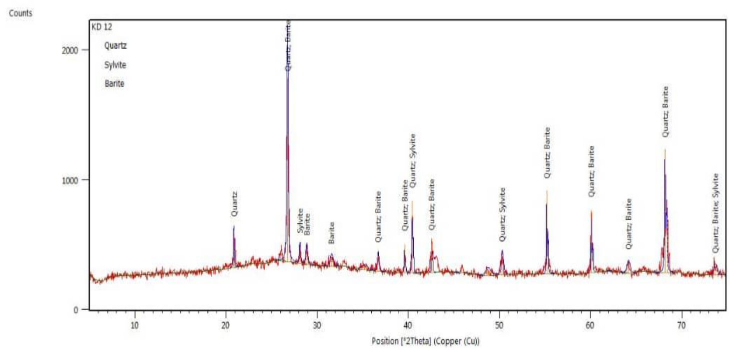

Figure 4e. XRD Diffractographs of Sandstones of Kanadi-1 Well

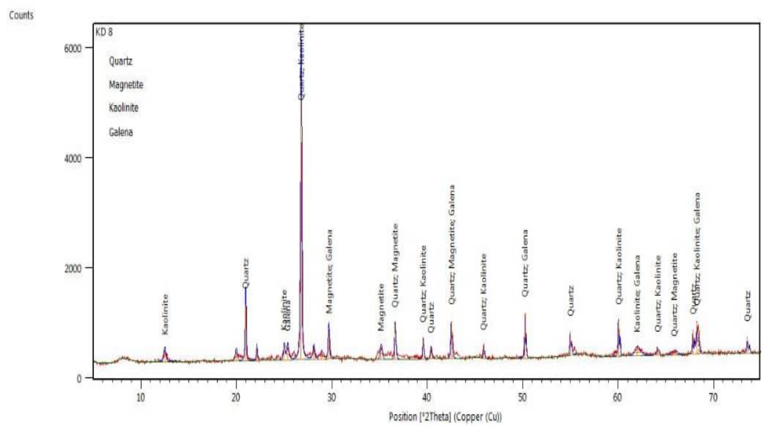

Figure 4f. XRD Diffractographs of Sandstones of Kanadi-1 Well

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	—

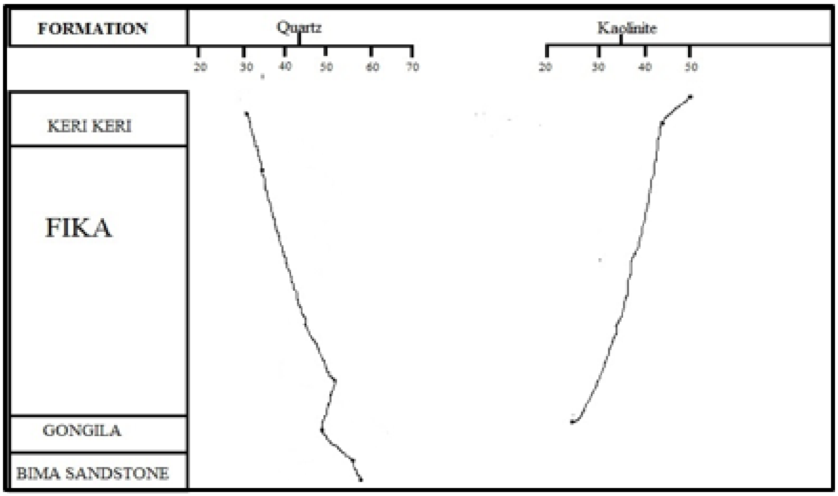

Figure 5. Log of mineral for Kanadi-1 well formation interpretation

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_2O_3	13.00	13.64	14.30	18.24	13.30	13.02	12.00
Fe_2O_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_2O	<0.001	0.63	1.00	1.04	1.60	1.40	0.84
K_2O	<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

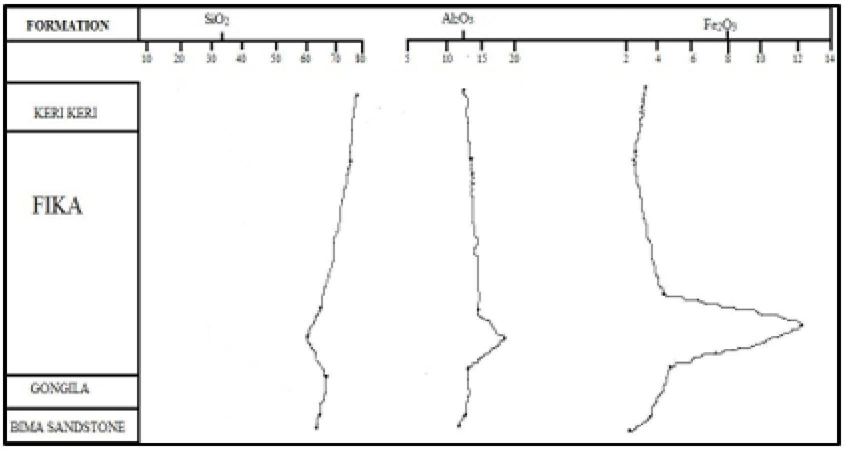

Figure 6. Log of major elements for Kanadi-1 well formation interpretation

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.

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