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ORIGINAL RESEARCH ARTICLE

GEOLOGICAL SETTING AND SOLID MINERAL POTENTIALS OF SOUTHERN BORNO, NORTHEASTERN NIGERIA

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ABSTRACT

This research work has principally succeeded in updating the geological map of Southern Borno and brought out zeolite as one of the prominent solid minerals to work on. The field mapping of the area constituting of Askira Uba, Bayo, Biu, Chibok, Damboa, Gwoza, Hawul, Kwaya Kusar, and Shani Local Government Areas indicate the occurrence of basement and sedimentary rocks. The crystalline rocks comprises of migmatites, gneisses, granites and basaltic rocks, dominantly occurring in Gwoza, Askira Uba, Chibok, Biu and Hawul, whereas the sedimentary formations cover Kwaya Kusar, Shani, Bayo and Damboa with outcrops of Cretaceous-Quaternary sediments comprising Bima Formation, Gongila Formation, Fika Shales, Gombe Sandstone, Kerri Kerri Formation and Chad Formation. Mineralogical evaluation of the Basement Complex rocks indicate the occurrences of feldspars, quartz, micas and ornamental stones, with the basalts chiefly hosting zeolite and quality gemstones (aquamarine, corundum, amethyst, tourmaline and topaz). The zeolites are typical of chabazite variety mostly developing from feldspathoid associated with mafic igneous/basic volcanic rocks. The Cretaceous-Quaternary sediments present quality clays, kaolinite, diatomite, trona and bentonite industrial minerals.

1.0 Introduction

The southern part of Borno state is located within longitudes 11° 40' 00"E and 14° 20' 00"E and latitudes 10° 15' 00"N and 10°20' 05"N in northeastern Nigeria. It politically comprises of 8 Local Governments Areas of Askira-Uba, Biu, Chibok, Damboa, Gwoza, Hawul, Kwaya-Kusar and Shani (Figure 1). Geographically, the area falls within the sudan savannah characterized by short shrubs and few scattered trees, with short wet-season (June-September) and long dry season (October-May). Topographically it is characterized by rugged terrain provided by the Mandara (Pulka-Gwoza-Chibok) mountains and the Biu plateau (Figure 2). The geology of southern Borno is typified by vast occurrence of Precambrian Basement Complex rocks in its eastern region, whereas the western flank of the area is underlain by the Tertiary-Quaternary basaltic rock of the Biu Plateau. Sedimentary rock of Albian-Tertiary age underlies the extreme western region and locally associated with volcanic intrusions.

A number of solid mineral resources, particularly industrial/non-metallic types (examples are feldspars, quartz, clays, dimension stones) and gem quality stones have been identified in the area. Good quality feldspar with high triclinicity (Δ) value (Baba et al., 1991) has been mined from Liga pegmatites in Gwoza area since 1985 for ceramic production while gem-quality stones, including tourmaline, garnet and topaz have also been identified and mined from Gunda area of Biu plateau in the 1990s (Baba, 2005).

This work intends to re-evaluate the geological setting of the area with the aim of further differentiating the rock types in more detail as well and their structural framework and their implications in possible mineralization processes. It also intends to re-examine the solid mineral resources potentials of the different rock types in the area with the aim of harnessing the exploration targets for possible exploitation.

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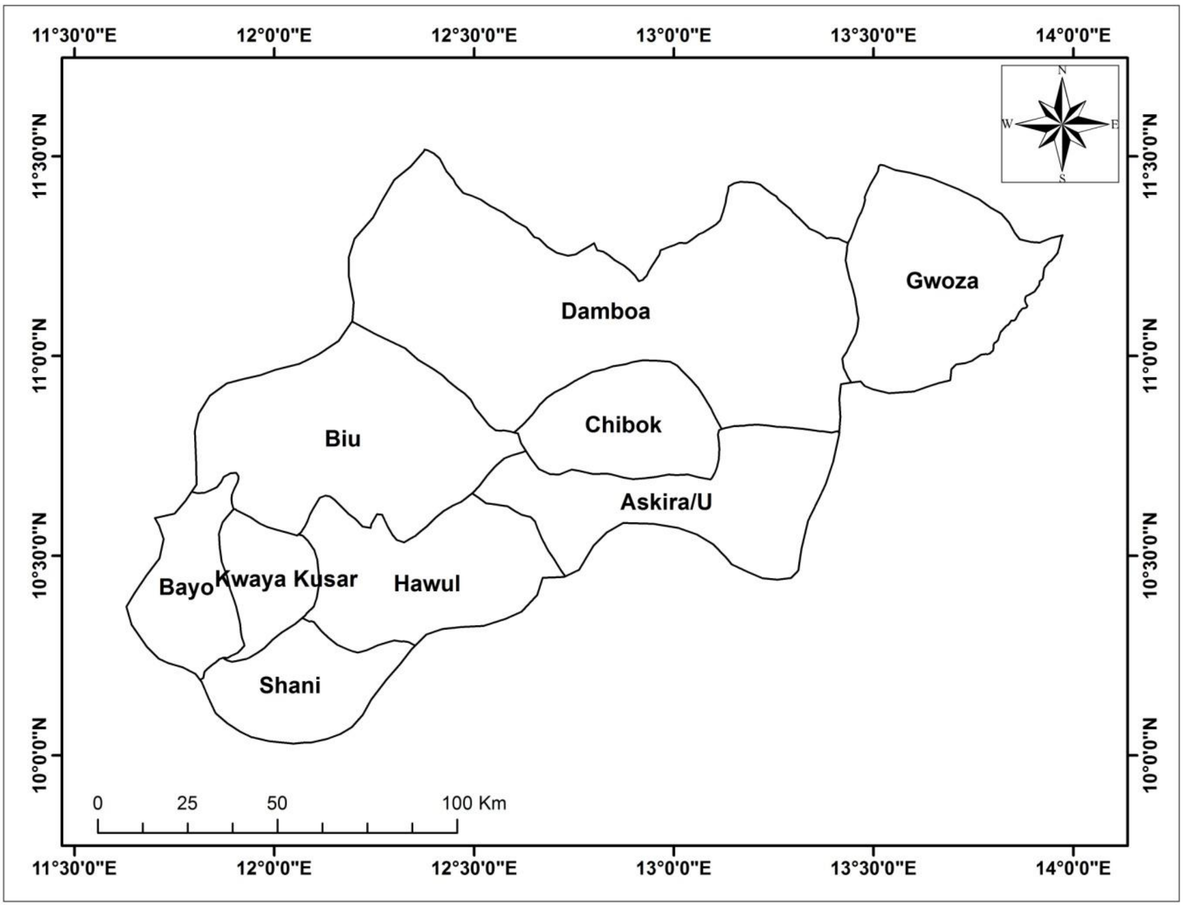


Figure 1: Political Map of Southern Borno

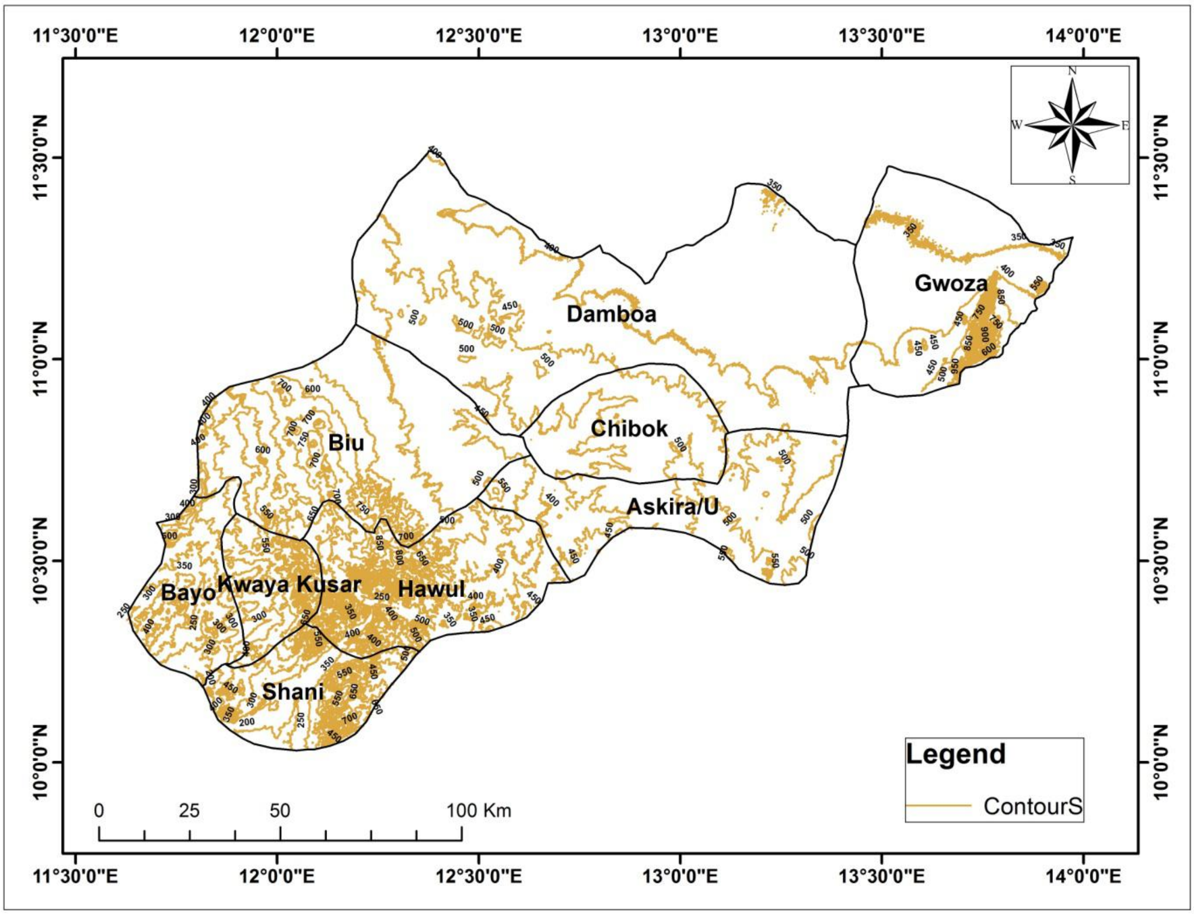


Figure 2: Topographic Map of Southern Borno

2. Materials and Methods

2.1 Geological Mapping

The southern part of Borno was mapped on a scale of 1:50,000 using topographic map as base map. A total area of about 24,150 km^2 was covered using traverse compass mapping technique. Representative rock samples were chipped, described on the spot as hand specimen. Samples were then labelled, the locations noted and plotted on the base map with the aid of the GPS which gives exact coordinates of sample points in terms of latitudes and longitudes. The megascopic features and characteristic field relationships of the formations, structural elements as well as possible mode of occurrence of the various rocks and formations in the areas were measured, described and recorded.

2.2 Thin section preparation

Rock and mineral samples collected from the field were taken to petrology and mineralogy laboratory of Geology Department, University of Maiduguri and were thin sectioned following the procedure outline by Kerr (1977) which involves cutting a thin slice from the rock samples using cutting machines. The slices were polished with abrasive powder until a required thickness of 0.03mm was attained. The polished surfaces of the slices were then mounted on the glass slides using araldite. The glass slides with the mounts were placed on the hot plate and heated for 10 minutes. The samples were removed from the hot plate and allowed to cool. The slides were once more polished to standard thickness of 0.03mm using abrasive powder of various grades on glass laps. Canada balsam drops were smeared on the glass slides while on the hot plate and very thin glass covers were placed on the finished polished surfaces in which gentle pressure were applied to remove trapped air bubbles as well as excess Canada balsam. The slides were allowed to cool, hardened while the overflow of the balsam was washed off using organic solvent. The slides were then properly labelled and subjected to petrographic studies using petrological polarizing microscope.

3. Results and Discussion

3.1 Geological Setting

Field mapping reveals that southern Borno is underlain by Basement Complex rocks, Cretaceous sediments and Tertiary-Quaternary volcanics (Figure 3).

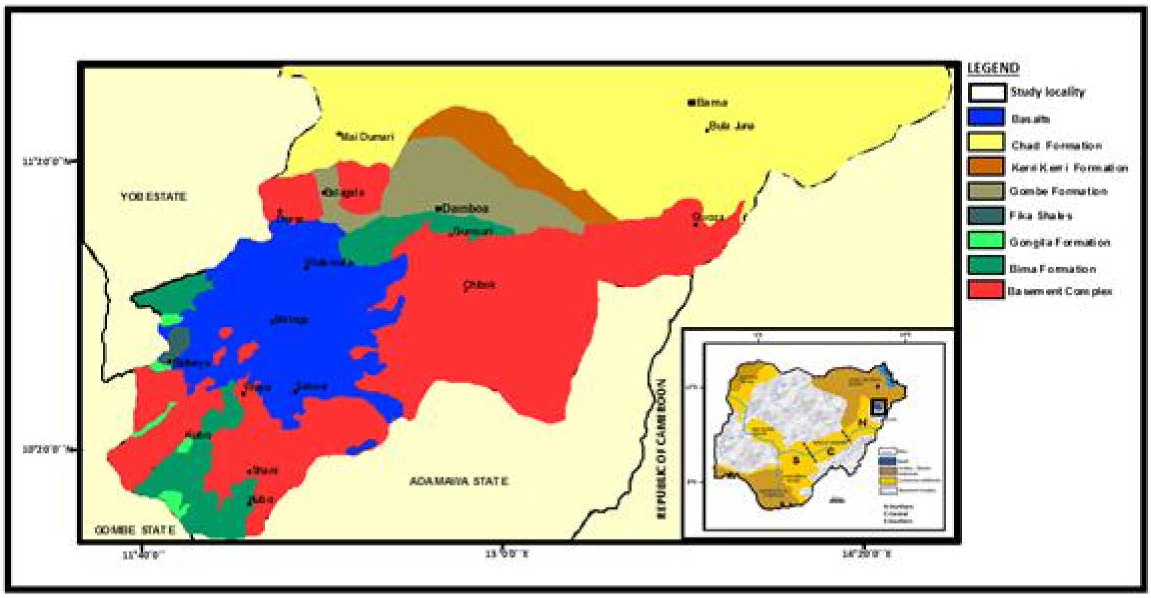


Figure 3: Geological map of Southern Borno (Inset-map of Nigeria showing the location map)

3.1.1 The Basement Complex rocks:

The Basement Complex rocks constitute about 60% and outcrop dominantly in the eastern part of the study area particularly in Pulka, Gwoza, Hambagda, Limankara and Chibok areas. The Basement Complex rocks are Precambrian in age the evolution of which has been attributed to four major orogenic episodes in Nigeria (Baba, 2005); the Liberian (2800±200 Ma), the Eburnean (2000±200 Ma), the Kibaran (1100±200 Ma) and the Pan-African (600±150 Ma). The whole of Africa was affected by the Liberian and Eburnean episodes but the Kibaran and

Pan-African are not pronounced in some areas on the continent. In Nigeria, the Kibaran activity, which was largely sedimentation and volcanism with subsequent metamorphism producing low-grade, N-S trending, gold bearing metasedimentary schist belts, was restricted to the western half of the country west of longitude 8° E (Baba, 2005). The Pan-African orogeny engulfed the whole of Nigeria making it fall fully within the Pan-African mobile belt.

Rocks resulting from the Liberian and Eburnean episodes are represented by migmatite-gneiss complex (MGC). These rocks are generally low-lying, highly deformed, petrologically confusing and structurally gost-looking units. In southern Borno the MGC outcrops at the margins of the prominent Mandara mountains in Pulka-Gwoza areas as well as Hambagda apparently enveloping the mountain range. The Pan-African orogeny on the other hand is the most extensive and widespread episode in Africa which has largely obliterated the footprints of the older episodes. It resulted in the emplacement of large volume of granitic plutons which are now generally referred to as "Older Granites" to distinguish it from the high-level Jurassic granites of central Nigeria which is called "Younger Granites" (Falconer, 1911). Recently however, the term "Pan-African Granitoids" is preferred by modern Nigerian geologists.

The Pan-African Granitoids in southern Borno vary in texture but are mineralogically similar except a few subordinate basic variants. The dominant variants include coarse porphyritic biotite granites (pink-feldspar and white-feldspar sub-variants), coarse grained granite, medium grained granites and fine grained granites with subordinate but genetically important pegmatites, aplites and dolerites. Fracturing and felsic veins (including the aplite) chacterize the closure of the Pan-African activity in Nigeria (Islam et al.,1989).

The Cretaceous sediments

The sediments in southern Borno are part of the Cretaceous-Recent sediments in the Nigerian sector of the Chad Basin. General sequence of the sediments include; Bima Formation, Gongila Formation, Fika shales, Gombe sandstones, Kerri-Kerri Formation and Chad Formation (Fig. 3). The Aptian-Albian Bima sandstone, encompasses the northern, western and extreme south western parts of the area, a continental formation represents the oldest sedimentary succession in the entire Northeast, which rests directly and unconformably on the Precambrian crystalline Basement Rocks and consists of three siliclastic members: the lower Bima (B1), middle Bima (B2), and upper Bima (B3) (Carter et al., 1963; Guiraud, 1990, 1991)). The formation generally consists of massively bedded, sparsely fossiliferous, poorly sorted, medium-coarse grained arenaceous feldspathic sandstone. It is mainly composed of sandstones, although the occurrence of shale intercalations has been reported (Carter et al., 1963, Avbovbo et al., 1986). The lithology is diverse, indicating accumulation under widely varying conditions, including fluviatile, deltaic and lacustrine depositional environments (Carter et al., 1963; Allix, 1983; Guiraud, 1990).

The Lower Bima Sandstone is the oldest unit and was interpreted as a proto-rift and syn-rift succession (Guiraud, 1990), which is a thick continental deposits being the infillings of semi-isolated grabens, with a variable thickness ranging from 0 to greater than 1500m. The sediments consist of poorly sorted, angular arkoses, granulestones, pebbles and boulder conglomerates. Fresh fragments of acidic rocks are common. Red to mottled colours are characteristic suggesting pedo-genetic features, and intercalations of volcanic rocks indicate contemporaneous volcanic activity (Popoff, 1988).

The thickness of the Middle Bima Sandstone ranges from 100-150m, consisting of gravelly to coarse-grained feldspathic sandstone dominated by large-scale trough and tabular cross bedding and clays. Palaeosols may occur at the top of this unit. Guiraud (1990, 1991.) reported fossil wood to which late Albian age was assigned.

The Upper Bima sandstone is fairly homogeneous and relatively mature fine to coarse-grained sandstone with pebbly beds and rare bands of calcareous sandstones characterized by tabular cross-bedding. Convulate bedding and overturned cross-bedding are common. Its thickness ranges from 500-1500m.

The Gongila Formation with outcrops restricted to the western half of the study area, overlies the Bima Sandstone which was deposited in shallow paralic environment hence regarded as transitional between the underlying continental Bima and full marine Fika Shale above. It consists of basal limestone and interbeds of shale and sandstone giving a thickness of 1500m (Hamza et al., 2002). The limestone is rich in ammonites and mollusc, these assemblages indicates early Turonian age (Carter et al., 1963).

The Fika Shale with occurrences in western part of the study area around Balbaya (Fig. 3) conformably overlies the Gongila Formation and it consists of a sequence of blue-black, gypsiferous and ammonite-rich shales with occasional thin limestone beds. It has a thickness of 1190m (Hamza et al., 2002). Fish, ostracod and reptile remains have been reported which supports Turonian-Santonian age (Carter et al., 1963; Kachroo et al., 2000).

The Gombe sandstone comformably overlies the Fika Shale with occurrences in the northern portion of the study area notably around Damboa and Balagala areas. It consists of sandstones, siltstones, mudstones and ironstones. It has amaximum thickness of 310m and it is of Maastritchian age (Zaborski et al., 1997).

The Kerri-Kerri Formation was observed to occupy the northern part of the study area, a purely continental deposit, comprises of grits and sandstones having well-developed cross-bedding structures suggesting deltaic environment. It is distinctly characterized by reddish and often capped by oolitic lateritic horizon. Based on field and palynological studies, a Paleocene age was assigned to it with thickness of 320m (Dike, 1993).

The Chad Formation outcrops in the extreme northern part of the mapped area and is made up of blue-grey, fine to coarse-grained sand, with intercalation of sandy clay, clay, grits, gravel and diatomite. It is lacustrine and fluviatile in origin. Based on some vertebrates' jaw bones and diatoms the formation is Pliocene-Pleistocene in age (Barber and Jones, 1960).

3.1.3 The Volcanics

There are two areas of volcanic occurrence in southern Borno, the Biu plateau and the Kirawaareas.Biu area was subjected to two volcanic eruptions, the Pliocene (5-3 Ma) and the Quaternary (< 1.4 Ma) (Grant and Freeth, 1972). These eruptions are represented by two compositionally similar but structurally different volcanic rocks, the "Biu type basalts and the Miringa-type basalts" together forming the spectacular Biu-plateau. Biu plateau is the largest area of volcanic rocks in Nigeria covering an area of about 500 Km2 (Carter et al., 1963) with an average elevation of 700m.

The Biu basalts belong to the early eruption and from field evidence, it is believed to have resulted from fissure (gentle) eruption now represented by extensive massive lava flows covering the entire southern part of the plateau. The later eruption (Miringa-type) is associated with violent eruption (vent-type) as evident by the occurrence of pyroclastic materials such as volcanic bombs, pumice, welded tuff etc. around volcanic cones. The two ages of Pliocene and Quaternary given by Grant and Freeth (1972) were further collaborated by the mineralogical work of Islam (1986) where the olivine phenocrysts in the Biu-type basalts were found to be usually altered, commonly to iddingsite, while those in the Miringa-types were relatively fresh. The Biu-type basalts areessentially "alkali olivine basalts" while the Miringa-type are mainly "basanites".

Kirawa volcanics are also Tertiary in age and form part of the Cameroon-line in the northeastern part of the study area. They are compositionally acidic as opposed to the basic nature of the Biu-plateau volcanic. Okeke (1991) identified two variants of Kirawa volcanic as "Commendites" and Pentellerites".

The Pentellerites are homogenous rhyolitic lavas while the commendites are tufaceous. From petrological point of view the commendites are younger as field evidence has shown them to contain xenoliths of the pentellerites.

3.2 Petrography

As stated above, southern Borno is underlain by Precambrian Basement Complex rocks, Cretaceous sediments and Tertiary-Quaternary volcanics. Because of the preliminary nature of this report, only the detail petrography of the basalts is presented.

Generally, the basalts consist of plagioclase feldspars, augite, olivines, nepheline, zeolite and opaque minerals. The plagioclases occur both as phenocrysts and as groundmass. The phenocrysts are colourless and subhedral in form with low relief and weak birefringence. They shows white to gray interference colour of first order and exhibit a combined albite and Carlsbad twinning (Figure 4) though some crystals show only albite twinning (Figure 5). The crystals have perfect cleavage in two directions perpendicular to one another. Augite occurs as pale green crystals having prismatic form of short dimensions. It has high relief and strong birefringence with pale green to greenish interference colour of the second order. It shows perfect cleavages in two directions normal to one another. Olivine occurs as large phenocrysts, yellowish in colour and euhedral in form. Some crystals occur both as subhedral and anhedral with high relief and strong birefringence. It shows pale blue to deep blue upper second order interfence colours. It is characterized by numerous irregular but characteristic Y-shaped fractures (Figure 6) and exhibits parallel extinction with evidence of alteration in most crystals. The nepheline is turbid white coloured and short prismatic form. It has perfect cleavage in two directions with low relief and weak birefringence which exhibits grey of first order interference colour. It shows symmetrical extinction and occurs as small phenocrysts with rows of inclusions in some crystals while some constitute the groundmass. Zeolite occurs as colourless and tabular in form having imperfect cleavages in two directions. Relief is low and birefringence is weak and shows gray to white first order interference colours (Figure 7). The mineral appears to fill empty cavities in the rock indicating that it is secondary material and the variety is recognized as chabazite variety. Pyroxenes occur dominantly in the groundmass where, at places, they cluster together forming a unique concentration (Figure 8).

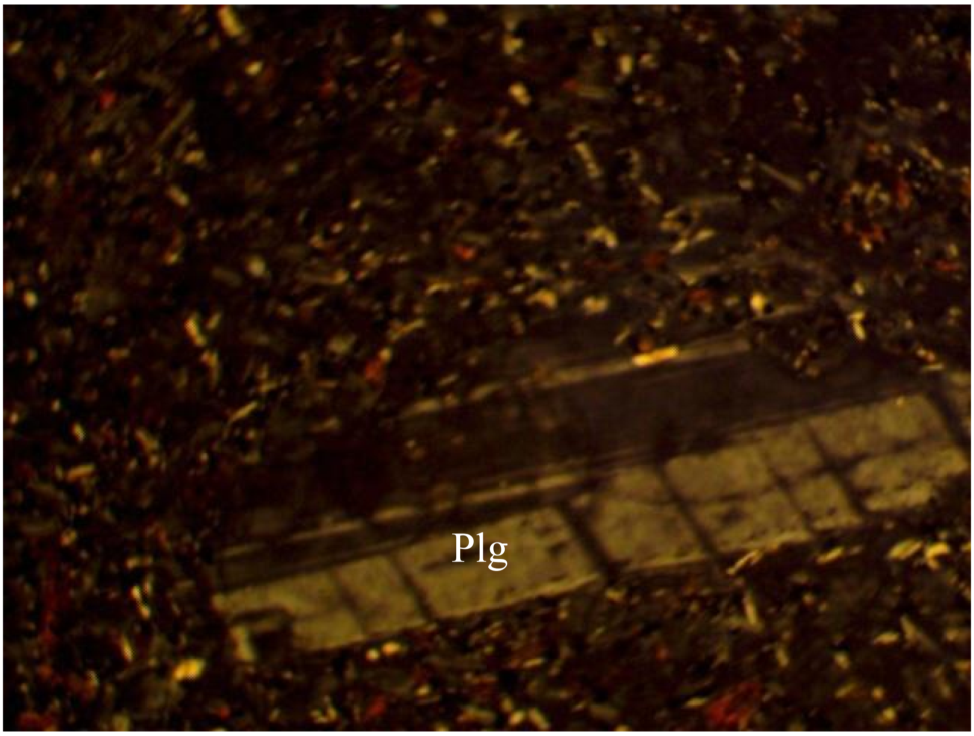


Figure 4: Photomicrograph of basalt showing phenocryst of plagioclase feldspar exhiting both Carlsbad and albite twinning

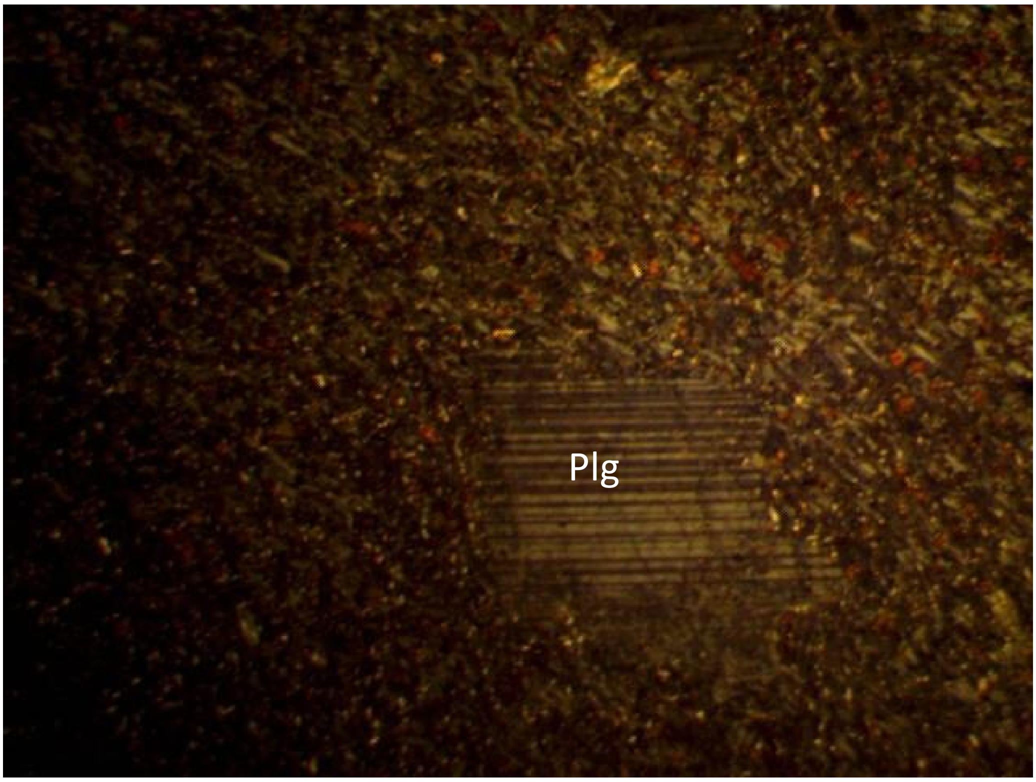


Figure 5: Photomicrograph of basalt showing plagioclase phenocryst in groundmass of olivine, augite, plagioclase and nepheline

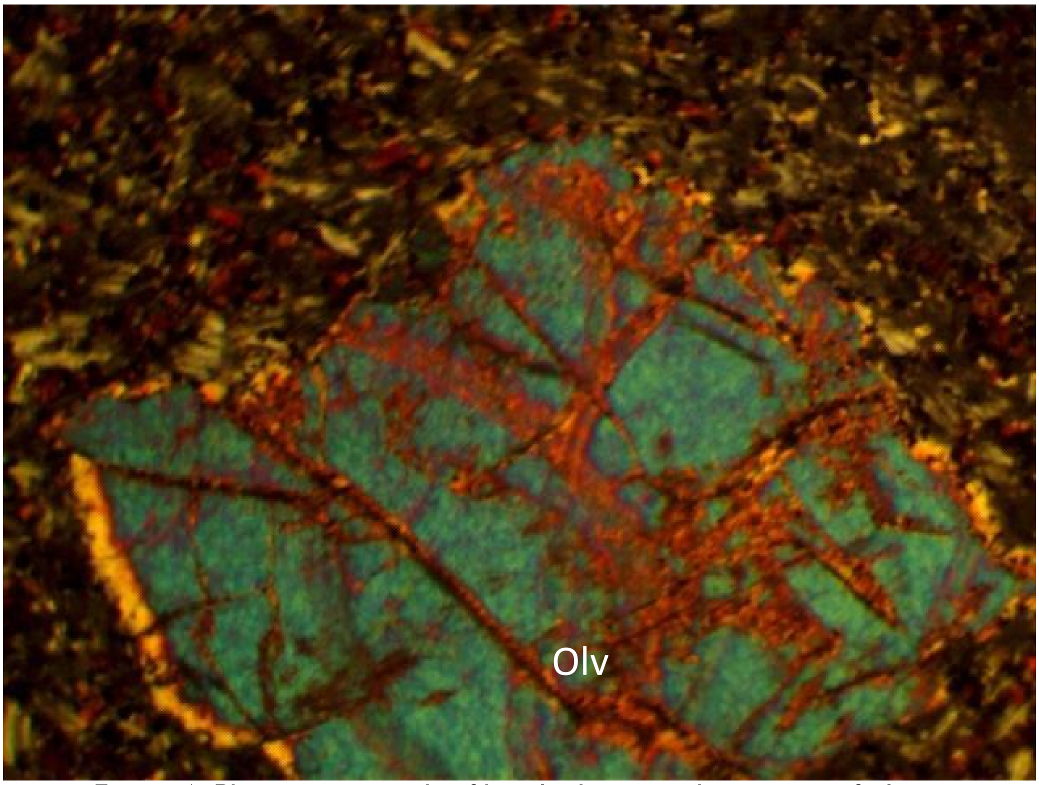


Figure 6: Photomicrograph of basalt showing phenocryst of olivine

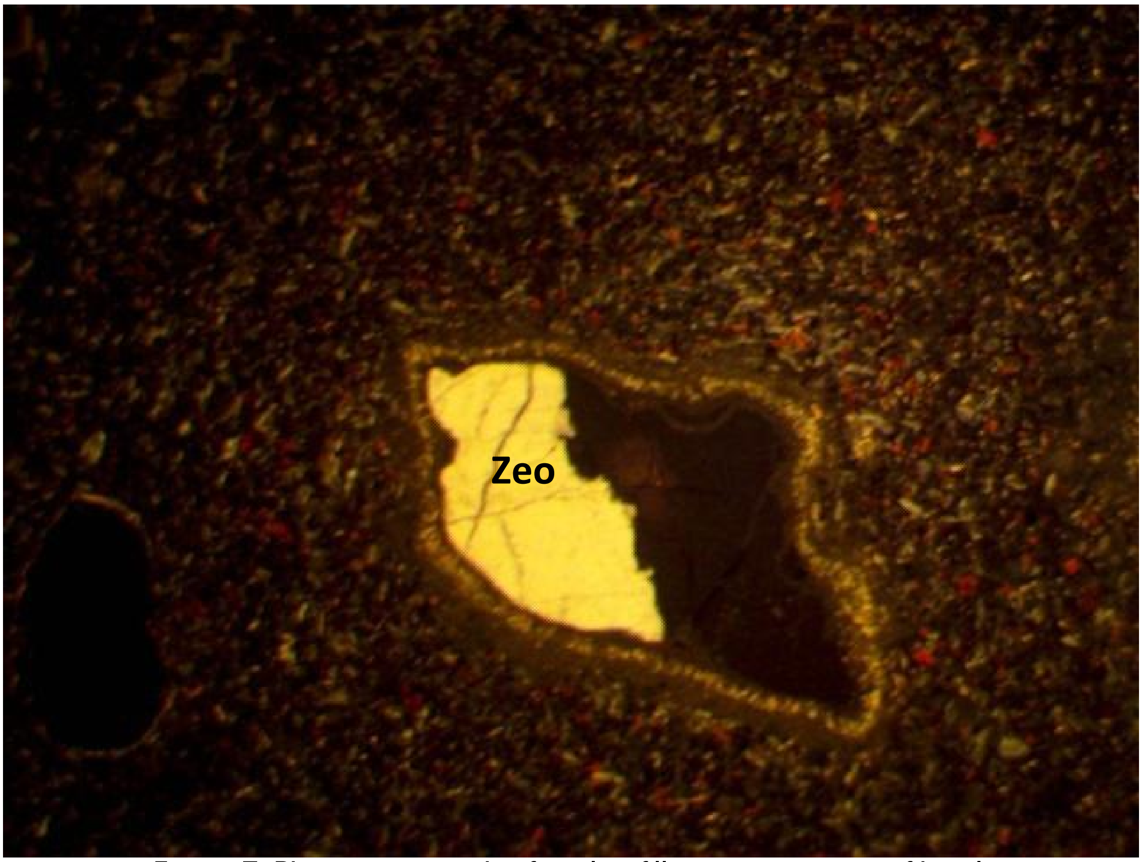


Figure 7: Photomicrograph of zeolite filling empty cavity of basalt

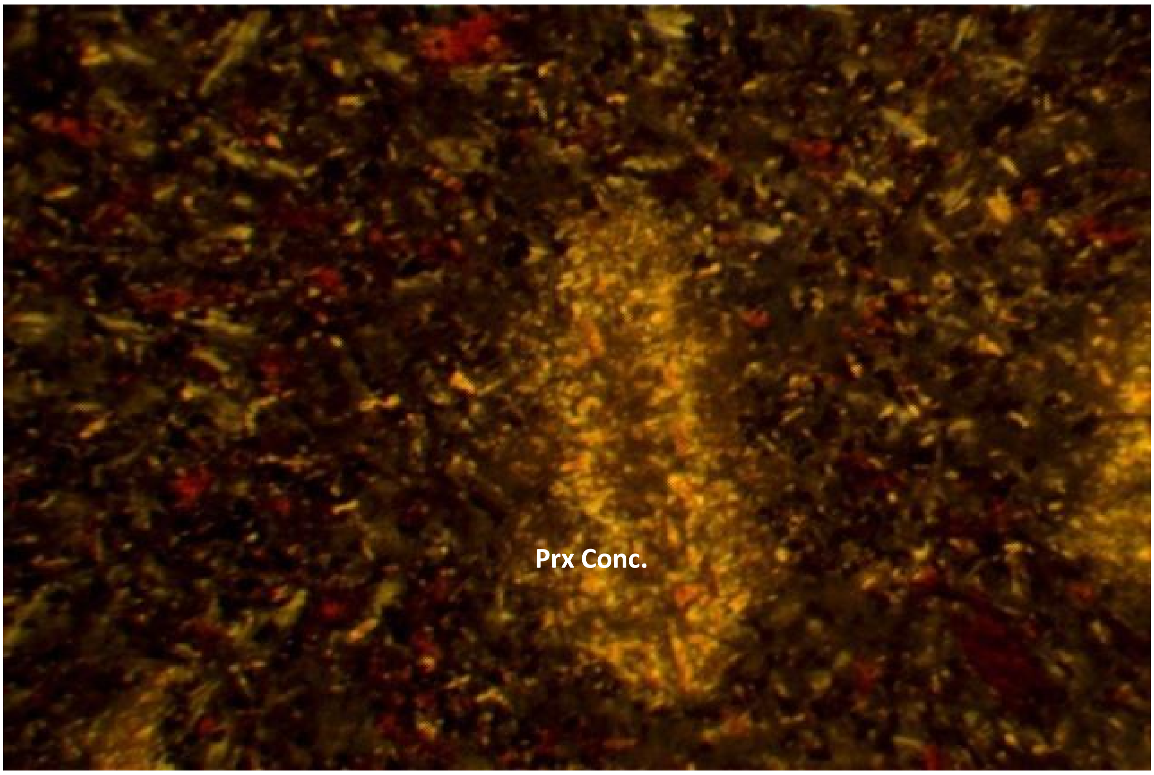


Figure 8: Photomicrograph of basalt showing pyroxene concentration (Prx conc.) in a groundmass of olivine, augite and plagioclase

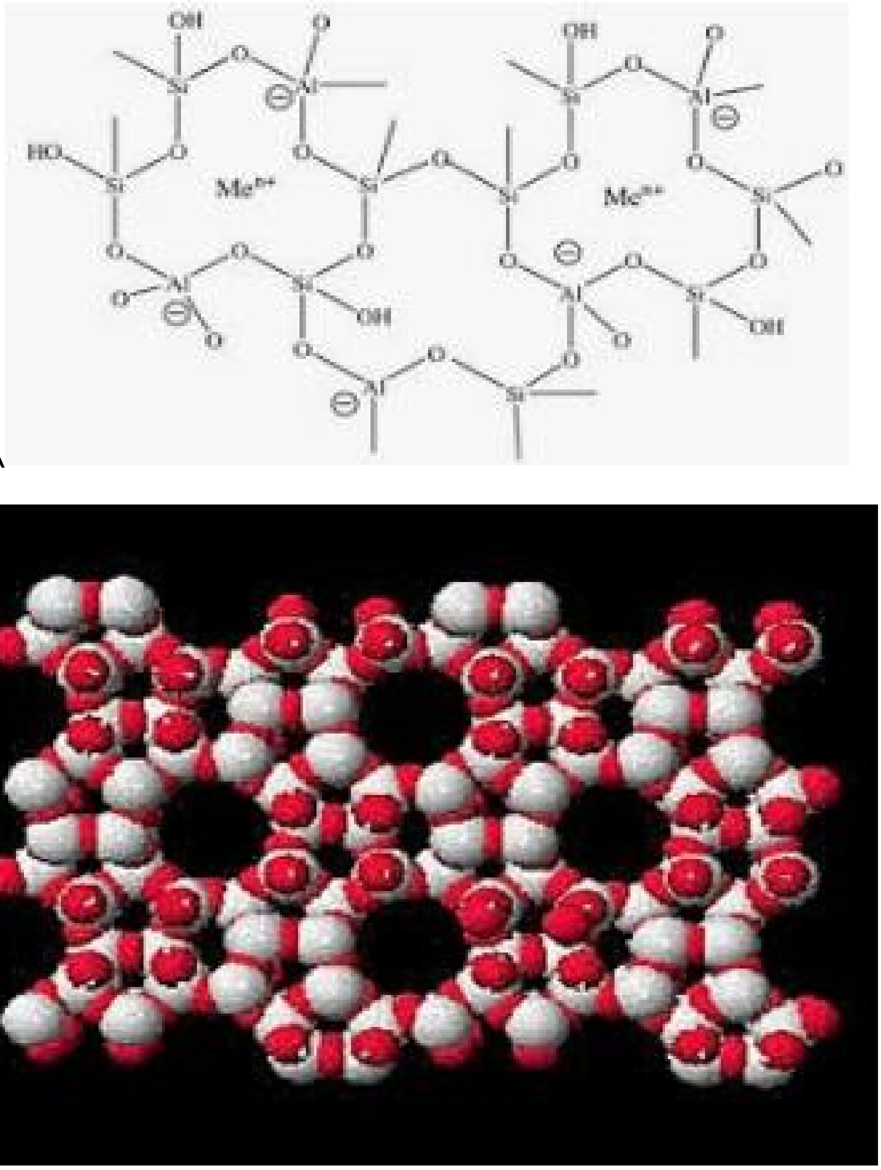
3.3 Mineralization

The various geological components of southern Borno are individually characterized by different types of solid mineral potentials. The Basement Complex rocks are known to harbour some industrial minerals such as feldspars, clays and ornamental stones among others. The

Cretaceous sediments on the other hand also host good quality clays, kaolin, diatomite, trona and bentonite. The Tertiary-Quaternary basalts host good quality gemstones and clays.
Because of the preliminary nature of this work only zeolite, occurring in the Biu-plateau basalts has been treated petrographically.

3.3.1 Zeolite

Zeolite is a group of hydrated aluminosilicate minerals consisting of over forty (40) varieties. All are of framework silicates (Figure 9a) containing open cavities capable of holding loosely bonded large cations and water. They are complex tektosilicates containing 3D network of SiO4and AlO4 tetrahedra linked to form channels, cages, rings or loops (Figure 9b). Because of these channels and cages in their structures cations and water molecules pass in and out of them without disruption.



A

B

Figure 9: Structures of zeolite, A: framework silicates and B: 3D network of SiO4and AlO4 tetrahedra linked to form channels

Each oxygen ion is shared by two Si^{4+}. Some number of Si^{4+} may be replaced by Al^{3+} and the charge deficiency is balanced by the introduction of N^{+}, K^{+} or Ca^{2+}. The open cavities are responsible for the low density of zeolite. The general formula is:

$$(Na^{+}, K^{+}, 1/2Ca^{2+})_{x}Z\ [(SiAl_{x})O_{2(x+y)}]_{z}.nH_{2}O \quad (1)$$

Occurrence of zeolites in southern Borno has been found to be within the basalts of the Biu plateau. The zeolite occurs in two generations. The first generation appear as primary constituent in the basalts and in some instances predate the late eruptions (Figure 10) where the basalt is seen to cross-cut the zeolite. The second generation of the zeolite is secondary in nature where it is seen to fill vesicles and cavities within the basalts (Figure 7), probably formed by late hydrothermal processes.

Physical and petrographic analysis of the zeolite shows that the variety is whitish in hand specimen with hardness of approximately 4 and specific gravity of about 2. In thin section the variety is colourless in plane polarized light and rhombohedron in form. Birefringence is high with grey to white interference colours and often zoned (Figure 7). These physical and optical properties suggest that the zeolite in the Biu basalts is chabazite ($CaAl_2Si_4O_{12}.6H_2O$) variety which is the most common and useful type. Other natural zeolite varieties include natrolite, laumonite, stilbite and sodalite. The Biu zeolite variety (chabazite) is closely related to feldspathoid associated with mafic igneous rocks/ basic volcanic rocks. Zeolites are industrial minerals used as drying agents, catalysts and washing materials.

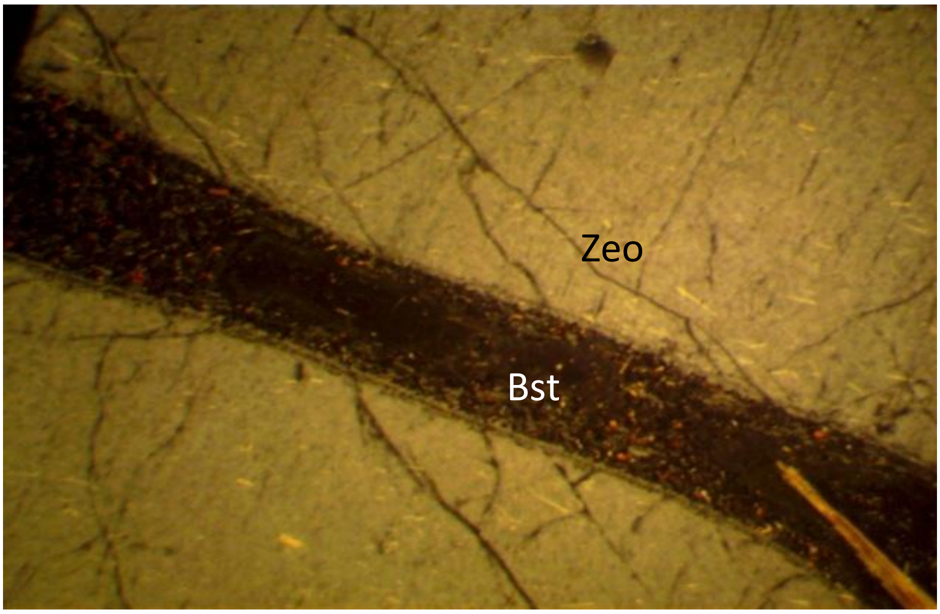


Figure 10: Photomicrograph of basalt showing zeolite being crosscut by groundmass of basalt

4.0 Conclusion

The landscape of the southern part of Borno State is characterized by Basement Complex rocks and Sedimentary covers. The Crystalline Basement is prominent around Gwoza, Askira Uba, Chibok and Biu which are differentiated into migmatites, gneisses, granites and basalt rocks. The sedimentary units dominate Kwaya Kusar, Bayo, Shani and Damboa with occurrences of Bima Formation, Gongila Formation, Fika Shales, Gombe Sandstone and Chad Formation.

The Basement Complex rocks host feldspar, Quartz, Mica mineralization and ornamental stones. The basaltic rocks are composed of zeolite mineralization and Gemstones comprising of Aquamarine, Corundum, Amethysts, Tourmaline and Topaz. The Cretaceous-Quaternary sedimentary rocks are rich in quality clays, kaolinite, diatomites, trona and bentonite industrial minerals.

References

Abaa, SI. and Najime, T. 2006. Mineralization in Precambrian rocks, central Nigeria.Implication for Oban-Obudu-Mandara-Gwoza Complex of Eastern Nigeria. Global Journal of Geological Sciences, 4 (2): 121-128.

Allix, P. 1983. Environments mesozoiques de la paritcnord-orientale du fosse de la Benue (Nigeria), Stratigraphic, Sedimentologic, Evolution geodynamique. Travaux Laboratoire science terre St. Jerome Marseille Bulletin, 21: 1-200.

Avbovbo, AA., Ayoola, EO. and Osahan, GA. 1986. Depositional and Structural styles in the Chad Basin of North-eastern Nigeria. AAPG Bulletin, 70: 1787-1798.

Baba, S., Islam, MR., El-Nafaty, JM., and Amate, MK. 1991. Exploration and evaluation of industrial minerals and rocks in the northern part of Mandara hills N.E, Nigeria. Journal of Mining and Geology, 27 (2): 11-14.

Baba, S., Emofurieta, WO. and El-Nafaty, JM. 1995. Petrochemistry of Liga hill, Gwoza area, N.E Nigeria. Borno Journal of Geology, 1(1): 35-58.

Baba, S. 2005. Geology and solid mineral potentials of crystalline rocks in Borno State, NE Nigeria. University of Maiduguri. Occasional Publication. Faculty of Science Seminar Series, 2: 11-19.

Baba, S., Abaa, SI. and Dada, SS. 2006. Preliminary petrogenetic study of some rocks from Gwoza area, NE, Nigeria. Global Journal of Geological Science, 4(2): 147-156.

Baba, S. 2011. Some geochemical considerations in the petrogenesis of Madagali granitoids, NE, Nigeria. Global Journal of Geological Science, 9(2): 253-263.

Carter, JD., Barber, W. and Tait, EA. 1963. The geology of parts of Adamawa, Bauchi and Bornu provinces in NE, Nigeria. Geological Survey of Nigeria Bulletin 30.

Dike, EFC. 1993. Stratigraphy and structure of the Kerri Kerri Basin, NE Nigeria. Journal of Mining and Geology. 27(1): 78-86

Falconer, JD. 1911. The geology and geography of Northern Nigeria. Macmillan and Co. Ltd. London, 295p.

Grant, NK and Freeth, SJ. 1972. Potassium-argon and strontium isotope ratio measurements from volcanic rocks in Northwestern Nigeria. Mineralogy and petrology, 35: 277-292.

Guiraud, M. 1990. Tectono-sedimentary framework of the early Cretaceous continental BimaFormation (Upper Benue Trough) NE Nigeria. Journal of African Earth Sciences, 10: 341-355.

Guiraud, M. 1991. Me'canisme de formation du basin cre'tace' sur de'crochements multiples de la Haute-Benoue (Nigeria). Bullet CentersReches Exploration-Production Elf- Aquitaine, 15: 11-67.

Hamza, H., Obaje, NG. and Obiosio, EO. 2002. Foraminiferal assemblage and palaeoenvironment of the Fika Shale, Bornu Basin, Northeastern Nigeria. Journal of Mining and Geology, 38 (1): 49-55.

Islam, MR. 1986. The petrological study of Biu Plateau basalts, Borno State, Nigeria. Annals of Borno, 3: 215-226.

Kachroo, RK., Ali, IJ. and Kurah, AL. 2000. Records of some ostracods from GongilaFormation NE Nigeria.

Kerr, PF. 1977. Optical Mineralogy. Fourth Edition, McGraw Hill Inc., New York: 492p

Okeke, PI. 1991. Petrology of Kirawa volcanic and Geochronology of some Gwoza rocks. Journal of Mining and Geology, 37: 77-84.

Popoff, M. 1988. Du Gondwana a'l' Atlantique, Sud: Connexions du fosse' de la Benoue avec les basins du nord-estbresilienjusqu'al' ouvature du golfe de Guinean Cretaceinfeneur. Journal of African Earth Sciences, 7: 409-431.

Zaborski, P., Ugodulunwa, F., Idonigie, A., Nnabo, P. and Ibe, K. 1997. Stratigraphy and structure of the Cretaceous Gongola Basin, northeastern Nigeria. Bulletin of center of research and exploration production, Elf-Aquitaine, 21: 153-185