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Geology, Occurrences and Industrial Applicability of Barite Deposit in Gombe Inlier within Gongola Basin Upper Benue Trough, Nigeria

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ABSTRACT

The extensive Geological Mapping in Gombe Inlier has revealed that the area is characterized by two major Rock types: The Basement complex rocks represented by the Rocks of Biotite Granite, Migmatite Gneiss which is surrounded by the Cretaceous Sedimentary Sequences which encompasses; BimaFormation,Yolde Formation, Pindiga Formation followed by Gombe formation. Barite Mineralization in Gombe Inlier occurs along veins that are structurally control within the Inlier. There is a progressive increase in the $BaSO_4$ content as well as specific gravity from the contact with the wall Rock toward the center of the vein, i.e. from creamy/white to smoky/dark variety. . For Gombe inlier deposit, obtained data indicate that it can be classified in to two grades Barite in terms of qualities and specifications for industrial applications. The creamy /white variety with 95.75% $BaSO_4$,94.35% $BaSO_4$ and 95.91% $BaSO_4$ with average specific gravity of 4.83 g/cm^3 ,4.61 g/cm^3 and 4.54 g/cm^3 , white streak and hardness of 3.2 is suggested to be grade one type. The smoky/dark variety with 90.30% $BaSO_4$,90.44% $BaSO_4$ and 90.06% $BaSO_4$ with average specific gravity of 3.81 g/cm^3 3.95 g/cm^3 and 3.33 g/cm^3 ,white streak and hardness of 3.3 can ben consider as grade two Barite .The chemical composition of the Barite, when compare with international standards and specifications for various industrial applications make it pure and good quality that make it suitable for use in various industries that requires the commodity.

KEY: Geology, Occurrence, Quality and Structures.

INTRODUCTION

Nigeria is a Naturally Endowed and Rich in variety of strategic solid Mineral Resources that are widely distributed across the country and the Sustainable Exploration and Exploitation of these Resources have the Potential of turning around the Economy of the Country. One of such identified strategic solid Mineral Resource that has the Potential of contributing immensely to the growth of the Nigerian Economy is Barite ($BaSO_4$). Barites mineralization occurred both in Basement complex and in the Sedimentary Basins of Nigeria and is also occurred within the entire length of the Benue Trough.Barite occurrence in Gombe Inlier is one of the neglected and under studied Barite in Nigeria. This study is aimed at investigating the geology, occurrences and Quality of the Barite mineralization in the area. Due to Rugged nature of the terrain, the study area is divided in to location A, B and C.

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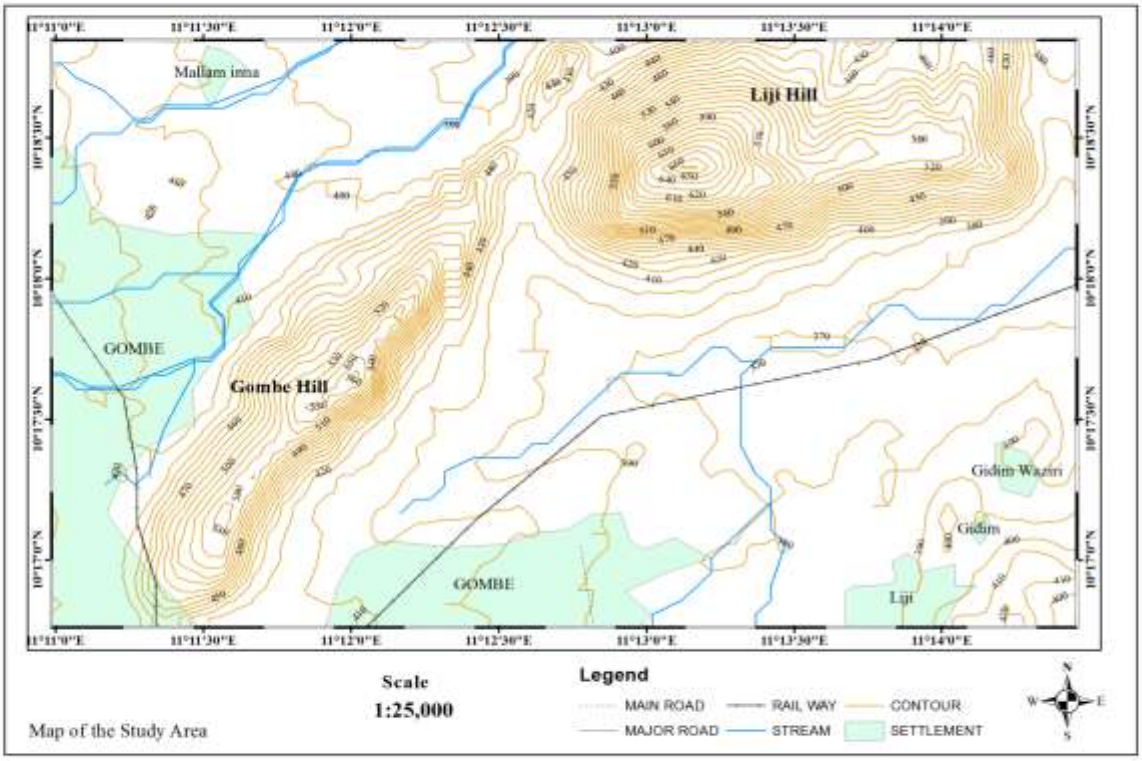

Figure1: Topographic Map of the study Area

Stratigraphy of Gombe Inlier

Gombe Inlier is located in the northeastern Nigeria within the Gongola Basin which is the one of the bifurcated arm of the Upper Benue Trough. It's the Basement Rock which exposed most of the sedimentary sequences of the Basin that encompasses Bima Sandstone, Yolde Formation, Pindiga Formation and Gombe Sandstone. The Inlier can be considered as Geological epitome of the Upper Benue Trough because is vividly displays general stratigraphic and structural styles of Gongola Basin within short and relatively small, easily accessible area. The lithostratigraphic sequences of the Inlier have been tectonically affected in most of the area by the two major faults (The NE-SW trending Gombe fault and N-S trending Wuro-ladde-wuro-dole fault).

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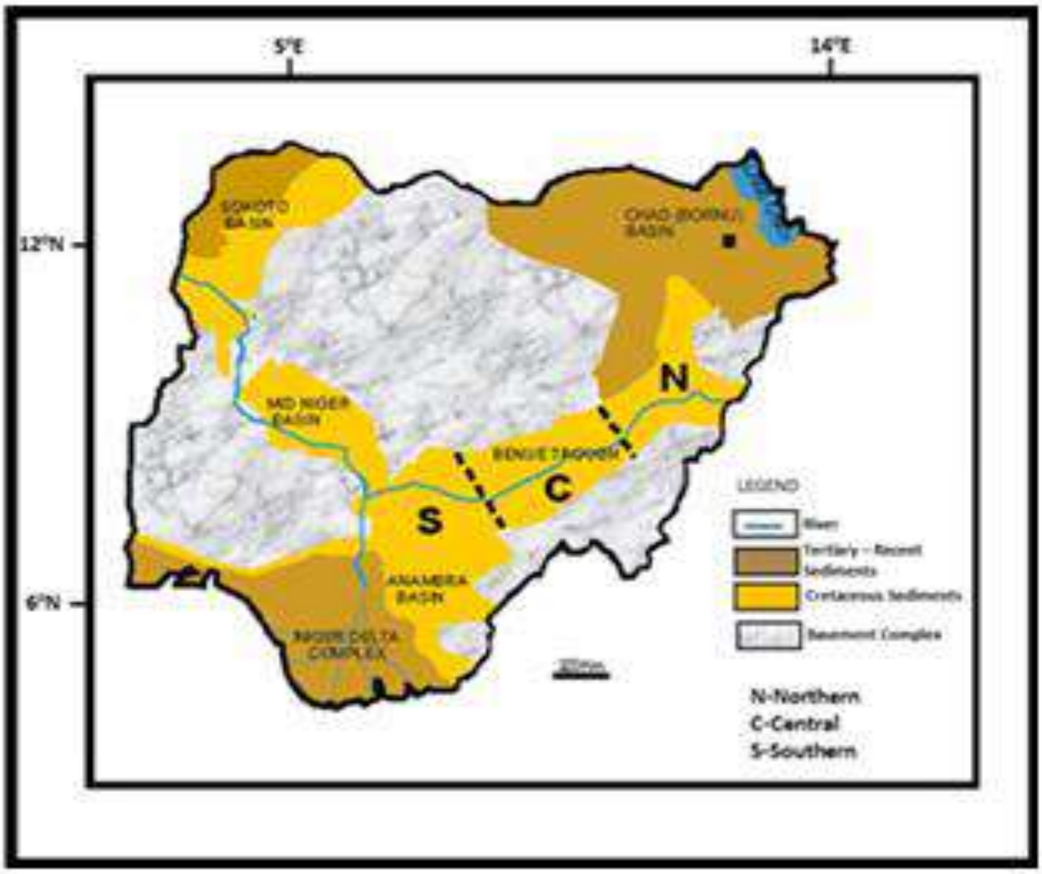

Figure 2: Geological Map of Nigeria showing the Benue Trough
(Modified from Abubakar et al., 2008).

Regional Tectonic Setting

The Benue Trough is a major NE – SW trending riftbasin of 50 – 150 km width. It extends for over 1000kmstarting from the northern margin of the Niger Delta in thesouth to southern margin of the Chad Basin in the north(Figure 1). The trough contains over 6000m of Cretaceous –Tertiary sediments associated with volcanics of which those pre-dating the mid-Santonian have been compressionallydeformed, faulted and uplifted in several places. It is geographically subdivided into lower, middle and upperportions (Figure 1). The Northern Benue Trough is Y –shaped, made up of two arms namely: the E – W trending Yola Arm, N-S trending Gongola Arm as shown in Figure 2.The Northern Benue Trough is believed to have formed from extensional processes during the Late Jurassic – Early Cretaceous separation of the continents of Africa and South America through the process of rifting (Grant, 1971; Olade,1974). However, Benkhelil (1989) is opposed to this rift model, suggesting that the reactivation of the Late Pan African transform fault in the South Atlantic during the Cretaceous developed sets of sinistral strike – slip faults are responsible for the development of the sub – basins in the Northern Benue Trough. The sedimentary sequence infilling of the Northern Benue Trough is made up of continental, transitional and marine deposits and they range from Aptian to Paleocene (Rabelle, 1990; Zaborski et al., 1997 and Dike, 2002). The Bima Formation, a continental formation, represents the basal part of the sedimentary succession in all the three arms of the Northern Benue Trough shown in Figure 3. It unconformably overlies the Precambrian basement complex and consists of three

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Siliciclastic members: the Lower Bima (B1), the Middle Bima (B2) and the Upper Bima (B3). Its lithology and depositional environments have been discussed by several authors (Carter et al., 1963; Allix, 1983; Guiraud, 1990). The Yolde Formation lies conformably on the Bima Formation in the whole of the Northern Benue Trough. This formation of Cenomanian age (Lawal and Maullade, 1986) represents the beginning of marine incursion into this part of the Benue Trough. The Yolde Formation was deposited in a barrier island/deltaic setting (Abubakar, et al., 2006; Shettima, 2007).

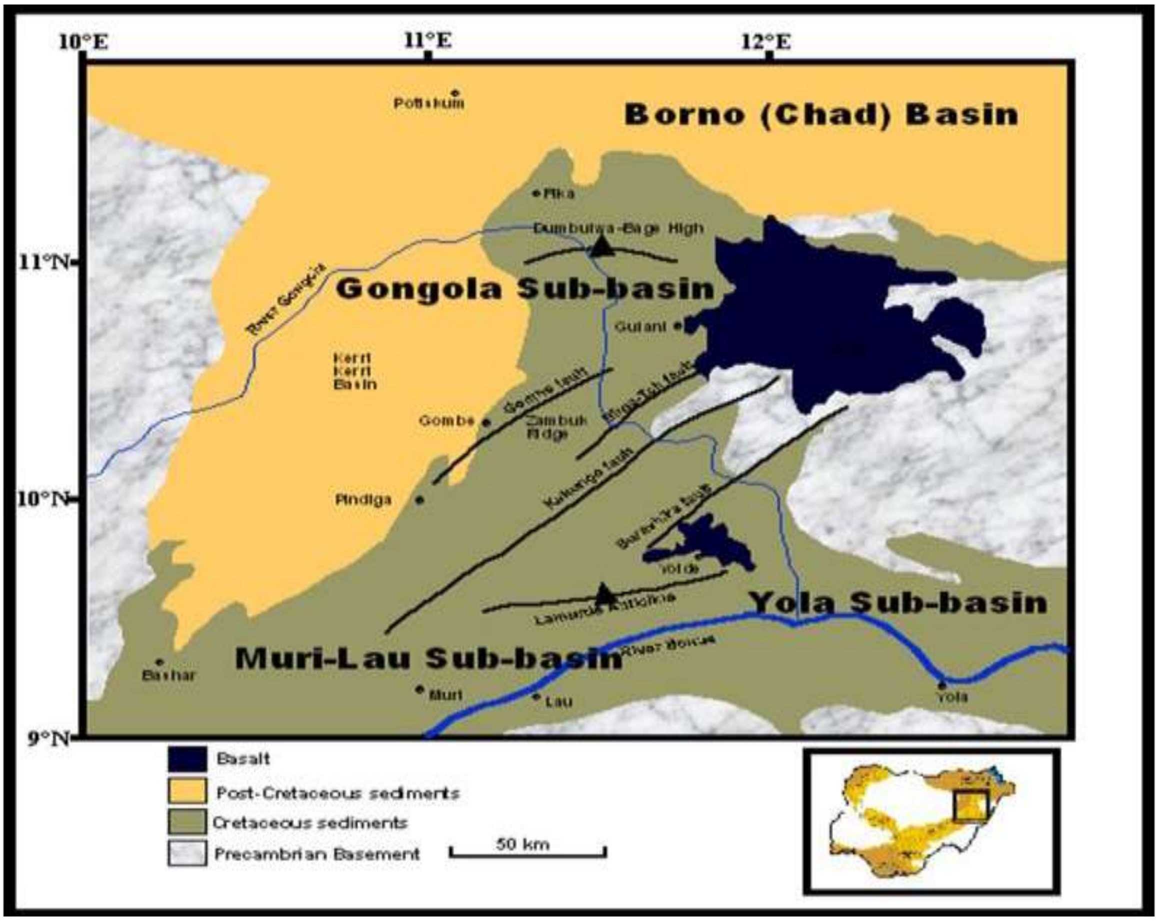

Figure 3: Geological map of the Northern Benue Trough (modified from Zaborski et al., 1997).

Gongola Sub-Basin

In the Gongola Sub – basin (Arm), the Yolde Formation is conformably overlain by the Pindiga Formation which is lateral equivalent to Gongila Formation and Fika Shale (Popoff et al., 1986), and they all represent a full marine incursion into the Gongola Arm (Figure 3). The estuarine/deltaic Gombe Formation of Maastrichtian age overlies the Pindiga Formation and it represents the youngest Cretaceous sediments in the Gongola Basin. The Northern Benue Trough is believed to have formed from extensional processes during the Late Jurassic – Early Cretaceous separation of the continents of Africa and South America through the process of rifting (Grant, 1971; Olade, 1975). However, Benkhelil (1989) is opposed to this rift model, suggesting that the reactivation of the Late Pan African transform fault in the South Atlantic during the Cretaceous developed sets of sinistral strike – slip faults are responsible for the development of the sub – basins in the Northern Benue Trough. The sedimentary sequence infilling of the

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NorthernBenue Trough is made up of continental, transitional and marine deposits and they range from Aptian to Paleocene (Rabelle, 1990; Zaborski et al., 1997 and Dike, 2002).

Yola Sub-Basin

In the Yola Sub – basin(Arm), the Dukul, the Jessu, the Sekuliye, the Numanha Shales and the Lamja Sandstones are the Upper Cenomanan-Santonian equivalents of the Gongila and Pindiga Formations of the Gongola Basin. The Turonian-Santonian deposit in the Yola Basin are lithologically and paleoenvironmentally similar to those in the Gongola Basin, except the Lamja Sandstone which is dominated by marine sandstone (Carter et al., 1963).

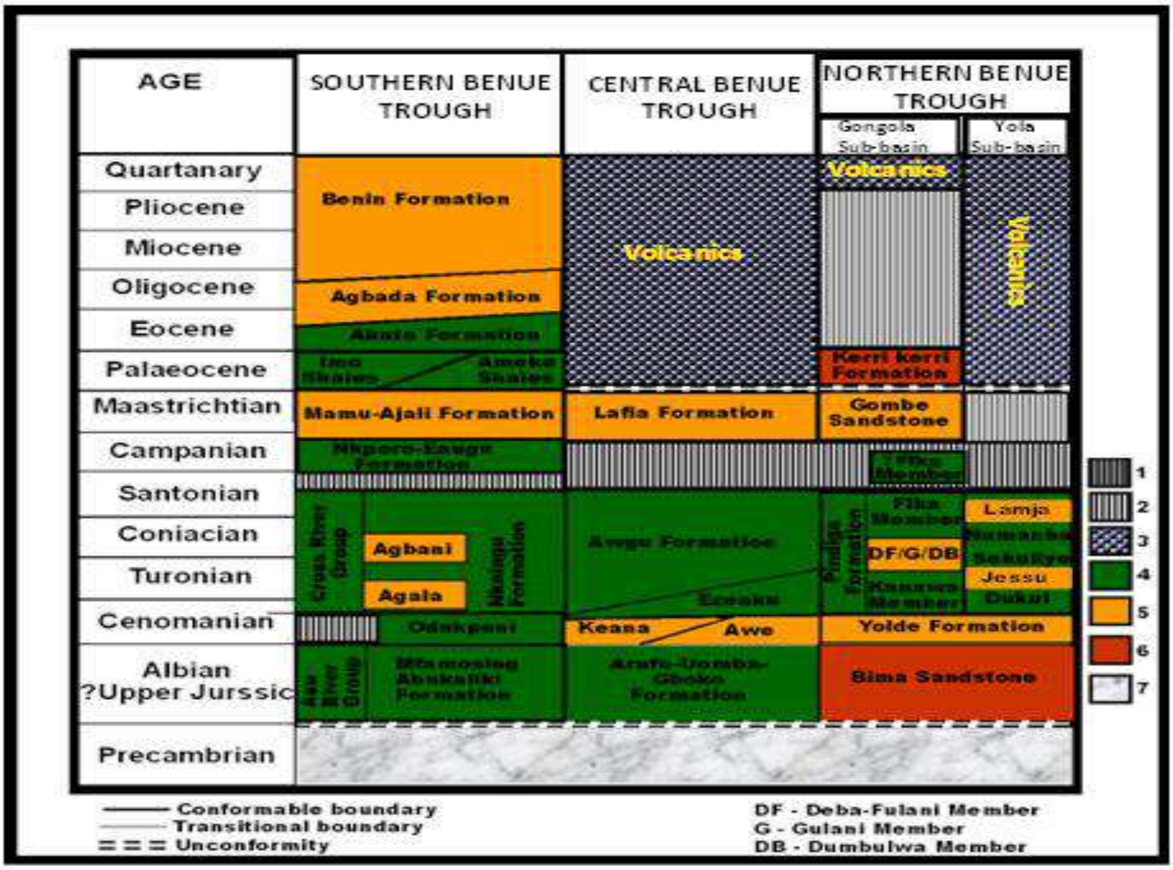

Figure 4: The stratigraphy of the Benue Trough (modified from Obaje et al., 1999)
.1-Hiatus, 2-Santonian and Cenomanian tectonism, 3-Basalt, 4-Marine sediments, 5-Transitional-marine sediments,6-Continental sediments ,7-Basement complex

Table 1: General Specification Standards for various uses of Barite Ores

Standard	Spec.Grav.	$BaSO_4$	Soluble Alkali	Heavy Metals	FeO_3	SiO_2	Al_2O_3
API Mud	4.2min	92%min	250ppm	N/A	N/A	N/A	N/A
ASTM Glass	N/A	95%min	N/A	N/A	0.15%max	1.5%	0.15%
API Paint	N/A	95%min	0.2%	N/A	0.05%	N/A	N/A
ASTM Chemical	NA	92%min	1.0%max	N/A	1.0%max	N/A	N/A
API Pharmaceutical		97.5%min	<0.01% ppm	<0.001%ppm	N/A	1.5%	N/A

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NA

Key: API(American Petroleum Institute), ASTM (American Society for Testing and Materials), Speg.Grav.(Specific Gravity), N/A =Not Applicable (Ene et al,.2012)

Table 2: Industrial specification for various uses of Barite Ores

Specification	Industries	Chemical constituent						Spec.gr.
		SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	$BaSO_4$	
IS	Oil and Gas	-	-	-	-	-	90%	4.20
	Chemicals	2% max.	0.1% max.	0.1% max.	-	-	90%	-
	Paint	-	-	-	-		95%Min.	-
	Glass	1.5% max.	0.5% max	0.15% max	-		96%Min.	-

Key = IS means Indian specifications (Indian mineral year book 2013-2015.)

MATERIAL AND METHOD

The Field Methods

The research began with the field work carried out mainly traverses purely on foot across the study area. Due to the rugged nature of the inlier the area is only accessible through foot path that linked to the inlier. The area is mapped using topographic map of Gombe Northwest sheet 152 on a scale of 1:50,000. Rock exposures outcropping were carefully observed and analyzed. Samples obtained from the field were analyzed macroscopically in hand specimen. The attitude readings takings with aid of Global positioning system, compass and clinometer were used for Rose and Stereo net plots.

The Laboratory Methods

The laboratory methods involved sample preparation, Geochemical and Geotechnical analysis of the samples in order to determine their chemical and physical characteristics.

Geotechnical Analysis

The Barite samples were pulverized to sieve out the uniform size of the Barite grains. The following apparatus are required to carry out the experiment:-

1-Density Bottle of 50 ml with stopper

2-Balance to weigh the material (accuracy 10gm)

3-Wash Bottle with distilled Water

The density bottles were washed, dry and weighed (M1).10g of sample was taken and transferred to the density Bottle and weighed (M2). Distilled water was added to the density bottle with sample, just enough to cover the Sample. The bottle was shaken to allow the sample and water to intermix. The vacuum desiccators was use to place the bottle without the stopper to notice the movement of air. The vacuum and lid of the desiccators was replaced and applied again. The procedure was repeated until no air was evolved from the Bottle. The specimen was removed from the desiccators. Air-free water was added until the bottle was full and then the stopper was inserted. The Bottle was

measured (M3). Emptied clean Bottle filled with distilled water and inserted stopper was measured (M4).
The specific gravity was determined using the formula:

$G = (M2 - M1)/ (M2 - M1) - (M3 - M4)$

Where M1 = Mass of empty pycnometer, M2 = Mass of pycnometer and dry soil
M3 = Mass of pycnometer, soil and water, M4 = Mass of pycnometer filled with water only
The same procedure was conducted three times on each sample and the average was taking.

Geochemical Analysis Using (X-Rf)

Total number of twelve selected samples was analyzed for major oxide concentration at Ashaka Cement laboratory. The samples were pulverized and 10g of the pulverized sample was weighed and mixed with the lithium metaborate and lithium tetraborate. The mixture was ignited in a preset furnace at 1150°C for ten minutes after being mixed in a platinum crucible .The crucible with a sample was placed on the crucible holder ,immediately the start button was pressed on for the commencement of the preparation process. Ammonium Iodide tablet as a releasing agent was added to the automatically heated sample which is mixed and cast in to a dish (mold). The glass Beads was labeled and slotted in to the energy dispersive X-ray fluorescence for major oxide (ED-XRF) after being cold, ready for the analysis. Each Bead was analyzed for the following oxides: $BaO, SiO_2 Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, P_2O_5, Mn_2O_3, TiO_2, Cl, Cr_2O_3, SrO$, SO_3

RESULT AND DISCUSSION

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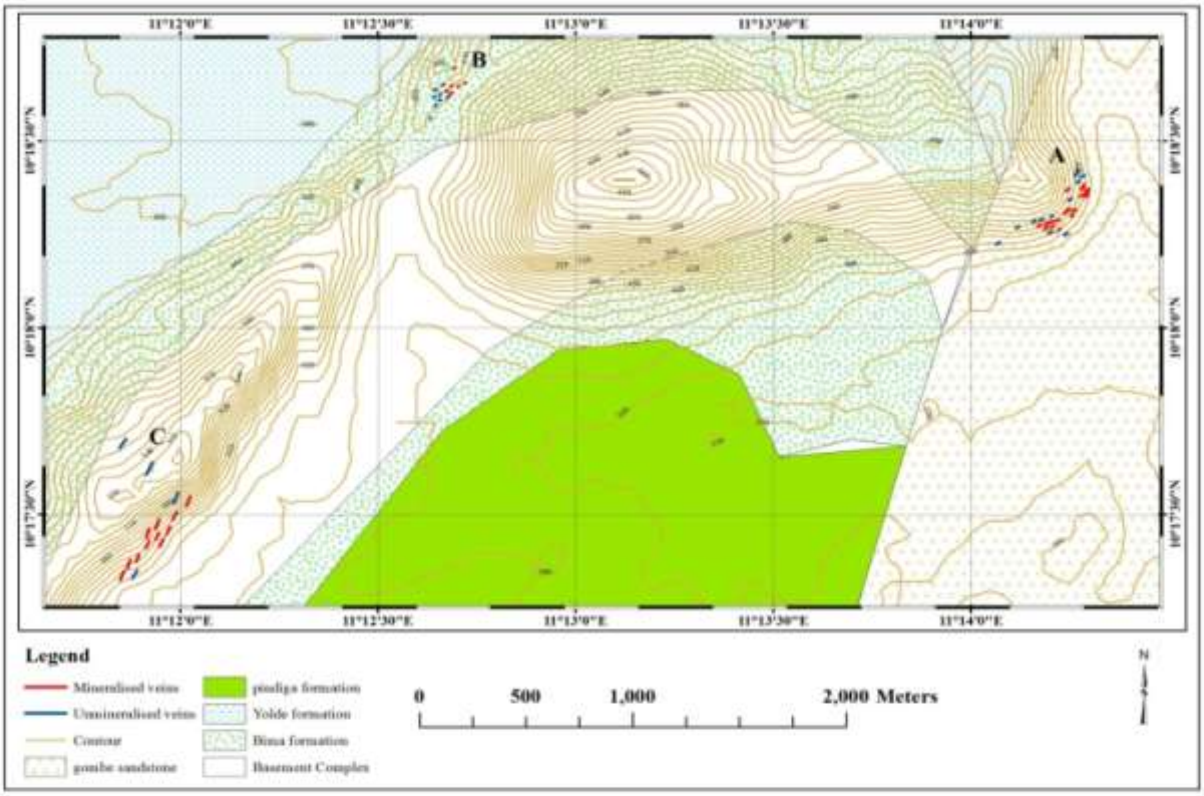

Figure 5: Geologic Map of the study Area.

Occurrances

Extensive field mapping in the study area has revealed that the area has comprises the Basement complex Rocks surrounded by the Cretaceous Sedimentary sequences which encompasses; Bima formation, Yolde formation, Pindiga formation, followed by Gombe formation. The crystalline Basement Rocks in the study area are represented by the Rocks types of Biotite Granite and Migmatite Gneiss . The predominant Rock type is Gneiss of medium to coarse grained textured and mesocratic in color. The alternations of light and dark colored bands of minerals are very obvious. It was observed toward the peak of the Inlier highly indurated and metamorphosed sandstone. The structural disposition was observed in the field, as the Barite Veins occurred along a faults lines trending NE-SW and ENE-WSW emplaced within the indurated sandstones and Gneisses. These trends are in consistent with the General trend of the Benue trough and of the two major faults that affected the area (Gombe fault and Wuro-ladde-wuro-ladde fault). It was suggested that the subsequent Igneous and episodes of Tectonic activities that affected the area are responsible for path ways in which the mineralizing fluids are accumulated and consolidated within these structures. One of striking characteristics of the Barite of Gombe Inlier is its lack of association with Galena and Sphalerite like in most occurrences along the Benue trough. The Barite is brittle, High Density,white streak when scratched by a knife blade or hit by a Hammer. Two varieties of Barite were identified on the basis of color, form, luster, cleavage and accessory minerals. The Creamy/whitish variety that is Granular, Crystalline, sub-vitreous and consist of quartz and the smoky /dark that is Crystalline and compacted, vitreous with the devoid of other Minerals.

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Plate 1: The Creamy/whitish variety that is Granular, Crystalline, sub-vitreous and consist of quartz

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Plate 2: The smoky /dark that is Crystalline and compacted, vitreous with the devoid of other Minerals

Geochemical Analysis and Result

Table 3: The geochemical analysis results (oxide composition) for the three locations

Chemical Parameters in wt%	Location A				Location B				Location C			
	$V1_A$	$V2_A$	$V3_A$	$V4_A$	$V1_B$	$V2_B$	$V3_B$	$V4_B$	$V1_C$	$V2_C$	$V3_C$	$V4_C$
$BaSO_4$	90.308	95.747	84.459	89.901	66.293	94.338	84.173	90.063	87.271	95.914	90.301	90.442
SiO_2	6.994	1.835	2.960	3.035	29.67	2.865	3.070	6.805	10.280	1.782	6.698	6.272
Al_2O_3	0.361	0.301	0.284	0.390	0.582	0.582	0.285	0.284	0.641	0.239	0.266	0.266
Fe_2O_3	0.022	0.160	0.024	0.025	0.395	0.187	0.027	0.058	0.051	0.051	0.051	0.249
CaO	5.106	0.606	1.256	5.118	1.947	0.718	1.315	1.620	0.600	0.567	1.524	1.657
MgO	0.237	0.077	0.163	0.252	0.148	0.374	0.228	0.137	0.471	0.061	0.160	0.075
K_2O	0.019	0.032	0.005	0.026	0.236	0.017	0.023	0.026	0.027	0.014	0.024	0.025
Na_2O	0.247	0.256	0.246	0.256	0.201	0.256	0.258	0.265	0.260	0.253	0.248	0.241
P_2O_5	0.005	0.002	0,004	0.000	0.004	0.004	0.002	0.005	0.005	0.005	0.000	0.009
Mn_2O_3	-0.060	-0.002	-0.049	-0.060	-0'045	-0.060	-0.055	-0.005	-0.054	-0.060	-0.062	-0.056
TiO_2	0.135	0.145	0.120	0.139	0.119	0.146	0.136	0.139	0.136	0.158	0.138	0.134
Cl	0.006	0.007	0.017	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.006
Cr_2O_3	0,001	0.002	0.000	0.003	0.002	0.001	0.001	0.005	0.000	0.000	0.003	0.000
SrO	0.689	0.714	0.540	0.682	0.689	0.579	0.545	0.664	0.316	0.717	0.664	0.673

Knowledge of the level of concentration of associated chemical species help in the elimination of unwanted species, that why the chemical composition of any mineral sample is of prime importance .The geochemical composition of the studied Barite from the Gombe Inlier is presented in Table 3.There is a considerable variation in the concentration geochemical facies. $BaSO_4$ concentration ranges from 84.459 to 95.747 wt% from location 'A', 66.293 to 94.338 wt% from location 'B' and 87.271 to 95.914 wt% from location 'C'. SiO_2 content ranges from 1.835 to 6.944 wt% from location 'A', 2.865 to 29.67 wt% from location 'B', and 1.782 to 10.280 wt% from location 'C'. There is a general low concentration of water soluble Element (CaO, MgO, K_2O, Na_2O, P_2O_5, Cl), heavy Metals concentrations are less than 1 wt% (Fe_2O_3, Al_2O_3, Cr_2O_3, TiO_2, Mn2O3, SrO) . The samples with general high concentration of the geochemical facies are those obtained from the center of the Veins, while those samples with the low concentration of geochemical facies are the ones obtained from the wall Rock contact. Following the Cathles (1991), Appleyard and Guha (1991), Omada and Ike (1996), Akpeke et al.(2006), Julius and Ntekim (2016), those Elements that showed higher concentration values in the samples from the contact with the wall Rocks than those at the center of the veins suggested that the flux of chemical species is drived from Hydrothermal solution to the host Rocks Minerals or vice versa during Alteration, precipitation, Assimilation, Diffusion, addition, subtraction or Replacement. The influence of the Host Rock on the fluid that Mineralized the Deposit is depend on and attributed to different properties of various Host Rocks which would have affected their ability to sustain fracturing, especially large, strong fractures. The investigated Barite Mineral samples are essentially made up of $BaSO_4$ and most of the samples obtained from

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center of Veins gave a relatively high percentage while those obtained from the wall Rock are of low percentage. This suggested that the samples from the center are differentiated and thus pure.

Geotechnical Analysis and Results

Table 4: Geotechnical analysis results for the three locations

Vein Numbers for Location 'A'	Specific Gravity for Location 'A' (g/cm^3)	Vein Numbers for Location 'B'	Specific Gravity for Location 'B' (g/cm^3)	Vein Numbers for Location 'C'	Specific Gravity for Location 'C' (g/cm^3)
$V1_A$	3.81	$V1_B$	3.33	$V1_C$	4.14
$V2_A$	4.83	$V2_B$	3.33	$V2_C$	4.15
$V3_A$	4.61	$V3_B$	4.54	$V3_C$	3.95
$V4_A$	4.22	$V4_B$	4.15	$V4_C$	4.15

The Geotechnical data of the studied Barite from the Gombe Inlier is presented in Table 4 below. It has indicated that the representative samples from location 'A' has a specific gravity values ranges from 3.81 to 4.61 g/cm^3 and the representative samples from location 'B' have a specific gravity values ranges from 3.33 to 4.54 g/cm^3, while the representative samples from location 'C' have a specific gravity values ranges from 3.9 to 4.15 g/cm^3. Some of the samples have shown low value of specific gravity. The samples obtained from the various locations that shown higher specific gravity value is attributed to their nature being obtained from the center of the Veins while those with low values are obtained at wall Rock.

Industrial Quality

One of the attributes that makes Barite desirable especially as weighing agent in drill mud in oil and gas industries is their specific gravity values of 4.5 g/cm^3 and above is considered pure while barite with specific gravity values from 4.2 g/cm^3 satisfies the requirements of most of the oil and gas industries and in other applications (Microfine 1999, Andrew 2003). In Gombe Inlier, the Barite obtained at the center of the Vein is considered to be of pure grade with average specific gravity of 4.83 g/cm^3 , 4.61 g/cm^3 and 4.54 g/cm^3 , 4.2 g/cm^3 while the Barite at the contact with wall Rock is considered moderate with average specific gravity values 3.33 g/cm^3 , 3.81 g/cm^3 , 3.95 g/cm^3 , 4.14 g/cm^3 , 4.15 g/cm^3 (table.......). The high grade variety of the Gombe Inlier Barite can be used in the oil and gas industries while the low grade can be used in the manufacturing of Glass, Rubber, paints, electric car battery and in the construction of radioactive laboratories and nuclear reactors. For Gombe inlier deposit, obtained data indicate that it can be classified in to two grades Barite in terms of qualities and specifications for industrial applications. The creamy /white variety with 95.75% $BaSO_4$,94.35% $BaSO_4$ and 95.91% $BaSO_4$ with average specific gravity of 4.83 g/cm^3 ,4.61 g/cm^3 and 4.54 g/cm^3 , white streak and hardness of 3.2 is suggested to be grade one type. The smoky/dark variety with 90.30% $BaSO_4$,90.44% $BaSO_4$ and 90.06% $BaSO_4$ with average specific gravity of 3.81 g/cm^3 3.95 g/cm^3 and 3.33 g/cm^3 ,white streak and hardness of 3.3 can ben consider as grade two Barite. When compared with the Barite from different places within Nigeria notably; Upper Benue trough (Dumne and Gulani), middle Benue trough (Makurdi and Azara) and southern Benue trough (Akpet), Gombe Inlier Barite is relatively more purer and of very good quality for various applications and uses.

CONCLUSION

Barite Mineralization in Gombe Inlier within Gongola Basin upper Benue trough Nigeria occur along veins that are structurally control within the Inlier. There is a progressive increase the $BaSO_4$ content as well as specific gravity from the contact with the wall Rock toward the center of the vein, i.e. from creamy/white to smoky/dark variety. The chemical composition of the Barite , when compare with international standards and specifications for various industrial applications make it pure and good quality that make it suitable for use in various industries that requires the commodity.

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