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Geology and Baryte Mineralization of the Liji Area, Upper Benue Trough, NE Nigeria

*Kamale, H.I., Mohammed, D.D., Umaru, A.O., Usman, U. A., Shettima, B., Shettima, B., Ibrahim Y. and Yerima, I. A.
Department of Geology, University of Maiduguri, P.M.B 1069, Borno State, Nigeria
Corresponding Author: Kamale, H.I

Abstract: *The geology of Liji area is composed of members of the Pan-African granitoids (granite and pegmatite) and the Cretaceous sedimentary rocks of Bima, Yolde, Pindiga and Gombe sandstone Formations. Epigenetic fracture and porespace filling baryte mineralization of short dimension (7-45m long and 1-3.5m wide) occur within granite, pegmatite and sandstone of the Bima Formation. Binary plots of the major oxides of silica, alumina, total iron, potash and soda indicated that, the rocks are discriminated into distal, proximal and baryte separates. The distal samples show linear trend which is considered as the main trend and exhibited normal mixed pattern of the samples before the advent of hydrothermal fluid with no discrimination of lithologies. The baryte separates occupy the same region in all the plots reflecting that the two barytes are of the same origin.*

Keywords: *Baryte, Mineralization, Hydrothermal, Epigenetic, Liji, Nigeria.*

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I. Introduction

The study area lies within topographic sheet 152 Gombe NW and NE which constitute parts of the Gongola arm of the Upper Benue Trough (Fig. 1). Geologically the area consists of inliers of Granites and Pegmatites surrounded by younger sediments such as Bima, Yolde, Pindiga and Gombe Formations. Epigenetic baryte mineralization occurs within granite and pegmatite in the Liji hill and sandstones of the Bima Formation in the Gombe hill.

Baryte is a mineral consisting of barium sulfate ($BaSO_4$). It occurs as veins or cavity-filling and mineral flat in a large number of depositional environments, and is deposited through a large number of processes including biogenic, hydrothermal and evaporation (Hanor, 2000). The commonest host rocks of baryte are sandstone, shales, limestones and clays. Barium can be replaced by strontium in a continuous solid solution from baryte to form celestine, anglesite and anhydrite hence these sometimes occur as associated minerals. Baryte is distinguished as colourless, white, light shades of blue, yellow, grey and brown. It could be fibrous or massive having orthorhombic to dipyramidal crystal symmetry. The cleavage is perfect parallel to base and prism faces, hardness is 3 - 3.5 on Mohs scale, with specific gravity of 4.3 – 5 g/cm^3 (Hanor, 2000; Gribble, 2004).

Baryte mineralizations in Nigeria occur within the Benue Trough and other localities in the basement rocks adjacent the Benue Trough and northwestern Nigeria. The Benue Trough is Nigeria's main but not exclusive source of baryte mineralization. Oden (2012) reported that occurrences of baryte are found in various localities of eight states within the Benue Trough. They include Alifokpa, Gabu and Osina in Cross River State and Ishiagu in Ebonyi State in the Lower Benue Trough; baryte fields occur in Azara, Akiri, Aloshi in Nassarawa State, Panyam and Faya in Plateau State, Ambua, Torkula, and Makurdi in Benue State in the Middle Benue Trough and Liji Hill in Gombe State, Ganye, Suwa and Sabin in Adamawa State and Gidan waya, Pupule, and Didango in Taraba State within the Upper Benue Trough.

There are atleast ten baryte fields in the trough each containing swarms of veins or concordant stratiform mineral flat of hydrothermal origin that are being scavenged by artisanal miners (Oden, 2012). The Pb-Zn-Cu-F mineralization along with baryte form a metallogenetic belt within the trough extending from Abakaliki in the Lower Benue, through Akwana, Arufu and Azara in the Middle Benue to Gwona, Gombe and Gulani area in the Upper Benue (Farrington, 1952; Olade, 1976; Ford, 1989; Wright, 1989; El-Nafaty, 2015; Kamale, 2018). Offodile (1976) reported baryte occurrences at Azara, Gbande, Chiata, and Keana within the Middle Benue Trough. While Tate (1959) gave reserve estimate of 40,000 tonnes to a depth of 20m for the Azara baryte locality, the defunct Nigerian Mining Corporation (1979) gave a semi-detailed reserve estimate of

730,000 tonnes for five out of eighteen veins of the Azara field, with an average specific gravity of 3.64 down to 30m depth.

Fyfe *et al*. (1978) reported two types of baryte occurrences in the field, the sediment hosted, stratiform, concordant type whose occurrence is very less frequent and has so far been reported in Alifokpa (Cross River State) and Gidan Waya in Ibi (Taraba State), and the discordant, vein type of occurrence, is by far the most common. The concordant type is hydrothermal in origin, lensoid in shape and frequently multilayered.

Ene *et al*. (2012) revealed that baryte also occur as disseminated nodules, strata bound as well as in two main vein sets namely: the NW-SE trend that is orthogonal to the main axis of the Benue Trough and comparatively younger N-S trend, crosscutting the other one in the Alifokpa, Gabu, and Osina in Southern Benue Trough. Oladapo and Adeoye (2011) carried out a geophysical investigation of Tunga area of Nassarawa state and reported that relatively high bouguer anomalies were recorded over regions underlain by baryte. The baryte occur as vein deposit hosted within sandstone. Laboratory analysis shows variable values of specific gravity ranging from 3.16 to 4.26 g/cm^3. El-Nafaty (2015) documented that epigenetic baryte mineralization occur as veins within the Bima and Yolde sandstone in Gaidam and Wuyaku of Gulani area in the Gongola Basin of the Upper Benue Trough. He reported stable sulphur isotope values for baryte minerals that ranged from 12.3-13.1 $^{o}/_{oo}$ CDT which indicated that the sulphur was souced from formational water. Kamale (2018) studied the Liji area and reported baryte mineralization hosted by basement and sandstone, based on stable sulphur isotope study he concluded that the baryte are of fresh water origin.

Daspan and Imagbe (2010) reported the occurrence of baryte hosted by low-grade metamorphic rocks mainly phyllites in veins of about 1.5km in extent and depth of 4m around Tsareta-Tungan Kudaku area of Zamfara state. The baryte is classed as a fissure filling vein type deposit that runs parallel to the Anka fault system, having variable specific gravity of 3.8 for surface deposits and 4.3 at deeper parts with $BaSO_4$ concentration ranging from 79.1% to 95.8%. Edu, (2006) reported basement gneisses, porphyritic and fine grained granite hosting barytes in parts of Taraba State.

This paper investigates the characteristics and origin of the baryte mineralization of Liji area, through the use of geology and major element geochemistry.

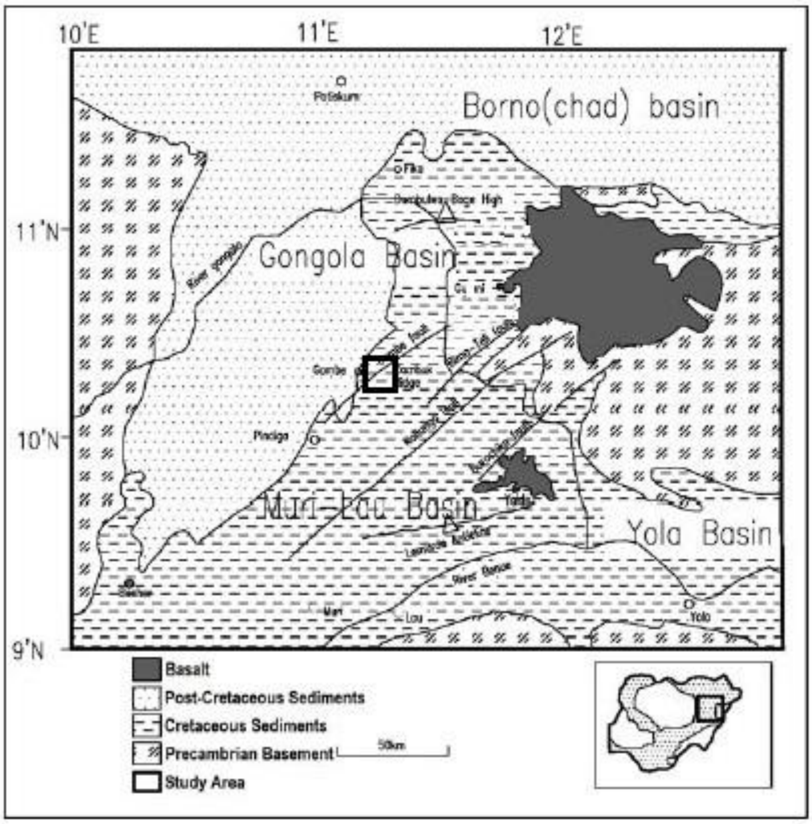

Figure 1: Geological Map of the Upper Benue Trough showing the study area (Modified from Zaborski, et al., 1997)

II. Methodology

Geological mapping of the Liji area was conducted using the topographic maps representing parts of Gombe sheet 152 NE and NW on a scale of 1:50,000. A total area of 144 Km^2 was covered employing the traverse-compass mapping technique with the aid of compass and Global Positioning System (GPS) for the accurate location of outcrops and other features. The geological map produced was digitized using ArcGis 9.3. The detailed geological maps of the baryte mineralization areas were digitized as well. Thirty six (36) rocks and mineral samples were thin sectioned in the petrology laboratory of the Department of Geology University of Maiduguri and the prepared slides were observed under the polarizing microscope. Ten rocks and mineral samples were analyzed for major element abundances at Bureau Veritas Minerals Laboratories (ACME-LAB), Vancouver, Canada. The samples were crushed and then pulverized to atleast 85% passing through the 200 mesh which was fused with metaborate/tetraborate and analyzed employing the ICP-MS analytical technique.

III. Geology and Petrography

The Liji area consists of granite, pegmatite, Bima Sandstone, Yolde and Pindiga Formations as well as Gombe sanstones (Fig. 1). The granite is melanocratic, coarse-grained and occurs as hills. In thin section it consists of quartz, orthoclase, plagioclase, microcline, biotite, muscovite with accessory apatite, zircon and opaques. Pegmatite occurs as large tabular bodies and also as minor veins criss-crossing the granite. It is leucocratic and very coarse-grained which consist petrologically of quartz, plagioclase, orthoclase, biotite and accessory opaque minerals. Bima sandstone is whitish, medium to coarse-grained feldspathic, indurated and silicified rocks. Quartz, microline, orthoclase and biotite are the dominant minerals with minor opaques. Limestone of Kanawa member of the Pindiga Formation occurs as loose slabs and blocks with some being cracked, others were petrified. Thin section studies revealed the presence of calcite, dolomite with minor quartz and microcline. Gombe sandstone consists of sandstone, siltstone, mudstone and ferruginous caps. They occur as pinkish and whitish with structural features such as laminations, bioturbations and liesegang rings. Quartz, feldspar and ferruginous minerals are present microscopically.

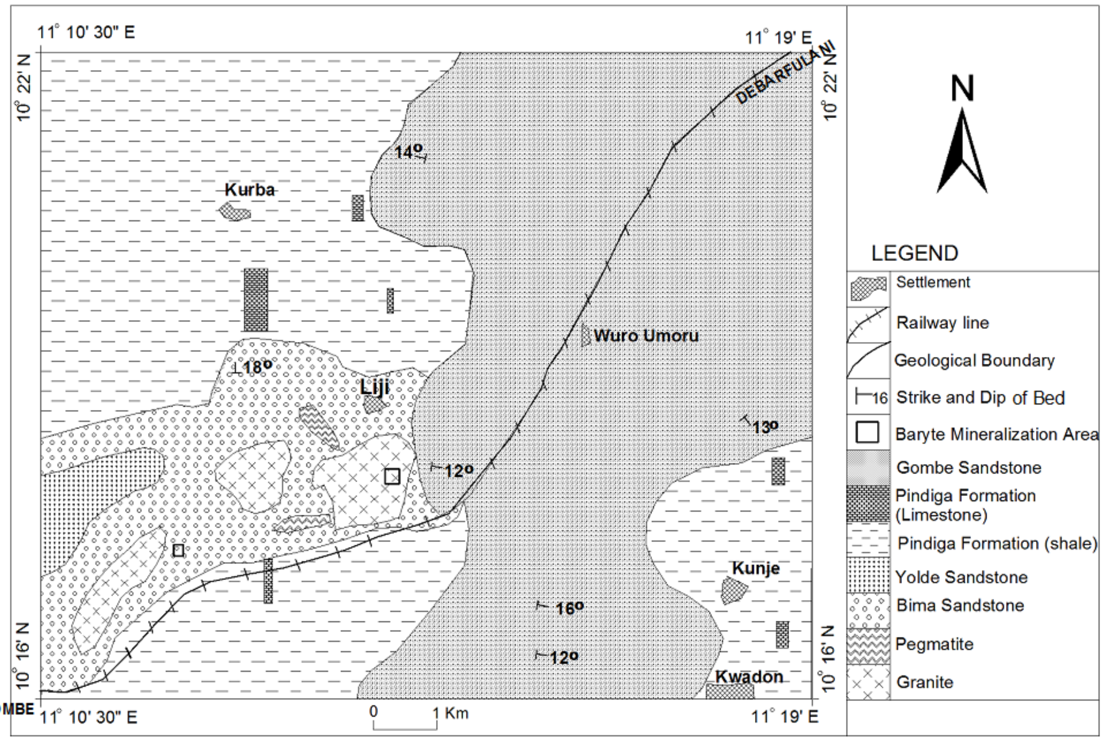

Figure 2: Geological map of Liji area.

Geology and Petrography of Mineralization Areas

The areas of baryte mineralizations were mapped in detail to establish the relationship between host rocks and baryte mineralization. The mineralization areas are outlined as:

i. Liji baryte mineralization Area (LBM)
ii. Gombe baryte mineralization Area (GBM)

Liji Baryte Mineralization Area (LBM)

The LBM is located within granite and pegmatite. Four baryte veins were identified in this area, three are hosted within granite and one hosted by pegmatite (Fig. 2). All the four veins strike E-W direction. The altered rock is dark brown and fine grained crumpled and baked due to heat of the hydrothermal fluid, micro veins of baryte were noticed to be associated with this zone, hematitization was recognized as the alteration product.

Four (4) bartye veins ranging in length from 7m to 45m long and width varying from 1m to 3.5m wide (Fig. 2). The main vein material (baryte) is creamy-white to brownish grey in colour and massive, with white streak, hardness is 3-4 on Mohr's scale. Cleavage is perfect in two directions at inclined positions. Some samples appear granular having non-metallic lustre. The specific gravity varies from 3.746 - 6.427 g/cm^3 with an average of 4.714 g/cm^3.

Petrogarhic investigation of the altered granite and pegmatite revealed the presence of quartz, orthoclase, biotite, baryte and opaque minerals (Plates 3 and 4). The baryte show no evidence of replacing the pre-existing minerals indicating fracture filling epigenetic style of mineralization.

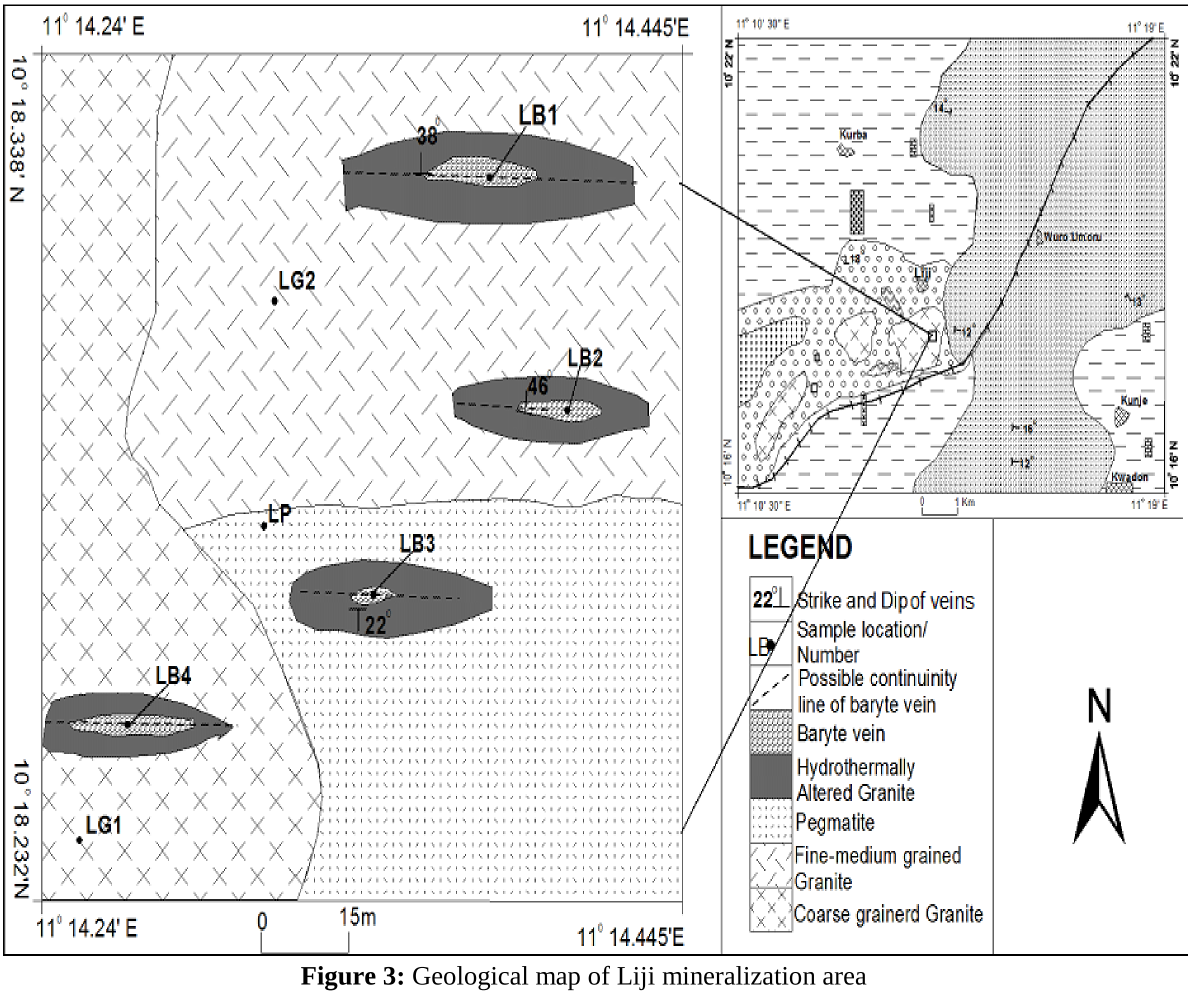

Figure 3: Geological map of Liji mineralization area

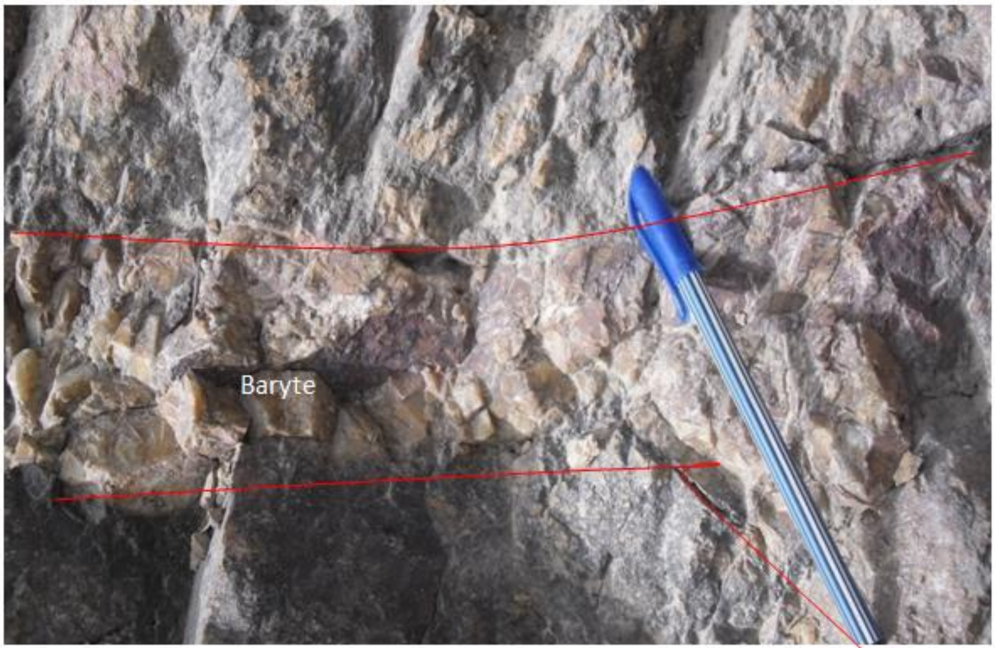

Plate 1: Baryte vein in granite (N10°18.342' and 11°14.422')

Plate 2: Baryte vein in granite (N10°18.303' and E11°14.444')

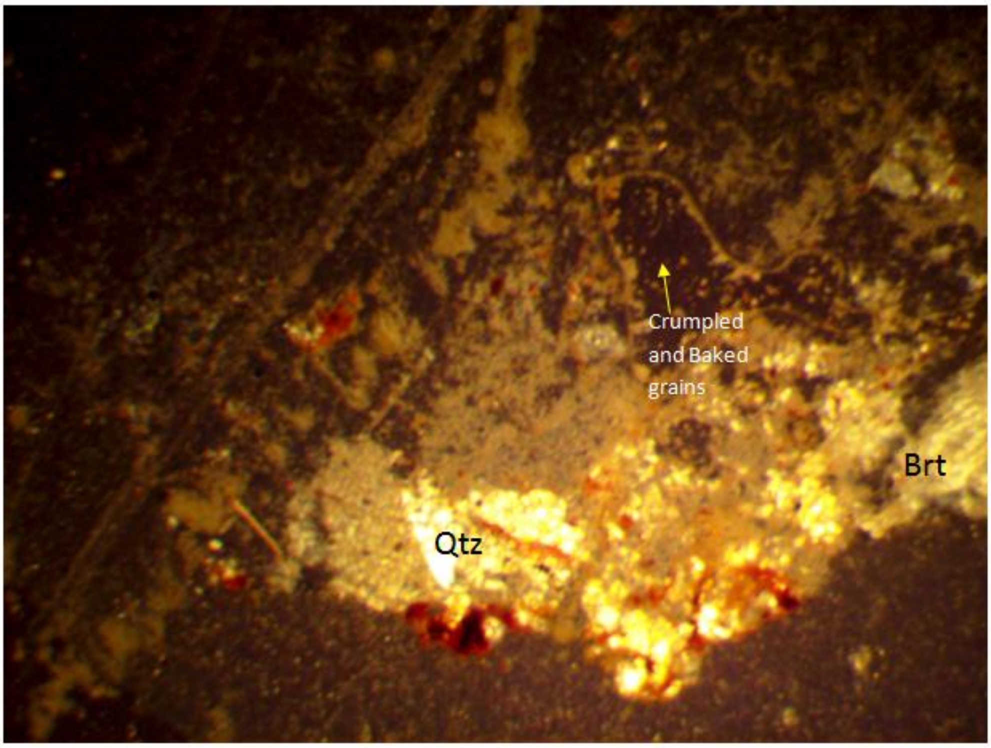

Plate 3: Photomicrograph of hydrothermally altered pegmatite showing: Baryte-Brt. Quartz-Qtz. Crumpled and baked grains as evidence of alteration. In crossed polarized light. Length of photograph= 6.7mm.

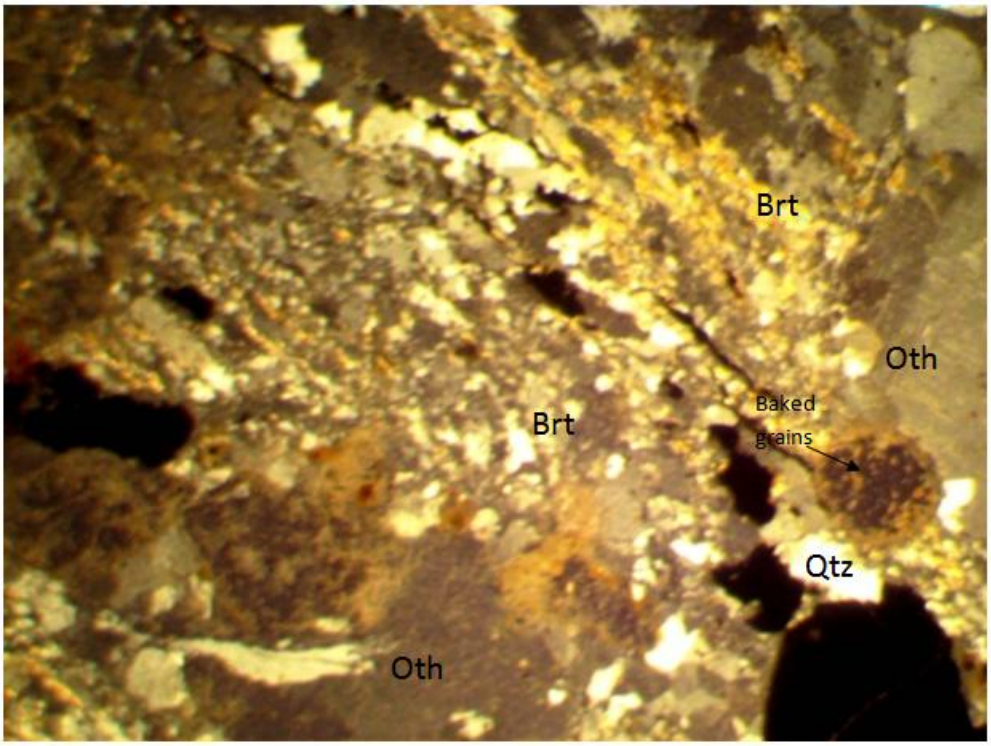

Plate 4: Photomicrograph of hydrothermally altered Granite showing: Baryte-Brt. Quartz-Qtz. Orthoclase-Oth and Baked grains as evidence of alteration. In crossed polarized light. Length of photograph= 6.7mm.

Gombe Baryte Mineralization Area (GBM)

The GBM occurs within highly indurated, steeply dipping beds of clastic sandstone and shaly units of the Bima Formation. Two baryte veins were identified in this area all of which trend in N-S direction. The first vein which is discontinuous (GB1, GB2, GB3) trends N-S extending for about 500m within hydrothermally altered Bima sandstone. The first part of the vein (GB1) is 32m long and 3- 4.5m wide (Fig. 4). Wall rock alteration product observed include hematitization and silicification where the altered sandstone became dark brown, hard and baked due to the heat of the hydrothermal fluid. Micro baryte veins were observed to be randomly injected into the altered sandstone (Plate 5). The baryte is creamy-white in colour with white streak and having hardness of 2-3 on Mohr's scale. It has perfect cleavage in two directions at inclined positions and it exhibits non-metallic lustre. The crystal system is orthorhombic having a specific gravity of 3.938g/cm^3. The physical properties of both GB2 and GB3 are similar to the GB1.

The second vein (GB4) is located about 1.3km SW of the GB3. It occurs within indurated shaly unit of the Bima Formation. It strikes N016E and dips 36^o E. The length is about 21m and the width ranges from 1.2m to 2.6m. The vein is surrounded by alteration zones which show veinlets of baryte randomly injected. These altered sandstones are also marked by change in colour and composition. The main vein material (baryte) is white in colour, massive and dense. It has hardness of 2-3 on Mohs scale with perfect cleavages in two directions and the specific gravity is 3.941 g/cm^3.

Thin section study of the hydrothermally altered sandstone shows that it is composed of quartz, microcline, orthoclase, baryte and biotite with minor amount of muscovite and opaque minerals (Plate 5 and 6). The baryte appears to fill the spaces between grains with no evidence of replacing the pre-existing minerals indicating that the style of mineralization is a porespace filling epigenetic type.

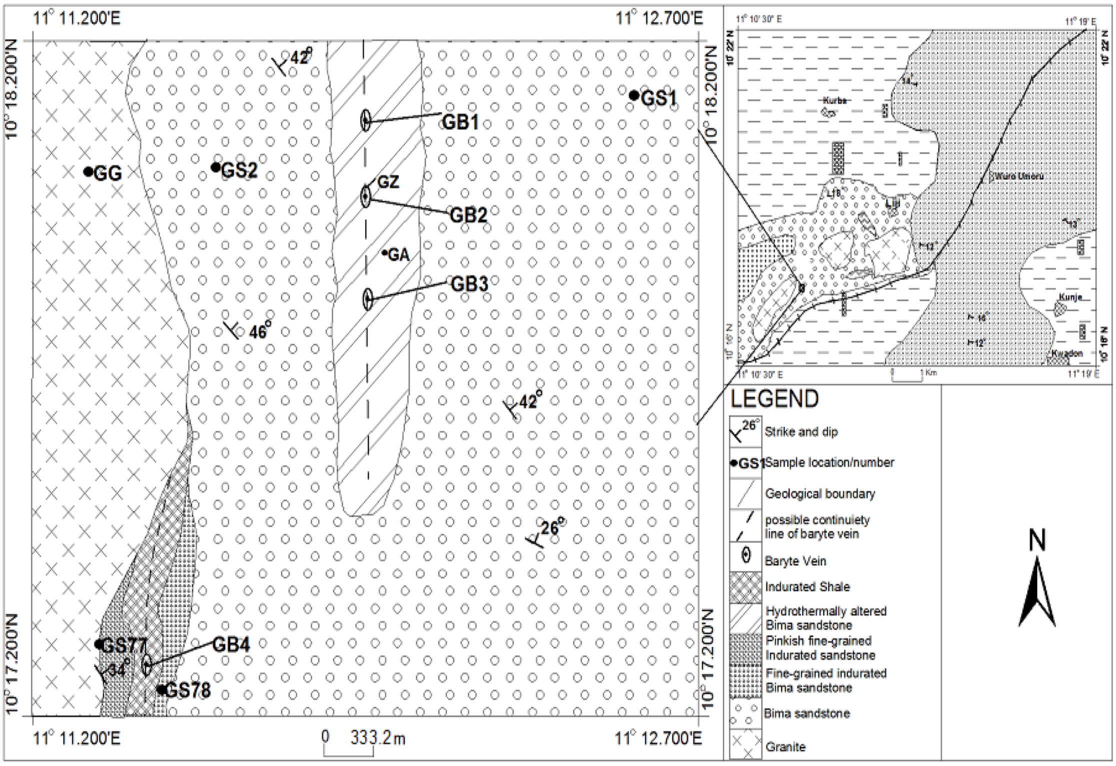

Figure 4: Geological map of Gombe mineralization area

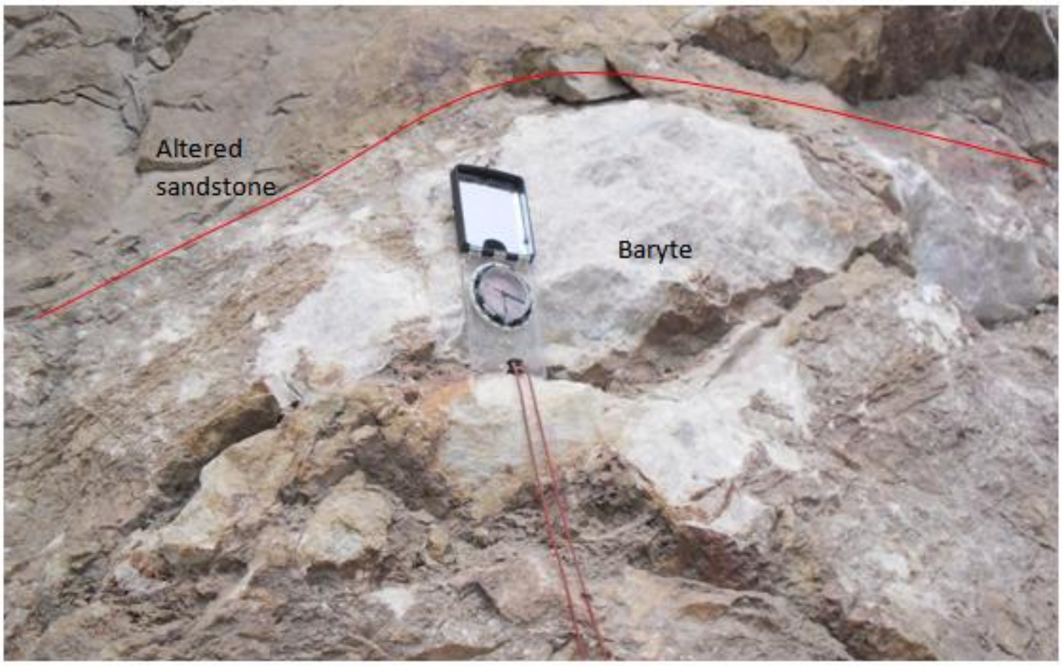

Plate 5: Baryte vein within within altered sandstone (N10°18.117' and E11°12.388')

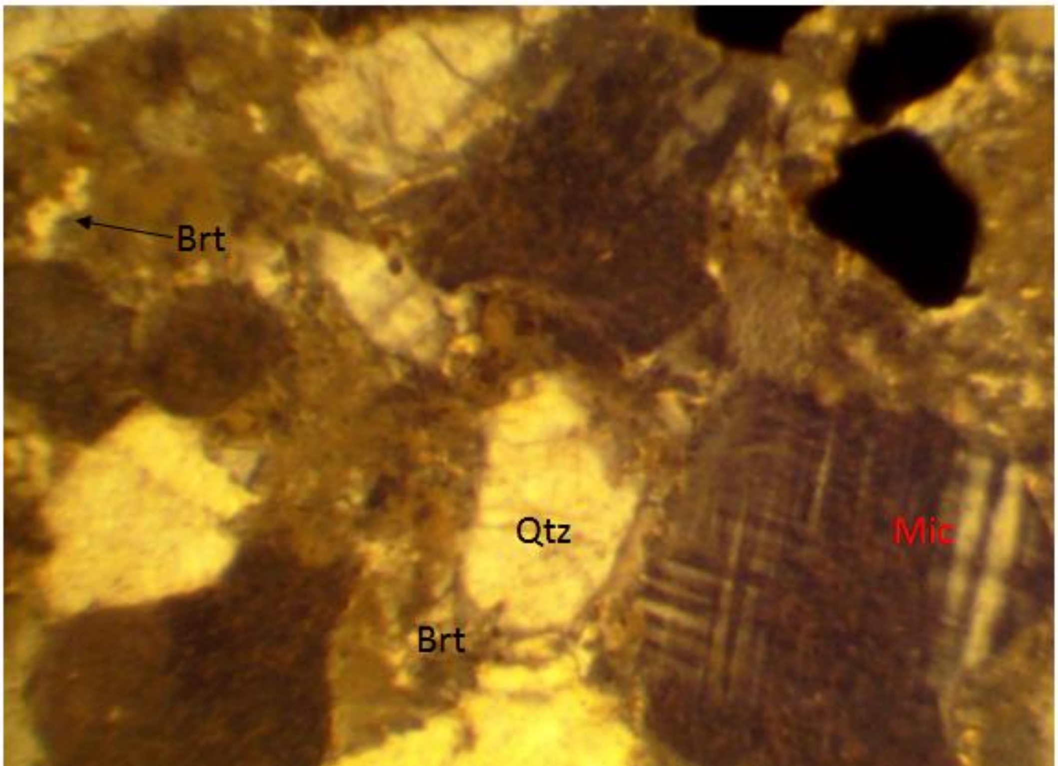

Plate 6: Photomicrograph of hydrothermally altered Bima sandstone showing: Quartz-Qtz. Microcline-Mic. Baryte-Brt. crossed polar. Length of photograph= 6.7mm.

IV. Geochemistry

Geochemical results for major element compositions of rocks and baryte separates of the Liji study area are presented in Table 1. A total of ten (10) samples were analyzed comprising of 5 from Liji baryte mineralization area (LBM) and the remaining five samples were obtained from Gombe baryte mineralization area (GBM). The LBM consists of two distal rocks of granite and pegmatite, two proximal hydrothermally altered granites and baryte separate. The GBM has two distal rocks of pegmatite and sandstone, two proximal hydrothermally altered sandstones and one baryte separate.

Table 1: Major Elements Composition of the Rocks of Liji Area.

	Liji Baryte Mineralization Area (LBM)					Gombe Baryte Mineralization Area (GBM)				
	Distal Granite and Pegmatite		Proximal and Zoned Altered Granite		Baryte Separate	Distal Pegmatite and Sandstone		Proximal Zoned and Altered Sandstone		Baryte Separate
Oxide (%)	LG	LP	LZ	LA	LB1	GP	GS	GZ	GA	GB1
SiO_2	76.86	80.25	56.12	65.97	10.33	75.48	88.46	72.38	57.87	11.80
Al_2O_3	12.30	10.23	3.01	13.46	0.05	13.58	5.87	6.41	6.10	0.01
Fe_2O_3	0.74	0.48	29.77	2.29	0.67	1.15	0.52	0.73	1.28	0.14
MgO	0.14	0.05	0.02	0.20	n.d	0.11	0.01	0.08	0.03	n.d
CaO	1.55	0.82	0.04	0.82	2.51	0.49	0.09	3.86	0.53	1.20
Na_2O	3.00	3.75	0.05	3.08	n.d	3.15	0.58	0.33	0.28	n.d
K_2O	2.92	1.94	0.99	4.99	n.d	5.19	3.92	4.15	4.27	0.02
TiO_2	0.07	0.03	0.12	0.47	n.d	0.06	0.07	0.24	0.14	n.d
P_2O_5	0.06	0.03	0.02	0.12	n.d	0.04	0.01	0.17	0.02	n.d
MnO	0.01	n.d	n.d	0.01	n.d	0.02	n.d	0.02	n.d	n.d
Oxide (%)	LG	LP	LZ	LA	LB1	GP	GS	GZ	GA	GB1
Cr_2O_3	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
LOI	1.9	0.7	3.3	2.1	1.5	0.7	0.3	3.3	1.6	0.9
SUM	99.55	98.28	99.91	99.77	15.06	99.99	99.99	99.77	91.16	14.07

Note: LG= Distal Granite; LP= Distal Pegmatite; LZ= Proximal Granite; LA= Proximal Granite; LB1= Baryte Separate; GP= Distal Pegmatite; GS= Distal Sandstone; GZ= Proximal Sandstone; GA= Proximal Sandstone; GB1= Baryte Separate.
n.d = not detected.

Major Element Distribution of LBM and GBM

In the LBM, the silica contents for distal (fresh) samples vary from 76.86 wt% for granite to 80.25 wt% for the pegmatite. In the hydrothermally altered (proximal) granites the silica content vary from 56.12 wt% to 65.97 wt% averaging 61.05 wt% while in the baryte mineral separate, the silica content is 10.33 wt% (Table 1). This result shows progressive depletion of silica content from the distal samples through the proximal samples which is believed to be the result of leaching related to the hydrothermal solutions on the host rocks. However, the 10.53 wt% silica content in the baryte separate which is rather high could be due to silica contamination. In the GBM, the silica content is 75.48 wt% and 88.46 wt% in the fresh unaltered distal pegmatite and sandstone respectively (Table 1). The silica content also ranges from 57.87 wt% to 72.38 wt% in the hydrothermally altered proximal sandstones with an average of 65.13 wt%. The silica content in the main vein material (baryte separate) is 11.80 wt%. The result show similar depletion of silica from the unaltered distal samples through the altered proximal samples, which is also believed to be the result of leaching as in the Liji mineralization area. However, the silica content of 11.80 wt% in the baryte separate is high reflecting silica contamination in the separate.

The alumina contents in the LBM, varies from 12.30 wt% and 10.23 wt% in the distal granite and pegmatite respectively. In the proximal granites the alumina content vary from 3.01 wt% to 13.46 wt%, with an average of 8.24 wt% while in the baryte separate the alumina content is 0.05 wt%. The depletion of alumina from distal to proximal indicates leaching of the rocks through the invading hydrothermal solution. In the GBM, however the contents of alumina in the distal pegmatite and sandstone are 5.87 wt% and 13.58 wt% respectively. The alumina contents ranges between 6.10 wt% and 6.41 wt% with an average of 6.26 wt% for the proximal sandstones. The baryte separate show alumina contents of 0.01 wt%. There is significant change in the alumina contents from distal sandstone (13.58 wt%) to proximal samples in the Gombe mineralization area which also reflect leaching effects.

In the LBM, the Fe_2O_3 contents show variation from 0.48 wt% to 0.74 wt% for the fresh granite and pegmatite samples while the values in proximal granite samples ranges between 2.29 wt% to 29.77 wt% with an average of 16.03 wt%. The Fe_2O_3 content in baryte separate is 0.01 wt%. Therefore, there is enrichment of Fe_2O_3 from the fresh to proximal samples which could be attributed to hematitization evidenced by marked reddish brown colour as an alteration effect. The Fe_2O_3 contents of the GBM is respectively 1.15 wt% and 0.52 wt% for the distal pegmatite and sandstone, but vary from 0.73 wt% to 1.28 wt% with an average of 1.01 wt% in the proximal sandstones, and have a value of 0.14 wt% in the baryte separate. It shows enrichment also from distal to proximal but not as prominent as in the LBM concentrations.

The soda contents of fresh granite and pegmatite of the LBM are 3.00 wt% and 3.75 wt% respectively. In the proximal granites the soda contents vary from 0.05 wt% to 3.08 wt% with an average of 1.57 wt% and in the main vein material (baryte) the soda value is below detection limit. There is also depletion of soda content from the fresh samples to the proximal granites. In the GBM, the distal pegmatite and sandstone have soda values of 0.58 wt% and 3.15 wt% respectively. The proximal sandstones yield soda values ranging from 0.28 wt% to 0.33 wt% with an average of 0.31wt% but the baryte separate yield 0.01 wt%. There is depletion of Na_2O value of the distal sandstone (0.58 wt%) to a 0.31wt% average in the proximal sandstones. This is attributable to the leaching of the host rocks by the hydrothermal solutions.

In the LBM, the values of potash are 2.92 wt% and 1.94 wt% for the distal samples of granite and pegmatite respectively. The proximal granites vary in potash contents from 0.99 wt% to 4.99 wt% with average of 2.99 wt% and the mineral separate (baryte) gave potash value of 0.01 wt%. No observable trend was recorded. The potash values in the GBM, is respectively 5.19 wt% and 3.92 wt% in the unaltered pegmatite and sandstone, while in the altered sandstones values range from 4.15 wt% to 4.27 wt% with average of 4.21 wt%, and the mineral separate have potash value of 0.02 wt%. This shows enrichment of potash from distal sandstone through the proximal sandstones.

Major Elements Discrimination Diagrams of LBM and GBM

The conspicuous enrichment and depletion of the five major oxides of Si, Al, Fe, Na and K necessitates the binary plotting of the oxides for the purpose of establishing a classification of the two (Liji and Gombe) mineralization areas. The plots of distal and combined (distal, proximal and baryte) samples were used for this purpose. The plots of SiO_2/Al_2O_3, SiO_2/Fe_2O_3, Al_2O_3/Na_2O, Fe_2O_3/Al_2O_3, and Fe_2O_3/K_2O (Fig. 5 a, b, c, d & e) for the distal samples showed established linear trends for the samples and were consequently considered as the main trends (MT) of the fresh distal samples to which other obtained trends for the mineralization can be compared to. The fresh unaltered sandstones, granite and pegmatite samples fall within these main trends exhibiting normal mixed pattern of the samples before the advent of mineralizing hydrothermal fluid. There is no observable discrimination of lithology noticed within the trends prior to invasion of hydrothermal fluid.

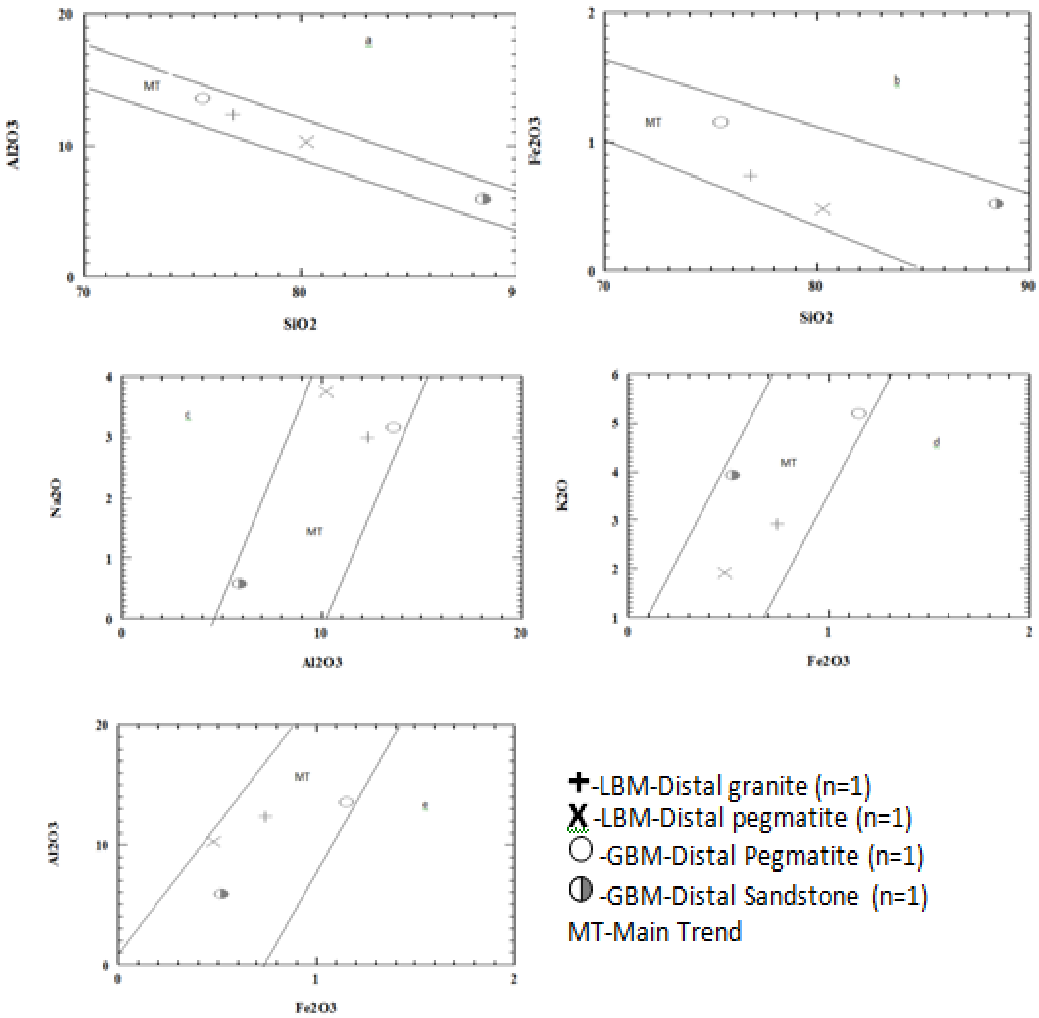

Figure 5: Plots of (a) SiO_2 / Al_2O_3, (b) SiO_2 / Fe_2O_3, (c) Al_2O_3 / Na_2O, (d) Fe_2O_3 / K_2O, (e) Fe_2O_3 / Al_2O_3 of distal samples of baryte mineralization areas.

The plots of the combined samples are as well presented in Fig. 6a, b, c and d. In all the plots, the samples are classified as baryte separate, proximal and main trend (distal). In addition to that, the three plots indicating mixing of the proximal samples (unclassified) while the baryte separate plot almost around the same point in each of the plots. These indicate that the two baryte mineralization areas are of same origin despite the varying host rocks of the mineralization.

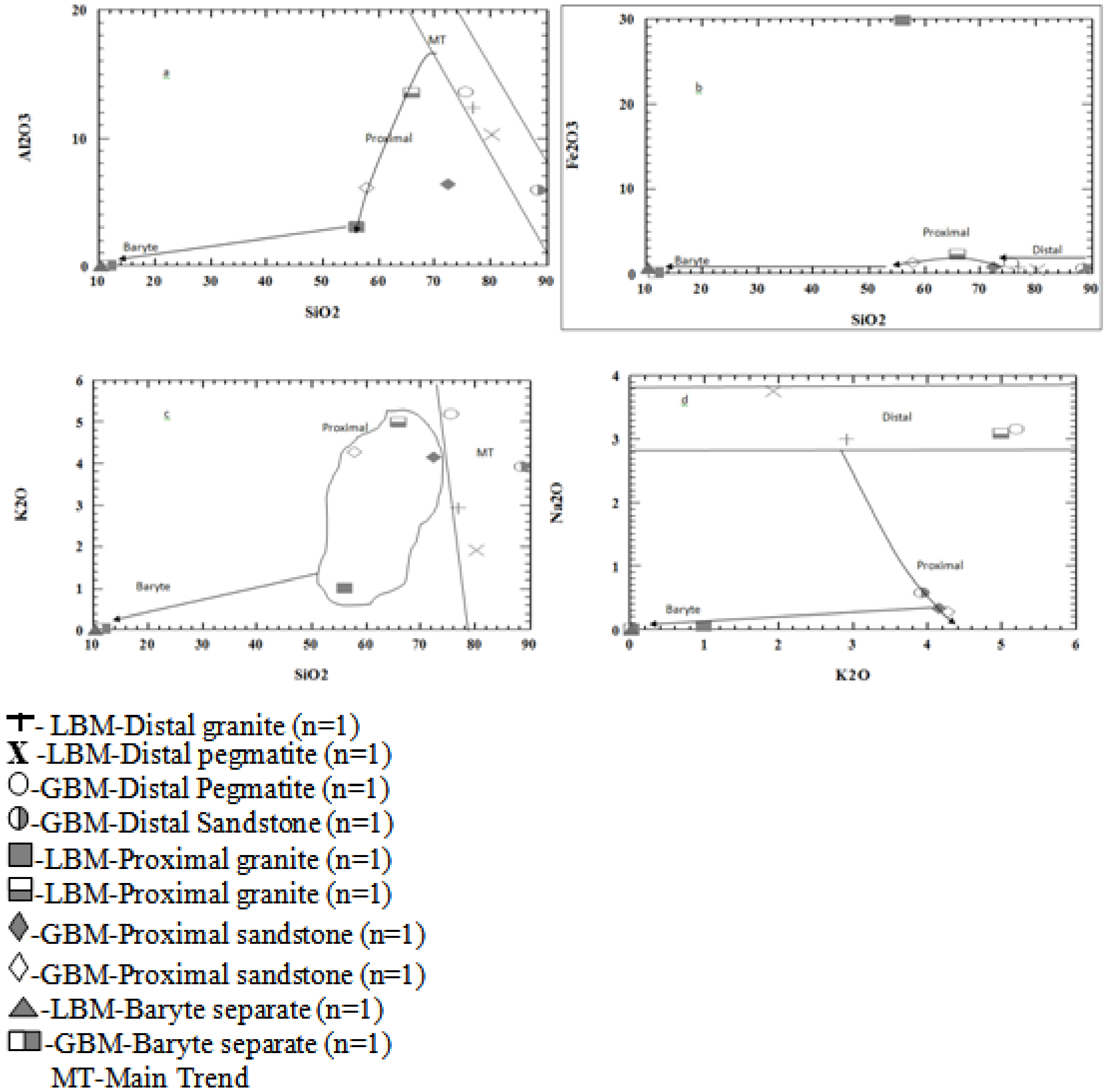

Figure 6: Plots of (a) SiO_2 / Fe_2O_3, (b) SiO_2 / Al_2O_3, (c) SiO_2 / K_2O (d) K_2O / Na_2O of Combined samples baryte mineralization areas.

V. Discussion

The baryte mineralization of the Liji area are of short dimension, the length ranges between 7m to 45m while the thickness varies from 1m to 3.5m wide. These characteristics are similar to those reported by El-Nafaty (2017) in the Gulani area of Upper Benue Trough where he indicated that the baryte veins ranged from 25 – 75m long and 3.5-5m wide. The average specific gravities of the barytes in LBM and GBM are 4.714 g/cm^3 and 3.943g/cm^3 respectively, indicating that the baryte of LBM has better quality compared to those of the GBM and that it has met the requirement for use in the production of drilling mud as set by American Petroleum Institute (API). The overall average specific gravity of 4.329 g/cm3 was obtained for the barytes of Liji area which is similar to those reported by Daspan and Imagbe, (2010) and El-Nafaty, (2017).

Thin section study of the altered granites, pegmatites and sandstones proximal to the veins of baryte shows that the baryte irregularly filled in the fractures and porespaces between mineral grains of the host rocks suggesting that the mineralization is both fracture and porespace filling epigenetic type. In a similar studies by El-Nafaty (2015) baryte were reported to fill fractures and porespaces of quartz and microcline being brittle minerals.

Binary plot of the distal samples show linear trend despite different lithologic units indicating that the normal background values before the advent of the mineralizing hydrothermal fluid. The plot of the combined samples indicated that the rocks are separated and classified into distal, proximal and baryte. The baryte falls in almost the same region in all the plots of the combined samples reflecting that the two barytes are of the same origin despite variable host lithologies.

Acknowledgement

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References

[1]. Daspan, R. I. and Imagbe, L. O. (2010). Preliminary investigation of the origin and quality of barytes in the Tsareta-Tungan Kudaku area, North-Western Nigerian Basement Complex. *Continental Journal of Earth Sciences* **5** (1): 8-13.

[2]. Deer, W. A., Howie, R. A. and Zussman, J. (1978). An introduction to the rock-forming minerals. Longman Group Ltd, London; LBS edition, 528p.

[3]. Edu, E. E. (2006). Interim report on assessment of baryte resources in Taraba State, Nigeria. Nigerian Geological Survey Agency Report (unpublished).

[4]. El-Nafaty, J. M. (2015). Rare earth element and suphur isotope study of baryte-copper mineralization in Gulani Area, Upper Benue Trough NE Nigeria. *Journal of African Earth Science,* **106:** 147-157.

[5]. El-Nafaty, J. M. (2017). Geology and trace element geochemistry of the barite-copper mineralization in Gulani area, NE Nigeria. *Journal of applied geology and geophysics*, **5**(2): 1-16.

[6]. Ene, E. G., Okogbue, C. O. and Dim, C. I. P. (2012). Structural styles and economic potentials of some baryte deposits in Southern Benue Trough, Nigeria. *Romanian Journal of Earth Science* **86** (1): pp. 27-40.

[7]. Farington, J. L. (1952). A preliminary description of the Nigerian lead-zinc field. *Economic Geology,* **47** (6): 583-608.

[8]. Ford, S. O. (1989). The economic mineral resources of the Benue Trough In: Kogbe, C.A. (ed.), Geology of Nigeria. Rock view (Nig.) Ltd, Jos, second revised edition: 473-484.

[9]. Fyfe, W., Price, N. J. and Thompson, A. B. (1978). Fluids in the earth's crust. Elselvier, Amsterdam. 383p.

[10]. Gribble, C. D. (2004). Rutley's elements of mineralogy. 27th edition. CBS Publishers and Distribution. New Delhi: 318p.

[11]. Griffith, E. M. and Paytan, A. (2012). Barite in the ocean – occurrences, geochemistry and palaeoceanographic applications. *Sedimentology,* **10:** 1-19.

[12]. Hanor, J. S. (2000). Baryte-Celestine geochemistry and environment of formation. In: Alpers, C.N., Jambor, J.L. and Nordstrom, D.K. (eds.), *Reviews in Minerals* **40:** 193-275.

[13]. Joseph, M. V., Adamu, S. and Mohammed, Y. B. (2007). Sulphur isotope characteristics and genetic mechanism for pyrite mineralization of Gombe hill, North East Nigeria. *Research Journal of Science,* **13** (1&2): 83-90.

[14]. Kamale, H. I. (2018). Geology and baryte mineralization potentials of Liji and Yelwa areas of northeastern Nigeria. Unpublished MSc. Dissertation University of Maiduguri.

[15]. Nigerian Mining Corporation (NMC), (1979). Reserve Estimate of Azara Baryte. Unpublished Report.

[16]. Oden, M. I. (2012). Baryte veins in the Benue Trough: Field Characteristics, the Quality Issues and Some Tectonic Implications. *Environmental and Natural Resource Research,* **2** (2): 1-31.

[17]. Offodile, M. E. (1976). The Geology of the Middle Benue, Nigeria. Publication from Paleontological Institute of University of Uppsala, Special Publication, **4:** 166-167.

[18]. Oladapo, M. I. and Adeoye, O. O. (2011). Geophysical Investigation of Baryte Deposit in Tunga, North-East Nigeria. *International Journal of the Physical Science.* **6** (20): 4760-4774.

[19]. Tate, R. B. (1959). Memorandum on the Baryte Deposits in the Benue Province. Geological Survey of Nigeria Report, 1266. (Unpublished).

[20]. Zaborski, P., Ugodulunwa, F., Idornigie, A., Nnabo, P. and Ibe, K. (1997). Stratigraphy and Structure of the Cretaceous Gongola Basin, Nigeria. *Bulletin Centre of Research and Production, Elf Acquitine* **21:** 153-185.

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