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Occurrence, Geochemistry And Industrial Quality of Dumne Baryte Deposit, Southeastern Hawal Massif, Northeastern Nigeria

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Abstract: *Baryte mineralization occurs as a vein along a fault line trending ENE – WSW (070^0) emplaced within the basement complex rocks in Dumne Area, Southeastern Hawal Massif, Northeastern Nigeria. The exposed mineralized vein spans a length of 25 meters with vein thickness of 5 meters and a depth of 9 meters from the surface. Physical character of the baryte at the center of vein shows smoky/colourless appearance while at the contact with the wall rock is creamy/white. Chemical analyses of representative samples of baryte from the center of vein showed 93.08% $BaSO_4$, and a specific gravity of 4.46 g/cm^3 while at the contact with the wall rock, $BaSO_4$ is 47.88% and specific gravity 3.35 g/cm^3. The baryte, viewed against international standards and specifications for various industrial applications make it pure, qualitative and suitable for oil and gas, rotor for x-ray tubes, paper, paint, textile, glass, and rubber industries.*

Keywords*: Dumne, Mineralization, Baryte, Fault, Basement, Benue Trough, Specific gravity, Nigeria.*

I. Introduction

Dumne area is situated at the tip of southeastern Hawal Massif, Northeastern Nigeria. It lies within the geographical coordinates, northing's 9^0 45^I and 9^0 51^I and easting's 12^0 15^I and 12^0 25^I (Fug.1). It is bounded in the west and south by the Gongola and Yola arms of the Benue Trough respectively. The geology of the area still remains largely unknown as no detail work has been done to delineate and describe the different rock units in the area. However, previous workers such as Oyawoye, (1972), McCurry (1976), Reyment, (1986), Rahaman, (1988), Ajibade and Fitches (1988), Kwache (1992), Bassey et al (1999) Adekeye and Ntekim (2004), Patrick, (2005), NGSA (2009 and 2010) and Bassey and Valdon (2011) reported that southern Hawal Massif consists of gneiss, granite gneiss, granites, some minor rocks such as dolerite, aplite, pegmatite and some minerals such as quartz crystals and baryte. Oluyide (1988), Bassey et. al (2006), Bassey (2006) and Kasidi (2007), reported that the basement complex rocks in this area are believed to be polycyclic having been affected by various tectonic events with different intensities resulting in different episodes of folding, faulting and granitic emplacement along the linear shear zones from Archean to late Proterozoic (Pan-African).

Fig. 1. Topographic map of Dumne.

II. Materials and Methods

Chemical compositions of 12 representative samples of baryte from different sampling points across the same vein (Fig. 2) and 2 samples of the host rocks (gneiss and granite) were analyzed at the National Geosciences Laboratory Research Center, (NGLRC) Kaduna, Nigeria. Atomic Absorption Spectrometry (AAS) was used to determine their compositions. Gravimetric precipitation was employed to measure the specific gravities of the samples. The inter-granular water (H_2O^-) was oven dried at 60^0C for 2 hours. The structural water (H_2O^+) was determined at loss of ignition (LOI) after heating the dried sample in a muffle furnace for 4 hours at 700^0C.

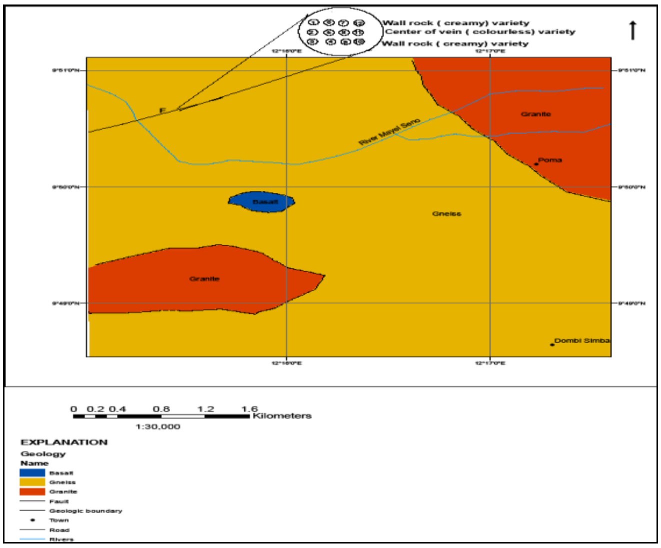

Fig. 2: Geologic map showing sampling points.

III. Occurrence

In Dumne area, it is difficult to discuss a unified geologic setting for the baryte deposit because mineralization appears to be controlled by diversified geologic conditions. From the submission of Wright (1976) and Benkhelli (1982), Dumne area belongs to a region where tectonic activities that caused formation of Benue Trough was accompanied by fracturing and faulting of rocks within the adjoining basement complex units. Subsequent igneous activities generated mineralizing fluids that accumulated and consolidated within these structures. This structural requirement was confirmed in the field, as the baryte vein occurred along a fault line trending ENE – WSW (070^0) emplaced within gneisses and granites. This trend is consistent with the general trend of Benue Trough and the general fracture trend of the host rocks. At the contact with the baryte vein, the host rock is brecciated and shows no wall alteration beyond the zone of brecciation which is 25 meters. One striking feature of the baryte at Dumne is its lack of association with galena and sphalerite like in most occurrences along the Benue Trough and the adjoining basement complex rocks. The baryte is brittle, high density, sulphurous odour and white streak when hit by a hammer or scratched by a knife blade. Two varieties were identified on the basis of colour, form, luster, cleavages and accessory minerals. The creamy/whitish variety which is restricted to the wall rock is tabular, granular, crystalline, sub-vitreous and consists of quartz and some opaque minerals with some particles of the host rock. The smoky/colorless variety restricted to the center of vein is pure, crystalline, compact, vitreous and devoid of other minerals.

Petrographic character

In thin sections, the baryte is brittle with cleavages, low birefringence and an extinction angle of approximately 38^0 observable under cross polars.

Geochemistry and Results

Table 1 shows the chemical composition of baryte samples from the vein; Table 2 shows the compositions of trace and REE in the baryte, table 3 shows chemical compositions of the host rocks while Table 4 shows the specific gravity of the baryte.

Table 1: Chemical composition (oxides) of baryte.

Wt %	Samples											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
SiO_2	36.00	1.09	36.77	36.42	0.72	36.80	37.00	0.84	36.87	36.90	0.70	36.81
Al_2O_3	0.089	0.110	0.088	0.094	0.120	0.094	0.090	0.16	0.091	0.097	0.15	0.092
SO_3	11.01	20.29	10.46	10.36	22.30	10.46	10.48	19.97	10.44	10.51	17.50	10.47
Fe_2O_3	0.45	0.10	0.40	0.50	0.15	0.48	0.41	0.12	0.45	0.47	0.16	0.47
TiO_2	0.69	-	0.70	0.46	1.45	0.38	0.76	2.80	0.40	0.72	2.54	0.39
MgO	0.15	0.01	0.10	0.09	0.01	0.12	0.11	-	0.012	0.09	-	0.11
CaO	10.17	0.12	11.00	13.23	0.10	11.05	10.57	0.15	10.97	10.70	0.14	11.00
Na_2O	0.03	-	0.01	0.01	-	0.02	0.02	-	0.01	-	-	0.02
K_2O	0.02	0.06	-	0.05	0.01	0.03	0.01	-	0.02	-	0.09	0.03
BaO	39.14	73.65	39.00	40.12	72.25	35.55	35.87	72.34	35.49	38.20	74.00	35.50
MoO_3	2.46	3.60	2.38	2.39	2.85	1.99	2.00	3.70	2.00	2.50	3.60	1.99
L.O.I.	0.50	0.11	0.47	0.44	0.12	0.48	0.41	0.11	0.49	0.46	0.13	0.49

Elements	Samples											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Zn	368.40	-	366.73	369.19	-	367.84	369.34	-	369.00	369.47	-	368.87
Cu	181.90	-	183.12	182.61	-	183.91	180.69	-	183.23	183.70	-	180.54
Ga	-	280.43	-	-	276.87	-	-	279.56	-	-	278.82	-
W	-	473.8	-	-	470.2	-	-	475.8	-	-	475.4	-
Re	459.90	-	460.78	461.45	-	461.67	462.34	-	459.90	461.28	-	460.87

Note: P1 = Prambe baryte sample 1 …P12 = Prambe baryte sample 12 while (–) = not detected.

Table 2: Chemical composition (minor/trace elements) of baryte in parts per million (ppm)

Table 3: Chemical composition of host rocks.

Oxides wt% / Parameter	SiO_2	Al_2O	SO_3	P_2O_5	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	BaO	MoO_3	LOI
Granite	60.50	9.19	-	0.04	3.23	1.44	1.03	4.11	1.87	10.27	0.92	-	0.59
Gneiss	57.20	7.40	-	1.40	14.54	2.05	2.13	6.59	2.95	5.59	2.34	-	0.77

Trace/REE	**ppm**						
	V	Mn	Zn	Nd	Eu	Ce	Re
Granite	-	394.74	-	85.73	259.08	162.82	-
Gneiss	531.19	1161	329.31	-	2072.64	-	615.04

Table 4: Specific gravities (SG) of the baryte.

Sample	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
SG	3.32	4.46	3.34	3.35	4.46	3.34	3.35	4.45	3.37	3.35	4.46	3.36

IV. Discussion of results

The chemical composition of any mineral sample is of prime importance as the knowledge of the level of concentration of associated chemical species help in the elimination of unwanted species. In Table 1, all the samples from the center of vein have high concentration of barium (BaO), molybdenum (MoO), potassium (K_2O), titanium (TiO_2), sulphur (SO_3) and aluminum (Al_2O_3) compared to those at the contact with the wall rock (Fig. 3). At the center of vein, BaO ranges from 72.25% to 74.00% (averaging 73.06%) and from 35.49% to 39.14% (averaging 37.36%) at the contact with the wall rock, MoO ranges from 2.39% to 3.70% (averaging 3.43 %) while at the contact with the wall rock, it ranges from 1.99% to 2.50% (averaging 2.21%). K_2O gave near equilibrium concentrations averaging 0.04% at the center, and 0.02% at the contact with the wall rock giving a difference of 0.02%. TiO_2 ranges from 1.45% to 2.80% (averaging 1.67 %) while at the contact with the wall rock, it ranges from 0.38% to 0.76% (averaging 0.56%). SO_3 which is a major constituent of baryte ranges from 17.50% to 22.30% (averaging 20.02%) at the center of vein while at the contact with the wall rock it ranges from 10.36% to 11.01% (averaging 10.52%). Al_2O_3 ranges from 0.11% to 0.16% (averaging 0.14%) while at the contact with the wall rock, it ranges from 0.09% to 0.097% (averaging 0.092%).

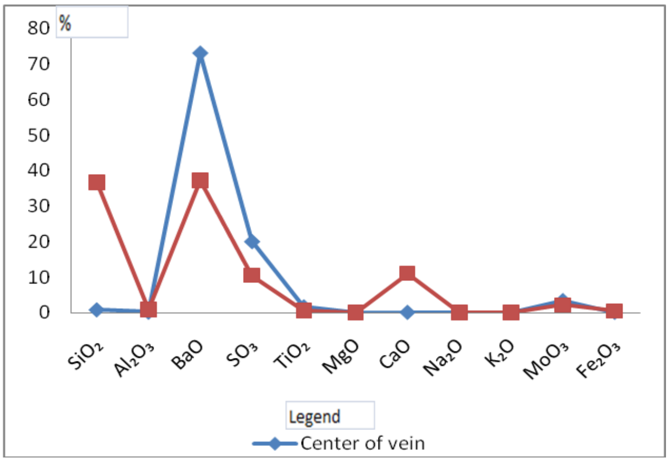

Fig. 3. Average compositional concentration of elements in the baryte vein.

This high content of BaO and SO_3 at the center of vein indicates that the mineralizing fluid contained high amount of BaO and SO_3 (Omada and Ike, 1996 and Akpeke et al. 2006).

All the samples from the contact zone have high concentration of silica (SiO_2) content ranging from 36.00% to 37.00%, (averaging 36.70%) while samples from the center of vein have low contents ranging from 0.70% to 1.09% (averaging 0.83%), calcium (CaO) is high ranging from 10.17% to 11.05%, (averaging 11.07%) compared to very low amount at the center of vein ranging from 0.10% to 0.15% (averaging 0.13%), Fe_2O_3 is low, ranging from 0.40% to 0.50% (averaging 0.45%) at the contact with the wall rock and from 0.10% to 0.16% (averaging 0.13%) at the center of vein. MgO ranges from 0.09% to 0.15%, (averaging 0.10%) relative to a consistent value of 0.01% at the center, and Na_2O ranges from 0.01% to 0.03%, (averaging 0.02%) but totally absent at the center. In the host rocks (Table 3), the average MgO content is 1.58%, Na_2O is 2.26%, Fe_2O_3 is high with a value of 8.89%, BaO ranges from 0.92% to 2.34% while MoO and SO_3 are totally absent. Following Cathles (1991), Appleyard and Guha, (1991), Omada and Ike (1996) and Akpeke et al. (2006), those elements that showed higher concentration values in samples from the contact with the wall rock than those from the center of vein suggests that the flux of chemical species is driven from the hydrothermal solution to the host rock 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 dependent on and attributed to differing properties of various host rocks which would have affected their abilities to sustain fracturing, especially large, strong fractures. The investigated baryte mineral samples are essentially made up of $BaSO_4$ and samples from the center of vein gave a relatively high percentage while those from the contact with the wall rock are of a low percentage. This suggests that the samples from the center of vein are more differentiated and thus are purer.

Concentration of some trace elements in the baryte and the host rocks were assessed (Table 2 and 3). Mn, V, Nd, Ce and Eu occurred in the host rocks and are absent in the baryte. Similarly, W, Ga and Cu occurred in the baryte samples and are absent in the host rock. This perhaps suggest that those elements that did not occur in the baryte and the host rocks were not useful and thus were not involved in the differentiation process at the center of vein and at the contact of vein with the wall rock (Appleyard and Guha, 1991). In the baryte sample, Zn is higher by 39.09 ppm whereas Re is higher by 153.37 ppm in the host rocks.

V. Industrial quality

One of the attributes that make baryte desirable especially as weighing agent in drill mud of the oil and gas industries is their specific gravity values. Baryte with specific gravity values of 4.5 g/cm^3 and above is considered pure while baryte with specific gravity values from 4.2 g/cm^3 satisfies requirements of most oil industries (Microfine 1999, Andrew 2003). In Dumne area, the baryte at the center of vein is considered to be of pure grade with average specific gravity of 4.46 g/cm^3 while baryte at the contact with the wall rock is considered moderate with average specific gravity values of 3.35 g/cm^3 (Table 4). The high grade varieties can be used in oil and gas industries while the low grade can be used in paint and glass industries. For Dumne deposit, obtained data indicate that it can be classified into two grades in terms of quality and specification for use in many industries. The smoky/colourless variety with 93.06% $BaSO_4$ and average specific gravity of 4.46 g/cm^3, white streak and hardness of 3.2 is the grade one type. The creamy/white varieties at the wall rock which has 48.12% of $BaSO_4$ and average specific gravity of 3.35 g/cm^3, white streak and hardness of 3.3 constitute the grade two types. When compared with barytes from different places within Nigeria notably; Makurdi and Azara (Middle Benue Trough), Akpet (southeastern Nigeria) and Didango (Upper Benue Trough), Dumne baryte is relatively more purer and of very good quality.

VI. Conclusions

Baryte mineralization in Dumne area, southeastern Hawal Massif, Northeastern Nigeria occur along faulted zone emplaced within granites and gneisses. There is a progressive increase in the $BaSO_4$ content and specific gravity from the contact with the wall rock towards the center of vein, i.e. from the creamy/whitish variety to the smoky/colourless variety. The chemical compositions of the baryte, viewed against international standards and specifications for various industrial applications make it pure, qualitative and suitable for use in various industries that require the commodity.

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