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THE NATURE AND ORIGIN OF BARITE MINERALIZATION IN AKPET AREA, OBAN MASSIF, SOUTHEASTERN NIGERIA

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ABSTRACT

Akpet area of Oban Massif in southeastern Nigeria has been generally regarded as barren of mineralization of economic significance. This study documents for the first time, the occurrence of substantial deposit of barite in five districts of the area. The mineralization generally occurs as veins emplaced in quartzite, schists, phyllite and sandstones. Some areas host unconformity-related vein-type mineralization between the basement rocks and overlying younger sediments. The mineralized area spans a length of about 30 km, with vein thickness varying between 0.5 – 2.5, and an estimated depth of 10m. In the light of geologic and geochemical data presented, the genesis of the deposit is attributable to the role of basinal brine fluid which extracted barium from basement sources and sulphate from sea water or evaporites. Physical and chemical analysis of representative samples of barite from the five localities shows that the barite meets the American Petroleum Institute (API) requirements. It has an average specific gravity of about 4.26. Currently, some of the veins are being mined by Pick and showel methods and the product hand-sorted.

KEYWORDS: Akpet, Barite, mineralization genesis

INTRODUCTION

In this Industrial age, it has become clear the extent to which the human race has become dependent on mineral resources. The demand for minerals in the country has made resources formally thought sufficient, now grossly inadequate. The need to critically examine areas formally considered barren of mineral resources has become imperative. Speculations on the occurrence of substantial deposits of barite in the Akpet area led to the study of barite exposures in the crystalline basement of Akpet and environs. The desire to document evidences of this barite occurrence has encouraged the authors to conduct further investigations on the barite in the area. Barite exploration in the area is still in its infancy and left in the hands of private miners who operates on "trial and Error" basis largely because mineralization tends to be on the surface. Another reason for the adoption of this crude method is that the miners are determined to operate at minimum cost according to Akpeke (2000).

Barite has a lots of uses even though petroleum well drilling appear to be a driving force in the demand for this industrial mineral that is used as a weighting agent in drill muds of oil wells. Sheikhs (1986) observed that oil industries consume about 96% of barite produced the world over, leaving a balance of about 4% for other industries.

DESCRIPTION OF STUDY AREA AND GEOLOGICAL SETTING

The area of investigations lies between Longitude 8° 00' E and 8° 15' E and Latitude 5° 30' N and 5° 45' N, and is situated within Akpet area (Fig. 1). This area includes Akpet-1, Akpet-Central and Okurike in Biase local Government area, and Agoi Ibami and Itu Agoi in Yakurr local Government Area, both in Cross River State. It also forms the northwester-most portion of Oban massif. The area lies within the equatorial rain forest zone, and relative inaccessibility is due to dense forestation. The dense and luxuriant forestation is also primarily responsible for the paucity of geological investigations in this part of the country.

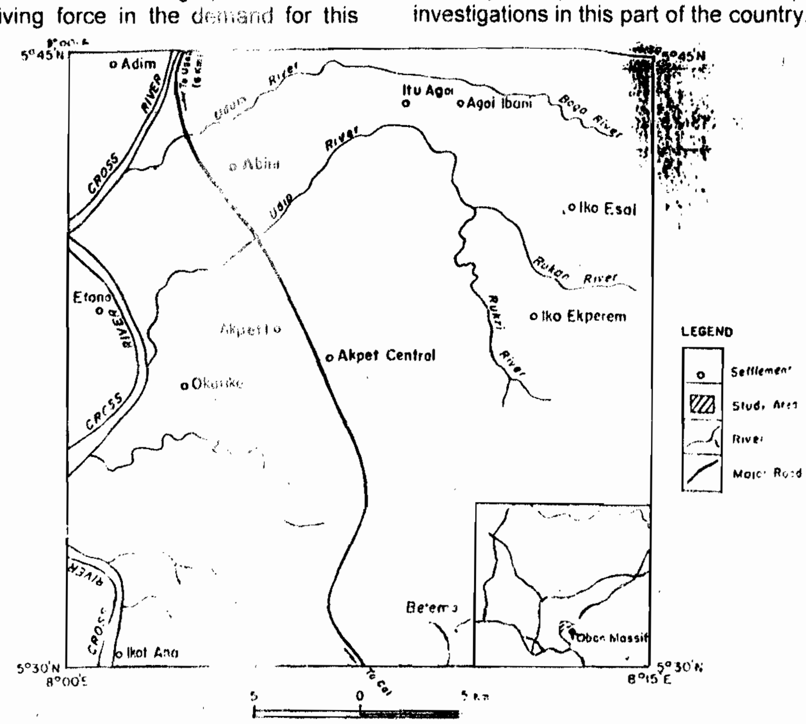

Fig. 1 LOCATION AND DRAINAGE MAP OF AKPET AREA OBAN MASSIF SOUTHEASTERN NIGERIA

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The geological features and characteristics of Akpet and adjoining areas are now well known; see for example, Hossain (1981), Ekwueme (1987, 1990, 2003) and Akpeke (2000). In summary, Akpet area, situated in the north of Uwet area, constitutes the northwestermost portion of Oban Massif. It is generally made up of both Precambrian crystalline basement rocks and Cretaceous Sedimentary deposits (Fig. 2). According to Ekwueme (1990), Precambrian crystalline rocks occurring in the area are comparable to those of Uwet area in the south, and include:

1. Phyllites, schists and associated quartzites which constitute low to medium grade metamorphic rocks of the area. These assemblages are often intruded by pegmatites containing rods of tourmaline, as well as granodiorite in the southern region

2. Coarse-grained gneiss that contain abundant equidimentional rhomps of potassium feldspars (and sometimes plagioclase), which gives the rock a characteristics augen gneiss appearance

The sedimentary rocks occur predominantly in the northern region of the area, with the bulk of the deposit in the northwestern section (Fig. 2). They include sandstone, limestone, calcareous sandstone and shale. Minor intrusive igneous rocks, which are essentially dolerite, occur within the sandstone close to the extreme northwestern margin of the area of investigation. Ekwueme (1987) investigated carbonate rocks of the area and recognized 3 carbonate lithofacies associated with the calcareous sandstone. These lithofacies include basal limestone, fossiliferous limestone and dolomitic limestone, which belong to the Albian Asu River Group, while the calcareous sandstones are believed to be of Turunian Exe-Aku Formation.

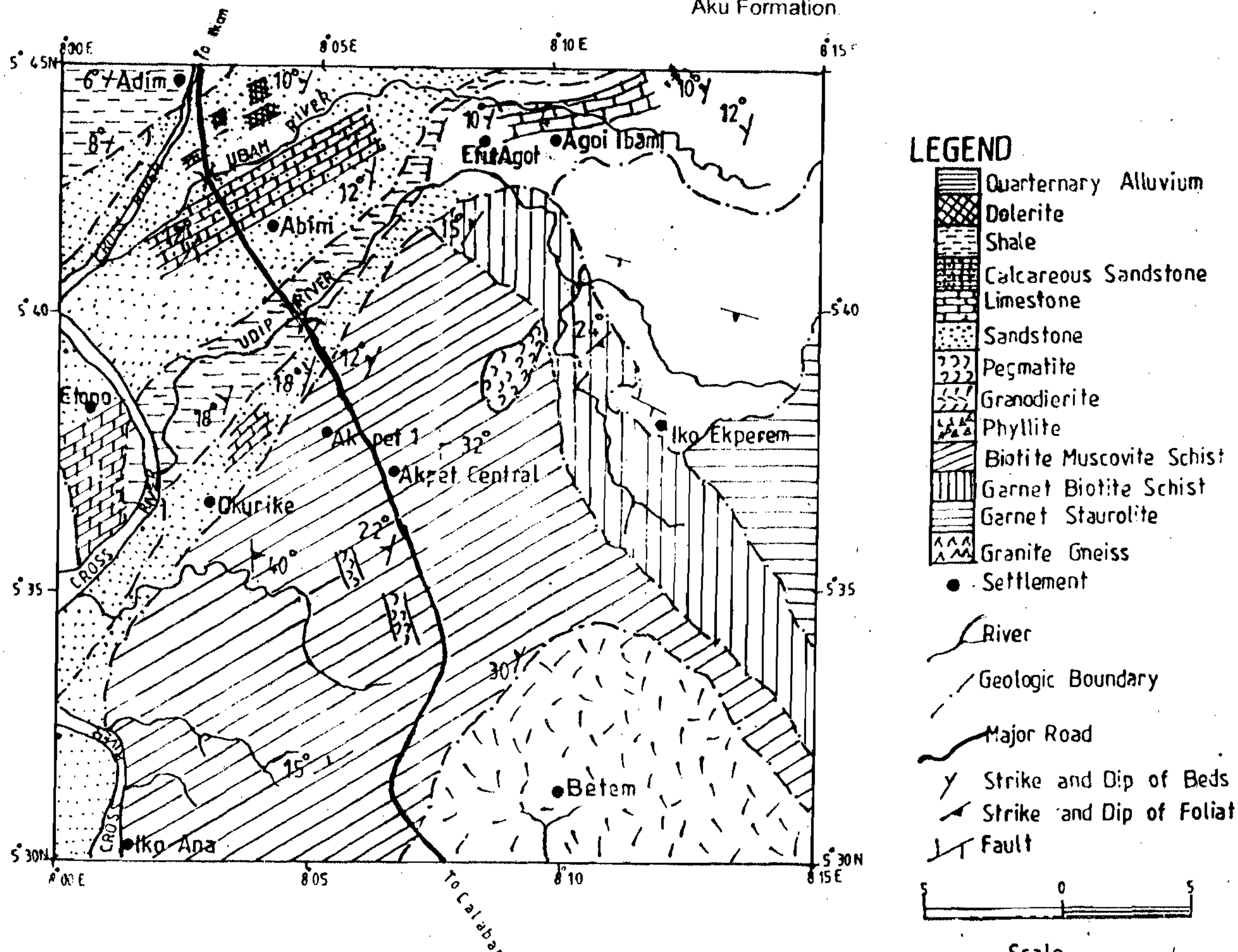

Fig 2. Geological map of Akpet Area, Southeastern Nigeria (After Ekwueme, 1990).

BARITE MINERALZATION

The Akpet barite outcrop in veins and veinlets in a widespread area. The mineralized area is a belt that spans from Agoi Ibami in the extreme northeastern section of the area in a NW-SE direction for a distance of about 30km and probably more along the length of the belt (Fig. 3). Although the actual width of the belt is not known, the thickness of the various veins varies between 0.5 – 2.5m with an average value that can be reasonably put at 1.54m. In most localities visited, the veins were observed to have an average depth of 10m. With these figures, an estimated barite reserve of 1.97×10^6 metric tonnes has been computed for the deposit.

The barite primarily occurs in veins and veinlets, with additional subordinate mineralization occurring within the altered host rocks (Table 1). Some area host unconformity-related vein-type mineralization between the basement rocks and overlying younger sediments. The barite veins are emplaced within the mineralized belts in a variety of host rocks (Fig. 3), including:

1. Low-medium grade phyllites, schists and associated quartzites of Akpet –1 and Akpet Central areas
2. Limestones and sandstone of Agoi Ibami, Itu Agoi and Okurike areas

The vein-lets, on the other hand, occur within gneissose rocks in areas such as Iko Esai and Iko Ekperem, which clearly fall outside the mineralized belt. The veins and veinlets generally have variable angle of dip with different direction of orientation. NE-SW, E-W, N-S, NW-SE, etc directions have been observed, but NE-SW direction, which is consistent with the general regional trend of the host rocks, appear to be the dominant direction of orientation.

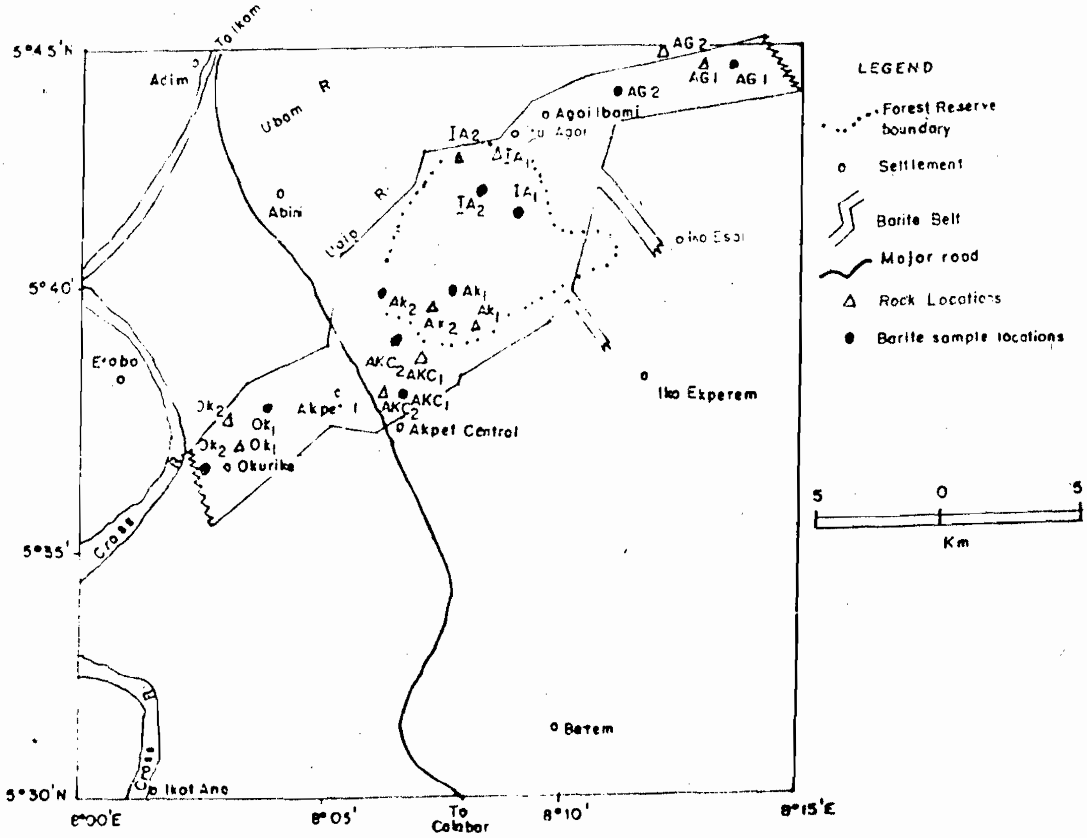

Fig. 3: Map of Barite mineralization zone in Akpet area

TABLE 1

Modal composition and mineralogical assemblages of the Host rocks of barite from Akpet Area, South-eastern Nigeria.

MINERAL	PHY	SST	QMS
Quartz	30	62	22
Plagioclase	4	3	6
Biotite	12	15	20
Muscovite	32	-	-
Chlorite	14	-	-
Zircon	-	9	-
Epidote	-	7	-
Tourmaline	Tr	-	4
Barite	8	4	48
Mineralogical Assemblages	Qtz-chl-Bio-Mus-Bar	Qtz-Alb-Bio Epi-Bar	Qtz-Alb-Bio-Bar

PHY: Phyllite from Akpet 1
SST: Sandstone from Okurike
QMS: Quartz-mica-schist from Itu Agoi
Tr: Trace

PETROGRAPHY

The barite mineral is typically colourless to whitish and grayish, granular to finely crystalline, and easily identified by its relative softness, high density for a non-metallic mineral and by sulphurous odour when hit by a hammer or scratched by a knife blade. In thin sections, the barite is brittle with one perfect cleavage and another less perfect cleavage that intersects at an angle of about 78°. Other characteristics of the mineral include low birefringence first –order interference colours and an extinction angle of approximately 35° observable under crosses nichols.

The modal composition of barite samples from Akpet area is presented in Table 1, while both modal composition and mineralogical assemblages the host rocks are in Table 2. According to Table 1, the modal proportion of barium in these rocks is not less than 86%. Also present in the barite are gangue minerals such as quartz, biotite, calcite and muscovite (Fig. 4). In Table 2, barite forms about 8% of the mode of the phyllites in Akpet area, 4% of the mode of sandstones from Okurike, and 48% of the mode of quartz – mica – schist from Agoi. None of these rocks contain less than 4% as the modal composition of barite, probable due to wall rock alteration.

Table 2: Composition of Barite samples in Akpet area, Oban massif South Eastern Nigeria

MINERAL	A G B	I A B	A K B
Barite	86	92	90
Quartz	10	2	4
Biotite	4	3	1
Muscovite	-	-	6
Calcite	Tr	3	-

AGB: Barite from Agoi Ibami
IAB: Barite from Itu Agoi
Ak B: Barite from Akpet 1

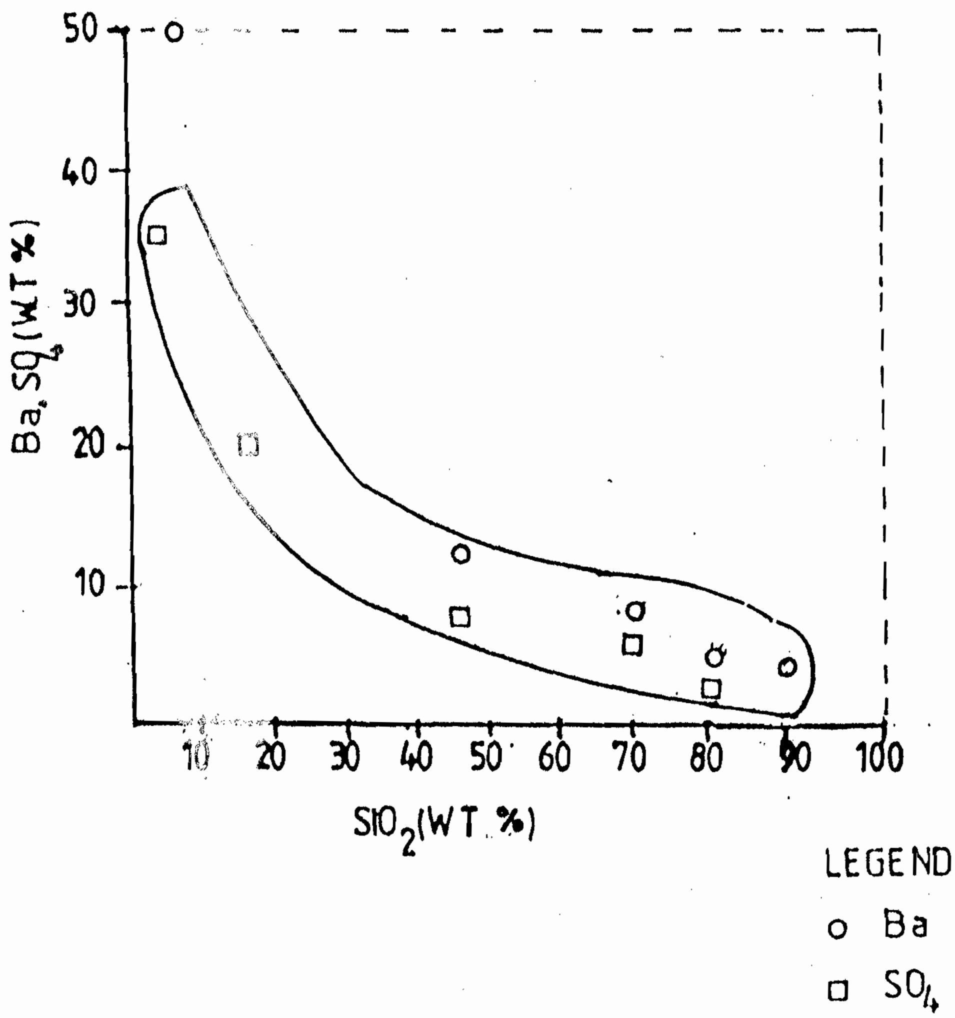

Fig 4 Plot of Ba and SO_4 versus SiO_2 for host rocks in Akpet area.

GEOCHEMISTRY AND QUALITY EVALUATION

A total of ten (10) representative samples of barite and another ten (10) representative samples of the host rocks were selected from all the localities of occurrence of the barite deposit for geochemical analysis after detailed examination of their polished and thin sections. The barite samples were also subjected to specific gravity determinations. Both the sample preparation and analysis were carried out in the Chemical and Physical laboratories of the Nigerian Mining Corporation, Jos. SiO_2 values were obtained by colorimetric methods and LOI by weight differences. Atomic absorption spectroscopy (AAS) technique was employed for the determination of the concentrations of other elements. Details on the analytical techniques are in Akpeke (2000).

Results of the major elements geochemical analysis of the host rocks and barite samples are respectively presented in Table 3 and Table 4, while results of the specific gravity determinations of the barite samples are Table 5. Detailed geochemistry is clearly not intended as parts of the present research, however striking geochemical features from the presented geochemical analysis Tables are briefly highlighted below.

Table 3 show that barium and sulphate concentrations of all the rocks are commonly high for rocks of such nature. Those of sandstones of Itu Agoi have the highest concentrations of more than 48% barium, while sandstones from Okurike Village host the least concentration of barium (about 4.15%). Also noteworthy is the fact that SiO_2 concentration is clearly directly related to the concentration of Ba and SO_4, and appear to have an inverse relationship with concentrations of Al_2O_3. Scatter plots of both Ba and SO_4 against SiO_2 (Fig. 4) reveal an inverse relationship between SiO_2 and each of Ba and SO_4. All these observations possibly highlight the relevance of significant wall rock alteration in the evolutionary history of the barite deposits.

Table 3

Major Elements Composition of Barite Host Rocks in Akpet Area, Oban Massif, Southeastern Nigeria

Wt%	AG1	AG2	IA1	IA2	AK1	AK2	AKCQ	AKC2	OK1	OK2
SiO_2	46.20	46.40	3.42	3.44	85.60	85.80	69.59	70.01	8.90	87.89
Al_2O_3	26.58	26.52	3.64	3.44	1.02	1.03	6.62	5.98	2.30	2.10
Fe_2O_3	1.56	1.60	3.30	3.26	0.54	0.60	3.23	3.21	0.16	0.24
TiO_2	0.33	0.35	0.15	0.16	0.43	0.42	0.46	0.45	0.1.2	0.14
Na_2O	0.08	0.08	0.07	0.08	0.10	0.08	0.1	0.09	0.10	0.09
K_2O	0.41	0.43	0.28	0.26	0.86	0.84	0.71	0.69	0.83	0.85
CaO	0.04	0.05	0.04	0.05	0.04	0.04	0.04	0.05	0.05	0.04
MgO	0.11	0.14	0.10	0.11	0.16	0.14	0.19	0.17	0.07	0.09
Ba	12.20	11.80	52.44	48.02	5.12	5.02	9.44	9.00	4.15	4.15
SO_4	8.43	8.45	32.51	35.61	3.52	3.56	6.52	6.46	3.10	2.90
LOI	3.54	3.56	2.62	2.58	2.30	2.40	3.31	2.90	1.20	1.21

AG: Schist from Agoi Ibami
IA: Quart-Mica-schist from Itu Agoi
AK: Phyllite from Akpet I
AKC: Gneiss from Akpet Central
OK: Sandstone from Okurike
LOI: Loss On Ignition.

Table 4

CHEMICAL COMPOSITION OF BARITE SAMPLES IN AKPET AREA, OBAN MASSIF, SOUTH EASTERN NIGERIA

Wt%	AGB1	AGB2	IAB1	IAB2	AKB1	AKB2	AKCB1	AKCB2	OKB1	OKB2	AZ1	AZ2
SiO_2	6.58	6.62	2.19	2.21	5.55	5.54	3.61	3.62	73.70	72.89	5.70	3.29
Al_2O_3	0.91	0.94	0.96	0.87	0.34	0.33	0.44	0.46	3.33	3.30	9.06	0.62
Fe_2O_3	0.09	0.07	0.15	0.13	0.04	0.05	0.14	0.13	1.07	1.09	9.14	6.67
TiO_2	0.004	0.004	0.004	0.005	0.003	0.004	0.40	0.44	0.09	0.08	0.05	
Na_2O	0.06	0.05	0.06	0.05	0.05	0.06	0.07	0.05	0.09	0.08	0.013	4.70
K_2O	0.02	0.03	0.04	0.03	0.002	0.001	0.004	0.004	0.79	0.08	0.018	1.18
CaO	0.05	0.05	0.07	0.06	0.09	0.09	0.08	0.07	0.05	0.05	1.40	0.25
MgO	0.08	0.07	0.08	0.08	0.07	0.08	0.06	0.05	0.09	0.10	1.10	1.24
Ba	53.64	53.62	56.10	56.00	54.80	54.78	55.62	55.71	10.80	10.75	47.01	46.60
SO_4	37.50	37.50	39.20	39.16	38.52	38.50	39.00	38.71	7.54	7.50	31.28	16.90
LOI	0.84	0.86	0.85	0.85	0.30	0.32	0.16	0.15	2.13	2.15	0.50	0.06

AGB: Barite vein in Agoi Ibami
IAB: Barite vein in Itu Agoi
AKB: Barite vein in Akpet I
AKCB: Barite vein in Akpet Central
OKB: Barite vein in Okurike
AZ_1: Barite vein in Azara (After Ajile, 1989)
AZ_2: Barite vein in Azara (After Bassey, 1988

TABLE 5
Specific gravities of barite samples from Akpet area Oban Massif Southeastern Nigeria.

	AGB1	AGB2	IA B1	IA B2	AKB1	AKB2	AKCB1	AKCB2	OKB1	OKB2	AVE
Specific Gravity	4.39	4.41	4.47	4.46	4.37	4.39	4.34	4.32	3.71	3.69	4.26

AGB: Barite from Agoi Ibami
IAB: Barite from Itu Agoi
AKB: Barite from Akpet 1
AKCB: Barite from Okurike
AVE: Average

The alkali index ($Na_2O + K_2O$) of all the host rocks analyzed is less than 1, and ranges from 0.32 to 0.94 wt % (Table 3), indicating that the rocks are alkali poor. The contents vary widely from 1.02% in Akpet samples to 26.58% in Agoi Ibami samples. TiO_2 in the rocks varies moderately from 0.12% - 0.46%, while MgO contents vary from 0.07 – 0.19%. A plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 as used by Garrels and Mackenzie (1971) to distinguish between rocks of sedimentary/metasedimentary and igneous character show that all the samples investigated exhibits metasedimentary character (Fig. 5). This underlines their sedimentary character, indicating that the compositional variation of the rocks is most likely inherited from sedimentary sources.

The chemical composition of the barite samples is of prime importance as the knowledge of the level of concentration of associated chemical specie helps in the elimination of unwanted species. The investigated barite samples are essentially made up of Ba, SO_4, minor SiO_2, and other chemical components that exist in trace concentrations (Table 4). Samples from Okurike are of very low quality. Their Ba and SO_4 concentrations are about 10.75 – 10.80% and &.50 –7.54% respectively, while the SiO_2 and Al_2O_3 components of these minerals constitute more than 70 % and 3% of the total chemical compositions.

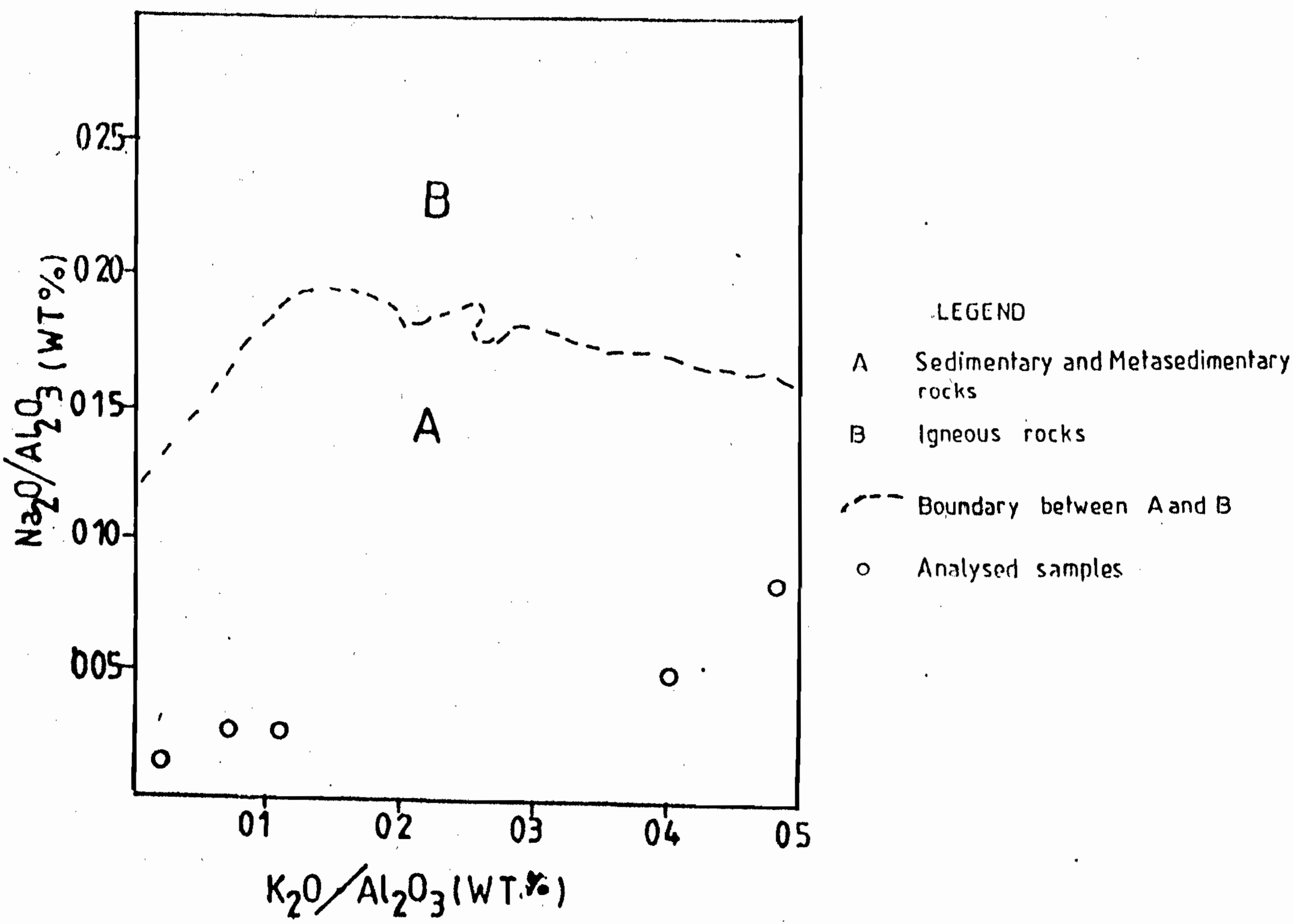

Fig 5 Plot of Host Rock Samples in Akpet Area on the Na_2O/Al_2O_3 Versus K_2O/Al_2O_3 Diagram (Dotted line after Garrels and Mackenzie, 1971)

When compared with barite samples from Azara area (Ajile, 1989; Bassey, 1988), it is clear that the Akpet barite is of a higher and better quality (Table 4). Excluding the Okurike samples, the barium and sulphate contents of Akpet barites respectively varies from 53.62 – 56.10% and 37.50 – 39.2%, compared to 46.60 – 47.01 and 16.90 – 31.28% values of the Azara barite. In addition, associated gangue minerals in the Akpet barite are negligible compared to the relatively higher levels of gangue minerals in the Azara barites as obvious from the chemical data presented in Table 5.

One of the qualities that make barite desirable, especially as weighting agent in drill mud of the oil and gas industries is their specific gravity values. Barite with specific gravity values of 4.5 and above is considered pure, and barite with specific gravity values from 4.2 satisfies the requirements of most oil industries (Sheikh, 1986). Apart from the deposits of Okurike area which has relatively lower specific gravity values, the Akpet barite is generally considered to be of the purest grade with specific gravity values ranging from 4.32 to 4.47 and an average specific gravity of 4.39.

ORIGIN AND TIMING OF BARITE MINERALIZATION

A thorough understanding of the basic geologic setting is pertinent to unravel the evolution and genesis of barite deposit in Akpet area. It is difficult to discuss a unified geologic setting for the mineral deposit in the area because mineralization appears to be controlled by diversified geologic conditions. The controlling factors are mostly structures, rock types, sedimentary processes and igneous activities.

Many hypotheses have been proposed to account for the origin of the southern Nigerian sedimentary basins, including the sediments in Akpet area. Kennedy (1965) suggested a rift valley origin. Stoneley (1966) added that the basin formation was in response to slight adjustment in the shape of Africa during its separation from South America. Benkhelil (1982) attributes the evolution of these basins to the extension of the equatorial oceanic fracture zones in the continent through the transcurrent movements along deep – seated basement faults. More recently, a model involving the juxtaposition of pull-apart basins along sinistral wrench faults have been proposed for the Benue Trough.

The opening of the South Atlantic Ocean in early Cretaceous times is thought to have initiated tectonism in the region of Southern Nigeria (Wright, 1968; Burke et al., 1972; Murat, 1972; Nwachukwu, 1972; Benkhelil, 1982). The origin of the southern sedimentary basins are intimately associated with the development of the Benue rift system, both being related to the opening of the of the south Atlantic ocean and the existence of the RRR triple junction, which was active in the early Cretaceous times under the Niger Delta miogeosyncline (Burke and Whiteman, 1970).

The age of 140 ± 0.1 Ma obtained for Obudu dolerites (Ekwueme, 1994) dates magmatic activities related to the early stages of rifting along the Benue Trough. Ekwueme (1994) suggests there may be a link between the formations of Obudu dolerite and rifting in the Benue Trough, and that if this assertion is correct, then rifting along the Benue Trough could have started in the Paleozoic. The sedimentary rocks within Akpet area are an extension of the Cretaceous sedimentary rocks within Benue Trough (Ekwueme et al., 1995).

An interesting observation in the Akpet area is the occurrence of barite deposit at the boundary between the Precambrian basement complex and the overlying Cretaceous sediments in places such as Okurike and Agoi Ibami. These places are probably faults of the Benue Trough hosting uncomformity vein-type barite mineralization between the basement rocks and Cretaceous sediments. Where barite deposit occur in sedimentary rocks as in Okurike, Agoi Ibami and Itu Agoi areas, the deposition may be tectonically controlled. Hence one could propose an ore genetic model that emphasizes the role of tectonic evolution of the Benue Trough. However, the nature and timing of magmatic activities in the Benue Trough remains unclear. Olade (1976) envisaged ore solution of the lead-zinc deposit in Nigeria as connate brines set into action by geothermal heat from mantle plume activities during Cretaceous rifting. It is the belief of these authors that such solution leached the metals from sediments and evaporates which combined with sulphur to form ore along permeable zones.

An important factor regarding the origin of barite in Akpet area is the source of barium. Introduction of barium by hydrothermal fluids has been suggested for many large deposits such as the ores in Nevada and Arkansas (Clarke and Mosier, 1989), and Farrington (1952) favoured a similar magmatic – hydrothermal origin for ore fluid accumulations in the Benue Trough. Derivation of barium from volcanic and intrusive rocks is possible in Akpet area because of the proximity of the Cameroun volcanic line to the barite zone in the area. However, the occurrence of barite veins in other areas such as in Azara (Ajile, 1989; Bassey, 1988), which lacks close spatial association with igneous intrusions argue against volcanic rocks being the sole contributor of barium in the area. Of considerable importance to this discussion is the observation that the analysis of barite host rocks in Akpet area show depletion of barite relative to the host rocks from inside the barite veins (Table 3). This depletion trend suggest that barium in the Akpet deposits may be related to those of the host rock, particularly the basement rocks where barium could be source from the feldspars just like Pb^{++} or Sr^{++}. The occurrence of barite mineralization in both the sediments and basement rocks in Akpet area also show a genetic linkage in relation to source of the metal for fluids that drain the basement. These suggestions agree with current opinion based on isotopic and fluid inclusion data (Akande et al., 1989). Akande et al. (1989), on the basis of observed strontium data, lead isotope composition of galena and REE patterns in fluorite, suggested that the Lower Paleozoic basement rocks in the Benue Trough or their weathered equivalents are likely sources for the Benue Trough ore components. That sulphur was probably contributed from the Cretaceous evaporates in the Trough as indicated by sulphur isotope studies. These authors further add that the sudden dewatering accompanying overpressure in the sedimentary basins (Bethke, 1985) was probably the mechanism for the expulsion of metal – bearing fluids through permeable fractures in the Cretaceous sediments. The gentle dip of the basement rocks are believed to have generated slow migration of the fluids, a condition necessary to prevent quick flushing and to allow adequate time for leaching of barium from the basement rocks for the barite deposits.

The origin of the sedimentary host rocks with obvious wall rock alteration effects is intimately associated with the development of the Benue rift system. Almost all the barite in Akpet area are located in the Cretaceous sedimentary rocks. The NE-SW trend of the barite veins show that they are hosted by boundary faults of the Benue Trough. The observation of barite deposit hosted mostly by Cretaceous sedimentary rocks, and the NE – SW trend of the barite veins suggest that mineralzation was possibly in the Cretaceous. It is also clear that Akpet barite deposits are probably lateral equivalents of the Azara, Dumgel and Ibi, all located further north within the Cretaceous sedimentary rocks in the Benue Trough.

CONCLUSIONS

Barite mineralzation with an estimated reserved of about 1.97 X 10^6 metric tones, occurring in Akpet area in southeastern Nigeria is hereby reported for the first time. The mineralization consists of various veins of different dimension, trending predominantly NE – SW. The occurrence of barite in Cretaceous sandstones with wall rock alteration effects suggest that the origin of the barite deposit is intimately related to the Benue rift system.

The precipitation of barium, derived from basement sources, to form barite deposits along permeable zones is suggested as the most probable genetic model for the Akpet barite deposits. The mineralization is thought to be Cretaceous and the metal- bearing fluids must have extracted B'' from basement sources and SO_4 from seawater or evaporate consistent with the findings of Akande et al. (1989).

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