GLOBAL JOURNAL OF GEOLOGICAL SCIENCES VOL 10, NO. 1, 2012: 85-98
COPYRIGHT© BACHUDO SCIENCE CO. LTD PRINTED IN NIGERIA. ISSN 1596-6798
www.globaljournalseries.com; Email: info@globaljournalseries.com

OCCURRENCE AND DISTRIBUTION OF BARITE MINERALIZATION IN CROSS RIVER STATE, SOUTH-EASTERN NIGERIA

BARTH N. EKWUEME AND GABRIEL B. AKPEKE

(Received 11 November 2011; Revision Accepted 20, January 2012)

ABSTRACT

Cross River State is composed of sedimentary rocks which constitute the Calabar Flank and metamorphic and intrusive rocks which crop out in the Oban massif and Obudu Plateau. This study establishes that barite mineralization occurs in the Cretaceous sedimentary rocks of the Calabar Flank as well as in the Precambrian basement rocks. In the Calabar Flank which is in the lower Benue Trough, the outcrops are widespread but mineralization is generally concealed. Barite occurrence has been studied in twenty two localities and the host rocks include sandstones, shales, dolerites, granite and gneiss. Shales and sandstones have the greatest occurrence of barite. The mineral occurs as veins trending NE-SW, N-S and NW-SE. They occur in a fracture system cross-cutting the lower Benue Trough axis suggesting a possible genetic relationship with the Azara barite mineralization of Benue Trough which is believed to be of hydrothermal origin.

KEYWORDS: Cross River State, Benue Trough, Barite, Host Rock,

INTRODUCTION

It is an indisputable fact that technology and development today are knowledge and information driven and not based on raw materials alone, as was the case in the past millennium. This is because you may have abundant raw solid mineral resources unexploited forever if the world is not made aware of such occurrence.

Many potential investors have always hinted that information and data on mineral potentials of Cross River State of Nigeria are not available (Cross River State Department of Mineral Development and Exploitation 2005). There have been speculations of barite occurrences across the length and breadth of Cross River State but very little has been documented on these reserves. Barite has a specific gravity of 4.5 in pure state but inclusion of other minerals may reduce (or in case of metallic inclusion, increase) the specific gravity.

Nigeria is a leading oil producing and exporting country. Barite of high density, chemical inertness and widespread occurrences is required as a weighting agent in drilling fluids and Nigeria spends a huge amount of revenue importing barite. The oil industry consumes about 96% of the world barite production whilst the remaining industries consume the balance of 4% (Maiha, 1996). The occurrence in Azara and other parts of the Benue Trough has not met the demand of oil companies in Nigeria. This study was therefore undertaken to among other things ascertain the extent of barite mineralization and its mode of emplacement in Cross River State of Nigeria.

GEOLOGICAL SETTING

Two giant spurs make up the Precambrian basement of southeastern Nigeria, namely the Oban massif and the Obudu Plateau (Fig 1). These spurs are the western prolongation of Cameroon Mountains into the Cross river plains of Southeastern Nigeria. The basements are overlain by Cretaceous sediments of the Calabar Flank in the south and west but separated by a Cretaceous sediment filled graben or Mamfe rift (Embayment) in the north. Orajaka (1964), Umeji (1988), Ekwueme (1990), Ekwueme and Onyeagocha (1985), Ekwueme (2003), Ukwang (1998), Ukaegbu (2003), Ephraim (2005), and Obioha and Ekwueme (2011) have studied in detail the Precambrian basement rocks in the area. These are composed of phyllites, schists, gneisses, granulites and migmatites intruded by rocks of granitic, mafic and ultramafic composition. They range in age from NeoArchaean to Pan-African (Ekwueme and Kroener 1997, 1998).

A dolerite in Obudu yielded $^{40}Ar/^{39}Ar$ plateau age of 140 ± 0.7Ma (Ekwueme 1994a). The basement has undergone polyphase deformation and polymetamorphism and several generations of folding, faulting, shearing and fracturing have been reported (Ekwueme 1987, 1994b). The dominant trend of the structural features comprising of planar and linear types is N-S to NE-SW (0-30^0). Minor trends in the NW-SE and E-W also occur and have been interpreted as relicts of pre-Pan African deformation episodes (Grant 1978; Onyeagocha and Ekwueme, 1982; Ekwueme 1987, 1994b). Bassey (1998) had suggested that the Oban massif and Obudu plateau could have been continuous prior to the formation of the Mamfe Basin which lies between them (Petters et al. 1987).

Barth N. Ekwueme, Department of Geology, University of Calabar, P. O. Box 3651 Unical P.O Calabar, Nigeria
Gabriel B. Akpeke, Department of Geology, University of Calabar, Calabar, Nigeria

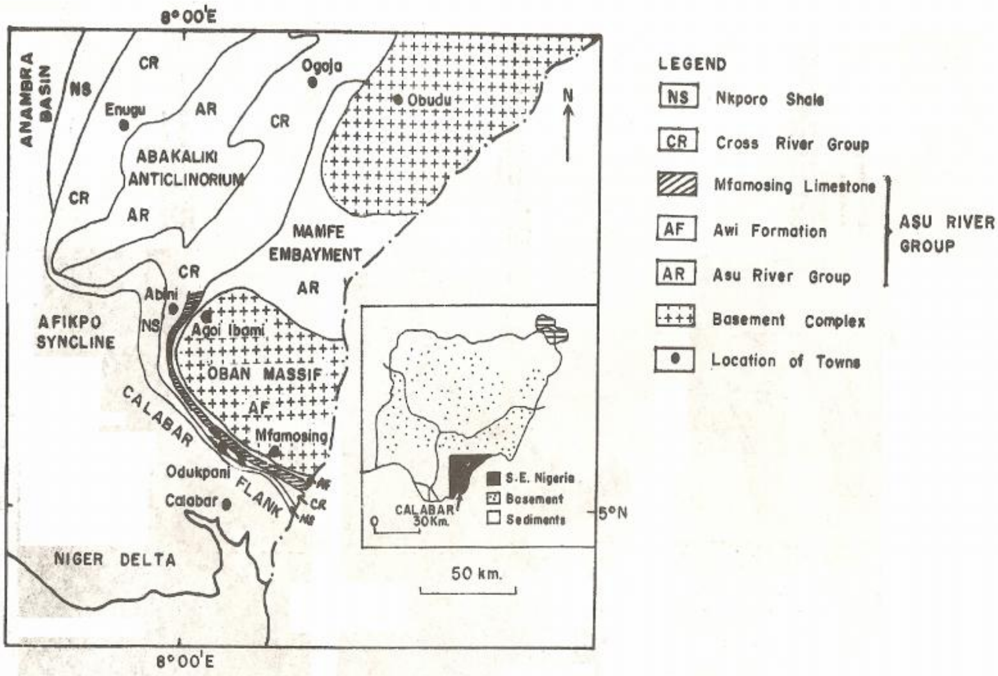

Fig 1: Geologic Sketch Map of South-Eastern Nigeria (Petters 1982).

The Mamfe Embayment (Fig 1) situated between the Oban massif and Obudu Plateau is predominantly a fluviatile clastic sequence that exhibits point bar fining-upward cycles and over bank mudrocks (Ekwueme et al. 1995). This formation has been described as the Asu River Group of Albian age. Associated with the sedimentary rocks of Mamfe rift are basaltic rocks which exhibit excellent columnar joints in the middle of the lava flow. The type locality of the Mamfe Formation is on the bank of Cross River at Mamfe in adjoining Cameroon Republic where 800m of massive arkosic sandstones with marl, sandy limestone and shale intercalations are exposed (Reyment 1965). The sequence in the Nigerian part of the Mamfe Basin comprises conglomeritic immature mudstones (Petters et al. 1987). Okereke and Onwuemesi (1989) have shown evidence of faulting at the edge of the Mamfe Basin.

The Calabar Flank (Fig. 1) comprises of lithologies such as sandstone, limestone, marl and shale. The oldest formation in the Flank is a sandstone shale sequence which is folded and lies unconformably on the Precambrian basement at Awi. This is the Awi Formation of Aptian-Albian age described by Adeleye and Fayose (1978). Overlying these rocks is the Mfamosing Limestone Formation of Petters (1982).The Eze-Aku shale of Reyment (1965) lies on the Mfamosing limestone. It has been described as Ekenkpon shale by Petters et al. (2010). Associated with these shales are bioturbatred marls which are overlain by Nkporo shale of Campanian-Maastritchtian age. The youngest formation in the Calabar Flank is the unconsolidated sand belonging to Benin Formation of Tertiary age.

FIELD OCCURRENCE AND DISTRIBUTION OF BARITE MINERALIZATION

Structural features are most important in the localization of the barite ore and have greatly influenced barite mineralization in the study area. The detailed features which determine the immediate localization of barite in the area are mainly unconformities and major faults.

The major faults of the Calabar Flank and the unconformities along the boundary between the basement and the sediments are favourable sites for the accumulation of the barite deposits in the study area. This is why some deposits are found to occur in lenses and impervious covers. Due to tectonic events that took place in the study area, layers of rocks have been folded into curves that are lower in the middle than at the end known as geosyncline. Obviously in a geosyncline, accumulation of sediments was followed by uplifting, faulting and folding. This is evident from the location of barite vein within the generalized stratigraphic chart at Agoi Ibami (Fig 2) in which the mineralization is concentrated within the sediments at the boundary between the basement and the sediments. These sediments are the carbonaceous shales, limestone, siltstone, and sandstone with the Cross River and Asu River Groups of the Albian sequence in the lower Benue Trough. It is possible that the mineralization episodes were in pulses occurring in basement, in cross-cutting intrusive and in sediments.

For instance, barite deposits found in Agoi Ibami occur in calcareous sandstones and carbonaceous shales with high permeability that helped to localize the mineral in these areas. The calcareous sandstone therefore allowed the mineralizing fluids to form barite deposits in this area. Overlying the basement complex in some parts of the study area are Cretaceous sediments of the Calabar Flank within which the barite mineralization occurs (Fig 3). The sketch of typical barites bearing dolerite dyke that occupies the boundary between sandstone and basement is shown in Fig 4.

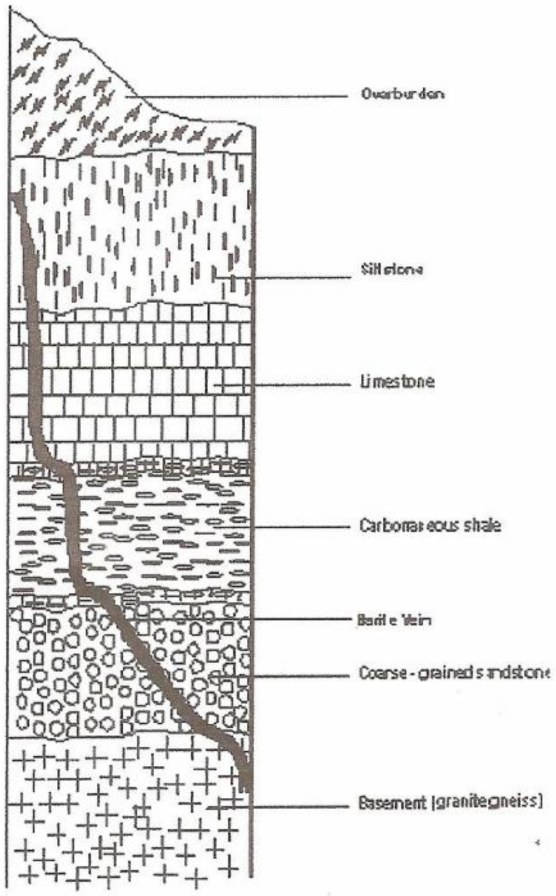

Fig 2: Location of barite vein in a generalized stratigraphic chart at Agoi Ibami (050 43'27" N, 080 12' 22"E)

0 50m Barite Length

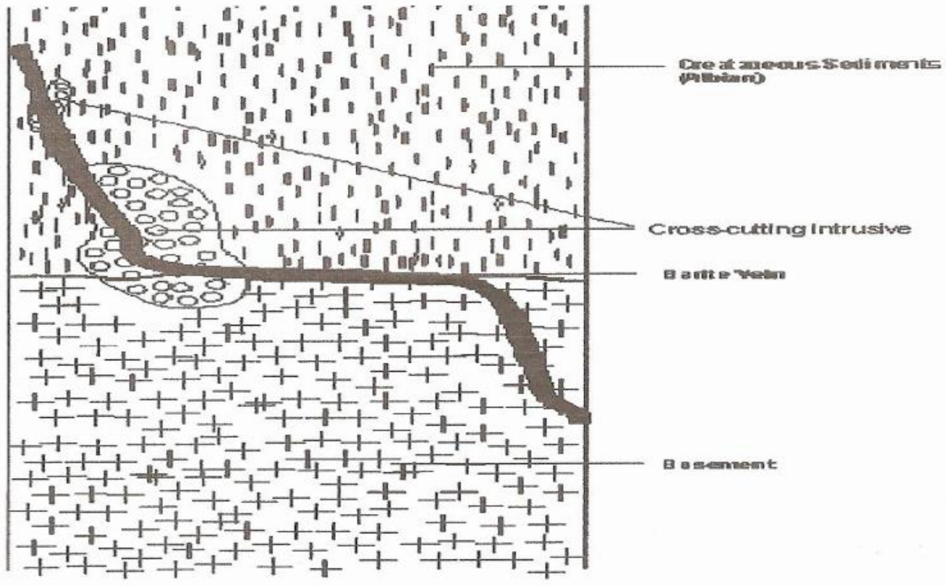

Fig 3: Generalized model of Barite Mineralization in Cross River State

0 50m

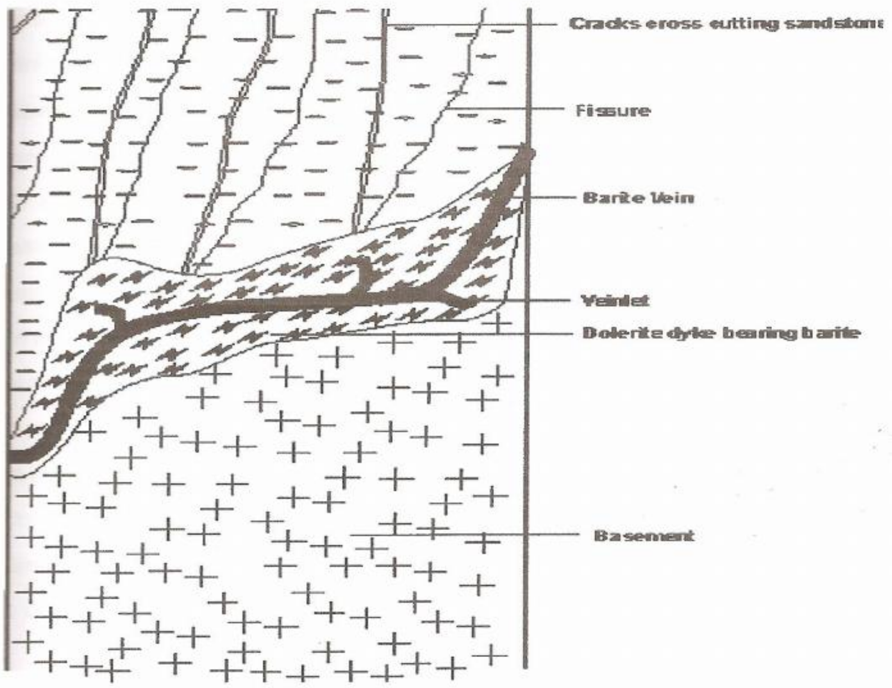

Fig 4: Sketch of barite bearing dolerite dyke occupying the boundary between sandstone and basement at Okurike (05^0 37^1 07"N, 08^0 31" 25"E)

0 50m

Barite deposits in Cross River State therefore occur in a variety of host rocks. These include sandstone, shales, carbonaceous shale, dolerite, granite and gneiss outcrops in which mineralization was observed to be widespread, suggesting the possibility of concealed (blind) mineralization. Barite in the study area was emplaced generally as veins and veinlets with different angles of dips. Most veins are emplaced in quartzite, dolerite, phyllites, sandstones and shale. However, Gabu and Osina deposits show some form of stratiform or bedded emplacement but still mainly as vein infilling in faults. The mineralization at Okokori shows a resistant physiographic relief associated with dolerite dyke. The host rock at this location is granite gneiss. Pegmatite veins cut across the gneiss.

Cretaceous sandstones have been found to host barite mineralization while some deposits are found at the boundary between basement rocks and the Cretaceous (Albian) sediments. Sporadic clusters of barite veins have been mapped in many localities (Fig 5). For instance, at Okurike there is a massive, fine- to medium-grained outcrop of sandstone. Cracks/fissures criss-cross the sandstone. Observations at pitting to about 5m revealed that the barite vein trends East-West in association with dolerite (Fig 4).

Agoi Ibami village is composed mainly of consolidated sandstone. Shale and limestone occur with shale underlying the limestone whilst silt-stone is overlying the limestone. All these rocks are underlain by the basement gneisses and schists. North of Agoi is a barite vein associated with dolerite dyke. The barite is hosted within medium-grained granite. In the area north of Agoi Ibami many veinlets of barite mineralization have different trends compared with the main vein. Some of the trends are $N50^0$, $N90^0$, $N78^0$ and $N61^0$ etc. Some are actually perpendicular to the main vein. Few of the veinlets are as wide as 0.8m in thickness. On pitting, weathered gneisses are exposed. The dolerite dyke here is also weathered. The dyke and barite vein run $N70^0E$ and virtually vertical (Fig 6).

Barite in Agoi Forest Reserve is hosted by aplitic veins emplaced in a highly weathered granite gneiss. The barite occurs in lenses of about 4m thick and 2m wide. The mineralization occurs inside dolerite dyke with crystalline galena (Fig 7).

At Ibogo, weathered granite gneiss occurs. The barite veins in the area are hosted by granite gneiss.

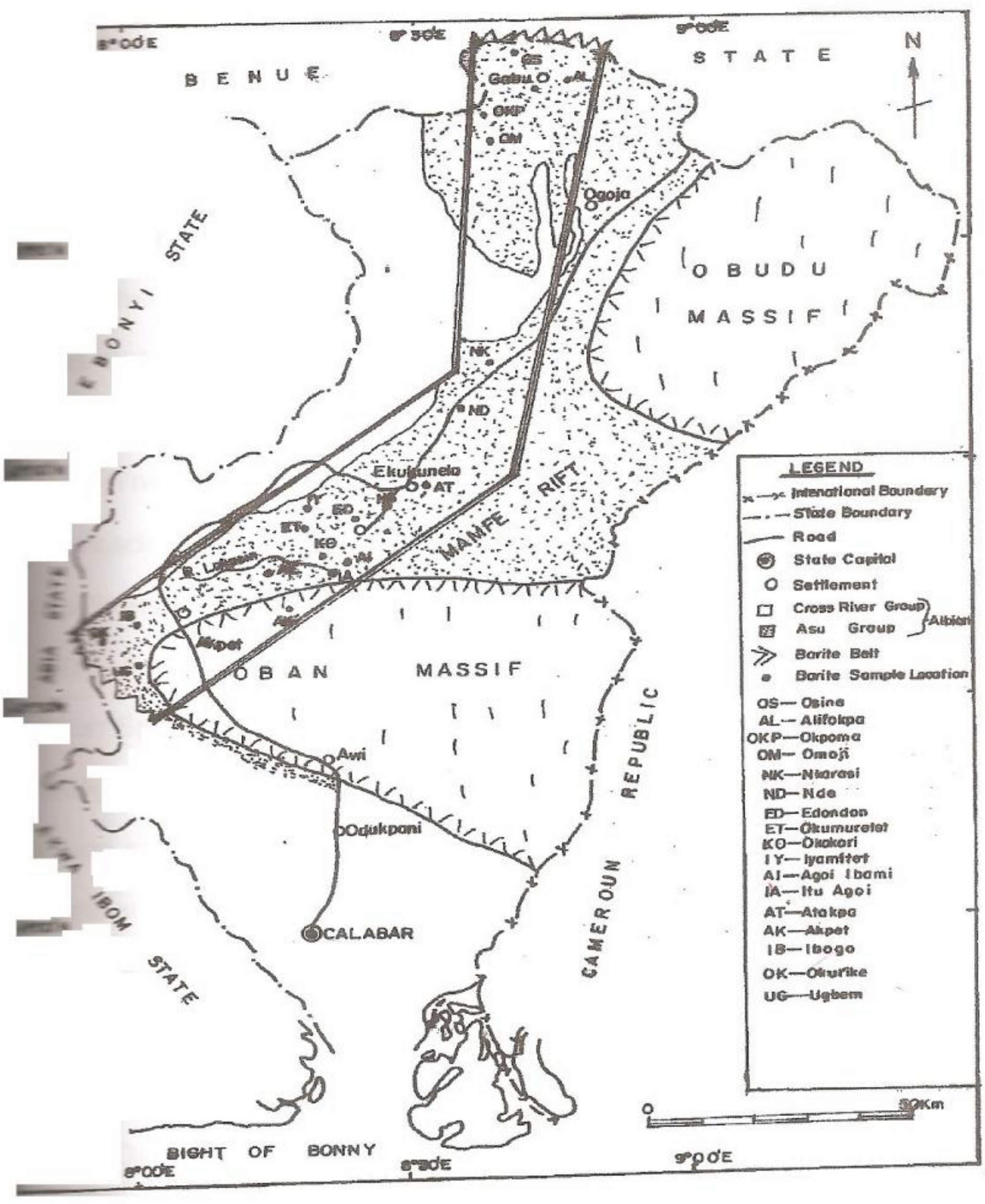

Fig 5: Map of Barite Mineralization Zone in Cross River State (Modified after Ekwueme, 2003)

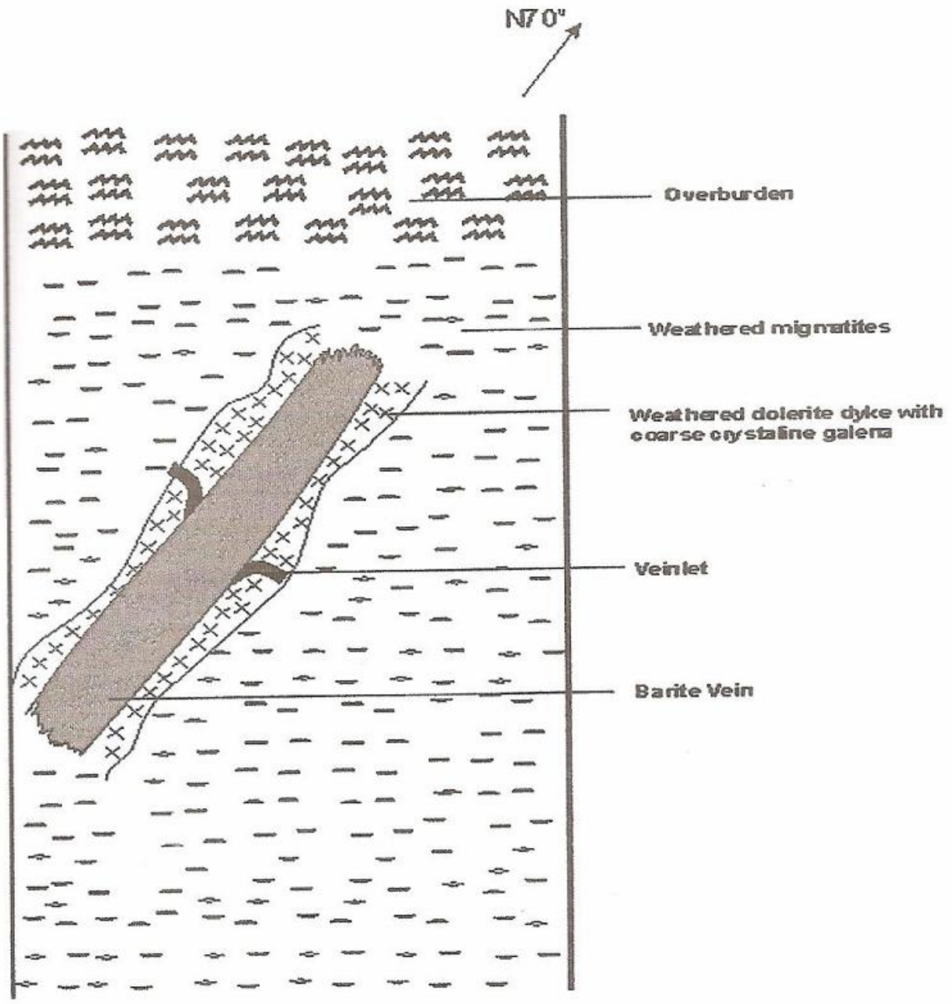

Fig 6: Schematic diagram of barite vein 1 at Agoi Forest Reserve (05^{0} 40' 46" 07" 27"E)

0 2m

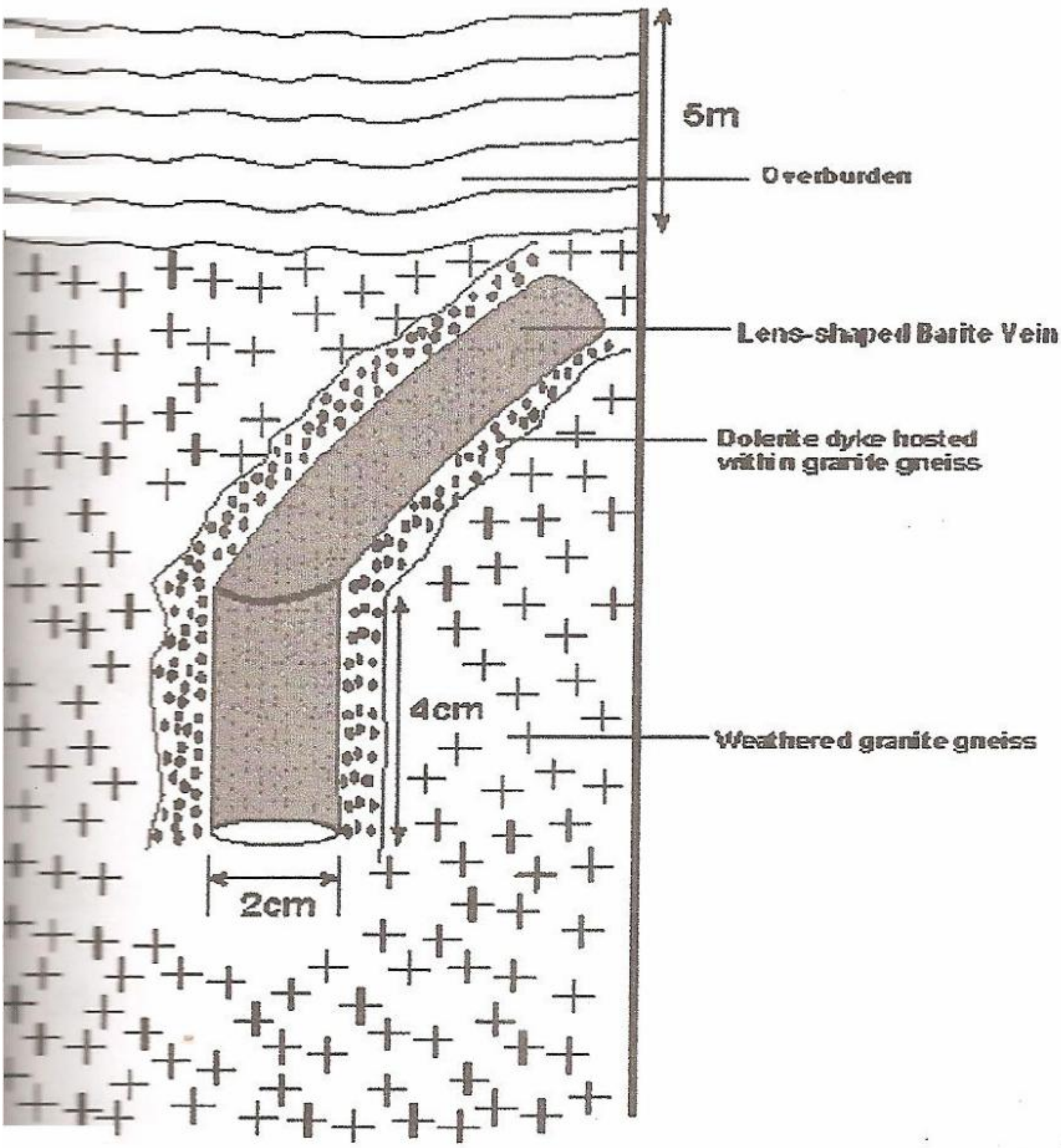

Fig 7: Orientation of barite vein 2 at Agoi Forest Reserve (05^0 40' 59" N 07" 27"E)

0 100m

Okokori, is a sandstone terrain intruded by dolerite. Barite mineralization here occurs within a dolerite.

At Ugbem, a sequence of alternating sandstone and shale beds occur. Here, barite mineralization is associated with fine-grained sandstone.

In the Akpet area, barite is emplaced in a dolerite dyke. Barite forms euhedral crystals on the fractures and joints of the dolerite. Well-developed flakes of muscovite are common in this area.

At Agoi Ekpo village (Fig.5), occurs compacted outcrop of sandstone to the west towards River Lokpoin. It is intruded by dolerite dyke as the traverse from the river to the village shows sandstone and dolerite outcropping. The dolerite dyke that bears barite mineralization is about 3m wide, dipping almost vertically. The dolerite dyke emplaced into granite is medium to coarse-grained in texture. Isolate crystals of galena occur in association with the barite.

At Iyamitet (Fig.5), the barite is associated with dolerite which in turn is hosted within the medium-to-coarse-grained granite. There is sulphide mineralization within the barite resulting in the formation of galena, sphalerite, and chalcopyrite.

Barite in Ekukunela occurs in two major parallel veins emplaced along fracture zone within the sandstone. In a horizon of about 70cm thick, dark-grey shale shows some woody characteristics. The woody characteristics of grey shale suggests the early stage coalification of a peat deposit. The second vein in Ekukunela is associated with dolerite dyke hosted by sandstone. Some dark shales and coal (lignite) occur in the area.

Barite at Atakpa is hosted by fine-grained consolidated sandstone. The barite crystals exhibit pseudomorphism on potassium feldspar. Two barite veins mapped at Nde are hosted by coarse to medium-grained sandstone on the bank of a small stream (Doy) that flows into Cross River.

Barite at Nkarasi (Fig. 5) is associated with granodiorite hosted by arkosic sandstone that is massive, medium to coarse-grained.

Three main barite veins mapped at Osina are associated with weathered dolerite dyke and are all hosted within the country rock of medium to coarse-grained consolidated sandstone. These veins are parallel and are separated by 10m and 5m thick country rock of sandstone. The barite here is of high quality, transparent with distinctive high specific gravity.

On the southwestern outskirt of Osina is Gabu and barite mineralization hosted by dolerite dyke within sandstone occurs here. This barite is also of high quality. Local mining of the deposit is going on in the area.

Single barite vein 1km in length was mapped at Omoji. The mineralization occurs within a weathered dolomite. Small and large boulders of predominantly dark coloured, medium to fine-grained dolomite occur in the area. Deposit of barite in Okpoma is associated with dolerite dyke and is hosted within coarse-grained sandstone; the barite vein is about 1km long.

Occurrence of barite veins in Cross River State as observed in the field are shown in Table 1. The zones of barite mineralization by Local Government Areas, localities, associated host rocks and GPS co-ordinates are tabulated for easy reference (Table 1). Yala LGA has the highest number of thirteen (13) veins, followed by Biase with eleven (11), while ten (10) veins each have been documented for

Table 1: Barite occurrence in Cross River State Southeastern Nigeria

S/N	LOCAL GOVT. AREA	LOCATION/HEIGHT ABOVE SEA LEVEL	GPS CO-ORDINATES	ASSOCIATED HOST ROCK	NO OF BARITE VEINS
1	Yala	Alifopa 156m	06^0 52' 13" N 08^0 48' 30" E	Dolerite/Sandstone	1
		Osina 213m	06^0 45' 47" N 08^0 45' 46" E	Sandstone	5
		Gabu 180m	06^0 52' 13" N 08^0 48' 30" E	Sandstone	3
		Omoji 341m	06^0 39' 47" N 08^0 24' 00" E	Dolerite	2
		Okpoma 153	06^0 36' 31" N 08^0 35' 56" E	Dolerite/Sandstone	2
2	Ikom	Ekukunela 181m	05^0 56' 44" N 08^0 31' 27" E	Sandstone	3
		Atakpa 207m	06^0 00' 09" N 08^0 34' 38" E	Sandstone	2
		Nde 140m	06^0 03' 53" N 08^0 36' 17" E	Sandstone	2
		Nkarasi 234m	06^0 17' 06" N 08^0 39' 14" E	Granodiorite/Sandstone	2
3	Obubra	Edondon 271m	05^0 51' 50" N 08^0 25' 39" E	Dolerite/Sandstone	2
		Okokori 227m	05^0 49' 50" N 08^0 25' 44" E	Granite/Gneiss	2
		Okumuretet 239m	05^0 50' 08" N 08^0 23' 11" E	Dolerite	1
		Iyamitet 216m	05^0 51' 29" N 08^0 20' 13" E	Dolerite/Granite	1
4	Yakur	Agoi Ibami North 228m	05^0 43' 27" N 08^0 12' 23" E	Dolerite/Granite	4
		Agoi Forest Reserve 220m	05^0 40' 59" N 08^0 07' 27" E	Dolerite/Migmatite	3
		Agoi Ekpo 168m	05^0 50' 08" N 08^0 16' 55" E	Dolerite	2
		Itu Agoi 206m	05^0 40' 46" N 08^0 07' 35" E	Clean Sandstone	1
5	Akamkpa	Iko Asai	Not taken	Granite/Gneiss	Trace
		Iko Ekperem	Not taken	Granite/Gneiss	Trace
6	Biase	Ugem 120	05^0 35' 20" N 08^0 01' 35" E	Fine Consolidation sandstone	2
		Akpet 1278m	05^0 30' 10" N 08^0 05' 05" E	Granite/Terrain	3
		Okurike 286m	05^0 37' 07" N 08^0 03' 25" E	Granite/Gneiss	3
		Igogo 278m	05^0 37' 43" N 08^0 08' 31" E	Granite/Gneiss	3
				Total	50

Ikom and Yakurr. Six (6) veins were observed in Obubra and traces of barite in form of veinlets were found in Akamkpa LGA. Detailed mineralization showing local geology and veins distribution in the three barite districts in Cross River State are shown in Figures 8, 9 and 10. Geographically, Cross River State is located in the Lower Benue Trough with barite mineralization belt of over 250km long.

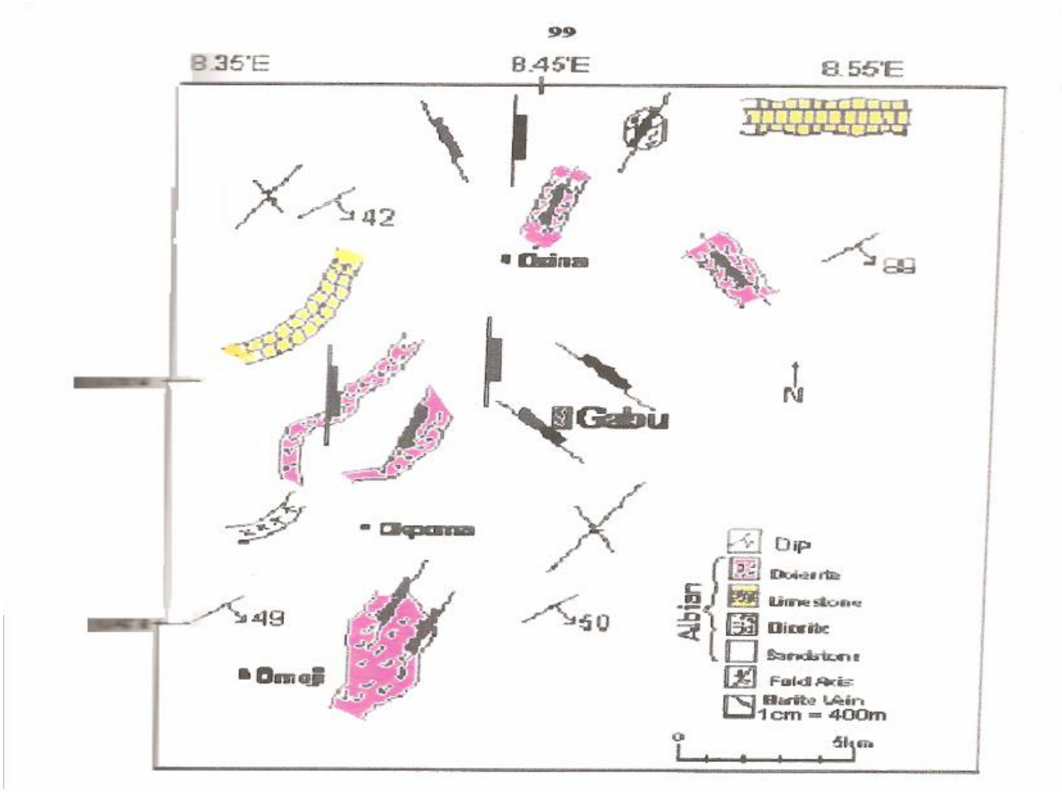

Fig 8: Local Geology and Veins Distribution in Gabu District

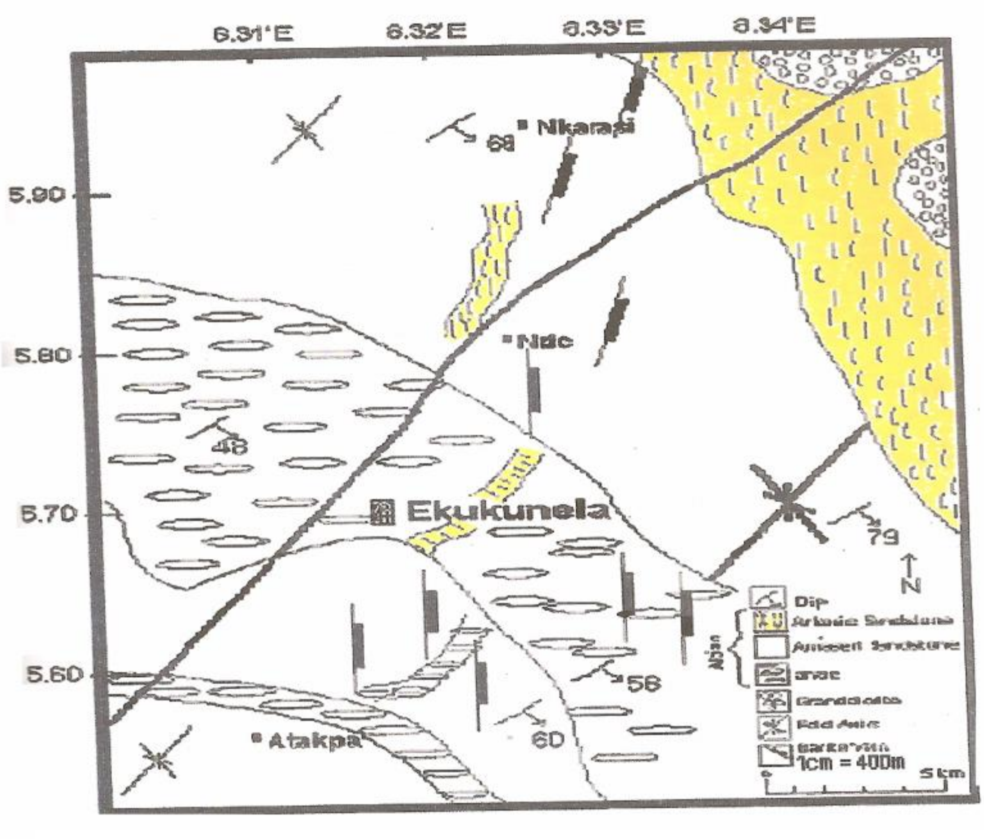

Fig 9: Local Geology and Veins Distribution in Ekukunela District

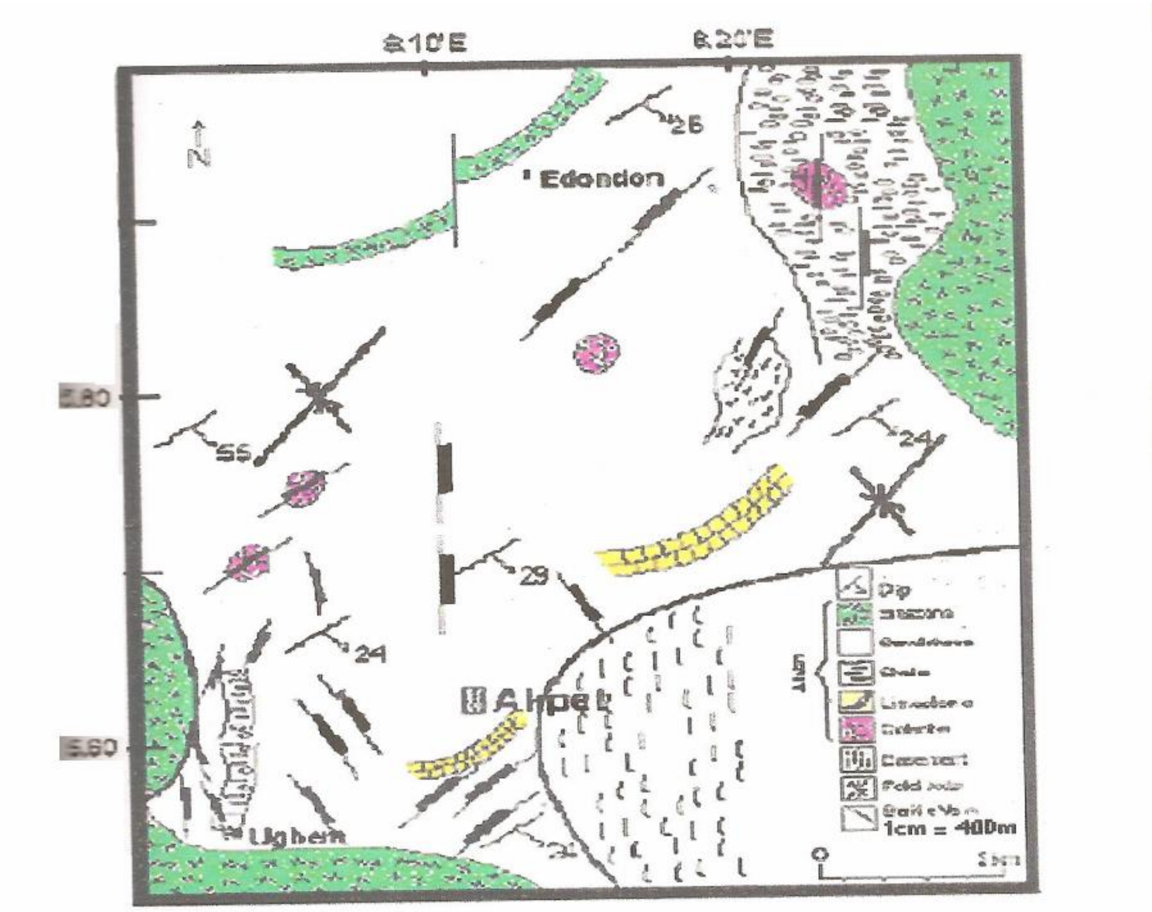

Fig 10: Local Geology and Veins Distribution in Akpet District

DISCUSSION

Barite occurrence and distribution in Cross River are controlled by structures and lithology. Barite occurs dominantly in sandstones, dolerites and shales underlain by the basement rocks which include schists, granite, and gneisses. Barite mineralization is localized mostly along the boundary between the Cretacerus sediments and the basement rocks. In these areas of mineralization faulting and unconformities were observed and the barite occurs as infilling in veins and faults of the study area.

The veins are of varying dimensions as shown in Table 1. The quality of barite is also variable in the area. However, a general trend of NE-SW for barite veins has been established (Fig. 11). The trend does not suggest that the mineralization is contemporaneous with the emplacement of the host rocks. Barite occurrence in Ikom-Mamfe is extensive and often associated with pyrite and chalcopyrite. This suggests widespread sulphide mineralization and hydrothermal fluid emanating from extensive dolerite intrusion could have concentrated the barite mineralization.

The thickness of the main veins varies between 1.2m and 4.2m with estimated average of 2.18m (Table 1). Exposed veins of about 1.2m and 4.2m wide occur at Agoi Ekpo and Osina. Veins up to 1.8m thick and above are often associated with feldspar and quartz impurities

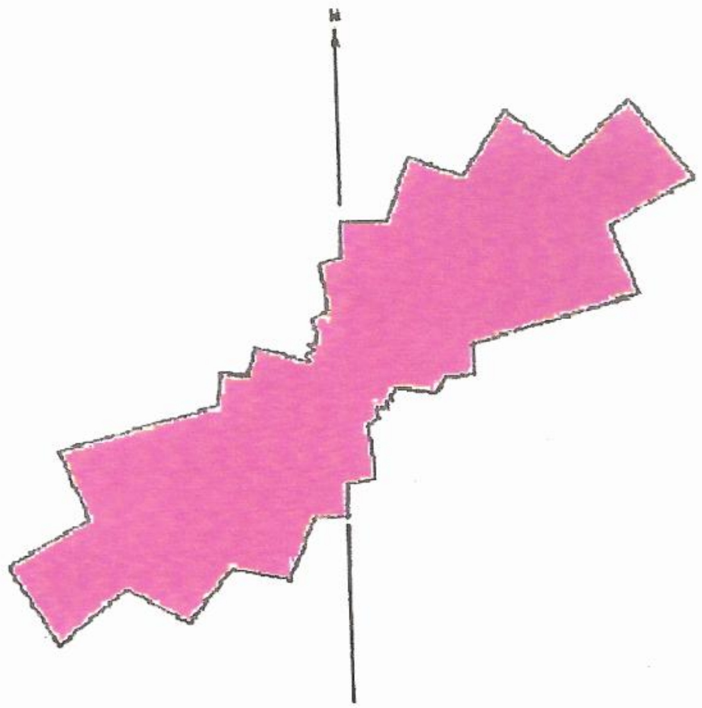

Fig 11: Diagram of Barite Veins Trend in Cross River State

depending on the host rock.

The quality of the barite varies from one vein to the other. The veins with the highest specific gravity barite of 4.45 were found in Osina and Gabu. The barite in these veins are transparent.

In a similar manner the veins at Osina is the longest (1220m) and has the highest barite reserve of 1008 metric tonnes. The shortest vein was mapped at Okurike. It is 69m long and has a barite reserve of eleven metric tonnes.

CONCLUSION

Barite deposits in Cross River State are hosted by variety of rocks including, sandstones, shales and dolerites. The barite deposits occur as veins trending generally NE-SW and extending for about 250km long. The occurrence of most deposits in association with dolerite intrusion suggests that hydrothermal activity played a major role in the formation of barite in the study area. The barite mineralization ranges from high- quality comprising veins with barite deposits having specific gravity of 4.45 and low-quality barite veins of less than 4.45 specific gravity. The reserves are high about 14 million metric tones (Akpeke 2008). It should be exploited for use as weighting agent in drilling fluids for the vast Nigerian oil industry.

ACKNOWLEDGEMENT

This work is a part of a Ph.D research carried out by GBA under the supervision of BNE. The authors are grateful to Professors Sam Akande and Victor Olarewaju for useful comments that improved the thesis. Dr. Saidu Baba made useful comments that improved the manuscript.

REFERENCES

Adeleye, D. R. and Fayose, E. A., 1978. Stratigraphy on the type selection of Awi formation, Odukpani area, Southeastern Nigeria. Nigerian J. Min. Geol. 15:35-37.

Akpeke, G. B., 2008. Investigation of the origin, nature and occurrence of barite mineralization in Cross River State, Southeastern Nigeria. Unpubl. Ph.D. Thesis, Univ. Calabar, Nigeria. 178pp.

Bassey, N. E., 1998. Aeromagnetic interpretation of Obudu and Environ. Unpubli. M. Sc. Thesis, Univ. Calabar, 46.

Ekwueme, B. N., 1987. Structural orientation and Precambrian deformational episodes of Uwet area, Oban massif, SE Nigeria. Precamb. Res; 31:269-289.

Ekwueme, B. N., 1990. Petrology of Southern Obudu Plateau, Bamenda Massif, Southeastern Nigeria. In: G. Rocc; and M. Deschamps (Coordinators) Recent Data in African Sciences, CIFEG Occas. Publi. 22:155-158.

Ekwueme, B. N., 1994a. Basaltic magmatism related to the early stages of rifting along the Benue Trough: the Obudu dolerite of southeastern Nigeria. Geol. J., 29: 269-276.

Ekwueme, B. N., 1994b. Structural features of southern Obudu Plateau, Bamenda massif, southeastern Nigeria. Preliminary Interpretations. J. Min. Geol 30 (1): 45-59.

Ekwueme, B. N., 2003. The Precambrian Geology and Evolution of Southern Nigerian Basement Complex. Univ. Calabar Press, 135.

Ekwueme, B. N. and Kroener, A., 1997. Zircon evaporation ages and chemical composition of migmatitic schist in the Obudu Plateau: evidence of palaeoproterozoic (ca. 1789Ma) event in the basement complex of southeastern Nigeria. J. Min. Geol 33 (2): 81-88.

Ekwueme, B. N. and Kroener, A., 1998. Single zircon evaporation ages from the Oban massif, Southeastern Nigeria. J. Afr. Earth Sci. 26(2): 195-205.

Ekwueme, B. N. and Onyeagocha, A. C., 1985. Metamorphic isograds of Uwet area, Southeastern Nigeria. J. Afr. Earth Sci. 3(4): 443-454.

Ekwueme, B. N., Nyong, E. E. and Petters, S. W., 1995. Geological Excursion Guide Book to Oban massif, Calabar Flank and Mamfe Embayment, Southeastern Nigeria. Dec-Ford Publi., Calabar, Nigeria, 36.

Ephraim, B. E., 2005. Petrology and Geochemistry of Northeastern Obudu Plateau. Unpubl. Ph.D Thesis, Univ Calabar.

Grant, N, K., 1978. Structural distribution between metasedimentary cover and underlying basement in the 600 M. Y. old Pan-African domain of West Africa. Geol. Soc. Am. Bull 89:50-58.

Maiha, H. A., 1996. Preliminary report on Azara barite deposits across River Awe Nigeria. Nigeria barite Mining and processing Company Ltd.

Obioha, Y. E and Ekwueme, B. N., 2011. Petrology and Chemical composition of gneisses of northwest Obudu Plateau, southeastern Nigeria. Global J. Pure and Appli. Sci. 17 (2): 215- 226.

Okereke, C. S. and Onwumesi, G. A., 1989. Gravity anomalies in the Nigerian Sector of the Mamfe Basin. J. Min. Geol., 25 (1&2): 211-214.

Onyeagocha, A. C. and Ekwueme, B. N., 1982. The pre-Pan-African structural features of North-Central Nigeria. Nigerian J. Min. Geol 19 (2):74-77.

Orajaka, S.O., 1964. Geology of the Obudu area, Ogoja Province, Eastern Nigeria. Le Naturalist Canadien, XC1 (3): 73-78.

Petters, S. W., 1982. Central West African Cretaceous Tertiary Benthic Foraminifera and Stratigraphy. Palaeontographic A179: 1-104.

Petters, S. W., Okereke, C. S. and Nwajide, C. S., 1987. Geology of the Mamfe Rift, S. E. Nigeria. In: G. Matheis and H. S. Schandelmeier (Editor), Current Research in African Earth Sci. Balkema, Rotterdam, p. 299-302.

Petters, S. W., Zaborski, P. M. P., Essien, N. U., Nwokocha, K. D. and Inyang, D., 2010. Geological Excursion Guidebook to the Cretaceous of the Calabar Flank, SE. Nigeria, 28.

Reyment, R. A., 1965. Aspects of Geology of Nigeria. Ibadan Univ. Press, Ibadan

Ukaegbu, V. O., 2003. The Petrology and Geochemistry of parts of Obudu Plateau Bamenda massif, southeastern Nigeria. Unpubl. Ph.D. Thesis, Univ. Port Harcourt Nigeria. 321pp.

Ukwang, E. E., 1998. Petrology and Geochemistry of Uwortung-Utugwang area, Obudu Plateau, southeastern Nigeria. Unpubl. M.Sc. Thesis, Univ. Calabar, Nigeria, 87pp.

Umeji, A. C., 1988. The Precambrian of part of southeastern Nigeria: a magmatic and tectonic study. In: P. O. Oluyide (co-ordinator), Precambrian Geology of Nigeria. Geol. Surv. Nigeria. Publ., 69-75.