STRATIGRAPHY AND STRUCTURAL PATTERNS OF THE BARYTE FIELDS OF YALA LOCAL GOVERNMENT AREA IN THE NORTHERN PARTS OF CROSS-RIVER STATE, NIGERIA

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ABSTRACT

This work discusses the stratigraphic and structural patterns of the baryte fields in Alifokpa-Osina -Gabu barite field in Yala Local Government Area of Cross-River State of Nigeria, with a focus to advocating adequate mining techniques. The stratigraphic sequence in the area consists of barytes and intrusive rocks as the basal beds, overlain by baked weathered clayey shales and limestones lenses, overlain by a feldspathic conglomeritic medium to coarse grained sandstones. The barytes have a variable colour which ranges from yellow to white and has a thickness that varies from about 1.4 ft to nearly 5 ft. The barytes also occur as vein fillers or as bedded deposits. Calcareous, ferruginous, or siliceous cementing material bound the barytes within the host rock. The medium to coarse grained feldspathic sandstones is very heavily fractured and has a prominent northwest – southeast (NW-SE) vein trend, and a northeast-southwest (NE-SW) vein trend The open pit or surface mining technique is suggested for the extraction of the barytes because of the lower thickness of overburden and its cost-effective nature when compared to other techniques.

Keywords: Baryte field, Fracture Directions, Trend Analysis, Overburden, Mining Techniques

1.0 INTRODUCTION

The Alifokpa-Osina-Gabu baryte field in Yala Local Government area contains huge barytes deposits with an abundant reserve which has not been exploited. The reasons for the non-usage of the huge barytes deposits in Nigeria is primarily and firstly due to the country's sole focus on petroleum and natural gas as source of income, and lack of adequate geological and geochemical knowledge of the barytes deposit. A description of the stratigraphic and structural patterns will be of immense help in the extraction of the mineral from the subsurface as the barytes are presently mined by local artisanal miners without good knowledge of the stratigraphy and structural patterns, which would have been of great utility. The occurrence of barytes in the Ogoja Province was first reported by McConnel (1949) and Farrington (1952) but there is no detailed description of the stratigraphy and structural pattern of the barytes in the study area. Other previous studies dwelt more on the vein types of the ore, saline water composition and its igneous association (Ezepue, 1984; Akande and Mucke, 1989; Uma and Leonart, 1992; Ekwere and Ukpong, 1994). The aim of this study is to describe the stratigraphy and structural patterns of the baryte ores and proffering best method of extracting the mineral from the subsurface. The study area (Figure 1) lies within the Abakaliki Basin in Southern part of the Benue Trough (Figure 2). The area is bounded by Longitudes 008˚30´E and 009˚00´E and Latitudes 06˚30´N and 07˚ 00´N and covers about 250 km^2. (Figure: 1.)

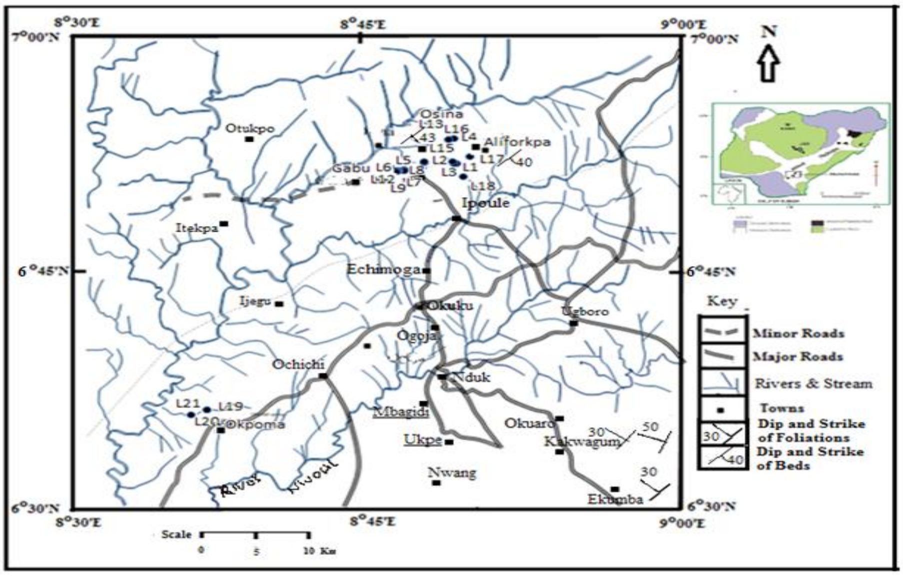


Figure. 1: Map of the (a) Study Area.

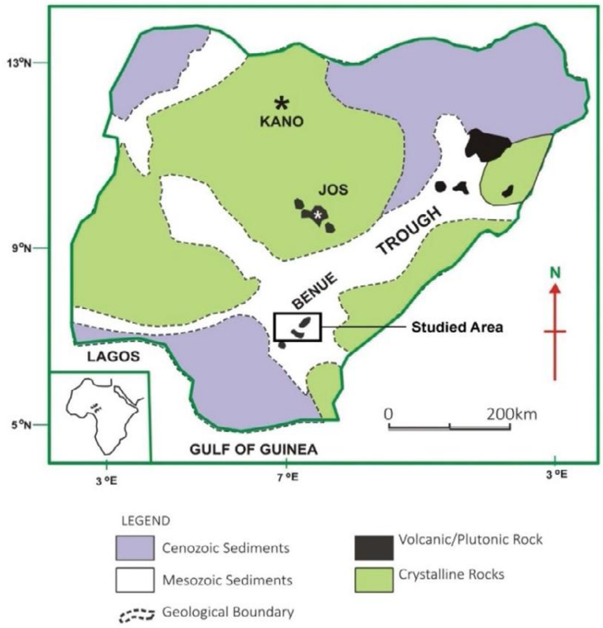


Figure: 2; Map of Nigeria showing the location of the study area within the Benue Trough (Modified after Reyment 1965).

2.0 TECTONIC AND GEOLOGIC SETTINHG

The study area lies within the lower part of the Benue Trough of Nigeria. The Benue Trough extends in a northeast direction, with a length of about 1000 km and a width of about 90 – 100 km. Benkhelil (1986) divided the Benue Trough into Lower, Middle and Upper parts, and has a N-S trending arm (Gongola arm) and an E-W trending arm (Yola arm) at its northern end (Offodile, 1989) The Benue Trough is also divided into the Lower/Southern, Middle/Central and Upper/Northern parts by Offodile (1989). The West African Pre- Cambrian shield is bifurcated by the Benue Trough in a NE – SW direction traversing through the Chad Basin to the Niger Delta. Benkhelil *et al* (1987) contends the trough to be fault bounded and records about 6000m of marine and fluvio-deltaic sediments.

Burke *et al* (1971), Olade (1975), Wright (1976), Offodile (1976), Benkhelil (1989), Kogbe (1989)) has variously studied the structural and tectonic history of the Benue Trough. A Y-shaped triple rift system was explained by Petters (1978), Hoque and Nwajide (1985) and Offodile (1989) as a possible means of origin and breakup of the Afro-Brazilian plate. As a result of the detachment of the African and South American plates and formation of the South Atlantic Ocean in the Early Cretaceous times, the Benue Trough developed into an Aulacogen, which is represented by the Abakaliki Benue Trough, a failed arm of the triple junction rift – edge system (Burke *et al* 1972; and Nwachukwu (1972). These processes led to the separation of Africa from the South America during the Aptian/Albian. An on-land resuscitation of the equatorial fracture zones such as, the Chain and Charcot fracture zones was a causative factor that initiated tectonism and its associated sedimentation. These tensional and compressional stresses created by tectonism with a deep penetration into the basement.

Murat (1972) suggested that the filling of the sedimentary basin was controlled by three major tectonic phases (Murat, 1972). The Albian tectonic phase was the first phase and its movement coincided with the major NE – SW trend of the Benue Abakaliki Trough. The Anambra Platform and the Afikpo Syncline developed during this time respectively on the West and East of the Benue Abakaliki Trough. The second phase occurred during the Campanian to Paleocene times during which time compressional movements occurred following the established NE – SW trend, resulting into folding of the Cretaceous sediments in the Benue Trough (Benkhelil, 1986). These compressional movements formed a succession of folds trending NE – SW direction, creating the Abakaliki Anticlinorium and the Anambra Basin, which down warped to the west, and Afikpo syncline to the east of the Abakaliki Anticlinorium. These depressions became major depositional centers for sediment deposition.

During the Santonian times, the tectonism was complemented folding and faulting as well as widespread outstanding magmatism which gave rise to the relatively high Abakaliki anticlinorium, and delimited by the synclines of the Anambra Basin to the west and Afikpo to the east. Sedimentation became shifted to these contiguous synclines from the positive geomorphic feature of the Abakaliki anticlinorium. The Albian-Aptian Asu River Group (ARG) sediments became first sedimentary infill in the Lower Benue Trough (the Abakaliki Basin). The Asu River Group is composed of thick laminated shales, feldspathic sandstones and subordinate limestones, as well as some volcanic intrusives and pyroclastics. These sediments lie unconformably on the Precambrian to Paleozoic Basement Complex rocks. The Cenomanian regression gave rise to a continental clastic sediment of the Keana / Makurdi sandstones of the Ezeaku Group. The Turonian transgression was marked by a transgressive phase which caused the deposition of widespread fossiliferous black to dark gray shales and limestones of the Ezeaku Group.

Wright (1976) and Ugwuonah and Obiora (2008) was of the view that the sediments were compressionally or extensionally folded in an unorogenic environment. The Benue Trough have been affected by at least two major sets of tectonic events, which include the pre-Turonian and the Santonian episodes. Compressional movements along the NE-SW trend characterize the Santonian episode in the Lower Benue Trough. This episode resulted to the folding, faulting and uplift of the Abakaliki Anticlinorium, which triggered a concurrent subsidence that influenced the Anambra Platform and shifted the depositional axis westwards. Some minor intermediate intrusives and associated Lead-Zinc mineralization characterize the tectonism. The sediments of the Asu River Group and the Ezeaku Formation contain Lead-Zinc and Fluorite-Barite mineralization. Aulacogens generally contain hydrothermal fluids that are precursors of fluorites and barytes mineralization.

Reyment (1965) proposed many of the lithostratigraphic units in the study area. He did the first detailed study of the stratigraphy of the southern Nigeria sedimentary basins. The three tectonic activities, shifts in the basin axis coupled with sedimentation led to three depositional phases in the Abakaliki - Benue stage (Aptian –

Santonian), the Anambra – Benue stage (Campanian – Middle Eocene) and the Niger Delta stage (Paleocene – Recent). The scope of this study lies on the Abakaliki – Benue stage. Deposited during the first stage of Abakaliki – Benue and Calabar Flank valley regions were the Asu River, Ezeaku and Awgu formations. The Anambra Basin was installed simultaneously as a flexural basin relative to the Abakaliki Anticlinorium after the squeeze during the Santonian.

The southwestern part of the Benue Trough is filled with an accumulation of up to 7 km of Lower Cretaceous (Aptian) to Palaeogene predominantly clastic sediments. Works on stratigraphic division of the units was carried out by Reyment and Ojoh (1992). In the Albian to Santonian phase, the depositional center was the NE – SW trending Abakaliki - Benue Trough, a graben-like structure flanked by the Anambra platform to the east and Ikpe/Afikpo platforms to the southwest. With the folding of the southern Benue Trough into the Abakaliki Anticlinorium, Afikpo and Anambra syncline, deposition shifted southernly. The third phase was the formation of the proto–Niger Delta during the Upper Eocene. The geologic map of the study area is shown in Figure 3 while the stratigraphic succession in the study area is given in Table 1.

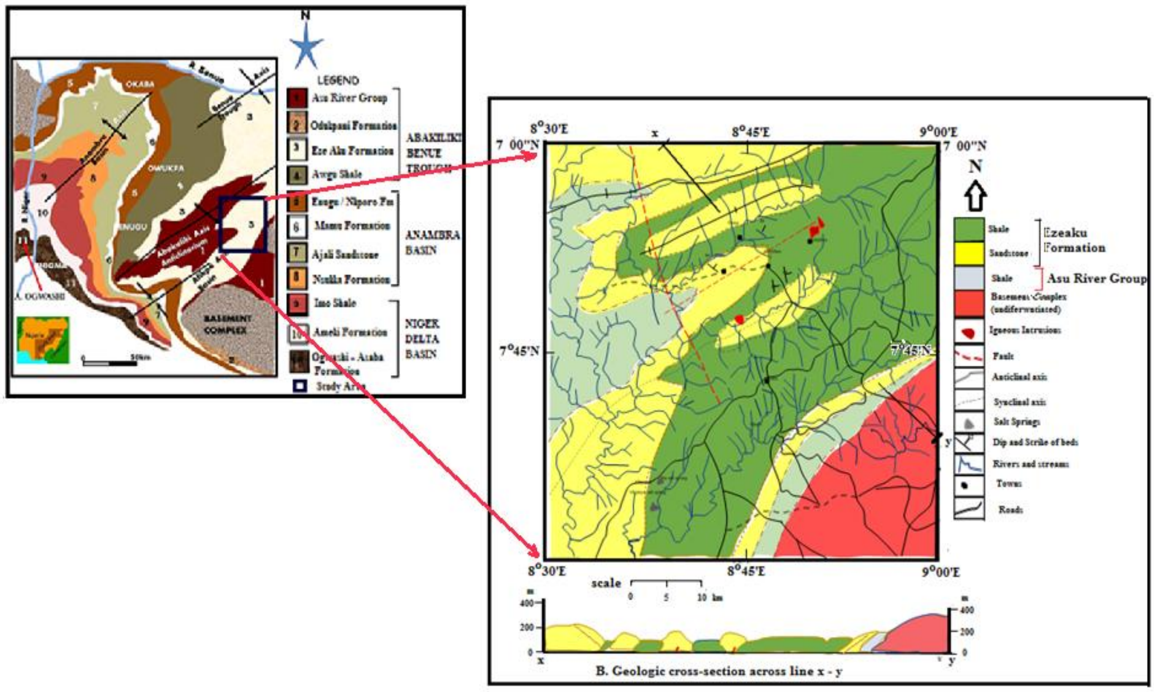
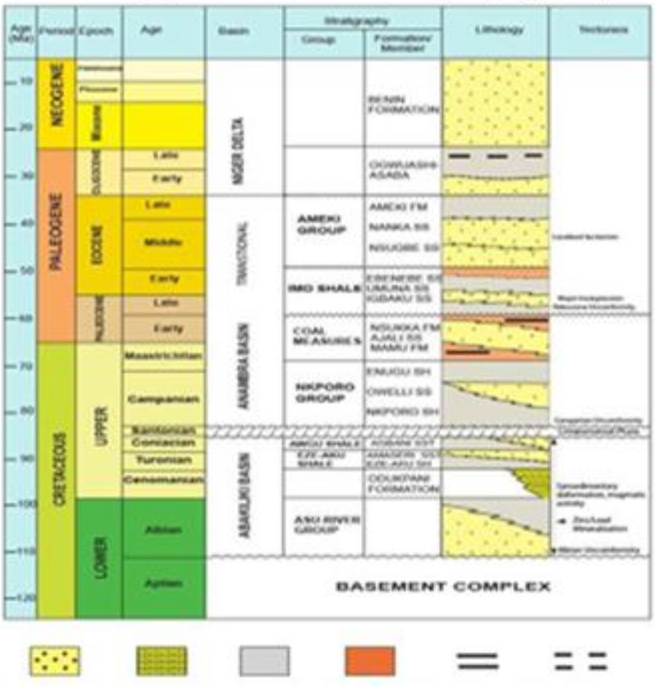


Figure. 3: Geological map of the study area showing its location within the (b) Geological map of Southeastern Nigeria.

Table 1: Stratigraphic succession in south-eastern Nigeria (Nwajide. 2013)



3.0 MATERIALS AND METHODS

Materials used in this study include Silver Compass, Global Positioning System (GPS), Geological Hammer, Measuring tape and a Field Notebook. Method of study involved geological fieldwork by logging and description of outcrops, measurement of attitudes of beds and fractures, sampling of baryte veins, associated lithologies and fractures. Location of outcrops (Longitudes and Latitudes) and elevations were taken with the Global Positioning System (GPS).

4.0 RESULTS

4.1 STRATIGRAPHY OF THE BARYTE FIELDS

The barytes were studied at seven locations around Alifokpa-Osina-Gabu, located in the northern parts of the study area. These locations are Saphira (L. 22), Echuji (L. 10) and Aji (L.4), in Alifokpa, Odokodo (L.11) and Gamubo site (L.19) at Osina and Gabu pit (L.14) and Galena/Baryte site (L. 17) at Gabu. (Figure 4). A generalized lithosection of the baryte field in the study area is shown in Figure 5.

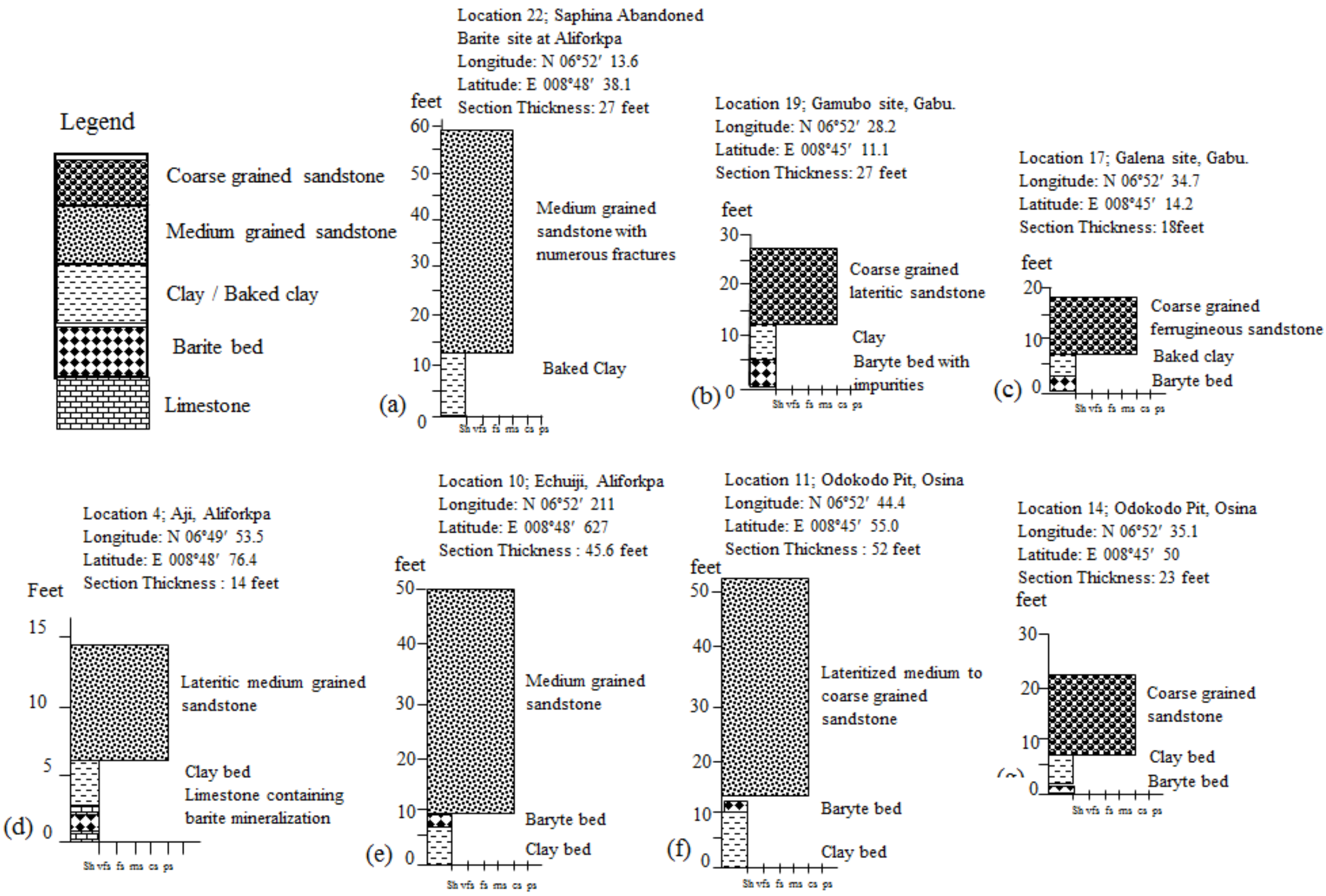
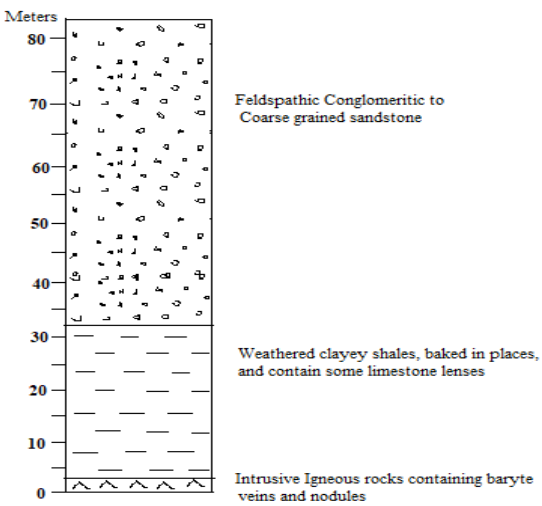


Figure. 4: Lithologic Sections of the barite outcrops



The stratigraphic section consists of barytes and basal intrusive rocks, overlain by weathered clayey shale that is often baked in places and sometimes containing limestone lenses and is overlain by a feldspathic conglomeritic medium to coarse grained sandstones (Figure 5) In some places like Aji section or Odokodo pit, the barite bed occurs above the clayey shale or within the shale. The thickness of the barite beds varies from about 1.4 ft to nearly 5 ft. The barytes deposit has a variable colour which ranges from yellow to white. The barytes occurred as vein fillers or as bedded deposit in association with the clayey shales, limestones and sandstones and are bound to the host rocks by calcareous, ferruginous, or siliceous cementing material. The medium to coarse grained feldspathic sandstones is very heavily fractured. The presence of some reddish tints on the host rocks suggests ferruginization. The overburden rocks in the baryte field in the Alifokpa-Osina-Gabu area consists of medium to coarse grained, conglomeritic and feldspathic sandstones. The thickness of the topmost strata varies from about 26 meters to about 59 m. within the study area (Table 2). Typical fractures and other features as observed in the field are shown in Figures. 6 and 7.

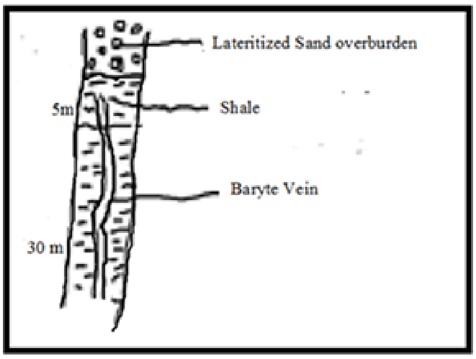


Figure 6: Vertical section of baryte mineralization in sandstone and weathered overburden in Gabu,

Table 1: Over Burden Thickness of Baryte Veins in the study area (Osina, Gabu and Alifokpa

Outcrop Loc	Outcrops of barytes	Overburden Elevation (m)	Outcrop Elevation (m)	Depth (m)
Loc 11	Osina	149	120	29
Loc 19	Osina	170	120	50
Loc 14	Gabu	128	103	25
Loc 17	Gabu	136	81	55
Loc 10	Alifokpa	135	109	26
Loc 22	Alifokpa	197	138	59

Figure 7a: Fractured Coarse grained ferruginous sandstone at Edichwa Alifokpa. Black arrow indicates the fracture

Figure 7b: Indurated and fractured sandstone at Gabu

Figure 7c: Whitish barite vien hosted by shale at Gabu. Black arrow indicates the vein

Figure 7d: Coarse grained sandstone outcrop at abandoned barite site

The highest concentration of barytes mining pits occur at Osina – Gabu areas, where some of the mining pits are up to 50m in depth. Mining in these zones are manually and mechanically carried out. Pb sulphide with an average width of 1.5cm have also been observed.

4.2 STRUCTURAL PATTERNS FOR BARYTES FIELD IN ALIFORPHA-OSINA- GABU BARYTES FEILD

The barytes ores occur within the strata as beds as well as in two main vein sets; a northwest – southeast (NW-SE) vein trend, and a northeast-southwest (NE-SW) vein trend (Table 3, Figure 8). In the fractured weathered shales, the barytes ores also occur as globular concretions. Other minerals occurring in association to barytes include quartz, galena, sphalerite and feldspar. Water pools occur within the fractured weathered shales.

TREND ANALYSIS

The trend analysis result in Table 3 and Figure 8 suggests two dominant fracture directions; a NW-SE trend and a NE-SW trend. The NW-SE trending veins is more common than the NE-SW veins. Measured dip of the barytes veins range between 84° to 89°. The dip of beds varies between 38° and 45° in the southeast direction while the beds strike northeast to southwest (NE – SW).

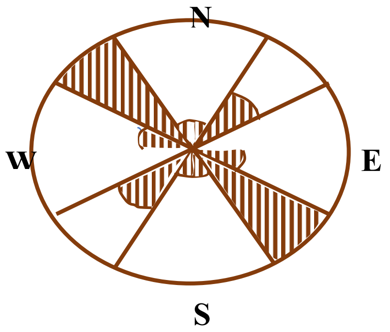


Fig. 8: Rose Diagram showing the general structural trend of the baryte veins in the Conglomeritic arkosic Sandstones

Table 3 Baryte veins / Fracture trend analysis in the Coarse-grained sandstones

Classes	Fracture/ Vein Measurements	No of Measurements per Class	Class Percentage
1-30 / 181-210	200 - 20	2	8.3
	198 - 18		
31-60/ 211-240	232 - 50	6	25
	235 - 55		
	240 - 60		
	244 - 64		
	228 - 48		
	230 - 50		
61-90/ 241-270		0	0
91-120/ 271-300	286 - 106	4	16.6
	290 - 110		
	294 - 114		
	300 - 120		
121-180/ 301-330	310 – 130	12	50
	312 – 132		
	328 - 148		
	325 – 145		
	320 – 140		
	326 – 146		
	329 – 149		
	320 – 140		
	324 – 144		
	302 – 122		
	306 – 126		
	318 – 138		
	316 - 136		
151– 180/ 331 - 360	340 - 160	2	8.3
	350 - 40		

4.3 DISCUSSION

Several methods of mining can be used in the extraction of barytes from the subsurface. These methods include underground, open pit mining (surface), placer, and in-situ mining. The method used often depends on the depth of the deposit. The underground method is used when the depth of the baryte deposit is high and usually access shafts or tunnel is constructed to reach the deposit. The underground method is usually more expensive and its used for targeting deeper deposits. Open pit mining or surface mining is used when the baryte deposit is close to the surface, and machineries such as bulldozers and excavators are used in removing the overburden. This is a cost-effective mining procedure when compared with underground mining method. Following the above discussions and considering the fractures and thickness of the overburden which varies from 26 ft to about 60 ft, the Open pit or surface mining method should be considered as the procedure suitable for the extraction of the barytes from the study area. Apart from the high cost of using the underground method, it is precluded from use on this deposit because of the unconsolidated nature of the overburden which will cause collapse of the shafts and tunnels constructed to access the deposits. Again, flooding of the shafts and tunnels will also create a lot of hindrance to accessing the deposits.

5.0 CONCLUSION

Logging and description of seven baryte outcrops at Alifokpa-Osina-Gabu area suggests the sections consist of a basal rock composed of bedded barytes and intrusive rocks, overlain by weathered and baked clayey shale / limestone lenses and a highly fractured feldspathic conglomeritic medium to coarse grained sandstones. The overburden thickness varies from 26 ft to 59 ft. The barytes occur within the strata as beds as well as in veins in the highly fractured feldspathic sandstones and as globular concretions in the weathered shales. Other associated minerals with the barytes are quartz, galena, sphalerite and feldspar. Two dominant vein patterns observed include a Northwest- Southeast trend and a Northeast-Southwest trend, with the NW-SE pattern being more common. The Open pit or surface mining method is advocated for use in the extraction of the barytes because of its cost effectiveness and easy of removal of overburden.

REFERENCES

Akande, S and Mucke, A. (1989). Mineralogical, textural and paragenetic studies of the leadzinccopper mineralization in the lower Benue Trough (Nigeria) and their genetic implications. Journal of African Earth Sciences, 9 (1): 23 -28.

Benkhelil, J., (1986). Structure and Geodynamic Evolution of the intracontinental Benue Trough (Nigeria). Ph.D. thesis, University of Nice, published by Elf Nigeria Limited.

Benkhelil, J., (1987). Cretaceous deformation, magmatism metamorphism in the Lower Benue Trough, Nigeria, Geol. J., 22: 467 – 493.

Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough, Nigeria. Journal of African Earth Sciences, 8: 251 – 282.

Burke K.C., Dessauvagie, T.F.J. and Whiteman, A.J. (1971). Opening of the Gulf of Guinea and geological history of the Benue depression and Niger Delta: Nature, 233: 51 – 57.

Burke K.C., Dessaauvagie, T.F.J. and Whiteman, A.J. (1972). Geological History of the Benue Valley and adjacent areas, In: Dessauvagie, T.F.J. and Whiteman, A.J. (eds), African Geology. Ibadan University Press, Ibadan, Nigeria, 187 – 205.

Ene, G.E., Okogbue C.O., Chidozie I.P., (2012), Structural style and economic potentials of some baryte deposits in Southern Benue Trough, Nigeria, Rahaman Journal of Earth Sciences 85: 1 -14.

Ezepue, M.C., (1984). The geologic setting of Lead – Zinc deposits of Ishiagu, Southeastern Nigeria. Journal of African Earth Sciences. 2: 97 – 101.

Hoque, M. and Nwajide C.S., (1985). Tectono-sedimentological evolution of an elongate intracratonic basin(aulacogen): the case of the Benue Trough of Nigeria. Journal of Mining and Geology, 21: 19 – 26.

Kogbe, C. A., (1989). Paleogeographic history of Nigeria from Albian times in: Kogbe C. A. (Ed), Geol. of Nigeria., Eliz. Pub. Co., 237 – 252.Rock view (Nigeria) Ltd, Jos., 257-276.

McConnel, R.B., (1949). Notes on the lead-zinc deposits of Nigeria and the Cretaceous stratigraphy of the Benue and Cross River valleys. Geological Survey of Nigeria Report, 752 (unpublished).

Murat, R.C., (1972). Stratigraphy and paleogeography of the Cretaceous and lower Tertiary in southern Nigeria. In: T.F.J. Dessauvagie and A.J. Whiteman, (Ed), African Geology, Ibadan University Press, Ibadan.

Nwachukwu, S.O., 1972. The tectonic evolution of the southern portion of the Benue Trough. Geological Magazine, 109: 411 – 419.

Offodile, M.E., (1975). A review of Geology of the Cretaceous of the Benue Valley. In: Kogbe, C.A. (Ed.), Geology of Nigeria, Rock View Ltd., Jos, 364 – 376.

Offodile, M.E., (1976). The geology of the Middle Benue Trough, Nigeria; Ph.D. Thesis, University of Uppsala, 4: 22 – 136.

Olade, M.A., (1975). Evolution of Nigerias Benue Trough (Aulacogen): A tectonic model. Geological Magazine, 112: 575 – 583.

Olade, M.A., (1976). On the genesis of Pb-Zn deposits in Nigerias Benue rift (Aulacogen): A reinterpretation. J. Min. Geol., 13; 20 – 27.

Olade, M.A., and Morton, R.D., (1985). Origin of Lead-Zinc mineralization in the southern Benue Trough, Nigeria, Fluid inclusion and trace element studies. Mineral Deposita, 20: 76 – 80.

Petters, S.W., (1978). Stratigraphic Evolution of the Benue Trough and its implication for the upper Cretaceous paleography of West Africa. Journal of Geol., 86: 311 – 322.

Reyment, R.A., (1965). Aspects of the geology of Nigeria. University of Ibadan Press, Nigeria, 145.

Ugwuona, E.N., Obiora S.C., 2008. Further evidence for extensional rather than compressional tectonic origin for the Benue Trough using the igneous rock association. Abstract volume, 44th Annual Int, Conf, of the Nigerian Mining and Geosciences Society, Abuja, 2008.

Uma K.O. and Leohnert E.P., (1992). The Brine fields of the Benue Trough, Nigeria: A comparative study of geomorphic: tectonic and hydro chemical properties, Journal of African Earth Sciences, 26: 23 – 29.

Werner, C.D., (1958). Geochemie und parageneses der saxonischen schwerspat-fluospatgange im schmalkaldener revive, Freiberger Forschungshefte, Reibe C, 47: 1178, 24 Abb; (Academic-Verlag), Berlin-zgl.Dss.Univ. Halle – Wittenberg, 1957.

Wang, Z. Stratigraphic distribution and geochemical characterization; Economic Geology, 86: 354 – 363.
and Li. G., (1991). Barite and Witherite deposits in Lower Cambrian shales of South China –

Wright, J.B., (1976) Origin of the Benue Trough: a critical review In C.A. Kogbe (Ed.). Geology of Nigeria, Lagos: Elizabethan publish. Co., 234 – 244.