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FUNDAMENTAL PROPERTIES AND THE SOCIAL IMPLICATIONS OF THE DEVELOPMENT OF THE BARITE DEPOSITS IN THE GBAJIMBA AREA OF BENUE TROUGH, NIGERIA

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ABSTRACT

Opportunities and challenges in barites business in Nigeria is examined in this paper as a first step in an overall strategy to create a unique platform for accelerated and sustainable exploitation, beneficiation and marketing of the commodity in Nigeria. While there are several barite deposits in Nigeria, only the deposits in Gbajimba area in the Middle Benue Trough were assessed for their fundamental properties. Using immersion and pycnometric methods of Specific gravity (SG) determinations, the SG of fifteen (15) representative samples taken from three mining sites (Tiza, Adagu and Torkula) ranges between 4.2231 and 4.3222. X – Ray Fluorescence (XRF) analysis of two of the samples yielded total barite (Ba) of 72.61% and 72.12% in Tiza and Adagu respectively, which correspond to a calculated total Barium Oxide (BaO_{2}) of 57.68% and 56.96%. The other relatively significant elements in the barite are Si, Fe, Sr, Ca, Al, Pb, Mg, Mn, P and Ni. XRD results show that the sample is predominantly barite with insignificant quantity of wenkite and Anadite. If unground barites could yield the above results, beneficiation of the barites in the study area could make Nigerian barites one of the best in the world, not only in terms of quality but in the cost of production because those that are being worked presently requires open-cast mining methods. Further exploration down dip may yield a larger reserve.

Key Words: *Artisanal, Benue Trough, unground barites, specific gravity, open-cast, overburden.*

INTRODUCTION

Wide spread occurrence of lead-zinc deposits within the metallogenic province of the Benue Trough probably, for a long time, led to the relegation of the barites within the province to a gangue deposit (Olade, 1975; Adekoya, 1999; Akpokodje, 2006). However, the recent policy of the government of Nigeria on local content appeared to have created interest in the development of this commodity. Barite has a distinctive high specific gravity of about 4.5 (Gribble, -1985), which makes it essentially useful in the formulation of drilling mud - a mixture of different types of chemicals in water or oil that is used as weighing agent in oil well drilling. Barite is also extensively used in the exploitation, beneficiation and marketing of the commodity in Nigeria. The main focus of the study is to evaluate the quality of the barites manufacture of paints, plastic, ceramic, chemical and glass industries.

In spite of its wide applications worldwide and its reported large occurrences in Nigeria, the Nigerian barite is yet to find a place even its market (Adekoya, 1999; Akpokodje, 2006), probably as a result of insufficient information on the extent and the physical properties of the commodity. Without any doubt, the lower Benue Trough holds a significant potential for untested barite resources, which occur not only in isolation as veins but in association with the wide spread Lead-Zinc deposits in the area (Tate, 1959; Rayment, 1965; Simpson, 1995). This study therefore is an initial stage in the overall strategy to create a unique platform for accelerated and sustainable

deposits in Gbajimba area in the middle Benue Trough (Figure 1) with a view to suggesting ways in which its mining could be improved to yield maximum mining efficiency. Specifically the deposits studied are from the mining sites at Tiza, Adagu and Tokula (latitudes $07^{0}35'06''$ and $08^{0}12'56''$N and longitudes $008^{0}23'02''$ and $009^{0}07'52''$E, respectively) in Gbajimba area of Guma Local Government of Benue State. The area falls within the lower part of the Middle Benue Trough and in the Cretaceous sediments. Detailed paragenetic relationship of the barite in relation to the Benue trough metallogenic province (Olade, 1975; Ogbeide, 1984; Ogundipe, 1987) is however not studied in this work.

REGIONAL GEOLOGY OF BENUE TROUGH

Location

The Benue Trough is a rift basin in the central West Africa that extends NNE-SSW for about 800 km in length and 150 km in width. The trough contains up to 6000 m of Cretaceous–Tertiary sediments of which those pre-dating the mid-Santonian have been compressionally deformed, faulted, and uplifted in several places (Obaje *et al*., 2006). It is bordered on either side by granite and gneisses of the crystalline basement with probable Proterozoic age (Obaje et al., 2006) and punctuated with igneous rocks in places. The Benue Trough is subdivided into a Lower, Middle and Upper portion for correlation purposes (Fig. 1). The evolution, geology and stratigraphic successions with emphasis on each of the Formations, bed thicknesses, lateral extensions and stratigraphic locations have been variously discussed by Carter *et al*. (1963); Murat (1972); Burke et al. (1976); Offodile (1976); Murat, (1972); Obaje (1994); Mair and Ramanaihan (1984) to mention a few. Somehow, an interrelationship exists in the sedimentary successions in the Benue Trough and its adjacent basins as summarized in Figure 1

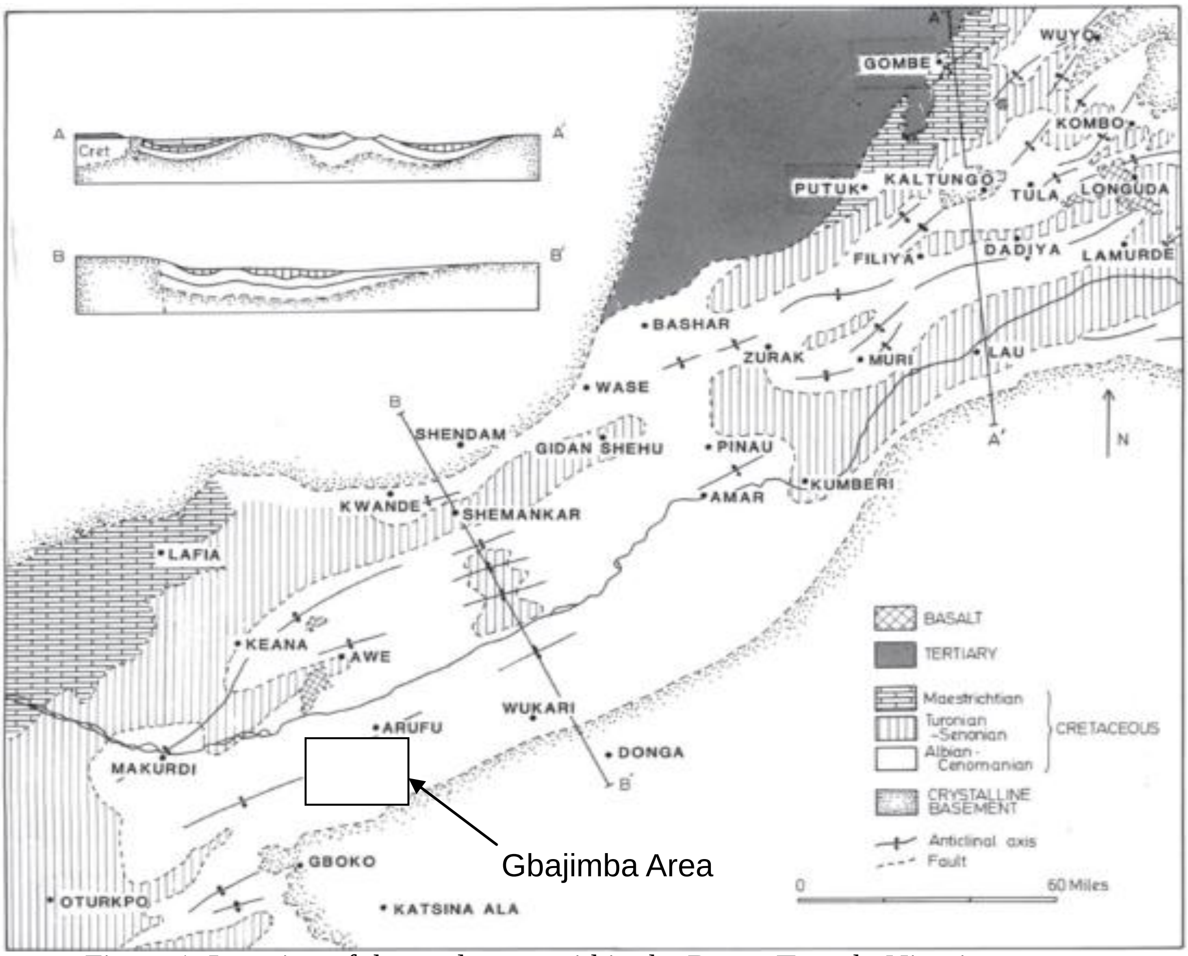


Figure 1. Location of the study area within the Benue Trough, Nigeria

METHODOLOGY

Data Gathering

Lithologic logging and characteristics of the barite deposits of each location were observed. The extent, form depth as well as the lithological layer in which the barite veins deposits occur were also noted. GPS readings of each mining pit visited were also taken. In each location, representative samples were collected for laboratory analysis.

Laboratory Analysis

Specific Gravity

Two methods were used in determining the specific gravity of the barite collected in each of the three locations visited for this study. The methods are: Pycnometric and Immersion methods. The pycnometric method involves the use of density bottles. The density bottle was weighed (a) and then filled to ¼ volumes with sample and weighed again (b). This was further filled with distilled water up to ¾ volumes and agitated by shaking, after which it was filled to the brim with distilled water and the outside was wiped, dried and weighed (c). The bottle was emptied, cleaned and then filled with distilled water and weighed (d).

The specific gravity was then calculated using this simple relation (Hough et al., 1991):

$$Sg = \frac{b-a}{(b+d)-(a-c)} \qquad (1)$$

Where:

S_g = Specific gravity
a = weight of bottle
b = weight of bottle + sample
c = weight of bottle + sample + water
d = weight of bottle + water

The immersion method was based on the Archimede's principle. Solid sample was weighed (M) and then immersed in water of a pre-measured volume. The increase in volume (V) of water was then noted. The specific gravity of samples was then determined using this formula (Hough et al., 1991):

$$Sg = \frac{W}{V2 - V1} \quad (2)$$

V = Volume of water displaced; $V = V_2 - V_1$;
Specific gravity = weight of substance (W) divided by volume of water displaced

X – Ray Fluorescence (XRF)

Samples were milled into powder using agate mortal. 25mg each of the samples was weighed into a crucible, dried and cooled in a desiccator. 20.0mg each of the dried samples was weighed and mixed with 0.80g stearic acid for pellet marking. The mixed sample was then transferred into a pellet cup containing 10.0g of stearic acid. The resulting product was pressed into a pellet with a 12 tons load grase by T40 hydraulic autopress. The resulting pellet was then transferred to X – ray analyzer sample holder ready for analysis. X – ray analyzer model type QX XRF was used for this analysis. This equipment made different calibrations for the different samples analyzed and it was equipped with a dedicated computer for data handling and operations. The prepared pellets were transferred to the sample holder for X – ray bombardment. The resulting secondary X – ray signals were obtained and processed for analysis using the appropriate data handling software. The percentage purity of barite in the samples was determined by presuming that all the BaO in the samples was used up in forming the barites. This formula was then used to get the percentage of barites in the samples (Isa, 2007):

$$\%\ \text{Barites in the samples} = \frac{\%\text{BaO x Molar weight of barite}}{\text{Molar weight of BaO}} \quad (3)$$

X-Ray Diffraction

Samples were pulverized using agate mortar. The coverts were washed using acetone. About 20mg of the pulverized samples were then put into the culvert (one for each sample) and pressed very well manually to smoothing the surface. All the particles that stick into the edge of the culvert were removed using tissue paper. The culvert with the sample was transferred to the X-ray diffractometer for analysis. The final output from the detector is a plot of various intensities against the 2θ or d values. Phase identification was done using search/match method from the database comprising of several thousands of known compounds and matching with the peaks identified from the unknown which is the spectrum acquired from the unknown sample. The spectrum provides information about mineralogy, variation in mineral composition and the corresponding crystal structures. The comparison between the XRD data base figures and sample spectrum was taken within $\pm 0.03^{\circ}$. The data base used for shale under study is supplied by International Center for Diffraction Data (ICDD).

PRESENTATION AND INTERPRETATION OF DATA

Field Observation and Mode of Occurrence of the Barites

Neither geophysical nor geochemical methods of investigation were used in barites exploration in the studied area. Existing pits, which are of different length, depth and width, depending on the depth at which the barite veins occur, suggests that the pits were dug manually by using simple implements such as shovel, digger, pick axes, cutlass, hoe chisels etc. Production processes include blasting of the deposit at considerable depth as observed from the marked pits.

At Tiza (07°53´46´´N, 008°4759´´) the topsoil is mainly clayey sand that is about 50cm thick. Clayey materials of about 30cm underlie this. The clay is underlain by sandstones of varying thickness ranging from 50cm – 3m with limestone or shale intercalations (Fig. 2). Depth extent of the pits ranges from 2.5m to about 20m

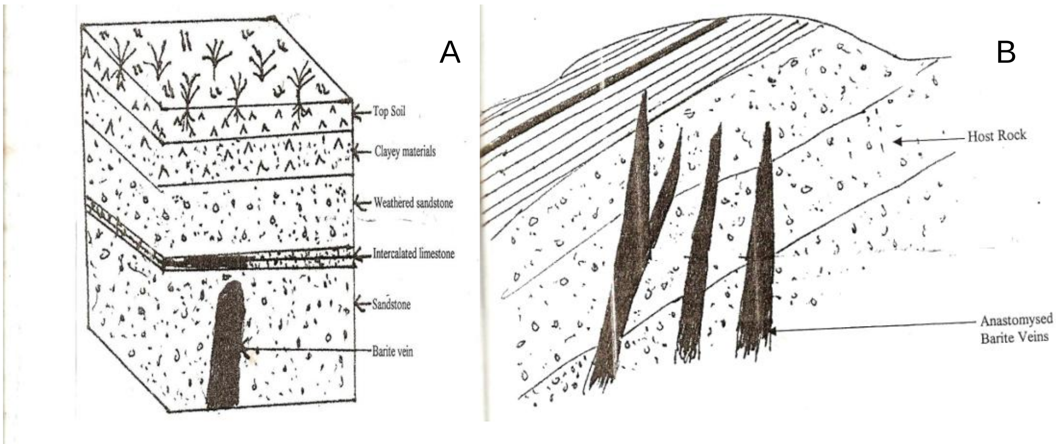


Figure 2. Schematic representation of the mode of occurrence of barite vein in Gbajimba area of middle Benue Trough, Nigeria.

Benches are made in the pit as the depth increases down pits (Plate 1A). Some of the pits were abandoned before completion as a result of accumulation of water (Plate 1B) or when the barite's vein is two deep from the surface. Two out of seven pits were abandoned as a result of the reasons given above. The veins are thin, less than 1meter thick with various degree of pinching and swelling, traceable for more than 2km along roughly N – S strike trend which at times bend to either sides. The colour ranges from white to off-white and the crystals are mainly granular.

Another important deposit is that of Adagu Site (07°56´42´´N, 008°46´38´´E). The overburden is like that of Tiza except that there is no intercalated limestone and shale on top of the barite veins. The thickness of the overburden is about 8m, and could be higher in some parts of the veins. At Adagu, the host rock (fine-medium grained sandstones) and the barite veins and veinlet appear to be highly weathered. This aids excavation but also poses problem of rock-wall instability. Veins' thicknesses range from 0.3m – 0.8m, while the colour of the barite ranges from rough brown to light. The veins trend NW – SE and dip almost vertically. Mining follows the linear orientation of the deposits. The depth of the deposit has not been ascertained because it has not been reached.

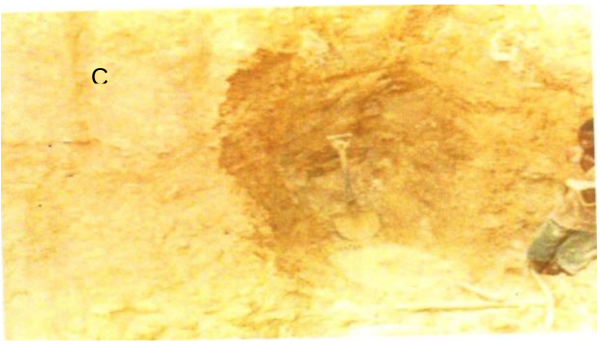


Plate 1.Photograph of typical barite mining sites in the Gbajimba area of Middle Benue trough, Nigeria. (A). Open-cast mining with benches. (B). Barite vein covered with water

The lithology of overburden at the Tokula mining site (07°58´56´´N, 008°49´54´´E) (Plate 1C) also resembles that of Tiza but has a thin film of somewhat reddish materials suspected to be iron oxide present on the deposit. The thickness of the overburden is more than 3m and has no limestone intercalation. The surface of the deposit appears to be weathered, probably as a result of the film of iron oxide observed on the deposits. The vein trends NE – SW. Level of production is low here because mining is mainly done during the dry season.

Fundamental Properties

Specific Gravity

The pycnometric method of determining the specific gravity consistently gave a relatively higher result than that of the immersion method (Table 1). This is expected because of the possibility of the presence of cavities in the lower density gangue minerals in the sample. Whereas in the pycnometric method, the cavities are eliminated by using crushed samples and a more accurate result is expected, baring human error.

Table 1. Specific gravity of barites collected from three mining localities in Middle Benue trough Nigeria.

Mining site	Average of five samples		Average of the two methods
	Immersion method	Pycnometric data	
Tiza	4.20672	4.2494	4.2231
Adagu	4.3111	4.3432	4.3222
Torkula	4.2059	4.3004	4.2532

Elemental Composition of the Barites.

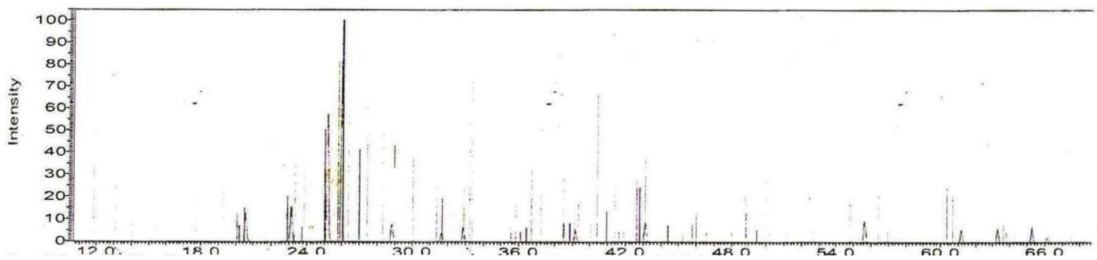
Only two of the samples collected were analyzed using XRF method in order to obtain the elemental composition (Table 2) and the calculated oxides (Table 3) of the barite. Table 3 reveals that the total barite in the samples are 72.61 and 72.12% in Tiza and Adagu respectively, which correspond to a calculated total BaO_2 of 57.68% and 56.96%. The other relatively significant elements are Si, Fe, Sr, Ca, Al, Pb, Mg, Mn, P and Ni. SrO is another constituent of the samples that could form sulphate mineral, Celestine ($SrSO_4$) with sulphur trioxide, SO_3. The amount of SrO in the samples from the two localities are 0.55% and 0.49%, which suggests a negligible occurrence of Celestine in the sample. Fe_2O_3 constitute 0.86% and 0.76% in the two samples. Silica (SiO_2) is another important constituent mineral in the samples. SiO_2 content amounts to 3.39% in Tiza and 3.12% in Adagu. This is an indication that sample that contains higher silica has lower barium and vice versa. The occurrence of barites vein in close association with limestone deposit in Tiza appears to have no significant influence on its amount (0.46%) of CaO.

Table 2: Elemental composition of barities obtained from Gbajimba l area

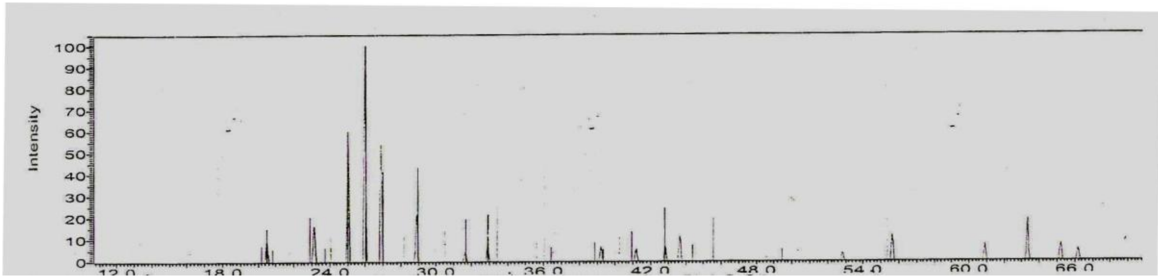
Element	Tiza	Adagu
Ba	72.61	72.12
S	22.35	22.23
Si	2.12	1.98
Fe	0.75	0.73
Sr	0.71	0.57
Ca	0.52	1.07
Na	0.64	0.57
Al	0.17	0.51
Pb	0.05	____
Mg	0.06	0.14
Mn	0.01	____
P	____	0.03
Ni	____	0.04
	100.00	100.00

Table 3: Calculated oxides composition of barities obtained from Gbajimba area, middle Benue Trough, Nigeria.

Element	Tiza	Adagu
BaO	57.68	56.96
SO_3	35.69	35.67
SiO_2	3.39	3.21
Fe_2O_3	0.86	0.79
Al_2O_3	0.65	0.83
SrO	0.55	0.49
Na_2O	0.60	0.50
CaO	0.46	1.33
PbO	0.03	____
NiO	____	0.02
K_2O	0.05	____
V_2O_5	____	0.01
TiO_2	0.03	___
T hO_2	0.01	___
MgO	____	0.19
	100.00	100.00



Barium Lead Sulfate; Barite, Plumbian. **Formula**; (Ba, Pb)SO4 -Barium Calcium Aluminum Silicate Hydroxide Hydrate; Wenkite; Wenkite.Formula: $Ca_5\ Ba_4\ Al_9SiO_{41}\ (OH)_3\ H_20$



Barium Lead Sulfate; Barite, Plumbian. **Formula**; (Ba, Pb)SO4 -Barium Iron Silicate Hydroxide Sulfur; Anandite-2\itm#1\Rg. Formula:Ba Fe3(Si, Fe) (O, OH)10 (OH)

Figure 3. XRD result of representative barite taken from two locations in the Gbajimba area of middle Benue State.

DISCUSSION

Specific gravity

The distinctive high specific gravity of barite is the most essential parameter upon which its use for oil drilling depends. Usually Specific gravity that is not lower than 4.1 are acceptable. The specific gravity of all the samples studied varies between 4.2059 and 4.3004 on the average. For commercial purpose, there are four types of barite products (Bonel, 2005): ground white paint grade – finely ground barites that is processed to remove decolouration; micronised barites – ultra-fine ground barites, almost entirely used by the chemical and medical industry; drilling grade; and unground barites – broken ore transported directly from a mine to grinding plant supplying the oil and gas drilling industry. The barite studied belongs to the unground product or direct ship which could still be subjected to beneficiation for value addition. Deposits in the area of study have specific gravity that is very adequate as weighing agent.

Comparison of Gbajimba Barite with that of other Parts of the World.

In Table 4 the chemical compositions of barite from some other parts of the world are shown**.** Although their specific gravities are not stated but chemically it could be observed that the elemental composition of Nigerian barites compare favorably well (Table 4), except for Aluminum Oxide and Iron Oxide that records a relatively higher value than that of Nigeria. Iron oxide is the most undesirable impurity while using barite for glass making. The tolerance level is about 0.5% of Fe_2O_3. The barites in the study area contain less than 1% Fe_2O_3 which could make it useless for glass making except after further processing. However in the chemical industry, iron oxide content of between 0.1% and 1.5% is acceptable, which makes the Nigerian barite suitable for the chemical industry. A total of silica and Aluminum oxide of 6% maximum is needed in the chemical industry. The total amount of the oxides in the barites studied is less than 6% (Table 4). The higher values of SO_3 in the Nigerian examples suggest that when the chemical composition is assessed in terms of $BaSO_4$ the quality of Nigeria barites should definitely improve. In Angleso barite of Japan and the Yoshioka barite Mine of England, the values of their PbO and SrO are higher (Table 4) than that of Nigeria with a corresponding low BaO_2 content. This suggests that the samples are anglesite and Celestine respectively. According to Chang *et al* (1996) PbO and SrO can form different sulphate minerals anglesite ($PbSO_4$) and Celestine $SrSO_4$ and are iso-structually equivalent of barite. While there are no data on the economics of these two deposits, the barite under study has a better quality as weighing agent than the two deposits sited.

Table 4: Barite Analysis from different parts of the world compared with that of the study area

Oxide	A	B	C	D	E	Tiza	Adagu
BaO	62.49	63.47	61.7	48.95	48.6	57.68	56.96
SO_3	34.09	34.67	34.67	32.24	36.2	35.69	35.67
SiO_2	2.01	0.02	0.02	__	__	3.39	3.21
CaO	0.38	0.13	0.16	__	__	0.46	1.33
MgO	__	tr	tr	__	__		0.19
Al_2O_3	0.05	0.35	0.23	__	__	0.65	0.83
Fe_2O_3	0.32	__	__	tr	__	0.86	0.79
SrO	tr	1.34	2.79	__	14.7	0.55	0.49
P_bO	__	tr	tr	17.78	__	0.03	____
H_2O^+	0.54	0.21	0.2	0.06	__		

(A). Azicular barite, Komonato town, Aomori Prefecture, Japan. (B). Yellow barite in Middle zones of druses, Dobroero Mine, Zletiro, Macedonia. (C). White barite in core of druses, Dobrevo mine, Zletiro, Macedonia. (D). Angleso barite, Shibukiro, Akita Prefecture, Japan, (E) Anal. Yoshioka Mine. Strontiobarite, (F) Clifon, England (compiled from Ohasi, 1920 and Chang et al 1996)

Economics Implications of Barite Mining in the Study Area

Barite mining has contributed largely to the economy of the people of Gbambija directly and indirectly. On the positive side, the villagers lease lands to miners, which have improved the income of the villagers. Also the miners employed some of the villagers in carrying out most of their mining activities. Even some villagers had become licensed miners as a result of the presence of barite deposits in the area. On a more positive side, a larger economic opening could be created by government further intervention in the exploration of barites in the study area (Kadak, 2005). The territory holds potential for bigger reserve at deeper level.

On the negative side, child labour is being encouraged in the area as most of the young school children engage themselves in unskilled labour in order to have daily returns from the miners. Efforts to discourage these young children by the miners were unfruitful due to the fact that the villagers are mostly stacked illiterate who thought that the miners intent to bring labourers from the city, and deny them of their right.

Environmental Implications of Barite Mining in the Study Area

In the area of study, the climate is tropical, with seasonal variation classified as wet and dry seasons. The area has a more prolonged wet season within early March to mid- October. In Tiza mining site, flooding during raining season makes mining extremely difficult and therefore limited to only the dry season. The vegetation of the Middle Benue is of the Guinea Savannah and is made up of shrubs, tall grasses, scattered coconut and palm trees and a lot of mango and citrus trees, which makes bush clearing for mining purposes easy. Human activities in the area is mainly farming, the commonest being food cropping which includes yam, cassava, rice and maize. Farming of citrus and mango are also prominent. Agricultural farmlands are also disrupted by mining activities. Lands that are supposed to be used for agricultural purposes are being destroyed thereby reducing food and other agricultural production in the area.

Feasibility of Mining Barite on large Scale in the Study Area

Although the barite deposits in the study area appear to be of good quality and likely occur in sufficient quantity (though in a scattered form) for economic exploitation, there are certain crucial factors to be considered to ascertain possible better commercial exploitation. Prominent among the factors is the mining technique. There are two ways of winning barites: open-cast mining and underground mining. Underground mining may be done by means of adits or shafts depending on the topography and the depth to the deposits. The open-cast methods or surface mining are presently employed in the study area because of its cheapness and the depth of the deposits. But there is an important challenge – the heavy rainfall that characterizes the wet season that is causing flooding, which makes excavation unstable and unsafe through the erosion of the poorly consolidated overburden. This has complicated and sometimes, rendered mining operation completely impossible thereby reducing effective working period. In addition, it is envisaged that if heavy-earth moving equipment is employed, additional cost will be incurred to restore the site to satisfying aesthetic environment or rehabilitate the land for cultivation as may be required under the environmental law. Not only could this, using any big machinery in the area, cause the land owners to demand exorbitant compensation.

In view of the above consideration, until it is proved by geophysical method that barite occurs at depth in the study area underground mining method, to side track the effect of flooding, is not feasible economically. Neither the use of heavy machineries encouraged. However, the present tools could be improved upon by provision of pay loaders.

CONCLUSIONS

From the foregoing, it is clear that the barite deposits in the study area desire further exploration using geophysical methods. The specific gravity of the barites meets the minimum required value of 4.2 for its use in the oil industry where it is a hot cake at present. With little value addition through processing or beneficiation, the barite would compete favorably well with barites from other part of the world. In addition to its usage in the oil industry other uses particularly in the chemical industries could be exploited to increase the demand for the barites. The known barite deposits occur at shallow depth, which makes the present open cast mining method suitable than the underground method. However the use of more sophisticated tools should be encouraged.

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