Records of NGSA, Volume 16, 44 - 67

Assessment of Gypsum Mineralization in Edo State, South-South Nigeria

[1]Adeoye, F. A. (Mrs.), [2]Oriere, L., [3]Ajadi, J.
Nigerian Geological Survey Agency, [1]Abuja, [2]Ilorin, [3]Abeokuta
August, 2011.

Abstract

An assessment of the gypsum deposit in Edo State was undertaken in a bid to appraise the extent, quality, quantity and economic viability of the deposit. Field studies revealed that the gypsum occurs within the grey shale and the clay shale overlying the basement around Sabongida-Ora, Afuze, Warake and Aviele areas located within the 1:50,000 sheets 283 (Ifon N.E.) and 284 (Ubiaja) areas of Edo State in the southwestern Nigeria. The mode of occurrence of the gypsum is mainly as thin flat bands and beds, vertical to sub vertical fracture-filling veins and dispersed, poorly developed granular crystals within the host shale. Mineralogical studies show that the gypsum occurs mostly in form of selenite, satinspar and gypsite while iron in form of ferrous carbonate (siderite) occurs as accessory. Chemical analysis of samples revealed that the gypsum is composed of 66% – 95% Calcium Sulphate ($CaSO_4.2H_2O$) and Siderite ($FeCO_3$) as accessory. The composition and purity of Edo gypsum indicate that it is potentially suitable for use in cement industry, POP and other construction additives.

INTRODUCTION

Edo State is bounded approximately by longitudes 5°00'30"E to 6°42'30"E and latitudes 5°40'22"N and 7°38'22"N (Fig. 1). The area of gypsum mineralization is located within the sedimentary area lying approximately between longitudes 5°18'30"E to 6°42'30"E and between latitudes 6°27'22"N and 7°14'20"N. The gypsiferous areas studied fall within Owan East, Owan West, Etsako East and Etsako West Local Government Areas of the State (Figs. 2 and 3).

Edo State is highly accessible with the East–West and the North–Benin expressways linking the State to other States in Nigeria. The gypsum mineralization areas can be accessed through major roads such as Uzebba–Auchi–Warake–Sabongida Ora, Auchi–Aviele, Sabongida–Eme Ora and Sabongida–Igbubezi roads.

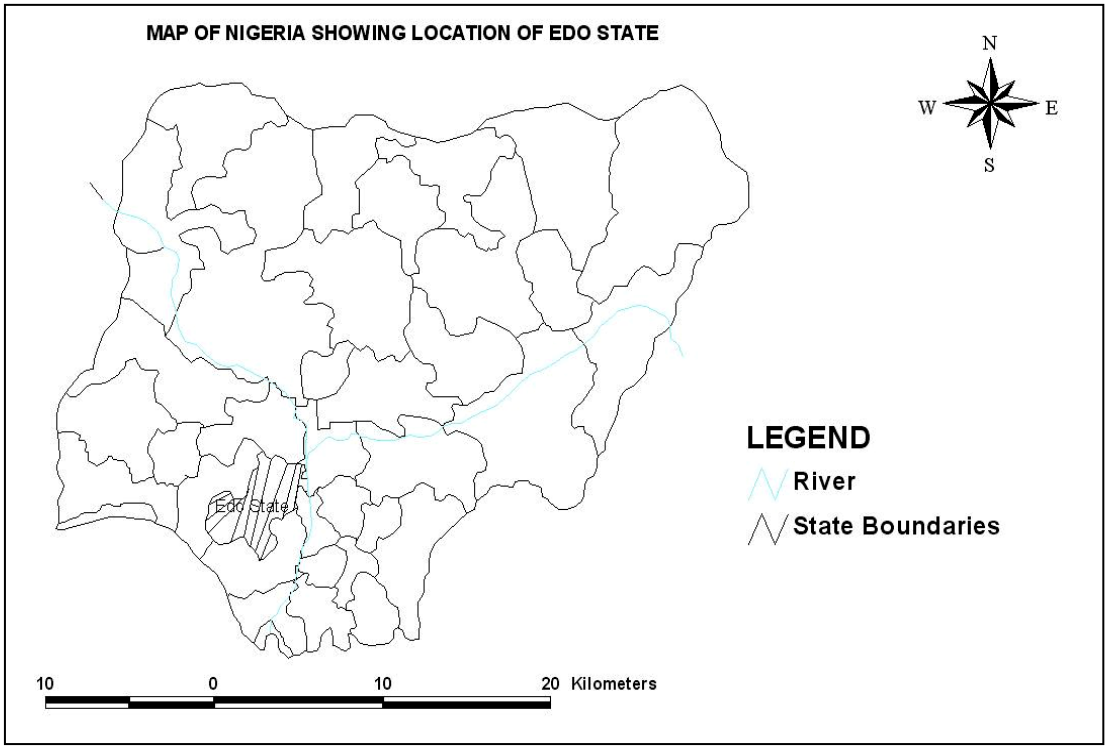


Fig. 1: Map of Nigeria showing the location of Edo State.

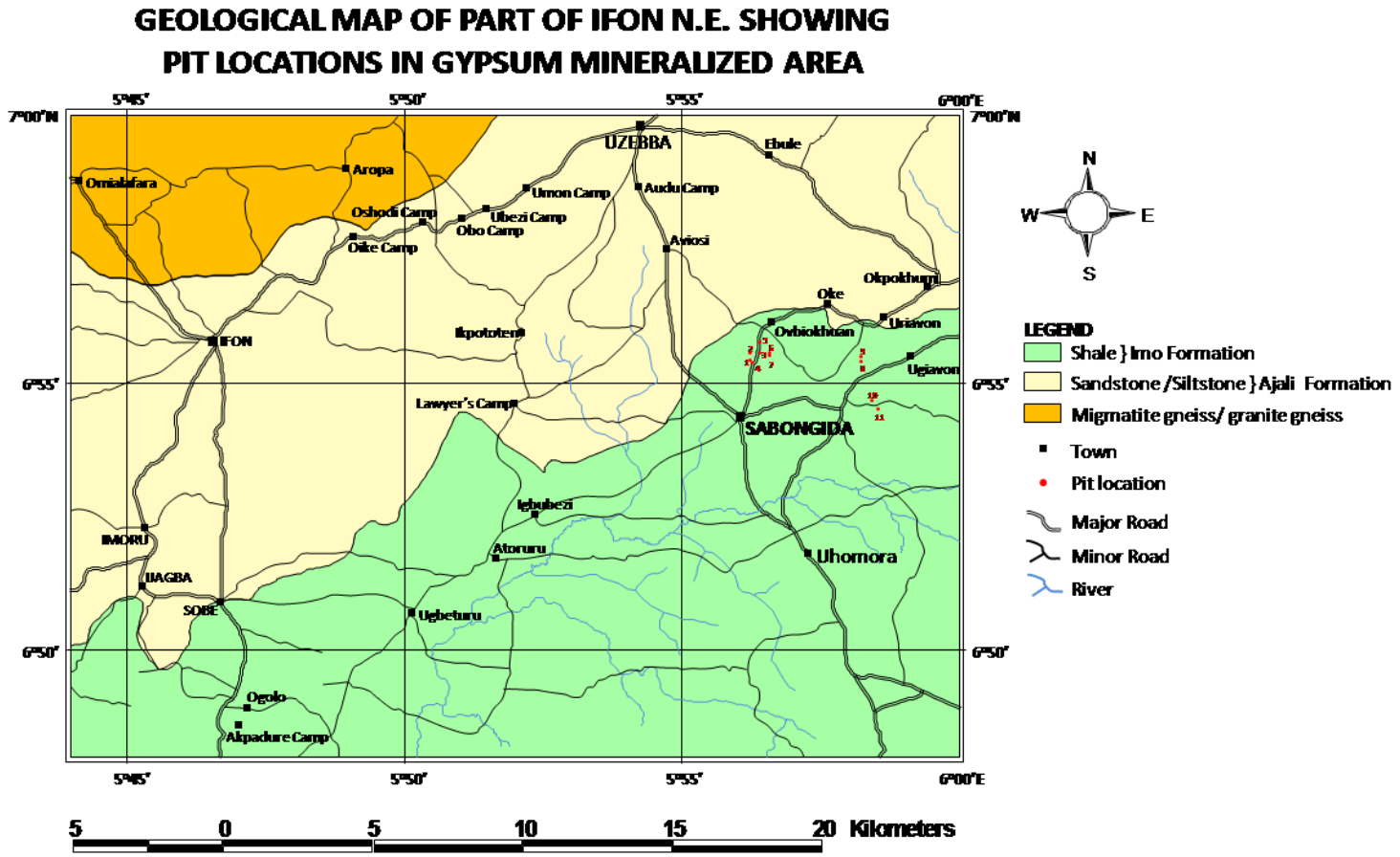


Fig. 2: Geological map of part of 1: 50,000 Sheet 284 (Ifon N.E.) showing pit locations.

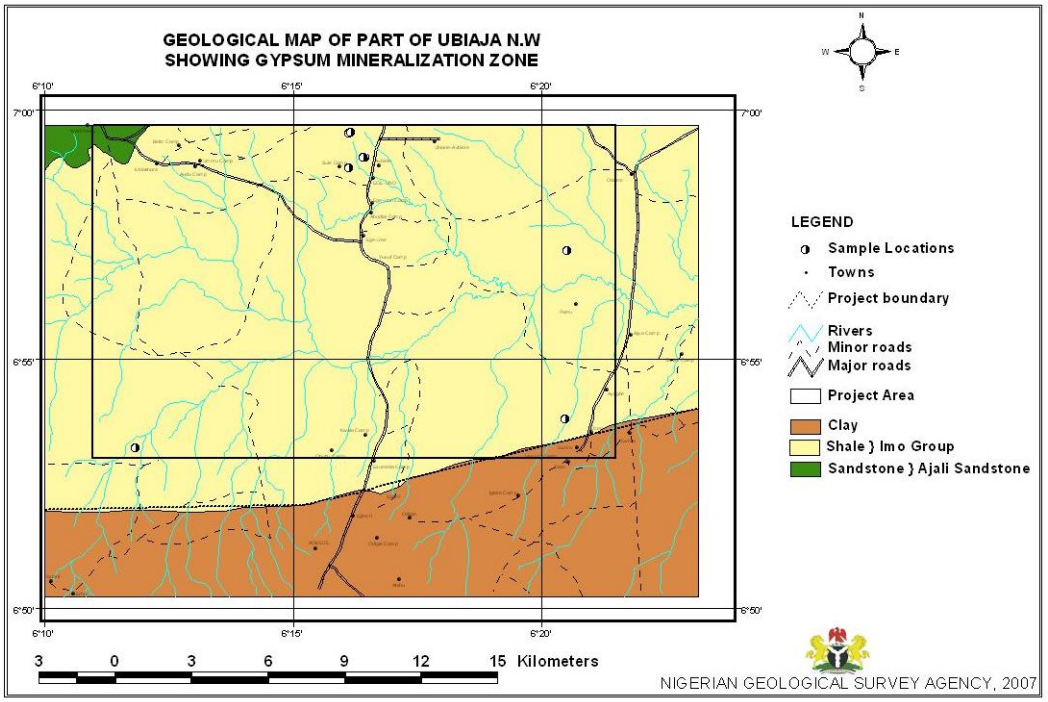


Fig. 3: Geological map of 1: 50,000 Sheet 284 (Ubiaja) showing pit locations.

GEOMORPHOLOGY/PEOPLE

The gypsum mineralization zone is low-lying and general characterized by flat to gently undulating peneplain. Physical features include rivers, ponds and swamps mostly in the southern part as well as the hilly terrain at Uzebba and at R. Aguba near Ogbonna in the northern areas. The hill at Uzebba consists of silty shale with occasional intercalations of ironstone (Fig. 4) and is located at the border of gypsum mineralization area, close to the boundary of Anambra Basin with the Basement Complex.

Major rivers in the area include Rivers Owan, Orle, Iguenviyoba etc. Areas around Afuze, Warake and Aviele are perennially swampy or flooded during the raining season. The area is inhabited by the Afemai/Etsako people in Owan/Etsako Local Government Areas while the Binis are in Ovia East Local Government Areas. Their occupation is mainly farming, lumbering and trading.



Fig. 4: A roadside hill at Uzebba consisting of silty shale - ironstone intercalations.

VEGETATION

The vegetation consists of rain forest type, typified by guinea savannah type vegetation in the northern part (Fig. 5) and closely spaced tall trees which are sparsely interspaced by overgrowth of less dense shrubs and grasses in the southern areas (Fig. 6). Trees found in the area are generally umbrella trees including iroko, mahogany, Acacia, palm and coconut trees, while food crops such as pears and banana are ubiquitous. The numerous swamps in the area are used for rice, maize, etc. cultivation.



Fig. 5: Vegetation consisting sparse trees interspaced with shrubs and grasses in a swampy gypsum mineralized area around Afuze.



Fig. 6: Thick vegetation consisting of tall trees in gypsum mineralized area around Sabongida-Ora.

PREVIOUS WORK

According to the work of Jones and Hockey (1964), thin layers and lenses of gypsum occurs within the Imo shale. The Nigerian Geological Survey at different times spanning between 1983 and 1987 also mapped the area on different scales of 1: 2,000,000, 1:100,000 and 1: 50,000, which also indicated occurrences of gypsum mineralization around Sabongida-Ora and Eme-Ora areas. The Nigerian Mining Corporation in 1977 similarly located exploratory pits in this area which revealed the occurrence of gypsum at Ovbiokhuan near Sabongida Ora, Aviele-Ubiane near Auchi, etc, but the pits have since collapsed and therefore are no longer accessible.

Oyeka (1973) also did some work on the gypsum and stated that it occurs in two layers. He recommended that pitting method be employed in further investigations because the auger machine used during his investigation could not penetrate 'stones' (hard pan) encountered in the course of drilling. These 'stones' are suspected by this investigation as belonging to the coarse lateritic layer just below the topsoil and/or the indurated ferruginized calcareous marker bands/layers overlying the shale beds (Figs. 10a). The abandoned previously dug pits have become covered and obscured, thus this project was therefore started afresh to access the gypsum.

The host shale belongs to the Imo Group which was described as being typically dark, very thinly laminated, fissile and contains abundant pyrite crystals but poorly fossiliferous (Wilson 1925, Wilson and Bain 1925). Adegoke (1981) stated that X-ray

and petrographic studies revealed the identical nature of Imo shale and Akinbo Formation in the Dahomey Basin, while Idowu et. al (2002), suggested they should be regarded as lateral equivalents (Table 1).

Table 1: Stratigraphic Sequence in Southern Nigeria Basin
(After Kogbe 1976, Ene et. al 1980, Idowu et. al 2002)

Jones and Hockey (1964)	Fayose (1970)	Present work	Omatsola and Adegoke (1981)
Age	Western Nigeria (Kogbe ,1976)	Western Nigeria	Eastern Nigeria (Kogbe ,1976)
Eocene	Ameki Formation Ilaro Formation Oshosun Formation	Unit 3 (in part)	Ameki Formation Lateral equivalent (Nanka Sand)
Palaeocene	Akinbo Formation Ewekoro Formation	Unit 2	Imo Formation
Maastrichtian	Abeokuta Formation		Nsukka Formation
? Older than Maastrichtian			

METHODOLOGY

The method employed for this investigation was mapping, pitting, logging, correlation of rock units, laboratory studies and geochemical analysis. Mapping was carried out on a scale of 1: 50,000 in the area which was divided on a grid of 200m x 300m. A total of sixteen (16) exploratory pits were dug; eleven (11) in Sabongida-Ora, three (3) each in Aviele and Okada areas and one (1) in Afuze area. Pitting is considered the cheapest method as it facilitates in-situ observation of the lithologies encountered in each pit dug. This may not be possible with core drilling method which often compresses the shale unit as the bit head penetrates the rocks. Pitting method was also advocated by Oyeka (1973) for the currently investigated gypsum mineralization areas.

Equipments used included compass, Global Positioning System (GPS), measuring tape, weight measuring machine, shovels, diggers, buckets, ropes, sample bags and permanent markers. For the purpose of this study, the area was divided into

three (3) segments namely Sabongida-Ora, Aviele and Okada areas, for ease of data management. Pits were located using Brunton compass and global positioning system (GPS).

One of the previously dug pit with proven gypsum occurrence, served as commencement point while other pits were located at about 150m to 200m intervals around it. A total number of sixteen (16) exploratory pits were dug for the gypsum investigation in Sabongida-Ora and nearby towns. These pits were dug to depths ranging 4 to 5m. The pits were carefully logged and correlated while representative samples of the different lithologic layers and mineralizations in each dug pit were collected. Samples were stored in well labeled sample bags, sorted out and forwarded to the laboratory for compositional analyses. Digital photographs of mineralized zones were taken in the field to aid interpretations. Apart from the pits dug during this present study, twenty two (22) abandoned old pits dug by earlier workers were found in the areas, most of which had caved in and are obscure.

LITHOSTRATIGRAPHIC CORRELATION

The stratigraphy is the same in all the pits dug except for variation in mottling of clay or shale layers due to differential ferruginization. The general stratigraphy in the area from bottom to top consists of very dark grey shale, grey shale, clay ironstone (hardpan), brown clay shale, reddish brown clay and capped by the clay with ferruginous grits. The lithostratigraphy is shown below (Figs. 7 and 8):

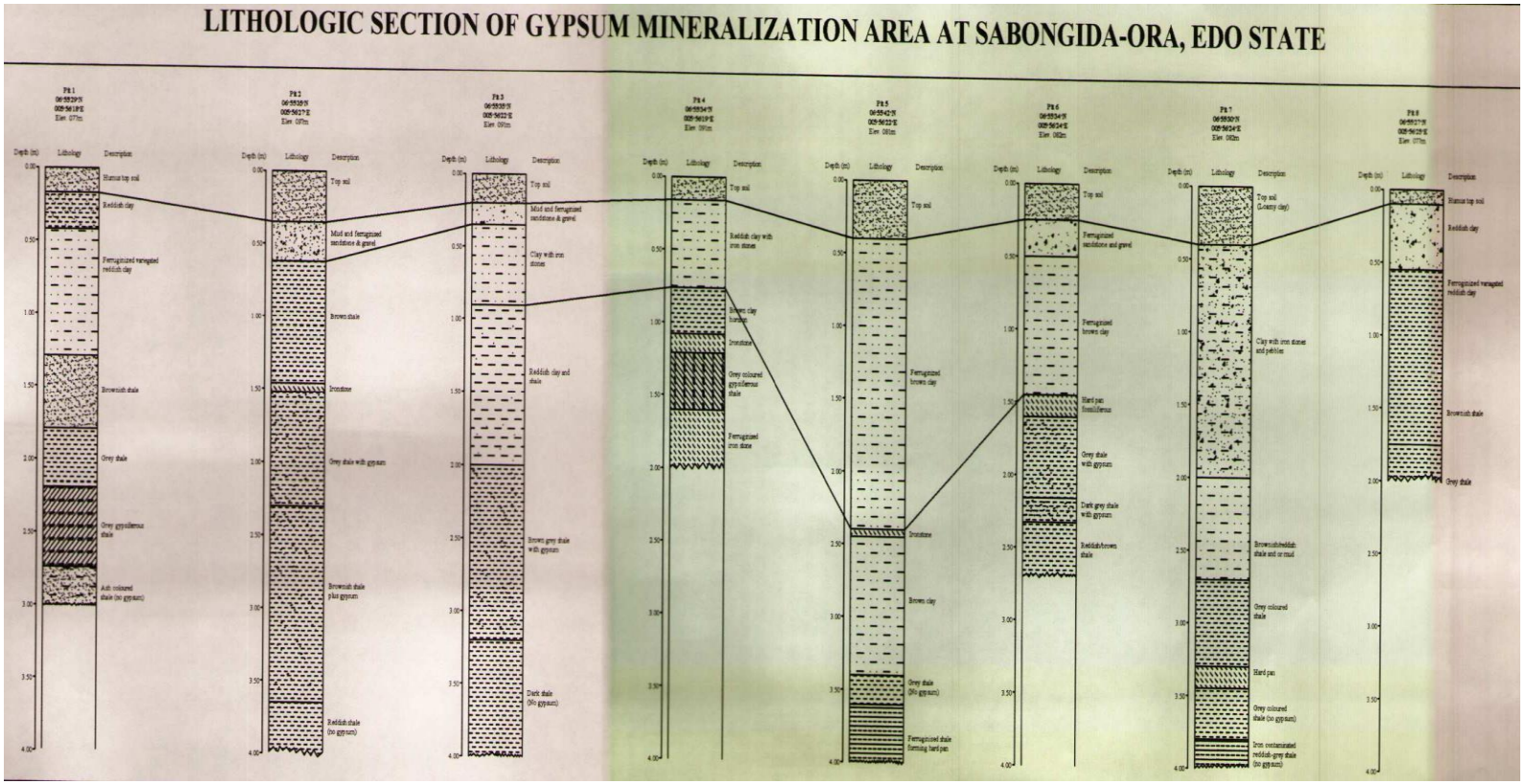


Fig. 7: Lithostratigraphic correlation of exploratory pits around Sabongida-Ora.

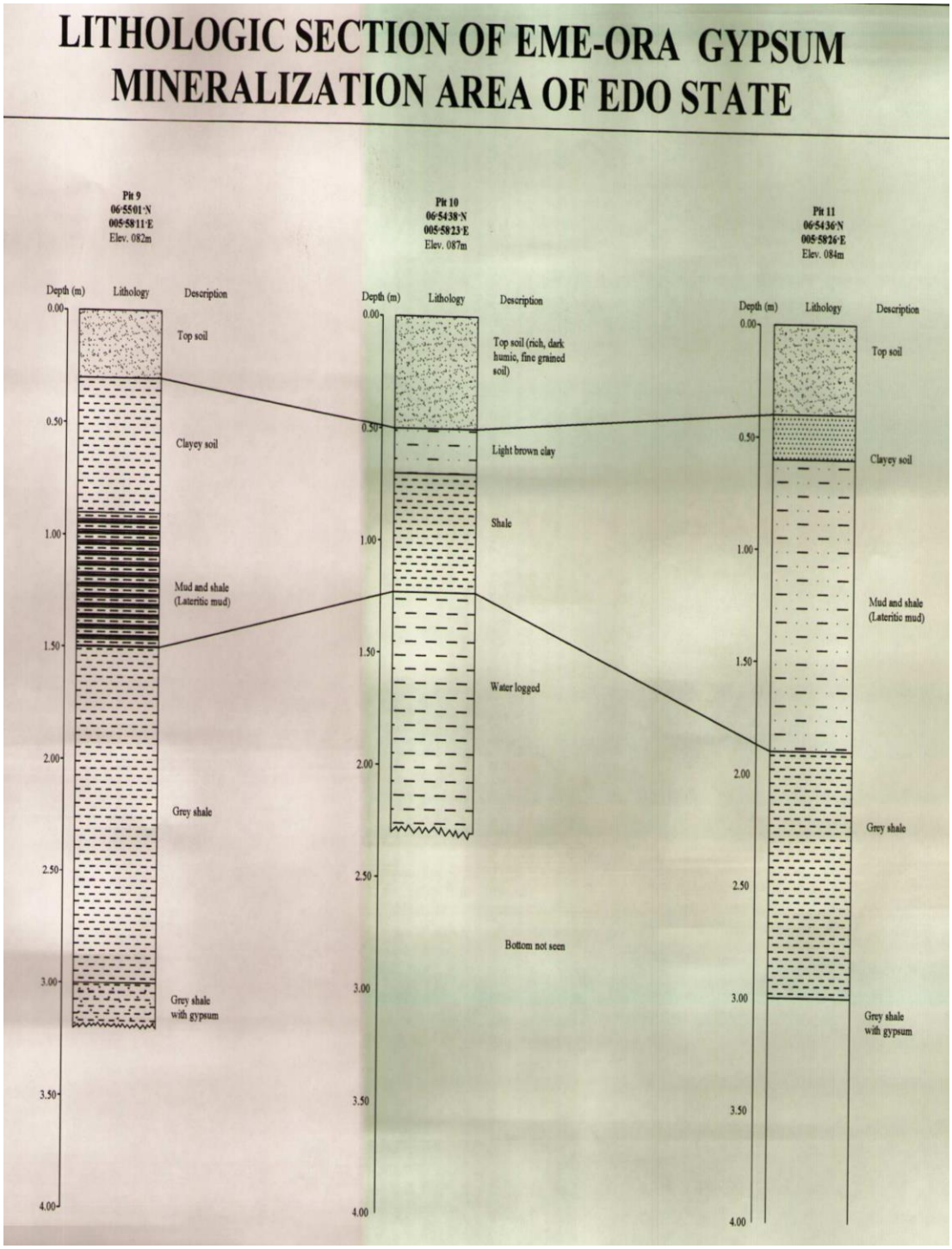


Fig. 8: Lithostratigraphic correlation of exploratory pits around Okada area.

LITHOSTRATIGRAPHIC DESCRIPTION

(a) Dark grey Shale

Very dark grey shale is the lowermost layer occurring approximately at a depth of 3.5m around Sabongida-Ora and Okada areas. It is black or dark grey in colour, compact, non-fissile and non-gypsiferrous. The dark grey colour is due to its high organic matter content and proximity to the coal layers.

(b) Grey Shale

Grey shale overlies the dark grey shale. It is grey or greenish grey in colour, laminated, fissile and contains layers and veins of gypsum. The first gypsiferrous layer was encountered at a depth of 7ft with strike of 103°, dipping 16° southwesterly in Pit 6 and it is separated from the next underlying gypsum layer by a shale bed with an average thickness of about 25cm. The gypsum bed consists of the selenite (transparent) variety (Fig. 9 and 10a) while the intervening layers within the shale layers contain cross-cutting veins and gypsum-filled fractures occurring as disseminated granular (sandy) variety called gypsite or satinspar.

The veins are about 0.2 – 6.0cm wide which appear to originates from the lower horizontal gypsum bed and thins out into the intervening shale above, just below the upper gypsum bed. In some dug pits, the grey shale layer is overlain by hard calcareous clayey ironstone bed referred to as hardpan which varies in thickness from 5cm – 15cm.

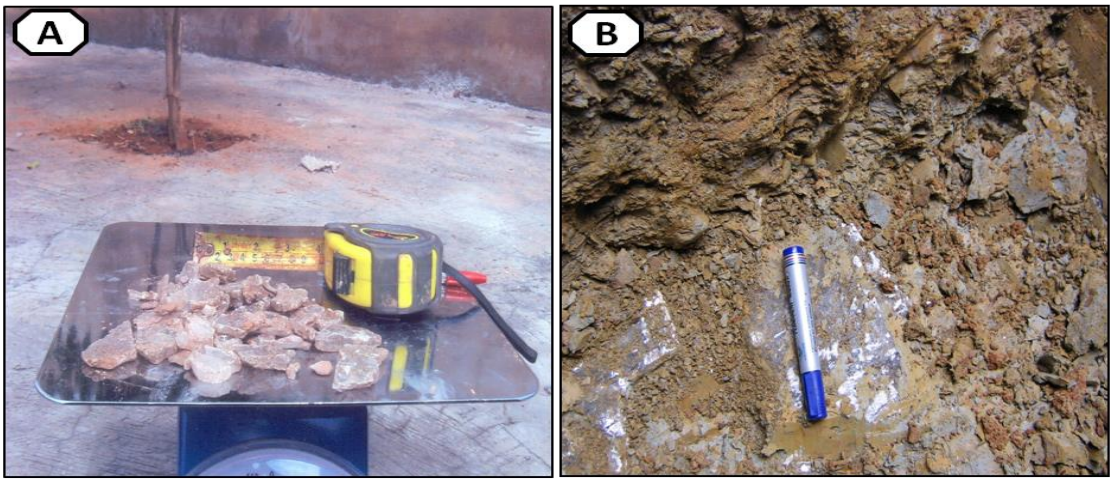


Fig. 9: (a) Gypsum obtained from Aviele and (b) gypsum lamina with dipping attitude within grey shale at Sabongida-Ora

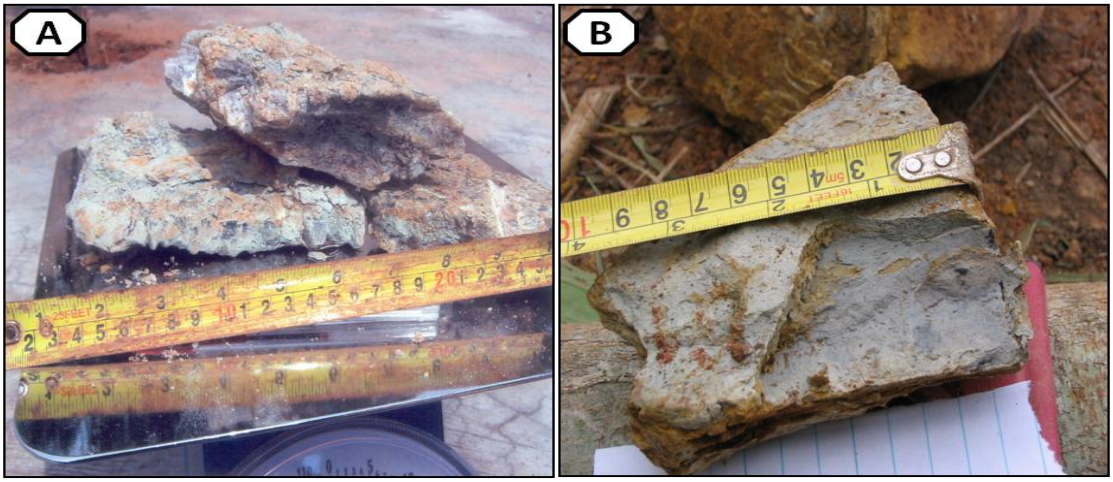


Fig. 10: (a) Gypsum obtained from a pit in Sabongida-Ora, (b) Ferruginous ironstone (Hardpan) overlying the gypsum layer.

(c) Brownish Clay shale

Brownish clay shale overlies the grey shale and its thickness varies from 0.3 - 300m thick. It is brown coloured, slightly fissile and contains lenses of gypsum in veins, veinlets and fracture fillings particularly below the calcareous hardpan. The gypsum here occurs as fracture filling of interspaces within mud cracks (Fig. 11).

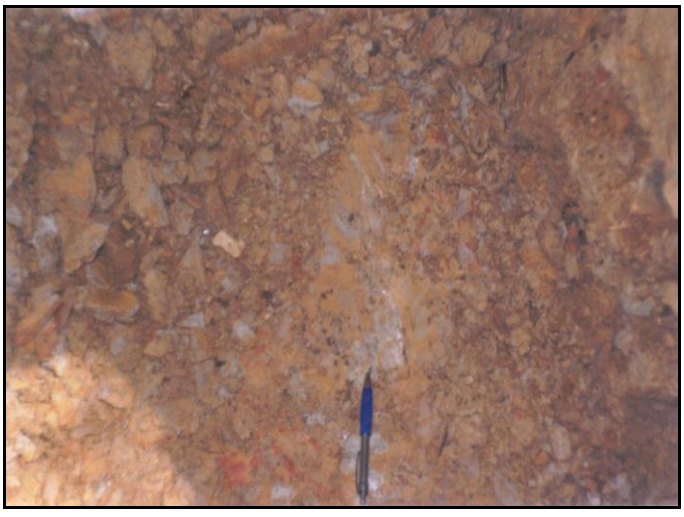


Fig. 11: Gypsum veins and fracture fillings within the brownish clay.

(d) Reddish brown Clay

Reddish brown clay overlies the brownish clay. It is reddish brown in colour, mottled (Fig. 12), massive and gypsiferrous, containing poorly developed granular gypsum crystals disseminated within the clay-shale as gypsite or satinspar (Fig. 13).

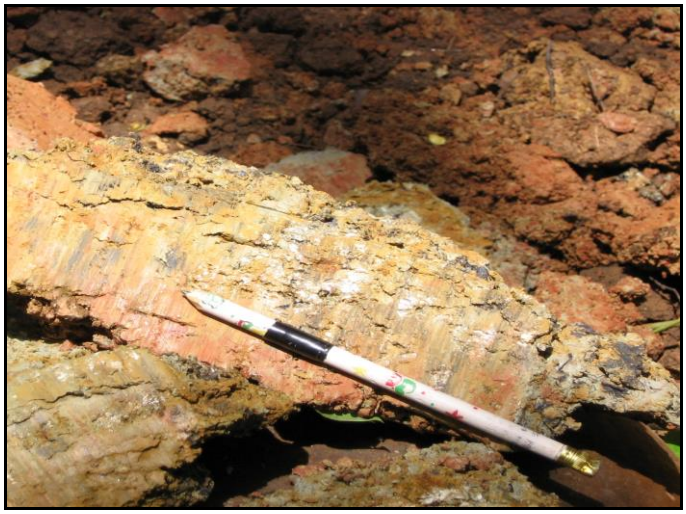


Fig. 12: Mottled reddish brown clay overlying the brownish clay in Sabongida-Ora area.



Fig. 13: Gypsum granules disseminated within reddish brown (mottled) shale.

(e) Clay

Clay, partly conglomeratic, underlies the topsoil at Eme-Ora. The clay is grey coloured, plastic and may contain brown or mottled spots in varying proportions. It`s thickness ranges from 1.0m to 2.0m at Sabongida-Ora to 3.0m at Eme-Ora. The mottled clay horizon is a zone where the clay is undergoing differential ferruginization, leaching out of ferrous (Fe^{2+}) to ferric ions (Fe^{3+}). The brown portion (lateritic clay) may be suitable for brick making.

(f) Clay with ferruginous grits and pebbles

The top humus soil overlies the mottled clay layer which consists of ferruginous grits, sandstone and pebbles of various sizes. This horizon may be light brown, reddish brown or grey in colour and ranges in thickness from 0.5 - 2.0m. It may be plastic and the pebbles vary in sizes from <0.5cm to 2.0 cm in diameter. They are rounded to subrounded and range in composition from quartz, reworked calcareous pebbles, ferruginous grits, etc (Fig. 14). This unit is believed to have been deposited in agitated condition due to changes in palaeoslope and is undergoing lateralization due to its proximity to the surface. This unit and the calcareous ironstone layers are the layers described by Oyeka as ‘stones’ that could not be penetrated by the auger drilling machine, thereby preventing conclusion of their investigation.



Fig. 14: A horizon of clay with ferruginous grits and pebbles.

CALCULATION OF INFERRED TONNAGE RESERVE ESTIMATE

At most of the pits where gypsum was observed, it started showing at a depth of about 2m and is often restricted within a 2.0m thickness. The reserve estimate calculation has been based on the areal extent of pits dug, weight of gypsum (Fig. 15), thickness of gypsiferrous layer and projected over the mineralization area.

The formula used is:-

$$\frac{\text{Weight of gypsum}}{\text{Weight of bulk material}} \times \frac{100}{1} = \%\ \text{gypsum}$$

% gypsum x thickness x area of influence x specific gravity = Estimated resource of gypsum.



Fig. 15: Weighing of gypsum at Sabongida-Ora.

Pit 1

Depth to gypsiferous layer =2.2m

Depth to bottom of layer =2.75m

Thickness of horizon = 2.75 – 2.2 = 0.55m

Wt of headpan = 2kg

Wt of headpan + shale + gypsum = 37.3kg

Wt of headpan + gypsum = 2.1kg

Wt of gypsum = 0.1kg

Wt of shale in headpan = 35.2.kg

Wt of gypsum and shale in one headpan =35.2 + 0.1kq =35.3kg

(1m³ = 48 Head pans of shale + gypsum)

Wt of gypsum + shale in 1m³ is = 35.3 x48 (headpan) =1694.4kg.

Wt of gypsum in $1m^3$ = 0.1 x 48 = 4.8kg
% wt gypsum = 4.8/1694.4 x 100/1 = 0.28%
Thickness sampled = 0.55m
Amount of gypsum observed = 4.8 x 0.28 x 10000 x 0.55 = 73920 kg
= **73.92 tonnes**

Pit 2
Depth to gypsum/shale =1.65m
Depth to bottom of gypsum/shale = 3.5m
Thickness of gypsum / shale = 1.85m
Wt of head pan = 2kg
Wt of pan + shale + gypsum =32.5kg
Wt of pan + gypsum = 3.5kg
Wt of shale + gypsum = 30.5kg
Wt of gypsum = 3.5 – 2 = 1.5kg
Wt of gypsum + shale in $1m^3$ = 30.5 x 48 = 1464kg
Wt of gypsum in $1m^3$ = 1.5 x 48 = 72kg
% of gypsum in $1m^3$ = 72/1464 x 100/1 = 4.9%

At a depth of 2.2m another measurement was taken
Wt of gypsum + shale = 26.8 kg
Wt of gypsum = 0.45kg
(48 head pan = $1m^3$ of shale + gypsum)
Wt of gypsum in $1m^3$ = 0.45 x 48 = 21.6kg
Wt of gypsum + shale in $1m^3$ = 26.8 x 48 = 1286.4
% of gypsum in $1m^3$ = 21.6/1286.4 x 100/1 = 1.68%
Average percentage of gypsum = 1.68 + 4.9/2 =3.29%
Average wt of gypsum in $1m^3$ = (21.6 + 72)/2 =46.8kg
Thickness of samples = 1.85m
Area of influence = 10,000 m
Amount of gypsum available = 46.8 x 3.29 x 1.85 x 10 000 = 284,848.2 Kg
Amount of gypsum in tonnes = **284.85 tonnes**

Pit 6
Depth to bottom of gypsum / shale = 3.7m
Thickness sampled = 2.05m
Wt of pan + shale + gypsum = 30kg

Wt of pan + gypsum = 5.5kg
Wt of shale + gypsum = 30 – 2 = 28kg
Wt of gypsum = 5.5 – 2 = 3.5kg
Wt of shale + gypsum in $1m^3$ = 28 x 48 = 1,344 kg
Wt of gypsum in $1m^3$ = 3.5 x 48 = 168 kg
Percentage of gypsum = 168/1344 x 100/1 = 12.5%
Thickness sampled = 2. 05m
Area of influence = $10,000m^2$
Amount of gypsum = 168 x 10,000 x 12.5 x 2.05 = 43,050,000 kg
Amount in tonnes = 43,050,000/1,000 = **43,050 tonnes**

Taking pits 1, 2, and 6 as representative of the area, then average amount of gypsum available = (43,050 + 73.92 +284.85)/3

= 43,408.77/3 = **14,469.59 metric tonnes**.

This is the inferred amount of gypsum reserve in tonnage at the Oke – Ora area of Edo state.

Therefore for study area of 4km by 1.5km = 6,000,000 m^2
The gypsum reserve estimate for the study area
= (14,469.59 x 6,000,000)/10,000 metric tonnes
= **8,681,754 metric tonnes**

This gypsum reserve estimate calculation is conservative as gypsum occurrence in lenses and the gypsum contained within fractures and veins in between the shale layers were not included in the calculation.

MINERALOGY

The type of clay is attalpulgite ($2MgO_3SiO_2.4H_2O$ - $Al_2O_3.5Si_2.6H_2O$), one of the minerals making up the palygorskite group of clay minerals, the constituent of fullers earth. Gypsum occurs in form of selenite or satinspar or gypsite. The mineralogy of the gypsum, as determined from the petrographic studies gave the photomicrographs presented in Figures 16, 17, 18 and 19.

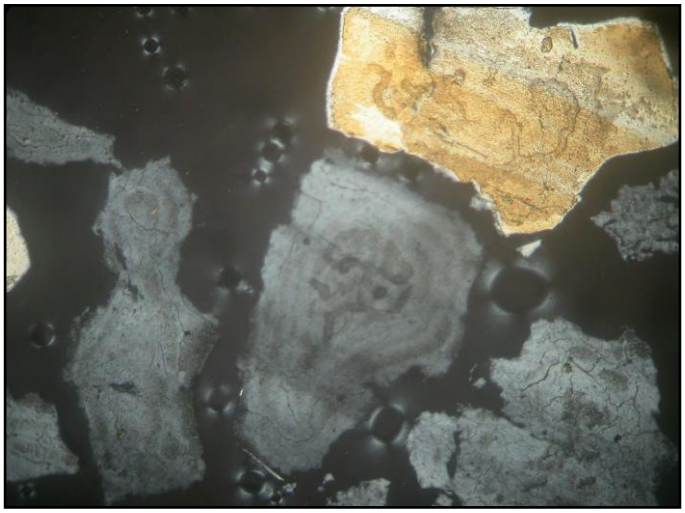


Fig. 16: Photomicrograph of dispersed gypsum crystals (Mag. = X 40)

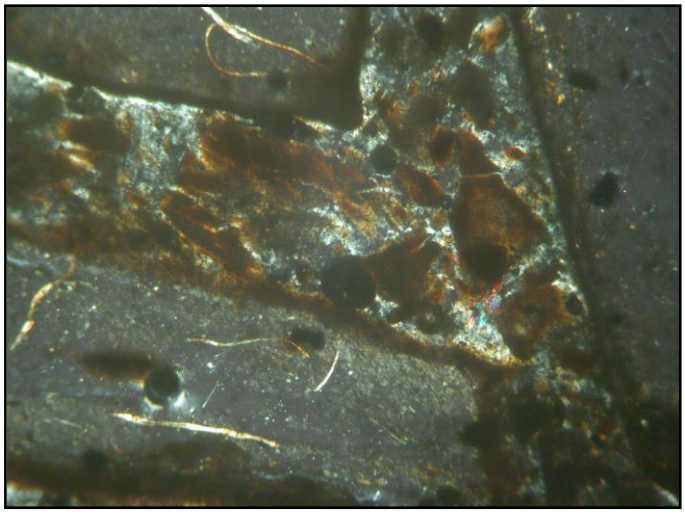


Fig.17: Photomicrograph of lath shaped gypsum crystals (Mag. = X 40)

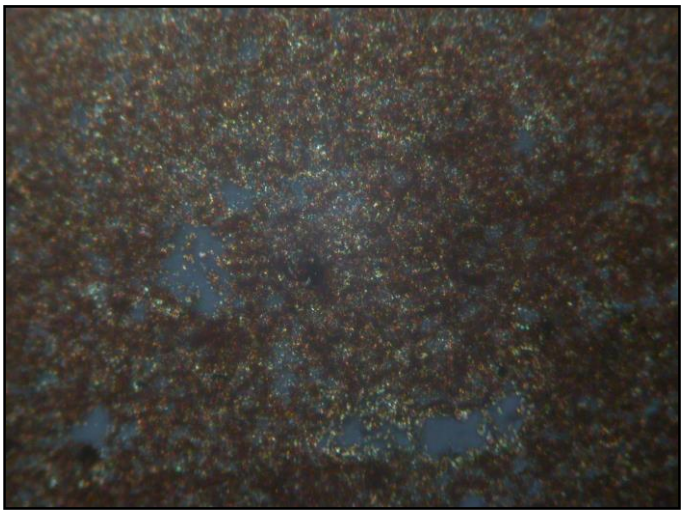


Fig. 18: Photomicrograph of clay ironstone showing siderite spherules (Mag. = x 40).

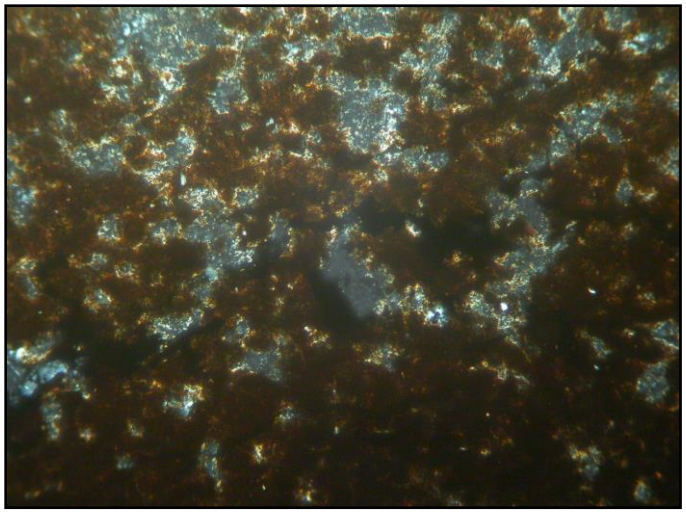


Fig. 19: Photomicrograph of clay ironstone showing siderite spherules (Mag. = X40).

STRUCTURE

The structures observed were beddings plains, laminations, and mud cracks/fractures (filled with gypsum). The area has a general slope from north to the coastal area in the south. This gently sloping peneplain is dotted with prominent hills of siltstone containing ironstone intercalations at Uzebba and around the sediment-

Basement contact. No gypsum was obtained from Uzebba but a yellowish pseudomorph of the cobweb-like weathered product was observed to be covering the Uzebba siltstone.

LABORATORY ANALYSIS

Sampling /Analysis.

A total of forty nine (49) samples were forwarded for geochemical analysis, out of which ten (10) of gypsum and grey shale samples were analyzed for 12 major oxides and seven (7) samples for 6 trace elements. The results are shown in tables 2 and 3 as well as Figures 20 and 21.

Table 2: Results of geochemical analysis of ten samples for major oxides

	FC01	**FC02**	**FC03**	**FC04**	**FC05**	**FC06**	**FC07**	**FCO8**	**FC 09**	**FC10**	**Total**
	S/Ora	S/Ora	S/Ora	S/Ora	S/Ora	S/Ora	S/Ora	S/Ora	Aviele	Aviele	
SiO_2	19.34	18.96	11.82	10.62	13.15	5.75	11.21	1.89	1.46	1.85	96.05
Al_2O_3	7.66	11.23	4.52	3.98	5.48	2.42	2.45	0.63	0.49	0.62	39.48
Fe_2O_3	3.19	4.27	1.38	1.39	1.43	1.12	2.09	0.15	0.23	0.21	15.46
MgO	0.72	1.08	0.38	0.33	0.42	0.23	0.58	0.05	0.05	0.07	3.91
CaO	20.88	14.71	27.07	27.4	25.68	29.45	45.95	33.1	33.49	32.34	300.07
Na_2O	0.02	0.03	0.01	0.01	0.02	0.02	<0.22	<0.01	<0.01	<0.01	0.36
K_2O	0.82	1.24	0.41	0.34	0.43	0.2	0.16	0.04	0.04	0.04	3.72
TiO_2	0.45	0.06	0.39	0.27	0.32	0.14	0.1	0.05	0.04	0.05	1.77
P_2O_5	0.029	0.028	0.024	0.026	0.023	<0.01	0.285 s	<0.01	0.02	0.02	0.466
MnO	0.05	0.07	<.01	0.01	<0.01	<0.01	0.28	0.05	0.04	0.02	0.55
LOI	18.8	17.7	20.2	2o.01	20.7	21.5	35.42	19.8	19.3	19.4	215.23
SO_3	27.59	33.4	33.89	54.48	32.3	39.16	1.77	44.55	44.85	45.20	357.19
Sum	99.55	115.18	100.04	118.87	99.96	100.01	100.52	100.33	100.02	99.83	
$CaSO_4.2H_2O$	86.07	78.21	81.16	101.93	86.34	66.62	125.92	97.40	97.64	96.94	918.19

Result of analysis for trace elements

Analytical instrumentation: Whole rock analysis, 0.2g sample fused with $LiBO_4/LiB_4O_7$ and analyzed by the ICP-ES method.

Table 3: Results of geochemical analysis of seven sample for trace elements.

Analyte	Ba	Ni	Sr	Zr	Y	Sc	Total C	Total S
Unit	Ppm	ppm	Ppm	ppm	ppm	Ppm	%	%
FC 01	66	29	113	81	15	70.05	10.94	
FC 02	82	48	113	119	22	10	0.05	8.25
FC 03	28	<20	137	59	6	4	0.06	14.15
FC 04	48	<20	136	65	8	3	0.07	11.82
FC 05	58	<20	290	26	4	2	0.03	15.7
FC 06	53	<20	290	26	4	2	0.03	15.7
FC 07	87	20	383	34	49	24	10.34	0.71

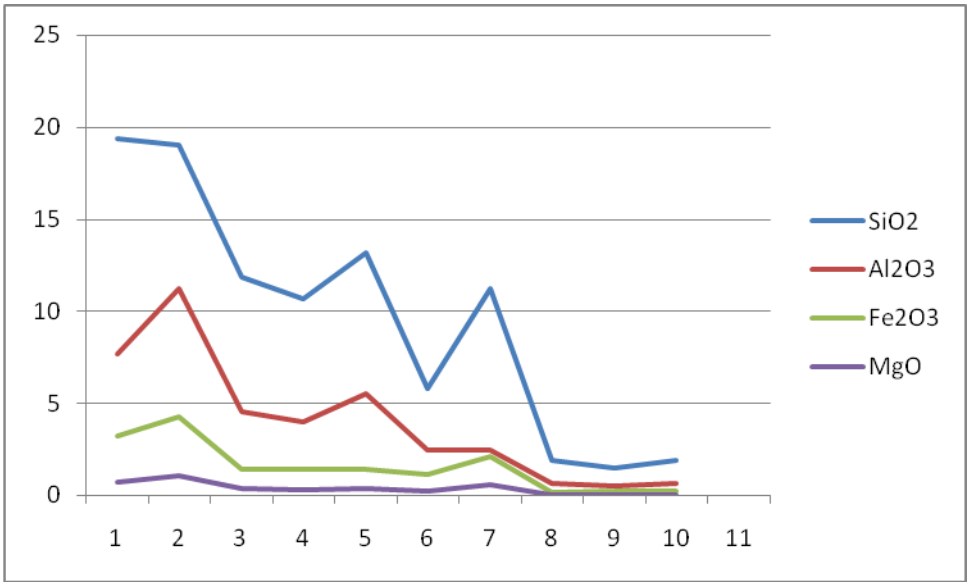


Fig. 20: A graphic compositional variation of four major oxides in ten selected samples.

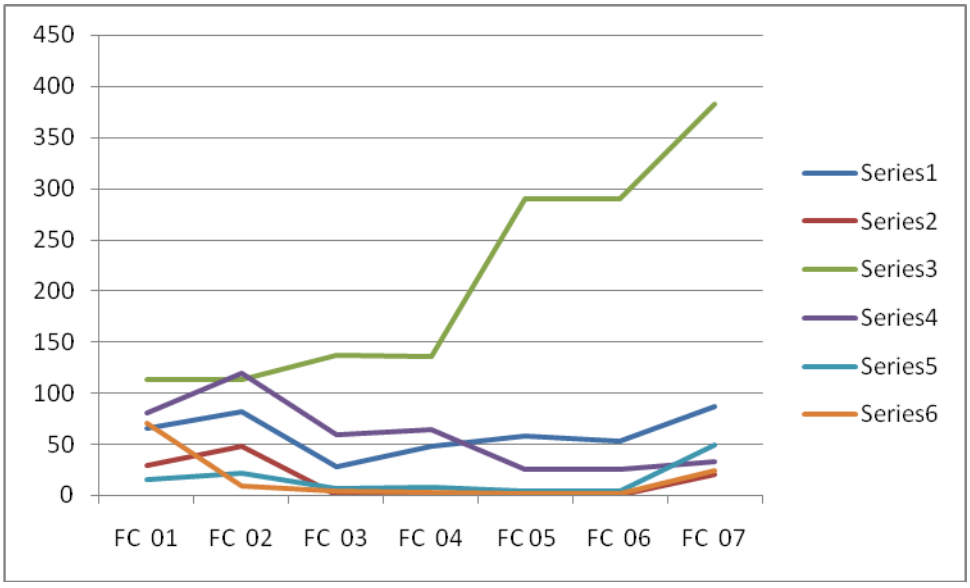


Fig. 21: A graphic compositional variation of six trace elements in seven selected samples.

LABORATORY ANALYSIS INTERPRETATION

The result of the geochemical analysis indicates that Barium (Ba) and Strontium (Sr) have appreciable values but all the values are generally less than 1000 ppm; therefore is low for all the trace elements and hence the impurities. Using Eckel (1922)

method who used the formula $CaO+SO_3+H_2O$ = weight of $CaSO_4.H_2O$ (gypsum). The average weight of 97.4% obtained indicate that the gypsum in Aviele is similar to that of Ewekoro which has > 90% (Elueze,1977) and Adoka gypsum from the middle Benue trough with 88.4% (Elueze, 1977). It is also higher than the imported gypsum from Morocco has 71.0 % (pers. comm. - Adekanmi, M. O).

GENETIC MODELS COMPARED WITH OCCURRENCES ELSEWHERE

A well established mode of formation of gypsum deposits worldwide is that idealized by Branson (1915) in which a brine filled basin having restricted circulation which permits limited replenishment of the brine as precipitation takes. The resulting concentration causes precipitation of the contained salts in the inverse of their solubility. An example of such deposit is the – A subzone of the Mississipian Windsor series of Canada. This type of deposition is also characteristic of present day formation of gypsum and anhydrite in Piano de Saleh in Eritrea. Piano de Saleh is perhaps the hottest known spot in the world today. A second mode of gypsum formation may be due to precipitation in spaces as ground water carrying sulphate ions from oxidation of sulfides, comes into contact with carbonate rocks.

A third but less understood mode of formation is that of Butler (1970) in which gypsum and anhydrite are precipitated in pre-existing sedimentary sequence of principally lagoonal limestone and intertidal algal limestone. The original sediment of calcium carbonate becomes dolomitized and the clastic sediments are unaffected chemically but become contorted and distorted as the gypsum crystals and anhydrite nodules grow in and around them. This type of deposit does not require an enclosed basin. The sabkha deposit in the Trucial coast of Arabia is an example of this.

The gypsum deposits in Nigeria are similar to Edo gypsum occurring as disseminations in shale and are diagenetic in origin. The concordant nature of the bedding planes of the gypsum layers with the bedding planes of the grey shale in the second gypsiferous layer of Edo gypsum suggests a combination of sabkha and diagenetic origins for Edo gypsum. Crystals of >5mm in diameter were obtained in pit 6 around Sabongida-Ora. Nigerian gypsum has low tonnage, and therefore cannot sustain the demand of large industries. However, small scale miners can thrive on them.

CONCLUSION

With an inferred tonnage value of less than 20,000 metric tonnes, the gypsum deposit at Ora cannot meaningfully support large industry. However, small scale

artisanal miners can thrive on it for the production of chalk, paint, etc. Aviele area appeared to be more promising but its tonnage and reserve estimate could not be established because the area was completely water-logged as at the time of this investigation. Some of these areas are only about 200m above sea level and are easily susceptible to perennial flooding particularly during the raining season. Entry was refused into Warake by the local Chiefs and Elders in council while Wepa area in Agenebode area is under dispute, and therefore could not be investigated for gypsum deposits. The determination of the tonnage in these promising areas will certainly boost the tonnage of gypsum in Edo State.

RECOMMENDATIONS

It is hoped that the outcome of this project has provided enough data and information on phosphate and gypsum deposits in Edo State for the would-be investors and Governmental planning. But in view of the aforementioned difficulties and challenges, however, the following recommendations are suggested:

1. At least two weeks reconnaissance/community liaison should be carried out before the commencement of the project. This will reduce, to the barest minimum, the time spent on such activities during project execution;
2. That core drilling be carried out at Aviele and Agenebode areas as hand-dug pit could not get to the maximum depth of the deposit;

ACKNOWLEDGEMENT

The team sincerely thanks the Director General of Nigerian Geological Survey Agency, Prof. Siyan Malomo for the opportunity to carry out this study. Our sincere appreciation goes to all the Directors of NGSA in particular Mr. E. O. Ayoade for his constructive criticism and supervision of this work. Similar gratitude also goes to the immediate past Director of Economic Geology Department, Mr. O. Ogedengbe for initiating the project. The external resource person, Dr. R. B. Bale is also worthy of high appreciation for his contributions. Also worthy of mentioning here for appreciation are Chief Igbinedion, Mr. Paul Odihirin, Mr. Ayo Ehimiyein and others including all the Nigerian Geological Survey Agency staff at the Headquarters who have contributed in one way or another to the success of the project.

REFERENCES

Adekanmi, M. O. (2007). Assessment of gypsum deposit in Sokoto State. NGSA Unpubl. Rpt. 61p.

Alicia, Kasprzyk and Fedenco, Orti (1998). Palaeogeographic and burial controls on anhydrite genesis in the Badenian basin. Inter. Assoc. of Sedimentologist (1998), 26 pp 235-240.

Appleyard, C. F. (1975). Gypsum and anhydrite. In: Leford, S. J. (Ed.). Industrial minerals and rocks, 4th Edition.

Branson, E. B. (1915). Origin of thick gypsum and salt deposits. In Inter. Assoc. of Sedimentologist (1998). pp 148-167.

Butler, G. P. (1970). Holocene gypsum and anhydrite of the Abu Dhabi Sabkha Trucial Coast. An alternative explanation of origin. Vol. 1, 120p.

Ejoro, I. Oloto, Odukoya, O. O. et al. (1979). Further phosphate investigation in southwest Nigeria. Phase 1, Geol. Surv. of Nig. Unpubl. Rept. pp 56-60.

Journal of Mining and Geology Vol. 41 No.2 Sept. 2005, pp 175-180.

Kendall, A. C. and Harwood, G. M. (1960). Marine Evaporites and Shorelines and Basins. In Sedimentary environments, processes, facies and stratigraphy (E. H. G. Reading, pp 281-34. Blackwell, Oxford).

Kogbe, C. A. (1975). Palaeogeographic history of Nigeria from Albian Times. In: Geology of Nigeria, pp 257-269. Rock view (Nigeria) Limited, Jos, Nigeria.

Mohammed El Tabalch et al. (1997). Evolution of late Triassic rift basin evaporates (Passai Formation) Newart Basin, Eastern North America Sedimentology, 44, pp 767-790.

Nigerian Mining Corporation, Jos (1993). Exploration for Gypsum in Nigeria.

Nton, M. E. and Elueze A. A. (2005). Compositional characteristics and industrial assessment of sedimentary clay beds in part of eastern Dahomey basin, southwestern Nigeria. ISSN pp 1116-2775.

Oyeka, A. N. (1999). Summary of known mineral resources of Edo State. Unpublished report, Geol. Surv. of Nigeria.

Philip, Kearey (1996). The New Penguin Dictionary of Geology. Penguin group. 165p.

Robertson Handford, C. (1982). Sedimentology and Evaporite genesis in a Holocene Continual-Sabkha playa basin, Bristol Dry Lake, California. Inter. Assoc. of Sedimentologists (1982) 29. pp 239-253.

Warren, J. K. (1991). Sulphate dominated sea-marginal and plant form evaporitic settings: Sabkhas and mud flats and saltems. In: Evaporites, Petroleum and Mineral Resource (Ed. J. J. Melvin) Elsevier, Amsterdam. pp. 69-187.