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Forms And Geochemistry Of Gypsum Deposits Around Tongo, Bajoga District, Funakaye L.G.A, Gombe State, Northeastern Nigeria

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Abstract:
Tongo Is Located In Funakaye L.G.A Of Gombe State Part Of Sheet 131SE Bajoga Which Falls Within The Gongola Arm Of The Northern Benue Trough. The Tongo Area Is Underlain By Predominantly Two Rock Types, The Conacian-Santonian Marine Shales Of Fika Member Which Is Part Of The Pindiga Formation, And Campanian-Maastrichtian Continental Sandstones Of Gombe Formation. The Sandstones Overlie The Shales Uncomformably. The Gypsum Mineralization In The Area Is Hosted By The Mudstone-Shale Of The Fika Member Of The Pindiga Formation. The Gypsum Occurs Concordantly Within The Shales But Discontinuous Within The Bedding Planes; And In Some Places, Crosscutting The Bedding Planes. They Appear In The Form Of Lenses; Seams And Veinlets Which Are Few Millimeters To Centimeters Thick And The Thickness Increase With Depth. The Depth Of Occurrence Of Gypsum In The Area Ranges From Seven (7m) To Sixteen Meters (16m) As Observed From The Mines In The Study Area. Three Different Gypsum Forms Were Observed In The Area; Balatino Laminated, Satinspar And Alabaster. Samples Were Collected On The Basis Of Depth Of Emplacement, Physical Appearance, Mining Location, And Associated Rock Unit At Various Mining Sites. A Total Of 10 Representative Samples Were Analyzed For Major Oxide Geochemistry Using XRF. The Analytical Data Shows The Ranges Of Concentrations Of Silica (Sio_2) From 3.25 – 9.65 Wt. %, Alumina (Al_2O_3) 0.66 – 3.18 Wt. %, Iron Oxide (Fe_2O_3) 0.22 – 3.17 Wt. %, Lime (Cao) 27.93 – 30.29 Wt. %; Sulphite (SO_3) 37.79 - 42.06 Wt. %; Potash (K_2O) 0.09 – 0.23 Wt. % With The Average Purity (Caso4. $2H_2O$) Of 87 %. Chemical Analysis Of The Gypsum Forms Confirmed That They Are High Grade With An Average Of 87 % $Caso_4.2H_2O$ For All The Samples Analyzed. This Falls Within The 84 – 100 % ASTM Standards Which Makes Tongo Gypsum Suitable For Use In The Manufacture Of Portland Cement.

Keywords: *Tongo, Gypsum, Grade, Balatino Laminated, Satinspar And Alabaster*

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I. Introduction

Nigeria's foreign earnings has been accounted for largely by petroleum (oil and gas) (BPE, 2006), and has remained the major supporter of its economy since it was first discovered in commercial volume in 1956. The recent fall in oil price in 2015 has led to the decline of the foreign earnings of Nigeria, thus, the need to diversify the economy to other sectors. Solid mineral sector is among the most promising sectors that can provide a sustainable economy. The government is coming up with policies to achieve that. So, there is need to search for more solid mineral occurrences to help increase the reserve. Gypsum mineralization is one of the key elements for Nigeria's industrial revolution for a self-reliant and durable economy especially in the agricultural and construction industries. The cement industries, as well as chemical, ceramic, pharmaceutical, paints and many other industries in Nigeria required gypsum as one of the most important raw material for their productions. It has long been recognized that simple evaporative concentration of sea water is insufficient to produce the great thickness of evaporate salts observed in the geologic record (Haruna, 1998). Raup (1970) proposed a brine mixing hypothesis for the salt in the Paradox basin of Colorado, which closely represents the probable source of gypsiferous materials and a good depositional model for gypsum. Raup (1982) conducted an experiment by mixing two brines (sea waters) of different evaporative history with different composition and specific gravity. Where he observed that, precipitation of gypsum can occur without further loss of water by evaporation. And it occurs from the under-saturated brine. Mineralization is known to be related to specific geologic features, which exert some measure of control and determine the occurrence of mineral deposits in any environment (Ntekem 2009). Uzuakpunwa (1981); Offodile (1982); Sonnenfeld (1991) and Uma (1998) have examined explanatory framework for evaporites and emphasized the role of structure and stratigraphy in their formation, accumulation and distribution. The determining factors that influence the formation and localization of gypsum in an environment are seen as geological variables. They include geomorphic, lithologic and physicochemical variables. Assessing the impact of these geological variables using field observation of gypsum occurrences can be valuable aids to prospecting and exploration. Tongo area is located between latitudes N 10° 39′ - N 10° 46′ and longitudes E 11° 19′ - E 11° 24′ within the Gongola arm of the Northern Benue Trough, along Gombe-Potiskum road, Northeastern Nigeria. It forms part of sheet 131 Bajoga SE and covers 118.5 sq. km. Figure 1 shows the topography of the study area.

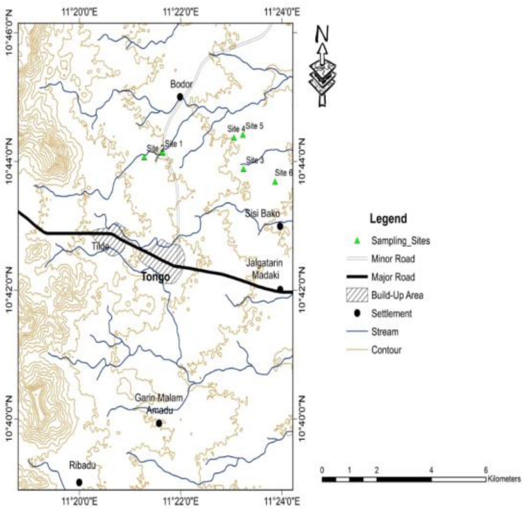


Figure 1: Topography of the study area and sample locations.

II. Regional Geology

According to Obaje (2009), the Benue Trough of Nigeria is a rift basin in West Africa that is part of a mega-rift system termed the West and Central Africa Rift System (WCARS). Other sedimentary basin within the WCARS includes the Termit Basin of Niger and Western Chad, the Bongor, Doba and Doseo Basins of Southern Chad, the Salamat Basin of Central African Republic and the Muglad Basin of Sudan (Figure 2). The origin and tectonic history of the Benue Trough and the entire WCARS is associated with the separation of Africa and South America (break-up of Gondwanaland) during the early Cretaceous time (Benkhelil,1989). This break-up was followed by the drifting apart of these continents, the opening of the South Atlantic and the growth of the Mid-Atlantic ridge (Benkhelil, 1989). The mechanism responsible for the origin and evolution of the Benue Trough is controversial. Several mechanisms have been proposed based on the rift system. The trough is considered to be a third arm of a triple junction beneath the present day Niger Delta. The earliest model given by King (1950) proposed tensional movements resulting in a rift as the controlling factor and this was subsequently supported by Carter *et al.* (1963), Cratchley, Jones (1965) and Cratchley *et al.* (1984). An observed axial zone of positive gravity anomalies flanked by linear negative anomalies on both sides was interpreted as an arrangement typical of rift valleys in general, and resulted from crustal thinning and elevation of crust-mantle boundary beneath the central parts of the rift. However, the problem with this model is the lack of conspicuous rift faults at the margins of the trough (Popoff *et al.*, 1986; Benkhelil and Robineau, 1983) and a generalized folding of the Cretaceous sediments. Also, Cretaceous magmatic activity associated with rift structures is very scarce, except in the Abakaliki area where it is only found close to, or along major faults.

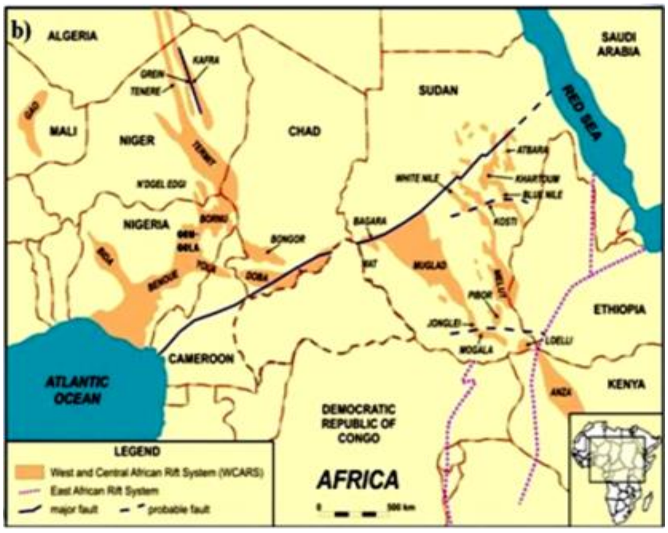


Figure 2: West and Central African Rift System (WCARS) (United Reef Limited Report, 2004)

The Benue Trough of Nigeria is an intracontinental basin between Central and West Africa that extends in a NE-SW direction. It is over 1000 km in length and exceeds 150 km in width. The Benue Trough is geographically subdivided into southern, central and northern parts (Figure 3). Its southern limit is the northern boundary of the Niger Delta Basin, while the Northern limit is the southern boundary of the Chad Basin. The Benue Trough is separated from the Chad Basin by an anticlinal structure termed the "Dumbulwa-Bage High" (Zaborski *et al.* 1997). The Benue Trough is filled with up to 6000 meters of Cretaceous sediments associated with some volcanics. The study area falls within the Gongola arm of the Upper Benue Trough. The Gongola sub-basin was interpreted as graben structure forming relay between the Benue Trough and the Bornu Chad rift (Abubakar, 2014). The stratigraphic sequences in this sub-basin are related to the variation in the paleo-environment caused by marked eustatic changes dictated by tectonic movements. The sedimentary facies are restricted to shallow water environment and the sediments include the detrital Bima Sandstone, transitional Yolde, marine Pindiga which is the lateral equivalent of Gongila and Fika Shales, Gombe Sandstone and Keri-Keri Formation (Table 1).

Figure 3: Generalized geological map of Nigeria (Abubakar, 2014)

Table 1: Stratigraphy of the Northern Benue Trough (Petters, 1982).

Age	Formation	Lithology	Paleoenvironment
Paleocene	Kerri-Kerri		Continental (fluviatile/lacustrian)
Maastrichtian	Gombe		Continental/Transitional (fluviatile, lacustrian,deltaic)
Campanian			
Santonian	Pindiga: Fika / Gongila		Marine
Coniacian			
Turonian			
Cenomanian	Yolde		Transitional ?
Albian	Bima		Continental
Precambrian	Basement Complex		

Sandstone Siltstone Claystone Shale Limestone

Granite, Gneiss, Migmatite, Schist Coal Uncomformity

III. Materials and Methods

Materials used include topographical map, global positioning system (GPS), compass, hand lens, measuring tape, ruler, field notebook, pencil, pen, permanent marker, masking tape, sample bag and a camera.

The field work was conducted in two stages, the reconnaissance and the detailed field work. The reconnaissance was conducted to search and locate areas where mining activity is taking place and have an overview of the geology of the area. Accessible routes were also discovered; six (6) sites where mining activities are active were discovered. During the detailed field work, different gypsum forms and their various carrier beds, structural and textural relationship between the different gypsum forms as well as depth of emplacement of the gypsiferous horizons were taken into cognizance. In the five mining sites visited, 20 gypsum samples were systematically taken. The mode of mining is pitting and tunneling. In a particular site, there are over 150 pits with majority of them connected from underneath by various tunnels. The pits range in depth from 7 to 16 meters. Ten representative gypsum samples were washed, dried and analyzed using X-ray fluorescence (XRF) at the Ashaka Cement Laboratory. Each representative sample was crushed using a crusher and then split into four using the sample splitter and taken to the Oven to heat it dry for about 7 to 10 minutes under 110^{o}C. The samples were pulverized using HERZOG mechanical grinder. The samples were then placed in the machine for about 10 seconds. Twenty grams (20 gm) of the powdered sample was weighed using “SAUTER RC 2013” sensitive weighing machine and mixed with 0.4 grams of strearic acid binder. The mixture was re-homogenized using the mechanical grinder for 10 seconds. It was poured into a small sodium hydroxide container (30 mm in diameter and 5mm thick) containing 1.5 gm of strearic acid. The container was placed in a “HERZOG” palletizing machine for 10 seconds after which a pellet was produced. The procedure was repeated for each gypsum sample. Each pellet was analyzed for SiO_2, Al_2O_3, CaO, MgO, SO_3, K_2O, Na_2O, $MgCO_3$, combine water and purity, using an Axios XRF machine. The summary of the stages involved is given in Figure 4.

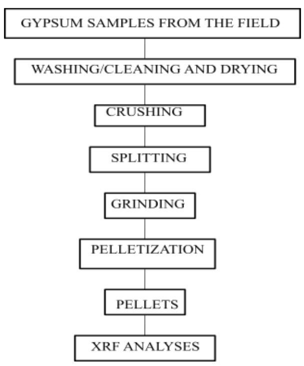


Figure 4: Steps for Gypsum Sample Preparation

IV. Result and Discussion

Geology and Field Relationship

Tongo area is underlain by predominantly two rock types, the Conacian-Santonian marine shales of Fika Member which is part of the Pindiga Formation, and Campanian-Maastrichtian continental sandstones of Gombe Formation. The sandstones overlie the shales uncomformably. Figure 5 shows the Geology of the study area. The shale produces a flat featureless topography on the eastern part of the study area. It is recognized by the black, shrinking clay soil on the surface (black cotton soil), and shale units across the drainages in the area as observed during the field exercise. The exposures are mostly shaly mudstones, dark grey when fresh, but light blue-green to grey when weathered. The shales in the area are classified into limestone-shale, gypsiferous shales and non-gypsiferous shales, while the sandstone in the study area is rich in iron and clays forming a ferruginous capping. It covered the western portion of the area, forming rugged and hilly topography. The brownish laterite downhill is covered with iron capping which was form as a result of leaching of silica by geochemical processes that affected the area.

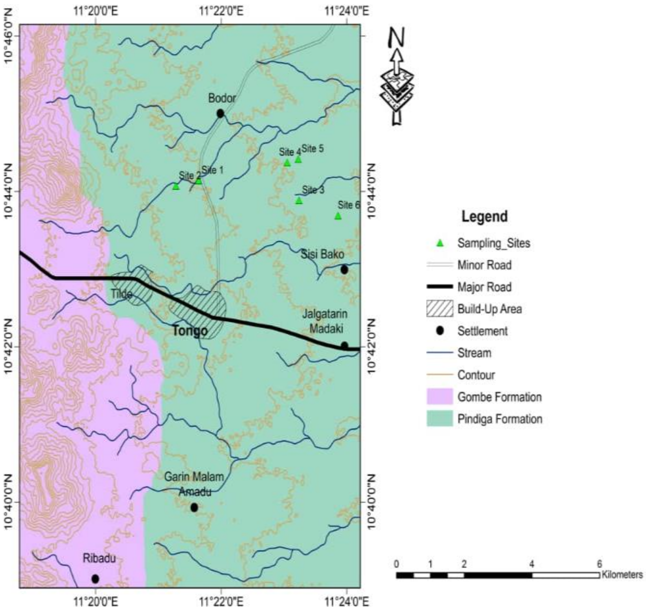


Figure 5: Geology of the Study Area

Occurrence of gypsum

The gypsum occurs concordantly within the shales but discontinuous within the bedding planes; and in some places, crosscutting the bedding planes (Plates I and II). They appear in the form of lenses; seams and veinlets which are few millimeters to centimeters thick and the thickness increase with depth. The depth of occurrence of gypsum in the area ranges from seven meters (7 m) to sixteen meters (16 m) as observed from the mines in the study area. Four lithological sections where gypsum occurs within the mines were constructed from Daban Officer, Bodor, Gadari and Damawake mine sites and are presented in Figures 6 - 9.

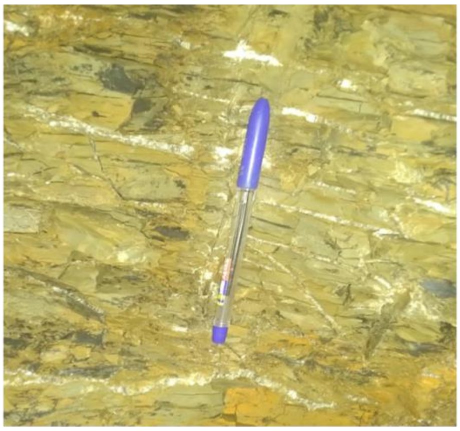


Plate I: Gypsum occurring concordantly within the shale

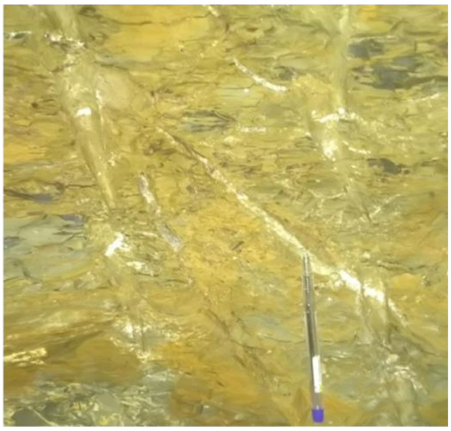
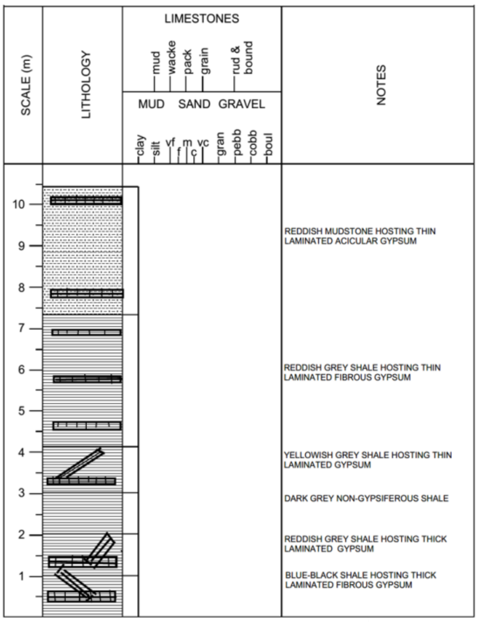


Plate II: Gypsum beds crosscutting the shale



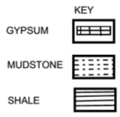


Figure 6: Lithological section of gypsum and shale layers at Gadari

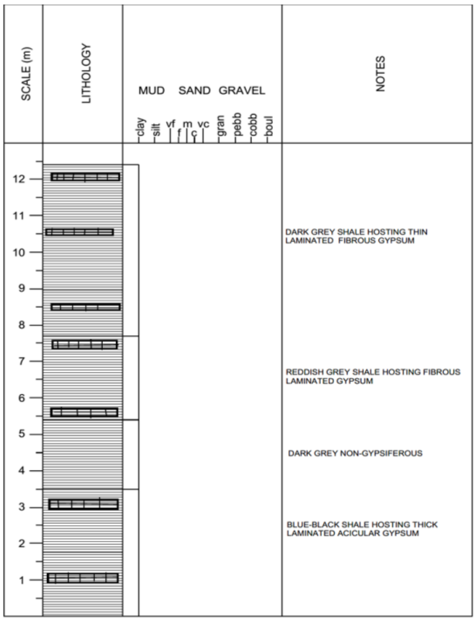


Figure 7: Lithological section showing gypsum and shale layers at Damawake

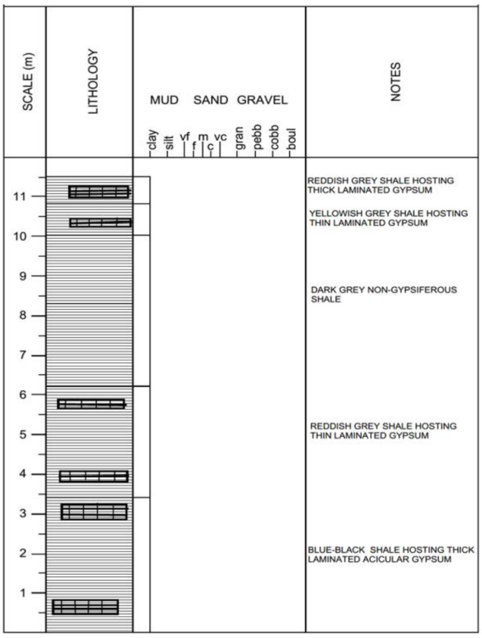
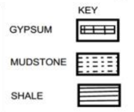


Figure 8: Lithological section of gypsum and shale layers at near Daban Officer



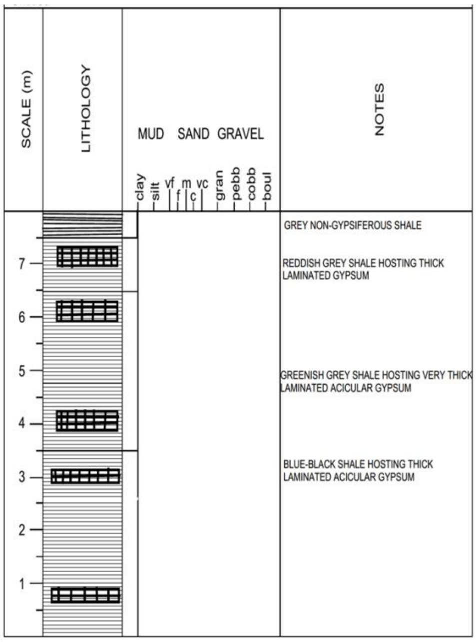


Figure 9: Lithological section of gypsum and shale layers at near Bodor

The mode of gypsum mineralization in Tongo area comprise of Syngenetic and Epigenetic deposition. This also indicates different time of deposition and most likely a different chemical composition thus a different grade. The gypsum occurs in two forms; regular patterns (beds/lenses) as shown in Plate I, and irregular pattern as shown in Plate II. At the northern part of the study area near Bodor (Figure 9), mineralization occurs in four (4) horizons, with thickness ranging from 0.6 – 2.5 cm. The depth of occurrence of mineralization ranges between one to sixteen (1 – 16) metres. It was also observed that the gypsum from the third (3^{rd}) horizon is thicker than the one from fourth. At Gadari village, which is about 2 km SE of Bodor, the mineralization occurs in five (5) horizons with some gypsum occurring in irregular pattern within the shale beds. The gypsum lenses occur vertically, crosscutting the horizontal beds (Figure 6). Fragments of gypsum are noticed within the shale unit hosting the mineralization. The thickness of gypsum bed at this location ranges from 1 – 2 cm. At Damawake, South of Gadari, the mineralization occurs in three (3) horizons with a thickness of 0.2 to 2.5 cm. Gypsum mineralization occurs from a depth of 1.4 to 14 meters (Figure 7).

Gypsum Forms

Three different Gypsum forms were identified in the area on the basis of depth, carrier beds and their physical structures namely: Balatino laminate, Alabaster and Satinspa gypsum.

Balatino laminated gypsum

The Balatino laminated gypsum consists of individual laminae about 2 mm thick. The gypsum is thinly bedded with smooth and transparent surfaces which is in line with (Haruna, 1998). It occurs as discontinuous seams of about 1.5-3.0 cm thick within the mudstone unit at depths between 0-4m at Gadari Mining Site.

Plate III: Balatino laminated gypsum

Satinspar gypsum

Satin Spar gypsum is a fibrous, silky form consisting of fibrous or acicular crystals and with a very rough surface oblique at its edges. They appear parallel to subparallel beddings of the blue-black shales. The thickness range from 2-6 cm and consist of vertically arranged fibers or acicular crystals which are perpendicular to the bedding of the shale as reported by (Haruna, 1998). They occur at Daban Officer, near Bodor, Damawake and Gadari in depths ranging from; 0.6-1.5m and 4.8-7.7m, 0.5-4.0 m and 0.5-8.0 m respectively. The size of the SatinSpar Gypsum increases with depth.

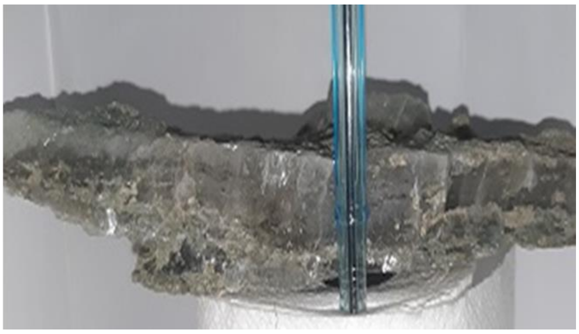


Plate IV: Satinspar gypsum

Alabaster gypsum

Alabaster gypsum form is massive with thick internal laminations. It was found at Daban Officer, near Bodor, Damawake and Gadari in depths ranging from; 7.7-11.5 m, 4.0-7.5 m, 8.0-12.4 m and 8.3-11.4 m respectively within the highly deformed blue-black shales. It is very heavy and has irregular, rough texture from outside surface. It is internally laminated and the laminations have thickness of 3-4 mm as reported by (Haruna, 1998).

Plate V: Alabaster gypsum

Geochemistry of gypsum

The result of the chemical analysis of the different gypsum forms are given in the table below, the samples were taken from different mining site at different depth, ranging from one (1) to sixteen (16) meters. Therefore, the geochemical data represents that of different locality within the study area (Table 2).

Table 2: Chemical Composition (Weight %) of Gypsum

Major Oxides	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
SiO_2	7.033	5.828	9.198	3.251	3.954	4.594	3.892	8.74	7.63	9.267
Al_2O_3	1.931	1.53	2.827	0.662	0.911	1.364	0.916	3.183	2.569	3.107
Fe_2O_3	3.169	0.953	1.266	0.22	0.257	1.694	0.429	1.135	0.812	0.986
CaO	28.101	29.568	28.257	30.867	30.164	29.428	30.297	28.007	28.671	27.927
MgO	1.249	1.205	1.303	1.097	1.151	1.199	1.077	1.232	1.232	1.202
SO_3	38.237	40.163	37.754	42.057	41.434	40.094	41.465	37.894	38.943	37.795
K_2O	0.22	0.148	0.281	0.09	0.099	0.121	0.121	0.228	0.191	0.221
Na_2O	0.063	0.071	0.065	0.074	0.069	0.071	0.068	0.06	0.066	0.059
Sum of Conc.	80.003	79.465	80.951	78.319	78.038	78.566	78.265	80.478	80.114	80.564
PURITY	79.151	83.137	78.152	87.059	85.769	82.995	85.832	78.44	80.611	78.236
Comb. Water	17.207	18.073	16.989	18.926	18.645	18.042	18.659	17.052	17.524	17.008

$CaSO_4$.$2H_2O$	83.545	87.804	83	91.85	90.243	87.564	90.421	82.953	85.138	82.73

Sample Identification
Sample 1, Sample 2 and Sample 3 - Balatino Laminated Gypsum
Sample 4, Sample 5 and Sample 6 – Alabaster Gypsum
Sample 7, Sample 8, Sample 9 and Sample 10 – Satinspar Gypsum

Table 3: Average Weight of the Gypsum Forms

OXIDES	X1	X2	X3	Y1	Y2	Y3	Z1	Z2	Z3	Z4	STM Standard (%)
$CaSO_4$	66.338	69.731	66.011	72.924	71.598	64.522	71.762	65.901	67.614	65.72	79.1
Mean $CaSO_4$		67.36			70.01			67.74			
MgO	1.249	1.205	1.303	1.097	1.151	1.199	1.077	1.232	1.232	1.202	<3.000
Mean MgO		1.25			1.149			1.186			
K_2O+ Na_2O	0.283	0.219	0.346	0.164	0.168	0.192	0.189	0.288	0.257	0.28	<0.603
Mean K_2O+ Na_2O		0.282			0.524			0.254			
Comb. Water	17.207	18.073	16.989	18.926	18.645	18.042	18.659	17.052	17.524	17.008	20.9
Mean Comb. Water		17.423			18.538			17.561			
$CaSO_4$. $2H_2O$	83.545	87.804	83	91.85	90.243	87.567	90.421	82.953	85.138	82.73	84-100
Mean $CaSO_4$. $2H_2O$		84.783			89.887			85.311			
Purity	79.151	83.137	78.152	87.059	85.769	82.995	85.832	78.44	80.611	78.236	
Mean Purity		80.147			85.274			80.779			

Sample Identification
X1, X2 and X3 = Balatino Laminated Gypsum
Y1, Y2 and Y3 = Alabaster Gypsum
Z1, Z2, Z3 and Z4 = Satinspar Gypsum

Table 3 shows the average chemical composition of the entire ten (10) samples collected. The results showed that the Alabaster gypsum form is the heaviest as such very suitable for the production of Portland cement. All the gypsum forms are of high grade because the $CaSO_4.2H_2O$ content in each gypsum form exceeds 70 % (Table 4 and Figure 10).

Table 4: Average weight of the gypsum forms

GYPSUM FORMS	$CaSO_4.2H_2O$ IN WT. (%)	AVERAGE WEIGHT (%)
	83.545	
X	87.804	84.783
	83.00	
	91.85	
Y	90.243	89.887
	87.567	
	90.421	
Z	82.953	
	85.138	85.11
	82.73	

X = Balatino Laminated Gypsum
Y = Alabaster Gypsum
Z = Satinspar Gypsum

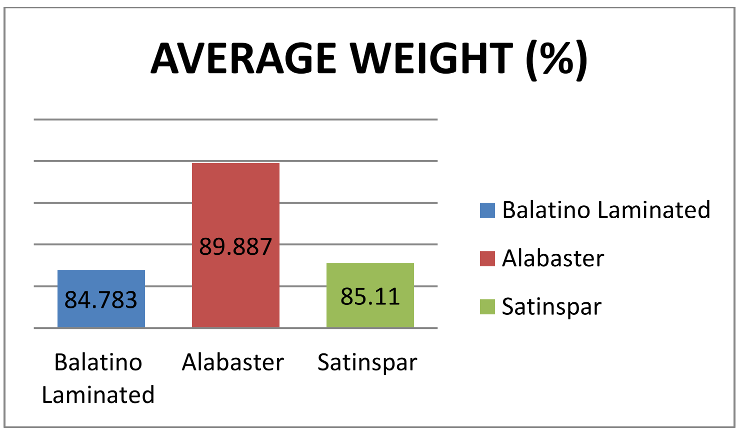


Fig. 10: A Bar chart of average weight % against Gypsum forms

Gypsum is seldom found in a pure state, but usually contains varying amount of shale, silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3) and other compounds which make it impure and also contribute enormously in lowering the grade of the mineral (Haruna, 1998). An assessment of the average purity of the Tongo gypsum gives a purity of 87 % (Table 3). Comparing the silica (SiO_2) content of the Tongo gypsum with that of the Morocco and Spain (Table 6), there is a difference of about 3.3, which if normalized would put the Tongo Gypsum in the grade of 90 % and above. Portland cement production tolerates relatively large amount of shale, silica (SiO_2) impurities (since clay is a component of the raw material mix in cement production). A high grade (about 84-100 wt % $CaSO_4.2H_2O$ standard) naturally occurring gypsum is needed for the manufacture of Portland cement (ASTM, 1981). The chemical analysis of the Tongo gypsum deposit showed that the purity ranges from 82-92 wt % which falls within the ASTM standard (Table 5).

Table 5: Chemical composition of gypsum from the study Area with the ASTM standards

OXIDES	Average weight (%)	ASTM Standard (%)
$CaSO_4$	70.01	79.100
MgO	1.149	<3.000
K_2O+ Na_2O	0.524	<0.603
Comb. Water	18.558	20.900
$CaSO_4.2H_2O$	89.88	84-100

Comparing the data from this research work with that of the imported gypsum from Morocco and Spain, it showed that the gypsum mineralization in Tongo area is lower in purity to that of Morocco and Spain. But, both met the ASTM standards of 84-100 % (Table 6).

Table 6: Comparison of chemical composition of gypsum from Nigeria, Morocco and Spain

OXIDES	Nigeria wt. (%) Tongo Gypsum	Morocco wt. (%) Moroccan Gypsum	Spain wt. (%) Spanish Gypsum
SiO_2	3.933	0.6	0.5
Al_2O_3	0.979	0.12	0.53
Fe2O3	0.723666667	0.05	0.16
CaO	30.153	33.89	31.44
MgO	1.149	-	-
SO_3	41.195	47.32	44.85
K_2O	0.103333333	-	-
Na_2O	0.071333333	-	-
Comb. Water	17.561	15.67	18.38
$CaSO_4.2H_2O$	85.27433333	96.88	94.67

Nigeria = Data from present work (Tongo)
Morocco = Data from Sillo and Okunsenogu (1994)
Spain = Data from Orazulike (1988)

Economic Significance of the Gypsum

All Gypsum forms are economically significant because they can be used as raw material in many industries such as; agriculture, cement, chalk, ceramics, cosmetics, food, glass and pharmaceuticals. The physical and chemical standards required for industrial application of gypsum depends on the end use. Due to the proximity of Ashaka Cement Plc to the gypsum deposit, it is recommended that the Tongo deposit be used as an alternative to the imported gypsum in order to cut down or stop the importation of that commodity completely.

V. Conclusion

The aim of the research which is to characterize the gypsum and their associated rock unit in Tongo area by studying the geology and geochemistry of the gypsum forms in order to assess their economic significance has been achieved. The following conclusions have been reached:

1) Tongo area is underlain by predominantly two rock types, the Conacian-Santonian marine shales of Fika Member which is part of the Pindiga Formation, and Campanian-Maastrichtian continental sandstones of Gombe Formation. The sandstones overlie the shales uncomformably
2) Gypsum mineralization occurs in numerous locations within the Fika Shale at Tongo area.
3) Chemical analysis of the gypsum forms confirmed that they are of high grade with an average of 84.78 %, 89.89 % and 85.11 % $CaSO_4.2H_2O$ respectively.
4) All the gypsum forms have an average weight % that falls within the 84-100 % ASTM standards. With this result, Tongo gypsum is considered suitable for use in the manufacture of Portland cement.

References

[1]. Abubakar, M. B. 2014, “Petroleum Potentials Of The Nigerian Benue Trough And Anambra Basin: A Regional Synthesis”, Science Research; Natural Resources, Vol. 5, Pp. 25-58p.(Http://Www.Scirp.Org/Journal/Nr) Http://Dx.Doi.Org/10.4236/Nr.2014.51005

[2]. Benkhelil, J. 1989, “The Origin And Evolution Of The Cretaceous Benue Trough, Nigeria”, Journal Of African Earth Science. Vol. 8, Pp. 251–282.

[3]. Benkhelil, J. And Robineau, B., 1983, “Le Fossé De La Bénoué Est-Ilun Rift?” Bulletin Centres Rech. Explor. – Prod. Elf-Aquitaine, Vol. 7, Pp. 315-321.

[4]. Bureau Of Public Enterprises (Bpe), 2006, “Nigerian Economy”, Bureau Of Public Enterprises Report 2006, 35p. Www.Bpe.Gov.Ng.

[5]. Carter, J. D., Barber W., And Tait, E. A., 1963, “The Geology Of Part Of Adamawa, Bauchi And Bornu Provinces In Northeastern Nigeria”, Bulletin Geological Survey Of Nigeria, Vol. 30, 99p.

[6]. Cratchley C. R. And Jones G. P., 1965, “An Interpretation Of Thegeology And Gravity Anomalies Of The Benue Valley,Nigeria” Overseas Geological Surveys Geophysical Paper, H.M. Stationery Office, Norwich Vol. 1, Pp. 1-26.

[7]. Cratchley C. R., Louis P. And Ajakaiye D. E., 1984, “Geophysical And Geochemical Evidence For The Benue-Chad Basin Cretaceous Rift Valley System And Its Tectonic Implications,” Journal Of African Earth Science, Vol. 2, No.2, Pp. 141-150.

[8]. Haruna, A. I. 1998, Geology, Geochemistry And Origin Of Gypsum Mineralization In North Eastern Nigeria (Chad Basin).

[9]. King, L. C., 1950, “Outline And Distribution Of Gondwanaland”, Geological Magazine, Vol. 87, No. 5, Pp. 353-359. Http://Dx.Doi.Org/10.1017/S0016756800077311

[10]. Ntekim, E.E., 2009, “Impact Of Geological Variables On Gypsum Mineralization: Assessment Of The Guyuk Gypsum Occurrences, N. E. Nigeria”, Continental Journal Of Earth Sciences, Vol. 4, Pp. 12-22.

[11]. Obaje, N. G., 2009,“Geology And Mineral Resources Of Nigeria”, Springer Dordrecht Heidelberg, London. 218p.

[12]. Offodile, M. E., 1982, “The Geology And Tectonic Of Awe Brine Field”, Journal Of Mining Geology, Vol. 19, Pp. 198-203.

[13]. Orazulike, D. M., 1988, “The Prospect Of Gypsum As An Ore In Pindiga, Bauchi State”. Unpublished Interim Technical Report For Detail Prospecting Of The Commodity. Submitted To Ashaka Cement Company Bauchi State. 3p.

[14]. Petters, S. W. 1982. Central West African Cretaceous- Tertiary Benthic Foraminifera And Stratigraphy. Paleontographical. Abt. A, Vol. 170: P.1-104.

[15]. Popoff, M., Benkhelil J., Simon, B. And Motte, J. J., 1986, “Approchegéodynamique Du Fossé De La Bénoué (N. Nigeria A Partir Des Données De Terrain Et De Télédètection,” Bulletin Des Centres De Recherches Exploration-Production Elf-Aquitaine, Vol. 7, No. 1, Pp. 323-337.

[16]. Raup, O. B., 1970, “Brine Mixing – An Additional Mechanism For Formation Of Basin Evaporates”, American Association Of Petroleum Geologists, Bulletin 54, Pp. 2246-2259.

[17]. Raup, O. B., 1982, Gypsum Precipitation By Mixing Sea Water Brines. American Association Of Petroleum Geologists. Vol. 66, No. 3, Pp. 363-369.

[18]. Sillo, C. E. And Okunsenogu, C.A. 1994; Adoka Gypsum And Its Suitability For Cement Production. Journal Of Min Ing And Geology. Vol. 30, No. 2, Pp. 169 – 174

[19]. Sonnenfeld, P., 1991, Evaporite Basin Analysis. Reviews In Economic Geology, Vol. 5, Pp. 159-168.

[20]. Uma, K. O., 1998, “The Brine Fields Of The Benue Trough, Tectonic And Hydrochemical Properties”, Journal Of African Earth Science, Vol. 26, No. 2, Pp. 261-275.

[21]. United Reef Limited Report, 2004

[22]. Uzuakpunwa, A. B., 1981, “The Geochemistry And Origin Of The Evaporate Deposit In Southern Half Of The Benue Trough, Nigeria”, Earth Evolution Science, Vol.1, Pp. 98-103.

[23]. Zaborski, P., Ugodulunwa F., Idornigie A., Nnabo P. Andibe K., 1997, “Stratigraphy And Structure Of The Cretaceous Gongola Basin, Northeast Nigeria,” Bulletin Du Centre Derecherches Elf Exploration Production, Vol. 21, No. 1, Pp. 153-185.