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OCCURRENCE AND GEOCHEMISTRY OF NAFADA GYPSUM, NORTH-EASTERN NIGERIA

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ABSTRACT

Gypsum deposits occur in numerous locations within the Senonian Fika Shale at Nafada, northeastern Nigeria. Geologic investigations at Baro Winde and Wuro Dabo mines indicate the occurrence of three varieties of gypsum namely, Balatino laminated, Alabaster and Satin Spar. These are interlayered within shale and mudstone. Geochemical analyses of the gypsum deposits by X-ray spectrometric technique gave both mean compositions of 91.57, 95.53 and 92.48 wt % of $CaSO_4.2H_2O$; 0.53, 0.23, and 1.05 wt % Magnesia (MgO); 0.14, 0.09, and 0.48 wt % Alkalis ($Na_2O + K_2O$) and purity of 95.03, 96.01 and 93.02 % for Balatino laminated, Alabaster and Satin Spar, respectively. These parameters suggest high-grade gypsum, which is suitable for the manufacture of Portland cement.

KEY WORDS: Nafada, Gypsum, Fika Shale, Occurrence, Balatino, Alabaster,Satin Spar.

INTRODUCTION

Nafada is about 96 km north of Gombe and lies within Longitude $11^0 15'$ and $11^0 25'$ E and Latitude $11^0 05'$ and $11^0 10'$ N (Fig.1). The study sites consisting of Baro Winde and Wuro Dabo mines are located about 4 km southwest and 9 km south of Nafada town, respectively (Fig.1). The areas are generally flat terrains and slightly undulating in some parts. A sandstone ridge, the “Dumbulwa Bage High” (Zarboski et al., 1997) surrounds the area.

The occurrence of gypsum within the Fika Shale in the Gongola Basin Upper Benue valley was first reported by Carter et al., (1963) and confirmed by Reyment (1965). Orazulike (1988) reported gypsum occurrence in Nafada and Bajoga areas of northeastern Nigeria. There had not been a proper documentation of the gypsiferous bodies in these areas since then.

The present work is designated to study petrographically the host rocks at two mines at Baro Winde and Wuro Dabo villages, to identify the different types of gypsum in the area and the mode and level of emplacement of the gypsiferous horizons. A geochemical analysis of the gypsum forms was carried out to determine their mineral grade and possible use in cement manufacturing.

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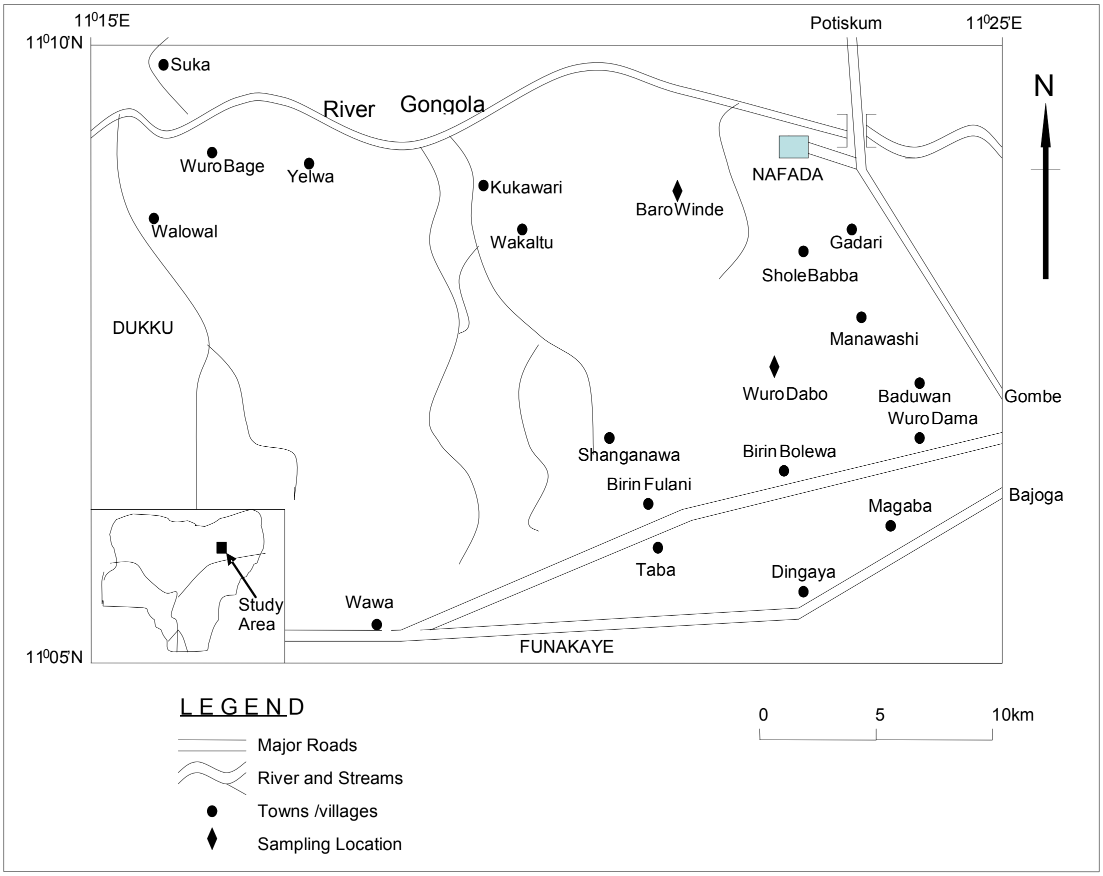

Fig, 1: Simplified Map of Nafada LGA Showing Sampling Locations

GEOLOGICAL SETTING

The geology of the Gongola Basin in the Upper Benue valley has been extensively discussed by many authors (Carter et al., 1963; Petters, 1982; Alix, 1983; Popoff et al., 1986; Benkhelil, 1988, 1989; Zarboski et al., 1997) among others. The stratigraphic succession in the Gongola Basin is given in Figure 2. The oldest sedimentary unit in the basin is the Albian Bima Formation, which was deposited under continental conditions. The formation lies unconformably on the Precambrian Basement Complex. The transitional Yolde Formation (Cenomanian) lies conformably on the Bima Sandstone and

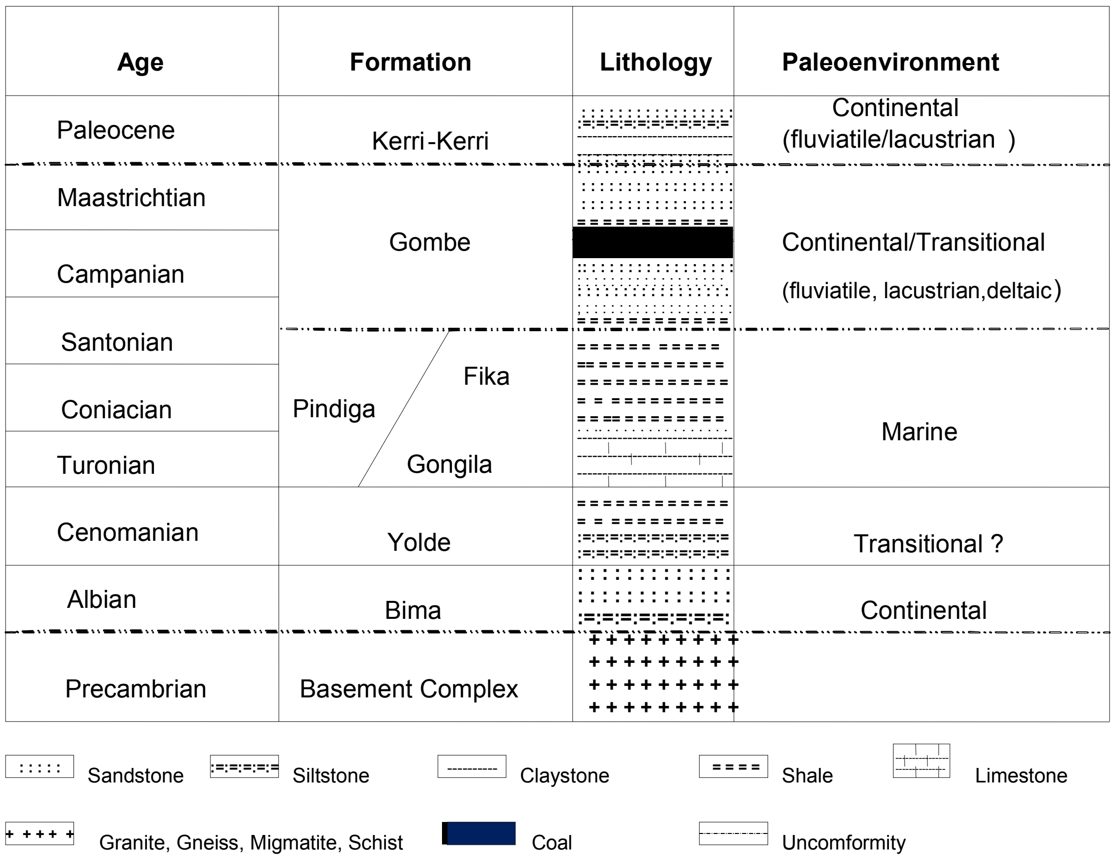

Fig.2: Stratigraphic succession in the Upper Benue Trough. Modified from Petters (1982)

represents the beginning of marine incursion into the Upper Benue Trough (Popoff et al., 1986). The Gongila Formation which is overlain by the Fika Shale is a lateral equivalent of the Pindiga Formation and lie conformably on the Yolde Formation. They represent full marine incursion into the Upper Benue Trough during the Turonian-Santonian times. The Santonian was a period of folding and deformation in the whole of the Benue Trough (Benkhelil, 1989). Post folding sediments are represented by the continental Gombe Formation (Maastrichtian) and the Kerri-Kerri Formation (Tertiary). The Gombe and Kerri-Kerri Formations are mostly restricted to the western part of the basin (Dike, 1993).

FIELD OCCURRENCE AND CHARACTERISTICS

Four pits were studied, two each at Baro Winde and Wuro Dabo mines. Attention was given to the study of the lithology of the host rock, the level of emplacement of the gypsiferous horizons and mode of occurrence of the gypsum bodies within the horizons.

The Fika Shale in Nafada area is composed of thick laminated non-gypsiferous red clay, gypsum-rich blue-black shale and mudstone, grey coloured highly fissile shale and sandy clay with occasional cobbles and pebbles. Figures 3 and 4 give typical stratigraphic sections of the Fika Shale as exposed in Baro Winde and Wuro Dabo mining pits, respectively.

Three types of gypsum occur within the Fika Shale at Baro Winde and Wuro Dabo mines. These include the Balatino laminated which occurs within the mudstone beds, Alasbaster and Satin Spar found within the blue-black shale beds. Balatino laminated and Alabaster types were encountered in the pits at Baro Winde mines, while Satin Spar occurred in the pit at Wuro Dabo mine.

The Balatino laminated gypsum consists of individual laminae about 2 mm thick. The gypsum is thinly bedded with smooth and transparent surfaces. It occurs as discontinuous seams of about 1.5-3.0 cm thick within the mudstone unit at depths between 5.4-6.5 m

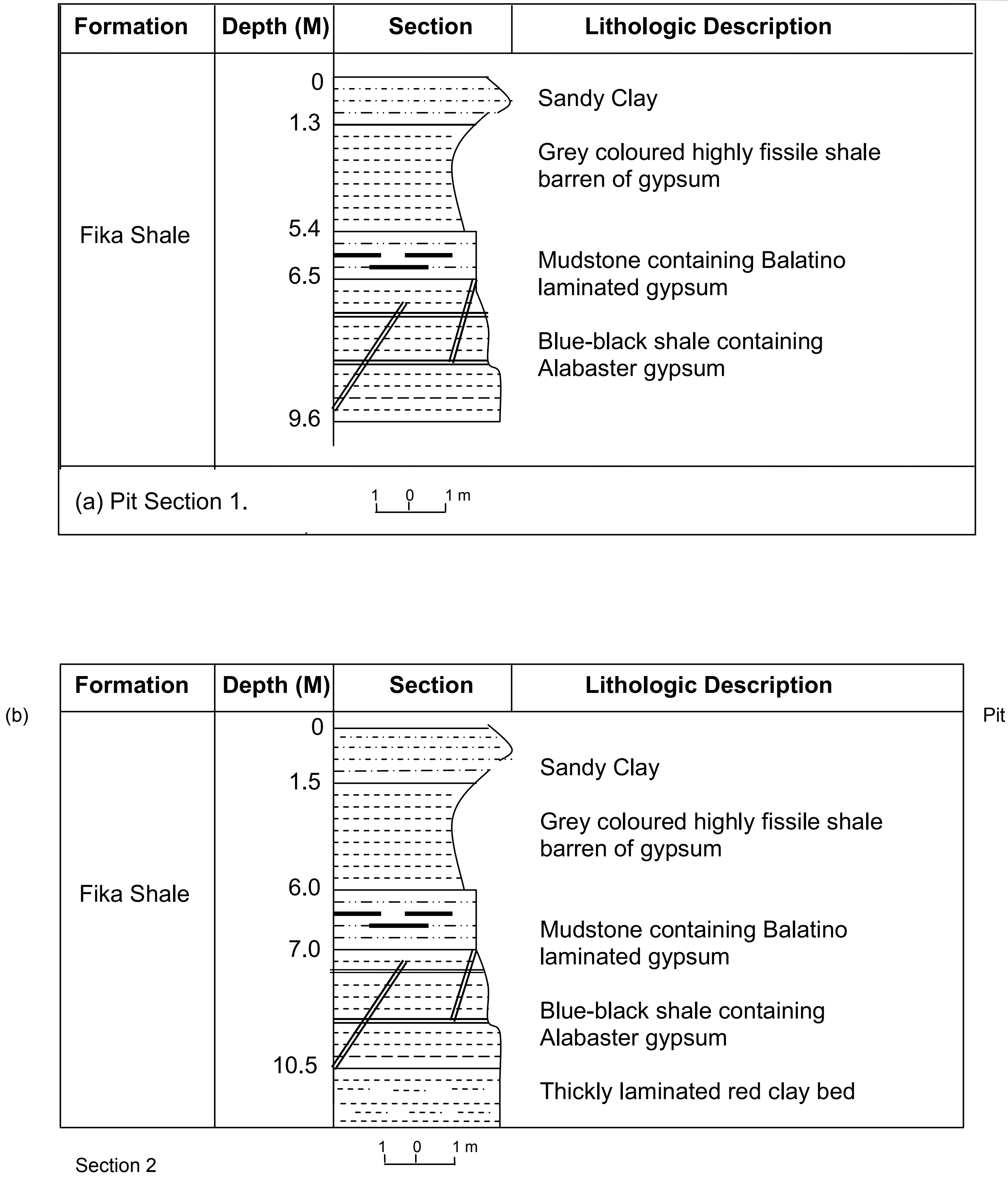

Fig. 3: Typical Stratigraphic Sections through the Fika Shale as exposed in Baro Winde Mining Site-

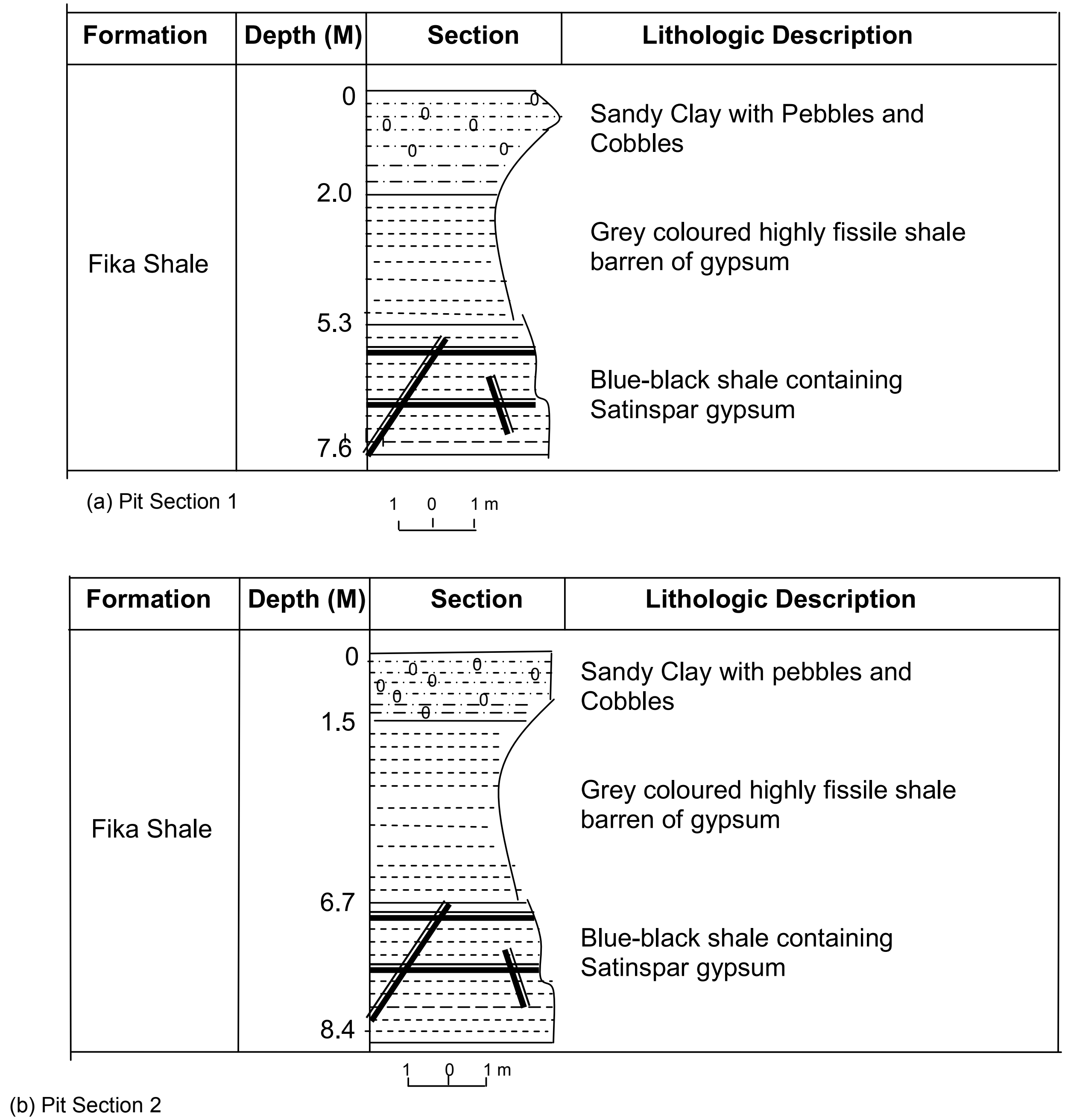

Fig. 4: Typical Stratigraphic Sections through the Fika Shale as exposed in Wuro Dabo Mining Site-Nafada

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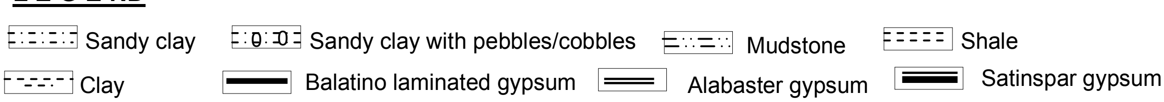

and 6.0-7.0 m in pit section 1 and 2 at Baro Winde mine, respectively (Fig 3.). According to Rouchy (1981) laminated gypsum in mudstone, as occurs at Baro Winde, represents primary marine crystallization of the mineral in muddy sediments and depicts early diagenesis at the sediment water interface.

The Alabaster gypsum is a compact massive variety, which is internally laminated with each laminae being about 5-6 mm thick. Unlike the Balatino laminated, it has a thick internal lamination, rough surface and is white to multi-coloured. The thick internal lamination is probably a characteristic of mega nodules of gypsum at a great depth (Holiday, 1970). This form of gypsum occurs mostly as continuous seams of about 2.5-4 cm thick. It is both concordant and alternates with the blue-black shale. The seams also occur as veinlets which cross-cut the bedding planes. The beds encountered, occur at depths between 6.5-9.6 m and 7.0-10.5 m in pits 1 and 2 in Baro Winde mine, respectively (Fig. 3)

Satin Spar gypsum is a fibrous, silky form consisting of fibrous or acicular crystals and with a very rough surface oblique at its edges. The oblique crystals probably resulted from numerous deformations of the stratification of the primary laminated gypsum form (Schreiber et al., 1976). The occurrence at Wuro Dabo mine is a continuous seam of about 3.5-6.0 cm thick and intercalating with the blue-black shale beds at depths between 5.3-7.6 m and 6.7-8.4 m in pits 1 and 2, respectively (Fig.4).The occurrence of gypsum as continuous seams which alternate with the blue-black shale beds suggests a continuous evaporitic section across the depositional basins. The veinlets which also cross-cut the blue-black shale bedding planes possibly resulted from a post-depositional solution and precipitation in fractures and joints (Maglione, 1981).

GEOCHEMICAL ANALYSIS

Methodology

Ten representative gypsum samples were analyzed using X-ray spectrometry analytical method at the Ashaka Cement Laboratory, at Ashaka, northeastern Nigeria. The samples were cleaned using a plastic brush and crushed using a metal mortar and pestle. The crushed sample was milled into powder using a "HERZOG" mechanical grinder. 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 0.1 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 X-ray spectrometer.

RESULTS

The results of the analyses as presented in Table 1, show that the analyzed gypsum forms contain an average of 91.57, 95.53 and 92.48 wt % $CaSO_4.2H_20$ for Balatino laminated Alabaster and Satin Spar, respectively (Table 2). These results indicate high quality gypsum materials, considering the American Society for Testing and Materials (ASTM) standard which stipulates that gypsum material should have not less than 70.0 wt % $CaSO_4.2H_20$.

Table 1: Relevant Oxide Composition (wt %) of Nafada Gypsum

Oxides	Sp. 1	Sp. 2	Sp.3	Sp.4	Sp.5	Sp.6	Sp.7	Sp.8	Sp.9	Sp.10
SiO_2	1.26	6.74	1.74	1.15	0.69	0.59	7.32	0.18	0.62	3.71
Al_2O_3	0.35	2.67		0.32	0.08		2.59	0.21	0.00	1.28
Fe_2O_3	0.18	1.16	0.51	0.19	0.09	0.15	0.94	0.34	0.15	0.55
CaO	30.55	28.10		30.57	30.97		27.58	30.97	30.65	29.68
MgO	0.41	0.95	0.15	0.43	0.23	0.14	0.43	0.07	0.33	0.22
SO_3	44.29	40.05		44.39	45.00		40.18	45.35	44.74	42.79
K_2O	0.06	0.19	30.54	0.06	0.05	30.78	0.19	0.04	0.05	0.12
Na_2O	0.02	0.02		0.02	0.02		0.02	0.02	0.02	0.02
$MgCO_3$	0.85	1.99	0.22	0.89	0.49	0.20	0.90	0.14	0.70	0.47
Combine										
Water	19.93	18.02	43.60	19.98	20.25	44.56	18.08	20.14	20.13	19.35
CaSO4.2H20	94.77	86.17		94.94	96.22		85.84	96.73	95.52	91.82
Purity	95.23	96.11	0.06	97.45	96.74	0.04	86.39	97.51	96.18	91.99
			0.02							
			0.82			0.02				
			19.62			0.78				
			93.76							
			93.74							
						20.06				
						95.42				
						95.85				

Sample Identification

Sp.1, Sp.2, Sp.3. -Balatino laminated gypsum

Sp.4, Sp.5, Sp.6. -Alabaster gypsum

Sp.7, Sp.8, Sp.9, Sp.10. - Satin Spar gypsum

Table 2: Average Composition of Nafada Gypsum

Parameters	Concentration in Weight %										ASTM Standard (%)
	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	C_4	
$CaSO_4$	74.84	68.15	74.14	74.96	75.97	75.36	67.86	76.34	75.39	72.47	
Mean	72.39			75.43			73.02				79.1
Combine water	19.93	18.02	19.62	19.98	20.25	20.06	18.08	20.14	20.13	19.35	
Mean	19.19			20.1			19.47				20.9
$CaSO_4.2H_2O$	94.77	86.17	93.76	94.94	96.22	95.42	85.84	96.73	95.52	91.82	
Mean	91.57			95.53			92.48				84-100
MgO	0.41	0.95	0.22	0.43	0.23	0.02	0.43	0.07	0.33	0.22	
Mean	0.53			0.23			1.05				Less than 3.0
$K_2O + Na_2O$	0.08	0.21	0.13	0.08	0.07	0.11	0.21	0.06	0.07	0.14	
Mean	0.14			0.09			0.48				Less than 0.603
Purity	95.23	96.11	93.74	95.45	96.74	95.85	86.39	97.57	96.18	91.99	
Mean	95.03			96.01			93.02				

Sample Identification

A_1, A_2, A_3. - Balatino laminated gypsum
B_1, B_2, B_3. -Alabaster gypsum
C_1, C_2, C_3, C_4 -Satin Spar gypsum

DISCUSSION

A high grade (about 84-100 wt % $CaSO_4.2H_20$ standard) naturally occurring gypsum is needed for the manufacture of Portland cement (ASTM, 1981); therefore the gypsum studied can be used for this purpose. In its natural form, high grade gypsum contains at least 79.1 wt % of $CaSO_4$ and 21.9 wt % combine water. The water content determines the stability field of any gypsum and so the loss of water by gypsum which converts it to anhydrite lowers the grade of the mineral. From Table 2, the average $CaSO_4$ in the respective gypsum forms studied is 72.39, 75.43 and 73.02 wt % for Balatino laminated, Alabaster and Satin Spar. This range of $CaSO_4$ values makes the gypsum forms slightly below the 79.1 wt % $CaSO_4$ ASTM standard for high grade gypsum. Table 2 shows that the average water content of the gypsum analyzed is 19.19, 20.1 and 19.47 wt % for Balatino laminated, Alabaster and Satin Spar, respectively. Considering the ASTM standard of 20.9 wt % water content for high grade naturally occurring gypsum, the Alabaster gypsum form is regarded as the most stable followed by Satin Spar and lastly the Balatino laminated. The stability field of the studied gypsum is attributable to their depth of emplacements (Holiday, 1970). The Balatino laminated is emplaced at a shallower depth range of 5.4-7.0 m in mudstone (Fig.3), a possible region of low circulation of ground water. The occurrence of Alabaster gypsum at a greater depth range of 6.5-10.5 m, (Fig.3), a possible region of high circulation of ground water placed it in advantageous position of becoming the most stable gypsum form in the study area.

Acceptable specifications for cement raw materials are Magnesia (MgO) less than 3.0%, and Alkalis ($Na_2O + K_2O$) less than 0.603%. From Table 2, the average Magnesia (MgO) is 0.53, 0.23, and 1.05 % for Balatino laminated, Alabaster and Satin Spar, respectively and Alkalis ($Na_2O + K_2O$) is 0.14, 0.09, and 0.48 % for Balatino laminated, Alabaster and Satin Spar, respectively. These results when viewed against the ASTM specifications, made Nafada gypsum suitable for use in Portland cement manufacturing.

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), magnesite ($MgCO_3$) and other compounds which make it impure and also contribute enormously in lowering the grade of the mineral (Kurt, 1984). An assessment of the average purity of the three gypsum forms gives a purity of 95.03, 96.01 and 93.02 % for the Balatino laminated, Alabaster and Satin Spar, respectively (Table 2). These results are attributable to the relative low amount of shale, silica, alumina, iron oxide and other compounds in the gypsum occurrences.

CONCLUSION

Gypsum mineralization occurs in numerous locations within the Fika Shale at Nafada area. Three forms of gypsum (Balatino laminated, Alabaster and Satin Spar) were identified in the study area. Chemical analysis of the three gypsum forms confirmed that they are high grade with an average of 91.57, 95.53 and 92.48 wt %, $CaSO_4.2H_20$ for the Balatino laminated, Alabaster and Satin Spar, respectively. With these results, Nafada gypsum is considered suitable for use in the manufacture of Portland cement.

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