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OCCURRENCE, GEOCHEMISTRY AND INDUSTRIAL QUALITY OF NAFADA GYPSYM DEPOSIT, NORTHEASTERN NIGERIA

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ABSTRACT

Three varieties of gypsum deposits occur in numerous locations within the Senonian Fika Shale in Nafada area, northeastern Nigeria. Geological investigations at Gonja, Warum, Ganko, Shole, Sudingo, Gadi, Mada and Papa mines show the occurrence of the three varieties namely: Satinspar, Selenite and Alabaster. These gypsum deposits occur within the gypsiferous Fika Shale with thicknesses within the span of 1 to 6 cm and depth of 0.2 to 15 meters. The gypsum are hosted within veins sometimes criss - crossing in some locations, pores and fractures inter layered within the fissile Fika Shale intercalated with mud. Analyses of seventeen fresh gypsum samples by X-ray spectrophotometer technique indicate mean average compositions of 93.06, 92.59 and 93.60 wt % of $CaSO_4.2H_2O$; 2.04, 2.32 and 1.80 wt % SiO_2; 0.38, 0.40, and 0.70 wt % of Fe_2O_3+AL_2O_3; 0.36, 0.34 and 0.11 wt % of MgO; 0.13, 0.14 and 0.13 wt of Alkalis (Na_2O +K_2O) and purity of 96.43, 96.48 and 96.42 for Satinspar, Selenite and Alabaster respectively. These chemical data indicate high grade of gypsum which may be suitable in: cement, ammonium sulphate fertilizer, pharmaceutical, ceramics/pottery, cosmetics, soil amendment, building, chemical, paints and textile industries.

Keywords: Senonian Fika Shale, Gypsum, Satinspar, Selenite and Alabaster.

INTRODUCTION

Nafada is located between latitude 11° 10'N and 10° 05'N and longitude 11° 15'E and 11° 25'E about 118.1 km along Deban Fulani – Bajoga road north of Gombe town in the Gongola Arm, Upper Benue Trough northeastern Nigeria (Fig 1). Gypsum mining sites were assessed around Birin Bolawa, Gadi, Ganko, Gonja, Mada, Papa, Shole, Sudingo, and Warun through minor roads to network of foot paths. Gypsum is a hydrated salt of CaSO4.2H2O in rock form mostly in sedimentary environment associated with shale, limestone, clay and mudstone. Gypsum is an indispensable industrial mineral and raw material in Nigerias' small, medium and major industries for sustainable economic development. The topography of Nafada and environs are generally flat lying and mostly undulating terrain at the mining sites with slope running from the southern to the northern part within an altitude of 259 to 357m above sea level. A sandstone ridge occurs surrounding these terrains at the extreme southern part of the study area otherwise known as the Dumbulwa Bage High described by (Zaborski et al., 1997). Falconer (1911) was the first to carry out mineral survey in northern Nigeria, Carter et al., (1963) first reported the occurrence of gypsum deposits within the sequence of blue black Fika Shale, and was later confirmed by Reyment (1965), who reported that the gypsiferous beds have thickness exceeding 420 meters. Gypsum occurrence in Nafada, Bajoga was reported by Orazulike (1988) and further investigations by Barka (2011) and Tabale (2014) who revealed that the Nafada gypsum forms are Satinspar, Selenite and Alabaster types. These workers confirmed

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that the Fika shales are gypsiferous and served as the major host rock for gypsum deposits. Gypsym was also reported by Ntekim (1999) and Mamnan et al (2007) in Guyuk and Cham area within the shale formations in the neighbouring Yola Arm of the Upper Benue Trough. (Fig 2) shows geologic map of the studied area.

Gypsum is one of the important raw materials for Nigeria's industrial development especially in cement and chemical industries.

This present work is aimed to assess the industrial quality of Nafada gypsum and environs for suitable application in the various industries like: cement, ammonium sulphate fertilizer, pharmaceutical, ceramics/pottery, cosmetics, soil amendment, building, chemical, paints and textile industries.

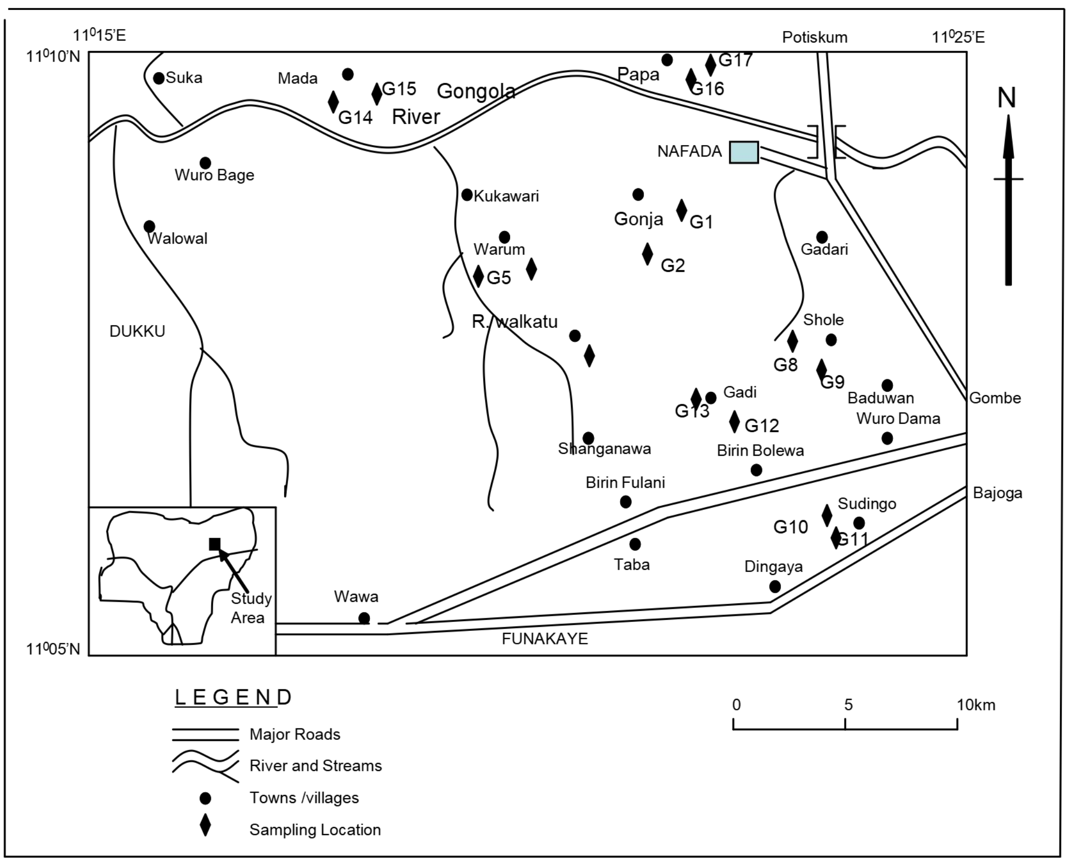

Fig I. Map of Nafada showing the study area and Sampling Locations

Source: Administrative map of Nafada (2002)

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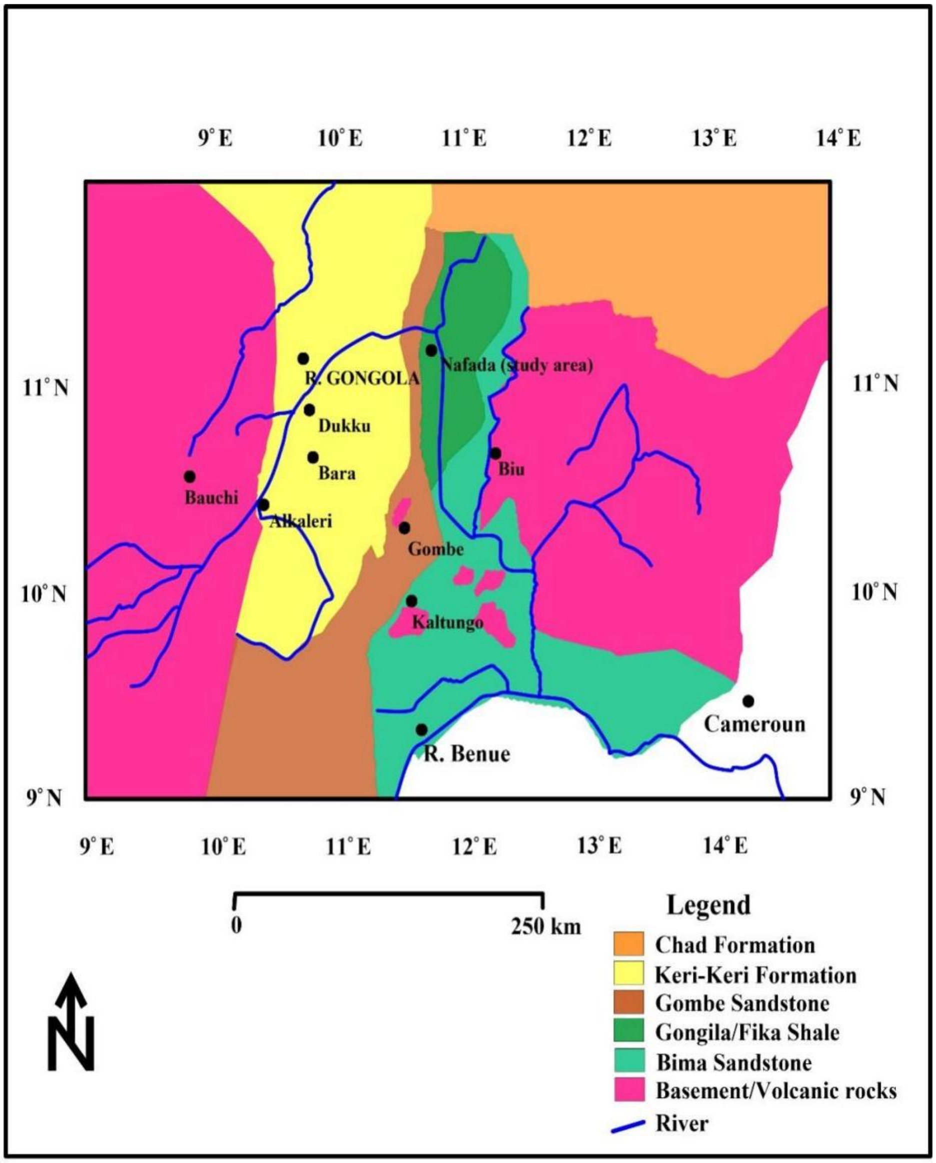

Figure 2: Geologic map of the Upper Benue trough showing the study area.

MATERIALS AND METHODS

Methodology

Chemical compositions of seventeen representative samples of gypsum from different sampling points (Table: 1) within the study area were analyzed at the Ashaka Cement Laboratory, Gombe Nigeria. The samples were brushed, clean and afterwards pulverized in a mechanical crushing machine into a fine powder of 125'microns. To produce pellets used for the analysis, 0.4g of granular stearic acid was mixed with 20g of powdered samples and then re-homogenized in a 'HERZOG' mechanical grinder for about 10 seconds. Then 1g of stearic acid was again added to the reground samples to fill the aluminium pelletizing mould, after which the mould was placed in a 'HERZOG' pelleting machine for 10 seconds. Each of the pellets was analyzed for SiO_2, Fe_2O_3, CaO, MgO, SO_3, K_2O, and Na_2O, combined water and purity (Table 1).

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Table 1: Composition of studied Nafada gypsum samples (wt %)

Sample	Gypsum type	Chemical parameters (wt %)											
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	Purity	Combined water	$CaSO_4$	$CaSO_4.2H_2O$
G-1	Satinspar	1.632	0.481	0.140	31.030	0.212	43.279	0.053	0.070	93.050	19.476	74.31	93.78
G-2		1.186	0.303	0.134	30.860	0.299	43.679	0.040	0.070	93.909	19.655	74.54	94.19
G-3		2.957	0.905	0.284	31.009	0.318	42.152	0.087	0.069	90.626	18.968	73.16	92.13
G-4		2.396	0.742	0.340	30.524	0.603	42.496	0.071	0.069	91.365	19.123	73.02	92.14
S-1	Selenite	4.895	1.698	0.810	29.365	0.584	40.891	0.134	0.067	87.916	18.401	70.26	88.66
S-2		1.736	0.508	0.148	30.540	0.218	43.599	0.055	0.069	93.738	19.620	74.14	93.76
S-3		1.266	0.332	0.133	30.754	0.277	43.718	0.045	0.069	93.995	19.673	74.47	94.16
S-4		1.550	0.411	0.168	30.689	0.269	43.416	0.051	0.070	93.345	19.537	74.11	93.64
S-5		2.136	0.651	0.258	30.566	0.347	42.877	0.066	0.070	92.185	19.295	73.44	92.74
A-1	Alabaster	1.618	0.455	0.259	30.523	0.194	43.680	0.051	0.069	93.912	19.656	74.20	93.86
A-2		3.451	1.305	0.534	29.710	0.205	42.447	0.096	0.069	91.260	19.101	72.16	91.26
A-3		0.651	0.163	0.099	30.758	0.018	44.458	0.028	0.071	95.586	20.006	75.22	95.23
A-4		2.083	0.633	0.531	30.365	0.323	43.069	0.064	0.069	92.599	19.381	74.06	93.44
A-5		1.755	0.508	0.112	30.329	0.037	43.863	0.040	0.070	94.306	19.738	74.19	93.93
A-6		0.587	0.149	0.136	30.783	0.020	44.579	0.035	0.070	95.845	20.081	75.36	95.42
A-7		0.922	0.373	0.494	30.565	0.013	44.122	0.025	0.070	94.862	19.855	74.69	94.54
A-8		3.298	1.265	0.890	29.502	0.079	42.481	0.095	0.068	91.334	19.116	71.98	91.10
Mean Values													
Satinspar		2.04	0.607	0.229	30.86	0.36	42.90	0.063	0.070	96.43	19.31	73.76	93.06
Selenite		2.32	0.720	0.303	30.38	0.34	42.90	0.070	0.069	96.48	19.31	73.28	92.59
Alabaster		1.80	0.606	0.382	30.32	0.11	43.59	0.054	0.070	96.42	19.62	73.99	93.60
Entire studied Nafada Samples		2.05	0.644	0.305	30.52	0.27	43.13	0.062	0.069	96.44	19.41	73.68	93.08

Sample Identification: G1, G2, G3, G4 = Satinspar Gypsum, S1, S2, S3, S4, S5 = Selenite Gypsum; A1, A2, A3, A4, A5, A6, A7 and A8, = Alabaster Gypsum

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Occurrence

Field investigations revealed that the Fika Shales consists of both thick laminated non-gypsiferous red clay and gypsum-rich blue-black shale and mudstone and grey coloured highly fissile and friable shale and clay with occasional pebbles where the three varieties (satinspar, selenite and alabaster) of gypsum occurs in pores and fractures within the fissile and friable Fika Shales. Three gypsum varieties are namely: alabaster, satinspar and selenite occur within the Fika Shale at different depth in different locations. Satinspar gypsum forms occur silky, fibrous to acicular crystals as thin beds (averagely 1-5cm) at an average depth of 10.5 meters in Gonja, Warum and Ganko area. It is transparent to translucent, fibrous, silky and acicular crystals commonly aligned parallel to sub-parallel to the bedding plane. Selenite gypsum forms outcrop as thin (averagely ≤5cm) continuous or discontinuous veins of prismatic crystals arranged vertically or obliquely to the bedding plane. It occurs at an average depth of 9.4 meters at Shole and Sudingo areas. Alabaster gypsum form is massive, fine grained with internal lamination. It is found in Birin Bolawa, Mada and Papa area within the highly friable Fika Shales as thin (averagely ≤ 6cm) discontinuous veins at an average depth of 7.5 meters.

RESULTS AND DISCUSSION

Geochemistry

During sedimentation processes, certain chemical differentiation involving decomposition of major sulphides (including pyrite and chalcopyrite) and carbonate (including calcite and malachite) minerals and uptake of free radicals leading to process of gypsum formation by dolomitization associated with many other minerals (Murray, 1964; Folk et al., 1974; Milovsky and Kononov, 1984). The various geochemical portioning during sedimentation process tend to fix the released ions from these associated (malachite, smithsonite, anglesite, cerusite) minerals as constituent admixture in the shale rock units. Aided by the high organic matter content of the carbonate rocks and the fine grained nature of the shale units released trace elements (e.g. Cu, Zn, Pb) adhere to the rocks and hence occur as impurities in gypsum bodies (Ntekim and Orazulike 2007).

Industrial Quality

Since water determines the stability of gypsum form, in its natural form, high grade gypsum contains at least 79.1 wt % of $CaSO_4$ and 20.9 wt % combined water. Therefore, any loss of water by gypsum forms would convert it to anhydrite and thus lower the quality of the mineral. In most cases this loss in water is accompanied by increase in constituent impurities. Relatively (Table 1) the three studied gypsum forms are about the same quality, except that the average combined impurity contents silica, alumina and iron oxide is least in Alabaster type (with 2.79) followed by Satinspar (2.87) and 3.33 for Selenite. Average values of $CaSO_4$ in the three studied gypsum forms are 73.76, 73.28 and 73.99 wt % for satinspar, selenite and alabaster respectively. This range of $CaSO_4$ makes the studied gypsum forms slightly below the American Society and Testing of Materials (ASTM) 79.1 wt % $CaSO_4$ for high grade gypsum (Table 2).

Comparison of Table 1 and Table 2, shows that the average water content in the studied gypsum is 19.31, 19.31 and 19.62 wt % for satinspar, selenite and alabaster respectively, depicting that the studied gypsum may also be regarded as stable because the value slightly fall below the ASTM standard of 20.9 wt % water content for high grade naturally occurring gypsum. According to Holiday (1970) the depth of emplacements of 10.5, 9.4 and 7.5 meters on the average for the studied

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gypsum is likely to have contributed to these slight differences in their stability field. By ASTM (1981) standard, naturally occurring high grade gypsum with about 84 – 100 wt % $CaSO_4.2H_2O$, less than 3.0% magnesia and < 0.603% alkalies is required for portland cement manufacture. Hence the studied gypsum with 93.06, 92.59.

Table 2: Average composition of Nafada gypsum relative to standards for various industries 93.60 wt % average $CaSO_4.2H_2O$, average (MgO) of 0.36, 0.34 and 0.11% and (Na_2O + K_2O) of 0.13, 0.14 and 0.13% [for Satinspar, Selenite and Alabaster forms respectively], can be used for this purpose.

Relative to the British Industrial Specification (BIS) the studied Nafada gypsum meets the BIS requirements for the various industries (Table 2). The BIS specification for cement production is 70-75% $CaSO_4.2H_2O$ [and 80-85% for export quality], 0.6 % (max) K_2O + Na_2O and 3.0% (max) of MgO; the studied gypsum has 93.08 % (max) $CaSO_4.2H_2O$, 0.13 % K_2O + Na_2O and 0.27 % MgO. BIS specification for ammonium sulphate fertilizer is 85-90 % $CaSO_4.2H_2O$, 6.0 % SiO_2, 1.0 % Fe_2O_3/Al_2O_3 and 1.5 % MgO, and the studied gypsum has 93.08 % $CaSO_4.2H_2O$, 2.05 % SiO_2, 0.49 % Fe_2O_3/Al_2O_3 and 0.27 % MgO; meaning that the studied gypsum is therefore suitable for ammonium sulphate fertilizer production. For surgical/pharmaceutical industry the BIS requires 96.0 % $CaSO_4.2H_2O$, while the studied gypsum has 93.08 % $CaSO_4.2H_2O$ which is slightly below, but could be beneficiated to meet up with the BIS required standard. Pottery has BIS specification of 85 % $CaSO_4.2H_2O$, 1.0 % Fe_2O_3/Al_2O_3 and 1.5 % MgO, while the studied gypsum has 93.08 % $CaSO_4.2H_2O$, 0.49 % Fe_2O_3/Al_2O_3 and 0.27 % MgO; hence is within the specified BIS requirement. Cosmetics manufacture has BIS specification of 75.25 % $CaSO_4.2H_2O$, 3.0 % (max) SiO_2, and the studied gypsum has 93.08 % $CaSO_4.2H_2O$, and 2.05 % SiO_2, so can be used for cosmetic manufacture. The studied gypsum with 93.08 % $CaSO_4.2H_2O$ averagely has met the specified limits for materials needed for soil amendment, building, chemical, paints and textile industries (BIS, 1997).

Kurt, (1984) opined that gypsum in its natural form usually contains impurities, probably due to varying amounts of shaly materials, silica, alumina, magnesia, iron oxide and other compounds, thereby lowering the grade of the mineral. The three studied Nafada gypsum forms show average purity of 96.43, 96.48 and 96.42 % $CaSO_4.2H_2O$ for Satinspar, Selenite and Alabaster respectively (Table 2). This rating portends materials suitable for use in the various manufacturing industries hence, Nafada gypsum is regarded as of good quality for industrial applications.

CONCLUSION

Gypsum occurs in various locations within the blue black Fika Shales at Nafada area. Three gypsum varieties (Satinspar, Selenite and Alabaster) were identified and their geochemical assessment reveals that the gypsum were of high grade with an average purity of 93.06, 92.59 and 93.60 % for the satinspar, selenite and alabaster respectively. These results indicate that the Nafada gypsum are suitable for industrial application in cement, ammonium sulphate fertilizer, pharmaceutical, ceramics/pottery, cosmetics, soil amendment, building, chemical, paints and textile industries.

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Table 2: American Society for Testing and Materials (ASTM 1981), British Industrial Specification (BIS 1997) and Raw Material Research Development Council (RMRDC 2005)

Samples/standards		Properties (wt %)							
		$CaSO_4.2H_2O$	Purity	Combined Water	SiO_2	Fe_2O_3 / Al_2O_3	MgO	Na_2O + K_2O	$CaSO_4$
Satinspar		93.06	96.43	19.31	2.04	0.38	0.36	0.13	73.76
Selenite		92.59	96.48	19.31	2.32	0.40	0.34	0.14	73.28
Alabaster		93.60	96.42	19.62	1.80	0.70	0.11	0.13	73.99
Studied Nafada gypsum		93.08	96.44	19.41	2.05	0.49	0.27	0.13	73.68
ASTM Specifications		84-100	-	21.9	-	-	<3.03	<0.603	79.10
BIS	Cement	70-75	-	-	-	-	3.0 (max)	0.6 (max)	-
	Soil amendment	50 (min)	-	-	-	-	-	-	-
	AS Fertilizer	85-90 (min)	-	-	6.0 (min)	1.0 (min)	50 (min)	-	-
	Pharmaceutical	96 (min)	-	-	0.7 (min)	0.1 (min)	50 (min)	-	-
	Pottery	85 (min)	-	-	-	1.0 (min)	50 (min)	-	-
	Building	75 (min)	-	-	-	-	-	-	-
	Chemical	94 (min)	-	-	-	-	-	-	-
	Paints	75 (min)	-	-	-	-	-	-	-
	Textile	82 (min)	-	-	-	-	-	-	-

ASTM = American Society for Testing and Materials; BIS = British Industrial Specification; Fertilizer = Ammonium sulphate fertilizer; max = maximum amount; min = amount.

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