GEOCHEMICAL STUDIES OF GYPSUM FROM NAFADA AND ENVIRONS NORTH-EASTERN NIGERIA

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Abstract: This research is aimed at determining the geochemistry and purity of gypsum within the Senonian Fika shale Upper Benue Trough, Gongola Arm in Nafada and environs for its industrial suitability. Seventeen (17) fresh samples from different localities were collected and analyzed using X-ray Fluorescence spectrometry (XRF) equipment for their oxides: SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, CaO, MgO, SO$_3$, K$_2$O and Na$_2$O. The results revealed that gypsum in the study area has high percentage purity of 87.9 - 95.6%. Comparing this result with the British Industrial Standard (BIS) it indicates a high grade gypsum forms that is suitability for different industrial usage (Agriculture, Medical, Pottery and Ceramic, Pharmaceutical, Chemical, Paints, Building, Construction etc).

Keywords: Upper Benue Trough, Gongola Arm, Senonian Fika Shale, Gypsum.

INTRODUCTION
Nafada and environs is located between latitude 11° 00’N to 10° 30’N and longitude 11° 00’E to 10° 30’E within the Gongola Arm of the Upper Benue Trough northeastern Nigeria (Fig. 1). The study areas includes Gonja, Warum located about 4 km southwest of Nafada, Shole, Gadi, Sudingo are located about 10km south of Nafada, Mada and Papa mines were located about 6 km northwest of Nafada town respectively (Fig 1). These areas are generally flat lying terrain and undulating in some areas. The area is generally surrounded by a sandstone ridge, the Dumbulwa Bage High (Zarboski et al., 1997). The occurrence of gypsum within the Fika Shale in the Gongola arm of the Upper Benue Trough was first reported by Carter et al; (1963) and later confirmed by Reyment (1965). Orazulike (1988) reported the occurrence of gypsum in Nafada and Bajoga areas. Barka (2011) also reported the occurrence of gypsum in Nafada area of Gombe State northeastern Nigeria. Ntekim 1999 and Mamman et al., 2007 also reported the occurrence of gypsum deposits in Cham and Guyuk in the Yola Arm of the Upper Benue Trough.

This present work attempts to study the geochemistry of gypsum deposits in the Cretaceous Fika shale of Nafada and environs. This is done in order to evaluate its quality and suitability for different industrial usage.

Geologic Setting
The Benue Trough is an intracontinental Cretaceous basin about 1000km in length elongated in the NE-SW direction resting unconformable on the Precambrian Basement. The geology of this basin was studied extensively by different workers (Falconer, 1911; Carter et al., 1963; Reyment, 1965; Burke et al., 1971; Chukwu-Ike, 1981; Petters, 1978and1982; Alix, 1983; Benkhelil, 1983; Popoff et al., 1986; Braid, 1992; Dike, 1993; Zarborski et al., 1997; Obaje et al., 1999; Offodile, 2006).

The stratigraphic succession of the Gongola basin shows that the oldest sedimentary unit in the basin is the Albian Bima Formation, which was deposited under continental environment and
lies unconformably on the Precambrian Basement rocks which Popoff et al; (1986) and Zarboski et al; (1997) assigned ages ranging from Pre-Aptian/Aptian to Albian Cenomanian. Early work by Raeburn and Jones, (1934) and recently Zarboski et al; (1997) consider Bima Formation as a group consisting of lower Bima (B1), middle Bima (B2) and Upper Bima (B3). Yolde Formation lies conformably on the Bima Sandstone and marked 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 lie conformably on the Yolde Formation; both formations were deposited under full marine environment into the Upper Benue Trough during Turonian-Santonian times. The Santonian period was a period of intense deformation and folding episode in the whole of Benue Trough (Benkhelil 1989).

METHODOLOGY
Seventeen (17) fresh samples were collected from the mining sites at depths ranging from 3 to 15 meters within the stratigraphic columns. The collected samples were analyzed using X-ray fluorescence (XRF) for major oxide concentration at Ashaka Cement laboratory, Gombe State. The samples were cleaned using a plastic brush and pulverized in a mechanical crushing machine into fine powder of 125μm. 20g of the powdered sample was weighed and mixed with 0.4g of granular stearic acid. The mixture was re-homogenized in a "HERZOG" mechanical grinder for 10 seconds. 1g of stearic acid was added to the reground sample to fill the pelletizing aluminium mould. The mold was later placed in a "HERZOG" pelleting machine for 10 seconds after which a pellet was produced. The procedure was repeated for each sample. Each Pellet was analyzed for SiO₂, Al₂O₃, Fe₂O₃, CaO, MgO, SO₃, K₂O and Na₂O, combine water and purity.

RESULTS AND DISCUSSION
The result of the analyzed samples is presented in table 1. The concentration of the various oxide composition of Nafada gypsum shows that, SiO₂ ranges from 0.6 to 3.5%, Al₂O₃ from 0.1 to 1.7%, Fe₂O₃ from 0.1 to 0.9%, CaO from 29.3 to 31.0%, MgO from 0.01 to 0.6%, SO₃ from 40.9 to 44.5%, K₂O from 0.02 to 0.13% and Na₂O from 0.06 to 0.07%. From this data, a ternary diagram was plotted for Ca, Mg and Fe and the result shows that the study area was highly enrich in Ca Fig 3. This result concur with Folk et al., (1974) that dolomitization of limestone through replacement of calcium (Ca²⁺) by magnesium (Mg²⁺) make calcium to be highly enriched and react with sulphate ion (SO₄²⁻) in the interstitial fluids to form gypsum. Variation diagrams were plotted figures 3 – 9 and the general trends shows high level of silica impurity in samples G5, G11 and G17. High concentration of silica as observed tend to lower the concentration of CaO and SO₃ as shown in samples G5, G11 and G17. However, the presence of the silica impurity has also affected the concentration of other oxides in figures 5-10. Relative assessment reveals that, purity of the studied gypsum samples varies between locations (Table 2). The Mada sample with mean purity value of 95.35 % is the purest followed by Gadi (94.09 %), Ganko (93.87 %), Gonja (93.48 %), Papa (93.10 %), Shole (92.10 %), Sudingo (92.59 %) and Warum (89.97 %) in decreasing order of average purity. This shows that, the Nafada gypsum is averagely of good quality.

Comparison of the studied gypsum characteristics (Table 2) to the British Industrial Specification (BIS) (Table 3) reveals that, the studied gypsum conform to the BIS specification.
for various industries except that of the surgical and pharmaceutical industry which requires a minimum of 96.0% CaSO$_4$.2H$_2$O. The studied gypsum has maximum of 93.0% CaSO$_4$.2H$_2$O.

The BIS specification for cement is 70-75% and 80-85% CaSO$_4$.2H$_2$O for export quality, 0.6% (max) K$_2$O + Na$_2$O and 3.0% (max) of MgO. The studied gypsum with 93.0% (max) CaSO$_4$.2H$_2$O, 0.13% K$_2$O + Na$_2$O and 0.235% MgO has met the BIS required standard limit.

BIS specification for ammonium sulphate fertilizer is 85-90% (min) CaSO$_4$.2H$_2$O, 6.0% (max) SiO$_2$, 1.0% (max) Fe$_2$O$_3$/Al$_2$O$_3$, and 1.5% (max) MgO. With 93.0% (max) CaSO$_4$.2H$_2$O, 2.007% SiO$_2$, 0.482% Fe$_2$O$_3$/Al$_2$O$_3$, and 0.235% MgO, the studied gypsum is within the BIS required specification for ammonium sulphate fertilizer production.

Pottery has BIS specification of 85% (min) CaSO$_4$.2H$_2$O, 1.0% (max) Fe$_2$O$_3$/Al$_2$O$_3$, and 1.5% (max) MgO, while the studied gypsum has 93.0% CaSO$_4$.2H$_2$O, 0.482% Fe$_2$O$_3$/Al$_2$O$_3$, and 0.235% MgO; hence is within the specified BIS requirement. Cosmetics manufacture has BIS specification of 75.25% (min) CaSO$_4$.2H$_2$O, 3.0% (max) SiO$_2$, and the studied gypsum has 93.0% CaSO$_4$.2H$_2$O, 2.007% SiO$_2$; can be used for cosmetic manufacture. The studied gypsum with 93.0% CaSO$_4$.2H$_2$O is within the specified specification for materials needed in building, chemical and paint industries and for soil amendment.

Similarly, according to BIS specification, gypsum with moisture content of 20.9 weight percentage (wt %) is regarded as pure gypsum. Those with low moisture content are regarded as impure while those with no moisture content have been transformed from gypsum to anhydrite. The studied Nafada gypsum has an average moisture content of 19.45 weight percentage (Table3) which is slightly below that of pure gypsum, while the average purity of the Nafada gypsum is 92.93%. From this result it can be deduced that the studied gypsum contain little amounts of other compounds hence, making them of good quality.

The mode of occurrence of gypsum from Nafada and environs shows that, gypsum occurs in pores and fractures and this indicate a diagenetic (secondary) origin. Gypsum with high amount of calcium oxide shows that their source is from limestone (Scott, 1984). The calcium ion could have come from calcareous materials present in the shale unit. Another possible source of calcium ions are from dolomitization of limestone concretions and nodules within the gypsiferous shale. Folk et al., (1974) reveals that, dolomitization of limestone through replacement of calcium (Ca$^{2+}$) by magnesium (Mg$^{2+}$) makes calcium to be highly enriched within the shale unit and reacts with sulphate ions (SO$_4^{2-}$) in the interstitial fluids to form gypsum according to the following equations (Murray, 1964).

\[
\text{CaCO}_3 + \text{Mg}^{2+} = \text{CaMg(CO}_3)_2 + \text{Ca}^{2+}
\]

Limestone Dolomite

\[
\text{Ca}^{2+} + \text{SO}_4^{2-} + 2\text{H}_2\text{O} = \text{CaSO}_4.2\text{H}_2\text{O}
\]

Gypsum

Also, a similar process of dolomitization and formation of gypsum and anhydrite has been observed at the Trucial Coast of the Arabian Gulf (Evans et al., 1969).

**CONCLUSION**

Field occurrence of gypsum bodies in Nafada area shows discontinuous and displacive patterns of vertical to sub-vertical cross-cutting minor fractures within the Senonian Fika shale as thin laminae (1-6 cm) is evident of diagenetic (secondary processes) origin. The geochemistry of
gypsum deposits within the Senonian Fika shale in Nafada and environs reveals that gypsum in the study area has high percentage purity of 90.6-95.8 wt%. These results concur with the British Industrial Standard, Raw Material Research Development Council (BIS:1290 -1973, RMRDC 2005) and Umeshwar 2005 indicating high grade gypsum form that is suitability for different industrial usage (Cement, Agriculture, Medical, Pottery and Ceramic, Pharmaceutical, Chemical, Paints, Building and Construction etc).

ACKNOWLEDGEMENT
I thank the management of Ashaka Cement Company for assistance with the analyses of the samples; I also appreciate Mr. Barka J. and Sheko for drafting the diagrams. The helpful comments of the reviewers are also appreciated.

REFERENCES


Geochemical Studies of Gypsum From Nafada and Environs North-Eastern Nigeria

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Fig I: Map of Nafada Showing the Study Area and Sampling Locations
Source: Administrative Map of Nafada (2002)
Fig. 2: Simplified Geological Map of the Upper Benue Trough (After Offidile, 2006.)
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**Fig 3: FCK Diagram for Gypsum of the Study Area**
Satinspar: G1, G2, G7, Selenite: G5, G6, G8, G9, Alabaster: G3, G10-G17

**Fig. 4: CaO Vs SiO₂ Variation Plot for Gypsum in the Study Area**
Satinspar – G1, G2, G7, Selenite – G5, G6, G8, G9, Alabaster: G3, G10-G17
**Fig. 5:** CaO Vs Al$_2$O$_3$ variation plot for Gypsum in the Study Area

Satinspar – G1, G2, G7, Selenite – G5, G6, G8, G9, Alabaster- G3, G10-G17

**Fig. 6:** CaO Vs Fe$_2$O$_3$ Variation Plot for Gypsum in the Study Area

Satinspar – G1, G2, G7, Selenite – G5, G6, G8, G9, Alabaster- G3, G10-G17
Alabaster – G3, G10 - G17
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Fig. 7: CaO Vs MgO Variation Plot for Gypsum in the Study Area
Satinspar – G1, G2, G7, Selenite – G5, G6, G8, G9, Alabaster – G3, G10 - G17

Fig. 8: CaO Vs K2O Variation Plot for Gypsum in the Study Area
Satinspar – G1, G2, G7, Selenite – G5, G6, G8, G9, Alabaster – G3, G10 - G17
Fig. 9: CaO Vs Na₂O Variation Plot for Gypsum in the Study Area

Satinspar – G1, G2, G7, Selenite – G5, G6, G8, G9, Alabaster – G3, G10 - G17
Table 1: Oxides Composition of Nafada Gypsum (in weight (%))

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<tbody>
<tr>
<td>SiO₂</td>
<td>1.632</td>
<td>1.186</td>
<td>2.957</td>
<td>2.396</td>
<td>4.895</td>
<td>1.736</td>
<td>1.266</td>
<td>1.550</td>
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<td>3.451</td>
<td>0.651</td>
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<td>AL₂O₃</td>
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<td>0.303</td>
<td>0.905</td>
<td>0.742</td>
<td>1.698</td>
<td>0.508</td>
<td>0.332</td>
<td>0.411</td>
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<td>0.163</td>
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<td>Fe₂O₃</td>
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<td>0.134</td>
<td>0.284</td>
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<td>0.148</td>
<td>0.133</td>
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<td>0.259</td>
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<td>MgO</td>
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<td>SO₃</td>
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<td>43.679</td>
<td>42.152</td>
<td>42.496</td>
<td>40.891</td>
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<td>44.458</td>
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<td>K₂O</td>
<td>0.053</td>
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<td>0.069</td>
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<td>0.069</td>
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<td>0.069</td>
<td>0.071</td>
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<td>76.571</td>
<td>77.781</td>
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<td>78.424</td>
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<td>93.995</td>
<td>93.345</td>
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<td>93.912</td>
<td>91.260</td>
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<td>94.306</td>
<td>95.845</td>
<td>94.862</td>
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Sample Identification: G1, G2, G7 = Satinspar Gypsum, G5, G6, G8, G9 = Selenite Gypsum, G3, G10- G17 = Alabaster Gypsum
### Table 2: Average Oxide Composition of Gypsum from Nafada and Environs.

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<tr>
<th>Oxide</th>
<th>Oxide composition (wt %)</th>
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<td>SiO$_2$</td>
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<tr>
<td>Al$_2$O$_3$/Fe$_2$O$_3$</td>
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<td>CaO</td>
<td>30.463</td>
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<td>MgO</td>
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<td>SO$_3$</td>
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<td>K$_2$O</td>
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<td>NaO</td>
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<td>Sum of concentration</td>
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<tr>
<td>Purity</td>
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<td>Combined water</td>
<td>19.451</td>
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<table>
<thead>
<tr>
<th>Industry</th>
<th>CaSO$_4$.2H$_2$O (%)</th>
<th>SiO$_2$ (%)</th>
<th>Fe$_2$O$_3$/Al$_2$O$_3$ (%)</th>
<th>MgO (%)</th>
<th>Na$_2$O+K$_2$O (%)</th>
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<tr>
<td>Cement</td>
<td>70-75(80-85) for export quality</td>
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<td>-</td>
<td>3.0(max)</td>
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<td>Soil Amendment</td>
<td>60.0(min)</td>
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<td>Ammonium Sulphate Fertilizer</td>
<td>85-90(min)</td>
<td>6.0(max)</td>
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<tr>
<td>Chemical</td>
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<tr>
<td>Paints</td>
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<td>-</td>
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<tr>
<td>Textile</td>
<td>82(max)</td>
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