Journal of Sciences and Multidisciplinary Research
Volume 6, No. 2, 2014
ISSN: 2277-0135

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

Tabale, R.P.
Geology Department
Gombe State University, Tudun-Wada Gombe, Nigeria.
E-mail: tabalepeter@yahoo.com

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_2O_3, Fe_2O_3, CaO, MgO, SO_3, K_2O and Na_2O. 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; Chukhu-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). The post folding episodes of 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).

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 125'm. 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 SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, K_2O and Na_2O, 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, SiO_2 ranges from 0.6 to 3.5%, Al_2O_3 from 0.1 to 1.7%, Fe_2O_3 from 0.1 to 0.9%, CaO from 29.3 to 31.0%, MgO from 0.01 to 0.6%, SO_3 from 40.9 to 44.5%, K_2O from 0.02 to 0.13% and Na_2O 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 (Ca^{2+}) by magnesium (Mg^{2+}) make calcium to be highly enriched and react with sulphate ion ($S0_3^{2-}$) 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 SO_3 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% $CaSO_4.2H_2O$. The studied gypsum has maximum of 93.0% $CaSO_4.2H_2O$.

The BIS specification for cement is 70-75% and 80-85 % $CaSO_4.2H_2O$ for export quality, 0.6 % (max) K_2O + Na_2O and 3.0% (max) of MgO. The studied gypsum with 93.0 % (max) $CaSO_4.2H_2O$, 0.13 % K_2O + Na_2O and 0.235 % MgO has met the BIS required standard limit. BIS specification for ammonium sulphate fertilizer is 85-90 % (min) $CaSO_4.2H_2O$, 6.0 % (max) SiO_2, 1.0 % (max) Fe_2O_3/Al_2O_3 and 1.5 % (max) MgO. With 93.0 % (max) $CaSO_4.2H_2O$, 2.007 % SiO_2, 0.482 % Fe_2O_3/Al_2O_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) $CaSO_4.2H_2O$, 1.0 % (max) Fe_2O_3/Al_2O_3 and 1.5 % (max) MgO, while the studied gypsum has 93.0 % $CaSO_4.2H_2O$, 0.482 % Fe_2O_3/Al_2O_3 and 0.235 % MgO; hence is within the specified BIS requirement. Cosmetics manufacture has BIS specification of 75.25 % (min) $CaSO_4.2H_2O$, 3.0 % (max) SiO_2, and the studied gypsum has 93.0 % $CaSO_4.2H_2O$, 2.007 % SiO_2 can be used for cosmetic manufacture. The studied gypsum with 93.0 % $CaSO_4.2H_2O$ 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).

$$\underset{\text{Limestone}}{CaCO_3} + Mg^{2+} = \underset{\text{Dolomite}}{CaMg(CO_3)_2} + Ca^{2+}$$

$$Ca^{2+} + SO_3^{2-} + 2H_2O = \underset{\text{Gypsum}}{CaSO_4.2H_2O}$$

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

Alix, P., (1983). Environments Mesozoiques de la pertie nord-orientale du fosse de la Bnuoue. Nigeria. Stratigraphic – Sedimentologie, Evolution Geodynamique. *Journal Travaux des Laboratoires des Sciences de la Terre*, Marseille, St-Jerome, 21:1-200.

Barka J., (2002). Geology and Geochemical Evaluation of Gypsum Occurrence Around Nafada Area Gombe State. (Unpublished B.Sc Thesis).

Benkhelil J, and Robinnea B., (1983). Lefosse de la Benoue est-il un rift, Bull. Centres Rech Explor-Prod. Aquitaine 7, 315-21.

Benkhelil, J., (1989). The Origin and Evolution of the Cretaceous Benue Trough Nigeria. *Journal of African Earth Sciences* 8(4): 251-282.

Braide, S.P., (1992). Studies on Sedimentary and Tectonics of the Yola Arm of the Upper Benue Trough; Facies Architecture and Their Tectonic Significance. *Journal of Mining and Geology,* 28 (2): 23-32.

BIS, (1997). British Industrial Specification for Gypsum Uses (IS: 1929 – 1973).

Burke, K.C. Dessauvagie, T. F. J. and Whiteman, A.J., (1971). Opening of the Gulf of Guinea and Geological History of the Benue Depression and Niger Delta. Nature Phys. Sci.233, 51-55.

Carter, J.D., Barber, W., Tait, E.A and Jones, J. P., (1963). The Geology of Part of Adamawa, Bauchi and Bornu Provinces of Nigeria. GSN Bull. 30: 109p.

Chukwu-Ike, I.M., (1981). Marginal Fracture System of the Upper Benue Trough in Nigeria and Their Tectonic Implications. *Earth Evolution Sci.* 2, 104-109.

Dike, E.F., (1993). Stratigraphy and Structures of Kerri-Kerri Basin, Northeastern Nigeria. *Journal of African Earth Science* 8. p 251-262.

Evans, G. E., Schmidt, V. Bush, P. and Nelson, H., (1969). Stratigraphy and Geologic History of the Sabka Abu Dhabi, Persian Gulf. *Sedimentology* 12, pp. 145-159.

Falconer J.D., (1911). The Geology and Geography of Northern Nigeria. London (MacMillan).

Folk R. L., (1974). Petrology of Sedimentary Rocks, 182p.

Mamman, Y. D, Orazulike, D.M and Ndaye, S.T., (2007). The Occurrence and Chemical Composition of Gypsum at Cham in the Yola Arm of the Upper Benue Trough N.E Nigeria. *Global Journal of Pure and Applied Sciences. V*ol. 13 No. 4 Pp 563 – 569.

Murray, R.C. (1964). Origin and Diagenesis of Gypsum and Anhydrite. *Journal of Sedimentary Petrology* 34: 512-523.

Ntekim E.E (1999). Preliminary Report on Gypsum Occurrence in Guyuk Area Northeastern Nigeria. *Global Journal of Pure and Applied Science*. Vol. 5. No.1.

Obaje, N. G. Ulu, O. K. Petters, S.W., (1999). Biostratigraphic and Geochemical Control of Hydrocarbon Prospect in the Benue Trough and Anambra Basin Nigeria. NAPE Bull. V. 14(1) P. 18-5.

Offfodile M. E., (2006). Appraising the Geology, Structure and Environment of Deposition as Indicators of Mineral Occurrences in the Gongola Basin of the Upper Benue Trough of Nigeria. A Paper Presented at NMGS Annual Conference Kaduna Pp 64-91.

Orazulike, D.M., (1998). 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.

Petters, S.W, Ekweozor, C.M., (1982). Petroleum Geology of the Benue Trough and South-Eastern Chad Basin, Nigeria. AAPG Bull. 66:1141-1149.

Petters, S.W., (1978). Stratigraphic Evolution of the Benue Trough and Its Implication for the Upper Cretaceous Paleogeography of West Africa. *Jour. of Mining and Geology.* 86 p.311-321.

Popoff, M., Wiedman, J. and Deklasz. I., (1986). The Upper Cretaceous Gongila and Pindiga Formation. Northern Nigeria Age. Stratigraphic Condition and Paleographic Implication- in Zaborski et al, (1997). Stratigraphy and Structure of the Cretaceous Gongola Basin Raw Material Research Development Council., 2005, Handbook on Specification of Raw Materials Utilized by Nigerian Industries 2nd Edition pp 143 – 282.

Reyment, R.A., (1965). Aspect of the Geology of Nigeria Ibadan University Press p.133.

Scott, P. W., (1984). Industrial Rocks and Minerals: Exploration and Evaluation. *Journal of Mining and Geology,* 21(1&2):1-12.

Umeshwar P., (2005). Economic Geology 2nd Edition CBS Publishers 319p.

Wright, J.B (1981): Review of the Origin and Evolution of the Benue Trough in Nigeria. Earth Evolution Sci. 1:98-103.

Zaborski .P, Ugodulunwa F. Idornigie A, Nnabo and Ibe K., (1997). Stratigraphy and Structures of the Cretaceous Gongola Basin, Northeastern Nigeria Bull. Center Rech EIF Exploration Prod. 21. Pp. 153 – 185.

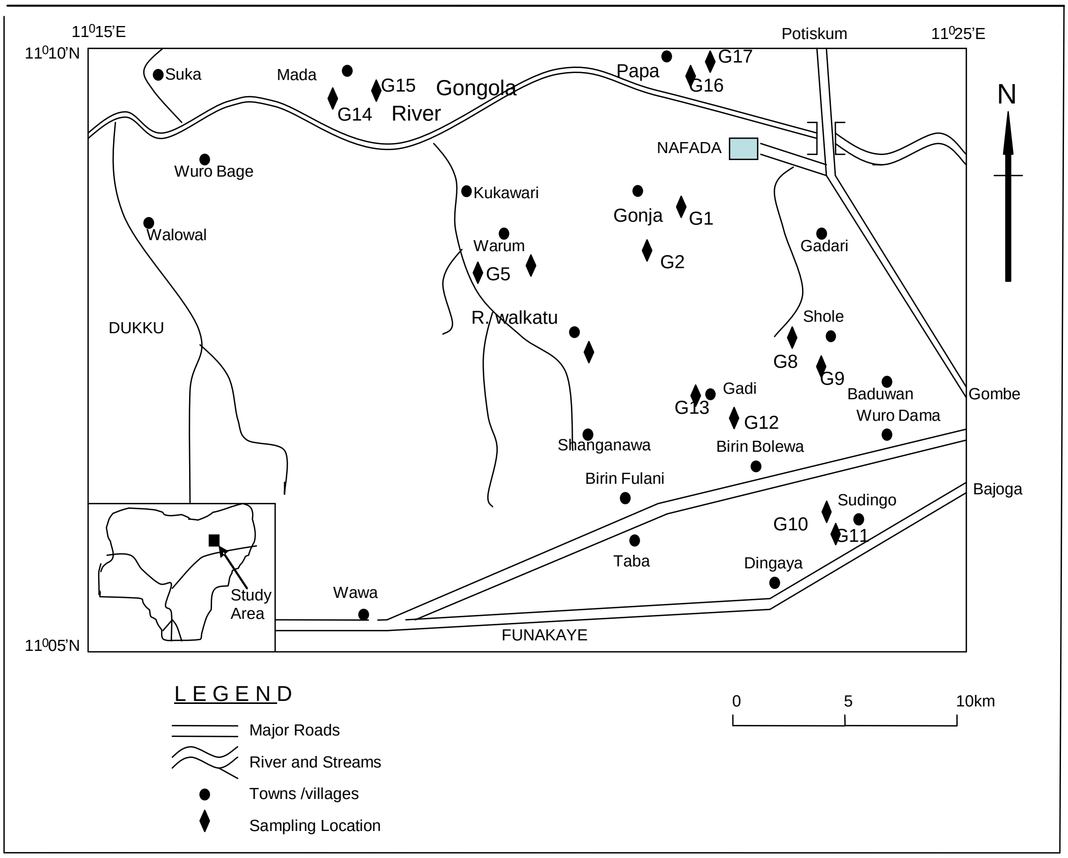

Fig I: Map of Nafada Showing the Study Area and Sampling Locations
Source: Administrative Map of Nafada (2002)

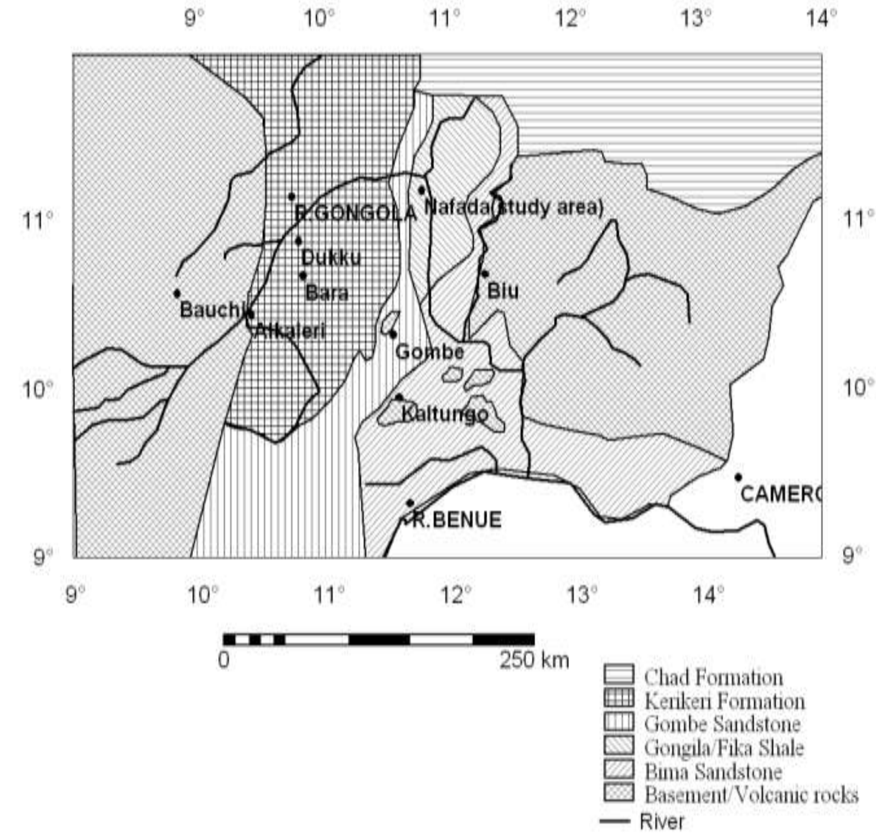

Fig. 2: Simplified Geological Map of the Upper Benue Trough (After Offidile, 2006.)

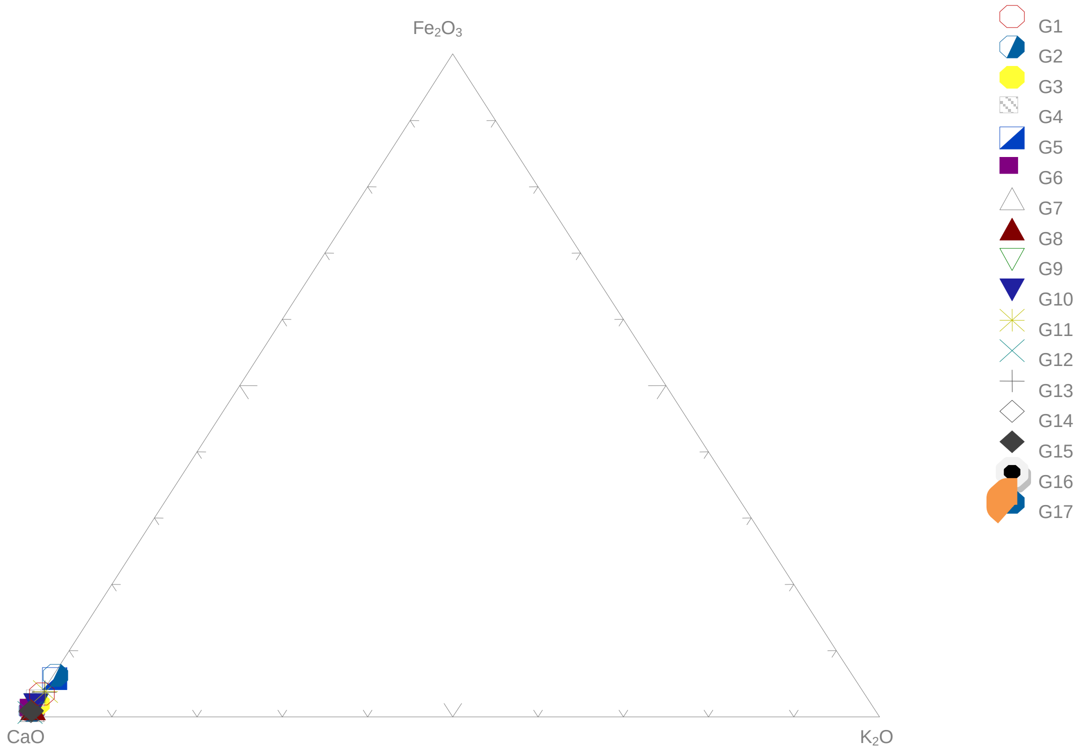

Fig 3: FCK Diagram for Gypsum of the Study Area

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

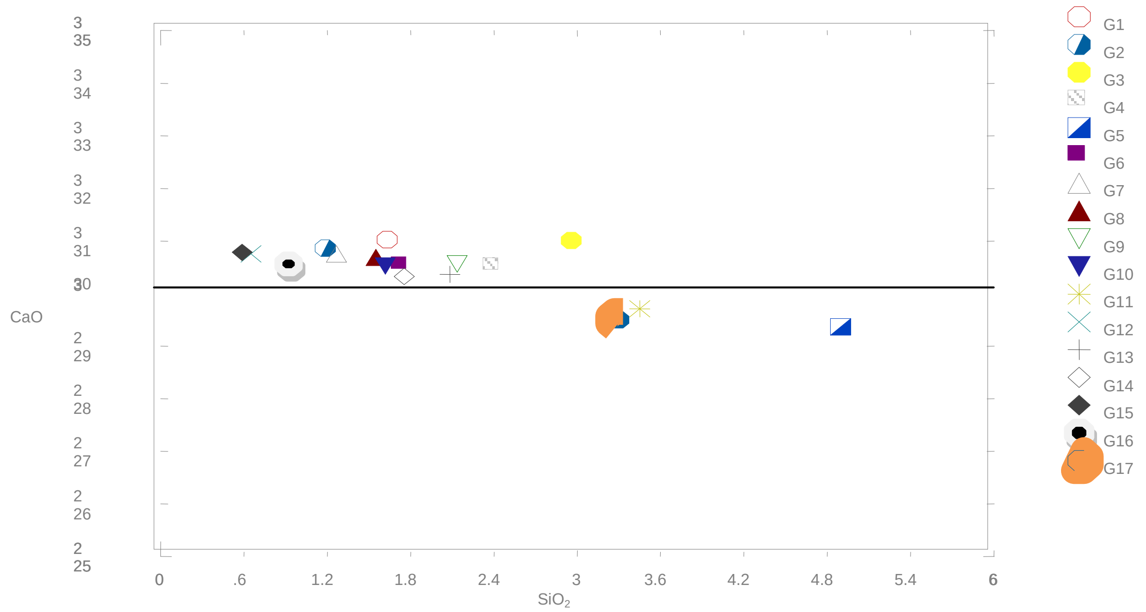

Fig. 4: CaO Vs SiO_2 Variation Plot for Gypsum in the Study Area

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

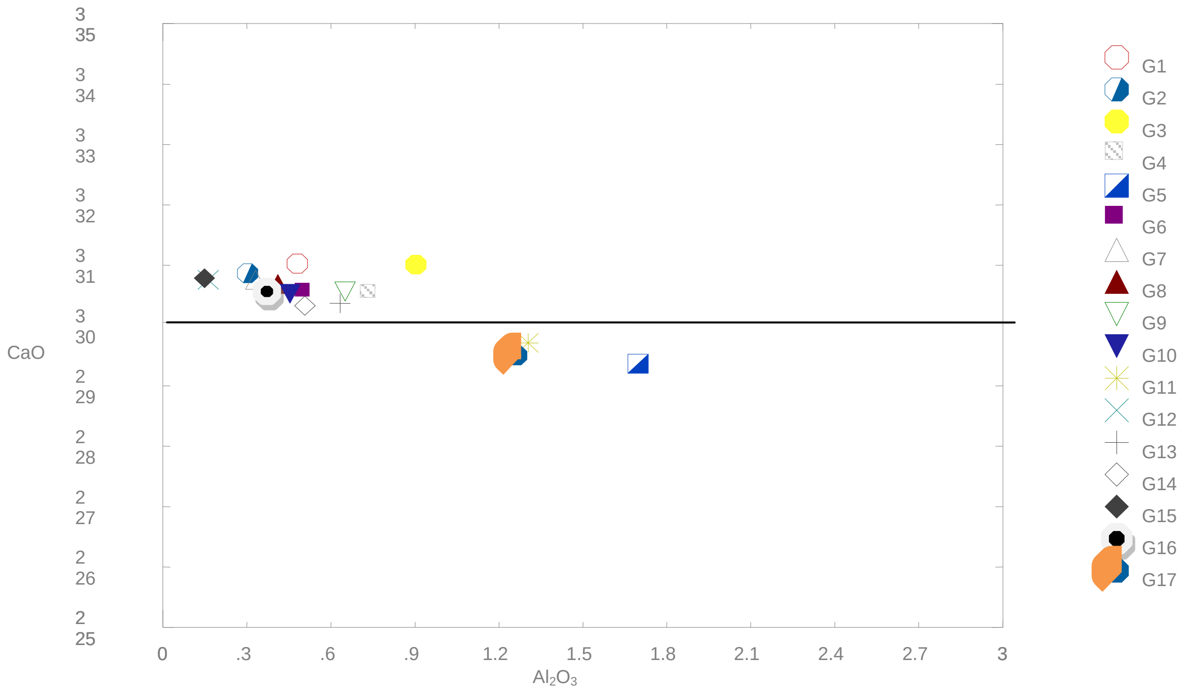

Fig.5: CaO Vs Al_2O_3 variation plot for Gypsum in the Study Area

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

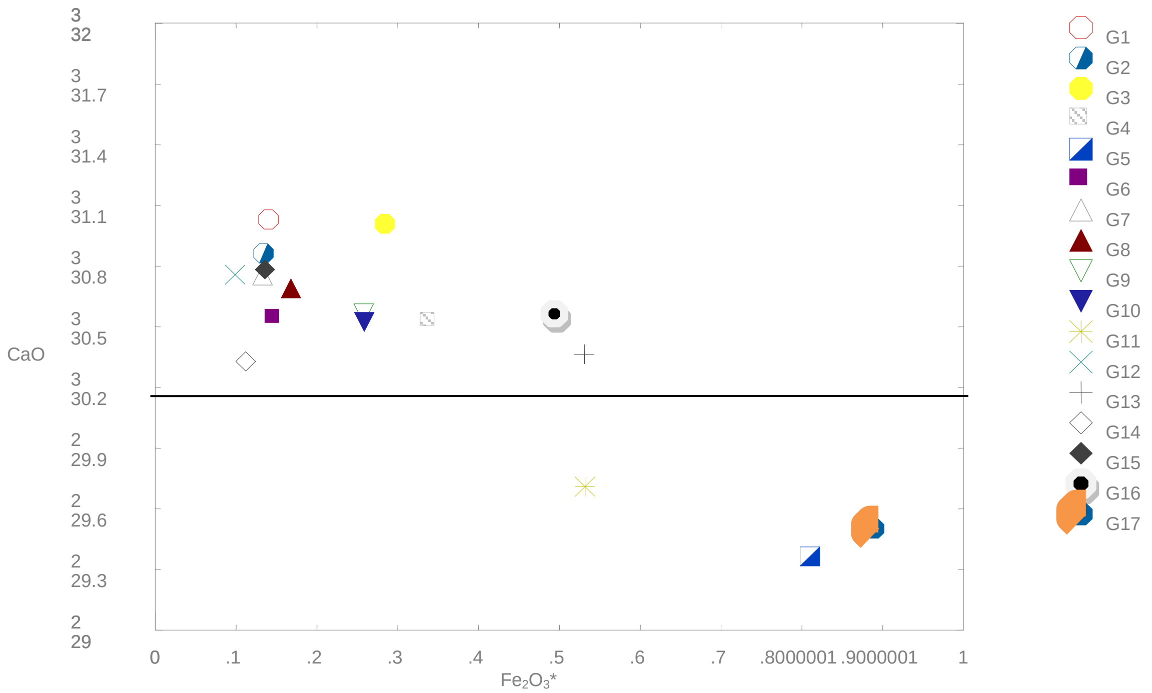

Fig.6: CaO Vs Fe_2O_3 Variation Plot for Gypsum in the Study Area

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

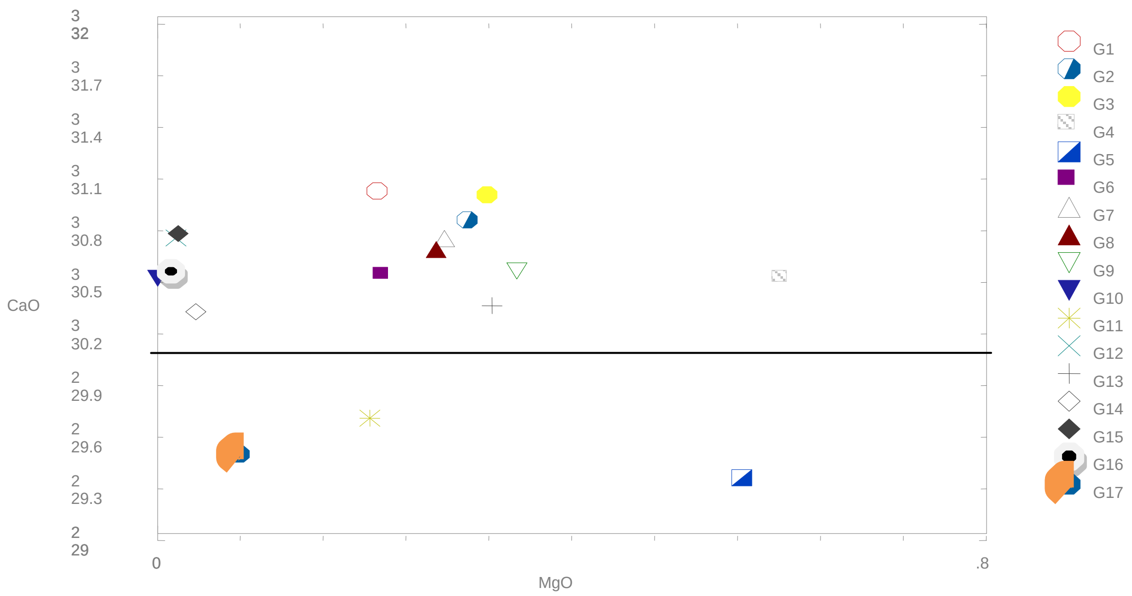

Fig.7: CaO Vs MgO Variation Plot for Gypsum in the Study Area

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

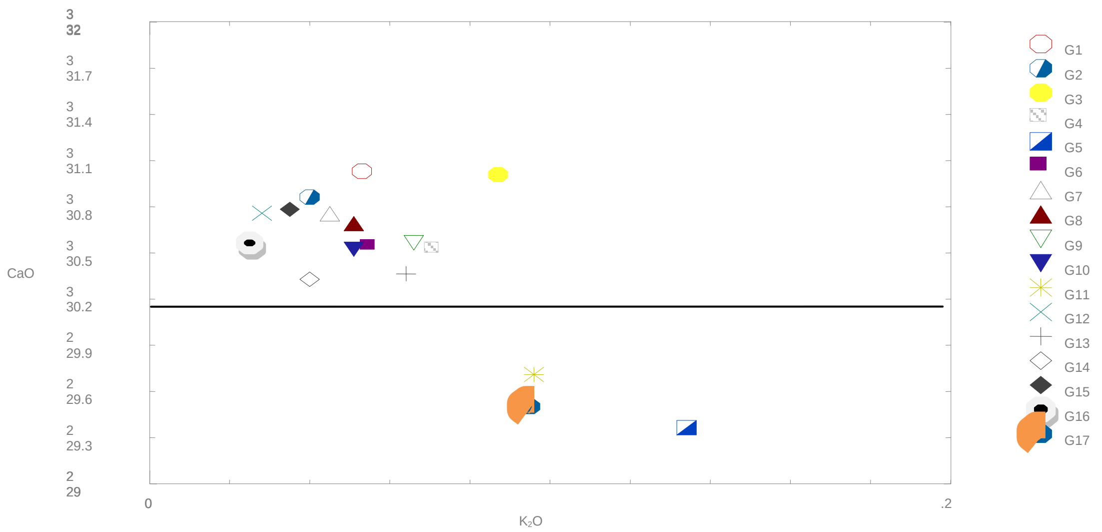

Fig.8: CaO Vs K_2O Variation Plot for Gypsum in the Study Area

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

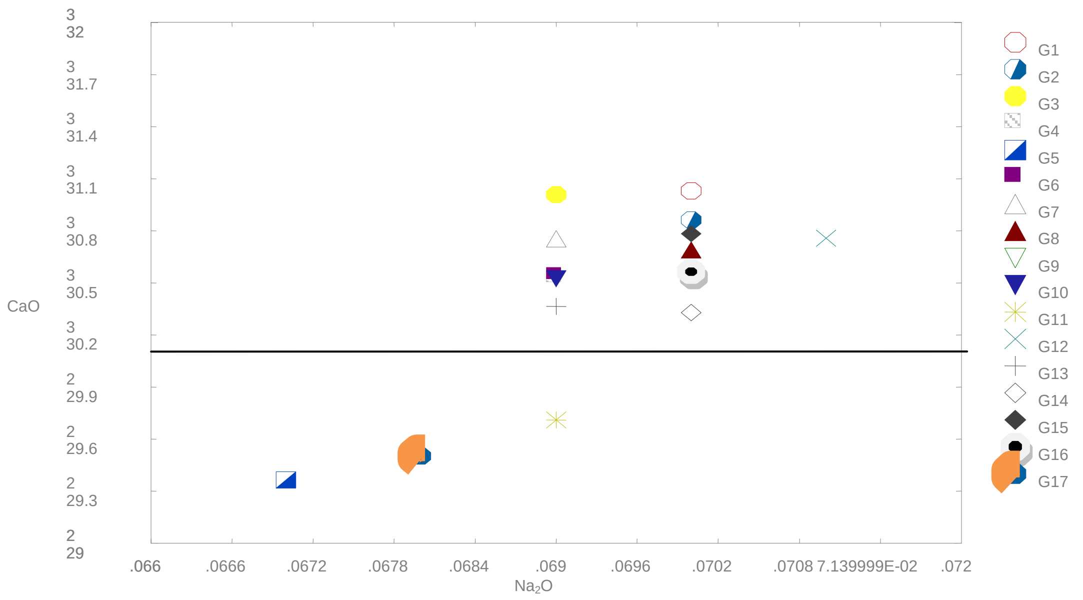

Fig.9: CaO Vs Na_2O Variation Plot for Gypsum in the Study Area

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

Table 1: Oxides Composition of Nafada Gypsum (in weight (%)

Elements in Oxide	SAMPLES																
	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8	G-9	G-10	G-11	G-12	G-13	G-14	G-15	G-16	G-17
SiO_2	1.632	1.186	2.957	2.396	4.895	1.736	1.266	1.550	2.136	1.618	3.451	0.651	2.083	1.755	0.587	0.922	3.298
AL_2O_3	0.481	0.303	0.905	0.742	1.698	0.508	0.332	0.411	0.651	0.455	1.305	0.163	0.633	0.508	0.149	0.373	1.265
Fe_2O_3	0.140	0.134	0.284	0.340	0.810	0.148	0.133	0.168	0.258	0.259	0.534	0.099	0.531	0.112	0.136	0.494	0.890
CaO	31.030	30.862	31.009	30.524	29.365	30.540	30.754	30.689	30.566	30.523	29.710	30.758	30.365	30.329	30.783	30.565	29.502
MgO	0.212	0.299	0.318	0.603	0.564	0.218	0.277	0.269	0.347	0.194	0.205	0.018	0.323	0.037	0.020	0.013	0.079
SO_3	43.279	43.679	42.152	42.496	40.891	43.599	43.718	43.416	42.877	43.680	42.447	44.458	43.069	43.863	44.579	44.122	42.481
K_2O	0.053	0.040	0.087	0.071	0.134	0.055	0.045	0.051	0.066	0.051	0.096	0.028	0.064	0.040	0.035	0.025	0.095
Na_2O	0.070	0.070	0.069	0.069	0.067	0.069	0.069	0.070	0.070	0.069	0.069	0.071	0.069	0.070	0.070	0.070	0.068
Sum of Conc.	76.896	76.571	77.781	77.240	78.424	76.875	76.595	76.624	76.971	76.849	77.815	76.246	77.137	76.713	76.320	76.557	77.677
Purity	93.050	93.909	90.626	91.365	87.916	93.738	93.995	93.345	92.185	93.912	91.260	95.586	92.599	94.306	95.845	94.862	91.334
Comb. Water	19.476	19.655	18.968	19.123	18.401	19.620	19.673	19.537	19.295	19.656	19.101	20.006	19.381	19.738	20.061	19.855	19.116

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.

Oxide	Oxide composition (wt %)
SiO_2	2.007
Al_2O_3/Fe_2O_3	0.482
CaO	30.463
MgO	0.235
SO_3	43.224
K_2O	0.061
NaO	0.069
Sum of concentration	77.017
Purity	92.931
Combined water	19.451

Table 3: British Industrial Specification, Raw Materials Research Development Council and Umeshwar (BIS: 1290 - 1973, RMRDC 2005 and Umeshwar 2005) for Various Industries

Industry	$CaSO_4.2H_2O$ (%)	SiO_2 (%)	Fe_2O_3/Al_2O_3 (%)	MgO (%)	Na_2O+K_2O (%)
Cement	70-75(80-85) for export quality	-	-	3.0(max)	0.6(max)
Soil Amendment	50.0(min)	-	-	-	-
Ammonium Sulphate Fertilizer	85-90(min)	6.0(max)	1.0(max)	1.5(max)	-
Surgical/Pharmaceutical	96.0(min)	0.7(max)	0.1(max)	0.5(max)	-
Pottery	85(min)	-	1.0(max)	1.5(max)	-
Building	75(min)	-	-	-	-
Chemical	94(max)	-	-	-	-
Paints	75(min)	-	-	-	-
Textile	82(max)	-	-	-	-

Reference to this paper should be made as follows: Tabale, R.P. (2014), Geochemical Studies of Gypsum from Nafada and Environs North-Eastern Nigeria. *J. of Sciences and Multidisciplinary Research,* Vol. 6, No. 2, Pp. 37 – 49.