CHARACTERIZATION AND APPLICATION POTENTIALS OF FIKA (YOBE STATE, NIGERIA) GYPSUM ORE FOR NATIONAL DEVELOPMENT

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Abstract
Characterization together with application potentials of Fika (Yobe state, Nigeria) gypsum ore was investigated. Constituent ore minerals were identified through petrographic study. Energy dispersed X-ray fluorescence spectrometry (ED-XRFS) was used to determine chemical composition and percentage concentration of each constituent mineral. Particle size analysis over the range of +2000µm to -65µm in ten different mesh sizes showed 125µm as the Mesh-of-grind (MOG). The overall results were analysed to suggest possible beneficiation techniques and viable areas of application.

Keywords: Dominant mineral, Wallboard, Dissemination, Infrared ray and Plaster of Paris.

Introduction
Gypsum is a white and soft (No 2 on Mohr's scale) mineral with IUPAC name 'calcium sulphate dihydrate, $CaSO_4.2H_2O$'. Cornelius (1996) It is a common mineral with thick and extensive evaporate beds in association with sedimentary rocks. These gypsum deposits are abundant in sedimentary environments around Fika, Yobe state. Gypsum occurs in nature as flattened and often twinned crystals and transparent cleavable masses called Selenite. It may also occur silky and fibrous, in which it is commonly called Satin Spar. During precipitation, minerals like halite, anhydrite, calcite, and pyrite are included. Broadhurst (2007) and Sidney (2008). Unwanted minerals inclusions are to be separated and removed during beneficiation stages from the valuables in accordance with the desired application requirements. Henkel and Gaynor (1996)

Analysis of minerals in an ore by optical mineralogy in thin-section is a critical step in any ore characterization exercise. Wills (2005). The work investigates the mineralogy of Fika Gypsum ore.

Being a natural insulator, gypsum is used in production of wallboard, a material for insulating interior walls of domestic buildings. Plaster of Paris and ordinary Portland cement are produced using averagely pure gypsum. In a very pure state however, gypsum can be used in glass making. Despite the local availability of gypsum deposits, most of these products are largely imported into the country. As there is no substitute for gypsum in its applications, production of acceptable indigenous gypsum based commodities is inevitably dependent on Nigeria's ability to produce pure gypsum from the locally available deposits in the country, including Fika deposits. This could be achieved with implementation of only a few changes in the present approach to the administrative and mining rules together with financial incentives. A perceptible change in the housing and agricultural practice could be made by this important mineral. Furthermore, gypsum can be used in the manufacture of the much needed elemental sulphur / sulphuric acid. These objectives can annually save foreign exchange for the nation to the tune of billions of Naira and in no doubt strengthen government hands economically as a non-oil revenue generation.

Literature Review

Physical and Chemical properties of Gypsum

Usually white in colour, gypsum could be colourless, gray, and reddish in various shades, brown or yellow. It is transparent to translucent with a monoclinic crystal system. Its specific gravity is 2.3+ with hardness of 2 on Mohr's scale. As a dihydrate salt, gypsum is highly soluble in hydrochloric acid and moderately soluble in water at 25^oC. About 2 to 2.5g dissolves in a litre of water. When heated to about 150^oC, 75% of its water of hydration is driven out to form plaster of Paris and at 200^oC it is converted to mineral anhydrite, $CaSO_4$. Brandes (1992).

Gypsum Optical Behaviour and Associated Minerals

The mineral Gypsum has a biaxial positive figure which shows low negative relief that can be more visible when viewed closely under petrographic microscopes. Its interference colours in standard thin section, 30µm, are firs-order gray and white like quartz. As an evaporate, gypsum is mostly found in layered sedimentary deposits commonly associated with halite(NaCl), anhydrite ($CaSO_4$), sulphur, calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), and pyrite (FeS_2). Sometimes corundum (Al_2O_3) co-exists. Broadhurst (2007) and Sidney (2008).

Characterization of Gypsum Ore

Petro microscopy and Mineralogical Composition Analysis

Transmitted polarized light microscopy on prepared gypsum thin section provides bases for identification and dissemination recognition of gypsum and its co-existing minerals in the ore through their respective optical behaviours. Jackson (2006). Both X-Ray diffraction (XRD) and Energy dispersed X-ray fluorescence Spectrometry(ED-XRFS) are efficient methods to reveal the ore's respective mineral compositions and proportions.[8]

Gypsum application

Production of Sulphur, Limestone and Magnesite

At 1050^oC, the mixture of gypsum with coal and brucite ($Mg(OH)_2$) in a kiln gives $CaS_{(S)}$, $MgO_{(S)}$ plus other compounds which are further treated to produce sulphur, limestone ($CaCO_3$) and magnesite ($MgCO_3$).

Production of Dihydrate and Anhydrite for Building materials

The possible processes of producing dihydrate granules and anhydrite for building materials such as wall board, plaster of Paris among others, are suggested in the activity network (figure 1) below.

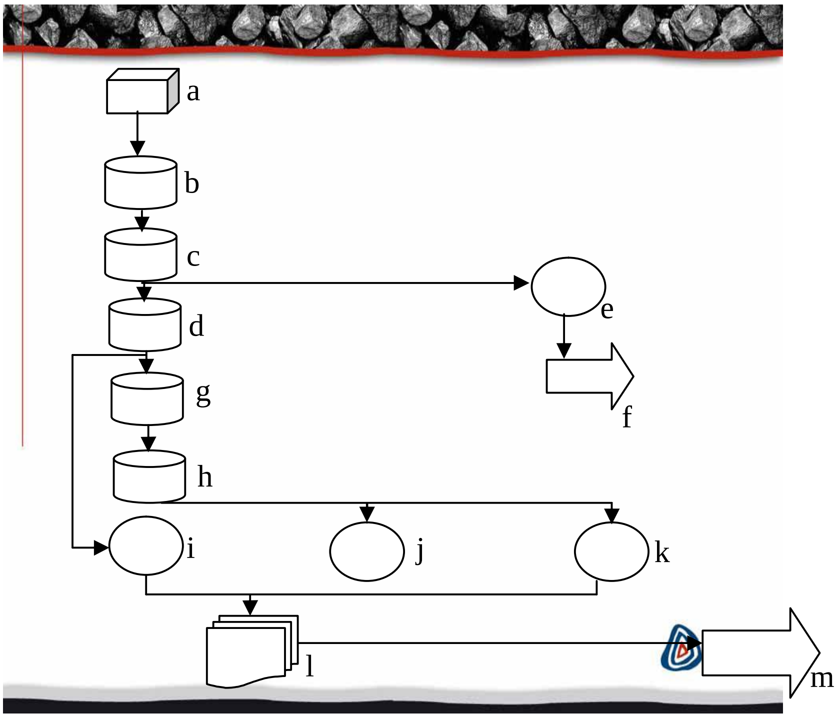

Figure 1: Production of dihydrate granules and anhydrite French (2008) and http://www.anglocoal.com.

a = Gypsum cake Receiving bay,
b = Mixing and granulating
c = Drying
d = Milling, multipurpose hammer mill
e = Dihydrate granules
f = transportation to market
g = calcining
h = milling
i = dihydrate powder
j = hemihydrates powder
k = anhydrite powder
l = bagging
m = to market

About 5% of gypsum is added to finished cement powder at approximately 5µm particle size to serve as hardening retarder, allowing for gradual and proper curing of concrete. French (2008) and Sidney (2008). Granules of dihydrate and anhydrite powder are further processed to make building materials in different forms.

Experimental Method

Samples Collection

Samples weighing up to 35Kg were randomly collected in six different spots of mining sites (local mining) of eastern part of Fika town suburbs.

Particle size analysis

The bulk ore was broken using sledgehammer, into sizes that could be fed into the roll crusher. Crushing was carried out in a roll crusher and final grinding in a laboratory ball mill. Sieving was carried out using mechanical sieve shaker by placing the ground ore in the uppermost standard sieve. The nest of the sieves was loaded with the ore and allowed to vibrate for 5 minutes. The sieves were taken apart and the amount of materials retained on each sieve was weighed and recorded. Wills (2005) and http://www.in.gov/indot/files/T 27

Ore characterization

Ore Petrography

Thin section:

For each thin section, a thin slice of the specimen was cut off and one side polished to a perfectly smooth, flat surface. This surface was attached to a thin glass slide using an epoxy resin. The slide was then mounted and the specimen was further reduced in thickness by rotary grinding with a standard grade of carbon-corundum powder. The specimen was then removed when almost transparent and finished to thickness less than 40microns by hand grinding on a glass plate. The specimen was washed and dried and the specimen surface was covered with a thin glass cover slip attached with the epoxy resin. Different fields were viewed and captured under the transmitted light microscope at magnification of × 10.

Ore chemical composition

The Mini Pal4 ED-XRFS of National Metallurgical Development Council (NMDC) Jos, Nigeria, was used to identify the mineralogical composition and determine the concentrations of major, minor and trace elements in the ore samples.

Result and discussion:

Size Analysis

Table 1 presents the result of the particle size analysis of the ore. Table 2 represents the chemical analysis of the ore as revealed by X-ray fluorescence. One observes from Table1 that the smaller the aperture size, the higher the weight% of ore retained up to the aperture size 125 μm, after which it declined with reduction in aperture size, Wills (2005). About 49.82% of the ground ore is over the size 125 μm, the ground of mesh. These suggest that the grounding of the ore saves energy when compared with other hard minerals such as hematite and magnetite in the grounding mill.

Table 1: Particle size analysis of fika gypsum ore

Mesh No	Weight % retained	Nominal aperture size (μm)	Cumulative % undersize	Cumulative % oversize
+8	1.65	2000	98.35	1.65
-8+20	6.49	850	91.86	8.14
-20+30	4.91	600	86.95	13.05
.-30+45	6.17	425	80.78	19.22
-45+60	9.44	250	71.34	28.66
-60+80	21.16	180	50.18	49.82
-80+125	27.62	125	22.56	77.44
-125+180	11.01	85	11.55	88.45
-180+250	7.41	65	4.14	95.86
-250	4.14		0.00	100.00

Thin Section Analysis:

The viewed captured fields under the petrological microscope are presented in plates 1- 3.

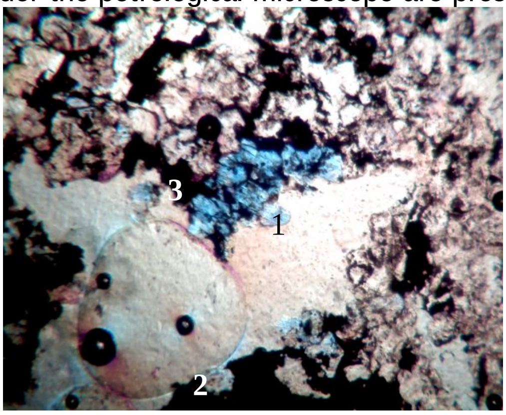

Plate 1: Petrography of Field A, at magnification of $\times 4$ in a plane polarized light

Manganese and iron minerals co-exist, displaying their normal opacity. Both are randomly disseminated throughout the field. Dominant gypsum mineral displays both first-order gray and white colouration. Silica (quartz) appears gray co-existing with aluminium mineral corundum. Also, the fairly pale pink colouration confirms the presence of corundum. Henkel (1996), Jackson (2006) and Dexter (2002).

1. Homogeneous subhedral gypsum crystal appears in its characteristics first-order white colour
2. Higher oxide manganese mineral displays the expected opacity, absorbing all colours in the light beam making it appear black together iron mineral hematite.
3. High relief corundum in its pleochoric blue colour.

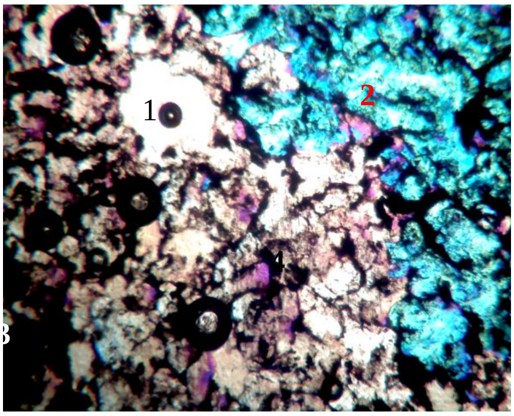

Plate 2: petrography of Field B at magnification $\times 10$ in a plane polarized light

The upper right side of field B shows anomalous colouration in blue, green and pink. This indicates the presence of Alumina (corundum). Manganese mineral in closeness with Fe_2O_3 scattered in around the field.

1. White homogeneous gypsum crystal (central circular opaque Mn and Fe minerals)
2. Corundum displays full pleochroism in its characteristics blue, green, pink and pale pink colouration. A large homogeneous network there.
3. Opaque manganese –iron minerals randomly disseminated in the field

   Quartz in its maximum interference gray appearance. Henkel (1996), Jackson (2006) and Dexter (2002).

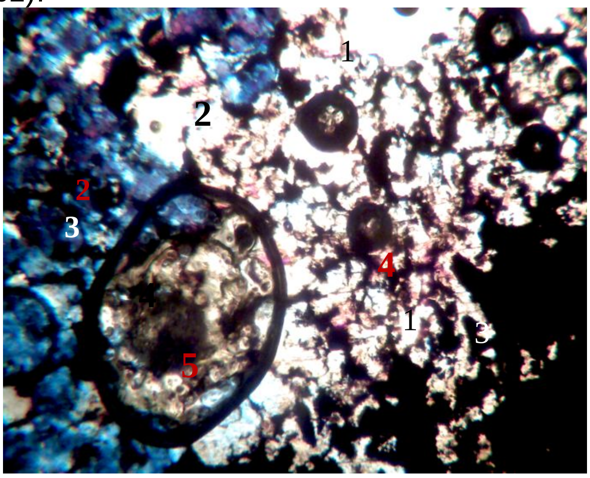

Plate 3: Petrograph of field D at magnification$\times 10$.

Field shows Aluminium mineral (corundum) bluish at upper left portion of the field down to left bottom portion of the field.

1. Pretty white gypsum crystal in its homogeneity.
2. Corundum
3. Mn/Fe minerals
4. Reddish edge suggests the presence of Hematite
5. Greyish-brown quartz surrounded by manganese ring. Henkel (1996), Jackson (2006) and Dexter (2002).

X-ray Fluorescence analysis: The result obtained from the X-ray spectroscopy, carried out at NMDC Jos, is presented in table 2.

Table 2: Chemical composition of fika gypsum ore by percentage (%)

Sample S5	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	NiO
Location 'E'	2.90	9.47	1.30	19.60	0.50	25.20	0.33	0.02	0.04	18.16	16.06	0.23
	CuO	ZnO	SrO	BaO	As_2O_3	La_2O_3	ZrO_2	PbO	MgO	Na_2O	Sc_2O_3	
	0.08	0.09	0.11	*ND	ND	ND	ND	ND	0.38	0.08	0.02	

*ND = not determined

The major elements in their compound forms include $CaSO_4$ (CaO and SO_3), MnO and Fe_2O_3. Al_2O_3 has a strong affinity for SiO_2 to produce Alumina Silicate. Silica (SiO_2) is normally quartz impurity which is a very hard substance. Low amount of silica (1-2%) can cause dramatic accelerated wear on gypsum processing equipment. Henkel and Gaynor (1996).

Among the trace element oxides are K_2O, CuO, NiO, ZnO, SrO, MgO and Na_2O. The Mg^+, Na^+ and K^+ salts readily go into the solution when calcined gypsum (stucco) is mixed with water and other additives in board mixer Henkel and Gaynor (1996). Major minerals Specific gravities are presented in table 3.

Table 3: Major minerals specific gravities. Dexter (2002).

Mineral	Al_2SiO_5	$CaSO_4$	MnO	Fe_2O_3
Specific gravity	3.18	2.32	4.24	5.2

Sharp differences exist among the minerals; a requirement for gravity separation method.

Inferences from the Petrography:
The petrographs show that constituent minerals are homogeneously disseminated in the ore. Mahmoodi (2006), a necessity for their proper liberation during comminution

Possible beneficiation roots:
Possible beneficiation roots for the gypsum ore are:
(a) Comminution $\longrightarrow$ Screening $\longrightarrow$ Electronic colour sorting (dry beneficiation)
(b) Comminution $\longrightarrow$ Screening $\longrightarrow$ Electrostatic sorting (dry beneficiation)
(c) Comminution $\longrightarrow$ Screening $\longrightarrow$ Air- separation (dry beneficiation). French (2008)
(d) Comminution $\longrightarrow$ Screening $\longrightarrow$ Calcining (thermal beneficiation)
(e) Comminution $\longrightarrow$ Screening $\longrightarrow$ Tabling (Gravity wet beneficiation) and froth flotation (chemical wet beneficiation).

The tabling exercise shall be of fine feed with less water, less feed, faster reciprocation and shorter stroke while the froth flotation shall utilize oleic acid as a collector to selectively collect oxides froth when gypsum sinks.

Possible areas of application of the beneficiation products:

a.) Gypsum concentrate

1. Production of sulphur, limestone and magnesite
2. Building materials such as sheet rock (wall board) plaster of Paris (POP) and cement
3. Ornamentals and glass making
4. Gypsum coated urea fertilizer

b.) Alumina, Quartz, Manganese and iron oxides concentrates

1. Glass and steel making. The iron and manganese concentrates could be used in the production of ferromanganese and ferro-alloys.

Conclusion

1. The ore is a complex ore type containing $CaSO_4.2H_2O$, Fe_2O_3, Al_2SiO_5 and MnO as its major minerals. The study also shows that the ore's Mesh-of-Grind (MOG) is 125 μm as revealed by the screen test.
2. The constituent minerals are homogeneous crystals averagely uniformly disseminated in some cases and randomly disseminated in some other cases. Sharp differences exist among the minerals specific gravities making gravity separation technique (wet beneficiation) a suitable beneficiation method.
3. Popular gypsum dry and thermal beneficiation processes (air-separation, electronic colour sorting and electrostatic separation) remain efficient concentrated methods.
4. A clean up froth flotation exercise is important for pure gypsum production.
5. While using gypsum concentrate in its areas of applications, the manganese, iron, silica and alumina minerals can as well be used in other areas such as steelmaking and production of glass with specific properties. Smallman (1999).

Reference

Brandes, E. A. and Brooks, G. B. (1992) "*Smithells Metals Reference Book". Seventh Edition.* Butterworth-Heinemann.

Broadhurst, J. L., Petrie, J. G. and Von Blottnitz, H. (2007). "*Understanding Element Distribution during Primary Metal Production"*. Trans. Inst. Min. Metall. C.

Cornelius, K. and Cornelius, S. H. (1993). *"Manual of Mineralogy" (after James, D. D). Twenty First Edition.* John Wiley and Sons.

Dexter Perkins, (2002*) "mineralogy" Second Edition*. Pp 365-379. Pearson Education Inc. 482 F.I.E Patparganj. Delhi 110092, India.

French R.R., (2008) *"Dry Beneficiation of Gypsum"*. info@oneMine.org

Henkels, P. J. and Gaynor, J. C. (1996). "*Characterizing Synthetic Gypsum for Wallboard Manufacture".* The Fifth International Conference on FGD and other Synthetic Gypsum.

Jackson, D. S. P & Dilce, F. R. (2006). Petrography of Gypsum-bearing facies of the Codo Formation (Lake Aptian), Northern Brazil. *Anais de Academia Brasileira de Ciencias, Vol. 78 No .3. Rio de Janeiro.*

Mahmoodi, S., Mogheiseh, E. & Heidari, A. (2006). “Morphology of gypsum and Halite in some gypsum rich soils of Bam region (South-east Iran)”. *Geophysical Research Abstracts, 8, 02361.*

Rutley’s. (2005). *Element of Mineralogy.* Twenty Seventh Edition. CBS Publishers and Distributors.

Sidney draggan, (2008) “*Gypsum” Encyclopaedia of Earth Eds. Cutler J. Cleveland, Washington D.C. Environmental Information Coalition, national Council for Science and the Environment*. http://www.eoearth.org/article/Gypsum>

Smallman, R. E. & Bishop, R. I. (1999). *Modern Physical Metallurgy and Materials Engineering; Science, Process, Applications. Sixth Edition.* Butterworth-Heinemann.

Wills, B. A. (2005). *Mineral Processing Technology. 3rd Edition.* Pergamon, New York http://www.anglocoal.com

Http://www.in.gov/indot/files/T 27 aashtoB.pdf. *Sieve Analysis of Fine and Coarse Aggregates;* AASHTOT 27.