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CHARACTERIZATION AND WORK INDEX DETERMINATION OF GAZUM FELDSPAR FOR EFFICIENT BENEFICIATION FOR INDUSTRIAL UTILIZATION

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Abstract

The characterization and work index determination of Gazum feldspar for efficient beneficiation have been carried out. Samples of feldspar were collected from Gazum in Langtang north local government area of plateau state kujama granite was source from stockpile of national steel raw materials exploration agency Kaduna, the sample collected were homogenized and spitted to form the head sample. Chemical and mineralogical analysis was carried on the head sample of Gazum feldspar using x-ray fluoresce (XRF) and X-Ray diffractometer (XRD) the specific gravity and liberation of Gazum feldspar were determined by work index determination using the standard bond's ball (grindability) method and the use of modified bond's ball method with kujama granite as reference mineral. The chemical analysis revealed that Gazum feldspar contains 23.33% NaO 50.036% 0.45% Fe_2O_3, 0.005% P_2O_5 0.085% So_3 0.929% CaO, 0.166 BaO 13.986% Al_2O_3 and 0.013 TiO_2.. The major mineral phase in the feldspar are quartz, orthoclase, illite, vermiculite, garment and sanidine. The department size of Gazum feldspar is 90 µm and its specific gravity 2.63.The work index of the

Keywords: Feldspar, characterization, Clay, work index, beneficiation.

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clay falls within 10.17 -10.95 kWh/t. The results of this work provided insight in Utilizing modern analytical techniques to enhance the mineralogical, chemical, and empirical data on grinding energy requirements, optimal flotation conditions, and reagent selection, which can serve as a foundation for future research and industrial applications.

Introduction

The knowledge of the peculiarities associated with minerals is a concern. Mineral/ore bodies are becoming increasingly complex, both from mineralogical and texture perspective, as grade continue to vary, due to continue earth, formative period (Rodoslovich,2022). As such, the industrial expectation of mineral as raw material for various applications has become a critical requirement for minerals Clay characterization research. (Alabi and Gbadamosi, 2021). The clamour for resources control being advocated by states with petroleum resources in their domain makes it necessary to develop, exploit, process and utilize our minerals resources particularly non-metallic minerals as every part of this country is blessed with minerals that could yield substantial revenue for sustainable development (Fatima *et al*, 2024). Feldspars are alumina-silicate type of minerals containing Sodium, Potassium, and Calcium elements in varying proportions. The most commercial use of Feldspar is in the manufacture of Pottery, Enamel, Glassware, and Ceramic materials. In addition, the hardness of the mineral also makes it desirable as an abrasive (Harison and Turner, 2023).

The key driving factor in feldspar market is traceable to the growing product demand in the manufacturing of Glass and Ceramic product filler applications Feldspar deposit can be found in Ajaokuta Local Government Area in Kogi, Abia, Ogun, Plateau, Ondo state, Edo, Adamawa, Ekiti, Katsina, Kebbi, Nasarawa, Niger and Taraba (Okoye and Abdulrahman, 2023).

Comminution is a process in which solid materials are reduced in size. Blasting can be described as the first stage of comminution carried out in the mine site in order to remove ores from the natural beds. Comminution in mineral processing plant takes place in the sequence of crushing and grinding processes (Maurice and Kenneth, 2023).

Because most minerals are fairly disseminated and ultimately associate with gangue, they must be ultimately "unlocked or liberated" before separation can be undertaken. The study area is Gazum feldspar in Langtang north local government area of plateau state. Langtang north headquarters in the town of Langtang at 9°0800"N 9°4700"E. It has an area of 188km^2 and a population of 140,643. The Langtang North is Taroh and is located in the low land of Plateau state. (Plateau State ICT, 2022).

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MATERIALS AND METHODS

The materials required for this work include: Feldspar sample obtained from Gazum in Langtang north local government area of Plateau state, Kujama Granite obtained from the stock pile of National Steel raw material exploration agency Kaduna.

Chemical Characterization

The head sample of Gazum Feldspar was pulverized (ground to fine powder) approximately 75µm, packed and labeled. 15g of the prepared sample was weighed each into a sample cup and placed in their respective measuring position on the sample changer of the machine the lab –X3 503 ICI model XRF. The machine was run, and the readings of the analysis was displayed.

Mineralogical Characterization

The mineralogical analysis of the head sample at Gazum Feldspar was carried out using PANanalytical X'Pert PRO model X – ray Diffraction (XRD) machine. The sample was ground to -10 µm and loaded unto the background sample holder and levelled. The instrument was switched on an allowed to warm for thirty (30) minutes. The spherical hand of the stage was pulled down and placed into the sample holder, into the sample position of the stage. The sample was then lifted back into sample measuring position. High voltage was activated, and measurement parameters were set. The start button was selected to initial acquisition and the result displayed as peak position at 2θ and X-Ray counts (intensity).

Work index Determination

The work index determination of Gazum feldspar has been carried out using standard bond ball method. The griding test was carried out using a ball mill of internal diameter of 305 mm (30.5 cm) and a length required for to reduce dry feed to 50% being 20 cm. The total volume of mill charge, is 459 cm^3, while the weight of mill charge is 13.2 kg. 1000 µm. The feed was ground for 100 revolution and screen between 106 µm but available was 90 µm. The oversize was returned to the mill alongside additional feed of equivalent weight of undersize, ground and screen between 90 µm. The experiment was repeated until the undersize obtained was 250% of oversize (circulating load). The experiment was further repeated until the mass of undersize produced per revolution was almost constant. The measure of grindability was obtained from the average of three equivalent masses of the undersize per revolution. Fractional sieve size analysis was carried out on feed to ball mill (80% - 1000 µm) and product of milling.

$$W_{iTest} = \frac{48.95}{D^{0.23}\, G^{0.82}\, 10\left(\frac{1}{\sqrt{P_{80}}} - \frac{1}{\sqrt{F_{80}}}\right)} kWh/t$$

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where;

Wi test = work index test mineral

D = internal diameter of mill

G = measure of grindability

P_{80} = 80% passing product of milling

F_{80} = passing feed to ball mill

The work index of Gazum feldspar was also determined using modified Bond's method (Berry and Bruce method), as a check on the standard bond method used. The reference sample used was Kujama Granite. The test and reference samples were ground to about 100% passing control sieve (355 µm). The ground samples were size between 355 µm and 32 µm respectively. The sieve fractions were collected and weighed. Particle size analysis spreads were prepared and 80% passing in each case was determined for both the test and reference samples. The feed to the milling process for both the test and reference sample were also subjected to size analysis and 80% passing, determined as well.

$$W_{ir} = W_{it} = W_{ir}\left[\frac{\left(\frac{10}{\sqrt{Pr}} - \frac{10}{\sqrt{Fr}}\right)}{\left(\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{Ft}}\right)}\right]$$

where:

W is work input in kilowatt hour per short ton for the reference ore.

W_t is work input in kilowatt hour per short ton for the test ore.

W_{ir} is work index of the reference ore.

W_{it} is work index of the test ore.

F_r is the diameter of the reference ore through which is 80% of feed passing 100 µm

P_t is the diameter of the test ore through which is 80% of the product passing 100 µm

F_t is the diameter of the test ore through which 80% of the feed passing 100 µm

RESULTS

Table 1: Result of Chemical Analysis of Head Sample of Gazum Feldspar

Composition	Concentration
SiO_2	50.063
Fe_2O_3	0.450
P_2O_5	0.005
SO_3	0.085
CaO	0.929
MgO	0.000
BaO	0.166
Al_2O_3	13.986
TiO_2	0.013
`Na_2O	23.33

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Table 2: **Result of Chemical Analysis of Head Sample of Kujama Granite**

Composition	Concentration(%)
SiO_2	68.15
Fe_2O_3	3.10
K_2O	5.20
SO_3	0.023
CaO	1.02
MgO	0.41
BaO	-
Al_2O_3	11.92
TiO_2	0.18
`Na_2O	2.02

Table 1, present the result of compositional analysis of head sample of Gazum Feldspar while Table 2 present the result of chemical analysis of Kajuma Granite sample. The result of chemical analysis of Gazum Feldspar revealed that it contains; 23.331% Na_2O, 10.043% K_2O, 50.063% SiO_2,13.986% AL_2O_3, and 0.450% Fe_2O_3 as major element and. Ag_2O, Nb_2O_3, MnO, and BaO as minor element. This depicts, high Barium, and Silica, low Alumina, Iron and Potassium, content in samples collected from Gazum Felspar. It was observed that Gazum Feldspar contains some amount of Potassium, but Sodium is the more abundant major electropositive element, implying that Gazum Feldspar is a Sodium rich Feldspar resource, making it a potential raw material for ceramic application. This is justified by the findings of Ashi et al, 2023 on the effect or type and grain size of feldspar on the thermal properties of ceramic sanitary wares. They found out that it is sodium feldspar and it favours thermal properties . However, The K_2O/Na_2O ratio in Kujama Granite is greater than one (1), making it a high K -Cal alkaline Granite.
NB: XRD peaks

Table 3:Result of XRD Mineral phase qualitative analysis of Gazum Feldspar

Mineral	% composition
Quartz	37
Orthoclase	15
Illite	9
Vermiculite	15
Garnet	15
Sanidine	19

It was observed from the result of mineralogical analysis, that Gazum Feldspar contains; Quarts, Orthoclase, Illite, Vermiculite, Garnet, and Sanidine as the Mineral phases. The composition represents; 37% Quartz, 15% Orthoclase, 9% llite, 15% Vermiculite, 15% Garnet

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and 19% Sanidine. The quantitative analysis result indicates that the value occurs in the form of Vermiculite containing Na -Feldspar. Table 4. The quantitative analysis result indicates the relative abundance of the major mineral phases and elemental composition as displayed in their chemical formulae. Elements such as Silicon, Aluminium, Iron, Barium and Potassium have been identified. Barium and Silica are of high proportion while, Alumina, Iron and Potassium are relatively low in concentration. Hence,t Gazum Feldspar is a Sodic Feldspar, in the form of Vermiculite. This result aggresses with Carla et al,2025 research on assessment of feldspar from central Portugal, pegmatites for sustainable ceramic application. They found out that the feldspar contain quartz, Microline, Albite and Muscovite are the major mineral phases. The major minerals in both feldspars fall within the same class of amphiboles.

Result of Determination of Work index of Gazum Feldspar Using Standard Bond Ball Method

$$\frac{G1+G2+G3}{3} = G$$

Where; G_1 = 2.83 g, G_2 = 2.45 g and G_3 =2.55 g, are measure of grindability.

G = 2.61 g

D = 20 cm

80% passing ball mill feed = 640 μm

80% passing product of milling = 422μm

From Wi test = $\frac{48.95}{D^{0.25}G^{0.82}\left[\frac{1}{\sqrt{P_{80}}}-\frac{1}{\sqrt{F_{80}}}\right]}$

$20^{0.82}2.61^{0.25}\frac{1}{\sqrt{42}}-\frac{1}{\sqrt{640}}$ = 10.17kwh/t

This signifies that the energy requires to comminute Gazum Feldspar from an infinite size to 80% passing 100µm (work index) is 10.17kwh/t. however; Khaled et al, 2024 examine the grindability of feldspar under similar conditions; 20-30% ball falling for an ideal filling of 25%and liberation size below 0.25mm. the experiment showed good agreement within a factor of 10 with the model for sodic feldspar

Table 4: Result of Fractional Sieve size Analysis of Feed to Ball Mill for Test Sample; (Gazum Feldspar)

Sieve Size Range (μm)	Wt (g)	Wt (%)	Nominal Aperture (μm)	Cumulative (%)	
				Oversize	Undersize
+ 355	3.92	02	355	02	98
− 355 + 250	33.32	17	250	19	81
−250 + 180	15.68	08	180	27	73
−180 + 125	19.60	10	125	37	63

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Sieve Size Range (μm)	Wt (g)	Wt (%)	Nominal Aperture (μm)	Cumulative (%)	
				Oversize	Undersize
−125 + 90	15.68	08	90	45	55
−90 + 63	27.44	14	63	59	41
−63 + 45	41.16	21	45	80	20
−45	39.28	20	Pan	100	00

Table 5: Result of Fractional Sieve Size Analysis of Product of Milling for Test Sample; (Gazum Feldspar)

Sieve Size Range (μm)	Wt (g)	Wt (%)	Nominal Aperture (μm)	Cumulative (%)	
				Oversize	Undersize
+ 355	7.90	04	355	04	96
− 355 + 250	3.95	02	250	06	94
−250 + 180	5.93	03	180	09	91
−180 + 125	11.85	06	125	15	85
−125 + 90	7.90	04	90	19	81
−90 + 63	57.28	29	63	48	52
−63 + 45	67.15	34	45	82	18
−45	35.55	18	Pan	100	00
	Total = 197.5				

Table 6: Result of sieve analysis of feed to ball mill for reference sample; (Kujama Granite)

Sieve Size Range (μm)	Wt (g)	Wt (%)	Nominal aperture (μm)	Cumulative (%)	
				Oversize	Undersize
+ 355	2.96	1.50	355	1.50	98.5
− 355 + 250	38.42	19.5	250	21.0	79.0
−250 + 180	35.46	18.0	180	39.0	01.0
−180 + 125	37.43	19.0	125	58.0	42.0
−125 + 90	15.76	08.0	90	66.0	34.0
−90 + 63	15.76	08.0	63	74.0	26.0
−63 + 45	21.67	11.0	45	85.0	15.0
−45	29.55	15.0	Pan	100	00.0

Table 7: Result of Fractional Sieve Size Analysis of Product of Milling for Reference Sample; (Kujama Granite)

Sieve Size range (μm)	Wt (g)	Wt (%)	Nominal Aperture (μm)	Cumulative (%)	
				Oversize	Undersize
+ 355	1.95	01	355	01	90
− 355 + 250	9.75	05	250	06	94
−250 + 180	11.7	06	180	12	88
−180 + 125	15.6	08	125	20	80
−125 + 90	27.3	14	90	34	66
−90 + 63	42.9	22	63	56	44

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Sieve Size range (μm)	Wt (g)	Wt (%)	Nominal Aperture (μm)	Cumulative (%)	
				Oversize	Undersize
$-63 + 45$	25.35	13	45	69	31
-45	60.45	31	Pan	100	00
	Total = 195				

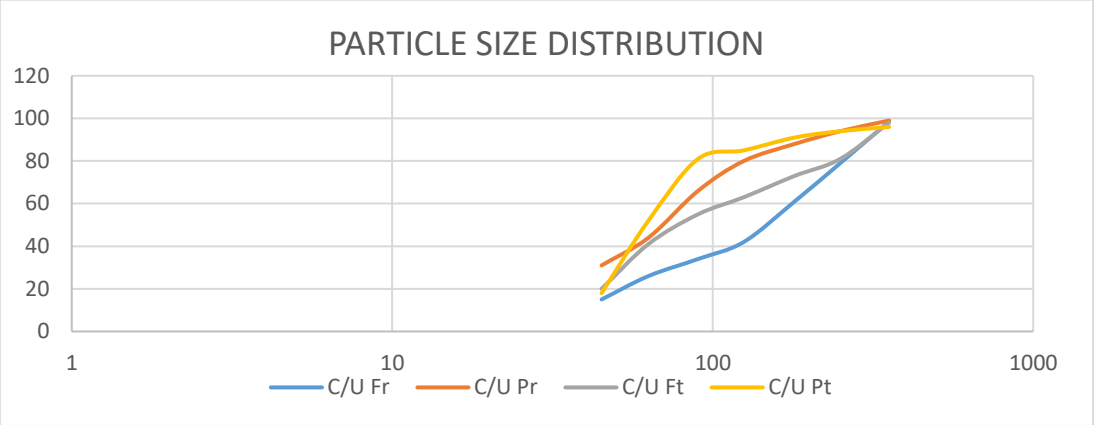


Figure: 2 : Plots of Cumulative Wt % passing against sieve size for both Gazum Felspar and Kujama Granite

$$w_i = w_{ir}\left[\frac{\frac{1}{\sqrt{P_r}}-\frac{1}{\sqrt{F_r}}}{\frac{1}{\sqrt{P_t}}-\frac{1}{\sqrt{F_t}}}\right] = 14.39\left[\frac{\frac{1}{\sqrt{125}}-\frac{1}{\sqrt{300}}}{\frac{1}{\sqrt{87}}-\frac{1}{\sqrt{220}}}\right] = \underline{10.95KWh/t}$$

The relevance of the use of modified Bond's method was to validate the result obtained using the method of grindability. It was observed from the findings of the work index test that the values obtained using the two methods are not far from each other being 10.17 kWh/t, using the standard Bond ball method and 10.95 kWh/t, using the modified Bond's method. The result therefore falls within the published work indices of Orthoclase, Vermiculite and Sanidine, ranging from 10.8 -13.4kwh/t. The result agrees. with the mineralogical composition of Gazum Feldspar, since it contains; Sanidine, Orthoclase and Vermiculite as its major mineral phases (Maurice, 2023). Hence, it can be justified that the work index of Gazum Feldspar is in the range of 10.17 – 10.95 kwh/t. The use of Kujama granite was based on geologic history of clay minerals, Hongium et al in 2024,successfully recovered feldspar, Quartz and Kaoline from weathered Granite.

CONCLUSION

From the findings of this work, it can be concluded that :

i. Gazum Feldspar contains **23.331% Na_2O, 10.043% K_2O, 50.063% SiO_2, 13.986% Al_2O_3, and 0.450% Fe_2O_3** as major elements, with **Ag_2O, Nb_2O_3, MnO, and BaO** present as minor elements.

ii. The major mineral phases identified in Gazum Feldspar include **Orthoclase, Illite, Vermiculite, Garnet, and Sanidine**.

iii. The work index of Gazum Feldspar falls within the range of **10.17 - 10.95 kWh/t** and the energy required for the comminution process is 14.2 kWh/t.

RECOMMENDATION

The results of this work provided insight in Utilizing modern analytical techniques to enhance the mineralogical and chemical characterization, as well as empirical data on grinding energy requirements. Optimal flotation conditions, and reagent selection, which can serve as a foundation for future research and industrial applications, should be investigated.

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