PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (5) 1009-1015 May 2023

Characterization of Feldspars Associated with Pegmatite of Dagbala Area for Ceramics and Glass Production in Southwestern Nigeria

OGBAMIKHUMI, A; EGUAGIE, AJ

Department of Geology, University of Benin, Benin City, Edo State, Nigeria
**Corresponding Author Email: alexander.ogbamikhumi@uniben.edu*

ABSTRACT: The pegmatite in the Dagbala area, southwestern Nigeria occurs as a dyke trending in a NW-SE direction which intrudes the Hornblende-Biotite-Granite. Geochemical, petrological, and mineralogical analyses were carried out on four (4) pegmatite samples obtained from the study area to determine the feldspar quality and the results were compared with commercial ceramic and glass grade to determine its suitability in ceramics and glass production. From the results, SiO_2 ranges from 74.97% to 72.06%, Al_2O_3 ranges from 15.16% to 15.05%, Fe_2O_3 ranges from 0.45% to 0.31%, Na_2O ranges from 5.56% to 2.76%, K_2O ranges from 8.42% to 3.53% and CaO ranges from 0.72% to 0.09% respectively. After comparing the results with the commercial ceramic grade and glass grade, it shows that they can be used as raw materials in the ceramic and glass industry. However, minor pre-treatment processes are required, such as magnetic separation, to reduce the Fe_2O_3 content and froth floatation to reduce the K_2O content in ceramic production. In glass production, magnetic separation should also be carried out to reduce the Fe_2O_3 content and froth floatation should be carried out to reduce the K_2O content. Additives should be added to increase the amount of CaO, Al_2O_3, and Na_2O present.

DOI: https://dx.doi.org/10.4314/jasem.v27i5.19

Cite this paper as: OGBAMIKHUMI, A; EGUAGIE, A. J. (2023). Characterization of Feldspars Associated with Pegmatite of Dagbala Area for Ceramics and Glass Production in Southwestern Nigeria. *J. Appl. Sci. Environ. Manage.* 27 (5) 1009-1015

Dates: Received: 17 February 2023; Revised: 08 April 2023; Accepted: 16 April 2023
Published: 30 May 2023

Keywords: Feldspar; Pegmatite; Ceramic; Glass; Dagbala

Feldspar is the most common rock-forming mineral making up about 60% of the earth's crust (Pakhomova et al, 2020). Feldspars are a group of aluminosilicate minerals which are usually white, pink, or very light in color, have a hardness of 6-6.5 on the Mohs' Scale of hardness, and perfect to good cleavage in two directions. Feldspars are a group of minerals with a general chemical formula of $xAl(Al,Si)_3O_8$, where x can be Sodium (Na) and/or Calcium (Ca) and/or Potassium (K) (Loughbrough,1993; Harben, 1995). Feldspars occur in igneous, metamorphic, and sedimentary rocks. It is most commonly found in igneous and metamorphic rocks like granite, basalt, pegmatite, schist, gneiss, etc. The pegmatite in the study area is hosted by the Biotite-Hornblende-bearing granite. Sharp contacts are observed between the pegmatite and the Biotite-Hornblende granite. The pegmatite intrusion runs from Northwest to Southeast. The crystalline structure of feldspars consists of an infinite network of SiO_2 and AlO_4 tetrahedra. The mineralogical composition of feldspars can be expressed in terms of the tenary system- Orthoclase ($KAlSi_3O_8$), Albite ($NaAlSi_3O_8$), and Anorthite ($CaAl_2Si_2O_8$). Solid solutions between K-feldspar and albite are called alkali feldspar. Solid solutions between albite and anorthite are called plagioclase feldspar. Only limited solid solution occurs between K-feldspar and anorthite, and in the other two solid solutions, immiscibility occurs at temperatures common in the earth's crust. Albite and barium feldspars are considered both plagioclase and alkali feldspars. Sanidine is stable at the highest temperatures, and microcline at the lowest. Perthite is a typical texture in alkali feldspars formed due to the

**Corresponding Author Email: alexander.ogbamikhumi@uniben.edu*

exsolution of contrasting alkali feldspar compositions during the cooling of an intermediate composition. The perthitic textures in the alkali feldspars of many granites can be seen with the naked eye. Microperthitic textures in crystals are visible using a light microscope, whereas cryptoperthitic textures can only be seen with an electron microscope. The alkali and alumina content of feldspars makes them industrially useful (Brown et al., 2017; Makinde and Makanjuola, 2019; Morozova, 2020; Bhattacharya et al., 2020). Alumina in feldspar provides hardness, workability, strength, and makes glass resistant to chemicals. Soda (Na_2O) and Potash (K_2O) in feldspars act as fluxes, they reduce the melting temperature so that less energy is used and decreases the amount of soda ash needed for glass making (Zhang et al, 2018; Garba *et at*., 2019). In the making of ceramic materials, feldspar can serve as a flux to form a glassy phase at low temperatures. It also improves the strength, toughness, and durability of the ceramic body and cements the crystalline phase of other ingredients (Mazen and Mohammad, 2014; De Dieu et al., 2020). Hence, the objective of this paper is to characterize the feldspars associated with the pegmatite of Dagbala area for ceramics and glass production.

MATERIALS AND METHODS

Description of Study Area: The study area lies approximately between longitude 6^0 11' 00''E to 60 13' 50''E and latitude 70 20' 00'' to 70 21' 20'' on a scale of 1:100,000. (Fig. 1). Nigeria lies approximately between latitudes 4^0N and 15^0N and longitudes 3^0E and 14^0E, within the Pan African mobile belt in between the West African and Congo cratons. Nigeria is dominated by crystalline and sedimentary rocks, both occurring approximately in equal proportions (Ogunyele et al, 2020). The crystalline rocks are made up of the Precambrian basement complex and the Phanerozoic rocks which occur in the Eastern region of the country and the North central part of Nigeria. The Precambrian basement rocks in Nigeria consist of the Migmatite Gneissic-Quartzite complex dated Archean to Early proterozoic (2700 – 2000Ma). Other units include the NE/SW trending schist belts predominantly developed in the western half of the country and the granitic plutons of the older granite suite dated Late Proterozoic to Early Phanerozoic (750 – 450Ma).

The southwestern Nigeria basement complex lies between latitudes 7^0N and 10^0N and longitudes 3^0E and 6^0E right in the equatorial rainforest region of Africa. The main lithology here includes amphibolite, migmatite, gneiss, granite, and pegmatite. Other significant rock units are the schist, made up of biotite-schist, quartzite-schist, talc-tremolite-schist, and the muscovite-schist.

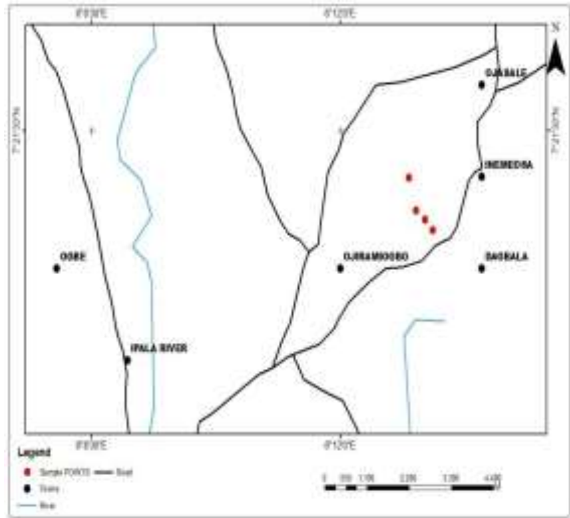

Fig 1: Location map of the study area (modified after GSN, 1974)

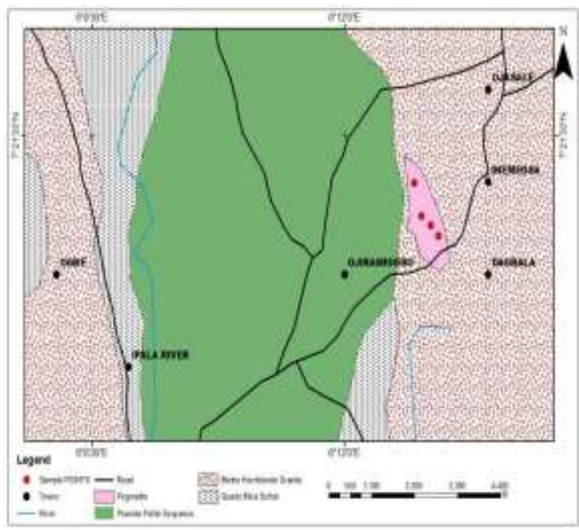

Fig 2: Geologic map of the study area showing part of the crystalline basement complex rocks in Nigeria

Different scholars have tried to classify the rocks of the basement complex of southwestern Nigeria according to their evolution. For this report, reference will be made only to work done by Odeyemi and Rahaman. According to Odeyemi (1976) in his work titled

Preliminary report on the field relationship of the basement complex around Igarra'', classified the rock types into four major groups, which are:

1. The migmatite-gneiss complex (oldest).
2. The metasediments comprising schist, calc-gneiss, metaconglomerate, and quartzite.
3. The porphyritic older granites and

4. The late discordant unmetamophosed syenite dykes (youngest).

Rahaman (1976, 1981) on the other hand classified the rocks of the basement complex of southwestern Nigeria as follows:

1. The migmatite-gneiss complex (oldest).
2. Charnockitic rocks, metagabbros, and pyroxene diorite.
3. Slightly migmatised to unmigmatised paraschists and metaconglomerate.
4. Older granites and
5. Unmetamorphosed diorite dyke (youngest).

It has been established that the Precambrian basement complex of Nigeria including southwestern Nigeria is polycyclic in nature, (Ajibade and Fitches, 1988). The southwestern Nigeria basement complex has undergone four (4) major orogenic events;

I. Liberian (Archean), 2500 – 2750Ma±25Ma.
II. The Eburnean orogeny (Early Proterozoic), 2000 – 2500Ma.
III. The Kibaran orogeny (Mid Proterozoic), 1100 – 2000Ma.
IV. The Pan African orogeny, 450 – 750Ma.

The Eburnean and the Pan-African orogeny are major events that modified the Precambrian Geology of Nigeria including the southwestern Nigeria basement complex. The Eburnean event is marked by the emplacement of the Ibadan granite gneiss in southwestern Nigeria which has been dated 2500±200Ma (Rahaman, 1988), and a pink granite gneiss at Ile-Ife southwestern Nigeria dated 1875Ma using U-Pb on Zircon. Thus, Archean to Pan-African ages has been suggested for the basement rocks of southwestern Nigeria (Fig.2). Few studies have been carried out on the basement complex due to the belief that it contains little or no mineralization.

Petrographic Analysis: Detailed analysis of the rock samples was carried out by preparing a thin section of the samples and studying it under a petrographic microscope. In optical mineralogy and petrography, a thin section is a laboratory preparation of a rock or mineral sample for view and analysis under a petrographic microscope, electron microscope, and various devices.

Sample Analysis Using X-Ray Fluorescence Technique: This method operates on the principle of atomic physics and quantum chemistry. Each sample was first oven-dried at a temperature of 60^0C. Afterward, the samples were crushed with an electric crusher and then pulverized for 60 seconds using Herzog Gyro-mill (Simatic C7-621). Pellets were prepared from the pulverized sample, first by grinding 20g of each sample with 0.4g of stearic acid for 60 seconds. 1g of stearic acid was weighed into an aluminium cup to act as a binding agent and the cup was subsequently filled with the sample to the level point. The cup was then taken to Herzong pelletizing equipment when it was passed at a pressure of 200KN for 60 seconds. The 2mm pellets were added into a sample holder of the X-ray equipment (Phillips PW-1800) for analysis. The specimens were exposed to the entire spectrum of photons consisting of primary radiations emitted from a standard X-ray tube. These irradiated specimen causes the elements in it to emit secondary fluorescence with their characteristic X-ray line spectra. The spectral line energies of wavelengths of the emitted lines were used in the quantitative analysis of the element in the specimen. The intensities of the emitted line were related to their concentration for quantitative analysis.

X-Ray Diffraction Analysis: The XRD analysis is based on passing an X-ray beam through a clay sample. The X-ray identifies the structural layers which are dependent on the d-spacing of the clay minerals. The d-spacing is the exact spacing of the crystal lattices which indicates the arrangement of the atoms in a mineral. The X-ray on passing through the clay samples gives peaks that are typical of each type diffracted along a group of planes and the way they are diffracted is characteristic of the arrangement of the atoms within the mineral. The interpretation of the diffractogram was done by using the reference conversion table to 20 to d-values for the Fek alpha radiation to the JCPDC manual (1972). After carrying out the different analyses in the lab, heavy minerals present can be remover by heavy minerals floatation.

RESULTS AND DISCUSSION

The major minerals identified from the photomicrographs obtained from the petrographic analysis of samples obtained in the study area are quartz, feldspars, and biotite while muscovite, opaque minerals, and heavy minerals are present in minor amounts as accessory minerals. The percentage of quartz in the rock was calculated from the point count (modal) analysis and it ranges from 40% to 37%, plagioclase feldspars ranges from 25% to 18% while microcline ranges from 25% to 15%. The percentage of plagioclase feldspars is higher than that of alkali feldspars in the rock. Due to the high relative abundance of light-colored minerals like quartz, plagioclase feldspars, and microcline, it can be said that the rock is felsic (Yilmaz, 2019; Olugbenga et al., 2019; Phelps et al., 2020).

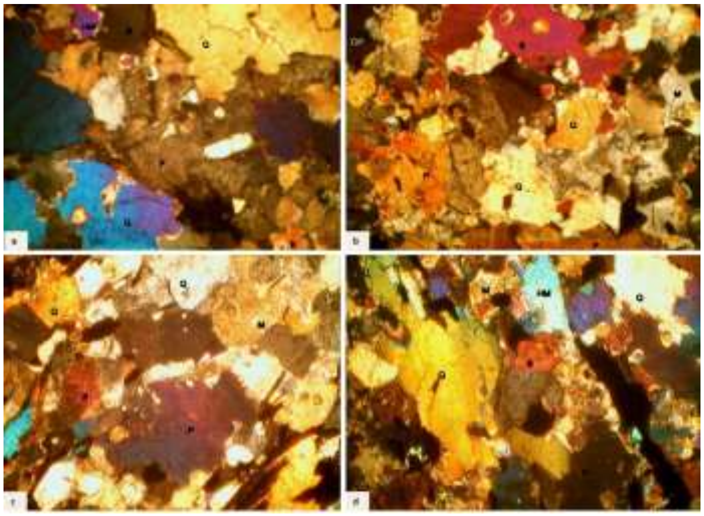

Fig 3. (a)Thin section of pegmatite sample 1 under petrographic microscope (b) thin section of pegmatite sample 2 under petrographic microscope (c) Thin section of pegmatite sample 4 under petrographic microscope (d) thin section of pegmatite sample 3 under petrographic microscope

Table 1: Mineralogy of the rock samples gotten by modal analysis

	Quartz (%)	Plagioclase (%)	Microcline (%)	Biotite (%)	Muscovite (%)	Opaque Minerals (%)	Heavy Minerals (%)
Sample 1	40	25	15	10	5	3	2
Sample 2	37	25	18	10	4	3	3
Sample 3	45	20	5	10	5	3	2
Sample 4	35	25	20	10	5	3	2

Table 2: Weight percent of the major oxides in the rock samples

Major oxides	**Weight percent (%)**				
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Average**
SiO_2	72.07	72.06	72.71	74.97	72.95
Al_2O_3	15.16	15.05	15.16	15.11	15.12
Fe_2O_3	0.39	0.31	0.45	0.40	0.39
TiO_2	0.01	0.01	0.02	0.01	0.01
CaO	0.09	0.09	0.72	0.27	0.29
P_2O_5	0.28	0.45	0.39	0.22	0.34
K_2O	8.42	8.08	8.20	3.53	7.06
MnO	0.06	0.02	0.02	0.04	0.04
MgO	0.10	0.07	0.06	1.11	0.34
Na_2O	2.76	3.37	5.56	5.28	4.24

Table 3: Trace element composition of the rock samples

Trace elements	**Parts per Million(ppm)**				
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Average**
Be	10	11	3	2	7
Cs	18	190	156	45	102
Co	6	4	13	8	8
Cu	28	11	36	25	25
Ta	70	76	77	104	82
Nb	78	72	80	95	82
Ni	17	8	29	10	16
Pb	6	2	11	3	6
Li	1	2	1	2	2
B	20	20	20	20	20
Rb	450	100	120	100	193
Zn	54	58	57	52	55
Zr	11	10	18	18	14
Mo	2	3	10	3	5
V	4	3	2	5	4

X-Ray Fluorescence: From the XRF analysis carried out, we can see that SiO_2 and Al_2O_3 are the major oxides in the rock with the other oxides like CaO, Na_2O, MgO, etc. being present in minor amounts. This shows that the rock is an aluminosilicate rock. The percentage of SiO_2 ranges from 74.97% to 72.06% and this is in line with the average values of rare metal Ta-Nb pegmatite of Nigeria. Also, Al_2O_3 ranges from 15.16% to 15.05%, Na_2O ranges from 5.56% to 2.76% and K_2O ranges from 8.42% to 3.53%. The trace elements present in the rock in parts per million are Beryllium(Be), Ceasium(Cs), Cobalt(Co), Copper(Cu), Tantalum(Ta), Niobium(Nb), Nickel(Ni), Lead(Pb), Lithium(Li), Boron(B), Rubidium(Rb), Zinc(Zn), Zircon(Zr), Molybdenum(Mo) and Vanadium(V). Caesium and Rubidium are greater than 100ppm while Zinc, Niobium, and Tantalum occur in amounts between 50-100ppm. Cobalt, Beryllium, Copper, Lead, Lithium, Boron, Zircon, Molybdenum, and Vanadium occur in amounts less than 50ppm.

*X-Ray Diffractometry***:** From the XRD analysis carried out, the minerals in the rock are quartz, feldspar, Kaolinite, illite, pyrite, calcite, and mica.

Quartz and feldspars show relatively high peaks which is indicative of high relative abundance compared to the other minerals present.

The results from the petrographic adn XRF analysis can be compared to the results gotten from the XRD which shows quartz and feldspars having high peaks and this is indicative of high relative abundance when compared to the micas and other accessory minerals like pyrite.

From the XRD, it is seen that kaolinite and illite are present in the rock samples, this is most likely as a result of weathering of some of the feldspars that were initially present in the rock (feldspars weather to form clay minerals). The overall evaluation of the feldspar deposits was done by carrying out petrographic, mineralogical, and geochemical analyses on the rock samples obtained from the area. From the chemical analysis carried out, it is seen that SiO_2 varies from 74.97% to 74.71%, Al_2O_3 varies from 15.16% to 15.11% and Fe_2O_3 varies from 0.45% to 0.39%. Based on the analytical results, the feldspars in the pegmatites of the Dagbala area were evaluated for application in the glass and ceramic industries.

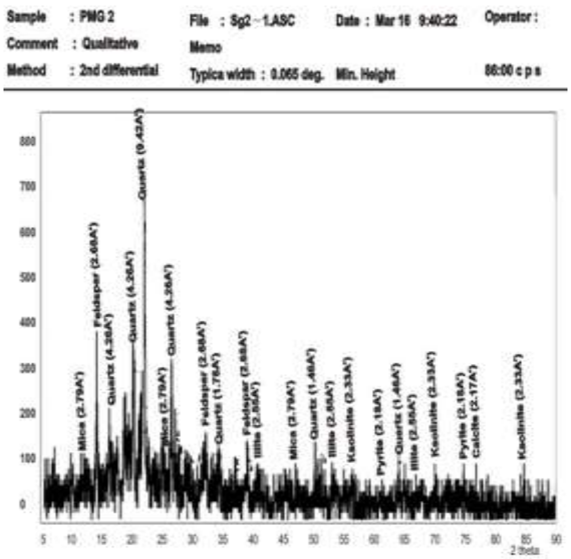

Fig 4. XRD results of Sample 1

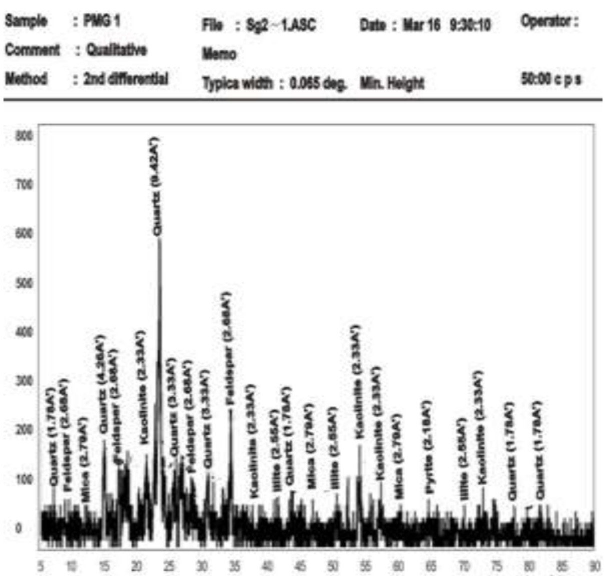

Fig 5. XRD results of sample 2

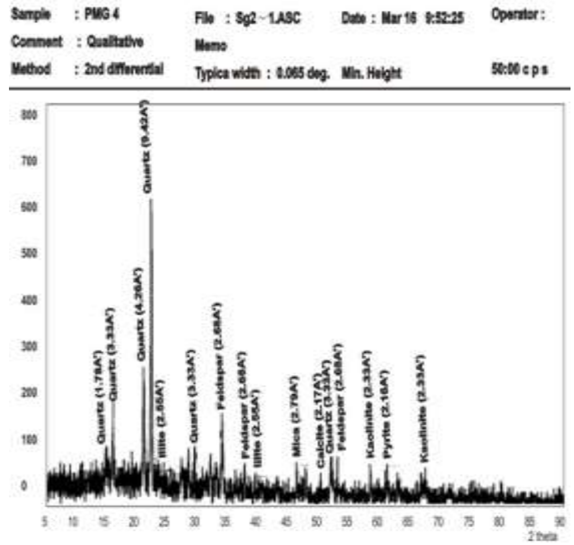

Fig 6. XRD results of sample 3

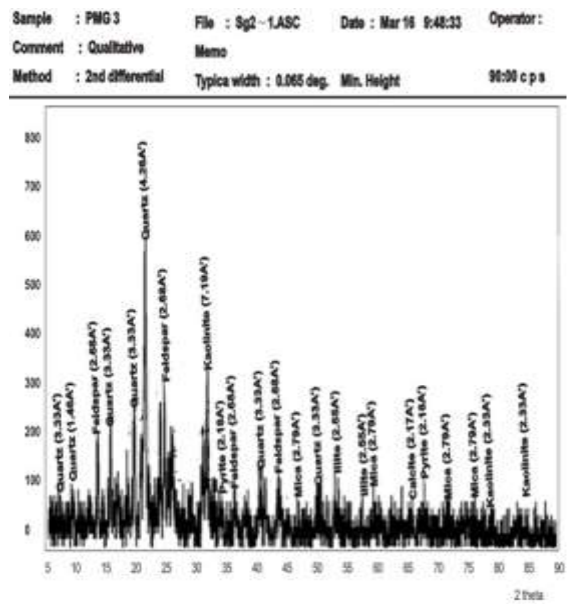

Fig 7. XRD results of sample 4

Comparing with commercial ceramic grade feldspar: The main ingredients affecting ceramic processing and the product quality are K_2O, Na_2O, Al_2O3, SiO_2, and Fe_2O_3. The composition of commercial ceramic grade feldspar is given in the table below

A comparison of the chemical composition of the pegmatite in Dagbala area and commercial ceramic grade feldspar is depicted above. The average values of the weight percent of the oxides in the samples obtained from the X-Ray Fluorescence (XRF) analysis were plotted against the weight percent of the oxides in the commercial ceramic grade. The chart demonstrates an obvious result showing that most of the components of the pegmatite in the Dagbala area are suitable for commercial ceramics production except the higher percentage of K_2O and the slightly higher percentage of Fe_2O_3. The Fe_2O_3 percentage must not be more than 0.3%. Excess Fe_2O_3 affects the quality of the final product by contributing to unwanted variations of the color towards gray rather than white. Therefore, magnetic separation and froth floatation pretreatment steps should be carried out to reduce the percentage of Fe_2O_3 and K_2O present.

Table 4: Chemical composition of the main ingredients of ceramic grade feldspar Loughbrough, (1993)

Constituent	%
SiO_2	75
Al_2O_3	15
$Fe2O_3$	0.3
K_2O	3.3
Na_2O	4.5

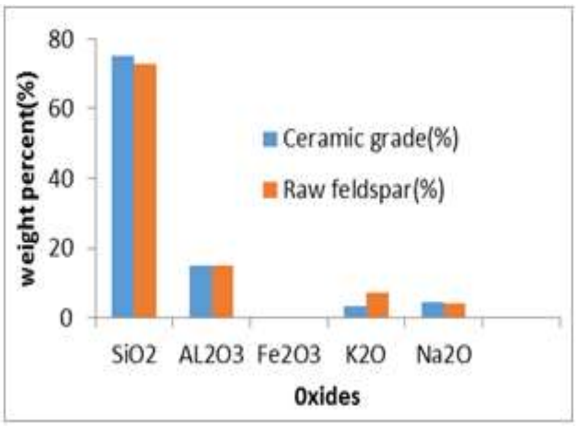

Fig 8. Showing comparison of the raw feldspar and the ceramic grade

Comparing with commercial glass grade feldspar: The main elements affecting glass processing and product superiority are K_2O, CaO, Na_2O, Al_2O_3, SiO_2, AND Fe_2O_3. The breakdown of commercial glass grade feldspar is shown in the table 5.

A comparison of the chemical composition of the pegmatite in Dagbala area and the commercial glass grade feldspar is depicted in the chart above. The average values of the weight percent of the oxides in the samples obtained from the X-Ray fluorescence (XRF) analysis was plotted against the weight percent of the oxides in the commercial glass grade. The results presented in the chart above that the pegmatite in the Dagbala area can be used as a raw material in the glass industry although some pretreatment should also be carried out.

Magnetic separation should be carried out to reduce the amount of Fe_2O_3 while Froth floatation should be carried out to reduce the amount of K_2O. It contains a low percentage of CaO, Al_2O_3 and, Na_2O therefore, additives should be added to increase them.

Table 5: Chemical analysis of the main elements of commercial glass grade feldspar Harben, (1995).

Constituent	%
CaO	1.85
SiO_2	68.9
Al_2O_3	18.75
Fe_2O_3	0.07
K_2O	3.85
Na_2O	7.15

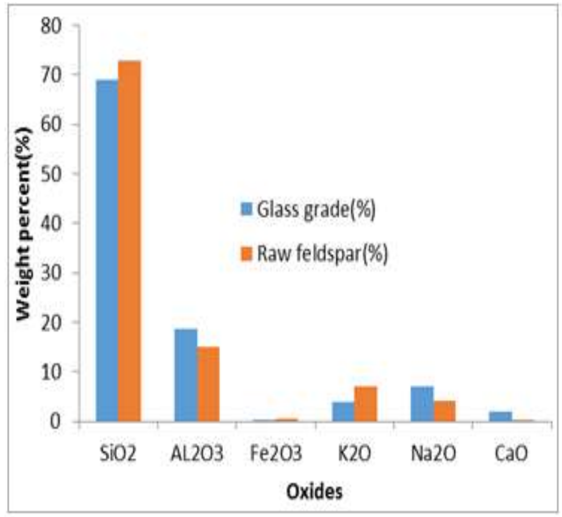

Fig 9. Showing comparison of the raw feldspar and commercial glass grade

Conclusion: The chemical analyses carried out on the pegmatite samples collected in Dagbala area indicates a promising economic production of feldspar as raw material for the ceramic and glass industries, after applying some additives and minor pre-treatment processes such as magnetic separation to reduce the Fe_2O_3 and froth floatation to reduce the K_2O content has been implemented.

REFERENCES

Ajibade, ZF; Fitches, WR (1988). The Nigerian Precambrian and the Pan African. *Geol. Nig.*, 4:45-53.

Bhattacharya, A; Qiu, Y; Bernard, GM; Butler, S;Mar, A; Michaelis, VK (2020). Annealing induced structural evolution in feldspar dental glass-ceramics investigated by solid-state NMR spectroscopy. *J. Solid State Chem.* 121501.

Brown, JA; Martins, T; Čern, ÝP (2017). The Tanco pegmatite at Bernic Lake, Manitoba. XVII. Mineralogy and geochemistry of alkali feldspars. *The Canadian Mineralogist,* 55(3), 483-500.

De Dieu Ndikumana, J; Bolarinwa, AT; Adeyemi, GO; Olajide-Kayode, J; Nambaje, C (2020). Geochemistry of feldspar and muscovite from pegmatite of the Gatumba area, Karagwe Ankole Belt: implications for Nb–Ta–Sn mineralisation and associated alterations. *SN Appl. Sci.* 2(9), 1-12.

Garba, A; Adekeye, JI; Akande, S; Ajadi, J (2019). Geochemistry and rare-metal bearing potentials of pegmatites of Gbugbu, Lema and, Bishewa areas of North Central Nigeria. *Geochemistry,* 9(3).

GSN, (1974). Geological Survey of Nigeria, Auchi Sheet 266.

Harben, P. W. (1995). The industrial minerals handbook. *Metal Bull.* 62-65.

Kayode, AA; Makanjuola, AA (2019). Alkali Feldspars from Pegmatites and Felspar Megacrysts from Western Nigeria. *J. Min. Geol.* 6(1).

Loughbrough, R (1993). Portugal's minerals, *Industrial minerals*, 308: 51-52.

Mazen, A; Mohammad, A (2014). Characterization of the Jordanian Feldspar Raw Materials for Application in the Ceramic and Glass Industries. *Intern. J. Min. Engineer. Mineral. Processing.* 3(2): 28-31.

Morozova, LN (2020). Rare-metal pegmatites of the Soldat-Myl'k pegmatite field: geology, geochemistry of rare elements. In IOP Conference Series: *Earth and Environ. Sci.* 539, (1): 012162.

Odeyemi, IB (1976). Preliminary report in the field relationships of the Basement Geology of Nigeria.

Ogunyele, AC; Obaje, SO; Akingboye, AS; Adeola, AO; Babalola, AO; Olufunmilayo, AT (2020). Petrography and geochemistry of Neoproterozoic charnockite–granite association and metasedimentary rocks around Okpella, southwestern Nigeria. *Arabian J. Geosci.* 13(16), 1-22.

Olugbenga, A; Okunlola, G; Udoudo, BO (2019). Petrochemical Characteristics and Age of Rare Metal (Ta-Nb) Mineralization in Precambrian Pegmatites, Komu, Nigeria. *Inter. J. Econ. Environ. Geol.* 21-26.

Pakhomova A; Simonova D; Koemets I; Koemets ; Aprilis G; Bykov M; Gorelova L; Fedotenko T; Prakapenka V; Dubrovinsky L (2020) Polymorphism of feldspars above 10 GPa. *Nat Commun* 11:2721.

Phelps, PR; Lee CTA; Morton, DM (2020). Episodes of fast crystal growth in pegmatites. *Nature communications,* 11(1), 1-10.

Rahaman, MA (1976). Review of the Basement Geology of Southwestern Nigeria. In: Geology of Nigeria

Rahaman, MA (1981). Recent Advances in the Study of the Basement Complex of Nigeria. First Symposium on the Precambrian Geology of Nigeria, Summary.

Rahaman, M.A (1988) Review of the basement Geology of Southwestern Nigeria. In Kogbe (ED): Geology of Nigeria.

Yılmaz, K (2019). Geochemistry of ultramafic, mafic, and felsic xenoliths from the Gölcük (Isparta, SW Turkey) alkali rocks: genetic relationship with arc magmas. *Arabian J. Geosci.* 12(9):306.

Zhang, Y; Hu, Y; Sun, N; Liu, R; Wang, Z; Wang, L; Sun, W (2018). Systematic review of feldspar beneficiation and its comprehensive application. *Minerals Engineer.* 128: 141-152.