Assessment of industrial applications of raw and Beneficiated feldspar from Odobola -ogodo pegmatite,part Idah sheet

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Assessment of Industrial Applications of Raw and Beneficiated Feldspar from Odobola-Ogodo Pegmatite, Part of Idah Sheet 267NW, North Central Nigeria

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Research Article

Abstract

Odobola-Ogodo area is part of the Basement Complex of Nigeria. It is underlain mainly by schists and intrusive granitic and pegmatite rocks along with sediments weathered from these rocks. A study of the area reveals the occurrence of feldspar deposits with a significant K_2O component (K-feldspar) which are hosted by the granitic and pegmatite intrusives. Mineralogical results by petrography and XRD show that the Odobola feldspar is predominantly microcline and albite types with averages of 50.7% and 42.6% respectively, and a trace of phlogopite as accessory mineral (6.7%). Geochemical data for the raw/beneficiated feldspar samples respectively show average weight percentages of major oxides as SiO_2 66.03/59.64, Al_2O_3 15.56/17.08, K_2O 13.40/15.70, Na_2O 5.68/7.59, CaO 0.13/0.008, Fe_2O_3 0.4/0.02, and MgO 0.10/0.009. The results of the analyses were compared with those of the Bureau of Indian Standards and popular commercial feldspar grades. Both the raw and beneficiated feldspar deposits from the area can be used in industries such as glass, ceramic tiles, sanitary wares and insulators, electrodes, cement, chemical and abrasives. However, the beneficiated feldspar is preferred in the higher quality products such as glass and ceramics. In addition to feldspar, mineral resources inferred in Odobola-Ogodo include quartz, tantalite and tourmaline. It is recommended that further studies would be necessary to identify flotation reagents that are more environmentally friendly than the conventional hydrofluoric acid.

Keywords: *Beneficiation, Ceramic, Feldspar, Glass, Pegmatite.*
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1.0 Introduction

Feldspar is a group of closely related rock forming alumino-silicate minerals, which contain varying proportions of potassium, sodium and calcium. The term "feldspar" originates from the Swedish word "fald," meaning "field," and the German word "Spat," which refers to any transparent or translucent material that is easily distinguishable [1-2]. Feldspar is the most abundant of all minerals, comprising over 50% of the earth's crust [3-5]. It forms the major constituent of most igneous and metamorphic rocks, as well as arkosic sediments. Commercial feldspar occurs in feldspar-rich pegmatite of Older granites [6]. The mineralized ores are metal-bearing pegmatites of Nigeria consist mainly of quartz, potash feldspar, albite, muscovite and less commonly, biotite and a range of accessory minerals including tourmaline, beryl, aquamarine, lepidolite and economically important cassiterite, columbite and tantalite [7].

The geology, use and production of feldspar in the world are widely documented [8-11]. It is estimated that about 85.90% of feldspar produced is used in the glass and ceramic industries, although it varies from country to country. Feldspar provides an inexpensive source of the alkali metals (sodium and potassium), and alumina. In the ceramic industry, especially in the manufacture of white ware, feldspar is the second most important ingredient after clay, feldspar is one of the important raw materials in the manufacture of glass. Feldspars are valued as raw materials that form a vital input in ceramic, glass, paper, chemical, agricultural, pharmaceutical, paints, plastics and rubber industries. Besides the use of feldspar as fluxes in the ceramic and glass industries, they can also be used as fillers and extenders in the paint, chemical, plastic, and rubber industries. They are used as decorative stones and chippings in the building and construction industries. The United States Geological Survey estimated that the world mine production of feldspar in 2024 was 33 million tonne. Feldspar may be replaced in some of its end uses by clays, electric furnace slag, feldspar-silica mixtures, pyrophyllite, spodumene, or talc. However, identified and undiscovered resources of feldspar are more than adequate to meet anticipated world demand.

The K-Feldspars have been popularly processed for the metallic potassium as fertilizer resource [12-13]. In a review of the beneficiation technology and mechanism of feldspar, Zhang et al noted that feldspar is the single most abundant mineral in the earth crust but is generally associated with other silicate, titanium, and iron minerals [14]. As a result, beneficiation of feldspar is necessary to obtain high-grade materials for industrial use. The beneficiation of feldspar ores from other silicate gangues is difficult due to their similarities in physical–chemical properties. They identified important parameters such as crystal structure, monovalent salts, flotation reagents, and particle size distribution. They therefore suggested mixed cationic/anionic collectors as a promising method for feldspar flotation. This research was initiated to determine the industrial applications of both raw and beneficiated feldspar from Odobola-Ogodo, using field study, mineralogy and chemistry. The specific objectives were to beneficiate feldspar samples from Odobola-Ogodo, to determine the mineralogical and chemical composition of the raw and beneficiated feldspar, and to evaluate the suitability of raw and beneficiated feldspar for various industrial end-uses.

2.0 Materials and Methods

2.1 Location and Geology

Figure 1 shows the location of the Study area, Odobola-Ogodo. It is situated within latitudes 7°20” to 7°30” and longitudes 6°30” to 6°40”. It is about 5 km southwest of Ajaokuta and the River Niger, and south of the Okene-Adogo-Ajaokuta Express. The area is also about 5km from the Itakpe-Warri railway line. The Odobola-Ogodo area is part of Nigeria’s Basement Complex which is among the three major lithological units that make up the geology of Nigeria (Figure 2). The Basement Complex forms part of the Pan-African platform of the crystalline rocks [15-17]. The schist belts comprise low grade metasediments trending N-S direction and considered to be upper Proterozoic supra-crustal rocks that have become in-folded into migmatite-gneiss quartzite complex. The Igarra schist belts are widely distributed in the Okene migmatite nucleus trending in a NNW direction, about 50 km long. The Igarra schist belt joins the Owo belt in the western part and trends NW and to the Itobe belt in the east extending into Muro hills in the north. The Igarra schist belt is intruded by porphyritic granites which have similar lithologies with the schist belt in Kabba, Jakura and Lokoja areas [18].

Ako and Onoduku [15], and Mamodu et al [17] described the regional and economic geology of Odobola-Ogodo Feldspar deposit. It is part of Nigeria's Basement Complex, which is characterized by schists, granitic intrusions, and pegmatitic rocks. These geological features play a significant role in the mineralization of the area. The region is dominated by Pan-African granitoids and pegmatites, which intrude into older metamorphic rocks. The granitoids and pegmatites are associated with tectonic activities that have shaped the mineralization processes. The pegmatites in this area typically occur as dykes and ridges, trending predominantly in a north-south direction. This structural alignment is a result of tectonic forces that influenced the emplacement of the intrusions. The granitic and pegmatitic intrusions are the primary hosts for feldspar deposits, particularly potassium feldspar (K-feldspar). They also contribute to the occurrence of other minerals such as quartz, tantalite, and tourmaline. Simple pegmatites in this area are barren and primarily composed of quartz, feldspar, and mica, while complex pegmatites contain additional minerals like tourmaline and tantalite, which are of economic interest. The genesis of these pegmatites is linked to the late stages of granitic magma crystallization, where residual melts rich in volatiles and rare elements crystallize to form pegmatitic bodies. The zonation in pegmatites suggests a progressive evolution of the residual melt, which enriches the pegmatites in feldspar and also enhances the concentration of rare elements like tantalum and gem-quality tourmaline.

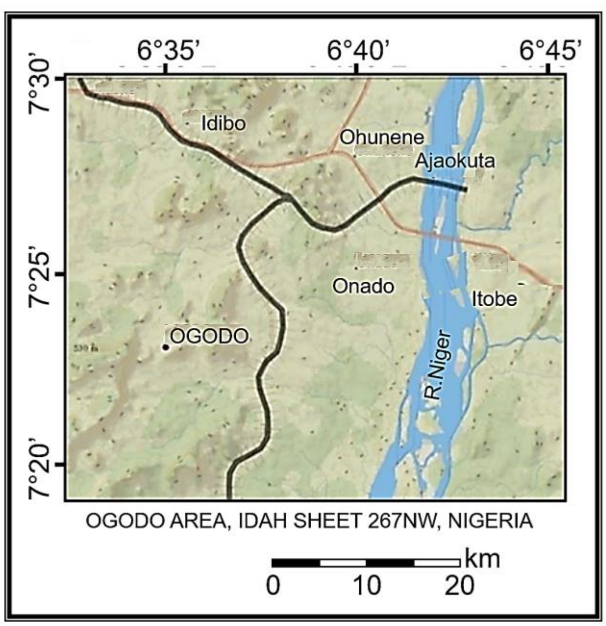

Figure 1. Location of Odobola-Ogodo Pegmatite (extracted from Google Earth [19])

The feldspar deposits in the area are significant, with proven reserves estimated at around 119 million tons. These deposits are suitable for various industrial applications, including glass, ceramics, and insulators. The presence of quartz, tantalite, and tourmaline further adds to the economic value of the region. Omanayin et al [20] show that the Odobola-Ogodo area is underlain by migmatite-gneiss, schist, with intrusions of granite and pegmatite. The pegmatites occur in tabular form with varying widths (2 centimetres – 6 metres) and lengths (12 – 200 metres). Principal joint direction is NNE-SSW which is believed to have influenced the pegmatite emplacement. Petrography of the representative rock samples revealed an average mineralogical composition of biotite (23.90%), microcline (22.15%), hornblende (15.05%), quartz (10.65%), plagioclase (10.35%), muscovite (8.00%), myrmekite (0.20%), andopaque and accessory minerals (9.70%). The pegmatites were dominated by microcline andplagioclase feldspars, and then muscovite, biotite, and accessory and opaque minerals.

2.2 Fieldwork and Sampling

During the fieldwork, rock samples of granites and pegmatites were collected from various rock types in the area. Sampling was facilitated by available roads, footpaths, rail road, river channels and quarry pits. Each outcrop was observed and described based on the mineralogy, grain size, colour, structural element, and mode of occurrence. The field relationships were also described, whether the rocks had been intruded by or they had intruded other rocks.

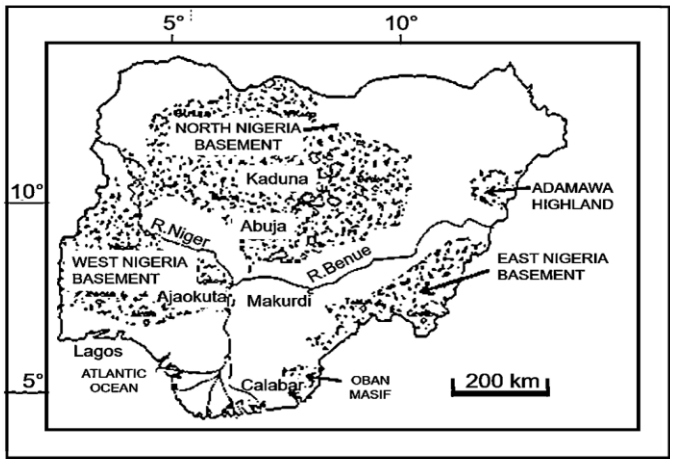

Figure 2. The Basement Complex of Nigeria (modified from Okonkwo & Winchester [21]

2.3 Laboratory Methods

The laboratory studies consisted of thin section at the Geology laboratory of Federal University of Technology Minna, X-ray Diffractometry (XRD) at Spectrum Laboratory Kaduna, Beneficiation tests in the mineral processing laboratories of Federal Polytechnic Kaduna, and whole rock geochemical analysis (XRF) at National Agency for Science and Engineering Infrastructure Akure.

2.3.1 Mineralogy

Each of the feldspar samples from the field was cut and reduced to smaller size using a mechanized diamond coated blade. The surface was then smoothed and polished on a platform containing carborandum powder of varying grades beginning from coarser, medium and down to finer grade of the abrasive. Prior to transfer from one grade to another grade of the abrasive, the rock was first washed with water to completely clean off the previous abrasive. Canada balsam was added to the glass slide and heated slightly on a hot plate, after which the polished side of the rock chip was placed on the glass slide and pressed with slight pressure to remove any trapped gas bubbles and then left to cool. The prepared thin section was finally viewed under the petrographic microscope, both under cross polarized light (XPL) and plane polarized light (PPL). The photomicrograph of the slide was thenj;. taken after identifying the different properties of the feldspar. Specimens were also retained for XRD analysis.

2.3.2 Beneficiation tests

Froth flotation was used for the beneficiation of the ground feldspar samples. The tests were conducted in Kaduna Polytechnic mineral processing laboratories, using the Denver flotation machine model BJAE. A slurry was produced from the ground feldspar samples and a conditioner was applied after the addition of the reagents. The conditioner was made favourable for the adherence of desired mineral particle to air bubbles by adding Amine (EDTA) as collector for the feldspar, the collecting time was set to 5min, sulphuric acid (H_2SO_4) and hydrofluoric acid (HF) were used to control the pH of the slurry. Hydrofluoric acid (HF) was used as depressant for silica, and pine oil as frother. The pH was maintained at 2.5 - 3.2. A rising current of air bubbles was then created and the froth laden on the surface was scooped, dried, and analyzed. General laboratory procedures and precautions were followed according to Wills and Finch [22].

2.3.3 X-Ray Fluorescence (XRF)

Nine feldspar samples were sent for analysis. Each feldspar sample was cut and reduced to 0.7cm size and then crushed in a steel jaw crusher, and pulverized to 0.07mm powder in a tungsten mill. The determination of the elemental composition was done using a Minipal 4 Energy Dispersive X-Ray dispersive spectrometer operated under 14Kv for the major oxides and 20Kv for the trace elements. Loss on Ignition (LOI) was determined gravimetrically where 1gram of the pulverized sample was heated at a temperature of 1000ºC in a furnace.

3.0 Results and Discussion

3.1 Field mapping

Figure 3 shows the geologic map of the study area. The field mapping shows that the area is made up of schists that have been intruded by granites and pegmatites. The schists are highly foliated and weathered, and the foliations are defined by the alternations of dark and white coloured mineral band (Plate 1a). They trend in the NW – SE direction and dip mainly in the western direction. The rocks are reddish brown in colour due to the effect of weathering. Texturally, the rock is fine grained and contains quartz, feldspar and mica. This observation is similar to that of Ako and Onodoku and Omanayin et al [15, 20]. The granitic rocks (Plate 1b) may be one of the oldest rocks in the area, which forms part of the Older Granite of Nigeria [18]. Field evidence shows that the granitic rocks in the area which intrude the schists are coarse grained and have a well-developed porphyritic texture. They are composed of essential minerals such as alkali feldspar, quartz, biotite with trace amounts of muscovite, garnet and epidote. The granites contain large crystals of feldspar, quartz, mica and in sharp contrast with the pegmatite. The pegmatites are extremely coarse grained and are intrusive to both the schists and the granites, and have been greatly exposed by erosion. They occur as very large dykes measuring 3 – 6 m wide and 10 – 30 m long. They are light in color and consist of extremely large grains of feldspar, quartz and mica essential minerals while tourmaline occurs as accessory mineral (Plate 1c). Large crystals of feldspar are shown in Plate 1d, from the pit where pegmatite has been broken down by illegal miners.

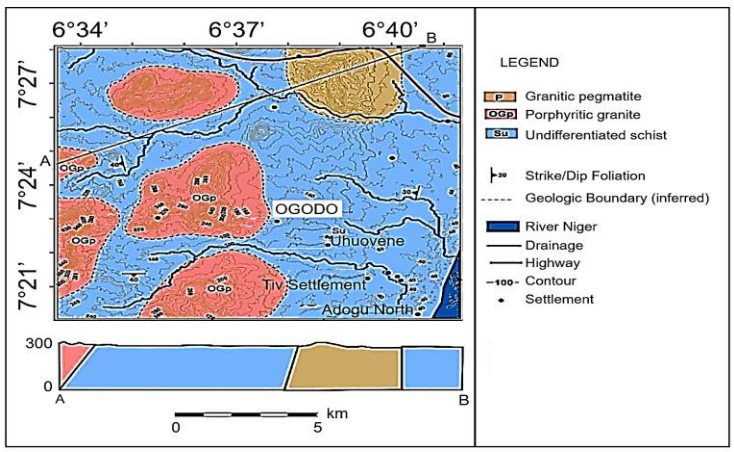

Figure 3. Geology map of Odobola-Ogodo

3.2 Mineralogy and Petrography

The thin sections show that the feldspar in the study area occurs as crystals with well-developed crystal faces and individual crystals measure about 5 – 7 cm in hand specimen. Examination of the thin sections under the microscope reveals that 80 % is made up of feldspar while the remaining 20% consist of quartz, biotite, and traces of altered minerals like sericite that occur along the fractures and cleavage planes of feldspar. The feldspar displays a pinkish colour and is thus an orthoclase or microcline. In some areas, the pink colour has been over-printed by a slightly reddish brown to green colour which indicates areas of incipient alteration of the mineral. Plate 2 shows the photomicrographs, under XPL and PPL. The minerals are predominantly feldspar (f), quartz (q), and mica (m). Figures 4 and 5, and Table 1 show the results of X-Ray Diffractometry (XRD). The samples indicate that the feldspar in Ogodo-Odobola area is predominantly microcline and albite type with an average of 50.7% and 42.6% respectively, and a trace of phlogopite as accessory mineral (6.7%).

3.3 Geochemistry

The results of the chemical analysis of nine different samples for the raw feldspar samples and five samples of the beneficiated feldspar are given in detail and summarized in averages and ranges of major oxides of elements in Tables 2 and 3. Feldspar from a nearby area of Zariagi showed comparable results comprising 58.98% SiO_2, 17.77% Al_2O, 2.87% MnO, 4.67%MgO, 1.22% CaO, 12.28% K_2O, and 0.82% TiO_2 [23]. XRD indicated that the rocks primarily consisted of quartz (53%) and feldspar (29%). Additionally, smaller amounts of albite (8.2%), illite (1.6%), chlorite (3.3%), muscovite (2.3%), and garnet (2.14%) were indicated.

(a) Schist with foliation, (b) Granite in sharp contact with pegmatite, (c) Pegmatite with large crystals of feldspar, quartz and mica, (d) Large crystals of feldspar from pegmatite pit

Plate 1: Rocks and minerals from Ogodo-Odobola

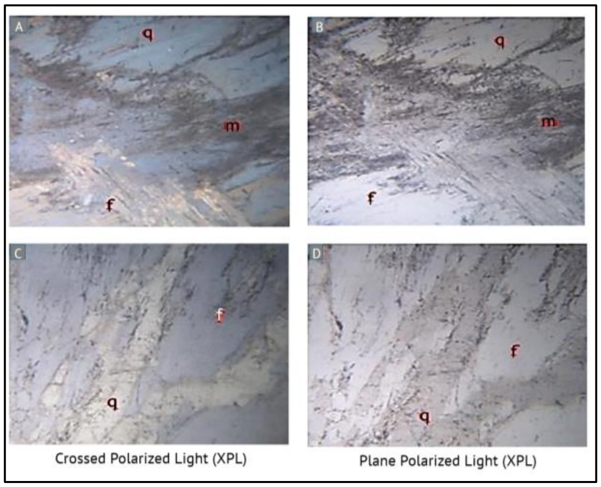

Plate 2: Photomicrographs of Feldspar from Ogodo-Odobola

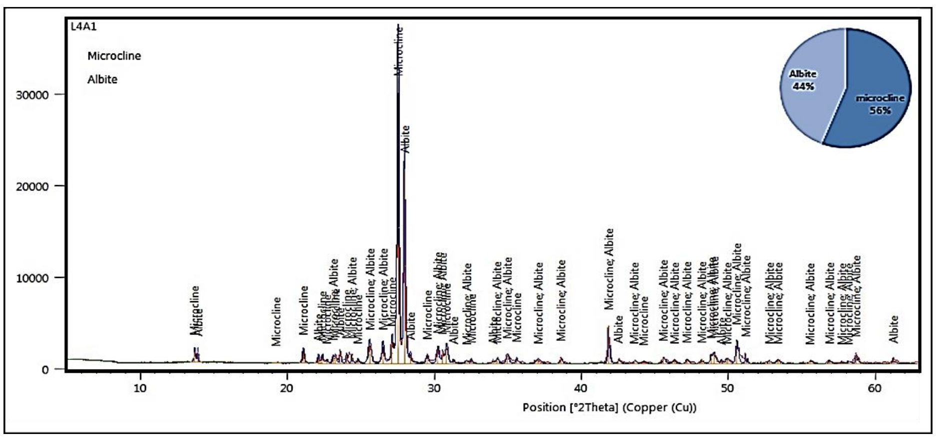

Figure 4. Diffractogram of Feldspar Sample L4A1

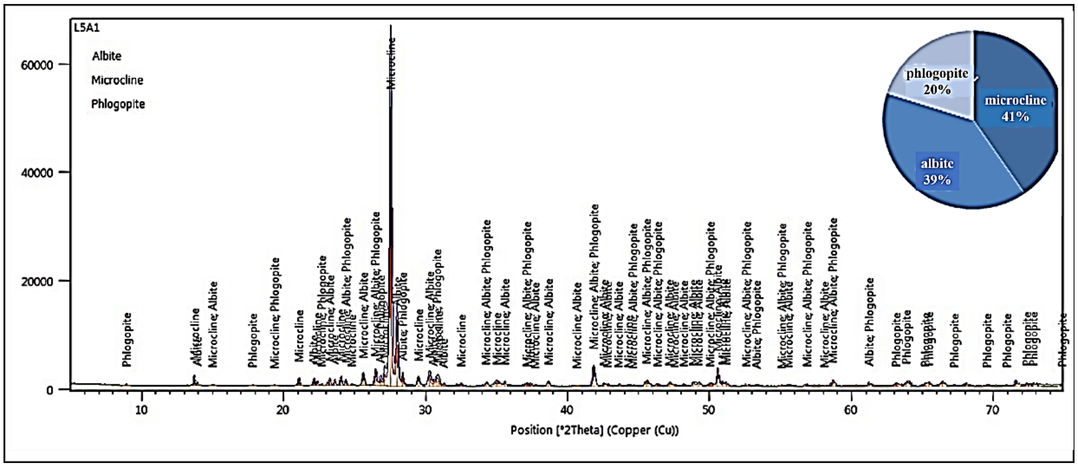

Figure 5. Diffractogram of Feldspar Sample L5A1

Table 1: Mineralogy of Feldspar samples from Odobola-Ogodo

Mineral Abundance	L4A1	L5A1	L6A1	Mean
Microcline	55	41	56	50.7
Albite	45	39	44	42.6
Phlogopite	0	20	0	6.7
Total	100	100	100	100

Table 2: Oxides of raw feldspar from Ogodo-Odobola

Oxide %	L4A	L4B	L4C	L5A	L5B	L5C	L5D	L6B	L6C	Range	Mean %
SiO_2	63.50	62.18	66.10	70.01	72.50	64.64	66.50	63.84	65.01	62-72	66.03
AlO_3	16.15	15.98	16.18	14.10	13.70	15.34	16.50	16.60	15.54	13-16	15.56
Na_2O	5.18	5.17	4.52	4.84	4.49	4.50	4.07	4.78	5.58	4-5	4.79
K_2O	15.0	16.0	14.20	10.8	9.7	15.30	12.45	14.30	12.93	10-16	13.40
CaO	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.1	0.1	0.1-0.2	0.13
MgO	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1
TiO_2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03		0.03
Fe_2O_3	0.3	0.4	0.3	0.3	0.6	0.5	0.3	0.3	0.6	0.3-0.6	0.4
Total	100	100	99.9	100	101	101	100	100	99.99		100

3.4 Industrial applications of Odobola-Ogodo feldspar

Table 4 shows the results of the geochemical analysis for major oxides of both the raw and beneficiated feldspar samples from Odobola-Ogodo, compared with the Bureau of Indian Standards [24]. This serves to assess their industrial best uses. Feldspars are expected to meet certain requirements in terms of sodium oxide (Na_2O) and potassium oxide (K_2O) contents [25-26]. Commercial feldspars are classified as those having at least 1.7 wt % Na_2O, and 10 wt % K_2O. But the Fe_2O must be very low (not more than 0.3 wt %) as higher proportions will have adverse effects on the quality of the final product [27-29].

The raw feldspar from Odobola-Ogodo meets the requirements for ceramics, glass, cement, as well as electrodes and insulator, abrasives, refractory and sanitary ware, while the beneficiated products meet the requirements for abrasives, refractory and sanitary ware. Glass and ceramics continue to be the major end uses of feldspar [8, 30]. The main oxides that determine the usability of the feldspar for glass production are SiO_2, K_2O, Al_2O_3, CaO, Na_2O, and Fe_2O_3. The composition of commercial glass grade feldspar (Table 4) demonstrates that most of the components of the raw feldspar deposit are suitable for glass industries. The raw feldspar also meets the specifications for glass industries. The Odobola-Ogodo raw feldspar may be preferred and more suitable for ceramics. From Table 4, the chemical composition of the raw feldspar is close to commercial grade ceramic specification and standards (Bureau of Indian Standards; Ministry of Energy and Mineral Resource [24, 32]. Hence this deposit can be used as a raw material for ceramics, especially because of its low Fe_2O_3.

The neatness of the end product and assuring the absence of defects in enamel are assisted by feldspar: e.g. ceramic tile glazes, enamel frits, giftware ceramic glazes, sanitary ware, electrical porcelain, and tableware. In combination of kaolin with quartz and orthoclase (potassium feldspar), it is used to manufacture porcelain, sometimes used for dental products and high-tension electrical insulators. Specifications for enamel frits and glazes include SiO_2 (60%), K_2O (5.5), Al_2O_3 (20%). The beneficiated Odobola-Ogodo feldspar is suitable for enamel in terms of SiO_2 (52-61%). It has high Fe_2O_3 (0.001-0.1%) and high K_2O (14-16%). It helps to lower the ceramic body temperature during firing and forming a glassy phase. It also facilitates the optimization process of vitreous ceramic body in sanitary ware, the porcelain in toilets and many other end-uses: urethane, paint, road aggregate, mild abrasives, with production of steel (welding electrodes).

Table 3: Oxides of beneficiated feldspar from Ogodo-Odobola

Oxides%	L4A	L5A	L5B	L5C	L5D	Range	Mean %
SiO_2	58.11	58.71	61.25	60.07	60.05	58-61	59.64
AlO_3	18.09	16.68	14.33	18.05	17.89	14 -18	17.08
Na_2O	8.80	7.93	7.99	6.50	6.75	6-8	7.59
K_2O	15.08	16.62	16.09	15.78	14.94	14-16	15.70
CaO	0.005	0.004	0.03	0.003	0.002	0.02-0.3	0.008
MgO	0.003	0.002	0.04	0.002	0.001	0.001-0.04	0.009
TiO_2	0.002	0.001	0.01	0.002	0.002	0.01-0.002	0.003
MnO	0.002	0.001	0.01	0.002	0.001	0.001-0.1	0.003
Fe_2O_3	0.01	0.02	0.03	0.03	0.01	0.04-0.3	0.02
Total	100	100	101	100	100	100-101	100

Table 4: Raw and beneficiated feldspar from Odobola-Ogodo compared with commercial grades

Constituent (wt %)	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	Fe_2O_3	MgO
Raw feldspar (Odobola)	62-72	13-16	4-5	6-10	0.1-0.2	0.3-0.9	0.100
Beneficiated feldspar (Odobola)	58-61	14-18	6-8	14-16	0.2-0.3	0.04-0.3	0.009
Glass	65-68	15-18	5-7	4-6	1.85	0.3	
Ceramics	68-75	15.00	3.30	4.50	-	<0.3	
Enamel Frits/Glazes	66.00	20.00	5.50	20.06	4.50	-	
Abrasives	60 min	18 min	2-5	0.60	2-5	0.45	
Refractory	60-65	18-19	5-6	-	5-6	<1.5	
Electrode	63-65	17-20	13-14	-	1-3	0.3	
Insulator	62-65	16-20	11-12.5	2-7	-	0.25	
Sanitary ware	65.50	17-20	1-3	0.3	-	0.30	
Grade 1: Glass & Ceramics	68±2	15±1	12.5±0.5	2.1±0.5	0.08±0.03	0.4±0.05	1±0.1
Grade 2: Cement	68±2	18±1	12±0.5	0.1±0.05	0.1±0.02	0.06±0.02	0.07±0.01
Grade 3: Chemical & Abrasives	70±2	18±1	11±0.5	0.1±0.5	0.08±0.03	0.1±0.05	0.1±0.01

Sources: Bureau of Indian Standards [24]; Imerys Minerals [28]; Sibelco Europe [29]; The Quartz Corp [30]

One of the batch constituents added for refractory grade material is feldspar. SiO_2 should be within 60-65%, Na_2O and K_2O (11 to 12%), Fe_2O_3 (1.5%). Odobola feldspar is thus suitable because of its low iron oxide content. Electrode: In the electrode manufacturing process, feldspar is used as a fluxing agent and to form slag. This protects molten metal from oxidation. For this, potash feldspar having SiO_2 (63-65%), Al_2O_3 (17-20%), (13-14%) of K_2O, 1-3% of Na_2O and Fe_2O_3 up to 0.3% is selected. The raw feldspar of Odobola-Ogodo is suitable for these uses because of the levels of SiO_2 (62-72.00%), Na_2O (5-4%), K_2O (10-16) and Fe_2O_3 (0.3%). Odobola-Ogodo feldspar samples would also find application in insulator, cement, chemical and abrasives, as it satisfies the requirement set for high quality commercial potassium feldspar.

3.5 Technical and environmental effects of feldspar beneficiation

The results from the chemical composition of both the raw and beneficiated feldspar samples reveal that SiO_2 for the raw feldspar range from 62-72% with an average of 66.03%, while the beneficiated feldspar ranges from 58-61% with an average of 59.64%. On the other hand, the Al_2O_3 content increased from a range of 13-16% in the raw feldspar sample to 14-18% in the beneficiated sample with an average of 15.56% to 17.08%. Hence, the beneficiation had removed impurities of SiO_2 while increasing the Al_2O_3 content. Similarly, the K_2O and Na_2O were higher in the beneficiated feldspar than in the raw feldspar, which ranges from 10-16%, 14-16% and 5-4%, 6-8% with averages of 13.40%, 15.70% and 5.68-7.59% respectively. The other oxides, CaO, MgO, and Fe_2O, all have lower values in the beneficiated feldspar, which range from 0.1-0.2% with a mean of 0.13%, while the beneficiated values range between 0.2-0.3 (mean of 0.008% for CaO), and for MgO and Fe_2O_3, ranging 0.1-0.1%, 0.001-0.04%, and 0.3-0.6, 0.04-0.3%, with a mean of 0.1, 0.009, and 0.4, 0.02%, respectively.

Abiola et al found that beneficiation increased silicon content and aluminum, and iron impurity reduced by over 50% while potassium was dominant [33]. The increased quartz in the mineral will improve the hardness, density, porosity, and rigidity of ceramic tiles as well as providing support and controlling shrinkage. Increasing the mineral quotient in feldspar will enhance its fluxing potential. Gougazeh also showed that the use of magnetic separation and flotation reduced the iron and titanium contents of Medina feldspar, which imparted color and decrease the feldspar quality, as well as produce a high-quality feldspar concentrate, which met the commercial grade specifications for the ceramics and glass industry [34]. The feldspar concentrate was produced with 65.18 % SiO_2, 19.02 % Al_2O_3, 0.06 % Fe_2O_3, 0.09 % TiO_2 9.09 % K_2O and 6.01 % Na_2O grades, which meet the commercial scale of feldspar. Gaied and Gallala showed that the conventional flotation with HF is still the most selective and effective method, although it has harmful impact on the environment and health [35]. Zhang et al therefore, noted that in the production of quality advanced materials, the processing of feldspar using clean and efficient methods remains a formidable challenge [14].

4.0 Conclusion

This study has shown that the Odobola-Ogodo area consists of schists which have been intruded by granites and pegmatite. The mineralogy results reveal that the feldspar in the area is predominantly microcline and albite types, with average of 50.7% and 42.6% respectively, and a trace of phlogopite as accessory mineral (6.7%). These results confirm that the feldspar component of Odobola-Ogodo pegmatite is predominantly microcline (potassium feldspar). This further corroborates the field observation and petrographic investigation. The geochemical results show that the raw and beneficiated feldspar meets the requirements for ceramics, glass, refractory, insulator, sanitary ware, electrodes, cement, chemical and abrasives industries. The raw feldspar may be preferable for abrasives and chemical industries because of the high SiO_2 content. The feldspar from this deposit is of high quality by virtue of its low Fe_2O_3 content as both the raw and beneficiated feldspar have Fe_2O_3 contents that range from 0.3-0.6 % and 0.01-0.03 %.

Recommendations

It is hereby recommended that the high grade potassium feldspar and low Fe_2O_3 content should be harnessed for various industries in Nigeria. In view of the rising global demand for feldspar products, developing the Odobola-Ogodo feldspar deposit would have a great impact on the industrial and economic status of the country. Further studies on the feldspar deposit may include reserves estimations and the use of a magnetic separator to further reduce the iron contents.

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Authors' contributions:

Zainab Usman: conceptualization, methodology, results analysis and interpretation, original manuscript preparation, review and editing, funding acquisition, **Irmiya Samson Amoka**: laboratory and project guide, data analysis and interpretation, type-setting, drawing graphics and software, manuscript review, editing and references; **Shuaib Abdulazeez Shehu**: fieldwork, writing guide, review, and funding; **Adekola Alabi**: field guide and review; **Bashir Mohammed Abdulraheem**: fieldwork, data collection.

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