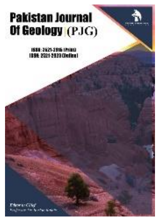
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-2915 (Print)
ISSN: 2521-2923 (Online)
CODEN: PJGABN

Pakistan Journal of Geology (PJG)

DOI: http://doi.org/10.26480/pjg.02.2024.106.112



CrossMark

RESEARCH ARTICLE

MINERALOGICAL AND GEOCHEMICAL INVESTIGATION OF FELDSPAR DEPOSITS FOR CERAMIC APPLICATIONS IN THE DAGBALA AREA, AKOKO-EDO, SOUTHERN NIGERIA

Fadiminiyi Gbenga Stephen, Aladin Anthony Ese and Maju-Oyovwikowhe G.E

Department of Geology, University of Benin, Edo State, Nigeria
****Corresponding Author Email: Fadgbenga01@gmail.com***

ARTICLE DETAILS

Article History:

Received 23 August 2024
Revised 18 September 2024
Accepted 08 October 2024
Available online 11 October 2024

ABSTRACT

Feldspar minerals are essential industrial minerals that have varied applications depending on their mineralogical and chemical compositions. This project aims to evaluate the geochemical properties of Feldspar deposits around Dagbala area to determine their suitability for ceramic production. The study combines field and laboratory analysis of the samples collected. Fieldwork was carried out in Dagbala area, Akoko-Edo, Southern Nigeria, where ten (10) rock chip samples were collected from six different locations during the dry season. The chemical and mineralogical properties of the Feldspar materials were determined using X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) analysis. The major mineral phases identified in the Feldspar samples from the studied areas were Muscovite, Quartz, Plagioclase, Albite, Microcline/Orthoclase, and Zircon. Geochemical analysis of the Feldspar deposits showed that they contained high Silica, SiO2 (72.71 – 74.97%; average: 73.11%) and Alumina, Al2O3 (15.05-15.16%; average 15.12%) with significant amounts of Potash (K2O) content (3.53 – 8.20%; average: 7.00%) and Soda (Na2O) content (3.37 – 5.56%; average: 4.94%), which are essential oxides for ceramic production. The ceramic suitability of these materials was assessed using the Bureau Indian Specification (BIS) and data from relevant literature. The results revealed that these raw materials are suitable for the production of ornamental ceramic ware.

KEYWORDS

Feldspar, Dagbala, X-ray Diffraction (XRD) and X-ray Fluorescence (XRF)

1. INTRODUCTION

Feldspars are the most prevalent group of rock-forming minerals found in nature, although they rarely occur as pure minerals (Klein et al., 1993). They are key components of various rock types such as pegmatite, granite, syenite (especially nepheline syenite), feldspathic sand, and sandstone (arkose). Economically, feldspar is significant in the production of glass and ceramics, and serves as a cementing agent in the manufacture of bonded abrasives like wheels and discs made from garnet, corundum, and emery. Additionally, feldspar is used as a filler and extender in products such as paint, cement, and concrete, as well as in fertilizers, insulating materials, and tarred roofing. It is also employed in pharmaceuticals, including anti-constipation medications, and as a coating for welding rods (Potter, 1996).

The Earth's crust is composed of the following mineral groups in the following proportions: feldspars make up 58%, pyroxene and amphiboles 13%, quartz 11%, micas, chlorites, and clay minerals 10%, carbonates, oxides, sulfides, and halides 3%, olivines 3%, and epidotes, aluminosilicates, garnets, and zeolites 2% (Ayse, 2010).

Feldspars are predominantly found in igneous rocks, indicating that they have crystallized from magma in both intrusive and extrusive igneous formations (Troll, 2002). They are also present in many metamorphic rocks, which are formed from pre-existing rocks containing feldspars. Additionally, feldspars are abundant in pegmatites, a type of intrusive igneous rock characterized by a very coarse texture, with large interlocking crystals typically exceeding 1 cm (0.4in) in size, and sometimes even greater than 1 meter (3ft) (Jones et al., 1964). Most pegmatites are composed of quartz, feldspar, and mica, sharing a silicic composition similar to granite, although less common intermediate and mafic pegmatites do exist. Pegmatites are notable for containing some of the world's largest crystals, including gemstones such as microcline, quartz, mica, spodumene, beryl, and tourmaline.

Some individual crystals can exceed 10 meters (33feet) in length (Schwartz, 1928). Many pegmatites are believed to originate from the final fluid fraction of a large crystallizing magma body. It has been observed that this residual fluid is highly concentrated in volatiles and trace elements, and its low viscosity allows molecules to move quickly and join existing crystals rather than forming new ones. This process enables the formation of very large crystals. While most pegmatites consist of simple mineral compositions similar to ordinary igneous rocks, some have a more complex composition, containing several rare minerals. An example includes pegmatites composed of lepidolite, tourmaline, and quartz from the White Elephant Mine in the Black Hills, South Dakota. Additionally, Proterozoic pegmatites from the northeastern Baffin Island, Nunavut, contain rare elements and are mined for valuable resources like lithium, beryllium, boron, fluorine, tin, tantalum, niobium, rare earth elements, and uranium. Pegmatites are known to contain exceptionally large crystals, with some of the largest ever discovered being feldspar crystals in pegmatites from Karelia, weighing thousands of tons. Nepheline syenite pegmatites often include minerals containing zirconium, titanium, and rare earth elements (Klein et al., 1993).

Gabbroic pegmatites typically consist of exceptionally coarse interlocking pyroxene and plagioclase crystals (Blatt et al., 1996). According to

Quick Response Code	Access this article online	
	Website: www.pakjgeology.com	**DOI:** 10.26480/pjg.02.2024.106.112

Cite The Article: Fadiminiyi Gbenga Stephen, Aladin Anthony Ese and Maju-Oyovwikowhe G.E (2024). Mineralogical and Geochemical Investigation of Feldspar Deposits for Ceramic Applications in the Dagbala Area, Akoko-Edo, Southern Nigeria. *Pakistan Journal of Geology, 8(2): 106-112.*

researchers, pegmatites are often found as irregular dikes, sills, or veins, particularly at the edges of batholiths, which are large masses of intrusive igneous rock (Klein et al.,1993).

It was reported that most pegmatites are closely related to large intrusions, both spatially and genetically (Jackson and Julia, 1997). Pegmatites may form veins or dikes within the intrusion itself but are more commonly found extending into the surrounding country rock, especially above the intrusion (Klein et al., 1993). Some pegmatites, which are surrounded by metamorphic rock, do not appear to have any connection to a larger intrusion. Pegmatites in low-grade metamorphic rock tend to be dominated by quartz and carbonate minerals, while those in higher-grade metamorphic rock are rich in alkali feldspar. Gabbroic pegmatites often occur as lenses within bodies of gabbro or diabase (Philpotts and Ague, 2009). Additionally, nepheline syenite pegmatites are common in alkaline igneous complexes (Blatt et al., 1996). Physical weathering of feldspar-bearing rocks can lead to the formation of sedimentary rocks containing feldspars. However, this is relatively rare because, in most environments, feldspars tend to alter into other materials, such as clay minerals like kaolinite ($Al_2Si_2O_5(OH)_4$).Physical weathering of feldspar-bearing rocks can lead to the formation of sedimentary rocks that contain feldspars; however, this is uncommon because, in most environments, feldspars tend to alter into other materials, such as clay minerals like kaolinite, with the chemical composition ($Al_2Si_2O_5(OH)_4$).Feldspars are generally categorized into two main groups: orthoclase/microcline and plagioclase. Orthoclase, microcline, and plagioclase, which are potassium aluminum silicates ($KAlSi_3O_8$), are common feldspars found in igneous and metamorphic rocks. Orthoclase is one of the most abundant minerals and occurs in various mineral environments. It is polymorphous with the minerals microcline and sanidine, meaning it exists in three forms. These three minerals comprise the potassium feldspar group and share similar physical properties, making them difficult to distinguish without X-ray analysis. The primary difference between them lies in their crystal structure: microcline forms in the triclinic system, while orthoclase and sanidine crystallize in the monoclinic system. Sanidine crystallizes at high temperatures and has a disordered monoclinic symmetry, whereas orthoclase crystallizes at lower temperatures and forms more ordered monoclinic crystals (Kimata et al., 1996). Microcline is the dominant feldspar in pegmatite formations and is an essential tectosilicate mineral that alters into igneous rock. It is often referred to as "straight fracture" due to its two cleavage planes intersecting at right angles. Microcline is a type of potassium feldspar, also known as K-feldspar. Orthoclase is a common component of most granite and other felsic igneous rocks, often forming large crystals and massive structures in pegmatites. Pure potassium orthoclase forms a solid solution with albite, the sodium-rich end member ($NaAlSi_3O_8$) of plagioclase. As the rock cools slowly within the Earth, sodium-rich albite lamellae separate by exsolution, enriching the remaining orthoclase with potassium. The intergrowth of these two feldspars results in a texture known as perthite, a laminated mixture of two feldspars.

Plagioclase is a series of isomorphous feldspar minerals with a complete solid solution range from pure albite ($NaAlSi_3O_8$) to pure anorthite ($CaAl_2Si_2O_8$). The minerals within this series share a similar genetic composition of albite and anorthite. The names of the minerals in this series are assigned based on their respective compositions of albite and anorthite: oligoclase (90-70% Ab, 10-30% An), andesine (70-50% Ab, 30-50% An), labradorite (50-30% Ab, 50-70% An), bytownite (30-10% Ab, 70-90% An), and anorthite (10-0% Ab, 90-100% An) (Nesse & Williams, 2000).

1.1 Beneficiation of Mineral

Mineral beneficiation is the process that most minerals must undergo before they can be used in ceramic manufacturing. Physical ore processing involves crushing and grinding coarse rocks. The particle size of the material can impact subsequent steps in the production process. An example of this is the production of corundum from a mineral, which involves a chemical transformation. Chemical ore processing includes methods for separating the desired mineral from unwanted waste products, such as dissolving the ore in a suitable solvent followed by filtration. The process of producing corundum is also a good example of chemical ore processing. Minerals often contain numerous impurities, and the purity of raw materials is reflected in the composition of the final product. For many ceramics, strict control over purity is essential. In such cases, the raw materials are synthesized. Additionally, many important ceramics do not occur naturally in mineral form and must be chemically fabricated. The synthesis of ceramic powders offers advantages, not only in reducing impurities but also in producing fine, well-defined particles with specific morphologies.

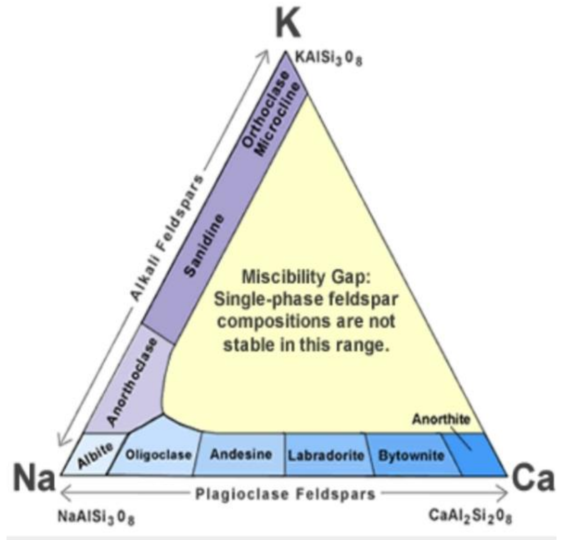


Plate 1: Major Classification of Feldspars (Hanneman, 2012)

Plate 1, illustrates how feldspar minerals are classified based on their chemical composition. The minerals positioned along the base of the triangle represent the solid solution series of plagioclase, ranging from albite to anorthite. Geologically, members of the plagioclase group are among the most common rock-forming minerals. They are crucial or dominant in most igneous rocks of the Earth's crust and are major constituents in a wide array of intrusive and extrusive igneous rocks, including granite, diorite, gabbro, rhyolite, andesite, and basalt. Plagioclase minerals are also significant components of various metamorphic rocks, such as gneiss, where they may originate from an igneous protolith or form during the regional metamorphism of sedimentary rocks.

Feldspars are widely utilized in the glass and ceramic industries. In the glass industry, they serve as sources of alkali and alumina, while in the ceramic industry, they are valued for their fluxing properties. The feldspar grades used in ceramics are distinguished by their low iron oxide content and are categorized based on their total feldspar content and specific Na_2O/K_2O ratios. These ratios can range from nearly pure potash feldspar (microcline) to almost pure sodium feldspar (albite). In earth sciences and archaeology, feldspars are used for dating methods, such as K-Ar dating, Ar-Ar dating, thermoluminescence dating, and optical dating.

Approximately 70% of feldspar is used in the production of glass products, with the remaining 30% used in ceramics and other products (Potter, 1996). The raw materials for glass production include silica sand, soda ash ($NaCO_3$), and limestone ($CaCO_3$), with feldspar making up 10-15% of the mixture. Alumina (Al_2O_3) from feldspar contributes hardness, workability, strength, and resistance to chemical corrosion and thermal shock in the final product. Alkali oxides (Na_2O and K_2O) from feldspar act as fluxes, lowering the melting temperature of silica sand in the batch, which reduces energy consumption, improves control over glass viscosity, and decreases the amount of soda ash needed (Kauffman and Van Dyk, 1994; Bourne, 1994).

Feldspar used in the ceramic industry is classified into three categories based on the degree of feldspar content. The first category includes low-grade feldspathic raw materials containing between 30% and 45% feldspar, with a total alkali content usually under 8%. The second category, or medium-grade feldspar, has a feldspar content ranging from 55% to 80%. These materials may also include notable amounts of quartz and iron oxide and are used in a variety of applications such as tile production and sanitary and technical porcelains. The third category consists of high-grade feldspars with more than 90% feldspar content. These are characterized by their low iron oxide levels, minimal compositional variation, and white color. High-grade feldspars are primarily used in the production of tableware, electrical and sanitary porcelain, glazes, porcelain enamels, and frits (Cebula et al., 1983). This research aims to assess the suitability of feldspar from pegmatite dykes in the Dagbala area for use in sculptural and ceramic industries.

2. Description of the Study Area

The study area is situated at latitude 70° 21' N and longitude 60° 09' E in the northern part of Edo State, Nigeria. It is underlain to the north by Precambrian Basement Complex and to the south by Cretaceous and Tertiary sediments. The northern region is rich in industrial and metallic minerals, which are currently being exploited at various stages. These minerals significantly influence the petrographic characteristics of the rocks. The Dagbala Community is located in the Akoko Edo Local Government Area. The primary transportation route in the area extends from Auchi through Sobe, Ogbe, Ikpeshi, Igarra, to Ibillo. Both the old and new roads were utilized for access during the study, along with several major footpaths indicated on the accessibility map.The climate of Dagbala and its surroundings is classified as warm-humid tropical, with distinct wet and dry seasons. The rainy season lasts about seven months (May to October), while the dry season spans roughly five months (November to April). Rainfall is moderate from March to May and becomes heaviest between June and September, with averages ranging from 1000 mm to 1500 mm. Temperatures can reach up to 36.7°C, particularly from February to April. The area falls within the Guinea Savannah vegetation belt, characterized by short trees and tall grasses, and experiences consistently high humidity with ample precipitation. The study was conducted during the rainy season, resulting in cool and wet mornings and sunny afternoons. The study area lies at the boundary between tropical rainforest and savannah, resulting in a mix of vegetation types. The region is divided into the wooded area belt in the central and southern parts of the state and the Guinea Savannah in the northern part, where the study area is located. Vegetation in the study area consists of sparsely distributed trees, herbs, shrubs, and grasses. Trees like mango and orange help mitigate erosion, and are predominantly found along fracture zones within plutonic bodies and on quartzite ridges where soil cover and groundwater retention are adequate. The main occupations of the Dagbala community are pastoralism and subsistence farming, with major crops including yams, cassava, pineapples, maize, and cocoa. Farming activities are typically conducted in valleys with loamy soils and high water tables. Bush burning and hunting are common practices among locals, and some farmers also produce small quantities of palm oil from palm trees.

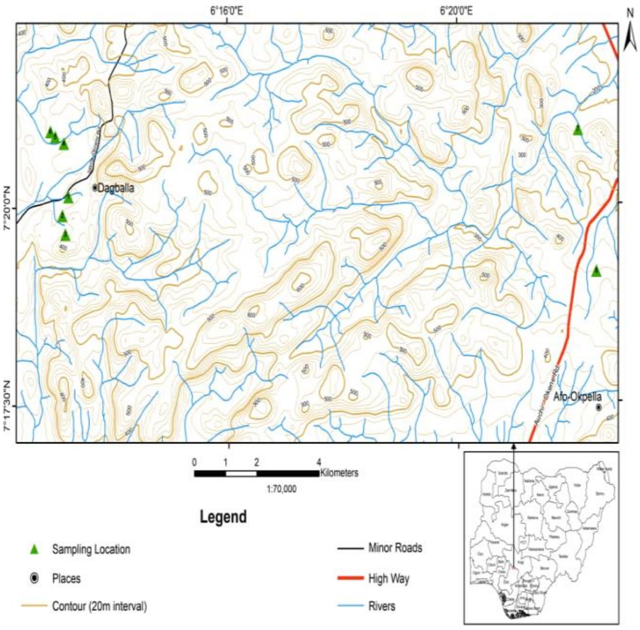


Figure1: Map of the Study Area Showing the Sampling Locations

2.1 Regional geology of the area

Extensive research has been conducted on Nigeria's general geology by prominent geologists with a particular focus on southwestern Nigeria such as Falconer in 1911; Odeyemi in 1981, Rahaman in 1976 and others. Field observations and radiometric dating indicate that the Nigerian basement complex reflects significant geological events dating back to 3000 Ma and underwent extensive deformation and remobilization during the Pan-African orogeny (less than 600 Ma) (Odeyemi, 1981). The basement complex is considered polycyclic, meaning it contains rocks of varying ages and origins within the same geological setting, and it has been affected by tectonic events from the Achaean to the Late Proterozoic (Pan-African). Rahaman reviewed the basement geology of southwestern Nigeria and identified five major rock groups (Rahaman, 1976). These include the Migmatite-Gneiss Complex, which consists of Biotite-Hornblende gneiss, quartzite, quartz schist, and lenses of Calc-Silicate rocks. Researchers further characterized this Complex as the most extensive rock unit in Nigeria's basement, noting its heterogeneous nature with Migmatites, orthogneisses, paragneisses, and various metamorphosed basic and ultrabasic rocks (Rahaman, 1988). Petrographic studies reveal that Pan-African reworking has led to the recrystallization of many minerals through partial melting, with most exhibiting medium to upper amphibolite facies metamorphism. The complex also includes migmatized

paraschists and metaigneous rocks such as pelitic schist, quartzite, talcose rock, metaconglomerate, and Calc-Silicate rocks. These rocks often form distinct belts, some of which host metamorphosed chemical sediments like marbles and banded iron formations (BIF), while others contain mafic to ultramafic rocks such as amphibolites and ultramafites. Minor felsic to intermediate metavolcanics and greywackes are also present. These rock groups are among the most thoroughly studied in Nigeria due to their associated mineral resources, including gold, BIF, marble, manganese, talc, and anthophyllitic asbestos (Truswell and Cope, 1963). The Older Granite group, which includes rocks ranging from granodiorite to granite and potassic syenite, was first described by (Falconer, 1911). Falconer differentiated these Older Granites from the Pan-African granitoids based on morphology and texture, distinguishing them from the Carboniferous-Cretaceous "Younger Granites" of the Jos Plateau Region. The granitoids include Biotite and Biotite-Muscovite Granites, Syenites, Charnockites, Diorites, Monzonites, Serpentinites, and Anorthosites. In many areas, coarse-grained Biotite-Hornblende Granites exhibit concordant foliation with the host schists. Unmetamorphosed dolerite dykes are believed to be the youngest rocks in the region.

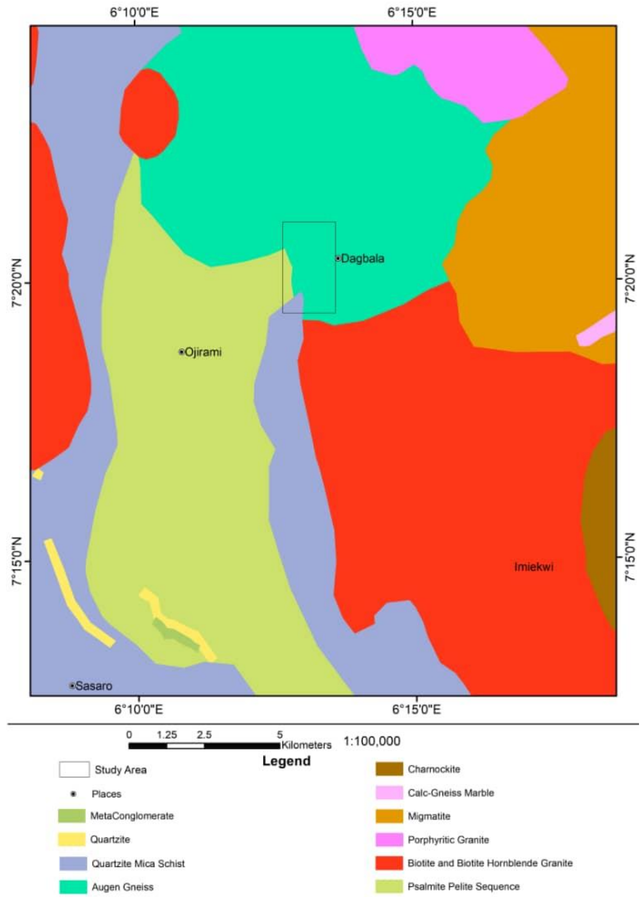


Figure 2: Regional Map of the Study Are

3. Materials and Methods

3.1 Materials

Fieldwork was conducted in the Dagbala area, where a total of 10 rock chip samples were collected from exposed pegmatite outcrops. The sampling took place during the dry season as shown in plate 2a&2b. Each sample was carefully labelled and stored in sample bags. Equipment used during the fieldwork included a field map at a 1:50,000 scale, a Global Positioning System (GPS), a compass/clinometers, geological and sledge hammers, a field notebook, masking tape, pens, a field camera, and sample bags. Chemical and mineralogical analyses were performed at Rolab Research and Diagnostic Laboratory, affiliated with the University of Ibadan, in Ibadan, Oyo State. Additional rational analyses were conducted at the Research Laboratory of the University of Benin, Benin City, to determine the oxide percentages. The results were then compared with existing literature. The feldspar samples, collected as rock chips, were first crushed into smaller particles and then milled into a fine powder using a rock crusher and ball mill at the Department of Geology, University of Benin.

The powdered feldspar was placed in a cleaned porcelain crucible and dried at 110°C for 15 hours in an oven.

Plate 2a and **2b:** View of Sampling location of the study at Dagbala area

3.2 Methods

3.2.1 Chemical analysis

The chemical analysis of the powdered feldspar sample was conducted using an X-ray fluorescence (XRF) instrument. Before the analysis, the sample was dried at 110°C for 8 hours to remove any moisture that may have been introduced during storage.

3.2.2 Mineralogical analysis

The samples were prepared for X-ray diffraction (XRD) analysis using the back-loading method described by Kleeberg et al. (2008). The analysis was carried out with a PANalytical X'Pert Pro powder diffractometer equipped with an X'Celerator detector, variable divergence and receiving slits, and Fe-filtered Co-Kα radiation. Phases were identified using X'Pert Highscore Plus software, with the receiving slit set at 0.040°. Data were collected over a 2θ range from 5 to 70°, with a counting time of 1.5 seconds. The temperature-scanned XRD data were obtained using an Anton Paar HTK 16 heating chamber with a platinum heating strip. The qualitative results are graphically represented below. Relative phase amounts (weight %) were estimated using the Rietveld method with the Autoquan Program, as detailed by (Young et al., 1994). The results are shown in Figures 3-10 and Table 1.

4. Interpretation of Results and Discussion

4.1 Comparisons between Feldspar used as a Ceramic Raw Material and Feldspar deposit around Dagbala

A comparison was made between the feldspar used as a ceramic raw material at the Department of Fine and Applied Art, University of Benin, Ekenwan Campus, and the feldspar deposits found around Dagbala. This comparison aimed to evaluate the suitability of the Dagbala feldspar deposits for use in the ceramic industry.

4.2 Interpretation of Feldspar Data obtained from the study area

According to the data presented in Table 1, the Feldspar samples exhibit a broad compositional range. They contain high levels of Silica (SiO2), ranging from 72.71% to 74.97%, with an average of 73.11%, and Alumina (Al2O3), ranging from 15.05% to 15.16%, with an average of 15.12%. The loss on ignition varies from 0.20% to 0.75%, with an average of 0.46%. Potash (K2O) content ranges from 3.53% to 8.20%, with an average of 7.00%, while Soda (Na2O) content ranges from 3.37% to 5.56%, with an average of 4.94%. These values align with the typical feldspar composition as noted by BIS (1992). Other compositional values are as follows: Iron content (Fe2O3) ranges from 0.31% to 0.45% (average: 0.40%); Calcium oxide (CaO) ranges from 0.27% to 0.72% (average: 0.45%); Phosphorus pentoxide (P2O5) ranges from 0.22% to 0.45% (average: 0.36%); Magnesium oxide (MgO) ranges from 0.06% to 0.11% (average: 0.10%); Manganese oxide (MnO) ranges from 0.02% to 0.04% (average: 0.03%); and Titanium dioxide (TiO2) ranges from 0.01% to 0.02% (average: 0.02%). These values are all below 1%.

Table 2 shows that the mean silica content (73.11%) in the feldspar from the studied area is higher than that found in feldspar samples from Ethiopia (67.61%), the US (69.59%), and Egypt (65.81%). The alumina content (15.12%) is also higher than the alumina content (15.11%) in feldspar from China used for sculpture at the Department of Fine and Applied Art, University of Benin, Ekenwan Campus. The iron content (0.40%) surpasses the iron content in standard feldspar from Ethiopia (0.15%) and Egypt (0.19%), but is similar to the feldspar used for sculpture in Benin. The magnesium oxide content (0.10%) is higher than that in feldspar from Ethiopia, Egypt, and the US (0.02%, 0.19%, and 0.00%, respectively). The calcium oxide content (0.45%) exceeds that in feldspar from China, the US, and Egypt (0.27%, 0.15%, and 0.02%, respectively). The sodium oxide content (4.94%) is higher than that in feldspar from the US and Egypt (2.30% and 2.97%, respectively). The potash content (7.00%) is greater than in feldspar from China and Ethiopia (3.53% and 6.95%, respectively). The Phosphorus pentoxide content (0.36%) is higher than in feldspar from China (0.22%), and above the detection limits in samples from Ethiopia and the US. The Titanium dioxide content (0.02%) is higher than in feldspar from China, Ethiopia, and Egypt (0.01% each). However, the mean silica content (73.11%) is lower than the 74.97% found in feldspar from China used for sculpture at the University of Benin. The alumina content is below that of feldspar from Ethiopia, the US, and Egypt (19.00%, 17.66%, and 18.35%, respectively). The iron content (0.40%) is lower than that in feldspar from the US (0.52%). The Manganese oxide content (0.03%) is below that found in feldspar from China (0.04%) and undetectable in samples from the US, Ethiopia, and Egypt. The Magnesium oxide content (0.10%) is slightly less than the 0.11% in feldspar from China. The calcium oxide content (0.45%) is lower than the 1.19% in feldspar from Ethiopia. Sodium oxide content (4.94%) is lower than in feldspar from China and Ethiopia (5.28% and 5.38%, respectively). Potash content (7.00%) is less than in feldspar from the US and Egypt (8.89% and 12.10%, respectively). The Titanium dioxide content (0.02%) is lower than the 0.09% found in the US.

According to Table 3, the Bureau of Indian Standards in 1991 specifies that iron content (0.40%) in the studied area and feldspar from China, Ethiopia, and Egypt is below the maximum allowable limit of 0.50%, except for the US (0.52%). The combined calcium oxide and magnesium oxide content (0.55%) in the studied area is below the maximum specification of 1.0%, except for Ethiopia (0.52%). Potash content (7.00%) and sodium oxide content (4.94%) are also below their respective maximum specifications (1.0% for potash and 6.0% for sodium oxide), with combined potash and sodium oxide content (11.94%) under the maximum allowable limit of 13%, except for Egypt (15.07%). Therefore, the feldspar from the studied area meets the criteria for ceramic production.

Table 1: Chemical composition of Major Oxide of Feldspar sample from the studied area

Sample (%)	Location 1	Location 2	Location 3	Location 4	Mean
SiO2	72.71	74.97	72.06	72.71	73.11
AI2O3	15.16	15.11	15.05	15.16	15.12
Fe2O3	0.45	0.40	0.31	0.45	0.40
MnO	0.02	0.04	0.02	0.02	0.03
MgO	0.06	0.11	0.07	0.06	0.10
CaO	0.72	0.27	0.09	0.72	0.45
Na2O	5.56	5.28	3.37	5.56	4.94
K2O	8.20	3.53	8.08	8.20	7.00
P2O5	0.39	0.22	0.45	0.39	0.36
TiO2	0.02	0.01	0.01	0.02	0.02
LOI	0.20	0.69	0.75	0.20	0.46

X-Ray Diffraction (XRD) analysis revealed that the feldspar deposit at Dagbala is primarily composed of muscovite, quartz, plagioclase, albite, microcline/orthoclase, and zircon. This composition is comparable to that of feldspar used for ceramic production at the Department of Fine and Applied Art, University of Benin, Ekenwan Campus as shown in Figure 6-10.

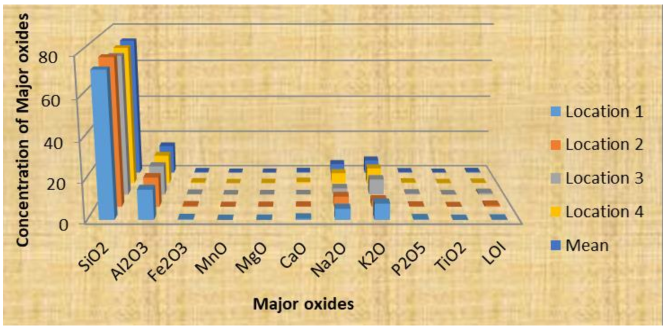


Figure 3: Concentration against Major Oxide of study area locations and mean

Table 2: Comparison of major elements of present study with result of Chinese sample obtained from University of Benin, Benin City and other literatures

Sample	Present Study	A (China)	B (Ethiopia)	C (US)	D (Egypt)
SiO2	73.11	74.97	67.61	69.59	65.81
AI2O3	15.12	15.11	19.00	17.66	18.35
Fe2O3	0.40	0.40	0.15	0.52	0.19
MnO	0.03	0.04	0.001	0.001	0.001
MgO	0.10	0.11	0.02	0.00	0.01
CaO	0.45	0.27	1.19	0.15	0.02
Na2O	4.94	5.28	5.38	2.30	2.97
K2O	7.00	3.53	6.95	8.89	12.10
P2O5	0.36	0.22	0.001	0.00	0.001
TiO2	0.02	0.01	0.01	0.09	0.01
LOI	0.46	0.69	0.49	0.19	0.44

A: (Obtained from Ekenwan Campus Dept. of Fine and Applied Art (Shanghai, 1999) B: (Ibisi, 1992), C: (D.Njoya et al, 2010), D :(Ashraf et al, 2007).

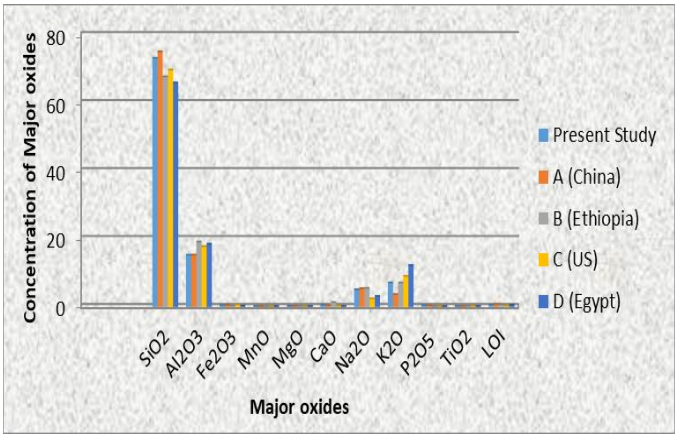


Figure 4: Concentration against Major oxides of present and previous studies

Table 3: Comparison of major oxides values with those of Bureau Indian Specification

Sampling location	Present Study	A (China)	B (Ethiopia)	C (US)	D (Egypt)	BIS Max Value
Fe2O3	0.40	0.40	0.15	0.52	0.19	0.5
CaO +MgO	0.55	0.38	1.21	0.15	0.03	1.0
K2O	7.00	3.53	6.95	8.89	12.00	9.0
Na2O	4.94	5.28	5.38	2.30	2.97	6.0
K2O+Na2O	11.94	8.81	12.33	12.33	15.07	13.0

A: (Obtained from Ekenwan Campus Dept. of Fine and Applied Art (Shanghai, 1999) B: (Ibisi, 1992), (BIS (in wt%) (Kaulir Kisor Chaterjee, 2008). C: (D.Njoya et al, 2010), D :(Ashraf et al, 2007).

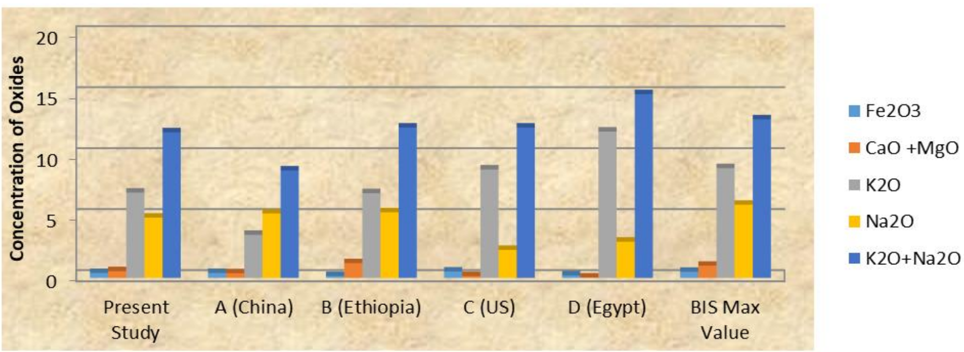
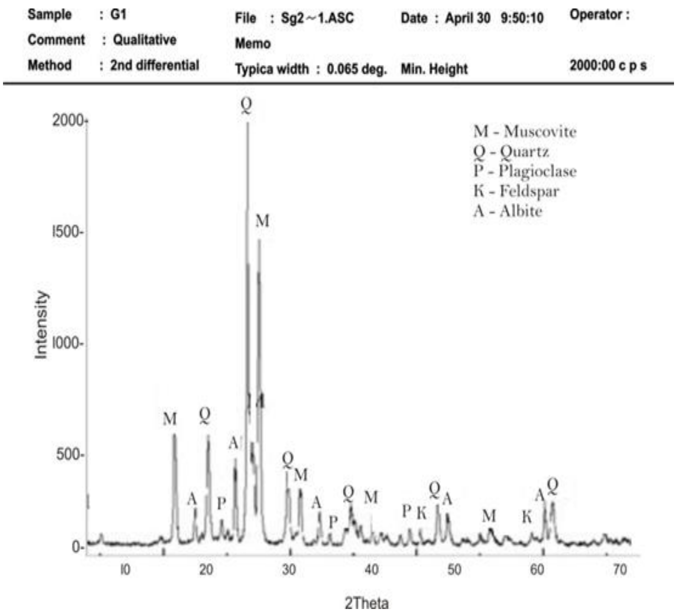


Figure 5: Concentration against BIS specification



Figures 6: X-Ray Diffractogram analysis of Feldspar sample from Location1

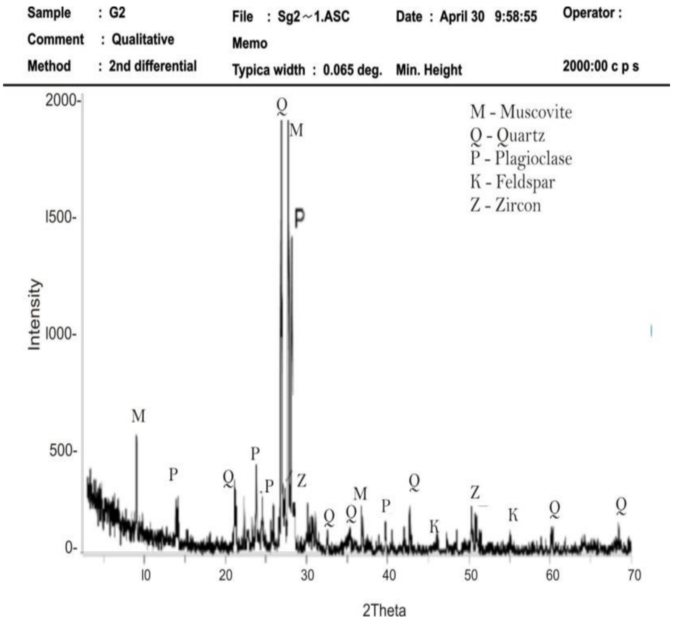


Figure 7: X-Ray Diffractogram analysis of Feldspar sample from Location 5

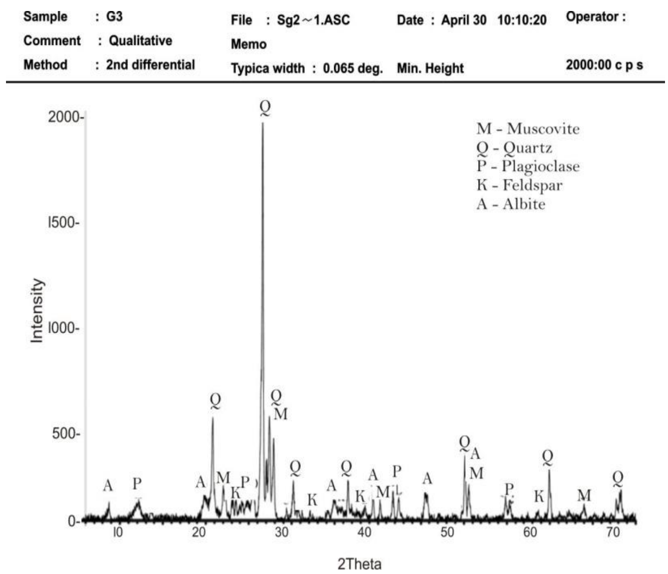


Figure 8: X-Ray Diffractogram analysis of Feldspar sample from Location

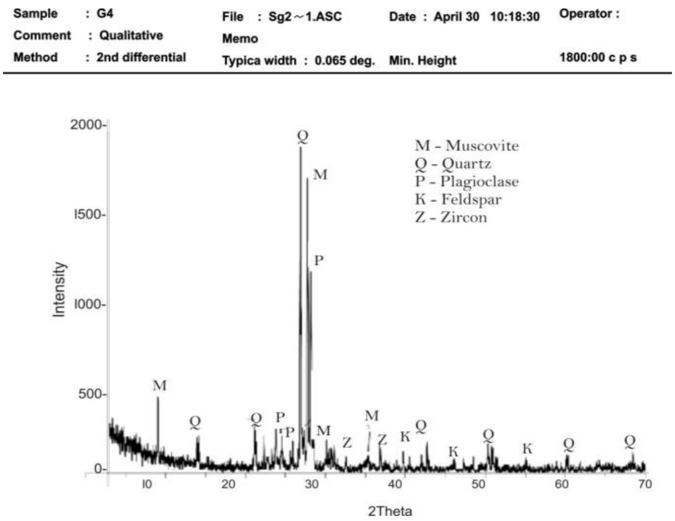


Figure 9: X-Ray Diffractogram analysis of Feldspar sample from Location 6

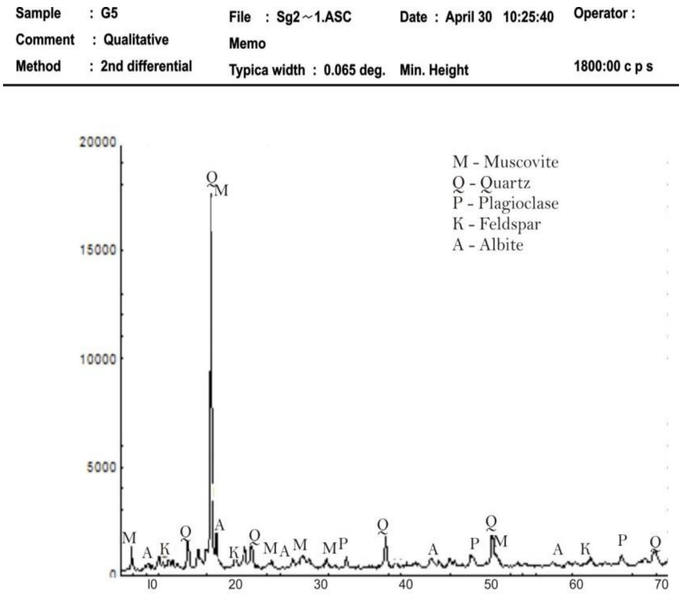


Figure 10: X-Ray Diffractogram of Feldspar from China being used in the Department of Fine and Applied Art, University of Benin, Ekenwan Campus, Benin City.

5. Conclusion and Recommendation

From the generated and analyzed data in the research work, it can be summarized that the major identified phases in the Feldspar samples from the studied areas are Muscovite, Quartz, Plagioclase, Albite, Microcline/Orthoclase, and Zircon. Geochemical analysis revealed that the mean compositions of Feldspar in the studied area were high in Silica (SiO_2) (72.71-74.97%; average: 73.11%) and Alumina (Al_2O_3) (15.05-15.16%; average: 15.12%). Potash (K_2O) content ranged from 3.53% to 8.20% (average: 7.00%), and Soda (Na_2O) content ranged from 3.37% to 5.56% (average: 4.94%), which are major oxides present in Feldspar for ceramic production. A comparison of these major oxides with literature values indicated that the oxides were within the specifications used in ceramic production. When compared with Bureau of Indian Standards specifications, the composition of Feldspar in the studied area did not exceed the maximum limits for ceramic production. Therefore, it can be concluded that Feldspar from the studied area is suitable for ceramic production. Indigenous raw materials for ceramic production are thus appropriate, which could reduce the need for imports and generate additional revenue for capital projects. This could also create direct and indirect employment opportunities for unemployed and employable youth.

References

Ashraf, M., Khan, Z.U., Haq, I.U., Amjad, M. (2007). Chemical and Mineralogical Properties of Feldspar for Industrial Use. International Journal of Applied Ceramic Technology, 4(2), Pp. 89-101.

Ayse, Y., 2010. Mineralogy and Petrology. Springer.

Blatt, H., Tracy, R. J., and Owens, B. E., 1996. Petrology: Igneous, Sedimentary, and Metamorphic (3rd ed.). W.H. Freeman.

Bourne, J. D., 1994. Glassmaking and the Role of Feldspar in the Glass Industry. Journal of Materials Processing Technology.

Cebula, R., Holtz, L., and Smith, J., 1983. Feldspar Classification and Industrial Applications. Journal of Ceramic Science.

Falconer, J. D., 1911) Geology of Nigeria. Geological Survey of Nigeria.

Hanneman, R. E., 2012. Major Classification of Feldspars. Springer Science & Business Media.

Ibisi, R.O., 1992. Ceramic Materials and Their Applications. Bureau of Indian Standards.

Jackson, J. A., and Julia, J. P., 1997. The Relationship Between Pegmatites and Intrusive Igneous Bodies. Cambridge University Press.

Jones, J. B., Willis, H. A., and Brown, C. J., 1964. Pegmatites: Their Formation and Composition. Oxford University Press

Kauffman, E. G., and Van Dyk, D. A., 1994. Industrial Applications of Feldspar in Glass and Ceramics. Materials Research Bulletin.

Kimata, M., Shimura, T., and Osaka, M., 1996. Crystal Structures of Potassium Feldspars and Their Geological Implications. Mineralogical Magazine, 60(2), Pp. 247-255.

Kleeberg, R., Bergmann, S., Bente, K., 2008. Back-loading Preparation Method. In: X-Ray Diffraction Analysis.

Klein, C., Hurlbut, C. S., and Dana, J. D., 1993. Manual of Mineralogy (21st ed.). John Wiley & Sons.

Nesse, W. D., and Williams, K. L., 2000. Introduction to Mineralogy (1st ed.). Oxford University Press.

Njoya, D., Tchamba, C., Mbuh, E., 2010. Comparative Study of Feldspar Properties for Ceramic Applications. Journal of Materials Science and Engineering, 25(4), Pp. 123-136

Odeyemi, I. D., 1981. The Basement Complex of Nigeria. In: Geology of Nigeria. Edited by Kogbe, C. A. Elizabethan Publishing Co.

Philpotts, A. R., and Ague, J. J., 2009. Principles of Igneous and Metamorphic Petrology (2nd ed.). Cambridge University Press.

Potter, M. J., 1996. Feldspar (1). U.S. Geological Survey.

Potter, M. J., 1996. Feldspar. U.S. Geological Survey Bulletin.

Rahaman, M. A., 1976. Review of the Basement Geology of Southwestern Nigeria. In: Geology of Nigeria. Edited by Kogbe, C. A. Elizabethan Publishing Co.

Rahaman, M. A., 1988. Recent Advances in the Geology of the Basement Complex of Nigeria. In: The Basement Complex of Nigeria. Edited by Ocan, A. T. University of Ife Press.

Schwartz, G., 1928. The Formation of Large Crystals in Pegmatites. Geological Society of America Bulletin.

Shanghai, J., 1999. Ceramic Raw Materials and Their Properties. Department of Fine and Applied Art, University of Benin, Ekenwan Campus.

Troll, V. R., 2002. Large-Volume Igneous Formations and Their Petrology. Elsevier Science.

Truswell, J. F., and Cope, B. R., 1963. The Geology of Nigeria's Basement Complex. Geological Survey of Nigeria.

Young, R.A., 1994. Rietveld Method and Relative Phase Quantification. In: Quantitative Phase Analysis.