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Analyzing the chemico-mineralogical composition of the Ilekpí silicate deposit

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ABSTRACT

Deposits of silicate minerals are raw materials essential in industrial uses such as glass manufacturing, ceramics, construction, and refractories. This research investigates the chemical and mineralogical composition of the deposit of Ilekpí silicate, to assess its suitability for industrial and geological characteristics. Representative silicate samples were collected from the deposit location, and evaluated using standard geochemical and mineralogical techniques, including the X-Ray Diffraction (XRD), and X-Ray Fluorescence (XRF). The results showed that the deposit is predominated by silica (SiO₂) with little amounts of aluminium oxides, iron oxides, and other trace elements. The mineralogical analysis revealed quartz as the most dominant mineral phase, having accessories of clay and feldspar minerals. The study indicates that the Ilekpí silicate deposit has immense potential for industrial uses, particularly in the production of glass and materials for construction. This research offers baseline data for resource assessments and sustainable application.

Keywords: Silicate deposit, Quartz, Chemical composition, Mineralogical analysis, XRF, XRD

1. INTRODUCTION

Silicate minerals is predominantly one of the most abundant groups of mineral (Jianget al., 2024) in the earth crust (Ziqiang et al., 2024), and plays an essential role in man processes of the industrial. They are widely applied in the manufacture of ceramics, glass, refractories,

cement, and electronic materials (Prati and Gandolfi, 2015; Rocio et al., 2020). The economic relevance of a silicate deposit relies widely on its mineralogical chemical purity, physical and composition characteristics (Oyedotun, 2018).

Nigeria is blessed with so much deposits of silicate mineral; however, so much remain under-explored and under-utilized. The deposits of Ilekpí silicate pose as one such resource with potential industrial value (Jimoh and Adebayo, 2025). A comprehensive detail of its chemical and mineralogical characteristics is necessary for evaluating its economic suitability and industrial applicability (Cárdenas-Pulido et al., 2023).

This research aims to analyze the chemical and mineralogical composition of the deposit of Ilekpí silicate using X-Ray diffraction and X-Ray fluorescence.

Silicate minerals are the most predominant group of deposits found in the earth crust (Ziqiang et al., 2024) (Subashini et al., 2024). The Ilekpí silicates deposit, located in Lampese, Akoko-Edo, Edo State, is immensely valuable, yet under-exploited mineral resource. Field studies and initial geological surveys indicated that this deposit has a high concentration of silicate minerals (Sharma et al., 2015; Zhang and Zhang, 2019; Holm et al., 2011), which may include kaolinite, feldspar, quartz, and mica, among others (Jiri Pinkas, 2005).

2. LITERATURE REVIEW

Silicate minerals represent the most widely and most immense category of rock-forming minerals (Adeyemi et al., 2021), constituting above 90% of the earth crust (Subashini et al., 2024). They are mainly composed of silicon (Edem et al., 2014) and oxygen, frequently combined with metallic elements such as aluminium, iron, calcium and magnesium.

These minerals form the framework structure (Khan et al., 2020), for most materials of geology, and are arranged according to the classification of silica tetrahedral (Guillaume et al., 2024).

Previous study revealed that the mineralogical constituent of silicate deposits sizeably affects their industrial applications. For instance, deposits rich in quartz are hugely sought for in the production of glass due to their high content of silica and low impurities. Silicate minerals such as quartz and feldspar are essential in the production of glass and ceramics (Zhivulin et al., 2022) because of their durability, high melting points and optical properties (Wang et al., 2018).

In Nigeria, researches have mainly focussed on silicate deposits in states like the Ogun State, Plateau States and Kogi State. Adekoya (2015) opined that several silicate deposits in Nigeria possess high content of silica, even though it varies significantly in impurity levels, hereby impacting their engineering applicability

In spite of these investigations, there has been limited research study on the deposit of Ilekpí silicates.

Thus, comprehensive chemical and mineralogical characterization (Wen et al., 2020); is necessary to fill up this knowledge gap (Salian et al., 2023). Oyedotun (2018) described XRF as a proved technique for establishing major elemental compositions of earth products.

Its merit includes suitability for solid samples (Sharma et al., 2015), relatively rapid analysis and its ability to offer important geochemical results. However, calibration, matrix effects, and sample preparation can affect analytical accuracy.

3. MATERIALS AND METHODOLOGY

3. 1. Geological Location of Ilekpi

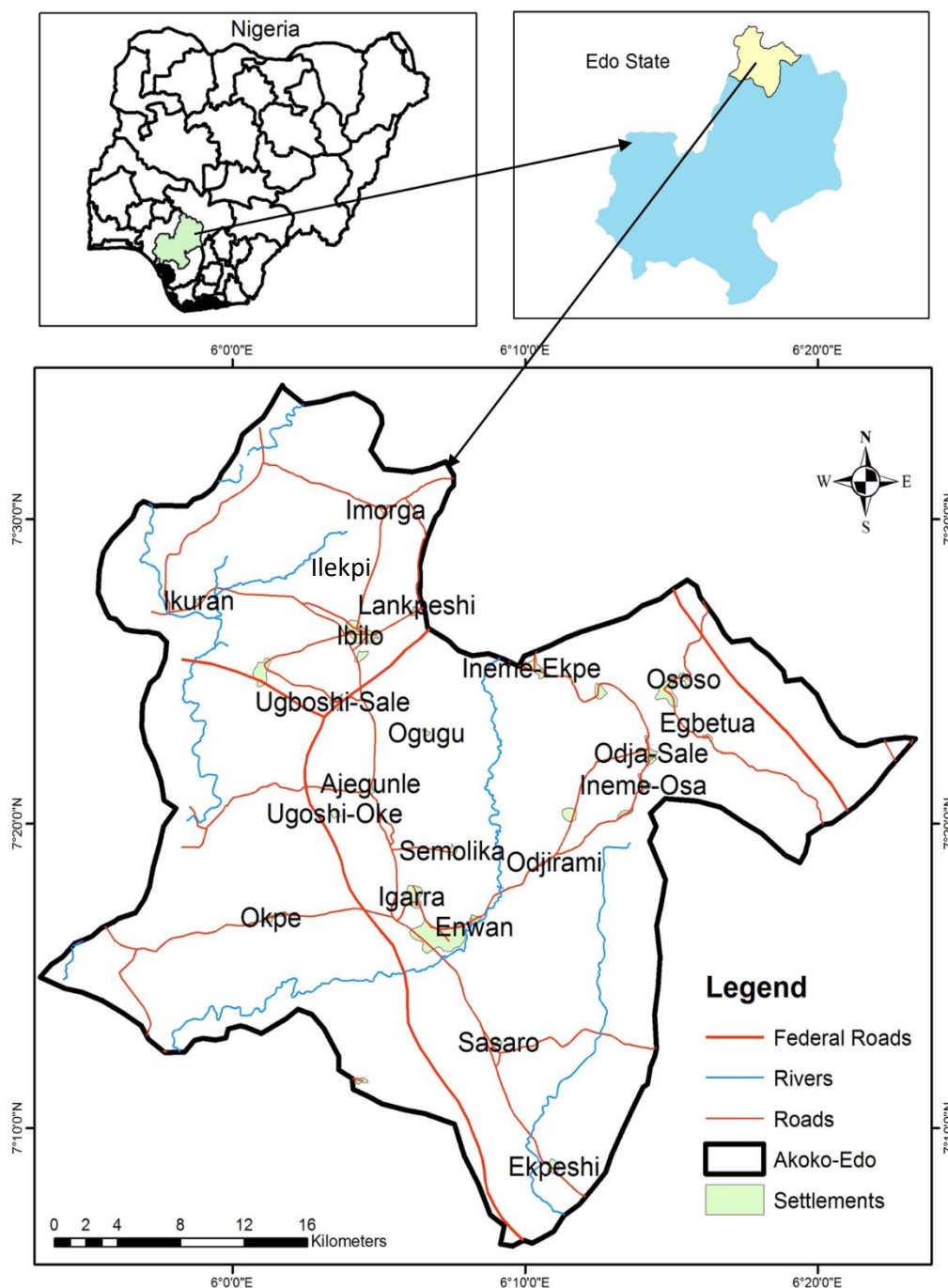


Figure 1. The Map of Edo State (Source: Amosu and Omotehinse, 2023).

The Ilekpi silicate deposit is located in a geological zone having sedimentary formations comprising of crystalline basement rocks typical of silicate mineralization areas. Ilekpi is one

of the nine geo-location quarters in Lampese, a town situated in the Akoko Edo Local Government Area of Edo State, Nigeria. Its estimated coordinates are Longitude 6°5'E and Latitude 7°30'N. Ilekpí is situated near the Kogi border, along the Ibilo-Abuja highways. It lies within the Schist Belt of Igarra, a part of the Nigerian basement complex, mainly embedded by diverse compilation of old precambrian basement complex rocks, including coarse-grained granodiorite, porphyritic biotite granite and amphibolites; high-grade of metamorphic rocks - pegmatic dykes, dolomitic marble, and magmatic gneiss, interspersed with very hard, silica-rich rocks – quartzite; and metamorphic rocks possessing rich platy minerals like the mica schist and the lateritic surface covers.

Minerals such as quartz, orthoclase, plagioclase, biotite, microcline, and hornblende are contained in the rock units, reflecting a complex history of geology shaped by numerous tectonic events, which include the Pan-african orogeny. Structural features such as fractures, joints, dykes and veins, are common, having joint patterns primarily trending south - west. Along with the rugged terrain, these structures are characterized by huge boulders, indicating a dynamic geological evolution of the area (Ugwu et al., 2025).

These formations add to the rugged nature of the landscape, characterized by ridges and rocky hills. This composition of geological aligns with the wider Akoko Edo area, peculiar for its chains of rocky hills and old ridges which stretch along the landscape (Imoukhuede and Egai, 2014).

3. 2. Sample Collection

Samples were collected representative from different points within the deposit to ensure accurate representation and characterization of the mine site. The samples were then cleaned, dried, and pulverized into smooth powder permitted for laboratory analysis.

3. 3. Analytical Techniques

3. 3. 1. X-Ray Diffraction (XRD)

Mineralogical Analysis was carried out with the use of the X-Ray Diffraction (XRD) to assess the phases of minerals present in the deposit, and its petrographic microscopy, i.e. used to evaluate grain size, texture, and distribution of impurity.

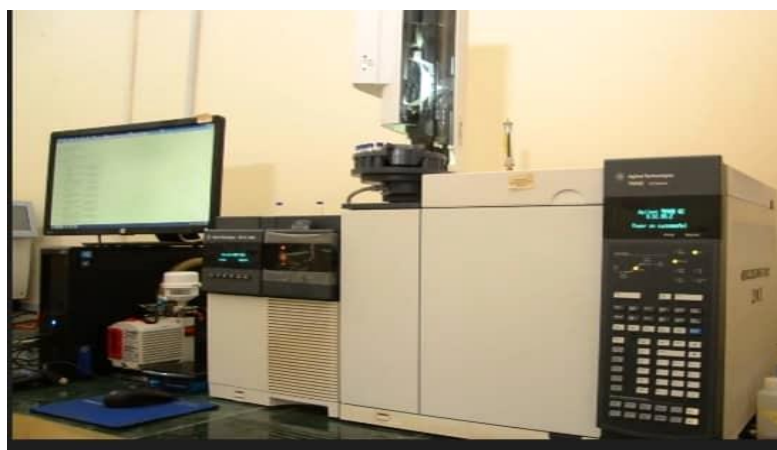


Figure 2. Machines used for XRD.

3. 3. 2. X-Ray Fluorescence (XRF)

Chemical composition analysis was conducted using the X-Ray Fluorescence (XRF) to identify the concentrations of SiO_2 , Fe_2O_3 , Al_2O_3 , K_2O , MgO , PbO , CaO , and so on.

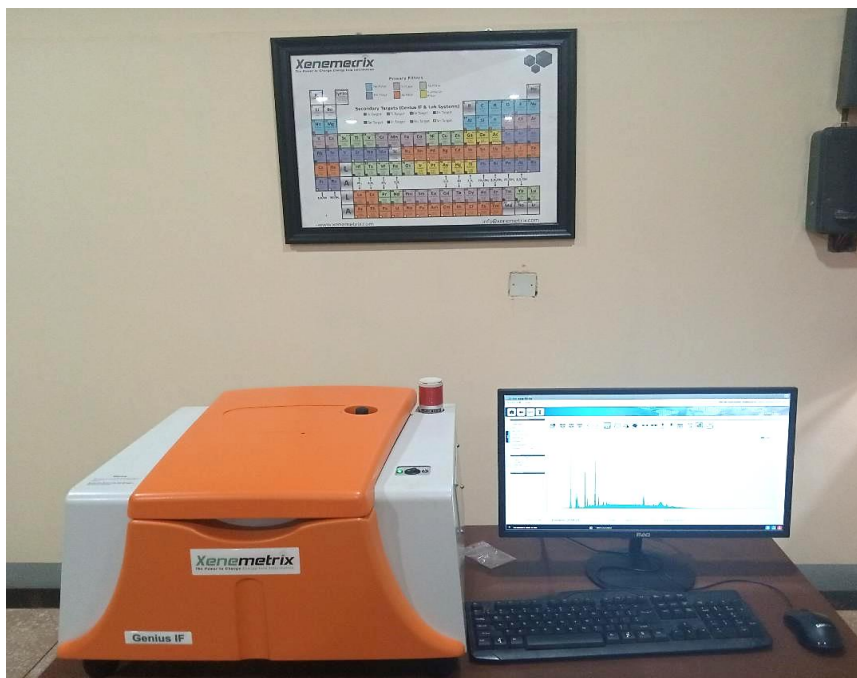


Figure 3. Machines used for XRF testing.

4. RESULTS AND DISCUSSION

4. 1. Results

4. 1. 1. X-Ray Diffraction (XRD) - (ASTM C1365 / E1876)

Table 1. Real and Expected Values Mineral % Content from XRD results.

Component / Location	Quartz (SiO_2) %	Orthoclase (K-feldspar: KAlSi_3O_8) %	Albite (Na-feldspar: $\text{NaAlSi}_3\text{O}_8$) %	Muscovite (Mica: $\text{KAl}_2(\text{AlSiO}_4)_2(\text{OH})_2$ %	Periclase (MgO) %	Goethite $\text{FeO}(\text{OH})$
L_1	43.3	40.3	13.815	2.43	0.79	
L_2	75.9	7.8	10.6	7.5		1.6
L_3	81.4	13	7	8		3.4
L_4	78.6	6.5	2.4	9.6		6.15
L_5	65.5	23.2	10.5	1.016		
Standard expected range % (ASTM, 2019)	50 – 85	< 15	5 – 30	1 – 15	Trace – 3 %	

4. 1. 2. X-Ray Fluorescence (XRF) - (ASTM C114)

Table 2. XRF element against concentration using study location.

Element / Location	Concentration				
	L_1	L_2	L_3	L_4	L_5
O	50.936	50.088	51.879	50.221	51.44
Na	1.898	2.416		1.834	
Mg	0	0	0	0	1.019
Al	0.876	2.186	2.168	2.010	1.997
Si	42.065	40.398	42.597	34.988	41.634
P	0	0	0	0	0.007
S	0.527	0.195	0.569	3.769	0.562
Cl	1.670	1.275	0.75	1.800	0.895
K	0.107	1.685	0.886	1.734	1.127
Ca	1.523	0.476	0.367	1.137	0.367
Ti	0.081	0.099	0.034	0.122	0.044
V	0.001	0.052	0.004	0	0.01
Cr	0.002	0.096	0.063	0.148	0.031
Mn	0.020	0.022	0.011	0.027	0.036
Fe	0.140	0.472	0.302	0.885	0.486
Co	0.008	0.005	0	0.015	0.015
Ni	0	0.038	0.007	0.008	0.003
Cu	0.063	0.051	0.032	0.053	0.053
Zn	0.002	0	11.98	0.037	0
Rb	0	0.003	0.002	0.005	0.004
Sr	0.004	0.003	0.001	0.005	0.002
Zr	0.003	0.001	0.002	0.004	0.001
Nb	0.004	0.009	0.005	0.007	0.005
Ag	0.011	0.020	0.007	0.026	0.016
Sn	0	0	0	0	0
Cs	0.015	0.042	0.032	0.051	0.02
Ba	0	0.218	0.188	0.067	0.105
Ta	0.030	0.107	0.052	0.040	0.079
W	0.007	0.024	0.007	0	0.023
Pb		0.017		0.006	

4. 2. Discussion

Considering the XRD mineral % content, in Table 1, location 3 has the highest amount of quartz, and location 1 has the lowest; location 1 has the highest amount of orthoclase - feldspar, and location 4 has the lowest; Location 1 has the highest amount of albite, and location 4 has the lowest; location 4 has the highest amount of muscovite, and location 5 has the lowest; only 1 location has information for periclase; location 4 has the highest amount of goethite, and location 2 has the lowest, even though information was no available for locations 1 and 5.

The mineral composition confirms quartz - feldspar rich material, similar to high-quality pegmatitic or granitic raw material, making for suitability of construction of infrastructures. It offers good bonding properties and rigidity, which makes it suitable for aggregates and ceramics. So, the XRD results indicate quartz - feldspar dominated composition with minimal mica content, suggesting high mechanical strength, excellent durability, and good thermal stability. The material is therefore suitable for construction applications, ceramic and glass industries, and moderate refractory uses.

Considering the XRF mineral compound concentration, in Table 2, location 3 has the highest amount of SiO_2 , 91.127 mg/cm² and location 4 has the lowest, 74.848 mg/cm²; location 4 has the highest amount of Fe_2O_3 , 1.265 mg/cm² and location 1 has the lowest, 0.200 mg/cm²; location 4 has the highest amount of SO_3 , 9.411 mg/cm² and location 2 has the lowest, 0.487 mg/cm²; location 1 has the highest amount of CaO , 2.131 mg/cm² and location 3 has the lowest, 0.513 mg/cm²; location 4 has the highest amount of K_2O , 2.086 mg/cm² and location 5 has the lowest, 0.117 mg/cm²; location 5 has the highest amount of BaO , 3.774 mg/cm² and location 1 has the lowest, 0.000 mg/cm²; location 4 has the highest amount of Al_2O_3 , 5.688 mg/cm² and location 5 has the lowest, 0.097 mg/cm²; location 4 has the highest amount of Cl , 1.800 mg/cm² and location 5 has the lowest, 0.001 mg/cm²; location 2 has the highest amount of Na_2O , 3.256 mg/cm² and location 1 has the lowest, 0.559 mg/cm²; even though information is no available for locations 4 and 5.

Considering the XRF mineral elemental concentration, in Table 2, location 3 has the highest amount of O , 51.879 and location 2 has the lowest, 50.088; location 3 has the highest amount of Si , 42.597 and location 4 has the lowest, 34.988; location 4 has the highest amount of S , 3.769 and location 2 has the lowest, 0.195; location 4 has the highest amount of Cl , 1.800 and location 3 has the lowest, 0.75; location 4 has the highest amount of K , 1.734 and location 1 has the lowest, 0.107; location 5 has the highest amount of Ca , 1.523 and location 3 and 5 have the lowest, 0.367; location 2 has the highest amount of Na , 2.416 and location 4 has the lowest, 1.834; even though information is no available for locations 3 and 5. The XRF results provides high SiO_2 content; moderate Al_2O_3 content and other oxides having less concentration, i.e. very minimal impurities, making it extremely high in pure silica material which is similar to quartzite, silica sand, or high-grade siliceous rock. This is required in the production of high-grade glass, quality ceramics, and high-strength concrete and manufacturing of refractories; mortar, building stone, road construction, and sand production.

4. 2. 1. Mineralogical Composition

XRD analysis confirmed that quartz is the predominant mineral phase within the deposit. Minor accessory minerals found include feldspar, albite, mica, periclase and goethite. The abundance of quartz established that the deposit is rich in silica and suitable for industrial and engineering applications.

4. 2. 2. Chemical Composition

XRF results showed that silicon dioxide (SiO_2) dominates the greatest percentage of the chemical composition. Other oxides revealed include aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), magnesium oxide (MgO) and calcium oxide (CaO),

The relatively low content of iron is peculiarly advantageous for the production of glass, as excessive iron can negatively affect coloration and transparency.

4. 2. 3. Industrial Implications

Based on the evaluated mineralogical and chemical characteristics, the Ilekpí silicate deposit is suitable for:

- i) Glass production;
- ii) Ceramic manufacturing;
- iii) Refractory use; and
- iv) Construction materials.

5. CONCLUSION

This research analyzed the Ilekpí silicate deposit, revealing its mineralogical and chemical composition. The results established that the deposit is mainly quartz-rich, with less accessory minerals. Chemical analysis indicated content of high silica and minimal levels of impurities, making Ilekpí silicate deposit suitable for different industrial and engineering applications, particularly production of glass and ceramic.

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