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Determination Of The Mineralogical Composition Of Dolomite Deposit Of Ikpeshi, Akoko Edo Lga, Edo State For Industrial Applications

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Abstract
This research project focuses on the thorough investigation of the mineralogical composition of selected dolomite samples from Ikpeshi Edo, State. The aim is to determine the mineralogical composition of dolomite samples for its industrial applications, and its objectives are to determine the relative minerals of dolomite using XRD, and the microstructure using SEM, and identify the level of impurities associated with it. The study employs advanced analytical techniques, including X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM) to characterize and quantify the mineral constituents within the dolomite samples. The research provides valuable insights into the mineralogical features, crystal structures, and elemental compositions of the dolomite from the results. The results show that the sample contains three minerals for sample A which are Dolomite $CaMg(CO_3)_2$ (84.0% by weight), Calcite($CaCO_3$) (8.0% by weight), and Quartz(SiO_2) (8.0% by weight) and for sample B the sample contains three minerals which are dolomite $CaMg(CO_3)_2$ (84.0% by weight), quartz (SiO_2) (7.9% by weight) and muscovite($KAl_2(Si_3Al)O_{10}(OH)_2$) (8.0% by weight). The SEM analysis shows the presence of Silicon, Potassium, Aluminum, Sodium, Iron, Magnesium, Calcium, Phosphorus, Sulphur, Chlorine, and Titanium with calcium being the most dominant element present taking 63.57% by weight, follow by Magnesium 27.90% by weight, Aluminum 2.22% by weight, and Sodium 2.22% by weight and the rest being impurities. Given the findings of this study, it can be concluded that Ikpeshi dolomite deposit is a calcium-dominated deposit that can be used in animal feeds, construction industry for road construction, concrete aggregate, and railroad ballast.

Key Words: *mineralogical, dolomite, mineral, samples, x-ray, chemical and weights*

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I. Introduction

Dolomite ($CaMg(CO_3)_2$) exists widely in sedimentary rocks, in particular as an essential component of dolostones and marlstones. It is also found in some igneous (carbonatites; Jacquemyn *et. al.*, 2015) and metamorphic rocks (Lloyd *et. al.*, 2017). Dolomite in sedimentary rocks is distributed in oceans (Wallace et. al., 2019) and continents (Jiang *et. al.*, 2018), from near surface to deep burial (Petrash *et. al.*, 2017). Dolomite rocks can form important ore deposits and reservoirs hosting oil and gas resources (Warren, 2000; Hou *et. al.*, 2016; Bi *et. al.*, 2018; Du *et. al.*, 2018).

The discovery of dolomite can be dated back more than 200 years. Yet the crystal structure of dolomite, especially under extreme temperature and pressure (e.g. lower mantle), remains highly topical. At high pressure, phase transition also occurs, and the crystal structure of dolomite as high-pressure polymorphs exists (Santillán *et. al.*, 2003; Mao *et. al.*, 2011; Merlini *et. al.*, 2012). Research on high-pressure polymorphs is still in progress. Such dolomite polymorphs are considered as the carbon-carrier mineral phases in the lower mantle (Mao *et. al.*, 2011).

The recent studies into dolomite polymorphs assist with understanding the geological storage of CO_2, and the Earth's carbon cycle (Merlini *et. al.*, 2012; Zucchini *et. al.*, 2017). In addition, the investigation of the stability of dolomite in subduction zones helps with determination of the dolomite decomposition boundary and the graphite/diamond phase boundary. The information of phase transition is also helpful to reveal the corresponding pressure-temperature relationship in subduction zones (Sato and Katsura, 2001; Antao *et. al.*, 2004; Morlidge *et. al.*, 2006).

The genesis of dolomite, par particularly at low temperature, remain contentious. Various models for the geological processes and the environments of dolomite crystallization have been previously proposed. However, the formation of dolomite still appears complicated as it is influenced by fluid chemistry, thermodynamics, kinetics, and time, which affect the nucleation and crystallization to form dolomite or the replacement of pre-existing carbonate (Peng *et. al.*, 2018). Dolomite still cannot be well synthesized at temperatures <50 °C in the laboratory (Rodriguez-Blanco *et. al.*, 2015). Some recent studies have suggested that microbes play certain roles in catalyzing dolomite formation at low temperatures, and the views have been tested in experiments (Vasconcelos and McKenzie, 1997; Warthmann *et. al.*, 2000; Bontognali *et. al.*, 2012; Petrash *et. al.*, 2017).

However, the growing scientific knowledge is expected to contribute to better utilizing dolomite with improved resources efficiency and sustainability.

Aim of this project work

The aim of this research is to determine mineralogical composition of dolomite samples for its industrial applications.

Objectives of this research

The objectives of this research are to:

(i). Determine the relative mineral of dolomite using XRD
(ii). Determine the morphology and microstructure of dolomite using SEM
(iii). Identify the level of impurities associated with dolomite.
(iv). Provide industrial applications of dolomite samples based on (i), (ii), and (iii) above.

II. Scope And Method

The scope of the research encompasses detailed mineralogical analyses, using X-ray diffraction (XRD) and scanning electron microscopy (SEM), to identify and quantify the mineral constituents within dolomite. Additionally, the investigation will extend to the assessment of dolomite's suitability and performance in various industrial processes, such as agriculture, construction materials, and manufacturing.

III. Brief Description Of The Study Location

Ikpeshi in Edo State lies within latitudes 7°06′00″N to 7°20′00″N and longitudes 6°08′30″E to 6°20′64″E southern Nigeria. Ikpeshi area lies within the Precambrian Basement Complex of Southwest, Nigeria. The Basement rocks are not ably the migmatite gneiss complex, schist (metasediment), older granite and late intrusive (Rahaman *et al*.., 1976, McCurry, 1976) Fig.1 shows the location and geology of the study area. The metasedimentary rocks at Ikpeshi areas comprise mainly quartz-biotite schist, calc silicate and marble, mica schist and granulies.

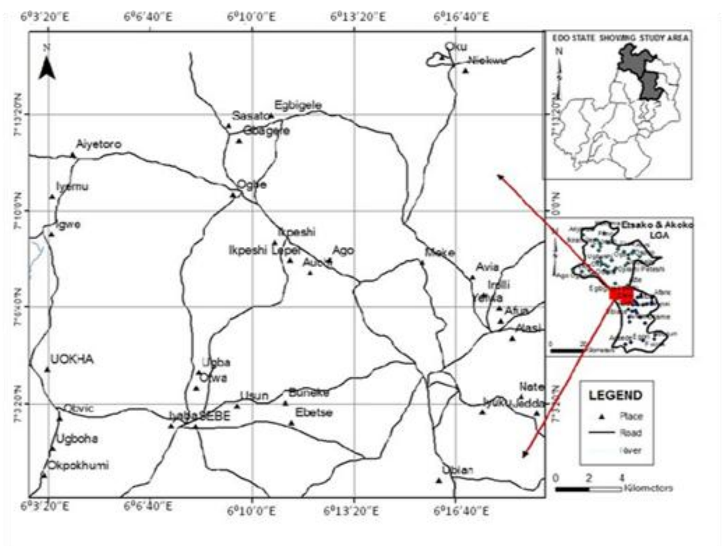


Figure 1: Location map showing the study area. (source from petrology and structural geology of Ikpeshi and it's environ of Igarra schist belt southwestern Nigeria**.** Agomuo M.S and Egesi N)

Dolomite occurs widely as the major constituent of dolostones and dolomite marbles (Klein *et. al., 2008*). Dolomite actually protodolomite is known to have formed fairly recently in restricted environments such as on supratidal flats that occur in The Bahamas and Florida Keys. Also, no dolomite has been synthesized in an environment comparable to natural conditions. Thus, the explanation for the formation of dolomite in these marine units remains in question. It is now thought that dolostones may be of various origins. Indeed, several different models have been suggested for dolomite formation, each based on diverse considerations, combined with empirical and / or experimental data (Dietrich *et. al.,* 2016)

Except for models invoking formation of dolomite by direct precipitation, a process thought by most geologists to apply to only a small percentage of all dolostones, each model is based on the assumption that the dolomite of dolostones has been formed by conversion of $CaCO_3$ sediment or sedimentary rocks to dolostone. Thus, the models have been formulated to account for this conversion, which is known as dolomitization. The most widely discussed models for dolomitization, either partial or complete, involve four chief variables: time, location with respect to the sediment-seawater interface, composition and derivation of the solutions involved, and fluxing mechanisms (Dietrich *et. al.,* 2016).

Crystal Structure of Dolomite

The investigation of the crystal structure of dolomite helps to understand the form of carbon reservoirs in the mantle, and the Earth's carbon cycle. The structure of dolomite can be categorized into ordered dolomite, and disordered dolomite. At pressures below 26 GPa, disordered dolomite cannot adapt to the increase in pressure through structural rearrangement and undergoes crystal phase transitions. This is possibly because in the disordered dolomite, Mg^{2+} and Ca^{2+} cations are randomly distributed between sites A and sites B. At pressures below 14 GPa, MgO_6 Octahedra are not easily regularized with increasing pressure (Zucchini *et. al.,* 2014).

A recent report by Stekiel *et. al*., (2019) calculated that the structure of disordered dolomite did not transition to dolomite- II until at least 58 GPa.

However, phase transition of disordered dolomite needs to be confirmed by further experimental studies. Therefore, the research on the structure and compressibility of dolomite in this section is based on ordered dolomite. At present, there is still no review report on the phase transition and crystal structure of dolomite, but a critical discussion on the phase transition and crystal structure is necessary to further understand the microstructure of dolomite.

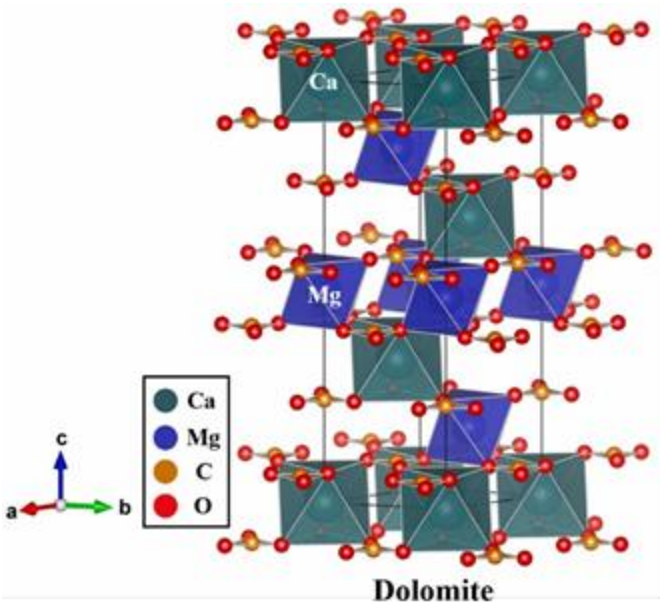


Fig 2.0 Dolomite crystal structure. Crystal structure data of dolomite from the American Mineralogist Crystal Structure Database (Crystal structure diagram generation from software VESTA). Green, blue, orange and red balls represent Ca, Mg, C and O atoms, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

IV. Methodology

Five crude dolomite samples were collected from Freedom Quarry in Ikpeshi, Akoko Edo LGA, upon close examination at the mining laboratory,. Two (2) samples were selected for XRD and SEM Analysis.

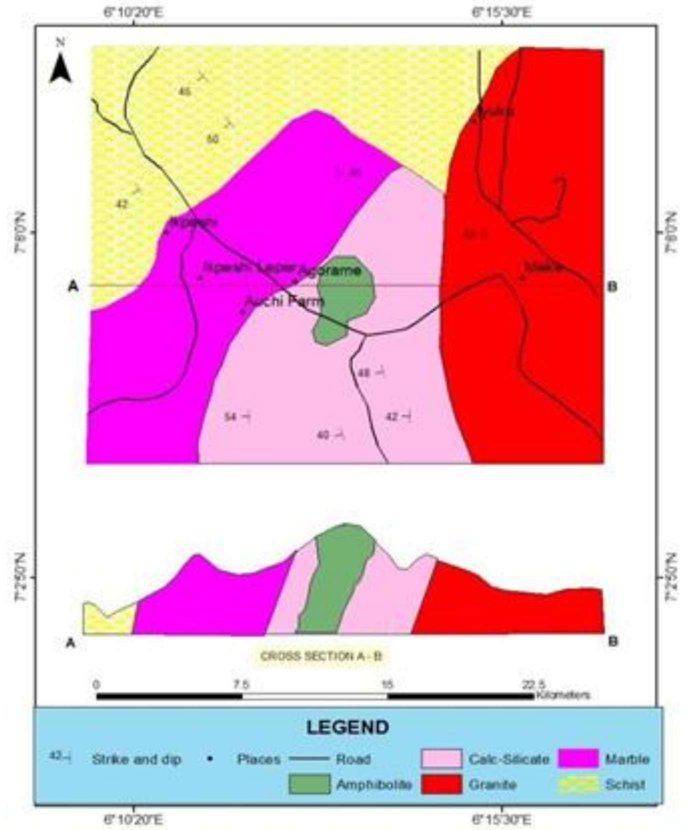


Figure 3.0 Shows the geological map of Ikpeshi and its environs. (source: Petrology and structural geology of Ikpeshi and its environ of Igarra schist belt southwestern Nigeria**.** Agomuo M.S and Egesi N)

The two samples were grounded and sieved (Pulverized) into particle size between 150 microns and 250 microns before XRD and SEM analysis. The following steps were taken in preparing (Pulverized) the samples for XRD and SEM analysis.

Samples Preparations:
These include the following procedures and processes, namely;
a. Size Reduction: Dolomite is generally received in large chunks from the quarries. It needs to be reduced to a fine powder before it can be used in various applications. This is done through braking with the use of Sledgehammer.
b. **Crushing:** Dolomite samples are crushed to below 8 mm size using a Fritsch laboratory crusher. This facilitates grinding in the next step.
c. **Grinding:** The crushed dolomite is then pulverized in a ball mill equipped with steel balls as grinding media. This process grinds the material into a fine powder usually below 250 microns in size. The ball milling machine was cleaned before pulverizing to ensure a pure sample.
d. **Screening:** The fine dolomite powder is separated from coarser particles through sieving or air classification. This ensures uniform particle size distribution as required by different end-use industries.
e. **Drying:** The pulverized dolomite was dried to remove excess moisture using rotary dryers. This is important to avoid lump formation during storage and transportation.
f. **Storage:** The dried and pulverized dolomite powder is stored in silos before transporting for XRD and SEM analyses to be carried out.

So in summary, dolomite is crushed, ground, separated, dried, and stored following standard mineral processing techniques before XRD and SEM text is carried out. The specific equipment and conditions may vary based on the end-user requirements.

V. Results And Discussion

a. Result of X-Ray Diffraction (XRD) Analysis For Sample A

The result below (Fig 4) and (Fig 5) show the qualitative and quantitative XRD analysis of Ikpeshi dolomite. It has been shown that the sample contain three minerals which are dolomite $CaMg(CO_3)_2$, calcite ($CaCO_3$) and quartz(SiO_2). The qualitative analysis (Fig 4.0) present results of the Bragg's angle in degree against the intensity in count of the various mineral present in the sample it also shows the diffraction patterns of dolomite(blue), calcite(brown) and quartz(green). The diffraction pattern of each material shows the dominance of dolomite, calcite and quartz with dolomite being the most dominant material in the sample. Analysis of the quantitative XRD revealed that dolomite phase was identified at Bragg's angle values approximately 31.5, 42.0, and 51.0 for dolomite, 30.0, 40.0, and 49.0 for calcite and 27.0, 60.0, and 68.0 for quartz. The quantitative XRD analysis shown as the pie chart in (Fig 5) revealed quantities of the various minerals present in the sample. It could be observed that the percentage weight of these minerals are 84.0wt%, 8.0wt%, and 8.0wt% for dolomite, calcite, and quartz respectively.

Various factors are likely to shift the 2-theta peak positions from one sample to another (Cook *et. al*., 1975). Some of these factors include slight differences in automatic goniometer alignment, occasional alterations of the sample and inaccurately positioning the sample in the sample (Cook *et. al*., 1975). However, these factors do not affect the manual interpretation of the plots, but they complicate computerized mineral identification. According to (Downs *et. al*., 1993) it is possible to determine the type of mineral in a soil that contains a mixture of minerals using just two peaks (Dutrow 1997).

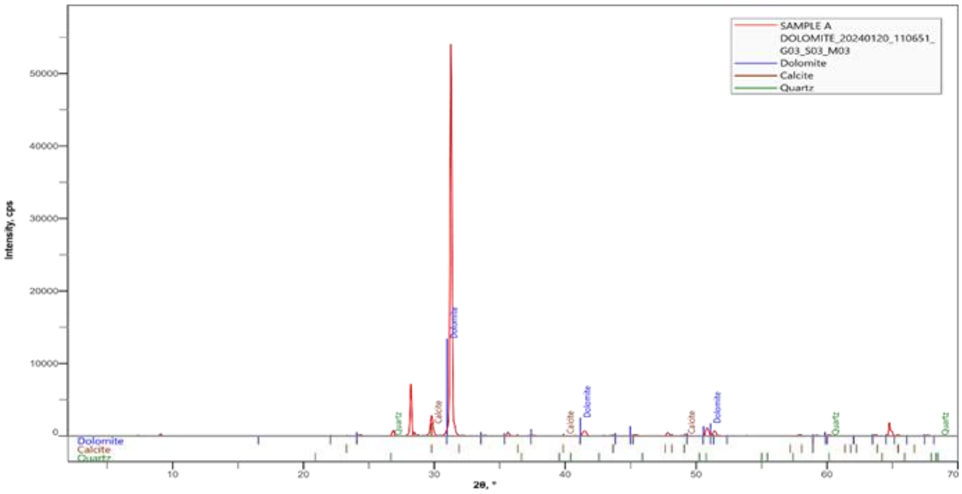


Figure 4: showing the qualitative XRD analysis of Ikpeshi dolomite Sample A

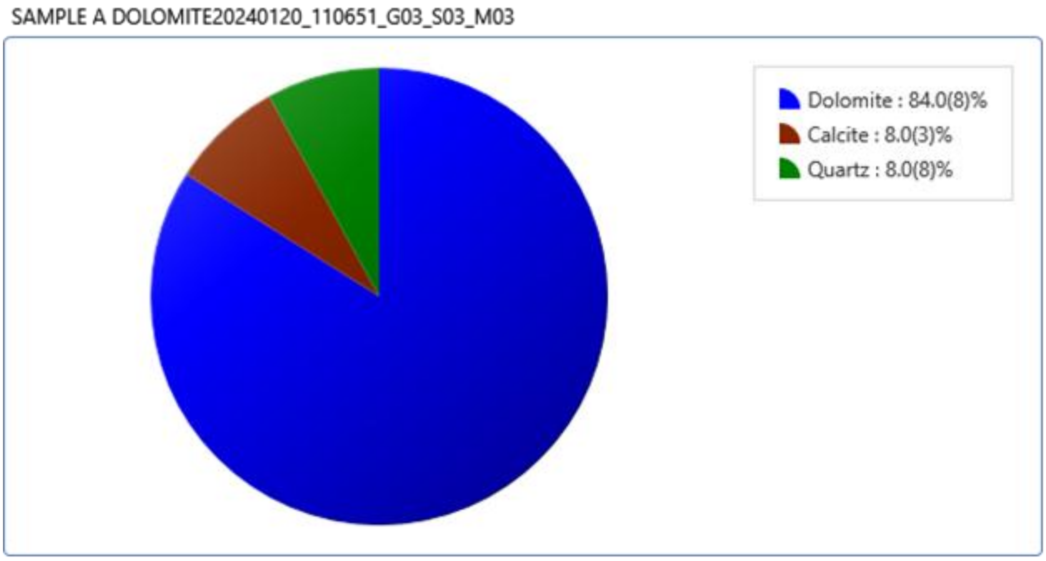
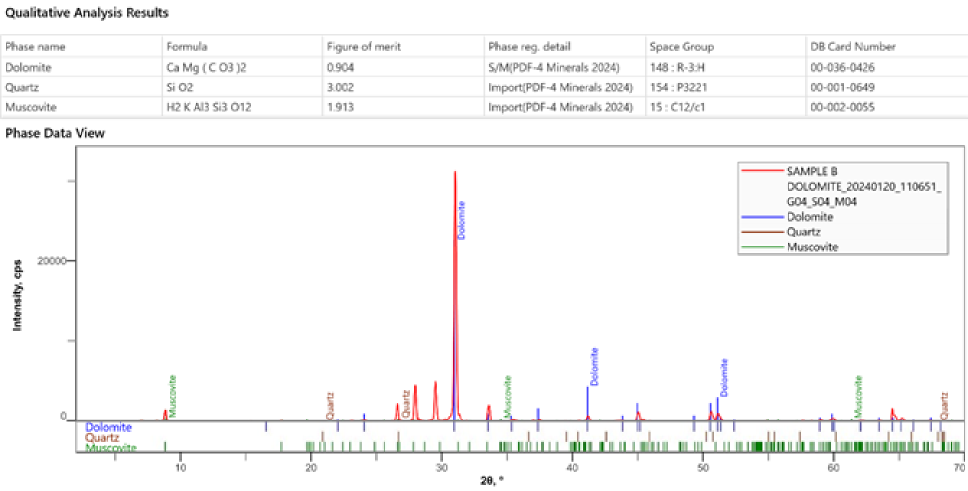


Fig 5: Showing the quatitative XRD analysis of Ikpeshi dolomite Sample A

b. Result of X-Ray Diffraction Analysis On Sample B

From the result below (Fig 6) and (Fig 7) shows the qualitative and quantitative XRD analysis of Ikpeshi dolomite. It has been shown that the sample contain three minerals which are dolomite $CaMg(CO_3)_2$, quartz (SiO_2) and muscovite($KAl_2(Si_3Al)O_{10}(OH)_2$). The qualitative analysis (Fig 6) present results of the Bragg's angle in degree against the intensity in count of the various mineral present in the sample it also shows the diffraction patterns of dolomite(blue), quartz(brown) and muscovite(green). The diffraction pattern of each material shows the dominance of dolomite, quartz, and muscovite with dolomite being the most dominant material in the sample. Analysis of the quantitative XRD revealed that Dolomite phase was identified at Bragg's angle values approximately 32.0, 42.0, and 52.0 for dolomite, 22.0, 27.0, and 69.0 for quartz and 09.0, 21.5, and 63.0 for muscovite.

The quantitative XRD analysis shown as the pie chart in (Fig 7) revealed quantities of the various minerals present in the clay. It could be observed that the percentage weight of the minerals are 84.0wt%, 7.9wt%, and 8.0wt% for dolomite, quartz, and muscovite respectively.


Qualitative Analysis Results

Phase name	Formula	Figure of merit	Phase reg. detail	Space Group	DB Card Number
Dolomite	Ca Mg (C O3)2	0.904	S/M(PDF-4 Minerals 2024)	148 : R-3:H	00-036-0426
Quartz	Si O2	3.002	Import(PDF-4 Minerals 2024)	154 : P3221	00-001-0649
Muscovite	H2 K Al3 Si3 O12	1.913	Import(PDF-4 Minerals 2024)	15 : C12/c1	00-002-0055

Fig 6 Showing the qualitative XRD analysis of Ikpeshi dolomite Sample B

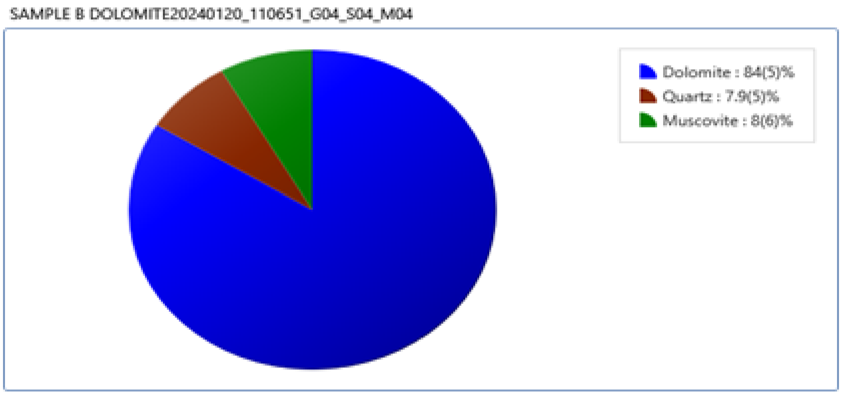


Fig 7: Showing the quantitative XRD analysis of Ikpeshi dolomite Sample B

c. Result of Scanning Electron Microscopy (Sem) of Sample A

Fig 8 Shows the SEM micrographs of Ikpeshi dolomite at 500x, 1000x, 2000x magnifications. Analysis of the micrograph shows that the dolomite possessed dispersed morphology having trigonal-rhombohedral shape with some level of crystal defects. The average particle size was estimated to be 313 μm. The elemental chemical characterization by scanning electron microscopy (SEM) in (Table 1) shows the presence of Silicon, Potassium, Aluminum, Sodium, Iron, Magnesium, Calcium, Phosphorus, Sulphur, Chlorine, and Titanium with calcium being the most predominant element present taking 63.57 wt%, follow by Magnesium 27.90 wt%, Aluminum 2.22 wt% and Sodium 2.22 wt%.

Table 1: Showing the elements data from scanning electron miscroscope (SEM) analysis of Ikpeshi dolomite Sample A

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
20	Ca	Calcium	52.08	63.57
12	Mg	Magnesium	37.69	27.90
13	Al	Aluminium	2.71	2.22
11	Na	Sodium	3.18	2.22
14	Si	Silicon	1.64	1.40
15	P	Phosphorus	1.43	1.34
16	S	Sulfur	0.73	0.72
17	Cl	Chlorine	0.31	0.33
19	K	Potassium	0.24	0.29
22	Ti	Titanium	0.00	0.00
26	Fe	Iron	0.00	0.00

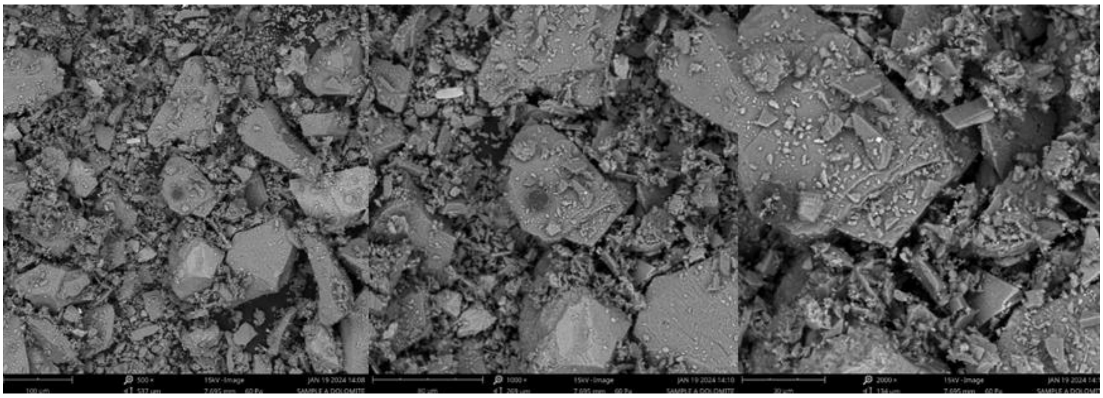


Fig 8: Showing the scanning electron miscroscope (SEM) analysis of Ikpeshi dolomite Sample A. Mag 500x, 1000x and 2000x.

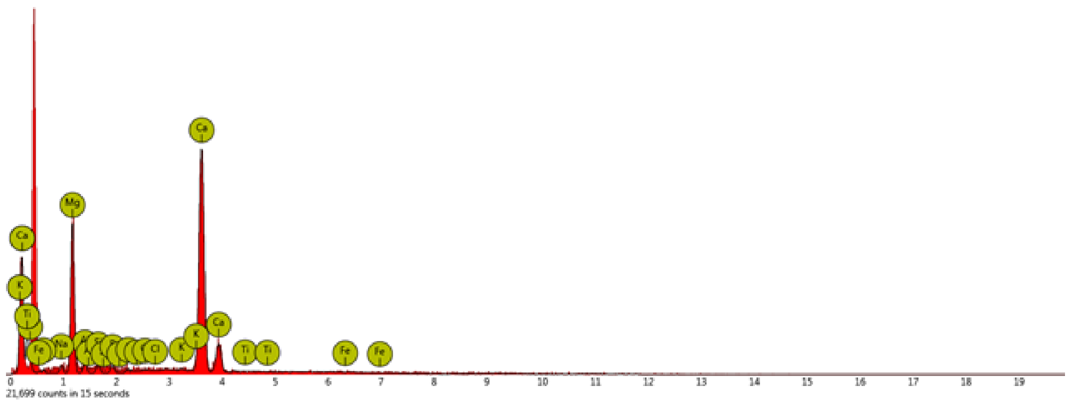


Fig 9: Showing the elements data from scanning electron miscroscope (SEM) analysis of Ikpeshi dolomite Sample A

d. Result of Scanning Electron Microscopy (Sem) On Sample B

(Fig 9) Shows the SEM micrographs of Ikpeshi dolomite at 500x, 1000x, 2000x magnifications. Analysis of the micrograph shows that the dolomite possessed dispersed morphology having trigonal-rhombohedral shape with some level of crystal defects. The average particle size was estimated to be 313 μm.

The elemental chemical characterization by scanning electron microscopy (SEM) in (Table 2) shows the presence of Silicon, Potassium, Aluminum, Sodium, Iron, Magnesium, Calcium, Phosphorus, Sulphur, Chlorine, and Titanium with calcium being the most dominant element present taking 56.56 wt%, follow by Magnesium 23.74 wt%, Aluminum 7.55 wt% and Sodium 6.18 wt%.

Table 2: Showing the elements data from scanning electron miscroscope (SEM) analysis of Ikpeshi dolomite Sample B

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
20	Ca	Calcium	45.93	56.58
12	Mg	Magnesium	31.78	23.74
14	Si	Silicon	8.75	7.55
13	Al	Aluminium	7.46	6.18
19	K	Potassium	1.34	1.61
11	Na	Sodium	2.22	1.57
15	P	Phosphorus	1.01	0.96
17	Cl	Chlorine	0.61	0.67
26	Fe	Iron	0.34	0.58
16	S	Sulfur	0.57	0.56
22	Ti	Titanium	0.00	0.00

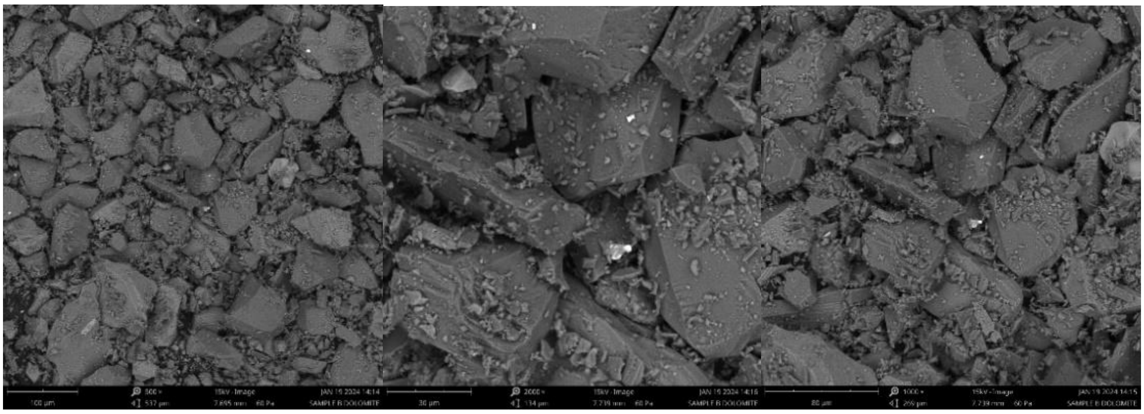


Fig 10: Showing the scanning electron miscroscope (SEM) analysis of Ikpeshi dolomite Sample B. Mag 500x, 1000x and 2000x.

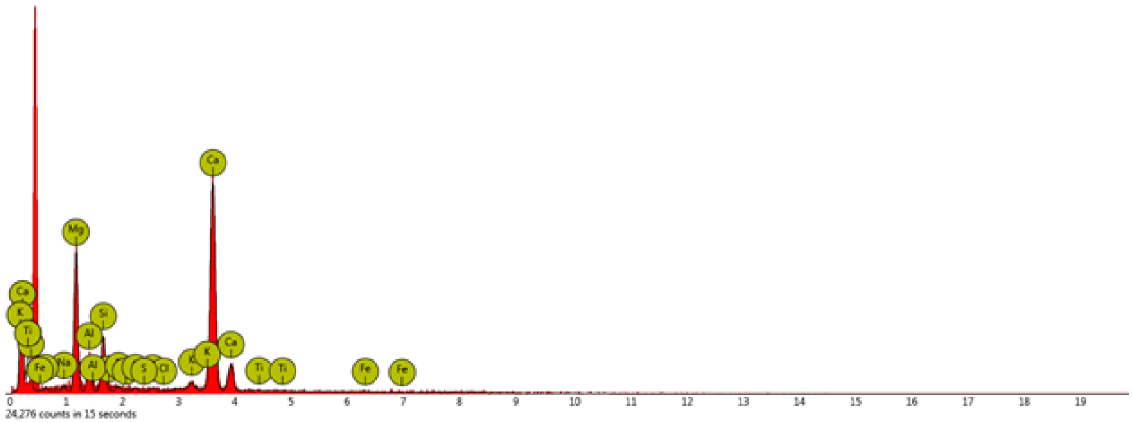


Fig 11: Showing the elements data from scanning electron miscroscope (SEM) analysis of Ikpeshi dolomite Sample B

VI. Conclusion

Mineralogical characterization of Ikpeshi deposit showed that it is a dolomite mineral consisting of 84% dolomite. Other impurity phases present in the ore were calcite, quartz, and muscovite they were present at 8%, 7.9%, and 8%, respectively. Chemical characterization of the ore further confirmed the presence of dolomite as indicated by substantial content of Calcium and Magnesium at 63.57 wt%, and 27.90 wt%, respectively. SEM Analysis of Ikpeshi ore has shown that the ore possessed dispersed morphology having a trigonal-rhombohedral crystal shape. Although, Ikpeshi ore was majorly a dolomite mineral it also contained some impurity minerals which were responsible for its higher $CaMg(CO_3)_2$ and SiO2 content compared to reported values (Pradeep *et. al.*, 2020) for pure dolomite.

Given the findings of this study, it can be deduced that Ikpeshi ore is calcium-dominated dolomite, also known as calcian dolomite, a type of dolomite rock that contains a higher percentage of calcium than any magnesium which has a wide variety of uses in different industries.

In the construction industry, Calcium-dominated dolomite is a popular material for crushed stone, which is used in road construction, concrete aggregate, and railroad ballast. It can also be used as a dimension stone for building facades and other architectural applications. However, in Agriculture, Ikpeshi dolomite will be suitable for the improvement of soil fertility and drainage. It can also be used to raise the pH of acidic soils.

In addition to these uses, calcium-dominated dolomite can also be used in a variety of other applications, such as Pharmaceuticals as an antacid and as a source of calcium and magnesium for the production of drugs. The dolomite content can even be improved if beneficiation of the ore is carried out.

VII. Recommendations

Dolomite is a widely used industrial mineral with diverse applications in construction, agriculture, metal production, glass production, and environmental remediation. Investigating the mineralogical composition of specific dolomite samples can provide valuable insights into their suitability for different industrial uses. I hereby recommend that Researchers:

I. Clearly define the origin, geological context, and any available information about the selected dolomite samples. Consider including samples from different geographic locations or geological formations to compare their mineralogical variations.
II. Instead of a broad investigation, focus on specific industrial applications you're particularly interested in. This will allow for a more targeted analysis and interpretation of the mineralogical data in the context of those applications.

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