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Geology and Petrography of Kanawa Member of Pindiga Formation Exposed at Ashaka Cement Quarry of the Upper Benue Trough, Northeasten Nigeria

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Abstract: The limestone facies of the Pindiga Formation in the Gongola Sub-basin represents a key sedimentary unit, extensively exposed at the Ashaka Cement Quarry. Limestone samples were collected and subjected to petrographic analysis. The thin sections were examined under plane and cross-polarized lights. Ten representative samples were analyzed to determine their mineral composition and optical properties. The results indicate that the limestone is dominated by calcite, dolomite, and iron oxide, with quartz and orthoclase as accessory minerals. Clay minerals, which constitute approximately 95% of the limestone, are not observable under a polarizing microscope. The presence of calcite and dolomite suggests potential for calcitization and dolomitization under favorable geochemical conditions. These findings highlight the industrial potential of the limestone for applications such as cement, fertilizer and glass production.

Keywords: Limestone, Pindiga Formation, Ashaka Quarry, Calcitization and Dolomitization

I. INTRODUCTION

The Upper Benue Trough, located in the Northeastern Nigeria, is a Y-shaped geological structure comprising three arms: the E-W trending Yola Arm, the N180ºE Gongola Arm (Gongola Basin), and the NE-SW trending main Arm (Muri-Lau Basin). The Bima Sandstone (Upper Aptian to Lower Albian) unconformably overlies the Basement Complex (Allix et al., 1981). Overlying formations include the Yolde Formation, followed by the Pindiga and Gongila Formations, with the Fika Shale as the youngest unit (Popoff et al., 1986). The Pindiga Formation consists of dark carbonaceous shales and limestone intercalated with lighter-colored limestone, shales and minor sandstone (Obaje et al., 1999). It is subdivided into five members: Kanawa, Gulani, Deba-Fulani, Dumbulwa, and Fika members (Zaborski et al., 1997), with thickness ranging from 200 m at Pindiga to 784 m at Dukku (Benkhelil, 1989). Depositional environments were predominantly marine with brackish marsh conditions in the upper sections (Petters, 1978). Ammonite assemblages indicate an Upper Cenomanian to Turonian age (Popoff et al., 1986), while palynology suggests Late Albian to Late Cenomanian deposition in Barrier Island, lagoon, and deltaic settings (Lawal and Moullade, 1986; Shettima et. al., 2007). At the Ashaka Cement Quarry, the Kanawa Member represents a Type I sequence, bounded below by a ferruginous crust atop the Upper Bima Sandstone and above by a correlative conformity within the Deba-Fulani Member (Zaborski et. al., 2015).

II. STUDY AREA

The Ashaka Cement Quarry is located at 10°55′00″N and 11°27′00″E within the N-S trending Gongola Basin of the Upper Benue Trough, Gombe State. It is bounded to the south by the Wuyo-Kaltungo High, a median zone separating the Gongola Basin from the Yola Arm. The Wuyo-Kaltungo High is characterized by NE-SW and N-S trending reactivated basement faults, which influenced Early Cretaceous sub-basin development (Guiraud, 1990). Streams in the Study Area are predominantly rainfall-fed, exhibiting seasonal variability. Drainage is dendritic, with the Gongola River serving as the main tributary to the Benue River, flowing east to west through Nafada before curving southward toward Dadin Kowa. The area is highly accessible via roads connecting Bajoga and Nafada, facilitating fieldwork and sample transport.

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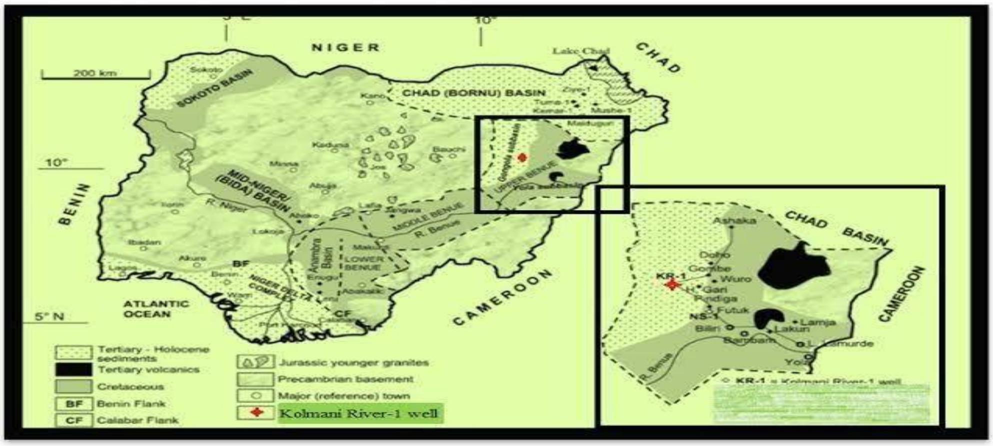

Fig.1: Map of Nigeria showing the Study Area (After Obaje, et al., 2000)

III. MATERIALS AND METHODS

A. Materials

Equipments used include a field notebook, base map, hammer, compass clinometer, hand lens, masking tape, measuring tape, GPS, sample bags, and dilute hydrochloric acid (HCl).

B. Methods

The compass traversing mapping method was employed, with offsets measured at right angles to points of interest. Traverse lines were pre-designed on a base map to account for relief, vegetation, and infrastructure, facilitating efficient field movement. Lithologic variations, rock fragments, vegetation changes, and topography were observed. Structural measurements, including dip and strike, and bed thickness were recorded. Representative rock samples were systematically collected, documented in the field notebook, numbered, and marked on the base map to ensure uniform coverage of the Study Area. Exposed rock sections (outcrops) were studied to identify lithology and sedimentary structures. Structural orientations were determined using dip and strike measurements, and representative rock samples were collected for laboratory analysis. Ten (10) representative samples were collected and labeled A – J. All the samples are light brown to creamy in colour, consolidated and fine-textured, with some showing minor whitish granular particles suspected as sand. Each sample reacted vigorously with dilute HCl, indicating carbonate content. Based on these observations, all samples were identified as limestone, with some suspected calcareous limestone. The samples were taken to the petrographic laboratory of the Department of Geology, University of Maiduguri, for petrographic analysis. Thin sections (~0.03 mm) were prepared by chipping and polishing rock samples with 120- and 800-grade abrasive powders, mounting them on glass slides using Araldite, and trimming to the required thickness. Slides were coated with Canada balsam, covered with a cover slip, dried, cleaned with organic solvents and detergent, and examined under a microscope to determine mineral composition and petrographic characteristics.

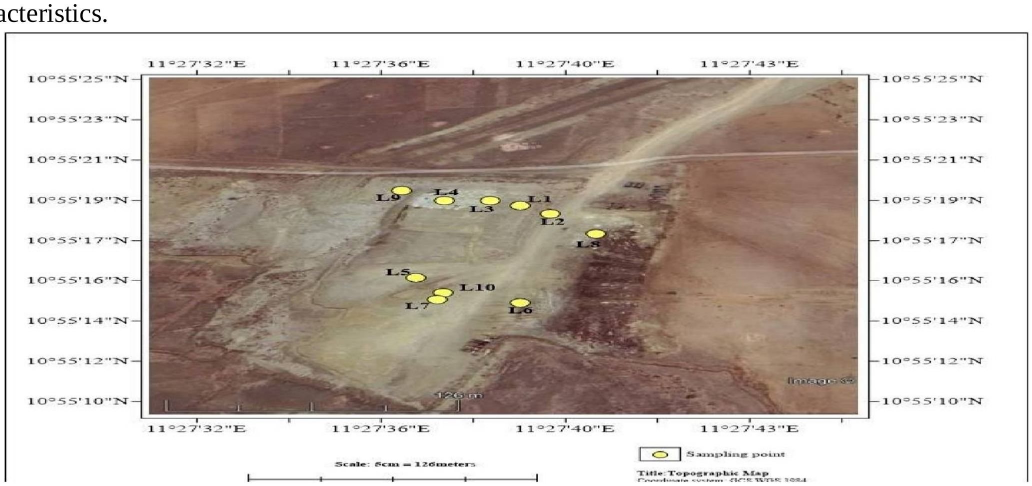

Fig. 2: Map of the Study Area showing sample locations

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IV. RESULTS AND DISCUSSION

A. Petrographic Analysis

Ten (10) representative limestone samples from the Pindiga Formation were prepared as thin sections and examined under a polarizing microscope. Mineral compositions were identified under both planepolarized light (PPL) and cross-polarized light (XPL). The mineral assemblages and optical properties of each slide are diagrammatically represented in Plates 1a to 10b.

1) Slide A

The thin section of Slide A contains calcite, dolomite, quartz, iron oxide, and altered feldspar (orthoclase). Calcite is colourless in plane-polarized light (PPL) but stains reddish-purple, occurring anhedrally with low relief, weak birefringence, symmetrical extinction, albite-like twinning, and pearl-grey interference colours under cross-polarized light (XPL). Dolomite is colourless, subhedral, shows two-directional cleavage, weak birefringence, polysynthetic twinning, and symmetrical extinction. Iron oxide is opaque black with high relief and no pleochroism, cleavage, birefringence, or extinction. Quartz is colourless, anhedral, with very low relief, weak birefringence (grey-white interference colours), parallel extinction, and no twinning. Altered feldspar appears reddish-brown, anhedral, with moderate relief, perfect cleavage in two directions, reddish interference colours, and lacks pleochroism, extinction, birefringence, or twinning.

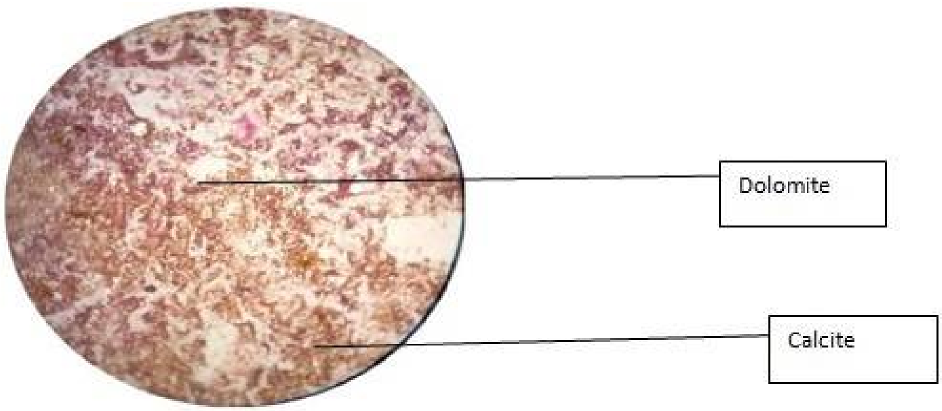

Plate 1a: Microphotograph of limestone (Slide A) under PPL (magnification x100)

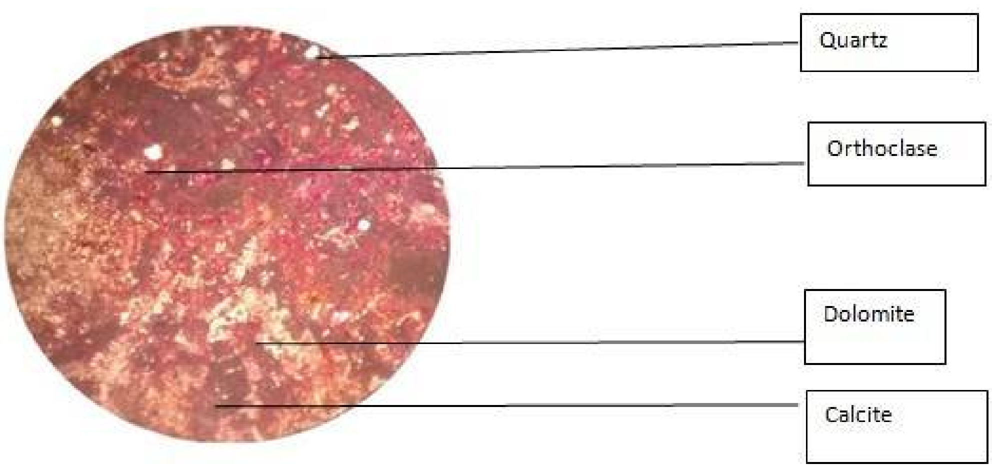

Plate 1b: Microphotograph of limestone (Slide A) under XPL (magnification x100)

2) Slide B

The slide is composed of calcite, dolomite, quartz, and iron oxide. Calcite appears colourless under PPL but turns reddish-purple when stained; it is anhedral with low relief, weak birefringence, pearl-grey interference colours, symmetrical extinction, and albite-like twinning. Dolomite is colourless and subhedral, showing inclined two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Quartz is colourless and anhedral, lacking pleochroism and cleavage, with very low relief, weak birefringence, grey to white interference colours, parallel extinction, and no twinning. Iron oxide is opaque black under both PPL and XPL, with high relief and no pleochroism, cleavage, birefringence, extinction, or twinning.

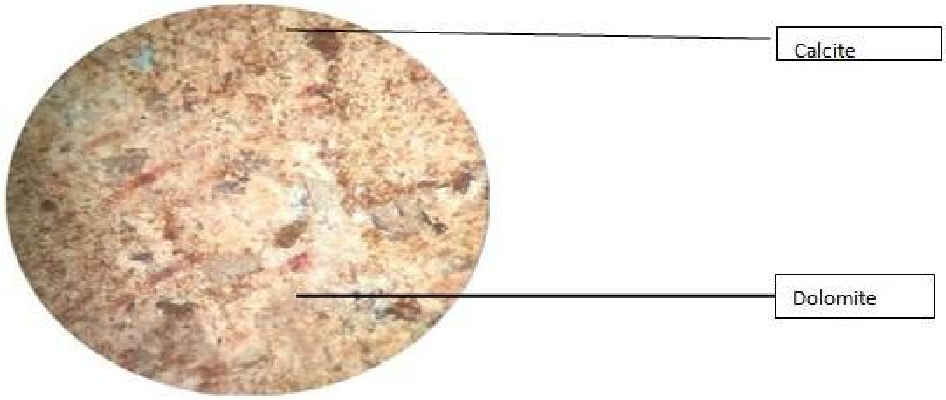

Plate 2 a: Microphotograph of limestone (Slide B) under PPL (magnification x100)

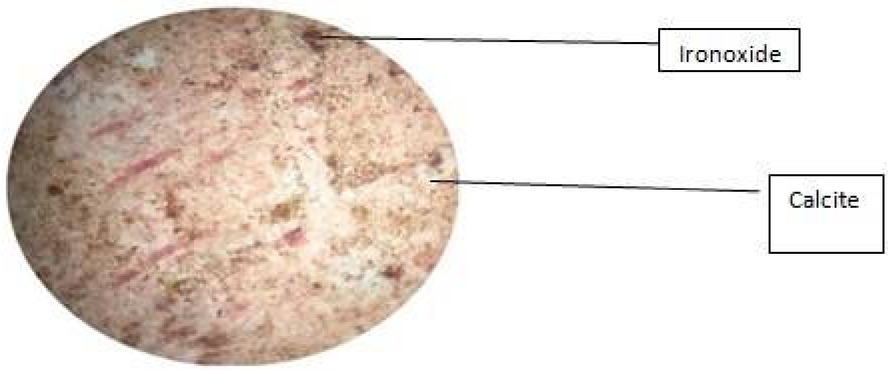

Plate 2b: Microphotograph of limestone (Slide B) under XPL (magnification x100)

3) Slide C

The slide is composed of calcite, iron oxide, dolomite, and quartz. Calcite is colourless under PPL but turns reddish when stained; it is anhedral with two-directional inclined cleavage, low relief, weak birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning. Iron oxide appears opaque black in PPL and crossed polars, showing high relief but no pleochroism, cleavage, birefringence, extinction, or twinning. Dolomite is colourless, subhedral, with inclined two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Quartz is colourless and anhedral, with no pleochroism or cleavage, very low relief, weak birefringence, grey to white interference colours, parallel extinction, and no twinning.

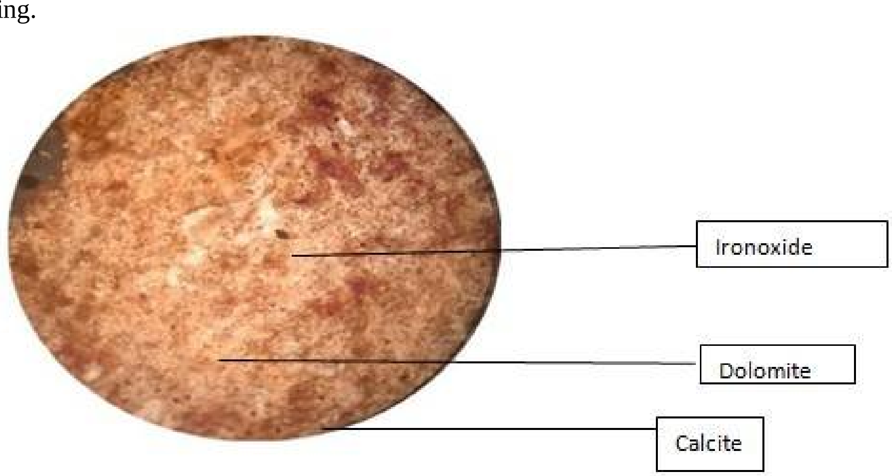

Plate 3a: Microphotograph of limestone (Slide C) under PPL (magnification x100)

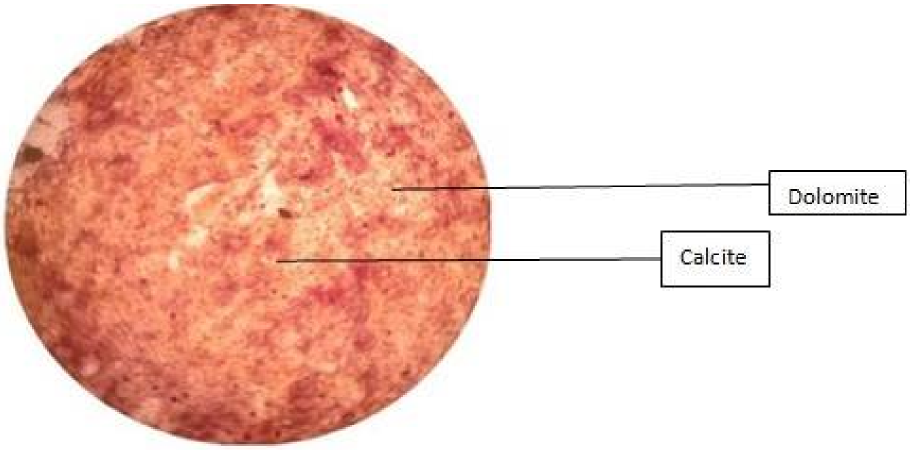

Plate 3b: Microphotograph of limestone (Slide C) under XPL (magnification x100)

4) Slide D

The thin section contains iron oxide, quartz, dolomite, and calcite. Iron oxide occurs as opaque black anhedral grains with high relief, lacking pleochroism, cleavage, extinction, and twinning. Quartz appears colourless, anhedral, with very low relief, weak birefringence showing grey to white interference colours, parallel extinction, and no twinning. Dolomite is colourless to pale grey, anhedral, with two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Calcite is colourless in plane light but stains reddish to purple, occurring as anhedral grains with two-directional cleavage, low relief, and weak birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning.

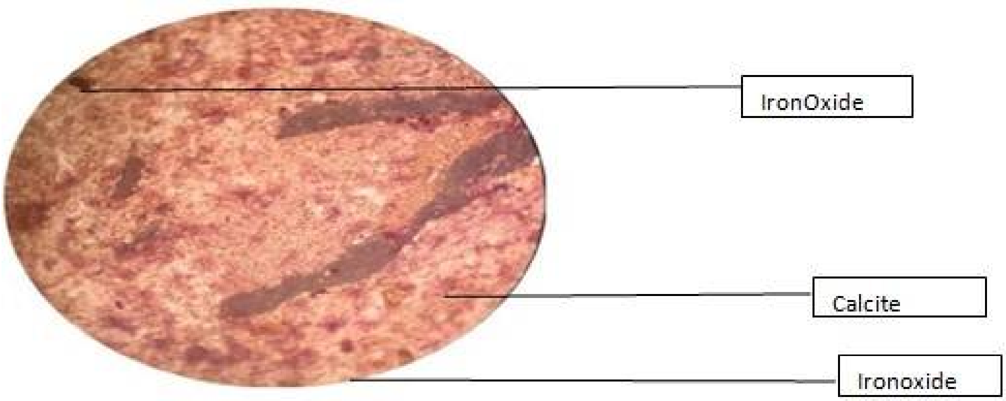

Plate 4a: Microphotograph of limestone (Slide D) under PPL (magnification x100)

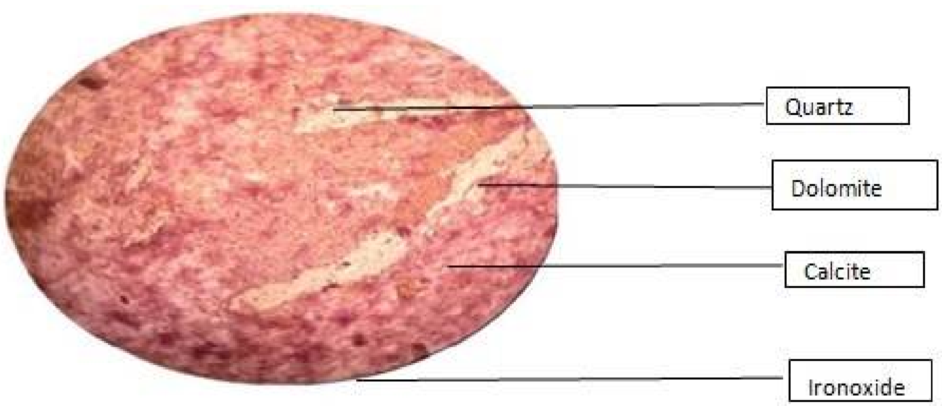

Plate 4b: Microphotograph of limestone (Slide D) under XPL (magnification x100

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5) Slide E

The slide contains dolomite, quartz, calcite, iron oxide, and altered feldspar. Dolomite appears colourless to pale grey under plane light, anhedral, with two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Calcite is colourless in plane light but stains reddish to purple, occurring as anhedral grains with two-directional cleavage, low relief, weak birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning. Iron oxide occurs as opaque black anhedral grains with high relief, lacking pleochroism, cleavage, birefringence, extinction, or twinning. Altered feldspar shows reddish-brown coloration in both plane and crossed polars, with perfect two-directional cleavage, anhedral form, moderate relief, reddish interference colour, and no extinction, birefringence, or twinning.

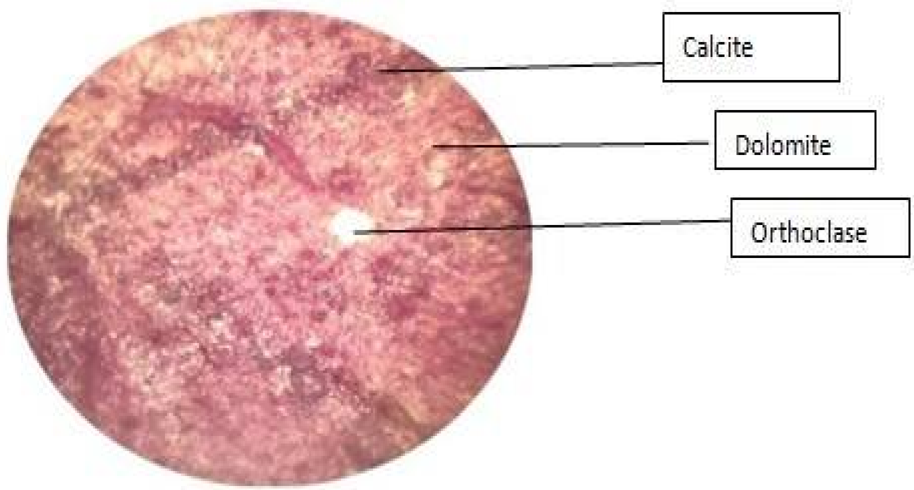

Plate 5a: Microphotograph of limestone (Slide E) under PPL (magnification x100)

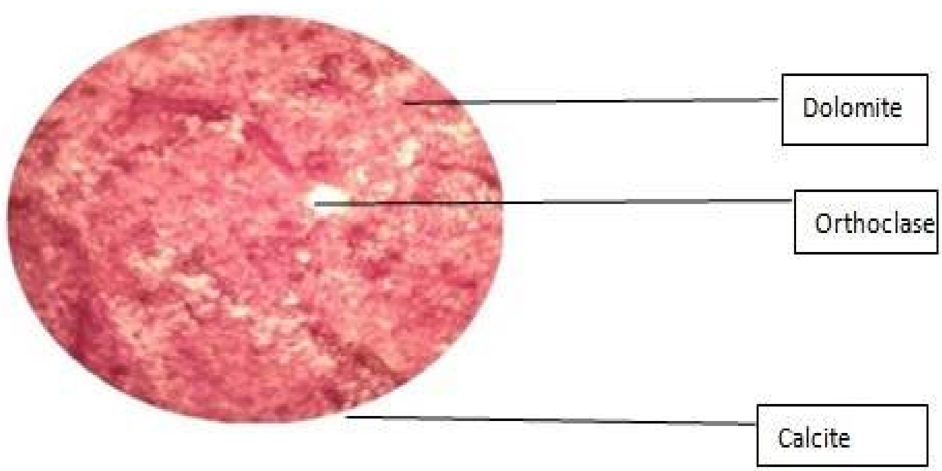

Plate 5b: Microphotograph of limestone (Slide E) under XPL (magnification x100)

6) Slide F

The slide is composed of iron oxide, altered feldspar, dolomite, calcite, and quartz. Iron oxide appears as opaque black anhedral grains under both PPL and XPL, with high relief but lacking pleochroism, birefringence, extinction, and twinning. Altered feldspar shows a reddish-brown coloration in both lights, with perfect two-directional cleavage, anhedral form, moderate relief, reddish interference colours, and no extinction or twinning. Dolomite is colourless to pale grey, anhedral, with two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Calcite is colourless in plane light but stains reddish to purple, anhedral with two-directional cleavage, low relief, weak birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning. Quartz is colourless, anhedral, with very low relief, weak birefringence, grey to white interference colours, parallel extinction, and no twinning.

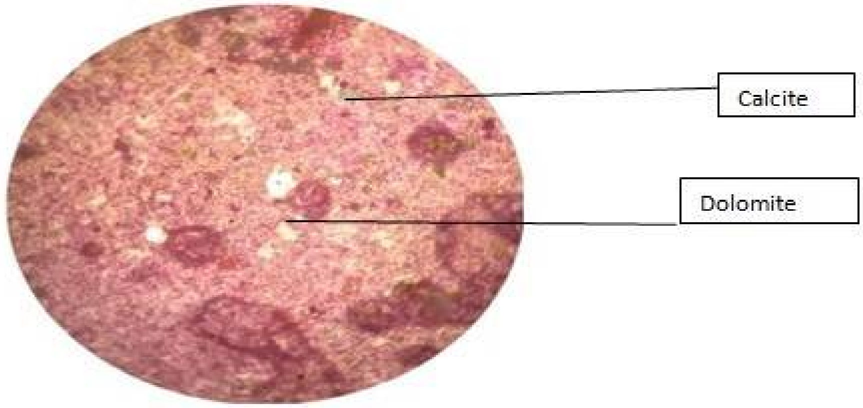

Plate 6a: Microphotograph of limestone (Slide F) under PPL (magnification x100)

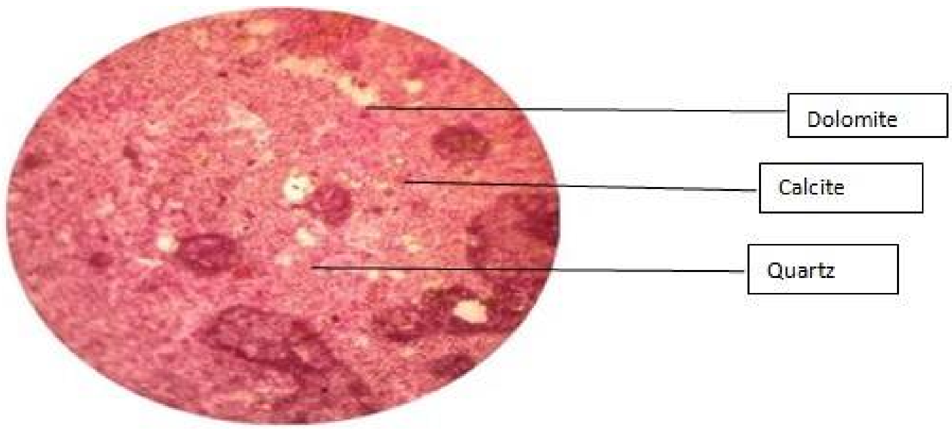

Plate 6b: Microphotograph of limestone (Slide F) under XPL (magnification x100)

7) Slide G

The slide consists of dolomite, calcite, quartz, altered feldspar, and iron oxide. Dolomite appears colourless to pale grey in plane light, anhedral with two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Calcite is colourless in plane light but stains reddish to purple, anhedral with two-directional cleavage, low relief, weak birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning. Quartz is colourless, anhedral, with no cleavage, very low relief, weak birefringence, grey to white interference colours, parallel extinction, and no twinning. Iron oxide occurs as opaque black grains under both plane and crossed polars, with high relief but lacking pleochroism, birefringence, extinction, or twinning.

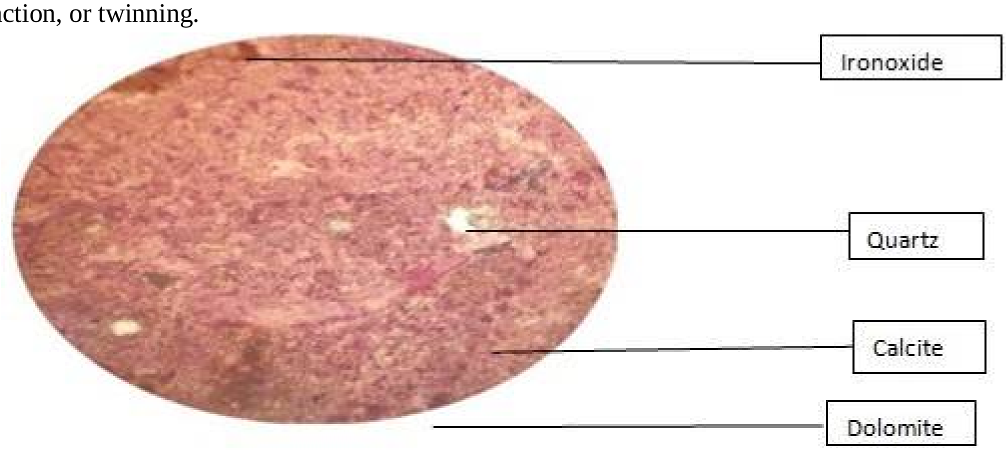

Plate 7a: Microphotograph of limestone (Slide G) under PPL (magnification x100)

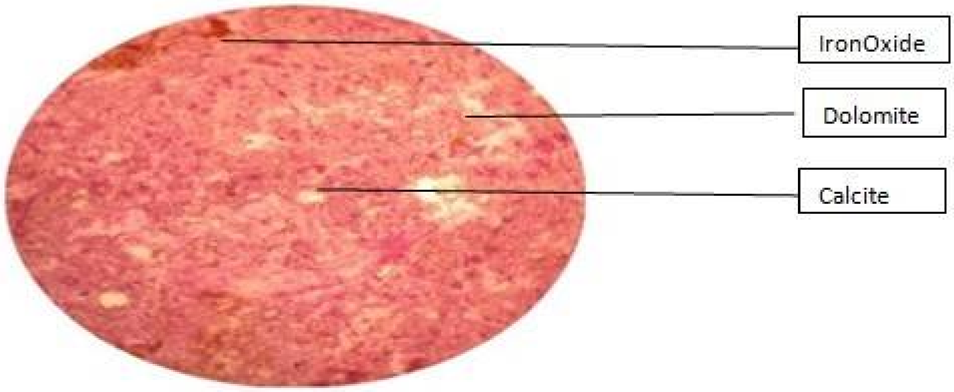

Plate 7b: Microphotograph of limestone (Slide G) under XPL (magnification x100)

8) Slide H

The slide comprises calcite, iron oxide, and quartz. Calcite is colourless in plane light but stains reddish to purple, occurring as anhedral grains with two-directional cleavage, low relief, moderate birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning. Iron oxide appears as opaque black anhedral grains with high relief, lacking pleochroism, cleavage, birefringence, extinction, or twinning. Quartz is colourless, anhedral, with very low relief, weak birefringence, grey to white interference colours, parallel extinction, and no twinning.

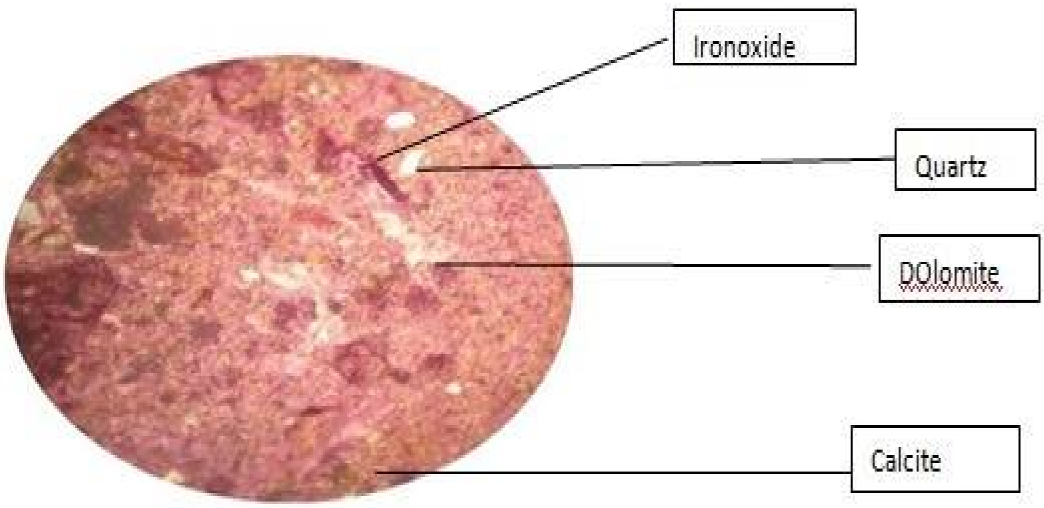

Plate 8a: Microphotograph of limestone (Slide H) under PPL (magnification x100)

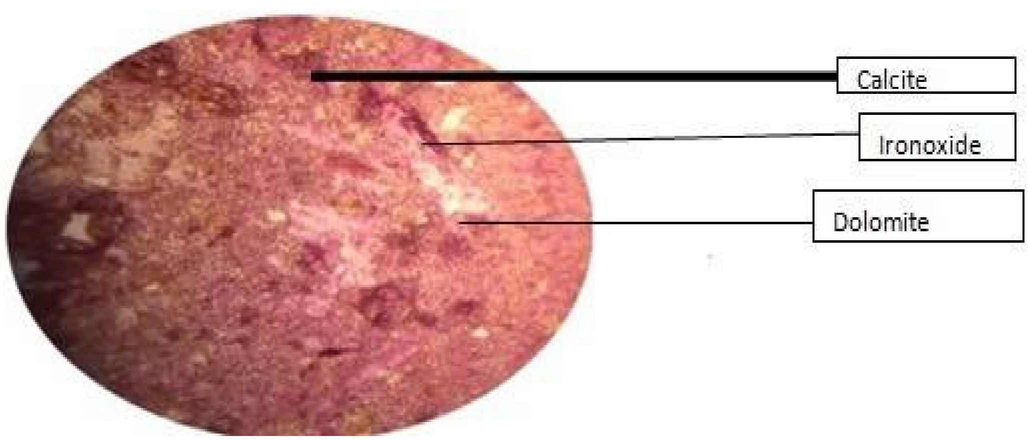

Plate 8b: Microphotograph of limestone (Slide H) under XPL (magnification x100)

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9) Slide I

The slide contains calcite, dolomite, iron oxide, and quartz. Calcite is colourless in plane light but stains reddish to purple, occurring as anhedral grains with two-directional cleavage, low relief, and weak birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning. Dolomite is colourless to pale grey, anhedral, with two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Iron oxide appears as opaque black anhedral grains with high relief, lacking pleochroism, cleavage, birefringence, extinction, or twinning. Quartz is colourless, anhedral, with very low relief, weak birefringence, grey to white interference colours, parallel extinction, and no twinning.

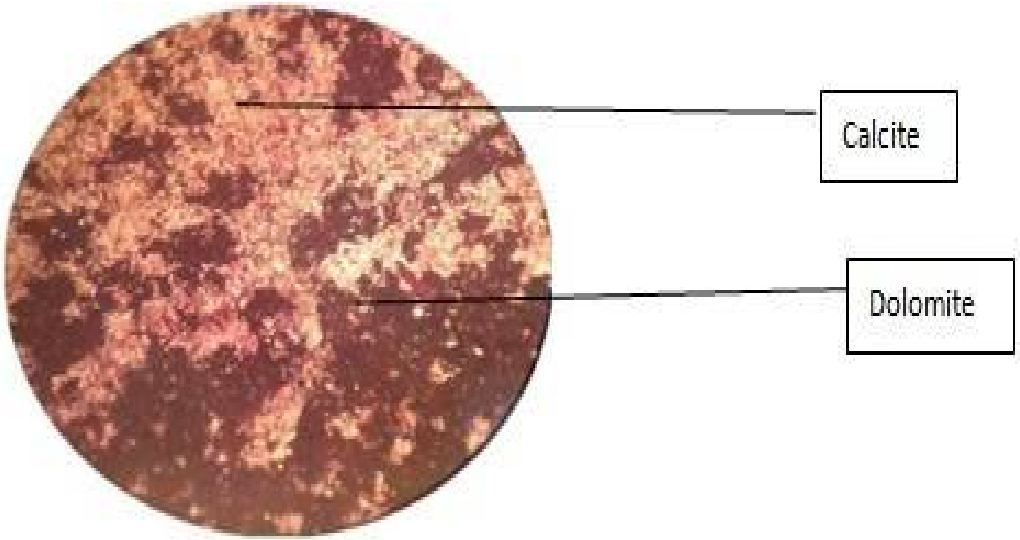

Plate 9a: Microphotograph of limestone (Slide I) under PPL (magnification x100)

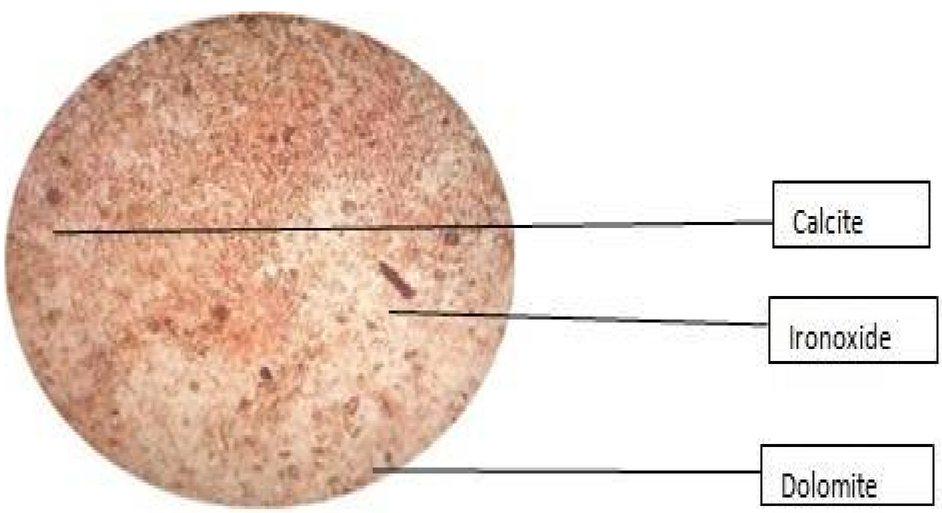

Plate 9a: Microphotograph of limestone (Slide I) under XPL (magnification x100)

10) Slide J

The slide comprises dolomite, calcite, quartz, and iron oxide. Dolomite is colourless to pale grey, anhedral, with two-directional cleavage, low relief, weak birefringence, symmetrical extinction, and polysynthetic twinning. Calcite is colourless in plane light but stains reddish to purple, anhedral with twodirectional cleavage, low relief, weak birefringence, pearl-grey to purple interference colours, symmetrical extinction, and polysynthetic twinning. Iron oxide appears as opaque black anhedral grains with high relief, lacking pleochroism, cleavage, birefringence, extinction, or twinning. Quartz is colourless, anhedral, with very low relief, weak birefringence, grey to white interference colours, parallel extinction, and no twinning.

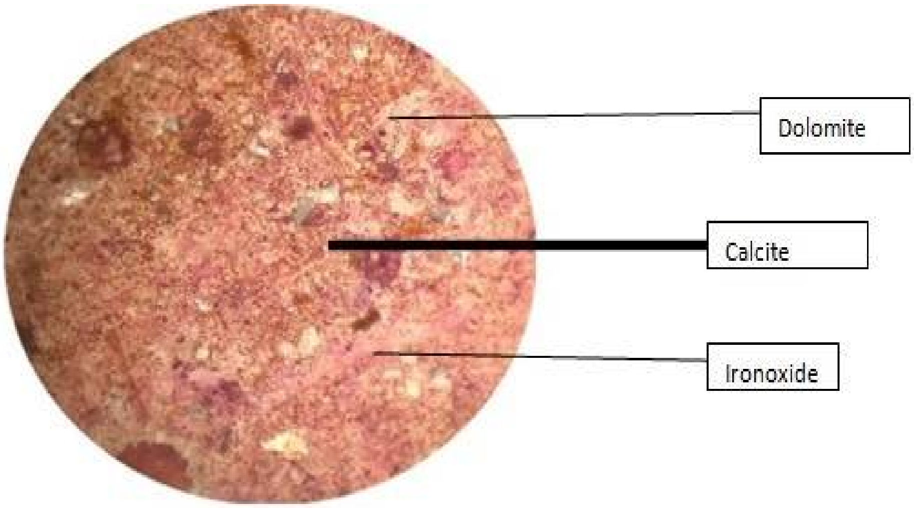

Plate 10a: Microphotograph of limestone (Slide J) under PPL (magnification x100)

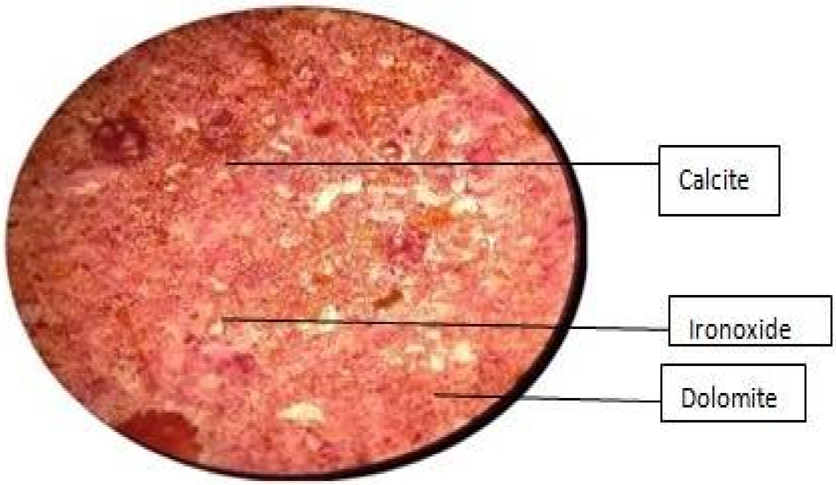

Plate 10b: Microphotograph of limestone (Slide J) under XPL (magnification x100)

Petrographic analysis of the Pindiga Formation revealed that iron oxide, calcite, dolomite, quartz, and feldspar are the predominant minerals. The limestone members are primarily composed of calcite, dolomite, and iron oxide, indicating potential dolomitization and calcitization under favorable conditions. Dolomitization requires a sufficiently high Mg/Ca ratio in the interacting water and adequate fluid flow through the rock to complete the reaction, producing dolomite. Calcitization, on the other hand, occurs under near-surface conditions, involving meteoric water with a high Ca/Mg ratio, facilitating the conversion of original minerals to calcite.

IV. CONCLUSION

Petrographic analysis of the Pindiga Formation limestone indicates that calcite, dolomite, and iron oxide are the primary minerals, while clay minerals, which constitute approximately 95% of the rock, are not observable under a polarizing microscope. The presence of calcite and dolomite suggests potential calcitization and dolomitization under favorable conditions. Given its abundance and mineral composition, the limestone of the Pindiga Formation is suitable for industrial applications, including cement, fertilizer, glass, and abrasives.

V. RECOMMENDATION

The study area hosts significant deposits of limestone, shale, and mudstone. A detailed assessment of the quantity and quality of these resources is recommended. Furthermore, it is advised that the Federal Ministry of Solid Minerals consider establishing a ceramic or cement industry in the region to utilize these materials for manufacturing cement, bricks, pottery, and related products.

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