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Research Paper

Petrographic Analysis of Pindiga Formation Exposed At Pantami Nayi Nawa Stream Channel, Gongola Basin, Northeastern Nigeria.

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Abstract
This research investigates the petrographic characteristics of the Pindiga Formation in Gombe State, Nigeria, focusing on shale, clay, and gypsum deposits exposed along the Pantami to Nayi Nawa stream channel. Field investigations documented the intercalated stratification of dark gray mudstone (shale) and limestone, overlain by thick shale units, while petrographic analyses using thin-section microscopy identified the mineralogical composition and texture of collected samples. The mineralogical assessment revealed the presence of quartz, feldspar (both orthoclase and altered feldspar), zircon, iron oxide, gypsum, and limonite. Observations of optical properties such as birefringence, extinction angles, and cleavage patterns further enriched the classification of these minerals. The study confirms the finegrained texture and sedimentary origin of the samples, highlighting depositional environments influenced by tectonic activities within the Upper Benue Trough. The minerals found under petrographic studies of the samples include Quartz, Altered Feldspar, orthoclase, limonite, Gypsum and Iron Oxide.

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I. Introduction

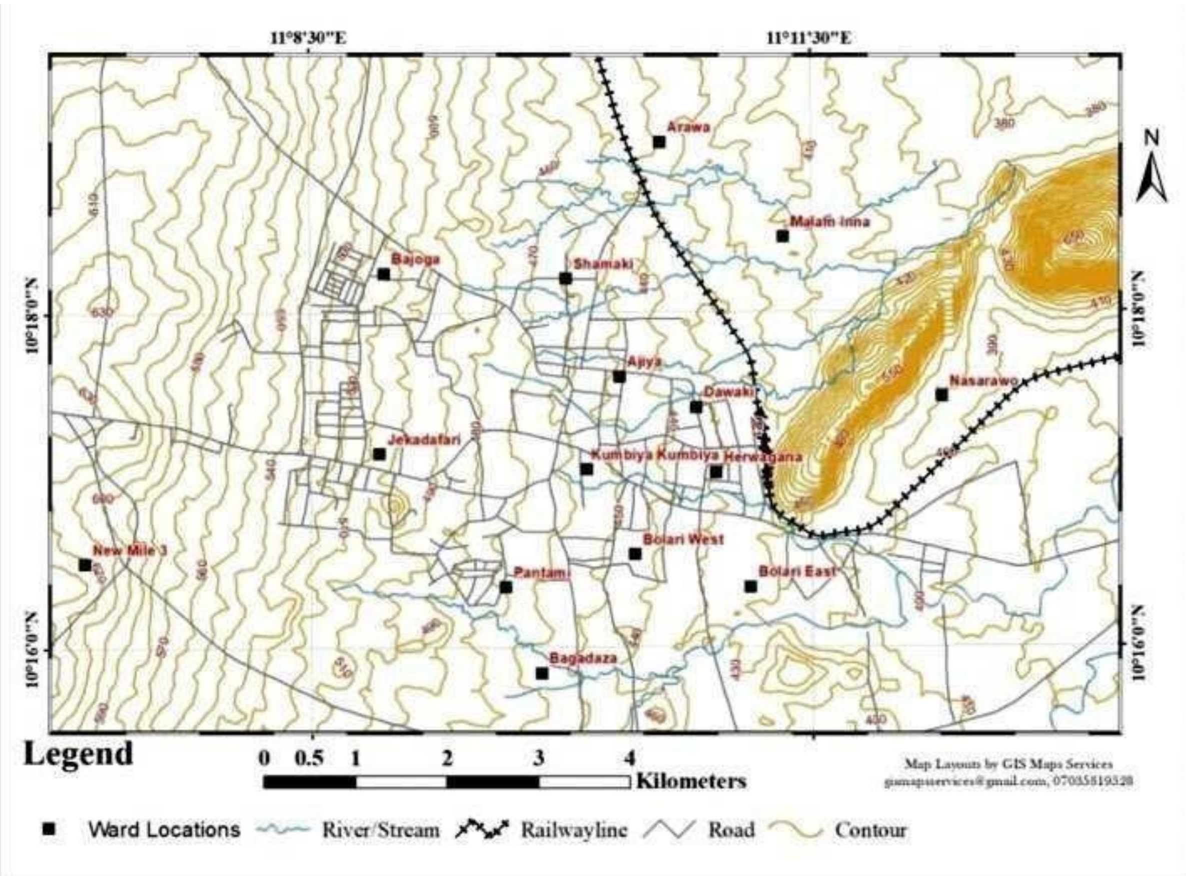
One of the significant intracratonic sedimentary basins is the Upper Benue Trough, which was formed in northeastern Nigeria in the course of rifting of the continent caused by the splitting of the African and South American plates in the Cretaceous period. This extensional tectonic regime resulted in the thickening of the sedimentary succession that was majorly made of sandstones, shales, and limestones which together form the basin architecture. Faulting, subsidence and sedimentation over geological periods also played a vital role in controlling the structural development of the basin. The Upper Benue Trough is also of paleontologic significance having produced some of the most interesting Cretaceous fossil assemblages, including the fossils of dinosaurs, and is an important economic region because of the presence of coal, limestone, iron ore and other mineral resources. Therefore, in the past the basin remains a focus of geological studies, mineral exploitation, and hydrocarbon exploration (Abimbola et al., 2008; Zaborski et al., 1998).Gombe Sub-basin is a unique sedimentary sub-unit of the Upper Benue Trough. The Zambuk Ridge separates it with the Chad Basin, a structural high where the strata of the sediments become thin and at places, are depicted by discontinuous basement inliers. The depositional age of the sedimentation of the Gombe Sub-basin lies between Albian and the Paleocene and the deposits lie unconformably on the Precambrian Basement Complex. Such sediments document a change in the Cretaceous through the early Tertiary (marine to continental) depositional settings (Zaborski et al., 1998).The stratigraphic unit of Pindiga Formation mainly takes place in the northwestern and the south-central areas of the study area, such as Wakil Aba, Danieshe, Zambuk, Labulbule, Kanawa, Boure, Garin Yerima, Baltungo and Nono. On-site observations of river channels cutting across the formation shows that well-enhanced stratification with intercalations of limestone and mudstone (shale) are formed. A dense layer of dark-grey shale and mudstone usually overlays these units, showing that they were deposited in relatively low-energy marine environments.

This paper will set out to establish the petrographic properties of Pindiga Formation as revealed along the Pantami-Nayi Nawa stream channel in the Gombe State, northeastern Nigeria with the view of enhancing the knowledge of its lithological composition, the depositional environment, and geological development.

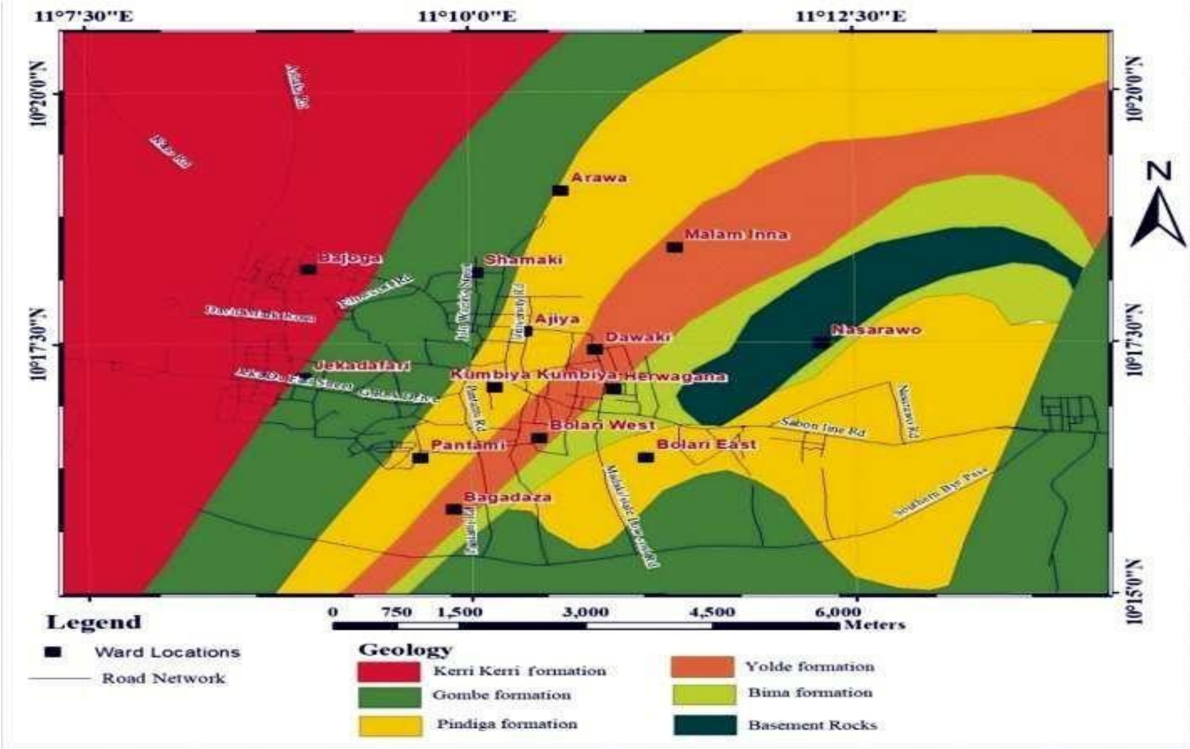
II. Study Area and Methodology

2.1 Location and Accessibility

The study area is located within Gombe town. It lies between latitudes 10°15'55 N to 10°16'53 N and longitudes 11°08'30" E to 11°11"30"E (fig. 1) The area is accessible by roads and numerous networks of footpath linking the Gombe town and village in the area. However, this easy accessibility to the area is hindered greatly during raining season because the soil is waterlogged. This also creates problems; the stream channel was followed during the mapping. The area of study has stream cuts/channels. But regionally Gombe town has an elevation of 450m to 515m above sea level, the settlement is on break in the slope which runs down from the plateau to the west of Gombe(Fig. 2). The slope of the plateau is regular and even up to the point where the change of gradient occurs. The town has numerous entrenched stream channels which run in kilometers. These stream channels drain the area. Most of these stream channels retain water that result from rainfall. There retention ability depends on the periods of rainfall and size of gullies which occur as a result of erosion, and these were also encountered during data collection. The drainage pattern is dendritic. The climate of the study area is discussed in relation to the general climatic of Gombe state. The climatic of Gombe state falls within the Sudan Savannah. It is very hot and dry for most part of the year. This area experience two seasons the rainy season and the dry season. The rainy season beginning mostly from May/June and end at late September/October. The hottest month is April. It has relative humidity which is about 94% in August and drop to less than 10% during the harmattan. During the dry season month of January to April. The average temperature is fairly exceeding 38°C but there is a cool period during the month of December to middle of February. During this period, the monthly average temperature falls below the annual by 5°C. With regard to the vegetation cover of the study area Gombe is in the northeast of the country and as such it falls into the Sudan Savannah zone. The area of study has a vegetation cover comprising of trees, such as baobab, thorny bush and scattered grasses and shrubs.



Fig, 1: Topographic Map of the study area Gombe State (source: google maps)



Fig, 2: Geologic Map of the study Area (source: google map)

2.2 Methodology
2.2.1 Materials
The following tools were utilized in the field to collect the samples from the field:
Global Positioning system (GPS), Geologic hammer, Compass, Field notebook, Pen,
Pencil, Eraser, Marker, Masking tape, Digital camera, Sampling bag and first aid kit.
2.2.2 Methods
The methods applied in this research work includes field work and laboratory analysis. Using a geologic hammer, new sample were taken from the rock outcrop during the field work, which included examining the rock outcrop. Samples from different outcrop were collected within the study area, the sampling include appropriate labels to identify the various stations and locations. Photographs of samples in field and coordinates of various samples were taken.
2.2.3 Laboratory Work
This involved petrographic analysis of five rock samples. A thin section is performed on the five samples, three shales, clay and Gypsum samples were analysed at petrographic laboratory of University of Maiduguri.
2.2.4 Thin Section Preparation
Thin section is the method whereby rock sample is prepared to 0.03mm thick. The rock sample is mounted on a prepared glass slide and observed under a microscope to see the mineral constituents of the rock samples collected. The materials used for the thin section preparation includes Glass slide, Canada balsam, detergent, Blade, cover slip, hot plate, abrasive powder, cutting machine, organic solvent, araldite (Epoxy). Below are the various steps in thin section preparation adopted by (Barber, 1981).
step 1
From the sample collected in the field, a piece of the rock is broken and refined on a glass lap using abrasive powder and water. The abrasive ranges from 70,120,200.400,500,600,700 and 800. The 800 grade is the finest of all the grades and was used to polish the piece of the rock broken from the sample to get a uniform surface. After using the 120 grades, the glass lap was washed and refined using 600 grades abrasive powders to obtain a smooth surface. It was then washed after refined.
Step 2
The glass slide on which the slide is to be prepared was refined using 800 grade abrasive powder for at least a minute. The glass slide was then washed and allowed for drying. The refined rock and the refined glass were then placed on a hot plate to a temperature of about 80°C.

Step 3
Araldite was mixed and smear upon the glass slide and the refined surface of the rock was placed on the glass slide containing araldite and it was fixed between the polished rock and the glass slide, it was allowed to solidify for about 5-10minutes.

Step 4
The mounted rock Sample was removed from the hot plate to cool to room temperature, the cutting machine level led it to a thickness of 0.05mm.

The remaining rock was cut off and polished again using 120 grade abrasive powders. The polishing was repeated using 120 and 80 grades until the required standard thickness of 0.03 was achieved.

Step 5
The razor blade was used to scratch of the excess araldite on the glass and Canada balsam was applied on a prepared slide and a cover slip or glass was mounted on top of the prepared slide. This was done to prevent thin slide from peeling off. The prepared slide is allowed dry for about 5-10 minutes on the hot plate. It was then removed, and organic solvent was applied. The organic solvent was used to wash of the excess Canada balsam after which detergent was used to wash the prepared slides. Finally, the thin slide is taken to microscope for optical investigation of the minerals in the samples.

III. Result And Discussion

The five samples were collected from within the study area and the samples were subjected to thin section and petrographic analyses. The sample were based on their colour and texture, and mineralogy are presented in table 1

Table 1: Field Description of Lithological Samples and Outcrops

Sample Code	Lithology / Material	Colour	Texture	Coordinates (N, E)	Plate No.	Description
PF2S1	Yellowish clay (Shale)	Yellow	Very fine	10°18′39″ N, 11°10′41″ E	Plate 1	Yellow shale outcrop
PF2S2	Ash shale	Ash	Very fine	10°15′52″ N, 11°09′59″ E	Plate 2	Ash-coloured shale outcrop
PF2S3	Shale	Milky	Fine	10°18′22″ N, 11°12′19″ E	Plate 3	Shale outcrop
PF2S4	Gypsum	Light greyish	Glassy	10°15′53″ N, 11°09′56″ E	Plate 4	Gypsum outcrop

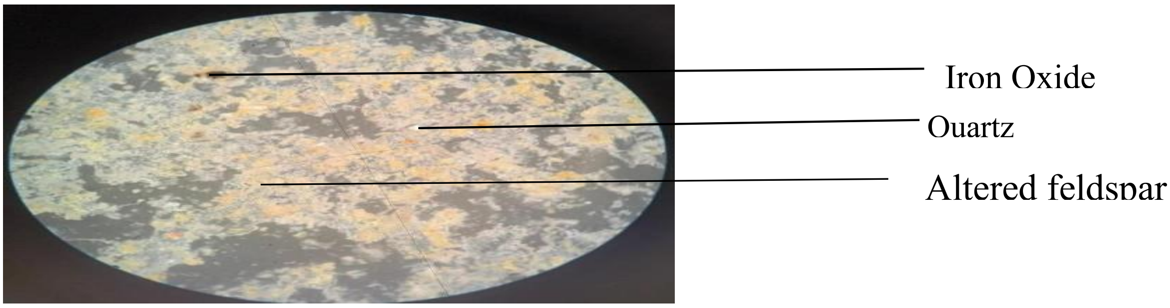
Plate 1: Yellow shale outcrop

Plate 2: Ash shale outcrop

Plate 3: Shale outcrop **Plate 4:** Gypsum outcrop.

Petrographic study
Five rock samples were examined in order to understand their mineral composition and texture by observing them under microscope.

Slide 1: Clay
The slide was observed to composed four (4) minerals, in order of abundance of quartz, altered feldspar, orthoclase, iron oxide and clay minerals which is the orange background.



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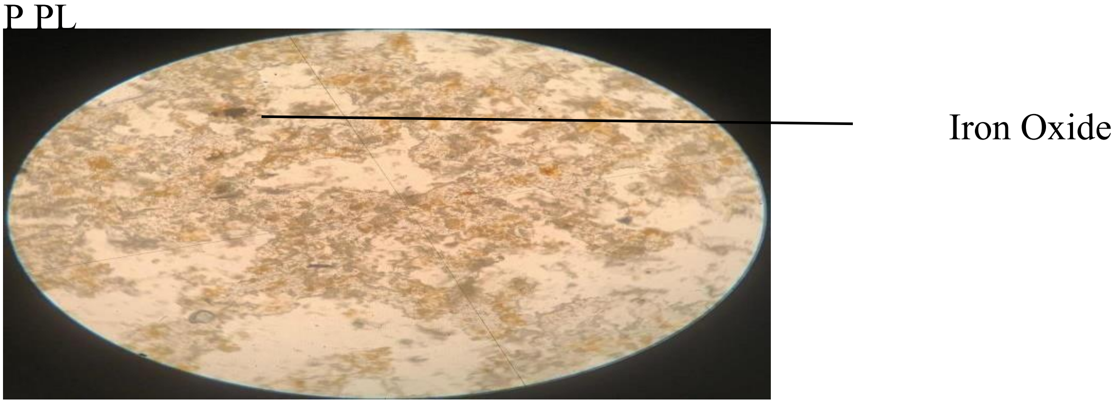

XPL Plate 5: Photomicrograph of Pindiga Formation (clay) (Magnification x 100)

Slide 2: **Shale**
The slide was observed to be composed of five (5) minerals which include Quartz, orthoclase, zircon, iron oxide, and limonite.

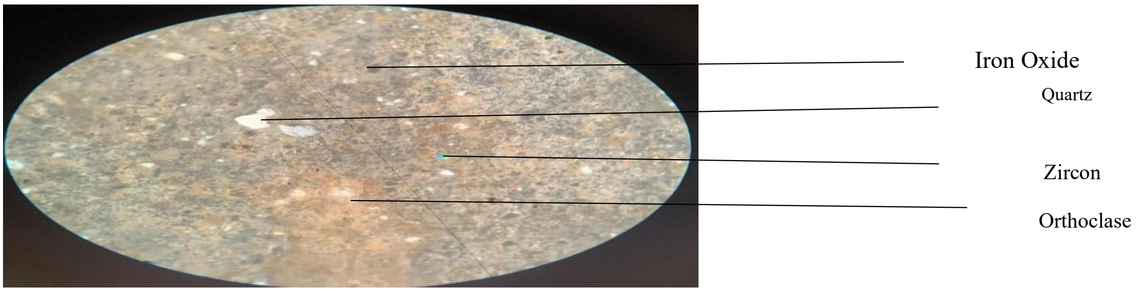

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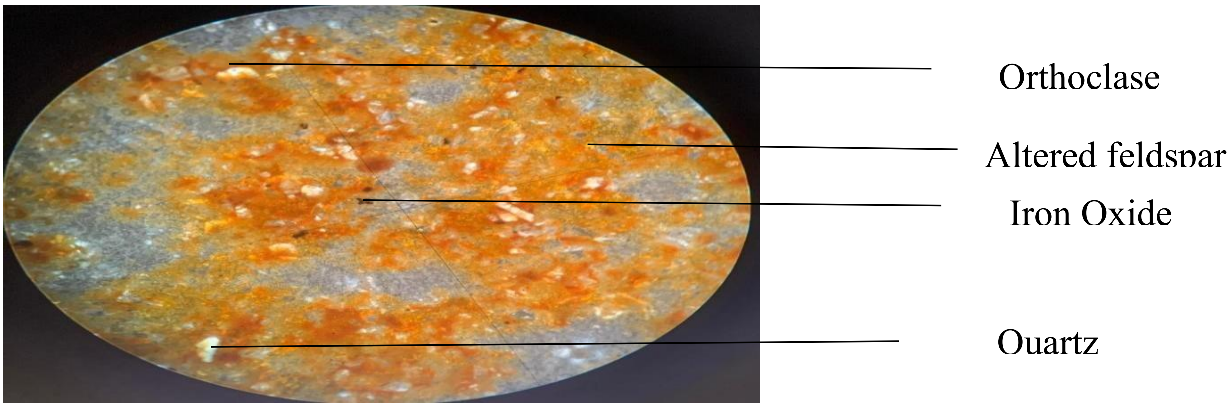
Plate 6: Photomicrograph of Pindiga Formation (shale) (x100 magnification)

Slide 3: Shale

The slide was observed to composed four (4) minerals which include Quartz, orthoclase, altered feldspar and limonite.



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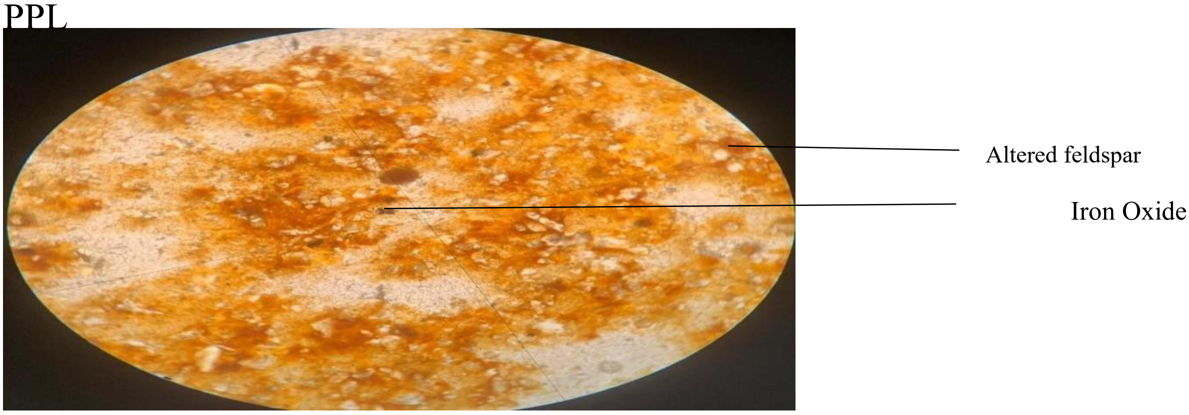

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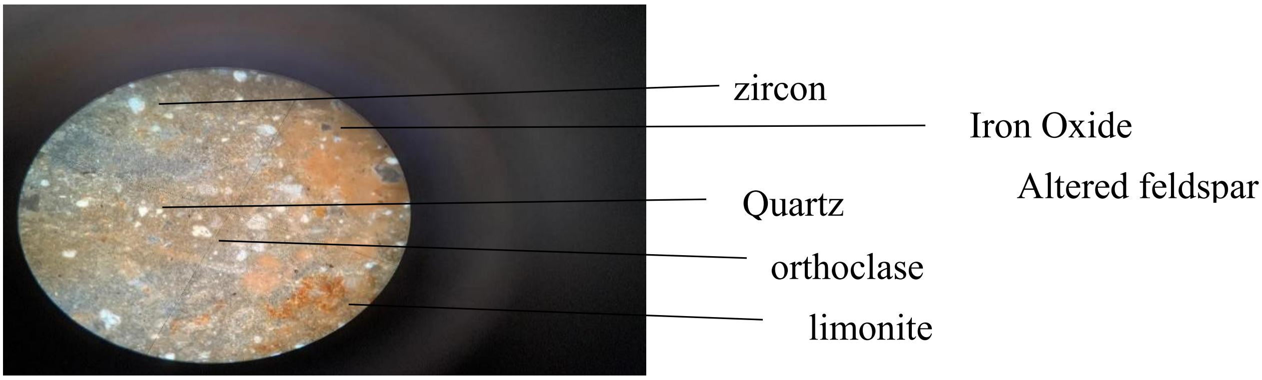
Plate 7: Photomicrograph of Pindiga Formation(shale) (x100 magnification) **Slide 4: Shale**

The slide was observed to composed six (6) minerals which include quartz, orthoclase, Altered feldspar, iron oxide, limonite, and zircon.



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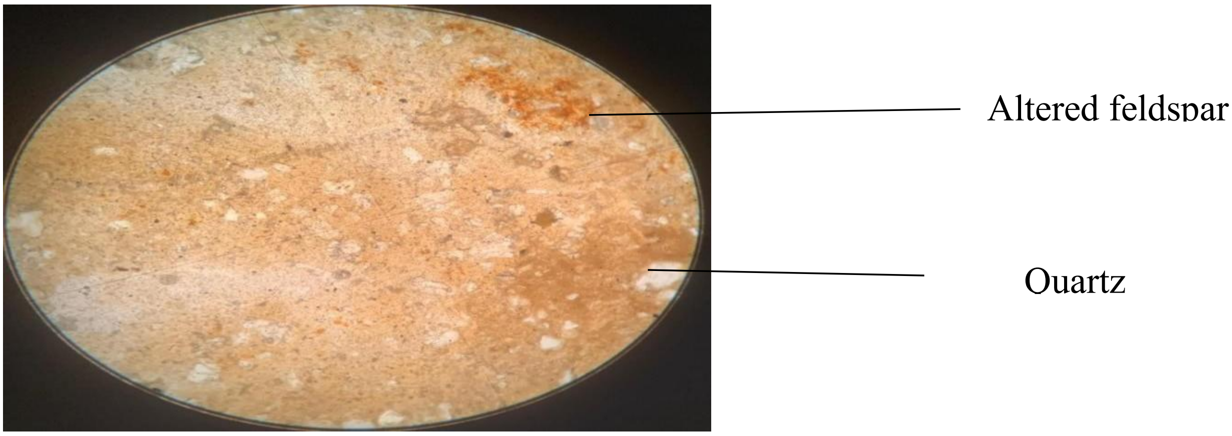

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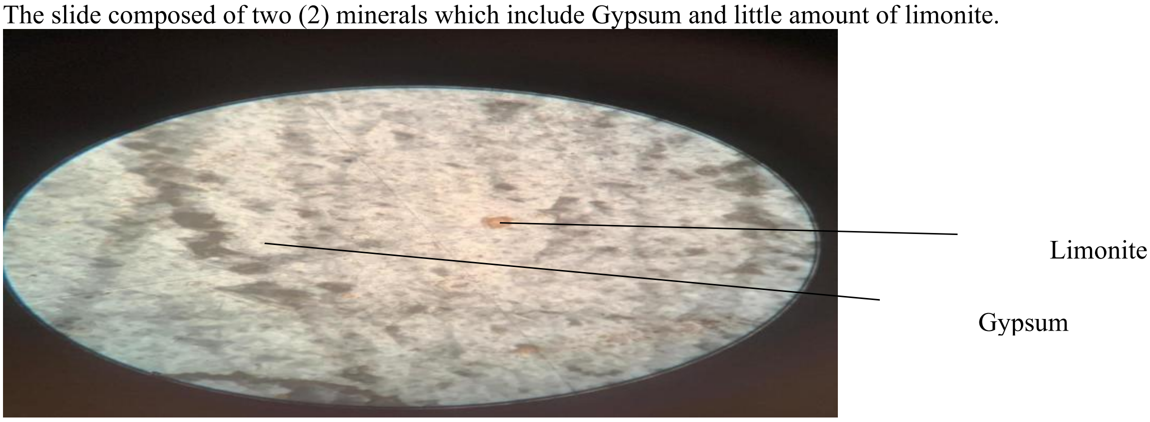
Plate 8: Photomicrograph of Formation (shale) (x100 magnification)

Slide 5: Gypsum

The slide composed of two (2) minerals which include Gypsum and little amount of limonite.



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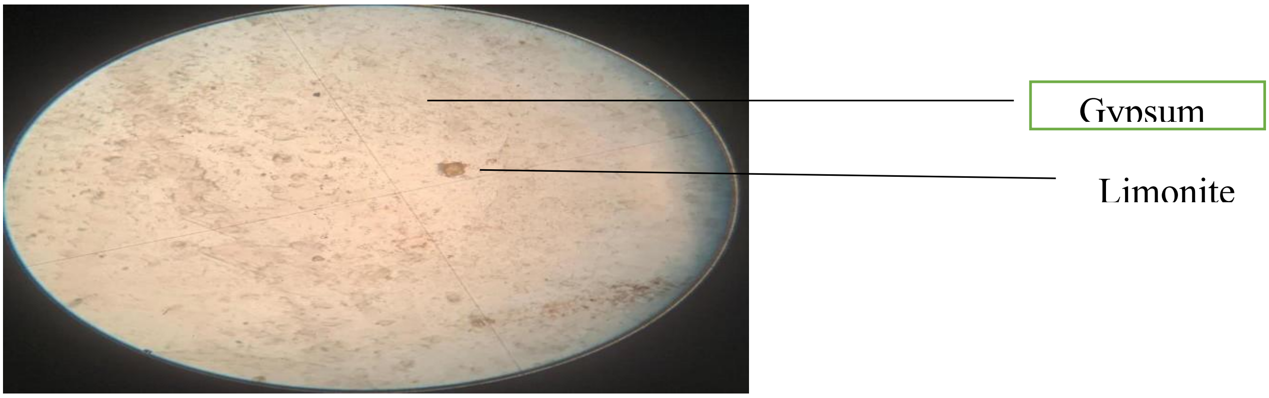

XPL

Plate 9: Photomicrograph of pindiga Formation (Gypsum) (Magnification x100)

The properties of the minerals observed are presented below:

Quartz

The mineral appeared colourless when observed under plane polarized light. It is non pleochrroici.e it does not change colour under plane polarized light even the microscope stage is rotated. Quartz does not have cleavage and was identified with anhedral form. The mineral has very low relief as well as weak birefringence. it looks grey to white of the first order interference colour, it has parallel extinction but no twinning was observed.it occurs in sample PF2S2 (clay), PF2S3 (shale), PF2S4 (shale), and PF2S6 (shale).

Altered feldspar

Altered feldspar refers to feldspar minerals that have undergone a process of chemical or physical alteration as the result of weathering and hydrothermal activity. The mineral looks orange to light brown in colour. It is non pleochroic i.e no cleavage was observed and appeared in anhedral form. It has high relief but no birefringence's due to effect of alteration it looks dark reddish brown as its interference colour, And no extinction angle as well as twinning. Altered feldspars occurs in sample PF2S2(clay), PF2S4(shale), PF2S6(shale).

Zircon

Zircon is a naturally occurring mineral primarily composed of zirconium silicate ($ZrSiO_4$). It is one of the most important and widely used minerals in geochronology and petrology due to its durability and resistance to weathering and alteration. The mineral looks colourless to pale neutral green colour under plane polarized light. It is non pleochroic i.e. no change in colour under plane light, even when the microscope stage is rotated. It does not have cleavage. It appears in cathedral to subhedral form. It has low to moderate relief but has high birefringence. it looks greenish blue colour or (upper second order) interference colour, it has parallel extinction, but no twinning pattern. It occurs in sample PF2S3(shale) and sample PSF2S6(shale). zircon

Iron oxide

Iron oxide minerals are group of minerals that consist primarily of iron and oxygen, these minerals forms as the result of hydrothermal process, weathering of iron bearing minerals, sedimentary process and biological process.The mineral looks black opaque in colour, it appears anhedral in form with high relief and no birefringence. Iron oxide have parallel extinction but no twinning pattern. Iron Oxide forms as the result of chemical weathering, these mineral occurs in sample PS2S2(clay), PS2S3(shale), PS2S4(shale), and PF2S6(shale)

Gypsum

Gypsum is colourless under plane polarized light, it is non pleochroic i.e, the colour does not change plane light. Gypsum shows perfect cleavage in only one direction, it has low relief and weak birefringence. Gypsum looks turbid grey to white of first order interference colour, it also shows symmetrical extinction angle but no any twinning pattern. Gypsum occurs only in PS2S7(Gypsum)sample

Limonite

Limonite composed of iron oxides and hydroxides which form as the result of weathering of iron rich rock formations. It looks light brown in colour under plane polarized light. It is non pleochroic due to its isotropic nature (no double refraction).it does not have cleavage and have anhedral form. Limonite has a very high relief but no birefringence due to its isotropic nature. Its remained reddish brown(dark) under crossed polars as its interference colour. The mineral does not show extinction and twinning pattern. Limonite occurs in sample PF2S6(shale) and sample PF2S7(Gypsum).

IV. Conclusion

The paper is an in-depth petrographic analysis of the Pindiga Formation of the Gongola Basin of the Upper Benue Trough, its mineralogical makeup, textural features, and the depositional environment. Bedding, laboratory studies prove an interbedded sequence of shale, mud, limestone, and gypsum with quartz-rich siliciclastic input, the presence of accessory feldspar and zircon pointing to mixed origin, and the content of gypsum as evidence of episodic conditions of evaporation. The very fine grained textures and iron oxidation marks indicate deposition at a low-energy environment with varying climatic and tectonic controls during the Cretaceous. The results confirm the developed theories about the Upper Benue Trough as an active tectonic basin and provide an economic perspective of gypsum and clay reserves as a part of the Pindiga Formation that could be used as a baseline of the future geochemical and resources assessment investigations.

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