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The Geology and Petrography of Rimin Zayam and Environs, Bauchi, North-East Nigeria

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Abstract

The geologic investigation of Rimin Zayam migmatites is aimed at determining the morphology, petrogenesis and geochemical behaviors of the rock outcrops. About sixty-seven samples were obtained from the field, thirty of the samples were selected, the thirty samples were divided into three, the first part was used to prepare thin section, the second part was used for geochemical analysis and the third part was preserved. Based on the macroscopic and microscopic studies of the study area, six distinct litho-petrological units were discovered. These includes; Ryolite Dyke, Biotite Granite, Metatexite (Banded Ortho-Gneiss, Stromatic Migmatite), Diatexite (Leucocratic Diatexite, Mesocratic Diatexite, Melanocratic Diatexite), Nebulite and Schist. They were petrographically studied to contain biotite, quartz, plagioclase feldspar, alkali feldspar, hornblende, pyroxene, etc. The presence of orthopyroxenes indicates an intensed prograde metamorphism (granulite facie). The area is affected by NE/SW trending Pan-African structures being cross-cut by NW/SE trending Cretaceous trends as evident from the Rose plot. The ductile stress that affected the terrain brought about the numerous ptygmatic folds which make the area to be declared a Shear Zone.

Keywords: Morphology, Petrogenesis, Geochemistry, Macroscopic, Microscopic

INTRODUCTION

A migmatite is a rock found in medium- and high-grade metamorphic areas that can be heterogeneous at the microscopic to macroscopic scale and consists of two, or more, petrographically different parts, which are petrogenetically related to each other, and to their protolith, through partial melting or segregation of the melt from the solid fraction (Sawyer 2008a). Migmatites are complex, high-grade rocks that have formed by partial melting. They have

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been recognised across most of geological time, develop in various tectonic settings, and can affect a wide range of protoliths. Consequently, migmatites are commonly encountered in the field where their complexity can confuse and intimidate the geologist. The target of this report is to provide an understanding of the terminology applied to migmatitic rocks, the processes that form them, and their importance.

Petrographic study of rocks in an area is a branch of petrology that focuses on the detailed description of the rocks. It involves detailed description of the mineral content, as well as the textural and structural relationship within the rock in that area. The most important aspect of petrographic study of rocks in an area involves the detailed analysis of the constituent minerals of the rocks by optical mineralogy in thin sections making use of the petrographic microscope; which of course is critical to the understanding of the origin of the rocks. Petrographic descriptions start with the geological field mapping which involves having an understanding of how to map the study area locating the various outcrops present and other geological features and structures and to make inferences about them. It involves the field notes at the outcrop and include megascopic description of hand specimens i.e. the description of macroscopic characters of the rocks.

The first part of this work deals with Field Relations which explains the physical descriptions of the rock outcrops, while the second part describes the petrography of the samples within the study area.

STUDY AREA

The study area is located on longitudes **E**$09^{0}15^{/}$ to $9^{0}20^{/}$ and latitudes **N**10^{0} $06^{/}$ to 10^{0} $11^{/}$. It covers an area of approximately 84.64km^{2}. A major road cut across the area, several minor foot paths and perennial streams (Figure 1). Nahuta, Rinji, Rimin Zayam, etc are the villages within the study area inhabited by mostly farmers, herders and artisanal miners.

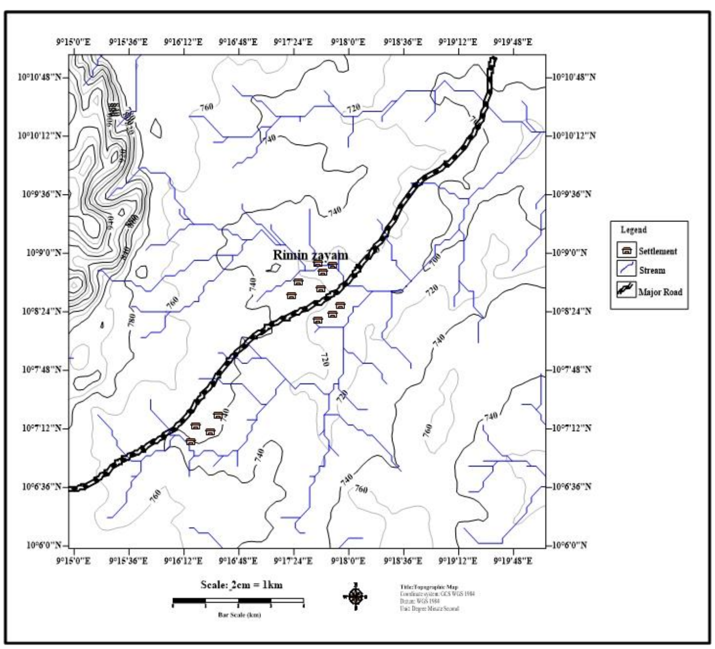

Figure 1: Location Map of the Study Area

MATERIALS AND METHODS

Materials:
The materials used in the course of this study both on the field and in the laboratory include the following: Topographic map of Toro carved out from the Federal Survey of Nigeria topographic map of Toro, 1963 (Sheet 148 SE) part of Bauchi State, Global Positioning System (GPS), compass clinometer, writing materials (field note, marker, pencil and ruler), cutlass, photographic camera, geologic hammer, sample bags, polarizing microscope.

Methods:
The methods employed in carrying out this study can be grouped into two headings of different activities and also involving different materials. And these are explained in details below:

a. Field method: The field work started with a reconnaissance survey of the area, the access roads, drainage channels, types of settlements and also taking note of the minor and major outcrops. This was followed by the detailed geological mapping involving the transverse method of field mapping, collection of representative rock samples from outcrops, road cuts etc. The geological hammer was used in collecting representative samples of each outcrop encountered.
Strikes and dips of outcrops and orientation of some structures were taken with the compass-clinometer and their location recorded with the global positioning system (GPS) and were plotted as a point data on the field topographic map. The rock samples collected were described megascopically (in hand specimen) in the field noting essentially their lithology, texture, structural features on the outcrops, field relationship with neighboring outcrops, mineralogy, and mode of occurrence, and were recorded in the field notebook and the rocks labelled accordingly. Sketches and photographs of important features like folds, fractures, faults and veins were made during the field mapping.

b. Laboratory/Table studies: This involved both the sample/thin section preparation and the petrographic study of the thin section produced from each rock sample.

Sample Preparation
In sample preparation, fresh rock samples were selected from the collections from the field. The main procedure of making the thin section are summarized below:

The rock samples were cut into chips of thickness and dimension 7mm by 10mm using rock cutting machine. They were later trimmed, grinded and lapped on glass plate using abrasive powder (carborundum) of grades 400, 500 and 700 microns respectively for 5minutes and the chips were washed in-between the grades to prevent contamination. The chips were then mounted on glass slides using araldite, and the thickness was further reduced by grinding and lapping respectively to attain the required thickness of 30microns. They were then washed, trimmed and cover with cover slips using Canada balsam, after which the final washing with methylated spirit was done. They were then dried, labelled and stored.
Necessary precautions such as avoiding breaking of thin sections during grinding, lapping and mounting; avoiding air bubbles being trapped during mounting and others, were adequately taken into consideration during the preparation of the thin sections.

Petrographic Study

The thin sections made from each rock representatives were carefully studied using Lietz Polarizing microscope in the departmental laboratory. The different minerals in each thin section were identified under both the plane polarized light (ppl) and crossed nicol modes of the microscope, using their optical properties such as colour, form, relief, cleavage, birefringence, extinction angle, orientation, twinning, and pleochroism in their identification.

Modal analysis of the mineral constituents were also done, based on visual observation of the abundances of the minerals in each thin section.

RESULTS

About thirty samples were selected for the work. The samples were used to prepare thin sections. Based on the macroscopic and microscopic studies of the study area, six distinct litho-petrological units were discovered. These includes; Ryolite Dyke, Biotite Granite, Metatexite (Banded Ortho-Gneiss, Stromatic Migmatite), Diatexite (Leucocratic Diatexite, Mesocratic Diatexite, Melanocratic Diatexite), Nebulite and Schist.

SCHIST

The palaeosome is the part of a migmatitic rock that was not affected by partial melting (**PLATE 1**) and which preserves structures (e.g. foliations, folds and layering) that are older than the partial melting event. The microstructure of the rock may be unchanged, or there could be minor changes in the size, form, and orientation of the grains (i.e. changes that would reflect sub-solidus metamorphic processes). This was discovered at the quarry location **N10^{0} 7/ 0.7//** and **E9^{0} 15/ 32.9//**.

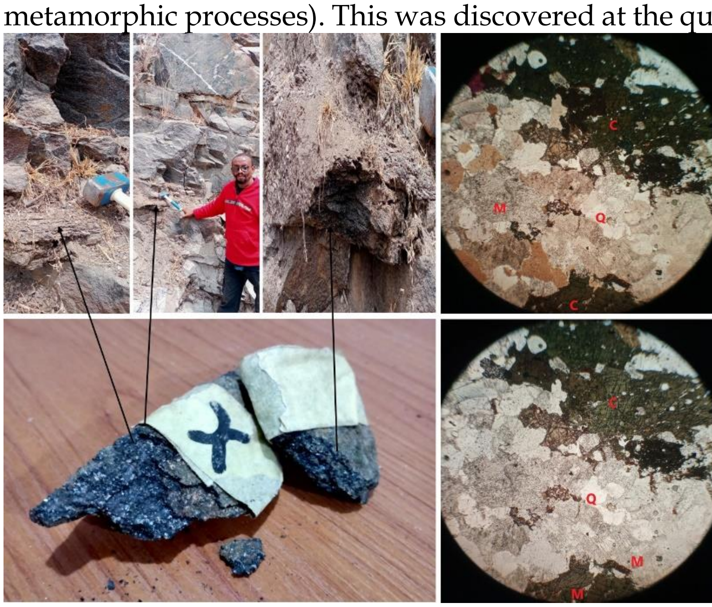

Plate 1: Field view, hand sample and photomicrograph of Schist from the quarry

METATEXITE

Metatexite migmatites in the area includes **banded orthogneisses** (which dominate the south eastern part around Rimin Zayam gold mining area) and **stromatic metatexites** which occurs within the quarry. They are more prominent towards the south eastern and south western part of the study area. The metatexite migmatites are those that still retain pre-partial melting structures. They consist of nearly parallel alternate of felsic and mafic bands (Plate 1). They are medium to coarse grained, the dark grey mafic bands are composed of mostly biotite, hornblende, plagioclase, orthopyroxenes, quartz and other accessory minerals. While the light-coloured felsic bands are dominated by quartz and orthoclase feldspars and plagioclase with small biotite and garnet. The stromatic migmatites consist of scattered irregular leucocratic bands, these leucocratic bands are parallel to the foliation planes. The leucocratic (lighter) band of both the banded orthogneiss and stromatic metatexites are small (few cm) parallel bands compared to the darker melanocratic band that is more dominant throughout, they developed along the planes of foliation.

BANDED ORTHO-GNEISS

This includes the Patch, Dilation and Net metatexites. They constitute the neosomes that preserves the pre-partial melting structures and microstructures. They are represented on **PLATE 2** below.

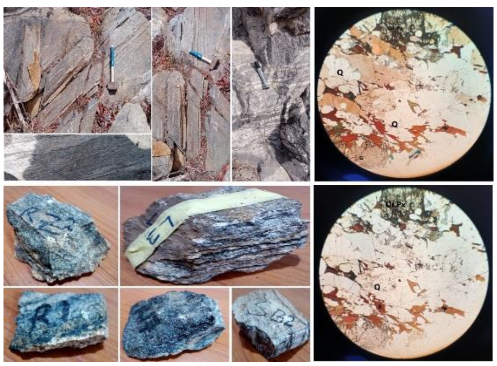

Plate 2: Field view, hand sample and photomicrograph of Banded Ortho-Gneiss closed to Rimin Zayam town

STROMATIC MIGMATITE

It seems evident that a number of different mechanisms can produce a stromatic morphology in a metatexite migmatite. Some stromatic-structured migmatites form because their protolith was strongly layered. Others formed by the repeated injection of melt along parallel planes of weakness during anatexis, and still others are the result of a drastic modification of precursor morphology by intense deformation.

Plate 3: Field view, hand sample and photomicrograph of Stromatic Migmatite

DIATEXITE MIGMATITE

A migmatite in which neosome is dominant and melt was pervasively distributed throughout. Pre-partial-melting structures are absent from the neosome, and are commonly replaced by syn-anatectic flow structures (e.g., magmatic or submagmatic foliations, schlieren), or by isotropic neosome. Neosomes are diverse, reflecting a large range in the fraction of melt, and they can range from predominantly **leucocratic** to predominantly **mesocratic** (e.g., unsegregated melt and residuum) to predominantly **melanocratic**. Paleosome occurs as rafts and schollen, but may be absent. Diatexites are mostly concentrated towards the western part of the study area.

In the early formed diatexite migmatite, the leucosomes and melanosomes are visible together with some pre-anatectic structures, but however, there is an intensed folding which led to ductile deformation of the rocks. It is also characterized by numerous occurrences of ptygmatic foldings and shear stresses. The leucocratic diatexite **(Plate 4)** predominates the quarry.

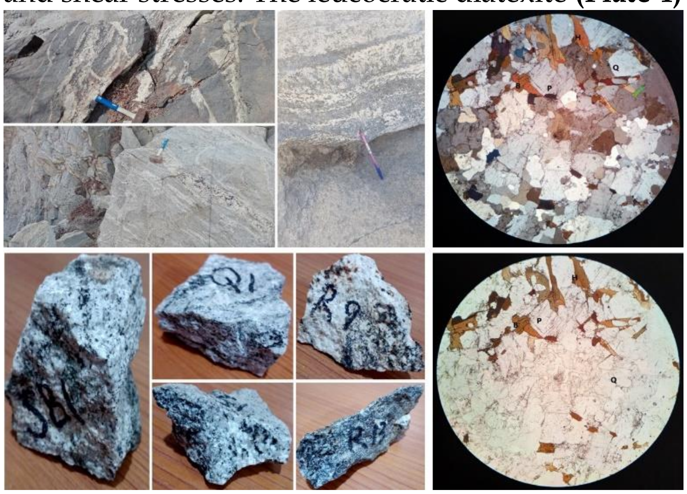

Plate 4: Field view, hand sample and photomicrograph of Schlieren Diatexite

NEBULITE

This is regarded as the final stage of anatectic migmatization (Ferre, et al 2002). It is locally referred to as the Bauchite (Dada, 1998). Two different varieties were noticeable within the study area; the white nebulite (WN) and the brown nebulte (BN). The white nebulites occurs within the quarry while the brown variety are more pronounced near the foot of Kondon Kaya Ring Complex. Carbon dioxide present within the crustal rocks aided in lifting up the temperature of the migmatites during deformation process. This accounts for the coarser grains in nebulites after the removal and emplacement of quartz diorite. Absence of CO_2 and pinkish k-feldspar led to the formation of under developed nebulite (white nebulites) with white k-feldspar.

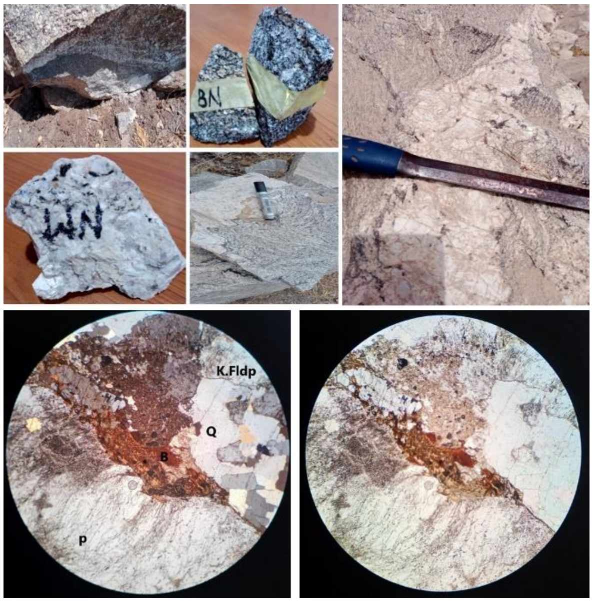

Plate 5: Field view, hand sample and photomicrograph of Nebulite

BIOTITE GRANITE

The Jurassic Biotite 'Younger' Granites within the study area are more prominent towards the western part of the study area. They are anorogenic, they intruded both the metatexites and diatexites with noticeable sharp boundary through a process called calderon subsidence. It was discovered at Tashan Mustapha village (N10^{0} 7$^{/}$ 32.78$^{//}$, E09^{0} 16$^{/}$ 6.67$^{//}$, elevation 738m). It trends N320W cross cutting the NE-SW Pan-African signatures.

Plate 6: Field view, hand sample and photomicrograph of Biotite Granite

RHYOLITE DYKE

This is regarded as the most silica-rich volcanic rock. It is predominantly fine-grained in texture (aphanitic). The rhyolites of Rimin Zayam area are generally porphyritic (ie containing larger mineral crystals known as phenocrysts embedded with fine-grained groundmass). The rhyolite dyke was mapped at location N10^{0} 08$^{/}$ 1.4$^{//}$, E09^{0} 16$^{/}$ 57.03$^{//}$ with an approximate elevation of 715.51m (above mean sea level).

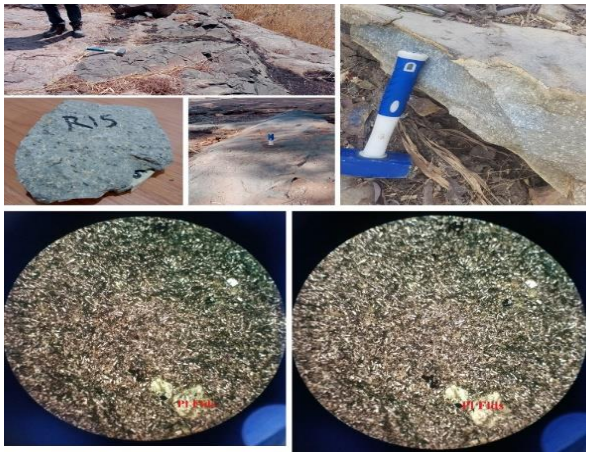

Plate 7: Photomicrograph, Field View and Hand Sample of Rhyolite Dyke

STRUCTURES

Numerous structures were studied in the area. They include; Foliation, Fractures, Fault, Lineations, Folds and Veins. The gneissic foliation planes (Plate 8) and lineations are more pronounced within the metatexites. Those structures were noticed to have been obliterated in the diatexites. Most of the foliation planes were observed to be trending in N-S direction and dipping gently. The foliation planes serve as conduit for fluid migration and storage.

Most of the quartz veins, fractures and minor faults mapped in the study are prominent within the low-level outcrops and trends in NE-SW direction. They are represented on the Lineaments Map (Figure 2), Table (Table 1) and plotted on the Rose Diagram (Figure 3 & 4).

Plate 8: Gneissic foliation noticeable within the metatexites

Plate 9: Fractures, Minor Fault, Joints and Veins within the study area

Folding was observed to be highly intensed within the metatexites (especially at the quarry site). The limbs of the folds are essentially horizontal and parallel, typical of Recumbent Folds that are normally prominent within areas of the greatest tectonic stress. The tension gashes and ptygmatic folding were vividly visible. The recumbent and ptygmatic folds characterize the terrane to be a Shear Zone (PLATES 9 and 10). This structural feature is capable of aiding the mobility of hydrothermal fluids within the area, this will in turn enriched the affected terrane with rare earth minerals.

Plate 10: Folding features within the study area

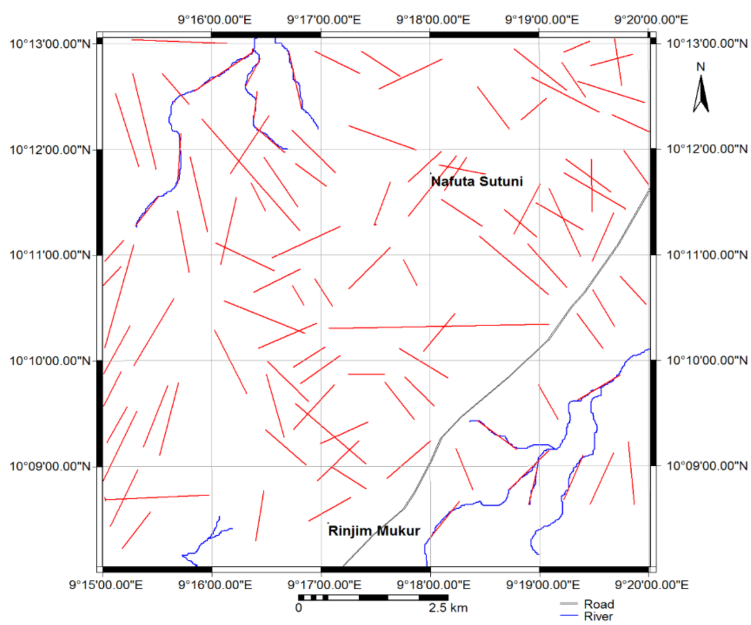

Figure 2: Lineament Map of the Study Area

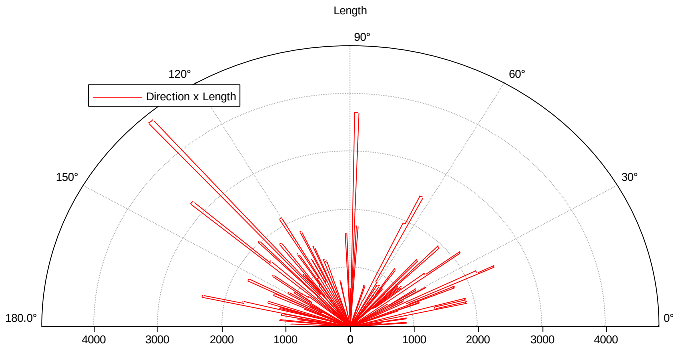

Figure 3: Rose Diagram of the linear structures

Table 1: Lineaments Strike Readings (from N10⁰ 7/ 5.8// to N10⁰ 12/ 11.8// and E9⁰ 15/ 31.8// to E9⁰ 15/ 50.0//).

S/NO	STRIKE READINGS	S/NO	STRIKE READINGS
1	S194⁰W	24	S226⁰W
2	S220⁰W	25	S230⁰W
3	N280⁰W	26	S170⁰E
4	N260⁰W	27	S166⁰E
5	N278⁰W	28	N330⁰W
6	S244⁰W	29	N350⁰W
7	S146⁰E	30	N032⁰E
8	S252⁰E	31	S152⁰E
9	S234⁰W	32	S100⁰E
10	N278⁰W	33	S098⁰E
11	S210⁰W	34	S101⁰E
12	S182⁰W	35	S170⁰E
13	S230⁰W	36	N060⁰E
14	N288⁰W	37	N075⁰E
15	S190⁰W	38	S095⁰E
16	S170⁰E	39	S111⁰E
17	N300⁰W	40	S120⁰E
18	S240⁰W	41	S140⁰E
19	S241⁰W	42	S105⁰E
20	S238⁰W	43	S130⁰E
21	N330⁰W	44	S180⁰W
22	N080⁰E	45	N020⁰E
23	S220⁰W	46	N330⁰W

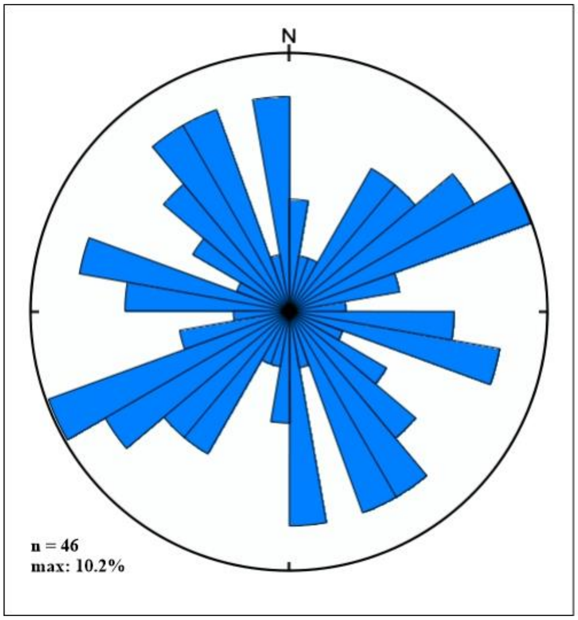

Figure 4: Rose Diagram of the field obtained linear structures

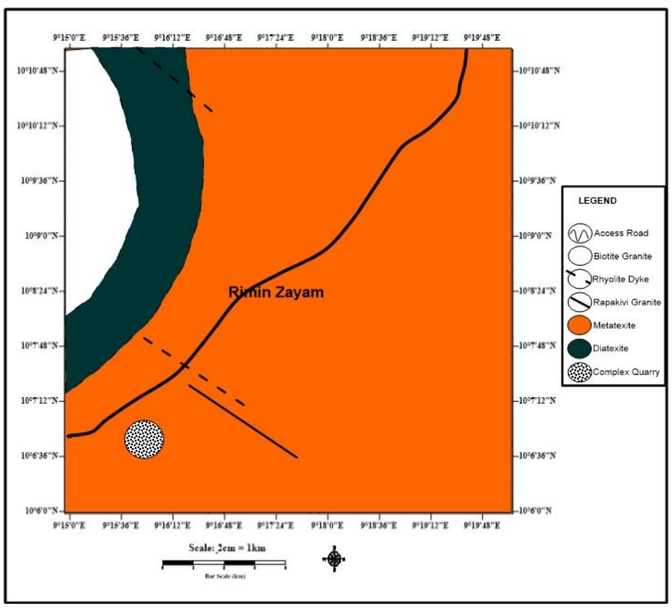

Figure 5: Geologic Map of the Study Area

DICUSSION OF RESULTS

Thin section studies were carried out for thirty carefully selected rock samples representing the studied area. The results revealed the dominance of some prominent minerals such as quartz, biotite, muscovite, plagioclase and microcline, orthoclase and hornblende. These minerals were studied under plane-polarized light and crossed nicols. Their photomicrographs, field view and hand samples are presented in **plates 1-7** respectively. The optical properties of the minerals studied includes; Shape, Habit, Colour, Pleochroism, Cleavage, Relief, Becke Line, Birefringence, Extinction Angle, Twinning, Zoning, Alteration, etc.

Based on the macroscopic and microscopic studies of the study area, six distinct litho-petrological units were discovered. These includes; Ryolite Dyke, Biotite Granite, Metatexte (Banded Ortho-Gneiss, Stromatic Migmatite), Diatexite (Leucocratic Diatexite, Mesocratic Diatexite, Melanocratic Diatexite), Nebulite and Schist (Figure 5).

They were petrographically studied to contain biotite, quartz, plagioclase feldspar, alkali feldspar, hornblende, pyroxene, etc. The presence of orthopyroxenes indicates an intensed prograde metamorphism (granulite facie).

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CONCLUSION

Based on the macroscopic and microscopic studies of the study area, six distinct litho-petrological units discovered. These includes; Ryolite Dyke, Biotite Granite, Metatexite (Banded Ortho-Gneiss, Stromatic Migmatite), Diatexite (Leucocratic Diatexite, Mesocratic Diatexite, Melanocratic Diatexite), Nebulite and Schist. They were petrographically studied to contain biotite, quartz, plagioclase feldspar, alkali feldspar, hornblende, pyroxene, etc. The presence of orthopyroxenes indicates an intensed prograde metamorphism (granulite facie). The area is affected by NE/SW trending Pan-African structures being cross-cut by NW/SE trending Cretaceous trends as evident from the Rose plot. The ductile stress that affected the terrain brought about the numerous ptygmatic folds which make the area to be declared a Shear Zone.

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