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Geology and Petrology of Rocks around Rijiyar Malan, Bauchi, Northeast Nigeria.

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Abstract

The study area is part of Bauchi sheet 149SW which falls within the Basement Complex of Nigeria. The study addressed the geology and petrography of Migmatite in the study area. In this study, the area was mapped on a scale of 1:25,000. Samples were collected at the flanks of the outcrops, railway cuts, road cuts as well as blasting sites within the area. Samples were collected based on morphological variations at each sample point. The first and second order morphological classifications of migmatites as being metatexite or diatexite such as their physical criteria were used as the guiding principle. This technique was repeated for the rest of the sampling points in the area covering about sixteen (16) different locations. A total of 12 representative samples were petrographically studied, which showed the presence of the various metamorphic and rock-forming minerals which include orthopyroxene, biotite, plagioclase, quartz, microcline, and graphite as observed within the field of view under the plane- and crossed-polarized light field. Field mapping together with the morphological features, it was observed that the area indicates various migmatite morphological units, viz: Banded orthogneiss, melanocratic diatexite, mesocratic diatexite and leucocratic diatexite. The microstructures in the form of intergrowth/ boundary migration of quartz, undulose extinction, and interstitial filling of micro fractures reveal that the rocks of the area are subjected to metamorphism.

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1.0 Introduction

The rocks of this area were studied by Dada et al. (2012), Falconer (1911), Haruna (2016), and Oyawoye (1959; 1962; 1965). This present work is aimed to investigate the migmatites in the light of prograde metamorphism. The study area is located on Bauchi sheet 149S.W. which lies between longitudes 10^0 11'00'' and 10^0 15'00''North of the Equator and latitudes 09^0 34'30'' and $09^0$38'30''East of the Greenwich Meridian (Figure 1). The area is accessible through road (notably Bauchi-Jos Federal Highways) and other numerous interconnected foot paths linking all parts of the study area. The area has medium-high level outcrops (500– 680m) of Precambrian Basement rocks.

Migmatites is a Greek word which literary means “mixed rock”. It was first introduced into the geological literature in 1907 by Jakob Johannes Sederholm.

Migmatite is a result of partial melting also known as anatexis. It is divided into metatexite and diatexite; the difference between the two are the late preserved pre-anatectic structure, whereas no pre-anatectic is preserved in diatexite, which is a result of balance between the degree of partial melting and melt fraction (Tasco and Moraes, 2019). Diatexite rocks may contain light-colored minerals called leucosome or dark-colored minerals called melanosome; migmatites can also be mesosome. Terminologies such as homogeneous and inhomogeneous are used to classify parts of the diatexite rock sample where the dark and light colors are observed.

Generally, leucosome have igneous characteristics and melanosome have metamorphic characteristics (Milord et al., 2001). So many perspectives exist about the origin of the heat responsible for the partial melting such as radiogenic heating, hot geotherm, and additional heat from mafic magma in the continental margin.

Oyawoye (1959) and Oyawoye (1961) concluded that probably most of Nigeria was covered by sedimentary rocks which experienced regional metamorphism, such as quartzite, amphibolite, schist, and calc-silicate in the Precambrian period. These rocks are still found in places where is not covered by the cretaceous sedimentary (sedimentary basin).

Geology together with the petrographic studies on the rocks are fundamental to classify rock types in terms of morphological forms.

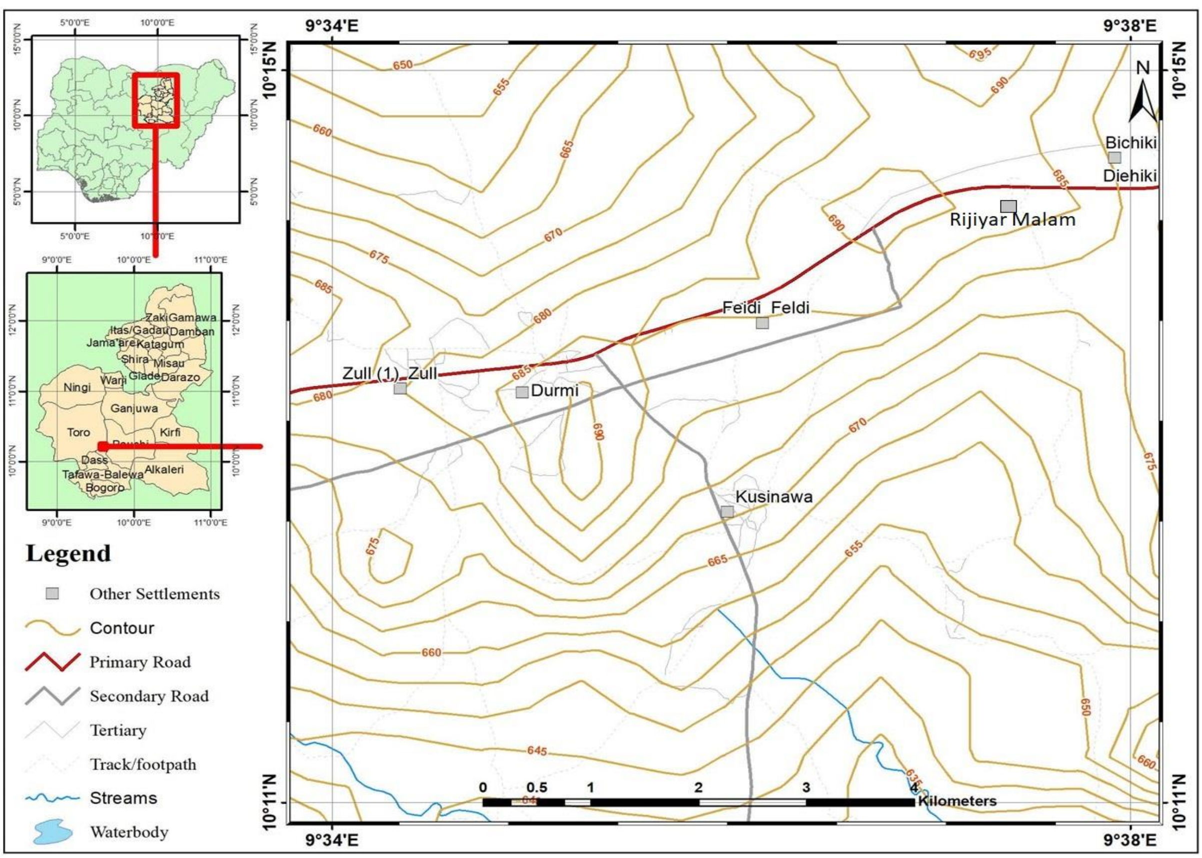

Figure 1. Topographic Map of the study Area

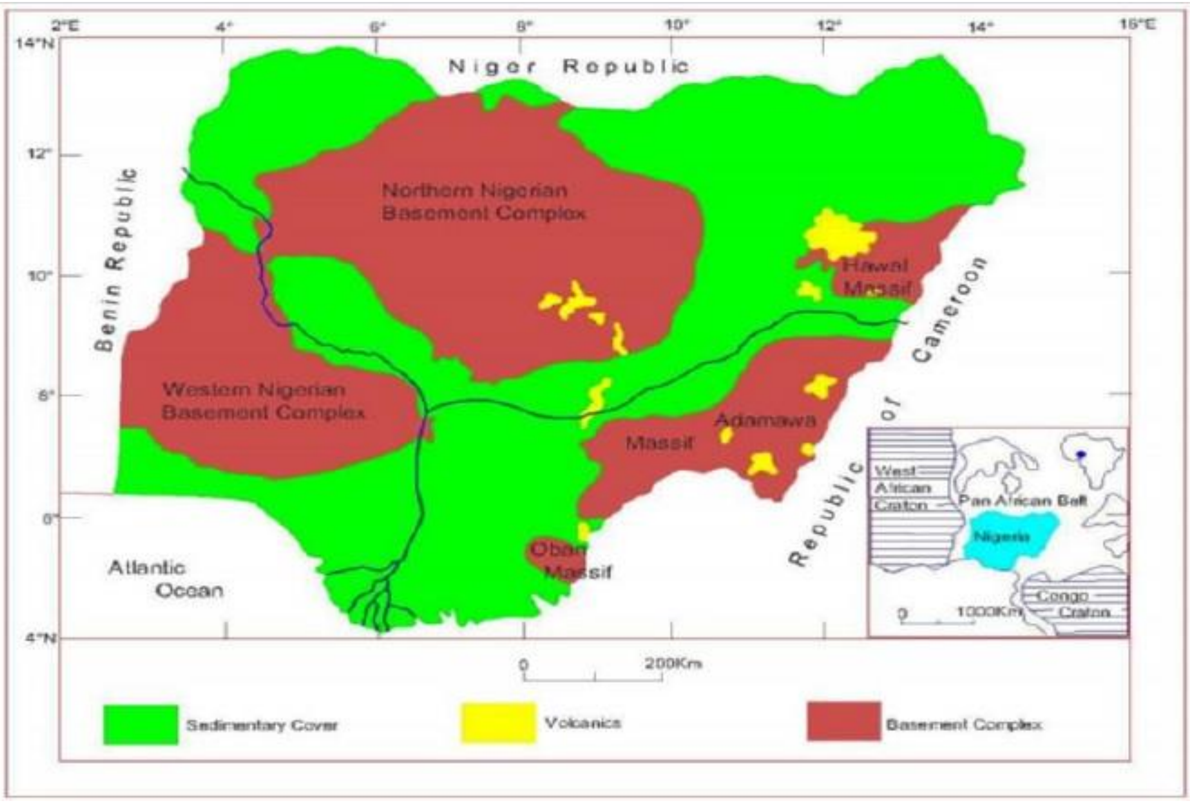

Figure.2:Generalized Geological Map of Nigeria (Haruna, 2016).

METHODOLOGY.

2.0 METHODOLOGY.

The method of mapping along profiles from one outcrop to another taking note of road and railway cuts as well as blasting sites that revealed sub-surface lithology was used in a systematic manner in the field in order to understand the geology of the area. Samples of fresh rocks units were taken at each location with coordinates, labeled using hammer, GPS and pens.

The first and second order morphological classifications of Sawyer and Hasalova *et al.* were used as the guiding principle. This technique was repeated for the rest of the sampling points in the study area covering about fifteen (16) different locations. A total of 20 samples were collected. The 16 samples collected were sorted and grouped into 4 on the basis of morphology. From the group, (12 in total) samples were picked for petrographic analyses.

Petrographic analysis involves the description of a rock sample in thin section using the optical microscope in the lab. This is more detailed than the macroscopic study, which involves looking at the rock sample with naked eye or through a hand lens to observe the color, texture, mineralogy and composition. The polished thin sections were prepared at Thin Section Laboratory of ATBU Bauchi, Nigeria from the 12 selected fresh samples for petrographic studies. The thin section of each sample was viewed in two modes the first with the analyzer out to produce or give the Plane-Polarized Light (PPL). In this mode, properties such as color, pleochroism, form, cleavage, relief and alteration could be seen. After this, the same slide this time with the analyzer produced the Cross-Polarized Light (XPL). In this mode, mineral properties such as interference colors, extinction angle, twinning and birefringence could be observed.

Hence, the best slide pictures are taken using phone camera mounted on the microscope with the aid of an adopter. The data were then compared with the results of the field mapping, presented and discussed below.

3.0 Results and Discussion

The selected samples from the field were coded thus: Melanocratic Diatexite (A1, A3), - Schlieren; Mesocratic Diatexite (B1, 2, 3); Leucocratic Diatexite (C1, 2, 6); Banded Orthogneiss (D1, 2, 3, 4). This section presents the results of the analyses which comprise the field relationship of the samples, their morphological classifications, and petrography followed by the geology of the area.

Field Relationship, Morphological Classification & Petrographic Descriptions:

Melanocratic Diatexite (A1, A3): Sample A1, and A3 were found coexisting together in the field near Durmi and Zull axis (Plate Ia). They are relatively homogeneous with no banding, medium grained texture with dark-coloured lithology (Plate I b). Morphologically, they are classified to be melanocratic diatexite – Schlieren migmatite, because of the presence of raft and schollen of paleosome (Plate II a). They are foliated with oriented biotite and plagioclase. Under microscope, samples A1 shows no relief. No cleavage, Carlsbad and albite twinning in plagioclase (Plate I d), interference colours include blue and grey which disappears as the stage is rotated (Plate 1d). The blue colour under PPL is for metamorphic muscovite. However, the brown colour remain both under PPL and XPL (Plate I b-c) signifying Orthopyroxene. Minerals of the rock include: Q = quartz P = plagioclase B = biotite M = Muscovite Opx = orthopyroxene.

While sample A3 (Plate IIc-d) under microscope shows low relief, no cleavage, no twining, grey interference colour which disappears as the stage s rotated. Miinerals of the rock are: Q = quartz F = feldspar B = biotite.

Mesocratic Diatexite (B1, B2, B3): Sample B1 and B2 covers southern part of the study area toward katsinawa axis (Fig. 3). Morphologically, the samples were classified to be mesocratic diatexite, because it undergone a textural homogenization that has destroyed the premigmatization structures (e.g., bedding and foliation) [(Plate III (a) and Plate IV (a)]. Under the microscope, all the samples show no relief, no cleavage, no twining, grey interference colour which disappears as the stage is rotated. However, the brown colour remain both under PPL and XPL. Quartz is colorless and occurs in large masses. Minerals of the rocks are: Pl= Plagioclase, Q=quartz, Bt=biotite, Kfs= K-feldspar, Opx= orthopyroxene.

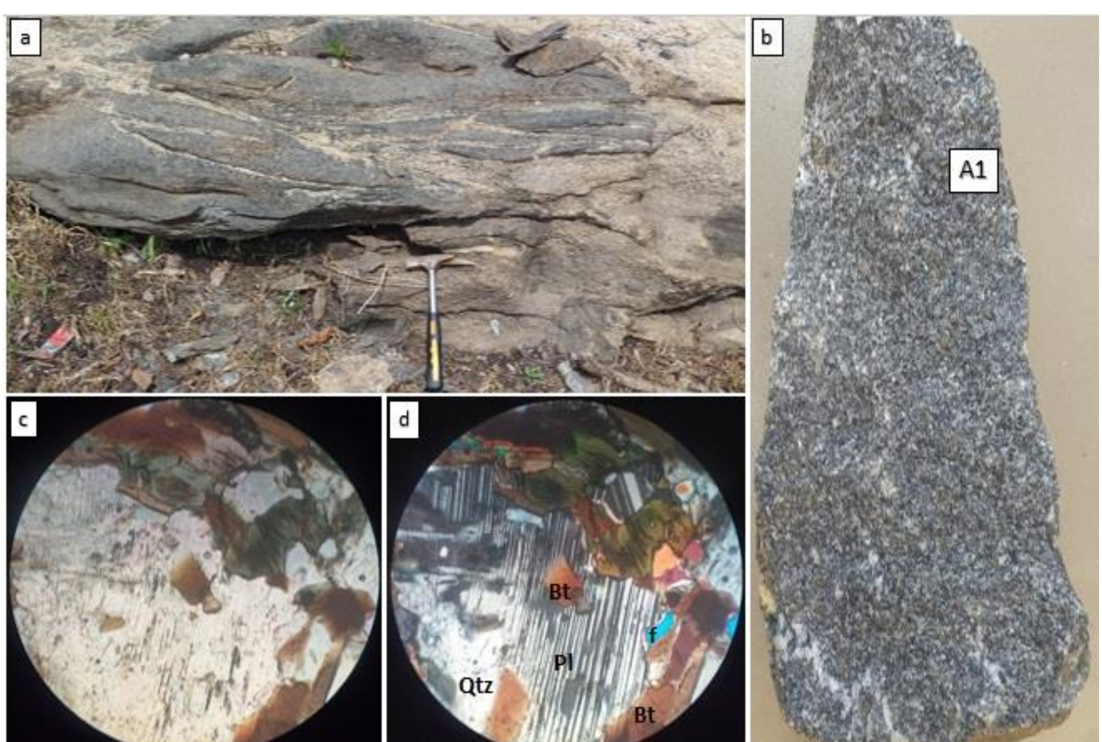

Plate I a) Field Occurrence of Melanocratic Diatexite -*Schlieren (Hammer as scale) (b) Hand Specimen of* Melanocratic Diatexite -*Schlieren (c-d) Sample A1 under Plane Polarized Light (PPL) and Crossed Polarized Light (XPL) - (magnification ×40).*

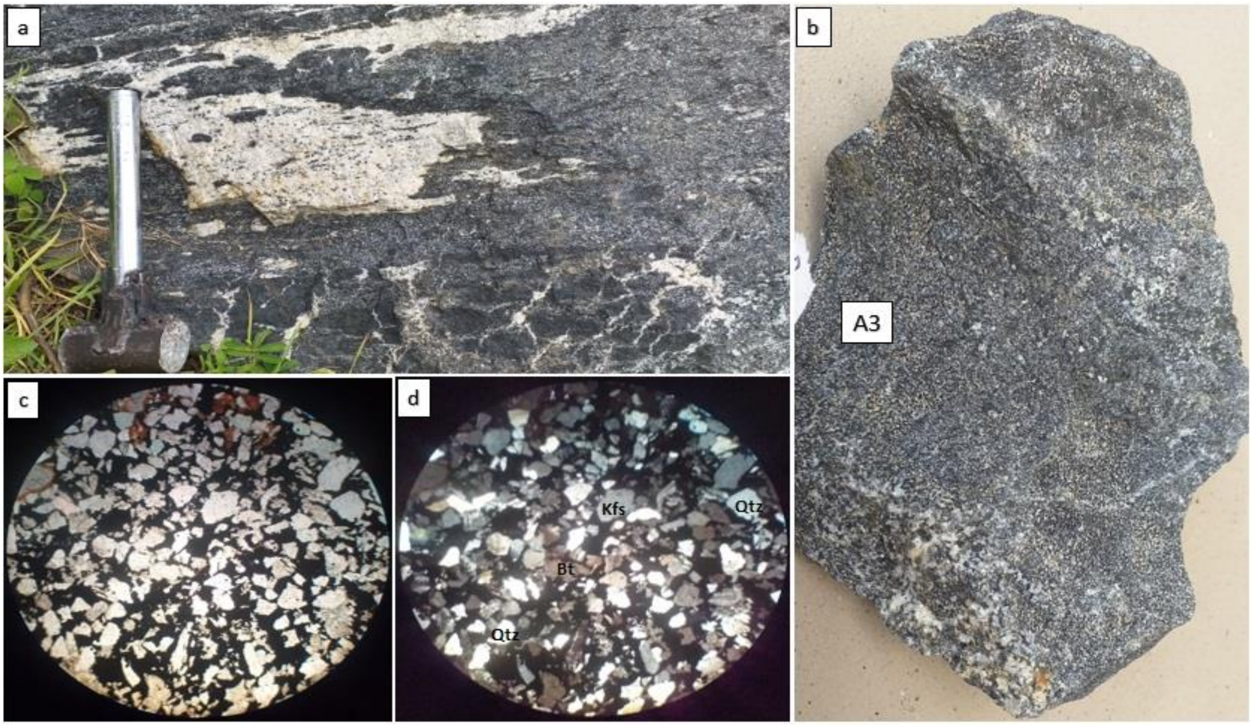

Plate II a). Field occurrence of Melanocratic Diatexite (b)Hand Specimen of Melanocratic Diatexite (c) Melanocratic Diatexite under Plane Polarized light (PPL) and crossed polarized light (XPL) - (magnification ×10).

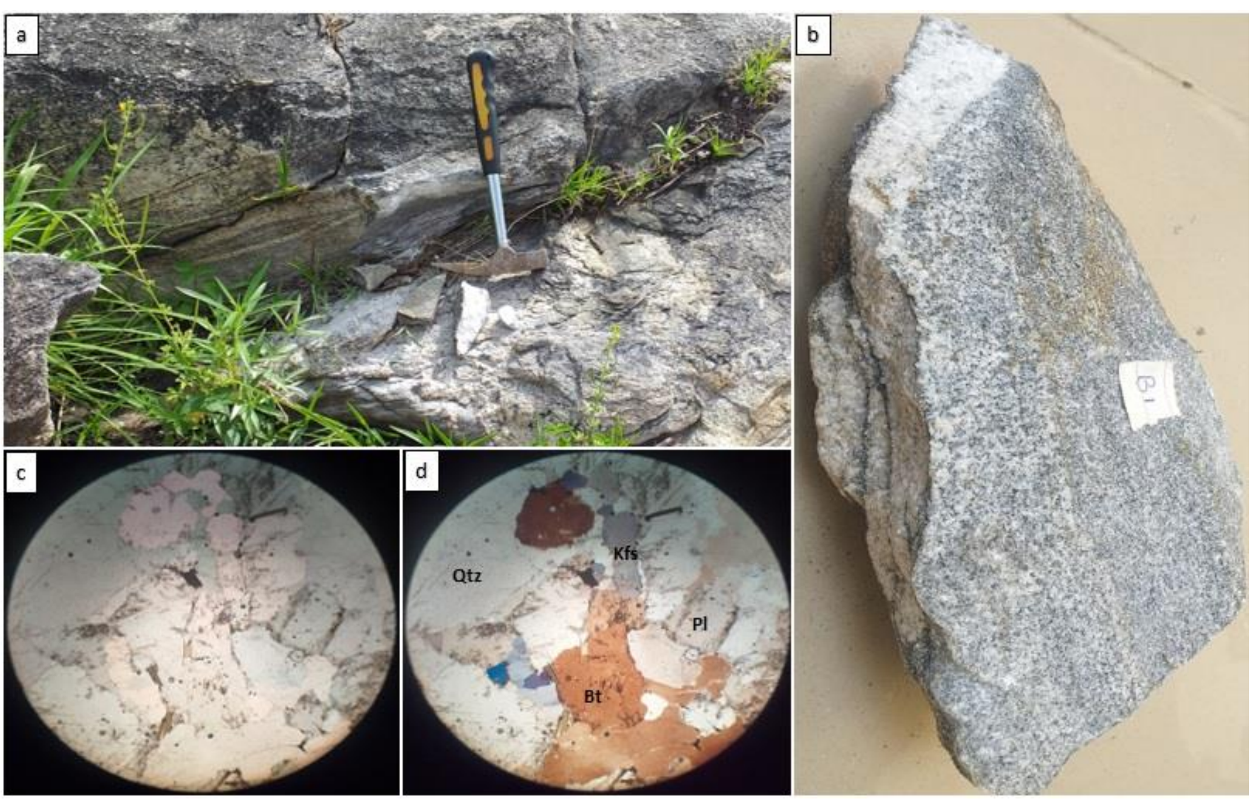

Plate III(a) Field Occurrence of Mesocratic Diatexite *(hammer is for scale) (b) Hand specimen of* Mesocratic Diatexite *(c) Sample B1 under plane polarized light (PPL) (d) under crossed polarized light (XPL) - (magnification ×40).*

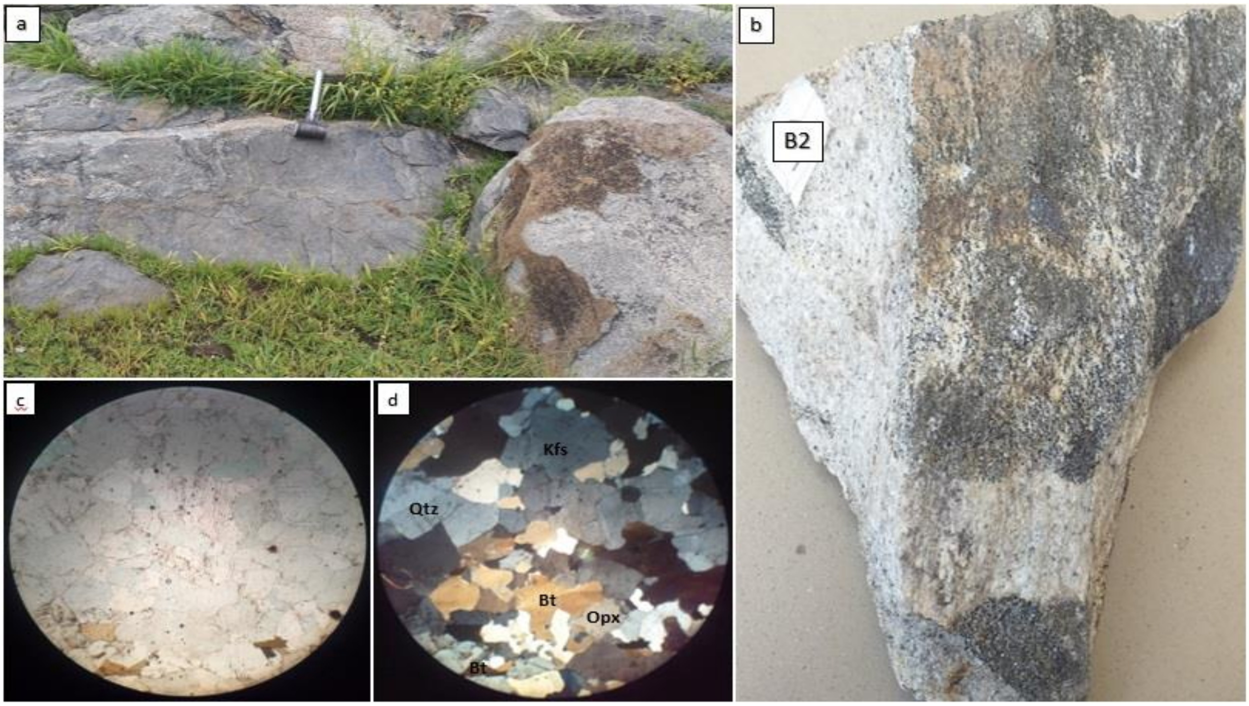

Plate IV (a) Field Occurrence of Mesocratic Diatexite *(Hammer as scale) (b) Hand Specimen B2 (c)* Mesocratic Diatexite *under plane polarized light (XPL) (d) under crossed polarized light (XPL). -Magnification 12x*

Leucocratic Diatexite (C1, C2, and C6): Sample C1 and C2 somehow cover covers the interesting part of the study area due to it varying appearance (Fig. 3). They are coarse in texture, pale-coloured body with no banding or gneissosity (Plate V (a)]. Morphologically, the samples were classified to be leucocratic diatexites because of the presence of leucosome bands found associated with the leucocratic diatexites [(Plate V (b), Plate VI (b)]. Under microscope, it shows predominantly felsic minerals, no relief, perfect cleavage in biotite and plagioclase which exhibits strong pleochroic halos, twinning, grey interference colour which disappear as the stage is rotated [(Plate VI (c-d)]. However, the brown colour remain both under PPL and XPL [(Plate VI (d)] signifying clinopyroxene. Quartz is colourless. Presence of quartz intergrowth (Myrmekite) [(Plate VI (d)]. Minerals of the rock are: Bt= Biotite, Q=quartz Pl=plagioclase.

Banded Orthogneiss (D1, & D2): Sample D1 and D2 observed as boulder exposures in field near Rijiyar Malan (Fig. 3). They are fine grained texture, and some samples retain low melt structure. Morphologically, the samples were classified to be banded orthogneiss (Plate VII a) due to presence of small volume of quartzofeldspathic veins or leucosome band developed from the hand specimen (Plate VI1a). Under the microscope (Plate VII b-c), sample D1 shows high relief, subhedral and euhedral crystals, cleavage, albite twinning (Plate VIIIc), grey interference colours which disappears as stage is rotated. However, the brown colour remains both under PPL and XPL) Plate VII b-c) signifying orthopyroxene as well as biotite. Minerals of the rocks are: Qtz=quartz, Bt=biotite, Pl=plagioclase Opx=orthopyroxene.

While sample D2 include both melanocratic and leucocratic part of metatexite [Plate VIII (a)]. Under the microscope, the sample shows high relief, cleavage, and twinning. Quartz grains exhibits undulose extinction and bulging of grains into one another XPL [Plate VIII (c-b)].

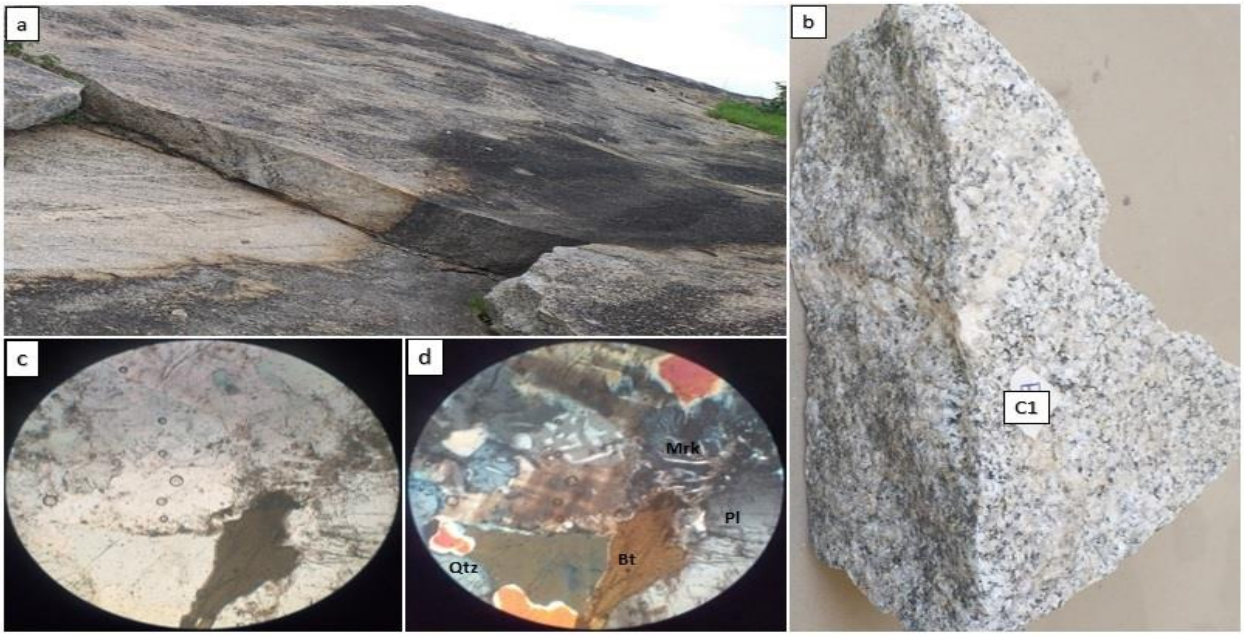

Plate V (a) Field Occurrence of Leucocratic diatexite (b) Hand specimen of Leucocratic diatexite (c) Leucocratic diatexite under plane polarized light (PPL) (d) under crossed polarized light (XPL) - (magnification ×40).

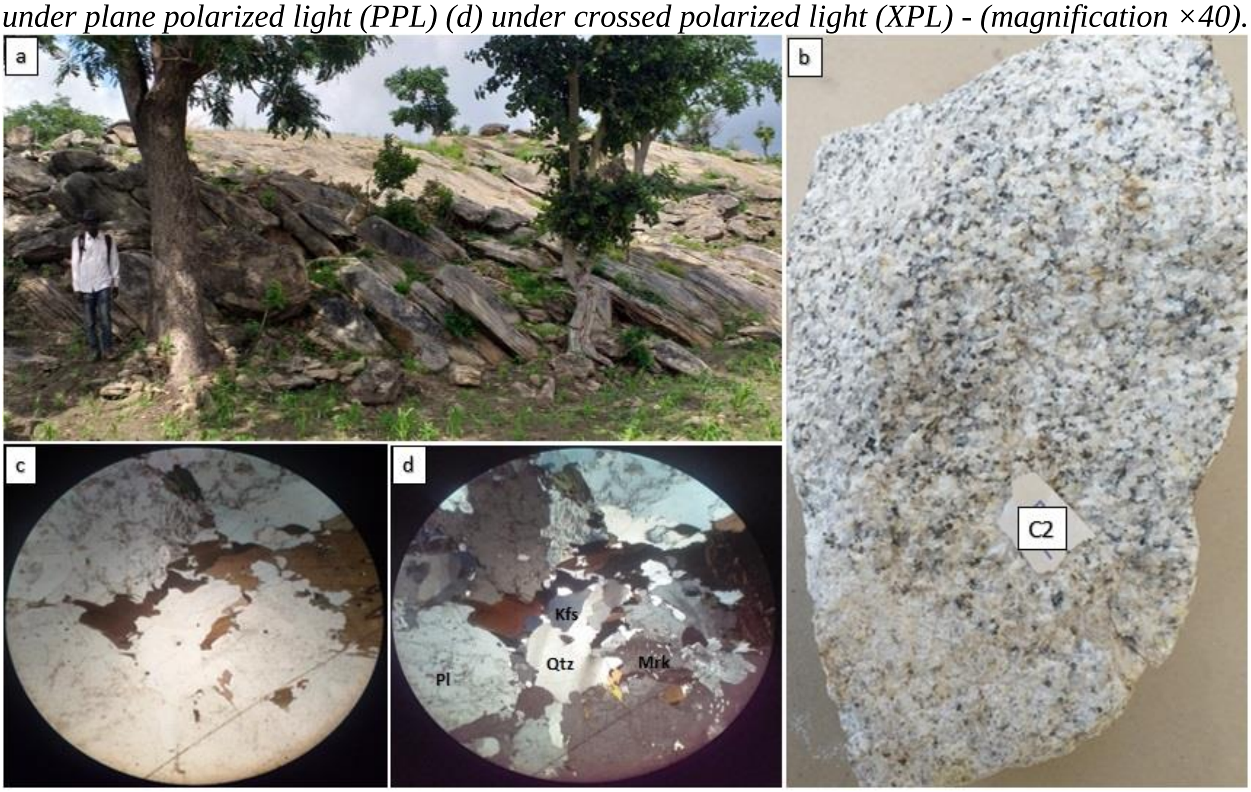

Plate VI (a) Field Occurrence of Leucocratic diatexite (b) Hand specimen of Leucocratic diatexite (c) Leucocratic diatexite under plane polarized light (PPL) (d) under crossed polarized light (XPL) - (magnification ×40).

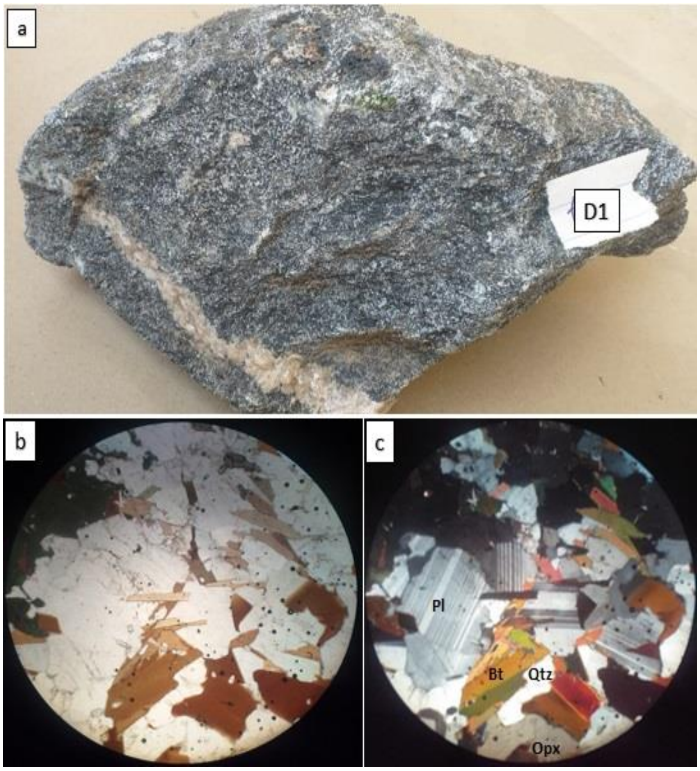

*Plate VII (a) Hand specimen of Banded orthogneiss (**b**) Banded orthogneiss under plane polarized light (PPL) (**c**) under crossed polarized light (XPL) - (magnification ×40).*

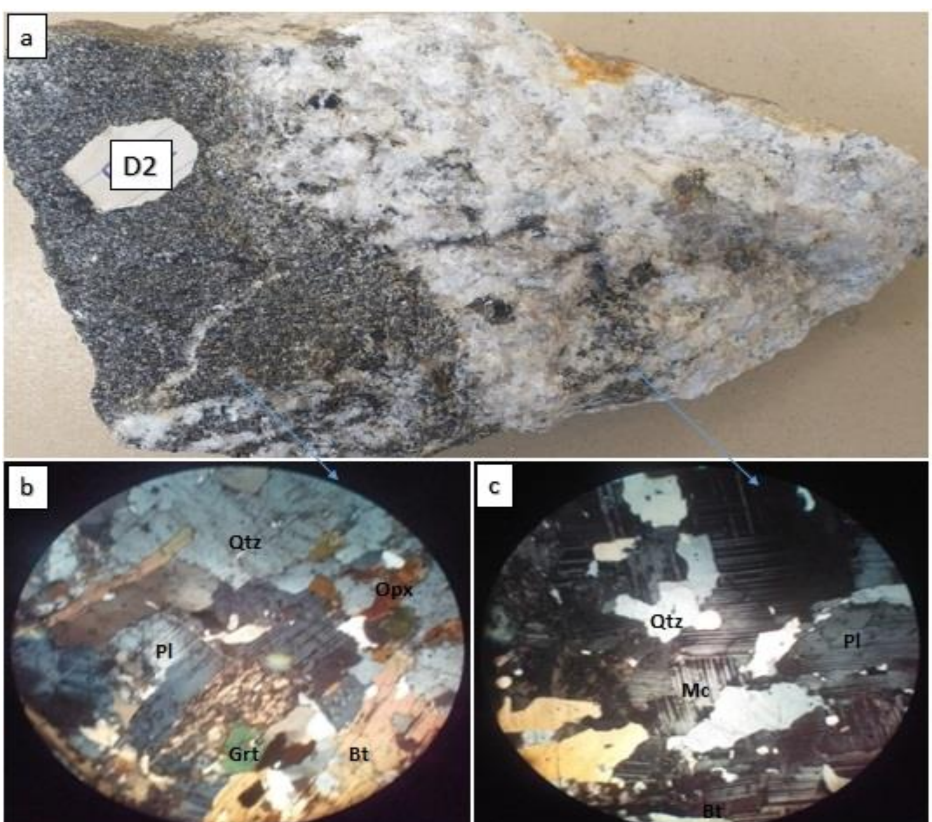

*Plate VIII (a) Hand specimen of Banded orthogneiss showing the Melanocratic and leucocratic part of metatexite (c) Banded orthogneiss under plane polarized light (PPL) (**c**) under crossed polarized light (XPL) - (magnification ×40).*

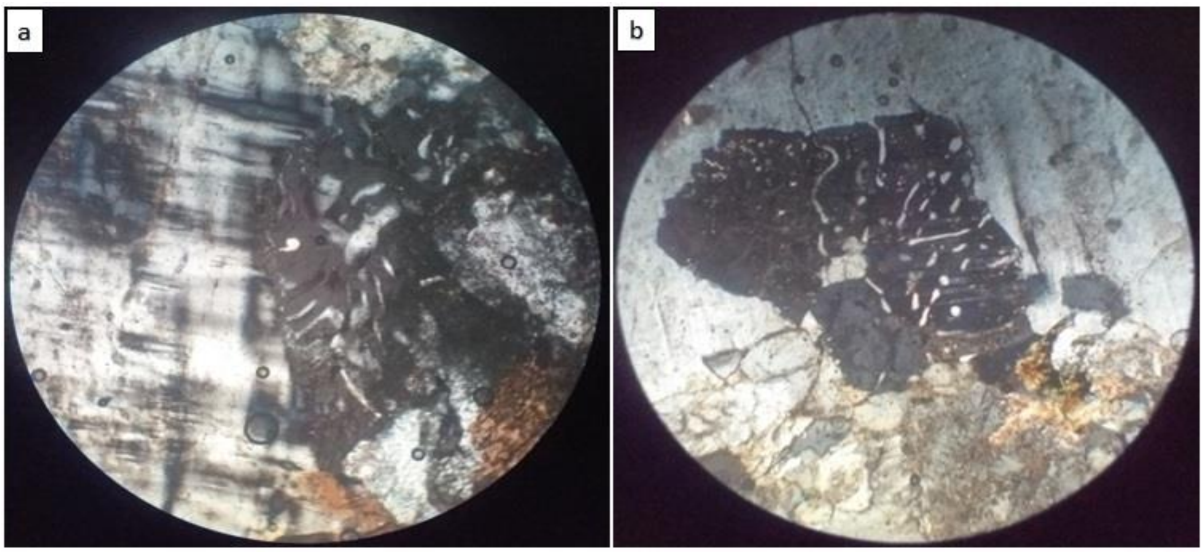

Plate IX. (a) and (b) Microstructures (arrow) leucocratic diatexite samples. Under plane-polarized light (magnification × 40).

MICROSTRUCTURE AND GEOLOGY.

Myrmekite is wormy quartz intergrowth in plagioclase, and was observed in some leucocratic diatexite samples [Plate IX (a) and (b)] (Collins, 2013). The geology of the area subdivided the morphological form of migmatite into metatexite and diatexite migmatite with banded orthogneiss in metatexite and melanocratic, mesocratic and leucocratic diatexite lithologic unit (Fig. 3). The banded orthogneiss is the oldest in age, with the rock consist properties of (protolith) rather than that of magma, and observed as boulder in the field due to the push up from inner part during the orogeny. The diatexite lithologic unit of Melanocratic, mesocratic and leucocratic are relatively younger, they undergone textural homogenization. Diatexites represents rocks with large melt fraction (Condie, 1989; Sawyer, 1998). Mehnert (1968) suggest that extensive partial melting give rise to diatexite modification. and shows a considerable range in lithology from melanocatic to mesocratic through to leucocratic diatexites. The contact between the rocks are gradational. Furthermore, all the rocks seem to have formed from one form of metasediments or the other to form the metatexite and diatexite migmatite through melting.

Discussion of the Results: Field relationship as observed has revealed that the rocks in the study area occur as migmatites (metatexites) and diatexites, based on the morphological classification of Sawyer (2008). The morphological approach subdivided the migmatite form into four (4) lithologic unit; Banded orthogneiss, Melanocratic, mesocratic and leucocratic. This section presents the discussions of the morphological and petrographic results of these rocks and they were compared with the results reported by other authors.

Morphological Features: The Schlieren – melanocratic diatexite (Plate III) has pale some as rafts and schollen. The mesocratic diatexite is intermediate in colour and it undergone a textural homogenization that has destroyed the premigmatization structures (e.g., bedding and foliation) and covers most of the katsinawa axis. [(Plate III (a) and Plate IV (a)]. The leucocratic diatexite tend to be lighter than mesocratic diatexite due to the higher silica content (Plate V, VI) and leucosome bands found associated with it. The metatexites were classified as Banded orthogneiss due to presence of small volume of quartzofeldspathic veins or leucosome band developed from it (Plate VII, VIII). They usually found as boulder exposures in field near Rijiyar Malan.

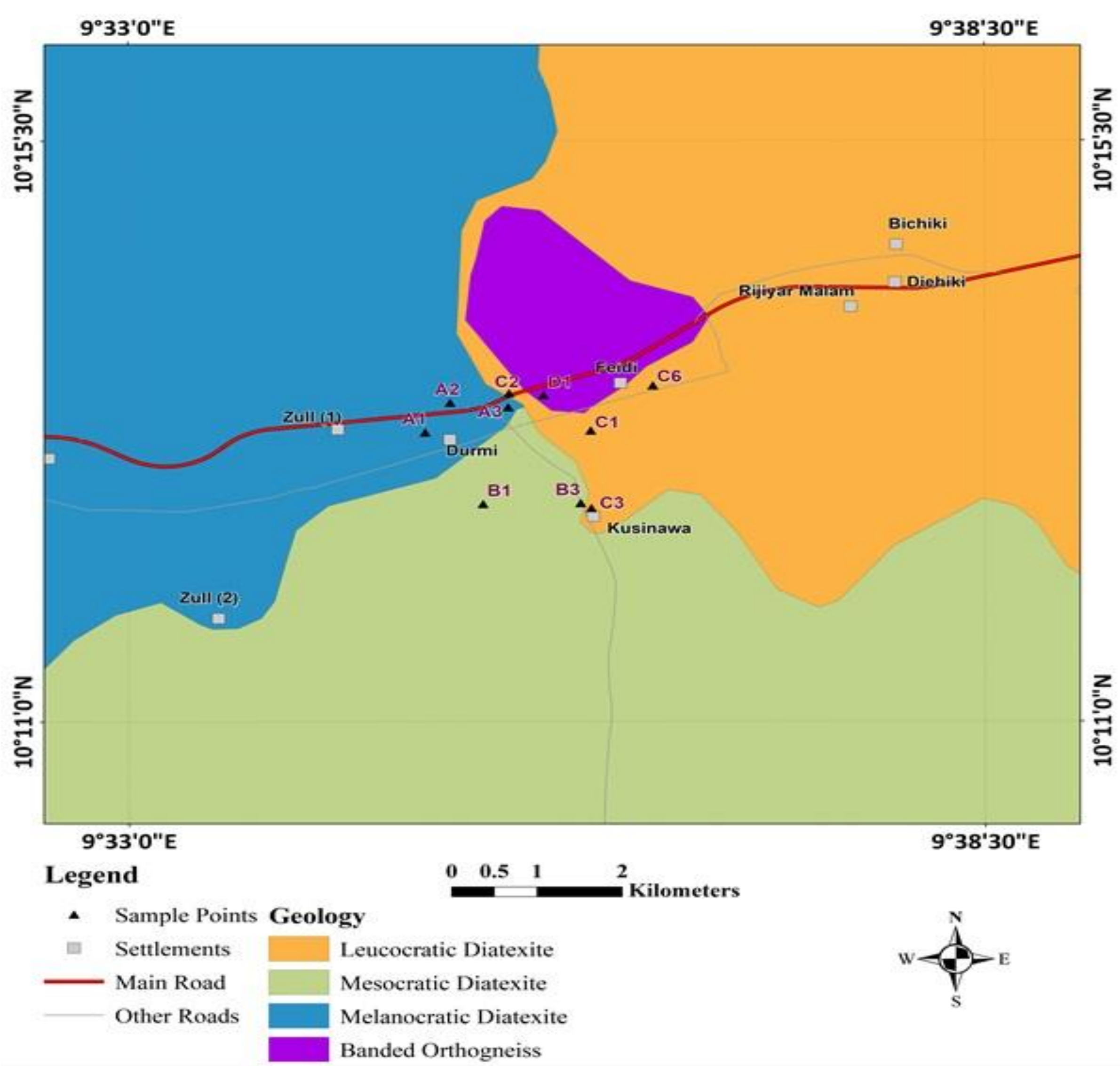

Figure. 3: Rocks found are Leucocratic ,Mesocratic, Melanocratic diatexite similar with works around the area (Babale et al., 2022; Salisu et al., 2022)

Petrographic Features: The petrology reveals the major minerals biotite, quartz and plagioclase shows well foliation indicating clearly the direction of magma flow, while the presence of accessory minerals such as pyroxenes in almost all of the samples signifies a granulite terrain. The occurrence of quartz in large grain and irregular shape in diatexite sample indicating grain boundary migration. The twinning in leucocratic diatexite slide is for albite which shows some sign of deformation or strain, while Most of the twinings in the petrographic slides are for either Labradorite or Bytownite. This is further confirmed by the presence of the pyroxenes which only exist at same temperature with either of the two. The residual plagioclase in restate are more of calcic except the one in a partial melt which is much more sodic, The graphite occur as opaque minerals (CO2) sourced both from the mantle and at the surface from the existing carbonates since we are dealing with a collisional zone where the rocks were sedimentary n origin. The CO2 heats up the system (carbonic dehydration (Clemens, ND)) enough to form very coarse grain through metamorphic process. II. Y Tan et al (2020) suggest CO2 (Graphite) can be aids in supplying the temperature needed for the exceptional coarse grained features through rapid cooling. The fractures connecting the opaque minerals signifies penetration of the CO2 and their orientation in same direction means the stress was regional stress not magmatic.

Microstructure: Myrmekite was observed in leucocratic diatexite samples (Plate IX). But interestingly, When plotted on feldspar diagram, the leucocratic diatexite sample moves towards albite (sodic), and can be of igneous type because it seems to have more sodic than calcic plagioclase, almost entirely albite which exists with biotite on Bowen's Series. The occurrence of this is an indication of somewhat metasomatism in conjunction with tectonic deformations. These distinctions have not been made by the previous authors.

CONCLUSION.

The aim of this research which is to study the Geology and petrology of migmatite in the light of prograde metamorphism has been achieved. From the field and laboratory results, the following conclusions were made:

(i) Migmatite crystalized from the metasediments. This was evident in their field occurrence as indication of reduced melt.

(ii) Migmatite were morphologicaly subdivide into four lithologic unit based on their physical criteria; Banded Orthogneiss, Melanocratic diatexite(Schlieren), Mesocratic diatexite and leucocratic diatexite respectively.

(iii) Biotite and quartz are mineral constituents of the rock, and the petrographical studies of various mineral assemblages of different morphological units indicate that the grade of metamorphism increases from metatexites, which is indicated by preferred elongation of biotite and abundance of orthopyroxenes, to diatexites, which is indicated by the general coarsening of quartz grain size. The contact between the rocks is gradational.

(iv) Partial melting is identified as the mechanism responsible for the melt differentiation and metasomatism in some places as evident by the presence of Myrmekite.

Recommendation

Based on the results obtained from the field and laboratory analyses carried out, the following recommendations are made:

i. It is clear that there was never a time when there was a pool of magma. Hence, detailed study into the origin, migration and deposition of the magma that formed these rocks of variable compositions should be carried out.

ii. Further study into the economic potentials of the area should be carried out as some of the samples show normative precious minerals (zircon, corundum, and rutile).

iii. Zircon saturation temperature study should be carried out as almost all the samples contain this element. This will facilitate the determination of the actual temperature of crystallization of the various rock units.

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REFERENCES.

Babale, S. I., Harauna, A. I., Aminu, M. B., & Salisu, S. M. (2022). *Science Forum (Journal of Pure and Applied Sciences). 22*, 422–431.

Bain, A. D. N (1926). The geology of Bauchi town and surroundin district. *Geological Survey of Niigeria Bulletiin, 9, 38-67.*

Collins, L. G. (2013). *Origin of myrmekite as it relates to K- , Na- , and Ca-metasomatism and the metasomatic origin of some granite masses where myrmekite occurs* . 1–137.

Dada SS. (2006). Akin Jinad & Co. Ibadan. In *Proterozoic evolution of Nigeria. In: Oshi O (ed) The basement complex of Nigeria and its mineral resources*.

Dada OA, Ashanu EC, Iyakwari S (2012). On the chemistry and geochemistry of amphiboles of Charnokite from Bauchi and Saminaka, Northcentral Nigeria: Genetic Implications. Int J Basic Appl Chem Sci 2012; 2(3):38-47.

Falconer DJ (1911).*The geology and geography of Northern Nigeria*. Macmillan, London, UK.

Haruna, I. V. (2016). *Lithology and Field Relationships of the Granitoids of Bauchi District , Northeastern Nigeria*. *4*(6), 31–40.

Hasalová, P., Janou, V., Schulmann, K., Š, P., & Erban, V. (2008). *From orthogneiss to migmatite : Geochemical assessment of the melt infiltration model in the Gföhl Unit (Moldanubian Zone , Bohemian Massif). 102,* 508–537. https://doi.org/10.1016/j.lithos.2007.07.021

Mehnert, K.R. (1968): Migmatites and the Origin of Granitic Rocks. Developments in Petro- Logy 1. Elsevier, Amsterdam. 393.

Milord I, Sawyer EW, Brown M (2001). Formation of diatexite migmatite and granite magma during anatexis of semi-pelitic metasedimentary rocks: an example from St. Malo, France J Petrol; 42(3):487–505; doi:10.1093/petrology/42.3.487.

Oyawoye, M. O. (1959). The petrology of the older granites around Bauchi. Nigeria (Doctoral dissertation,Durham University.

Oyawoye MO (1961). On an occurrence of fayalite quartz-monzonite in the basement complex around Bauchi, Northern Nigeria. Geol Mag: 98(6):473-82

Oyawoye, M. O. (1965). Bauchite: a new variety in the quartz monzonitic series. *Nature,* 205(4972), 689-689.

Salisu, S. M., Haruna, A. I., Halilu, M., Abdullahi, F., & Ahmad, T. G. (2022). *Morphological Studies and Petrogenetic Relationship of Metatexite Cum Diatexite Migmatites Around Buzaye Area , Bauchi , Nigeria*. *3*(2021), 380–394.

Sawyer, E. W., M. B. (2008). *Working with Migmatites* (illustrate). Mineralogical Association of canada, 2008.

Tanko I.Y, Jatau B.S, Usman H.O (2020). Petrography, geochemistry and mineralization Potential of the pegmatite of Janjala area, North central Nigeria. J Min. Sci: Vol.8: 34-51.

Tasco L. H, Moraes R. Evaluation of the contributions of possible sources to the leucosome of the diatexite of Socorro-Guaxupé Nappe, in the Alfenas Region, MG, Brazil. Brazil J Geol49:1–12; doi: 10.1590/2317-4889201920180066.

Yahuza, I.; Maigari, A. S. and Isah, B. (2018). Geology and Groundwater Potentials of a Basement-Sedimentary Boundary of Masur Area of Bauchi State, North - East Ngeria. *Journal of Applied Geology and Geophysics, 6(6),* 23–32. https://doi.org/10.9790/0990-060 6022332