The Geology of Migmatite Rocks of Miya and Environs, Ganjuwa L. G. A., Bauchi State, Northeastern, Nigeria

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Abstract

The geology of migmatite rocks of Miya and environs, Ganjuwa L.G.A., Bauchi state Northeastern Nigeria was found to be one of the Northern Nigerian basement complex that was affected by Pan African Orogeny and series of metamorphic circles. The study area was underlain by granulite metamorphic facie rocks with schlieren, diatexite and nebulite migmatite as the major rock types. The main aim of this research work was to identified rock types underlying the study area through systematic field mapping and sampling. The field work carried out revealed that the rocks were migmatite that were affected by Pan African shear stress which causes deformations and structural dispositions where some rocks were affected and tilted to almost 89^{o} and the rocks were found to be prograding from schlieren-diatexite-cum nebulite migmatites. The nebulite reaches the peak of prograde metamorphism forming charnockite (bauchite), in some places quartz diorite and granulitic granulite were found as extract or pockets (i.e. when the magma contain excess silica it has to be exsolved/remove from the system before a charnockite (bauchite) will be form). Petrographic studies reveal that the migmatites contained quartz, biotite, plagioclase, orthoclase feldspars, orthopyroxene, olivine, sillimanite, cordierite, garnet and opaque minerals under cross polarized light. Myrmikite intergrowth and sericitization process and evidence of grain scale fluid migrations were also seen in some slides. The research come up with the conclusions that the area was underlain by schlieren, diatexite, nebulite migmatites and tin, lithium, monazite mineralization was inferred.

Keywords: *Migmatite, Orogeny, Structural disposition, Prograde metamorphism, Exsolved, Petrography, Mineralization.*

1. INTRODUCTION

The study of migmatite rocks is of prime importance in the context of nowadays proliferations of various economic mineral found within the migmatite rock, despite the fact that the information on Nigerian migmatite gneiss is relatively scanty probably because of its structural complexity, polycyclic nature and nontangible economic mineralization was related to the migmatite in most of the previous literatures. The study area lies within the northern Nigerian basement complex which was underlain by granulite facies metamorphic rocks that were subjected to series of Pan African shear stresses where exhumation process exposes series of gradations and deformations within the migmatite rocks and sporadic occurrences of the charcockites with younger granite to the northeastern and northern area respectively. Even though migmatite forms an integral part of the basement complex of Nigeria, its origin has generated much debate among scholars, some authors believed it is of sedimentary origin while others believed it is igneous. So also, some authors relate it to Eburnean (Rahaman and Lancelot, 1984) while some to Pan Africa in age (Ferre 2006, Tubosun 1983). Dietrich and Mehnert, (1961) they described migmatite by terminologies having inconsistent nomenclature. Oluyide *et al.*, (1998); Dada, (2006) believed the Pan-African tectonothermal event had homogenized all basement rocks while the combined effects of metasomatism, dynamic metamorphism, migmatization and magmatism produced the various rock types based on their original compositions. Migmatite-gneiss underlies several localities in Northeastern Nigeria.

1.2 Location and Accessibility

The Study area covers between latitude 10˚ 48′ 00″N to 10˚ 59′ 00″N and longitude 09˚ 36′ 00″E to 10˚ 02′ 00″E, sheet 29 Ganjuwa NW figure 1. The area is easily accessible although by foot, motor bike and some parts by motor vehicle. The study area is bounded by Bayama, Kariya-Wudufa, Tsagu, Burku and Dela towns to the northeast, Zara, Kurbulli, Jimbim, Baya towns to the southeast, Kafin Madaki, Kwanan Labi and Kafin Liman towns, to the south, Ringim, Wushi and Filin Shagari towns to the west, Kariya, Miya, Natsira towns to the center and to the northwest towns are; Gadar Maiwa, Bunga and Gasinan Kawari towns.

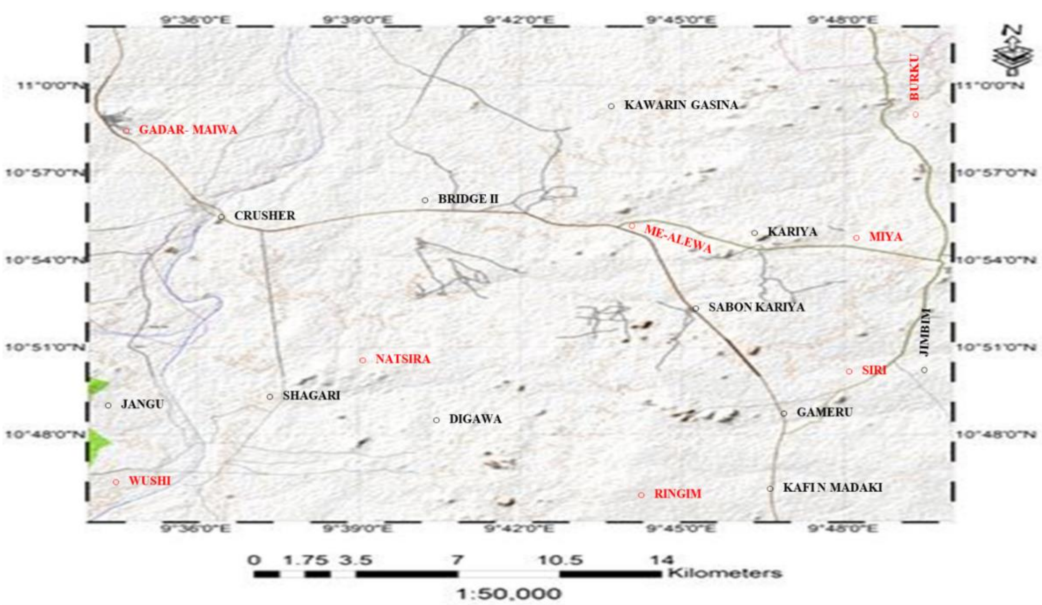


Figure 1. location map of the study area.

1.3 Topography

The topography of the study area ranges from low, medium and high level outcrops. Most especially in areas where diatexite and nebulite were exposed have higher elevations. The level of emplacement of rocks in the study area gives a kind of gentle slope towards northwestern part of the study area. During the field work the banded orthogniesses was found to be low level outcrop usually along stream channels and highly depressed areas, then followed by straumatic migmatites and schlieren cum-nebulitic migmatite have the higher elevation all over the area mapped figure 2.

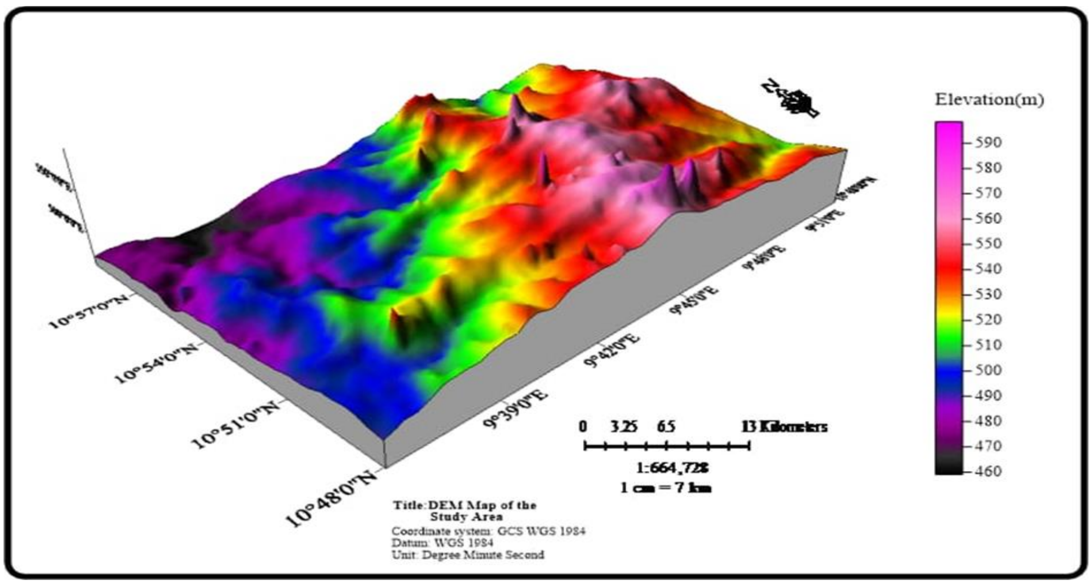


Figure 2. Digital Elevation Map of the study area

2.0 REGIONAL GEOLOGIC SETTINGS

The basement complex of Nigeria forms part of the Pan-African mobile belt (Ferré, *et al.*, 2002; Adetunji *et al.*, 2016). Precisely, the West African Craton has been affected by several orogenic episodes between 3.57 Ga and 600 ± 150 Ma. It is the part of the Benino-Nigeria shield (Dahomeyide fold or orogenic belt) which extends westward and continues to Benin-Togo and to the east to Cameroun with younger crystalline rocks and sedimentary cover in some areas (Fig. 3). The belt was originally believed to be product of collision between active Pharusia shield and passive West African Craton with westward subduction leading to oblique docking of the terrane near the east margin of the Craton (Caby 1989).

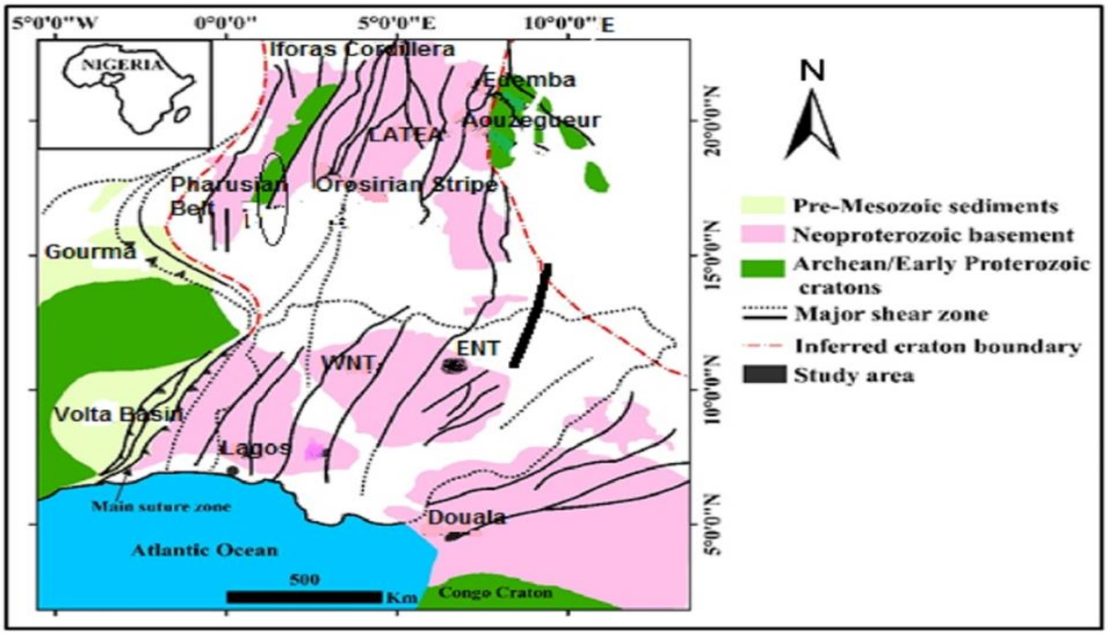


Figure 3: Regional geological map showing the study area in relation to Pan-African mobile belt and the cratons (modified Caby 1989; Black et al. 1994, Liegeois et al. 1994, Ferré et al. 1996 and Ferre et al. 2002). WNT western Nigeria terrane, ENT eastern Nigeria terranes

The Nigerian basement complex rocks comprise suites of migmatite gneiss complexes, schist belts, older granites, younger granites and volcanics. These are the major litho-petrological components that make up the geology of Nigerian Basement complex (Fig.4) and is unconformably overlain by Cretaceous and younger sediments Obaje (2009). On the basis of an assessment of available Rb-Sr and K-Ar ages on mobile belts formed in Africa *500* Ma ago the term 'Pan-African' was coined by WQ Kennedy in 1964 (Kroner and Stern 2005).

The Nigerian basement complex forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons (Fig. 5) and south of the Tuareg Shield (Black, 1980). The eastern part of the belt consists of a high-grade granite gneiss terrain of the Nigerian province partly consisting of Paleoproterozoic rocks which were migmatised at 600 Ma. This deformation and metamorphism were considered to have resulted from oblique collision of the Nigerian shield with the West African Craton followed by anatectic doming and wrench faulting (Kroner and Stern, 2005).

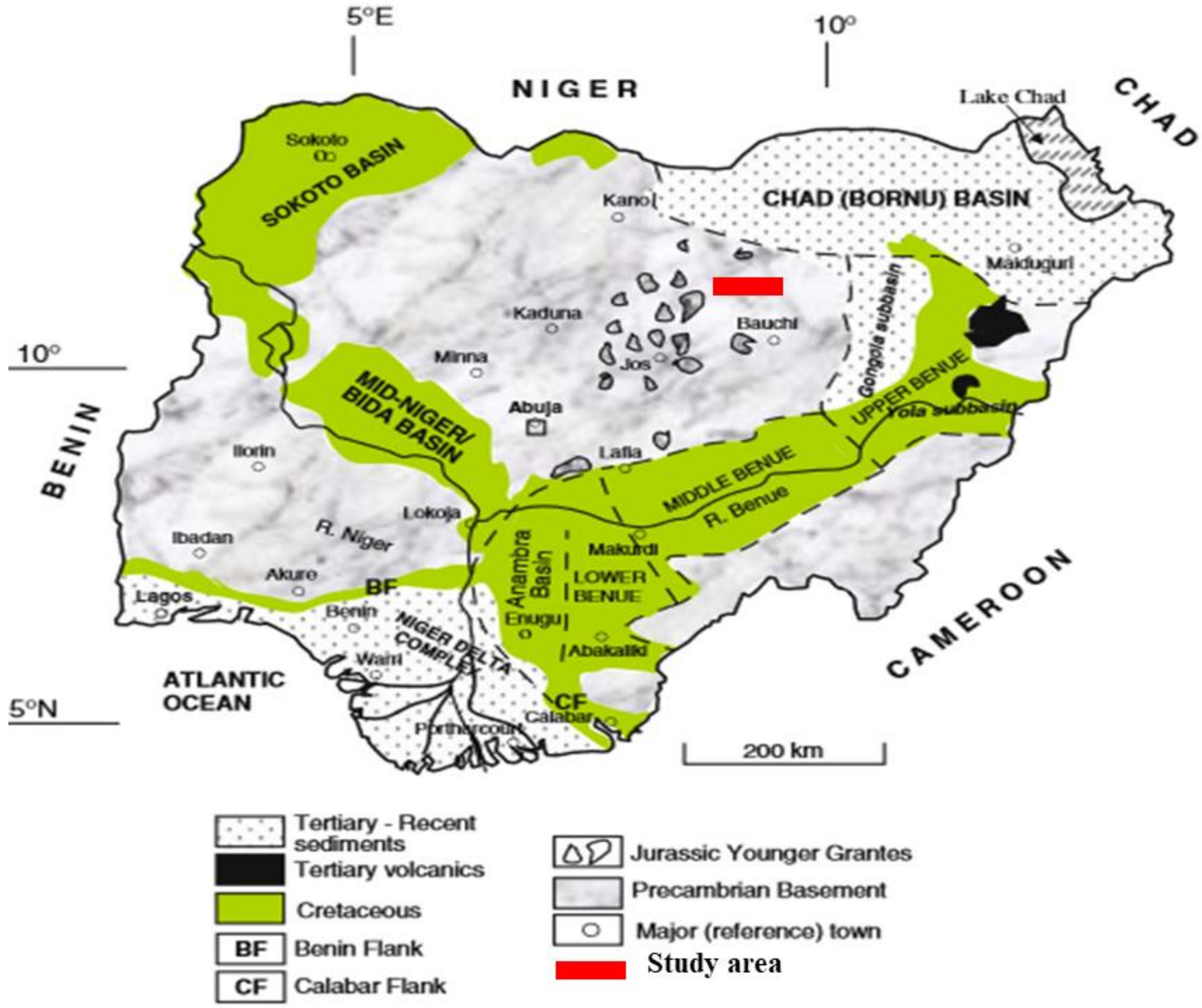


Figure 4: Map of Nigeria showing rock types (Obaje 2009)

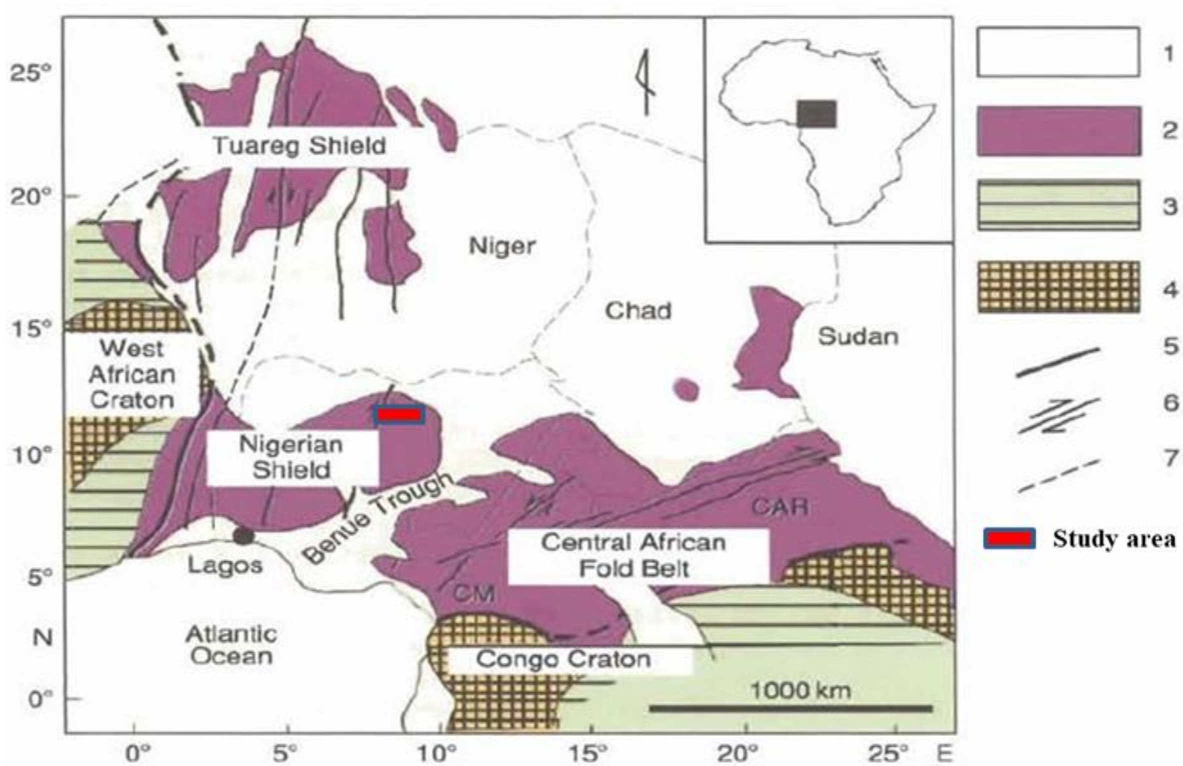


Figure 5: A Sketch map showing Pan-African domains in West Central Africa. 1. Post-Pan-African Cover 2. Pan-African domains 3. Pre-Mesozoic platform deposits 4. Archaean to Paleoproterozoic Cratons 5. Craton limits 6. Major strike-slip faults 7. State boundaries. CAR: Central African Republic CM: Cameroun. Adapted from Kroner and Stern (2005).

2.1 The Migmatite/Gneiss

According to Oyawoye (1965), He grouped the migmatites into two types, namely; the lit-par-lit gneiss and the migmatitic gneiss. In the lit-par-lit gneiss, according to Oyawoye (1965) the Paleosome (a granulite or high-grade schist of the ancient metasediment) occurs with quartz-feldspar veins and dykes in parallel orientation. In the migmatitic gneiss, the paleosome also is quartz-microcline veins but, the melanosome which is biotite or banded gneiss, is dissected into irregular blocks.

Ferre' 2006, reported the occurrences of granulite facies rocks and anatexites within high-temperature amphibolites facies rocks along Bauchi- Toro axis. This area exposes high-grade metamorphic rocks of contrasted character depending on their distance from Neoproterozoic monzonitic plutons. In this area a medium to high pressure and temperature amphibolite and granulite facies have been recognized in different localities with the formation of orthopyroxene-bearing tonalitic-dioritic leucosomes, garnet-bearing and the emplacement of charnockitic-monzonitic plutons (fig. 6).

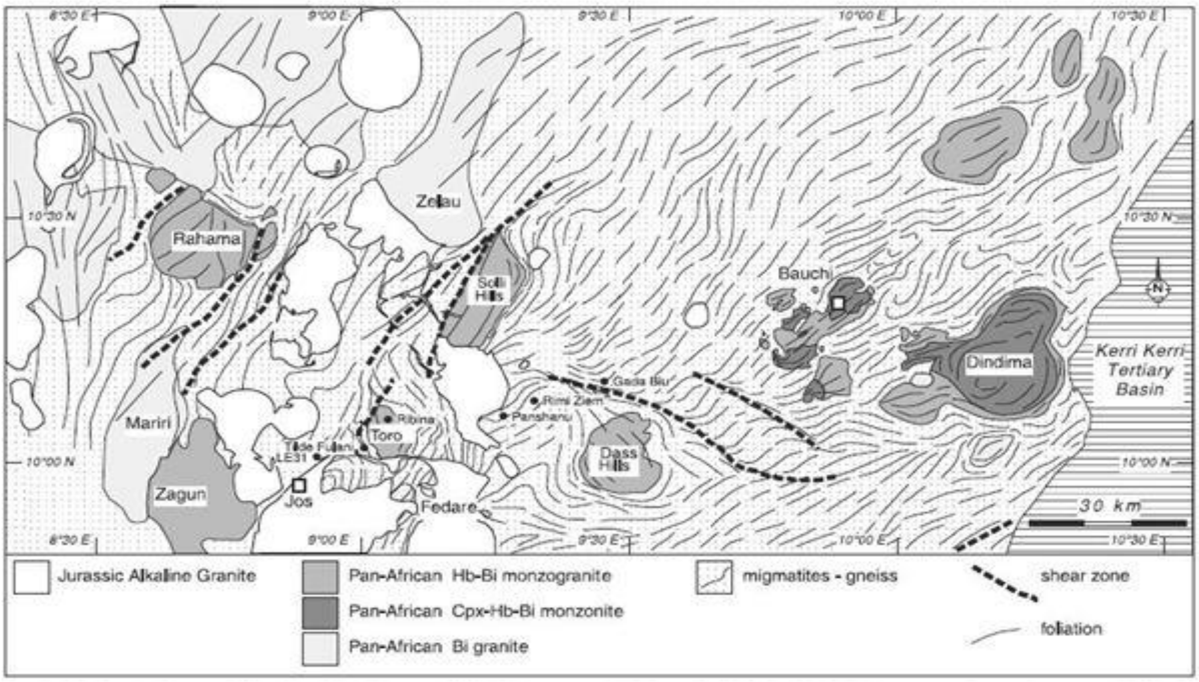


Figure 6: Geological map of the Jos–Bauchi area. (Adapted from Ferre' 2006).

2.2 The Older Granites

The granitoids of Bauchi district was first investigated by Falconer (1911) and later by Bain (1926); Oyawoye (1959); Ferre' (2006) and Haruna (2016). To differentiate them from the Plateau granite ring intrusions known as the younger granites the gneisses, granites, granodiorites, diorites and migmatites in this complex were collectively called older granites by Falconer (1911).

The review of Cooray (1974) further came up with another family of rocks (the intrusive) to the works of Oyawoye (1965) and further effected some changes in the conclusions of Oyawoye (1965) as follows:

(a) That the older granites and related charnockitic rocks are of intrusive rather than metasomatic origin.

(b) The older granites and granodiorites based on the relative time of emplacements and deformation are subdivided into; syn-tectonic microcline-megacrystic, partly foliated granites, late- tectonic, less richly megacrystic, weakly foliated xenolithic granites and granodiorites with cross-cutting contacts and occasional thermal aureoles (McCurry and Wright, 1977; Jones and Hockey, 1964).

(c) The general north-south to northeast-southwest (N-S, NE-SW) structural pattern in the basement complex suggest a polyphase metamorphism that affected the basement complex rocks, and the complex bears the imprints of at least, three plutonic events during the Eburnean, Kibaran and the Pan-African orogenic episodes (Grant, 1978).

The biotite-hornblende granite is strongly lineated striking about S220°W together with diorite were separated by the fayalite-quartz monzonite, except in the North West (NW), where it turns east-west. Generally, this lineation is concordant with that of the surrounding gneisses. The general foliation is north east-south west (NE-SW) but, local variations occur (Oyawoye, 1959).

2.3 Charnockites (Bauchite)

In Bauchi area and some parts of southwestern Nigeria most of the Older Granite rocks occur as dark, greenish-grey granites with significant quantities of olivine (fayalite) and pyroxene occurring with quartz, feldspars and micas. For this unusual composition, the Older Granites in these areas are termed Bauchite (in Bauchi area) and Oyawoyites (after Oyawoye who first mapped them in 1965) in southwestern Nigeria. Both the Bauchites and Oyawoyites constitute the charnockitic rocks (Charnockites) of the Basement Complex (Obaje 2009).

According to Dada (1989), it was at Toro that charnockite was first described within the Nigerian basement by Falconer (1911) where it was then referred to as a "quartz diorite porphyrite". It was assumed to present a certain affinity with the basic members of the charnockitic series of the Ivory Coast. Wright (1970) described it as an annular complex of hypersthene diorite at the centre of three circular concentric granites. He considered the hypersthene diorite as older than the granites from contact relations. Cooray (1975) in his review of charnockitic rocks of Nigeria came to the same conclusion, using for argument the presence of granitic veins in the diorite, of dioritic xenoliths in granites and microcline porphyroblasts in the diorite. A field study of the same hybrid rocks led Rahaman (1981) to consider both the granites and the charnockites as either contemporaneous or the latter emplaced shortly after the former. The basement in Toro area consists of gneisses and migmatites into which the Toro Charnockitic Complex intruded (Dada et al., 1989); Older Granites and charnockites which constitute the complex proper and undeformed basic (doloritic) dykes considered to be later than the Pan-African Granites.

2.4 The younger granite

The Mesozoic younger granite ring complexes of Nigeria form part of a wider province of alkaline anorogenic magmatism. They occur in a zone 200 km wide and 1,600 km long extending from northern Niger to south central Nigeria. Rb/Sr whole rock dating indicates that the oldest complex of Adrar Bous in the north of Niger is Ordovician in age, with progressively younger ages southwards. The most southerly ring complex of Afu is Late Jurassic in age (Bowden *et al.*, 1976). Aeromagnetic anomalies suggest that a series of buried NE–SW lineaments of incipient rifts controlled the disposition of the individual complexes (Ajakaiye, 1983).

3.0 MATERILAS AND METHODS

3.1 Materials

The materials used during the field work include the following; Topo map of the study area was used to demarcate the area of interest and all possible features were noted. Global Positioning System (GPS) for taking the coordinates, masking tape for rapping the collected samples, marker for proper labeling, field note book for recording the information collected from the field, sampling hammer for collection of samples, sampling bags for packaging the samples, compass clinometer for measuring the attitude readings, biros for writing, measuring tape for acquiring the different sizes of structures encountered during the field work within the study area and safety boot for easy traversing of the area without fear of any danger.

Plate 1: Materials used.

3.2 Methods: Two (2) methods were used for the purpose of this research work. These methods are the field and laboratory works.

3.2.1 Field work method: The field work started with reconnaissance field work by traversing the study area and relating the information acquired during desk study in order to identify the gaps within the study area, followed by detailed field mapping, in which sixty-six (66) rock samples were collected at different strategic locations of outcrops and also, attitude readings were measured and recorded.

The sixty-six (66) rock samples collected based on morphological forms (texture, structures and colour) were grouped into twelve (12) and 35 representative samples were sorted and selected for further laboratory studies.

3.2.2 Laboratory studies method

The laboratory work was petrographic (thin section) analysis method using rock cutting and polishing machine. Ten (10) selected samples were used for petrographic analysis. The rock samples were cut to a reasonable small size, placed on glass slide using araldite, the samples were placed on hot plate for about 2-5 minutes and forceps was used to remove air bubbles then the samples were allowed to cool for 5-10-minute clamp the slide and gradually polished it using carborundum power, while observing under the petrographic microscope. The thinned glass slide was taken to the hot plate and scrapped to the size of the cover slip. Canada balsam was used to gum the glass slide, then keep to dry for two (2) days and later scrap gun debris off from the edges of the glass slides. The slides were washed using detergents and methylated spirit, then the slides were allowed to dry and labelled ready for further studies.

The ten (10) prepared slides were subjected to petrographic studies in which minerals with different petrographic characteristics were viewed in two different modes (i.e., plane polarized light and cross polarized light).

Under plane polarized light (ppl), the analyser was pulled out and the following features observed are; colour, pleochroism, form, cleavages, relief. Under cross polarized light (xpl), the analyser was pushed in the following features were observed; interference colours, extinction angle, twinning.

The studies and identifications were carried out with the aid of electronic microscope at Applied Geology Laboratory, Abubakar Tafawa Balewa University, Bauchi, plate 2.

a. Hot plate, araldite, Canada balsam, and other accessories

b. Rock cutting and polishing machine. c. Electronic petrographic microscope

Plate 2: Laboratory equipment used for petrographic (thin section) analysis

4.0 RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The results of field work carried out in the study area revealed that the rocks consist of different morphological forms of migmatite grading from metatexite from western part around Wushi, Shagari and Gadar Maiwa towns, schlieren cum-diatexite to the center around Kariya, Siri, Gala and Miya towns and nebulite at the south-eastern part of the study area around Kafin Madaki, Zara, Burku, Jimbim and Kurbulli towns, flanked by younger granite along the northern coast at Kawari, Kariya-Wudufa, Tsagu and Burku towns.

The outcrops have ranges of elevation from low level, medium to high. Most especially in areas where diatexite and nebulite were exposed have higher elevations.

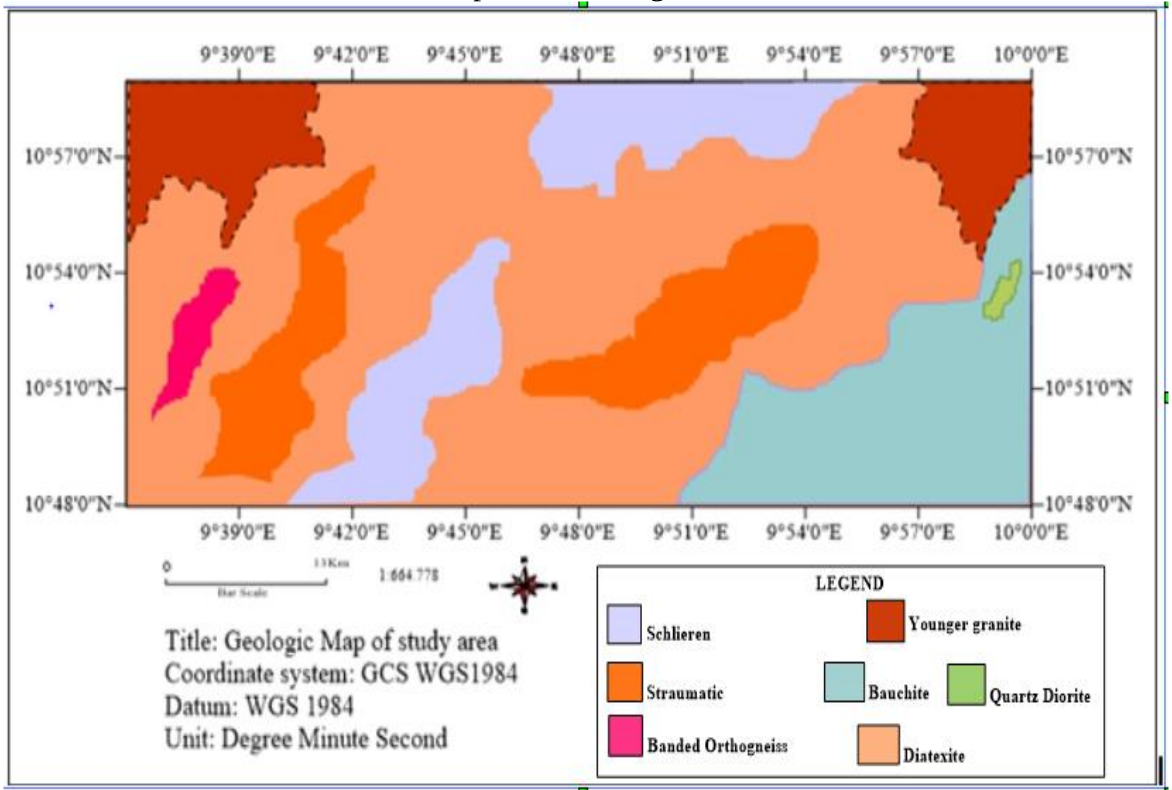
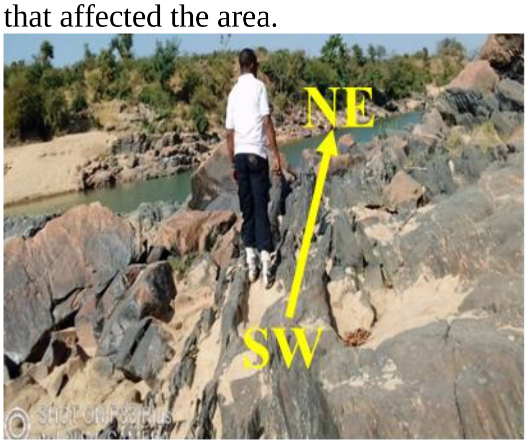


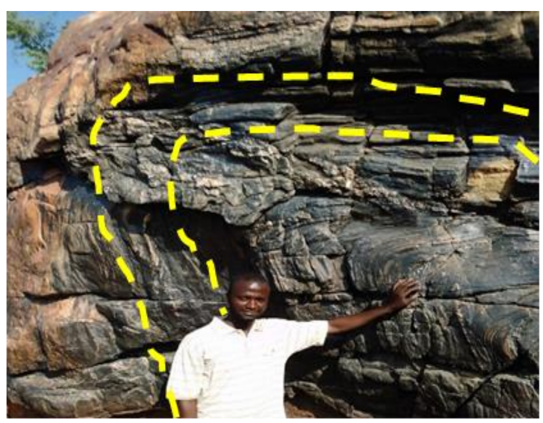
Figure 7: Geologic Map of the study area

4.2 Field and Petrography

During the field work some structural dispositions were encountered at some locations where the rocks were tilted/inclined to almost 90° striking NE-SW direction as shown in plate 3a, faults and recumbent fold were seen plate 3b. These structural disposition were as a result of shear stresses that affected the area.



a. Faulted rocks at Gadar Maiwa river



b. Recumbent fold exposed at Gadar Maiwa river

Plate: Structural dispositions

The petrographic studies carried out on various rock samples collected revealed some important information that are related to events, field relationship and even the tectonic history that affected the rocks in the study area. Various rock samples were subjected to petrographic studies and the results were grouped based on morphological forms of the rocks in questions. Sample L6 is a leucocratic diatexite that is medium to coarse grained migmatite displaying stringers of garnet mineral, under thin section mineral quartz, biotite, orthopyroxene and metamorphic muscovite were seen and in plate 4b and 4c an evidence of grain scale fluid migration was seen as some minerals were aligned along a uni-direction and are stretched signifying shear stress acted upon the rock plate 4c red arrow indicating direction of the movement.

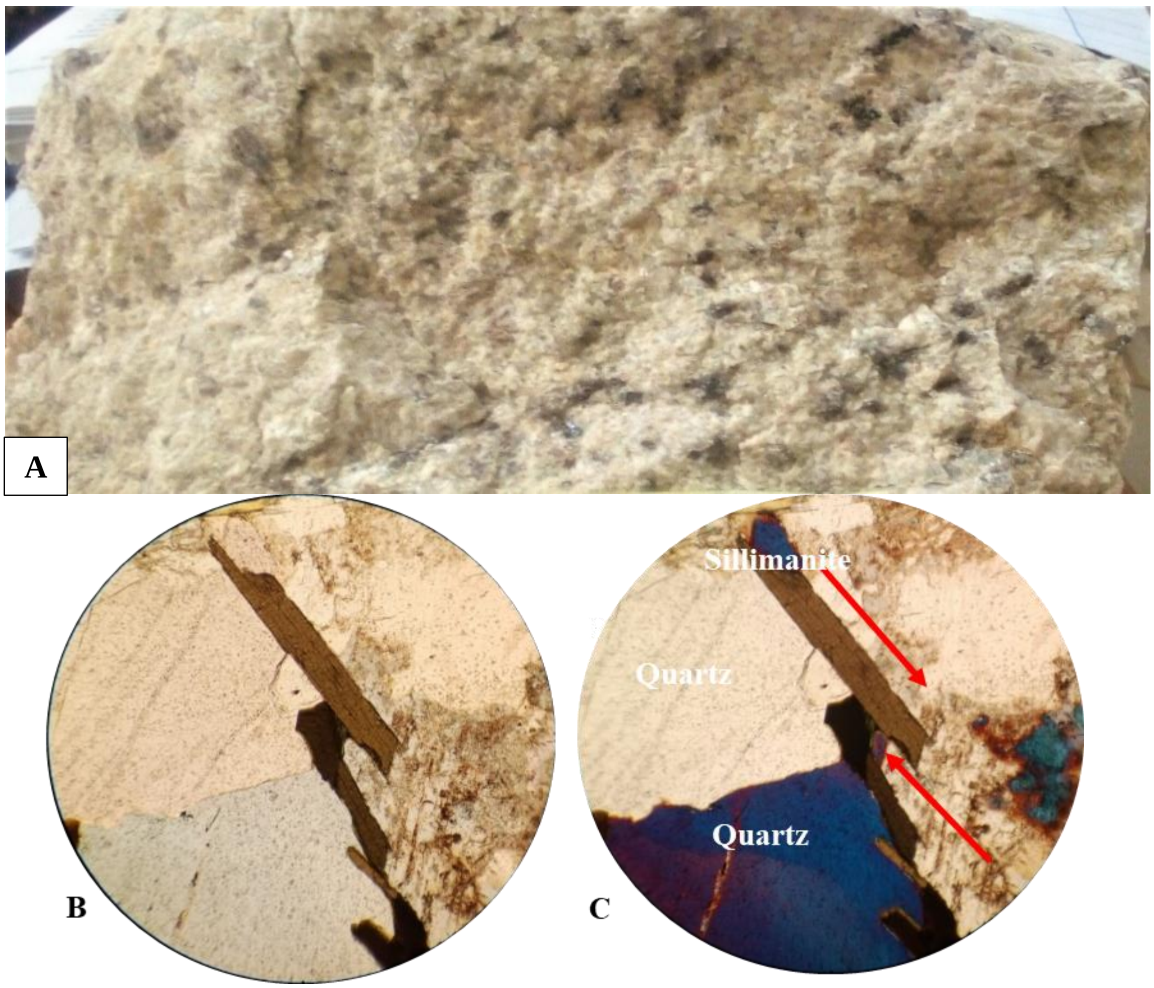


Plate 4. A: Hand sample of L6 (Leucocratic diatexite) B and D ppl, C and E XPL (100um)

The field work carried out in the study area revealed the occurrence of granulitic granulite in location LK3C a hand sample was collected plate 5a. The rock sample is granitic in nature but since it occurred under metamorphic terrain, the name will be granulitic granulite according to Ferre 2007 and Sawyer 2008; also the rock was studied under thin section using high power electronic petrographic microscope in which biotite was the only mineral seen under plane polarized light whereas under cross polarized light biotite, orthopyroxene and Pleuchroic halo were observed plate 5c.

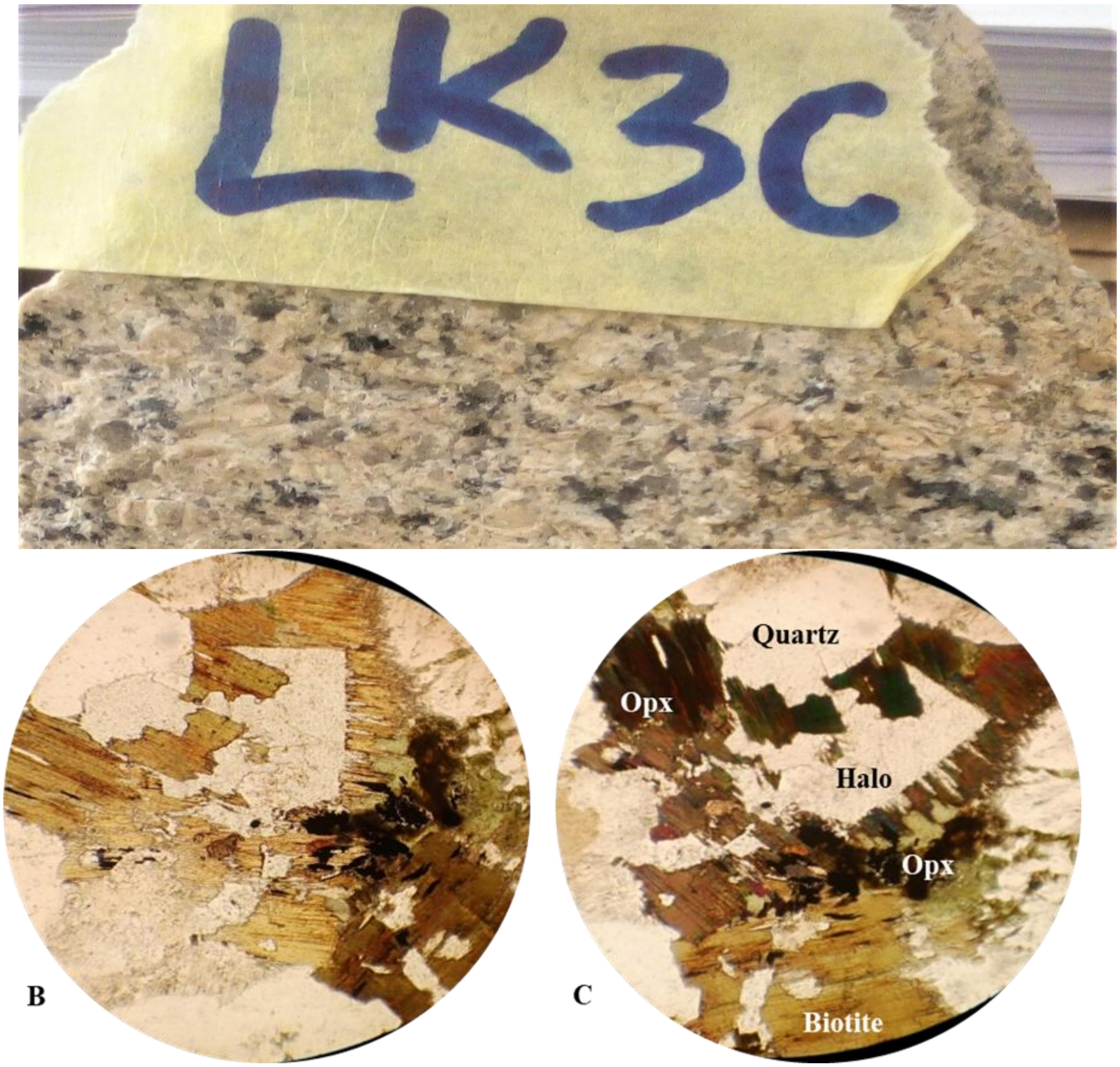


PLATE 5: A. Hand sample LK3C (granulitic granulite) B (PPL) and C (XPL) (x100)

In continuation with the field work another milestone has been achieved by encountering an end member of the morphological form of migmatite that is nebulite (Charnockite to be precise) for the first time within the study area which was unreported plate 6.

So also, an evidence of transformation not intrusion was established during the field work within the study area in which classical examples was seen and noted plate 6a, 6b is showing how the rock was transforming from one form diatexite into another form nebulite migmatite (i.e. from diatexite into nebulite) no sharp boundary rather gradational boundary, this changes may occur possibly as a result of transformation and presence of brine or CO_2 that inhibit the heating of the system thereby favouring the development of K-feldspar grains that lead to the formation of nebulite (bauchite) Harlov *et al* 2006a, plate 6a with yellow dot lines at Kurbulli town and plate 6b at Sawi town around Zara area Miya district.

A. Diatexite transforming into nebulite at: Kurbulli area

B. Sawi area

C. Onion pealing at Kwanan Labi

D. Foliation plain at Kumin Galamba area

Plate 6. Field view of different varieties of nebulite.

A hand sample of brown bauchite was collected from the field at location LF1 in which the rock was coarse grained feldspar, quartz and biotite as major mineral in hand specimen. During petrographic studies under plane polarized light the mineral biotite, orthopyroxene, olivine (with two cleavages cross cut at 120^o angle) and opaque minerals were observed and under cross polarized light myrmikite intergrowth, sericitization, quartz, olivine in blue when rotating the stage and orthopyroxene in green were also seen plate 7b. Myrmikite is formed when tectonic strains increase, the places with incomplete replacement are taken up by wartlike myrmekite intergrowth. Also evidence of grain scale fluid migration was observed on plate 7F; 7G where some minerals appear as they are in liquid form flowing within inter grains of the rock under study.

A. Hand sample LF1 (Brown bauchite)

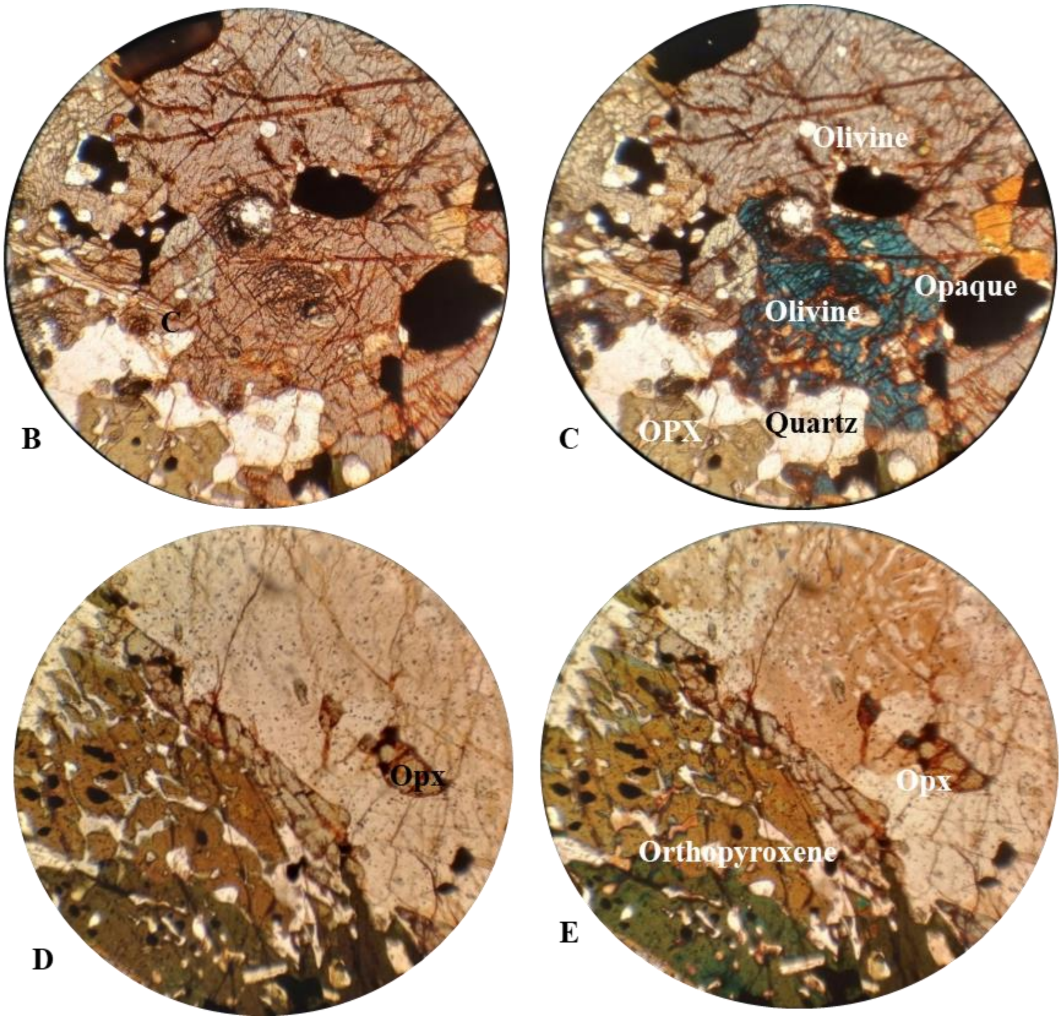


Plate 7. Petrography of sample LF1 B and D PPL, C and E XPL (100um)

CONCLUSIONS

The research work carried out on the geology of granitoids of Miya and environs, Ganjuwa, Bauchi state, Northeastern Nigeria the following conclusions were made:

1. The study area forms part of extensive aggregated complex of migmatite-gneiss unit of northeastern Nigeria that has been affected by Pan African shear stress
2. The migmatite-gneiss vary significantly in their textural and structural attributes but slightly differed in mineralogical features.
3. The study area has the following lithology; schlieren, diatexite, nebulite and younger granite
4. Occurrence of charnockite was identified and reported
5. Tin, lithium and monazite mineralization was inferred.
6. The updated geologic map of the area was produced

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