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### Geology, Petrography and Geochemistry of Lukshi Area Around Dass, Sheet 149 SW, Northern Eastern Nigeria

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#### ABSTRACT

*The study area Lukshi and its environs is part of Dass sheet 149-SW, Bauchi state, Northern Eastern Nigeria. Bounded by Latitudes 10°04'00"N and 9°59'00"N and longitudes 9°23'00"E and 9°22'00"E. Detailed geological mapping of the research area was carried out to update the previous geology information of the study area, the field observation indicates four lithological units of Migmatite: Diatexite, Nebulite, Stromatic and Banded orthogneiss. Biotite, muscovite, quartz, feldspar are the major minerals seen during petrographic studies, and the migmatite showed little fractionations as they formed from medium temperature minerals to low temperature (Andesine to Oligoclase) coinciding with anorthoclase and microcline mineral assemblages at the discontinuous series arm of the Bowen reaction series. In variations diagrams, the compositional trends for the analyzed sample are characterized by negative correlation between  $TiO_2$ ,  $Fe_2O_3$ ,  $MgO$ ,  $CaO$  &  $P_2O_5$  with increased  $SiO_2$  but positive correlation between  $Na_2O$ ,  $K_2O$  and  $Al_2O_3$  with increasing  $SiO_2$  even though some erratic and scattered distribution are also observed. The tectonic classifications of different authors indicated that the migmatite are peraluminous and peralkaline. They formed under syn-collision to late orogenic and anorogenic tectonic settings.*

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## 1. Introduction

The study area Lukshi and its environs, lies between latitudes  $10^{\circ}04'00''\text{N}$  and  $9^{\circ}59'00''\text{N}$  and longitudes  $9^{\circ}23'00''\text{E}$  and  $9^{\circ}22'00''\text{E}$ , it is part of Dass sheet 149-SW . The study area is located within the Pan African Older Granite, the area is accessible through numerous interconnected foot paths and untarred roads linking all parts of the study area. The study is focused on studying the geology, petrography and geochemistry of Lukshi and its environs and also to deduce the geologic setting of the rock types. A total of ten 10 samples from strategic

locations of different lithology were carefully selected and analyzed for major elements (oxide), trace elements as well as rare earth elements. In addition, four (4) major rock samples were studied petrographically. The petrographic studies will reveal the mineralogical composition, and the whole-rock geochemical studies will reveal the chemical composition of the samples, which together with the results from structural analysis data obtained will be used to give a better understanding of the geology, Petrography and Geochemistry of the study area.

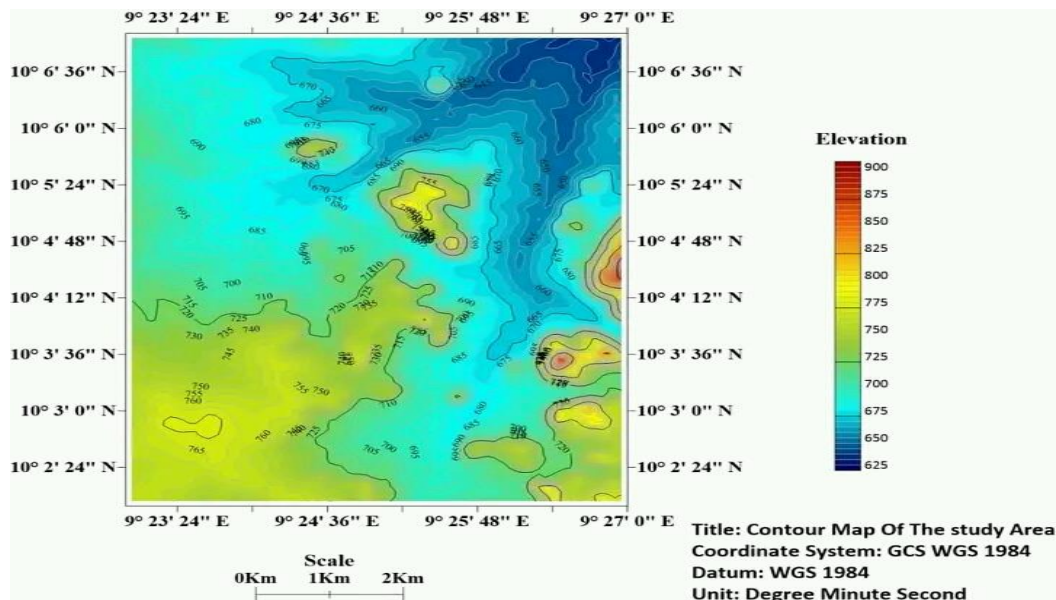


Figure1: Location map of the study area. (Source: Google earth)

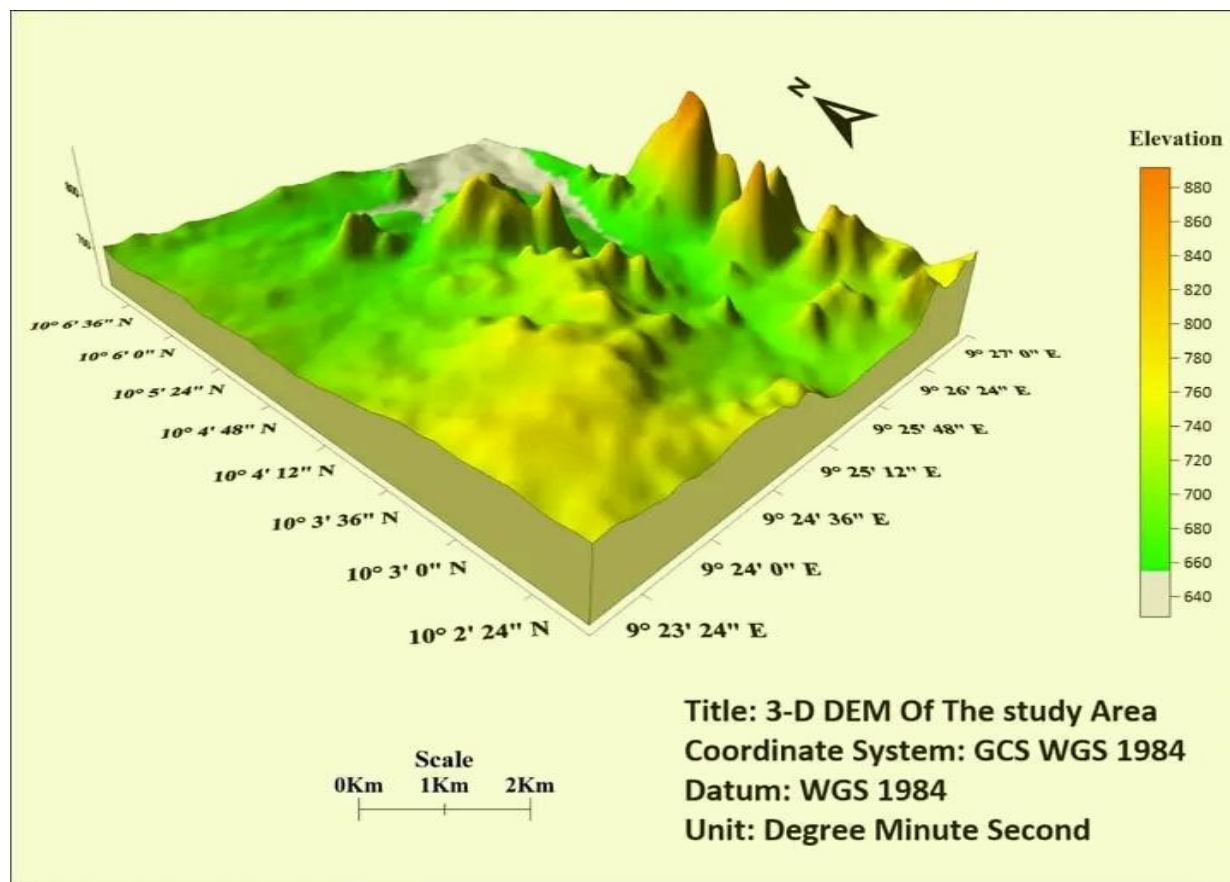


Figure 1: Digital Elevation map of study area (Source: Google earth)

## II Geological Background

The Jos-Bauchi transect is a representation of the Neoproterozoic (Pan-African) Belt of Northern Nigeria as it exposes high-grade metamorphic rocks of contrasted character depending on their distance from Neoproterozoic monzonitic plutons (Ferre and Caby, 2006).<sup>[5] [6]</sup> The Bauchi area provides evidence that high grade metamorphic conditions and anatexis are met by the combination of widespread regional amphibolites facies conditions and local contact metamorphism due to pluton emplacement. Hence most basement if not all of the study area shows the 550±100 Ma ages (Ferre and Caby, 2006)<sup>[5] [6]</sup>. The Bauchi area has foliations running through it, these were deduced from field data, SLAB images and previous maps (Wright, 1971). It has in place biotite-muscovite granite which form elongated plutons parallel to the regional

structures suggesting a syn-tectonic emplacement, and biotite- hornblende granites which have more rounded shapes moulded by country rock structures in conformity envelopes, suggesting a late tectonic emplacement (Ferre *et al.*, 1998).<sup>[6]</sup>

A migmatite is a rock found in medium and high-grade metamorphic areas that can be heterogeneous at the microscopic 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 2008). The Migmatite was introduced as a new rock formed where older foliated granite, was introduced by the younger granite by Sederholm (1907). While Edward Sawyer describes the Migmatite as a rock found in medium and high-grade metamorphic

areas that can be heterogeneous at the microscopic to macroscopic scale and that consist of two or more.

### III Methodology

To achieve the objective of this research, a set of materials and method were applied. The methodology adopted for data acquisition, analysis, processing and the procedures followed while planning and carrying out the geological, petrographic and geochemical investigations are described as follows. GPS, Compass clinometers, Geological hammer, Sample sack, Tape rule, Camera, Camera, Pen and Pencil and Paper tape.

#### Field Method

Mapping and Sample collection were carried out during the detail field work, observations of the different rock units were conducted to know the geology of the area at a scale of 1:25000. Representative surface rock samples were taken from each plutonic suite according to their mineralogical and lithological variations and areal coverage for petrography and whole rock geochemistry. A total of ten surface rock samples were collected from the study area and data were recorded based on the mineralogical compositions, texture and colour of the rocks with and without the aid of high magnification lens.

Laboratory Method;

**Petrographic analysis:** About ten selected samples were resized or reduced by cutting machine to a size of (10x5) cm<sup>2</sup> and were sliced into two parts using rock cutter at thin section laboratory of geology Department, Abubakar Tafawa Balewa University Bauchi (one piece for thin section or rock geochemistry, and the remaining for reference and stored in laboratory).

The selected samples for thin sections were further resized by using secondary cutting machine. First the rock samples were cut and trimmed into rectangular slab. Further cutting was then followed till it reduced to the required size to be polished by polishing machine.

Thin sections were prepared at thin section laboratory of geology Department, Abubakar Tafawa Balewa University Bauchi. Transmitted light microscopy was used to identify mineralogical compositions, modal proportions and classifications, texture, grain size, alterations, micro structural features and etc.

**Geochemical analysis:** First the hand sample was cut down to a size for crushing. The samples were first dried in oven dry overnight and then crushed by primary and secondary crusher. Later they were homogenized, split and pulverized to minus 200mesh, which resulted in 100gram representative powder. Major, minor and trace elements concentration was analysed using X-Ray Fluorescence (XRF) at the Gombe state university, department of geology central laboratory for whole rock analysis. A total of ten (10) representative samples selected from the study area were analyzed.

### IV Result

The field occurrence and relationships of the various rock types observed during the field work were basically the signatures of their genesis/origin. Hand specimen of various rock types sampled at different locations were observed in the field and interpreted based on major rock forming minerals (mineralogy), colour, structures and textural characters.

Below is the geology map of the study area based on the field work conducted and sampling was on the bases of rock variation and association in the field (figure 3).

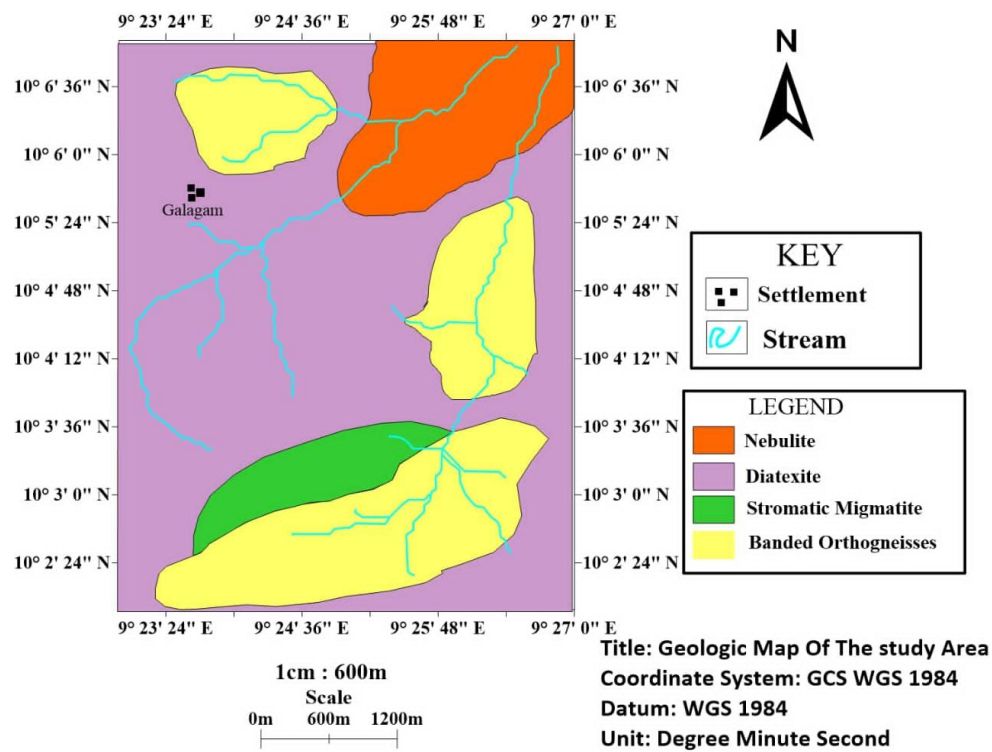


Figure 3: Geological map of the study area

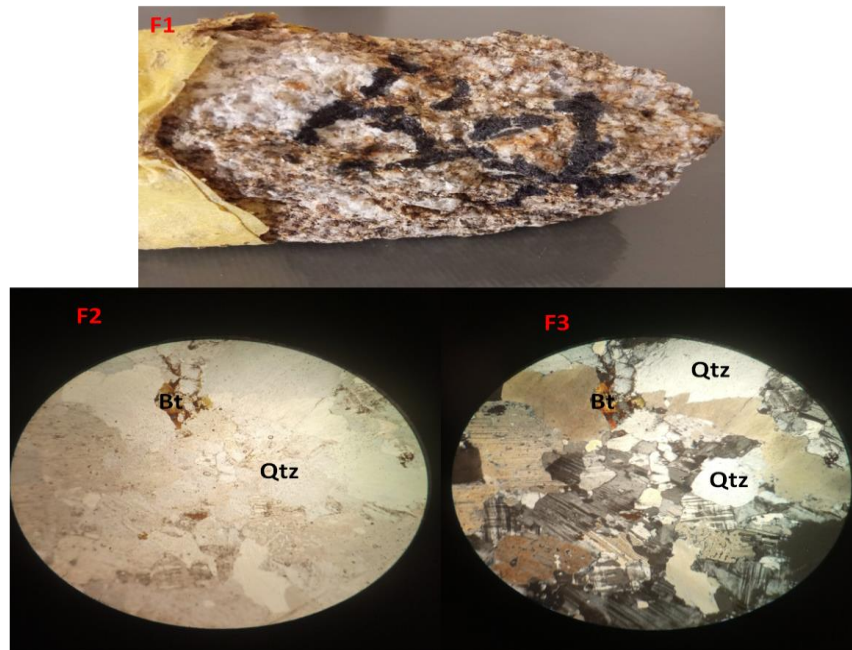


Plate I: Hand specimen photograph of diatexite samples (F1). Photomicrograph of diatexite samples under plane polarized light (F2) and cross polarized light (F3) Q: Quartz, Sil: Sillimanite. Bt: Biotite, Plg: Plagioclase Magnification  $\times 10$



**Petrography:**

**Diatexite:** The Diatexites in the study area is the most widespread and abundant Morphology in the study area. They underwent a textural homogenization that has destroyed the premigmatization structures (e.g., bedding and foliation). They are highly characterized by

obliterated foliations (Plate I). These folds are Magmatic fold and have no relationship or association with bedding or layering of the Protolith. The diatexites found in the study area show a considerable range in morphology from mesocratic to melanocratic through to leucocratic diatexites.

**Table 1: General Mineral Properties of the diatexite under Plane and Crossed Polarised Light**

	PPL	XPL
<b>Quartz</b>	1. Colourless 2. No relief 3. No cleavage	Wavy or undulatory extinction under cross polarized light
<b>Biotite</b>	Strongly colour	No twining
<b>Plagioclase</b>	Colourless	Albite twining
<b>Muscovite</b>	Colourless	Light bluish interference colour

**Nebulite:** The nebulite in the study area exhibits phenocrysts which are pick in colour, having the longer axis aligned parallel to the biotite flake as also seen in the (plate IV). The petrographic

properties in the study area are as follows, biotite and muscovite are found interstitial of the quartz porphyroblasts.

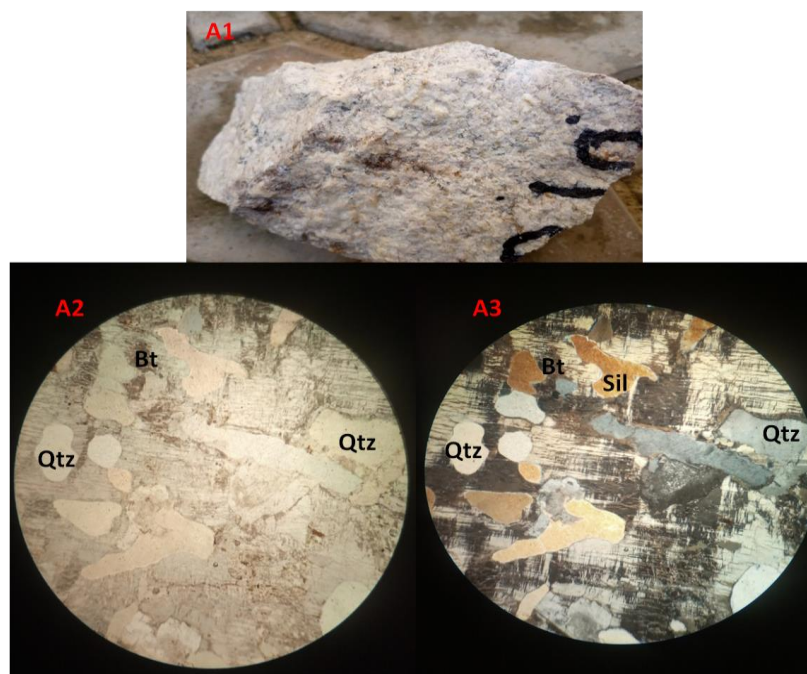


Plate II: Hand specimen photograph of Nebulite samples (A1). Photomicrograph of diatexite samples under plane polarized light (A2) and cross polarized light (A3) Q: Quartz, Sil: Sillimanite. Bt: Biotite, Plg: Plagioclase Magnification  $\times 10$

Table 2: General Mineral Properties of the nebulite under Plane and Crossed Polarised Light

	PPL	XPL
Quartz	1. Colourless 2. No relief 3. No cleavage	Wavy or undulatory extinction, twining none under cross polarized light
Biotite	Habit Anhedral Strongly colour brown High relief	No twining Incline extinction angle
Plagioclase	Colourless	Albite twining
Muscovite	Colourless	Light bluish interference colour
Silimenite	No relief Colourless Perfect cleavages	Yellowish interference colour Vitreous luster and white streak
Plagioclase	Colourless	Albite twining
Muscovite	Colourless	Light bluish interference colour
Silimenite	No relief Colourless Perfect cleavages	Yellowish interference colour Vitreous luster and white streak

**Straumatic Migmatite:** This type of migmatite contains numerous thin and laterally continuous bands of leucosome that are oriented parallel to the major plane of anisotropy in the palaeosome, which are typically compositional layering or a solid-state foliation. The individual leucosome

bands can have melanosome on both sides, only on one side, or it can be absent. The petrographic properties in the study area are as follows, biotite and muscovite are found interstitial of the quartz porphyroblasts.

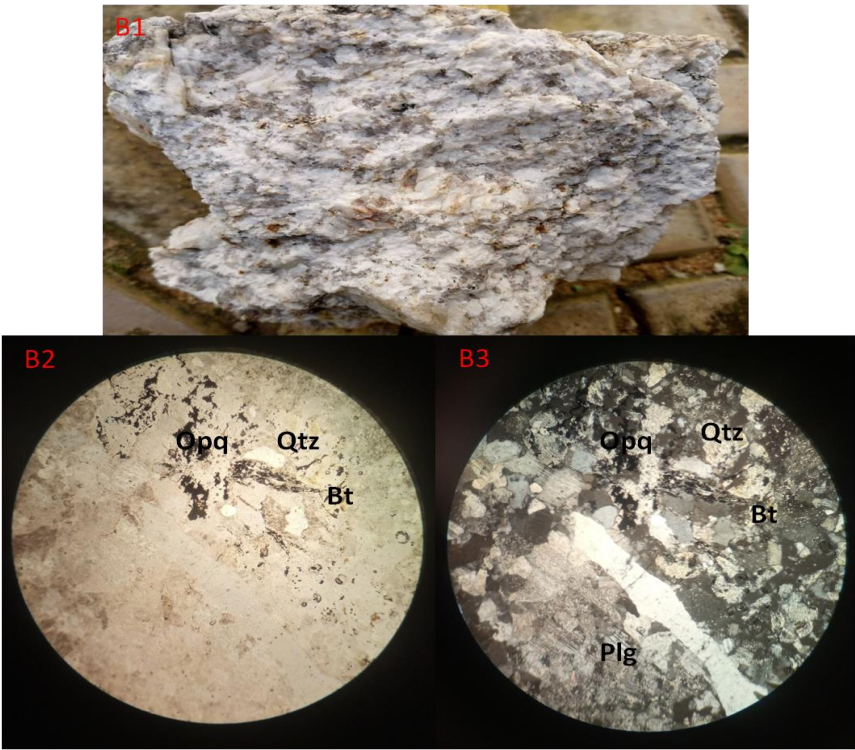


Plate III: Hand specimen photograph of Stromatic samples (B1). Photomicrograph of diatexite samples under plane polarized light (B2) and cross polarized light (B3) Q: Quartz, Sil: Sillimanite.Bt: Biotite, Plg: Plagioclase Magnification ×10

Table 3: General Mineral Properties of the stromatic under Plane and Crossed Polarised Light

	PPL	XPL
Quartz	1. Colourless 2. No relief 3. No cleavage	Wavy or undulatory extinction under cross polarized light
Biotite	Biotite showing Perfect Cleavage in One direction, and brownish	Elongated platy Brown with one directional cleavage
Plagioclase	Colourless	Ttwinning visible
Silimanite	Silimanite is colourless	Silliminite has second order interference colour, Pale Yellowish
Opaque Minerals	Opaque minerals	Opaque minerals

**Banded Orthogneiss:** The Banded Orthogneiss observed as boulder exposures in field. They are fine grained texture, and some samples retain low melt structure. Morphologically, the samples were classified to be banded orthogneiss (Plate VIa) due to

presence of small volume of quartzofeldspathic veins or leucosome band developed from the hand specimen (Plate X1a). Banded orthogneiss have both the leucosome and melanosome part Minerals of the rocks are: Qtz=quartz, Bt=biotite, Pl=plagioclase

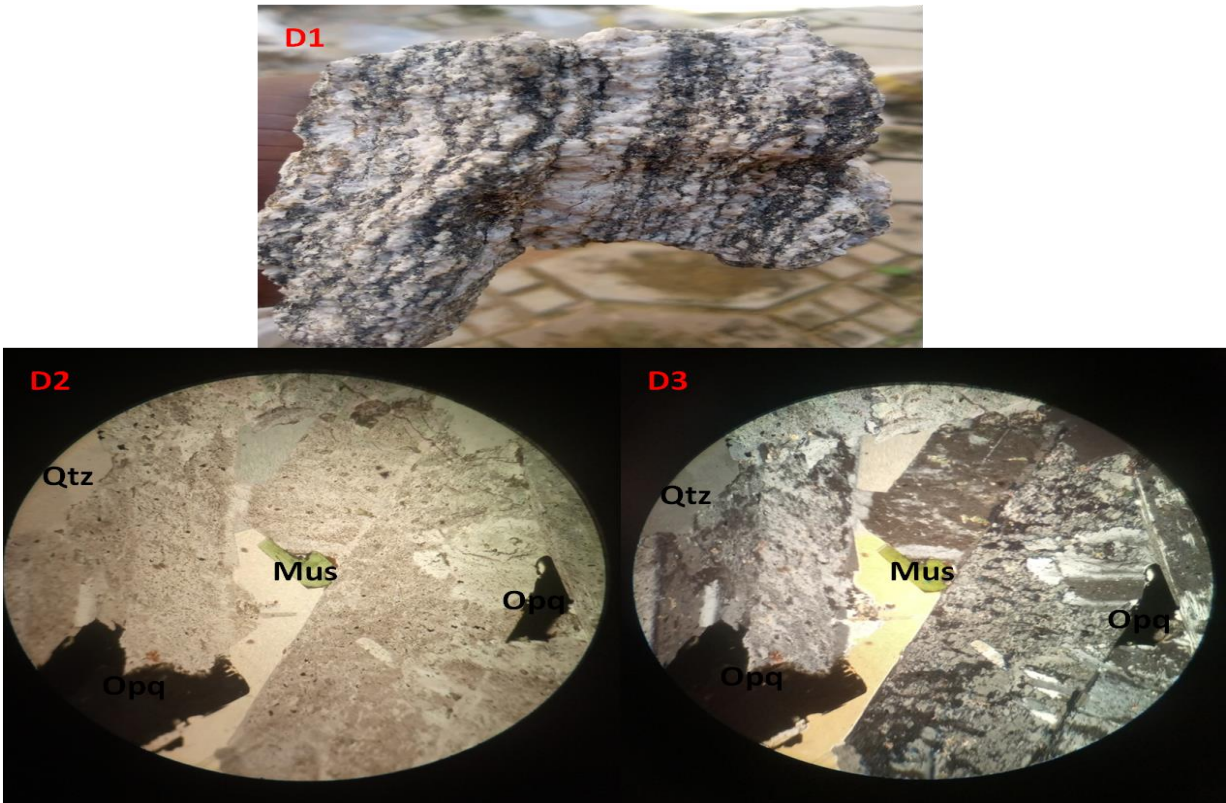


Plate VI: Hand specimen photograph of Banded orthigneiss samples (D1). Photomicrograph of diatextite samples under plane polarized light (D2) and cross polarized light (D3) Q: Quartz, Sil: Sillimanite. Bt: Biotite, Plg: Plagioclase Magnification x10



Table 4: General Mineral Properties of the banded orthogneiss under Plane and Crossed Polarized Light

	PPL	XPL
Quartz	1. Colourless 2. No relief 3. No cleavage	Wavy or undulatory extinction under cross polarized light
Biotite	Elongated platy	Elongated Platy Brownish Biotite
Opaque minerals	Opaque minerals	Opaque minerals
Muscovite	One set perfect cleavage Moderate relief	Light greenish interference colour

**Geochemistry:**

The geochemical data for ten representative rocks samples from the study area are analyze to understand the elemental composition and deduce the tectonic history of the migmatite.

**Whole-Rock Major, Minor and Trace Element**

The rocks in the study area ranges their SiO<sub>2</sub> content from 46.3 wt% to 71.7 wt% and show variable range in concentration on their major, minor and trace element content.

In general, the rage of major, minor and trace element for the whole samples analyzed was described as follows SiO<sub>2</sub> values vary from 46.3 wt% to 71.7 wt%, TiO<sub>2</sub> ranges from 0.09-2.24%, Al<sub>2</sub>O<sub>3</sub> from 10.1-13.7%, Fe<sub>3</sub>O<sub>2</sub> from 0.446-15.6, MnO from 0.027-0.274, MgO from 0.281-3.54, CaO from 0.780-13.6, Na<sub>2</sub>O from 1.78-2.466, K<sub>2</sub>O from 1.41-12.2, P<sub>2</sub>O<sub>5</sub> from 1.71-2.08.

***Table 5: Major element oxide data of whole rock samples from the study area ( wt %)***

Major Oxide	DIT4	DIT10	DIT13	DIT15	DIT30	DIT33	BOT20	FEL14	STM17	STMB5
SiO <sub>2</sub>	69.3	70	70.1	67.1	66.8	70.5	46.3	70.8	71.7	71.5
CaO	1.32	0.786	2.053	1.76	0.595	13.6	2.33	0.589	2.38	0.092
Al <sub>2</sub> O <sub>3</sub>	12.8	12.2	10.1	11.7	13.9	11.8	12	11.2	13.7	12.6
P <sub>2</sub> O <sub>5</sub>	1.77	1.94	1.78	2.08	1.58	1.92	1.94	1.85	1.71	1.75
Fe <sub>2</sub> O <sub>3</sub>	0.446	0.559	4.76	4.37	2.63	0.285	15.7	1.14	0.884	0.715
MgO	0	0	0.554	0.365	0.281	0	3.54	0.116	0	0
K <sub>2</sub> O	10.9	12.1	7.3	7.46	7.55	12.2	1.41	9.35	8.64	8.06
Na <sub>2</sub> O	2.81	2	1.78	2.32	4.26	2.22	2.44	2.05	2.1	2.46
TiO <sub>2</sub>	0.09	0.066	1.04	0.891	0.775	0.06629	2.14	0.262	0.119	0.092
MnO	0.0098	0.0685	0.069	0.126	0.0159	0.0585	0.274	0.0209	0.136	0.027

***Table 6: Trace element data of whole rock samples (PPM)***

Trace Element	DIT4	DIT10	DIT13	DIT15	DIT30	DIT33	BOT20	FEL14	STM17	STMB5
V	28	23.1	35.3	38.2	29.5	22.1	177	35.6	69.5	66.6

Ni	97	80.3	107	125	110	72.8	190	124	183	233
Cu	36.8	28.4	105	100	87.5	19.8	216	42	71.2	69.1
Zn	30.2	18.6	26.8	36.1	28.6	20.5	32.9	24.3	32	34.2
Y	0	0	15.2	18.3	23.1	0	60.2	0	3.55	3.85
Zr	14.9	23	16.4	52.5	26.6	15.1	59.4	7.84	19.9	26.6
Sr	45.2	36.4	415	614	404	42	340	109	28.6	45.2
Rb	695	420	600	746	324	466	1050	834	201	634
As	544	556	447	480	596	548	39.4	466	308	345
Rb	695	420	600	600	324	466	1050	834	201	634
Sr	45.2	36.1	415	614	404	42	340	109	28.6	42.5
Zr	14.9	23	16.4	52.5	26.6	15.1	59.4	7.84	19.9	26.6
Y	0	0	15.2	18.3	23.1	0	60.2	0	3.55	3.85
Nb	0	16.45	8.49	8.43	7.33	6.96	12.2	5.94	0	7.46
Ag	1100	966	1060	1380	690	1070	286	1410	1240	590
Ba	173	177	22.8	17.5	61.1	158	48.7	67.1	200	113
Pd	0	0	35.5	197	136	0	75.6	0	0	0
La	0	0	83.3	264	255	0	127	0	26.8	0
Ce	0	20.9	23.7	80.9	70.1	0	0	15.3	25.7	0
Nd	0	0	16.5	30.1	50.9	23.1	0	9.66	17.4	10.2

### Characteristic of Major and Minor oxides

Harker variation diagrams are used to understand the processes occurring during the evolution of magmas. Major elements versus  $\text{SiO}_2$  variatoin diagram (Harker diagram) are useful in petrological interpreation (Harker et al., 1996). In Harker variation diagram, as indicated on the (fig 10) below:  $\text{MgO}$ ,  $\text{FeO}$ ,  $\text{CaO}$ ,  $\text{TiO}_2$  decerases with incearse silica ( $\text{SiO}_2$ ) even though some erratic and scattered distribution are also observed.

There linear trend in most samples may indicate that the concentrations of most element are significantly changed form their primary abundance.  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$  and  $\text{Al}_2\text{O}_3$  increase with increase in silica.

The compositional trends for the analyzed sample are characterized by a decrease of  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{CaO}$  &  $\text{P}_2\text{O}_5$  with increased  $\text{SiO}_2$  whereas  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$  and  $\text{Al}_2\text{O}_3$  increases with increasing  $\text{SiO}_2$ .

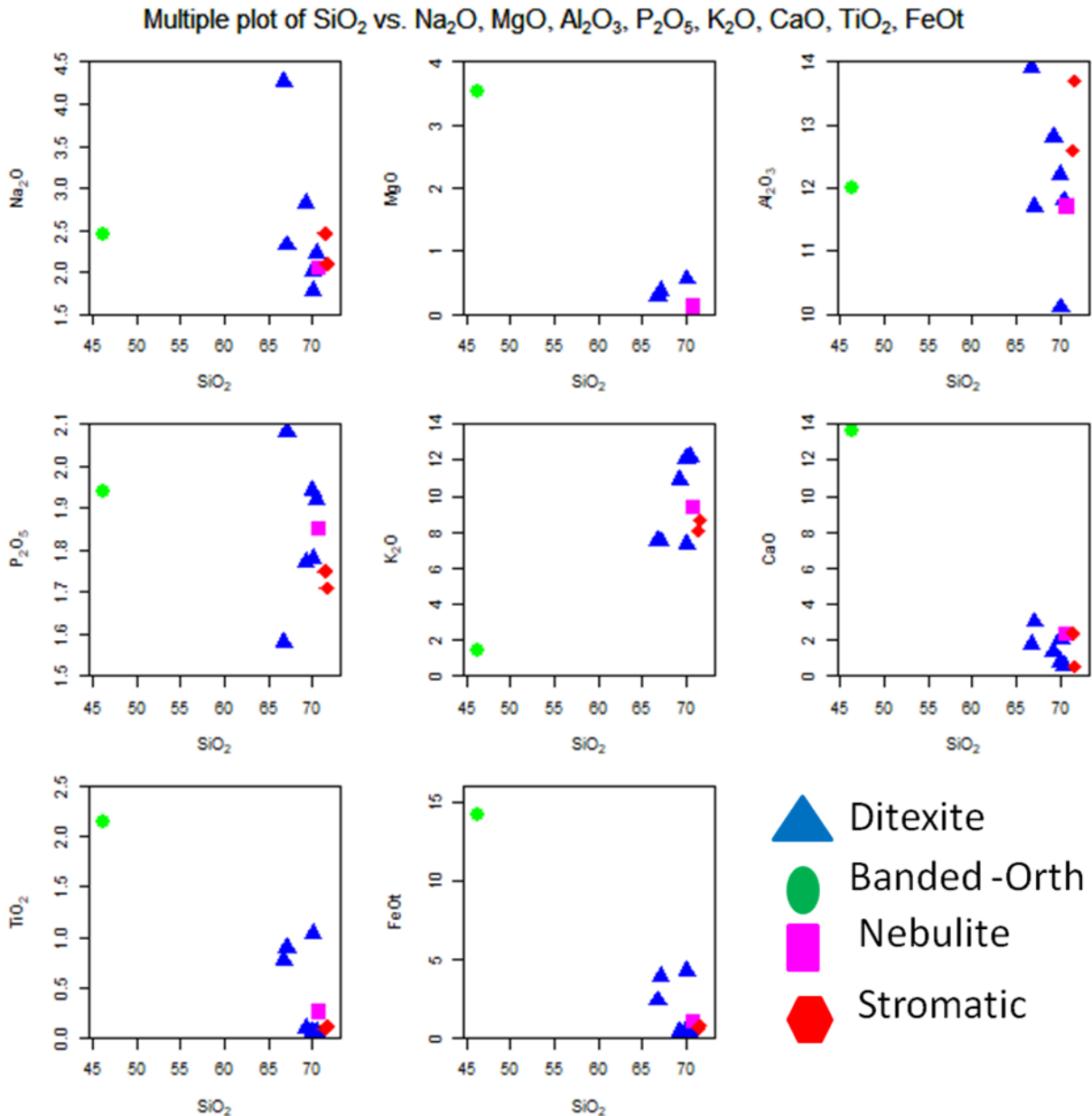


Figure 4: Multiple plots of  $\text{SiO}_2$  vs  $\text{Na}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{P}_2\text{O}_5$ ,  $\text{K}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{TiO}_2$ ,  $\text{FeOt}$

### Trace Elements Geochemistry

Trace elements play significant roles in revealing the petrogenetic and evolutionary history of rocks. It has been observed that major element

composition in rocks tend towards uniformity and it is only their trace element compositions and ratios that provide clues to their unique differences and petrogenesis.

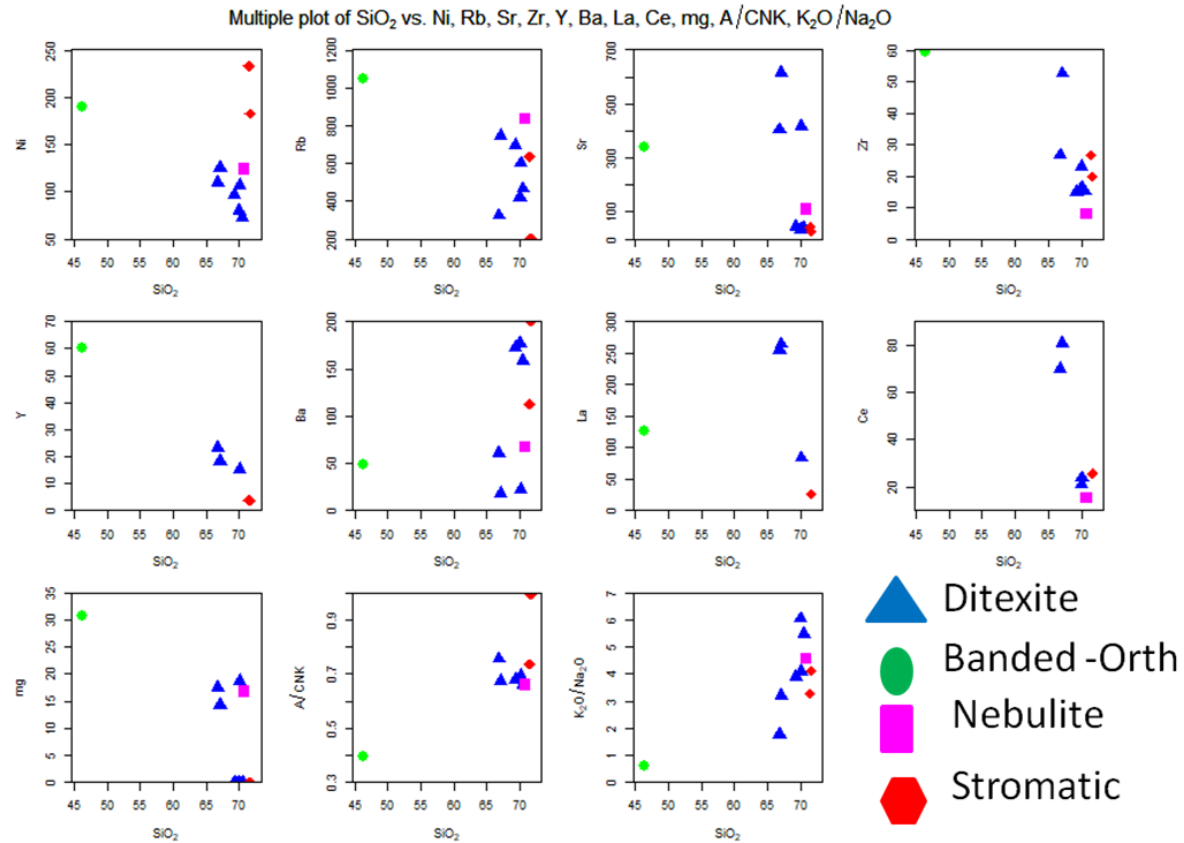


Figure 5: Multiple plot of  $\text{SiO}_2$  vs Ni,Rb, Sr, Zr, Y,Ba, La, Ce,Mg, A/CNK,  $\text{K}_2\text{O}/\text{Na}_2\text{O}$

### Geochemical Classification of Analysed Sample

#### AFM Classification

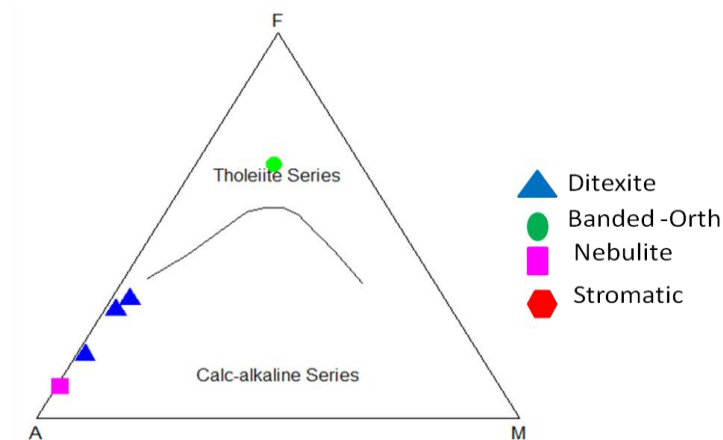


Figure 6: AFM plots showing the distribution of the rocks within the fields of tholeiite and calc-alkaline series after Irvine and Baragar (1971)<sup>[15]</sup>



As indicated from (Fig 6) the analysed sample falls within the calc-alkaline series while banded orthogneiss fall within the tholeiitic domain. Those that plot in the field of calc-alkaline series owing to the fact that these rocks have high percentage of CaO and K<sub>2</sub>O relative to FeO\*, and

MgO and those that plot within the field of tholeiitic series due to these rocks have high percentage of FeO\*, and MgO relative to CaO and K<sub>2</sub>O.

QAP Plot:

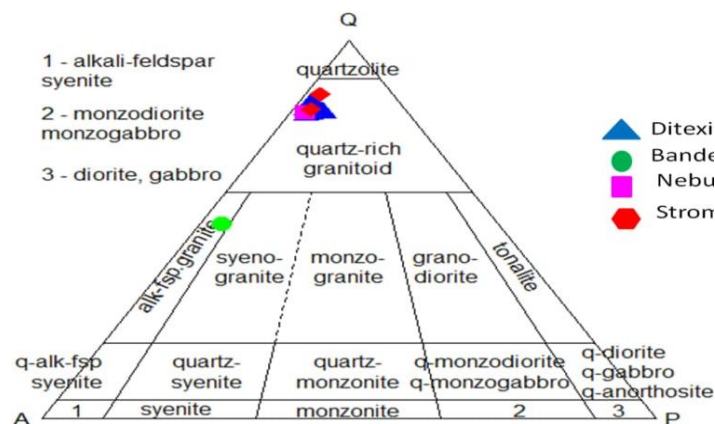


Figure 7: QAP Diagram

This plot is used to classify rocks into various magma origins, from the available data of this research work the granitoid rocks fall under

quartz rich granitoids with the exception of Banded orthogneiss sample which falls under alkali-feldspar-granite domain figure 7.

TAS Classification (Middlemost 1994) <sup>[16]an[d17]</sup>

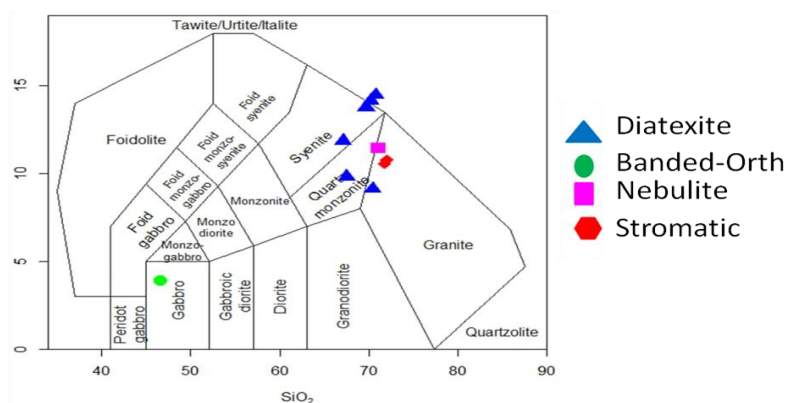


Figure 8: Geochemical classification diagram (Middlemost 1994) <sup>[16][17]</sup> for rock samples analysed.

In TAS diagram, by Middlemost 1994, <sup>[16]</sup> and <sup>[17]</sup> the diatexite falls within the quartz monzonite to syenite and nebulite, stromatic all fall within the granite domain whereas banded orthogneiss fall

within the gabbro domain figure 8. This transition between the rocks in the study area indicates their relative change in silica content.

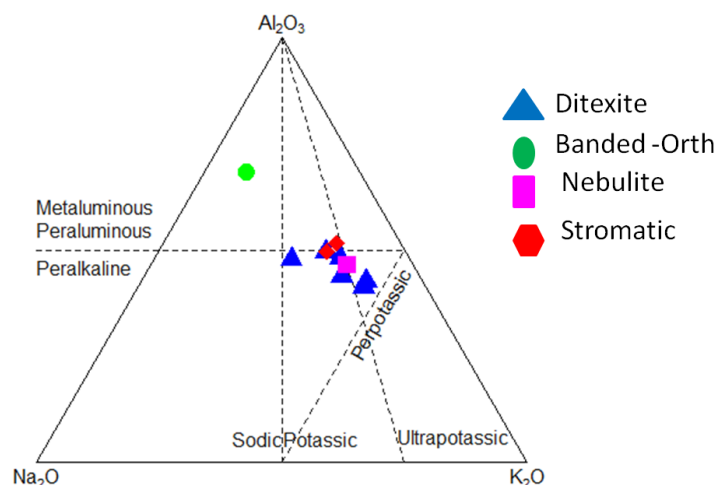


Figure 9: Molar Plot of  $\text{Na}_2\text{O}-\text{K}_2\text{O}-\text{Al}_2\text{O}_3$

In the Molar Plot of  $\text{Na}_2\text{O}-\text{K}_2\text{O}-\text{Al}_2\text{O}_3$ , the granitoid rocks in the study area fall under peralkaline domain with the exception of Banded Orthogneiss have been at the peraluminous field, possibly indicating supracrustal origin (paragneisses) figure 9.

#### Feldspar Diagram

Figure 10 (a) is a plagioclase feldspar plot, in which rocks in the study area were plotted in order to know a type of feldspars that are within rocks and the effects of temperature of crystallizations during the formation of the rocks by relating it to Bowen reaction series. The feldspar ternary plot of plagioclase show that the feldspars were formed during prograde

metamorphism ( fractional crystallization of magma), the time of cooling in which the granitoids fall within the domain of Andesine to Oligoclase plagioclase feldspars which are low temperature mineral assemblages when compared on to Bowen reaction series where the results of feldspar plot showed relationship with the discontinuous series, this is why the rocks contained most of biotite, anorthoclase and microcline minerals.

In figure 10(b), the feldspar ternary was based on alkali feldspar, the result of the plot show that the alkali feldspars are Anorthoclase, Sanidine and Orthoclase, which confirmed the result of petrographic studies.

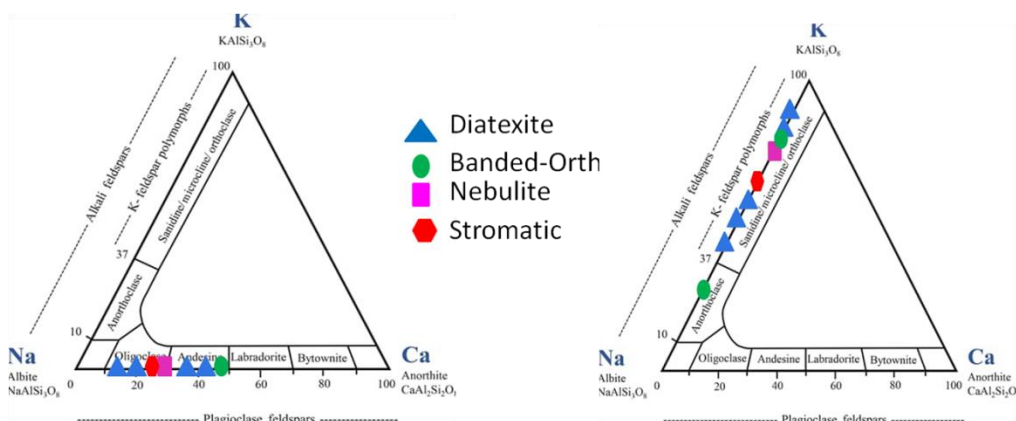


Figure10: (a)Plagioclase feldspar ternary plot (b)The ternary Alkali feldspar plot

### Tectonic Setting

The geochemical data were plotted on various major tectonic discrimination diagrams. On the Rb vs Y + Nb and Nb vs Y tectonic discrimination

diagram, all the sample were grouped within the Syn-collisional and Volcanic Arc Granite domain (figure 11).

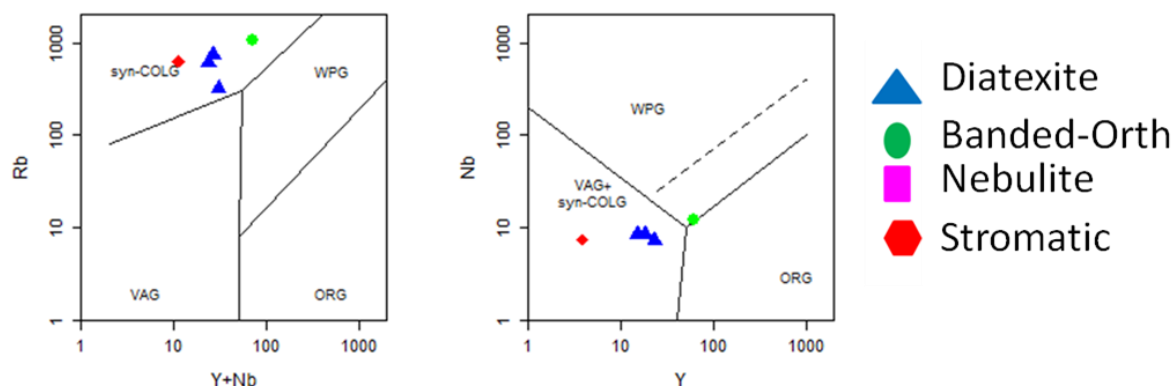


Figure 11: Plots of the analysed rocks on the tectonic discrimination diagram (a) Rb vs (Y+Nb) (b) Nb vs Y of Pearce et al (1984).<sup>[12][13]</sup>

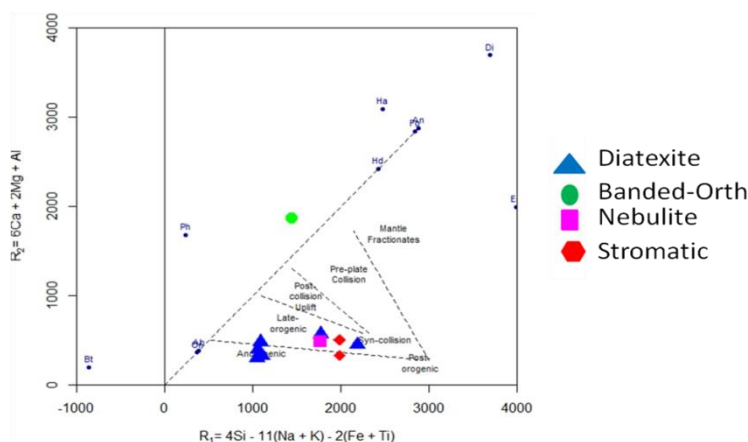


Figure 12: R1-R2 Batchelor and Bowden (1985)<sup>[3]</sup>

The R1-R2 Batchelor and Bowden (1985)<sup>[3]</sup> binary plot figure 12 above, was used in this research work and the granitoid rocks in the study area show multiple tectonic environment settings, in which the diatexite, nebulite and stromatic migmatite fall under the syn-collision to late collision domains whereas the diatexite strictly fitted into the anorogenic field there by supplementing the earlier plot of Molar index which indicated that they are peralkaline in nature figure 9 above. This plot also indicated that there is magma fractionation between the

granitoid rocks in the study area and possibly magma mixing occurred between the migmatite and the younger granite.

### V Discussion

Detailed geological mapping was conducted in the study area and it reveals that the granitoids are migmatites and younger granites. The migmatites have graded from fine to medium grained, colours ranges from mesocratic to leucocratic with some displaying banding and

mineral partings. Biotite, muscovite, quartz, feldspar are the major minerals seen during petrographic studies. Geochemical and petrographic studies reveal that the rocks have granite to quartz rich-monzonite origin and tectonically were formed under syn-collision to late collision settings.

### Conclusions

From the research conducted in the study area and different interpretation methods were used the following conclusions were drawn:

- I. The rocks in the study area are migmatite specifically banded orthogneiss, schlieren cum-diatexite.
- II. The dominant minerals are quartz, biotite, feldspar and orthopyroxene
- III. various classification plots used showed that the migmatite rocks are

granite, quartz rich-monzonite, calc-alkaline.

- IV. The tectonic classifications of different authors indicated that the migmatite are peraluminous and peralkaline. They formed under syn-collision to late orogenic and anorogenic tectonic settings.
- V. The migmatite showed little fractionations as they formed from medium temperature minerals to low temperature (Andesine to Oligoclase) coinciding with anorthoclase and microcline mineral assemblages at the discontinuous series arm of the Bowen reaction series.

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