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Petrography and Geochemistry of Bada'u and its Environ, Katsina State Northwestern Nigeria

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ABSTRACT

The systematic studies of petrography and geochemistry of Bada'u revealed that the area are underlain by crystalline rocks of the Basement Complex, which is categorized as the low grade schist belt. The mapped area is situated within Malumfashi Local Government area of Katsina State, part of Malumfashi sheet 79 NW, which lies between latitudes 11°51'0.00"N to 11°55'00"N and longitude of 7°32'0.00"E to 7°35'0.00"E. The rock units were mapped in the sub-area on a scale of 1:25,000, covering an area of about 40km². The major lithological units mapped in the study area comprises basically of mica schist intercalated with quartzites, porphyritic granites, and minor lithology which includes granite-gneiss, gneiss. The study area shows the evidence of post and syn-Tectonic (Primary and Secondary) structures such as joints, fracture, zenolith, and quartz veins. The dominant joint trend and Quartz veins of the study area are N-S E-W directions respectively which follows the general trend of structures resulting from Pan-African Orogeny. Seven rock samples were collected for both petrography and geochemical studies (2 samples of granites, two samples of gneiss and three samples of mica schist). The major minerals observed under plane polarized and cross polarized light microscope of the granite-gneiss, mica schist and granites are Quartz, feldspar (orthoclase), and micaceous minerals (Biotite and Muscovite) respectively. The geochemical result shows that the rock units within the study area have high percentage of SiO₂ and Al₂O₃ concentration in wt%. This suggest that the rocks within the study were formed from a silica rich source. The granite within the area are peraluminous and shows calc-alkaline characteristics, and occur in syn collision environment as revealed under various geochemical classification plots. The gneiss in the area also have high percentage of SiO₂ and Al₂O₃, suggesting a calc-alkaline affinity. The lesser amount of Na₂O against K₂O reflect an abundance of K-feldspars rock forming silicate. The mica schist also has high percentage of SiO₂ and Al₂O₃, the high aluminium enrichment in mica schist reflects the control of their composition by aluminum clay minerals, the mica schist specifically has high Barium contents which indicate K – feldspar rich source rock. The chemical concentration of Rb is similar to their derivation from shales or metapelites, which is a reflection of their origin.

Keyword: Occurrence, Classification, Evolution, Origin, igneous/metasedimentary rock units.

1.0 INTRODUCTION

The mapped area is situated within Malumfashi local government area of Katsina state, part of Malumfashi topographic sheet 79 NW. the area is bounded by latitudes N11°49'00" and N11°53'00" and longitude E7°34'00" and E7°37'00" covering an area extent of 40km² on a scale of 1: 25,000. The schists of the study area, belong to the Malumfashi schist belt located in the NW of Nigeria. It is one of the twelve schist belts so far recognized in Nigeria, comprising basically of schists, migmatite-gneiss, quartzite, and Pan-African granite with aplite and pegmatite forming

minor lithologies. Malumfashi schist belt consists mainly of muscovite and biotite schist and phyllite interbedded with thin quartzites, McCurry (1976). The pelitic rocks include minor graphitic and feldspathic schists, and contain frequent quartz and quartz-tourmaline veins. Interbedded quartzites are dominantly massive. Well-bedded quartzite units, sometimes several tens of metres thick, also occur. Minor rocks are spessartite quartzite, calc-silicate rocks and anthophyllite cordierite schist. Amphibolite form occasional discontinuous bands, with the largest occurrence being only approximately 12 m thick. The Malumfashi schist belt has been compared

lithologically with the Kushaka schist belt, Grant (1978). But there are other important differences: (1) the quartzites are detrital and not chemically precipitated iron-silica formations; and (2) rocks of basic igneous composition are much less important. The rocks represent a fairly well differentiated sequence of muds and fine-grained sands. Structurally, the Malumfashi belt appears similar to the Zungeru-Birnin Gwari Schist belt, matching it closely in size and form, Grant (1978).

Different models had been put forward for the evolution of the schist belts in Nigeria. McCurry (1971) is in favor of the evolution of the schist belts through ensialic processes. (Ajibade and Wright, 1989) favored the evolution through ensimatic processes, Ogezi (1981) and Holt (1982) suggested that the formation of rift zones where sufficient extension led to the production of small basin favored formation through both ensialic and ensimatic. Geochemical features presented by (Danbatta, 2001) suggested the Kazaure Schist Belt to be of sedimentary origin, probably generated from the metamorphism of shale greywacke. The Malumfashi schist belt has been studied by McCurry (1976) on a regional scale on the basis of petrography and not geochemistry. The research conducted by the Nigerian Geological Survey Agency (NGSA) has not been published yet. This study investigates the geochemical and petrogenetic features of part of Malumfashi schist belt, around Bada'u area, in order to reconstruct its evolution.

2.0 MATERIAL AND METHODS

Field study and laboratory work constitute the research methodology. The field study involved of mapping of all the lithological units within the study area. The study was carried out utilizing

rock exposures along roads and stream channels. Spatial relationship, texture and structural characteristics of the rock exposure were studied. A base map was used to mark the corresponding points where rocks occur in the field and were sampled. Detail observation of lithological contacts was also done by careful studying of areas in the field where lithologies change from one type to another.

In the laboratory, rock thin sections were prepared from representative rock samples collected from the field and the thin sections were prepared and used for petrographic studies. Both the thin section preparation and the petrographic study were done at Vineyard geological company.

Seven rock samples were taken from the field, which two samples of granites, two samples of gneiss and three samples of mica schist for geochemical analysis at Nigeria Geological Survey Agency, Kaduna.

The whole rock geochemical analyses were done using X-ray fluorescence (XRF) for major oxides and inductively coupled plasma mass spectrometry (ICP-MS) for trace elements. The reported detection limits for the major oxides and trace elements are presented in Table 1.

3.0 RESULTS AND DISCUSSION

3.1 Petrographic Description of Major and Minor Lithological Units

Two major rock units underlain the study area which are mica schist interbedded with quartzites and granite as shown in figure 1, though their other minor lithologies such as gneiss and granite-gneiss.

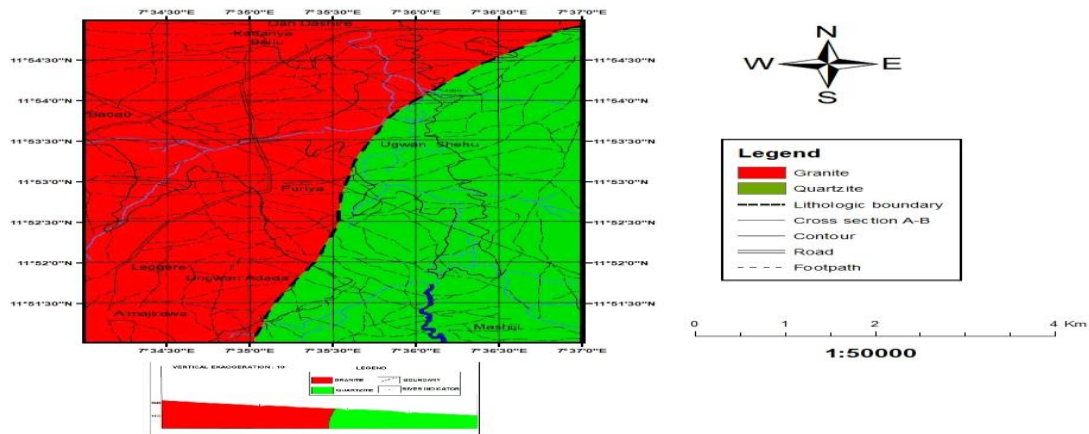


Figure 1: Geological Map of the Study Area

Field Occurrence/Description of Gneiss: gneiss is one of the minor rock mapped within the study area. They normally have strong foliation caused by high temperature and pressure changes which led to the parallel arrangement of alternating light and dark-colored minerals. The protolith (granite) possibly metamorphosed into granite-gneiss to gneiss due to intense temperature and pressure conditions of regional metamorphism.

Petrographic Descriptions Gneiss: The minerals orthoclase feldspars and quartz are found interlocking as well as the biotite. The minerals observed in plane polarized light (ppl) and under cross polarized light (xpl) are; Quartz and Biotite. The Orthoclase Feldspar and quartz is anhedral

and colourless to white with the absent of extinction and it is moderately relief. Biotite crystals are brown to dark with its distinct two directional cleavages and it is Euhedral in size.

In plane polarized light, Quartz is the most abundant mineral present in the rock sample and it appears colourless to white in PPL whereas blue to milky color in XPL. It constitutes about 40% of the rock visual estimation. Orthoclase Feldspar observed appeared milky color in PPL and colourless in XPL and up to about 40% of the rock. Biotite crystals constitute about 20% of the rock and Brown to dark in both XPL and dark in PPL. (See plate 1 and figure 2)

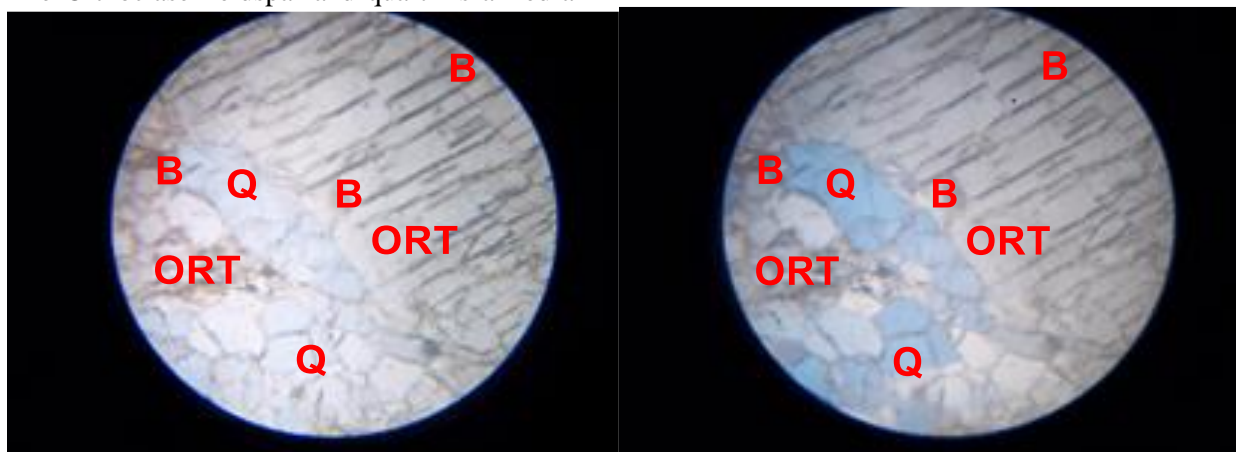


Plate 1: Photomicrograph of gneiss A&B under (xpl) and (ppl) showing mineral composition; Q = Quartz, B = Biotite, ORT= Orthoclase.

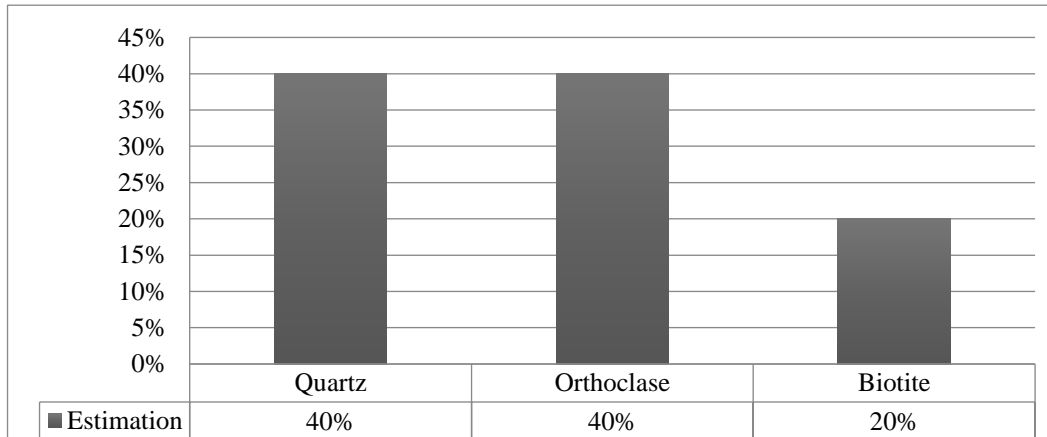


Figure 2: Estimated modal mineralogical composition of gneiss.

3.1.1 Quartzite Interbedded with Schist

Quartzite in the study area appears as scattered ridges and mostly intercalated with schist around the study area. Quartzite indicate fault zone and formed as a result of metamorphism of sandstone. Mineralogical composition of quartzite is mainly quartz making about 60% and some other minerals like feldspar, iron, etc. The quartzites' great resistance to both physical and chemical weathering makes them stand-out high amongst other lithologic types, they appear brownish-redish in colour which is as a result of oxidation, but fresh samples are clear whitish in colour. Quartzite is non-foliated metamorphic rock.

The major rock types are metamorphosed shaley like sedimentary rock which are now referred to as quartz-biotite-muscovite schist. These change laterally into coarse-grained feldspar-bearing micaceous schists which are medium to coarse grained with mineralogy mainly of muscovite/biotite and quartz, foliated with a well-defined schistosity due to the presence of those

platy minerals. The schist is associated with cobble and pebbles of quartzite which is an indication of schist underlying the area. The schist shiny flakes of micaceous minerals (muscovite and biotite but dominantly muscovite) and plagioclase feldspar. It is badly weathered in burrow pits along river channel. Differential weathering of the terrain has produced a low-lying topography where the schist outcrops.

3.1.2 Petrographic Descriptions of Mica Schist

The rock schist analysis under the microscope is mainly characterized by quartz, and biotite. The quartz is anhedral and colourless with the absent of extinction and it is moderately pleochroic. Biotite crystals are brown with its distinct two directional cleavages and it is Euhedral in size. Quartz crystals observed is Blueish to milky in XPL and colourless in PPL and up to about 40% of the rock. Biotite crystals constitute about 60% of the rock and Brown color in both XPL and PPL (see plate 2 and figure 3).

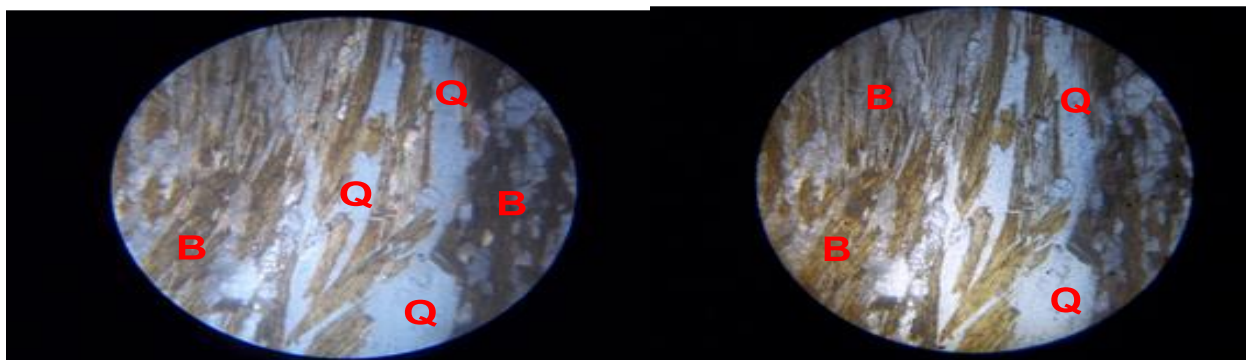


Plate 2: Photomicrograph of Mica Schist A&B under (xpl) and (ppl) showing mineral composition; Q = Quartz, B = Biotite.

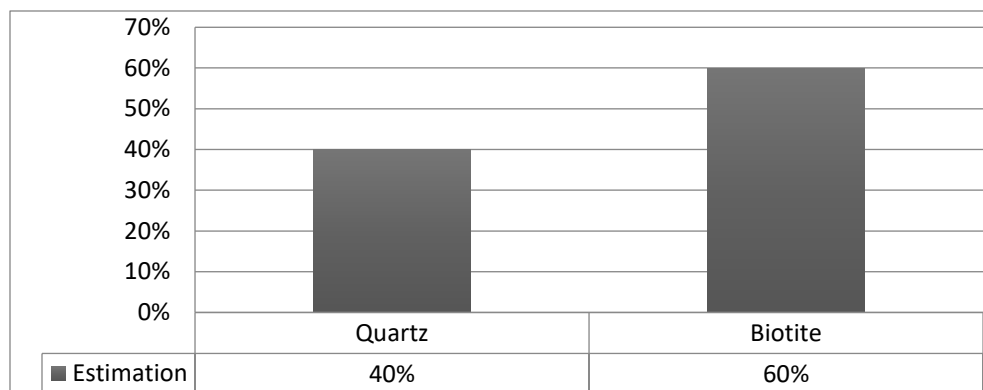


Figure 3: Estimated modal mineralogical composition of Mica Schist

3.1.3 Field Occurrence of Porphyritic Granite

Granite is a plutonic/intrusive igneous rock formed when molten and silica rich magma intrudes the crust and solidifies. In the study area the Granite occupies about 45% and are characterized by distinguishing structures such as fractures, joints and veins. The granite in the study area are coarse grained in textures. The rock occurs as intrusions ranging in size from small outcrops, Low lying inselberg to large whalebacks in nature. It underlain half portion of the mapped area as shown in figure 1. These rock displays both textural and mineralogical variations from one outcrop to another or even within the same outcrop. They are mostly leucocratic with medium to coarse grained texture. The granite has undergone severe weathering regime to form lateritic ridges.

In hand specimen a fresh sample shows almost even distribution mineral crystal grains of quartz, feldspar and muscovite. However, in some locations the feldspar is found forming large crystal. The properties observed using a hand lens is given as; **Colour:** Leucocratic, **Texture:** Porphyritic, **Mineralogy:** Quartz, feldspars, and micaceous minerals. **Field name:** Porphyritic Granite.

3.1.4 Petrographic Description of Porphyritic Granite

The minerals observed in plane polarized light (ppl) and under cross polarized light (xpl) are; orthoclase, quartz, biotite. The crystals of quartz are anhedral in shape, moderately paleochroic in cross polarized light (xpl), The color of the mineral is blueish to milky in cross polarized light and appeared to be colourless under in plane polarized (ppl), The mineral is zoned. It has low relief. The percentage composition of quartz in the rock is about 40%. The biotite occurs as very large with two clear cleavage direction and euhedral in form (see plate 3 and figure 4). The colour of the mineral is brown both plane and cross polarized light, with poorly pleochroism and extinctions. It has low relief and makes up 20% of the minerals present. The crystals of orthoclase are anhedral in shape and occur as phenocryst. The minerals appeared to be light blue to milky colour in (xpl) and colourless in (ppl). It has low relief, moderately paleochroic with treddy (albite) twinning. The orthoclase makes up the percentage compositions of about 40% minerals presents. (See plate 4 and figure 4)

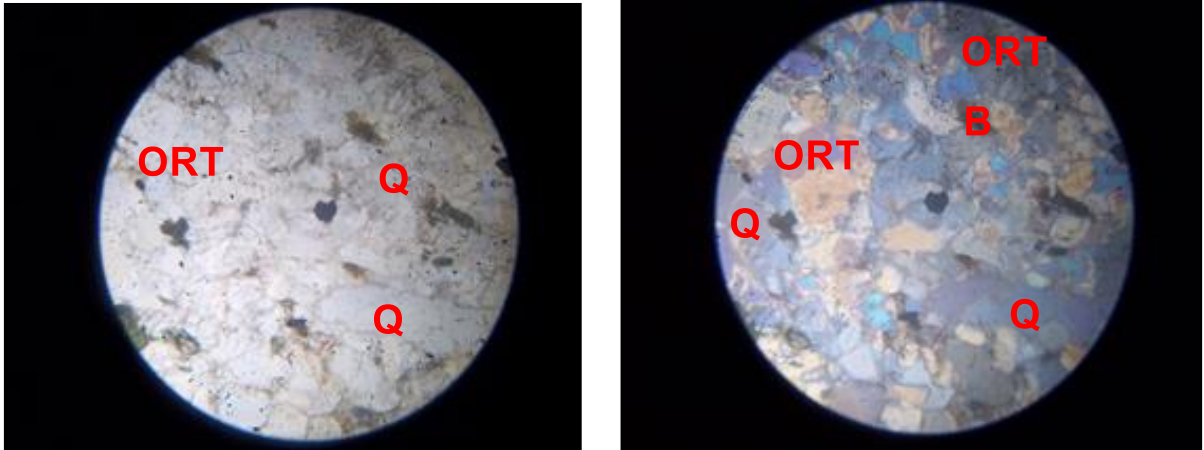


Plate 3: Photomicrograph of granite A&B under (xpl) and (ppl) showing mineral composition; Q = Quartz, B = Biotite, ORT= Orthoclase.

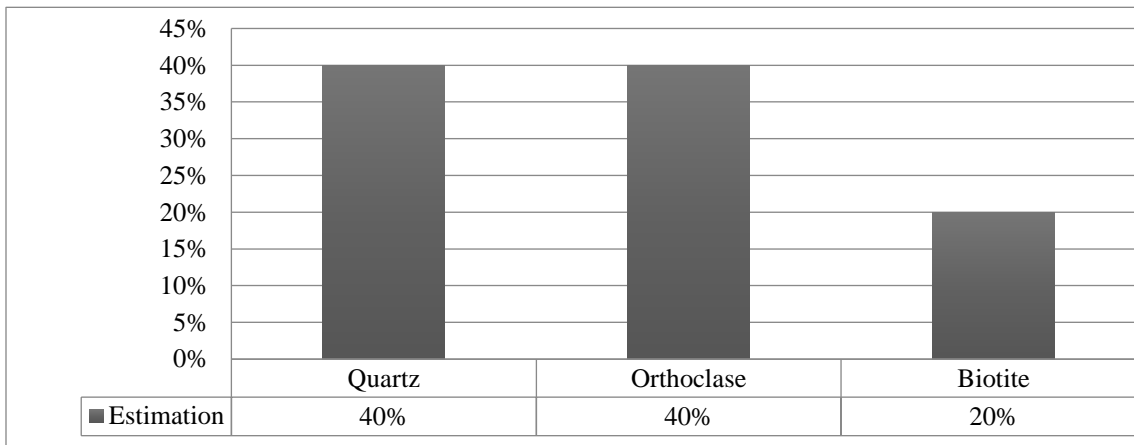


Figure 4: Estimate modal mineralogical composition of Granite

3.2 Geochemical Result Interpretation

The results from geochemical analysis are presented in Table 1 and 2. (The data generated is used for the calculations of the average major, and trace elemental composition). The data was

interpreted using a geochemical data tool kit (GCD Toolkit 3.0). Major elements are reported in weight percent (wt%) while Trace elements are reported in parts per million (ppm).

Table 1: Major Elements Composition of the Rock Samples in the study Area

Rock Name/Elements	Granite 1	Granite 2	Gneiss 1	Gneiss 2	Mica Schist 1	Mica Schist 2	Mica Schist 3
SiO ₂	72.86	71.01	78.12	74.42	74.42	75.09	70.83
Al ₂ O ₃	13.98	13	12.37	12.13	11.29	13.36	15.41
Fe ₂ O ₃	2.48	6.29	1.38	1.44	5.46	3.05	2.54
MgO	1.04	1	1.9	0.98	1.09	0.28	0.39
CaO	2.04	1.11	0.79	1.02	0.07	0.01	0.08
MnO	0.04	0.16	0.03	0.08	0.11	0.01	0.02
Na ₂ O	0.1	0.2	0.12	0.06	0.24	0.1	0.43
K ₂ O	5.08	5.84	4.35	4.04	3.03	4.44	6.64
TiO ₂	0.43	0.22	0.63	0.29	0.6	0.31	0.33
P ₂ O ₅	0.12	0.11	0.12	0.11	0.08	0.03	0.04

Total	99.17	92.86	99.81	99.65	96.41	96.73	96.74
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Table 2: Trace Elements Composition of the Rock Samples in the Study Area

Element (PPM)	Granite 1	Granite 2	Granite-gneiss 1	Granite-gneiss 2	Mica Schist 1	Mica Schist 2	Mica Schist 3
Ba	1536	1619	258	140	522	367	948
Co			15	8	19.8	4.2	3.6
Cs			0.5	0.5	9.9	7.5	8.5
Cu	27	12	12	15	34.4	11.7	11.6
Ga			5	8	16.9	19.3	22.1
Ni	27	4	16	19	49.2	121.2	68.8
Rb	134	107	11	5	176.6	198.8	260.2
Sc	21	10	3.8	2.8			
Sr	242	323	20	13	25.1	25.3	41.3
Th	26.1	10	3.7	5.1	7.8	18.2	25
U	1.4	1	2	1	2.6	1.7	4.3
V	137	70	33	76	103	18	17
Y	32	29	15	14	28.7	46.4	65.6
Zn	102	50	18	18	88	2	25
Zr	363	288	28	27	158	268.5	265.3
La			11	11.1	34.7	36.4	68.5
Ce			16	16	93.9	89.9	117.8
Nd			8	8	30.5	45.9	61.2
Sm			2.2	1.6	6.01	9.85	12.32
Eu			0.6	0.5	1.31	1.37	1.54
Tb			0.5	0.5	0.87	1.45	2.03
Yb			1.4	1.5	2.96	5.52	6.48
Lu			0.21	0.22	0.45	0.84	0.95

3.2.1 Interpretation of Geochemical Data

Symbols & colours by Petrology

◇	Granite-gneiss
△	Granite 1
+	Granite 2
×	Mica Schist

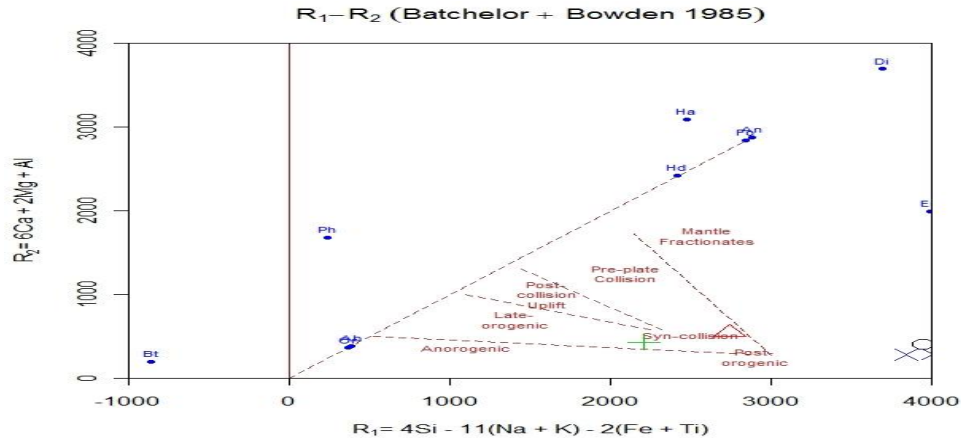


Figure 5: Plot showing the tectonic setting of the granites after (Batchelor + Bowden, 1985)

Granite tectonic discrimination – Frost et al. (2001)

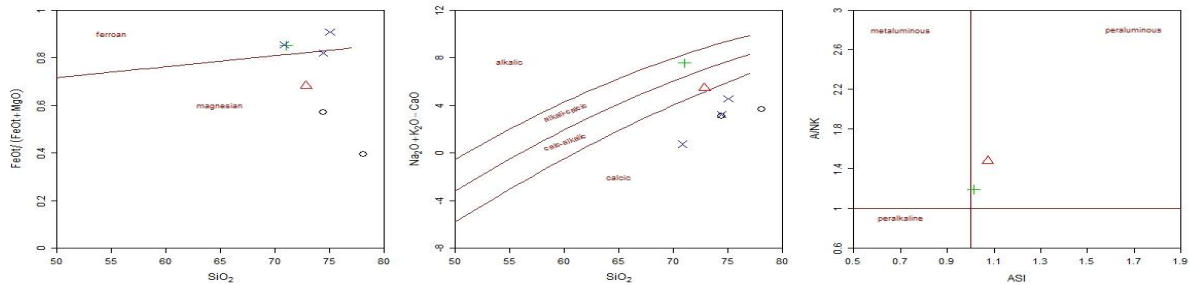


Figure 6: Tectonic discrimination plots showing the different composition of the rocks within study area (Frost *et al.*, 2001)

Granite tectonic discrimination – Maniar and Piccoli (1989)

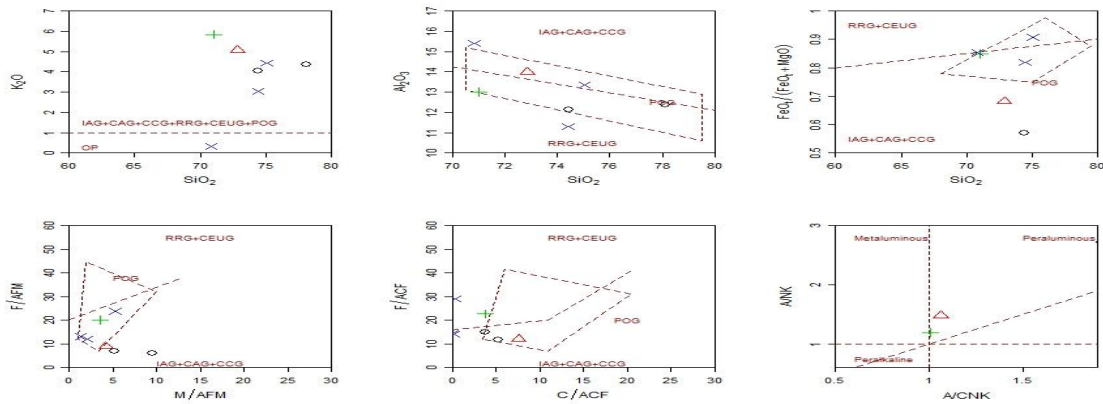


Figure 7: Tectonic discrimination diagrams showing the various tectonic environments of the rocks within study area (Maniar and Piccoli, 1989)

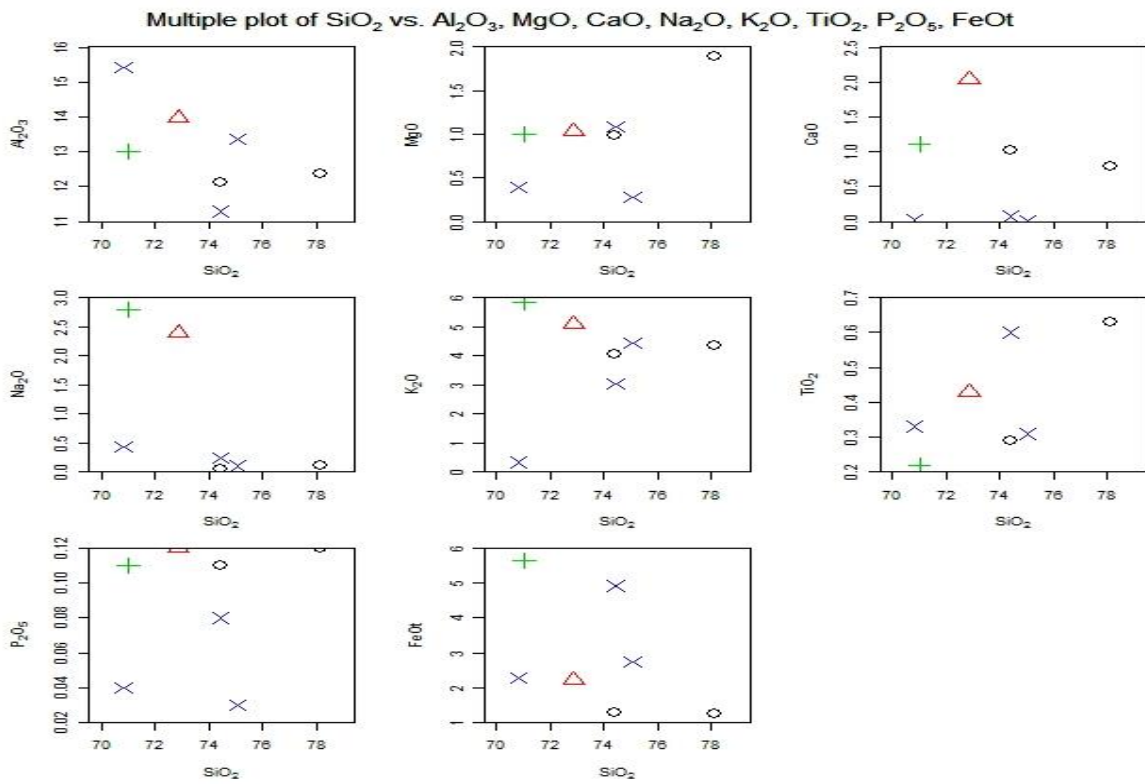


Figure 8: Harker Variation diagram of SiO₂, against Al₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂, P₂O₅, Fe₂O₃

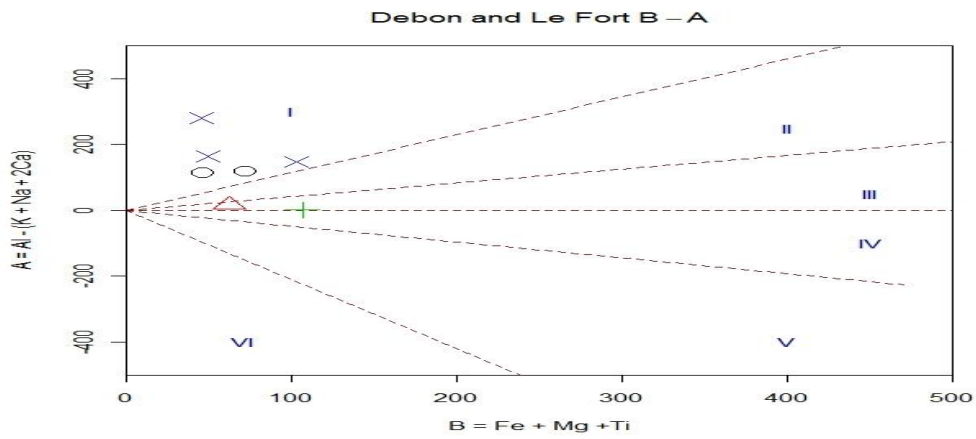


Figure 9: Plot of Debon and Le fort. B - A

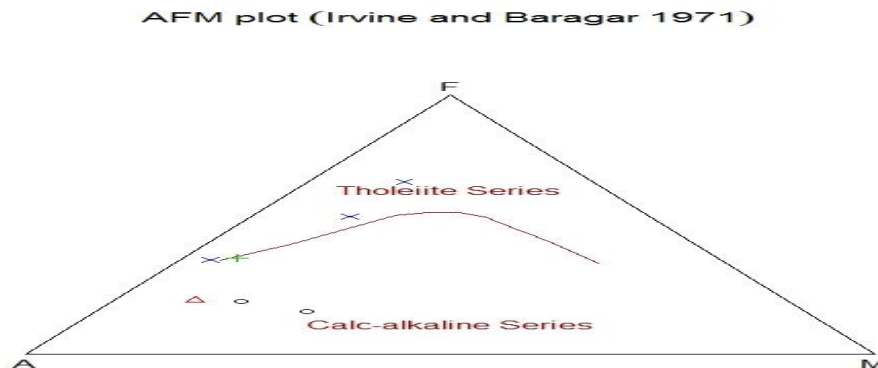


Figure 10: AFM plot showing the series of the rocks within study area. After (Irvine and Baragar, 1971)

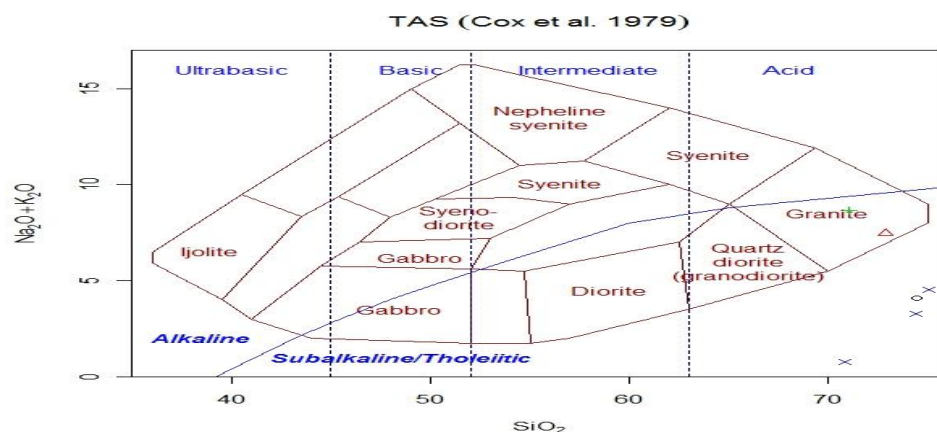


Figure 11: Plot of Na_2O versus SiO_2 (indicating acidic nature of granite I & II)

3.2.2 Major Element Analysis of Gneiss

The major elements of the sample gneiss (1 & 2) exhibit high SiO_2 of 78.12 wt% and 74.42 wt% respectively. The two sample also show low concentration of Fe_2O_3 and MgO (1.38 wt% and 1.448 wt%) and (1.9 wt% and 0.98 wt%) respectively. These suggest that they were derived from a felsic source. This was confirmed by the petrogenetic plot of (Cox *et al*, 1979, Figure 11), the lesser ratio of Na_2O to K_2O in both samples reflects an abundance of K – feldspar rock forming silicate that is orthoclase and biotite.

The alumina (Al_2O_3) contents of the sample gneiss (1 & 2) are 12.37 wt% and 12.13 wt% respectively, thereby suggesting a calc-alkaline affinity. This was confirmed by the petrogenetic plot (Figure 10) of Irvine and Baraga (1971). This could also be due to then low Fe – Mg bearing silicate minerals.

3.2.1.1 Trace Elements Analysis of Gneiss

The trace elements of the sample gneiss (1 & 2) shows a high concentration of Ba which is an indication of K – feldspar rich protolith. Ni and Co are relatively enriched in both samples.

3.2.3 Major Element Analysis of Mica Schist

The mica schist in the study area shows a high content of SiO_2 (74.42 wt%, 75.09 wt% and 70.83 wt%) respectively and high Al_2O_3 content of 11.29 wt%, 13.36 wt% and 15.41 wt% respectively. The K_2O content is in excess when compared to Na_2O . The high Al_2O_3 enrichment in the mica schist reflects the control of their composition by aluminum clay minerals. The ratio of $\text{K}_2\text{O}/\text{Na}_2\text{O}$ reflects probably secondary addition of potassium (K – metasomatism) during metamorphism. The MgO content is in excess compared to CaO content in the range of (0.01 – 1.09 wt %). Since MgO content is in excess of CaO content. It is perhaps indicating the almost carbonate – free nature of the protolith. The low CaO content results from the decomposition of

plagioclase in the source materials during weathering.

3.2.3.1 Trace Element of Mica Schist

The mica schist specifically has high Ba concentration ranging from 367 to 948 ppm, Rb from 260.2 to 198.8 ppm. This concentration is typical of the supracrustal rocks. Zircon (Zr) concentration is a reflection of the presence of detrital zircon (Zr) in the rock. Sr content range between 11.6 to 34.4 ppm. While Co concentration range between 3.6 to 19.0ppm. The chemical concentration of Rb is similar to their deviation from shales or metapelites, which is a reflection of their origin. Rb/Sr ratio is > 0.4% which is typical of pelitic metasediments high Ba indicate K – feldspar rich source rock.

3.2.4 Major Element Geochemistry of Granite

From the result of the analysis of the major element oxides provided in the table 1 above the rock generally shows variation in the composition of the oxides. The samples Granite (1 & 2) have silica composition of 72.86 wt% and 71.01 wt% respectively but the composition of MgO, P₂O₅, CaO, and TiO₂ is very minute. These samples Granite (1 & 2) have a considerable amount of Fe₂O₃, Al₂O₃, and K₂O. The high silica content points to the felsic nature of the rocks and therefore they that are supersaturated with respect to SiO₂. They are well enriched in Al₂O₃ greater than the sum total of Na₂O + CaO + K₂O which indicate that the two granitic samples are peraluminous in nature (figure 7 and 9). The Fe₂O₃ is present also in considerable amount having composition of 2.48% and 6.29% respectively.

The granites show a slight range of variation in their SiO₂ content (71.01 wt% – 72.86 wt %) with high alkali Oxide shown in the (table 1). The sample granite 2 has low CaO, MgO, MnO, P₂O₅ and TiO₂ and subordinate Fe₂O₃. The low ratio of MgO (1.0) to Fe₂O₃ (6.29) suggest that granite (2) is enriched in iron. Similarly, the P₂O₅ and MnO range from 0.11 – 0.12 and 0.04 – 0.16 respectively. (See table 1).

The granites have similar trends on the AFM plot (Irvine and Baragar 1971) (Figure 10) that is, both Granite (1 & 2) fall in the Calc-alkaline series. In

Figure 5 (Batchelor + Bowden, 1985) shows that both granite (1 & 2) occur within the same tectonic environment (Syn-collision) (see figure 5) that is, they were probably formed through syn-collisional processes related to subduction related magmatism. Although granite (1&2), occur in the same tectonic environment. They also differ in some cases, Frost *et al* (2001) plot of FeO/(FeO_t + MgO) vs SiO₂, Na₂O + K₂ – CaO vs SiO₂ (figure 6) shows that granite 1 is magnesian while granite 2 is ferroan. The Maniar and Piccoli (1989) (plot in figure 7) shows that granite (1 & 2) fall within the IAG (Island arc granitoid), continental collision granitoid (CCG) and continental arc granitoid (CAG). Suggesting collision evolutionary processes. A plot of TAS (Cox et al, 1979) (Figure 11) shows that both granite (1 & 2) are both acidic in nature.

3.2.5 Trace Element of Granites: The two granite samples show a variation of trace elements and some of these could be used in tectonic discrimination diagrams (O' Hara, 1980). The Barium content of granite (1 & 2) is very high with about 1536 – 1619 ppm respectively (table 2), this indicates that the magma is enriched with K – feldspar. Furthermore, the high content strontium (Sr) of 242 ppm and Rubidium of 134 ppm indicates that the magma source must have rich in Sr and Rb. It also indicates the likely crustal origin of the magma and the less efficient removal of these elements by mafic and silicic phenocryst.

4.0 CONCLUSION

The lithology revealed from systematic mapping and petrographic examinations shows that the mapped area is underlain by rocks of basement complex. The mapped area lies within Malumfashi local government area of Katsina State, part of Malumfashi sheet 79 NW, which lies between latitudes 11°51'0.00" N to 11°55'00"N and longitude of 7°32'0.00"E to 7°35'0.00"E covering an area of about 40km². The rocks within the study area comprises majorly of porphyritic granite, schist and quartzite. Where granite gneiss, gneiss forms minor lithology.

The study area revealed the evidence of Post and syn-Tectonic (Primary and Secondary) Structures such as joints, fracture, xenolith, and quartz veins.

The dominant joint trend and Quartz veins of the study area is N-S E-W directions which follows the general trend of structures resulting from Pan-African Orogeny. The major minerals observed under plane polarized and cross polarized light microscope of the representative rocks sample are Quartz, orthoclase, and micaceous minerals (Biotite and Muscovite). The geochemistry shows that the rock within the study area have the high percentage of SiO₂ and Al₂O₃. This suggest that the rocks within the study were formed from a silica rich source. The granite within the area are peraluminous. The granite also shows calc-alkaline characteristics, and occur in syn collision environment. The gneiss in the area also have high percentage of SiO₂ and Al₂O₃, suggesting a calc-alkaline affinity. The lesser ratio of Na₂O and K₂O reflect an abundance of k-feldspars rock forming silicate. The mica schist also has the high percentage of SiO₂ and Al₂O₃, the high Aluminium enrichment in the Al₂O₃ reflects the control of their composition by aluminum clay minerals, the mica schist specifically has high Barium contents which indicate K – feldspar rich source rock.

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