IIARD International Journal of Geography & Environmental Management (IJGEM)
Vol. 10 No. 3 2024 E-ISSN 2504-8821 P-ISSN 2695-1878 www.iiardjournals.org (Online Version)

Geology and Economic Potentials of Migmatite Around Filin Shagari, Kafin Madaki (SHEET 129 NW & SW) Bauchi N.E, Nigeria

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D.O.I: 10.56201/ijgem.v10.no3.2024.pg321.344

Abstract

The rocks in the study area were carefully mapped and studied to understand their relationships, geological setting, distribution, structures in order to harness their economic potentials. The area is located within Pan African Older Granite in the Northwestern region of Ganjuwa L.G.A. in Bauchi state and is accessible through Bauchi-Ningi Road about 15km off from Federal High way. Adopting the Sawyer classification of migmatite, the rocks within the research area have few morphologies predominantly the Banded orthogneiss, Diatexites, massive Pegmatite ridges, and pocket of Nebulite. Morphological changes in the rocks were critically observed due to partial melting rate and possible deformation due to shear stress which possibly acted on the banded orthogneiss that was tilted vertically. Geochemical analyses from XRF and studies indicate that the presence high concentration of Al_2O_3 *and* SiO_2 *indicating a possible metasedimentary source and with further analysis to ascertained the economic potentials of the rocks AAS was also conducted on some selected samples that indicated some signals of lithium mineralization. And from the field observation hydrothermal fluid tend to be occupying the foliation planes of these banded orthogneiss to form mineralization.*

Keywords: *Filin Shagari, Nebulite, Diatexites, Banded Orthogneiss, Pan African, Hydrothermal*

1. Introduction

The study area is located around filin Shagari village, Ganjuwa local government area of Bauchi State, northeastern Nigeria and within the basement complex of Nigeria with little or no research attention was given apart from recent work by Haruna, 2016 and Kariya, 2019. But this research work also aims at revealing the possible economic potentials of the rocks that have possibly undergone series of metamorphism. The rocks around filin Shagari area consist of different varieties of migmatite rocks which occurs in association with the younger granites that intruded the study area along the fractured zones. Pegmatite dykes and lodes occurring horizontally as sills along foliation planes in metatexites, also quartz ridges were observed at some places like Makodi harmlets forming high elevation ridges. The rocks in the study area had undergone polycyclic deformation thereby causing the formation of both micro and macro structures. Secondary structures (foliations, folds, micro faults, joints, quartz veins, fractures, ptygmatic folding,) in the rocks can be use as clues to determine geologic history of the area. The structures in the area are mostly trending N-S and NE-SW conforming to the Pan African structures, some structures are believed to be syntectonic (the foliation plains) which are E-W in their orientation. The Pressure-temperature conditions of metamorphism appear to vary from place to place as displayed by the rock units observed in the area during the field work where intensity of shear stress causes various deformation effects affected the rocks in the study area.

1.1 Location of Study

Filin Shagari, the study area is located within latitude N 10˚42′0″ and N 10˚48′0″ and longitude E 9˚37′12″ and E 9˚32′24″ covers an area of approximately 124.89km² North West of Ganjuwa Local Government area of Bauchi State Nigeria. The area is bounded by Ningi – Burra ring complex on the western part which is an extension of the Jos – Plateau ring complex of the younger granites in north central Nigeria. The main rocks within the study area consist of metatexites (banded orthogneiss). Gradational metamorphic changes to leucocratic diatexites was also noticed towards the southern part and nebulitic granite on north and eastern part respectively. These rocks are exposed by exhumation most especially the banded orthogneiss that is well exposed along a structurally controlled stream channel and was tilted vertically at 90^{o}. Two extensive quartzite ridge trending at N18˚E and N22˚E respectively, with the former at a higher elevation and extending few metres while the later, extend to some few kilometres.

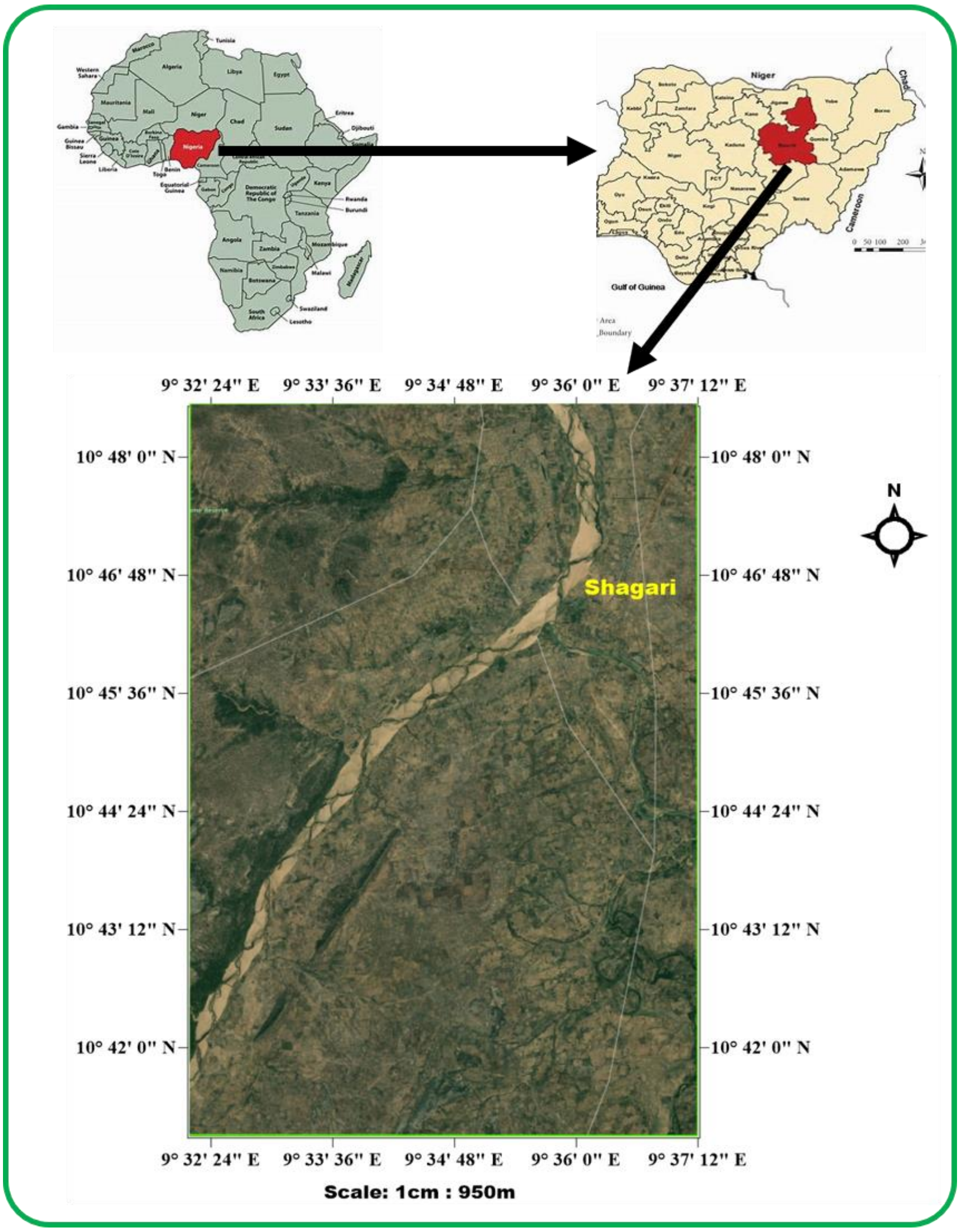


Figure 1. Geographic location of Filin Shagari in northwest of Ganjuwa Local Government Area.

2.0 Local Geology of the Study Area

The local geology of the study area was gotten little or no attention from the early researchers, which makes the area a virgin one. In view of that, this research intends to use the geology of Bauchi area as local geology of the area, since some part of Bauchi has almost similar geologic history with the study area.

2.1 Migmatite / Gneiss

The migmatites / gneisses in this group, Oyawoye (1965) recognized two major types of gneisses which include: the biotite gneiss and the banded gneiss. He also grouped the migmatites into two types, namely; the lit-par-lit gneiss and the migmatitic gneiss. In the lit-par-lit gneiss, according to the author, 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. On the basis of petrography, Oyawoye (1965) suggested that the gneisses and migmatites originated through silica-potash metasomatism.

Areas of the Jos-Bauchi transect has revealed several occurrences of granulite facies rocks within high-temperature amphibolites facies rocks and anatexites. It 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 Ferre' (2006).

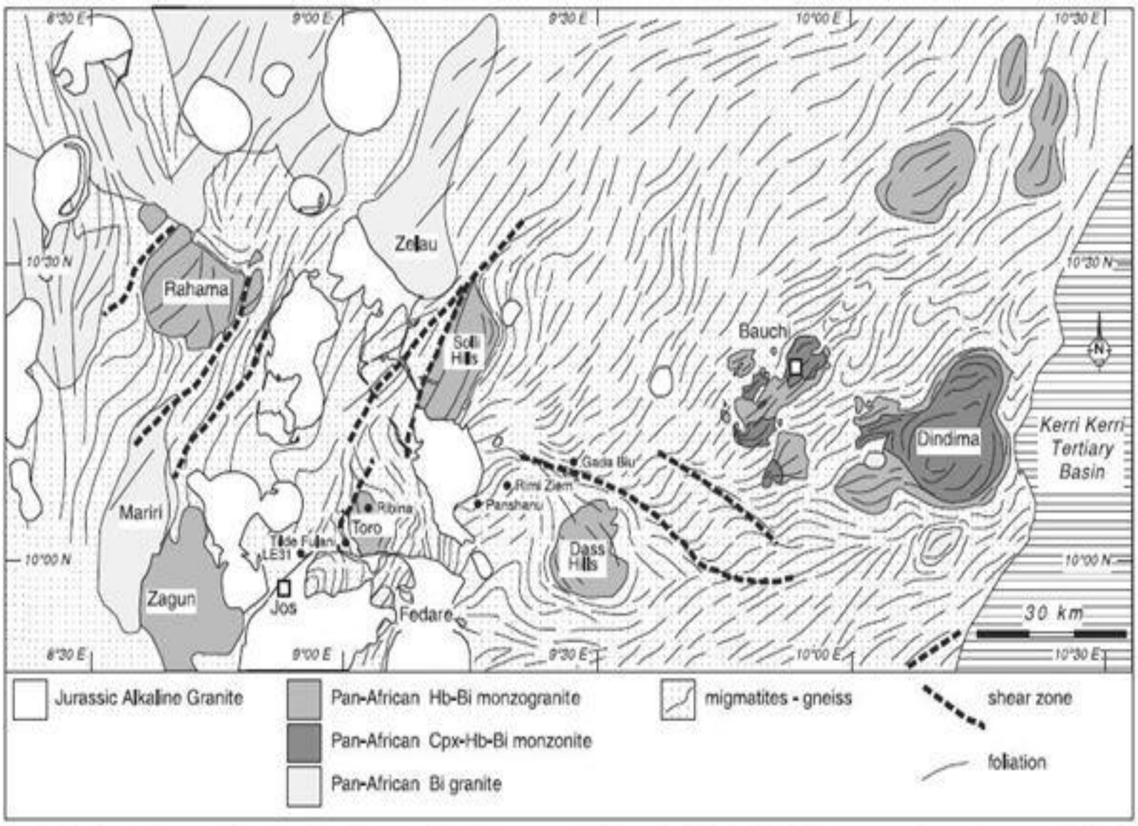


Figure 2: Geological map of the Jos–Bauchi area. Foliations compiled from field data, SLAR images and previous maps (Wright,1971) in Ferre' 2006.

2.3 The Migmatite – Gneiss Complex (MGC)

The migmatite–gneiss complex (MGC) is generally considered as the basement complex sensu stricto (Rahaman, 1988; Dada, 2006), some authors referred to them as migmatite-gneiss-quartzite complex (Rahaman and Ocan, 1978). It is the most widely spread of the component units in the Nigerian basement with heterogeneous assemblage of migmatites, orthogneises, paragneisses, and a series of basic and ultrabasic metamorphosed rocks. Evidence of Pan

African reworking have been seen in petrographic studies displaying medium to upper amphibolites facies metamorphism. The migmatite–gneiss complex has ages ranging from Pan-African to Eburnean. Lithologically, similar rocks in other parts of Nigeria especially in the northeast and southeast, have given only Pan-African age Tubosun, (1983).

Mehnert (1971) employs migmatite terminology based on their macroscopic appearance. (Urban, 1992; Schulmann et al., 1994; Hasalová et al., in press-a) uses two major deformation events recorded in this gneiss-migmatite complex. The deformation phase D1 resulted in formation of steep, west dipping solid-state foliation S1, represented by compositional layering in the banded orthogneises (Fig. 5a). The D2 deformation led to the development of a large crustal-scale shear zone and was associated with reworking and folding of S1 compositional layering that is locally preserved in elongated relict domains (Fig. 3). These relict domains with gently folded S1 fabric are surrounded by highly deformed zones with tightly folded S1 fabric. Locally the S1 fabric is completely transposed into the new S2 foliation dipping gently to the SW. The resulting composite S1–2 fabrics is characterized by banded structure with polymineralic K-feldspar- and plagioclase rich domains resembling stromatitic migmatite (Fig. 3c). Detailed field study revealed that, with increasing degree of deformation, the stromatitic migmatite gradually passes into more isotropic schlieren migmatite (Fig. 3d) still containing rootless folds modifying the relics of the S1 fabric. This rock type is alternating with irregular bodies or elongated lenses of felsic fine-grained nebulitic migmatite (Fig. 3e).

With regard to the above findings, Hasalová et al, (2008) classified the migmatites into four (4) groups based on structural deformation on the mineral assemblages as follows;

(a) The banded orthogneiss is characterized by monomineralic banding, defined by recrystallized K-feldspar, plagioclase aggregates and quartz bands, alternating with layers rich in biotite, garnet, sillimanite and apatite.

(b) The stromatitic migmatite is marked by the onset of disintegration of the original monomineralic banding and is composed of plagioclase and K-feldspar aggregates with subordinate quartz. These aggregates are rimmed by biotite locally overgrown by fibrolitic sillimanite.

(c) The schlieren migmatite is made of K-feldspar– quartz-rich and plagioclase–quartz-rich aggregates. The original banding is distinguishable only from the modal content of the mineral phase dominant in these feldspar aggregates.

(d) The nebulitic migmatite represents the most isotropic rock type, completely lacking relics of the original gneissosity. The migmatite occurs as irregular flat bodies or elongated lenses.

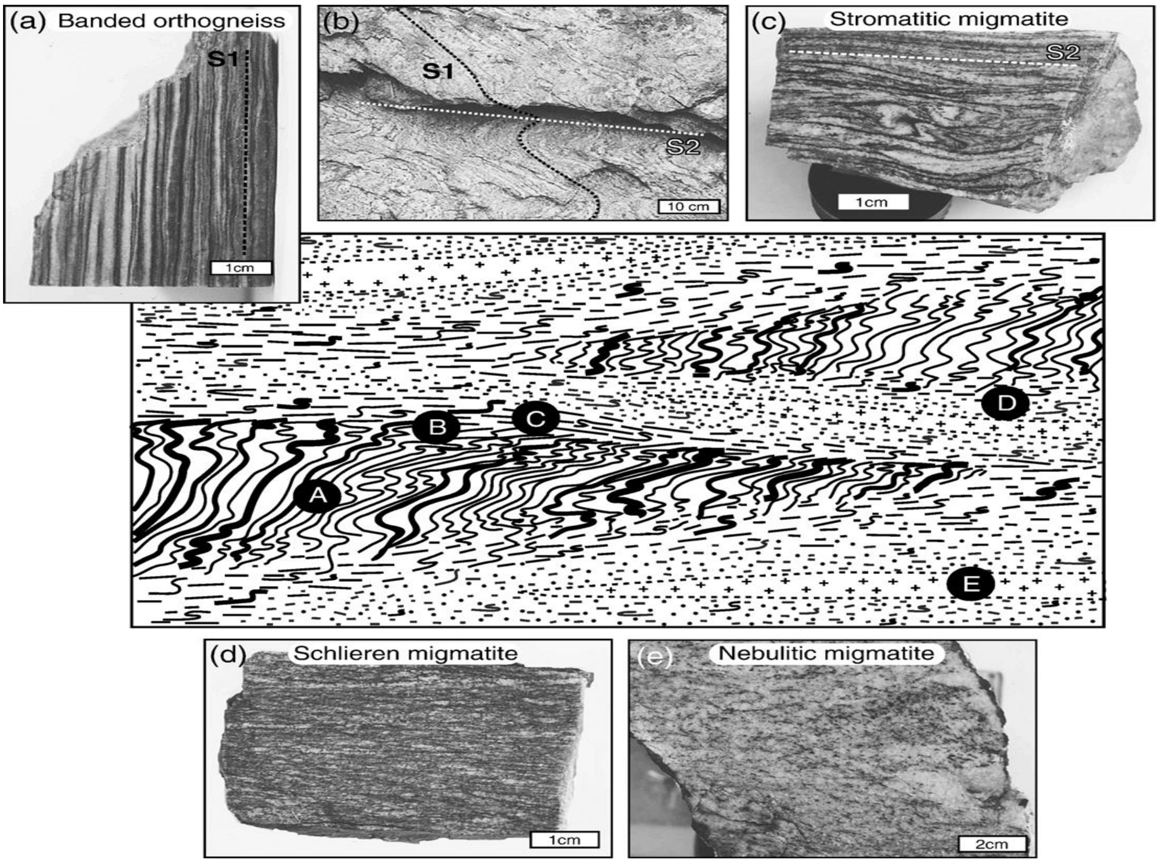


Figure 3: Sketch showing the individual gneiss and migmatite types and their relationships within an outcrop (the width of the figure is 5m; modified after Hasalová et al., in press-a). Banded orthogneiss with distinct S1 compositional layering (a) is folded and transposed (b) to the stromatitic migmatite (c) that passes gradually to the schlieren migmatite (d) and finally to the completely isotropic nebulitic migmatite with no relics of gneissosity (after Hasalová et al, (2008)*).*

2.4 The Schist Belt

The schist belts comprise low grade, metasediment-dominated belts trending N-S developed most in the western half of Nigeria. These belts are considered to be Upper Proterozoic supracrustal rocks which have been infolded into the migmatite-gneiss-quartzite complex. The lithological variations of the schist belts include coarse to fine grained clastics, pelitic schists, phyllites, banded iron formation, carbonate rocks (marbles/dolomitic marbles) and mafic metavolcanics (amphibolites). Some may include fragments of ocean floor material from small back-arc basins.

Although, some authors have different opinions on the origin of the schist belt; Rahaman (1976) and Grant (1978) suggested that there were several basins of deposition, whereas Oyawoye (1972) and McCurry (1976) consider the schists belts as relicts of a single supracrustal cover. Olade and Elueze (1979) consider the schist belts to be fault-controlled rift-like structures. Grant (1978), Holt (1982) and Turner (1983), based on structural and lithological associations, suggested that there are different ages of sediments. However, Ajibade et al., (1979) disagree with this conclusion and show that both series contained identical deformational histories.

The structural relationships between the schist belts and the basement were considered by Truswell and Cope (1963) to be conformable metamorphic fronts. The schist belt rocks are generally considered to be Upper Proterozoic. The geochemistry of the amphibolites complexes within the schist belts has also led to controversy. Klemm et al. (1984) have concluded that the Ilesha belt may be an Archaean greenstone belt. Olade and Elueze (1979), Ogezi (1977) and Ajibade (1980) have favoured dominantly ensialic processes in the evolution of the schist belts while Ajayi (1980), Rahaman (1981) and Egbuniwe (1982) have stressed that some include oceanic materials with tholeiitic affinities. Some metallogenetic features of the schist belts are relevant to these problems; the apparent absence of subduction related mineral deposits may be indicative of a limited role for the ensimatic processes; the distribution of primary gold occurrences in some belts but its marked absence in others may indicate that they do not represent a single supracrustal sequence. The schist belts are best developed in the western part of Nigeria, west of 8°E longitude, though smaller occurrences are found to the east but only sporadically.

2.5 The Older Granites (Pan African Granitoids)

The term “older granite” was introduced by Falconer (1911) to distinguish the deep-seated, often concordant or semi-concordant granites of the basement complex from the high-level, highly discordant tin-bearing granites of Northern Nigeria (the younger granite). The older granites are believed to be pre-syn and post-tectonic rocks which cut both the migmatite-gneiss-quartzite complex and the schist belts. They range widely in age (750-450 Ma), composition and representing magmatic cycle associated with the Pan-African orogeny. The rocks of this suite range in composition from tonalities, diorites, granodiorites to granites and syenites. Charnockites form an important rock group emplaced during this period. They are generally high-level intrusions and anataxis has played an important role (Rahaman, 1981). The older granites suite is notable for its general lack of associated mineralization although the thermal effects may play a role in the remobilization of mineralizing fluids.

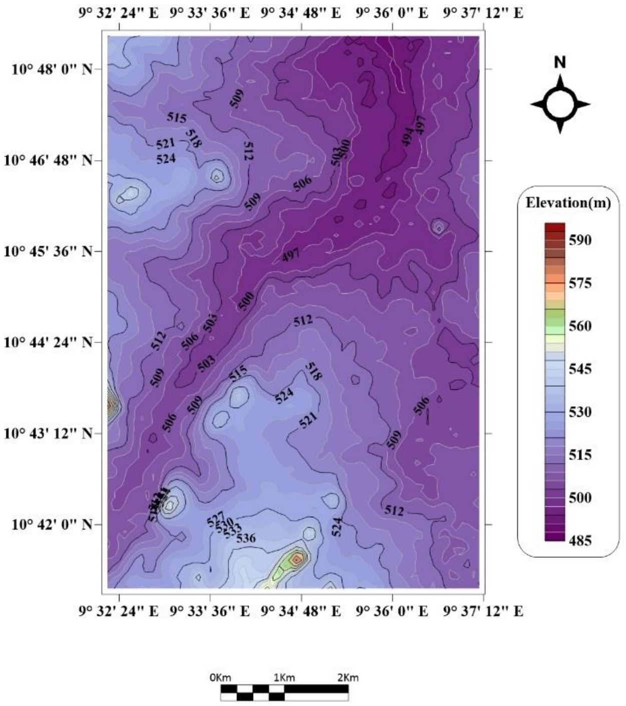
Dada (2006) was of the opinion that the term “Pan African granitoids” be used for the older granites not only on the merit of age which was not available at the time they were named older granites, but because it covers several important petrologic groups formed at the same time.

The granitoids which outcrop with the schist belts in northwestern and southwestern Nigeria include biotite granites, biotite muscovite granites, syenites, charnockites, serpentinites and anorthosites. Rahaman (1988) discarded the earlier classification of members of the older granites suite on the basis of their texture, mineralogical composition and the relative timing of their emplacement. In its place, members of the older granite suite were classified as follows, based mainly on the textural characteristics: Migmatitic granite, Granite gneiss, Early pegmatites and fine-grained granite, homogeneous to coarse porphyritic granite, Slightly deformed pegmatite aplites and vein quarz and undeformed pegmatites, two-mica granites and vein quartz.

In northern Nigeria, the abundance of Pan-African granites appears to increase eastward, occurs as isolated intrusions in some places (McCurry, 1973), whereas in the region between Rahama and the Mesozoic-Cenozoic cover the intrusive granites and related rocks envelope remnants of migmatites.

McCurry (1973) divided the granites into two main groups according to their field relationships. The first “syntectonic” group comprised elongate batholithic sheets that are partly concordant and foliated. The second group “late tectonic” are made up of poorly foliated discordant bodies, rich in mafic xenoliths and having a lower proportion of potash feldspar.

Older granite rocks therefore occur in most places where rocks of the migmatite-gneiss complex or of the Schist Belt occur. However, older granites are particularly noteworthy in and around Wusasa (Zaria), Abuja, Bauchi, Akwanga, Ado-Ekiti and Obudu areas.



Title: Contour Map Of The study Area
Coordinate System: GCS WGS 1984
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Unit: Degree Minute Second

Figure 4. Contour map of the studied area.

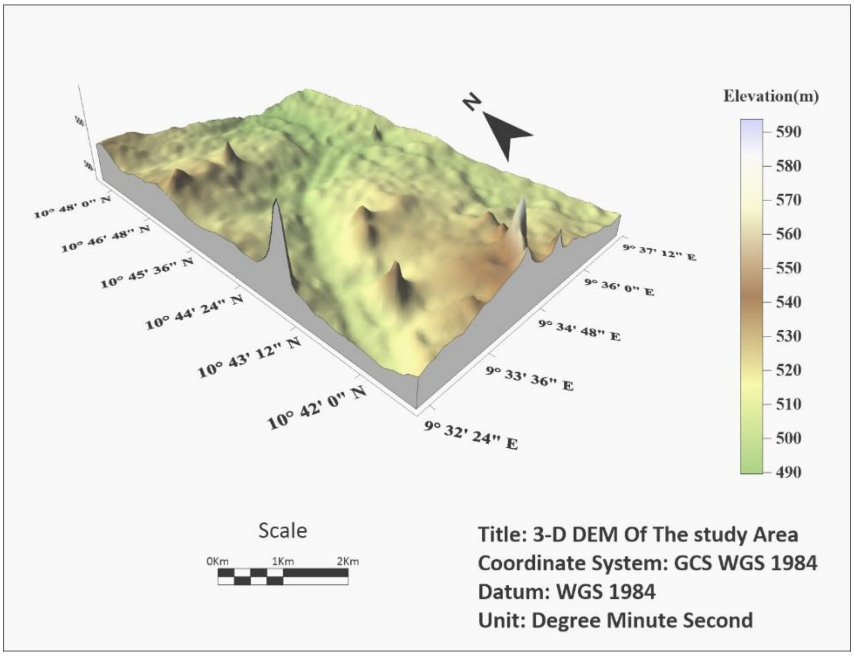

Figure 5. Digital Elevation Model (DEM) of the studied area.

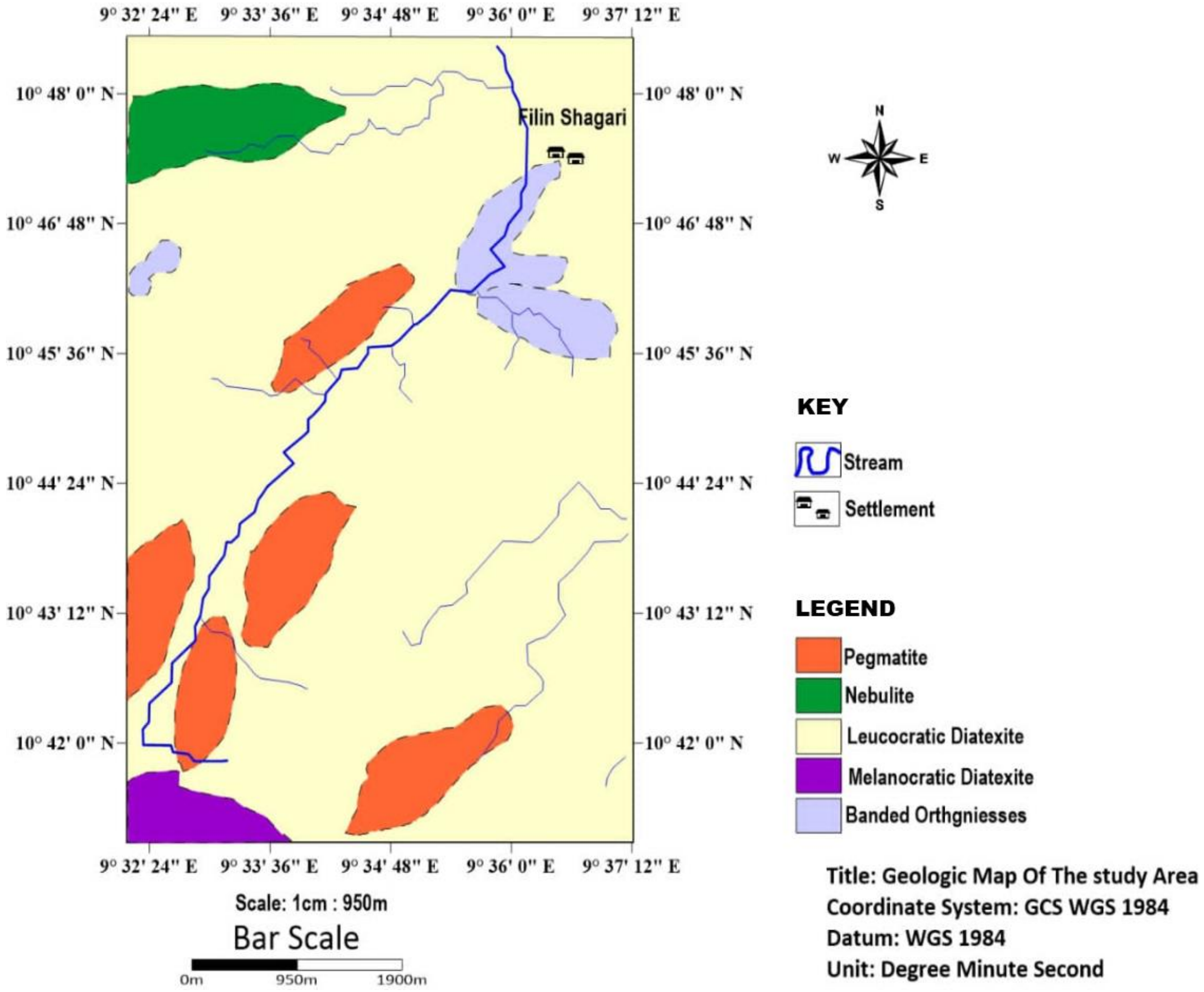

Figure 6. Geologic map of the studied area based on 1cm: 950m

3. Research methods

The research in this study consist of two parts: field and laboratory studies. Field studies include identifying the different types rocks and structures within the study area and their relationship. And how this structure possibly affects this rocks towards economic enrichment of minerals. Furthermore, sampling of these rocks are pre-requite for laboratory studies include preparing of 14 rocks samples for thin section and optical mineralogy and petrographic studies, analyzing 9 samples by XRF for major and trace elements, and 4 sample by AAS for lithium. Finally, these analyses were processed by Excel and GCDKit.

4.0 RESULTS AND DISCUSSION

4.1 Field Relationships

Plate 1: Field View of Pegmatite ridge in–situ **(a)** and Hand Specimen **(b)** The Pegmatite Ridge at Filin Shagari.

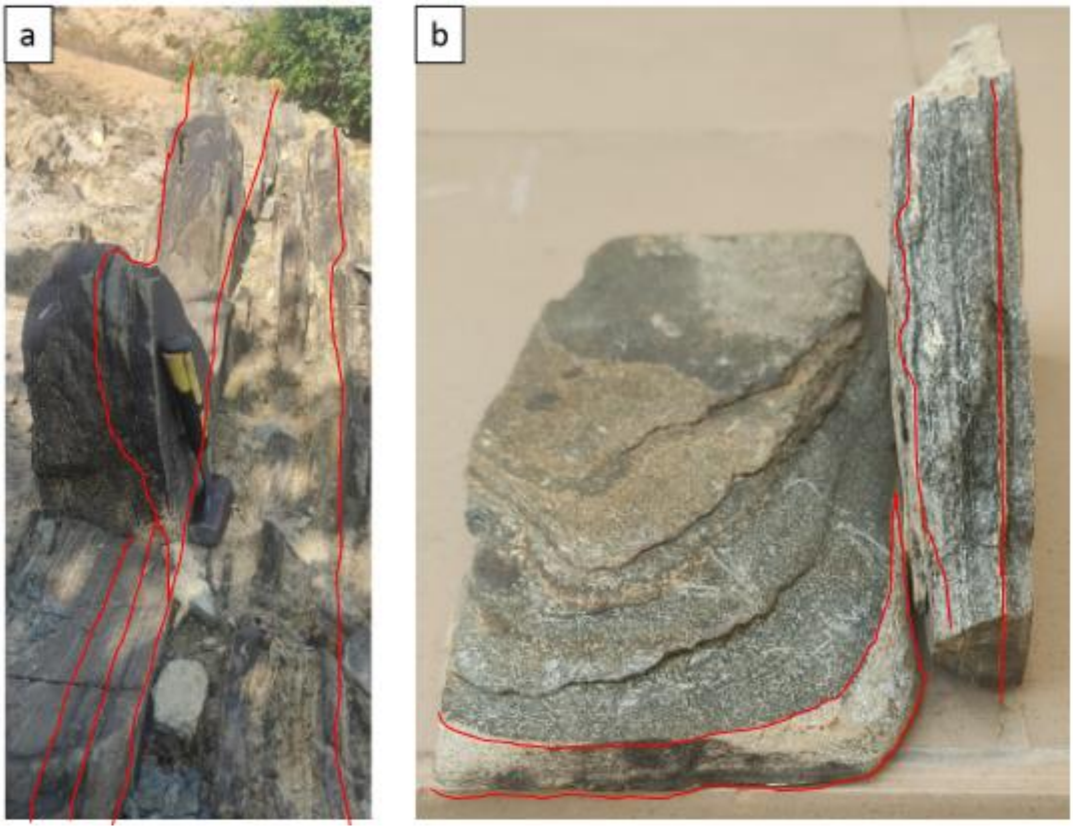

Plate 2: Field View of tilted Banded orthogneiss (**a**) and Hand Specimen Banded Orthogneiss showing felsic and mafic band

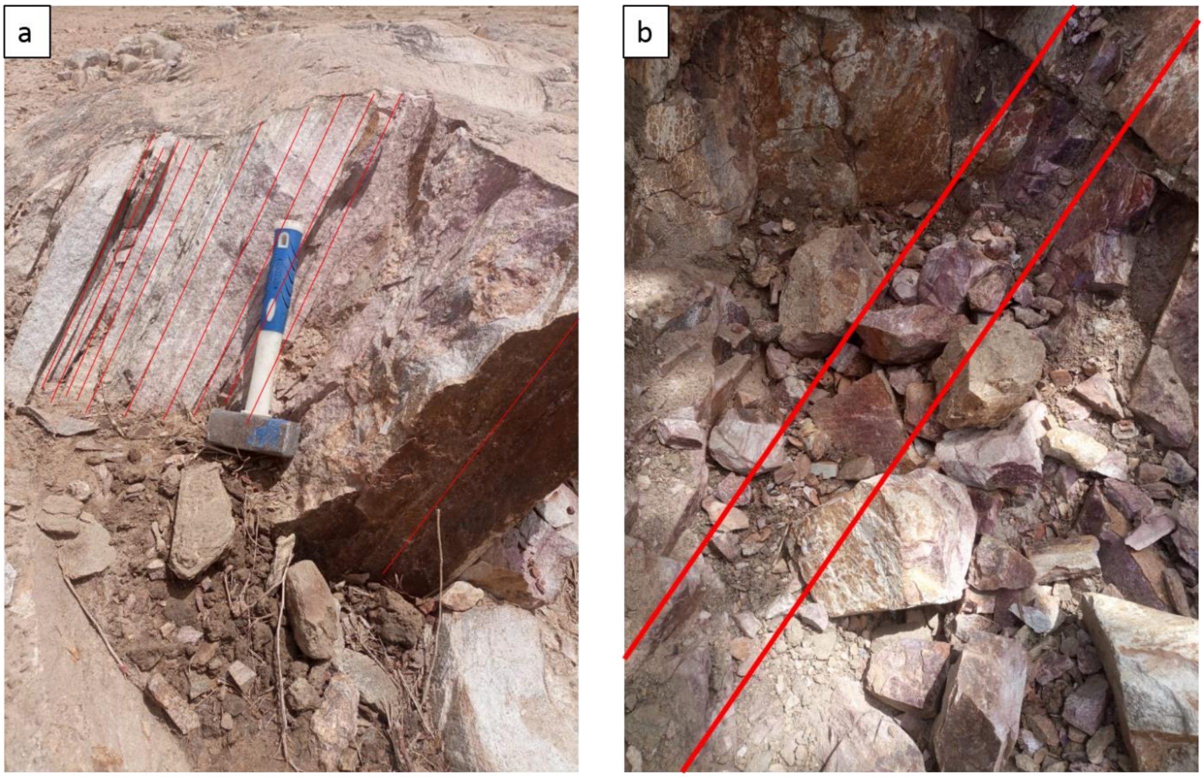

Plate 3: (a) Field view of Banded orthogneiss with pinkish change in coloration due to enrichment of hydrothermal fluid invasion (b) Foliation planes acting as conduit for migration of hydrothermal fluid and mineralization of litium.

Plate 4: (a) Field view and raft remnant of metatexite within Diatexite (b) Diatexites in Hand Specimen.

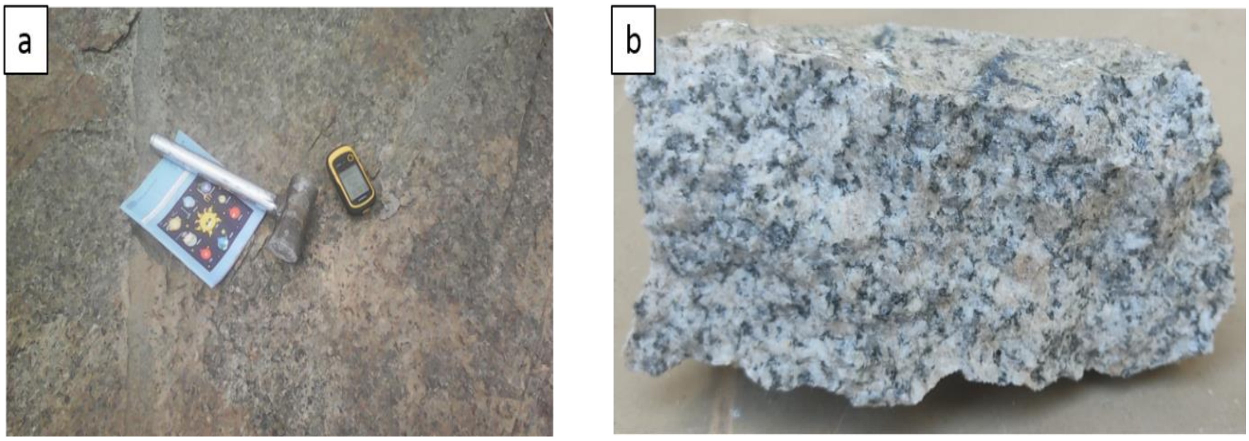

Plate 4: (a) Field view and (b) Hand Specimen of Nebulite

4.2 Geochemistry

Studying the geochemical characteristic of filin Shagari rocks, 9 samples were analyzed at Nigerian Geological Survey Agency (NGSA) laboratory at Kaduna for major and trace elements by XRF analysis method, and additional 4 sample that were collected during backed checked were also analysed for lithium at the Geochemistry Laboratory of Applied Geology Department of Abubakar Tafawa Balewa University Bauchi. The results of both analyses are presented below in table 1 & 2.

Table 1. The result of samples analysis from the studied area by XRF method (major elements in wt% and trace elements in ppm)

Major Oxides	MDK2	MDKA02	KMA01	MKDB02	NE	MKDA03	KF01	MKD D02	JIRJIR Composition %
SiO_2	78.11	50.33	73.60	90.70	72.34	61.34	53.22	90.89	59.30
CaO	0.32	3.09	0.20	0.12	Nd	0.08	0.01	0.06	1.20
MgO	0.06	8.65	0.03	0.01	Nd	0.01	Nd	Nd	5.99
SO_3	Nd	0.10	Nd	Nd	Nd	Nd	Nd	Nd	0.05
K_2O	3.12	1.03	2.68	1.30	2.20	18.40	10.23	1.00	8.10
Na_2O	1.00	0.90	1.20	0.40	0.81	1.00	0.88	0.53	0.86
TiO_2	0.70	1.43	1.00	0.02	0.03	0.86	Nd	0.02	0.03
MnO	Nd	0.05	Nd	0.04	Nd	0.08	0.04	Nd	Nd
P_2O_5	Nd	Nd	0.06	Nd	Nd	0.05	Nd	Nd	Nd
Fe_2O_3	1.83	18.30	1.40	1.30	2.40	1.00	18.00	0.87	7.40
Al_2O_3	12.30	13.40	12.00	2.40	16.00	14.12	12.42	4.77	13.50
LOI	1.00	2.40	2.78	0.85	2.78	2.87	3.60	1.00	1.76

Total	97.44	97.28	92.17	96.29	93.78	96.94	94.8	98.14	96.43

Table 2: Trace Elements Data

	MDK2	MDK A02	KM A01	MKD B02	NE	MKD A03	KF	MKD D02	JIRJI
V	201.8	401	482	663	520	613	521.5	723	722
Cr	118.5	145	245	316.5	230.1	325	216.1	232	212.3
Cu	482	134.5	340	382	313	293	454	424	435
Sr	1830	1310	2070	1820	1540	270	1240	3230	6230
Zr	5710	1220	1500	1200	1000	720	1200	1630	1640
Ba	690	3150	1800	2010	930	100	3100	680	690
Zn	120	87	560	370	40	60	97	50	58
Ce	33	52	54.5	63.7	42.7	45.5	63	55.8	58.03
Pb	75.5	26.8	867.5	56.8	25.5	18	26.7	83	84
Bi	0.144	0.109	0.87	5.1	1.89	0.219	0.09	0.751	0.451
Ga	34	39.5	22.5	5.5	32	17.8	39.8	26.5	26
As	22.5	7.5	10.25	3	15	7	7.02	15	15.05
Y	10.3	15.5	3.9	4.3	14.8	39.2	15	3	2.9
Ir	5	10	6.09	2.02	3.1	3.13	20	2006	2.06
Au	0.07	0.02	0.448	0.2	0.224	0.024	0.24	0.4	0.43
Ni	0.056	<0.001	<0.001	<0.001	0.038	0.005	<0.001	<0.001	0.74
Rb	21.6	29	30.4	36	30	9.84	29.5	36	39
Mo	15.5	32.01	83	0.009	48.5	14.55	32.01	<0.001	<0.001
Co	<0.001	0.001	0.213	<0.001	0.02	0.01	<0.001	5.5	5
Cd	0.09	0.034	1.192	0.005	0.998	<0.001	0.034	<0.001	<0.001
Ru	0.032	0.015	0.001	1.23	0.002	<0.001	0.005	8.8	8.6
Eu	0.65	0.22	2.06	340	1.24	0.82	0.14	38.5	38
Re	14	12.5	36	<0.001	12	11	10	<0.001	<0.001
Nb	20.2	17	20.35	42	20.12	14.3	20.22	18	17
Ag	0.65	0.4	0.09	0.54	1.12	0.67	0.11	1.2	1.5
Ta	70.5	42.15	64.2	55	36	63	42.1	41.2	41
W	12.5	0.891	1.46	5.06	0.96	13.3	0.891	0.882	3.83
Hf	38.45	33	21.5	24	20	16	33	11	14
Yb	2.14	4.04	6.95	0.46	2.11	1.56	4.14	5.9	5
In	0.72	2.1	0.09	2.23	1.9	3	2.1	8	8.5
Se	0.2	<0.001	0.012	0.28	0.21	0.28	<0.001	<0.001	<0.001
U	0.201	<0.001	0.007	0.001	0.022	<0.001	0.001	<0.001	<0.001
Th	0.41	2	2.2	0.3	0.86	0.22	1.5	0.2	0.22
Sb	8.51	7.13	14	4.3	6.13	12	7.03	4.24	3.6
Ge	14	20.5	41	4.3	4.1	14.5	24.5	68.5	65.5
Sn	51.1	21.5	19	19.8	17	9.3	21.6	35	43.3

Table 3. The results of samples analysis for Lithium from the studied area by AAS method in CONC (mg/L).

NO.	CONC(mg/L)	AA	BG	SD	RSD (%)
BK	0.000	0.000		0.000	0.000
L1B	0.003	0.000		0.001	108.6
LP1b	0.134	0.018		0.001	3.288
LP1	0.135	0.019		0.000	1.107
L5B	0.009	0.001		0.001	49. 68

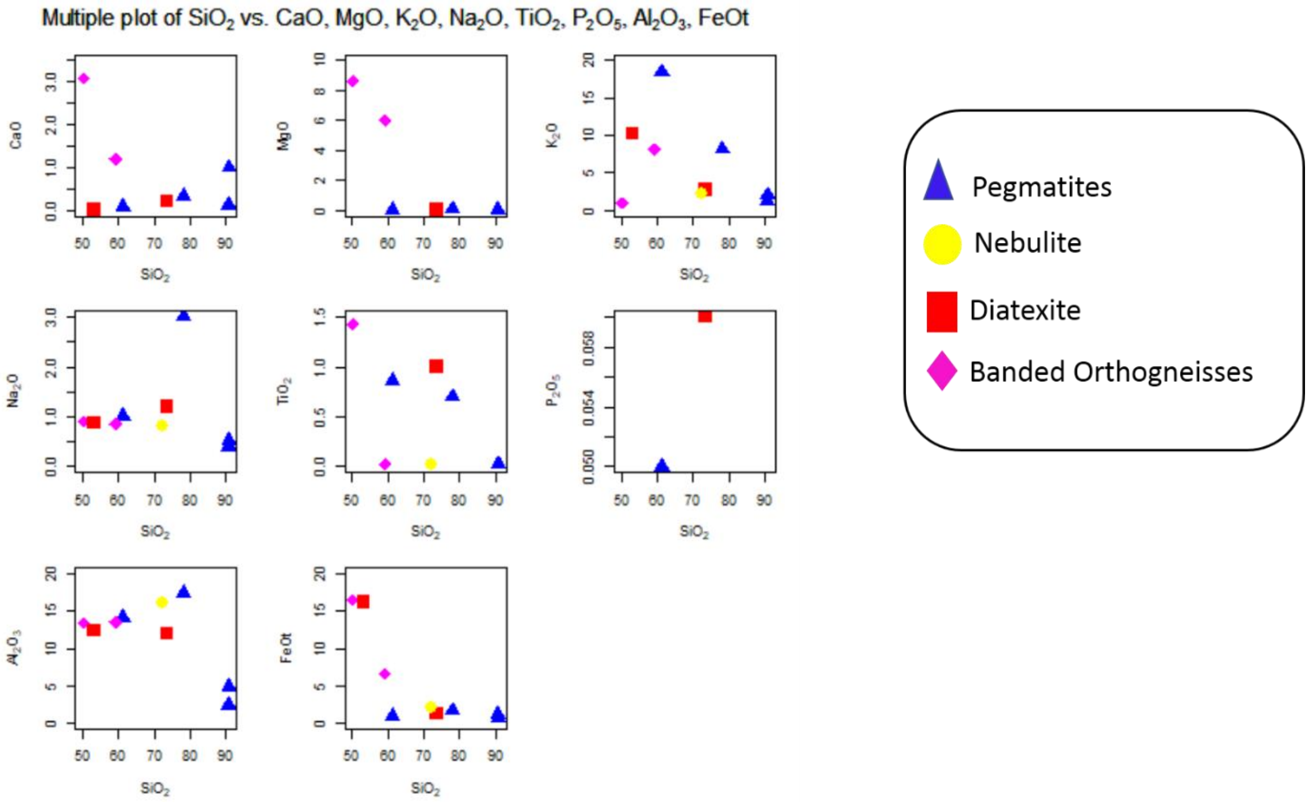

Figure 7. Harker's variation diagram between SiO_2 and major oxides.

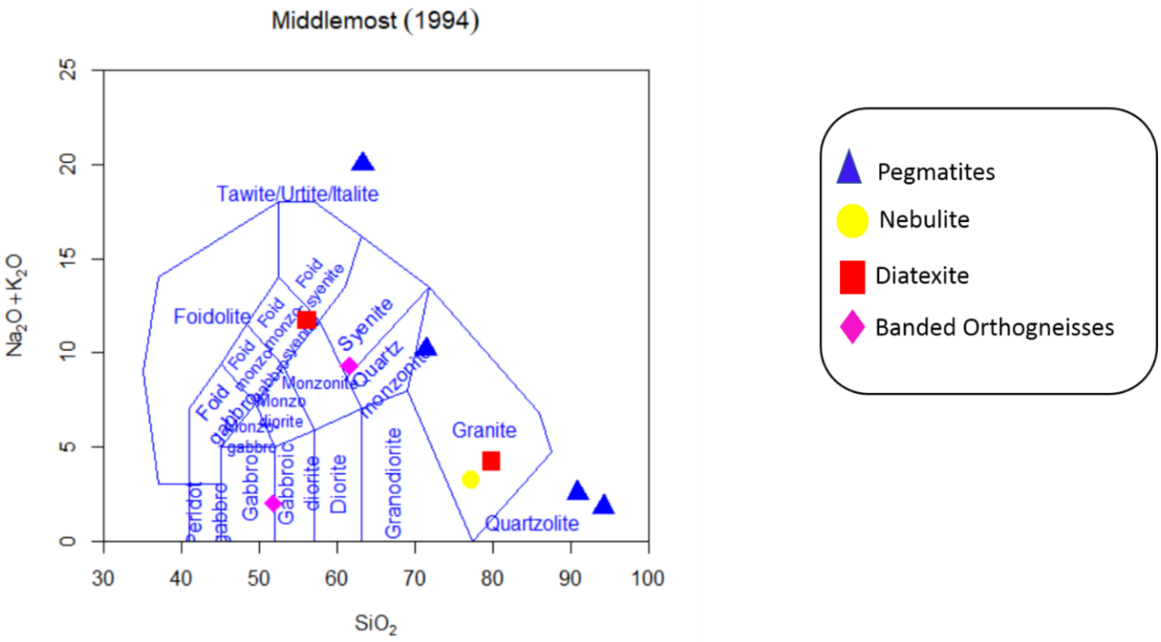

Figure 8. SiO2 versus Na2O + K2O diagram (middlemost 1985)

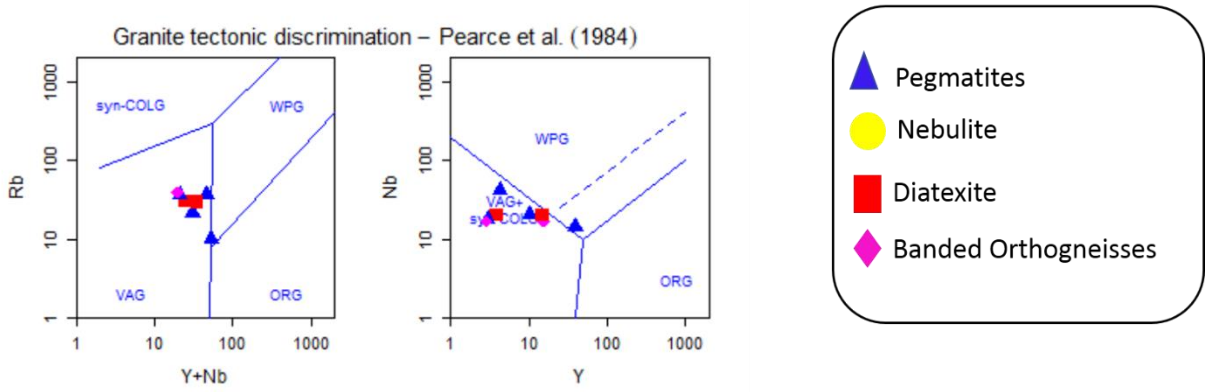

Figure 9. Granite tectonic discrimination diagram – Pearce et al (1984).

From the above discrimination diagram all of the rock samples fall within the Volcanic Arc Granites which implies that they are all S-type signatures.

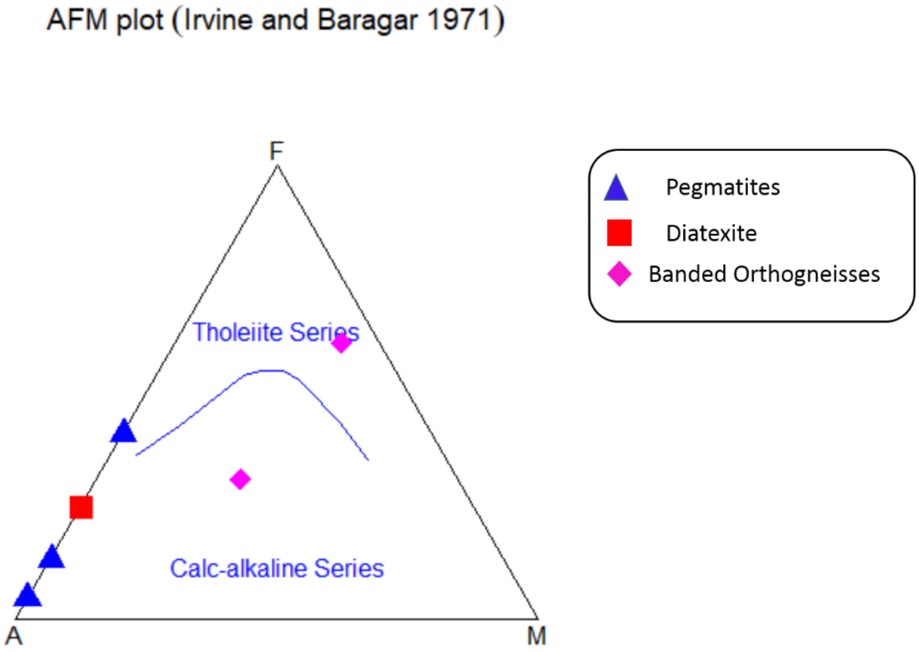

Figure 10. The AFM triangular diagram indicate that the rock units are Calc-alkaline series (Irvine and Baragar 1971).

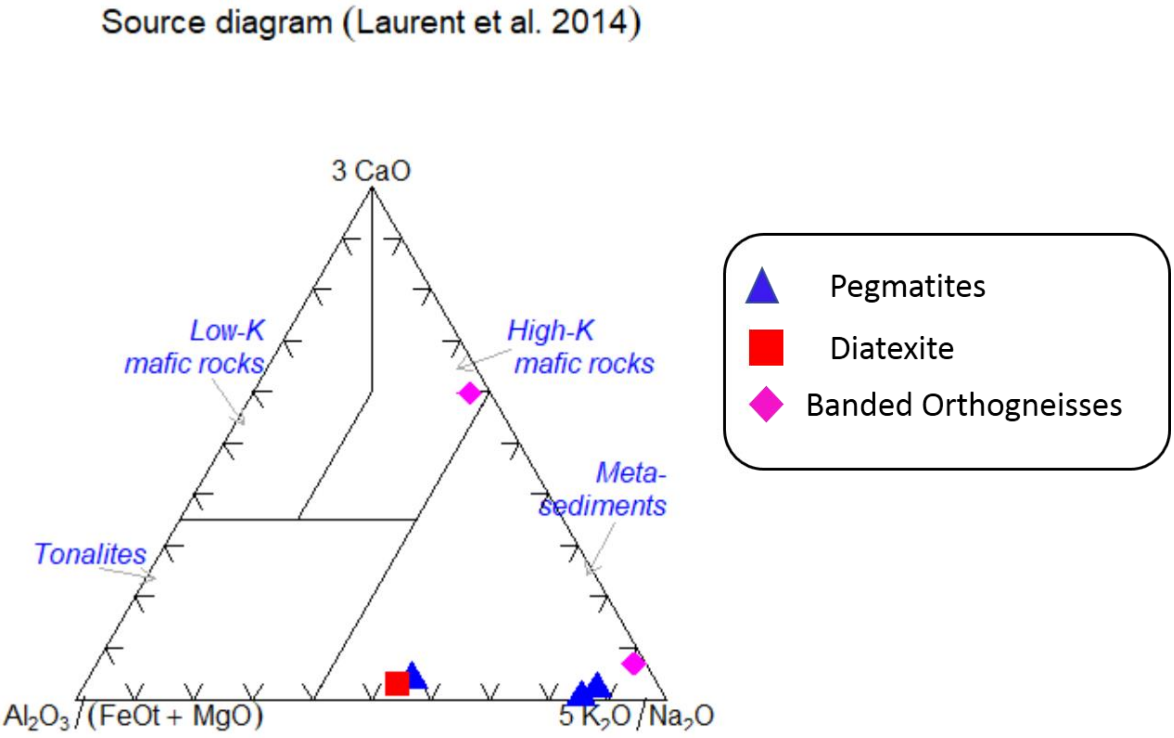

Figure 11. Source diagram (Laurent et al. 2014)

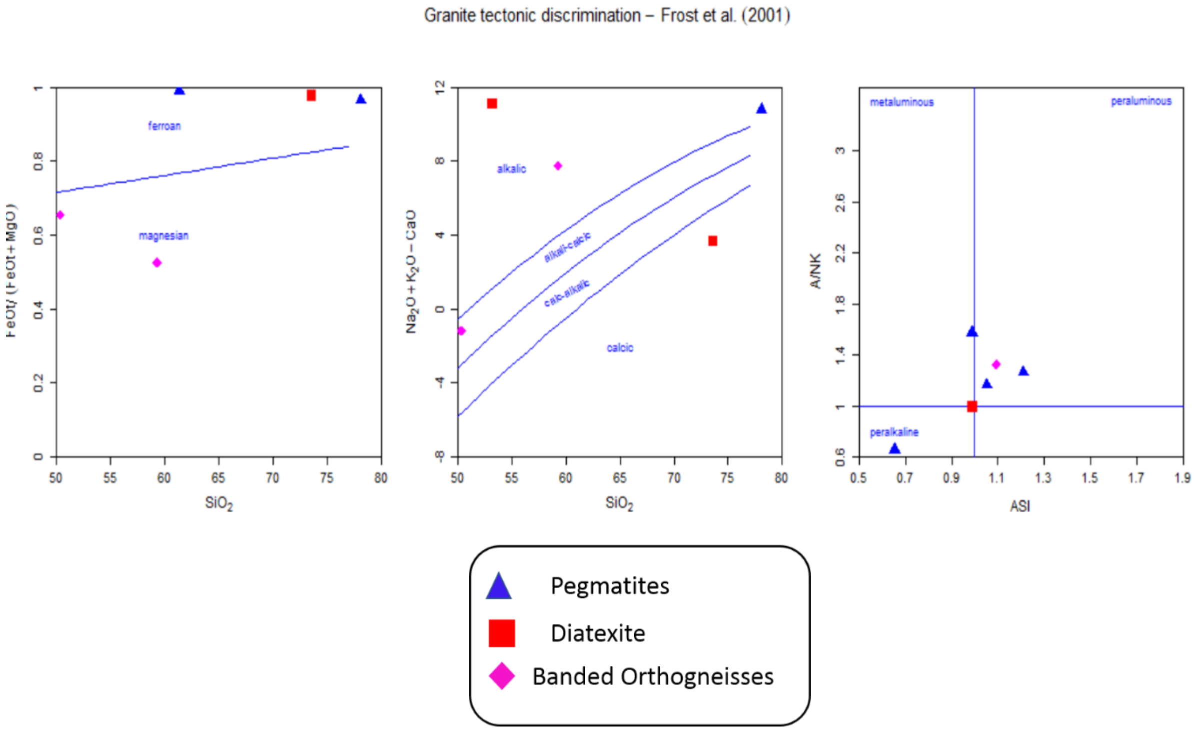

Figure 12. Modified Alkali Lime Index diagram and ASI diagram after Frost 2001.

Based on the above Granitic tectonic discrimination plots above Figure 9A, there is a significant increase in the ferromagnesian (Fe-Mg) in the banded orthogneiss with low silica content and while in the pegmatite and the diatexites are highly rich in silica SiO_2. Figure 9B, based on the calcic – alkali index rocks of filin Shagari are alkali rich most especially the banded orthogneisses. Figure 9C, this indicate the rocks are peraluminous.

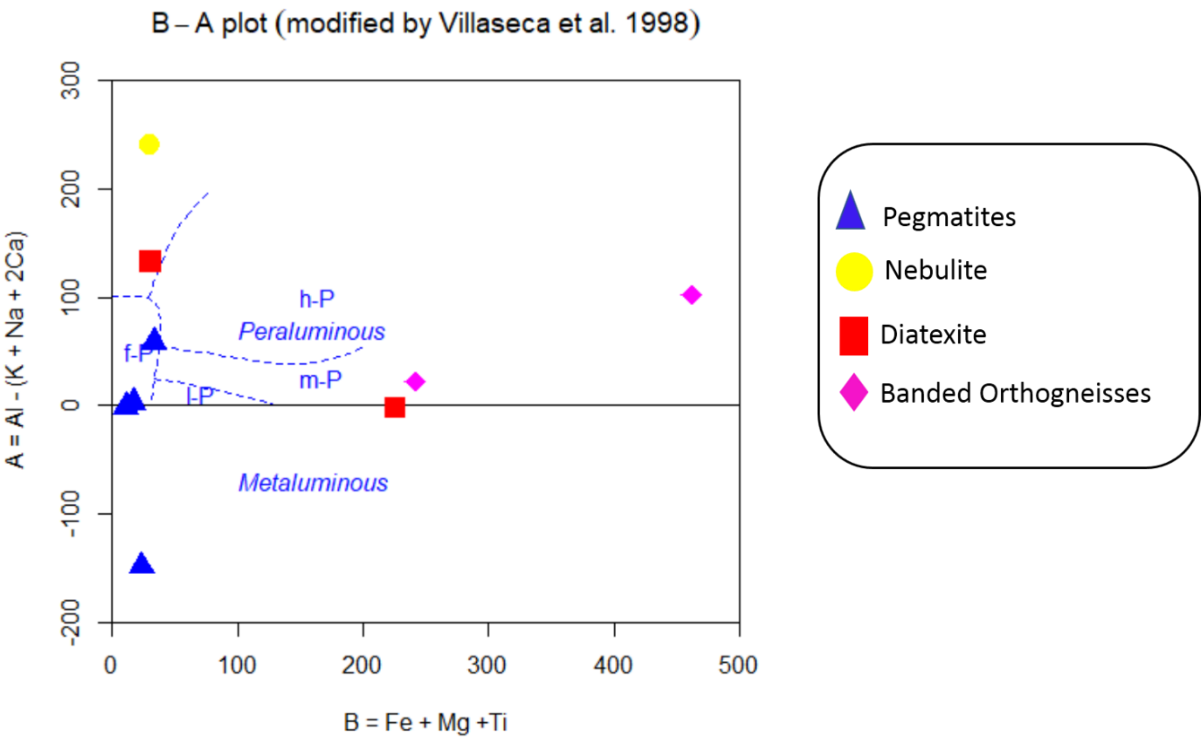

Figure 13. SiO2 vs K2O diagram (B-A plot modified by Villaseca et al. 1998)

The B-A diagram as proposed by Debon and Le Fort (1983) with classification fields for various types of peraluminous rocks designed by Villaseca et al. (1998) were plotted. The B = Fe + Mg + Ti parameter reflects the content of mafic minerals and the A = Al – (K + Na + 2Ca) parameter reflects the amount of aluminum incorporated into feldspars (calculations are based on millications). All the rocks from the study area plot in the peraluminous domain. They all fall in the highly Peraluminous field (Figure 10).

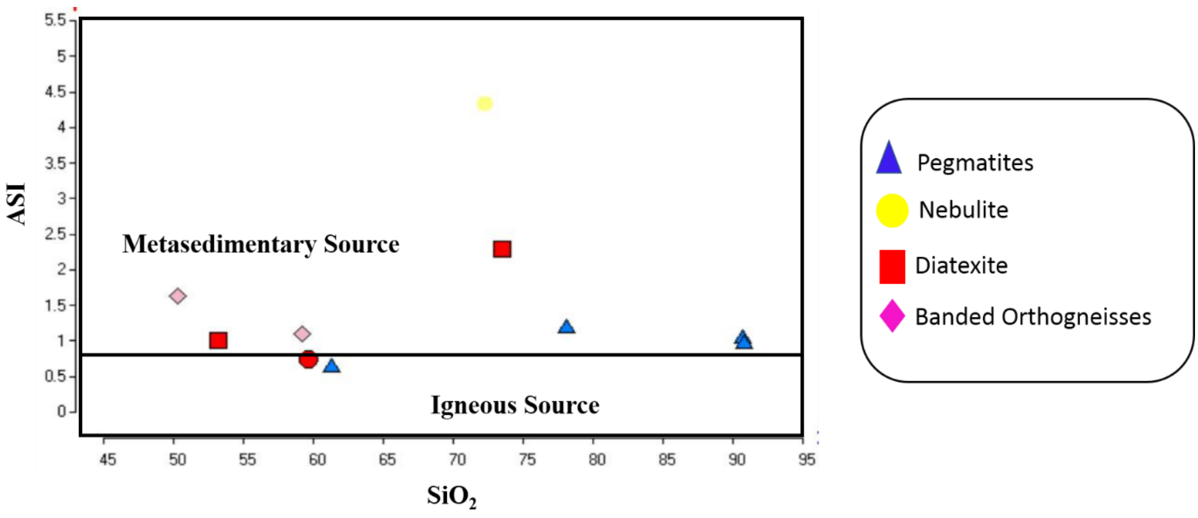

Figure 14: SiO_2 versus Al_2O_3/ ($CaO + Na_2O + K_2O$) Diagram (After Clarke et al. 2005).

All the rocks in the area fall within the metasedimentary source as the source of the protolith

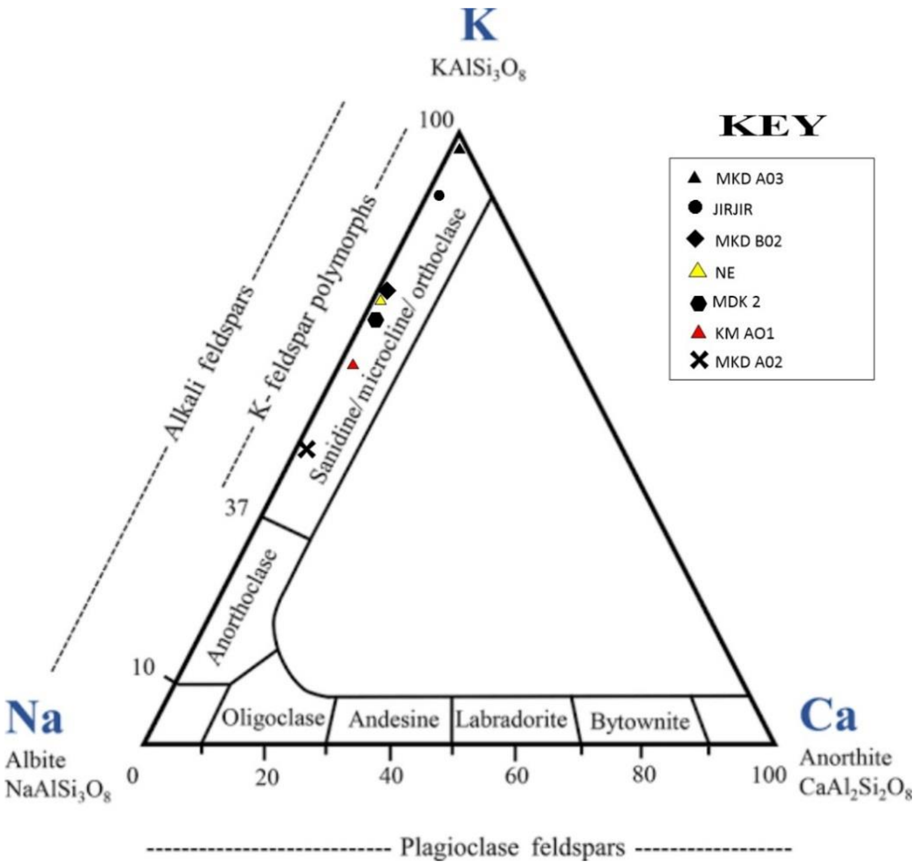

Figure 14. Feldspar Diagram of Solid Solution Series between Albite and Orthorclase.

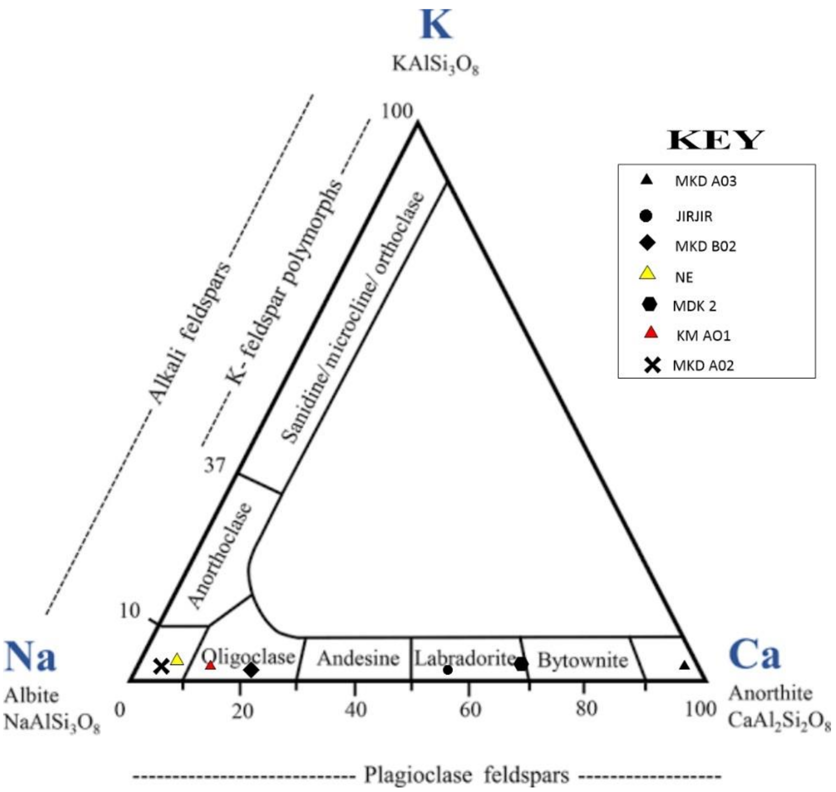

Figure 15. Feldspar Diagram of Solid Solution Series between Albite and Orthoclase

From the feldspar plot above the Banded orthogneisses falls within labradorite domain while the Diatexites fall within the Albite region, the pegmatites falls in the anorthite labradorite and oligoclase.

4.3 Conclusion

The following conclusions can be drawn after a critical evaluation and studies of the geochemical data obtain from XRF and results from the AAS which is married with field occurrence and the morphological relationships of these rocks combined with other parametres.

1. The research area has few morphological units of migmatites which include banded orthogneiss that are structurally tilled vertically due to shear stress, diatexites, pegmatite ridges and a pocket of nebulite at the flank.
2. The research area has been subjected to low grade metamorphism and tectonism resulting to the exposures of the banded orthogneiss along the structurally controlled stream.
3. Massive ridges of Pegmatite were also noted, that may possibly host mineralization of heavy metals and rear earth elements (REE).
4. The foliation planes of the Banded orthogneiss are acting as conduit for the hydrothermal fluid.

5. The migmatites are S-type granite in origin and have undergone incomplete solid-solution and low fractionation.

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