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Geology and Petrochemistry of Rocks from 1:50,000 Sheet 272 (Katsina Ala) SE, North Central, Nigeria

Oladimeji, R.G.[1], Abhulimen, G.P.[1] and Dambatta, U.A.[2]
[1]Nigerian Geological Survey Agency, Abuja, Nigeria.
[2]Department of Geology, Ahmadu Bello University, Zaria, Nigeria.
Corresponding E-mail: oladi21may@yahoo.com

Abstract
The Nigeria- Cameroon border stretching from Adamawa Mountain through Mabilla Plateau and Obudu to Oban massif has not been adequately mapped due to the ruggedness of the terrain and density of vegetation. The geological mapping of 1:50,000 Sheet 272 (Katsina Ala) SE was carried out to identify and study the rock units, their structural features, mineralogical composition and potential ore mineralization. Field mapping of surface geological features and outcrops along road cut, dug pits and stream channels was carried out. Fifty six (56) outcrops were visited. Rocks mapped include banded gneiss, granite gneiss, porphyritic biotite granite, medium- coarse –grained granite and quartz mylonite. Structural data such as foliation, joints, folds, lineation and mineralogical composition of the various lithological units were identified, measured and recorded. Five samples were selected for geochemical analysis while ten samples were studied petrographically. Major, trace and rare earth elements (REE) determination was carried out by using Inductively Coupled Atomic Emission Spectrophotometer (ICP- AES) and an Inductively Coupled Plasma Spectrometry (ICP- MS) techniques. The thin section study was also done using polarizing microscope. The results from the interpreted geochemical and petrographic studies classified the samples as S- type granitoids and peraluminous .The bivariate of Nb vs. Y and Y and Rb plots suggest Volcanic Arc and Syn-collision granitic origin for the samples. The ternary plot of TiO_2, K_2O and P_2O_5 suggests continental field for the samples as against the oceanic field while the binary plot of alkali and silica suggests subalkaline. Multi- element (N) plot of Sun and MacDonough (1989) shows enhancement of LREE over MREE and HREE and this is a typical signature of granitic rocks. TAS plot suggests that all samples belong to the granitic clan of igneous rocks. Rose plot from the lineaments extracted from satellite imagery and the one plotted from the data generated from structural features expressed the structural trends of 1:50,000 Sheet 272 Katsina Ala SE to be NE-SW / NW-SE as major while N-S is minor. The granitic rocks and granite gneiss will be useful for construction purposes, dimension stone and as floor tiles. Kaolin is for making paper, rubber and paint while laterite can be used in the area for making brick for building construction .The joints associated with the granitic rocks could serve as conduits for water movement and accumulation where groundwater can be tapped for man use.

Keywords: *Geology, Petrochemistry, Rocks, Sheet 272, Nigeria*

Introduction

The Nigeria- Cameroon border stretching from Adamawa Mountains through Mabilla Plateau and Obudu to Oban Massif has not been adequately mapped due to the ruggedness of the terrain and density of vegetation. Therefore, the rock types in this axis have not been adequately studied and mineral potential of the region is unknown. The mapping exercise was carried out to identify and study the rock units, their structural features, mineralogical compositions and potential ore mineralization.

Location*:* 1:50,000 Sheet 272(Katsina Ala) SE has 7º 00′ 00" -7º 15′ 00" N and 9º 15′ 00" -9º 30′ 00" E as coordinates. It shares boundary with ¼ degree Sheet 272 Katsina Ala SW,1/4 degree Sheet 272 Katsina Ala NE , ¼ degree Sheet 273 Takum SW in the east and ¼ degree Sheet 291 Obudu NE .1/4 degree Sheet 272 (Katsina Ala SE) falls within Benue State, North Central Nigeria.

Benue State which is in the Middle Belt region of Nigeria lies within Longitudes 07º 30′ and 10º 00′ E and also within Latitudes 06º 15′ and 08º 25′ N. It is bordered by Nasarawa State in the north, Taraba State and Cameroon Republic in the east, Cross River, Ebonyi and Enugu States in the south, and Kogi State in the west Fig 1. The State is named after the river Benue which runs through the length of the state.

Previous Work: Previous work done in the area was the geological mapping of 1:50,000 Sheets 272 Katsina Ala SW, NE, and NW by the then Geological Survey of Nigeria (GSN) in 1985 under the Ministry of Mines and Power.

General Geological Setting

1:50,000 Sheet 272(Katsina Ala) SE lies within the northern part of the Nigerian Basement Complex .The Nigerian Basement Complex forms part of the Pan –African mobile belt and lies between the West African and Congo Cratons and South of Toureg Shield (Black 1980). On a regional basis and in terms of structures and

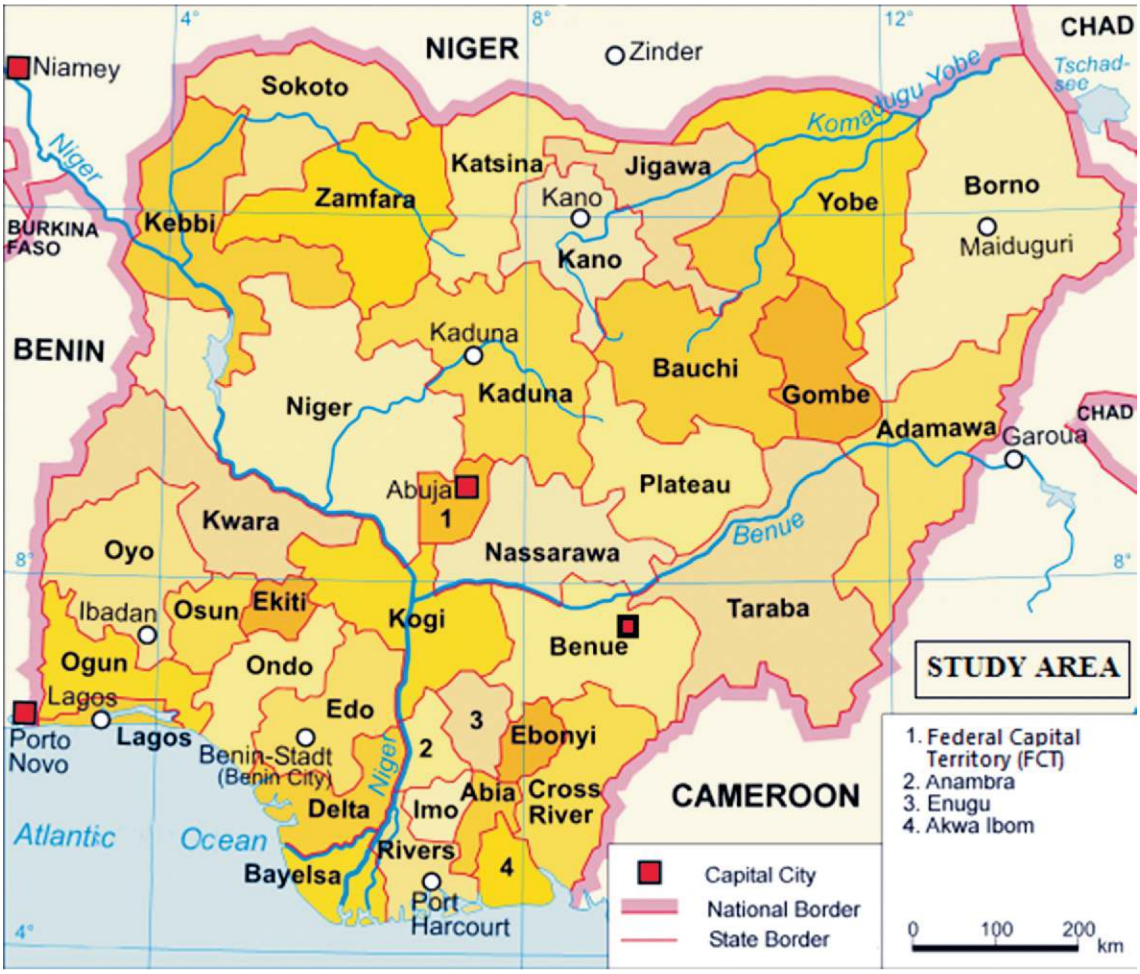

Fig. 1: Map of Nigeria showing study area

geochronology, Africa has been divided into four cratonic areas separated by more recent orogenies i.e. Rhodesia Transvaal Craton, The Tanzania Craton, the Angola – Kasai Cratons and the West African Craton (Clifford, 1966). After the Kiberian event 1100+ 200 Ma ago (Clifford 1967).The Kibaride belt was added to the Angola- Kasai and Tanzania Cratons to form a single large stable unit, The Congo Craton. The Namaqualand-Natal Belt was also incorporated into the Rhodesia-Transvaal Craton to form the Kalahari Craton.

Geochronogical and geologic data suggest that a major part of Africa outside the three Cratonic areas described above was affected by late Precambrian to early Palaeozoic orogenesis and basement reactivation designated by Kennedy 1964 as the Pan African Thermotectonic Episode. The Precambrian of West Africa also has been divided on the basis of geochronological data into two zones

1. The West African Craton which has been since the Eburnean Orogeny 2000+ 150 Ma ago (Bonhomme 1962) and
2. The mobile belt area surrounding the West African Craton which has been affected by the 600 +150 Ma Pan African Orogeny.

The West African Craton is bounded to the west and east by mobile belts which were affected by the Pan African Orogeny 600 +150 Ma ago. East of the West African Craton, the Pan African mobile belt is exposed in two segments: the Touareg Shield in the Hoggar and Adrar des Iforas (Caby et al, 1981) and the Benin- Nigeria Shield separated by the sediments of the Iullummeden Basin (Trompette, 1980).

The Benin–Nigeria Shield has also been subdivided into three structural units (Affaton et al, 1978). Starting from the west to the east; these are the Buem series, the Atocol unit and the Benin plains which extend eastwards into the Nigerian Basement Complex.

Regional Geological Setting: The Nigerian Basement Complex rocks are categorized into three main subdivisions (Rahaman et al, 1987).

1. Migmatite –gneiss complex
2. Metasedimentary – metavolcanic complex
3. Pan African Older Granite series.

In age relationship, the banded gneiss with the associated metasediments are the oldest rocks of the basement and dated to be Liberian (Grant 1970) while the granite gneiss and migmatite were generated during Eburnian Orogeny (Hurley, 1966, Cooray, 1974, Rahaman et al, 1987, Ocan 1990).

Field Investigation

Field mapping of surface geological features and outcrops along road cut, dug pits and stream channels was carried out. Structural data such as foliation, joints, folds, lineation, and mineralogical compositions of the various lithological units were identified measured and recorded

Fifty six outcrop locations were mapped and found to consist of (a) Banded gneiss of about (60%), (b) granite gneiss of about 10%, (c) Biotite granite of about (10%), (d) Porphyritic granite of about (10%) and (e) Coarse-medium grained granite of about (10%).

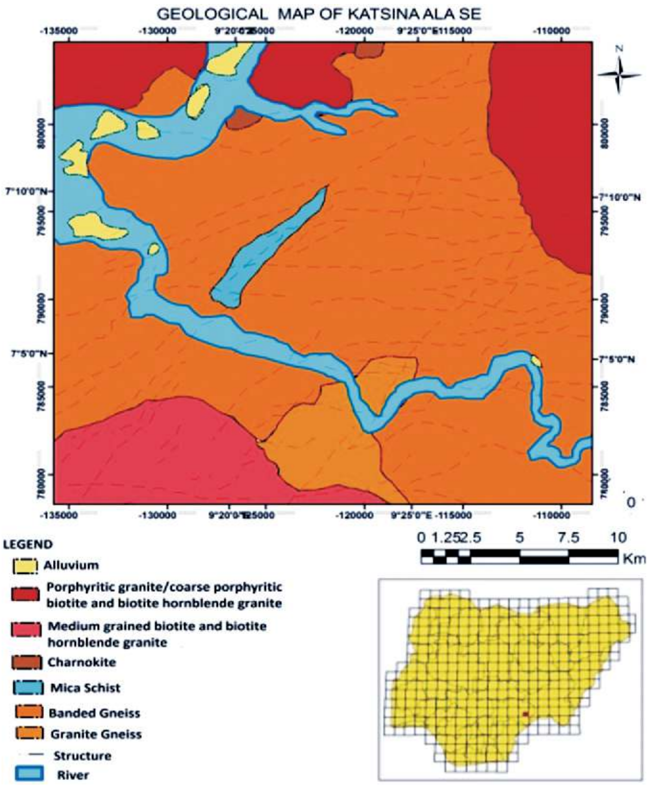

Fig. 2: Geological map of Katsina Ala SE

The banded gneiss always occurs in the lowland and river channels and the rock is strongly foliated. The banding is defined by a preferred orientation of feldspar, quartz and mica (Fig 3).

Fig. 3: Stromatic structure in banded gneiss

The associated structures in banded gneiss include, stromatolic structures, boudinage, Chevron and Open folds.

Fig. 4: Field photograph showing boudinage in the banded gneiss

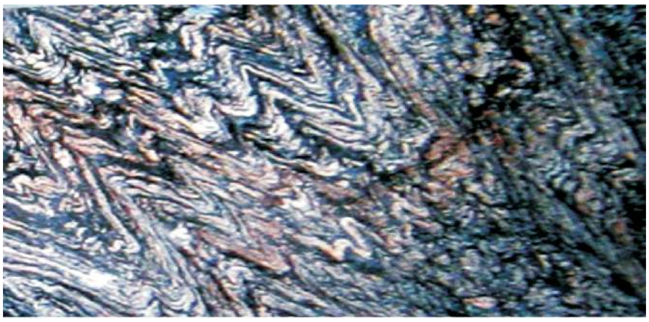

Fig. 5: Field photograph showing chevron fold in banded gneiss

Fig. 6: Field photograph of banded gneiss showing open fold

In thin-section, the granite gneiss with xenomorphic crystal of quartz is in abundance than idiomorphic ones.It is made up of quartz, biotite, microcline and plagioclase feldspars. Accessories are muscovite, sericite and garnet. Fig. 7.

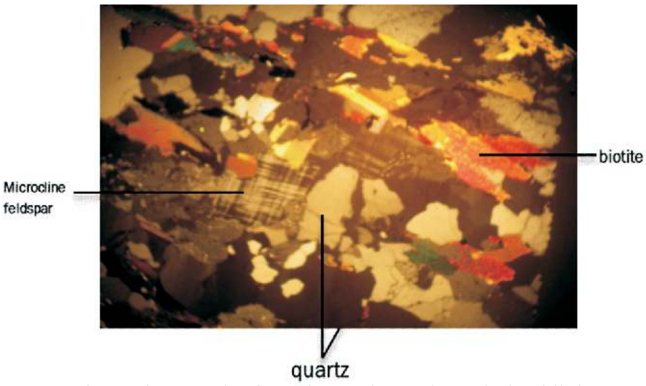

Fig. 7: Photomicrograph of granite gneiss under polarized light showing microcline feldspar, biotite and quartz.

Under thin section, porphyritic granite is porphyritic in texture and contains megacrysts of alkali feldspar. It consists of quartz, microcline and plagioclase feldspars and biotite. Apatite, zircon, sphene are accessory minerals observed (Fig. 8).

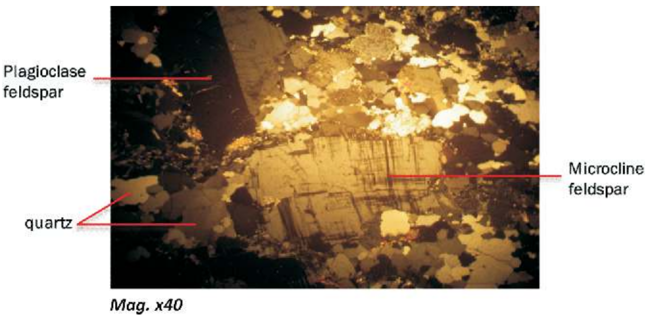

Fig. 8: Photomicrograph of porphyritic granite under plane polarized light showing plagioclase and microcline feldspar and quartz

Mineralogically, coarse grained granite consists of alkali feldspar, quartz and biotite under thin section and accessory minerals are zircon and apatite (Fig. 9).

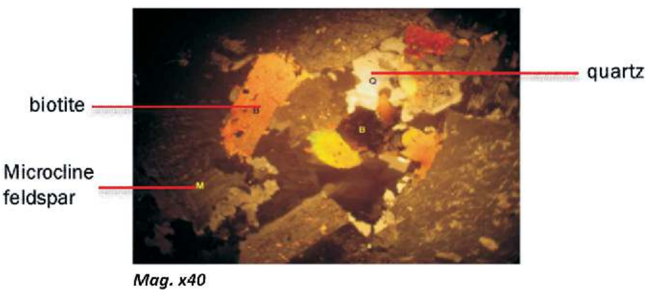

Fig 9: Photomicrograph of coarse grained granite under plane polarized light showing microcline, quartz and biotite

Under polarizing microscope, mylonite is fine grained with strong foliation matrix in which quartz grains are embedded. The foliation in the matrix is marked by preferred alignment of biotite flakes. The rock is composed of quartz, biotite and feldspar as mineralogical composition identified (Fig. 10).

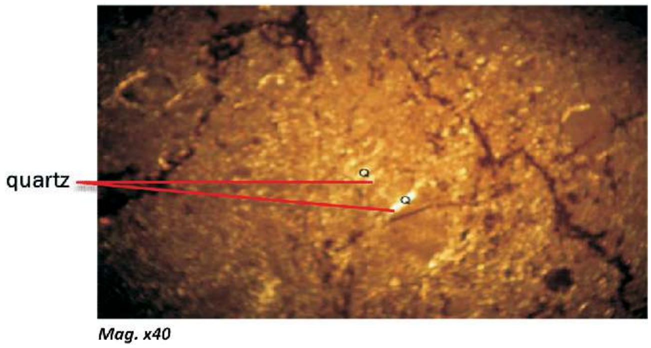

Fig10: Photomicrograph of quartz mylonite under plane polarized light showing quartz

Plots of Remotely Sensed and field data

Rose plots of remotely sensed and field data show that the structural disposition of the area follows the regional trend of fracture patterns in the Nigerian Basement Complex. These Rose plots display average trends of NE-SW, NW-SE, and minor N-S and E-W trends. Lineament map of 1:50,000 Sheet 272 (Katsina Ala) SE was extracted from Landsat ETM+ image.

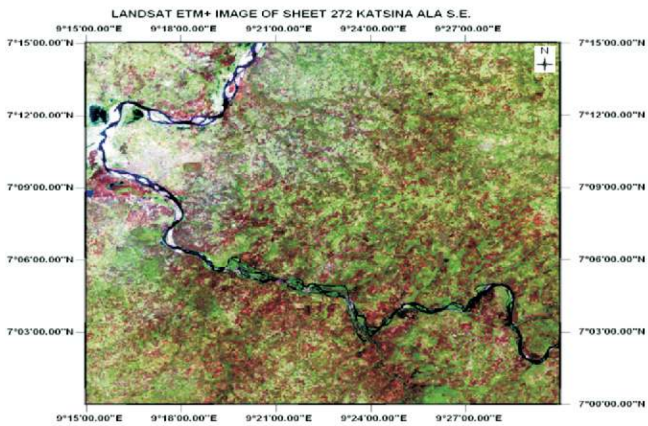

Fig. 11: Landsat ETM+image of 1:50,000 Sheet 272(Katsina Ala) SE

Geochemical analysis of samples and results

Five representative rock samples were selected for geochemical analysis. The initial preparation involving crushing and pulverizing was carried out at National Geosciences Research Laboratories, Kaduna. The samples were then sent to the ACME Laboratories Limited, Vancover, Canada for litho- geochemical

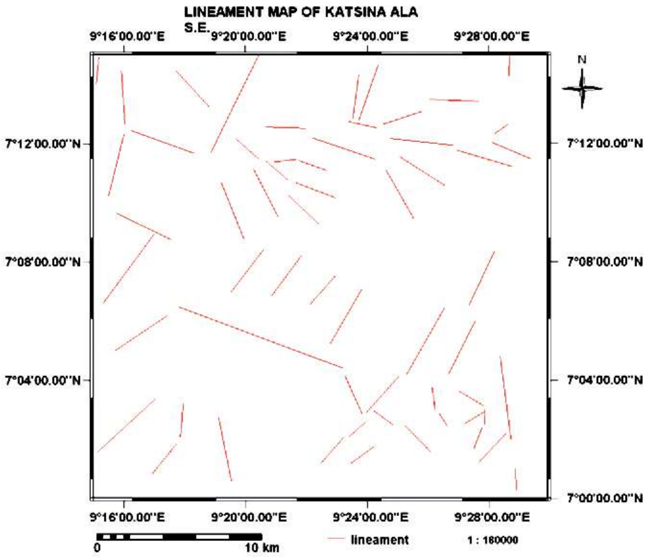

Fig. 12: Lineament map of 1:50,000 Sheet 272 (Katsina Ala) SE

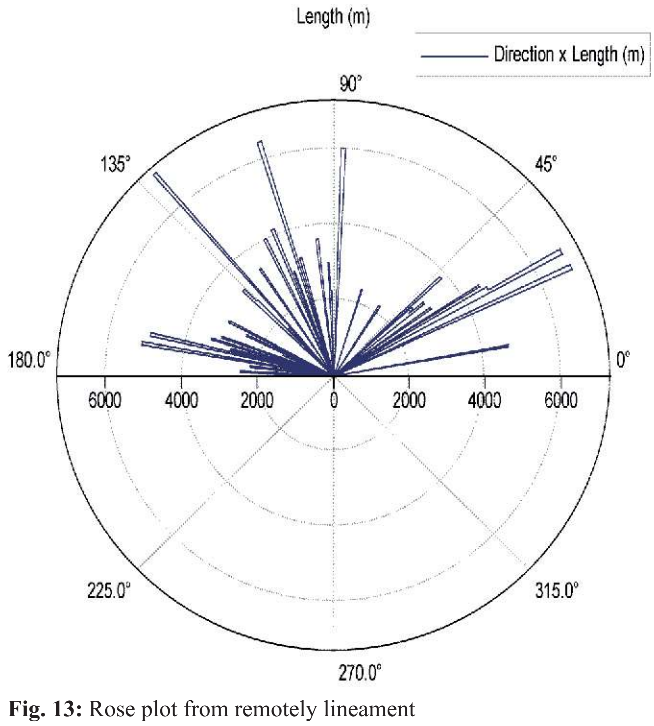

Fig. 13: Rose plot from remotely lineament

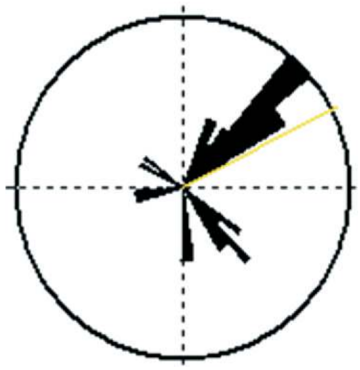

Fig. 14: Rose plot from data generated from joint and foliation

analysis. Major, trace and rare earth elements were determined, using lithium metaborate/tetraborate fusion, Inductively Coupled Atomic Emission Spectrophotometer (ICP AES) and an Inductively Coupled Plasma Spectrometry (ICP MS) technique developed by the Laboratories.

Table 1: Major Oxides of rocks from study area

Major oxides	RG5B %	RG 13 %	RG18 %	RG 27 %	RG 33 %
SiO_2	67.27	68.79	64.51	68.75	64.76
Fe_2O_3	4.064	3.792	2.948	4.450	8.715
CaO	1.497	2.994	4.519	1.413	2.560
P_2O_5	0.275	0.119	0.376	0.248	0.397
MgO	0.746	1.111	3.217	0.415	0.547
TiO_2	0.736	0.447	0.444	0.663	0.980
Al_2O_3	14.345	13.948	13.740	12.890	13.060
Na_2O	4.115	5.335	2.797	2.615	2.590
K_2O	5.700	1.338	5.169	4.109	4.193
Total Oxides of Major Elements	98.85	97.97	97.82	95.65	97.90
Na_2O+K_2O	9.815	6.673	7.966	6.724	6.783
FeO/MgO	4.899	3.070	0.824	9.643	14.329
Al_2O_3/Na_2O+K_2O+CaO	1.3	1.4	1.101	1.59	1.4
FeO/FeO+MgO	0.830	0.754	0.452	0.906	0.935
Al_2O_3/Na_2O+K_2O	1.462	2.090	1.724	1.917	1.925
	Biotite granite	Granite gneiss	Medium grained granite	Coarse grained granite	Porphyritic granite

Table 2: Trace Elements of rocks from study area

Trace elements	RG5B ppm	RG 13 ppm	RG 18 ppm	RG 27 ppm	RG33 ppm
Hf	2.32	0.03	1.88	2.99	1.70
Li	34.8	27.8	64.3	39.2	32.70
Rb	192	33,1	85.4	193	108.1
U	1.7	0,1	5.3	2.9	2.2
Ba	884	580	663	1241	2032
Sr	307	285	229	254	249
Th	53.6	1	13.2	74.1	10.4
Ta	1.1	0.9	2	2.1	2.1
Nb	21.44	2.89	12.74	38.54	49.44
Cs	2.6	0.5	2.9	2.3	1.9
Ga	32	19.76	27.8	28.05	27.35
In	0,03	0.02	0,11	0.14	0.19
Re	0.002	0,002	0.01	0,002	0.01
Se	0,03	0.4	0.3	2.7	1.1
Te	0.05	0.52	0.87	0.05	0.09
Ti	1.35	0.18	0.84	1.59	0.79
Be	3	1	5	5	1
	Biotite granite	Granite gneiss	Medium grained granite	Coarse grained granite	Porphyritic granite

Table 3: Rare Earth Elements of rocks from study area

REE	RG5B ppm	RG13 ppm	RG18 ppm	RG27 ppm	RG33 ppm
La	50.29	5.742	10.395	76.56	26.664
Ce	2676.1	334.312	570.24	4204.04	1992.32
Pr	3.618	0.470	0.829	6.810	3.819
Nd	57.54	8.880	14.340	122.400	84.18
Pm	17.84	9.8	34.3	168.756	173.656
Sm	16.18	2.953	5.669	39.091	34.958
Eu	0.076	0.035	0.041	0.124	0.235
Gd	1.071	0.324	0.946	6.09	5.453
Tb	0.038	0.014	0.033	0.169	0.188
Dy	0.65	0.325	1.008	5.103	5.46
Ho	0.014	0.014	0.042	0.196	0.238
Er	0.12	0.08	0.32	1.52	1.66
Tm	0.03	0.03	0.09	0.33	0.39
Yb	0.08	0.1	0.28	1.28	1.5
Lu	0.34	0.34	0.068	0374	0.442
	Biotite granite	Granite gneiss	Medium grained granite	Coarse grained granite	Porphyritic granite

Discussion and Interpretation of Results

Alphabetic classification of granitoids

The alphabetic interpretation of granitic rocks was introduced by Chappell and White in 1974. They recognised two distinct granitoid types in the Lachlan fold belt of eastern Australia. The I –type granitoid is metaluminous to weakly peraluminous, relatively sodic and has a range of silica content of 56-64 wt % SiO_2. It was inferred to have formed from a mafic metaigneous source. The other type is strongly peraluminous, relatively potassic and restricted to higher silica compositions of 64 – 77 wt % SiO_2. Chappell and White (1974), called this S- type granitoid because they were inferred to have formed from melting of metasedimentary rocks. The SiO_2 wt % of samples from the project area are 67.27 (RG 5B), 68.79 (RG13), 64.51(RG 18), 68.75 (RG 27) and 64.76 (RG 33). Based on Chappell and White (1974), classification the samples are peraluminous and S-type granitoids. Also, the samples are peraluminous because the combined molecular oxides of Na and K are less than the molecular proportion of aluminium oxides Table 1). Also, in Table 1, the molecular proportion of Na, K, Ca oxides are still less than the molecular proportion of aluminous oxides; this confirms samples to be peraluminous and to be S-type granitoid as against being metaluminous I-type. Furthermore, Chappell and White have distinguished S-type and I- type granites by the ratio of molecular oxides of $Al_2O_3/(Na_2O+K_2O+CaO)$. They concluded that S- type granites have the ratio to be greater than 1.1 and I- type granites have the ratio which is less than 1.1.Table 1 shows that all the samples have ratios of their molecular oxides of $Al_2O_3/(Na_2O+K_2O+CaO)$ to be greater than 1.1.

Table 4: Modal Composition of rock samples from study area

Modal composition	KTSE 4A	KTSE 5B	KTSE 6	KTSE 8B	KTSE 13	KTSE 18	KTSE 24	KTSE 27	KTSE 33	KTSE 35
Quartz	50	55	70	60	55	55	95	25	30	95
K-feldspar	15	25	4	25	7	25	4	50	50	4
Plagioclase		4			15	10		4		
Biotite	15	15	25	10	20	10		20	17	
Muscovite										1
Hornblende										
Pyroxene	10									
Amphibole	10									
Accessoriess		2	1	3	2		1	1	2	
Opaque ore		1		2	1				1	
	Charno kite	Biotite granite	Quartz mica schist	Granite gneiss	Medium grained granite	Medium grained granite	Quartz mylonite	Coarse grained granite	Porphyritic granite	Pegmatite

O'Neil et al (1977) have suggested that some of the chemical aspects of S-type and I-type granitoids are reflected in the mineralogy. They concluded that hornblende was common in the mafic I- types and absent in S-type granitoids. Hine et al (1978) found the

S-type granitoids to be dominantly quartz Rich and contained biotite, apatite and garnet. The petrographic study of the rock samples from the study area showed SiO_2 wt %, for RG 5B (55), 13 (55), 18(55) RG 27(25) and 33(30). This shows that quartz is generally present in the sample while biotite was found to be commonly present under the polarizing microscope. Modal percentage of biotite in the samples, RG 5B is (15%) and RG 13 (20%), RG 18 (10%), RG 27(20%) and RG 33 (17%). Muscovite, apatite and garnet are found to be either present as accessory or secondary minerals. Petrographic study is in supports of S-type granitoid of the samples.

According to Loiselle and Wones (1979), the non-deformed and anorogenic rock will be relatively potassic with higher total alkalis and low CaO, and also peraluminous. Table 1 depicts RG 13to be relatively depleted in K_2O and therefore it is deformed and orogenic. It was observed under polarized microscope that RG 13 has strained biotite crystals than euhedral ones and also wavy extinction of quartz crystals but these parameters were not observed in the other samples. RG 13 is foliated while RG 5B, 18, 27 and 33 are non-foliated. The field mapping exercise showed that RG 13 is foliated but other rocks were not.

Plot of Na_2O +K_2O vs. SiO_2

TAS (SiO_2 vs. $Na_2O + K_2O$) plot shows all samples plotting in the granitic clan of plutonic rocks with RG 18 and RG 33 tending towards quartz diorite or granodiorite.

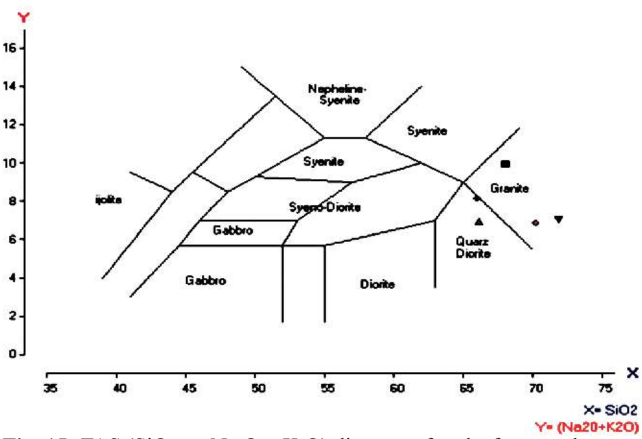

Fig. 15: TAS (SiO_2 vs. $Na_2O + K_2O$) diagram of rocks from study area

Ternary plot of TiO_2, K_2O and P_2O_5

Ternary plot of TiO_2, K_2O and P_2O_5 depicts the majority of the samples plotting towards the K corner. This shows the enhancement of K relative to Ti and P. It is observed that all the samples plot in the continental field as against oceanic field .This suggests that the samples are continental in origin.

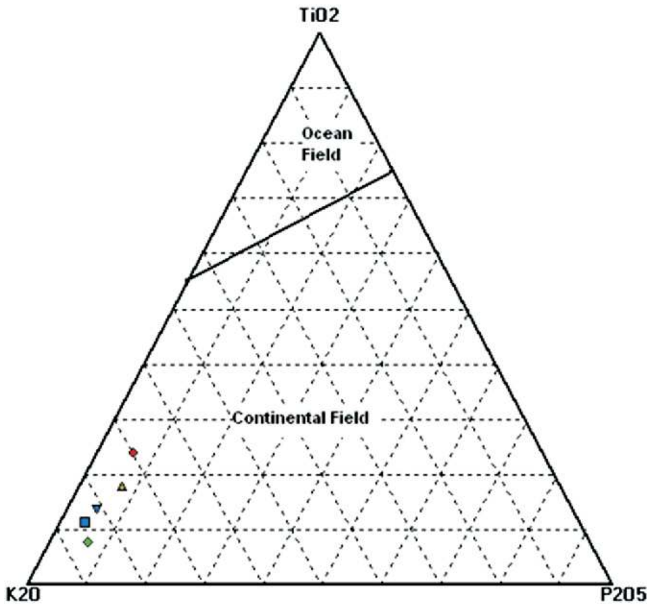

Fig. 16: Ternary plot of TiO_2, K_2O and P_2O_5

Ternary Plot of Al, Fe and Mg

Ternary plot of Al, Fe and Mg shows that the majority of samples plot towards the Al corner .This trend depicts that the samples are enhanced in Al relative to Fe and Mg suggesting peraluminous nature of the samples (Fig. 17).

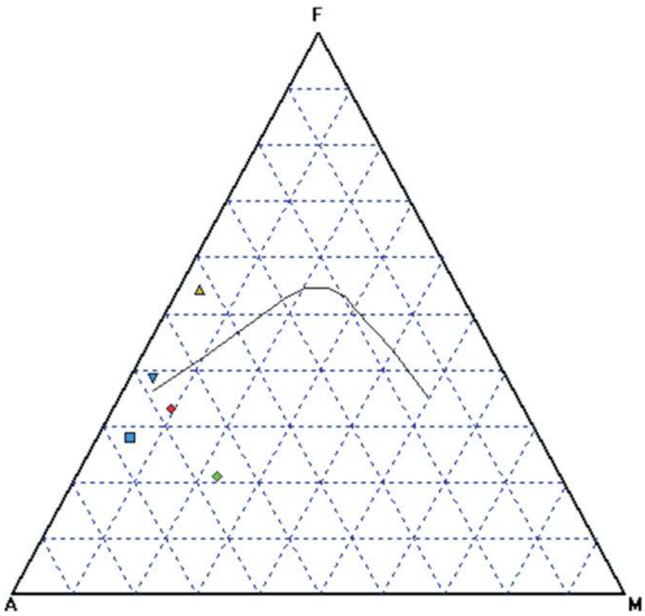

Fig 17: Ternary plot of AL, Fe and Mg

Normalised chondrite (REE) and Multi-element (N) trace elements) of Sun and MacDonough (1989)

Normalised chondrite plot of Sun and Mac Donough (1989) suggests that there is general enrichment of LREE (La-Pm) compared with MREE (Sm-Dy) and HREE (Ho-Lu), This pattern is typical of granitic rocks while multi-element (N) plot of Sun and MacDonough (1989) suggessts that there is general enhancement of LREE compared with MREE and HREE. This is typical of granitic rocks. Ce is enhanced in all the samples while La and Pr are depleted (Figs 18 and 19). This is a typical of moderately fractionated granitoids. Eu is enhanced relative to others in MREE and HREE**.**

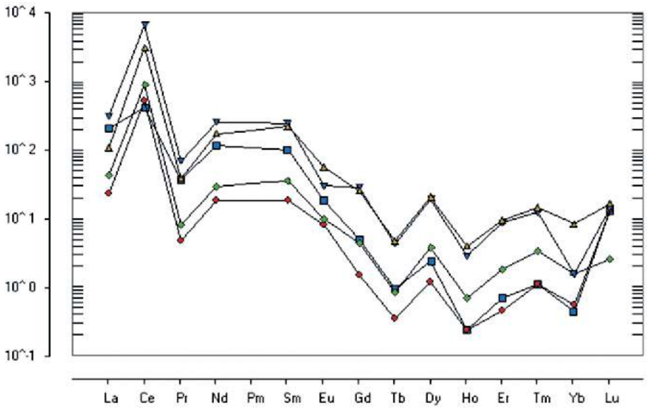

Fig. 18: REE on normalised chondrite plot of Sun and MacDonough (1989)

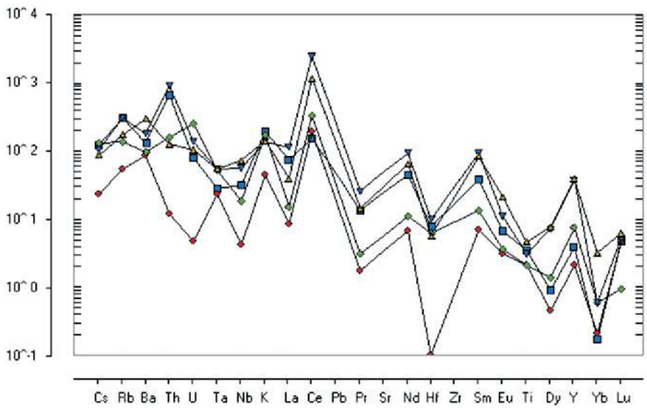

Fig. 19: Trace elements and REE on multi-element (N) plot of Sun and MacDonough (1989)

Discrimination Bivariate Plots of Trace Elements

Pearce et al. 1984 introduced a geochemical method to characterize the tectonic environment of granitic rocks. Geochemically, he distinguished four major tectonic environments which are oceanic ridge granites, volcanic arc granites, within plate granites and collision granites. The best discriminators were plots of Nb vs Y, Ta vs Yb, Rb vs. Yb +Ta and Ta vs Rb.

Plots of Nb vs Y and Ta vs Rb suggest that the samples are from volcanic arc and syn-collision environments (Figs. 20 and 21) while discrimination bivariate plot of Rb vs Yb+Ta(Fig 22) suggest the samples are from volcanic arc and syn-collision source.

S-type granites are from accumulated sediments in the fore arc which were buried and partially melted during plate convergence collision between two plates and this is related to Sn, Ta, Nb,W mineralization. By geochemical indication, S-type granites are highly fractionated. I –type granitoids are from partial melting of igneous rocks from the continental and oceanic lithospheres often found some distance in level from the subduction zone and the granites are poorly fractionated. This is related to Au, Cu, Mo, Ag mineralization. A-type granites are related to rift zones in Proterozoic and non-cratonic areas while M–types are found in Island arc terrain.

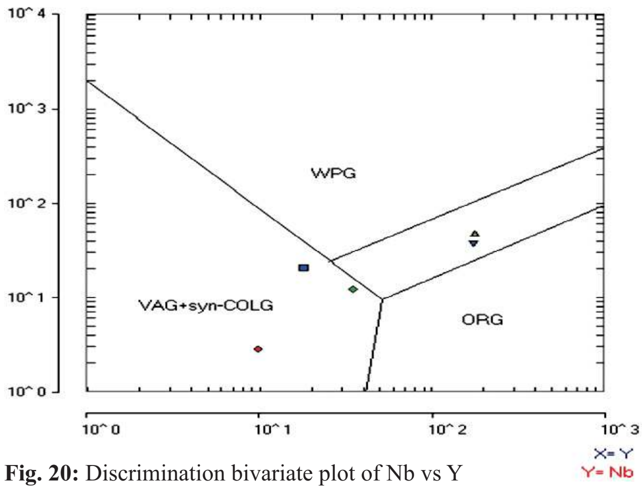

Fig. 20: Discrimination bivariate plot of Nb vs Y

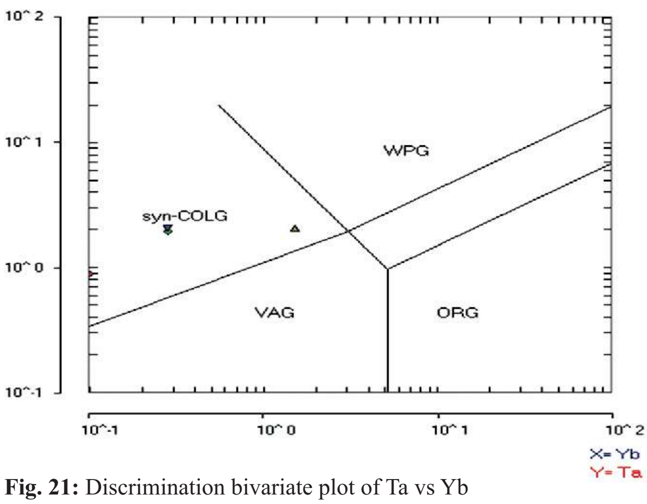

Fig. 21: Discrimination bivariate plot of Ta vs Yb

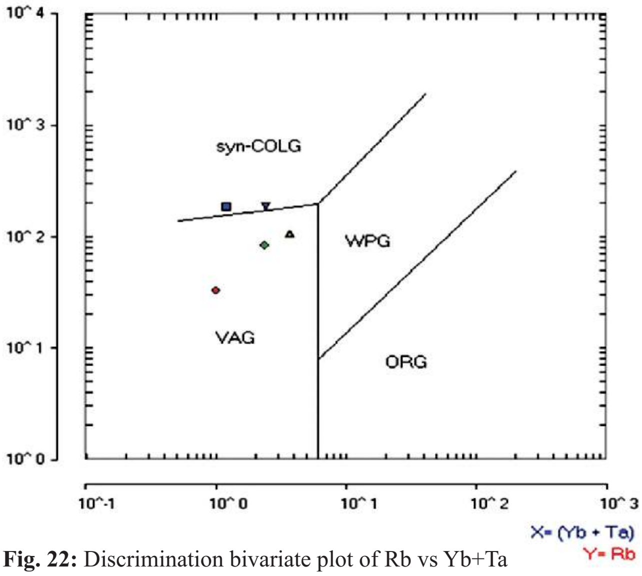

Fig. 22: Discrimination bivariate plot of Rb vs Yb+Ta

Plot of Na_2O+ K_2O vs. SiO_2

The plot of $Na_2O + K_2O$ vs SiO_2 adopted after Miyashiro (1978) suggests that the samplese subalkaline as against alkaline (Fig 23).

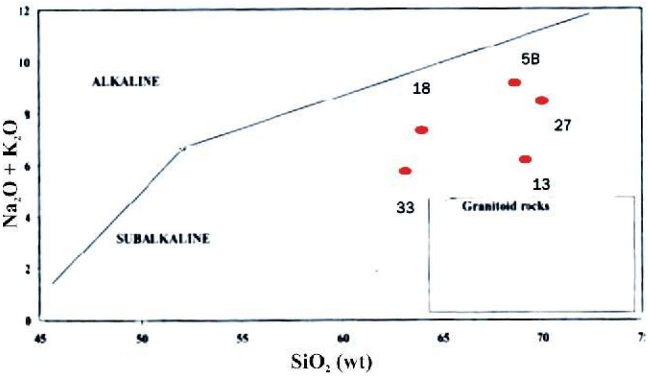

Fig. 23: Plot of Na_2O+ K_2O vs. SiO_2

Binary Plot of FeO/ FeO+MgO vs. SiO_2:

The binary plot of FeO/FeO+MgO vs. SiO_2 showing the boundary between ferroan plutons and magnesian pluton. Fig. 24 suggests that samples RG 5B, 13 and 27 are S-type granites based on the relative amount of SiO_2 present (Table 1.This is supported by Chappell and White that S-type granitoids are more enhanced in SiO_2, (> 64%). RG 18 falls within I-type supported by the relative amount of mafic minerals (CaO and MgO) present in the sample.This is called magnesian-cal alkali granitoid (Table 1. It is also inferred from the plot that RG 33 falls within A-type granite based on the relative amount of Fe_2O_3 and CaO. This is referred to as ferroan - cal alkali granitoid as depicted in Table 1.

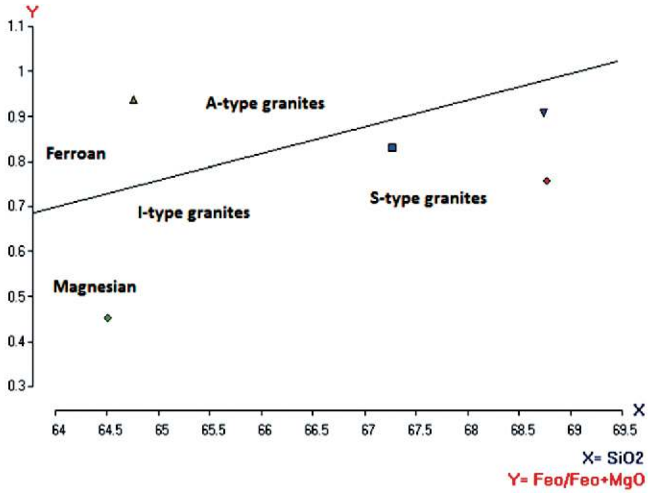

Fig. 24: Binary plot of FeO/FeO+MgO

Petrographically,Hine et al suggested that S-type granitoids contain high percentage of quartz, averagely rich in biotite and with little or no hornblende. In comparison with Hine et al numerous works on petrography, this study suggests S-type granitoids for the RG 5B, RG 13, RG 18 RG 27 and RG 33 Tables 4.

Economic Geology

The granitic rocks and granite gneiss could be useful for construction purposes, dimension stones and as floor tiles. Polished granite is a popular choice for kitchen countertops now due to its high durability and aesthetic qualities. With increasing amounts of acid rain in parts of the world, granite has begun to supplant marble as a monumental material, since it is much more durable. Laterites can be used as a base course in place of stone in road construction. Thick laterite layers are porous and slightly permeable, so the layer can function as aquifer. Laterites are used in acid solution, followed by precipitation to remove phosphorous and heavy metals at sewage treatment facilities.

Conclusion and Recommendation

The field data and petrographic studies suggest that the area is underlain by the Basement Complex Rocks. Geochemical results suggest that the rocks are S-type granitoids and enriched in Sn, Ta, Nb and W. The Total Alkali-Silica plot indicates that the rocks belong to granitic clan of igneous rocks with their progenitor being of continental origin. The Rose plots indicate that the major structural trends are NE-SW, NW-SE with minor N-S and E-W trends. Further field investigation is recommended to authenticate the true nature of granitoids mineralisation in the area of investigation.

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