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Geology, Geochemistry and Petrogenesis of Precambrian Rocks of Part of Sheet 244 of Ado-Ekiti, Southwestern Nigeria

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Abstract
The geology, geochemistry and petrogenesis of Precambrian rocks of part of sheet 244 (Ado-Ekiti), Southwestern Nigeria is reported in this paper. The study area was mapped systematically and the lithologies encountered include migmatite gneiss, granite gneiss, older granite, and charnockite. The various structures mapped on the outcrops are compositional banding, pinch and swell structures, joints, xenolith inclusions among others. The gneisses cover the largest proportion (≈60%) of the study area while the Older granites and charnockites cover the North Eastern and Southwestern part of the area. Six fresh samples of rocks were analysed for petrographic study while another six representative samples (2 per rock type) were also analysed for geochemical composition using Atomic Absorption Spectroscopy. The petrographic study reveals the dominance of quartz, biotite, plagioclase and microcline in the thin sections for the different rock types. The geochemical analyses of the rocks show in percentage average SiO_2compositionof 67.63 in charnockites, 67.09 in granites and 67.99 in gneisses. Alumina varied from 13.77% in the charnockites, and the lowest in the gneisses with 12.91%.The high percentage composition of SiO_2 obviously indicate siliceous nature of all the rock units in the area with low content of Fe_2O_3 and MgO as well as various discriminatory diagrams establishing a common petrogenetic origin related to igneous material source.
Keywords: Lithologies, Precambrian, Geochemistry, Petrogenesis, Protolith

1. Introduction
The study area lies between 5°23' E to 5°30' E and 7°53' N to 8°05' N of sheet 244 (Ado-Ekiti) and include 3 localities (Iye, Itapaji and Omu-Titun) in Ekiti, Southwestern Nigeria. The study area falls within the Precambrian Basement of Nigeria. The rocks of the Precambrian basement complex include the migmatite-gneiss complex, the schist belts and the granitoids. Literature reveals that several works of various interests and extent by different authors have been reported in the area [Rahaman, 1976; Olarewaju, 1987; Olarewaju, 1988; Oyinloye and Ojo, 1988; Oyinloye and Obasi, 2006 just to mention but a few]. Evaluation of the geochemical composition using X-Ray fluorescence spectrometry and petrographic study through thin sections of the rocks have become necessary to obtain comprehensive geological information of this part of sheet 244. Scholars have attributed some Precambrian rocks such as gneisses in the Nigeria basement Complex to sedimentary origin while others are of the opinion that it is magmatic in origin. Burke, et al. (1972) opined that the granite gneiss was derived from isochemical metamorphism of a shale-graywacke sequence (a sedimentary origin). Onyeagocha (1984) on the basis of field and geochemical evidence proposed an igneous origin by partial melting of crustal rocks for the granite gneisses of north-central Nigeria. This research therefore describes the geology of the study area with the aim of using geochemical and petrographic study to determine the petrogenesis of the main rock units in the area.

2. Location and Accessibility of the Study Area.
The localities within the study area include Iye, Itapaji and Omu-Titun (Fig. 1). These villages are generally accessible with good road network with few settlements having very bad roads which posed little difficulty in accessing the areas. Generally, the rocks are well exposed.

3. Materials and Methods.
The methods of study adopted for the different aspects of this work include field and laboratory operations. The field operations involved systematic geological field mapping exercise carried out to critically study the occurrence and field relationship of all the rock types. Fresh representative rock samples were collected for both field and laboratory studies and the coordinates of the location were accurately recorded using Global Positioning System (GPS). Preliminary examination and identification of each mineral constituent were done on the samples with the aid of hand magnifying lens. A total of seventeen rock samples were collected which were labelled properly and put in a sample bags for onward transmission to the laboratory. A total of six (6) fresh representative samples of granite gneiss, granite and charnockite were prepared for thin section study. The analysis was carried out in the Department of Geology and Mineral Science, University of Ilorin, Nigeria. Another six fresh samples (2

representing each rock type) were selected and prepared for geochemical analysis using the Atomic Absorption Spectrophotometer (AAS) carried out at the Department of Chemistry, Forte Hare University, South Africa.

4. Results and Discussion

4.1 Rock Types and Lithological Relationship in the Study Area

The systematic geologic field mapping exercise revealed that the study area is dominated by crystalline rocks that are either igneous or metamorphic in nature which belongs to part of the Precambrian basement rocks of Southwestern Nigeria. The study area is underlain by migmatite gneiss, granite gneiss, Pan African granite, and charnockites (Fig.1). The gneisses (migmatites gneiss and granite gneiss) cover the largest portion (over 60%) of the study area. Occurring in varying dimensions in the gneisses are quartz veins which cut across the whole length and width of the host rocks. Compositional variations in the outcrops are indicated by closely spaced alternating bands of leucocratic (quartz and feldspars) and melanocratic (biotite, hornblende and opaque) minerals.

The older granites cover the North Eastern part of the study area (Fig. 1). The granites are distinguishably unique because of their visible minerals, lack of foliation, fine-medium grained texture and compact interlocking crystals that developed during the crystallisation of magma. Noticeable on the he outcrops are lot of quartz, aplite and pegmatite intrusions. Field examination using hand lens revealed the presence of quartz, feldspar, muscovite and biotite as main minerals in the granite rocks in the area.

The charnockites represent intrusive rocks that were possibly emplaced during the Pan-African orogeny. The rocks appear as oval or semi-circular hills of between five and ten meters (5-10 m) high with a lot of its boulders at different locations around the area. They are predominantly encountered in the Southwestern part of the study area. They are generally massive, dark-greenish in colour with medium to coarse grained texture. Features encountered in the area include pinch and swell structure, faults, joints, quartz vein, Micro folds, pegmatitic intrusions, solution holes and xenolith inclusion (Plate 1).

4.2 Petrographic Features

In thin sections, the rocks contain quartz which appears colourless under plane polarized light and plagioclase distinguishable by its polysynthethic twinning. Other minerals are microcline typified by cross-hatched twinning; biotite which is brownish in thin section and occur as plates and laths showing preferential alignment with the foliation planes.

4.2.1 Gneisses

The petrographic study of gneisses in the study area reveals minerals quartz, biotite, feldspar (plagioclase ± microcline) and muscovite in the thin sections (plates 2a, 2b and 2c). The modal composition which was by visual estimation) reveals that feldspar hasthe highest percentage of minerals (Table 1). The modal composition of plagioclase as estimated under the microscope is about 73%, followed by biotite with 15.8% and microcline which is about 11%.

The gneiss at Kunbi community (GN2) has low percentage of plagioclase and microcline amounting to ≈ 5.3% and 21% respectively. Muscovite is also identified with about 5% composition, while quartz accounts for highest percentage about 58%. The gneiss at Iyemero (sample GN3) has about 50% quartz. Other minerals identified under the microscope include plagioclase (20%), microcline (18%) and biotite (12%) in that order.

4.2.2 Granites

The petrographic study of the granite samples in the study area reveals dominance of quartz, plagioclase, biotite and microcline in order of abundance. The modal composition of the minerals of the rock as shown in the thin section (plates 2d and 2e) reveals that quartz in sample GR4, accounts for 56% forming the highest percentage. This is followed by plagioclase amounting to 34% and biotite which is least represented by 10%. In sample GR5, quartz also dominates with 69% and plagioclase is comparatively high with 23% while microcline accounts for just 8%.

4.2.3 Charnockites

The petrographic study of the rock samples reveals minerals quartz, plagioclase feldspar, and microcline as shown in plate 2f. In the slide for sample CH6, quartz dominates with a high 74% composition. No muscovite was identified but microcline is a bit low with 12% while plagioclase and biotite are the lowest in composition (i.e. 8% and 6% respectively) on the micrograph.

4.3 Geochemistry

The results as shown in Table 2 reveal that silica (SiO_2) is the most abundant oxide with an average value of 67.63% in the charnockites, 67.09% in granites and 67.99% in the gneisses. The percentage composition of SiO_2 is highest in the gneisses, charnockites and the granites having the lowest. This implies that the rocks analyzed are acidic in nature and they must have formed from crystallization of an acidic magma because the silica content being greater than 65% (Elatikpo, et al., 2013). Alumina (Al_2O_3) has the highest composition in charnockites (13.77%) and the lowest in the gneiss (12.91%). The composition of ferromagnesian oxides (Fe_2O_3 and MgO) has varying abundance in the samples. $Fe_2O_3 + MgO$ is 4.42% in charnockites, 4.48% in granites and 4.25% in gneisses.

The Fe_2O_3 increases in composition from granites (3.48%) to the charnockites (3.40%) and then least in gneisses (3.27%). The magnesia is considerably low in all the rock samples with the same average value of 0.23% in charnockites and granite while gneisses is 0.25%. Calcium oxide composition is generally low having average values of 0.79% in charnockites, 0.78% in granites, and 0.73% in the gneisses respectively. The composition of Na_2O varies from a mean of 2.74 for charnockites, 2.69% for granites, and 2.66% in the gneisses. Potash (K_2O) averaged 5.90% in charnockites, 5.95% in granites and 5.51% in gneisses respectively. The K_2O/Na_2O ratios averaged 2.17% in charnockites, 2.22% in granites and 2.02% in gneisses all within the same range of values (Table 2). The consistent higher content of potash to soda in all the rock samples reflects the abundance of K-bearing rock forming minerals e.g. microcline and biotite, and this observation is similar to an earlier report of Oyinloye (2002) in some Ilesha rocks.

However lower K_2O / Na_2O ratio recorded for hornblende gneisses of Ilesha area has a lower average value of 1.42% (Oyinloye, 2011). Total alkaline concentration is relatively high i.e. K_2O+Na_2O, which averaged 8.64% in both charnockites and granites, differ in gneisses (8.17%) reflecting high concentration of feldspars. Titanium Oxide (TiO_2) is generally very low in all samples (≤0.02%).

4.4 Petrogenesis

Charnockites and gneisses generally have diverse origin, spanning a range of metamorphic and igneous derivations which implies that igneous or metamorphic fabric can be exhibited. While gneisses may have disputed origin, most authors in the Nigeria basement complex have provided unequivocal evidences that the charnockites are igneous in origin (Olarewaju, 1988; Kayode, 1988). Some scholars have attributed gneisses to metasedimentary origin (Oyinloye, 1998) while others trace the origin of some gneisses (e.g. quatzo-feldpathic gneisses) to igneous origin (Rahaman, and Ocan, 1978).

Elueze and Bolarinwa (2004) had opined that it is difficult to propose a single mode of origin for the gneisses in the Nigerian basement due to their variable compositions from location to location, hence geochemical data are to be treated on their own merit as acquired and in conjunction with field report. Considering the geochemical result in Table 2, the high SiO_2 composition (≥72.44%) coupled with low Fe_2O_3 and MgO, suggest that the rocks in the study area are granitic. Again, the non-variability of the alumina (Al_2O_3) contents within the value ≥12.37wt % in all the samples analyzed suggests a calc-alkaline affinity which could be due to their low Fe-Mg bearing silicate mineral contents.

Representatives of the analyzed samples were plotted in discrimination diagrams in other to establish their protolith. The discrimination bivariate plot of sedimentary/metasedimentary and igneous series of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 (Garrels and Mackenzie, 1971) presented in figure 2 shows that majority of the samples plotted within the igneous field. Applying the current data on the AFM triangular discriminant diagram for petrogenetic study according to Irvine and Baragar (1971) which was also plotted as shown in figure 3. Considering the Fe_2O_3 and MgO abundance, all the analyzed samples plotted within the calc-alkaline magmatic field and so supported the above deduction.

These deductions thus go in line with Oyinloye and Ojo (1988).that concluded that igneous model for granitic and charnockitic rocks of Ado-Ekiti and its environs are similar. Some authors (e.g. Oyinloye, 2011) had provided a petrogenetic link between the charnockites and granites of Ado-Ekiti based on field and geochemical data. In the current study, this close association of these rocks in the field was also observed and similar geochemical data leads one to the conclusion that rocks have a common origin. Consequence on these, the geochemical data of the charnockites, granites and gneisses of the study area is in support of the igneous origin model. The AKF plot, for the rocks also support that all the rocks have common petrogenetic origin of felsic source because all the data plotted within the quartzo-feldspathic field as shown in figure 4.

5. Conclusion

The geology, geochemistry and petrogenesis of the Precambrian rocks of part of sheet 244 (Ado-Ekiti), Southwestern Nigeria have been studied and is reported in this paper. The geochemical data of rocks reveals high felsic composition ($SiO_2 \leq 72.44\%$). The percentages of Fe_2O_3 and MgO are considerably low. The geochemical characteristics of these rocks indicate it is potent for calc-alkaline affinity. The discrimination diagrams for establishing protolith by [15] are suggestive of a common petrogenetic origin that is related to igneous source material and this is implicated in AFM ternary diagram.

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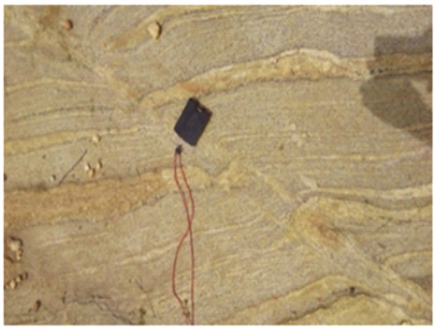
Table 1: Showing modal composition of minerals in the various rock types in the study area.

Sample ID	Rock Type	Minerals (%)				
		Plagioclase	**Quartz**	**Biotite**	**Microcline**	**Muscovite**
GN1	Gneiss	---	73	16	11	---
GN2	Gneiss	5	58	11	21	5
GN3	Gneiss	20	50	12	18	---
GR4	Granite	34	56	10	---	---
CR5	Granite	23	69	---	8	---
CH6	Charnockite	8	74	6	12	---

Table 2: showing the geochemical result of rocks of the study area.

Major Oxides	Charnockite		Ave.	Granite		Ave.	Gneisses		Ave.
	R1A	**R1B**		**R4A**	**R4B**		**R2**	**R5**	
SiO_2	67.93	67.32	67.63	66.69	65.87	67.09	72.44	68.87	67.99
Al_2O_3	13.94	13.60	13.77	12.37	12.53	13.24	11.96	11.87	12.91
Fe_2O_3	3.39	3.40	3.40	3.80	3.42	3.48	2.73	2.56	3.27
CaO	0.79	0.79	0.79	0.82	0.65	0.77	0.69	0.51	0.73
MgO	0.21	0.24	0.23	0.21	0.28	0.23	0.38	0.18	0.25
K_2O	5.87	5.93	5.90	5.98	6.09	5.95	3.58	4.8	5.51
Na_2O	2.56	2.91	2.74	2.59	2.66	2.69	2.7	2.42	2.66
TiO_2	0.02	0.02	0.02	0	0.02	0.02	0.01	0.02	0.02
SO_3	0.05	0.02	0.04	0.02	0.02	0.03	0.01	0.01	0.02
LOI	5.16	5.55	5.36	7.32	8.32	6.34	5.37	8.55	6.50
Others	0.08	0.22	0.15	0.2	0.14	0.16	0.13	0.21	0.16
Total	99.92	99.78	99.85	99.8	99.86	99.84	99.87	99.79	99.84
K_2O/ Na_2O	2.29	2.04	2.17	2.31	2.29	2.22	1.33	1.98	2.08
K_2O+Na_2O	8.43	8.84	8.64	8.57	8.75	8.64	6.28	7.22	8.17
Fe_2O_3+MgO	4.39	4.43	4.42	4.83	4.35	4.48	3.80	3.25	4.25
* R1A and R1B = Charnockites, R4A and R4B = Granites, R2 and R5 = Gneisses									

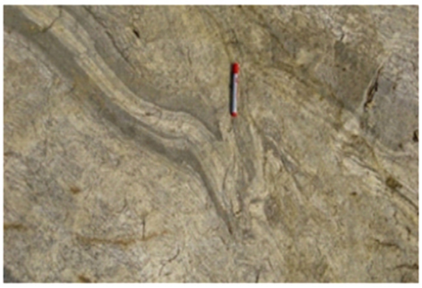
a. Swell and pinch structure visible on the granite gneiss at Iye community



b. Sinistral fault on granite gneiss at Iye Ekiti.

c. Distinctive joints on the host rock (Charnockite) at Itapaji Ekiti.

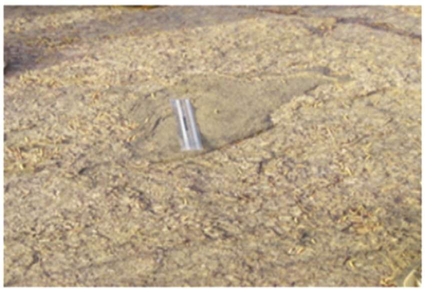
d. Quartz veins cross-cutting the breadth and width of host rock at Itapaji Ekiti



e. Chevron folds on rock at Itapaji Ekiti.

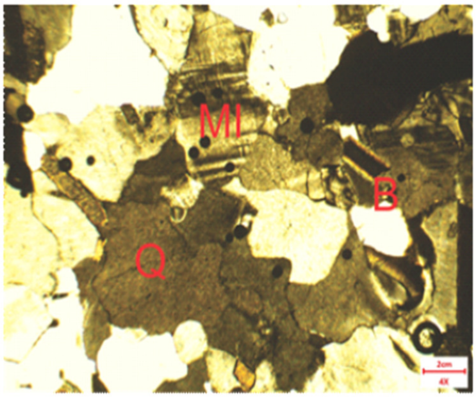
f. Pegmatite intrusion on gneiss at Iye Ekiti

g. Solution holes due to differential chemical weathering on granite at Iye Ekiti

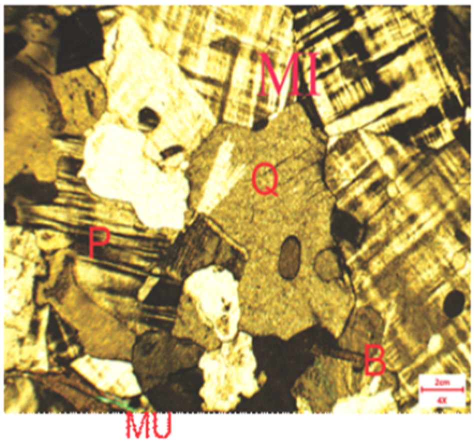


h. Xenonolith inclusion in the medium to coarse grained granite at iye Ekiti

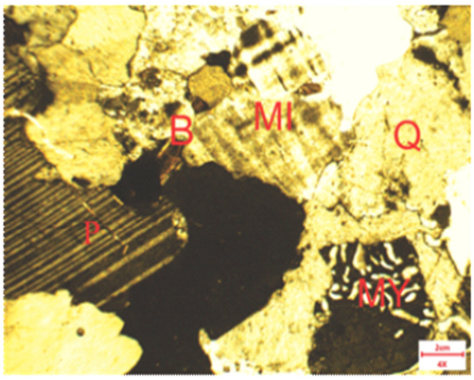
Plate 1: showing features and structures encountered on the field



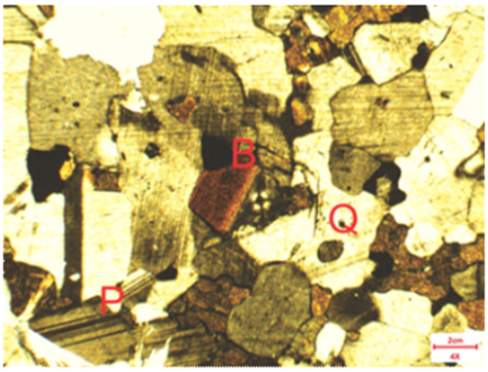
a. Gneiss (GN1) from Iye community



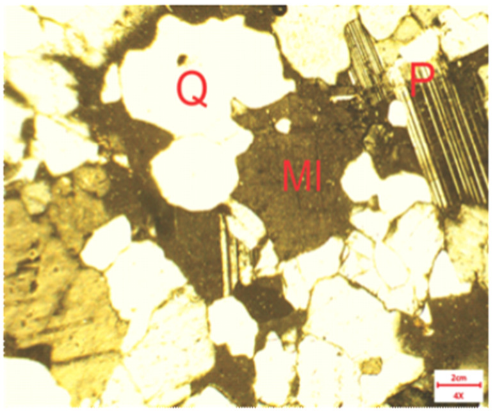
b. Gneiss (GN2) from Kunbi community



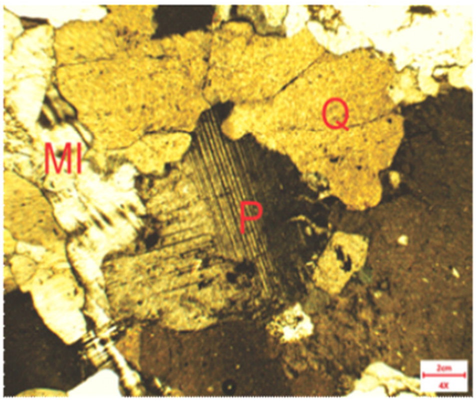
c. Gneiss (GN3) from Iye community



d. Granite (GR4) from Iye community



e. Granite (GR5) from Iye community



f. Charnockite (CH4) from Omu-Titun community

(MI=Microcline, Q=Quartz, B=Biotite, P=Plagioclase, MU=Muscovite, MY=Mymikite)

Plate 2: Photomicrograph of the rock samples under crossed polar

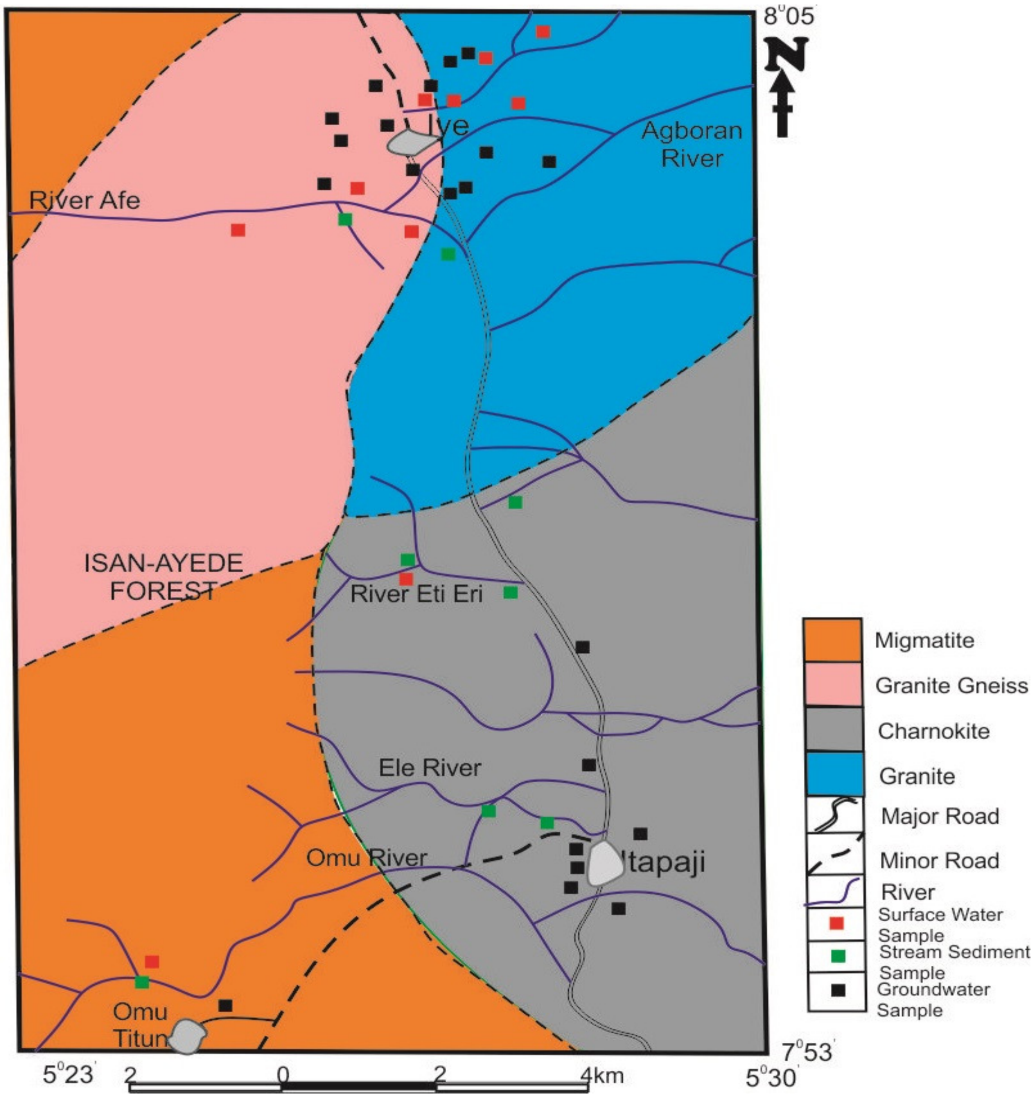


Figure 1: Geological Map of the Study Area.

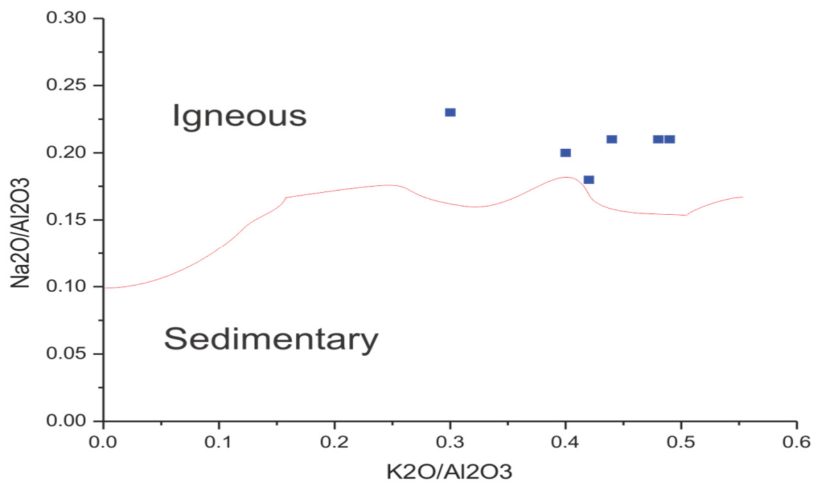


Figure 2: Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot for the basement rocks in the study area (After Garrells & Mackenzie, 1971) suggesting an igneous source material

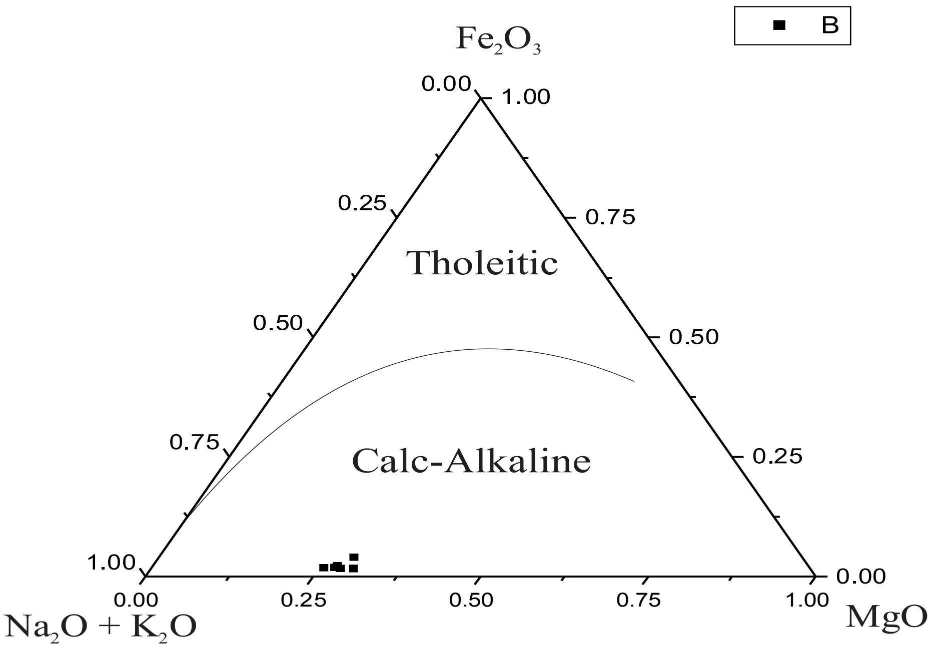


Figure 3: AFM ternary graph showing the samples plotted in the calc-alkaline field (After Irivine and Baragar, 1971).

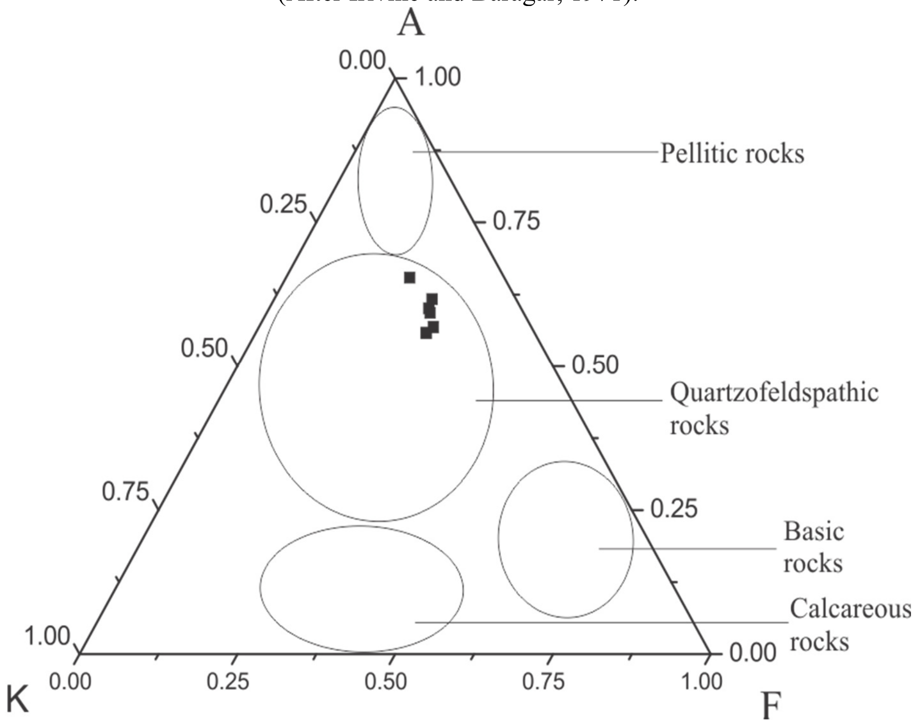


Figure 4: The field of the rocks in AKF triangular diagram (after Eskola, 1915).