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Petrological Characteristics of Different Rocks in North Central Nigeria

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Abstract

The study describes the petrology of different types of rocks found in Oke Ode area of kwara state north central Nigeria; four (4) samples each of all types of rocks found in the area were examined during the study. Special emphasizes were given to major oxides, trace elements and rare earth elements. The field characteristics, description and distribution of the different rock types found in the study area are determined using the field techniques, inductively coupled plasma atomic emission spectrometry (ICP –AES) and inductively coupled plasma mass spectrometry (ICP-MS). It was observed that most of the rock found has been affected by chemical weathering and erosional processes which leads to the formation of lateritic soil found in the area, petrochemical and geochemical results give clear evidence that distinctly sub-alkaline affinity is a characteristic feature of the rocks which are dominated by calc-alkaline suits.

1. Introduction (head 1)

Petrological basement complex rock of south west and north central of Nigeria lie within the Pan-African mobile belt [1] of Proterozoic age. The Oke- ode area of kwara state is part of the basement complex of Nigeria and is underlain mainly by Granite, Pegmatite, Aplite, Granodiorite, metamorphic and Amphibolite. It lies within latitude $8^0 36'0''$N and $8^0 30'0''$Nand longitude $5^0 00'0''$E and $5^0 07'0''$Eand it is in the Northeastern part of Ilorin Kwara State, Nigeria. Petrology is aimed studying the beginning, development, alteration, intergradations, and the reconstruction of rocks [2]. Geologists know that rocks are not so petrified as most people think, but full of movements and action [3]. Much like a biological species, so a rock species has a life and a history from cradle to grave. In some epoch, it has been known that the present-day thickness and areal extent of Phanerozoic sedimentary strata increase gradually with deceasing in geological age. This pattern has been interpreted either as reflecting an increase in the rate of sedimentation toward the present [4] or as resulting from better preservation of the younger part of the geologic record [5]. The petro-genetic character of the rocks as established on the Na_2O/Al_2O_3 against K_2O/Al_2O_3 plot [6] above shows that the rocks are largely of sedimentary origin. The provenance of sedimentary rocks is usually inferred from the framework constituents of the rocks [7]. The relatively high content of Ba in contrast to Rb in Table 2 below indicates K-feldspar-rich protoliths. This implies that there is a strong possibility of the sedimentary source. This is also shown by the relatively high Ba, Rb and Sr in most of the samples (Okonkwo and Winchester, 1996; Okonkwo, 2005). Petrographic and geochemical results give clear evidence that distinctly sub-alkaline affinity is a characteristic feature of these rocks, which are dominated by calc-alkaline suites. Figures 1 and 2 will show the clear geographical map of Nigeria and the study location.

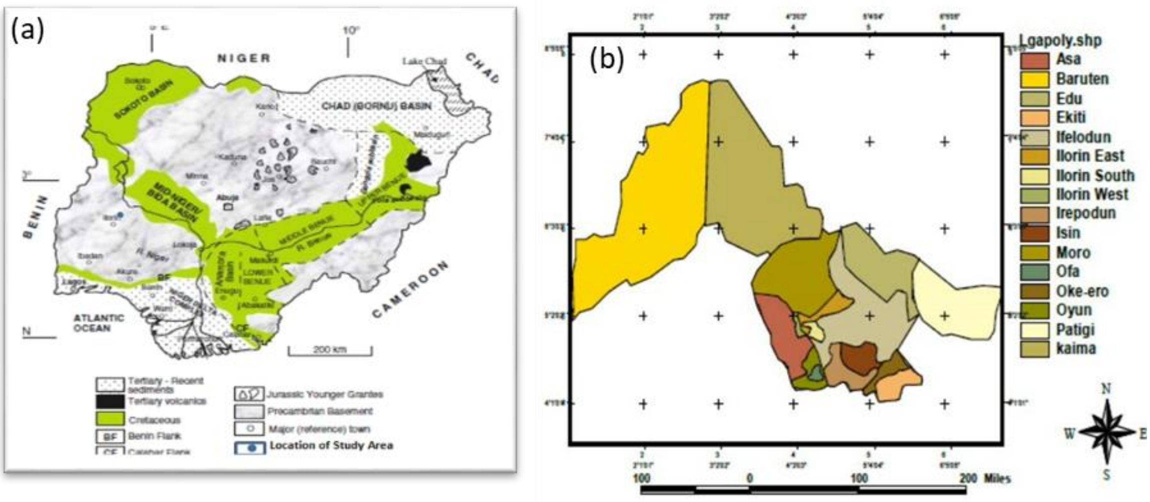

Figure 1: (a) Geological map of Nigeria showing the location of study area, (b) geological map location of the main study area (Modified from Obaje 2009 [8]).

1.1 **joint structures in granite and dextral fault in granite**

Joint is a break fracture of natural origin in the continuity of either a layer or body of rock that lacks any visible or measurable movement parallel to the surface (plane) of the fracture. Although they can occur singly, they most frequently occur as joint sets and systems. A **joint set** is a family of parallel, evenly spaced joints that can be identified through mapping and analysis of the orientations, spacing, and physical properties [9, 10]. And **Fault** is a planar fracture or discontinuity in a volume of rock, across which there has been significant displacement as a result of rock-mass movement. Large faults within the Earth's crust result from the action of plate tectonic forces, with the largest forming the boundaries between the plates, such as subduction zones or transform faults. Energy release associated with rapid movement on active faults is the cause of most earthquakes. The structural feathers of joint and fault are shown in figure 3a and 3b

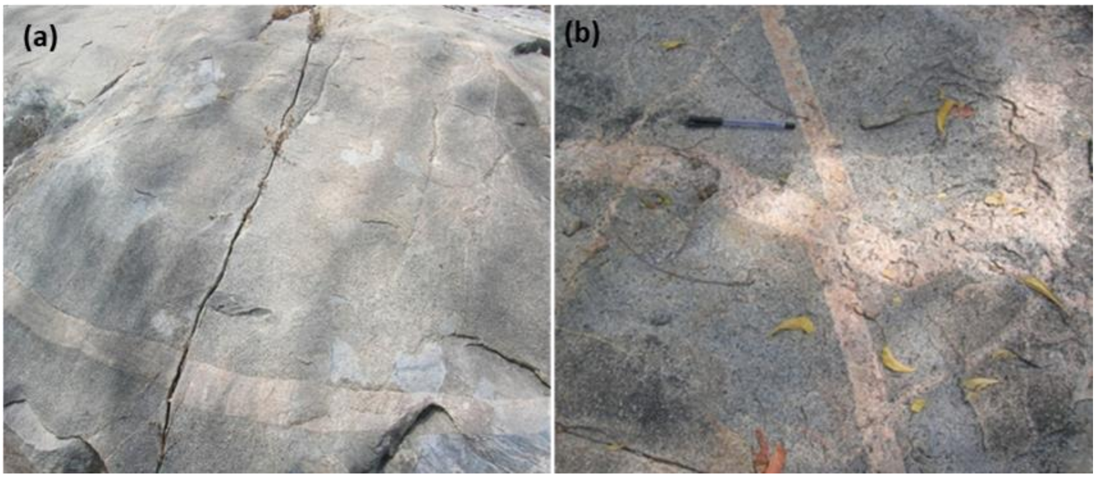

Figure. 2: (a) joint structure in granite (b) dextral fault in granite of the study area.

1.2. Folds and Veins

Folds are bent or wave like structure on rocks. Folds occur when an originally flat and planar surface is bent or curved as a result of permanent deformation. Fold form under varied conditions of stress, such as hydrostatic pressure, pure pressure and temperature

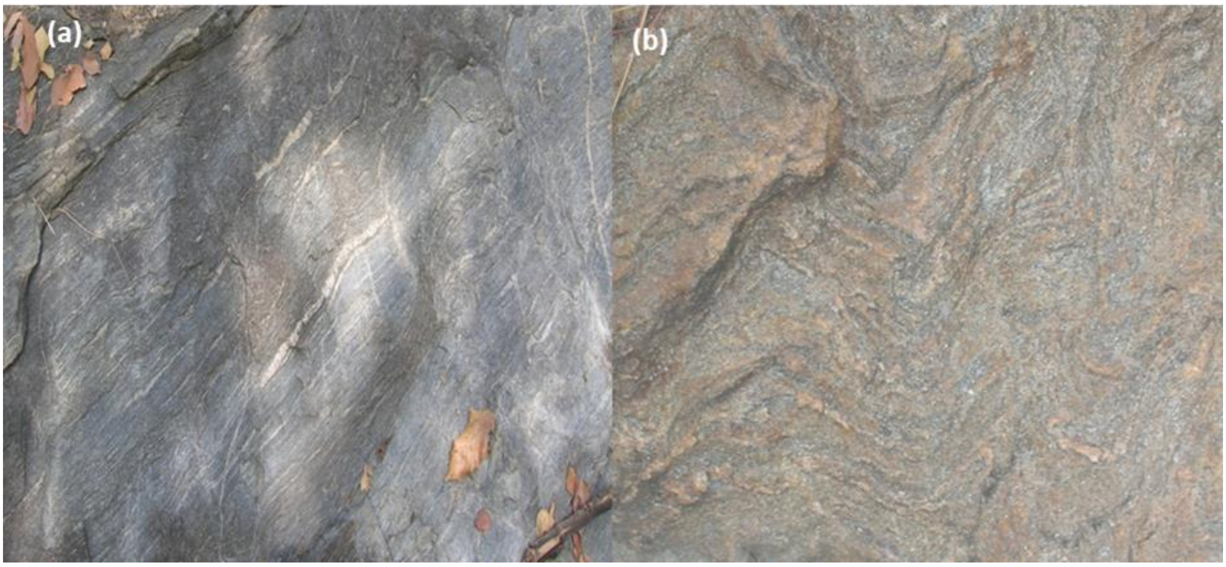

Figure 3. (a) Foliations in a weakly migmatised schist, (b) Fold observed in the study area

1.2. SITE DESCRIPTION

The study site (Oke-Ode) is located within Ifelodun local government area (latitude $8^0$36'0''N $8^0$30'0''N and longitude $5^0$00'0''E and $5^0$07'0''E) of Kwara state, North central Nigeria [5]. The area is characterized by two seasons, which are wet and dry season with average high amount of rainfall. This corresponds to that of guinea savannah which is a transition zone from tropical rainforest to savannah vegetation [7]. This vegetation characteristic is responsible for the growth of scattered tall trees, bushes and shrubs in the study site. Climatically, the study area lies within the tropical climate, well defined by wet season which begin from April to October while the dry season start from November and end in March. The topography is well defined by striking continuous hills, impacting topographical undulations which surround the area [14]. The highest point in the area is the quartzite ridge which is about 1250meter above the sea level and the lowest is about 1150meter above the sea level [1]. Valleys in the area separate the hills and the low land which also serve as the flow path for rivers in the area. The rivers in the area are well defined with gully and channel erosional features.

The major occupation of people in the area is hunting and farming. Most farmers make ridges along steep slope for growing of crops like maize, cassava, yam and guinea corn etc. Because of the vegetation of the study site, cattle activity is also prominent in the area, making the area a transient settlement for nomadic herdsmen.

2.1. METHODOLOGY

We employed inductively coupled plasma atomic emission spectrometry (ICP-AES) and inductive coupled plasma mass spectrometry (ICP-MS) analysis for this research study. ICP-AES were used to confirm the major elements through the injection of an aerosol of the rock into the plasma at high temperature, ionized argon. While Inductive coupled plasma mass spectrometry (ICP-MS) is used to determine then trace and rare earth elements (REE) in the rock sample. The aerosol rock sampled dissociates into constituent ions of the rock sampled at high temperature plasma before injection into a device for analyzing the respective masses.

3.1. RESULT AND DISCUSSION

Crude samples of the rocks in the study area were analyzed for both major oxide and trace element concentrations using the Inductively Coupled Plasma analytical technique. Inductively Coupled Plasma Emission Spectrometry (ICP-ES) is used to determine the major oxides while Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used for the determination of the trace elements and rare earth elements. The analytical results are presented in tables table 1, 2 and 3 below which shows the geochemical results of the rocks in the study area showing different elements and their oxides. As it was deduced from the result, the major oxide data (wt %) composition presented in table 1 below, the samples from the study area have the silica content ranging from 45.72 wt % to 74.51 wt % with an average of 60.115 % where sample AP and Gd have relatively low silica content of (45.72%, 49.30%, 54.01%, 52.71%) and (49.96%, 57.31%, 51.60%) respectively, while sample G and Sc are siliceous having silica contents greater than 65%. Alumina content (Al_2O_3) ranging from 2.43% -17.83% in aplite. Sample G have the highest content of Na_2O ranges from 2.66%-5.36%. The granite samples generally have low Fe_2O_3 content ranging from 0.84% - 8.51% with sample G3 having the least and sample G4 having the highest. MnO content is generally low ($\leq$ 0.34%) in the entire samples. The MgO content is generally high in the sample AP3 and AP4 (15.63% and 8.99% respectively). CaO content is highest in sample AP3 (20.82%) and lowest in G3 (0. 33%). TiO_2 content is relatively low in all the samples though samples Gd and AP4 (1.28% and 1.26% respectively) have the highest and sample G3 (<0.01%) has the lowest. From the trace elements composition (ppm), Ba is more in samples, G1, Gg2 and Gd3. Sr is more in, Sc1, Gd1 and Gd3. The Rb is more in samples Gd2, Sc2. Samples G2 and Gg1 show high Zr content.

Table 1: Result of geochemical analysis showing Major Oxides of rocks in the study area.

COMPOUNDS (%) /	**AP1**	**AP 2**	**AP 3**	**AP4**	**G 1**	**G2**	**G3**	**G4**	**Gd1**	**Gd2**	**Gd3**	**Gd4**	**SC1**	**SC2**
SiO_2	45.72	49.20	54.01	52.71	65.29	73.34	74.51	56.06	49.96	57.31	51.60	52.34	63.78	69.13
Al_2O_3	15.09	15.22	2.43	17.83	15.92	13.34	14.60	16.15	16.10	14.69	17.83	17.31	16.41	14.90
Fe_2O_3	11.37	10.53	4.97	9.32	4.20	2.22	0.84	8.51	10.39	10.21	10.21	9.72	4.49	2.50
MgO	5.49	8.99	15.63	4.54	1.76	0.75	0.02	4.55	6.25	6.03	4.73	4.75	1.95	1.96
CaO	17.77	12.70	20.82	6.72	3.14	1.46	0.33	6.03	7.24	1.66	7.13	6.67	3.61	0.99
Na_2O	1.29	1.25	0.32	3.04	3.50	2.66	5.36	2.87	2.56	1.87	3.09	2.96	3.59	3.13

K_2O	0.13	0.23	0.11	2.84	4.49	5.36	3.59	3.23	3.52	5.24	2.56	2.78	4.24	5.66
TiO_2	1.41	0.94	0.11	1.26	0.46	0.22	<0.01	1.01	1.33	0.82	1.28	1.28	0.51	0.38
MnO	0.20	0.17	0.18	0.12	0.07	0.04	0.11	0.13	0.12	0.34	0.13	0.12	0.06	0.07
LOI	1.0	0.3	1.0	0.6	0.5	0.4	0.1	0.5	1.4	1.1	0.4	1.1	0.6	0.8
Total	99.81	99.75	99.71	99.85	99.93	99.98	99.97	99.85	99.85	99.81	99.87	99.86	99.93	99.93

Table 2: Result of geochemical analysis showing the trace elements.

SAMPLES	AP1	AP 2	AP 3	AP4	G 1	G2	G3	G4	Gd1	Gd2	Gd3	Gd4	SC1	SC2
Mo	0.71	0.47	0.29	0.62	0.75	0.52	0.31	0.44	0.62	0.19	0.48	0.57	6.56	0.18
Cu	144.73	60.09	6.94	32.63	9.98	26.11	5.37	28.30	51.88	42.21	48.46	26.24	20.6	2.89
Pb	5.80	1.53	2.57	12.96	30.69	50.29	15.44	13.87	14.95	11.71	12.34	13.90	29.85	30.20
Zn	71.7	68.6	95.9	90.3	52.7	35.6	7.5	86.40	73.9	228.3	107.4	93.7	52.0	48.4

Ag	79	119	45	<20	<20	41	<2.0	75	<20	<20	74	<20	31	30
Ni	78.2	181.2	7.1	40.0	26.0	12.1	1.9	47.3	69.6	142.4	38.4	43.4	21.7	19.7
Co	62.6	54.8	10.1	27.1	9.7	5.0	<0.2	24.6	37.6	28.7	30.4	26.8	11.8	6.3
Mn	1521	1315	1373	922	546	299	600	968	891	2635	989	902	477	520
As	1.0	0.8	1.1	1.1	1.6	<0.2	0.3	0.6	0.4	2.0	1.2	1.6	0.7	0.9
U	0.3	<0.1	0.2	1.1	1.0	1.8	7.6	0.6	1.1	5.7	1.3	0.7	1.2	1.5
Av	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Th	1.0	0.3	1.0	2.3	9.4	9.3	6.6	9.9	9.9	11.1	6.6	3.3	9.6	6.2
Sc	52.9	43.7	4.4	20.51	6.3	2.9	18.4	6.5	6.5	19.9	18.4	21.0	6.5	4.7
Sr	208	101	80	675	677	367	5	651	796	234	739	728	867	165
Cd	0.23	0.14	0.27	0.11	0.04	<0.02	0.18	0.13	0.08	0.07	0.08	0.12	0.04	0.03
Sb	0.13	0.03	0.18	0.13	0.10	0.05	0.03	0.16	0.05	0.04	0.13	0.10	0.06	<0.02
Bi	0.74	0.71	0.14	0.31	0.07	<0.04	3.22	0.76	<0.04	1.00	0.23	0.19	<0.04	0.13
V	353	261	44	152	52	20	<1	119	237	131	159	161	66	28
Ba	112	45	43	1298	1909	841	8	1678	1618	1612	1779	1566	2343	1275
Cr	13.8	368	6	80	31	15	2	121	150	326	91	90	35	30
W	50.4	46.4	0.1	0.4	0.3	0.2	1.0	0.5	0.2	0.5	0.4	0.4	0.3	0.4
Zr	18.4	11.8	7.7	8.6	11.3	69.9	19.3	6.5	14.3	38.8	9.8	9.1	13.5	46.1
Sn	1.2	2.7	2.2	5.5	3.0	1.9	2.3	5.8	2.3	23.0	2.4	2.4	1.3	3.0
Be	<1	<1	1	8	3	4	34	16	2	25	2	3	2	7

Li	<1	21.0	4.3	99.9.	23.7	107.8	13.6	150.3	61.4	1633	160.3	96.6	123.3	395.6
Y	30.0	22.3	20.4	28.1	13.9	14.5	4.2	26.0	21.7	22.2	30.4	31.3	11.0	6.7
Hf	0.99	0.63	0.45	0.71	0.38	2.44	1.02	0.45	0.99	0.82	0.63	0.66	0.50	1.23
Rb	4.8	7.6	4.4	41.3	82.3	99.5	421.7	50.7	67.8	555.3	54.8	42.6	76.8	278.6
Ta	0.4	0.2	0.9	2.2	0.6	1.6	15.2	1.0	0.4	0.6	0.6	0.5	0.3	0.2
Nb	3.59	1.93	1.70	12.71	9.06	12.58	53.2	13.69	9.20	21.34	11.91	11.85	5.87	3.01
Cs	0.2	0.8	0.1	8.1	7.8	2.5	20.8	22.0	1.7	118.7	10.4	5.4	2.9	28.5
Ga	20.77	16.81	5.62	23.92	17.93	18.96	16.97	20.62	20.86	26.87	23.67	23.97	18.36	16.97
In	0.10	0.04	0.10	0.10	0.03	<0.01	<0.01	0.08	0.05	0.14	0.07	0.11	<0.01	<0.01
Re	0.007	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	0.004	0.003	<0.002
Se	0.4	<0.3	<0.3	<0.3	0.5	<0.03	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Te	0.39	0.57	0.64	0.23	0.20	<0.05	<0.05	0.25	<0.05	0.10	0.25	0.25	0.09	<0.05
TI	<0.05	<0.05	<0.05	0.49	0.60	0.41	2.24	0.62	2.20	6.01	0.86	0.45	0.46	2.20

Table 3: Result of geochemical analysis showing the rare earth elements

SAMPLES	AP1	AP 2	AP 3	AP4	G 1	G2	G3	G4	Gd1	Gd2	Gd3	Gd4	SC1	SC2

La	5.4	2.7	12.6	27.2	49.3	16.0	1.4	41.4	49.6	16.7	24.9	36.9	59.6	19.5
Ce	14.9	6.78	33.59	69.91	94.60	28.85	3.04	88.82	100.0	41.48	69.26	89.23	105.6	39.81
Nd	9.8	6.2	22.1	40.4	32.3	15.2	0.9	40.1	44.4	16.2	41.6	50.0	31.5	11.2
Gd	4.4	3.5	4.2	7.9	3.0	2.8	0.4	6.4	5.1	4.0	7.6	8.8	3.5	2.5
Ho	1.3	1.0	0.7	1.3	0.6	0.6	<0.1	1.0	0.9	1.0	1.2	1.3	0.4	0.4
Tm	0.5	0.5	0.3	0.5	0.2	0.2	<0.1	0.4	0.3	0.4	0.5	0.4	0.2	<0.1
Tb	5.5	2.6	1.8	2.6	1.4	1.4	0.5	2.7	2.0	2.6	3.1	2.7	1.0	0.5

<u>KEY:</u> AP= aplite, G= granite, Sc= schist

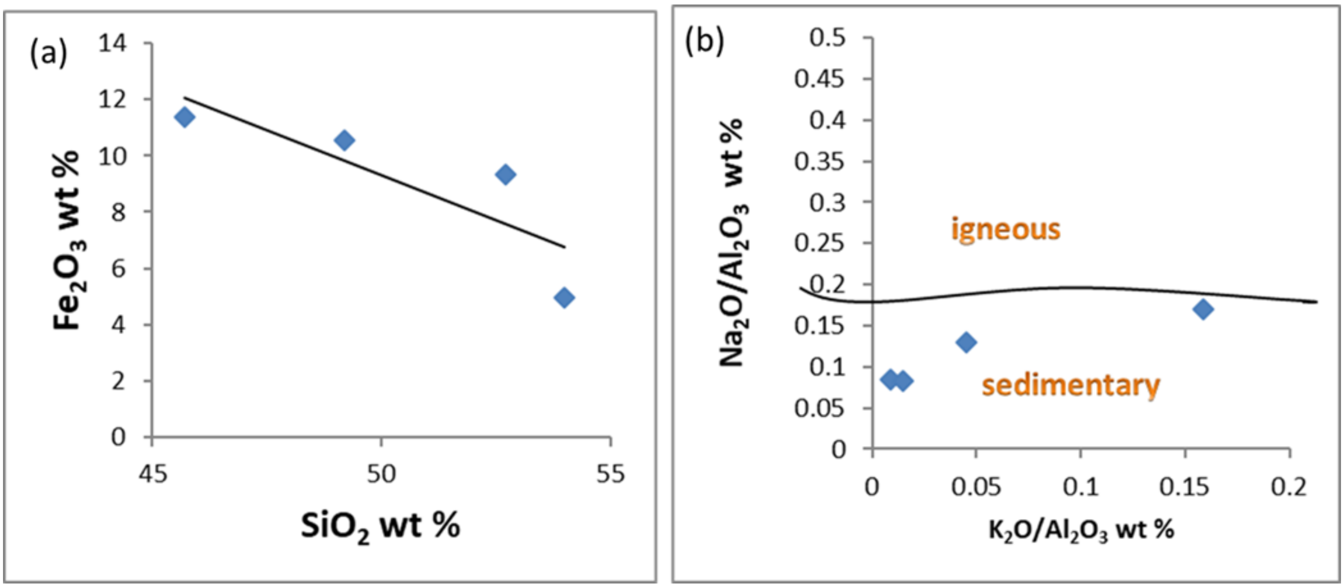

Figure 4: Harker diagram of Fe_2O_3 for Aplite group, (b) Plot of Na_2O/Al_2O_3 against K_2O/Al_2O_3 for the aplite

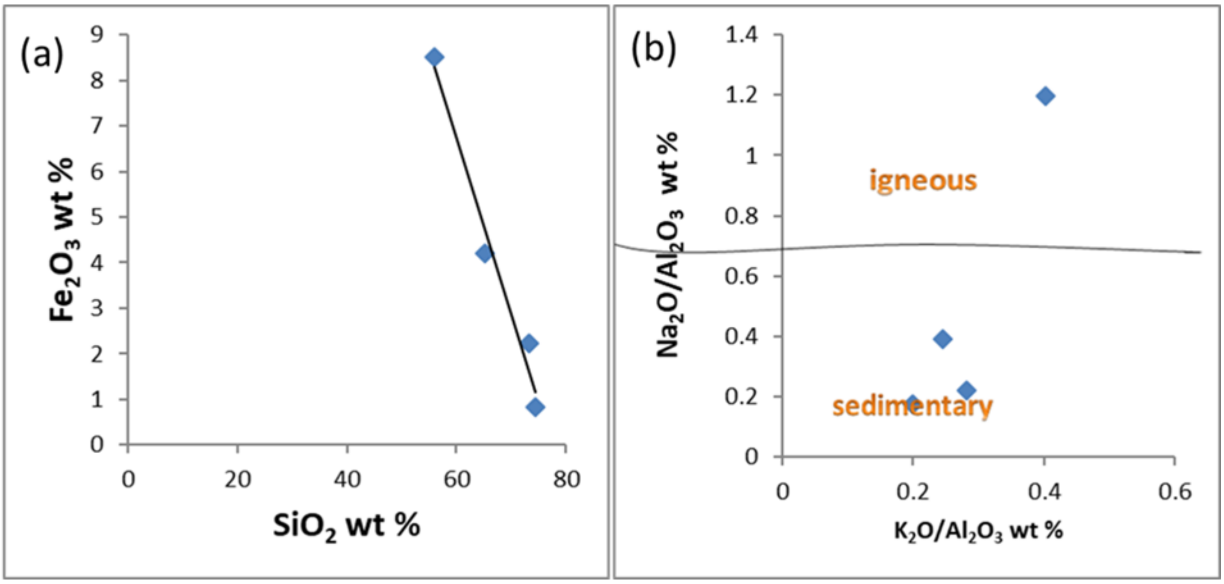

Figure 5. Harker plot of Fe2O3 against Granite (b) Plot of Na2O/Al2O3 against K2O/Al2O3

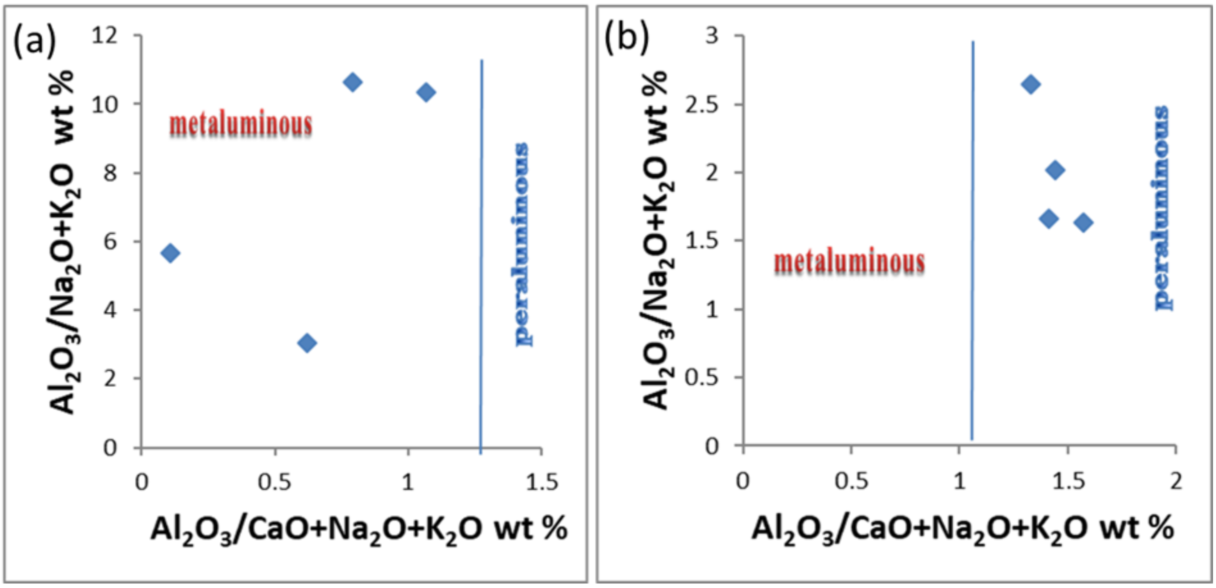

Figure 6. Al_2O_3/Na_2O+K_2O versus $Al_2O_3/CaO+Na_2O+K_2O$ (b) Plot of $Al_2O_3/CaO+Na_2O+K_2O$

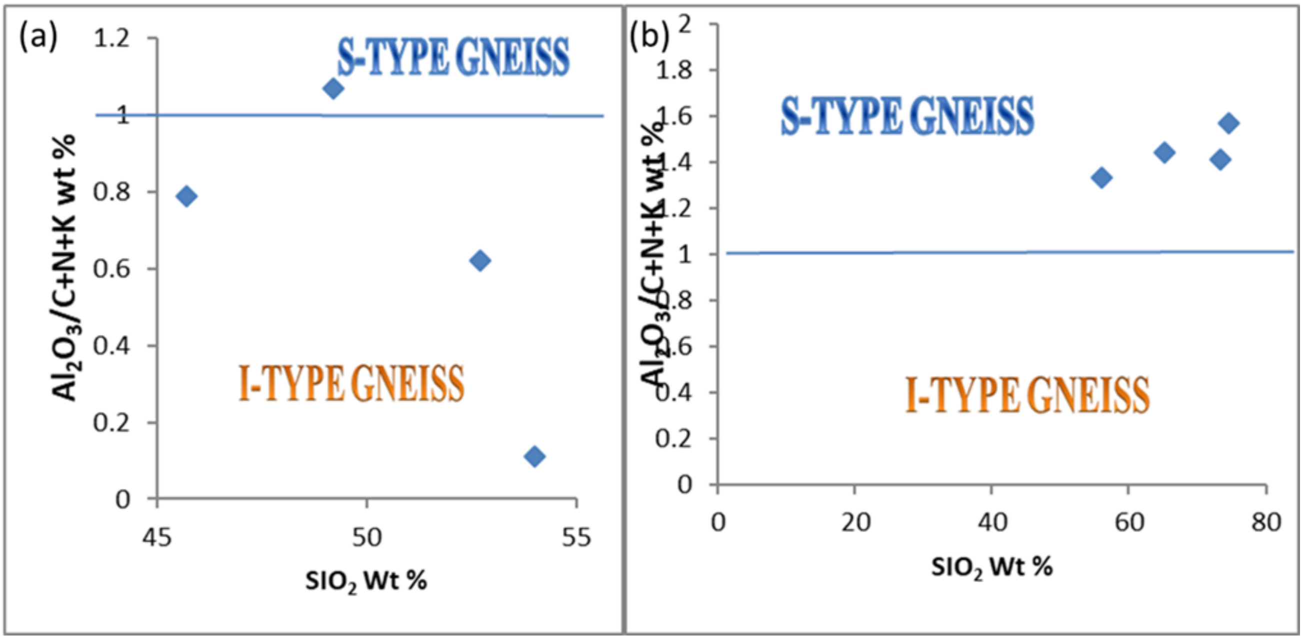

Figure 7. (a) Al_2O_3/C+N+K wt % versus SIO_2 Wt % (b) Al_2O_3/C+N+K wt % versus SIO_2 Wt % for the study area

3.2 PETROGENESIS

The petro genetic character of the rocks as established on the Na_2O/Al_2O_3 against K_2O/Al_2O_3 plot (Garrells and Mackenzie, 1971) above shows that the rocks are largely of sedimentary origin. The provenance of sedimentary rocks is usually inferred from the framework constituents of the rocks (Pettijohn, 1975; Dickinson and Vallani, 1980; Okonkwo, 2005). The relatively high content of Ba in contrast to Rb in Table 2 above indicates K-feldspar-rich protoliths. This implies that there is a strong possibility of the sedimentary source. This is also shown by the relatively high Ba, Rb and Sr in most of the samples (Okonkwo and Winchester, 1996; Okonkwo, 2005).

- ✓ Plots in Fig. 4.1.7 and Fig. 4.2.0 show that rocks in Oke-Ode area are of sedimentary origin and peraluminous.
- ✓ The aluminium saturation index (ASI) shows that the rocks are peraluminous.
- ✓ Petrographic and geochemical results give clear evidence that distinctly sub-alkaline affinity is a characteristic feature of these rocks, which are dominated by calc-alkaline suites.

This research work has revealed that the mapped area lies in the basement complex of Nigeria and has been affected by several orogenic events. The rocks found in the area include quartzite, schist, granodiorite, granite, amphibolite's, pegmatite, aplite, and quartz veins. The textural and structural characteristics of some of these rocks indicate that the study area has undergone regional metamorphism. The metamorphism altered the sedimentary protolith of the metasedimentary rocks (quartzite and schist) in the area. The rocks are characterised by joints, faults, lineations and foliations. These were formed because of ductile and brittle deformation that the area was been subjected to. Multiphase deformation is revealed in the various phases of fracturing and folding.

The metamorphic rocks are essentially of sedimentary origin while the granitoids may be product of partial melting of the pre-existing sedimentary protolith.

Conclusion

Field examination and geochemical evidence have provided useful indications for the petrology of Oke-Ode area. The geologic mapping of the study area reveals that the lithologic units in the area include granite, quartzite, amphibolite, granodiorite, and schist. Geochemical (major, trace elements and REE), geological and petrological studies revealed that all these crystalline rocks are genetically related and had evolved by progressive deformations. From the geochemical analysis, the rocks samples analysed were inferred to be of sedimentary origin. Some of the rocks in the study area such as granite is good for building and construction purposes. The schist presents opportunity for exploration of metalliferous and non-metalliferous minerals, which are characteristics of schist belt.

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