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PRELIMINARY REVIEW OF THE GEOLOGY OF THE HORNBLENDE BIOTITE GNEISSES OF OBUDU PLATEAU SOUTHEASTERN NIGERIA

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ABSTRACT

The Obudu Plateau, southeastern Nigeria is dominantly underlain by gneissose rocks with migmatitic characteristics, one of which is the hornblende-biotite gneiss. The gneisses are banded with quartz and plagioclase as the major minerals in the leucosome while hornblende and biotite occur in the palaeosome. Geochemically, the rocks are enriched in silica and alumina with an average of 71.6wt% and 14wt% respectively. Geochemical plots indicate that they are calc-alkaline to tholeiitic in character and derived from protoliths of igneous origin with minor sedimentary input.

KEYWORDS: Obudu Plateau, migmatitic gneiss, calc-alkaline

INTRODUCTION

Migmatitic Gneisses belong to one of the four major rock types in the Nigerian Basement Complex, specifically the Migmatite – gneiss – quartzite complex (Rahaman,1988). Rocks of this complex are presumed to be the oldest and have been dated to be pre-Pan African in age (2.8 -1.3Ga; Ekwueme 1990). The migmatitic nature of the rocks reflects the nature of the deformation and high-grade metamorphism these rocks have been subjected to. The Nigerian Basement Complex is said to have evolved through a series of tectonothermal events of which at least three episodes of deformation have been recognised (Grant, 1970; Rahaman and Lancelot, 1984; Dada,1998).

In Southeastern Nigeria, the Obudu Plateau is one of the exposures of the Precambrian basement rocks (Figure 1) and belongs to the Nigerian topographic sheet 291 (Obudu). This sheet has been studied in sections; NE, NW, SE, SW by various workers (e.g Orajaka, 1964; Ekwueme, 1994; Ukaegbu, 2003; Ukwang et. al., 2003; Ephraim, 2009; Obioha and Ekwueme, 2011) and these workers have grouped and described the migmatite gneisses in the area as garnet - sillimanite gneiss, garnet – hornblende gneiss, or plainly as migmatite gneiss. This study is an attempt to take a holistic look at the Obudu sheet and present a preliminary account of the petrology and geochemistry of the hornblende-biotite gneiss in the area.

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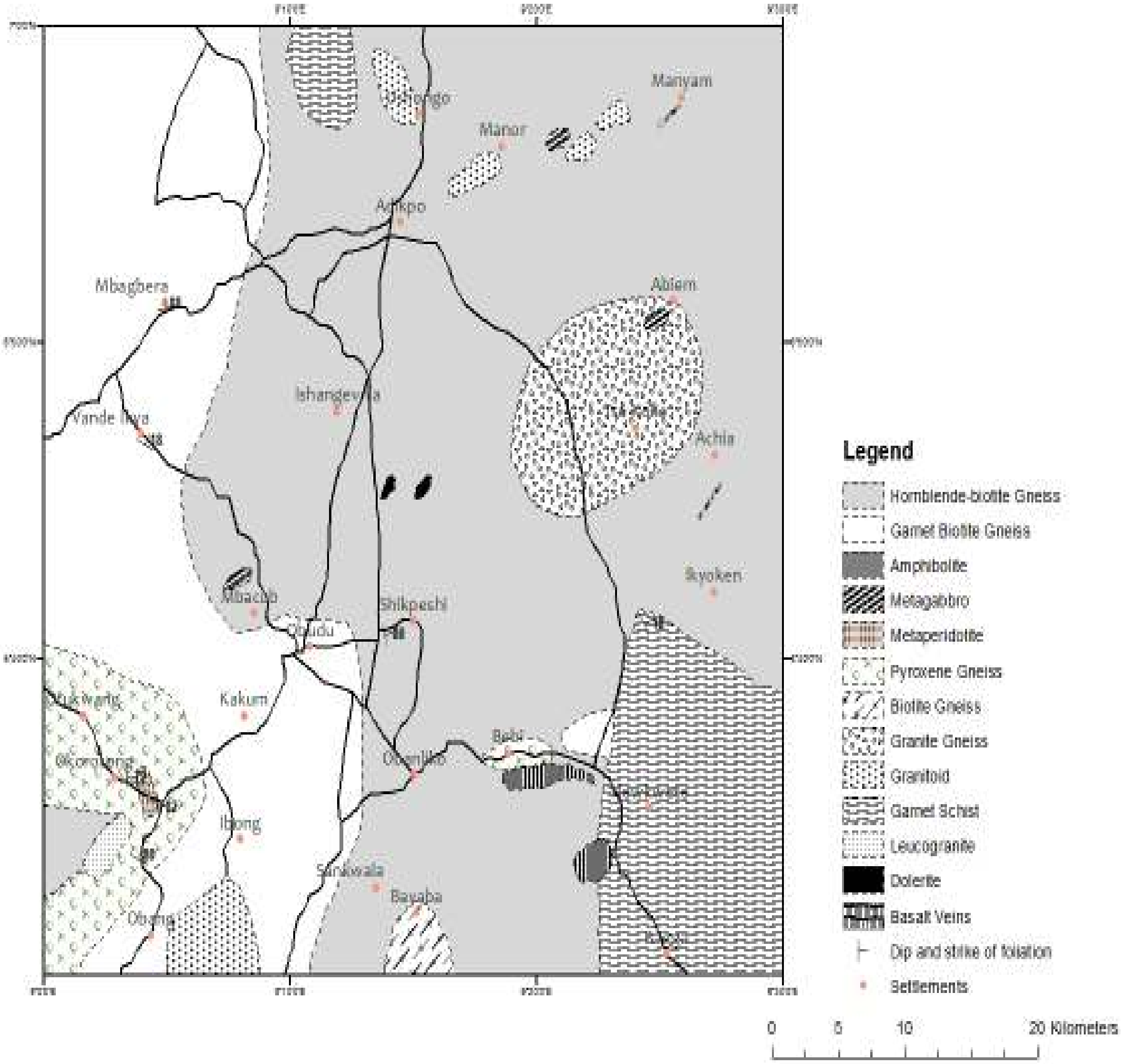

Figure 1: Geologic map of Nigeria showing the study area (modified from Woakes et al., 1987)

Regional Tectonics

The Obudu Plateau is one of the outcrops of the Nigerian Precambrian basement in southeastern Nigeria. It is an extension of the Bamenda Massif into southeastern Nigeria. The lithological variations in the region include high grade metamorphic rocks consisting dominantly of gneisses and schists that have been migmatised and intruded by unmetamorphosed granites, dolerites, aplites and quartzo-feldspathic veins. Also associated with these rocks are minor occurrences of metagabbros, amphibolites and metaquartzites. Archaean, Eburnean and Pan-African ages have been obtained from rocks of these region (Ekwueme, 2003; Ukwang et al., 2012). The similarity between the ages and lithology of rocks of southeastern Nigerian basement to rocks of the northern Cameroon basement and the Central African Fold Belt (Ekwueme, 2003, Ephraim 2005) have led workers to suggest that the southeastern Nigerian basement evolutionary history is linked to the Pan-African mobile belt in Central Africa. According to Toteu et al., (2004), the Pan-African belt in Central Africa is due to a continent-continent collision that involved the northern edge of the Congo craton as the passive margin and the Adamawa-Yadé and western Cameroon domain as the active margin.

Field Occurrence and Characteristics

The study area is underlain by gneisses and schists within which are bodies of amphibolites, metagabbros, dolerites and granitoids. The dominant foliation trend is N-S to NE-SW with an average dip of 55 degrees. The schists are restricted to the southeastern part of the study area and are migmatitic in nature. Where they occur within the gneisses, they are seen underlying riverbeds and are extensively weathered.

Gneissose rocks cover about two-thirds of the study area and consist of pyroxene gneiss, garnet-biotite-gneiss, hornblende-biotite gneiss and biotite gneiss (Figure 2). Generally, the gneissose rocks are mesocratic and medium grained and exhibit conspicuous alteration of light and dark coloured bands.

The hornblende-biotite gneiss constitutes the dominant rock type in the study area and have been described in other publications as migmatitic gneiss (e.g Ephraim, 2009). It generally consists of the metamorphic host rock (palaeosome) and leucocratic injections (leucosomes). The leucocratic injections consist mainly of quartz and feldspar and often occur as elongate continuous bands giving the rock a banded appearance. At other places, the leucosomes form coarser pegmatitic veins that dissect the rock irregularly. Other deformation structures include foliations, augen structures, pinch and swell structures. In the Shikpeshe mountains and Iykoken hill regions where extensive partial melting was observed, large regions of the rocks were almost totally felsic and could be described as quartzite. The banding is broader and rocks show ptygmatic folding, minor folds and minor shear zones (Figure 3). At the Amire River bed Manyam and Achia, the hornblende-biotite gneiss has been intruded by multiple dolerite dykes that range from 20 to 130cm in width and trend NE-SW. Generally, the hornblende-biotite gneiss occurs as highs and show extensive weathering such that fresh outcrops are scarce.

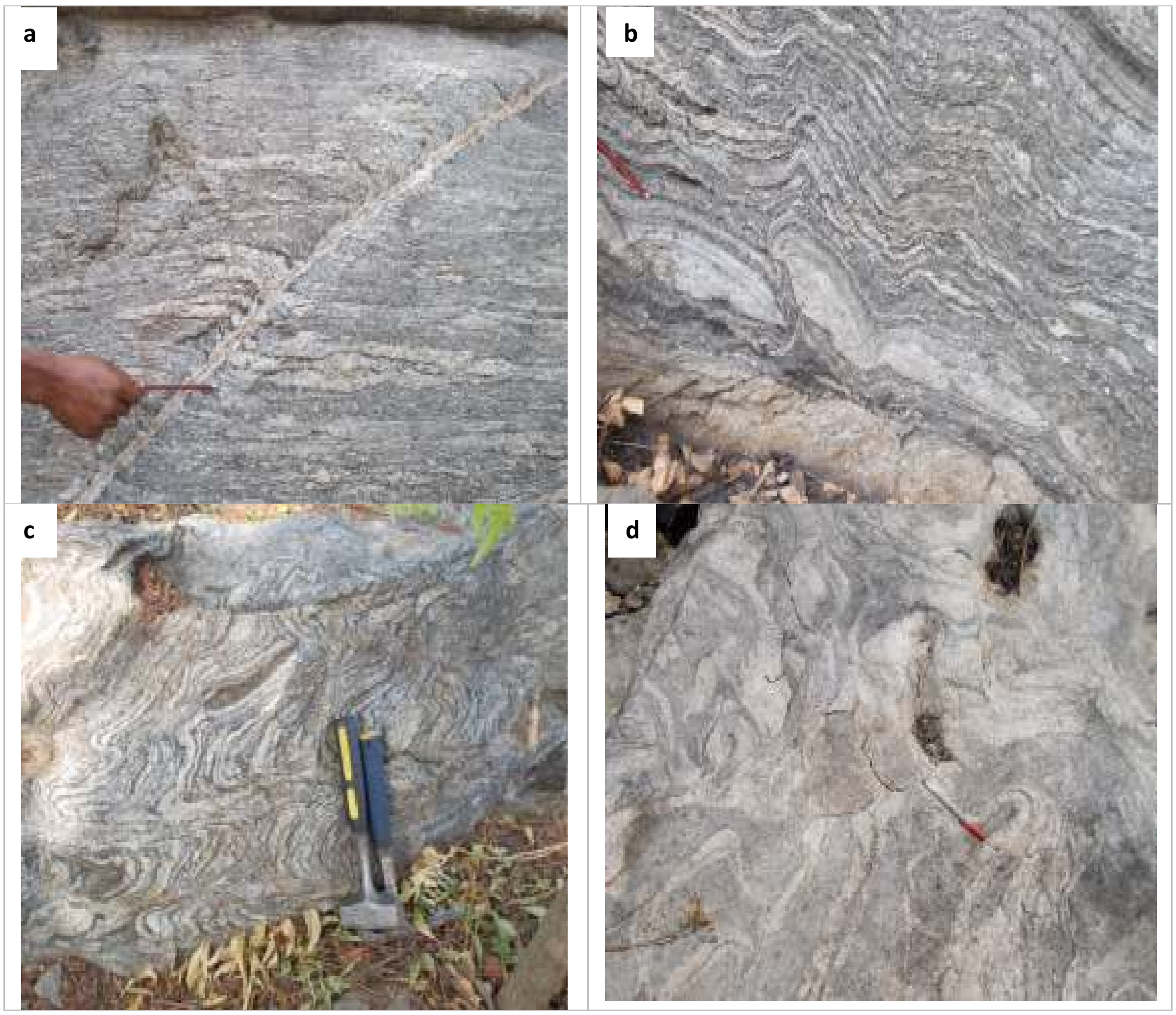

Figure 3. Field characteristics of the hornblende biotite gneiss. (a) Minor shear zone (b) pinch and swell structures (c)micro folds (d) contorted foliation

Table 1: Average Modal Composition of the Hornblende -Biotite Gneiss.

	ADP-06	ADP-08	ADP-09	ADP-24	ADP-25	IA-08	IA-09
Quartz	10	50	30	30	30	28	30
Plagioclase	30	20	30	25	15	30	20
K-Feldspar	-	-	5	7	20	5	20
Biotite	-	15	10	10	20	15	20
Muscovite	-	-	-	-	5	-	5
Hornblende	50	10	10	20	-	10	-
Orthopyroxene	5	-	10	-	-	5	-
Clinopyroxene	-	-	-	-	-	5	-
Sillimanite	-	-	-	-	5	-	-
Sphene	-	-	-	-	1	1	-
Opaques	5	3	5	8	2	1	5

Petrography of the Hornblende-biotite Gneiss

Table 1 shows the modal composition of the hornblende-biotite gneiss. The leucocratic mineral phases are composed predominantly of quartz and plagioclase. The quartz grains show undulose extinction and consist of irregularly shaped crystals and in some samples occurs as sub-grains. Inclusions of biotite, plagioclase and opaques occur in some grains and quartz also occurs as inclusions in pyroxene. Quartz is less common in the melanocratic mineral phases.
Plagioclase in this rock has an average modal percentage of about 27% with a mean plagioclase composition of An_{43} (andesine) and exhibits twinning on albite laws. A few shows combined albite and carlsbard twining as well as deformation twins. Core to rim extinction was also observed in a few crystals. Sericitization of the plagioclase mineral is prevalent and the grains are generally subhedral. K-feldspar crystals are subordinate to plagioclase and are mostly microcline.
Biotite occurs in sections as lath shaped crystals showing perfect cleavages in one-direction. It is strongly pleochroic from light brown to dark/orange brown. The biotite grains make up about 15% of the hornblende-biotite gneiss volume. The biotite grains along with hornblende define the foliations of these rocks.
Hornblende is a common mineral in these rocks but is however absent in some samples from the Shikpeshie and Ikyoken hill region (in these areas, the rocks show high level of partial melting). The grains are mostly anhedral and strongly pleochroic from green to greenish brown. Most of the crystals encountered show inclined extinctions with angles between 18° and 22°. A few basal sections showing characteristic cleavage were also observed.
Orthopyroxene occurs as a minor constituent of some samples. The grains are subhedral to anhedral and in some samples contain inclusions of quartz, plagioclase and hornblende. Some of the crystals show one clear cleavage trace with parallel extinction. Several, however show two cleavage traces that intersect almost at right angles.
Sillimanite and muscovite crystals occur in the rocks that lack hornblende as a minor constituent. The sillimanite occurs as swirled fine fibrous crystals mostly alongside with biotite. Other accessory minerals are sphene and opaques. The opaques occur mostly as irregularly shaped crystals.

Table 2. Major element oxides and Niggli values of hornblende biotite rocks from Obudu

	1	2	3	4	5	6	7	8	9	10	11	12	13
Oxides	GHG1	GHG2	GHG3	NG1	GB3	NK1	BK4	D 11.4	D26.3	BGM1	BGM2	UK1	UK2
SiO_2	71.8	68.77	72.06	74.98	71.11	72.63	72.11	72.29	72.8	69.54	70.33	69.96	71.45
TiO_2	0.45	0.39	0.2	0.17	1.08	0.84	0.89	0.42	0.12	0.39	0.22	0.54	0.24
Al_2O_3	14.89	15.63	12.68	13.1	14.02	13.42	13.99	13.28	14.5	14.01	14.23	13.39	15.29
$Fe_2O_{3(Tot)}$	1.64	2.41	0.65	1.05	2.88	2.54	2.58	4.34	2.03	3.56	2.75	5.99	2.22
MnO	0.02	0.03	0.02	0.01	0.01	0.01	0.04	0.07	0.03	0.04	0.04	0.1	0.04
MgO	0.5	1.3	2.84	0.28	0.81	0.29	0.27	0.66	0.26	1.53	1.16	1.98	0.65
CaO	1.39	3.37	1.4	0.65	0.69	0.63	0.64	2.77	0.89	3.89	3.97	2.3	2.25
Na_2O	2.78	4.53	4.13	2.16	2.16	2.18	2.19	4.4	3.48	3.67	4.11	2.51	4.4
K_2O	5.89	1.47	5.42	6.38	6.34	6.67	6.56	1.07	5.08	1.3	0.73	2.16	3.04
P_2O_5	0.11	0.09	0.02	0.1	0.17	0.19	0.18	0.09	0.1	0.09	0.04	0.09	0.07
LOI	0.49	0.65	0.45	0.59	0.54	0.58	0.54	0.5	0.6	0.55	0.46	0.56	0.23
Total	99.96	98.64	99.87	99.47	99.81	99.98	99.99	99.89	99.89	98.57	98.04	99.58	99.88
Niggli Values													
al	48	44	36	49	45	46	47	39	47	38	40	36	44
fm	8	14	21	8	18	14	14	21	11	23	18	35	13
c	8	17	7	4	4	4	4	15	5	19	20	11	12
alk	36	25	36	39	33	37	36	25	37	20	21	17	30
mg	0.65	0.69	0.95	0.51	0.53	0.31	0.29	0.23	0.21	0.46	0.45	0.4	0.36
k	0.58	0.18	0.46	0.66	0.66	0.67	0.66	0.13	0.49	0.19	0.11	0.37	0.31
si	395	327	342	475	384	420	409	357	395	319	336	322	352

1, 2, 3. Data from SE Obudu (Ekwueme, 2003); 4, 5, 6, 7.Data from NE Obudu (Ephraim, 2009); 8, 9. Data from NW Obudu (Obioha 2011); 10, 11.Data from NE Obudu (Obiora, 2012); 12,13. Data from SW Obudu (Ukaegbu, 2003)

Geochemical Characteristics

Several workers have studied the geochemistry of the hornblende biotite gneiss. Table 2 is a compilation of major element and Niggli values from five authors (Ekwueme, 2003, Ukaegbu, 2003, Ephraim, 2009, Obioha 2011, Obiora, 2012) and a review of the trends in the data follows.

The hornblende-biotite gneisses have high SiO_2 content (68.77 to 72.63 wt%). The silica content of the rock is reflected in the Niggli q and si values. The positive q values indicate silica oversaturation. Al_2O_3 values range from 12.68 to 15.63 wt % with Al_2O_3 >($CaO+Na_2O+K_2O$) indicating the peraluminious nature of the rocks. Na_2O and K_2O contents are relatively high and range from 2.16 to 4.53wt% and 0.73 to 6.67wt% respectively. This is consistent with the high content of feldspars and biotite in the rock. Analysis from four of the five authors generally indicated Na_2O higher than K_2O in their samples. Samples analysed by Ephraim (2009) have higher K_2O values. CaO values are variable and range from 0.63 to 3.97wt%. Total Fe reported as Fe_2O_3 is also variable and ranges from 0.65 to 5.99 wt %, but generally lies between 2-3wt%. The rock is manganese poor as MnO values are less than 0.1wt%. Contents of TiO_2 and MgO range from 0.12 to 1.08wt% and 0.26 to 2.84 wt% respectively.

Both sedimentary and igneous parentage have been suggested for the hornblende-biotite gneiss (Ekwueme, 2003; Ephraim 2009). In the al-alk versus Niggli c diagram (Figure 4), most of the rocks plot in the field of igneous rocks. However, data from NE Obudu clearly show a trend extending from the feldspar line towards high al-alk value at nearly a constant c value. This is also corroborated on the Na_2O/Al_2O_3 versus K_2O/Al_2O_3 discrimination diagram after Garrels and Mackenzie (1971) (Figure 5), where most of the samples also plot in the meta-igneous field with the data from NE Obudu plotting in the metasedimentary field albeit, close to the boundary. This trend could be interpreted as the protolith being mainly of igneous parentage with minimal sedimentary input.

To define the chemical affinity of the rocks, the data were plotted on TAS diagram, (Figure 6) where the samples clearly plot in the sub-alkaline series field. Further discrimination of this field using the FMS diagram of Miyashiro (1974; Figure 7), had some samples plotting in the tholeiitic series and the rest in the calc-alkaline series. On the Jensen diagram (Figure 8), only two samples which had Fe_2O_3 values of 1wt% and less plotted on the calc-alkaline field. The rest of the data plotted on the tholeiite field.

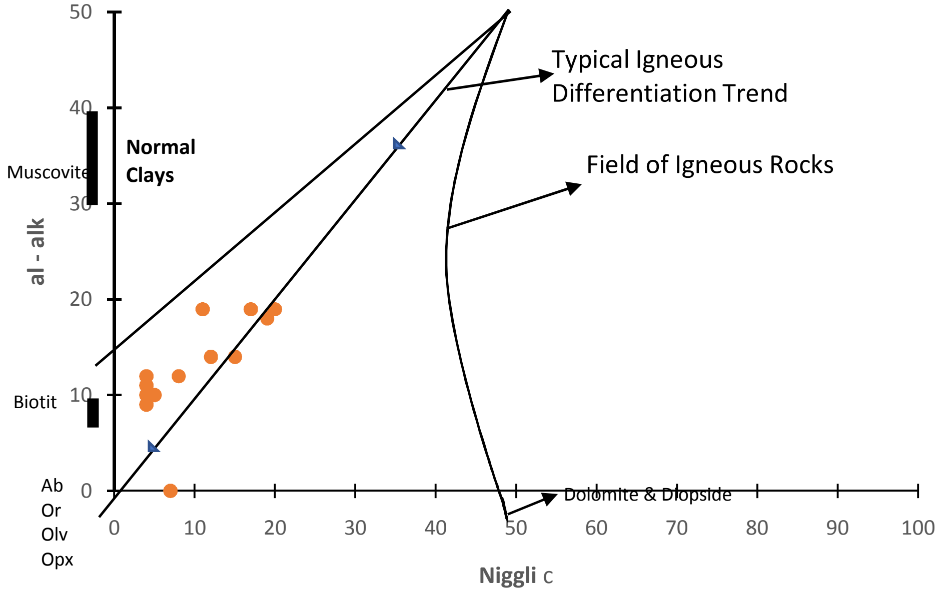

Figure 4. Niggli al-alk against Niggli c Plot (after Leake and Singh, 1986) showing the variation trends in the hornblende biotite gneisses.

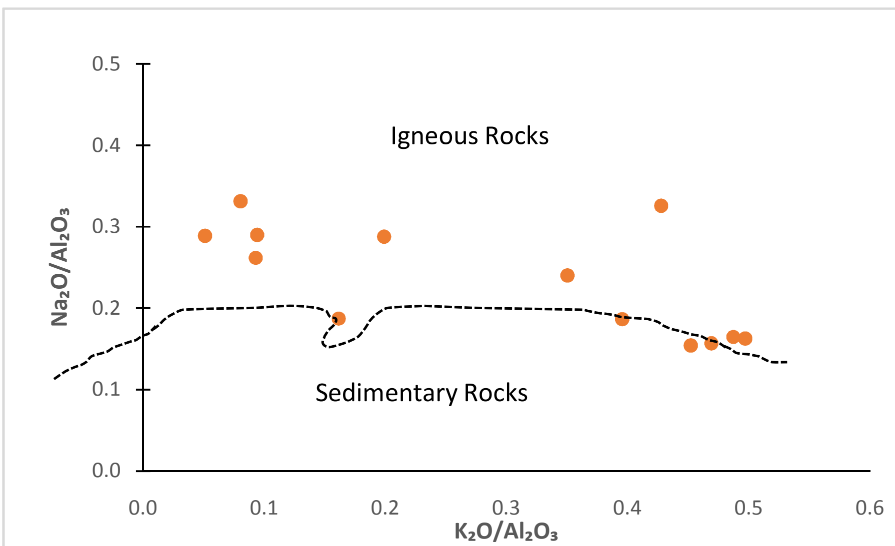

Figure 5. Na_2O/Al_2O_3 versus K_2O/Al_2O_3 discrimination diagram for hornblende biotite gneiss of Obudu (After Garrels and Mackenzie,1971)

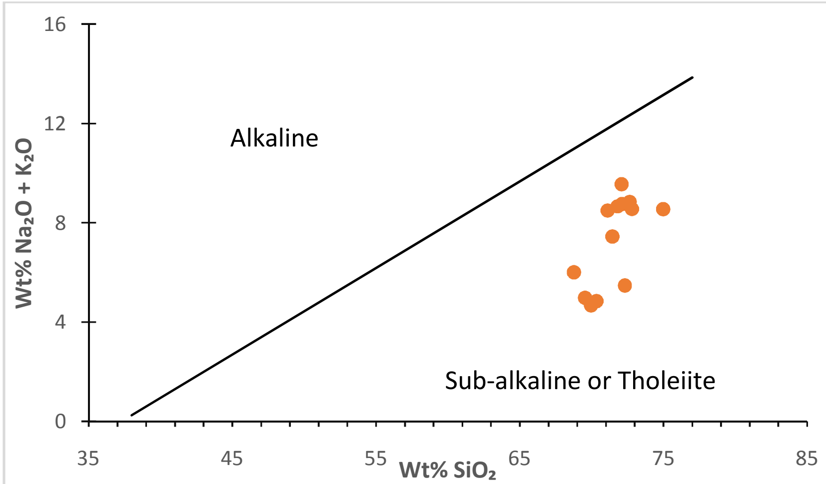

Figure 6.: Plot of hornblende biotite gneiss data on TAS diagram (Boundary lines from Rickwood 1989)

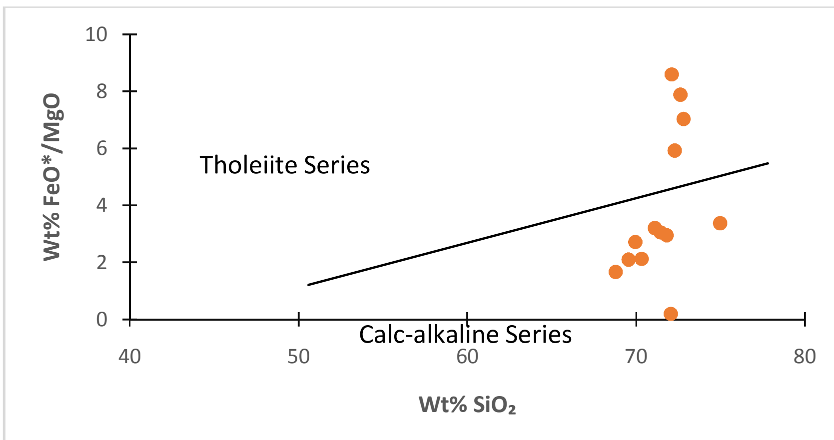

Figure 7.: Plot of hornblende biotite gneiss data on FMS diagram (after Miyashiro, 1974)

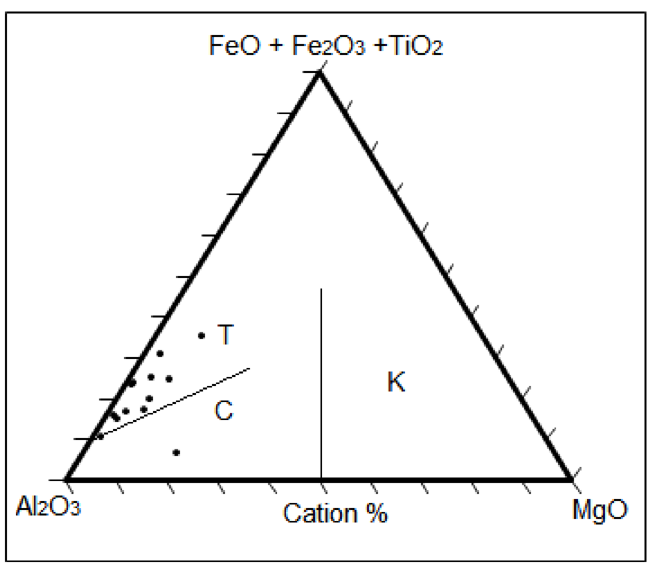

Figure 8.: Plot of hornblende biotite gneiss data on the Jensen diagram (after Jensen, 1976). T = Tholeiite, C = Calc-alkaline, K = Komatiite (modified using Tri-plot Graham and Midley, 2000)

Summary and Conclusions

The hornblende-biotite gneiss that occurs in the Obudu plateau have experienced high grade metamorphism of the upper amphibolite to granulite facies. This is indicated by the presence of sillimanite and orthopyroxene in some of the samples. The rocks have undergone partial melting, resulting in the formation of abundant leucosomes, which are generally parallel to the foliation of the host rocks and the presence of structures that are characteristic of migmatitic terrains such as augen structures and contorted foliation. The gneisses are generally enriched in silica, alumina and alkalis. Geochemical studies show that the protoliths of the rocks are calc-alkaline to tholeiitic in nature and that the protoliths may be of a mixed nature comprising both igneous and sedimentary rocks.

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