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Petrogenesis of Granite Gneisses Around Igangan-Tapa-Inamere Area, Southwestern Nigeria

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Abstract
Precambrian granite gneisses and migmatites constitute the basement complex in some parts of Nigeria, with different modes of origin proposed by different authors based on available data. This study was carried out to determine the origin of granite gneisses around Igangan area, southwestern Nigeria. Geological mapping was carried out on a scale of 1:50000 to delineate the rock types, and thin sections of the identified rocks were studied under the petrologic microscope. Whole Rock analysis of 8 samples of the granite gneisses was carried out using Inductively Coupled Plasma Mass Spectrometry (ICP-MS); results were interpreted using descriptive statistics and major and trace element plots. The granite gneisses are slightly foliated, trend NE-SW, and display a slight easterly dip. They are composed of plagioclase + k-feldspar + quartz + biotite $\pm$ hornblende and accessory minerals including apatite, zircon and magnetite; perthitic intergrowth was observed in the feldspars. The gneisses are enriched in Na_2O relative to K_2O, have alumina content below 15% and high SiO_2 content. Average concentration of Ba and Sr are below the crustal average while the average value of Rb is above that of the average crust. The gneisses are also characterized by low mean values of Ni, Cr, Co; high LREE/HREE ratio and a negative Eu anomaly. Geochemical plots and CIPW norm values favor an igneous origin for the gneisses, reveal that they are calc-alkaline and were metamorphosed at 650-700°C. Plots of Ni vs V, Sc vs V and Ce/Sm vs Ce showed that the primary signature of the gneisses have been preseved; with plagioclase fractionation and fractional crystalisation being the dominant features observed in the gneisses. Field, petrogrpahic and geochemical features revealed that the granite gneisses are of igneous origin and their primary features have been preserved due to low grade metamorphism which did not involve partial melting of the protolith.

Keywords: *Gneisses, trace elements, fractionation, low grade metamorphism*

Introduction

Granite gneisses are one of the major petrological units, making up about half of the polycyclic Nigerian Basement complex which has been affected by different episodes of orogeny (Kroner et al., 2001). Grant (1970) with the aid of the Rb/Sr method proposed an igneous origin for the Ibadan granite gneisses; Freeth, (1971) proposed a sedimentary origin for the granite gneisses; while Burke et al. (1972) believed some of the gneisses in Nigeria are products of isochemical metamorphism of shale and greywacke beds. In 1978, Rahmaan and Ocan proposed an igneous origin for the granite gneisses while based on field and geochemical evidence, Onyeagocha, (1984) also proposed an igneous origin for granite gneisses of north central Nigeria. Oyinloye (1992) on the basis of petrology, field mapping and structural analyses reported that the prominent gneissic foliations observed on some of the gneisses suggest that metamorphism actually reached an upper amphibolite facies in the rocks of the Basement complex in Southwestern Nigeria. In spite of the various studies conducted, no single mode of origin has been accepted for the granite gneisses due to insufficient geochemical data to adequately distinguish between the igneous and sedimentary gneisses and their compositional variation (Rahmaan and Ocan, 1978; Elueze and Bolarinwa, 2004). The present study is therefore aimed at elucidating the petrogenesis of granite gneisses around Tapa-Inamere area of southwestern Nigeria which are yet to be characterized, in a bid to better understand the genesis of granite gneisses of the Nigerian Basement Complex.

Study location

Igangan – Tapa -Inamere area is located within the basement complex of southwestern Nigeria (Figure 1). It lies within the Pan-African belt which was formed from the collision of the passive continental margin of the West-African Craton and the active margin of the Tuaregshield during the Pan African tectonic event (Burke and Dewey, 1972; Leblanc, 1981; Black et al, 1979, Caby et al, 1981). The Nigerian basement complex is Precambrian in age and bears the imprint of the Liberian (ca 2500Ma), Eburnean (ca 2000Ma) and Pan-African (ca 600Ma) tectonic events; broadly grouped into the migmatite gneiss complex, the schist belts and the older granite suite (Turner, 1983; Oversby, 1975; McCurry and Wright, 1977; Annor and Freeth, 1985; Rahaman 1998).

The migmatite gneiss complex consists mainly of migmatites and gneisses of different origin as well as meta-igneous rocks of basic to ultrabasic composition; the schist belts consists of fine grained clastics, pelitic schists, phyllites, banded iron formations, marble and amphibolites with imprints of the Kibaran (ca. 1200Ma) and Pan African tectonic events (Grant et al 1972). The older granites consist of orogenic (Pan-African) igneous rocks emplaced within the migmatite gneiss complex and the schists belts with varied lithology comprising granites, granodiorites, diorites, tonalities, syenites and pegmatites.

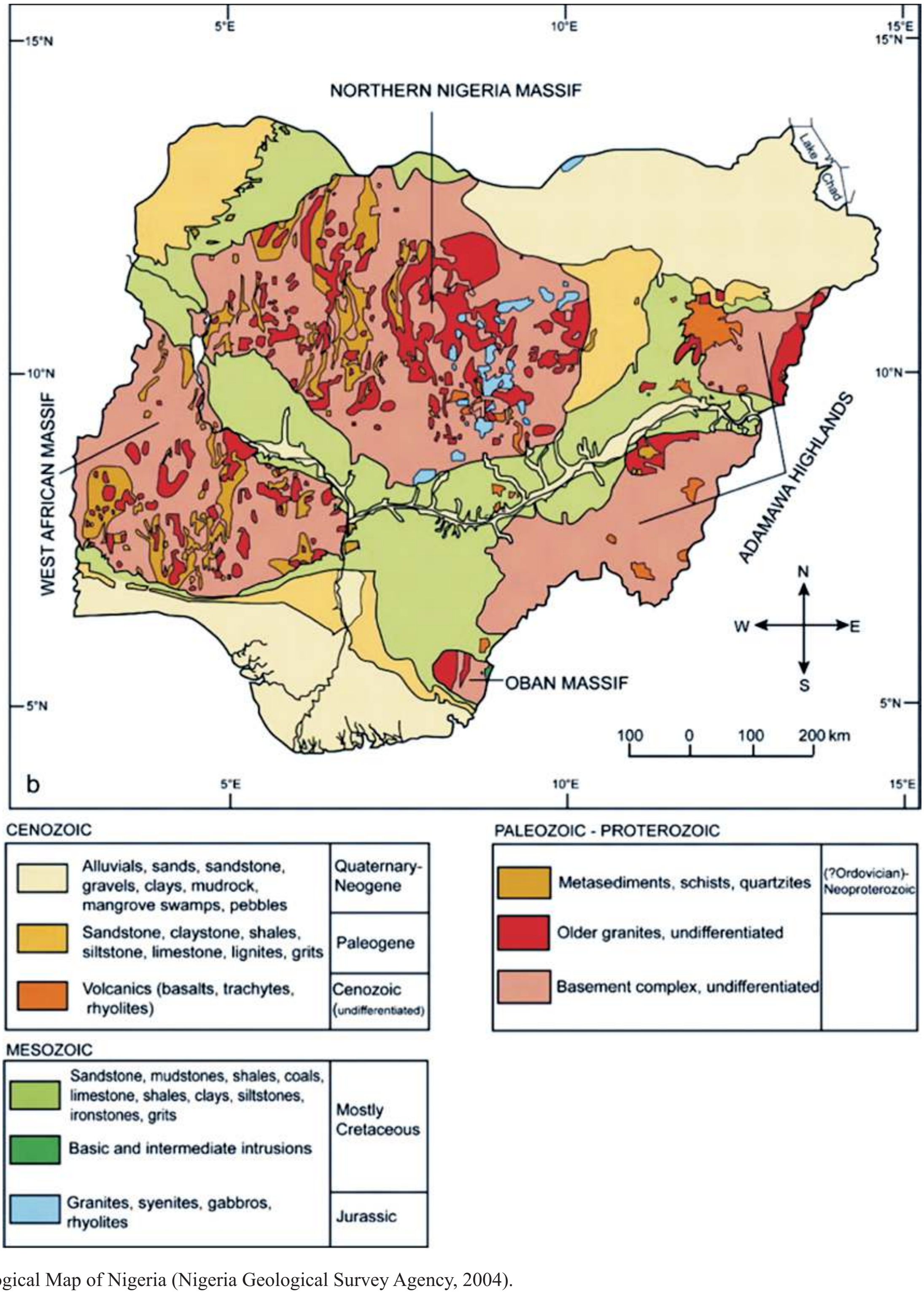

Fig. 1: Geological Map of Nigeria (Nigeria Geological Survey Agency, 2004).

Materials and methods

Geological mapping of the area was carried out on the scale of 1:50,000, representative samples of different rock types were collected and structural measurements were also taken. Petrographic analysis was done on thin sections cut from representative samples using a transmitted light microscope at the Department of Geological Sciences, University of Cape Town. 8 samples of granite gneisses were analysed for their major, trace and rare elemental concentrations at the Bureau Veritas Minerals (BVM) Laboratories Limited, Vancouver, British Columbia, Canada using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) instrumentation method. The procedure employed involved multi-acid digestion of 0.25g of representative sample to ensure complete mineral digestion.

Result and Discussion

Field Occurrence and Petrography

The granite gneisses occur as semi rounded to elongated, low lying to massive outcrops which is a common feature in the case of granite gneisses of igneous origin with the direction of the longer axis possibly determined by the strike of the associated metasedimentary rocks (figure 2 and figure 6). They are leucocratic (grey), slightly foliated and medium grained, with a NE-SW trend. The rocks which are homogenous display a slight easterly dip.

In hand specimen, quartz, feldspar, and biotite are visibly observed while petrographic examination revealed a composition of plagioclase + k-feldspar + quartz + biotite $\pm$ hornblende and accessory minerals including apatite, zircon and magnetite. Under the microscope, the rocks can generally be seen as a mixture of feldspars and quartz, in which lie small plates of biotite. The biotite is less abundant than quartz and feldspar, generally with a less pronounced parallel orientation. In a larger number of sections, some orthoclase and plagioclase grains show granophyric intergrowth, with narrow irregular, curving convergence toward the center of the feldspar grain. This granophyric intergrowth may be characteristic of feldspars of igneous origin. Biotite shows little or no alignment in thin section; it is strongly pleochroic from greenish brown to pale yellow and has subhedral elongate crystals. Quartz grains in some samples show signs of recrystallisation (Figures 2-4).

Fig. 2: Field photograph showing granite gneiss in Igangan-Tapa-Inamere area

The slight foliation which is defined by mafic (biotite rich) and felsic (quartz and feldspars) mineral bands in the gneisses is not conspicuous in thin sections. The gneisses are characterized by textures which denote previous deformation effects such as slightly and well deformed pegmatite veins, and folded quartzo-feldsphathic veins. Some of the cross-cutting pegmatites veins display ptygmatic folding (Figure 3). The gneisses are also characterized by joints and folds formed as a result of deformation experienced during metamorphism and as response to various tectonic events associated with the Pan-African Orogeny. The foliations, veins/veinlets, folds and fractures in granite gneisses are oriented principally in the NW-SE direction (Figure 5).

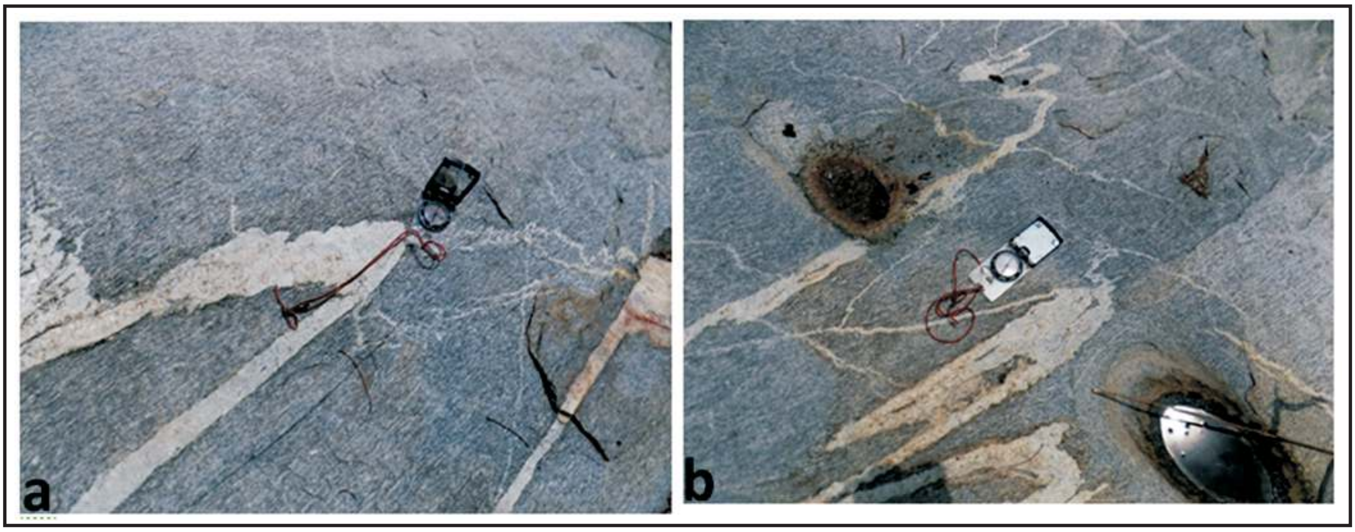

Fig. 3: Slightly foliated gneiss with quartzo-feldsphathic intrusions around Inamere and pegmatitic fold in granite gneiss with quartzo - feldsphathic intrusions around Inamere.

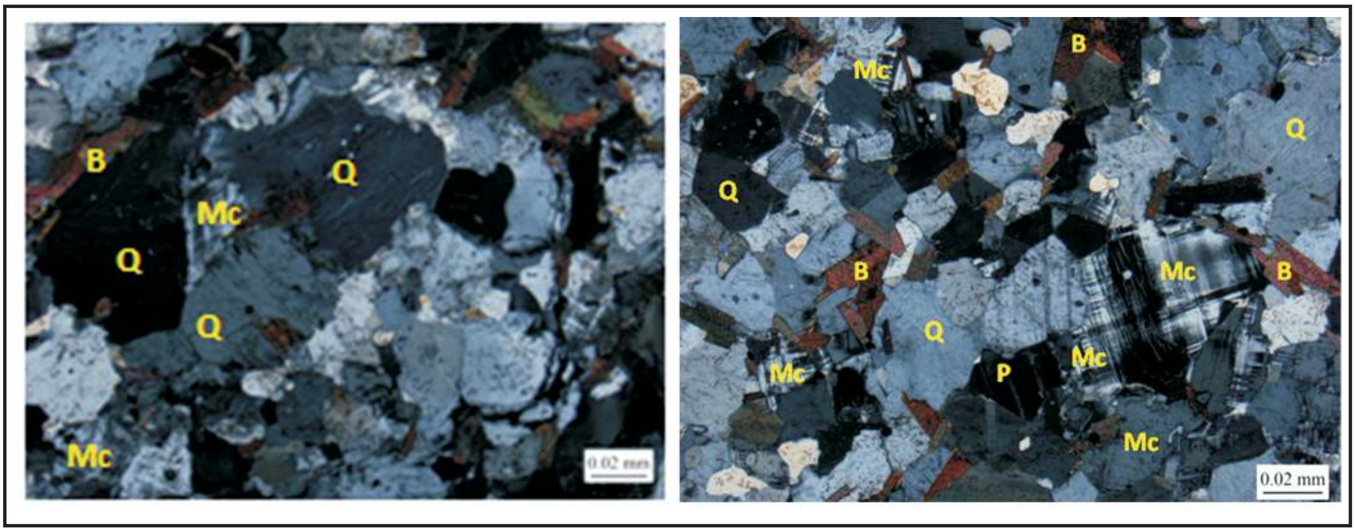

Fig. 4: Photomicrograph of granite gneiss around Idiyan under transmitted light showing recrystallisation of quartz grains, euhedral grains of biotite, subhedral grains of quartz and microcline.

Geochemistry

Geochemical results revealed granite gneisses are characterized by high SiO_2 content (71.1-76.66%). K_2O varies from 2.27-3.05%, Na_2O varies from 3.08-4.66% with an enrichment of Na_2O relative to K_2O (Table 1). K_2O/Na_2O ratio of 0.56-0.89 is indicative of abundant sodium feldspars in the gneisses (Oyinloye, 1992). Alumina content is low, ranging from 12.56-13.19%. This restricted range suggests a calc-alkaline affinity with alumina greater than total alkalis in all samples. The alumina saturation index is greater than one in all cases (1.01-1.1), suggesting the availability of corundum in their norm (Tables 1 and 4).

Enrichment of Al_2O_3, K_2O and Na_2O is also reflected in the AFM diagram with the granite gneisses plotting in the calc-alkalic field due to the abundance of biotite and feldspars in the rocks (figure 7). The major elemental concentrations suggest a granitic source for the granite gneiss and this was confirmed by the petrogenetic plots (Garrels and Mackenzie, 1971; Figure 7).

The high silica content of the gneisses clearly indicates a felsic nature, this is supported by the low Fe_2O_3 content and mean values of Na_2O and K_2O which reflects the abundance of K-rich rock forming silicates like biotite and microcline. This trend is characteristic of Archaean granitic rocks (Martin, 1986; Oyinloye, 2011). K_2O values are moderate and indicate calc-alkaline affinity

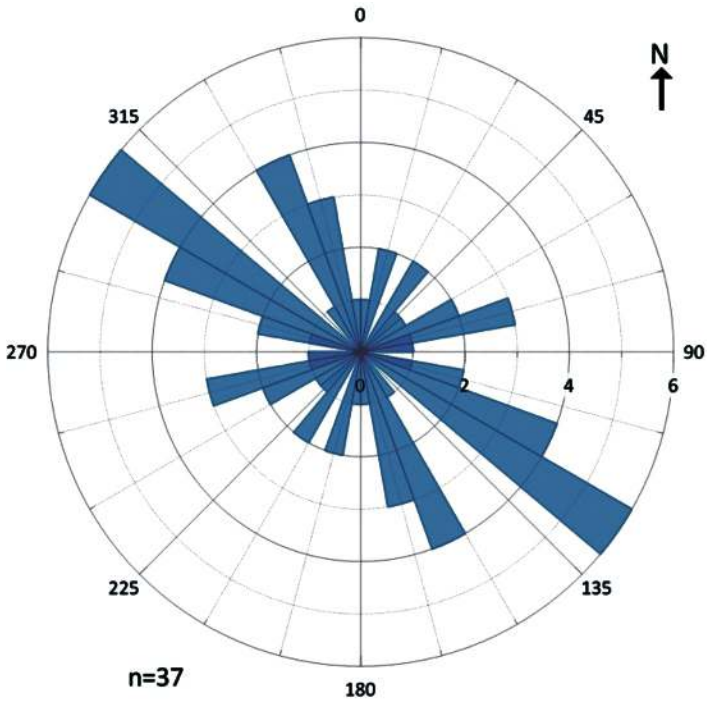

Fig. 5: Rosette diagram showing the NNW-SSE orientation of joints in granite gneisses in the study area.

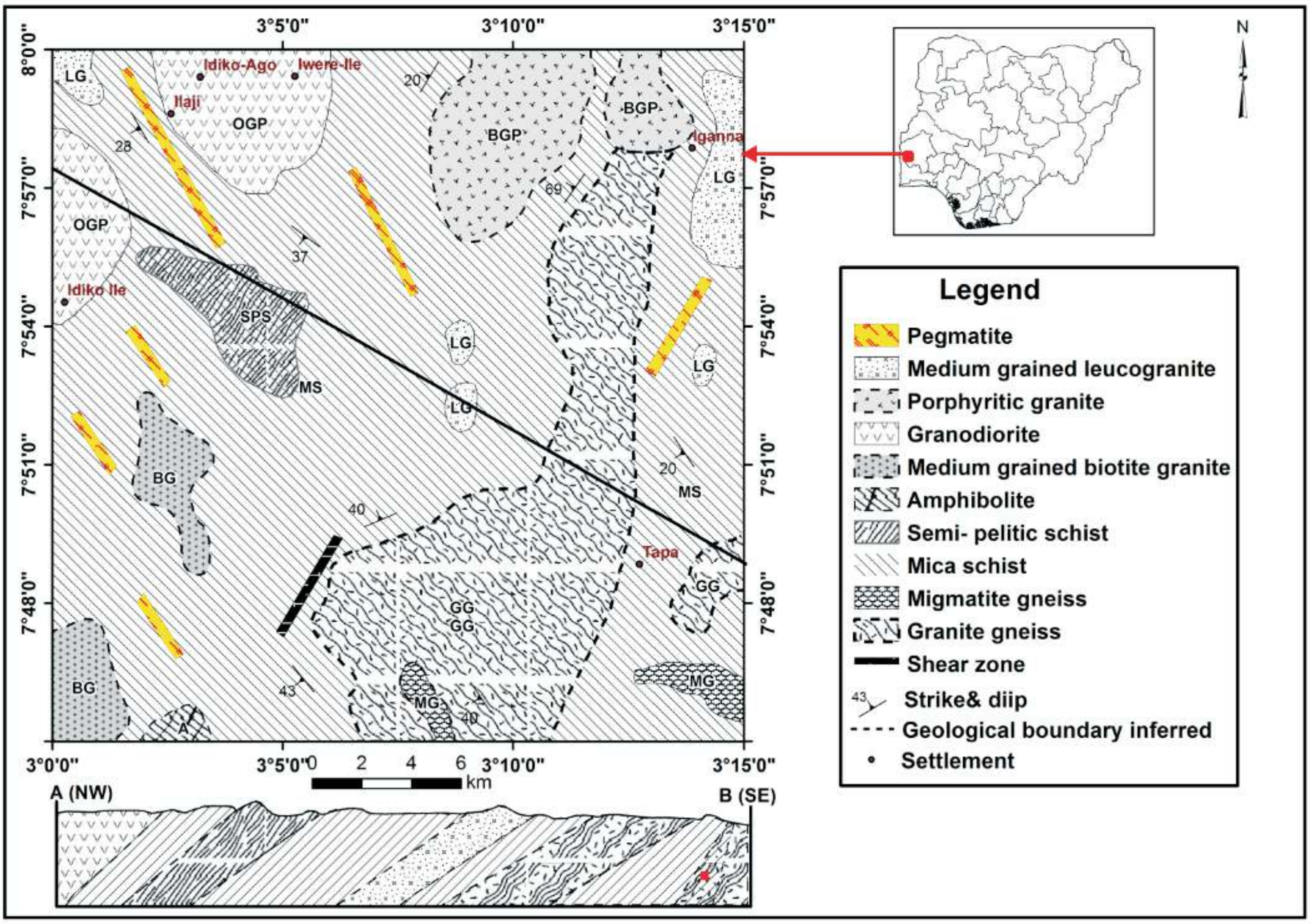

Fig. 6: Geological map of the Igangan-Tapa-inamere area.

Table 1: Major Elemental concentration for granite gneisses around Igangan-Tapa-Inamere area

sample number	1	2	3	4	5	6	7	8	Mean ± SD
SiO_2	73.97	71.47	71.57	71.35	75.88	76.29	71.1	76.66	73.54 ± 2.45
Al_2O_3	13.05	12.85	13.17	12.94	12.6	12.56	13.19	12.79	12.89 ± 0.24
Fe_2O_3	2.93	4.62	4.58	4.56	1.97	2	4.6	1.12	3.30 ± 1.46
K_2O	2.76	2.74	2.27	2.64	2.61	2.41	2.61	3.05	2.64 ± 0..23
Na_2O	3.75	3.08	3.24	3.22	4.47	4.25	3.21	4.66	3.73 ± 0.64
CaO	1.55	2.49	2.55	2.55	0.99	1.02	2.55	0.57	1.78 ± 0.85
MgO	0.96	1.54	1.54	1.53	0.61	0.63	1.54	0.28	1.08 ± 0.52
MnO	0.06	0.07	0.07	0.08	0.06	0.06	0.07	0.06	0.07 ± 0.01
P_2O_5	0.09	0.09	0.08	0.08	0.07	0.08	0.08	0.09	0.08 ± 0.01
TiO_2	0.31	0.5	0.49	0.54	0.2	0.21	0.52	0.11	0.36 ± 0.17
K_2O/Na_2O	0.74	0.89	0.7	0.82	0.58	0.57	0.81	0.65	0.72 ± 0.12
Na_2O+K_2O	6.51	5.82	5.51	5.86	7.08	6.66	5.82	7.71	6.37 ± 0.76
ASI	**1.09**	**1.02**	**1.06**	**1.01**	**1.05**	**1.1**	**1.04**	**1.07**	1.05 ± 0.32

Table 2: Major Elemental concentration for granite gneisses around Igangan-Tapa-Inamere area

sample number	1	2	3	4	5	6	7	8	Mean ± SD
Mo	0.62	1.78	1.88	1	0.51	0.64	1.49	0.41	1.04 ± 0.59
Cu	16.6	36.5	23.7	25.5	12.8	18.7	44.5	9.8	23.51 ± 11.87
Pb	26.25	24.85	24.08	23.57	29.06	29.41	24.55	29.64	26.43 ± 2.56
Zn	85.7	132	140.9	136.9	60.6	57.1	149.3	31.1	99.20 ± 46.03
Ni	11.4	17.4	17.6	18	8.2	8.3	19.5	4.6	13.13 ± 5.68
Co	7.3	12	12.6	12.2	5	4.8	13.1	2.4	8.68 ± 4.28
U	9.3	3.9	4.5	3.4	5.5	4.1	4.6	6.1	5.18 ± 1.88
Th	16.4	27.9	22.1	20.2	12.6	23.1	28.3	3.8	19.30 ± 8.21
Sr	85	116	118	119	67	68	121	48	92.75 ± 29.29
V	34	54	54	54	22	23	56	10	38.38 ± 18.41
Cr	27	44	44	44	19	21	46	12	32.13 ± 13.85
Ba	364	572	588	551	256	276	587	143	417.13 ± 178.81
Zr	69.3	86.9	108.6	131.7	43	43.3	125	25.2	79.13 ± 40.34
Sn	4.1	4.5	4.4	4.3	3.1	3.1	4.6	2.8	3.86 ± 0.73
Sc	5.7	8.5	8.7	9	4	4	8.7	2	6.33 ± 2.75
Y	16.7	25.6	26	28.9	11.6	13.2	30.1	7.6	19.96 ± 8.70
Rb/Sr	2.06	0.74	0.63	0.75	2.93	2.83	0.8	6.15	2.11 ± 1.89
Ba/Sr	4.28	4.93	4.98	4.63	3.82	4.06	4.85	2.98	4.32 ± 0.69
Th/U	1.76	7.15	4.91	5.94	2.29	5.63	6.15	0.62	4.31 ± 2.40
U/Th	0.57	0.14	0.2	0.17	0.44	0.18	0.16	1.61	0.43 ± 0.50
Ba/Rb	2.08	6.7	7.92	6.16	1.3	1.43	6.03	0.48	4. ± 2.96

(Figure 8). Increasing Al_2O_3 and CaO content with decrease in SiO_2 and systematic decrease in Na_2O implies a decrease in sodic plagioclase and increase in anorthite content which further suggest a plutonic origin for the granite gneisses (Figure 9).

The gneisses are also characterized by low MgO (1.12-4.62 wt %) and TiO_2 (0.28-1.54 wt. %) values, indicative of a felsic character. The MgO/ Fe_2O_3 + MgO ratio ranges from 0.20-0.25 (average 0.24) which is low compared to the value of the pure primitive upper mantle (0.68-0.75; average 0.70) (Wilson, 1991) which implies an high fractionation of the parent rock.

Major normative minerals are orthoclase, albite, hematite, hyperstene, anorthite, quartz and, corrundum while minor normative minerals are rutile, ilmenite and zircon (Table 4). Plot of Normative Corundum versus

Table 3: Major Elemental concentration for granite gneisses around Igangan-Tapa-Inamere area

sample number	1	2	3	4	5	6	7	8	Mean ± SD
La	35.5	62.7	47.4	45.5	27.2	46.8	62.7	10.5	42.29 + 17.62
Ce	69.23	129.03	91.52	89.62	49.67	88.01	120.67	17.17	81.87 + 36.46
Pr	8.1	15.6	10.9	10.7	5.8	10.9	14.2	2.3	9.81 + 4.33
Nd	28.4	54.3	39.9	38.9	20	38.1	52.1	8.6	35.03 + 15.49
Sm	5.6	10.6	8.2	7.8	4	7.2	9.8	1.9	6.88 + 2.92
Eu	0.6	1	0.8	0.9	0.4	0.6	1	0.3	0.7 + 0.27
Gd	4.7	8.1	6.5	6.6	3.5	4.8	8.9	2	5.64 +2.32
Tb	0.6	1.1	0.9	1	0.4	0.5	1.1	0.2	0.73 +0 .35
Dy	3.8	5.8	5.5	5.9	2.8	3.2	6.5	1.5	4.38 + 1.80
Ho	0.7	1	1	1.2	0.4	0.5	1.1	0.3	0.78 + 0.35
Er	1.8	3.1	3	3.2	1.3	1.4	3.6	0.8	2.28 + 1.06
Tm	0.3	0.5	0.5	0.6	0.2	0.2	0.6	0.1	0.38 + 0.20
Yb	1.8	3.3	3.4	3.8	1.4	1.6	3.4	0.9	2.45 + 1.13
Lu	0.3	0.5	0.5	0.7	0.2	0.3	0.6	0.1	0.40 + 0.21
Nd/Sm	5.07	5.12	4.87	4.99	5	5.29	5.32	4.53	5.02 + 0.25
Yb/La	0.05	0.05	0.07	0.08	0.05	0.03	0.05	0.09	0.06+ 0.02
La/Lu	118.33	125.4	94.8	65	136	156	104.5	105	113.13 + 27.60
Eu/Eu*	**0.35**	**0.32**	**0.32**	**0.37**	**0.32**	**0.29**	**0.32**	**0.47**	0.35 + 0.06
(La/Sm)N	3.48	3.24	3.17	3.2	3.73	3.57	3.51	3.03	3.36 +0.24
∑REEs	161.43	296.63	220.02	216.42	117.27	204.11	286.27	46.67	193.60 + 83.65

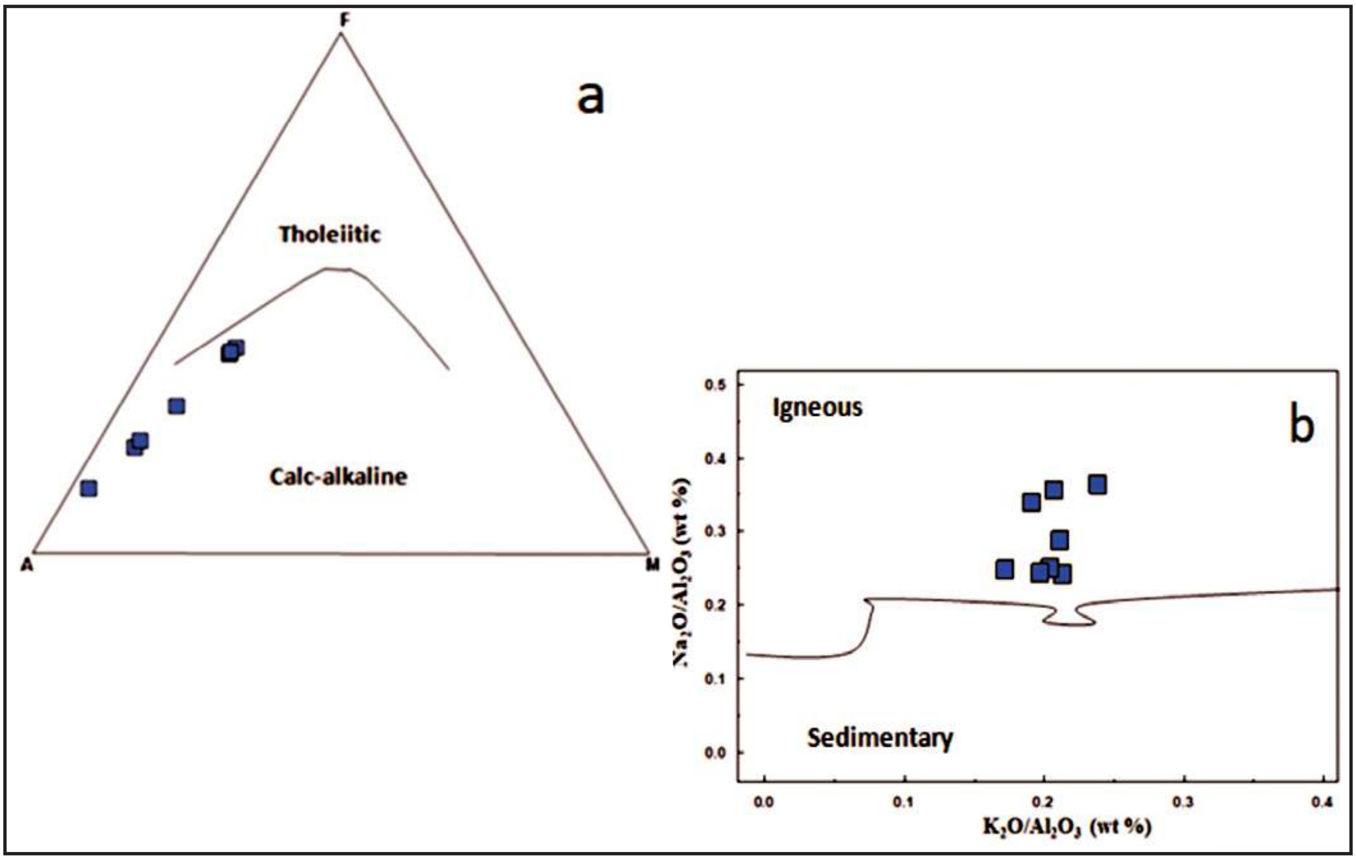

Fig. 7: AFM diagram for granite gneiss rocks (after Irvine and Baragar, 1976); Na_2O/Al_2O_3 vs K_2O/Al_2O_3 to discriminate between igneous and sedimentary origin for gneisses in Igangan area after (Garrels and Mackenzie, 1971).

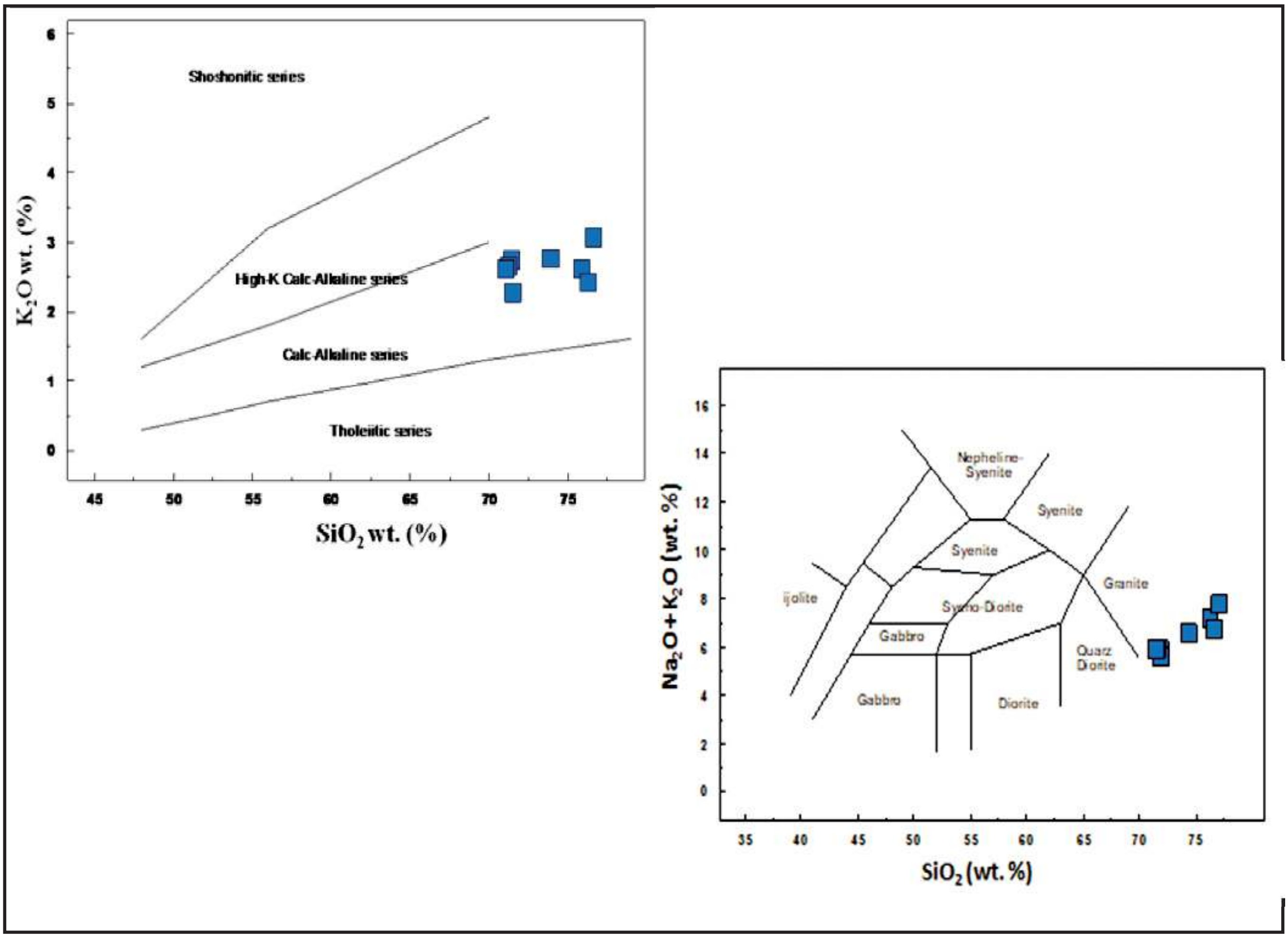

Fig. 8: K_2O versus silica plot for gneisses in the Igangan area (after Le Maitre et al., 1989) SiO_2 versus ($Na_2O + K_2O$) diagram showing the granitic protolith of gneisses in the study area (Cox et al., 1979)

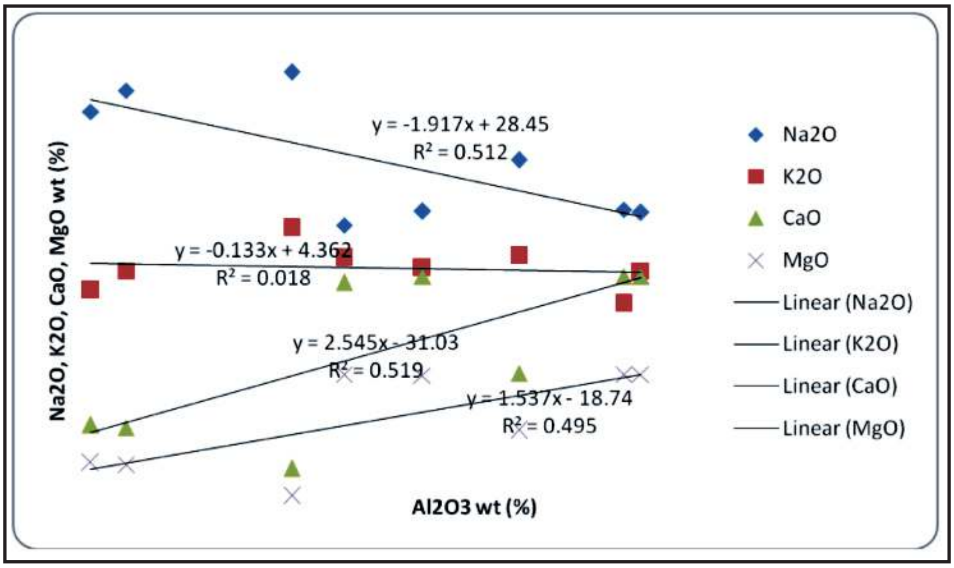

Fig. 9: Variation diagram of individual oxides against alumina (lines represent correlation between oxides and alumina)

Table 4: CIPW norm results for granite gneisses

sample number	1	2	3	4	5	6	7	8
Apatite	0.21	0.21	0.19	0.19	0.17	0.19	0.19	0.21
Chromite	0.01	0.01	0.01	0.01	0	0	0.01	0
Zircon	0.01	0.02	0.02	0.03	0.01	0.01	0.03	0.01
Ilmenite	0.13	0.15	0.15	0.17	0.13	0.13	0.15	0.13
Orthoclase	16.31	16.19	13.41	15.6	15.42	14.24	15.42	18.02
Albite	31.73	26.06	27.42	27.25	37.82	35.96	27.16	39.43
Anorthite	7.2	11.92	12.28	12.28	4.53	4.62	12.29	2.28
Corundum	1.25	0.45	0.88	0.29	0.76	1.27	0.58	0.99
Hematite	2.93	4.62	4.58	4.56	1.97	2	4.6	1.12
Hyperstene	2.39	3.84	3.84	3.81	1.52	1.57	3.84	0.7
Quartz	37.05	35.62	36.43	34.93	37.02	39.41	34.83	36.48
Rutile	0.24	0.42	0.41	0.45	0.13	0.14	0.44	0.04
CIPW TOTAL	99.46	99.51	99.62	99.57	99.48	99.54	99.54	99.41

mol. $Al_2O_3/(Na_2O+K_2O+CaO)$ revealed an igneous origin for gneiss (Figure 10) and Q-Ab-Or and Ab-An-Or ternary diagrams where plotted from CIPW data; Q-Ab-Or of Luth*et al*., (1964) with isotherms of Winker *et al*., (1975) revealed the protoliths gave pH_2O between 1 and 10 kb and crystallisation temperature between 630 and 700°C while CIPW normative compositions of An, Ab and Or on the An-Ab-Or ternary diagram with two cotetic lines and isotherms at 1kb and 5kb after James and Hamilton, (1969) and Winkler *et al*., (1975) respectively. The plots revealed the parent rocks of the gneisses metamorphosed at a temperature range of 650 to 700°C (Figure 11) but mineral chemistry studies will be needed to confirm this baro-thermometric result.

Trace Elements

Trace element plots have been found to be very useful

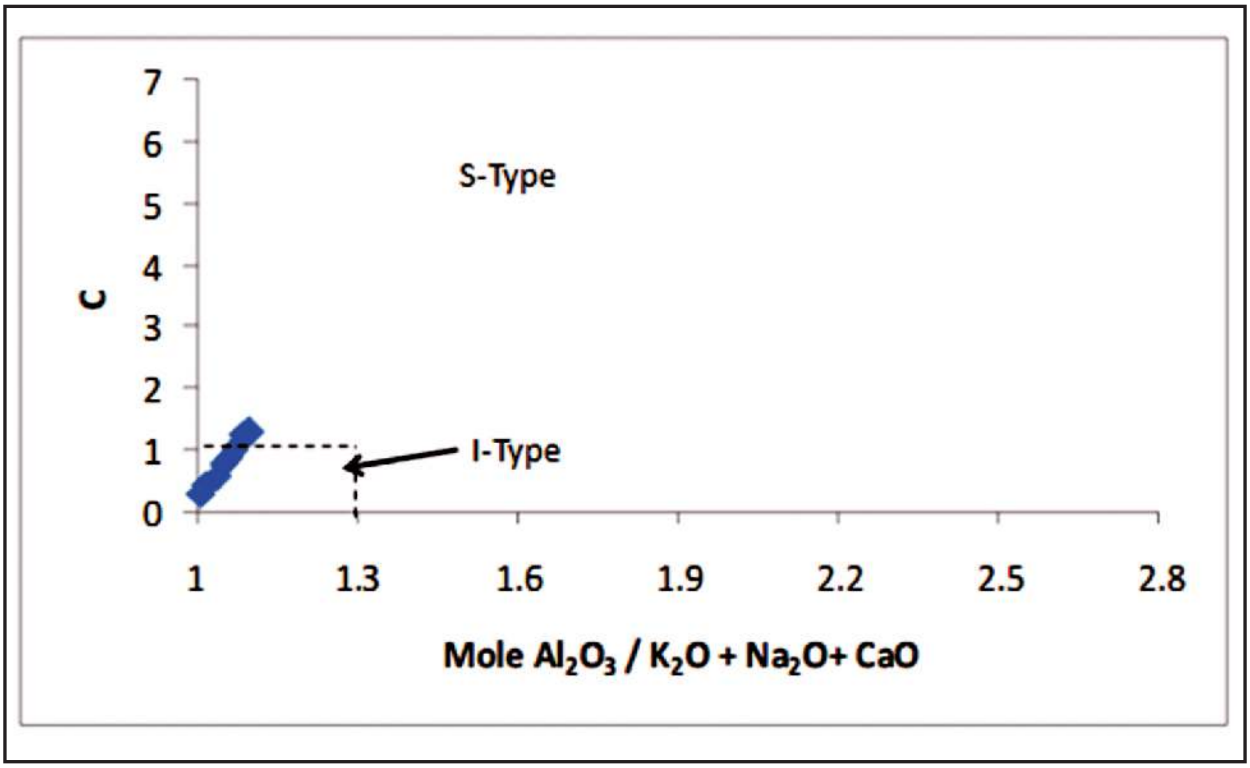

Fig. 10: Normative Corundum versus mol. $Al_2O_3/(Na_2O+K_2O+CaO)$ for classification of I Type and S-type igneous rocks (Method based on Waldo and Rickard, 1990).

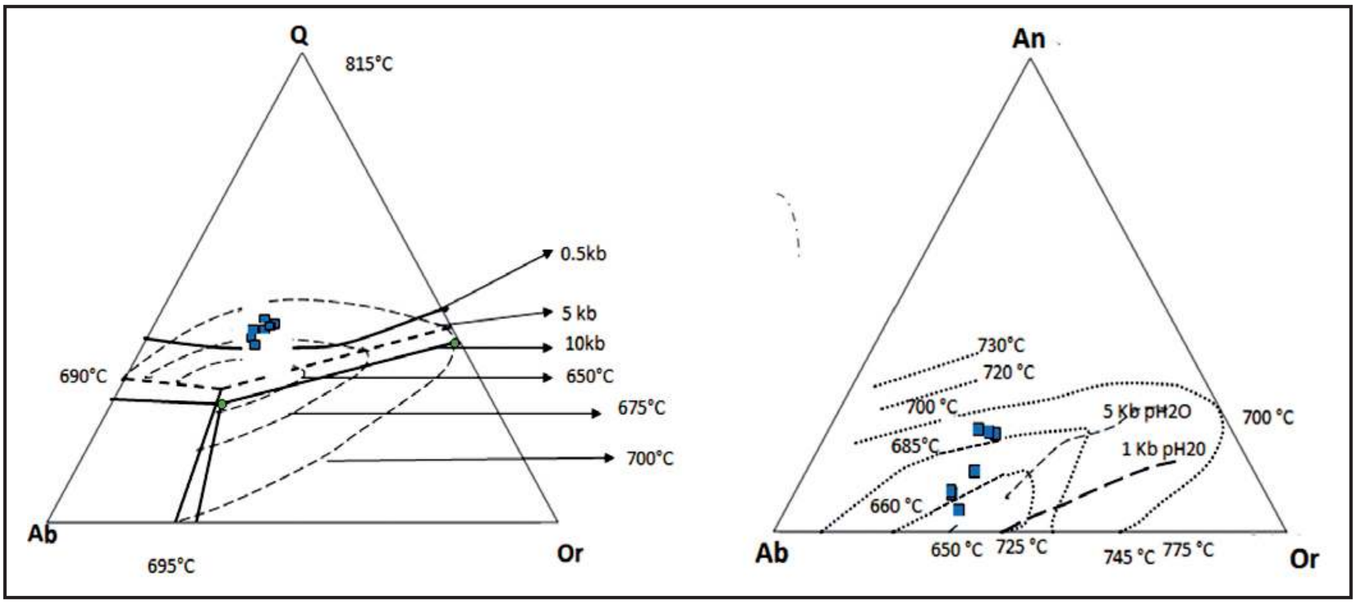

Fig. 11: Normative An-Ab-Or diagram and normative An-Ab-Or diagram with projection of cotectic lines at 1kb and 5kb after James and Hamilton (1969) and Winkler *et al.* (1973).

for delineating geological processes and infer the genesis of rock types. Ba varies between 143-588ppm, with an average of 417ppm which is below the mean crustal value of 435ppm; Rb ranged 74-295ppm, with an average of 150ppm which is above the mean crustal value of 90ppm (Taylor, 1965) while average Sr values are 93ppm (table 2).

Mean values of Ni, Cr, Co are 13ppm, 32ppm and 9ppm respectively (table 2) and this further reflects the felsic character of the gneiss. Average Rb concentration in the gneisses is due to the high concentration of k-feldspars in which Rb can substitute for K in minerals, average Sr and Ba are low and this could be due to low substitution of Ba and Sr for K in k-feldspar and Ca in plagioclase respectively; low concentration of Sr indicates low concentration of minerals such as plagioclase, pyroxenes and hornblende in which Sr can replace Ca in their structure.

Trace elemental plots of Ni vs V (Rollison, 1993) and Sc vs V (Rollison, 1993) (Figure 12) revealed geochemical variations in the studied gneisses is based on plagioclase fractionation.

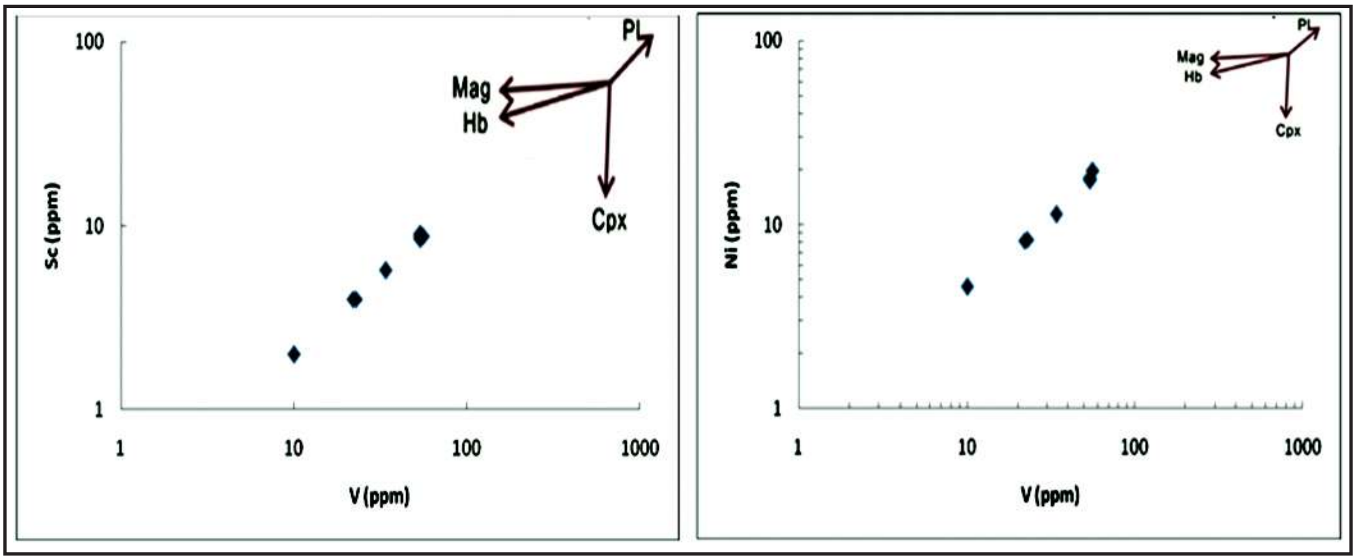

Fig. 12: Sc versus V diagram and : Ni versus V diagram, showing crystal fractionation trends of primary mineral of clinopyroxene (Cpx), hornblende (Hb), plagioclase (Pl), and magnetite (Mag), with partition coefficients from Rollison, (1993).

Geological studies have reported that the effects of alteration and metamorphism on granitoid orthogneisses are minimal on HFSEs, REEs (except Ce and Eu) as well as some transition metals (such as Cr, Ni, Co, V and Sc) (Polat et al., 2002; Polat and Hofmann, 2003; Guo et al., 2015a). These elements are therefore considered immobile in comparison with Large Ion Lithophilie elements (LILEs) which include K, Na, Pb, Th, Rb and Ba which are mobile and highly susceptible to secondary geological processes such as metasomatism. Using the criteria proposed by Polat and Hofmann (2003) and the absence of distinct Ce anomalies (0.76-0.9) in the studied gneisses indicate that the primary chemical signature of these rocks has not been significantly erased during late alteration and metamorphism (Figure 13; Polat et al., 2002; Polat and Hofmann, 2003).

The concentrations of Y, Th and U are 7.6-30.1ppm (average, 19.96ppm), 3.8 -28.3ppm (19.30ppm) and 3.4- 9.9ppm (5.18ppm), respectively while Th/U ratio ranges from 0.62 -5.94ppm (4.31ppm). Low concentration of Y may be due to low abundance of hornblende in the gneisses while low Th values possibly resulted from minimal crustal contamination. The average Th/U ratio of 4.31 is within the typical range of values for granitic rocks which is 3 to 5 (Rogers and Adams, 1969b). Low grade regional metamorphism of the gneiss and the high Th/U ratio suggests most of the uranium is not stably bound. All samples are high in K relative to Th, and most are high in Th relative to U. The Low U and high Th/U suggest the granite gneisses have lost appreciable amount of labile uranium during metamorphism responsible for the decrease in whole rock uranium content post emplacement of the protolith (Dostal and Capedri, 1978, Knudsen *et al*., 1997*b*).

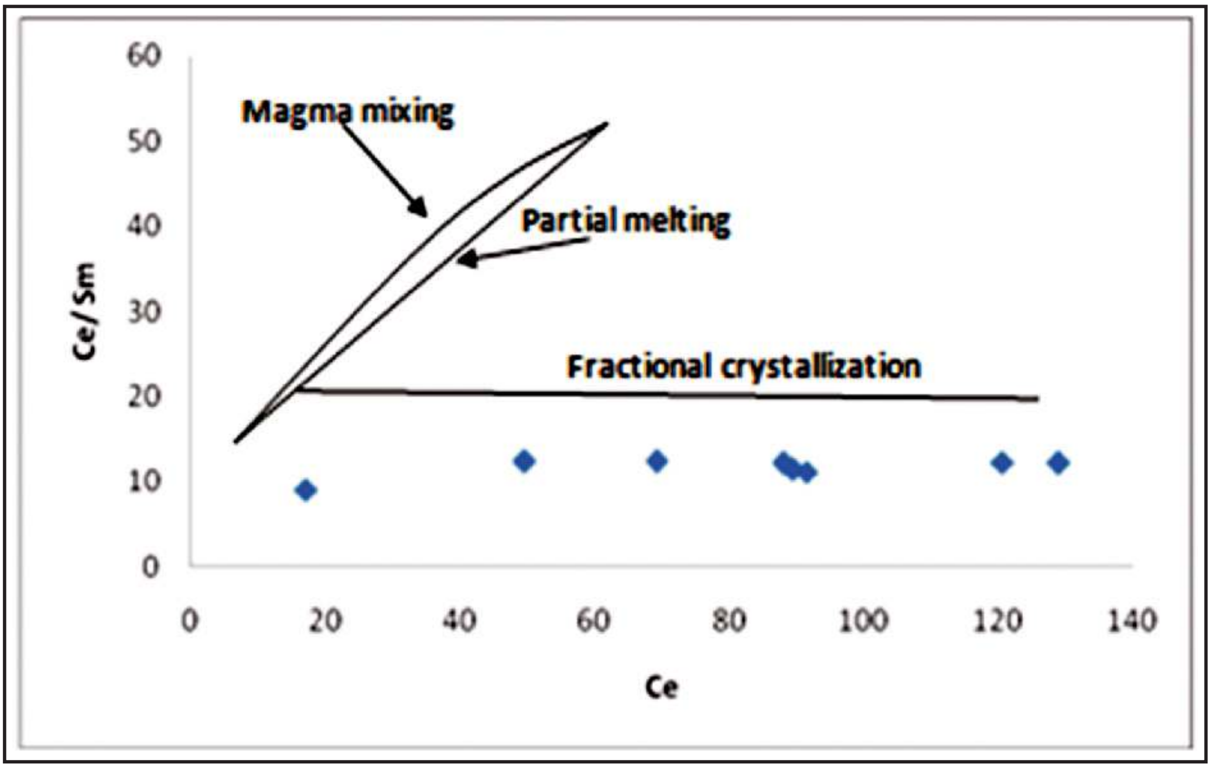

Fig. 13: Ce/Sm versus Ce (ppm) diagram, showing the geochemical variations of the samples which are dominantly controlled by the fractional crystallization processes (modified after Schiano et al., 2010).

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La/Lu ratios varies from 65-156, La/Yb from 11.06-29.25, Nd/Sm from 4.53-5.32, $(La/Sm)_N$ from 3.03-3.73 while Eu/Eu* ranges from 0.29-0.47. The rocks also displayed HREE range of 6-26ppm, LREE range of 41-273ppm, $\sum$ REE ranging from 47-297ppm and a flat HREE pattern (Tale 3, Figure15). The ratios indicate a negative europium anomaly while low $\sum$REE indicates lower abundance of minerals such as monazite, apatite and sphene which concentrates these elements.

The gneisses display nearly consistent moderate fractionation pattern which is characterized by a strong

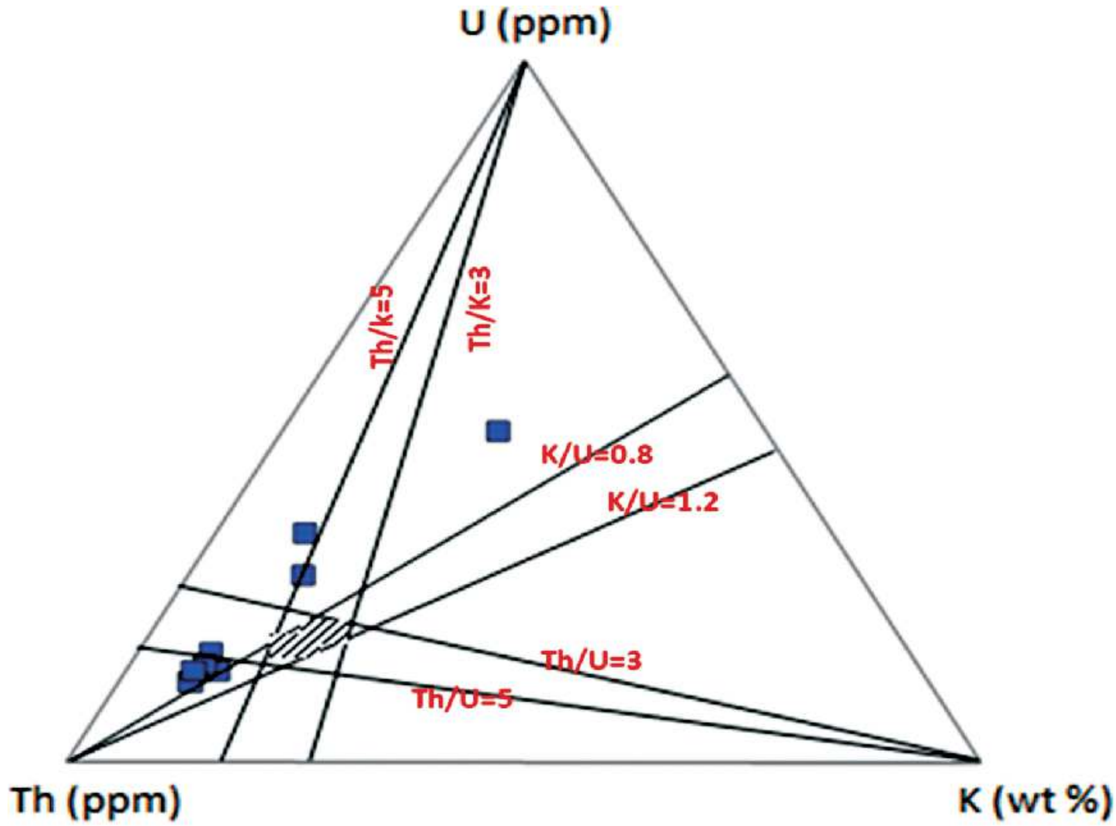

Fig. 14: Ternary diagram showing the relative abundances of U, Th, and K for gneisses. The shaded portion represents the greatest frequency of granites on a world-wide basis (Rogers and Adams, 1969a, b)

negative Eu anomaly and an enrichment of LREEs relative to HREEs It was inferred from the Ce/Sm vs Ce plot (Schiano et al., 2010) that fractional crystallization is the dominant geochemical process in the granite gneissess with no input from magma mixing and partial melting (Figure 13) Normalisation of gneisses to continental crust and incompatible elemental plots using values of Sun and McDonough, (1989) and Taylor and McClennan, (1985) respectively reveal enrichment of Cs and Ta while Ba, Sr and Ti were depleted in all samples (figure 15). Results also revealed depletion in transition elements such as Co, V, Ni as well as depletion of high field strength elements (HFSE) such as Hf, Th, U, Ta, Nb and Zr; and this accounts for the lower proportion of apatite, zircon and sphene in the gneisses.

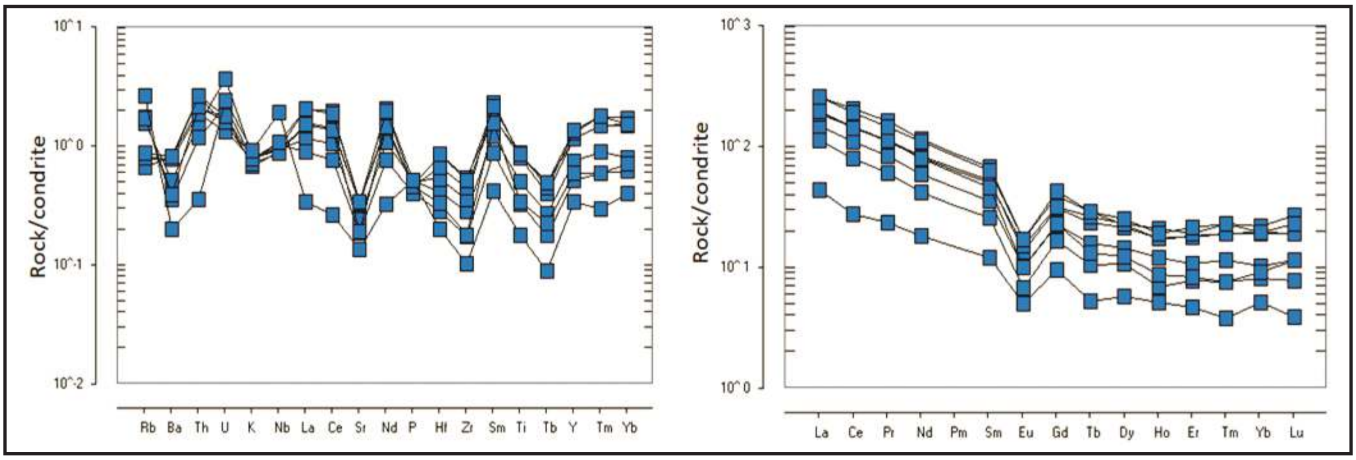

Fig. 15: Incompatible elements plot for granite gneisses values after Talyor and McCleann, (1989) and chondrite normalised plot for granite gneisses chondrite values after Sun and McDonough, (1985).

Conclusion

Field and geochemical investigation has revealed an igneous origin for the granite gneisses of Igangan- Tapa - Inamere area. The gneisses are of granitic origin, they have calc-alkaline affinity and they metamorphosed at temperatures of 650 to 700°C based on CIPW plot of Ab-An-Or. The rocks retain most of the features of their igneous protolith with the LILE, HFSE; REE concentration and patterns observed to be effects of primary crystallization and not remobilization of elements during metamorphism/metasomatism.

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Pictorial view of the new NMGS House under construction at Abuja.