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PRELIMINARY PETROGENETIC STUDY OF SOME ROCKS FROM GWOZA AREA, NE NIGERIA

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ABSTRACT

Gwoza area (NE, Nigeria) is the least known of all the basement complex areas in Nigeria. This paper attempts to present a geological map and some major, and trace element compositions of some of the rocks with the aim of motivating more detailed and collaborative work in the area. Granitic rocks (Pulka granites) most probably of Pan-African age, intrusive into low-lying older metasediments, dominantly underlie the area. The older metasediments are generally migmatitic gneisses of amphibolite facies and are commonly banded, striking N-S with near vertical dips. The rocks are commonly faulted and crosscut by quartzo-feldspathic veins and except for the granites, are folded. The gneisses and granites around Limankara area are strongly tectonized-giving rise to mylonitic rocks in which rhyolites were later emplaced along the fault planes probably during Tertiary.

The occurrence of partially digested schistose xenoliths and compositional zoning in some feldspar phenocrysts are suggestive of magmatic origin for the granites. Furthermore, the exsolution texture among the feldspars, the graphic intergrowths between feldspars and quartz and the host o accessory minerals of apatite, zircon, sphene and opaque minerals are typical of magmatic granites. Major elements and normative compositions placed the granites within granites and quartz-monzonite fields. Some chemical characteristics such as the average value of normative corundum and the appearance of diopside considered along with high Na_2O content (>3.20%) are suggestive of I-type granites. Some discrimination diagrams such asAFM and Alk.Ratio Vs SiO_2 show that the granites, like most other Pan-African granites in Nigeria are calc-alkaline while differentiation indices generally greater than 80 further support the igneous origin of these granites.

KEYWORDS: Calc-alkaline, Granite, Gwoza, Magmatic,Petrogenetic.

INTRODUCTION

The study area (Gwoza) is located in the northeastern part of Nigeria situated within latitudes 10^0 57^1N and 11^0 15^1N and longitudes 13^0 33^1E and 13^050^1E. It is part of the N-S trending Mandara Hills forming the NE portion of the Nigerian Basement complex within the Pan-African mobile belt.

The area is bordered in the north by the Cretaceous Chad Basin sediments and to the west by the Tertiary-Quaternary Biu-basalts. To the east, the hills extend into the Cameroon while it is separated from the SE basement rocks of Obudu Massif by the right arm of the Cretaceous Benue trough (Fig.1).

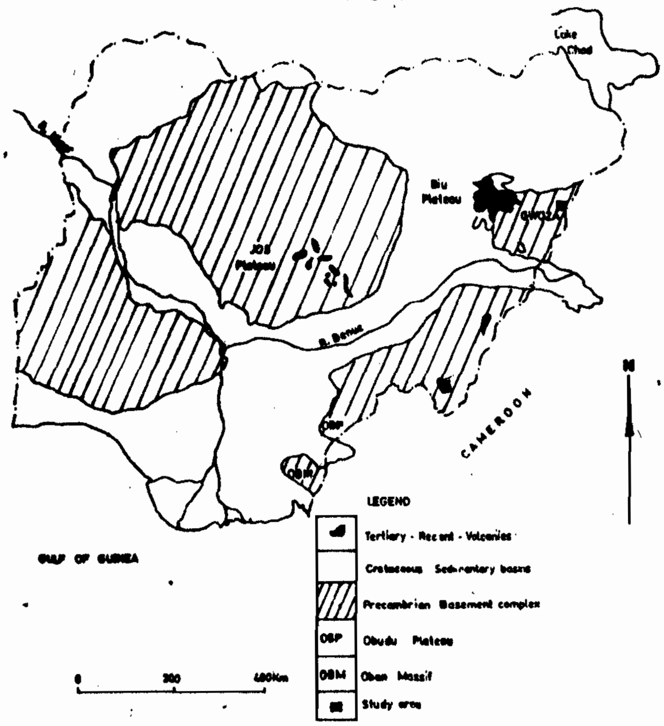

Fig 1: Simplified geological map of Nigeria showing the study area in relation to SE Nigeria and the Cameroon.

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Geologically, the area is underlain by a series of metamorphic and igneous rocks believed to be of Pre-Cambrian age (Basement Complex). Most published works have shown this area as being underlain by undifferentiated basement complex rocks. However, Islam et. al (1988), Islam and Baba (1992) and Baba et. al (1991) have tried to differentiate the rock units broadly. They have shown the area as been underlain by Older Granites (in broad sense) enveloped in a magmatite-gneisses-quartzite complex considered as country rocks. The country rocks outcrop along the margins of, and as xenoliths within the granite bodies.

In this work, while all the rock types are discussed in terms of field occurrences, only the granite members are chemically analysed and the data discussed. Since the study area is considered as the northern extension of the Obudu-Oban basement rocks in the southeast, separated only by the Benue trough, it is hoped that this preliminary work will motivate collaborative research on the two areas for better understanding of the geological setting and evolution of the Nigerian Basement Complex.

GEOLOGICAL SETTING AND PETROGRAPHY

The study area is composed of low-lying gneisses, quartzites, minor amphibolites and granites (fig.2).
The migmatitic gneisses outcrop more often at the margins of the hilly granites where sharp contact relationship is more common than gradational. They also appear as xenoliths

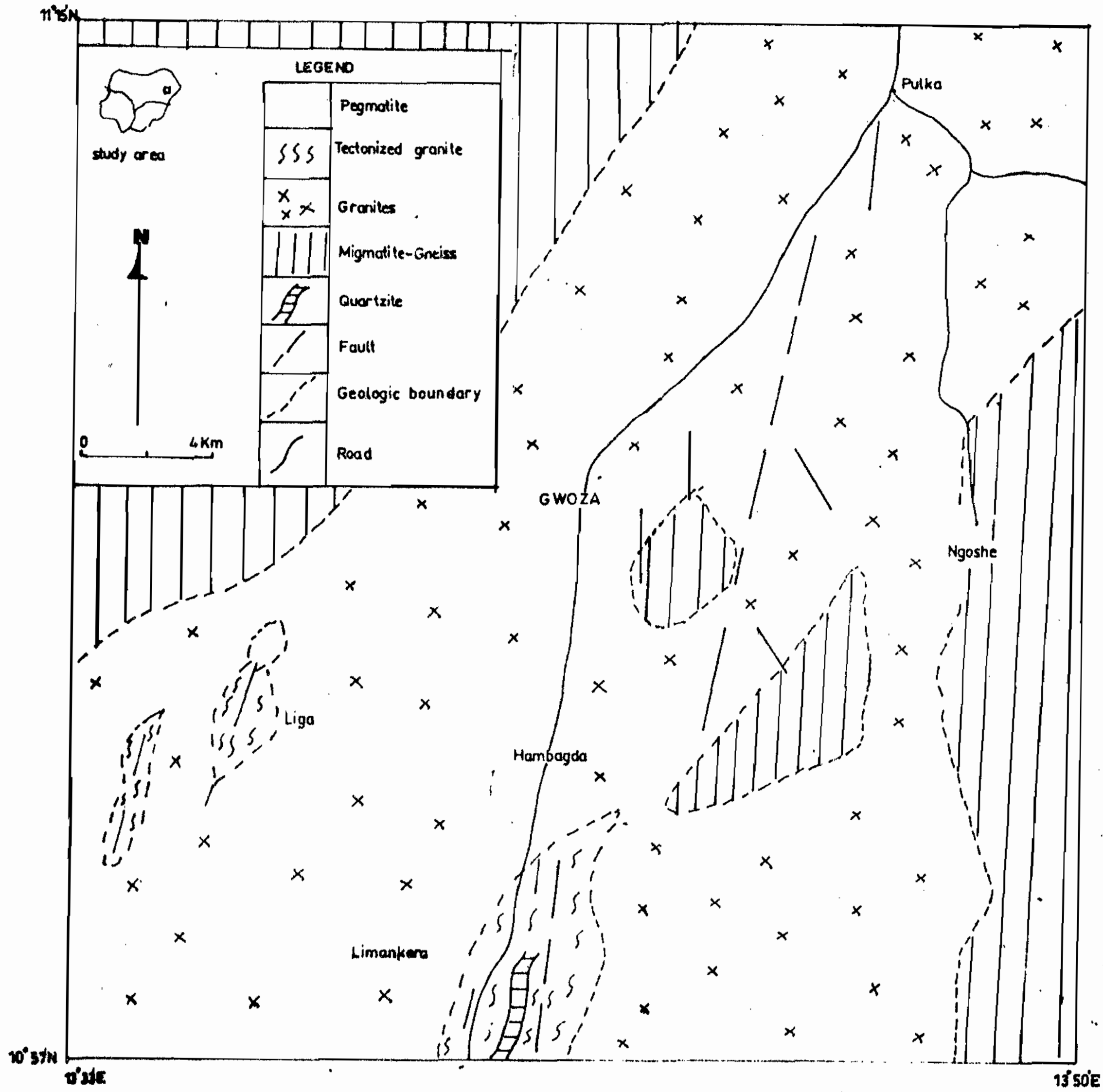

Fig. 2: Geological Map of Gwoza area (Modified after Baba et al,1991)

within the granites. In Hambagda quarry, south of Gwoza, the gneisses are well exposed and it is apparent that the gneisses were migmatized by the intruding acid magma resulting into distinct felsic and mafic bands of few millimetres to tens of centimetres (Plate.1).

Although it is generally difficult to prove the origin of the leucosome and the melanosome materials in migmatites, the cross cutting relationship of the acid materials and the host mafic material makes it possible to suggest that the acid materials were injected in fluid form. This feature of crosscutting quartzo -feldsparthic veins is very similar to those discussed from the gneisses in SE Nigeria (Ekwueme 2003).

Furthermore, the migmatitic gneisses contain xenoliths of the unmigmatised older metasediments of amphibole schist, which may imply that metamorphism had reached almost the highest grade of amphibolite facie at the time of Pan-African magmatism. Ekwueme (2003) reported the occurrence of amphibolites as lenses and pockets within the gneisses of Oban Massifs. Such xenoliths are also reported in western Hoggar, Algeria by Kaissa et.al (2003).

Plate 2: A dolerite dyke displaced by a fault

Plate 1: Banded gneiss cross-cut by quartzo – feldspathic veins

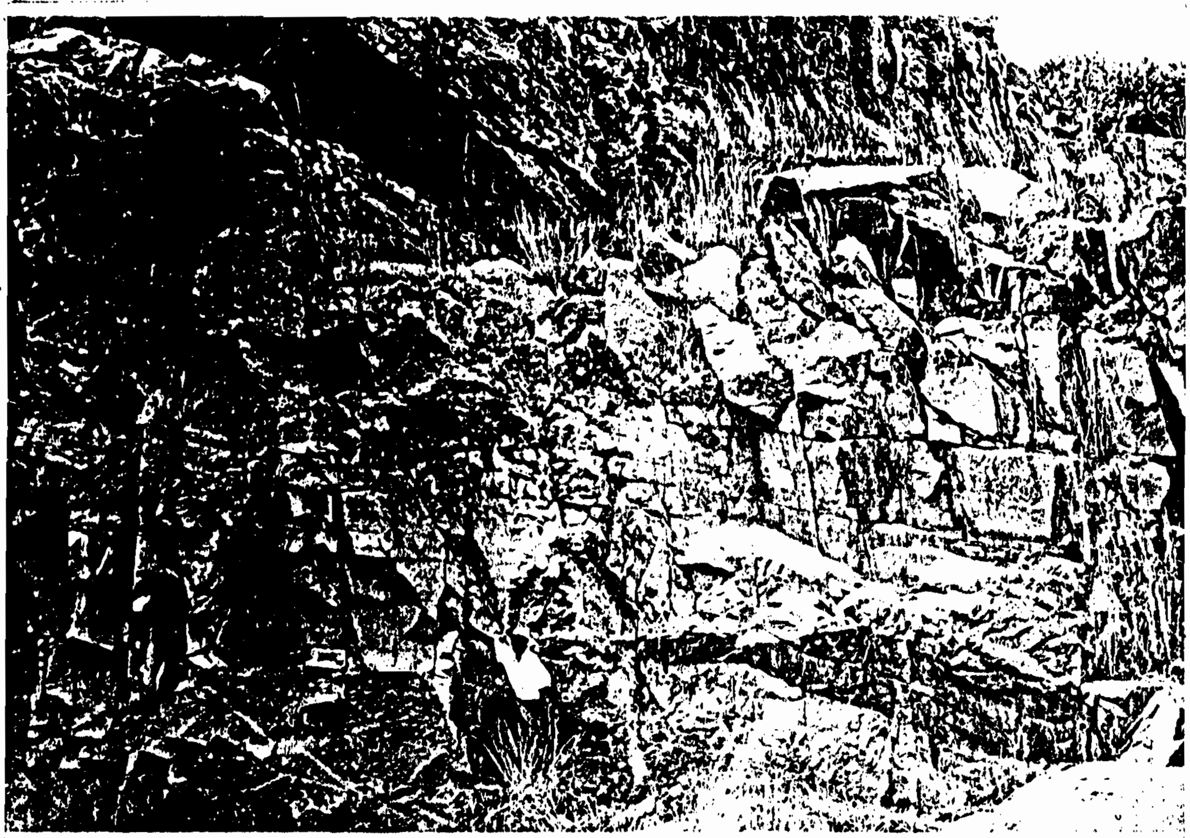

Plate. 2: A granite section showing dolerite dyke displaced by a fault

Quartz aporphyses are common within the migmatitic gneisses thus confirming high-grade metamorphic conditions. Banding in the gneisses trends approximately N-S ranging from NOO^0-$NO8^0$ while dips are near vertical in all cases ranging from 87^0-90^0.

The granites are the dominant outcrops practically forming the main Mandara Hills. They vary in texture from fine-medium-and coarse grained to coarse porphyritic variants with gradations between them. Pegmatites and aplites are also common. Mineralogically, however, they are very similar with quartz, orthoclase, microcline, plagioclase (oligoclase-andesine) and biotite as essential minerals. Apatite, zircon, sphene and opaques are the common accessory minerals.

The proportions of these minerals may vary slightly with the coarser variants of the granites apparently containing more biotite. It is important to note that no two –mica granite has been observed in the area, though some pegmatitic veins may contain both biotite and muscovite flakes in the coarse porphyritic granites. Some of the feldspar phenocrysts exhibit compositional zoning which petrographically implies possible magmatic origin. Furthermore, these granites commonly contained partly digested schistose xenoliths, which are undoubted evidence for igneous origin as reported in Onyeagocha (1986) on some Older Granites from northern Nigeria. Dolerite dykes cross-cut most granite variants and were seen to have been displaced in places by later faulting (Plate 2) and such phenomena have been reported in Obudu Plateau (Ekwueme, 2003).

Major faulting in the area generally trends N-S and NNE-SSW with minor and perhaps younger NW-SE and E-W faults. The faulting appears to be post- granite emplacement and affected all rock units. In the southern part of the study area (Limankara and Liga), both the granites and the gneisses are tectonized resulting in the formation of cataclasites. Magnetic anomaly and satellite imagery interpretations carried out by Bassey (2006) indicated NE-SW, N-S, E-W and NW-SE trending structures in Limankara area which extend for over 20km southward. Abdelsalam et.al (2002) recognised two structural trends in the Saharan metacraton; an early ENE-WSW trend and a younger N-S trend which was also reported in Toteu (1990) to have extended into the Cameroon and eastern Nigeria. In the northern tip of the study area (Pulka), fault breccia and silicified rocks characterize the fault zone.

GEOCHEMISTRY

Because of the preliminary nature of this work only samples of the granites believed to be Pan-African (Older Granites) were analysed for major and trace element compositions.

Fe_2O_3, MgO, MnO,N_2 O and TiO_2 as well as Ba, Rb, Sr Zn, Co,Cr and Ni were determined using Perkins-Elmer(3058 model) Atomic Absorption Spectrometer at Obafemi Awolowo University, Ile-Ife. One gram each of pulverised, homogenised and quartered sample was digested with hydrofluoric and hydrochloric acids (7:1 ratio) and perchloric acid was later used to clear the solutions. The solutions were then made up two 250ml and 100ml for major and trace elements determinations respectively.

SiO_2, K_2O and CaO were determined using XRF (Minimate 4015) Spectrometer with Minimal software at the University of Maiduguri. Pressed powdered samples were used and the procedure includes creating an application, calibrating the application, validating the calibration and sample measurement. Pures as supplied by the manufacturers and prepared standards were run to check the accuracy of the results.

Major element geochemistry

The major element compositions are presented in table 1. Silica (SiO_2) content of Pulka granites ranges from 68.82% in the medium-coarse grained granite to 73.81% in the fine-medium grained granite with an average of 71.88%. The K_2O values range from 5.08% in the fine-medium grained granite to 5.88% in the fine grained granite to 6.55% in the aplite while the Na_2O content ranges from 2.76% in the coarse porphyritic granite to 4.05% in the fine to medium grained granite. The CaO content on the other hand is least in the fine-medium grained granite (0.08%) and highest in the coarse porphyritic granite (2.53%).

1-5 medium-coarse grained granite, 6 – 10 fine-medium grained granite; 11 coarse porphyritic granite; 12 – 15 fine-grained/aplitic granite; 16 – 17 cataclastic granite; 18 dolerite

When the average values of these oxides are compared with similar rock types from other places (Table 2), it can be observed that the Pulka granites are very similar to Igbeti granites in SW Nigeria (Rahaman et.al, 1983). They are

Table 1: **Major elements and Normative Mineral Compositions of Some Rocks from Gwoza Area, NE Nigeria**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	70.60	69.18	68.82	72.89	72.00	73.32	72.29	73.81	73.38	73.26	70.51	69.77	74.40	76.40	73.90	69.43	69.04	59.96
TiO_2	0.30	0.25	0.31	0.29	1.00	0.21	0.11	0.07	0.28	0.40	01.70	0.80	0.20	0.10	0.47	0.37	0.38	1.57
Al_2O_3	13.91	16.31	16.86	14.20	14.63	13.81	14.66	13.55	13.62	13.83	14.96	15.12	13.50	13.10	14.54	15.62	15.05	21.10
Fe_2O_3	2.30	2.04	2.19	1.99	1.72	1.73	1.53	2.00	1.74	1.80	1.43	1.22	1.40	1.90	0.73	2.94	2.85	4.86
MnO	0.05	0.02	0.03	0.03	0.01	0.02	0.01	0.01	0.04	0.04	0.06	0.01	0.01	0.01	bd	0.04	0.04	0.03
MgO	1.03	0.88	0.52	0.54	0.25	0.55	0.54	0.47	0.44	0.44	0.19	0.21	0.04	0.04	0.06	0.74	0.67	1.86
CaO	2.09	1.28	1.16	1.06	2.52	0.97	1.48	1.68	1.08	0.08	2.53	2.52	0.58	0.10	1.43	1.86	2.68	5.19
Na_2O	3.44	3.66	3.36	3.39	3.22	3.26	3.66	3.17	3.55	4.05	2.76	3.49	2.81	3.30	3.14	3.02	3.80	3.69
K_2O	5.80	5.43	5.23	5.20	5.18	5.46	5.88	5.8	5.59	5.86	5.58	5.23	5.55	5.53	6.90	5.37	5.09	2.79
P_2O_5	0.08	0.50	0.09	0.10	0.06	0.01	0.01	0.03	0.12	0.22	0.05	0.04	0.02	0.02	0.04	0.02	0.08	0.06
L.O.I.	0.04	0.45	0.41	0.28	-	0.66	0.50	0.35	0.20	0.23	-	-	0.48	0.50	-	0.59	0.40	-
Total	99.04	100.00	98.98	99.97	98.07	100.10	100.67	100.22	100.04	100.21	99.07	98.41	99.99	101.00	100.21	100.20	100.08	100.11
Q	21.70	24.28	25.54	2.90	22.20	29.26	23.86	31.39	27.52	24.46	39.10	23.98	30.89	34.00	29.33	24.16	19.86	8.11
Or	34.52	32.29	31.18	30.62	30.62	32.29	34.50	28.49	32.85	34.52	26.72	31.16	38.97	32.85	35.10	31.72	30.06	16.70
Ab	29.38	30.93	28.31	28.83	27.26	27.79	31.10	26.83	29.88	34.04	23.60	29.36	23.59	27.79	28.74	25.69	32.59	31.46
An	6.40	5.29	5.31	5.29	12.24	4.73	6.40	8.14	5.01	2.50	12.24	10.02	2.50	0.56	7.23	9.18	9.18	25.88
Di	3.22	-	-	-	-	-	0.70	-	-	0.70	-	1.86	-	-	-	-	3.0	-
Hy	5.81	5.24	5.10	5.08	1.79	3.92	-	-	3.75	0.95	1.20	0.23	0.10	0.10	0.61	4.35	4.42	10.03
C	0.94	2.45	3.57	1.12	2.24	0.82	3.34	0.14	0.20	1.55	1.02	-	0.82	1.53	0.31	0.42	-	1.53
Il	0.61	0.46	0.61	0.93	1.97	0.46	0.15	0.46	0.40	0.76	1.37	0.91	0.38	0.15	0.91	0.76	0.61	3.03
Ap	0.33	1.09	0.19	0.22	0.13	-	0.09	0.06	0.31	0.06	0.13	0.10	0.04	0.04	0.12	0.03	0.07	-

also similar to the anatectic granites from northern Cameroon (Totue, 1990) which is on the eastern side of the study area, except for the slightly higher silica content of the latter. They generally compare well with most of the Pan-African granitoids in Nigeria though some are slightly more potassic (e.g. Ilesha granites).

Table 2: **Average major and some trace element compositions of granitic rocks and various other Older Granites from the Pan-African Terrain**

	1	2	3	4	5	6
SiO_2	74.68	75.57	73.60	73.60	69.67	71.88
TiO_2	0.23	0.06	0.01	0.08	.29	0.37
Al_2O_2	12.64	14.16	16.17	13.92	15.17	14.55
Fe_2O_3	0.23	0.56	0.17	0.17	1.34	1.85
FeO	-	-	0.13	0.52	-	-
MnO	0.05	0.02	0.01	0.01	0.05	0.03
MgO	0.39	tr	0.17	0.12	0.38	0.45
CaO	0.93	1.40	0.52	1.24	1.71	1.52
Na_2O	5.05	2.62	2.79	3.62	2.56	3.35
K_2O	4.47	4.18	6.85	5.12	5.28	5.47
P_2O_5	0.06	tr	0.06	0.03	0.31	0.09
Total	98.72	98.57	100.48	98.43	96.76	99.56
Ba	586	851	990	950	836	620
Co	<10	<10	-	-	-	-
Cr	<10	<10	-	-	-	<10
Sn	<10	<10	25	<5	-	11
Rb	103	82	255	180	204	305
Sr	190	32	21	400	210	67
Zn	-	-	12	-	-	66

1. Foliated granites from Northern Cameroon (Toteu et al, 1987)
2. Anatectic granites from Northern Cameroon (Toteu, 1990)
3. Granitic rocks from Ilesha area, SW Nigeria (Elueze, 1987)
4. Fine-grained granite from Northern Nigeria (Olarewaju and Rahaman, 1982)
5. Igbeti porphyritic biotite granite SW Nigeria (Rahaman et al, 1983)
6. Pulka granite NE Nigeria (This work)

Normative quartz ranges from 21.20% in medium-coarse grained granite to 39.10% in the coarse porphyritic granite while orthoclase is from 26.72% in coarse porphyritic granite and 38.97% in aplite. Conversely, the normative albite is least in aplite (23.60%) rising to 30.93% in medium-coarse grained granite and up to 32.51% in cataclastic granite. Normative anorthite on the other hand is least in aplite (0.56%) and highest in coarse porphyritic granite agreeing with the high CaO content in the later.

AFM plots of the Pulka granites (Fig. 3) show that the rocks are typically calc-alkaline. The alkaline nature is demonstrated by their clustering near the A apex. This nature is further

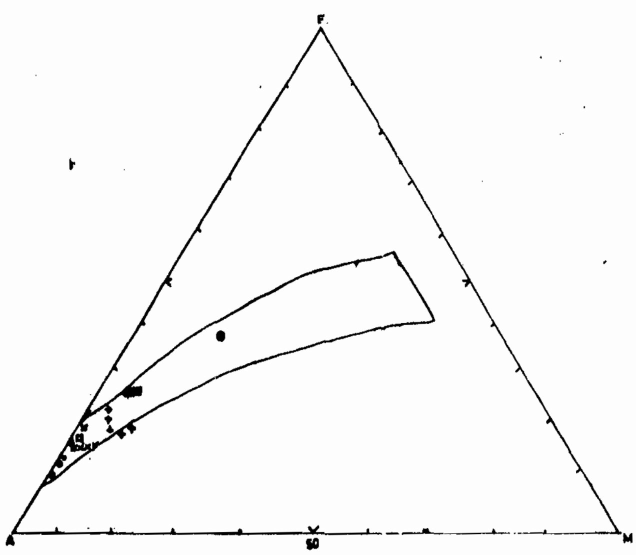

Fig.3: AFM diagram for Gwoza rocks

Key:
o....... aplites
• .... fine grained granites
x....... fine-medium grained granites
+....... medium-coarse grained granites
□....... coarse porphyritic granites
■....... cataclastic granites
●....... dolerite

confirmed in the SiO2 Vs alkalinity ratio (AR) variation diagram (Fig. 4) where the samples plot more within calc-alkaline field with a few falling in the alkaline region.

In the KCN variation diagram (Fig.5) all the samples plot within the granitic field indicating some oegree of fractional crystallization. A similar trend is further observed in the An-Ab-Or variation diagram (Fig. 6)

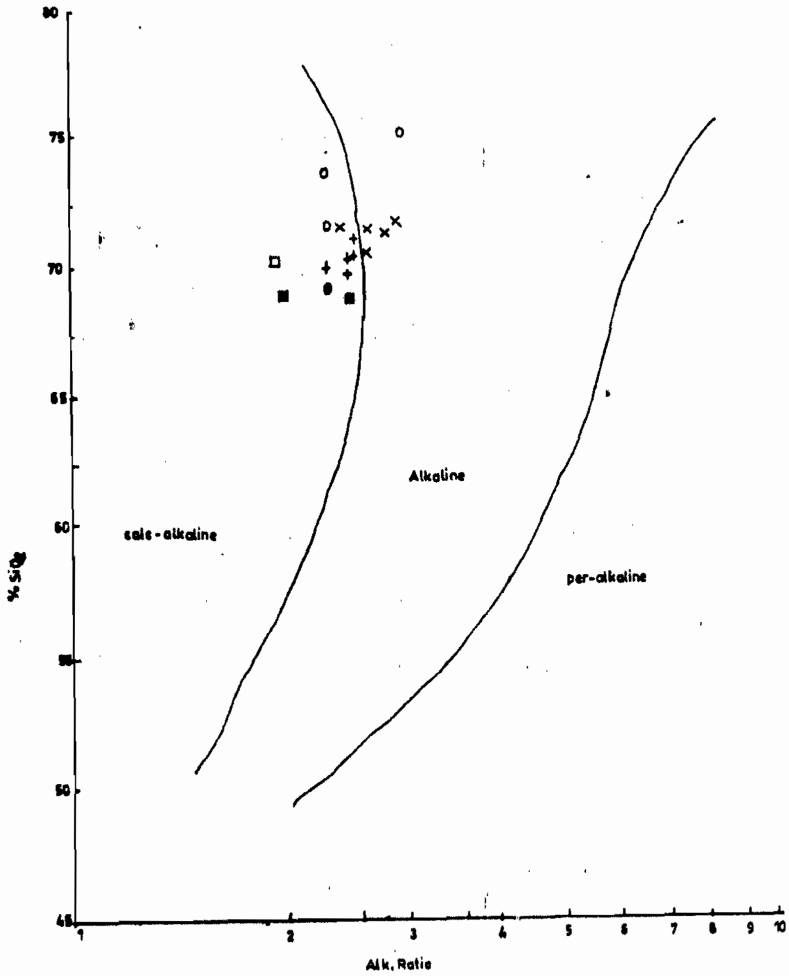

Fig. 4 Alkalinity ratio Vs SiO_2 values for Gwoza rocks (Key as in Fig. 3).

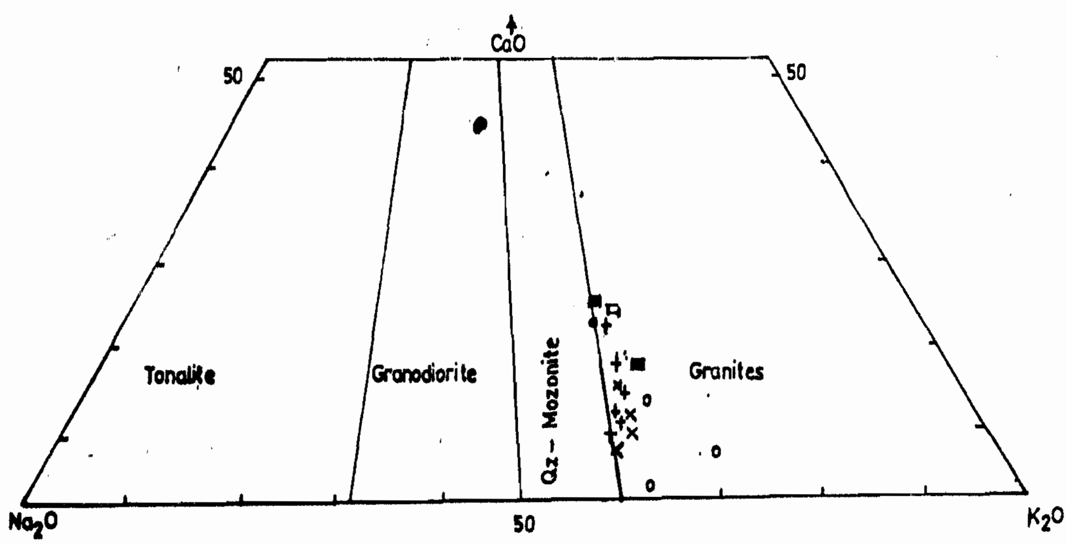

Fig 5: CaO-Na_2O-K_2O diagram showing the position of Gwoza rocks (after condie and Hunter, 1976) Key as in Fig 3.

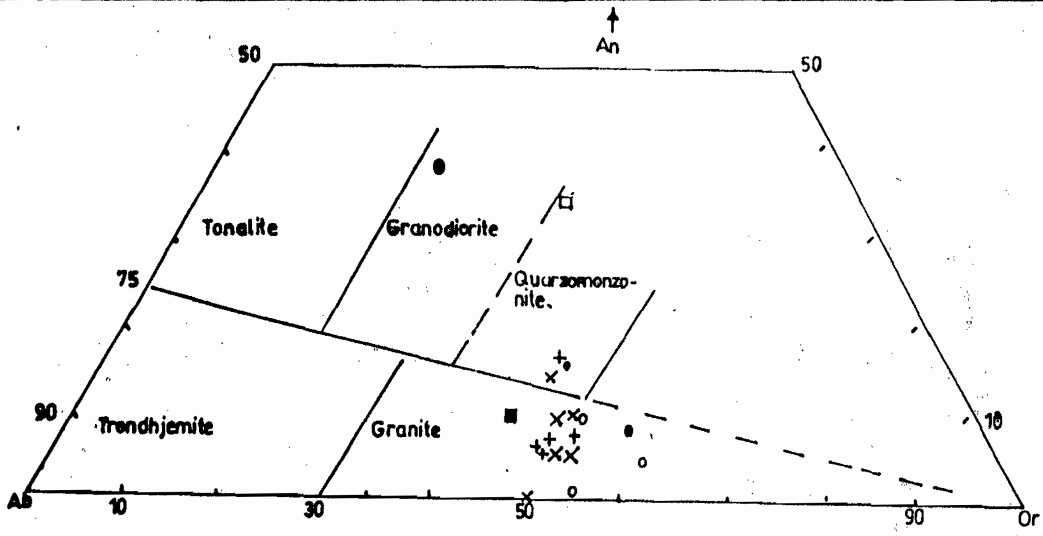

Fig.6: An-Ab-Or diagram (o'connor, 1965) showing plots of Gwoza rocks. Symbols as in Fig.3.

Trace element geochemistry:

Trace element contents and elemental ratios of the Pulka granites are presented in Table 3. Rubidium and Ba values range from 224ppm to 390ppm and from 438ppm to 780ppm respectively in the granites. The relatively high Ba content observed in the cataclasite is attributed to post-magmatic activity, which produced sericite providing more favourable sites for Ba capture. Strontuim values range from 42ppm to 86ppm in the Pulka granites. These values are considered low when compared with other Older Granites from Nigeria with values more than 100ppm (Baba, 1990).

Table 3: Trace elements abundances (ppm) and some elemental ratios

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Ba	674	558	620	780	-	600	700	490	597	500	-	-	438	450	-	830	816	-
Co	2.0	1.35	1.80	2.05	2	1.75	2	1.05	1.67	1.22	-	-	0.08	0.9	-	2.3	1.7	-
Cr	10	10	13	12	2	7	10	10	10	9	1.5	1.5	8	6	1	19	15	4
Sn	14	14	14	16	-	8	11	15	11	13	3	3	5	6	2	25	18	12
Li	21	20	34	31	-	12	9	9	26	7	-	-	5	3	-	60	61	-
Ni	1.3	0.	1.0	1.4	0.	1.0	1.2	0.3	0.8	0.7	0.2	0.6	0.4	0.4	0.2	1.4	1.6	3
Rb	224	283	289	274	-	369	390	340	355	266	-	-	375	319	-	256	228	-
Sr	58	86	74	67	-	53	72	75	67	48	-	-	60	42	-	79	93	-
Zn	119	81	104	127	45	72	80	54	70	64	20	20	24	38	20	133	117	50
K/Rb	193	170	159	159	-	123	139	175	131	182	-	-	137	144	-	174	192	-
K/Ba	64	84	73	55	-	76	70	86	78	97	-	-	124	102	-	53	52	-
Ba/Rb	3	2	2.1	2.9	-	1.6	2	2	1.7	1.9	-	-	1.1	1.4	-	1.6	1.8	-
Rb/Sr	4.23	3.29	3.82	4.09	-	6.96	4.86	3.20	5.30	5.58	-	-	9.68	1.81	-	3.24	2.18	-
Ba/Sr	12.74	6.49	8.36	11.69	-	11.32	9.72	6.53	8.91	10.42	-	-	10.68	16.67	-	10.58	8.79	-
Ca/Sr	143	174	124	123	-	131	147	180	115	119	-	-	101	27	-	168	190	-
Ni/Cr	0.13	0.08	0.08	0.12	0.03	0.14	0.12	0.03	0.08	0.08	0.13	0.4	0.05	0.01	0.02	0.08	0.09	0.75

Key as in Table 1.

The K/Rb ratios range from 123 in fine-medium grained granite to 193 in medium-coarse grained granite while K/Ba varies from 55 in medium-coarse grained granite to 124 in the aplite. In contrast to K/Ba, Ba/Rb is lowest in aplite (1.4) and highest in the medium-coarse grained granite (3). In addition, the Ba/Sr ratio is lowest in the medium-coarse grained granite (6.49) and highest in the aplite (16.67). Plots of Rb against Sr for these rocks in the crustal thickness grid of Condie and Hunter (1976) suggest that the basement into which these granites were emplaced was more than 30km thick (Fig.7) as explained for Ilesha granitic rocks in Elueze (1987).

DISCUSSION

As earlier stated, Pulka granites are only texturally variable but very similar in mineralogical and consequently chemical compositions. The average SiO2 content of the granites is 71.88%, ranging from 68.82% in medium-coarse grained granite to 76.40% in aplite. These values appear high when compared with the values of 58%-67% for Pan-African calc-alkaline rocks in Nigeria reported in Umeji (1991). However average values of 73.60% were reported for similar rocks in northern Nigeria (Olarewaju and Rahaman, 1982) and 75.54% in northern Cameroon (Totue, 1990).

The AFM variation diagram (Fig. 3) and alkalinity ratio Vs SiO2 variation diagram (Fig. 4) show that Pulka granites are calc-alkaline in nature. This finding appears to disagree with Islam and Baba (1990) who did not consider the fact that the alkali ratio (K_2O:Na_2O) in the studied granites is greater than 1 but less than 2.5. According to Wright (1969) when the alkali ratio is K_2O:Na_2O >1<2.5, then the total alkalis used in the calculation of alkalinity ratio (AR) is modified and replaced with 2(Na_2O). When this modified ratio is used, majority of the samples fall within the calc-alkaline field.

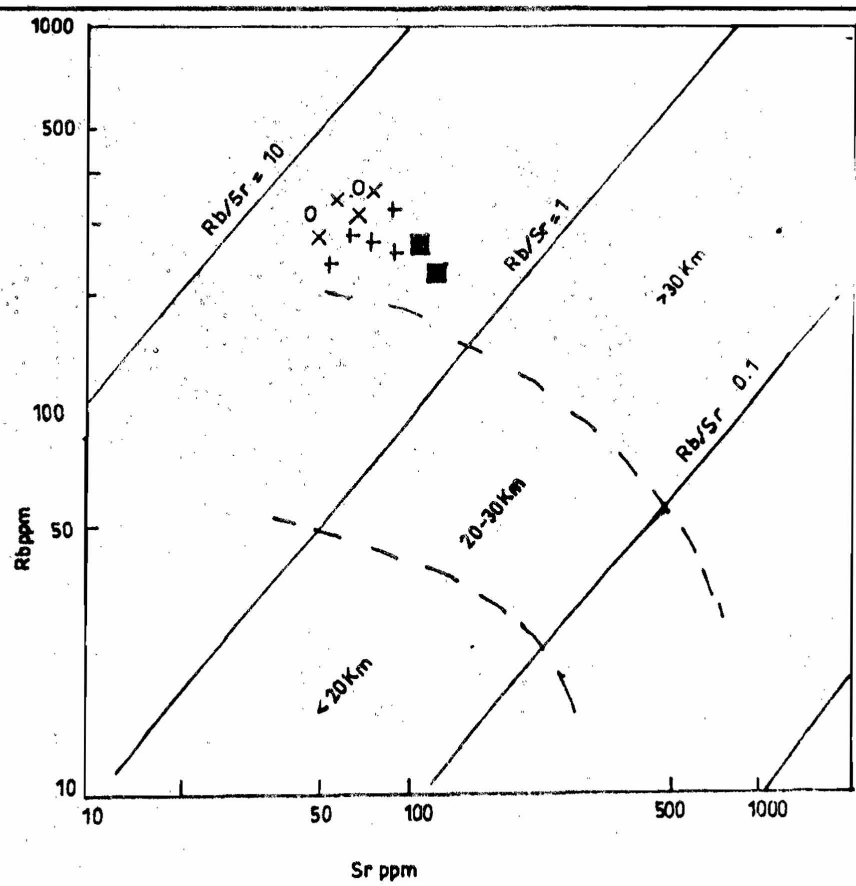

Fig.7: Rb Vs Sr diagram for Gwoza rocks (Symbol as in Fig 3).

These variation diagrams (Figs. 3 & 4) taken together with the CaO-Na_2O-K_2O variation diagram (Fig.5) do not only show that the rocks are calc- alkaline but also give slight linear trend indicating fractional crystallization. This linear trend is further exhibited in the An-Ab-Or variation diagram (Fig. 6) and is suggestive of possible genetic relationship (Ewers and Scott, 1977).

The average normative corundum of Pulka granites is above 1% (c.1.3%) while normative diopside is absent in 13 out of the 19 samples analyzed. This chemical character again does not agree with the I-type granites earlier suggested by Islam and Baba (1992). However, the average Na_2O content of 3.35% and K_2O of 5.47% in the studied granites (Table 3) are suggestive of I-type granites. According to Chappel and White (1974) S-type granites values for Na_2O and K_2O should be less than 3.2% and 5% respectively.

Al_2O_3/ (Na_2O+K_2O+CaO) ratio for S-type granites should be greater than 1.1. The high ratios in the studied granites (1.23-1.73 with an average of 1.51) disqualified the rocks from being S-type. Again, the Na_2O/K_2O and K_2O/CaO ratios of the granites range from 0.71-4.85 and 1.81-5.63 with averages of 2.28 and 4.02 respectively. These ratios according to Turner and Veroohgen (1960) are high and suggestive of magmatic origin for the rocks studied. The values for differentiation index (DI) of the granites under study range from 80.08 to 94.64. Thornton and Tuttle (1960) have experimentally shown that fractional crystallization in magma tends to produce liquids enriched in alkaline-alumina silicates (petrogeny's residua system) whose DI values range from 65-95. The values in the studied granites (80.08-94.64) indicate highly fractionated melts for the rocks.

It has been observed that the Ba content is exceptionally high in the cataclastic granites. This high abundance could be attributed to post-magmatic activity, which produced sericite providing more favourable sites for Ba capture. The K/Rb values for most of the granites have values of over 150, which fall within the crustal range (150-300). Trace elements in Rb-Sr variation diagram (Fig. 7) further show the general fractionation trends earlier observed in the major element variations. Looking at the overall general compositions of these granites taken together with the variation diagrams, there appears to be some degree of fractionation amongst the granites. However, the number of samples analyzed is too few to make categorical statement on that.

CONCLUSIONS

Migmatitic gneisses, schist, quartzite and the Older Granite suite underlie Gwoza area in north-eastern Nigeria. The field relationship between the Older Granite suite and the other rocks is observed to be intrusive and cross-cutting. The Older Granites referred to as "Pulka granites" are similar in mineralogy but can vary greatly in texture, ranging from fine grained/aplitic to coarse grained and even porphyritic with all gradations in between. Occurrence of partly digested schistose xenoliths and the compositional zoning in some feldspar phenocrysts in the granites suggest that they are igneous in nature and magmatic in origin.

Chemical characteristics of these granites, obtained from the major and trace element concentrations and their ratios as well as some variation diagrams suggest that the granites are calc-alkaline in nature, magmatic in evolution and highly fractionated. The granites mainly show I-type characteristics though some S-type features are also exhibited. This underscores the need for more trace element analyses of the rocks particularly the REE and more importantly their isotopic signatures. Since the area is a continuation of the Cameroon basement complex, the work aimed at motivating a collaborative research on the two adjacent areas. The geology of the basement complex rocks of the study area is the least known in Nigeria and there is need to encourage this attempt for an extensive investigation.

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