

## Geochemistry of Precambrian gneisses in the eastern part of the Oban massif, Southeastern Nigeria

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### Abstract

The basement of the eastern Oban massif is composed of a wide range of texturally and mineralogically different types of gneissic rocks. Migmatitic gneisses are characterized by high contents of silica and related trace elements while granite and biotite-hornblende gneisses have relatively lower values of these elements.

Geochemical variation diagrams suggest that the gneisses evolved from a calc-alkaline magma of quartz-diorite to granodiorite composition. This demonstrates that orthogneisses exist in the basement complex of Nigeria.

### Introduction

The Nigerian basement which lies between the Archaean cratons of West and Central Africa has received attention for many years and descriptions and reviews of the geology have been presented by many workers including Oyawoye (1964, 1972), Cooray (1977), Rahaman (1976), Elueze (1982). The Nigerian basement constitutes part of the zone of Pan-African reactivation ( $600 \pm 150$  Ma; Kennedy 1964, Clifford 1970). The reactivation of the basement consisting mainly of gneisses and migmatites was induced mainly by the intrusion of older granites (McCurry 1973). The older granites are the only undisputed products of the Pan-African orogeny in the Nigerian basement (Cahen et al. 1984).

The Oban massif forms part of the southeastern basement complex of Nigeria and is surrounded by Cretaceous and younger sedimentary rocks which constitute the Mamfe embayment in the north,

Abakaliki Anticlinorium and Afikpo syncline in the West and Calabar Flank in the south (Fig. 1). The Oban massif located in the equatorial rainforest has been studied in the west by Rahman et al. (1981), Ekwueme (1985), Ekwueme & Onyeagocha (1986), Ekwueme et al. (1988) and in the east by Raeburn (1927) who studied tinstone in the Calabar district. Gneisses and migmatites in a range of textural and mineralogical varieties constitute the main rock types. They have been shown to lie in the sillimanite zone of the Barrovian type metamorphism (Ekwueme 1990).

The origin of the various gneisses (Rahaman 1976, Oshin 1984) is one of the major petrological problems of the Nigerian basement. Most of the published data point to a derivation of these rocks from sediment (Burke et al. 1976, Rahaman 1976; Ekwueme & Onyeagocha 1986). In this contribution, we present mineralogical and chemical data which suggest that gneisses in the eastern Oban massif are of igneous origin.

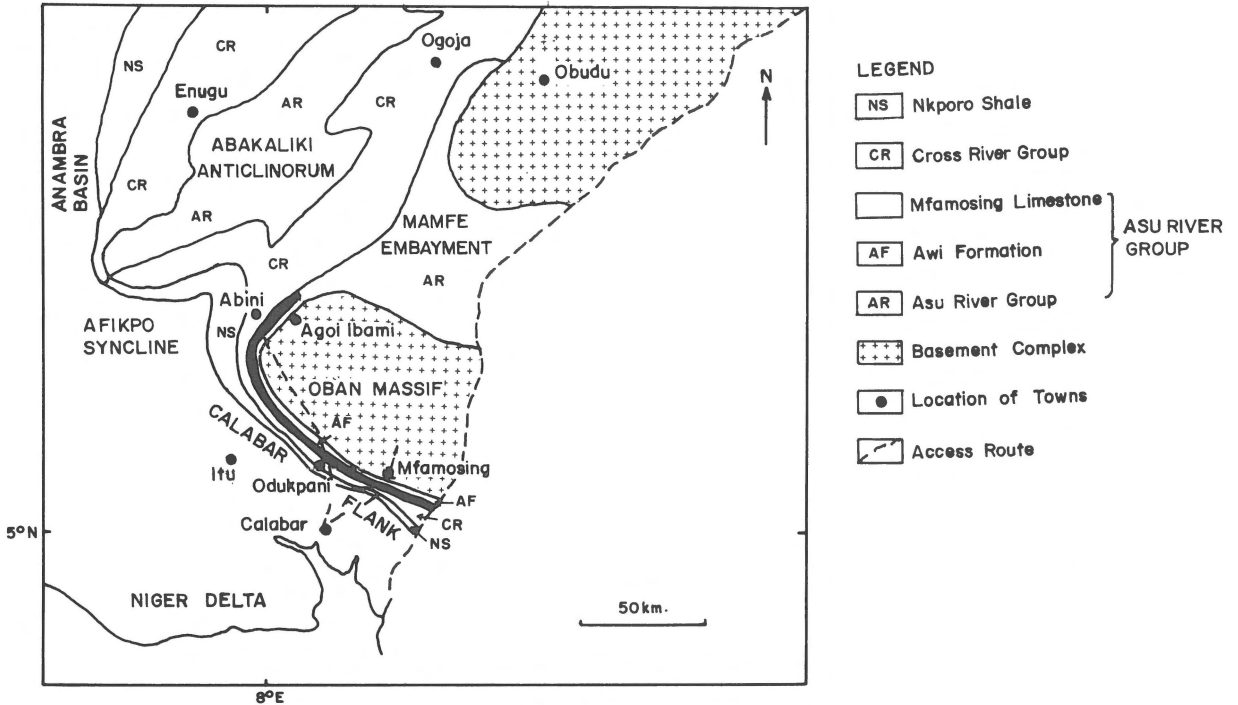


Fig. 1. Geologic sketch map of South Eastern Nigeria.

### Geologic setting

The migmatitic and granite gneisses (abundance in the given order), the most dominant lithologic units of the east Oban massif, are exposed at Oban, Aking, Orem, Ndebiji and Ikpai (Fig. 2). The migmatitic gneiss is well exposed in the Nigerian Mining Corporation quarry in Oban. The rocks are generally banded, coarse-grained, isoclinically folded and display mica axial planar foliation (Fig. 3). The fold axes trend north-south, parallel to the regional trend of the foliation. Some of the phyllosilicates have been altered to chlorite and smooth chloritic surfaces separating individual layers of banded gneisses vary from less than one centimetre to over six centimetres in places. In all, leucocratic bands are thicker than the melanocratic ones (fig. 3). In addition to the banded aspect of this gneiss, there are irregular dissections of some outcrops by a network of quartzo-feldspathic veins and dykes (Fig. 4) confirming the occurrence of agmatite-type of migmatitic gneiss in the area. The dominant minerals in the leucocratic portion are quartz and

feldspar whereas chlorite and biotite predominate in the melanocratic bands.

### Mineral composition

The average modal composition of the migmatitic gneiss (Table 1) shows that the rock is quartzo-feldspathic and rich in biotite. The quartz crystals are large and together quartz, plagioclase and K-feldspar occur in the groundmass as well as megacrysts. The plagioclase is oligoclase with a composition of about  $AN_{24-26}$ . K-Feldspar consists of both microcline and orthoclase. Myrmekitic intergrowths of plagioclase and K-feldspar are occasionally found in some sections. The migmatitic gneiss has been subjected to at least two phases of deformation and alterations of primary minerals. Sericitization of plagioclase together with the chloritization of biotite (Fig. 5) suggests that the migmatitic gneiss has undergone local retrograde metamorphism. Epidote was a primary mineral and has

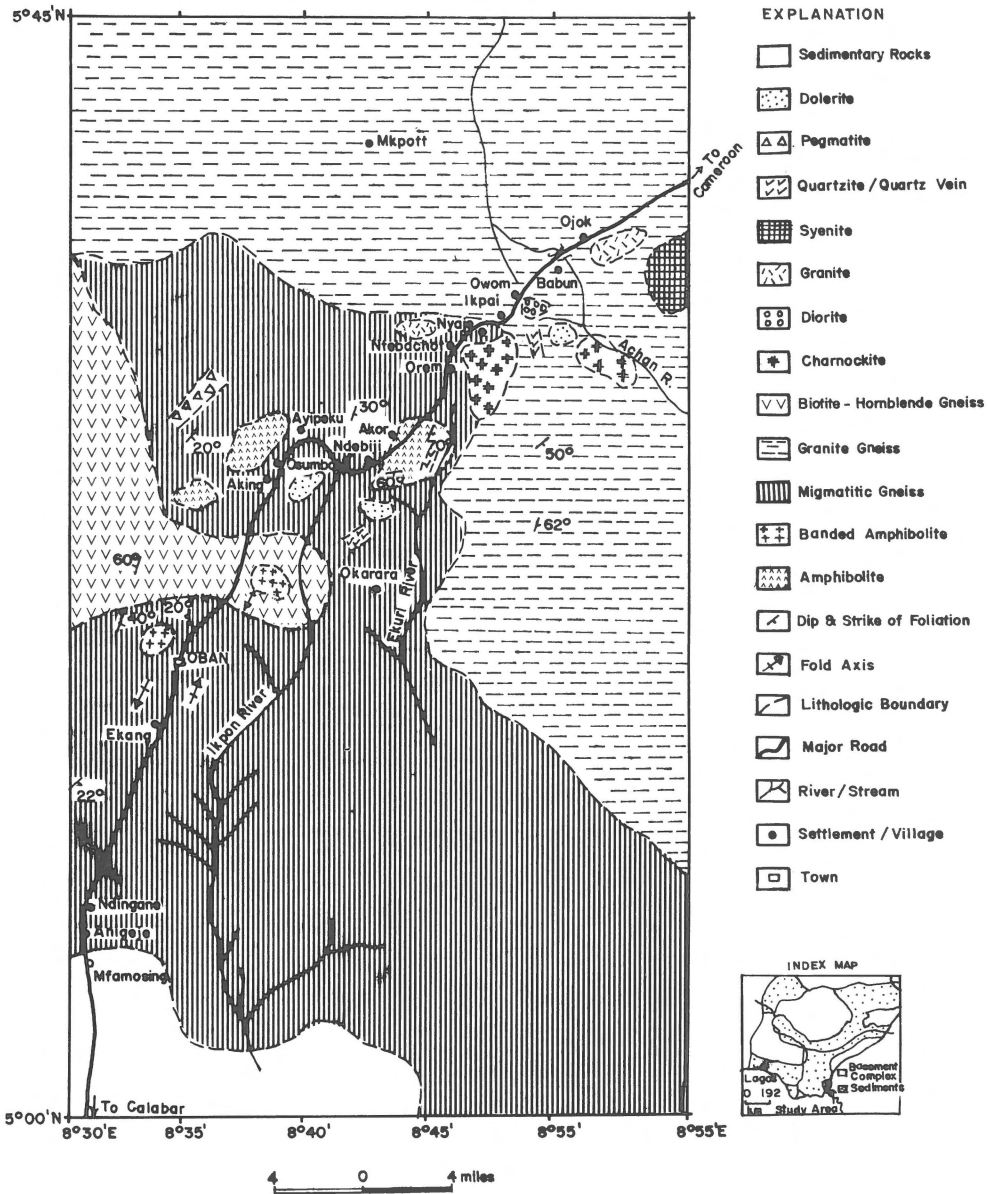


Fig. 2. Geological map of Eastern Oban Massif, Southeastern Nigeria.

been observed in some samples which have been affected by granulation and recrystallization.

Granite gneisses are exposed mostly along river banks at the eastern border of the Oban massif. The rock is also quartzo-feldspathic and foliated. The megacrysts include quartz and K-feldspar which occur either as clots or as augen-shaped tablets. They range in size between one and three centimetres and are parallel to the regional N-S

trend. They, therefore, enhance the foliation of the granite gneiss which is defined mainly by flakes of biotite and elongated prisms of hornblende. The modal composition of the granite gneiss is shown in Table 1. It is mineralogically similar to the migmatitic gneiss with which it is closely associated in the field. Dynamic recrystallization of quartz is common and is associated with development of mortar texture (Fig. 6).





Fig. 5. Replacement of biotite by chlorite ( $\times 2.5$ , CPL).

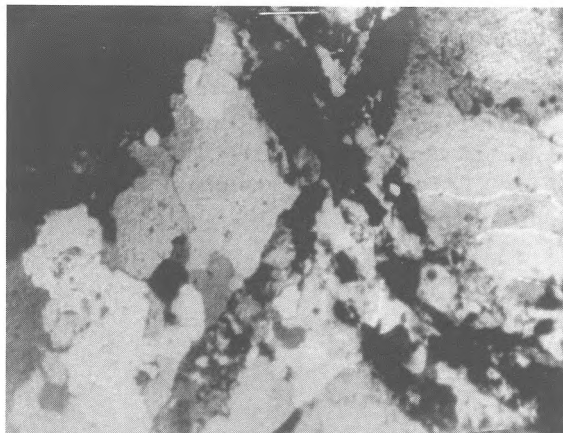


Fig. 6. Mortar texture in granite gneiss ( $\times 2.5$ , CPL).

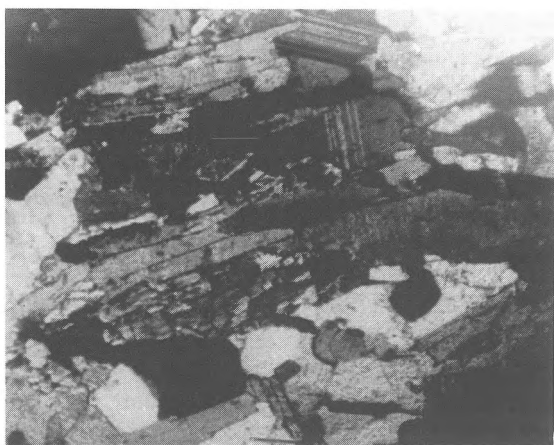


Fig. 7. Foliated biotite hornblende gneiss ( $\times 2.5$ , CPL).

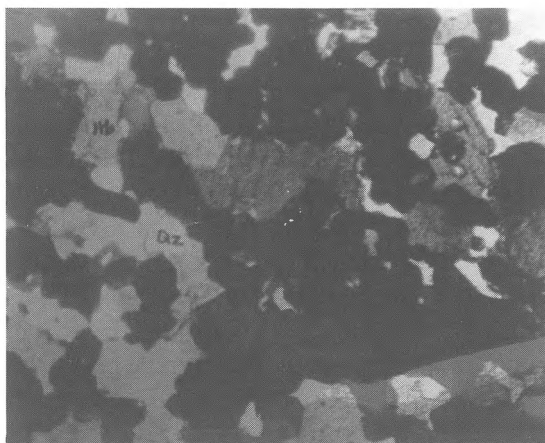


Fig. 8. Garnet rich biotite hornblende gneiss ( $\times 2.5$ , CPL).

migmatitic gneiss. The modal proportion of K-feldspar is low ( $<1\%$ ) in this gneiss and it contains 15% biotite and 30% hornblende (Table 1). The dominant plagioclase here is andesine ( $An_{38-46}$ ) being more basic than the plagioclase in the granite and migmatitic gneisses. Foliation is defined by both hornblende and biotite (Fig. 7). The biotite is reddish brown in colour whereas two generations of hornblende can be recognized. The younger crystals are greenish in colour with faint pleochroism while the older crystals are reddish brown and strongly pleochroic. Hornblende and biotite overgrow epidote.

Associated with the biotite-hornblende gneiss of Oban massif is a coarse-grained, foliated and dark coloured gneiss. This rock is enriched in garnet and contains also hornblende. Garnet comprises 65 per cent of the mode of this rock (Table 1) and forms a chain of minerals which enhances the foliation of the rock (Fig. 8).

The gneisses in the eastern Oban massif enclose enclaves of homogeneous and banded amphibolites (Fig. 2). The contacts between the gneisses and amphibolites are sharp whereas the contacts between the gneisses, where discernible, are gradational.

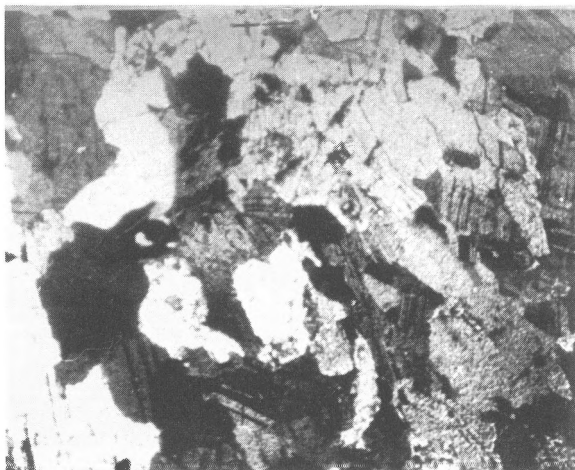


Fig. 9. Amphibolite in the Oban Massif ( $\times 2.5$ , CPL).

Amphibolites occur as massive to scattered dark boulders at Oban, Okarara, Orem, Aking, Ndebiji etc (Fig. 2). Locally, the banded amphibolites grade into the banded gneisses towards the summit of hills on the area. Banded amphibolite is abundant in channels of Achan and Ekuri rivers near Akor. Homogeneous amphibolites are dark, medium-grained and highly foliated in the ENE-WSW ( $60\text{--}70^\circ$ ) direction. The average modal compositions of the amphibolites are shown in Table 1. Hornblende and plagioclase define the strong foliation of the rocks (Fig. 9). The average plagioclase composition of the amphibolite is  $An_{44}$  though albitization of the plagioclase in outcrops at Aking and Ikpai has caused a decrease of anorthite content from  $An_{44}$  to  $An_{31}$  and  $An_{32}$ .

#### Chemical composition

Representative samples of each rock type were selected for detailed geochemical studies. Major and trace elements were determined using X-ray fluorescence (Norrish & Hutton 1969) in the Department of Geology, University of Manchester. The rock composition and their CIPW norm are given in Tables 2 and 3. Other features of the samples are also given in Figs. 10, 11, 12, 13 and 14.

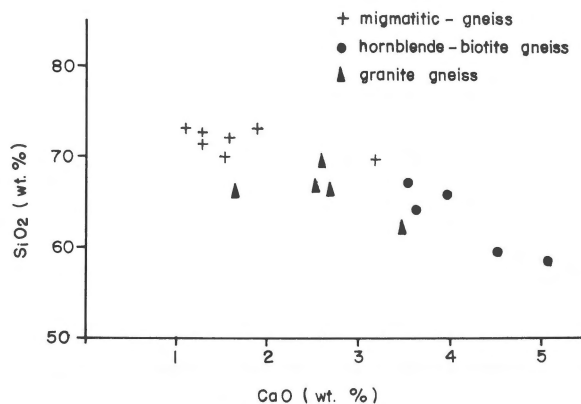


Fig. 10.  $SiO_2$  versus CaO plot for gneisses.

#### Major elements

$SiO_2$  ranges from about 73 wt% in the migmatitic gneiss to 58 wt% in the biotite-hornblende gneiss. The migmatitic and granite gneisses are generally siliceous containing more than 68%  $SiO_2$ . A plot of the gneisses on a  $SiO_2$ -CaO variation diagram (Fig. 10) shows an overall negative correlation with the migmatitic gneisses plotting at higher  $SiO_2$ -CaO ratios.  $Al_2O_3$  values range from 13 to about 17%.  $Na_2O$  and  $K_2O$  show only slight variation. The concentration of  $Na_2O$  ranges from 2.49 to 4.92%.  $K_2O$  displays the highest concentrations (approx. 6.04%) in the migmatitic gneiss and this is consistent with the high concentration of K-feldspar in these rocks. The granite gneiss also contains up to 5.98%  $K_2O$ . The biotite-hornblende gneiss contains less  $K_2O$ . A plot of  $Na_2O/Al_2O_3$  against  $K_2O/Al_2O_3$  (Fig. 11), used by Garrels & Mackenzie (1971) to distinguish between sedimentary/metasedimentary and igneous rocks shows that most of the samples fall within the igneous field indicating their igneous character and origin. The compositional variation here could be largely inherited from a differentiated parent igneous suite. When the rocks are plotted on a CaO- $Na_2O$ - $K_2O$  ternary diagram (Fig. 12) and the compositional variation field of acid to intermediate igneous rocks (Condie 1967) are superimposed, the values show a wide-spread from granodiorite to quartz monzonite confirming that the compositional variation could be inherited from a differentiated parent calc-alkaline

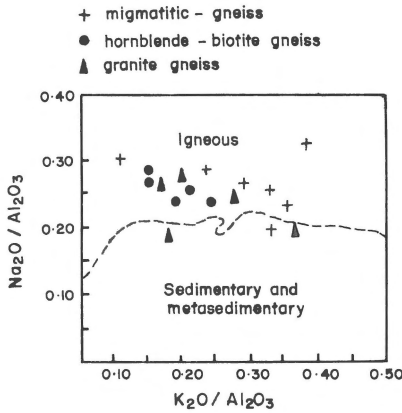


Fig. 11. Plot of gneisses on the  $Na_2O/Al_2O_3$  versus  $K_2O/Al_2O_3$  diagram (after Garrels and Mackenzie, 1971).

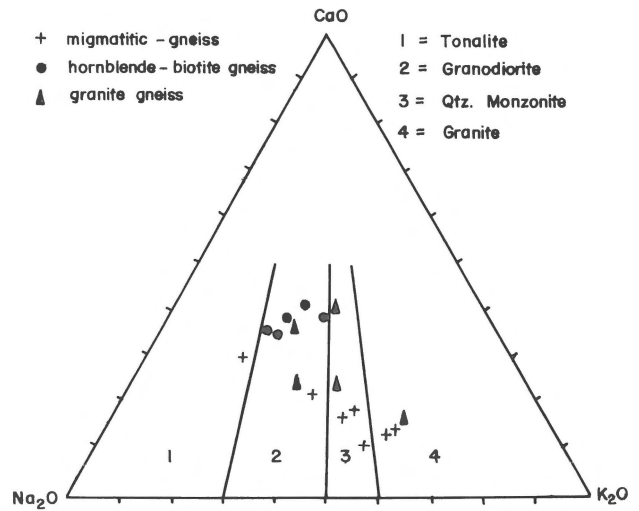


Fig. 12.  $Na_2O - K_2O - CaO$  diagram for gneisses.

Table 2. Major element and normative composition of gneisses in Eastern Oban massif

	Migmatites							Biotite-hornblende gneiss						Granite gneiss				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
SiO <sub>2</sub>	73.78	69.56	73.09	73.47	71.37	68.74	70.07	66.65	67.65	64.38	59.11	68.50	69.60	66.30	66.83	68.01	68.75	
TiO <sub>2</sub>	0.33	0.39	0.24	0.26	0.42	0.36	0.44	0.44	0.80	0.84	1.10	1.05	0.49	0.56	1.41	0.65	0.33	
Al <sub>2</sub> O <sub>3</sub>	13.20	16.21	14.51	14.36	15.09	16.53	14.57	14.46	14.59	16.08	17.20	13.23	12.32	15.43	14.49	14.23	15.47	
Fe <sub>2</sub> O <sub>3</sub> *	2.80	2.42	2.23	1.89	2.99	2.64	3.76	3.74	5.38	5.85	6.06	3.48	4.86	3.52	3.52	3.63	2.95	
MnO	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.07	0.08	0.67	0.08	0.07	1.40	0.06	0.11	0.05	0.06	
MgO	1.00	1.03	0.33	0.52	0.72	0.57	1.25	3.69	1.27	2.09	3.42	2.75	1.74	1.66	2.76	1.09	1.31	
CaO	1.92	3.21	1.10	1.67	1.31	1.48	1.53	4.04	3.58	3.64	5.37	2.53	2.60	1.72	3.60	2.64	2.56	
Na <sub>2</sub> O	3.72	4.92	3.43	3.36	2.78	3.45	3.75	3.66	4.14	4.36	3.98	3.32	3.16	2.79	2.49	4.52	3.97	
K <sub>2</sub> O	3.11	2.02	5.00	4.24	5.22	6.04	4.32	3.03	2.09	2.29	3.20	3.78	3.71	5.98	4.42	4.45	4.39	
P <sub>2</sub> O <sub>5</sub>	0.12	0.18	0.08	0.12	0.06	0.09	0.25	0.21	0.45	0.34	0.46	0.43	0.12	1.89	0.37	0.33	0.20	
Total	100.03	99.98	100.06	99.94	100.02	99.95	99.99	99.99	100.03	100.54	99.98	99.14	100.00	99.91	100.00	99.60	99.99	
<i>CIPW NORM</i>																		
Q	39.62	25.20	32.74	36.21	32.91	30.89	28.25	20.52	26.45	19.43	8.00	25.65	27.48	28.58	24.88	19.93	24.42	
Or	20.82	11.85	31.47	27.44	33.79	34.88	28.14	18.16	12.59	13.80	19.84	22.74	21.68	39.66	26.62	28.08	29.82	
Ab	35.66	42.00	30.77	31.16	25.82	28.34	34.58	31.57	36.16	37.96	34.66	28.94	26.72	26.58	21.35	41.11	38.48	
An	0	15.23	0	0	0	0	0	14.47	15.46	16.97	20.14	10.23	11.95	0	15.58	0	0	
C	0.58	0.52	1.74	1.37	2.68	1.55	1.12	-	-	0.53	-	-	-	1.54	-	-	-	
Di	-	-	-	-	-	-	-	4.07	0.35	-	3.76	2.015	2.78	-	-	5.15	0.40	
Hy	2.82	4.10	2.40	2.94	3.90	3.33	6.16	9.88	6.46	8.93	10.33	7.45	8.16	3.12	7.83	3.70	5.77	
Il	0.12	0.77	0.49	8.52	0.80	0.66	1.00	0.93	1.57	1.72	2.24	2.02	0.91	0.15	2.79	1.31	0.71	
Ap	0.35	0.32	0.33	0.35	-	0.34	0.68	0.32	0.96	0.64	0.98	0.95	0.31	0.36	0.95	0.66	0.36	
Total	99.51	99.99	99.94	99.00	99.90	99.99	99.93	99.92	100.00	99.98	99.95	99.95	99.99	99.99	100.00	99.94	99.96	

\* Total Fe as Fe<sub>2</sub>O<sub>3</sub>.

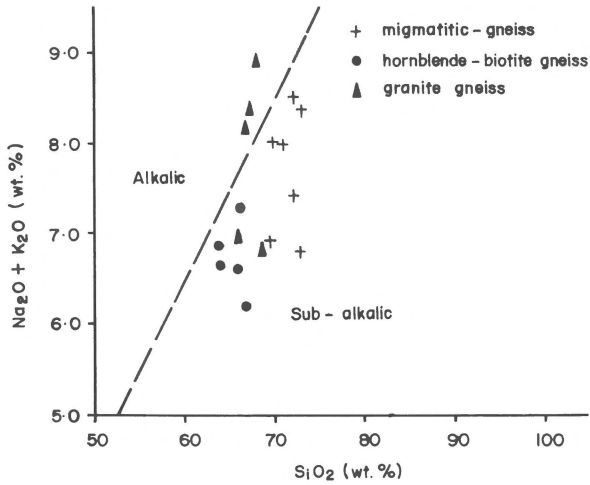


Fig. 13. Alkali – silica diagram for gneisses (after Irvine and Baragar, 1971).

magma. The calc-alkaline character is confirmed by an alkali-silica diagram (Fig. 13).

#### Trace elements

The difference between different gneisses can easily be seen in their chemical composition and this is discussed for the gneisses studied.

The migmatitic gneisses are richer in Rb than

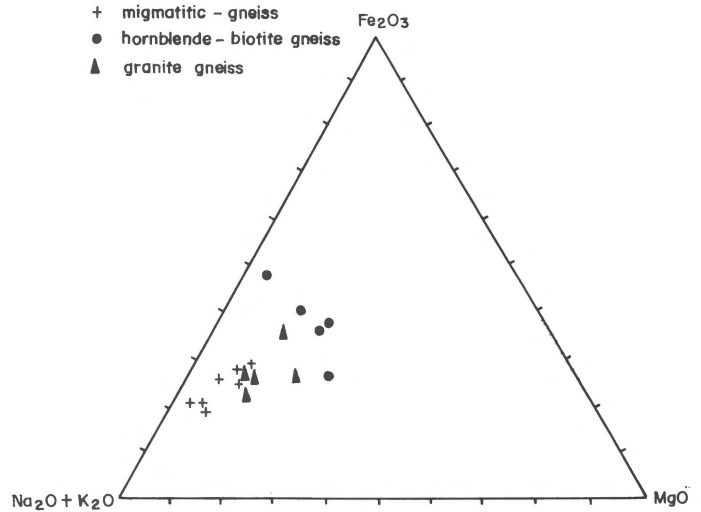


Fig. 14. AFM diagram for gneisses.

the., biotite-hornblende and granite gneisses. The values are, however, lower than the value of 150 ppm quoted for granites (Taylor 1965). This could imply that the melt was derived from a small degree of partial melting of the source material. This is confirmed by K/Rb ratios for the gneisses. The concentrations range between 81 and 248 and are considered normal for granite rocks.

The migmatitic gneisses have lower values of Sr than the other two. The biotite-hornblende and granitic gneisses may have been derived from

Table 3. Trace element composition of gneisses in Eastern Oban massif

	Migmatites							Biotite-hornblende gneiss					Granite gneiss				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
V	23	26	7	21	16	17	25	61	37	62	109	46	60	49	35	37	30
Cr	42	32	23	25	24	26	33	233	78	69	167	140	60	94	107	28	74
Ni	15	2	5	9	2	2	7	93	42	60	99	78	172	42	96	11	14
Ba	785	1208	1232	726	1995	1535	851	702	745	461	1173	1960	652	1232	1006	1061	1146
La	35	37	41	35	36	25	61	50	54	20	58	36	34	26	24	55	33
Cu	16	3	9	4	8	6	8	10	11	5	29	16	133	45	154	8	8
Zn	42	43	45	54	57	42	112	49	88	98	80	83	78	65	98	94	48
Rb	96	103	101	116	118	123	123	72	82	63	68	72	32	133	75	65	90
Sr	163	199	130	169	216	181	153	405	225	407	772	722	101	445	331	573	509
Zr	303	214	224	162	259	226	223	154	316	198	304	326	167	192	225	277	181
Y	31	11	34	63	60	17	61	20	75	22	28	27	80	27	45	18	16
Nb	10	6	10	24	5	4	18	8	22	22	20	25	14	13	20	13	8
Ba/Rb	8.18	11.73	12.20	6.26	16.91	12.48	6.92	9.72	9.09	7.32	17.25	27.22	20.38	9.26	13.41	16.32	12.73
Rb/Sr	0.59	0.52	0.78	0.69	0.55	0.68	0.80	0.18	0.36	0.15	0.09	0.10	0.32	0.30	0.23	0.11	0.18
K/Rb	134.38	81.55	205.94	149.14	183.90	183.74	145.53	175.00	106.10	50.79	192.65	218.06	281.25	180.45	244.00	284.62	200.00

sources rich in Sr. The migmatitic gneiss has higher Rb/Sr ratios (0.52–0.80) than the other two (0.09–0.96) which are similar to values obtained for Pan African granites in north-central Nigeria (Van Breemen et al. 1977).

The gneisses however have comparable Zr concentration which range from 154–326 which are comparable to average granites (180 ppm).

The Y concentrations for the gneisses are near normal when compared with the value of 40 ppm quoted for granites (Taylor 1965). This suggests that the gneisses may have been derived from melts formed from partial melting of a lower degree.

## Discussion

The gneisses of the eastern Oban massif show variation in mineralogy and element geochemistry (Tables 1 and 2). The chemical and modal compositions of the migmatitic and granite gneisses have striking similarity to the hornblende-biotite granodiorite of Nockolds (1954) and the average granodiorite of Cox et al. (1979), while those of the biotite-hornblende gneiss is similar to the average diorite of Cox et al. (1979). Evidence for the igneous origin of these rocks include the enclaves of amphibolites and sharp contacts with other rocks. Ekwueme (1985) analyzed amphibolites in the Oban massif and reported that the banded variety is derived from calc-alkaline high alumina basaltic magma while the others are tholeiitic in composition. These are consistent with the plots of the data on  $\text{Na}_2\text{O}/\text{Al}_2\text{O}_3$  versus  $\text{K}_2\text{O}/\text{Al}_2\text{O}_3$  diagram of Garrels & Mackenzie (1971) and the  $\text{CaO}-\text{Na}_2\text{O}-\text{K}_2\text{O}$  diagram of Condie (1967) which demonstrate that the rocks are igneous in origin and that magma composition ranges from granodiorite to quartz monzonite.

Published data on gneisses from the western half of the Nigeria basement (e.g. Elueze 1982, Rahaman 1976) suggest a sedimentary origin for the gneisses. The plot of the data on the Alkali-silica and AFM (Fig. 14) diagrams and other features show that the progenitors of the gneisses were sub-alkalic and may have been derived from calc-alkaline magma.

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