Ghana J. Sci. **46** (2006), 13-25

PETROLOGY AND GEOTECTONIC SETTING OF THE BASEMENT COMPLEX ROCKS AROUND OGOJA, SOUTH-EASTERN NIGERIA

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Abstract

The basement complex, located at the south-eastern borders of Ogoja town in the south-eastern part of Nigeria, consists of two varieties of migmatitic gneisses, namely banded and augen gneisses, which, in some cases, are inter-layered with amphibolite. Many concordant to discordant quartzofeldspathic veins in these gneisses are related to granitoid rocks, namely porphyritic granites, coarse-grained leucogranite, aplitic granite, and granodiorite. The occurrence of plagioclase (An_{35-44}), hornblende, almandine garnet and staurolite in the gneisses is an evidence of metamorphic conditions of the amphibolite facies grade. Mineral constituents and major element oxide data indicate that the gneisses are meta-sedimentary rocks derived from the metamorphism of pelites, whereas the amphibolite are meta-igneous rocks derived from a basic rock of subalkaline affinity. The banded gneisses possess NNW-SSE foliation trends, which are typical of pre-Pan-African deformation events, whereas the augen gneisses have NNE-SSW trends which are typical of Pan-African events. The granitoids are commonly foliated and lack clear magmatic contact with the gneisses. They are sub-alkaline, with alkali contents ranging from 6.87 to 9.65 per cent, and potash greater than soda. Their field, petrographic and geochemical features suggest that they were emplaced through remobilization, possibly accompanied by alkali-metasomatism during the Pan-African thermotectonic event. Discrimination of their tectonic environment agrees with an origin in a subduction environment of the continental type.

Résumé

Obiora C. S.: *Le cadre de pétrologie et de géotectonique de roches complexes au sous-sol autour d'Ogoja, au sud-est du Nigéria.* Le complexe du sous-sol situé au sud-est et à l'est de frontières de la ville d'Ogoja dans la zone au sud-est du Nigéria consiste en deux variétés de gneiss migmatitiques, à savoir: Les gneiss bandés et d'augen parfois avec l'amphibole entre les couches. Les veines quartzifeldspathiques concordantes et discordantes nombreuses dans ces gneiss sont liées aux roches granitoïdes, à savoir: les granits porphyriques, les leucogranits à gros grains, le granit d'aplite et la granodiorite. L'apparition de plagioclases (An_{35-44}), la hornblende, le garnet d'almandin et la staurolite entre les gneiss est une preuve de conditions métamorphiques de la qualité de faciès amphibolique. Les constituants minéraux et les données d'oxyde d'élément majeur indiquent que les gneiss sont métasédiments, dérivés de métamorphisme de pélites alors que les amphiboles sont métaignées, dérivées de roche basique de l'affinité subalcaline. Les gneiss bandés possèdent les directions de la foliation NNW-SSE, qui sont typiques d'événements de déformation prépanafricains, alors que les gneiss d'augen ont les directions NNE-SSW qui sont typiques d'événements panafricains. Les roches granitoïdes sont généralement foliées manquant la relation de contact magmatique véritable et vive avec les gneiss. Elles sont subalcalines, ayant de hautes teneurs d'alcali, avec une potasse plus élevée que la soude. Leur gisement, les caractéristiques pétrographiques et geochimiques suggèrent qu'elles étaient emplaçées par la remobilisation, peut-être accompagnées par alcali-métasomatisme pendant l'événement thermotectonique panafricain. Distinction de leur environnement tectonique s'accorde avec une origine dans un environnement de subduction du type de l'arc continental.

Introduction

The basement complex in south-eastern Nigeria crops out in two areas, namely the Oban Massif and the southern parts of the Bamenda Massif covering Ogoja and Obudu areas (Fig. 1). The rocks in the Oban Massif have been studied by Ekwueme (1987), Rahman *et al*. (1988), Ekwueme & Ekwere (1989) and Ekwueme & Kroner (1998).

Also, those in Obudu areas have been studied by Orajaka (1963), Ekwueme (1991, 1994) and Ejimofor, Umeji & Turaki (1996). The basement complex in these areas are similar to those in other parts of the Nigerian basement complex in the occurrence of migmatitic gneisses which are intruded by granitoid rocks in many places.

The Nigerian basement complex, which is part of the Pan-African mobile belt, lies between the West African craton, the Congo craton and south of Tuareg shield (Fig. 1). It was deformed by different pre-Cambrian thermotectonic events, which were accompanied by progresive regional metamorphism.

Each of the thermotectonic events produced characteristic imprints on the basement rocks. However, the Pan-African event was so pervasive that it obliterated most of the structures of the earlier events, leaving only their traces (McCurry, 1971a; Rahaman, 1976; Grant, 1978; Ekwueme, 1987, 1994). The structures produced by this widespread event trend commonly N-S to NE-SW whereas those of the other earlier events, including the early part of the widespread Pan-African event trend ENE-WSW, E-W and NW-SE (McCurry, 1971ab; Grant, 1978; Ekwueme, 1987). The thermotectonic events were also accompanied by the intrusion of syn-to late-tectonic granites and granodiorites. Common varieties of the granites include porphyritic biotite-and biotite-hornblende granites, as well as non-porphyritic types, commonly non-foliated (McCurry, 1971a). These Pan-African granites were termed “Older granites” to distinguish them from the Jurassic (Younger) granites with which they are closely associated in the basement of Northern Nigeria (Falconer, 1911).

There are not much studies on the basement rocks around Ogoja town and its environs. It is, therefore, the aim of the paper to give an account of the basement complex rocks in Ogoja areas with emphasis on their field characteristics, petrogra-

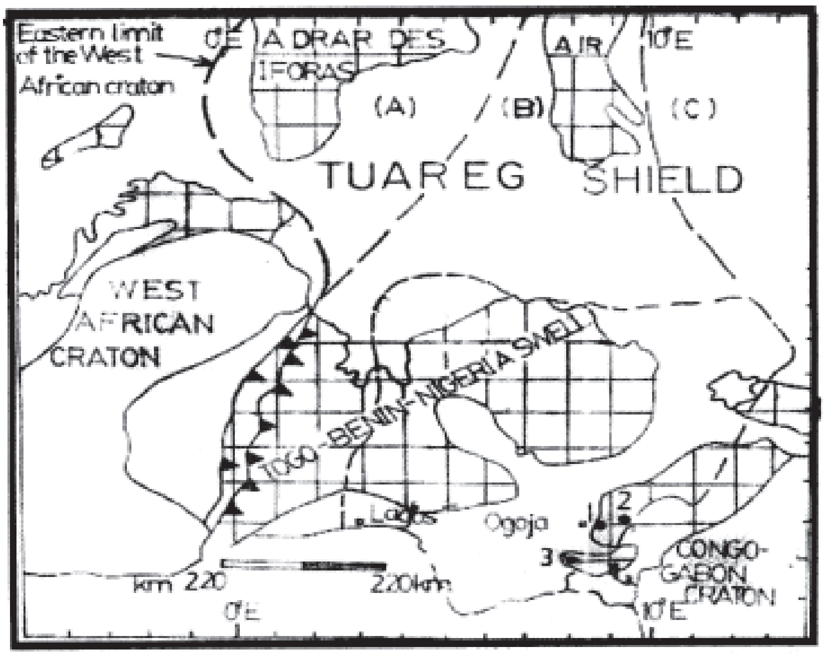

Fig. 1. Geological map of parts of West Africa showing the position of Nigeria and its Pan-African basement, the Congo-Gabon craton, the West African craton and the Turareg shield (Adapted from Wright *et al.*, 1985)

phy and major-element geochemistry. Deductions on their petrogenesis, geologic and tectonic history have also been attempted.

Experimental

Descriptiion of the lithologic units

The basement complex is exposed about 17 km to the east and 8 km to the south-east of Ogoja town. The basement consists of migmatitic gneisses which are intruded by different bodies of porphyritic granites, coarse grained leucogranite, aplitic granite, and granodiorite (Fig. 2). The gneisses are also inter-layered with amphibolites. The basement is unconformably overlain by conglomeratic arkosic sandstones. Average modal compositions of the basement complex rocks, determined from thin section microscopy by point counting are presented in Table 1.

Migmatitic gneisses

These are predominantly banded gneisses. One important variety of these gneisses occurs as augen gneisses in the southern parts of the study area.

Banded gneisses. These consist of alternations of leucocratic bands with melanocratic, gneissic layers. They are medium grained and gray in colour. Thickness of the bands varies from a few millimeters to 6 cm. The gneissic layers are up to 25 cm thick in some places. The foliation trend is NNW-SSE (320^o - 345^o) with dips in the range of 17^o - 68^o both to the north-east and south-west directions. In some cases, ENE-WSW trends, with dips to the north-west direction are also common. The outcrops are characterized by pegmatite dykes and numerous quartzo-feldspathic veins, which are concordant to the foliation trends. Faulting and folding (symmetrical and ptygmatic folds) of the

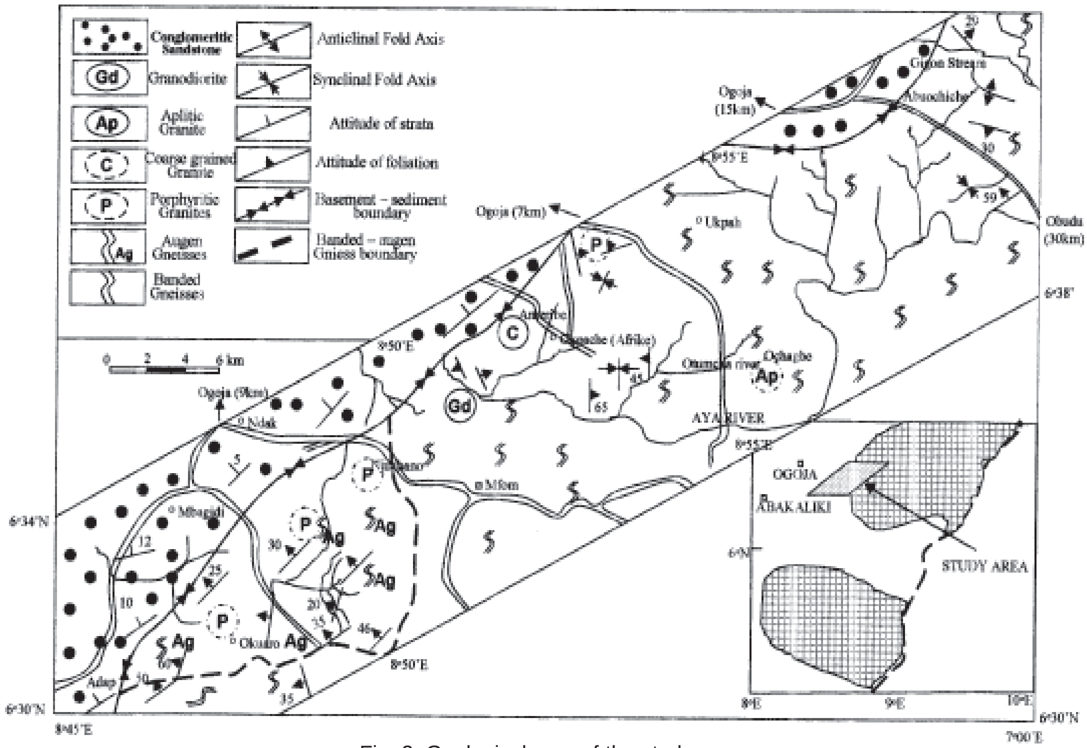

Fig. 2. Geological map of the study area

TEBLE 1

Average modal compositions of rocks from the basement complex

Sample	*MGB/ 011*	*MGB/ 022*	*MGB/ 033*	*MGB/ 044*	*AMP/ 045*	*PG/ 050*	*PG. 051*	*PG/ 052*	*PG/ 053*	*CG/ 060*	*AG/ 061*	*GD/ 062*	*P/ 063*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Quartz	33.4	42.8	58.5	27.8	10.4	44.5	42.5	28.3	36.2	43.6	30.2	39.6	22.0
Microcline	1.3	5.0	2.7	14.5	0	20.8	23.9	25.0	35.8	12.5	41.8	13.7	78.0
Orthoclase	0	3.2	0	0	0	0	0	0	6.0	34.5	1.4	0	0
Plagioclase	27.1	14.3	13.3	28.9	9.6	14.0	16.0	21.7	2.8	6.2	10.6	23.6	0
Biotite	28.0	29.3	22.1	21.0	18.6	15.9	13.4	16.7	19.2	0	15.3	14.3	0
Hornblende	1.3	0	3.4	3.0	55.8	6.8	3.4	8.3	0	0	0	0	0
Garnet	8.2	0	0	2.2	0	0	0	0	0	0	0	0	0
Staurolite	0	0	0	2.6	0	0	0	0	0	0	0	0	0
Chlorite	0	2.0	0	0	0	0	0	0	0	0	0	3.4	0
Apatite	0.7	0.4	0	0	0	0	0	0	0	0	0	0.6	0
Iron ore (opaques)	0	3.0	0	0	5.6	0	0	0	0	3.2	0.8	4.7	0
Total	100	100	100	100	100	100	100.2	100	100	100	100.1	100.9	100

Numbers 1 and 2 are banded gneisses; 3 and 4 are augen gneisses; 5 is amphibolite; 6, 7, 8 and 9 are porphyrite granites; 10 is coarse leucogranite; 11 is aplitic granite; 12 is granodiorite; 13 is pegmatite.

foliation and the quartzo feldspathic veins are common.

The gneisses consist of quartz and feldspars in the light coloured layers, and biotite and quartz in the dark coloured layers. Garnet (almandine) is also an essential constituent of the dark coloured layers. Apatite and magnetite are accessories (Table 1). The anorthite composition of the plagioclase in the melanocratic layers is An_{44} whereas in the leucocratic layer it is An_{10}. Lath-shaped aggregates of biotite define the foliation in the melanocratic layers.

Augen gneisses. These are coarse-grained, dark grey-coloured rocks characterized by "eye-shaped" or lense-like aggregates of quartz and feldspars, resulting from deformation of the granitic (leucocratic) and gneissic components of the migmatitic gneisses. Their foliation trend is NNE-SSW (15^o - 40^o), with dips of 25^o - 65^o to the northwest. There are also less common trends in the NNW-SSE, with dips up to 47^o, also to the northwest. Quartz and quartzo-feldspathic veins with similar attitude as those in the banded gneisses are abundant. Microfolds, joints and faults are also numerous. The anorthite composition of the plagioclase in the augen gneisses is An_{35}.

Amphibolites. These melanocratic (black), medium grained rocks, rich in hornblende and biotite, (Table 1) are encountered in the outcrops of the banded gneisses. The occurrences are common at the sections along the Aya and Otumchu rivers in Afrike town and the Gigon stream in Abuagborukum, located at the central and the northern parts of the study area, respectively. At the Aya river sections, the rocks are inter-layered with the gneisses whereas they occur as discrete boulders at the sections of the Otumchu river and the Gigon stream. The thickness of the layers averages about 40 cm. The composition of the plagioclase is An_{42}. Generally, the rocks are foliated as shown in the alignment of mafic minerals.

Granitoid rocks

Porphyritic granites. Four bodies of these rocks occur in the study area. Of these, three intruded the augen gneisses while one occurs within the banded gneisses. These granitic rocks are light coloured, coarse grained and show very weak alignment of the mafic minerals. They are distinctly porphyritic, with phenocrysts of well-formed, white feldspars (Na-plagioclase and microcline) embedded in a finer mass of quartz, biotite and hornblende. Opaques (magnetite) are accessories. The rocks are exposed in farmlands, quarries and along stream channels.

Coarse-grained leucogranite. This extremely coarse-grained rock occurs within the banded gneisses exposed along the America-Nshebori road (Fig. 2). It contains randomly oriented crystals of quartz and alkali feldspars (orthoclase, microcline and albite). Some of the crystals of the constituent minerals which are large (up to 6 cm across) stick out within the boulders of the rock scattered around the hill.

Aplitic granite. This granite constitutes an elongate (N-S) hill, locally known as "Elebekon hill" in Ochagbe, central part of the study area. The hill is 170 m long and 60 m wide. This rock is medium grained, porphyritic and fairly leucocratic. It consists of phenocrysts of microcline in 'sugary' groundmass of quartz, biotite, Na-plagioclase (albite, An_7) and opaques (magnetite). The rock is weakly foliated by the alignment of biotite which occurs in euhedral, lath-shaped forms. Crystals of biotite also form aggregates in some parts of the rock. On the outcrop, the porphyritic texture of the rock is more pronounced towards its margins, with the phenocrysts being made up of pink-coloured K-feldspars.

Granodiorite. This rock intruded the banded gneises at the bank of Aya river around Afrike town. It is emplaced in an orientation, which is essentially N 10^o E. Its contact with the host rock is sharp and discordant. The modal composition is shown in Table 1. The plagioclase in the rock is oligoclase (An_{12}).

Pegmatitic dykes and sills. These occur as small, unmappable units within the migmatitic gneisses. Most of them have sharp, discordant contacts with the gneisses. Few large ones are concordant to the regional trend of foliation and show a contact effect (baking) on the country rocks. Also, their margins are chilled. These rocks contain mainly quartz and microcline (Table 1).

Methods of analyses

Representative samples of the different rocks were selected for major element chemical analyses. Altogether, eight rock samples, made up of four samples of the migmatitic gneisses, one sample of amphibolite, and three samples of the granitic intrusives were analyzed. The major element oxides, $Si0_2$ and $A1_20_3$, were analysed by the ultraviolet (UV) visible spectrophotometry whereas Fe_20_3, (t), P_20_5, Na_20, and Ca0 were determined from atomic absorption spectrophotometry (AAS) analyses at the Soil Science Department Laboratory, University of Nigeria, Nsukka. The other oxides, Fe0, Mg0, and Mn0, were determined by titration using the method of Shappiro & Brannock (1962) at the Geochemistry Laboratory of the Department of Geology, University of Nigeria, Nsukka.

Results

The results of the analyses are presented in Tables 2 and 3. The results of the magmatitic gneisses (Table 2) compared favourably with those obtained for pelitic gneisses by Chinner (1960) and Van de Kamp (1968). Such gneisses are characterized by dominance of K_20 over Na_20, high alumina to alkali ratios, and generally low Ca0 and Mg0 contents. The results of amphibolite are much the same as the average composition of amphibolites, determined by Huang (1962) (Table 2). The chemistry of the granitic intrusives (Table 3) is comparable to those obtained for Pan-African granitic rocks in other parts of the Nigerian basement

TABLE 2

Major element chemical analyses and Niggli numbers for representative samples of the migmatitic gneisses and amphibolite

			Major element oxides *T*				
	1	*2*	*3*	*4*	*5*	*6*	*7*
SiO_2	54.39	53.40	59.80	56.64	52.76	54.94	50.30
TiO_2	n.d.	n.d.	n.d.	n.d.	n.d.	1.17	1.60
Al_2O_3	25.16	26.07	22.11	23.89	15.09	25.41	15.70
Fe_2O_3	1.99	1.79	1.87	1.94	3.92	1.00	3.60
FeO	7.00	8.58	6.15	6.65	7.11	7.07	7.80
MnO	0.09	0.07	0.08	0.08	0.24	0.09	0.20
MgO	2.42	1.93	2.12	2.29	5.60	2.44	7.00
CaO	0.68	0.55	0.60	0.65	8.35	0.69	9.50
Na_2O	0.85	0.68	0.75	0.81	2.18	0.86	2.90
K_2O	3.46	3.76	3.04	3.28	4.31	3.49	1.10
P_2O_5	0.01	0.01	0.01	0.01	0.31	0.01	0.30
LOI	2.63	2.10	2.31	2.50	0.39	2.66	n.d.
Total	98.68	98.94	98.84	98.74	100.26	99.83	100.0
			Niggli numbers				
si	1.825	1.759	2.303	2.021	1.321	1.901	1.181
al	0.247	0.256	0.217	0.234	0.148	0.249	0.154
fm	0.183	0.189	0.161	0.173	0.288	0.172	0.320
c	0.012	0.010	0.011	0.012	0.149	0.012	0.170
alk	0.051	0.051	0.044	0.048	0.081	0.051	0.059
mg	0.330	0.250	0.330	0.330	0.490	0.350	0.530
k	0.725	0.784	0.727	0.729	0.570	0.720	0.200

*n.d. = not determined.
Analysis No. 1 is augen gneiss, 2 is banded gneiss, 3 and 4 are garnetiferous banded gneiss and 5 is amphibolite.
No. 6 is average composition of hematite-freee gneisses (Chinner, 1960).
No. 7 is average of 200 amphibolites (Haung, 1962; p. 418).

(Oyawoye, 1964; Macleod, Turner & Wright, 1971; Olarewaju & Rahaman, 1982; Rahman, Ekwere & Azmatullah, 1988).

Discussion

Petrogenesis and geotectonic setting

Migmatitic gneisses. The basement in Ogoja areas attained the amphibolite grade of metamorphism. This is shown in the occurence of plagioclase (An_{35-44}), hornblende, almandine garnet and staurolite. These are typical minerals of the amphibolite facies as presented in the scheme for determining metamorphic facies by Dusel-Bacon, Brew & Douglass (1996). The folding of gneissose foliation, occurrence of ptygmatic folds, abundance of quartzo-feldspathic veins, and the variations in the anorthite compositions with albite (An_{10}) in the leucocratic layers and andesine (An_{35-44}) in the melanocratic layers are all evidence of the existence of a partially molten melt ("anatectic melt") during the metamorphism of the rocks. The rocks, therefore, may have originated under meta-

TABLE 3

Major element chemical analyses for the granitic intrusives, compared with analyses of some Pan-African granites

	1	*2*	*3*	*4*	*5*	*6*
SiO_2	64.96	69.43	72.42	69.76	68.62	66.43
TiO_2	n.d.	n.d.	n.d.	0.24	0.62	0.59
Al_2O_3	16.25	13.05	14.29	15.92	14.51	16.04
Fe_2O_3	1.90	1.76	1.14	0.44	1.38	1.23
FeO	0.90	3.34	2.07	1.05	2.65	2.44
MnO	0.09	0.09	0.11	0.03	0.05	0.03
MgO	0.76	0.70	0.46	0.34	0.72	1.84
CaO	2.58	2.39	2.91	1.46	2.16	3.32
Na_2O	3.57	3.31	3.02	4.19	3.47	3.63
K_2O	6.08	5.63	3.85	5.46	4.77	4.00
P_2O_5	0.27	0.25	0.20	0.08	0.22	0.24
LOI	0.38	0.35	0.20	0.48	0.66	n.d.
Total	97.74	100.30	100.67	99.45	99.83	99.89
$Na_2O + K_2O$	9.65	8.94	6.87	9.65	8.24	7.63
FeO(T) + MgO	3.56	5.86	3.67	1.83	4.75	5.51
Molar						
$(Al_2O_3/CaO+K_2O+Na_2O)$	0.89	0.82	0.99	1.03	0.98	0.98

*n.d. = not determined.
Analyses 1 and 2 are porphyritic granites; 3 is aplitic granite.
Analyses No. 4 and 5 are averages for microgranite and porphyritic granites (Olarewaju & Raham, 1982).
Analyses No. 6 is average for porphyritic granites (Rahman *et al*., 1988).

morphic conditions which are similar to those in the fourth regime of metamorphism described by Holland & Lambert (1969) since they possess the features which indicate mobility and plastic deformation. Similar grades of metamorphism had been recorded in southern Obudu (Ekwueme, 1994), northern Obudu (Ejimofor, Umeji & Douglass, 1996), and eastern Oban Massif (Ekwueme & Ekwere, 1989).

The presence of staurolite and almandine garnet, which are typical minerals of pelitic rocks suggests that the gneisses were derived from pelitic sedimentary rocks. As already shown, the nature of the gneisses is evident in the results of their geochemical analyses. For a clearer picture of the nature of these progenitors of the gneisses, Niggli numbers, $al = Al_2O_3 + Cr_2O_3$, $alk = Na_2O + K_2O$, mg = the ratio of MgO to fm, where $fm = (Fe_2O_3 \times 2)$ + FeO + MgO, c = CaO + SrO + BaO, k = the ratio of K_2O to the total alkalies, *alk* (Hatch, Wells & Wells, 1972) were computed for the major element oxide data (Table 2). The relations between the numbers, *c* and *mg*, *k* and *mg*, and *c*, *mg* and *al-alk* were plotted in Fig. 3-5 using the approach by Van de Kamp (1968). The pelitic nature of these gneisses is further evidence that most parts of the metamorphic basement complex in Nigeria are metasedimentary (Ekwueme & Onyeagocha, 1986; Ejimofor, Umeji & Douglass, 1996). The differences in the lithologic types within the complex, however, reflect differences in the compositions of the parent sedimentary rocks and possibly differences in grade of metamorphism.

Like other parts of the Nigerian basement complex, the Ogoja areas have evidence of a polyphase deformation as recorded in the multiple trends of

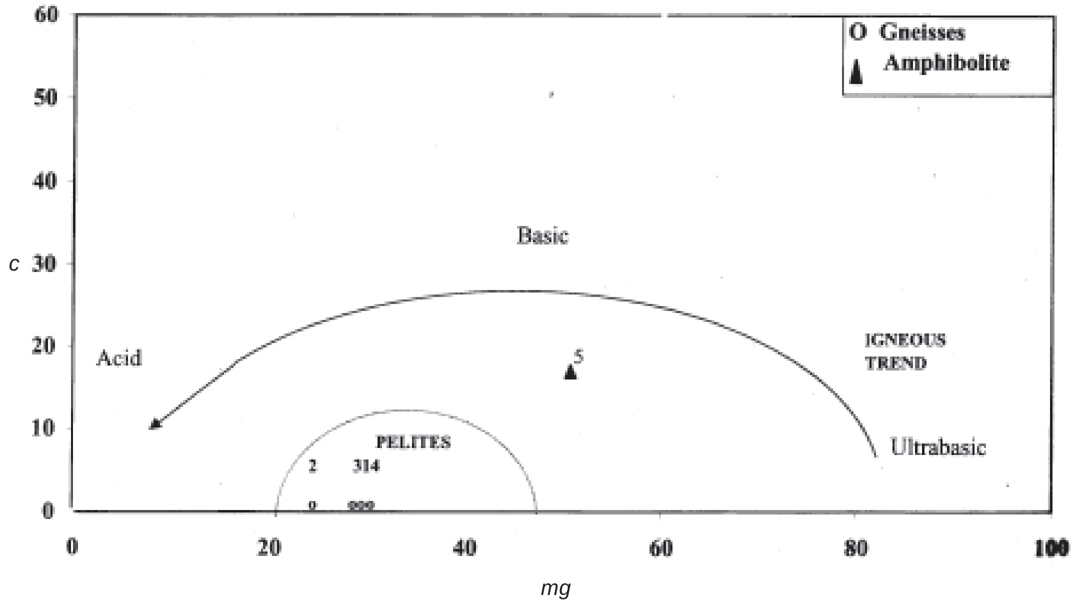

Fig. 3. Plot of Niggli *c* against *mg* for the gneisses and the amphibolite

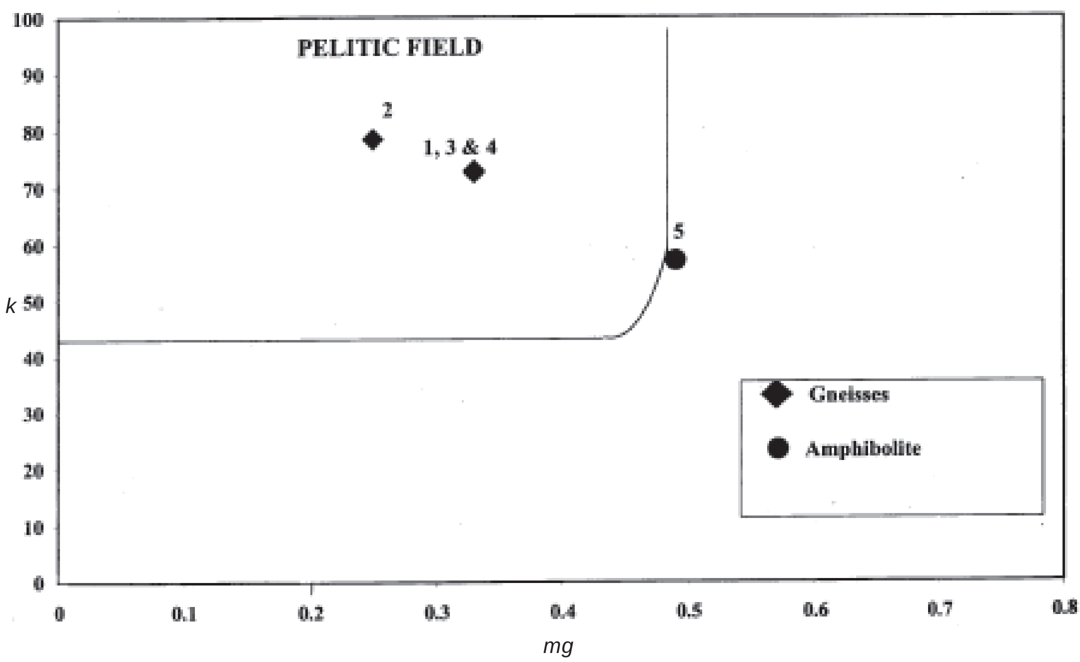

Fig. 4. Plot of Niggli *k* against *mg* showing the pelitic nature of the gneissses

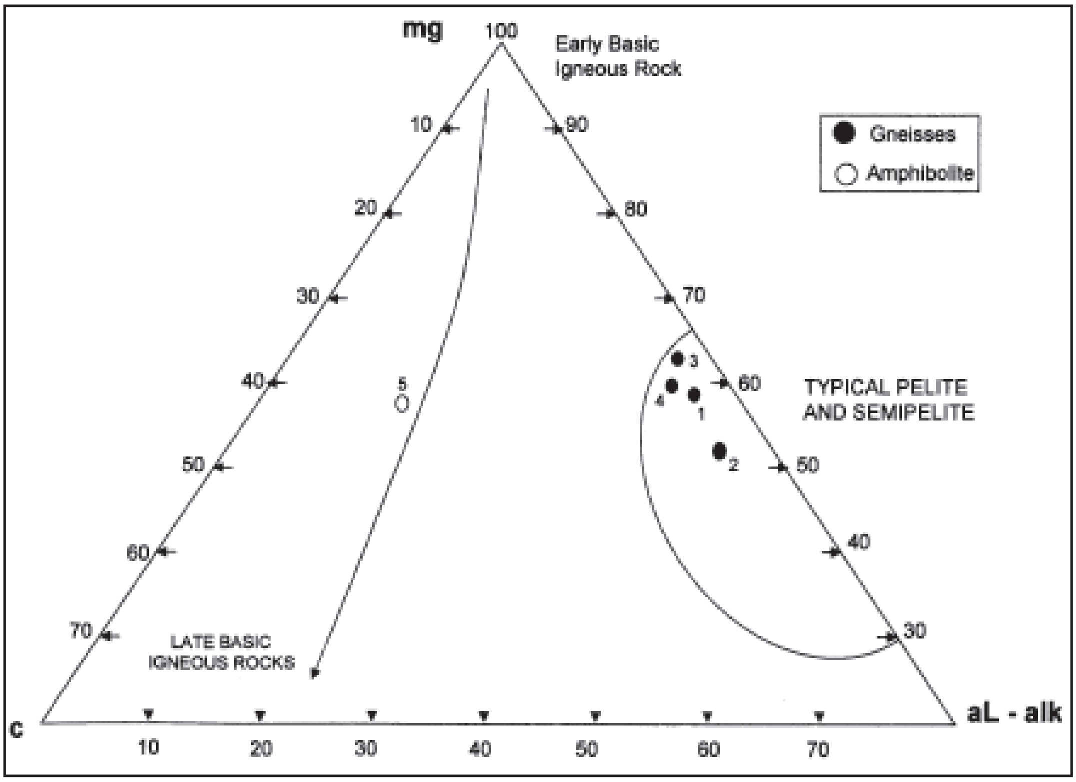

Fig. 5. Ternary plots of Niggli *c, al-alk* and *mg* illustrating the pelitic nature of the gneisses and Igneous nature of amphibolite

the foliation in the migmatitic gneisses. At least two phases of deformation might have occurred. The predominant NNW-SSE trends and the E-W trends in the foliation of the banded gneisses are typical of pre-Pan-African events (Rahaman, 1976a; Grant, 1978; Ekwueme, 1987, 1994). However, according to McCurry (1971a), the E-W trends are also common in the first phase of deformation during the Pan-African. On the other hand, the predominant NNE-SSW trends in the augen gneisses are typical of the Pan-African event, especially the second phase (McCurry, 1971a; Rahaman, 1976a; Grant, 1978; Ekwueme, 1987, 1994). The banded gneisses may, therefore, be Eburnean or Kibaran in age while the augen gneisses are of Pan-African age based on these structural trends.

Amphibolites. Plots of the Niggli numbers of the representative sample of the amphibolites in Fig. 3-5 suggest that they were derived from the metamorphism of a basic igneous rock, unlike the gneisses which have pelitic progenitors. Using the diagram of Miyashiro (1978), the sample plots as sub-alkaline (Fig. 6), thus, suggesting that the parent magma of this progenitor had a sub-alkaline (calc-alkaline or tholeiitic) affinity.

Granitoid rocks. The absence of sharp and clear magmatic contact relations, the presence of foliation, as well as the subalkalic nature of these rocks, attest that they belong to the Pan-African granite suite which were emplaced during the Pan-African thermotectonic event. However, their high content of bases, with potash greater than soda, suggests that their evolution might have been at-

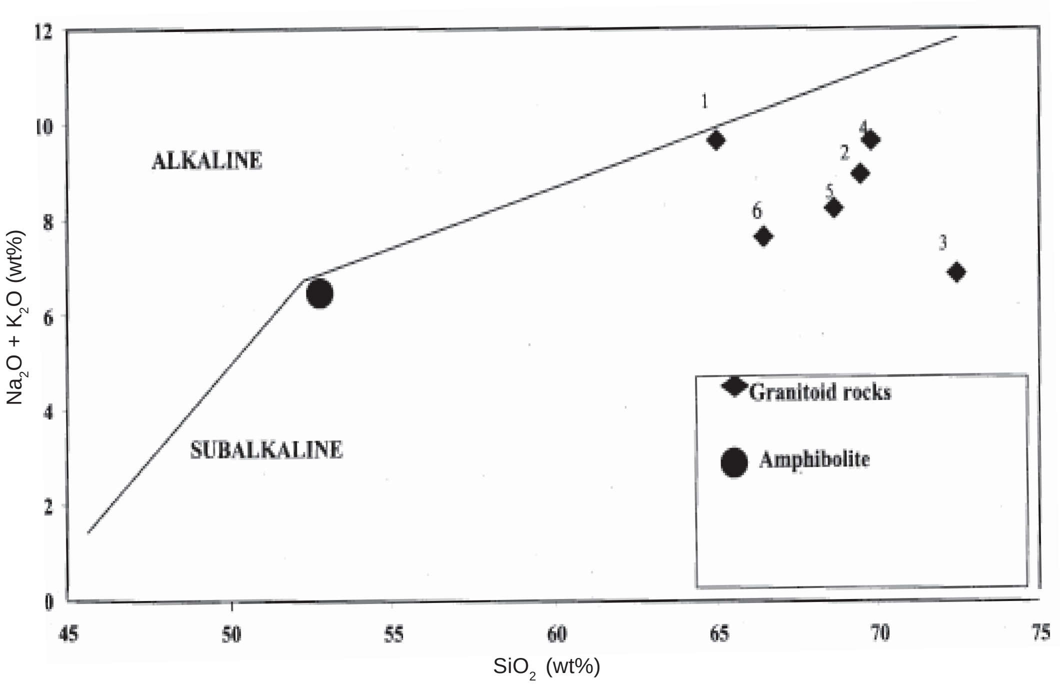

Fig. 6. Alkali *versus* silica diagram for the granite intrusives and the amphibolite. Dividing line is after Miyashiro (1978).

tended by alkali-metasomatism. It is, therefore, very likely that these granites were emplaced through remobilization by granitization, accompanied by metasomatism involving the introduction of K^+ and Na^+ from an unknown source into the pre-existing basement rocks. The granitization might have taken place during the anatectic melting of the pre-existing crustal (basement rocks during the Pan-African thermotectonic event. This origin of the Pan-African (Older) granites through metasomatic anatexis had been favoured by several workers (Carter, Barber & Talt, 1963; Rahaman, 1976b; Olarewaju & Rahaman, 1982) in the Nigerian basement. As shown in the plots of total alkalis against silica (Fig. 6), these granitic intrusives have the same affinity (sub-alkaline) as the amphibolite.

Using the discrimination scheme for tectonic environments of granitoid rocks based on major element oxides, described by Maniar & Piccoli (1989), the granitoid rocks, as well as other similar rocks from other parts of the Nigerian Pan-African basement, were plotted as orogenic granitoids (Fig. 7). Their molar $A1_20_3$ *versus* ($Ca0 + K_20 + Na_20$) ratios which are less than 1.00, suggest that they are either of the island or continental arc orogenic environment rather than a collision setting. This result is consistent with that obtained by Obiora & Umeji (1997) for the Pan-African granites using immobile trace element data, plotted on the Rb *versus* (Y + Nb) diagram of Pearco, Harris & Tindle (1984). Based on this discrimination, it is likely that the Pan-African granites in Nigeria originated through the subduction of the lithosphere beneath an ancient oceanic crust at the eastern margin of the West African craton underneath the Tuareg shield (Fig. 1). The origin of these granites through the collision of a volcanic arc with the West African craton, about 600Ma proposed by Black (1980) presupposes that the convergence at this

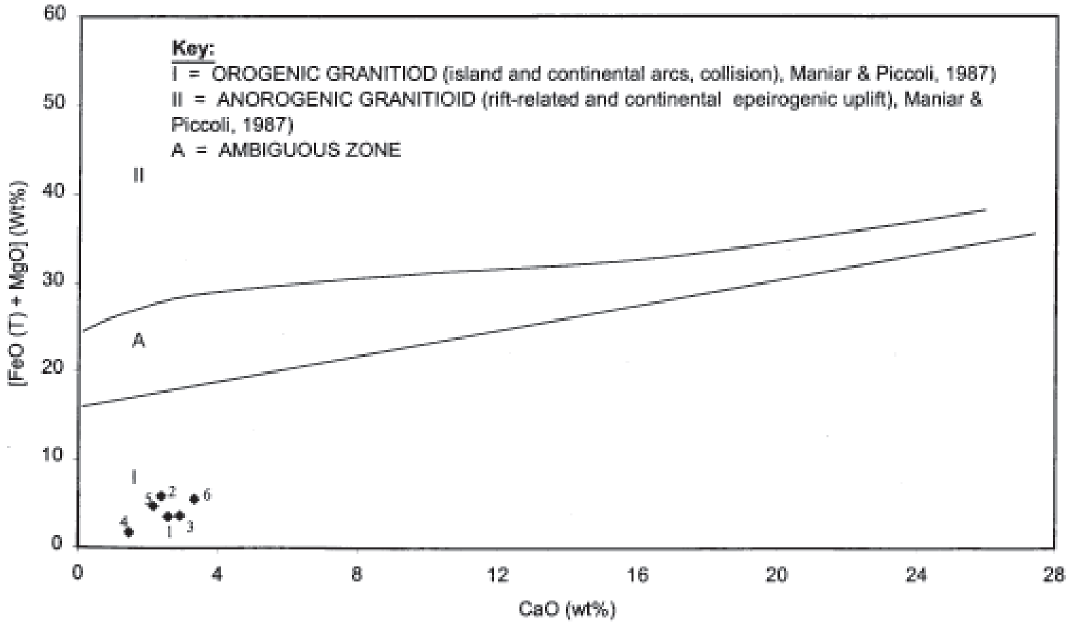

Fig. 7. Plot of [FeO (T) + MgO] (Wt%) *versus* CaO (wt%) for tectonic discrimination of the granitic intrusives (Maniar & Piccoli, 1989)

subduction margin culminated in a collision.

It should, however, be noted that subduction or volcanic arc granites can resemble collision granites when arc magmatism merges with collision magmatism (Pearce, 1996). Discrimination between rocks from the two environments in such cases is not possible with the Rb *versus* (Y + Nb) diagram of Pearce *et al*. (1984). Unlike this trace element discrimination scheme, the major element oxide scheme of Maniar & Piccoli (1989) is capable of discriminating between the two environments. In addition to the major element oxide discrimination, radiometric age determinations will be necessary in establishing the existence of more than one generation of the Pan-African granitoids. The success of tectonic discrimination of granitoids, using major element oxide, necessitates that the approach be given much attention since the major element oxides constitute the greatest proportion of the minerals that are found in the rocks from different environments (Rahaman, 1998, personal communication). More reliable results can, however, be obtained by employing the major element schemes together with the trace element schemes.

Conclusion

The following conclusion can be drawn from the discussion on the petrogenesis and geotectonic settings of the basement complex rocks in Ogoja areas:

1. The basement attained the amphibolite grade of metamorphism as in other parts of the Nigerian basement. The basement also reached the anatectic stage of metamorphism or ultrametamorphism.
2. The progenitors of the basement gneisses were pelitic sedimentary rocks.
3. The basement was deformed in two phases (i.e. polyphase deformation). The first phase of deformation was characterized by pre dominant NNW-SSE trends of foliation and was pre-Pan-African. This was recorded in the banded gneisses. Conversely, the second phase occurred during the Pan-

African. Its imprints, which are predominantly NNE-SSW trends, are recorded on the augen gneisses.

4. The amphibolites in the basement gneisses were derived from the metamorphism of a sub-alkaline, basic igneous rock.
5. The granitoid rocks belong to the Pan-African granite suite (Older granites of Nigeria), which have sub-alkaline (calc-alkaline) affinity. They might have been derived from an alkali-metasomatic anatexis of the pre-existing crustal (basement) rocks during the Pan-African thermotectonic event (Rahaman, 1976; Olarewaju & Rahaman, 1982).

Acknowledgement

The author is grateful to all who assisted him in diverse ways during the research, especially Gabriel Ajogwu who assisted in the field work, Stanley Ani who aided in analyses, F. Ugochukwu who did the cartographic work, M. A. Rahaman who introduced the author to the method of tectonomagmatic discrimination of granitic rocks based on major element geochemistry, A. C. Umeji who read the manuscript and Timi-Odiase Kings who drew the maps using auto-cad software.

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Received 6 Jul 04; revised 13 Jun 05.