K–Ar ages of some metamorphic rocks of Oban massif and their implications for the tectonothermal evolution of Southeastern Nigeria

Barth N. EKWUEME*, Tetsumaru ITAYA** and Hisatomo YABE***

**Department of Geology, University of Calabar, Calabar, Nigeria*

***Research Institute of Natural Sciences, Okayama University
of Science, 1-1 Ridai-cho, Okayama 700-0005, Japan*

E-mail: itaya@rins.ous.ac.jp

****Present address: Sobaraya Co. 3-5-17 Omote-cho,
Okayama 700-0822, Japan*

The following K–Ar ages have been obtained on mineral separates from some metamorphic rocks in the Oban massif: amphibolites (592–930 Ma), banded gneisses (492–538 Ma), granodioritic gneiss (502 Ma), schists (514–519 Ma) and charnockite (481 Ma).

Comparison of these ages with previous dates obtained by the Rb–Sr whole rock method and the Pb–Pb evaporation technique on single zircon throws light on the cooling history and orogenic events in the Oban massif. The banded gneiss in the Oban massif yields a zircon age of 1932 ± 5 Ma, indicating that it was emplaced during the early Proterozoic (Eburnean orogeny). The K–Ar age of 492–538 Ma suggests that these rocks were metamorphosed during the Pan-African orogeny. This age is similar to the Rb–Sr isochron age of 510 ± 10 Ma earlier suggested to be the age of migmatization in the Oban massif.

The amphibolite yielded Rb–Sr isochron ages of 784 ± 31 Ma and 1313 ± 37 Ma. The age of 1313 ± 37 Ma fits into the Kibaran event. The K–Ar hornblende age of 930 ± 37 Ma on the same amphibolite strongly suggests that this amphibolite belongs to an event older than Pan-African (600 ± 150 Ma) and has not been reset perfectly by the Pan-African event.

The migmatitic schists in the Oban massif yielded a Rb–Sr isochron age of 527 ± 16 Ma which has been interpreted as the age of its migmatization. One sample of this schist, however, gave a model age of 676 ± 24 Ma. The K–Ar ages for the Oban massif schists (514–519 Ma) are close to the Rb–Sr isochron age of ca. 527 Ma and confirm that a metamorphic event occurred in the area at this time. This was followed by final cooling at 515 ± 10 Ma.

Charnockite in the Oban area has yielded a zircon age of 584 ± 20 Ma, which is Pan-African. The age possibly dates the time of formation of the charnockites. The K–Ar age (481 Ma) obtained in this study is approximately 100 Ma younger than the zircon age and possibly dates the subsequent cooling of the charnockite through hornblende blocking temperature.

Keywords: K–Ar age, metamorphic rocks, Oban massif, Pan-African, Nigeria

I. Introduction

The Nigerian basement consists dominantly of a gneiss–migmatite complex associated with a supracrustal metavolcanosedimentary series. Intruding these rocks are the older

Granites (Pan-African) and younger Granites (Jurassic) as well as mafic, ultramafic and intermediate rocks (Oyawoye, 1972). Burke *et al.* (1976) and Annor and Freeth (1985) have shown that the Nigerian basement consists of highly deformed and metamorphosed igneous and sedi-

mentary rocks. This complex nature of the basement together with paucity of radiometric data has posed a problem in unravelling the sequence of events and the geologic history of the area.

Early dating techniques of rocks in the Nigerian basement employed predominantly Rb-Sr and K-Ar methods in the southwestern part of the country. The ages obtained showed that the basement is polycyclic (Grant, 1970; Annor and Freeth, 1985). Evidence of Liberian (2800 ± 200 Ma), Eburnean (2000 ± 200 Ma), Kibaran (1300–900 Ma) and Pan African (800–500 Ma) events has been reported (Fitches *et al.* 1985) in the Southwest and Northwest regions. Even then, there are still controversies concerning the exact orogenic events that have affected the Nigerian basement. For instance, Affaton *et al.* (1991) do not believe Kibaran event and Ajibade (1988) is of the view that only the Pan African event affected the Nigerian basement.

Radiometric ages obtained recently for the southeast Nigeria suggest that the area which comprises of Oban-Obudu massif was affected by the Eburnean, Kibaran and Pan-African events. Most of the ages were obtained by the Rb-Sr method. Most recently, some zircon ages was obtained on these rocks of southeast Nigeria based on the Pb-Pb evaporation techniques of single zircon (Ekwueme and Kroner, 1998).

In this study, some metamorphic rocks of the Oban massif have been dated by K-Ar method. The K-Ar ages in other areas have thrown light on the cooling and exhumation history, shown metamorphic grade effects and constrained orogenic events (Easton, 1986; Dombrowski *et al.*, 1994). Muller-Sohnius and Horn (1994) yielded K-Ar ages to determine geochronology of tectonic and magmatic events and were able to constrain the age of deformational episodes and the date of alkaline magmatic events in Kordofan, Sudan. Brock-

amp *et al.* (1994) used the K-Ar method to date period of fluid transport and hydrothermal alteration along fault system in northern Black Forest, Germany. In the present study, K-Ar ages are compared with the available Rb-Sr and zircon Pb-Pb ages in order to unravel the tectonothermal evolution of the Oban massif.

II. Description of metamorphic rocks

The Oban massif is composed of metamorphic rocks which include schists, gneisses, amphibolites and charnockites. These rocks have been intruded mainly by granites, granodiorites and dolerites (Fig. 1). A detailed description has been given in Ekwueme (1990a), Ekwueme *et al.* (1995) and Ekwueme and Kroner (1998). Only a brief description of the analyzed metamorphic rocks is given here.

1. Amphibolites

Amphibolites occur as a minor lithologic unit in the Oban massif (Ekwueme, 1990b). These rocks are closely associated with unmetamorphosed dolerites in the area. They are inter-layered with the migmatitic gneiss, garnet-mica schist, phyllite and kyanite-sillimanite schist in the Oban massif. Ekwueme (1990b) recognised two types of amphibolites in the area: homogeneous and banded varieties. The homogeneous amphibolites occur as rounded massive blocks enclosed within the migmatitic gneisses near Akor and Ndebiji and interlayering with phyllites and garnet-mica schist in Calaro near Uwet (Fig. 1). Foliation is strong in the amphibolites and it trends dominantly $60-70^\circ$ with dips near vertical. This is discordant to the foliation of their host rocks which shows a dominant trend of N-S to NE-SW ($0-30^\circ$). The dominant minerals in the homogeneous amphibolites are hornblende (70%), plagioclase and opaque oxides. The composition of plagioclase ranges from An 30–40 whilst the hornblende is brownish in colour. Some samples are enriched in garnet crystals

and these define a linear chain which enhances the foliation. Accessory minerals in the homogeneous amphibolites are quartz, chlorite, biotite, calcite and epidote.

The banded amphibolites occur as massive outcrops in the channels of Erokut River in Awi near Oban. The rock is thinly banded and has a sharp contact relationship with the migmatitic gneisses and schists. It is also associated with pegmatitic granite. The banded amphibolite is medium- to coarse-grained and has a foliation which dips of 20 to 30° in the north-east. Near vertical dips were also recorded in some outcrops. Isoclinal folds with axes trending 250° and undeformed mafic dykes trending 146° were mapped in the banded amphibolite. All minerals identified in the homogeneous amphibolites also occur in the banded variety. In addition, quartzo-feldspathic layers (25%) are the distinct features of the banded amphibolite. The bands are thought to be prod-

ucts of metamorphic differentiation by high-grade regional metamorphism rather than primary sedimentary layering. The restriction of the banded amphibolite to the area above the kyanite-sillimanite isograd of Ekwueme and Onyeagocha (1985) and its close association with migmatitic gneisses and schists are evidence that high-grade metamorphism affected this amphibolite (Ekwueme, 1990a).

Chemically, the amphibolites are olivine tholeiites (Table 1) and resemble those emplaced in the ocean-floor and island-arc environment. The compositions plot in the fields on discriminating diagrams which indicate within-plate and/or plate-margin tectonic setting (Ekwueme, 1990b).

2. Charnockites

Charnockites occur widely in the Nigerian basement and have been reported in all regions of the country (Oyawoye and Makanjuola, 1972). This has led to the suggestion that there

Table 1. Average major element composition of some metamorphic rocks of Oban massif, SE Nigeria

Rock Type	Amphibolite		Charnockite	Banded gneiss	Granite gneiss		Schist
Location	Uwet	Akor	Orem	Oban	Ikot Ekperem	Ikot Ekperem	Ikot Ekperem
SiO ₂	50.00	42.60	62.23	62.52	69.71	64.79	
TiO ₂	1.26	4.50	0.67	0.50	0.71	0.90	
Al ₂ O ₃	12.10	15.00	16.78	14.32	15.13	15.56	
Fe ₂ O ₃	2.10	2.10	7.43	4.38	2.70	6.39	
FeO	10.00	18.00	nd	nd	nd	nd	
MgO	8.86	5.17	0.31	1.28	1.06	3.07	
MnO	0.19	0.31	0.10	0.40	0.03	0.13	
CaO	8.30	9.40	3.84	2.19	2.43	2.14	
Na ₂ O	1.82	1.32	2.88	3.18	3.87	3.55	
K ₂ O	2.36	0.39	4.71	4.61	3.55	2.21	
P ₂ O ₅	0.13	0.22	0.29	0.20	0.14	0.17	
LOI	1.34	0.55	0.12	1.42	0.67	0.72	

was once widespread granulite facies metamorphism as represented by the distribution of charnockites (Hubbard, 1975; Ekwueme, 1990c; Affaton *et al.*, 1991). However, some workers believe that charnockites in Nigeria are magmatic rocks intruded into the migmatite-gneiss complex (Orajaka, 1971; Rahaman and Ocan, 1978; Tubosun *et al.*, 1984). Cooray (1977) and Newton (1992) have shown that both magmatic and metamorphic charnockites occur and field criteria could be used to distinguish them.

In the Oban massif, charnockites form part of the Precambrian basement rocks. They occur both in the eastern and western part of the Oban massif. In the eastern Oban (Fig. 1), the charnockites trend northeasterly and are best exposed at Orem, Ntebachot, Nyaje, Ikpai, Owom and in channels of Achan River near the Cameroon border (Ekwueme and Caen-Vachette, 1992). These rocks occur as large, coarse-grained, rounded and massive bodies that are greenish for fresh outcrop but brownish for spheroidally weathered one. They show a foliation trend of N-S to NE-SW which is parallel to the foliation of migmatitic gneisses and amphibolites associated with them. Unlike the occurrences in southwest Nigeria

(Tubosun *et al.*, 1984), the charnockites in the eastern Oban massif are not very closely associated with granites. Rather, intermediate rocks (diorite, syenite, quartz-monzonite) and basic rocks (dolerites, amphibolites) occur together with the charnockitic rocks. Ekwueme (1990a) has shown that the diorites and charnockites are similar in composition and that the former may be a retrogressive product of the latter. The charnockites in the eastern Oban massif were analyzed in this study. They qualify as metamorphic charnockites (granulite) under Cooray's (1977) classification because they are foliated and associated with high-grade metamorphic rocks (Ekwueme, 1990a). Mineralogically these charnockites are composed of microperthite (25%), amphibole (15%), plagioclase of An 27-30 (22%), quartz (27%), orthopyroxene (4-11%). In the western Oban massif, charnockites appear as an intrusive into garnet mica schists of Ekwueme and Onyeagocha (1985) (see also Ekwueme *et al.*, 1995). These charnockites are coarse-grained and unfoliated. They have not been analyzed in this study.

The chemical composition of the charnockite is shown in Table 1. It has relatively high alkali content indicating the alkaline nature of

the magmatic precursor.

3. Schists

The schists in the basement of southeastern Nigeira was confirmed by Ekwueme (1994). Schists occur in both the Oban Hills and Obudu Plateau. They range from low to kyanite-sillimanite grade and are migmatitic in part.

In this study, the schists analyzed are those occurring on the Nigerian geological sheet 314 (Ugep SW), which covers the northwestern part of the Oban massif. These are the first isotopic ages on schist. Ekwueme (1990d) has described the schists in southwest Ugep where low-grade metamorphic rocks occur. They are generally fine-grained and foliated. The foliation dips moderately ($15-30^\circ$) towards the east. Some quartz crystals in the rock are elongated and define a stretched lineation in the schist. This lineation is parallel to the foliation and plunges $24-30^\circ$. In places where schists in the area have been intruded by pegmatites, rods of tourmaline define a lineation in the rocks. In Ikot Ekperem, the schists were affected by faulting.

On the basis of petrography, the schists in northwest Oban have been classified into quartz-mica and garnet-mica schists (Ekwueme, 1990d). The dominant minerals in the two types of schists are quartz (20-35%), phyllosilicates (muscovite, chlorite and biotite, 41-52%), untwinned plagioclase (8-10%). In addition, tourmaline (13%) is an important phase in quartz-mica schist whilst garnet (10%) occurs in the garnet-mica schist. Ekwueme (1995) has shown that the schists are metasedimentary rocks derived from predominantly pelitic protolith. The chemical composition of the schist is given in Table 1.

4. Banded gneiss

In the eastern Oban massif, migmatitic gneisses consisting of agmatite and banded gneiss are the dominant rock types. They are associated with pegmatitic granites, pegmatitic

boulders and pegmatitic veins. The banded gneiss is more abundant than the agmatite, and the best exposures occur in the now abandoned Nigerian Mining Corporation Quarry in the Oban village (Fig. 1). It is coarse-grained and conspicuously banded ranging from 1cm to 3 cm in thickness. The leucocratic (light) bands are composed predominantly of quartz and K-feldspar, whereas the melanocratic (dark) bands contain chlorite, biotite and garnet. The minerals forming the dark portion of the banded gneiss show a strong axial plane foliation. Folds are tight to isoclinal, though chevron, recumbent and pygmatic folds also occur. Boudinage and pinch-and-swell structures are common on the fold limbs. The banded gneiss in the Oban massif therefore classifies on the basis of structure as 'early migmatite' described by Ajibade (1988).

The average major element composition of banded gneiss is shown in Table 1. The rock is similar to an orthogneiss derived from a granodioritic protolith (Ekwere and Ekwueme, 1991). It plots in the arc-syn collisional field of Pearce *et al.* (1984). The protolith was a calc-alkaline intrusive rock (Ekwere and Ekwueme, 1991).

The gneiss from southwest Ugep in the northwest Oban massif was also analyzed in this study and has a similar composition with the banded gneiss in the eastern Oban.

III. K-Ar age determination

Two amphibolites, one charnockite, two schists, three banded gneisses and one granodioritic gneiss (Table 2) were selected for dating. The samples selected were relatively fresh and the locations are shown in Fig. 1.

The selected samples were crushed and sieved. Plagioclase, biotite and/or hornblende were separated from the amphibolites, hornblende from charnockite, muscovite and biotite from schists, and biotites from the banded

Table 2. K-Ar age data of mineral separates from some metamorphic rocks of Oban Massif, SE Nigeria

Sample Number	Location	Rock Type	Mineral	Lab. No.	K(wt.%)	Rad. ^{40}Ar (10^{-6}ccSTP/g)	Age(Ma)	Non-rad. argon(%)
L22	Uwet	amphibolite	biotite	S30-181	5.300 ± 0.106	14410 ± 170	592 ± 12	0.7
			plagioclase	S30-243	0.401 ± 0.020	402.5 ± 4.3	242 ± 12	3.6
NN2	Akor	amphibolite	hornblende	S30-183	0.460 ± 0.023	2171 ± 23	930 ± 37	2.9
			plagioclase	S30-242	0.266 ± 0.013	889.3 ± 9.2	704 ± 30	2.1
OR1	Orem	charnockite	hornblende	S30-182	0.630 ± 0.013	1348 ± 14	481.0 ± 9.5	2.0
256	Ikot Ekperem	schist	muscovite	S30-148	7.823 ± 0.156	18080 ± 190	514.5 ± 10.1	0.3
AT2	Akpet	schist	biotite	S30-93	7.130 ± 0.143	16630 ± 190	519 ± 10	0.3
180	Ikot Ekperem	granitic gneiss	biotite	S30-94	6.960 ± 0.139	15630 ± 160	501.9 ± 9.8	0.2
OQ4	Oban	banded gneiss	biotite	S30-91	7.110 ± 0.142	16590 ± 180	519 ± 10	0.2
OMB4	Oban	banded gneiss	biotite	S30-187	7.647 ± 0.153	16810 ± 180	492.6 ± 9.7	0.5
OB1	Oban	banded gneiss	biotite	S30-186	7.255 ± 0.145	17650 ± 190	538 ± 11	0.3

gneisses. The method used to concentrate mineral separates is based on physical properties such as specific gravity and magnetic susceptibility. Plagioclase separates were treated with diluted HCl acid and then washed in an ultrasonic bath with distilled water.

Analyses of potassium and argon in mineral separates and calculations of ages and errors were carried out following the methods described by Nagao *et al.* (1984) and Itaya *et al.* (1991). Potassium was analyzed by flame photometry using a 2000 ppm Cs buffer. Its analytical error is within 2% at the 2 sigma confidence level. Argon was analyzed on a 15 cm radius sector type mass spectrometer with a single collector system using an isotopic dilution method and an argon 38 spike (Itaya *et al.*, 1991). Multiple runs of standard (JG-1 biotite, 91 Ma) indicate that the error of argon analysis is about 1% at the 2 sigma confidence level. The decay constants for ^{40}K to ^{40}Ar and ^{40}Ca , and ^{40}K content in potassium used in the age calculation are from Steiger and Jäger (1977) and are $0.581 \times 10^{-10}/\text{year}$, $4.962 \times 10^{-10}/\text{year}$ and 0.0001167, respectively.

IV. Results and their evaluations

The results of the analyses are listed in Table 2. The amphibolites of west Oban massif are significantly younger than those of east Oban. The plagioclase K-Ar age of 242 ± 12 Ma obtained from the west Oban massif amphibolite appears meaningless. The biotite K-Ar age of 592 ± 12 Ma is significant and indicates that these rocks were metamorphosed during the Pan-African orogeny. Rb-Sr whole rock ages of 527 ± 16 Ma and 672 ± 24 Ma had earlier been obtained from the Uwet schists with which the amphibolites are interlayered (Ekwueme *et al.*, 1988). The plagioclase K-Ar age of 704 ± 30 Ma confirms that these rocks were also affected by the Pan-African event. This age is comparable to the Rb-Sr whole-rock isochron age of 784 ± 31 Ma obtained on banded amphibolite in Awi (Ekwueme and Caen-Vachette, 1989). However, the hornblende age of 930 ± 37 Ma is significantly older than the generally accepted Pan-African age range of 800–500 Ma (Liegeois *et al.*, 1994). Ekwueme and Caen-Vachette (1989) reported a Rb-Sr whole rock isochron age of 1313 ± 37 Ma on this amphibolite and interpreted it as

regional metamorphic episode accompanying Kibaram (1300–1000 Ma) orogeny (Cahen *et al.*, 1984). The K–Ar age of 930 ± 37 Ma appears to confirm that these amphibolites formed in an event older than Pan–African and have not been reset perfectly by the Pan–African event.

The K–Ar ages obtained from charnockites, schists and gneisses in the Oban massif fall within the Pan–African range of 800–500 Ma. This indicates the dominance and the pervasiveness of the Pan–African event in this area. The consistency of the ages is indicative of their geological significance (Muller-Sohnius and Horn, 1994). Discordance in K–Ar ages with Rb–Sr and $^{40}\text{Ar}/^{39}\text{Ar}$ ages for the same rock suite suggests possible presence of excess argon (Reddy *et al.*, 1993).

V. Discussion

The Pan–African orogeny is the only undisputed tectonothermal event believed to have affected the Nigerian basement. Paucity of radiometric age data has, however, hampered the full understanding of the nature of the Pan–African event in the West Africa shield. There is also a difficulty to understand it with the occurrence of relict ages of Liberian, Ebunian and Kibaran orogenies within the Pan–African belt. This perhaps led Ajibade and Wright (1989) to propose that the Southern Pan–African domain in west Africa is an aggregation or “mosaic” of island arc, interarc (ensimatic) basins and continental fragments. In a similar manner, Liegeois *et al.* (1994) and Black *et al.* (1994) suggested that the eastern Tuareg shield is a collage of three displaced terrains shaped, and partly accreted during the Pan–African orogeny (750–550 Ma), but not as a homogeneous body. They formulated a geodynamic model characterized by a two-stage Pan–African orogeny. The early Pan–African (750–660 Ma) was a strong collisional event whilst the late Pan–African orogeny (650–

580 Ma) produced large horizontal displacements and high K calc-alkaline batholiths. The K–Ar ages obtained in this study from the metamorphic rocks in the Oban massif fit into the late Pan–African event of Liegeois *et al.* (1994). An exception is the amphibolites of the eastern Oban massif which appear to be early Pan–African to Kibaran in age.

K–Ar ages have been interpreted as cooling and exhumation ages, and the deformation timing accompanying the exhumation (Itaya and Fukui, 1994). Watkins *et al.* (1994) believe that internally consistent K–Ar ages provide close estimates of ages of crystallization. Easton (1984, 1986) observed that the Rb–Sr and K–Ar ages obtained from rocks of the Yellow knife Greenstone Belt and the Grenville province both in Canada are generally about 100 Ma younger than the corresponding zircon ages from the same rock unit. The clustering of K–Ar and Rb–Sr ages was significant in Spessart crystalline complex, NW Bavaria Germany (Dombrowski *et al.*, 1994). This was thought to provide an age of crystallization in the Brandberg and Okenyenya igneous complexes, Namibia (Watkins *et al.*, 1994) and was interpreted as recording a short period of rapid uplift following deformation and amphibolite facies metamorphism (see also Kroner *et al.*, 1992).

The Rb–Sr whole-rock ages on schist, charnockite, banded gneiss and amphibolite are also shown in Table 3 which shows some coherence with the K–Ar ages. The age concordance confirms the geological significance of the ages and suggests that the rocks were not significantly affected by over printing or initial excess radiogenic argon (Watkins *et al.*, 1994). Zircon ages have been obtained for the charnockite and banded gneiss using the Pb–Pb evaporation techniques (Ekwueme and Kroner, 1998). The Zircon age of the charnockite in the Oban massif is 584 ± 20 Ma whilst that of

Table 3. Comparison of Rb-Sr whole rock ages (Ekwueme *et al.*, 1988; Ekwueme, 1990a; Ekwueme *et al.*, 1991; Ekwueme, 1992), Pb-Pb zircon ages (Ekwueme and Kroner, 1998) and K-Ar ages (This study) on the same rock suites within the Oban Massif, SE Nigeria

Rock Type	Location	Rb-Sr age (Ma)	Pb-Pb zircon age (Ma)	K-Ar age (Ma)
amphibolite	Akor	1313 $\pm$ 37		930 $\pm$ 30
				704 $\pm$ 30
	Uwet			592 $\pm$ 12
				242 $\pm$ 12
	Awi	784 $\pm$ 31		
charnockite	Orem	1289 $\pm$ 153	584 $\pm$ 10	481 $\pm$ 10
	Orem	546 $\pm$ 24		
schist	Kwa Falls	527 $\pm$ 16		
	Kwa Falls	576 $\pm$ 24		
	Akpet			519 $\pm$ 10
	Ikot Ekperem			515 $\pm$ 10
gneiss	Ikot Ekperem			502 $\pm$ 10
	Oban			519 $\pm$ 10
	Oban			493 $\pm$ 10
	Oban		1932 $\pm$ 5	538 $\pm$ 11
	Mbarakpa	510 $\pm$ 11		
	Old Netim	676 $\pm$ 26		

banded gneiss is 1932 ± 5 Ma. The Rb-Sr age of the charnockite is 546 ± 24 Ma whilst no reliable Rb-Sr isochron age was obtained from the banded gneiss. An agmatite in the Oban massif, however, yielded a Rb-Sr isochron age of 510 ± 11 Ma (Ekwueme *et al.*, 1991; Ekwueme, 1992). The K-Ar age for the charnockite is like those in the Grenville Province approximately 100 Ma younger than the zircon age for the rock.

It appears from the K-Ar dates that the periods of cooling and date of uplift/deformation differed from one type of rocks to the other in the Oban area, although these events took place mainly during the late Pan-African period.

VI. Conclusion

K-Ar ages obtained from some metamorphic rocks of the Oban massif indicate that the area was significantly affected by the late Pan-African. However, some amphibolites have not been reset perfectly by the Pan-African event. During these periods, metamorphism

ranging from middle greenschist to amphibolite facies was accompanied by cooling and exhumation and associated deformation of the rocks. The rate of cooling and uplift seem to differ from one metamorphic rock to the other in the Oban massif. The available Rb-Sr whole rock isochron ages are comparable with the K-Ar mineral ages obtained in this study but both are significantly younger than the zircon ages which are interpreted here as dating the emplacement of the rocks.

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References

- Affaton, P., Rahaman, M.A., Trompete, R. and Sough, J. (1991), The Dahomeyide orogen: tectonothermal evolution and relationships with the Volta Basin. In *The west African orogens and circum-Atlantic correlative* (Dallmeyer, R.D. and Lecorche, J. Eds.). Springer-Verlag, New York, 107-122.
- Ajibade, A.C. (1988), Structural and tectonic evolu-

- tion of the Nigerian basement with special reference to NW Nigeria. Intern. Conf. Proterozoic Geol. High-grade terrains, Univ. Ife, Nigeria, 22.
- Ajibade, A.C. and Wright, J.B. (1989), The Togo-Benin-Nigeria shield: Evidence of crustal aggregation in the Pan-African belt. *Tectonophys.*, **165**, 125-129.
- Annor, A.E. and Freeth, S.J. (1985), Thermo-tectonic evolution of the basement complex around Okene, Nigeria, with special reference to deformation mechanism. *Precambrian Res.*, **28**, 269-281.
- Black, R., Latouche, L., Liegeois, J.P., Caby, R. and Bertrand, J.M. (1994), Pan-African displaced terranes in the Tuareg shield (Central Sahara). *Geology*, **22**, 641-644.
- Brockamp, O., Clauer, N. and Zuther, M. (1994), K-Ar dating of episodic Mesozoic fluid migrations along the fault system of Gernbach between the Moldanubian and Saxothuringian (Northern Black Forest), Germany. *Geol. Rundsch.*, **83**, 180-185.
- Burke, K., Freeth, S.J. and Grant, N.K. (1976), The structure and sequence of geological events in the basement complex of the Ibadan area, Western Nigeria. *Precambrian Res.*, **3**, 537-545.
- Cahen, L., Snelling, N.J., Delhal, J. and Vail, J.R. (1984), The geochronology and evolution of Africa. pp 512, Clarendon Press, Oxford.
- Cooray, P. (1977), Classification of the charnockitic rocks of Nigeria. *J. Min. Geol.*, **14**(2), 1-6.
- Dombrowski, A., Okrusch, M. and Henjest-Kunst, F. (1994), Geothermobarometry and geochronology on mineral assemblages of orthogneisses and related metapelites of the Spessart crystalline complex, NW Bavaria, Germany. *Chem. Erde.*, **54**, 85-101.
- Easton, R.M. (1984), Compilation of geochronologic data for the Yellow knife greenstone belt and vicinity, district of Mackenzie, N.W.T. *Contrib. Geol. N.W.T.*, **1**, 1-20.
- Easton, R.M. (1986), Geochronology of the Grenville Province. In *The Grenville Province* (Moore, J.M., Davidson, A. and Baer, A.J. Eds.). Geological Association of Canada Special Paper, 31, 127-173.
- Ekwere, S.J. and Ekwueme, B.N. (1991), Geochemistry of Precambrian gneisses in the eastern part of the Oban massif, South Eastern Nigeria. *Geol. Mijinb.*, **70**, 105-114.
- Ekwueme, B.N. (1990a), Rb-Sr ages and petrologic features of Precambrian rocks from the Oban massif, South Eastern Nigeria. *Precambrian Res.*, **47**, 271-286.
- Ekwueme, B.N. (1990b), Mafic dykes in the Precambrian basement of southeastern Nigeria. In *Mafic dykes and Emplacement Mechanism* (Paker, A.J., Rickwood, P.C. and Tucker, D.H. Eds.). A.A. Balkema, Rotterdam, 295-311.
- Ekwueme, B.N. (1990c), Petrology of southern Obudu Plateau, Bamenda Massif, South Eastern Nigeria. In *Recent data in Africa Earth Sciences* (Rocci, G. Deschamps, M. Eds). CIFEG Occasional Publication, Paris, France, 155-158.
- Ekwueme, B.N. (1990d), On the occurrence of crystalline (basement complex) rocks in SW Ugep, Nigeria. *J. Min. Geol.*, **26**(1), 69-74.
- Ekwueme, B.N. (1992), Rb-Sr age of Pan-African migmatites in the Oban massif of South Eastern Nigeria. *J. Afr. Earth Sci.*, **15**, 65-72.
- Ekwueme, B.N. (1994), Structural features of southern Obudu Plateau, Bamenda massif, SE Nigeria: preliminary interpretations. *J. Min. Geol.*, **30**(1), 45-59.
- Ekwueme, B.N. (1995), Geochemistry of crystalline basement rocks in SW Ugep, Nigeria. Dec-Ford *J. Pure and Appl. Sci.*, **1**, 15-28.
- Ekwueme, B.N. and Caen-Vachette, M. (1989), Kibaran ages from the Oban massif in the Pan-African belt of Nigeria. *J. Afr. Earth Sci.*, **9**, 719-723.
- Ekwueme, B.N. and Caen-Vachette, M. (1992), Kibaran charnockites in Oban massif in the Pan-African belt of Nigeria. *IGCP Project 255 Newsletter/Bulletin* **4**, 67-71.
- Ekwueme, B.N. and Kroner, A. (1998), Single zircon evaporation ages from the Oban massif, South Eastern Nigeria. *J. Afr. Earth Sci.*, **26**(2), 195-205.
- Ekwueme, B.N. and Onyeagocha, A.C. (1985), Metamorphic isograds of Uwet area, South Eastern Nigeria. *J. Afr. Earth Sci.*, **3**(4), 443-454.
- Ekwueme, B.N. and Onyeagocha, A.C. (1986), Geochemistry of metasedimentary rocks of Uwet area, Oban massif, South Eastern Nigeria. *Geol. Rundsch.* **75**, 411-420.
- Ekwueme, B.N., Caen-Vachette, M. and Onyeagocha, A.C. (1988), Rb-Sr geochronology of metasedimentary schists and gneisses in the Oban massif, South Eastern Nigeria. *J. Min. Geol.*, **24**, 119-124.
- Ekwueme, B.N., Caen-Vachette, M. and Onyeagocha, A.C. (1991), Isotopic ages from the Oban

- massif and southeast Lokoja: implications for the evolution of the basement complex of Nigeria. *J. Afr. Earth Sci.*, **12**(3), 489-503.
- Ekwueme, B.N., Nyong, E.E. and Petters, S.W. (1995), Geological Excursion Guidebook to Oban massif, Calabar Flank and Mamfe embayment, South Eastern Nigeria. pp. 36, Dec-Ford Publishers, Calabar, Nigeria.
- Fitches, W.R., Ajibade, A.C., Egbuniwe, I.G., Holt, R. and Wright, J.B. (1985), Late Proterozoic schist belts and plutonism in NW Nigeria. *J. Geol. Soc. London*, **142**, 319-337.
- Grant, N.K. (1970), Geochronology of Precambrian basement rocks from Ibadan, Southwestern Nigeria. *Earth Planet. Sci. Lett.*, **10**, 29-38.
- Hubbard, F.H. (1975), The Precambrian crustal development in Western Nigeria: indications from the Iwo region. *Bull. Geol. Soc. Amer.*, **86**, 548-554.
- Itaya, T. and Fukui, S. (1994), Phengite K-Ar ages of schists from the Sanbagawa southern marginal belt, central Shikoku, SW Japan: Influence of detrital mica and deformation on age. *Island Arc*, **3**, 48-58.
- Itaya, T., Nagao, K., Inoue, K., Honjou, Y., Okada, T. and Ogata, A. (1991), Argon isotope analysis by a newly developed mass spectrometric system for K-Ar dating. *Mineral. J.*, **15**(5), 203-221.
- Kroner, A., Pallister, J.S. and Fleck, R.J. (1992), Age of initial oceanic magmatism in the late Proterozoic Arabian shield. *Geology*, **20**, 803-806.
- Liegeois, J.P., Black, R., Navez, J. and Latouche, L. (1994), Early and late Pan-African orogenies in the Air assembly of terranes (Tuareg shield, Niger). *Precambrian Res.*, **67**, 59-88.
- Muller-Sohnius, D. and Horn, P. (1994), K-Ar dating of ring complexes and fault systems in Northern Kordofan, Sudan: evidence for independent magmatic and tectonic activity. *Geol. Rundsch.*, **83**, 604-613.
- Nagao, K., Nishido, H., Itaya, T. and Ogata, K. (1984), K-Ar age determination. *Bull. Hiruzen Res. Inst.*, **9**, 19-38.
- Newton, R.C. (1992), An overview of charnockite. *Precambrian Res.*, **55**, 399-405.
- Orajaka, S. (1971), The petrogenesis of the Obudu-type enderbite. *J. Mines, Metals, Fuels (Cuttia)*, 94-98.
- Oyawoye, M.O. (1972), The basement complex of Nigeria. In African geology (Dessauvague, T. F.J. and Whiteman, A.J. Eds.). Ibadan Univ. Press, Nigeria, pp. 67-99.
- Oyawoye, M.O. and Makanjuola, A.A. (1972), Bauxite: a fayalite-bearing quartz monzonite. 24th Intern. Geol. Congress. Section 2, 251-266.
- Rahaman, M.A. and Ocan, O.O. (1978), On relationships in the Precambrian migmatitic gneisses of Nigeria. *J. Min. Geol.*, **15**, 23-32.
- Reddy, S.M., Cliff, R.A. and East, R. (1993), Thermal history of the Sonnblick Dome, Southeast Tauern window, Austria: implications for heterogeneous uplift within the Pennine basement. *Geol. Rundsch.*, **82**, 667-675.
- Steiger, R.H. and Jäger, E. (1977), Subcommission on geochronology convention on the use of decay constants in geochronology and cosmochronology. *Earth Planet. Sci. Lett.*, **36**, 359-62.
- Tubosum, I.A. Lancelot, J.R., Rahaman, M.A. and Ocan, O.O. (1984), U-Pb Pan-African ages of two charnockite-granite associations from southwestern Nigeria. *Contrib. Mineral. Petrol.*, **88**, 188-195.
- Watkins, R.T., McDougall, I. and LeRoex, A.P. (1994), K-Ar ages of the Brandberg and Okenyenya igneous complex, northwestern Namibia. *Geol. Rundsch.*, **83**, 348-356.

ナイジェリア東南部オバン地塊変成岩類の K-Ar 年代とその意味

Barth N. Ekwueme, 板谷徹丸, 矢部久智

ナイジェリア東南部オバン地塊に産する代表的な変成岩類の鉱物 K-Ar 年代測定を実施した。角閃岩の年代は 592-930 Ma であった。縞状片麻岩が 492-538 Ma で花崗片麻岩は 502 Ma である。結晶片岩が 514-519 Ma で、チャーノックイトが 481 Ma であった。得られた鉱物 K-Ar 年代のほとんどは凡アフリカン変動の年代範囲に入ることから、凡アフリカン造山帯の構成岩類と判断される。しかし、角閃岩類の一部は 930 Ma の角閃石年代を示した。それは明らかに凡アフリカン変動より古い時代に形成された角閃岩を示唆するが、凡アフリカン変動での完全なリセットを免れたと判断される。結晶片岩の白雲母年代 (514 Ma) と黒雲母年代 (519 Ma) は本地域から得られた最初の放射年代であり、凡アフリカン変動の結晶片岩であることを示している。