

U-Pb GEOCHRONOLOGY OF METASEDIMENTARY SCHISTS IN AKWANGA AREA OF NORTH CENTRAL NIGERIA AND ITS IMPLICATIONS FOR THE EVOLUTION OF THE NIGERIAN BASEMENT COMPLEX

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ABSTRACT

The geology of Akwanga area of northcentral Nigeria is dominated by schists, metaigneous gneisses and weakly to non-foliated granites. The Schist shows grades up to the sillimanite zone of the Barrovian type regional metamorphism and occurs as xenoliths in other rocks of the area. The zircons separated from a sample of the Schists show growth zoning and a number of grains display distinct cores and rims. Out of 131 analyses 117 yielded useful geochronological data. 67 of these gave 90-110% concordant results. Most ages scatter between 600 and 1100Ma with distinct peaks at 700, 850 and 1000Ma. A few Archaean Zircons are also present but a minority of grains yielded Palaeoproterozoic ages (1700-2200Ma). These first-ever geochronological data from rocks of Akwanga area are further evidence of the polycyclic nature of the Nigerian basement. They confirm that the Pan-African orogeny, though pervasive, did not obliterate traces of earlier events in the Akwanga area.

KEYWORDS: Akwanga, Zircon, Archaean, Palaeoproterozoic, Polycyclic.

INTRODUCTION

McCurry (1976) recognized two classes of metamorphic rocks of sedimentary origin in the Nigerian Basement complex: the "Older Metasediments" was used to describe metasedimentary rocks deposited some 2,500Ma ago surviving in gneisses and migmatites. Oyawoye(1964) and Rahaman (1976) referred to these rocks as older metasedimentary series or the gneiss-migmatite-quartzite complex. "Younger metasedimentary belts" were considered to have been deposited some 1000-800Ma ago. This group of rocks is also referred to as the Newer metasedimentary series and comprise pelites and semi-pelites that have been metamorphosed to form migmatized to non-migmatized paraschists in the Basement Complex of Nigeria (Oyawoye 1972; Rahaman 1976; Ajibade 1979). It was earlier thought that the Newer Metasediments occupy N-S trending belts (schist belt), that they are isoclinally infolded into the older metasediments and that they are restricted to the western half of Nigeria. Extensive geologic mapping and detailed geochronological studies have shown that both the Older and Newer Metasediments occur in every part of Nigeria (Ekwueme and Onyeagocha 1985; Ekwueme and Kroner 1997; Kroner et al. 2001).

In this contribution, metasedimentary rocks in the Akwanga area of northcentral Nigeria have been isotopically studied with a view to determining their ages

and their implication for the tectonothermal evolution of the Nigerian Basement Complex.

BRIEF DESCRIPTION OF METASEDIMENTS

Onyeagocha (1979, 1984) and Onyeagocha and Ekwueme (1982) carried out a pioneer geological mapping of Akwanga area of northcentral Nigeria. These authors mapped the northwest quadrant of the Nigerian topographic sheet 209 (Akwanga NW) in detail. The area lies between longitudes 8° 00'E and 8° 15'E and latitudes 8° 45'N and 9° 00'N and belongs to the Nigerian Basement complex.

The rocks in the area include Schists which are the metasediments, augen gneiss and granite gneiss which are thought to be metaigneous. They were intruded by granites, pegmatites and dolerites (Fig. 1.)

The metasediments in Akwanga area are schists and these were described by Onyeagocha (1984) as River Andu schists and gneisses, migmatites, metaquartzites and ultramafic schists (Fig.1). Ekwueme (1978) mapped and studied in detail the schists in Kokona area which is the southwest part of northwest Akwanga area. This schist has been dated in this study. According to Ekwueme (1978) about one-third of Kokona area is underlain by schists. The largest outcrops occur in the valley of the tributary of River Andu which drains the area. Schists also occur as inclusions in other rocks in the area e.g. in Sabon

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Gida Augen Gneiss in which case it is unmappable. In the stream channel and south of Sabon Gida, a massive fresh outcrop of schists occurs. The schists is fine-grained in texture and dark in colour. The schistosity strikes northeast. This schist extends to Tudun Wada in the central part of Kokona area. Here, It is medium grained and thinly banded (1-2mm wide). The light band is composed of feldspar and quartz whilst the dark band shows parallel alignment of biotite. The layers are possibly indicative of the sedimentary origin of the schists.

As noted by Onyeagocha (1984) the River Andu schist is in many locations e.g. west of Garaku to Angwan Mayo (Fig. 1) intermingled with migmatite and migmatitic gneiss. They are also associated with pegmatitic veins and dykes and in one location at Angwan Mayo the schist with E-W foliation trend has been transected by migmatite trending N-S. Onyeagocha and Ekwueme (1982) pointed out that such offset of foliation trends depicts that at least two deformation episodes affected the rocks in the Akwanga area and that the E-W trend represents the earlier pre-Pan African deformation whilst the N-S trend is due to the Pan-African tectonothermal event (cf. Grant 1978; Mullan 1979).

Petrography: Ekwueme (1978) identified three categories of schists on basis of petrography in the Kokona area: Mica schist, Hornblende-biotite schist and Garnetiferous mica schist. The modal composition of these schists are shown in Table 1. The mica schist is medium-grained and prismatic tourmaline crystals up to 5mm long occur in some samples. Plagioclase composition is An26-32 and the crystals are polysynthetically twinned. A sample from Gudindi contains staurolite (up to 10%). The presence of staurolite indicates that the protolith of the schist was possibly pelitic in composition. The Hornblende biotite schist is coarse grained. The anorthite content of plagioclase in this schist is An26-33. Some portions of this schist is banded.

On the basis of the petrography of the River Andu schist, Onyeagocha (1984) assigned the Akwanga area to the Barrovian type of regional metamorphism. The occurrence of kyanite and silimanite in some River Andu schist samples is an evidence of high-grade metamorphism. The plagioclase composition ranges from oligoclase to andesine and schists and gneisses in the area are associated with anatectic migmatites and granites indicative of temperature high enough to initiate partial melting. Onyeagocha and Ekwueme (1990) estimated the temperature in Akwanga area to have reached 600-750°C whilst their estimate for pressure is 5-8kbar.

GEOCHEMISTRY

Kalsbeek et al. (2012) analyzed a representative sample of the schist in Kokona area and the chemical composition is shown in Table 2. A plot of the chemical data on the Na₂O/Al₂O₃ against K₂O/Al₂O₃ diagram of Garrels and Mackenzie (1971) used to discriminate between metaigneous and metasedimentary rocks shows that the protolith of the schist was sedimentary. Na₂O is however higher than K₂O in the rock indicating that it is a greywacke or semi-pelitic. The composition approximates that of an average greywacke reported in Pettijohn (1975). Infact, the schist plots in the field of Franciscan greywacke of Brown et al. (1979) in the SiO₂ vs CaO diagram. And in the ACF diagram of Winkler (1967) the Akwanga schist plots in the field of greywacke. The Niggli norm of the schist was calculated and it shows positive quarzal (q= +138) and upto 38% Niggli al. A plot of Niggli al – alk vs. Niggli C shows that the rock falls outside the igneous envelop confirming that the parent rock was sedimentary.

Kalsbeek et al. (2012) also obtained Rb-Sr and Sm-Nd data for the Akwanga schist (Table 4). The Th/U value of the schist is also shown in Table 4. The Initial ⁸⁷Sr/⁸⁶Sr ratio of 0.71879 indicates that the schist is a product of tectonothermal reworking of crustal sediments at about 600Ma ago. The Th/u ratio is 0.61 whilst the Tdm is 1.46. it has an End (600) value of -1.12, suggesting it contains mainly Neoproterozoic detrital material.

GEOCHRONOLOGY

The schist from Kokona analyzed in this study was collected from 08°01'N and 08°48'E in the Akwanga area of northcentral Nigeria. Zircons for U-Pb geochronology were separated using standard techniques-crushing and sieving to <300µm, washing on a Holman-Wilfley shaking table followed by hand picking. Hand picked zircon grains were set in 1-inch epoxy mounts, sectioned and polished to approximately half their thickness. Back-scatter images of the zircons were obtained by Scanning Electron Microscopy (SEM) at the Geological Survey of Denmark and Greenland (GEUS) and analytical spots (diameter 25µm) were selected with the help of the SEM images. Isotopic analysis was performed by laser ablation single collector magnetic sector field-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at GEUS, using a Thermo-Fischer Element 11 sector field ICP-MS coupled to a Newwave UP213nm Nd-YAG laser ablation unit. The methods applied essentially follow those of Gerdes and Zeh (2006), Frei et al. (2006) and Frei and Gerdes (2009).

The GJ-1 zircon (609Ma), Jackson et al. (2004) was used as primary standard. The chronological data were presented as ²⁰⁷Pb/²⁰⁶Pb age probability diagrams prepared with the help of the Age Display programme of Sircombe (2004).

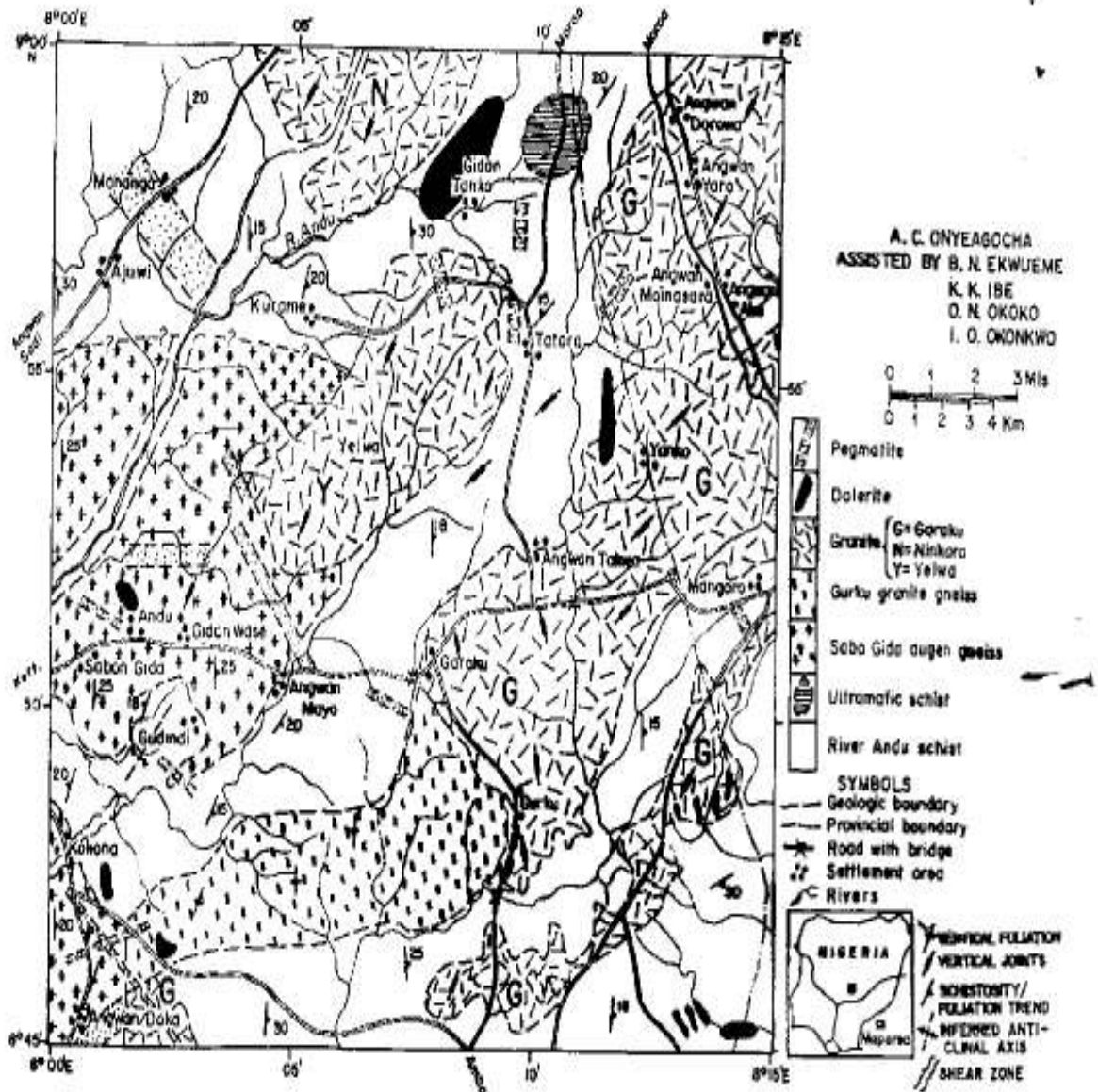


Fig. 1. Geologic map of Akwanga NW (Geological Survey of Nigeria sheet 209 NW).

(After Onyeagocha 1984)

RESULTS

Zircons separated from the schist in Kokona area of northwest Akwanga are broadly subhedral, sometimes with preserved pyramidal faces. They are relatively small and subby, mainly 65-125 μm in length (mean length 95 μm) and with aspect ratios mainly 1.4-2.5 (mean 2.1). Many grains show growth zoning, and a number of grains display distinct cores and rims, too thin for analysis, and small irregular outgrowths are commonly present.

Out of 131 analyses 117 yielded useful geochronological data; 67 of these gave 90-110% concordant results. U and Th concentrations vary widely,

60-3000ppm and 7-1350ppm respectively. Mean values for U, Th and Th/U are 485ppm, 263ppm and 0.61. Most ages scatter between 600 and 1100Ma, with distinct peaks at 700, 850, and 1000Ma (Fig. 2). A minority of grains yielded Palaeoproterozoic ages (1700-2200Ma). A few Archaean zircons are also present. One zircon rim with an age of 669 \pm 46Ma had very low Th/U (0.01) and is considered to have formed during metamorphism. All other zircons in Kokona schist and the age distribution is similar to that of Oti Group of Volta Basin in Ghana (Kalsbeek et al. 2012) and Kwa Falls schist of southeastern Nigeria (Ekwueme et al. 1988).

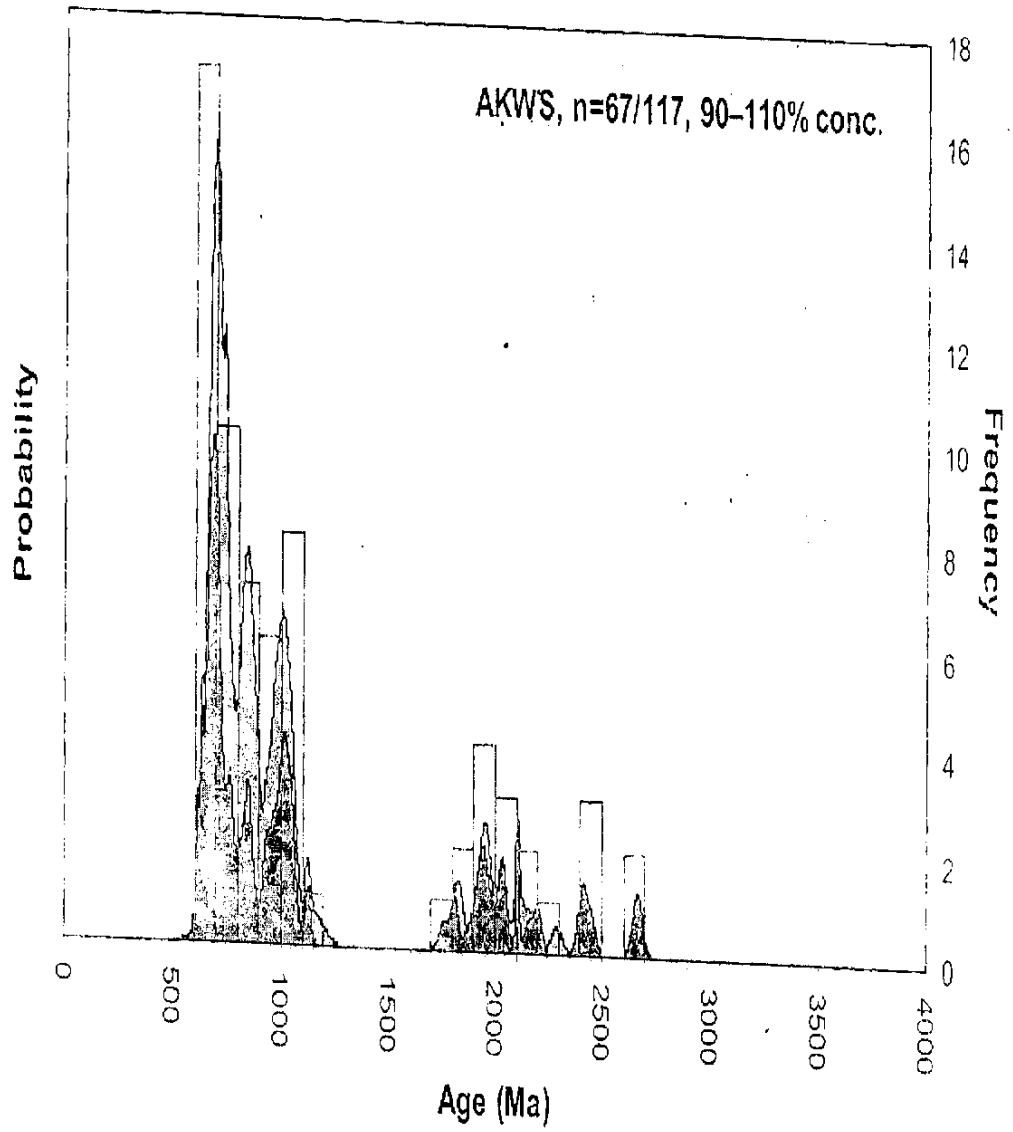


Fig. 2. $^{207}\text{Pb}/^{206}\text{Pb}$ zircon age probability diagram representing samples of schist in Akwanga area of Northcentral Nigeria.

DISCUSSION

The polycyclic metamorphism and polyphase deformation that affected the Nigerian Basement complex have been adequately reported in petrological literature (Oyawoye 1972, Rahaman 1976, McCurry, 1976, Dada 1999; Onyeagocha 1984; Ajibade 1972; Kroner et al. 2001, Ekwueme and Kroner 2006 among others). These authors showed that in many parts of Nigeria rocks that have been affected by Liberian ($2800\pm 200\text{Ma}$), Eburnean ($2000\pm 200\text{Ma}$) and Pan-African ($600\pm 150\text{Ma}$) occur and sometimes in one locality. Ekwueme (1989) for instance, discussed the tectonothermal events that affected rocks including schists in Uwet area, Oban massif southeastern Nigeria. He showed that the main phase of metamorphism that affected the rocks in the area was Pan-African dated at $\text{Ca.}676\text{Ma}$. Ekwueme (2004) showed that the Uwet schists are extension of Poli schists in northern Cameroon. Ekwueme and Kroner (1997, 2006) showed that similar schists occur in the Obudu Plateau which is a part of the Bamenda massif of Cameroon Republic and ages representing the Archaean, the Palaeoproterozoic and the Pan African events affected the Obudu schists in Bagga Utanga.

Pidgeon et al. (1976) had reported Archaean ages in rocks in Ibadan area which are dominantly Pan-African in age. In a similar manner Annor (1983) had reported older ages occurring together within dominantly Pan-African rocks in Egbe area of southwest Nigeria. The schists in northwest Nigeria have also shown ages of Archaean, Palaeoproterozoic and Pan African (Ajibade et al. 1979).

The identification of zircons of Archaean, Palaeoproterozoic and Pan-African ages in Kokona area of northwest Akwanga in northcentral Nigeria which is the result of the first-ever isotopic dating of rocks for this part of the Nigerian basement is a further evidence of the polycyclic nature of the entire Basement Complex of Nigeria. It confirms the assertion that Pan-African event

that affected rocks in many parts of Nigeria did not obliterate traces of earlier events (Mullan 1979, Grant 1978, Ekwueme 1987; Onyeagocha and Ekwueme 1982). In the Mayo Dayo area of northwest Akwanga the truncation of the pervasive Pan-African foliation trend (N-S) by an E-W trending one (Onyeagocha 1984) is an elegant evidence that pre-Pan African ages and pre-Pan African structural features occur in the Nigerian Basement complex and this demonstrates the polyphase nature of the deformation.

CONCLUSION

Schists belonging to the older metasedimentary series of McCurry (1976) occur in Akwanga area of northcentral Nigeria. These schists which were metamorphosed up to the uppermost amphibolite facies of the Barrovian type yielded dominantly Neoproterozoic age of 669Ma but contain detrital zircons showing relict ages of Archaean and Palaeoproterozoic. These ages are a further evidence of the polycyclic and polyphase nature of the Nigerian Basement complex.

DEDICATION

This paper is dedicated to the cherished memory of Prof. Anthony Chukwuma Onyeagocha who died 28th August 1987. He was the first geologist to carry out a detailed geological mapping of northwest Akwanga area of northcentral Nigeria in 1978-1979.

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Table 1: Modal Composition of schists in Kokona area NW Akwanga

SAMPLE:	1	2	3	4	5
Plagioclase	10	5	10	15	15
Biotite	35	45	35	35	30
Muscovite	20	20	20	-	-
Hornblende	-	-	-	25	23
Quartz	30	30	30	25	25
Granet	2	-	2	-	-
Tourmaline	2	-	1	-	2

Table 2: Major Element Composition of Analyzed Sample

SiO ₂	68.20
TiO ₂	0.73
Al ₂ O ₃	14.20
Fe ₂ O ₃ Total	5.65
MnO	0.09
MgO	2.23
CaO	1.59
Na ₂ O	2.91
K ₂ O	2.62
P ₂ O ₅	0.16
Volatile	1.07
Sum	99.47
A/CNK	1.35

Table 3: Trace Element Composition of Analyzed Sample

CS (PPM)	5.5	La (PPM)	25.93
Rb	94	Ce	53.13
Ba	522	Pr	7.11
Pb	16	Nd	26.60
Sr	214	Sm	5.78
Y	32	Eu	1.26
Th	7.5	Gd	5.12
Cu	1.9	Tb	0.84
Zr	185	Dy	4.96
Hf	4.7	Ho	1.12
Nb	11	Er	2.89
Ta	1.2	Tm	0.48
Zn	70	Yb	3.04
Cu	6.7	Lu	0.47
Ni	42		
Sc	13		
V	94		
Cr	86		
Co	19		
Ga	17		

Table 4: Rb-Sr and Sm-Nd isotope data for analyzed sample

SAMPLE	Rb (PPM)	Sr (PPM)	$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$	T*Sr (Ga)	Sm (PPM)	Nd (PPM)	$^{147}\text{Sm}/^{144}\text{Nd}$	$^{143}\text{Nd}/^{144}\text{Nd}$	T_{DM}^{**} GND (T=0)	GND (600Ma)
Kokona Schist	94	206	1.32	0.71879	0.73	5.32	25.60	0.1257	0.512302	1.47-6.56	-1.12

Tsr: Values is a model age calculated for individual samples assuming initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of 0.705.

** T_{DM} : Model age according to the depleted mantle model of Goldstein et al. (1984). Sample analyzed at Institute of Geography and Geology, University of Copenhagen Denmark.

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