GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES, VOL.8, NO. 3 JUNE 2002:319 - 324
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Rb-Sr ISOCHRON DATING OF GRANITOIDS FROM THE KAZAURE SCHIST BELT, NW NIGERIA

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(Received 12 December 2001; Revision accepted 16 April 2002)

ABSTRACT

The results of Rb-Sr isochron dating of granites from the crystalline basement complex of Kazaure Schist Belt are presented in this paper. Whole rock Rb-Sr radiometric age determination of five samples of a syntectonic coarse-grained porphyritic granite define a 4-point whole-rock Rb-Sr isochron (MSWD=1.2) corresponding to an age of 592 $\pm$ 14 Ma, the initial $^{87}Sr/^{86}Sr$ ratio being 0.7097 $\pm$ 0.0004.
This is distinctly a Pan-African age and is taken as the time of emplacement and crystallization of a granitic magma formed from a reworking of a pre-existing continental crust. The initial $^{87}Sr/^{86}Sr$ ratio indicates a significant contribution of older crustal materials by partial melting to the granitic magma.

Key Words : Kazaure Belt, Geochronology, Isochron, Pan African, Crust.

INTRODUCTION

Nigeria lies in the Pan-African mobile belt and is underlain by Basement Crystalline rocks and sedimentary rocks. Within the Nigerian basement complex, three broad lithological units are usually distinguished:- a basement of migmatites and gneisses; younger low to medium grade metasediments and metavolcanics which formed distinct N-S trending belts within the migmatite-gneiss complex, and syntectonic to late tectonic Older Granite suite (Fitches, et. al., 1985; Ajibade and Wright, 1989; Ekwueme, 1990a; Annor, 1995). Available isotopic age data and field relationships show that the Older Granite intrudes the basement and the metasediments, and is the youngest of the three lithologic units of the basement complex (Grant, 1978; Ekwueme, 1990b).

The Kazaure Schist Belt (KZSB) lies in the eastern margin of the zone containing the north-western Nigeria schist belts, where its northeastern side is partly covered by sediments of the Chad sedimentary basin (Fig. 1). Reconnaissance geological field work with a view of documenting the lithologies of the Kazaure belt, among other things, has been carried out by Morton (1967), Turner and Webb (1974), Aderotoye (1977) and Danbatta (1999).

The KZSB is composed of an area of low grade metasediments and metavolcanics that comprise of quartzites, conglomerates, schistose rocks, meta-rhyolites with rare ferruginous quartzites (iron formation). These are bounded by gneisses, older quartzites and intrusive granites (Fig. 1). The ages of the granitic rocks from Kazaure Schist Belt have not been previously determined.

The present study was carried out to determine the age and origin of the granitic rocks in the area, using the whole-rock Rb-Sr method, in order to provide important constraints in any attempt to model the evolution of the crust in the Kazaure Schist Belt terrain.

NATURE OF SAMPLES

All of the five granite samples reported are taken from separate co-magmatic porphyritic granite bodies, the locations of which are indicated in Fig. 1, with sample UD60 occurring near the Kalangai fault zone. The porphyritic granite ranges from medium to coarse grained and is commonly massive to weakly foliated. It is characterised by large pinkish microcline phenocrysts in a fine to medium grained matrix. The weak foliation is due to a weak planar orientation of the microcline phenocrysts.

In thin section, the five porphyritic granite samples (UD39, -60, -66, -67, -68, and -69) are essentially composed of variable amounts of K-feldspar (27% - 33%), albite-oligoclase (sodic) plagioclase (30 - 33%) and quartz (Table 1). These account for 96% of the rock, the rest is mainly biotite and/or muscovite. Accessories include zircon, apatite, sphene and opaque minerals.

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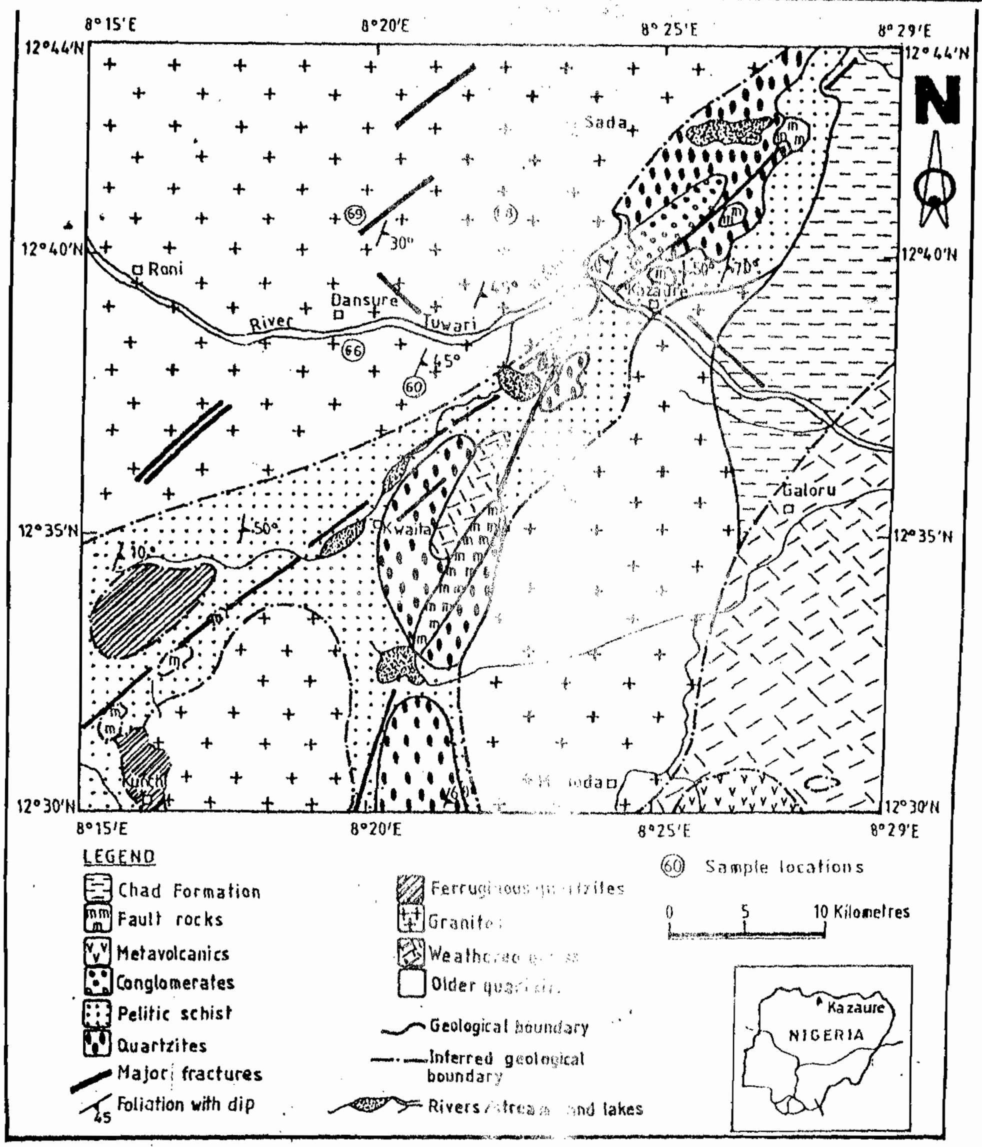

Fig. 1 Geological map of the Kazaure area

Under the microscope, sample UD53 is the only one that appears slightly weathered with evidence of chloritization of biotites.

ANALYTICAL PROCEDURES

The whole-rock geochemical and geochronological analytical procedures applied in the Geochemical laboratories of the Department of Earth and Planetary Sciences, McGill University, Montreal, Canada, were employed for the major elements (wt.%) determination and Rb-Sr isochron dating. 2-10 kg representative samples of the porphyritic granite were collected from different localities exhibiting fresh rocks (Fig. 1).

The whole-rock samples were initially washed, dried and split into smaller fragments using a hydraulic splitter. Some of these fragments were then crushed and reduced to powder in an agate barrel Tema grinder for about 22 minutes. Fused glass beads were prepared for X-Ray Fluorescence (XRF) analysis of major elements using 0.40g of the sample powders mixed with borax flux (mixture of prefused lithium tetraborate,

Table 1. Modal composition of porphyritic Granite samples from Kazaure area.

Sample No.	UD39	UD60	UD66	UD67	UD68	UD69
Quartz	32.0	35.0	33.0	28.0	33.0	31.0
Plagioclase	30.0	27.0	30.0	27.0	32.0	30.0
Potassic feldspar	31.0	33.0	32.0	27.0	28.0	33.0
Biotite	1.5	1.5	2.0	4.0	2.5	2.0
Muscovite	1.5	0.5	1.0	-	-	2.0
Opaque minerals	4.0	3.0	2.0	4.0	3.5	2.0

lithium metaborate and LiF), and ignited for 20 mins at 1200°C in graphite crucibles. The whole-rock dating method involves analyzing splits from rock fragments (prepared as described above) for total Rb and Sr concentrations, as well as for the strontium isotopic composition.

All the major elements (wt.%), Rb and Sr concentrations in the whole rock powders were determined using an automated Phillips PW2400 XRF Spectrometer System, with data controlled by a Phillips X40 Software package. The lower limits of detection for the major elements is 0.01% (10 ppm). Volatile constituents (H_2O- and loss on ignition, LOI) were determined by drying the sample at 110°C (H_2O) followed by roasting in a Sanyo 551 muffle furnace at 1000°C. The chemical compositions of these five samples are shown in Table 2.

The Rb/Sr ratios were determined by the conventional isotopic dilution method (Pankhurst and O'Nions, 1973). It followed the separation of Sr using standard cation-exchange following sample dissolution in HF-HNO3-HCL. Blanks were in order of 1 ng. The Sr compositions were measured in the McGill University Isotope Laboratory on unspiked samples using a JEOL-05RB Mass spectrometer. The Mass spectrometer separates charged atoms and molecules on the basis of their masses as they moved in magnetic and/or electrical fields.

The initial $^{87}Sr/^{86}Sr$ ratios were normalized for $^{86}Sr/^{88}Sr = 0.1194$ (Table 2). Analytical errors of $\pm$ 1.5% and $\pm$ 0.05% were assigned for the $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$, respectively. Errors quoted in the results are 2 sigma of the means (McIntyre et al., 1966; Brooks et al., 1972). All computations and analytical procedures for the mass spectrometric analyses were controlled by an automatic online computer. Regression line (slope and intercept) for the whole rock isochron was calculated according to the least squares methods of York (1969) and Williamson (1968). Goodness of fit of the regression line was tested by the value MSWD = SUMS/(n-2) as described by Brooks et al. (1972). The age was calculated using $Rb = 1.42 \times 10^{-11}\ yr^{-1}$, the constant recommended by the IUGS Subcommission (Steiger and Jager, 1977).

ISOTOPE RESULTS AND COMPUTATIONS

The isotopic analyses of five whole rock samples are given in Table 2 and on a conventional isochron diagram in Fig. 2. The isochron was calculated for 4 samples, excluding sample UD53 as its weathered nature and occurrence near a major fault zone may have caused loss of radiogenic ^{87}Sr. The regression equation Y =

Table 2. Chemical analyses (major elements in weight %) of granite rock samples from Kazaure Schist belt region, NW Nigeria.

Sample No.	UD39	UD60	UD66	UD67	UD68	UD69
CHEMICAL COMPOSITION (weight percent)						
SiO_2	71.04	70.18	70.02	70.88	70.85	71,13
TiO_2	0.44	0.44	0.42	0.44	0.43	0.45
Al_2O_3	14.62	14.79	14.71	14.33	14.13	14.25
$(Fe_2O_3)T$	3.56	3.66	3.21	3.31	3.31	3.49
MnO	0.06	0.06	0.05	0.05	0.05	0.07
MgO	0.47	0.49	0.44	0.46	0.46	0.43
CaO	1.79	1.80	1.80	1.78	1.76	1.71
Na_2O	3.22	3.22	3.28	3.20	3.23	3.24
K_2O	5.02	5.03	5.19	5.08	5.18	5.13
P_2O_5	0.38	0.38	0.40	0.39	0.39	0.39
LOI	0.12	0.13	0.12	0.11	0.11	0.16
Total	100.7	2 99.88	99.70	100.22	100.08	100.60
NORMATIVE COMPOSITION						
ap	0.27	70.18	70.02	70.88	70.85	71.13
il	0.13	0.13	0.11	0.11	0.11	0.15
or	30.05	30.07	31.01	30.36	30.86	30.72
ab	27.60	27.58	28.07	27.39	27.56	27.79
an	8.20	8.18	8.24	8.21	8.08	[illegible]
hy	0.78	0.81	0.73	0.76	0.76	0.71
q	29.31	28.85	27.24	29.00	28.36	29.30
hm	3.62	3.71	3.26	3.36	3.35	3.53
ru	0.38	0.38	0.37	0.39	0.38	0.38
q + ab + or	95.16	94.68	94.56	94.96	94.86	95.35

$(Fe_2O_3)T$ = total FeO + Fe_2O_3.

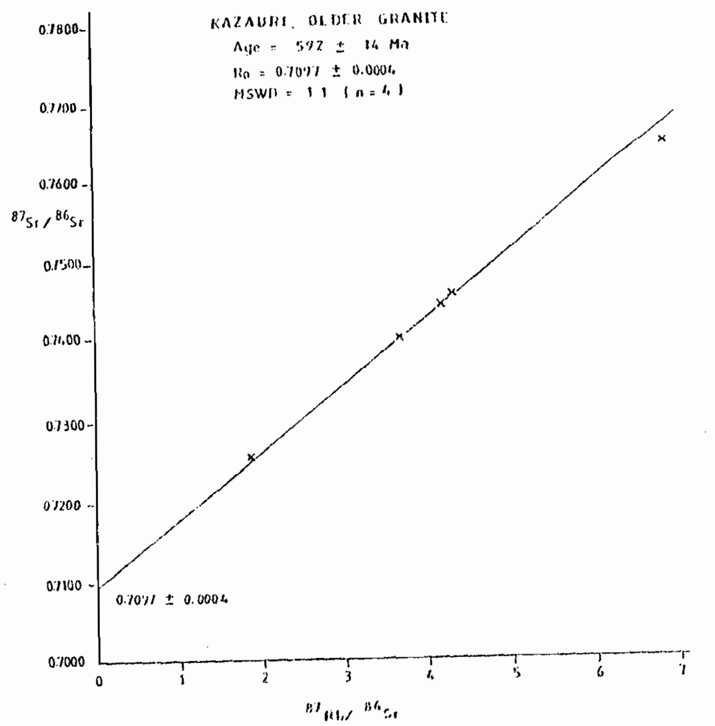

Fig. 2 Rb - Sr isochron diagram for the whole rock samples from the Kazaure belt Older Granites.
Ro stands for isotopic - ratio of initial Sr; MSWD represents "Mean Square of Weighted Deviates", and n is the number of points forming the isochron

Table 3. Rb-Sr analytical data for granite samples from Kazaure Schist belt region, NW Nigeria.

Sample No.	Rb (ppm)	Sr (ppm)	Rb/Sr	87Rb/86Sr ($\pm$ 1.5%)	#87Sr/86Sr ($\pm$ 0.0020)
UD39	138	197	1.43	4.1545	0.74431
UD60	140	329	2.35	6.8539	0.76452
UD66	159	110	0.63	1.8539	0.72553
UD68	133	166	1.25	3.6537	0.74328
UD69	145	212	1.46	4.3529	0.74563

Rb-Sr: Quoted errors at 2 sigma level, Sr ratios reproducible to 0.05%.

#=$^{87}Sr/^{86}Sr$ atomic ratio normalized to $^{86}Sr/^{88}Sr$ of 0.1194 ppm = Mg/g

0.7097 + O.OO8407 X, has produced a least-squares line through the porphyritic granite samples (MSWD = 1.2) which corresponds to an initial ($^{87}Sr/^{86}Sr$, Ro) of 0.7097 $\pm$ 0.0004, and T (the time of establishment of this isotopic composition) of 592$\pm$ 14 Ma.

The $^{87}Sr/^{86}Sr$ ratio of the Sr common to all minerals in the rock (Ro) is the isotopic ratio of the initial Sr as given by the intercept of the regression line. The MSWD of 1.2 is just slightly more than 1, and this means the residual variance is less than experimental variance. These ages and Ro values are broadly similar to the ones obtained for other Older Granite complexes in NW Nigeria (Jacobson et al., 1964; Ogezi, 1973; van Breemen et al., 1977; Ajibade et al., 1987), and may provide evidence for the origin of granitic activity in the area.

INTERPRETATIONS AND CONCLUSIONS

It has been possible to obtain an isochron on the granites that cut the Kazaure Schist Formation, as well as deduce the relationships between them and the various rocks in the belt. Apart from demonstrating the time of formation of the granite, the isotopic data has also placed a lower limit on the age of the KZSF and older gneisses. This is because the metasediments and gneisses must clearly be older than 592 $\pm$ 14 Ma., the age of the granite that intrudes them.

The result obtained suggests numerous interesting features of the basement complex in the Kazaure area. The data can be used to interpret the origin of the granitic magmas in KZSB. This can be done by using strontium isotopes which are very useful tracers for detecting mantle derived material (Faure, 1977). The $^{87}Sr/^{86}Sr$ ratios obtained for mantle derived oceanic basalts are in the range of 0.702 - 0.705 (Faure, 1977; Middlemost, 1985), while igneous rocks with sialic origin have initial $^{87}Sr/^{86}Sr$ ratios of between 0.71 and 0.78 (Hurley, 1968).

The range of initial ratios obtained from the Kazaure granite is from 0.72553 to 0.74563 with a mean average of 0.73969. These ratios lie within the range of values obtained from reworked crust. In addition, the Ro value of 0.7097 $\pm$ 0.0004 for the granitoids from Kazaure lies above mantle values, towards values of lower crust. As such, the Kazaure granitoids can be interpreted as derived from lower crust or a reworked pre-existing continental crust of probable Archaen age (Ekwueme, 1990c).

The Rb/Sr age of 592 $\pm$ 14 Ma obtained from the Kazaure Schist Belt granites confirmed their suggested Pan-African age, which indicates the time of original emplacement of a granitic magma derived from lower crust. In other words, the initial Ro value of 0.7097 $\pm$ 0.0004 for the Kazaure granite has indicated it to be a recycled crustal material with a long crustal history.

Rahaman (1988) broadly classified granitic activity in the Nigerian Basement into 3 groups: pre 600 Ma, 560 $\pm$ 40 Ma and about 500 Ma. The age of the Kazaure granite compares averagely well with Rb/Sr whole rock ages previously classified under the second group. Rb/Sr ages obtained from some other Older Granite complexes in Nigeria that fall within this group include those of Jacobson et al. (1964), Ogezi (1973) and Grant (1978).

In the Kusheriki area to the southwest of the KZSB, Jacobson et al., (1964) have reported Rb-Sr single whole rock age of 549 $\pm$ 14 Ma for a porphyritic granite. Broadly similar whole rock Rb-Sr age of 565 $\pm$ 46 Ma were obtained by Ogezi (1973) on a gneissic granite from Saibodaji area of Gusau, in northwestern Nigeria. Grant (1978) also showed that some of the Older Granite plutons in northwestern Nigeria were emplaced around 500 Ma ago.

Several other workers have obtained Pan-African whole rock Rb/Sr ages on rocks of the Older Granites that fall within the pre 600 Ma group of Rahaman (1988). These include Hurley (1966), Harper et al. (1973), Van Breemen et al. (1977), Pidgeon et al. (1978), Rahaman et al. (1983) and Ekwueme (1987).

The Kanoma syenite has yielded a whole-rock Rb/Sr age of 619 ± 36 Ma which is indicating the time of emplacement of the pluton (Hurley, 1966). Harper et al. (1973) showed that the Pan-African event took place between 700-600 Ma ago. Van Breemen et al. (1977) and Pidgeon et al. (1978) have however concluded from several Rb/Sr analytical data that Pan-African granitic activity in Nigeria took place between 670 to 530 Ma.

An age of 617 ± 37 Ma and initial $^{87}Sr/^{Sr}86$ ratio of 0.7120 ± 0.0016 were reported for the coarse-grained porphyritic granite of Igbeti area of southwestern Nigeria by Rahaman et al., (1983), who interpreted the Ro value as indicating significant older crustal component in the magma. Ekwueme (1987) has also reported similar whole rock Rb/Sr isochron age of 676 ± 26 Ma and an initial low $^{87}Sr/^{Sr}86$ ratio of 0.70682 ± 0.00039 (slightly above mantle derived ratio) on a Kyanite gneiss from the Oban Massif.

On the basis of available data, Ajibade et al. (1987) reported that most Rb/Sr isotopic measurements on the Older Granites from Nigeria give initial $^{87}Sr/^{86}Sr$ ratio of 0.7065 to 0.7125. These initial ratios are above the Upper mantle value of 0.701, 600 Ma ago. Cahen et al. (1984) have also reported data on the Rb/Sr age of several granite bodies from Nigeria, which are similar to the above initial ratios. These workers have interpreted the initial $^{87}Sr/^{86}Sr$ ratios as suggesting lower crustal materials or mantle derived materials that are heavily contaminatd by crustal rocks.

Dada (1995) reviewed all the published radiometric ages and drew attention to the fact that they do not correspond to any specific crustal event. He also suggests the significant involvement of older Archaean crustal components during the formation of the Late Proterozoic crust in the Nigerian basement.

It can be concluded that a lower crustal source for the granitic rocks in northwestern Nigeria, is the interpretation that fits the present existing one on the genetic evolution and emplacement of the Older Granites in Kazaure area, and possibly other parts of the NW Nigerian basement.

ACKNOWLEDGEMENT

The Rb-Sr isochron dating was carried out in McGill University on the basis of a co-operation of the Departments of Geology of the Ahmadu Bello University and McGill University, under the CIDA funded Nigerian Indigenous Building Materials Project. The assistance of Professor E.C. Ike, Professor B. Ekwueme, Professor R. Doig and Professor A. Tariq is gratefully acknowledged. I also thank my two anonymous reviewers who offered numerous useful suggestions that greatly improved the work.

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