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# POTASSIUM-ARGON AGES OF GNEISSES FROM THE BASIN GRANITOID IN SOUTH-EASTERN GHANA

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**Abstract**

Biotite and hornblende from gneiss samples from the basin granitoid in South-eastern Ghana were separated and analyzed for potassium-argon (K / Ar) ages. The results indicated that the gneisses have average biotite and hornblende ages of 1942 ± 11 Ma and 2044 ± 17 Ma, respectively. The highest single hornblende age of 2092 Ma was recorded for the amphibolite gneiss, which is a protolith of tholeiitic basalt. These ages fall within the main phase of the Eburnean thermo-tectonic event. The defined ages correspond to the metamorphic event, and are expectedly lower than the average ages of 2270 Ma (Pb/Pb), 2116 Ma (U/Pb), 2216 Ma (Rb/Sr, WR Isochron), and 2240-2290 Ma (Sm/Nd, Model) determined for the basin granitoid in other parts of Ghana and the reported Birimian age (2000-2300 Ma). This confirms that the basin granitoid was derived from older basement rocks, and that its emplacement was contemporaneous with the activities that resulted in the emplacement of the Birimian volcanic rocks and sediments. A period of 70 to 250 Ma separates the period of emplacement of the basin granitoid and subsequent metamorphic activities. However, the period of metamorphism of the basin granitoid (1922-2045 Ma) was contemporaneous with the intrusion by the Nsawam microgranite (1996 ± 43 Ma), and that of the Tarkwaian sediments by the K-rich granitoid (1968 ± 49 Ma).

**Résumé**

WOODE, A. & AGYEI, E. K.: *Les âges de potassium-argon du bassin granitoïde au sud-est du Ghana.* La biotite et la hornblende d'échantillons gneissiques du bassin granitoïde au sud-est du Ghana étaient séparées et analysées pour les âges de potassium-argon (K/Ar). Les résultats indiquent que les roches gneissiques avaient les âges moyens de biotite et de hornblende de 1942 ± 11 Ma et 2044 ± 17 Ma, respectivement. Le seul âge le plus élevé de hornblende de 2092 Ma était obtenu de gneiss amphibologique, qui est protolithe de basalte tholeiitique. Ces âges tombent dans la phase majeure de l'événement Eburnean thermotectonique. Les âges définis correspondent à l'événement métamorphique et ils sont comme espéré plus bas que les âges moyens de 2270 Ma (Pb/Pb), 2116 Ma (U/Pb), 2216 Ma (Rb/Sr, WR Isochrone) et 2240 - 2290 Ma (Sm/Nd, Modèle) obtenus pour le bassin granitoïde dans d'autres parties du Ghana et l'âge Birimian signalé (2000 - 2300 Ma). Ceci confirme que le bassin granitoïde était dérivé de roches plus âgées au sous-sol et que son emplacement était contemporain avec les activités qui aboutissaient à l'emplacement de roches volcaniques et de sédements Birimians. Une période de 70 à 250 Ma sépare la période d'emplacement du bassin granitoïde et les activités métamorphiques postérieures. La période de métamorphisme du bassin granitoïde (1922 - 2045 Ma) était toutefois contemporaine avec l'intrusion par la roche microgranitique de Nsawam (1996 ± 43 Ma), et celle de sédiments Tarkwaians par le K-riche granitoïde (1968 ±49 Ma).

## Introduction

The early Proterozoic Birimian greenstone belt (2000-2290 Ma) and the associated granitoids constitute an important geological unit in Ghana, as they host most of the country's mineral potential. Several studies of the associated granitoids (Kesse, 1985) indicate that they display distinctive field characteristics and variable geochemical, mineralogical, and textural properties. However, only few dates exist for the granitoids associated with the Birimian in Ghana.

Recent studies (Agyei *et al.*, 1987; Hirdes, Davis & Eisenlohr, 1992; Taylor *et al.*, 1992; Opare-Addo, Browing & John, 1993) have provided some insight on the evolution of these granitoids. Hirdes *et al.* (1992) dated the basin granitoid around Sunyani and Kumasi, using U/Pb zircon and monazite dating methods, and had ages of 2088 and 2116 Ma, respectively. The variation in the ages of these granitoids ($\approx$ 30 Ma) has been attributed to compositional differences between the Kumasi and Sunyani basins by these authors. Taylor *et al.* (1992) dated the basin granitoid using Rb/Sr, Sm/Nd, U/Pb, and Pb/Pb methods. Samples for the dating were collected from Cape Coast township, Upper West Region of Ghana and around Kumasi, and the following ages were recorded: 2270 Ma (Pb/Pb), 2116 Ma (U/Pb), 2216 Ma (Rb/Sr, WR Isochron), and 2240-2290 Ma (Sm/Nd Model). They also recorded ages of 1968 $\pm$ 49 Ma for the belt granitoid, 1968 $\pm$ 49 Ma for K-rich granitoid, 2600 Ma for the Winneba granitoid, and 2.01 to 2.29 Ga for the Birimian.

Agyei *et al.* (1987) were among the first to report on dates on granitoids from the Nsawam area. They recorded average age of 1996 $\pm$ 43 Ma for microgranites, using the Rb/Sr method. Woode (1994) indicated similar ages, using K/Ar date of biotite of (1944 $\pm$ 45 Ma).

This paper presents results of K/Ar geochronogical data to subsequent studies by Agyei & van Landewijk (1984). To understand the evolution of early Proterozoic rocks in Ghana, the paper determines the metamorphic ages of the basin granitoid in Nsawam, using the K/Ar dating technique, and relates them to the reported ages of other granitoids in Ghana and the Birimian. Samples for the geochronological investigation were collected from Nsawam in the Eastern Region of Ghana, about 35 km from Accra (Fig. 1). The area falls within the Cape Coast (Basin) granitoid, the largest granitoid body in southern Ghana that extends over a length of 160 km with an average width of 64 km.

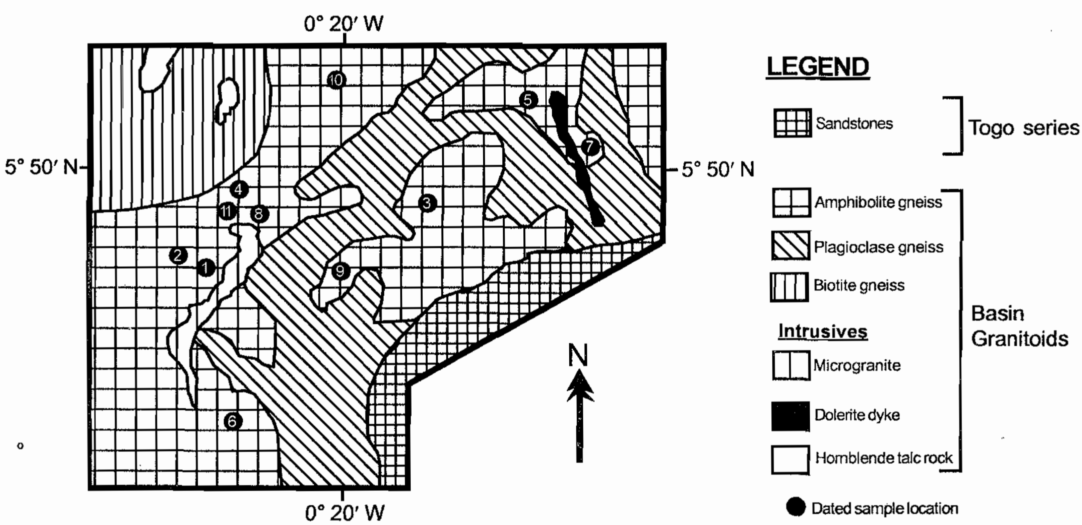


Fig. 1. Geological map of Nsawam (S.E. Ghana).

### Geological setting

Rocks occurring in the basin granitoid in Nsawam include biotite and amphibolite gneisses. These have been intruded by potassium-rich microgranite, dolerite, and hornblendite. The intrusives occupy fractured and/or weak zones created as a result of tectonic activities .The amphibolite gneisses have been found to be from tholeiitic basalt (Woode, 1994).

The gneisses occur alongside the migmatites, which were emplaced at deep crustal levels of 5 K-bars (Opare-Addo *et al.,* 1993), and share boundary with sandstones and siltstones of the Togo series (Fig. 1). At least the two types of metamorphism that exist in the granitoid are progressive and retrograde metamorphism. The amphibolite facies assemblage of the progressive metamorphism was overprinted by the greenschist facies assemblage of the retrograde metamorphism (Woode, 1994).

Other granitoid bodies in Ghana include belt and K-rich granitoids, previously known as Dixcove and Bongo granitoids, respectively; and Winneba granitoid. The granitoids have intrusive relations with the Birimian of Ghana which comprise five northeast-southwest trending volcanic belts separated by extensively folded sedimentary basins (Fig. 2). The volcanic belts are mainly basaltic in composition with few occurrences of andesitic, dacitic and rhyolitic rocks, and the sedimentary basins consist of volcanoclastic sedimentary rocks, sandstones, and argillites. Tarkwaian sediments, including sandstones, conglomerates and slates, overlie the Birimian.

According to Wright, Hasting & Jones (1985), the Birimian rocks were deposited in ensialic intracontinental basins and deformed by differential epeirogenic movements.

The basin granitoid occurs within the sedimentary basins of the Birimian. It is

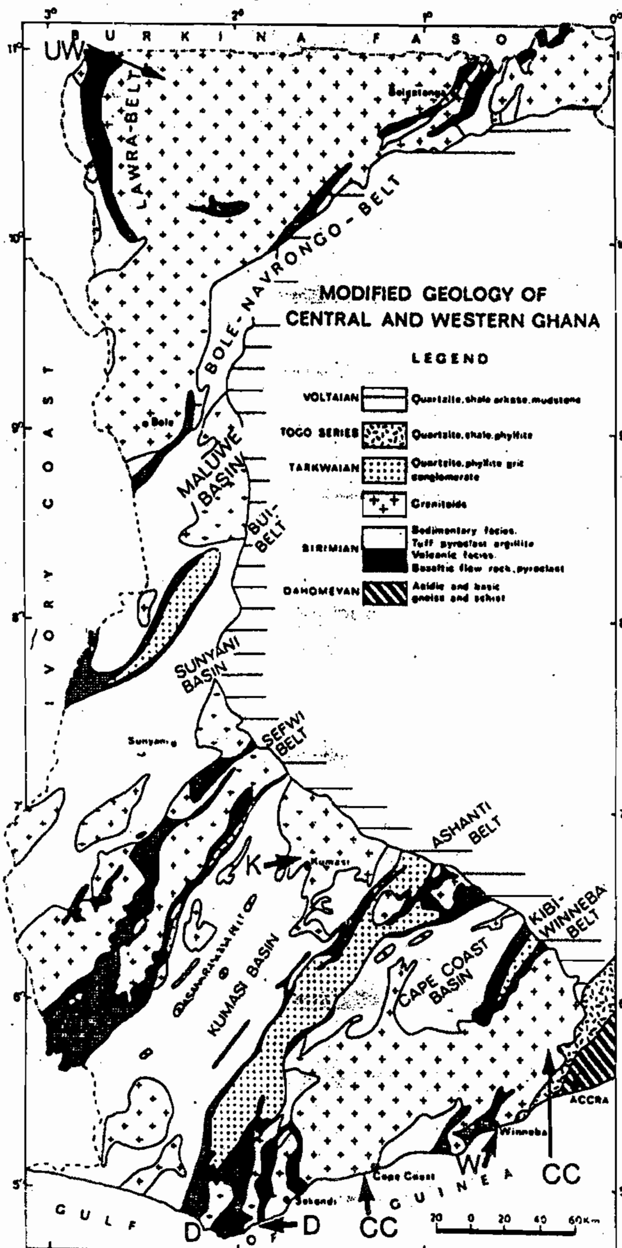


Fig. 2. Geological sketch map of West Africa including principal sampling sites of granitoids (UW = Upper West, K = Kumasi, D = Dixcove, CC = Cape Coast; W = Winneba).

synorogenic and may have been derived by granitisation and partial melting of Birimian metasediments and remobilization of older basement rocks of the West African craton (Leube *et al.,* 1990; Taylor *et al.,* 1992). It is characterized by foliations subparallel to that of the Birimian. This has been interpreted to mean it intruded the Birimian during the regional deformation (Eisenlohr & Hirdes, 1992).

The belt granitoid is late orogenic and mostly unfoliated and associated with the Birimian volcanic belts. It is characterized by abundant hornblende and typically dioritic to granodioritic in composition. Eisenlohr & Hirdes (1992) indicated that the belt granitoid is not post-deformation, but emplaced toward the end of the deformation. The K-rich granitoid intruded the Tarkwaian sediments. They are peraluminous and granitic in composition.

## Analytical procedure

Fresh and clean samples of biotite and amphibolite gneisses were selected from the study area for analysis. The samples were then crushed and sieved. Pure samples of biotite and hornblende were separated using magnetic separator and heavy liquids for potassium and argon determination.

The percentage potassium in each sample was determined, using the EEL flame photometer. After extraction in a high vacuum system, the purified argon was determined by isotope dilution methods, using MS10 mass spectrometer and high purity $^{38}Ar$ as tracer.

The tracer volume was measured using a pure biotite standard B133 with radiogenic $^{40}Ar$ content of 0.413 $mm^3g^{-1}$ and $K_20$ content of 9.45 per cent collected from University of Newcastle-Upon-Tyne.

Errors indicated in this work are one standard deviation of the mean.

## Results and discussion

Tables 2 and 3 show the average biotite and hornblende ages calculated from Table 1. The sample points have been plotted on Fig. 1.

Sample-point 7 had the highest biotite age of 2003 Ma, while Sample-point 1 indicated the lowest age of 1922 ± 1 Ma. This suggests that the radiogenic clock reset earlier at Sample-point 7 than at the rest of the sampling points. The average biotite age of the gneisses is 1942 ± 11Ma.

Due to the higher blocking temperature of hornblende, its ages are higher than those of biotite (Table 3). The highest hornblende age is 2092 Ma. It occurs in the amphibolite gneiss. The lowest hornblende age is 2015 Ma.

The ages are consistent with other ages determined for the migmatites in the basin granitoid by Agyei & van Landewijk (1984). The average age of the hornblende is 2044 ± 17 Ma.

The ages in Tables 2 and 3 fall within the main phase of the Eburnean thermo-tectonic event, but are lower than the reported Birimian age of 2.01-2.29 Ga and the ages of the belt, basin, and Winneba granitoids of 2.21-2.26 Ga, 2.26-2.28 Ga, and 2.60-2.62 Ga, respectively (Taylor *et al.,* 1992). It is, however, contemporaneous with the ages of K-rich granitoid and the Nsawam microgranite.

The dates support the findings of Agyei *et al.* (1987) that the basin granitoid is not post-Birimian but early or pre-Birimian, and that the early proterozoic period was marked by plutonic and tectonic activities, metamorphism, and deformation of crustal rocks.

A period of 70-250 Ma separates the period of emplacement of the basin granitoid (2088-2290 Ma) and the period of metamorphism (1922-2045 Ma). This period of metamorphism is contemporaneous with the intrusion of the basin granitoid by the Nsawam microgranite (1996 ± 43 Ma), and the intrusion of the Tarkwaian sediments by the K-rich granitoid (1968 ± 49).

The Rb/Sr and K/Ar dates of the microgranite indicate that it was metamorphosed about 52 Ma after its emplacement.

The K-rich granitoid and the microgranite were emplaced during the period in which the basin granitoid was metamorphosed. Further work would have to be done to establish any lithological

TABLE 1

*Radiogenic $^{40}Ar$ and age data of rock samples from Nsawam area*

| Sample point | Mineral | K/% | $^{40}Ar_{AT}$/% | $^{40}Ar_{rad}$/$m^3g^{-1}$ | Wt for Ar analysis/g | Age /Ma |
|---|---|---|---|---|---|---|
| 1 | Biotite | 8.14 ± 0.16 | 2.7 | 0.89990 | 0.061700 | 1921 |
| | | | 1.5 | 0.90180 | 0.059510 | 1923 |
| | | | 8.4 | 1.01940 | 0.052785 | 1908 |
| 2 | Biotite | 9.32 ± 0.07 | 1.9 | 1.02660 | 0.056730 | 1917 |
| | | | 1.7 | 1.05320 | 0.044850 | 1947 |
| | | | 3.6 | 1.03300 | 0.039090 | 1924 |
| 3 | Biotite | 9.27 ± 0.02 | 8.8 | 1.02460 | 0.057460 | 1947 |
| | | | 2.8 | 1.04510 | 0.024655 | 1930 |
| 4 | Biotite | 9.2 ± 0.04 | 5.0 | 1.07794 | 0.055775 | 1934 |
| | | | 1.3 | 1.04334 | 0.053060 | 1951 |
| 5 | Biotite | 9.19 ± 0.07 | 1.8 | 1.05170 | 0.061155 | 1962 |
| | | | 1.7 | 1.02340 | 0.059510 | 1923 |
| | | | 2.0 | 0.97063 | 0.052110 | 1911 |
| 6 | Biotite | 8.28 ± 0.07 | 1.5 | 0.92350 | 0.044950 | 1931 |
| | | | 13.5 | 0.94560 | 0.029370 | 1960 |
| 7 | Biotite | 9.0 ± 0.10 | 3.8 | 1.06540 | 0.056530 | 2003 |
| 8 | Hornblende | 1.31 ± 0.01 | 7.2 | 0.15970 | 0.162500 | 2039 |
| | | | 3.2 | 0.15364 | 0.159025 | 1992 |
| 9 | Hornblende | 1.22 ± 0.01 | 14.04.5 | 0.14203 | 0.163550 | 1983 |
| | | | | 0.15235 | 0.131725 | 2068 |
| 10 | Hornblende | 0.15 ± 0.01 | 28.5 | 0.03653 | 0.164095 | 2092 |
| 11 | Hornblende | 1.08 ± 0.01 | 12.7 | 0.13220 | 0.117010 | 2043 |
| | | | 4.7 | 0.03527 | 0.137610 | 2047 |

TABLE 2

*Average biotite ages from Nsawam and surrounding areas*

| Sample point | Rock type | Average age (Ma) |
|---|---|---|
| 1 | Biotite gneiss | 1922 ± 1 |
| 2 | Biotite gneiss | 1924 ± 8 |
| 3 | Biotite gneiss | 1939 ± 9 |
| 4 | Biotite gneiss | 1643 ± 9 |
| 5 | Biotite gneiss | 1943 ± 20 |
| 6 | Biotite gneiss | 1961 ± 30 |
| 7 | Biotite gneiss | 2003 (single date) |

relationships between them, bearing in mind that the microgranite is also potassium rich. Field and petrographic evidence show that the microgranite might have been emplaced from igneous source close to the surface in fractures and faults, and later affected by retrograde metamorphism under greenschist facies (Woode, 1994).

The belt granitoid seems to be contemporaneous with the basin granitoid, according to data from a previous study (Table 4). However, the

TABLE 3
*Average hornblende ages from Nsawam and surrounding areas*

| *Sample point* | *Rock type* | *Average age (Ma)* |
|---|---|---|
| 8 | Amphibolite gneiss | 2015 ± 23 |
| 9 | Amphibolite gneiss | 2025 ± 42 |
| 10 | Amphibolite gneiss | 2092 (single date) |
| 11 | Amphibolite gneiss | 2045 ± 2 |

TABLE 4
*Comparison of age data from Taylor* et al. *(1992); Hirdes* et al. *(1992), and this study*

| | *Rb/Sr WR Isochron (Ma)* | *U/Pb WR Isochron (Ma)* | *Sm/Nd model (Ga)* | *K/Ar (Ma)* |
|---|---|---|---|---|
| Birimian | | | 2.21- 2.31 | |
| Belt granitoid | 1891±314 | | 2.20 - 2.24 | |
| Basin granitoid | 2216±72 | 2088 - 2116 | 2.24 - 2.29 | 1922±1<br>2045±2 |
| K-rich granitoid | 1968 ±49 | | | |
| Winneba granitoid | | | 2.59 - 2.60 | |

absence of foliation in the former suggests that it is post-deformation.

## Conclusion

Two main conclusions can be drawn from this study. The metamorphism of the basin granitoid occurred between 1922 and 2045 Ma, a period of 70 to 250 Ma after its emplacement. The period of metamorphism coincided with the magmatic activities, which resulted in the emplacement of the Nsawam microgranite and the K-rich granitoid.


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