Permian Ages of “Younger Granites” from Mounio Province (Gouré area, Southeastern Niger)

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ABSTRACT

The Mounio province, located in Southeastern Niger, consists of Pan-African formations intruded by the “Younger Granites” ring complex. In the study area, the “Younger Granites” are represented by volcanic to acid plutonic rocks with hyperalkaline trends (pyroclastic rocks, rhyolites, microgranites, granites, syenites), forming in the North, a circular structure called Gouré ring complex. Preliminary geochronological datings of the Mounio granites have yielded Carboniferous ages. However, recent investigations carried out in this province have identified structures similar to Pan-African deformation structures, such as folds and several generations of schistosity/foliation. Analysis of the relationship between deformation and magmatism has removed any ambiguity regarding the relative age of the deformation. This study focuses on the radiometric dating of the “Younger Granites” of Gouré area, in order to update the geochronological data. Thus, three samples (pyroclastic rock, rhyolite, microgranite) were dated by the K-Ar method on total rock using a mass spectrometry type MI 1201 IG. Radiometric dating results assign a Lower Permian age (293-287 Ma) to the “Younger Granites” Ring Complex of the Mounio Province in Niger, classically considered to be Carboniferous in age.

Keywords: Mounio Province, Gouré, “Younger Granites”, Pan-African mobile belt, Geochronology.

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I. INTRODUCTION

The Mounio Province, located in southeastern Niger, is an integral part of the Pan-African mobile belt which extends from the Hoggar in the North to the Gulf of Benin in the South, including the Touareg and the Benino-Nigerian Shields (Fig. 1). It consists of Pan-African formations intruded by a ring Complex called “Younger Granites”. The latter is classically considered as the ultimate anorogenic manifestations of an intraplate magmatism, in this part of the Trans-Saharan mobile belt. In the study area, granitic complexes are represented by volcanic to acid plutonic rocks with hyperalkaline trends. Several authors have discussed the ages of the anorogenic complexes of the “Younger Granites” Province of Niger-Nigeria, whose emplacement indicates migratory ages from Ordovician to Cretaceous, respectively from the North (Aïr, Niger) to the South (Jos Plateau, Nigeria) (Fig. 2) [1]-[8]. However, very few radiometric datings have been carried out in the Mounio Province, which occupies an intermediate position between the Aïr complexes (to the North) and those of Nigeria (to the South). The only published studies concern the data on the granites of Kourdohol in west Gouré (302 ± 5 - 296 ± 5 Ma) and Adoumchi in South Mounio (~ 295 - ~ 289 Ma) obtained by the Rb-Sr method on total rock (Fig. 3), [4], [6]. Most of the ages mentioned have been assigned to Jurassic [9] or

Devono-Carboniferous [10], based on geological correlations. Recent field works have described deformation structures such as folds, sometimes showing high ductility and several slaty cleavages, with various orientations: N00°-N20°, N110°-N125° and N140°-N160°. It's therefore necessary to verify whether these are Pan-African structures and/or host rocks, as is the case in the North of the study area where metasediments of paleo-neo-proterozoic age are in contact with the annular complex. Additional radiometric data are needed to chronologically calibrate the age of the various deformation structures affecting the Gouré “Younger Granites”, in order to remove any ambiguity. The K-Ar dating method on total rock, implemented during this study, allows to update the ages of emplacement of the Mounio “Younger Granites” and the associated deformations. The objective of this study is to determine the radiometric age of the “Younger Granites” of the Gouré area. In a specific way, it's to:

- determine the age of the magmatism of the Mounio “Younger Granites”,
- chronologically calibrate the age of the deformations with that of the magmatism of the study area,
- place the Mounio province in its regional geological context.

II. STUDY AREA

A. Geological Setting

The Mounio basement which is a part of the Pan-African mobile zone, located to the East of the West African Craton (WAC), is located in the Southern part of the Trans-Saharan mobile belt which extends from the Hoggar in the North to the Gulf of Benin in the South (Fig. 1). This mobile belt, result of the convergence between four cratons: The West African Craton, the São Francisco Craton, the Congo Craton, and the Saharan Metacraton [11]-[14].

It consists of a Paleo-Neo-Proterozoic basement, deeply remobilized during the Pan-African orogeny (750-450 Ma) [12], [15]-[20]. From a global point of view, the Pan-African mobile zone is one of the many Neoproterozoic orogenic chains which participated in the accretion of various cratonic blocks, thus forming the Supercontinent of

Gondwana between 750 and 500 Ma. Subsequently, Gondwana began to break up, from the Paleozoic, which led to: (i) the emplacement of anorogenic alkaline granitic complexes commonly called “Younger Granites” and, (ii) the development of Meso-Cenozoic rifts [17], [21], [22]. These anorogenic complexes include the “Younger Granites” Province of Niger-Nigeria. The post-Pan-African magmatism of this province continued until the Quaternary, according to a meridian alignment, associated with a migration from the North to the South [23], [24], [4], [6]. From North to South, these are: the Lower to Middle Paleozoic in age complexes of the Air Massif (northern Niger), the Upper Paleozoic in age “Ring Complexes” of the Damagaram-Mounio (southern Niger), and the Cretaceous-Jurassic in age “Younger Granites” of the Jos Plateau (Central Nigeria) [1]-[8], [25].

Fig. 1. (a): Reconstitution of the Western part of the Gondwana from the Paleozoic to the Mesozoic, showing the different Cratons. (b): Location of the Mounio province in the Trans-Saharan mobile belt (the blue box outlines the location of the study area) [11], [12], [17], [26]-[33].

B. Mounio Province Geology

The Mounio province extends over 80 km from North to South of the Gouré city to the nigero-nigerian border and over 30 to 40 km from East to West (Fig. 3). The geology of this area is dominated by the so-called “Younger Granites” complex which intruded older terrains during two magmatic cycles [34], [35]. The “Younger Granites” form to the North of Gouré city, a circular structure called “Annular Complex of Gouré” (Fig. 3). The first cycle includes rhyolites (with a vitreous, microlithic or porphyritic texture), and rhyolitic

pyroclastic rocks (including breccias, tuffs and ignimbrites). These volcanic rocks were intruded by a hypovolcanic set including microgranites, and then by plutonic bodies including syenites and granites (Fig. 3), representing the second magmatic cycle.

Throughout the Mounio area, the old terranes which are paleo-neo-proterozoic in age [9] are over laid by the sedimentary cover of the Continental Hamadian and the recent aeolian formations [36] except of some metasediment's outcrops (Fig. 3).

Fig. 2. Distribution of Paleozoic and Mesozoic Ring complexes of Niger and Nigeria. Air (Middle Paleozoic): 1A.Adrar Bous, 3A.Tamgak-Enfoud Group, 12.Tarraouadji; Southern Niger (UpperPaleozoic): 1D.Zinder, 2D.Tchouni-Zarniski, 3D.Gouré, 4D.Matsena; Nigeria (Mesozoic): Jos Tray, 17J.Afu. [6].

Fig. 3. Geological map of the Mounio province (after [9], supplemented by field data) showing the location of the sampling points.

III. METHODOLOGY

A. Choice of Method

The province of Mounio is made up of acidic, alkaline to hyperalkaline, magmatic and metamorphic rocks. The K-Ar dating method is suitable for these types of rocks because

they are rich in mobile elements such as potassium, including the radioactive isotope ^{40}K which decays into ^{40}Ar . The choice of this technique is one of the most suitable alternatives, given the difficulty in finding certain elements (such as zircon), in the thin sections of the Mounio zone, necessary for testing other dating methods (such as the U-Pb

method). The K-Ar method gives excellent results on igneous rocks [37], given the speed of magmatic intrusions thus favoring the closure of the system [38]. For metamorphic rocks, this technique provides relatively good results compared to other methods such as U-Pb where the age of zircons is less precise, due to the loss of the Pb elements and the presence of very small inherited components [39].

B. Analytical Technique

Three samples, noted GMS₂₃ (microgranite), GMS₄₉ (rhyolite), and GMS₇₀ (pyroclastic rock) (location fig. 3) were submitted for total rock K-Ar geochronological analysis at ACTLabs laboratory of Canada. The samples were first assayed by X-rays (XRF) fluorescence which is an analytical technique that provides quantitative potassium (K) element data prior to the total rock K-Ar radiometric dating. Aliquots of each of the three samples were taken and weighed in an aluminum container. Appropriate weights are introduced into the extraction unit, heated to ~ 100 °C for 2 days in order to remove surface gases from the samples. Argon is extracted from the samples in a boiler at a temperature of 1700 °C. The determination of the content of radiogenic argon was performed twice using the MI-1201 IG mass-spectrometer by isotope dilution method with ³⁸Ar as a peak, which is introduced to the sample system before each extraction. The extracted gases were cleaned up in two purification system. Then pure Ar is introduced into the custom-built magnetic sector of the mass spectrometer (Reinolds type). It should be noted that the test was performed twice on each sample to ensure the reliability of the results. Two globally accepted levels (P-207 Muscovite and 1/65 “Asia” rhyolite matrix) were measured for ³⁸Ar tip calibration. For age calculations, international constant

values were used as follows: $\lambda_K=0.581\times10^{-10}y^{-1}$, $\lambda_\beta=4.962\times10^{-10}y^{-1}$, $^{40}K=0.01167$ (At.%). The certainty of the ages calculated fall within 1 σ error.

IV. RESULTS AND DISCUSSION

A. Data analysis and Interpretation

Geochronological investigations in general, require knowledge of the geological context of the study area and a petrographic study of the rocks to be dated. Previous works have shown that the province of Mounio is dominated by an anorogenic alkaline complex except for a few metasediments' hints. The data presented relate to the results of petrographic and radiometric analysis of the formations. The latter are composed of Gouré rhyolites, Adoumchi microgranites and pyroclastic rocks of Gajiya (Fig. 3).

1) Gouré Rhyolites

The Gouré rhyolites outcrop in the form of small hills encircling the Gouré city (fig. 3). They are pinkish to greyish in color, marked by a microlitic porphyritic texture (Fig. 4a). The mineralogical composition is characterized by millimetric to centimetric crystals of automorphic quartz, alkaline feldspars, pyroxenes, biotites, embedded in a quartzofeldspathic mesostasis (Fig. 4a, 4c, 4d). The latter is dotted with reddish splotches of iron oxides (Fig. 4a), in which phenocrysts of pyroxenes and plagioclases are embedded (Fig. 4a). These more or less porphyritic rhyolites (Fig. 4c, 4d), with abundant mesostasis, sometimes present magmatic bedding (orientation of plagioclase phenocrysts). At the outcrop scale, the Gouré rhyolites are locally affected by a tight fracture cleavage N140° to N160° trending (Fig. 4b).

Fig. 4. Gouré Rhyolites. Outcrop view showing microlitic texture (a) and tight fracture cleavage N140° to N160° trending (b). Microphotography with a polarizing microscope in polarized and analyzed light (c) and non-analyzed polarized light (d). [Qz: Quartz. Fk: Potassic feldspars. Ms: Mesostasis. Bt: Biotite].

Radiometric dating of the Gouré rhyolite sample gave an age of 293 ± 7 Ma (GMS₄₉, Table I, II), which would be that of the setting up of the rhyolite. Petrographic analysis shows that this rock is characterized by the lack of deformed or oriented minerals, which implies that there was neither intercrystalline ductile deformation nor metamorphic deformation (Fig. 4c, 4d). The tight fracture cleavage could then be contemporaneous with the cooling period of the rhyolitic lava.

2) Adoumchi Microgranites

The Adoumchi microgranites also exhibit a fracture cleavage, indicating an average direction of N00°, giving the rock a prismatic flow at the outcrop (Fig. 5a). Their pinkish facies with micrograined texture is retypical of hypovolcanic rocks. Adoumchi microgranites consist of quartz, orthose, muscovite, biotite, plagioclase, hornblende, and a cryptocrystalline mesostasis (Fig. 5b, 5c, 5d). These minerals don't show any intercrystalline deformation (Fig. 5b, 5c, 5d).

Total rock dating, by the K-Ar method, of these microgranites gives an age of 288 ± 6 Ma (GMS₂₃, Table I, II). Here too, the absence of deformed or oriented minerals implies that neither intracrystalline ductile deformation nor metamorphic deformation occurred (Fig. 5b, 5c, 5d). The

N00° fracture cleavage observed would be contemporaneous with the magma cooling period.

3) Pyroclastic rocks of Gajiya

These are rocks with rhyolitic tuffaceous facies (Fig. 6a), rich in potassic feldspars (Fig. 6a, 6b, 6c, 6d). These rocks are characterized by automorphic K-feldspar porphyroclasts, automorphic smoky quartz and quartzofeldspathic cryptocrystalline mesostasis (Fig. 6c, 6d). The outcrop is characterized by a magmatic bedding oriented mainly N10°-N20°. The Gajiya pyroclastic rocks are affected by a variety of microfolds, most often anisopachous, reflecting a high ductility of the magmatic material during the microfolding (Fig. 6a). Subsequently, this rock was affected by several generations of fracture cleavage, oriented N10°-N30°, N60°-N80° and N100°-N125° (Fig. 6b). The description of the thin sections under a polarizing microscope shows that the minerals are not deformed. These pyroclastic rocks have therefore not undergone metamorphic deformation. The deformation structures observed at the outcrop (microfolds, magmatic bedding) would therefore be deformation linked to the conditions of the setting up of the magma.

Radiometric dating by the K-Ar method on a total rock gave an age of 287 ± 6 Ma (GMS₇₀, Table I, II), which would be that of the establishment of the magmatic material and deformations associated with it.

Fig. 5. Adoumchi Microgranites. Outcrop view showing an N00° fracture cleavage and a prismatic flow (a). Photography with the binocular magnifying glass (b). Microphotography with a polarizing microscope with polarized and analyzed light (c) and unanalyzed polarized light (d). [Qz: Quartz. Or: Orthose. Mu: Muscovite. Pl: Plagioclase. Ms: Mesostasis, Bt: Biotite].

Fig. 6. Gajiya pyroclastic rocks. Outcrop view showing a folding deformation, intersected by N100°-125° trending schistosity (a and b). Microphotography with a polarizing microscope in polarized and analyzed light (c) and unanalyzed polarized light (d). [Fk: Potassic feldspars. Ms: Mesostasis].

TABLE I: THE RESULT OF THE K-AR GEOCHRONOLOGY TEST

Sample's ID	K, %	⁴⁰ Ar rad, (ng/g)	⁴⁰ Ar atm (%)	Age (Ma)	Erreur 1σ
GMS ₂₃	3.72	80.62 ± 0.27	9.7	288	6
GMS ₄₉	4.00	88.30 ± 0.3	13.5	293	7
GMS ₇₀	5.26	113.60 ± 0.4	8.5	287	6

B. Discussion on the Obtained Ages

Radiometric data obtained by the K-Ar method on total rock samples from the Mounio Province, yield lower Permian ages (293±7 to 287±6 Ma) [40]. These results are relatively younger than those resulting from the previous works of [6] and [4] who respectively obtained, by the Rb-Sr method on total rock, ages ranging from 305±5 to ~295 Ma and from 296±5 to ~289 Ma from the same field (Table II).

Rhyolites and microgranites from Mounio showed respectively ages of 293±7 Ma and 288±6 Ma. Their macroscopic and microscopic petrographic aspects (Fig. 4, 5) are those of the igneous rocks. The K-Ar method applied to alkaline igneous rocks provides good results [37]. These ages would correspond to the period of successive setting up of the alkaline complexes of the “Younger Granites” Province of Niger-Nigeria [1], [2], [4], [6]. Thus, the fracture cleavage observed in the rhyolites of Gouré (N140°-N160°) and in the microgranites of Adoumchi (N00° on average) would rather be contemporaneous with the cooling period of the magma.

As for the pyroclastic rocks of Mounio, they clearly show ductile deformation structures (Fig. 6a). However, the microscopic study shows that this deformation is not recorded by the minerals, except for the fractures consistent with the N100°-N125° fracture cleavage which affected the potassium feldspar porphyroclasts. This rock would therefore be affected by deformation structures linked to the conditions of setting up of the magma. It would then be synmagmatic deformation structures.

The results of this study correspond to a distinctly Permian period [40] unlike the carboniferous age attributed to the “Younger Granites” of Mounio by [6] and [4]. These new radiometric data also contrast the Jurassic and Devonian-Carboniferous periods proposed respectively by [9] and [10].

In general, the available geochronological data in the study area which are: (i) from 293±7 to 287±6 Ma (K-Ar on total rock) resulting from this study, (ii) from 296±5 to ~289 Ma (Rb-Sr on total rock) from [4] and, (iii) from 305±5 to ~295 Ma (Rb-Sr on total rock) from [6] (Table II), show increasingly younger ages from the North to the South of Mounio, relatively to the type of method used (Fig. 3). This observation is in agreement with the conclusions of [6] and [4] on the migratory character of the ages of the establishment of the “Young Granites” of Niger-Nigeria (from the Ordovician in Air, to the Cretaceous in the Jos Plateau, in Nigeria). This means that the magmatism of the Mounio province would have started in the extreme North with the setting up of the Gouré annular structure before gradually migrating Southwards, towards Nigeria.

TABLE II: GPS LOCATION AND RADIOMETRIC AGES OF THE BASEMENT SAMPLES OBTAINED BY K-AR DATING (DURING THIS STUDY) AND RB-SR DATING [4], [6]

Samples analyzed	Geographical coordinates in degree-minute-second		Radiometric ages		Method/material dated
	Longitude	Latitude	Measured ages	Recalculated ages	
Adoumchi Microgranite	E10°13'14"	N13°46'47"	288±6 Ma (this study)		K-Ar on Whole rock
Gouré Rhyolite	E10°16'38"	N13°58'58"	293±7 Ma (this study)		K-Ar on Whole rock
Pyroclastic rocks of Gajiya	E10°15'22"	N13°53'55"	287±6 Ma (this study)		K-Ar on Whole rock
Granite of Kourdohol	E10°10'00"	N14°00'00"	302±5 Ma (Bowden, 1976)	296 ± 5 Ma (Karche & Vachette, 1978)	Rb-Sr on Whole rock
Granite of Adoumchi	E10°14'53"	N13°45'06"	~ 295 Ma (Bowden, 1976)	~ 289 Ma (Karche & Vachette, 1978)	Rb-Sr on Whole rock

V. CONCLUSION

Geochronological data obtained by the K-Ar method on the Gouré massif, give Permian ages ranging from 293±7 to 287±6 Ma, unlike the Carboniferous ages classically assigned to the Mounio “ring complex”. These ages correspond to the period of setting up of the Mounio “Younger Granites”. The deformation structures observed on the volcanic, hypovolcanic and plutonic terrains of Mounio alkaline annular complex, would then result from tectono-magmatic events, Permian in age. From a regional point of view, these results confirm the migratory ages of the Niger-Nigeria “Younger Granites” provinces and the establishment of the granite complex of the Mounio province during the Hercynian period.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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