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Geochemistry (Geochronology)

Evidence of ca 1.6-Ga detrital zircon in the Bafia Group (Cameroon): Implication for the chronostratigraphy of the Pan-African Belt north of the Congo craton

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Abstract

The southern part of the Central African Fold Belt (CAFB) in Cameroon is a southward regional-scale nappe-stacking domain (the Yaoundé Domain). It comprises the Neoproterozoic Yaoundé Group, thrust onto the Congo craton, and the poorly known Bafia Group, which is classically assumed to be a (Palaeoproterozoic) tectonic slice of basement overthrusting the Yaoundé Group to the north. New field observations, zircon U–Pb, and whole-rock and garnet Sm–Nd data allow a better understanding of the Bafia Group within the context of the CAFB. The Bafia Group is probably a Neoproterozoic metasedimentary sequence, comparable to those situated north of the Congo craton (Poli, Lom, and Yaoundé). In addition to the Palaeoproterozoic to Archean source, the detrital zircons in the Bafia Group are inherited from 1617 ± 16 Ma granitoids. Our results also led us to discuss the source and provenance of the Bafia Group's gneiss protoliths, and the metamorphic evolution of this group. ***To cite this article: J.N. Tchakounté et al., C. R. Geoscience 339 (2007).***

Résumé

Existence de zircons détritiques de 1,6 Ga dans le groupe de Bafia (Cameroun) : conséquence pour la chronostratigraphie de la chaîne Panafricaine au nord du craton du Congo. La partie méridionale de la chaîne panafricaine d'Afrique centrale (CAFB) au Cameroun constitue un important domaine d'empilement de nappes, le domaine de Yaoundé. Ce dernier comprend le groupe de Yaoundé, chevauchant la bordure nord du craton du Congo, et le groupe de Bafia, peu connu, mais généralement considéré comme une écaille de nappe du socle paléoprotérozoïque chevauchant le groupe de Yaoundé au nord. Les

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nouvelles observations de terrain ainsi que les nouvelles datations U–Pb sur zircon et Sm–Nd sur roche totale et sur grenat permettent de mieux situer le groupe de Bafia dans le contexte de la CAFB. Il s'agit d'une séquence métasédimentaire, probablement d'âge Néoprotérozoïque, comme les groupes de Poli, de Lom et de Yaoundé de la CAFB. En plus de la source paléoprotérozoïque à archéenne, le groupe de Bafia a révélé l'existence de zircons détritiques, produits de l'érosion de granitoïdes mis en place à 1617 ± 16 Ma. Nos données ont également permis de discuter la provenance des sources détritiques du groupe de Bafia, ainsi que son évolution métamorphique par rapport à celle du groupe de Yaoundé. ***Pour citer cet article : J.N. Tchakounté et al., C. R. Geoscience 339 (2007).***

Keywords: U–Pb Ages; Sm–Nd Ages; Bafia Group; Mesoproterozoic; Nappe tectonics; Cameroon

Mots clés : Âges U–Pb ; Âges Sm–Nd ; Groupe de Bafia ; Mésoprotérozoïque ; Tectonique en nappe ; Cameroun

Version française abrégée

Introduction

Au Cameroun, la partie méridionale de la chaîne panafricaine d'Afrique centrale (CAFB) comporte deux domaines tectoniques majeurs (Fig. 1A) : le domaine de Yaoundé, constitué par les formations néoprotérozoïques du groupe de Yaoundé et impliqué dans une tectonique en nappe à vergence sud, et le domaine de l'Adamaoua, dominé par des granitoïdes panafricains, spatialement associés à de grands cisaillements transcurrents et intrusifs dans un complexe gneissique d'âge Paléoprotérozoïque à Néoprotérozoïque. Le métamorphisme dans les deux domaines est de haut grade, avec des paragenèses granulitiques bien préservées dans le domaine de Yaoundé, mais relictuelles et plus ou moins rétromorphosées dans celui de l'Adamaoua. Réinterprétant la carte géologique de la région, Noizet [9] utilise la télédétection pour différencier une série de Bafia, qu'il considère comme une écaille du socle chevauchant le groupe de Yaoundé. Dans ce contexte, le Groupe de Bafia pourrait représenter la limite méridionale du domaine de l'Adamaoua. Cette interprétation a été renforcée par la découverte d'assemblages granulitiques rétromorphosés dans la région de Bafia [15], et par l'âge zircon de 2100 Ma obtenu sur les gneiss de la région de Makénéné, à l'ouest de Bafia [18]. Les nouvelles datations U–Pb et Sm–Nd présentées dans cette étude permettent cependant d'attribuer un âge Néoprotérozoïque au groupe de Bafia, même si le matériel constituant date essentiellement de la fin du Paléoprotérozoïque, et de discuter l'incidence des résultats sur l'évolution tectonique de la partie sud de la CAFB.

Contexte géologique

La région de Bafia (Fig. 1) est constituée par un ensemble de gneiss variés plus ou moins migmatitiques : gneiss à hornblende et biotite, gneiss à grenat et biotite et gneiss à plagioclase et biotite, interstratifiés de bancs d'amphibolites et de quartzites, et associés à des métaplutonites d'âge Panafricain. La composition chimique de ces gneiss rappelle une séquence sédimentaire à protolithes immatures, constitués de grauwackes et de *shales* (Fig. 2). La région est caractérisée par des structures orientées NNE, soulignées par des niveaux de quartzite très déformés, marqueurs de l'extension régionale NNE–SSW. Ces structures résultent de deux phases majeures de déformation (D1 et D2), avec développement de plis isoclinaux, de foliations et plans de cisaillement à faible pendage, ainsi que de linéations d'étirement. Les critères cinématiques attestent un transport des nappes vers le SSW. Les assemblages minéralogiques témoins du métamorphisme de haut degré sont préservés dans les granulites basiques (Cpx + Grt + Hb + Pl + Qtz et Cpx + Opx + Grt + Pl + Hb + Qtz). La rétromorphose est marquée par le développement de plagioclase II, de hornblende II, de biotite II et de chlorite autour des grenats, de couronnes de hornblende II autour des hornblendes primaires et de symplectites à plagioclase II + quartz au point de contact entre les grenats et les clinopyroxènes.

Géochronologie

Des analyses U–Pb sur zircon et Sm–Nd sur roche totale et sur grenat ont été effectuées sur des échantillons prélevés à l'ouest de Bafia (Fig. 1A et B). Les zircons datés dans cette étude proviennent de deux échantillons (89-66 et IG-45), récoltés dans la carrière de Bayomen. Ce sont des gneiss à biotite, caractérisés par un rubanement compositionnel souligné par la variation de la proportion de grenat, témoignant ainsi de l'origine sédimentaire du protolithe. Les données TIMS-ID sur zircons (Tableau 1), fortement discordantes, s'alignent sur une discordia

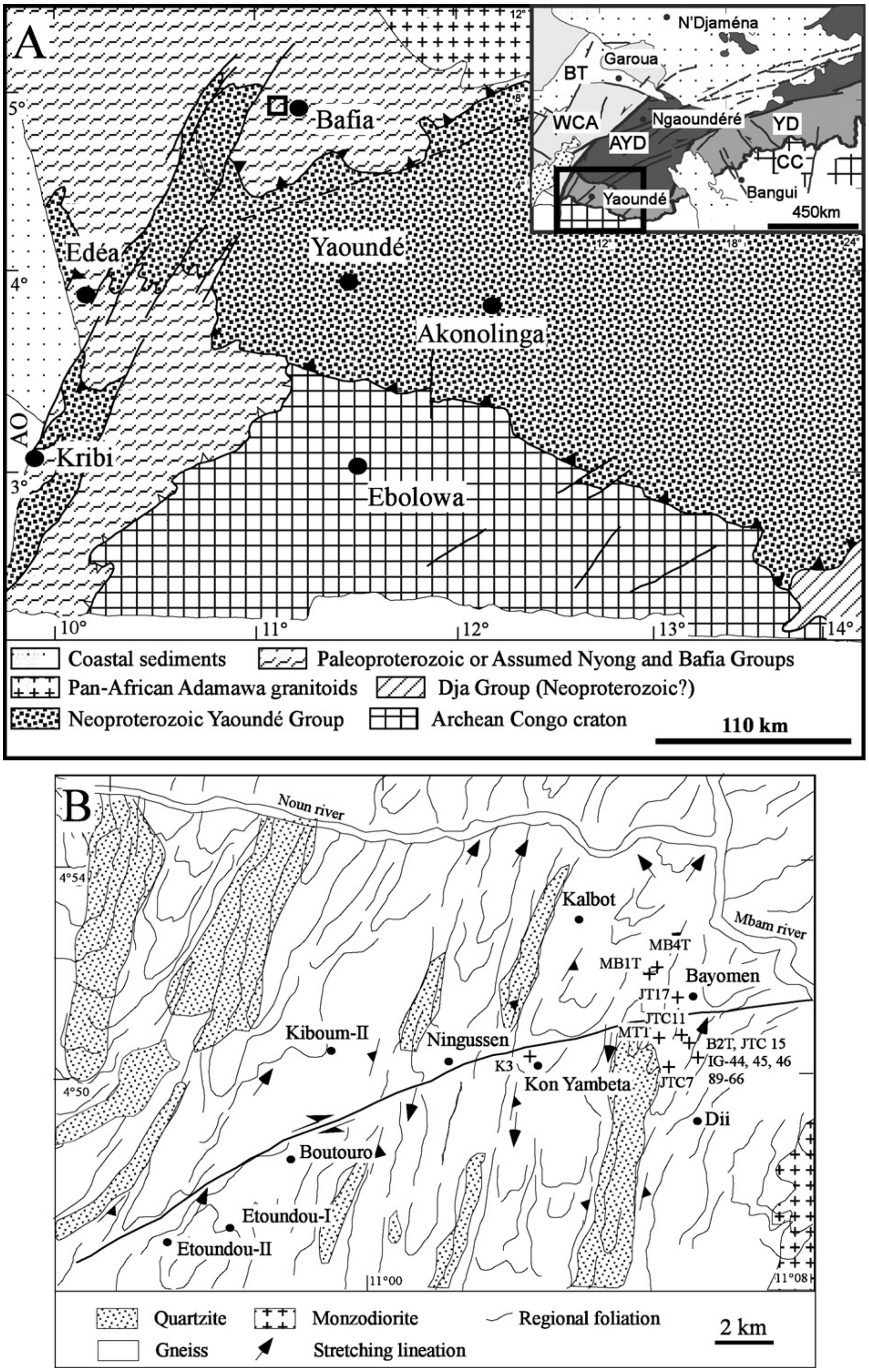

Fig. 1. (**A**) Location of the Bafia region in the framework of the Pan-African belt north of the Congo craton; AO, Atlantic Ocean. Inset [19]: patterns are as follows: grids, Congo craton; dark grey; Adamawa–Yadé Domain (AYD); medium grey, Yaoundé Domain (YD); light grey, West Cameroon Domain (WCD); heavy dots, Cameroon Line; light dots, Mesozoic sediments; BT, Benue Trough. The square in the inset localizes Fig. 1 (A). The square west of Bafia localizes the studied area. (**B**) Geological map of the studied area.

avec des intercepts à 607 ± 66 et 1603 ± 35 Ma (Fig. 3). Des 13 analyses ponctuelles SIMS effectuées (Tableau 2 et Fig. 5), neuf points donnent un intercept supérieur à 1617 ± 16 Ma, comparable aux données TIMS-ID et que nous interprétons comme l'âge de cristallisation des zircons magmatiques. Les résultats Sm–Nd (Tableau 3), couplés aux données zircons, montrent que les gneiss du groupe de Bafia dérivent d'un protolithe d'âge Archéen à fini-Paléoprotérozoïque. En revanche, sur les cinq âges T_{DM} sur les amphibolites interstratifiées dans les gneiss, deux montrent des âges généralement plus jeunes, indiquant l'existence d'un matériel d'âge Néoprotérozoïque dans leur protolithe. Deux couples roche totale–grenat donnent des âges imprécis (628 ± 68 et 674 ± 87 Ma), mais qui indiquent clairement l'âge Panafricain du métamorphisme.

Discussion et conclusion

Les résultats présentés dans cette étude permettent de mieux situer le groupe de Bafia dans le contexte de la CAFB. Bien que leurs évolutions tectono-métamorphiques soient similaires, le groupe de Bafia se distingue de celui de Yaoundé par l'abondance de métagrauwackes et la rareté des métapélites, d'une part, et par la rétromorphose des assemblages granulitiques dans le faciès amphibolite, d'autre part.

Les résultats U–Pb sur zircons obtenus à partir des deux méthodes TIMS-ID et SIMS sont cohérents et indiquent un âge de 1617 ± 16 Ma pour la cristallisation des zircons magmatiques hérités dans les métasédiments du groupe de Bafia. Ceci montre que le groupe de Bafia est plus jeune que 1600 Ma, et pourrait s'être déposé au Néoprotérozoïque, à l'instar des autres séquences sédimentaires (groupe de Yaoundé, Poli, Lom) de la CAFB au nord du craton du Congo. L'âge Panafricain du métamorphisme est indiqué à la fois par les âges U–Pb sur zircons (intercept inférieur) et Sm–Nd sur des couples roche totale–grenat, et par l'âge de 600 Ma obtenu sur une monzodiorite syntectonique de Ngaa Mbappé [20].

Pour expliquer la différence de comportement des assemblages granulitiques (rétromorphosés à Bafia et vers le nord, mais bien préservés à Yaoundé), nous suggérons que l'activité tectono-métamorphique à l'intérieur de la chaîne (vers le nord) se serait poursuivie au-delà de l'empilement des nappes sur le craton. Toteu et al. [20] ont estimé que la tectonique en nappe a commencé vers 610 Ma, avec la mise en place des nappes profondes en conditions de granulite faciès, et s'est poursuivie après 600 Ma, avec les nappes plus superficielles (cas de Bafia) en conditions de faciès amphibolite. En conséquence, la tectonique transcurrente dans l'Adamaoua, ainsi que la mise en place des granitoïdes associés auraient eu lieu principalement après la tectonique en nappe (c'est-à-dire après 600 Ma).

La présence des zircons détritiques datés à 1617 ± 16 Ma dans les métasédiments du groupe de Bafia, non seulement montre que le protolithe des métasédiments provient de plusieurs sources d'âges variés, mais indique aussi, et ce pour la première fois, la contribution des formations d'âge fini-Paléoprotérozoïque à l'évolution crustale de la CAFB. La synthèse de l'ensemble des données disponibles montre qu'il est plus vraisemblable que les sources ayant alimenté les sédiments du groupe de Bafia aient été situées au nord (domaine de l'Adamaoua) plutôt qu'au sud (craton du Congo).

1. Introduction

The southern part of the Pan-African (Neoproterozoic) Central African Fold Belt (CAFB) comprises two major tectonic domains (Fig. 1(A)): the Yaoundé Domain, which is largely dominated by the Neoproterozoic metasedimentary sequence of the Yaoundé Group and involved in a regional scale southward nappe tectonics, and the Adamawa Domain, which is dominated by Pan-African granitoids intruding a complex terrane of Palaeo- to Neoproterozoic gneisses intensively overprinted by regional-scale transcurrent shear zones [19]. Both domains are at high-grade metamorphism; granulite facies assemblages are widespread and well preserved in the Yaoundé Domain, but they are relict and more or less retrogressed into amphibolite facies in the Adamawa Domain. Reinterpreting the geological map [21], Noizet [9] used remote-sensing analyses to distinguish a Bafia Group north of Yaoundé, which he interpreted as a basement tectonic slice overthrusting the Yaoundé Group. This makes the Bafia Group a potential southern limit for the Adamawa Domain. This interpretation was later

Fig. 1. (**A**) Situation de la région de Bafia dans le contexte de la chaîne Panafricaine, au nord du craton du Congo. Encart [19] : grilles, craton du Congo ; gris sombre, domaine Adamaoua-Yadé ; gris moyen, domaine de Yaoundé ; gris clair, domaine Ouest Cameroun ; points serrés, ligne du Cameroun ; points espacés, sédiments mésozoïques ; BT, fossé de la Bénoué. Le cadre dans l'encart localise la Fig. 1 (A). Le cadre à l'ouest de Bafia localise le secteur d'étude. (B) Carte géologique du secteur étudié.

reinforced by the presence of granulite facies assemblages retrogressed during the Pan-African nappe tectonics in the Bafia region [15], and the occurrence of a ca 2.1-Ga zircon age recorded on the Makenene gneisses, west of Bafia [18]. Based on the new U–Pb and Sm–Nd geochronological data presented in this paper, we conclude that the Bafia Group is not Palaeoproterozoic, but is potentially a Neoproterozoic sedimentary sequence, and we discuss the consequence of these ages for the regional tectonic history of the southern CAFB.

2. Geological framework

The Bafia region (Fig. 1(B)) is underlain by high-grade heterogeneous gneisses comprising dominant hornblende–biotite gneisses interleaved with garnet–biotite gneisses, plagioclase and biotite gneisses, quartzites, and amphibolites, all intruded by Pan-African metaplutonic rocks (e.g., Ngaa Mbappé monzodiorite at the southeastern corner of the studied area). Mafic granulites occur as boudinaged bands and lenses within migmatized gneisses. The compositions of the gneisses (Fig. 2) range from greywackes of intermediate composition to shales, suggesting a sedimentary sequence derived mostly from immature sediments. The region is characterized by NNE-trending structures well defined on the map (Fig. 1(B)) by highly deformed quartzites, markers of the regional NNE–SSW extension. These structures result from a two-phase deformation (D1 and D2) associated with recumbent folds, flat-lying foliation and shear plane, and NNE–SSW trending stretching lineation. Kinematic criteria deduced from the asymmetry of folds and C/S planes indicate a top-to-the-SSW sense of movement during nappe tectonics. The deformation occurred largely under high-grade conditions. The presence of migmatitic melts along S2 foliation and C2 shear planes indicates that the nappe tectonics was coeval with migmatization. Mineral assemblages attesting to granulite facies conditions during the early stage of the metamorphic evolution are preserved within mafic granulites. They include: Cpx + Grt + Hb + Pl + Qtz and Cpx + Opx + Grt + Pl + Hb + Qtz. The mafic granulites also show evidence of retrograde metamorphism with development of plagioclase-II rims around garnet, hornblende-II rims around hornblende-I, and symplectitic growth of plagioclase-II + quartz at the contact between garnets and clinopyroxenes. These textures probably resulted from a decompression following the peak metamorphic conditions.

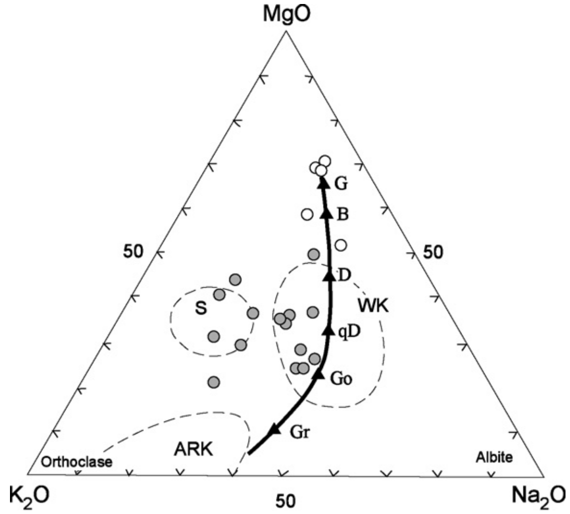

Fig. 2. Geochemical characteristics of the Bafia Group's rock-types in the $MgO–K_2O–Na_2O$ diagram [5]. Solid circles, gneisses; open circles, amphibolites. The solid line shows the composition trend of plutonic rocks with granite (Gr), granodiorite (Go), quartz diorite (qD), basalt (B), gabbro (G). Dashed contours delimit the field of shales (S), greywackes (WK), and arkoses (ARK).

Fig. 2. Caractérisation géochimique des différentes formations géologiques du groupe de Bafia dans le diagramme $MgO–K_2O–Na_2O$ [5]. Cercles pleins, gneiss variés ; cercles vides, amphibolites. La ligne en gras montre la tendance compositionnelle des roches plutoniques avec granite (Gr), granodiorite (Go), diorite quartzitique (qD), basalte (B), gabbro (G). Les pointillés délimitent les champs des *shales* (S), grauwackes (WK) et arkoses (ARK).

3. Geochronology

Zircon U–Pb and whole-rock and garnet Sm–Nd analyses have been carried out on samples taken west of Bafia (Fig. 1A and B). The only data available on the Bafia region are the ca 600-Ma zircon age of the Ngaa Mbappé monzodiorite (Fig. 1B), whose emplacement was synchronous with the nappe tectonics [20] and the 2.3-Ga Sm–Nd crustal residence age on the garnet–biotite gneiss at the Bayomen quarry (sample 89-66, [18]). A few zircons from sample 89-66 yielded very discordant plots with intercepts at 607 ± 66 and 1603 ± 35 Ma (Table 1 and Fig. 3; unpublished TIMS-ID data from Toteu, database of 1993). Although the lower intercept reflected the Pan-African age of the tectono-metamorphic imprint, the upper intercept was difficult to interpret because of complex structures (core and rims) observed in some zircons under the binocular microscope. Recently, another sample collected at the Bayomen quarry (IG-45) was processed; it gave enough zircons for detailed studies, including Scanning Electronic Microscope (SEM) analyses. In addition, representative samples from the region were collected for whole-

Table 1
U–Pb TIMS-ID results for zircons of 89-66 and IG-45 gneisses from the Bayomen Quarry (Bafia)

Tableau 1
Résultats TIMS-ID d'analyses U–Pb sur les zircons des gneiss 89-66 et IG-45 de la carrière de Bayomen (région de Bafia)

Sample	Fraction	Size (mg)	U ppm	Pb ppm	$\frac{^{206}Pb}{^{204}Pb}$ (obs.)	Isoplot data $\frac{^{207}Pb^*}{^{235}U}$	± 2σ (pct)	$\frac{^{206}Pb^*}{^{238}U}$	± 2σ (pct)	Correl. coeff. (rho)	$\frac{^{207}Pb^*}{^{206}Pb^*}$	± 2σ (pct)	Calculated ages $\frac{^{206}Pb^*}{^{238}U}$ age	± 2σ (Ma)	$\frac{^{207}Pb^*}{^{235}U}$ age	± 2σ (Ma)	$\frac{^{207}Pb^*}{^{206}Pb^*}$ age	± 2σ (Ma)
89-66	NM-2	0.032	145	31	2874	2.1468	0.89	0.17967	0.75	0.853	0.08661	0.46	1065.2	8.0	1164.0	10,4	1353.0	9.9
89-66	M-2 clear	0.030	119	26	6944	2.2676	0.58	0.18591	0.56	0.976	0.08846	0.13	1099.2	6.2	1202.3	7.0	1392.5	2.4
89-66	M-2 pink	0.025	137	36	6098	2.8369	0.59	0.22091	0.58	0.990	0.09314	0.14	1286.7	7.5	1365.4	8.1	1490.7	1.6
89-66	M-2 single	0.052	262	70	12346	2.8493	0.50	0.22182	0.49	0.986	0.09316	0.08	1291.5	6.3	1368.6	6.8	1491.1	4.4
IG-45	Zr-3/05 single	0.013	50	13	1940	2.6307	1.20	0.20881	1.18	0.986	0.09137	0.20	1222.5	14.4	1309.3	15.7	1454.4	3.8
IG-45	Zr-6/05 single	0.022	74	20	3200	2.9230	0.67	0.22890	0.61	0.922	0.09262	0.26	1328.7	8.1	1387.9	9.3	1480.1	4.9

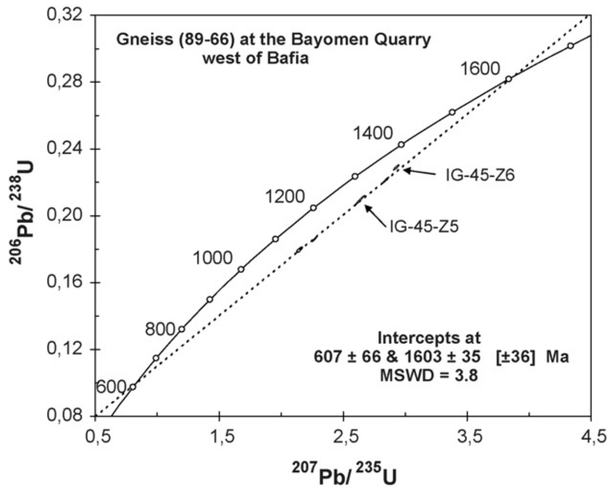

Fig. 3. Concordia diagram for gneiss (89-66) from the Bayomen Quarry (TIMS results). Results for two single grains of IG-45 from the same quarry plot close to the discordia line.

Fig. 3. Diagramme concordia du gneiss (89-66) de la carrière de Bayomen (résultat TIMS). Les points de deux monozircons lG-45 de la même carrière tombent près de la concordia.

rock and garnet Sm–Nd analyses. TIMS-ID on zircons and Sm–Nd analyses were performed at the Isotopic Geochemistry Laboratory (University of Kansas, USA), while SIMS analyses on zircons were carried out on the Cameca IMS1270 ion microprobe at the CRPG, Nancy (France), following the analytical techniques described in Deloule et al. [2]. Additional Sm–Nd whole-rock analyses were obtained at the Isotopic Geochemistry Laboratory of the Cornell University (USA).

3.1. U–Pb results

Both 89-66 and IG-45 are hornblende–biotite gneisses containing plagioclase, K-feldspar, garnet, titanite, oxides, and zircon. Zircons are pink in colour, with few grains displaying euhedral morphology; however, most grains show abraded edges, probably as the result of transport. Core and rim structures observed under the binocular microscope appear more complex when observed by SEM. Cathodoluminescence images show light domains (low U content), which appear within the grain, surrounding the grain, or as irregular patches crosscutting the original magmatic zoning of the zircons (Fig. 4). These structures do not look like classical metamorphic overgrowths, as those described by Sommer et al. [13] and Tenczer et al. [16] in the Mozambique belt. At least, part of the observed structures may be interpreted as the result of metamorphic recrystallisation, probably under fluid

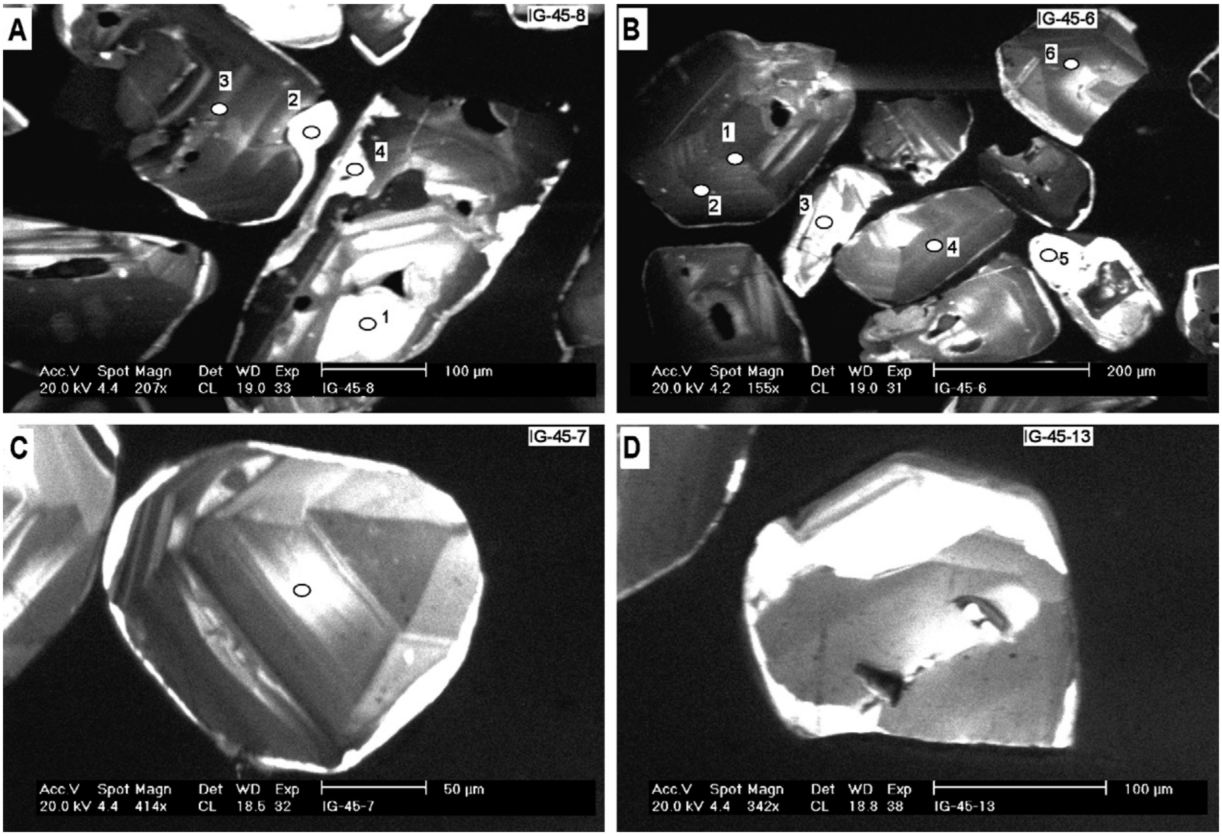

Fig. 4. Selected cathodoluminescence photos of analysed zircons from sample IG-45. Note the light U-poor zones do not correspond to classical metamorphic overgrowths around magmatic zircons; the recrystallization appears at the edge and at the core, and independently of the magmatic zoning of the zircons. The small labelled ellipses locate the analytical spots (not at scale).

Fig. 4. Quelques photos en cathodoluminescence des zircons de l'échantillon IG-45. Notez que les zones à faibles teneurs en U ne correspondent pas aux surcroissances métamorphiques classiques autour des zircons magmatiques ; les recristallisations apparaissent au cœur et sur les bordures, indépendamment du zoning magmatique des zircons. Les petites ellipses et les chiffres associés indiquent les points de sonde (non à l'échelle).

action. Results for TIMS-ID of two single zircons from sample IG-45 (Table 1), together with 89-66 data, give a poorly defined discordia with intercepts at 567 ± 130 and 1577 ± 55 Ma (not shown in Fig. 3). Thirteen SIMS spot analyses on sample IG-45 are shown in Table 2 and plotted in Fig. 5. Two analyses are very discordant ($^{206}Pb/^{238}U$ ages around 700 Ma) and two others show large error ellipses. The regression of the other nine data gives an upper intercept of 1617 ± 16 Ma, consistent with the TIMS-ID results; we interpret it as the crystallization age of the magmatic zircons. The two very discordant plots with $^{206}Pb/^{238}U$ age at 688 ± 17 and 642 ± 22 Ma were recorded on light domains, one on the rim and the other on the core; they display low U contents, very low Th/U ratios (0.01 and 0.02) and lower Pb contents (3 and 5 ppm) than the dark domains (9–70 ppm). They also display higher $^{204}Pb/^{206}Pb$ ratios, and their discordant position on the concordia diagram may result from an undercorrection of the common lead contribution to the $^{207}Pb/^{235}U$ ratio. We interpret these light domains as the result of a partial recrystallization during the Pan-African metamorphism, with a major lead loss (>90%) for the two discordant analyses.

3.2. Sm–Nd results

Results for different rock-types from the Bafia region are shown in Table 3 and Fig. 6. Data are consistent with derivation of gneisses mostly from a Palaeoproterozoic to Archean protolith, with most of the T_{DM} ages ranging in between 2.1 and 2.6 Ga. On the other hand, interleaved amphibolites display T_{DM} range from 2.8 to 0.69 Ga, indicating that the protolith for some amphibolites comprises a dominant proportion of young Neoproterozoic component. The two whole rock-garnet pairs (IG-44 and IG-45) give imprecise ages (628 ± 68 and 674 ± 87 Ma, respectively), due to low radiogenic

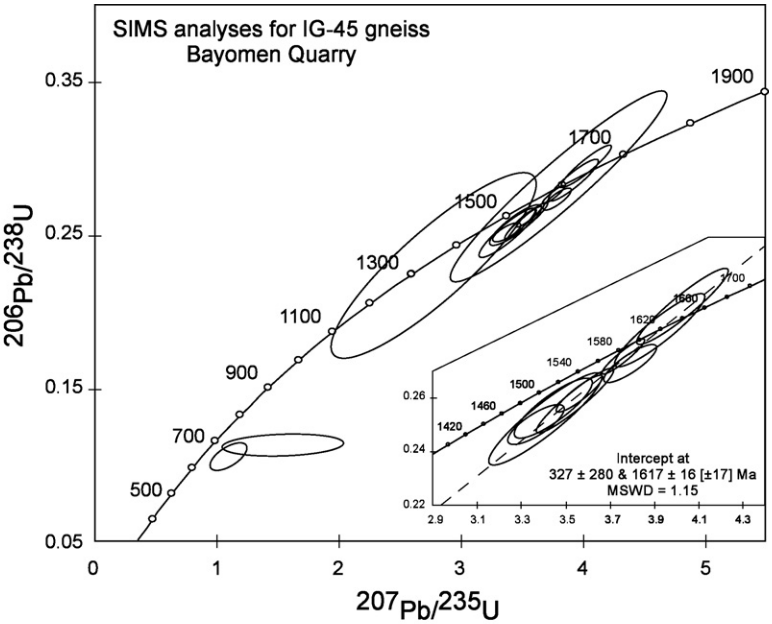

Fig. 5. Concordia diagram for gneiss (IG-45) from the Bayomen quarry (SIMS results). Inset: detail for the nine analyses close to the upper intercept.

Fig. 5. Diagramme concordia du gneiss (IG-45) de la carrière de Bayomen (résultats SIMS). Médaillon : détails des neuf analyses proches de l'intercept supérieur.

composition of garnets and/or remobilization of LREE during retrogression [6]. Nevertheless, they are consistent with zircon data from samples 89-66 and IG-45 and clearly indicate the Pan-African age of the metamorphism.

4. Discussion and conclusion

Data presented in this paper allow a better understanding of the Bafia Group in the context of the CAFB. Field and petrographic observations indicate that the tectonic evolution leading to the major southward nappe thrusting is quite similar to that of the Yaoundé Group. However, the Bafia Group is characterized by the abundance of metagreywackes and the scarcity of metapelites, which dominate the Yaoundé Group. Although both groups experienced granulite facies conditions during the early stage of metamorphism, the corresponding granulite facies assemblages are more or less retrogressed in Bafia, whereas they are well preserved in Yaoundé.

U–Pb results on zircons using both TIMS-ID and SIMS methods are consistent and point to an age of 1617 ± 16 Ma for the crystallization of magmatic zircons in the studied samples. This suggests that the erosion of plutonic rocks of this age provided detritus for the Bafia metasediments. This also indicates that the Bafia Group is younger than 1600 Ma, and is definitely not Palaeoproterozoic. The time range of the sedimentation is not well constrained from our data; however, the group is probably Neoproterozoic in age as it is the case in the other sedimentary sequences (Yaoundé, Poli, and Lom) north of the Congo craton. The effects of the high-grade metamorphism on the studied zircons were generally weak; however, both zircon and Sm–Nd garnet whole-pair results support its Pan-African age (despite the age, error and methods used), which can be better constrained by the 600-Ma age for the syntectonic Ngaa Mbappé monzodiorite involved in the nappe tectonics [20].

As mentioned above, the granulite facies assemblages in the Bafia Group are scarce and poorly preserved, compared to those of the Yaoundé Group. These characteristic features of retrogressed granulites are also described northward in the Adamawa Domain ([8,11] and Bouyo Houketchang, work in progress). As the time range for the regional metamorphism is probably the same (620–600 Ma) for the belt north of the Congo craton [14,20], what then is the cause of the difference in the preservation of the granulite facies assemblages compared to the Yaoundé Group? We suggest that the tectono-metamorphic activity in the internal part of the belt outlasted the stacking of nappe units on the Congo craton. Toteu et al. [20] estimated that this tectonics started between 616 and 611 Ma under the peak conditions of the granulite metamorph-

Table 2
U–Pb SIMS results for zircons of IG-45 gneiss from the Bayomen quarry (Bafia)

Tableau 2
Résultats SIMS d'analyse U–Pb sur les zircons du gneiss IG-45 de la carrière de Bayomen (région de Bafia)

Grain spot	Pb (ppm)	U (ppm)	Th (ppm)	Th/U	f206 (%)	$\frac{^{204}Pb}{^{206}Pb}$	Radiogenic ratios $\frac{^{206}Pb}{^{238}U}$	±	$\frac{^{207}Pb}{^{235}U}$	±	$\frac{^{207}Pb}{^{206}Pb}$	±	Correl. Err.	Ages in Ma $\frac{^{206}Pb}{^{238}U}$	±	$\frac{^{207}Pb}{^{235}U}$	±	$\frac{^{207}Pb}{^{206}Pb}$	±
IG45z5	55	218	221	1.01	0.00	0.000084	0.294	0.006	4.028	0.085	0.0993	0.0076	0.932	1662	29	1640	17	1611	14
IG45z6c1	28	128	208	1.62	0.00	0.000060	0.252	0.007	3.408	0.104	0.0980	0.0125	0.913	1450	36	1506	24	1586	23
IG45z6r2	40	180	190	1.05	0.00	0.000034	0.262	0.003	3.562	0.042	0.0987	0.0053	0.896	1498	14	1541	9	1600	10
IG45z6r3	9	40	52	1.28	0.00	0.000241	0.256	0.005	3.443	0.072	0.0975	0.0110	0.851	1470	23	1514	16	1576	21
IG45z6c4	41	175	280	1.60	0.00	0.000048	0.275	0.003	3.760	0.039	0.0990	0.0038	0.931	1569	13	1584	8	1605	7
IG45z6r5	9	47	32	0.67	0.00	0.000219	0.230	0.025	2.782	0.342	0.0878	0.0587	0.878	1333	129	1351	88	1379	109
IG45z6c6	33	134	202	1.51	0.00	0.000131	0.285	0.006	3.926	0.083	0.0998	0.0086	0.915	1618	28	1619	17	1620	16
IG45z7	18	76	74	0.97	0.00	0.000108	0.273	0.003	3.792	0.049	0.1008	0.0070	0.836	1556	15	1591	10	1638	13
IG45z8c1	5	56	1	0.02	0.00	0.000721	0.105	0.004	1.101	0.062	0.0762	0.0432	0.639	642	22	754	29	1101	84
IG45z8r2	3	26	0	0.01	0.02	0.003455	0.113	0.003	1.550	0.202	0.0999	0.1280	0.199	688	17	950	78	1621	221
IG45z8c3	70	314	438	1.39	0.00	0.000041	0.259	0.005	3.542	0.072	0.0992	0.0069	0.940	1485	25	1537	16	1608	13
IG45z8r4	45	185	198	1.07	0.00	0.000026	0.281	0.025	3.802	0.362	0.0980	0.0294	0.951	1598	127	1593	74	1586	54
IG45z9	9	42	38	0.90	0.00	0.000201	0.250	0.003	3.366	0.052	0.0976	0.0098	0.777	1439	16	1496	12	1578	18

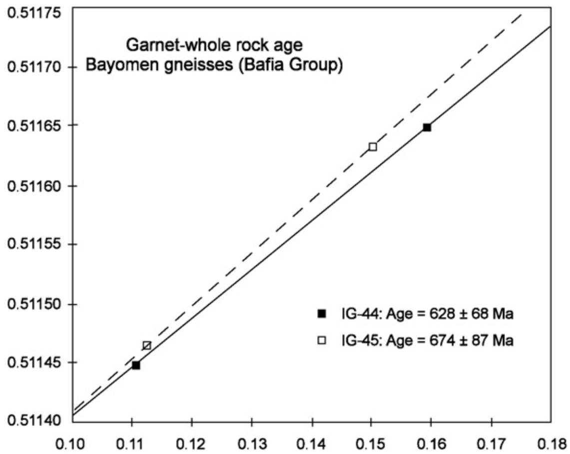

Fig. 6. $^{147}Sm/^{144}Nd$ versus $^{143}Nd/^{144}Nd$ plot for gneisses (solid squares) and amphibolites (open squares) from the Bafia Group. The inset shows the histogram of T_{DM} ages.

Fig. 6. Diagramme $^{147}Sm/^{144}Nd$ en fonction de $^{143}Nd/^{144}Nd$ pour les roches du groupe de Bafia : gneiss (carrés pleins), amphibolites (carrés vides). L'encart montre l'histogramme des âges T_{DM}.

ism and continued until 600–590 Ma under medium- to low-grade conditions, with the oldest nappe at the south and the youngest (e.g., the Bafia nappe) toward the north. In this regard, the transcurrent tectonics associated with emplacement of granitoids in the Adamawa region may have developed mostly after the nappe tectonics (e.g., after 600 Ma), both representing post-collisional events [7,19]. The Sm–Nd crustal residence ages for gneisses are Archean to Palaeoproterozoic. However, the presence of homogeneous 1617 ± 16-Ma detrital zircons (proximal deposits?) evidences that the gneisses are mixture products formed between the Archean and the Late Palaeoproterozoic. The amount of old material in gneiss may have been important, as indicated by the negative ε_{Nd} value calculated at 1.6 Ga (Table 3). These characteristics make the protolith for the Bafia Group different from those of the Nyong and the Ntem complex, which show typical Archean ages [17]. To constrain the source provenance for the Bafia Group, it is important to locate the possible origin of the ca 1.6-Ga zircons recorded here for the first time in the CAFB. Late Palaeoproterozoic alkaline granites and syenites are recorded in the Hoggar and northeastern Brazil; in particular, an age of 1521 ± 7 Ma was obtained on Augen gneisses west of Recife and north of the Pernambucco Shear Zone [12], which was adjoined to central Africa in pre-drift reconstruction. Looking at their Nd T_{DM} ages, the source provenance for the Bafia metasediments may be located northward (e.g., the Adamawa domain in Cameroon and the Pernambuco–Alagoas and Transverse

Table 3
Sm-Nd analytical data for whole rocks and minerals from different rock-types of the Bafia region

Tableau 3
Données analytiques Sm-Nd sur roche totale et sur mineraux de différents types de roches de la region de Bafia

Sample	Type	Nd (ppm)	Sm (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	$\pm 2\sigma$	ε_{Nd} (today)	(t) (Ga)	ε_{Nd} (t)	T_{DM} (Ga)
IG-44 WR	Gneiss	64.60	11.83	0.1107	0.511449	± 9	−23.2	1.6	−5.6	2.35
IG-44	Garnet	18.48	4.87	0.1594	0.511649	± 15	−19.3		(0.628 ± 0.68)	
IG-45 WR	Gneiss	84.35	15.68	0.1124	0.511465	± 9	−22.9	1.6	−5.6	2.37
IG-45	Garnet	24.58	6.11	0.1502	0.511632	± 11	−19.6		(0.674 ± 0.87)	
IG-46 WR	Amphibolite	38.73	9.06	0.1414	0.512355	± 10	−5.5	0.6	−1.3	1.44
89-66	Gneiss	68.64	12.57	0.1107	0.511473	± 18	−22.7	1.6	−5.1	2.33
JTC7[b]	gneiss	78.89	15.39	0.1185	0.511410	± *30*	−24.0	1.6	−7.9	2.63
JTC17[b]	Amphibolite	15.57	4.67	0.1822	0.512480	± *30*	−3.1	1.6	−0.1	2.79[a]
K3[b]	Amphibolite	27.25	5.61	0.1251	0.512040	± *30*	−11.7	0.6	−6.2	1.72
JTC15[b]	Amphibolite	19.69	3.91	0.1207	0.511300	± *30*	−26.1	.16	−10.5	2.89
MB1T[b]	Amphibolite	50.45	9.84	0.1185	0.512620	± *30*	−0.4	0.6	5.7	0.69
MB4T[b]	Gneiss	9.98	1.51	0.0917	0.510490	± *30*	−41.9	1.6	−20.4	3.23
B2T[b]	Gneiss	112.7	21.08	0.1136	0.511450	± *30*	−23.2	1.6	−6.1	2.44
MTT[b]	Gneiss	52.23	10.35	0.1204	0.511750	± *30*	−17.3	1.6	−1.7	2.12
JTC11[b]	Gneiss	67.45	12.99	0.1170	0.511380	± *30*	−24.5	1.6	−8.2	2.64

$^{143}Nd/^{144}Nd$ normalized to $^{146}Nd/^{144}Nd$ = 0.72190. $\varepsilon_{Nd}(0)$ calculated relative to CHUR(0) = 0.512638. Model ages (T_{DM}) were calculated according to the single-stage model of DePaolo [3]. Primary ages used for ε_{Nd}(t) for gneisses is 1.6 Ga. ε_{Nd}(t) and T_{DM} were not calculated for mineral fractions or rock samples whose growth lines have poorly controlled intersections with the depleted mantle (DM) curve; ( ) denotes an isochron age defined by garnet-whole rock tie-line.

[a] Imprecise because of high Sm/Nd.

[b] Analyses performed at the Isotopic Geochemistry Laboratory of the Cornell University (US); numbers in italic represent laboratory uncertainties at the 2σ level[4].

Domains in Brazil, [1,18]). Sources of similar origin were also suggested for the metasedimentary rocks of the Yaoundé and Sergipano Groups [10].

The results from this study and those available in the Pan-African belt north of the Congo–São Francisco cratons reveal the persistence of Late Palaeoproterozoic to Mesoproterozoic ages, either as recognized rock units or as inheritance. However, data are still insufficient and there is a need, particularly in central Africa, for detailed geological mapping and geochronology in order to understand the significance and the impact of the crust of this age range on the genetic processes of the Pan-African granitoids. Similarly, this study has also revealed the complexity of the central Cameroon region (e.g., Adamawa), where detailed work is still necessary to discriminate between basement and Neoproterozoic sedimentary sequences and to understand the structural links between the Yaoundé Domain (nappe tectonics) and the Adamawa Domain (transcurrent tectonics). In this context, the Bafia Group, which displays the tectonic and metamorphic features of both the Yaoundé and Adamawa tectonic domains, may be located at their transition zone.

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