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C. R. Geoscience 337 (2005) 551–562

http://france.elsevier.com/direct/CRAS2A/

Geochemistry (Geochronology)

New U–Pb zircon ages from Tonga (Cameroon): coexisting Eburnean–Transamazonian (2.1 Ga) and Pan-African (0.6 Ga) imprints

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Received 22 June 2004; accepted after revision 24 January 2004

Available online 10 March 2005

Presented by Zdenek Johan

Abstract

The central domain of the Pan-African Belt in Cameroon is characterized by abundant porphyritic granitoids, which were emplaced synkinematically and variably orthogneissified in relation with ENE-striking steeply dipping transcurrent shear zones. These plutonic rocks have intermediate to felsic compositions and constitute a high-K calk-alkaline series. Conventional U–Pb zircon dating yields an age of 618 Ma for this syntectonic Pan-African magmatism in the Tonga area. The country rocks are made of metabasites (garnet amphibolites) and tonalitic to trondhjemitic gneisses, which suffered two distinct orogenic cycles: the first one is the Palaeoproterozoic Eburnean–Transamazonian cycle at 2.1 Ga and the second one is the Pan-African orogenesis. These new ages confirm the existence of an extensive Palaeoproterozoic crust in Cameroon and question the areal extent of the Congo–São Francisco craton towards the north. ***To cite this article: E.L. Tanko Njiosseu et al., C. R. Geoscience 337 (2005).***

Résumé

Nouveaux âges U–Pb sur zircons à Tonga (Cameroun) : une double empreinte éburnéenne–transamazonienne (2,1 Ga) et panafricaine (0,6 Ga). Le domaine panafricain centre-camerounais est caractérisé par un abondant magmatisme granitique. Ces granitoïdes se sont mis en place à la faveur de grands décrochements de direction ENE. Ils sont de composition intermédiaire à acide et constituent une série calco-alcaline fortement potassique, datée à 618 Ma dans la région de Tonga par la méthode conventionnelle U–Pb sur zircons. L'encaissant comprend des métabasites (amphibolites à grenat) et des gneiss tonalitiques à

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doi:10.1016/j.crte.2005.02.005

trondhjémitiques, qui ont subi deux cycles orogéniques distincts : d'abord le cycle éburnéen–transamazonien vers 2,1 Ga, puis l'orogenèse panafricaine vers 0,6 Ga. Ces nouvelles données géochronologiques impliquent l'existence d'une croûte ancienne paléoprotérozoïque, qui pose le problème du prolongement septentrional du craton de Congo–São Francisco au Cameroun.

Pour citer cet article : E.L. Tanko Njiosseu et al., C. R. Geoscience 337 (2005).

Keywords: U–Pb zircon ages; Cameroon; Pan-African; Eburnean–Transamazonian; Shoshonitic plutonism

Mots-clés : Datation U–Pb sur zircons ; Cameroun ; Panafricain ; Eburnéen–Transamazonien ; Plutonisme shoshonitique

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Version française abrégée

1. *Introduction et contexte géologique*

La chaîne panafricaine nord-équatoriale ou orogène d'Afrique centrale affecte la plus grande partie du Cameroun [36]. Du sud au nord, on y reconnaît trois domaines géodynamiques distincts (Fig. 1a) :

(*i*) le domaine sud comprend un ensemble de séries sédimentaires (Ntui–Betamba, Yaoundé, Ayos–Mbalmayo–Bengbis). Associées à un magmatisme alcalin [26], ces séries se sont déposées dans un contexte de rift intracontinental ou de marge amincie et ont subi un métamorphisme de haute pression et haute température à 616 Ma [21,28,39]. Elles ont été charriées sur le craton du Congo vers le sud [18]. Ce chevauchement majeur se poursuit en Centrafrique par la nappe des Oubanguides ;

(*ii*) le domaine centre-camerounais, qui comporte de nombreux plutons syntectoniques panafricains dans un encaissant fortement métamorphique formé de gneiss et d'amphibolites [25] ;

(*iii*) le domaine nord, caractérisé par un magmatisme calco-alcalin dans un contexte d'accrétion entre 800 et 600 Ma [37,38].

Le domaine centre-camerounais, zone de transition entre les parties nord et sud de la chaîne panafricaine au Cameroun, est un vaste domaine, qui s'étend entre la faille de la Sanaga (au sud de Bafia) et la faille de Tcholliré–Banyo (au nord du plateau de l'Adamaoua). Ces grands décrochements, d'orientation NE–SW, semblent avoir guidé la mise en place de plutons calco-alcalins présentant une orthogneissification d'intensité variable [12,23,24,35]. La région de Tonga est située dans la partie sud de ce domaine. Le but de cette note est, premièrement, de caractériser les plutonites panafricaines mises en place dans ce secteur et, deuxièmement, de dater les principaux types pétrographiques présents. Les résultats sont d'une importance capitale pour les modèles géodynamiques de l'Afrique centrale au Protérozoïque. En particulier, l'existence d'une croûte anté-panafricaine dans la chaîne panafricaine d'Afrique équatoriale est une question clé à laquelle on se propose de répondre [27].

La région de Tonga, d'une superficie de 420 km^2 (Fig. 1b), est formée de deux ensembles distincts : (1) un ensemble métamorphique fait de métabasites et de gneiss, au sein desquels on reconnaît une phase de déformation D1, caractérisée par une foliation subhorizontale S1 et, localement, une phase D2 associée à des structures cisaillantes redressées (foliation S2) en zone autour d'une direction NE–SW (Fig. 1c), (2) un ensemble magmatique de granitoïdes plus ou moins orthogneissifiés, généralement porphyroïdes, mis en place en conditions syncinématiques lors de la phase de déformation D2. Une estimation des températures et pressions atteintes au cours du métamorphisme lié à la phase D1 à partir de l'assemblage grenat–clinopyroxène–plagioclase [2] donne des températures de l'ordre de 850 °C et des pressions de 1 à 1,2 GPa. En revanche, le baromètre *Al-in-hornblende* [9,32] indique que les granitoïdes syncinématiques D2 ont cristallisé à des pressions de l'ordre de 0,5 GPa.

2. *Pétrographie et géochimie des échantillons datés*

Trois échantillons caractéristiques ont été retenus. Leur localisation est indiquée sur la Fig. 1b et leur composition chimique (éléments majeurs et traces) est présentée dans le Tableau 1.

Le granitoïde syncinématique TG24 (N5°00.00′, E10°40.12′) est composé de plagioclase, feldspath potassique, quartz, biotite et amphibole. Apatite, zircon, allanite, sphène et opaques constituent les phases accessoires. C'est une monzonite quartzique métalumineuse, ferrifère et potassique ($K_2O/Na_2O = 1{,}26$). Les roches plutoniques associées, toutes mises en place lors de la phase D2, sont généralement plus riches en silice. Elles sont souvent porphyroïdes. Elles présentent un caractère métalumineux à faiblement peralumineux ; la valeur du rapport molaire A/CNK comprise entre 0,83 et 1,03 en fait des granitoïdes de type I. Dans le diagramme K_2O en fonction de SiO_2 ([31] ; Fig. 2), ces roches correspondent à une série shoshonitique. Les teneurs en Ba (1504–6810 ppm), en Sr (281–2646 ppm) et en Zr (307–502 ppm) sont très élevées. Les spectres de terres rares sont très fractionnés et présentent un enrichissement marqué en terres rares légères (Fig. 3).

L'amphibolite à grenat TG5 (N5°02.38′, E10°42.09′) comprend : amphibole (50 %), grenat almandin (20 %), plagioclase (15 %), salite (10 %), quartz (5 %), sphène, apatite, zircon et opaques. C'est une roche riche en titane et en fer. La richesse en Nb contraste avec l'appauvrissement habituel en cet élément dans les basaltes d'arcs. Le spectre des terres rares (Fig. 3) est caractérisé par un enrichissement en terres rares légères, similaire à celui des basaltes alcalins ou des tholéiites continentales [41]. Il s'agit donc d'un ancien magma basaltique intraplaque ayant (re)cristallisé dans les conditions de la croûte inférieure.

Le gneiss plagioclasique à biotite et amphibole TG10 (N4°97.28′, 510°43.59′) comprend : plagioclase (45 %), quartz (20 %), amphibole (15 %), biotite (12 %), feldspath potassique ($\leqslant 5$ %), apatite et magnétite (<1 %), ce qui correspond à un protolithe tonalitique. Les teneurs en éléments majeurs et traces indiquent un magmatisme calco-alcalin pauvre en K (Fig. 2). Le spectre de terres rares (Fig. 3) est très fractionné avec un appauvrissement relatif en HREE et une anomalie positive en Eu.

3. Géochronologie

Une étude U–Pb sur zircons du granitoïde TG24, de l'amphibolite à grenat TG5 et du gneiss à biotite et amphibole TG10 a été faite par la méthode classique. Les zircons ont été séparés et abrasés [11], leur analyse étant réalisée sur un spectromètre Finnigan Mat 262 RPQ II à l'Institut de géochimie de l'université de Göttingen (Tableau 2). Dans le cas des roches encaissantes métamorphiques, les différentes fractions s'alignent sur une discordia, dont les intercepts supérieurs (Fig. 3) à 2080 ± 15 Ma (amphibolite à grenat) et 2110 ± 13 Ma (gneiss à biotite et amphibole TG10) et les intercepts inférieurs à 618 ± 50 Ma et 650 ± 26 Ma montrent que ces roches ont été d'abord impliquées dans une histoire paléoprotérozoïque vers 2,1 Ga, avant de subir l'empreinte panafricaine. Les zircons de l'échantillon TG24 sont des cristaux typiquement magmatiques ; les cinq fractions analysées s'alignent sur une discordia (Fig. 3), mais sont proches d'un intercept supérieur à 618 ± 20 Ma (MSWD = 1,1), qui est interprété comme l'âge de cristallisation du magma.

4. Discussion et conclusions

La région de Tonga est caractérisée par des granitoïdes panafricains plus ou moins orthogneissifiés, de nature calco-alcaline potassique à shoshonitique, mis en place lors d'une phase D2 correspondant à de grands cisaillements transcurrents de direction est–ouest à NE–SW. Ces granitoïdes syncinématiques fournissent un âge de 618 Ma, qui est l'âge de leur cristallisation, et donc aussi l'âge de la phase D2 correspondant au fonctionnement des grands cisaillements. Sur le plan géochimique, ils sont très semblables à d'autres granitoïdes panafricains syncisaillement, déjà caractérisés au nord-ouest comme au sud de la zone d'étude [23,34], ainsi qu'au Brésil [30]. Il est à noter que cet événement D2 est contemporain du métamorphisme de haute pression et haute température, reconnu dans le domaine sud-camerounais [28].

L'encaissant métamorphique comprend des métabasites et des gneiss plagioclasiques à biotite et amphibole, donc des roches orthodérivées, qui ont préservé une structure D1 caractérisée par une foliation subhorizontale. Ces roches donnent des âges (intercepts supérieurs) paléoprotérozoïques (2,1 Ga), interprétés comme âges de cristallisation, et des âges (intercepts inférieurs) correspondant à un métamorphisme panafricain vers 650 et 618 Ma. Les paragenèses des métabasites permettent de préciser les conditions D1, qui sont de haute température (850 °C) et de haute pression (1 à 1,2 GPa), donc très différentes des conditions de pression attribuées à D2 (0,5 GPa). L'écart de pression (0,5 à 0,7 GPa) entre les métabasites et les granitoïdes syn-cisaillement implique l'érosion d'environ 20 km d'épaisseur de croûte continentale entre les phases D1 et D2, qui sont donc des phases distinctes et séparées dans le temps par au moins 20 Ma, sinon plus. D2 étant maintenant bien datée à 618 Ma, il est difficile de faire de D1 une phase de déformation panafricaine antérieure, car l'orogenèse panafricaine ne commence probablement pas beaucoup avant 620 Ma, en Afrique centrale comme en Afrique de l'Ouest [10]. Cela impliquerait alors que D1 corresponde à un épisode tectonique paléoprotérozoïque. L'âge de cet épisode (2,1 Ga) est proche des âges de 2,05 Ga obtenus au Sud-Ouest du Cameroun [29,39]. Ces âges coïncident avec le paroxysme de l'orogenèse éburnéenne–transamazonienne qui a soudé les parties brésilienne et africaine du craton du Congo–São Francisco et qui se manifeste aussi par une intense activité magmatique en de nombreux endroits du monde [13,14]. La région de Tonga et, probablement, tout le domaine centre-camerounais doivent être considérés comme un ensemble continental paléoprotérozoïque repris par l'orogenèse panafricaine. Par suite, l'orogenèse éburnéenne–transamazonienne, déjà reconnue dans le Sud du Cameroun [19,39], doit être maintenant mieux caractérisée sur l'ensemble du pays.

1. Introduction and geological setting

The North-Equatorial Fold Belt or Central African Orogen is a major Pan-African orogen linked to the Trans-Saharan belt of western Africa and to the Brasiliano Orogen of northeastern Brazil. In Cameroon, the Pan-African realm [36] is made of three domains from south to north (Fig. 1a):

(*i*) the southern domain comprises Pan-African metasedimentary units, such as the Ntui–Betamba, Yaoundé and Mbalmayo units; the protoliths of these units were deposited in a passive margin environment at the northern edge of the Congo craton and were metamorphosed under high P conditions at 616 Ma [21,28,39]. An alkaline magmatism [26] was also recognized in association with these Pan-African units. The rocks of this southern domain were thrust onto the Archean Congo craton towards the south [18]. The thrust continues towards the east, forming the Oubanguides Nappe in the Republic of Central Africa;

(*ii*) the central domain lies between the Sanaga fault to the south and the Tchollíré–Banyo fault to the north. These large NE-striking transcurrent faults, as well as the Adamaoua fault inside the central domain, are regarded as possible prolongations of the major shear zones of NE Brazil in a pre-drift Gondwana reconstruction [5]. This central domain consists of high-grade gneisses intruded by widespread Pan-African syntectonic plutonic rocks of high-K calc-alkaline affinities [12,23,24,35];

(*iii*) the northern domain consists of subordinate 830-Ma-old volcanics of tholeiitic and alkaline affinities associated with metasediments known as the Poli series. Widespread 630–660-Ma-old calc-alkaline granitoids, presently orthogneissified, result from a major episode of crustal accretion. A Palaeoproterozoic crustal source in this region is attested by the presence of 2-Ga old inherited zircons in the granitoids [37].

The study area near Tonga extends over 420 km^2 and belongs to the southwestern part of the central domain. Previous reconnaissance work only recognized high-grade gneisses and amphibolites. Actually, the area is formed of two distinct lithotectonic sets: a metamorphic set and a magmatic set. The metamorphic set is composed of metabasites (mainly garnet-bearing amphibolites) and banded migmatitic gneisses. It records a first phase of deformation D1, underlined by a subhorizontal foliation parallel to the compositional layering (Fig. 1c). The magmatic set comprises more or less orthogneissified calc-alkaline granitoids, which crop out close to shear zones characterizing the second phase of deformation D2 and were emplaced during D2. The S2 foliation planes are mildly to steeply dipping and strike N70°E in average; they are underlined by injected granitic melts. The aim of the study is to characterize these metamorphic and plutonic rocks. Are they of similar ages or not? This is of major importance to constrain geodynamic models speculating on the existence of an older crust reworked during the Pan-African orogenesis [40]. Eventual pre-Pan-African remnants will be compared to Palaeoproterozoic rocks identified elsewhere in Cameroon.

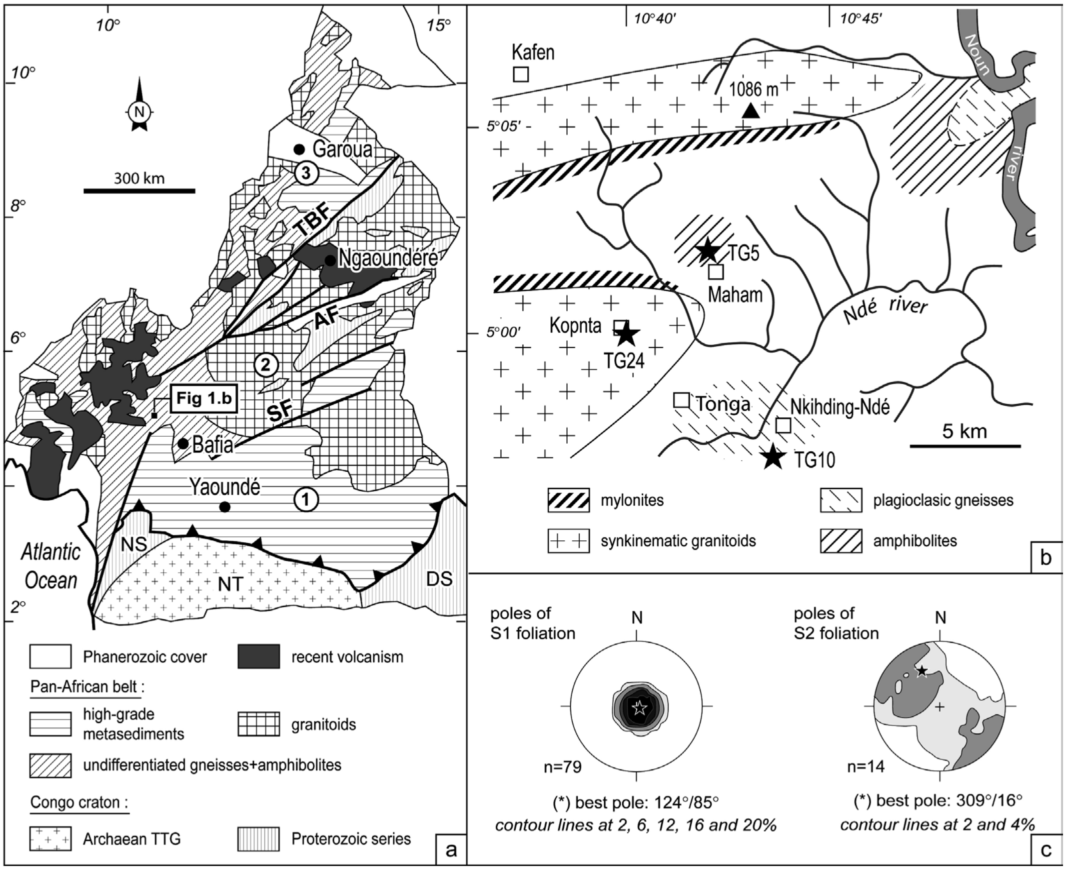

Fig. 1. (**a**) Geological map of Cameroon with main lithotectonic domains: (**1**) southern domain corresponding to the Yaoundé series thrust on the Congo craton, (**2**) central domain, (**3**) northern domain; **AF**: Adamaoua fault, **DS**: Dja series, **NS**: Nyong series, **NT**: Ntem complex, **SF**: Sanaga fault, **TBF**: Tchollíré–Banyo fault, (**b**) geological sketch of Tonga area with location of dated samples, (**c**) projection diagrams of S1 and S2 foliation poles.

Fig. 1. (**a**) Carte géologique du Cameroun avec les principaux domaines lithotectoniques : (**1**) domaine sud correspondant aux séries de Yaoundé charriées sur le craton du Congo, (**2**) domaine central, (**3**) domaine nord ; **AF** : faille de l'Adamaoua, **DS** : séries du Dja, **NS** : séries du Nyong, **NT** : complexe du Ntem, **SF** : faille de la Sanaga, **TBF** : faille de Tchollíré–Banyo, (**b**) esquisse géologique de la région de Tonga avec situation des échantillons datés, (**c**) diagrammes de projection des pôles des foliations S1 et S2.

2. Petrography and geochemistry of studied samples

2.1. Syntectonic granitoids

Syntectonic, locally orthogneissified, granitoids occur as syn-D2 intrusive bodies. Sample TG24 has been selected for geochronology; its location (N5°00.00′, E10°40.12′) is indicated in Fig. 1b. The rocks are medium-grained. Foliation is either magmatic or acquired during solid-state deformation. Foliation planes are underlined by the preferred orientations of feldspar, biotite and/or amphibole crystals and by the elongate shapes of quartz grains. Plagioclases have andesine to oligoclase compositions and are normally (sometimes reversely) zoned. Amphibole is mainly ferroedenite. Biotite crystals display Al, Ti and Fe-rich compositions. Accessory minerals are apatite, allanite, titanite and zircon. The rocks are silica-saturated, with SiO_2 ranging from to 57 to 70% (Table 1). They display high total alkali contents (7 to 9%). They are metaluminous to slightly peraluminous (molar A/CNK =

Table 1
Major and trace element contents of rocks from Tonga area. A/CNK = $[Al_2O_3]/[CaO + Na_2O + K_2O]$ (mol)

Tableau 1
Composition des roches de la région de Tonga (éléments majeurs et traces) ; A/CNK = $[Al_2O_3]/[CaO + Na_2O + K_2O]$ (mol)

	Synkinematic granitoids						Country rocks	
	TG24	MHE3	BT2	M	TG9	BT6	TG5	TG10
SiO_2 (w %)	57.40	59.97	62.70	64.32	67.43	69.57	48.84	66.78
Al_2O_3	16.Q2	16.15	16.27	15.4	14.35	14.4	14.06	16.31
Fe_2O_3*	7.54	7.70	6.06	5.17	4.11	3.45	15.54	3.97
MnO	0.08	0.05	0.06	0.03	0.02	0.02	0.19	0.03
MgO	3.37	2.25	1.46	1.48	0.68	0.57	4.64	1.22
CaO	5.08	3.96	3.34	3.02	3.24	1.34	9.12	3.8
Na_2O	3.33	3.41	3.88	3.47	3.24	3.23	2.77	5.13
K_2O	4.21	4.01	3.87	4.85	5.31	5.73	1.31	1.19
TiO_2	1.39	1.21	1.12	0.9	0.72	0.6	2.26	0.44
P_2O_5	0.51	0.50	0.46	0.34	0.22	0.19	0.40	0.14
l.i.	0.59	0.44	0.35	0.066	1.73	0.44	0.57	0.5
Total	99.52	99.65	99.57	99.046	101.05	99.54	99.7	99.51
A/CNK	0.83	0.94	0.98	0.93	0.84	1.03	0.62	0.98
Ni (ppm)	50	38	7	19	9	5	37	16
Cr	94	87	9	39	24	14	26	23
V	126	98	95	65	32	25	333	51
Rb	159	200	203	174	190	183	33	22
Sr	582	490	392	780	291	281	442	344
Ba	1513	1509	1504	2456	1700	1699	449	703
Y	20	17	8	12	15	8	28	3
Zr	309	307	312	348	502	405	164	163
Nb	26	26	26	20	19	14	30	3
Th	17	29	29	30	41	36	6	1

l.i. = loss on ignition.

A/CNK = molar ratio $[Al_2O_3]/[CaO + Na_2O + K_2O]$.

* Total Fe as Fe_2O_3.

0.83–1.03), hence corresponding to I-type granitoids after [6]. In the K_2O vs SiO_2 diagram (Fig. 2), they plot in the shoshonitic domain of [31]. In addition, they are ferro-potassic rather than magnesio-potassic rocks. Large ion lithophile element (Rb and Ba) and high field strength elements (Zr and Th) display high to very high contents. REE patterns (Fig. 3) are very fractionated ($(La/Yb)_N = 52–125$) with a pronounced LREE enrichment and a small negative Eu anomaly ($Eu/Eu^* = 0.5–0.8$).

2.2. Garnet amphibolite (TG5)

The studied garnet amphibolite (TG5) from Maham III is a dark-green rock composed of hornblende (50%), pyroxene (10%), garnet (20%), plagioclase (15%) and quartz (5%). The rock shows two main deformation imprints associated with metamorphic recrystallisation. The first phase (D1) is represented by the S1 foliation, commonly flat-lying and striking N40°E, outlined by a compositional layering and by the preferred orientations of biotite lamellae, feldspar crystals and amphibole fishes. These foliation planes mould relictual (ante-D1?) clinopyroxene–garnet assemblages. The L1 mineral and stretching lineation trends N0–30°E with a nearly horizontal plunge towards the south-south-west. P1 folds occur as decimetre-sized isoclinal folds with S1 as the axial plane schistosity. Their axes are roughly parallel to L1. These D1 structures were not observed in the previously-described granitoids. The D2 deformation phase is responsible for a S2 schistosity (average strike N80°E) transposing S1, and for amphibolitic boudins with average lengths of 15 cm and pinch-and-swell structures. Quartzo-feldspathic leucosomes

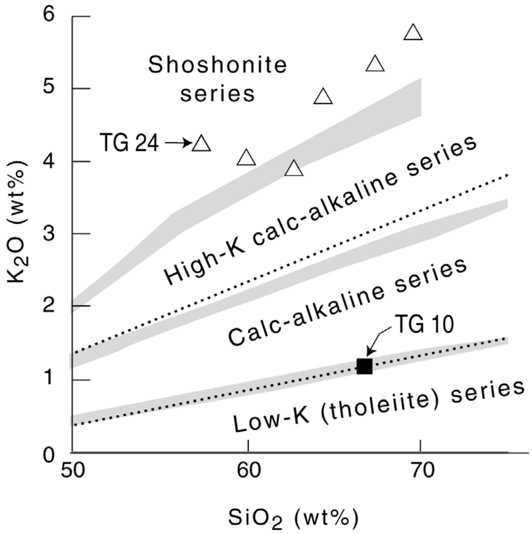

Fig. 2. K_2O versus SiO_2 diagram with different magmatic domains after [31].

Fig. 2. Diagramme K_2O versus SiO_2 avec les différents domaines magmatiques d'après [31].

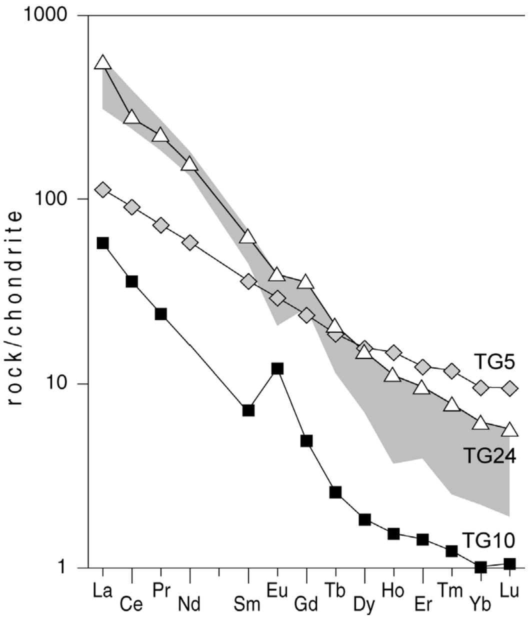

Fig. 3. Rare-earth element patterns (normalization after [4]); shaded area: synkinematic granitoids.

Fig. 3. Spectres de terres rares (normalisation d'après [4]) ; zone en grisé : granitoïdes syncinématiques.

locally infill pressure shadows between boudins. Microprobe analyses reveal that hornblende is ferropargasite ($X_{Fe} = 0.59$–0.62), and plagioclase is andesine (An33–38). Garnet is an almandine–pyrope–grossular solid solution, with high almandine content (up to 56%). The chemical composition of this garnet amphibolite is that of a common basic rock (Table 1). The rock is poor in Si and transition elements, but rich in Fe, K, Ti, Ba, Zr and Th, suggesting its derivation from continental tholeiitic magma [41]. REE patterns are moderately fractionated ($(La/Yb)_N = 12$), with LREE enrichment characteristic of intracontinental alkali or tholeiitic basalts (Fig. 3).

2.3. Biotite–amphibole gneiss (TG10)

Biotite–amphibole gneisses are the most abundant rocks in the Tonga area, where they constitute half of total outcrop areas. They are fine- to medium-grained, grey-coloured, with alternating millimetre thick ferromagnesian-rich and quartzofeldspathic layers. They are composed of plagioclase (45%), quartz (20%), hornblende (15%), biotite (12%), K-feldspar ($\leqslant 5\%$) and accessories, such as zircon, apatite and magnetite ($\leqslant 1\%$). In the studied sample (TG10), unzoned plagioclase is oligoclase (An25–30) and amphibole is ferropargasite or ferroedenite ($X_{Fe} = 0.5$–0.6). The biotite–amphibole gneisses display the same two phases of deformation as those recognized in garnet amphibolites. They are intermediate to felsic rocks, with low Ti, Mg and Fe contents. The selected sample has a tonalitic composition, rich in alkalis ($Na_2O + K_2O = 6.32\%$), with $Na > K$, hence its location at the boundary between the low-K and medium-K calk-alkaline fields (Fig. 2). REE patterns (Fig. 3) are well fractionated ($(La/Yb)_N = 58$) with LREE enrichment, HREE depletion ($Yb_N = 1$) and Eu positive anomaly ($Eu/Eu^* = 2$).

2.4. Thermobarometry

In the amphibolites, pressures were calculated from the garnet–clinopyroxene–plagioclase barometer [20] and temperatures from the garnet–clinopyroxene thermometer [2], and the garnet–hornblende barometer [8]. Pressure and temperature estimates are 1–1.2 GPa and 850 (±50) °C, pointing to granulitic lower crustal conditions corresponding to ante- or syn-D1 conditions. Recognition of the appropriate assemblage in the synkinematic granitoids enables us to calculate P using the Al-in-hornblende barometer [9, 32], yielding emplacement conditions around 5 kb, i.e. at mid-crustal level.

3. Geochronology

3.1. Previous geochronologic studies

In Cameroon, only Rb–Sr whole rock and mineral ages were available before 1987 [3]. Since 1987, zircon U–Pb dating has permitted to date the Pan-African orogeny in northern and southern Cameroon and to unravel an older inheritance [22,29,37–39]. To the south, in Yaoundé series, a high-pressure granulitic metamorphism occurred at about 616 Ma and the sedimentary protoliths may be not older than 1 Ga. By contrast, in northern Cameroon, the metasedimentary and meta-igneous rocks gave ages around 2.1 GPa, suggesting the presence of Palaeoproterozoic rocks in this area, but intense reworking in high-grade conditions also occurred during the Pan-African Orogeny. Ages around 2 Ga had already been recognized in the cratonic part of southern Cameroon [39]. Our new data enlighten the case of the central part of the fold belt.

3.2. Analytical methods

Chemical preparation and analyses have been done at the ‘Geochemisches Institut’ of the University of Göttingen (Germany). Samples 15–20 kg in weight were collected from fresh outcrops, broken, pulverized, and sifted. Zircons were separated and zircons concentrates were purified using heavy liquids (bromoform), nitric acid washes and handpicking. Purified concentrates were split into various fractions (> 160 µm; 160–150 µm; 150–120 µm; 100–90 µm; 80–60 µm; 60–40 µm; < 40 µm). Zircon analyses (Table 2) were performed on fractions of 40 to 50 grains, previously submitted to air abrasion to eliminate their external altered zones [11]. After zircon dissolution, Pb and U were separated using procedures recommended by [15] and [17] and the solution was aliquoted, with one split spiked with a mixed ^{235}U–^{208}Pb tracer solution. In all cases, the samples are sufficiently radiogenic. Decay constants used are those of [33]. Data were assigned uncertainties of 0.06% for ^{207}Pb/^{235}U and 0.16% for ^{206}Pb/^{238}U. Mass-spectrometry was performed on a Finnigan MAT 262 RPQ II.

3.3. U–Pb results

Zircons from the garnet amphibolite TG5 are colourless, cloudy and elongate; they preserve a magmatic zonation, but no inherited core. In the biotite-amphibole gneiss TG10, zircons are colourless, light yellowish and cloudy; crystals are either prismatic elongate or small, rounded, multifacetted, without internal structure. Isotopic data give concordant ages to the upper intercept at 2080 ± 15 Ma and 2110 ± 13 Ma and lower intercepts at 618 ± 50 Ma and 650 ± 26 Ma, respectively for TG5 and TG10 (Fig. 4).

Zircons from the synkinematic granitoid TG24 are yellow in colour, euhedral, elongate, cloudy, devoid of any inclusions, internal structure or zonation. They are typical magmatic crystals. The discordia for five different fractions defines an upper intercept with an age of 618 ± 20 Ma (Fig. 4).

4. Discussion and conclusions

4.1. Age and tectonic significance of the syntectonic granitoids

The syntectonic granitoids are shoshonitic intrusives emplaced along D2 shear zones, hence a more or less pronounced orthogneissification acquired at pressure conditions around 0.5 GPa. Therefore, the 618-Ma age of TG24 corresponds to this peculiar magmatic event, as well as to the age of this D2 transcurrent event, hence clearly related to the Pan-African orogeny. High-K calk-alkaline to shoshonitic magmatism closely associated with various major Pan-African shear zones has been described in many places of the Pan-African realm, either in Cameroon [23,34] or elsewhere, e.g., in Nigeria and Brazil [7,30]. There, this magmatism occurred in post-collisional conditions during transcurrent tectonics at 580–550 Ma. By comparison, the synkinematic potassic plutonism in Cameroon occurred earlier, between 620 and 580 Ma, and therefore it appears nearly coeval with the high P–high T metamorphism and nappe tectonics recognized along the southern edge of the Pan-African belt [29].

Table 2
U/Pb analytical results for zircons from samples TG5, TG10 and TG24

Tableau 2
Résultats analytiques U–Pb pour les zircons des échantillons TG5, TG10 et TG24

Fractions (µm)	Concentrations (1)		Observed $^{204}\mathrm{Pb}/^{206}\mathrm{Pb}$	Atomic ratios (2)				Calculated ages (3)		
	U (ppm)	Pb (ppm)		$^{206}\mathrm{Pb}/^{238}\mathrm{U}$	$^{207}\mathrm{Pb}/^{235}\mathrm{U}$	$^{207}\mathrm{Pb}/^{206}\mathrm{Pb}$	$^{208}\mathrm{Pb}/^{206}\mathrm{Pb}$	$^{206}\mathrm{Pb}/^{238}\mathrm{U}$	$^{207}\mathrm{Pb}/^{235}\mathrm{U}$	$^{207}\mathrm{Pb}/^{206}\mathrm{Pb}$
(a) Garnet amphibolite TG5										
> 150	246	82	0.00006	0.3481	5.601	0.12111	0.1016	1860	1927	1965 ± 02
> 120	350	131	0.00003	0.3315	5.681	0.12095	0.1257	1884	1969	1984 ± 01
> 100	301	95	0.00001	0.3399	5.869	0.12439	0.1102	1899	1910	1997 ± 02
90	290	101	0.00002	0.3404	5.621	0.12195	0.1002	1901	1943	1981 ± 02
> 75a	170	71	0.00020	0.3421	5.669	0.12225	0.0995	1899	1960	1990 ± 02
> 75b	152	55	0.00015	0.3324	5.191	0.12050	0.0974	1833	1927	1984 ± 01
(b) Biotite–amphibole–gneiss TG10										
> 160	150	45	0.00012	0.2797	4.461	0.11820	0.0986	1890	1950	1980 ± 01
> 120	145	41	0.00007	0.2635	4.304	0.11898	0.0933	1821	1969	1985 ± 04
100	171	45	0.00018	0.2629	4.409	0.12014	0.1102	1856	1901	1960 ± 01
80	188	50	0.00020	0.2685	4.409	0.11897	0.0861	1895	1925	1961 ± 05
(c) Synkinematic granitoid TG24										
> 160	285	31	0.00029	0.087645	0.728970	0.02862	0.3011	615	618	625 ± 03
160–120	201	24	0.00015	0.095225	0.795080	0.02718	0.2997	611	617	621 ± 08
100	294	33	0.00016	0.090712	0.723080	0.04149	0.2793	617	619	625 ± 05
80	294	34	0.00055	0.095150	0.816610	0.05905	0.2041	614	619	625 ± 03
60–40	204	25	0.00016	0.094176	0.786590	0.05827	0.2897	617	618	621 ± 03

(1) = U, Pb concentrations corrected for analytical blank.

(2) = Corrected for blank (see text).

(3) = Calculated ages according to [33] in Ma. Errors of atomic ratios are given at 2σ level.

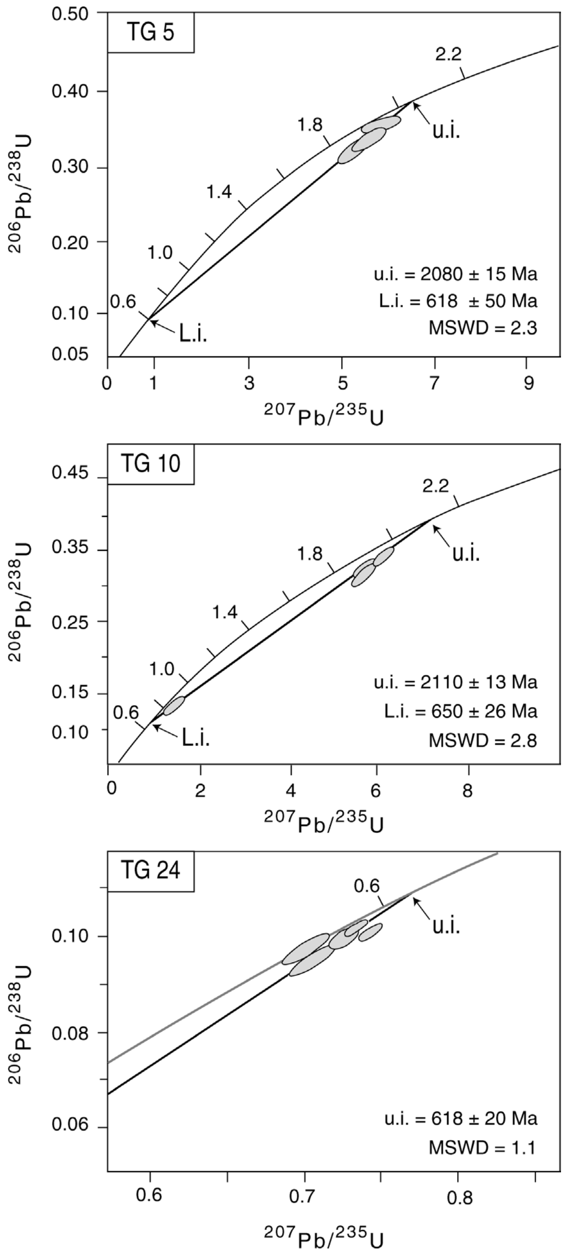

Fig. 4. Concordia plots for the U–Pb zircon results.

Fig. 4. Diagrammes Concordia des résultats U–Pb sur zircons.

4.2. *Age and tectonic significance of the metamorphic country rocks*

Country rocks are characterized by a flat-lying foliation, that is attributed to a D1 event and that has been locally transposed by the D2 deformation. In the studied amphibolite (TG5), the lower intercept at 618 Ma very likely corresponds to this D2 Pan-African transcurrent tectonics. This amphibolite shows a typical high-pressure granulite facies assemblage, pointing to much higher pressure conditions for D1 than for D2 at the outcrop level. The pressure gap (0.5–0.7 GPa) is such that it implies an uplift of about 20 km. Hence, D1 must have occurred at least 20 Myr (or more) before D2. However, it is difficult to admit that the Pan-African orogeny began much earlier than 620 Ma in central Africa as in western Africa [10]. Therefore, the D1 structural features may not have been acquired during a Pan-African event, but rather during an earlier history. Besides, the regular zonation, the absence of a core and the general subeuhedral form of the elongate zircons from TG5 suggest magmatic growth conditions. Thus, the upper intercept age of the amphibolite (2080 ± 15 Ma) is regarded as the crystallisation age of the mafic protolith. It is suggested that the zircons grew during a HP–HT event, synchronous with basaltic magma emplacement in the deep crust at about 2.1 Ga.

In TG10 gneiss, the euhedral forms of the zircons also call for a magmatic origin, despite the lack of zoning. Thus, the upper intercept dates the emplacement of the magmatic protolith at 2110 ± 13 Ma. This low-K calk-alkaline magmatism represents juvenile continental crust, possibly generated by partial melting of a mafic protolith, such as subducted young oceanic crust or the roots of an oceanic plateau. In both cases, restitic amphibole (± garnet) would explain the major and trace element contents of the melt [16]. The lower intercept at 650 ± 26 Ma is attributed to Pb loss and resetting during the Pan-African tectono-metamorphic imprint.

4.3. *Existence of a Palaeoproterozoic crust in central Cameroon*

The Tonga area of central Cameroon is a Palaeoproterozoic domain, which was reworked during the Neoproterozoic orogenesis at around 0.6 Ga. The 2.1–2.0 Ga ages are similar to those obtained from the Nyong Series, which constitute the western part of the Congo craton (Fig. 1a). Grey gneisses from the Nyong Series are regarded as reworked Archaean TTG (tonalites–trondhjemites–granodiorites) [19]. Isotopic data point to the derivation of most of the Nyong Series from 2.9-Ga-old protoliths [39]. In Tonga area, no Archaean inheritance is evidenced, unlike in northern Cameroon [38]. Hence, we regard the central part of the Cameroon basement as a Palaeoproterozoic juvenile crust, which has been accreted to the Congo craton during the Eburnian–Transamazonian orogeny. This orogeny is responsible for the linkage of the Brazilian and African parts of the São Francisco–Congo craton and involved various continental fragments on both sides of the present Atlantic Ocean [13,14]. Our data emphasize the importance of the Eburnian–Transamazonian orogeny in Cameroon, which had been somewhat unappreciated so far. The existence of large Palaeoproterozoic crustal segments in central Cameroon raises the question of the northern limits of the Congo craton, which may extend up to north of the Pan-African fold belt [1]. Moreover, a detailed scheme of the Eburnian–Transamazonian orogeny in Cameroon remains to be drawn.

Acknowledgements

Comments by J.-L. Bouchez, H. Porada, and G. Wörner improved the manuscript. Financial support from the French and German Ministry of Cooperation is acknowledged. C. Cavaré-Hester is thanked for technical assistance. This is a contribution of IGCP No. 470.

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