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U/PB DATING OF PRECAMBRIAN ROCKS FROM NORTHERN CAMEROON, OROGENIC EVOLUTION AND CHRONOLOGY OF THE PAN-AFRICAN BELT OF CENTRAL AFRICA

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Abstract

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Northern Cameroon has been classically divided into an old 'basement complex', a Middle Proterozoic cover ('séries intermédiaires') and granites emplaced during the Pan-African orogeny. New U/Pb geochronological data on different rock units from this region are presented. A rhyolite from the Poli schists ('séries intermédiaires') gives an age close to 800 Ma. Migmatitic gneisses of the 'basement complex' seem to derive from different detrital or magmatic sources. The metadiorites and foliated granites of the 'basement complex' give ages around 630 Ma. The 800 Ma age is interpreted as dating volcanic activity, probably related to the initial stage of the Pan-African evolution. Ages around 630 Ma date a syn-tectonic plutonism dominated by a regional-scale basic to intermediate plutonic suite (BIP). Zircons of the BIP suite are almost concordant and show no evidence of inheritance; the suite shows calc-alkaline affinity and relatively low $^{87}Sr/^{86}Sr$ initial ratios; thus the BIP suite represents material newly added to the crust during the Pan-African orogeny. These data are at variance with previous interpretations of this part of the mobile belt as old Precambrian crust reactivated during the Pan-African orogeny. The previous distinction between the 'séries intermédiaires' and a regional 'basement complex' must be reappraised, similar ages being found in both units. A chronological succession of the Pan-African evolution is established and tentatively compared with that of the Trans-Saharan belt in Nigeria and Hoggar.

Introduction

Northern Cameroon belongs to the Pan-African mobile belt of Central Africa, which is the sourthern prolongation of the Trans-Saharan belt (Bessoles and Trompette, 1980; Cahen et al., 1984). It occupies a critical position between the West African craton situated 2500 km to the west, the Congo craton about 1500 km to the south, and a possible ill-defined Nilotic craton (Rocci, 1965; Klerkx, 1979) to the east. The region is thus important for an understanding of the geodynamics of the Pan-African orogeny. Concerning the large region stretching from Central Hoggar and including much of the Nigerian shield situated just on the other side of the Benue trough, most of the available data favour a long and complex crustal evolution, including deep Pan-African crustal reactivation (Grant, 1969, 1978; Oversby, 1975; Ber-

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trand and Lasserre, 1976; Rahaman and Emofurieta, 1983).

The Trans-Saharan belt is the result of a late Proterozoic collision between the West African craton and the Touareg–Dahomeyan shield (Black et al., 1979; Bessoles and Trompette, 1980; Caby et al., 1981). During approximately the same period, the Congo craton might have collided with an eastward extension of the Nigerian shield (Jegouzo, 1984; Nzenti et al., 1984). Far to the NE, the Arabo-Nubian domain is characterised by a succession of arc–arc collisions and/or microplate collages but, the western limit of this accretive zone and the corresponding cratonic area are poorly defined (Bentor, 1985; Kröner, 1985; Vail, 1985; Ries et al., 1985; Stoeser and Camp, 1985); the area including Western Sudan, the Uweinat area in Libya, Northern Centrafrican Republic and Chad is still poorly known, especially concerning the extent of Pan-African activity (Pegram et al., 1976; Poidevin, 1983).

The consequences of these collisions and their likely interactions in the evolution of Northern Cameroon are still in question. Detailed data from Central Hoggar (Bertrand et al., 1986) and recent synthetic papers dealing with the geology and geochronology of Nigeria (Tubosun et al., 1984; Fitches et al., 1985) can be used as starting points.

Previous works

Precambrian rocks of Northern Cameroon are classically divided into two groups (Koch, 1959; Dumort and Peronne, 1966):

(1) a basement complex composed of metasediments, amphibolites, orthogneisses, and syn- to late-tectonic granites. It was metamorphosed under amphibolite-facies conditions and comprises widespread migmatites;

(2) the Poli–Bibemi–Maroua group, part of the so-called 'séries intermédiaires' (Bessoles and Lasserre, 1977). It is composed of low-grade to amphibolite-facies metavolcanics and metasedimentary rocks. It was considered to lie unconformably on the basement complex but direct evidence of such an unconformity has never been described. From regional lithological correlations, Bessoles and Lasserre (1977) suggested the period 1800–1200 Ma for the deposition of the 'séries intermédiaires', but the eastward prolongation of these series in Centrafrican Republic was interpreted as Archaean in age (Mestraud, 1982).

The available geochronogical data and field observations show that the relationships between the two groups are more complex and Pan-African ages are recorded in all units: the basement complex, the 'séries intermédiaires' and the post-tectonic granites (Lasserre, 1967; Lasserre and Soba, 1979). Despite these data, the basement complex and even the 'séries intermédiaires' (Bessoles and Lasserre, 1977) was still considered as older than the upper Proterozoic, and this is why their geological evolution has been interpreted in terms of crustal reactivation during the Pan-African orogeny (or thermal event).

Geological setting

Northern Cameroon is characterised by a regional vertical NE–SW trending foliation except for locally disturbed zones, probably related to late E–W strike-slip faults. In the metamorphic rocks, two stages of deformation (D1 and D2) may be defined. D1 corresponds presumably to an originally flat-lying foliation, associated with rutile, garnet and kyanite-bearing assemblages in pelitic rocks. D2 corresponds to upright folds associated with a regional low-pressure type metamorphism and widespread migmatites. The metamorphic associations of D1 are generally destroyed during D2. Later deformations are associated with polyphased wrench-faulting.

A field-based relative chronology of the different structural and petrographic units in Northern Cameroon has recently been proposed (Toteu et al., 1984; Toteu and Penaye, 1985; Dumont et al., 1985). The sketch maps of

Figs. 1 and 2 are a tentative re-interpretation of previous maps according to this chronology. The following units have been distinguished:

(1) gneisses with interlayered amphibolites, restricted pelitic layers and occasional calc-silicate boudins. They are intensively migmatised. This unit corresponds partly to the 'basement complex' as previously defined.

(2) Low-grade schists composed of volcanoclastics, metagreywackes and metavolcanics (basalts, rhyolites). This unit corresponds to the 'série intermédiaire' as previously defined.

Both units (1) and (2) have undergone the D1 and D2 tectono-metamorphic evolution. A metamorphic break separates the two units in most cases and is probably related to tectonic contacts, but in some sections, a continuous variation of metamorphic grade through medium-grade micaschists has been observed.

(3) Pre-tectonic (relative to D2) intrusive

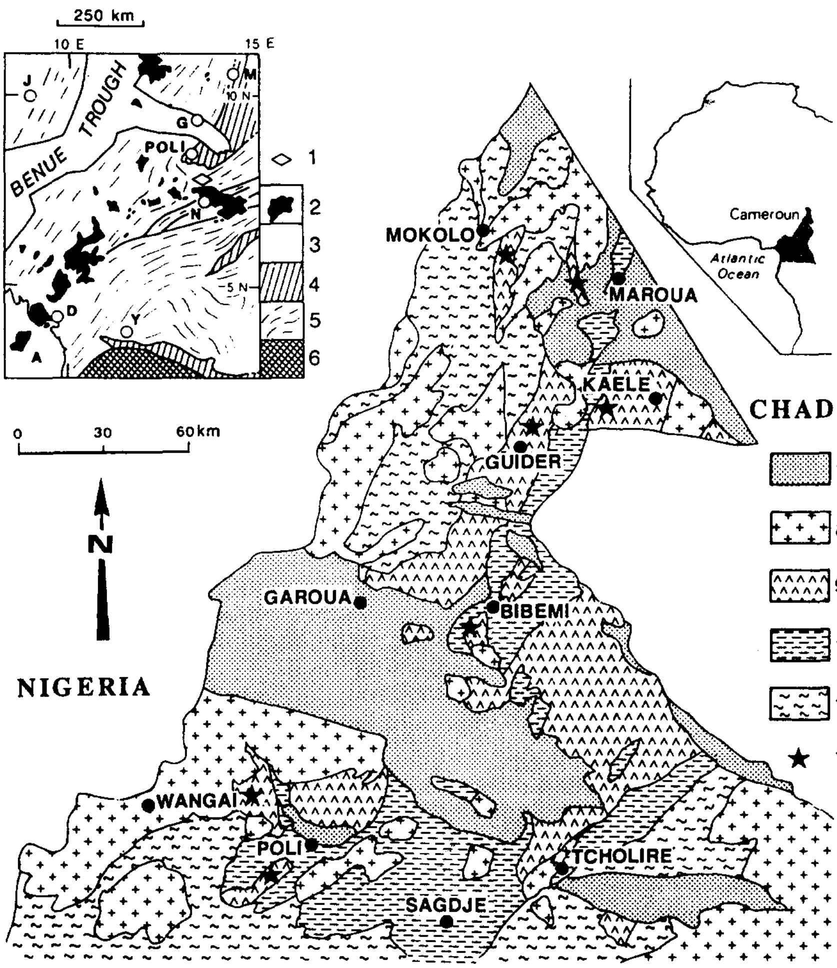

Fig. 1. Sketch map of Northern Cameroon. Position of the Northern Cameroon in the mobile belt of Central Africa (left inset map): (1) location of the amphibolitic gneisses of Mbé area, North Ngaounderé; (N), see the geochronological section for explanations; (2) recent volcanism; (3) Phanerozoic; (4) schist belts; (5) gneisses, amphibolites, migmatitic complex and granitoids; (6) Ntem Archaean complex; (A) Atlantic Ocean; (D) Douala; (G) Garoua; (J) Jos; (M) Maroua; (N) Ngaounderé; (Y) Yaoundé. Lithology of Northern Cameroon: (7) Phanerozoic; (8) pre- to late-tectonic granites; (9) basic to intermediate plutonic (BIP) suite; (10) low-grade schists; (11) gneisses and amphibolites. Stars (12) show the location of the geochemical samples.

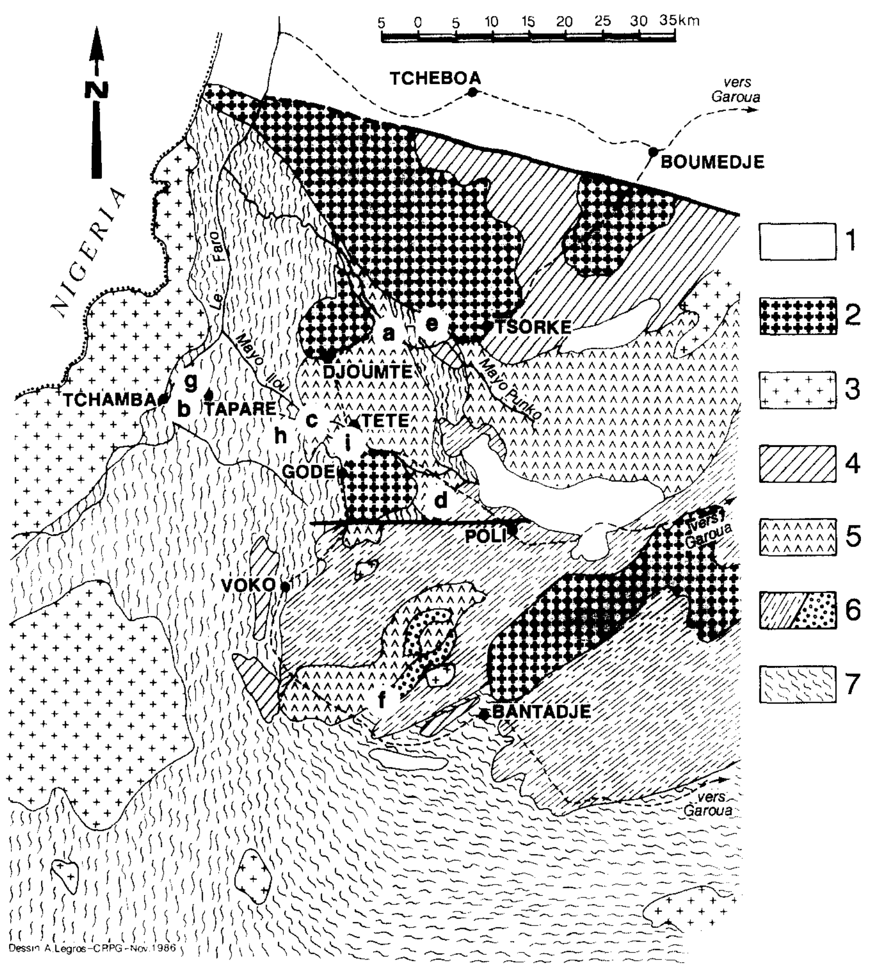

Fig. 2. Location of geochronological samples in the West Poli region. Lithology: (1), post Pan-African cover; (2) post-tectonic intrusions; (3) syn- to late-D2 intrusions; (4) foliated granites; (5) basic to intermediate plutonic (BIP) suite; (6) low-grade schists and associated rhyolites (dots); (7) gneisses. Samples locations: (a) Mayo Punko metadiorite, Go 79; (b) Tchamba metadiorite, Fa1, Iso 1, Iso 6; (c) Mayo Ilou metagranodiorite, Go 169; (d) Garé metagranodiorite, Pt 74; (e) Bakonwa foliated granite, G; (f) Hosséré Goldyna metarhyolite, Po 2; (g) Taparé migmatitic gneiss, Go 247; (h) Mayo Bandilé migmatitic gneiss, Fa 2; (i) Tété bridge metadiorite, Go 24 and Go 210 to 215.

rocks were previously considered as part of the basement; they are actually interleaved with gneisses and schists of units (1) and (2). They are mainly composed of a basic to intermediate plutonic suite (BIP), but granites showing a similar structural evolution also occur. In the field and from existing maps, these granites are often difficult to distinguish from the late-D2 granites (see below). The BIP suite includes hornblendites, gabbros, diorites and quartz-diorites. The most common rock types are diorites and quartz-diorites, with green hornblende, biotite, plagioclase and quartz as the main mineral association; accessory minerals are sphene, zircon, apatite and oxides. They are well exposed at Tete bridge and along the sections of the Mayo Ilou and Mayo Punko (West of Poli). These rocks were previously described as 'augen migmatites' (Koch, 1959; Schwoerer, 1966; Dumort and Peronne, 1966), 'Kaéle orthogneisses' (cf. Bessoles and Trompette, 1980), the 'gabbro–diorite synkinematic intrusions' (Koch, 1959) and 'basic sills' (Le Fur, 1971). They extend probably toward the south:

Koch (1953) and Guiraudie (1955) have mapped augen-migmatites in the region west of Ngaounderé and around Banyo. Only the coarse to medium-grained type, easily identified in the field, has been shown in Fig. 1 and 2 but there is still a large probability for some rock types of the gneissic unit (1) to belong to this plutonic group, e.g. the medium to fine-grained amphibolitic gneisses from Tchamba area.

From structural observations, one may distinguish:

(a) metadiorites and metagranodiorites intruded in the schist group, showing polyphased (D1, D2) deformation under low-grade conditions;

(b) similar rocks only affected by D2;

(c) metadiorites and metagranodiorites associated with gneisses, showing local cross-cutting relationships with respect to S1, but strongly deformed and locally melted during D2. They also show an earlier fabric characterised by a discrete layering and a strong flattening of mafic xenoliths predating D2 folding (D1 syntectonic magmatic fabrics (?)). These structural features suggest a syn- to late-D1 emplacement, followed by a strong D2 deformation; and

(d) medium to fine-grained amphibolitic gneisses associated with the gneisses (e.g. Tchamba area). They have a dioritic composition and show an intense transposition of D1 structures and evidence of melting during D2. Such rocks probably predate D1.

The emplacement of the BIP suite started before the D1 event and continued after it. The suite has been affected by a second phase of deformation and metamorphism. It can be thus considered as roughly syn-tectonic relative to D1 and pre-tectonic relative to D2. The differences in the metamorphic grade and deformation pattern broadly reflect the different emplacement levels of the various intrusions.

(4) Large NE–SW trending slightly deformed plutons of intermediate to acid rocks, especially porphyritic granites, cross-cut D1 and D2 structures. Gneisses and amphibolites are melted along their contacts. They are interpreted as a late-D2 plutonic event.

(5) Post-tectonic cross-cutting circular granites and syenites.

From this classification, the following points may be outlined:

(1) the gneisses and the orthogneisses of the BIP suite (the previous 'basement complex') and schists ('série intermédiaire') appear to have undergone a similar tectono-metamorphic evolution. This interpretation differs from that of Ngako (1986) which follows the previous regional basement-cover distinction of Koch (1959) and Dumort and Peronne (1966);

(2) an important part of the 'basement complex' is composed of plutonic rocks emplaced at different stages of the tectono-metamorphic evolution;

(3) plutonic rocks of comparable composition and structure are also present in the schist group; and

(4) the schist group comprises identified volcanic rocks.

To constrain a reasonable evolutionary model of the mobile belt, we carried out a geochronological study of some key rock units. In addition, a preliminary geochemical study has been undertaken on the BIP suite; as there were no available data on these rocks, we have attempted to confirm their belonging to the same chemical group by sampling in many parts of the Northern Cameroon.

Geochemistry

Samples are from west, south and SW Poli, Bibemi, Guider, Kaele and Maroua areas (Fig. 1). Major and trace elements (38 samples) and REE (6 samples) were measured by ICP method at the C.R.P.G., Nancy (France). Six additional samples were analysed by X-ray fluorescence for Zr, Nb and Y at the University of Nancy I.

Analyses of six selected samples are given in Table I (samples Go 24 to Iso 6); trace elements and REE are plotted in Fig. 4. The most

TABLE I

Analysis of selected samples of the BIP suite of Northern Cameroon: (Po 8, Po 9) gabbroic rocks; (Go 24, Go 28, Go 100, Go 79, Fa 1, Iso 1, Iso 6, Pt 74 and Go 169) dioritic and granodioritic rocks. Other rocks collected for geochronological studies: (G) foliated granite; (Po 2) rhyolite; (Go 247 and Fa 2) migmatitic gneiss

Oxides %	Gabbros		Diorites and granodiorites									Gr	Rh	Gneisses	
	Po 8	Po 9	Go24	Go28	Go 100	Go 79	Fa 1	Iso 1	Iso 6	Pt 74	Go 169	G	Po 2	Go 247	Fa 2
SiO_2	51.76	50.29	62.62	60.15	59.04	57.34	58.07	58.86	58.62	63.54	66.85	74.68	77.90	73.53	68.38
Al_2O_3	10.32	13.67	15.35	15.56	16.12	17.15	16.19	15.70	15.77	15.25	15.46	12.64	11.21	13.10	15.87
Fe_2O_3	9.10	8.97	5.24	6.53	6.94	7.09	6.94	6.12	6.36	4.84	3.44	1.20	1.59	2.17	4.50
MnO	0.17	0.13	0.08	0.09	0.11	0.16	0.11	0.09	0.09	0.08	0.08	0.05	0.05	0.05	0.11
MgO	10.06	11.66	2.23	3.48	4.06	3.51	3.67	3.47	3.53	2.01	1.45	0.39	0.78	0.79	2.31
CaO	12.87	8.21	4.24	5.52	5.21	5.90	5.88	5.50	5.52	4.83	2.92	0.93	0.34	2.47	4.07
Na_2O	1.97	3.11	3.96	4.13	3.82	4.03	4.15	3.97	4.24	4.08	3.37	5.04	4.59	4.03	4.03
K_2O	0.41	0.68	3.30	2.64	2.61	1.92	2.25	2.57	2.34	2.48	3.79	4.47	1.50	1.79	2.89
TiO_2	0.65	1.16	0.89	1.14	0.77	1.03	1.22	1.16	1.20	0.59	0.53	0.23	0.20	0.59	0.55
P_2O_5	0.08	0.19	0.25	0.35	0.29	—	0.36	0.33	0.31	0.07	0.08	0.06	—	—	—
P.F.	1.27	2.27	0.83	0.46	1.34	1.29	1.01	0.86	0.81	1.94	0.45	0.42	1.25	0.50	0.92
Total	99.20	100.34	99.06	100.46	100.31	99.42	99.85	98.63	98.79	99.71	98.75	100.11	99.41	99.53	99.63
Traces ppm															
Ba	188	227	740	1043	853	—	955	1218	1100	721	840	586			
Co	142	120	26	35	72	—	44	43	43	33	40	< 10			
Cr	448	471	75	62	178	—	54	76	76	22	41	< 10			
Cu	< 10	39	< 10	< 10	16	—	< 10	19	< 10	142	< 10	< 10			
Ni	171	314	32	30	50	—	52	45	47	17	22	< 10			
Sr	250	458	411	797	570	949	859	883	906	784	429	190			
V	241	245	112	123	129	—	172	155	153	105	85	16			
Rb	13	5	98	52	61	35	48	37	47	40	121	103			
Zr	55	61	216	222	207	244	114	131	155	125	—	—			
Nb	12	10	8	5	6	9	9	8	8	6	—	—			
Y	20	15	28	23	24	24	18	17	20	15	—	—			
REE ppm															
La	5.18	6.09	24.11	29.69	13.93										
Ce	12.26	12.18	49.72	60.62	30.92										
Nd	9.05	9.55	26.97	33.08	22.94										
Sm	2.71	2.75	5.53	6.30	4.95										
Eu	0.83	0.87	1.07	1.55	1.32										
Gd	2.86	2.45	4.28	4.60	3.98										
Dy	3.07	2.49	3.68	3.35	3.77										
Er	1.62	1.28	1.93	1.49	1.79										
Yb	1.58	1.17	2.03	1.39	1.91										
Lu	0.22	0.12	0.32	0.17	0.29										

important features are the low Ti (< 1.2 wt.%) and the high Ba and Sr contents. The SiO_2 content of most of the samples ranges from 53 to 62 wt.%; only four gabbroic rocks have $SiO_2 < 52$ wt.%. In AFM diagram, points fall in the calc-alkaline field (Fig. 3).

When the REE and other trace elements abundance of two gabbroic and three dioritic rocks from the Poli region are compared, the following characteristics may be outlined (Fig. 4a,b):

(1) the chondrite-normalised REE patterns

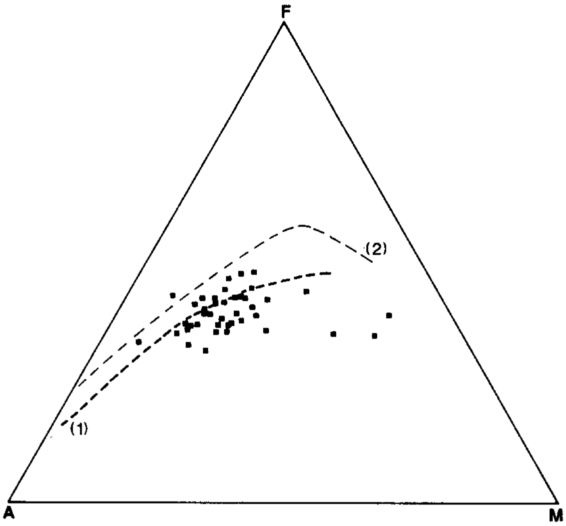

Fig. 3. AFM plots of the BIP suite of Northern Cameroon. The trend of calc-alkaline suite from Lower California (1) pass through the cloud defined by the BIP suite; the Japanese calc-alkaline trend (2) is above the cloud.

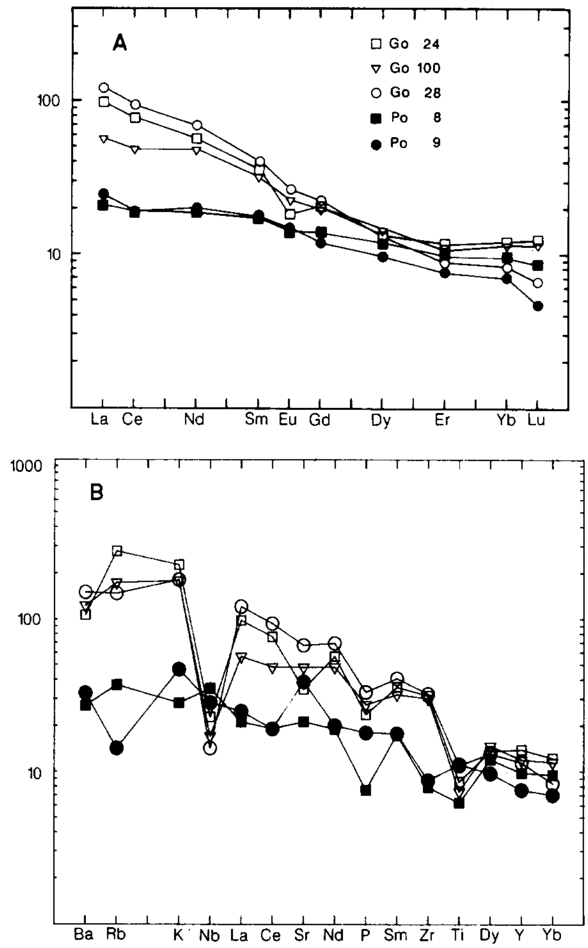

Fig. 4. (A) Rare-earth elements abundance normalised to chondritic abundances of the BIP suite: gabbroic rocks (solid square and solid circle); dioritic rocks (open square, open circle and open triangle). (B) Spidergrams of the BIP suite normalised to chondritic abundances; same symbols as in Fig. 3a.

of the gabbros are almost flat (Fig. 4a) and the corresponding spidergrams have no negative Nb and Ti anomaly (Fig. 4b). These samples may be tentatively identified as derived from continental basaltic magmas (Thompson et al., 1984) associated to a stage of continental breakup; and

(2) dioritic rocks are more enriched in LREE and show pronounced Nb and Ti troughs, probably indicative of a continental crust component. The pattern displayed is comparable to those of subduction-related magmas.

The regional scale of the sampling does not permit a more detailed geochemical discussion, but from the present data it appears that a large part of the BIP suite has calc-alkaline affinity with subduction-related characteristics. More detailed investigation of these rocks together with the metabasalts of the schist group and amphibolites interlayered in gneisses is necessary for an understanding of their petrogenesis.

Geochronology

A geochronogical study was carried out on rocks from the Poli region where detailed structural and petrographical data are available. Studied rock units are: pre-D2 BIP suite (samples Go 79, Fa 1, Go 168 and Pt 74; a, b, c and d, respectively, in Fig. 2), a pre-D2 foliated granite (sample G; e in Fig. 2), a rhyolite of the schist group (sample Po2; f in Fig. 2) and a migmatitic gneiss probably of sedimentary origin (samples Go 247 and Fa 2, g and h in Fig. 2). In addition, an amphibolitic gneiss of Mbé area (50 km north Ngaounderé, Fig. 1, inset) has been studied. A short description of the samples is given in the annex and their chemical compositions are listed in Table I.

Zircons were dissolved in small teflon bombs with HF (Krögh, 1973). Two attacks were done on the same fraction, one was for the determination of the lead composition, the other was spiked before attack with a mixed $^{208}Pb/^{235}U$ spike. Lead and uranium were separated on an anionic resin following a method slightly modified from Mahnes et al. (1978). Pb was loaded with H_3PO_4 and silica gel on a single Re filament. U was loaded on a W filament with Ta and H_3PO_4 and run on oxide beam. The concentration ratios are accurate at c. 1.5%. The error on the $^{207*}Pb/^{206*}Pb$ ratio is propagated from the analytical uncertainties in the $^{207}Pb/^{206}Pb$ and $^{206}Pb/^{204}Pb$ ratios and the estimated precision of the common lead composition. Only for $^{206}Pb/^{204}Pb$ ratios <500, does the uncertainty arising from the common lead correction become significant. Calculation of ages and errors was achieved with the method of Minster et al. (1979). The analytical results are given in Table II and concordia diagrams are shown in Fig. 5.

Mayo Punko metadiorite (Go 79, Fig. 5a): data points plotted on the $^{206*}Pb/^{238}U$ vs. $^{207*}Pb/^{235}U$ concordia diagram are almost concordant around 625 Ma. The best estimate of the emplacement age is considered to be the average of the $^{207*}Pb/^{206*}Pb$ model ages, i.e. 633+/−3 Ma, the regression calculation giving a negative lower intercept.

Tchamba metadiorite (Fa 1, Fig. 5b): the representative points of five fractions are almost perfectly concordant: 639+/−1 Ma, 632+/−1.5 Ma, 615+/−4 Ma, 612+/−7 Ma, 610+/−3 Ma (errors calculated from the intercept of the concordia with a 2 sigma error ellipse). A downward migration along the concordia with the increasing grain size is observed. This may be related to large inclusions of phosphate (apatite?) observed in larger zircons by SEM.

Mayo Ilou metagranodiorite (Go 169, Fig. 5c): the analyses of three fractions display little spread on the concordia diagram and define an upper intercept at 635+/−10 Ma and a lower intercept around 100 Ma.

Garé metagranodiorite (Pt 74, Fig. 5d): the age determined by the $^{207*}Pb/^{206*}Pb$ ratios on three of the five fractions analysed are around 660 Ma. The two largest fractions give older $^{207*}Pb/^{206*}Pb$ ages. One analysis (150 μm) has a low $^{206}Pb/^{204}Pb$ ratio, but the $^{207*}Pb/^{206*}Pb$ age is greater than 800 Ma with different common lead corrections. Taking out the point with low $^{206}Pb/^{204}Pb$ ratio, the regression line intersects the concordia at 800+40/−35 and 340+/−60 Ma, MWSD=7. From field observations, a 665+/−10 Ma age obtained if the larger zircons are excluded seems to be closer to the emplacement age. The older $^{207*}Pb/^{206*}Pb$ age of the two larger fractions may probably be explained by the presence of inherited zircons.

Bakonwa foliated granite (G, Fig. 5e): data points on the concordia diagram show a greater discordancy than the zircons from the metadiorites. In addition, zircons contain three times more uranium. The discordia line from these points gives an upper intercept at 660+50/−40 Ma and a lower intercept around 100 Ma (MWSD=2.08). A few percent of zircons from this rock are yellow and turbid and may be inherited grains.

Hosséré Goldyna metarhyolite (Po 2, Fig. 5f): zircons from this rock are broken and some large inclusions of alumino-silicate have been seen by SEM. These inclusions may account for the low measured $^{206}Pb/^{204}Pb$ ratios. One fraction is almost concordant at 830 Ma, the other two are more discordant. A regression line gives an upper intercept with the concordia at 830+/−12 Ma and a lower intercept at 120+/−60 Ma (MSWD=1.14). Owing to the low $^{206}Pb/^{204}Pb$ measured, different common lead corrections were tested. The differences in apparent ages calculated using the common lead isotopic composition at 800 Ma (following the continental lead evolution from Stacey and Kramers, 1975) do not exceed 2 Ma.

Taparé and Mayo Bandilé migmatitic biotite gneisses (Go 247, Fig. 5g and Fa 2, Fig. 5h): the

TABLE II

U/Pb analytical results. Size of the zircon fractions in microns

Grain sizes	Pb (ppm)	U (ppm)	$^{206}Pb/^{204}Pb$	$^{207*}Pb/^{235}U$ (1)	$^{206*}Pb/^{238}U$ (2)	$^{207*}Pb/^{206*}Pb$ (3)	Apparent ages (Ma) (1)	(2)	(3)
Mayo Punko metadiorite (Go 79)									
> 150	23.4	218	626	0.8402	0.10058	0.06058	619	618	625
> 100	23.0	224	4522	0.8219	0.09812	0.06075	609	603	630
> 75	25.0	238	3820	0.8318	0.09947	0.06065	611	615	627
> 45	25.5	245	4058	0.8348	0.09912	0.06108	617	610	643
Tchamba metadiorite (Fa 1)									
> 150	13.3	121	780	0.8188	0.09859	0.06045	607	606	612
> 100	14.4	130	1472	0.8279	0.09931	0.06046	612	610	620
> 75	16.1	148	2569	0.8199	0.09837	0.06045	608	605	620
> 45	17.2	151	3450	0.8771	0.10432	0.06098	640	640	639
> 35	18.1	164	4029	0.8641	0.10313	0.06077	632	633	631
Mayo Ilou metagranodiorite (Go 169)									
> 100	31.5	327	4544	0.7628	0.09154	0.06043	576	565	619
> 75	38.0	364	3165	0.8340	0.09946	0.06081	616	611	633
> 45	44.6	435	1065	0.8147	0.09806	0.06026	605	603	613
Garé metagranodiorite (Pt 74)									
> 150	13.2	142	250	0.9219	0.09994	0.06691	663	614	835
> 100	17.8	171	4291	0.8625	0.09964	0.06278	632	612	701
> 75	21.8	205	3642	0.8623	0.10148	0.06163	631	623	661
> 45	26.5	265	1718	0.8006	0.09411	0.06170	597	580	664
> 35	34.0	350	4213	0.7700	0.09082	0.06149	580	560	656
35	34.2	351	559	0.7743	0.09136	0.06147	582	564	656
Bakonwa foliated granite (G)									
> 150	104	1333	1052	0.6230	0.07440	0.06073	491	462	630
> 75	58	740	738	0.6374	0.07614	0.06072	500	473	629
> 45	80	1095	625	0.5894	0.07103	0.06018	470	442	610
< 45	53	747	633	0.5734	0.06863	0.06060	460	428	625
Hosséré Goldyna metarhyolite (Po 2)									
> 75	14.5	99	393	1.2532	0.13609	0.06679	825	823	831
> 45	16.7	143	351	0.9913	0.10860	0.06620	699	665	813
Magn.	19.8	165	339	1.0119	0.11155	0.06579	709	682	799
Taparé migmatitic gneiss (Go 247)									
> 150	56.1	534	1499	0.9319	0.10449	0.06468	669	641	764
> 100	68.7	635	5918	0.9656	0.10644	0.06579	686	652	800
> 75	64.2	570	3837	0.9989	0.11110	0.06524	703	679	782
> 150RB	—	—	3125	0.8904	0.10260	0.06292	647	630	706
> 150C	20.5	197	2116	0.9135	0.10330	0.06414	659	634	746
Mayo Bandilé migmatitic gneiss (Fa 2)									
> 75	59.4	530	5242	0.9906	0.10987	0.06534	699	672	787
< 75	60.5	569	12700	0.9322	0.10438	0.06477	668	640	767
> 100RB	84	780	5836	0.9467	0.10601	0.06478	676	649	768
> 100C	—	—	2988	1.0560	0.11691	0.06550	732	713	790
Sphene									
(1)	4.22	45.2	133.2	0.7356	0.09138	0.05838	560	563	544
(2)	4.27	45.2	133.2	0.7466	0.09222	0.05857	566	568	557
Mbé amphibolitic gneiss (MB 1)									
> 150	44.0	153	7249	4.5512	0.27950	0.11810	1740	1589	1928
> 100	39.7	147	13285	4.2860	0.26148	0.11888	1691	1497	1940
> 75	44.0	163	4878	4.3589	0.26311	0.12016	1705	1506	1959
> 45	48.7	178	5152	4.3884	0.26762	0.11893	1710	1529	1940

Common lead correction $^{206}Pb/^{204}Pb = 18.60$, $^{207}Pb/^{204}Pb = 15.50$; $^{208}Pb/^{204}Pb = 38.6$.
RB = rounded brown zircon; C = clear zircon.
Sphene (1) usual correction, (2) corrected with a Pan-African sulphide composition from another environment.
Unquoted concentration = weight of sample fraction < 1 mg.

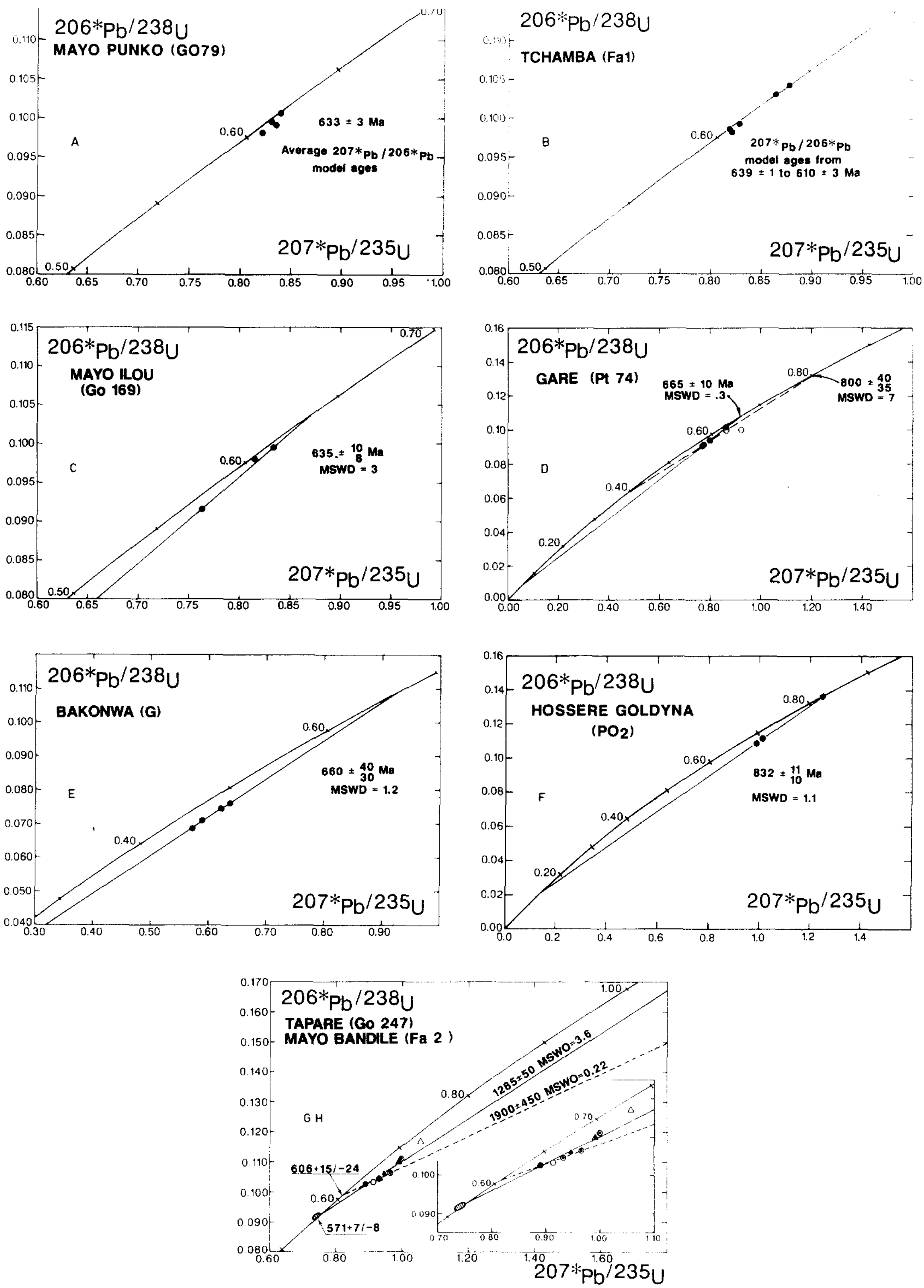

Fig. 5. Concordia diagrams: the letters are the same used for the localisation of the samples in Fig. 2. Concordia curve is graduated in Ga. (A) Go 79: Mayo Punko metadiorite, in the gneiss complex; the given age is the average of the $^{207*}Pb/^{206}Pb$ ages; (B) Fa 1: Tchamba metadiorite, in the gneiss complex; (C) Go 169: Mayo Ilou metagranodiorite, in the gneiss complex; (D) Pt 74: Garé metagranodiorite, in the Poli schists, solid circles correspond to zircons < 100 microns used for the 665 +/− 10 Ma discordia, the open circle (zircon = 150 microns) situated below the two lines has a low $^{206}Pb/^{204}Pb$ ratio and has not been used in the calculations (see text); (E) G: Bakonwa foliated granite, in the gneiss complex; (F) Po 2: Hosséré Goldyna metarhyolite, in the Poli schists; (G) and (H) Go 247: Taparé migmatitic gneisses, open circle = clear zircons, solid circle = turbid zircons, spotted circle = mixed zircon population. Fa 2: Mayo Bandilé migmatitic gneisses, open triangle = clear zircons, solid triangle = turbid zircons, spotted triangle = mixed zircon population. An upper intercept c. 2000 Ma (dashed line) may be obtained if the plots of the Fa 2 clear population, the two Go 247 and Fa 2 mixed populations situated above the corresponding discordia and the Fa 2 sphene (hatched ellipse) are excluded, see text.

zircons of these two samples are characterised by the presence of at least two morphological types. About 50% of the grains are almost rounded, yellow-brown and turbid while the others are clear, pink and with distinct facets. All analyses plotted together define a discordia with intercepts on concordia at 1285+/−50 Ma and 571+/−8 (MWSD=3.6). The lower intercept was tentatively precised with the analysis of the Fa 2 sphene; due to the high common lead content of these sphenes, the age was corrected with the lead composition of a Pan-African sulphide (Table II). The age defined by the upper intercept is lower than the minimum age obtained on zircons from Mbé area (see below); looking at the analysis performed on separated types of zircons (turbid and clear), the concordia may be interpreted as representing a mean age of mixed populations; the age of the different protoliths might be 2000 Ma and perhaps c. 850 Ma. Further analyses are necessary to solve this indetermination.

Mbé amphibolitic gneisses (Mb 1, Table II): the four analysed fractions display too small a spread on the concordia diagram to precisely define an age. The average of the $^{207*}Pb/^{206*}Pb$ model ages is 1940 Ma. Further data are necessary to determine the intercepts and their significance, but inheritance of an old crustal component is obvious.

$^{87}Sr/^{86}Sr$ initial ratio

Five samples of metadiorite from Tete bridge (i in Fig. 4), similar to the Mayo Punko diorite were analysed for strontium isotopes. Data points (Table III) are clustered and no precise age was obtained (an age of 640+/−130 Ma with an initial ratio of 0.704 is obtained if a duplicate of the sample Go 213 is included). However, the initial ratios recalculated using the 630 Ma zircon age obtained on the Mayo Punko metadiorite vary between 0.7043 and 0.7045.

Similarly, initial ratios of the Tchamba metadiorite were calculated using the Fa 1 age of 625 Ma for two samples from the same rock unit (Iso 1 and Iso 6, Table I) sampled in close vicinity to Fa 1. The values are, respectively, 0.7061 and 0.7063 (Table III), slightly higher than those determined for the Tete bridge samples.

Initial ratios determined on the metadiorites are then relatively low. They imply either the participation of mantle material in the source or an origin by partial melting of a low Rb/Sr source such as lower crustal granulites. The almost concordancy of most of the zircons suggests that no older material was implicated or, at least, a short crustal residence for the magma source.

Discussion

The new geochronological data obtained on the western part of the Poli region support a Pan-African age for the tectono-metamorphic evolution of this part of the mobile belt. As most of the ages in the range 800–600 Ma represent emplacement ages of plutonic and volcanic rocks with restricted inheritance, the classical interpretation in terms of reactivation must be reappraised. Particularly, as expected from structural and metamorphic observations, it is no longer necessary to distinguish chronologically between the 'séries intermédiaires' and a regional 'basement complex' because, except for the evidence of inheritance in the latter, the determined age range is identical in both groups.

An older age was obtained to the south of the area studied; near Mbé (north of Ngaounderé), amphibolitic gneisses yield a minimum age of ~2000 Ma. From the experimental points, it is not possible to know if this age corresponds to the age of a reactivated basement or to that of detrital zircons in a younger sedimentary formation as is probably the case for the zircons from Taparé and Mayo Bandilé. This area should be surveyed in greater detail, together with the Adamaoua domain where, from previous maps, old gneisses may be suspected (Koch, 1953; Guiraudie, 1955; Lasserre, 1962).

TABLE III

Rb/Sr analytical results

	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr_i$
Tété Bridge metadiorite					
GO 210	83	543	0.442	0.708284(37)	0.70427
GO 211	82	520	0.457	0.708548(34)	0.70445
GO 212	79	533	0.432	0.708422(42)	0.70457
GO 213	73	515	0.410	0.708153(36)	0.70447
GO 214	81	544	0.433	0.708196(25)	0.70433
GO 215	81	497	0.470	0.708624(26)	0.70439
Tchamba metadiorite					
ISO 1	45.2	942	0.1391	0.707310(29)	0.70607
ISO 6	47.4	978	0.1404	0.707507(40)	0.70625

Error 2% on the $^{87}Rb/^{86}Sr$ ratio. $(^{87}Sr/^{86}Sr)_i$ are calculated with the Mayo Punko (GO 79) zircon age (630 Ma) for the first series and with the Tchamba metadiorite (Fa 1, 625 Ma).

No clear structural or petrographical criterion can yet be defined to solve this indetermination and to evaluate the extent of such a possible basement. On the basis of granulite-facies remnants observed to the south of Poli, Ngako (1986) postulated the existence of a pre-schist basement; this assumption is debatable especially if one refers to the recent data on foliated charnockitic rocks in SW Nigeria, which yield Pan-African ages (Rahaman and Emofurieta, 1983; Tubosun et al., 1984); apparently similar rock types have been previously described in Northern Cameroon in the Faro and Banyo areas (Koch, 1955).

Except for this still insufficiently documented basement, the oldest age recorded in the Poli region is close to 800 Ma and was obtained on metarhyolites. As part of the gneisses are likely to be of sedimentary origin, their zircons may represent a mixture of detrital zircons from an older basement and from the volcanic rocks emplaced c. 800 Ma ago. Thus, the c. 800 Ma age may be interpreted as representing a major volcanic stage, and age indications of this range in the gneisses suggests that a part of them may partly correspond either to altered volcanics or to clastic products of local derivation.

This 800 Ma old volcanic event probably corresponds to the initial stage of the Pan-African evolution. The assumed extensional signatures of this volcanism are: the tholeiitic metabasalts of the schist group (Ngako, 1986), the tholeiitic amphibolites interlayered in the gneisses (metabasalts or metadolerites? Toteu, work in progress) and the peralkaline rocks associated with the rhyolites (Koch, 1955). During the upper Proterozoic, the volcanism was probably accompanied by the deposition of immature clastic and volcano-clastic rocks which form part of the gneisses. This assumed extensional regime may have occurred approximately at the same time as the oceanic opening postulated along the eastern margin of the West African craton further West (Black et al., 1979).

The ages around 630 Ma correspond to a pre to syn-tectonic (D1) plutonic event (the BIP suite), so that they give a good approximation of the D1 age. The BIP suite shows calc-alkaline affinity. The $^{87}Sr/^{86}Sr$ initial ratios obtained and the REE and spidergram patterns of the suite are indicative of a crustal contamination. The analysed zircons are, however, often almost concordant (Fa 1, Go 79 and Go 169) and show no evidence of inheritance. Those rocks are thus principally composed of material newly added to the crust. From the geochemistry and the close relationships with a major tectonometamorphic event, the BIP suite corresponds more likely to syncollision intrusives (as is the case for most of the rocks forming the Iforas batholith in Mali (Liégeois et al., 1986), than to subduction-related cordilleran granitoids.

Bessoles and Trompette (1980) suggested the period between 600 and 550 Ma for the emplacement of most of the syn-tectonic granites corresponding to the syn- to late-D2 intrusions of group (4). Although these rocks have not been analysed, such an assumption is likely, when compared to the new data presented here. However, most of the data supporting this estimate are Rb/Sr biotite model ages and more probably correspond to the cooling age of the intrusions. As the Godé post-tectonic granite was dated at 546+/−15 Ma (Toteu et al., 1986), the syn- to late-D2 plutonic emplacement and the D2 age must be closer to 600 Ma than to 550 Ma. Although imprecise, the age indicated by the Fa 2 sphenes is in agreement with this interpretation.

In Nigeria, a two-stage magmatic evolution at 631+/−18 and 580+/−10 Ma has been identified (Tubosun et al., 1984), but it is not clear if the older stage is linked with a large-scale crustal reactivation as described in Central Hoggar (Bertrand et al., 1986). These two stages may be compared with our D1 and D2 tectonic events, respectively. In Southern Cameroon, a deep-seated nappe tectonics overthrusts the Yaoundé granulitic gneisses and the Mbalmayo schists onto the Archaean Ntem complex (Nedelec et al., 1986). These tectonics are associated with migmatisation dated at 565+/−22 Ma from a whole-rock Rb/Sr isochron (Lasserre and Soba, 1979; recalculated by Cahen et al., 1984). This event may be correlated with our D2.

From the preliminary geochemical data presented here, an important volume of I-types granitoids (at least 20% of the Northern Cameroon) is identified and corresponds to material newly added to the crust, although an unquantified crustal contamination is likely. Zircon ages from gneisses and schists support an upper Proterozoic origin for part of the corresponding protoliths with evidence of older inheritance. These features suggest that crustal accretion occurred during the Pan-African orogeny, but its precise geodynamic site and the relative volume of accretion are still in question. The emerging picture is at variance with the previous works, where this part of the mobile belt was interpreted as dominated by an old Precambrian crust reactivated during the Pan-African orogeny. Accretive domains have already been recognised in many Pan-African regions: Adrar des Iforas (Liégeois et al., 1986), Arabo-Nubian shield (Vail, 1985), but they correspond to well-identified palaeo-island arcs. To establish an evolutionary model for the Northern Cameroon, the reliable observations are:

(1) the volcanism of the earliest stage suggests an extensional environment and crustal thinning; concurrently, there is no clear evidence of shelf conditions and of the proximity of a continental margin;

(2) during a major tectonic event (D1), calc-alkaline plutons were emplaced; as these magmas are associated with a compressive tectonic event rather than with a subduction-related cordillera, they represent more likely syncollision intrusives; furthermore there is no known position for a nearby suture zone nor any oceanic remnant;

(3) the later stage (D2) presents all the features normally associated with a collision, e.g. compressive folding, strike-slip faults, widespread anatexis and LP metamorphism;

(4) the Touareg and Dahomeyan shields display schist belts whose probable ages are in the same range as those of Northern Cameroon, although some of them are assumed to be Kibaran in age. They include the Maru and the Anka belts in SW Nigeria (Holt et al., 1978; Fitches et al., 1985), the Kushaka and the Birnin-Gwari belts in NW Nigeria (Grant, 1978), the Uwet schists (Ekwueme and Onyeagocha, 1986), the latter being probably the southern prolongation of the Poli schists in SE Nigeria;

they also include the previous 'séries intermédiaires' in Cameroon, Chad and Centrafrican Republic. Some of these schist belts have been tentatively related to a suture (McCurry and Wright, 1977), but generally, as in Northern Cameroon, direct evidence of such sutures is missing. Furthermore, whether the surrounding gneisses belong to a possible basement or not is an unsolved problem in many places of the mobile belt; and

(5) there is a broad similarity in the age range determined for the succession of events in the area situated between the Congo craton and the West African craton: the estimated initial stage of the Pan-African evolution of Northern Cameroon is comparable to the oceanic opening along the West African craton; the estimated age of D1 (630 Ma) is similar to that of the collision-related intracontinental nappe tectonics described in Central Hoggar (Bertrand et al., 1986) and to the emplacement of syntectonic charnockitic bodies in the Nigerian shield; the age of D2 (close to 600 Ma) is comparable to the assumed age of the nappe tectonics in Southern Cameroon, to the age of most of the 'older granites' in Nigeria (Van Breemen et al., 1977) and to the age of the main collision along the West African craton (Black et al., 1979).

To explain the tectonics and magmatism of Northern Cameroon independently of a subduction, an alternative model might be the development of intracratonic basins whose evolution is related to the major opening and the closure of the ocean along the West African craton. Such continental domains may be compared to the Basin and Range province where a wide and long-lived extension zone was accompanied by the intrusion of calc-alkaline rocks (Eaton, 1982). Such an evolution could explain the restricted preservation of inherited features, a thin continental crust seeming less able to produce contamination than a normal or thickened crust. A similar model was recently proposed to explain the Kibaran evolution of Burundi (Klerkx et al., 1984).

In the contorted pattern drawn around and inside Africa by the Pan-African belts, Northern Cameroon represents a keystone to our understanding of the structural and geodynamic links between the Trans-Saharan, the Egypt–Sudan and the Mayombe–Katanga branches of the Pan-African net.

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Appendix

Description of the samples

(1) Mayo Punko and Tete bridge metadiorite (Go 79, Go 24, Go 210 to Go 215)

They are coarse to medium-grained orthogneisses intruded in the gneiss complex and show locally cross-cutting contacts with respect to D1 gneiss structures. Magmatic layering and flattened mafic xenoliths redeformed during D2 are present. The main foliation is defined by biotite, green hornblende and lenses of plagioclase. Superimposed retromorphic association is characterised by epidote + chlorite + sericite. Accessory minerals are sphene, zircon, apatite and oxide.

(2) Tchamba metadiorite (Fa 1, Iso 1 and Iso 6)

It is a fine-grained migmatitic rock showing a polyphased deformation with a strong transposition during D2. No clear contact relationships with the surrounding gneisses have been observed. The mineralogy is the same as for Go 79 but retrogressive associations are absent.

(3) Mayo Ilou metagranodiorite (Go 169)
It is a fine-grained rock intrusive in migmatitic gneisses and showing polyphase deformation (D1 and D2), D2 foliation being the most developed. Contacts with the gneisses are concordant. The mineral association comprises quartz+/−K feldspar + plagioclase + biotite + green hornblende.

(4) Garé metagranodiorite (Pt 74)
This coarse to medium-grained rock intruded in the Poli schists. Its plutonic origin is attested in the field by the presence of intrusive magmatic contacts between these rocks and the schists. Both schists and metagranodiorites show the same D1 and D2 tectono-metamorphic evolution in low-grade conditions. The mineral assemblage corresponding to the main foliation includes quartz + chlorite + muscovite + K feldspar + plagioclase + epidote. Accessory minerals are apatite, sphene and zircon.

(5) Bakonwa foliated granite (G)
The rock is a fine-grained granite showing a polyphase tectono-metamorphic evolution in medium-grade conditions. The mineralogical composition is: quartz+K feldspar+biotite.

(6) Hosséré Goldyna metarhyolite (Po 2)
This light-coloured rock shows phenocrysts of quartz, K feldspar and plagioclase in a schistose groundmass composed of fine-grained quartz+sericite+/−epidote+oxide+zircon. The S1 foliation outlined by quartz and sericite is folded during D2.

(7) Taparé and Mayo Bandilé migmatitic gneisses (Go 247, Fa 2)
Migmatitic gneisses are interlayered with amphibolites and contain calc-silicate boudins. They are probably metasedimentary in origin. D1 structures are intensively transposed during D2. The migmatitic mobilisates were preferentially emplaced along D2 folds axial planes. The mineralogical composition is: quartz+K feldspar+plagioclase+biotite. Retrogressive muscovite and chlorite are occasional.

(8) Mbé amphibolitic gneiss (Mb 1)
They are dark migmatitic gneisses showing polyphased (D1 and D2) deformation. They are affected by late-D2 wrench faulting; an associated mylonitic foliation with fine-grained biotite and quartz locally cross-cut the P2 folds. The rock contains green hornblende, biotite, plagioclase and quartz, sphene, apatite, zircon, oxides. Retromorphic epidote and chlorite are also present.

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