Cameroon: a Tectonic Keystone in the Pan-African Network[1]

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Abstract

The place of Cameroon in the Pan-African network of orogenic belts is examined in terms of a detailed survey of the Poli and Yaoundé regions located in the northern and southern parts of the country respectively. In the Poli region, although the first stage (D1) of the evolution is still poorly understood, the younger D2 and later events involved northeast–southwest movement, resulting in wrench faulting and thrusting. The migmatized gneissic formations of the Poli region, previously interpreted as an old basement, now appear more likely to represent partly high-grade equivalents of the Poli schists (800 Ma). The abundance of younger Pan-African calc-alkaline orthogneisses interleaved both in the schists and in the gneisses (630 Ma) is a salient characteristic of the Poli region. Comparison with the Yaoundé region, where strongly metamorphosed platform sediments are thrust to the south-southwest onto the Congo craton, suggests that the Sanaga–Adamaoua region, situated between the two areas studied, represents a boundary zone between a stable craton-controlled zone to the south and a partly accreted crust to the north. The ubiquity of northeast–southwest directions of tectonic movement in southern and western Africa suggests that the model of continental transform faults controlling Pan-African tectonics in southern Africa can be applied to central and western Africa.

Résumé

La situation du Cameroun au sein du réseau des chaînes Pan-Africaines est discutée d'après les résultats d'études détaillées menées dans les régions de Poli et de Yaoundé, au nord et au sud du pays. Dans la région de Poli, la première étape (D1) de l'évolution est encore mal comprise; l'évènement D2 et les évènements tardifs correspondent à une direction de mouvement nord-est–sud-ouest responsable de charriages et de décrochements. Les formations gneissiques migmatisées de la région de Poli, interprétées jusqu'à présent comme représentant un vieux socle, sont maintenant considérées en partie, comme des équivalents métamorphiques de haut degré des schistes de Poli datés à 800 Ma. Une autre caractéristique importante de la région de Poli est un important volume d'orthogneiss de composition calco-alcaline, plus jeunes (630 Ma), interstratifiés aussi bien dans les gneiss que dans les schistes. La comparaison avec la région de Yaoundé, au sud, où des sédiments de type plateforme, très métamorphiques ont été charriés vers le sud-sud-ouest, sur le craton du Congo, suggère qu'il existe, dans la région intermédiaire de la Sanaga–Adamaoua située entre les deux régions étudiées, une frontière majeure: au sud, il s'agit d'un domaine influencé par la proximité du craton stable, tandis qu'au nord, une partie importante de la croûte résulte d'une accrétion d'âge Protérozoique supérieur. La similitude des directions de mouvement d'âge Pan-Africain entre les parties méridionales et occidentales de l'Afrique suggère que le modèle impliquant que la tectonique Pan-Africaine de la partie sud de l'Afrique est commandée par une grande zone de cisaillement à caractère transformant, peut aussi s'appliquer aux parties centrales et occidentales du continent.

INTRODUCTION

Proterozoic orogenic belts occur as sinuous zones forming complex nets around older cratons in all continents. In North America, there are several belts that evolved during the 2000–1600 Ma time range; whereas in Africa, a similar belt pattern is the result of Pan-African tectonic activity, which occurred about 600 Ma ago. Both Pan-American and Pan-African activity occurred through continental accretion, island-arc and continental-margin magmatism, and possibly accretion of displaced terranes (Black *et al.*, 1979; Lewry, 1981; Condie, 1982; Stoeser and Camp, 1985).

In Africa, well-defined linear belts were formed by ensialic processes, Wilson-cycle-type evolution, or thermal reactivation of old terranes; the latter interpretation is generally applied to less well-known regions where geochronological data are scarce and structural information is lacking. In Cameroon, although evidence for a Pan-African imprint was well documented in terms of Rb/Sr age determinations, most of the metamorphic units were considered, until recently, to represent a Lower Proterozoic cover with respect to the Archean granulites and granites of the Congo craton (Bessoles and Lasserre, 1977).

The location of Cameroon in the Pan-African network is of prime importance as it forms the link between the Transaharan belt (Cahen *et al.*, 1984), the Mayombe – West Congo belt, and northeastern Brazil (Fig. 1). Intervening cratons are the West African craton, the eastern limit of which is well defined in Togo, Benin, Mali, and Algeria (Black *et al.*, 1979; Trompette, 1979; Affaton *et al.*, 1980); the Congo–Chaillu craton, cropping out in southern Cameroon, Centrafrican Republic, Gabon, Congo, and Zaïre; and a still ill-defined Nile craton to the northeast (Rocci, 1965).

Two areas are currently being studied in detail: northern Cameroon (Ngako, 1986; Njel, 1986; Toteu *et al.*, 1986) and the Yaoundé region in southern Cameroon (Nzenti *et al.*, 1984, 1988; Nedelec *et al.*, 1986; Nzenti, 1987). They are separated by the Sanaga–Adamaoua region, where assumed Pan-African mylonites are largely hidden by Mesozoic to recent uplift and associated volcanism and faulting (Fig. 1).

In northern Cameroon, several areas scattered along the southwestern end of the Poli schist belt have been investigated. This schist belt belongs to the Bessoles' "Séries intermédiaires," classically attributed to the Lower or Middle Proterozoic. However, new geochronological data (Toteu *et al.*, 1987) indicate that it represents a Late Proterozoic volcaniclastic assemblage and that some gneisses and a large part of the orthogneisses, previously attributed to the basement complex (Bessoles and Trompette, 1980), are also Late Proterozoic in age.

In southern Cameroon, a study of the Yaoundé migmatites and granulites has confirmed Bessoles and Lasserre's (1977) hypothesis of large-scale Pan-African nappes emplaced onto the Congo craton, but has also shown that the granulite facies metamorphism of the Yaoundé migmatites is Pan-African in age (Ball *et al.*, 1984; Jegouzo, 1984; Nzenti *et al.*, 1984, 1988).

The aim of this paper is to compare the tectonic evolutions of northern and southern Cameroon and to discuss their places in the Pan-African orogenic network.

TECTONIC AND METAMORPHIC EVOLUTION OF NORTHERN CAMEROON

Geological setting of the Poli schist belt

The most detailed maps available are those of Koch (1959), Schwoerer (1965), and Le Fur (1971). Le Fur (1971) proposed a lithostratigraphic sequence for the southwestern part of the schist belt (Fig. 2). From bottom to top, the sequence is as follows: (1) gneisses and migmatites of the "basement complex"; (2) the Sakje Formation, composed of leptynites, mica schists, quartzites, amphibolites, calc-schists, with some conglomerates; (3) a lower volcanic unit composed of tuffs of intermediate composition,

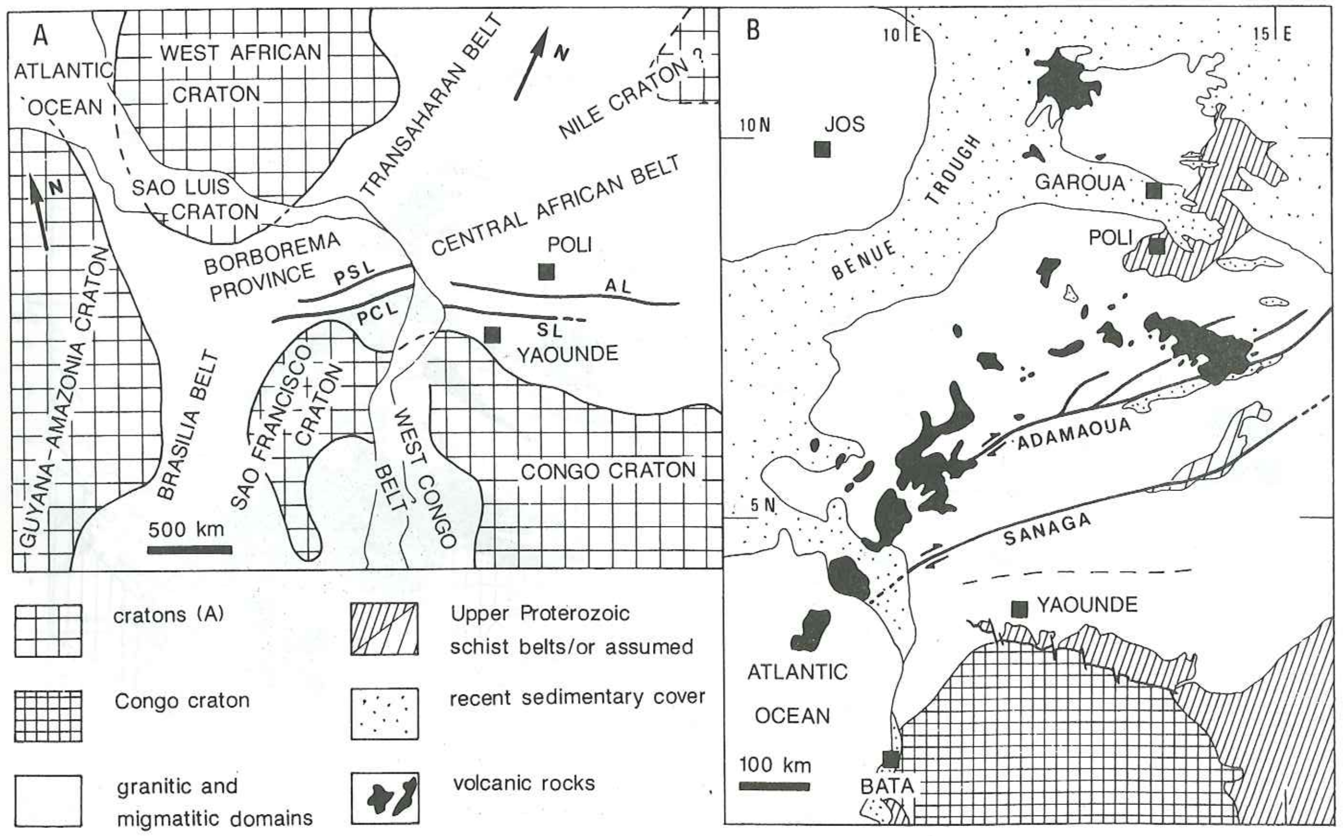

Figure 1. *(A) Location of the main cratonic areas and fold belts in Africa and South America (fit of continents from Bullard* et al. *(1965)). Abbreviations: PSL, Patos lineament; PCL, Pernambucco lineament; AL, Adamaoua lineament; and SL, Sanaga lineament. (B) Sketch map of major tectonic features of Cameroon. Adamaoua and Sanaga lineaments are indicated; the broken line corresponds to the northern limit of the Congo craton from gravimetric data (in Dumont, 1986).*

keratophyric tuffs and lavas, spilitic tuffs and lavas with pillow lavas; and (4) an upper clastic formation with metapelites.

The stratigraphic and tectonic relationships of these formations, however, are not clear because, according to the map, the older formation crops out more frequently towards the centre of the belt, whereas the younger pelitic formation shows, in places, transitional metamorphic relationships with the "basement complex." It now appears that this stratigraphic succession was based mainly upon differences in metamorphic grade and the presence of recognizable volcanics. Nowadays, the gneissic and migmatitic units are no longer assumed to represent only an old basement with respect to the schists (Toteu *et al.*, 1987; Toteu, 1987). New critical observations are listed below.

(1) The occurrence in both schists and gneisses of calc-alkaline orthogneisses (the "basic to intermediate plutonic" (BIP) suite), which are broadly synchronous with the older recognized deformation event (D1). These orthogneisses locally form more than half the volume of the previous "basement complex"; they are well dated in the 660–630 Ma range.

(2) The tectonic evolutions of both groups are comparable in spite of contrasting metamorphic grades, i.e., tangential deformation involving the development of a gently dipping schistosity (D1), followed by a compressional folding with subvertical axial planes (D2). Metamorphic grade corresponding to the second phase is of MP/LT type in the Poli schists and of MP/HT type in the gneisses. The age of the older deformation is defined only by the D1 pre- to syntectonic emplacement of 630 Ma old basic to intermediate plutons. The D2 event corresponds to a major foliation transposition, commonly accompanied by widespread migmatization and culminating in the late-tectonic emplacement of large granitic batholiths with an age of about 580 Ma.

(3) There is evidence for a volcanic event characterized by tholeiitic (Njel, 1986) and alkaline felsic volcanics in the schist belt. These volcanic rocks are 830 Ma old (Toteu *et al.*, 1987), thus confirming the Upper Proterozoic age of the Poli schists (see also Ekwueme (1987) for the adjacent Nigerian basement). Some amphibolites belonging to the gneissic units have chemical compositions similar to the metavolcanics associated with the Poli schists.

(4) No clear petrographic or structural criteria have been found to support a basement–cover relationship, but both metamorphic and tectonic transitional contacts have been recognized. Nevertheless, some 2000 Ma old inherited zircons in the gneisses (Toteu *et al.*, 1987; Penaye, 1988) indicate either that part of the banded gneisses and migmatites represents genuine basement or, in some cases, that a basement source was present in the vicinity to provide material for clastic sediments interleaved with the volcanics.

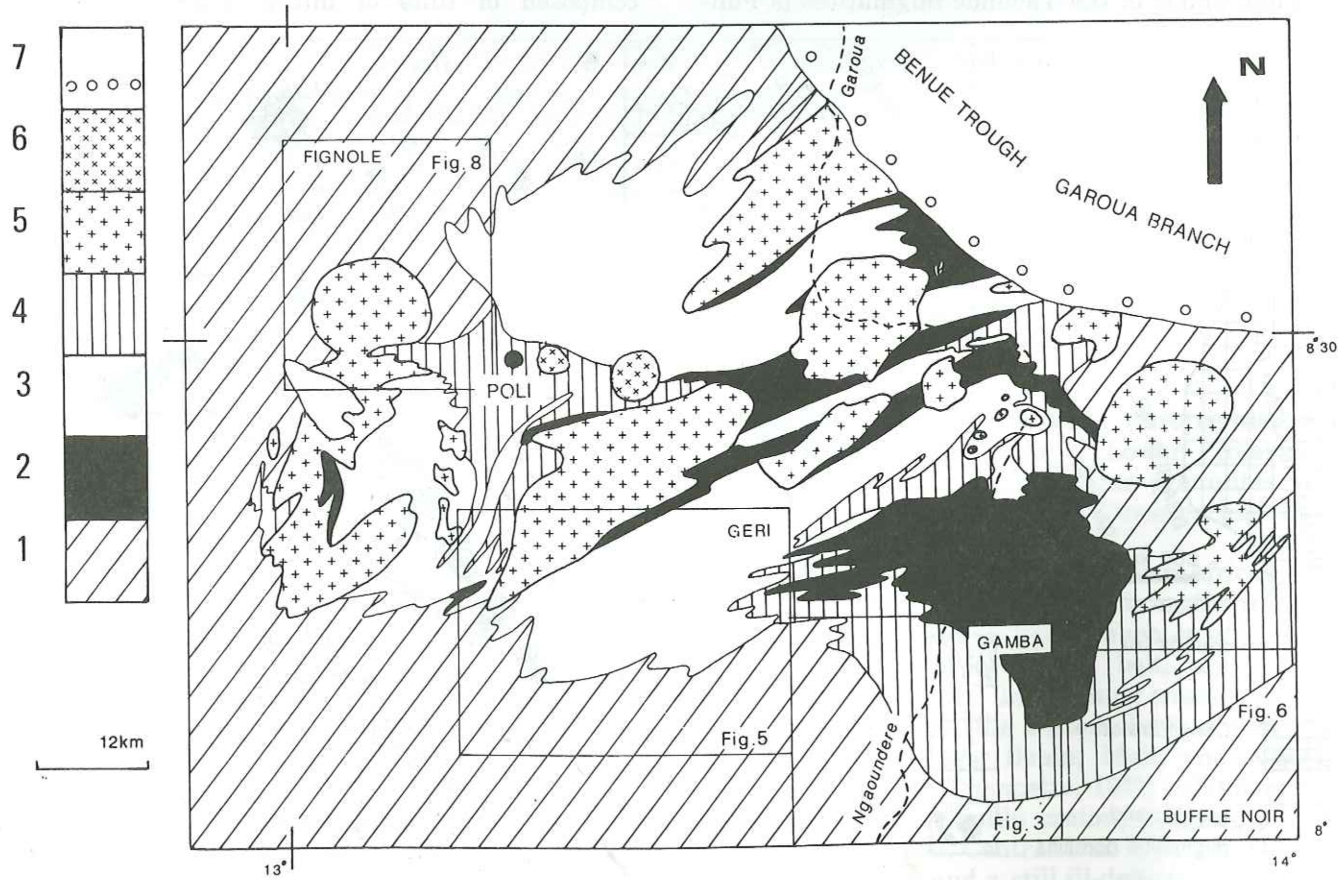

Figure 2. *Geological sketch map of the Poli region (modified from Le Fur (1971)). Study areas are indicated with the corresponding figure number. Legend: (1) gneisses and migmatites, (2) Sakje Formation, (3) lower volcanic unit, (4) upper clastic unit, (5) undifferentiated syn- and post-D2 granites, (6) Tertiary younger plutons, and (7) sedimentary cover of the Benue trough.*

Structural evolution of the southwestern end of the Poli schist belt, Gamba and Geri areas

The Gamba area (Figs. 3 and 4) is currently being studied by one of us (SA). Map and structural observations indicate a sharp tectonic and metamorphic contact between schists and gneisses. This contact is marked by retrogressive mylonitic gneisses. Along the northwestern contact (Fig. 3), vertical mylonites show a horizontal lineation interpreted to result from dextral wrench faulting.

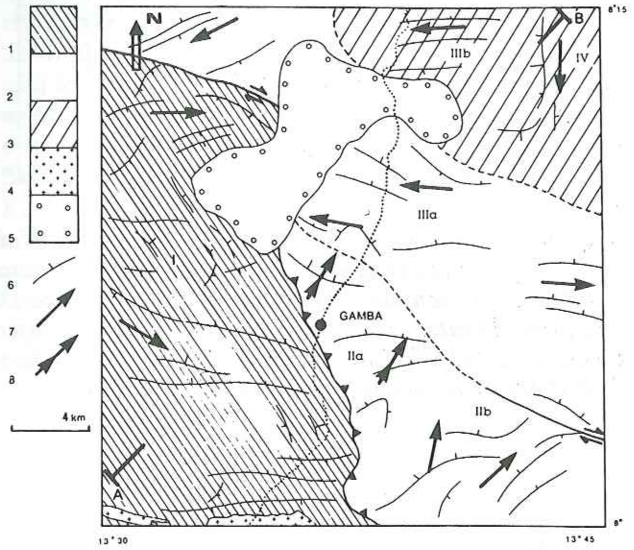

Figure 3. *Structural sketch map of the Gamba area. Legend: (1) gneisses and migmatites, (2) schists, (3) mica schists, (4) late-D2 granites, (5) Lower Paleozoic (Mangbei Formation), (6) foliation trajectories, (7) plunge direction of D2 fold axes, and (8) plunge of L2 stretching lineations. The bold line with black triangles represents a thrust plane. Line A–B is the cross-section shown in Figure 4.*

Toward the southeast, northeast-dipping (50°) mylonites and schists, together with northeast-plunging fold axes, suggest that schists overlie the gneissic domain (domain I on Fig. 3) along a thrust contact.

The gneisses contain an important proportion of orthogneisses and exhibit what was originally a flat-lying foliation (S1), parallel to a compositional banding, associated with conformable migmatic mobilizates. Except for its commonly well-defined foliation and the presence of relict minerals such as garnet, the geometry and thermal regime of the D1 event cannot be reconstructed. During the D2 event, D1 textures have been almost completely recrystallized and S1 heterogeneously refolded by trains of tight, upright to overturned, east–west trending folds with subhorizontal axes. Anatexis became more important with increasing intensity of D2 deformation and culminated approximately within the most tightly folded zones where the S1/S2 transposition is most intense. Anatexis partly erased previous planar and linear structures, and grades to a subhomogeneous anatectic granite that crops out in the southern part of the area studied.

In the schists, three domains (numbered II–IV on Fig. 3) have been defined with similar lithologies but slight differences in metamorphic grade. In domain II, which follows the schist–gneiss contact, D2 folds refold S1 foliation and have north-northeast trends and varying plunges (IIb); whereas in the IIa domain, a downdip stretching lineation is associated with a steeper S2 cleavage (50° to the northeast). In mylonites close to the contact, shear-sense criteria indicate a northward, down to northeast, movement direction along the thrust plane. Domain III is characterized by east–west trending, overturned (IIIa) to upright (IIIb) folds, with subhorizontal axis and associated cleavage; these F2

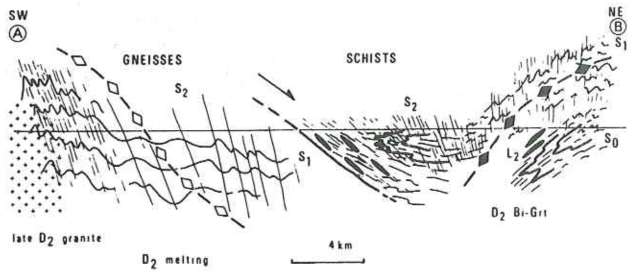

Figure 4. *Gamba area cross-section. S0, S1, and S2 are indicated. Solid diamonds correspond to the D2 biotite isograd; open diamonds correspond to D2 melt-rocks. The arrow indicates the latest retrogressive movement along the thrust plane; the apparent normal movement is probably related to late-D2 doming and granite emplacement.*

folds refold S1. Domain IIIb shows a northward increase in metamorphic grade. S0/S1 relationships suggest the existence of an F1 large-scale recumbent fold. Domain IV, where fold axes trend north–south, is less well understood; together with the IIIb domain, it shows a higher metamorphic grade.

In the schematic section shown in Figure 4, domain II is interpreted as representing the hanging-wall block of a nappe, deformed under simple shear conditions, whereas compressive east–west folding and north–south flattening characterizes both the underlying gneisses and the schists situated above the sheared sole. The thrust itself is likely to correspond to a late increment in the D2 progressive deformation as indicated by the metamorphic break between schists and gneisses and by the retrogression shown by the mylonites.

The Geri area (Ngako, 1986) is situated west of the Gamba area, where the schist–gneiss contact runs east–west (Fig. 5). Ngako's interpretation of the structure of the area is based on the contention that the gneisses may represent a basement because of the presence of granulite-facies remnants. The most important features in this area are as follows:

(1) A strip of retrogressed gneisses follows the contact between schists and gneisses, as in the Gamba area where the eastern extent of this contact shows a horizontal stretching lineation. A strike-slip fault may explain part of the variation of L2 trajectories shown on the map.

(2) The Bantadje unit, considered by Ngako as belonging to the basement, corresponds to foliated granites similar to those of the Bakonwa type (660 Ma old, Toteu *et al.* (1987)).

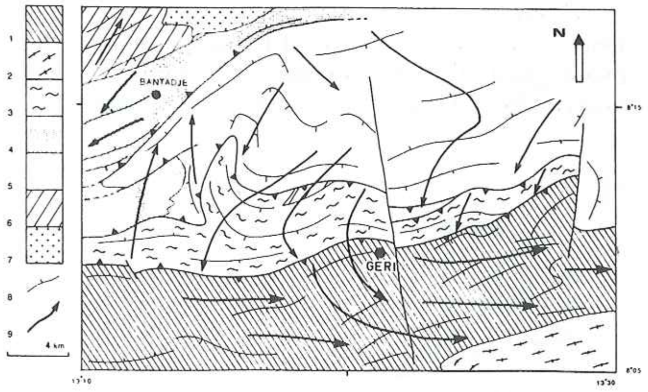

Figure 5. *Structural sketch map of the Geri area (modified and reinterpreted from Ngako (1986)). Legend: (1) gneisses and migmatites; (2) metadiorites; (3) retrogressed gneisses; (4) Bantadje Formation, foliated granites; (5) schists; (6) mica schists; (7) late-D2 granite (Kogue granite); (8) foliation trajectories; and (9) D2 fold axes and L2 lineation plunges. Bold lines with black triangles represent thrust planes.*

Structural evolution of the eastern edge of the Poli schist belt, Buffle Noir game reserve area

The Buffle Noir area (Figs. 6 and 7) is currently being studied by one of us (JP). Metamorphic terranes here exhibit a regional northeast–southwest trending steep foliation. Two main formations have been defined.

(1) In the north, a low- to medium-grade schist formation (Poli schists, 3 and 4 on Fig. 6) is made of volcaniclastic rocks (greywackes) with minor limestones and felsic to mafic metavolcanics.

(2) In the south, a heterogeneous high-grade gneissic formation contains two separated units of metagreywackes (1 on Fig. 6) with mafic volcanics and interleaved metadiorites. Rare layers of metapelite are also present. The southernmost unit contains many relicts of granulitic association. The two units are separated by a laccolith of syntectonic metatonalites (2 on Fig. 6) containing large enclaves (1 m to 1 km in size) of gneisses and tentatively interpreted as deep-seated equivalents of the Poli tholeiitic volcanics (Penaye, 1988). This formation is affected by southward-increasing migmatization.

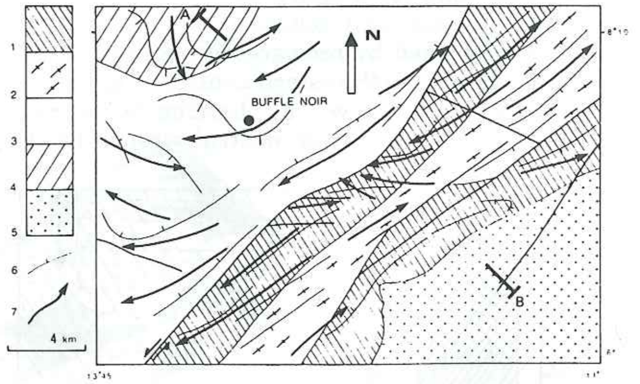

Figure 6. *Structural sketch map of the Buffle Noir area. Legend: (1) gneisses and migmatites; (2) metatonalites; (3) schists; (4) mica schists; (5) late-D2 granites, diorites, and gabbros; (6) foliation trajectories; and (7) D2 fold axes and L2 lineation. Line A–B is the cross-section shown in Figure 7.*

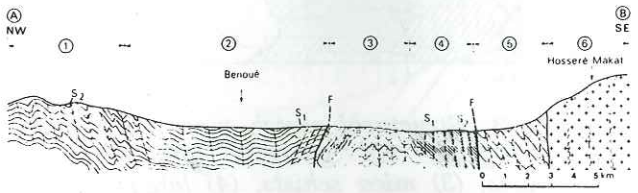

Figure 7. *Buffle Noir cross-section. Legend: (1) mica schists, (2) schists, (3) northern gneissic unit, (4) metatonalites, (5) southern gneissic unit, and (6) late-D2 granites, diorites, and gabbros.*

The contact zone between the Poli schists and the gneisses is a N40°E to N55°E trending sinistral strike-slip fault, which is outlined in the field by low-grade mylonites. Faults with the same trend are scattered across the whole region and late dextral faults are also found with the same direction. A syn- to late-tectonic subalkaline plutonic complex (gabbros, diorites, and porphyritic granites; 5 on Fig. 6) intrudes the gneissic formation in the southeastern corner of the area.

The structural evolution of this area can be summarized as follows:

(1) The older S1 surface was probably originally flat lying and locally still has this attitude. In the gneisses, the foliation is defined as a compositional banding with granulite-facies relicts, and, in the schists, as the main schistosity transposing both a faint earlier planar structure and the stratigraphic markers. Rare F1 isoclinal folds show various axial orientations.

(2) The younger S2 surfaces are parallel to the axial planes of a new set of decimetre to decametre F2 folds. In the gneisses, S2 is a biotite-bearing schistosity or a migmatitic foliation. F2 folds are characterized by nearly horizontal axes and steep axial planes. Gently plunging intersection lineation and local mineral lineation are both parallel to fold axes. Migmatization is widespread and small-scale conjugate shear zones (N0°E and N110°E) are linked to the end of this event. In the schists, most F2 folds also have steep axial planes, but some are nearly flat-lying. F2 fold axes vary both in direction and in axial plunge. The S2 axial plane direction is marked by a strain-slip cleavage in the low-grade rocks, grading into a biotite transposition schistosity in the medium-grade micaschists.

The main sinistral strike-slip movements occurred during the D2 phase. Dextral movements appear to have taken place later, under lower metamorphic conditions. The most simple interpretation to explain the D2 patterns (Fig. 6) is to consider the F2 folds as en echelon folds with respect to the sinistral shear zone. However, the axial direction of F2 folds shows extension amounts (indicated by rare stretched minerals, pancake shapes of feldspars, symmetrical boudinage, and conjugate shear zones) too moderate, considering the angle between F2 axes and the shear zone (about 15–20°), to be explained adequately in this manner.

Structural evolution of the western edge of the Poli schist belt, Fignole area

The main feature of this area (Fig. 8), currently being studied by SFT, is a continuous increase in metamorphic grade from the Poli schists to the gneisses. The area is characterized by vertical north-northwest–south-southeast trending foliations. However, northeast–southwest to east–west trends occur locally in the schists (Fig. 8). Isoclinal D1 folds associated with an originally flat-lying foliation and rotational structures observed in garnets suggest a simple-shear regime. In both schists and gneisses, D1 lineations are scarce; their relict character is due to strong transposition and recrystallization during D2. Where preserved, D1 trends are N110°E–N130°E, with varying plunges.

The D2 event is characterized by tight, upright folds with a vertical axial plane foliation. D2 axes and lineations are parallel and show variable plunge (0 to 50°S or 50°N). D2 migmatization increases toward the west, where late-tectonic granites associated with agmatites are emplaced. On the contrary, in the easternmost part of the area, the S1 foliation is commonly outlined by early

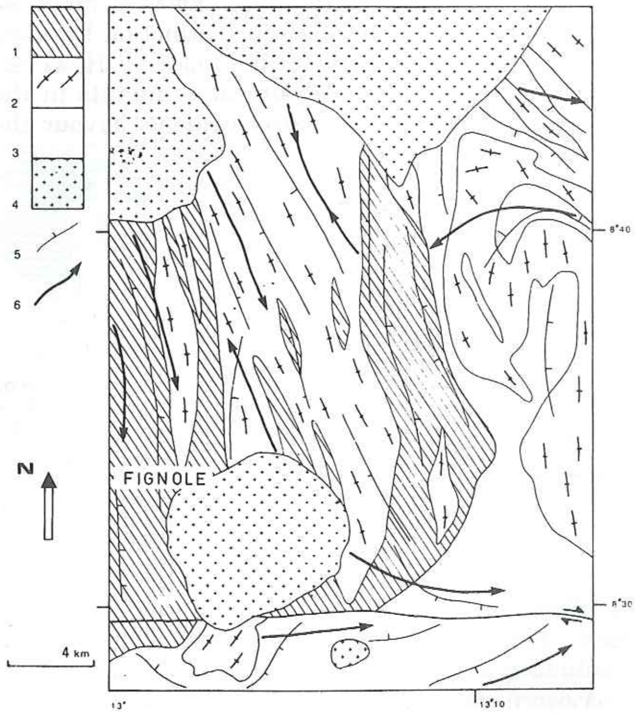

Figure 8. *Structural sketch map of the Fignole area. Legend: (1) gneisses and migmatites, (2) metadiorites (BIP), (3) schists, (4) late- and post-D2 granites, (5) foliation trajectories, and (6) D2 fold axes plunge direction.*

melts, but D2 metamorphic associations are always retrograde: in gneisses and mica schists, garnet and kyanite are retrogressed into biotite and muscovite; in the schists, epidote is fractured. This zonality suggests that D2 isograds dip eastward.

Late D2 shear zones display N80°E–N110°E (dextral) and 0–N160°E (sinistral) conjugate directions.

The Fignole area is thus dominated by the existence of a vertical S2 foliation showing an east–west shortening direction, but there is no evidence of strong north–south stretching.

Tectonic evolution of north Cameroon

The Upper Proterozoic age of the Poli schists is supported by the 800 Ma age of a major volcanic event showing alkaline to tholeiitic affinities; this event could be interpreted as an extensional stage (Toteu *et al.*, 1987). The calc-alkaline basic to intermediate plutonic suite is characterized by low initial ratios (0.7043–0.7045; Toteu *et al.*, 1987) and was interpreted as resulting from a 630 Ma old collision; it is clearly related to the first deformational phase.

No basement can clearly be delineated on a map, although it is assumed from the preservation of granulitic relicts. The similarity of the structural evolution of both schists and gneisses must be stressed as it does not allow a distinction between old and new material to be made. However, petrographical criteria (granulitic remnants in the gneisses) and geochronological evidence favour the presence of ca. 2000 Ma old material, possibly mixed with younger detrital material.

D1 seems to be part of a major nappe-forming event. However, no clear stretching lineation has been observed and axes of early isoclinal folds are highly variable in direction, even though a N100°E to N130°E maximum has been observed in some places. Consequently, it is premature to propose a vergence or movement direction for D1.

D2 tectonic evolution can be related to the development of a system of major wrench faults parallel or subparallel to a northeast–southwest movement direction (Fig. 9). A similar interpretation, involving tear faults or intracontinental transform faults, has already been proposed to explain the tectonic evolution of the Irumides belt in Zambia (Daly, 1986b). Most of the F2 fold axial directions may be explained either as en echelon folds associated with a sinistral wrench fault (Buffle Noir) or as compressional folds, at right angles to the movement direction (Fignole). In restricted areas (nappe contact of Gamba), F2 folds may have developed parallel to the movement direction. In the same way, the north-south trending F2 folds of the Fignole–Kogue area could also be en echelon folds associated with a dextral wrench fault; however, this cannot explain the F2 pattern displayed south of Kogue, in the Geri area. Such a dextral shear zone was proposed recently to explain the emplacement of the Kogue granite pluton (Bassahak, 1988). In the Buffle Noir area, the low angle between fold axes and the shear zone implies a large amount of strain, which would be accompanied by a shear component in the folds, a feature that has not been recognized. However, if deformation was initiated under conditions close to melting, the total finite strain may not have been entirely recorded. Alternatively, if the F2 axial direction is considered as representing the perpendicular to the shortening direction in each point, the observed regional variation may be the result of the impingement of an unmelted block, situated to the northeast below the Poli schist domain, against a melting zone. Such a model postulates a movement direction similar to that of the tear fault model, and is consistent with the location of D2 migmatites.

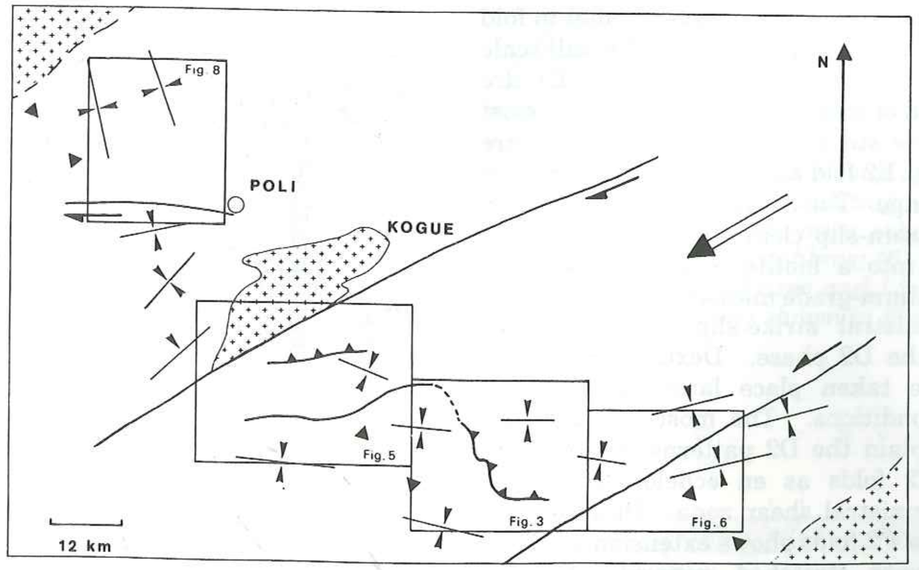

Figure 9. *D2 tectonic evolution of the Poli area. Opposite arrows represent local shortening directions and corresponding D2 schistosities. Opposite triangles represent late-D2, northwest–southeast shortening directions expressed by discrete conjugate shear planes. The distribution of D2 structures is controlled by a southwest movement direction that induced major tear faults and associated thrusts; emplacement of syn- to late-D2 granitic plutons may be controlled by the late-D2 shortening direction.*

The late D2 compressional event, shown by the ubiquitous presence of conjugate shear zones with the same direction throughout the region, cannot be interpreted in terms of the above models. It corresponds to a northwest–southeast shortening direction, at right angles to the major wrench faults. As this direction is perpendicular to the alignment of late-tectonic granitic batholiths, it may reflect the emplacement of these commonly large plutons. This assumption is supported by the increased melt material associated with late D2 shear zones close to batholiths (e.g., west of Fignole).

TECTONIC AND METAMORPHIC EVOLUTION OF SOUTHERN CAMEROON

South of the Adamaoua mylonitic zone (Fig. 1), the Pan-African fold belt is composed of reworked Archean formations in the west (Nyong and Lokundje series) and of low- to high-grade metasedimentary formations in the east (Mbalmayo and Yaoundé series) (Fig. 10).

From field, structural, and chemical data, both the Yaoundé and Mbalmayo series (Nedelec *et al.*, 1986; Nzenti *et al.*, 1988) are interpreted as shallow-water sedimentary sequences composed mainly of shales and volcanogenic greywackes with dolomitic marls, dolomites, evaporitic sediments, quartzites, and iron-rich beds. These sequences were probably deposited in intracontinental extensional basins or on an epicontinental platform at the northern passive margin of the Congo craton; there is no evidence of subduction-related volcano-sedimentary formations.

The tectono-metamorphic evolution of the Yaoundé series is monocyclic (Ball *et al.*, 1984) and results from the succession of two deformation stages (Nzenti *et al.*, 1988). The first stage (D1) is marked by the development of an S1 surface representing the tectonic transposition of a compositional layering. D1-related prograde metamorphism reached high-pressure granulite facies conditions (800°C, 12 kbar (1.2 GPa)) and triggered widespread migmatization. The subsequent deformation (D2) is characterized by strong shear movements, first enhanced by melting and then evolving under retrograde conditions. The direction of movement indicated by the stretching lineation parallel to fold axes is N20°E–N40°E, with a southward transport direction. The retrograde metamorphic assemblages indicate an inverted metamorphic gradient: metamorphic grade increases from the foreland (Congo craton) to the core of the nappe (Yaoundé region), with a north-dipping foliation (Fig. 11). The age of this D2 event is estimated at 565 Ma (Lasserre and Soba, 1979).

The Nyong series has been interpreted recently as an early Proterozoic nappe, thrust to the south onto the Congo craton (Feybesse *et al.*, 1986). However, it seems more likely that it is a basement nappe of Pan-African age as the direction of movement and the foliation trajectories are in continuity with those of the Yaoundé series. Gravimetric data (Dumont, 1986) suggest that the Congo craton extents to the north beneath the Yaoundé nappe (Figs. 10 and 11). Thus, the nature and structure of the Pan-African formations south of the Adamaoua line are governed by the presence of an old continental crust and correspond to southward-moving nappe sheets. Such an environment precludes the presence of a suture in this region.

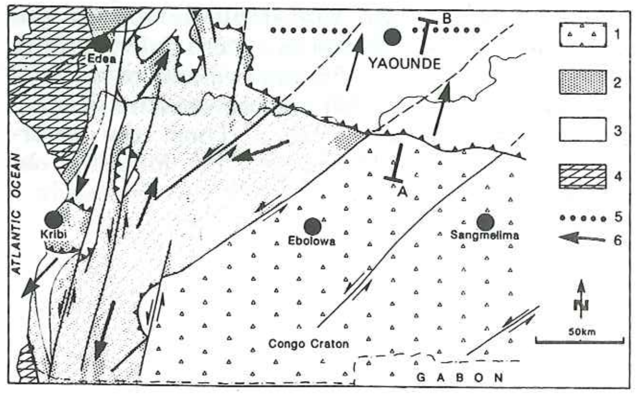

Figure 10. *Structural sketch map of southern Cameroon (data from Nzenti* et al. *(1988) and Feybesse* et al. *(1986)). Legend: (1) Ntem granulites (Archean Congo craton), (2) Nyong series (reworked Archean), (3) Yaoundé and Mbalmayo series (Upper Proterozoic), (4) Cretaceous to Recent formations, (5) assumed northern limit of underlying Archean craton (from Dumont, 1986), and (6) plunge direction of the stretching lineation. Line A–B is the cross-section shown in Figure 11.*

DISCUSSION AND CONCLUSION

Tectonic evolution

Our work has focused on the northern (Poli region) and southern (Yaoundé region) areas of Cameroon. There is a critical area between that is still poorly known, the Sanaga–Adamaoua region. After comparing the northern and southern regions, we will discuss possible working hypotheses concerning the Sanaga–Adamaoua region.

The average movement directions are similar in both northern and southern regions (N20°E in the south, N50°E in the north). In the Yaoundé region, this corresponds to a true transport direction, verging toward the Archean craton, with a large amount of stretching; in the north, the northeasterly direction corresponds to a wrench-fault system with associated folds, interpreted as representing tear faults. The corresponding S2 foliations are flat lying in the south and steeply dipping in the north, although an interesting exception is the wrench and thrust system developed along the western edge of the Congo craton (Fig. 10; Jegouzo, 1984). During the D2 event, high-grade metamorphic conditions seem to be higher pressure in the south (Nzenti *et al.*, 1988). From available geochronological data, the end of metamorphism is identical in both regions, around 570 Ma (Lasserre and Soba, 1979; Toteu *et al.*, 1987).

All of these features confirm that most of Cameroon belongs to the same Pan-African belt (Bessoles and Lasserre, 1977). However, the geodynamic environments are different: platform sediments thrust onto the stable craton in the south, and Upper Proterozoic crustal thinning linked to emplacement of a large volume of juvenile magmas in the north, followed by collision-related calc-alkaline magmas (BIP). Thus, the intermediate region is truly critical. The following observations may be useful for a better understanding of this region.

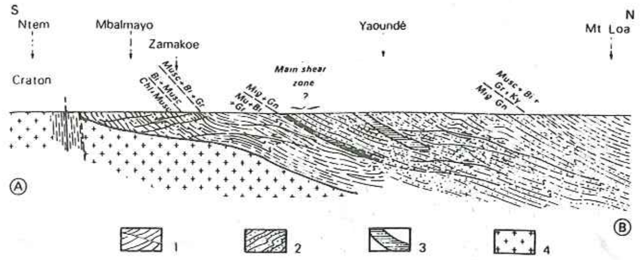

Figure 11. *Ntem–Yaoundé cross-section. Legend: (1) low-grade metamorphic formations, (2) high-grade granulitic and migmatitic formations, (3) pyriclasites, and (4) Ntem Archean granulites.*

(1) The limit between the areas dominated by N50°E and N20°E directions is situated between the Adamaoua line and the Sanaga wrench fault (Fig. 1). It is locally outlined by a narrow, low-grade, volcano-sedimentary belt (Lom series of unknown age). It is also, based on gravity data, the northernmost possible extent of an underlying stable craton (Dumont, 1986).

(2) Along the northern edge of the Adamaoua line, gneisses similar to those of the Poli region contain premigmatitic granulitic remnants in gently dipping mylonites (E. Ngangom, personal communication, 1987).

(3) A 10-km step in crustal thickness has been determined from seismic data (Stuart *et al.*, 1985), with a thin crust (23 km) north of the Adamaoua; it was considered as a young feature associated either with the Cameroon volcanic line or with the Benue trough, but, based on the presence of an undeformed Lower Paleozoic formation (Mangbei series), this northern Cameroon thin crust could be a Pan-African inheritance.

The suture problem

In West and Central Africa (Fig. 12), well-defined cratons comprise both Archean nuclei and Lower Proterozoic assemblages whose internal pattern in terms of orogenic belts and/or domains is still poorly understood. This is also the case in South America, where Archean and Lower Proterozoic formations are both present in the Guyana and Sao Francisco cratons.

The only well-identified Pan-African suture zone is known along the eastern edge of the West African craton (Black *et al.*, 1979; Lesquer and Louis, 1982). The westernmost tectonic domain of the Transaharan belt, east of the craton, is considered to represent a complete Wilson cycle from oceanic opening to major collision, probably involving several microcontinents. Other possible sutures shown on Figure 12 are highly speculative, and are discussed below.

(1) Along the eastern edge of the Air mountains (Niger), an ophiolitic assemblage has been studied recently (Cosson *et al.*, 1987) in a thrust belt first mapped by Black *et al.* (1967). This thrust belt forms a northeast-verging tectonic contact between overthrust high-grade gneisses and low-grade metavolcanics and ultramafic bodies. This entire package has been thrust onto a basement (and its undetached Late Proterozoic cover (Proche Tenere series)). The rocks here may be comparable with gneissic assemblages of Lower Proterozoic polycyclic rocks in central and eastern Hoggar (Bertrand et al., 1986). This likely suture has been extended on Figure 12 to the Tiririne belt in Algeria, and toward the south to the Damagaran region, where highly deformed rocks have been noted (Liegeois *et al.*, 1985). The Tiririne belt has been previously interpreted as an intracontinental linear fold belt (Bertrand *et al.*, 1978).

(2) East of Lake Chad, a major gravity anomaly, unfortunately occurring in a region entirely covered by recent formations, has been delineated by Louis (1970), who, owing to the similarity in pattern with anomalies in the circum-West African craton, tentatively proposed that it could represent another suture zone. This hypothesis was recently discussed by Freeth (1984). Such a suture may well explain the geodynamic evolution of northern Cameroon and also the calc-alkaline granitoids occurring in Tibesti region (Pegram *et al.*, 1976).

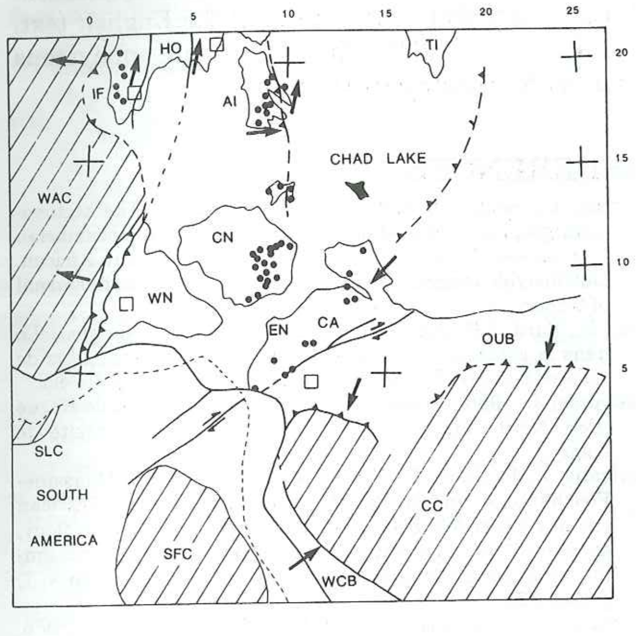

Figure 12. *Cameroon geodynamic environment. The hatched areas correspond to Archean and/or Lower Proterozoic cratons (contacts are modified from Louis (1970)). Lines with triangles correspond to well-defined or assumed suture zones or to major thrust zones. Arrows indicate the mean movement directions: in the West African craton (WAC), arrows are located for clarity on the stable foreland, but actually represent the stretching lineation occurring in the westernmost thrust sheet; elsewhere, arrows represent the average direction of the stretching lineations. Dots indicate younger alkaline granites. Open squares correspond to areas where Eburnean or older ages have been determined. Cratonic areas: WAC, West African craton; CC, Congo craton; SFC, Sao Francisco craton; and SLC, Sao Luis craton. Pan-African belts: WCB, West Congo belt; OUB, Oubanguides belt; IF, Adrar des Iforas; HO, Hoggar; AI, Air; TI, Tibesti; WN, CN, and EN, western, central, and eastern Nigeria; and CA: Cameroon.*

(3) In the Centrafrican Republic, Poidevin (1983) recently proposed the existence of another Pan-African belt, the Oubanguides, which, albeit an area of uncertainty, extends eastward the major thrust contact of the Yaoundé gneisses onto the Congo craton. The Oubanguides belt is still poorly documented and, as for southern Cameroon, there is no direct evidence for a suture.

(4) There is no major gap with northeastern Brazil (Borborema province), especially if most of the structures of this area are Brazilian in age (i.e., Pan-African) according to Caby and Arthaud (1986). However, there is no consensus about the tectonic evolution of northeastern Brazil and many Brazilian geologists favour interpretations where pre-Upper Proterozoic features play an important role (Jardim de Sa *et al.*, 1987).

A general remark must be made concerning the location in western and central Africa of alkaline "anorogenic" complexes of any age, from Late Pan-African to Recent, with respect to possible Pan-African sutures. In most cases, the alignments of younger granites follow identified or suspected sutures on their active margin side. In southern Cameroon, however, Late Pan-African alkaline complexes (A. Michard, unpublished data; E.N. N'Sifa, personal communication; R.W. Van Schmus, personal communication) are far from any suture and occur in the southwestern corner of the thrust and wrench-fault belt. The assumption of a partly asthenospheric origin for some alkaline ring complexes (Liegeois and Black, 1984; Liegeois, 1987) and the control of their emplacement by the latest wrench faults (accompanied with a reversal of movement), which ended the collision process in the Iforas region (Boullier *et al.*, 1986), suggest a severe disturbance of the lithosphere–asthenosphere boundary ("harpoon effect" of Liegeois and Black, 1984). Such a disturbance may have lasted for hundreds of millions of years and controlled the "anorogenic" intrusives.

The Pan-African network

On Figure 13, major Pan-African tectonic features have been indicated at the continental scale. As synchronism is not certain, we have considered all the proven or assumed movement directions in the 700–500 Ma time span. Data are from Bertrand *et al.* (1986), Black *et al.* (1979), Boullier (1982), Cosson *et al.* (1987), Coward (1981), Daly (1986a), Leblanc (1975), Lecorche (1985), Shackleton (1986), and Villeneuve (1987). The similarity of northeast–southwest lineament directions in South Africa and West Africa indicates that Daly's model (1986a), suggesting continental transform fault control, may also be applied to Central and West Africa. However, the Mozambique belt and the Arabo–Nubian shield in northeast Africa and Arabia seem to have evolved differently. Thus, the Adamaoua fault zone and its Northeast Brazil counterparts (Patos and Pernambuco lineaments) may have, on a large scale, the same significance as the Schliesen–Mwembeshi–Chimaliro zone in South Africa (Daly, 1986a). Areas of assumed reworked crust have been delineated within Pan-African domains (Fig. 13). In the Transaharan belt, such areas (Central Hoggar – Nigeria and Western Hoggar granulites) suggest that old, pre-Pan-African microcontinents, incorporated into the belt, separate linear zones of younger Upper Proterozoic crust. The main aim of future research will be to determine the extent of crustal accretion during the Pan-African orogenesis. In this respect, much work remains to be done in the central part of Cameroon. Furthermore, as we cannot be sure of the existence of a major suture along the Chad gravity anomaly, Pan-African interaction between the Congo craton and the Nigeria Eburnean reactivated basement is still a major problem on which depends any interpretation of the largely unknown regions of southern Sudan and Libya (toward the hypothetical Nile craton).

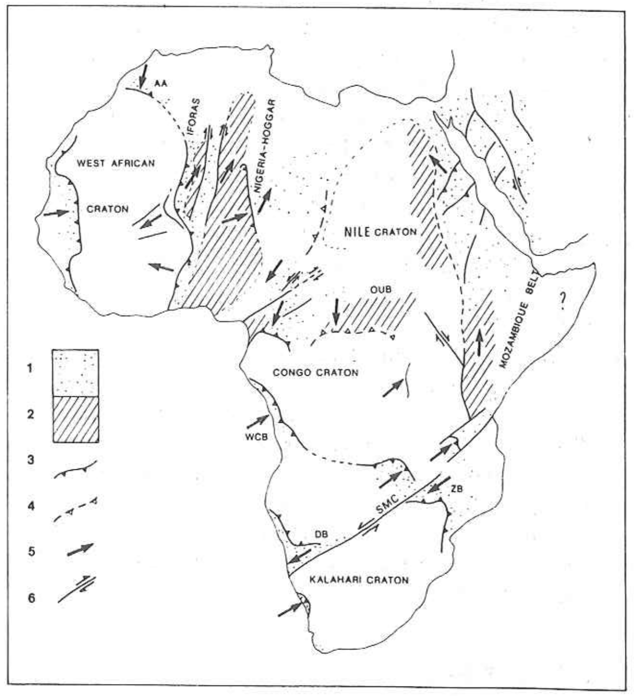

Figure 13. *The Pan-African network. Legend: (1) Pan-African domains, (2) reworked Lower Proterozoic and Archean basement within Pan-African domains; (3) major sutures and thrust zones, (4) assumed sutures and thrust zones, (5) mean relative movement directions between blocks (from literature interpretation) and/or average stretching lineation with recognized or apparent movement (see text for references), and (6) main wrench-fault systems. Abbreviations: AA, Anti-Atlas (Morocco); WCB, West Congolian belt; DB, Damara belt; ZB, Zambezi belt; OUB, Oubanguides belt; and SMC, Schliesen–Mwembeshi–Chimaliro shear zone.*

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