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The geometry of the Archean, Paleo- and Neoproterozoic tectonics in the Southwest Cameroon

La géométrie de la tectonique archéenne, paléo- et néoprotérozoïque dans le Sud-Ouest du Cameroun

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A B S T R A C T

The foliations, lineations, fold axes trajectories and shear zones kinematics vary from the Archean Ntem and Paleoproterozoic Nyong complexes to Neoproterozoic Oubanguide complex. The S_1, S_2 and S_3 typified foliations are folded in F_2, F_3 and F_4 cartographic folds equivalent to thrust slices while the L_1, L_2 and L_3 lineations are oriented SSE-NNW, west-east and sub-north-south in the above complexes, respectively. Both, the foliations and lineations confirm the transport top-to-the east of the Nyong nappe onto the Congo craton during the Eburnean orogeny under amphibolitic conditions and as the transport top-to-the SSE of the Yaounde nappe onto the Ntem and Nyong complexes during the Pan-African event under granulitic to green schist conditions. The paleostress of fault and shear zones display crustal thinning and horizontal extension oriented east-west, NW-SE and sub-north-south in the Ntem, Nyong and Oubanguide complexes. All these tectonic features, completed by north-south and east-west cross sections, demonstrate litho-chrono-stratigraphical, structural and angular discordances between the three complexes.

R É S U M É

Les trajectoires des foliations, linéations, axes des plis et la cinématique des zones de cisaillements varient des complexes Archéen du Ntem, Paléoprotérozoïque du Nyong au complexe Néoprotérozoïque de l'Oubanguide. Les foliations définies S_1, S_2 et S_3 dans ces trois complexes ont été plissées en plis cartographiques F_2, F_3 et F_4 correspondant à des écailles tectoniques alors que les linéations L_1, L_2 et L_3 sont respectivement orientées SSE-NNW, W-E et sub-N-S. Ces foliations et linéations confirment le transport vers l'Est de la nappe du Nyong sur le craton du Congo pendant l'orogenèse éburnéenne sous des conditions amphibolitiques et celui vers le SSE de la nappe de Yaounde sur les complexes du Ntem et du Nyong pendant l'orogenèse panafricaine sous des conditions allant des granulites aux schistes verts. Les paléocontraintes des failles et des zones de cisaillement établissent un amincissement crustal doublé d'une extension horizontale orientée E-W,

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NW-SE et sub-N-S dans les complexes du Ntem, Nyong et Oubanguide. Tous ces traits tectoniques complétés par des coupes nord-sud et est-ouest matérialisent des discordances structurales, angulaires litho-chrono-stratigraphiques entre ces trois complexes.

1. Introduction

The basement of the South Cameroon consists of the Ntem complex and Mobile Zones. The Ntem complex (NC) of Archean age represents the Cameroonian portion of the Archean Congo craton (Lasserre and Soba, 1976) while Mobile Zones are differentiated into the Nyong and Oubanguide complexes (Fig. 1). The Nyong complex (NyC) of Paleoproterozoic age is the Cameroonian domain of the West Central African Fold Belt (WCAFB) that occurred during the Congo and Sao Francisco cratons collision (Feybesse et al., 1998; Lerouge et al., 2006; Maurizot et al., 1986; Penaye et al., 2004). It borders the western side of the Ntem complex and the Central African Fold Belt (CAFB, Fig. 1b, c). The Oubanguide complex (OC) of Neoproterozoic age corresponds to the CAFB (Abdelsalam et al., 2002; Nzenti et al., 1988; Oliveira et al., 2006). Despite the rich and available petrographical, geochemical and geochronological literatures for the above complexes, structural relationships between these complexes are still incompletely defined. The South of Yaounde area geological relationships in the SW Cameroon are worthy of interest because it is located at the junction of three major domains that is presented here, especially regarding structural data. The present work brings recent structural features from the NC, NyC and OC boundary zone. It outlines the geometry of the above complexes and establishes their relationships through their foliation, lineation and trajectory, shear zones, kinematics as well as structural sketches and cross sections between the NC, NyC and OC.

2. Geological setting

The NC consists of charnockite, tonalite, gneiss and metagabbro (Fig. 1c, d). It has experienced, as did the whole NC, a polyphased deformation. The nonrotational deformation D_1 occurred at ca. 3100 ± 100 Ma (Sm/Nd whole rock isochron, Toteu et al., 1994b) under granulitic condition as in the Haute Noya, Mitzic-Oyem gneisses in the Mont de Cristal Complex in Gabon and Ebolowa gneisses in the NC (Caen-Vachette et al., 1988; Lasserre and Soba, 1976). It has emplaced a subvertical S_1 foliation oriented N80E to N120E and north-south, observed in relict greenstones belts and TTG series and C_2 sinistral shear planes trend N0E to N45E–N50E, associated with partial melting of the TTG and greenstones belt country rocks (Shang et al., 2004b; Tchameni et al., 2001). The D_2 coaxial tectonics dominantly was responsible of the charnockitization (Caen-Vachette et al., 1988; Tchameni et al., 2001; Toteu et al., 1994b) and peaked between 2950–2850 Ma [(Rb/Sr whole rock, Caen-Vachette et al., 1988; U/Pb, zircon, Toteu et al., 1994b)]. The NC suffered Earlier Archean rifting dated at ca. 2700 Ma followed by the opening of Nyong, Ogoue, Ayina, Ikoke-Waka and Franceville intracontinental basins between 2515–2435 Ma (Caen-Vachette et al., 1988). It has been affected by the Eburnean event during the Congo and Sao Francisco cratons collision, individualising the WCAB complex in its western border and suffered lower effect of the Pan-African event.

The NyC results from the Congo and Sao Francisco cratons collision between 2400–1800 Ma (Feybesse et al., 1998; Lerouge et al., 2006; Penaye et al., 2004). It consists of TTG, anorthosite, metagabbro, charnockite, gneiss, migmatite, alkali metasyenite, amphibolite, garnetite, eclogite, quartzite and BIF and has been affected by a D_1, D_2, D_3 polyphased deformation (Feybesse et al., 1998; Maurizot et al., 1986; Minyem, 1994; Nédélec et al., 1993; Owona, 2008; Toteu et al., 1994). D_1 is represented by the S_1 foliation preserved in hinges of F_2 folds. The rotational non-coaxial deformation D_2 emplaced S_2 flat-laying, L_2 stretching lineation, F_2 fold, and blastomylonitic shear zones. During this phase, the NyC forms Paleoproterozoic nappes which were transported top-to-east onto the NC during amphibolite to amphibolitic metamorphism and peaked at ca 2050 Ma (Feybesse et al., 1998; Maurizot et al., 1986). Sinistral shear zones have dissected this Nyong nappe (Feybesse et al., 1998; Minyem, 1994; Penaye et al., 2004). The NyC, bordered by the NC and OC in the north-east, has been reworked during the Pan-African orogeny (Penaye et al., 2004).

The Neoproterozoic OC started its evolution with the opening of the Yaounde, Poli, Lom and Bafia basins between 800–700 Ma (Feybesse et al., 1998; Numbem Tchakounte et al., 2007; Toteu et al., 2006a). It extends from Southwest Sudan to the gulf of Guinea coastline and continues further westward to northeastern Brazil. It actual configuration is related to the Neoproterozoic collision between the Congo, West African and the Saharan metacraton (Abdelsalam et al., 2002; Castaing et al., 1994; Feybesse et al., 1998; Oliveira et al., 2006; Trompette, 1994). The CAFB constitutes the OC most southern lithostructural unit bordering the NC and NyC. It consists of low- to high-grade metapelites, migmatite, amphibolite, metadiorite, monzonite, granite, charnockite, diorite, tonalite, syenite, trondhjemite, gabbro, tillite, quartzite, norite, peridotite and dolerite (Numbem Tchakounte et al., 2007; Nzenti et al., 1988; Toteu et al., 1994, 2006b). The CAFB has suffered the granulitic to amphibolitic retrograde Pan-African orogeny that peaked between 616 Ma (Sm/Nd-Grt, Toteu et al., 1994b) and 613–586 Ma (U/Th/Pb-Mnz, Owona, 2008; Owona et al., 2011) from the D_1 compressive tectonic as well as horizontal pure shear to a D_2 dominantly sub- to horizontal simple shear regime (Ball et al., 1984; Jegouzo, 1984; Mvondo et al., 2007a). During the same period, the CAFB registered granite intrusions

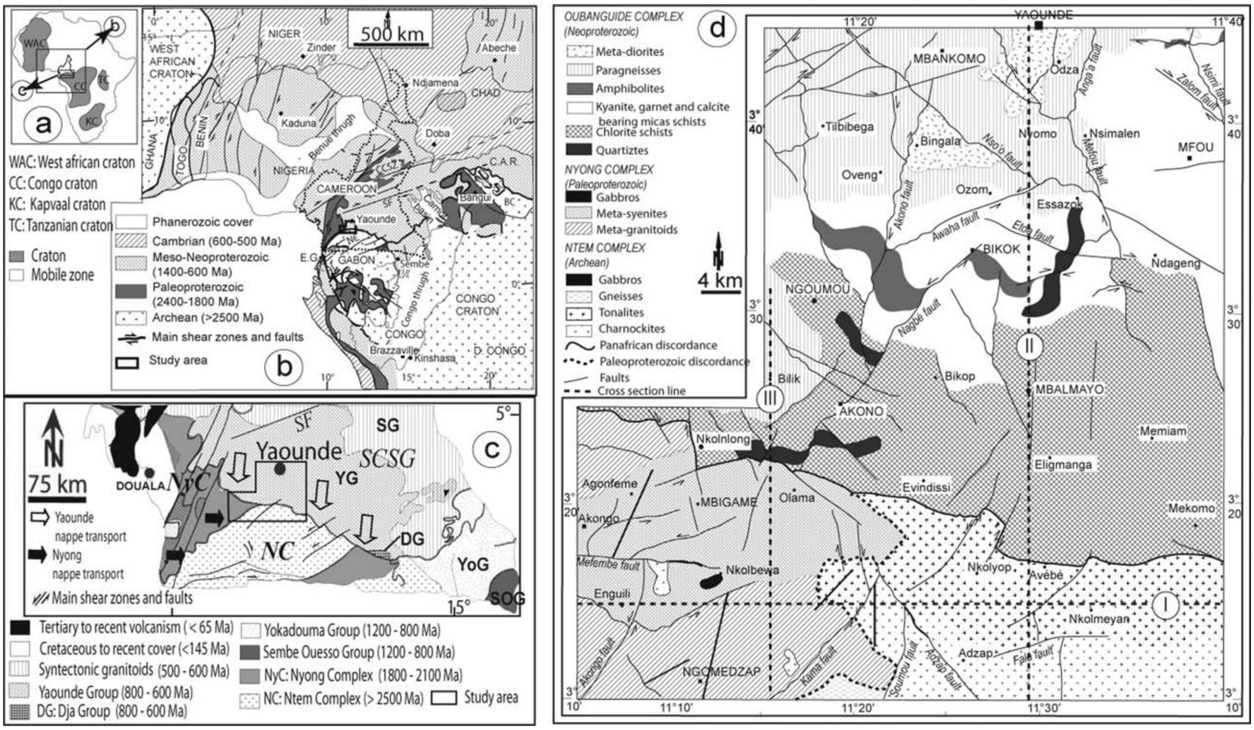

Fig. 1. (a) African cratons and mobiles zones. (b): Geological sketch of the west-central Africa modified after Castaing et al. (1994) and Ngako et al. (2003). CMR: Cameroon; CAR: Central African Republic; EG: Equatorial Guinea; CAFB: Central African Fold Belt; CCSZ: Central Cameroon Shear Zone; SF: Sanaga Fault. Blooded dashed outline roughly marks the political boundary of Cameroon. (c) Southern Cameroon geological map (Modified after Ngako et al., 2003; Numbem Tchakounte et al., 2007; Penaye et al., 2004; Toteu et al., 2006b). SCSG: Southern Cameroon SuperGroup; NC: Ntem complex; NyC: Nyong Complex; SG: Sanaga Group; YG: Yaounde Group; DG: Dja Group; YoG: Yokadouma Group; SOG: Sembe-Ouesso Group. The location of study area (Fig. 1d) is shown. (d): Geological sketch of the SE of Yaounde.

Fig. 1. (a) Cratons africains et zones mobiles. (b) Schéma géologique de la connexion Centre-Ouest Afrique modifiée selon Castaing et al. (1994) et Ngako et al. (2003). CMR : Cameroun. CAR : République centre-africaine ; EG : Guinée équatoriale ; CAFB : ceinture plissée centre-africaine ; CCSZ : Cisaillement centre camerounais ; SF : faille de Sanaga. Le contour noir discontinu représente la frontière politique du Cameroun (c). Carte géologique du Cameroun méridional(modifiée selon Ngako et al., 2003 ; Numbem Tchakounte et al., 2007 ; Penaye et al., 2004 ; Toteu et al., 2006b). SCSG : Supergroup sud camerounais ; NC : complexe de Ntem ; NyC : complexe de Nyong ; SG : groupe de Sanaga ; YG : groupe de Yaoundé ; DG : groupe de Dja ; YoG : groupe de Yokadouma, SOG : groupe de Sembe-Ouessso. La zone étudiée est indiquée à la Fig. 1c. (d) : schéma géologique du Sud-Est de Yaoundé.

(Kwékam et al., 2010). It forms the Yaounde nappe made of "tectonic scales", transported top-to-SSW onto the NC and NyC. This nappe is dissected by WNW–ESE to NE–SW striking dextral shear zones as the Central Cameroon shear zones and Sanaga Fault (Fig. 1b, Ngako et al., 2003; Njonfang et al., 2008).

The treatment of lineations and foliations were realized with the commercially available program SpheriStat. See the Stesky R.M., Sperhistat User's Manual, Pangaea Scientific, Brockville, Ontaria, Canada. For fault slip analysis, we calculated the orientation of principal stress axes and the reduced stress tensors (e.g., Angelier, 1984) in the computer Turbo Pascal program packages of Sperner et al. (1993) and Sperner and Ratschbacher (1994). See Appendix B for details in Ratschbacher et al. (2003).

3. Structural data

3.1. Ntem complex

The S_1 foliation is displayed by the greywacke, BIF, sillimanite-bearing paragneisses and amphibolite layers. It is sub- to vertical and oriented NNW-SSE to east-west on both sides of the Adzap fault (Fig. 2). It defines two average values, 62 067 and 42 302, predicting F_2 cartographic folds [Fig. 2a, 2d; 5(b)/(a)], different from the east-west S_1 foliation orientation described in literature (Feybesse et al., 1987; Maurizot et al., 1986). The foliation is folded in mega folds F_2, tight to open sub-north-south cartographic synclines, with A_2 fold axes oriented mainly NNW-SSE. They form circular or "dome" structures in the Abodveng window inside the NyC (Fig. 2). The best-fit great circle for poles of S_1 corresponds to F_2 folds oriented 60 085 (Fig. 2d). Other mega folds F_2 inferred from the equal area stereogram projections along great circles of poles foliations S_1 [Fig. 2, 5(b)/(a)]. The L_1 stretching lineation is oriented SE-NW to west-east in the NC. Its trajectories are locally reoriented west-east in the western side of Adzap fault. Its average value of 353 36 underlines its submeridian character, parallel to secant to fold axis A_2. Generally, L_1 and A_2 support the displacement top-to the NNW and ENE (Fig. 3a, d). Normal dip-slip fault types oriented NNE-SSW, NNW-SSE, WNW-ESE and ENE-WSW generated by various stress fields, define deep valleys and guide hydrographical patterns (Fig. 4a, d; Angelier, 1994; Angelier and Mechiel, 1977). The Adzap fault oriented

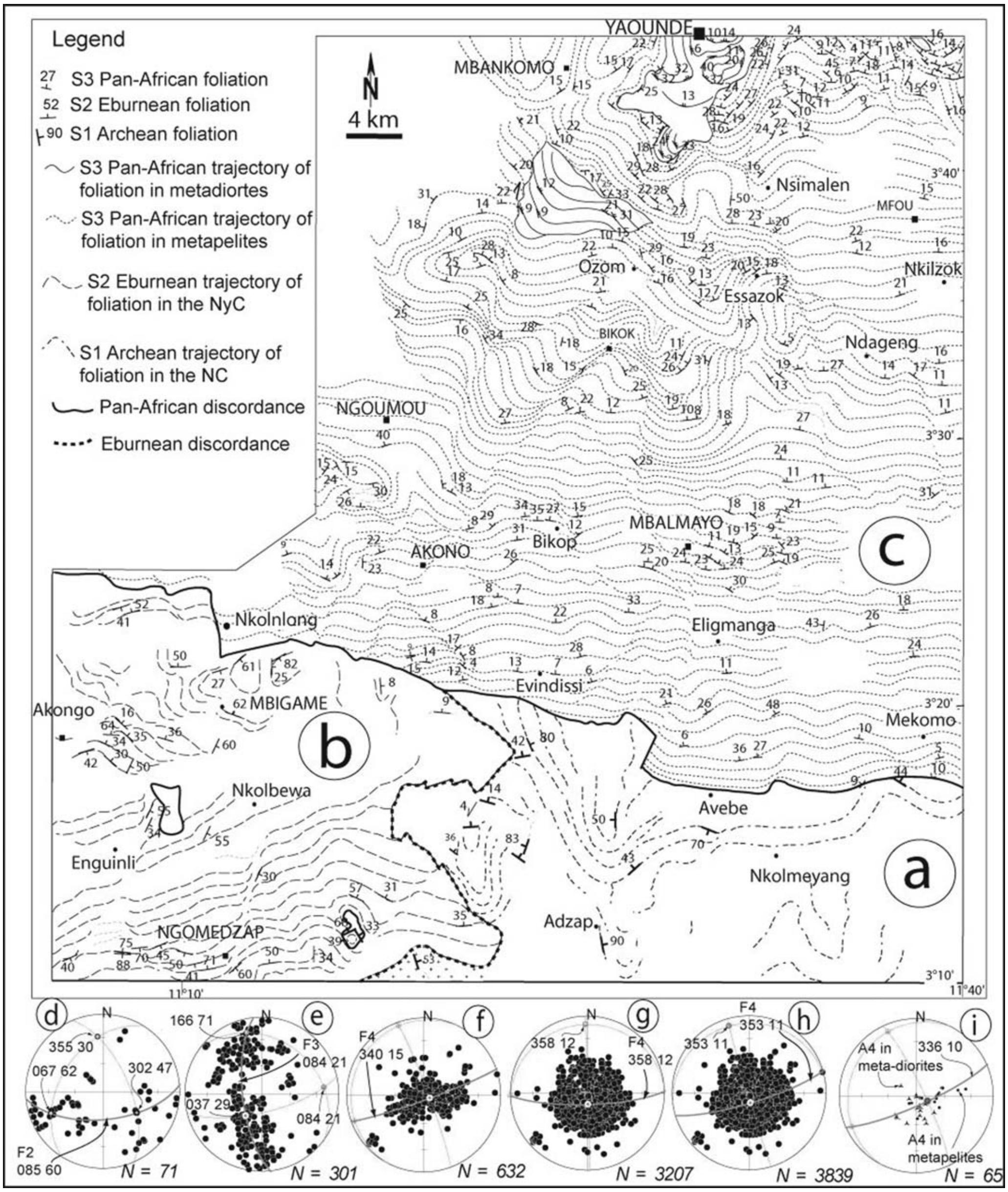

Fig. 2. The S_1, S_2 and S_3 foliations structural sketch in the boundary zone between the NC (a), NyC (b) and OC (c), respectively. Note the structural angular discordance displayed by these foliations (Owona, 2008). The subvertical S_1 foliation is folded in sub-north-south F_2 cartographic folds due to an east-west compression in the NC (a, d). The S_2 foliation mainly oriented SW-NE is folded in F_3 cartographic folds in reaction to a NW-SE compression in the NyC (b, e). The S_3 foliations in the OC is inconsistent and folded in the Yaounde latitude under an east-west compression becoming east-west in the NC and NyC borders (c, f, g, h). (d) Synthetic stereogram of Archean S_1 foliation forming an east-west fold showed by the best fit in the NC. (e) Synthetic stereogram of Eburnean S_2 foliation forming an NW-SE to NNW-SSE F_3 fold showed by the best fit in the NyC. (f, g, h) Synthetic stereogram of Pan-African S_3 foliations forming the dome and basin structure in metadiorites, metapelites and the OC. (i) Synthetic Pan-African A_4 axial planes parallel to S_3 foliations in the OC. Poles of foliations S_n and axial planes A_{n+1} are plotted in equal area lower hemisphere that displays great circle of cartographic folds F_n.

Fig. 2. Schéma structural des foliations S_1, S_2 et S_3, à la zone frontière entre NC (a), NYC (b) et OC(c) respectivement. À noter la discordance angulaire structurale montrée par ces foliations (Owona, 2008). La foliation subverticale S_1 est plissée en plis cartographiques F_2 sub-nord-sud, en raison d'une compression est-ouest dans NC (a, d). La foliation S_2 principalement orientée SW-NE est plissée en plis cartographiques F_3, en raison d'une compression NW-SE dans NyC (b,e). Les foliations S_3 dans OC sont incohérentes et plissées, à la latitude de Yaoundé, sous l'effet d'une compression est-ouest devenant est-ouest aux limites de NC et NyC (c, f, g, h). (d) Stéréogramme synthétique de la foliation archéenne S_1 formant un pli est-ouest qui apparaît le mieux dans NyC (f, g, h). Stéréogramme synthétique de la foliation éburnéenne S_2 formant un pli F_3 NW-SE à NNW-SEE, qui apparaît le mieux dans NyC. (f, g, h). Stéréogramme synthétique des foliations pan-africaines S_3 formant une structure en dôme et bassin, dans les métadiorites, métapélites et dans OC. (i) Plans axiaux pan-africains A_4 synthétiques, parallèles aux foliations S_3 dans OC. Les pôles de foliations S_n et des plans axiaux A_{n+1} sont représentés en projection équivalente dans l'hémisphère inférieur qui présente un grand cercle de plis cartographiques F_n.

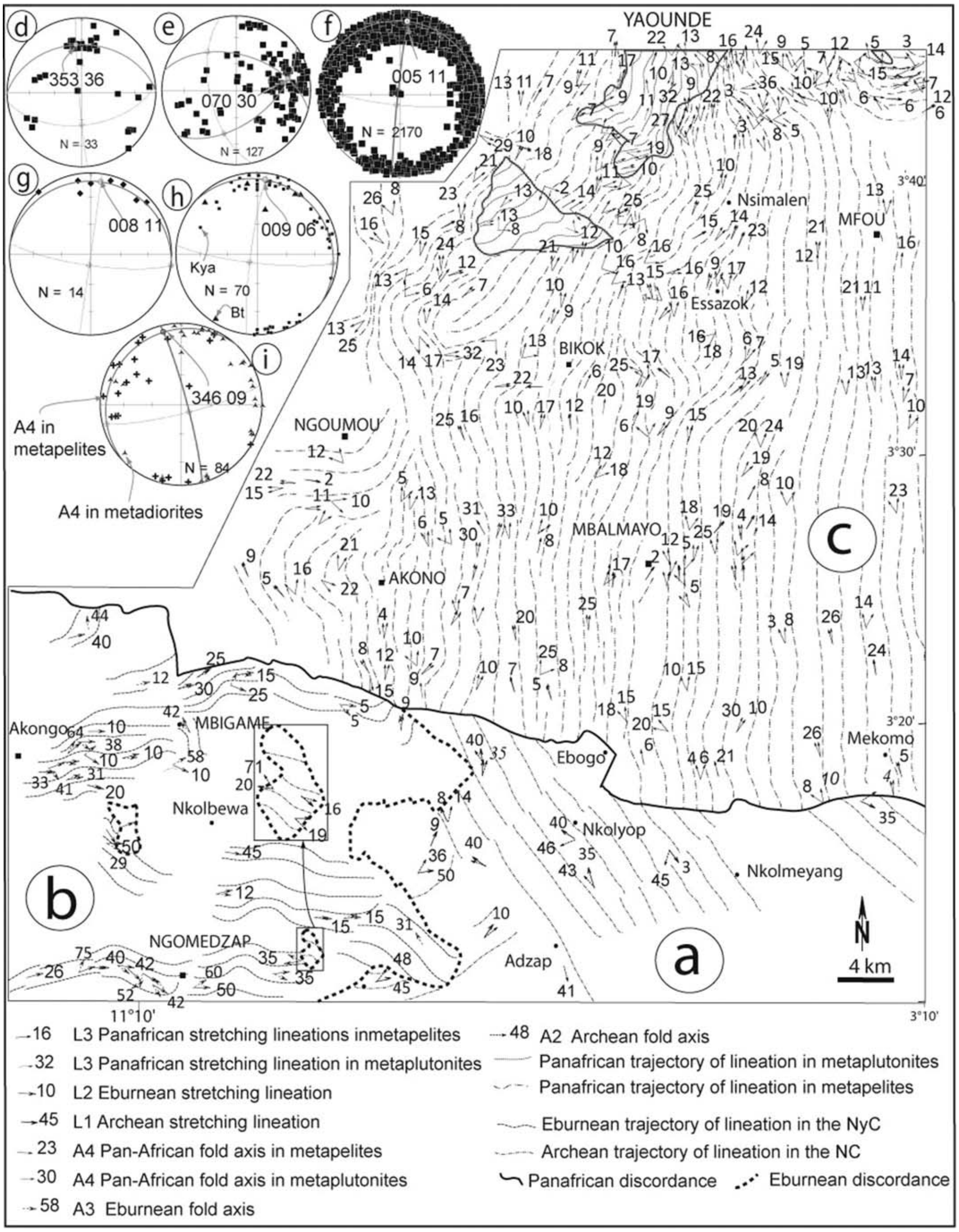

Fig. 3. The L_1, L_2 and L_3 lineations and A_2, A_2, A_4 fold axes structural sketch in the boundary zone between the NC (a), NyC (b) and OC (c), respectively. Note the structural angular discordance displayed by these lineations (Owona, 2008). The L_1, A_2 and trajectories of lineations are mainly oriented SE-NW, suggesting an east-west to WE-NW compression in the NC (a, d). (b, e) The L_2, A_3 and trajectories of lineations are mainly oriented west-east, suggesting a north-south compression in the NyC. It confirms the transport top-to the east of the Nyong nappe onto the NC. (c, f, g, h, i) The L_3 stretching and mineral lineations are mainly sub-north-south as A_4 fold axes in the OC, reoriented around N090 and N270 because of refolding. They support the major east-west compression and corroborated the transport top-to the South of the Yaounde nappe onto the NC and NyC. Poles of lineations L_n and fold axes A_{n+1} are plotted in equal area lower hemisphere.

Fig. 3. Schéma structural des linéations L_1, L_2, L_3 et des axes de pli A_2, A_3, A_4 dans la zone frontière entre NC(a), NyC(b) et OC(c), respectivement. À noter la discordance angulaire structurale indiquée par ces linéations (Owona, 2008). L_1 et A_2 et les trajectoires de linéation sont principalement orientés SE-NW, suggérant une compression est-ouest à WE-NE dans NC(a, d).(b, e) L_2 et A_3 et les trajectoires de linéation sont principalement orientés ouest-est, suggérant une compression nord-sud dans NyC. Ceci confirme le transport vers l'est de la nappe de Nyong sur NC(c, f, g, h, i). L'étirement L_3 et les linéations minérales sont principalement sub-nord-sud, comme les axes de pli A_4 dans OC, réorientés autour de N090 et N270 en raison du replissement ; ils corroborent la compression majeure est-ouest et le transport vers le sud de la nappe de Yaoundé sur NC et NyC. Les pôles des linéations L_n des axes de pli A_{n+1} sont représentés en projection équivalente dans l'hémisphère inférieur.

NNW-SSE seems to be a major fault, responsible for geometric difference on both its sides. For the whole NC, reconstructed paleostresses reveal a σ_1 vertical and a σ_3 horizontal sub-east-west (Fig. 4 g). This result supports that NC faults happened under a crustal shortening and sub-east-west extension tectonics. The cross sections parallel to hinges of F_2 folds and L_1 complete the geometry of the NC (a) and its relationships with the Nyc and OC. The NC compressed in east-west during it ductile phase, is thrusted in west-east and north-south by the Nyong (b) and Yaounde (c) nappes, respectively [Fig. 5(c)/(a), (b)/(a) and (c)/(b)].

3.2. Nyong complex

The S_2 typified foliations is the most striking structure in the NyC. It is represented, by in BIF, meta-granodiorite, meta-syenite and paragneiss layers and oriented WSW-ENE to north-south, sub-parallel to magmatic and metamorphic layering sheared by blastomylonitic S/C shear zones structures (Fig. 2). Its undulations define F_3 asymmetrical cartographic folds designed type [Fig. 2, 5 (b)/(a) and (c)/(b)]. These F_3 folds form north-east and south-west anticlines and synclines with A_3 fold axes oriented mainly NE-SW. Other F_3 mega folds inferred from equal area stereogram projections along great circles of poles S_2 foliations with average values that correspond to northern and southern sides oriented 29 037 and 71 166 (Fig. 2e). The L_2 include stretching and amphibole lineations, parallel, oriented WSW-ENE to WNW-ESE nearer to 084 21, the axes A_3 average value (Fig. 3b, e). Faults are normal, inverse dip-slip and vertical strike-slip fault types, oriented east-west, NE-SW, NNE-SSW and ENE-WSW (Fig. 4b). Akongo, Kama and Mefembe faults are major faults guiding rivers of the same names and individualising deep valleys. They were generated by the σ_1 vertical and σ_3 horizontal NW-SE (Fig. 4b, e, g). This result predicts that the NyC faults occurred under the crustal shortening and NW-SE horizontal extension regime. The cross sections parallel to hinges of F_3 folds and L_2 stretching lineation represent the geometry and the middle position of the NyC (b) on the NC (a) and under the OC (c). The NyC is compressed in NW-SE during it ductile stage. In its relationships with the NC and the OC, the NyC thrusted as the Nyong nappe (b) in west-east the NC (a) [Fig. 5 (b)/(a)] and, is thrusted in north-south by Yaounde (c) nappes [Fig. 5(c)/(b)].

3.3. Oubanguide complex

Two main $S_{0/1/2}$ and S_2 foliations have been identified in metapelites and metadiorites, respectively (Mvondo et al., 2003, 2007; Owona, 2008; Owona et al., 2011). Both are treated here as S_3 foliations for comparison with S_1 and S_2 in the Ntem and Nyong complexes, respectively. The S_3 foliation in metapelites is perturbed and folded in the Yaounde area with north, north-east, north-west, south-west, west and east dip becoming homogenous and generally east-west in the contact zone with NC and NyC (Fig. 2). In the south-east of Yaounde, its average did-dip direction value is 12 358 (Fig. 3 g). The S_3 foliation in metadiorites defines "dome and basin" structures with average values 13 060, 04 346 and 79 048 in Binguela, Ngoa-Ekele and Afamba metadiorites, respectively (Fig. 2f, g). The S_3 foliations form the most striking structural feature with a southward verging Yaounde tectonic nappe transported top-to-the SSE onto the NC and NyC (Mvondo et al., 2003, 2007a; Mvondo Ondoa et al., 2009; Owona, 2008; Owona et al., 2011). The undulations of the S_3 foliations draw F_4 cartographic folds corresponding to northward and southward anticlines and synclines with A_4 fold axes oriented mainly north-south to NNE-SSW [Fig. 2, 5(c)/(a), (c)/(b))]. Other F_4 mega cartographic folds are inferred from equal area stereographic projections along great circles of poles the S_3 foliation (Fig. 2f, g, h). On the contrary to the foliation, metapelites and metadiorites display a common L_2 lineation typified L_3. L_3 includes the stretched, mineral and boudinated varieties in the OC (Fig. 2c, f). The L_3 stretching lineation plunges in north-west, north-east, south-east and south-west, as in the Yaounde area, suggesting the foliation undulation and folding. Its overall orientation is 005 11 (Fig. 3f). Locally, it is reoriented around N090 and N270 because of the refolding. The L_3 crenulated lineation is oriented 008 11 (Fig. 3 g). The kyanite, biotite, amphibole, clinopyroxene and quartzo-feldspathic aggregates form the L_3 mineral lineation oriented N009 06 in metapelites (Fig. 3 h). The biotite, amphibole, clinopyroxene and quartzo-feldspathic aggregates L_3 lineation oriented 015 15 in the metadiorites. The overall submeridian and parallelism character of L_3 lineation types represent a proof of the transport top-to-the south of the Yaounde nappe onto the Ntem and Nyong complexes. Faults are the NW-SE to north-south normal dip-slip and sinistral and dextral vertical strike-slip types (Angelier, 1994; Angelier and Mechiel, 1977). The Mefou, Akono, So'o and Ossoé Kobock Rivers are guided by most of them, constituting the proof of the structural control of the hydrographical patterns (Owona et al., 2003). The lack of cartographic offsets suggests their postorogenic stress relaxation or neotectonic event emplacement. The paleostress reconstructed reveals that these faults were generated by an overall σ_1 subvertical and σ_3 horizontal NNE-SSW (Fig. 4c, f, g). They suggest a crustal shortening and NNE-SSW extension phase established in the OC. The cross sections parallel to hinges of F_4 folds, L_3 stretching and mineral lineations represent the OC (c) and its relationships with the NC (a) and the NyC (b). The OC as the Yaounde nappe, is transported top-to the south onto the NC [Fig. 5 (c)/(a)] and, the NyC [Fig. 5(c)/(b)].

4. Discussion

The results of recent structural geology investigations in the junction of the Ntem, Nyong and Oubanguide complexes in the SW Cameroon allows the following discussion and comparison on the Archean, Paleoproterozoic and Pan-African deformations.

4.1. Ntem complex

The S_1 foliation is emplaced by a granulitc D_1 tectonothermal event (? Saamian orogeny; Elmi and

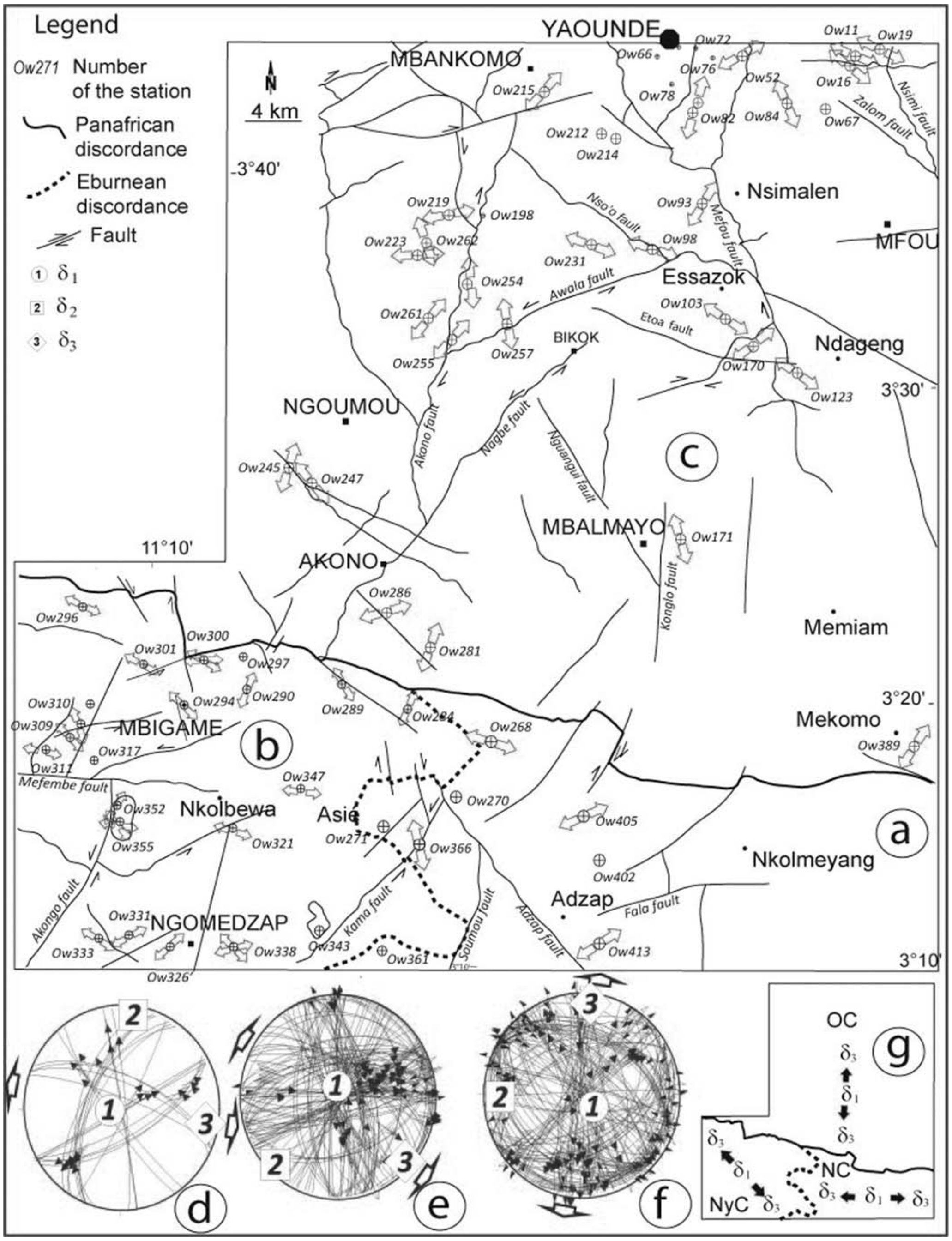

Fig. 4. The fault and paleostress axes structural sketch in the boundary zone between the NC (a), NyC (b) and OC (c), respectively. Note the overall crustal thinning with σ_1-vertical in all complexes (d, e, f) associated to σ_3-west-east extension in the NC (d, g), σ_3-NW-SE extension in the NC (e, g) and σ_3-north-east extension in the OC (f, g). (g) the synthetic sketch of overall paleostresses underline the structural angular discordance between the NC, NyC and OC as displayed by the foliations, folds and lineations (Owona, 2008). 1, 2, 3 are principal stress axes determined in the Turbo Pascal program packages (Sperner et al., 1993; Sperner and Ratschbacher, 1994; Ratschbacher et al., 2003).

Fig. 4. Carte de fraturation et des axes des paléocontraintes dans la zone frontière entre NC(a), NyC(b) et OC(c), respectivement. À noter l'amincissement crustal généralisé, avec σ1-vertical dans tous les complexes (d, e, f), associé à une extension σ3-ouest-est dans NC(d,g), σ3-NW-SE dans NyC(e, g) et σ3-nord-est dans OC (f, g). (g) Schéma géologique de tous les paléostress soulignant la discordance angulaire structurale en NC, NyC et OC, comme le montrent les foliations, les plis et les linéations (Owona, 2008). 1, 2, 3 sont les contraintes principales déterminées dans le programme Turbo Pascal (Sperner et al., 1993 ; Sperner and Ratschbacher, 1994 ; Ratschbacher et al., 2003).

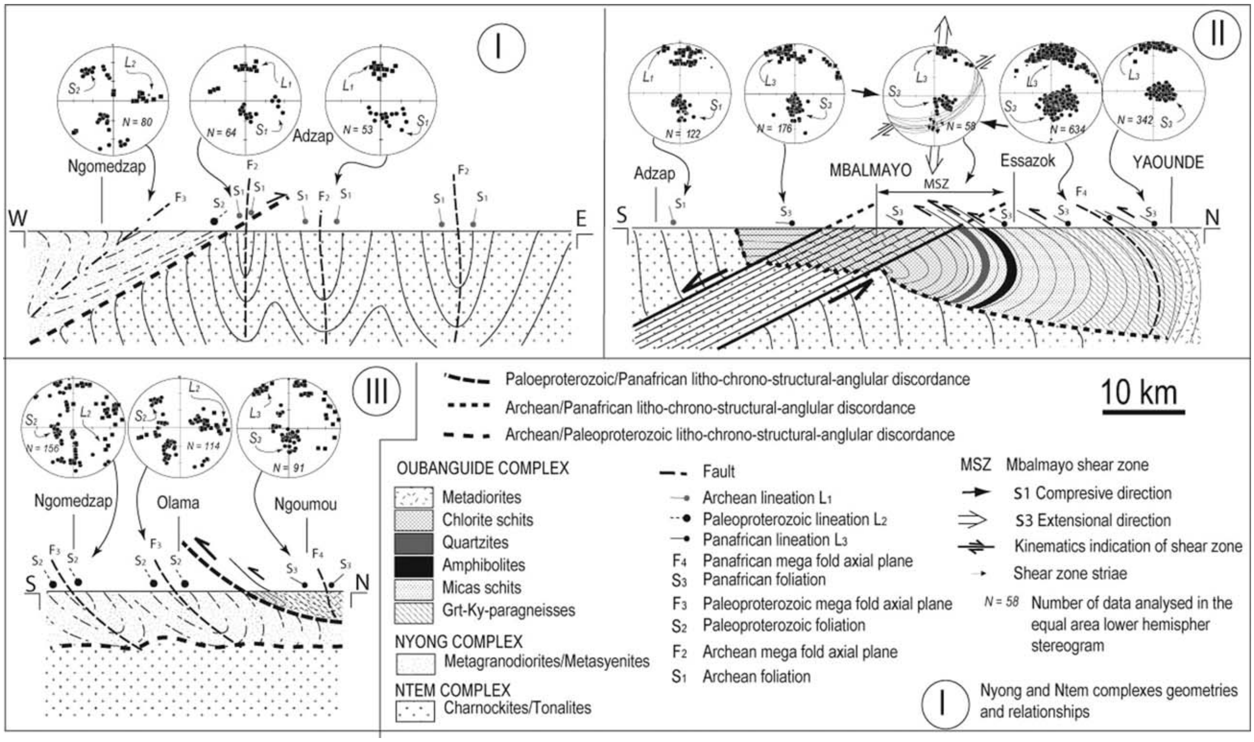

Fig. 5. Geological cross sections displaying relationships between the NC (a), NyC (b) and OC (c). The (c)/(a) and (c)/(b) sections are north-south, parallel to Panafrican F4 fold hinges and L3 stretching and mineral lineations kinematic in (c) characteristics at the boundary zone between the NC and the OC in one hand, between the NyC and the OC. Both sections represent the top-to-the south sense of the Yaounde nappe onto the NC and NyC. The (c)/(a) section complete the previous of Mvondo Ondoa et al. (2009) on the Mbalmayo shear zone occurred under amphibolitic to green schist conditions with a typical pole of foliation, lineation, shear planes and faults striae stereogram showing its paleostress orientations. The (c)/(b) section reveals the NC and the NyC relationships in their boundary zone. The (b)/(a) section is east-west is parallel to Paleoproterozoic F3 fold hinges and L2 stretching and mineral lineations kinematic in (b) characteristics at the boundary zone between the NC and the NyC. It represents the top-to-the east sense of the Nyong nappe onto the NC and NyC under amphibolitic conditions. This section shows the NC east-west compression represented by F2 mega folds.

Fig. 5. Coupes géologiques montrent les relations entre NC(a), NyC(b) et OC(c). Les coupes (c)(a) et (c)(b) sont nord-sud, parallèles aux charnières de pli F_4 panafricains et à la cinématique des linéations L_3 d'étirement et minérale (c), caractéristiques de la frontière entre le NC et OC d'une part, et entre le NyC et OC d'autre part. Les deux coupes représentent le déplacement vers le sud de la nappe de Yaoundé sur le NC et NyC. La coupe (c)(a) complète la précédente fournie par Mvondo Ondoa et al. (2009) sur la zone de cisaillement de Mbalmayo mise en place dans des conditions allant des amphibolites aux schiste verts, avec stéréogramme typique des pôles de foliation, linéation, plans de cisaillement et stries de faille montrant les orientations des paléocontraintes. La coupe (c)(b) révèle les relations le NC et NyC. La coupe (b)(a) est est-ouest et parallèle aux charnières de plis F_3 paléoprotérozoïques, à la cinématique des linéations L_2 d'étirement et minérale la cinématique en (b), caractéristiques de la frontière entre le NC et NyC; la coupe représente le déplacement vers l'est de la nappe de Nyong sur NC et NyC, dans les conditions amphibolitiques. Cette coupe montre la compression est-ouest de NC, représentée par les méga-plis F_2.

Babin., 2002) dated at ca. 3100 ± 100 Ma (Sm/Nd whole rock isochron, Toteu et al., 1994b) under a nonrotational deformation (Caen-Vachette et al., 1988; Lasserre and Soba, 1976). Its two average values of 62 067 and 42 302 (Fig. 2a, d) different from the east-west strike known in literature (Shang et al., 2004b; Tchameni et al., 2001) attested of an east-west D_2 Archean compression tectonic stage that peaked between 2950–2850 Ma [(Rb/Sr whole rock, Caen-Vachette et al., 1988; U/Pb, zircon, Toteu et al., 1994b) the? Ouzzalian orogeny (Elmi and Babin., 2002). D_2 that has folded the S_1 foliation in north-south F_2 cartographic folds or syncline did not generate a new foliation but induced the charnockitization of the Ntem complex (Caen-Vachette et al., 1988; Toteu et al., 1994). The L_1 stretching lineation is oriented 353 36 with overall SE-NW trajectory, parallel to A_2 main fold axis, oriented 355 30 (Fig. 2d; 3a; d). That west-east local reorientation is linked to the Adzap fault offsets (Fig. 2). The normal dip-slip faults have been emplaced by σ_1 sub-vertical paleostress and σ_3 sub-east-west horizontal paleostress (Fig. 4a, d, g). They corroborate the crustal thinning of the D_3 brittle stage according the statistical treatment of the faults slickenside and scratching attitudes (Sperner et al., 1993; Sperner and Ratschbacher, 1994) and their classification and stress orientations (Angelier and Mechiel, 1977; Angelier, 1994). These Archean faults can be younger than 2700 Ma and are considered as the earliest riftings stage in the Ntem complex (Feybesse et al., 1998).

4.2. Nyong complex

The S_2 foliation is oriented 029 37 and 166 71 (Fig. 2b, e). It characterized the Eburnean amphibolite to granulitic tectonothermal event that peaked at ca 2050 Ma (U/Pb-Zr, Feybesse et al., 1998; Penaye et al., 2004). It is folded in asymmetric F_3 cartographic folds type with the best fit attitude oriented 21 084 under a NW-SE to north-south compression tectonic stage (Fig. 2b, e). They form the Nyong tectonic nappe transported top to the east onto the

Congo craton (Feybesse et al., 1998; Tack et al., 2001; Penaye et al., 2004) as attested by the sub- to parallel A_3 fold axial oriented 084 21, the stretching and amphibole L_2 lineations types oriented 070 30 (Fig. 2b, e; Fig. 3b, e). The L_2 lineations confirm in the SW Cameroon, the eastwards transport of the Nyong nappe onto the NC or/and the WCAFB onto the CC concordant to previous results available in the literature (Feybesse et al., 1987, 1998; Ledru et al., 1994; Maurizot et al., 1986; Penaye et al., 2004; Shang et al., 2004a; Tchameni et al., 2001). According to the TURBO PASCAL program (Sperner et al., 1993; Sperner and Ratschbacher, 1994) and their classification and stress orientations (Angelier and Mechiel, 1977; Angelier, 1994) normal, inverse dip-slip and vertical strike-slip faults in the NyC happened under an overall crustal thinning and NW-SE extension regime according to the sub-vertical $\sigma 1$ and the sub-horizontal $\sigma 3$ determined paleostresses (Fig. 4b, e, g). Some of these faults correspond to transcurent faults, coeval to the Pan-African Yaounde tectonic nappe (Miyem, 1994; Penaye et al., 2004; Toteu et al., 1994).

4.3. Oubanguide complex

The S_3 foliations in metapelites and metadiorites occurred during the Pan-African tectonothermal event that ranged between 650–540 Ma and peaked between 616 Ma (Sm/Nd-Grt; Toteu et al., 1994b) and 613–586 Ma, U/Th/Pb-Mnz, Owona, 2008) under mainly the simple shear regime (Fig. 2c, f, g, h). These S_3 foliations are inconstant in comparison with S_1 and S_2. They vary in the north on high- to medium-grade metapelites and metadiorites and become sub-east-west in low-grade chlorite schist in the south and contact zone with the NC and NyC, contradicting or discrediting their statistical overall average value 11 353. Consequently, the F_4 cartographic folds are closed to compressed anticlines, synclines and dome and basin confined in high- to medium grade metapelites (Fig. 2a). Above F_4 mega folds that form the Yaounde nappe suggests a variable east-west compressive tectonic phase confined in the north maintained or becoming north-south in the south. The similarity of elongated quartzo-feldspathic, amphibolitic aggregates and stretched L_3 lineations, and boudins are confirmed in metagranitoids and metapelites as demonstrated in literature in the OC (Mvondo et al., 2003, 2007; Owona, 2008). They plunge north-west, north-east, south-east and south-west and suggest foliation undulation and folding with 005 11 as overall orientation (Fig. 3c, f, g, h, i). Kyanite and biotite mineral L_3 lineations are oriented 009 06 (Fig. 3f), parallel to the main A_4 fold axis, oriented 346 09 (Fig. 3 g). These results confirm the transport top to the south of the Yaounde nappe onto the NC and NyC (Mvondo et al., 2003, 2007; Mvondo Ondoa et al., 2009; Owona, 2008). However, the L_3 lineations are locally reoriented N090 and N270 (Fig. 3c) suggesting the refolding and/or faulting (Mvondo et al., 2003, 2007; Owona, 2008). The normal dip-slip, sinistral and dextral vertical strike-slip faults in the OC attributed to post-orogenic stress relaxation or neotectonic events (Mvondo et al., 2007a), at ca. < 545 Ma are characterized by overall subvertical σ_1 and north-south subhorizontal σ_3 suggests a crustal thinning environment (Fig. 4c, f, g).

4.4. Ntem, Nyong and Oubanguide complex relationships

The NC, NyC and OC represent three lithostructural units in their boundary zone, which varies from one complex to another, with respect to their lithology, mineralogy, geothermobarometry, structural geology and geochronology (Owona, 2008). The S_1 foliations, L_1 lineation, F_2 mega folds, A_2 fold axes and faults are related to the Saamain and Ouzzalian orogeny for the Archean NC. The S_2 foliations, L_2 lineation, F_3 mega folds, A_3 fold axes and faults are inferred to the Eburnean tectonothermal event for the Paleoproterozoic NyC. The S_3 foliations, L_3 lineation, F_4 mega folds, A_4 fold axes and faults have been generated by the Panafrican orogeny. These structural imprints define the geometry and relationships of the NC, NyC and OC (Figs. 2–5). The NC, compressed in east-west, defined F_2 mega folds with hinges oriented sub-north-south parallel to A_2 axes and L_1 stretching lineation during its ductile stage. It is thrusted in west-east by the Nyong nappe and in north-south, by the Yaounde nappe (Feybesse et al., 1998; Mvondo et al., 2007; Mvondo Ondoa et al., 2009; Owona, 2008; Penaye et al., 2004). The NyC compressed during the ductile phase in NW-SE, formed F_3 asymmetrical mega folds with west-east hinges parallel to A_3 axis and L_2 mineral and stretching lineations, and was transported top-to the east onto the NC under amphibolitic conditions (Owona, 2008; Penaye et al., 2004). It is thrusted in north-south by the OC or Yaounde nappe and located stratigraphycally between the NC and OC. The OC compressed mainly in east-west during the ductile phase, defined F_4 mega folds with north-south hinges parallel to the A_4 fold axis and L_3 stretching and mineral lineations. During its transport top-to the south onto the NC and OC (Mvondo et al., 2003, 2007; Owona, 2008; Toteu et al., 2006b), the Yaounde nappe has defined the Mbalmayo shear zone under amphibolitic to green schist metamorphic conditions (Mvondo Ondoa et al., 2009). The geometry and relationships define litho-chrono-structural- and angular discordance between the NC, NyC and OC associated to an overall crustal thinning during their brittle stage.

5. Conclusion

To determine the geometry and structural relationships between the Archean NC, Paleoproterozoic NyC and Neoproterozoic OC at their boundary zone in the SW Cameroon was the main objective of this work. It appears at the end that the geometry of the above complexes is defined by their foliation, lineation, cartographic folds and trajectory as well as faults. The foliations are the most striking structures in the above complexes and folded in large scale anticline/syncline or "dome and basin" structures in each lithostructural unit. They define the Nyong nappe transported top to the east on the NC during the Eburnean orogeny as well as the Yaounde nappe, top to the SSE onto the NC and NyC during the Panafrican tecthonothermal event. Above structural imprints vary from one complex to another by their age, origin, nature, geometry and define litho- chrono-stratigraphical, structural and angular discordances between the NC, NyC and OC that have suffered crustal thinning.

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