PROTEROZOIC CONTINENTAL GROWTH IN WESTERN AND CENTRAL AFRICA

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Summary
Continental growth in western/central Africa a large part of the west African craton produced during the 2.3-2 Ga period. In the Pan-African belt, Neoproterozoic continental growth mainly relates to the 900-700 Ma period, coeval with that occurring in the Arabian-Nubian shield. Intraoceanic arc terranes have been identified, but most of the juvenile rocks of Late Neoproterozoic rocks were accumulated above a thinned, attenuated and fragmented Paleoproterozoic crust.

Introduction
The west African craton (WAC) stabilised since 2 Ga is delimited from surrounding Neoproterozoic fold belts by major thrustings, strike-slip shear zones and sutures. To the east, the Neoproterozoic Pan-African belt is part of a >5.000 km long linear orogenic belt that matches with the Brasilian belt from NE Brazil. Major S-directed thrustings onto the the Congo craton form its sharp E-W boundary in the southeast (Fig. 1). Its architecture is dominated by trans-continental N-S shear zones that delimit elongate terranes of variable age, origin and evolution. Continental growth in this part of Africa mainly relates to the Paleoproterozoic and the Neoproterozoic periods.

Paleoproterozoic crustal growth
The west African craton (WAC, Fig. 1) was stabilized around 2 Ga. Precise U-Pb zircon ages and Sm-Nd data obtained in its southern part support the model of a vertical accumulation of juvenile mafic to felsic volcanics, volcaniclastic rocks, deep sea sediments and prekinematic intrusive magmas obove oceanic plateaus during the 2.3- 2.1 Ga period (Abouchami *et al*, 1990). Cratonization completed around 2 Ga occurred through docking and lateral assembly of displaced terranes east of the Liberian Archean nucleus, that was reworked in its eastern part. Most structures are charaterised by upright folding under greenschist facies metamorphism synchronous with the upward emplacement of syn-kinematic granitoids. Larger batholiths are surrounded by amphibolite facies thermal aureoles and anatexis. The northern part of the WAC in eastern Eglab include low-grade metavolcanics and volcaniclastic rocks deposited above gneisses of assumed Archean age, unaffected by compressive events and cut by 2 Ga old huge K-rich granitic bathholiths. In contrast, imbrication between Paleoproterozoic rocks and Archean gneisses characterises the western Eglab east of the Amsaga Archean granulitic nucleus.

Tuareg terranes and Neoproterozoic crustal growth
Thancks to continuous Saharan outcrops and to systematic dating, several terranes are well identified in the Tuareg shield (Black *et al*., 1994 and references therein).
Paleoproterozoic rocks from reworked ensialic domains share a pre-2 Ga common evolution with the WAC, but the basement was burried below a thick cratonic to peri-cratonic, mainly quartzitic cover corelated with the Espinhaço supergroup of eastern Brazil. Associated A-type magmatism is dated at 1.7-1.8 Ga. Deposition of ca 1 Ga old (?) stromatolite carbonates grading to more subsiding equivalents and rift facies was followed by crustal thinning, continental fragmentation and opening of Neoproterozoic oceanic domains during the 900-720 Ma period. Very few occurrences of possible ophiolite have been identified, but at least two arc terranes have been recognised. The older accretionary period Ma west of the $4^{0}50'$ shear zone is dated between 900 and 840 Ma, whereas eastern Hoggar may represent a significant addition of Neoproterozoic juvenile crust to the east of the central Hoggar paleocontinent and was cratonised around 730 Ma. The opening of a large oceanic domain is revealed by the main Pan-African suture zone delineated from Ghana to south Moroco, that represents the sharp eastern boundary of to the WAC. Terranes with active continental margin evolution east of the suture essentially consist of Late Neoproterozoic volcanic graywackes and plutono-volcanic assemblages. They represent together with underplated mafic rocks crustal additions of juvenile material above the thinned Paleoproterozoic continental crust. Two giant slices of a Paleoproterozoic granulitic terrane (PGT) formed by Archean protoliths relate to a distinct microcraton possibly rooted by a keel of cold lithosphere. Neoproterozoic oceanic terranes are best known in the west along the Pan-African suture.

Late Neoproterozoic tectono-metamorphic events
The amalgamation of the Tuareg shield terranes was completed through the multi-phase Pan-African orogeny. The first event known in central Hoggar (880-840 Ma) relates to the cratonization of the oldest arc terrane that includes slices of MOR gabbros and peridotites. The early Pan-African tectono-metamorphic event (750-700 Ma) affected the easternmost part of the Tuareg shield and a large reworked continental domain including **Air** and possibly the eastern part of the Nigerian shield. The main Pan-African tectono-metamorphic episode (630-580 Ma) occurred after a long-lived subduction period in the west. This event well dated by the emplacement of syn-kinematic calc-alcaline batholiths affected diachronously most terranes and produced major nappes and crustal thickening. lt resulted from the NE-SW collision between the 2 Ga old rigid WAC and the growing orogenic zone rooted by warm and soft lithosphere. During the late Pan-African (580-520 Ma), the trans-continental system of strike-slip faults formed together with NS open folds. It displays a pattern comparable to that from central Asia and formed as a result of transpression and lateral escape of lithospheric blocks during late NE-SW shortening and building up of the >1000 km wide orogenic segment.

Lower crustal regimes and decratonisation of former Paleoproterozoie shield areas
Polycyclic gneisses from central Hoggar display a Neoproterozoic recumbent foliation and HP/HT metamorphism with relict eclogites. This 400 km wide zone of reworked basement and related thick Meso to Neoproterozoic basinal cover sequences comprises large allochthonous slivers of subducted Paleoproterozoic (and Archean) continental crust. Exhumation through low-angle thrustings was acompagned by near isothermal decompression and widespread anatexis, and followed by the emplacement of syn-kinematic batholiths around 630-580 Ma. Other continental areas such as parts of the Nigerian shield were decratonised under a HT- LP thermal regime following

minor crustal thickening, with little evidences of nappes. Simple N-S open to tight upright folding of linear N-S trending synformal schist belts and updoming of anatectic elongate domains under dextral transpressive setting are the ubiquitous features in many parts of Nigeria. These domains were intruded by hot, frequently anhydrous syn-kinematic plutons of both mantle (syenite), hybrid (gabbro, diorite) and crustal (charnockite) derivation emplaced at variable crustal levels in transpressive sites (Ferré *et al.* 1998). Relaxed paleogeotherms suggestive of lithospherie thinning allowed LP granulite facies conditions to affect large domains around 600-580 Ma.

The Pan-African suture zone

A unique island arc assemblage subjected to >70% of E-W shortening delineates the suture zone in northern Mali (Dostal et al., 1994). lt exposes from its volcanic-volcaniclastic, greenschist facies superstructure (bimodal volcanics and volcanic graywackes) to its mafic roots represented by 730 Ma old tonalitic plutons, gabbro-noritic lopoliths and mafic granulites. Gabbro-troctolite-norite to mafic diorites are the only syn-and late-kinematic intrusives of this >150 km wide arc, considered as intraoceanic according to its geochemical and isotopic (Nd/Sm, Pb, Rb/Sr) signature (Caby *et al.* 1989). Allochthonous mafic massifs exposed at deeper and deeper crustal levels towards the southern part of the belt are HP mafic granulites and garnet that rest above low-angle mylonitic sole thrusts with lenses of kyanite eclogites. They represent subducted arc roots that have been thrusted above the passive paleomargin of the WAC (Caby 1989). Slices of mylonitic gabbro and serpentinite are the only candidates of possible oceanic crust and mantle relics of the assurned large Pan-African ocean that closed around 630 Ma through a low-angle E-dipping subduction.

Shallow crustal evolution of back-arc basins and active paleocontinental margin

The western terranes west of the $4^0$50' Kandi fault record a typical cordilleran evolution during the Late Neoproterozoic period. Domains floored by stretched continental crust or by 900-800 Ma old arc-derived crust have been burried below thick accumulations of turbiditic volcanogenic graywackes adjacent to N-S volcanic belts and pre-kinematic calcalkkaline plutonic ridges. Such domains are characterised by a mostly greenschist facies imprint and have been deformed only by N-S open folds. 600-580 Ma old syn-kinematic batholiths display however large LP thermal aureoles and LP anatectic roots. The two giant slices of PGT, possible analogue of the Arequipa block docked along the Pacific subduction in the southem Andes, are delimited from adjacent terranes by steep strike-slip shear zones representing in part cryptic sutures. Indeed slices of serpentinites and MORB type assemblages with HP rnetamorphism (pyrigarnites, retroeclogites, rare glaucophane) have been identified along the western mylonitic shear zone (Caby, 1996). A 600 Ma old mafic and peralkaline late-kinematic dike complex of pure mantle derivation according to Nd/Sm and Rb/Sr signature (Kaddour *et al*, in 1999) also documents syn-orogenic crustal addition and the lithospheric character of the shear zone.

NW Hoggar nappes

NW Hoggar exposes a high level nappe of Paleoproterozoic basement and undetached cover, which moved southward more than 50 km onto Late Neoproterozoic turbiditic graywackes. A complete E-W crustal section is exposed in this area: the shallower structures are representei by open synclines of graywackes with steep axial plane, greenschist facies incipient cleavage related to regionally developped N-S open folding post-dating the nappes. A deeper level consists in plui-kilometre in size N-S trending recumbent folds synchronous with intermediate pressure metamorphism. The deepest level consists in unretrogressed granulite facies rocks occurring beneath sheets of calc-alcaline granitoids (derived from rnelting of the graywacke series) with anatectic roots. These granulites of regional extent are spatially connected with gabbro-norite-troctolite intrusions and suffered near isothermal HT decompression.

Late Pan-African/Cambrian stage

The >8 km red molassic series with associated rhyolitic volcanism, A type granites and syenites (530-520 Ma) are best represented in the western Hoggar graben and residual basins. Early tholeiitic basalts, andesites and late rhyolites also occur in a narow intramontane basin in southern Benin. In contrast, continuous sedimentation and associated calc-alkaline volcanism occured in a possible back-arc setting east of the suture zone in northern Mali. Renewed E-W shortening accompagned by greenschist facies metamorphism affected the basins located along major shear zones, whereas a flat extensional cleavage is observed in the central Hoggar molassic basins opened on the site of former back arc basins. The age of the main phase of NS folds having affected such extended regions is equal to that of the molasse, now constrained by the 523+-0.9 Ma age (U-Pb, zircon) of a calc-alkaline pluton typical of the "Taourirt" group (Paquette *et al*. 1998).

Subducted passive paleomargin of the west African craton and the foreland nappes

The pre 800 Ma and post 700 Ma comprehensive sedimentary series exposed in both the Gourma and the Volta foreland basins are overlain in the east by parautochthons and by thin nappes of phyllites. The Timétrine nappes (Ti) in northern Mali were emplaced westward above a flat sole thrust onto the cratonic cover of the WAC. These include possible remnants of the former ocean/continent transition in the form of serpentinite protrusions emplaced within terrigeneous flyschs, and olistoliths of both pillow basalt and shelf carbonates, all affected by incipient blueschist facies metamorphism. The inner metamorphic nappes mainly comprise metaquartzites and passive margin metasediments. The Gourma fold and thrust belt is a 200 km wide arcuate belt of upright open folds with steep axial-planar slaty cleavage. It represents a deformed aborted rift filled by more than 15 km of Neoproterozoic sediments including marine carbonates, slope facies and terrigeneous clastics. >40 km of NE-SW shortening are evidenced by a window of extruded WAC rocks + cover overlain by the thin greenschist facies metamorphic nappes. The internal nappes are characterised by phengite-garnet-kyanite-rutile assemblages that portray a HP/LT metamorphism, with distinct units containing unretrogressed kyanite eclogites and UHP rocks. The discovery of coesite in an eclogitic micaschist is evidence that parts of this passive paleo-margin were subducted to 100 km depth under a perturbed geotherm of 8^0/km (Caby, 1994). Such low value is feasable only in Alpine-type subduction regimes involving cold oceanic lithosphere. South of 10^0 5 these HP nappes with kyanite eclogites boudins are caped by discontinuous slabs of HP pyrigarnites representing the allochthonous subducted mafic arc

roots that delincate the E-dipping suture. The HP belt is overlain in the east by the HT/LP polycyclic gneisses of the Benin-Nigerian province that includes thoroughly reworked Archean basement and related Proterozoic cover sequences.

The Mauiritanides/Rockelides

A >2000 Km long, linear fold belt fringes the WAC to the west and the south. This two-stage orogen is devoid of syn-collisional and post-collisional magmatism. Thin Late Variscan nappes with multiple flats and ramps were emplaced eastward onto the undeformed Proterozoic to Carboniferous cover of the WAC. This structural style is characteristic of the central and northern Mauritanides. The nappes include in central Mauritania slices of a polycyclic basement and related pre-800 Ma cover, both affected by HP subduction-type metamorphism (12-14 kbar, T550-600^{0}C), with $^{4O}Ar/^{39}Ar$ metamorphic/cooling ages around 600 Ma. Higher nappes consist of monocyclic units that only suffered Late Variscan metamorphism of HP affinity. These comprise an inner Neoproterozoic arc-type terrane, an Early Paleozoic rift sequence with ultramafic protrusions, Cambrian (?) ophiolites and Lower Paleozoic sediments. Strike-slip motions along longitudianl shear zones were coeval with the latest eastward transport of the nappes around 270 Ma.

Conclusion

Paleoproterozoic continental growth around an Archean nucleus during the 2.2- 2 Ga preriod generated large portions of the west African craton, followed by cratonisation at 2 Ga, with little evidence of reworking of Archean material. In the trans-Saharan pan-African belt, eastern Hoggar reepresent Neoproterozoic accreted terranes of arc affinity stabilised since 730 Ma. In central Hoggar west of the $4^{O}50'$ shear zone, the apparent crustal growth during the 900-700 Ma period mainly relates to the vertical addition of thick volcanic and volcaniclastic series above a previously thinned and attenuated paleoproterozoic crust. In contrast, the evolution of the Mauritanides illustrates a complete diachronism of tectono-metamorphic events west and east of WAC. Pan-African structures and the major shear zones of the Trans-Saharan belt, that are so characteristic of Gondwanaland, accurately match those of NE Brazil (Caby, 1989).

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