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STRUCTURAL EVOLUTION OF PRECAMBRIAN BASEMENT ROCKS OF JEBBA AREA, S.W. NIGERIA

C. T. OKONKWO

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ABSTRACT

Geological studies show that the Jebba area, S.W. Nigeria is underlain by metasedimentary and metaigneous rocks including gneisses which have been intruded by Neo-Proterozoic (Pan-African) granitic rocks. The metamorphic rocks including migmatitic gneiss, quartzofeldspathic gneiss, metagreywacke, quartzite, quartz-mica schist and granitic gneiss have been subjected to polyphase deformation. Early, D_1, deformation gave rise to recumbent folds associated with axial planar foliation. Later, D_2 event produced asymmetrical folds and axial planar crenulation cleavages. The D_3 episode was associated with ductile thrusting at deeper crustal levels and D_4 with brittle thrusting at upper crustal levels, as well as tight to open folds with subhorizontal axial planes. D_5 involved strain localisation along steep, strike-slip faults.

KEYWORDS: Jebba area, polyphase deformation, foliations, folds, ductile thrusts, stretching lineations, brittle thrust faults, strike-slip faults

INTRODUCTION

The Nigerian basement complex forms part of the internal zone of the Pan-African orogenic belt east of the West African craton (Fig. 1) This basement complex comprises Archean and Proterozoic rocks which have been subjected to Liberian (ca 2700Ma), Eburnean (ca 2000 Ma) and Pan-African (ca 600 Ma) orogenic events (Grant 1970, Oversby 1975, van Breemen *et al* 1977, Fitches *et al* 1985, Rahaman 1988, Dada *et al* 1994). The existence of the Kibaran (ca 1100 Ma) event in Nigeria claimed by some workers (Ogezi 1977, Ekwueme 1987) on the basis of some Rb/Sr dates on metamorphic rocks is not generally accepted (Ajibade *et al*, 1987).

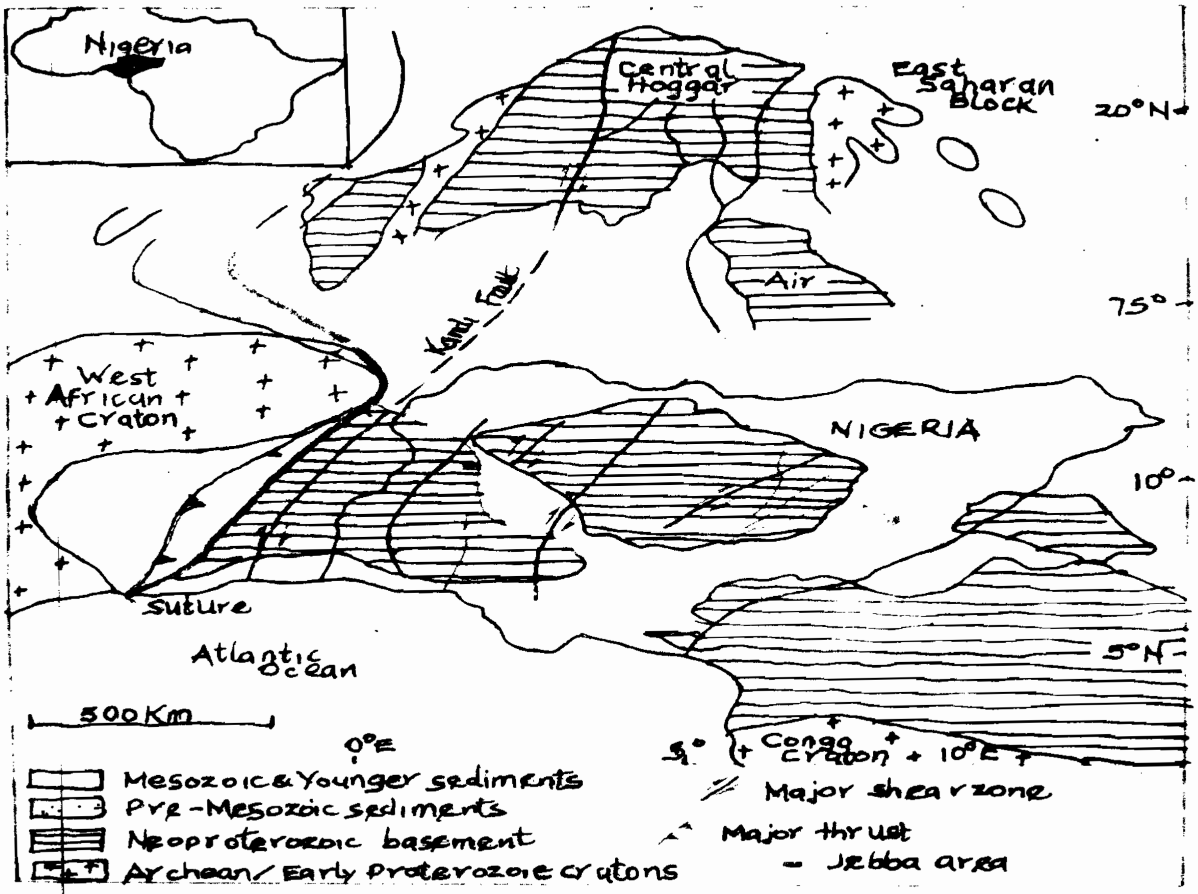

Fig. 1: Index map of the Trans-Saharan belt showing the location of Nigeria including Jebba area (after Ferre *et al* 2002)

C. T. Okonkwo, Department of Applied Geology, Federal University of Technology, Akure, Nigeria.

The polyphasal nature of the deformation of the Nigerian Precambrian basement rocks has been recognised by several workers eg Annor and Freeth (1985), Fitches et al (1985), Ajibade and Wright (1988), Odeyemi (1988), Rahaman (1988), Ekwueme (1987), and Ukaegbu and Oti (2005).

Since Okonkwo (1992) much more work has been done in the Jebba area; the field mapping has been extended to Aderan in the west, more data have been collected enabling a better understanding of the structural relationships and the structural development of the rocks in this area. This paper discusses the structural evolution of Jebba area in the light of these new developments.

LITHOSTRATIGRAPHY OF JEBBA AREA

The Jebba area is underlain by metasedimentary and metaigneous rocks which have been intruded by post-tectonic granitic rocks of probable Pan-African age (Fig. 2) A provisional lithostratigraphic classification of these rocks is presented here.

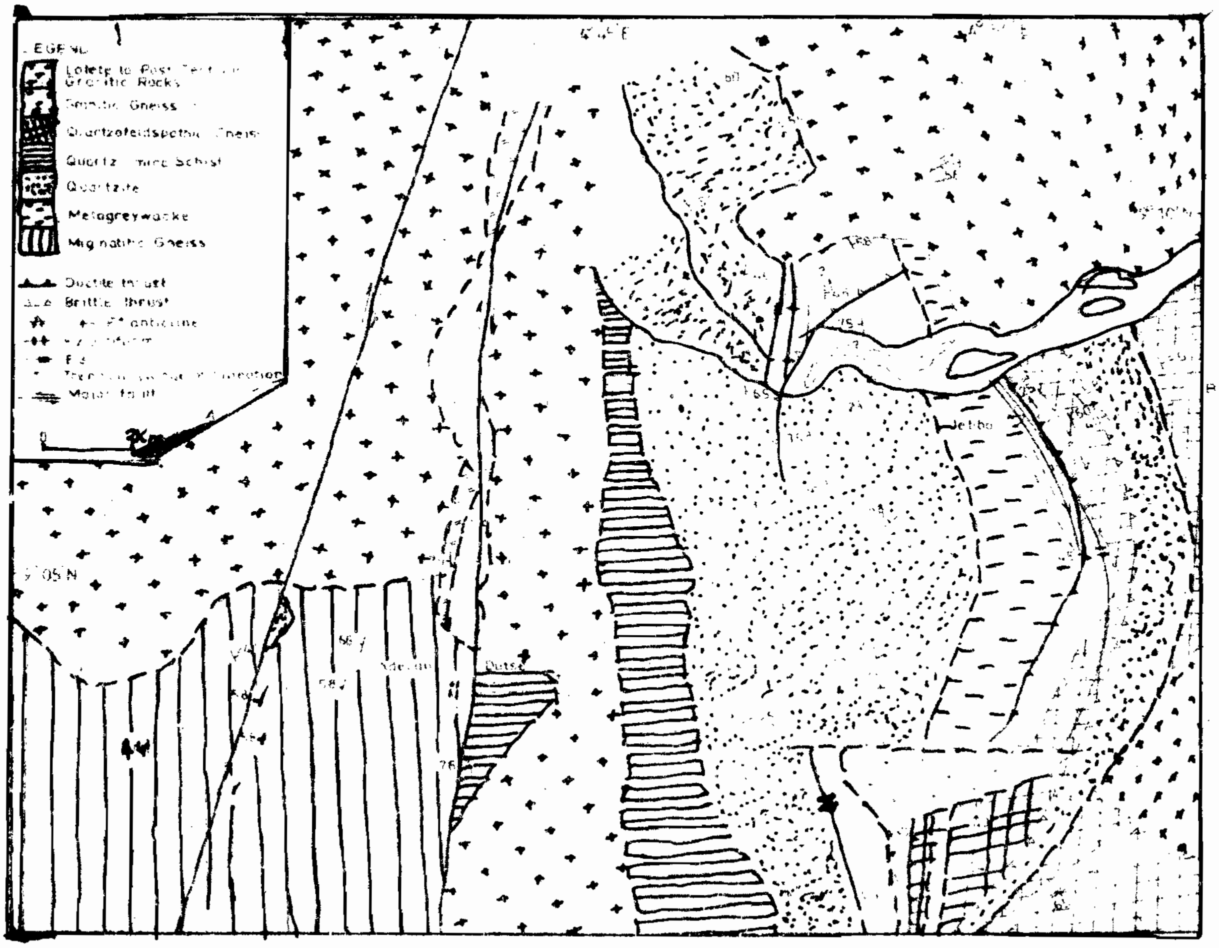

Fig. 2: Geological map of Jebba area

Migmatitic Gneiss

This unit outcrops in the western part of the study area and comprises a sequence of variably migmatised gneisses with concordant quartzo-felspathic segregations and bands. Locally it may also comprise augen gneiss components. The paleosome appears to be dominantly metaigneous and the migmatisation seems to be be the pro ducts of both metamorphic segregation and injection of granitoid material.

Quartzofeldspathic Gneiss

This unit outcrops in the eastern part of the area and comprises a sequence of grey, gneisses containing quartz, microcline, plagioclase and biotite which may locally contain thin concordant to subconcordant granitic veins.

Metagreywacke

A sequence of grey, quartz - plagioclase- and biotite-bearing psammitic rocks is exposed in the eastern part of Jebba area (Fig. 2). Occasionally, these rocks show relict grading with quartz-and feldspar- rich bases and biotite-rich tops. These petrographic characteristics suggest that these rocks were immature psammitic sediments similar to greywackes (Pettijohn 1975).

Thin, pale-coloured and discontinuous 0.5 to 5cm thick calc-silicate-rich bands containing epidote, plagioclase, biotite, actinolite and sphene occur sporadically within the metagreywacke. Concordant to discordant sheets of amphibolite containing hornblende, oligoclase, epidote, minor quartz, biotite and accessory sphene occur within the metagreywacke. The metamorphic assemblage in much of this unit indcates greenschist facies of metamorphism.

Quartzite

A sequence of quartzites which is locally micaceous is exposed in the N-S trending ridges extending from west of Jebba in the northwest to west of Biribiri village in the south-west (Fig. 2). Near the contact with the metagreywacke, the sequence is marked by 3 to 5m thick lenses of pebbly quartzite containing pebbles of white vein quartz and smoky quartz as well as smaller grains of microcline in a matrix of finer quartz and muscovite grains interpreted as representing a matrix-supported conglomerate.

The quartzites locally show preserved cross-stratification and locally occur as thinly-bedded, flaggy units. Also locally, crystals of randomly-oriented tourmaline grains occur especially within foliation planes in the quartzites and 30 to 200m thick quartzite units occur as intercalations in the metagreywacke (Fig. 2).The eastern band of quartzite possess evidence of higher grade of metamorphism in the upper amphibolite facies which was probably acquired in deeper levels of the crust.

Quartz- Mica Schist

A sequence of quartz-biotite muscovite schists structurally overlies the quartzite in the west (Fig. 2). Locally the schists contain thin psammitic bands which are gradational with the schists probably reflecting original sedimentary grading. The schists range from dominantly muscovite-rich bands to more biotite-rich ones best exposed in Dutse village (Fig. 2).

Granitic Gneiss

This unit is exposed east of Jebba town (Fig. 2) where it occupies a N-S belt between the metagreywacke and quartzofeldspathic gneiss. The granitic gneiss is a pinkish, medium-grained rock containing quartz, K-feldspar, oligoclase, minor biotite and muscovite along with accessory ilmenite, epidote, sphene and chlorite. This unit is marked by heterogeneous strain producing rocks from weakly deformed granite to mylonitic granitic gneiss.

Late- to Post-tectonic Granitic Rocks

Several bodies of undeformed granitic intrusions occur within the metasedimentary rocks (Fig. 2). The rocks comprise mainly medium-grained granites and granodiorites which contain variable amounts of quartz, microcline, plagioclase, biotite and minor hornblende. A porphyritic variety occurs in the northern margin of the study area.

STRUCTURAL HISTORY

Five phases of deformation termed D_1, D_2, D_3, D_4 and D_5 have been recognised in the Jebba area.

D_1 Structures

Foliation

A penetrative foliation, S_1, is widely-developed in the various metamorphic rocks. The character of this foliation varies from a preferred orientation of micas and amphiboles in the metasedimentary rocks and amphibolites to gneissic banding in the gneisses. The attitude of the S_1 foliations is highly variable in the area as a result of their initial orientation and subsequent rotations during the D_2 and later events. The gross distribution of the S_1 planes define the geometries of the major fold structures in the area (Fig. 2).

S_1 is generally parallel to bedding, So, in the metasedimentary rocks except at the closures of the F_1 folds where it cuts the bedding at high angles (Fig.3).

Fig. 3: F_1 (D_1) folds in quartzite with axial planar S_1 foliations

Folds

The earliest recognised minor folds (F_1) deform the bedding as defined by lithological banding and possess an axial planar foliation, S_1 (Fig. 3). They are generally tight to isoclinal, locally, recumbent structures. Minor F_1 fold axes and other lineations show some scatter on stereographic plots (Fig. 4) probably as a result of their variable rotation by later deformation events (Ramsay 1967).

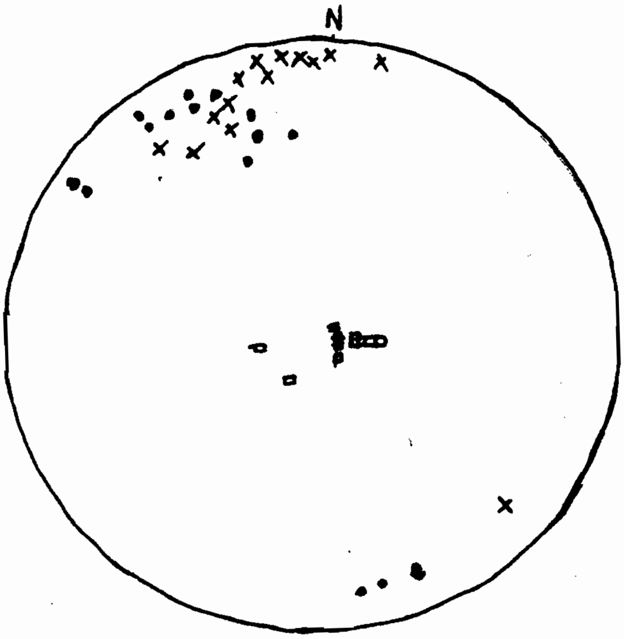

Fig. 4: Equal area stereographic plot of minor F_1 fold axes (crosses), ductile shear zone lineations (filled circles), poles to brittle thrust planes (open squares)

Major Fold

Rock exposures in the northwestern part of the area show a belt of subhorizontal S_1 foliations which are approximately perpendicular to the almost vertical bedding in the quartzite (Fig. 5). This belt is also marked by F_1 minor recumbent folds with axial planar cleavage. The relationships of these structural elements here indicate the closure of a major F_1 recumbent fold (Fig.

6). The fold axial surface is locally steepened in the east by later F_3 folding and late thrusting.

Fig. 5: Subhorizontal S_1 foliations perpendicular to the bedding in quartzite at major fold closure

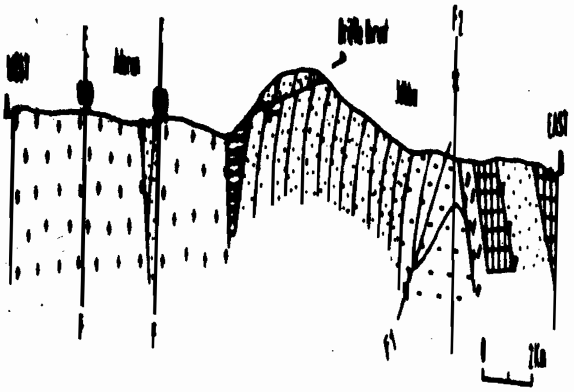

Fig. 6:. Structural (E-W) cross-section showing the major structures across the area (symbols as in Fig. 2)

D_2 Structures

Foliation

A younger set of crenulation cleavages, S_2, locally deform the S_1 foliations and are axial planar to later generation of folds. They are best developed in more micaceous lithologies.

Folds

A group of tight, asymmetric folds (Fig. 7) commonly deform the rocks. These structures fold D_1 structural elements and are locally associated with a crenulation cleavage. Locally, as in NW and NE sectors, they, the F_2 folds, occur as open to close recumbent folds which have caused the steepening of the earlier structures. They are related to a major antiformal fold structure, the Jebba Antiform, (Figs. 2 & 6). Interference between F_2 m inor folds and F_1 minor folds gave rise to coaxial, hook-type patterns (Fig. 8) similar to type 3 of Ramsay (1967) and Ramsay and Huber (1987).

Fig. 7: Tight, asymmetrical F_2 folds in quartzite

Fig. 8: F_1 and F_2 fold interference producing a type 3 (hook-type) pattern

Major Fold

A major fold associated with this event in the area is the Jebba antiform (Fig. 6) which has refolded the D1 recumbent major fold.

D_3 Structures

Ductile Thrust

A major N-S trending shear zone lies at the contact between the the metagreywacke and the granitic gneiss (Fig. 2). The granitic gneiss has been strongly sheared and the original mineral grains have been subjected to a very high degree of grain size reduction. The shear zone fabric, S_3, is also locally marked by the tectonic interbanding of granitic bands with those of the metagreywacke to produce a banded gneiss. The granitic bands were boudinaged and drawn into asymmetric augens (Fig. 9) with increase in the strain intensity indicating a top to the SSE sense of shear Stretching lineations in the shear zone trend NNW-SSE and plunge very shallowly (Fig. 4).

Fig. 9: Asymmetric augens of granitic gneiss in the shear zone indicating top to the SSE transport

D_4 Structures

Thrust Faults

Flat- lying to gently - dipping thrust faults occur at several horizons in the Jebba area. These thrust faults are especially well - exposed in the quartzites in the northwestern part of the area. They cut the limbs and other parts of early, D_1, tight to isoclinal folds in quartzite (Fig. 10). The thrusts therefore appear to have formed after the development of these early folds. They are mainly westerly dipping imbricate fans (Fig. 11) which are locally, densely developed in the quartzite with tectonic transport to the east. The total displacement on each fault cannot be ascertained because of lack of appropriate markers. It is known that imbricate thrusts are very efficient means of shortening and thickening a sequence (Boyer and Elliot 1982) so although the displacement on each fault may be small the aggregate displacement on the series of faults may be considerable. Locally, there are also easterly-dipping backthrusts which intersect the forethrusts producing pop-up structures.

Fig. 10: Shallowly-dipping thrust fault truncating early, F_1 fold in quartzite

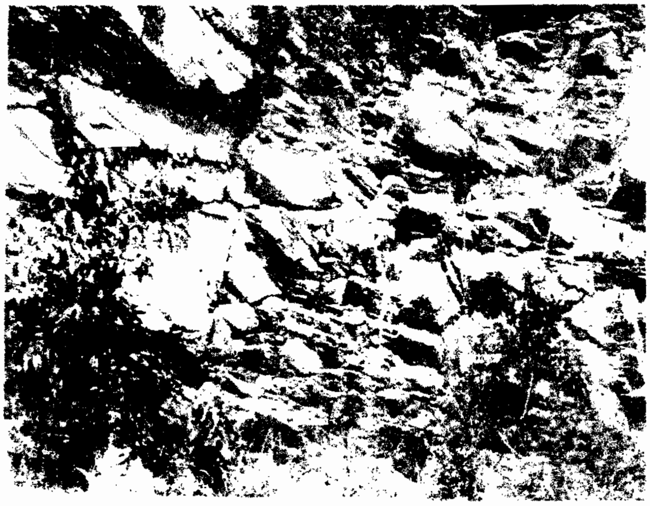

Fig. 11: Shallowly-dipping imbricate thrust faults in the quartzite

Folds

There are tight to open, asymmetrical minor folds with generally subhorizontal axial planes which deform the shear zone fabric (Fig. 12) as well as the dominant foliation n, S_1. These folds are responsible for the steepening of the foliations, locally within the zones of imbricate thrust faults and ductile thrusts.

Fig. 12: Late SE-verging asymmetrical folds with subhorizontal axial planes which deform the shear zone fabric

Extensional Faults

Locally, minor, brittle, extensional faults occur in the quartzites. These are late structures and may be a reflection of a phase of gravitational spreading associated with late-orogenic uplift (Platt and Lister 1985).

D_5 Structures

Major Strike-slip Faults

Two major subparallel approximately N-S-trending and steeply-dipping faults have been mapped in the Aderan area (Fig. 2). These faults are defined by cataclasites and mylonites developed in the truncated rocks especially the quartzites (Fig. 13) and the granites. Stretching lineations in the mylonitic granitic gneisses are sub-horizontal. Since these faults cut both the older metamorphic rocks and the presumably Pan-African granites the faulting is interpreted to be late Pan-African (Late Proterozoic) in age.

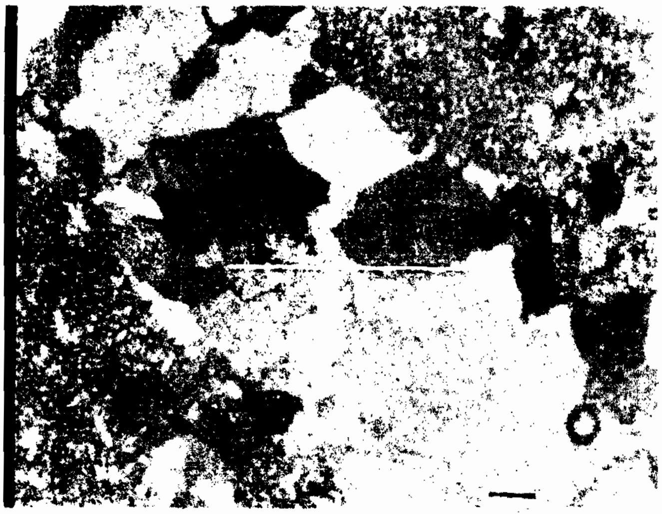

Fig. 13: Photomicrograph of cataclastic, very fine-grained quartzite which has been cut by a late quartz vein in a fault, NW of the study area. (Scale bar represents 0.32 mm)

DISCUSSION AND REGIONAL CORRELATIONS

Deformation of the Precambrian basement rocks of Jebba area was polyphase; the early phases involved contractional structures which were associated with the Pan-African orogenic convergence. These structures including major recumbent folding and ductile thrusting at deeper (lower) structural levels have SE-directed transport. This early phase of crustal shortening was followed by late folding which caused local steepening of the earlier structures.

A later phase of brittle thrusting cross-cut the earlier folds and structures reflecting a SE-verging shear and an out of sequence deformation of previously folded and deformed sequences in a break-back sequence (Butler 1992).

Several, major , approximately, N-S-trending fault zones have been recognised in Nigeria eg Kalangai Fault (Truswell and Cope 1963), Zungeru (Ajibade 1982), Ifewara (Caby and Boesse 2001). Although these faults have been mostly recognised as showing strike-slip displacement there are indications of oblique-slip and even earlier thrust displacements on them. In the Central Hoggar Belt to the north of the Nigerian Basement Complex (Caby 1989) had recognised similar shear zones in the Trans-Saharan Belt of the Tuareg Shield.

In Jebba area the D_1 recumbent folding and the ductile thrusting predated the brittle thrusting in the quartzite. Boesse *et al* (1989) also recognised the nappes of Ife- Ilesha area as D_1 structures. Caby (1989) and Caby and Boesse (2001) have argued that the D_1 thrusting and nappe formation in SW Nigeria is of Pan-African age and is similar to that observed in central Hoggar (Lapique *et al.* 1986) with ages bracketed between 629 and 618 Ma (U-Pb on zircons - Bertrand *et al*, 1986).

In the Nigerian basement complex, there is a general lack of appropriate radiometric dates to constrain the timing of these deformational events. However, since the brittle and ductile shear zones also affected some Pan-African granitic rocks, it appears that these structures in Jebba area are also Late Proterozoic (Pan-African) in age..

These structures (nappes, ductile shear zones, thrusts and strike slip faults) in the Jebba area are similar to those described from the Ife region of SW Nigeria by Caby (1989), Caby and Boesse (2001), and in Lokoja area by Ajibade and Wright (1989). Ferre *et al* (2002) have also described nappe tectonics and strike-slip movements in Pambegua-Bauchi area associated with granite emplacement. All these indicate a regime of horizontal tectonics associated with Pan-African continental convergence was of widespread occurrence in this sector of the Pan-African mobile belt.

Some of these structures are also geometrically similar to metamorphosed thrusts and nappes described from the Scottish and Scandinavian Caledonides (Butler 1984, Barr *et al* 1986, Holdsworth 1989, and Gee 1975) and also the Appalachians (Hatcher 1978) and the Hoggar (Caby *et al* 1981). The thrust faults are very similar to those described by Booth and Shone (1999, 2002) from the Cape Fold Belt, South Africa.

CONCLUSIONS

1. Early deformation associated with Pan-African orogenic convergence involved major recumbent folding and ductile thrusting.
2. These early structures were refolded by coaxial F_2 and later F_3 folds which along with late brittle thrusting led to local steepening of these structures. Late north- westward-directed back-thrusting also truncated the earlier structures..
3. Late- orogenic crustal uplift and gravitational spreading associated with strain localisation were marked by brittle faulting, including extensional faults and conjugate transcurrent faults.

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