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GEOLOGY OF THE PAN-AFRICAN BASEMENT COMPLEX IN UBE-WULKO AREA OF AKWANGA, NORTHCENTRAL NIGERIA

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ABSTRACT
The Ube-Wulko area of southeast Akwanga falls within the Pan-African remobilized Basement Complex of northcentral Nigeria. It consists of intensely multi-deformed high grade polymetamorphic basement rocks, predominantly composed of migmatitic gneisses and schists and subordinate quartzites, marbles, and pegmatite and dolerite dykes which intrude mainly the migmatitic gneisses. The structural grains of the metamorphic rocks trend N-S to NE-SW, while about thirty weakly foliated and non-foliated pegmatites and several dolerite dykes are structurally controlled along ancient NW-SE and NE-SW tectonic lineaments. The foliated pegmatites intrude only the migmatitic gneisses, while the non-foliated pegmatites intrude both the migmatitic gneisses and schists. Schists represent the oldest rock unit and dolerites, the youngest. Lithologic characteristics of the metamorphic sequences suggest sedimentary parentage. Mineral composition (kyanite, sillimanite and calcic plagioclase), migmatization and complex deformation indicate at least medium pressure-high temperature amphibolite facies of the Barrovian type.
KEY WORDS: Petrology, structure, metasediments, Basement, Akwanga

INTRODUCTION
The study area is located on the piedmont area of the steep scarp of the Jos Plateau and bounded by latitudes 8^o50^1N to 8^o55^1N and longitudes 8^o25^1E to 8^o29^1E in southeast of Akwanga town of northcentral Nigeria (Fig.1). It lies within the Pan-African tectono-metamorphic belt of the Nigerian Precambrian Basement Complex between the West African and Gabon-Congo cratons (Kennedy, 1964). Precambrian migmatitic gneisses and schists dominate the basement rocks of southeast Akwanga. Gneisses from northcentral Nigeria have been suggested to be the oldest basement rocks in Nigeria (Oyawoye, 1972; Ekwueme and Kroener, 1998; Dada *et al*. 1998). Important works done on the geology of Akwanga include those by Smulikowski and Olatunji (1980), Onyeagocha and Ekwueme (1982), Onyeagocha (1984), Ayi (1988), Nyikwagh, (1990). These works cover a wide range of topics, which have led to the present knowledge on the general geology of the area. This research paper is an attempt to use the field occurrence, metamorphism, magmatism and structural imprints to determine the geotectonic evolution of the basement of the Akwanga area.

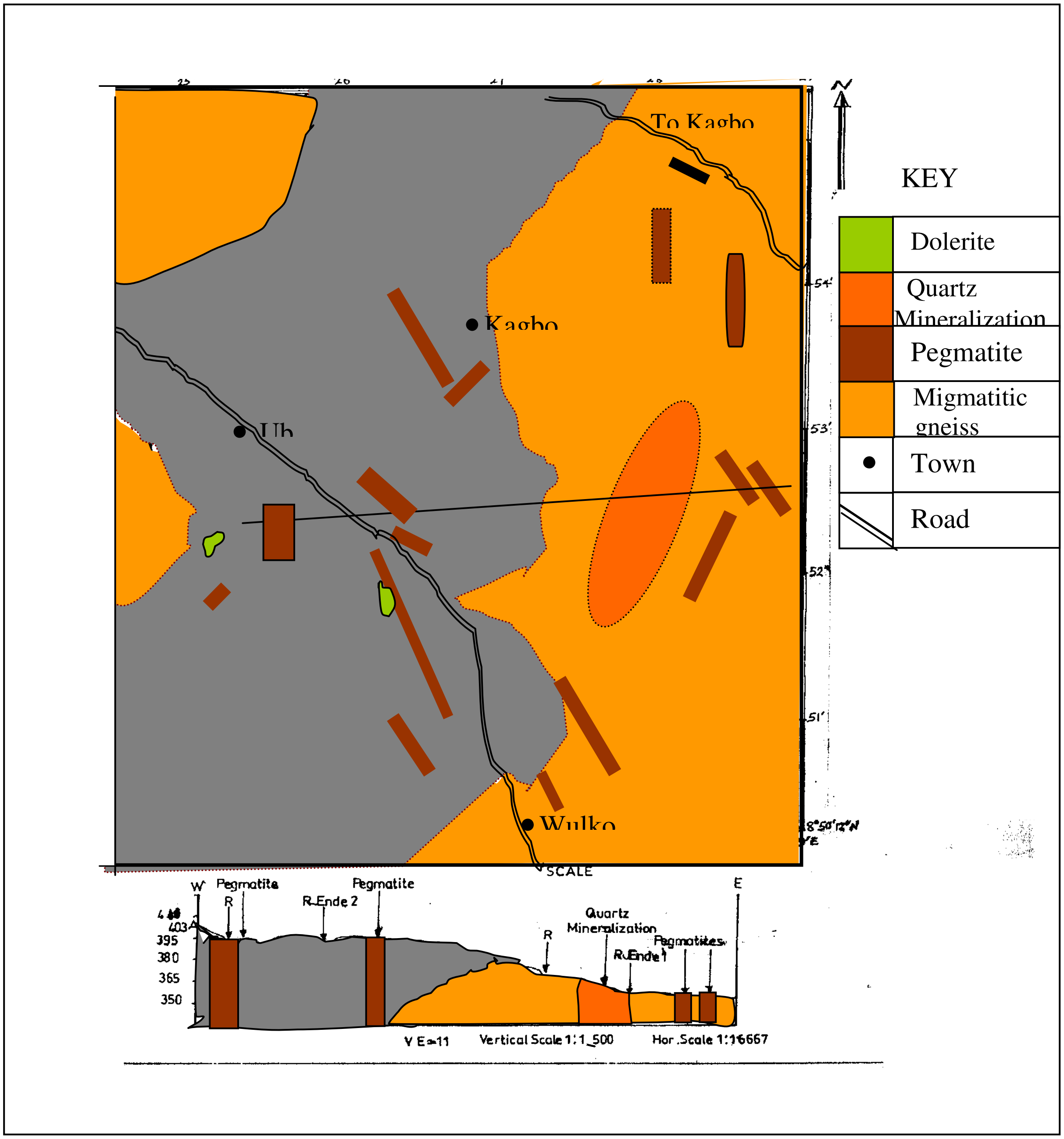

Fig. 1. Geological Map of Ube-Wulko area of Akwanga

GEOLOGICAL SETTING

Southeast Akwanga is part of the piedmont of the Jos Plateau and is relatively flat but with occasional plateaux and hills, compared to the surrounding topography. Migmatitic gneisses and schists, amphibolites, quartzites, marbles, pegmatite and dolerite dykes occur in the area in varying proportions. However, the migmatitic gneisses and schists are predominant and form a continuous elongated N-S to NE-SW regional belt parallel to the main structural grains of the Basement Complex of Nigeria. The geological boundaries between the migmatitic gneisses and migmatitic schists are gradational in a general north-south trend. There are two generations of schists in the study area; one occurs as xenoliths in the migmatitic gneisses, while the other occurs as mappable low-lying weathered body.

PETROLOGY

Metamorphic Rocks: These are the most widespread rocks in the study area. They are mainly migmatitic gneiss-schist complexes. The lithologic boundaries between the two complexes run roughly N-S and are more or less gradational. Local effects of contact metamorphism between some dolerite dykes and marble in Wulko have altered the host rocks to skarn. Minor and microfaults also show local cataclasis.

Migmatitic Gneiss Complex: The migmatitic gneisses cover mainly the eastern part, which is more granitic. They are dark grey to dark green in colour with white patches. They generally show granitic textures, and are characterised by the presence of numerous linear leucosome and melanosome bands running N-S parallel to the foliation of the rock units. They are medium to very coarse-grained in texture, with few porphyroblasts of quartz. The leucosome bands range in width from 1mm-10cm.

The migmatitic gneisses have pegmatitic textures, in the leucosome bands and this may be as a result of lit-par-lit injection or tension gash infillings. Under thin section, the gneisses reveal idiomorphic to hypidiomorphic texture with poikiloblastic relationship between quartz crystals, and plagioclase crystals completely enclosed by euhedral biotite crystals. Fine grained textures between coarse textures (Fig. 2) appear to indicate deformation episode in the migmatites. This probably explains why the newly formed minerals are fine, and usually located at the contacts surrounded by the original mineral grains. The light bands form a network pattern on the migmatitic gneisses. They are holocrystalline with fine to medium grained texture. They contain anhedral crystals with myrmeckitic (or vermicular) texture (Fig. 3).

The modal compositions of the gneisses vary from outcrop to outcrop. Some outcrops are non-migmatitic with strong gneissic or granitic structures, while others tend to be migmatitic with the characteristic flow structures exhibited as numerous thin leucosome (neosome) and thick melanosome (paleosome) bands. The widths of the leucosome range from 1 mm to 10 cm, whereas their lengths depend on the extent of the outcrops. They frequently show stromatic and occasionally ptygmatic structures. The stromatic gneisses have porphyroblastic texture, with anhedral to euhedral crystals. The mineral composition is mainly feldspar (microcline and microperthite) and granular quartz. The abundance of potash feldspar and myrmeckites with little plagioclase indicates that these migmatites are alkaline in nature. The dark portions of the rocks display a more schistose structure and contain a lot of biotite, quartz, plagioclase (andesine-labradorite), actinolite, apatite and opaque minerals. Average modal analysis of the migmatites shows microcline (25%), quartz (30%), biotite (25%), albite (15%), apatite (2%) and sillimanite (3%). The undulose extinction in some crystals of quartz is indicative of ductile deformation of the rocks. The modal composition and texture of the migmatitic gneisses vary from place to place.

Some of the gneissic structures appear to be products of metamorphic segregation, although the leucosome bands indicate effects of partial melting. The bands here show alternation of quartzo-feldspathic bands (2mm to 1cm), while the dark bands are relatively thicker (1cm – 1.5cm).

Schists: The schists represent the second largest rock unit in the area. They have been intensely weathered, thus they show dull appearance with obliterated structures (Fig. 4). However, two types of schists (weathered brown schists and dark xenolithic schists) were identified in the field. The weathered schists are brownish in appearance and cover much of the study area. The second schists are dark coloured, and outcrop at Wulko. They also occur as xenoliths or lensoids in the gneisses, and have flow structures (Fig. 5). The lenses are on the average 3m long and 20cm wide. Average modal values of the schists are k-feldspar (22%), quartz (32%), albite (30%), apatite (10%), sillimanite (6%).

Amphibolites: Two types of amphibolites occur in the study area. The first are dark holocrytalline anhedral to euhedral coarse-grained rocks, showing poikiloblastic texture. These amphibolites are composed of mainly actinolite, biotite, plagioclase (labradorite), large but few patches of quartz, garnet as phenocrysts and poikiloblasts, apatite and some ore minerals. The abundance of apatite shows that these amphibolites are ortho-derived. The second type of amphibolites shows segregation structures with light colour bands in thick dark colour bands. They are fine grained and compose of amphibole (hornblende), rounded grains of quartz, plagioclase (labradorite), epidote (zoisite) and opaque minerals. The abundance of epidote in these amphibolites indicates sedimentary origin.

Quartzites: These rocks are light coloured or white, holocrystalline with very fine grained, almost splintery texture. The crystals are anhedral but show interlocking texture. The mineralogical composition is quartz (98%) and a few actinolite needles.

Marble: The marble is white in colour, with medium to coarse grains, and anhedral under the microscope. It is composed of mainly calcite (84%), while epidote (6%), orthopyroxene (4%), clinopyroxene (2%) and ore minerals (4%). A close observation of the rhombohedral cleavages of the calcite crystals reveals evidence of microfaulting (Fig. 6). The cleavage lines are displaced, predominantly in dextral sense.

IGNEOUS ROCKS: Pegmatites, aplites and dolerites are the main igneous intrusives in Ube-Wulko area, and are quantitatively subordinate to the metamorphic rock units.

They intrude the basement in random manner.

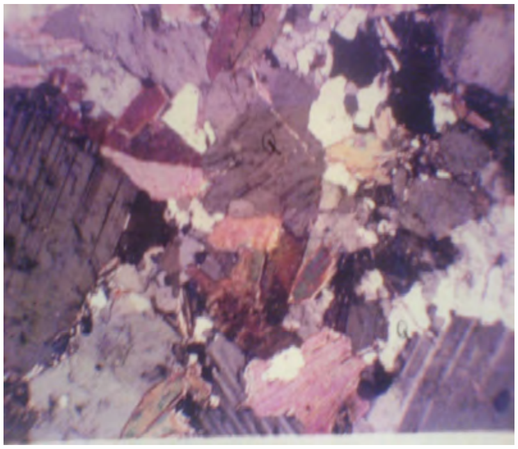

Fig. 2. Migmatitic gneiss, showing quartz, plagioclase and biotite. Fine grains between coarses indicate deformation effect.

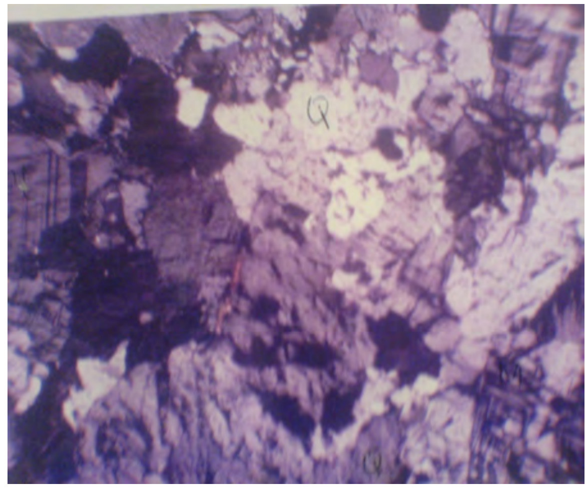

Fig. 3. Myrmeckite or vermicular texture exhibited by the gneisses.

Fig. 4. Weathered schist

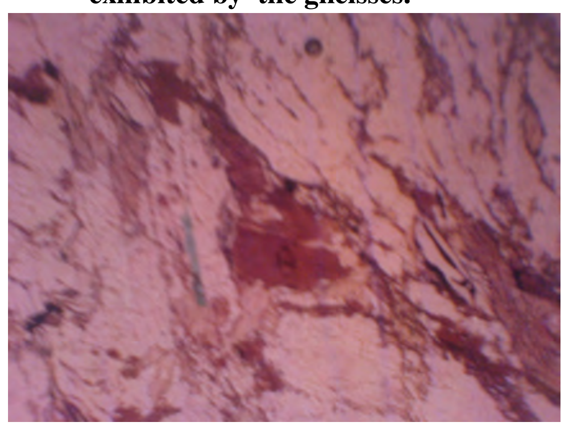

Fig. 5. Flow structure in mica schist

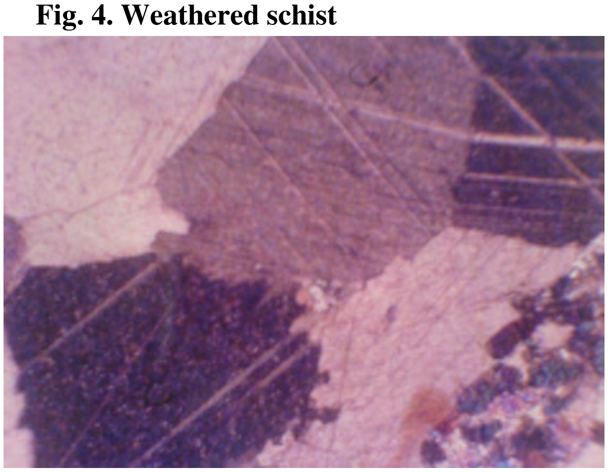

Fig. 6. Marble showing micro-cleavage with sutured and curved grain boundaries. Minerals include calcite with epidote and pyroxene at the lower right corner.

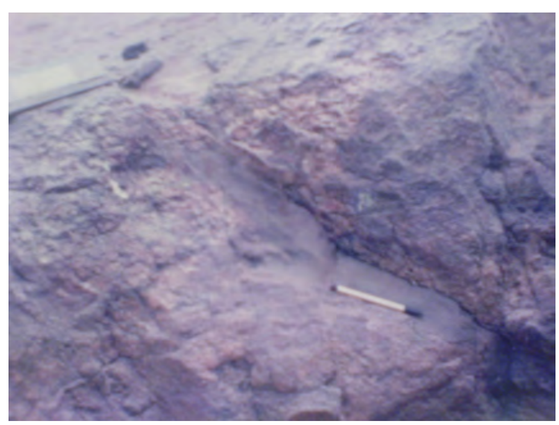

Fig. 7. Weakly foliated pegmatite dyke

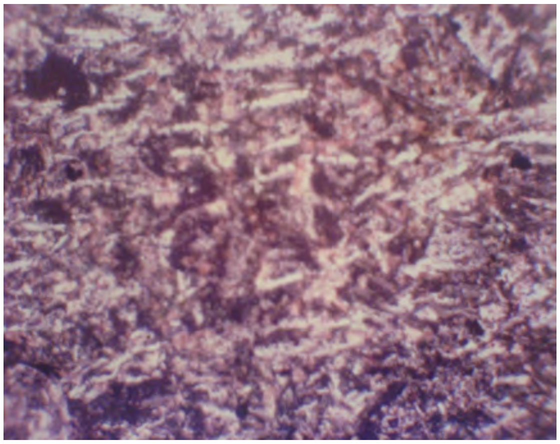

Fig. 8. Ophiotic texture of a dolerite sample

Fig. 9. Minor strike-slip fault

Pegmatites: About thirty pegmatite dykes, seventeen of which are mappable, are randomly distributed in Ube-Wulko. Very coarse-grained (about 3cm) to large crystals (about 30cm) of pegmatites are ubiquitous in the area. In some few cases, they occur in swarms or form parallel series (ridge and valley structure), separated by an average distance of a few meters. A few relatively small-sized pegmatites intercept bigger pegmatite bodies. Some occur as stumps of partially exposed pegmatites, while some others occur as sills. There are two types of pegmatite in the map area: weakly foliated and non-foliated pegmatites. The weakly foliated pegmatites (Fig. 7) exhibit fairly constant textural characteristics and occur in irregular pattern. The non-foliated types show textural zoning and are either disseminated boulders or outcrop as tabular bodies or hills of width of few meters to about 80m or more and length ranging from a few meters to over 500m. They exhibit fairly constant strike and dip. In the zoning, coarse grains of K-feldspar, muscovite and quartz occur at the rims, while coarser quartz gains occur at the centre.

Some of the pegmatites are fractured, weathered and foliated in a general north-south direction. The pegmatites and aplites are associated with the migmatitic gneisses and schists, and constitute the main acid intrusives in the area. They occur as dykes and are generally unmetamorphosed as against the highly metamorphosed and deformed country rocks. In a few cases, some of the pegmatites are weakly foliated in NE-SW and NW-SE directions. The foliated pegmatites are spatially restricted to the migmatitic gneisses, and they are also crosscut by dolerite dykes. They show mainly sharp contacts with their host rocks. However, both types trend generally northwest-southeast and northeast-southwest.

The mineralogy of the pegmatites is fairly constant, but modal mineral compositions vary. However, their mineral compositions include quartz, microcline, plagioclase, muscovite and rarely biotite and other accessory minerals, which include tourmaline. The simple microcline-quartz-mica pegmatites are common in the area. Microcline occurs in both microperthitic and non-microperthitic forms. Some of the microcline has been albitized resulting in the simulation of albite bands. Quartz occurs as irregular grains or euhedral crystals. Some of the pegmatites have strained quartz crystals with preferred orientation. Muscovite occurs both in book and niddle forms. It is the dominant mica in the pegmatites. Modal proportions were not attempted because of the variability in mineral distribution and large grain sizes of the crystals of the pegmatites. Aplites occur in association with the pegmatites in the study area. Under the microscope, the quartz grains are ribbon–like with brittle strains and interstitial cummingtonite. The grains show effects of both ductile deformation evident in undulose extinction, and brittle deformation shown in patchy extinction and powdering in the quartz crystals.

Dolerites: These intrude all other rock units in the study area. They occur as dykes, randomly distributed and weathered to clusters of lensoid outcrops of spheroidal boulders. Some outcrops show chilled margins. Tension gashes are present in some of the outcrops, occurring as linear streaks of about 2mm wide and a few cm long. The tension gash infillings are composed of light coloured minerals. Under thin sections, the dolerites are muttled, and show glomeroporphyritic and sometimes ophitic texture with randomly arranged laths of plagioclase (Fig. 8). The main mineral contents are phenocrysts of pyroxene (augite), plagioclase and few olivine and iron ores, and groundmass of clinopyroxene. The average modal composition is as follows: feldspar (47%), clinopyroxene (augite) (35%), olivine (3%) and iron ore (10%).

STRUCTURES

The major structures in southeast Akwanga include foliation, folds, tension gashes, joints and minor faults. Minor faults and microfaults show local cataclasis. The predominant structures trend N-S to NE-SW and this conforms to Pan-African structural pattern. The structures exhibited by the migmatitic gneisses are parallel to the bedding and lamination of the original pre-migmatitic supracrustal formation. In some cases, the schists are ptygmatic, and show schistose structures resulting from biotite crystal lineation. The schists exhibit crenulation cleavages. Undulose extinction in large crystals of quartz indicates deformations in the rocks.

Foliation and Folds: Foliation in southeast Akwanga is characteristically N-S with parallel alignment of mafic minerals such as micas and amphiboles. The migmatites are principally stromatic. The foliation is parallel to the xenoliths of schists in migmatitic gneisses with trend mainly N-S to E-W approximately to geological boundaries, which indicates isoclinal type of folding (Smulikowski, 1980). Some of the contorted veins of the gneisses form ptygmatic folds.

Joints: Joints are common in all the rock units. There are two major sets of joint trends in NW-SE and NE-SW directions in the migmatitic gneisses. These are followed by NNW-SSE (or approximately N-S) and E-W trends. There are also two major joint sets in the schists trending mainly NNE-SSW and NEE-SWW (approximately E-W).

In all rock units the joints were mostly near vertical to vertical.

Faults and Tectonic Stress: Minor strike slip faults occur in the study area. North-South and NE-SW trending veins crosscut and displace the E-W trending veins with slips of about 4-6 cm long (Fig. 9). In some cases, NNW-SSE trending fractures displace N-S or NE-SW trending veins with strike slip up to 40 cm or about 15 cm respectively. Also the N-S trending veins are either truncated or crosscut by NE-SW trending veins. In Kagbo area (Fig. 1) the NNW-SSE displace the NW-SE trending veins. Sinistral faults are dominant over the dextral types. Under thin section, microfaults are evident in rhombohedral cleavages of calcite in the marble. In some of the rocks, mylonitic deformation is evident in the ribbons and fine grinding of quartz. Structural imprints are more in the migmatitic gneisses than in any other rock type in the area.

DISCUSSION

Metamorphism and Migmatization: Mineral parageneses of the rocks in Ube-Wulko area indicate attainment of unimodal metamorphic facies of amphibolite grades. This is confirmed by the dominance of plagioclase of andesine to labradorite composition in the migmatitic gneisses and schists, occurrence of kyanite and sillimanite in the schists and high temperature indicated by anatectic migmatites. Occurrence of kyanite, sillimanite, and plagioclase suggests at least medium-pressure type of the Barrovian type facies series. Ekwueme (1990) also mapped rocks of Barrovian type facies grades in the Plateau.

Plastic deformation is indicated by lenticular leucosome minerals, ptygmatic folds and undulose extinction in quartzo-feldspathic minerals indicate plastic deformation (Ukaegbu and Oti, 2005). Anatexis parallel to the foliation of the gneisses resulted to migmatization and pegmatite emplacements in the area. Migmatization of the kyanite- sillimanite gneisses represents an early phase under water-rich condition in the emplacement of the Older Granite series (McCurry, 1989).

Magmatic Evolution: Tectonism under rising temperature gives rise to various degree of partial melting of the crust (Bowden et al. 1984) and older metaigneous rocks (Roberts and Clemens, 1993). Subduction and the consequent collision at the eastern margin of the West African craton (McCurry and Wright, 1977; Turner, 1983) produced extensive melting of the older rock suites resulting to the emplacement of the mainly calc-alkaline pegmatitic and basaltic intrusions.

The presence of biotite and muscovite in the paragenesis of the pegmatites indicates that water vapour contributed to the crystallization history of the pegmatites. The emplacement of foliated older pegmatites is considered to be due to syn-Pan-African remobilization, while the younger pegmatites were probably due to late tectonic Pan-African emplacements. Tectonic activities probably initiated in the upper mantle remobilized the Ube-Wulko area of the Pan-African belt. The pegmatite dykes were probably derived from extreme metamorphism of the host metasedimentary basement rocks. The pegmatites were emplaced in NE-SW to NW-SE ancient lineaments, and were probably of the same age with the Older Granites, hence slightly foliated due to the effects of the dying phase of the tectonism that emplaced the dolerite dykes.

Geotectonic History: The E-W collision of the West African craton and westward moving plate formed N–S to NE-SW trending structures parallel to the edge of the West African craton (Black et al. 1979; Champenois et al. 1987), and this is consistent with the structural patterns of the entire Nigerian Basement Complex and northern Cameroun (McCurry, 1976; Rahaman, 1976; Onyeagocha, 1984; Toteu *et al*., 1990). The collision that produced highly deformed series with multidirectional orientations of folds, lineaments and faults during the Pan-African orogeny reconfigurated the tectonic pattern of Ube-Wulko area. Undeformed basic intrusives were later emplaced parallel to the major N-S trends in the area.

The ubiquity of folds in the area infers tectonic origin of the planar features. Brittle to ductile deformations and ubiquity of such characteristics as complex disharmonic, drag and ptygmatic folds and shear zones played dominant roles in the development of the deformation history of the Ube-Wulko area. The numerous minor strike-slip fault with dextral and sinistral displacements mapped in the area probably resulted from cooling and contraction of folded metamorphic rocks (McCurry, 1971; Ekwueme, 1994). The dominant N-S to NE-SW trends suggest E-W to ESE-WSW tectonic arc succeeding the subduction and collision between the passive West African craton and the westward moving eastern Sahara plate (Champenois et al. 1987). The random orientations of some of the intrusive dykes appear to define this stress pattern.

The structural features of southeast of Akwanga that are dominated by roughly N-S trends (N15) with subordinate compressional stress in NW-SE trends (N105-N110) conform to the regional structural disposition in the Nigerian Basement Complex (Nyikwagh, 1990). The structural elements of the Ube-Wulko indicate polydeformation history involving pre-Pan-African to Pan-African orogenies. The Pan-African N-S deformation imprints are preponderant and pervasive in the area. These structures are similar to structures in the western half of Nigeria, the Obudu Plateau and the Cameroon (Ukaegbu and Oti, 2005).

CONCLUSION

The Precambrian basement rocks of southeastern Akwanga of northcentral Nigeria are composed of kyanite-sillimanite biotite migmatitic gneisses and seem to be derived from sedimentary protolith. The gneissic structure of the quartzo-feldspathic bands suggests extensive permeation of anatectic magma derived from partial melting along the foliation of the gneisses. Structures such as foliation, folds, tension gashes, joints and minor faults in the mapped area have resulted from processes of tectonism and metamorphism. These deformative processes accompanied one another at different episodes and have resulted to the geologic structures of the Basement rocks of the area. The events terminated with the emplacement of the dolerite dykes. Tectonic activities probably initiated in the mantle remobilized the crust in the Ube-Wulko area. Rifts developed, possibly due to crustal decoupling within the collision arc, appear very penetrative to allow vast volume of magma intrusions in the area.

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