



A review of Geotectonic Evolution of the Nigerian Crystalline Basement Complex.

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ABSTRACT

The evolution of the Nigerian basement complex can best be described in the regional context of the Pan African orogenic belt of West Africa. It is seen as a collision type orogeny with an eastward dipping subduction zone. The Basement Complex rocks are considered to be the result of at least four (4) major orogenic cycles of deformation, metamorphism and remobilization which correspond to the Liberian (2700Ma), the Eburnean (2000Ma), the Kibaran (1100Ma) and Pan- African cycles (600Ma). Thus the Basement Migmatite gneiss is said to evolved through three major geotectonic events: the initiation of crust forming processes, the emplacement of granites and Pan-African event. While the Schist Belts evolved through both ensialic and ensimatic processes. The trace element geochemistry of Nigerian Pan-African granites indicate that the granitic magmas were mainly derived from mantle sources but were heavily contaminated by crustal material and also by partial melting of lower crust. Another important characteristic feature of the basement tectonics is the wide spread occurrence of fractures and are indicated by lineaments as silicified sheared rocks and zones, which are form as dykes and ridges, also straight channeled streams which exploit the weak zones of the earth. Therefore, the principal fracture directions in the basement complexes are the N-S; NNE-SSW, NE-SW, NNW-SSE and to a lesser extent, the E-W.

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INTRODUCTION

The Nigerian Basement Complex is located in the Pan-African mobile belt sandwiched between the West African craton to the west and the Congo craton to the south east (Fig. 1). It is considered to be part of the reactivated Pan-African belt that resulted from the collision of the passive continental margin of the West African craton and active margin of the Taureg Shield. This Trans-Saharan-Pan-African orogenies led to the development of various high grade metamorphism, massive granite plutonism and late Orogen tectonics (Ominigbo *et al*, 2020; Okonkwo and Ganev, 2012). The basement is divided in to two contrasting provinces viz: the Western and the Eastern Nigerian provinces. The Western Nigerian Province is characterized by an Archean basement comprising tonalite-trondhjemite-granodiorite (TTG)-type

orthogneisses and amphibolites (Rahaman, 1988) and a cover of synformal schist belts (Grant, 1978; Fitches *et al.*, 1985; Ajibade *et al.*, 1987) ranging from green schist to amphibolite facies (Caby, 1989).

The Eastern Nigerian Province is characterized by high-grade metamorphic rocks (Onyeagocha & Ekwueme 1990), pervasive migmatization and granite plutonism (Wright, 1977; Ferre *et al.*, 1996) and a tin metallogenic province (Woakes *et al.*, 1987) and are typically Eburnean.

The present review is aimed at providing an overview of the geotectonic evolution of the basement complex of Nigeria that highlights the major lithologic units, geochronology, and structural aspects of the Nigerian Basement, in the overall framework of its evolution.

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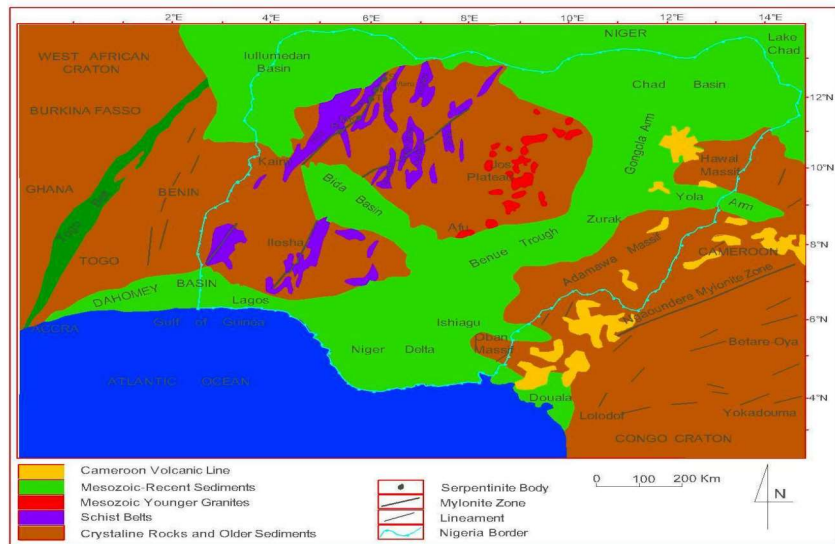


Fig 1: Location of the Nigerian Basement Complex between the West African and Congo Craton, in relation to Hoggar and Borborema Provinces (after Haruna, 2017).

LITHOLOGIES OF THE NIGERIAN BASEMENT COMPLEX

The Nigerian Basement is underlain by five different rock units (Rahaman, 1988; Danbatta, 2008; Ominigbo, *et al.*, 2020). These

include: Migmatite-gneiss-quartzite complex, Schist belts, Older Granites, metamorphosed to unmetamorphosed calc-alkaline volcanics and Hypabyssal rocks, and Unmetamorphosed dolerite dykes, basic and syenite dykes.

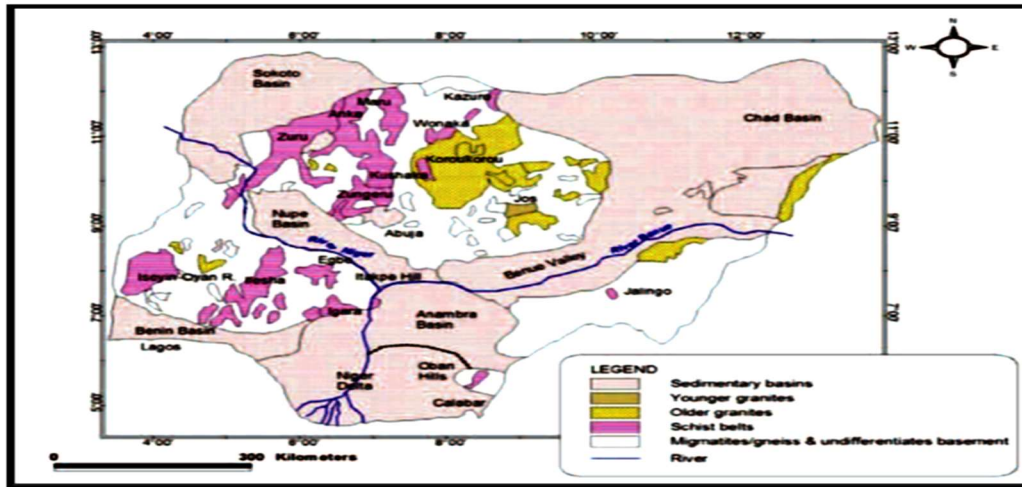


Fig 2: Geological Map of Nigeria (adapted after Black, 1980).

MIGMATITE GNEISS COMPLEX (MGC)

The migmatite gneisses are the oldest rocks in the basement and are thought to be

reworked older crust by orogenic events (Haruna, 2017) and considered as the Basement complex sensu-stricto (Rahaman, 1988; Dada, 2006), it is the most wide spread and forms the groundmass

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in which all other rocks seem to occur. Oyawoye (1972) recognized the following rock types as part of MGC: Banded gneiss; augen gneiss and pegmatites. However, Rahaman and Ukpon (1981) gave a petrologic division of the MGC that includes: (a) grey foliated biotite acid or biotite hornblende quartz feldspathic gneiss of tonalitic to granodioritic composition, which is also known as the "grey gneiss"; (b). mafic and ultramafic components which when present, often outcrop as discontinuous boudinaged lenses or concordant sheets of amphibolites with minor amounts of biotite-rich ultramafic; and (c) Felsic components of a varied group of rocks consisting essentially of pegmatite's, aplite, quartz oligoclase veins, fine-gained granitic gneiss, and porphyritic granites etc.

These three components may or may not be present together on a single outcrop. Also, petrographic evidence indicates that the Pan-African reworking led to recrystallization of many of the constituent minerals of the migmatite – gneiss complex by partial melting, with majority of the rock types displaying medium to upper amphibolites facies metamorphism and are Archean in age (Dada *et al.*, 1995).

SCHIST BELTS (Metasedimentary and Metavolcanics)

The Schist belts are composed of older metasediments and the low-grade younger metasedimentary and metavolcanic rocks that are well developed in the western part of Nigeria west of longitude 8°E (Western Province), though smaller occurrence are found in the east. In the

South east and North eastern Nigeria (Eastern Province), Rahaman and Ukpong (1981) reported the occurrences of schists in Jalingo and the Oban Hills (Fig. 2), while Haruna, 2017 reported the occurrences of schist around Madagali (Hawal Massif), Toungo and Gayam (Adamawa Massif). There are nine major schist Belts in NW Nigeria, and these include: i) Anka; ii) Maru; iii) Birnin-Gwari; iv) Wonaka; v) Malumfashi; vi) Kazaure; vii) Toto; viii) Zuru and ix) Kushaka (Fig.3).

In the south western part of Nigeria there are three of such belts viz: i) Iseyin-Oyan river belt; ii) Ife-llesha belts; and iii). Igarra-Kabba –Lokoja belt. The Iseyin-Oyan river belt appears to form part of the Archean gneiss quartzites schist sequence in the Ibadan area (Burke *et al.*, 1976). The Ife-llesha belt consists of two contrasting rock assemblages separated by a NNE trending Ifewara fault (Klemm *et al.*, 1984; Boesse and Ocan, 1988; Elueze, 1988). The Igarra-Kabba-Lokoja belt consist of metapelites with interlayered quartzites and marble (Turner, 1983; Annor, 1998).

The lithologies of the schist belts have similarities and generally consist of coarse-fine grained clastics, pelitic schist, phyllites, banded iron formation (BIF), Carbonate rocks (marbles) dolomitic marbles and mafic metavolcanics (amphibolites), some may include fragments of ocean floor material from small back-arc basins. Based on structural and lithological association Ajibade *et al.* (1979) concludes that the schist belts contained identical deformational histories and mapped a structural break. In age the schist belt rocks are considered to be upper Proterozoic.

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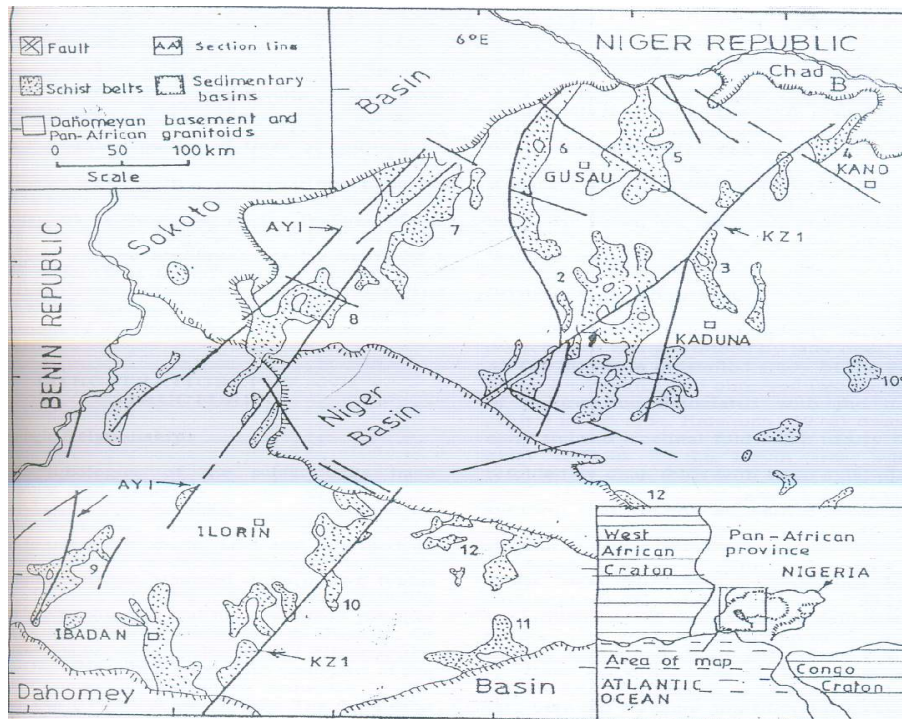


Fig. 3: Simplified geological map of the Northern and Southern part of the western half of Nigeria, showing the distribution of the schist belts and the locations of major lineaments (after Garba, 2002).

THE OLDER GRANITE

The term older granite or Pan-African granitoids was introduced by Falconer (1911) to differentiate the deep-seated, often concordant or semi-concordant granites of the basement complex from the high-level, highly discordant tin-bearing granites of north central Nigeria. They included; the pre, syn and post tectonic granitoids which intruded both the migmatite gneiss-quartzite complex and schist belts. They range widely in age (750 – 450 Ma) and were formed during a magmatic cycle associated with Pan-African orogeny. The rocks range in composition from tonalites and diorites through granodiorites to true granite and syenite. Charnockites also form an important rock group emplaced during this period. They are generally high level intrusions and anatexis has played an important role during their formation (Rahaman, 1988)

VOLCANICS AND HYPABYSSAL ROCKS

Sub-volcanic complexes occur in several places in north-west and north-east Nigeria, and are either or partly intrusive into Older Granite bodies. They include: volcanic arc tuffs, rhyolites, rhyodacites and dacites, and are chemically similar to high calc alkaline volcanics and hypabyssal rocks presently occurring at the margins of the Pacific orogenic event. Preliminary age determination in northwestern Nigeria indicates that these rocks were emplaced during epeirogenic uplift and regional cooling towards the close of Pan-African orogeny, while temperatures in the granites were still above the blocking temperature for biotite. This may account for the general absence of chilled contacts and for the high degree of alteration in many of these rocks. Common alteration minerals are; calcite, epidote and secondary sericite and the original composition is often difficult to determine.

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DOLERITE DYKES, BASIC AND SYENITE DYKES

Dolerite dykes are wide spread in the basement and have been described in association with all the other rock types. They occur as tabular and unmetamorphosed bodies, often with chilled margins. They cut across pre-existing foliation in the host rocks and are regarded by most authors as the young members of the basement complex. They range in size from few millimeters to several metres in thickness. Structurally, they mostly tend to follow NE-SW and ENE-WSW directions i.e. they are related to the major fracture directions which have been recognized within the Basement (Rahaman 1988).

GEOCHRONOLOGY AND OROGENIC EVENTS IN THE NIGERIAN BASEMENT

The Nigerian basement rocks are believed to be the result of at least four (4) major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2700Ma), the Eburnean (2000Ma), the Kibaran (1100Ma) and Pan-African cycles (600Ma). The first three cycles were characterized by intense deformation and Isoclinal folding accompanied by regional metamorphism, which was further followed by extensive migmatization. The Pan-African deformation was accompanied by regional metamorphism, migmatization and extensive granitization and gneissification.

LIBERIAN EVENT

Rocks of the migmatite gneiss of the Nigerian basement have been correlated with the basement rocks of Dahomey, which led to believe that the greater part of the Nigerian basement is Dahomeyan i.e. older than 2600Ma. McCurry, 1973. Grant (1970) suggested an age of 2800Ma from Ibadan on banded gneiss, which was confirmed by Oversby (1975).

Evidence for the presence of rocks of Archean age was also obtained using the Pb-Pb method from the Ibadan area of South Western Nigeria, where an age of 2750Ma was obtained on some dolerite dykes which cut banded gneiss (Oversby, 1975). Similar ages of 3100 have been obtained using Rb-Sr method from the Kaduna migmatite (Ogezi, 1977). U-Pb zircon ages of

2500Ma – 2400Ma on grey gneisses from northern and SW Nigeria were found.

EBURNEAN EVENT

Grant (1969; 1970) obtained a ten (10) point Rb-Sr Isochron of 2280 + 75Ma from Ibadan granite gneiss and K-Ar mineral and whole rock ages of 478 – 569Ma from the same samples and some minor intrusions. The granite gneiss was believed to have intruded into the banded gneisses (Grant, 1970; Burke *et al.*, 1976). Moreover, according to Grant (1970) the K – Ar ages reflect the imprint of the Pan-African event which he considered to be largely a thermal event. However, Ogezi (1977) obtained indications of Eburnean event and older ages from gneisses and migmatites from various parts of northwestern Nigeria. Data on the Kaduna (Kabala) migmatites are mostly scattered between 3100Ma and 2400Ma reference lines on the isochron diagram. The ages of Kaduna (Badarawa) migmatites are also scattered between 2600Ma and 2100Ma. While Malam Tanko and Malunfashi migmatites show a much broader age of 600 and 3100Ma reference lines.

Rahaman (1976) have obtained a data on grey gneisses which indicate an eburnean event from parts of south-western Nigeria, (the ages ranges between 1850-2500Ma).

THE KIBARAN

The Kibaran orogeny is recognized in several regions of Africa. It is named from the Kibaran mountains of eastern Zaire and the age of the orogeny ranges from 1300Ma for the main tectonic phase, to 900Ma for the emplacement of late granites and pegmatite's (Cahen *et al.*, 1984). The Kibarides have been interpreted as ensialic, floored by and terminated within an older continental basement (Kroner, 1984).

The present of Kibaran event is the most hotly contested event in Nigeria. The first evidence for a Possible Kibaran event was provided by Grant *et al.* (1972) who obtained Rb- Sr isochron age of 1175Ma – 140Ma from Ile – Ife gneiss. Ogezi, 1977 obtained an age of 1065 – 65Ma on the Maru belt phyllites, he interpreted this age as dating the metamorphism of the phyllites and concluded that the Kibaran was a major orogenic

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event in north western Nigeria. This date was confirmed by a re-run of the same samples (Ajibade, 1980). Ogezi, 1977 also indicated possible Kibaran effects from migmatites and gneisses of MallamTanko and Malunfashi area, the Funtua migmatites and the Kaduna Badarawa pegmatite's. It is emphasized that the Kibaran age is not widely accepted either in Nigeria or in the Hoggar, as no granites have given this age. The U/Pb Zircon age of 1850Ma reported by Rahaman, 1988 from the Ile – lfe granite gneiss invalidates the precise Rb/Sr isochron age of 1275Ma obtained by Grant, 1978 on the same granite gneiss body.

PAN-AFRICAN

This Pan- African orogenic event is a continent wide event which led to the reworking of the older crust, giving rise to a polycyclic basement and imposing a broadly N-S structural trends on the region (Ominigbo, 2022). It was during this event that the wide spread, Older Granites were emplaced in to the pre-existing migmatite – gneiss complexes and the schist belts. The majority of age determination in Nigeria are Pan-African, roughly between 750 and 450Ma (Truswell and Cope, 1963; Ajibade, 1980). The studies by Van Breemen *et al.*, (1977) in north – central Nigeria have gone a long way in establishing the Pan-African age of Older Granite emplacement in Nigeria. The Panyam foliated granite yield Rb-Sr isochron age of 677 + 161Ma. The Bauchi foliated granite gave an Rb- Sr isochron age of 609+12Ma.

Ogezi (1977) obtain Rb – Sr isochron ages of 679+ 65 Ma and 794+73Ma of the mainchi granodiorite and Zaria porphyroblastic granite respectively. The older of these ages is considerably higher than the 610Ma peak of plutonism. Matheis and Caen-Cahette (1983) have reported seven Rb-Sr isochron and four Rb-Sr mineral ages from Older Granites and pegmatite's from Aramoka, Ifero, Egbe and in south western and Wamba in central Nigeria. The Rb/Sr isochron ages range from 632 + 16Ma for the Egbe granite to 534 for the Egbe pegmatite. Most of the pegmatites gave ages of 550 – 535Ma.

But muscovite from Aramoko area gave Rb-Sr age of 490 + 14Ma. Ajibade (1980) consider

that these results indicate that the emplacement of the pegmatites is distinctly later than the Older Granites. Biotite from Aramoko and Ijaro gave Rb/Sr age of 185 + 6Ma and 185+5Ma respectively. These ages were interpreted as indicating a late thermal event related to the emplacement of the Jurassic Younger Granite ring complexes and that the effect of the Younger Granites emplacement is probably more wide spread than was previously supposed. Danbatta (2008) obtain Rb-Sr Pan-African age of 592 + 14 from the Kazaure granitoids.

FAULTS AND SHEAR ZONES

A characteristic feature of the basement complex tectonics is the wide spread occurrence of fractures, a general term used to describe any break or rupture in a rock, and indicated by such lineaments as silicified sheared rocks and zones, which form as dykes and ridges, also straight channeled streams which exploit the weak zones of the earth. The principal fracture directions in the basement complexes are the N – S; NNE –SSW, NE-SW, NNW-SSE and NW-SE. The E-W structures are localised in their occurrence to such areas as Akure and the eastern flank of the country (Fig 4) and presumable that the E-W fractures are the oldest and difficult to recognize in the field and aerial photographs.

The N-S fractures, easily identified as prominent scarp surfaces and depressions, appear to have controlled the major N-S following streams e.g. the lower Niger, and are also found around the Jos plateau. They are traceable as far north as the Taureg area of Niger republic (Ball, 1980). These fractures are also marked by considerable shearing and brecciation, features attributable to brittle deformation. Other structural trends include the NE-SW and NW-SE conjugate ones being characterized by a dextral sense of movement. The faults have been interpreted to result from transcurent movements. The Benue and Niger troughs are aligned parallel to the conjugate sets, as are several, other comparable sets on either side of the troughs. The NNE-SSW and NNW-SSE conjugate sets are also well developed on the basement complex (Fig.4). Some of the important lineament features include the:

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- (i) Pambeguwa- Bauchi shear zones (Ferre *et al.*, 1998)
- (ii) The Anka belt fractures in the north western parts, which are characterized by concavo planar surfaces,
- (iii) The Ifewara fault (Wright, 1976), which is most likely the southern equivalent of the Zungeru system, a lineament traceable to the Niger republic.

In the Jos Plateau and the extreme eastern parts, these conjugate set appear to control the emplacement of the volcanic rocks and plugs of Cretaceous to recent age, aligned principally along these directions.

Also Wright (1970), discussed major N.E trending faults in Nigeria. These faults are strike slip faults which he considered connected to the initiation of fractures in the South Atlantic.

Present Landsat studies also reveal the existence of these lineaments west of Kaduna and Zaria. These are the Yelwa and Kalangai (Truswell & Cope, 1963) shear faults. The former possibly passes as traces beyond Katsina under sediments, while the latter is suspected to continue beyond Kano also in to the sediment.

Two main trends have been captured by Landsat Tm Study by Goki *et al.* (2011) and include NW-SE longer lineament and a second pair of NE-SW and NNE-SSW trends, which appear to be abundant but spatially discontinuous and shorter. These trends coincide with deep aeromagnetic trends, which have been attributed to an extension of Atlantic fracture zone that extends into the Nigerian basement complex (Olasehinde and Annor., 1990).

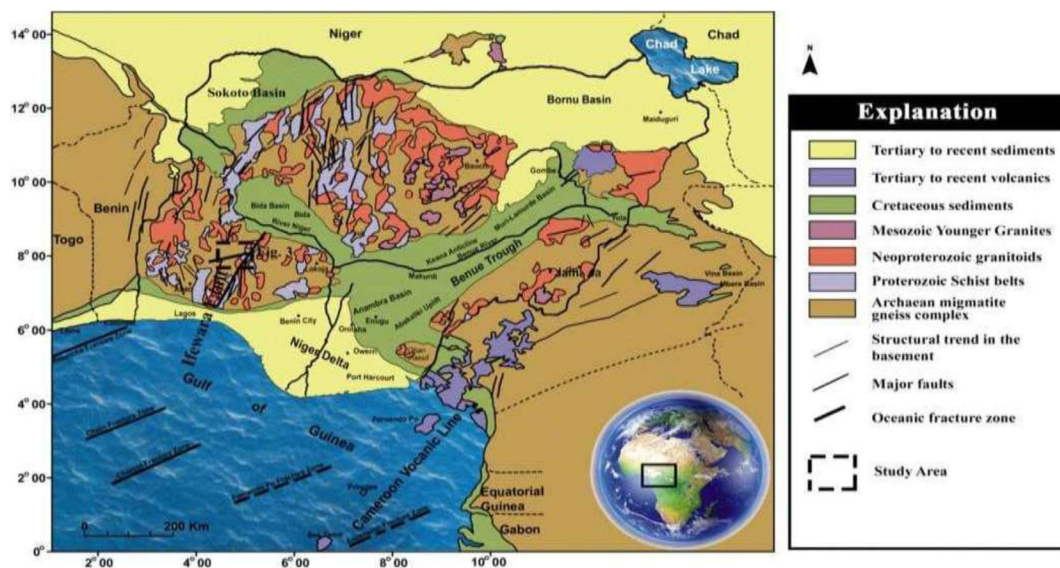


Fig 4: Generalized geological map showing Structural trends in Nigerian Basement Complex (Adapted from Salawu *et al.*, 2021)

FOLDS AND FOLIATIONS

Field and laboratory studies indicate that the foliations present in the basement complex rocks are essentially tectonic and metamorphic in origin. Hence, in the migmatite gneiss complex the dominant foliation, defined by alternating dark and light bands and prominent gneissity in the migmatite gneiss complexes, trend roughly N- S with variations between NW-SE and

NE-SW. East-West foliations have also been recorded locally, especially in the migmatitic rocks around Kishi, north of Shaki (Ayoade, 1984), the Kabba region (Hockey *et al.*, 1986) and South of Minna (Sheet 185, Paiko). These are probably the earliest folded structures which are now preserved as relicts, especially in the migmatites. Mullan (1978) is of the opinion that they are pre-Older Granite i.e. pre-Pan African events.

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The Precambrian schists, phyllites and quartzites of the metasedimentary series, have been shown to have preserved in them more than

four foliations representing four folding phases as shown in table 1.



Fig 5: Show a sketch of the tight- isoclinal fold.

- i. The earliest folds were seen in small scale structures from BirninGwari ,Zungeru areas (Grant, 1978; Ajibade, 1980) and Abuja. The folds are tight to isoclinal with steep to vertical hinges and exhibiting widely varying wavelengths (Fig.5).
- ii. The second folding phase is similar in profile to the earliest structures.
- iii. The third generation of minor folds is open and smooth.
- iv. The fourth folding is typified by strain slipped cleavage and kink bands of restricted occurrence.

Such multiple folding phases have also been recognized in the metasedimentary rocks around Okene (Hockey *et al.*, 1986) and Anka region (Ogezi, 1988; Egbuniwe, 1982). On a regional scale, at least four folding phases superposed on each other have been established especially in the more ductile metasedimentary formations (Table 1).

Table 1: Deformation and structural history established for the schist belts in the NW Nigeria (after Danbatta, 2008)

Belt/Sour ce of Informati on	Kazaure Belt (Danbat ta ,2002)	Malumfa shi Belt (Mc Cury,19 73)	Anka Belt (Holt,19 82)	SW of Zuru Belt(Danbatta, 1991)	Kushaka Belt (Grant,19 78)	Birnin Gwari (Ajibade,19 80)	Maru Belt (Egbuniwe, 1982)
Deformat ion events							

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D4					Rare and relict minor folds. Local development of strain-slip cleavage	Steeplly dipping folds and kinks. Axial planes strike N-S/E-W.	Steeplly dipping kinks with E-W strike
D3				Open folds with smooth profiles and sleep NNE-SSW axial planes dip	Open folds with NNE-SSW axial planes. Axes plunge north and south.	Open folds NE-SW axial dip and rounded or angular crest.	Open to tight Chevron folds and tight to isoclinal folds
D2	Upright isoclinal s folds with NNE-SSW axial planes. Cleavages developed	Tight to isoclinal s D _L fold with N-S axial planes strike. Cleavages developed	Steeplly dipping, E-w striking bands.	Tight to isoclinal folds with moderate plunging axes, N-S cleavages developed.	Tight to isoclinal disharmonic folds with steep axes. Axial planes strike N-S	Co-planar with D ₁ . Open to isoclinal large scale folds of S, schistosity. Axial planes strike NE-SW.	Open to isoclinal folds. Steeplly dipping N-S striking cleavage.
D1	Relict recumbent isoclinal s folds with N-S trending axial planes. Mostly obliterated.	Early ENE-WSW foliation mated to D _E folds. Largely obliterated.	Open to isoclinal s upright folds with NNE-SSW axial planes and Axes.	Rare and obliterated minor folds with shallowly dipping E-W to ENE-WSW trends. S ₁ axial plane cleavage.	Rare minor folds with E-W axial planes.	Folding of cover rocks on NE-SW trending axial planes. Cataclastic deformation of basement cover contact. Cleavage well developed.	Relicts flat lying folds with N-S axes and S ₁ cleavage. Folds obliterated by transposition

Hence the Nigerian basement complex consists of a series of close to open antiforms and synforms, which are better preserved in the north – south trending quartzite's, banded iron formations and related rocks.

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EVOLUTIONARY MODELS OF THE NIGERIAN BASEMENT COMPLEX

The Evolution of Nigerian basement is considered to be related to the activities taking place at the plate boundary. It involved crustal extension and continental rifting at the West African craton margin, about 1000Ma ago, which led to the formation of graben like structures in western Nigeria, and the subsequent deposition of the rocks of the schist belts. Closure of the ocean at the cratonic margin about 600Ma and the crustal thickening in the Dahomeyan led to the deformation of the sediments, the reactivation of pre-existing rocks and the emplacement of the Pan-African granite. So, the geotectonic setting in which the rocks of the basement originated, are similar to those of Island arc and bark arc settings.

EVOLUTION OF THE BASEMENT MIGMATITE – GNEISSES (MGC).

The migmatite-gneisses are well exposed in the Nigerian basement complex (McCurry 1976; Rahaman 1976; Dada 1998; Ekwueme, 1995). The gneisses of the migmatite – gneiss complex of Nigeria are inter leaved with amphibolite that may be derived from the mg rich rocks such as continental basalts (Caby *et al.*, 1990; Dada, 1999). The Archean migmatite gneiss complex represents a reworked TTG terrain of migmatite – gneiss, including plagioclase rich leucosomes and potassic augen, cross – cut by quartz veins, aplites and pegmatites of late Proterozoic age as determined from lower intercept ages on U-Pb Concordia (Dada, 1999). The heterogeneous nature of Pan- African remobilization is evident in places where Paleoproterozoic rocks have survived 600Ma resetting, e.g. the Kabba Okene gneisses (Annor 1995). While in some areas the isotopic record of accessory minerals such as zircon, monazite, tantalite and apatite in pre-Pan- African rocks has been completely reset during the Neoproterozoic (Dada, 1999). According to Rahaman and Ocan (1978) the MGC evolved through three major geotectonic events: (a) the initiation of crust forming processes during the early Proterozoic (2000 Ma) example the Ibadan grey gneisses considered by Woakes *et al.*; (1987) has been derived directly from the mantle. (b) Emplacement

of granites in early Proterozoic (2000 Ma), and (c) Pan- African events (450Ma- 750Ma).

EVOLUTION OF THE SCHIST BELTS

The Nigerian schist belts are assumed to be of two types (Danbatta, 2007); those composed of older metasediments (mainly found in SW Nigeria) and the low-grade younger metasediments (mainly found in NW Nigeria).

The closure of the ocean at the West African cratonic margin led to the deformation and metamorphism of the sediments and underlying basement during the Pan- African Orogeny (Oyawoye, 1972; McCurry, 1973; 1976; Ajibade, 1971; 1976; Chukwu-Ike, 1978; Danbatta, 1999). But Vaniman (1976) see the existence of a major sedimentary trough to be responsible for the deposition of the Nigerian schist belts. A similar scenario was postulated by Chukwu-Ike (1978), who argued that the schist belts in NW Nigeria are fault bounded ensialic troughs. Similarly, Turner (1983) considered the Anka belt with Maru, Birnin-Gwari, Wonaka, Malumfashi and Kazaure belts, as originating in one back arc basin. The Zuru and Kushaka belts were also considered to have formed in a separate basin, with the Zuru quartzites representing basin margin deposits. The evolution of the schist belt is also considered in the context of Eburnean deformation, under extensional and compressional regimes (Danbatta, 2008). Schist belts without Mafic and Ultramafic rocks but with documented presence of Algoma BIFs are considered ensialic and Eburnean in age. BIFs are absence in those schist belts whose origin is ascribed to ensimatic processes and Pan-African in age.

The structural control is also important for the evolution of the Schist belts; the huge Anka-Yauri – Iseyin (AYI) and the Kalangai – Zungeru – Ifewara (KZI) lineaments that traverse throughout the area are considered as deep-faults defining tectonic blocks. Along the AYI fault Zone, Wilson Cycle processes involving the opening and closing of east – west back arc oceans have operated at least locally. Closure of the basins led to the deformation of the sediments, the reactivation of pre-existing rocks and the formation of the remaining schist belts and syn orogenic Plutonism. All the models of evolution of

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Nigerian schist belts over the years could be classified under ensialic and ensimatic processes.

Ensialic Models

According to those in favour of ensialic evolution processes, crustal thinning in response to initial crustal extension and continental rifting at the cratonic margin some 1000Ma ago, lead to deposition of sediments in graben like structures floored by continental crust. The closure of the ocean at the West African cratonic margin led to the deformation and metamorphism of the sediments and underlying basement resulting in the formation of the schist belts and reactivation of older basement during the Pan-African Orogeny (Oyawoye, 1972; McCurry, 1973; 1976; Turner, 1983; Ajibade *et al.*, 1987; Danbatta, 1999). While Vaniman (1976) proposed the existence of a major sedimentary trough to be responsible for the deposition of the Nigerian schist belts, Chukwu-lke (1978) argued that the schist belts in NW Nigeria are fault bounded ensialic troughs.

Turner (1983) considered the Anka belt with the Maru, Birnin Gwari, Wonaka, Malumfashi and Kazaure belts, as originating in one back – arc basin. The zuru and kushaka belts were considered to have formed in a separate basin, with the Zuru quartzite, representing basin margin deposits. Fitches *et al.* (1985) and Udoh (1988) envisaged complex volcano-sedimentary trough deposits, with the formations in the belts being lateral facies equivalents. Corroborating this view, Ajibade *et al.* (1987) for the entire Nigerian schist belts who proposed the formation of back-arc graben like structures in Pan-African times to be responsible for the formation of the schist belts.

Ensimatic Models

Ensimatic models of evolution had also been repeatedly proposed to explain the evolution of some of the schist belts (e.g. Ogezi, 1988; McCurry and Wright, 1977; Holt *et al.*, 1978; Utke, 1987; Danbatta, 1991; Elueze, 1992). For the Anka, Ife – Ilesha and Zuru belts, earlier works suggested that oceanic basins closed to form some of the schist belts, invoking the formation of marginal back-arc basins floored by oceanic materials that accepted sediments. The closure of these basins led to the deformation and

metamorphism of the sediments and reactivation of older metasediments.

Holt (1982) observed that the Anka metavolcanics have chemical characteristics of both island arcs and continental environment. He concluded that the schist belts were deposited in a retro-arc basin related to the subduction processes along the margin of the West African craton. The Anka fault system in the zuru belt and Ifewara fault system have ensimatic affinities. The Anka and Zuru belts are considered as a pair of belts that evolved through ensimatic processes.

Ensialic and Ensimatic Models

According to Danbatta (2008) who proposed a new evolutionary model for the Nigerian Schist Belts suggesting that the belts evolved from both ensialic and ensimatic processes because of common characteristics such as the presence of BIFs and close proximity to KZI fault zone. He also considered, the Wonaka, Kazaure, Zungeru, Birnin Gwari, Malumfashi, Igarra-Kabba-Lokoja schist belts as a group of eastern older belts. They are assumed to have been formed by similar ensialic processes in Eburnean times with some deviations in general evolutionary trend.

The new model by implication has shown that schist belts associated with the AYI fault zone including the Anka, Zuru, Maru, Kushaka, Iseyin and Ife-Ilesha belts are Pan-African in age and were generated by ensimatic means. He also considered the BIF-bearing eastern schist belts to be older than the western schist belts where BIFs are absent. On this basis and considering the concordant models of evolution earlier proposed for the different belts, the poorly known Wonaka belt is also likely to contain BIFs, as it could have truly formed through ensialic regimes. This new model rejects the previous wholly ensialic and wholly Pan-African

GENESIS OF THE OLDER GRANITE

A number of geochemical and isotopic data have recently become available on the granitoids of the Nigerian basement and have answered the question on the origin of granites, i.e. whether they are juvenile additions to the crust

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or represent remobilized crustal rocks (Van Breeman *et al.*, 1977). Some of the granitoids show an iron-enriched fractionation pattern which is closer to the trend shown by tholeiitic rocks. The granitoids belong to the 1 – type of White and Chappel (1974).

Rb – Sr isotopic measurement on the Older Granite from different parts give initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios which range from 0.7065 – 0.7125. These initial ratios are significantly above the “expected” upper mantle values 600Ma ago. The expanded composition and the trace element geochemistry of the Nigerian Pan-African granites indicate that the granitic magmas were mainly derived from mantle sources but were heavily contaminated by crustal material and also by partial melting of the lower crust. This suggestion was confirmed by other workers e.g. Danbatta (2008) on Kazaure granitoids who concluded that a lower crustal source for the granite rocks in northwestern Nigeria, is the interpretation that fits the present existing one on the genetic evolution and emplacement of the Older Granites in Kazaure schists and possibly other parts of the NW Nigerian basement.

SUMMARY AND CONCLUSION

Nigeria is situated within the active Pan-African region of Orogenies which is considered to be a mobile belt in the eastern flank of the stable West-African craton. Therefore the crystalline rocks that crops out in Nigeria are predominantly gneiss, migmatites, gneissose granite and schists, these form the basement on which sediments were deposited and unto which igneous rocks were emplaced.

Geochronological works has demonstrated that the Nigerian basement complex includes rocks of Liberian, Eburnean, Kibaran and Pan-African ages. Also, the evolution of the basement can best be seen in the western part of the basement, which attest to the polycyclic nature of large parts of the basement. The distribution of age and field evidence from eastern Nigeria and western Cameroun also point to the existence of mainly Pan-African rocks.

The most prominent of the structural trends is the N-S planar structures but relicts of E-W, NE/SE and NW/SE structures are preserved.

The basement is also characterized by several sets of fractures with Northeasterly-Northwesterly conjugate sets predominating.

Plate tectonic models have been applied to explain the evolution of the Pan-African belt east of the West-African Craton, although some workers still appear to favour ensialic models.

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