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ON THE EVOLUTION OF THE KAZAURE SCHIST BELT OF NW NIGERIA: A RE-INTERPRETATION

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ABSTRACT

All previous models of evolution of the Kazaure Schist Belt (KZSB) invoked a simple ensialic mechanism in the context of Pan-African deformation which led to the formation of a marginal back-arc basin floored by continental materials that accepted sediments. The closure of these basins in Pan-African times led to the deformation and metamorphism of the sediment and reactivation of older sediments. Taking into account the presence of Banded Iron Formations (BIFs), metavolcanics and the Kalangai-Zungeru-Ifewara (KZI) fault in the belt, a new model of its evolution is proposed.

The new model of evolution of the KZSB considers the evolution of the belt by invoking a simple ensialic mechanism under extensional and compressional regimes, in the context of both Eburnean and Pan-African deformations, as well as Pan-African intrusion of calc-alkaline granites and volcanics. It is effective in explaining the occurrence of BIF, quartzites, conglomerates, and Pan-African granitoids in the belt; and emphasizes the presence of the KZI fault in the evolution of the Kazaure belt. The study led to the conclusion that the belt has formed through ensialic processes, and an evaluation of previous data suggested in previous works is consistent with the new view that the KZSB may represent remnants of Paleoproterozoic cover rocks infolded within an Archaean migmatite-gneiss complex during an Eburnean event, and become reactivated during the Neoproterozoic Pan-African event.

KEY WORDS: Evolution, Ensialic, Back-arc basin, Pan-African, Eburnean.

1. INTRODUCTION

The polycyclic Nigerian basement terrain consists of Archaean, Eburnean as well as Pan-African granitic and metamorphic rocks into which are folded discontinuous N-S schist belts (Ajibade, 1976; Ekwueme and Kroner, 1994; Dada, 1998; Dada et al., 1993; Danbatta, 1991). The schist belts are composed of low-grade deformed metasediments and metavolcanics that are intruded by granitoids. One of this is the Kazaure Schist Belt (KZSB) which lies in the eastern margin of the NW Nigeria basement mostly within Jigawa state of Nigeria and parts of Kano and Katsina states. Its extreme northeastern portion is covered by sediments of the Chad and Gundumi formations, while its eastern and western sides are flanked by a migmatite–gneiss–granite basement terrain (Figs. 1 and 2).

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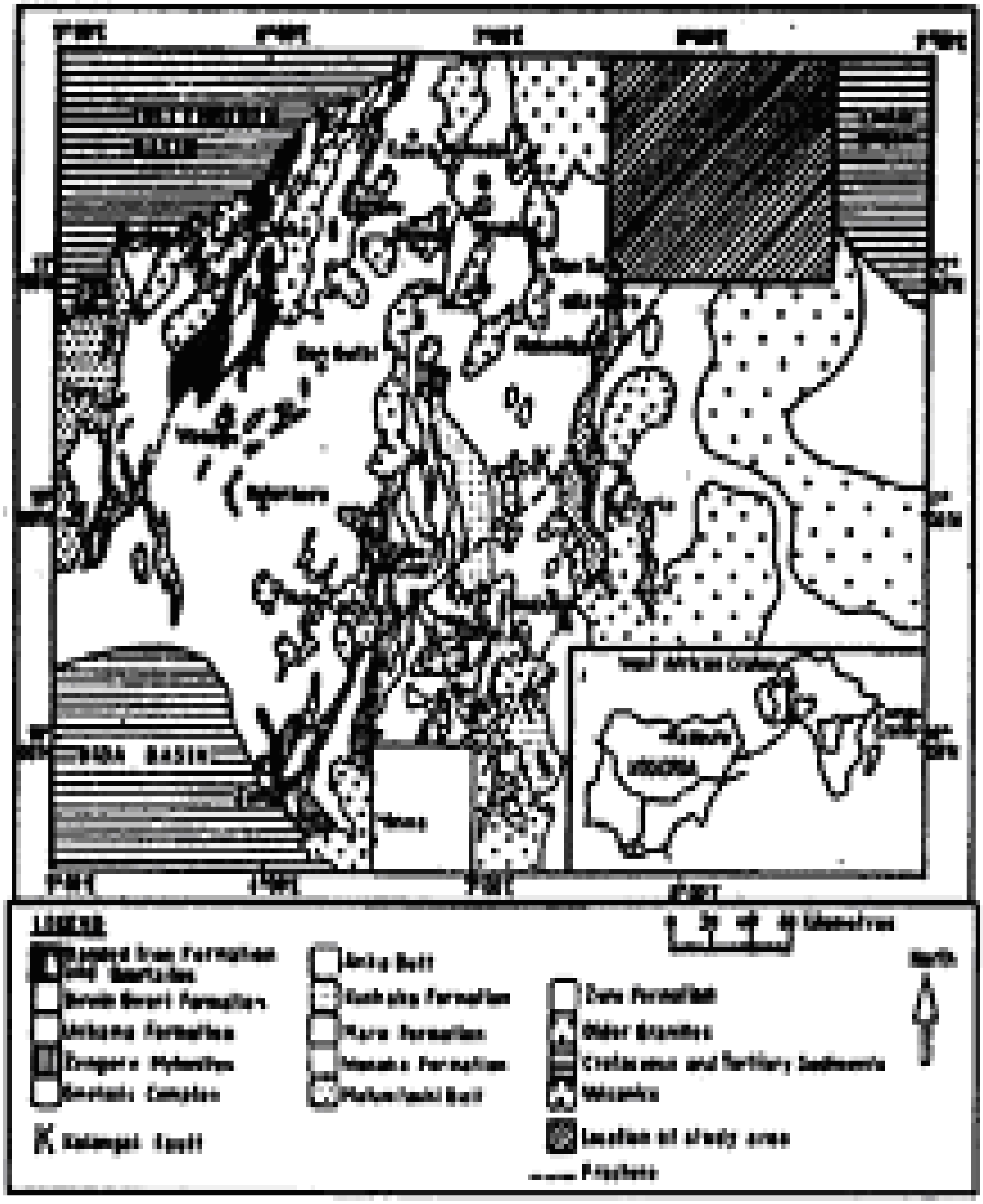

Fig. 1. The study area superimposed on the geological map of NW Nigeria (modified from Ajibade, 1980).

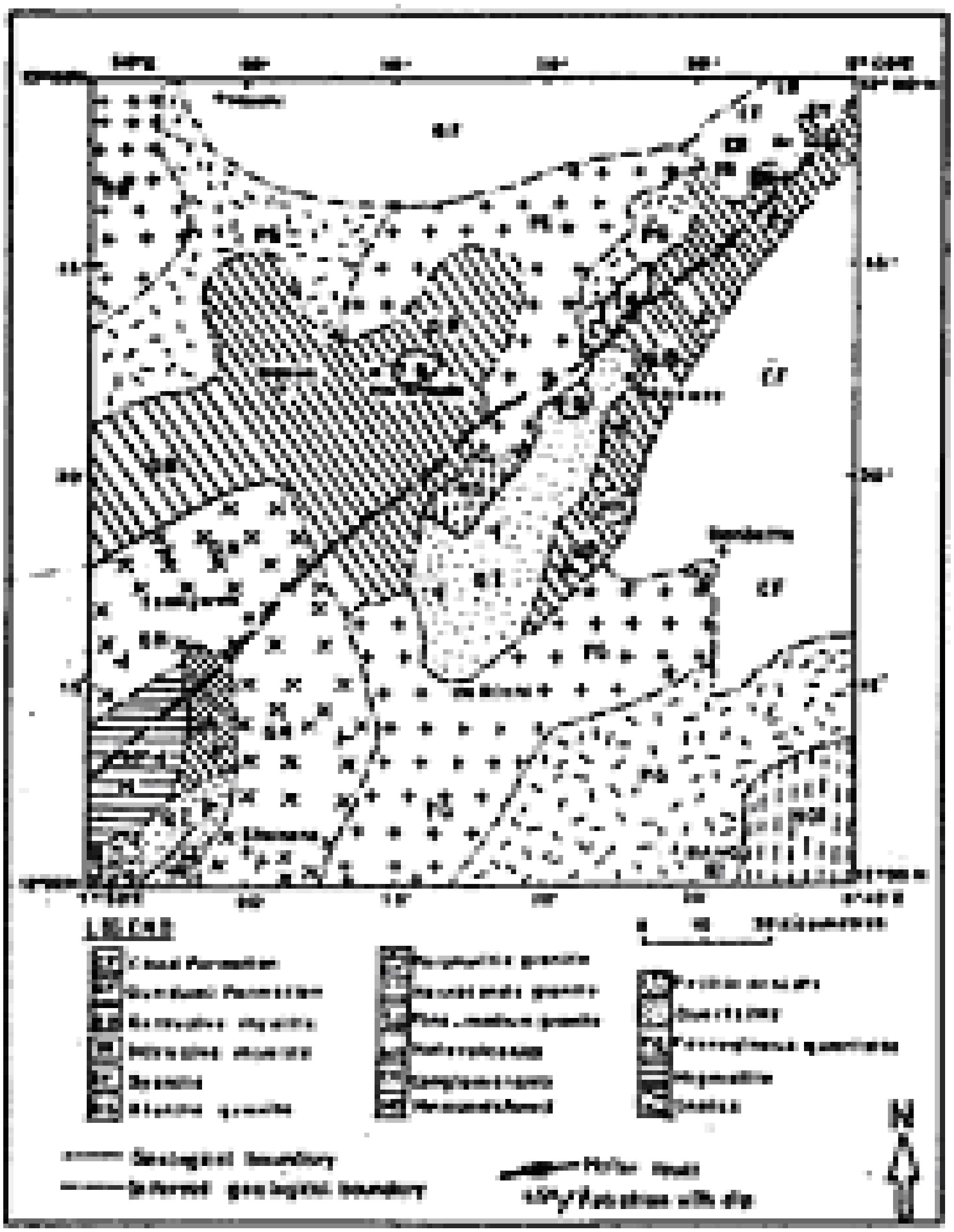

Fig. 2. Geological map of Kazaure and adjacent areas (This work).

Just like the Birrimian sequence of Ghana is cut by 2100 Ma granitoids (Wright et al., 1985) so also are the metasediments of Western Nigeria (Grant, 1970; Rahaman et al., 1983, Annor, 1995; 1998). Late Proterozoic granitic rocks yielding Eburnean (Paleoproterozoic) ages within the Nigerian basement have been documented by a number of other workers such as Grant et al. (1972), Van Breemen et al. (1977), Caen-Vachete and Umeji (1987). Ajibade et al. (1987) reviewed the nature of the early Proterozoic Eburnean event in Nigeria which clearly indicates the importance and involvement of the Eburnean event in the evolution of the Nigerian Basement. According to these authors, the Eburnean event was accompanied by sedimentation, deformation, as well as metamorphism and syntectonic igneous activity.

The Eburnean orogeny is regarded as the last major orogenic event to have affected the West African craton on a regional scale (Wright, 1985). It is considered to have resulted from a continent-continent collision along an eastward dipping-plane, now marked by the occurrence of a thick mylonite zone along its suture at Sassandra (Wright, et al., 1985; Ferre et al., 1996).

The geology, structures, metamorphic history and mineralization of the KZSB have been summarized in a number of reports and papers, such as those of Morton (1967), Turner and Web (1974), Aderotoye (1977), Turner (1983), Ajibade et al. (1987), Danbatta (1999; 2001; 2002; 2003a) and Ibrahim (2002). These workers have shown that the belt consists of metasediments, metavolcanics and banded iron-formations that are intruded by Pan-African Older Granites. Some of these previous works in the KZSB are not recapitulated here, only generalized descriptions that will aid in constraining the evolution of the belt are given.

The outstanding point of contention about the belt concerns its mode of evolution and timing of formation and deformation of the basin of deposition.

All the previous models of evolution of the KZSB proposed a Pan African age for the belt, and that its crustal components were deformed and metamorphosed for the first time during the Pan-African event. This paper reviews some of these earlier arguments published to date concerning the evolution of the KZSB, bearing in mind the recent work by Danbatta (1999;2003b) and Aliyu (2006) which clearly demonstrated the occurrence of BIFs in the belt, as well as the models of evolution earlier proposed for belts with similar BIFs occurrence.

2. Lithologic and Structural Relationships

The main lithological units of the KZSB include migmatitic-gneiss basement, low-grade "younger metasediments", acid and intermediate metavolcanics, granites, fault rocks, as well as rare Algoma-type banded iron formations (BIFs). However, there are no mafic or ultramafic rocks in the belt. The "younger metasediments" consist of pelitic to semi-pelitic schists, quartzites, metaconglomerates, metasandstones and calc-silicate rocks; while the metavolcanic rock is a meta-rhyolite which is restricted to the middle portion of the belt (Fig. 2). The granites that intrude the KZSB comprise of porphyritic and fine-grained Older Granite with isotopic age of 592 ± 14 Ma, which demonstrates the time of their formation as well as the lower age limit of the metasediments and gneisses they intruded (Danbatta, 2002).

Other descriptions of the belt are contained in Ibrahim (2004) who mapped two types of metasediments within the belt: Older Metasediments (mainly found in the west) and Newer Metasediments (mainly found in the east); with the two separated by Older Granite plutons. The older metasediments are deeply weathered and the hills in the area are covered with thick lateritic ironstone cover and exposures are difficult to find. This may explain why Turner (1983), Ajibade et al. (1987) and Danbatta (1999; 2003a) have mapped the area as a gneiss-migmatite-granite terrain.

However, the present study has revealed the KZSB to be composed of two contrasting rock assemblages separated by the NE-SW to NNE-SSW trending dextral Kalangai fault (Danbatta, 2003b). To the west of this fault are BIFs and highly laterised pelitic schist association (the so called older metasediments); while the eastern part of the fault is made up of fresher metasediments that are composed of phyllites, quartzites, schists, metasandstones, and metaconglomerates exhibiting differing degree of weathering, preservation and exposure (Fig. 2). They are separated from each other by elongate NNE–SSW trending ridges of fault breccias and mylonites (Danbatta, 2001; 2003b).

The Kazaure BIFs occur as narrow bands associated with the highly weathered phyllites, quartzites and schists, and are mainly oxide facies variety; though minor outcrops of silicate facies were mapped at Wawanrafi area (Danbatta and Garba, 2001; Ibrahim, 2004). The pyritic nature of the fine-grained laminated metapelites suggests that the Kazaure oxide facies BIFs were deposited under anoxic conditions with high Eh in a quiet and shallow marine environment, in line with the suggestion of Lepp and Godich (1984) and James (1992), who showed that oxide facies iron formations are characteristically found in the shallow parts of a depositional environment. The documented silicate facie BIF at Wawanrafi is interpreted as a metamorphic equivalent of the oxide facies mainly at intermediate Eh values.

Recent work on the Kazaure BIF by Danbatta (2003) and Ibrahim (2004) has outlined its main characteristics that show similarities to Algoma type BIFs. The Kazaure BIF is a dark grey, banded rock with a rhythmic alternation of light grey silica rich and darker iron-oxide rich bands, Texturally and mineralogically the BIF is similar to the Algoma Birnin Gwari and Maru BIFs (both are fine-grained), and have similar ore mineral content (haematite, magnetite and limonite), with quartz, barite and other accessories forming the gangue minerals. According to Aliyu (2004), total iron oxide (Fe_2O_3T) content of the BIF ranges from 41.50 – 90.88% with an average of 61.29%, and the total elemental iron ranges from 29.0 – 63.5% with 43% as average. These values are comparable to the Fe content of the Algoma BIFs of Birnin Gwari, Maru and Muro areas, which varies between 34% - 42% (Adekoya, 1996; Mucke et al., 1996).

Thus, there are close similarities between the Algoma BIFs of the KZSB and Precambrian BIFs described elsewhere associated with the Nigerian schist belts (Adekoya, 1993; 1996; Mucke, 2003; 2005; Mucke et al., 1996). The Nigerian BIFs are assigned to Lake Superior BIFs type which evolved from continental sediments derived during the Late Archaean/Early Proterozoic (2500-1900 Ma) period. As such the Kazaure BIFs are assigned to the Lake Superior BIFs group, since the rocks associated with them are similar to those associated with the Lake Superior BIFs.

Danbatta (2001) has made a detailed study of the structures in the KZSB where he observed its complexly deformed nature, with earlier overturned folds being refolded by later upright ones. Field and petrographic evidence indicate that two major phases of ductile deformation (D1 and D2) are associated with the rocks in the study area. The D1 event formed an early tight to isoclinal NNE-SSW trending folds with nearly flat-lying axial surfaces mostly in the NE part of the belt, while the regional D2 event produced open to isoclinal N-S trending D2 folds with steep axial planes that refolded the earlier ones. A major NE-SW trending regional dextral fault system, the Kalangai-Zungeru-[illegible] times. Some of the rocks that occur along the KZI fault zone are brecciated and mylonitized in several places (Ball, 1980; Danbatta, 2003b).

3. Previous models of evolution

Since the recognition that a Wilson cycle operated east of the West African craton and ended with a continent-continent collision about 600 Ma ago (Fig. 3), the tectonic evolution of the Nigerian Basement Complex has been related to these events e.g. Burke and Dewey (1972), Trompette (1979), Caby et al. (1981), Ajibade et al. (1987) and Danbatta (2003b).

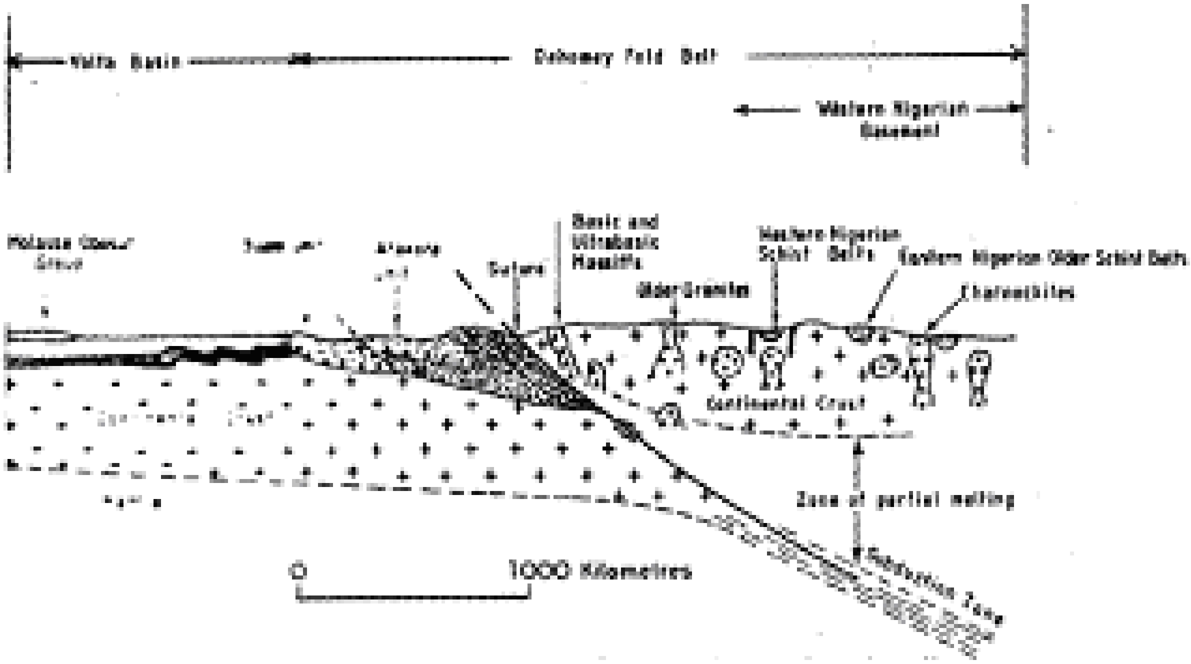

Fig. 3. Evolution of the West-African region during Pan-African time (Modified after Trompette, 1979).

All the previous models of evolution of the KZSB argued that its evolution is probably related to ensialic graben-like structures formed during the Pan-African late-Proterozoic event (McCurry, 1971; Turner, 1983; Ajibade et al., 1987; Danbatta, 2003a).

According to these models crustal thinning in response to initial crustal extension and continental rifting at the West African cratonic margin some 1000 Ma ago, led to the formation of a marginal back-arc palaeo basin floored by continental crust in Western Nigeria; and deposition of sediments within it. The closure of the ocean along an east-dipping Benioff zone at the West African cratonic margin led to the deformation and metamorphism of the sediments and underlying basement, resulting in the formation of the KZSB and reactivation of older basement during the Pan-African orogeny (Turner, 1983; Ajibade et al., 1987). As such, all the previous models have assigned a Pan-African age to the KZSB on the basis of the then available data.

4. Discussion of a new Model of Evolution

To properly explain the evolution of the KZSB, a mechanism must be postulated by the new model, which is effective in explaining the occurrence of BIF, quartzites, conglomerates and KZI in the belt. In this regard, Nigerian BIFs are assigned early Proterozoic (2500-1900 Ma) age as evidenced by their similarities to Lake Superior-type BIFs and the presence of procaryotic microfossils that are likely formed 2 Ga ago (Adekoya, 1996; Mucke, 2003). According to this argument, the presence of Algoma BIF's in a schist belt can be used as a chronostratigraphic marker to constrain the age of the sedimentary progenitors of the belt to a Paleoproterozoic age. More recent studies have also emphasized the role of Eburnean event in the formation of Nigerian schist belts (Rahaman and Ocan, 1978; Dada, et al., 1993; Annor, 1995; Olabaniyi, 1997; Annor et al., 1998; Mucke, 2003).

This and other published arguments for the effect of Eburnean on Nigerian schist belts with BIFs, led to the formulation of a new model for the KZSB whose main features include crustal extension and thinning and the development and deformation of palaeo-basins. The formation of the Kazaure palaeo-basin of deposition was ascribed to processes related to subduction at the West African cratonic margin during the early stages of the Eburnean orogeny (Fig. 4).

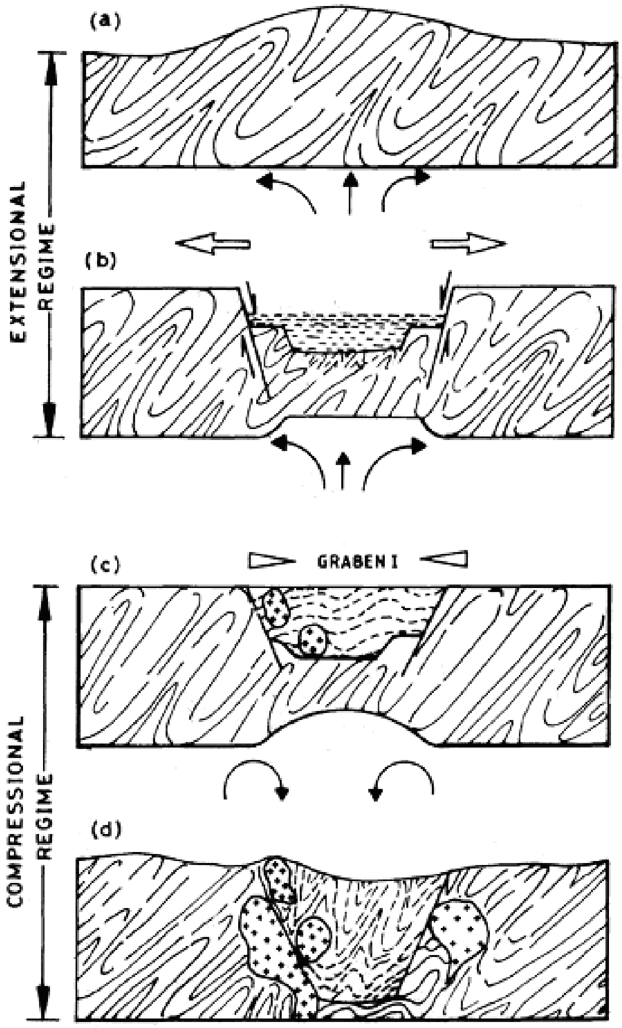

Fig. 4. Diagrams showing hypothetical evolution of the KZSB. a). Doming of Archaean basement (pre-Eburnean), b). Tension/Rifting (Eburnean), c). D1 event during Eburnean, d). D2 event during Pan-African (Present work).

During this time (2000 ± 200 Ma), plume related plate tectonic processes led to back-arc extension and development of a marginal basin environment in the Nigerian-Benin shield (Wright, et al., 1985; Ferre et al., 1996). This was sufficient for the formation of epicratonic basins or troughs in which were deposited the earliest clastic sediments and chemical materials of the BIFs.

The initial sedimentation was platform and it corresponds to the initial stages of rifting, basin-forming and subsequent deposition of the orogenic cycle culminating in the Eburnean tectono-thermal event (Table 1).

Table 1. Classification of lithologies in KZSB area

S. No.	Classification	Geological History	Rock types

6.	Sedimentary rocks	Youngest cover rocks	Superficial deposits, Chad & Gundumi Formation
5. S	Daura Igneous Complex rocks (Mesozoic)	Extrusive & intrusive activities leading to formation of Younger Granites	Syenites, rhyolites, biotite granite
4.	Intrusive Suite	Fracturing, faulting, high level magmatic activities	Older Granites, quartz & pegmatite veins
3.	Reactivated Suite & D2 event (Pan-African)	Orogenesis, deformation, metamorphism & reactivation of pre-existing rocks	Schists, quartzites, silicate facie BIF, metasandstones, metaconglomerates, fault breccias "& mylonites
2.	Younger Metasediments & D1 event (Eburnian)	Geosynclinal deposition, orogeneses, deformation & metamorphism	Schists, quartzites, oxide facie BIF, metasandstones & metaconglomerates
1.	Crystalline Basement (Archaen/Liberian)	Possible early formation of migmatitic-gneiss complex	Gneiss, migmatites & Older Metasediments

ubsequently, the Eburnean closure of the ocean at the cratonic margin along an easterly dipping Benioff zone led to D1 deformation in the KZSB. According to this hypothesis D1 deformation and metamorphism in Nigerian schist belts with documented occurrences of Algoma BIF's are pre-Neoproterozoic in age. Sufficient characterization of this orogenic activity in the Kazaure area reveals its ensialic character similar to the case in some of the NW Nigeria schist belts (Danbatta, 2003a).

The Paleoproterozoic Eburnean event was followed by two major episodes of Neoproterozoic crustal activities which are involved in the evolution of the Nigeria's basement. These are the Kibaran (1100 ± 200 Ma) and the Pan-African (600 ± 50 Ma orogeneses (Grant et al., 1972; Grant, 1978). Kibaran involvement is still a subject of divergent views, but the Pan- African event is firmly confirmed and is considered to be related to the subsequent closure of the ocean at the cratonic margin about 600Ma ago and crustal thickening in the Dahomeyan (Fig. 3). Furthermore, this episode of Pan-African compression coupled with the prevalent temperature conditions led to metamorphism and D2 deformation; as well as the reactivation of pre-existing rocks (e.g. older sediments), and the emplacement of the Older Granites.

The rock types found within the KZSB include migmatites, gneisses, metasediments, metavolcanics and Pan-African Older Granites. The protoliths of the metasediments are clastic detrital sediments accumulated in a shallow and quiet back arc basin floored by sialic crust. This assumption is based on their content of coarse clastics, dominated by quartzites, metasandstones, metaconglomerates and other immature sediments. Both were first deformed and regionally metamorphosed during Eburnean time. The different lithological association of the metasediments may be a function of the relative location of their protoliths to the main basin. The presence of conglomerates and thick quartzites, suggests a continental littoral environment located at the basin margin. The conglomerates were deposited in a much higher energy environment than the pelites, e.g. a shallow basinal environment like continental shelf or deltaic environment. The BIFs and quartzites were deposited at quiet and shallow water depositional environment. The Kazaure oxide facie BIF and their associated metasediments are considered to have formed through a low amphibolite facies regional metamorphism, while the silicate facies resulted from reactivated fault movements that affected the oxide facies during Pan-African times (Danbatta, 2002; Mucke, 2003). The fresher metasediments can however be viewed as a reworked portion of the pre-existing metasediments. They possibly represent a reworked portion of the pre-existing Eburnean metasediments, as a result of deformation, metamorphism and Older Granite plutonism caused by crustal thickening related to the Pan-African event (Fiches et al., 1985).

Melts were generated from partial melting of the lower crust and upper mantle that mainly intruded as Older Granites., The geochemistry of the Older Granitoids in KZSB appear to indicate their calc-alkaline nature and I-type characteristics similar to magmas generated from igneous source materials in subduction and continent-continent collision zones (Holt et al. 1978; Ajibade et al., 1987; Danbatta, 2002). The main tectonic activity ceased between 600 and 550 Ma and its waning stages are accompanied and followed by late-tectonic and anorogenic intrusion of granitoids (often alkaline and including ring complexes like the adjacent Daura Younger Granites), occurring on sites of former tectonic activity (Turner and Webb, 1974).

In addition, there seems to be a kind of geographical correlation between some of the NW Nigerian schist belts as you move from east to west (Fig. 5).

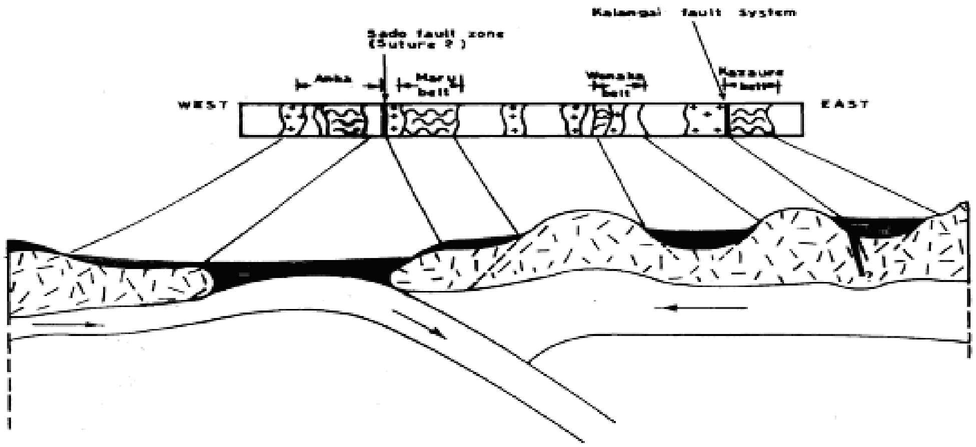

Fig. 5. Diagrams showing hypothetical evolution of the KZSB and adjacent NW Nigerian schist belts. Note the ensimatic origin of Anka belt (Modified after Danbatta, 2000).

Viewed from the northernmost part of the country, as you move from east to west, the Kazaure belt seems to be the northern projection of the Malumfashi belt. Turner (1983) had earlier observed the similarities between the two belts, as well as considered them together with Anka, Maru, Birnin Gwari and Wonaka belts; as forming in one back-arc basin. With the exception of the Anka belt (whose origin is ascribed to ensimatic processes by e.g. Ogezi, 1977 and Holt, 1982), and Wonaka; all the other members of this group of schist belts (Maru, Malumfashi, Kushaka, and Kazaure) contained BIFs and their evolutions are ascribed to ensialic processes. As the evolution of the less studied Wonaka is likely to be ensialic due to the absence of mafic-ultramafic rocks, it may also contain BIFs.

5. Summary and Conclusions

On the basis of available data, the origin of the KZSB can now be explained in the context of ensialic processes that comprise of both Eburnean and Pan-African deformation episodes. The genesis of the belt is explained by postulating the existence of a small pre-Eburnean basin in the context of Eburnean ensialic deformation, under extensional and compressional regimes. The new model ascribed D1 to the Eburnean event and D2 to the Pan-African event. This view was corroborated on the basis of field and laboratory studies that emphasize the presence of Algoma-type BIF and Kalangai fault in the KZSB (Danbatta, 1999; 2002; 2003; Aliyu, 2006).

Based on structural data and lithological associations, Grant (1968; 1978), Holt (1982) and Turner (1983) concluded that some of the Nigerian schist belts were affected by two major Neoproterozoic Deformation cycles in the Kibaran and Pan-African, while others were only affected by the Pan-African event. There are convincing evidence of similarities in structure, lithologies and metamorphism between the KZSB and BIF's bearing Nigerian schist belts. Through so many common characteristics, these BIF's bearing Nigerian schist belts may wholly be considered as having formed by similar processes with some deviations in general evolutional trend.

The present model is in agreement with some previous models, but with some modifications that tried to explain the contrasting lithologies between some of the belts. It favours the evolution of these belts through ensialic processes in Birrimian times, and considered the schist belts to be involved in Paleoproterozoic Eburnean (2 b.y.) as well as Neoproterozoic Pan-African events. This is consistent with the viewpoints earlier suggested by Burke and Dewey (1972), and Elueze (1992). The KZSB evolved in an ensialic restricted basin which has survived erosion on older basement crust.

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