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Review of the Basement Geology and Mineral Belts of Nigeria

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Abstract: *The mineral belts of Nigeria include both Pan African structures (N-S, NNE-SSW, ENE-WSW), well preserved in the Western Province of the Nigeria basement complex and the Mesozoic to Early Cenozoic structures (NE-SW and ENE-WSW), less well defined in the Eastern Province of the Nigeria basement. Analyses of these belts revealed that the stress pattern of the Nigerian landmass has changed appreciably from N-S and NNE-SSW trend to NE-SW and ENE-WSW trend over a period of time from Pan African to Early Cenozoic. These changes have led to the growth of intraplate tensional stresses with the resultant development of tensional features such as the Sn-Ta pegmatite belt, the Sn-Nb Younger Granite belt and the Pb-Zn Benue Trough. The mineral belts are connected with deep seated structural features probably extending down to the upper mantle but do not source their metals from this depth except in the case of Cr-serpentinite. The structures serve more as passages for heat/fluid needed to mobilise the metals for redeposition in favourable structures than conduits for transfer of metals from the mantle. The mineral belts source their metals from the adjoining wallrocks, basement rocks and/or sedimentary rocks.*

Keywords: *Basement complex, Mineral belts, Nigeria, Uranium*

I. Introduction

Nigeria is situated within the Pan African mobile belt and sandwiched between the West African Craton to the west, the Taureq Shield to the north and the Congo Craton to the southeast (Fig. 1). About half of the total area of Nigeria landmass is underlain by rocks of the Precambrian age known in the country as the Basement Complex. The remaining half is covered by Cretaceous to Quaternary sediments and volcanics. The basement complex is divided into two provinces[1]: The Western Province and the Eastern province. The Western Province is approximately west of longitude 8ºE, typified by N-S to NNE-SSW trending schist belts separated from one another by migmatites, gneisses and granites. This trend is believed to be the result of Pan African orogeny involving collision between the West African Craton and the Pan African mobile terrain with and eastward dipping subduction zone. The schist belts are differently interpreted as small ocean basins[2], infilled rift structures[3] or synclinal remnants of an extensive supracrustal cover[4]. The Eastern Province lies approximately east of longitude 8ºE and is more nearly NE-SW. When followed eastward into Cameroon, the trend changes to ENE-WSW (e.g Ngaoundere mylonite zone and the schist belts near Batare). The Eastern Province comprises mainly migmatites, gneisses and large masses of Pan-African granitoids (Older Granites) intruded in Jos plateau, by Jurassic peralkaline granites. Except for smaller schist occurrences around Madagali (Hawal Massif), Toungo and Gayam (Adamawa Massif) and Oban Massif in southeast, the Eastern Province is marked by the absence of major schist belts.

This paper reviews the basement geology and mineral belts of Nigeria with a view to updating existing information on the belts. The review derives mainly from works of[5],[6] with contributions from other sources.

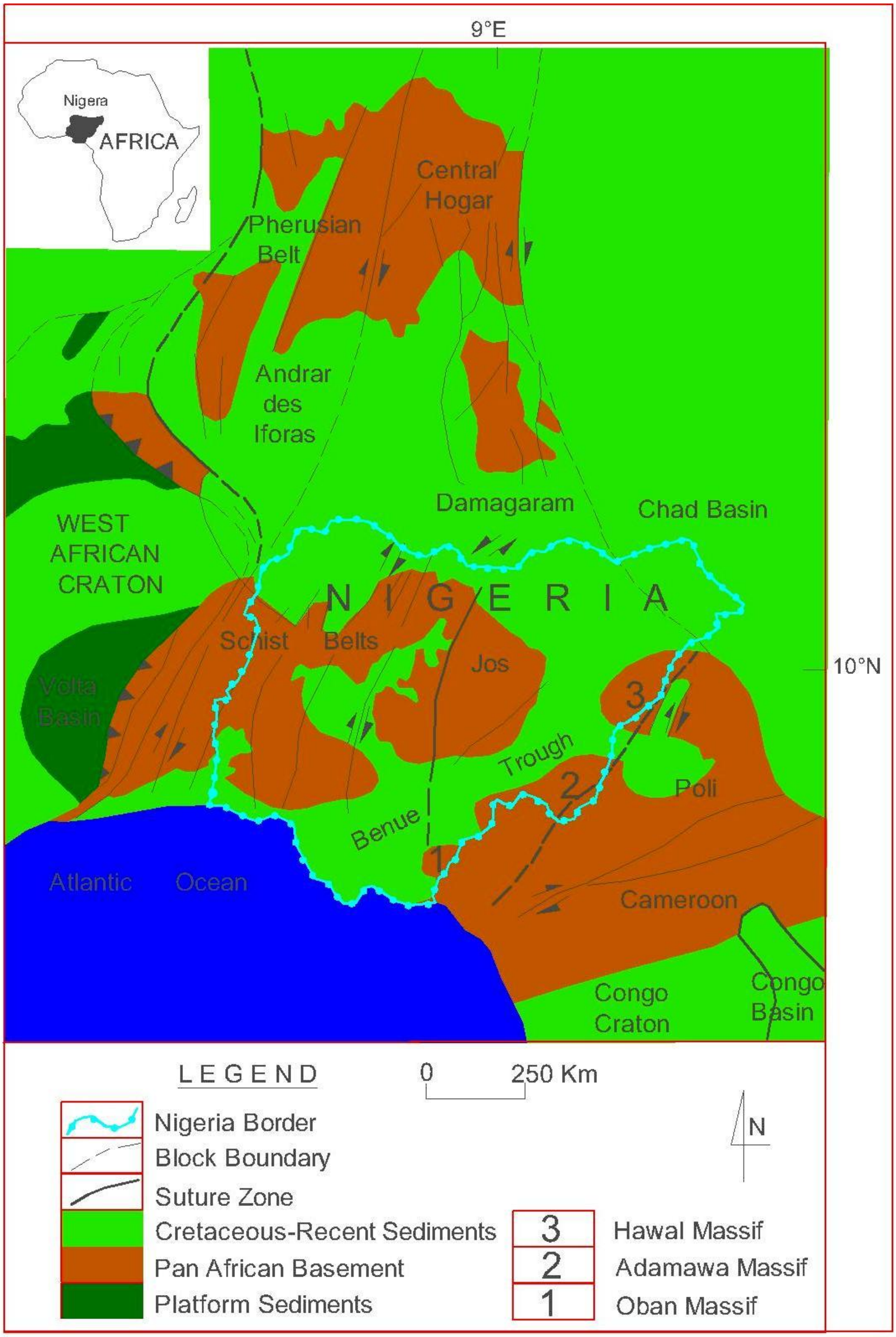

Fig. 1 Regional tectonic setting of Nigeria[15]

II. Geology and Evolution of the Nigerian Basement Complex

Nigeria is almost equally divided between crystalline basement rocks and Cretaceous to Quaternary sediments and volcanics. The basement complex is commonly described under three lithologic groups: A migmatite gneiss complex (MGC), the schist belts and Older Granites suites (Fig. 2). The Cretaceous to Recent sediments are preserved in structurally controlled basins (Benue, Bida, Niger Delta, Dahomey, Sokoto and Chad).

The Migmatite gneiss complexes are believed to be the oldest rocks of the Nigeria Basement Complex. Much of the complex is believed to be reworked older crust (probably Liberian in age) which have been further reworked by later orogenies like the Eburnean (2000 $\pm$ 200 Ma) and the Pan African (600$\pm$150 Ma) with addition of the granitoids and the schist belts.

Although evidence of sedimentation and deformation during Kibaran (1300-1100 Ma) have been recognised[16], no magmatic event of this age have been recorded. The Kibaran was followed by ages ranging from 900-450 Ma representing the imprint of the Pan African event which gave rise to migmatite, gneisses, Older Granite intrusives and similar lithologic units.

The middle and late Paleozoic age is not represented by any magmatic or sedimentation event. The Mesozoic is marked by uplift and intrusion of a series of anorogenic, alkaline, shallow sub-volcanic intrusive known as the Younger Granites which fall within a N-S narrow belt in the western part of the Eastern Province (Fig. 2) and extends north ward into Niger Republic.

The middle Cretaceous marked the beginning of sedimentation following the development of early rifts that were initiated in early Jurassic. Marine transgression marked by the growth of transcontinental seas and epirogenic movements resulted in the formation and infilling of the many basins flanking the basement highs[17]. Periodic sedimentation continued through the Tertiary and Quaternary[18].

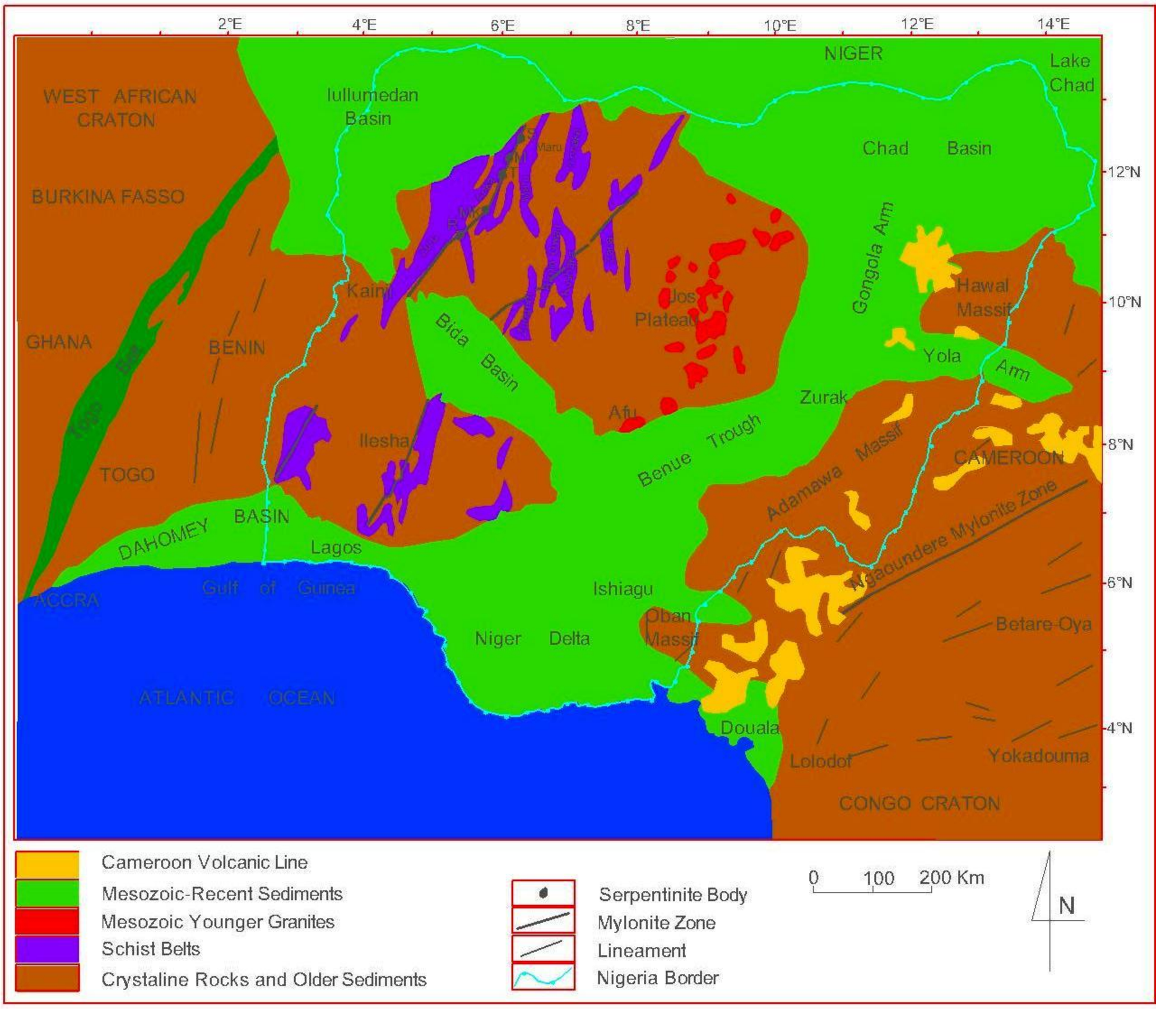

Fig. 2 Geology of Nigeria and the adjoining areas[19]

III. Mineral belts

Mineral belts in Nigeria are divided into the Pan African mineral belts and the Mesozoic to Cenozoic belts. The Pan African Mineralisation belts include the Gold schist belts, the Chromite belt and the Sn-Ta Pegmatite belt all in the Western Province of the Nigerian Basement Complex. The Mesozoic-Cenozoic belts are the Younger Granite Sn-Nb Belt and the Benue Trough Pb-Zn in the Eastern province of the Nigeria Basement Complex. It should be stated here that Mineral belts as use in this work does not mean the same thing as metallogenic province, as the belts are relatively small and the deposits in each, not necessarily formed by the same geologic processes or the same metallogenic event. Thus the mineral belts are simply linear geologic features in which small and mostly low grade epigenetic and/or syngenetic mineral occurrences and deposits of a particular paragenesis are found.

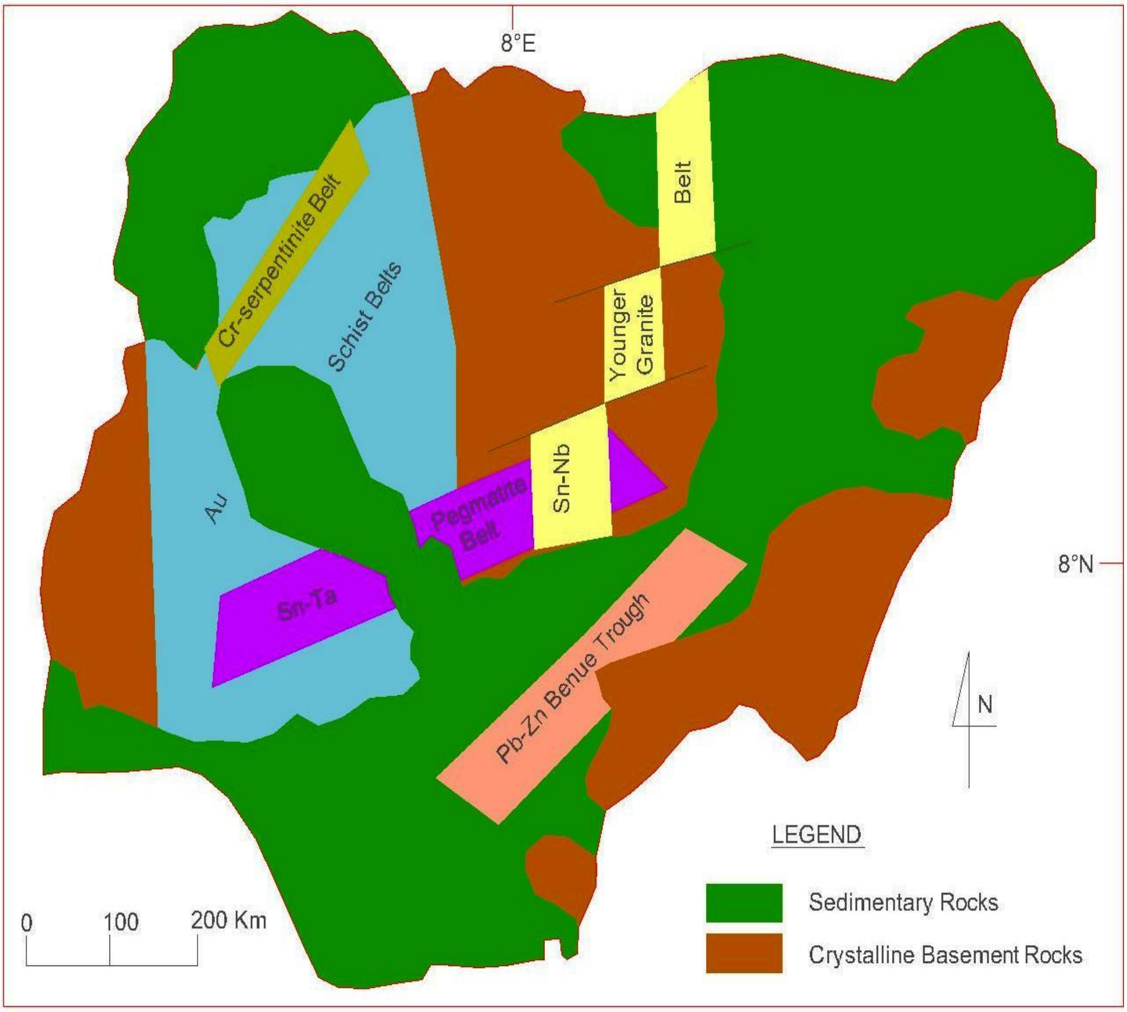

Fig. 3 Major mineral belts of Nigeria[6]. Au, Cr-serpentinite, Sn-Ta belts = Pan African; Sn-Nb, Pb-Zn belts = Mesozoic to Early Cenozoic.

3.1 Au Schist Belts

Areas of gold mineralisation in Nigeria are associated with the regional NE-SW and NNE-SSW fault systems. Gold occurs both in placers and primary veins in several areas within the schist belts in the western province of the Nigeria basement complex from Anka and Maru through Malele, Bin Yauri, Birnin Gwari in the northwest to Okolom, Ilesha and Iperindo in the southwest[7]. The schist belts boundaries have been variously described as metamorphic fronts[20], synclinal remnant unconformities[4], mylonites[1] and rift bounding faults[3]. The gold veins are hosted by various rock types ranging from gneisses, schists, phyllites and quartzites to amphibolites and aureoles of granitic intrusions. The regional and local controls are mainly structural, made up of a system of transcurrent and subsidiary faults and other structures of Pan African age[21]. According to[7], the regional faults were probably the main conduits from which the gold mineralising fluids were subsequently focused into the subsidiary structures, along which interaction of the fluids with suitable wall rocks or structures caused gold deposition.

The regional fault systems described above have been suggested to be possible Pan African crustal sutures[22],[23],[24]. Such relationship is characteristic of mesothermal gold deposit worldwide[7]. Mesothermal gold deposits are spatially related to regional lineaments[25],[26],[27],[28],[29]. The spatial relationship with transcrustal lineaments is a probable indication that the gold deposits are products of convergent margin tectonics[30],[31],[32]. The association of the lineaments with magmatic bodies couple with their extensive length (>100 km) suggest that they are transcrustal structures extending into the lower crust and mantle[28].

3.2 Sn-Ta Pegmatite Belt

Sn-Ta Pegmatites are concentrated in a well defined 500 km long, ENE-WSW trending belt from Ilesha area in southwestern Nigeria to Wamba area in Jos Plateau (Fig. 3), although smaller occurrences have been reported in Oban Massif, southeastern Nigeria[33],[34] and recently in the Kushaka schist belt of Northwestern Nigeria[7]. Within this belt, the individual pegmatite bodies generally trend in a N-S direction. The pegmatites are intrusive hosted by rocks such as migmatites, gneisses, schists and granites of the Pan African basement and major fault lineaments[[35],[36],[34].

The pegmatites in SW Nigeria occur in metavolcanic sedimentary schist belts as vertical to sub vertical dykes, often cross-cutting and display pinch and swell structures[33],[36] similar to that of the gold veins in the schist belt. Mineralised pegmatites consist of Quartz, K-feldspar, albite, muscovite, biotite, lepidolite and accessory minerals such as tourmaline, beryl, zircon, apatite and monazite[33]. In Jos Plateau, the pegmatites occur in gneisses.

Late Pan African ages (562-534 Ma) have been recorded for the rare metal pegmatites of central and southwestern Nigeria[37] suggesting emplacement during the end of Pan African Magmatic activity. The mineralised pegmatites have generally been regarded as late stage residual fluids of the common Older Granites in the basement areas. For instance[24] thought that since the pegmatites appear to be emplaced along major fault lineaments, albitisation and rare metal mineralisation may have been the result of Na-rich hydrothermal solutions from the mantle along ancient lineaments. However[37] have shown that the Rb-Sr ages of pegmatites and the adjoining Older Granites differ by as much as 100 Ma and therefore do not support a cogenetic origin. Consequently, it has been suggested that the rare metal pegmatites of central and southwestern Nigeria are probably the products of high grade metamorphism or partial melting and leaching processes of the basement units than the real magmatic phase of the Older Granites. [35]also suggest derivation of rare metal pegmatites mineralisation especially in southwestern Nigeria from the reactivation of deep seated tectonic lineaments combined with partial melting and external fluid supply. [36]presents evidence to show that the development of rare metal pegmatites of Wamba area of central Nigeria is genetically related to late tectonic granite magmatism which was controlled by the late Pan African NE-SW shear system.

3.3 Cr-Serpentinite Belt

The Cr-serpentinite belt is a well defined, 300 km long, NE-SW trending linear feature which cuts across the N-S schist belts in NW Nigeria (Fig. 3). On a large scale, this linear feature is a major shear zone and in detailed is both sinuous and branching[6]. It contains alignment of serpentinite and basic bodies stretching from Ribah through Tungan Kudaku and Maikwonaga to Sado[5] (Fig. 4). While majority of these bodies are serpentinite with relics of olivine and amphibole-rich rocks, a good number of them contain disseminated chromite and Mn-rich ilmenite. In some instances, the chromite occurs in tectonically disrupted layers[38].

The geochronology of these bodies remains problematic, although the metasediments in which the bodies intrude have been assigned to Upper Proterozoic. Since the bodies are clearly cut by diorites of the Older Granite series, they are probably mid-Pan African in age.

It is generally agreed that these bodies are mantle derived and were tectonically emplaced in a plastic condition with serpentinisation as a late stage phenomena. It has also been suggested that this belt represents a suture with the serpentinites as remnant ophiolites[6].

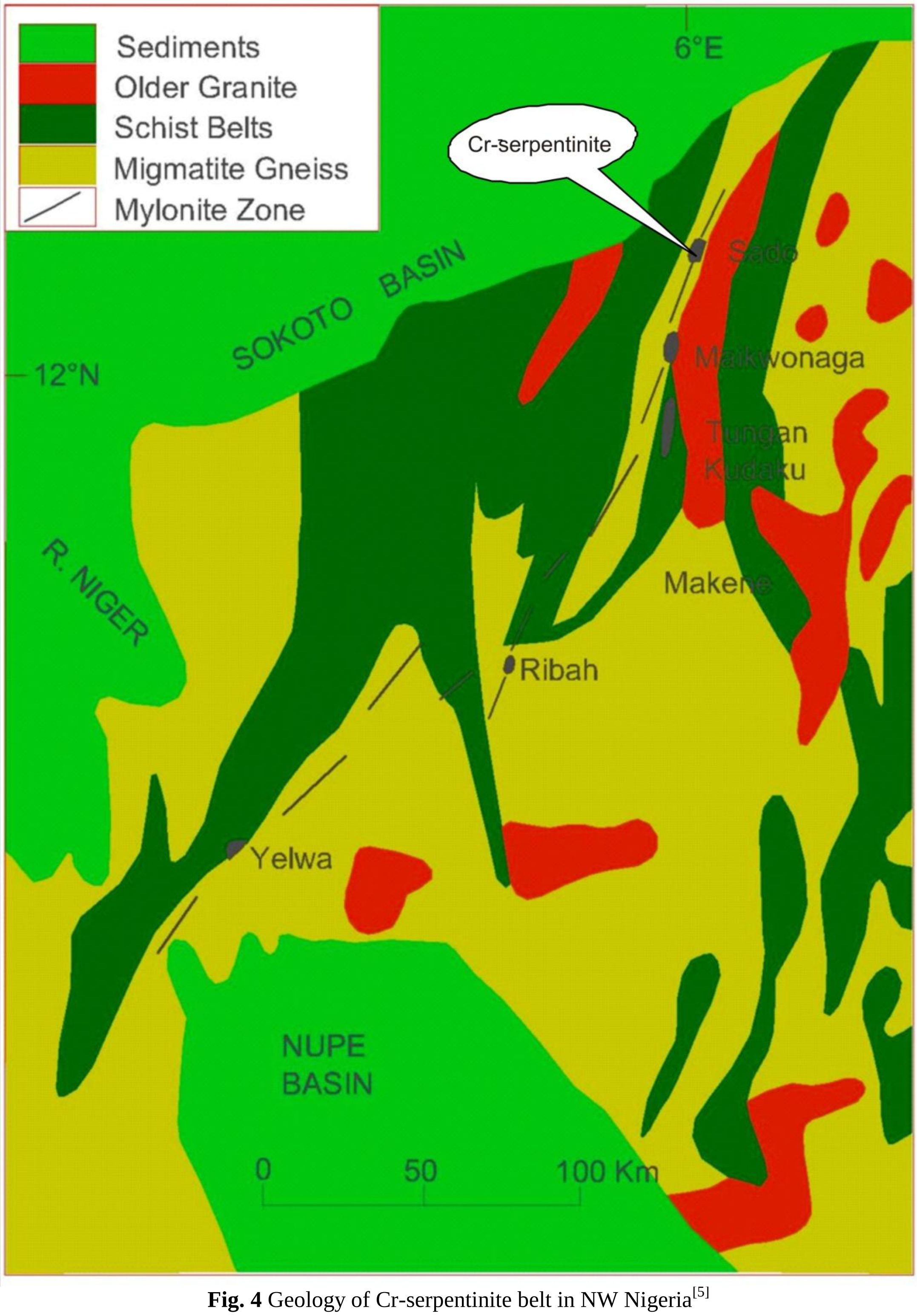

Fig. 4 Geology of Cr-serpentinite belt in NW Nigeria[5]

3.4 Sn-Nb Younger Granite Belt

The Mesozoic anorogenic alkaline Younger Granites occur as ring complexes in the western part of the Eastern Province of the Nigeria basement complex. They are the southern part of a 1,300 km long, 150 km wide chain of ring complexes that extend from Afu on the northern part of the Benue Trough through Ririwai in Kano to Air in Niger Republic. It is a N-S belt of extensional volcanic[16] which is off-set by ENE-WSW transform like faults in both the north and south (Fig. 3). These two major lineament trends (N-S and ENE-WSW) have been described as fracture directions of extensional deformation in the basement rocks[39]. The ring complexes become systematically older when followed northward along the N-S trend and westward along the ENE-WSW trend. A migrating continental plate over a hot spot (mantle plume) at or near the lithosphere has been widely accepted as a plausible explanation for the progressive age changes. The ring complexes are similar to those occurring in the eastern Hoggar of southern Algeria and Cameroon-Nigeria border where they are called 'Granites Ultimes'.

The Mesozoic Younger Granite are comprise of arfvedsonite, hastingsite and biotite granites, fayalite granite porphyries, syenites and trachytes with remnants of rhyolites, ashes, tuffs and ignimbrites which are preserved in complex circular structures[6]. Primary ore minerals occur as disseminated cassiterite, columbite-tantalite and rare earth minerals, and as veins of cassiterite, wolframite or sulphite[40]. These form the sources of the economically important alluvial deposits. Intersection of the Younger Granite Sn-Nb Belt and the Pegmatite Belt in the northern part of the Middle Benue trough marks the greatest development of economic mineralisation in the former[6].

3.5 Pb-Zn Benue Trough

The Benue Trough is a 1000 km long, 50-150 km wide, intraplate rift depression initiated in the latest Jurassic to early Cretaceous times[41]. It is genetically related to the opening of the equatorial domain of the South Atlantic[42]. Filled with continental and marine sediments, the trough splits at its northern end into the Yola and Gongola arms with each, traceable into major trans-African structures[43]. The evolution of the Benue Trough was accompanied by Mesozoic to Cenozoic magmatism which was volumetrically restricted but scattered throughout the trough[44]. From about 70 Ma, magmatism of the adjoining Cameroon line replaced the Mesozoic to Early Cenozoic magmatism of the Benue Trough. The prominent 'Y' shape and the size similarity between the Benue Trough and the Cameroon Line (Fig. 2) led to a suggestion that the two were related to a common hot-zone in the asthenosphere, over which the African plate moved, and therefore that they form a migrating rift system.

Along the NE-SW length of the Benue Trough, N-S trending veins with galena, sphalerite and sporadically, chalcopyrite occur mostly at the crest of anticlines and only in sediments of pre-Santonian age within a NE-SW belt[6]. These extend for about a distance of 500 km from Ishiagu in southwest to Zurak in northeast. The gangue minerals of the veins vary from siderite in the southeast to fluorite in the Middle Benue and barites in the northwest. It was initially thought that the many small igneous bodies intruding the sediments of the Benue Trough were responsible for the origin of the open-fissure filled veins[45]. However[46] demonstrated the significance of connate brines emanating from deep burial of sediments and geothermal heat flow associated with rifting.

Within this belt and the adjoining basement, pockets of uranium occurrences have also been discovered. These occurrences which include the Bima sandstone-hosted Zona uranium occurrence, the Mika uranium prospect[47], the Monkin occurrences[48] and the Kanawa occurrence[49] have received the attentions of[8],[9],[10],[11],[12],[13],[14]. However, no definite mineralization trend has been established for these occurrences.

IV. Discussion

The mineral belts of Nigeria can be conveniently divided based on age, into the Pan African structures (N-S, NNE-SSW, ENE-WSW), well preserved in the Western Province of the Nigeria basement complex and the Mesozoic to Early Cenozoic structures (NE-SW and ENE-WSW), less well defined in the Eastern Province of the Nigeria basement.

The Pan African N-S and NNE-SSW structures of the schist and serpentinite belts are considered as principally of compressional plate boundary type connected to the continent-continent collision of the West African craton and the Trans-Saharan terrain during the Pan African orogeny. The later ENE-WSW structures of the pegmatite Sn-Ta belt have been interpreted as intraplate tensional features related to the splitting apart of the African and South American continents. This belt has been attributed to deep seated lineaments along which there was elevated heat flow leading to higher grade metamorphic conditions.

The Mesozoic to Early Cenozoic N-S structures of the Younger Granite Sn-Nb mineralisation, like the ENE-WSW pegmatite belts and the NE-SW structures of the Benue Trough Pb-Zn, have been interpreted as intraplate tensional features related to the splitting apart of the African and South American continents. The Benue Trough NE-SW structures and the ENE-WSW structures resemble trends of the adjoining Cameroon line and further east, the E-W trending edge of the Congo craton.

The mantle components in both the serpentinite and the Younger Granites have lead to a general belief that both the Pan African mainly N-S and the Mesozoic to Early Cenozoic ENE-WSW trends which define the mineral belts of Nigeria are deep seated extending to crust-mantle boundary[6]. However, these deep seated structures appear to have contributed more in providing high energy as heat flow required for the mobilisation of metallic components for subsequent redeposit in favourable structures. Consequently, the source of metals in the mineral belts seem to be deep seated only for the Chromite of the serpentinite belt. The source of metals from the remaining belts appears to be from the host rocks. The sources of Au (of the schist belts) and of Sn-Ta (of the pegmatite belts) are from the adjoining wallrocks, while the Pb-Zn of the Benue Trough is believed to be leached from the sub-adjacent basement and/or sedimentary rocks[6]. Two sources (the crust and the mantle) have been proposed for the Younger Granite Sn-Nb.

Mineralisation is structurally controlled and related to the intersection of the mineral belts and cross structures. That is the case for Au, Sn-Ta of the pegmatites, Sn-Nb of the Younger Granites and Pb-Zn of the Benue Trough but not the case for Cr-serpentinite with a clear mantle source.

The two structural trends of the Nigerian basement, N-S (to NNE-SSW) and the ENE-WSW have been correlated with the oceanic fracture zones of the Atlantic Ocean which are probable extensions of pre-existing continental zones of weakness[50].

V. Conclusion

Analyses of the Nigeria metallogenic belts, have shown that the stress pattern of the Nigerian landmass has changed appreciably from N-S and NNE-SSW trend to NE-SW and ENE-WSW trend over a period of time from Pan African to Early Cenozoic. These changes have led to the growth of intraplate tensional stresses with the resultant development of intraplate tensional features such as the Sn-Ta pegmatite belt, the Sn-Nb Younger Granite belt and the Pb-Zn Benue Trough in contrast to the N-S compressional plate boundary type related to the continent-continent collision between two entities (the West African craton and the Trans-Saharan mobile belt).

The mineral belts are connected with deep seated structural features probably extending down to the upper mantle but do not source their metals from this depth except in the case of Cr-serpentinite. The structures serve more as passages for heat/fluid needed to mobilise the metals for redeposition in favourable structures rather than conduits for transfer of metals from the mantle. The mineralisation belts source their metals from the adjoining wallrocks, basement rocks and/or sedimentary rocks.

The understanding of these mineral belts and discovery of others can boost exploration successes in Nigeria. However, no particular trend has so far been discovered for pockets of sandstone-hosted and vein-type uranium occurrences in the Benue Trough and the adjoining basement. Furthermore, it is still not clear if the uranium occurrences are related to any specific metallogenic event. Detailed study of these occurrences may contribute to a better understanding of their pattern of distribution and the discovery of more since most mineral belts are thought to represent zones in which the metallic components were derived from the pre-existing rocks.

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