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MINERALIZATION IN PRECAMBRIAN ROCKS OF CENTRAL NIGERIA: IMPLICATIONS FOR THE OBAN-OBUDU-MANDARA-GWOZA COMPLEX OF EASTERN NIGERIA

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ABSTRACT

Granitic rocks of Jurassic age, referred to generally as the Younger Granites of Nigeria, intruded the late Precambrian to Lower Palaeozoic basement rocks in a N-S zone nearly parallel to the Precambrian N-S basement rocks of the Oban-Obudu-Mandara-Gwoza complex separated by the Benue rift trough. Rock types common to the two zones are mainly gneisses, migmatites, charnockites and a series of granites and granodiorites.

Mineralization in the basement rocks in central Nigeria within the Younger Granite province and the surrounding area is in pegmatites, quartz veins and hydrothermally produced metasomatic rocks. The basement pegmatites and quartz veins are mineralised as a result of reactivation by hydrothermal fluids associated with the emplacement of the Younger Granites. These fluids also metasomatized the basement rocks within the vicinity of the individual ring centres depositing ore minerals as well as depositing economic minerals as wall rock alteration products.

The main minerals produced by metasomatism of the basement rocks include topaz, sapphires and rubies, beryl and fluorite associated with some sulphides like sphalerite, chalcopyrite, greenockite and minor cassiterite. This mineral association may vary in another location with the appearance of minor monazite, pyrite and zircon closely associated with sphalerite and opaque minerals. However, in the pegmatites and quarz veins the main minerals are columbite, tantalite, wolframite, cassiterite and the gem minerals.Further Tertiary volcanic activity also introduced minerals like barite , Pb-Zn and salt springs in the basement and Cretaceous rocks of the Benue basin. Such metasomatic zones along with the pegmatites and quartz veins in the basement rocks of the Oban-Obudu –Mandara-Gwoza complex should be targets for mineral exploration since gem minerals and tin with associated tantalite have been reported in the area and could be a metallogenic province in Nigeria.

KEYWORDS: alkaline magmatism, metallogeny, metasomatism, mineralization, remobilization.

INTRODUCTION

The Nigerian Younger Granites are regarded as belonging to an alkaline silica oversaturated province among several other complexes in Africa (Fig1). These Phanerozoic oversaturated alkaline provinces occur exclusively in the Pan-African domains except the Tertiary to Recent volcanics (Black et.al 1985).

In west Africa, ***the Iforas oversaturated alkaline province*** of ring complexes composed of nordmarkites, peralkaline and metaluminous granites and granite porphyries, have yielded Cambrian Rb-Sr whole rock ages between 560 and 540 Ma (Liegeois and Black 1985 , Ba et al. 1985). In this region, the Pan-African has been interpreted as the result of an oceanic closure with collision around 600 Ma ago between the passive margin of the West African craton and the active margin of the eastern edge of the Tuareg shield (Black et al 1979, Caby et al 1981, Fabre et al. 1982) . The alkaline ring complexes cut a late Pan-African cordilleran type composite calcalkaline batholith which during collision has been subjected to rapid uplift and unroofing (Liegeois and Black 1983).

The ***Tadhak province*** situated 150 km to the west of the Iforas province, is strongly undersaturated and associated with carbonatites (Sauvage and Savard 1985). It lies on the edge of the West African craton stabilized 2000 Ma ago and is devoid of Pan-African magmatism. Permain in age, it is structurally and spatially related to a north-south rift (Tesoffi graben) close to the suture (Liegeois et al 1983).

The Aiir (480-400 Ma), Damagaram (320-290 Ma) and Nigeria (215-140 Ma) alkaline "Younger Granite" provinces are a unique feature in the world of practically continuous within-plate anorogenic volcanism and plutonism with progressive southern shift of centres of magmatic activity (Bowden et al. 1976, Karche and Vachette 1976). While similar rock types are developed through-out the three provinces, the main varieties being acid lavas (rhyolites, comendites and ignimbrites), nodmarkites, aegririne-arfvedsonite granites, fayalite-hedenbergite granites, amphibole-biotite granites, biotite granites and minor amounts of intermediate and basic rocks. Their relative proportions change from north to south; peralkaline granites and quartz syenites predominate in the Aiir where they are associated with anorthosites (Black 1965, Black et al. 1967, Moreau, 1982; Leger 1985), and in the Damagaram (Black 1963,Mignon, 1970), whereas metalumious and subaluminous granites are the most prevalent rock types in Nigeria (Jacobson et al. 1958). The three provinces lie between longitudes 8^0E and 10^0E in a 1300km long north-south belt bound by shear zones which correspond to a polycyclic segment of the Pan-African orogenic belt invaded by abundant calcalkaline granites (Abaa 1982), which probably are largely of crustal origin (Black 1980). In Aiir, extensive transcurrent faulting occurred prior to the emplacement of the ring complexes and was accomplished by crustal doming as indicated by the southerly tapering out of the Palaeozoic along the western border of the Aiir (Karche and Vachette 1976). To the south in Nigeria, Rahaman et al.(1984) have shown that the migration of centres occurred along ENE-WSW and NNW-SSE lineaments; the ENE-WSW lineaments correspond to the direction of late Pan-African dextral transcurrent faults in the basement and are parrarel to the marginal faults of the Benue trough which has recently been interpreted as a pull-apart basin determined by sinistral shear (Benkhelil 1982), and which contains transitional basalts and alkali rhyolite which have yielded a Rb-Sr age of 113$\pm$ 3 Ma (Umeji and Caen-Vachette 1983).

The Cameroon silica saturated alkaline provin (Fig2)ranging in age between 60 and 30 Ma, but which includes an early complex dated at 550 Ma, also occurs within the Pan-African domain with abundant calc-alkaline granitoids (Lasserre 1978). The massifs are aligned on the north-north-easterly "Cameroon line" defined by the Fernando Po, Principle and Sao Tome islands. The NNE-faults observed in southern Cameroon are sinistral transcurrent faults, which offset the Cretaceous basin (Black et al 1985).

Sibuet and Mascle (1978) have shown that the Nigerian alkaline Younger Granite province and Cameroon line lie roughly on arcs corresponding to the early pole of rotation (before 80 Ma) for the opening of the Benue trough and suggest that it is a pull-apart basin formed by overall sinistral shear in line with the Charcot fault zone (Mascle 1976, Benkhelil 1982). Whereas the Nigerian alkaline Younger

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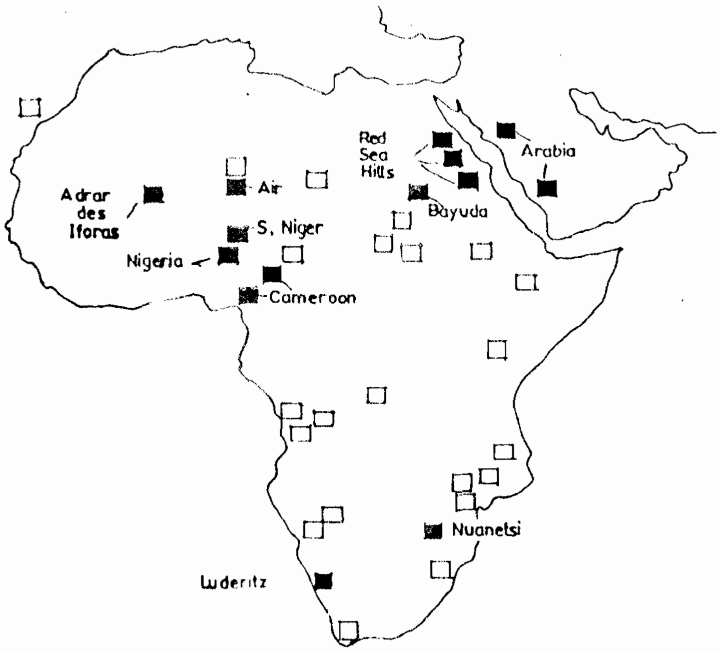

Fig 1 Sketch map of Africa indicating late precambrian and phaerozoic Alkaline granite ring complexes (after Bowden 1985). Closed squares represent specific named localities discussed in West Africa: Open squares are other locations of oversaturated alkaline complexes.

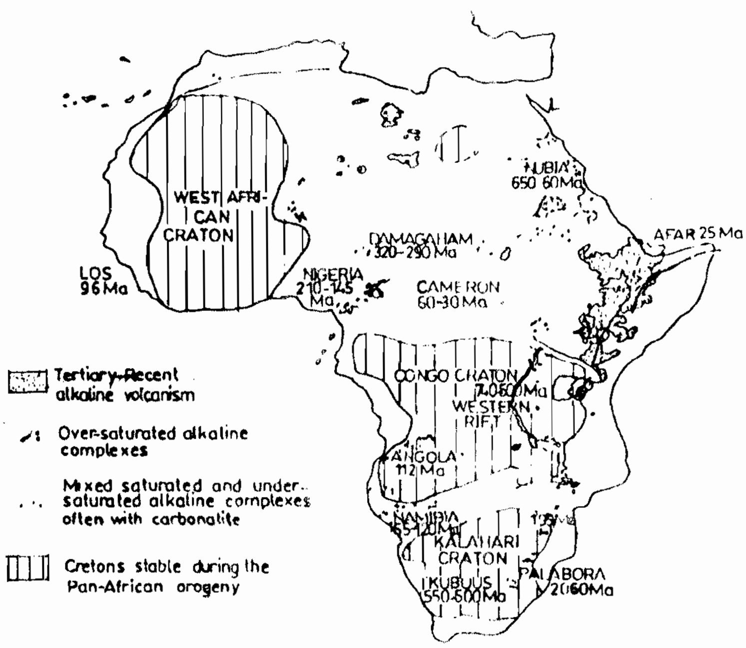

Fig 2 Sketch map showing distribution of alkaline complexes in Africa (after Black et al 1985) in relation to the West African and the Congo Cratons. Note the Nigeria-Niger-Cameroon oversaturated alkaline Complexes in-between.

Granite province precedes the oceanic opening, the Cameroon occurrences are later.

Examining alkaline ring complexes in their regional setting may also lead to conclusions of economic interest. So far no explanation has been given as to why tin mineralization, which characteristically is concentrated in S-type granites, is important in some silica saturated alkaline provinces and absent in others. When the country rock is composed mainly of mantle-derived calc-alkaline granitoids or volcanic assemblages, e.g Iforas, Corscica, New England, Saudi Arabia, Red Sea Hills, or oceanic crust, e.g Kerguelen Islands, there is little or no tin (Bonin 1982). On the other hand, the chances of finding economic tin deposits are considerably enhanced, when the province cuts crustally derived granitoids which have already redistributed and concentrated tin, e.g Nigerian Pan African granites and Sn-bearing pegmatites (Clifford 1966; Black 1984).

This paper aims at highlighting various areas in Africa where alkaline anorgenic complexes have aided mineralization in the Pan Africa belts due to remobilization. Ephasis is placed on studies carried out in Nigeria where such occurrences have occurred and to emphasize the fact that this may be enough evidence to find similar mineralization along the Oban-Obudu-Mandara-Gwoza basement axis in the eastern part of the country hitherto not paid attention.

MINERALIZATION

Many of the alkaline anorogenic complexes are aligned along the former Pan-African mobile zones and all possible source material for remobilisation as economic minerals has been contributed during these plate collision events (Almond, 1967). This means that most of the anorogenic centres should be important sites for mineralization of U-Nb, Zn and Sn. Despite a number of ambitious prospecting programmes in for example Egypt, Sudan, Saudi Arabia, there are very few recorded mineralization centres in anorogenic settings of economic importance, and none which equate with the extensively mineralised Nigerian anorogenic province (Barth et al 1983). There are several possible explanations. Perhaps there remain a number of important discoveries to be made, or erosion has removed much of the evidence of primary mineralization. The search for alluvial and eluvial deposits of resistant minerals like cassiterite, pyrochlore, and others could help in locating possible recent sources of mineralization. A third explanation is that fluid reactions and or deposition by alkali metasomatism has not been so intense in poorly mineralised ring complexes. This explanation certainly is supported by substantial petrological evidence on the Sudan centres (Vail 1985) and many also apply to the Egyptian and Saudi Arabia occurrences (Bowden 1985, Abaa 1991).

It has been stated on numerous occasions that if the Pa-African crust is mineralised with Nb,Sn, and so on, then it is a natural consequence that the Phanerozoic ring complexes emplaced into these regions should also be mineralised . This situation may be supported in the Nigerian Basement (Bowden et al 1985) and the Younger Granite province (Kinnaird 1985), but does not appear to be confirmed in detail elsewhere in Africa, despite the occurrence of Pan-African mineralization.

Nature of Mineralization in Basement and Younger rocks

The alkaline ring complexes have extensively mineralised not only the pre-existing basement rocks but also the earlier rocks emplaced by the same alkaline magmatism such as porphyries and rhyolites (Abaa 1985). The nature of such mineralization is as follows:

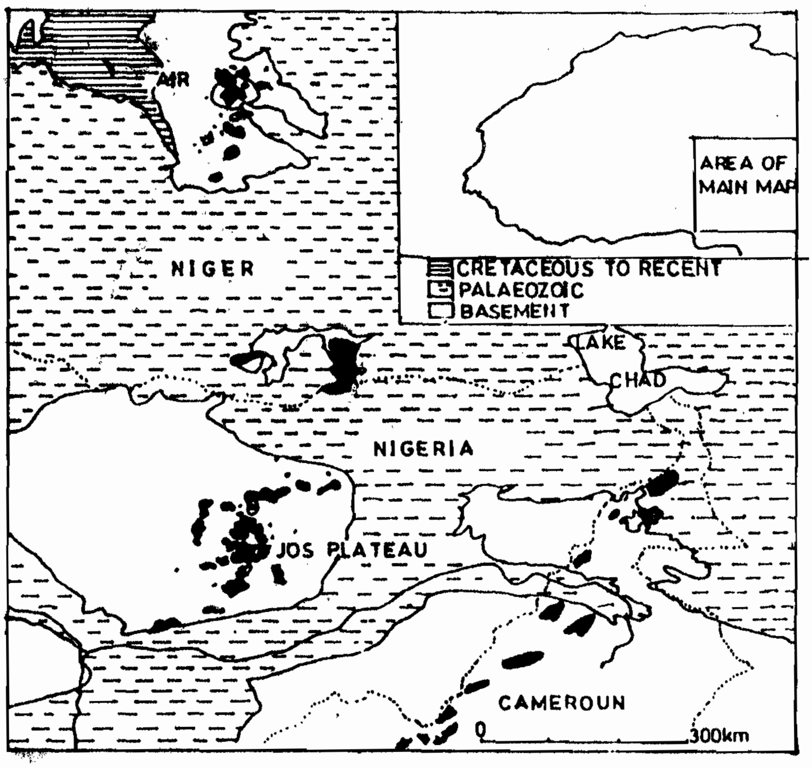

Fig 3 The Alkaline ringcomplexes of Niger-Nigeria and Cameroon(black shading) and the basement pre-cambrian associated with them (unshaded areas).Modified from Kinnaird (1985)

Irregular shaped replacement bodies: Irregularly shaped replacement zones containing massive or disseminated ore may occur in the roof and contact zones of biotite granite bodies of the alkaline complex. Generally they are composed of mica-rich greisens formed by hydrogen ion metasomatism of rock already altered by potash metasomatism. The green coloured mica is in the compositional range Fe siderophyllite to Li siderophyllite and is accompanied by quarz± fluorite± siderite with cassiterite and sulphides (Table 1).

In the mineralised zone, deposition of cassiterite and wolframite, accompanied by siderite , was followed by massive sphalerite and chalcopyrite, then pyrite and green fluorite (Abaa, 1976) . The dark iron sphalerite, with up to 17% Fe forms massive well twinned crystals <25 cm in size which are brecciated and recemented by late stage wolframite-bearing quartz veins. Brecciation probably took place during sphalerite formation as the chalcopyrite exsolution blebs within the sphalerite are elongated into rods. The shpalerite clasts often have a thin crust of quartz crystals.

Quartz veins: The quartz veins are generally vertical and vary from massive milky veins 30m wide to clear comb-textured veins 1cm wide. Virtually all the granites of the province show late stage quartz-veining but only those granites which have disseminated mineralization have ores within the quartz veins Mineralised quartz veins also occur in the basement within 2km of the Younger Granites (Abaa 1983)

Wall rock alteration may occur marginal to the quartz veins or the veins may infill fissures in a lode system with mineralised greisen. Also the quartz veins may cut the granite or country rock without any marginal alteration.

The quartz veins that occur in the basement are generally characterized by wolframite of ferberite composition and occurs sporadically as bladed crystals, at the margins or vein centres, oriented parallel or perpendicular to the strike of the veins. The wolframite is accompanied by some cassiterite and minor sulphides and often by bismuth minerals. Well-cleaved leaves, up to 2cm in size, of native bismuth have been found in several complexes (Kinaird 1985).

The wolframite-rich quartz veins of the Dagga Allah area occur at a greater distance from the Younger Granites than is usual. It seems likely that they are related to Younger Granites which may exist at shallow depth within the Dagga Allah ring-dykes (Abaa 1982) and geophysical prospecting supports this possibility (Ajakaiye 1983).

Mineralised ring dykes: Ring-dykes of granite porphyry characterize many of the complexes. Fluids escaping along these steeply dipping fractures locally react with, and mineralise the porphyry. Where fluid interaction has occurred, the fine grained matrix has been largely altered to a greisen assemblage leaving the K-feldspar phenocysts unaltered or partially transformed to microcline. Often these petrological changes are limited to narrow zones although the degree of reaction may be locally intense (Bowden and kinnaird 1984).

The mineralization is characterized by a sulphide assemblage of ores dominated by spalerite, chalcopyrite and galena, with pyrite ,pyrrhotite, stannite, arsenopyrite and molybdenite.

At Zarara quarry in the ring-dyke of the Banke complex the porphyry has been bracciated and cemented by mineralising fluids and late stage vein quartz. Miarolitic cavities lined with microcline contain elongate prismatic quartz crystals. It is apparent that there are several phases of deposition of the major ore minerals and that mineralization was repeatedly emplaced in several lode systems.

Table 1: Examples of lOcations with Jurassic Mineralization in basement rocks of Central Nigeria

Location	Mineralization types	Ore minerals
Bangwelli near Dagga Allah Complex	Fissure-filling and Quartz-sulphide-cassiterite veins within altered zones	Sphalerite, galena, Chalcopyrite, pyrite, arsenopyrite and stannite
Ginyain Banke Complex	Stockworks and stringers of the Quartz wolframite cassiterite veins	Cassiterite,wolframite, columbite ilmenite and minor sulphides
Gindi Akwati near Rop Complex	Veinlike greisen bodies with brecciation and minor late fissure-infilling	Sphalerite, pyrite chalcopyrite arsenopyrite, greenorckite and minor cassiterite
Kigom around Kigom Complex	Irregular pockets of impregnations and comb textured veinlets	Native bismuth, bismuthinite, galena, sphalerite with irregular blocks of molybdenum
Kogo near Tibchi-Yelli Comlex	Stringers and disseminations in massive greenish greisen	Cassiterite, Columbite, minor wolframite with ilmenite and zircon
Rishi near Saiya Shokobo Complex	Veinlike greisens and veins with slightly reddened wall rock, brecciation and disseminations	Fluorite, topaz minor cassiterite and wolframite
Uke- Keffi area near Mada Complex	Pegmatites and quartz feldspar veins in unaltered basement rocks	Nb- Tantalite, aquamarine, emeralds and minor topaz.

Implications for the Oban-Obudu - Mandara-Gwoza Complex of Eastern Nigeria

The Nigerian and Cameroon oversaturated alkaline complexes are similar in composition and are both anorogenic, within plate and of long time duration (Bowden and Turner 1974; Abaa 1991). The two oversaturated alkaline provinces are where the subvolcanic intrusions are overwhelmingly syenitic to granitic in composition with gabbroic rocks occupying normally about 5% of the total area extent. Exception is in the Cameroon (Mboutou) where gabbros are associated with layered sequences including leucogabbros, anorthosites, and monzo-anorthosite Syenites and alkaline granites have textural, petrological and chemical characteristics which are distinctly different from other granitoids and related rocks (Lammeyre and Bowden 1982). They form collectively part of the A-type spectrum (where A stands for anhydrous, alkaline, anorogenic as well as aluminious) to distinguish them from the well-known broad classification of S and I types (Chappell and White 1974, Loiselle and Wones 1979).

The most significant chemical feature of these granites is that slight differences in the proportions of Na, K and Al can produce striking changes in the mineralogy of the A -type suite. The most characteristic feature is the anomalous enrichment in Zr, Zn,Nb,Y Th, U, LREE, HREE (Abaa 1982) coupled with high Rb/Sr ratios. Some of the these features are found in biotite granites but with dramatically less Zr, Hf,Nb and HREE (Bowden 1979).

The evolution and separation of a peralkaline fluid phase from A-type granites has been experimentally demonstrated(Burt 1981, Manning 1981) and can be recorded by distinctive suites of subsolidus minerals and specific geochemical changes. Minerals characteristic of sodic metasomatism include albite, microcline, aegirine, alkali amphiboles (ferroricherite to lithian arfvedsonite), micas (annite, protolithionite, zinnawaldite, cryophyllite), and a range of accessory minerals including chevkinite, astrophyllite, narsarsukite and cryolite (Bonin, 1982, Bonin and Giret 1984 and Abaa 1985). Potassic metasomatism is withnessed by the occurrence of intermediate to ordered microcline, mica compositions from annite to ferrous siderophyllite, and amphibole compositions ranging from ferroedenite to ferroactinolite. Acid metasomatism involves instability of previously formed minerals to give breakdown assemblage, referred to as greisens (Abaa 1982).

From the mineralization viewpoint there are many parallels with the carbonatites particularly with the abundance of sphalerite, rare-earth minerals, zircon and complex titanium-zirconyl silicates, uranium and thorium, columbite and pyrochlore. Such a distinctive alkaline mineralization suite, possibly related to an alkali carbonate fluid phase, is superimposed on a more normal, less alkaline group of ore minerals such as cassiterite, wolframite, chalcopyrite and galena, a further correlation between Central Nigeria and Cameroon. (Bowden and Kinnaird 1978)

Besides the similarities of the saturated alkaline provinces of Nigeria and Cameroon, there are other similarities during the Mesozoic-Tertiary-Recent.

The tertiary recent volcanic rocks of the Nigeria-Cameroon province lie within the Pan-African belt of West Africa (which here consists of Archean and Proterozoic basement reactivated during the Pan-African orogeny) but are confined to the eastern part and are absent from the area west of the Jos Plateau. This eastern area has been one of relative instability during the Mesozoic and Tertiary, with the development of deep sedimentary basins, sometimes faulted, and intervening basement swells where erosion has given considerable surface relief (Cratchley and Jones 1965, Turner 1971, Marechal and Vincent 1972, Olade 1975). Volcanic activity in the province is partly concentrated along the NE-SW Cameroon line. This is well defined in its oceanic section and far inland as the Bamenda Highlands, but then is replaced by a wide fan shaped distribution pattern (Fig 4).

Several of the main volcanic regions are characterised by basement uplift: the Jos Plateau, and the Bamenda Highlands, the Mambilla Plateau, the Adamooua Plateau. Similarly the basement in the Biu Plateau area is a structural culmination between the Benue and Chad basins although topographically it is not a very significant swell. The association between volcanism and uplift basement is not exclusive, as shown by the outcrops of volcanic rocks in sedimentary basins such as the Benue Trough and Cross River valley.

Structural control over location of volcanism is often seen in alignments of volcanoes. The Miringa volcanic zone is a pronounced volcanic lineament, although with a length of

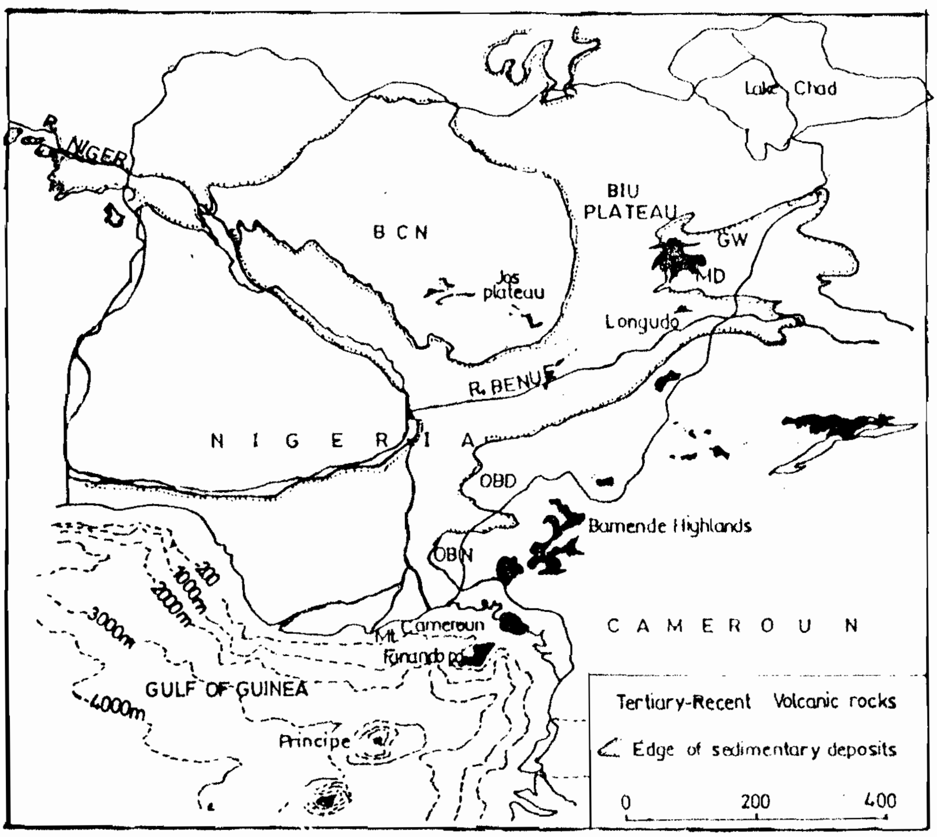

Fig 4 Sketch map indicating mineralized basement areas in Nigerian alkaline province (BCN) and possible areas of mineralization in eastern Nigeria OBN = Oban massifs; OBD = Obudu; MD = Mandalla and GW = Gwoza precambrian areas.

only 55km it is by no means comparable in scale to the Cameroon line. Its NNE trend matches some smaller volcanic alignments on the Jos Plateau (MacLeod et al. 1971), but differs from the E-W alignment of the Garkida plains volcanoes and the NW-SE line of the Song volcanoes further south. The volcanism has possibly followed major fractures in the basement although the NE-SW faults of Cretaceous age cutting the basement adjacent to the Biu Plateau have not apparently exerted any control. A possible more fundamental tectonic control can be suggested in the earth movements forming the Chad Basin during the Pleistocene . A prolongation of the Miringa zone corresponds roughly to the hinge line separating the deep central part of the basin where Chad sediments accumulated to thicknesses of 800 m from the very shallow western part (Barber 1965). Those activities too have contributed substantial ore mineralization in the Nigeria basement as well as the Cretaceous rocks of the Benue Basin. Minerals produced this period include commercial barite, sulphides of Pb and Zn and the associated salt springs (Ekwueme 2005). The basement areas west of the Cameroon are therefore also sites of mineralization associated with the Cameroon volcanic line and such areas include the Oban-Obudu-Mandara-Gwoza complex which should also constitute a metallogeny as indicated in Fig 5.

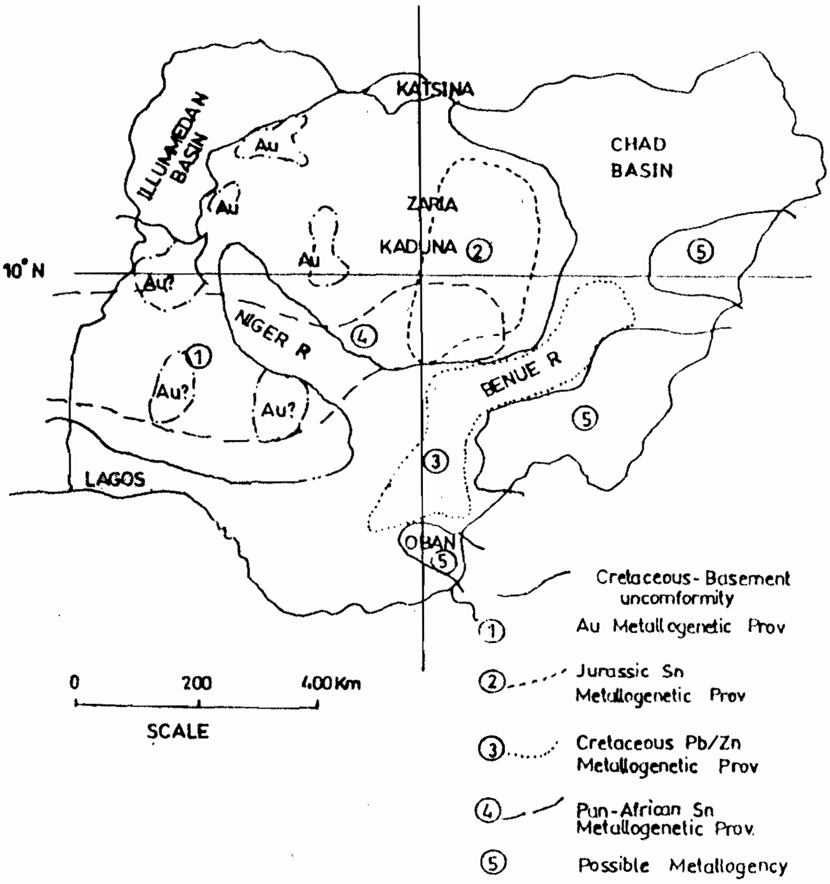

Fig 5 Metallogenic map of Nigeria indicating that the Oban-Obudu-Mandara-Gwoza areas have not been studied fully for their mineralization. (modified from Woakes 1988).

CONCLUSIONS

During the uprise of differentiated liquids from the magma chamber to the level of the ring complexes at a rate of the order of $5x10^{-2}$ cm s^{-1} (Bonin 1982), all the crystals are floated and remain in contact with the liquids. Differentiation occurs by flowage (Bhattacharji 1966) in the feeding conduits (Bagnold effect, Barriere 1976): the early minerals can assemble as microgranular enclaves of olivine-clinopyroxene- amphibole-plagioclase (Bonin 1982) which are segregations in the liquid and which form masses with a diffuse outline often rounded but sometimes net-veining the host-rock and the scarcity of mafic microgranular enclaves in alkaline series is characteristic when compared with calc-alkaline series (Didier 1973).

During the emplacement of an alkaline ring complex, juvenile fluids derived from the crystallization of the magma and recycled crustal fluids react with the solid rocks to give rise to hydrothermal alteration products which may be associated with metallic concentrations. The geochemical systems can then be profoundly modified and isotopic systems are still more sensitive. In this scheme, which invokes the crust through hydrothermal leaching, it is not necessary to have an important component obtained by anatectic melting of the crust. Such systems usually introduce substantial ore mineralization in the pre-existing country rocks.

In the Oban-Obudu -Mandara- Gwoza basement area, these A-type granites in the vicinity have been shown to be dominated by the separation of a fluid phase as is recorded by distinctive suites of subsolidus minerals and specific geochemical changes (Liegeois et al 1983). If these fluid phases have affected the Oban-Obudu-Mandara-Gwoza massifs as in Central Nigeria then there must have developed an abundance of sphalerite, rare-earth minerals, zircon and complex titanium-zirconyl silicates and columbite. Such a distinctive alkaline mineralization suite related to the alkaline granitic fluid phases must have been superimposed on the more less alkaline but more or less calc-alkaline group of Oban-Obudu-Mandara-Gwoza rocks with less alkaline group of ore minerals such as cassiterite, wolframite, galena, chalcopyrite, barite and gem minerals and should be targets for mineral exploration.

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