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

S. I. ABAA and T. NAJME

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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 replacement 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 quartz 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 feldspars have been reported in the area and could be a metallogenic province in Nigeria.

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

INTRODUCTION

The Nigerian Younger Granites are regarded as belonging to an alkaline type over-saturated province among several other alkaline provinces in Africa (Fig 1). These Phanerozoic over-saturated alkaline provinces occur exclusively in the Pan-African domains except the Tertiary to Recent volcanics (Black et al. 1985).

In west Africa, the Iforas over-saturated alkaline province of ring complexes composed of noradimorphite, peralkaline and metafeldspathic 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 560 Ma age between the passive margin of the West African craton and the active margin of the eastern edge of the Guinean 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 calcalzakite batholith which during collision has been subjected to rapid uplift and unroofing (Liegeois and Black 1983).

The Tadheh 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. It is in age it is structurally and spatially related to a north-south rift (Tesoffi graben) close to the sutures (Liegeois et al. 1983).

The Allir (480-400 Ma), Damagearam (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), nodular quartz-rich syenite-pegmatoid 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 Air where they are associated with anorhotites (Black 1985, Black et al. 1997, Moreau, 1982, Leger 1985), and in the Damagearam (Black 1983, Mignon, 1970), whereas metasomatised and subaluminous granites are the most prevalent rock types in Nigeria (Jacobson et al. 1958). The three provinces lie between longitudes 8°E and 10°E 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 (Ayaba 1982), which probably are largely of crustal origin (Black 1980). In Air, extensive transcurrent faulting occurred prior to the emplacement of the ring complexes and was accomplished by crustal doming as indicated by the southerly tapering of the Peraezoic along the western border of the Air (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 paralleled to the marginal faults of the Benue trough which has recently been interpreted as a pull-apart basin determined by sinistral shear (Benkheli 1982), and which contains transitional basaltic and alkali rhyolite which have yielded a Rb-Sr age of 113±3 Ma (Umeji and Caen-Vachette 1983).

The Cameroon alkaline rifted alkaline province (Fig 2) 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 masses are aligned on the north-northeast “Cameroon line” defined by the Fernando Po, Principle and Sao Tome islands. The NNE-trending observed in southern Cameroon are sinistral transcurrent faults, which offset the Cretaceous basin (Black et al 1985).

Soubat and Mascle (1973) 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 Chocot fault zone (Mascle 1976, Benkheli 1982). Whereas the Nigerian alkaline Younger
Fig 1 Sketch map of Africa indicating late pre-cambrian and phanerozoic 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.
MINERALIZATION IN PRECAMBRIAN ROCKS OF CENTRAL NIGERIA

Grainite 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. Iberia, Corsica, 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 1986, Black 1984).

This paper aims at highlighting various areas in Africa where alkaline anorogenic complexes have aided mineralization in the Pan Africa belts due to remobilization. Emphasis 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-Mmanders-Gwoza basement axis in the eastern part of the country thus far 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 remobilization as economic minerals has been contributed during these plate collision events (Almeid, 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 aluvial 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 intensive 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 Pan-African crust is mineralised with Nb, Sn, and so on, then it is a natural consequence that the Phanerzoic 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 monzogranites (Abaa 1985). The nature of such mineralization is as follows.

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Fig 3: The Alkaline ring complexes 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. In regularly 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 siderophylite to Li siderophylite and is accompanied by quartz, fluorite, siderite, and 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 then 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 remelted by late stage wolframite-bearing quartz veins. Breciation probably took place during sphalerite formation as the chalcopyrite exsolution blebs within the sphalerite are elongated into rods. The sphalerite clasts often have a thin crust of quartz crystals.

Quartz veins. The quartz veins are generally vertical and vary from massive milky veins 35m wide to clear comb-textured veins 1cm wide. Virtually all the granite of the province show late stage quartz-veining but only those granites which have disseminated greisens. 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 occur sporadically as bladed crystals, at the margins of vein centres, oriented parallel or perpendicular to the strike of the vein. 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 localities (Kinimait 1985).

The wolframite-rich quartz veins of the Dogga 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 Dogga Allah ring-dykes (Abaa 1982) and geophysical prospecting supports this possibility (Ajaikaye 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, a fine grained matrix has been largely altered to a greisen assemblage leaving the K-feldspar phenocrysts 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 Kinimait 1984).

The mineralization is characterized by a sulphide assemblage of ores dominated by sphalerite, 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 breciated and cemented by mineralising fluids and late stage vein quartz. Microlitic 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 Jurassic Mineralization in basement rocks of Central Nigeria

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

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 granite in composition with gabbric rocks occupying normally about 5% of the total area extent. Exception is in the Cameroon (Mboufou) where gabbrics 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 (Lammyere and Bowden 1982). They form collectively part of A-type spectrum (where A stands for anhydrous, alkaline, anorogenic as well as aluminium) to distinguish them from the well-known broad classification of S and I types (Chappell and White 1974, Lalouille and Wones 1973).

The most significant chemical feature of these granites is that slight differences in the proportions of Na, K
MINERALIZATION IN PRECAMBRIAN ROCKS OF CENTRAL NIGERIA

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 (Abba 1982) coupled with high Rb/Sr ratios. Some of these features are found in biotite granites but with dramatically less Zr, Hf, Nb and HREE (Bowden 1979).

The evolution and separation of a peraluminous 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 metamatism include albite, microcline, aegirine, alkalai amphiboles (ferropicrite to lithium arfvedsonite), mesas (annite, protolithionite, zinnwaldite, cryophyllite), and a range of accessory minerals including chevkinite, astrophyllite, navarskite and cryolite (Bonin, 1982; Bonin and Grest 1984 and Abba 1985). Potassic metasomatism is witnessed by the occurrence of intermediate to ordered microcline, mica compositions from anitie 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 (Abba 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-zirconium 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, chloropirite 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 terrigenous 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 basements where erosion has given considerable surface relief (Cratechy and Jones 1965, Turner 1971, Marechal and Vincent 1972, Olate 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 Adamoua 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 basin 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 alignment 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; OB-D = Obudu; MD = Moundia and GW-Gwoza pre cambrian 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 600 m from
the very shallow western part (Barber 1969). 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 $5 \times 10^6$ cm$^3$ 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 1975): the early minerals can assemble as
microgranular enclaves of olivine-clinoptyroxene-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 anastatic 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 (Ligeois et al. 1983). If these fluid
phases have affected the Oban-Obudu-Mandara-Gwoza
massifs as in Central Nigeria then 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
granite fluid phases must have been superimposed on the more less alkaline but more or less calc-alkaline group of Obu-Obudu-Mandara-Gwiza 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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