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Petrology and gold mineralization of the amphibolite belt, Ilesha area, Southwestern Nigeria*

Anthony Azubuike Elueze
Department of Geology, University of Ibadan, Ibadan, Nigeria

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Abstract

The Ilesha amphibolite belt is composed of metasedimentary rocks and a mafic complex comprising mostly amphibolites and amphibole schists, with intercalations of talc bodies. These assemblages occur within a polycyclic basement of largely ancient gneisses and migmatites, and underlie alluvial gold deposits. In addition, the district is characterized by minor and major structural features including folds, fractures and lineaments which commonly have a northerly strike.

Auriferous quartz veins are known to be emplaced along structural elements in the amphibolite complex.It is believed that the alluvial gold deposits were derived from weathered auriferous veins and veinlets. Sulfur contents of the amphibolites and amphibole schists are relatively high, supporting the occurence of sulfides, possibly in relation to primary gold.

The mafic units are magmatic and are therefore considered the ultimate source of the vein-type gold deposits. On the basis of overall geological and geochemical characteristics, it is suggested that the mineralization was linked to metamorphic-hydrothermal processes.

Introduction

For many decades, the Ilesha area within the Precambrian basement complex of southwestern Nigeria (Fig. 1), has been widely known for the substantial production of gold, mainly from alluvial workings (De Swardt 1953). These are concentrated in a district west of Ilesha (Fig. 2) where the underlying and possible source rocks constitute what is essentially referred to as the 'amphibolite belt'. These rocks generally belong to the Proterozoic schist belts of Nigeria which are believed to have evolved largely within the time span of ca. 1700–600 Ma (Elueze 1981a, Bear 1981). Apart from gold, minerals of potential economic interest include nickeliferous pyrrhotite (Onuogu & Ferrante, 1965), lateritic iron and chrome and industrial raw materials, notably talc.

In terms of structural features, lithologies and mineralization, the Proterozoic schist belts of Nigeria show notable similarities with Archaean greenstone belts of southern Africa (Hubbard 1975). However, the latter contain much larger volumes of mafic to ultramafic units and assemblages of lower metamorphic grade. An impressive number of gold deposits in the world occur in the Archaean greenstone terrains, and their geological and metallogenic settings are relatively well known

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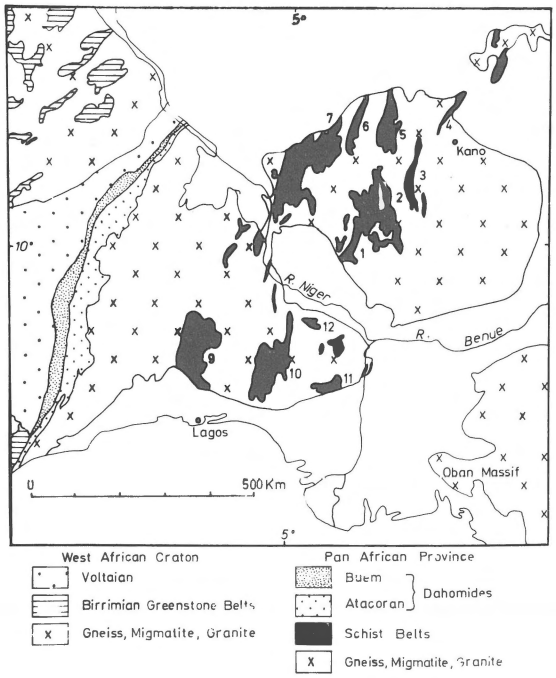

Fig. 1. Compilation map showing the generalized geology of the eastern part of the West African Shield, and location of the schist belts in Nigeria (10 is Ilesha).

(e.g. Viljoen 1982). This paper discusses the distribution of the principal rock units of the Ilesha amphibolite belt and their relationships, particularly with respect to gold mineralization.

Geological setting

The Precambrian basement complex of Nigeria is composed essentially of a crystalline suite, with northerly trending linear schist belts (Fig. 1). The older crystalline complex largely comprises gneisses and migmatites, plus minor quartzitic and calc-silicate-bearing units, and bears imprints of Liberian (ca. 2500 Ma) and Eburnian (ca. 2000 Ma) events (Oversby 1975). The Proterozoic schist belts (Elueze 1981a; Turner 1983) occupy narrow troughs mainly within the western part of the ancient gneiss-migmatite complex (Fig. 1). They include predominantly metasediments which, as in the Ilesha area, are generally associated intimately with bodies of mafic and ultramafic rocks. Grant et al. (1972) and Bear (1981) have indicated that the effects of the Kibaran event (ca. 1200 Ma) are represented within the schist belts. Although this assertion is disputed by some workers (e.g. Rahaman 1981), Pan-African (ca. 600 Ma) granitic bodies commonly intrude the lithologies of the older crystalline complex and the schist belts. The regional strike of foliation of the rocks and principal lineaments is generally N-NE trending. Metamorphic grade is essentially greenschist to amphibolite facies. The former is attained mostly in the metasediments. Higher grade, commonly upper amphibolite facies, is prominent in the older gneiss-migmatite complex.

In the Ilesha area (Elueze 1977) the rock units are structurally divided into two main segments by a major northerly trending fault system. The eastern segment comprises mostly extensive psammitic assemblages, granitic gneisses and intrusive granites (Hubbard 1975), while the amphibolite belt largely constitutes the western segment. The amphibolite belt (Fig. 2) includes a variety of quartzites/quartz-schists, quartz-mica schists and a mafic complex composed mostly of amphibolites and amphibole schists, with related meta-ultramafites found commonly as bodies of talc/tremolite schists.

Petrology

Gneiss-migmatite complex

This occurs mainly in the southeastern part of the district, and is partly delimited by faults (Fig. 2). Outcrops within the fracture zones are finely foliated. Minor fold patterns of leucocratic veins and quartz lenses occur randomly. Biotite commonly forms selvages on the lenses. Elsewhere, samples display a banded fabric, with biotite and often hornblende forming the melanocratic layers. Felsic ptygmatites and tabular masses of pegmatite are found frequently in the rock.

In thin sections, quartz, plagioclase and microcline are anhedral in aggregates. Hornblende forms slender crystals with marked parallel orientation, while biotite is found as flaky intergranular

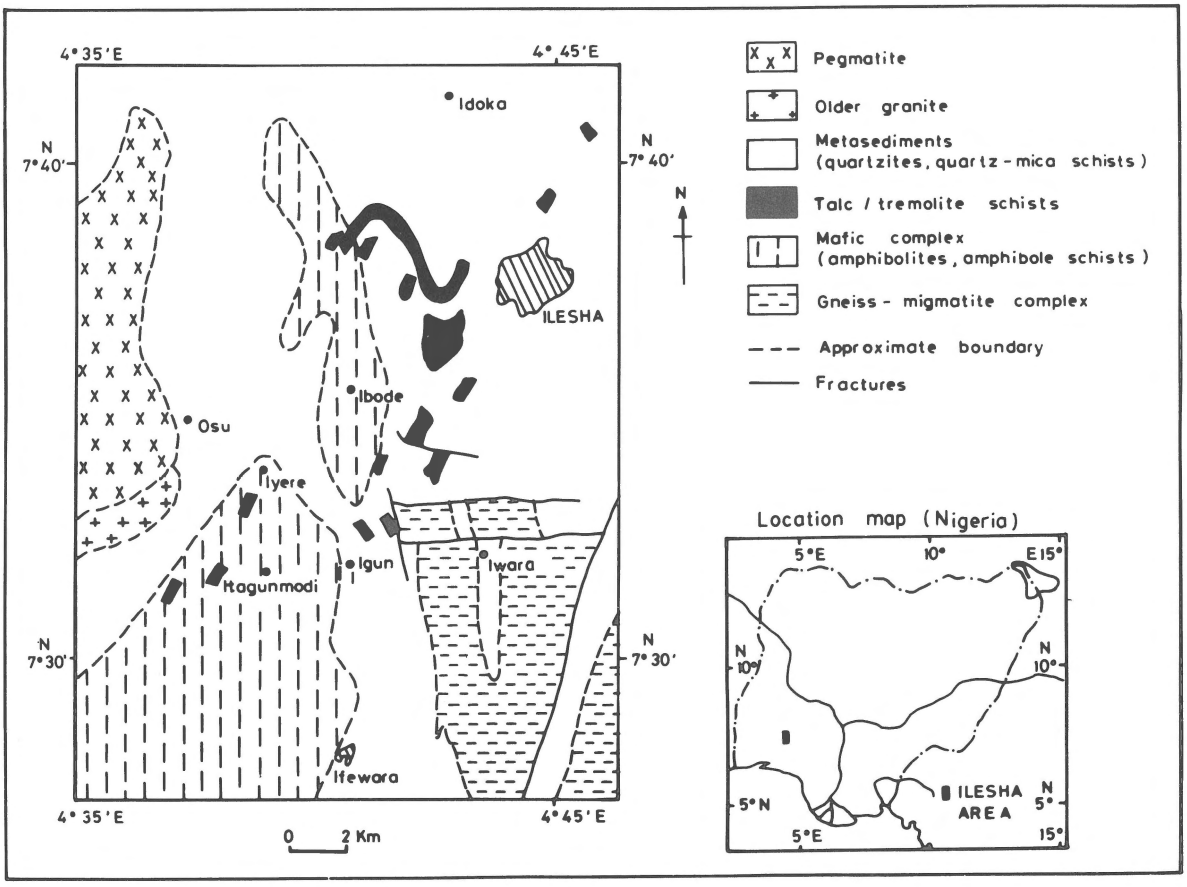

Fig. 2. Geological map of the amphibolite belt of the Ilesha area in south-western Nigeria.

cystals. Sericite occurs in minor amounts, and tends to replace plagioclase. The tectonized samples display typical mortar structures, and lensoid felsic grains are girdled by darkish streaks comprising shreds of biotite, opaque and sphene. Epidote which is often zoned, may be observed.

Mafic complex

The mafic complex is composed mainly of amphibolites and occurs as two major bodies surrounded by a number of smaller exposures within the metasediments (Fig. 2). Outcrops exhibit marked variations in field and textural characteristics and mineralogical compositions (Table 1). The bodies are commonly massive in character, but are locally banded or schistose in fabric. The textural changes often indicate an increase in felsic constituents or a prominence of tremolite/antinolite or even chlorite. A variety is found to contain appreciable quantities of epidote and microcline. In addition, anthophyllite-bearing units are other types within the mafic complex. Outcrops consist mostly of fibrous to needle-like aggregates of anthophyllite with substantial amounts of opaque components. Tremolite schists are composed essentially of tremolite/actinolite, sometimes in rosette arrangement, and minor percentages of talc, calcite and opaques. The major chlorite schist body occurs south of Igun (Fig. 2). Samples generally show typical nodular textures, with garnet crystals found within aggregates of chlorite flakes, alternating with quartz-rich layers.

In some areas, e.g. to the southeast of Itagunmodi or northwest of Ifewara (Fig. 2), gneissic or

feldspathic amphibolite is found dominantly. Outcrops contain varying proportions of hornblende and feldspar. Bands of hornblende crystals may be observed alternating with discontinuous felsic layers. Apatite crystals are conspicuously developed in most exposures which commonly bear irregular and discontinuous quartzo-feldspathic bodies and quartz veins. Under the microscope, hornblende porphyroblasts with frayed margins may enclose plagioclase, apatite and secondary pods of calcite. Hornblende is at times rimmed by biotite, while plagioclase often displays bent twin lamellae. Large garnet crystals are prominent, especially in slides rich in plagioclase and quartz.

Talc/tremolite schists

In the area, talc-rich rocks are widely distributed, although they are commonly not extensive (Fig. 2). Elueze (1977) has shown that they occur either along amphibolite margins or are associated with folds, faults and other structural features.

The assemblages are of a variable nature in terms of mineralogy and texture. They may be essentially made up of talc and, in addition, may contain tremolite, chlorite or muscovite. In some occurrences, schistosity is imparted by the parallelism of talc flakes. Others may be rather massive in character. In addition, samples may develop crenulations or parting planes along the foliation. Masses of quartz are commonly found in close association with the talc bodies.

Metasediments

Metasedimentary units are intimately related to the amphibolites (Fig. 2). They include quartzites/quartz schists, quartz-sericite/muscovite schists, quartz-chlorite/biotite schists and quartz-biotite schists. These rocks generally grade into each other. In general, biotite-bearing schists occur most extensively, and minor masses of a variety containing conglomerations of garnet enclosed by biotite grains, are also encountered within the mafic complex. Samples of the biotite schists are well foliated due to the lepidoblastic habit of abundant biotite flakes alternating with granulose felsic layers. Thin sections show different compositions, and garnet with or without staurolite may be found in notable percentages (Table 1).

Structural features

Minor and major structural elements characterize the amphibolite belt. Besides foliation and linea-

Table 1. Average modal compositions of some rocks of the Ilesha amphibolite belt.

	Massive amphibolite	Banded amphibolite	Tremolite schist	Feldspathic amphibolite	Biotite schist
Hornblende	78	60	–	40	–
Tremolite	–	–	75	–	–
Anthophyllite	–	–	15	–	–
Biotite	–	–	–	–	32
Plagioclase	–	10	–	38	3
Quartz	3	18	–	12	43
Sphene	8	3	–	–	–
Garnet	–	–	–	3	10
Staurolite	–	–	–	–	8
Opaques	9	6	–	–	–
Others	2 (ap., pl., ep.)	3 (ap., ep., ga.)	10 (ta., op., ca.)	7 (ap., sp., op.)	4 (op., ca., to., mu.)

(ap. = apatite, ca. = calcite, ep. = epidote, ga. = garnet, mu. = muscovite, op. = opaques, sp. = sphere, ta = talc, to. = tourmaline).

tion in the different rocks, the mafic complex essentially forms a major anticlinal fold with a northerly plunging axis roughly coincident with a median zone of magnetic anomaly (Elueze 1977). Other folds are marked by bands of quartzites/quartz schists and lenses of ultramafic rocks. Fractures and shear zones are well developed and they sometimes define the boundaries between rock units. The gneiss-migmatite is prominently truncated by faults. Some of these are easterly trending and include the 'Iwara fault' (cf. De Swardt 1953). Several structural trends observed on aerial photographs and consistent with field observations, are associated with zones of alluvial gold deposits. In some places, the axial zones of folds exhibit shear displacement.

Mineral resources

Gold mineralization in the Ilesha amphibolite belt may be broadly differentiated into primary and secondary types. The former occurs as auriferous quartz veins and disseminations in amphibolites and related rocks. However, gold won from the area is mainly from secondary enriched deposits in alluvial channels. Most of the workings are concentrated around the central zone particularly close to Itagunmodi (De Swardt 1953; Elueze 1977).

Auriferous quartz veins and stringers in the amphibolite belt are commonly localized along fractures, folds and foliation planes. There are also indications, particularly from studies on mine workings, that some occurrences are related to the contacts between the biotite-rich rocks and amphibolites/talcose bodies (Oyawoye 1976; Elueze 1977). The talc/tremolite schists are generally associated with folds and shear zones. Samples of quartz from the veins and mine dumps are usually laminated and bear mica flakes along parting planes. These characteristics inferably reflect the effects of subsequent deformation probably associated with the Pan-African event (Elueze 1977).

Sulfides comprising arsenopyrite, pyrrhotite, pentlandite and chalcopyrite are often present in the veins, and are also found as specks in the adjacent amphibolites. Other related ore minerals are magnetite and ilmenite. The majority of the rocks have S and TiO_2 contents of above 500 ppm and 2%, respectively. The anthophyllite/tremolite-rich units are particularly elevated in S abundance which may be up to 0.75%. P_2O_5 concentrations (at times >5%) are appreciably high in the apatite-bearing gneissic amphibolites. These are commonly traversed by felsic mobilisates.

On the whole, petrochemical trends show that the assemblages of the mafic complex are largely metavolcanics (Olade & Elueze 1979). However, notable compositional changes in units such as the felsic varieties, are due perhaps to alteration associated with reactivation and remobilization.

The alluvial deposits are believed to have resulted principally from the discharge of gold due to weathering of the auriferous veins and stringers, and mechanical accumulation of nuggets and grains along the drainage system. Interpretation of geochemical data show that secondary dispersion of metals in the area, generally reflects lithological, environmental and mineralization controls. Infiltration may also have contributed to the concentration of the gold nuggets within the weathered profiles, prior to their distribution into the alluvial channels. Mining in the district has mostly been by pitting and excavation of old and active stream beds, and panning of the sediments. Outputs have dwindled from about 800 kg in the 1940's to below 10 kg in the 1970's.

Other mineral resources include the talc-rich rocks with high MgO content (ca. 30%). These have some prospects for exploitation as industrial raw materials. In addition, some of the mafic rocks are significantly enriched in iron (ca. 20% total Fe) and ultramafic bodies have high Ni and Cr values (>1500 ppm). There are some indications that the residual soils derived from these rocks, correspondingly have potential for concentrations of lateritic iron, nickel and chrome.

Discussion and conclusion

The amphibolite belt of the Ilesha area shows close relationships between mafic/ultramafic units and pelitic/semi-pelitic assemblages. Prominent struc-

tural features in the area include folds, lineaments and fractures. Petrochemical data indicate that the mafic rocks are essentially metavolcanics.In addition, the biotite schists are comparatively elevated in TiO_2, Ni and Cr concentrations, and may be partially of volcanic origin (Elueze 1981b).

On the basis of petrological and geochemical characteristics, structural dispositions and field relationships, it is deduced that as elsewhere (cf. Worthington & Kiff 1970) these volcanics are possibly the ultimate sources of the gold. Keays & Scott (1976) emphasized that the potential of any rock as a source for the formation of epigenetic gold ore body, is largely dependent on the availability of 'excess' or 'reactive' gold. This includes the occurrence of gold in sulfides, in mesostasis phases, and on grain boundaries. Consequently, the presence of sulfides and minimum melt phase could have enhanced the derivation of gold from the volcanics. Furthermore, Robert et al. (1971), Gottfried et al. (1972) and Viljoen (1982) stressed that despite a low primary gold abundance in a source rock, mineralization is mainly a function of the capability of the mobilizing agent or fluid and the availability of favourable structural sites for deposition. The latter in particular, abound in the amphibolite belt (De Swardt 1953; Elueze 1977).

The Ilesha area occurs within the Precambrian basement complex of Nigeria which essentially has a polycyclic evolution (Turner 1983). The earliest event possibly tallies with the Liberian (ca. 2500 Ma). Subsequent orogenic episodes include the Eburnian (ca. 2000 Ma), the Kibaran (ca. 1200 Ma) and the Pan-African (ca. 600 Ma). Each event involved partly or wholly, the emplacement of a granitic suite, intensive thermal activity and reactivation/remobilization. In particular, it is believed that the Kibaran tectogenesis was marked by granite intrusion and metamorphism in the Ilesha schist belt. This is consistent with the age of 1190 ± 140 Ma yielded by the neighbouring Ife granite-gneiss (Grant et al. 1972). Metamorphism-hydrothermal activities may therefore have contributed significantly to the development of the gold veins and the generation of the felsic and phosphorous-rich amphibolites. It is noteworthy that as demonstrated by Elueze (1977) the association of P-Fe-As is the major indicator to gold mineralization in the amphibolite belt.

It is envisaged that the metallogeny was linked with metamorphism during deformation and with leaching of rocks by hydrothermal fluids. The acquired metal complexes were subsequently transported and deposited along fold crest and troughs, shear zones, fissures, foliation planes and lithological margins, as veins containing gold and sulfides. Elueze (1977) had proposed that this initial phase (probably of Kibaran age) predates the Pan-African event which was rather marked by renewed deformation.

Except in the felsic amphibolites, extensive alteration is not apparent in the country rocks, which possibly supports the idea that the amounts of hydrothermal fluid involved were likely not enormous. The assertion of Sawkins (1972) lends credence to the view that the energy and solutions required for the redistribution of gold, quartz and accompanying sulfides could have been provided by metamorphism. On the other hand, Roberts et al. (op. cit.) identified precipitants as the additional major requirement for gold mineralization. In the Ilesha area, these may include zones of lithological contrast, such as the margins of pelitic units and talcose bodies (Elueze 1977). Else, deposition would have been initiated principally by the drastic reduction in stress and temperature during fluid migration along the dislocations. This may have entailed the development of dilatant zones for the concentration of gold and accompaning minerals. Secondary accumulation of gold, through weathering processes, is of much importance in the Ilesha district, as evident in the sizeable recoveries from placer deposits.

Other potential mineral resources include lateritic iron, nickel and chrome. In addition, are the disseminated sulfides and oxides comprising arsenopyrite, pyrrhotite, pentlandite, magnetite and ilmenite in the mafic units, and talc in the ultramafic bodies. On the whole, this study has defined major areas for follow-up investigation.

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