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Metallogenesis of the Lode Gold Deposit in Ilesha Area of Southwestern Nigeria: Inferences from Lead Isotope Systematics

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Abstract. Studies were carried out on the geochemistry of 18 representative samples of the granite gneiss host rock, common Pb dates on six granite gneiss whole rock samples, six feldspar sample separates, and six samples from the lode gold deposit in the Ilesha schist belt. The AFM plot for the biotite granite gneiss indicated that its protolith was derived from a subduction related tectonic setting. The granite gneiss had low U/Pb and Th/Pb ratios (0.10 to 0.31 and 0.33 to 1.31, respectively), and upper crustal Pb content of 30-47 ppm. The $^{207}Pb/^{204}Pb$, $^{206}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$, were extremely homogeneous in the host rock, the feldspar, and the pyrite indicating derivation from a subduction related environment like a back arc or island arc. The two-stage Stacy and Kramers (1975) Pb-Pb model dating method of interpretation adopted in this study indicated that the granite gneiss was emplaced at 2750 ± 25 Ma in an orogen. On analysis, common Pb in pyrite yielded an average model age of 550 Ma. This Pb systematics indicated that Au was derived from the volcanics in the Ilesha schist belt by hydrothermal leaching, transported through the same medium and deposited in the massive quartz veins as thio-complexes from which native gold was liberated through interaction of the ore fluid and spinnels in the host rock.

Keywords: metallogenesis, orogen, schist belt, isochron, Nigeria geology, protolith, tectonic, gold, lead isotopes, lead dating, granite gneiss

Introduction

The schist belts in Nigeria constitute an integral part of the Nigerian basement complex, and are noted for gold, iron, tin, tantalum, niobium and marble minieralisation. The Nigerian schist belts, which have been described as Archaean greenstone belts (Wright and McCurry, 1970), cover over 400 km^2 along a N-S trend confined prominently to the western half of Nigeria. On the basis of isotope studies, Archaean, Mid-Proterozoic, or Late Proterozoic ages have been suggested for the schist belts by different workers (Dada *et al.*, 1998; 1989; Annor, 1995; Rahaman *et al.,* 1991; Rahaman, 1988; Elueze, 1982; Odeyemi, 1981; Oversby, 1975; Oyawoye, 1972; Grant, 1970; Russ, 1957). Others, on the basis of petrological, geochemical and structural studies, are of the opinion that the schist belts are Pan-African in age (Rahaman *et al.*, 1988; McCurry, 1976). Pan-African granitic rocks or the older granites commonly intrude into the migmatitic gneisses and units of the schist belt (Elueze, 1987). Tubosun *et al.* (1984) and Rahaman *et al.* (1991) also observed that Pan-African metamorphic imprint was very prominent on the older basement rocks, especially the migmatitic and granitic gneisses. According to Ajibade *et al.* (1989), the southwestern Nigeria schist belts are of two age generations, one represented by migmatite gneiss complex sequence, probably of Archaean to Early Proterozoic age, while the other is believed to be of Late Proterozoic age. The schist belts consist dominantly of pelites, which are represented by phyllites, garnet-bearing carbonaceous schist, mica-schist, chlorite-schist, chlorite, and graphite-schist (Adekoya, 1988).

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The Ilesha schist belt occurs in the southwestern Nigeria and is famous for the alluvial and lode gold mineralisation that it contains. This belt is separated into two different lithological groupings by the Ifewara-Zuugeru major fault (Fig. 1). In the western half of the belt, the lithology includes amphibolites, hornblende gneiss, biotite schist, talc tremolite schist, quartz-muscovite, Pan-African granite, and pegmatite. Alluvial gold deposits occur at Igun and Itagunmodi in this section of Ilesha schist belt within the amphibolite terrain. In the eastern section of Ilesha schist belt, the terrain consists of granite gneisses, migmatite gneiss, quartz-muscovite schist, and Pan-African granite. A system of auriferous quartz veins occurs in the biotite granite gneiss between Odo and Iperindo villages in this section of the schist belt.

Both the granite gneiss host rock at Iperindo and the lode gold deposit have not been dated. In the present study, the Pb-Pb systematics of the granite gneiss host rock, feldspar and pyrite, which are associated with gold mineralisation in Ilesha schist belt, were studied with a view to establishing the possible dates of emplacement, mineralisation, tectonic evolution, and gold metallogenesis in the belt.

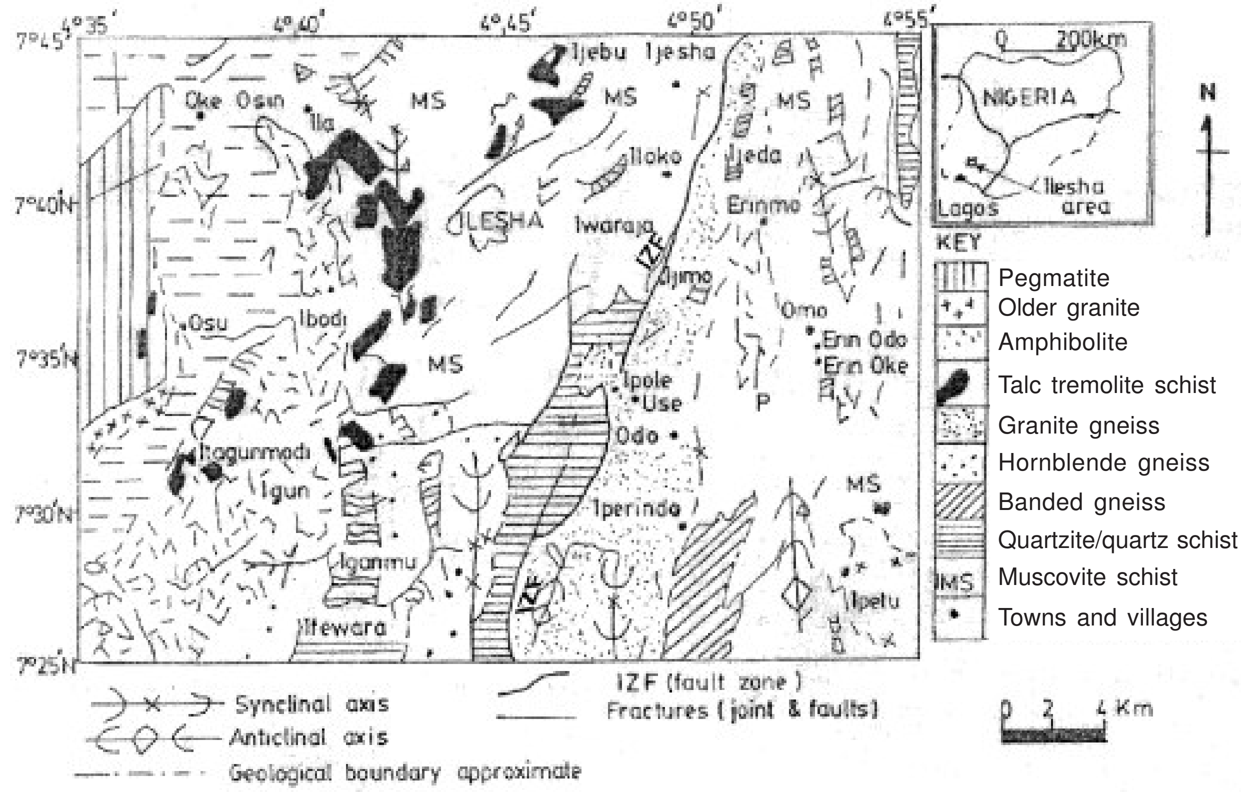

Fig. 1. Geological map of Ilesha schist belt, southwestern Nigeria (modified from Elueze, 1982).

Materials and Methods

Field work was carried out in the Ilesha schist belt to study the various lithological units and obtain samples for laboratory analysis. The petrography was studied on polished thin sections. Major and trace elements were analysed from glass beads and compressed rock powder pellets, respectively, using an X-ray fluorescence (XRF) equipment attached to a computer printer. Lead (Pb-Pb) analysis was carried out at the NERC Isotope Geoscience Laboratory, Keyworth, UK. This analsyis was done on a Finigan MAT 261 mass spectrometer equipped with Pb multicollector. Lead isotopes ratios were corrected for mass fractionation effects at 0.16% atomic mass unit (a.m.u.) for the Finigan MAT 261 mass spectrometer according to repeated runs on the NBS 981. Samples were leached in 3 M HCl. The precision level attained for the Pb-Pb isotopic analysis was better than 0.2% for the whole rock, feldspar, and pyrite analytical runs. The 2σ error for isotopic dilution analysis of Pb concentration is 2%. The whole rock feldspar $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ plot gave an initial ratio of 12.809 and mass spectrometer within-runs detection limit; mass fractionation effect (MSWD) of 16 with a slope of 0.163.

Results and Discussion

Petrography. The biotite granite gneiss host rock of the Iperindo gold deposit is of medium grained texture. It is foliated, and folded with prominent synclinal and anticlinal axes (Fig. 1). Where gneissic banding is prominent, mafic and felsic bands alternate. The biotite granite gneiss is composed of quartz, K-feldspar, some plagioclase, biotite and hornblende, and few muscovite. Commonly, large veins of quartz and feldspar, which can be up to 30 cm wide (Plate 1), are observed on the biotite granite gneiss. The general strike of rocks in this belt is NE-SW and dips are to the east at about 75° on the average. Plunge angles of folds are from 40-70° in a NE direction (cf. Elueze, 1982).

In thin section, the biotite granite gneiss is composed of quartz, biotite, K-feldspar, minor plagioclase, and hornblende. Other minor minerals include garnet and chlorite. Apatite, monazite, ilmenite and zircon occur as accessory minerals. Polished sections revealed that pyrrhotite, pyrite, minor sphalerite and galena were present as primary sulphides.

In the biotite grantie gneiss terrain, lode gold deposits occur in fractures as stock-work of massive quartz veins together with sulphides between Odo and Iperindo villages (Fig. 1). This gold deposit is structurally localized in a brittle-ductile shear zone. The most prominent and dominant sulphide in Iperindo lode gold deposit is pyrite, which occurs in two generations. The first generation pyrite occurs in idioblastic forms with traces of tourmalin inclusion (Plate 2A).

Plate 1. A relatively wide (30 cm) quartz vein in biotite granite gneiss around Iperindo lode gold deposit, southwestern Nigeria.

The second generation pyrite consists of uniform idio-blastic forms and cross-cuts the first generation pyrite (Plate 2B). Gold, though closely associated with the second geneation pyrite, does not form any intergrowth with pyrite or any other sulphide in this deposit. Gold occurs as free independent grains in quartz fissures and may be surrounded by minute specks of gold and pyrite (Plate 3). Most of the gold grains occur as irregular or egg-shaped independent grains in sizes between 97 and 100 microns (Plate 3A and 3B, respectively). For the Pb isotope analysis, the uniform second generation pyrite was extracted and analysed.

Geochemistry. Geochemistry studies included the analysis of major elements, trace elements, and Pb-Pb isotope geochemistry for model dating.

Major elements. The average concentration of SiO_2, Al_2O_3, Na_2O, and K_2O in the granite gneiss samples were normal for this type of rocks (Table 1). The consistently higher K_2O than Na_2O, and hence K_2O/Na_2O ratio greater than 1 recorded in the biotite granite gneiss, is an evidence of more abundant potassium bearing rock forming silicates and also indicates typical Archaean granitic rock (Martins, 1986). The contents of $Fe_2O_{3(T)}$, MgO, CaO and P_2O_5 present in the biotite granite gneiss were very low (Table 1) and these reflect less mafic character of the biotite granite gneiss. On plotting the AFM diagram for the biotite granite gneiss samples, all plotted within the calc-alkaline fractionation trend (Fig. 2), which indicates the development of felsick silicates in preference to the ferromagnesian minerals in a subduction related tectonic environment where mantle had been metasomatised by crustal materials to form a mixed hydrous magma (Wilson, 1991).

Trace elements. Barium (Ba) concentration in this granite gneiss, which ranges from 350-1634 ppm, seems to be anomalous, perhaps due to plagioclase and the presence of hornblende in the mineralogy of the rock. High Rb concentration (average 206 ppm) was possibly due to substitution of Rb for K in the microcline and biotite components of the rock. Strontium (Sr) concentration (average 247 ppm) was equally abundant in this rock, probably due to plagioclase and hornblende content of the rock. Zirconium (Zr) concentration (average of 292 ppm) reflects the presence of apatite and zircon which harbour this element. Average Y content (26 ppm) may reflect the presence of Y bearing hornblende in this rock. The concentrations of Ni, Cr, Co and V were low indicating that the protolith of this rock did not originate from a pure mantle source. Copper (Cu) and Zn contents of the granite gneiss are possibly associated with the silicates and the primary sul- phides in the granite gneiss. Tin (Sn) is perhaps associated with mica in this granite gneiss.

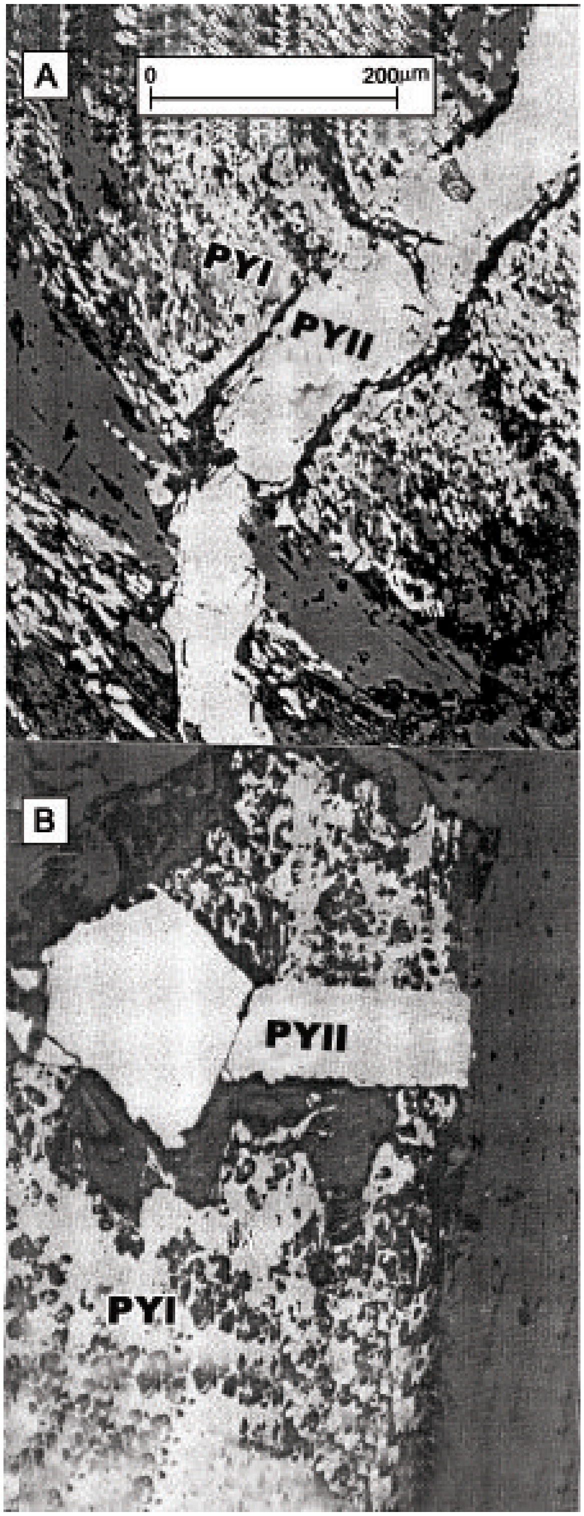

Plate 2. **(A)** Second generation pyrite (PYII) cross-cutting first generation pyrite (PYI) in Iperindo gold deposit; **(B)** idioblastic second generation pyrite (PYII) cross-cutting first generation pyrite (PYI) from Iperindo load gold deposit, southwestern Nigeria.

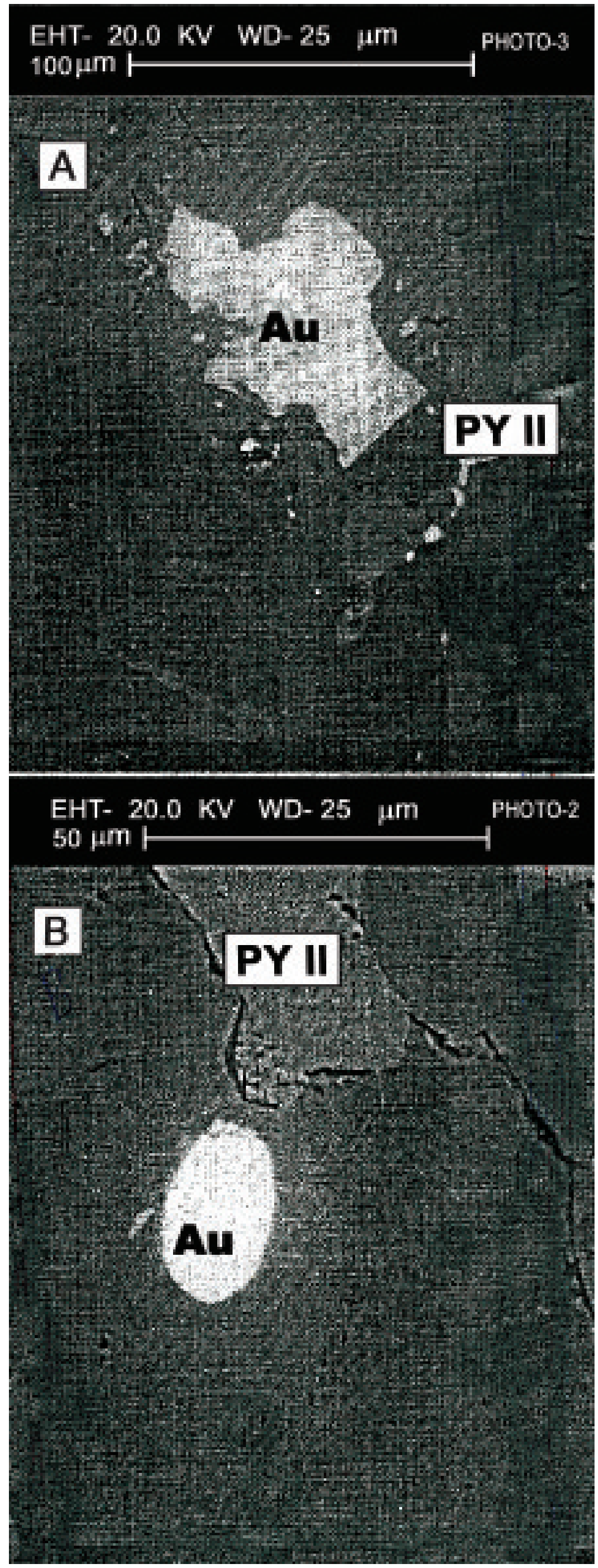

Plate 3. **(A)** Irregular large grain of native gold, 100 microns from Iperindo lode gold deposit; **(B)** egg-shapped native gold grain, 97 microns from the Iperindo lode gold deposit, southwestern Nigeria.

Table 1. Geochemical data for major and trace elements of 18 representative samples of the biotite granite gneiss host rock of Iperindo lode gold deposit in Ilesha area, southwestern Nigeria

	Weight range*	Mean weight*
Major elements		
SiO_2	70.12-76.77	73.50
TiO_2	0.03 – 0.60	0.30
$A1_2O_3$	11.80 – 16.08	13.66
$Fe_2O_{3(T)}$	1.33 – 3.47	2.30
MnO	0.01 – 0.45	0.07
MgO	0.24 – 0.93	0.80
CaO	0.43 – 2.23	1.22
Na_2O	1.34 – 3.38	2.19
K_2O	4.47 – 6.58	5.08
P_2O_5	0.03 – 0.94	0.13
L0I	0.05 – 1.14	0.19
Total	99.24 – 101.54	100.16
Trace elements		
Pb	30 – 47	36
Ba	350 – 1634	998
Sn	0 – 12	6
Zn	30 – 110	53
Cu	50 – 180	68
Ni	6 – 62	19
Cr	0 – 44	17
S	45 – 442	163
La	28 – 93	60
Ce	93 – 222	132
Cs	0 – 42	18
V	15 – 53	32
Co	108 – 222	151
Rb	150 – 275	206
Sr	140 – 465	247
Y	8 – 36	26
Zr	144 – 455	292
Nb	4 – 24	18
Pt	0 – 23	13
Nd	0 – 84	41
U	0.10	5
Th	10 – 50	23
Ga	0 – 25	16
Ta	0 – 7	3
Sc	0 – 23	4
Cd	0 – 11	4
K / Na	1.32 – 4.11	2.3
U / Pb	0.00 – 0.51	0.14
Th / Pb	0.26 – 1.35	0.64

*major elements are reported in oxide weight percent (%), trace elements are reported in parts per million (ppm); $Fe_2O_{3(T)}$, total iron, reported as Fe_2O_3; LOI = loss on ignition; average was calculated with one standard deviation of the mean

The radioactive elements noted to be present were Pb, Th, U, and Nd. The concentration of crustal Pb in this granite gneiss falls within the normal range for such granite gneisses, which may range form 10-100 ppm (Faure, 1986). Uranium (U) had an average concentration of 5 ppm in all the samples analysed, while thorium (Th) had an average concentration of 23 ppm. Neodymium (Nd) showed an average of 41 ppm. The average ratios of U/Pb and Th/Pb were very low, which were 0.14 and 0.64, respectively.

Lead (Pb-Pb) isotope geochemistry and determination of model dates. Uranium (U) and Th bearing minerals often contain radiogenic Pb, while common Pb comes from minerals like galena, K-feldspar, pyrite and other sulphides. These minerals, which contain common Pb, always have low U/Pb and Th/Pb ratios as recorded for the biotite granite gneiss in Ilesha schist belt (Table 1). The U/Pb and Th/Pb ratios of rocks may be changed by metamorphic processes affecting such rocks. Low U/Pb and Th/Pb ratios in a rock suggest that the Pb isotopic composition had not changed with time, hence the rationale behind making use of the whole rock and K-feldspar samples from the Ilesha schist belt-biotite granite gneiss since it satisfied the above conditions.

Lead (Pb-Pb) model dates. The Pb isotopic data for the Ilesha schist belt is presented in Table 2. The whole rock samples, analysed for Pb-Pb isotopes, were from the biotite granite gneiss from Iperindo area (Fig. 1). The samples from the biotite granite gneiss revealed limited scatter points on the Pb-Pb isochron (Fig. 3), but with a well-defined trend. The Pb-Pb results for the six K-feldspar separates (plotted in addition) were from the biotite granite gneiss and were comparable to the equivalent whole rock. The results for all the wall rock and feldspar samples fit well to the indicated best fit line which corresponded to a two-stage isochron 2750 ± 25 Ma, with an initial ratio of 12.809 and (MSWD) mass spectrometer within-runs detection limit; mass fractionation effect) of 16 (Fig. 3).

On plotting the Pb-Pb data on Zartman and Doe (1981), the Pb-Pb evolutionary curves that emerged (Fig. 4) indicated that five out of six of the whole rock samples plotted between the two curves (orogen, OR and upper crust, UP), while only one plotted outside the curves. Five of the six feldspar samples plotted within the orogen. Also, all the six pyrite samples plotted at a point between OR and UP in the orogen, where crustal and mantle materials were partially melted to generate the initial magma from which the protolith of this granite gneiss was formed (cf. Zartman and Doe, 1981).

The interpretation of Pb model dates in this report is based on the two-stage model of Stacey and Kramers (1975) as discussed below. The two-stage evolutionary Pb model of Stacey and Kramers (1975) was based on the fact that primordial Pb evolved between 4.57 Ga and 3.70 Ga (billion years ago). The initial ratio of the reservoir was 9.192, but this changed to 9.732 by geochemical differentiation at 3.70 Ga, as represented by point Q (Fig. 5), and the reservoir has remained undisturbed until the present. On the Stacey and Kramers (1975) growth curve, the granite gneiss whole rock and feldspar Pb experimental points plotted to the left of the geochron Q-P (Fig. 5) crossing the growth curve at point N, giving an initial ratio of 12.809, which was due to geochemical differentiation. The experimental Pb-Pb isochron yields a model age of 2750 ± 25 Ma (million years ago) (Fig. 3). This implies that Pb was withdrawn from the unradiogenic 3.70 Ga reservoir and incorporated into the feldspars and protolith of the granite gneiss at about 2750 ± 25 Ma. This model age, which is Archaean, is therefore the age of emplacement of the protolith of the biotite granite gneiss host rock of the Iperindo lode gold deposit.

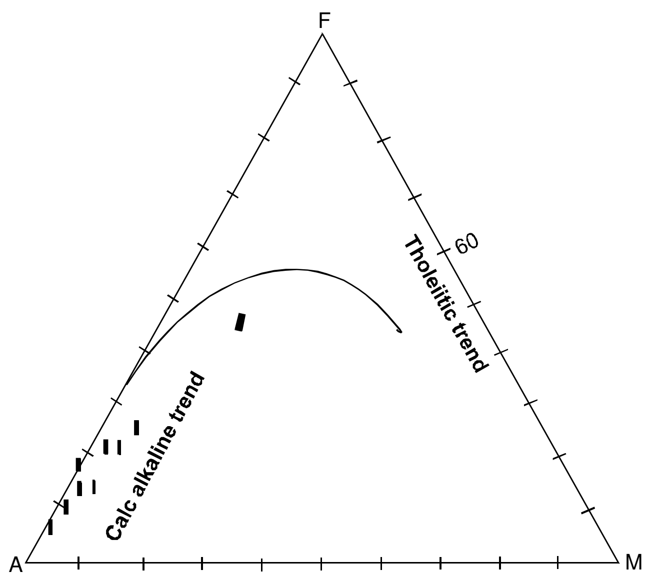

Fig. 2. A=Al_2O_3; F=FeO (total iron); M=MgO (AFM) diagram for the biotite granite gneiss, from Ilesha area, southwestern Nigeria.

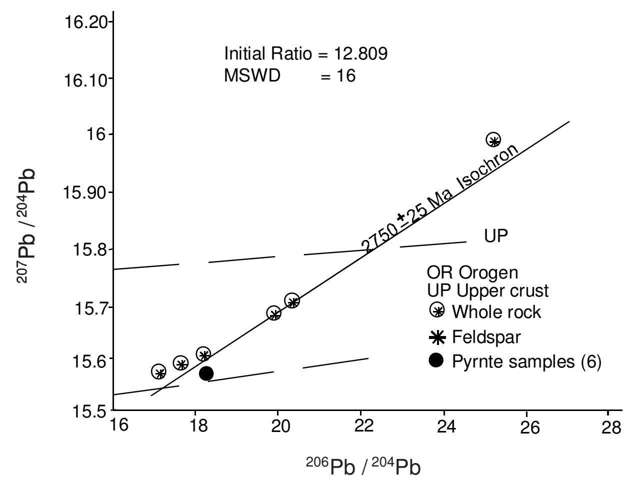

Fig. 4. Plumbotectonic plots using Pb-Pb from K-feldspar whole rock and pyrite samples (based on Zartman and Boe, 1981).

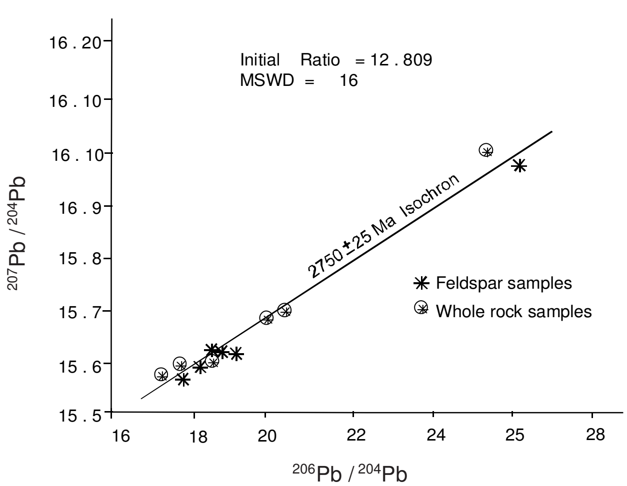

Fig. 3. Lead (Pb-Pb) whole rock and K-feldspar isochron diagram for biotite granite gneiss and K-feldspar from Ilesha schist belt, southwestern Nigeria.

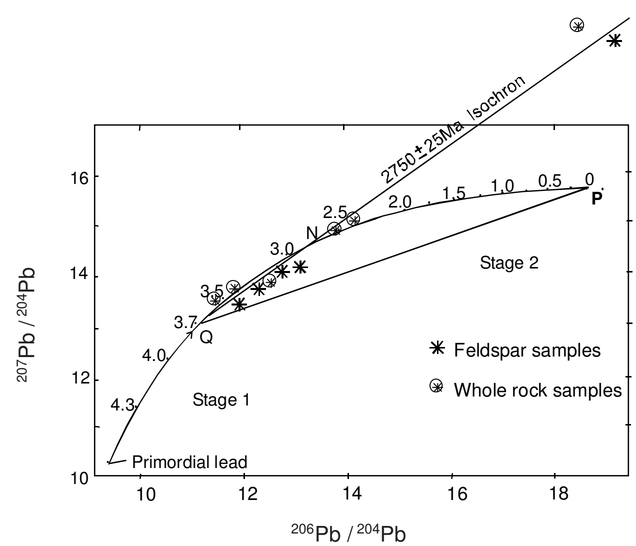

Fig. 5. Whole rock and K-feldspar Pb experimental data points on the two-stage growth curve of Stacey and Kramer (1975).

Table 2. Lead (Pb-Pb) data for granite gneiss, K-feldspar and pyrite from Iperindo vein gold, southwestern Nigeria

Whole rock samples	^{206}**Pb/**^{204}**Pb**	^{207}**Pb/**^{204}**Pb**	^{208}**Pb/**^{204}**Pb**	^{208}**Pb/**^{206}**Pb**	^{207}**Pb/**^{206}**Pb**	Sample weight	
P25C7	20.555	16.100	41.151	2.0021	0.7833	0.179	
P29C1	16.992	15.662	38.656	2.2751	0.9217	0.151	
P29C2	17.468	15.663	37.307	2.1358	0.8966	0.162	
P2AC3	18.698	15.801	39.800	2.1286	0.8450	0.150	
P30C1	19.951	16.062	39.817	1.9958	0.8051	0.157	
Mean	18.773	15.858	39.350	2.1080	0.8510		
Pryrite samples	^{206}**Pb/**^{204}**Pb**	^{207}**Pb/**^{204}**Pb**	^{208}**Pb/**^{204}**Pb**	^{208}**Pb/**^{206}**Pb**	^{207}**Pb/**^{206}**Pb**	Model age	
P13V18	18.237	15.721	38.086	2.0885	0.8621	529	0.071
P25V16	18.290	15.742	38.185	2.0878	0.8606	529	0.042
P29V17	18.237	15.721	38.086	2.9001	0.8611	554	0.056
P2AH13	18.237	15.721	38.086	2.0924	0.8635	573	0.64
P3OV20	18.237	15.721	38.086	2.0911	0.8624	556	0.057
P3OV24	18.237	15.721	38.086	2.0911	0.8624	560	0.078
Mean	18.348	15.725	38.103	2.2252	0.8630	550	
Feldspar samples	^{206}**Pb/**^{204}**Pb**	^{207}**Pb/**^{204}**Pb**	^{208}**Pb/**^{204}**Pb**	^{208}**Pb/**^{206}**Pb**	^{207}**Pb/**^{206}**Pb**	Sample weight	
P24 CA	18.423	15.800	38.270	2.0774	0.8577	0.106	
P25 C9	18.295	15.756	38.397	2.0988	0.8612	0.121	
P2A C9	18.809	15.799	38.314	2.0370	0.8399	0.129	
P30 CS	17.459	15.673	37.427	2.1439	0.8977	0.127	
P33 C7	18.042	15.767	39.237	2.1748	0.8739	0.126	
	18.210	15.759	38.329	2.1064	0.8661		
Mean slope	**1. sig***	**Intercept**		**Age**	**2. sig****		
0.163	0.002	12.809	**MSWD 16**	2750	25 .27		

*= 1 sigma (one standard deviation of the mean; **= 2 sigma (two standard deviation of the mean)

The whole rock samples were isotopically homogeneous with slight deviations from the mean values of ^{207}Pb/^{204}Pb = 15.858, ^{206}Pb/^{204}Pb = 18.773, ^{208}Pb/^{204}Pb = 39.350, ^{208}Pb/^{206}Pb = 2.1080, ^{207}Pb/^{206} Pb = 0.85110 (Table 2). Feldspar samples showed more isotopical homogeneity with Pb content in each sample showing only very slight variations from the mean values of ^{207}Pb/^{204}Pb = 15.759, ^{206}Pb/^{204}Pb = 18.210. ^{208}Pb/^{206}Pb = 38.329, ^{208}Pb/^{206}Pb = 2.1064, ^{207}Pb/^{206}Pb = 0.8661 (Table 2). This type of extreme Pb isotopic homogeneity indicates derivation from a subduction related environment, like a back arc or an island arc where mantle and upper crust materials are thoroughly mixed to generate magma (Billstrom, 1990). The Ilesha schist belt had earlier been described as the one that evolved in a subduction environment of island arc and marginal basin (Oyinloye, 2002; Oyinloye and Odeyemi, 2001; Oyinloye, 1998; Oyinloye and Steed, 1996; Burke and Dewey, 1972). The linear trends displayed by the whole rock Pb data on the growth curve reflects a mixing process between varying amounts of upper crust and mantle materials (Billstrom, 1989; Huhna, 1989; Vassjoki, 1981).

Metallogenesis of Iperindo lode gold deposits. Six pyrite samples from the auriferous quartz veins (gold ore) from Iperindo were analysed for Pb isotopes. The data obtained (Table 2) showed that Pb isotopes in these pyrite samples were extremely homogeneous and very similar in value to those obtained from the whole rocks and feldspar (Table 2). Many of the pyrite samples contained Pb isotope that only varied a little from the mean values of ^{207}Pb/^{204}Pb = 18.344, ^{206}Pb/^{204}Pb = 15.725, ^{208}Pb/^{204}Pb = 38.103, ^{208}Pb/^{206}Pb = 2.2252, ^{207}Pb/^{206} Pb = 0.8630 (Table 2).

On the Zartman and Doe (1981) evolutionary curves, all the pyrite Pb plotted between the two curves just like the whole rock and feldspar samples (Fig. 4), indicating genetic relationship, i.e., derivation from an orogen where the upper crust had been subducted into the mantle (note: only one of the pyrite Pb samples appears, because they all clustered at a point). It may be noted from the model ages calculated for each pyrite sample, Pb varied from 529 Ma - 573 Ma with a mean of 550 Ma (Table 2). The pyrite Pb ages were calculated since all the samples clustered at a point and did not define a line of best fit. Going by the earlier interpretation above, the extreme Pb isotopes homogeneity shown by the Pb in pyrite in the gold deposits may indicate derivation from rocks formed from a mixed crustal and mantle material (volcanics-proto-continent precursor rocks of amphibolites and amphibolite schists) for the Pb in pyrite which forms a prominent gangue in Iperindo lode gold deposits. Lead derived from the crust and upper mantle were emplaced by volcanic activity without contaminating Pb from crust and this explains why the pyrite Pb isotopes do not vary much from the mean values (Table 2). The component of ordinary Pb was probably withdrawn from its reservoir before 2750 ± 25 Ma as a result of magma generation and protocontinent rock formation. There was hydrothermal invasion of the volcanics leading to leaching of Au from these rocks, the removal of Pb from the reservoir, and incorporation into pyrite at about 550 Ma.

Source of Au in Iperindo lode gold deposits. From the Pb isotopes data in pyrite which are found in close association with gold at Iperindo, it may observed that the Au content of the lode gold deposit originated from volcanic rocks that were formed as a result of mixing of crustal materials with the upper mantle as explained above. This association of gold with mafic rocks is often considered a critical factor in the genesis of quartz gold lodes in greenstone terrains (Keays, 1984). Gold and pyrite must have been leached by hydrothermal fluid which invaded the volcanic rocks and transported into the site of deposition.

Lattanzi *et al*. (1989) considered that source rock need not be highly enriched in Au since ore forming fluids can produce enrichment of Au mineralisation through interaction with a host rock containing only a few parts per billion of Au. They argued that rocks like granite gneisses in which some gold deposits are found, like that of Iperindo, can be the source of Au in such deposits. However, in such cases the alteration halo will be very large, in the order of hundreds of metres, before the sparcely disseminated Au in the host rock can be leached and concentrated to form a huge deposit. At Iperindo, the alteration selvage is very narrow (less than 5 m on the average), and hence the granite gneiss could not have been the source of Au in the deposit.

Mechanism for transportation of Au at Iperindo. The Au derived from the volcanic rocks possibly in the western section of Ilesha schist belt was transported and deposited in the granite gneiss host rock around Iperindo in the eastern section of the belt (Fig. 1). Romberger (1986) suggests that Au is transported as reduced sulphur complexes which in most natural systems are deposited in response to fluid oxidation and depletion of total solution sulphur, resulting in pyrite formation in the ore fluid. Carbonyl complexing is a means by which Au is mobilized and transported as reduced species in low redox stage ore fluids (Fyfe and Kerrich, 1984). This explains the common Au-carbon association as observed in the form of gangue graphite or CO_2 liquid and gas in Iperindo ore fluid (Oyinloye and Steed, 2004; Oyinloye, 1992). Carbonyl cyanide and thiocyanide complexes are capable of transporting gold in an ore fluid (Hurchinson and Bunmgton, 1984). According to Schmidt- mum (1985) and Lattanzi *et al.* (1989), sulphur, carbon and chlorine are the elements in hydrothermal fluids which are capable of forming complexes with Au than do most other metals. However, Seward (1984) noted that sulphide species are the most effective complexing agents for gold in a sulphur rich fluid, hence Au in Iperindo deposit may have been transported as sulphide complexes since it was enriched in sulphides. Gold may have been transported in the Iperindo gold deposit as thiosulphide complexes, such as Au $(H_2S)^{-2}$ (Leitch *et al.,* 1991).

Precipitation of quartz veins at Iperindo. Coarse crystals, which are often characteristic of the Archaean quartz veins as observed at Iperindo, indicate growth in open space under high pressures (Nesbitt and Muehlenbach, 1988). Fault movement (for instance along IZF; Fig. 1) may result in sudden rupture and creation of open spaces (fractures) in the nearby rocks into which fluid flows. The sudden drop in pressure causes deposition of sulphides and Au (Leitch *et al.*, 1991). Gradual decrease in fluid flow for a considerable length of time after precipitation would promote coarse quartz crystal growth and precipitation. After quartz precipitation, which sealed fractures in the host rock, pressure rose again and rupture reoccurred creating subsidiary fractures and fissures in the quartz veins into which sulphides and gold were precipitated at Iperindo.

Precipitation of gold at Iperindo. The wall rock alteration, which took place at the site of gold deposition at Iperindo, may have caused changes in the Eh or pH by the reaction of the ore fluid with the host rock minerals. This led possibly to subtle changes in the chemistry of the fluid which induced dramatic changes in gold solubility. Precipitation of sulphides, which followed decreased sulphur activity, and therefore destabilised Au-thio-sulphide complexes in the ore fluid. The interaction between ore fluid and spinnels, such as magnetite, breaks down the Au-thio-complexes liberating native gold and forming rutile. On cooling of the H_2O-CO_2 mixture (Oyinloye and Steed, 2004; Oyinloye, 1992) phase separation resulted in marked reduction in pH of the remaining fluid, and extensive precipitation of native Au in the quartz veins resulted at Iperindo (cf. Drumond and Ohmoto, 1985). This model of Au precipitation explains why the Iperindo gold deposit consists mainly of pure native independent unalloyed gold type.

Conclusion

Geochemical and Pb isotopes data obtained in this research indicated that the protolith of the granite gneiss in the Ilesha schist belts was derived from a mixed source (upper crust and mantle), possibly in an orogen. The Pb-Pb systematics for the biotite gneiss host rock of the Iperindo gold deposit indicated that the rock's protolith was derived from a subduction related environment where upper crust and mantle materials have been mixed to generate a mixed magma. The Pb-Pb model dates showed that the biotite granite gneiss in Ilesha schist belt was emplaced at about 2750 ± 25 Ma. Plumbotectonic plots for the granite gneiss, feldspar content and pyrite from the auriferous quartz veins revealed that the granite gneiss and gold minernalisation were formed in an orogen from a largely unradiogenic source that subsequently suffered contamination during a later event (550 Ma) when gold mineralisation took place in the Ilesha schist belt. Gold was derived from the volcanic rocks in the belt through hydrothermal leaching, transported through the same medium and deposited in the granite gneiss host rocks at Iperindo.

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