K. Adomako-Ansah[1], T. Mizuta[1], D. Ishiyama[1],
N.Q. Hammond[2], M. Yamamoto[1]
[1] *Akita University, Akita, Japan, adomako@gipc.akita-u.ac.jp*
[2]*Council for Geoscience, Pretoria, South Africa*

ARCHEAN BANDED IRON FORMATION GOLD-HOSTED DEPOSIT IN THE AMALIA GREENSTONE BELT, SOUTH AFRICA: ORE TEXTURES AND GEOCHEMICAL FEATURES OF MINERALIZATION

На основании изучения минералогических и структурных особенностей и изотопного состава C, O, Sr месторождения Блю Дот, локализованного в формации железистых кварцитов зеленокаменного пояса Амалия, обсуждаются механизмы рудообразования и источники флюидов. Основные типы изменений, наложенные на железистые кварциты – карбонатизация, хлоритизация, развитие сульфидов. Золото-сульфидное оруденение связано с контактами наложенных кварц-карбонатных жил и железистых кварцитов. По составу арсенопирита температура образования продуктивной ассоциации оценивается ниже 300–350 °С. На основании изотопных данных в качестве источника флюида предполагаются син- и пост-тектонические гранитоиды.

Introduction

This study investigates the mineralogical, textural and C-O-Sr-isotopic characteristics of gold mineralization and discusses their implication(s) for the ore-forming mechanism and source of ore fluids in the Archean banded iron formation (BIF)-hosted Blue Dot gold deposit of South Africa.

Regional Geology

The Blue Dot gold deposit is located in the Archean Amalia Greenstone Belt (AGB), which forms part of the Amalia-Kraaipan terrane of N-S trending greenstone belts, situated in the western Kaapvaal craton (Fig.1). It is approximately 4~5 km wide and 55 km long. Banded iron formation is the only distinct outcrop in the studied area [Jones and Anhaeusser, 1993]. The highly deformed, sub-vertically inclined volcano-sedimentary rock units of the AGB are generally fault-bounded and partially engulfed by abundant intrusive syn- to post-deformational granitoids [Schmitz et al., 2004]. Three episodic granitic intrusions have been recorded in the belt: (1) tonalite-trondjemite-granodioritic gneiss (TTGs) dated at 3.08 Ga and represents reworking of older basement granitic rocks, (2) syn-tectonic granodioritic plutons of the Kraaipan group dated at 2.93 Ga and, (3) post-tectonic Schweizer-Reneke K-rich quartz monzonites dated ca. 2.88 Ga, believed by many researchers to have played a major role in controlling gold mineralization in the region [Anhaeusser & Walraven, 1999].

Ore deposit geology

Three discrete BIF-hosted gold orebodies namely; Bothmasrust, Abelskop and Goudplaats, have been recognized at the Blue Dot gold deposit. The BIF units are flanked by mafic schist and muscovite-carbonate-chlorite-quartz schist in the footwall (F/W), and chlorite schists in the hanging wall (H/W). The Amalia BIF is subdivided into two units: (i) jasper-rich BIF and (ii) jasper-free BIF. The jasper-free variety is the common BIF type in the Amalia greenstone belt. However, it is the veined jasper-rich BIF that is commonly sulfidized and mineralized. Quartz, chlorite and carbonate (i.e. siderite, ankerite, dolomite and minor calcite) constitute the main gangue mineral assemblage in the BIF with minor amounts of muscovite. In less-altered, undeformed BIF units, platy magnetite occurs as fine-grained, unaltered layers, while chert is partly intergrown with siderite and chlorite. In highly deformed units, the magnetite is re-crystallized into coarse grains and undergoes pseudomor phic replacement by hematite. This hematitic alteration is prominent in portions where the quartz-carbonate veins crosscut the BIF layerings. In this study, the term mineralized BIF is used to represent sulfidized altered/bleached jasper-rich or jasper-free BIF units that are related to crosscutting quartz-carbonate veins, whiles non-mineralized BIF represents the non-sulfidized, less altered BIF units that are not veined.

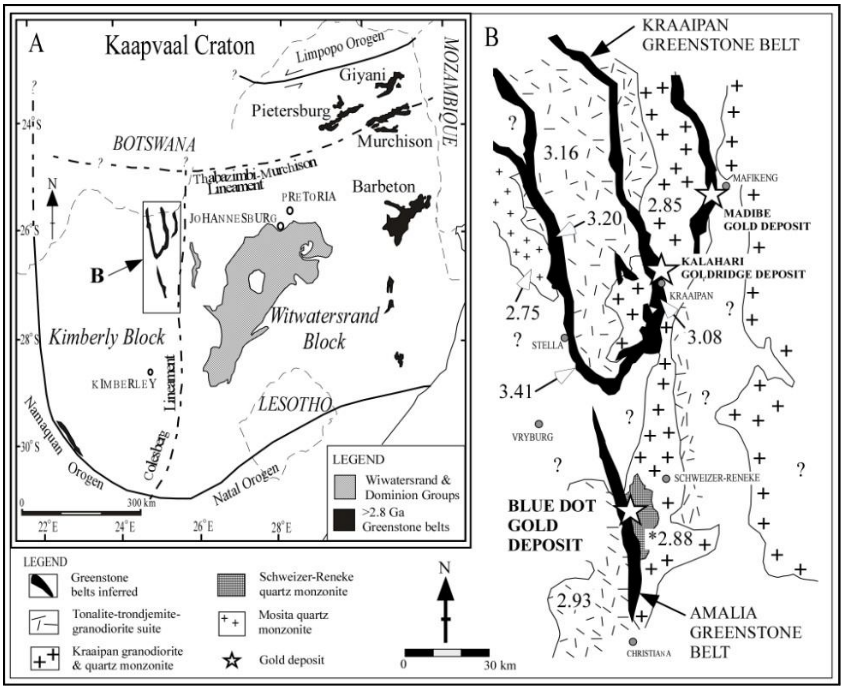

Fig. 1. Location of the Blue Dot gold deposit in Amalia Greenstone belt.

Hydrothermal alteration and ore precipitation mechanism

The crosscutting, vein-related gold mineralization and hydrothermal alteration show some relationship with the lithologies present at Amalia. The main alteration processes associated with the mineralization include carbonatization, which is characterized by the replacement of magnetite and hematite by carbonates such as siderite in BIF and replacement of quartz by ankerite-dolomite series, chloritization (characterized by chlorite replacement of magnetite and quartz in BIF and, quartz, carbonate and albite in schists), hematization (characterized by alteration of magnetite to hematite), sulfide precipitation (characterized by pyrite ± chalcopy-rite ± arsenopyrite precipitation in the BIF) and rare potassium metasomatism (characterized by sericitic replacement of albite, quartz and chlorite). Sulfide precipitation and associated gold mineralization is restricted to the proximity of contacts between BIF and quartz-carbonate veins [Kiefer, 2004; Adomako-Ansah et al., 2013]. Pyrite (with minor chalcopyrite and arsenopyrite; Fig. 2a, b) is the dominant sulfide mineral [Adomako-Ansah et al., 2013] and restricted to the zones of sulfide precipitation in the mineralized BIF. Gold occurs as rounded to irregular-shaped inclusions and as fracture fills in pyrite (Fig. 2c). Previous authors proposed pyrite-gold precipitation by sulfidation of magnetite±hematite in the BIF [Kiefer, 2004] or hematization of pyrite [Vearncombe, 1986]. However, petrographic investigation by Adomako-Ansah et al. [2013] shows non-replacement textures between hydrothermal pyrite and coexisting recrystallized magnetite±hematite minerals and does not suggest sulfidation of the Fe-oxides. Rather, it suggests conditions of contemporaneous sulfide-gold precipitation with magnetite-hematite recrystallization. Also, in the BIFs, most of the sulfide-gold mineral assemblages are petrographically observed within quartz-carbonate layers rather than magnetite-hematite layers (Fig. 2).

Mineral chemistry of ores and temperature for gold mineralization

A simplified paragenetic sequence for the principal minerals occurring in the Blue Dot gold deposit is illustrated in Fig. 3. Arsenopyrite grains show a general composition from 28.6 to 30.8 at. % As with negligible base metal contents. Less or no variation in rim-to-core compositions, absence of zoning and the negligible base metal contents in arsenopyrite from the various analyzed samples suggest that conditions of crystallization were fairly stable (i.e. the sulfide precipitation, and consequent gold mineralization, probably occurred during one hydrothermal event). Temperature estimated by using the arsenopyrite-pyrite geothermometer of Scott [1983] for associated gold mineralization, based on the As contents of arsenopyrite, is < 300–350 °C (Fig. 4). Native gold grains from both mineralized BIF and veins, indicate an average value of Au 0.92 Ag 0.08 and a high relative fineness of 952±5, which is consistent with the observed range for most Archean lode gold deposits [Adomako-Ansah et al., 2013]. C-O-Sr isotopic signatures on ore fluid source and formation environment.

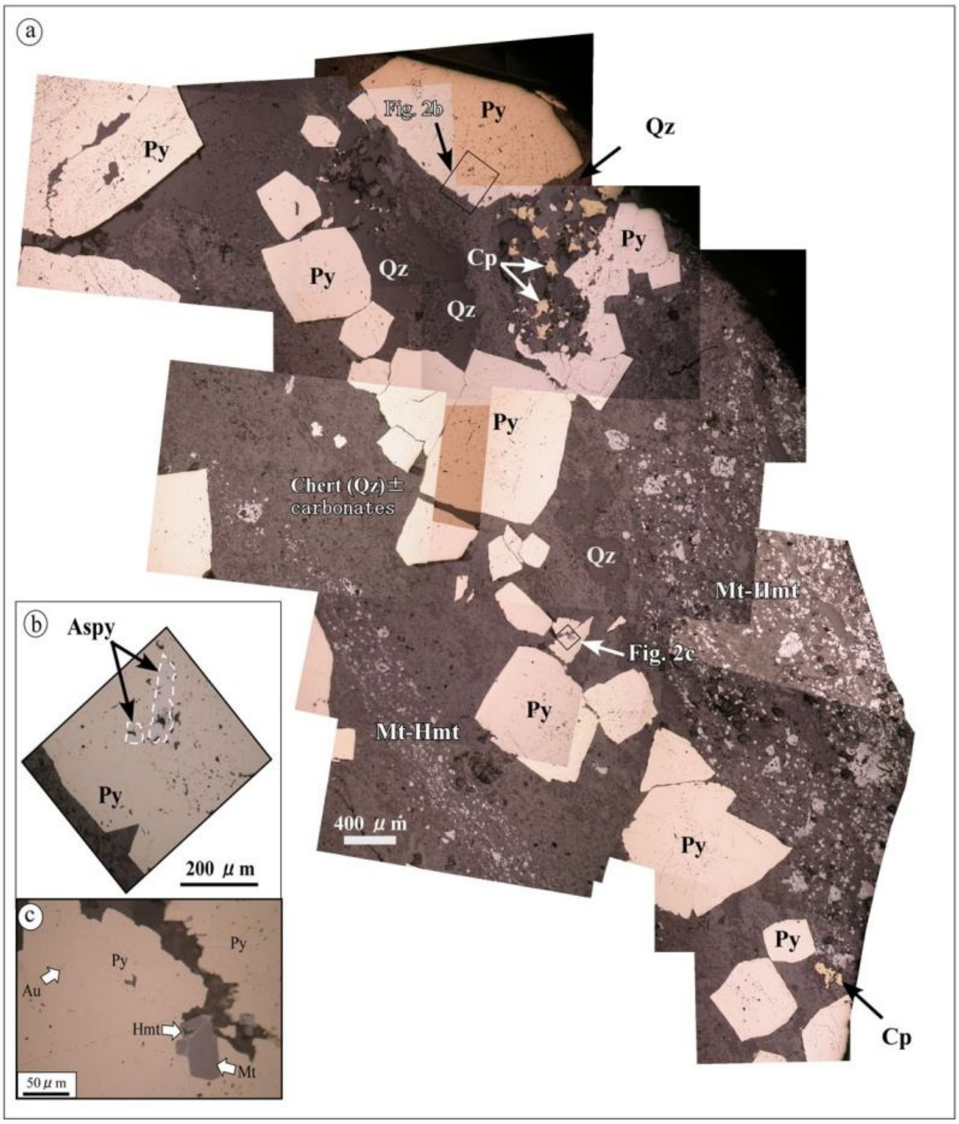

Fig. 2. Ore minerals and textures of mineralization.

Geochemical data from C, O and Sr isotopes of carbonates and O isotopes of quartz (summarized in Table; this study) suggest that the hydrothermal ore fluid responsible for the associated gold mineralization in the Amalia BIF was sourced from magmatic fluids that are temporally and spatially represented by the syn-to-post tectonic granitoids in the studied area. Tight clustering of S-isotope data of +1.8 to +2.5 per mil for the S in the ore fluid at the Blue Dot deposit [Adomako-Ansah et al., 2013] also indicates a probable magmatic or mantle origin according to Ohmoto [1986] for a cluster of –3 to 3 per mil S-isotopic data. Geochemical studies on the surrounding granitoids by Kiefer [2004] indicated that the Schwiezer-Reneke quartzmonzonite, largely tipped to be the potential source for the exolved ore fluids, formed from mixing of magmas derived from partial melting of depleted mantle-wedge and TTG sources.

C-O-Sr isotopic signatures on ore fluid source and formation environment

Geochemical data from C, O and Sr isotopes of carbonates and O isotopes of quartz (summarized in Table 1; this study) suggest that the hydrothermal ore fluid responsible for the associated gold mineralization in the Amalia BIF was deep-sourced, and likely from magmatic fluids that are temporally and spatially represented by the syn-to-post tectonic granitoids in the studied area. Tight clustering of S-isotope data of +1.8 to +2.5 per mil for the S in the ore fluid at the Blue Dot deposit (Adomako-Ansah et al., 2013) also indicates a probable magmatic or mantle origin according to Ohmoto (1986) for a cluster of -3 to 3 per mil S-isotopic data. Geochemical studies on the surrounding granitoids by Kiefer (2004) indicated that the Schwiezer-Reneke quartzmonzonite, largely tipped to be the potential source for the exolved ore fluids, formed from mixing of magmas derived from partial melting of depleted mantle-wedge and TTG sources.

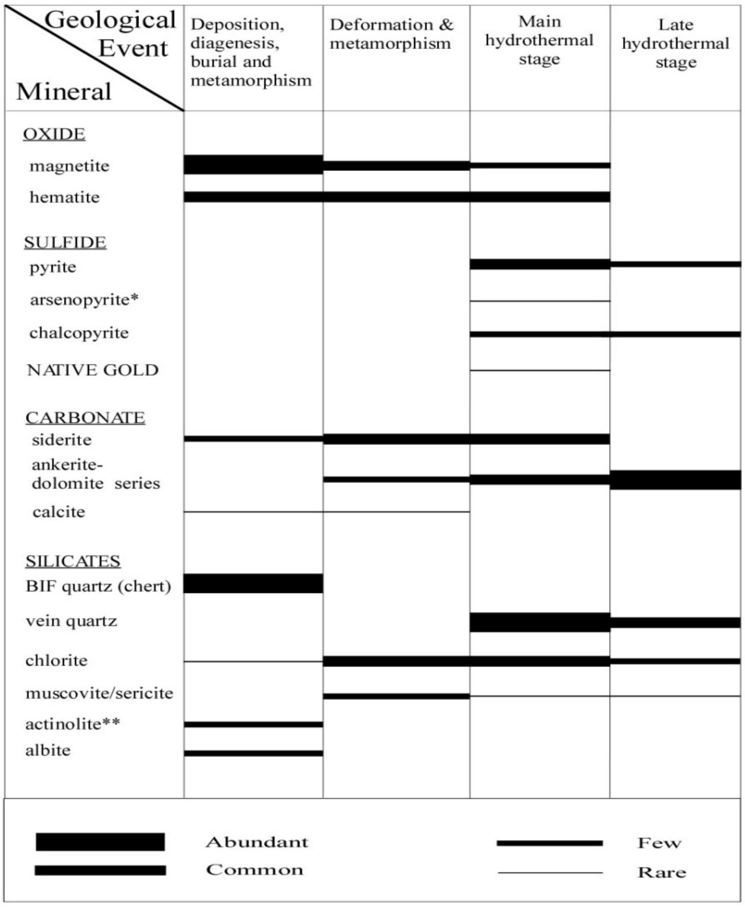

Fig. 3. Paragenetic sequence of principal minerals in the Blue Dot gold deposit

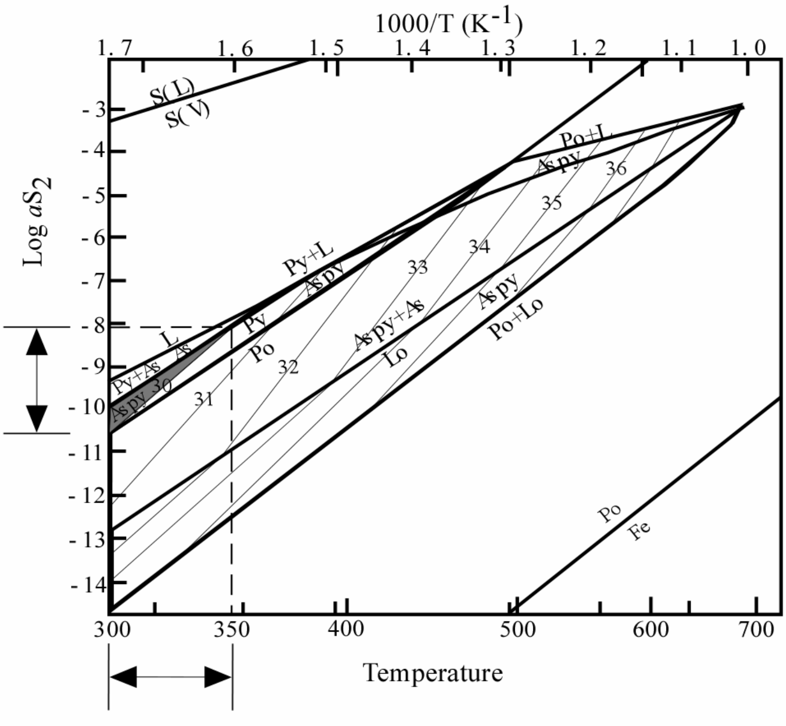

Fig. 4. Arsenopyrite geo-thermometer. Shaded regioin is the ore-forming condition for gold mineralization at the Blue Dot gold deposit

Table

$\delta^{13}C$ of carbonates and $\delta^{18}O$ of quartz of gold mineralization in the Amalia BIF

Sample	Host lithology	Carbonate	Remark	$\delta^{13}C_{PDB}$ (‰)	$\delta^{18}O_{smow}$ (‰)
C17-20	Vein in mineralized BIF	ankerite	Q-C vein	-3.2	17.2
C11-5A-3	-»-	Fe-dolomite	–»–	-3.7	16.3
C17-15B	-»-	ankerite	–»–	-4.8	13.5
C17-23B	-»-	ankerite	–»–	-3.1	16.3
C17-6	Vein in hanging wall schist (non mineralized)	Fe-dolomite	–»–	-3.8	16.3
V8-3	Mineralized BIF	Fe-dolomite	whole rock	-3.4	15.0
V8-10PIb	-»-	siderite	–»–	-5.0	13.5
V8-12PII	Cherty band from mineralized BIF	siderite	–»–	-4.8	13.8
AB22-15A	Mineralized BIF	siderite	–»–	-3.4	13.6
V8-26(b)	Mineralized BIF	Fe-dolomite	–»–	-4.2	14.4

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V.N. Anfilogov[1,2], Y.V. Khachay[3]

[1]Institute of Mineralogy UB RAS, Miass, Russia

[2]National Research South Ural State University, Chelyabinsk, Russia

[3]Institute of Geophysics UB RAS, Yekaterinburg, Russia

FORMATION OF THE EARTH'S CORE AND SILICATE LAYERS

Предложена принципиально новая модель гетерогенной аккумуляции Земли. Она позволяет объяснить механизм образования частично расплавленного железо-никелевого ядра на начальном этапе формирования Земли и обосновывает новый механизм дифференциации вещества в процессе аккумуляции Земли. Процесс аккумуляции завершается отложением на поверхности Земли материала углистых хондритов. Из этого материала будет сформирована внешняя твердая оболочка Земли.