博 士（理 学） エウィス ティンティン ユニンシー

学位論文題名

METALLOGENIC CONTEXT OF THE ARINEM TE-BEARING GOLD-SILVER-BASE METAL DEPOSIT, WEST JAVA, INDONESIA

（インドネシア,西ジャワ島のTeを伴う金－銀－ベースメタル金属鉱床の成因論的背景）

学位論文内容の要旨

The Arinem deposit placed at the island of Java as a part of West Java province of Indonesia. Unexploitated Arinem deposit to date has been regarded as low to intermediate sulfidation epithermal with Arinem, Bantarhuni and Halimun as mineralized veins. This study documents the complex of mineralogy, geochemistry and water-rock interactions focused on Arinem and Bantarhuni veins. In the study of Arinem deposit, questions relevant to the understanding of epithermal deposit in general are addressed such as: what is the style of mineralization? What was the source of the mineralizing fluids and where was this source located?. The major Arinem vein trending N20°W to N10°E and dipping 68 to 83° western. The Arinem vein exposed at elevation of 365-530 m above sea level, 3-5 m width and extend for about 2,000 m with around 1.1-9.0 g t^{-1} Au respectively. The Bantarhuni vein located western part with zone length about 2,300 m and width 3-5 m shows gold grade 2.0-5.0 g t^{-1}. The mineralization age of 8.8 to 9.9±0.3 Ma yielded from K/Ar dating of altered illite co-existing with quartz vein. The epithermal veins of Arinem are hosted by the Early to Middle Miocene of the andesitic volcanic rocks of tuff, tuff breccia and lava belong to the Old Andesite Jampang Formation and show different degrees of alteration.

Core logging and petrographic studies of both veins reveals similar mineralogy and paragenesis. Mineral deposition occurred in three stages (four for Bantarhuni vein), those are: 1) deposition of vuggy-massive-banding crystalline quartz-sulfide; 2) Sulfide-rich of banded-brecciated-massive sulfide-quartz; 3) alternating massive-crystalline barren of quartz; and 4) barren coarse grained carbonate. The main gangue minerals are quartz and calcite. The Arinem deposit has a typical polymetallic association, ore minerals are mainly composed of sulfide minerals of sphalerite, galena, chalcopyrite and pyrite with some minor and trace minerals of arsenopyrite, marcasite, pyrrhotite, bornite, argentite, electrum, and Te-bearing mineral of hessite, stutzite, petzite, tetradymite and altaite, with occurrences of hematite, enargite, tennantite and tetrahedrite at later stage. The fluid inclusion study resolved homogenization temperature and salinity ranges typical of low-intermediate sulfidation epithermal deposits; 155° to 325°C (average 194° to 267°C) and 0.2 to 4.3 wt% NaClequiv. respectively.

Textural relationships suggest that introduction of tellurides in Arinem deposit postdate formation of sulfide and it is closely related to the later introduction of sulfosalt minerals of enargite, tennantite and tetrahedrite in the system. The sulfide and telluride mineralogy, as well as the composition of sphalerite are used to constrain fS_2 and fTe_2 values of the hydrothermal solutions. Geochemical environment of ore deposition equilibrium thermodynamics estimation indicated the chemical condition of hydrothermal fluid are under log fS_2 values around -8 to -6 of stage IB and the value is decrease to -16 in stage IIC. Approaching to late stage II the log fS_2 is increase to -11 with introducing of enargite, tennantite and tetrahedrite. The log fTe_2 is increase from less than -15 up to -8 approaching the stage IIB and then decreased to -15.5 in stage IIC of mineralization together with decrease of temperature in the stability field for altaite and galena. Calculated log fO_2 (-39 to -36.5) and log fS_2 (-16 to -6) ranges indicate that the hydrothermal fluids were reducing which is also pointed to the typical of low to intermediate sulfidation system.

The co-deposition of the electrum with sulfides was caused by a decrease of sulfur in solution as a result of deposition of the sulfides and was also promoted by loss of H_2S gas during boiling episodes of early stage I of mineralization. Effervescence of CO_2 is thought to have been a factor in the precipitation of the tellurides, in that it shifted the pH of the hydrothermal fluids to neutral while destabilizing gold bisulfide complexes. Coincident fracturing allowed the influx of denser, oxygenated waters from the surrounding host rock which also promoted mineralization in more acid condition at later stage II mineralization. The average range temperature and neutral to slightly acid pH of mineralization were indicating that $Au(HS)^{2-}$ is the dominant dissolved form of Au. The gold ore body formed approximately 235 m below the paleo-water table.

The $\delta^{18}O$ mineral values determined in quartz associated with ore stages range from -6.01 to (-0.56) per mil. The δD values measured from fluid inclusions in quartz associated with ore in the two veins range from -66.0 to (-34.0) per mil. The oxygen and hydrogen isotopes composition of the fluids, suggest that the veins were formed by dominated deeply circulated meteoric water mixing with magmatic fluids. The slightly light sulfur isotope (-5.5 to -1.8 per mil) suggest that sulfur was derived from the magmatic, or igneous rock either by leaching of those elements at the time of hydrothermal fluid circulation or due to assimilation and melting of the igneous rock in a deep seated magma chamber. The close proximity and similar characteristics of both Arinem and Bantarhuni veins indicates that the mineralization occurred as part of a single hydrothermal system. Additionally, slightly high temperature, lower Au/Ag ratios and higher base metal contents in the Arinem veins suggests that the Arinem vein are proximal with respect to the possible centre of the district and therefore, the thermal center of the district could be to the south to southeast part.

The association of ore minerals from Arinem deposit is slightly different from that of the other gold mineralizations in western Java, such as Pongkor, Cirotan, Cibaliung, Cisungsang and Cikidang. The ore mineralogy of the western most of West Java such as Pongkor, Cibaliung, Cikidang, Cikotok and Cirotan is characterized by the dominance of silver-arsenic-antimony sulfosalt with silver selenides and rarely tellurides over the argentite, while the eastern most Arinem deposit are dominated by silver-gold tellurides. The Arinem seems represent the Te-type and other represent Se-type deposits. Mineralogical and geochemical different can be explained by variation of the host rock, and physicochemical conditions that existed during gold-silver deposition among those deposit.

学位論文審査の要旨

主　査	教　授	松　枝　大　治
副　査	教　授	永　井　隆　哉
副　査	講　師	三　浦　裕　行

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近年、地質時代における島弧の地質テクトニクス環境で形成された熱水性金銀鉱化作用の成因に関する研究が国際的に盛んに行われている。しかし、これまでその多くはその生成条件や形成年代の推定、熱水の起源及び金元素の固定に関わる成因の解明を目指してきた。しかし、金銀作用の伴う随伴微量元素、特にTeやSeの様な微量元素の挙動について注目された例は極めて少数であり、それらに関する詳細な研究は不十分であったといえる。国際的には、島弧環境のマグマ活動に伴う浅熱水性金銀鉱床では、マグマ起源の水の関与度に関わる「低硫化型」及び「高硫化型」金鉱化作用の特性と起源・成因おける議論がまだ集結していない状態にある。この問題解決には、随伴微量元素や安定同位体組成等に関わるより詳細な検討が必要であると考えられ、改めて同タイプの鉱床に関して個別に詳細な記載と実験データに基づいた明快かつ精細な成因論の展開が待たれている状況にある。

本論文は、このような現況にある熱水性金銀鉱床の成因論に関して、インドネシア西ジャワ島のTeを伴う鉱脈型金銀鉱床において、詳細な野外・ボーリングコア調査及び室内研究を基にその成因論的検討と生成環境について検討したものである。特に、今回検討の中心となったArinem鉱床に関して、鉱床学的、鉱物学的、同位体地球化学的な観点から詳細な研究を行い、これまでインドネシアにおいて殆ど未知であったTeを伴う金銀鉱床の存在を明らかにし、その鉱床特性および鉱床生成に関与した流体の性状・起源を明らかにすると共に、その成因と生成条件を詳細に検討したものである。本研究を通じて、西ジャワ島に広く発達する浅熱水性金銀鉱床がSe型とTe型とに大別され、それらの分布は胚胎母岩の種類のみならず、マグマ-熱水系の時空的配置

により規制されることを明らかにした。

これを要するに、著者は、インドネシア西ジャワ島における島弧の地質テクトニクス環境での浅熱水性金銀鉱化作用について、それらの成因及び鉱化流体の起源を明らかにすると共に、胚胎母岩の違いにより生じた鉱化作用の特性に関する新知見を得たものであり、国際的な熱水性金銀鉱床の成因論の展開に関して貢献するところ大なるものがある。

よって著者は、北海道大学博士(理学)の学位を授与される資格あるものと認める。