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学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Genesis of precious metal mineralization in the Central Kamchatka, Far East of Russia
(極東ロシア、中央カムチャツカにおける貴金属鉱化作用の成因)

Epithermal deposits hosting broad range of precious metals ($\pm$ telluride or selenide) are dominantly located in the volcanic-arc setting of the Pacific Ocean region. Epithermal style Au-Ag mineralizations are occurred from the dilute, meteoric-water enriched, low and typically variable in temperatures hydrothermal fluids (150-300°C) at depth within 2 km from a present surface under distinctly variable physicochemical conditions.

In this PhD paper, epithermal type of precious metal deposits associated with volcanic calderas of coincident age have been studied. The main aim of this research is to estimate physicochemical conditions of mineral deposition, to define the style of mineralization and to constrain the genetic models of Au-Ag-Te Aginskoe and Au-Ag Baranevskoe epithermal mineralizations in the Central Kamchatka mining district. Additionally, the attempt to define factors controlling the chemical composition of the Au-Ag alloy and the relationship of volcanism to the ore formation process was made. The information provided in this dissertation includes absolutely new data obtained from fieldworks, laboratory studies and a compilation of the existing Russian literature pertaining to regional fault systems that control metallic mineralization in Central Kamchatka.

Results of this study show that volcanic-hosted Au-Ag-Te and Au-Ag mineralization of Kamchatkan volcanic arc are similar on the physicochemical characteristics with typical LS precious metal deposits located elsewhere in Pacific Region (for examples, Au-Ag Hishikari and Au-Ag-Te Kushikino in Japan; Au-Ag-Te Acupan in Philippines and Au-Ag-Te Emperor in Fiji).

The Aginskoe mine including Aginskoe, Viyun and South-Aginskoe deposits located in the Central Kamchatka mining district. The Aginskoe deposit of Late Miocene is a main one consisting of 14 steeply dipping to SE and NW quartz-adularia vein groups intruded into a sequence of andesitic basalt volcanic rocks of Middle Miocene. Unexposed epithermal veins of 300 m in length contain native gold, gold-silver-tellurides, sulfides and various secondary minerals much of which are still not identified.

Gold-silver-telluride-bearing ores have been formed from 7.1 to 6.9 Ma based on K/Ar dating of vein adularia. Aginskoe veins are confirmed to be formed in six paragenetic stages. Productive Au-Ag-Te mineralization is occurred in the stage II in crustiformed banded ores, characterized by presence of adularia, calcite and silica gel precursors.

Dominated vein minerals are native gold, calaverite, hessite, altaite, petzite, chalcopryrite, and sphalerite accompanying with minor electrum, pyrite and galena.

Specific characteristic of the Aginskoe vein system suffered strong ore oxidation down to level of 1160 m. The oxidized gold-silver tellurides, rare intermetallic compounds such as bilibinskite, bessmertnovite and bogdanovite and mustard gold as products of ore oxidation were formed in the stage IV classified as a supergene. Calaverite is the one of Au-bearing tellurides, recognized as fragments or preserved relicts in the intensively

oxidizing ores, was used for the estimation of $f\text{Te}_2$. Au-Ag tellurides of stage II were deposited from fluids of 250-260°C temperatures and salinity less than 2 wt% NaCl at $\log f\text{Te}_2 < -9$, and $\log f\text{S}_2$ is assumed to be -13. Ratio of $f\text{Te}_2/f\text{S}_2$ is decreased as the ore deposition proceeds further. Native gold (Au 88-92 at%) was simultaneously deposited with Au-bearing tellurides such as calaverite prior to deposition of altaite-hessite-sphalerite assemblages. In oxidation zone native mustard gold was released from primary Au-bearing tellurides due to high solubility of Te in the oxidation zone. Boiling phenomena is confirmed by presence of adularia, wide range of homogenization temperature, types of inclusions and quartz textures. Quartz of stage II and amethyst of post-ore stage IV have values of $\delta^{18}\text{O} = -3.3$ and -3.0 (-1.3) ‰, individually. Quartz-adularia-carbonate veins were deposited from the meteoric water-enriched hydrothermal fluids circulated at the shallow depth.

The Baranevskoe deposit is located within the Balkhach super-volcano caldera in the south-east of the Central Kamchatka mining district in approximately 40 km to the south-east from the Aginskoe Au-Ag-Te deposit. Veins system of the Baranevskoe deposit consists of two principally different ore types: cupriferous and gold-silver-quartz-carbonate-adularia ores formed under different physicochemical conditions and the fluid source. Also gold is found in hosting alkaline type metasomatites. Cupriferous ores have been formed prior to gold-silver from probably different the fluid source. Cupriferous ores consist of early pyrite-electrum-chalcopyrite-bornite-sphalerite and later tetrahedrite-tennantite assemblages. Bornite and chalcopyrite are showing micrographic texture caused by the relatively rapid cooling of the hydrothermal fluid. Electrum (Au 59-64 at%) is very rare mineral in this ore type usually associates with pyrite and chalcopyrite. The tetrahedrite-tennantite series mineral is predominant by tetrahedrite component showing random distribution of Sb and As within tetrahedrite_{ss}. Tetrahedrite was likely occurred in replacing of chalcopyrite and chalcopyrite-bornite. Tetrahedrite in cupriferous ores is characterized by a high Cu content with a high Zn/Fe ratio. Fluid inclusions show low-temperature fluids of about 154-232°C with salinity of 0.7-1.1 wt% NaCl equiv.. Although, liquid-rich inclusions were observed in co-existing with gaseous inclusions, a boiling is not confirmed yet. Presence and dominance of the tetrahedrite and types of the alteration rocks suggests deposition of Cu-bearing ores from the low-temperature slightly alkaline fluid of high $f\text{S}_2$ relegates to the intermediate sulfidation state. The gold-silver ores occur as open-fractures filling veins, tiny stockworks and carbonate-rich ores. Both veins and stockwork are characterized by abundant occurrence of gold in association with sphalerite, galena, pyrite, chalcopyrite and trace amounts of tetrahedrite-tennantite. Carbonate-rich veins host moderate amounts of gold crystallized in interstices. The Au content in electrum varies broadly from 52 to 72 at%. Based on the fluid-inclusion studies quartz-carbonate-adularia veins, stockwork and carbonate-base ores are confirmed to be deposited from the hydrothermal shallow-depth fluids with relatively low temperatures 190-280°C and a low salinity approximately 2wt% NaCl equiv.. Alteration rock styles support fluid of slightly acid-neutral to alkaline-neutral pH state.