1 Introduction

The Chatree mining area is located in the Loei-Phetchabun-Nakhon Nayok volcanic belt, about 300 km north of Bangkok in Thailand. The Chatree deposit consists of five defined prospects and five open pits. The A and Q prospects (Au mineralization) are located in the northern part of the Chatree deposit. The C, H, D, Kw and Ke pits (Au mineralization) are distributed in the central part of the deposit. The B (Au mineralization), N and V (Cu-Mo mineralization) prospects occur in the southern part of the deposit. Ore bodies studied are the Q, A, B, N and V prospects. Geology of the Chatree deposit consists of andesite lava, monomictic andesitic breccia, polymictic andesitic breccia, volcanic sedimentary breccia and fiamme breccia. Au mineralization (250±0.8 Ma, Salam et al., 2008) is developed in polymictic andesitic breccia and volcanic sedimentary breccia strata. Granodiorite occurs at the N and V prospects approximately 2 km far from the Q prospect. The granodiorite (243±5 Ma, Salam et al., 2008) intruded into andesite lava. Cu-Mo mineralization is recognized in the granodiorite (N and V prospects). The age of mineralization of the Chatree deposit is Early Triassic. The aim of study is to elucidate the styles of gold and copper mineralization and to estimate the source of gold in the Chatree deposit.

2 Epithermal Au Mineralization at the Q, A and B Prospects

The ore bodies of the Au-bearing quartz veins of the Q, A and B prospects consist of veins, veinlets and stockwork bodies. The Au-bearing quartz veins can be classified into five stages; Stage I: Qz-Ad-Cal-ccp-py-el (major Au mineralization), Stage II: Qz-Ad-Cal-Ilt-ccp-py-el, Stage III: Qz-Ad-Cal-Ilt-Chl-ccp-py-el, Stage IV: Qz-Cal-Ad-Ilt-Chl-Lmt-ccp-py-sp-tet-el (major Au mineralization) and Stage V: Cal-Qz-py. Mineral assemblage in Stage IV at the Q prospect (laumontite, illite, adularia, chlorite and calcite) indicates that the formation temperature of the Au-bearing quartz veins of Stage IV was approximately 200°C. Based on the mineral assemblage of Stage IV in the Q prospect, the log \((a_{Ca^{2+}}/(a_{H^+})^2)\) of hydrothermal solution forming Stage IV is estimated to be 8.7 to 8.8 at 200°C. \(f_{CO_2}\) is estimated to be 1 bar at 200°C. \(P_{H_2O}\) is estimated to be 16 bars. Therefore, total pressure of the hydrothermal solution is approximately 20 bars at 200°C suggesting that the Au-bearing quartz veins of the Q prospect took place about 200 m below the paleosurface. The flamboyant and brecciated textures of the Au-bearing quartz vein of Stage IV suggest that gold was precipitated from the hydrothermal solution that was supersaturated by boiling.

3 Cu-Mo Mineralization at the N and V Prospects

Cu-Mo-bearing quartz veins occur in the altered granodiorite and andesite lava. Quartz veins of the Cu-Mo mineralization are divided into 5 types from early to later such as Types A, B, C, D and E. Quartz veins of Types A, B and C occur in the granodiorite and quartz veins of Types D and E occur in altered andesite lava. Type E quartz vein cut Type D quartz vein. The thickness of quartz veins ranges from 0.5 to 5 mm. The mineral assemblages of Types A, B and C quartz veins consist of Qz-Chl-Ilt-mol-py-ccp, Qz-Chl-Ilt-ccp-py and Qz-Chl-Ilt-ccp-py-sp-po, respectively. Types D and E quartz veins are composed of Qz-Chl-py-ccp-sp-po and Qz-ep,
respectively. Cu content of Types A, B and C quartz veins are high, while Cu content of Types D and E quartz vein are low.

4 Fluid inclusion Study

Fluid inclusions in the Cu-Mo-bearing quartz veins and the Au-bearing quartz veins are composed of secondary fluid inclusions. The fluid inclusions in the Cu-Mo-bearing quartz veins can be divided into three types according to the phase assemblage at room temperature by Roedder (1984): (1) liquid-rich two-phase fluid inclusions, (2) vapor-rich two-phase fluid inclusions and (3) multiphase solid-bearing fluid inclusions. The multiphase solid-bearing fluid inclusions contain halite and reddish hematite in addition to liquid and vapor. Homogenization temperatures of liquid-rich fluid inclusions range from 100°C to 450°C with salinity of fluid inclusions ranges from 0.1 to 4.0 wt% NaCl eq. The homogenization temperatures of multiphase solid-bearing fluid inclusions range from 220°C to 450°C with salinity of fluid inclusions ranging from 32 to 38 wt% NaCl eq. The salinity of vapor-rich fluid inclusions can be divided into the fluid inclusions having low salinity ranging from 0.1 to 1.0 wt% NaCl eq. and the fluid inclusions having slightly higher salinity ranging from 1.0 to 4.0 wt% NaCl eq. Based on the phase assemblages and salinities of fluid inclusions, the Cu-Mo mineralization at the N prospect is thought to be formed at the temperature of 450°C with a pressure of 450 bars. Depth of the formation of the Cu-Mo mineralization is estimated to be about 1 km.

The fluid inclusions in the Au-bearing quartz veins in the Q, A and B prospects can be separated into two different fluid inclusion types such as monophase liquid fluid inclusions and liquid-rich fluid inclusions based on the classification by Roedder (1984). Homogenization temperature of secondary fluid inclusions of the B, A and Q prospects are 150°-310°C, 105°-295°C and 85°-150°C, respectively. Salinities of secondary fluid inclusions range from 0.2 to 3.5 wt % NaCl eq. The homogenization temperatures of secondary fluid inclusions of quartz veins in the Chatree mining area decrease from the N prospect (Cu-Mo mineralization in the southern part of the Chatree mining area) through the B and A to Q prospects (Au mineralization in the northern part of the area). There is the possibility that secondary fluid inclusions in the deposit were formed by hydrothermal activity associated with the Cu-Mo mineralization.

5 Sr Isotopic Study

Sr isotopic ratios of weakly altered andesite, strongly altered andesite, the Au-bearing quartz veins and fresh andesite dikes cutting the quartz veins in the Q and A prospects (Au mineralization) and altered andesite and altered granodiorite in the N prospect (Cu-Mo mineralization) were examined. Sr isotopic ratios of the weakly altered andesite, the strongly altered andesite and the fresh andesite dikes are 0.705563-0.723909 and 0.705566-0.705676, respectively. Sr isotopic ratios of the Au-bearing quartz veins of the Stages I and IV at the Q and A prospects are 0.707597 and 0.711655-0.720887, respectively. The Sr isotopic ratios of Au-bearing calcite veins of Stage V in the Q and A prospects range from 0.705190 to 0.705764. Sr isotopic ratios of the altered andesite and the altered granodiorite in the Cu-Mo mineralization at the N prospect have range of 0.705595-0.706362 and 0.704273-0.704329, respectively. Sr isotopic ratio of diorite 1 km far from the Chatree deposit is 0.704337. Sr isotopic ratios of Permian limestone and Triassic limestone near the Chatree deposit are 0.707484 and 0.706517, respectively.

The diorite and the altered granodiorite at the N prospect have similar Sr isotopic ratios while the altered andesite at the N prospect having slightly higher Sr isotopic ratios. The higher Sr isotopic ratios of the altered andesite suggest the possibility of the interaction between andesite and hydrothermal solution that interacted with limestone and/or hydrothermal solution in seawater origin having higher Sr isotopic ratios (0.705595-0.706362). On the other hand, the Au-bearing quartz veins and the strongly altered andesite lava have very high Sr isotopic ratios. The strongly altered andesite lava in the Q prospect is thought to be formed by interaction between the andesite lava and hydrothermal solution having high Sr isotopic ratio.

Sr isotopic ratios of the strongly altered andesite and the Au-bearing quartz veins are similar to Sr isotopic ratios of sedimentary rock consisting of shale (Hosono et al., 2003). The facts suggest that the hydrothermal solution forming the Au-bearing quartz vein of the Chatree deposit was reacted with Carboniferous-Permian strata beneath the Chatree deposit and the Au in the Chatree deposit was derived from the sedimentary strata beneath the Chatree deposit. It is also thought that the hydrothermal solution forming Cu-Mo mineralization and Au mineralization of the Chatree deposit were different.

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Reference