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Mass transfer associated with chloritization in the hydrothermal alteration process of granitic pluton

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Abstract

This study, along with our previous studies (Yuguchi et al. 2015, 2019a), reveals the hydrothermal alteration processes in a pluton, with a focus on the mass transfer between minerals and hydrothermal fluid. It also depicts the sequential variations in fluid chemistry as alteration progresses. Hydrothermal alteration of the Toki granite in Tono, Japan—the study area of this research—progressed through the successive processes of chloritization, plagioclase alteration, and precipitation of a carbonate. This paper describes the alteration processes of hornblende chloritization, K-feldspar chloritization, and the formation of fracture-filling chlorite through petrography and mineral chemistry. A set of singular value decomposition analyses was conducted to obtain reaction equations for the chloritization processes, which facilitates the quantitative assessment of mass transfer between the reactant and product minerals, and the inflow and outflow of components through the hydrothermal fluid. Several types of chloritization reactions (including biotite chloritization) can be characterized by their reaction with the inflow of Al^{3+}, Fe^{2+}, Mn^{2+}, and Mg^{2+} and the outflow of H_4SiO_4, Ca^{2+}, K^+, and F^-.

The age and thermal conditions of hornblende chloritization (64–54 Ma and 330–190 °C), K-feldspar chloritization (68–53 Ma and 350–210 °C), and precipitation of fracture-filling chlorite (66 and 63 Ma, 340 and 320 °C) overlap with those of biotite chloritization (68–51 Ma and 350–180 °C). The chloritization reactions (this study and Yuguchi et al. 2015) and plagioclase alteration (Yuguchi et al. 2019a) represent sequential variations in fluid chemistry at temporal conditions from 68 to 51 Ma as the temperature decreased from 350 to 180 °C. As the alteration proceeds, the concentrations of aluminum, iron, manganese, and magnesium ions in the hydrothermal fluid decrease gradually, and those of calcium, hydrogen, and fluorine ions increase gradually.

Hornblende chloritization is associated with formation of magnetite and ilmenite. The thermal conditions of the hydrothermal fluid yielding the formation of magnetite and ilmenite can be interpreted by the chemical characteristics of chlorite around their associated minerals. The formation temperature of magnetite was higher than that of ilmenite, implying a decrease in oxygen fugacity in the hydrothermal fluid with the decrease in temperature from 280–310 to 220–250 °C.

Keywords: Hydrothermal alteration, chloritization, dissolution and precipitation, mass transfer, singular value decomposition (SVD) analysis