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Hydrothermal chloritization processes from biotite in the Toki granite, Central Japan: Temporal variations of of the compositions of hydrothermal fluids associated with chloritization

Takashi Yuguchi[1,*], Eiji Sasao[1], Masayuki Ishibashi[1] and Tadao Nishiyama[2]

[1]Mizunami Underground Research Laboratory, Geoscientific Research Department, Sector of Decommissioning and Radioactive Waste Management, Japan Atomic Energy Agency, 1-64, Yamanouchi, Akiyo, Mizunami, Gifu 509-6132, Japan
[2]Department of Earth and Environmental Sciences, School of Science, Graduate School of Science and Technology, Kumamoto University, 2-39-1, Kurokami, Chuo-ku, Kumamoto 860-8555, Japan

Abstract

This paper describes the biotite chloritization process with a focus on mass transfer in the Toki granitic pluton, Central Japan, and also depicts the temporal variations in chemical characteristics of hydrothermal fluid associated with chloritization during the sub-solidus cooling of the pluton. Singular value decomposition (SVD) analysis results in chloritization reaction equations for eight mineral assemblages, leading to the quantitative assessment of mass transfer between the reactant and product minerals, and inflow and outflow of components through the hydrothermal fluid. The matrices for SVD analysis consist of arbitrary combinations of molar volume and closure component in the reactant and product minerals. The eight reactions represent the temporal variations of chemical characteristics of the hydrothermal fluid associated with chloritization: the progress of chloritization results in gradual increase of silicon, potassium, and chlorine and gradual decrease of calcium and sodium in the hydrothermal fluid with temperature decrease. The biotite chloritization involves two essential formation mechanisms: chlorite formation (CF) mechanism 1, small volume decrease from biotite to chlorite and large inflow of metallic ions such as Al^{3+}, Fe^{2+}, Mn^{2+}, and Mg^{2+} from the hydrothermal fluid, and CF mechanism 2, large volume decrease and large outflow of the metallic ions into hydrothermal fluid. Chlorite produced with CF mechanism 1 dominates over that of CF mechanism 2, resulting in the gradual decrease of the metallic components in the hydrothermal fluid with chloritization progress. The chloritization reactions also give the temporal variations in physicochemical parameter of the hydrothermal fluid: a gradual decrease of pH and a gradual increase of redox potential in the hydrothermal fluid as chloritization proceeds. The combination of continuous reactions based on compositional variations in chlorite together with corresponding continuous Al^{IV} variations gives an indication of the temporal variations in rates of decreasing and increasing concentration of chemical components in the hydrothermal fluid associated with chloritization. The biotite chloritization and resultant temporal variations of chemical and physicochemical characteristics in hydrothermal fluid act as a trigger for the successive dissolution–precipitation process of a granitic rock.

Keywords: Chloritization, fluorine-bearing biotite, hydrothermal fluid, tetrahedral aluminum in chlorite, singular value decomposition (SVD) analysis