American Mineralogist, Volume 104, pages 536–556, 2019

Role of micropores, mass transfer, and reaction rate in the hydrothermal alteration process of plagioclase in a granitic pluton

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Abstract

This paper describes the plagioclase alteration process with a focus on the role of micropores, mass transfer, and reaction rate in the Toki granitic pluton in central Japan. The plagioclase alteration process involves albitization, K-feldspathization, and the formation of illite, calcite, fluorite, and epidote, which is classified into three categories based on their distribution: overall alteration throughout the plagioclase grain (Type A), alteration at the cores of the grain (Type B), and the partial alteration at the rims of the grain (Type C). Micropores form during the incipient stage of plagioclase alteration by dissolution of the anorthite component, and then contribute to the infiltration of hydrothermal fluid into the plagioclase, resulting in further progress of the alteration. The distribution of the micropores within the plagioclase is a key factor of the alteration, resulting in the Type A–C distribution patterns. Another factor in plagioclase alteration is the mass transfer of the components released from biotite by chloritization. The overall reactions lead to the quantitative assessment of mass transfer between the reactant and product minerals during the alteration: the alteration involves the inflow of H_4SiO_4, Al^{3+}, Fe^{2+}, Mn^{2+}, Mg^{2+}, K^+, CO_2, and F^-, and the outflow of H_2O, H^+, and Ca^{2+}. The age of the plagioclase alteration was determined to be 59.2 ± 1.4 Ma by illite K-Ar geochronology. The combination of this age and the time-temperature (*t-T*) path determined by thermochronometry yields a temperature range from 290 to 305 °C. Chronological data suggest that the serial alteration processes from biotite chloritization to plagioclase alteration occurred during 68–51 Ma and at a temperature of 180–350 °C within the rock body. The biotite chloritization and plagioclase alteration led to sequential variations in the fluid chemistry: the concentrations of aluminum, iron, manganese, and magnesium ions in the hydrothermal fluid decrease gradually, and the concentrations of calcium and fluorine ions in the fluid increase gradually as the biotite chloritization and plagioclase alteration proceed. Both processes also cause variations in the pH of the hydrothermal fluid that affect the dissolution of plagioclase. The infiltration rate of the hydrothermal fluid (HFI rate) and the potassium transfer rate (K_T rate) through the micropores into the plagioclase represent the mass transfer rate of the alteration: the maximum HFI rate ranges from 38.0×10^{-6} to 68.1×10^{-6} μm/year and the maximum K_T rate ranges from 36.3 $\times 10^{-6}$ to 64.1×10^{-6} μm/year. These rates can be used to determine the rate of the plagioclase alteration reaction, which ranges from 9.25×10^{-13} to 3.45×10^{-12} gram atom oxygen cm^{-2} s^{-1}. The mass transfer rate and reaction rate are possible indicators that relate the extent of hydrothermal alteration in the plagioclase to the timescale.

Keywords: Hydrothermal alteration, micropores, mass transfer, albitization, illite K-Ar age, Toki granitic pluton