American Mineralogist, Volume 108, pages 1275–1288, 2023

Geochemical processes and mechanisms for cesium enrichment in a hot-spring system

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Abstract

Geothermal systems in Tibet, a crucial geothermal region in China, belong to the Mediterranean-Himalayan geothermal belt and are characterized by a broad distribution of cesium (Cs) bearing geyserite deposits. Targejia, one of the largest Cs-bearing geyserites in southern-western Tibet, contains 1.446×10^4 tons of Cs. The highest ore grade reaches 2.89 wt%, and the ore-forming process can be subdivided into mineralization stages I to V. Cs is heterogeneously distributed in geyserites. Herein, two Cs-bearing ores are investigated, with distinct characteristics of (1) low-Cs-bearing ore (amorphous silica opal-A and opal-CT type) with low Cs (average of ~0.2 wt%), Na, K, Al, and Ca contents, and (2) high-Cs-bearing ore (clay type) with high-Cs (average of ~1.40 wt%), -Na, -K, -Al, and -Ca contents. It is reported for the first time that Cs primarily exists in clay rather than in amorphous silica opal. The Cs-enrichment mechanisms are different for the above two Cs-bearing geyserite types: (1) The deprotonated –OH, surrounded by water molecules, controls the amount of Cs absorbed on the geyserite surface (Si–OH) in the low-Cs-bearing ore. (2) The variable Cs content depends on the Al content because Al substitutes Si, yielding more negative charges to absorb Cs in the high-Cs-bearing ore. Geothermal fluid loading-mass elements, such as Cs and SiO_2, precipitate as amorphous silica (opal) with clay minerals. Mineral saturation index modeling was used to predict the most applicable physical parameters for ore formation. The results confirm that the ore forms at ~85 °C and a pH of ~8.5 in the Na-Cl system at stage V. The degree of Cs enrichment reduces from the latest stage V (0–4 ka) to the early stage IV (4–17 ka), and is controlled by clay dissolution, which might further relate to the climate change in Tibet's Holocene. Fluid-rock interaction modeling shows that dissolution–reprecipitation induces a higher order of amorphous silica formation and clay dissolution at >40 °C and pH of 5–9 at stages V and III, excluding Cs from the ore.

Keywords: Cs, enrichment mechanism, amorphous silica, clay