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Silicon isotope systematics and geochemical constraints on the enrichment mechanism of rare metals in geothermal areas of southern Tibet, China

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The Qinghai-Tibetan Plateau comprises five major suture zones and six terranes. These deep crustal geological structures are the sites of intense geothermal activity, which form the most famous Himalaya geothermal areas with different types of hot spring deposits. Compared with other geothermal areas, the abundant rare metal enrichments (e.g., cesium ore deposits) in siliceous sinter is a unique feature, which is particularly well distributed along the north and south sides of the suture in the Shiquanhe-Yarlung Zangbo geothermal area.

In this study, the hydrochemical characteristics, silicon isotope geochemistry, and rare earth element (REE) patterns in the geothermal water, steam, and sinter in the Kawu, Semi and Dage Jia occurrences were investigated in an attempt to explore geochemical processes occurring in the water-rock system. The contents of B, Li, Si, and Cs in spring samples range from 100 to 450 ppm, 60 to 300 ppm, 40 to 150 ppm, and 60 to 500 ppm, respectively, almost two orders of magnitude higher than that in steam. The REE patterns show that samples trend toward light REEs with negative Eu anomalies. In the springs, the molar ratio of Na/Cl>1 shows that strong water-rock reactions occurred in the ground, and the negative Eu anomaly is attributed to the crystallization of feldspar from geothermal water.

The silicon isotope composition of springs varies from -0.84±0.06‰ to -0.62±0.13‰ in Kawu, from -0.64±0.09‰ to -0.46±0.11‰ in Dage Jia, and from -1.79±0.14‰ to -0.99±0.18‰ in Semi. The δ^{30}Si values of springs in the research area are more negative than that of any other hydrothermal waters in the world. The δ^{30}Si values of steam are from -0.92±0.10‰ to -0.20±0.13‰ in Dage jia, +0.10±0.12‰ to +0.54±0.03‰ in Semi, and that of sinter are from -1.80±0.03‰ to -0.13±0.08‰, and -1.03±0.09‰ to +0.12±0.08‰, respectively. The silicon isotope values indicate that the dominant recharge of geothermal water may be from ground water and the isotope fractionation mechanism can be described by the Rayleigh fractionation model. The dissolution of silcrete with the δ^{30}Si silcrete of -5.4‰ at low temperature contributes to the negative δ^{30}Si value in groundwater. This implies that there are large-scale heat sources to make circulated groundwater warmer and evolve to geothermal water with higher temperature.

Considering the high temperature and pressure of geothermal springs, as well as the unusual enrichment of alkali metals (Li, Rb, Cs) and volatile elements in the geothermal water, we suggest that the heat source may be related to magmatic activity and most elements originate from residual magmatic fluids or magma degassing in southern Tibet. However, the depleted silicon isotopes also suggest strong water-rock interactions during groundwater circulation in the geothermal systems. As a typical incompatible element, Cs is not only easily enriched in residual magmatic fluids but also transmitted into water from rocks during water-rock interactions. Thus, both residual magmatic fluid mixing and extensive water-rock interactions can lead to Cs and related element enrichments in the high temperature geothermal waters in Tibet.