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Ba isotopes reveal the role of magmatic fluids in lithium enrichment in granitic pegmatites

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As one of the most important sources of Li, granitic pegmatite Li deposits, which typically have high grades, are widespread globally and are key to securing the future Li supply. Magmatic fluids should play an important role in Li mineralization in granitic pegmatites. When and how they contribute to the transport and enrichment of Li, however, remain poorly constrained. Ba is a fluid-mobile element, and Ba isotopes have been used to trace the contribution of magmatic fluids to rare metal enrichment. Here, we measured Ba isotope compositions of borehole samples, including granitic pegmatites, granitic aplites, granites, and metasedimentary rocks, from the Jiajika gneiss dome (eastern Tibetan Plateau). The pegmatite veins are spatially zoned around the two-mica granite. Li mineralization within the pegmatite zones far from the granite constitutes the largest hard rock-type Li deposit in Asia (with LiO_2 >3.0 Mt). The granitic pegmatites show the largest range of $\delta^{138/134}$Ba (-2.44‰– 0.47‰) among all samples. Their Ba isotope compositions, however, do not show a systematic variation with depth. The granitic aplites and granites have relatively limited $\delta^{138/134}$Ba ranges (-1.08‰– -0.22‰ and -0.67‰ – -0.28‰, respectively), and $\delta^{138/134}$Ba of the metasedimentary wall rock samples basically falls around the average of the upper continental crust. Our Ba isotope data do not support a petrogenesis of direct anatexis of metamorphic source. The similar $\delta^{138/134}$Ba of granites and granitic aplites indicate insignificant Ba isotope fractionation in this evolutionary stage. During further evolution to pegmatite, the local K-feldspar-controlled fractional crystallization, while being responsible for the slightly elevated $\delta^{138/134}$Ba of the minority pegmatite samples, cannot explain the extremely low $\delta^{138/134}$Ba of most ones. Considering obvious magmatic-hydrothermal interaction features and low Ba contents of most pegmatite samples (<50 μg/g with an average of 17.7μg/g), their Ba isotope compositions are likely to be modified by fluid components. Previous experimental studies indicate that exsolved magmatic fluids from the parental two-mica granite are most likely to provide extra light Ba isotopes. These magmatic fluids accompanying granitic pegmatite melts should be the key medium for Li transport and enrichment to the distal end of the veins.