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3He/4He anomalies in Li-minerals: A potential new tool for dating LCT-pegmatites

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The age of LCT (Lithium-Cesium-Tantalum) pegmatites and their timing relative to spatially-near plutons are commonly debated. Dating pegmatites is challenging because thermal overprinting or late hydrothermal alteration can reset or perturb mineral isotopic systems, making it difficult to isolate the age of crystallization. Additionally, zircon, a widely used geochronometer, is often radioactively damaged in pegmatites because of high U contents, compromising U–Pb dating accuracy. Here, we explore an alternative chronometer; 3He, a well-known stable isotope, is produced from 6Li by neutron capture and is otherwise rare compared to 4He. Thus, 3He/4He could provide an alternative isotopic system for dating pegmatites that contain Li-rich minerals, including spodumene (LiAl(SiO3)2) and Li-rich tourmaline. However, helium is known diffuses rapidly, and the robustness of this chronometer is unknown. There is no experimental data on the diffusion of helium in Li-minerals, and thus the closure temperature for the 6Li-3He system in them has never been calculated.

To determine these diffusion parameters, helium was extracted from spodumene and tourmaline by incremental step-heating. Samples were first crushed under vacuum to eliminate contamination from potential fluid inclusions. Sieved grains were then pyrolyzed under vacuum in 50°C steps of 30 min until depletion. The isotopic compositions were analyzed with a Thermo HELIX-MC mass spectrometer at the Geotop Noble Gas Laboratory. An Arrhenius plot was used to calculate the diffusion parameters. The diffusion experiments confirmed 6Li production of 3He with high 3He anomalies; all samples had 3He/4He ratios greater than crustal levels (0.02 Ra, where Ra is the atmospheric ratio of 1.384 x 10-6). The most extreme He isotopic ratio, 3He/4He, was measured in a ca. 600 Ma old spodumene from Araçuai, Brazil, yielding 15000 ± 576 Ra, 760,000 times the crustal ratio. The activation energy of 4He found in an Mn-bearing spodumene (19.6 ± 0.6 kcal/mol) is comparable to the low-end of reported Ea of apatite (Ea= 18.8 ± 0.3 kcal/mol, [1]). Closure temperatures will determine if these Li-bearing minerals are open or closed systems for helium, and whether they are accurate recorders of LCT-pegmatite age.

[1] Shuster & Farley (2009), Geochimica et Cosmochimica Acta 73, 183-196.