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High $\delta^{18}O$ variability in baddeleyite (ZrO_2) from different magmatic environments: insights from trace elements, Raman spectroscopy and SEM imaging.

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Most high-precision uranium-lead (U-Pb) dating studies focus on zircon ($ZrSiO_4$) since this is a common accessory mineral in felsic rocks and the processes that cause Pb loss in zircon are relatively well understood. However, zircon is often scarce or absent in mafic rocks, therefore other U-bearing phases such as baddeleyite (ZrO_2) are commonly dated instead. Unlike zircon, the processes that remobilize Pb in baddeleyite are poorly understood, limiting geochronological interpretations of discordant baddeleyite ages. In this study, we aim to study the trace element composition, the oxygen isotope composition and the structure of baddeleyite as they have been fundamental to understanding Pb mobility in zircon. Notably, oxygen isotope compositions are typically used as a proxy for fluid alteration in minerals such as zircon, quartz, and monazite, but remain largely unexplored in baddeleyite. Here, we present new oxygen isotope, trace element, and Raman data from baddeleyite grains of different ages and provenance, coupled with SEM images. The samples come from mafic intrusives in large igneous provinces, from intraplate alkaline intrusives or from a meteoritic impact melt rock. In several samples, baddeleyite shows low-$\delta^{18}O$ values (as low as -4‰) with high intrasample variability (up to 7 ‰) whereas zircon from the same sample shows less variability (1-3 ‰). With a few exceptions, most of the baddeleyite grains analyzed appear not to be in high temperature $\delta^{18}O$ equilibrium with the zircon. Trace element concentrations in baddeleyite do not correlate with $\delta^{18}O$ or with higher self-irradiation (U+Th concentrations). Raman spectroscopy is being used to further assess the correlation between radiation damage and chemical composition. Some of the high variability, low-$\delta^{18}O$ baddeleyite populations show pervasive zircon overgrowths and replacements in SEM images, whereas others appear pristine. By combining the isotopic, chemical, and structural data with future high precision TIMS U-Pb analyses, we aim to further our understanding of baddeleyite as a mafic rock chronometer and improve geochronological interpretations.