Investigating Pb loss in baddeleyite

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Baddeleyite (ZrO_2) is a trace phase that can be found in small evolved melt pockets in mafic rocks. Baddeleyite incorporates U into its crystal structure during growth and rejects Pb, much like zircon, $ZrSiO_4$ (its silicate equivalent), making it an excellent mineral for U-Pb dating. Initial studies to date mafic rocks discovered that baddeleyite is much more robust to secondary Pb loss than zircon. When zircon and baddeleyite were dated from the same samples, zircon often suffered from Pb loss, yielding discordant results, whereas baddeleyite typically was concordant or close to concordant (e.g. Heaman and LeCheminant 1993). However, after the introduction of the chemical abrasion technique to remove the areas of zircon affected by Pb loss and get reliable and concordant U-Pb ages (Mattinson, 2005), it became apparent that baddeleyite crystals, which are not amenable to chemical abrasion (see Rioux et al. 2010), are more prone to Pb loss than previously thought (Schaltegger and Davies, 2017).

Here we investigate the possible mechanisms for Pb loss in baddeleyite. We use Raman spectroscopy and transmission electron microscopy to determine the cumulative effects of U decay on the structure, we also use trace element geochemistry and electron imaging to assess the effects of secondary alteration on baddeleyite crystals. We show that baddeleyite is much more robust to radiation damage than zircon, and shows almost no long range disorder due to alpha recoil, this is similar to monazite. However short range disorder is observed in Raman spectra with band broadening which roughly correlates to alpha dose. We also show that alpha recoil ejection can be a viable mechanism for Pb loss from baddeleyite in some cases, since typical baddeleyite have a high surface area to volume ratio. However, most investigated baddeleyite crystals do not show consistent trends between geochemistry, structure and Pb loss suggesting that fast pathway diffusion may be the most viable mechanism for Pb mobility in most cases.

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