American Mineralogist, Volume 108, pages 543–551, 2023

Effects of thermal annealing on water content and $\delta^{18}O$ in zircon

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Abstract

Primary water and oxygen isotope composition are important tools in tracing magma source and evolution. Metamictization of zircon due to U-Th radioactive decay may introduce external secondary water to the crystal, thereby masking the primary water and oxygen isotope signature. Recently, Raman-based screening has been established to select the low-degree metamict zircons. However, such an approach may not be appropriate for ancient samples, in which nearly all zircons are metamict. It was reported that thermal annealing can potentially heal crystals and retrieve primary water content and $\delta^{18}O$ information from metamict zircons, given the weaker hydrogen bond of secondary water than that of primary water. Heating experiments at temperatures of 200–1000 °C over a period of 2–10 h reveal that annealing can effectively recover primary water and oxygen isotopes from metamict zircons. Primary water in crystalline and metamict zircons remains intact when heated at <700 °C, while secondary water can be effectively expelled from metamict zircons when heated at 600 °C for >4 h, which represent the optimal annealing treatment condition. Hydrothermally altered zircon is an exception. It only yields the minimum estimate of its primary water contents at 600 °C over a period of >4 h, probably due to partial primary water loss during metamictization for hydrothermal zircons. Moreover, the proportion of low-$\delta^{18}O$ (<4.7‰) zircon grains that may be influenced by secondary water dropped from ~21% at <600 °C to ~9% when annealed at >700 °C. This study therefore provides the basis for applying zircon water and $\delta^{18}O$ proxies to geologically ancient samples.

Keywords: Metamict zircon, secondary water, primary water, oxygen isotopes, thermal annealing, diffusion