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Tracking the fluid history of a Cordilleran gneiss dome: sub-micron-scale resolution U-Th-Pb age, oxygen isotope, and Ti concentration of monazite and zircon rims

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Zircon and monazite are the premier mineral chronometers capable of preserving isotopic records of tectonothermal events. While both phases are variably susceptible to fluid-mediated recrystallization, monazite is generally more pervasively affected. In order to decipher the mid- to lower-crustal fluid history of a high-grade terrain, we carried out ultra high-spatial resolution ion microprobe measurements to examine the rims of zircon and monazite crystals. The depth profiling mode of analysis we employed allows recovery of otherwise undecipherable micron-scale records. The Valhalla complex, British Columbia, exposes deeply exhumed metapelite and gneisses that were deformed and partially melted from $\sim$60 to 50 Ma, as documented by U-Pb zircon (60 Ma) and Th-Pb monazite (58 to 51 Ma) geochronology. Biotite Ar-Ar thermochronology indicate that the affected rocks cooled and were rapidly exhumed by 50 to 48 Ma. To better understand the Eocene post-crystallization/fluid history of the complex, we measured U-Pb ages, δ^{18}O, and Ti concentrations of unpolished zircon crystal faces and Th-Pb ages and δ^{18}O of monazite from migmatitic biotite gneiss and metapelite samples. The depth profiling analyses yield a consistent age of 51 Ma over 4 μm from the migmatitic biotite gneiss. Analyses of sectioned and polished grains reveal a weighted mean age of 57.5 $\pm$ 1.3 (MSWD: 1.8). In comparison, the zircon rims from the metapelite yield a variety of rim ages with the youngest at 50 Ma. Zircon interiors from the metapelite preserve detrital ages of ca. 1.4 Ga. Oxygen isotopic analyses of conventionally sectioned and polished monazite reveal heavy δ^{18}O values of ca. 8.0 to 9.0 per mil that imply pervasive re-equilibration with metamorphic fluids. Zircon is much less dramatically affected. In the case of both samples, zircon rims systemically yield heavy δ^{18}O values (up to 10.0 per mil), similar to the monazite δ^{18}O values. In comparison, the interior compositions of the zircon yield values down to 5.5 per mil. Ti concentrations of unpolished zircon crystal faces and grain interiors yield temperatures of 720 to 650 ºC, suggesting that the complex remained at high temperature until late in its history. The results show that the Valhalla complex underwent rapid cooling from $>$650 ºC to 300 ºC within 1 m.y. Furthermore, these results indicate that deformation- and fluid-mediated recrystallization of zircon and monazite occurred at or near peak conditions as late as 51 Ma. Ultra-high spatial resolution measurements of U-Th-Pb ages, oxygen isotopes, and Ti concentrations combine powerfully to quantify the thermal and melt/fluid history of gneiss domes and other high-grade terrains.