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Experimental study of zircon coarsening in quartzite $\pm H_2O$ at 1.0 GPa and 1000 °C, with implications for geochronological studies of high-grade metamorphism

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ABSTRACT

The rate and mechanism of zircon coarsening in quartzite $\pm H_2O$ at 1.0 GPa and 1000 °C were characterized by performing time-series experiments in a piston-cylinder apparatus. Anhydrous experiments show no significant growth of zircon or textural modifications after 24 h. In the presence of 1–2 wt% H_2O, zircon (2 wt%) in coarsely powdered quartz recrystallized in the first 8 hours so that mean crystal size decreased relative to the starting material. After 8 h zircon grew by Ostwald ripening and by coalescence of crystals, and maintained its position on quartz grain boundaries, even while quartz crystals coarsened, by recrystallizing in the fluid. Fitting the experimental data produced the growth-rate equation $\log (\langle D\rangle^n - \langle D_0\rangle^n) = \log (\langle D\rangle^2 - \langle D_0\rangle^2) = \log (t - t_0) + \log K_n = \log (t - t_0) - 5.9$, where $\langle D\rangle$ is mean diameter in micrometers, the subscript 0 denotes initial value at time zero, t is experiment duration in seconds, and K_n is the growth-rate constant with units of $\mu m^2/s$ (five experiments, $r^2 = 0.988$). A value of $n = 2$ suggests that growth is interface controlled, with the rate limited by dissolution and precipitation on the crystal surface. An equivalent growth-rate equation is $\langle D\rangle - \langle D_0\rangle = K_{1/n}\, t^{1/n} = K_n^{1/n}\, t^{1/n} = (1.12 \times 10^{-3}\ \mu m/s^{1/2})\, t^{1/2}$, a parabolic rate law equation that can be used to demonstrate that zircon in the presence of H_2O at 1000 °C grows fast enough by Ostwald ripening to produce micrometer-thick overgrowths in <10 y. Rapid coarsening of zircon by Ostwald ripening will occur during thermal metamorphism when fluid is present. Addition of fluid (and possibly melt) greatly increases the rate of coarsening, suggesting that most metamorphic rims form nearly instantaneously during fluid influx (or anatexis), and that U-Pb rim ages date such events.