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Crystal size distribution of amphibole grown from hydrous basaltic melt at 0.6–2.6 GPa and 860–970 °C

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Abstract

We carried out three series of amphibole crystallization experiments from hydrous basaltic melt to calibrate the dependence of crystal growth rate on temperature and pressure in amphibole-bearing igneous rocks. One series of 100 h duration multi-anvil experiments were carried out at a constant pressure of 0.6 GPa and variable temperatures from 860 to 970 °C. The second series was conducted at a constant temperature of 970 °C and variable pressures from 0.6 to 2.6 GPa. The third series examined the time dependence at 970 °C and 0.6 GPa, with durations from 1 to 100 h. A verification experiment showing both reproducibility and the ability of these three series to predict behavior at novel conditions was performed in a piston cylinder at 1.0 GPa and 900 °C for 63 h. All experiments yielded mostly amphibole in a quenched glass of granitic to granodioritic composition. We used the two-dimensional thin section method to measure the crystal size distribution (CSD) of amphibole in the experimental products. Concave-down CSD curves at small sizes indicate a textural coarsening process during the crystallization. The CSD data were inverted using canonical CSD theory for CSD growth rate; maximum and average growth rates of amphibole were also inferred directly from the maximum and average grain size and crystallization time. The maximum growth rate is, of course, always larger than the average growth rate, which is in turn slightly larger than the CSD growth rate, suggesting that CSD growth rate is an adequate measure of the average growth rate of a mineral in magmatic rocks. The CSD growth rate increases with increasing temperature in the isobaric series and with increasing pressure at constant temperature. However, the growth rate is negatively correlated with crystallization time at constant temperature and pressure. Based on the experimental results, a functional form for evaluating growth rate at known pressure and temperature from an observed amphibole CSD was developed and applied to a diorite collected from the eastern Tianshan Mountains, Xinjiang Uygur autonomous region, NW China. The estimated growth rate of amphibole is between 1.6×10^{-9} mm/s and 5.6×10^{-7} mm/s, and combined with petrological constraints on pressure and temperature, the corresponding crystallization time was between 0.1 and 4.3 yr in the natural diorite.

Keywords: Amphibole, basalt, high temperature–high pressure, crystal-size distribution, growth rate, crystallization time