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Rate of antigorite dehydration at 2 GPa applied to subduction zones

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Abstract

A mixture of antigorite, forsterite, and enstatite was reacted at 2 GPa pressure, with water, to study kinetics of the reaction $Mg_{48}Si_{34}O_{85}(OH)_{62}$ = 10 $Mg_2Si_2O_6$ + 14 Mg_2SiO_4 + 31 H_2O.

Reaction progress, F, which can vary between +1 and –1, was measured by comparing areas under X-ray diffraction peaks for run products with corresponding peaks for the starting material. Rates for dehydration and hydration can be regressed with the equation:

$$r\frac{\mathrm{F_R}}{\mathrm{t}} = \mathrm{K_r A_\theta^o}\left[-171\left(1-\frac{T_{\mathrm{eq}}}{T}\right)\right]^n \ \mathrm{mol/cm^3_{rock}/s}$$

The function F_R accounts for the decrease in A_θ, specific surface area, from A_θ° at F = 0 to 0 at F = 1:

$$\mathrm{F_R} = \frac{1}{1-p}\left[1-\left(1-\mathrm{F}\right)^{1-p}\right]$$

where p, ~0.50 for elongate grains, characterizes grain shape. Regression of the rate equation for dehydration runs can be combined with A_θ°, measured on the antigorite starting material, to give reaction rate K_r: –9.2(l.2) × 10^{-15} mol/s/cm^2. With that rate, we calculate that well-defined conventional reversal brackets of 5 °C around the equilibrium temperature would require run lengths of 729(99) h, considerably longer than in this or any previous study.

The rate equations can be applied to the question of overstepping of antigorite dehydration below arcs. One modeled geotherm 40 km below a slab surface crosses the antigorite dehydration reaction at about 2 GPa; the slab takes 3 × 10^5 years to warm one degree. For grain sizes in a serpentinite in the 0.1 to 10 cm range, complete dehydration would take 10^4–10^5 years. During that time, the plate would travel no more than a kilometer past the point of first dehydration. If earthquakes associated with dehydration occurred on timescales of 10^3–10^4 years, complete dehydration of a volume of plate would require 10–100 separate dehydration events.

Keywords: Petrology, kinetics, antigorite dehydration rate, serpentine in subduction zones