

High temperature reactions of serpentine group minerals

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Serpentine minerals are important components of the oceanic crust and play a chief role in lithosphere dynamics; for this reason, their structural and mineralogical modification with temperature have major implications (e.g., Ulmer and Trommsdorff 1995; Escartin et al. 2001;). Despite the huge amount of work devoted to the temperature-induced dehydroxylation and recrystallization reactions of serpentine minerals in air at ambient pressure, several issues are still open to debate: the nature and stability of amorphous dehydroxylate phases, the nature and stability field of talc- and chlorite-like phases possibly appearing during the reaction path, possible topotactic relationships between the serpentine and newly formed phases forsterite and enstatite, the nature of the pyroxene phase, and a comprehensive model based on kinetic parameters is still missing. The thermal transformation, stability field, and reaction kinetics of serpentine minerals antigorite, chrysotile, and lizardite have been studied to draw a comprehensive model for their dehydroxylation and recrystallization reactions. In situ X ray powder diffraction (XRPD) and kinetic studies were combined with transmission electron microscopy (TEM) observations to describe the mechanisms of dehydroxylation and later high-temperature crystallization.

It was found that the three serpentine polymorphs decompose at different temperatures. Chrysotile is stable up to 750 °C, lizardite up to 775 °C and antigorite decomposes at 800 °C. During dehydroxylation, a metastable transition phase with a characteristic peak around 9 Å was observed in antigorite and, to a minor extent, in lizardite (Gualtieri et al. 2012). Rietveld refinements confirmed that the 9 Å phase actually possesses a talc-like structure. It was found that when the heating rate is fast (that is > 30 °C/min), the talc-like phase is not observed. When the heating rate is slower (< 30 °C/min), the talc-like phase is observed. Regardless the rate of heating, talc is never observed in chrysotile indicating both a crystal chemical (thermodynamic) and kinetic control of the reaction. The kinetic parameters and reaction mechanism for lizardite and antigorite dehydroxylation in air at ambient pressure were calculated using the Avrami models and compared to those of chrysotile. For both lizardite and antigorite, the kinetics of dehydroxylation is controlled by diffusion. Apparent activation energy of the reaction in the temperature range 612–708 °C was 184, 221 and 255 kJ/mol for chrysotile, lizardite and antigorite, respectively. The reaction sequences of chrysotile, lizardite, and antigorite leading to the formation of stable high-temperature products (i.e. forsterite and enstatite) are described taking into account previous topotactic and dissolution-recrystallization models.

References:

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