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Statistically learned nonlinearity of the postspinel phase boundary in Mg_2SiO_4 and its implications for slab dynamics and morphology

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Several generations of experimentalists have extensively studied the location and Clapeyron slope of the *ringwoodite â†” bridgmanite* + *periclase* postspinel transition because of its geodynamical implications, along with other phase transitions in the Mg_2SiO_4 phase diagram that are relevant to the mantle transition zone conditions, using *ex situ* (quench) or *in situ* experiments in the multi-anvil apparatus (MA) [e.g., 1, 2] as well as *in situ* experiments in the laser-heated diamond anvil cell (LH-DAC) [e.g., 3, 4]. Historically, the postspinel boundary has been conceived as a linear boundary, but a recent experimental study [5] suggests the postspinel boundary has a nonlinear Clapeyron slope, though based on a free-hand drawing of the boundary. There is not yet a global assessment of phase stability observations in Mg_2SiO_4 that provides a statistically-optimized Mg_2SiO_4 phase diagram and determines its phase boundaries and their uncertainties self-consistently, despite three decades of experimental focus on one specific phase diagram. A more robust estimate of the nonlinearity of the postspinel boundary becomes imperative for accurately predicting the subduction-transition zone interactions and improving our interpretation of the observed slab morphologies.

Here, we report a new experimental dataset on phase stability in Mg_2SiO_4 at 16–28 GPa and 1573–2723 K, obtained from LH-DAC experiments with *in situ* synchrotron X-ray diffraction, along with a compilation of previously-published *in situ* experimental datasets. We develop a statistical learning framework for high-pressure phase diagram determination and focus on its application to constrain the locations and Clapeyron slopes of the phase transitions in Mg_2SiO_4 at transition zone conditions. Our global analysis of the compiled Mg_2SiO_4 data finds that the postspinel boundary is nonlinear, and its Clapeyron slope varies locally (averaged within ±50 K) from $-2.3^{+1.3}_{-1.7}$ MPa/K at 1900 K, to $-1.0^{+2.0}_{-2.3}$ MPa/K at 1700 K, and to $-0.0^{+2.3}_{-3.0}$ MPa/K at 1500 K.

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