American Mineralogist, Volume 102, pages 2494–2504, 2017

The equation of state of wadsleyite solid solutions: Constraining the effects of anisotropy and crystal chemistry

Johannes Buchen[1,*], Hauke Marquardt[1], Tiziana Boffa Ballaran[1], Takaaki Kawazoe[1], and Catherine McCammon[1]

[1]Bayerisches Geoinstitut, Universität Bayreuth, 95440 Bayreuth, Germany

Abstract

A quantitative knowledge of the equation of state of wadsleyite solid solutions is needed to refine thermodynamic and thermoelastic models for the transition zone in Earth's upper mantle. Here we present the results of high-pressure single-crystal X-ray diffraction experiments on two crystals of slightly hydrous iron-bearing wadsleyite with Fe/(Mg+Fe) = 0.112(2), $Fe^{3+}/\Sigma Fe$ = 0.15(3), and 0.24(2) wt% H_2O up to 20 GPa. By compressing two wadsleyite crystal sections inside the same diamond-anvil cell, we find a negligible influence of crystal orientation on the derived equation of state parameters. Volume and linear compression curves were analyzed with finite strain theory to demonstrate their mutual consistency for the Reuss bound indicating quasi-hydrostatic stress conditions. The results on the here-studied wadsleyite crystals are incorporated into a multi-end-member model to describe the equation of state for wadsleyite solid solutions in the system Mg_2SiO_4-Fe_2SiO_4-MgH_2SiO_4-Fe_3O_4. For the hypothetical ferrous wadsleyite end-member, Fe_2SiO_4, we find a substantially larger bulk modulus than expected by extrapolating currently accepted trends. The multi-end-member equation of state model may serve as a basis for the calculation of phase equilibria and the interpretation of seismic observations regarding the transition zone.

Keywords: Wadsleyite, transition zone, equation of state, solid solution, diamond-anvil cell