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Experimental evidence for the survival of augite to transition zone depths, and implications for subduction zone dynamics

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Abstract

(Ca,Mg)-rich clinopyroxenes are abundant in Earth's upper mantle and subduction zones. Experimental studies on the thermoelastic properties of these minerals at simultaneous high pressure and high temperature are important for constraining of the composition and structure of the Earth. Here, we present a synchrotron-based single-crystal X-ray diffraction study of natural diopside-dominated augite [$(Ca_{0.89}Na_{0.05}Mg_{0.06})(Mg_{0.74}Fe_{0.11}Al_{0.14}Ti_{0.01})(Si_{1.88}Al_{0.12})O_{6.00}$] at P and T to ~27 GPa and 700 K. The experiment simulates conditions in cold subducting slabs, and results indicate that augite is stable over this pressure and temperature range. A third-order high-temperature Birch-Murnaghan equation was fit with the pressure-volume-temperature data, yielding the following thermoelastic parameters: K_{T0} = 111(1) GPa, K'_{T0} = 4.1(1), $(\partial K_0/\partial T)_P$ = –0.008(5) GPa/K and $\alpha_T = 4(1)\times10^{-5}\ K^{-1} + 2(3)\times10^{-8}\ K^{-2}$ T. A strain analysis shows that the compression along the three principal stress directions is highly anisotropic with ε1:ε2:ε3 = 1.98:2.43:1.00. Additionally, high-pressure structural refinements of room-temperature polyhedral geometry, bond lengths and O3-O3-O3 angle were investigated to ~27 GPa at ambient temperature. Pressure dependences of polyhedral volumes and distortion indicate that the substitution of Al^{3+} for Si^{4+} significantly changes the compressional behavior of the TO_4-tetrahedron in augite. Density calculations of this augite along a subducting slab geotherm suggest that augite as well as other common clinopyroxenes would promote slab stagnations at transition zone depths if they are metastably preserved in significant quantities.

Keywords: Pyroxenes, augite, high pressure and temperature, single-crystal X-ray diffraction, subduction zone