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Thermoelasticity of silicate perovskites and magnesiowüstite and its implications for the Earth's lower mantle

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ABSTRACT

By assuming an ideal two-component mixture of (Mg,Fe)SiO_3 perovskite (MgPv) and (Mg,Fe)O magnesiowüstite (Mw), and by using a thermoelastic model for mantle minerals developed previously, we can reproduce the PREM values of density and velocities v_P and v_S of compressional and shear waves of the lower mantle within ±0.12%, ±0.28%, and ±0.56% except for the transition layers at the both boundaries. The molar fractions and atomic fractions of iron for MgPv and Mw were adjusted to reproduce the PREM values of ρ, v_P, and v_S above the point of z = 871 km (which is slightly inside the lower mantle) under constant-entropy condition. This depth avoids the boundary effect. The adiabatic bulk and shear moduli of the mixture are calculated by the Hashin-Shtrikman method for MgPv and Mw and then arithmetically averaged. The temperature profile was calculated assuming that the lower mantle is adiabatic and T(670 km) = 1873 K. The temperature at the top of D'' becomes 2444 K. Being added the temperature increment of 840 K over D'' (z = 2741–2891 km) estimated by Stacey and Loper (1983) to our value, the temperature at the core-mantle boundary (CMB) becomes 3284 K in agreement with T(CMB) of 3300 ± 500 °C by Brown and McQueen. The molar ratios of Fe/(Mg + Fe) and (Mg + Fe)/Si become 0.12 and 2.10. The calculated thermal expansivity, α, of the mixture under lower mantle conditions is in agreement with α of the lower mantle calculated directly from PEM data by Brown and Shankland, and Anderson. For the addition of 5 mol% of $CaSiO_3$ perovskite to our model, the essential feature of the result is unchanged and the wt% of SiO_2, MgO, FeO, and CaO become 40.7, 44.6, 11.0, and 3.7.