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Experimental temperature measurements of Fe-bearing silicate minerals and glasses to 1.6 TPa

Bethany A. Chidester, Marius Millot, James Badro, Razvan Caracas, Erik J. Davies, Dayne E. Fratanduono, Megan Harwell, Margaret Huff, Stein B. Jacobsen, Patricia Kalita, Seth Root, Dylan K. Spaulding, Joshua P. Townsend, and Sarah T. Stewart

The Earth and other terrestrial planets experienced one to several giant impacts during accretion and growth. Dynamic simulations of planetary impacts rely on equations of state that define the properties of materials under extreme pressure and temperature conditions. Recent experiments on forsterite, the Mg-endmember of the olivine mineral series, have shown that traditional analytical equation of state models have largely over-estimated the shock temperatures of this material[1], requiring a reformulation of the heat capacity to match the data[2,3]. The correction to the equations of state should be material dependent, and is likely different in compositions that include Fe in the structure. Here, we present experimental shock temperature measurements from the Sandia Z Machine and OMEGA EP facilities on the most abundant minerals in Earth's upper mantle, olivine ($(Mg,Fe)_2SiO_4$)[4] and enstatite/bronzite ($(Mg,Fe)SiO_3$) to over 1 TPa in pressure. We find that Fe-bearing compositions shock to slightly higher temperatures than the end-member species. We also present shock compression and temperature measurements on a bulk silicate Earth (pyrolite) glass composition, analogous to a magma ocean. At low pressures, pyrolite is more compressible and shocks to higher temperatures than olivine or enstatite, but not quartz. However, at higher pressures (>600 GPa), pyrolite behaves very similarly to the crystalline silicates. Our experimental data are then combined to create a general analytical equation of state for silicates for use in planetary impact models.

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