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Insights into the fate of volatile species during the planetary life cycle from shock-release experiments

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Refractory elements (e.g., Si, Mg and Ca) have similar abundances in the bulk silicate Earth relative to chondrites. However, for many elements with lower condensation temperatures – and thus higher volatility – estimates of the chemical abundances in the Earth are orders of magnitude lower than chondritic values. A hypothesis to account for this discrepancy is that volatile elements were lost to space during the violent, high-energy processes of planetary accretion, formation and differentiation. However, the Earth has retained long lived reservoirs of volatiles species including He-3 and primordial water. Observations of polluted white dwarf photospheres also have indicated that volatile atomic species survive the process of planetary destruction suggesting that there may be atomistic mechanisms active at high pressure and temperature conditions that aid in the retention of volatile species.

To understand how primordial volatile atomic species may be retained at the extreme pressures and temperatures of planetary interiors and during the dynamic processes of planetary formation and destruction, we have performed shock-release experiments from shock states of 100-200 GPa using the Z machine at Sandia National Laboratories. The Z machine is a pulsed power facility that magnetically accelerates a flyer plate via the Lorentz force. Shock-release experiments measure the sound velocity at extreme pressure-temperature conditions along the Hugoniot from the overtake of the rarefaction wave in the shocked material. This technique has been successfully used to determine the sound velocity, density, and Grüneisen parameter of melts at high pressures. Our starting materials are SiO_2 glasses with volatiles content from 0-2wt% water and up to 2wt% Ar. Preliminary results at 150 GPa show that while densities for all composition melts are comparable, hydrous silicate melts are less compressible than anhydrous melts and have faster P-wave velocities. The experimental data are consistent with complementary LAMMPS molecular dynamic simulations that show that hydrous melts are stiffer than their anhydrous counterparts at the same pressure conditions in the Earth's Deep mantle. These results have implications for interpreting the structure, dynamics, and evolution of planetary interiors.

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