Decoupling of the elastic and volumetric properties of silicate glasses at high pressure

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The density and elastic properties (moduli and velocity) of silicates at high pressures and temperatures are fundamentally important to understanding the physical structure and evolution of the Earth's interior. Density and the elastic properties of materials at high pressures are not typically measured independently, but rather calculated by integrating one property to obtain the other. In crystalline silicates, densification at high pressure is largely accommodated by compression of the interatomic distances while phonon velocities propagate via lattice vibrations, leading to a thermodynamic relation between the incompressibility measured for static (isothermal – volumetric) and dynamic (adiabatic – elastic) methods. Commonly, the ratio of the isothermal to adiabatic bulk moduli (K_{T0} and K_{S0}, respectively) used for crystalline silicates is applied to amorphous silicates – glasses and melts – to perform these same integrations. However, the validity of this approach for amorphous silicates has yet to be clearly demonstrated. We independently measure the volumetric and elastic response on compression up to 6 GPa for naturally occurring basalt glass (Columbia River Basalt) using high pressure X-ray microtomography and GHz ultrasonic interferometry, respectively. In the basaltic glass, we find that K_{S0} measured by dynamic methods is ~30% greater than K_{T0} measured by static methods, being considerably greater than expected by the relationship given by $K_S/K_T=1+\alpha\gamma T$. We propose that the flexibility of the aluminosilicate network in amorphous materials leads to volume reduction that does not arise from the compression of interatomic potentials, but rather from the rotation and rearrangement of the rigid polyhedra, which can account for observed a decoupling of K_{T0} and K_{S0}.