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Can silicate melts in the Earth's upper mantle be seismically detected? A shockless-compression study on Thor

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Coauthors

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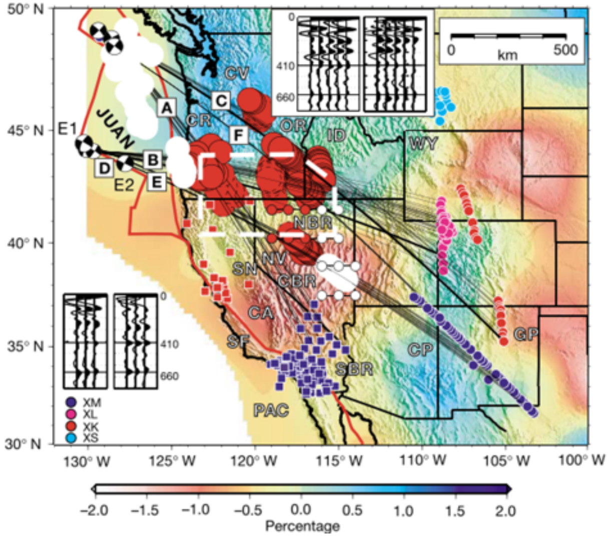
Observed geophysical anomalies at the MTZ

Low-velocity zone atop the 410-km seismic discontinuity in the northwestern United States

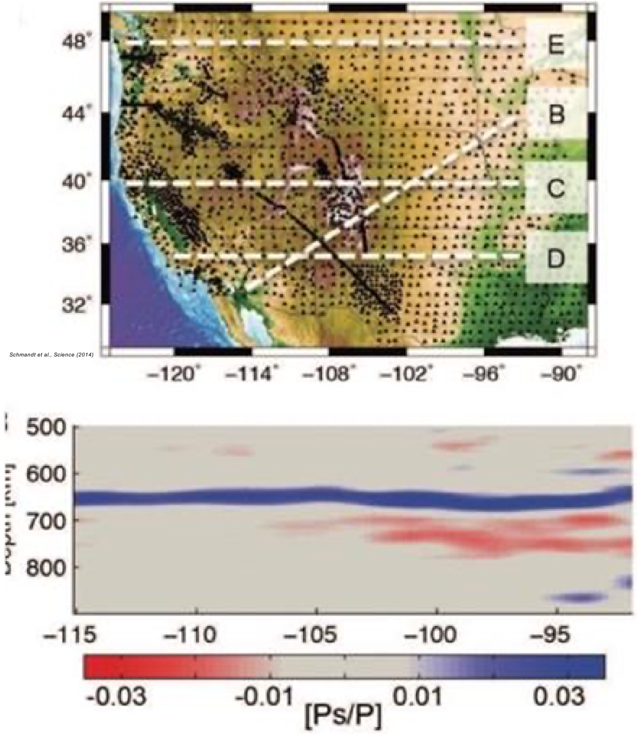
Teh-Ru Alex Song[1], Don. V. Helmberger[1] & Stephen P. Grand[2]



Song et al., 2003

Dehydration melting at the top of the lower mantle

Brandon Schmandt,[1*] Steven D. Jacobsen,[2*] Thorsten W. Becker,[3] Zhenxian Liu,[4] Kenneth G. Dueker[5]



Schmandt et al., 2014.

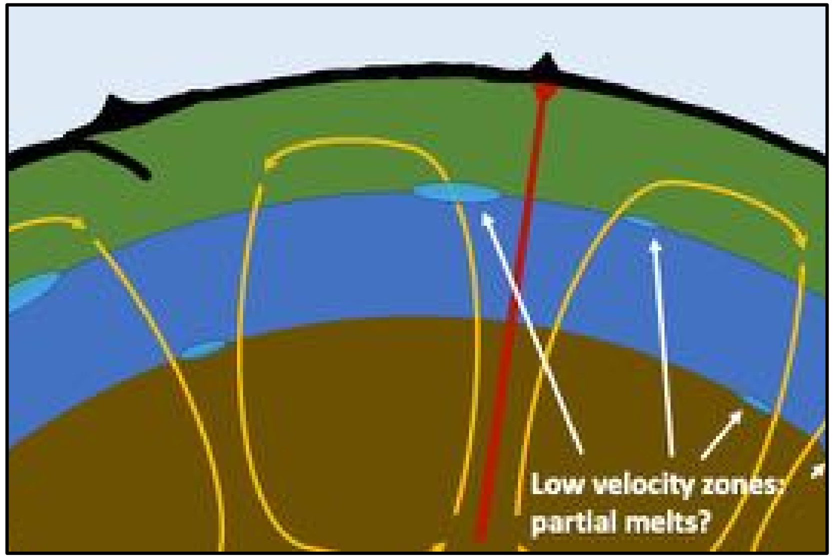
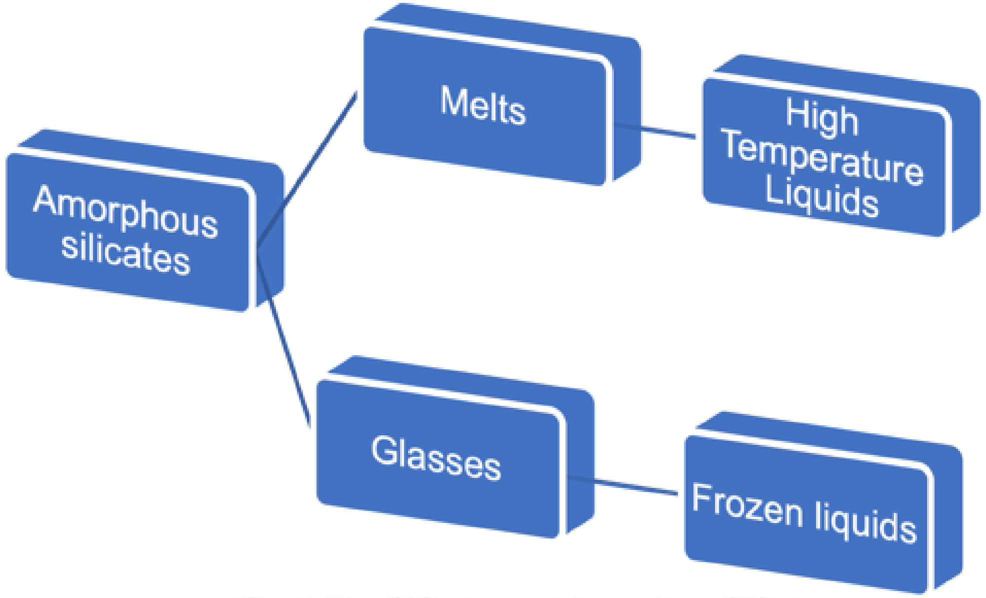


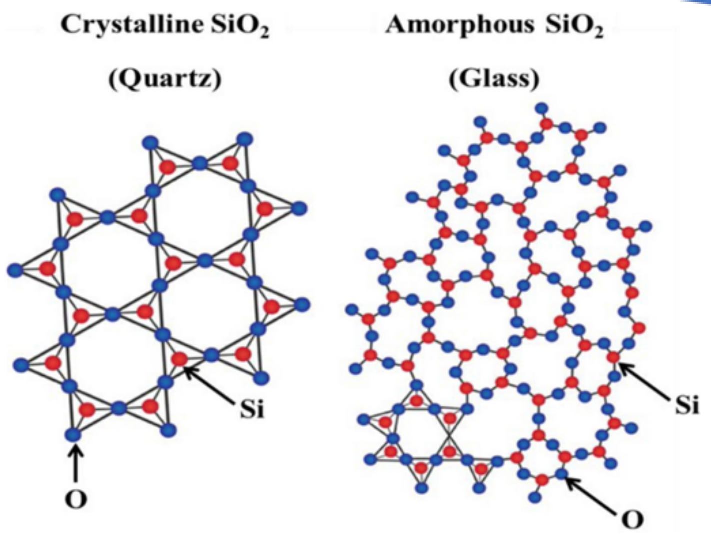
Figure modified from Bercovici and Karato (2003), Hirschmann (2006) and Sakamaki (2013).

Electromagnetic detection of a 410-km-deep melt layer in the southwestern United States

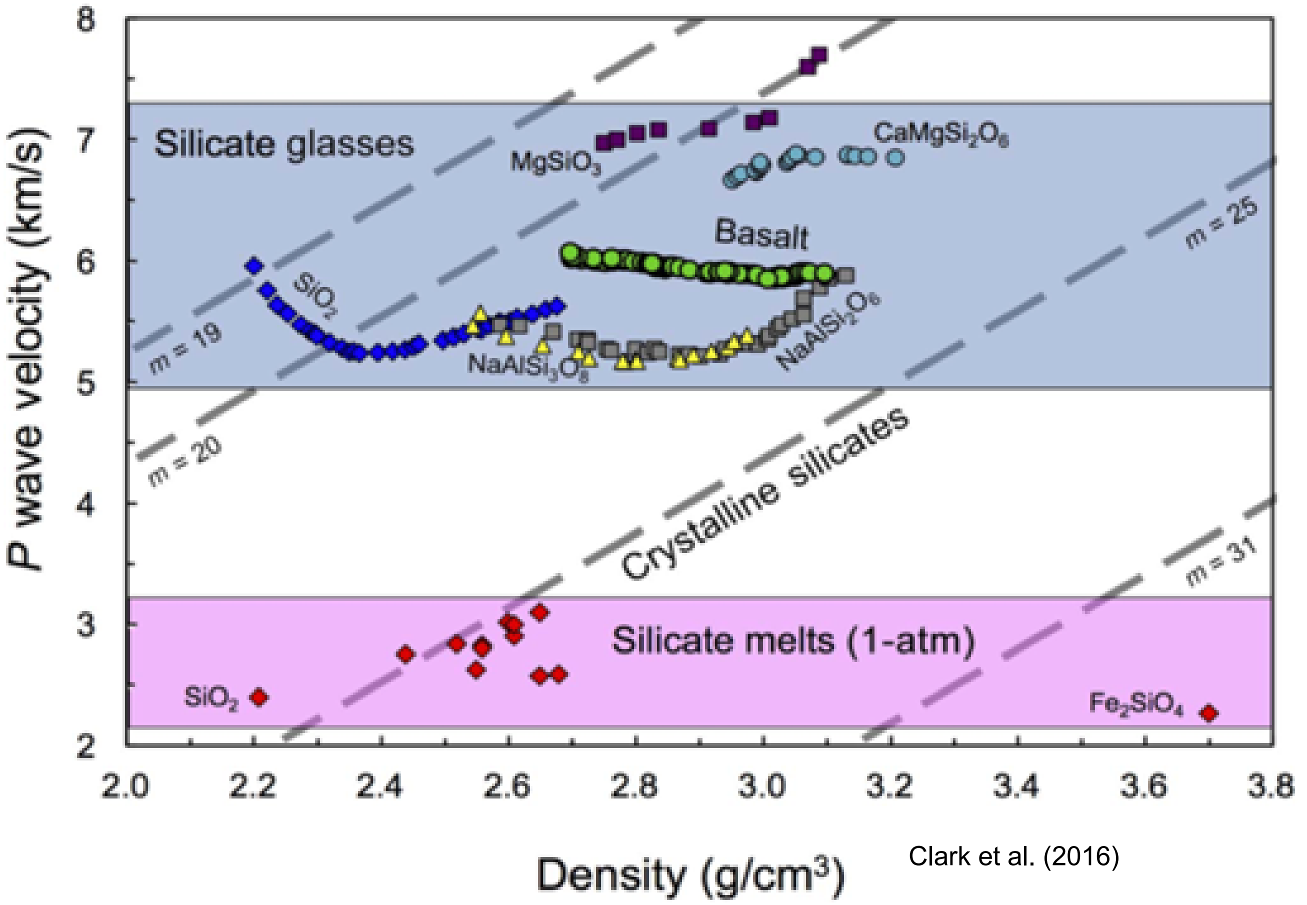
Daniel A. Toffelmier[1] & James A. Tyburczy[1]

Anomalous behavior of amorphous silicates



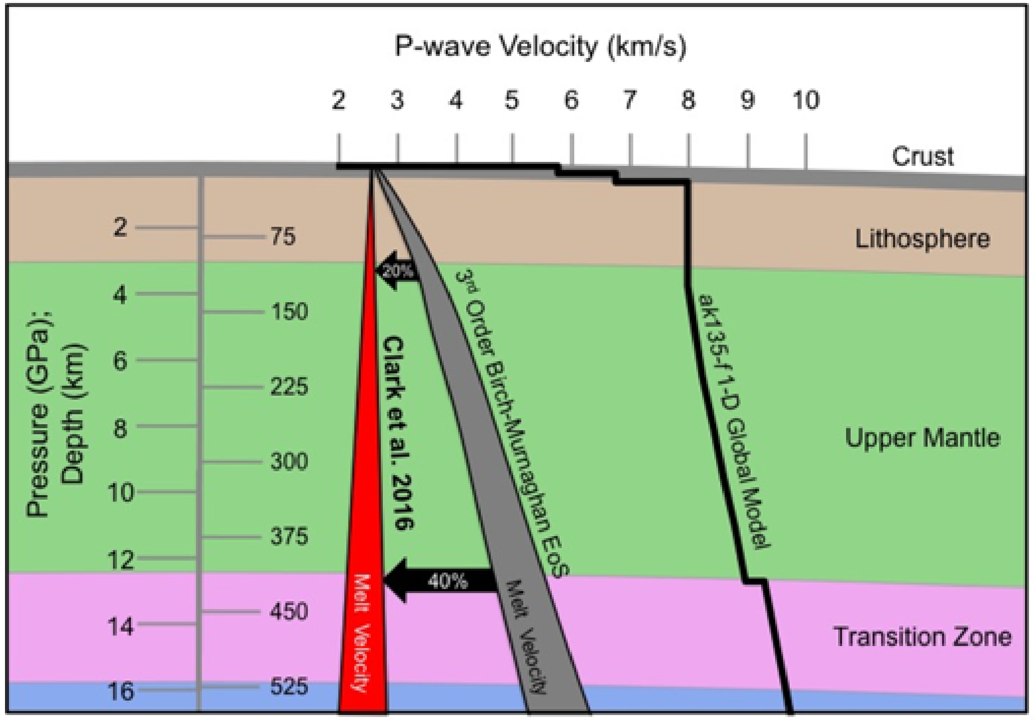


physicsopenlab.org



Clark et al. (2016)

Motivation: Define EOS of melts to interpret regions of low seismic velocities



APS Science Highlight (2016)

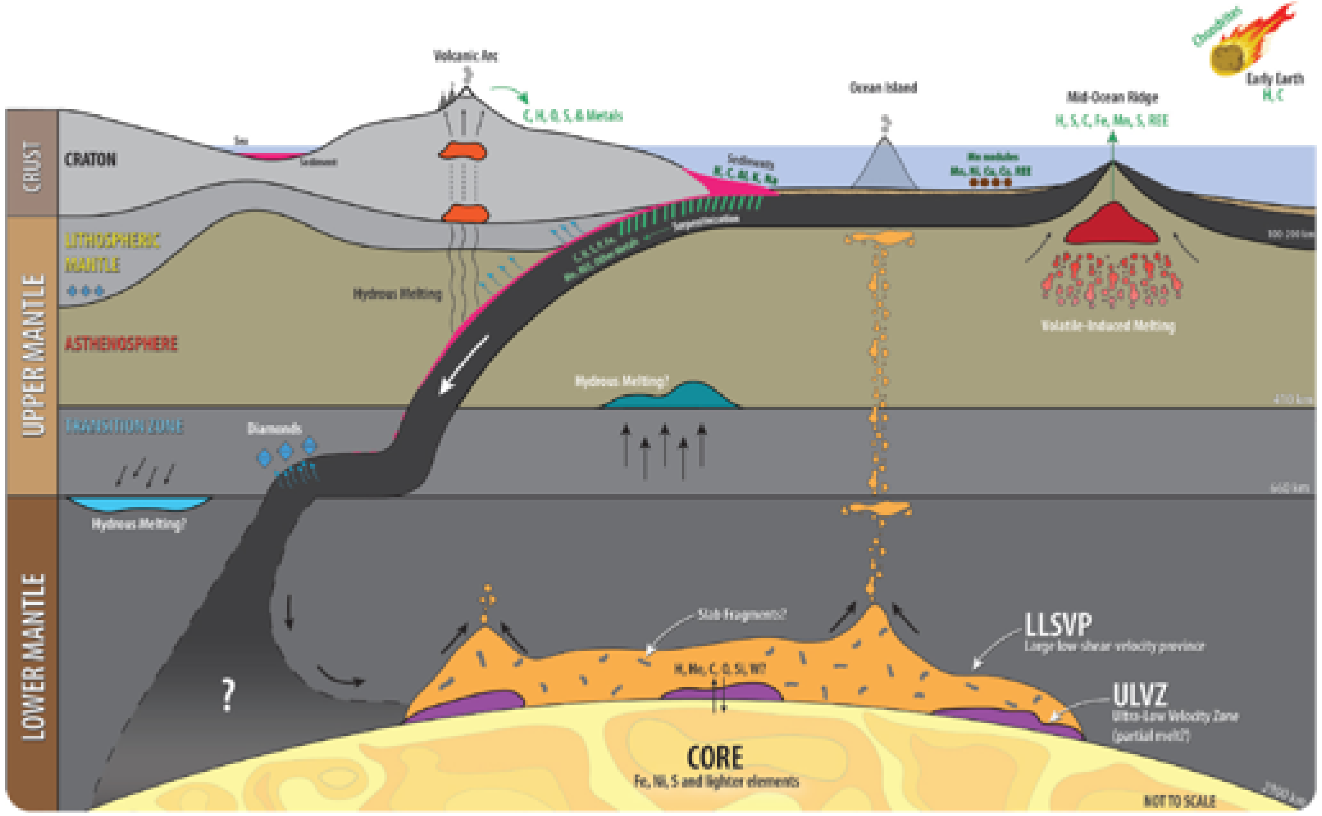


Figure from *A Vision for NSF Earth Sciences 2020-2030: Earth in Time*

Thor uniquely mimics mantle geotherm

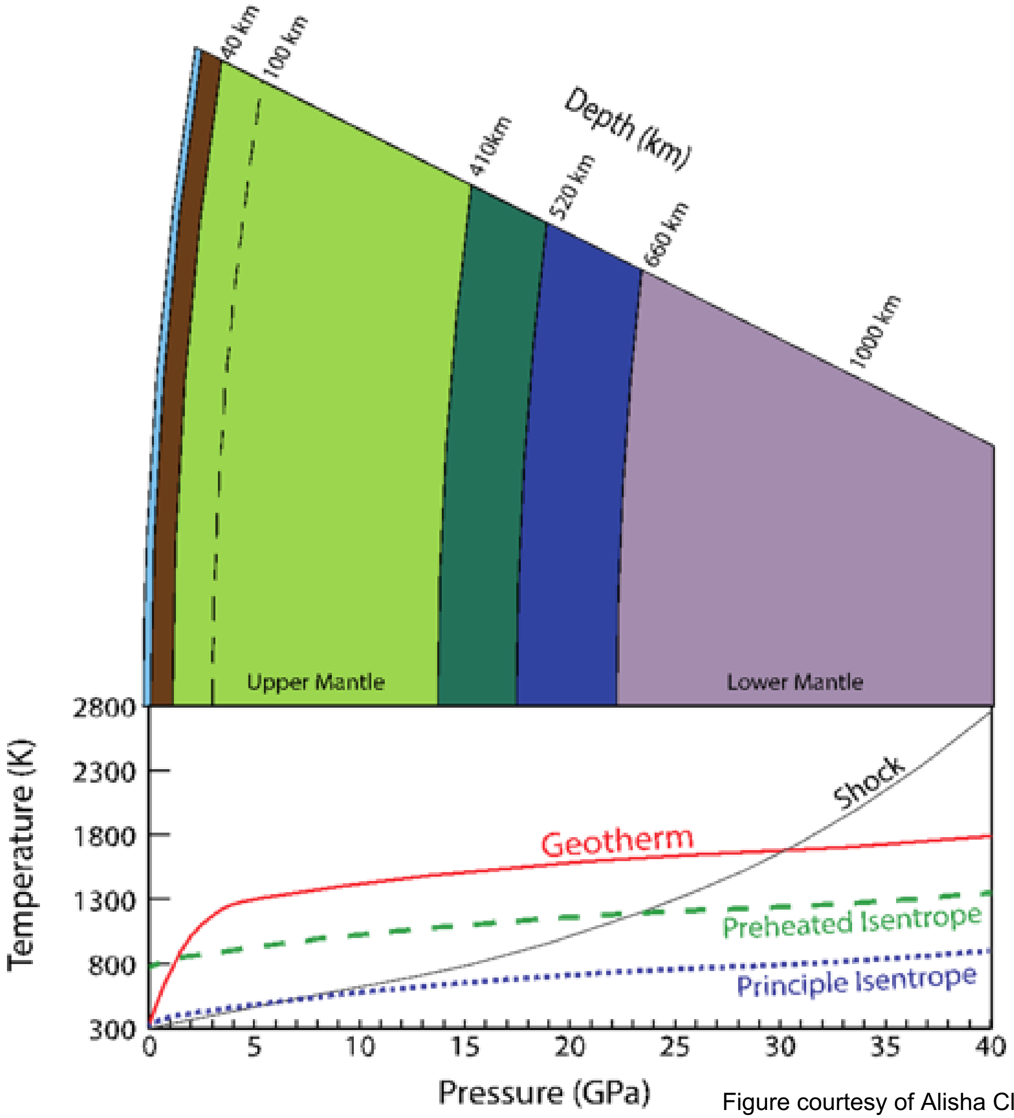


Figure courtesy of Alisha Clark

Photo courtesy of Steven Jacobsen

Energy storage in Thor

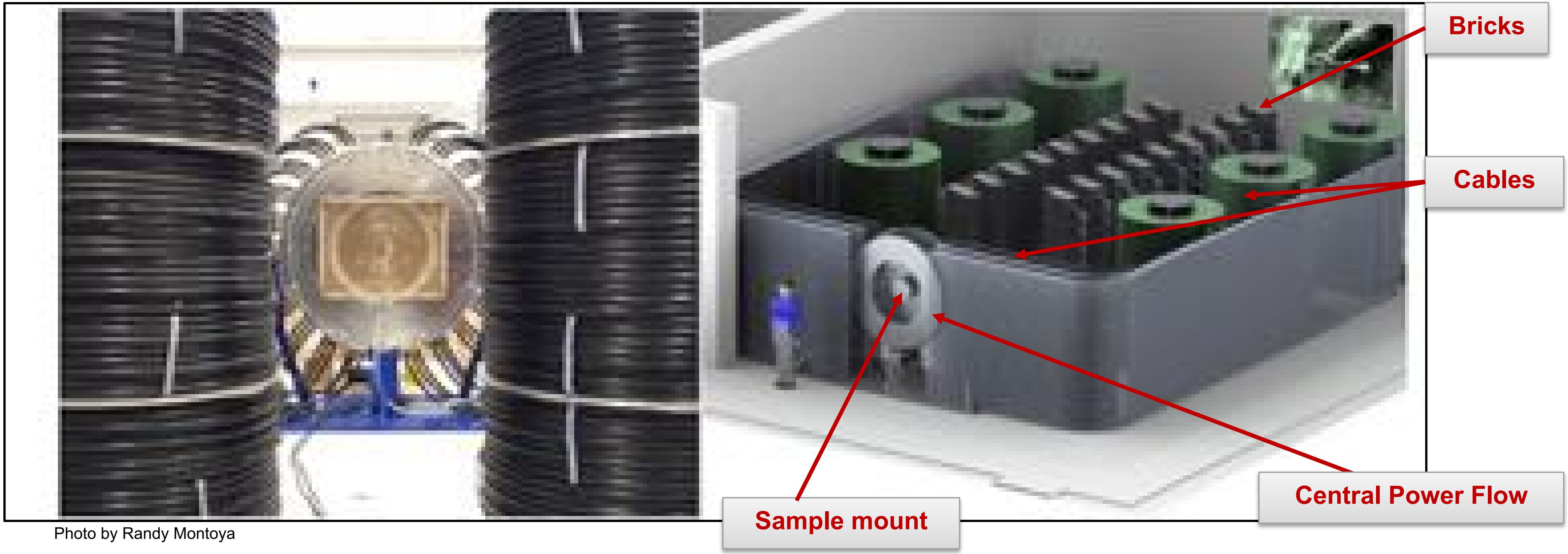
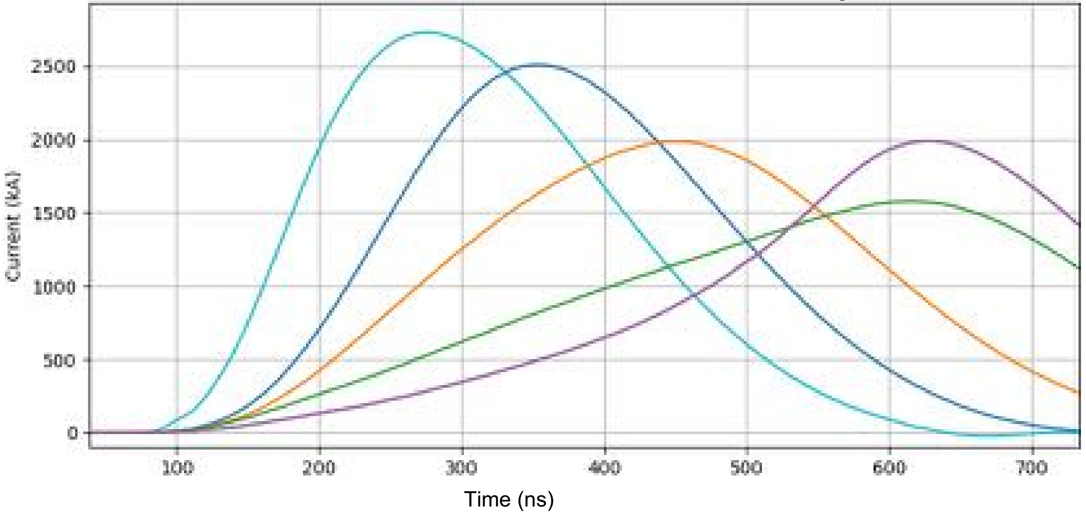
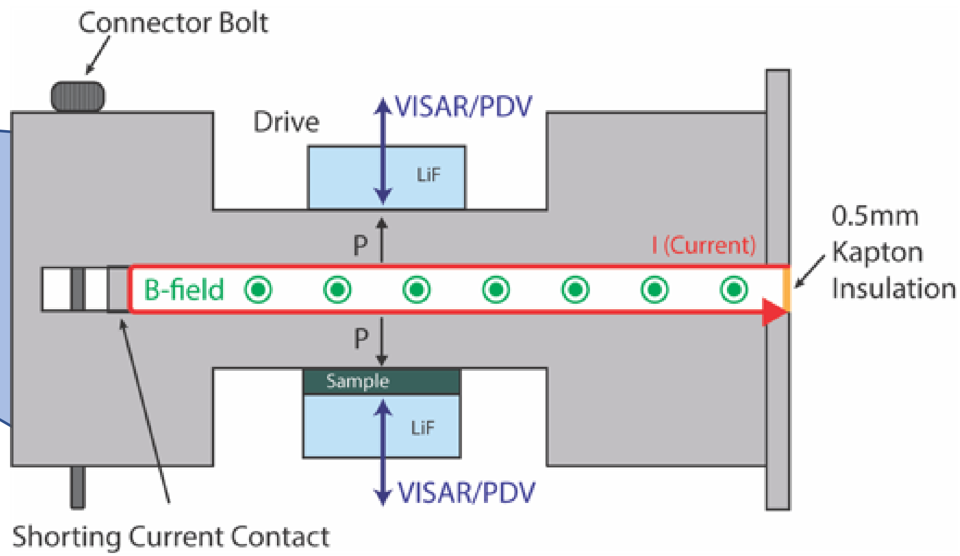


Photo by Randy Montoya

Pulse shaping enables access to pressure and temperature conditions at MTZ

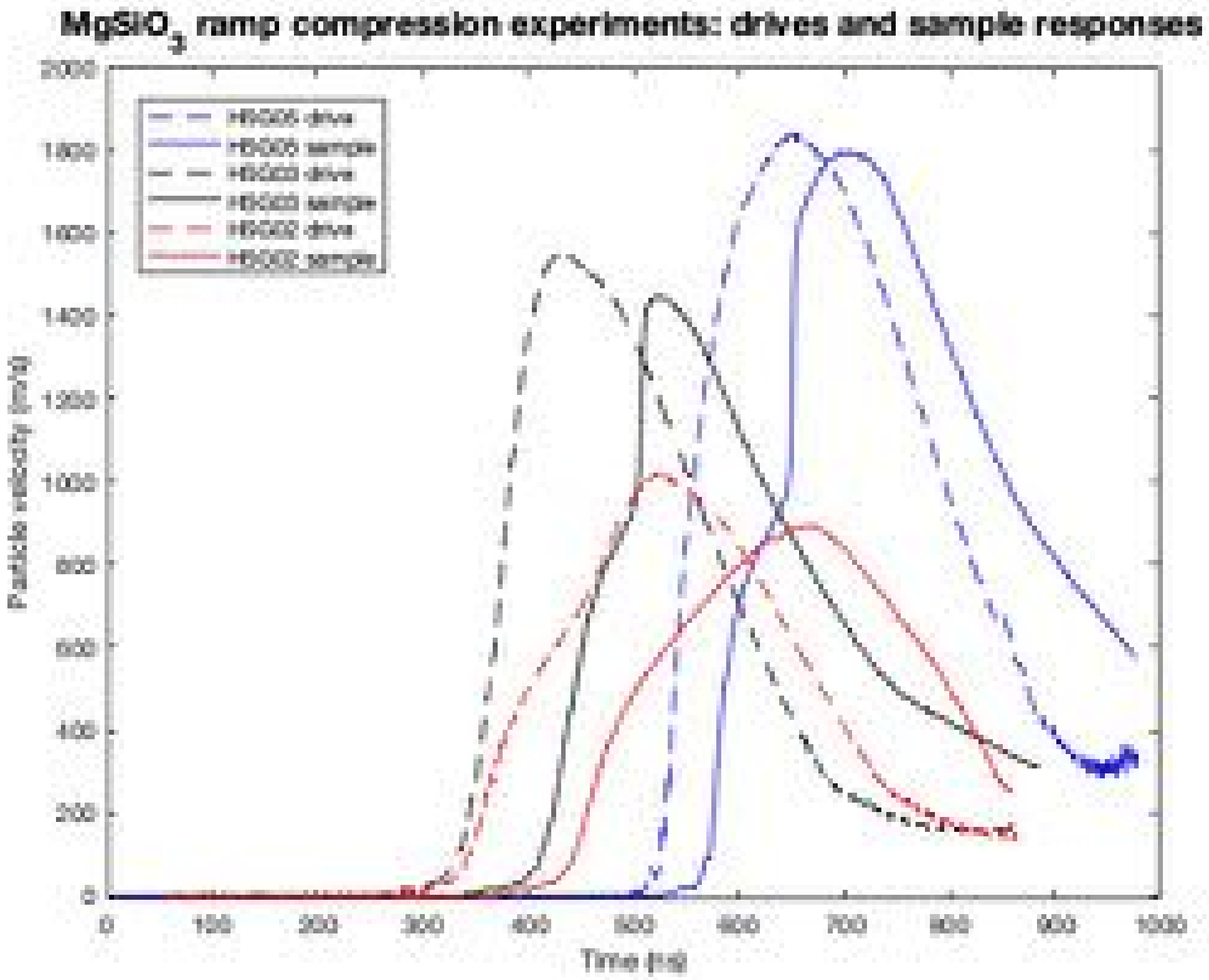
Photo courtesy of Steven Jacobsen



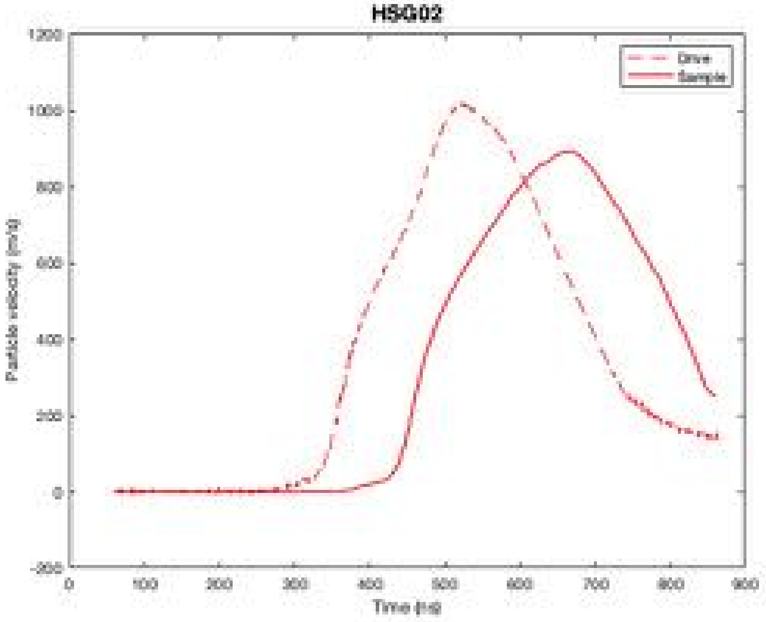


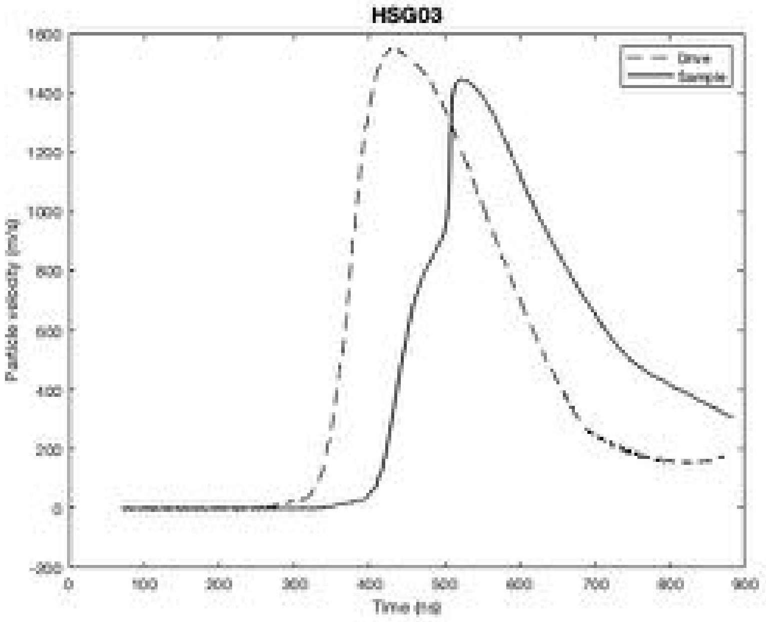
Initial results on $MgSiO_3$ glasses

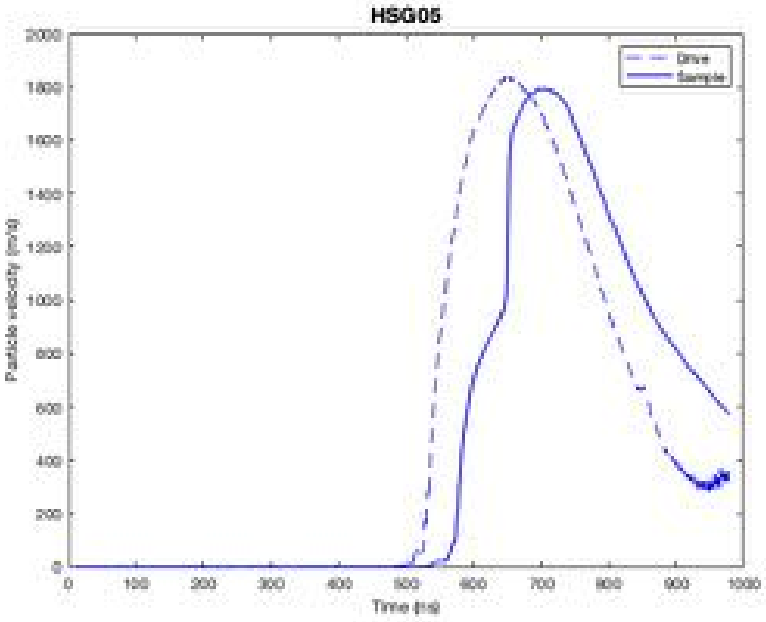
Experiment name	Glass attributes (incl. thickness)	Pressure range
HSG 02	$MgSiO_3$ (680 μm thick)	0 to 11 GPa
HSG 03	$MgSiO_3$ (455 μm thick)	0 to 18 GPa
HSG 05	$MgSiO_3$ (465 μm thick)	0 to 30 GPa



$MgSiO_3$ ramp compression experiments: drives and sample responses





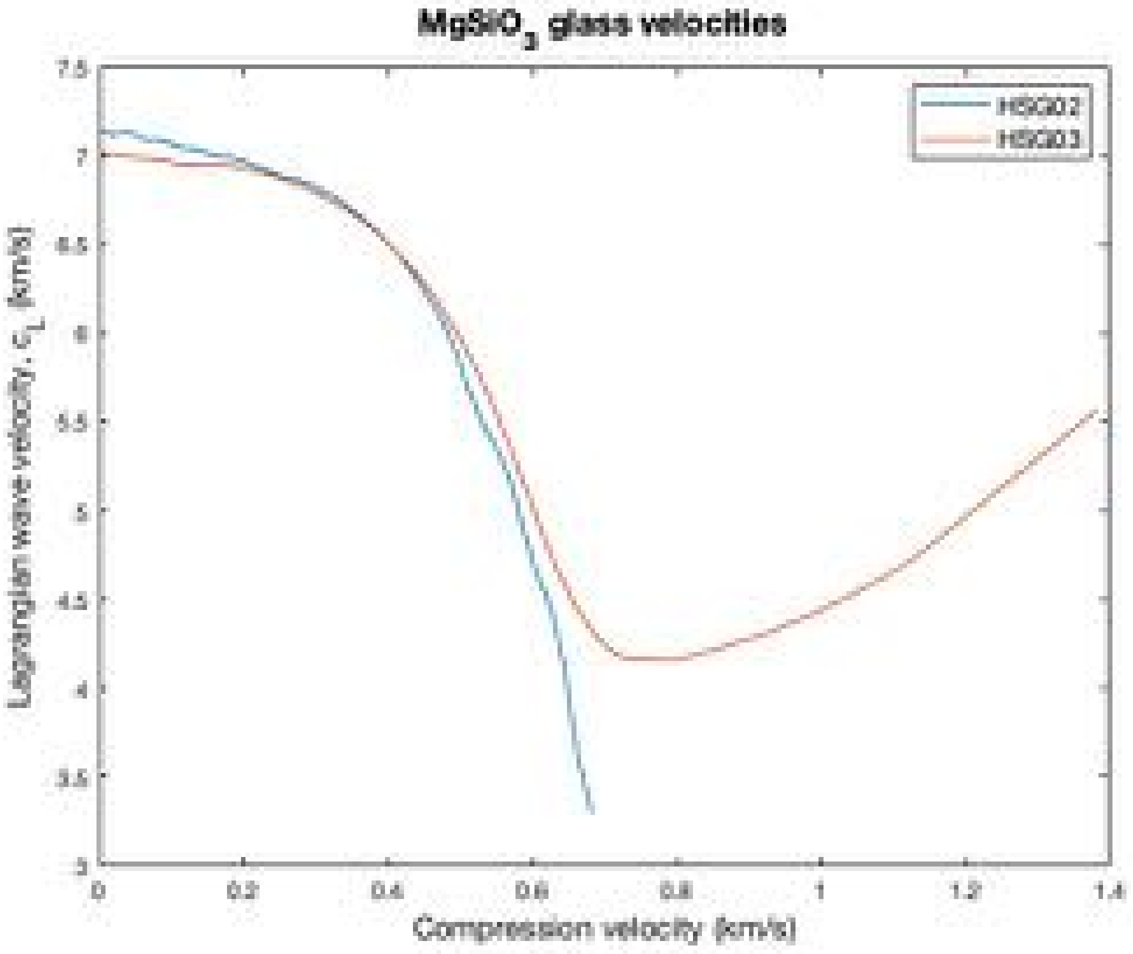


Characterizing P dependent behavior w/ C_L

- Lagrangian sound velocity, c_L, as a function of particle velocity, u_p

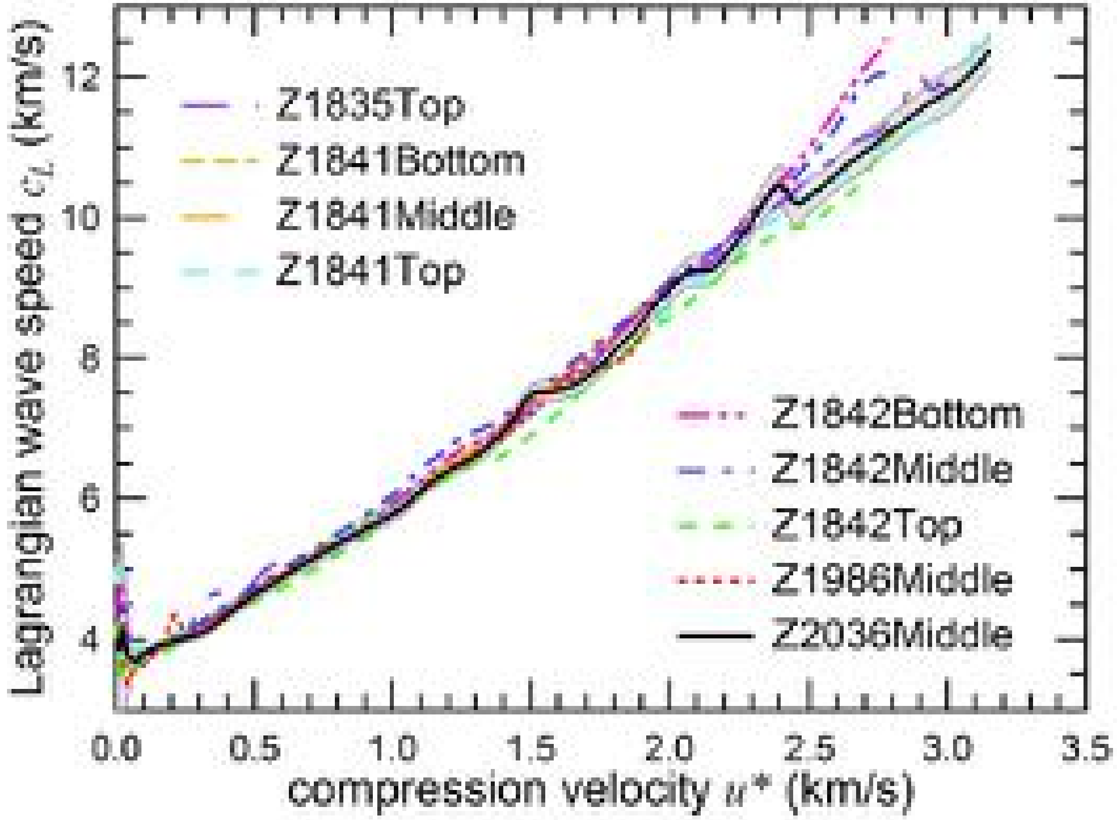
$$c_L(u_p) = \frac{\Delta x}{\Delta t(u_p)}$$

- Decrease in Lagrangian wave velocity followed by steady increase up to 18 GPa

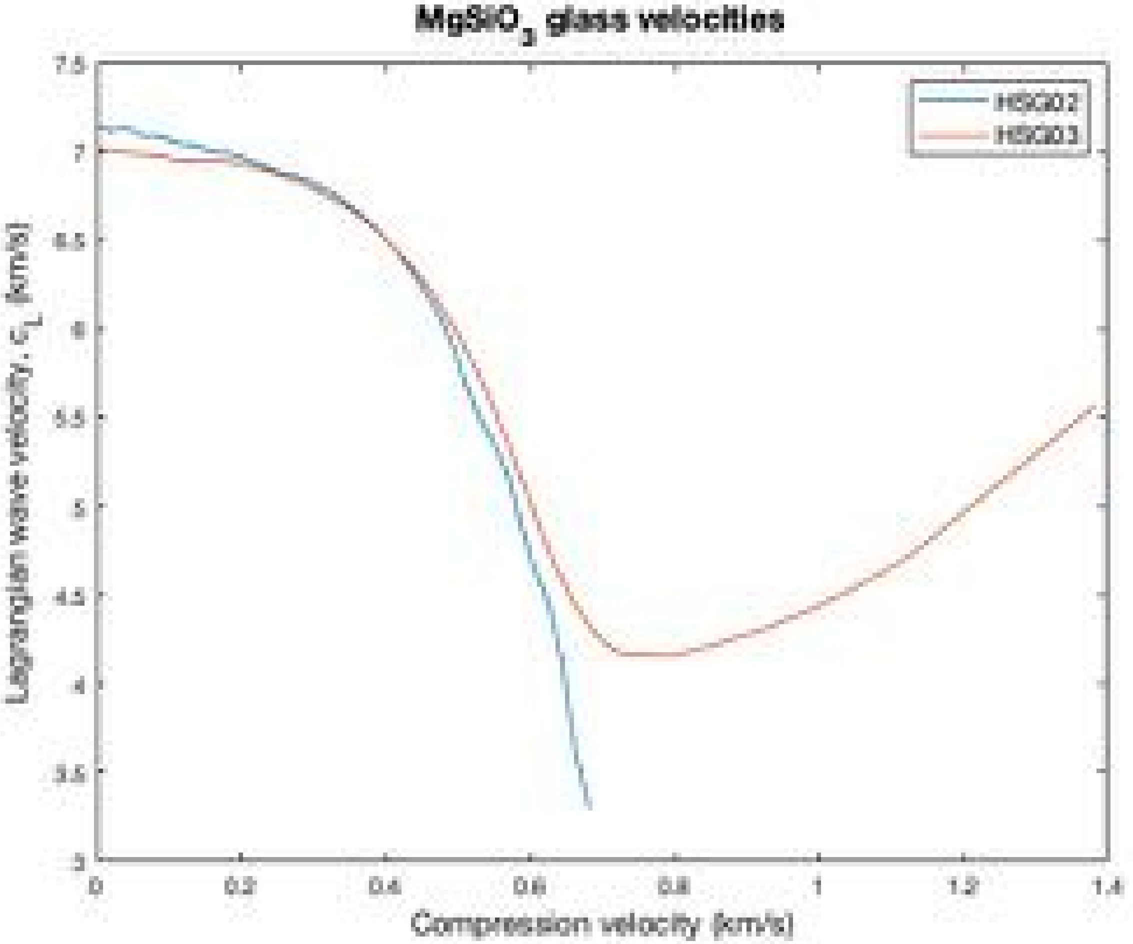


C_L vs. u* in crystalline and amorphous materials

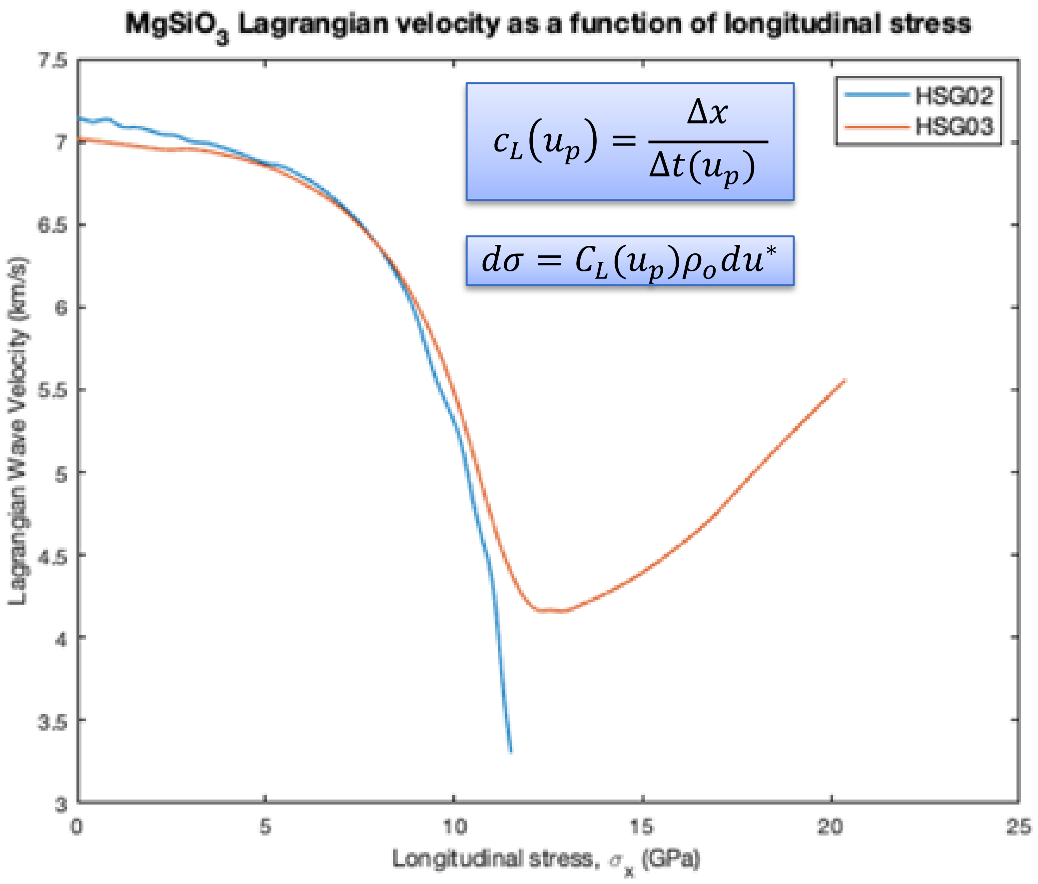
C_L vs. u* for 9 dual-sample ramp compression experiments on tantalum



Davis, J.-P., et al. (2014)

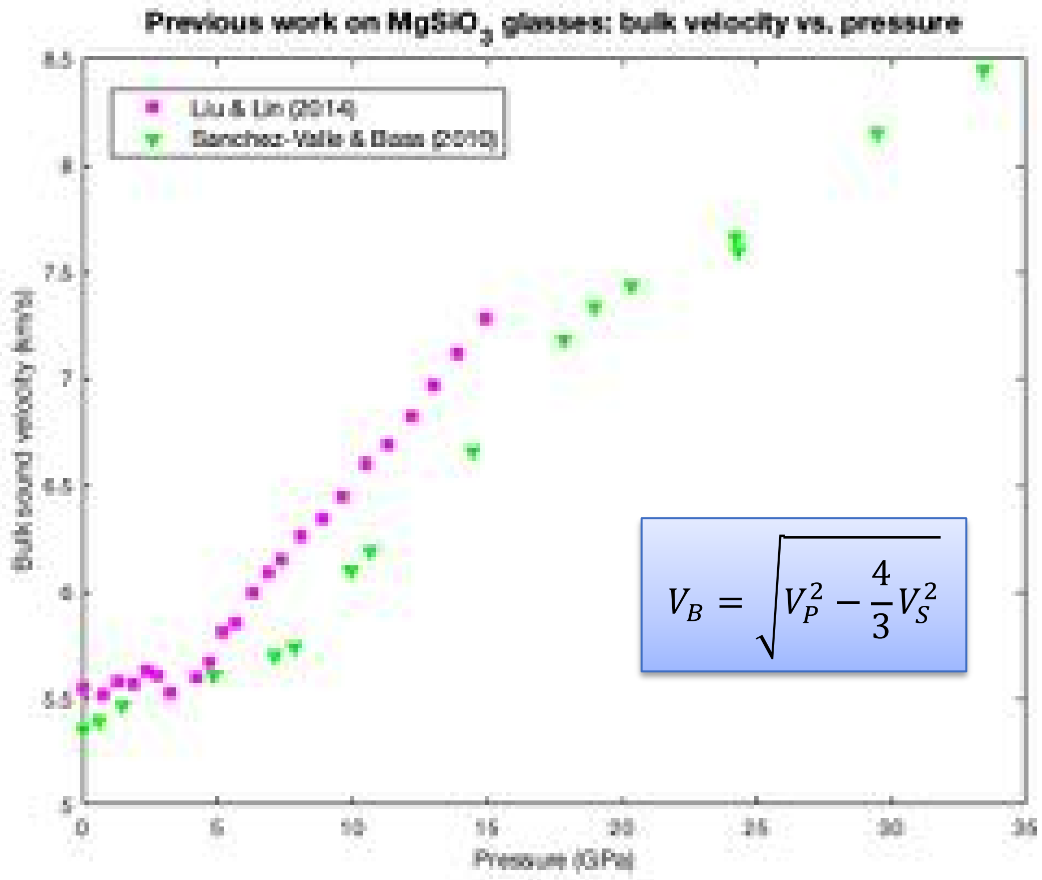


Acoustic velocities in dynamic vs. static compression experiments



$$c_L(u_p) = \frac{\Delta x}{\Delta t(u_p)}$$

$$d\sigma = C_L(u_p)\rho_o du^*$$



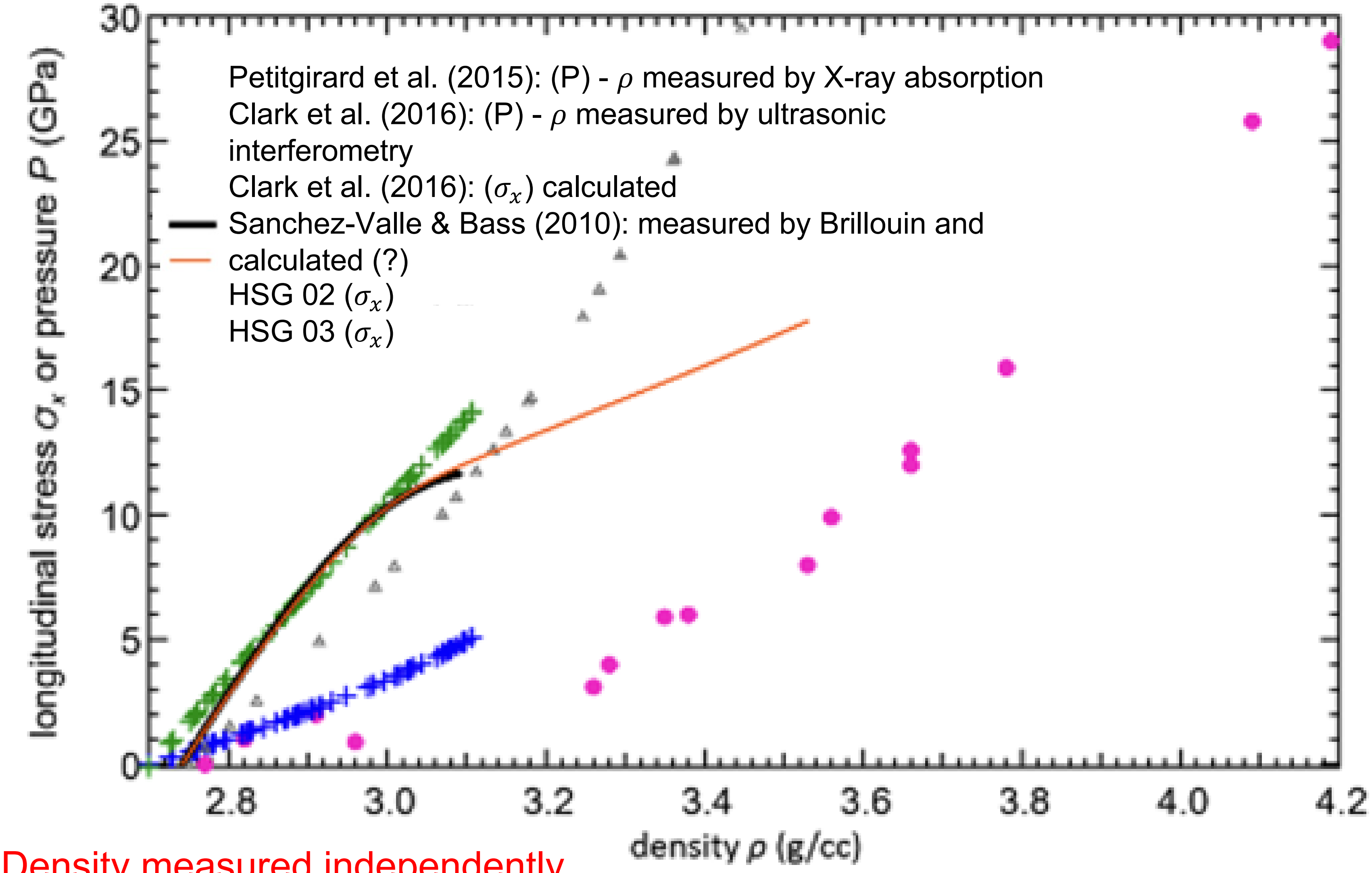
$$V_B = \sqrt{V_P^2 - \frac{4}{3}V_S^2}$$

Pressure vs. density

- Densification begins around 10 GPa, continues through 18 GPa
- Samples exhibit elastic behavior to 10 GPa

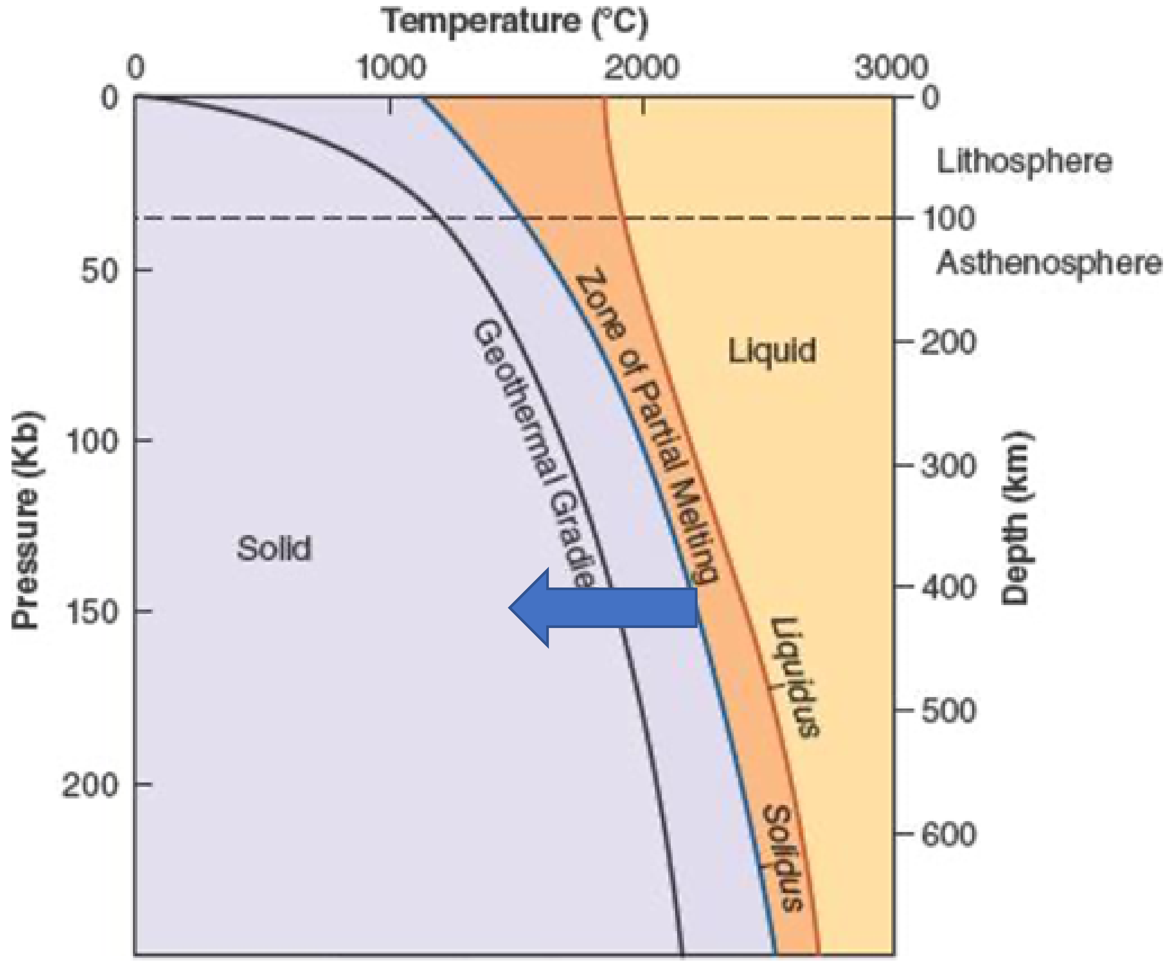
$$\sigma_x = \int V_P d\rho$$

Density measured independently



Future work

- Continue processing data from HSG 04, HSG 05, HSG 06 to determine behavior above 18 GPa
- Acoustic velocity measurements on SiO_2 to expand compositional range
- $MgSiO_3$ and SiO_2 with increasing water contents, up to >1.5 wt. % H_2O to look at effect of volatiles on seismic velocities
- Develop equation of state for $MgSiO_3$ and SiO_2 glasses



Thank you!

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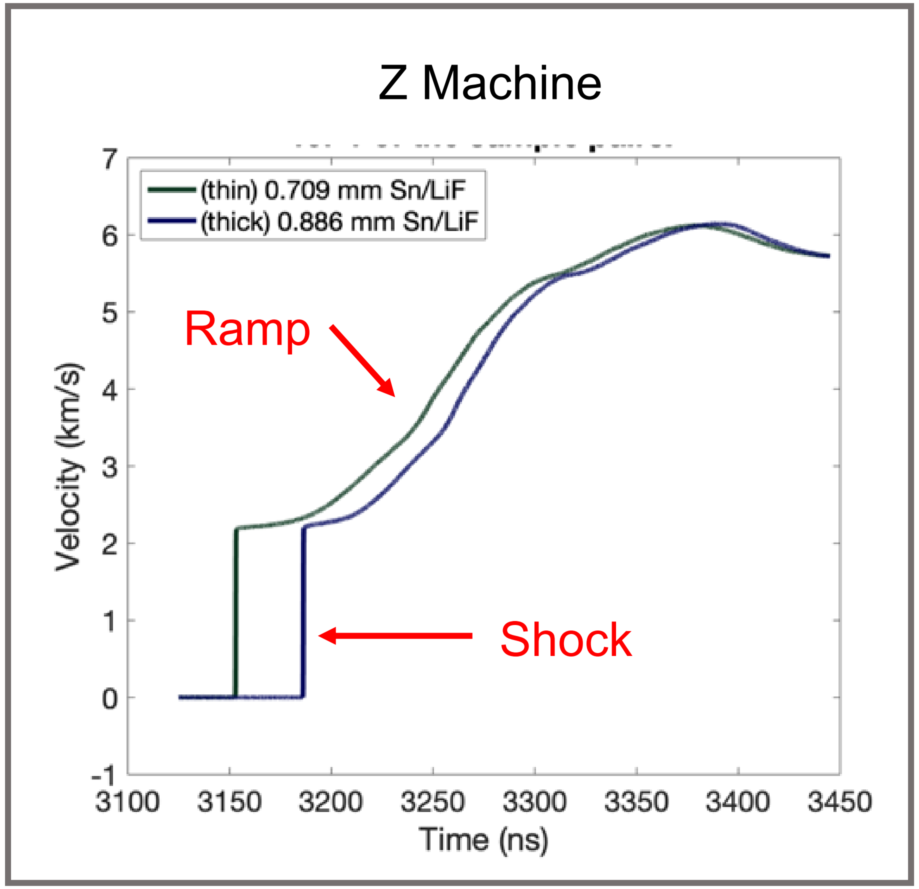
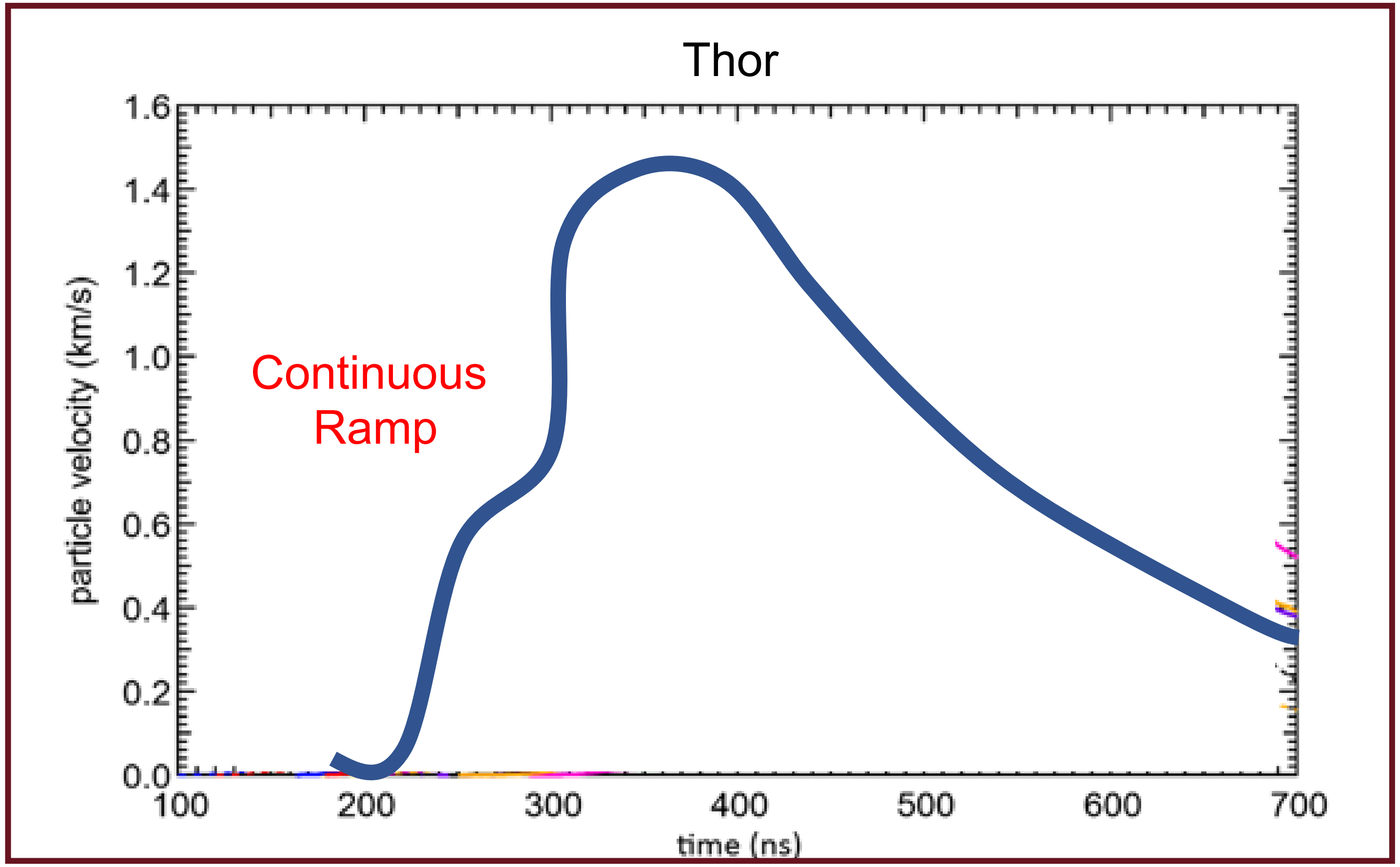
Thor reaches mantle PT conditions continuously

- Ramp compression mimics geotherm more effectively than other methods of compression





From Seagle & Porwitzky, 2017