SAND2021-9717C

Origin of Earth's water: Role of hydrous melts at extreme P-T conditions

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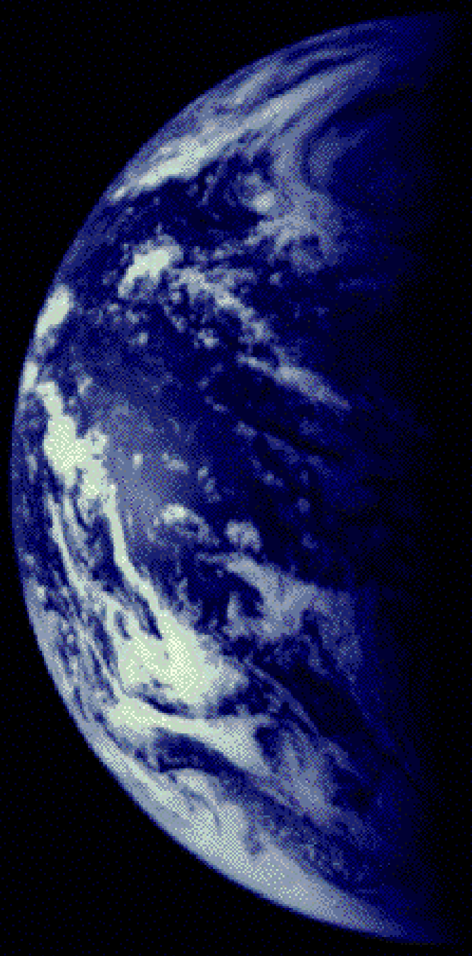
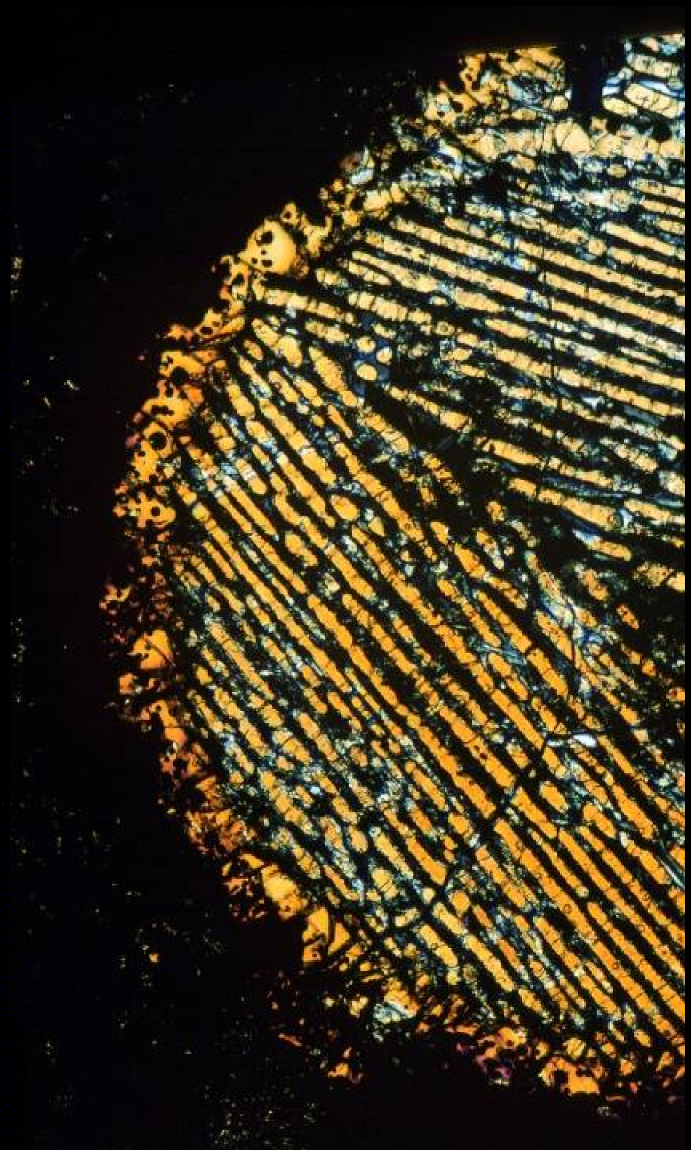
Water abundant in planetary building blocks.





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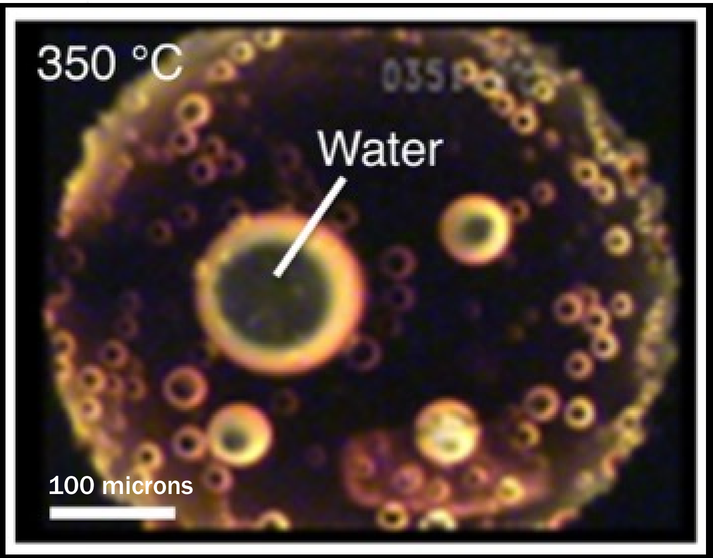
Precometary organic matter: A hidden reservoir of water inside the snow line

Hideyuki Nakano[1,10], Naoki Hirakawa[1,11], Yasuhiro Matsubara[1], Shigeru Yamashita[2], Takuo Okuchi[2], Kenta Asahina[3], Ryo Tanaka[4,12], Noriyuki Suzuki[4], Hiroshi Naraoka[5], Yoshinori Takano[6], Shogo Tachibana[7,8], Tetsuya Hama[9], Yasuhiro Oba[9], Yuki Kimura[9], Naoki Watanabe[9] & Akira Kouchi[9]

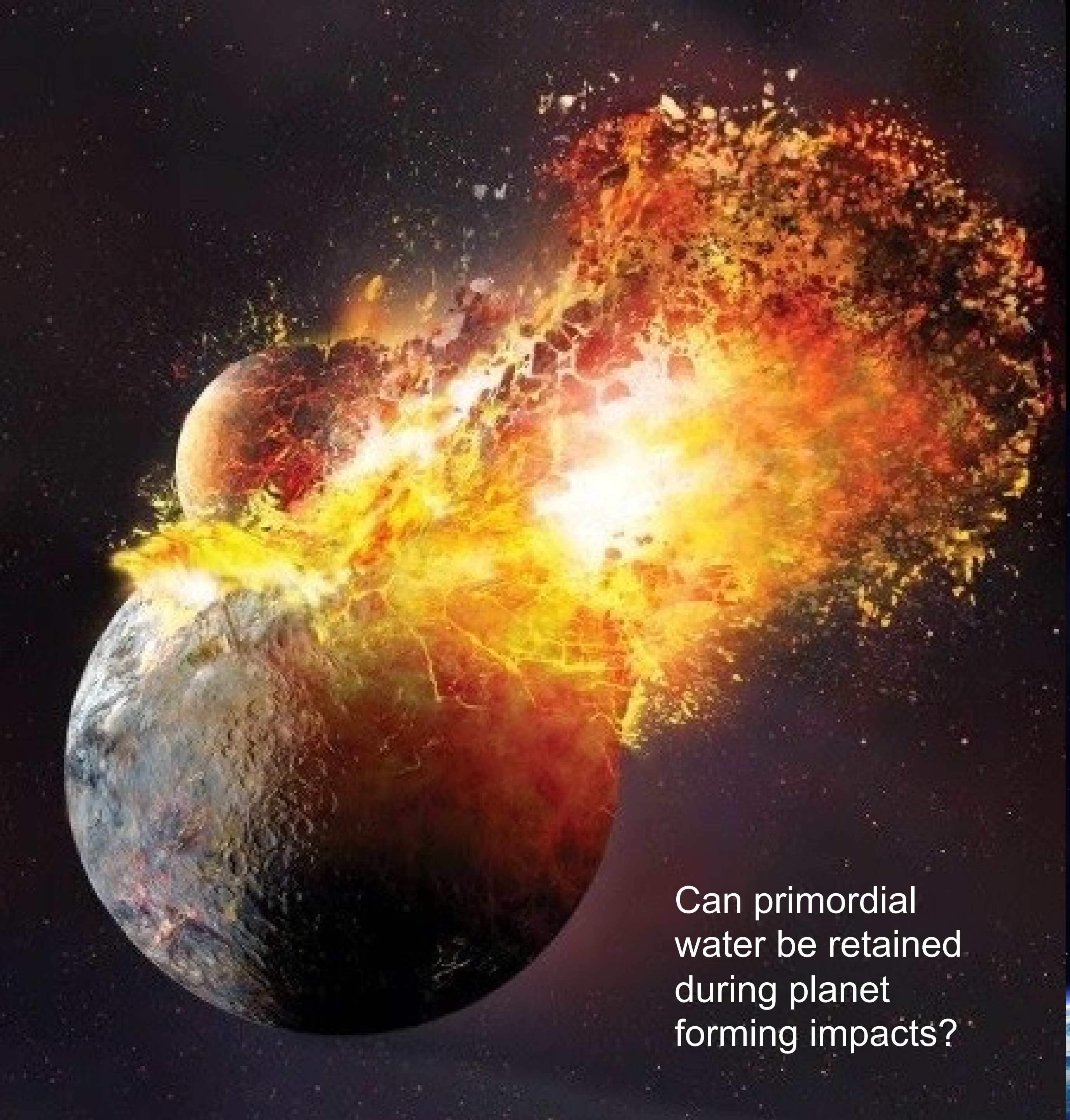
The origin and evolution of solar system bodies, including water on the Earth, have been discussed based on the assumption that the relevant ingredients were simply silicates and ices. However, large amounts of organic matter have been found in cometary and interplanetary dust, which are recognized as remnants of interstellar/precometary grains. Precometary organic matter may therefore be a potential source of water; however, to date, there have been no experimental investigations into this possibility. Here, we experimentally demonstrate that abundant water and oil are formed via the heating of a precometary-organic-matter analog under conditions appropriate for the parent bodies of meteorites inside the snow line. This implies that H_2O ice is not required as the sole source of water on planetary bodies inside the snow line. Further, we can explain the change in the oxidation state of the Earth from an initially reduced state to a final oxidized state. Our study also suggests that petroleum was present in the asteroids and is present in icy satellites and dwarf planets.

Published: 08 May 2020



Other experimental studies have largely focused on WHERE water is in the present-day Earth.

We want to understand the dynamics of HOW water is incorporated during planet formation.



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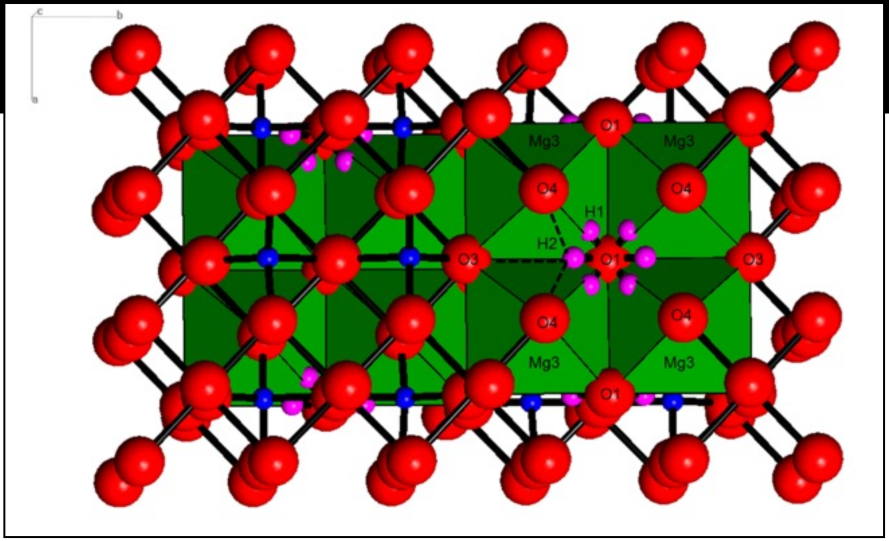
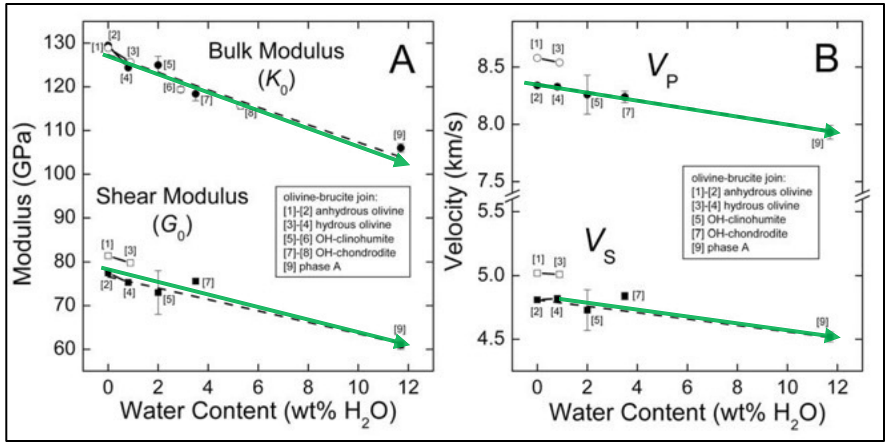
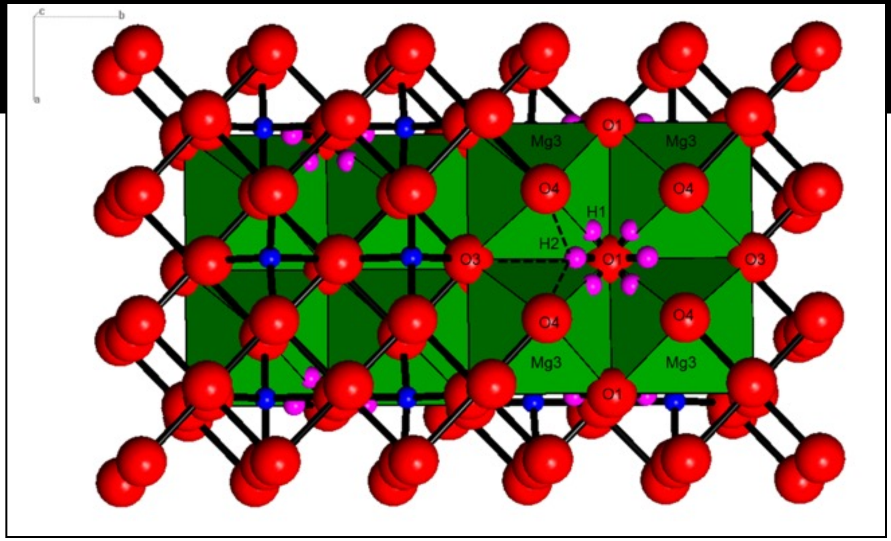
EFFECT OF VOLATILES

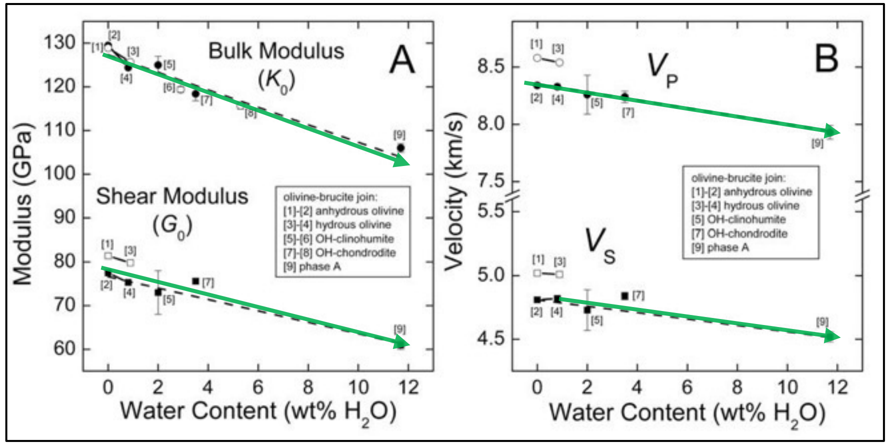




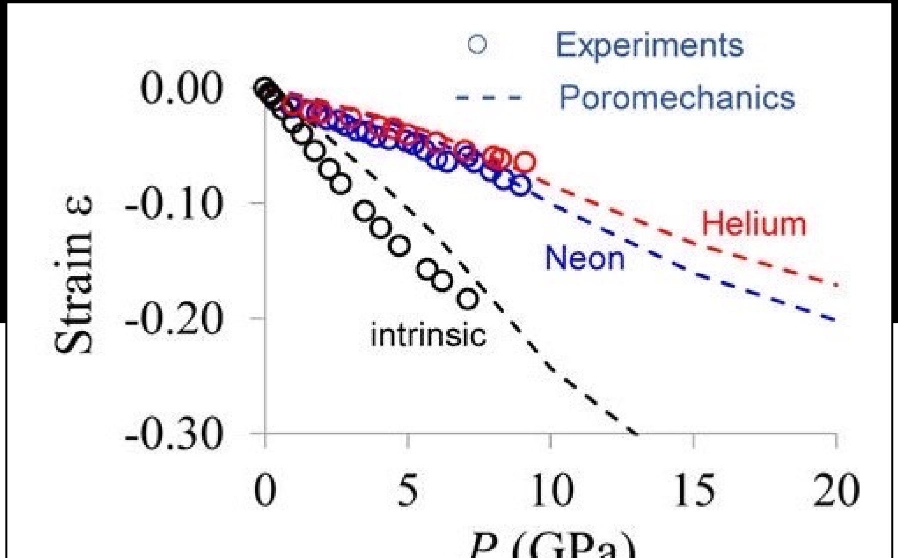
Jacobsen et al. 2008

EFFECT OF VOLATILES

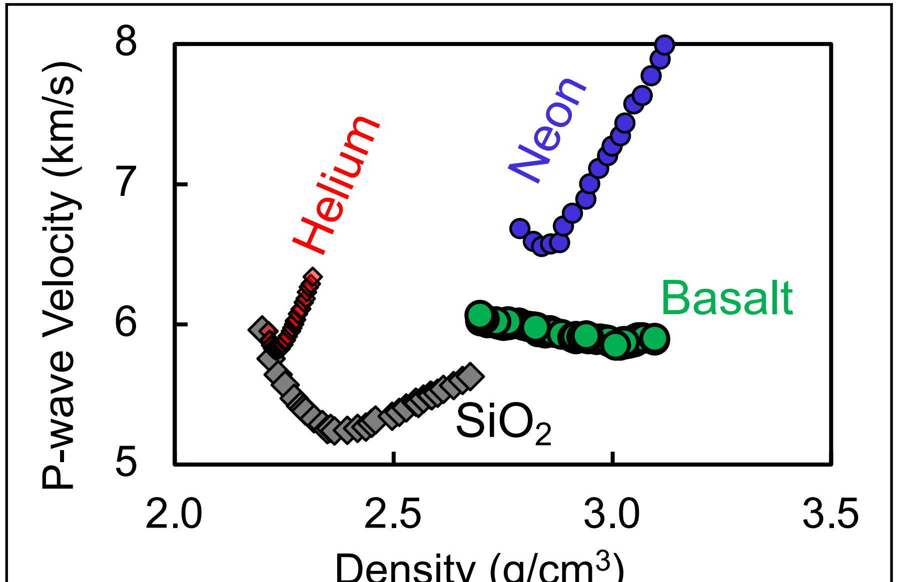




Jacobsen et al. 2008

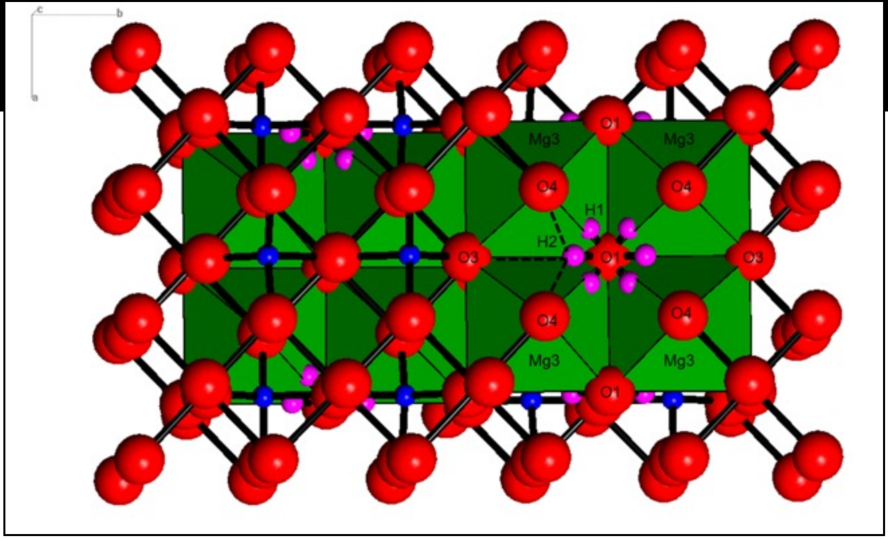


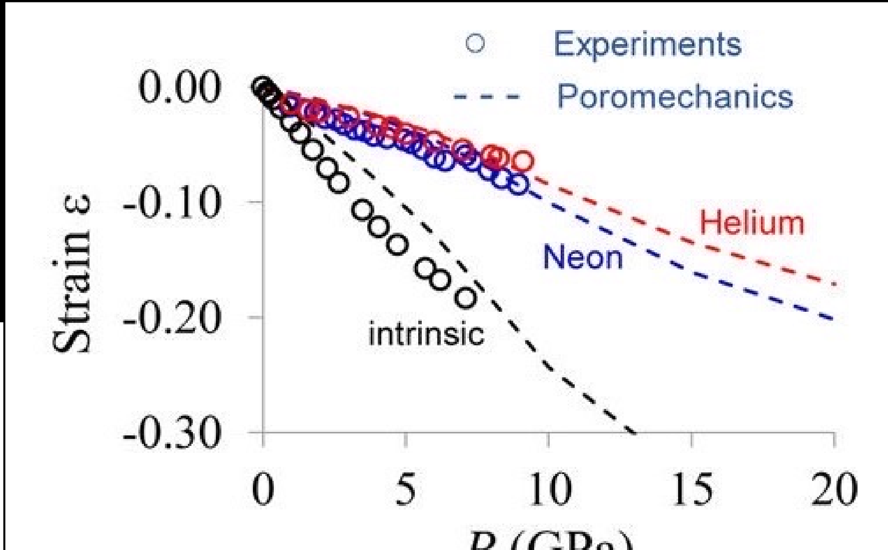
Weigel et al. 2012



Clark et al. 2016

EFFECT OF VOLATILES





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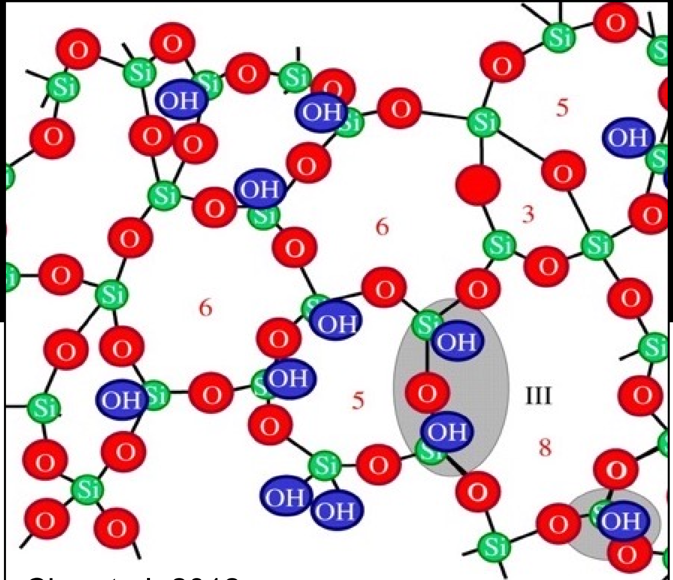
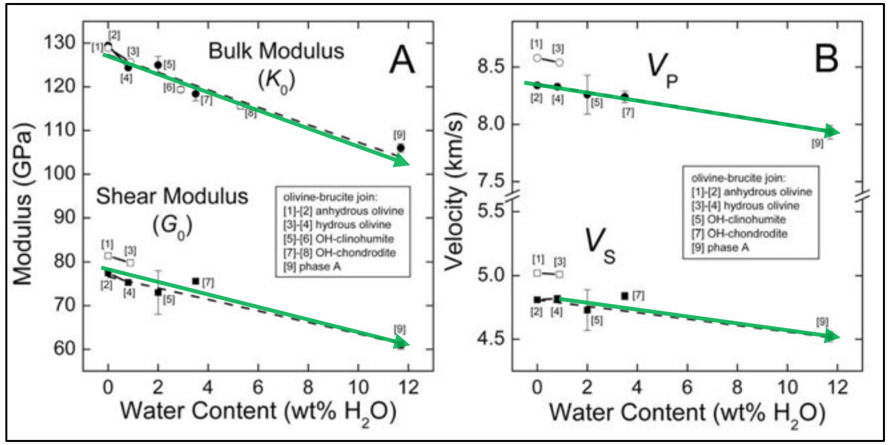
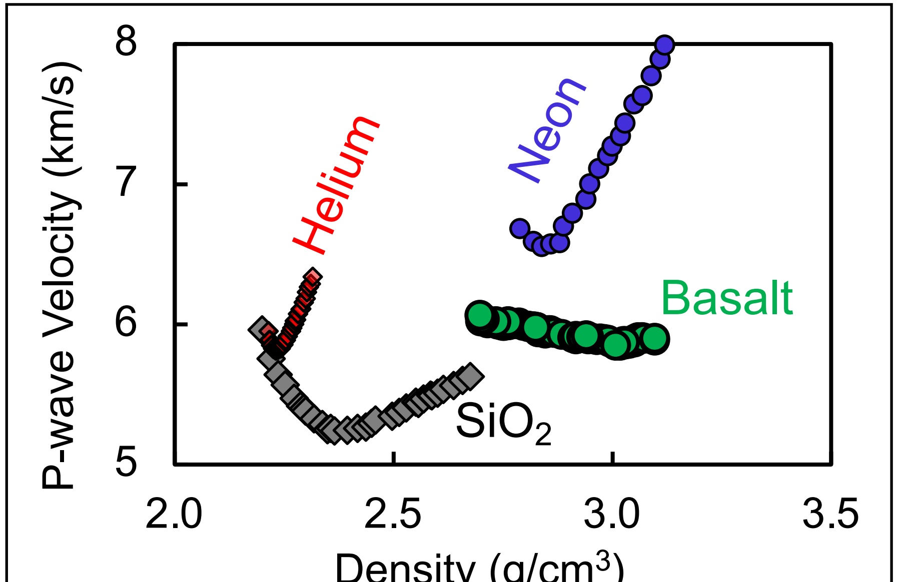


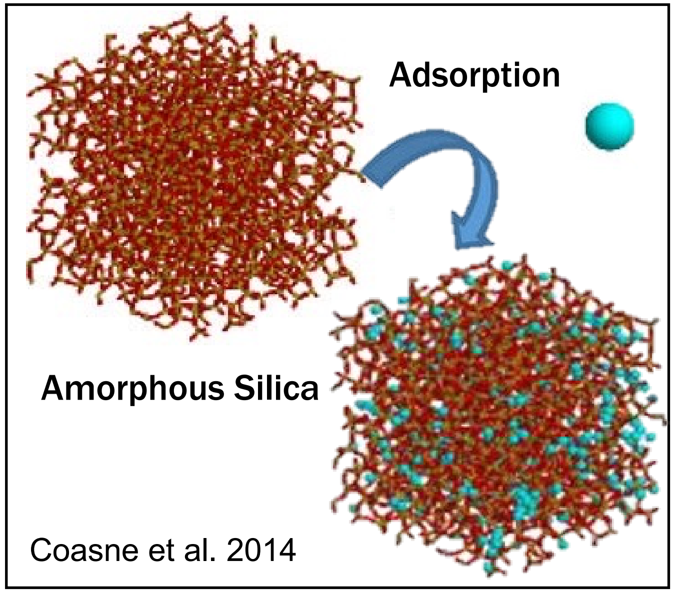
Che et al. 2012



Jacobsen et al. 2008

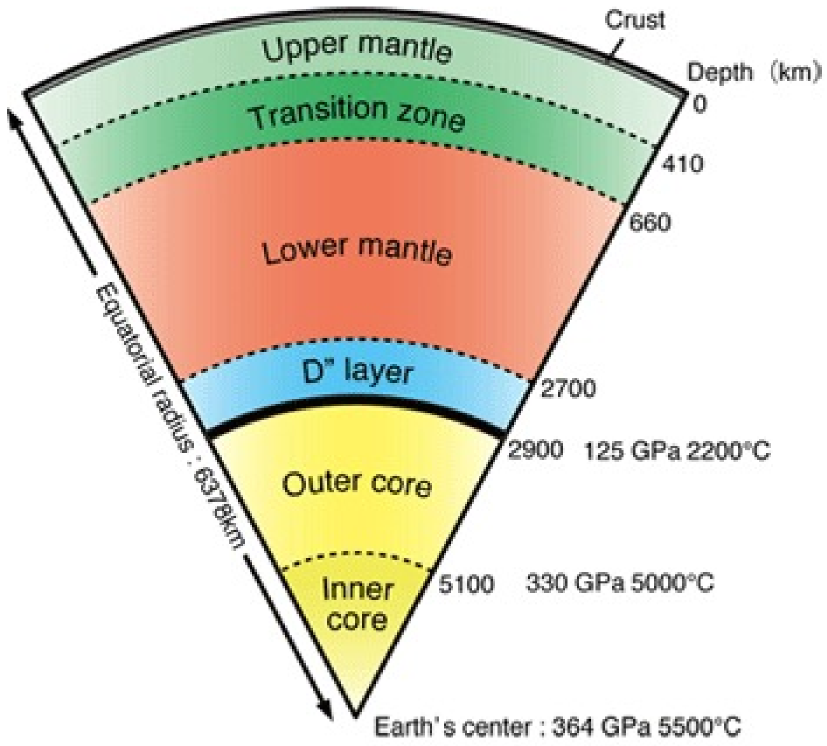


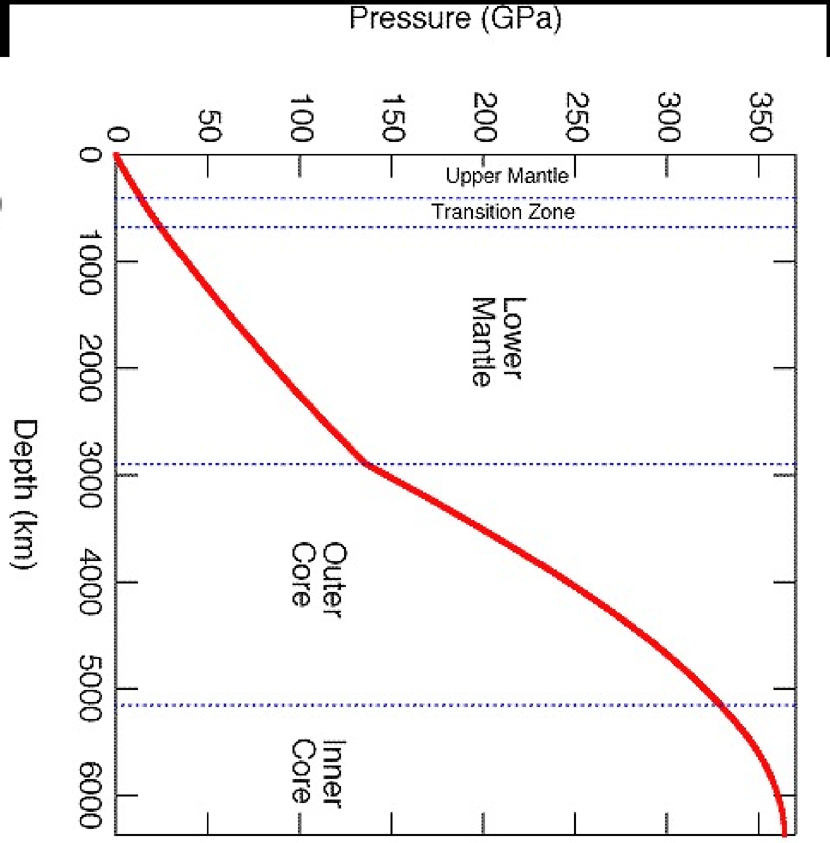
Clark et al. 2016

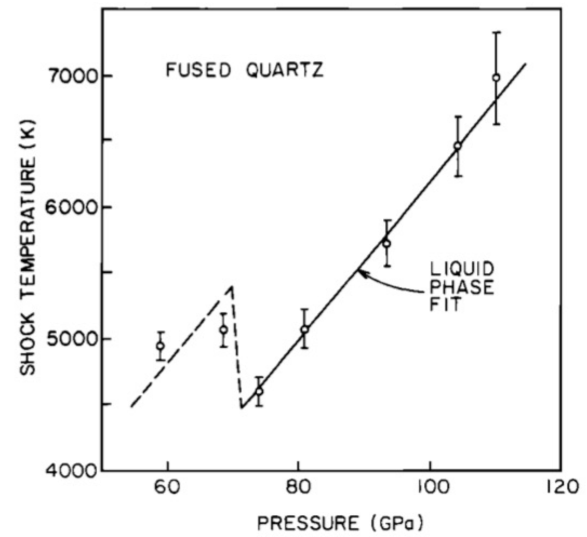


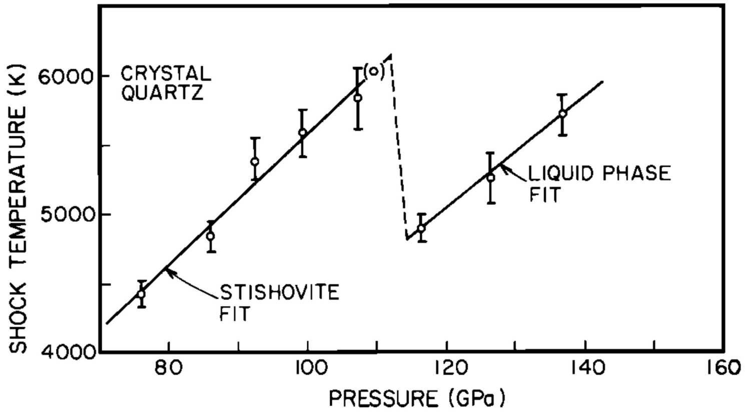
Coasne et al. 2014

SHOCK-RAMP OF SiO_2 GLASS



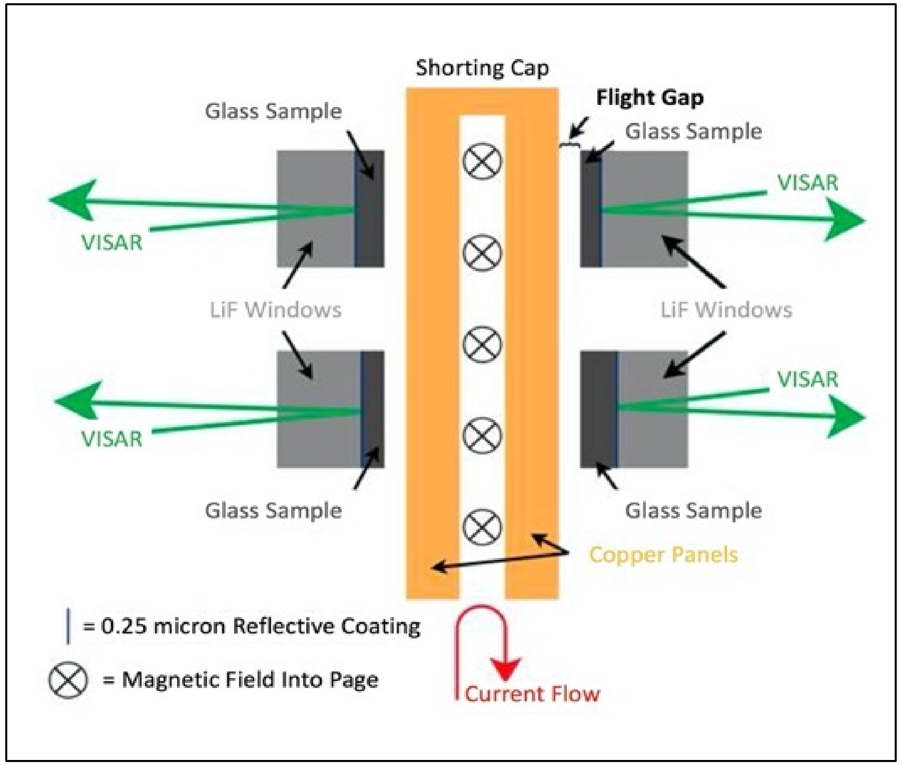


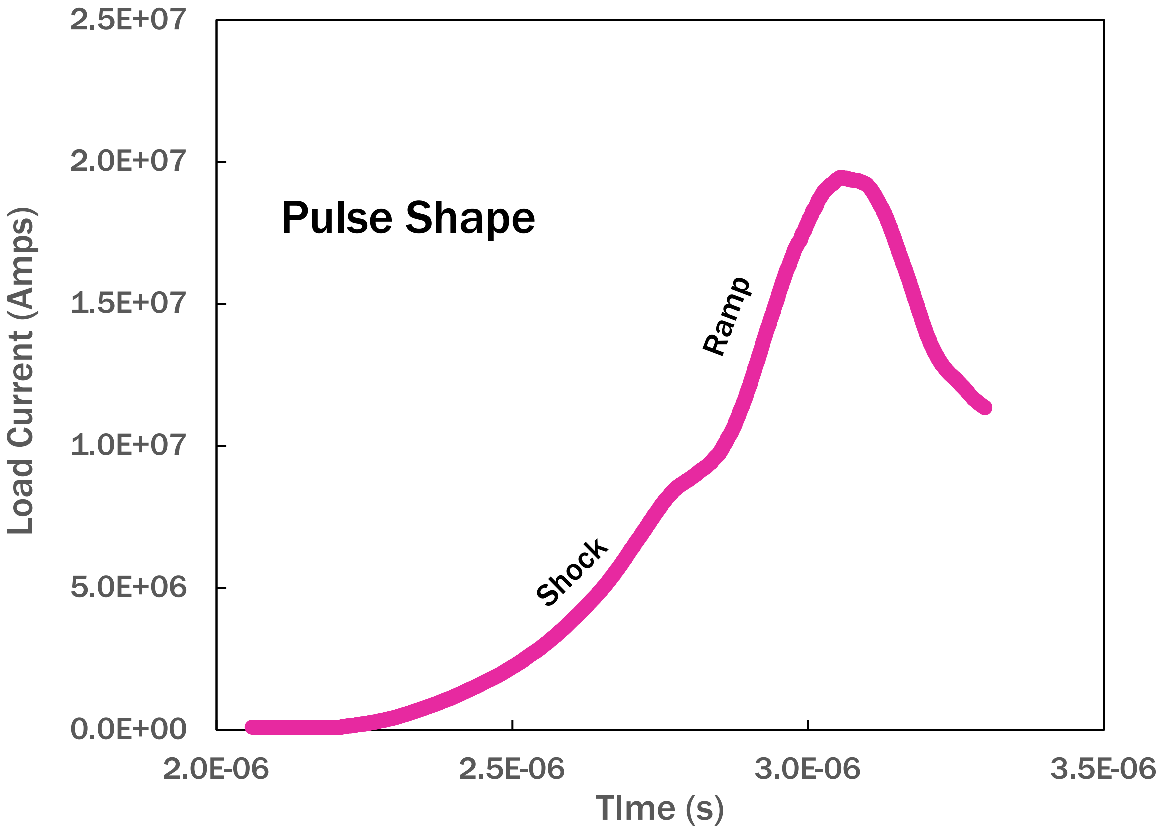




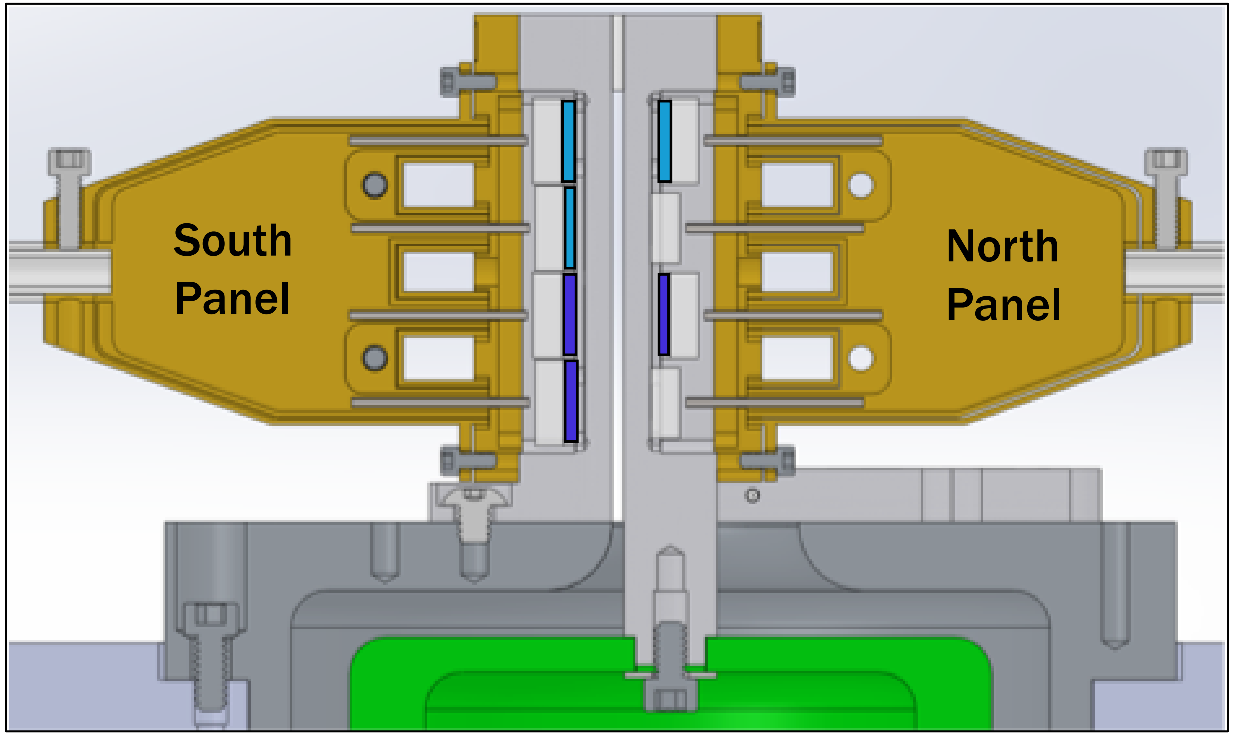
Lyzenga et al. 1983

SHOCK-RAMP EXPERIMENTS

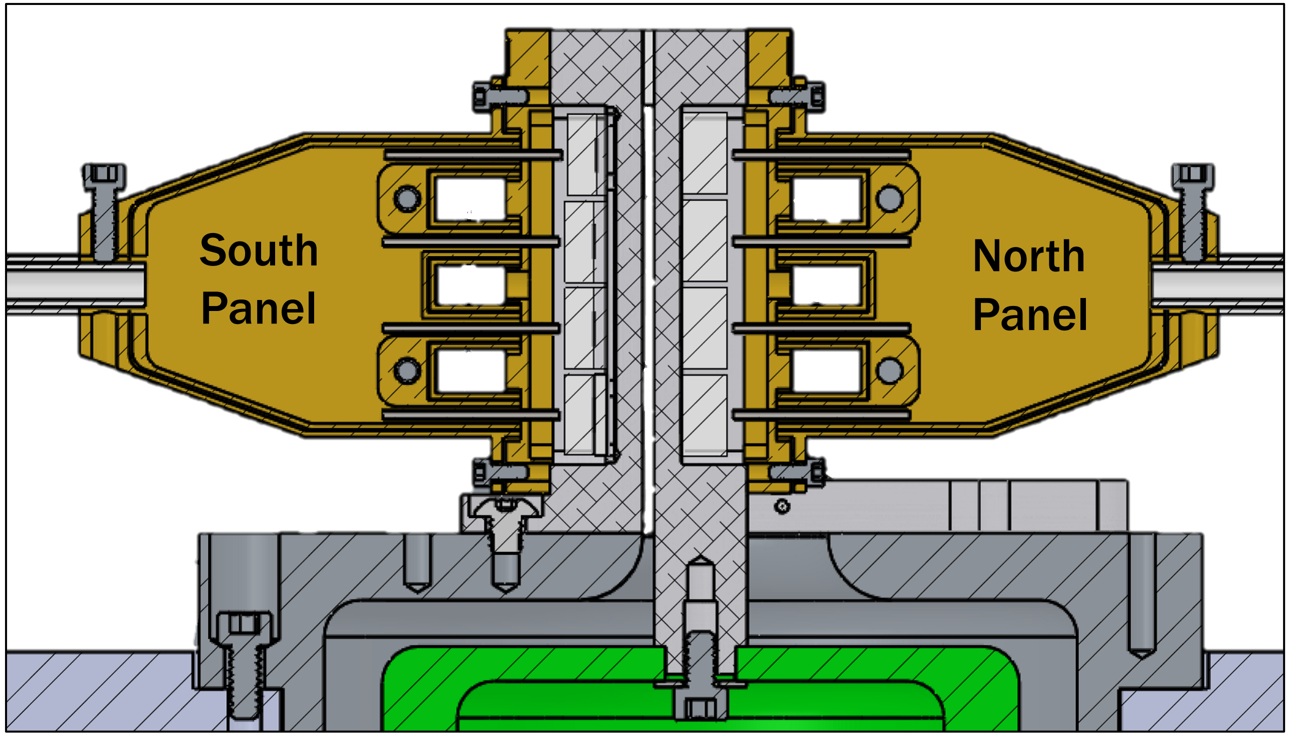




TWO DIFFERENT STRIP LINES



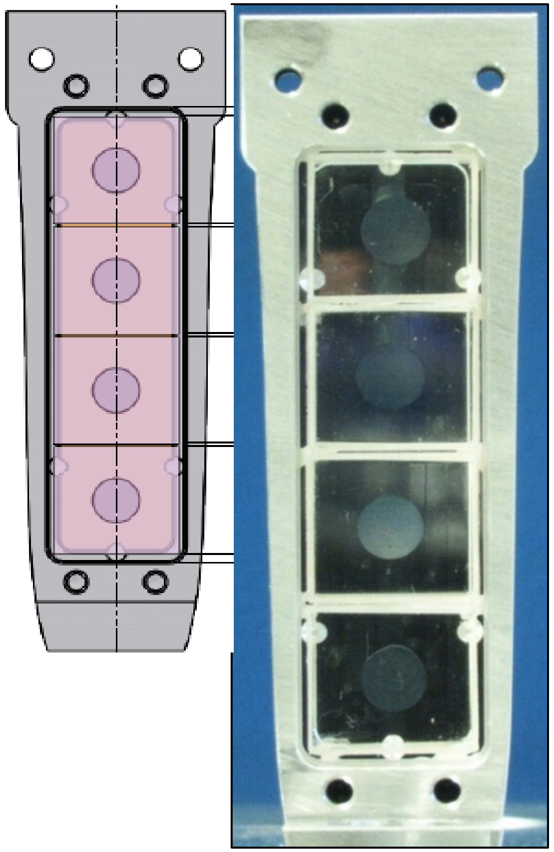
2 Drive – 6 Samples



4 Drive – 4 Samples

STARTING MATERIALS
CORNING INCORPORATED

South Panel



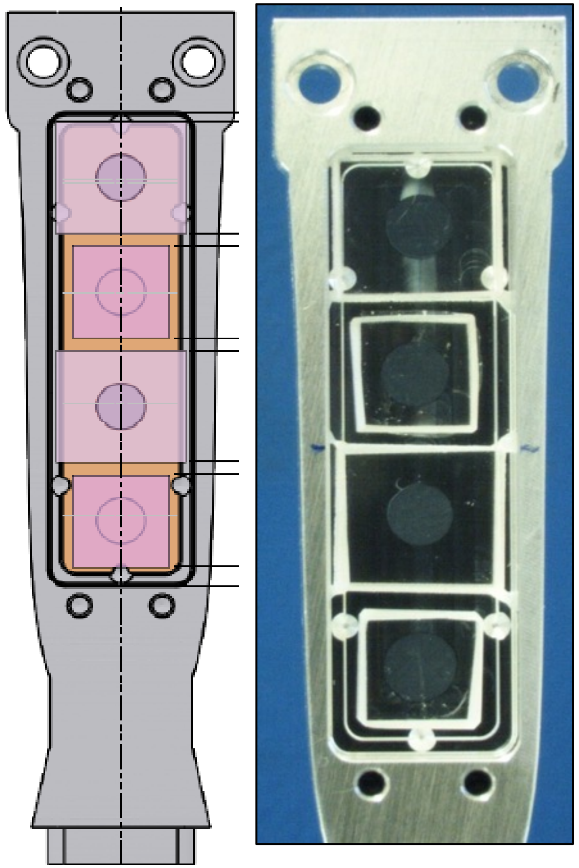
Dry (1 ppm) SiO_2 –
1.2 mm

Dry (1 ppm) SiO_2 –
1.0 mm

Damp (1000 ppm) SiO_2 –
1.2 mm

Damp (1000ppm) SiO_2 –
1.0 mm

North Panel



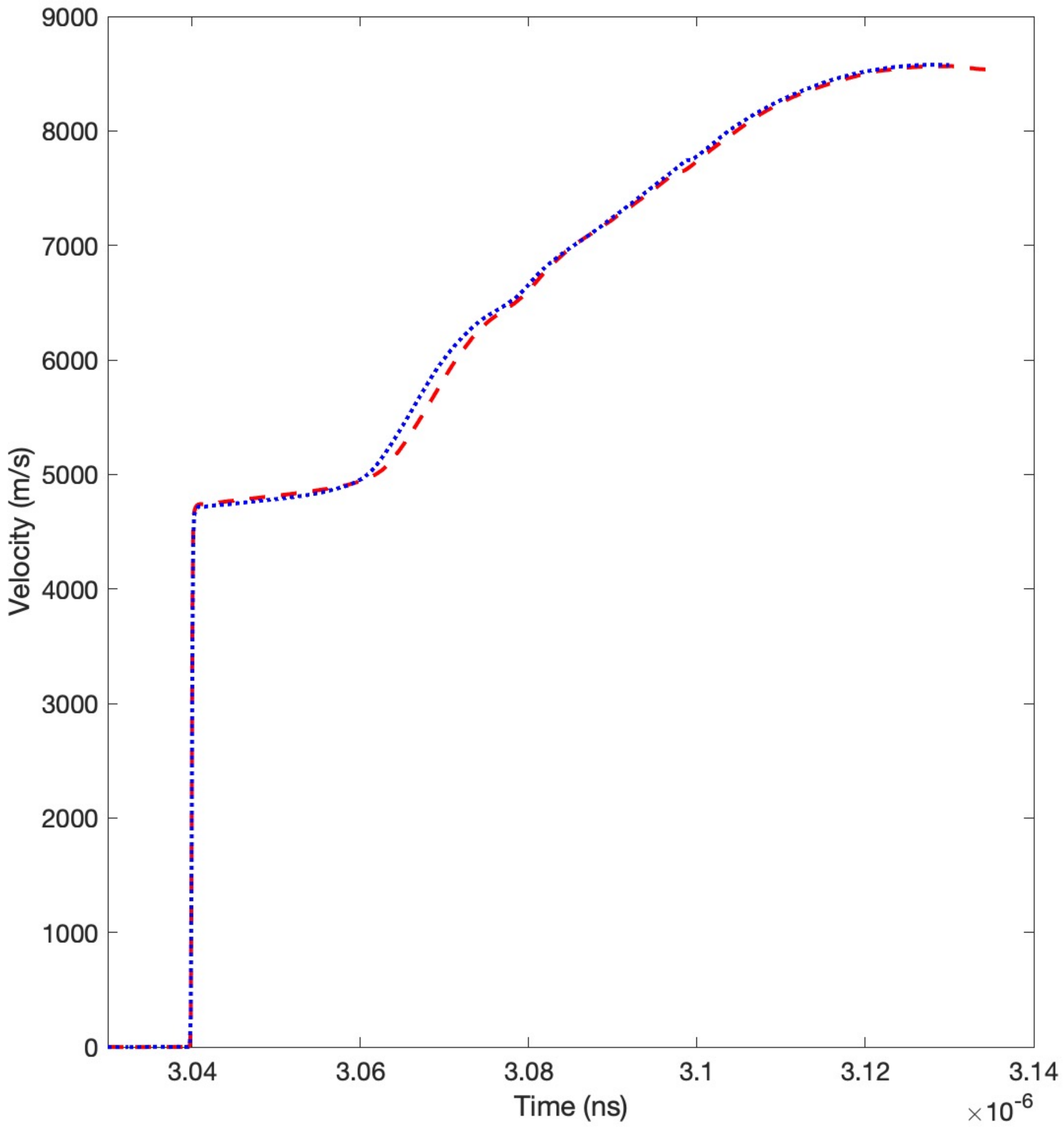
Dry (1ppm) SiO_2 –
0.8mm

LiF Window Only

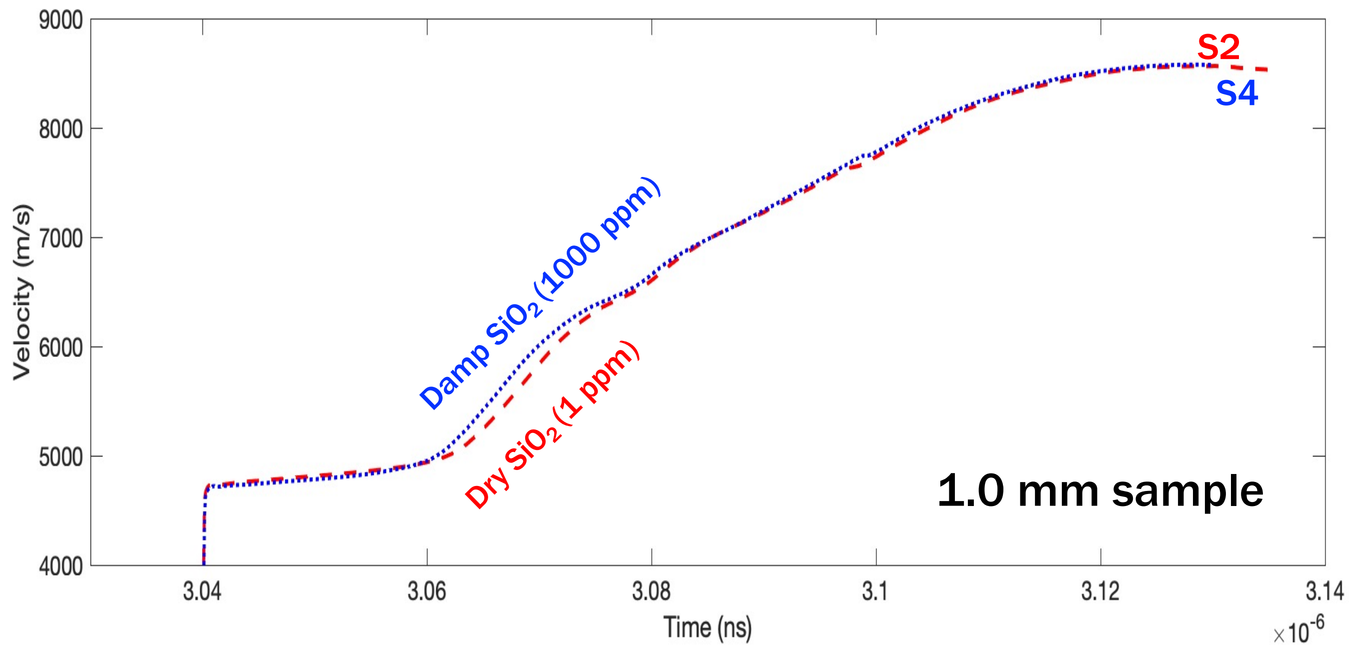
Damp (1000 ppm) SiO_2 - 0.8mm

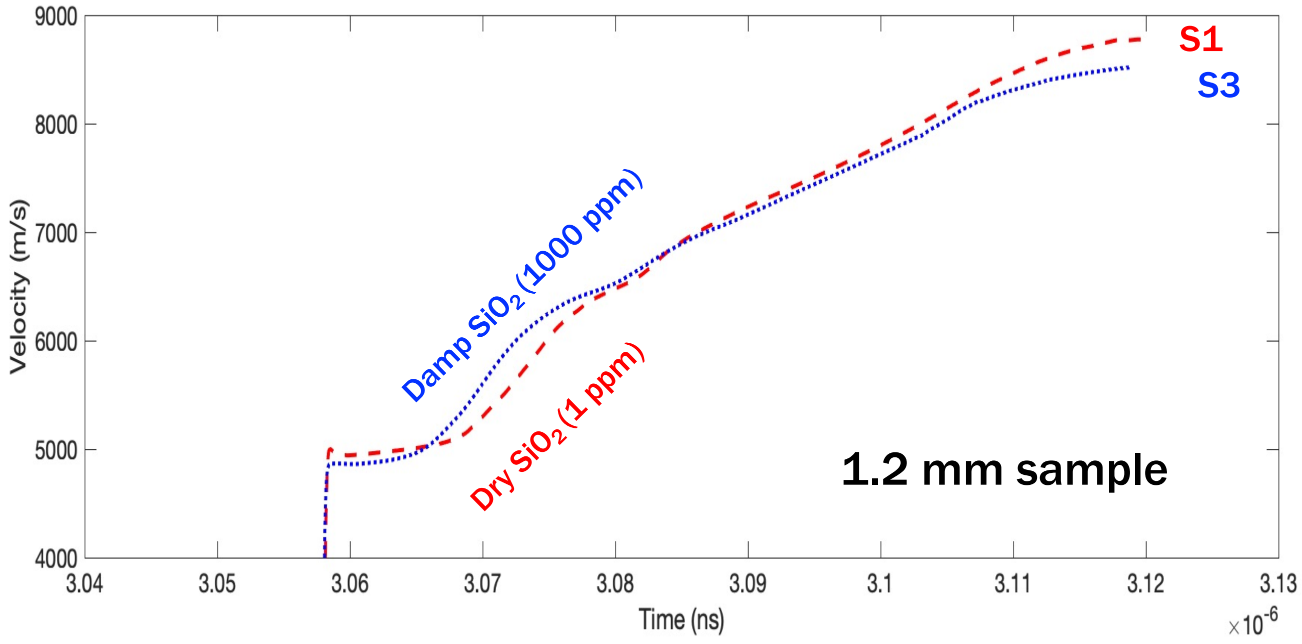
LiF Window Only

MEASURED VELOCITY



MEASURED VELOCITY





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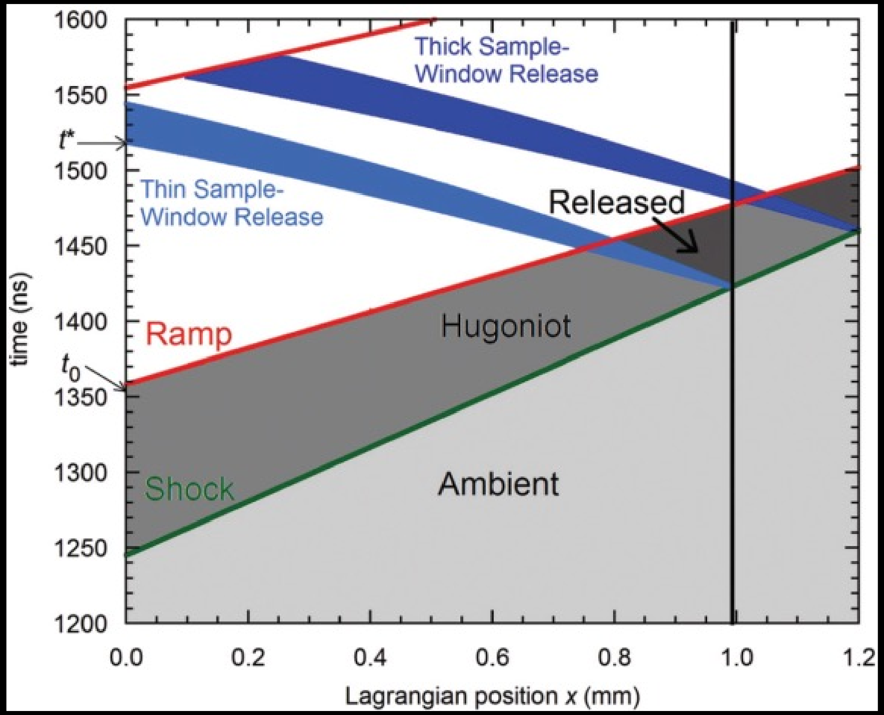
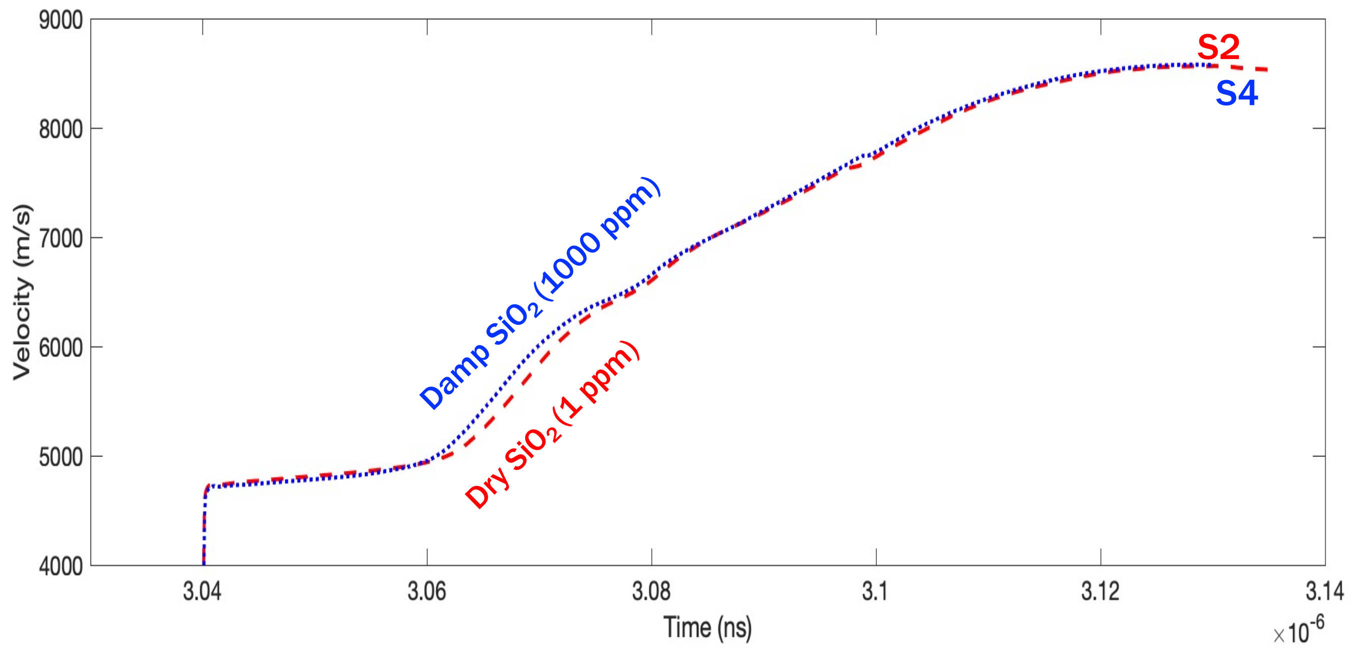
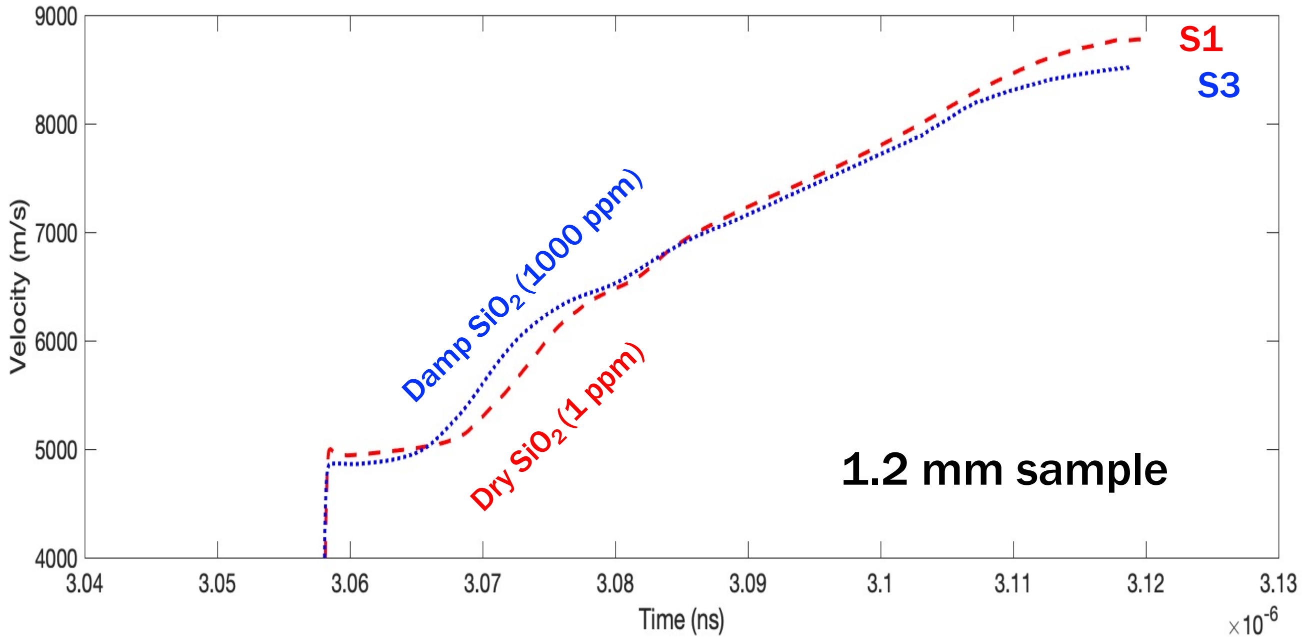
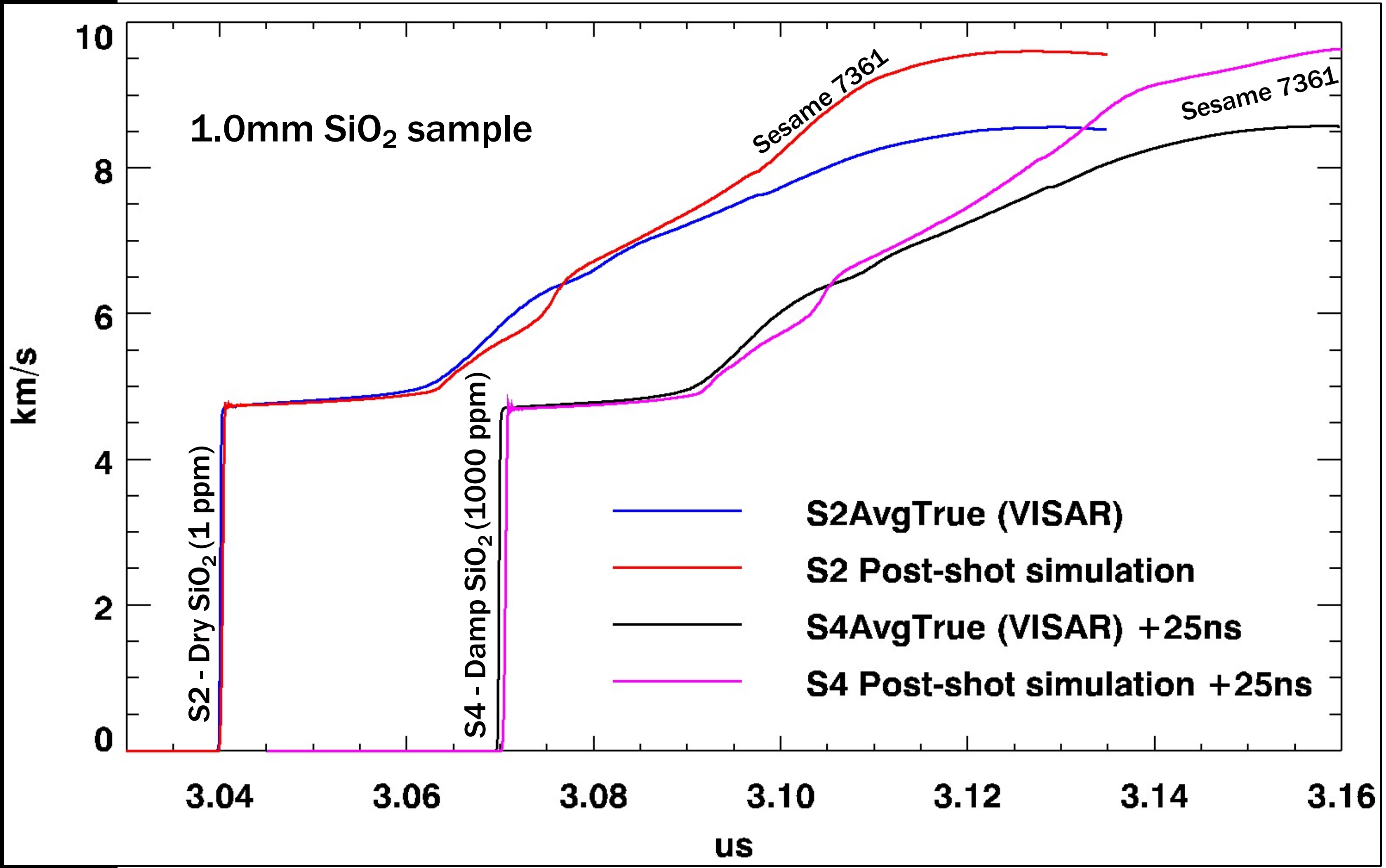


Seagle et al. 2013



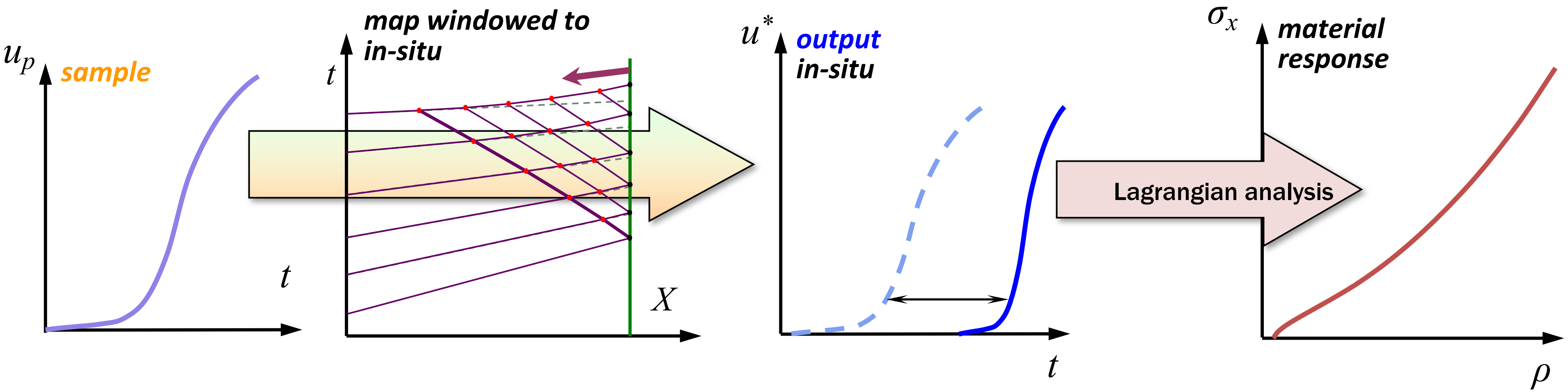


VELOCITY COMPARISON WITH SESAME 7361



ITERATIVE LAGRANGIAN ANALYSIS (ILA) DETERMINES STRESS-DENSITY PATH FROM VELOCIMETRY OF LIF-WINDOWED "DRIVE" AND SAMPLE

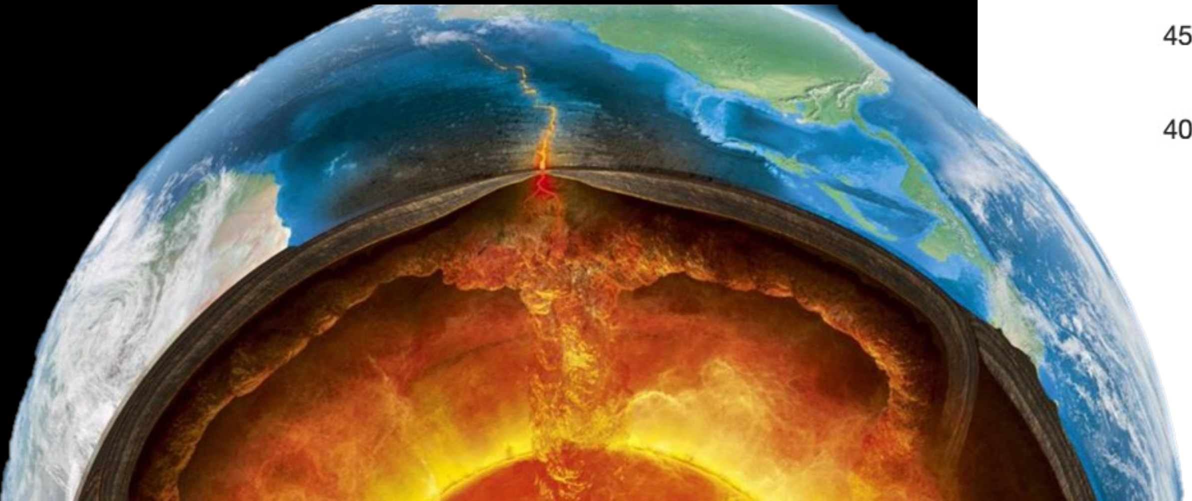
S. D. Rothman & J. Maw (2006)
J.-P. Davis et al. (2014)
Seagle et al. (2021)

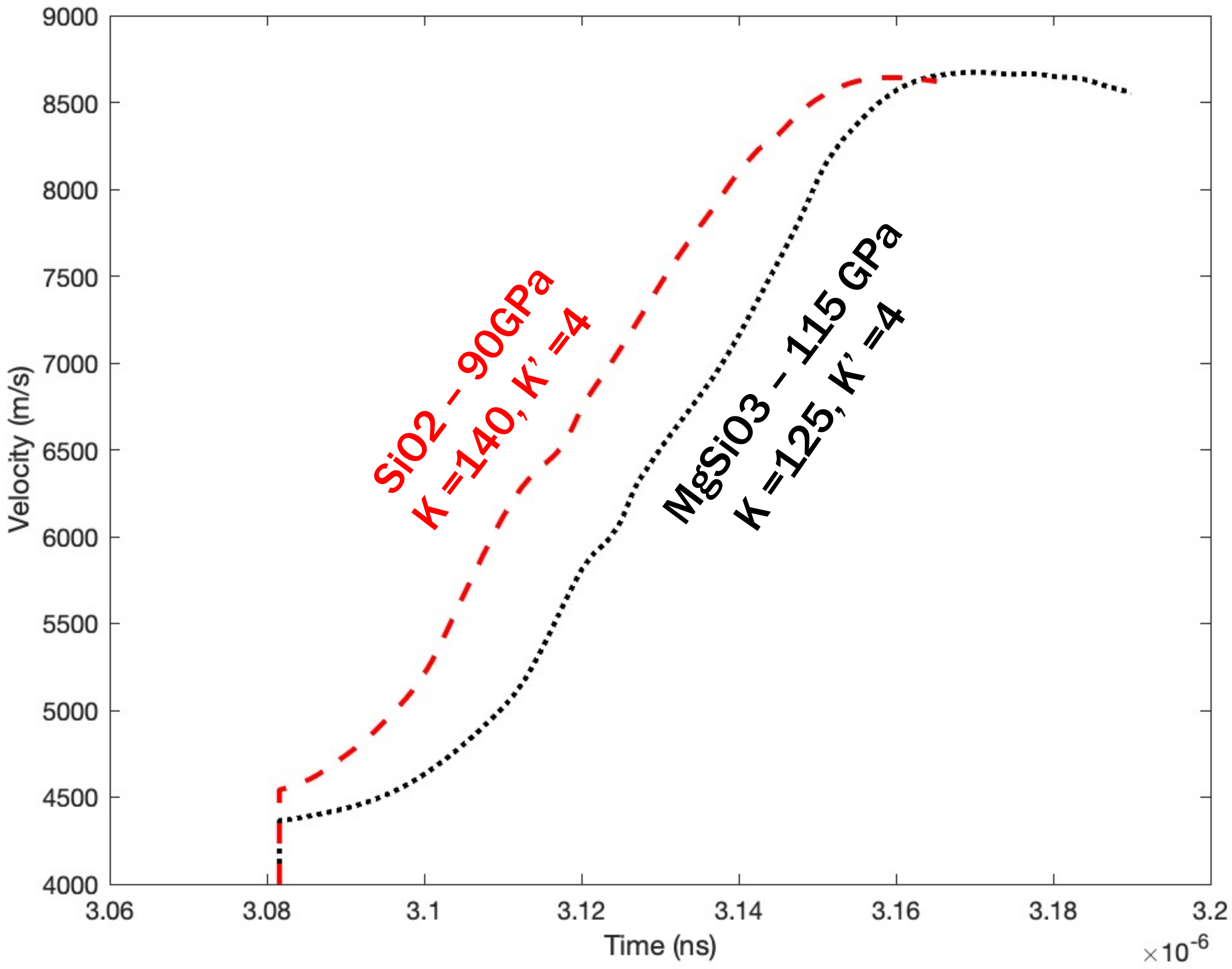


$$\frac{d\rho}{\rho^2} = \frac{du^*}{\rho_0 c_L}$$

$$d\sigma_x = \rho_0 c_L du^*$$

EXPANDING COMPOSITION

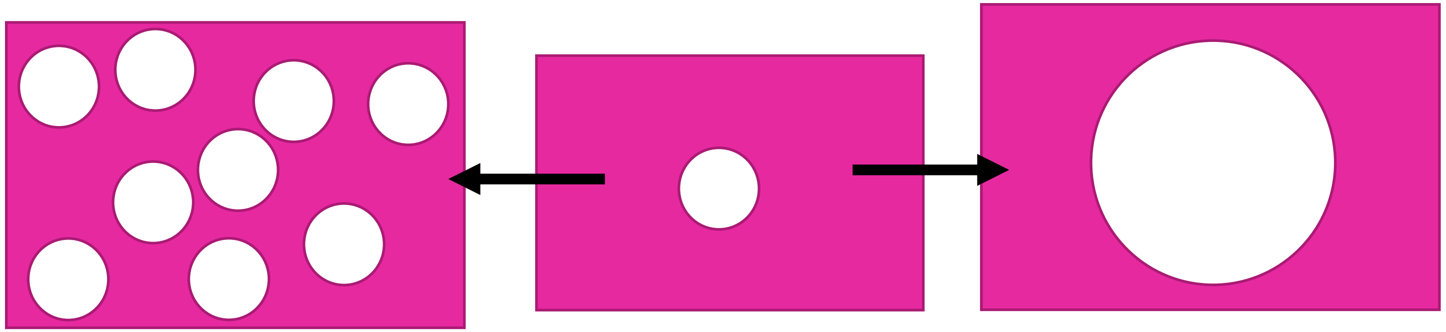




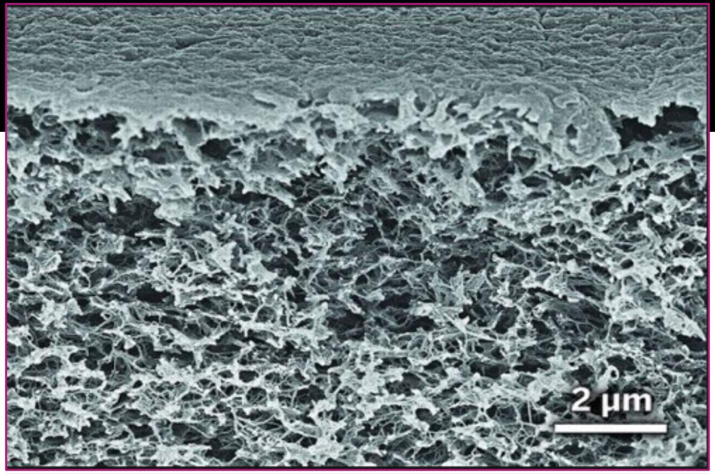
Akins et al. 2002, 2004

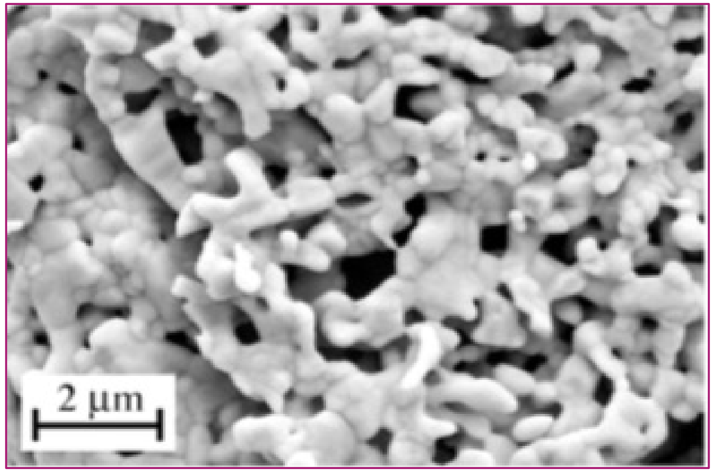
POROUS MEDIA MODEL

Modeling the Shock Hugoniot in Porous Materials
Kyle Cochrane (*Sandia*) – ZFSP Workshop 2017



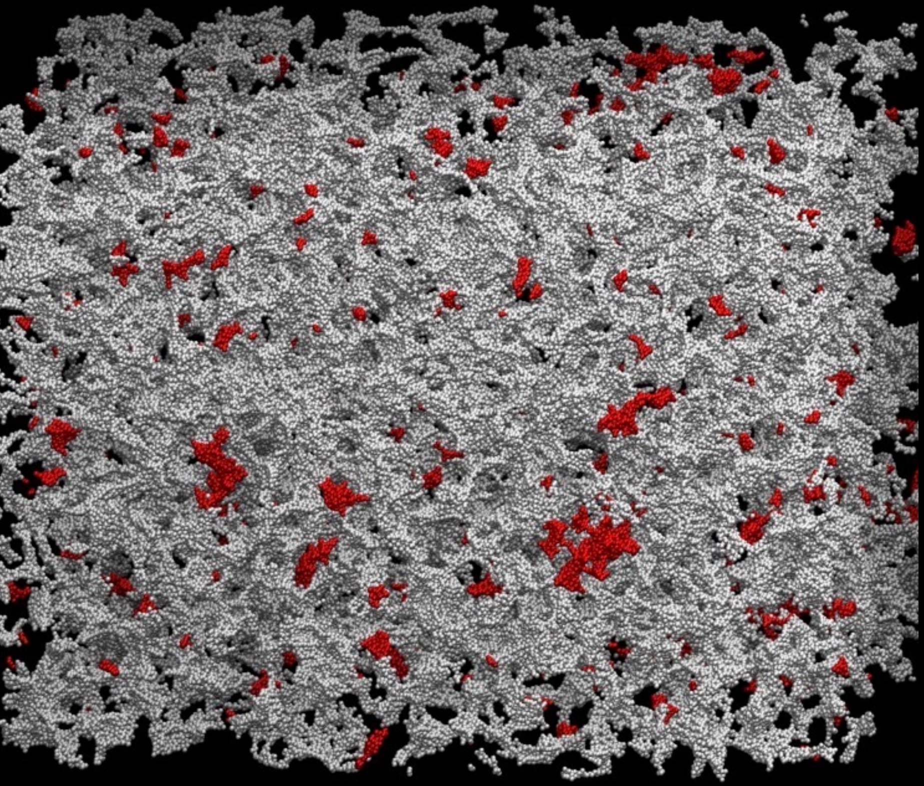
Increasing porosity growing the number of voids – or with a growing void





Micrographs of aerogel and porous tantala Ta_2O_5

MOLECULAR DYNAMICS – LAMMPS



MD simulation from LAMMPS of silica (SiO_2) glass with 90% porosity. Image from J.M.D. Lane

With Matt Lane (*Sandia*)

Recently used to study

- pressure waves
- void collapse
- crush-up
- Melt
- solid-solid phase transition

EXPECTED OUTCOMES

- Determination of extent of network flexibility and decoupling of elastic and volumetric properties for amorphous silicates by simultaneous density and velocity measurements on the Z-machine. These data are critical for equation of state development for amorphous materials.

- Determination of the compressibility and water retention capabilities of silicate liquids at pressures corresponding to the deep mantle to address the question of what is the origin of Earth's water and mechanism(s) for water retention during planet-formation processes.

- Development and expansion of applications for LAMMPS and the Porous Media model will benefit for SNL for both fundamental and programmatic research.

- Provide experimental calibration of the Porous Materials Model and comparison to static data. P-T range ideal for supplementary experiments on Thor and DICE.

THANK YOU

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