SAND2020-7981PE

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

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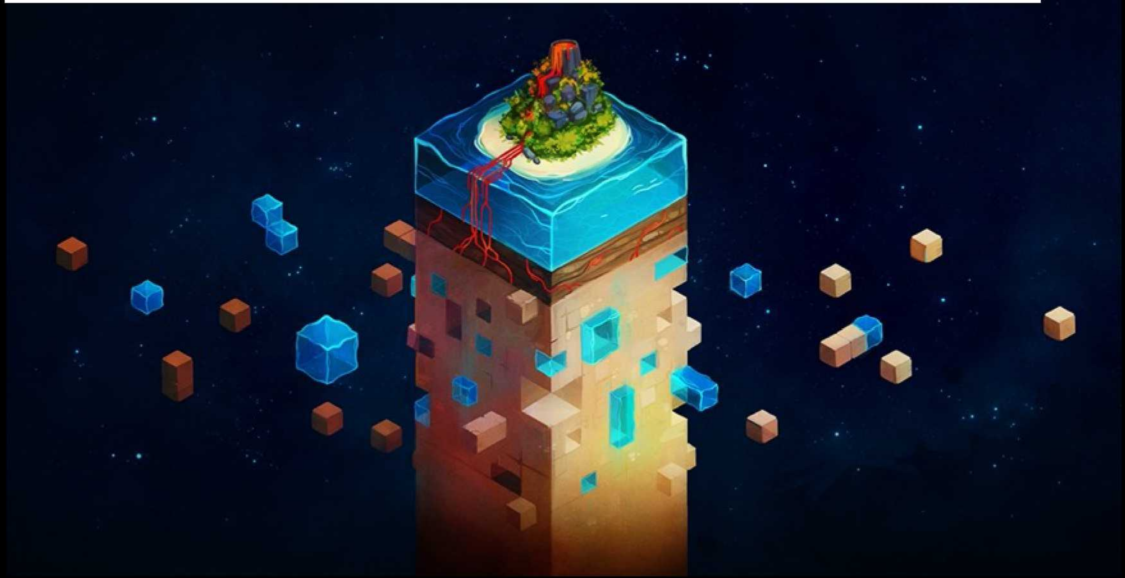
GEOPHYSICS

The Hunt for Earth's Deep Hidden Oceans

By MARCUS WOO

July 11, 2018

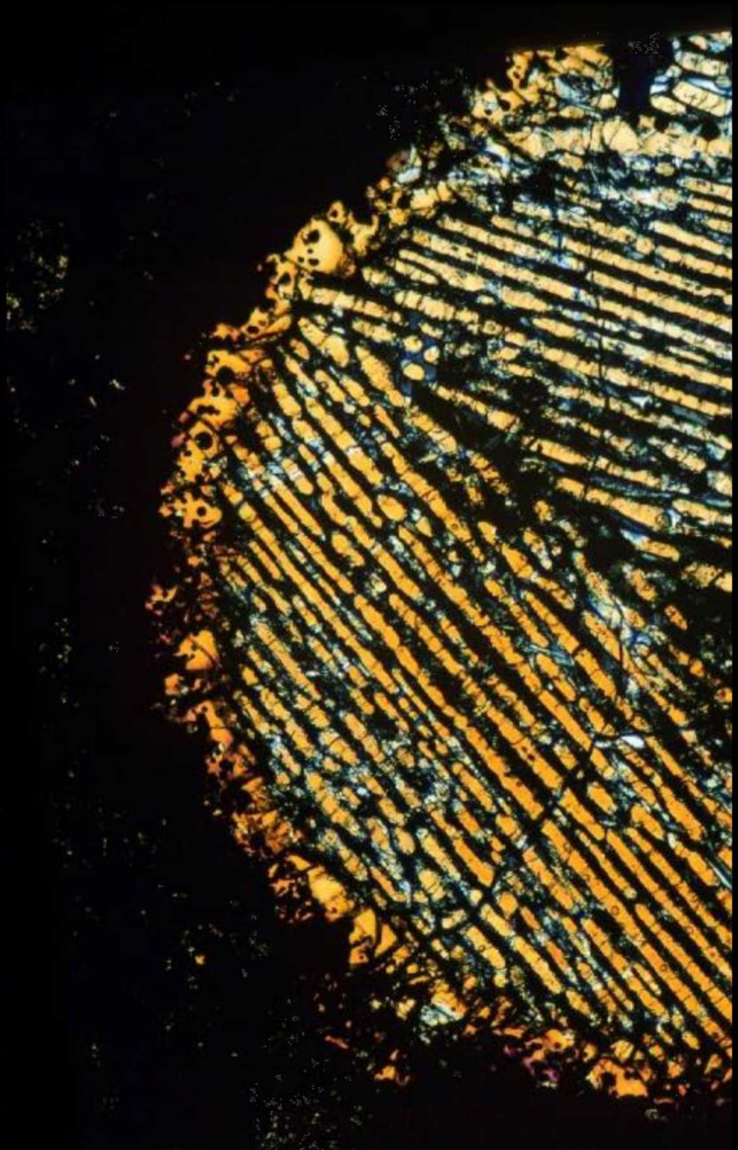


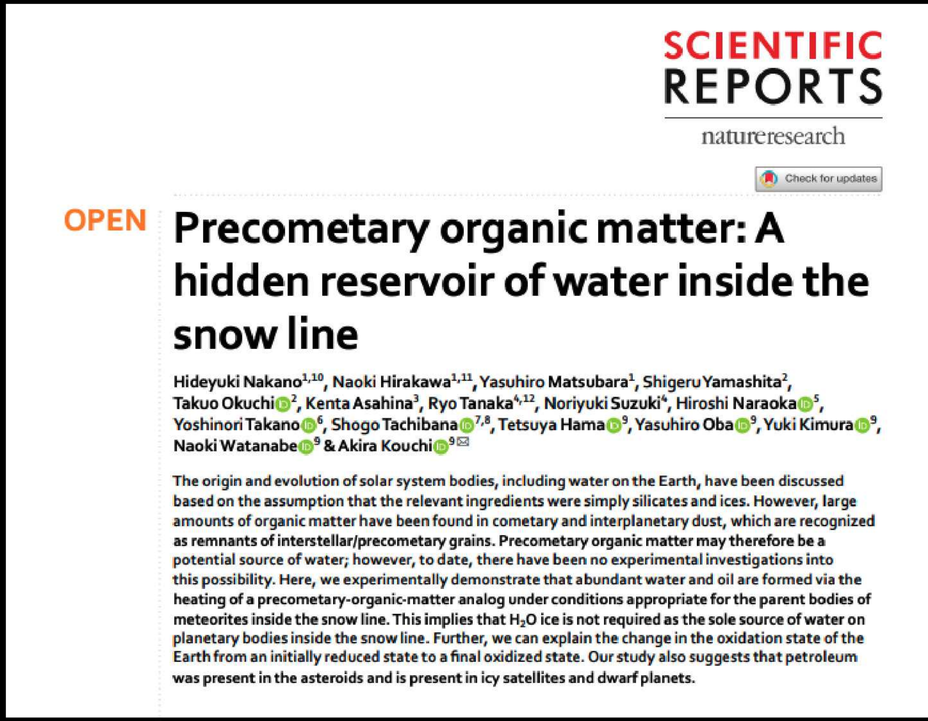
BBC | Home | News | Sport | Weather | Shop | Earth | Travel | 29 October 2014

The Genius Behind | Earth | Water

Are there 'oceans' hiding inside the Earth?

Water abundant in planetary building blocks.





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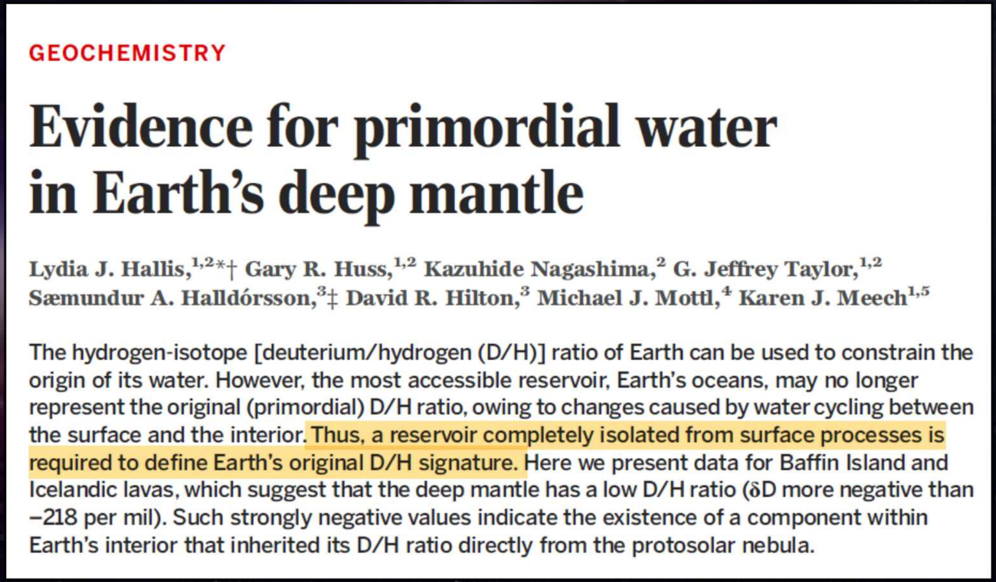
Precometary organic matter: A hidden reservoir of water inside the snow line

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.


Late Veneer?

D/H ratio oceans: ~150 x10^{-6}
D/H ratio carbonaceous chondrites: ~150-200 x10^{-6}
D/H ratio most comets: ~300 x10^{-6}
D/H ratio of 67P (2015): ~ 540 x 10^{-6}



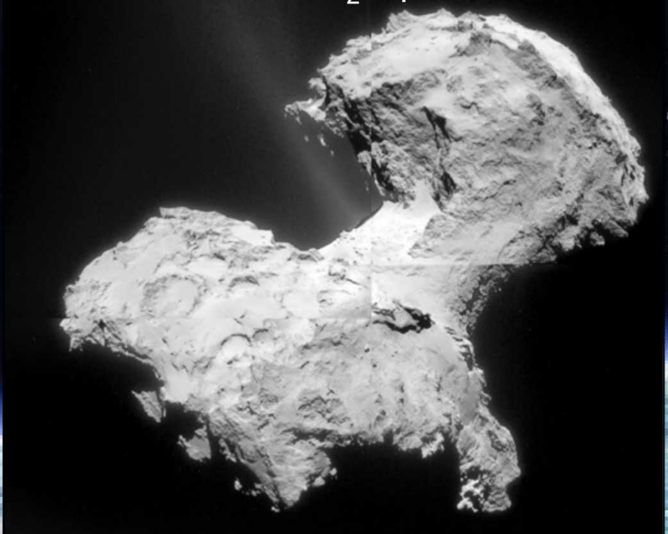
GEOCHEMISTRY

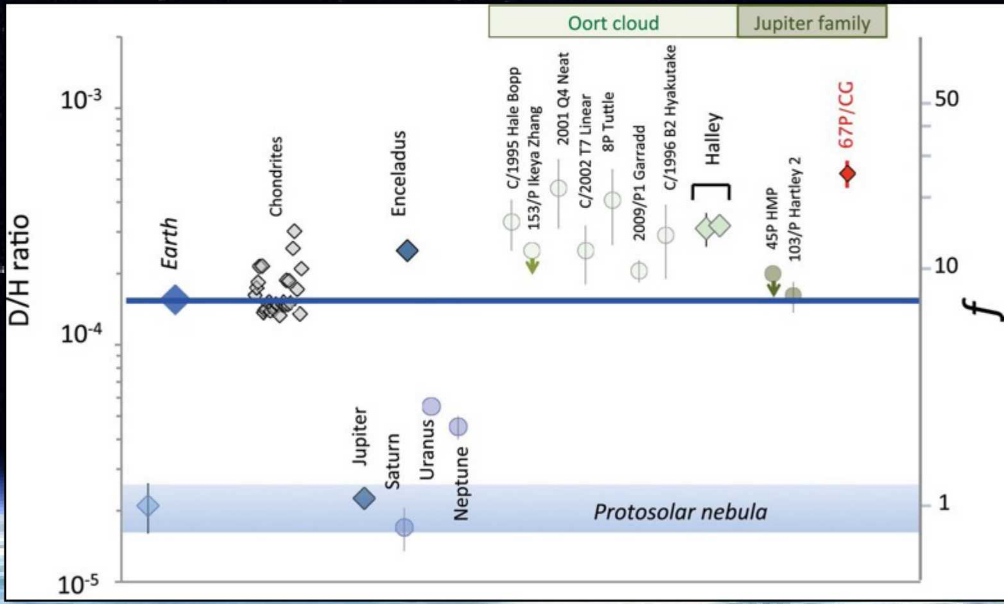
Evidence for primordial water in Earth's deep mantle

Lydia J. Hallis,[1,2]*† Gary R. Huss,[1,2] Kazuhide Nagashima,[2] G. Jeffrey Taylor,[1,2] Sæmundur A. Halldórsson,[3]‡ David R. Hilton,[3] Michael J. Mottl,[4] Karen J. Meech[1,5]

The hydrogen-isotope [deuterium/hydrogen (D/H)] ratio of Earth can be used to constrain the origin of its water. However, the most accessible reservoir, Earth's oceans, may no longer represent the original (primordial) D/H ratio, owing to changes caused by water cycling between the surface and the interior. Thus, a reservoir completely isolated from surface processes is required to define Earth's original D/H signature. Here we present data for Baffin Island and Icelandic lavas, which suggest that the deep mantle has a low D/H ratio (δD more negative than −218 per mil). Such strongly negative values indicate the existence of a component within Earth's interior that inherited its D/H ratio directly from the protosolar nebula.

Comet 67P (Churyumov-Gerasimenko)
Releases liters of H_2O per second



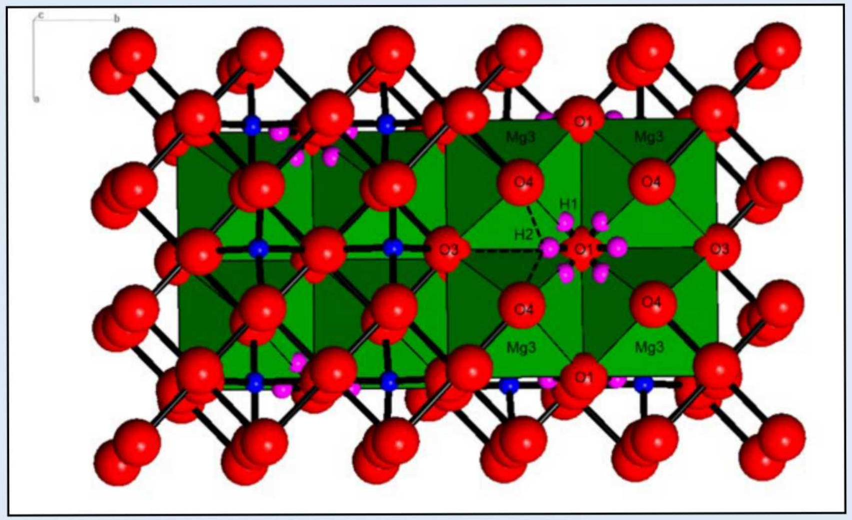


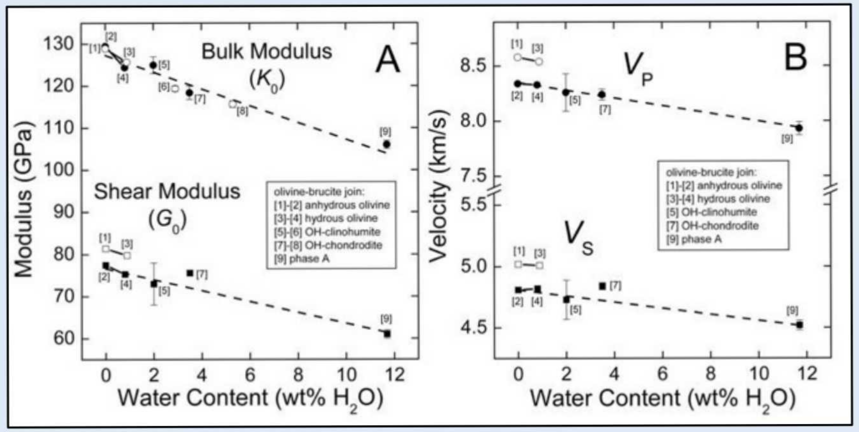
Altwegg et al. (2015)
Science 347, 6220

1) Can primordial water be retained during planet forming impacts?
2) If so, how is water stored in Earth's deep magma ocean?

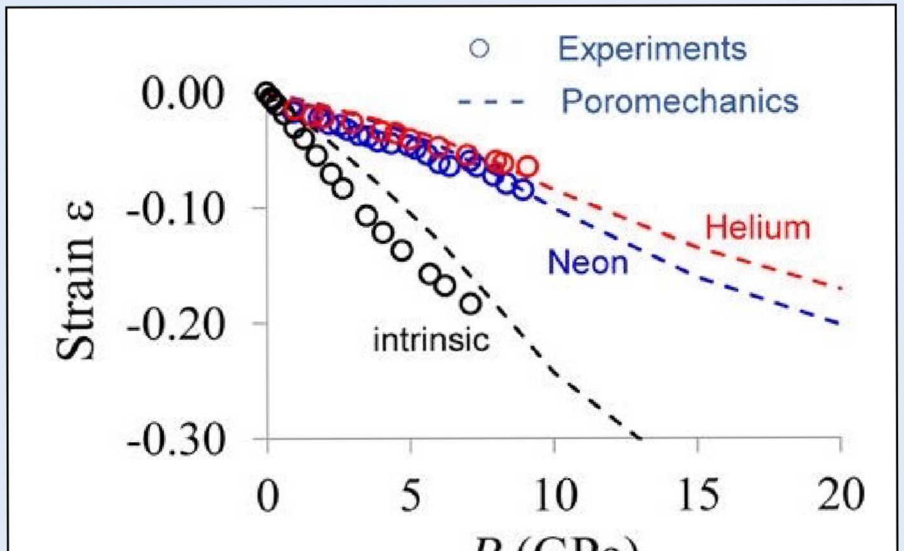
TIM BERTELINK VIA WIKIPEDIA

Effect of volatiles

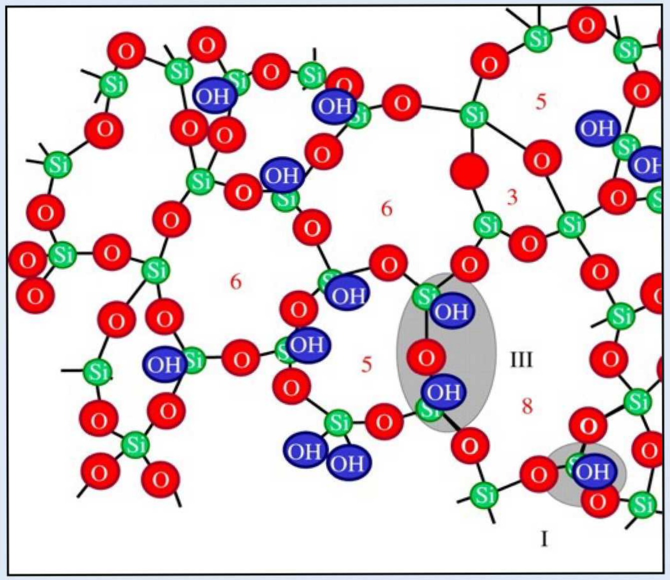




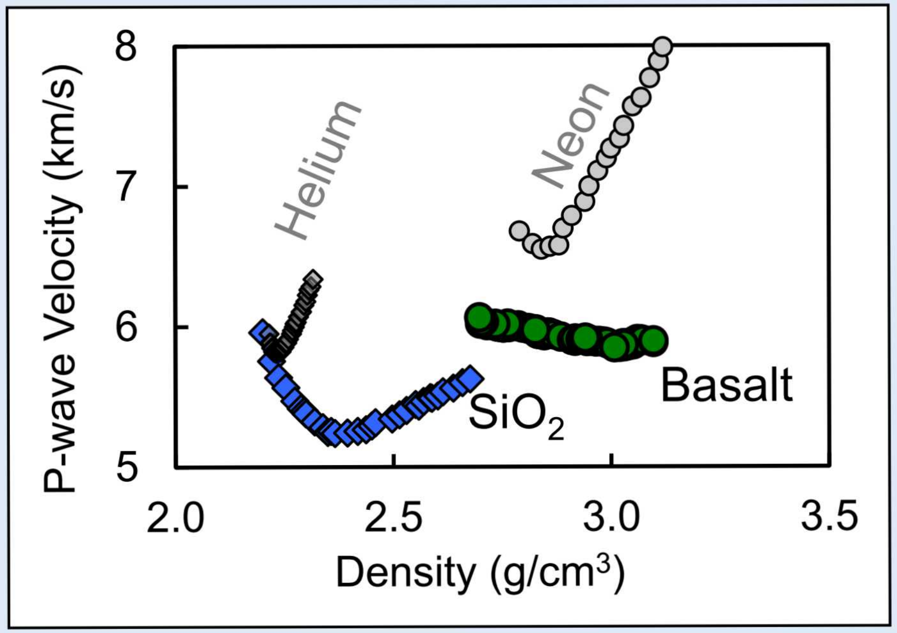
Jacobsen et al. 2008



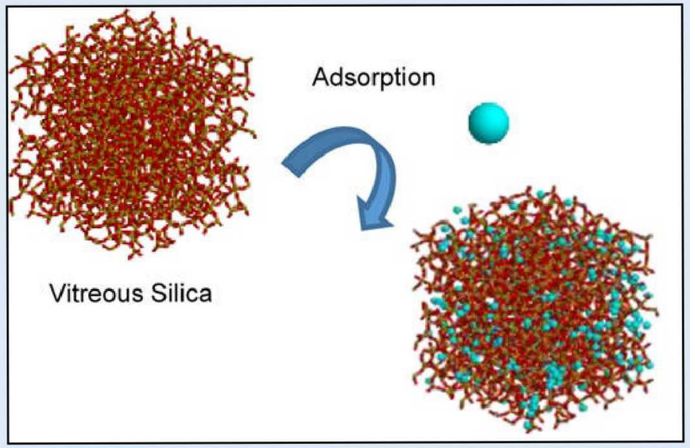
Weigel et al. 2012



Che et al. 2012



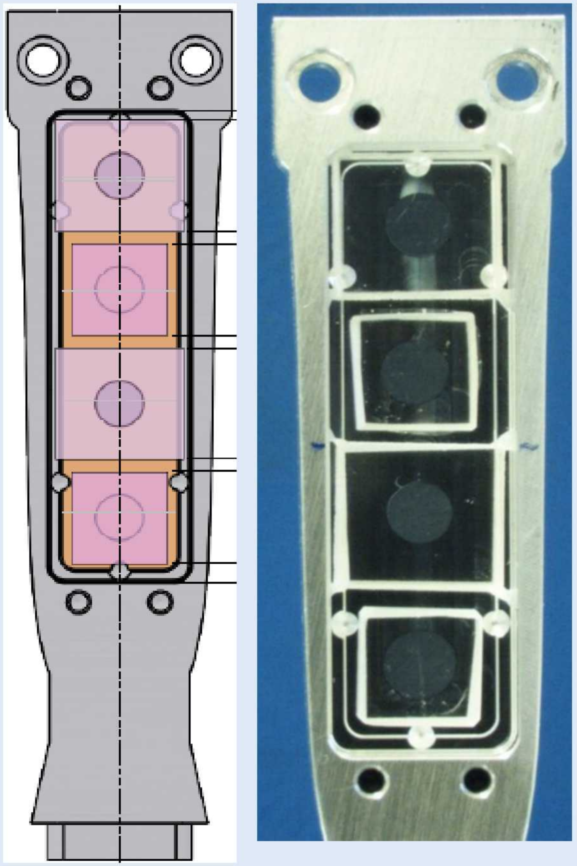
Clark et al. 2016 *JGR*



Coasne et al. 2014

Starting Materials – Corning Inc.

North Panel



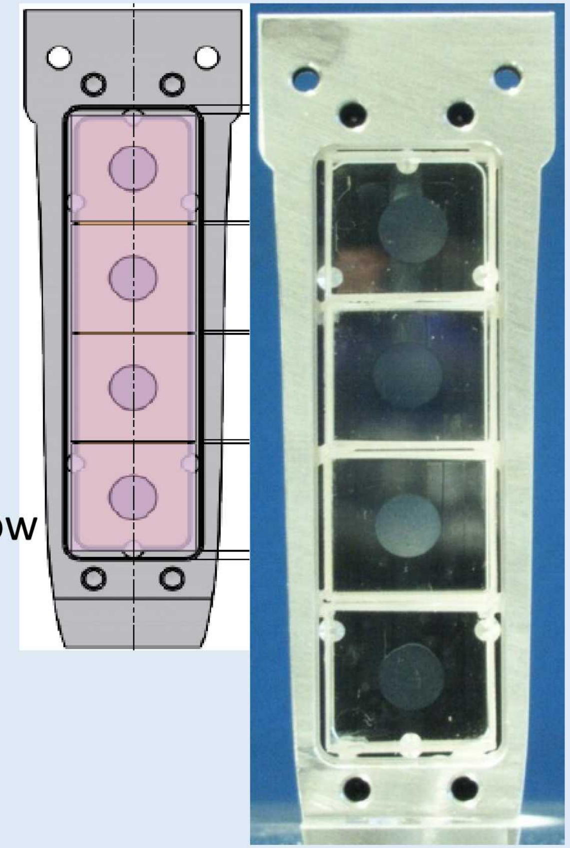
Dry SiO_2 (0.8mm)- LiF Window

LiF Window

Damp SiO_2 (0.8mm)- LiF Window

LiF Window

South Panel



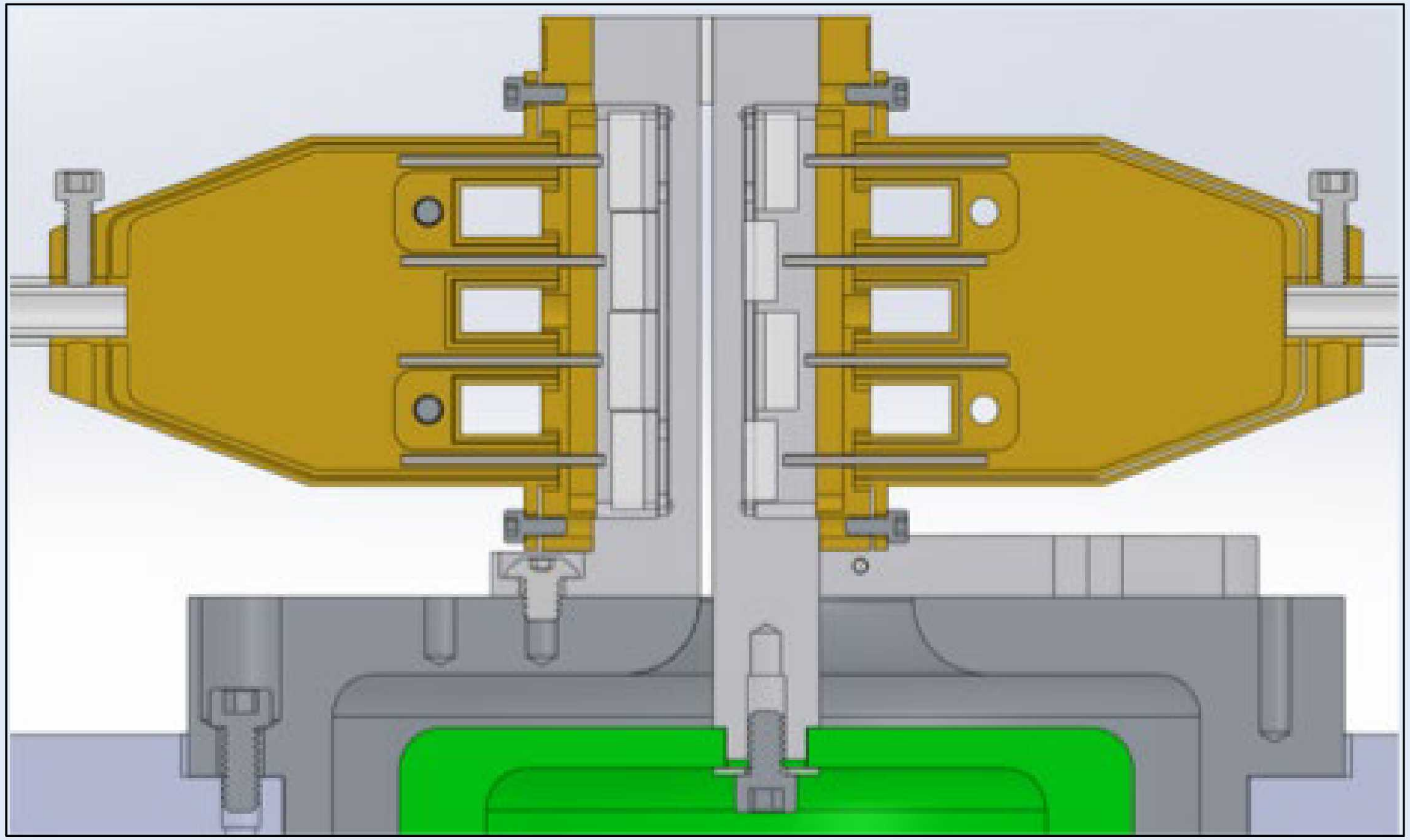
Dry SiO_2 (1.2 mm)- LiF Window

Dry SiO_2 (1.0 mm)- LiF Window

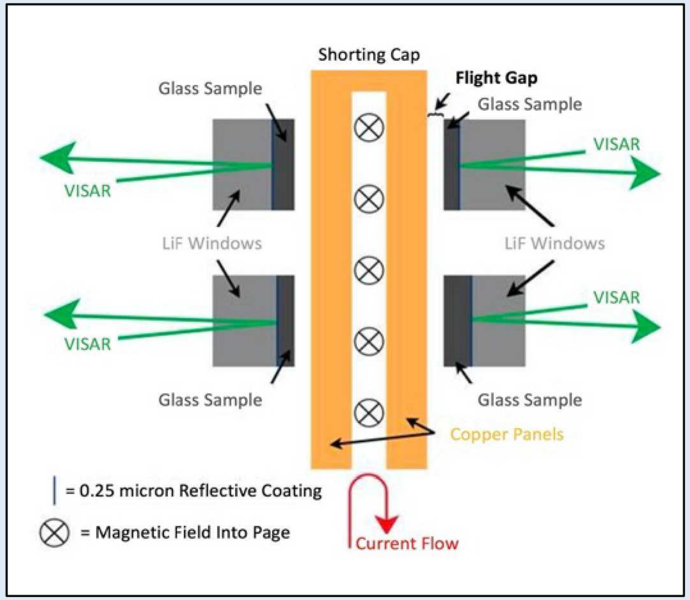
Damp SiO_2 (1.2 mm)- LiF Window

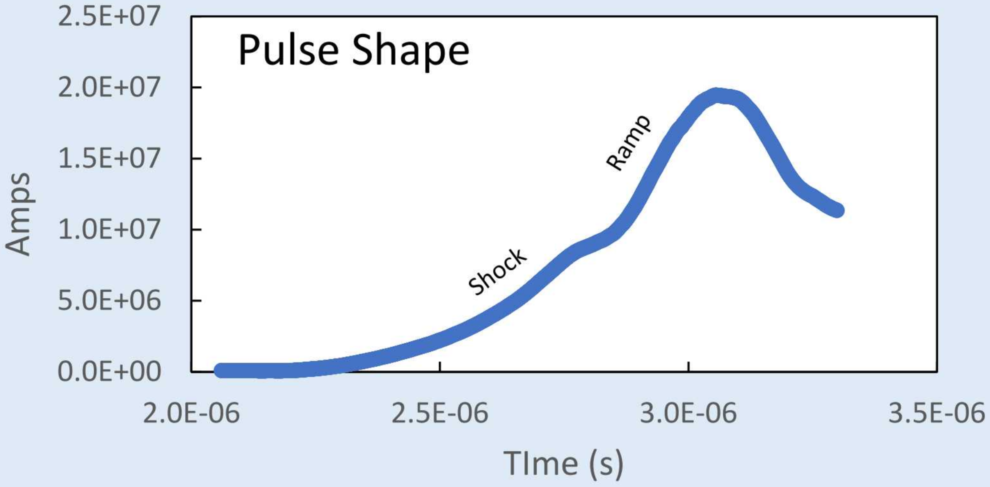
Damp SiO_2 (1.0 mm)- LiF Window

Strip-line Geometry Shock-Ramp Experiments

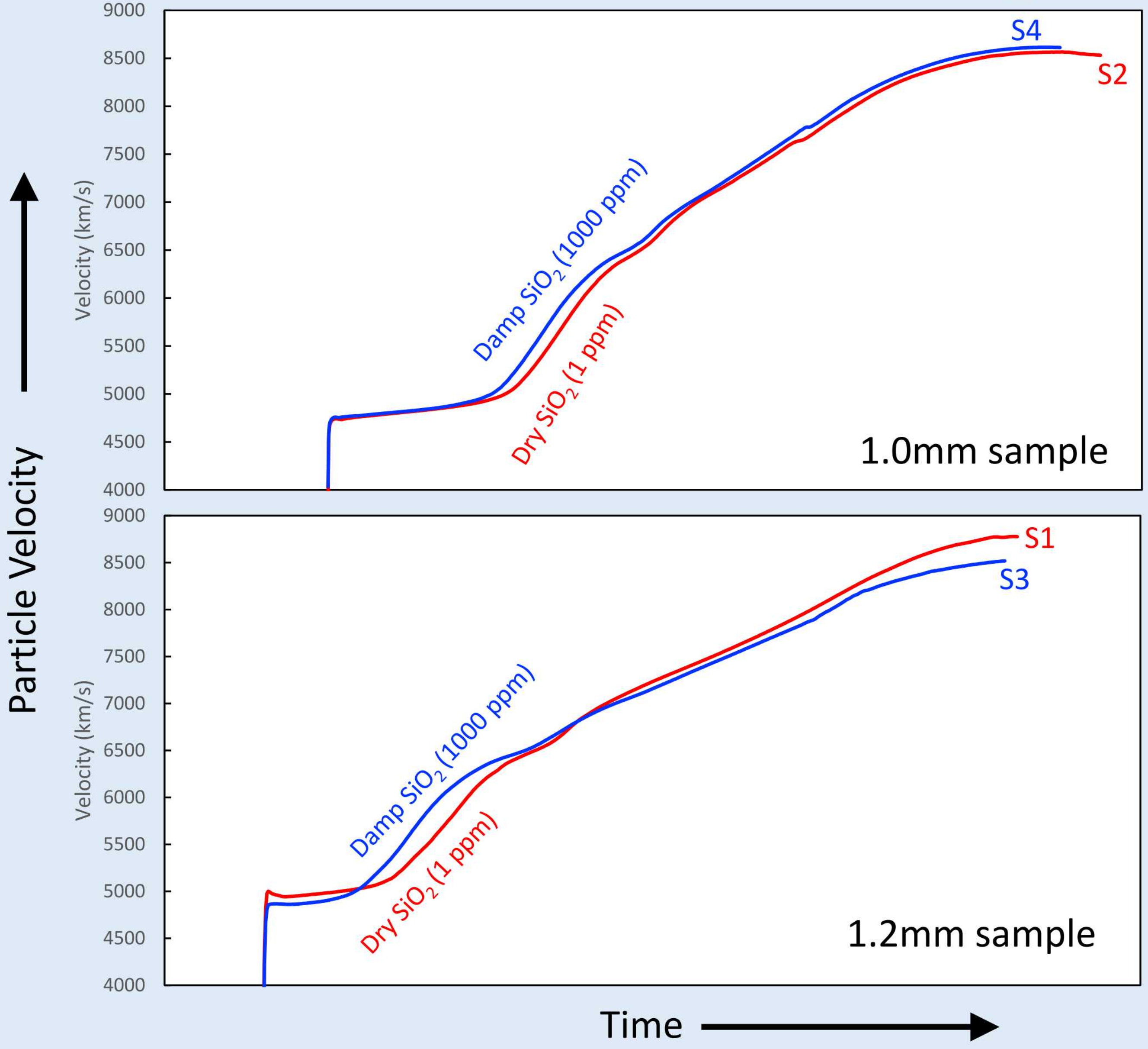


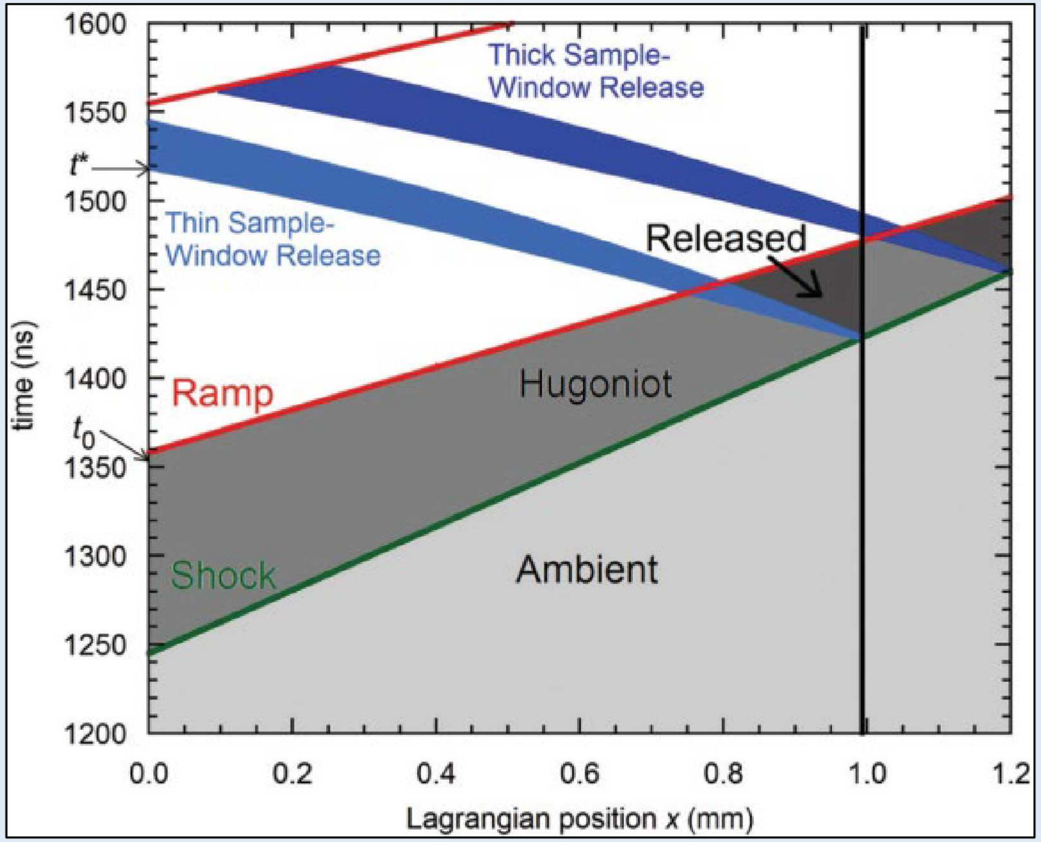
Experimental Design for dry and damp SiO_2 Z-shot





Particle Velocities – SiO_2





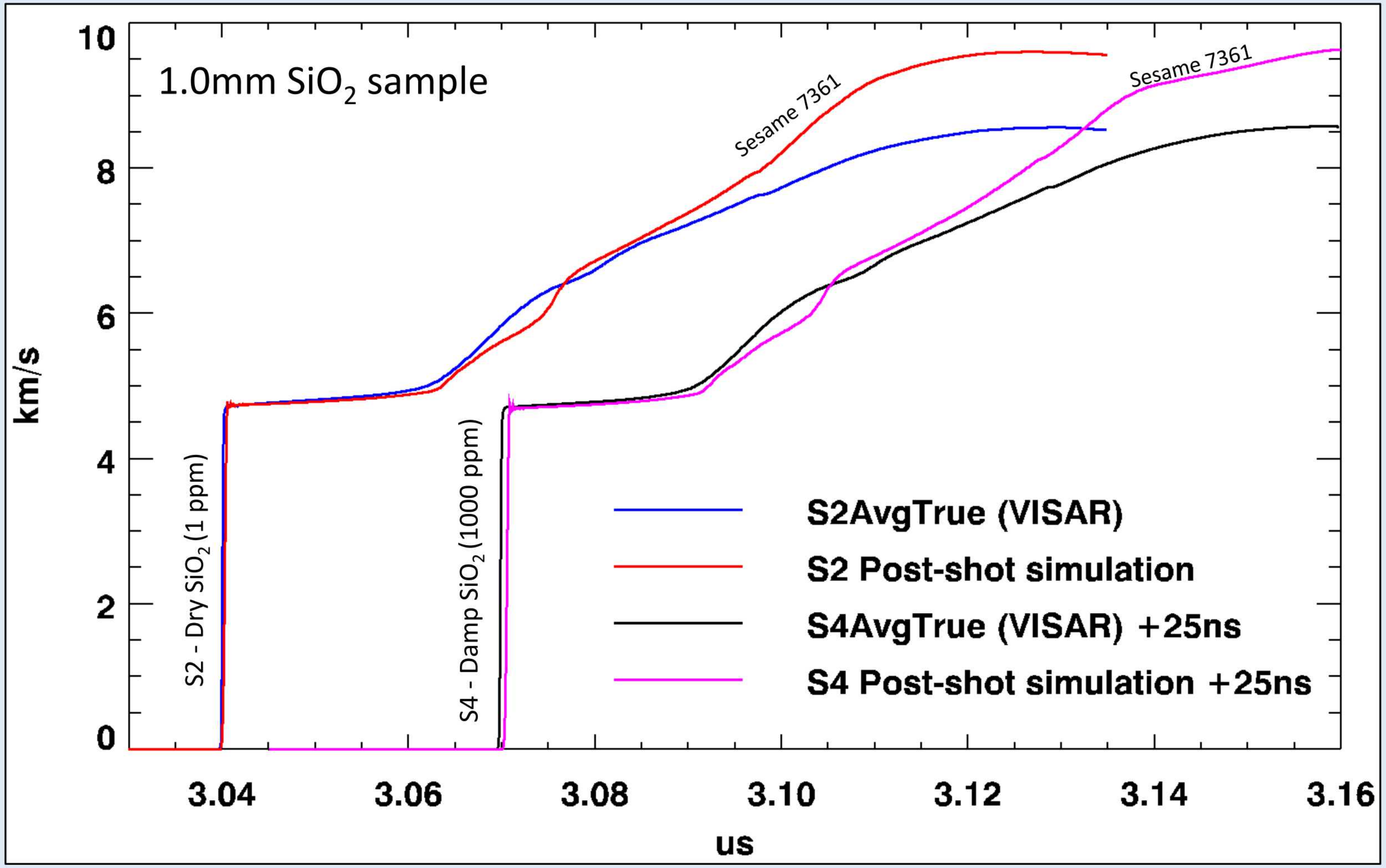
Shock-ramp compression: Ramp compression of shock-melted tin

C. T. Seagle, J.-P. Davis, M. R. Martin, and H. L. Hanshaw

Appl. Phys. Lett. **102**, 244104
(2013); https://doi.org/10.1063/1.4811745

- Exploring different window materials and experiment geometry for next Z-shots

Velocity comparison with Sesame 7361



- Forward simulation with Sesame 7361
- Quite off at high pressure along the ramp! Even for the extremely pure SiO_2.
- While the shock is a good fit for the forward model, the is mismatch in curvature at start of ramp between data and Sesame 7361 forward model.
- Working with Theory group:
  - Kyle Cochrane
  - Matt Lane
  - Josh Townsend

Porous Media Model

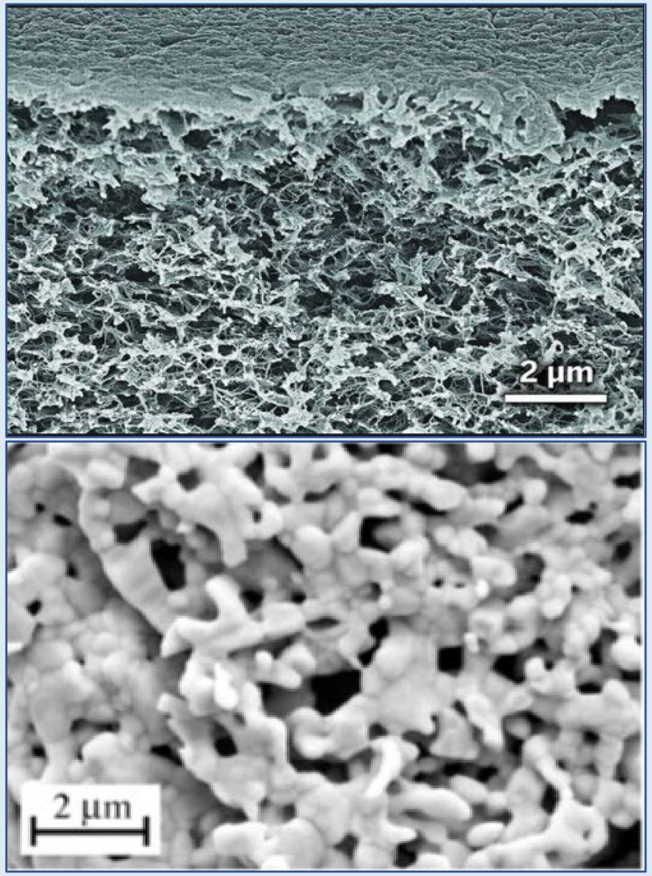
Modeling the Shock Hugoniot in Porous Materials

Kyle Cochrane (*Sandia*) – ZFSP Workshop 2017

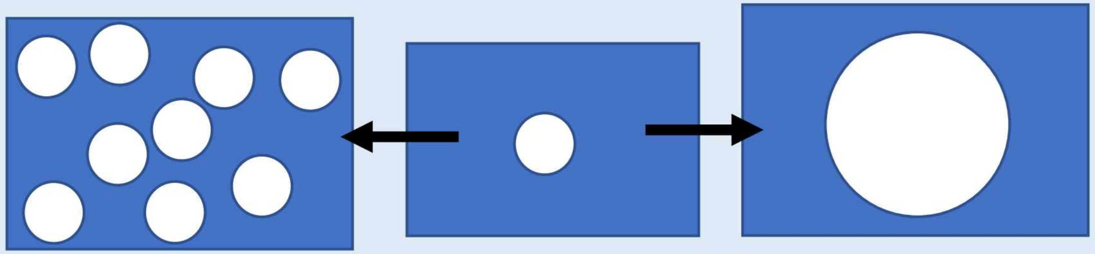
- Porous materials have added complexity compared to full-density systems

- The behavior of porous materials is important for many applications – and challenging to model
  - silica aerogel is used to mimic liquid deuterium and impedance match target materials

- There is a way to incorporate porosity into first-principles simulations of shocked materials



Micrographs of aerogel and porous tantala Ta_2O_5



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

Molecular dynamics – LAMMPS

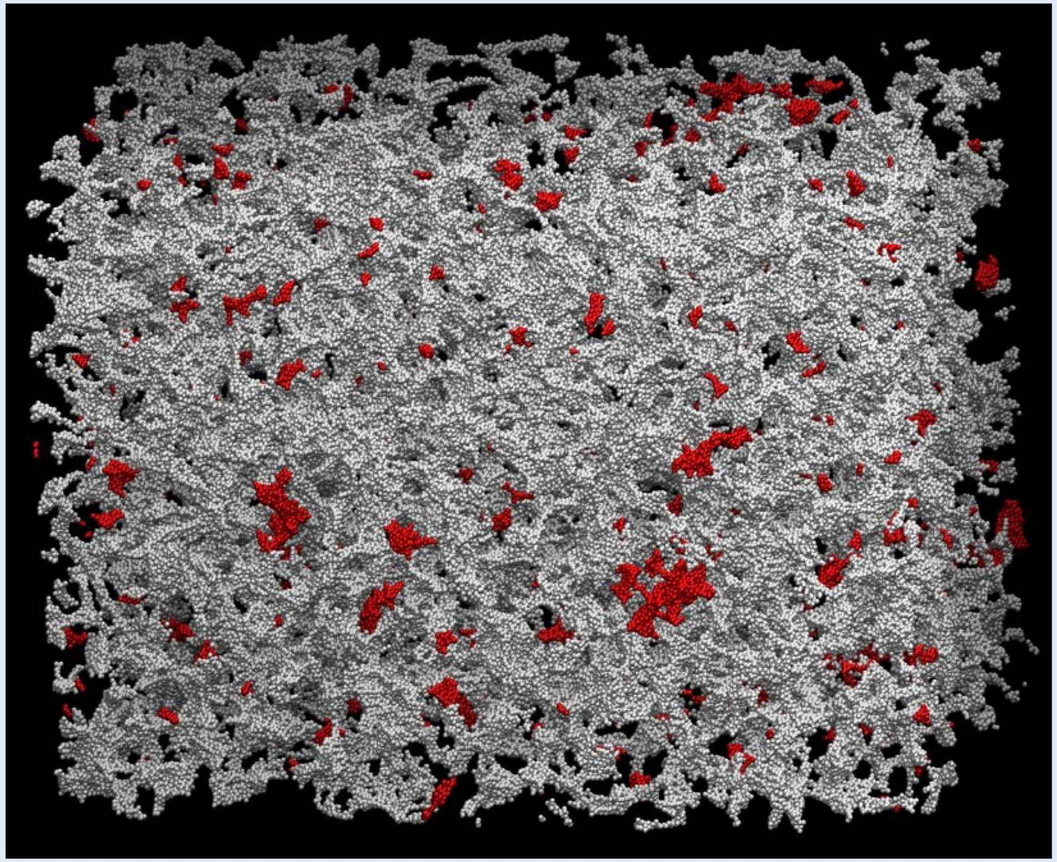
With Matt Lane (*Sandia*)

MD code simulating billions of atoms – important for materials lacking long range order.

Simulates shock and ramp compression.

Already has several SiO_2 interatomic potentials
- Three body imperical
- Chemically-reactive bond-order

Recently used to study
- pressure waves
- void collapse
- crush-up
- Melt
- solid-solid phase transition

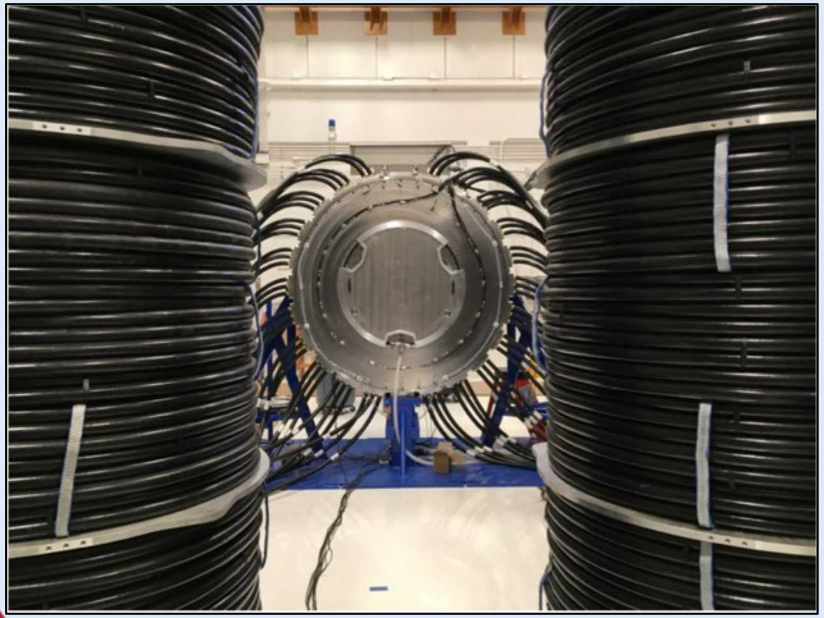


MD simulation from LAMMPS of silica (SiO_2) glass with 90% porosity. Image from. J.M.D. Lane.

Experiments on Thor and DICE

Graduate Student Lindsay Harrison (*CU Boulder*)
With Brian Stolzfus and Jean-Paul Davis (*Sandia*)

1. Direct comparison of the results from theory and dynamic compression with static compression experiments and MD simulations in the literature.
2. Sample recovery of these supplementary experiments on THOR at DICE can be used to investigate the retention of water in planetary materials during impact events.
3. Application to the present-day mantle transition zone.



Thor

Dynamic Integrated Compression Experimental Facility

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 applic4ations 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.

Funding & Support

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