EARTH-LIFE SCIENCE INSTITUTE

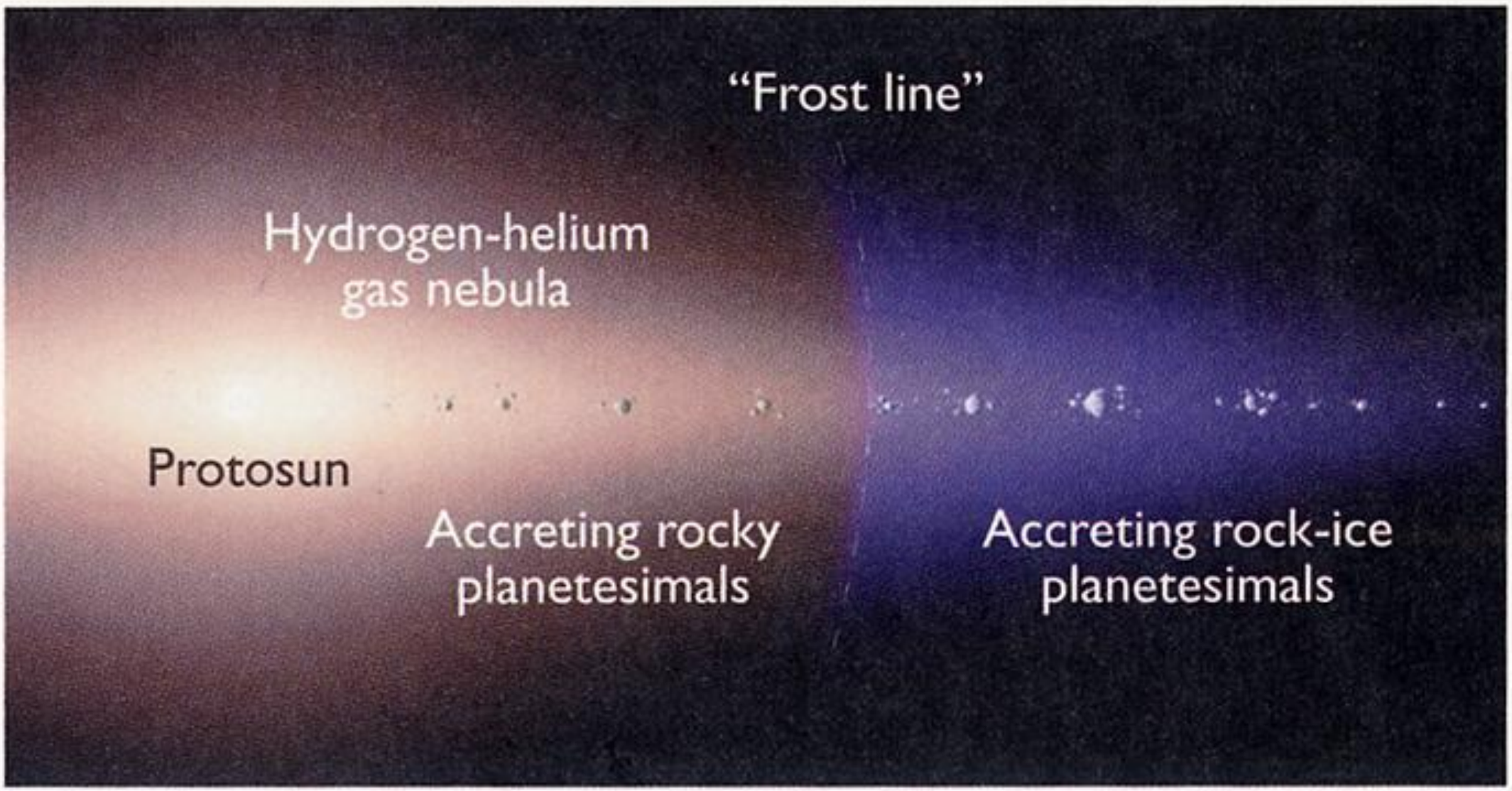
Christine Houser

Water, water everywhere, except the lower mantle

Tokyo Institute of Technology

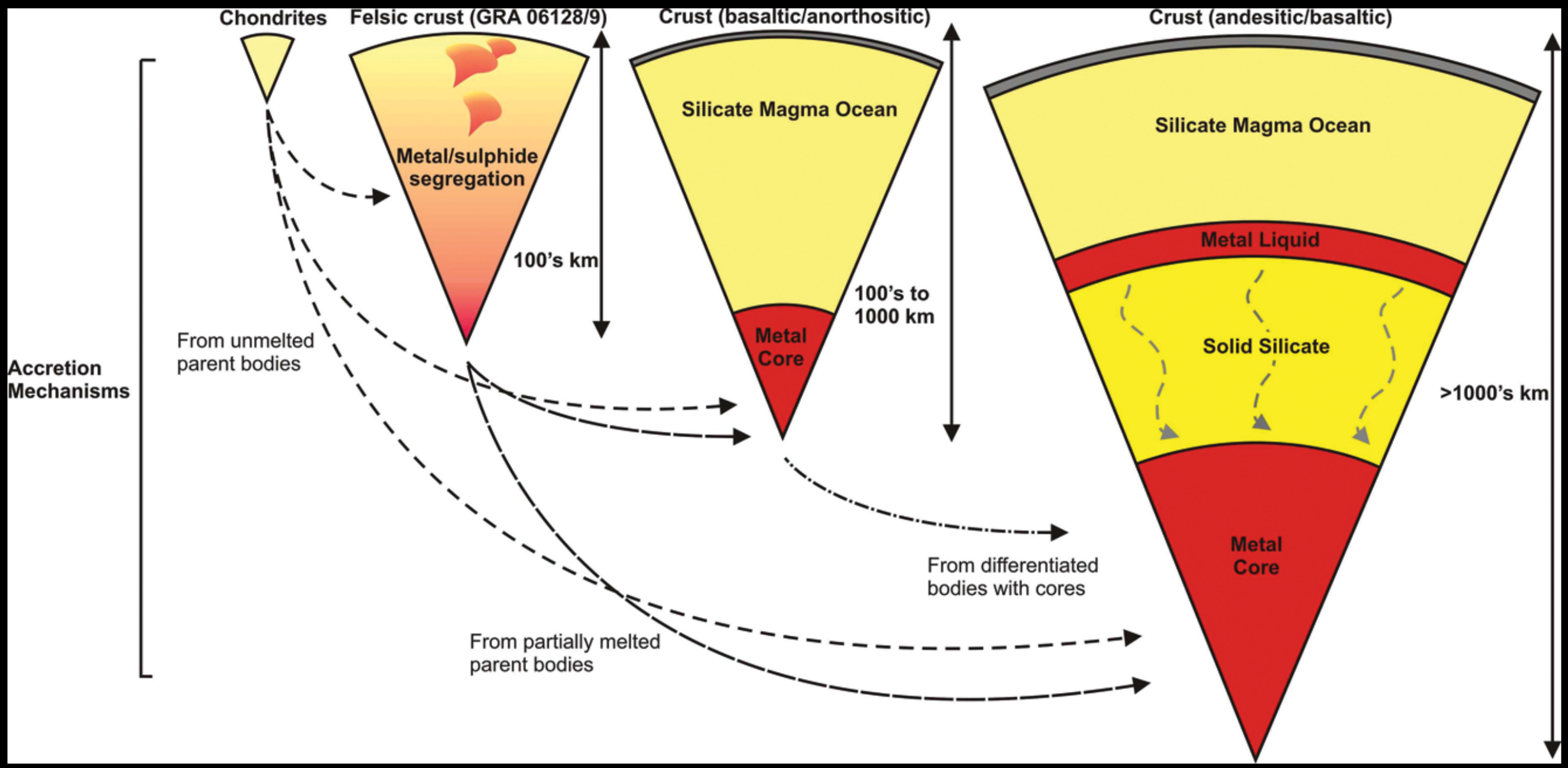
World Premier International

Water in the early solar system



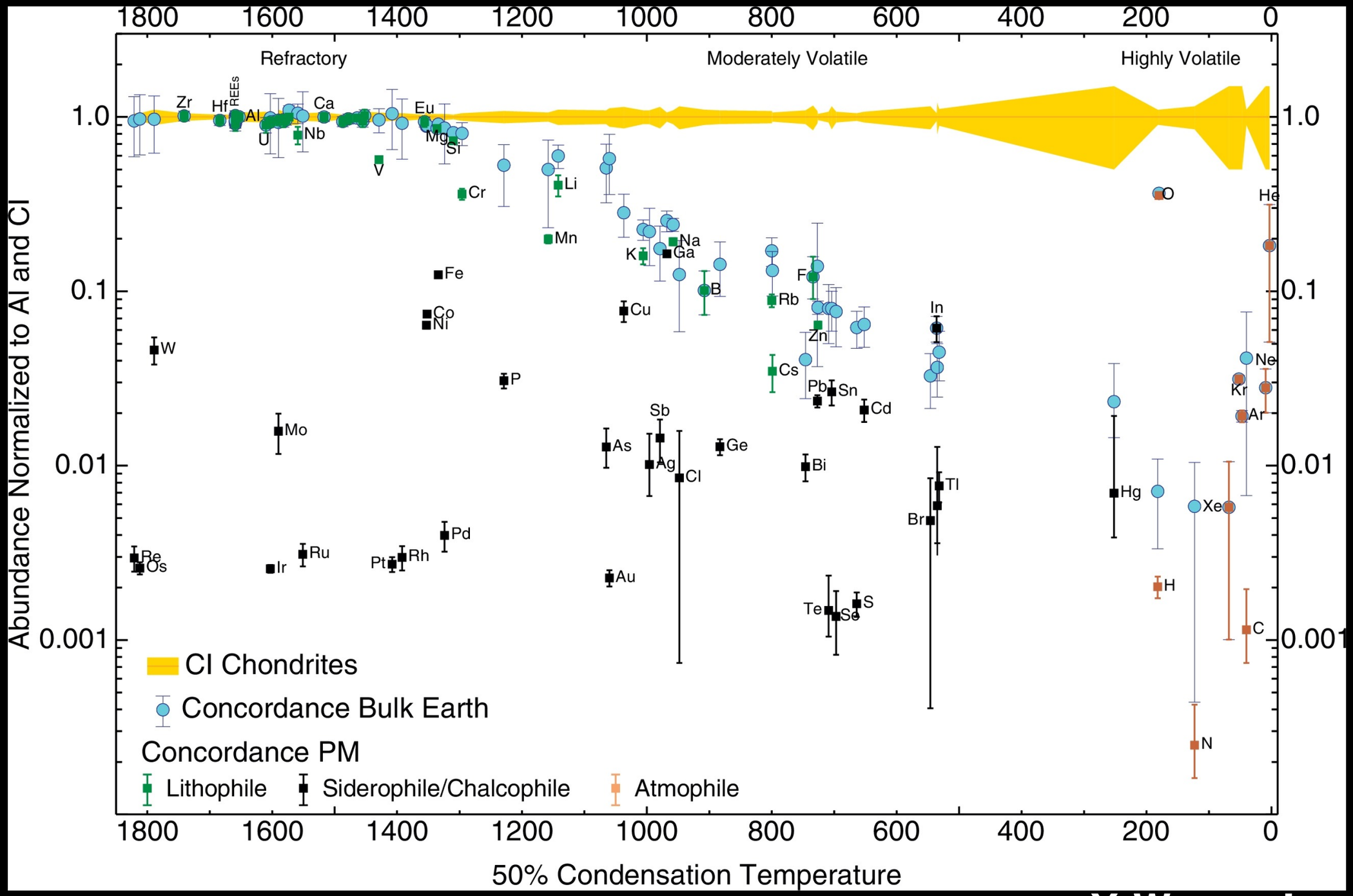
Sean Raymond

Accretion leads to volatile depletion



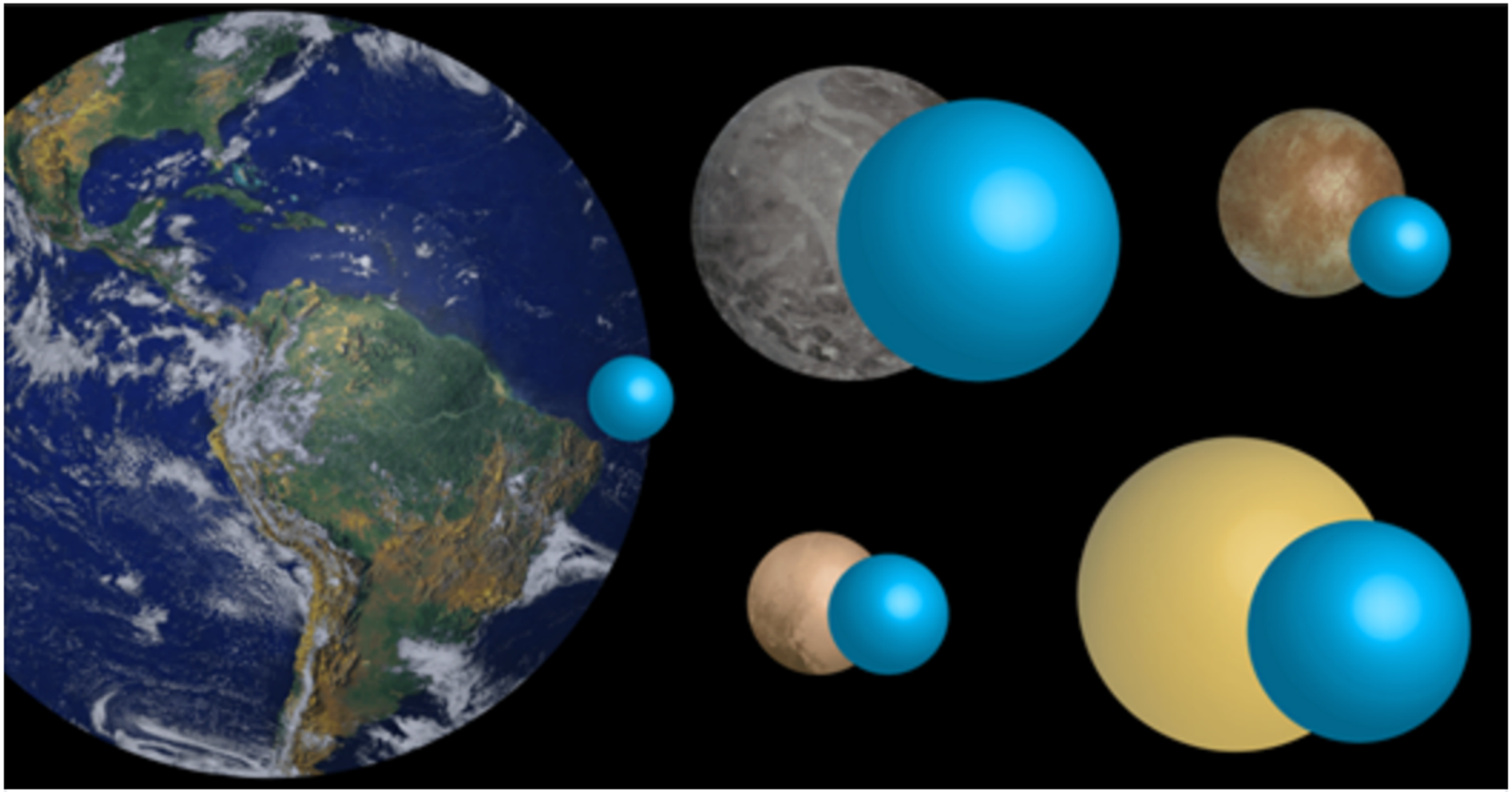
S. Day, Geology Today, 2015

Accretion leads to volatile depletion



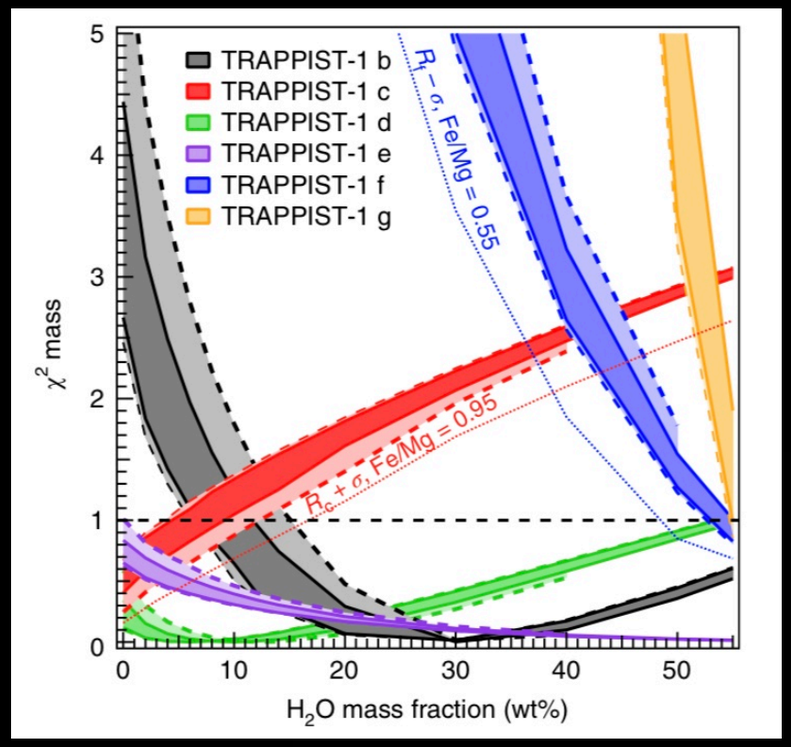
Y. Wang+, Icarus, 2018

Yet, the solar system is full of water



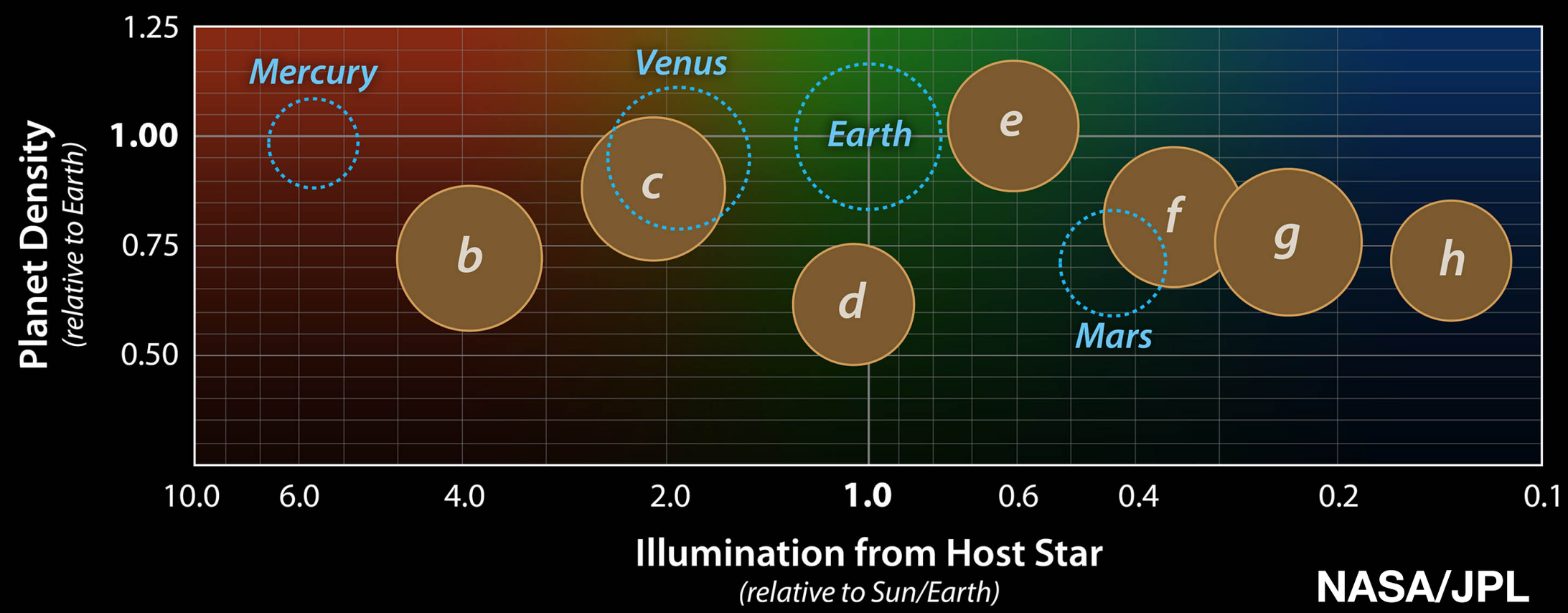
S. Vance

And others likely are too..



Unterborn+, Nat. Astronomy, 2018

TRAPPIST-1/Solar System Comparison



NASA/JPL

Upper Mantle

Lithos 240–243 (2016) 402–425

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

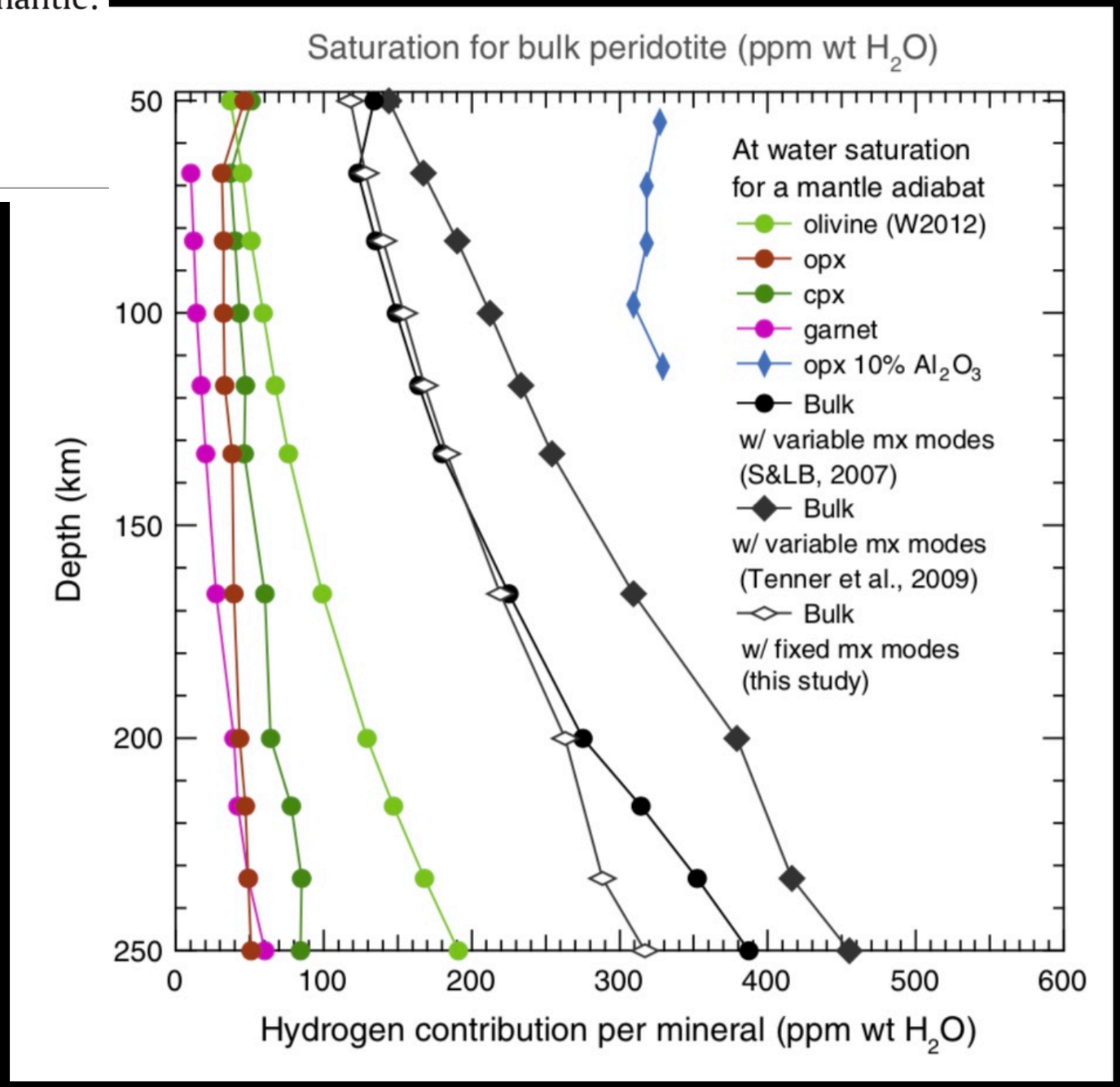
Invited review article

Distribution and transport of hydrogen in the lithospheric mantle: A review

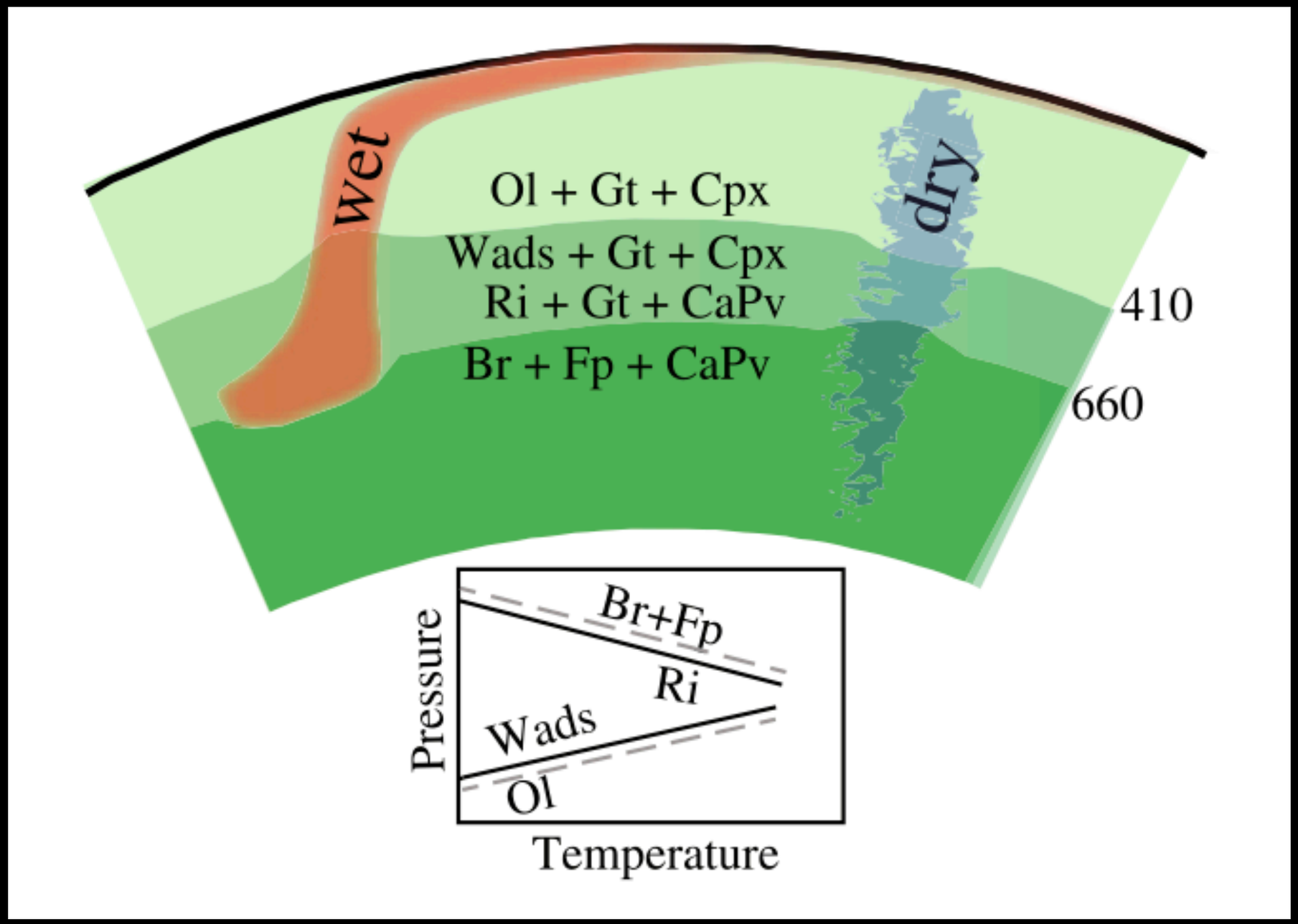
Sylvie Demouchy [a,*], Nathalie Bolfan-Casanova [b]

[a] Géosciences Montpellier, Université Montpellier & CNRS, CC 60, Place E. Bataillon, 34095 Montpellier cedex 5, France
[b] Laboratoire Magmas et Volcans, Université Blaise Pascal & CNRS, 5, rue Kessler, 63000 Clermont-Ferrand, France

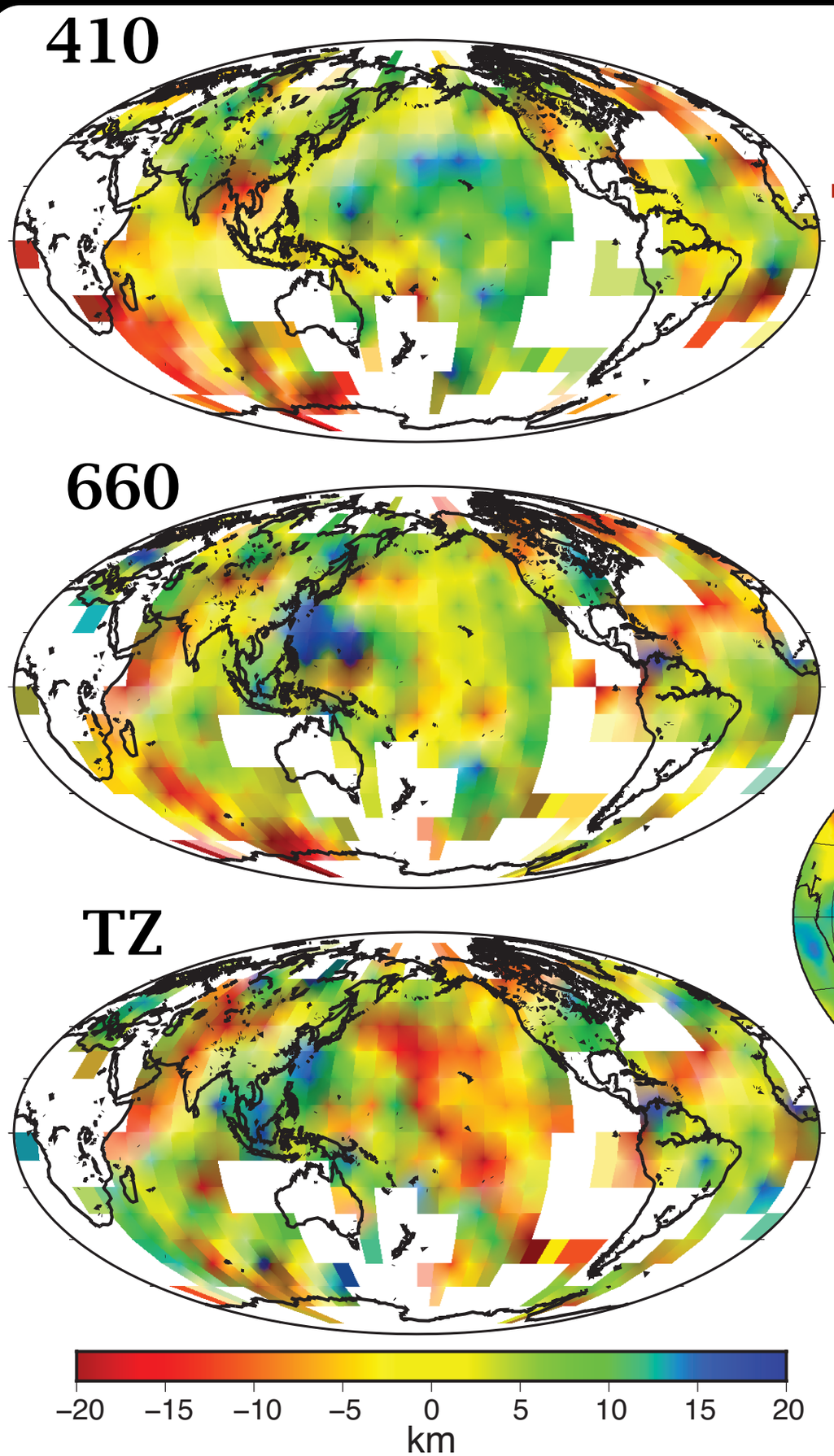
- Have natural samples.
- Have more experiments.

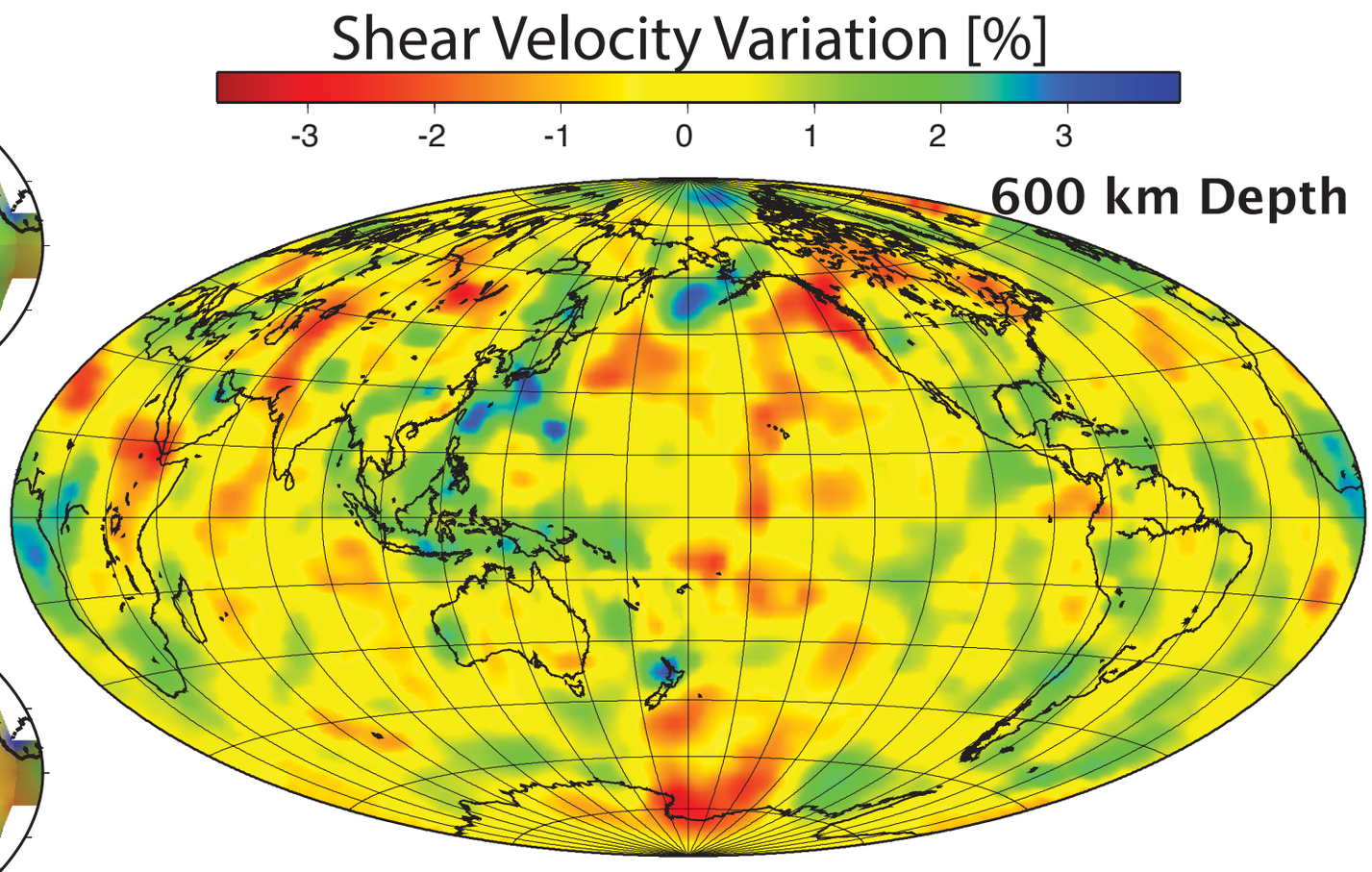


Need TZ topography and velocity to distinguish between temperature and water



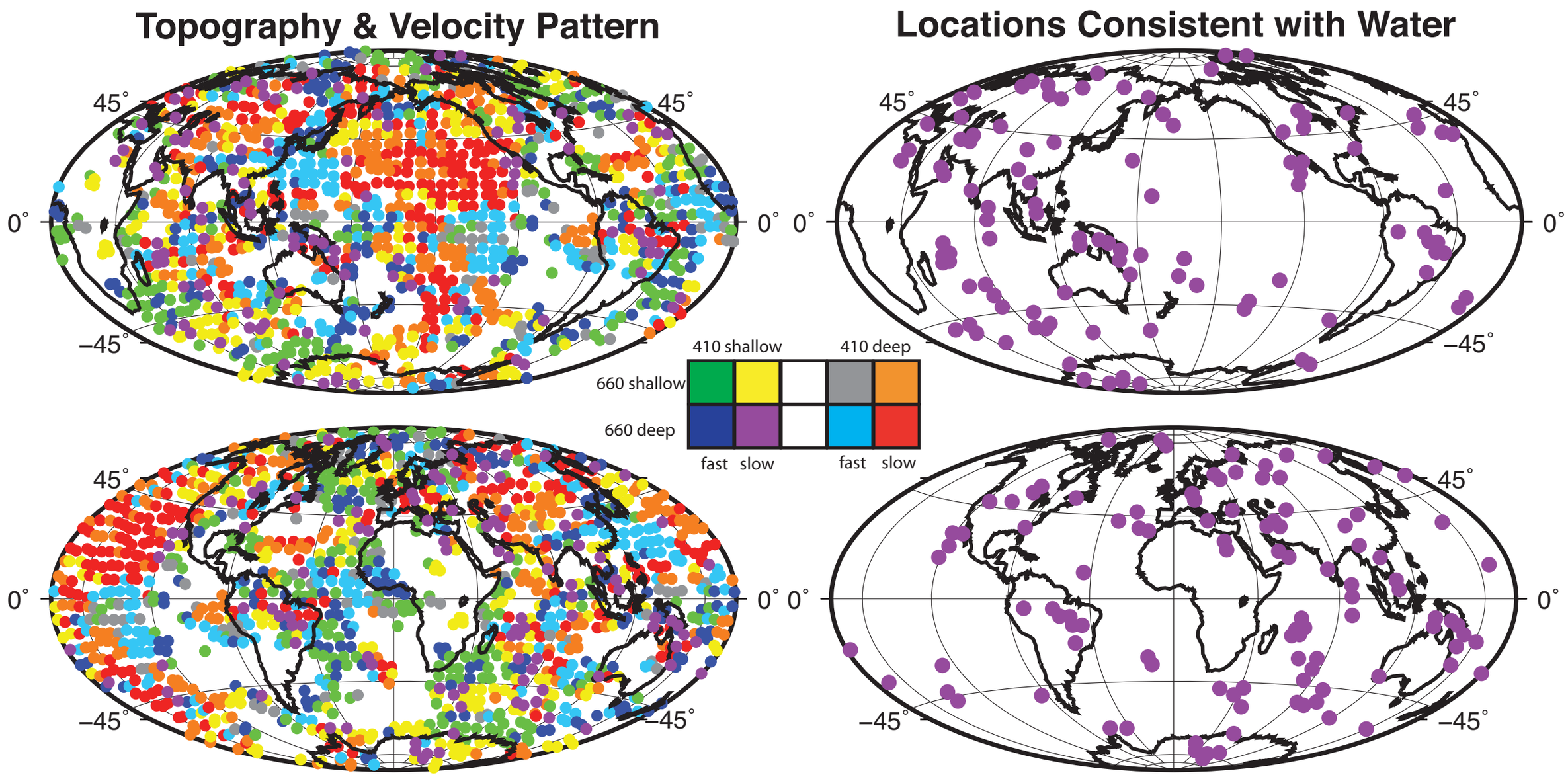
Combine TZ topography with shear velocity





HMSL-S06
TZ constrained by surface and lower-mantle body waves

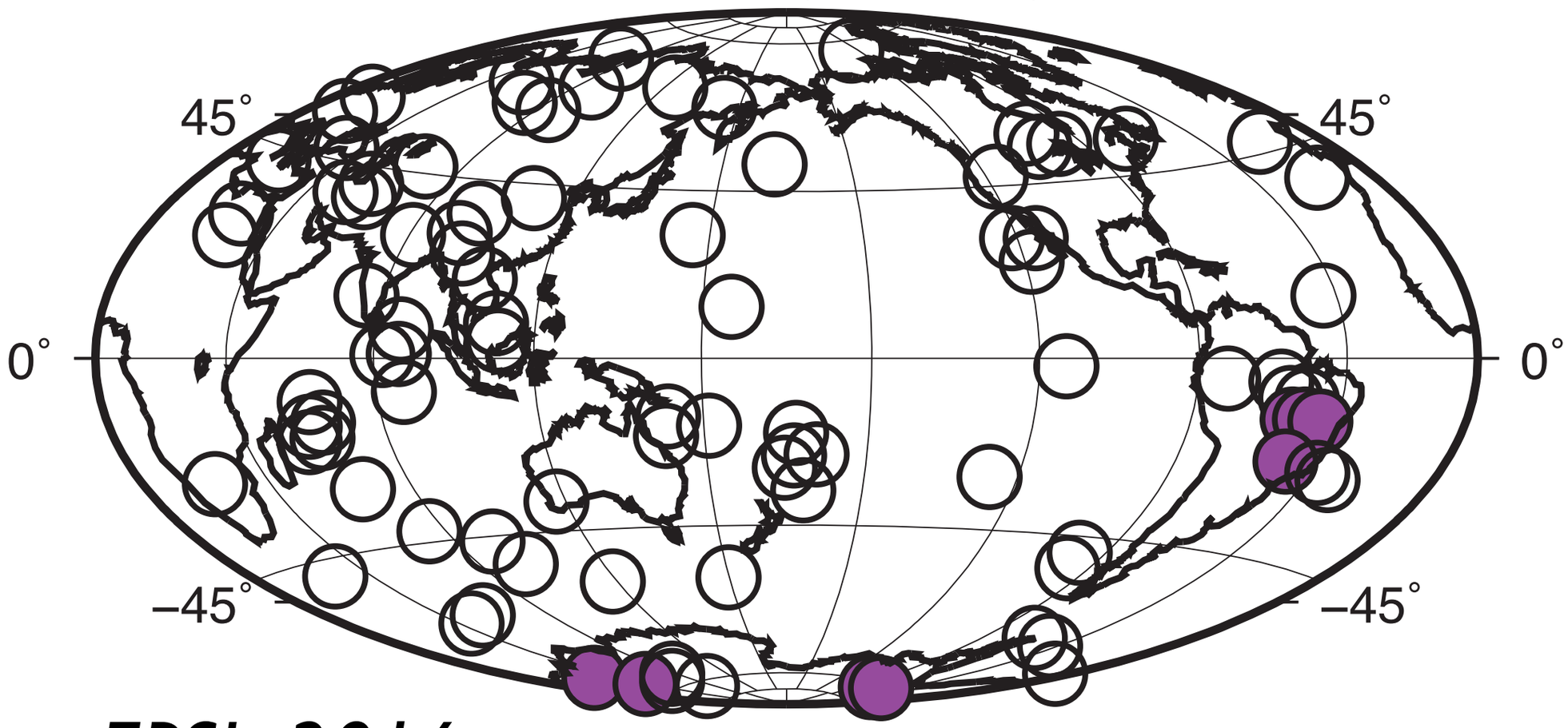
Mapping Water Content



Only 105 out of 1300 bins (8%) are consistent with water.

Very few locations where grouping is greater than random

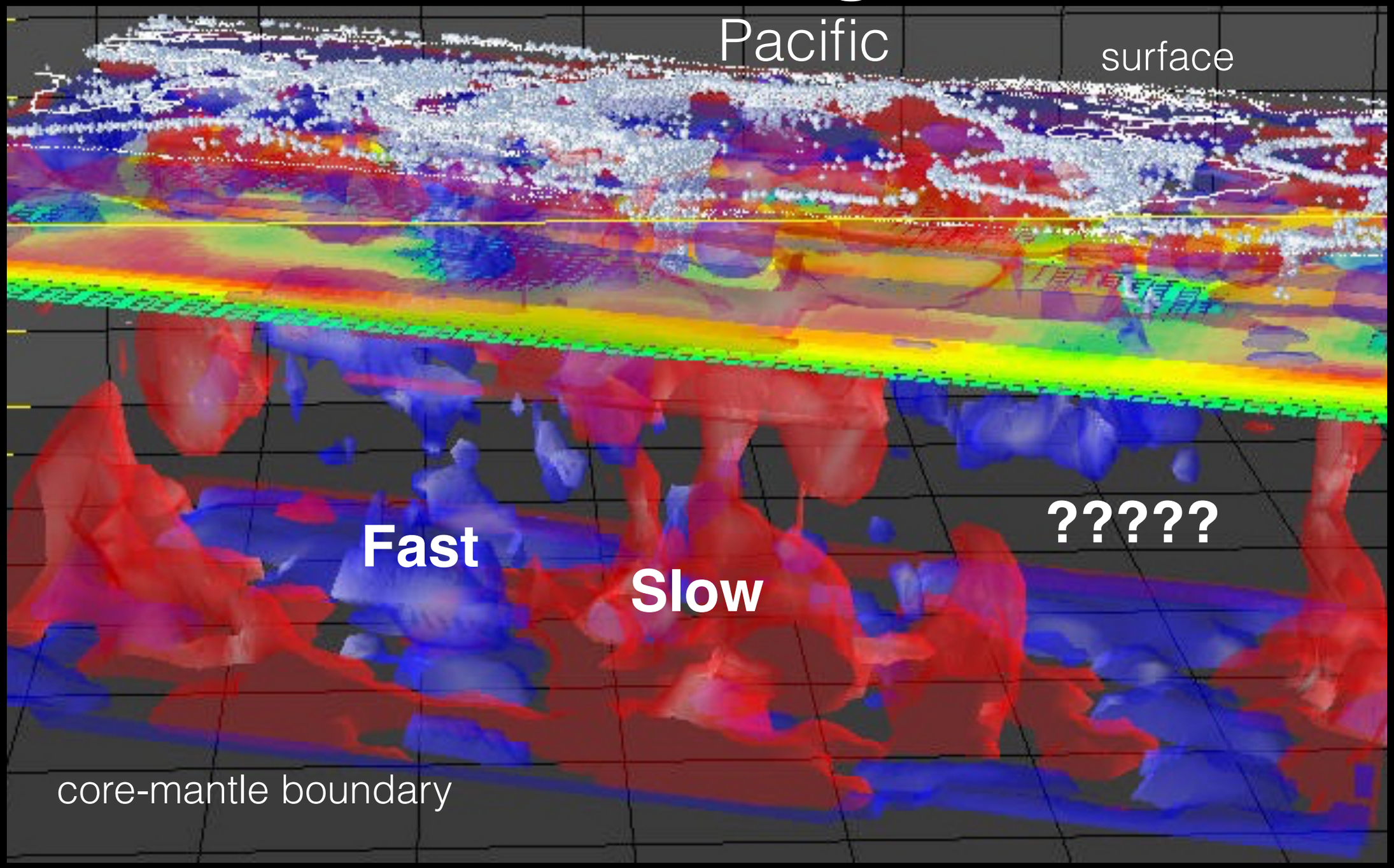
Case 8: - Vs, - 410, + 660



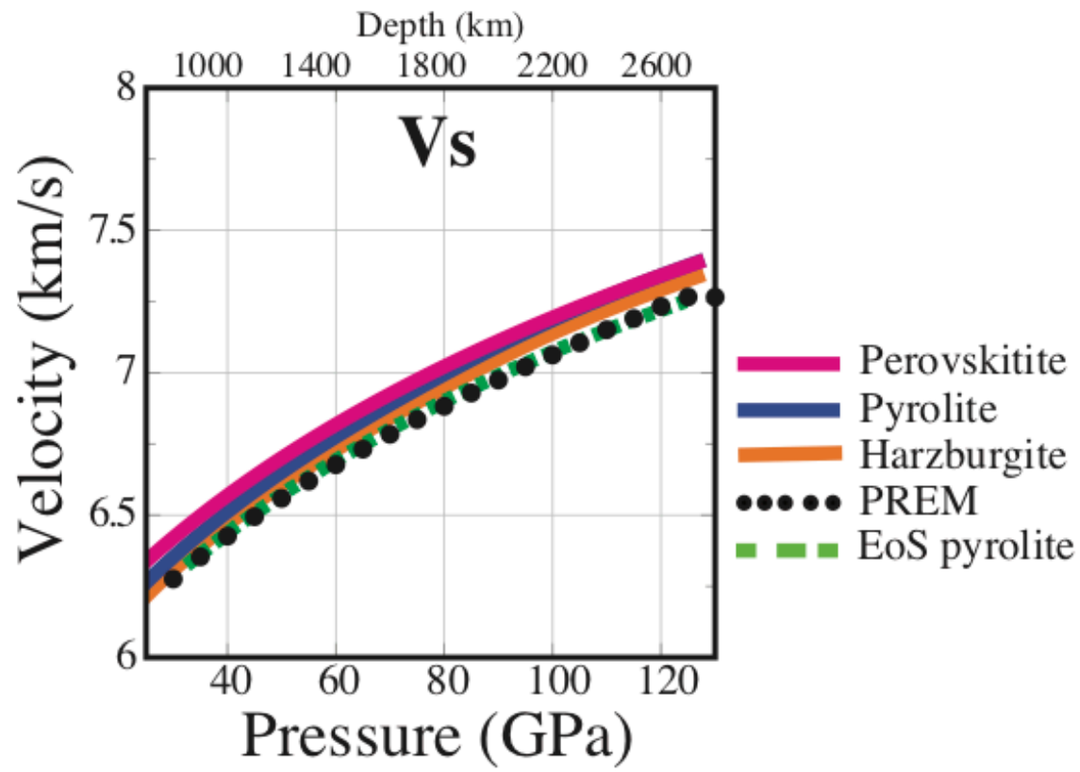
Houser, EPSL, 2016

What is ambient mantle?

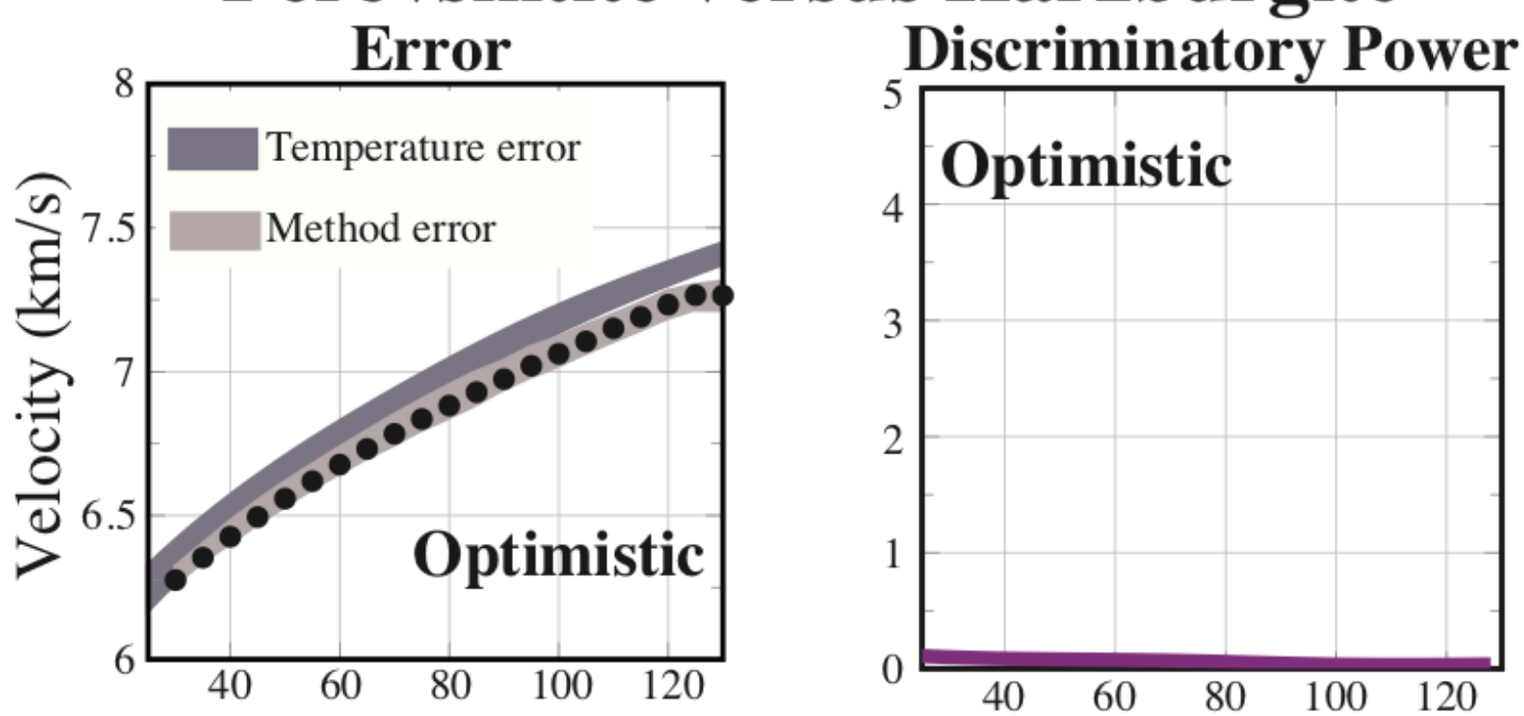
red=slow, blue=fast
clear=average=???



Shear Velocity

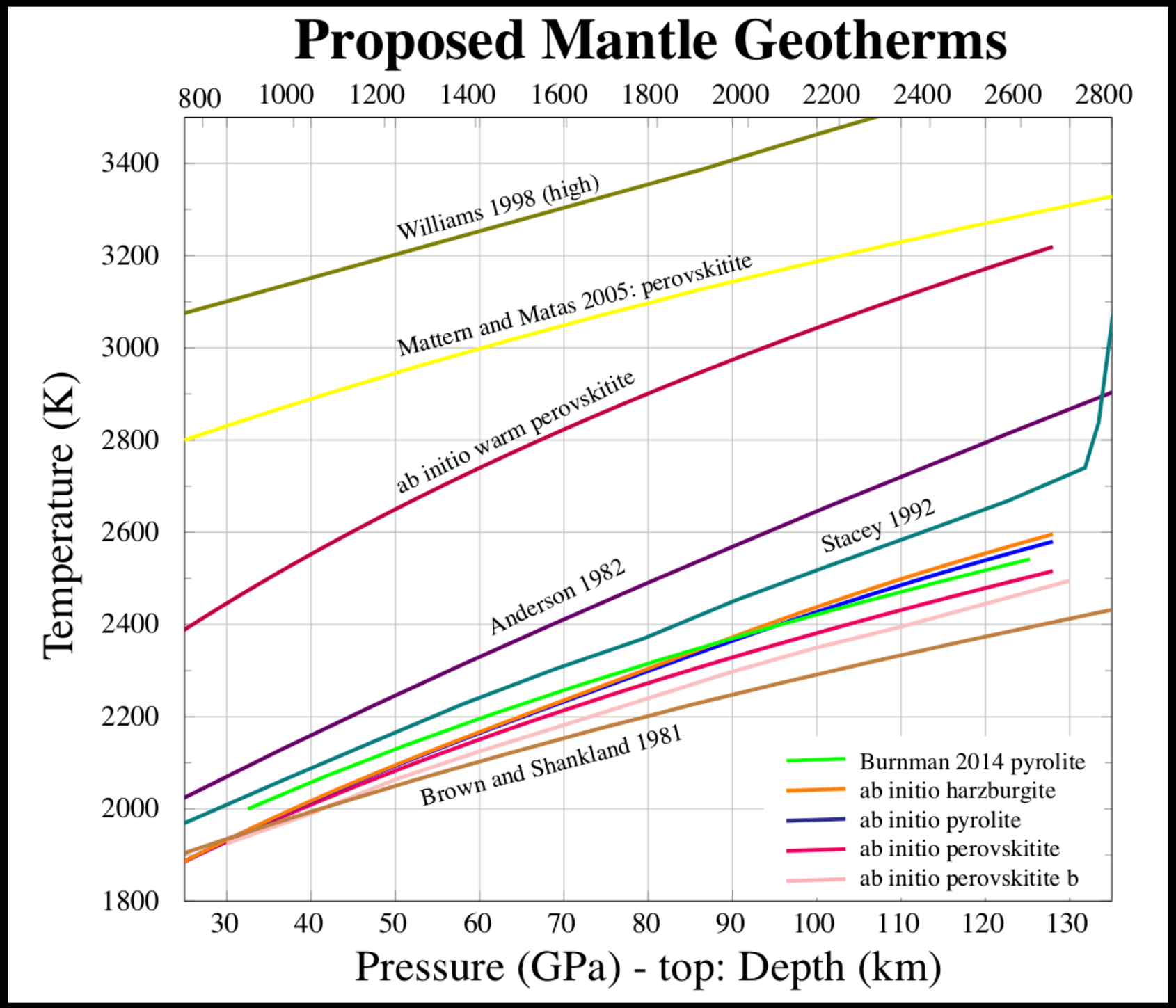


Comparing Fit to PREM: Perovskitite versus Harzburgite

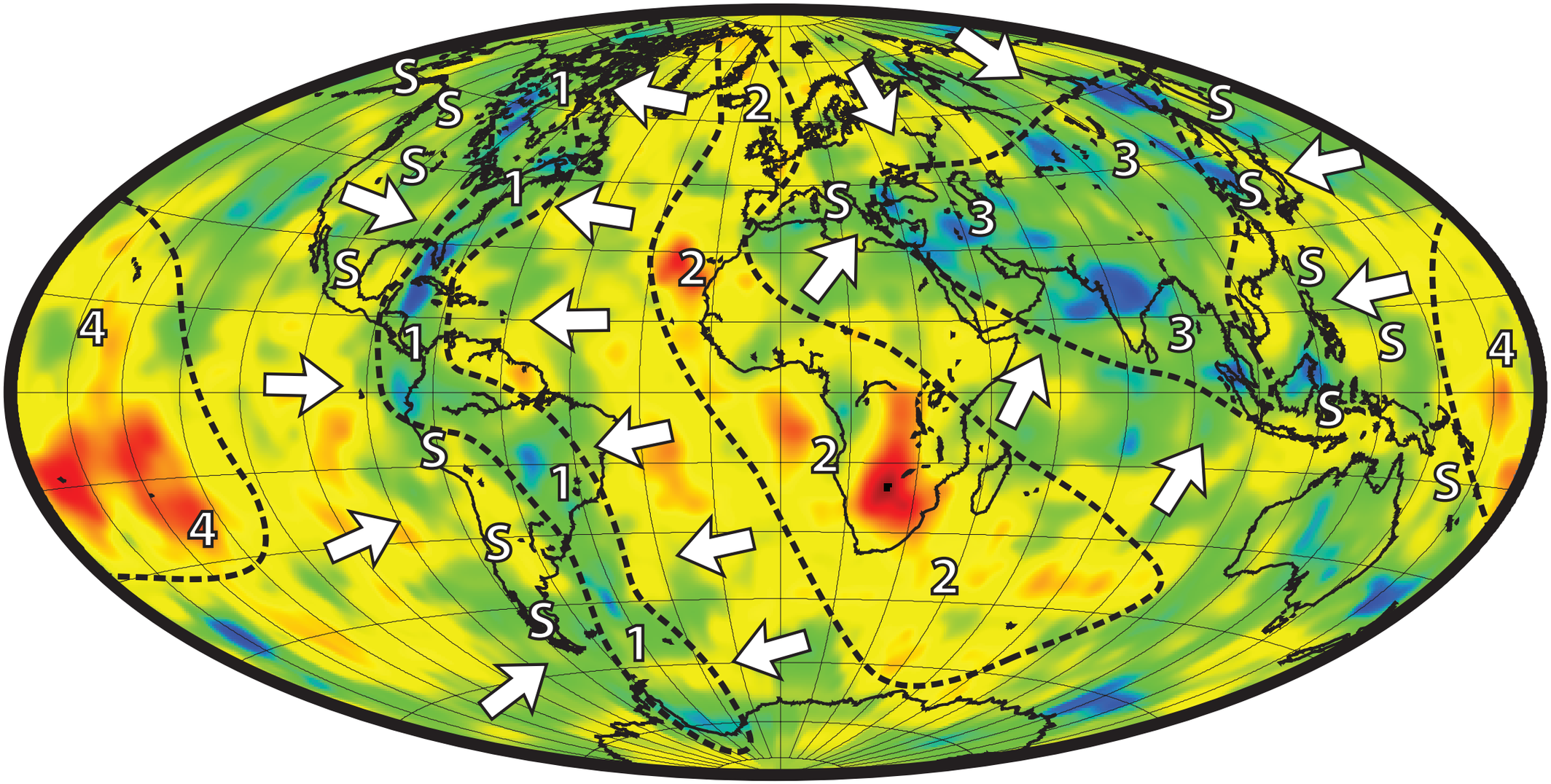


Houser+, PEPI, sumitted

At least 400 K temperature uncertainty in lower mantle



Today's BEAMS:
The ambient lower mantle



Lateral Shear Velocity Anomaly (1,000-2,200 km Depth Average)

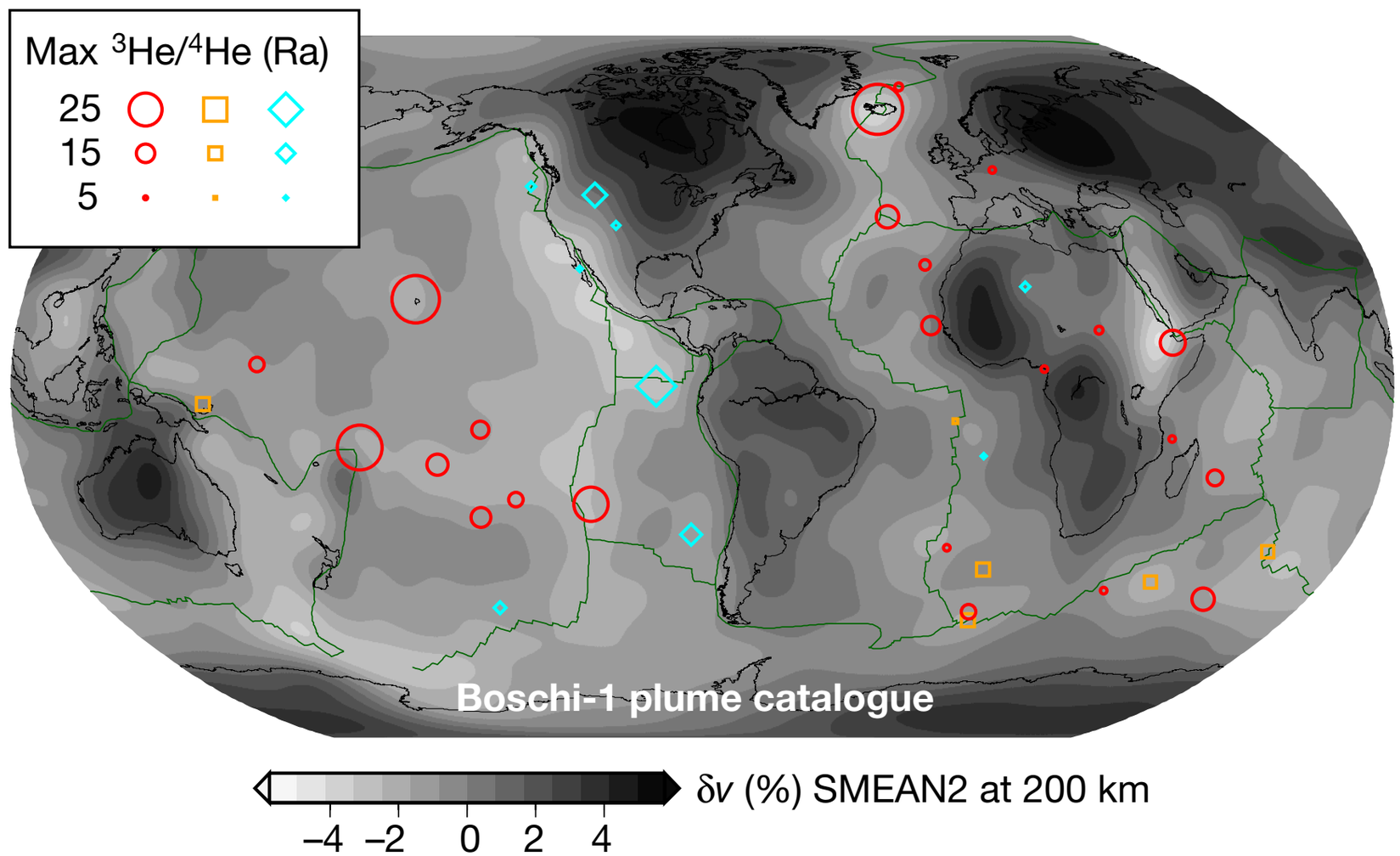
Geochemistry argues for ancient-primordial reservoirs

LETTER

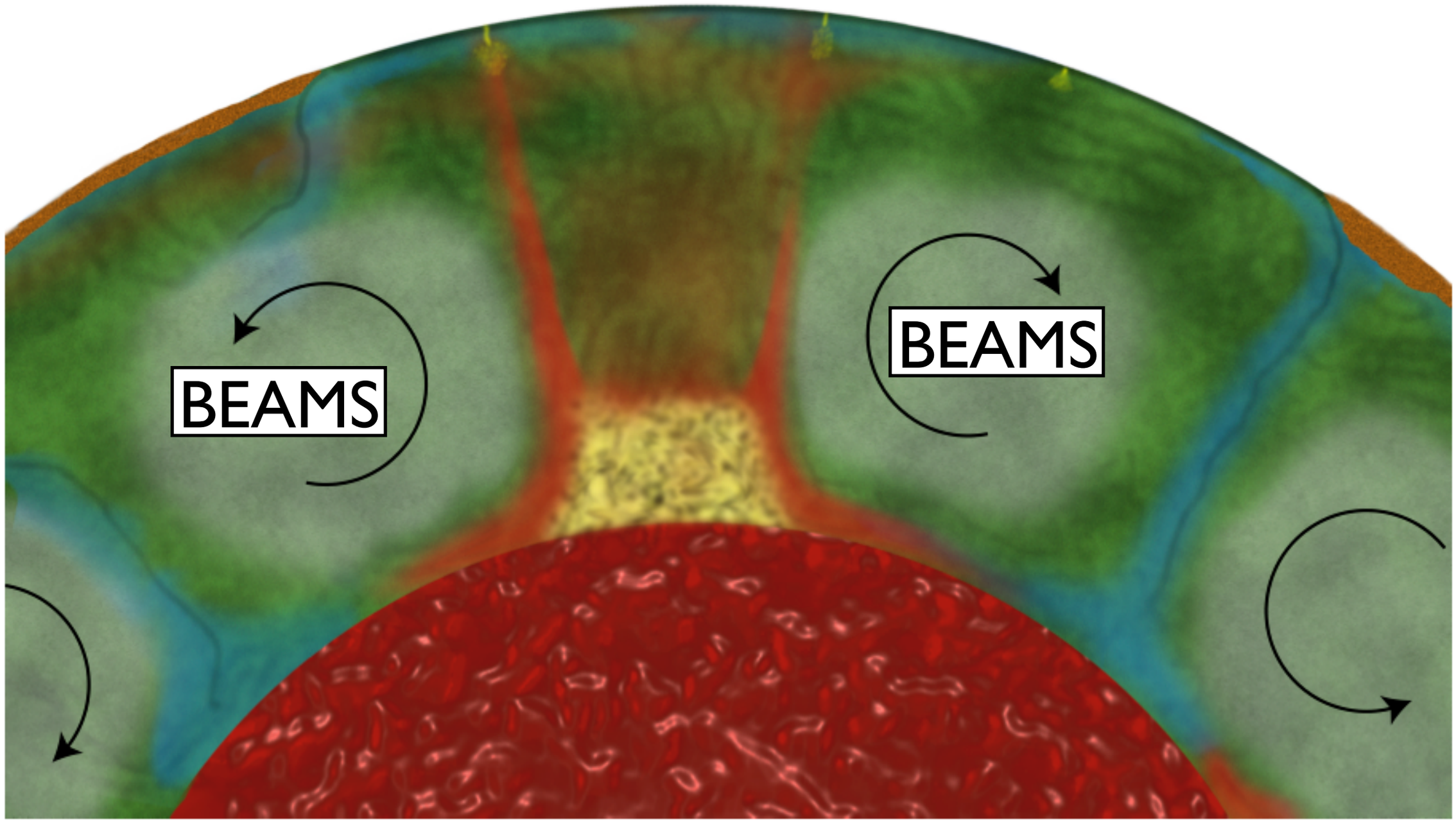
doi:10.1038/nature21023

Primordial helium entrained by the hottest mantle plumes

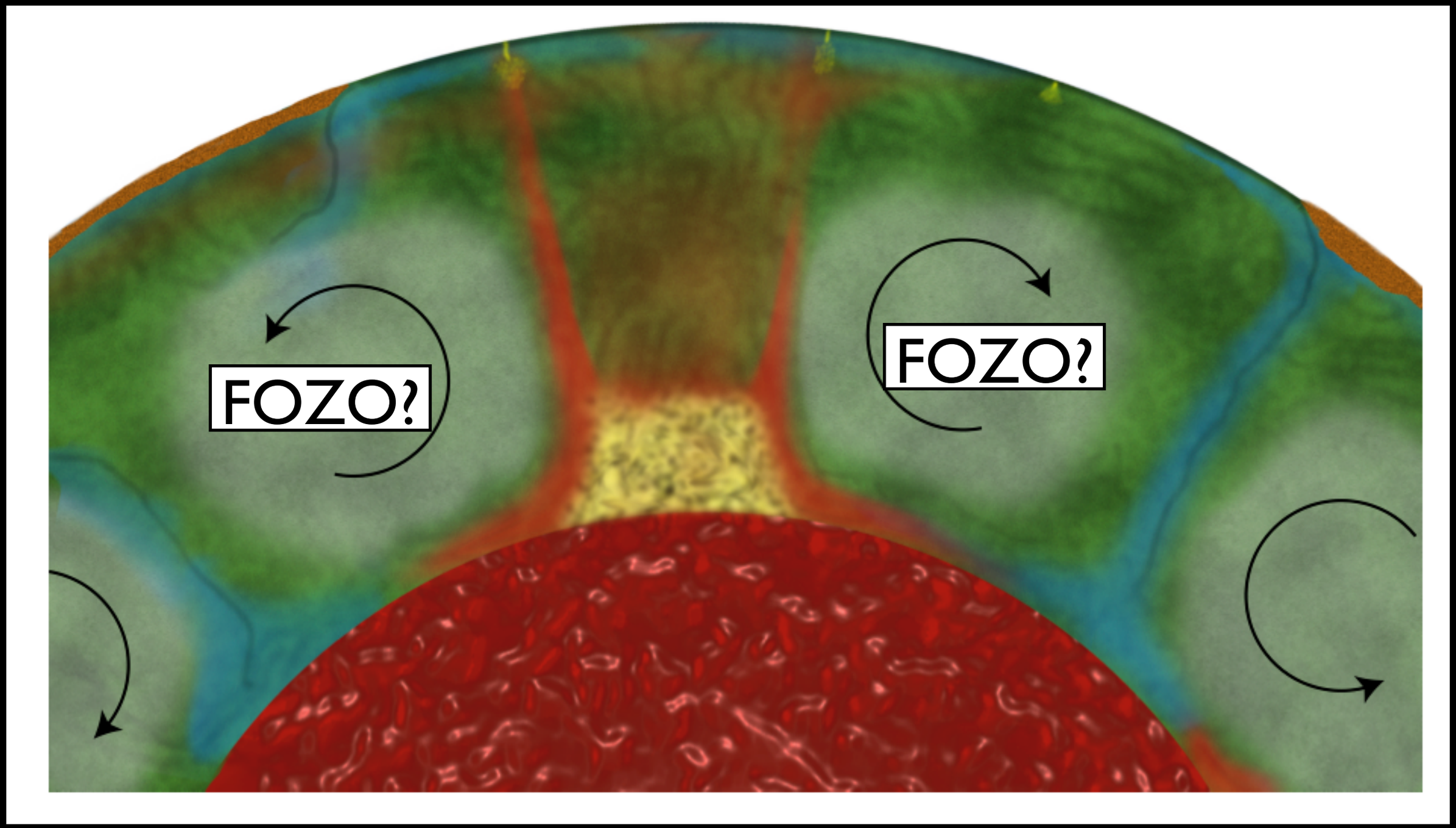
M. G. Jackson[1], J. G. Konter[2] & T.W. Becker[3]



Bridgmanite **E**nriched **A**ncient **M**antle **S**tructure

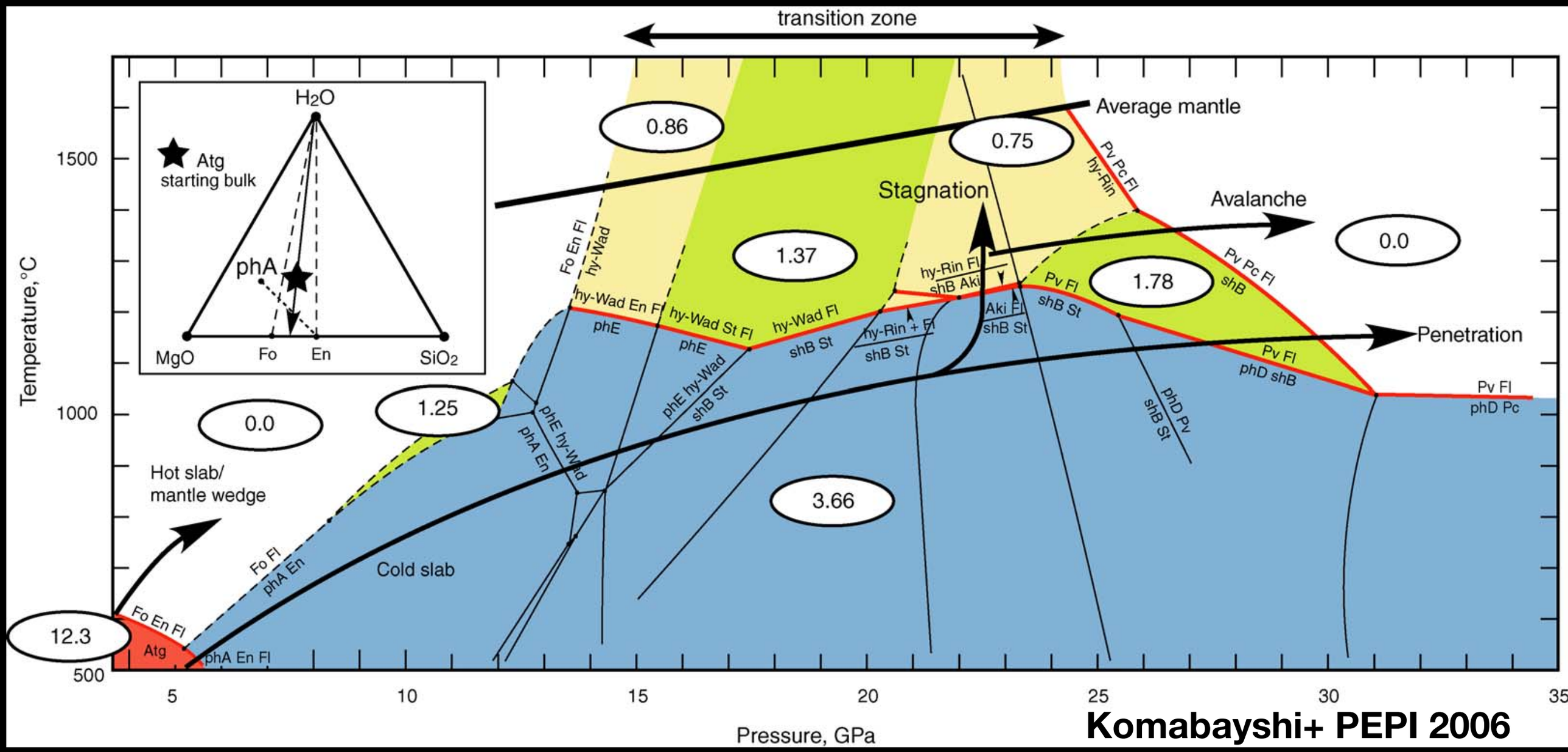


Bridgmanite Enriched Ancient Mantle Structure



Let’s look at fluxes.

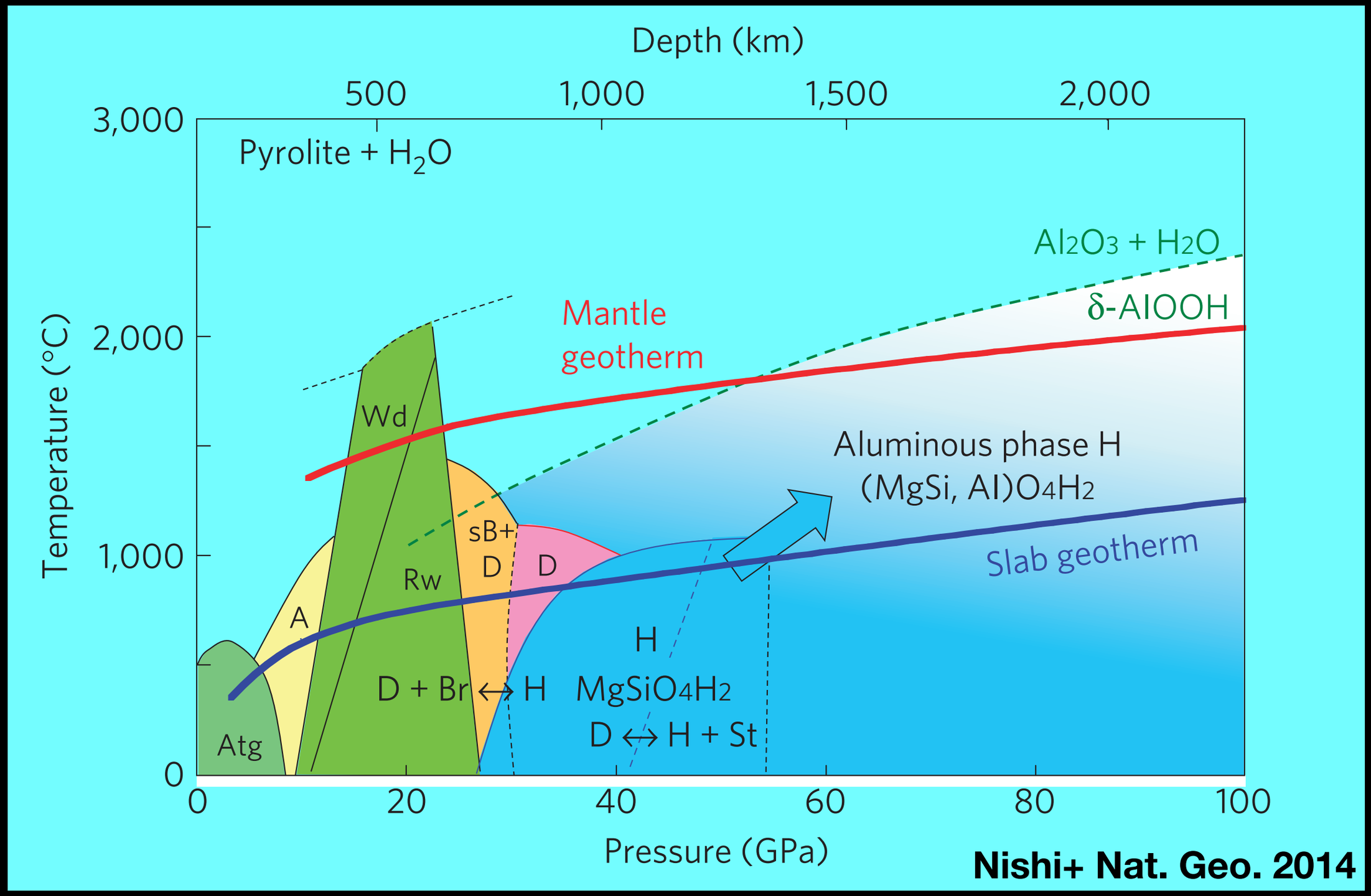
Need Low Temperature



Komabayshi+ PEPI 2006

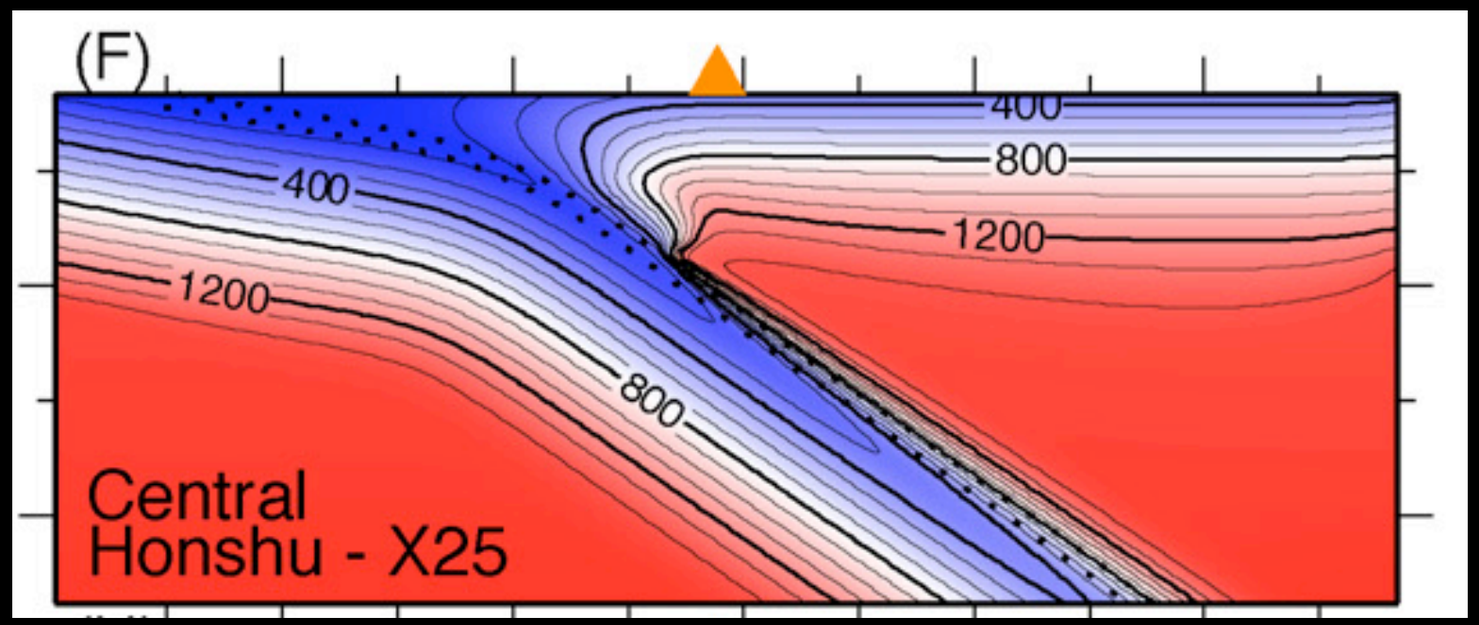
Ito and Katsura, 1989

Aluminum increases water storage potential



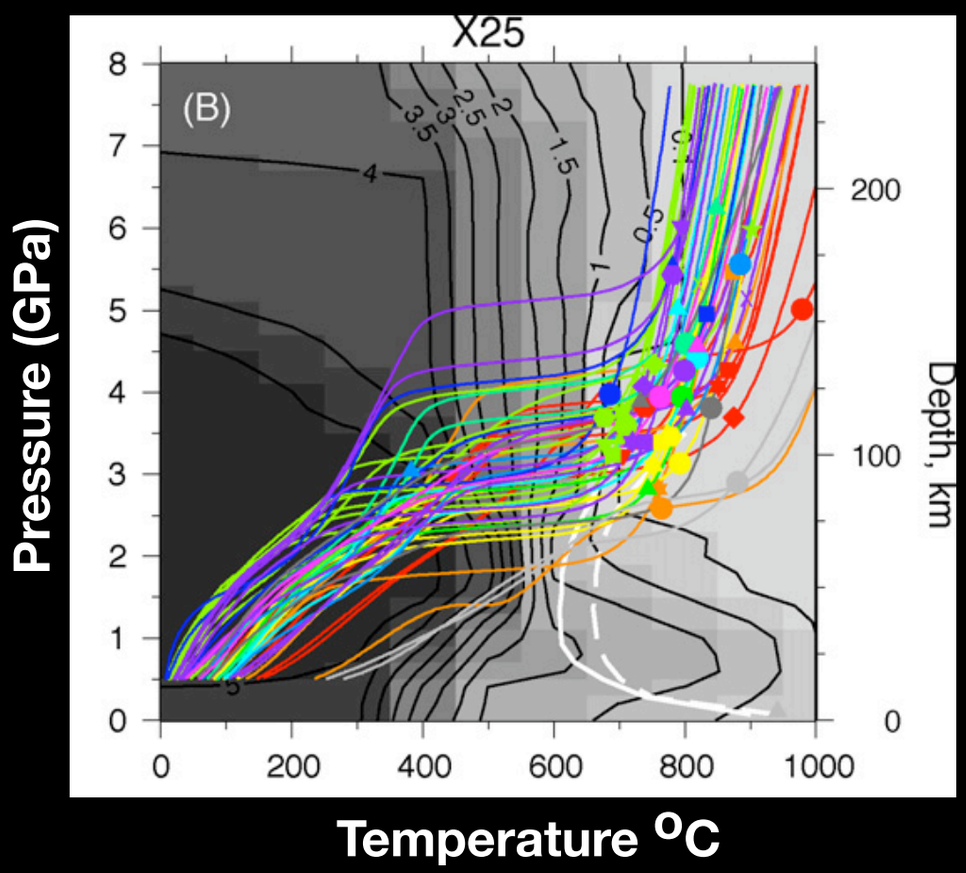
Nishi+ Nat. Geo. 2014

Slab temperature models

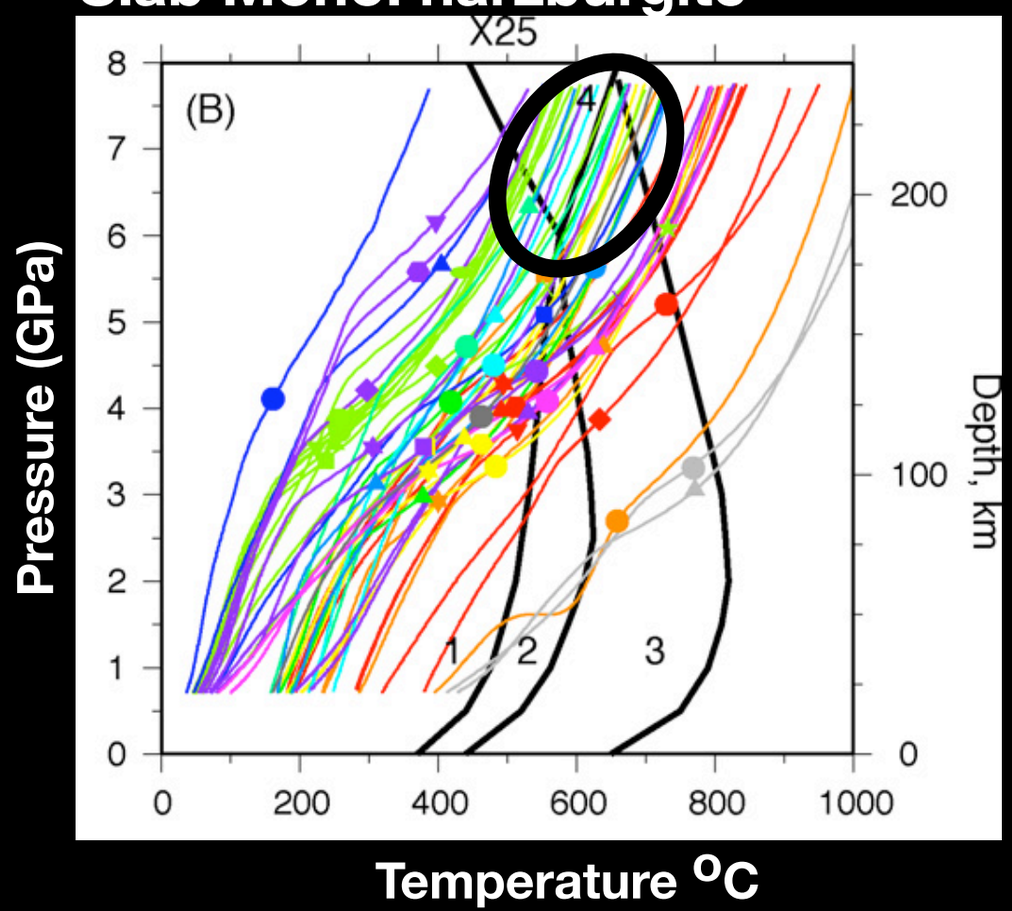


Syracuse+, EPSL, 2010

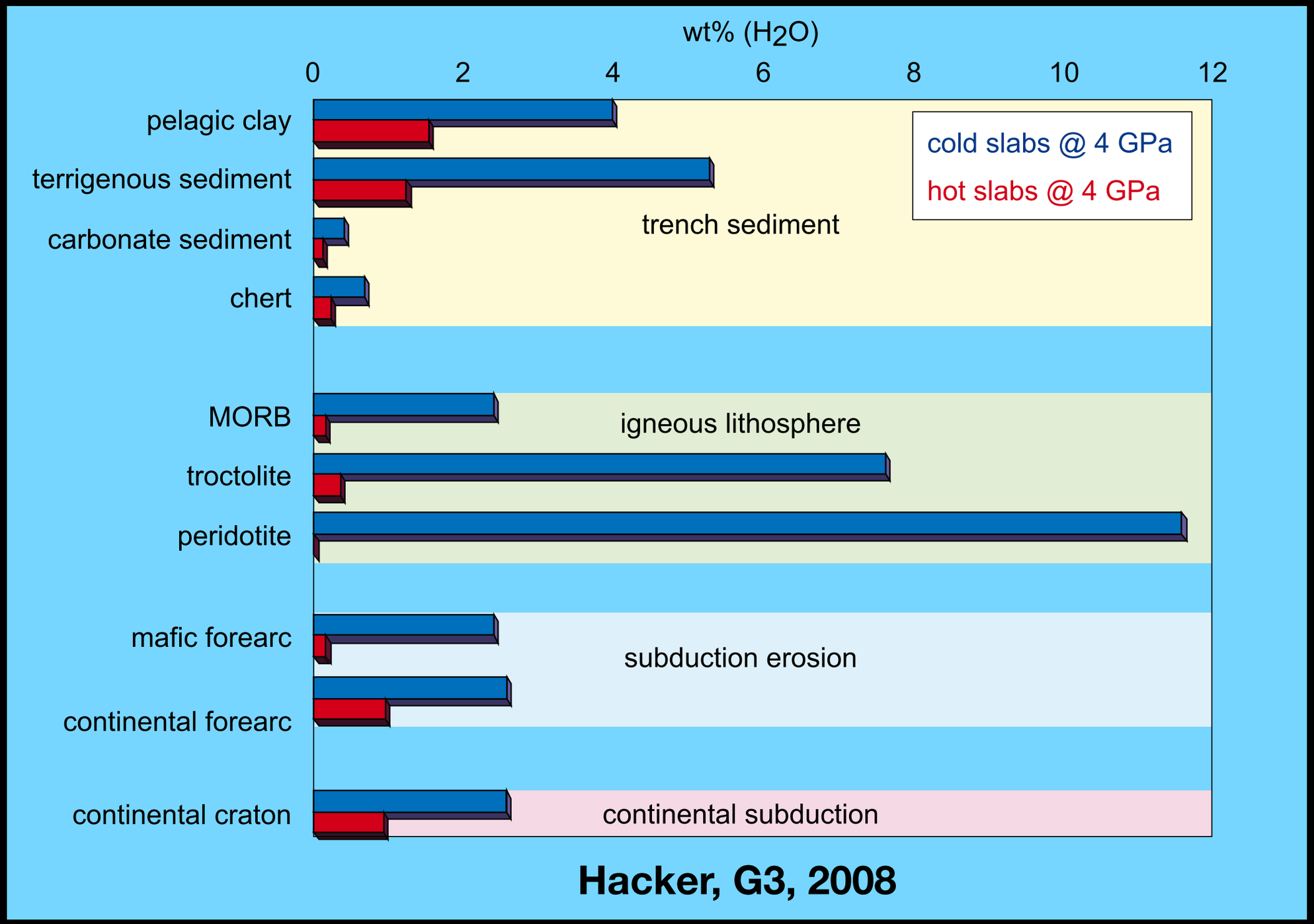
Top of Slab: basalt



Slab Moho: harzburgite



Mantle rock, not crust, most likely to transport water past arc



Earth's surface water loss to the interior

- Low end: Parai and Mukhopadhyay, EPSL, 2012: ~2x10^13 mol/yr -> lose 25% of Earth surface water in 1 Gyr
- High end: Rupke+, EPSL, 2004: ~9x10^13 mol/yr -> lose 100% in 1 Gyr

Other constraints: D/H ratio

Earth and Planetary Science Letters 497 (2018) 149–160

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

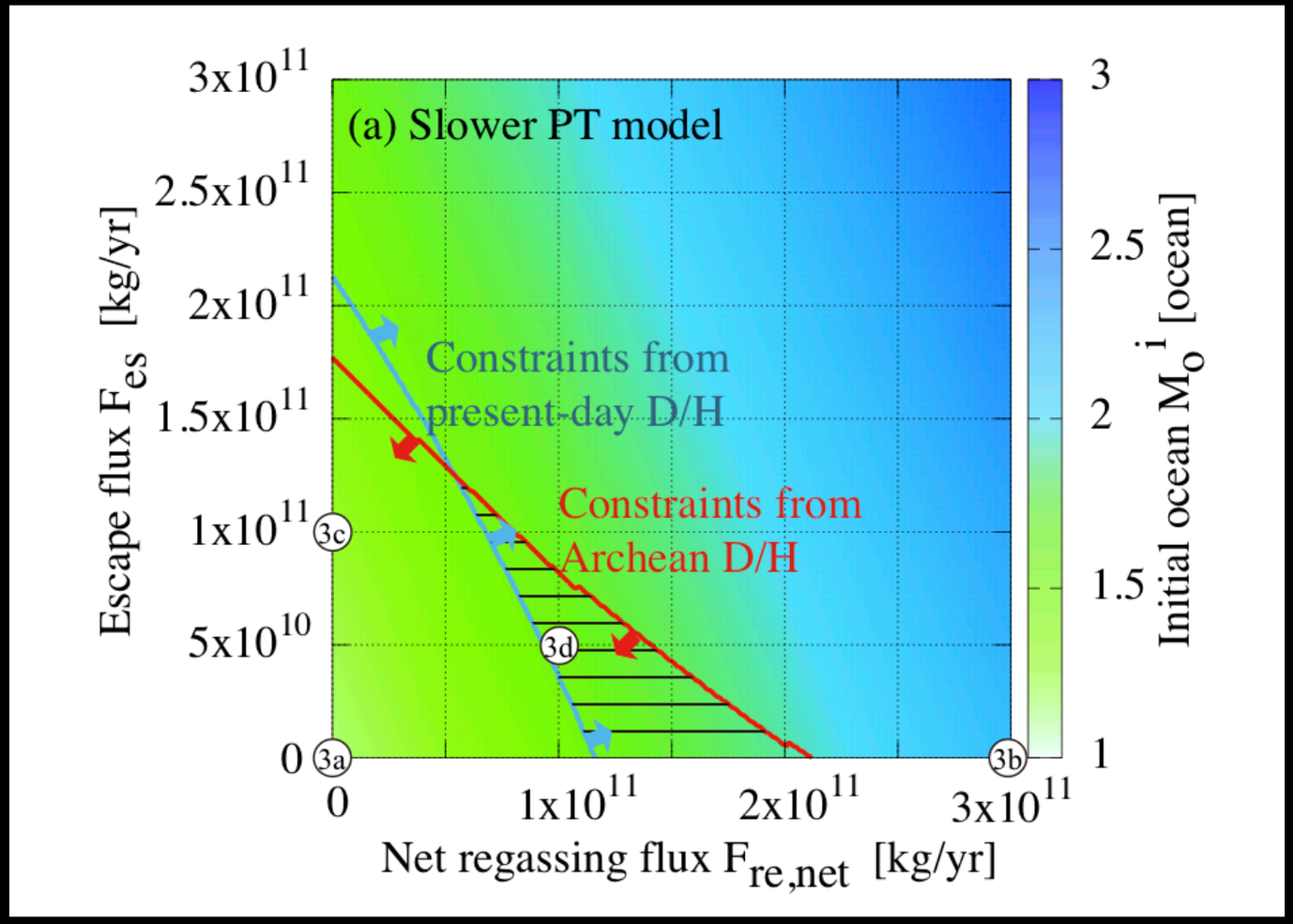
Subduction and atmospheric escape of Earth's seawater constrained by hydrogen isotopes

Hiroyuki Kurokawa *, Julien Foriel, Matthieu Laneuville, Christine Houser, Tomohiro Usui

Earth-Life Science Institute, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8550, Japan

A true ELSI collaboration

- Find 3 scenarios to fit the current observations.
- Suggest observations to test the scenarios.
- On scenario requires regassing one ocean: sure, that's easy.



The Earth is not a sponge, but hydrogen can leak into the interior

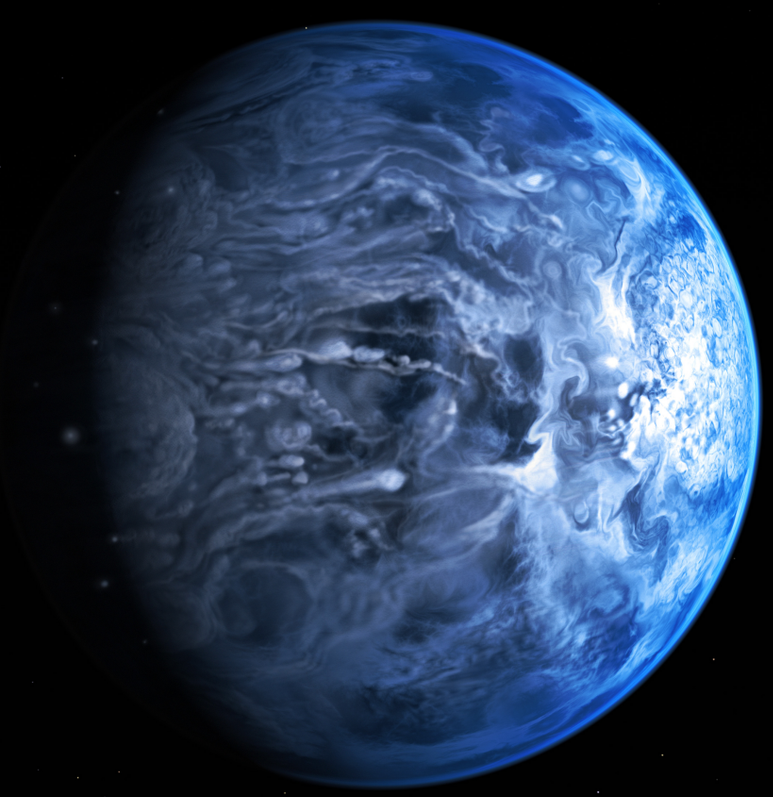
- Cases where subduction does manage to shove water into its interior, the hydrogen is not stable at interior pressures and will likely return to the surface.

- If water (i.e. H) could be stored in the lower mantle rocks and if it was transported to the lower mantle efficiently, then we would have no ocean.

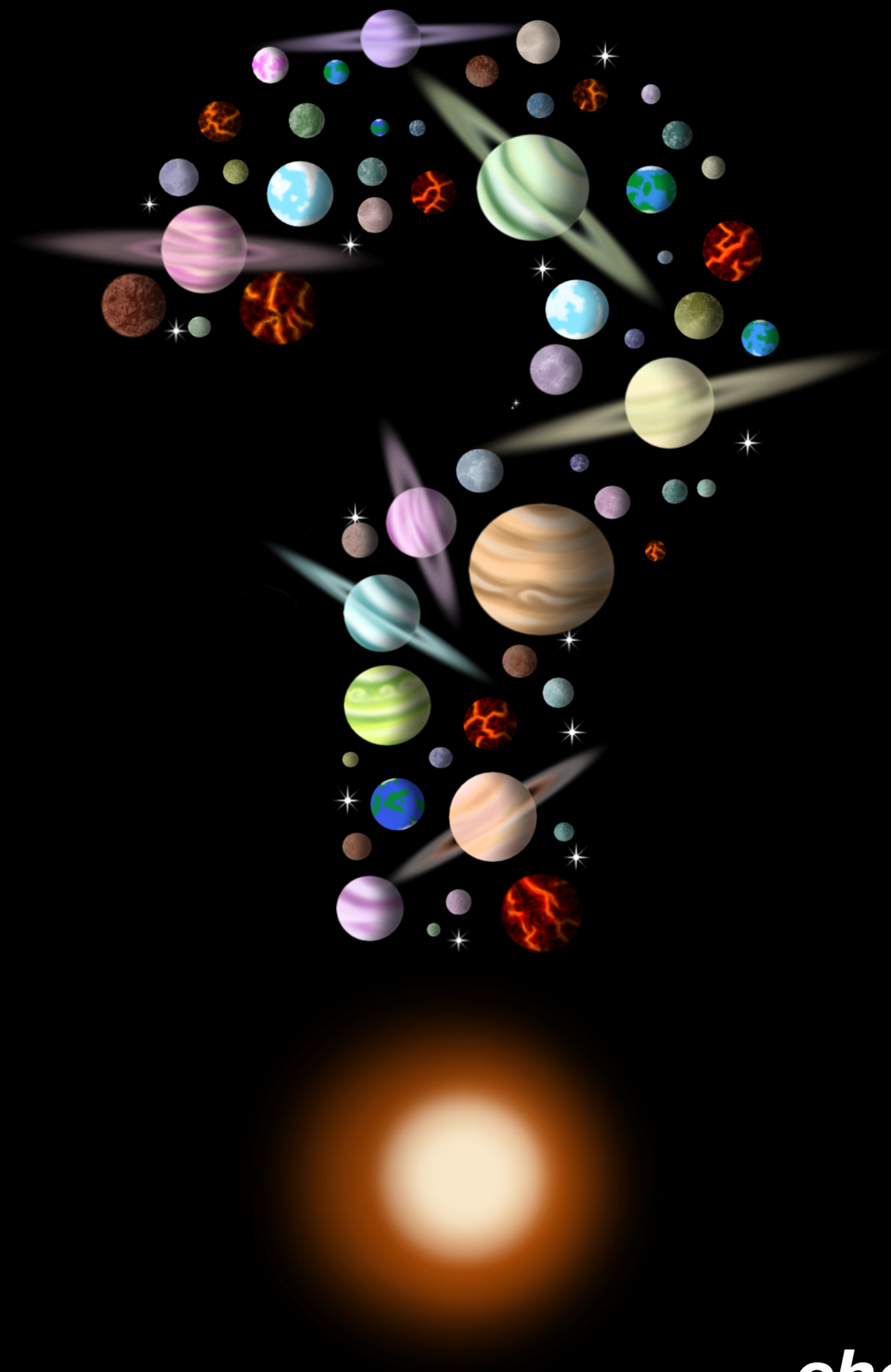
What if liquid water has little to do with water and everything to do with rock?

Rockability?

The conditions for which rock can develop and sustain feedbacks between the surface and the interior controls the state of water at the surface.

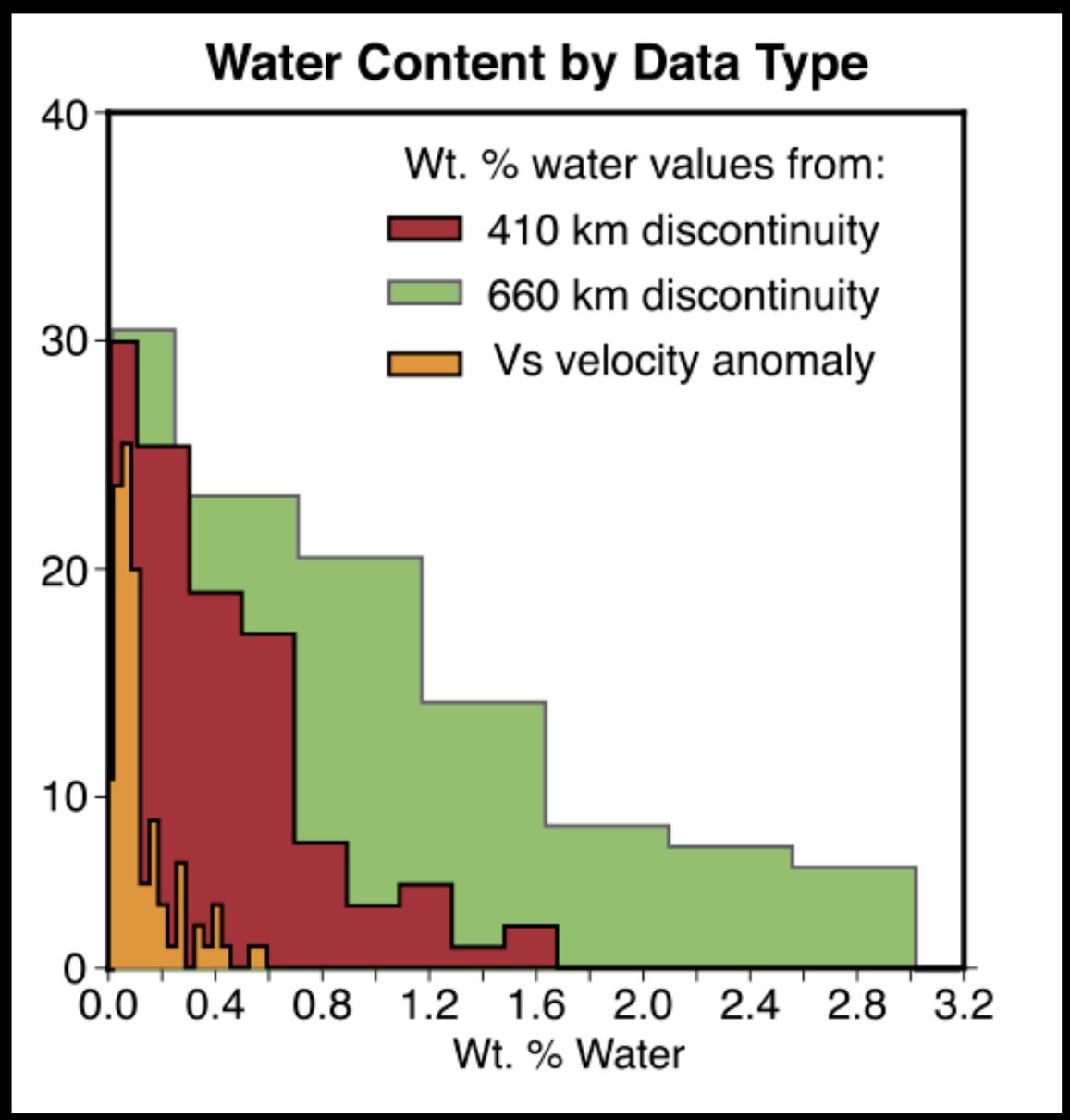


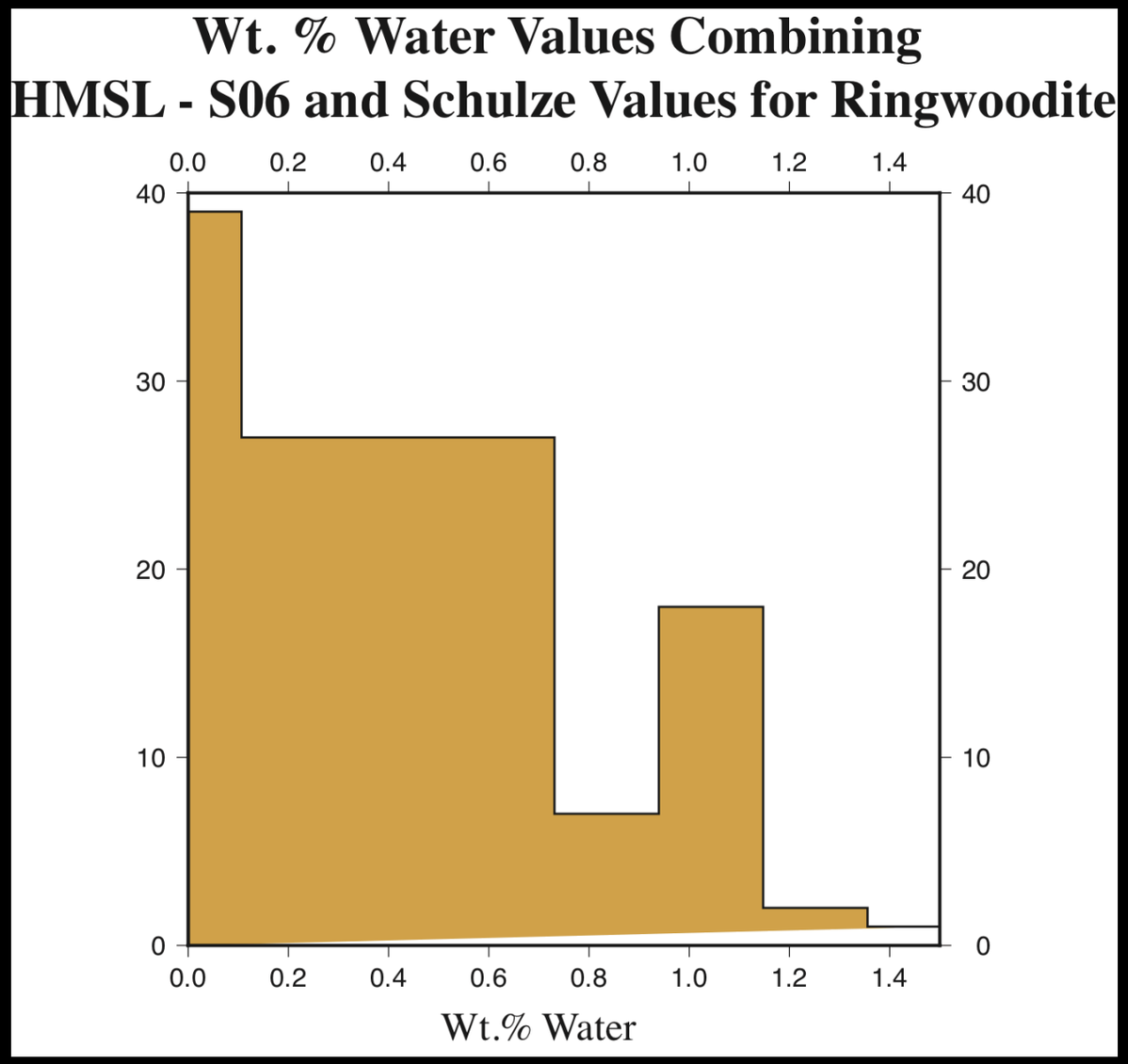
© Japan Meteorological Agen/SI/REX



chouser@elsi.jp

Using the Schulze+ 2018 results





Houser, EPSL, 2016