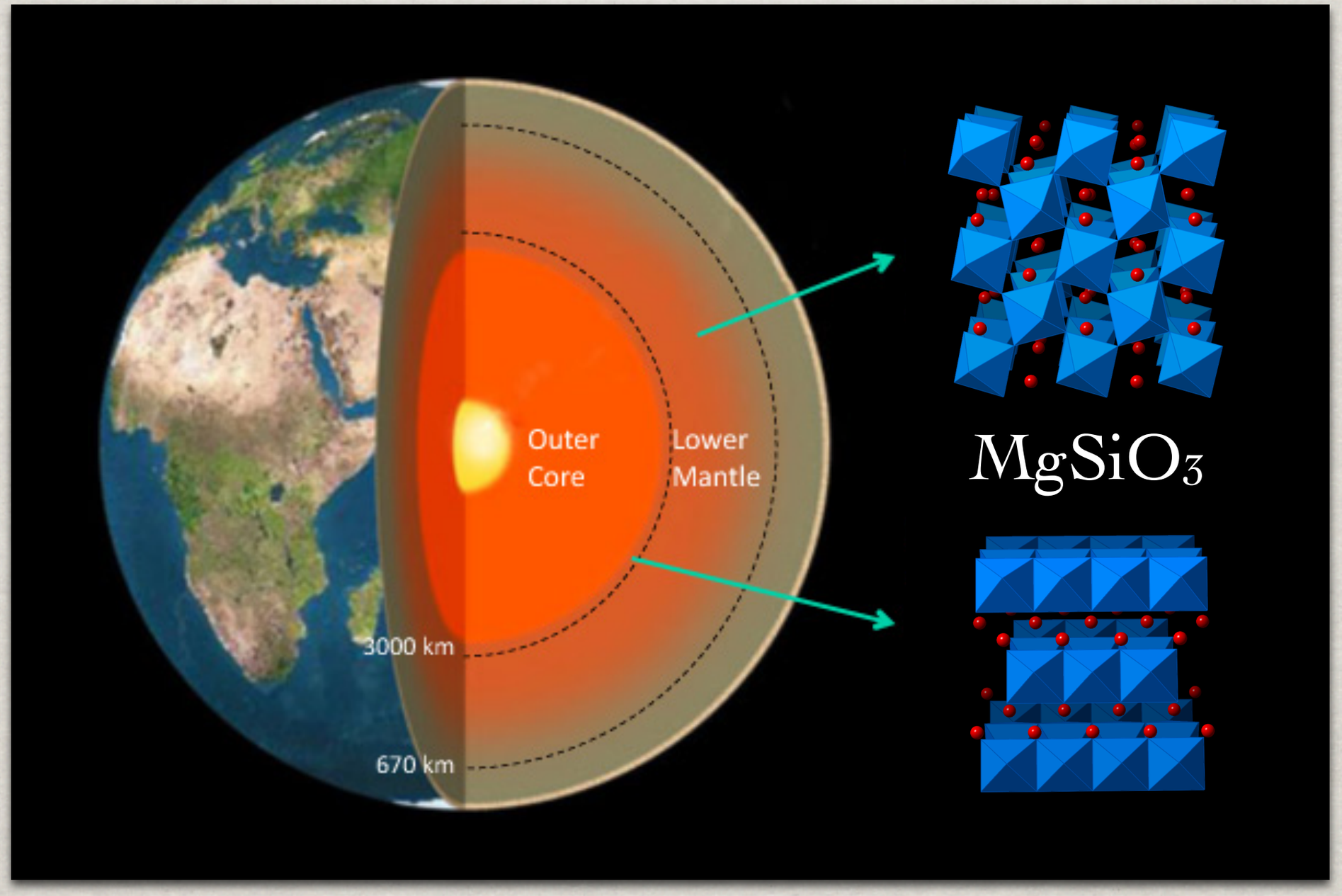
Phase Transitions in the Lowermost Mantle

S.-H. Dan Shim[1],
B. Grocholski[2], K. Catalli[3], and V. Prakapenka[4]

[1]Arizona State University, [2]Smithsonian Institution,
[3]Livermore National Lab [4]University of Chicago

Thanks to: NSF, DOE, NNSA

Post-Perovskite Transition



Murakami et al. (2004) Science, Oganov and Ono (2004) Nature, Shim et al. (2004) GRL

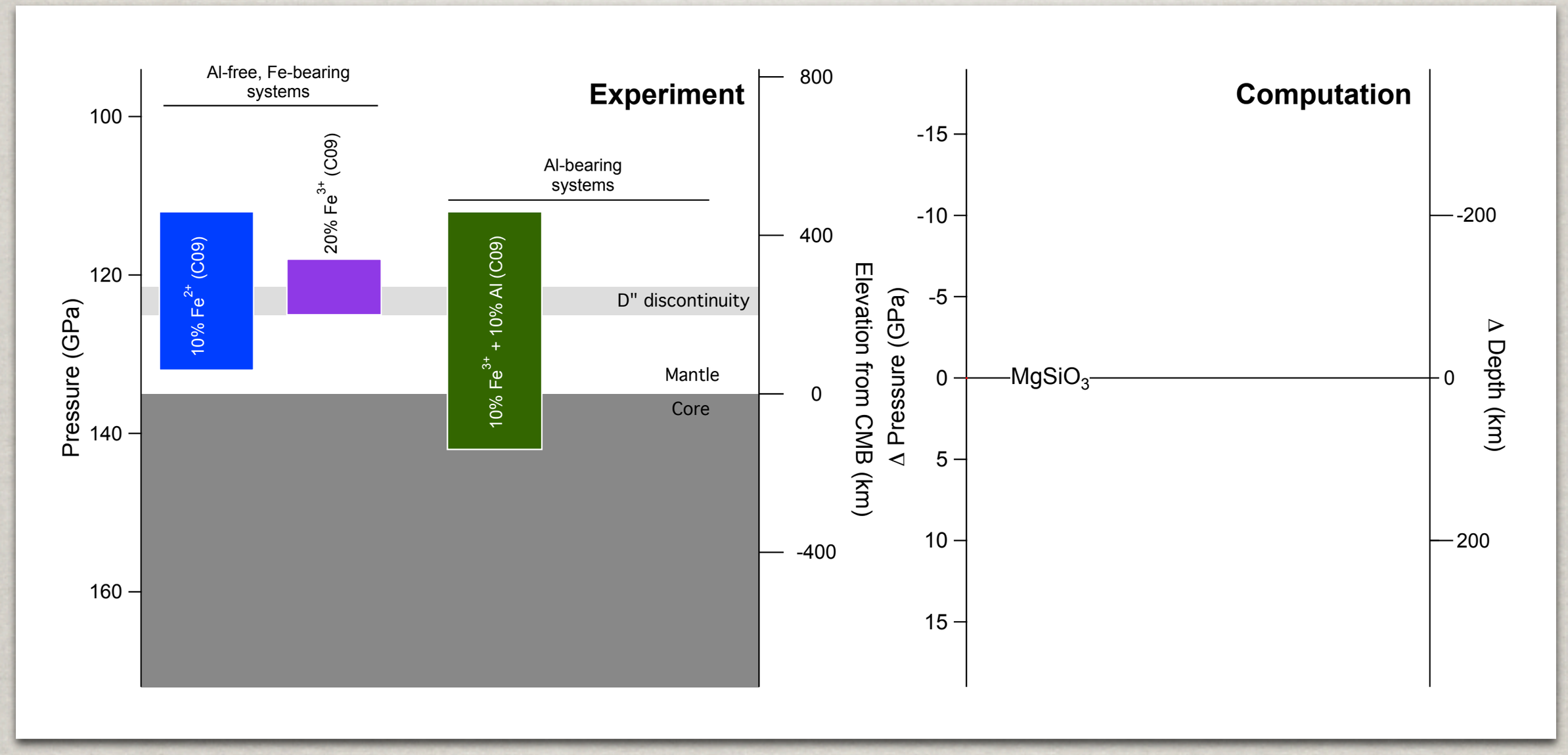
The perovskite ➛ post-perovskite transition was found at the pressure-temperature conditions similar to those of the D" discontinuity.

Discontinuity and Phase Boundary

Discontinuity and Phase Boundary

- Depth vs. Pressure
- Thickness vs. Width of mixed phase region

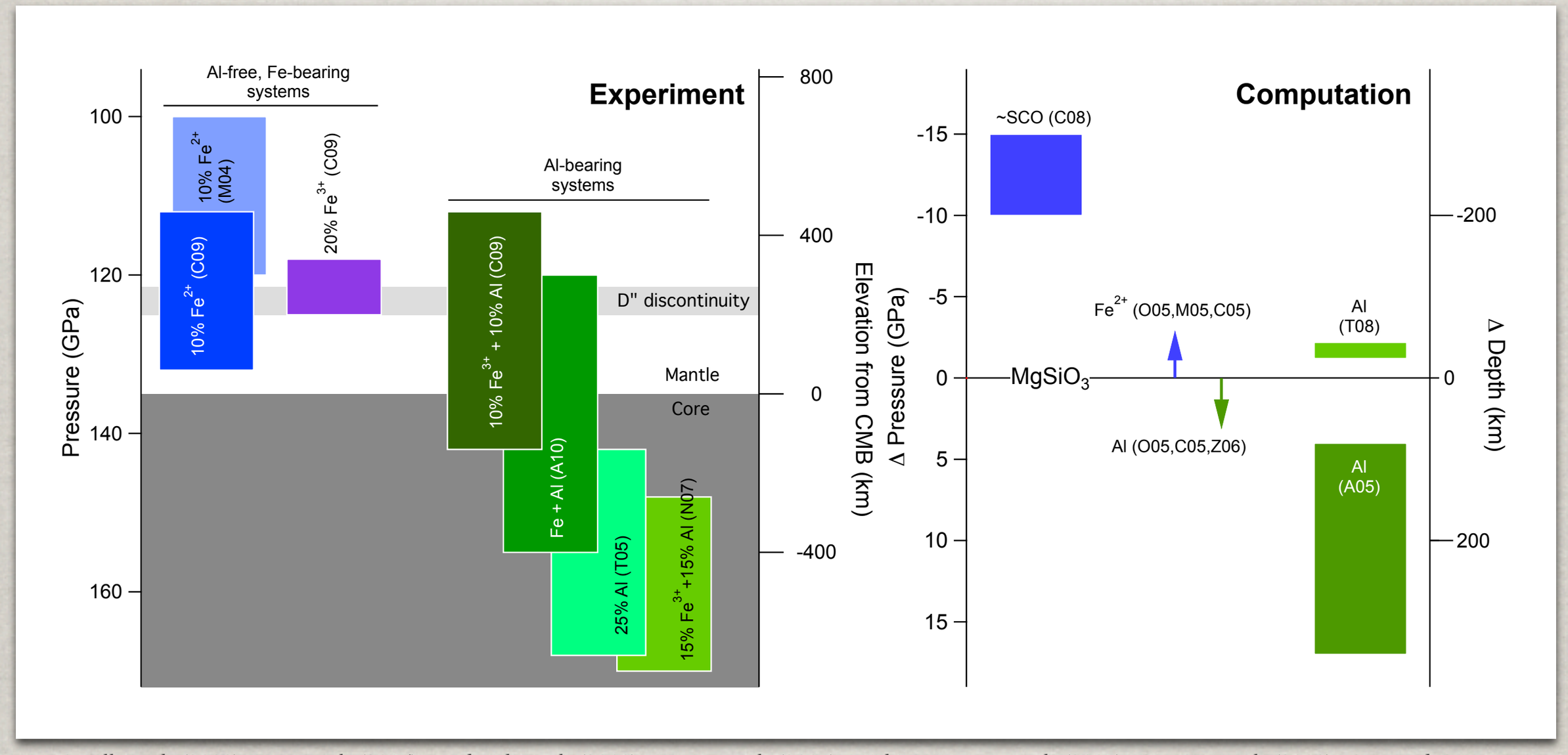
Compositional Effects



Catalli et al. (2009) Nature

Both Al and Fe^{2+} increase the thickness of the transition much greater than that of the D" discontinuity

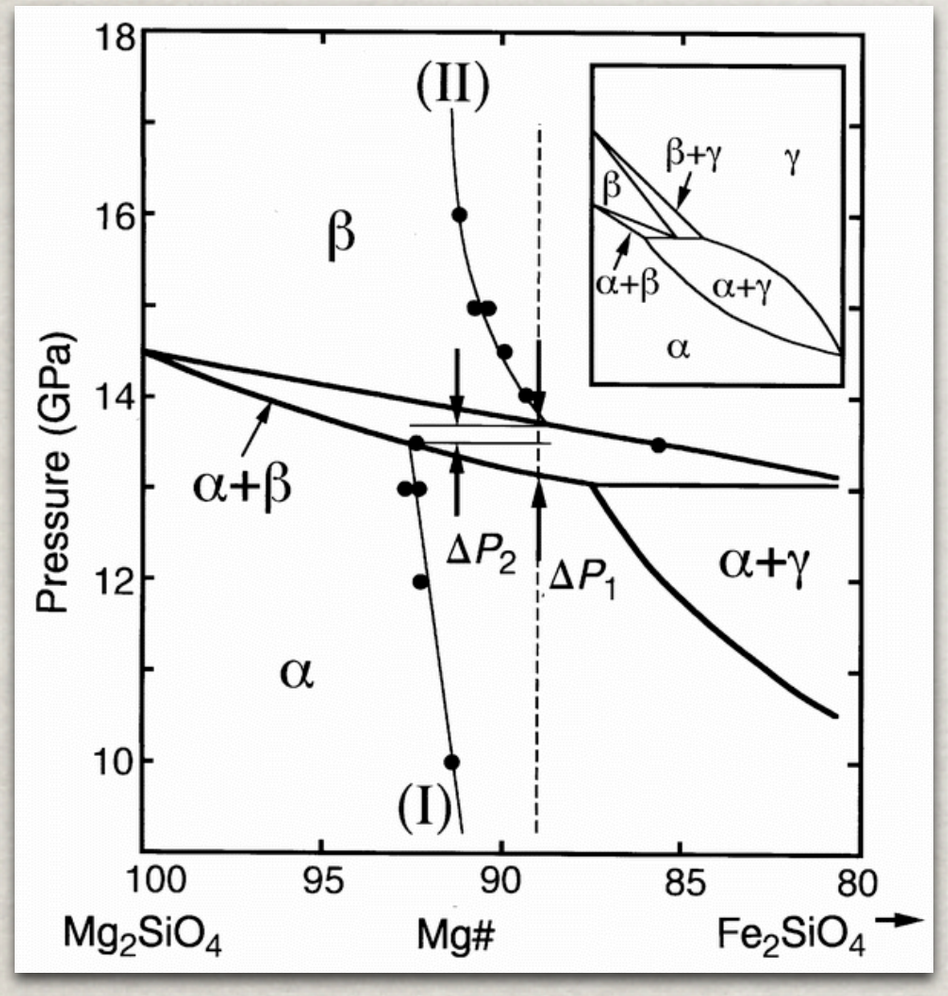
Compositional Effects



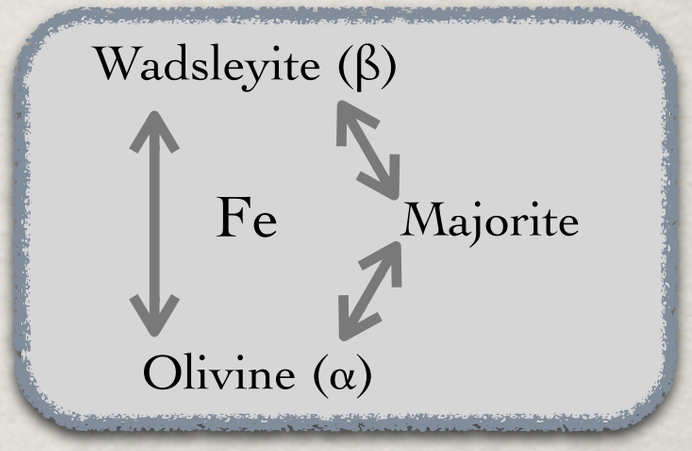
Catalli et al. (2009); Mao et al. (2004); Andrault et al. (2010); Tateno et al. (2005); Nishio-Hamane et al. (2007); Caracas et al. (2008); Ono and Oganov (2005); Mao et al. (2005); Caracas et al. (2005); Zhang and Oganov (2006); Tsuchiya et al. (2008); Akber-Knutson et al. (2005)

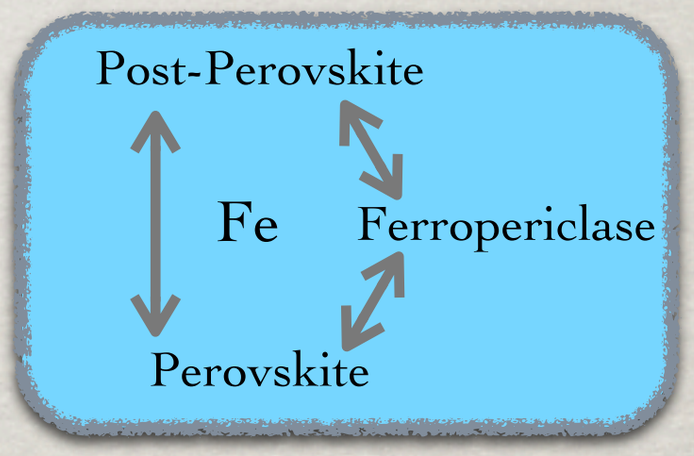
Both Al and Fe^{2+} increase the thickness of the transition much greater than that of the D" discontinuity

Element Partitioning



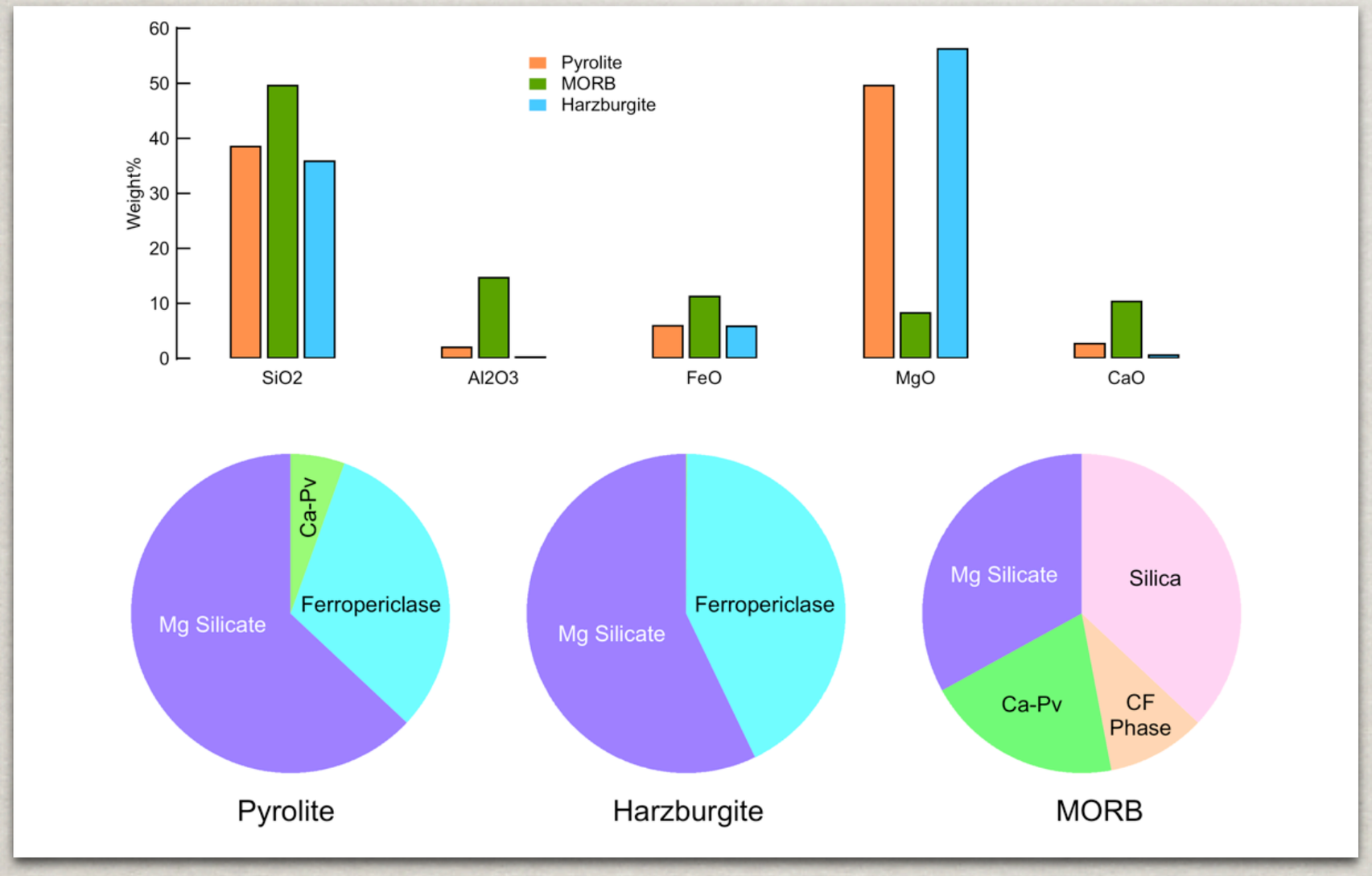
Irifune et al. (1998) Nature

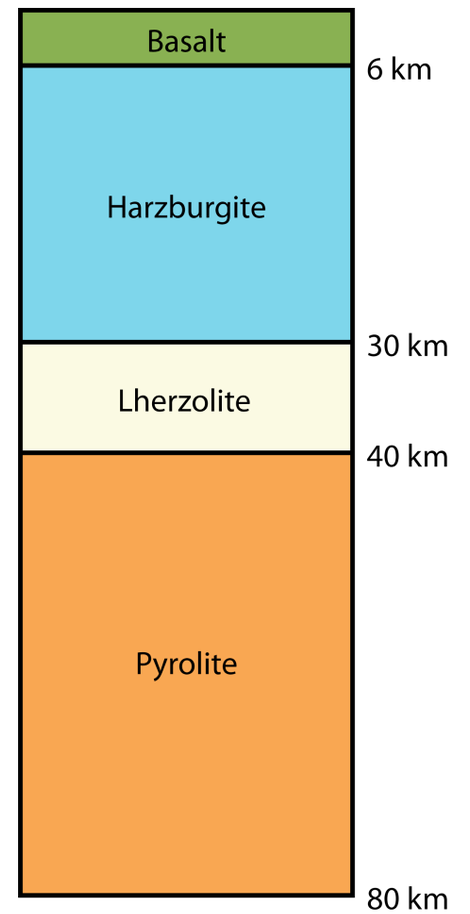




Thickness of a phase transition can be decreased significantly by element partitioning with phases which do not participate the phase transition.

Mantle Rocks

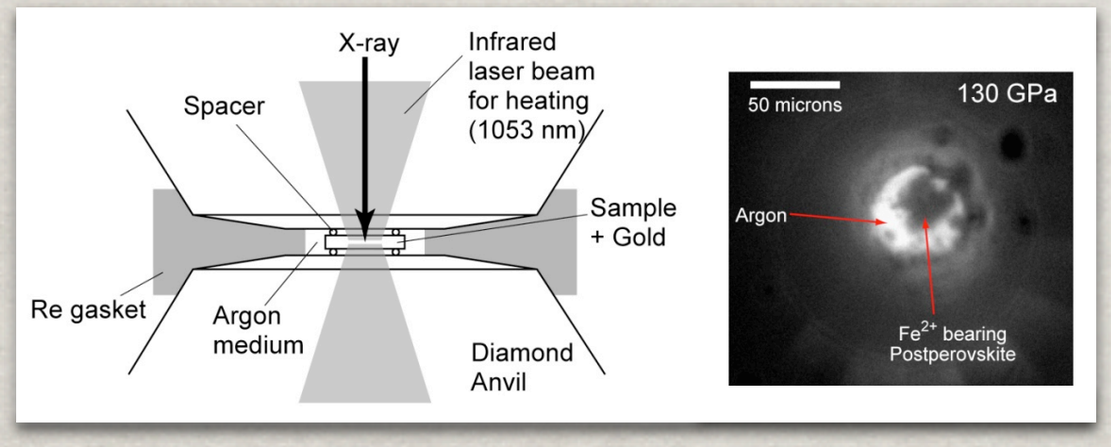


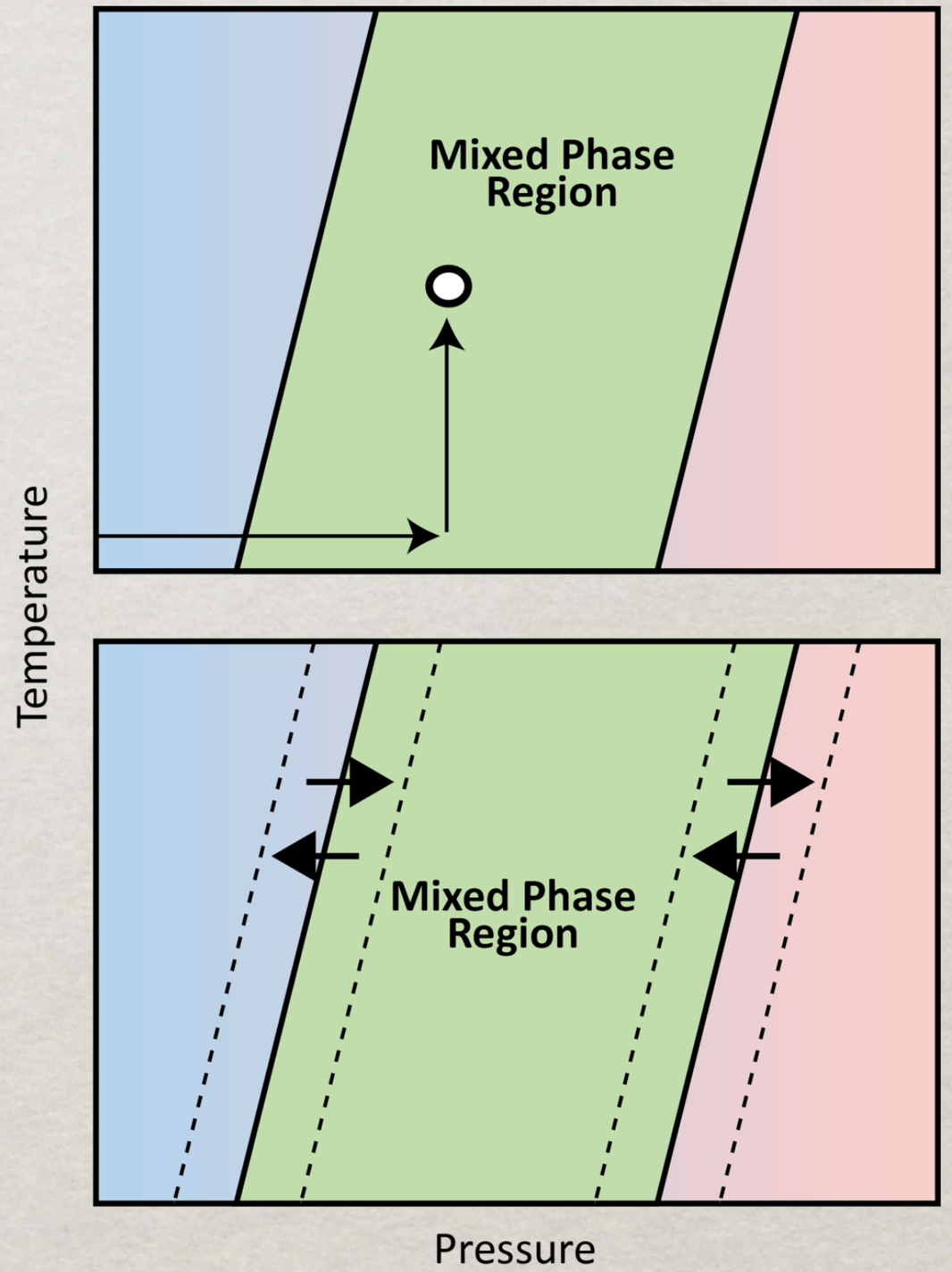


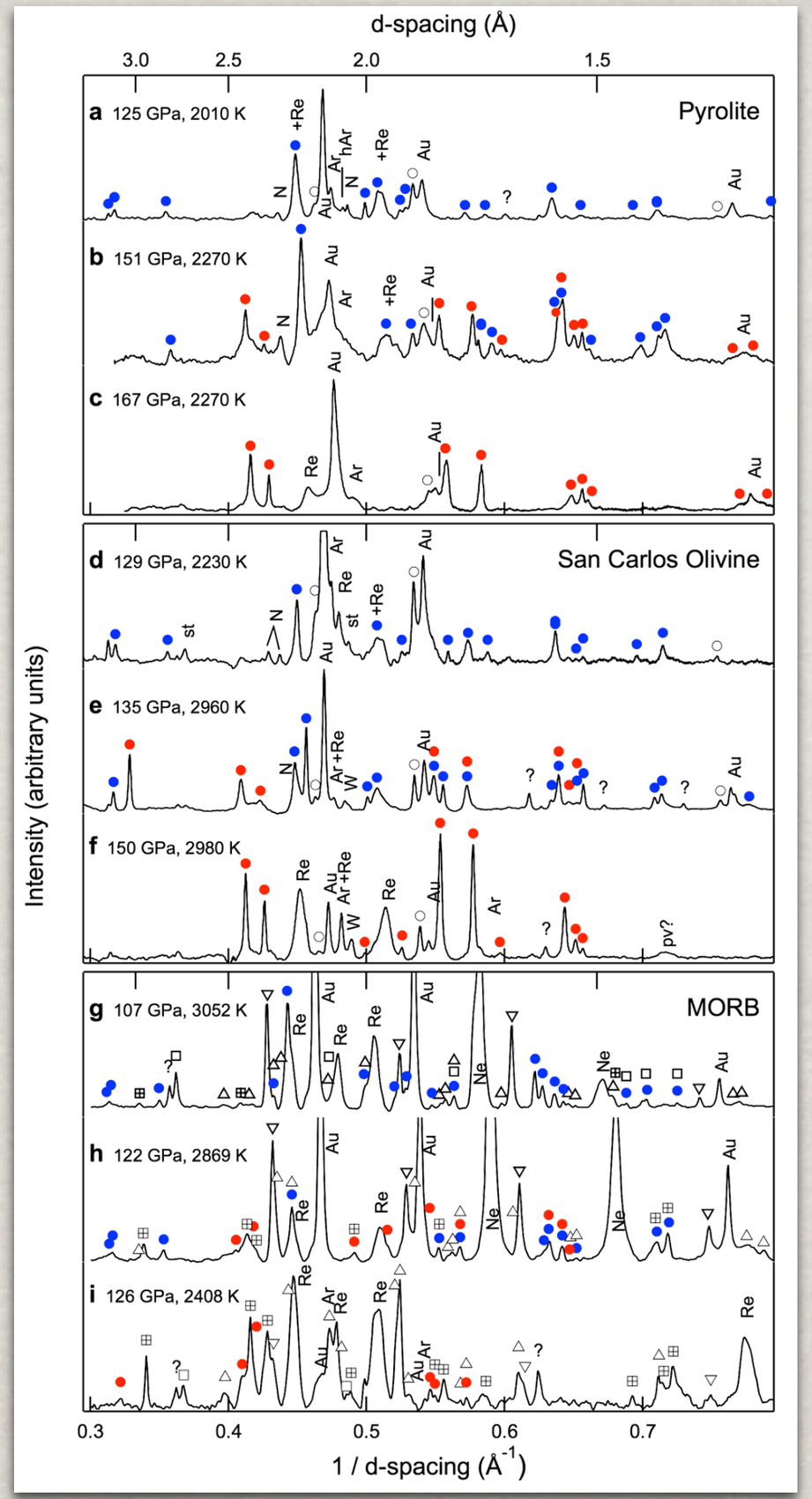
Oceanic Lithosphere
by Ringwood (1982)

Experiments

- ✳ Crystalline (San Carlos olivine), Glass (Pyrolite and MORB) starting materials
- ✳ Ar/Ne medium, Gold pressure scale
- ✳ Two different types of measurements
  - Heating of fresh starting materials
  - Reversal measurements







Perovskite

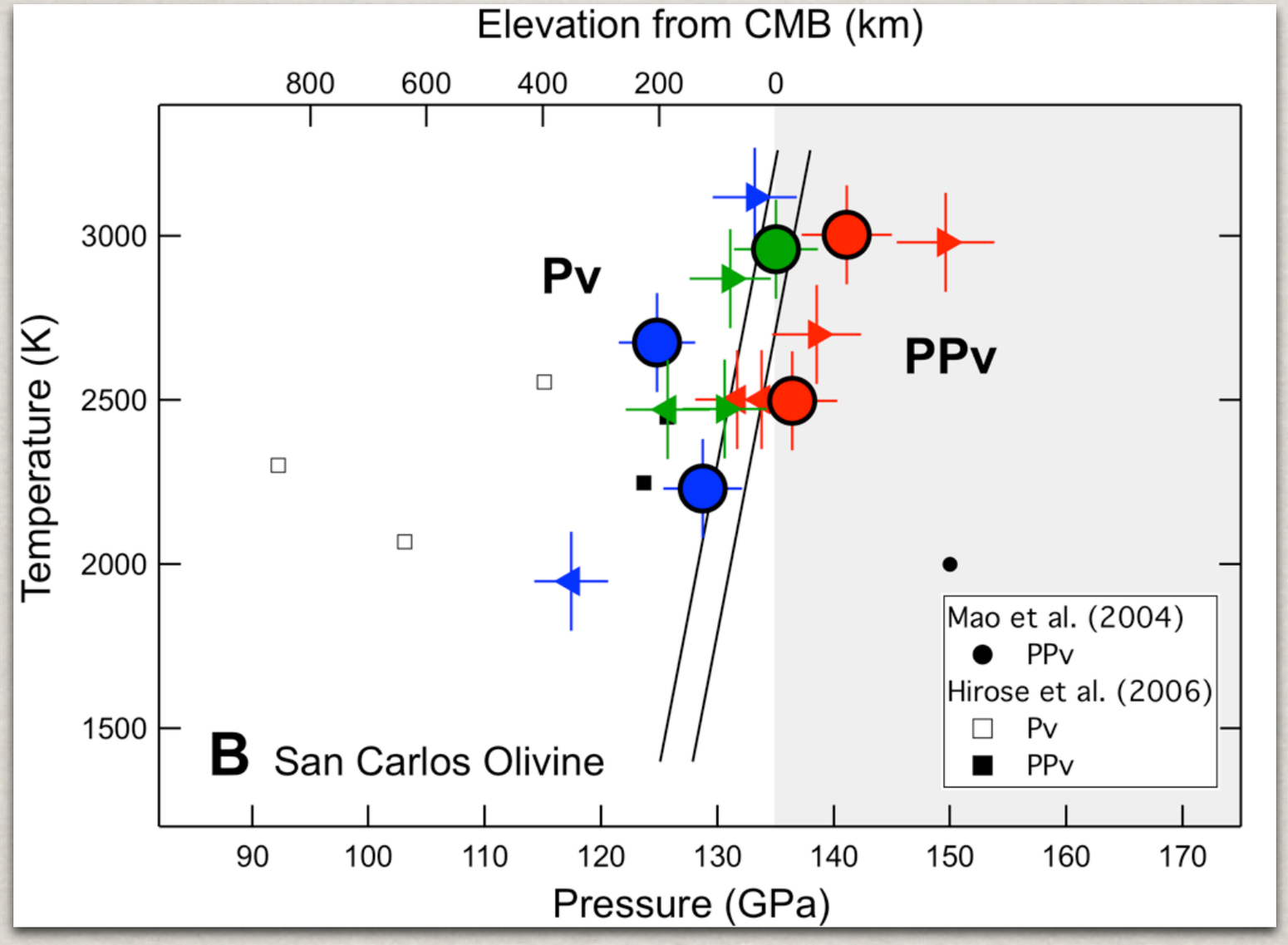
Post-perovskite

Grocholski et al. (2012) PNAS

Composition Comparison

	Fe in Pv	Al_2O_3 in Pv	Ferropericlase
Pyrolite	~10 mol%	5 mol%	~30 mol%
San Carlos olivine	~10 mol%	0 mol%	50 mol%

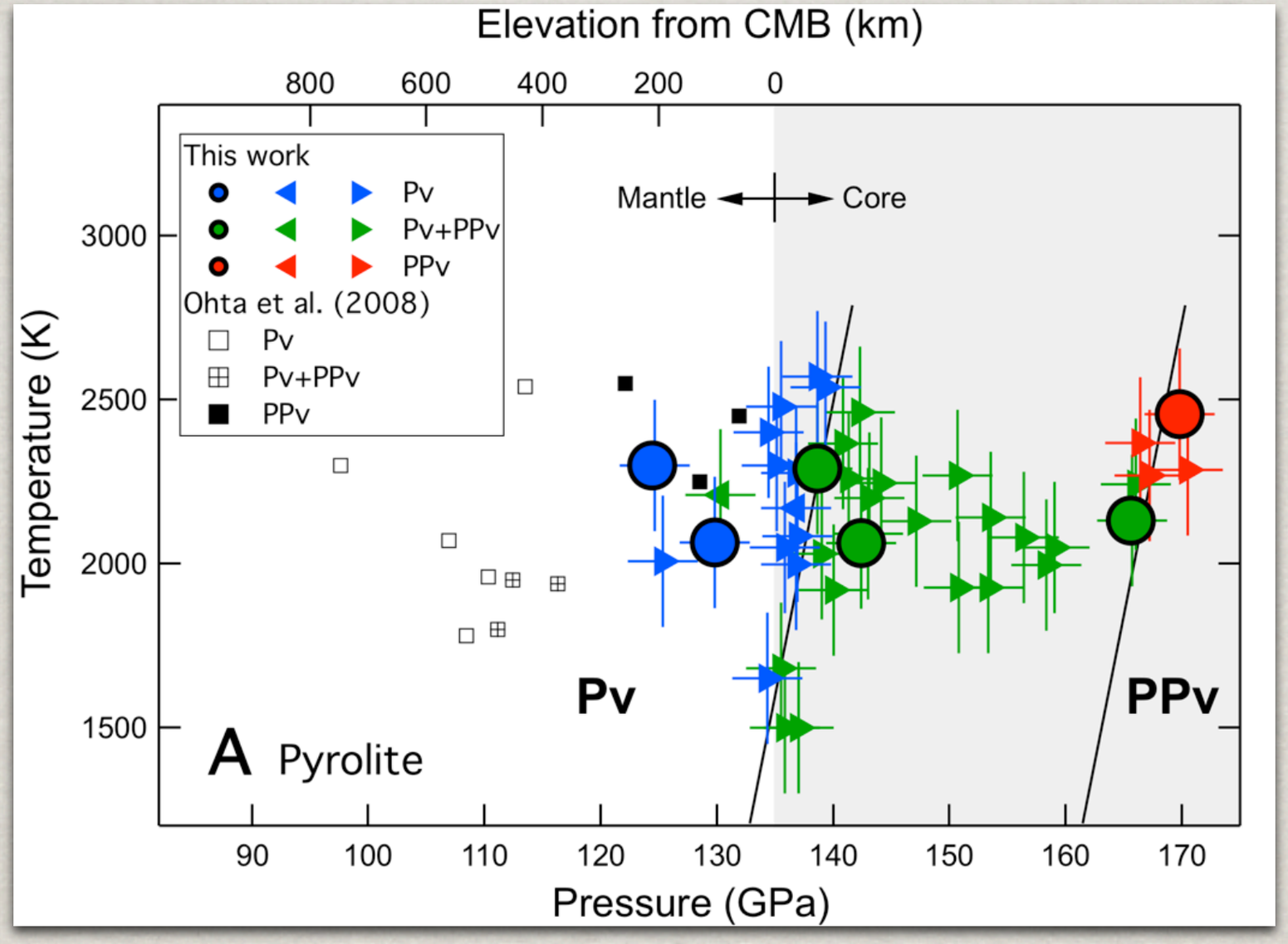
San Carlos Olivine



Grocholski et al. (2012) PNAS

Sharp post-perovskite transition in San Carlos olivine

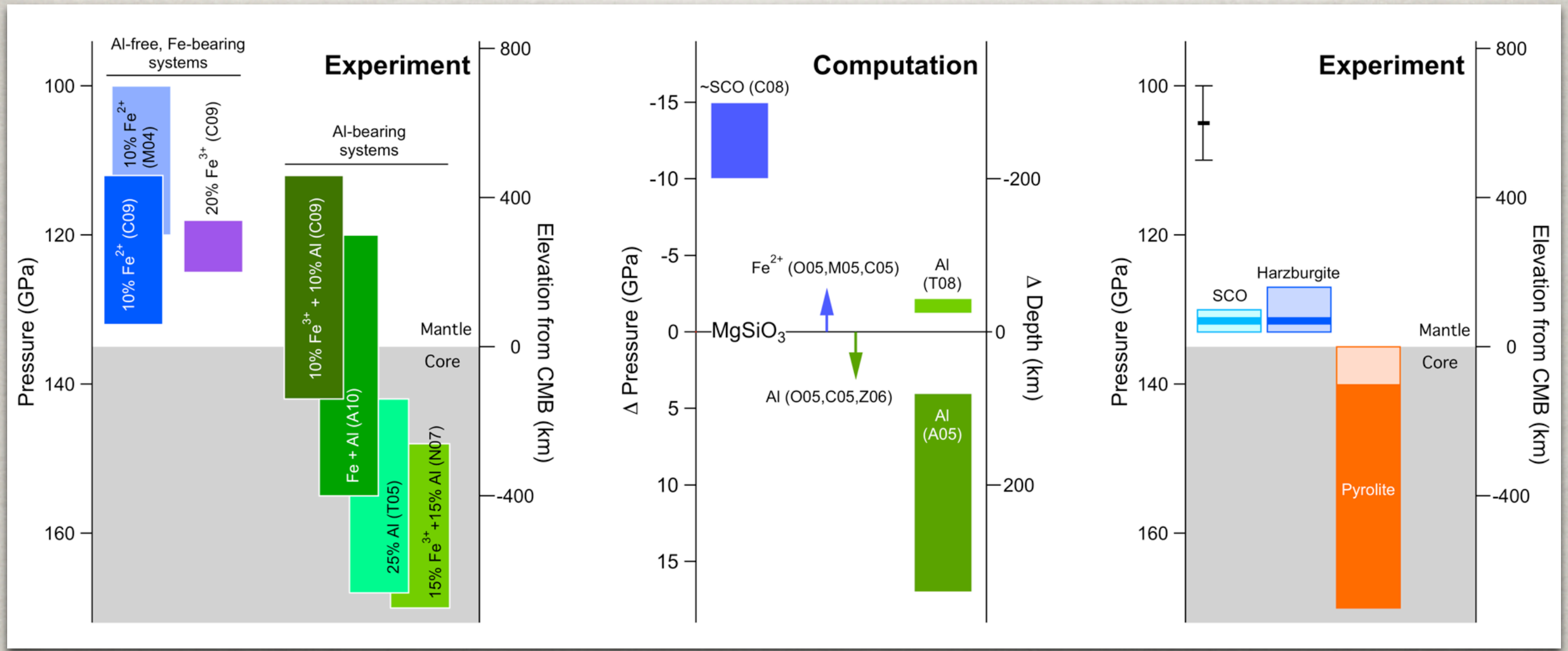
Pyrolite



Grocholski et al. (2012) PNAS

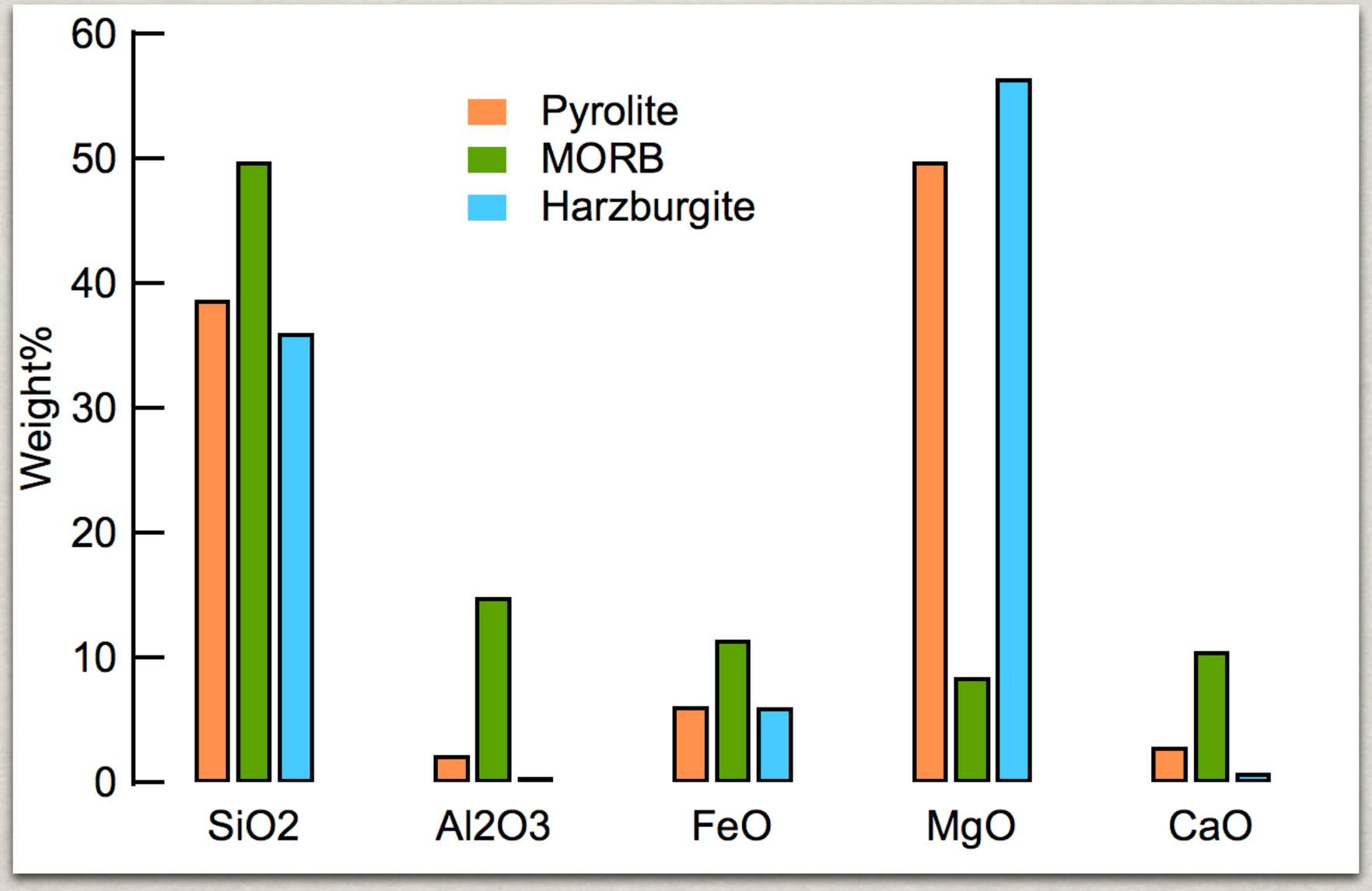
Broad post-perovskite transition in a pyrolitic mantle

Comparison



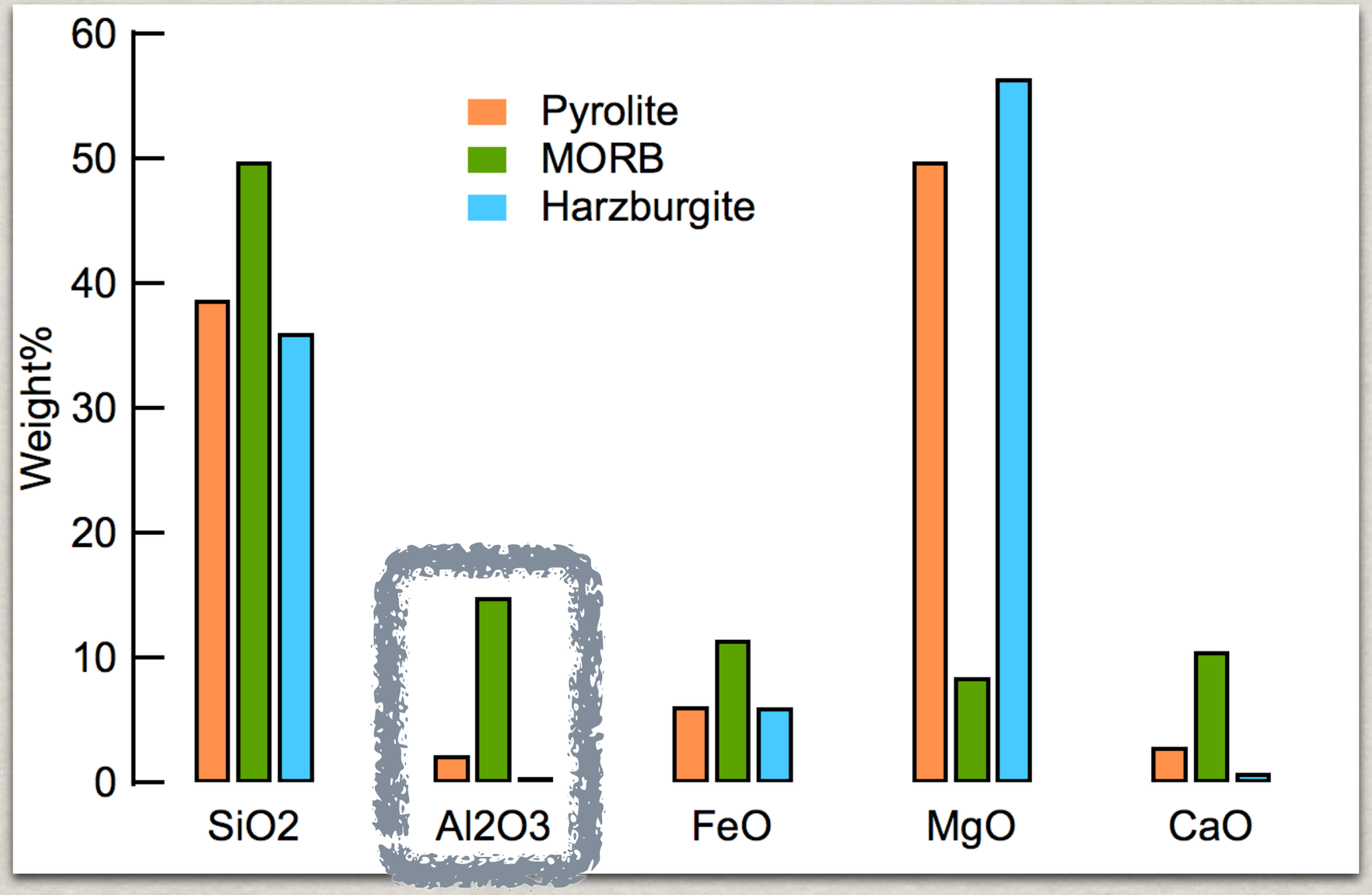
Grocholski et al. (2012) PNAS

Composition of MORB



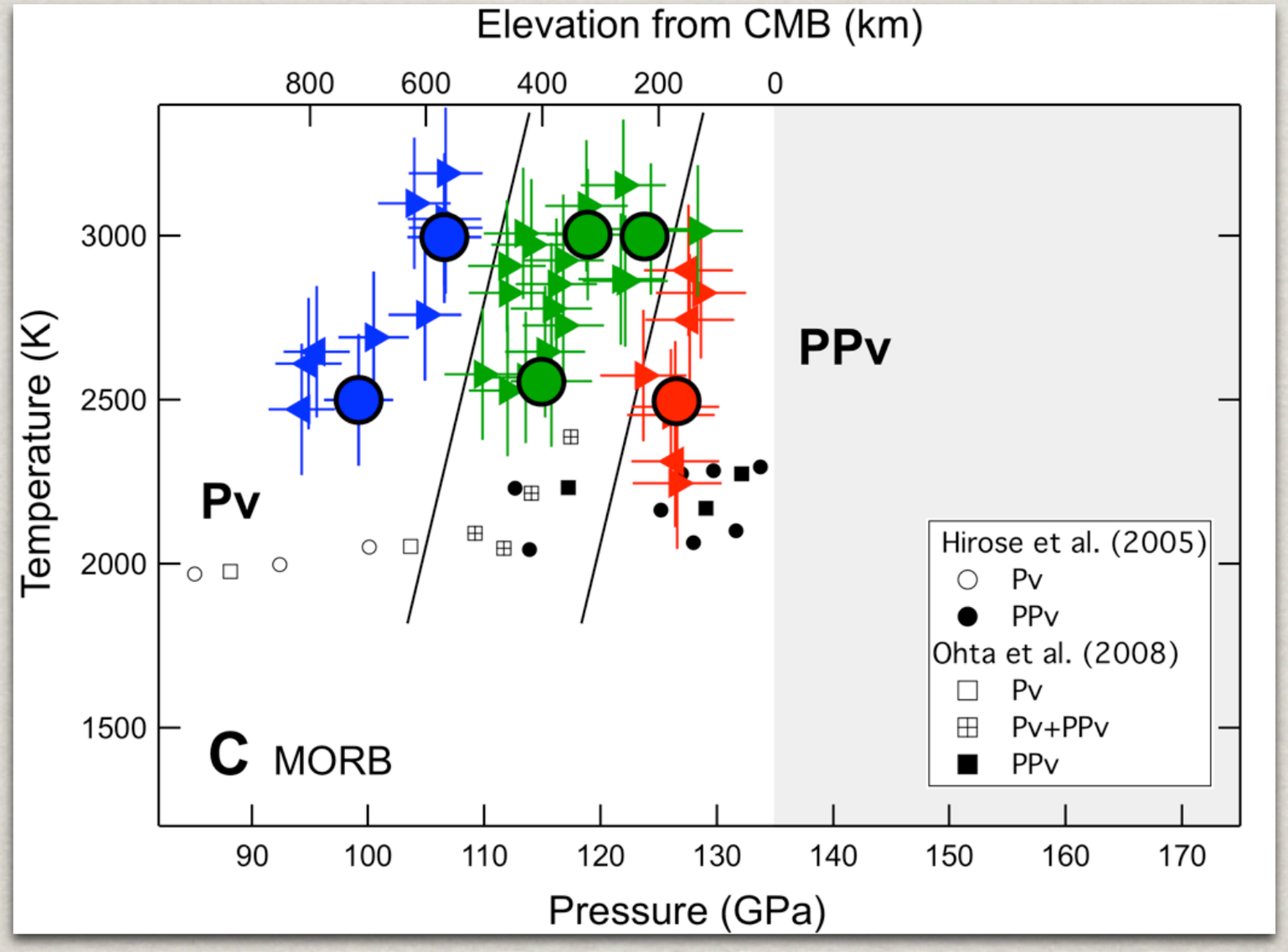
MORB has a very large amount of Al and Si

Composition of MORB



MORB has a very large amount of Al and Si

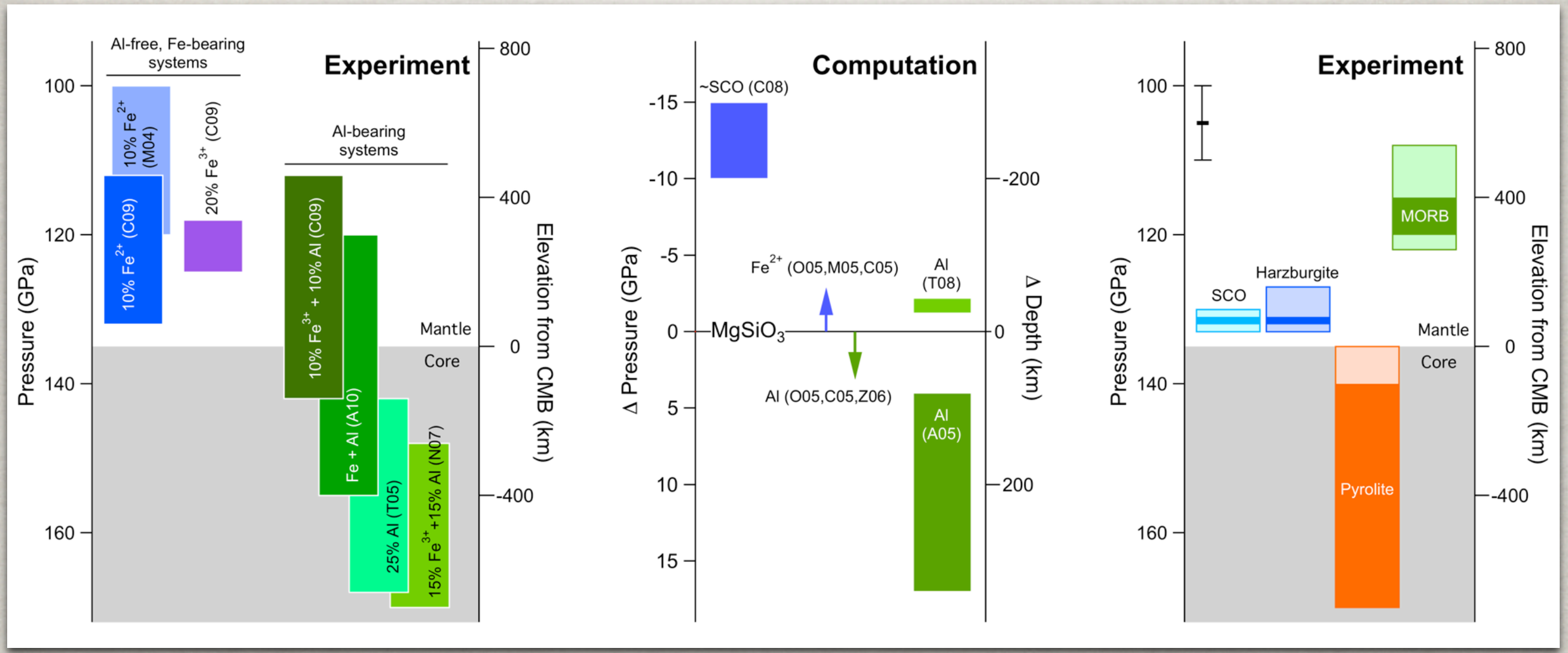
MORB



Grocholski et al. (2012) PNAS

Sharp, shallow post-perovskite transition in MORB

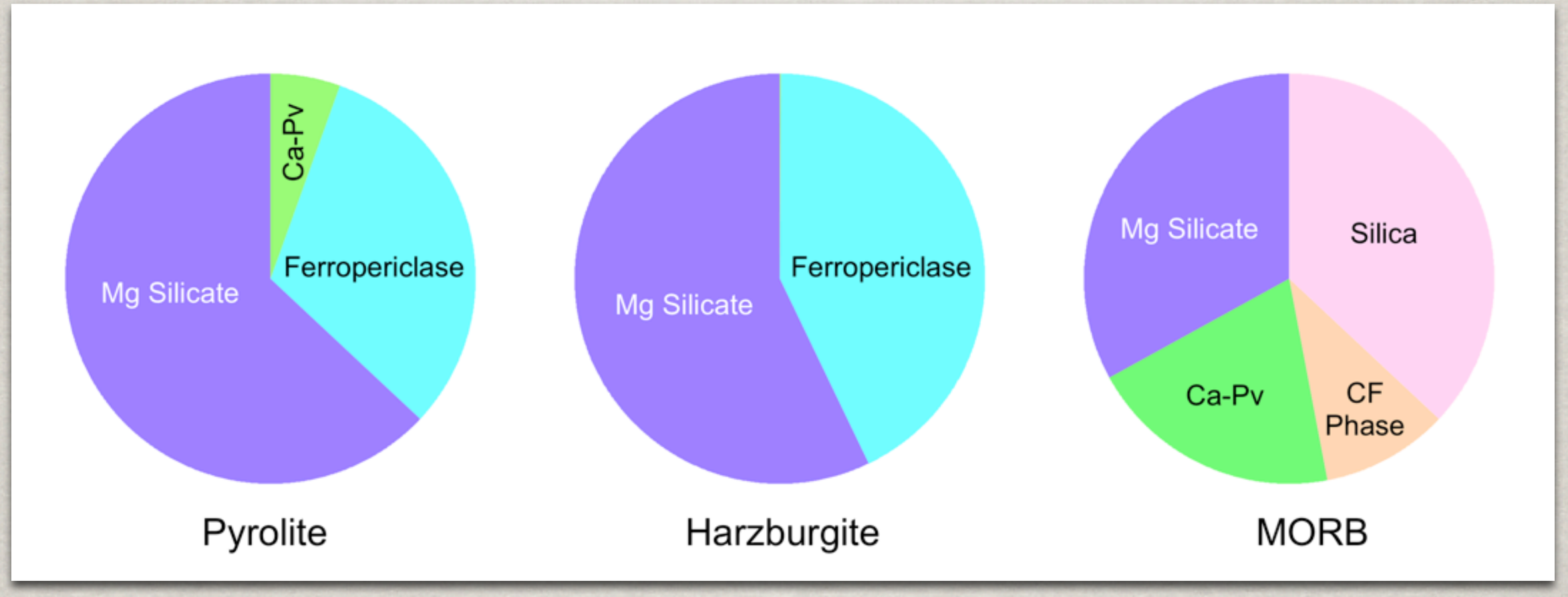
Comparison



Grocholski et al. (2012) PNAS

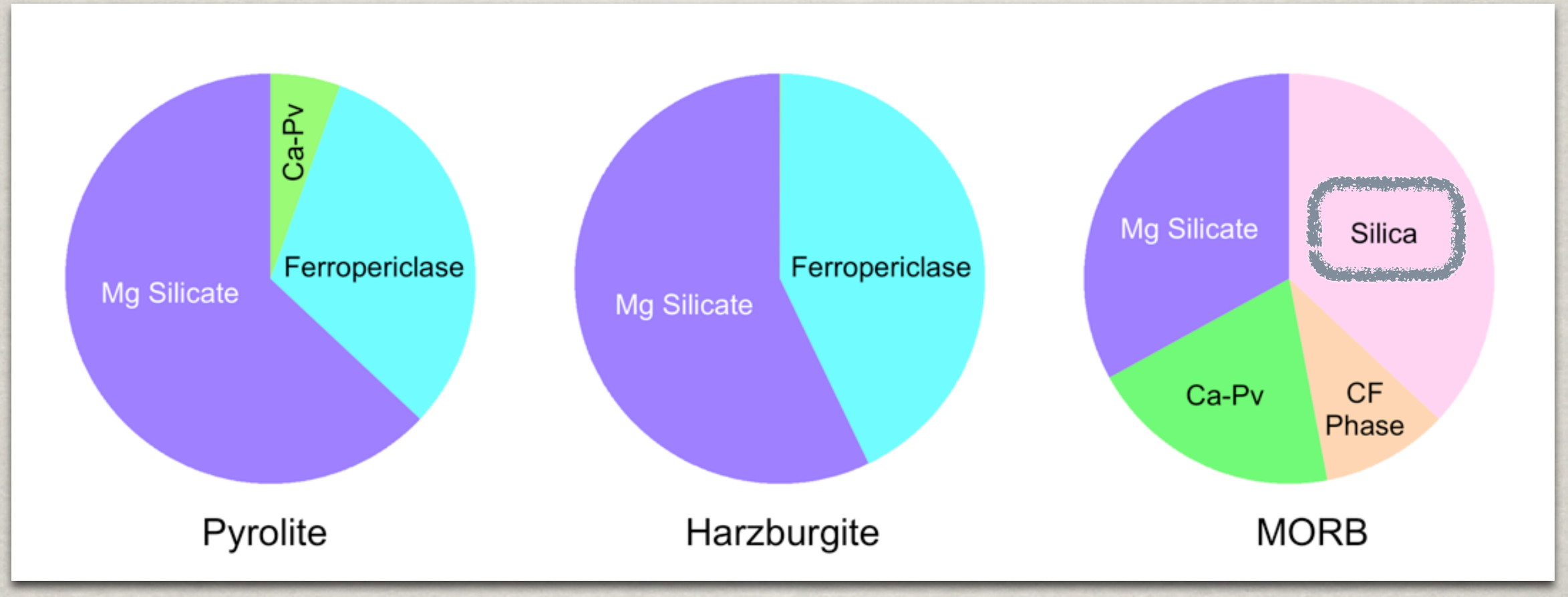
MORB has a shallow post-perovskite boundary

Mineralogy of Mantle Rocks



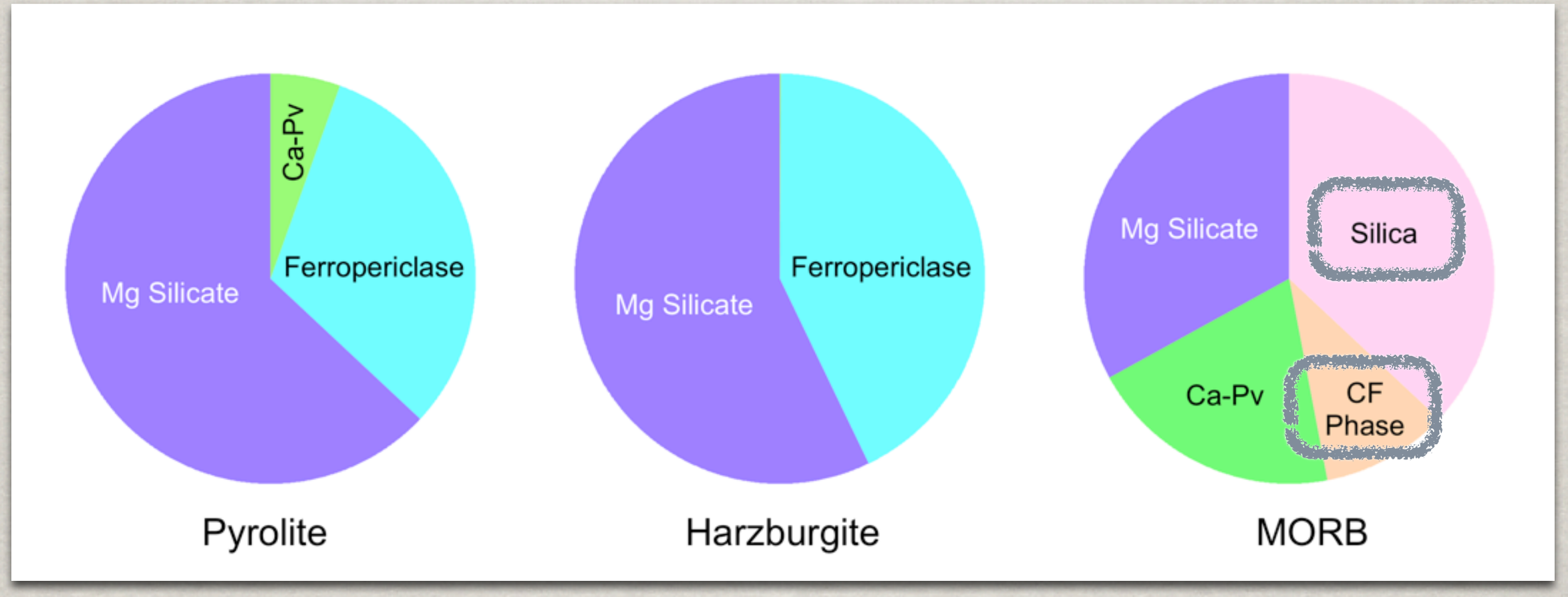
MORB contains large amounts of Al-bearing minerals

Mineralogy of Mantle Rocks



MORB contains large amounts of Al-bearing minerals

Mineralogy of Mantle Rocks



MORB contains large amounts of Al-bearing minerals

Element Partitioning

Less Al ⟷ More Al

Harzburgite

Perovskite

Fe Ferropericlase

Post-perovskite

Pyrolite

Perovskite

Al **Fe** Ferropericlase

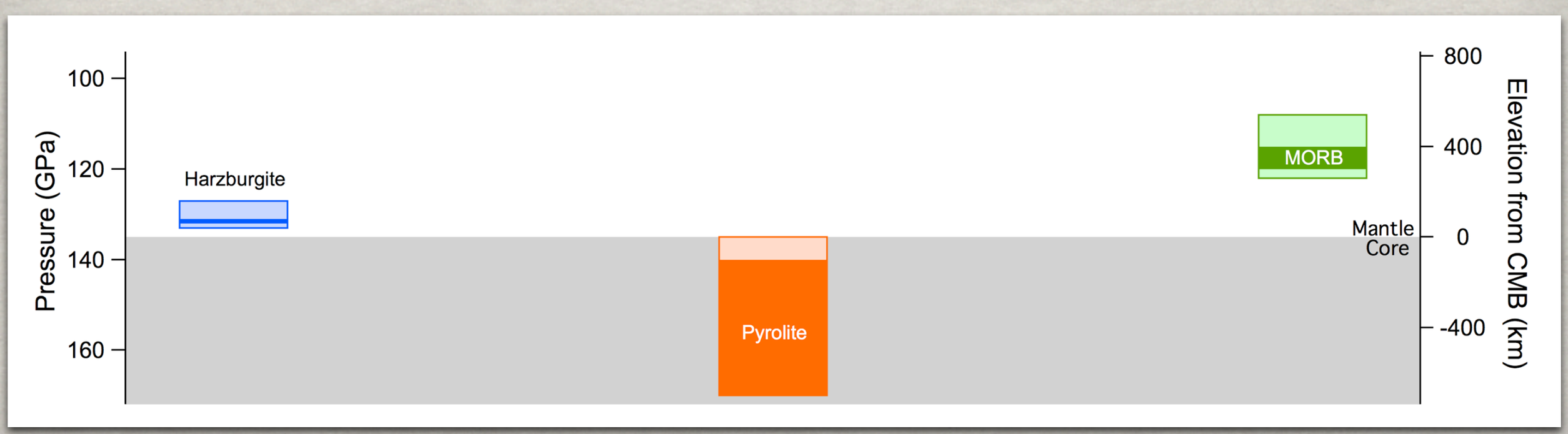
Post-perovskite

MORB

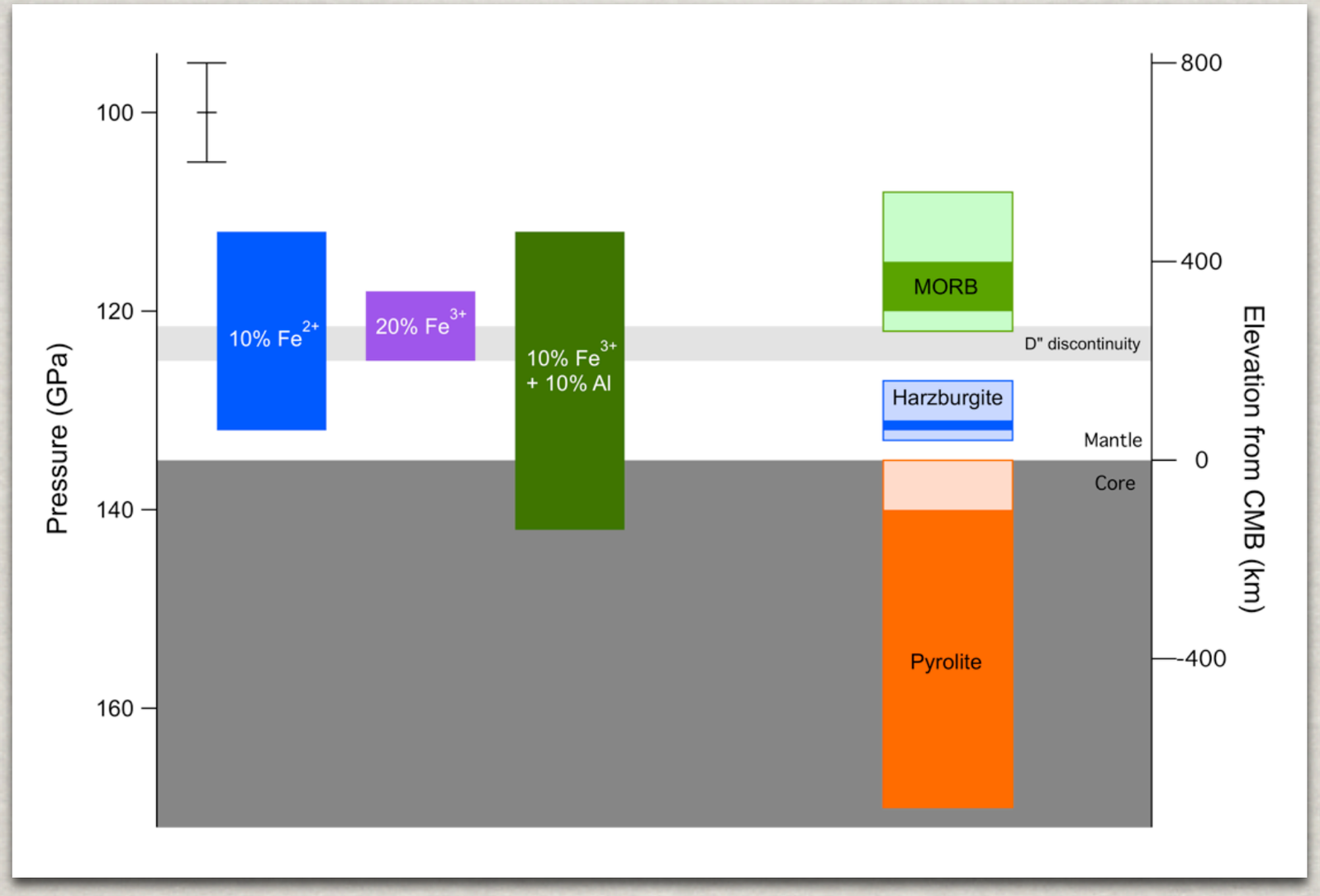
Perovskite

Silica **Al** **Fe,Al** CF phase

Post-perovskite



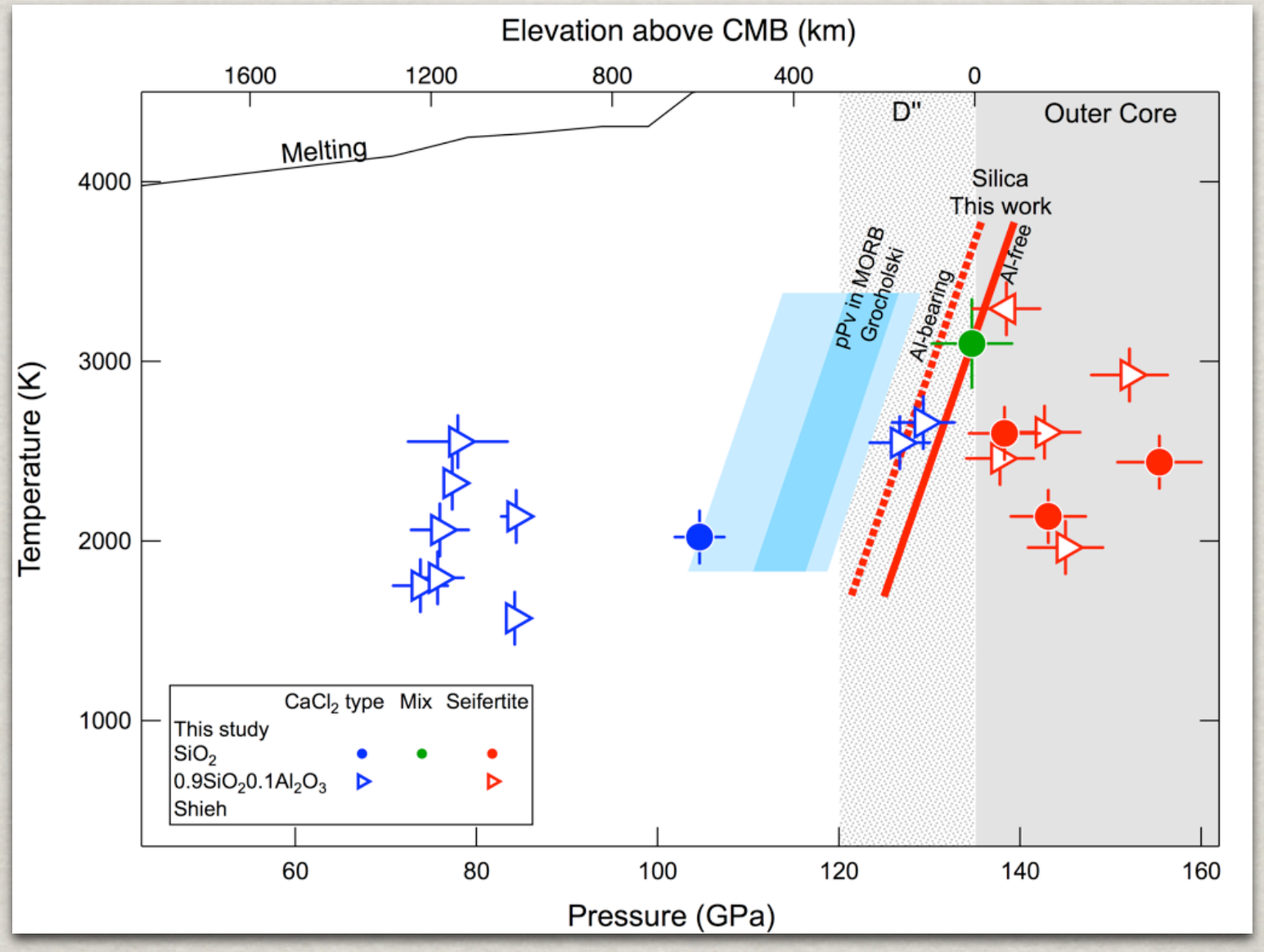
Summary of Results



Grocholski et al. (2012) PNAS

MORB or high Mg/Si materials more likely have detectable post-perovskite transition in the lower mantle

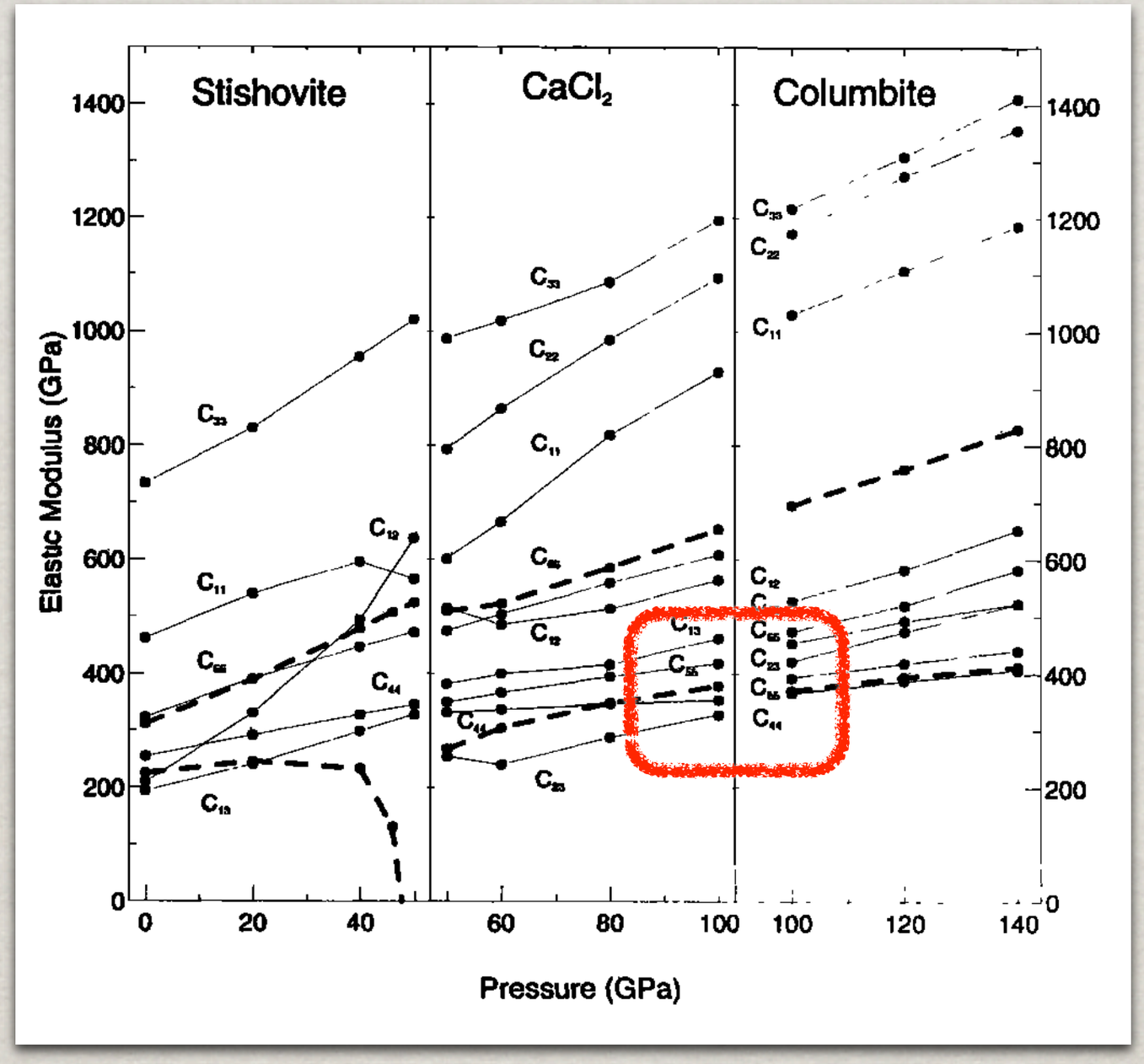
Phase Boundary in Silica



Grocholski et al. (2012) under revision

Modified Stishovite ($CaCl_2$ type) ➛ Seifertite
in MORB, sediments, and core-mantle reaction products

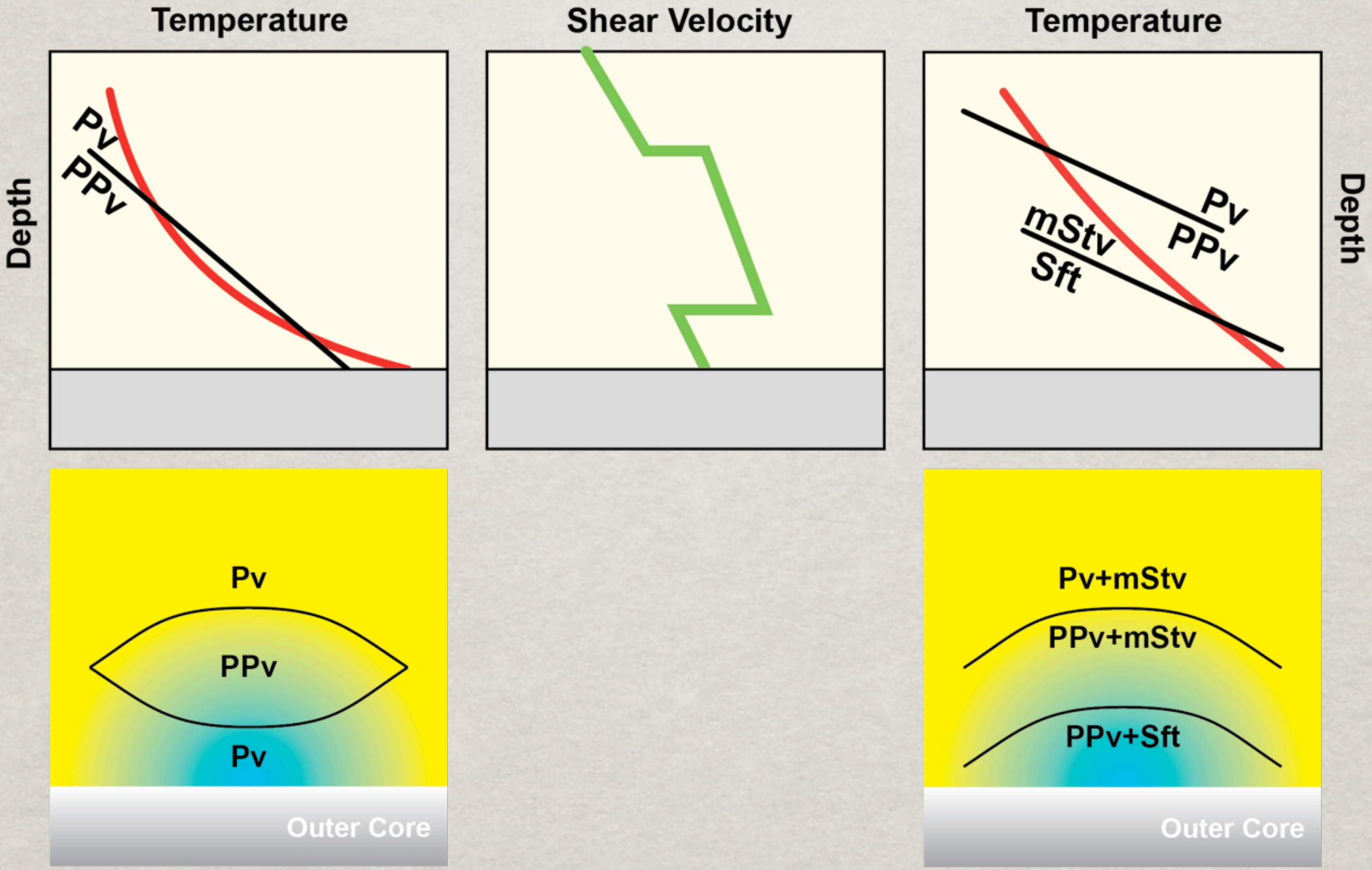
Shear Wave Velocity



Karki et al. (1997) GRL

Shear wave velocity decreases at the silica phase transition in D"

Double Discontinuity Structures



Thermal Probe

Chemical Probe

Future Work

Future Work

- Element partitioning among different minerals.

Future Work

- Element partitioning among different minerals.

- Exploration of other compositions, chondritic, solidified mantle melts, etc.

Future Work

- Element partitioning among different minerals.

- Exploration of other compositions, chondritic, solidified mantle melts, etc.

- Mineralogy of the lower mantle.