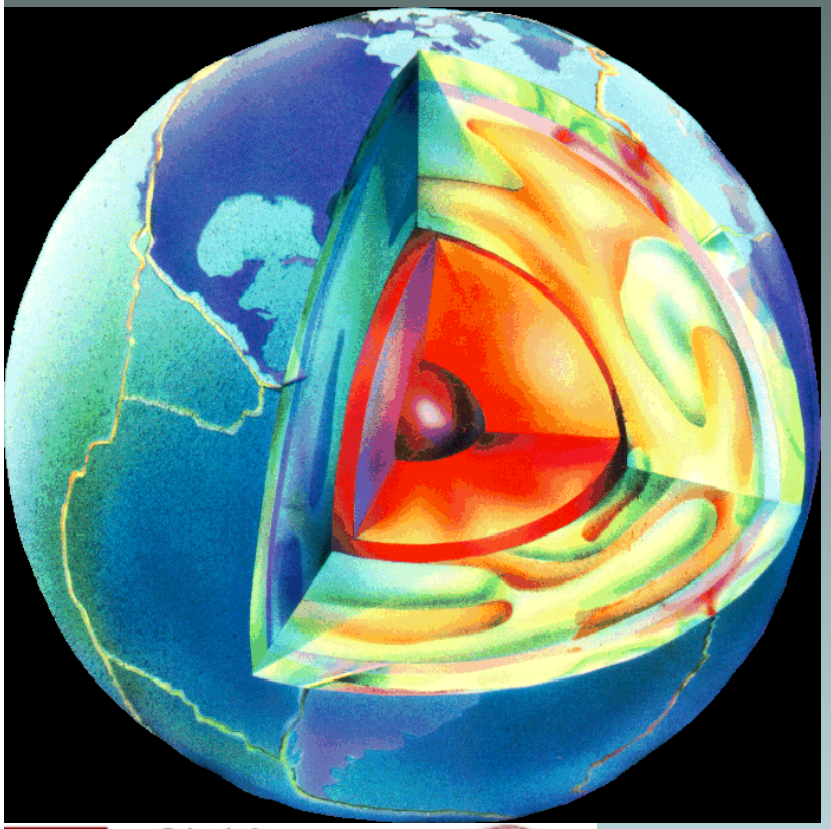
The Effect of Abundance Ratios on Rocky Planet Structure

Wendy Panero
Ohio State University



THE OHIO STATE UNIVERSITY School of Earth Sciences

CIDER
Cooperative Institute for Dynamic Earth Research

Columbus, OH

University View | Change Station

4:03 PM EST on February 19, 2015 (GMT -0500)

Active Advisory: **Wind Chill Advisory** Active Notice: **Record Report**, **Local Storm Report**

Elev **755** ft **40.00** °N, **83.03** °W | Updated 24 sec ago

7.2 °F

N 2.2

Overcast

Feels Like **7** °F

Wind from **NW**
Gusts **8.3** mph

Tomorrow is forecast to be ***WARMER*** than today.

Today
High **10** | Low **-9** °F
20% Chance of Precip.

Yesterday
High **19.9** | Low **4.3** °F
Precip. **0** in

Sun & Moon

7:19 am | 6:12 pm | **New Moon, 1**% visible

Pressure	**30.15** in
Visibility	**6.0** miles
Clouds	**Scattered Clouds 3500** ft **Overcast 4300** ft
Windchill	**7** °F
Dew Point	**-10** °F
Humidity	**44**%
Rainfall	**0.00** in
Snow Depth	*Not available.*
UV	**1** out of 12
Pollen	**.50** out of 12
Air Quality	*Not available.*
Flu Activity	*Not available.*

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METAR KCMH 192051Z 28016KT 6SM HZ
SCT035 OVC043 M14/M22 A3022 RMK
AO2 SNE1957 SLP254 VCSH ALQDS
P0000 60000 T11441217 53001
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Radar | Satellite | Webcams | WunderMap | Nexrad

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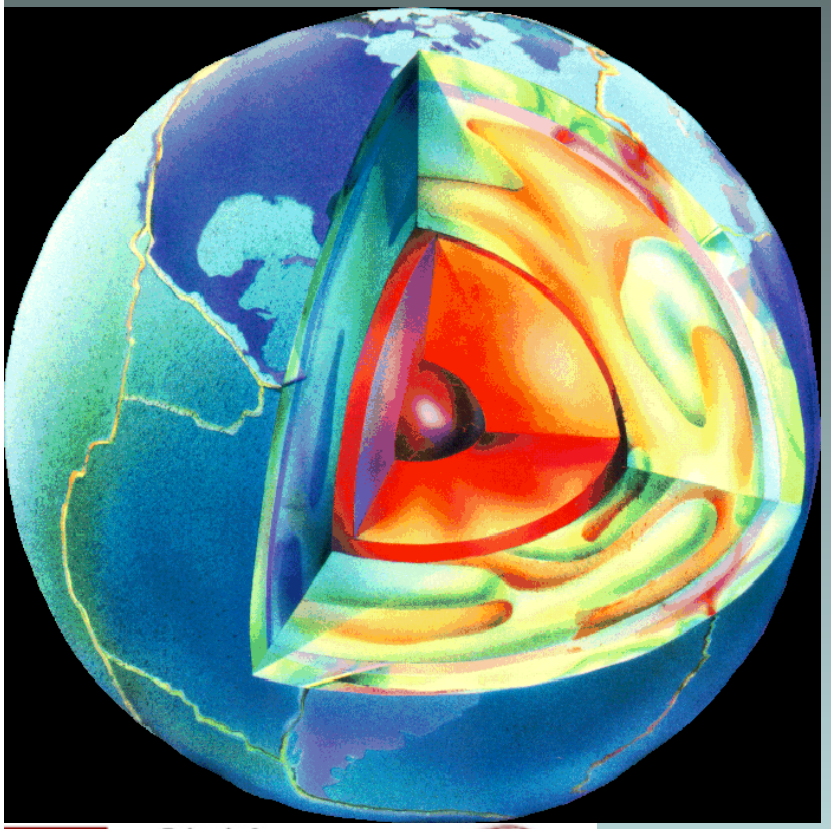

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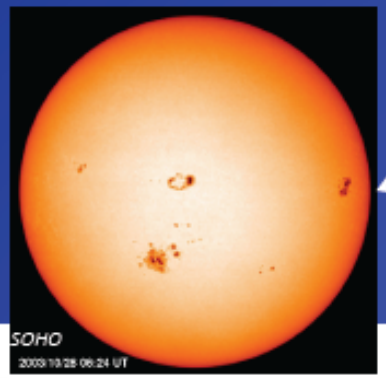
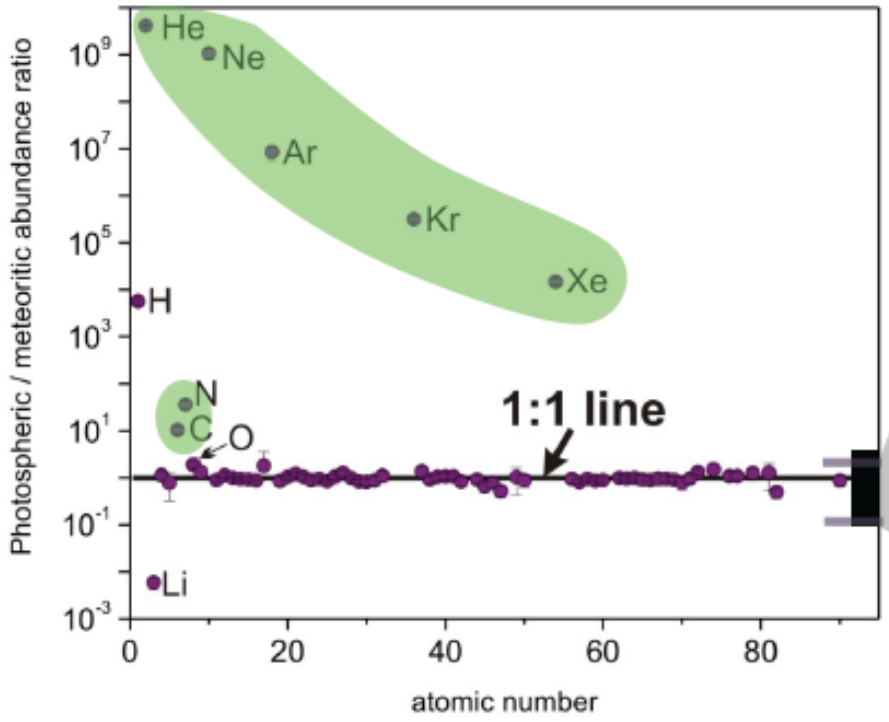
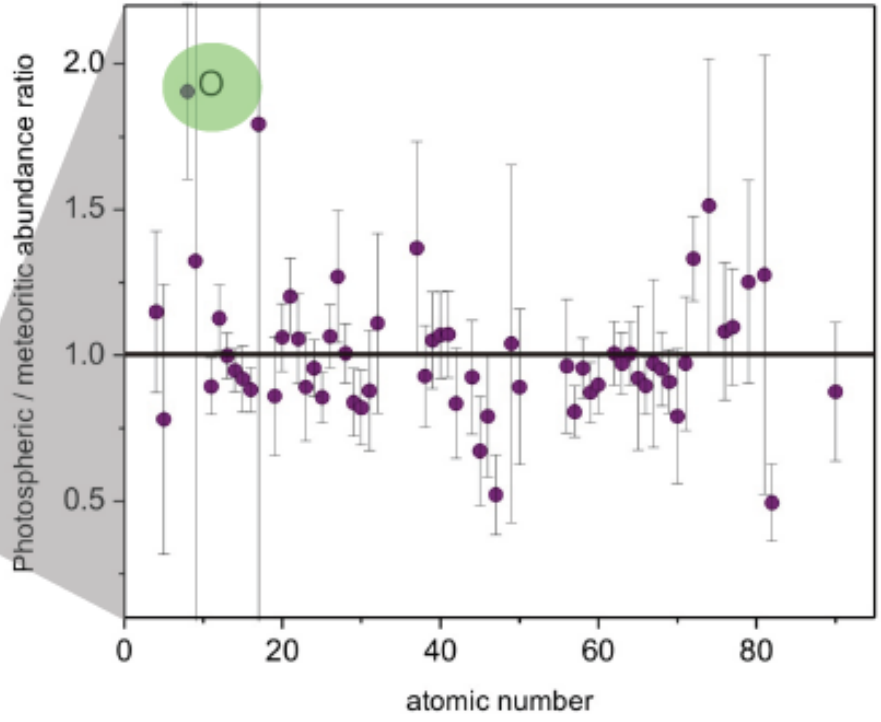


Sun's Photosphere (today)

CI chondrite (4.56 years old)



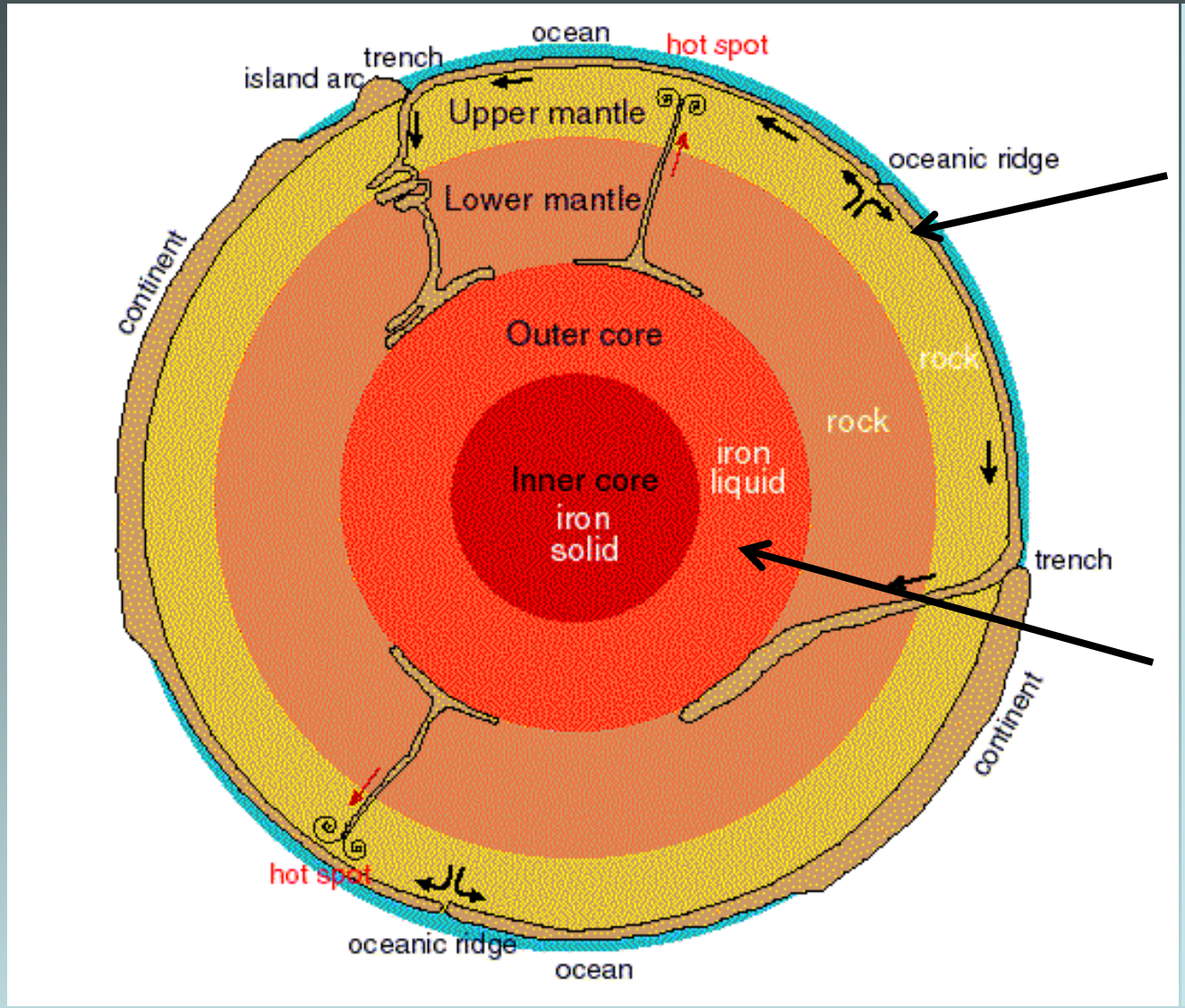


Asplund et al. 2009
Lodders et al. 2009

All subsequent processing is recorded in the deviation from this correlation

Courtesy of K. McKeegan

Earth Structure

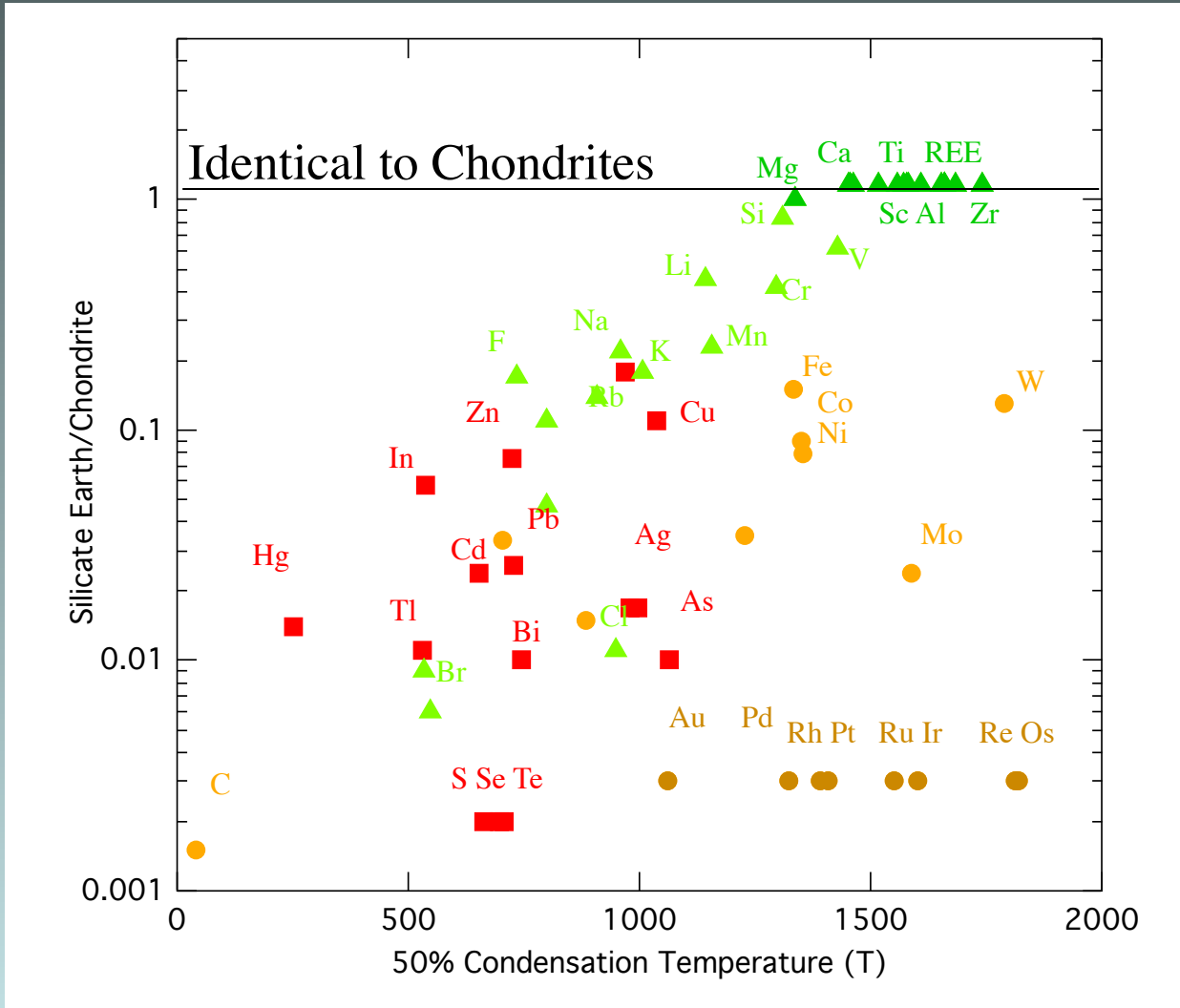


Two Major Divisions:

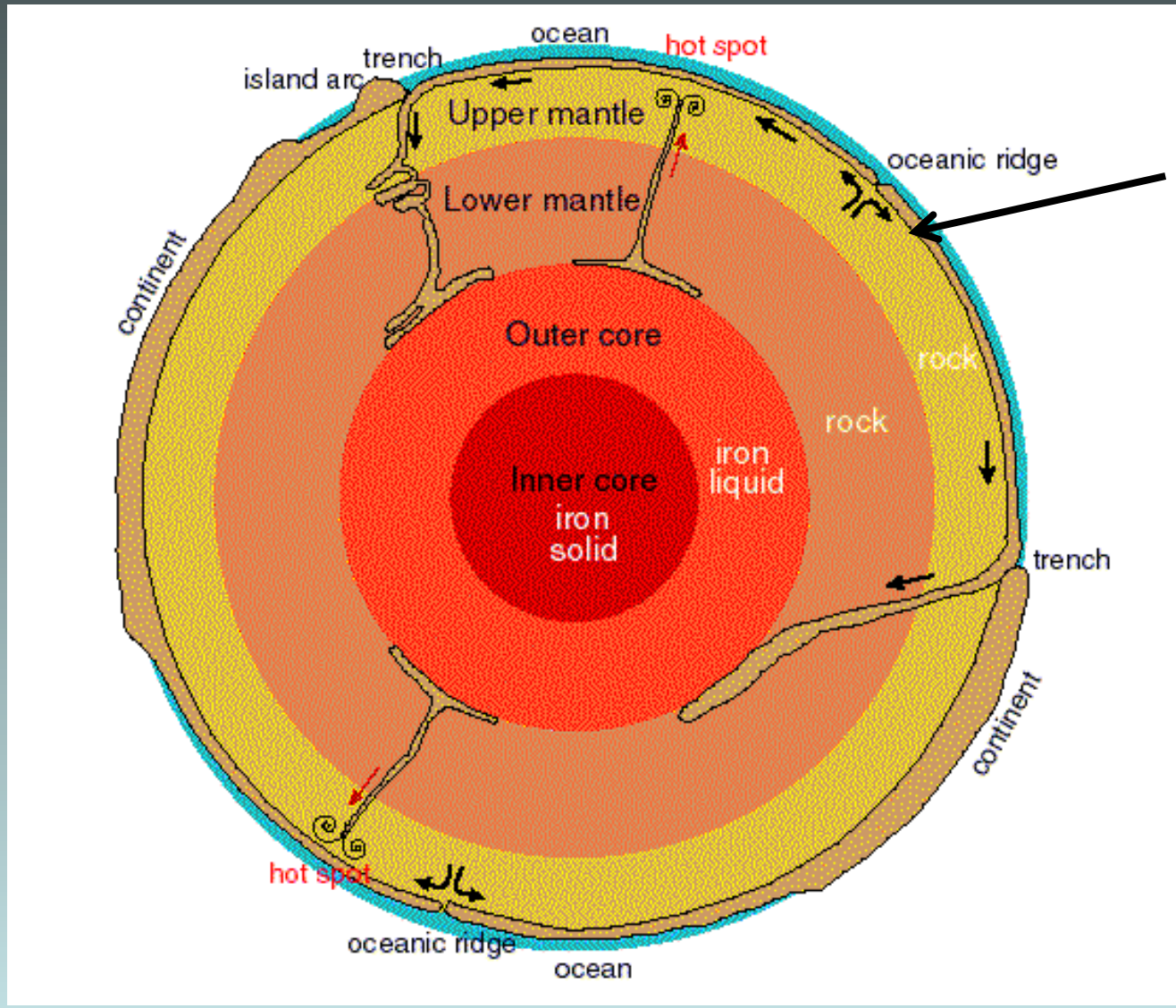
***The silicate Earth: The crust and mantle are composed of silicate ceramics.**

***The core: Primarily iron, with some Ni and "light" elements Hidden from direct sampling.**

Composition of the (Silicate) Earth

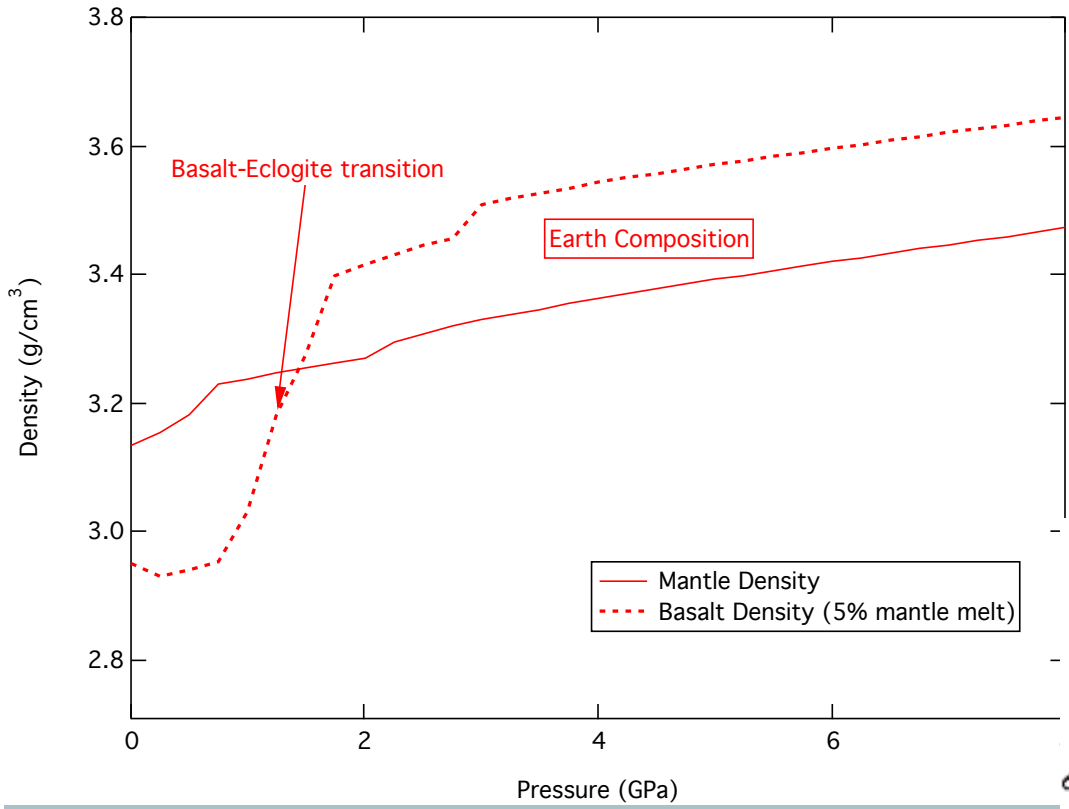


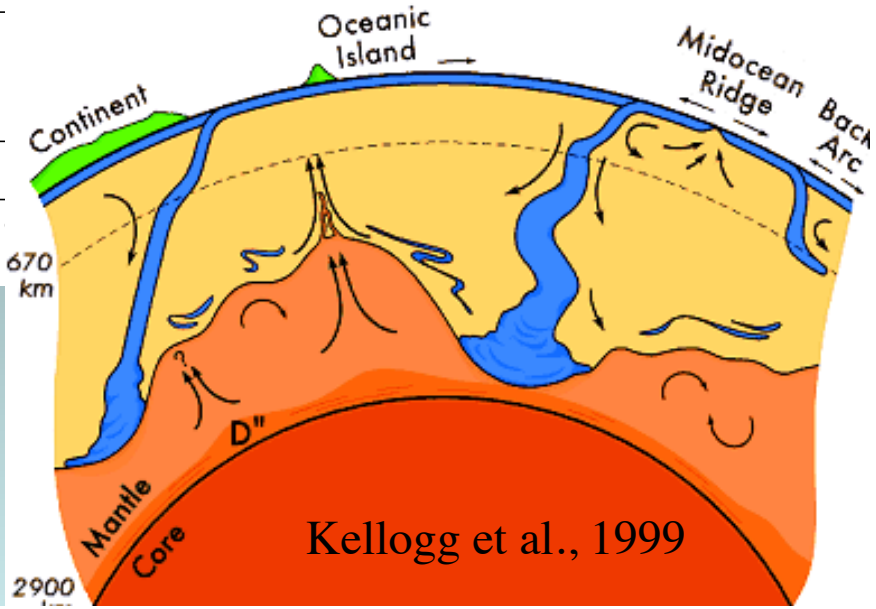
Earth Structure



***The silicate Earth:**
Solid convective motions in the mantle give rise to melting at the surface, sinking of dense oceanic crust creating plate tectonics.

Earth Mantle Dynamics & Surface Plate Tectonics





Kellogg et al., 1999

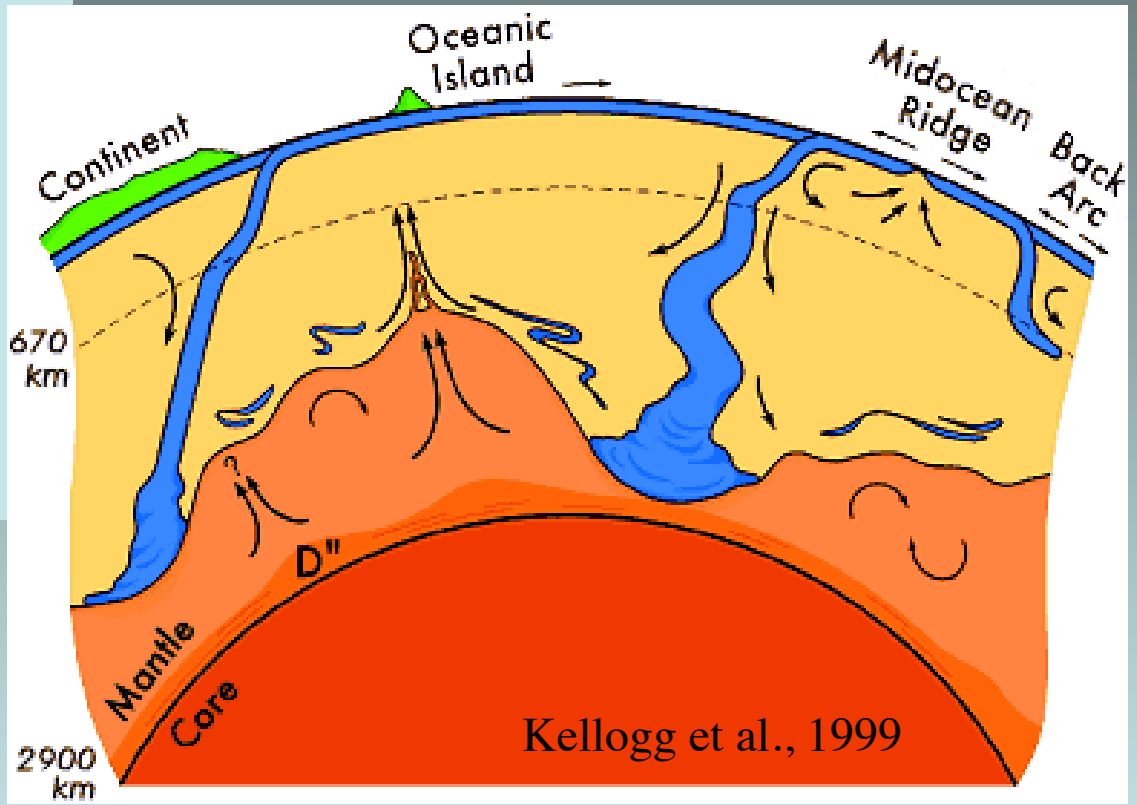
Earth Mantle Dynamics

$$Ra = \frac{g\rho^2 \alpha H D^5}{\eta \kappa k}$$

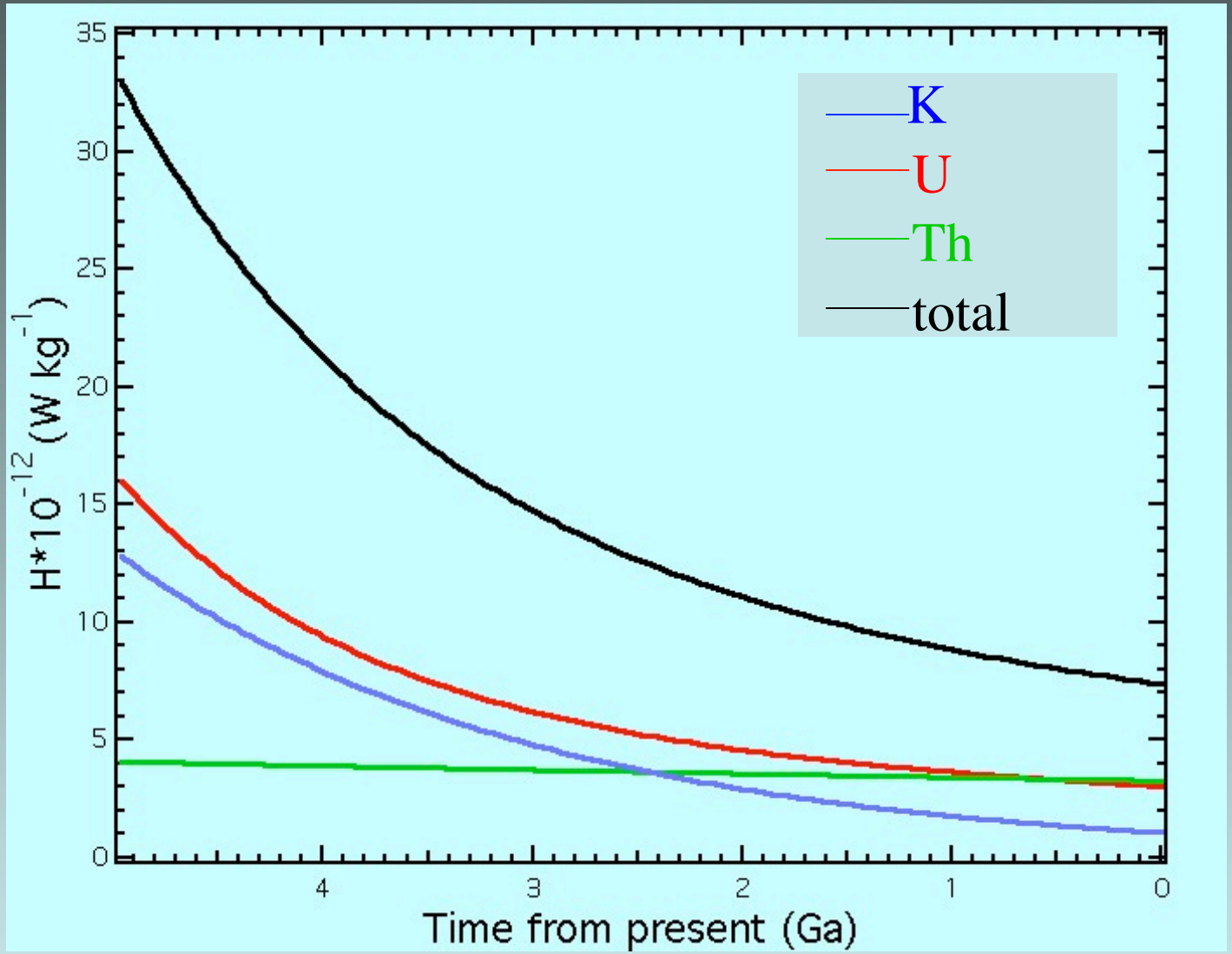
H radiogenic heat production
η Viscosity (fxn composition, T)
D Layer thickness

Mantle Concentrations of radioactive isotopes

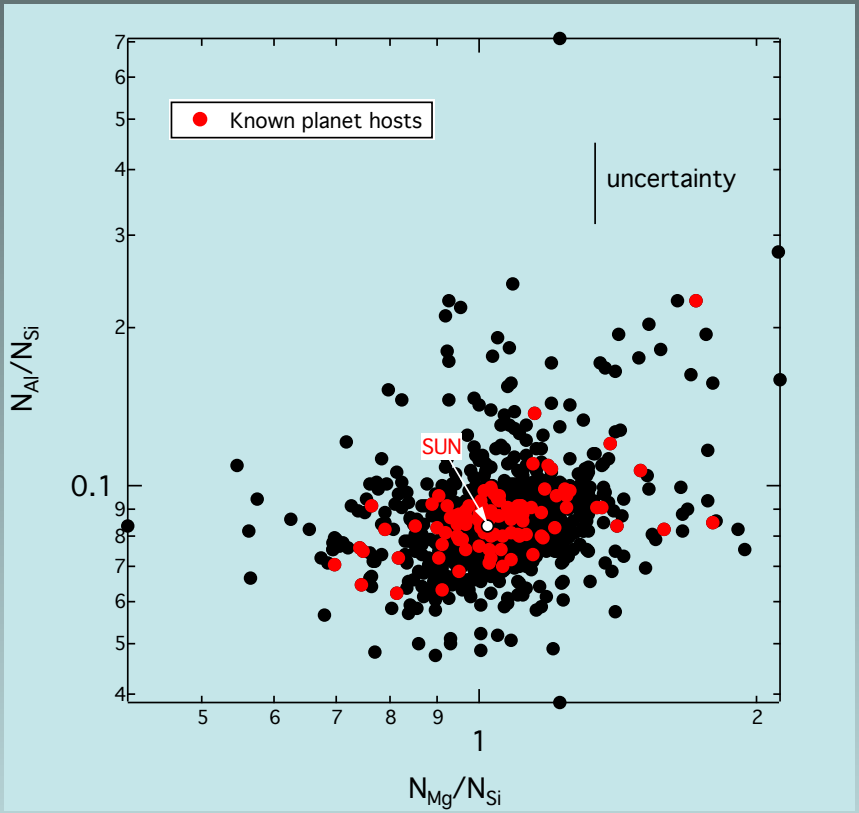
^{238}U	20 ppb
^{235}U	1 ppb
^{232}Th	100 ppb
^{40}K	280 ppm

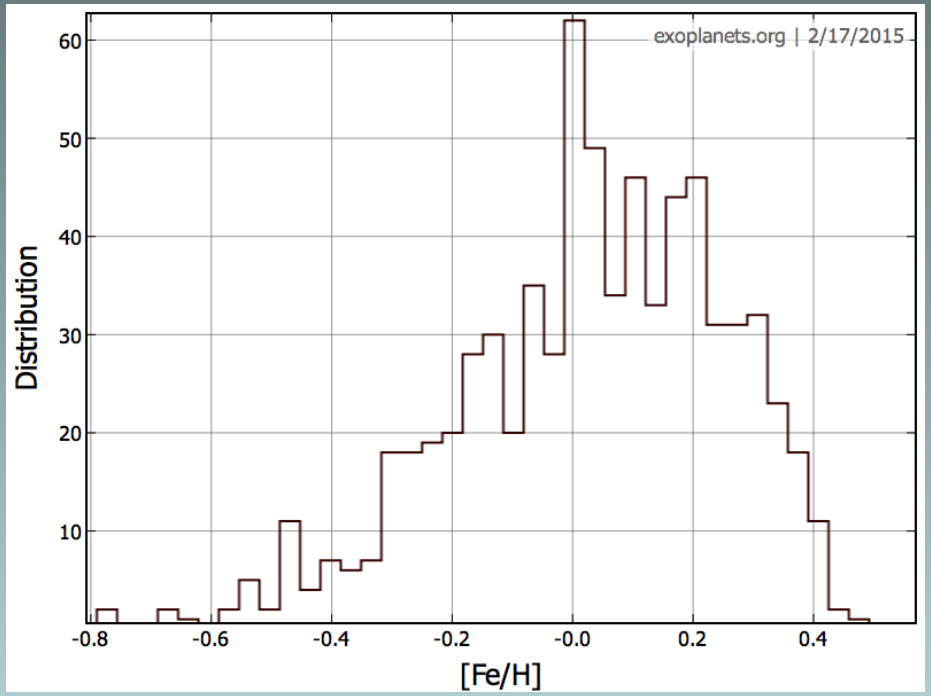


Planetary Dynamics from Interior Heat Production



Compositional variation in exoplanet hosts

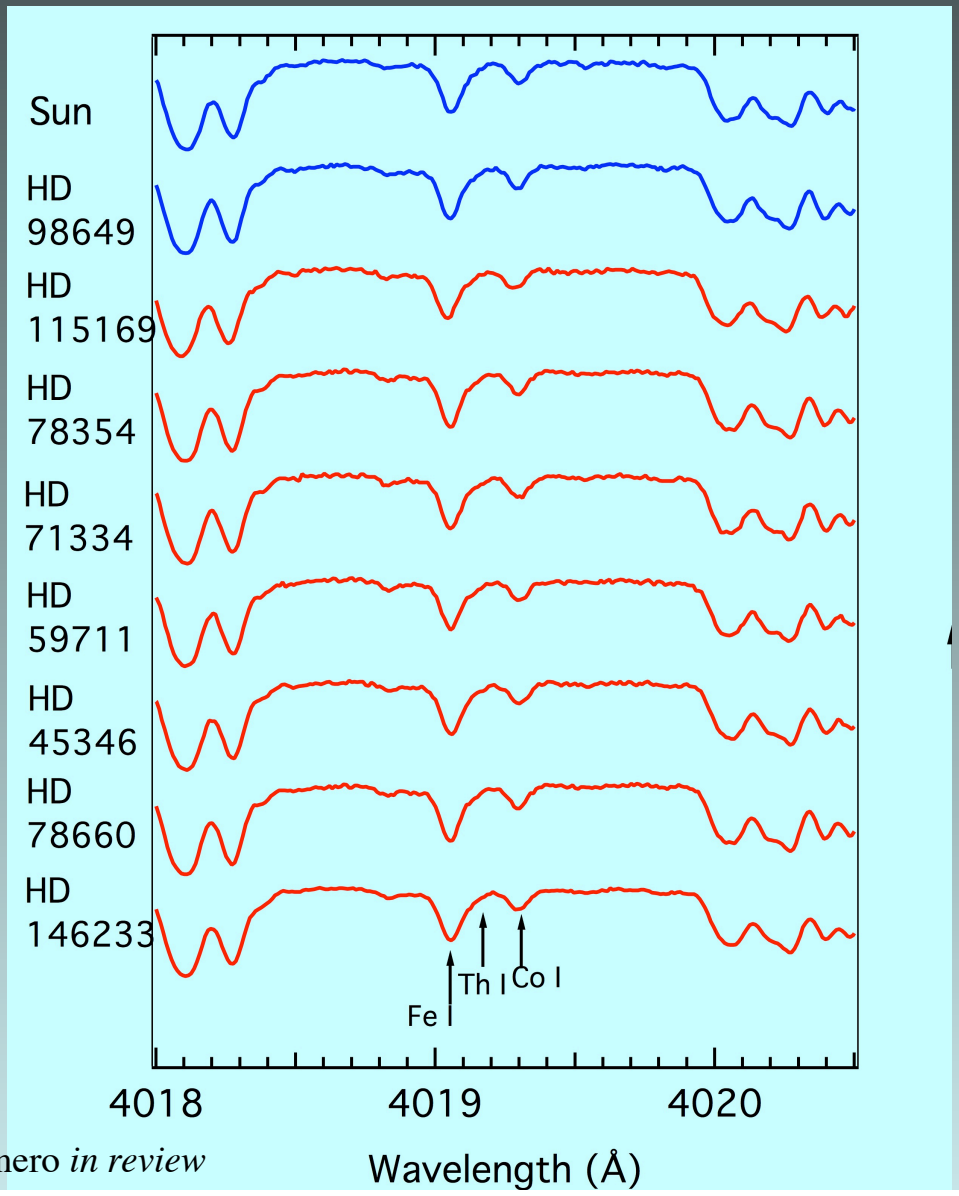




Data from
Adibekyan et al., 2012

Trace Element Variation?

Thorium variation in Solar Analogues

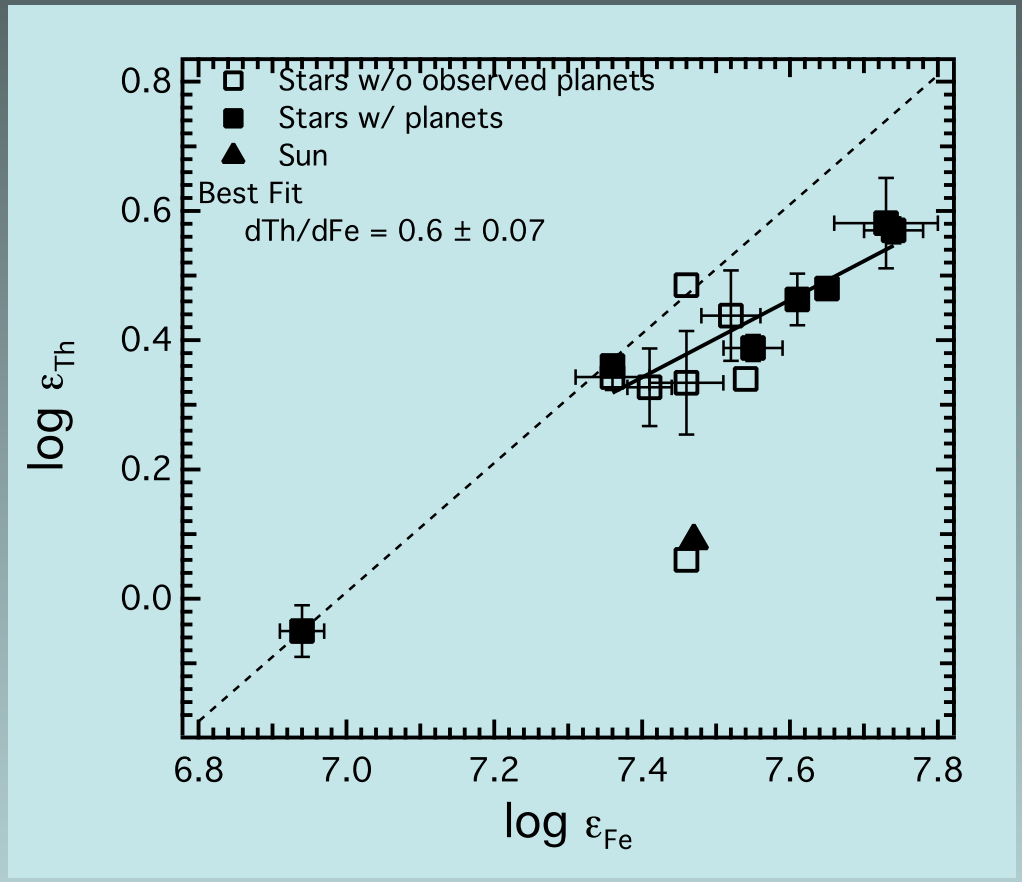


—With known planets

—Without known planets

Unterborn, Johnson, Panero *in review*

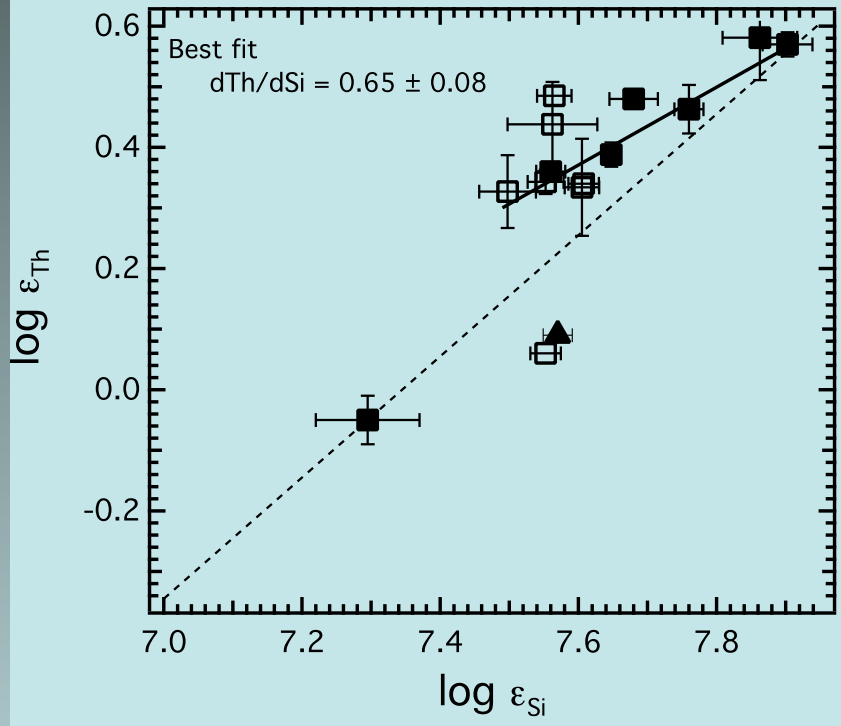
Thorium variation in Solar Analogues

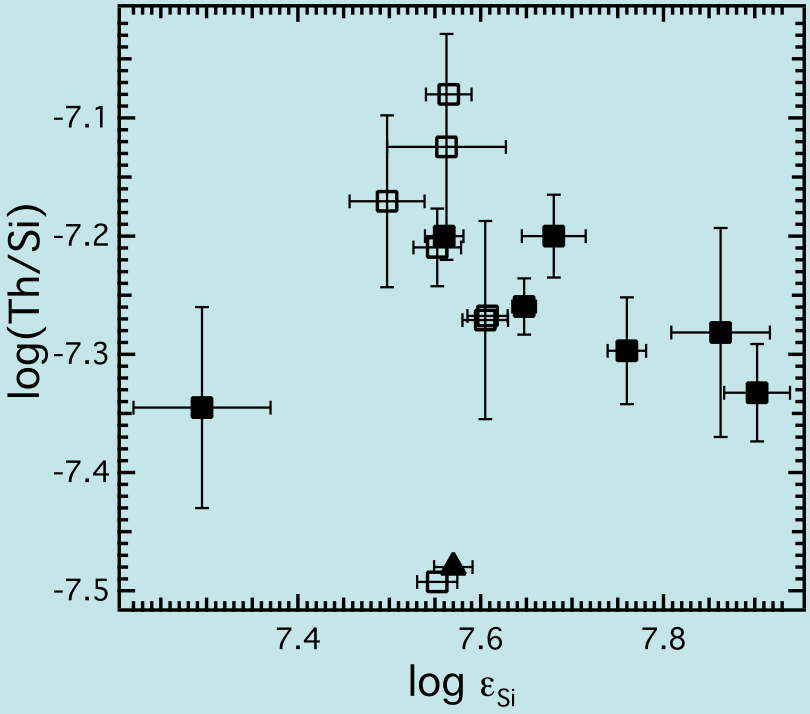


*Factor of ~3 variation in Th content

Unterborn, Johnson, Panero *in review*

Thorium variation in Solar Analogues

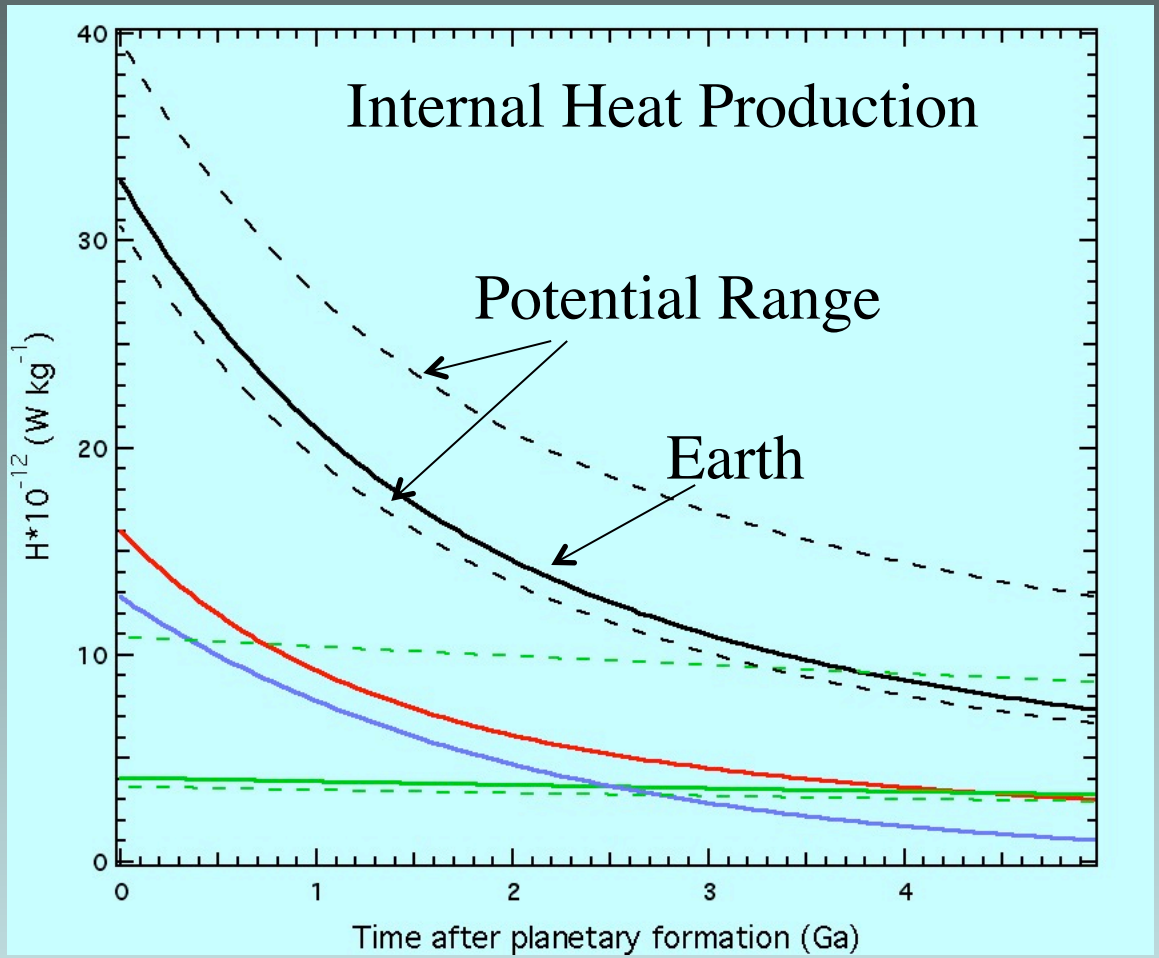




*Factor of ~3 variation in Th content

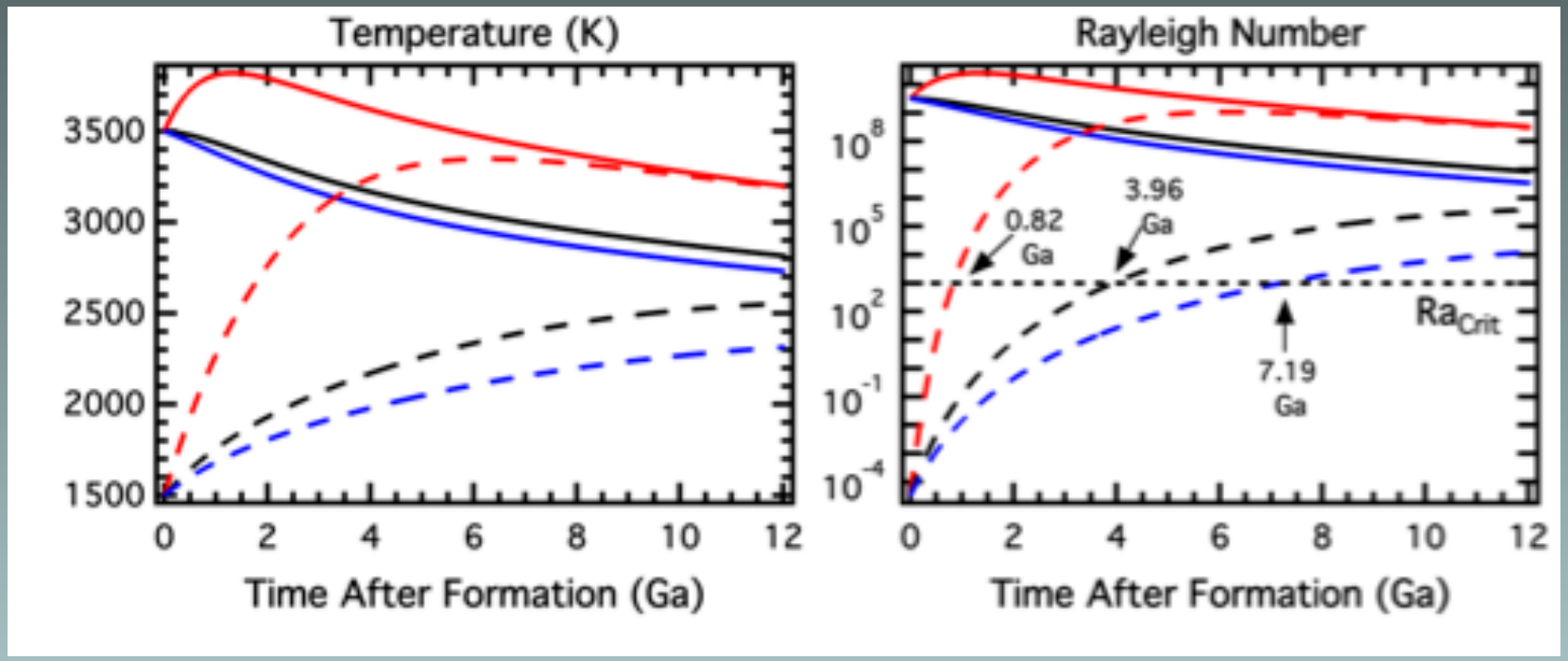
Unterborn, Johnson, Panero *in review*

Thorium variation in Terrestrial Planets



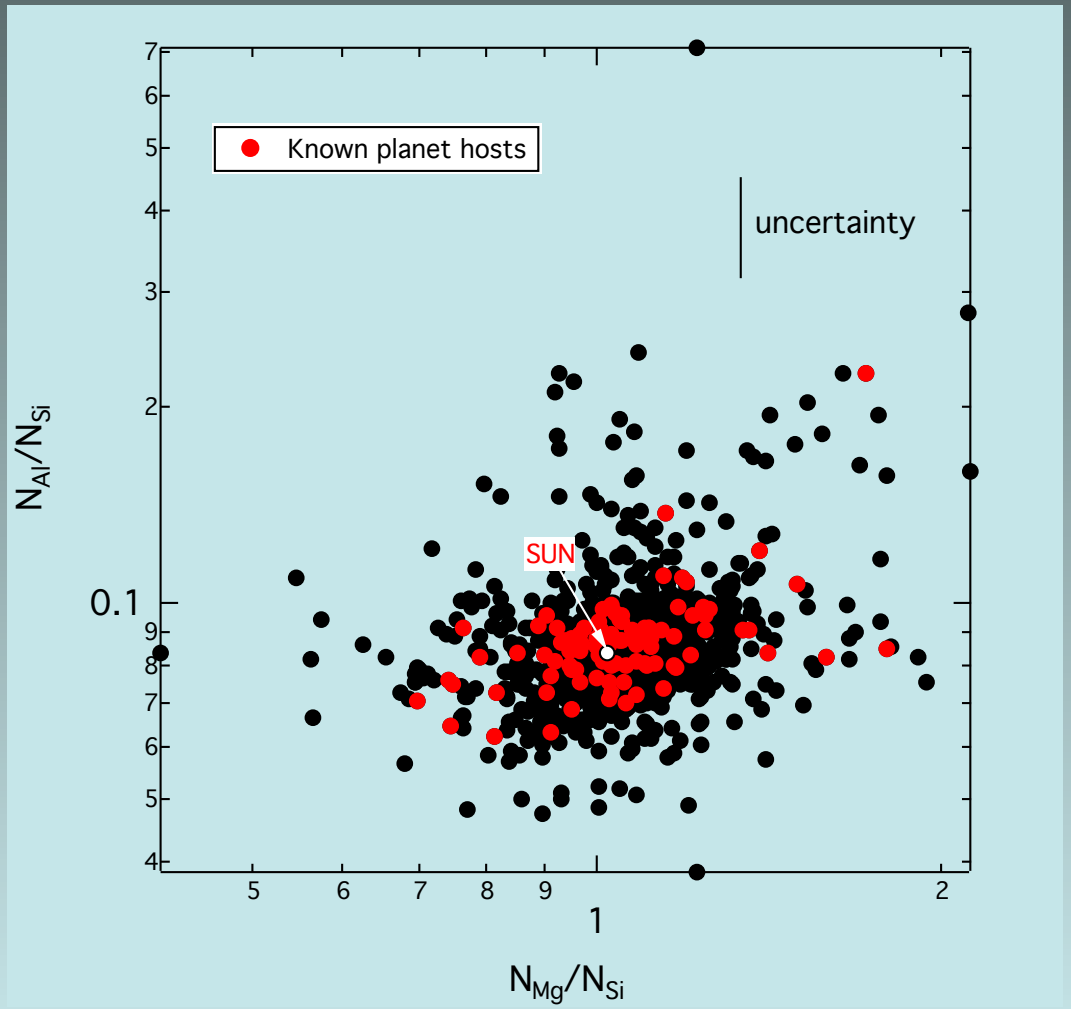
K
U
Th
total

Thorium variation in Terrestrial Planets



Unterborn, Johnson, Panero *in review*

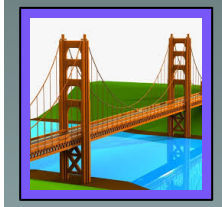
Compositional variation in exoplanet hosts: Major Element Variation



Data from
Adibekyan et al., 2012

Mantle Mineral Primer

Olivine + polymorphs β-ol, γ-ol (aka Wadsleyite and Ringwoodite)
$(Mg,Fe)SiO_4$
Holds water (1-2 wt% H_2O)
Breaks down to bridgmanite and ferropericlase ~25 GPa

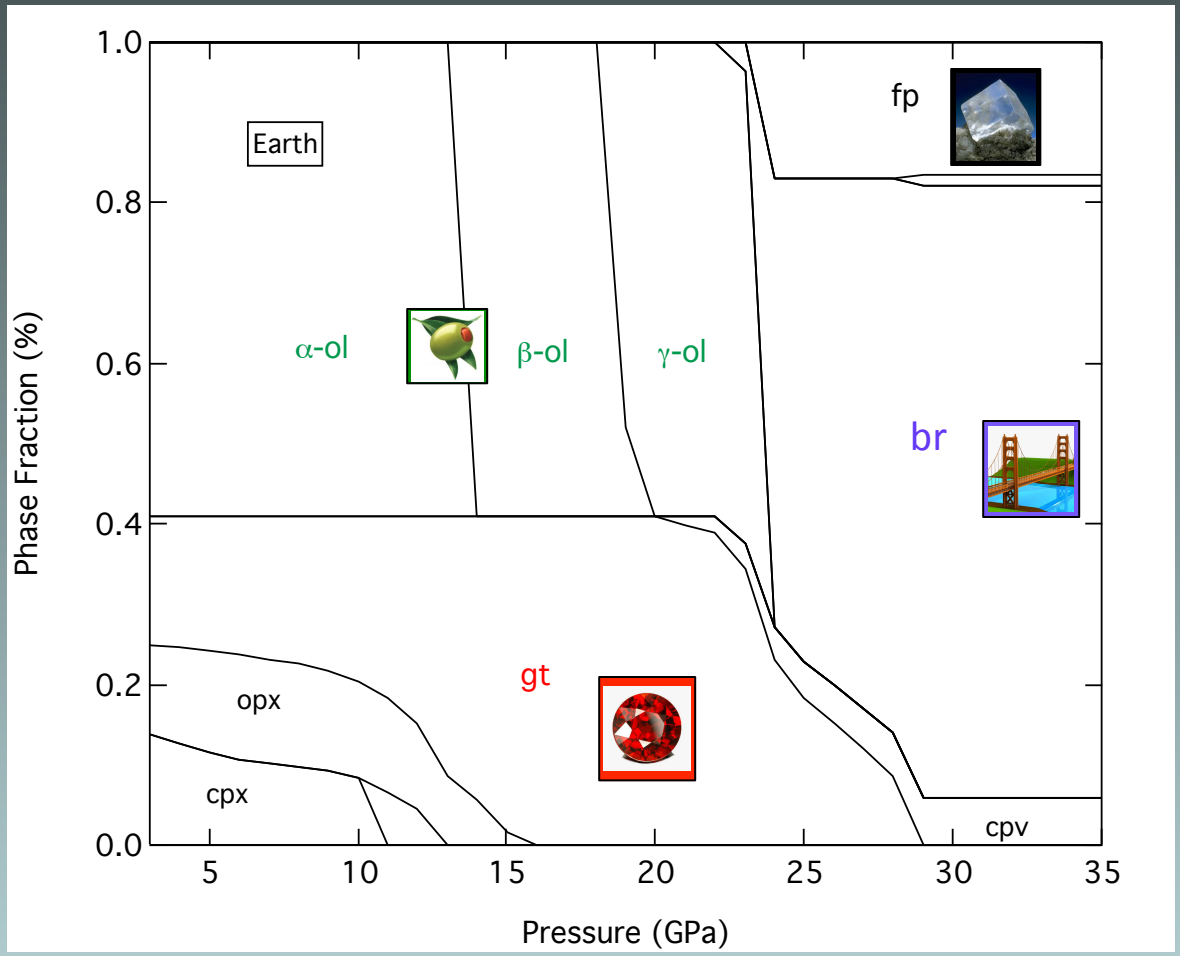


Bridgmanite
$(Mg,Fe)SiO_3$
Stable > 25 GPa (aka Mg-Si perovskite)
Doesn't hold water. Stiff.

Ferropericlase (aka magnesiowüstite)
(Mg,Fe)O
Doesn't hold water. Weak.

Garnet (aka majorite, pyrope, almandine, spessartine, andradite, grossular, uvarite)
$A_3B_2Si_3O_{12}$
Holds a little water.
Breaks down to bridgmanite ~30 GPa

Earth Mantle Mineralogy



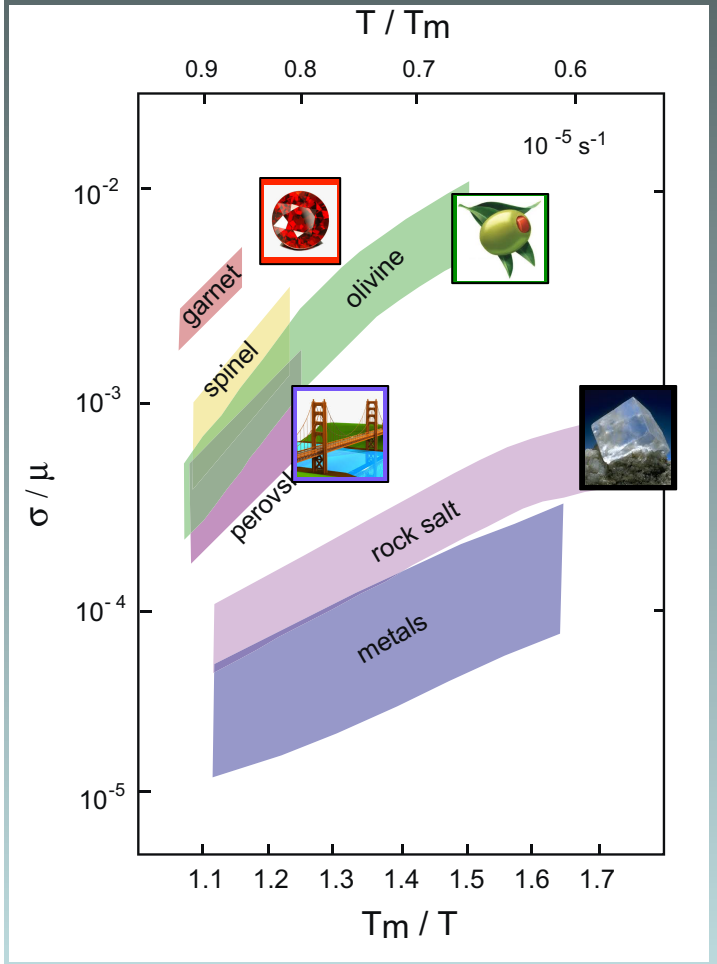
Calculated mineralogy for pyrolitic MgO, FeO, SiO_2, CaO, Al_2O_3, Na_2O system along a 1600 K adiabat using HeFESTo (Stixrude and Lithgow-Bertelloni 2007)

Water capacity ~10x Earth surface oceans, mostly in olivine

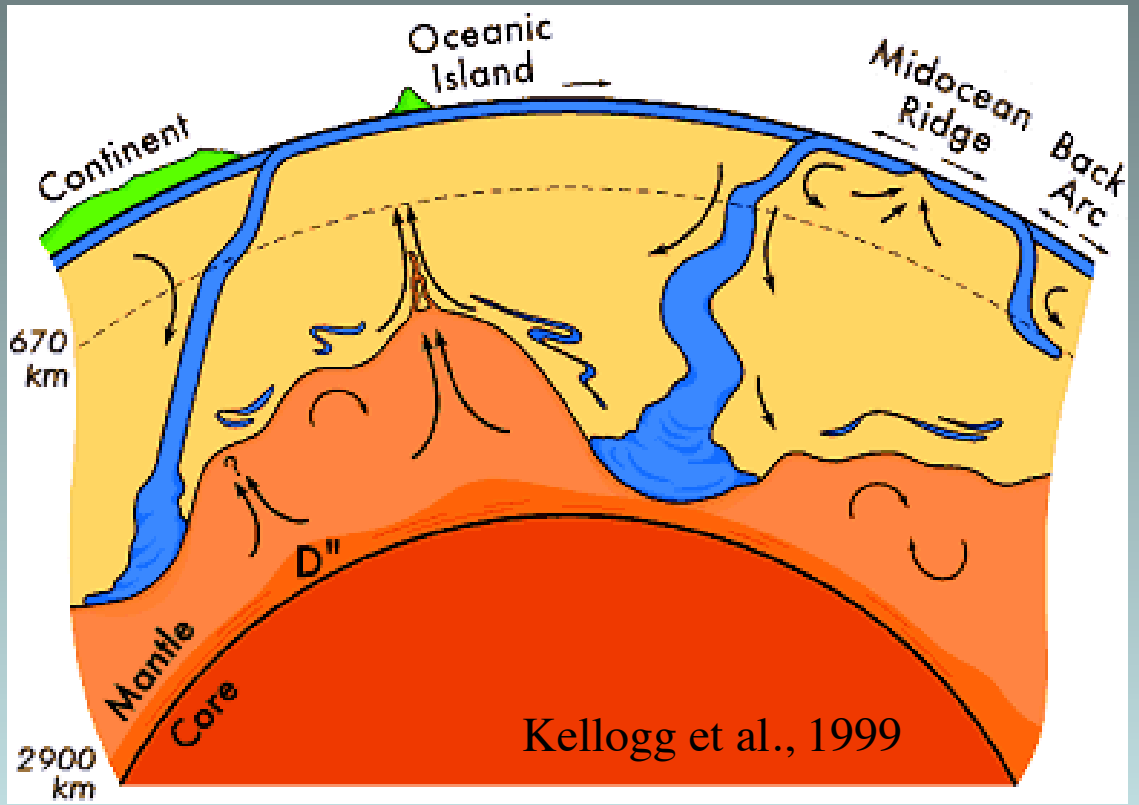
Earth Mantle Dynamics

$$Ra = \frac{g\rho^2 \alpha H D^5}{\eta \kappa k}$$

H radiogenic heat production
η Viscosity (fxn composition, T)
D Layer thickness



Karato, 2011

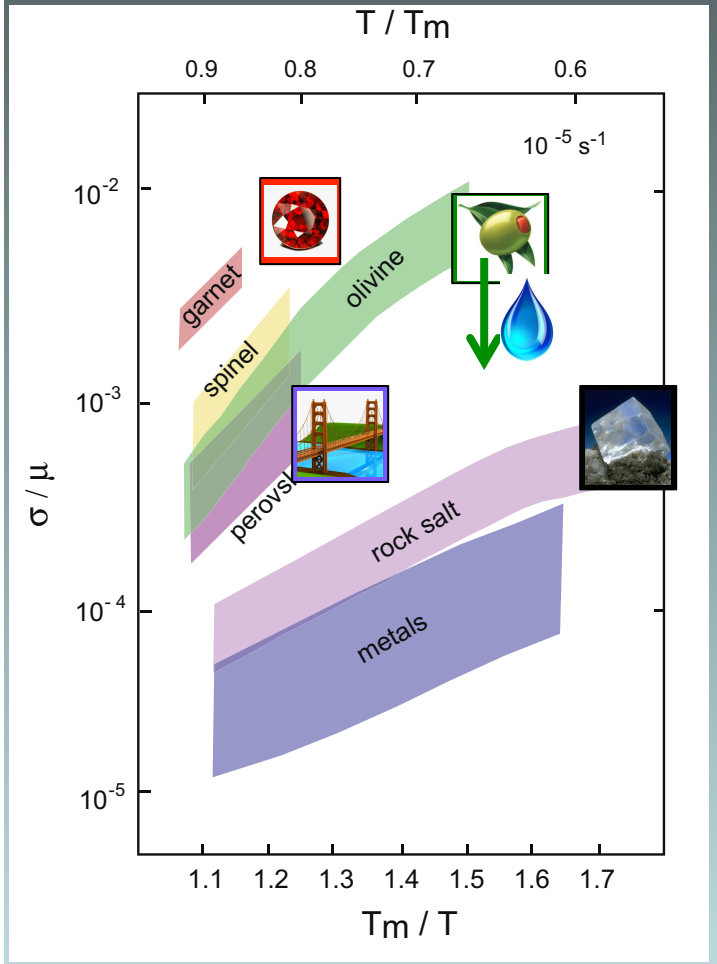


Kellogg et al., 1999

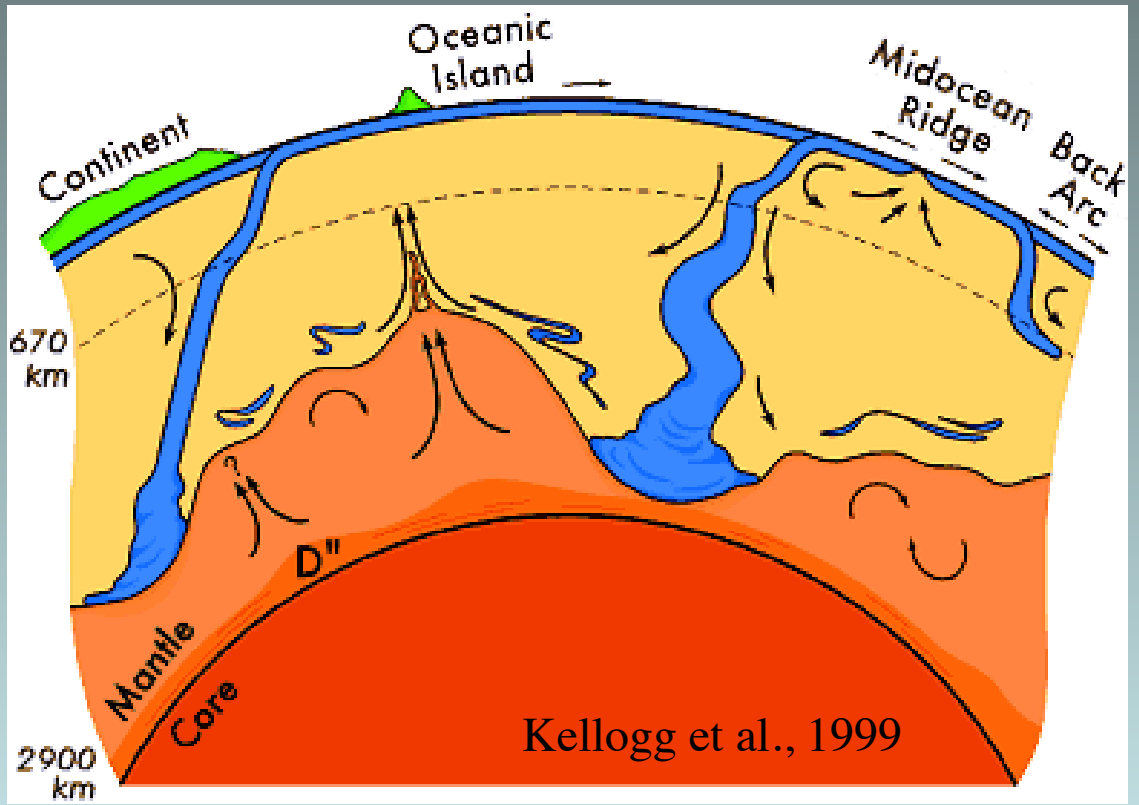
Earth Mantle Dynamics

$$Ra = \frac{g\rho^2 HD^5}{\eta\alpha k}$$

H radiogenic heat production
η Viscosity (fxn composition, T)
D Layer thickness



Karato, 2011

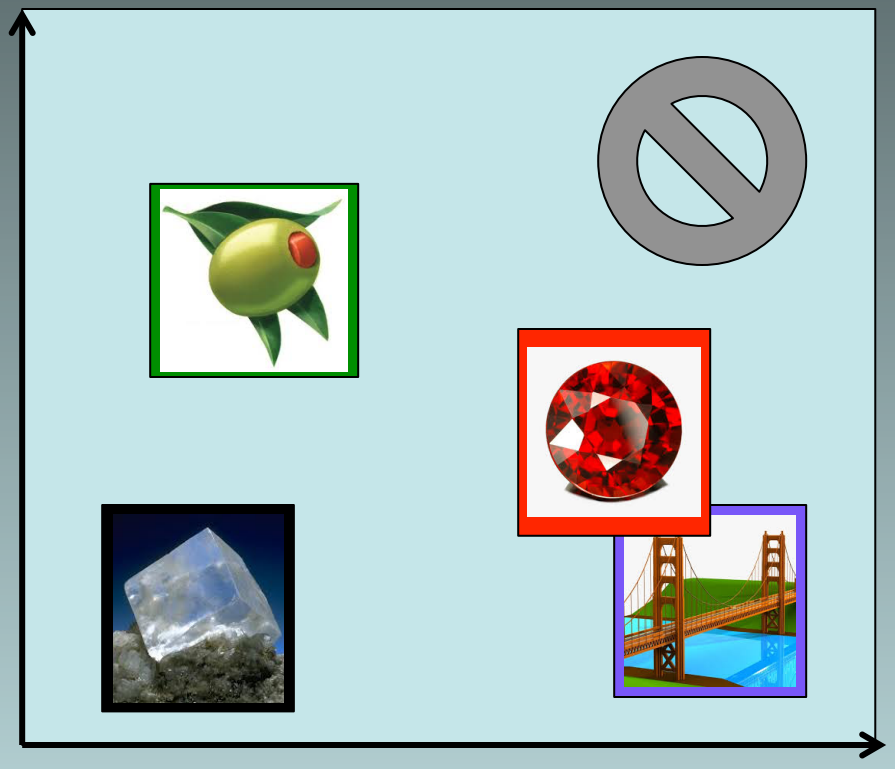


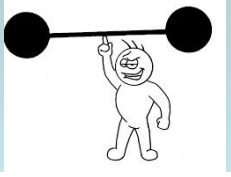
Kellogg et al., 1999

Mantle Mineral Primer

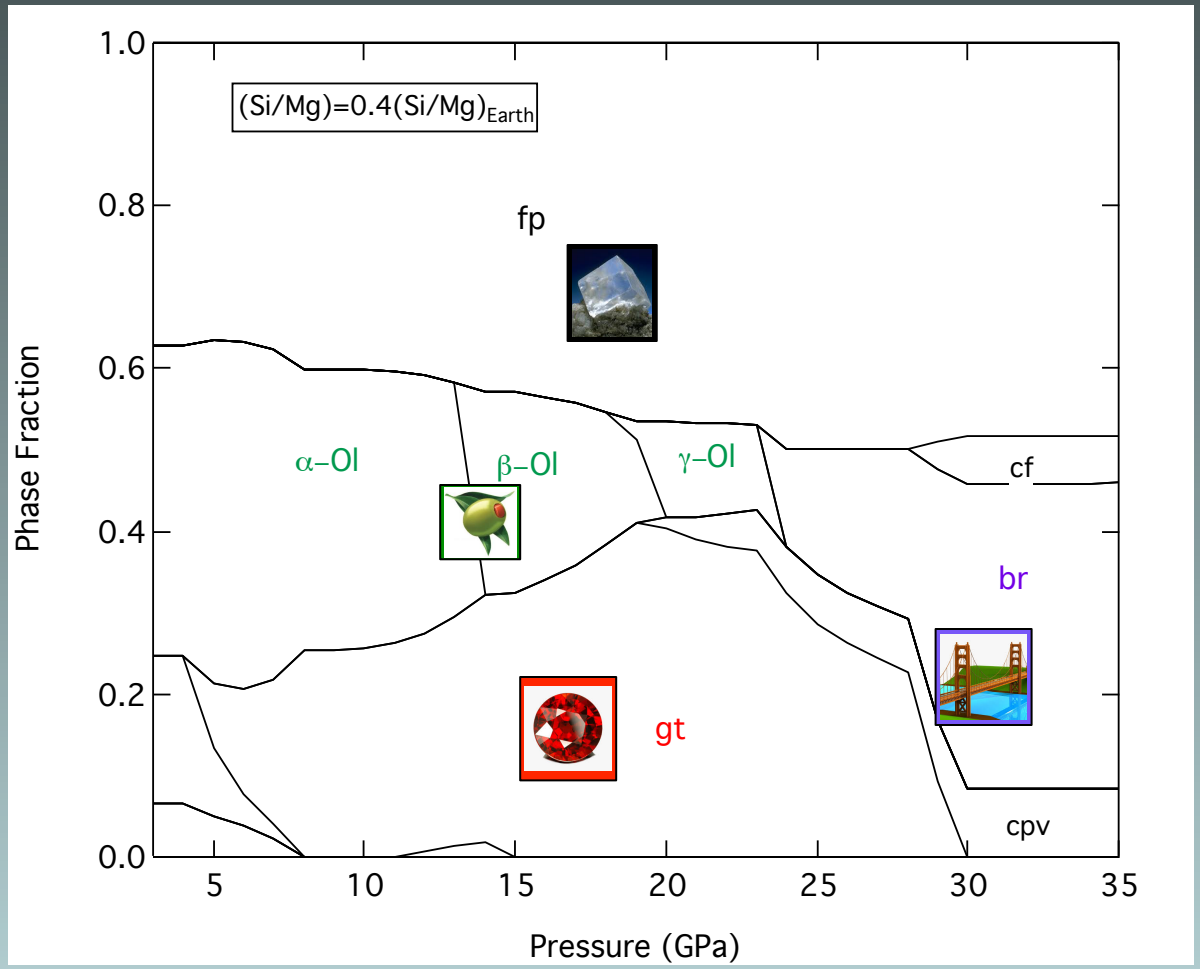
"Wet"

Dry



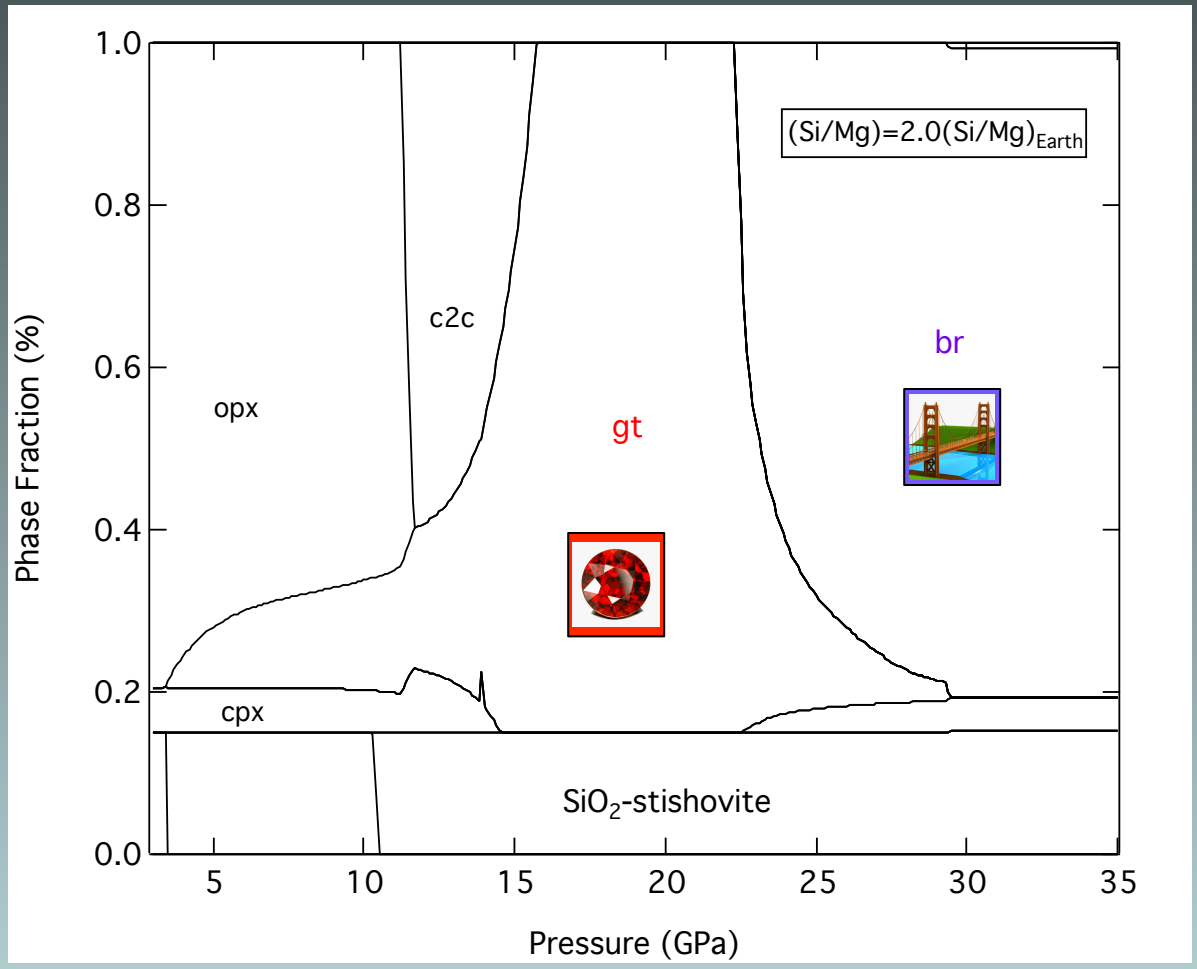


Composition Controls Water Storage



Dominated by ferropericlase; ~1 ocean of water capacity
Very weak mantle throughout

Composition Controls Water Storage



No olivine or ferropericlase; ~0.1 ocean of water capacity
Very stiff mantle throughout

Compositional Impact on Plate Tectonics