Venus surface compositions suggest upper mantle temperatures like Earth, so why is there no magnetic field?

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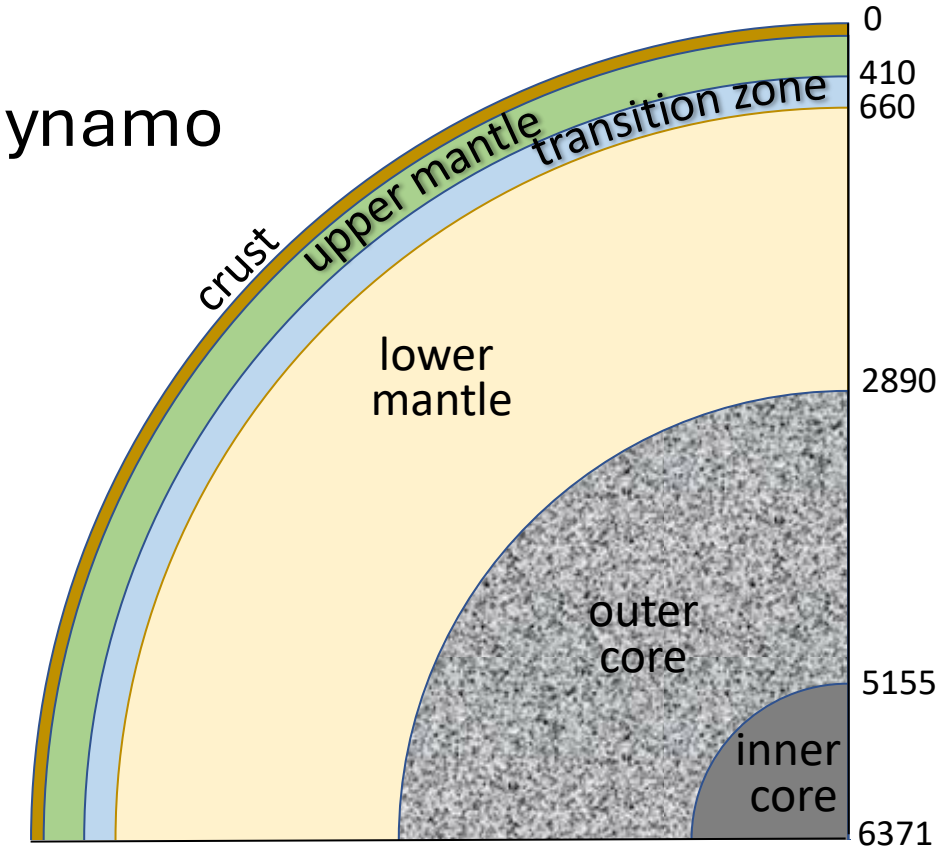
Wed, 30 Apr, 10:55–11:05 (CEST) Room 2.23

Venus & Earth interior comparison

Earth

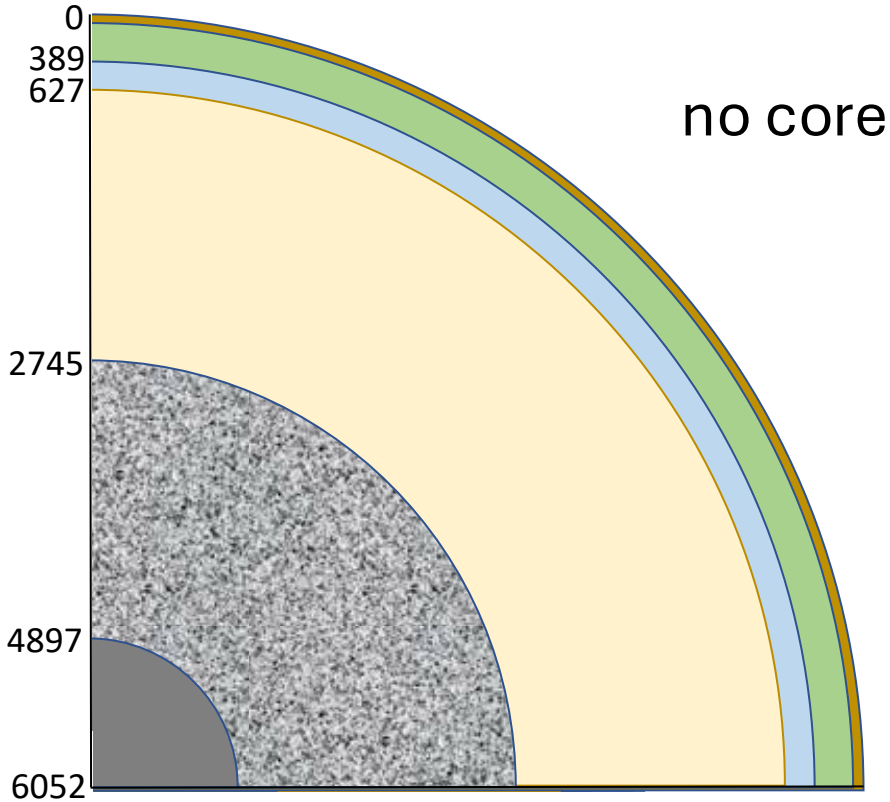
core dynamo



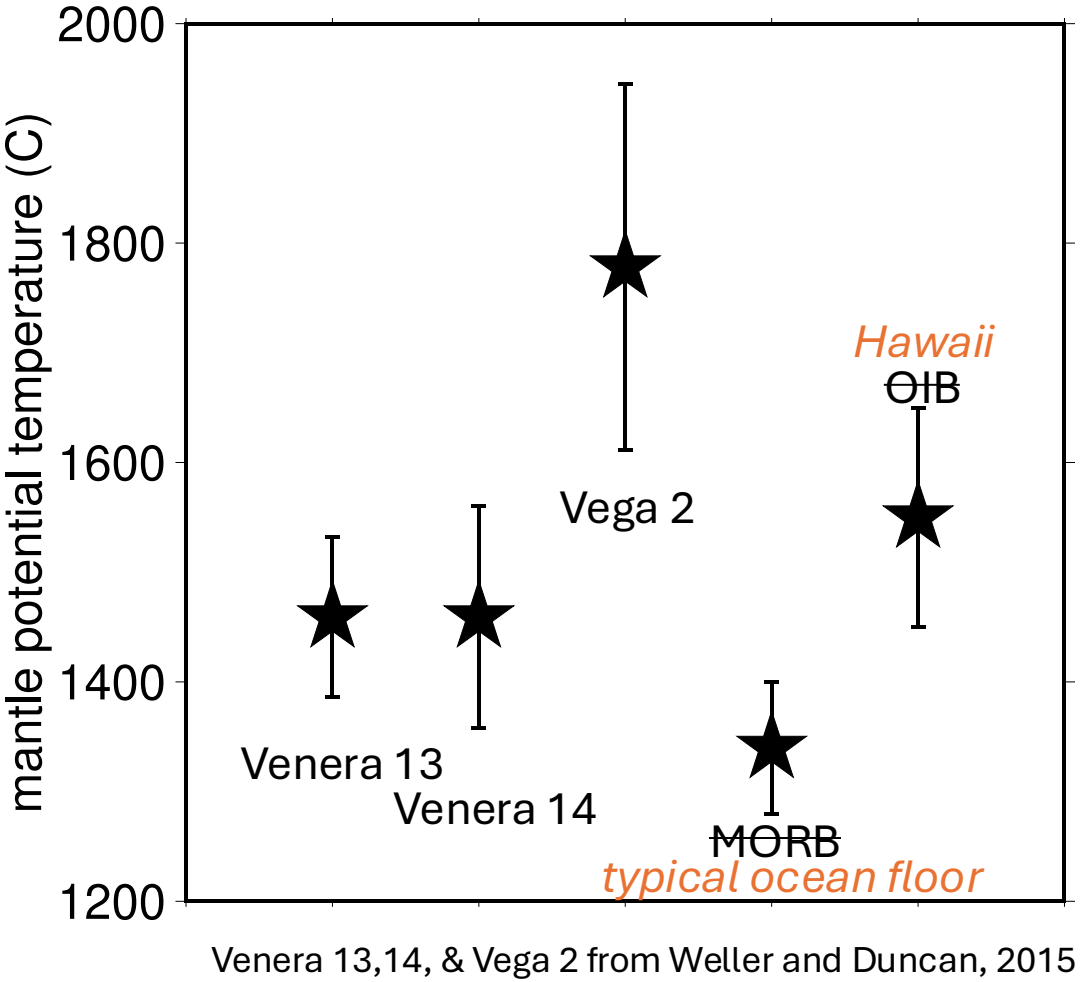
Venus

*for Venus I scaled Earth by 6052/6371, this is about as accurate as any model we have

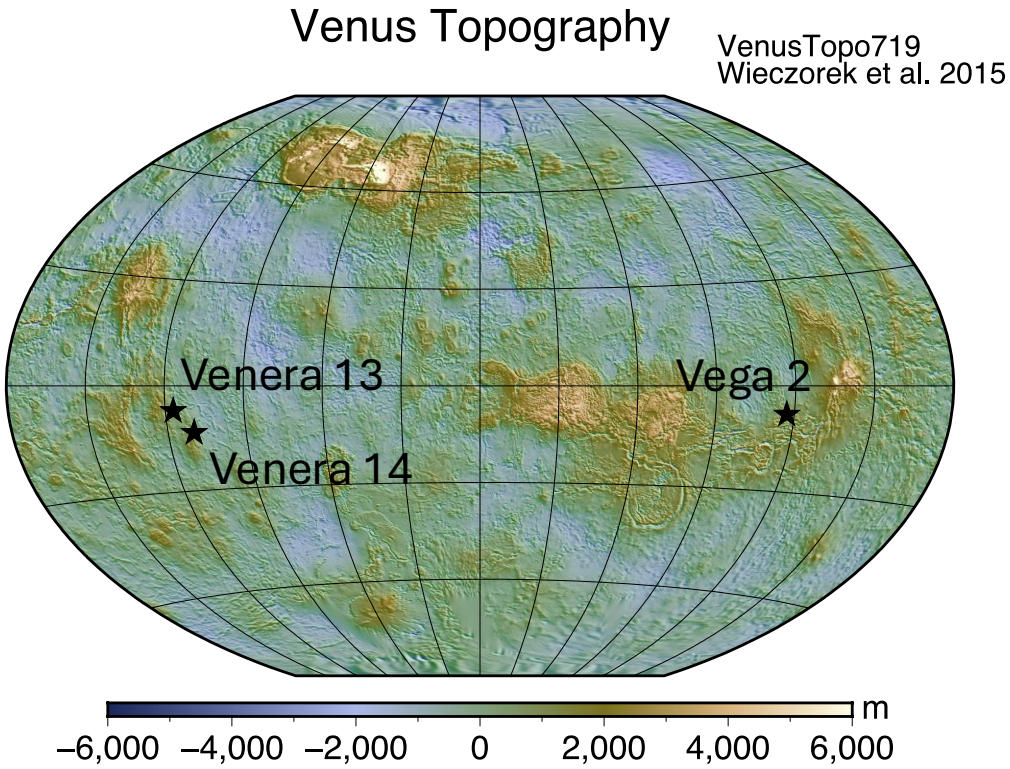
no core dynamo



Venus mantle temperature constraints

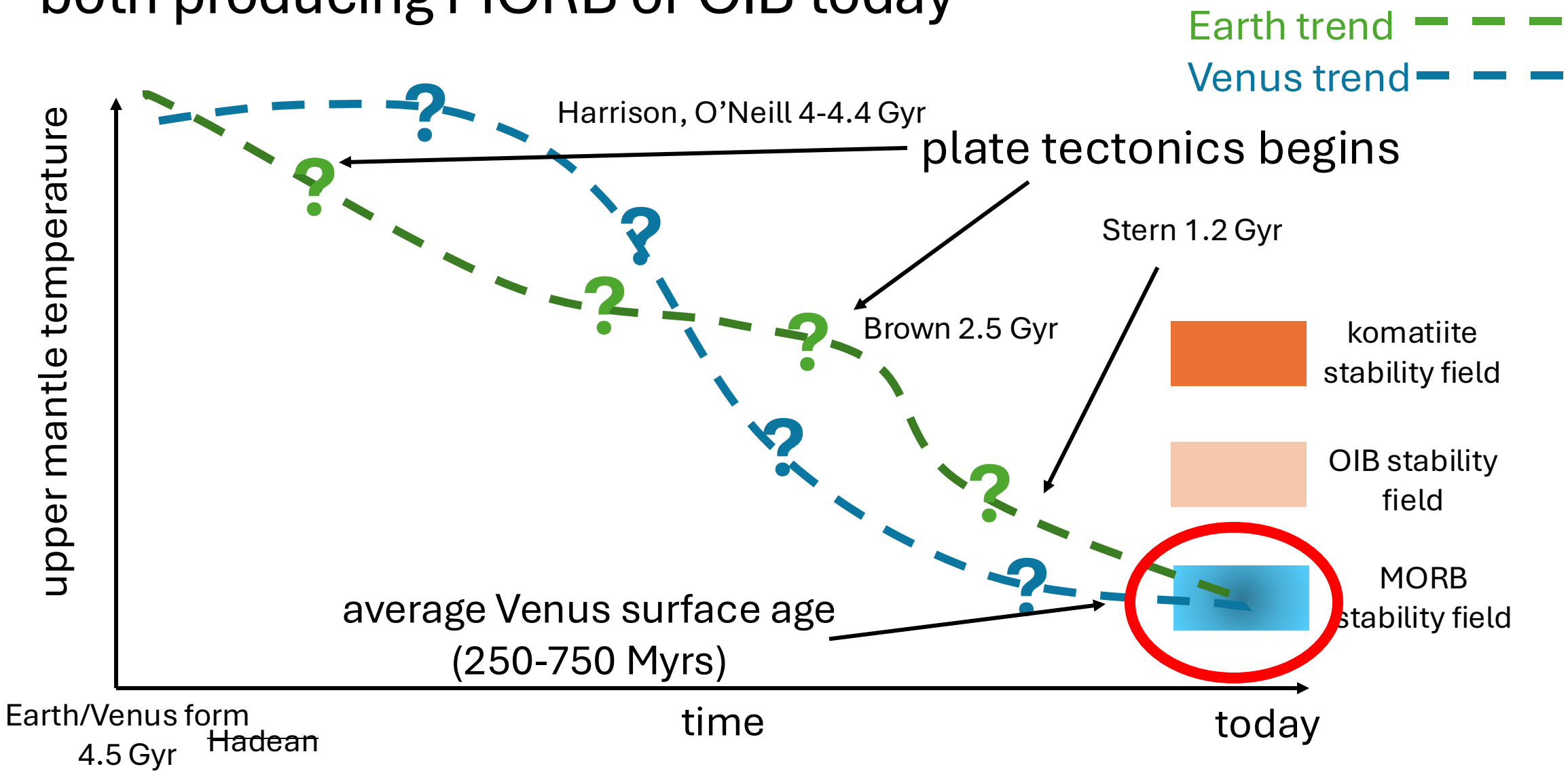


Venera 13,14, & Vega 2 from Weller and Duncan, 2015

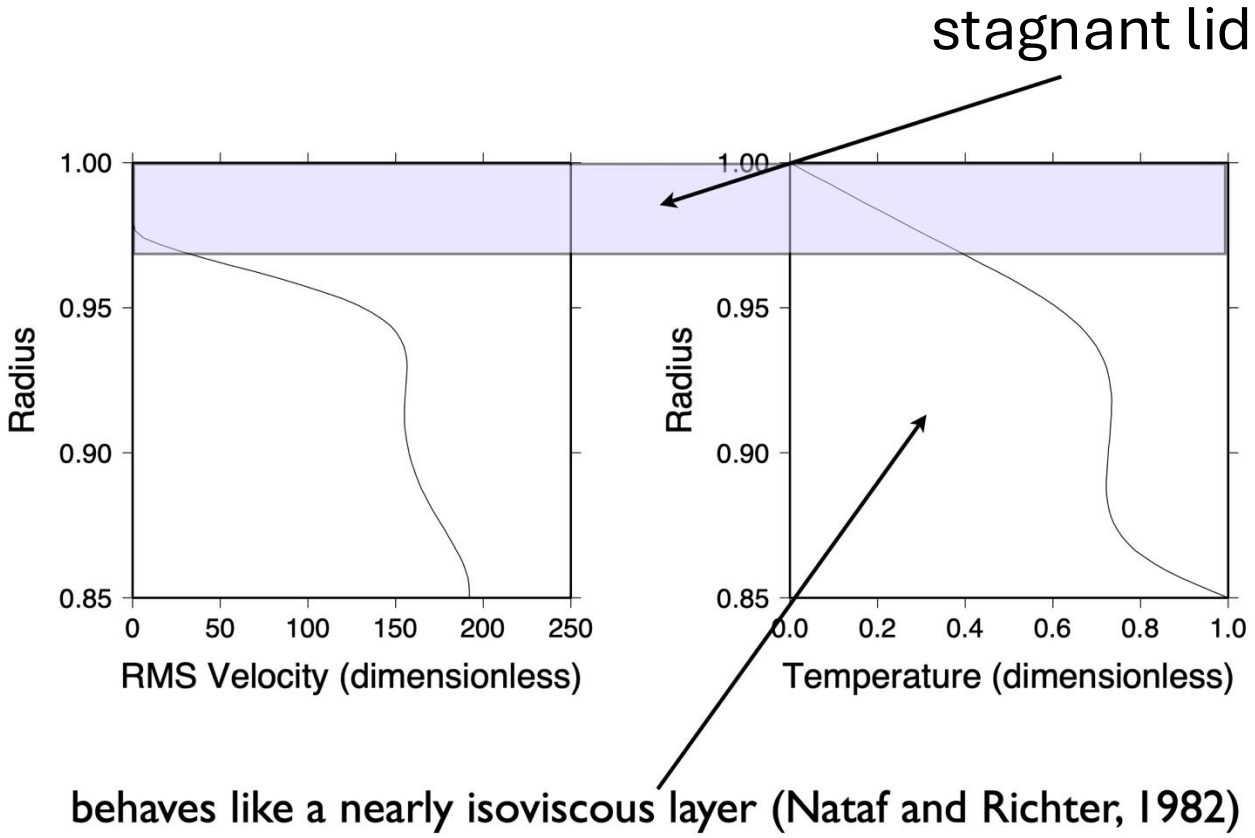


Huge error bars on some elements (Mg)!!

regardless of their different paths, Venus and Earth are both producing MORB or OIB today



stagnant-lid convection

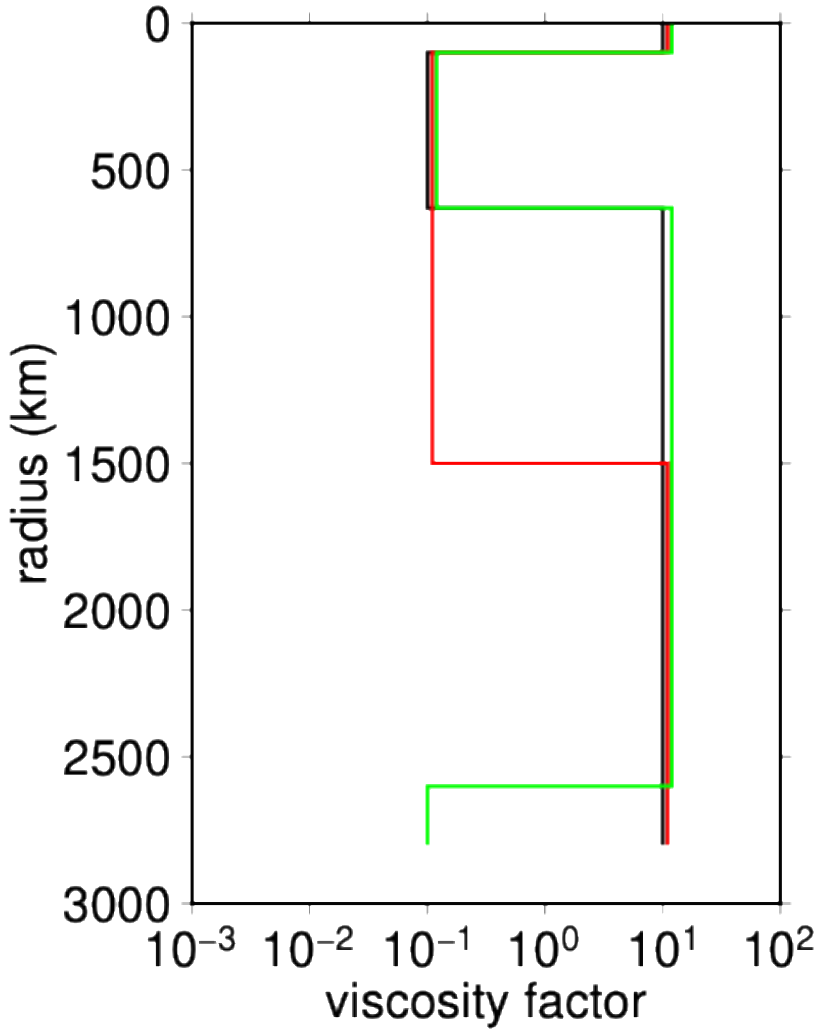


average over all longitude and latitude for a fix radius

the shaded layer at the top has zero velocity and a linear increase in temperature (diffusion)

this indicates a stagnant lid

compare different Venus viscosity models



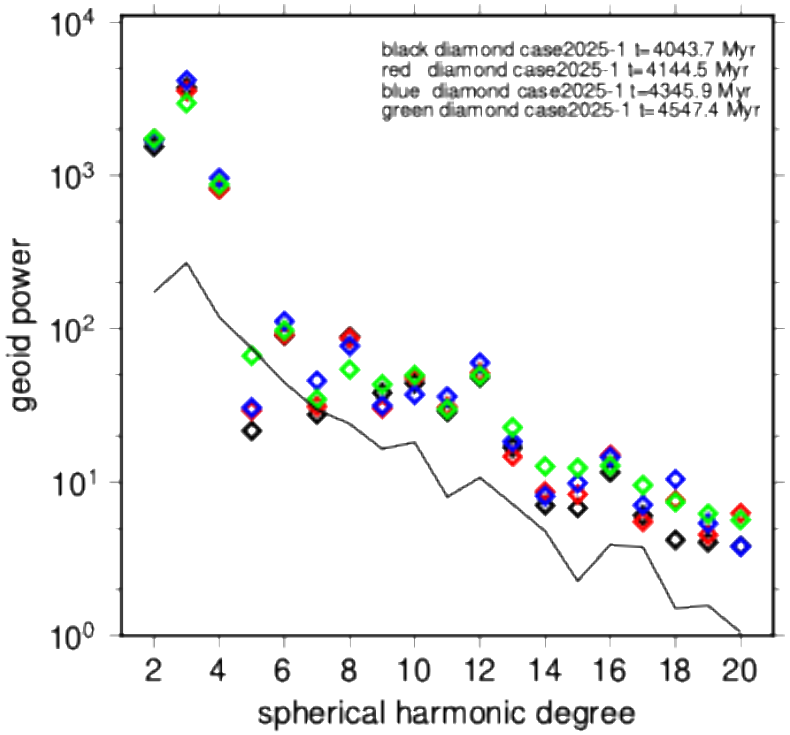
Kiefer and Hager, 1991

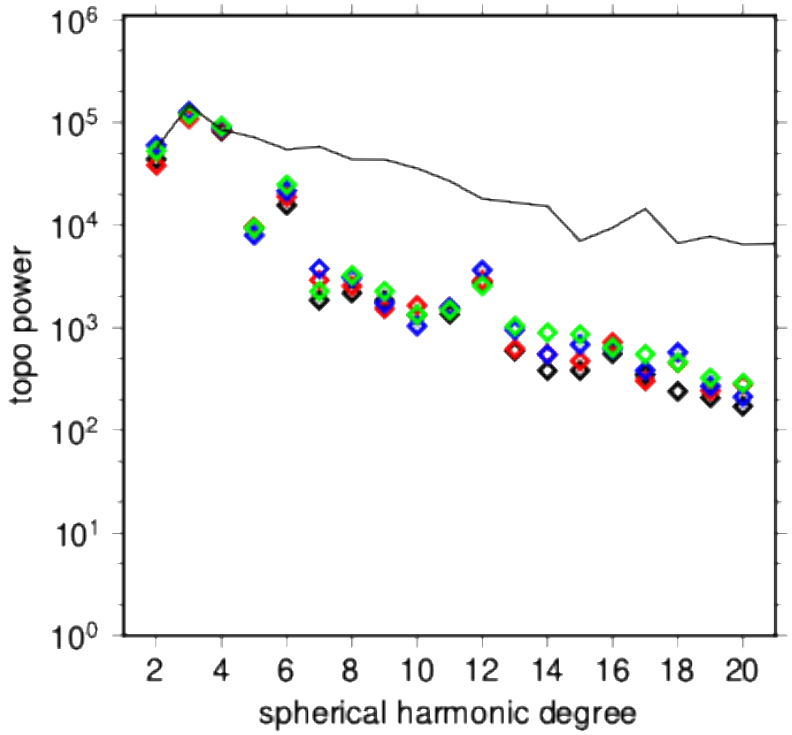
Maia et al., 2023

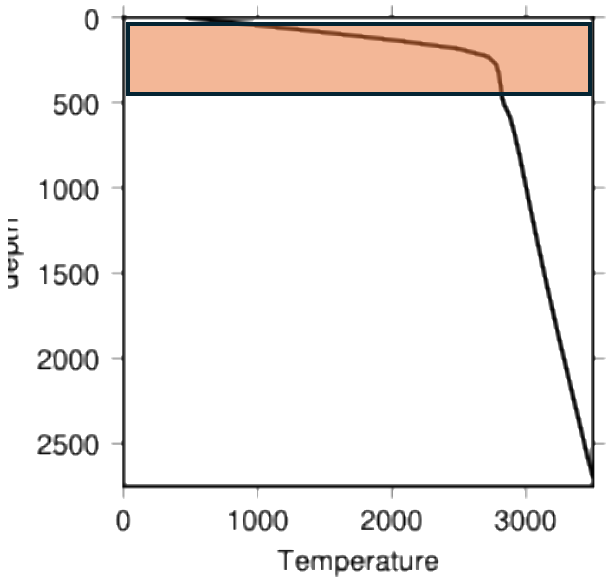
O'Rourke, 2018*

Kiefer and Hager, 1991

	l3 > l2 > l4	l4-l10	l>10
pattern	✓	✓	✓
amplitude	✗	✓	✗



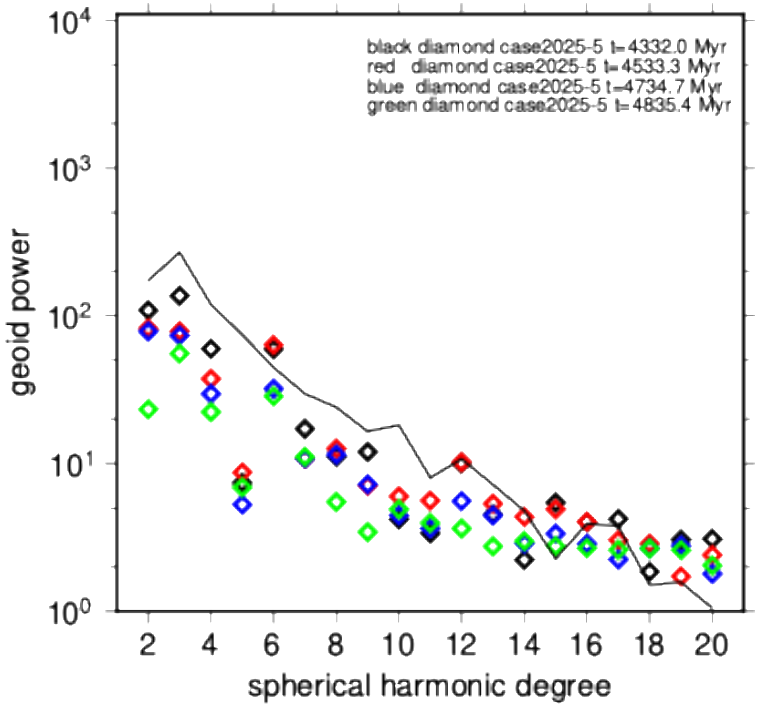


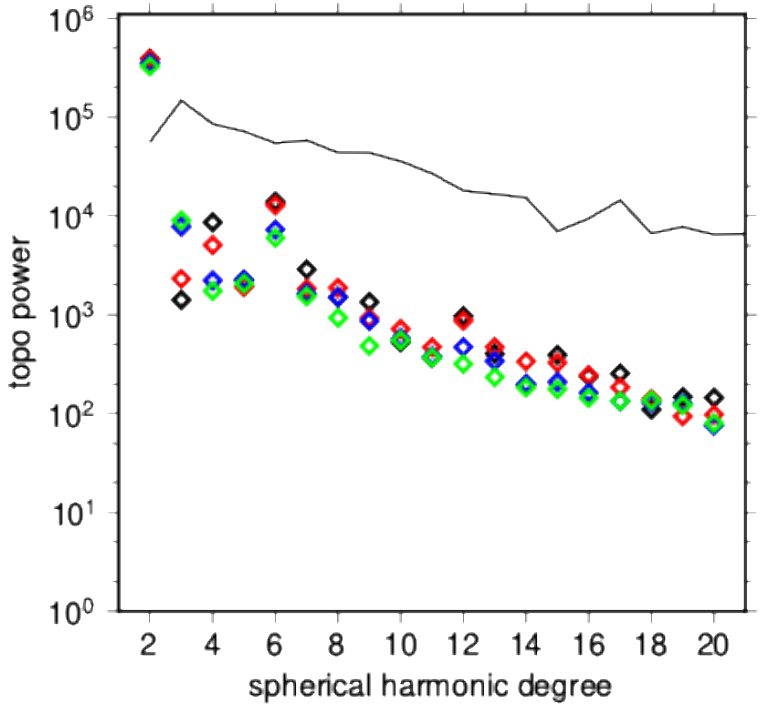


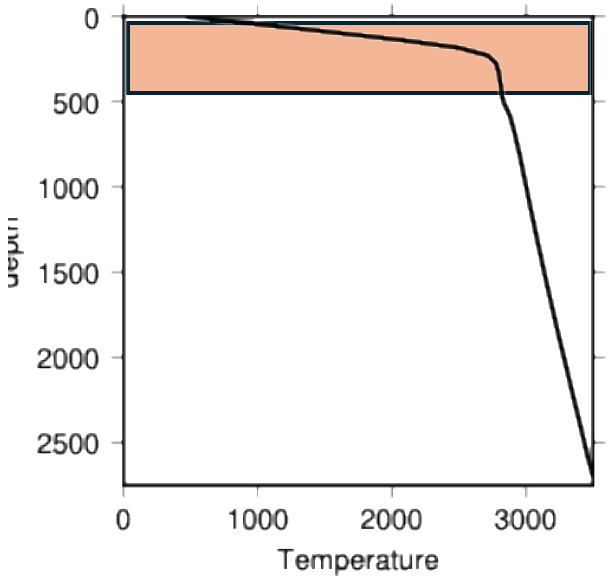
Too Hot!

Maia et al, 2023

	l3 > l2 > l4	l4-l10	l>10
pattern	✓	✓	✓
amplitude	✓	✓	✗







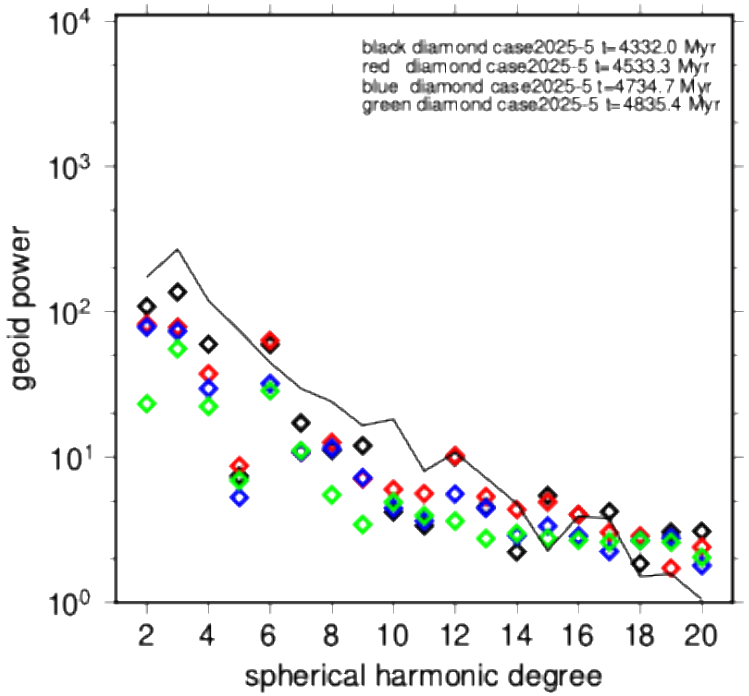
Too Hot!

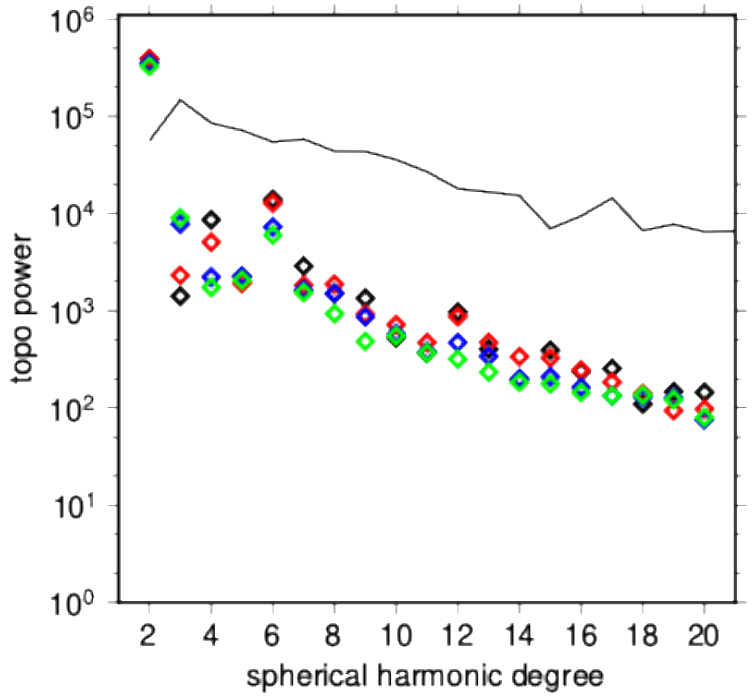
O’Rourke, 2018

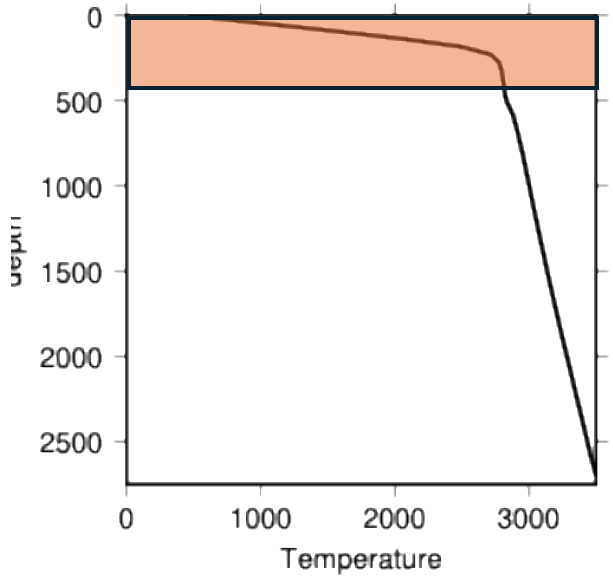
O’Rourke doesn’t produce a viscosity model but suggests a basal magma ocean may exist today.

This is a modification of Kiefer and Hager, 1991

	l3 > l2 > l4	l4-l10	l>10
pattern	✗	✓	✓
amplitude	✓	✓	✓



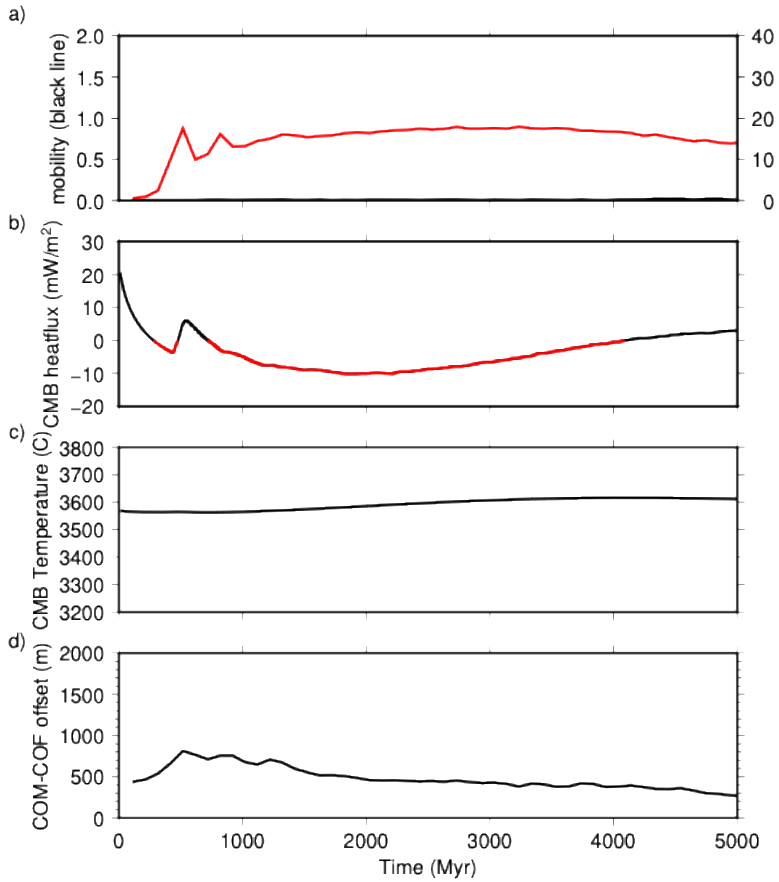




Too Hot!

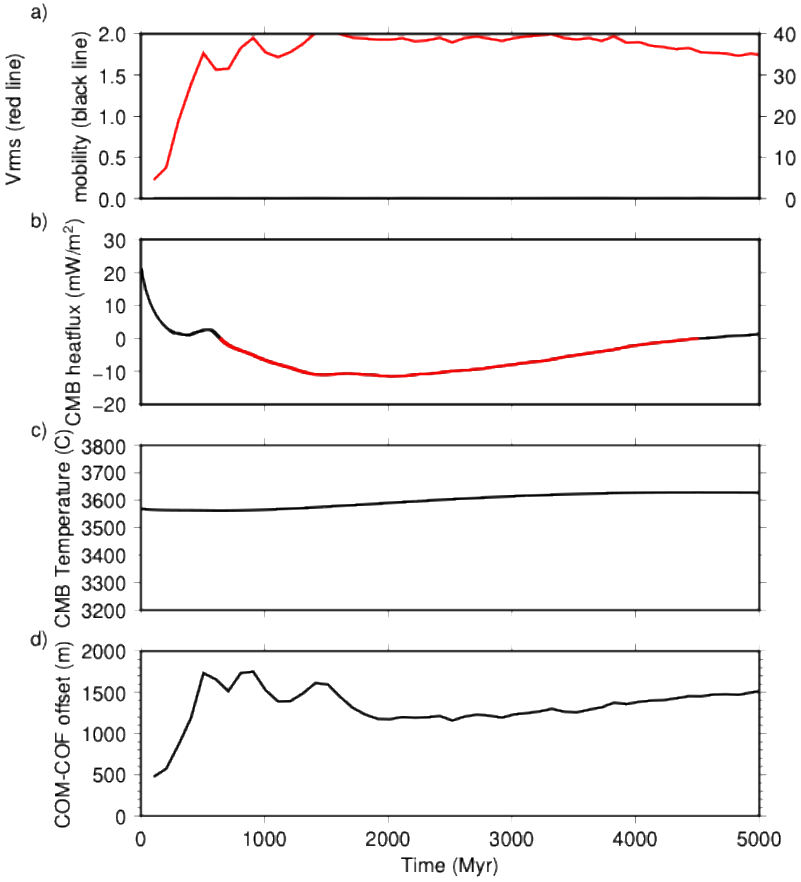
all cases have negative CMB heat flow from 1-4 Gyr

Kiefer and Hager, 1991



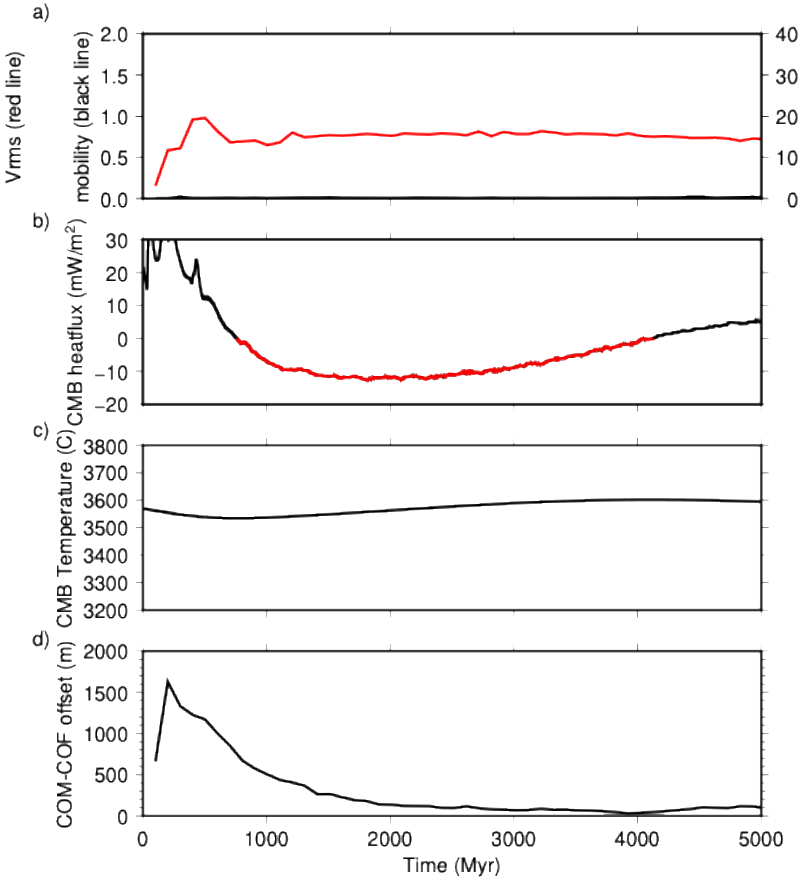
case2025-1

Maia et al., 2023



case2025-5

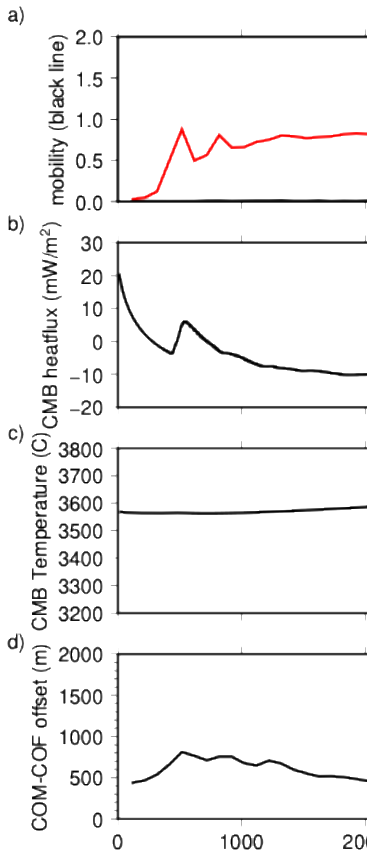
O'Rourke, 2018

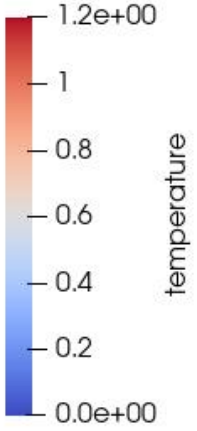


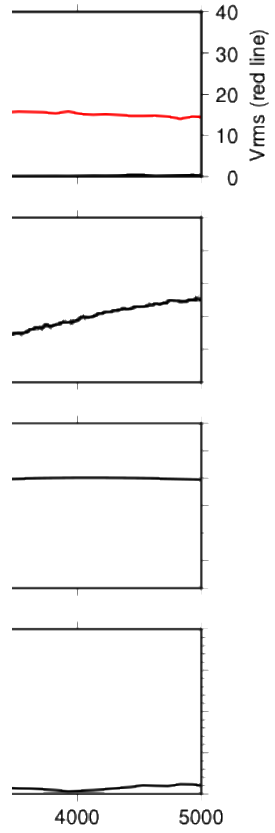
case2025-4

all cases have negative CMB heat flow from 1-4 Gyr

Kiefer anc



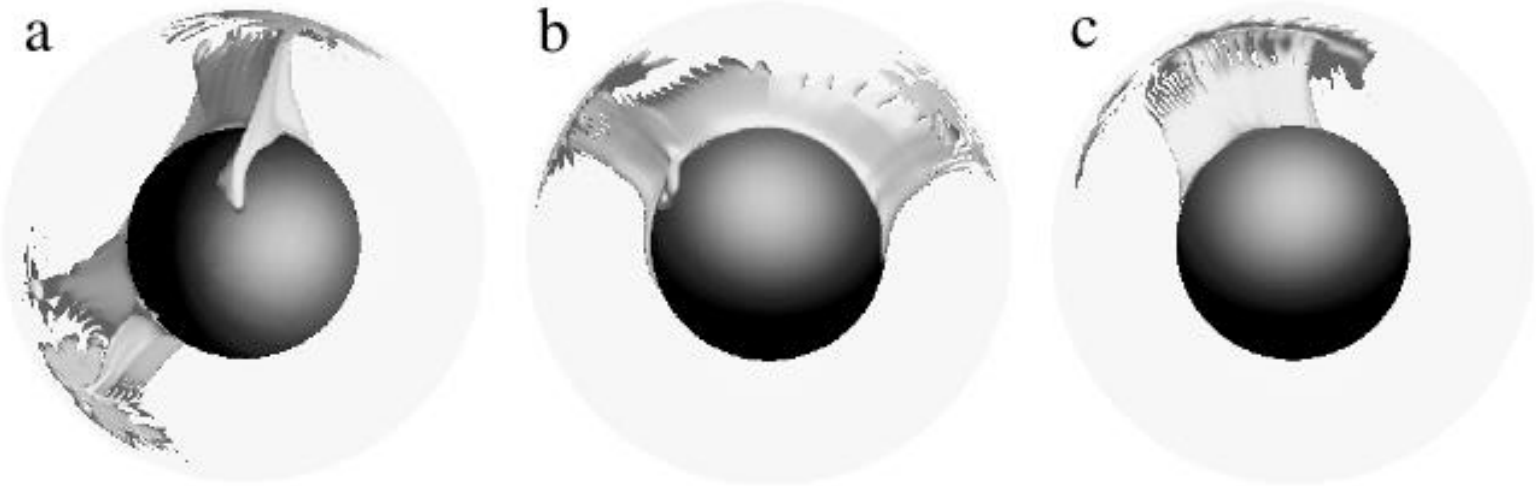


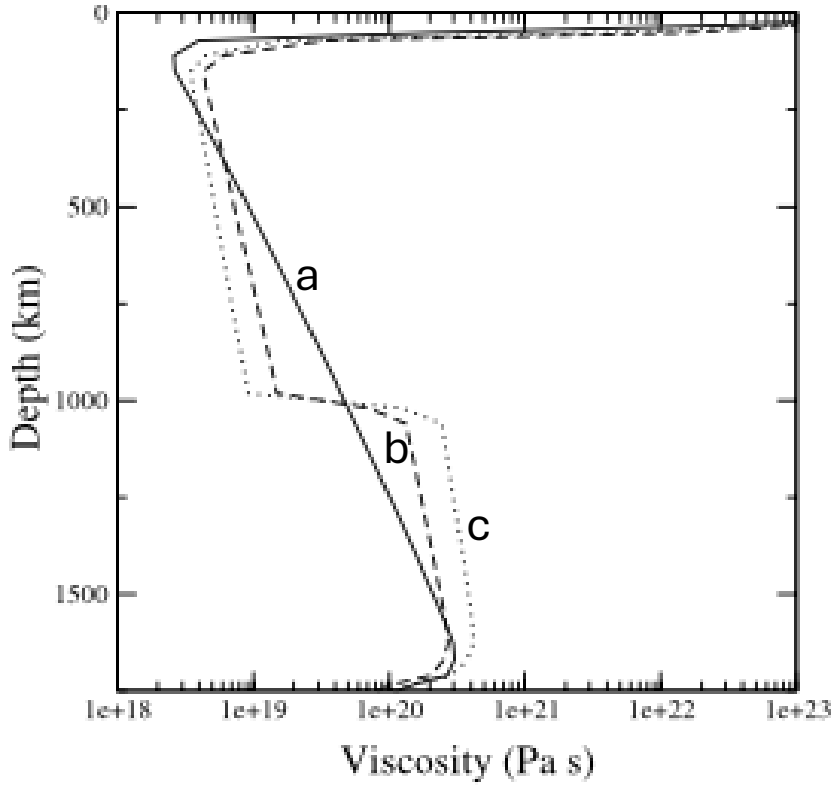


case2025-4

Maia et al, 2023 has a large degree 1 overturn, violates COM-COF offset observation

large viscosity increase at mid-mantle leads to degree 1 overturn (Roberts and Zhong, 2006)

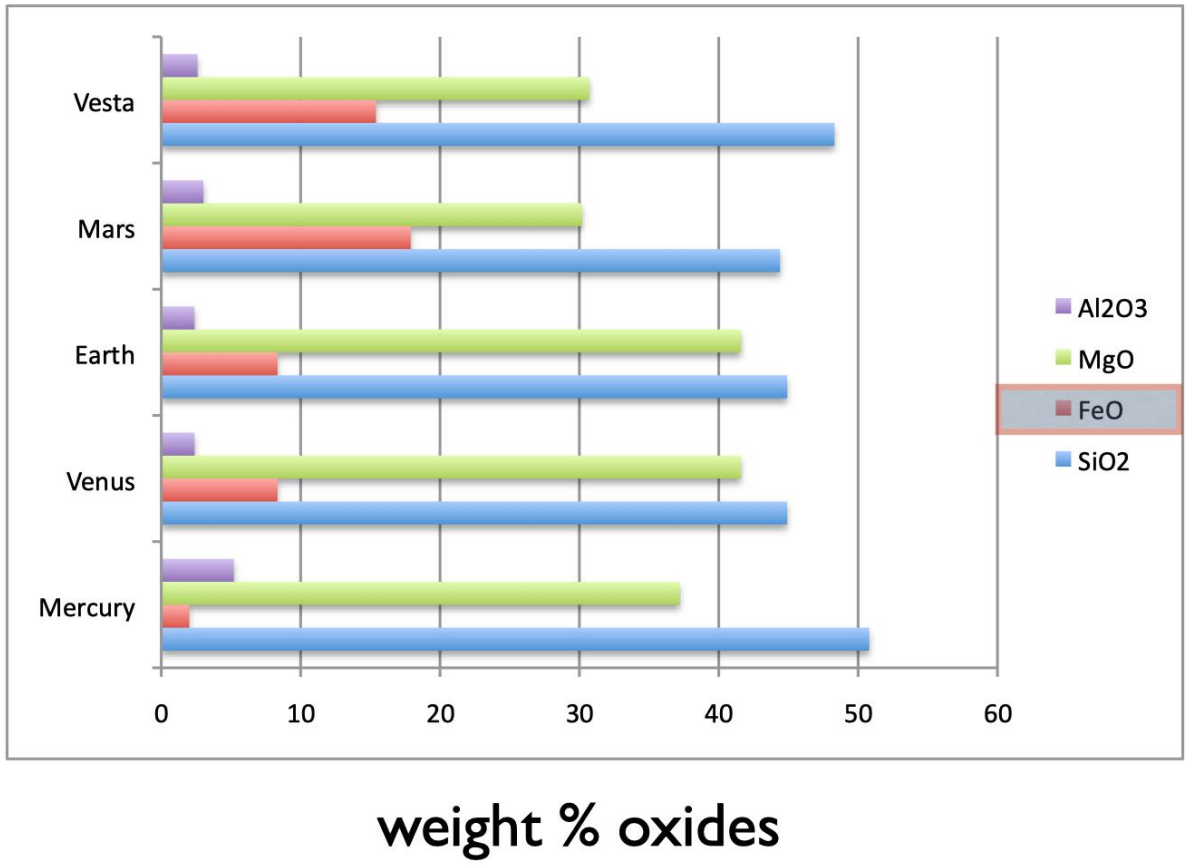




conclusions: *caveat, all models may be too hot!*

- the Kiefer and Hager, 1991 viscosity model matches the distinctive l3 > l2 > l4 pattern but, the magnitude of the geoid PS is too large
- the Maia et al., 2023 viscosity model leads to a degree 1 instability, which violates the COM-COF offset constraint
  - *modify the Maia et al., 2023 viscosity model by smoothing out viscosity step? (e.g. Steinberger et al., 2010)*
- all calculations have negative CMB heat flow (heat flowing into the core from the mantle) from 1-4 Gyrs, which should suppress a core dynamo
  - *a consequence of nearly identical mantle & core starting temperatures along with the concentration of HPE's in the mantle*

Earth & Venus Basalts

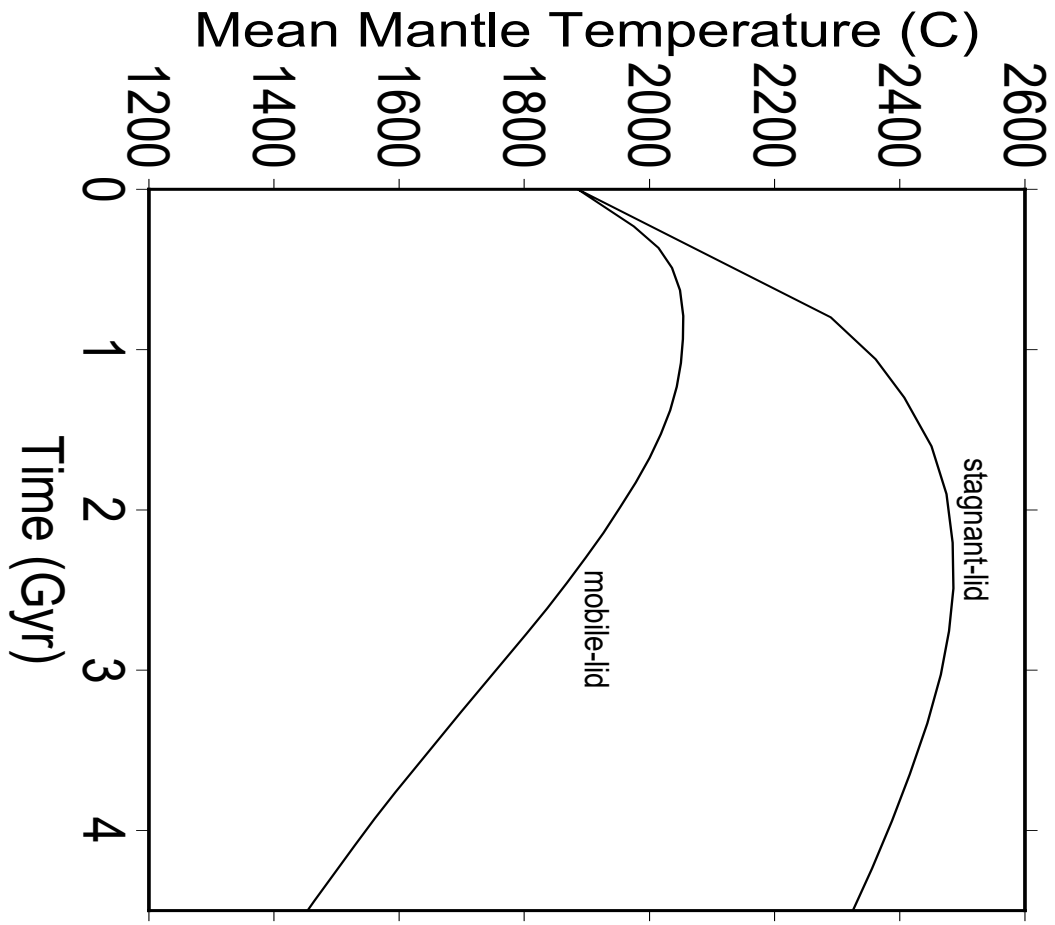


Mg/Fe ratio related to melting temperature

Venus and Earth (MORB) are nearly identical

Venus interior temperature at the melt zone is nearly identical to MORB environment!!

characteristics of stagnant lid convection



more heat is trapped within the planet than if the top “boundary layer” (or system of plates) cannot sink into the interior

stagnant lid mantles are hotter than mobile lid mantles, all other things held constant

mobile lid does not equal plate tectonics

Alfred Wegner circa 1929 *photo: Alfred Wegner Institute*

taken from Mountain Mystery Blog by Ron Miksha

first March for Science?

subduction: one plate sinking beneath the other, asymmetric

ridges: symmetric (or nearly so) spreading

transform faults: rotation in a shell of constant radius (curl of a scalar field)

Mantle Parameter	Value
density	4,000 kg/m^3
thermal expansion coefficient	$2.0x10^{-5}$ K^{-1}
gravity	8.87 m s^{-2}
surface temperature	700 K
convective temperature drop	2,024 K
radius of planet	$6.052 x10^6$ m
radius of cmb	$3.110 x10^6$ m
thermal diffusivity	10^{-6} m^2 s^{-1}
reference viscosity	$4x10^{20}$ Pa s
Rayleigh number	$9.1x10^7$
adiabatic gradient	0.3 K km^{-1}
activation energy (rheology)	325 kJ $mole^{-1}$
yield stress	100, 250, 500 MPa