Mercury, and Venus, and Mars, oh My!

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overarching themes:

1) We learn a lot about the Earth by studying Mercury, Venus, and Mars

2) There is a remarkable diversity of planets around a single star

1) behavior of the top boundary layer

plate tectonics

episodic mobile lid

stagnant lid
(if convecting at all)

stagnant lid

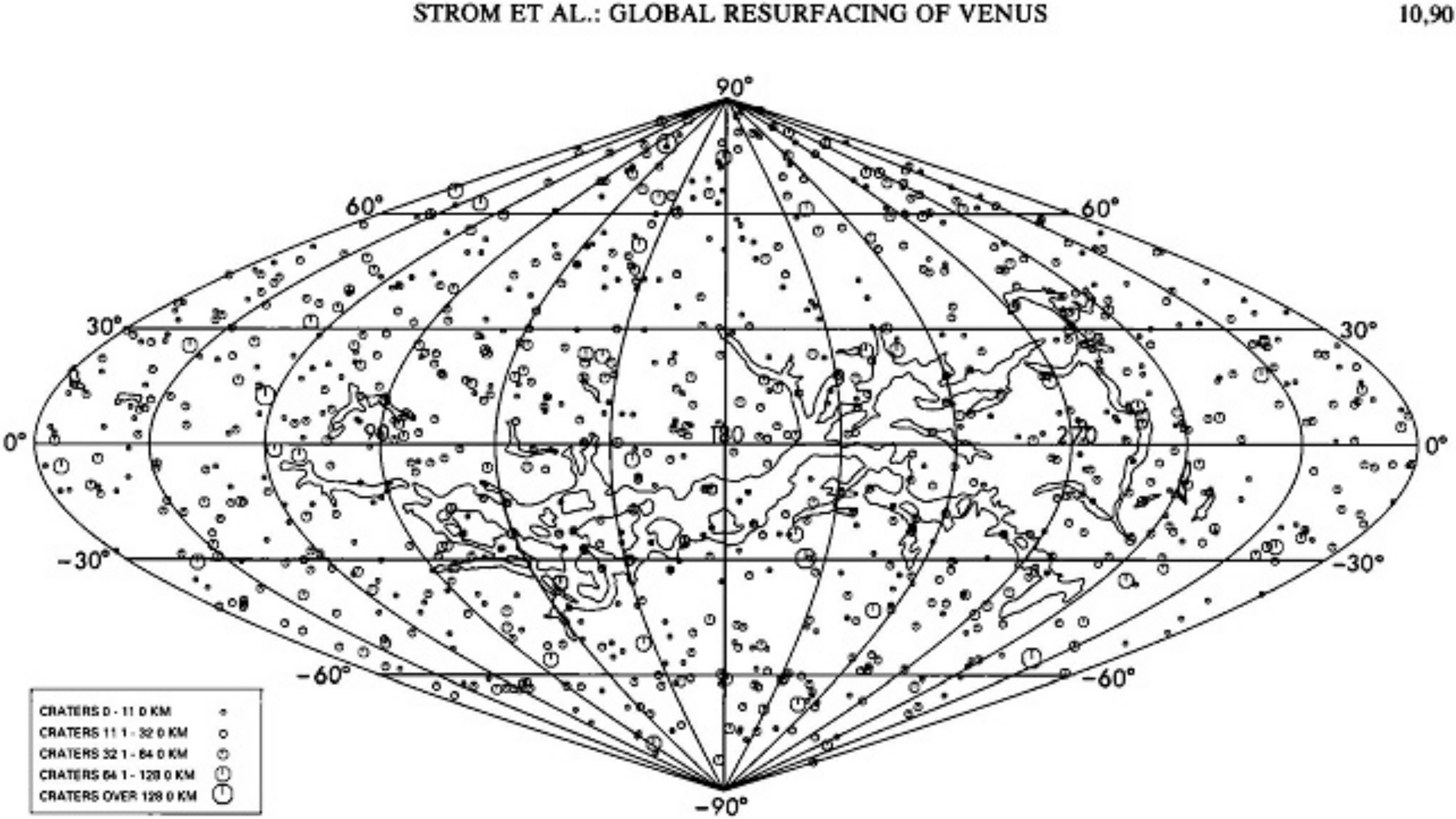
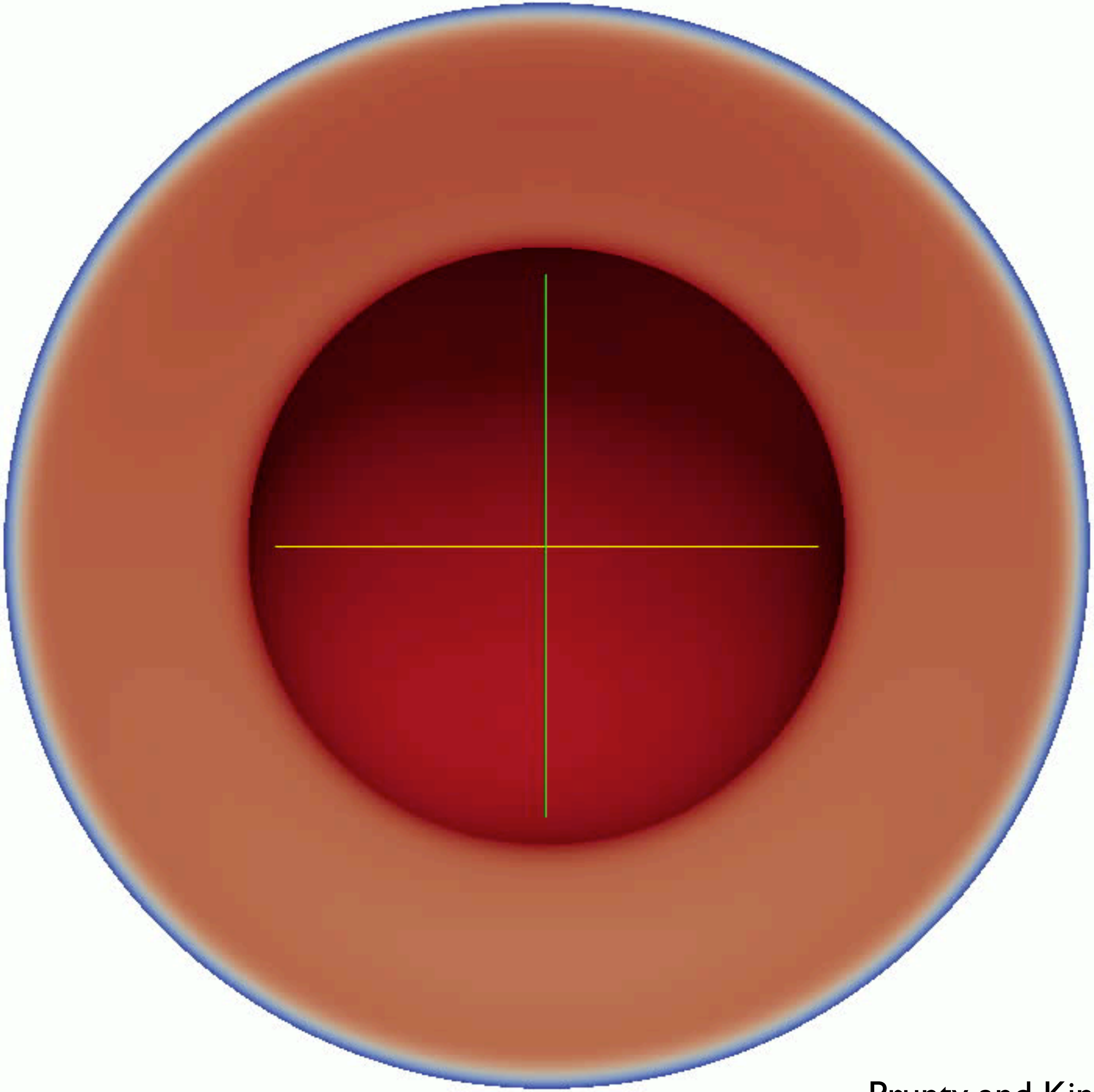
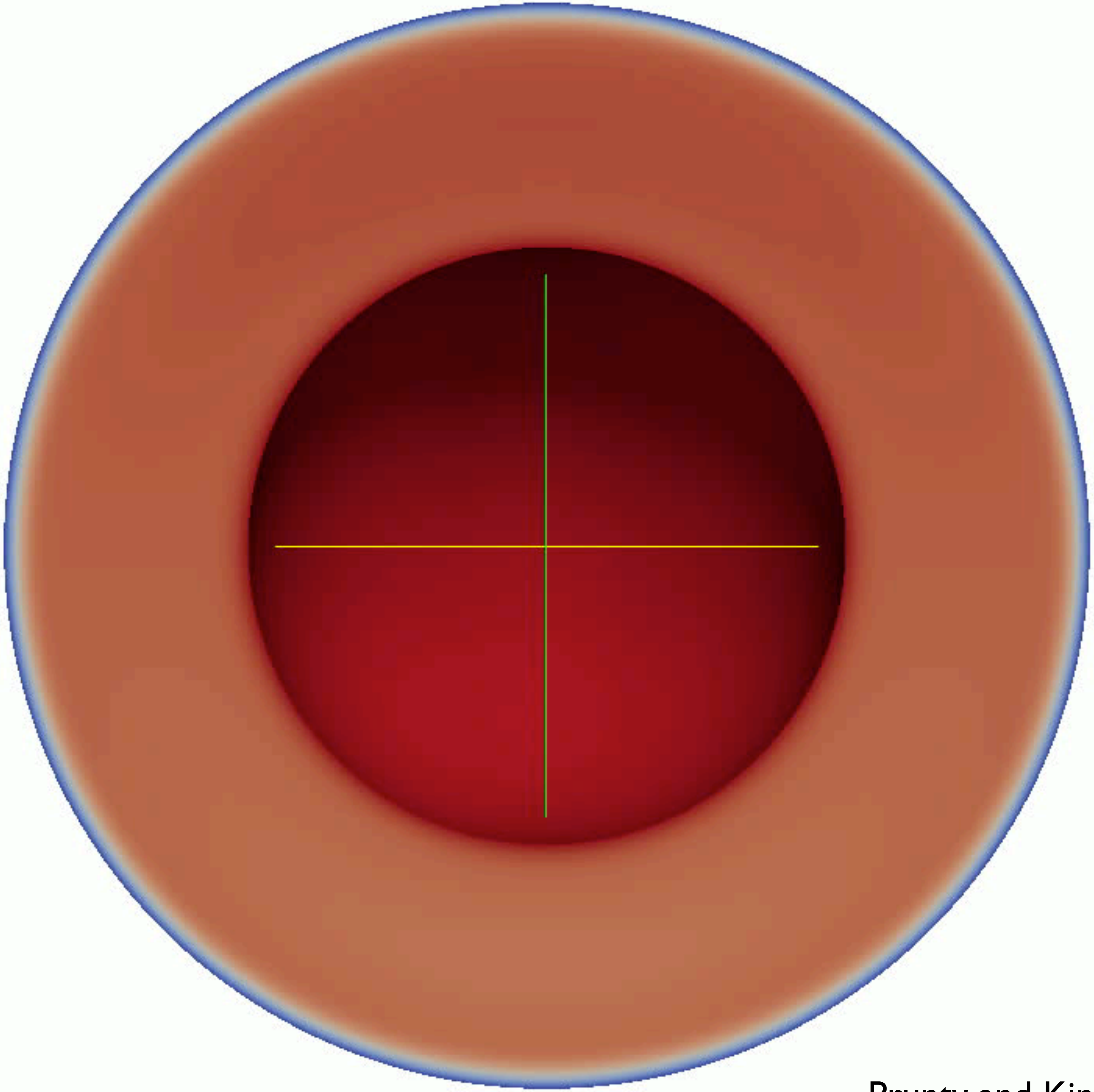


Figure 1a. Map in sinusoidal equal-area projection showing the sizes and distribution of the 932 impact craters on 98% of Venus' surface. Sizes of symbols are scaled to crater diameter bins but not to map. Shaded areas indicate fracture belts of concentrated extensions (modified from *Schaber* [1982] using Magellan data).



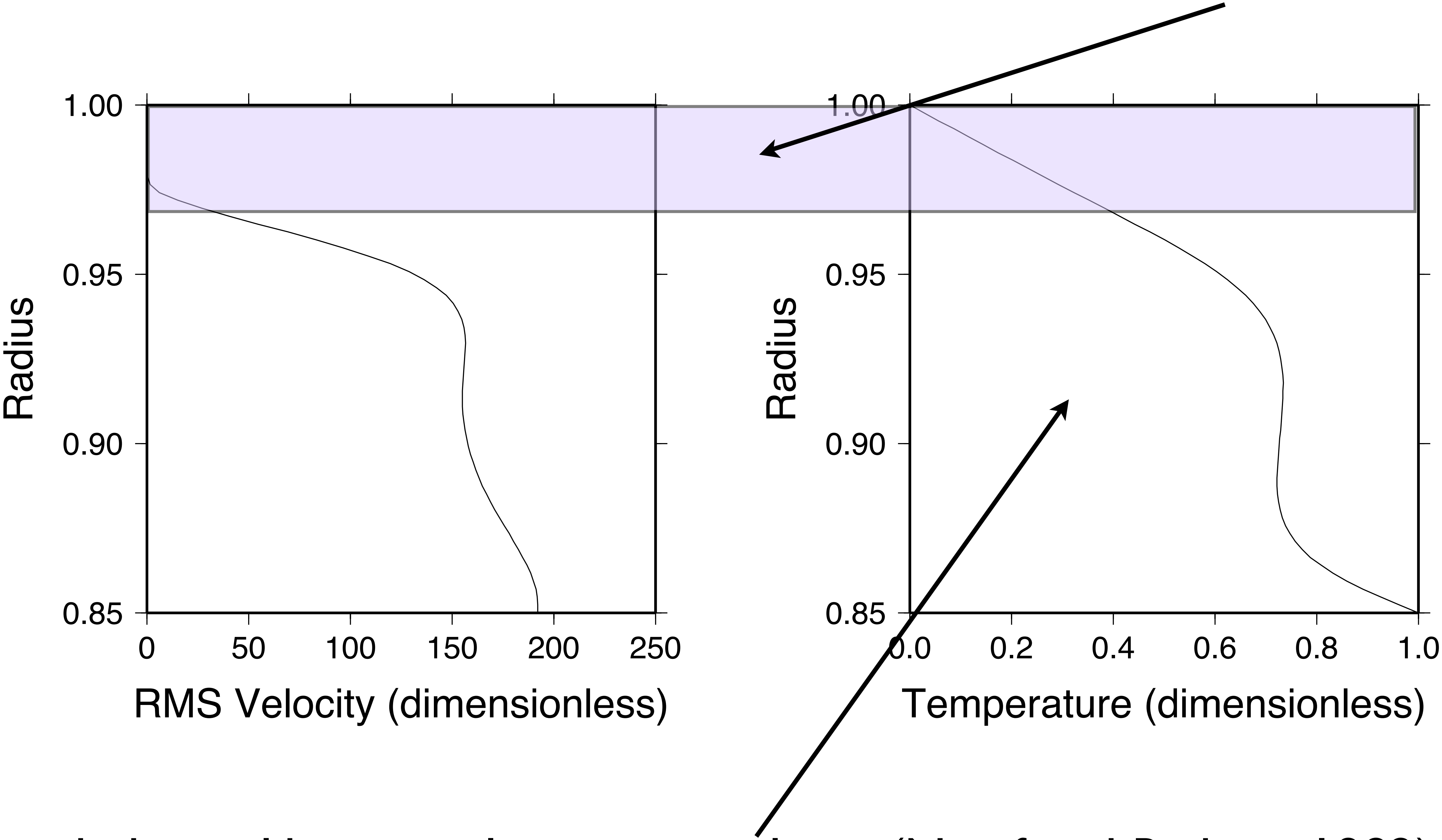
Prunty and King, AGU, 2014



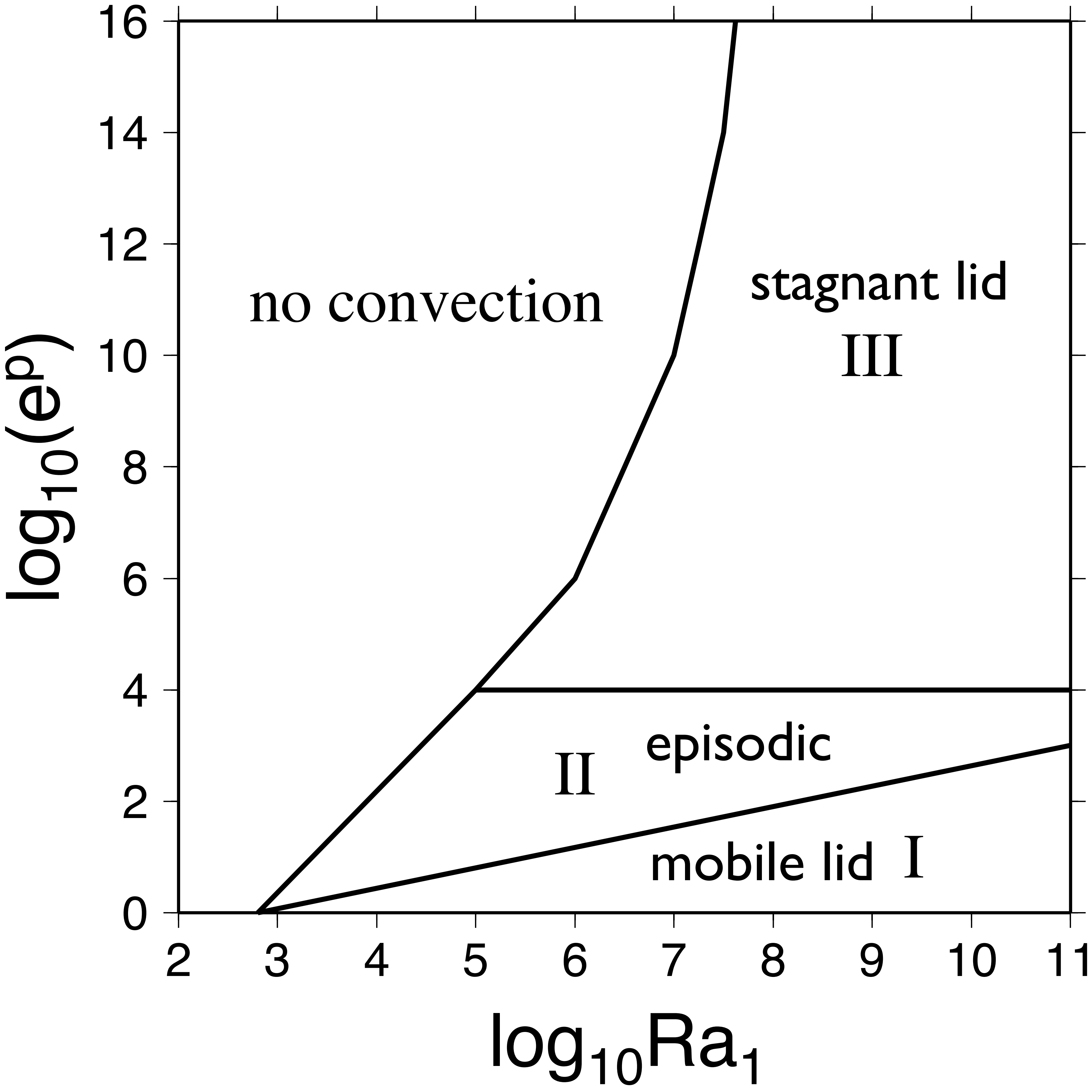
Prunty and King, AGU, 2014

value at given radius averaged over θ, φ

stagnant lid

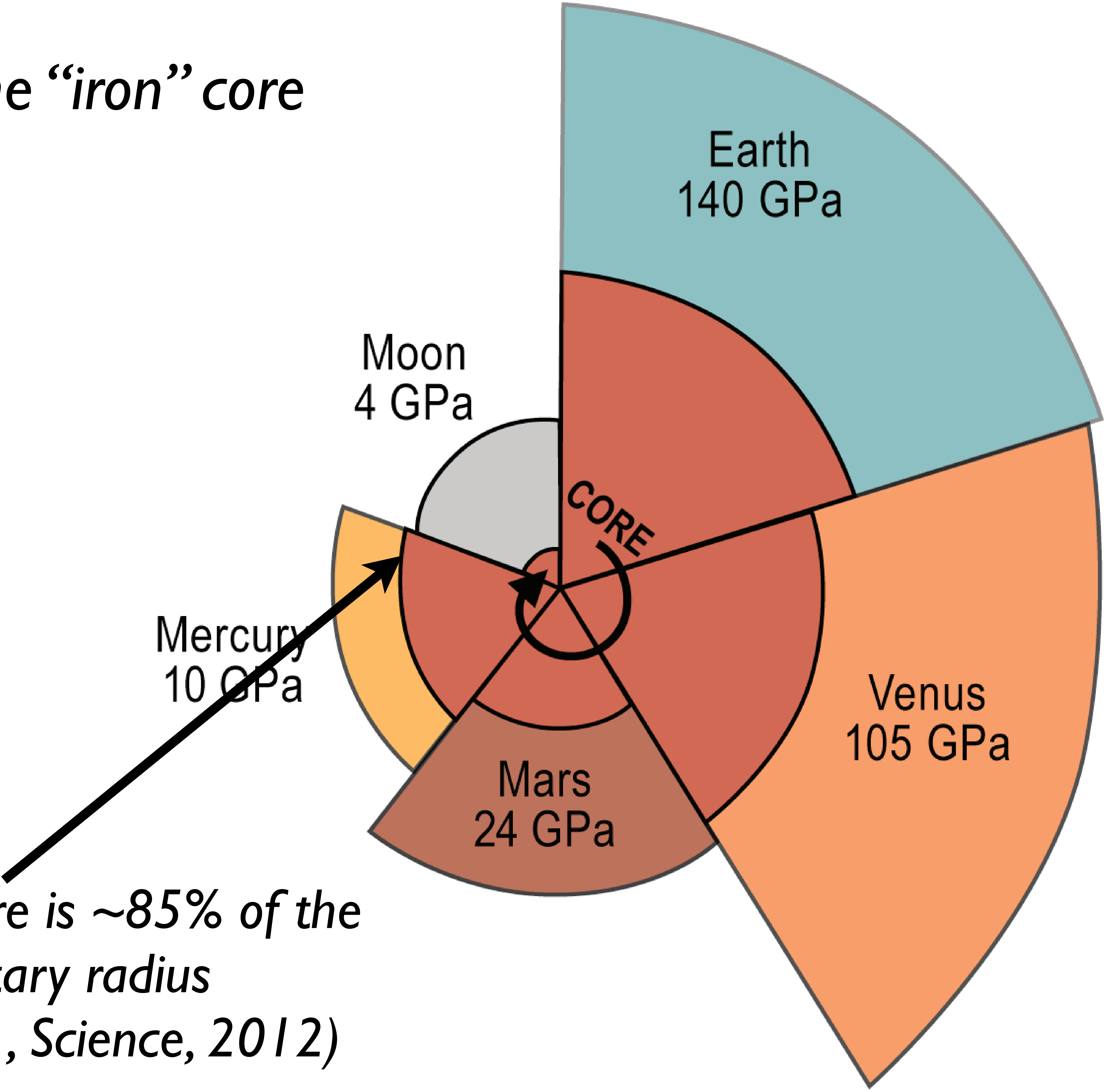


behaves like a nearly isoviscous layer (Nataf and Richter, 1982)



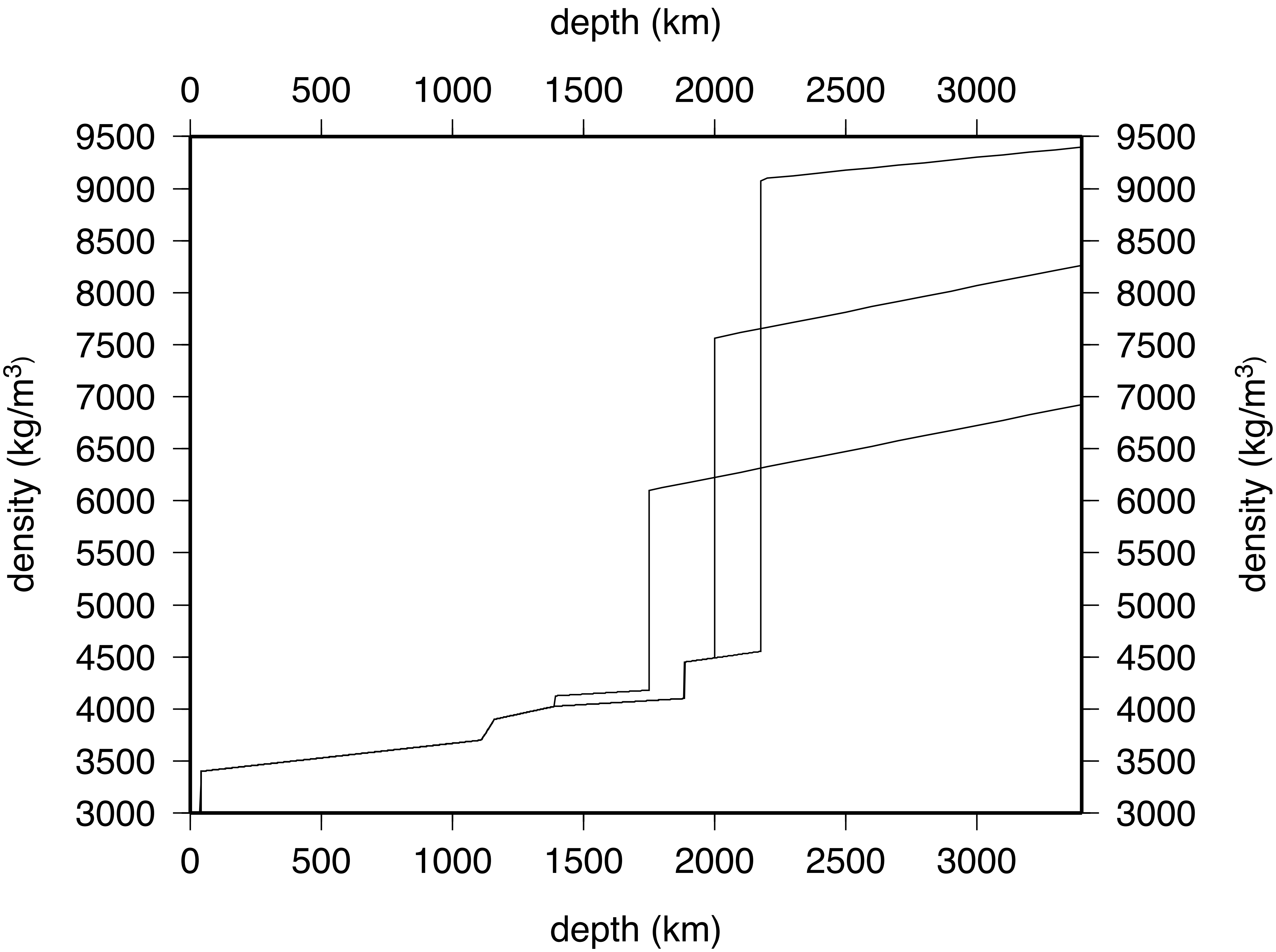
Solomatov, 1995

2) size of the "iron" core



Mercury's core is ~85% of the planetary radius (Smith et al., Science, 2012)

figure credit: Kevin Righter and Leanne Woolley, LPI

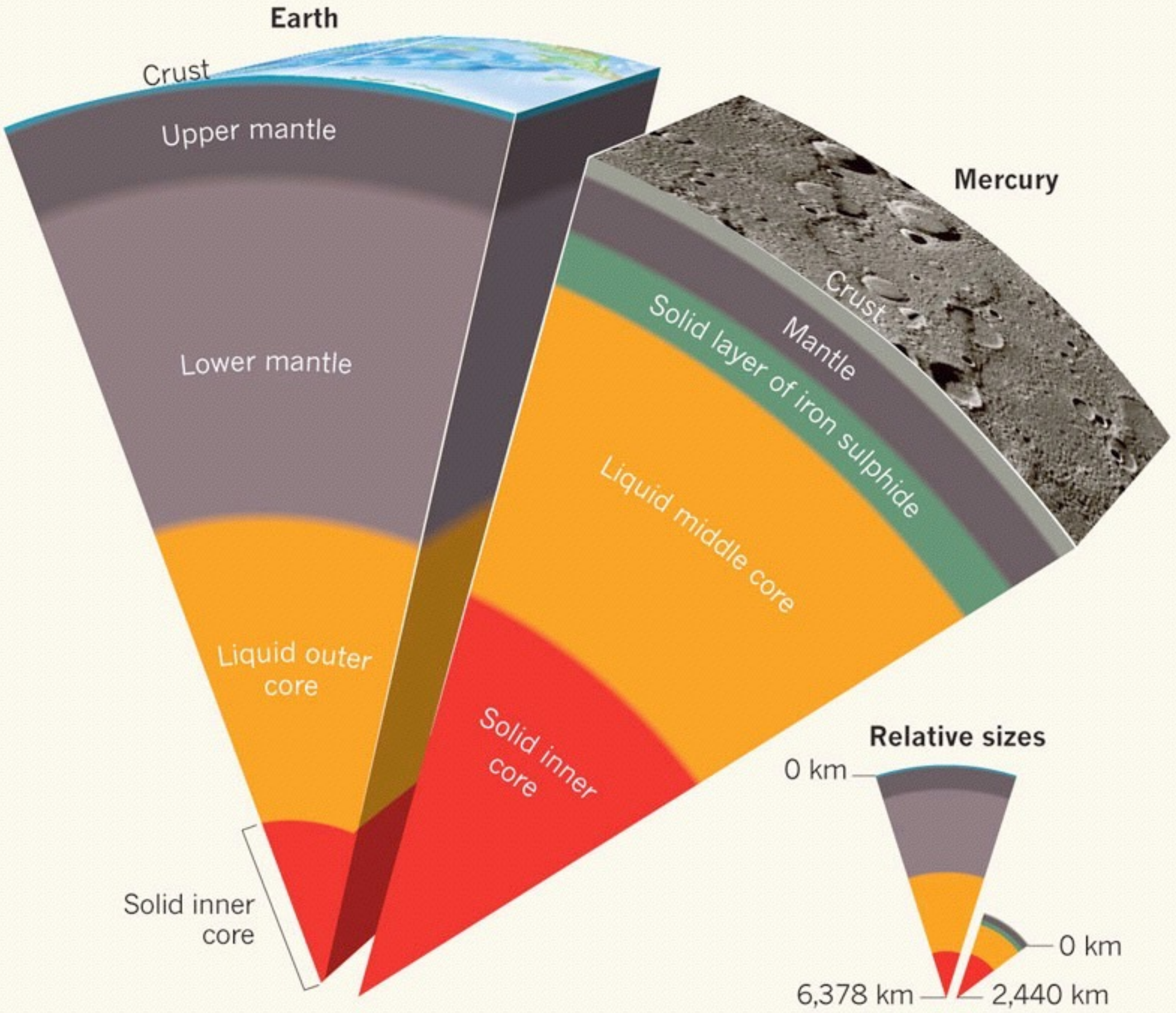


Bertka and Fei, Density profile of an SNC model Martian interior and the moment-of-inertia factor of Mars, *Earth and Planet. Sci. Lett.*, 157, 79–88,1998

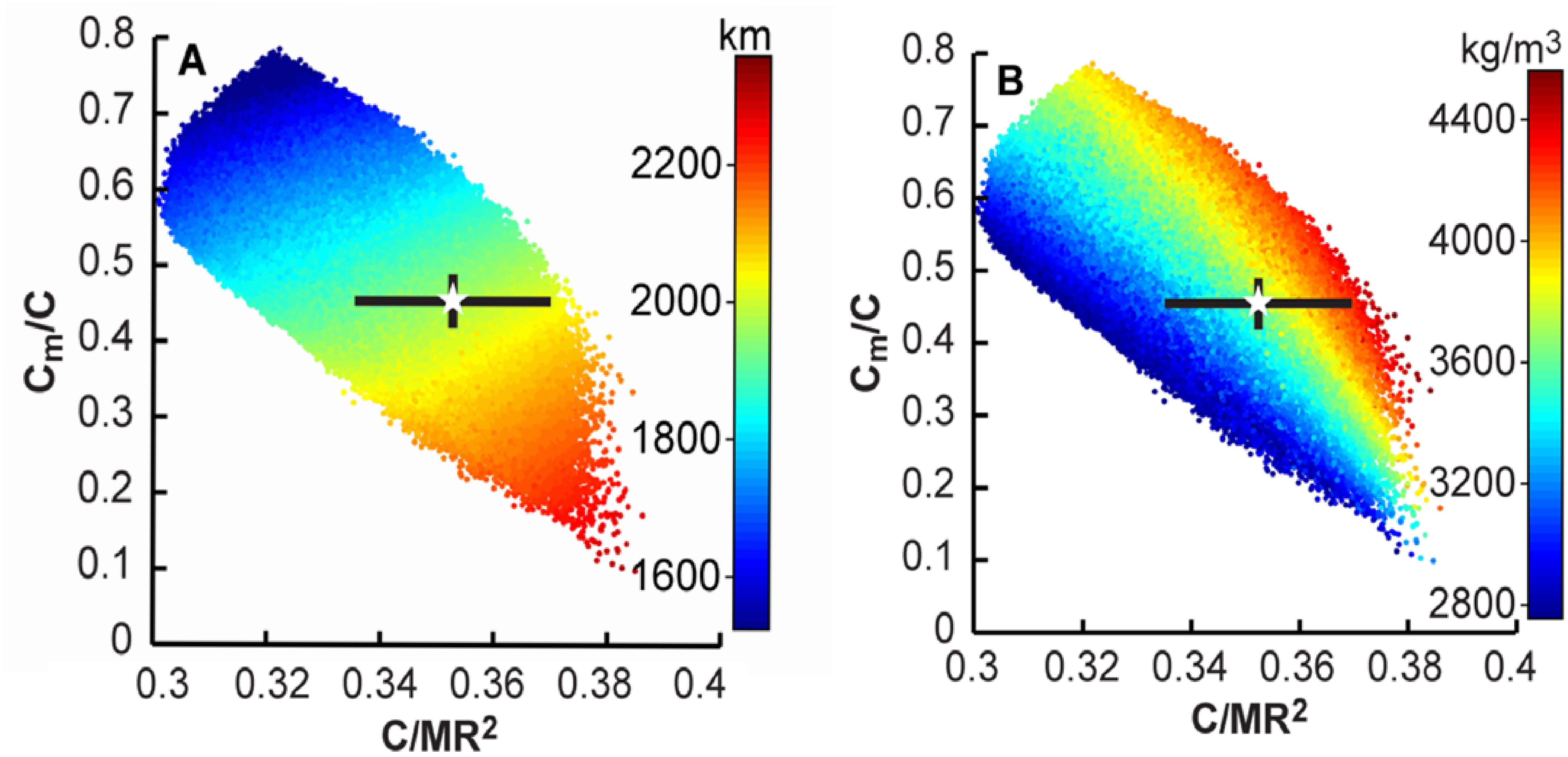
Mercury’s shrinking mantle through time

	observational constraint	mantle thickness (km)	mantle density (kg/m^3)
Mariner 10	ρ_{ave}, g	600	3350
Harder and Schubert, 2001	Fe/FeS phase diagram	440+/-420	3350+/-250
Smith et al., *Science*, 2012	MOI	410+/-37	3600
Margot et al., *JGR*, 2012	MOI, spin state	440	3200
Hauck II et al., 2013	MOI, EOS	420+/-20	3380+/-200

to fit the MOI, may require an iron sulphide layer



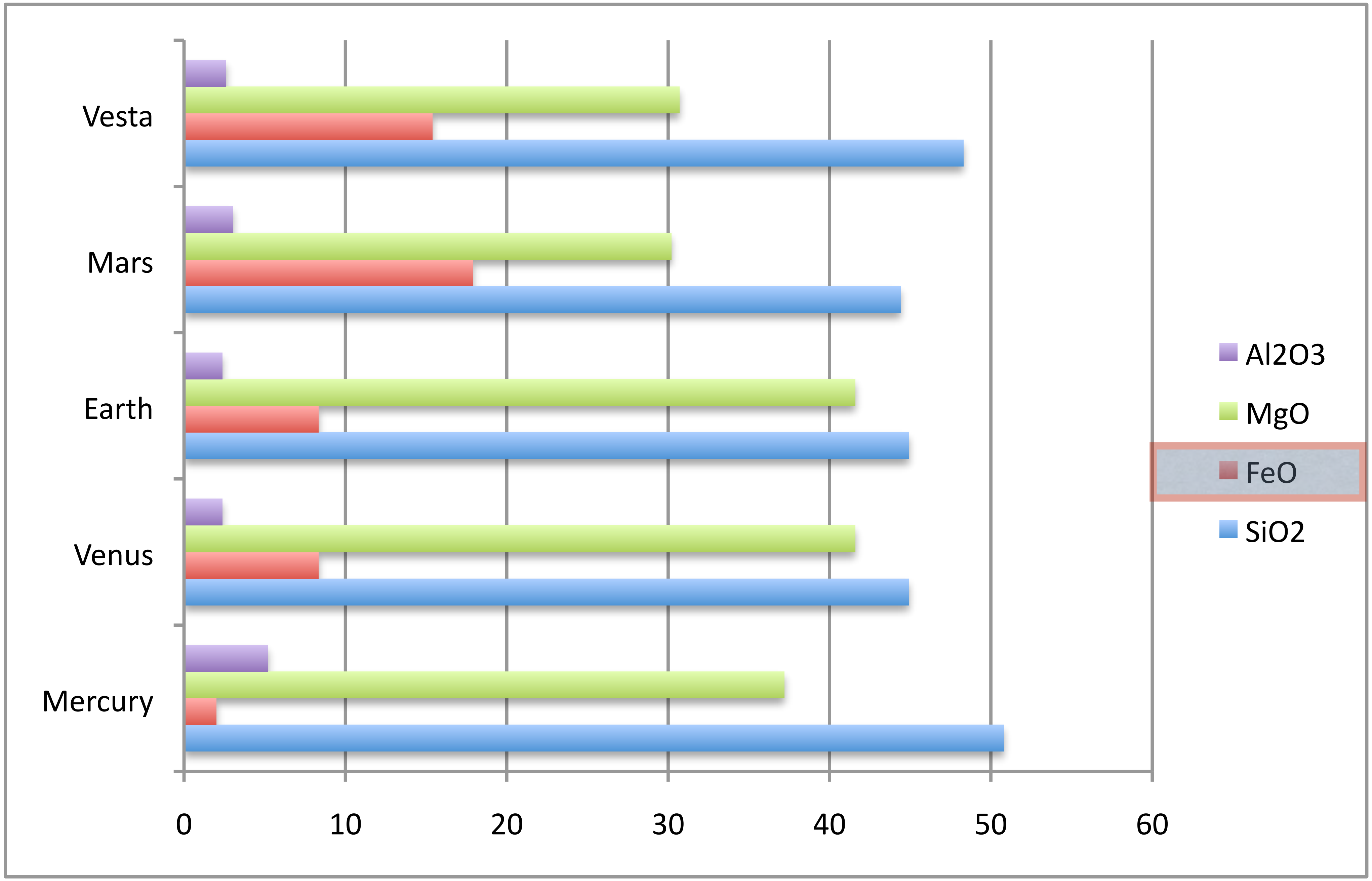
Mantle thickness and density constrained by moment of inertia



410 +/- 37 km “mantle” with density of 3650 +/- 225 kg/m^3

Smith et al., *Science*, 2012

III) iron abundance in bulk mantle



weight % oxides

Incompressible

Momentum Conservation

Energy Balance

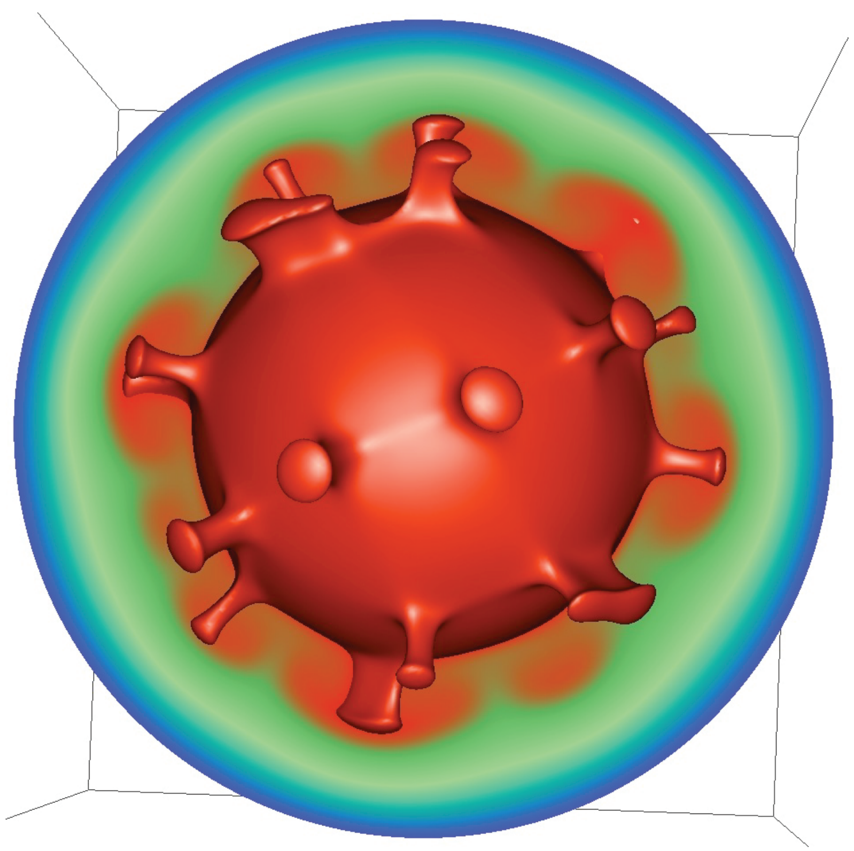
Incompressible

Momentum Conservation

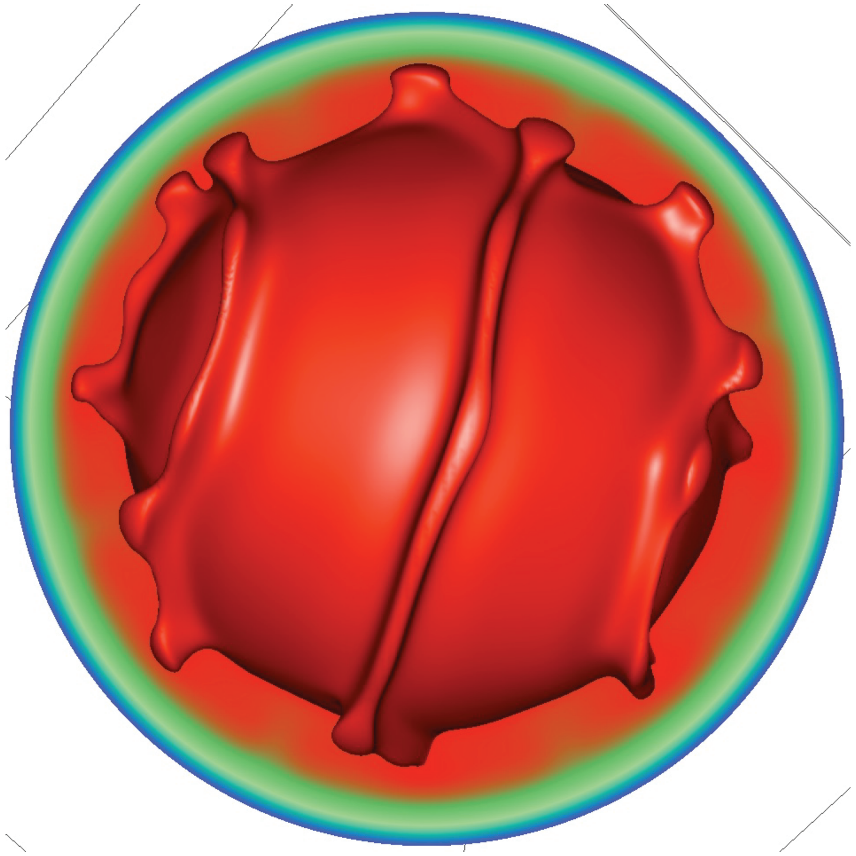
Energy Balance

Convective Planforms in a Spherical Shell

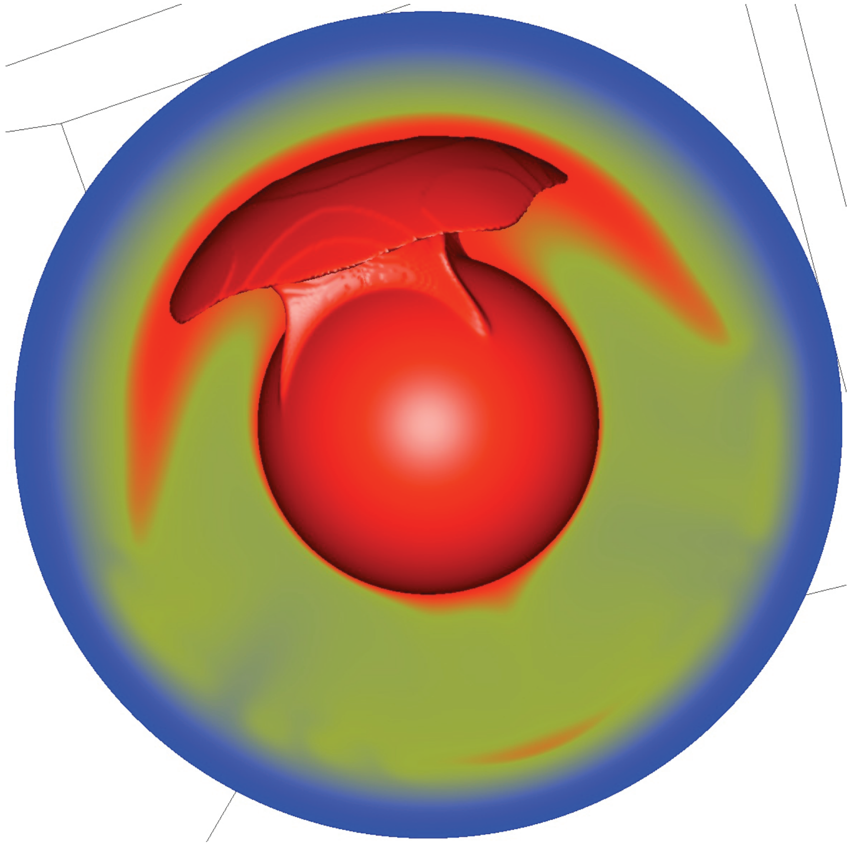
The pattern of upwellings and downwellings (planform) of convection is controlled by rheology, internal structure (e.g., changes in phase) and thickness of the shell.



multi-plume

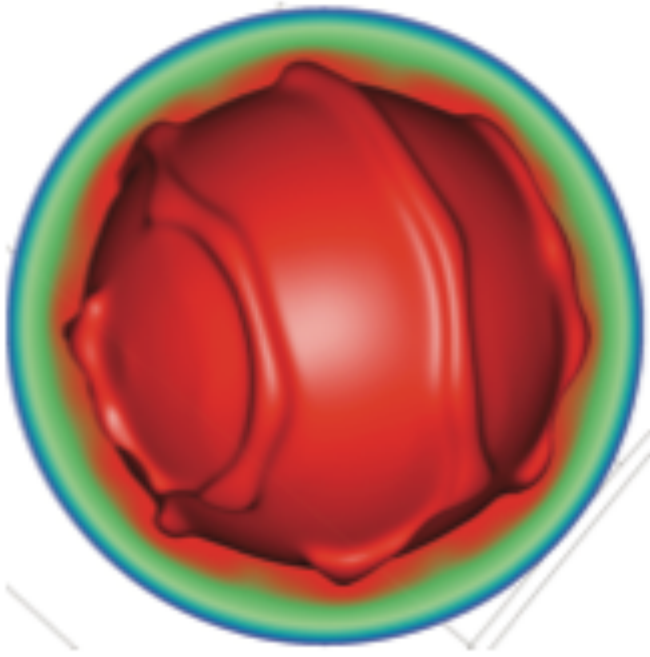


rolls

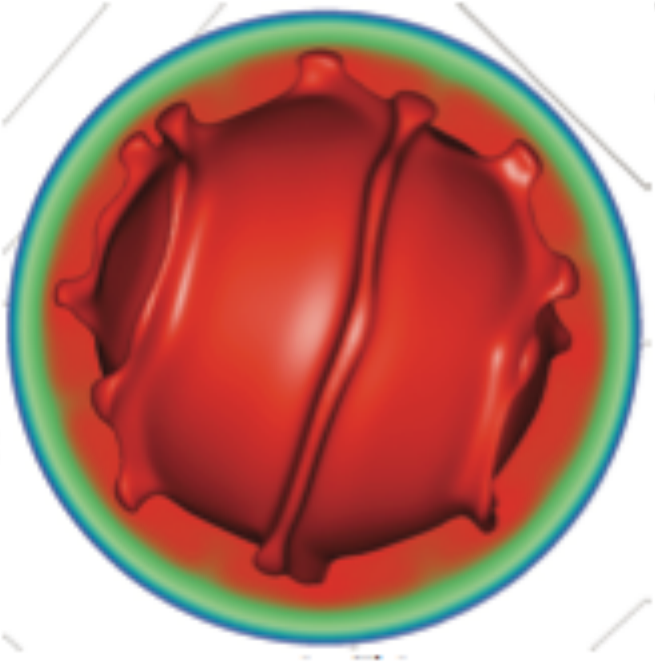


degree-one convection

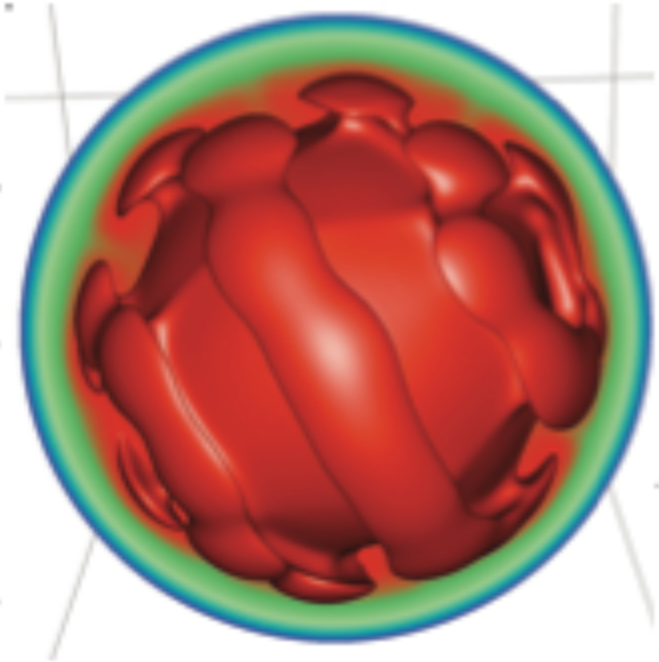
convective planforms in a spherical shell fora fixed Rayleigh number



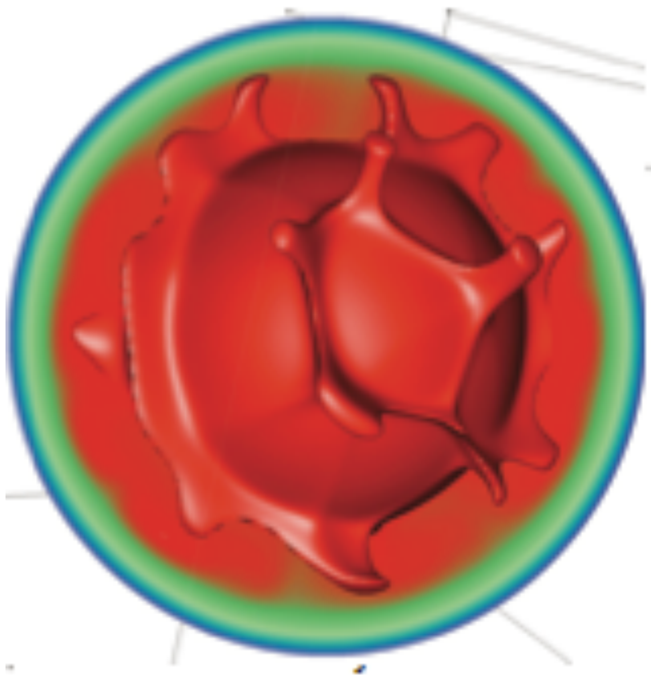
$r_c = 0.75\ r_p$



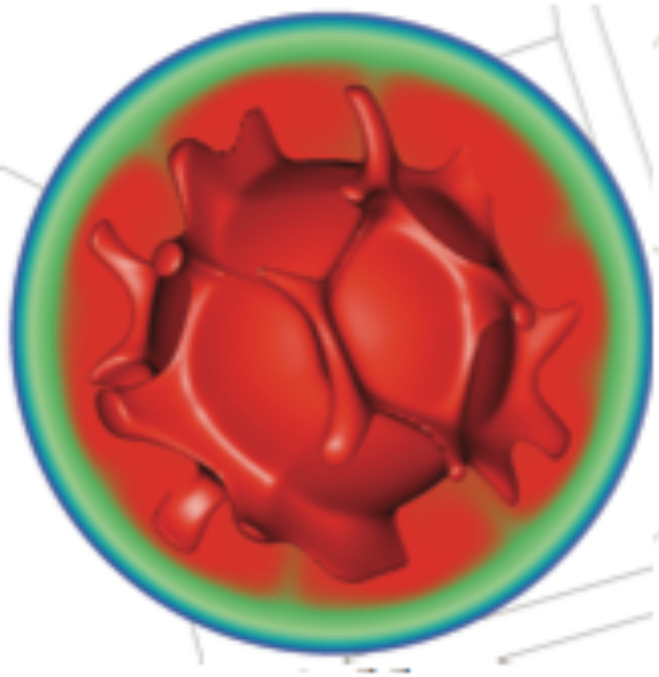
$r_c = 0.70\ r_p$



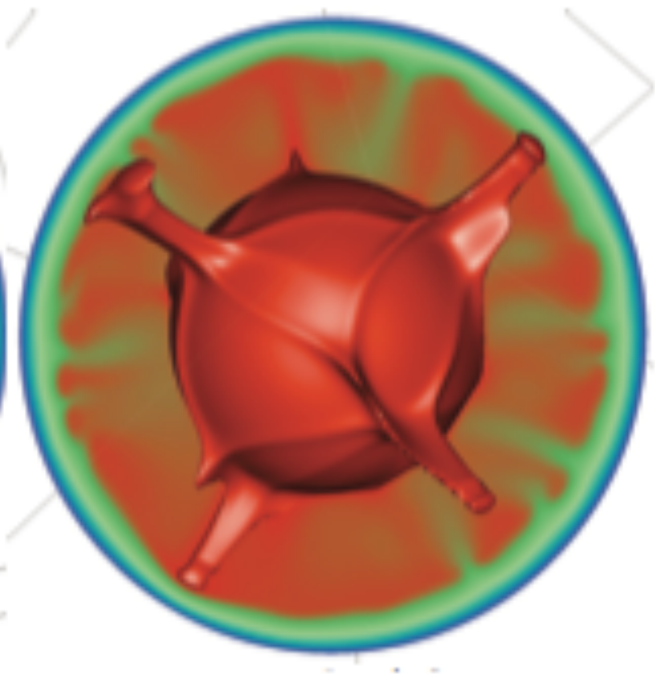
$r_c = 0.65\ r_p$



$r_c = 0.60\ r_p$



$r_c = 0.55\ r_p$



$r_c = 0.48\ r_p$

Nature Geosciences

LETTERS

Pattern of lobate scarps on Mercury's surface reproduced by a model of mantle convection

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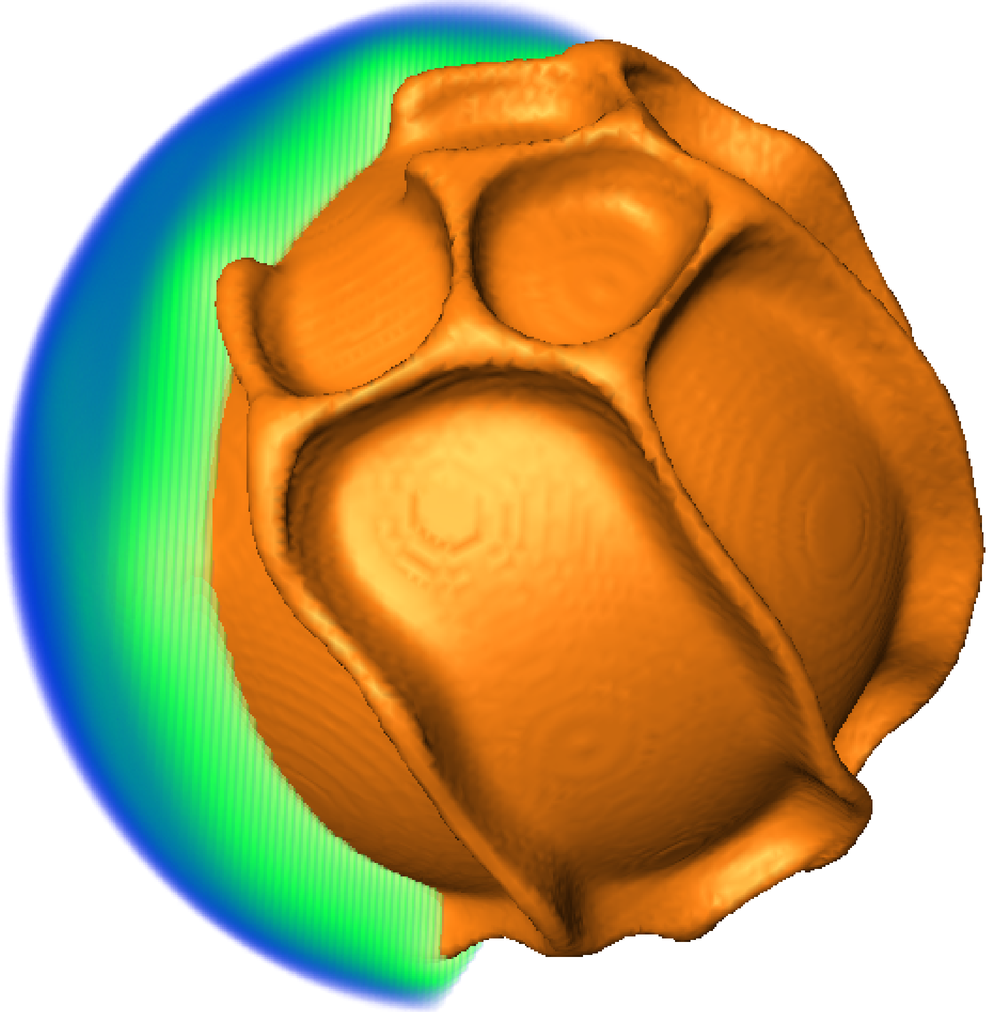


Watters et al., 2013

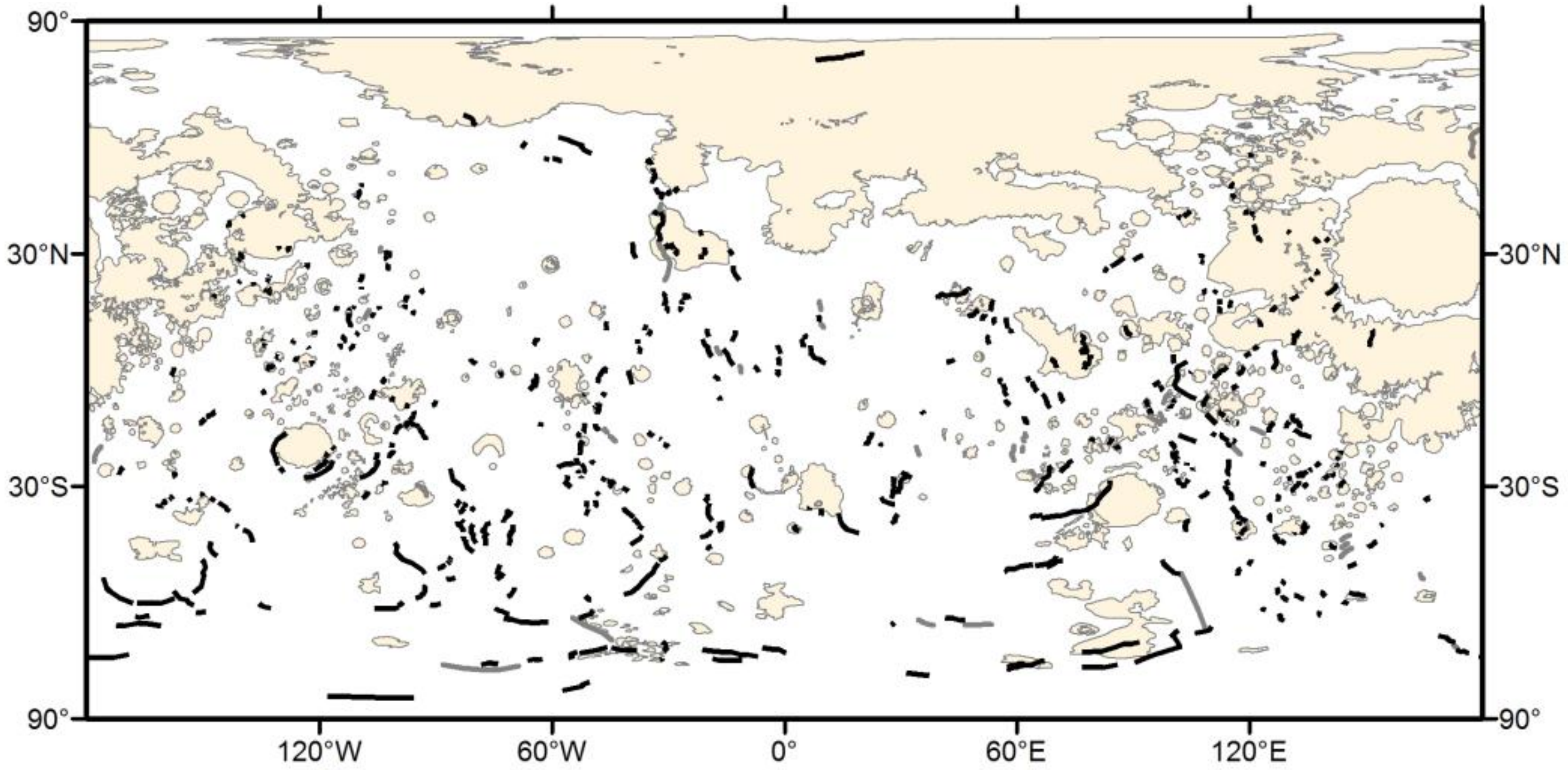


Figure 1. Tectonic landform map of lobate scarps (black) and high-relief ridges (gray) on Mercury. Such features are distributed in broad, longitudinal bands. Smooth plains units [19] are shown in tan.

Discovery Rupes, 550 km long scarp

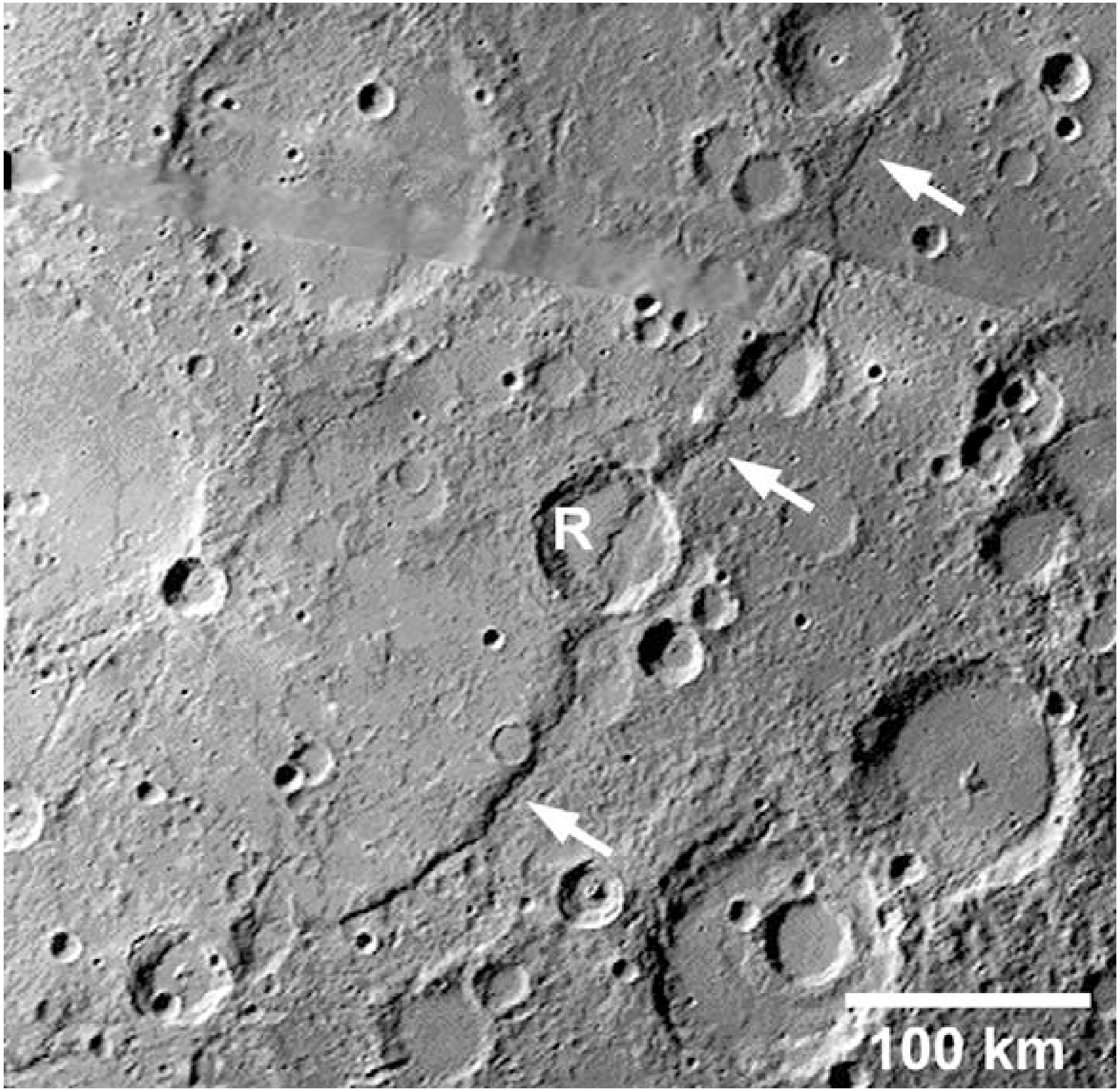
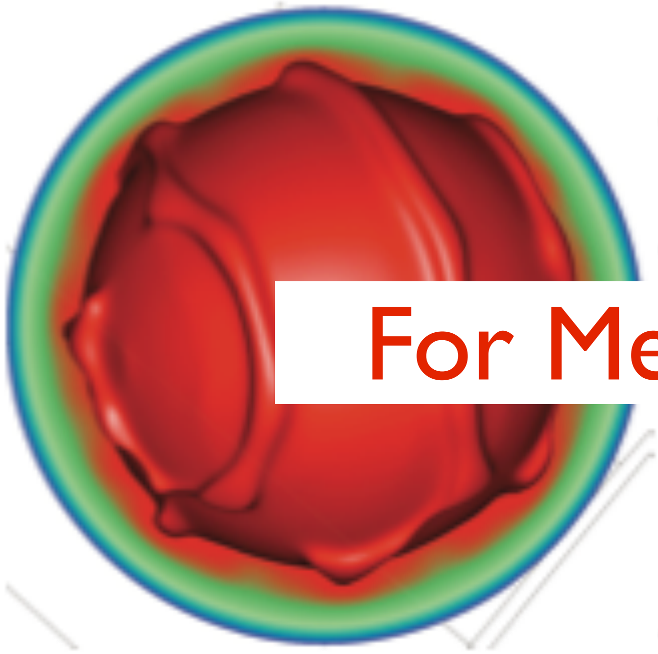


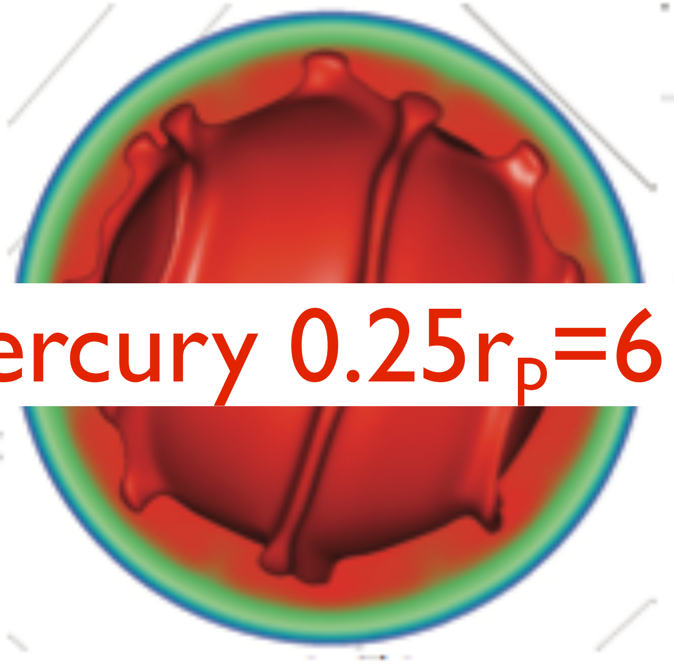
Fig. 5: Mariner 10 mosaic of Discovery Rupes (arrows)

convective planforms in a spherical shell for a fixed Rayleigh number

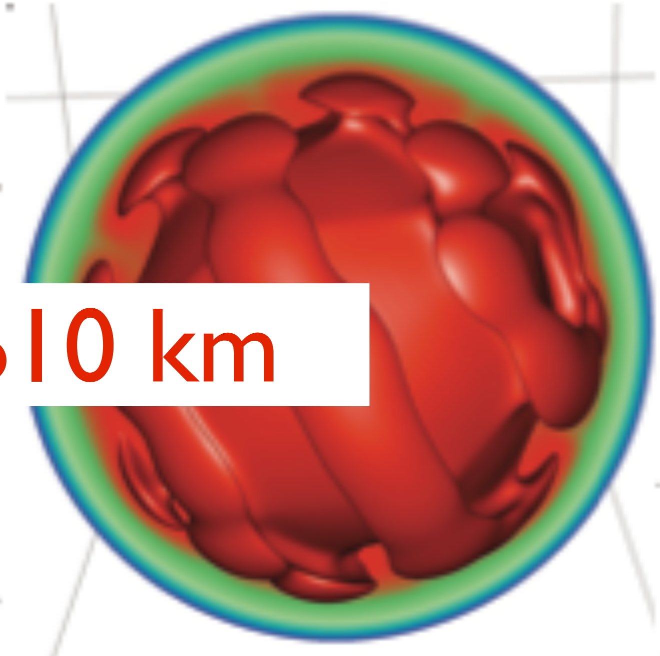
?



r_c = 0.75 r_p

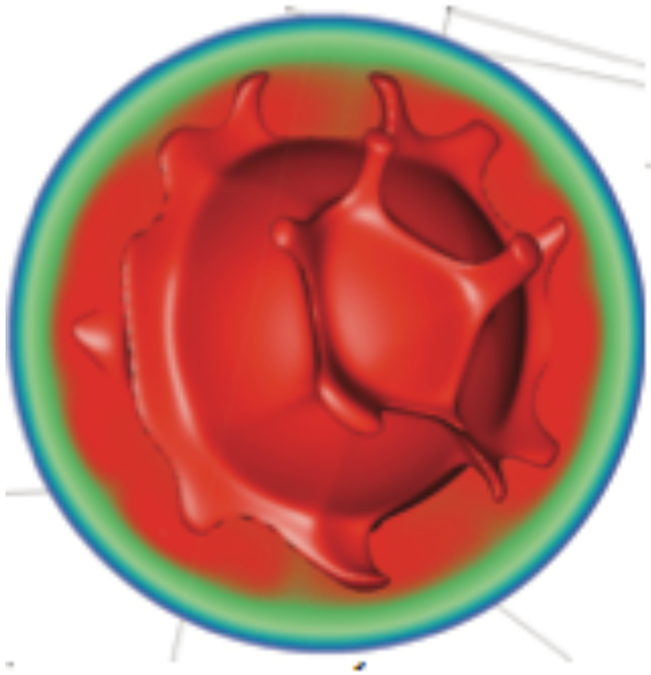


r_c = 0.70 r_p

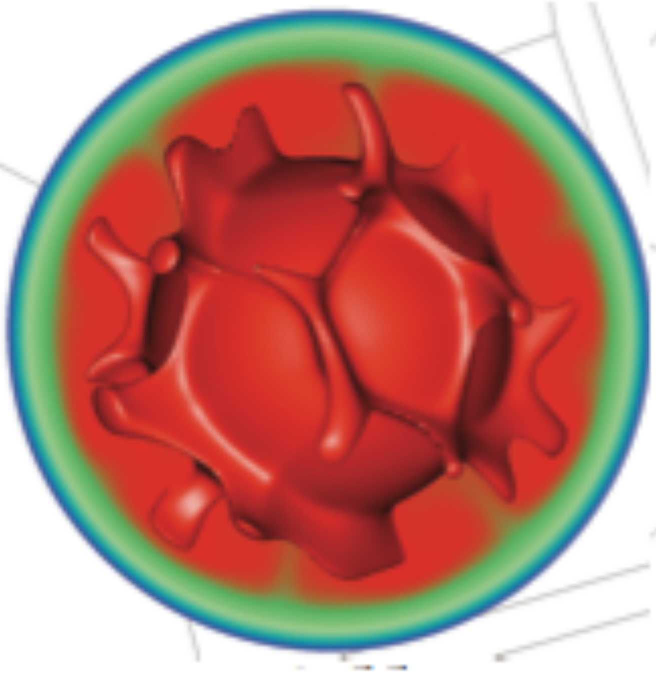


r_c = 0.65 r_p

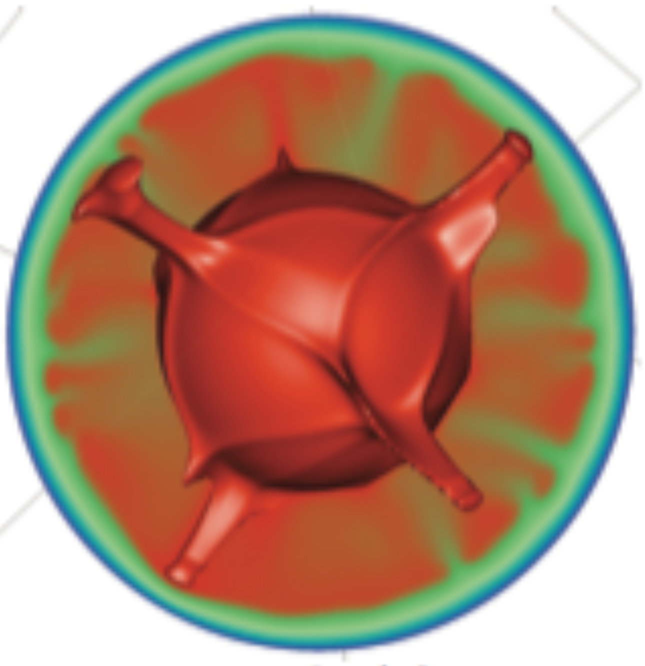
For Mercury 0.25r_p=610 km



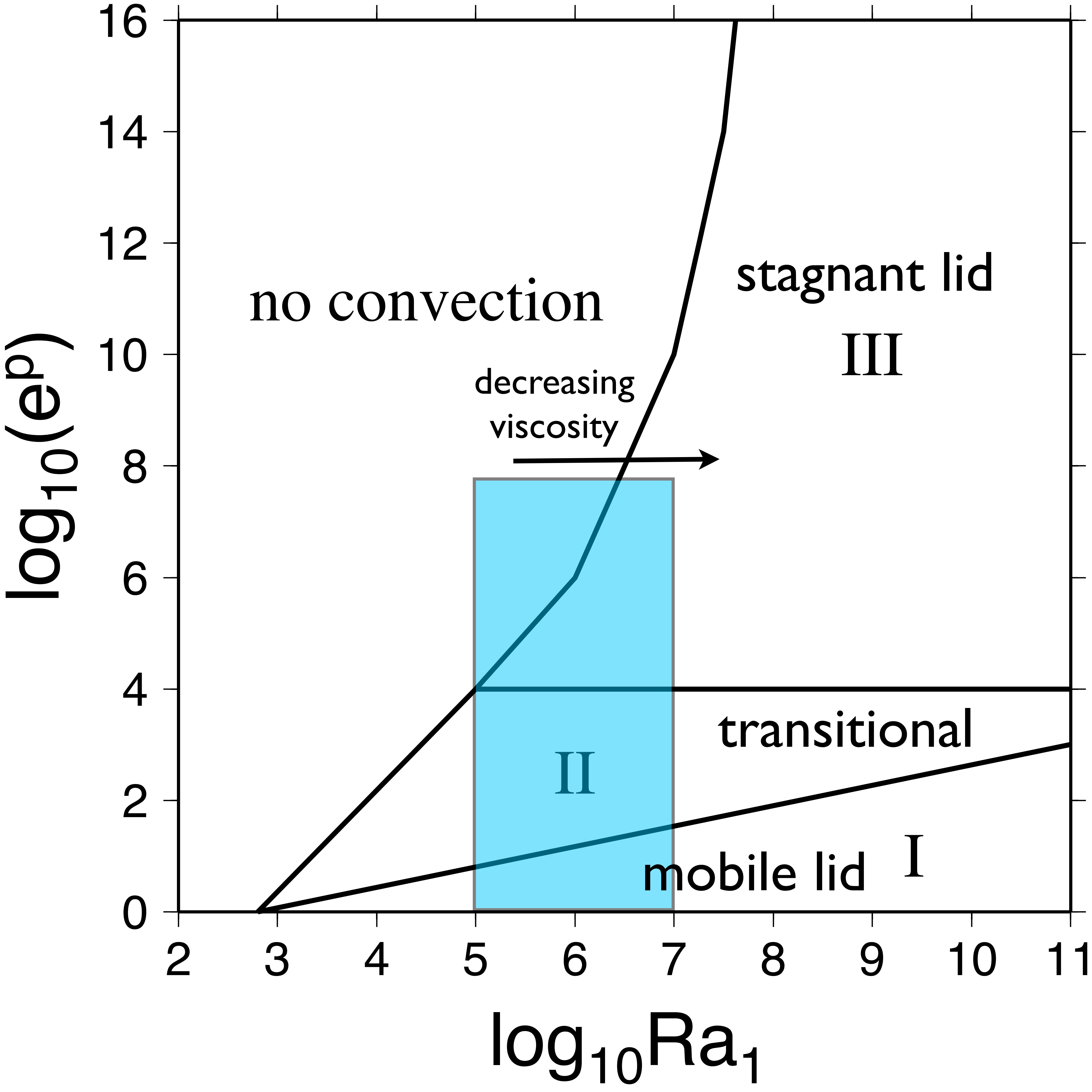
r_c = 0.60 r_p



r_c = 0.55 r_p

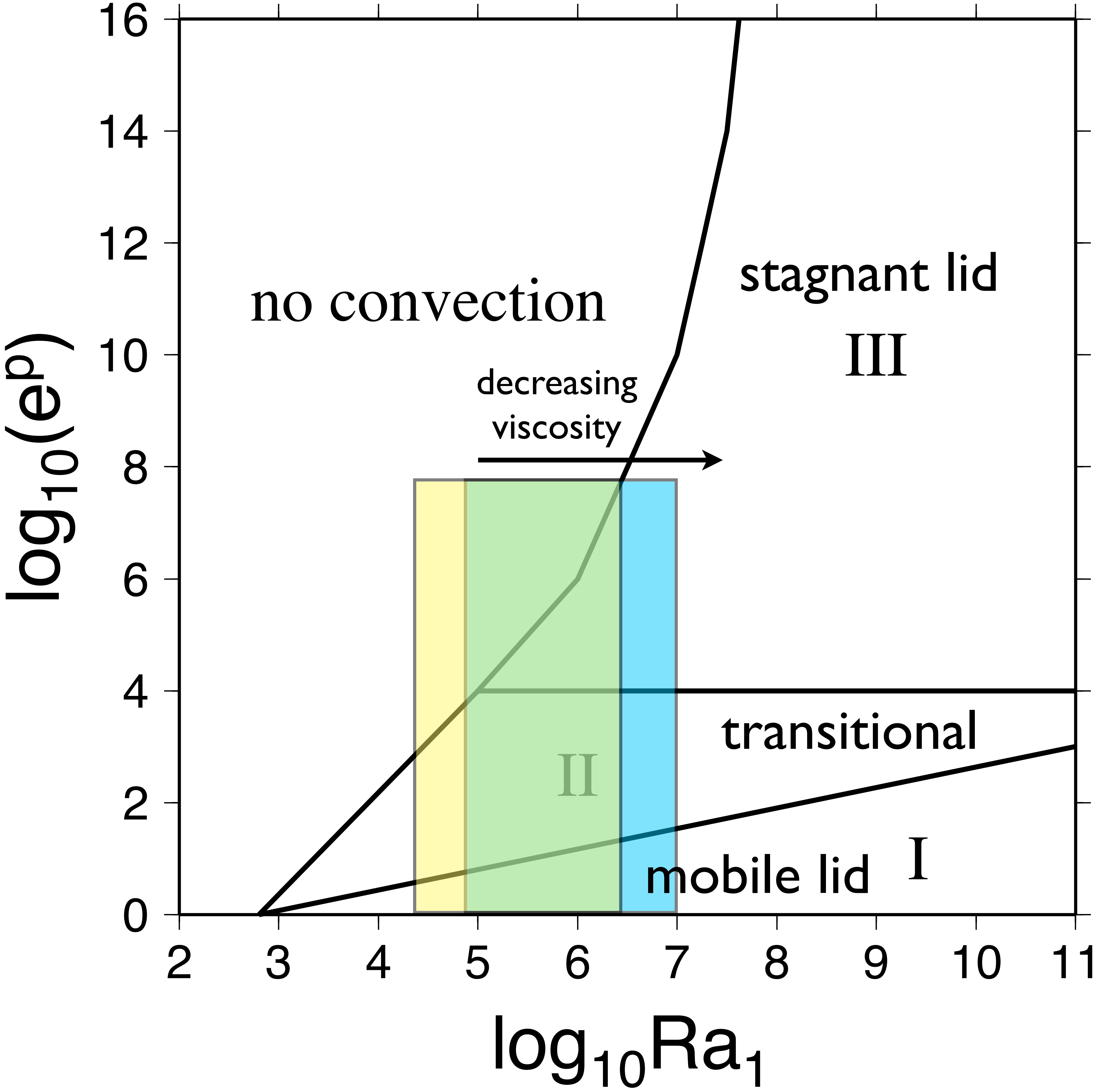


r_c = 0.48 r_p



King 2008
D=600 km
$\eta_o=10^{19}-10^{21}$ Pa s

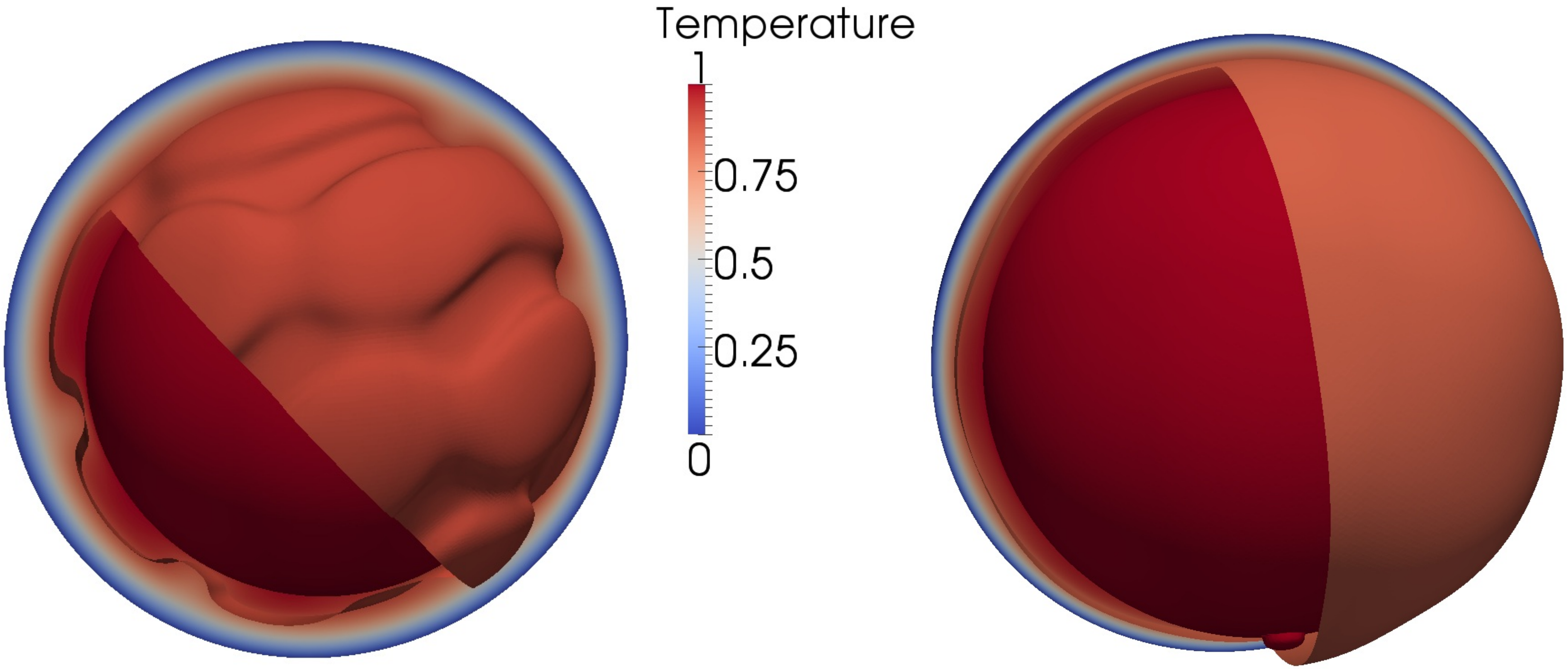
Solomatov, 1995



King 2008
D=600 km
$\eta_o = 10^{19}$-10^{21} Pa s

D=400 km
$\eta_o = 10^{19}$-10^{21} Pa s

Solomatov, 1995

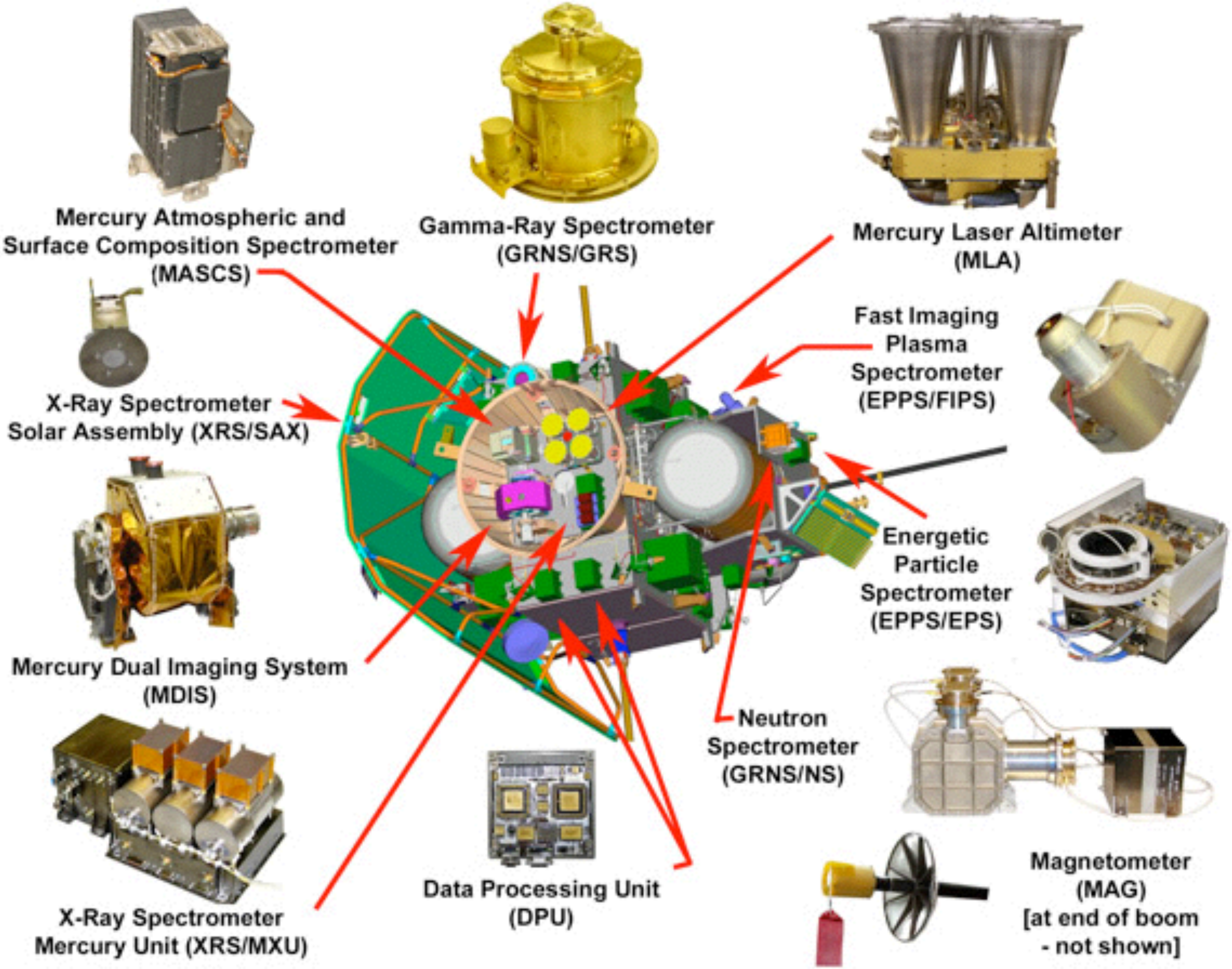


R_c = 0.75
D=610 km

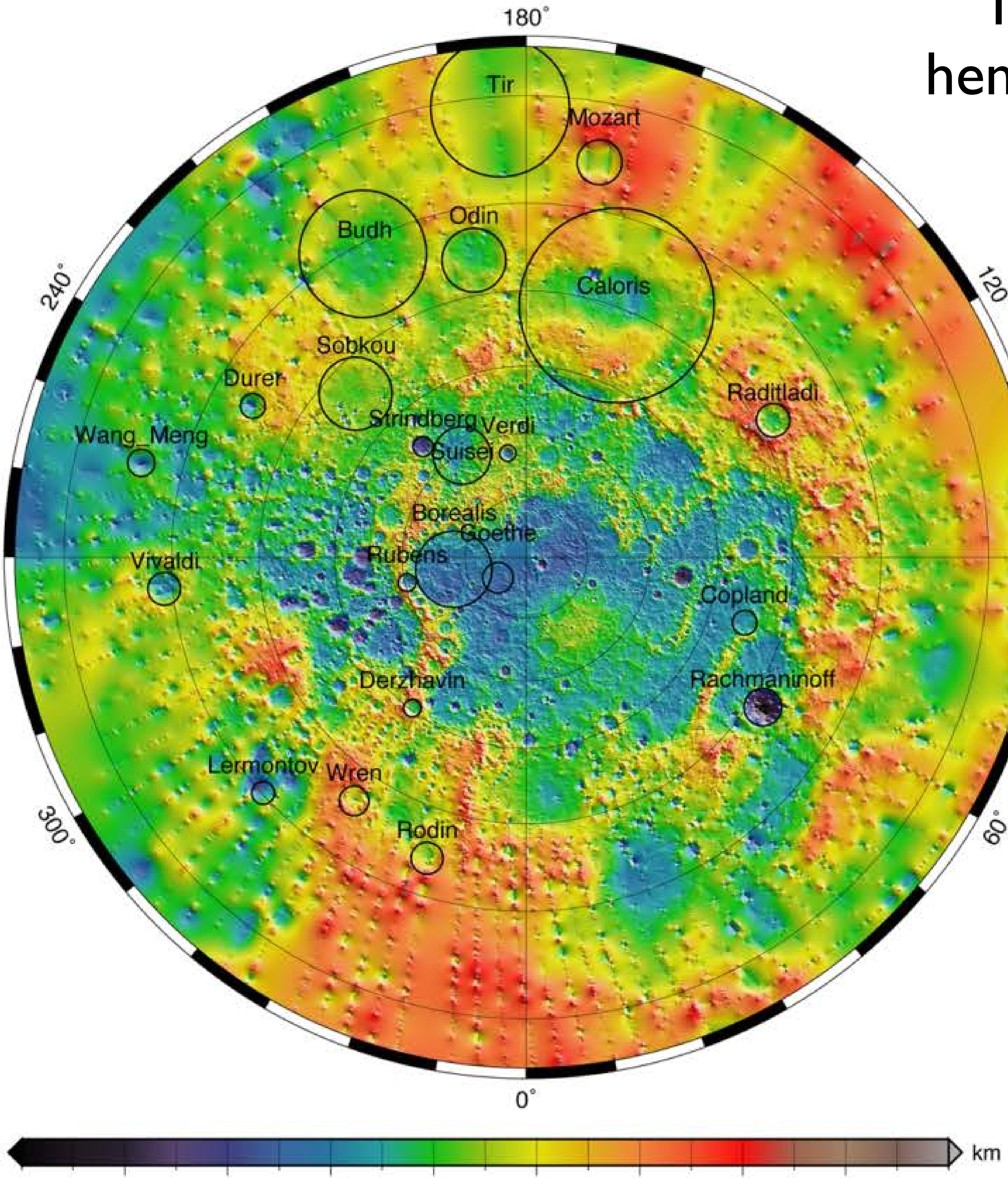
R_c = 0.85
D=366 km

MESSENGER: MErcury Surface, Space ENvironment, GEochemistry and Ranging

- Launched: 2004
- First Mercury Flyby: January 14, 2008
- Second Mercury Flyby: October 6, 2008
- Third Mercury Flyby: September 29, 2009
- Orbit insertion: March 18, 2011

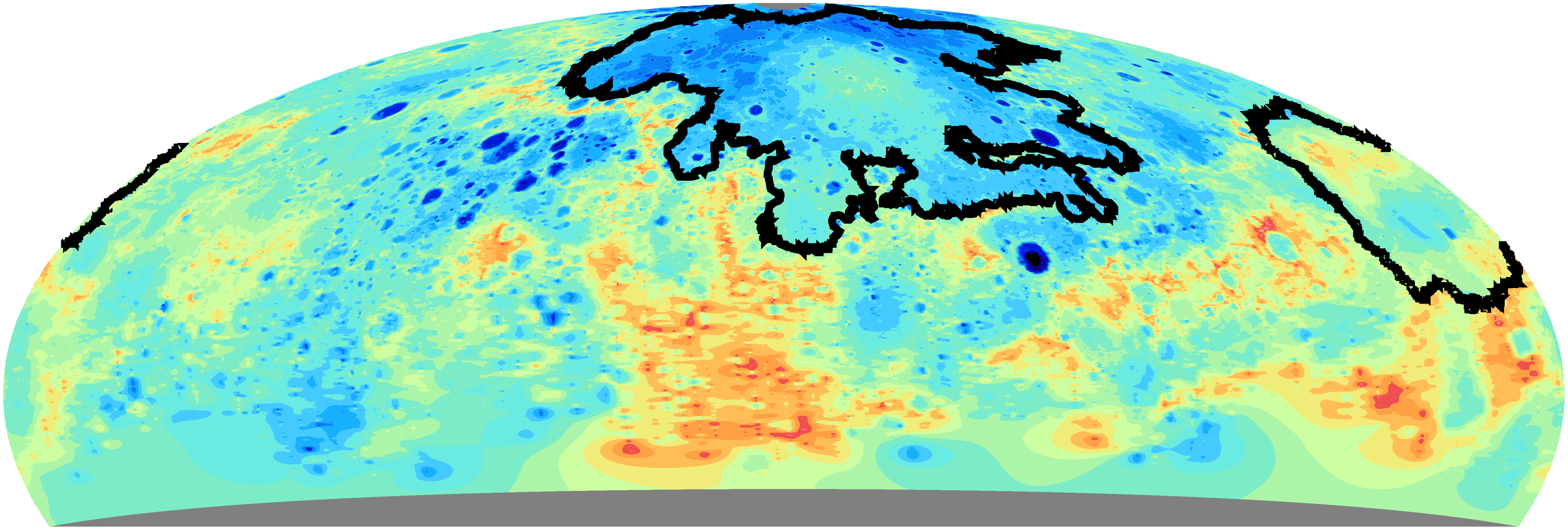

Mercury Atmospheric and Surface Composition Spectrometer (MASCS)
Gamma-Ray Spectrometer (GRNS/GRS)
Mercury Laser Altimeter (MLA)
X-Ray Spectrometer Solar Assembly (XRS/SAX)
Fast Imaging Plasma Spectrometer (EPPS/FIPS)
Energetic Particle Spectrometer (EPPS/EPS)
Mercury Dual Imaging System (MDIS)
Neutron Spectrometer (GRNS/NS)
X-Ray Spectrometer Mercury Unit (XRS/MXU)
Data Processing Unit (DPU)
Magnetometer (MAG) [at end of boom - not shown]

Mercury northern hemisphere topography

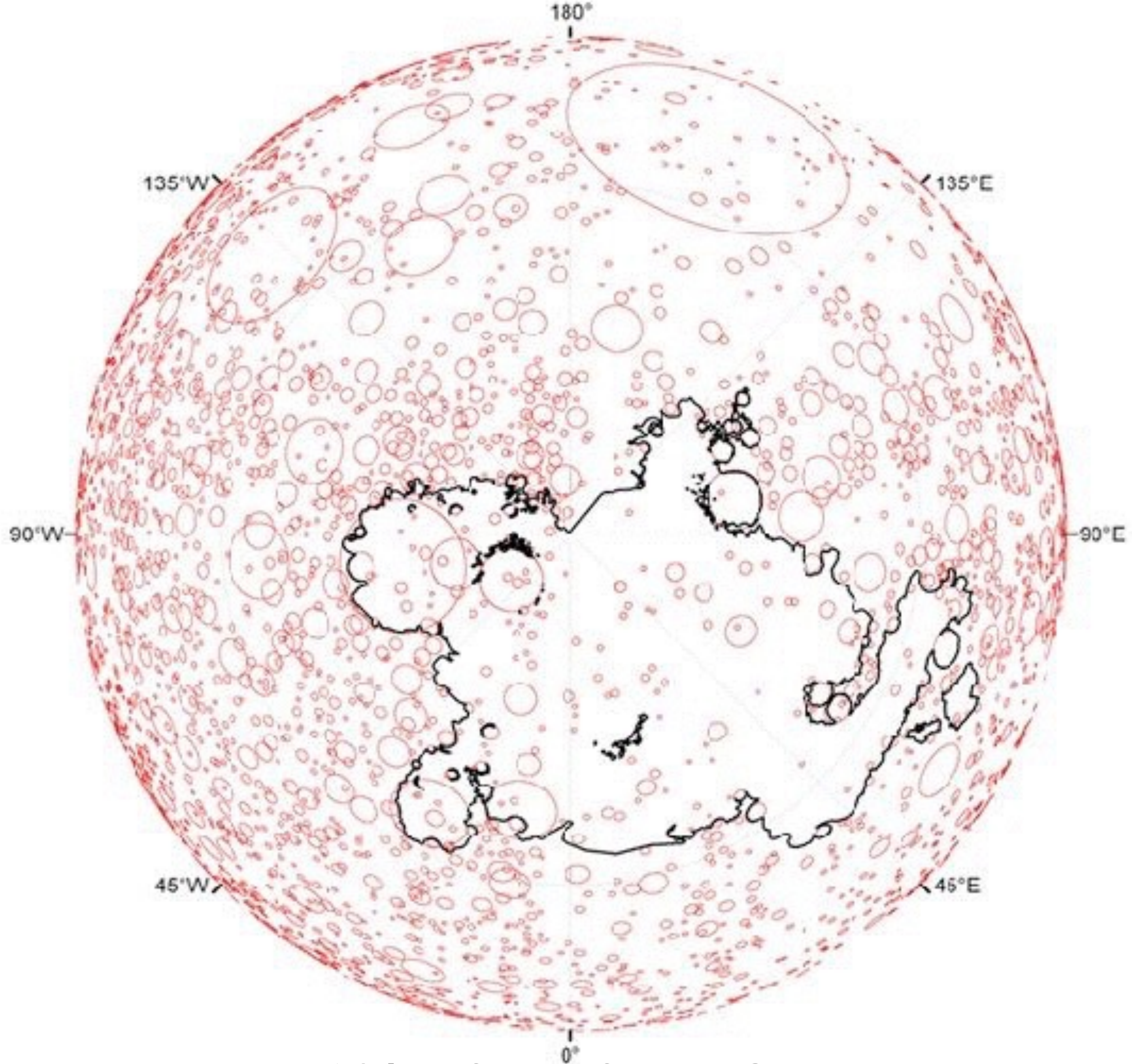


Zuber et al., *Science*, 2012

MLA topography (red high - blue low)

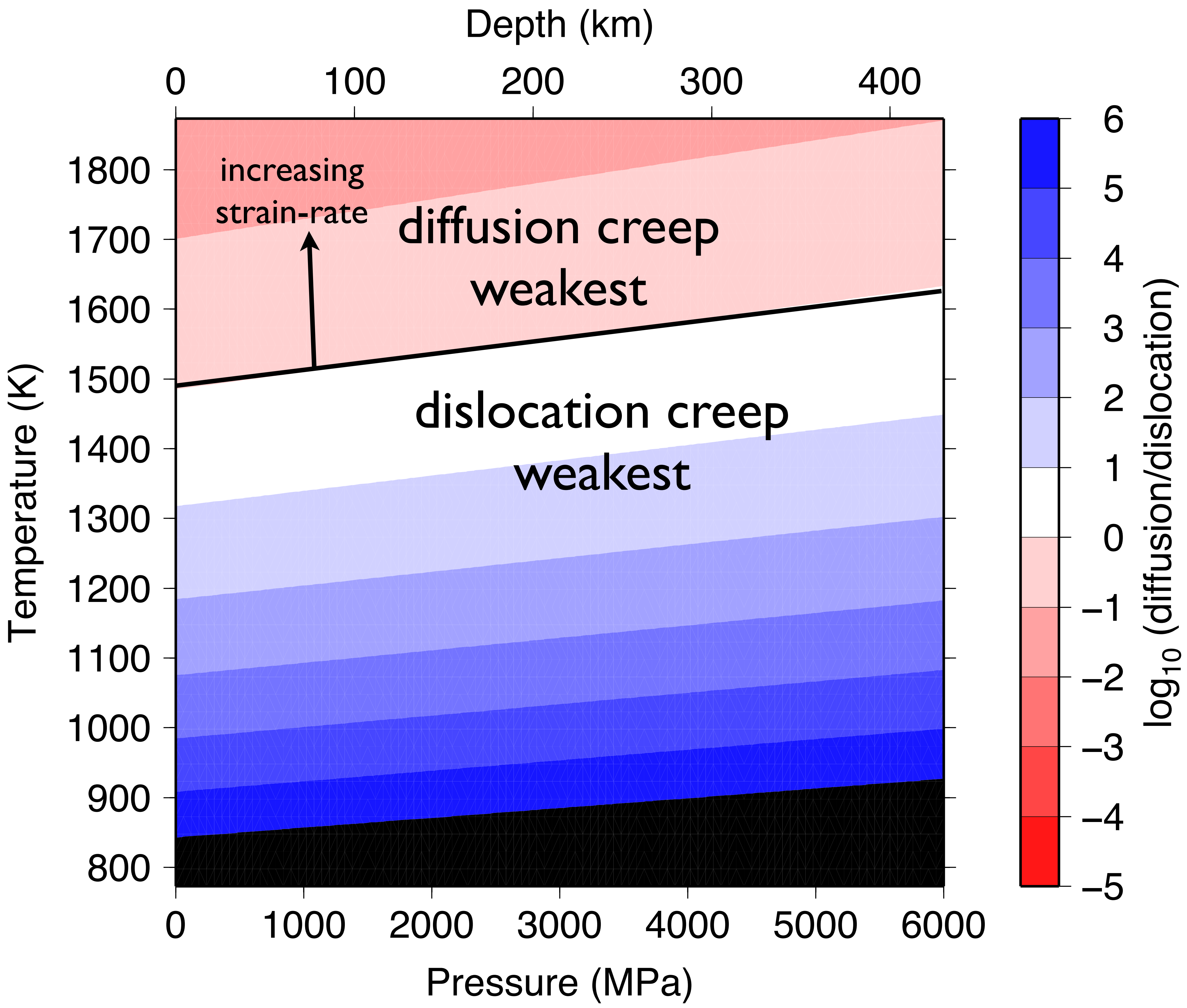


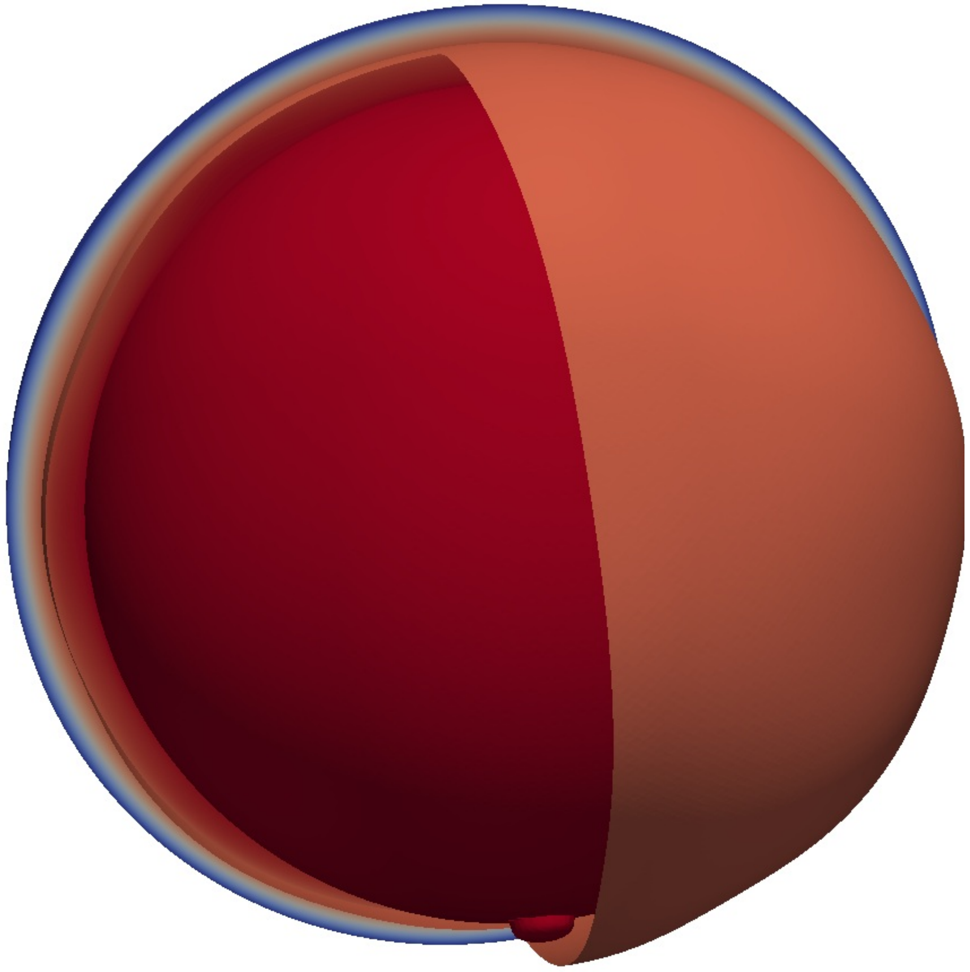
Outlined regions: Northern Volcanic Plains & Caloris Volcanic Region



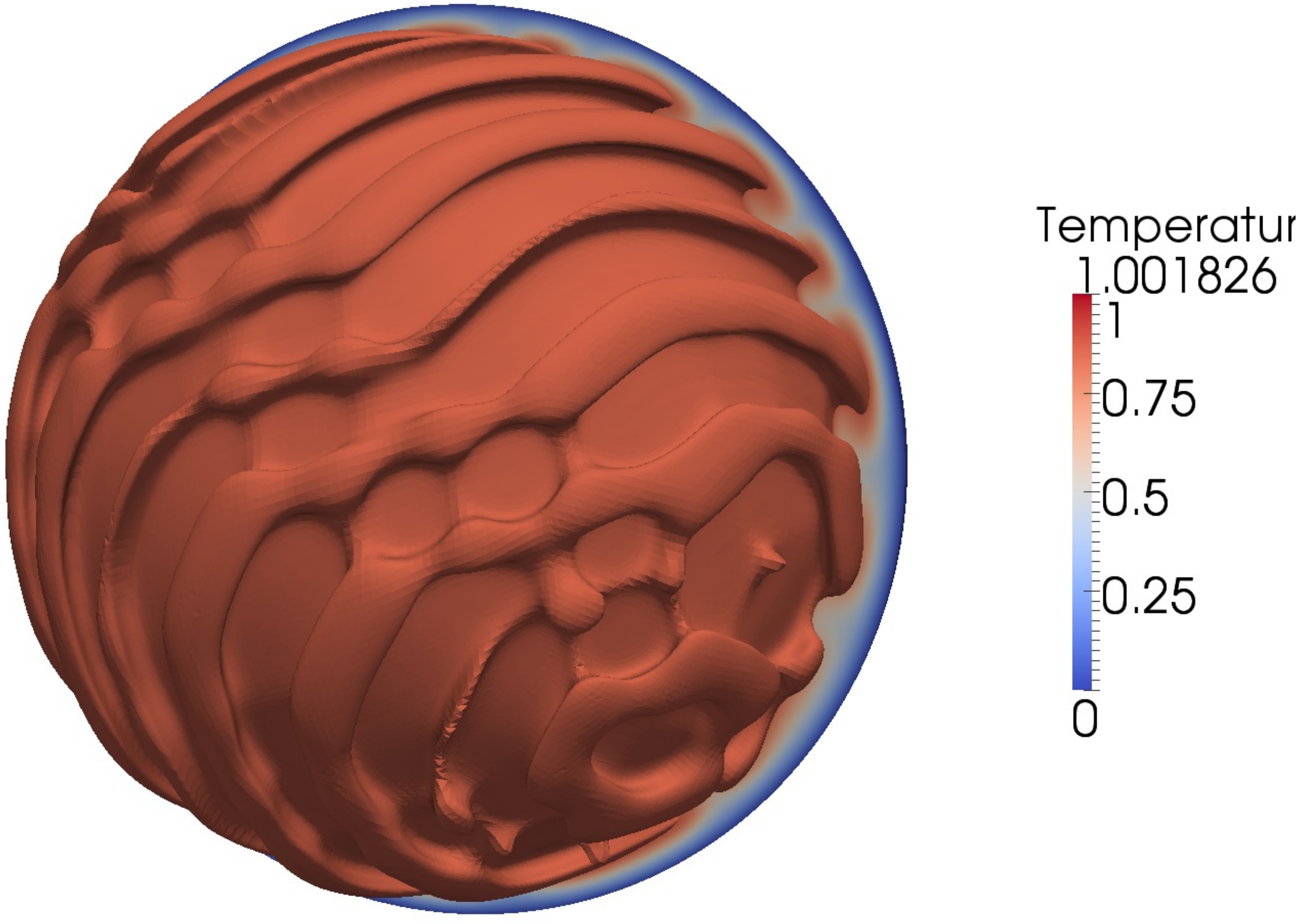
Volcanic Plains 6% of surface, fill craters 1.5 km deep
also very smooth

dry diffusion/dislocation creep ratio d=10 mm εdot=$10^{-17}s^{-1}$



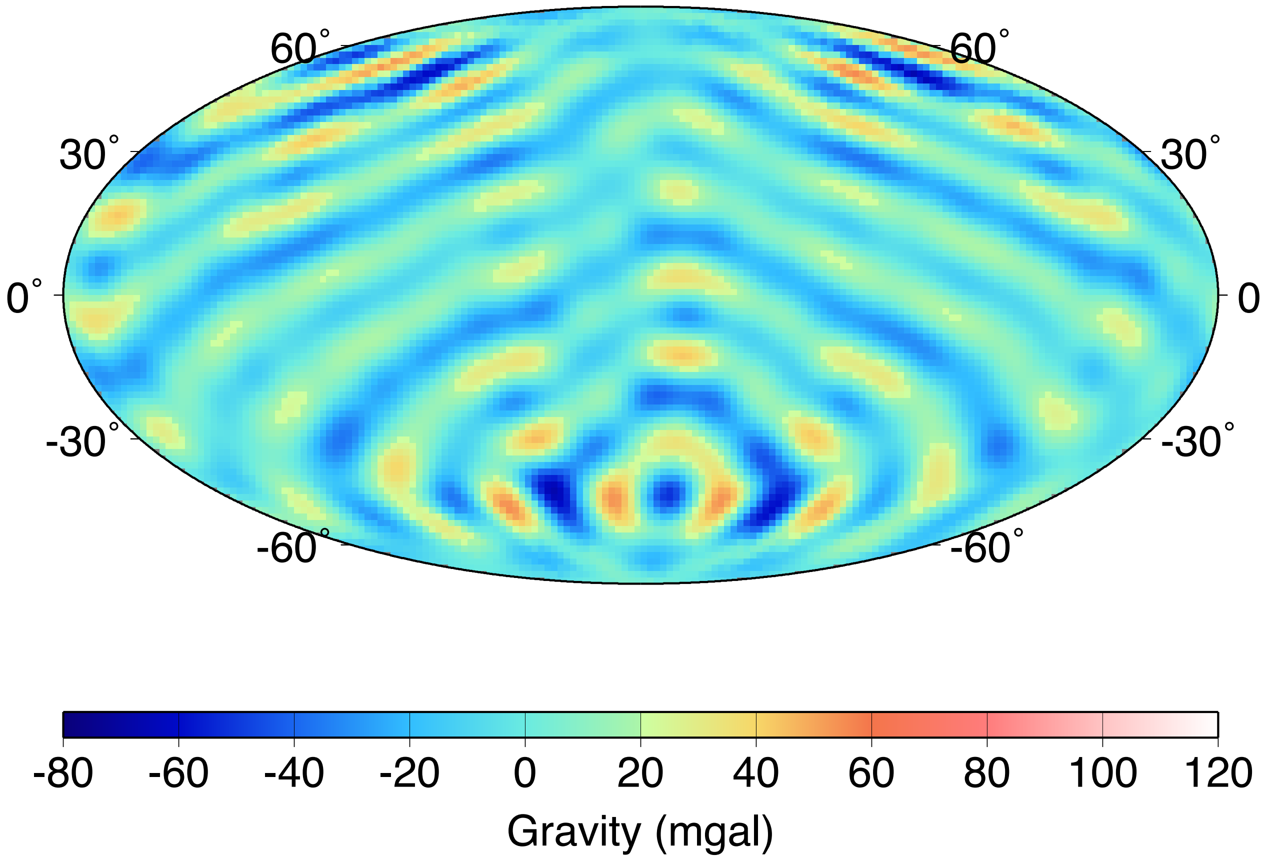


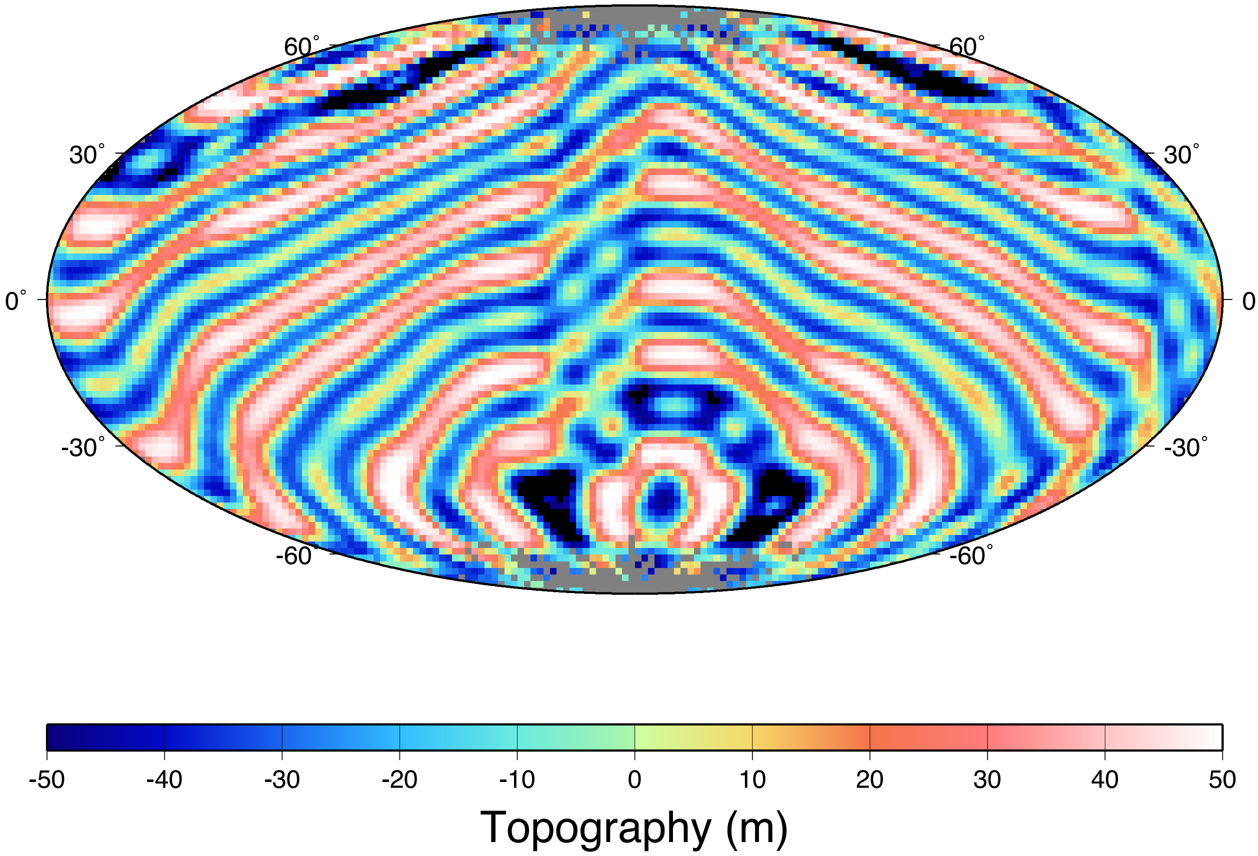
R_c = 0.85, diffusion creep
n=1

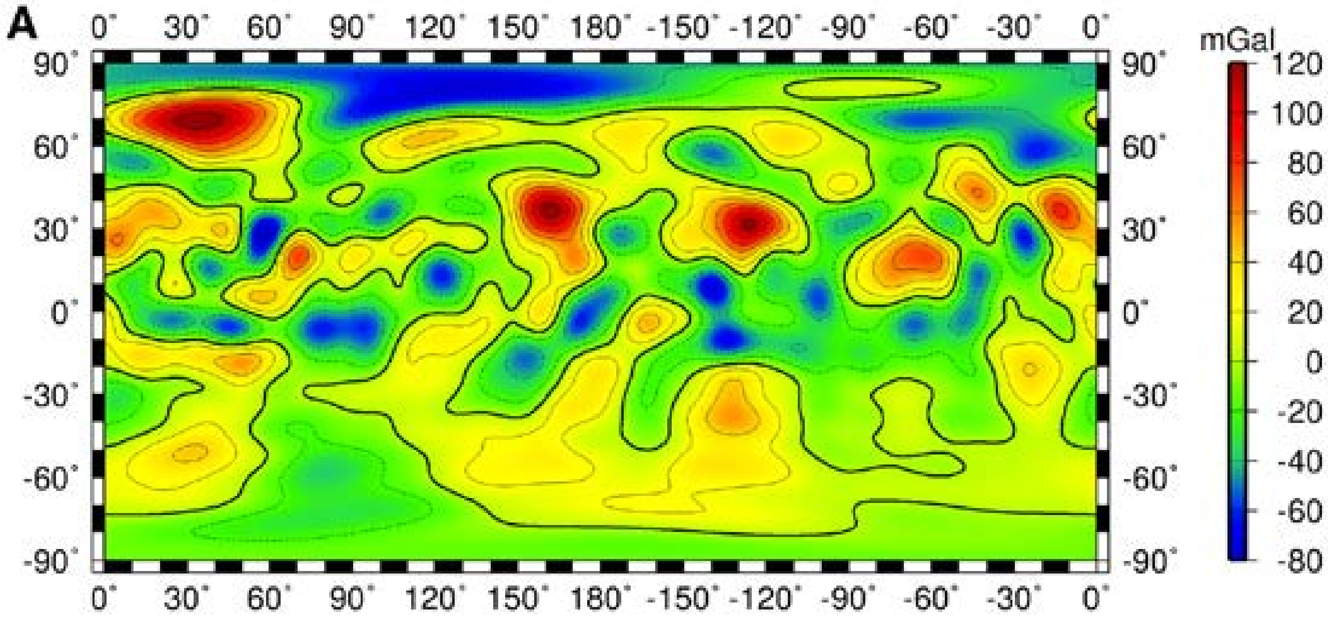


R_c = 0.85, dislocation creep
n=3

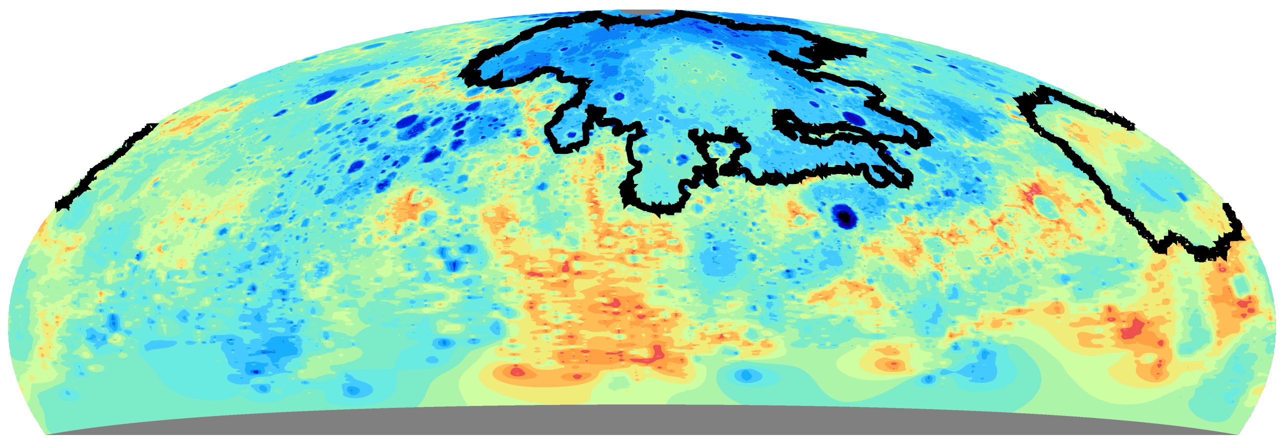
R_c = 0.85, dislocation creep







Smith et al., *Science*, 2012



JOURNAL OF GEOPHYSICAL RESEARCH VOLUME 57, NO. 2 JUNE, 1952

ELASTICITY AND CONSTITUTION OF THE EARTH'S INTERIOR*

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(Received January 18, 1952)

*Unwary readers should take warning that ordinary language undergoes modification to a high-pressure form when applied to the interior of the Earth; a few examples of equivalents follow:

High-pressure form:	*Ordinary meaning*:
certain	dubious
undoubtedly	perhaps
positive proof	vague suggestion
unanswerable argument	trivial objection
pure iron	uncertain mixture of all the elements