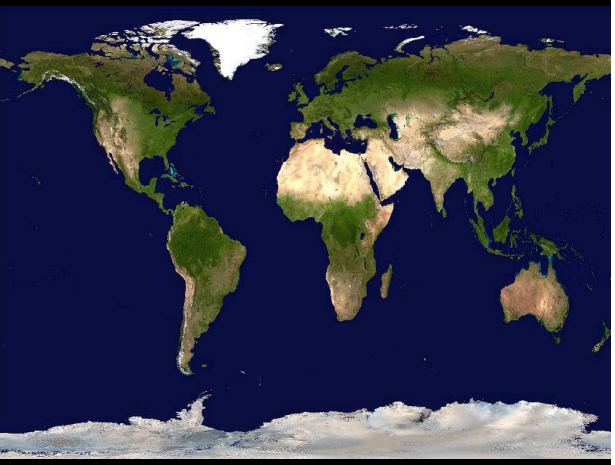
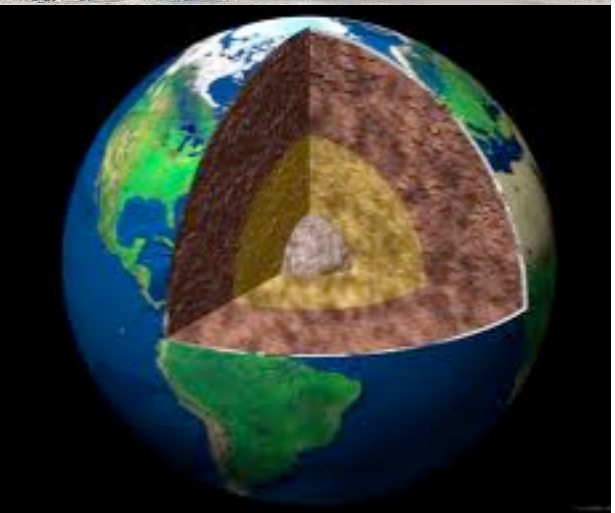


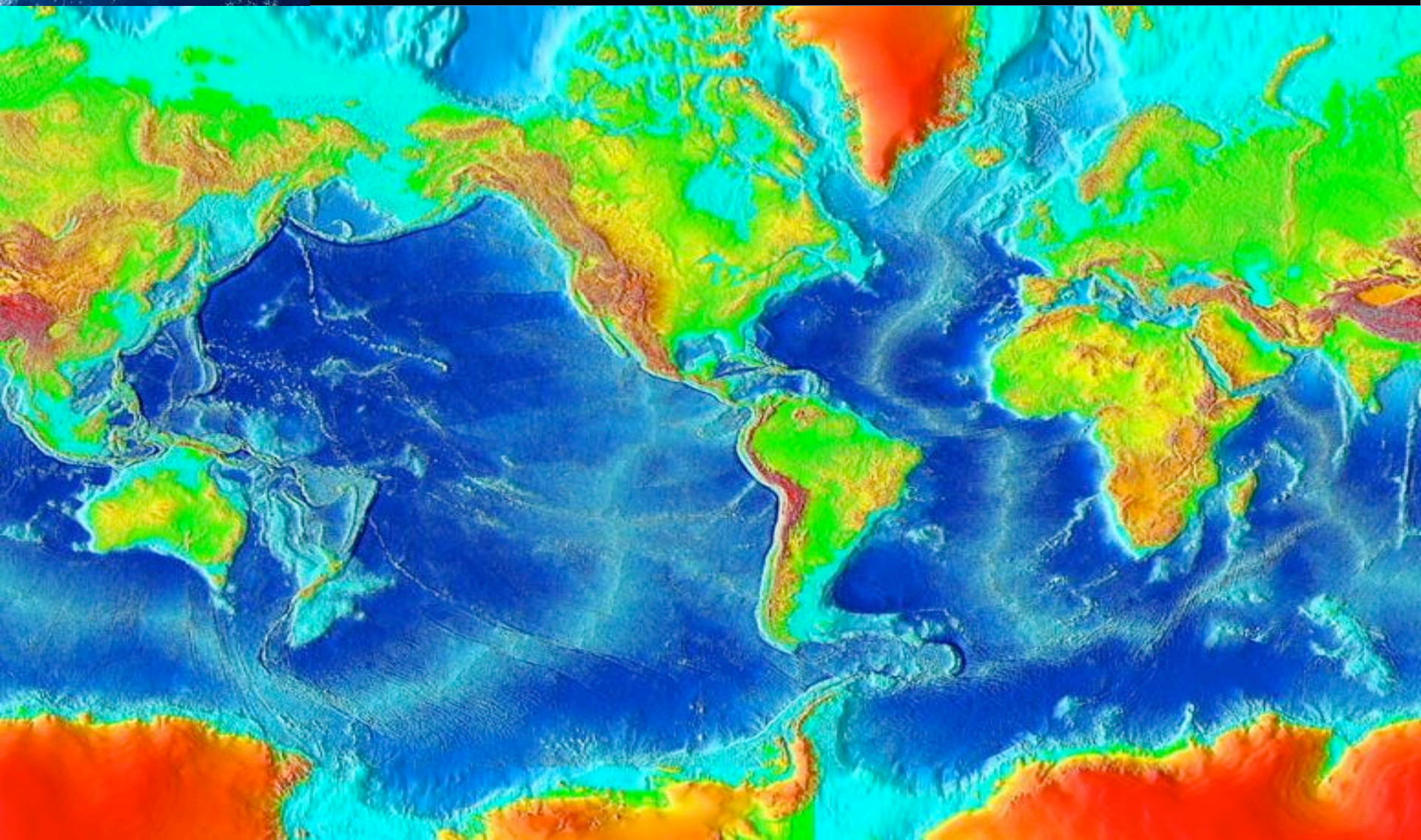


Why is this planet to be the Earth?

- The water *vs.* shore planet Earth
- How to make the continent
- The reason for operation of plate tectonics
- Water: its contribution to the Earth evolution

Y. Tatsumi（CPS/Kobe-U)

The Water Planet Earth

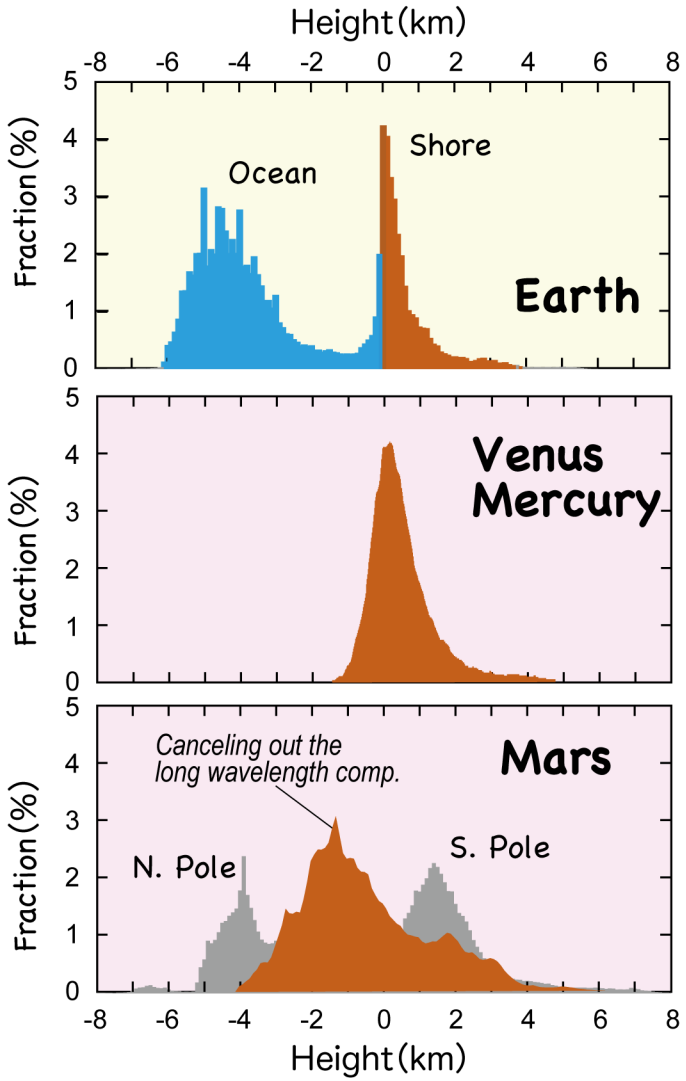


The Water Planet Earth

Water:

- covers ~70% of the Earth's surface
- weighs 1.4×10^{18} ton
- has been playing key roles in the evolution of the Earth system

The Shore Planet Earth



Bi-modal height distribution:

lowland → ocean

highland → shore

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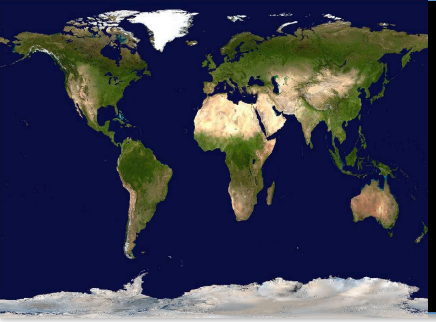
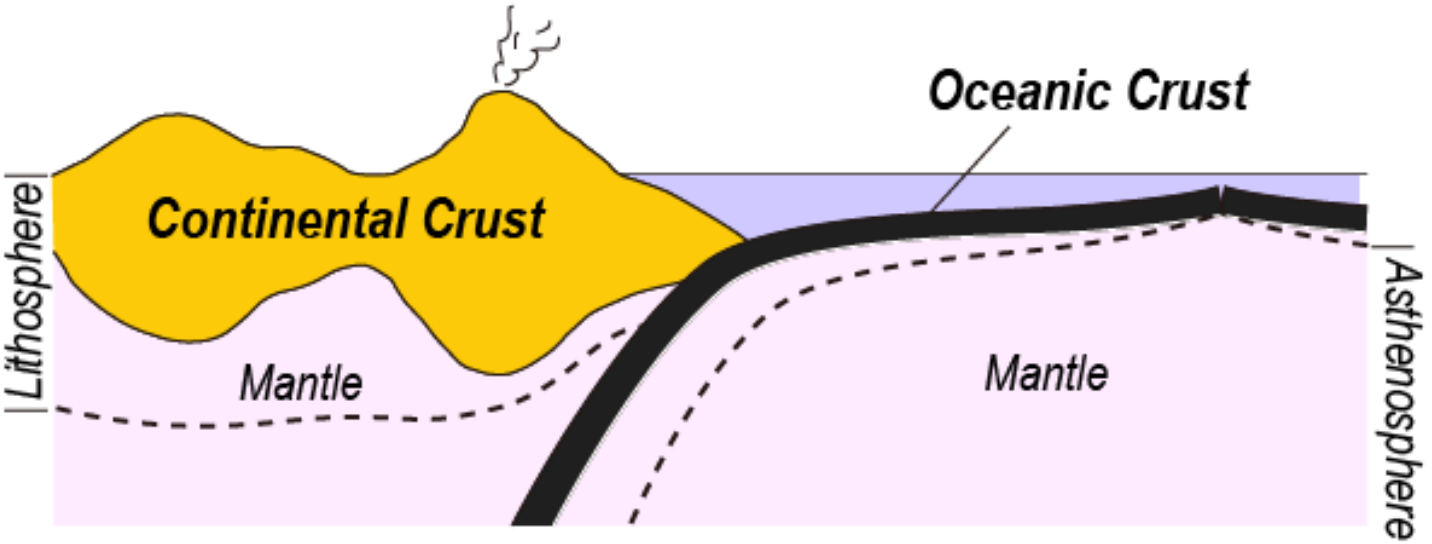
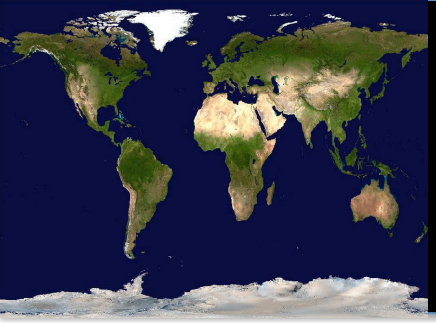
←M ≠ Mo



Continent *vs.* Ocean

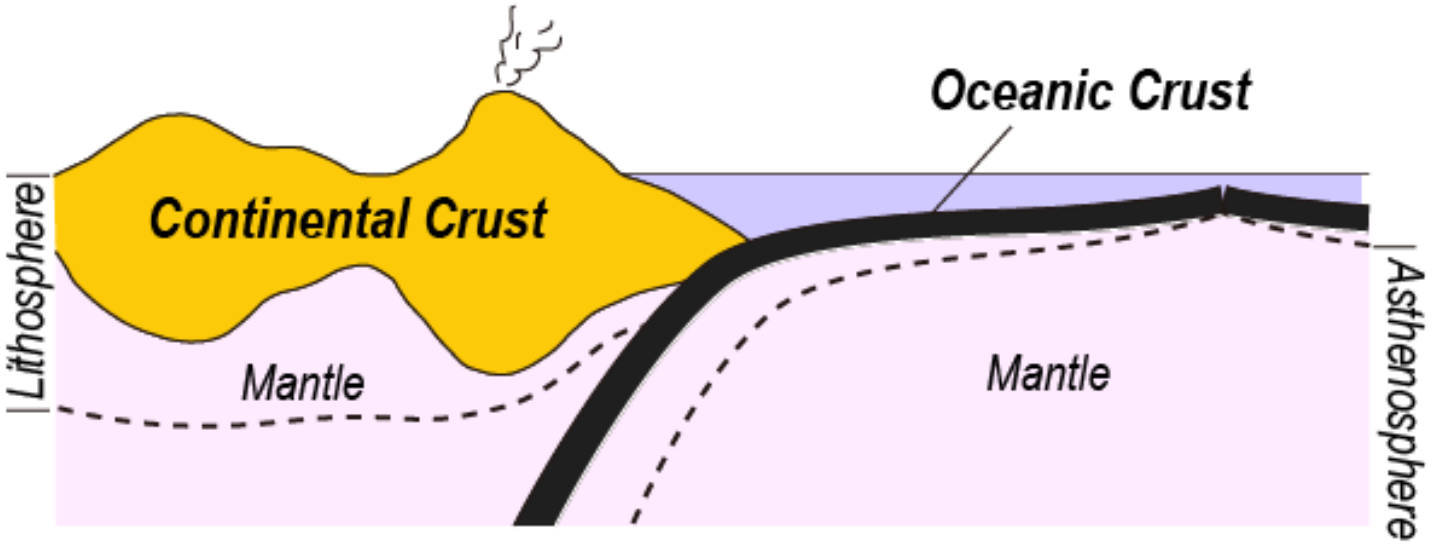
	Continental Crust	Oceanic Crust
Height	850 m	-3800 m
Thickness	40 km	6 km

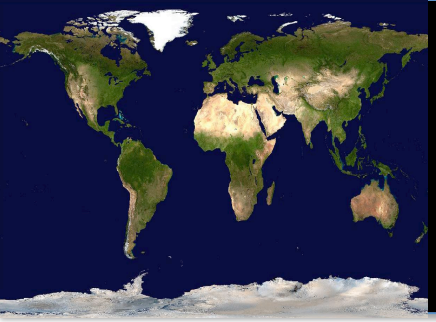




Continent *vs.* Ocean

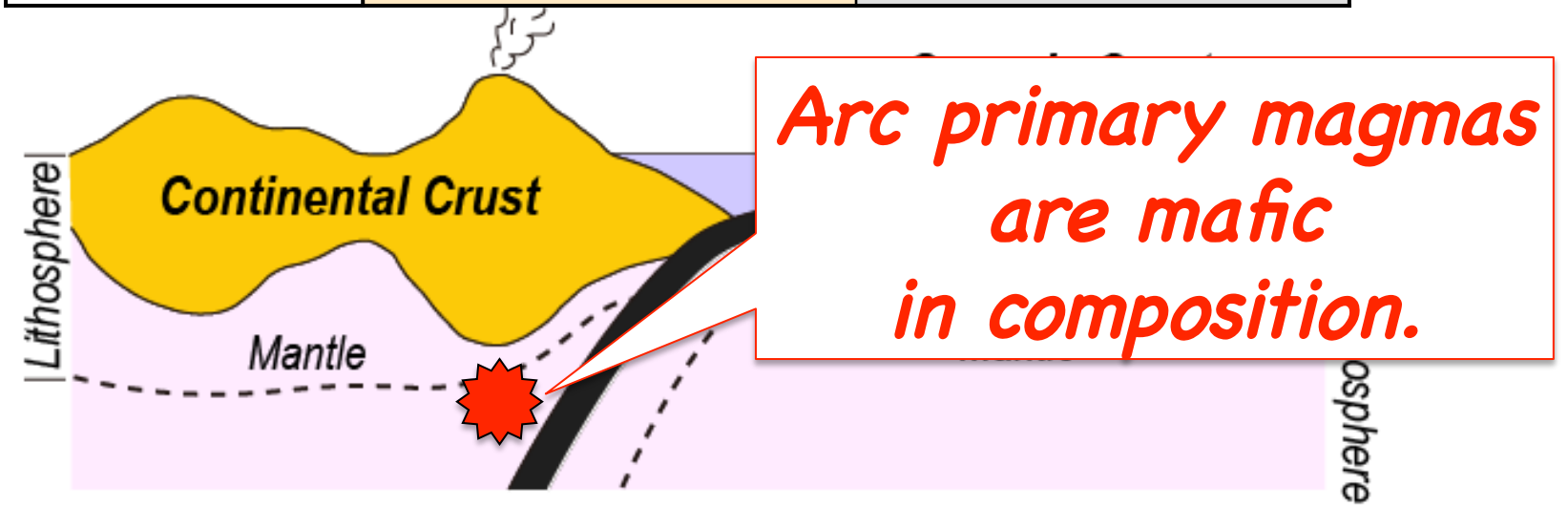
	Continental Crust	Oceanic Crust
Height	850 m	-3800 m
Thickness	40 km	6 km
Composition	intermediate	mafic
Density	2.7	3.0





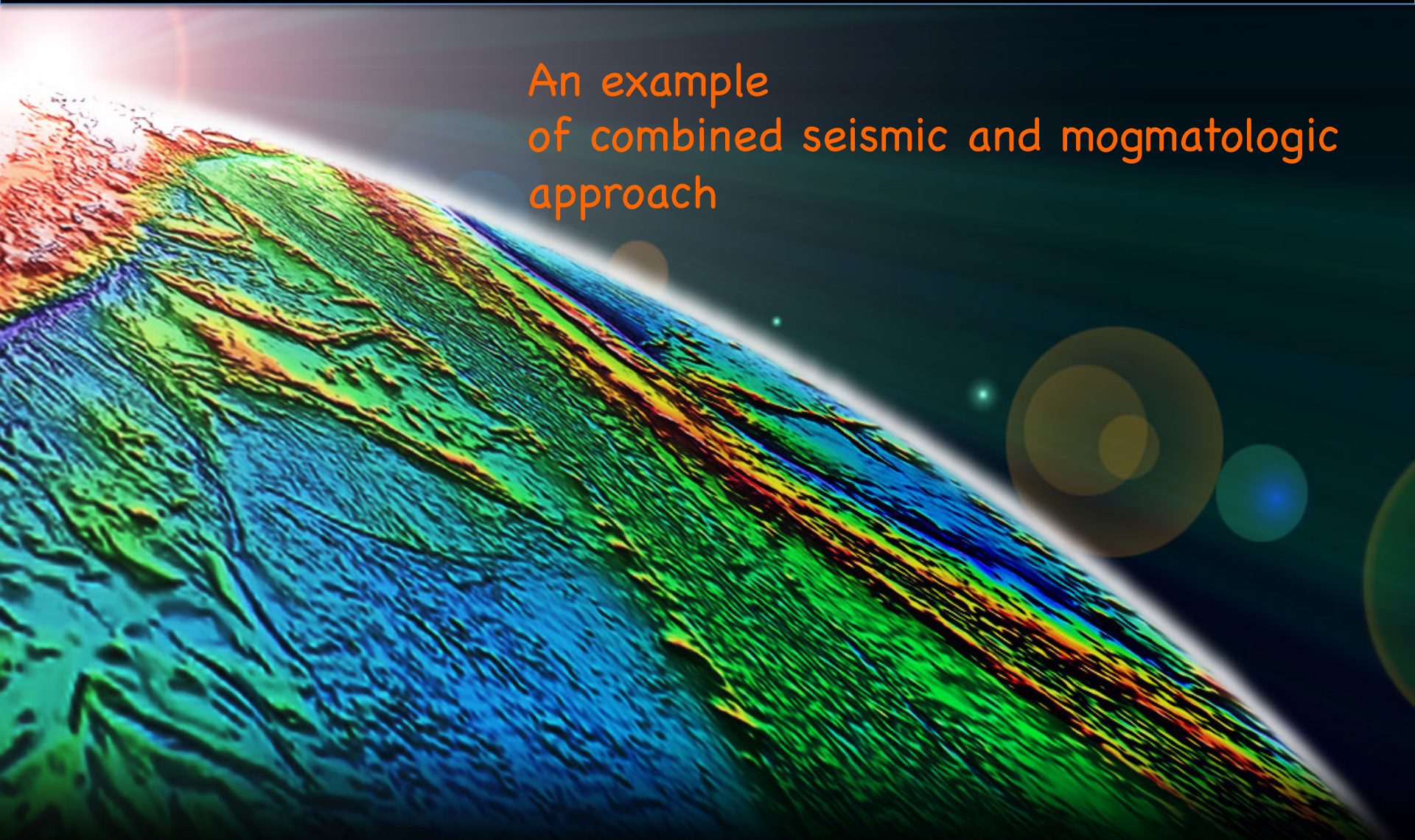
Continent *vs.* Ocean

	Continental Crust	Oceanic Crust
Height	850 m	-3800 m
Thickness	40 km	6 km
Composition	intermediate	mafic
Density	2.7	3.0
Birth Place	arc	MOR



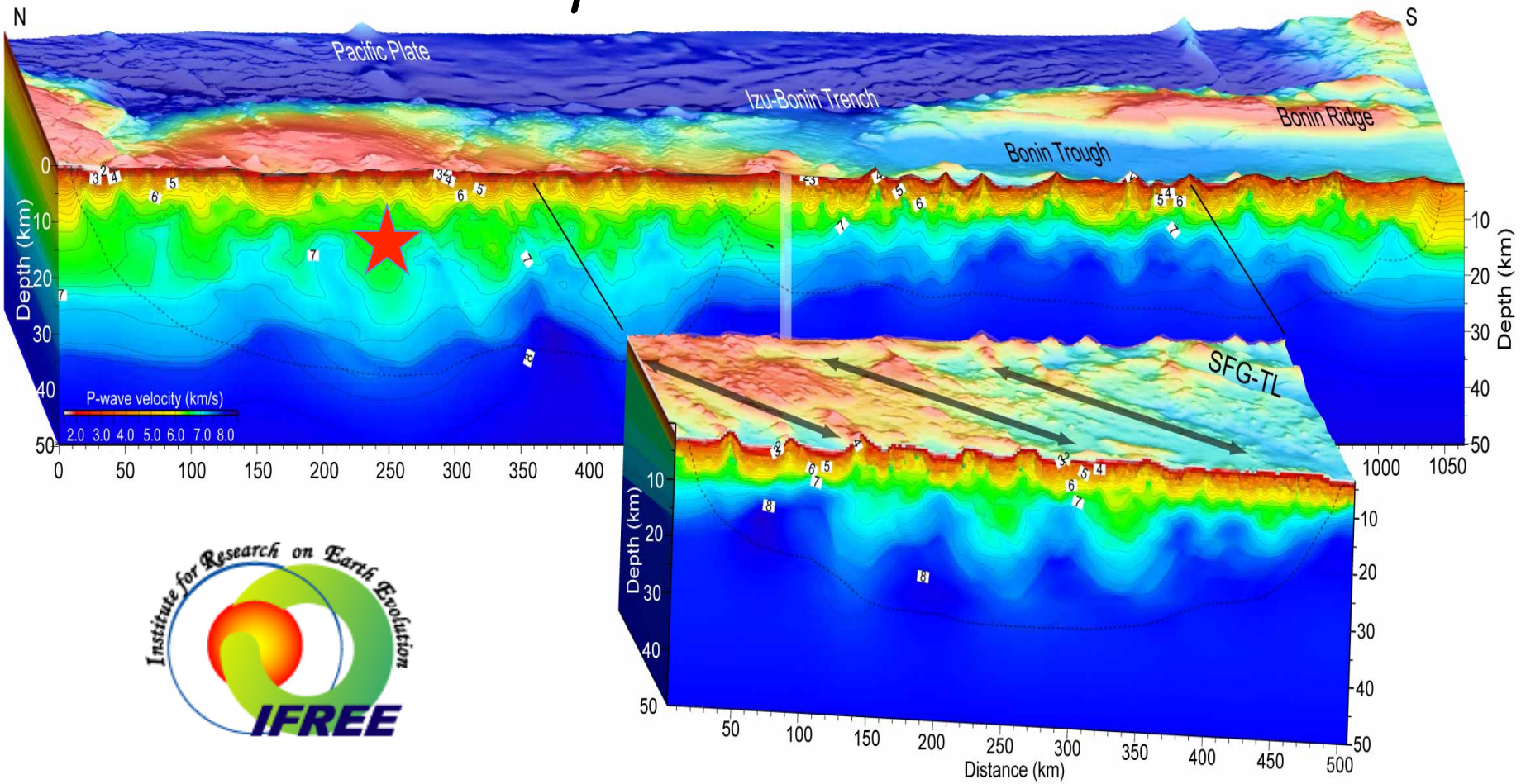
Arc primary magmas are mafic in composition.

Ocean creates continent: Project IBM



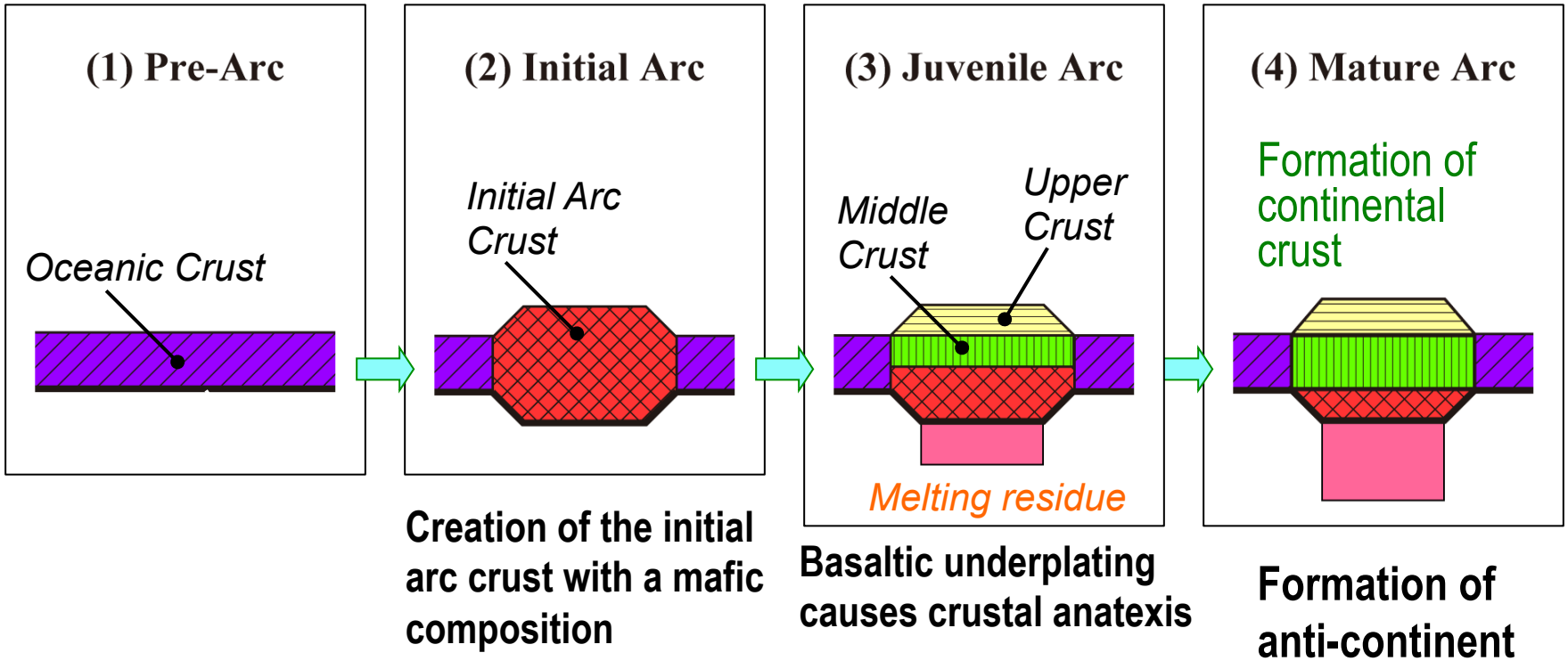
Seismic imaging of IBM crust/mantle

Ubiquitous creation of continental crust with 6.5km/s *Vp*



Institute for Research on Earth Evolution
IFREE

Arc evolution: creating continental crust and anti-continent



Creation of the initial arc crust with a mafic composition

Basaltic underplating causes crustal anatexis

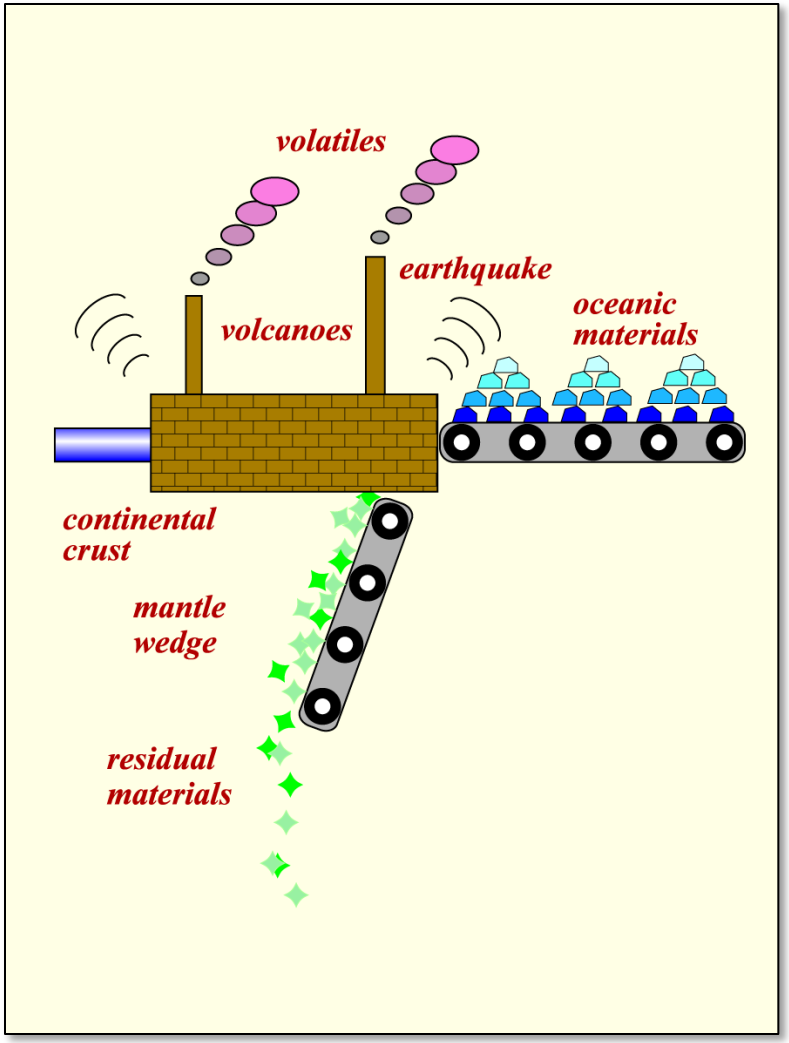
Formation of anti-continent

Crust-mantle transformation across the transparent Moho

→ discharging the ultramafic anti-continent to the mantle

→ evolving arc crust from mafic to intermediate compositions

Subduction zones working as a factory



Raw materials

- Oceanic material:
  sediments + MORB
- Mantle wedge material

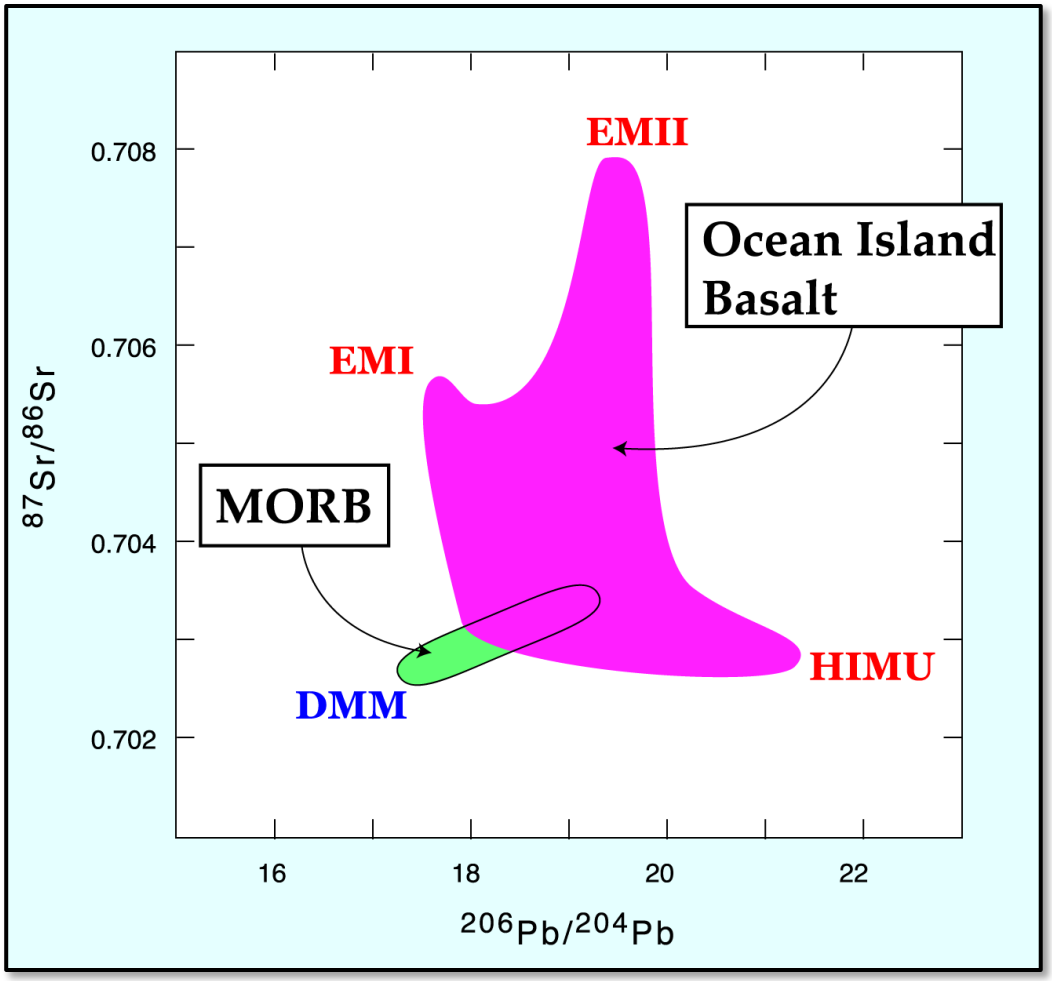
Products

- Magma/Volcanoes
- Volatiles
- Continental crust

Wastes

- Chemically modified sediment
- Chemically modified/fresh MORB
- Anti-continent

SubFac vs. HotspotFac

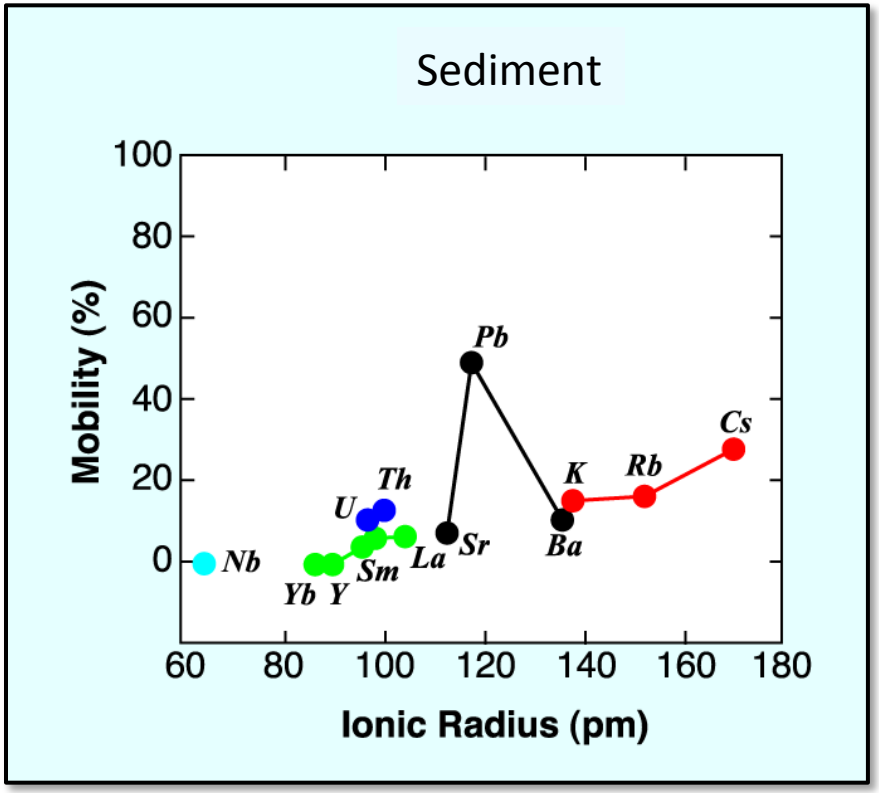


3 enriched reservoirs in the deep mantle

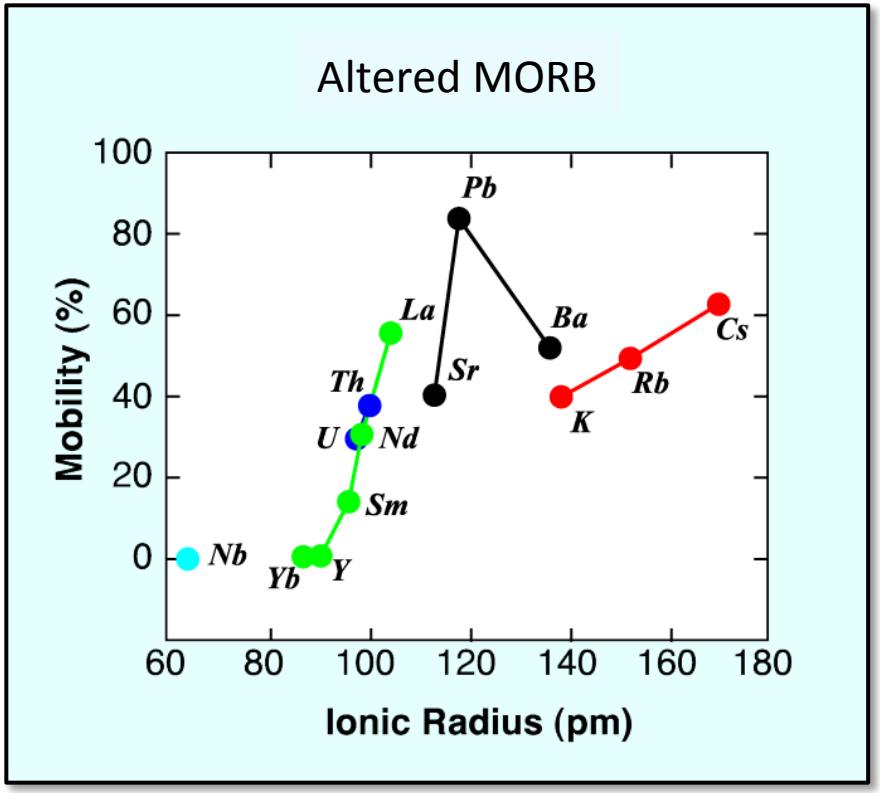
vs.

3 wastes from SubFac

Chemical modification via dehydration

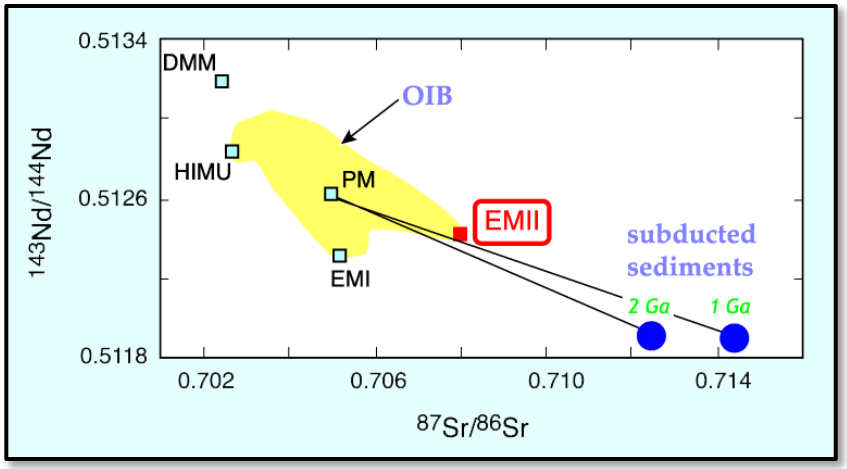


Aizawa et al. (1998)

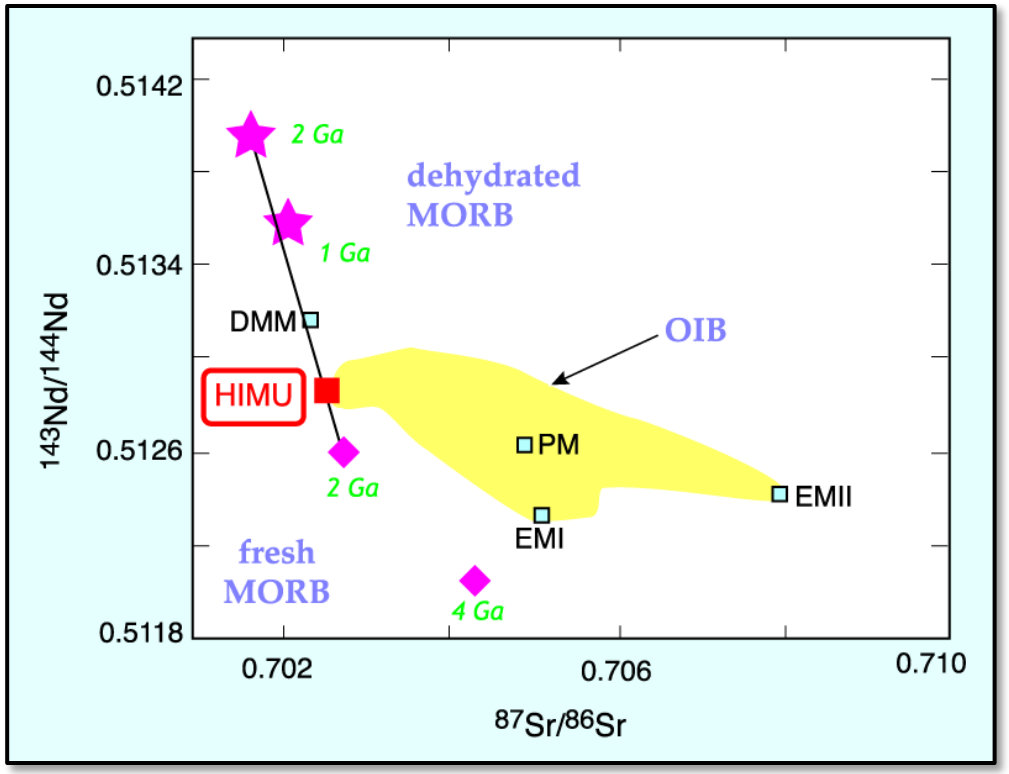


Kogiso et al. (1997)

Isotopic evolution of sediment & MORB



Aizawa et al. (1998)

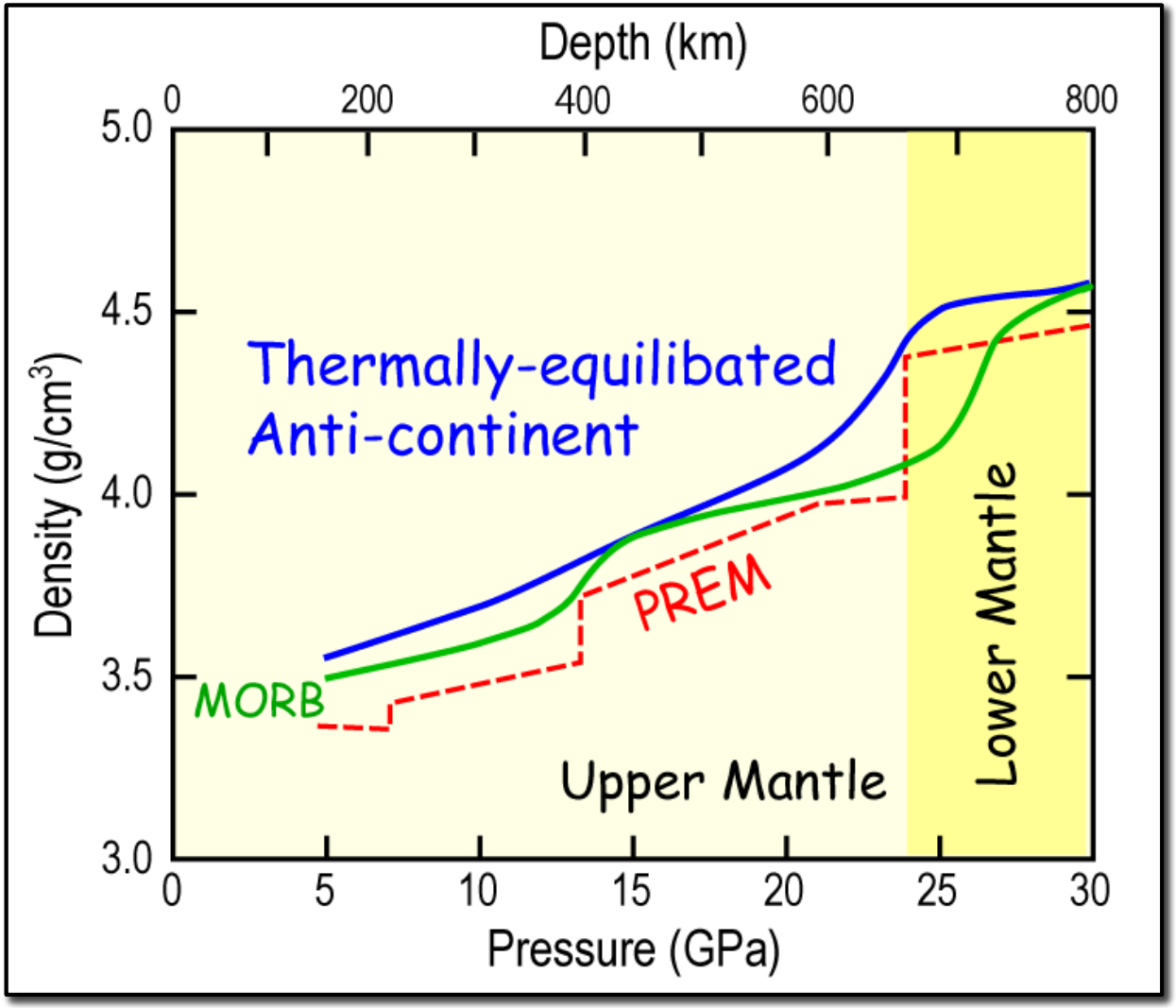


Tatsumi & Kogiso (2005)

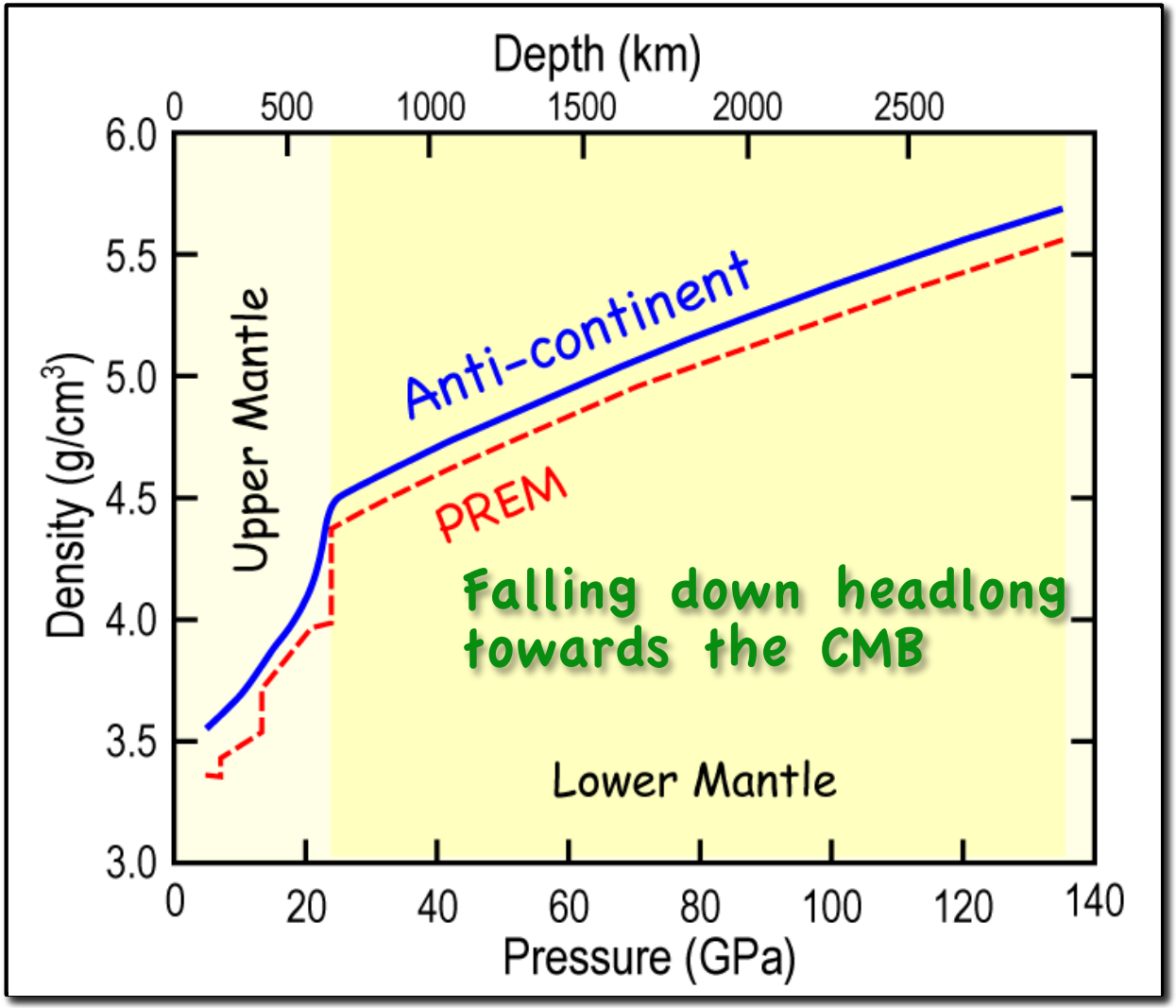
Dehydrated sediments → EMII

Dehydrated+fresh MORB → HIMU

Fate of the anti-continent: density change



Fate of the anti-continent: density change



Volume of accumulated anti-continent

- **Existing continent: 7.4×10^9 km^3**
- **CC Comp:20% melting of IBC**

↓

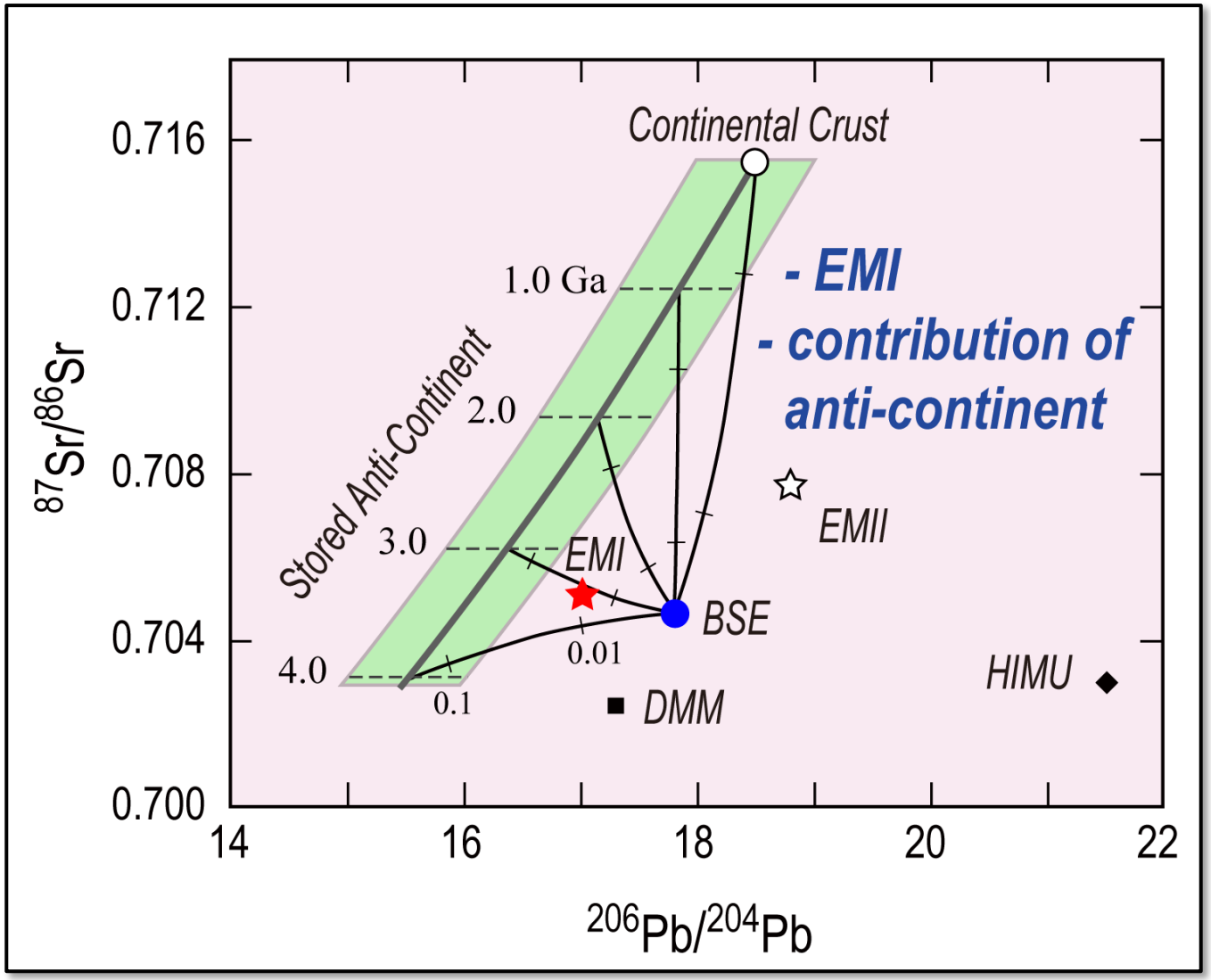
Accumulated A-C: 2.9×10^{10} km^3

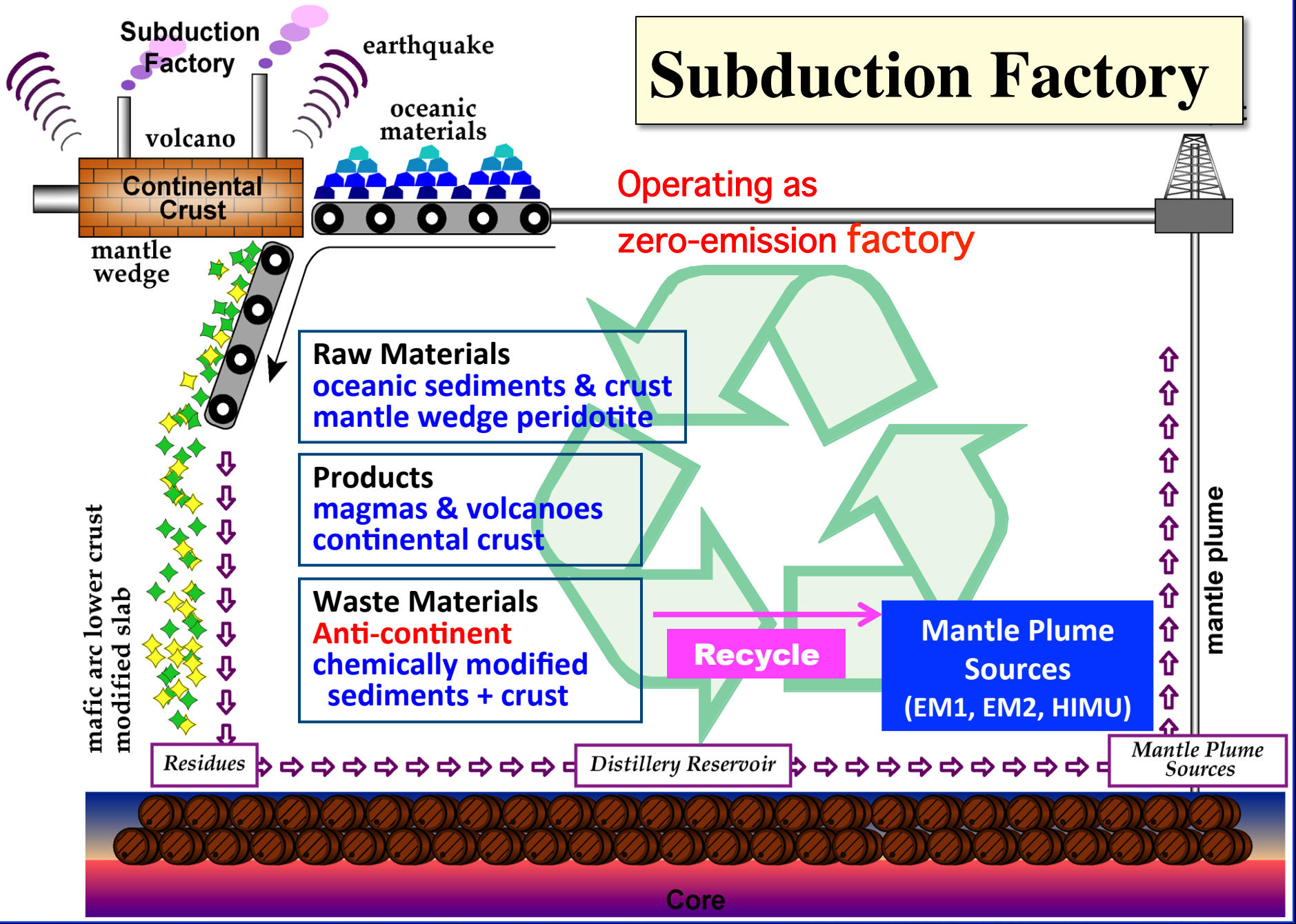
~200km layer above CMB

↓

D" layer: Accretion of A-C?

Fate of the anti-continent: isotopic evolution





Operation of SubFac: Consequence of plate tectonics

Why has plate tectonics been working solely on the Earth?

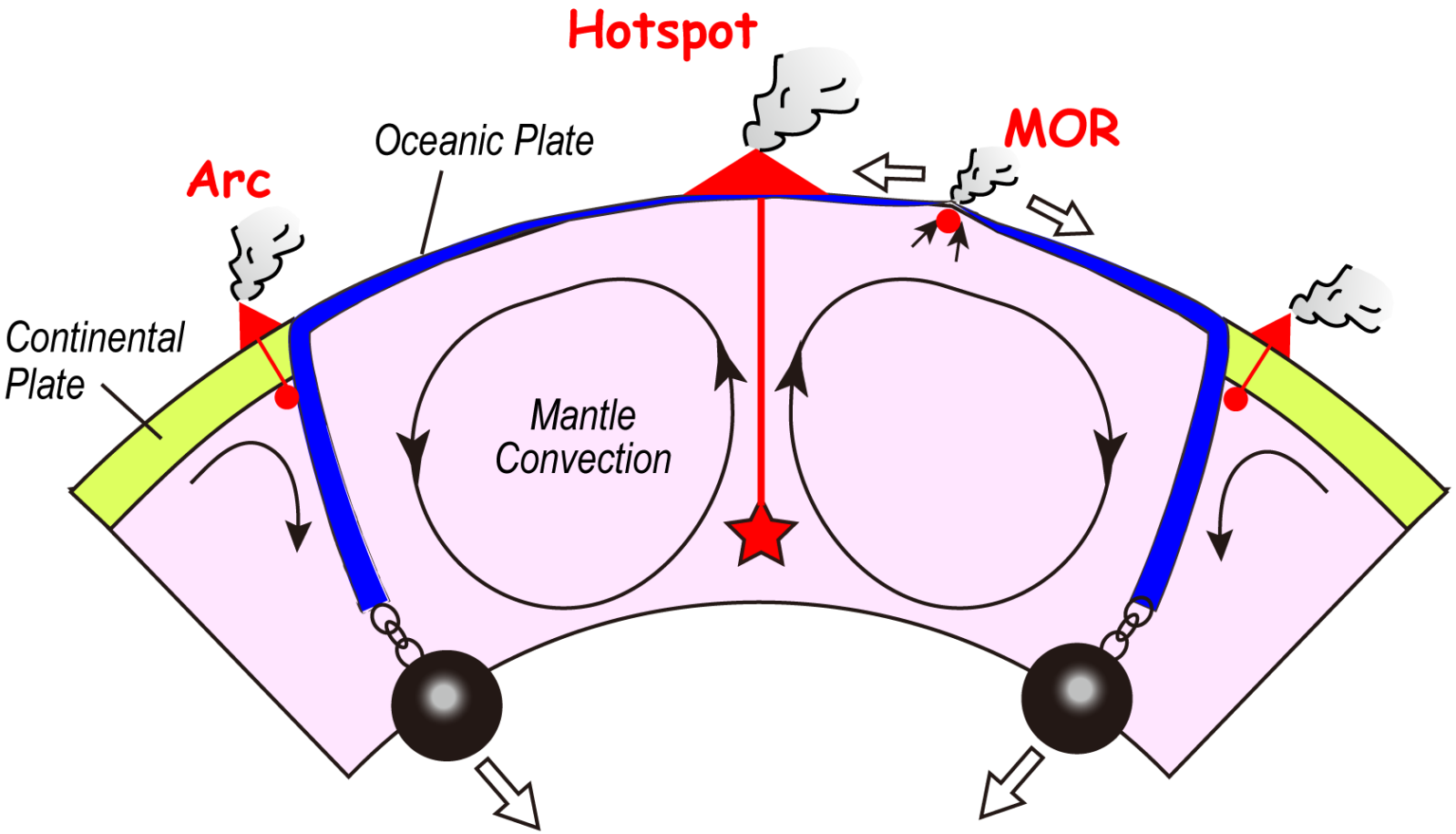
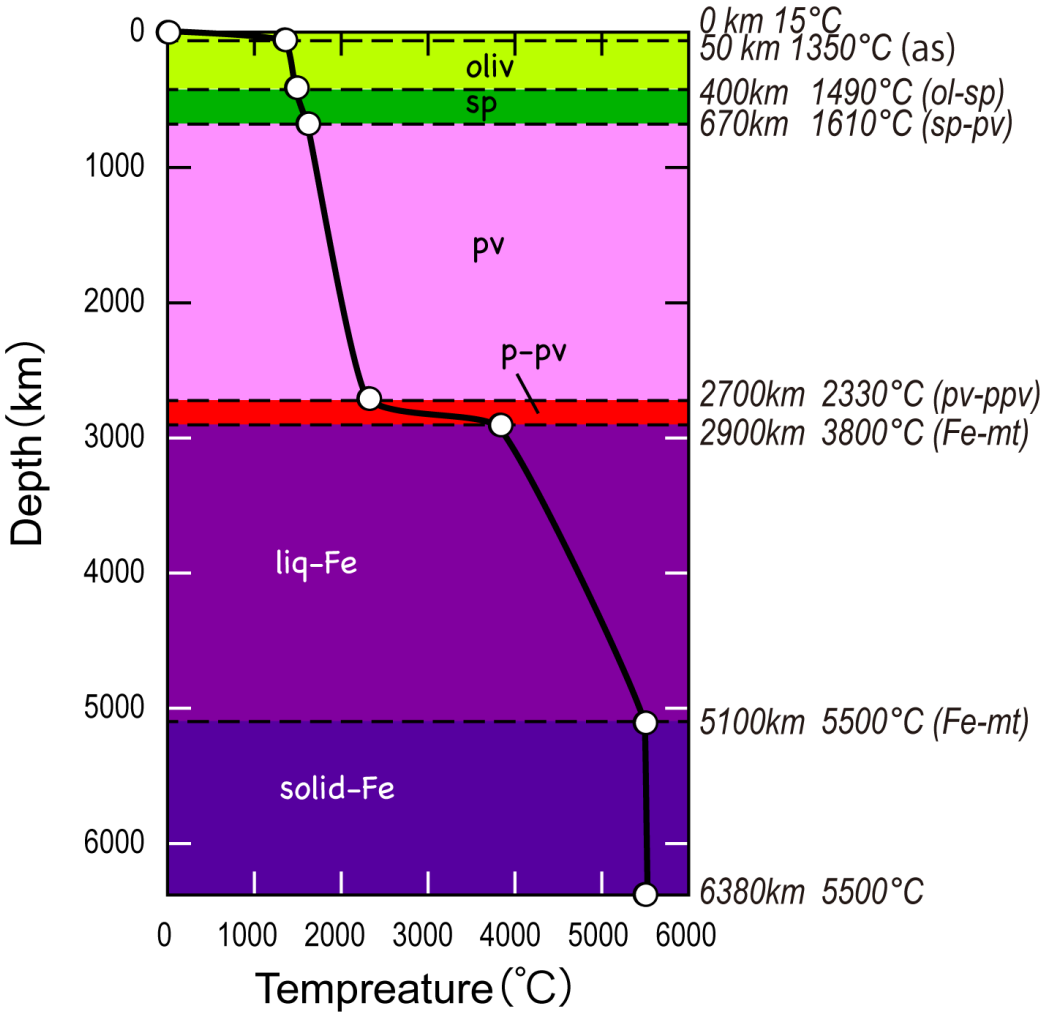


Plate tectonics: consequence of mantle convection

The Earth as an heat engine:
Temperature of the Earth's interior



The layered Earth
← Phase changes

Phase boundary
Depth of discontinuity
→ Temp. at the depth

Too small IC
→ little temp. grad.

The Earth as an heat engine:
Heat transfer in the solid mantle

Heat transfer:

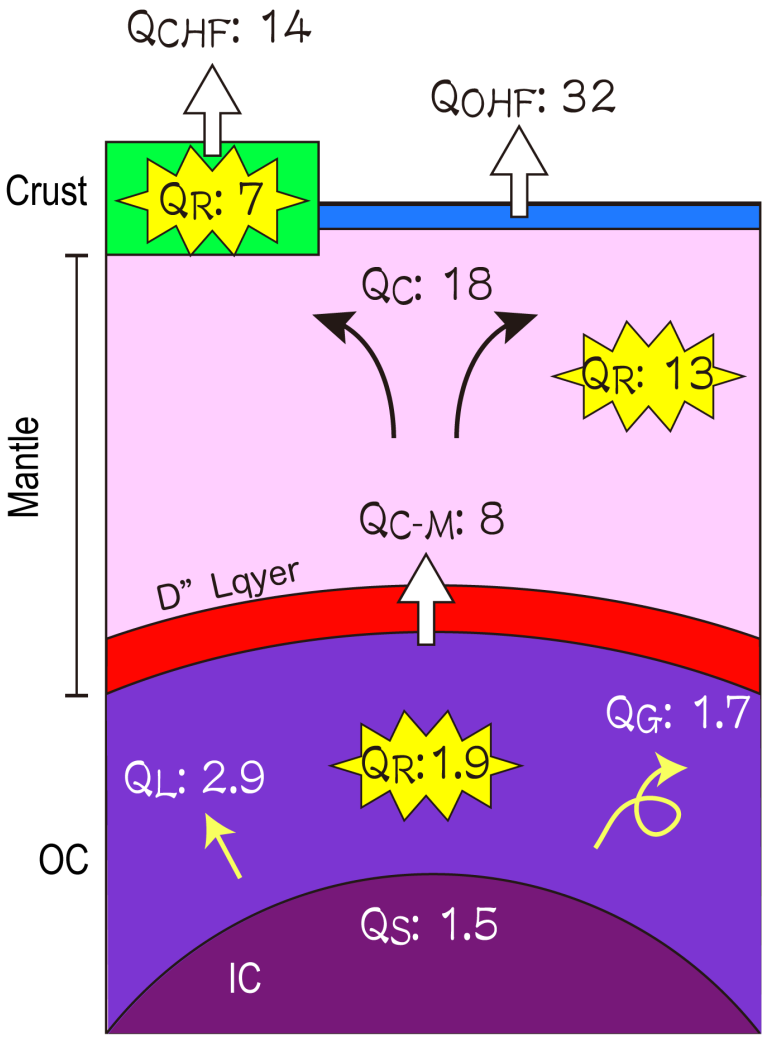
thermal radiation, heat conduction and convection

Conduction or convection?

$$Ra \equiv \frac{\rho_0 g \alpha (T_1 - T_0) b^3}{\mu \kappa}$$

Ra>10^6 for the mantle >> critical Ra

The Earth as an heat engine:
Heat transfer by mantle convection



Heat loss from the surface

$Q_{CHF}+Q_{OHF}=46$ TW

Heat from the core

$Q_{C-M}=8$ TW

←ΔT,κ, d of D" TBL

Latent heat : 2.9

Gravitational work: 1.7

Radioactive heating: 1.9 (K=300ppm)

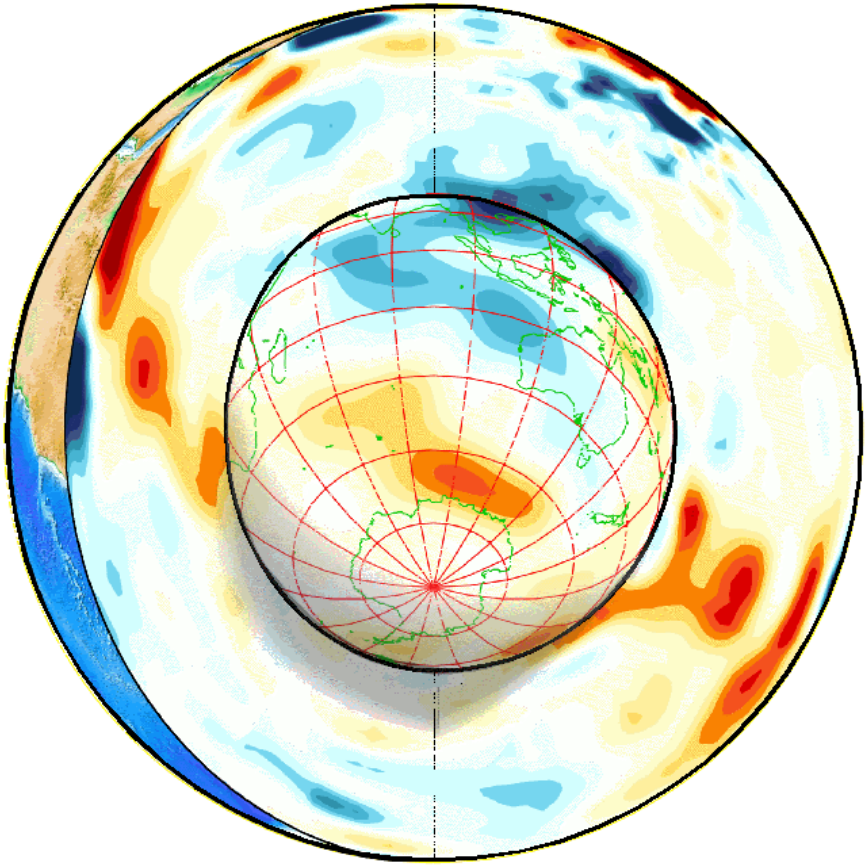
Core cooling: 1.5

Heat budget in the mantle

$Q_C=46-8-Q_R=18$ TW

→ mantle convection

The Earth as an heat engine:
Heat transfer by mantle convection



$$Qc = V \times \rho \times Cp \times \Delta T / \Delta t$$

$\rho = 4 \times 10^3$

$Cp = 10^3$

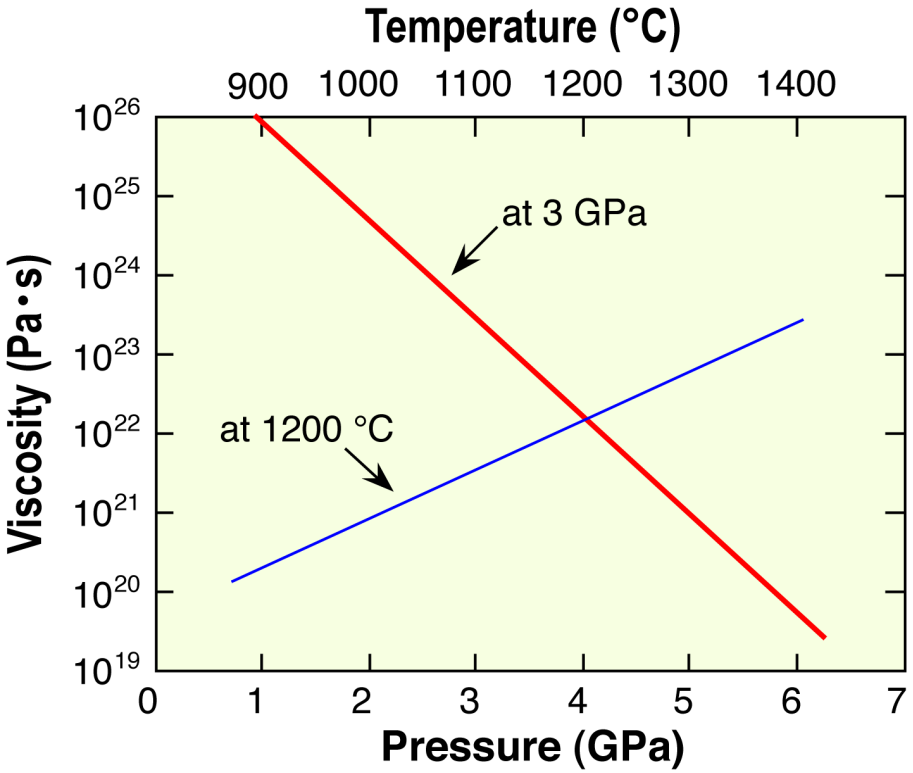
$\Delta T = 10^3$

Δt = 5cm/y for 2900km

V = ΦSP Plume, 500km

Qc=10TW~ 18TW

Mantle Convection vs. Plate Tectonics:
P/T dependence of viscosity



$$\eta = \eta_0 \exp\left(\frac{E + PV}{RT}\right)$$

T-dependent mantle viscosity
→ litho- & astheno-sphere
→ plate tectonics

Mantle Convection vs. Plate Tectonics:
Stagnant Lid Convection

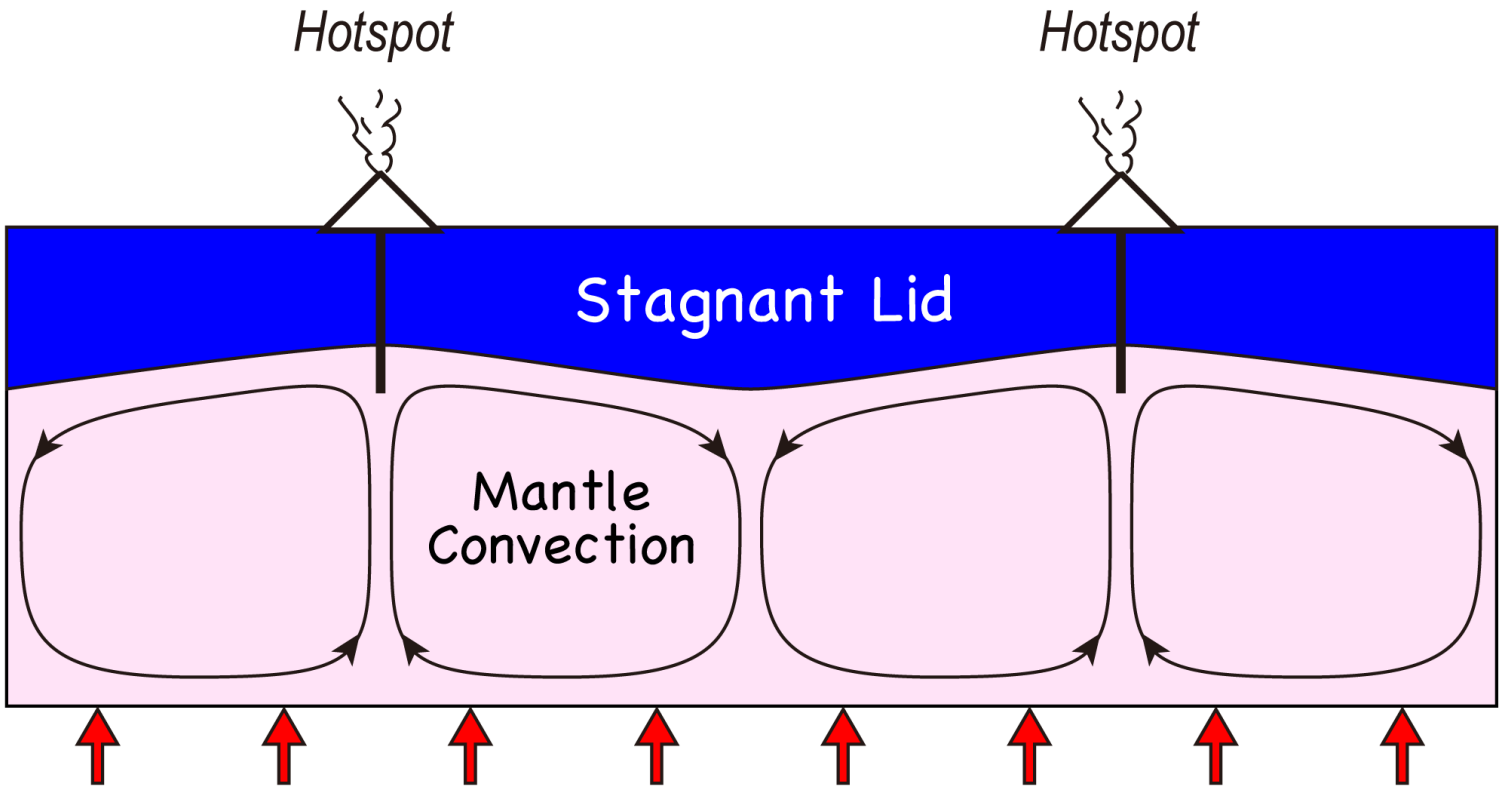
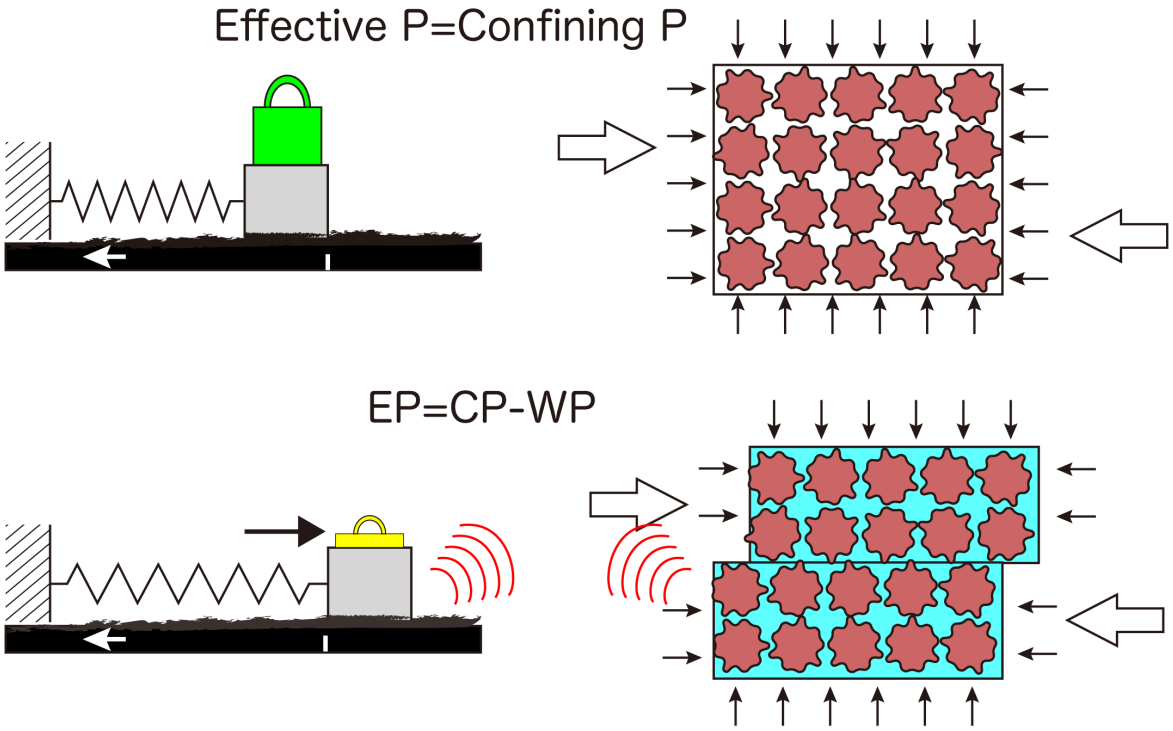


Plate is highly stagnant → Plate tectonics does not work
Mantle convection in the Venus and Mercury

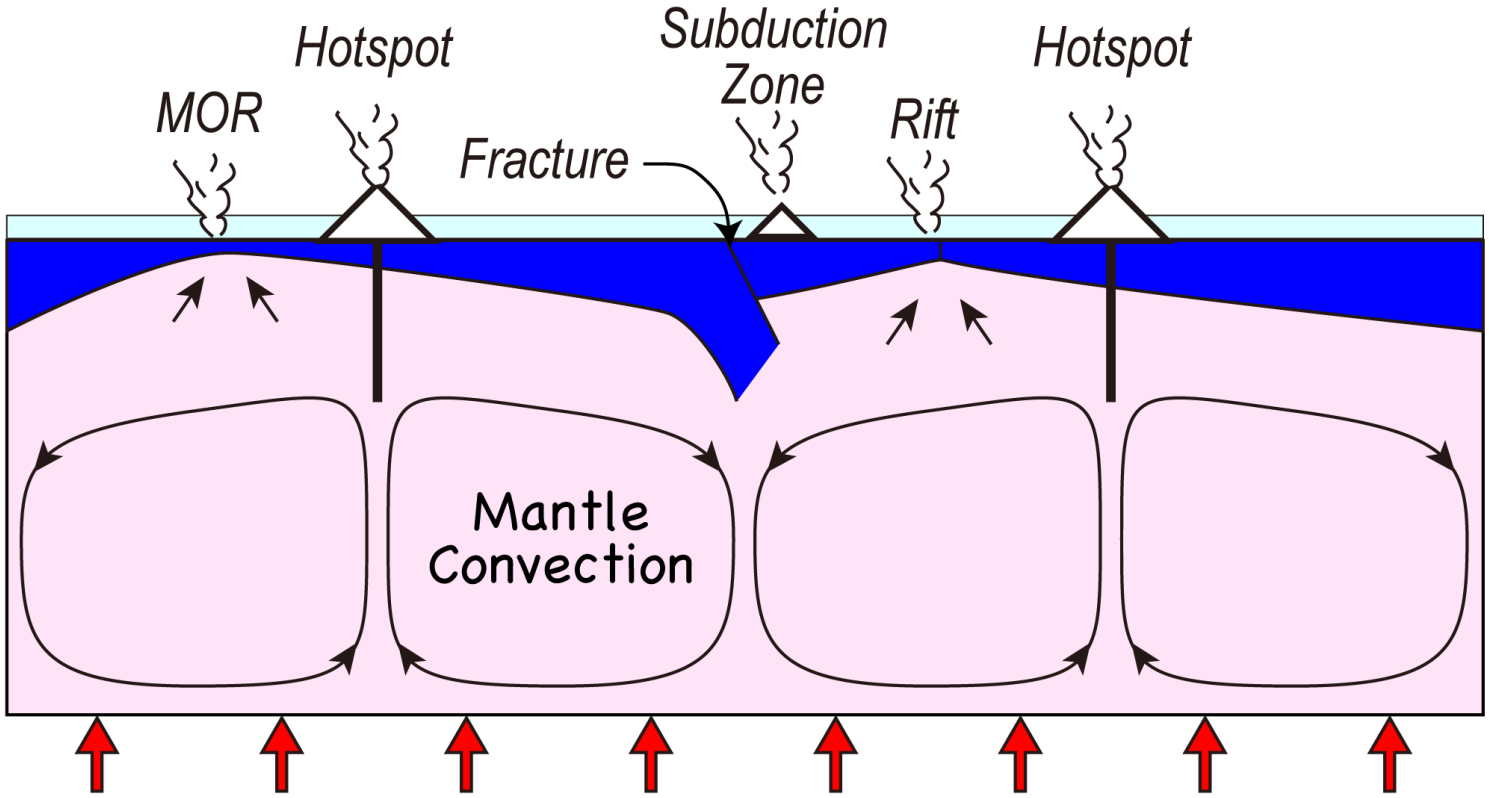
Mantle Convection vs. Plate Tectonics: Strength of 'rock'



Water reduces the strength of rock

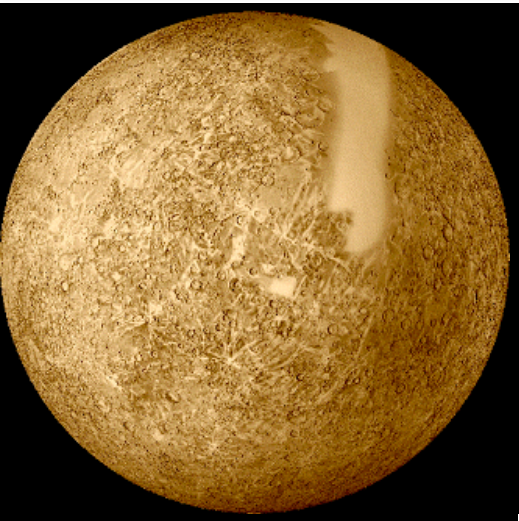
→ The surface liquid water is critical in plate motion

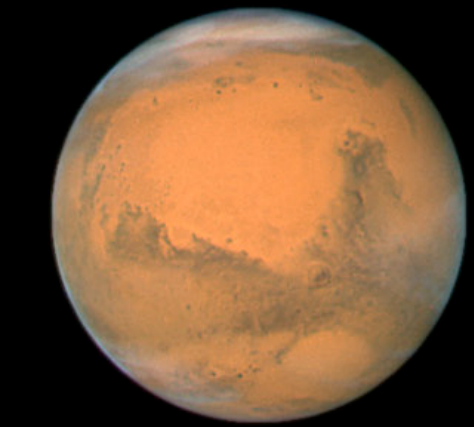
Mantle Convection vs. Plate Tectonics: The role of fracture within the plate



Liquid water → Fracture → Plate Tectonics

The presence of water at the surface:
the ultimate cause of being the Earth

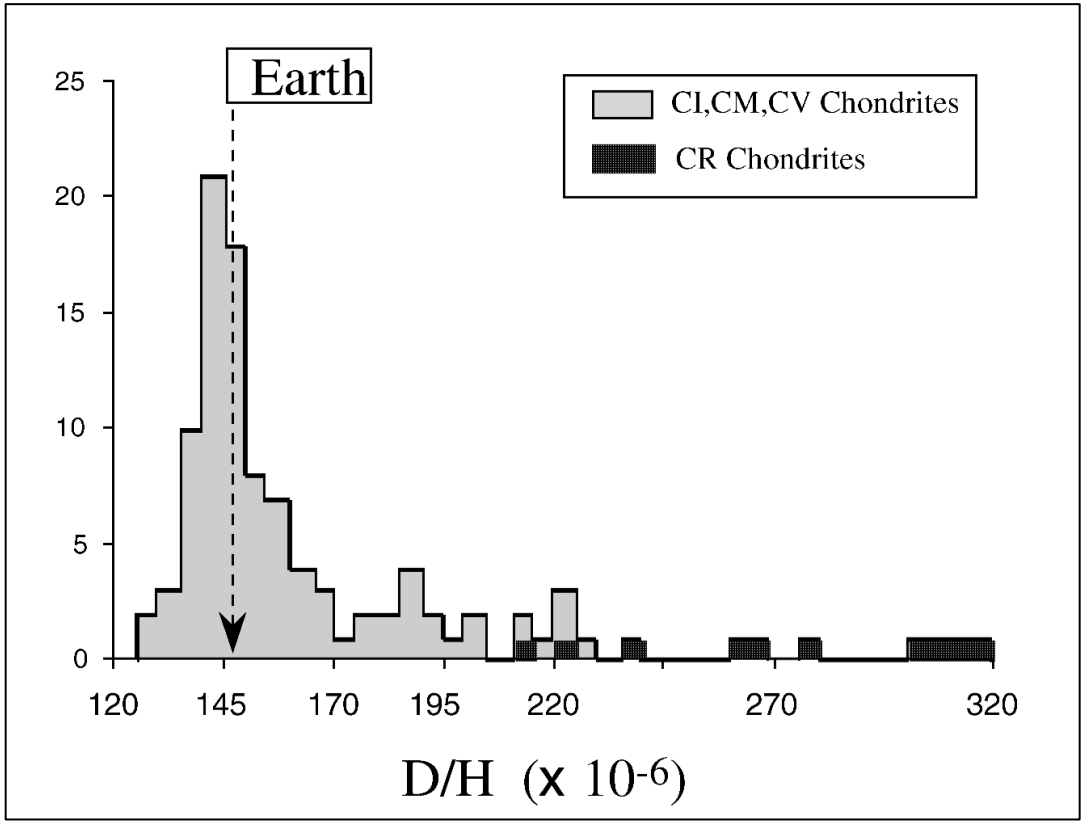




- The origin of water
- The conditions suitable for the presence of liquid water

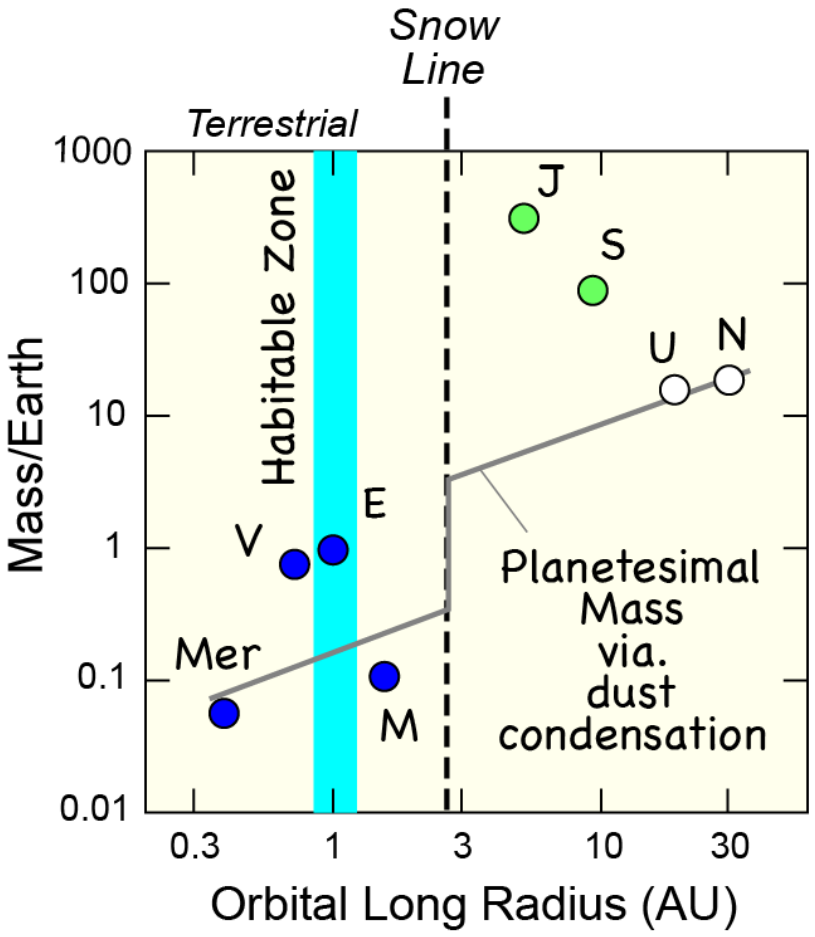
Why liquid water at the surface?
Origin of water

Carbonaceous chondrite:
A plausible source of the Earth and water



- Max. 17wr% H2O
- Deuterium/Hydrogen ratio identical to the Earth (ocean)

Why no liquid water at the surface?
Mars



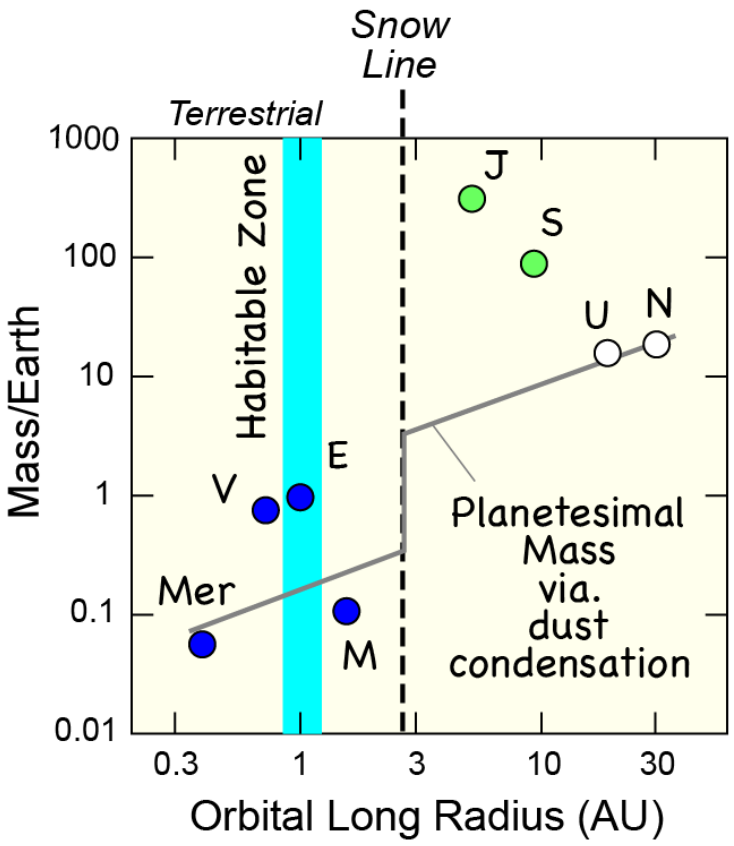
- Earth/Venus: giant impact
- Mars: Planetesimal mass

Mars used to be a water planet by green house effect

←Dissipation of atmosphere

←Too small mass

Why no liquid water at the surface?
Venus



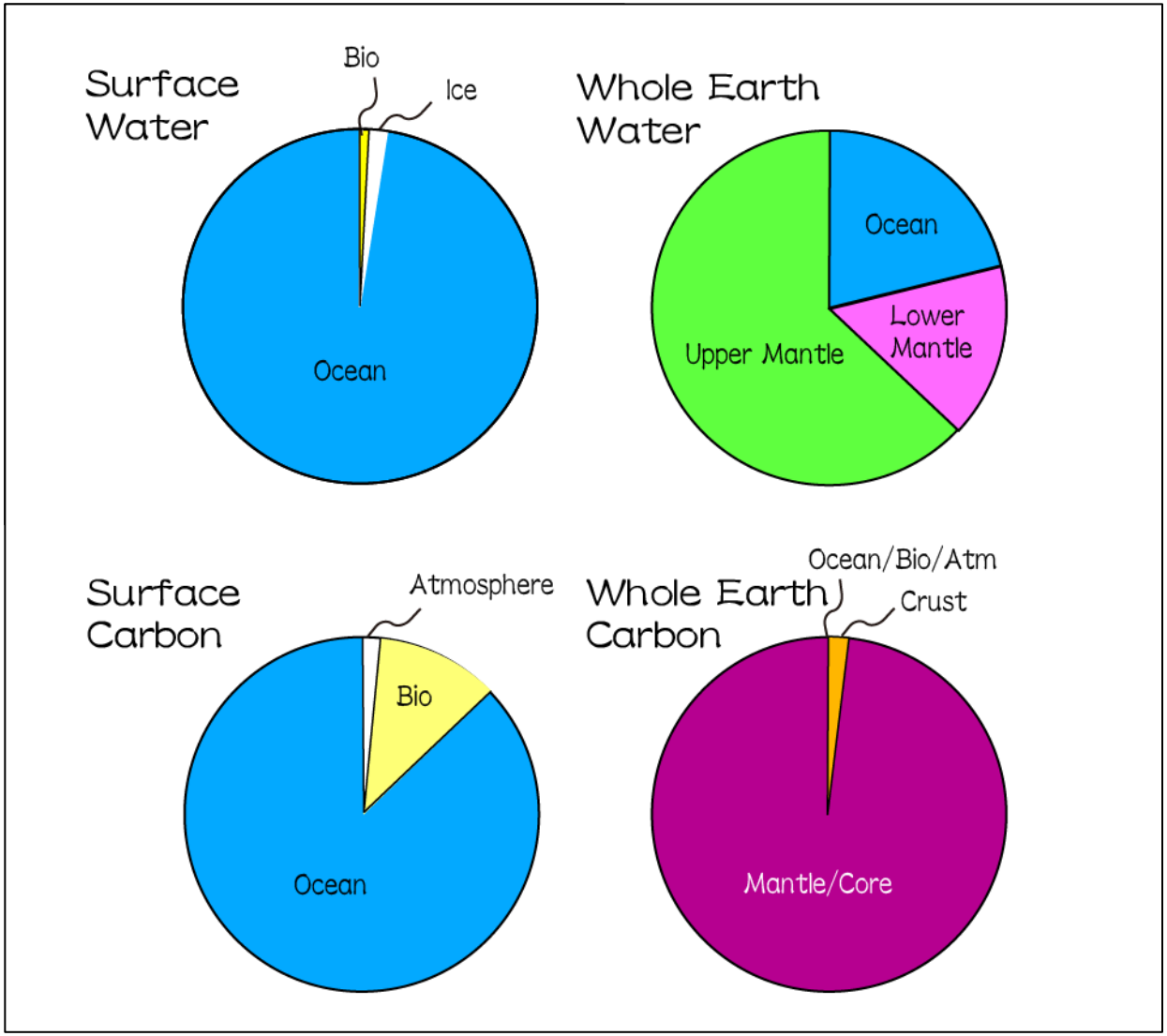
- ✧ Severe heating by sunshine
  →higher-T for liq. water
- ✧ Simple but not true
  ←highly reflective atmosphere

Strong green house effect by CO_2-rich atmosphere

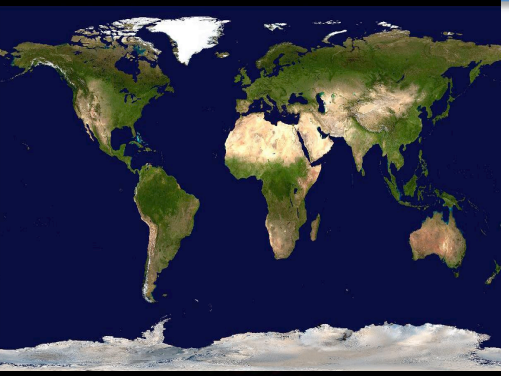
←Decomposition of H_2O into H and O by severe UVR and subsequent dissipation to the space

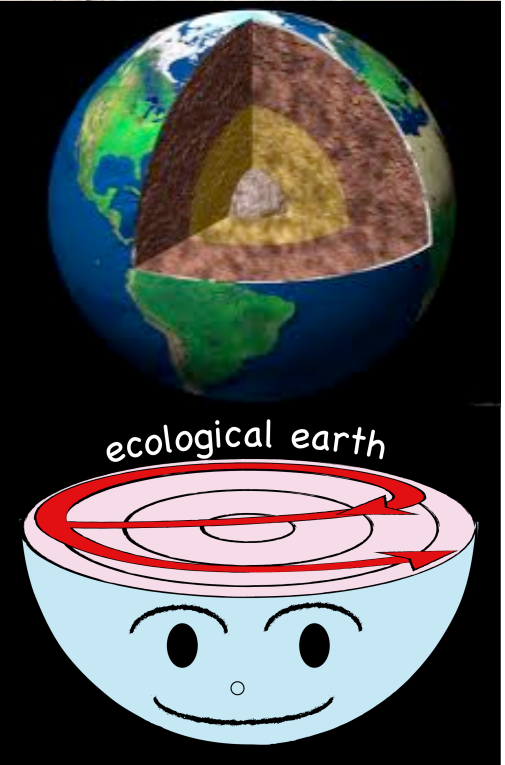
←No carbonate deposition in liq. water

Water in the Earth



Earth's interior:
→Huge reservoir of CHO





Why is this planet to be the Earth?

- The Earth is the only planet having both continent/ocean, i.e., high/lowlands
- This is caused by operation of plate tectonics
- Plate tectonics is triggered by both mantle convection and the presence of liquid water at the surface
- The distance from the Sun and the mass of the Earth are essential parameters in the presence of liquid water
- Distribution of CHO in the Earth's interior is to be understood

Thanks…