Mantle Convection

Lecture 13

Layered Convection
Layered Convection

- Mantle convection results in chemical differentiation

- This depends on the degree of partial melting, which in turn depends on temperature, composition and water content

- Process of chemical differentiation in upper mantle well understood

- Presence of distinct chemical reservoirs separated for more than a billion years

- Their exact locations and mechanisms of survival poorly understood
MORB vs OIB

- base of lower mantle that is a slab graveyard
- delamination of continental lithosphere
- layered mantle convection
Layered Mantle Convection

- jump in P-wave velocity at 660 km
- descending slabs sometimes stopped at 660
- geochemical studies:
  - abundance of $^{40}$Ar
  - $^{3}$He/$^{4}$He higher than $\sim$10 times the atmospheric value

![Image of P-wave and S-wave seismic structure models](image-url)
\[ P_h \equiv \frac{\Gamma(\frac{\Delta \rho}{\rho})}{\alpha \rho g h} \]

Enhanced for:
- 3D convection
- higher Rayleigh number

**Rayleigh number** : vigour of convection; \( Ra \sim 10^6 \)

\[ Ra = \frac{g \rho \alpha \Delta T d^3}{\kappa \eta} \]

Critical Rayleigh number : point at which convection initiates; \( Ra_c \sim 10^3 \)
Nusselt number: ratio of heat transported via convection to heat transported via conduction.
Phase changes at 400 and 660 km

Increasing Rayleigh number

Mantle becomes stratified

Mantle avalanches (Tackley, 1993)
Transition zone water filter model

Whole-mantle convection and the transition-zone water filter

David Bercovici & Shun-ichiro Karato

Department of Geology and Geophysics, Yale University, PO Box 208109, New Haven, Connecticut 06520-8109, USA