Announcements

Field trip 1 conflicts:

April 22-23 vs. April 29-30

Reading: p. 46-47

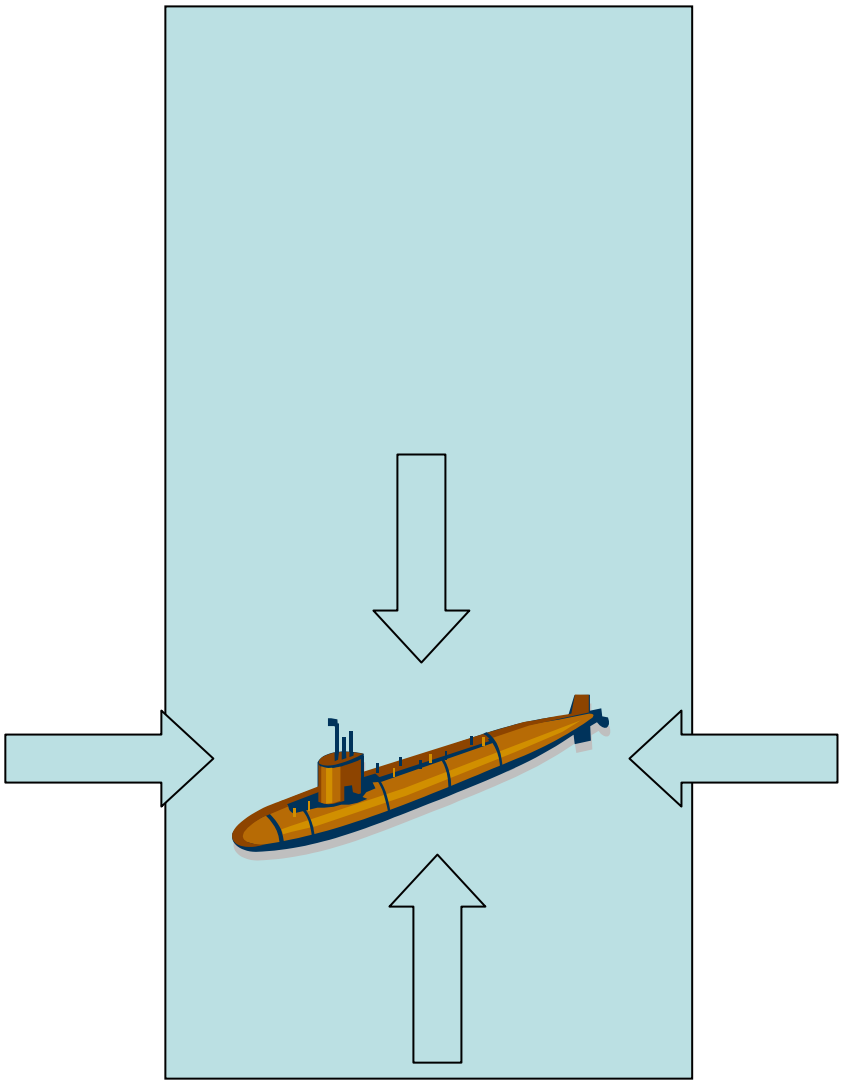
(Lab: Chapter 2 and 3; optical mineralogy book)

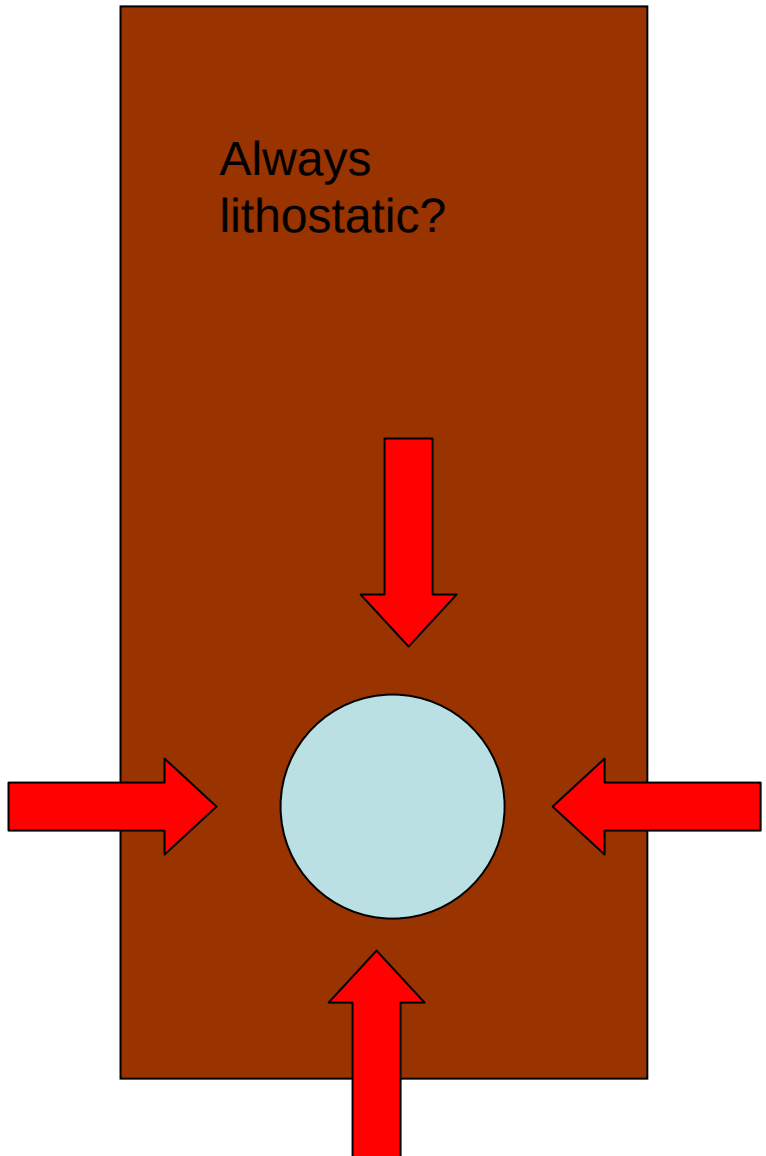
Homework 1 should be ready soon

Today's topics:

- Pressure as a function of depth in the Earth
- Geothermal gradients
- Mechanisms for generating melt in tectonic settings

Hydrostatic and lithostatic pressure





The Pressure Gradient

- P increases = ρgh
- Nearly linear through mantle
  - ~ 30 MPa/km
  - ≈ 1 GPa at base of ave crust
- Core: ρ incr. more rapidly since alloy more dense

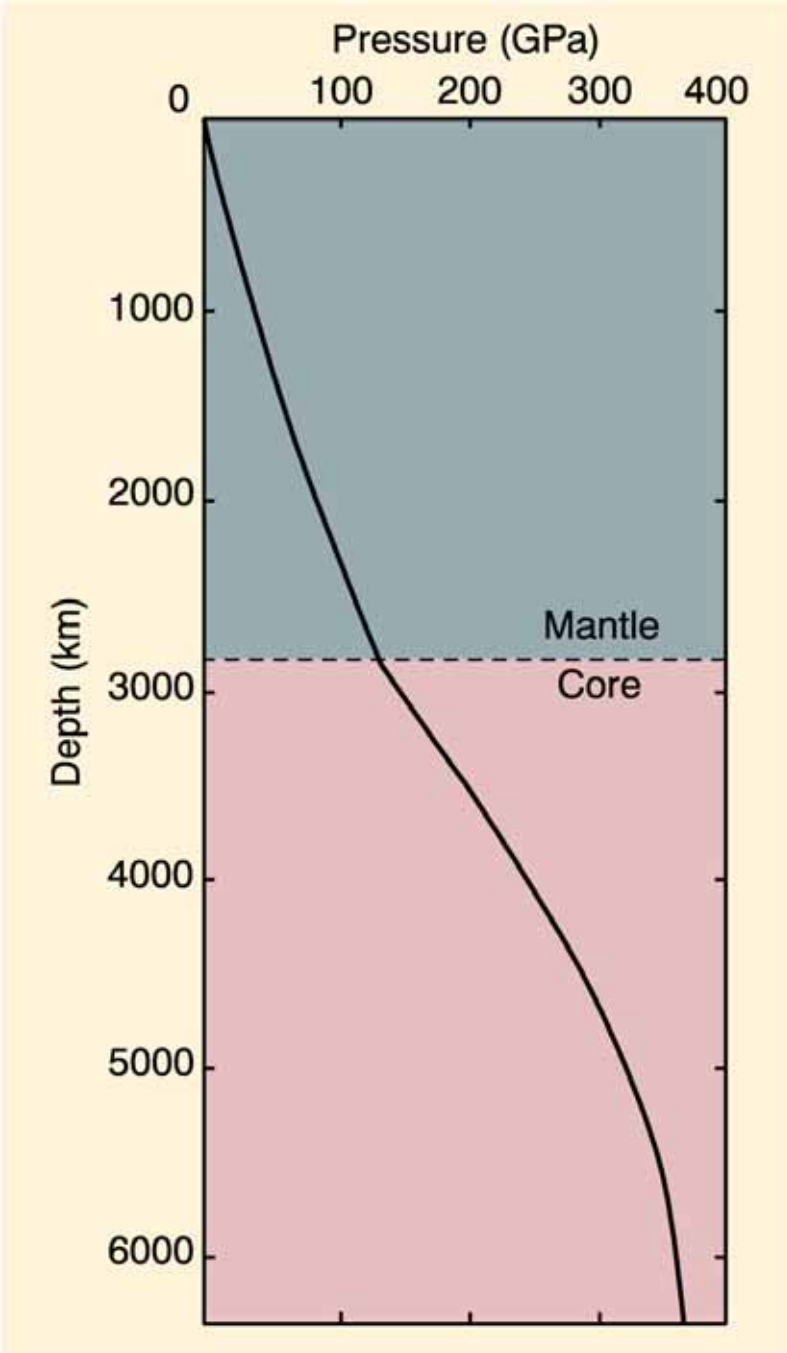
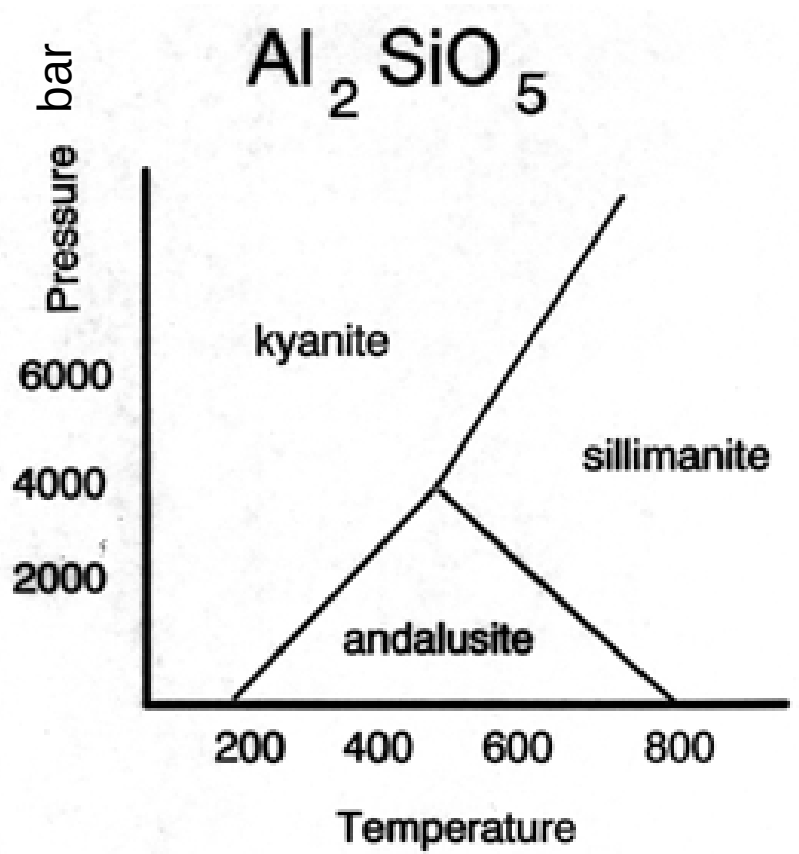


Figure 1-8. Pressure variation with depth. From Dziewonski and Anderson (1981). Phys. Earth Planet. Int., **25**, 297-356. © Elsevier Science.

Converting pressure and depth units

- **1 GPa = 10 kbar = 1000 MPa**
- **1 GPa/35 km**
- **About 3 kbar/km**

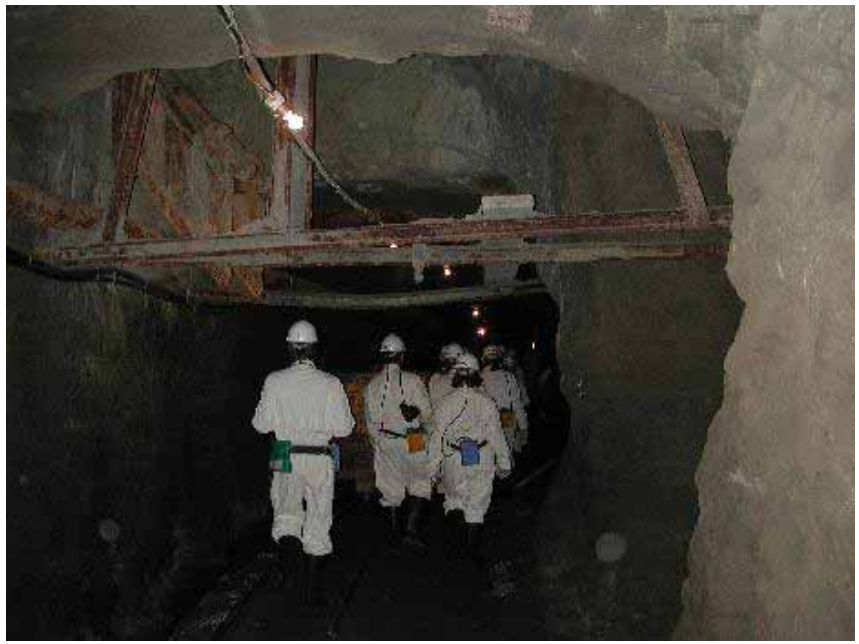
- **Example of how we will use these conversions:**



Measuring the temperature as a function of depth

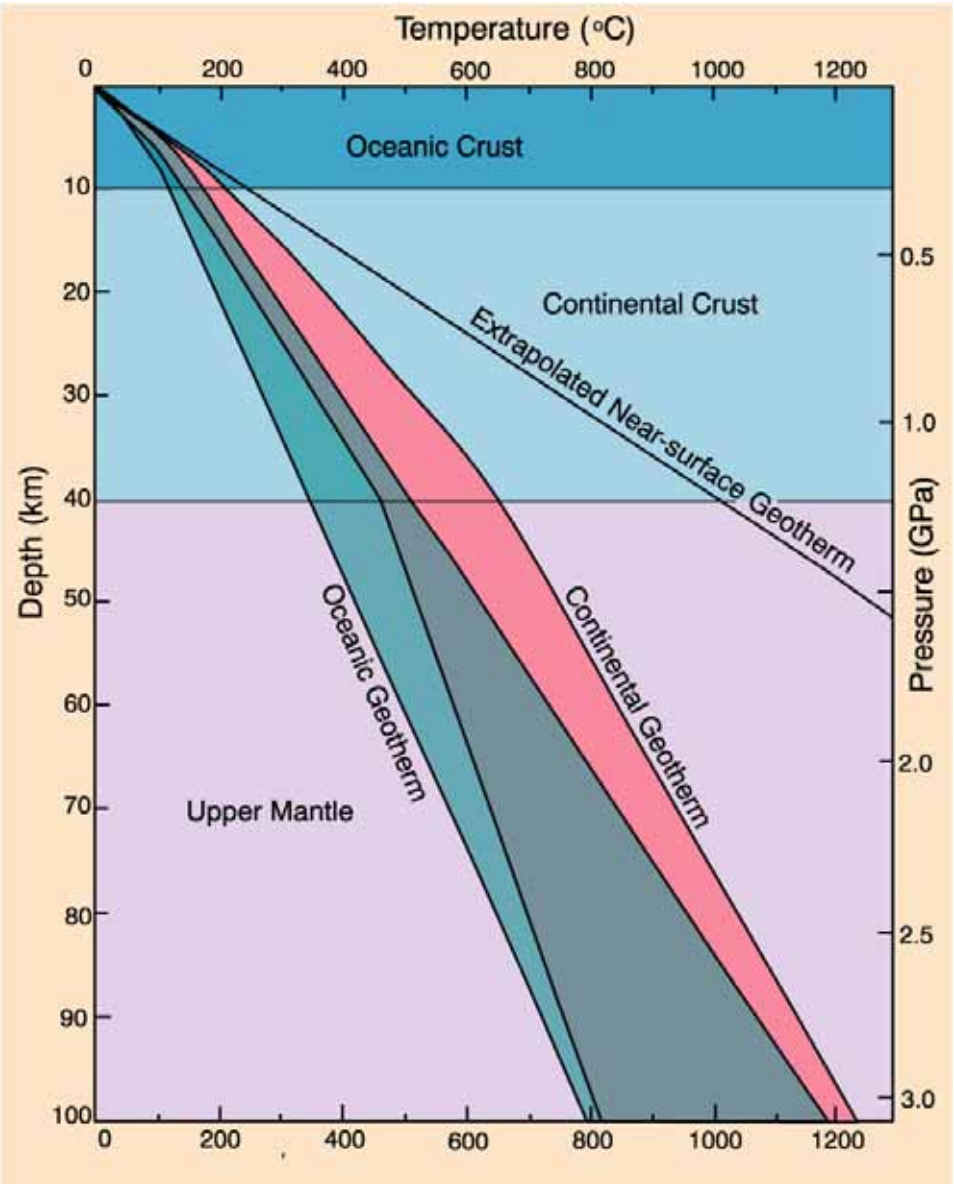
- What do you expect the temperature profile of Earth (geothermal gradient) to look like?

- How could we make measurements of temperature as a function of depth?



LJ

The geothermal gradient



- ~25°C / km near surface
- Oceanic geotherm “cooler” than continental geotherm
- ~0.3°C / km mantle below 200-250 km
- Why is geothermal gradient so much steeper in crust?

From Winter, Intro to Igneous and Metamorphic Petrology

Heat Sources in the Earth

- 1. Heat from the early accretion and differentiation of the Earth
  - still slowly reaching surface
- 2. Heat released by the radioactive breakdown of unstable nuclides

$$^{238}U \longrightarrow {}^{206}Pb$$

$$^{235}U \longrightarrow {}^{207}Pb$$

$$^{232}Th \longrightarrow {}^{208}Pb$$

$$^{40}K \longrightarrow {}^{40}Ar$$

0.2 cal/g/yr for ^{40}K

Radiogenic isotopes: important production of heat in the crust

U, Th, K

- How do these elements partition between minerals (olivine, pyroxene) and melt?

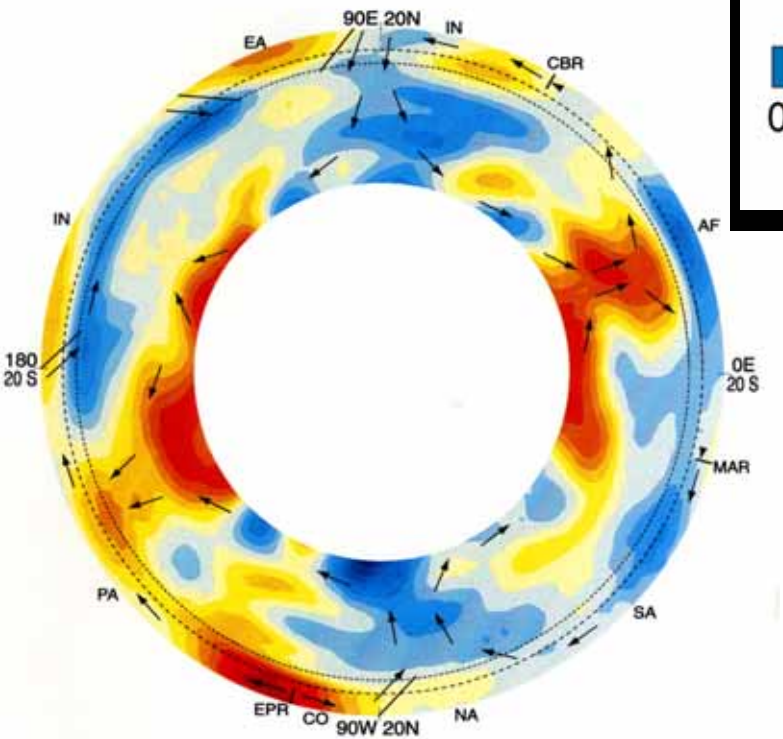
K heat generation ~100x
greater in crust than in mantle

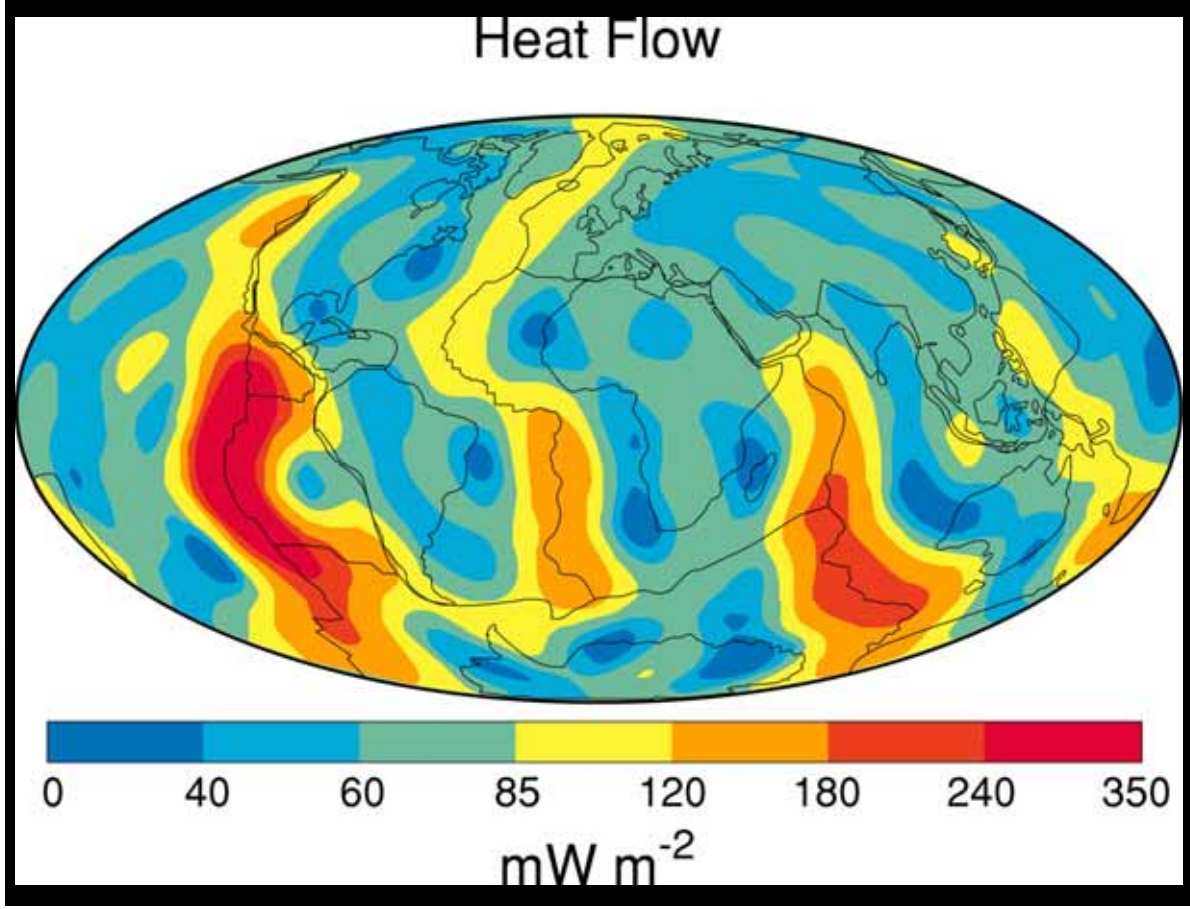
Mechanisms for transfer of heat

1. **Conduction: transfer of kinetic (vibrational) energy**
2. **Convection: movement of material**
3. **Advection: passive transfer of heat with rocks that are already in motion**
4. **Radiation: transfer energy with light- need to be translucent or transparent!**

Which apply to the Earth?

The Geothermal Gradient



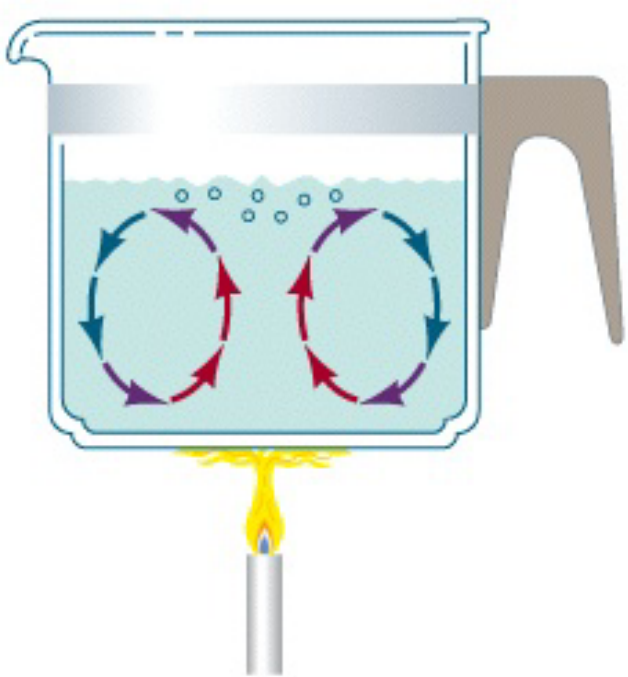


Pattern of global heat flux variations compiled from observations at over 20,000 sites and modeled on a spherical harmonic expansion to degree 12. From Pollack, Hurter and Johnson. (1993) Rev. Geophys. 31, 267-280.

Cross-section of the mantle based on a seismic tomography model. Arrows represent plate motions and large-scale mantle flow and subduction zones represented by dipping line segments. EPR =- East pacific Rise, MAR = Mid-Atlantic Ridge, CBR = Carlsberg Ridge. Plates: EA = Eurasian, IN = Indian, PA = Pacific, NA = North American, SA = South American, AF = African, CO = Cocos. From Li and Romanowicz (1996). J. Geophys. Research, 101, 22,245-72.

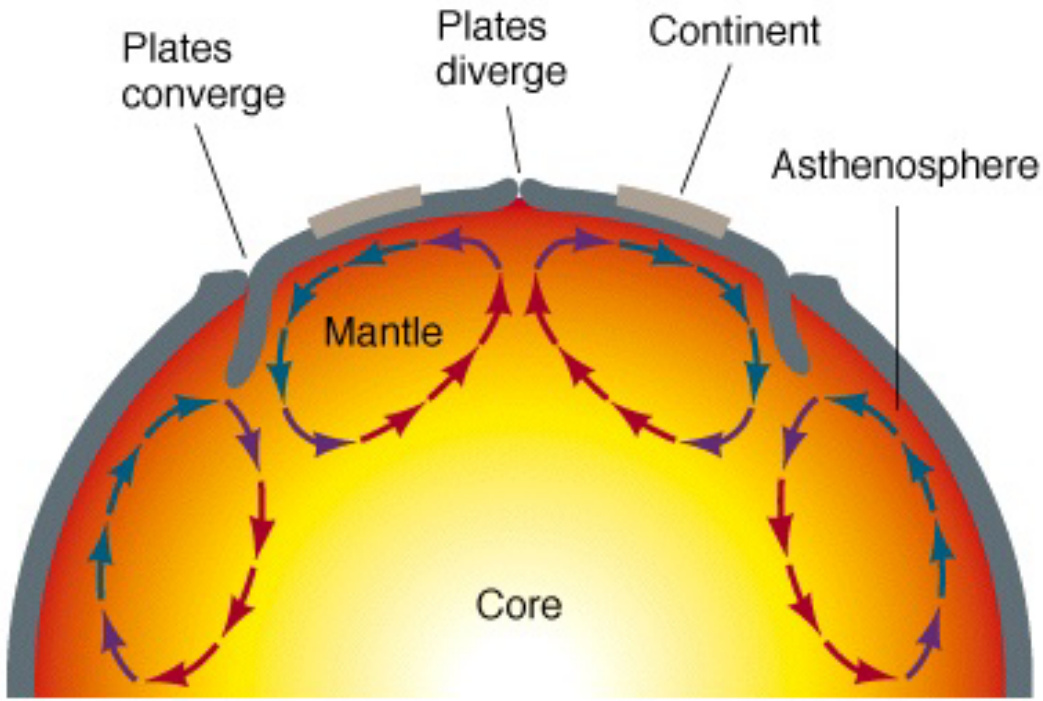
Convection in action

- Water on stove



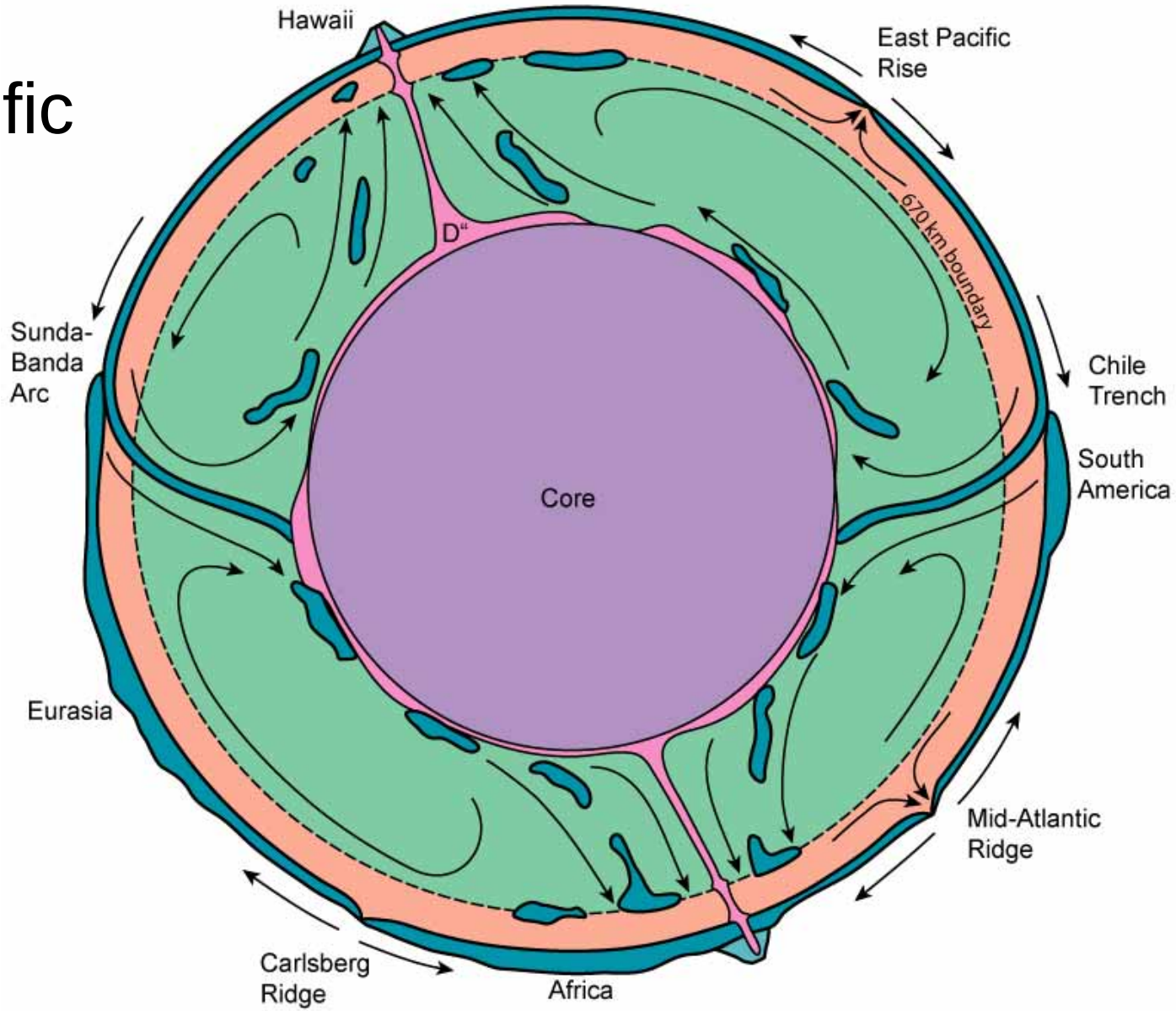
(a)

Tectonic plates on mantle



(b)

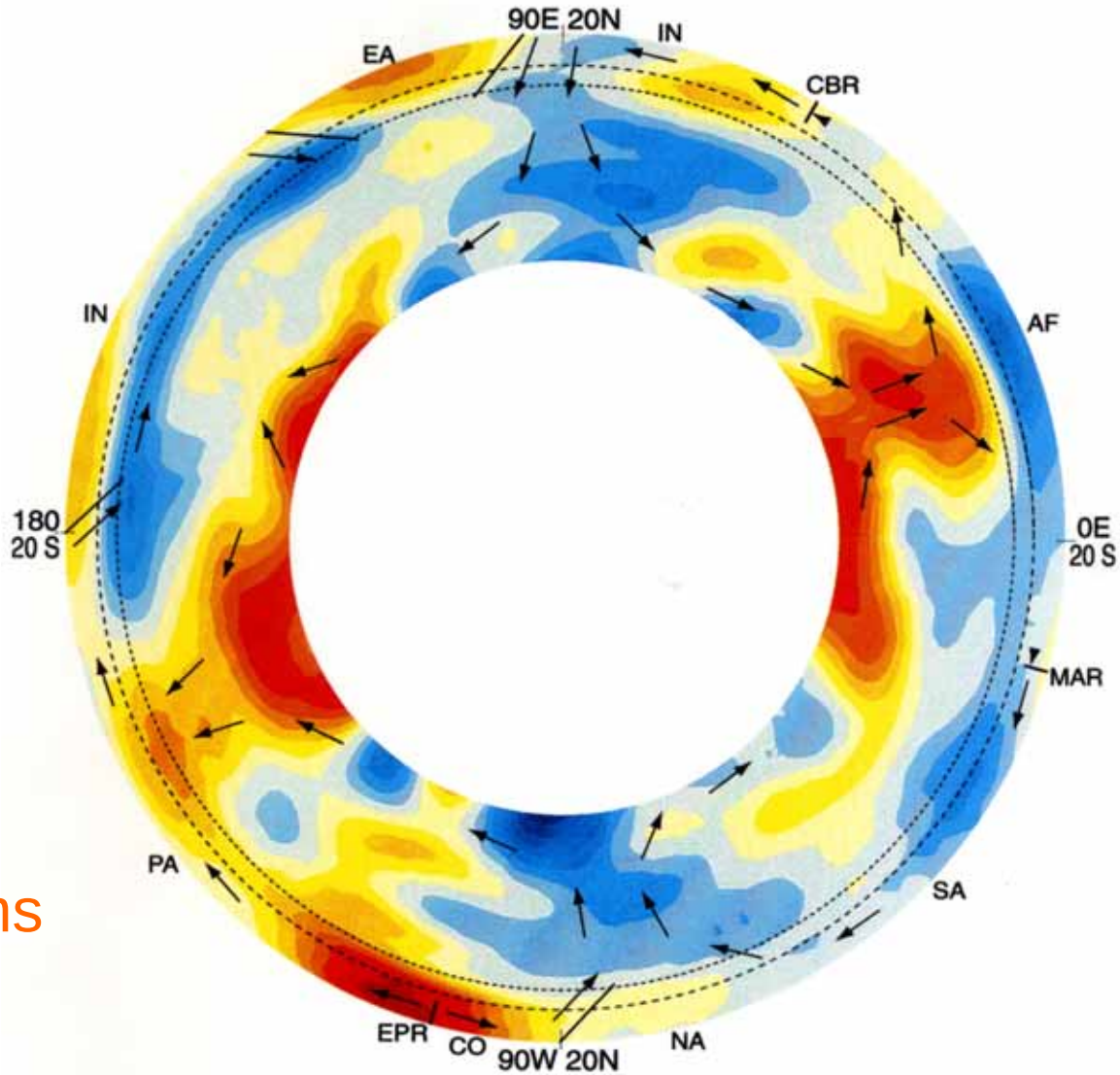
More Specific Convection Diagram



Mechanisms for transfer of heat

1. **Conduction: transfer of kinetic (vibrational) energy**
2. **Convection: movement of material**
3. **Advection: passive transfer of heat with rocks that are already in motion**
4. **Radiation: transfer energy with light- need to be translucent or transparent!**

Melting in the Earth



What are mechanisms for melt generation?

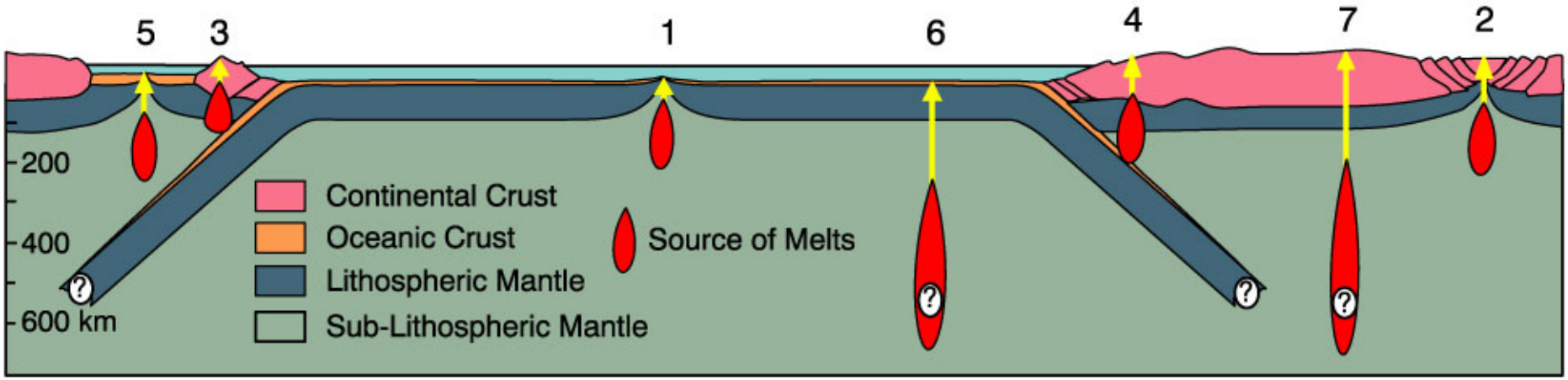
Cross-section of the mantle based on a seismic tomography model. Arrows represent plate motions and large-scale mantle flow and subduction zones represented by dipping line segments. EPR =- East pacific Rise, MAR = Mid-Atlantic Ridge, CBR = Carlsberg Ridge. Plates: EA = Eurasian, IN = Indian, PA = Pacific, NA = North American, SA = South American, AF = African, CO = Cocos. From Li and Romanowicz (1996). J. Geophys. Research, 101, 22,245-72.

Ways to instigate melting (phase change)

1. **Heat something up (melt butter on stove)**
2. **Add something to lower the melting temperature (add salt to ice)**
3. **Decompress (shaving cream, liquid nitrogen)**

Match these processes to where they occur in the Earth

Plate Tectonic - Igneous Genesis



1. Mid-ocean Ridges
2. Intracontinental Rifts
3. Island Arcs
4. Active Continental Margins
5. Back-arc Basins
6. Ocean Island Basalts
7. Miscellaneous Intra-Continental Activity
   - kimberlites, carbonatites, anorthosites...

Summary of important points

- Pressure gradient and conversion between pressure and depth
- Thermal gradient and heat sources in Earth
- Generation of melts in tectonic settings