Earth and Planetary Sciences (ES1101)

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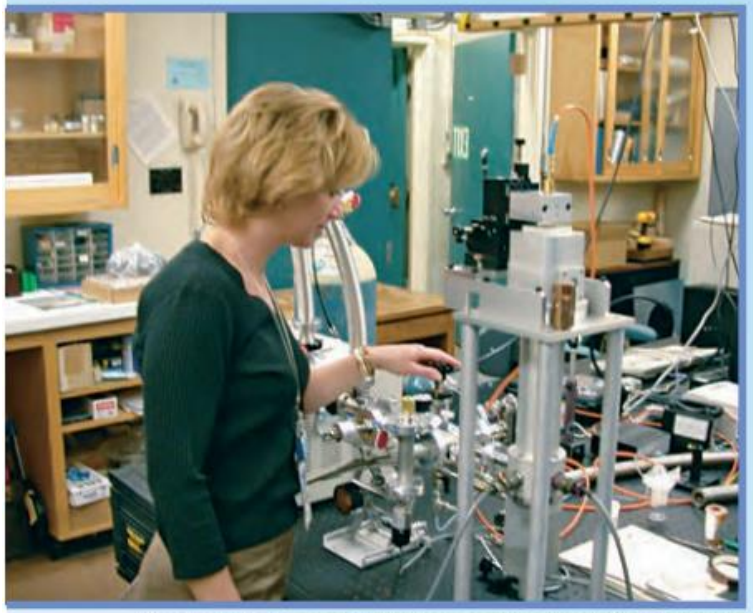
Interior of the Earth

Recreating the Deep Earth

Seismology alone cannot determine the nature of the materials deep in Earth's interior. Additional information must be obtained by other techniques. Mineral physics experiments can measure physical properties of rocks and minerals such as stiffness, compressibility, and density while simulating the extreme conditions of the mantle and core.

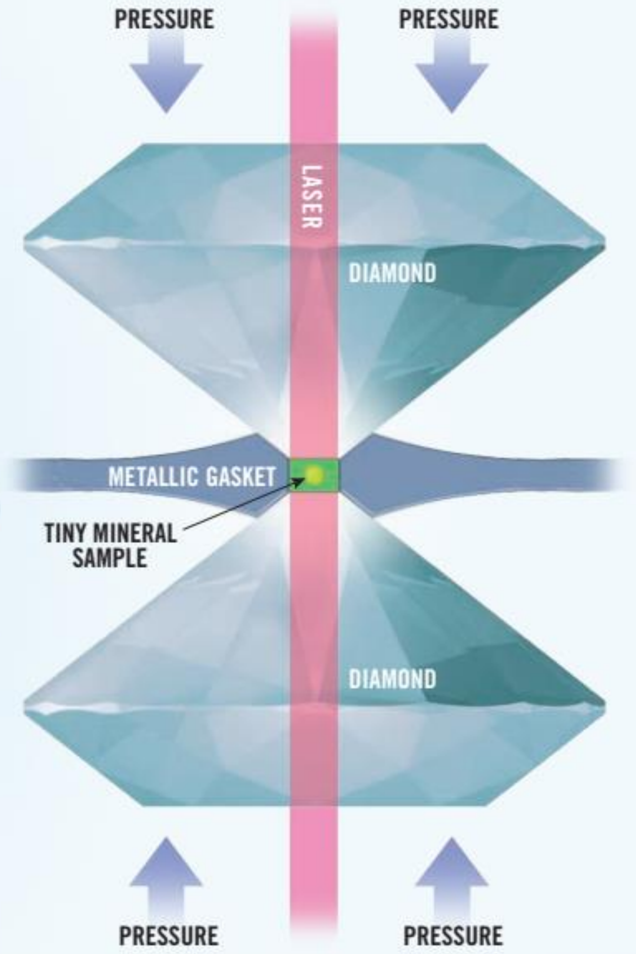


C.Arache, D. Jackson and S.T. Weir/Lawrence Livermore National Laboratory

One experiment examines the temperatures and pressures at which one mineral phase will become unstable and convert into a new "high-pressure" phase. These experiments are useful because they help identify where phase changes take place within Earth.

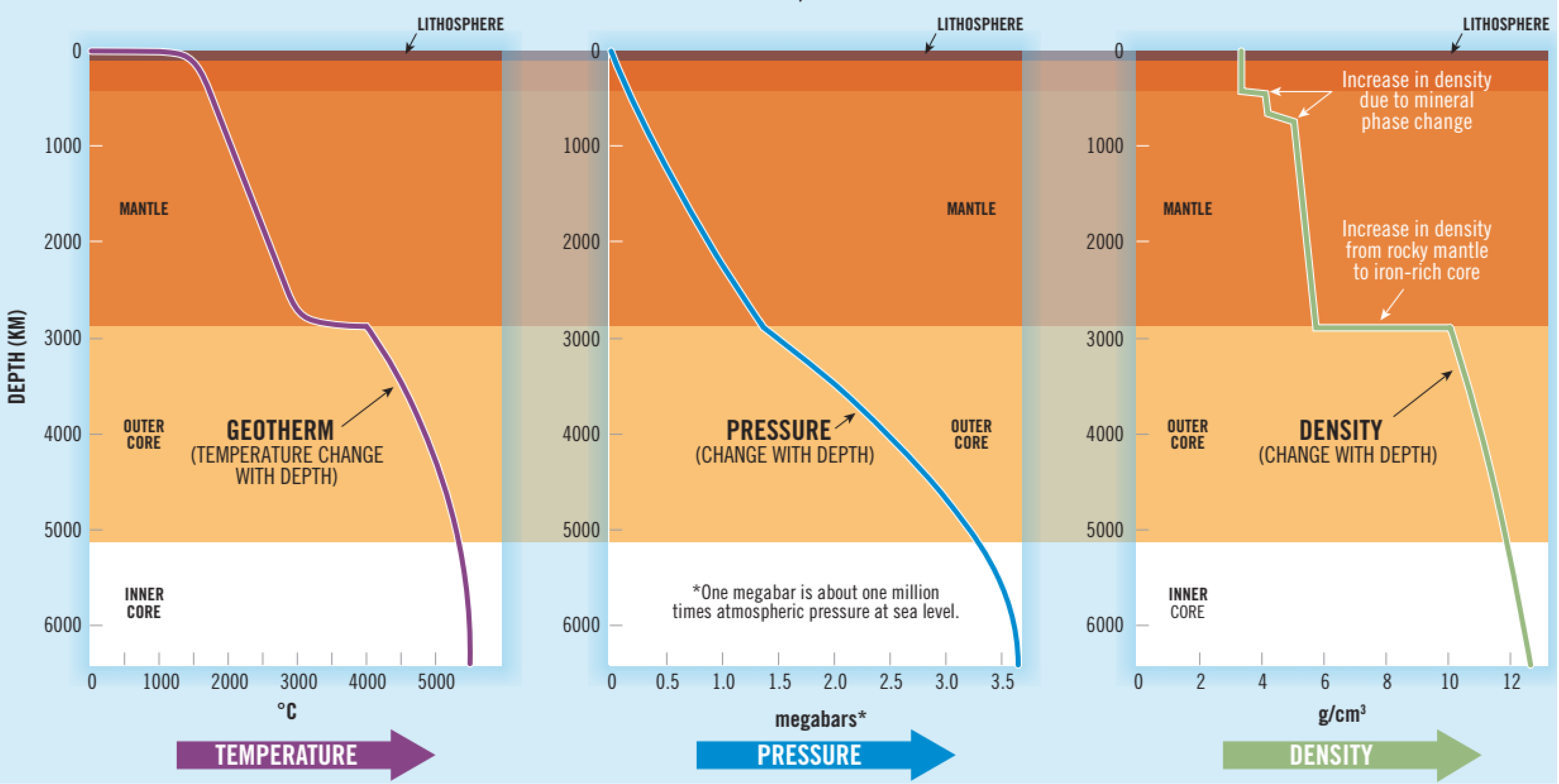
Most mineral physics experiments are conducted using diamond-anvil presses like the one shown here. These take advantage of two important properties of diamonds—hardness and transparency. The tips of two diamonds are cut off, and a small mineral sample is placed between them. By squeezing two diamonds together, pressures as high as our planet's interior have been simulated. High temperatures are achieved by firing a laser beam through the diamond and into the mineral sample.

Douglas L. Peck Photography



Question:
What two properties of diamonds make them ideal for use in a diamond-anvil press?

These experiments have also helped identify where changes in temperature, pressure, and density occur in Earth's interior, as shown in the graphs below.



Heat Sources in the Earth

- **Heat from the early accretion and differentiation of Earth:**
  - **Kinetic energy released by impacts with the planetesimals heated its outer regions.**
  - **Gravitational energy released by differentiation of the core heated its deep interior.**

- **Heat released by the radioactive decay of unstable nuclei.**

Heat transfer

- **Radiation**
- **Conduction**
- **Convection**

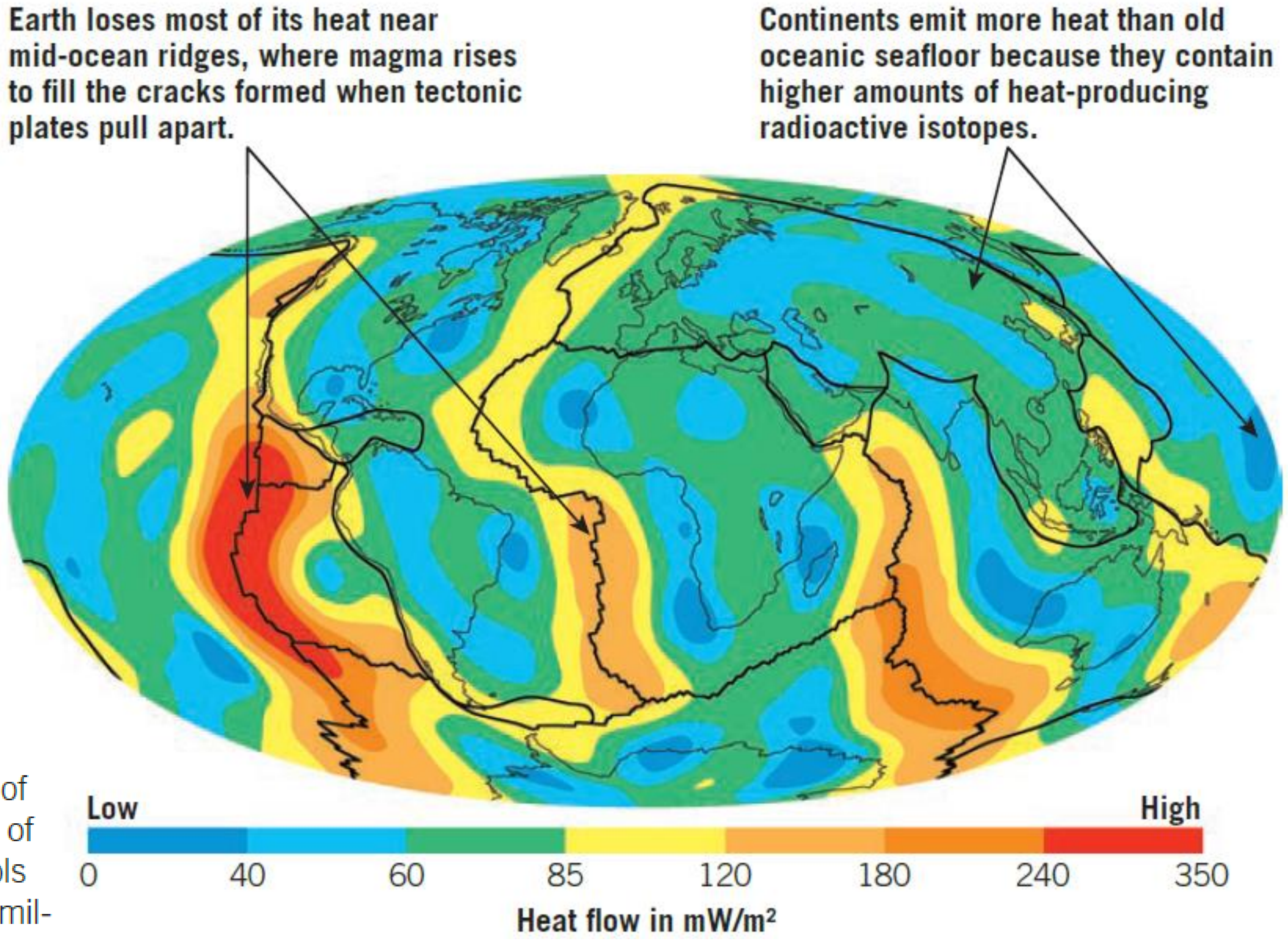


Figure 12.12

Rate of heat flow at Earth's surface A map of the rate of heat flow out of Earth as it gradually cools over time, measured in milliwatts per square meter.

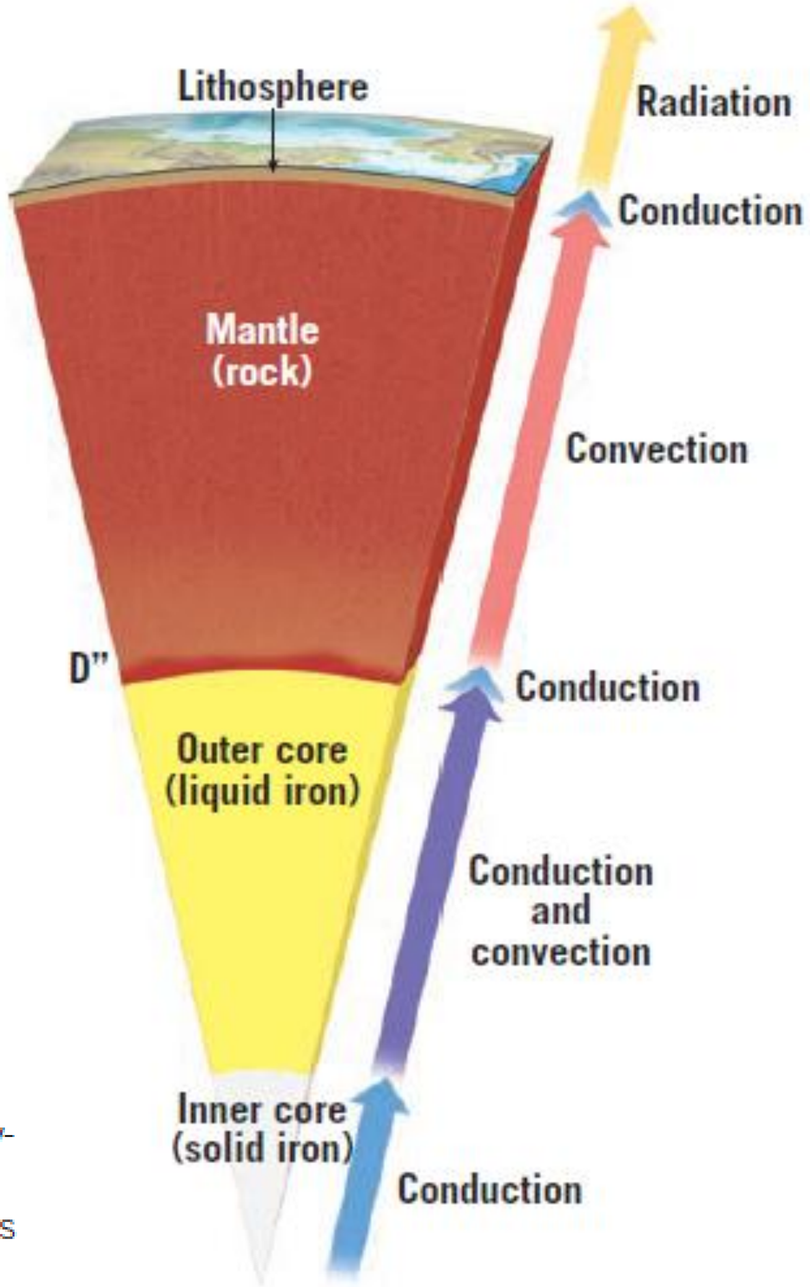


Figure 12.14

Dominant types of heat transfer at various depths Heat travels from Earth's interior to the surface through the processes of convection and conduction. However, Earth ultimately loses its heat to space through radiation.

Geothermal Gradient

- **Heat is transported in the lithosphere by conduction mainly.**

- **Measurement of heat flow shows that continental areas have lower heat flows than ocean basins.**

- **Consequently, the continental geotherm is located at relatively lower temperature side of the oceanic geotherm in the lithosphere.**

- **From the asthenosphere downwards in the mantle, heat transport is by convection, which should theoretically homogenize the temperature distribution, and the two geotherms should merge.**

- **There are various estimates of geothermal gradients in the lithosphere, but The continental geotherm is always at lower temperatures than the oceanic geotherm.**

Geothermal Gradient

~15°C/km to 75 °C/km in lithosphere

~0.5°C/km in convective mantle

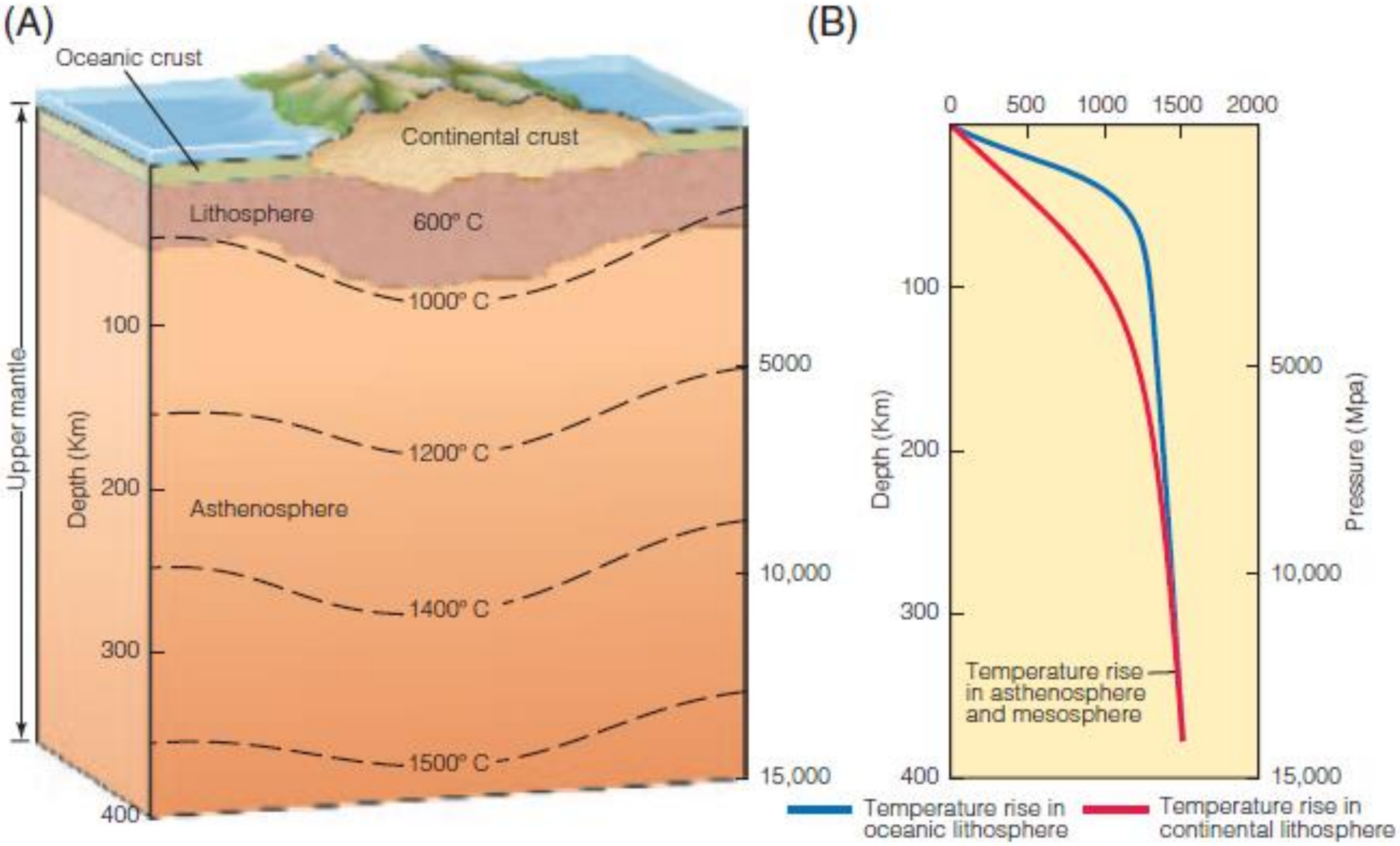


FIGURE 2.11 Geothermal gradient
Temperature increases with depth. (A). The dashed lines are *isotherms*, lines of equal temperature. Temperature increases more slowly under the continents than under the oceans. The lithosphere is thicker under the continents, so heat flows more slowly to the surface in those areas. (B). This is the same information as shown in (A) but in graph form. Earth's surface is at the top, so depth (and corresponding pressure) increases downward. Temperature increases from left to right.

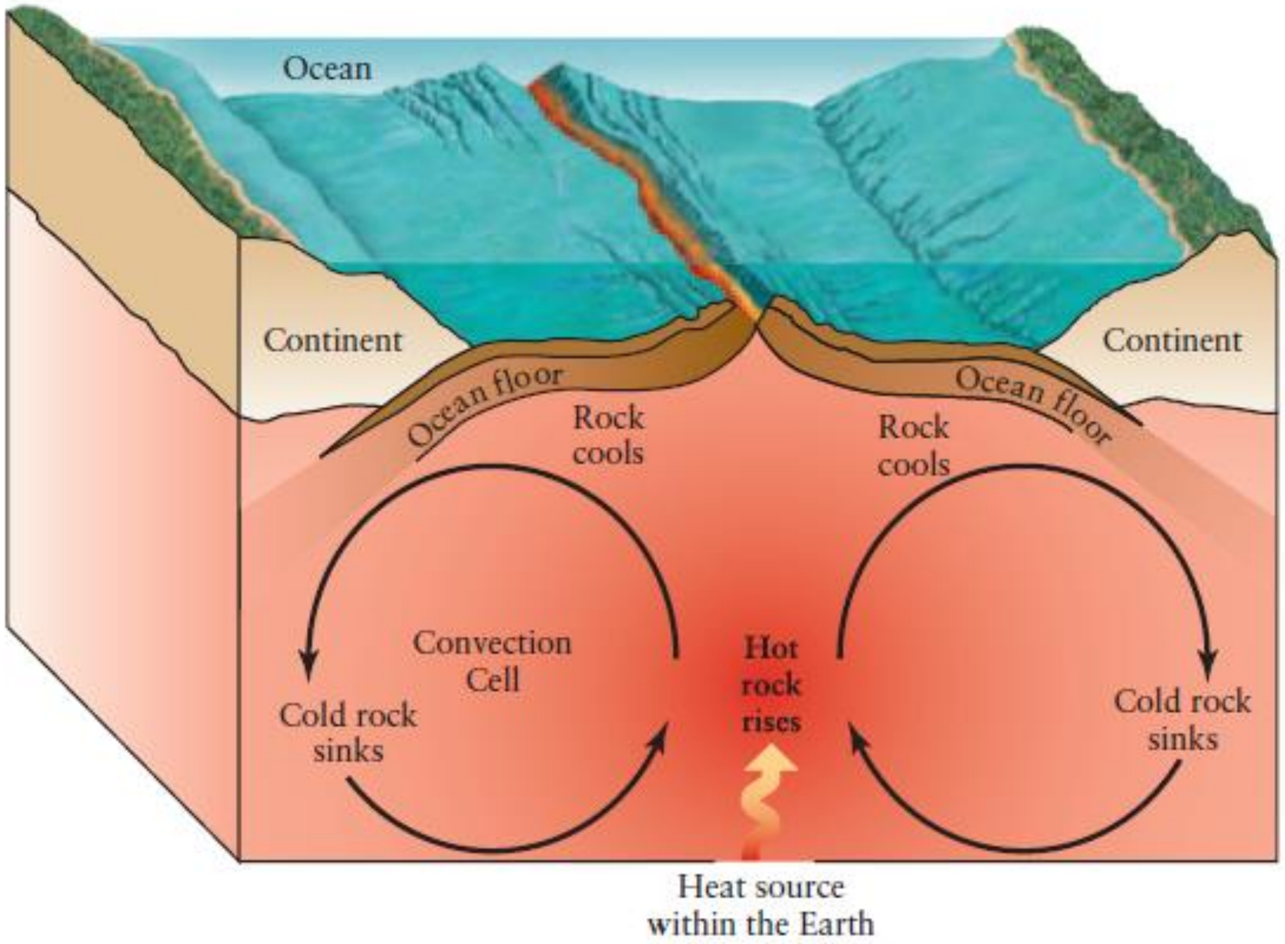
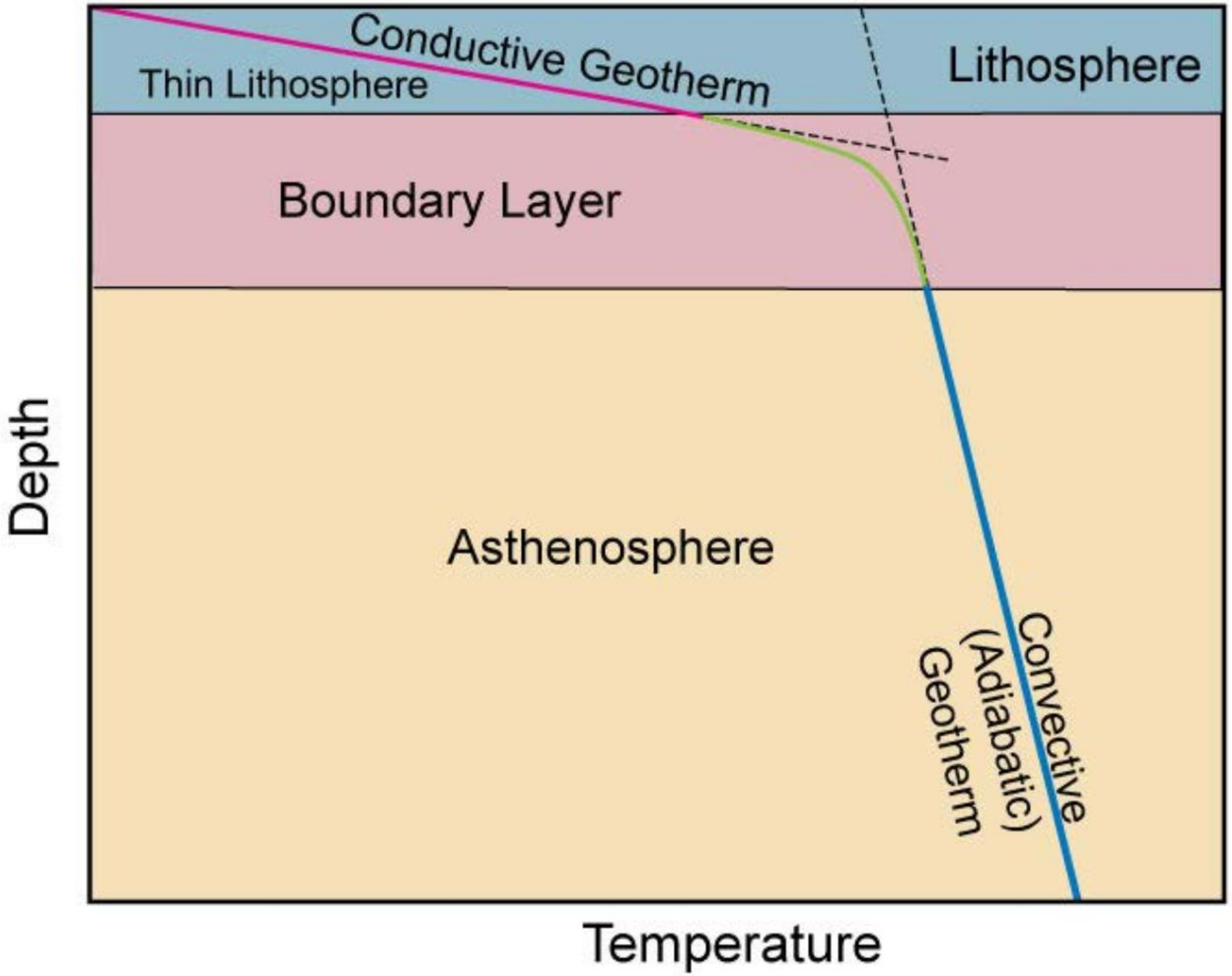


FIGURE 2.10 Convection in Earth's interior
Hot rock rises slowly from deep inside Earth, cools, flows sideways, and sinks. The rising hot rocks and sideways flow are the source of plate tectonic motion, and have an enormous influence on the shapes and distribution of land masses and ocean basins on Earth's surface.

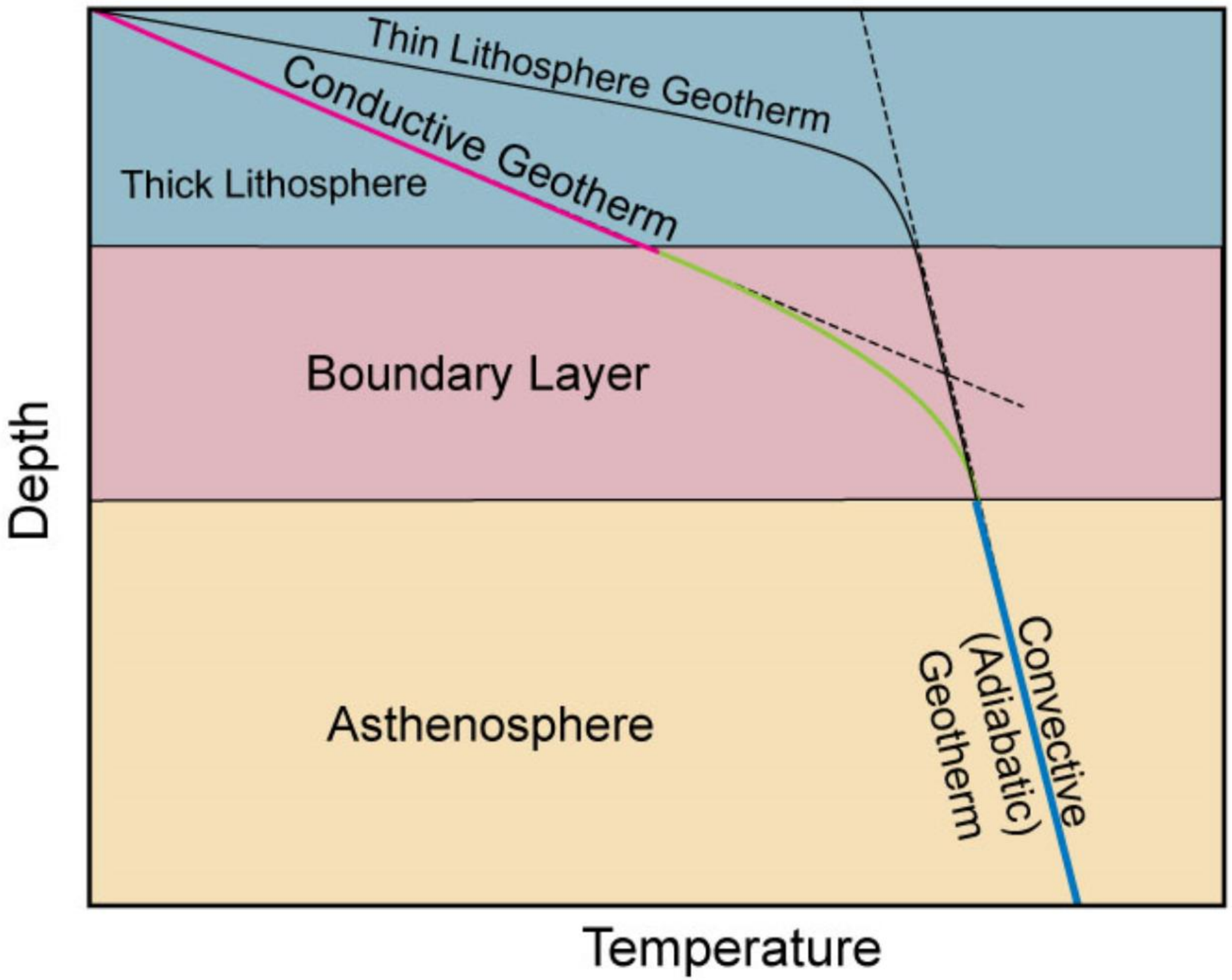
Geothermal Gradient

Figure 1.9 Diagrammatic cross-section through the upper 200-300 km of the Earth showing geothermal gradients reflecting more efficient adiabatic (constant heat content) convection of heat in the mobile asthenosphere (steeper gradient in blue)) and less efficient conductive heat transfer through the more rigid lithosphere (shallower gradient in red). The boundary layer is a zone across which the transition in rheology and heat transfer mechanism occurs (in green). The thickness of the boundary layer is exaggerated here for clarity: it is probably less than half the thickness of the lithosphere.



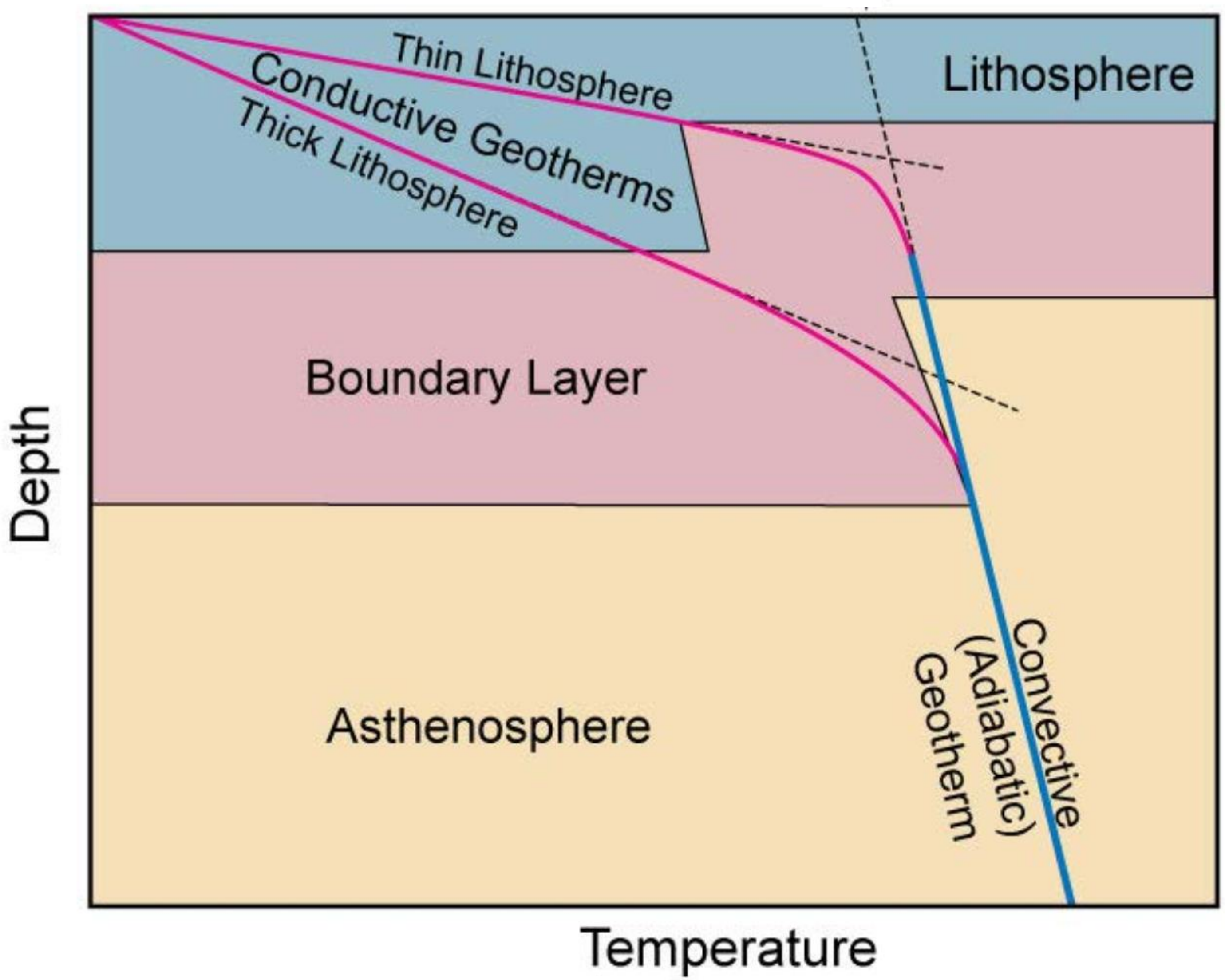
Geothermal Gradient

Figure 1.9 A similar example for **thick** (continental) lithosphere.



Geothermal Gradient

Figure 1.9 Notice that thinner lithosphere allows convective heat transfer to shallower depths, resulting in a **higher** geothermal gradient across the boundary layer and lithosphere.



Geothermal Gradient: an estimate

FIGURE 14.10 ■ An estimate of Earth's geotherm, which describes the increase in temperature with depth (yellow line). The geotherm first rises above the melting curve—the temperature at which peridotite begins to melt (red line)—in the upper mantle, forming the partially molten low-velocity zone. It does so again in the outer core, where the iron-nickel alloy is in a liquid state. The geotherm falls below the melting curve throughout most of the mantle and in the solid inner core.