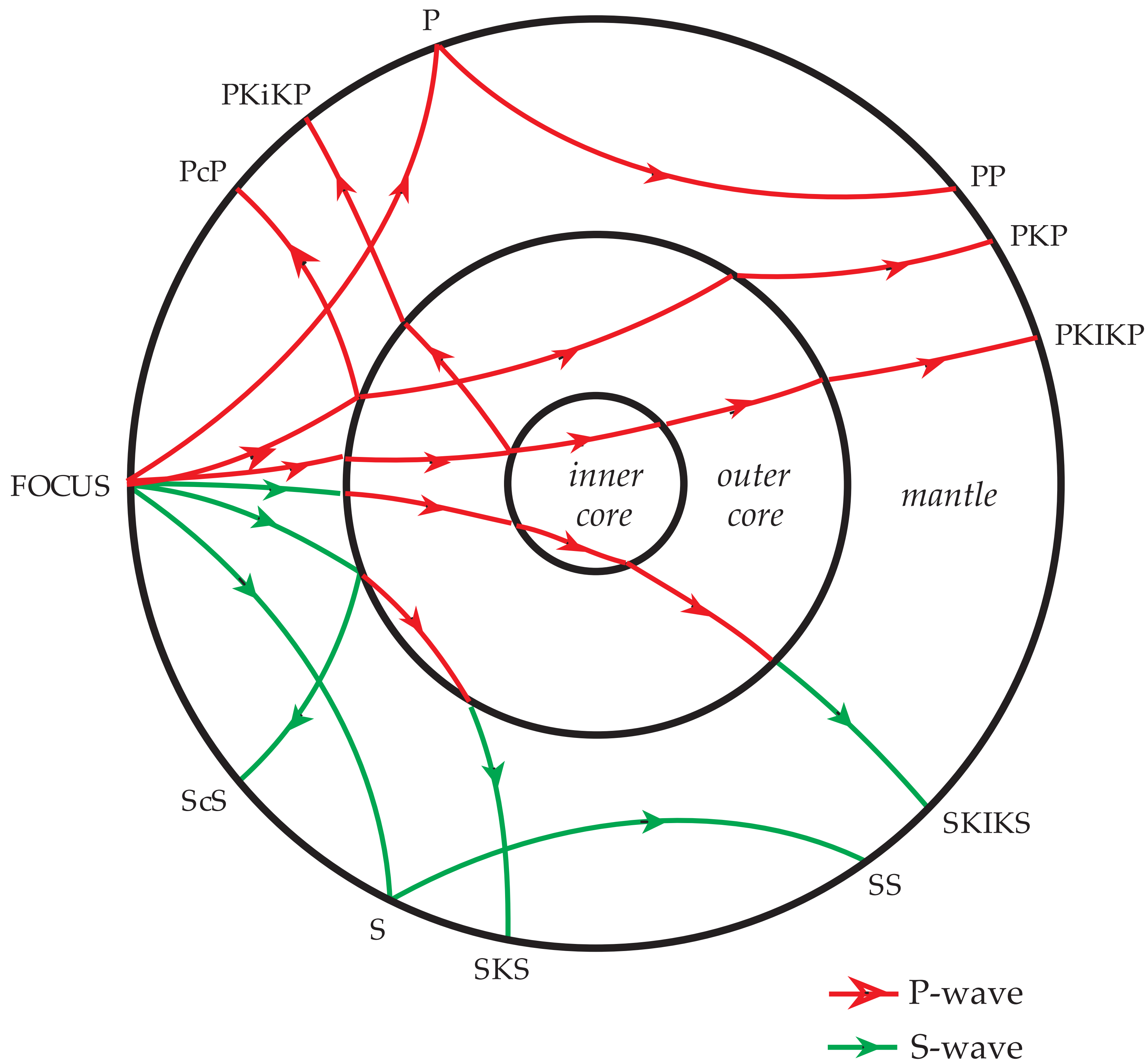
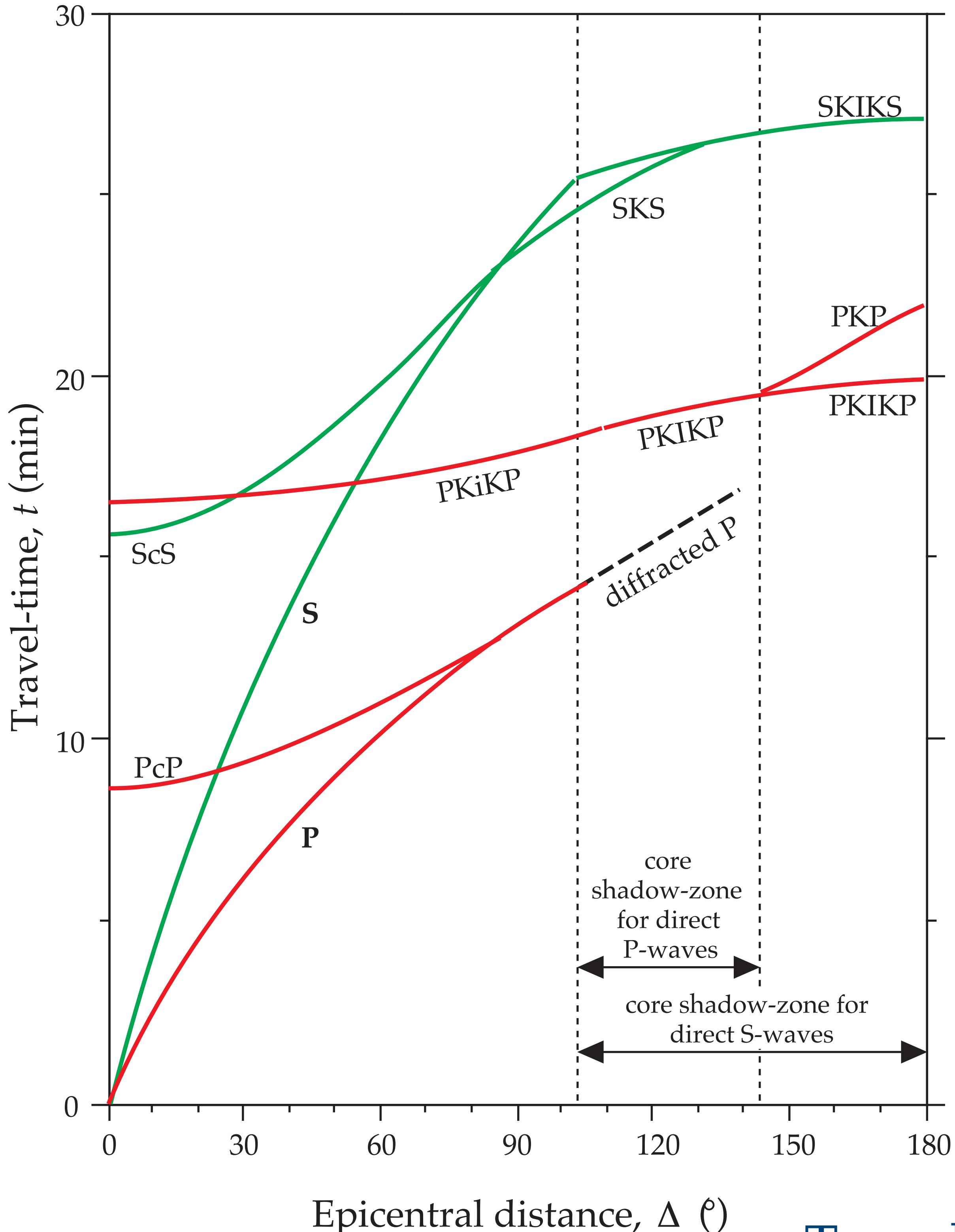
04- Das Erdinnere II

Examples of seismic waves

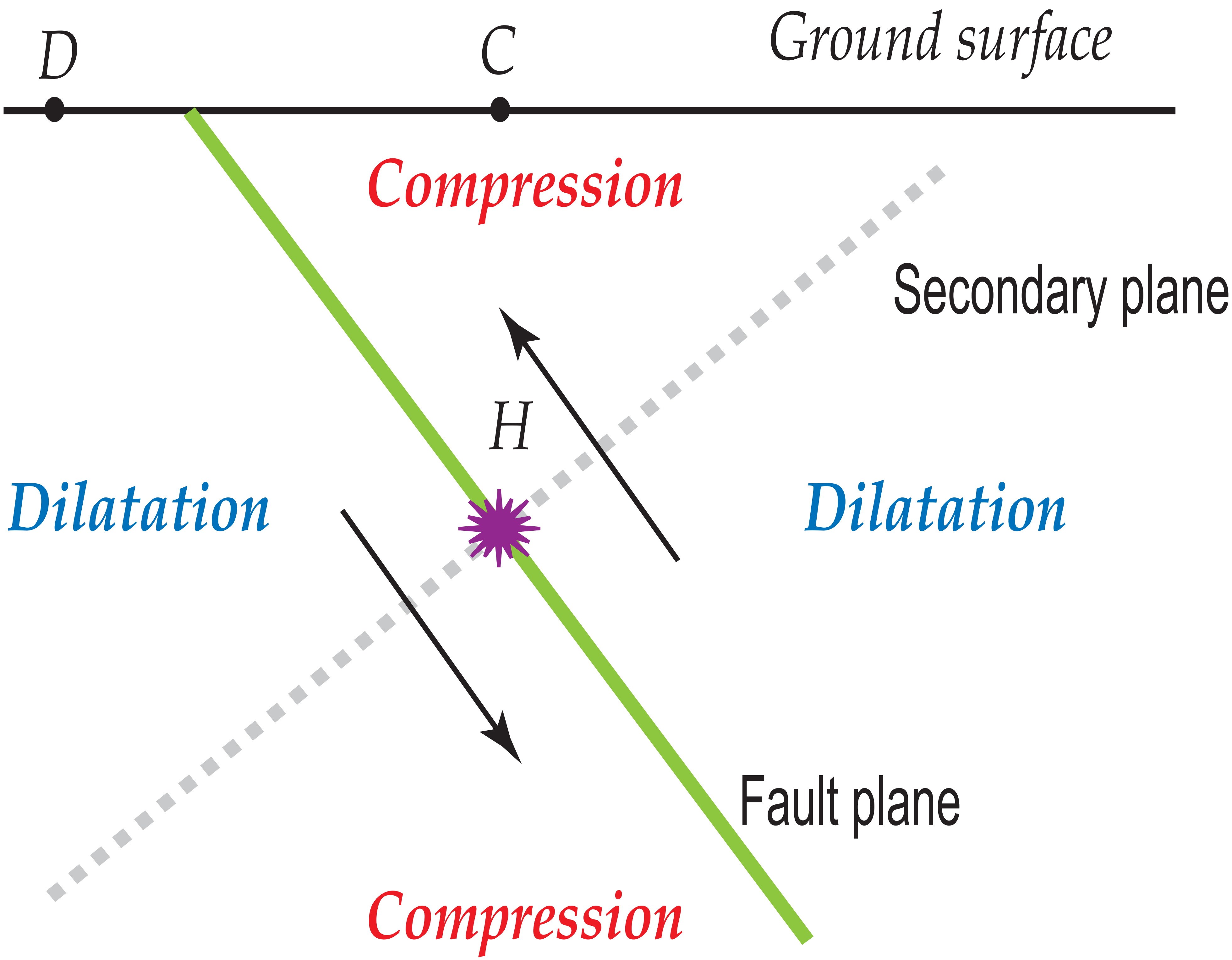


Seismic wave paths of some important refracted and reflected P-wave and S-wave phases from an earthquake with focus at the Earth's surface.

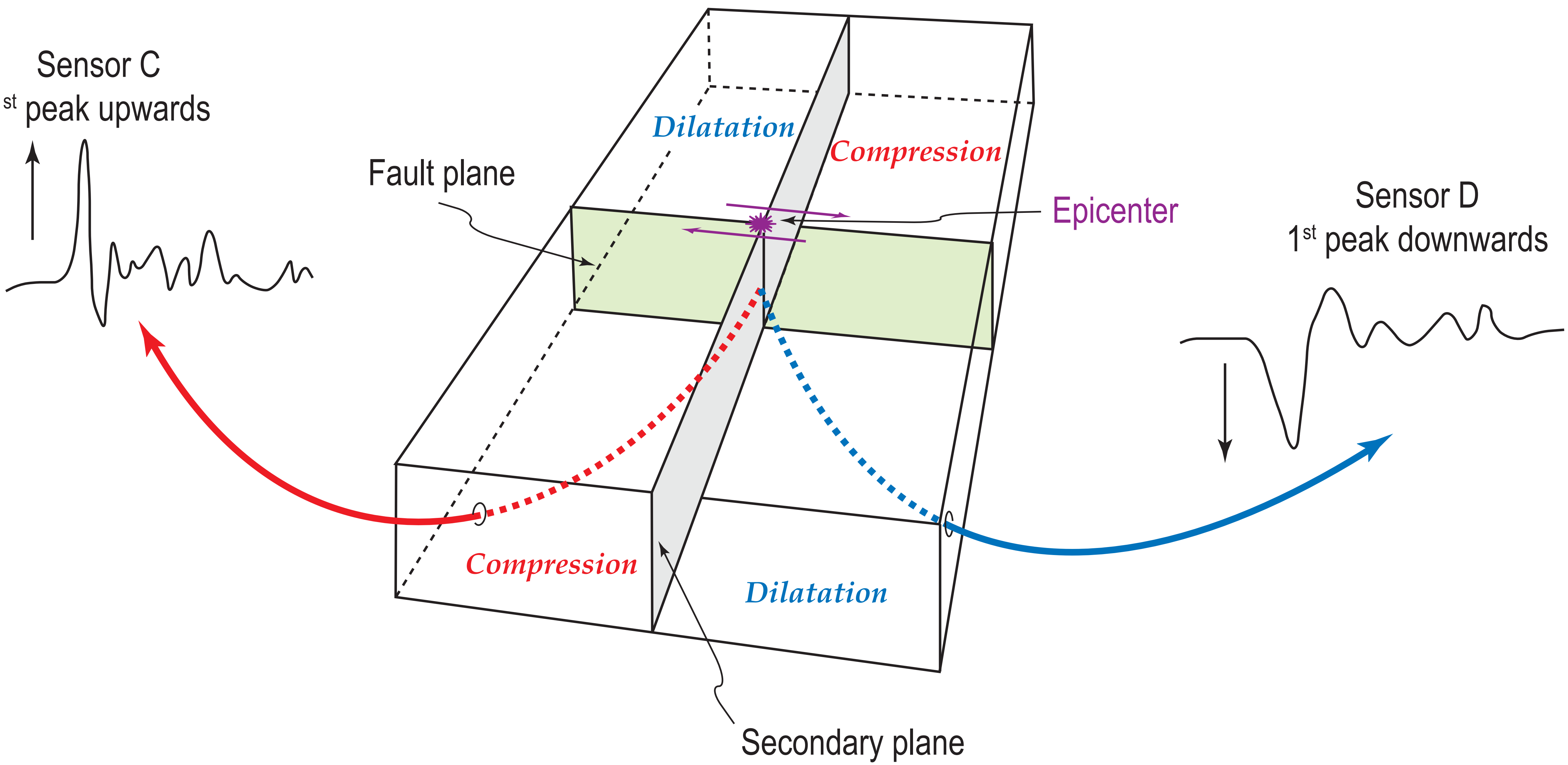


Travel-time versus epicentral distance (t–Δ) curves for some important seismic phases (modified from Jeffreys and Bullen, 1940)

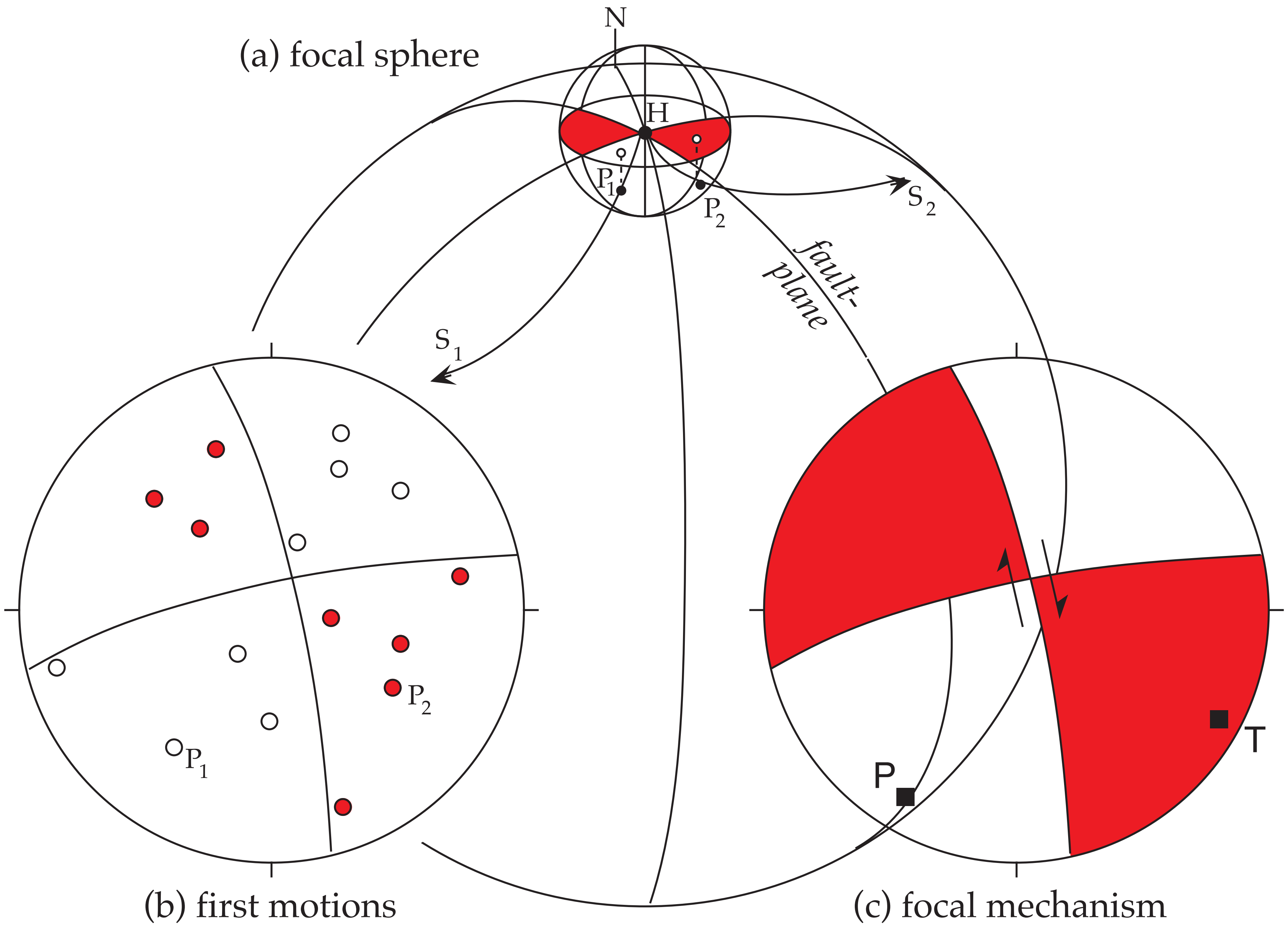
Fault plane solution



Fault plane solution

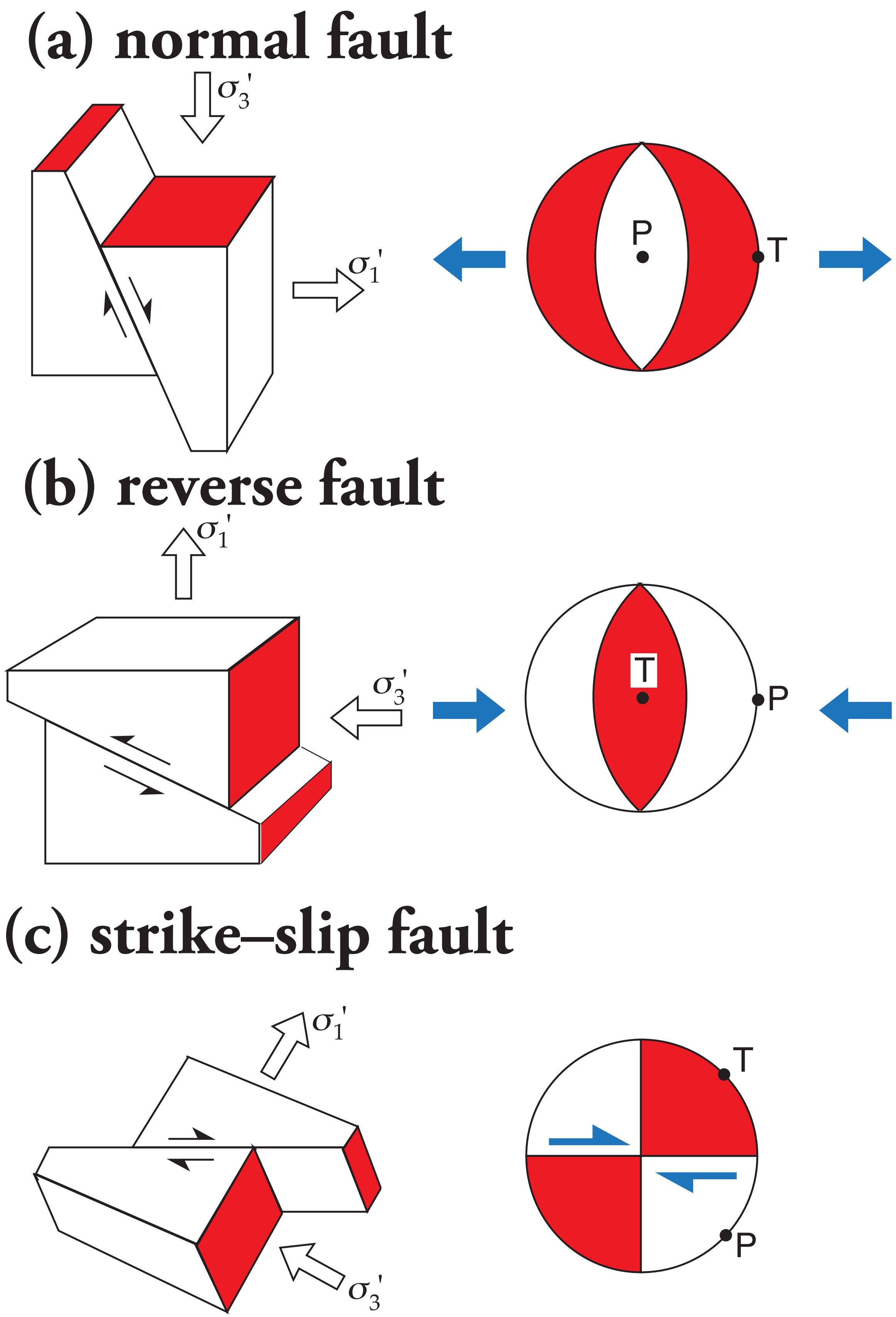


Fault plane solution



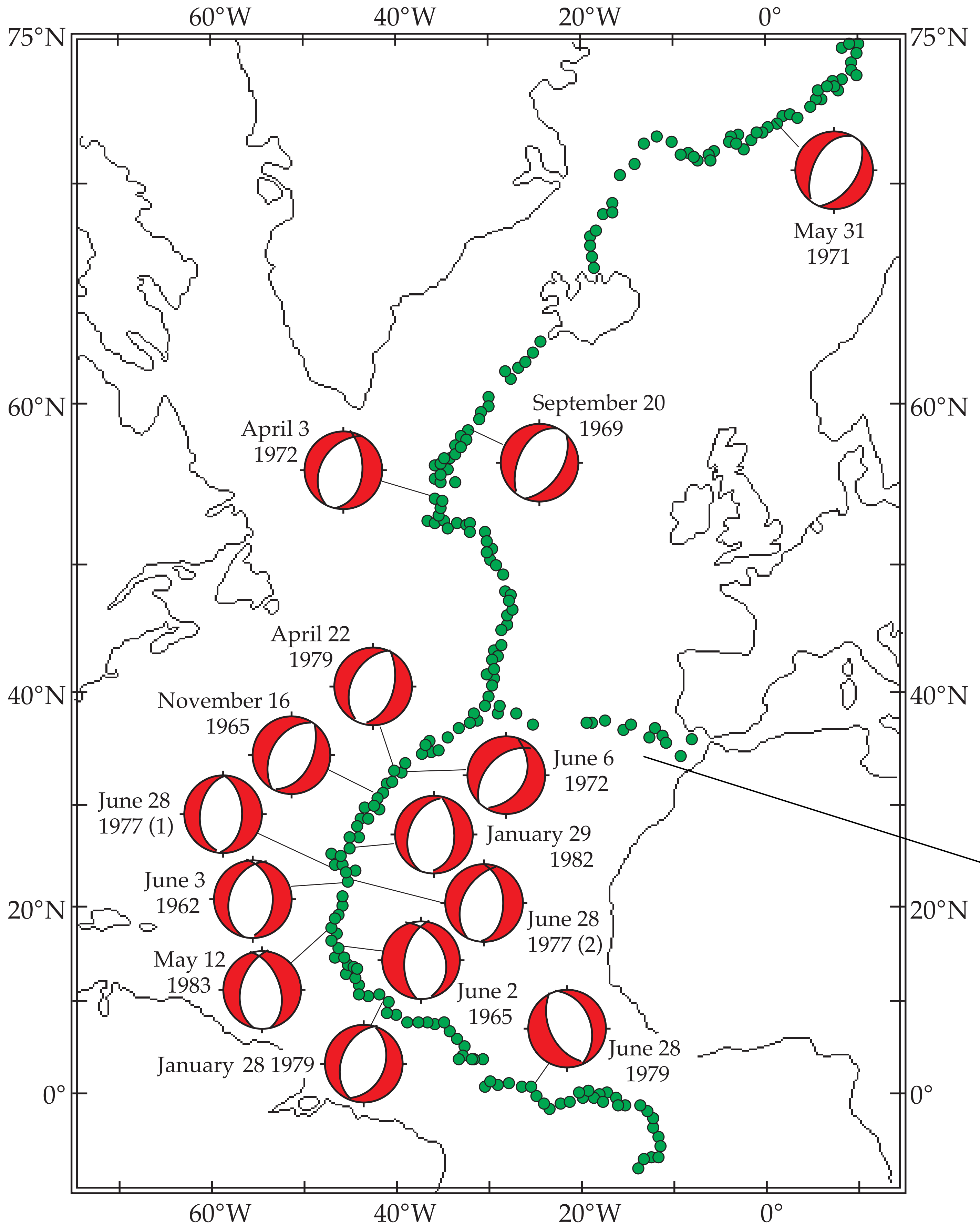
Method of determining the focal mechanism of an earthquake. (a) The focal sphere surrounding the earthquake focus, with two rays S1 and S2 that cut the sphere at P1 and P2, respectively. (b) The points P1 and P2 are plotted on a lower-hemisphere stereogram as first-motion pushes (solid points) or tugs (open points). (c) The best-fitting great circles define regions of compression (shaded) and tension (unshaded). The P- and T-axes are located on the bisectors of the angles between the fault-plane and auxiliary plane.

Fault plane solution



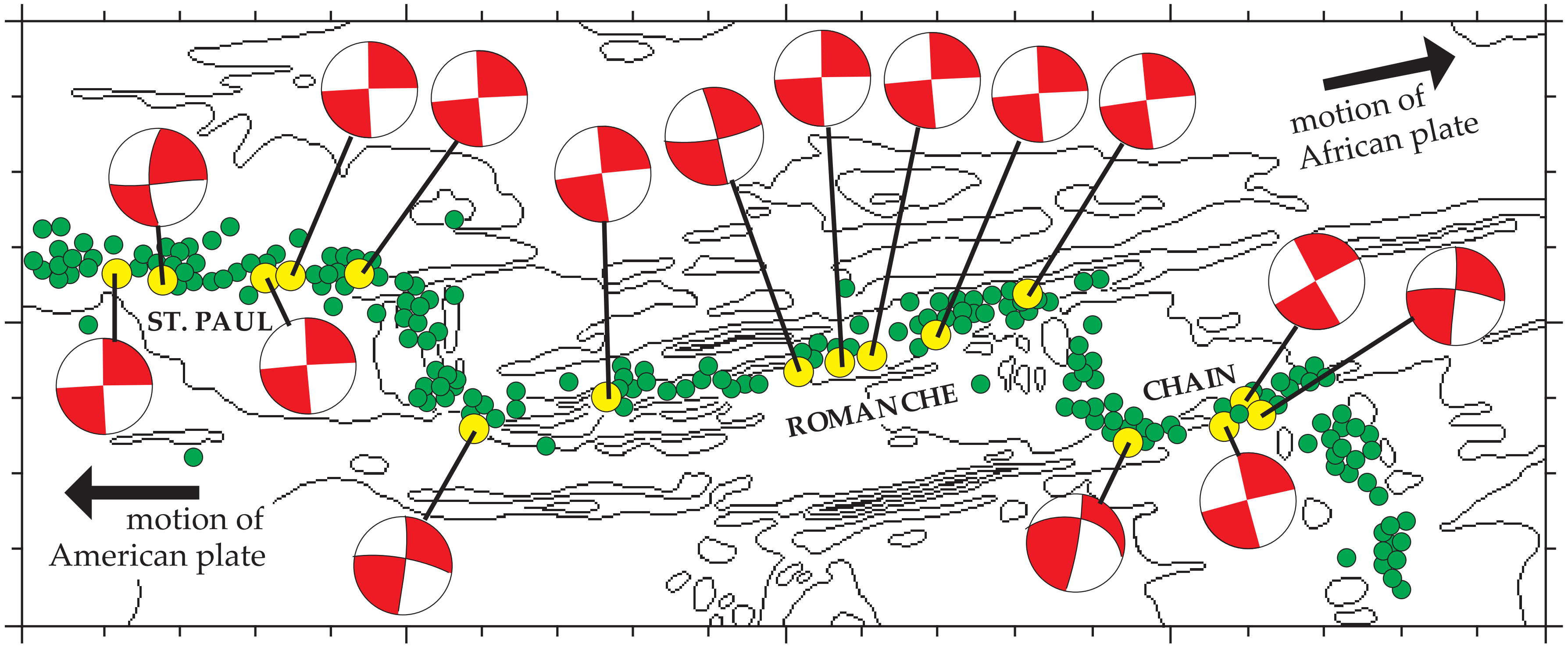
The different types of fault plane solution

Example of Fault plane solution: Atlantic ridge



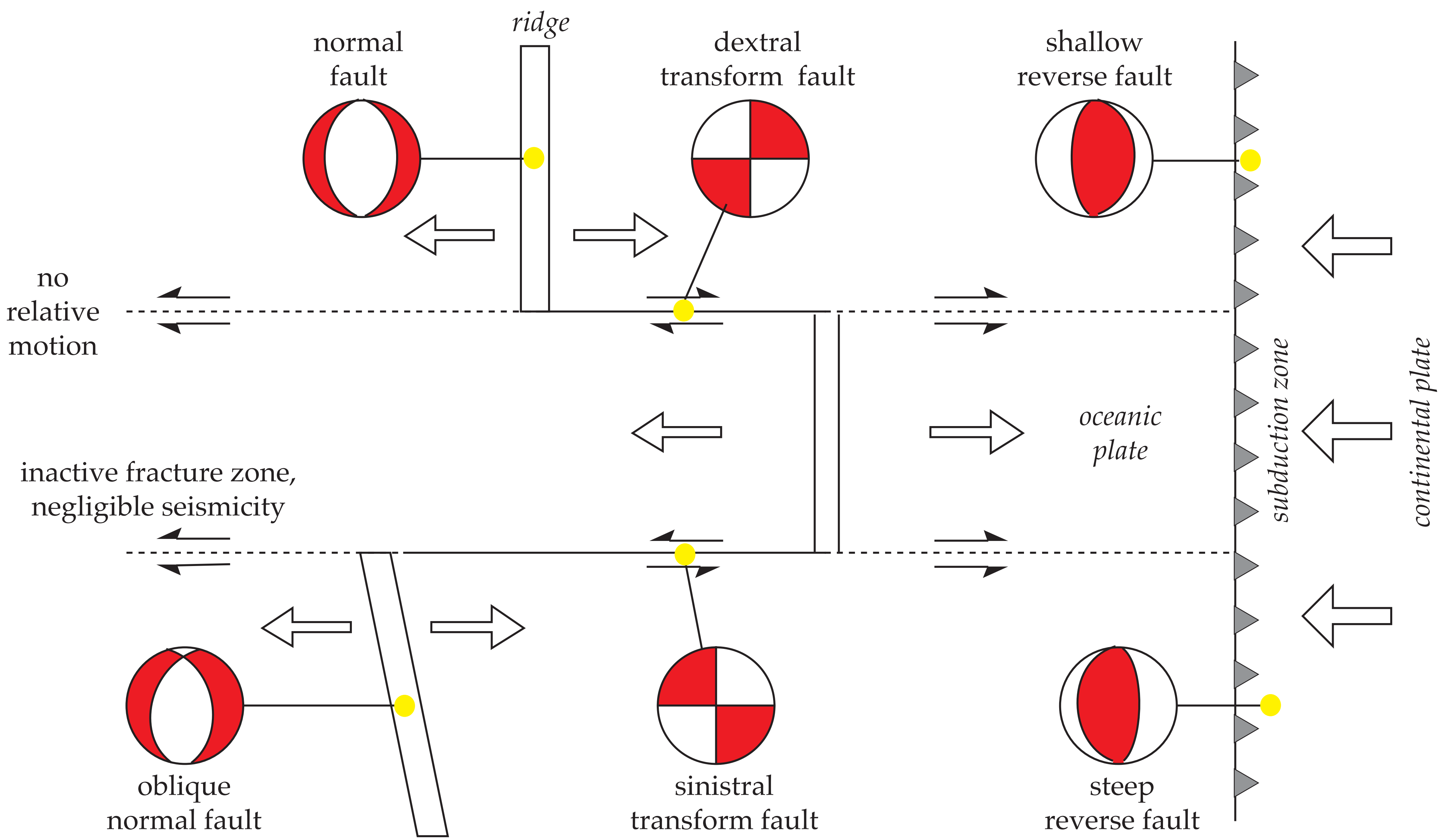
Fault-plane solutions for earthquakes along the Mid-Atlantic Ridge, showing the prevalence of extensional tectonics with normal faulting in the axial zone of the spreading center (based on data from Huang et al., 1986).

Example of Fault plane solution: Romanche fault



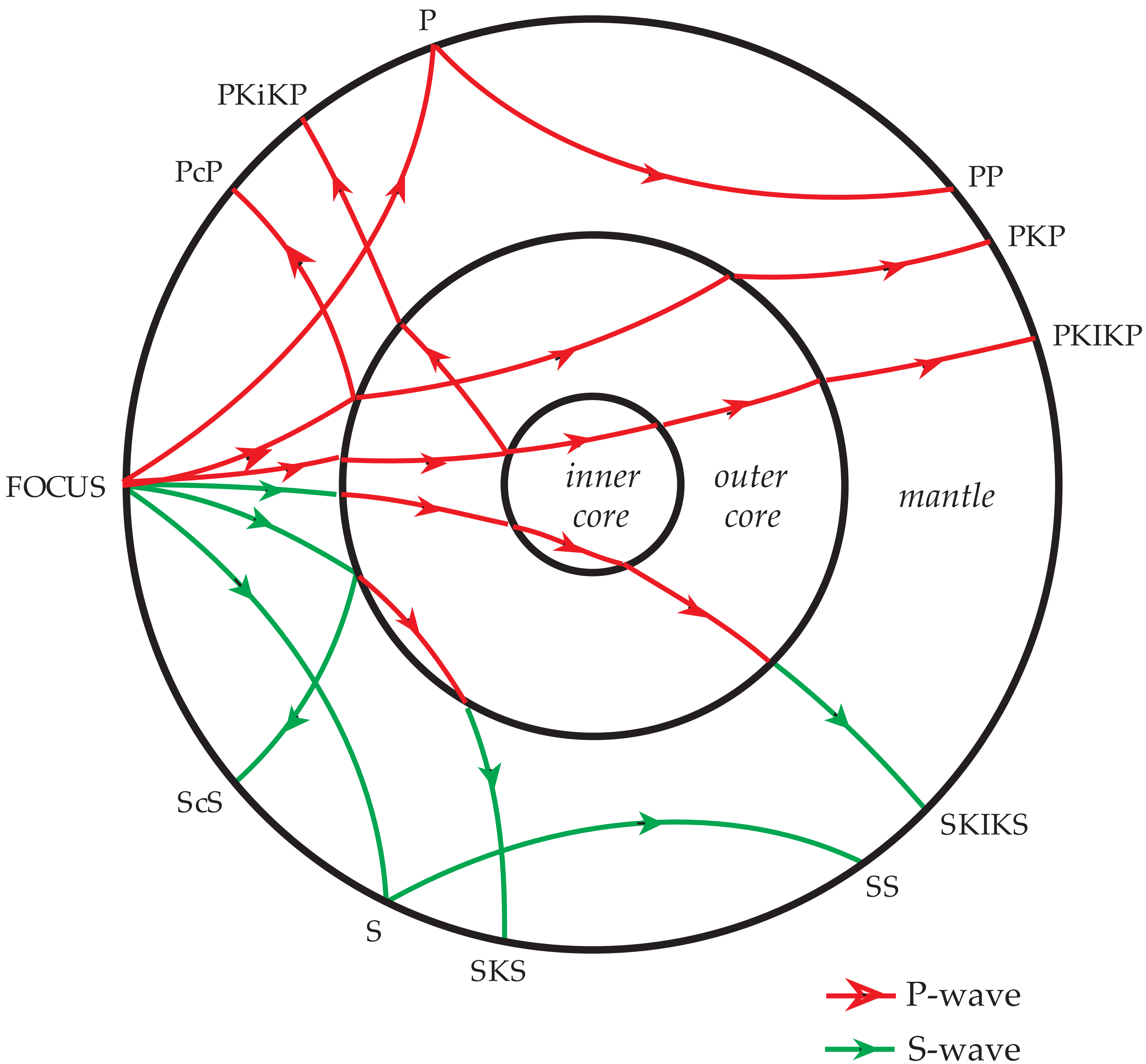
Fault-plane solutions for earthquakes on the St. Paul, Romanche and Chain transform faults in the Central Atlantic ocean (after Engeln et al., 1986). Most focal mechanisms show right lateral (dextral) motions on these faults, corresponding to the relative motion between the African and American plates.

Example of Fault plane solution



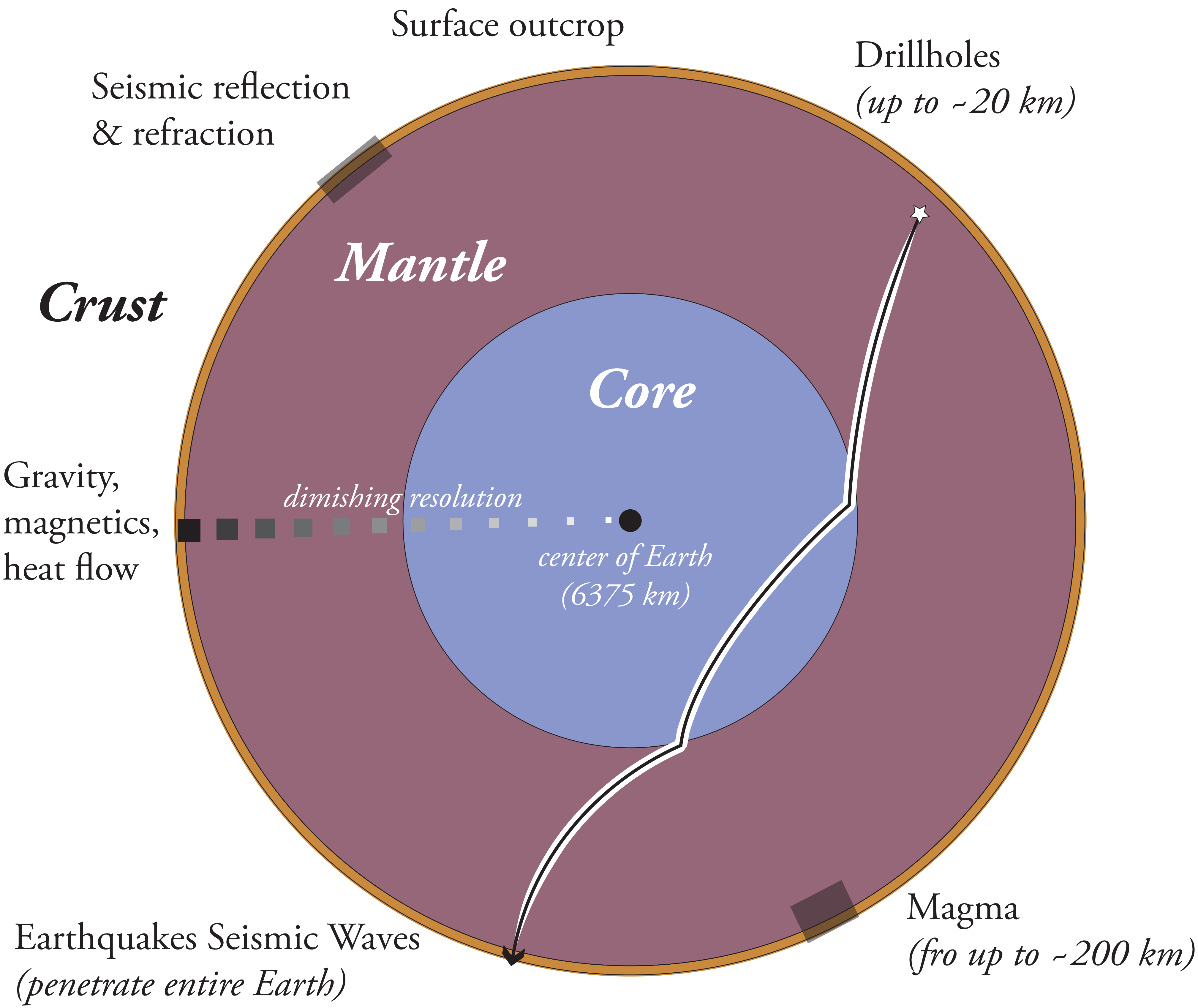
Fault-plane solutions for hypothetical earthquakes at an ocean ridge and transform fault system. Note that the sense of movement on the fault is not given by the apparent offset of the ridge. The focal mechanisms of earthquakes on the transform fault reflect the relative motion between the plates. Note that in this and similar figures the sector with compressional first motions is shaded.

Examples of seismic waves

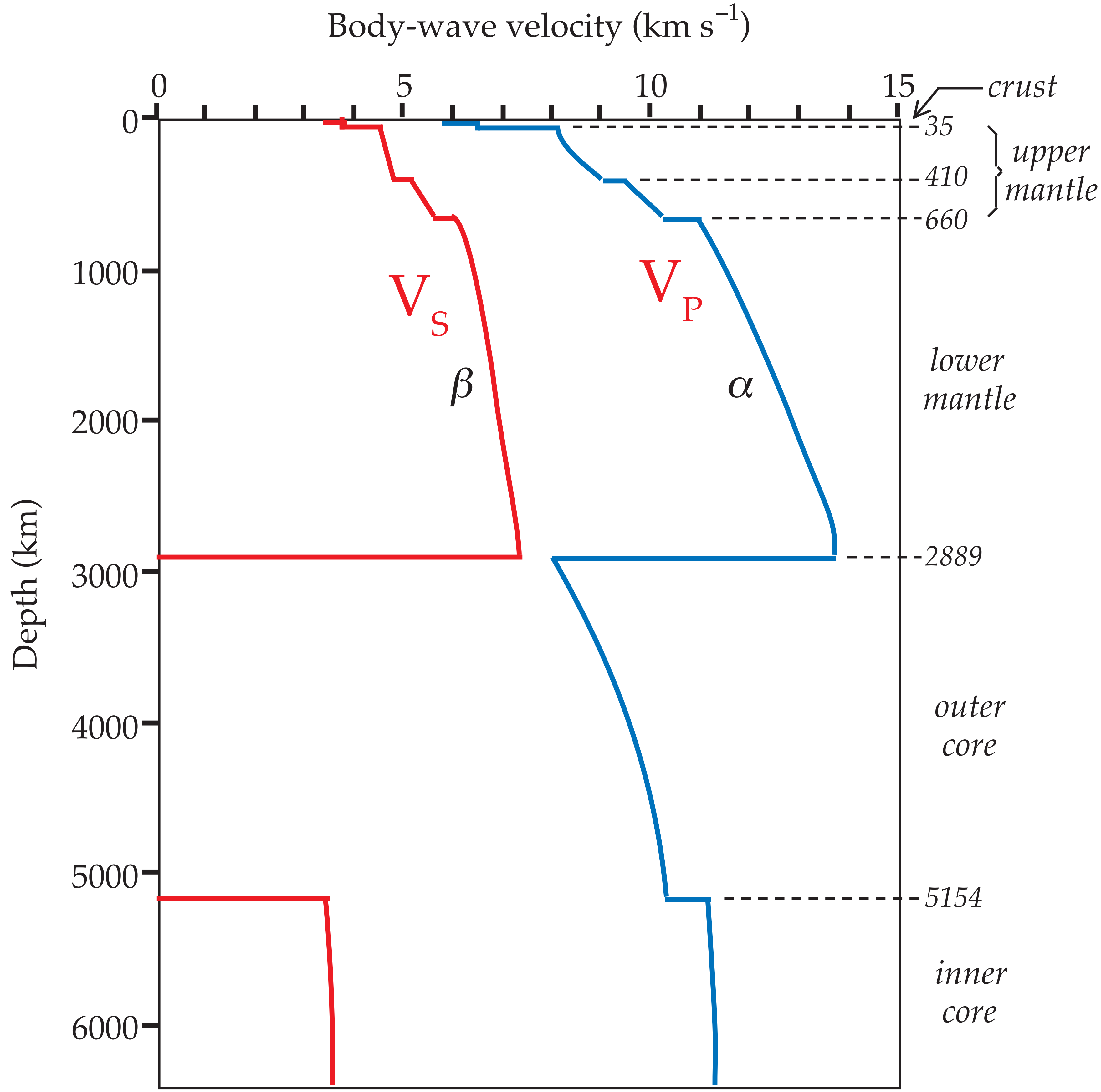


Seismic wave paths of some important refracted and reflected P-wave and S-wave phases from an earthquake with focus at the Earth's surface.

Simple model of the earth

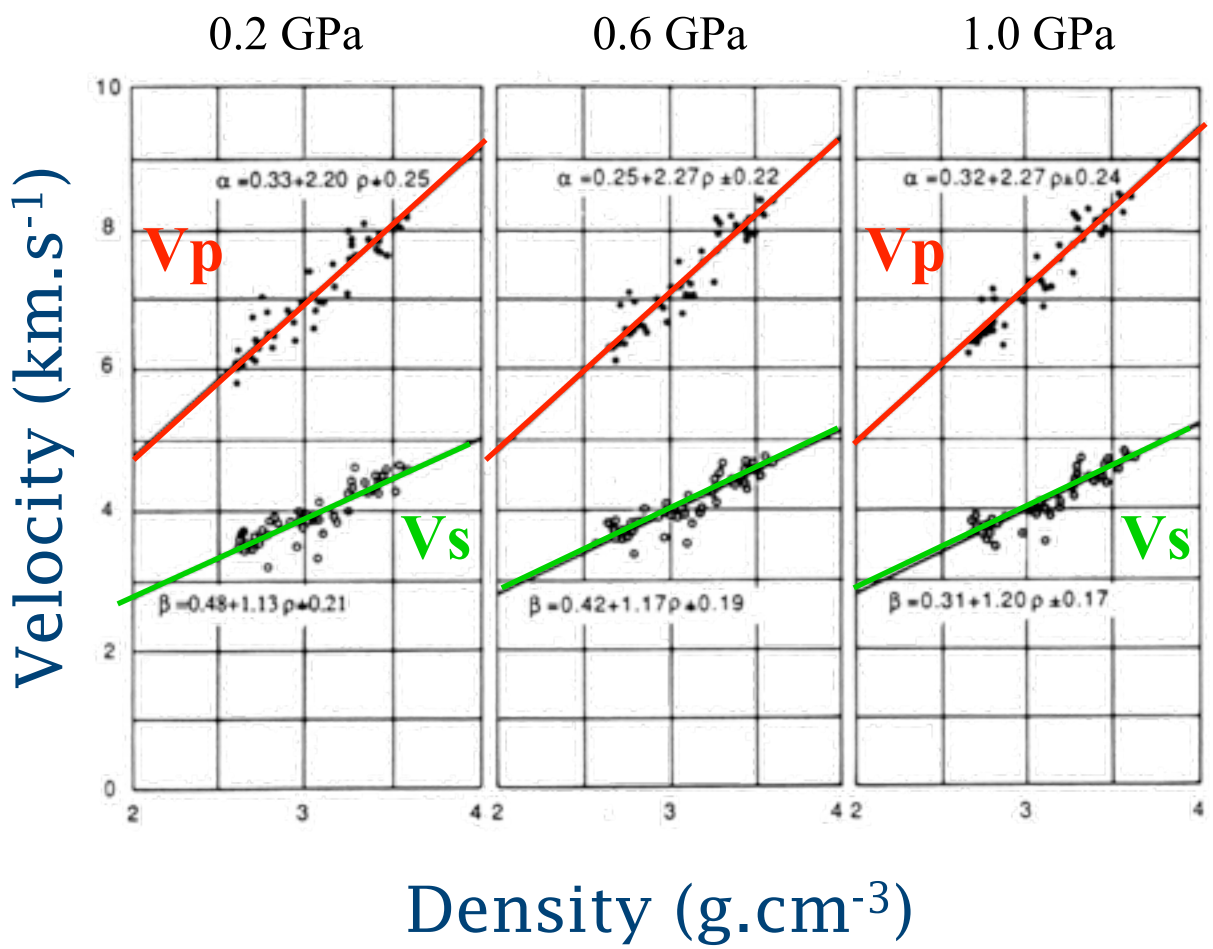


Seismic velocities model for the Earth

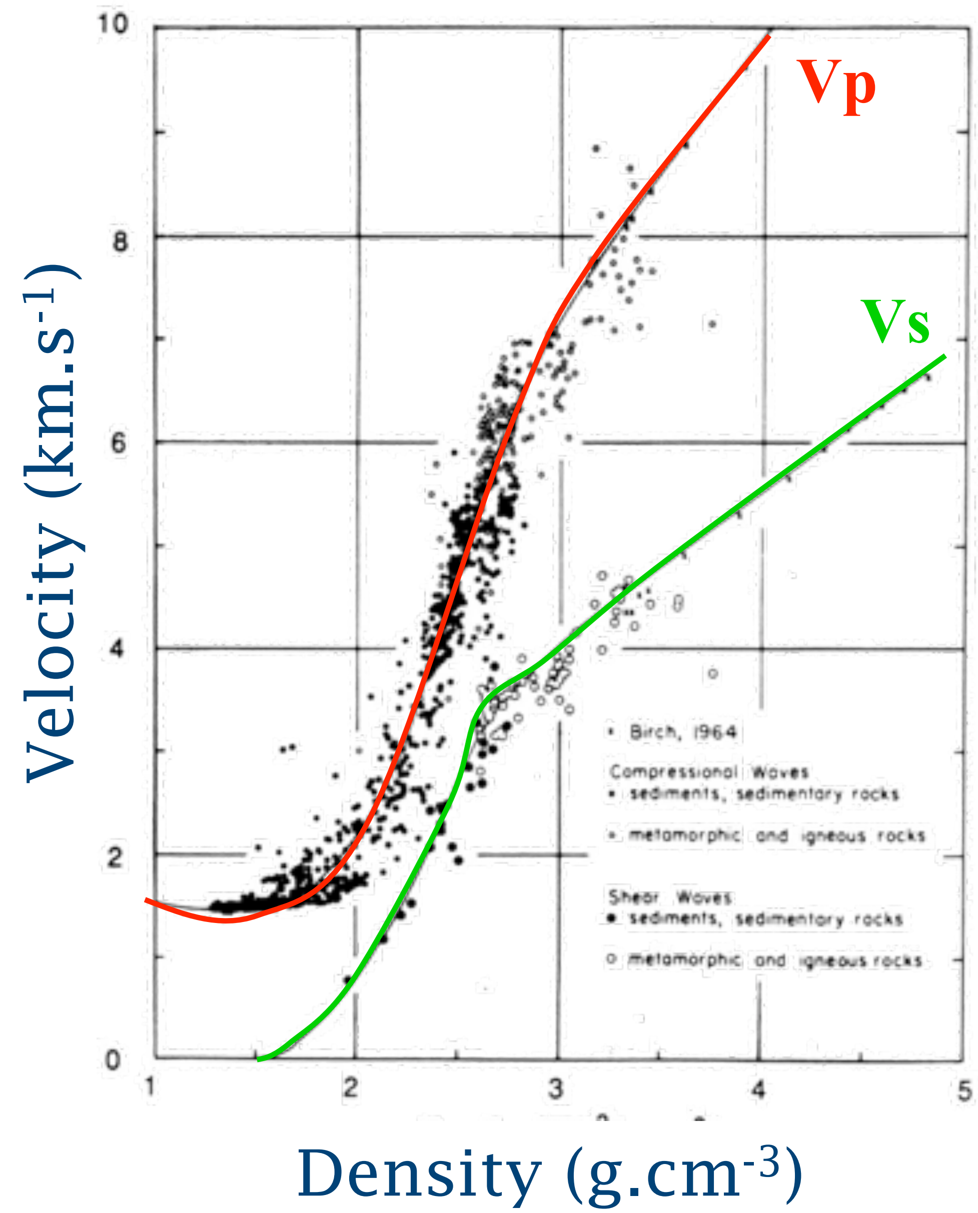


Relation Seismic waves - density

Birch's law (1964)



extended Birch's law



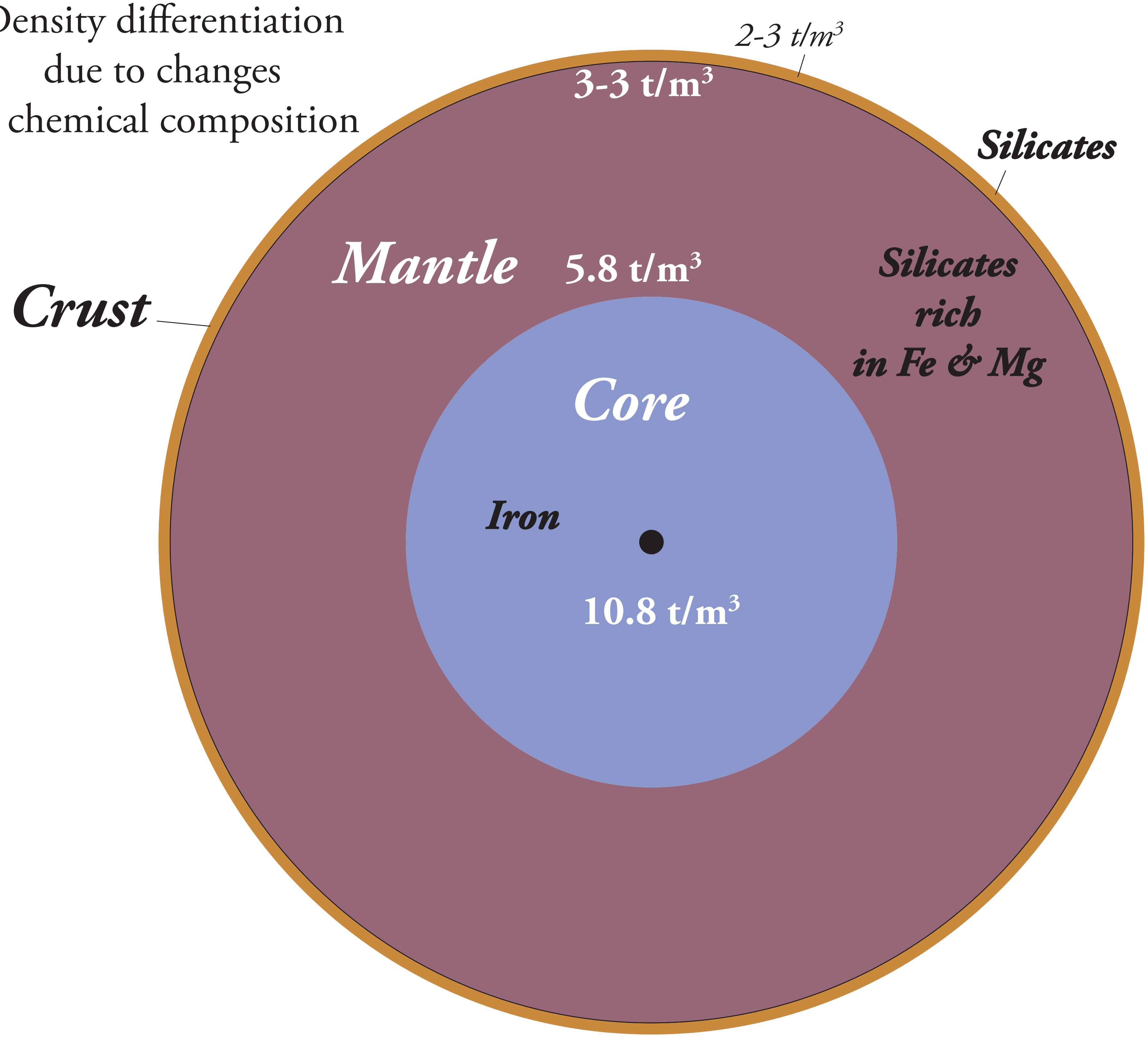
Ludwig et al., 1970

$$V=a\rho+b$$

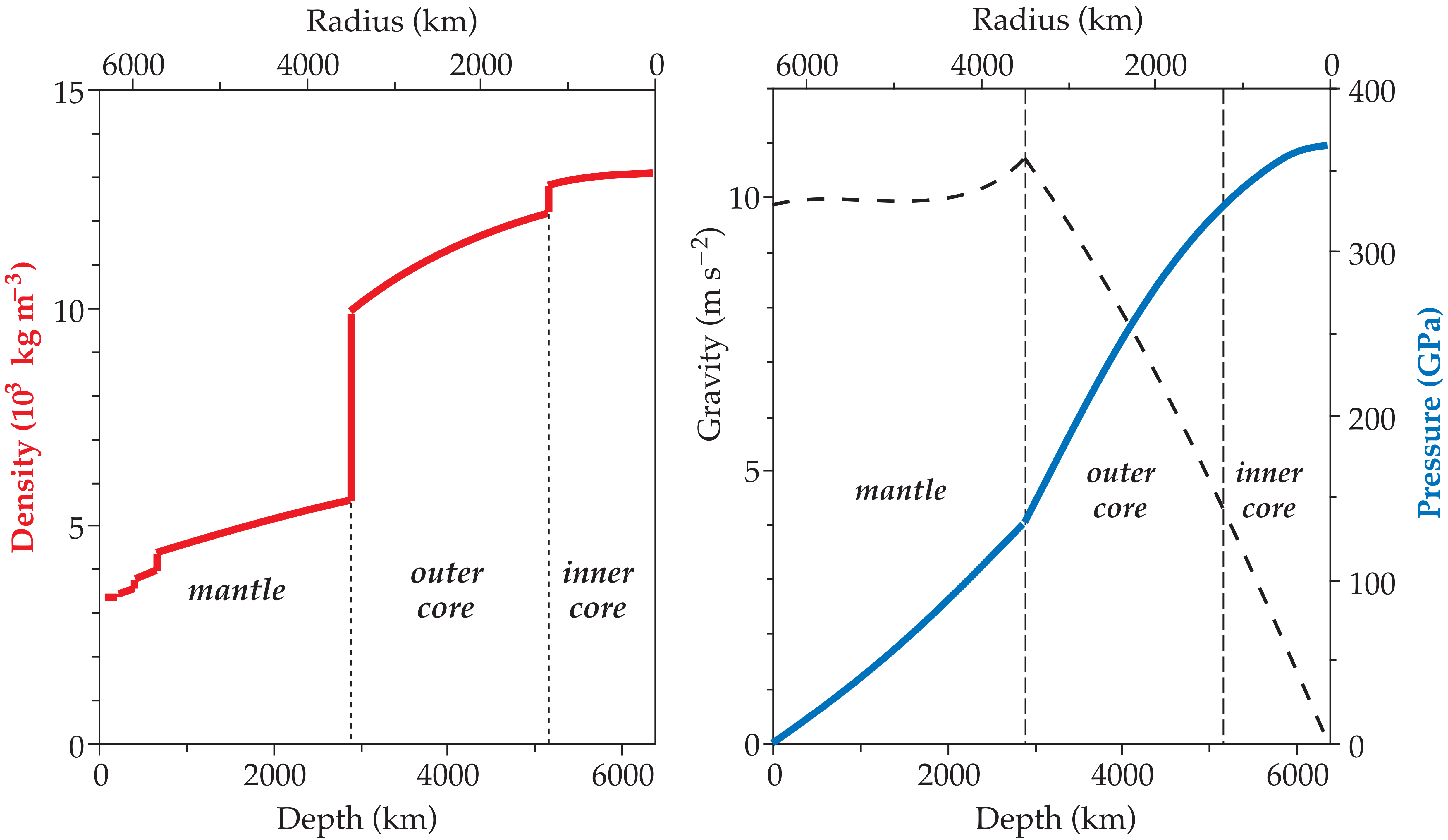
where **a & b** are parameters characterizing the rocks and **V & ρ** are respectively the seismic velocity and the density of the rocks

Simple model of the earth

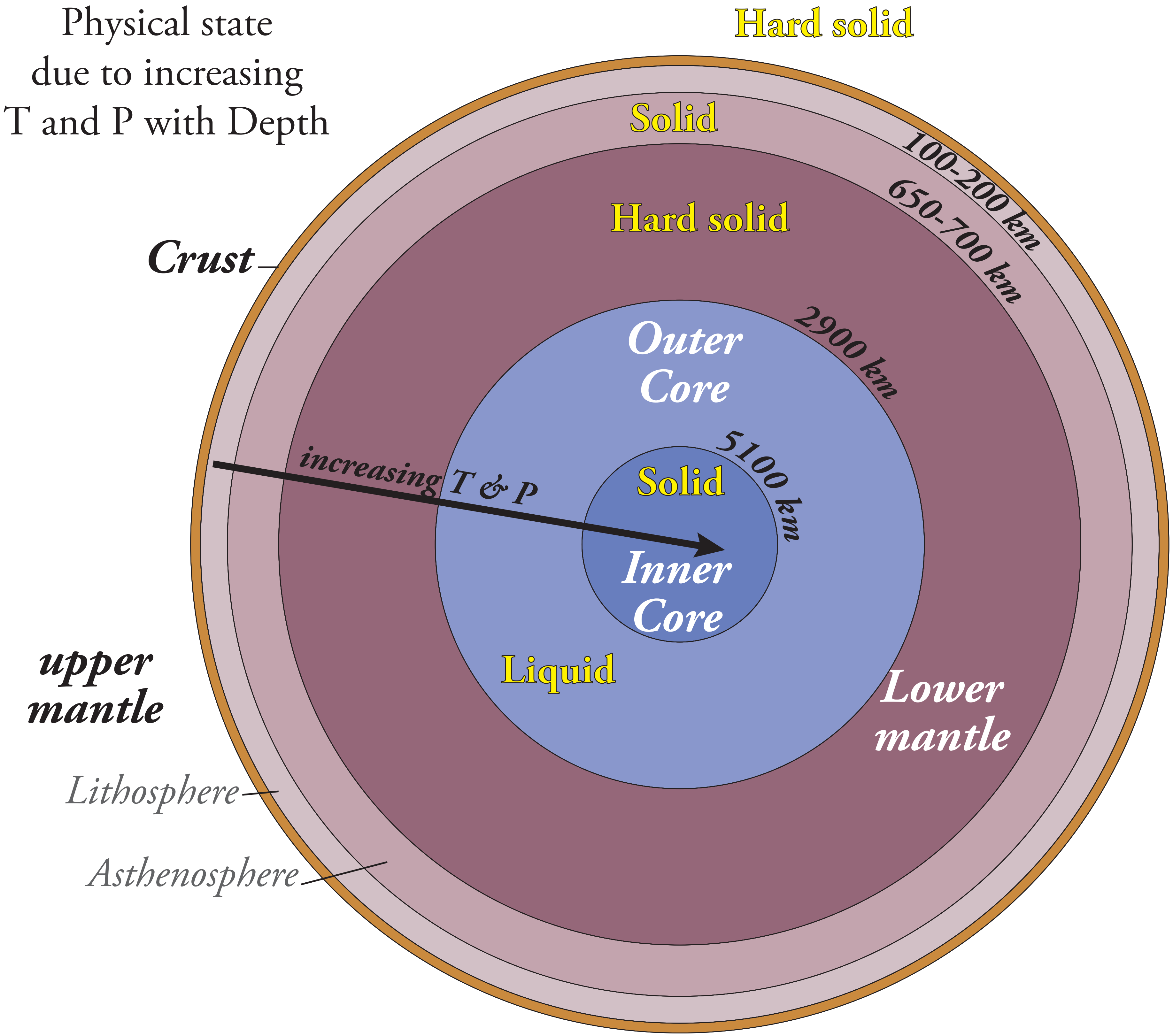
Density differentiation
due to changes
in chemical composition



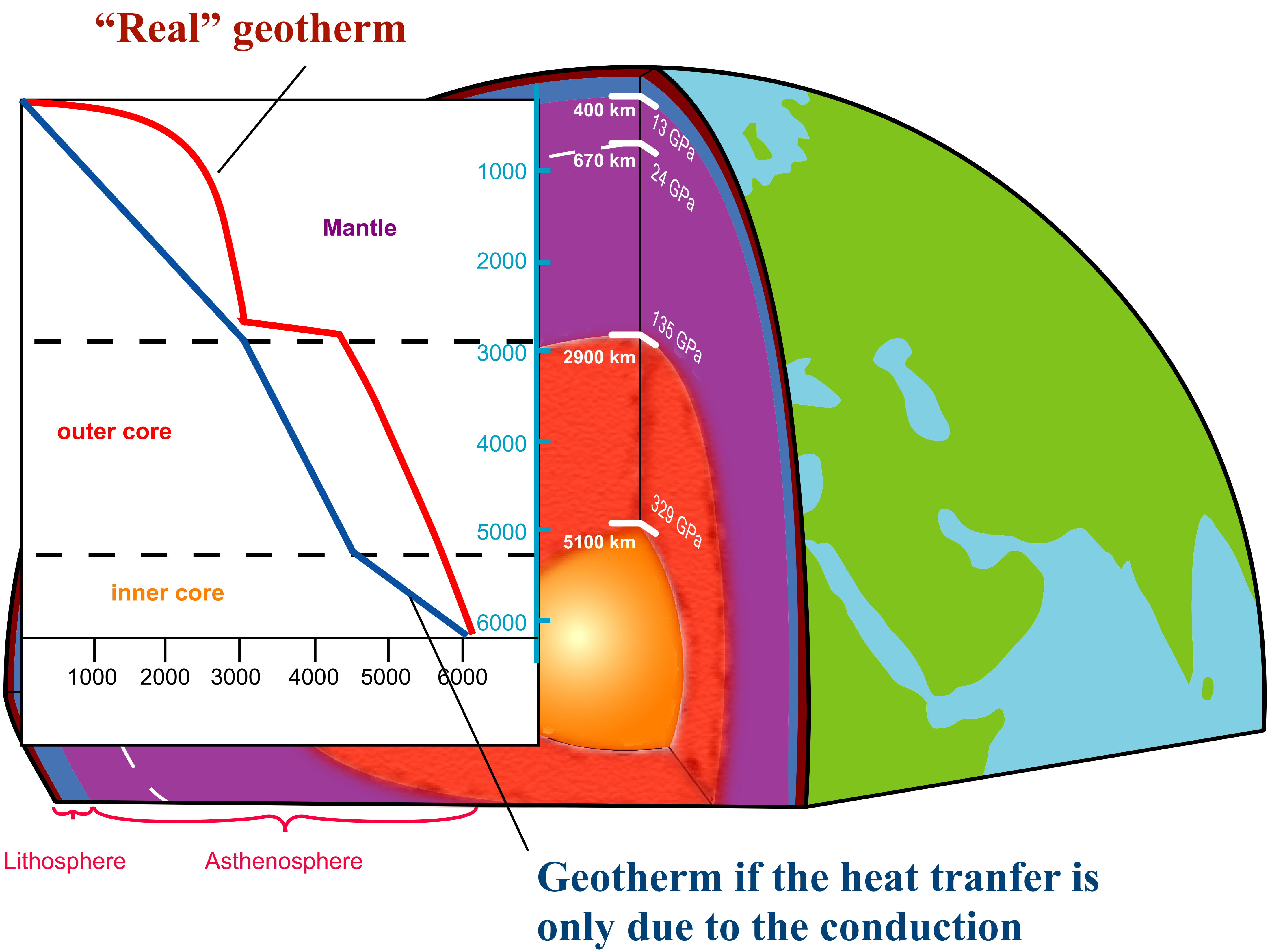
Density-pressure inside the Earth



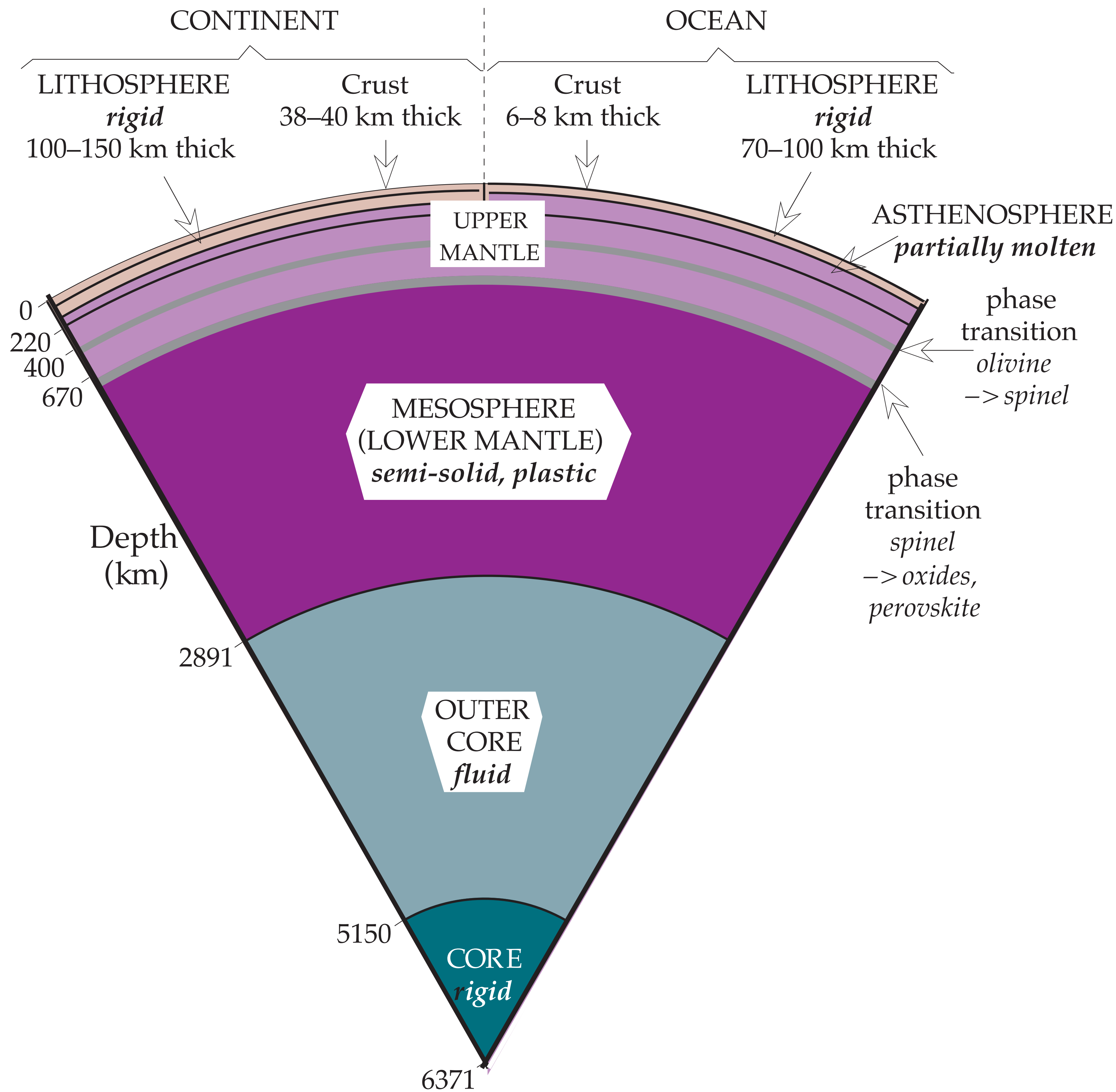
Physical state
due to increasing
T and P with Depth



Isothermen in der Erde

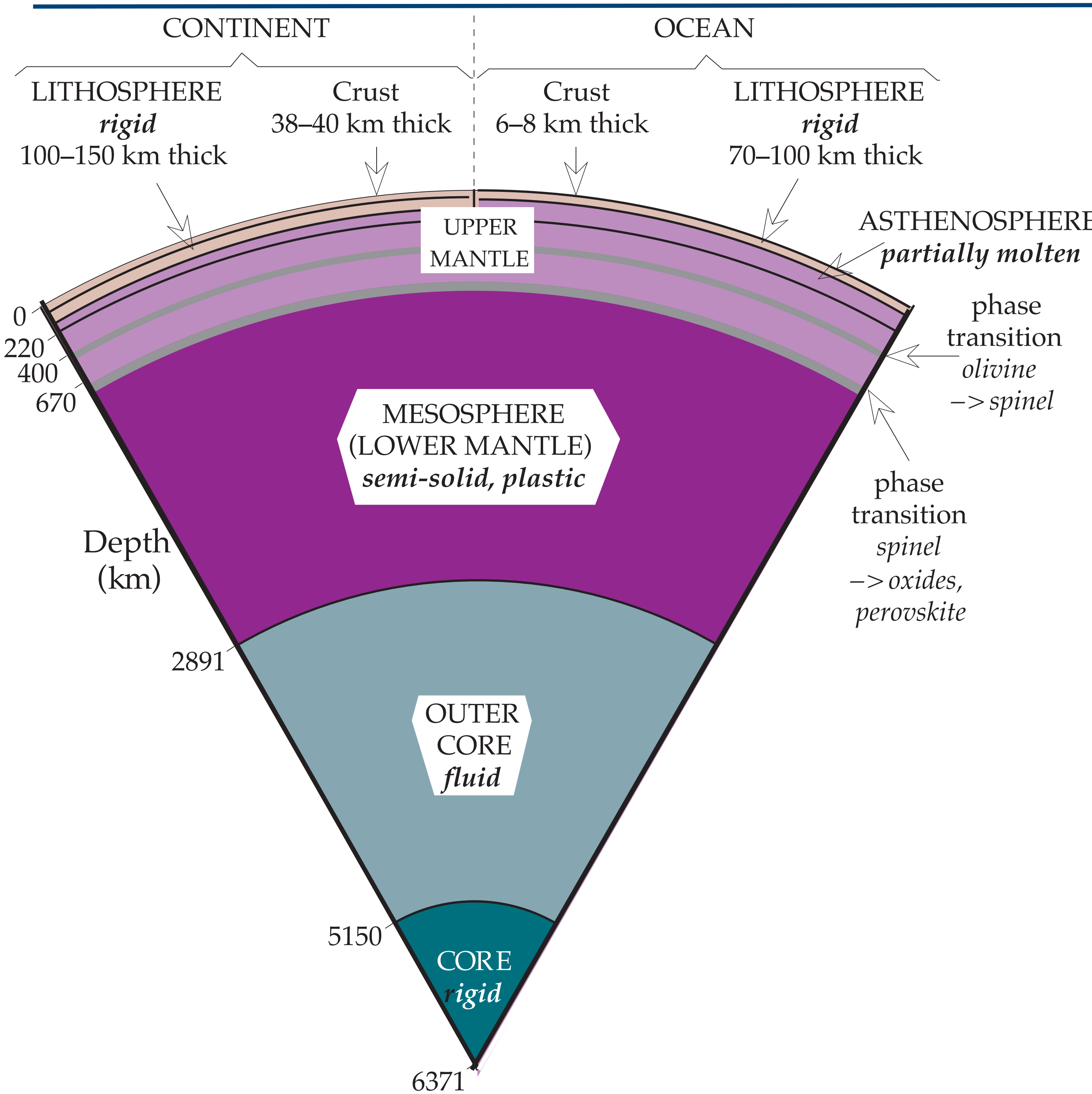


Model of the Earth



Module BP 11 - 04
R. Bousquet 2009-2010

Description of the Earth: the crust



Oceanic crust: 0.099% of Earth's mass; depth of 0-10 kilometers

The oceanic crust contains 0.147% of the mantle-crust mass. The majority of the Earth's crust was made through volcanic activity. The oceanic ridge system, a 40,000-kilometer network of volcanoes, generates new oceanic crust at the rate of 17 km^3 per year, covering the ocean floor with basalt. Hawaii and Iceland are two examples of the accumulation of basalt piles.

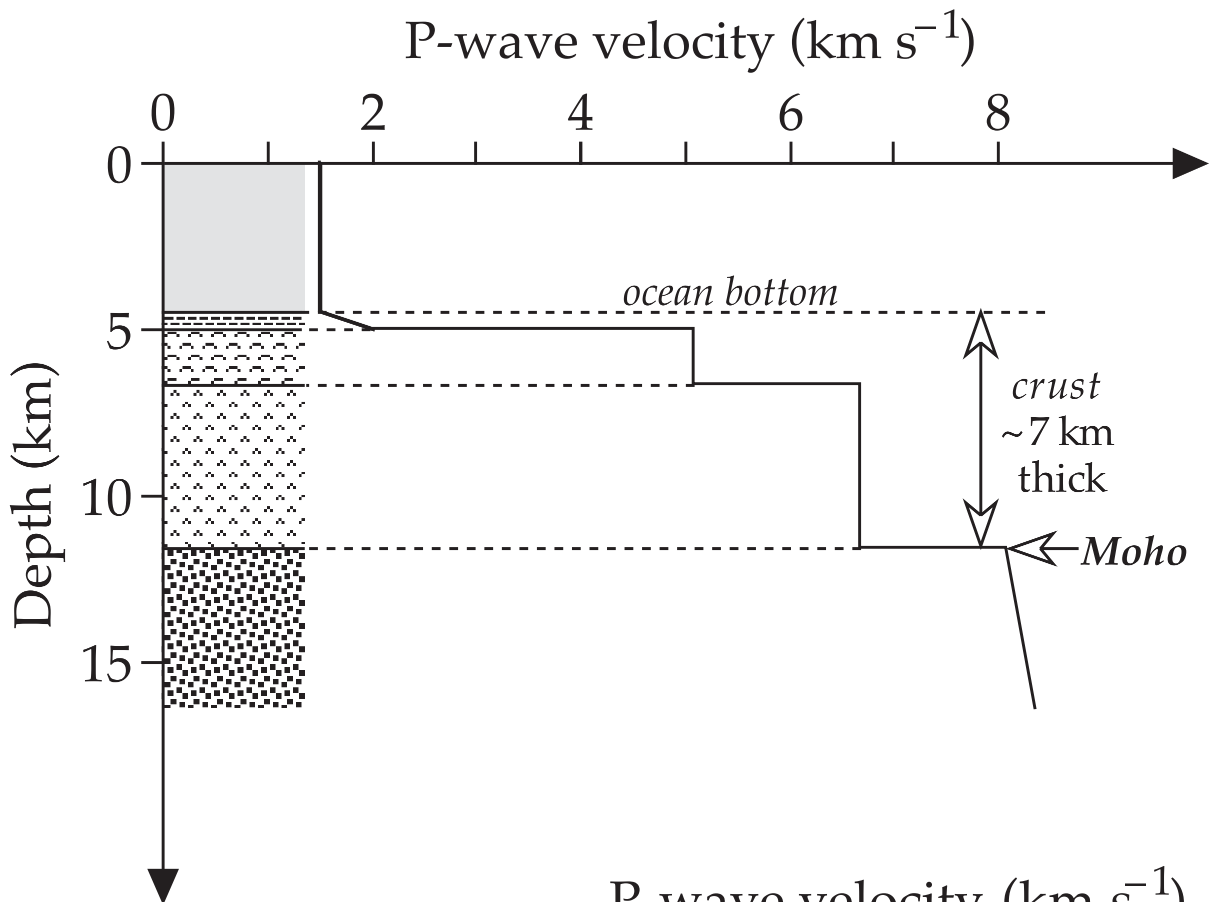
Continental crust: 0.374% of Earth's mass; depth of 0-50 kilometers.

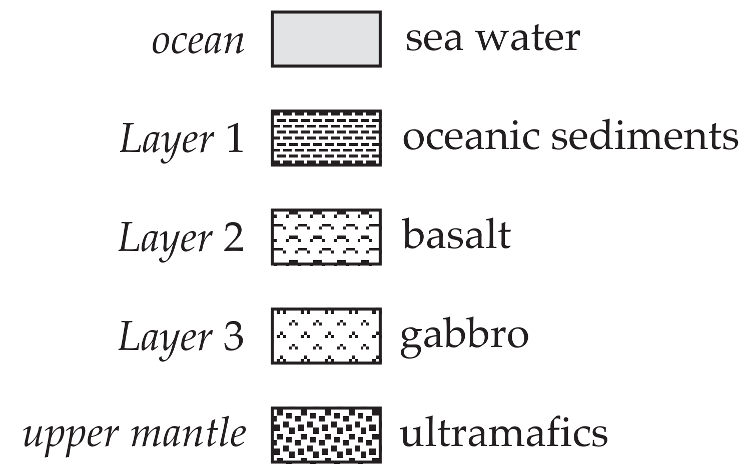
The continental crust contains 0.554% of the mantle-crust mass. This is the outer part of the Earth composed essentially of crystalline rocks. These are low-density buoyant minerals dominated mostly by quartz (SiO2) and feldspars (metal-poor silicates). The crust (both oceanic and continental) is the surface of the Earth; as such, it is the coldest part of our planet. Because cold rocks deform slowly, we refer to this rigid outer shell as the lithosphere (the rocky or strong layer).

R. Bousquet 2009-2010

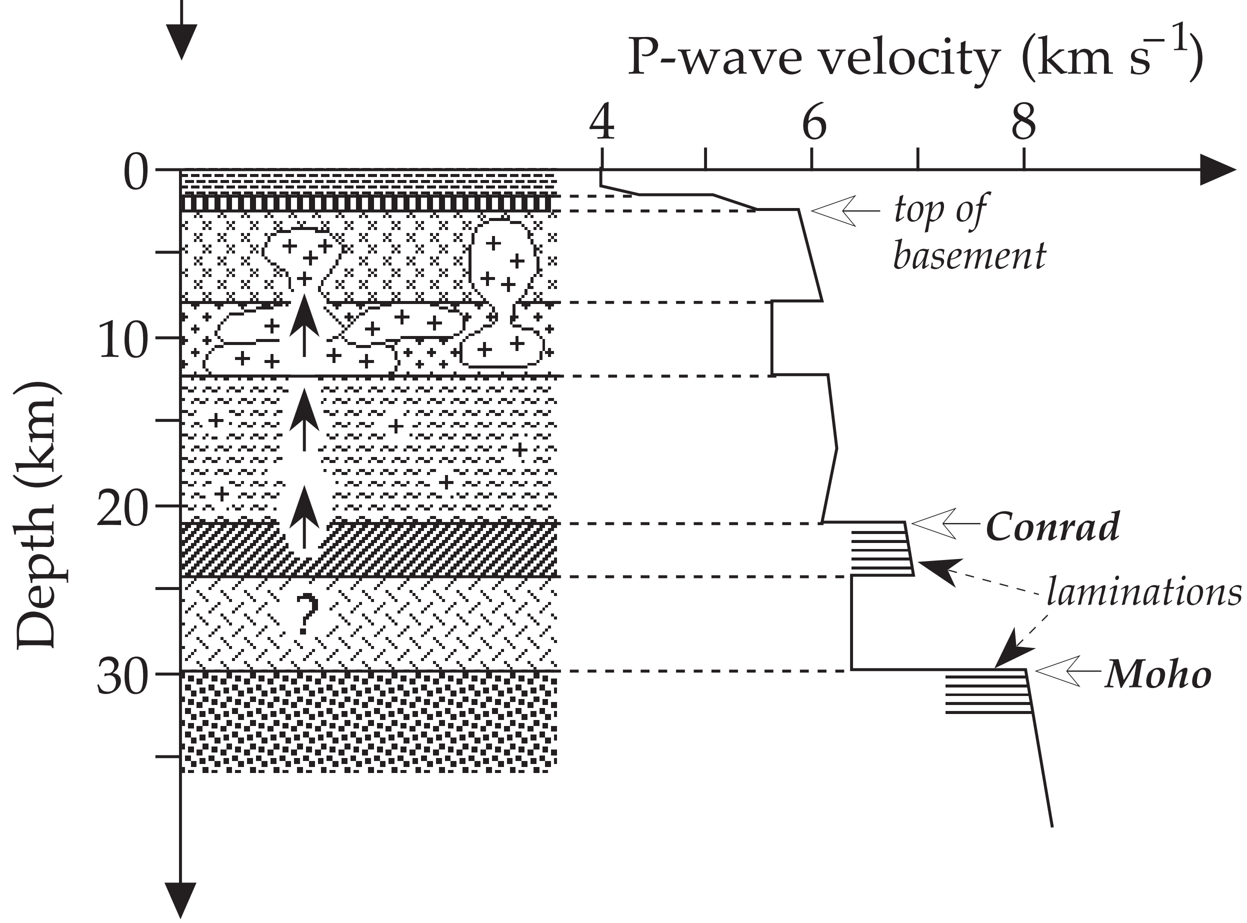
Description of the Earth: the crust

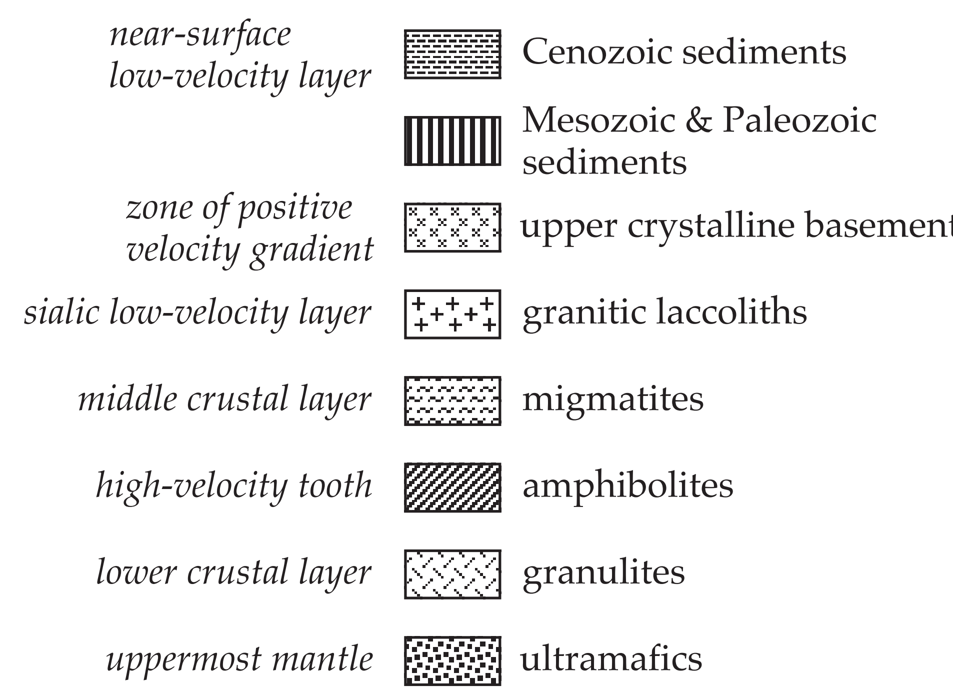
Generalized petrological model and P-wave velocity–depth profile for **oceanic crust**



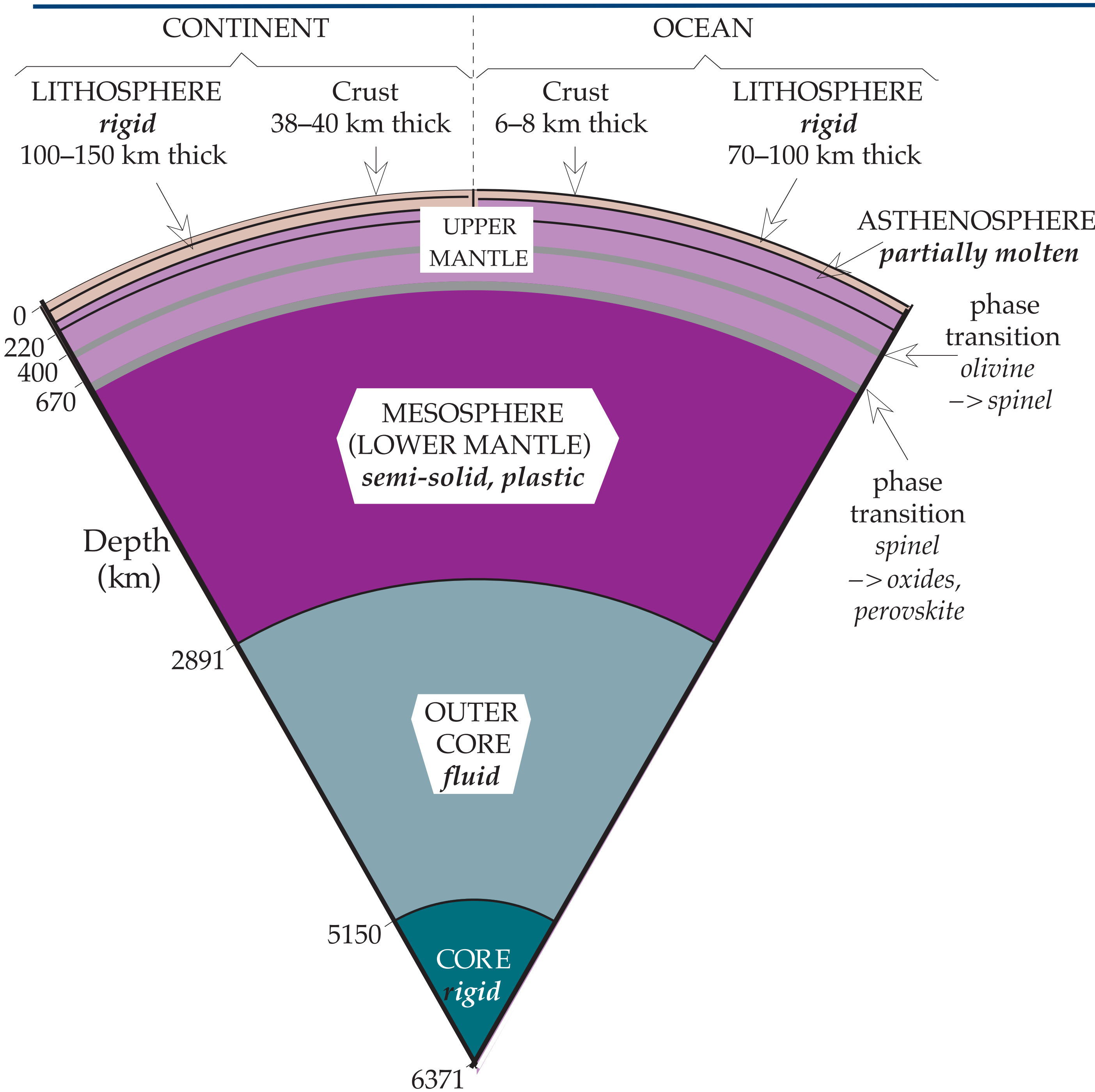


Generalized petrological model and P-wave velocity–depth profile for **continental crust**





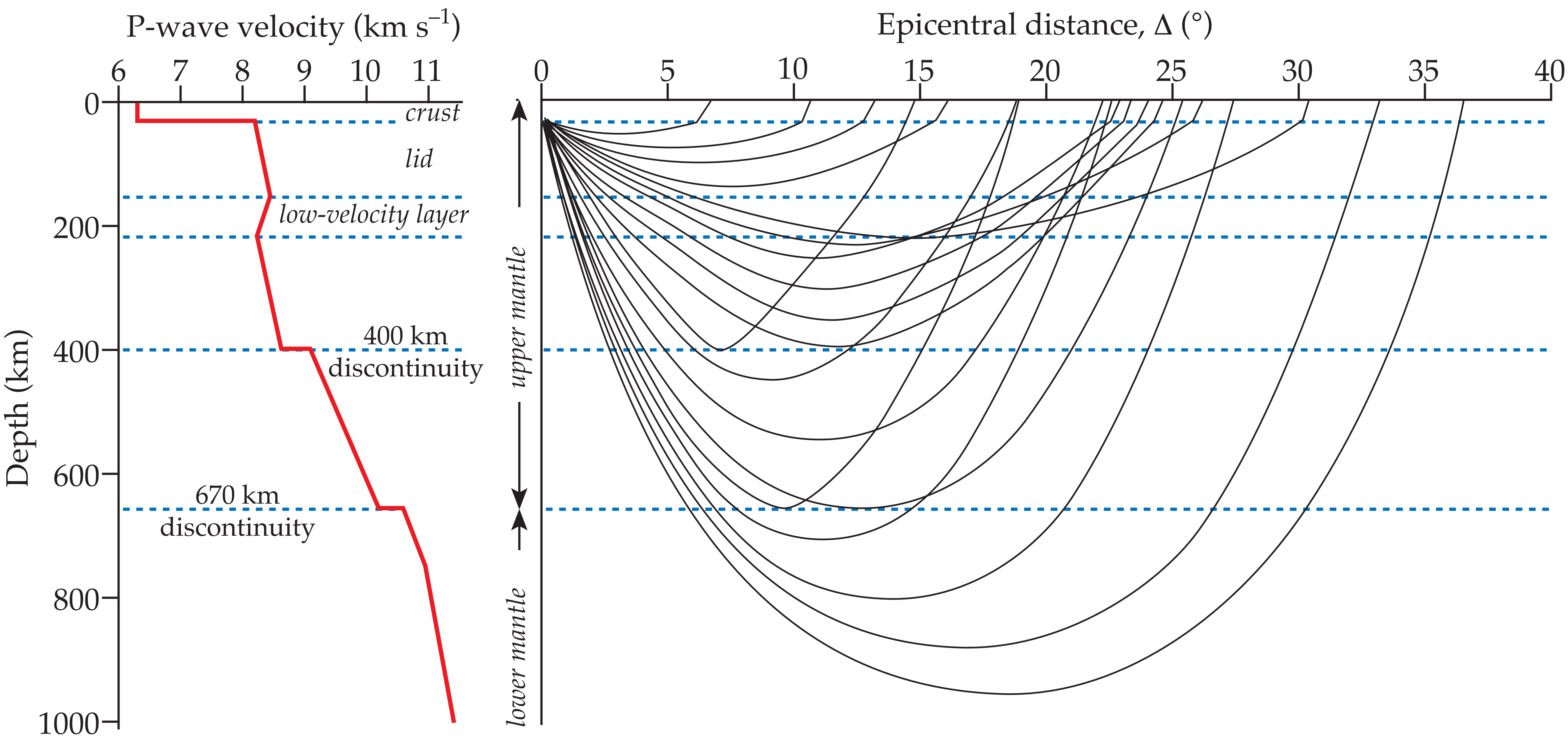
Description of the Earth: the upper mantle



Upper mantle: 10.3% of Earth's mass; depth of 10-400 kilometers

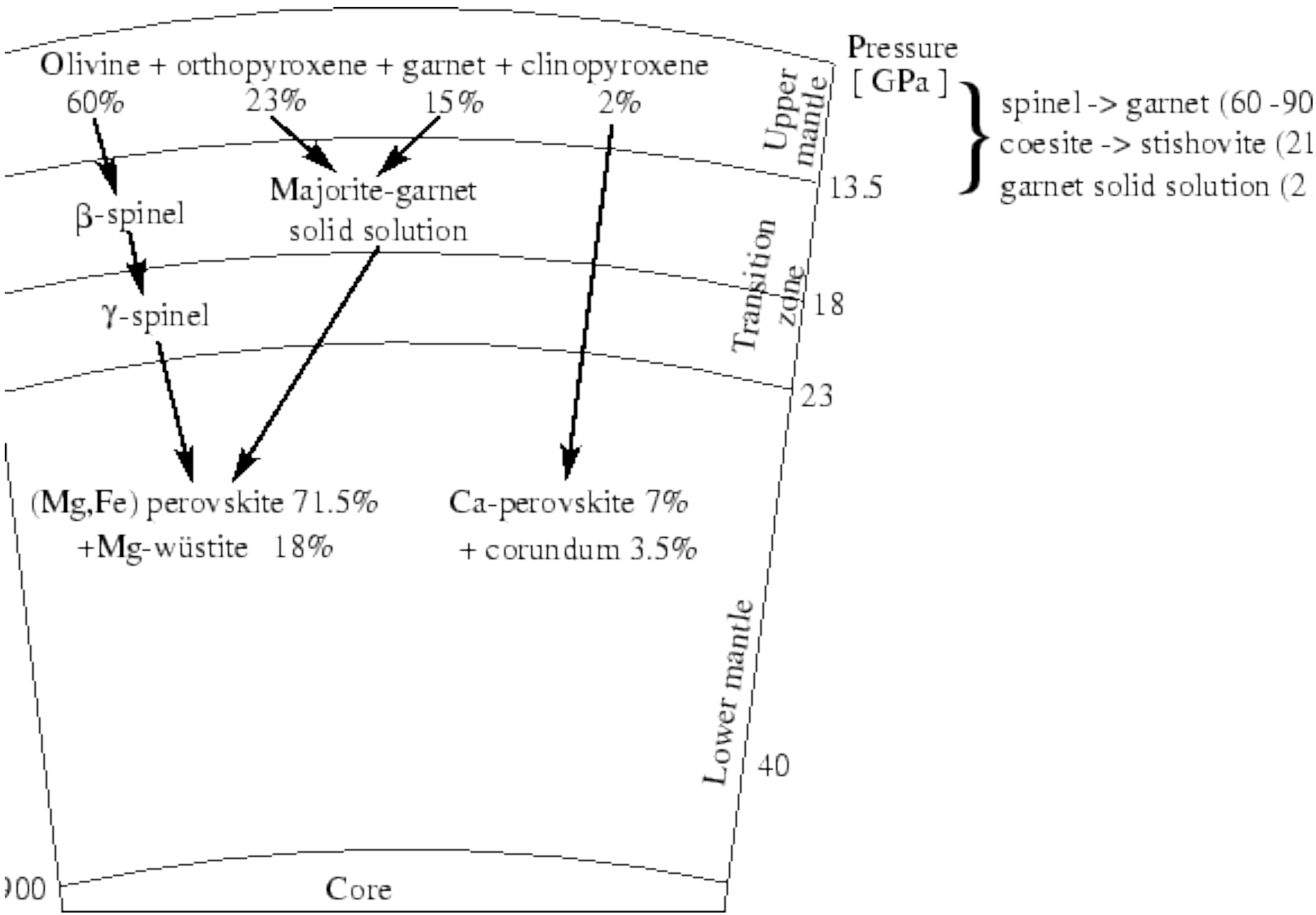
The upper mantle contains 15.3% of the mantle-crust mass. Fragments have been excavated for our observation by eroded mountain belts and volcanic eruptions. Olivine (Mg,Fe) 2SiO4 and pyroxene (Mg,Fe)SiO3 have been the primary minerals found in this way. These and other minerals are refractory and crystalline at high temperatures; therefore, most settle out of rising magma, either forming new crustal material or never leaving the mantle. Part of the upper mantle called the asthenosphere might be partially molten.

Description of the Earth: the upper mantle



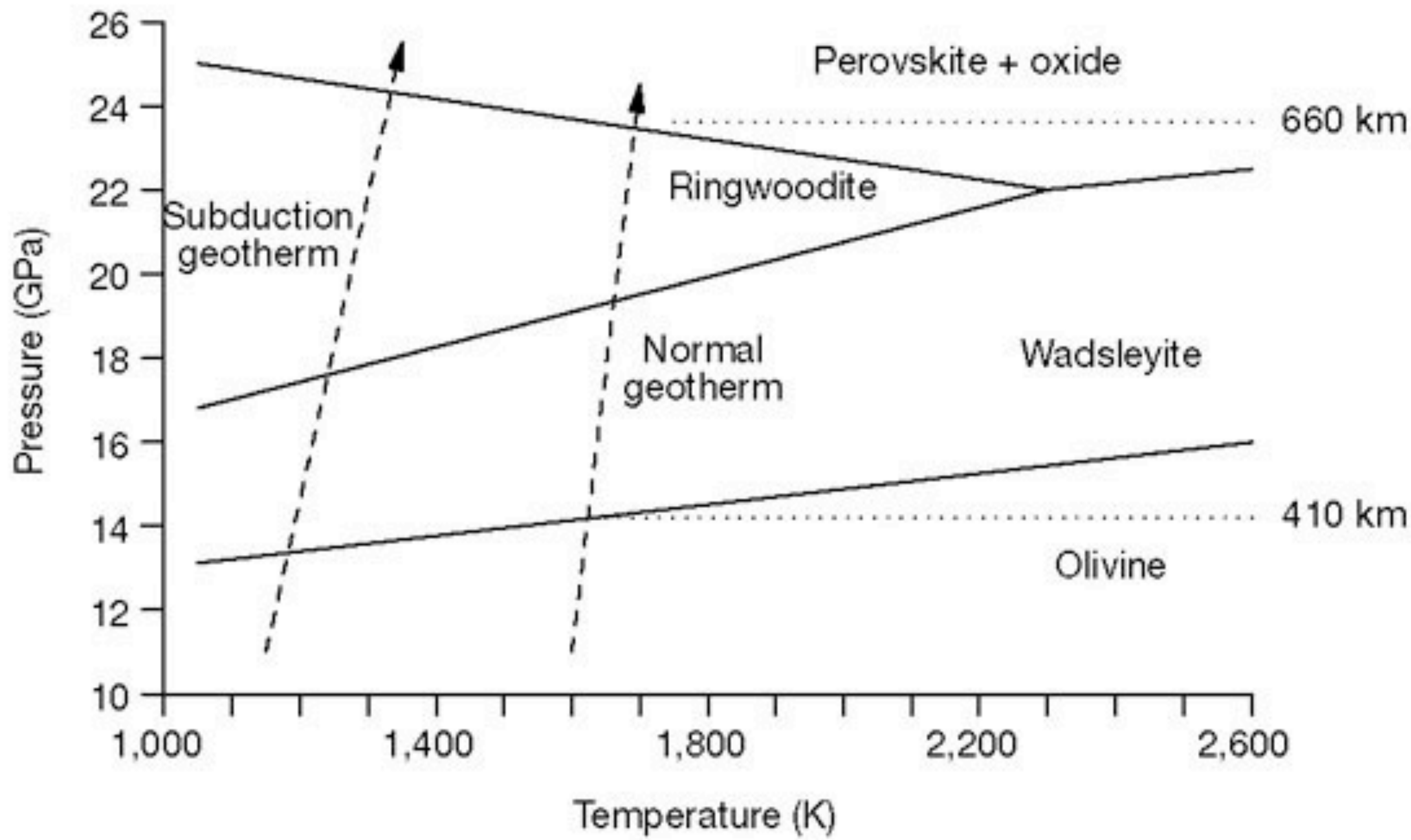
Description of the Earth: the upper mantle

Mineral Composition 2



Description of the Earth: the upper mantle

Phase Transformation



Olivine undergoes pressure dependent transformation to the spinel structure (Ringwoodite), and then breaks down to Perovskovite.
The transformations correlate with the major seismic discontinuities, and probably generate part of the Signal.

Description of the Earth: the upper mantle

Olivine Phases

$$(Mg,Fe)_2SiO_4 = (Mg,Fe)_2SiO_4$$

Olivine → Wadsleyite

Pressure 13-14 GPa
410 km.

$$(Mg,Fe)_2SiO_4 = (Mg,Fe)_2SiO_4$$

Wadsleyite → Ringwoodite

Pressure 18 GPa.
520 km.

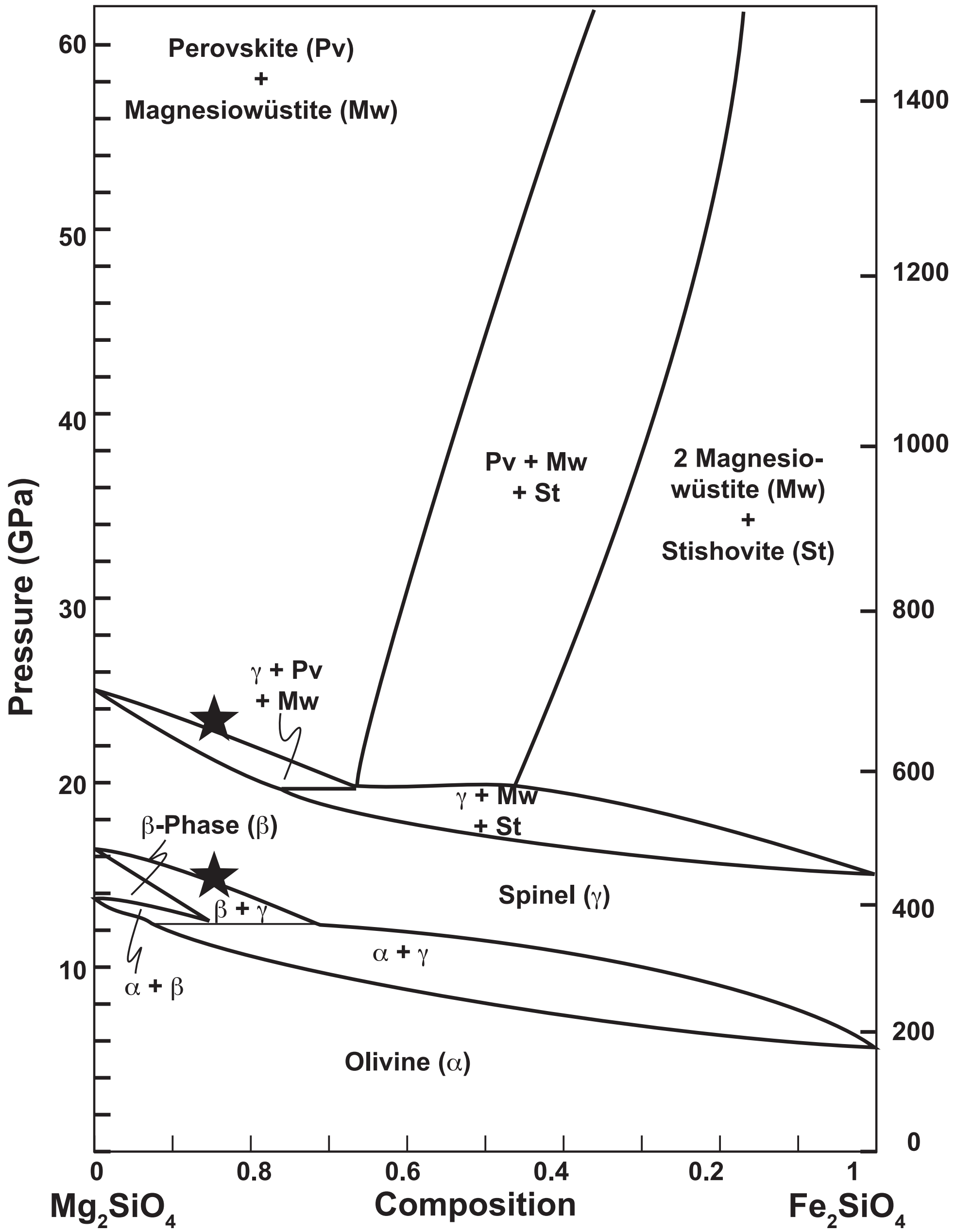
$$(Mg,Fe)_2SiO_4 = (Mg,Fe)SiO_3 + (Mg,Fe)O$$

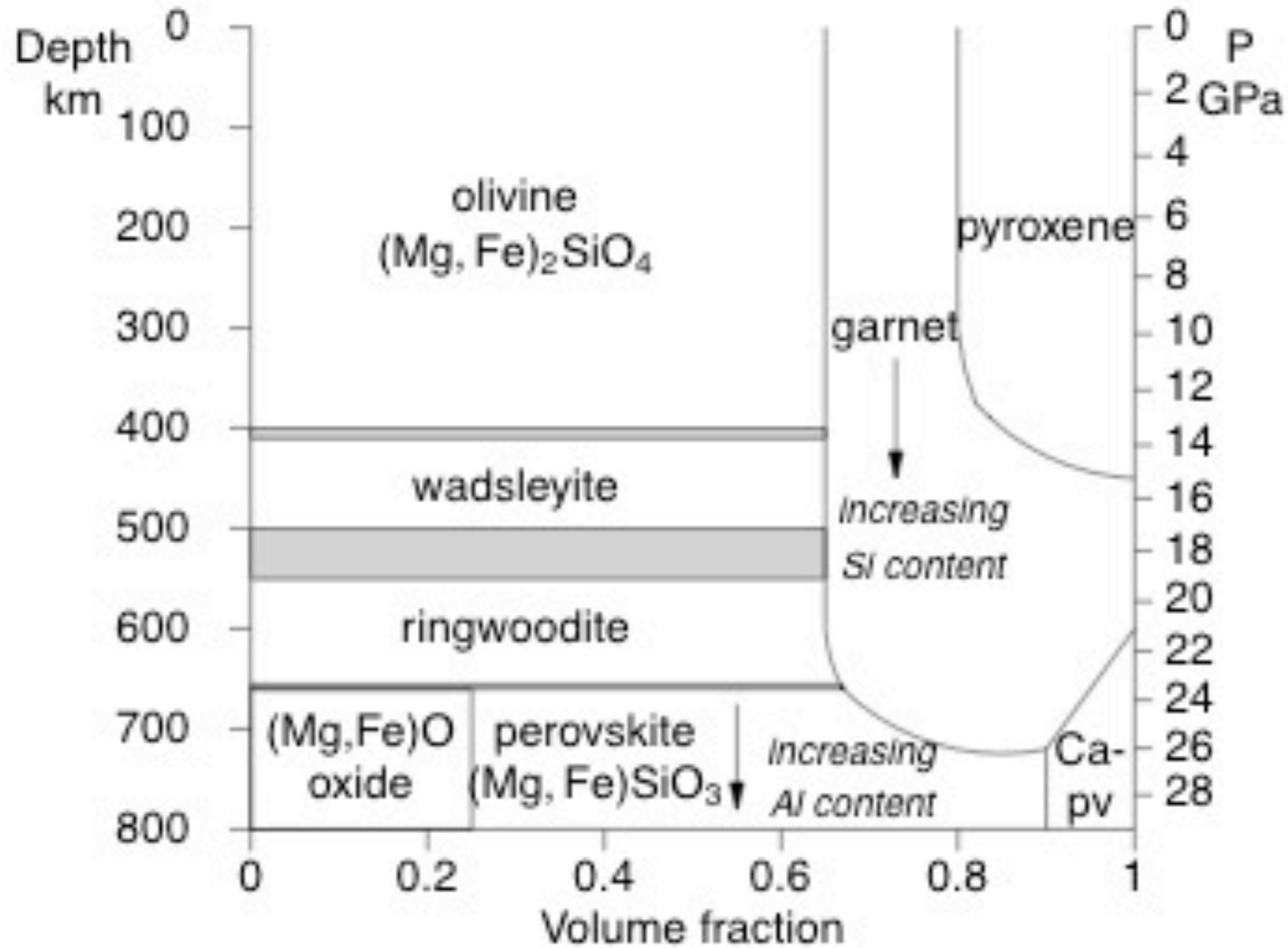
Ringwoodite → Peroskovite + Magnesiowüstite

Pressure 23 GPa.
660 km.

Description of the Earth: the upper mantle

Mineralogy of the mantle: influence of the chemical composition

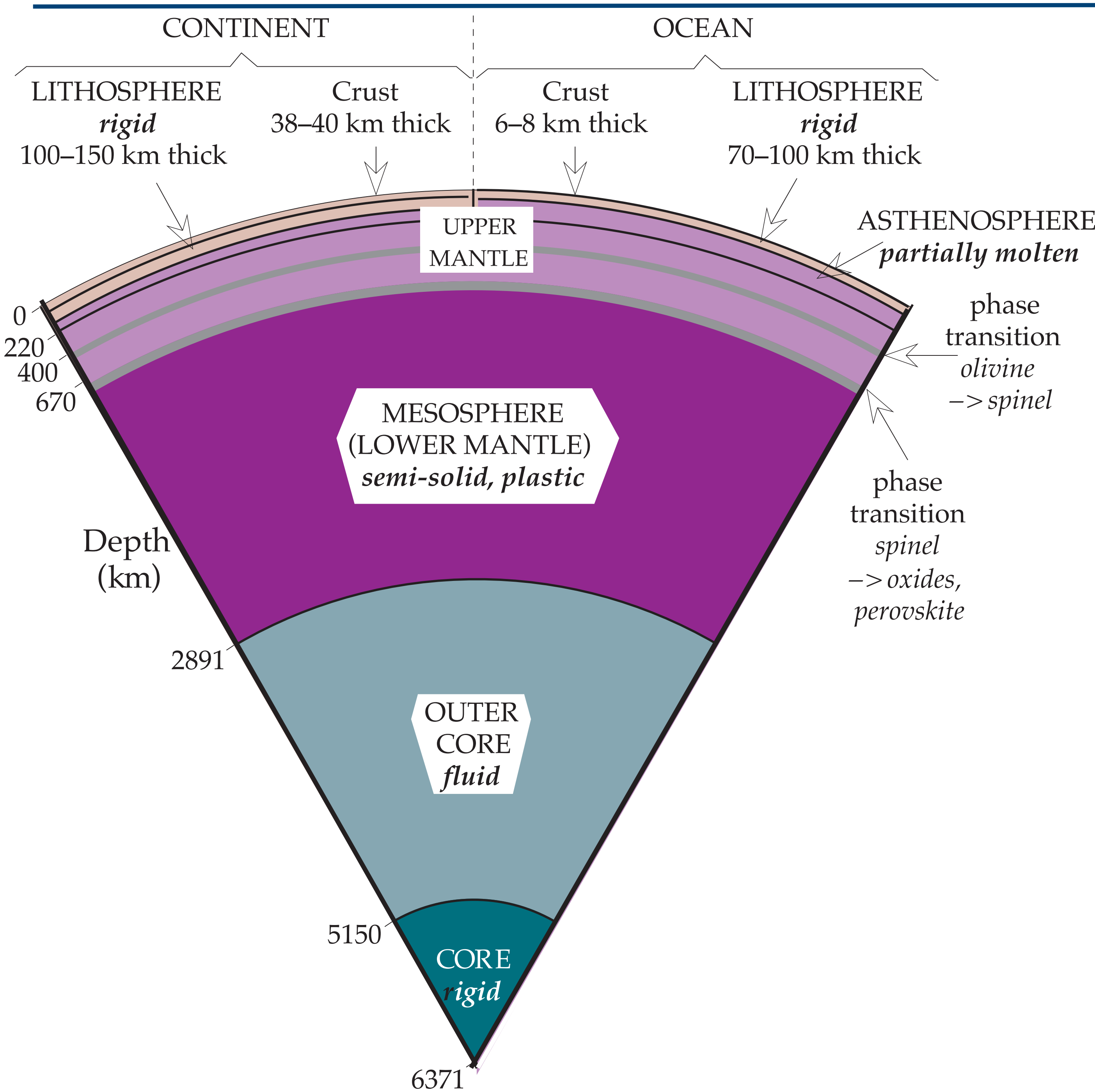




(Helffrich, 2003)

Module BP 11 - 04
R. Bousquet 2009-2010

Description of the Earth: transition zone



Transition region: 7.5% of Earth's mass; depth of 400-650 kilometers

The transition region or mesosphere (for middle mantle), sometimes called the fertile layer, contains 11.1% of the mantle-crust mass and is the source of basaltic magmas. It also contains calcium, aluminum, and garnet, which is a complex aluminum-bearing silicate mineral. This layer is dense when cold because of the garnet. It is buoyant when hot because these minerals melt easily to form basalt which can then rise through the upper layers as magma.

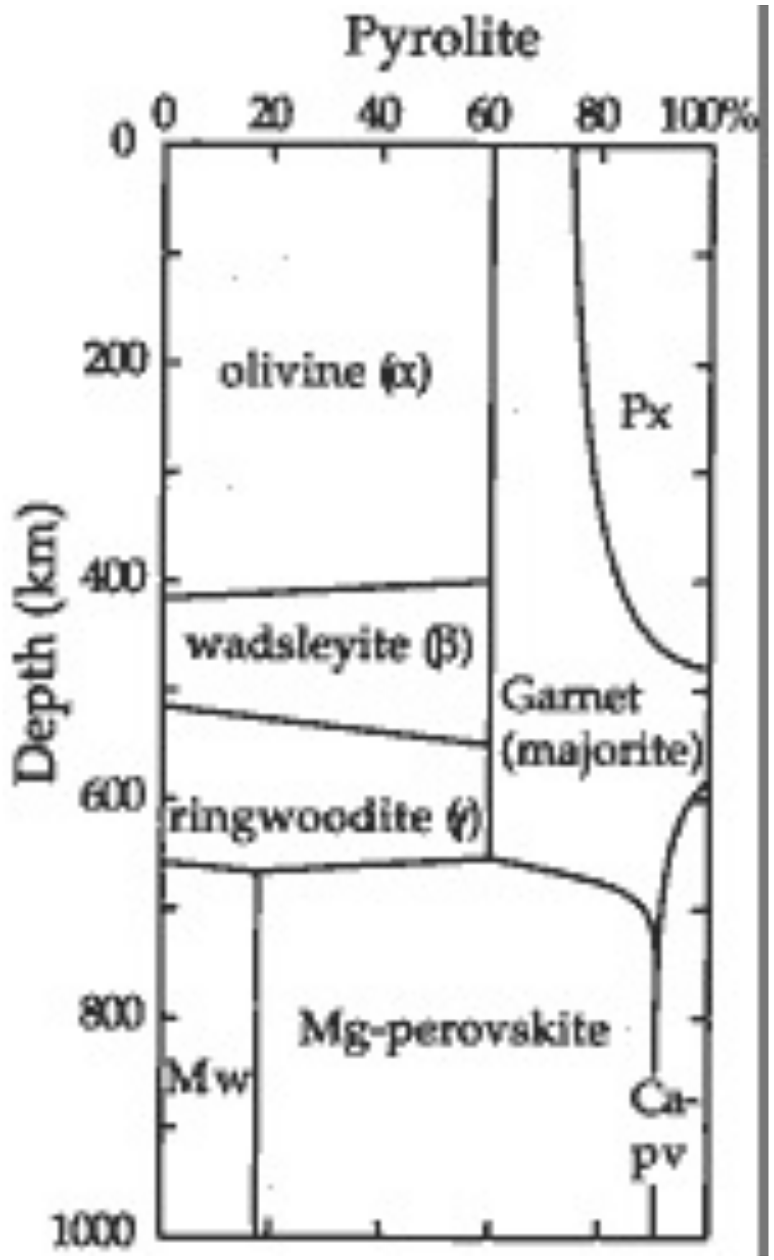
Description of the Earth: transition zone

Pyroxene - Garnet Phases

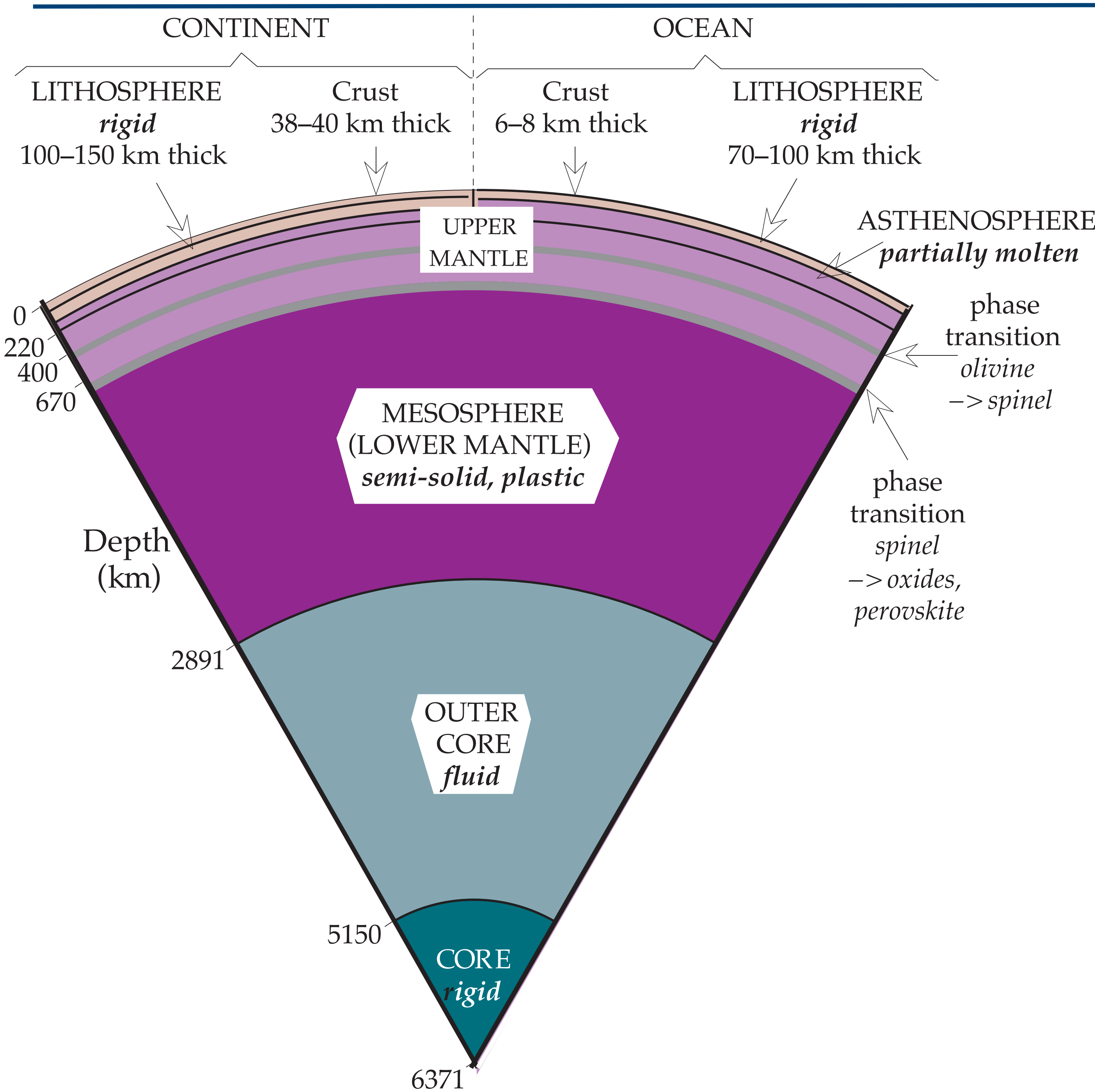
Transformation of non-olivine components are also important (30%). This phase changes are gradual and lead to changes of slope of velocity.

Pyroxene starts to dissolve into the garnet
Structure at 350 - 500 km.

At about 580 km $CaSiO_3$ perovskovite
Exsolves from garnet.



Description of the Earth: the lower mantle



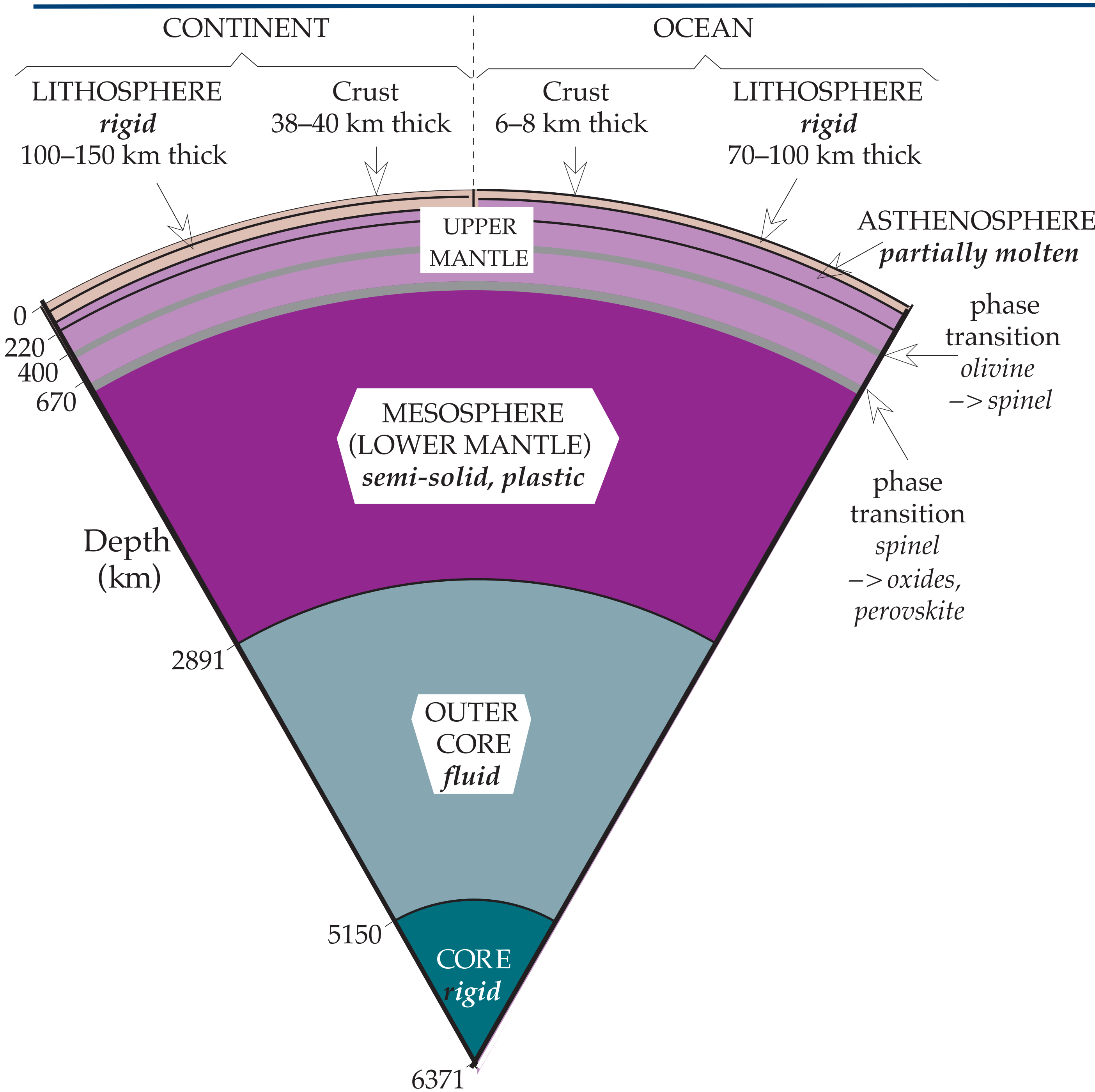
Lower mantle: 49.2% of Earth's mass; depth of 650-2'890 kilometers

The lower mantle contains 72.9% of the mantle-crust mass and is probably composed mainly of silicon, magnesium, and oxygen. It probably also contains some iron, calcium, and aluminum. Scientists make these deductions by assuming the Earth has a similar abundance and proportion of cosmic elements as found in the Sun and primitive meteorites.

D": 3% of Earth's mass; depth of 2'700-2'890 kilometers

This layer is 200 to 300 kilometers (125 to 188 miles) thick and represents about 4% of the mantle-crust mass. Although it is often identified as part of the lower mantle, seismic discontinuities suggest the D" layer might differ chemically from the lower mantle lying above it. Scientists theorize that the material either dissolved in the core, or was able to sink through the mantle but not into the core because of its density.

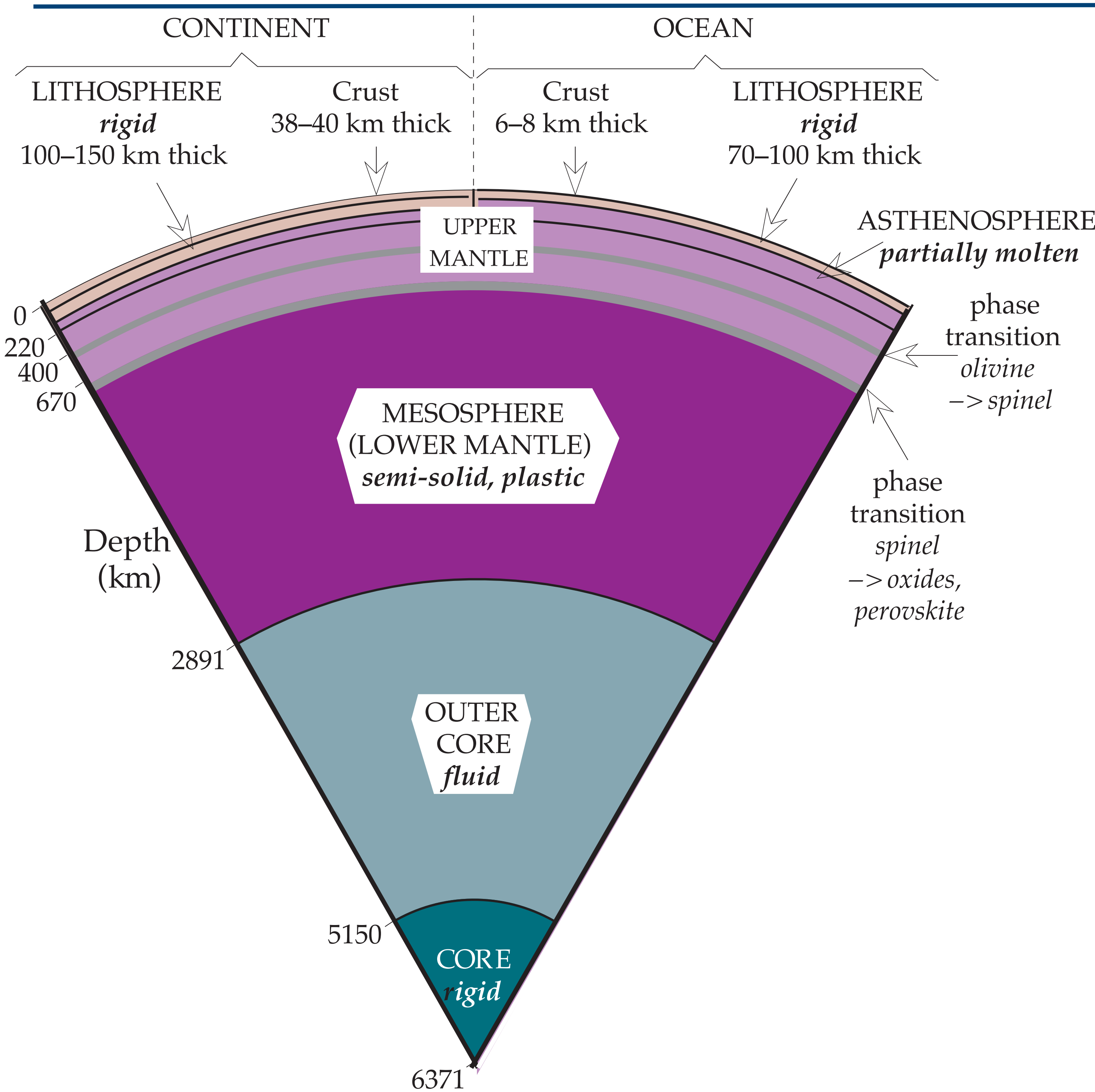
Description of the Earth: the outer core



Outer core: 30.8% of Earth's mass; depth of 2,890-5,150 kilometers

The outer core is a hot, electrically conducting liquid within which convective motion occurs. This conductive layer combines with Earth's rotation to create a dynamo effect that maintains a system of electrical currents known as the Earth's magnetic field. It is also responsible for the subtle jerking of Earth's rotation. This layer is not as dense as pure molten iron, which indicates the presence of lighter elements. Scientists suspect that about 10% of the layer is composed of sulfur and/or oxygen because these elements are abundant in the cosmos and dissolve readily in molten iron.

Description of the Earth: the inner core



Inner core: 1.7% of the Earth's mass; depth of 5,150-6,370 kilometers

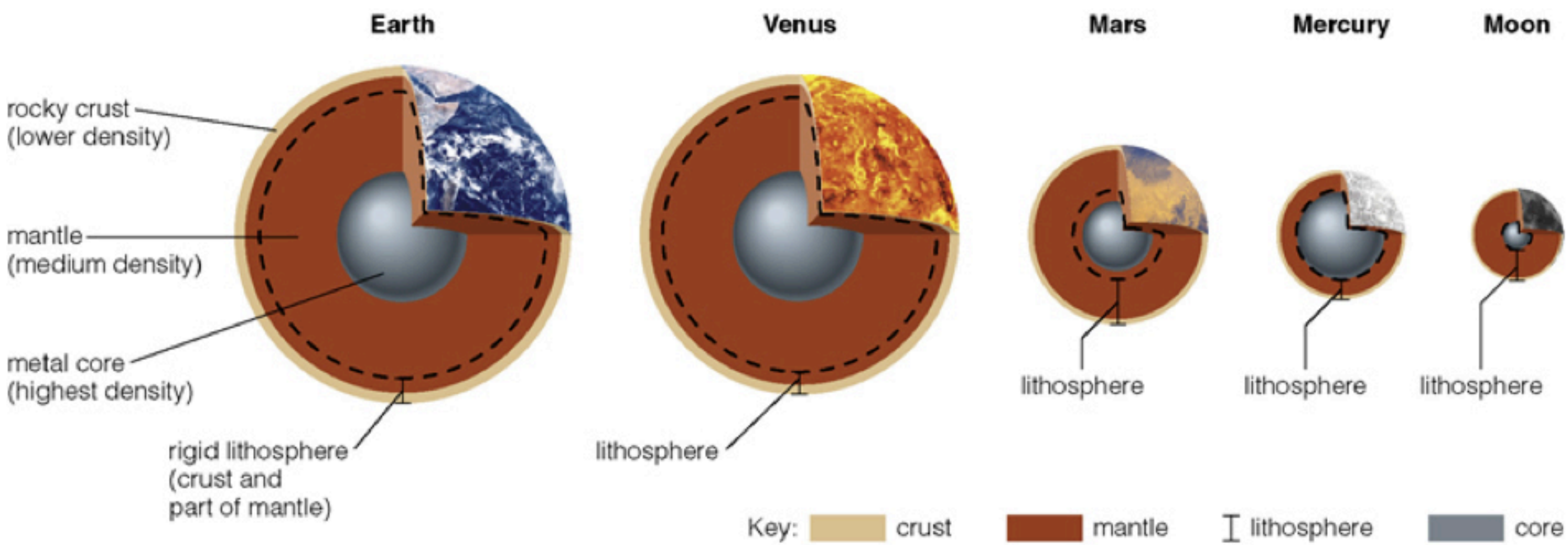
The inner core is solid and unattached to the mantle, suspended in the molten outer core. It is believed to have solidified as a result of pressure-freezing which occurs to most liquids when temperature decreases or pressure increases.

Comparison of the different planets

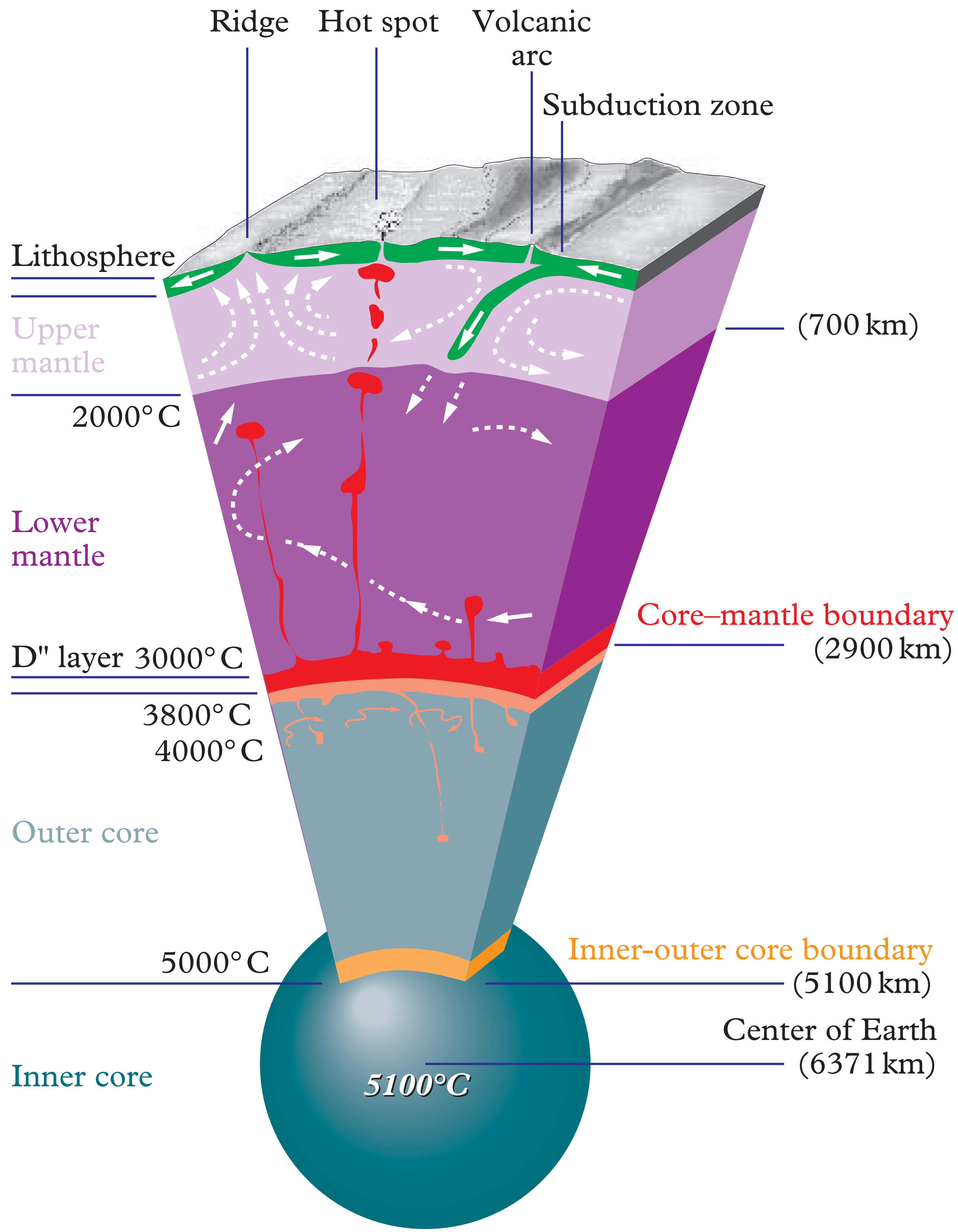
The internal structure of the terrestrial planets are similar. They all have
Core – High density metal
Mantle – Medium density rocky materials, such as silica (SiO_2), ***hot, semi-solid***
Crust – lowest density rocks, such as granite and basalt (black lava rock…)

The layering of different density materials occurs due to *differentiation – heavy materials sink to the bottom while lighter material rise to the top…*

Lithosphere: The coolest and most rigid layer of rock near a planet's surface. Molten lava of Earth exists at a very narrow region beneath the lithosphere

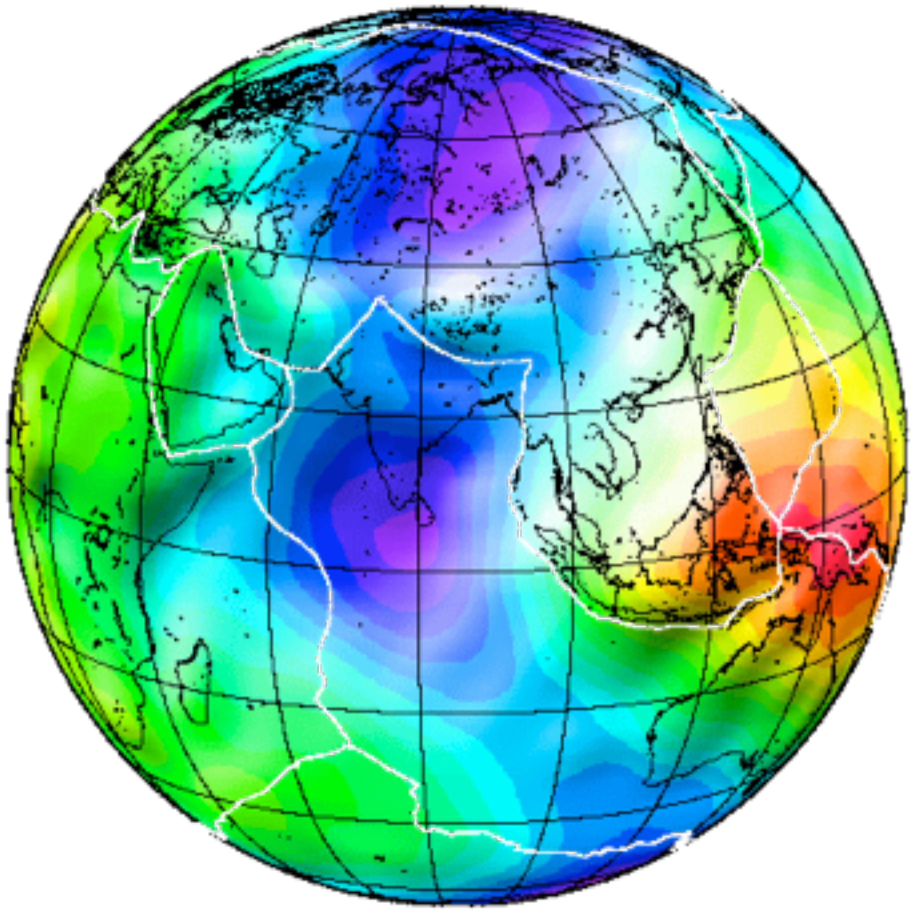


A nother view of the Earth



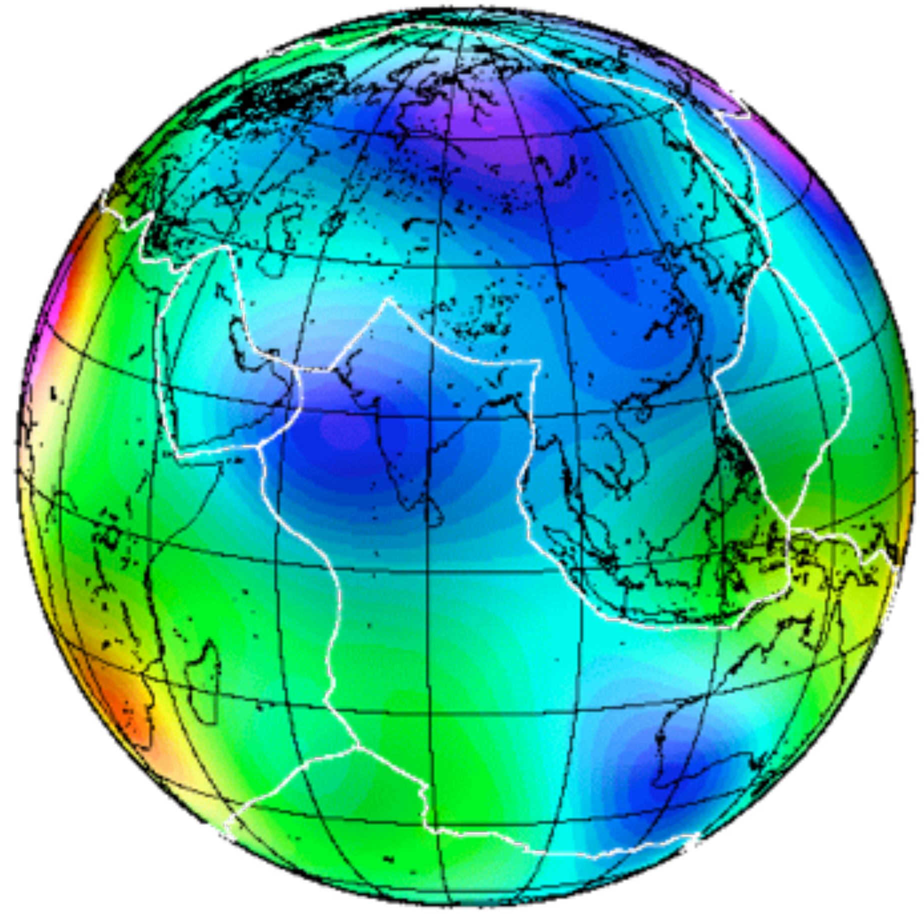
Origin of the Geoid : density anomalies

Geoid over India



Blue=low gravity
Red = high gravity

Seismic tomography in the mantle



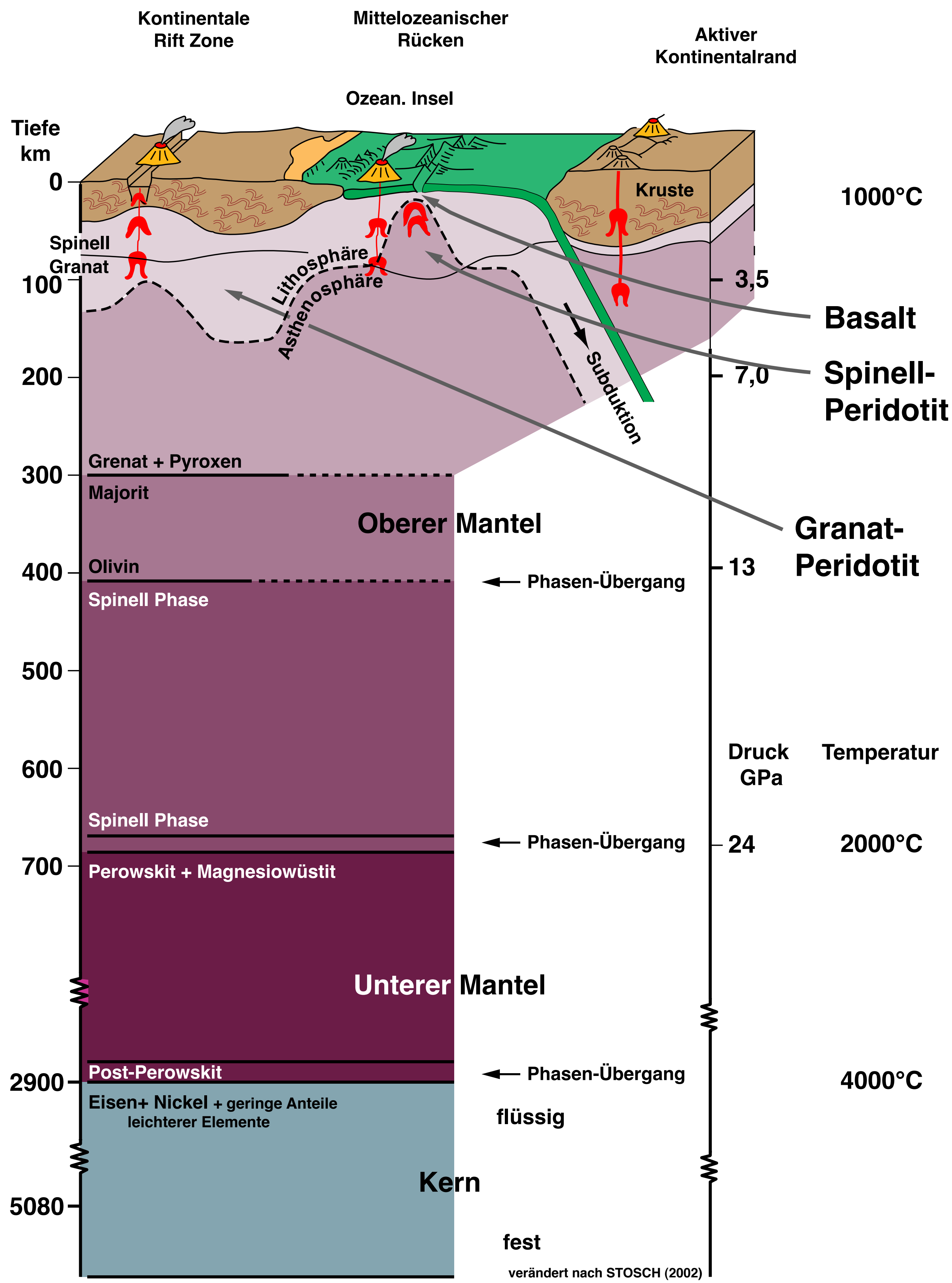
Blue="cold"="more dense"
Red = "hot" = "less dense"

It is very clear that long wavelength Geoid lows are associated to cold and dense material in the mantle. Therefore :

Long wavelength Geoid = density anomalies in the mantle

short wavelength Geoid = surface topography (i.e. mountains)

Summary of the structure of the Earth



R. Bousquet 2009-2010