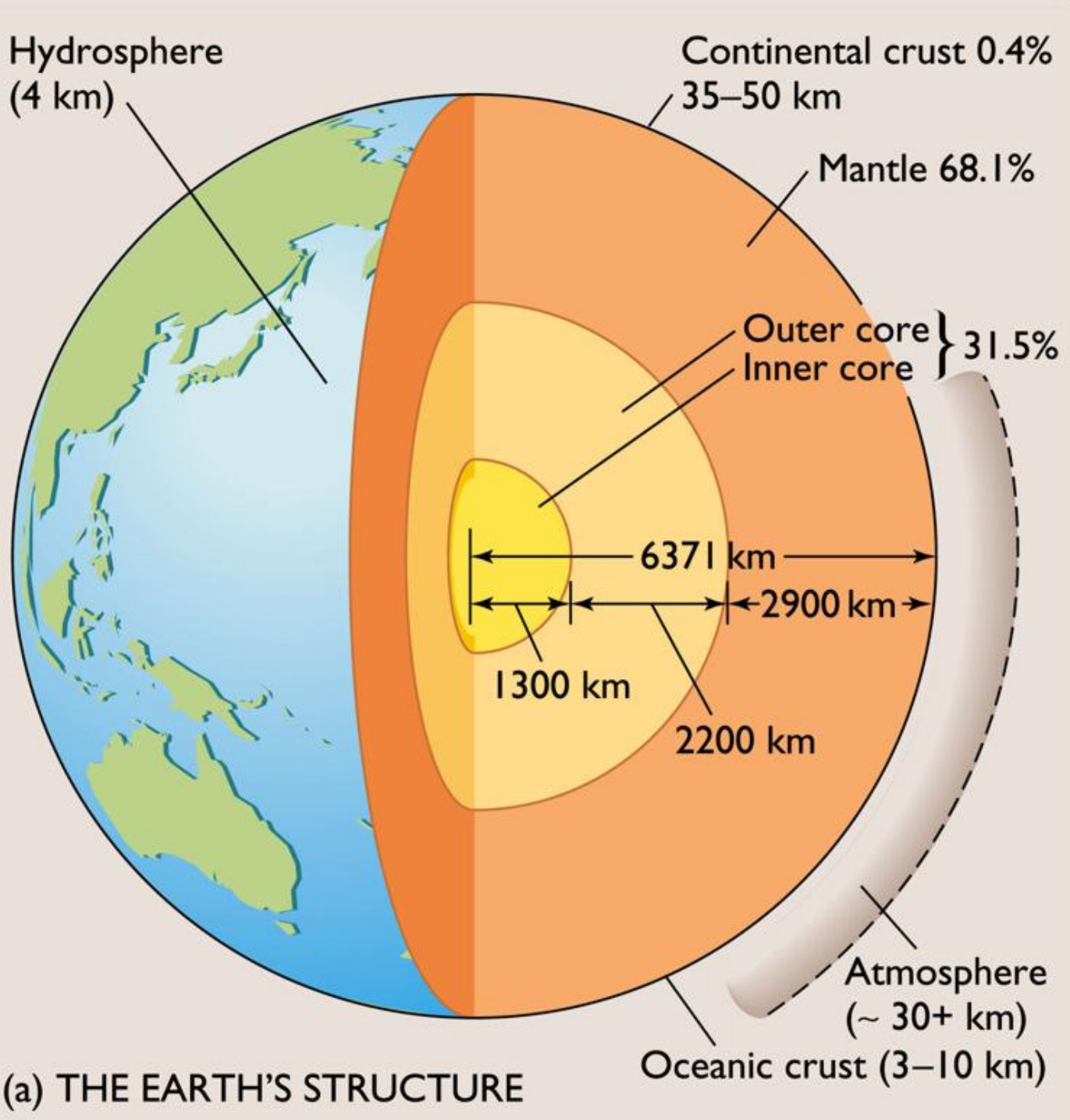
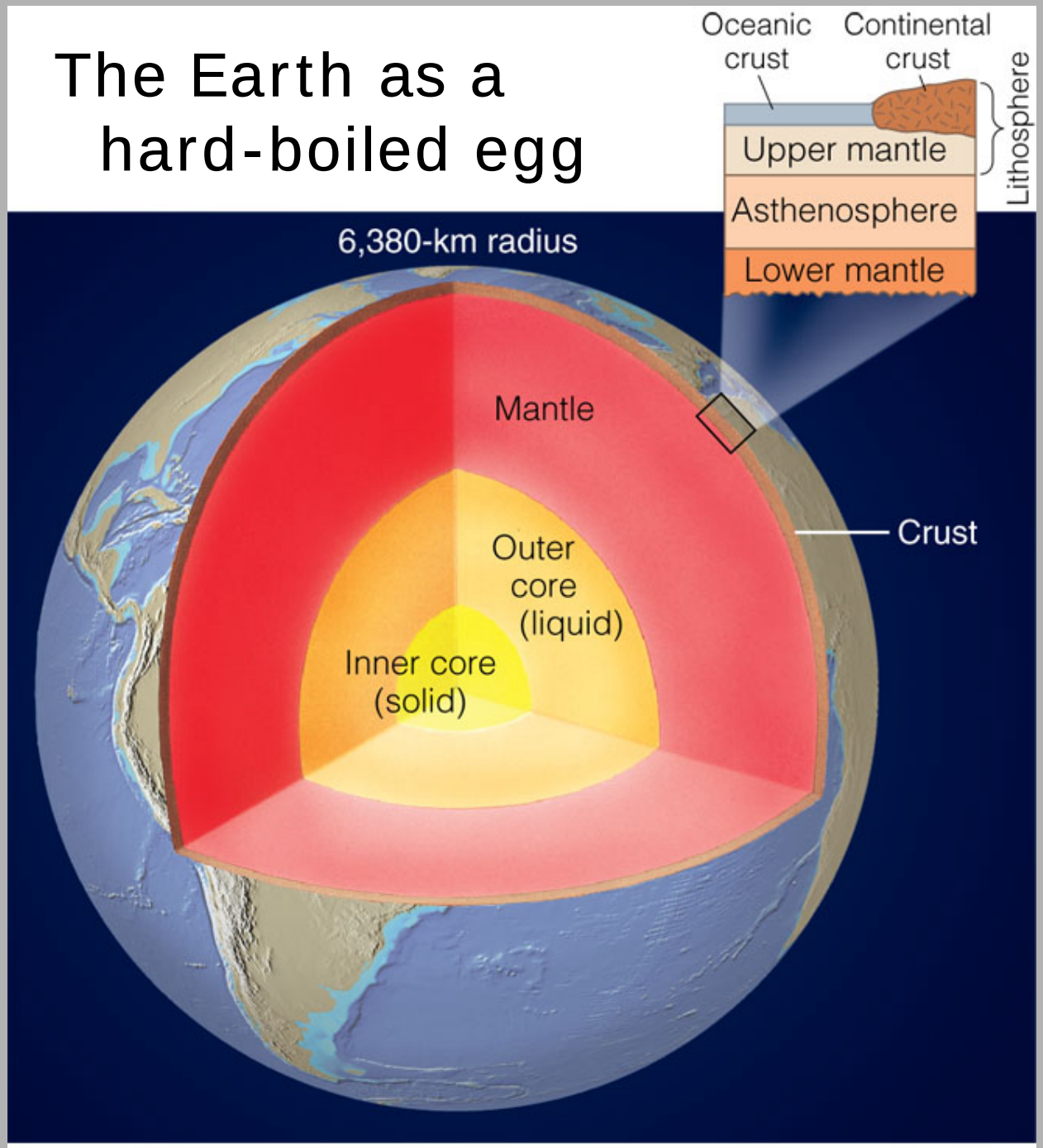
Earth Structure

note the external layers:

Hydrosphere
Atmosphere



The Earth as a hard-boiled egg



Earth Structure

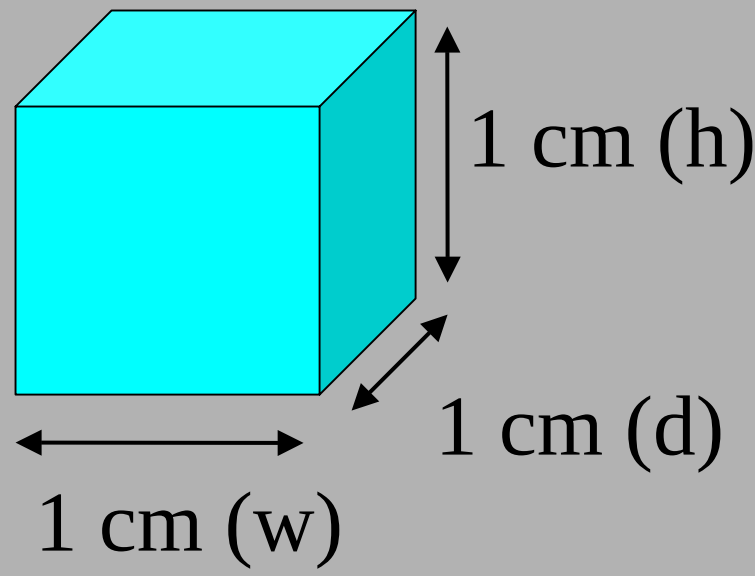
Average density of Earth = 5.5 g / cm^3

Density of crust: continents = 2.7 g / cm^3
ocean floor = 3.3 g / cm^3

Density

$$\textbf{Density} = \frac{\textbf{Mass}}{\textbf{Volume}}$$

Units are $\dfrac{\textbf{grams}}{\textbf{cm}^3}$

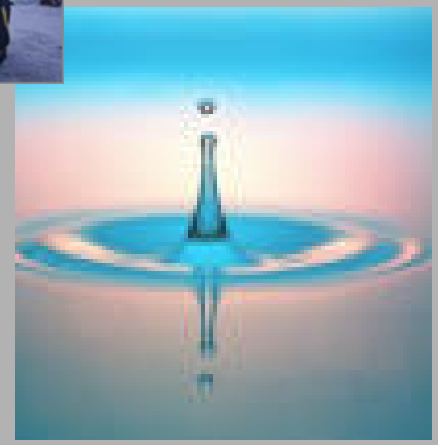


Density - some examples

Air = 0.00129 g/cm^3

Ice = 0.917 g/cm^3

Water = 1.0 g/cm^3 ***remember this***



Granite = 2.65 to 2.8 g/cm^3

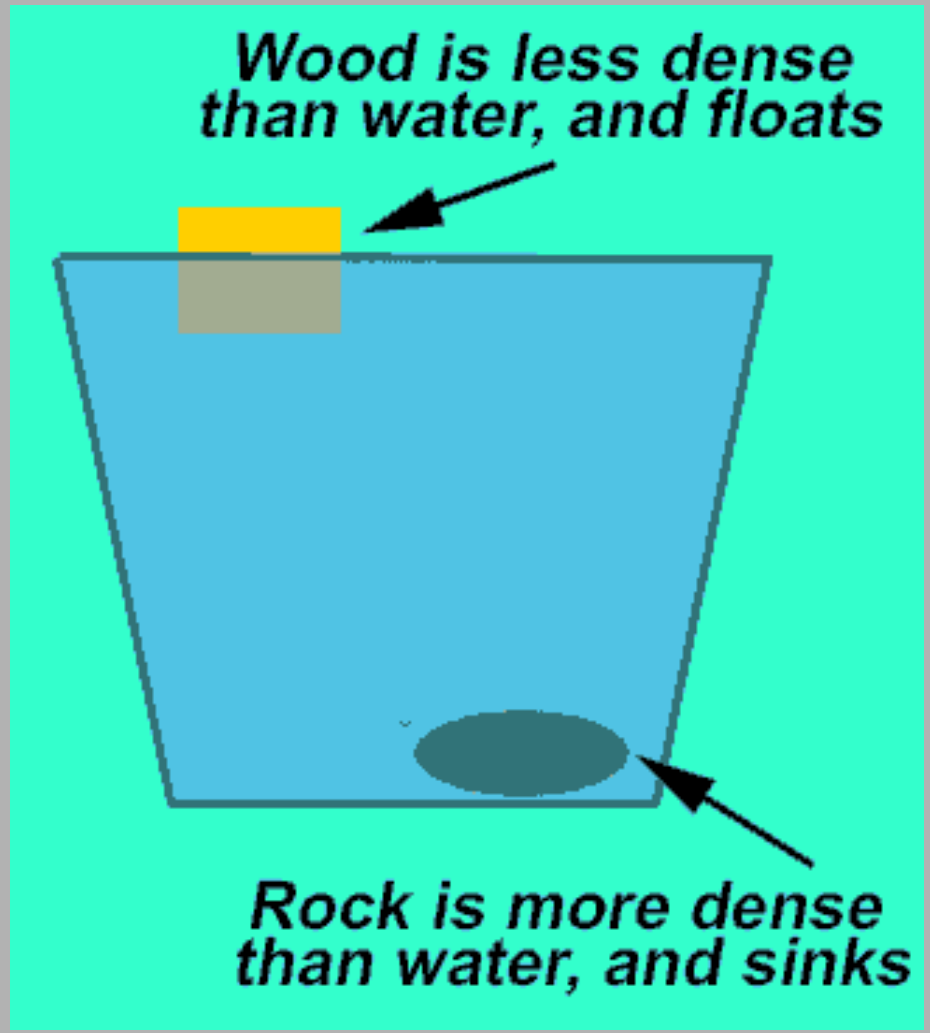
Iron = 7.86 g/cm^3

Gold = 19.3 g/cm^3

Density

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Would this demonstration work using solids?



Earth Structure

Average density of Earth = 5.5 g / cm^3

Density of crust: continents = 2.7 g / cm^3
ocean floor = 3.3 g / cm^3

this difference reflects mostly a change in **composition**, some effect from **pressure**

What does it imply that oceanic and continental crust are MUCH lower density than the average?

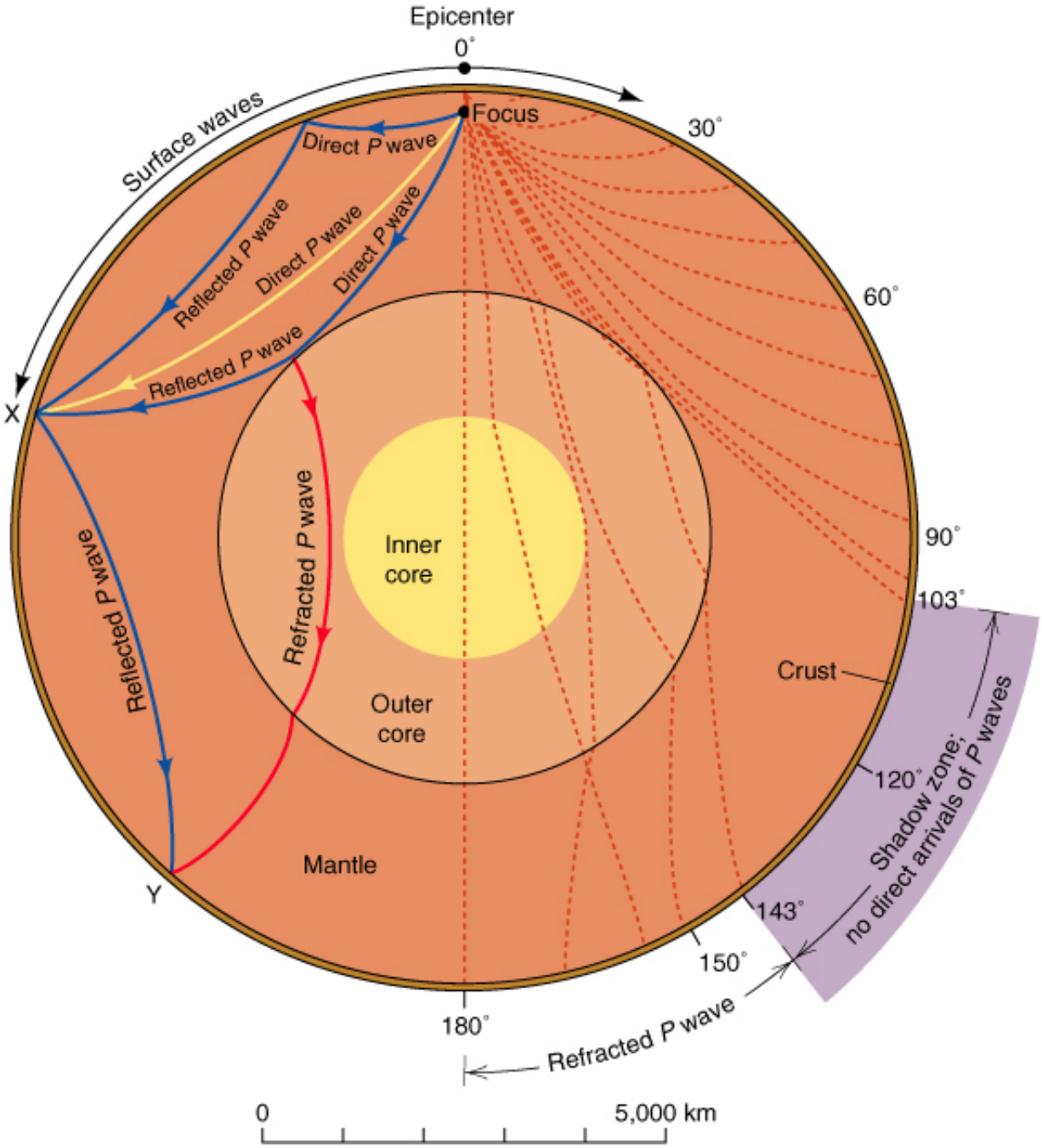
Earth Structure: Layers (version I)

Three main layers
by **composition**:

crust
mantle
core

These are determined by seismic velocity
and inferred rock composition

How Can We Interpret the *Internal* Layers of the Earth?



Seismic Waves

Different types of seismic waves

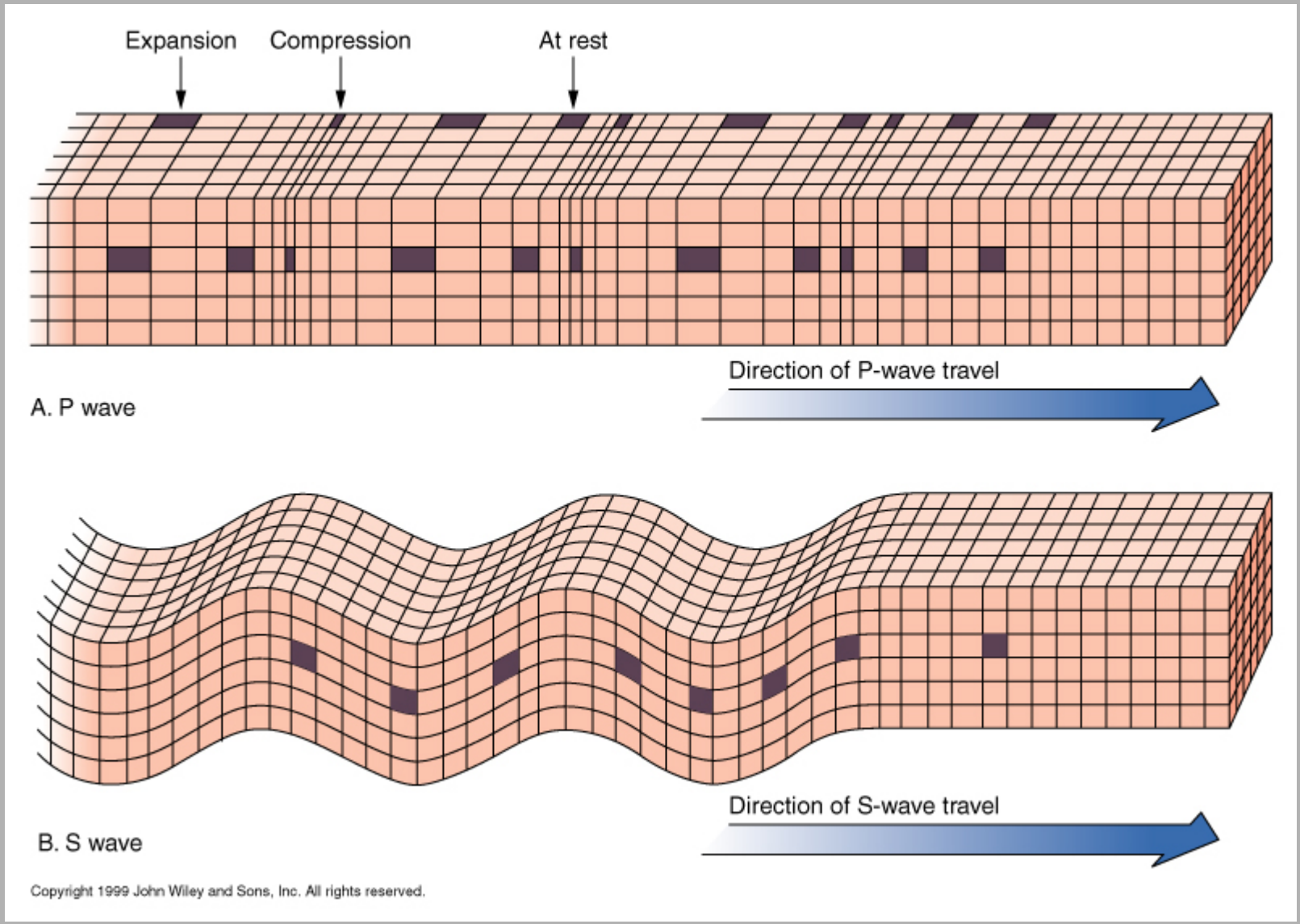
Compression and **shear** are determined by:
direction of initial motion and
characteristics of the medium

Example of diving into water

Pressure and Shear Waves

P

S



Seismic Waves

Primary (P) Waves -- **compression**

higher velocity - arrive first

propagate through solid or liquid

significantly lower velocity in liquid

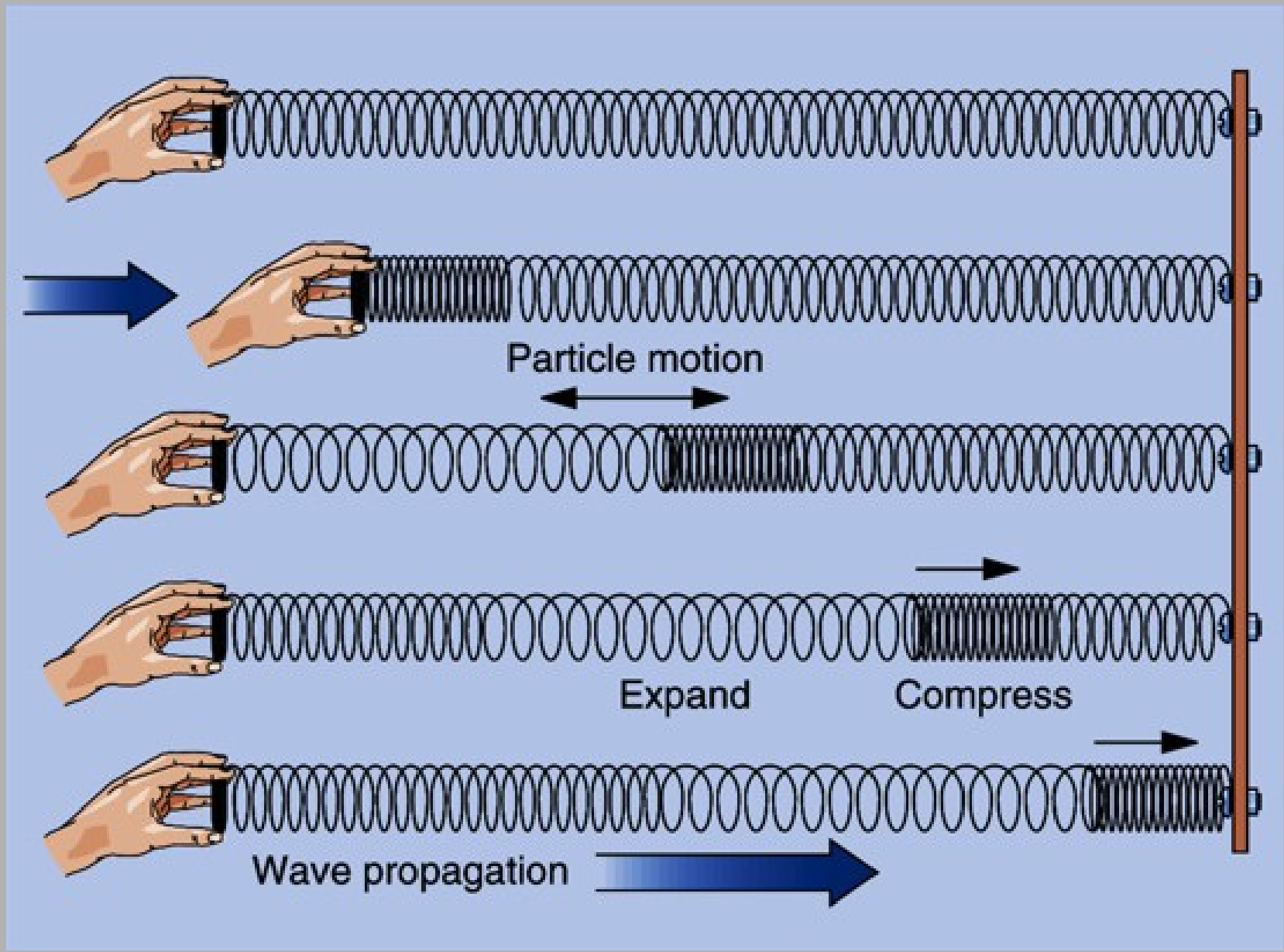
Secondary (S) Waves -- **shear**

lower velocity

propagate through solid, but not through liquid

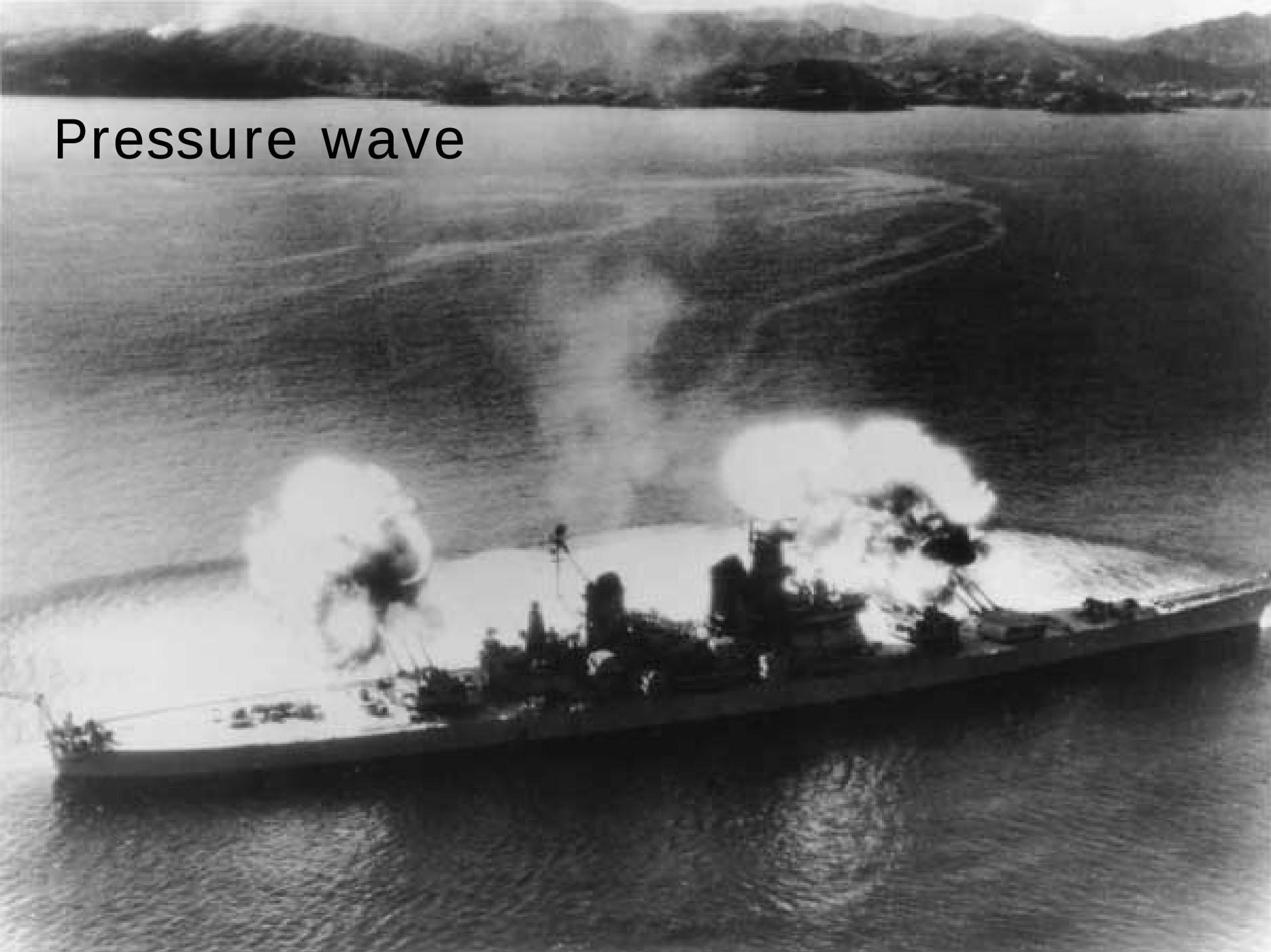
can result in “shadowing”

P wave (Primary or “pressure”)

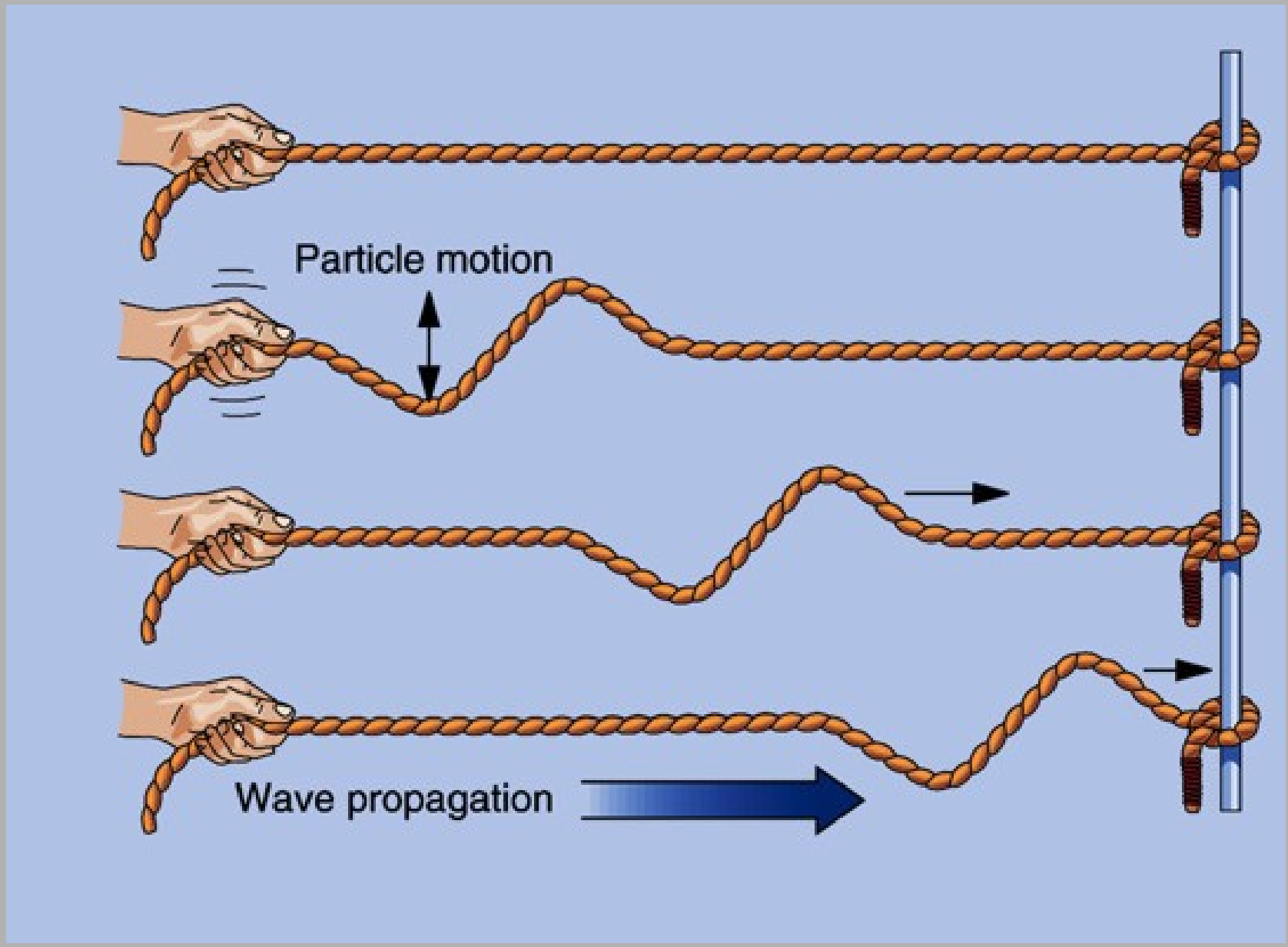


Pressure wave

- Propagates outward in all directions (spherical)


Pressure wave

S wave (Secondary or “shear”)



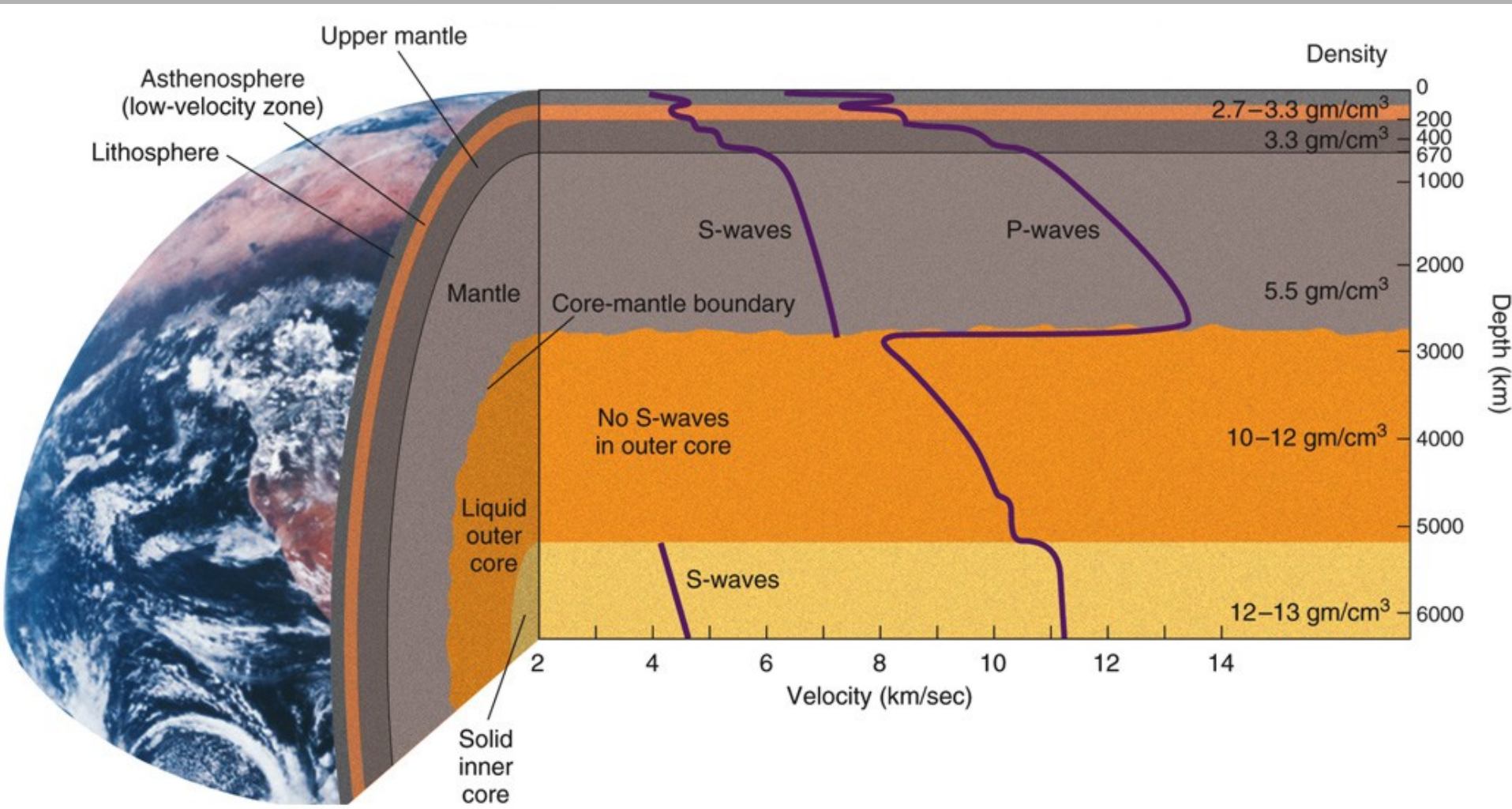
Seismic Waves

Velocity of seismic waves through:

	V_p	V_s
Crust	5 - 7.4	3 - 4 km / sec
---------- Moho separates layers ----------		
Mantle	7.9 - 8.2	4.7 - 4.8 km / sec

Earth layers by seismic velocity

Velocity changes with material and density



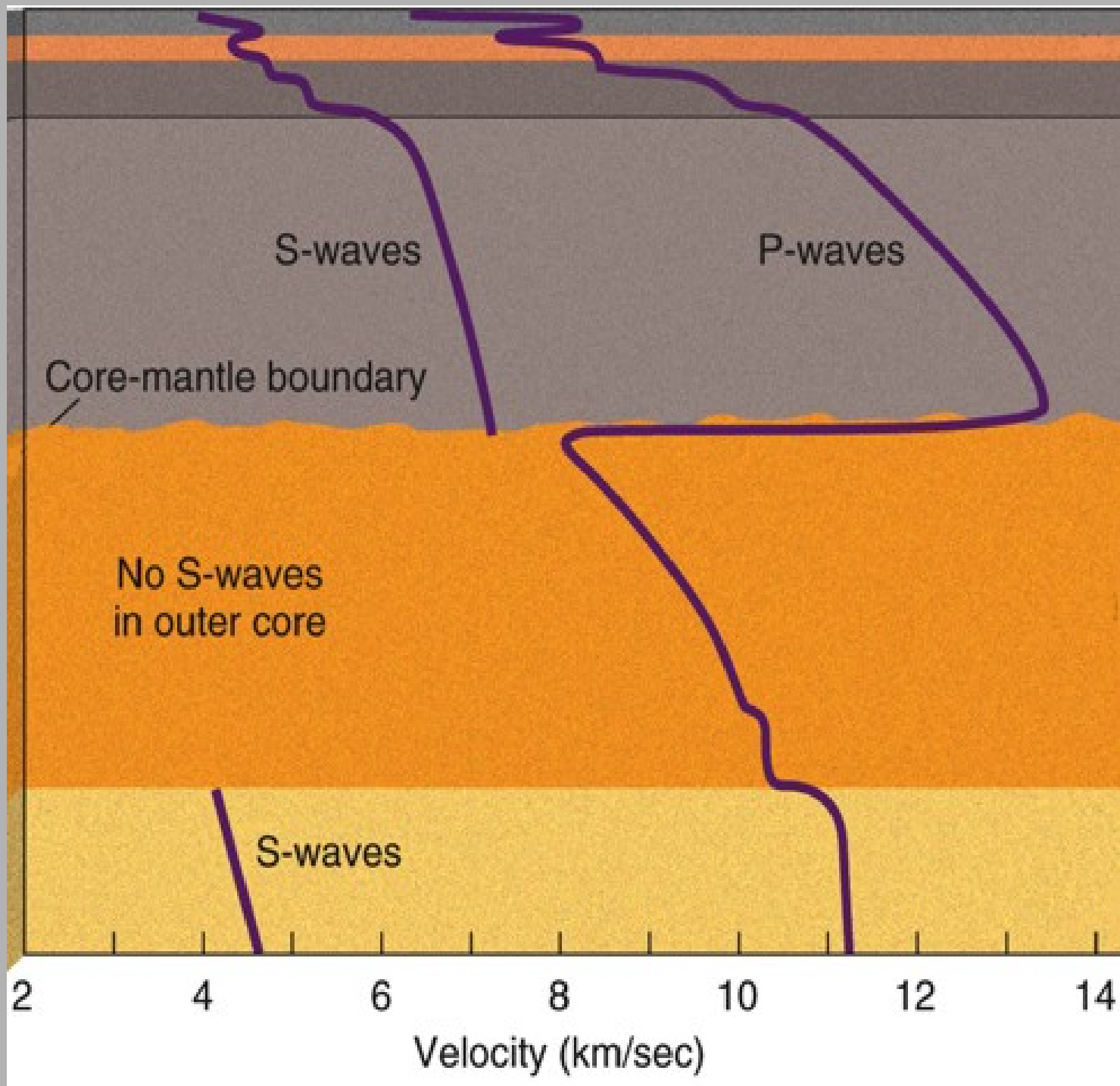
crust

upper mantle

lower mantle

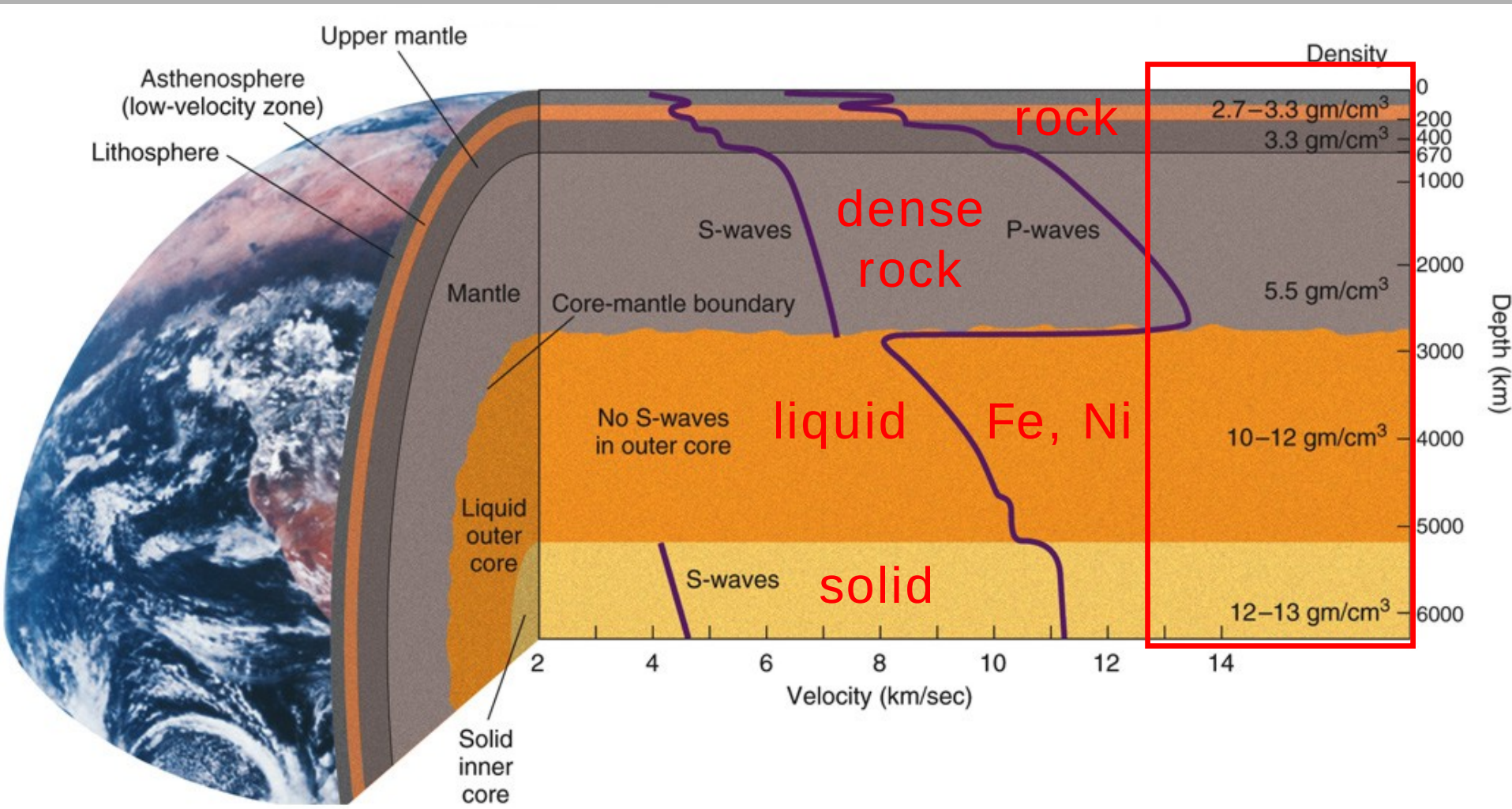
outer core (liquid)

inner core (solid)

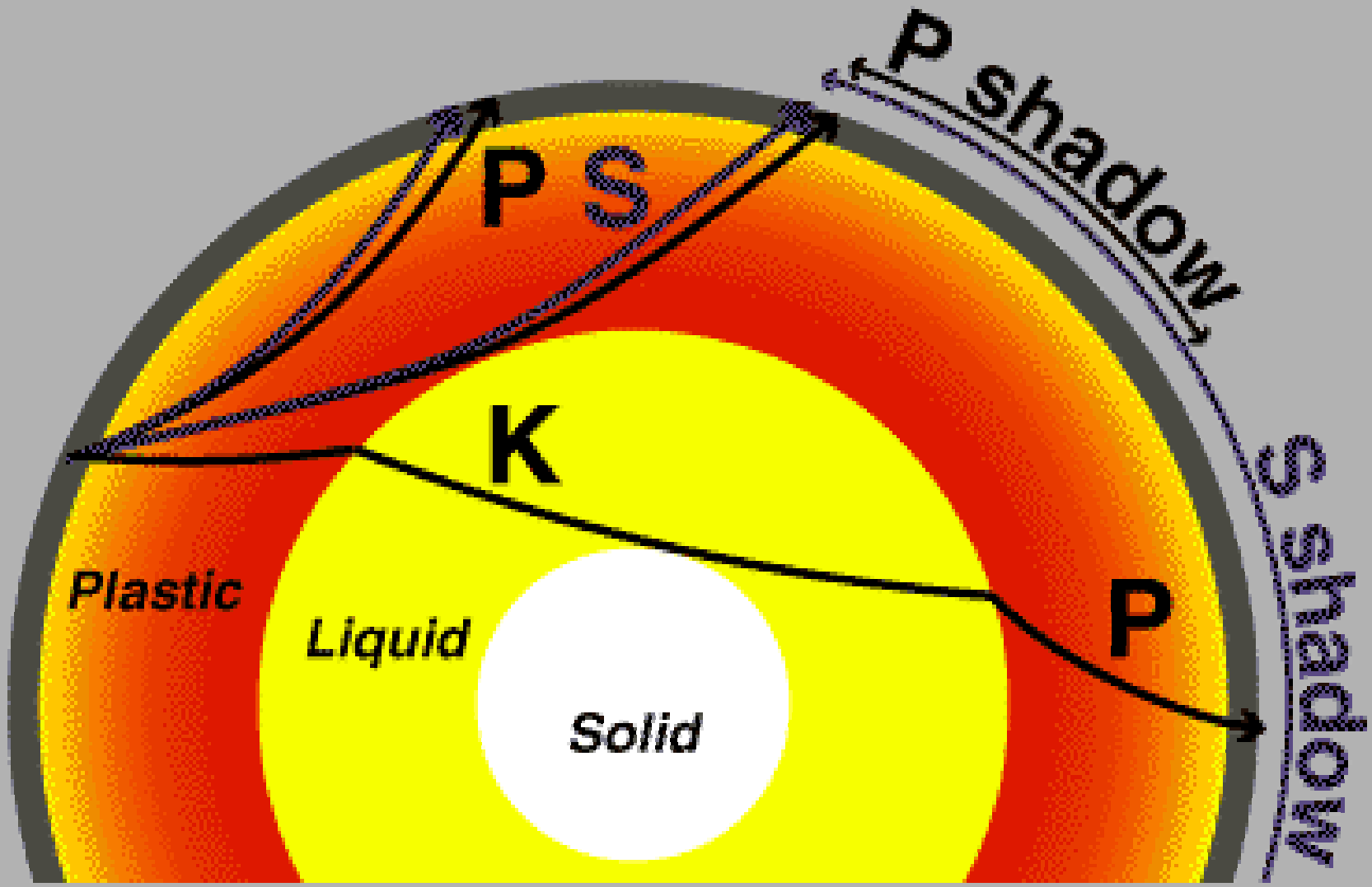


Earth layers by seismic velocity

Note the densities of the mantle and core



Seismic Shadow Zones

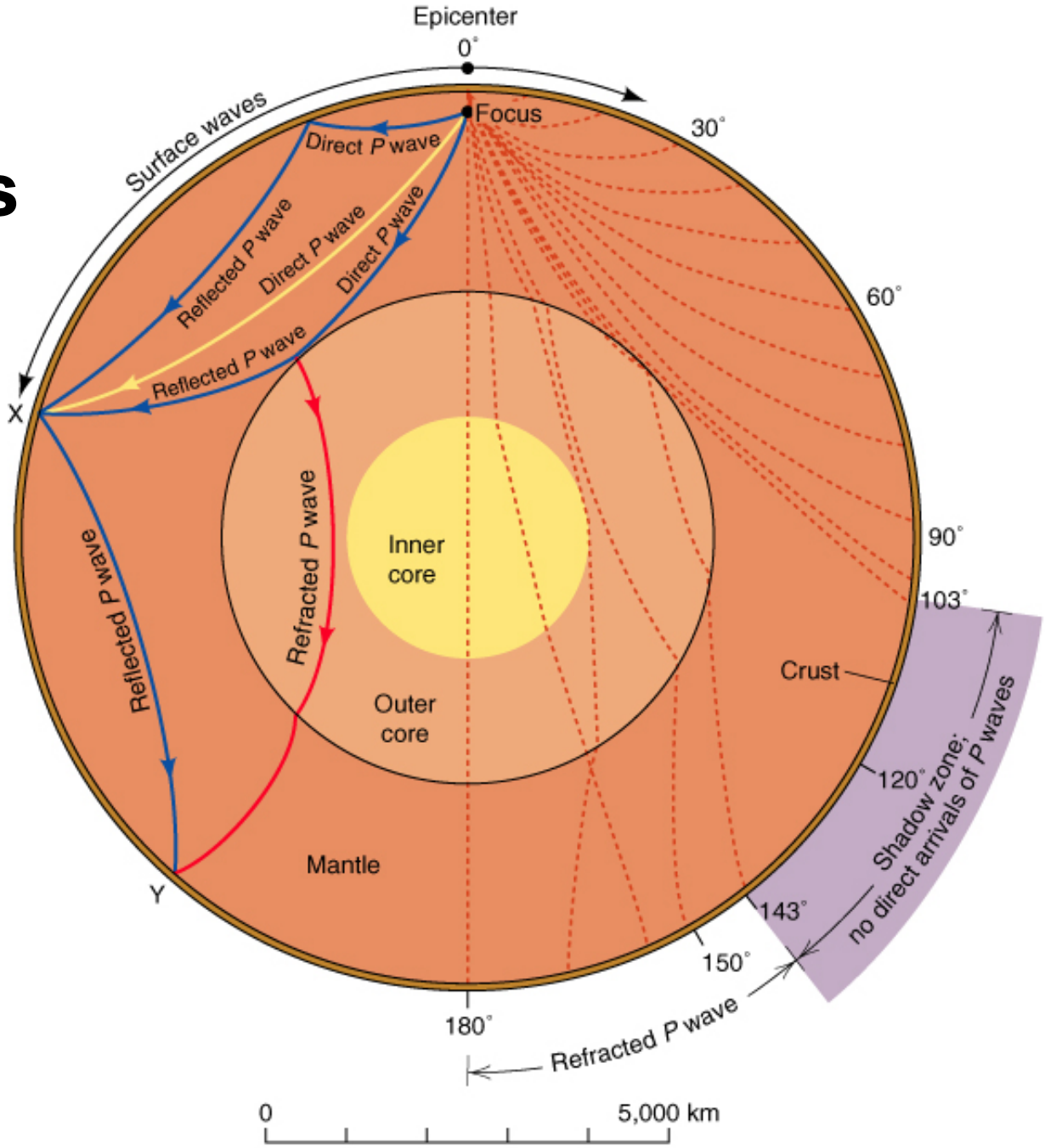


Effect of **Refraction**

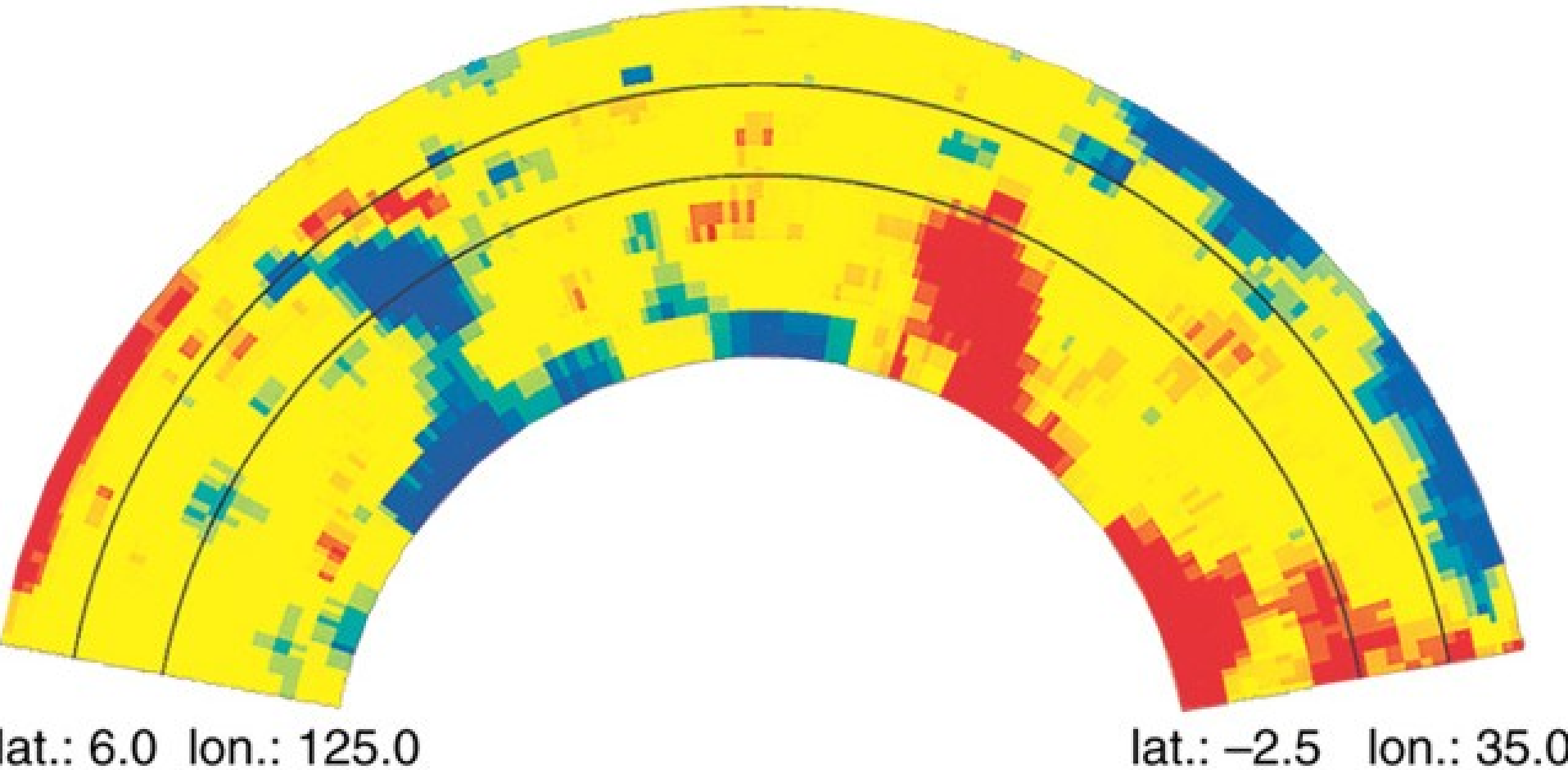
any wave bends toward the **slower** medium

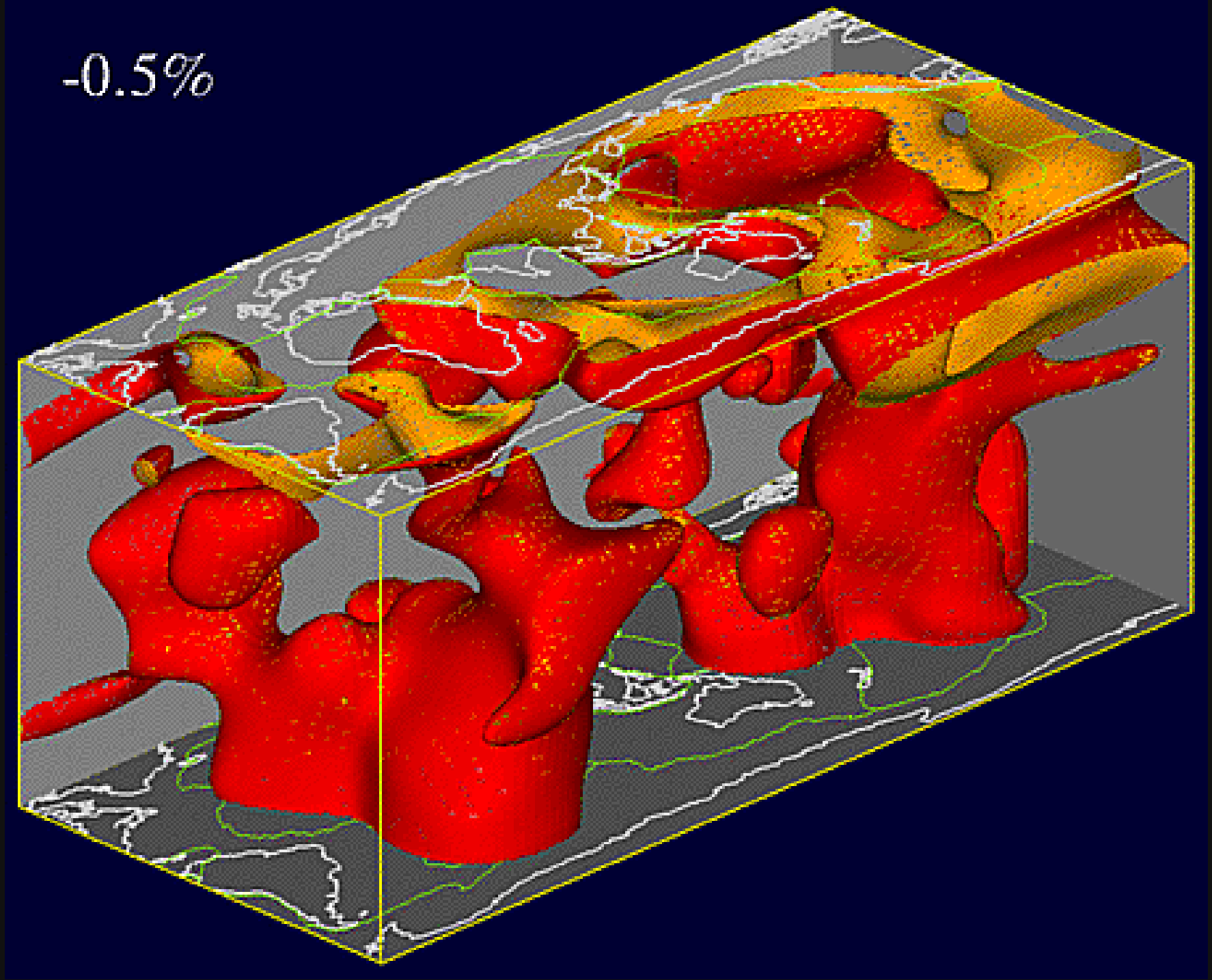
Tomography of the Earth's Interior

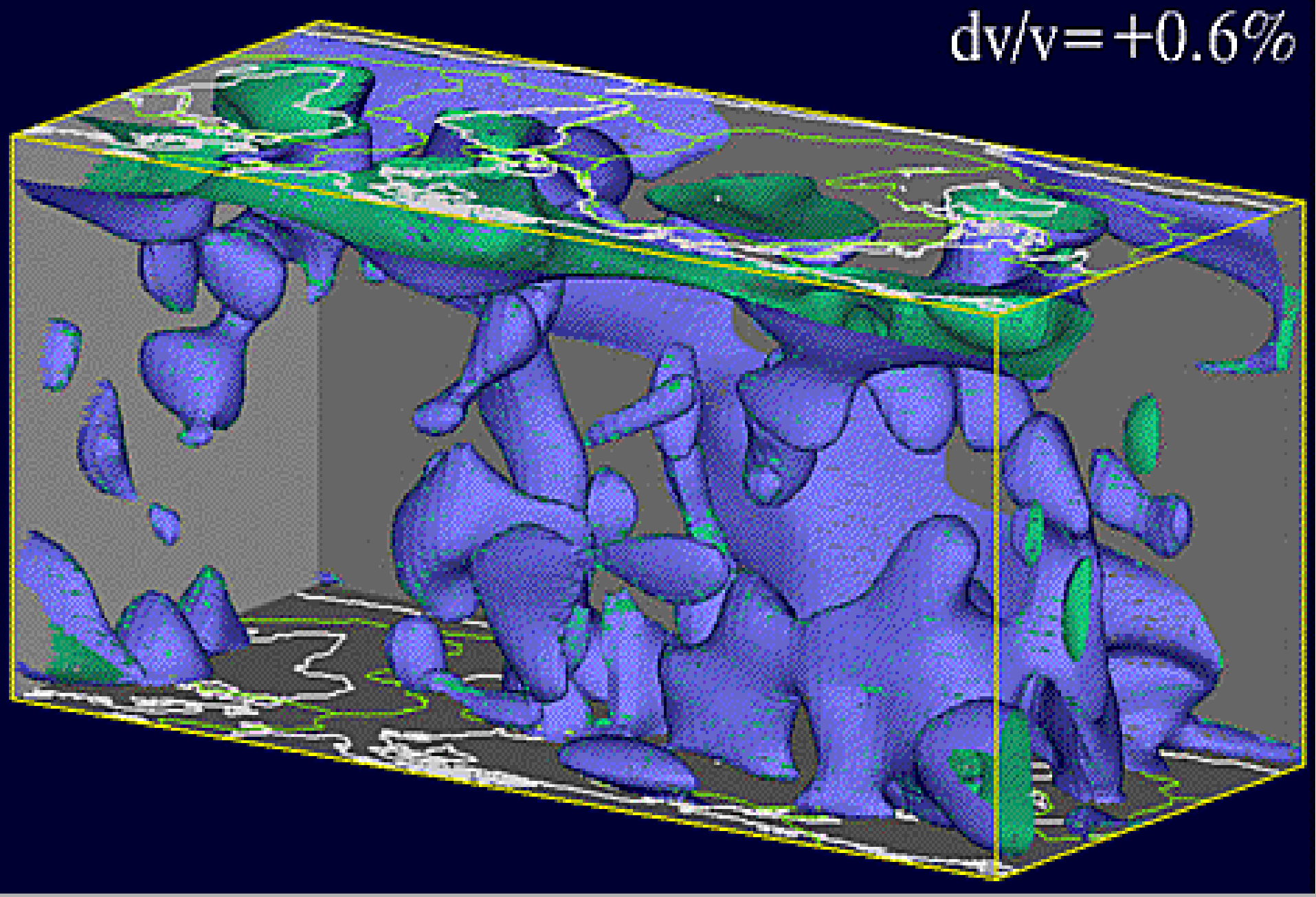
What is a CAT scan?



Cross section of mantle velocity




-0.5%


dv/v=+0.6%

Earth Structure: Layers (version II)

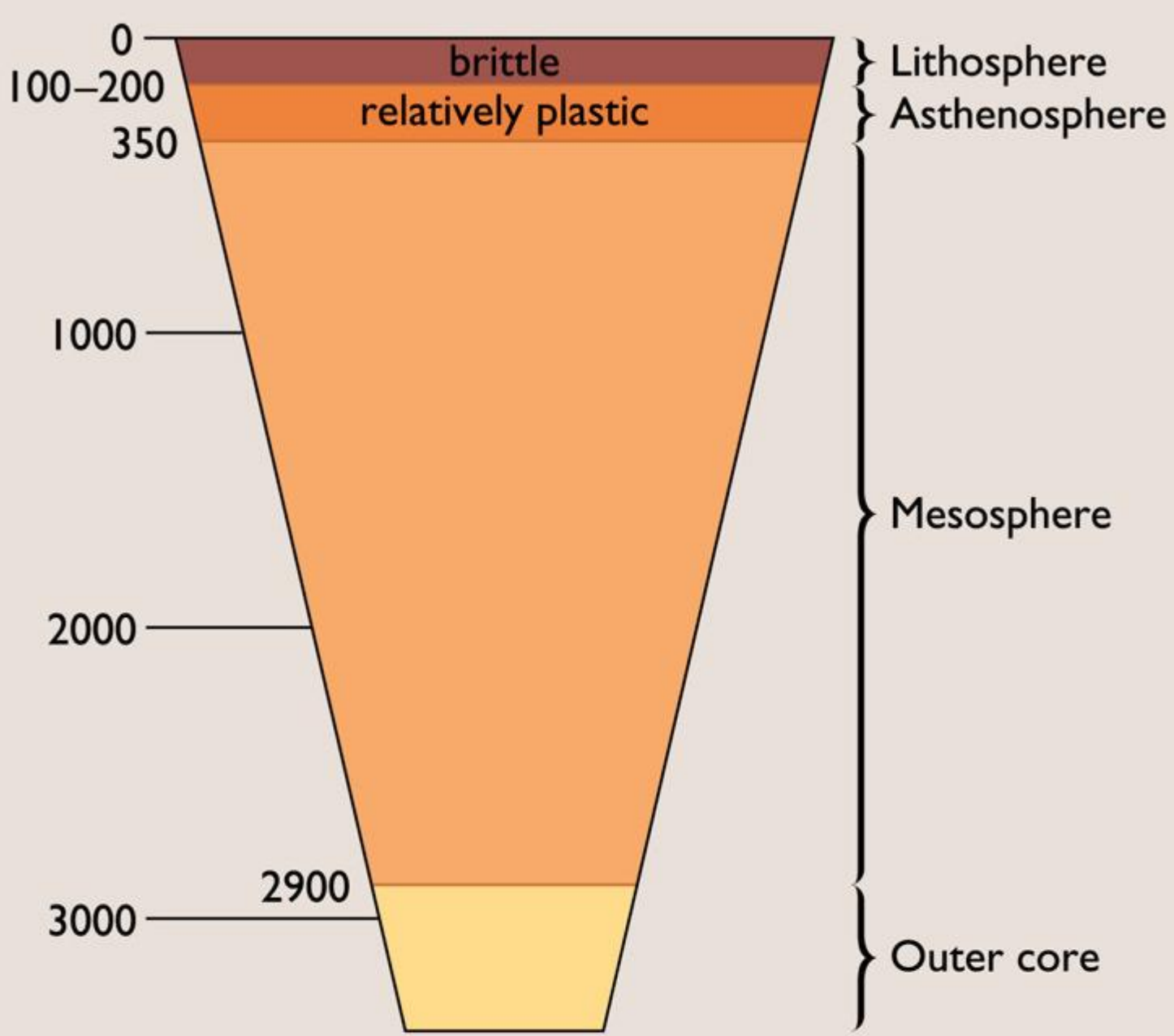
Another way of looking at Earth's interior :

defined by strength and viscosity
(not composition)

Lithosphere
Asthenosphere
Mesosphere
Core

Earth Structure

Layers



(b) LAYERED, INTERNAL STRUCTURE OF THE EARTH

Earth Layers: Lithosphere

lithosphere – “rock” (or “hard”)

cool, rigid rock near surface

crust and upper layer of mantle

<u>on average</u>:
100 km thick beneath oceans
150 km thick beneath continents

Earth Layers: Asthenosphere

asthenosphere -- “soft” (“hot Silly Putty”)

near melting point

mixture of melted, partially melted, and solid components

flows with pressure
100 - 700 km

Earth Layers : Mesosphere

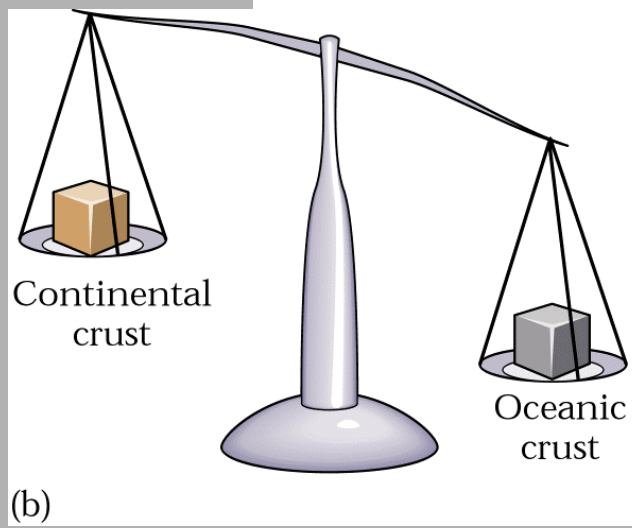
mesosphere -- “middle”

pressure dominates -- rocks are solid

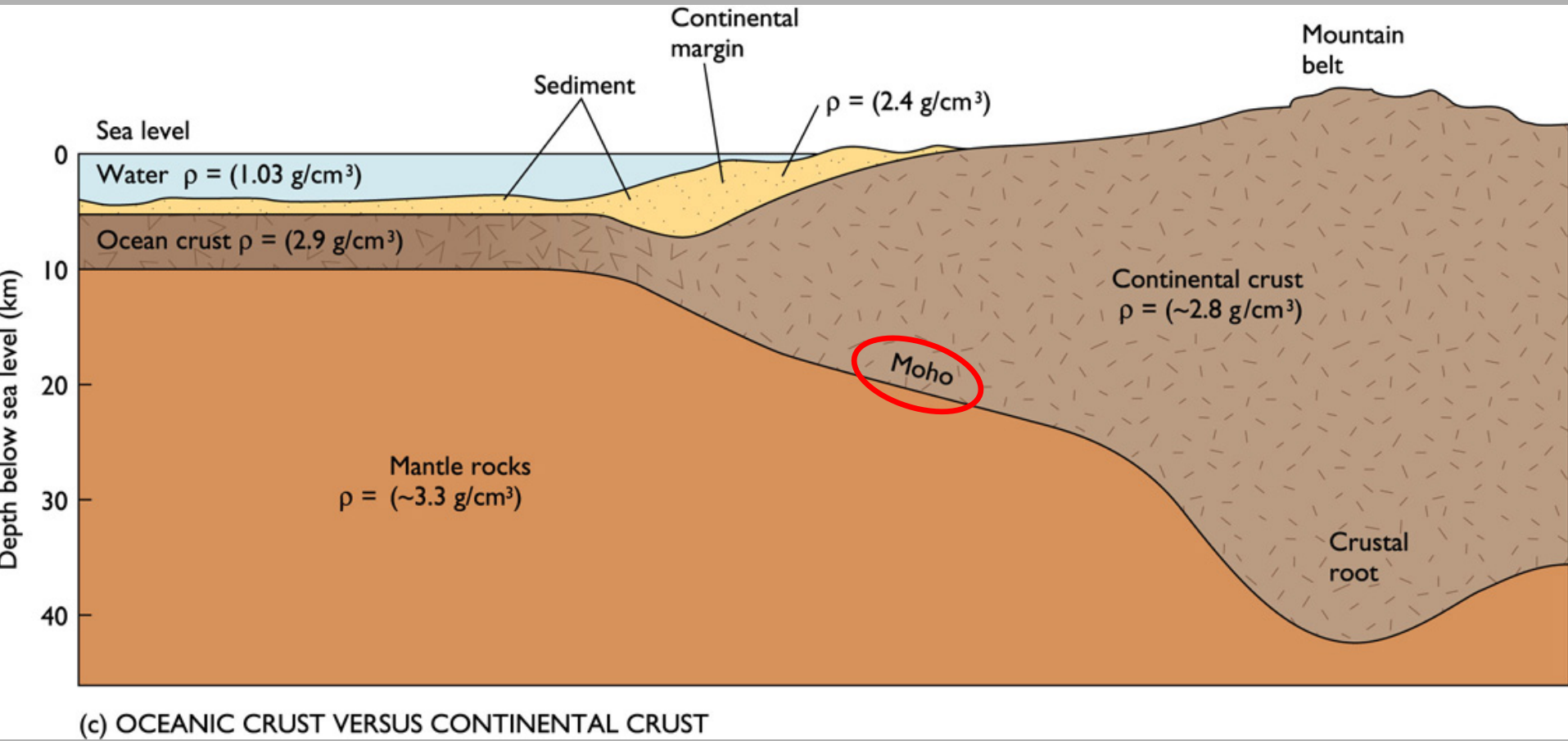
most of the mantle
700 - 2900 km

Lithosphere

Relative density:



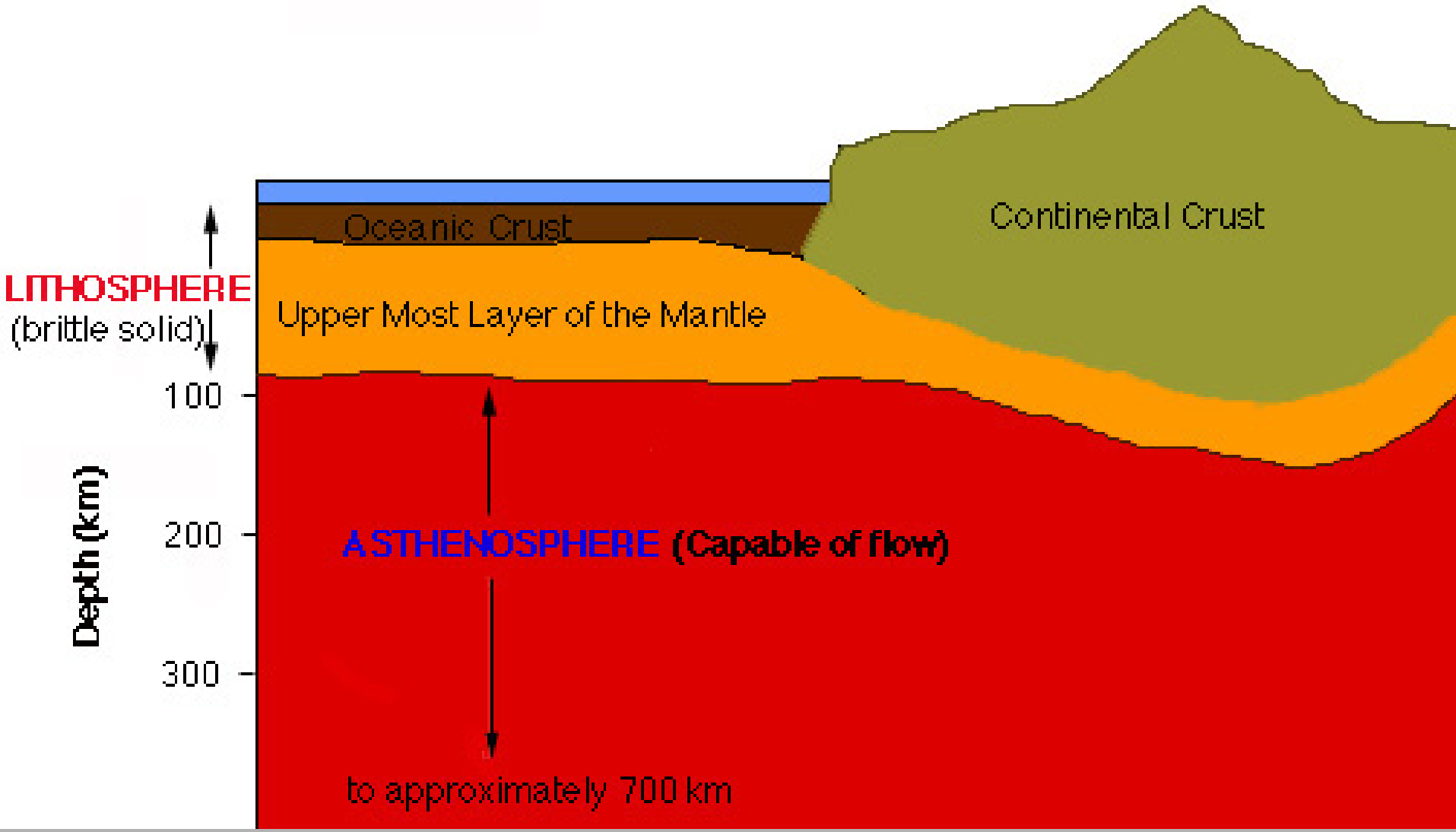
Cross Section of Crust (and Upper Mantle)



(c) OCEANIC CRUST VERSUS CONTINENTAL CRUST

The Moho – boundary between the Crust and Mantle

Earth Structure: Layers

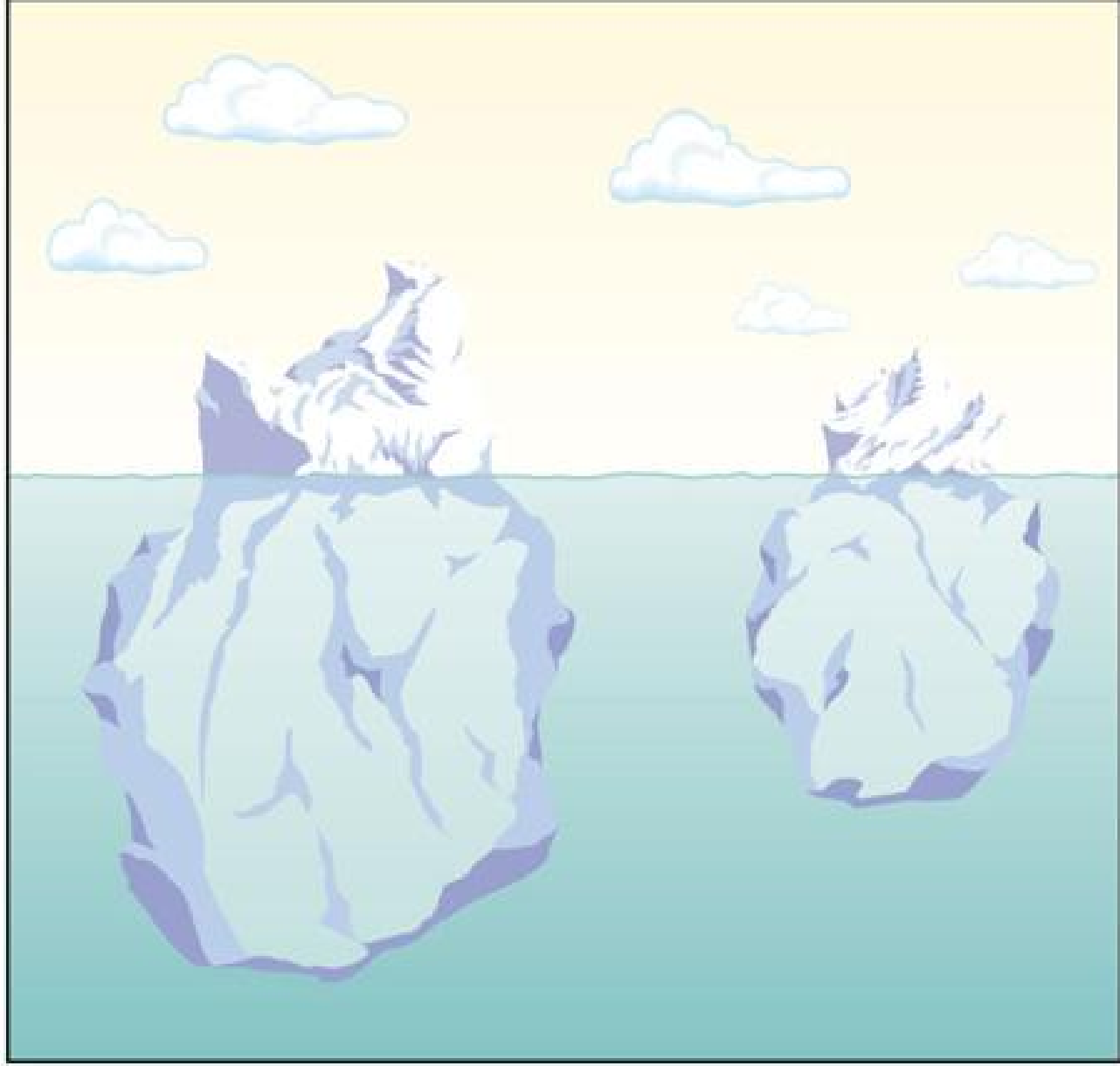


Granite – Diorite – Basalt

Continents – Andes-type subduction – Ocean basins

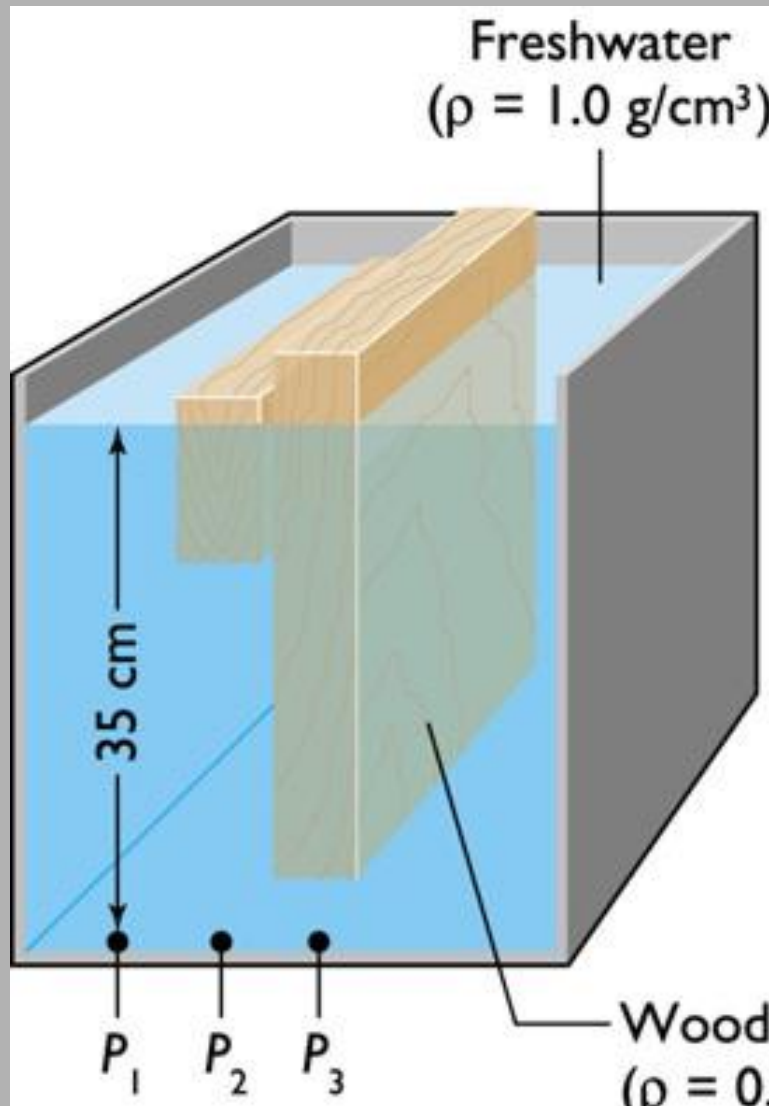
Isostasy

Buoyancy
and
Plasticity



(b) ICEBERGS

Isostasy Experiment



$P = \rho g h$ = (density)(gravity)(height)

$P_1 = g[(1.0)(35)] = 35\ g$
(WATER)

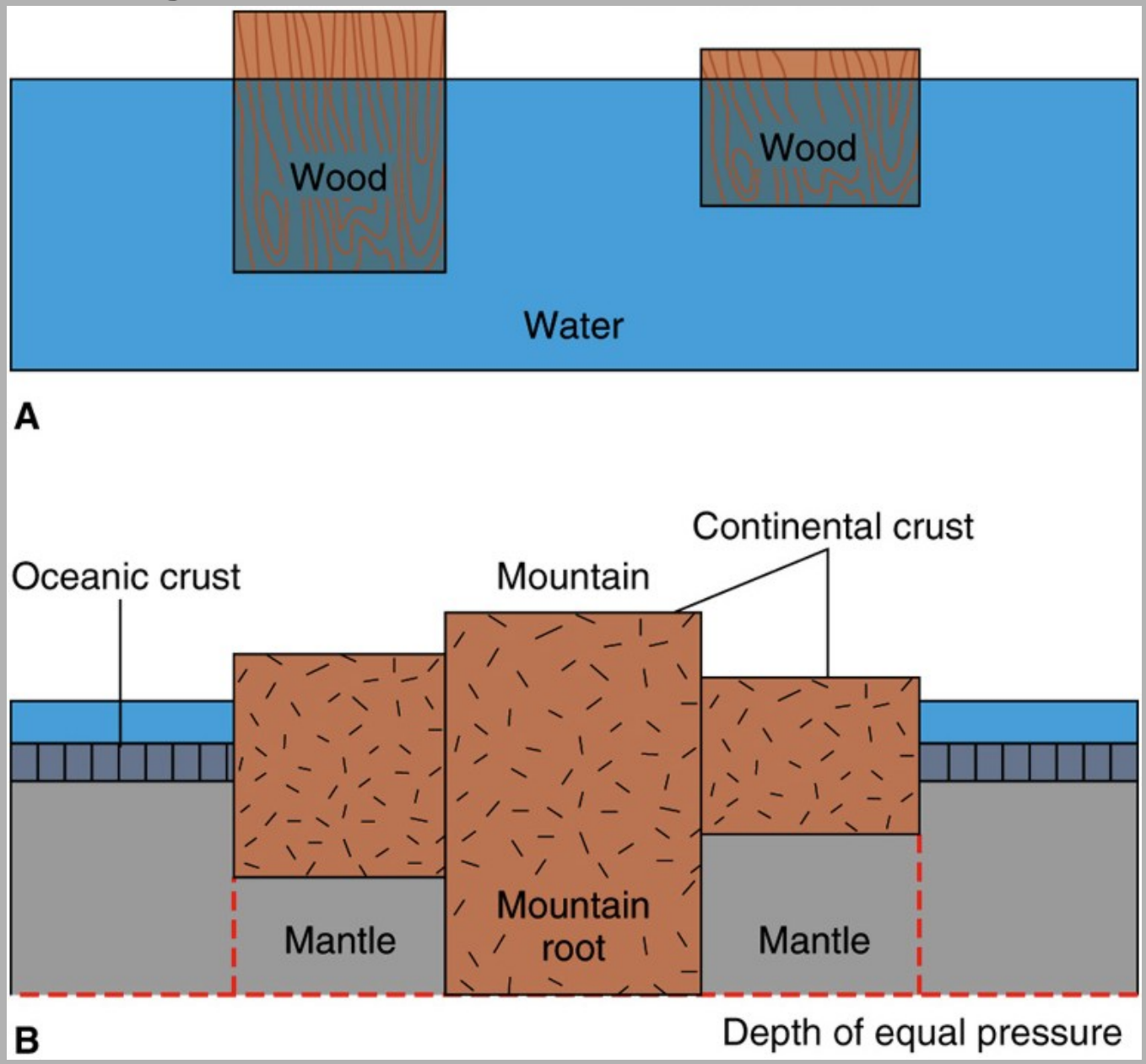
$P_2 = g[(0.95)(10.5)] + [(1.0)(25)] = 35\ g$
(WOOD + WATER)

$P_3 = g[(0.95)(31.6)] + [(1.0)(5)] = 35\ g$
(WOOD + WATER)

$P_1 = P_2 = P_3$

(a) BUCKET EXPERIMENT

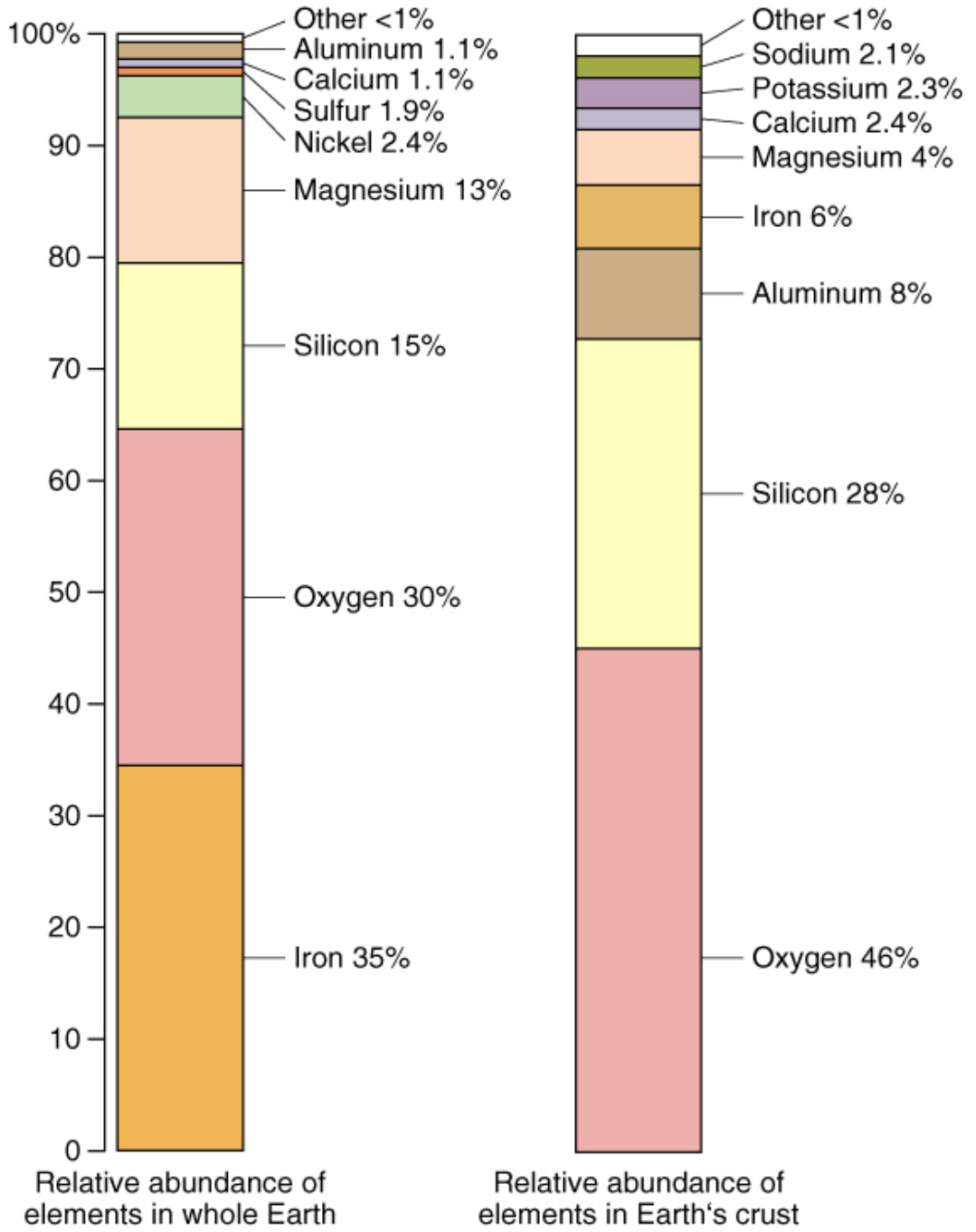
Isostasy of continents



Chemical Differentiation

Whole Earth is enriched with:
- iron
- magnesium
- nickel (core)

Crust has more:
- silicon
- oxygen
- aluminum



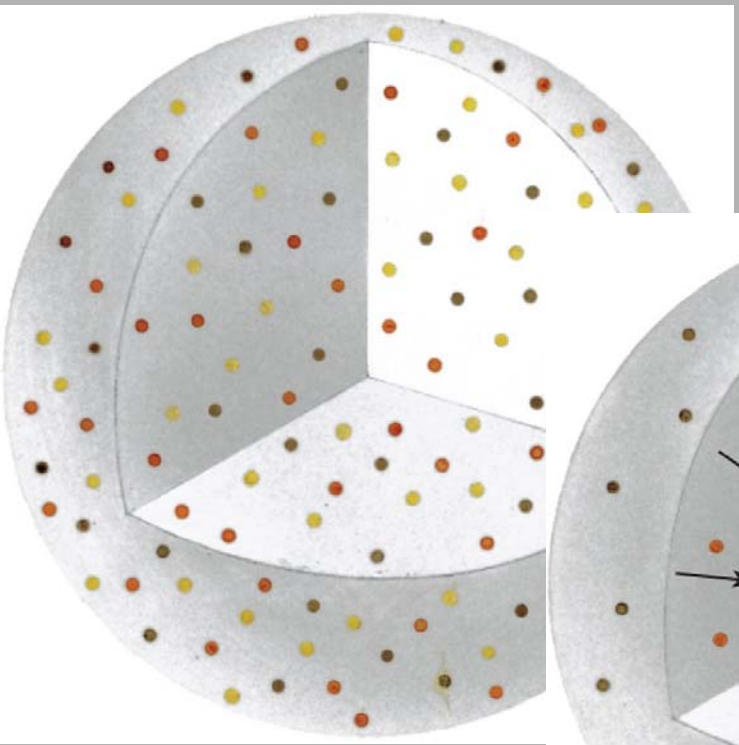
Composition - density of compounds

Si, Al, O	**sialic**	**crust**
Fe, Mg, SiO_4	**mafic**	**mantle**
Fe, Ni	**metallic**	**core**

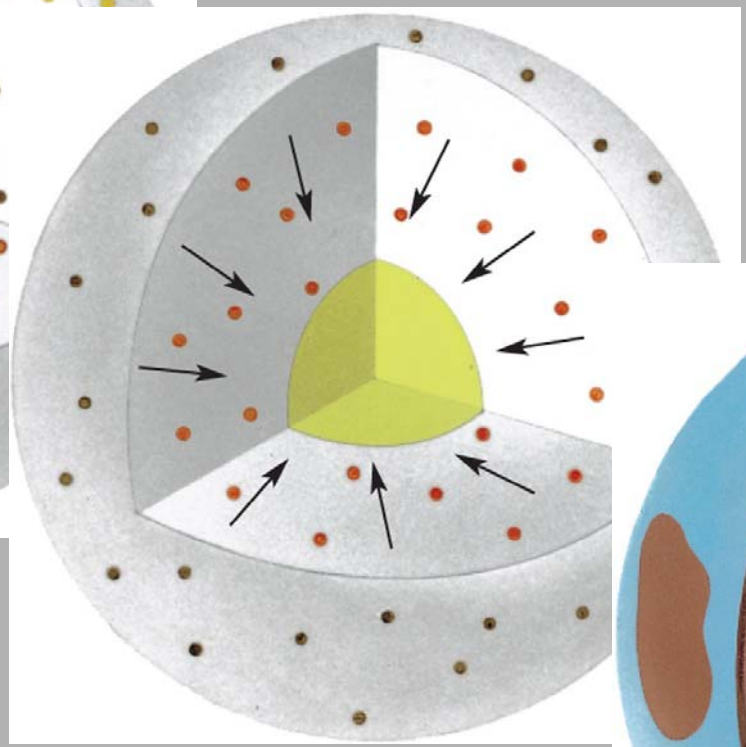
Why Differentiation?

Early evolution of the planet

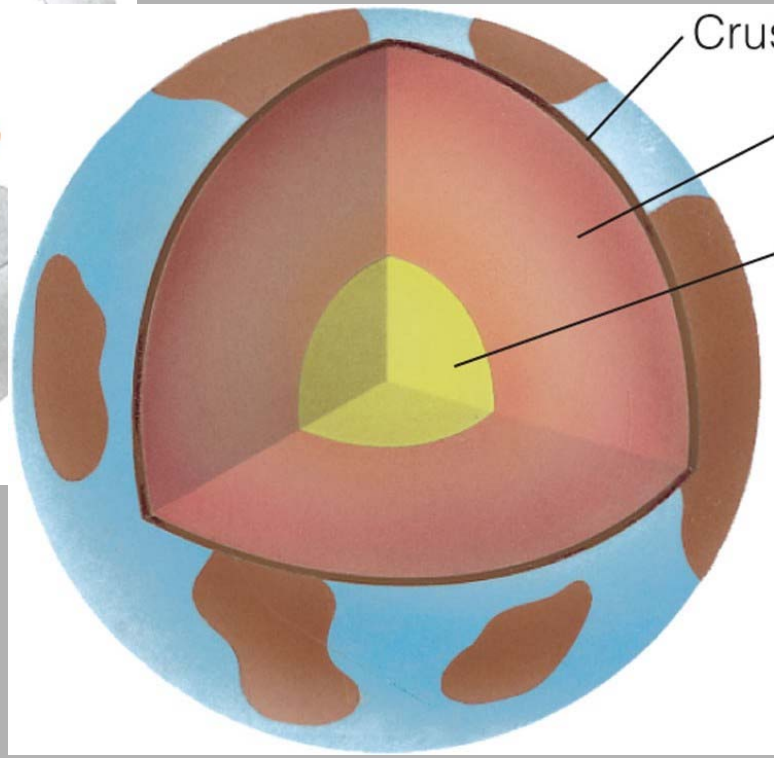
Accretion, melting, and differentiation



Accretion



Melting



Differentiation

A quick review

Just to make a point:

In your notebook, write down the following …

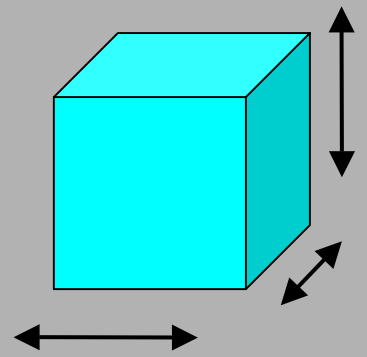
Venus Mars Jupiter

Sun Moon Earth

A quick review

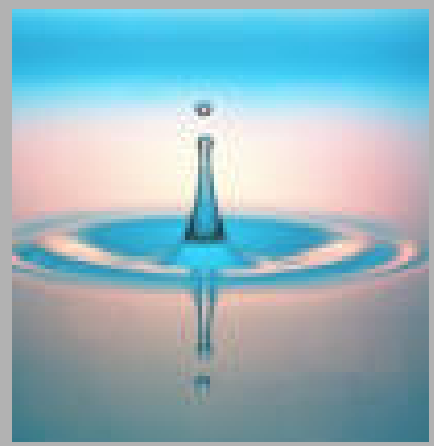
A basic concept: Density

mass per unit volume



In the metric system, what is the reference for density?

Water = 1.0 g/cm^3

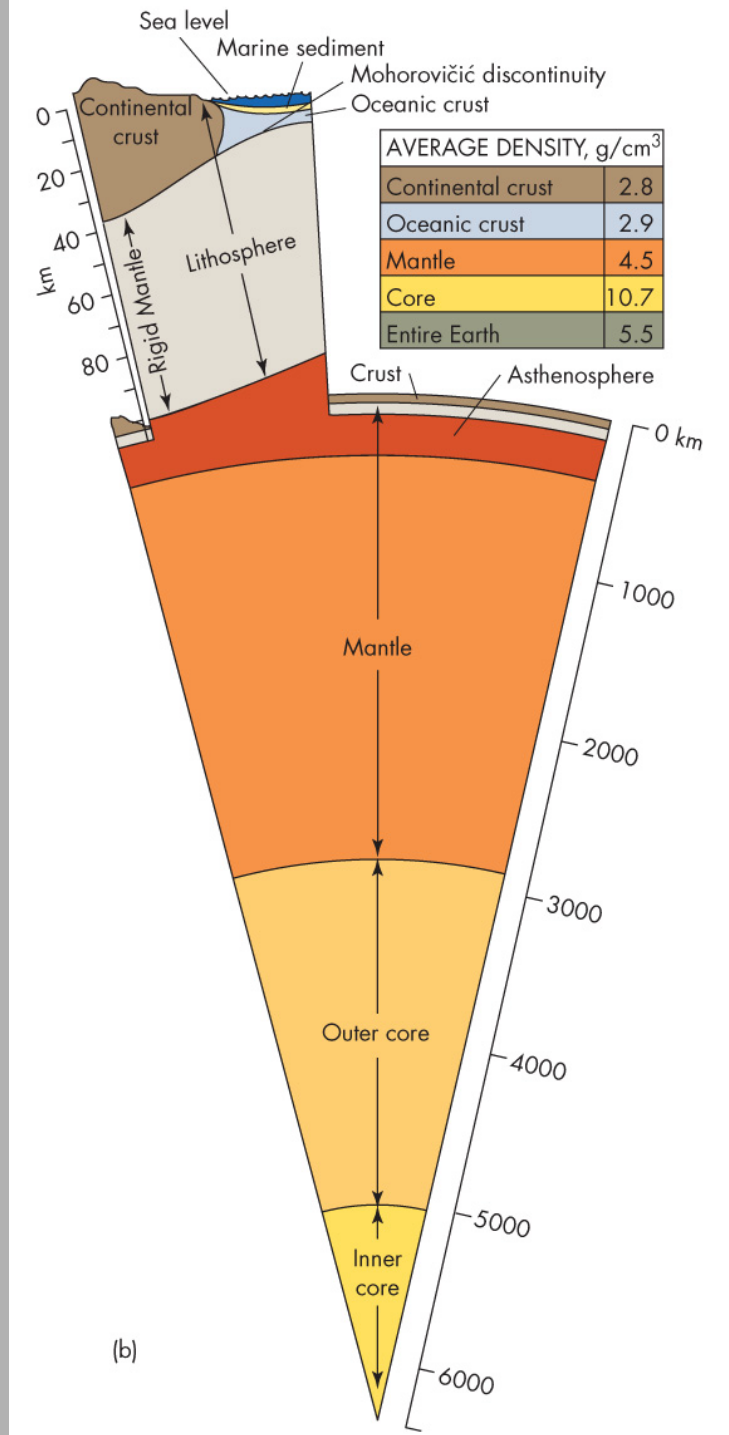


A quick review

The interior layers of the Earth are stratified by density

From the top:

Crust	rock
Mantle	dense rock
Core – outer	metal
– inner	(Fe, Ni)



A quick review

How can we tell what's inside the Earth?

Drilling to recover rocks? Does that work?

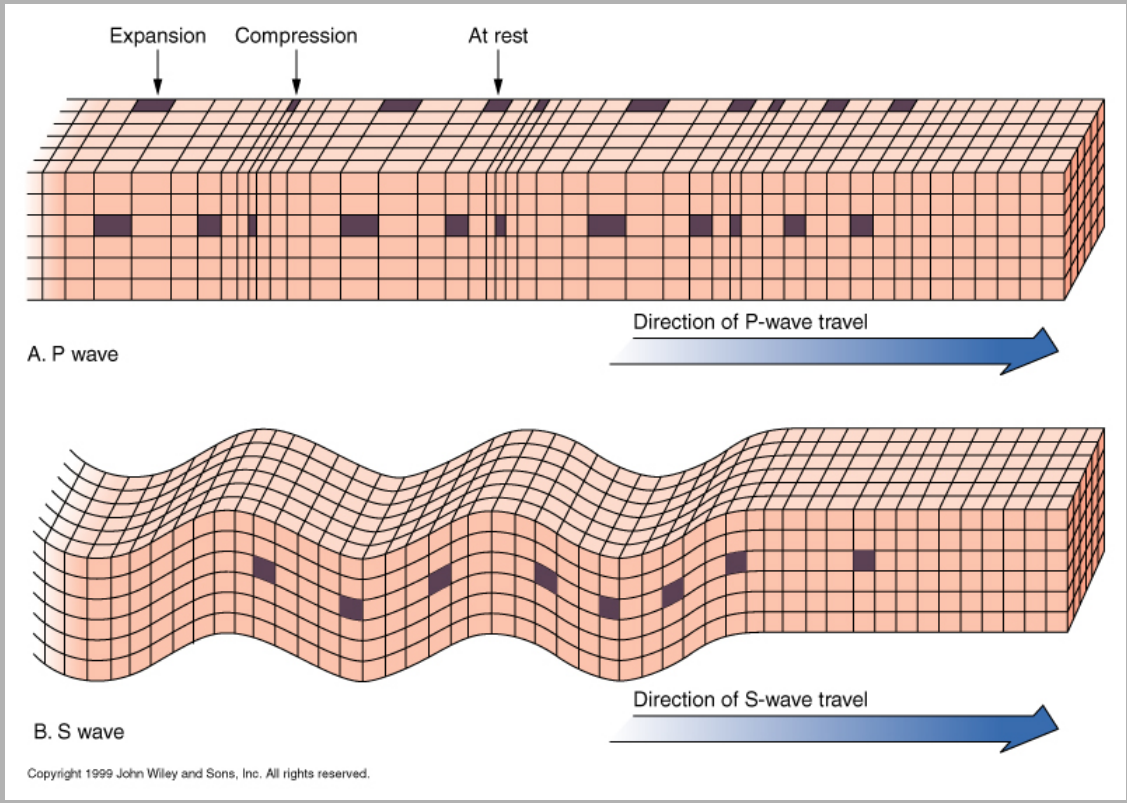
Listening around the outside. Remote sensing.

Space rocks – meteorites

A quick review

Seismic waves: Pressure (P) and Shear (S)

P



S

compression
faster
move through
solid or liquid

shearing
slower
can NOT move
through liquid

What produces seismic waves?

A quick review

What can happen to seismic waves inside the Earth?

Change velocity – What's the relationship?

Hot : Lower Density : Lower Velocity

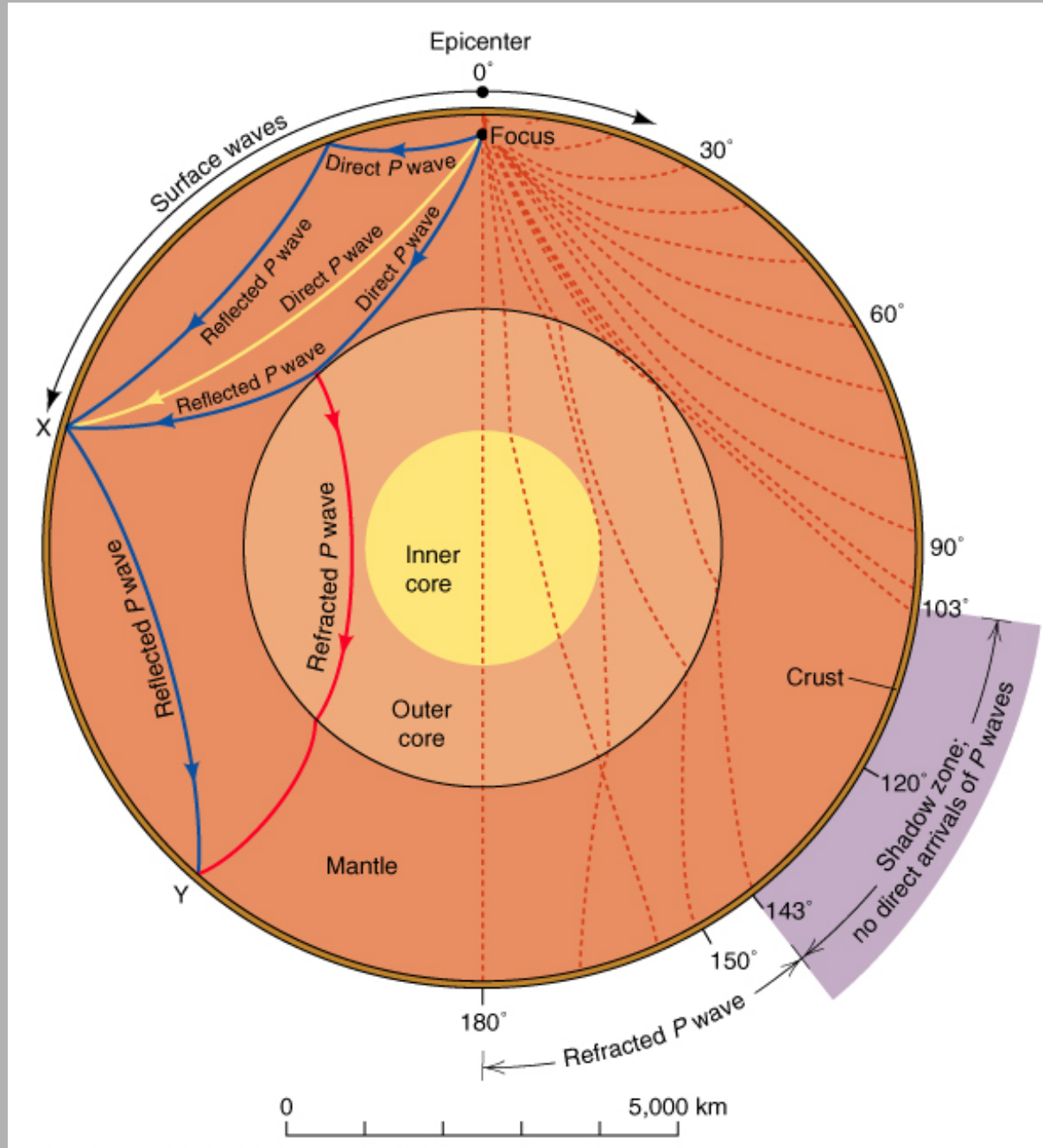
Shear waves stopped – by liquid material

Reflect – Off boundaries between layers

Refract – Bend to the slower material

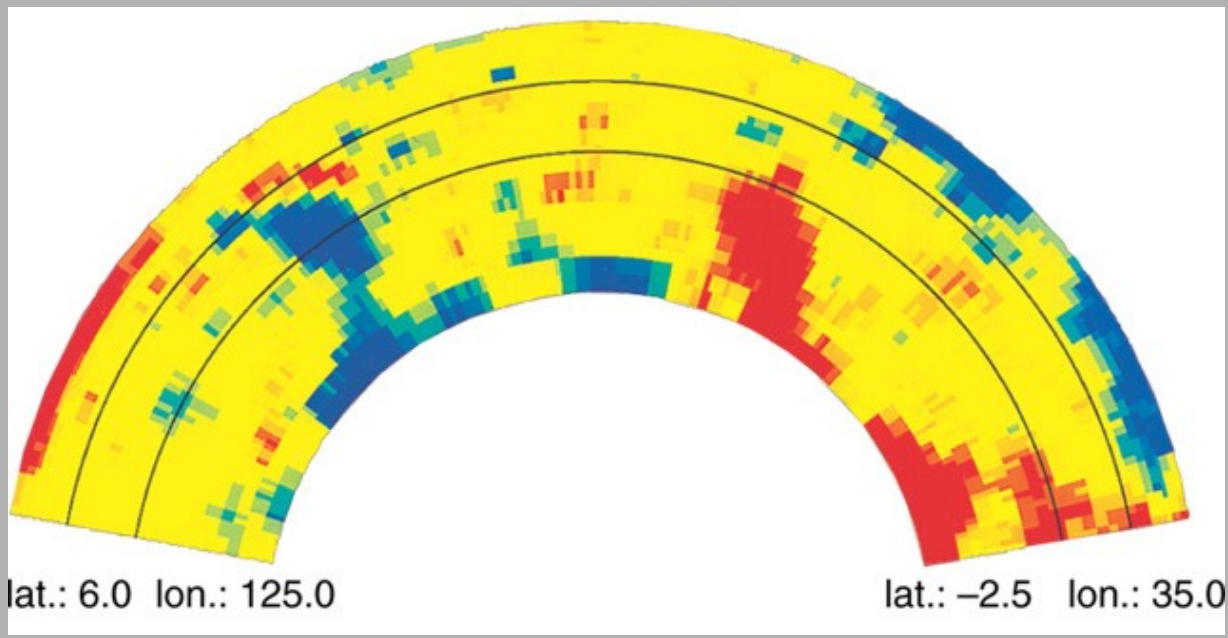
A quick review

Seismic waves inside the Earth

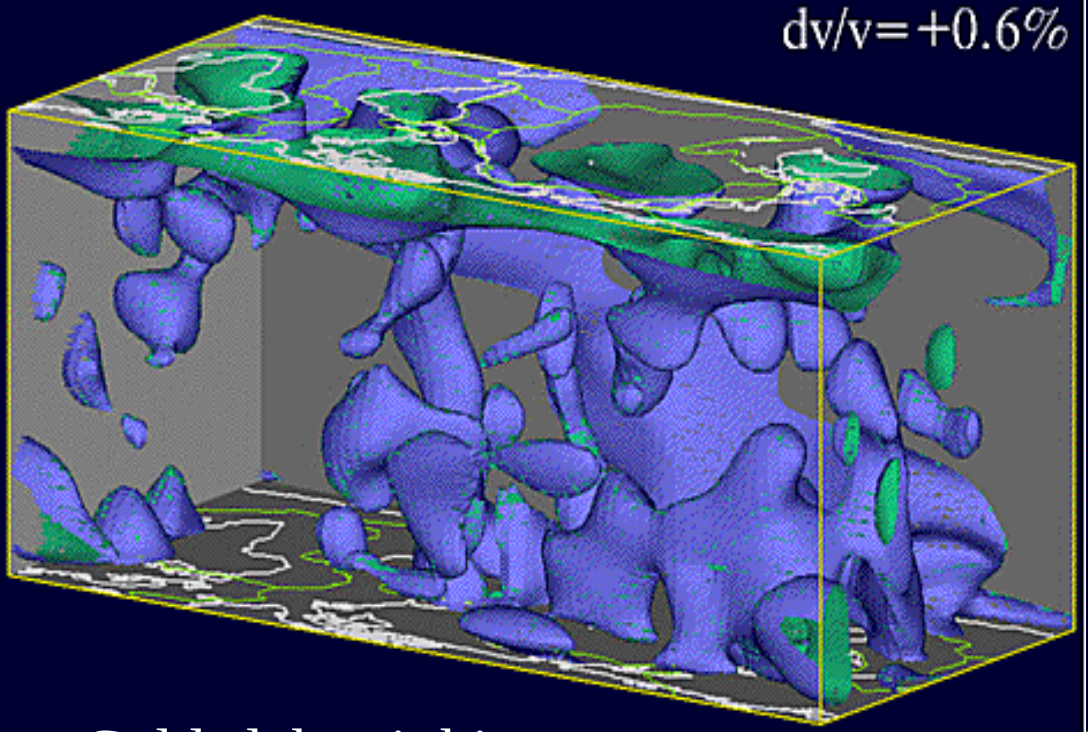


A quick review

"Seeing" inside the planet:
Seismic tomography

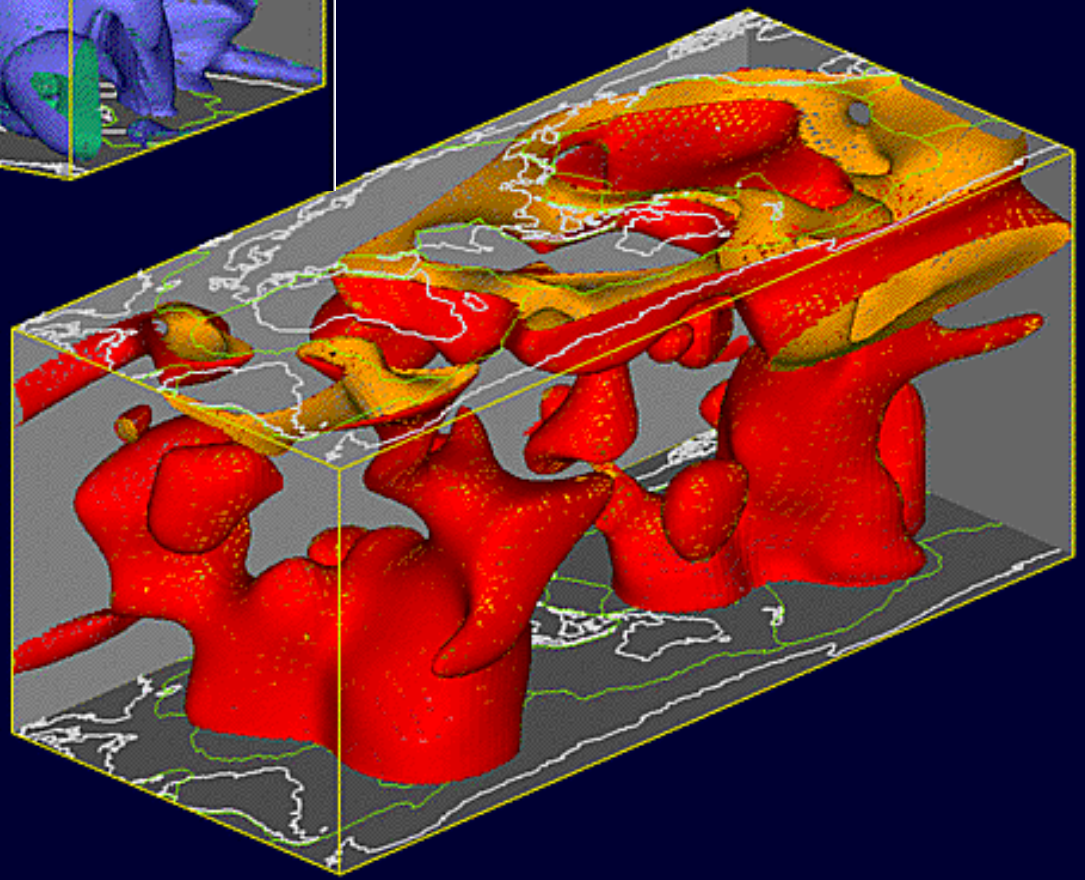


One slice across the Pacific Ocean near the equator



Cold slabs sinking

Hot plumes rising



****

Evidence of
mantle convection

****

A quick review

Earth Structure: Layers (version II)

defined by strength and viscosity
(not composition)

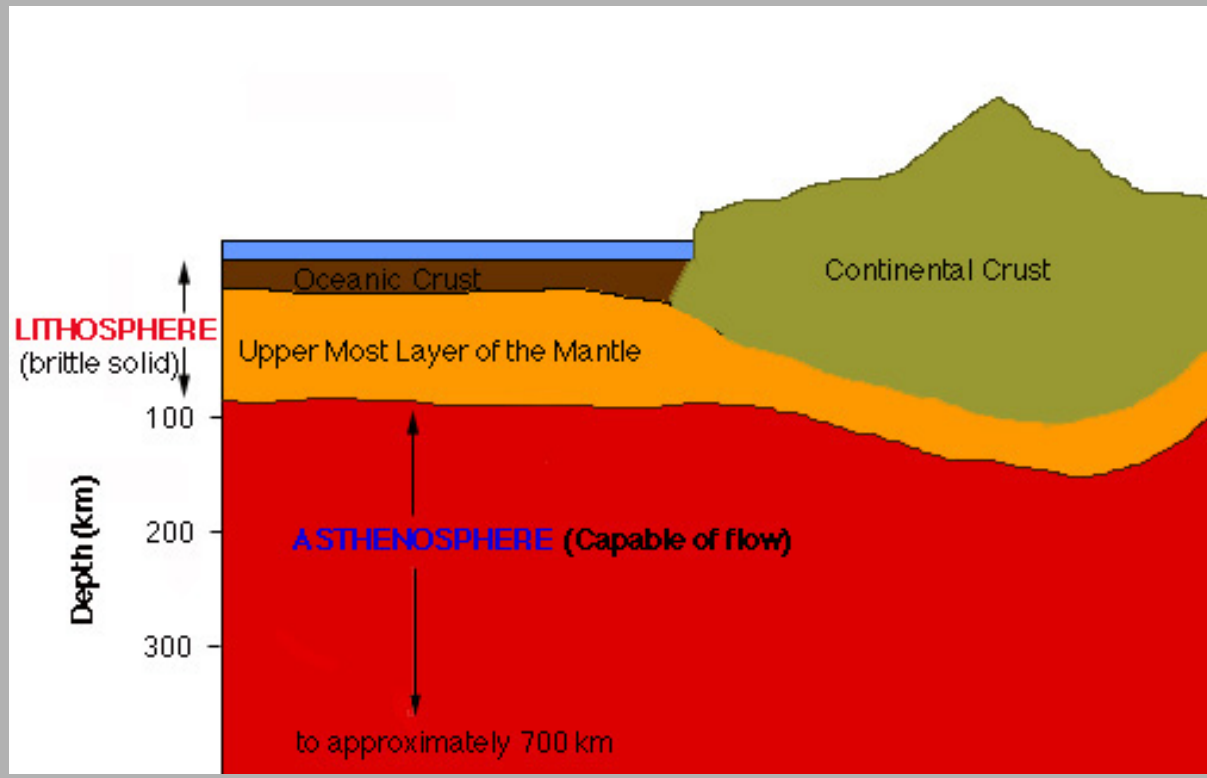
Lithosphere	cool, tectonic plates
Asthenosphere	hot Silly Putty
Mesosphere	largest volume
Core	heat source

A quick review

Lithospheric plates

Supported by the uppermost part of the mantle welded onto the bottom of the crust

Floating on the asthenosphere



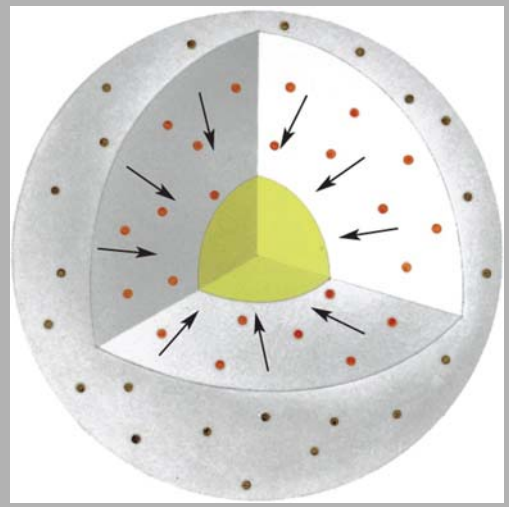
A quick review

Different Earth materials

Si, Al, O	**sialic**	**crust**
Fe, Mg, SiO4	**mafic**	**mantle**
Fe, Ni	**metallic**	**core**

Why Differentiation?

Early evolution of the planet



Granite – Diorite – Basalt

Continents – Andes-type subduction – Ocean basins

A quick review

The continents and ocean crust are floating

Buoyancy and isostasy