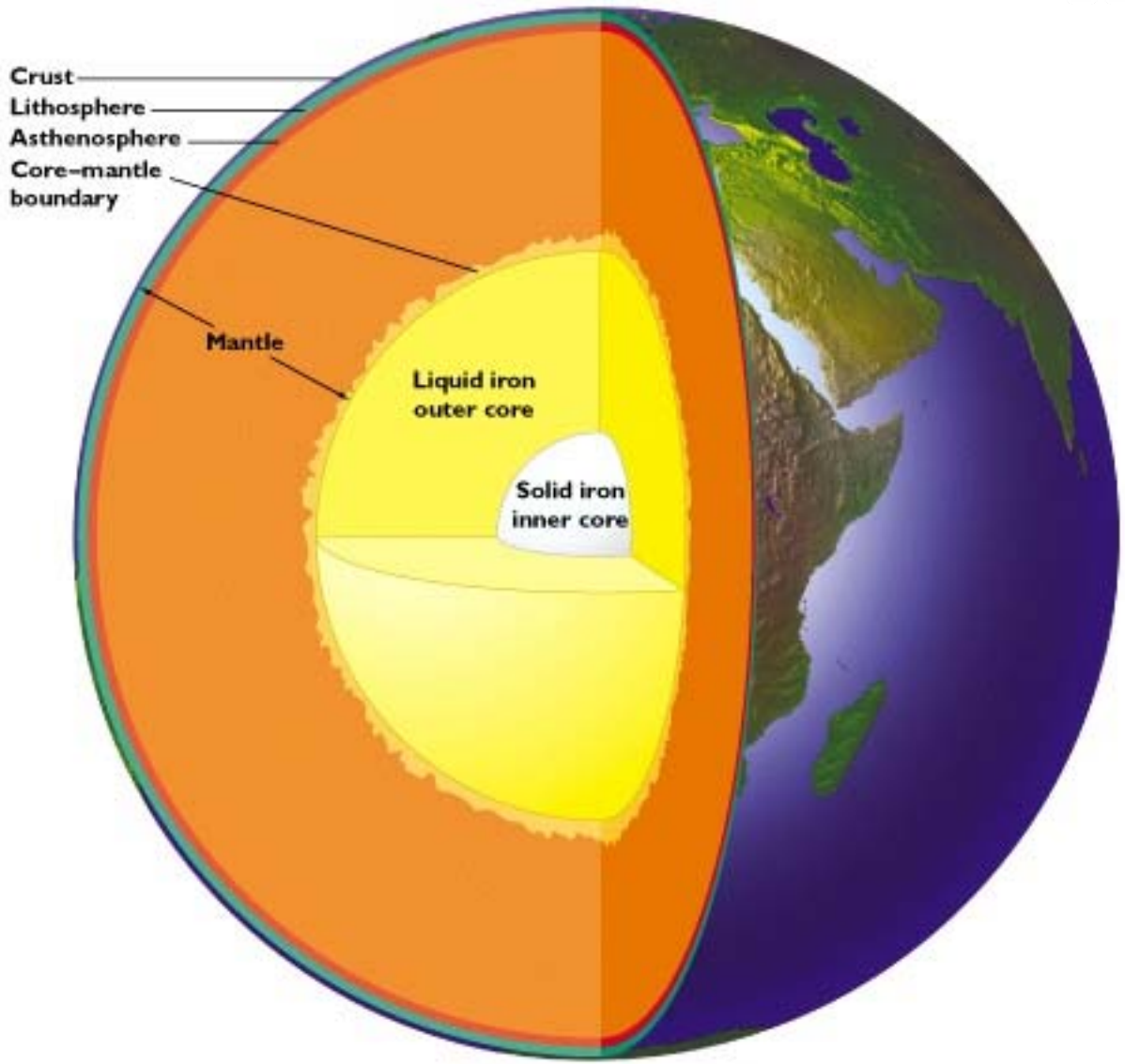
14-Exploring Earth's Interior

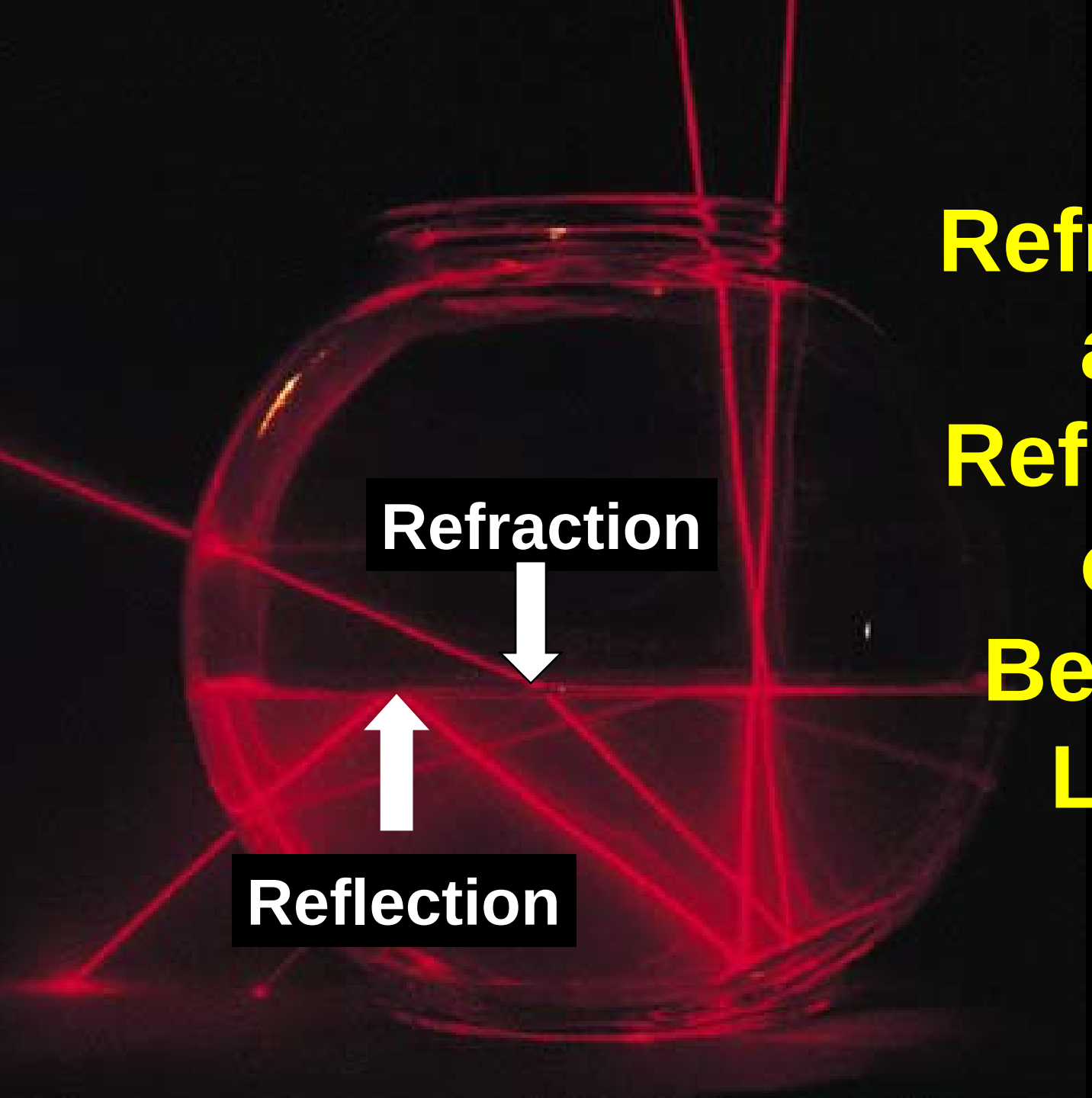


Tools Used to Look Inside Earth

- Seismisity
- Isostacy
- Heat Flow
- Gravity
- Magnetism

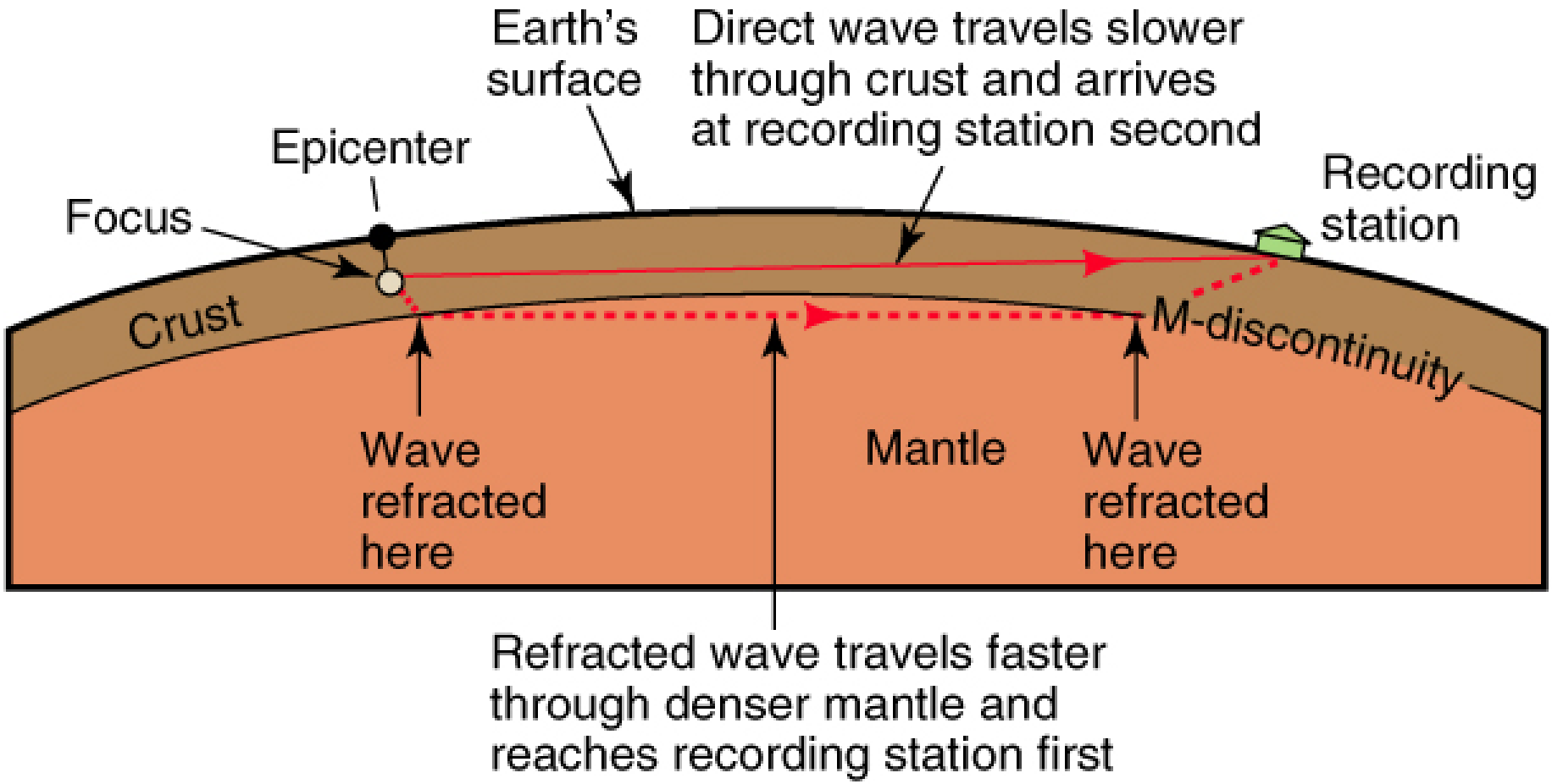
How We Know the Structure of the Earth

- Seismic velocity depends on the composition of material and environment.
- Seismic behavior is used to tell us about the interior of the Earth.
- When waves move from one material to another they change speed and direction.

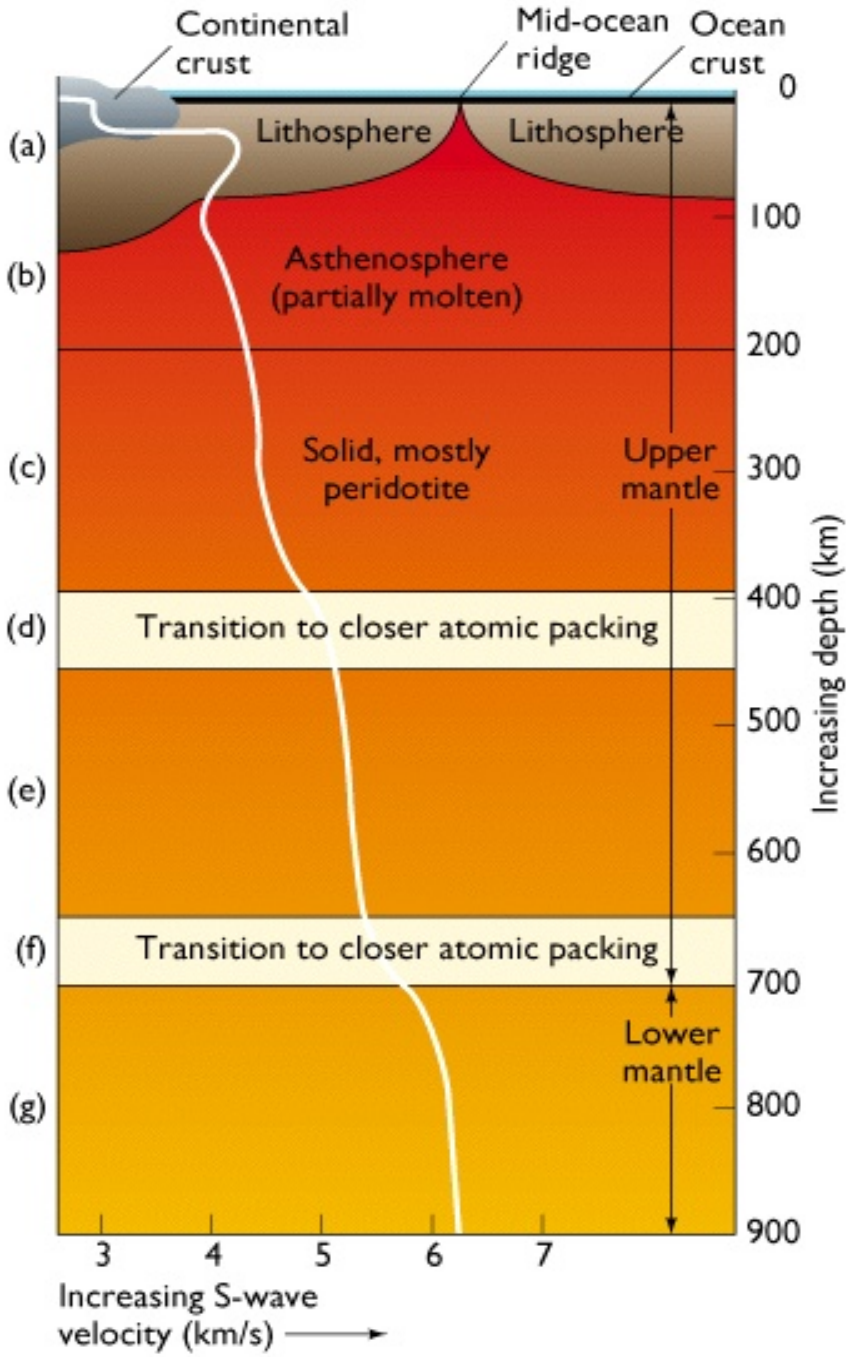


Refraction and Reflection of a Beam of Light

Travel paths for seismic waves

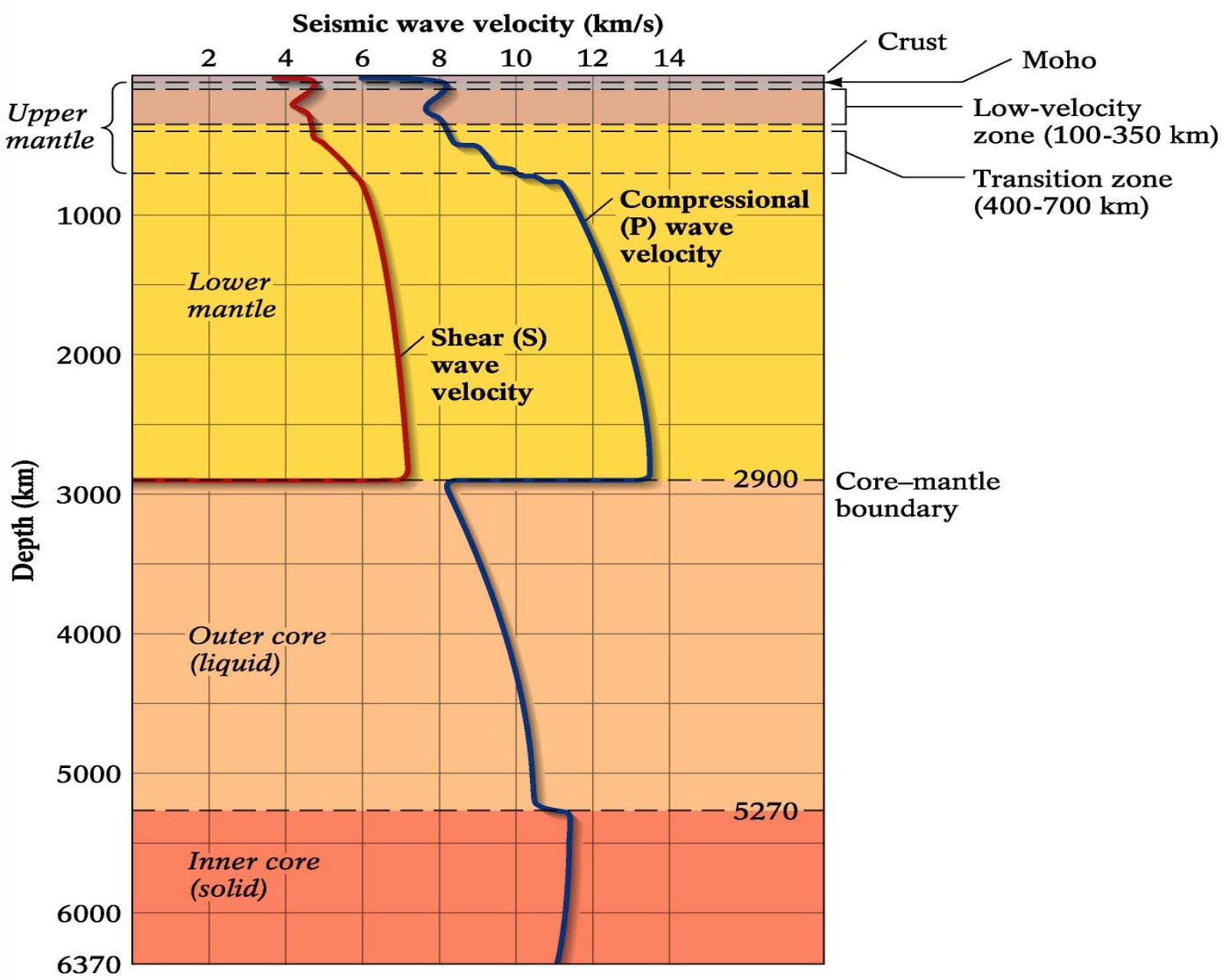


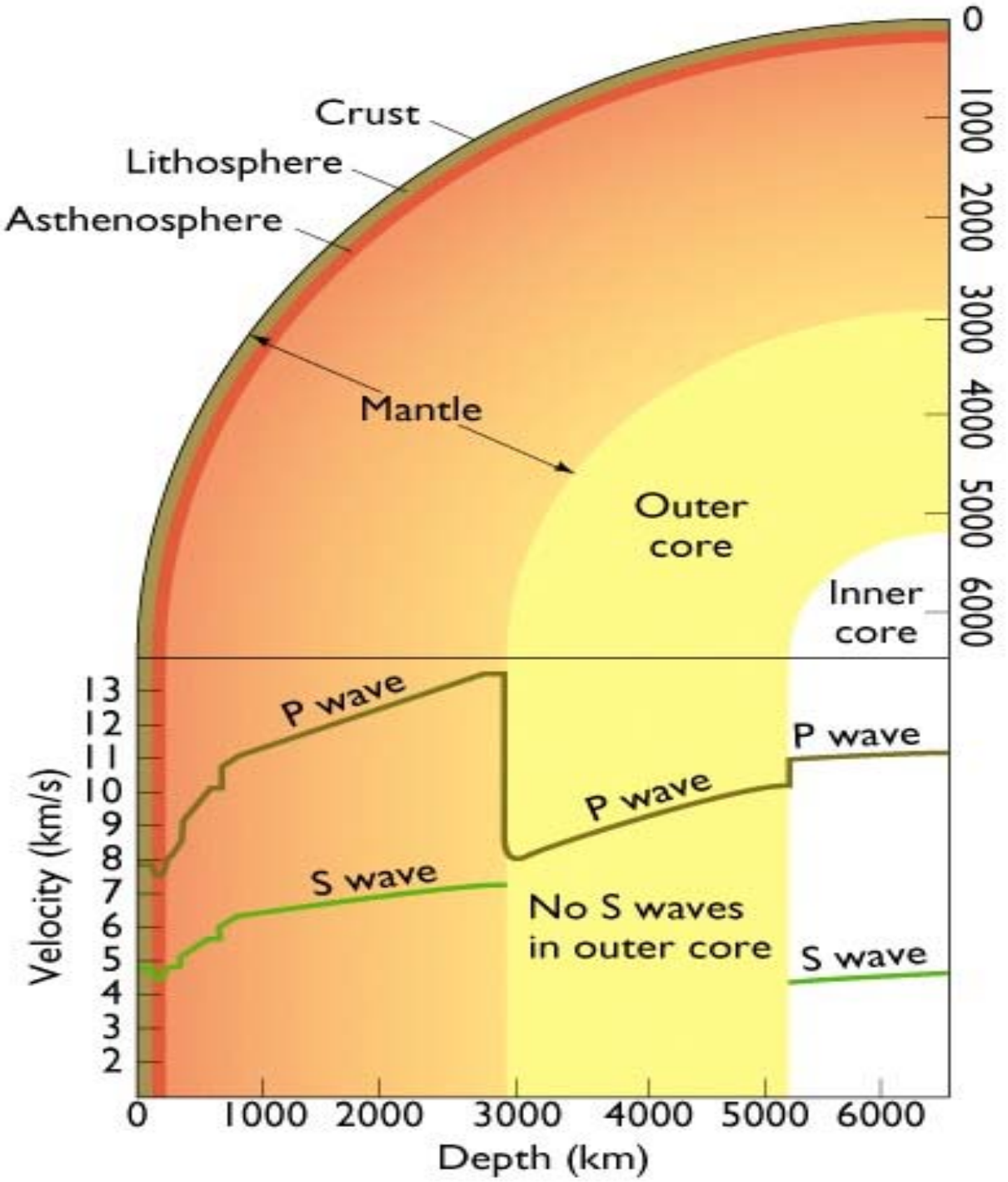
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Structure of the Crust and Upper Mantle

The behavior of P and S waves





Changes in P-and S-wave Velocity Reveal Earth's Internal Layers

Structure of the Earth

Study of the behavior of seismic waves tells us about the shape and composition of the interior of the Earth:

- *Crust*: ~8–70 km, intermediate composition
- *Mantle*: ~2800 km, mafic composition
- *Outer core*: ~2200 km, liquid iron
- *Inner core*: ~1500 km, solid iron

CRUST

- Continental Crust - inhomogeneous
- Avg. composition - granite, 30-70 km thick, V = 6kps, D = 2.7g/cc
- Oceanic Crust - homogeneous
- Avg. comp. - basalt, ~8 km thick, V = 7kps, D = 3g/cc, Ophiolite
- Moho - bottom of crust, V = 8kps

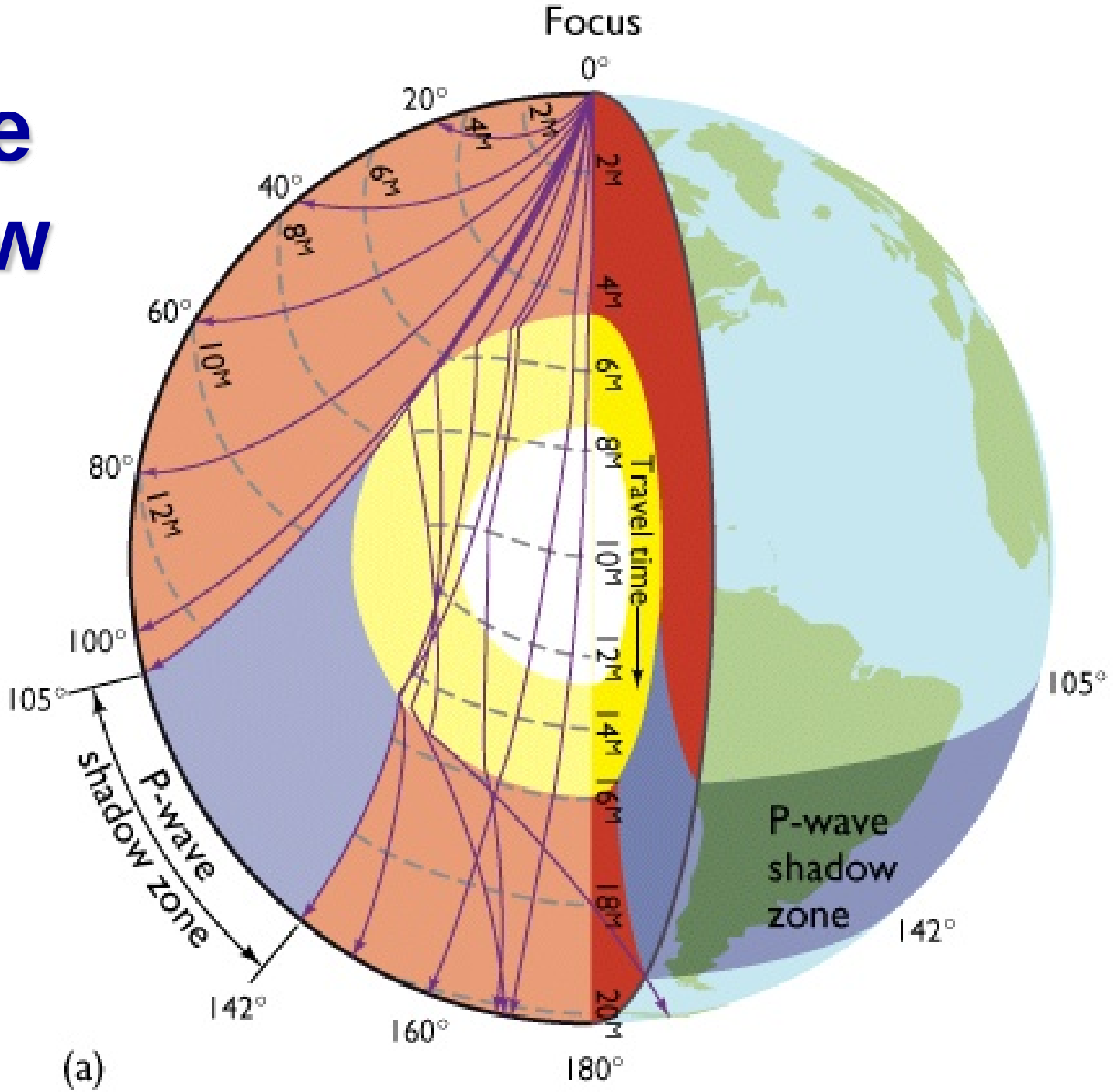
MANTLE

- Upper mantle - chemically layered & inhomogeneous
- Lithosphere - PLATES, 100 km thick, peridotite, in xenoliths
- Asthenosphere - plastic zone topped by LVZ, to 700 km depth
- Lower mantle - more homogeneous to 2900 km deep
- Guttenberg Discontinuity - S-waves go!

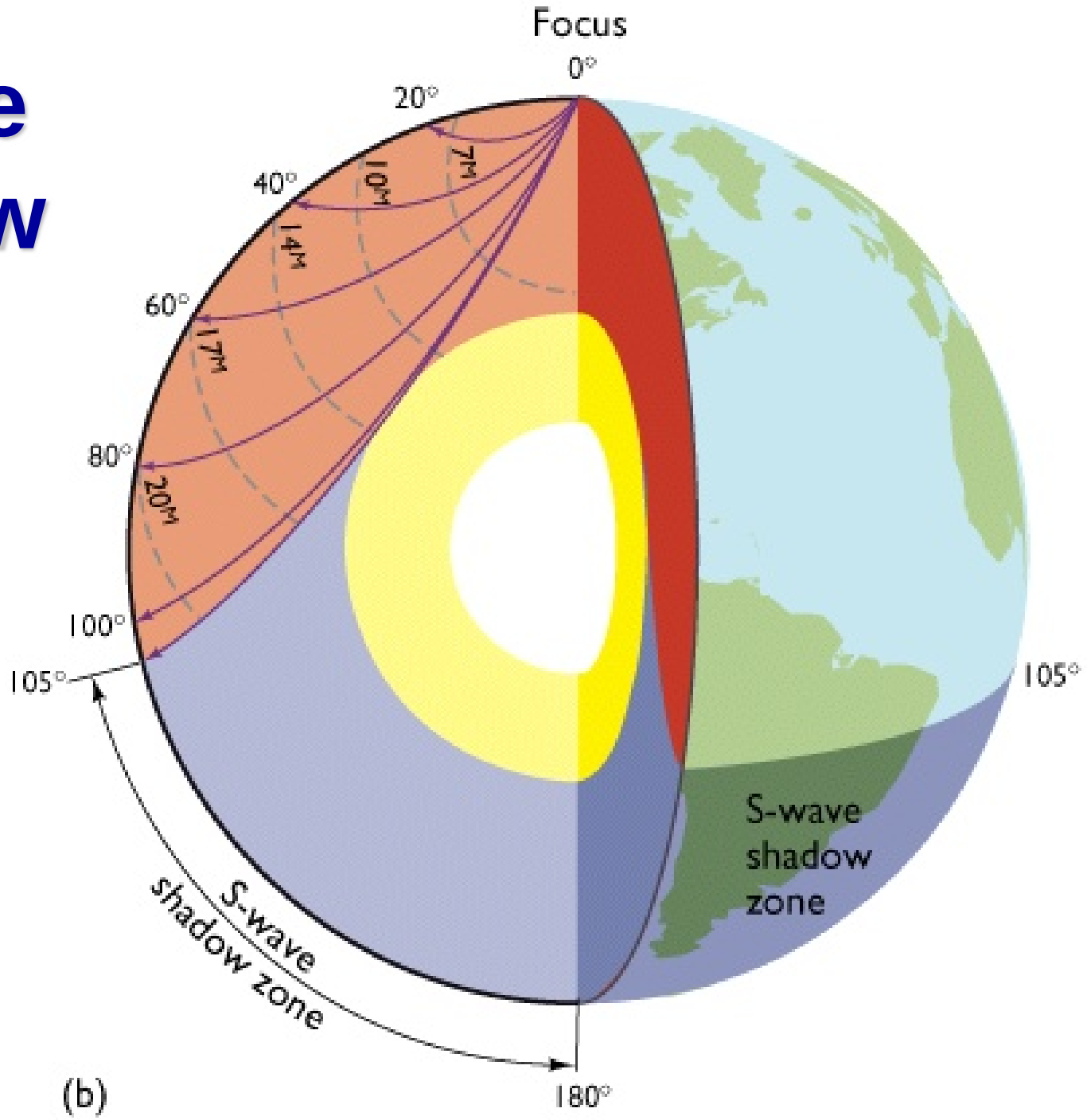
CORE

- Outer Core - Liquid Fe, ~2200 km thick, No S-waves transmitted -> S- & P-wave Shadow Zones
- Inner Core - solid Fe (some Ni, Co, S, C), ~2500 km thick
- How do we know? Meteorites, Earth's rotation, magnetic field

P-wave Shadow Zone



S-wave Shadow Zone



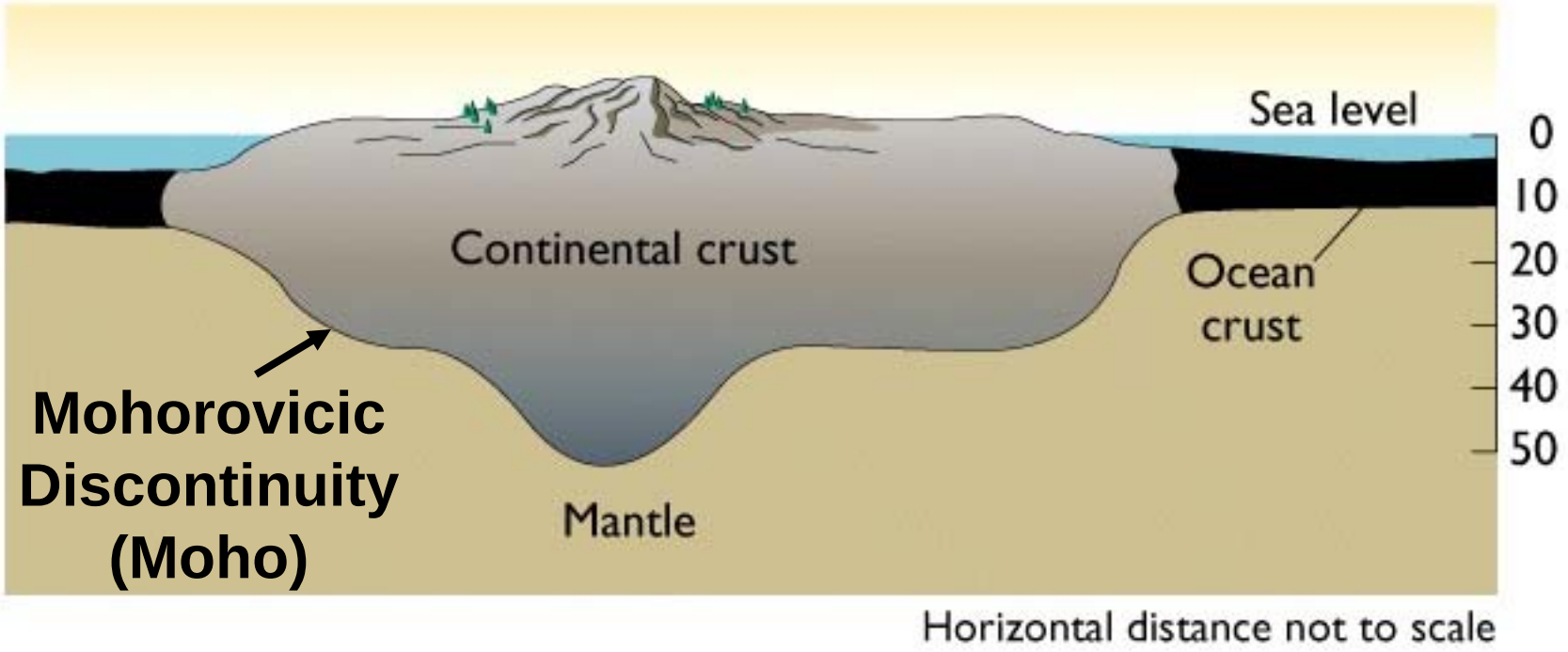
Anomalies

- Any deviation from standard or normal values
- Positive - reading is greater than the standard
- Negative - reading is less than the standard
- Gravity, isostatic, magnetic & heat

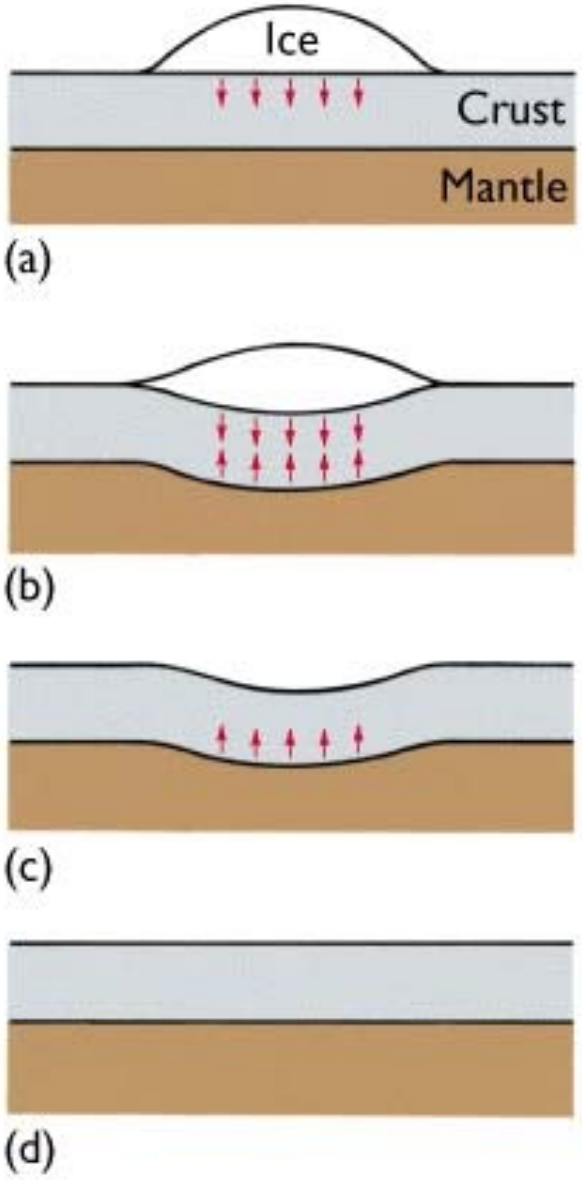
Isostasy

- Buoyancy of low-density rock masses "floating on" high-density rocks; accounts for "roots" of mountain belts
  - Crust is thickest under high elevations
- Lithosphere floats on asthenosphere
  - Denser units sink (subside)
  - Lighter units float (uplifts)
- Accounts for most vertical motion on Earth
  - Volcanoes, glaciers, erosion

The less dense crust “floats” on the less buoyant, denser mantle



Crust as an Elastic Sheet



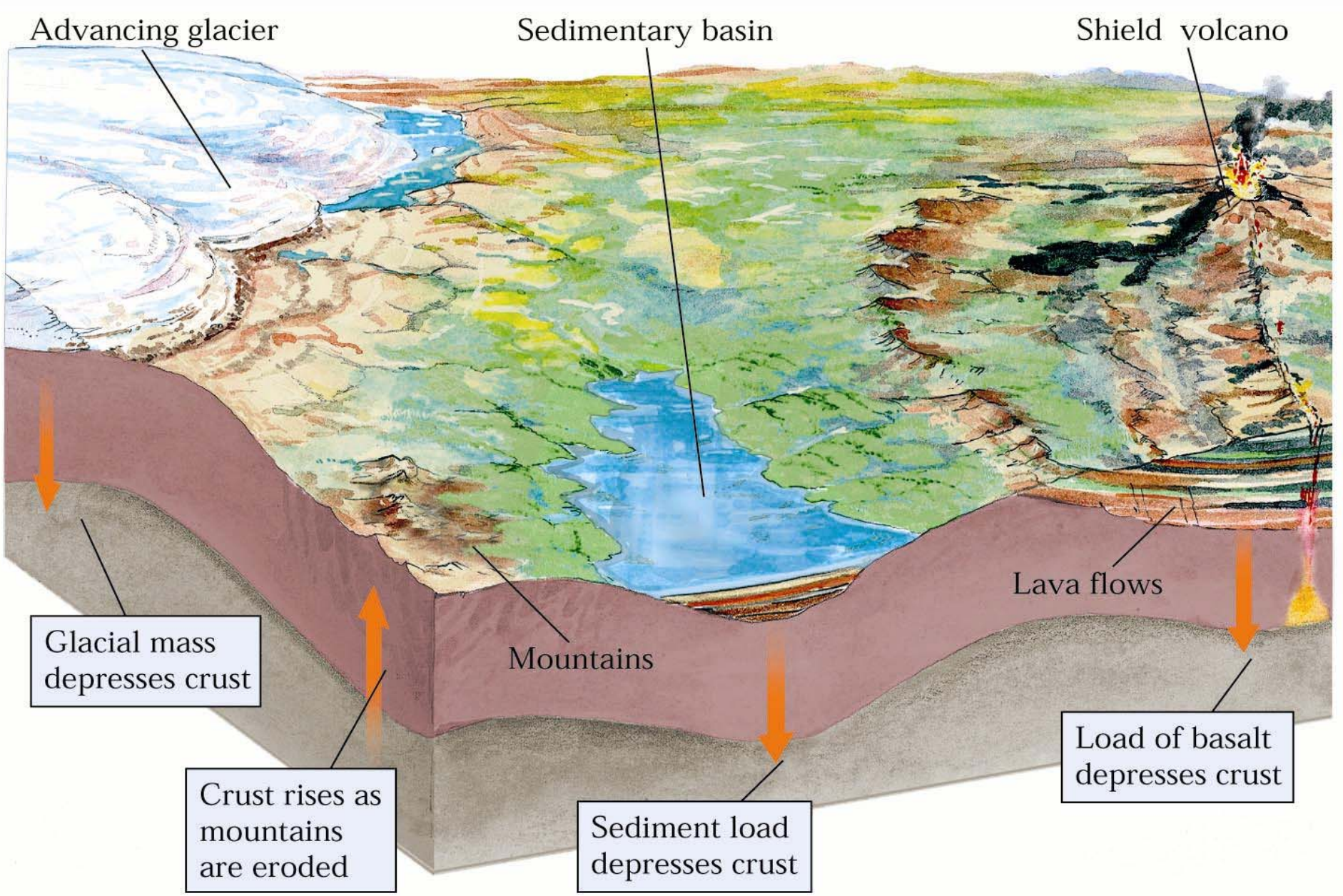
Continental ice loads the mantle

Ice causes isostatic subsidence

Melting of ice causes isostatic uplift

Return to isostatic equilibrium

Isostatic adjustments.



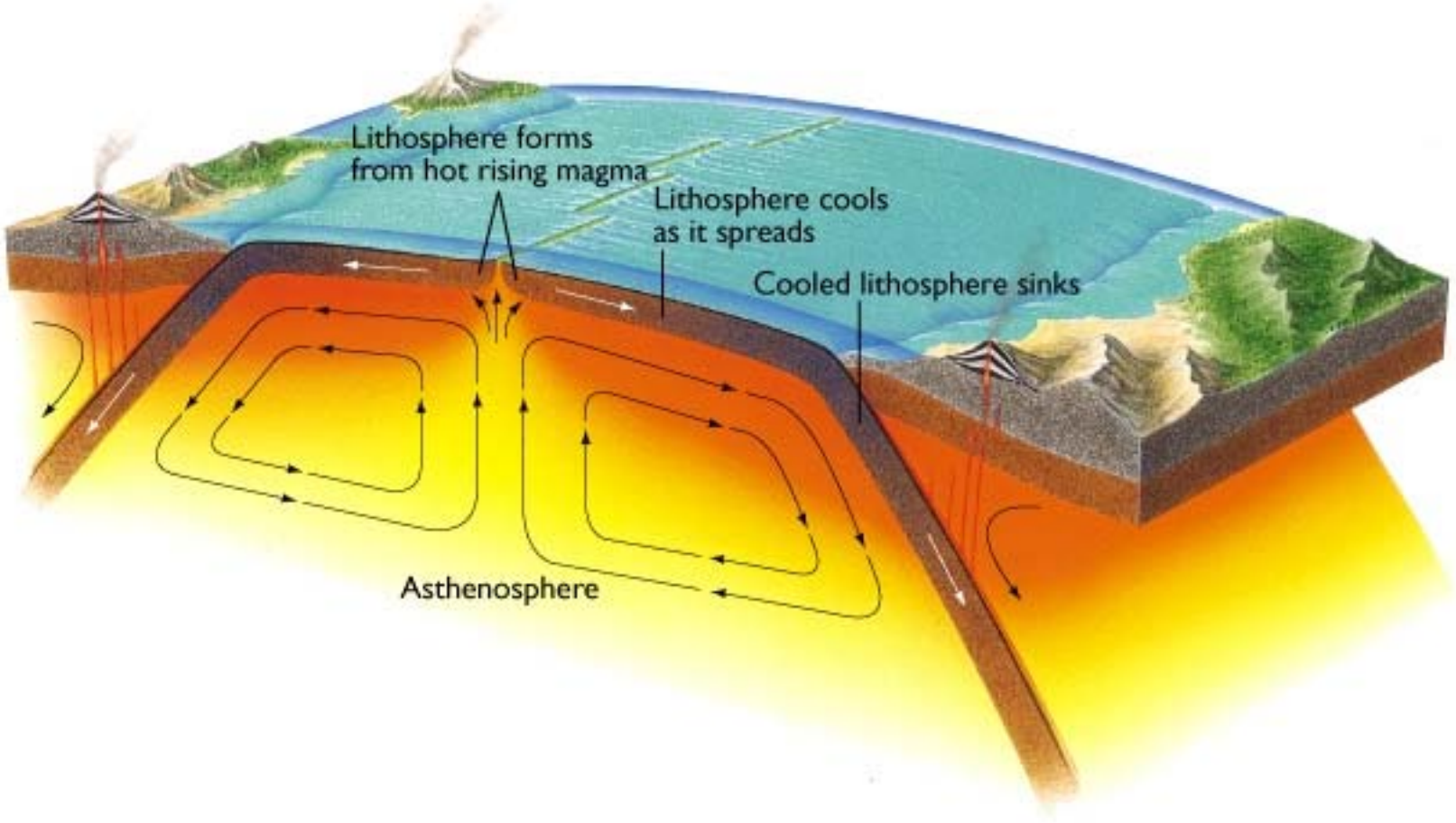
Isostatic uplift of 300 m after melting of ice sheet



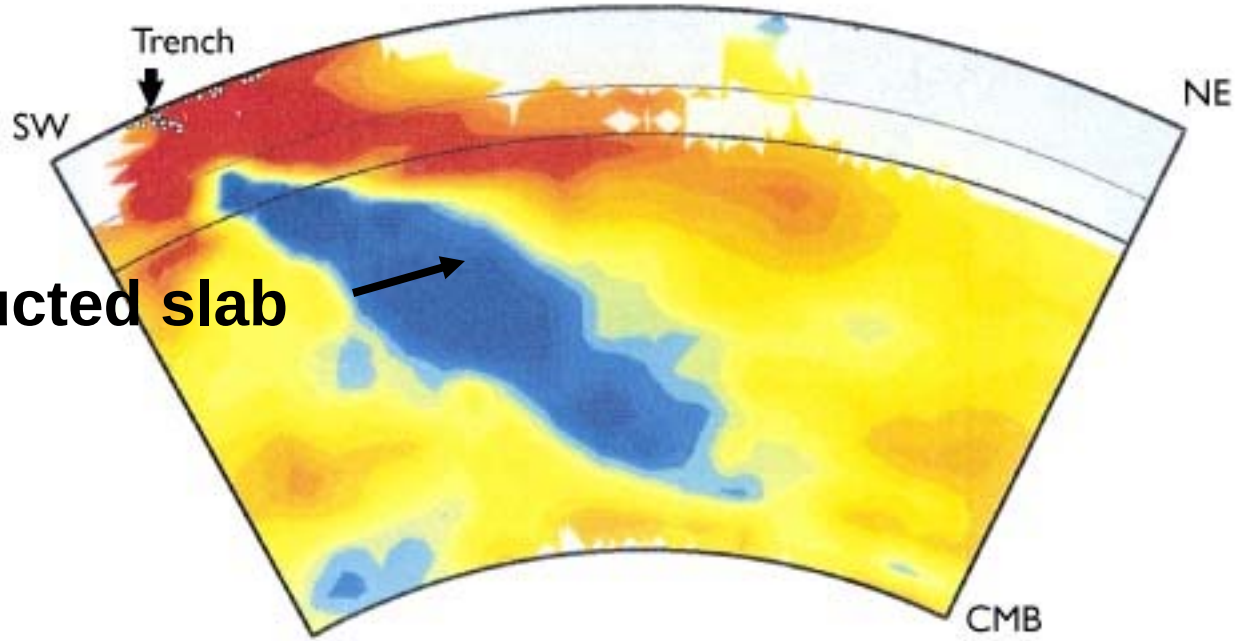
Earth's internal heat

- Original heat & subsequent radioactive decay
- Moves by Conduction & Convection
- Earth is cooling off
- Both crustal rocks are about the same temperature

Upper Mantle Convection as a Possible Mechanism for Plate Tectonics



Seismic Tomography Scan of a Section of the Mantle

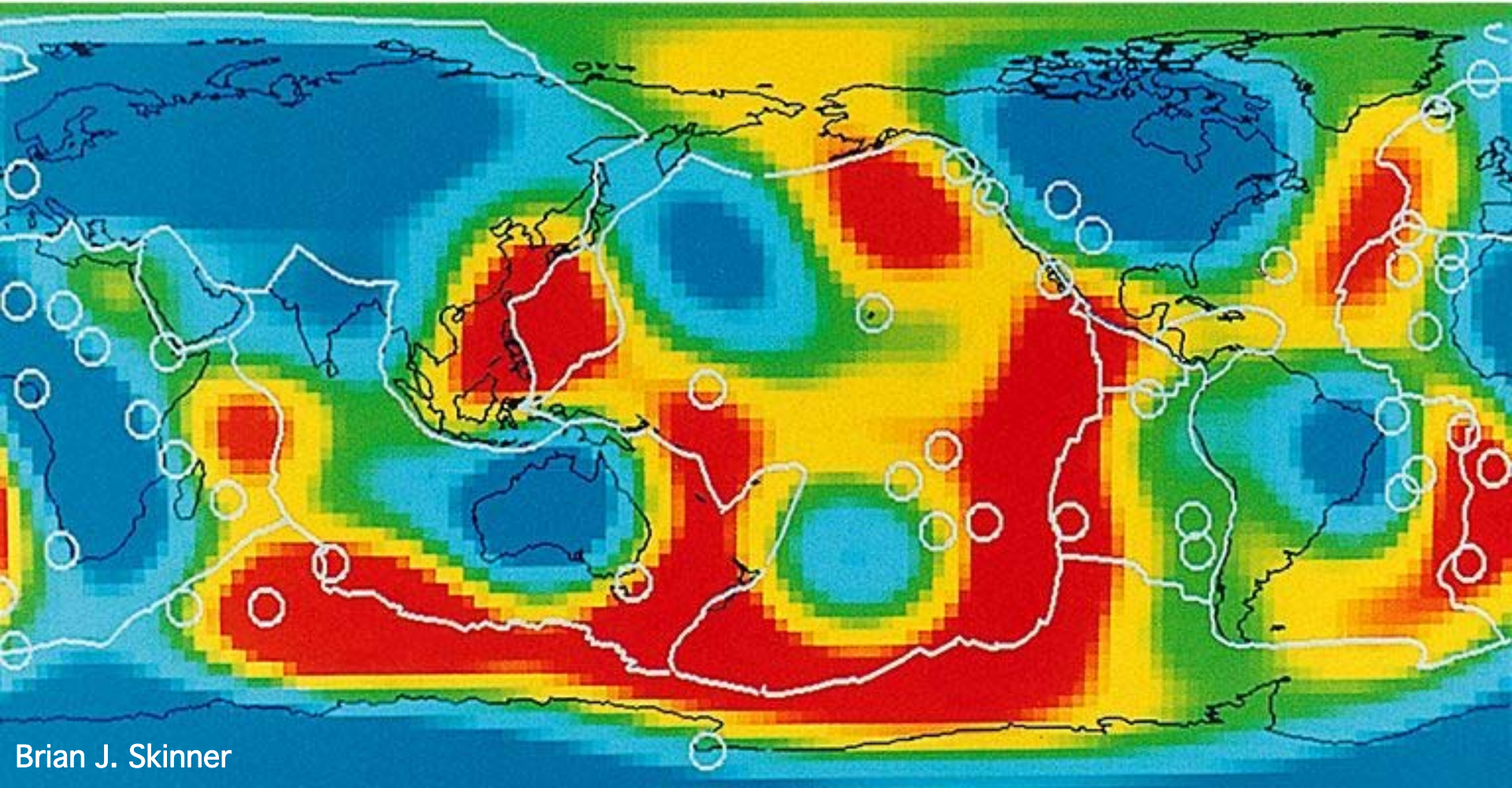


Subducted slab

Seismic tomography records variations in P-wave velocity, which correlate with the temperatures of matter in Earth's interior.

- Slower P waves, indicating warmer-than-average matter
- Average-speed P waves, indicating average-temperature matter
- Faster P waves, indicating cooler-than-average matter
- No data

Seismic Tomography of the Upper Mantle



Brian J. Skinner

Temperature *vs*. Depth

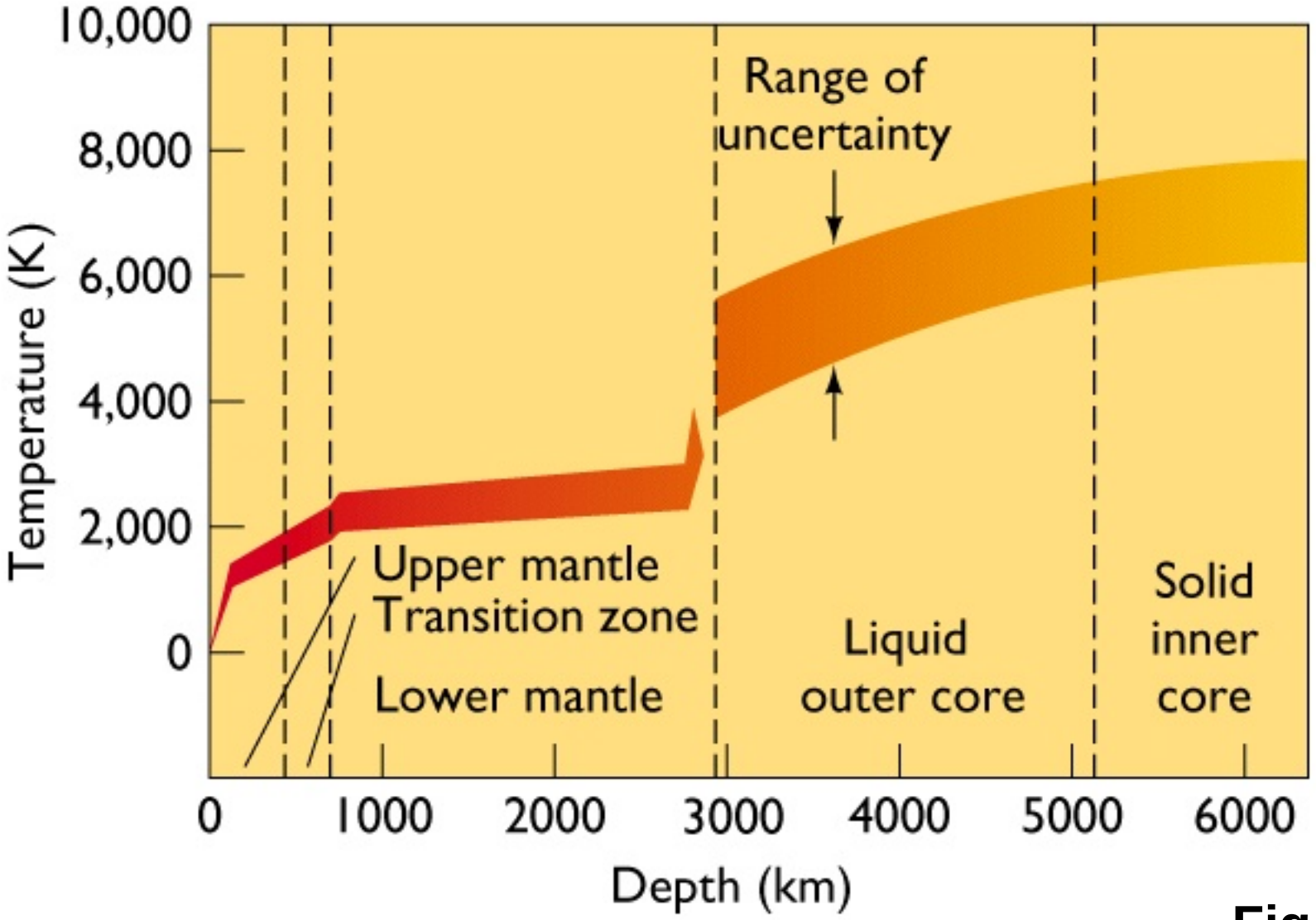
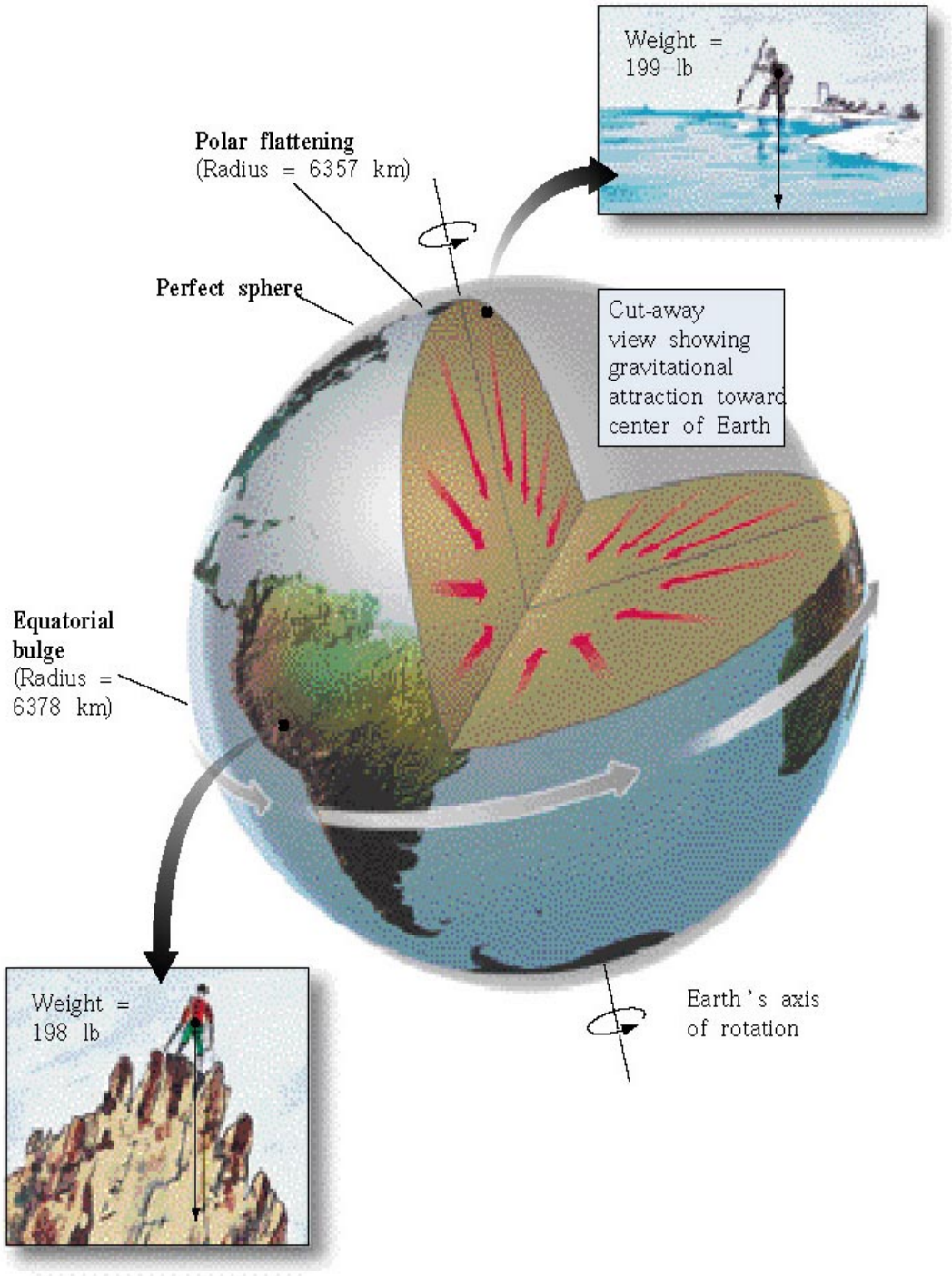


Fig. 19.10

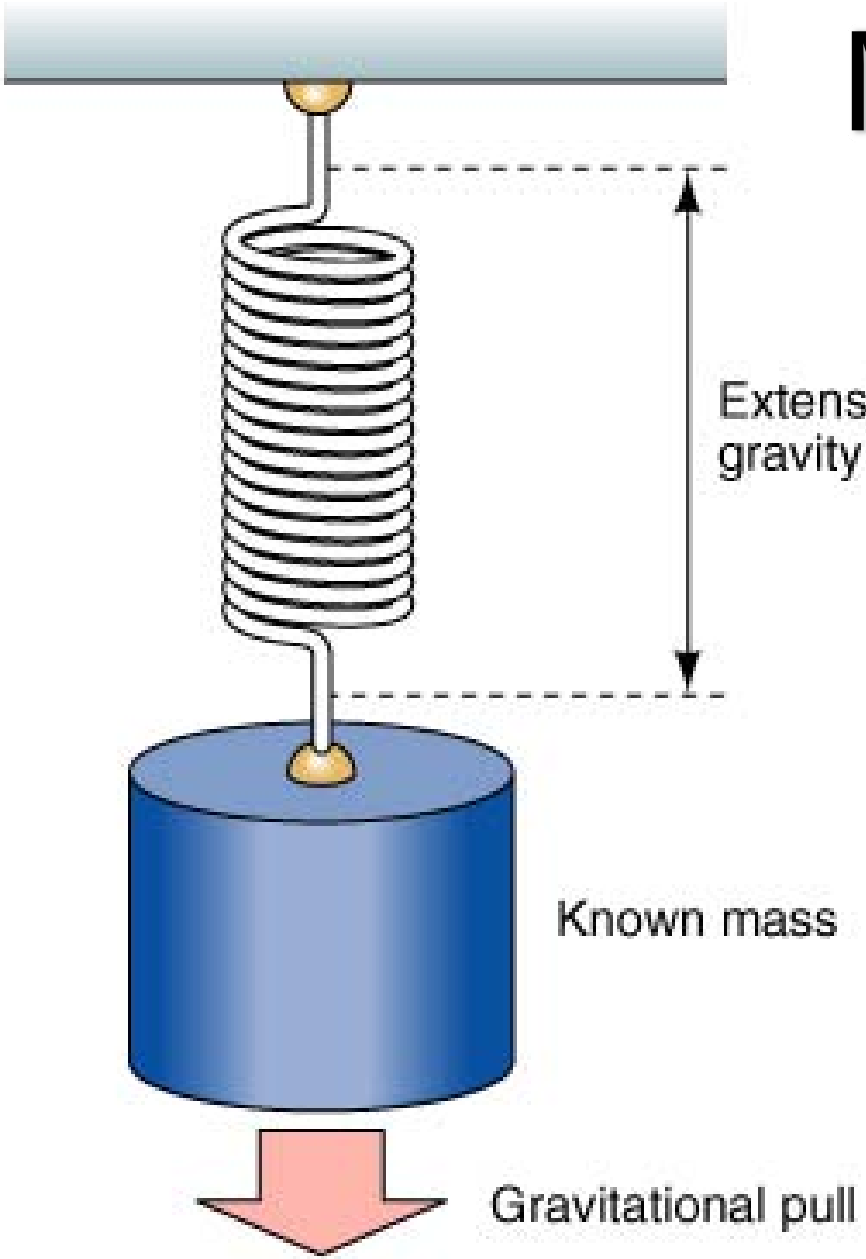
Gravity

- Function of mass of an object and the distance between the object's and the Earth's centers' of mass
- Read local gravity field with a gravimeter
- Anomaly - any deviation from normal value of gravity
  - Positive - hugh density mass
  - Negative - low density mass (greatest over trenches)

Gravitational attraction of the Earth.

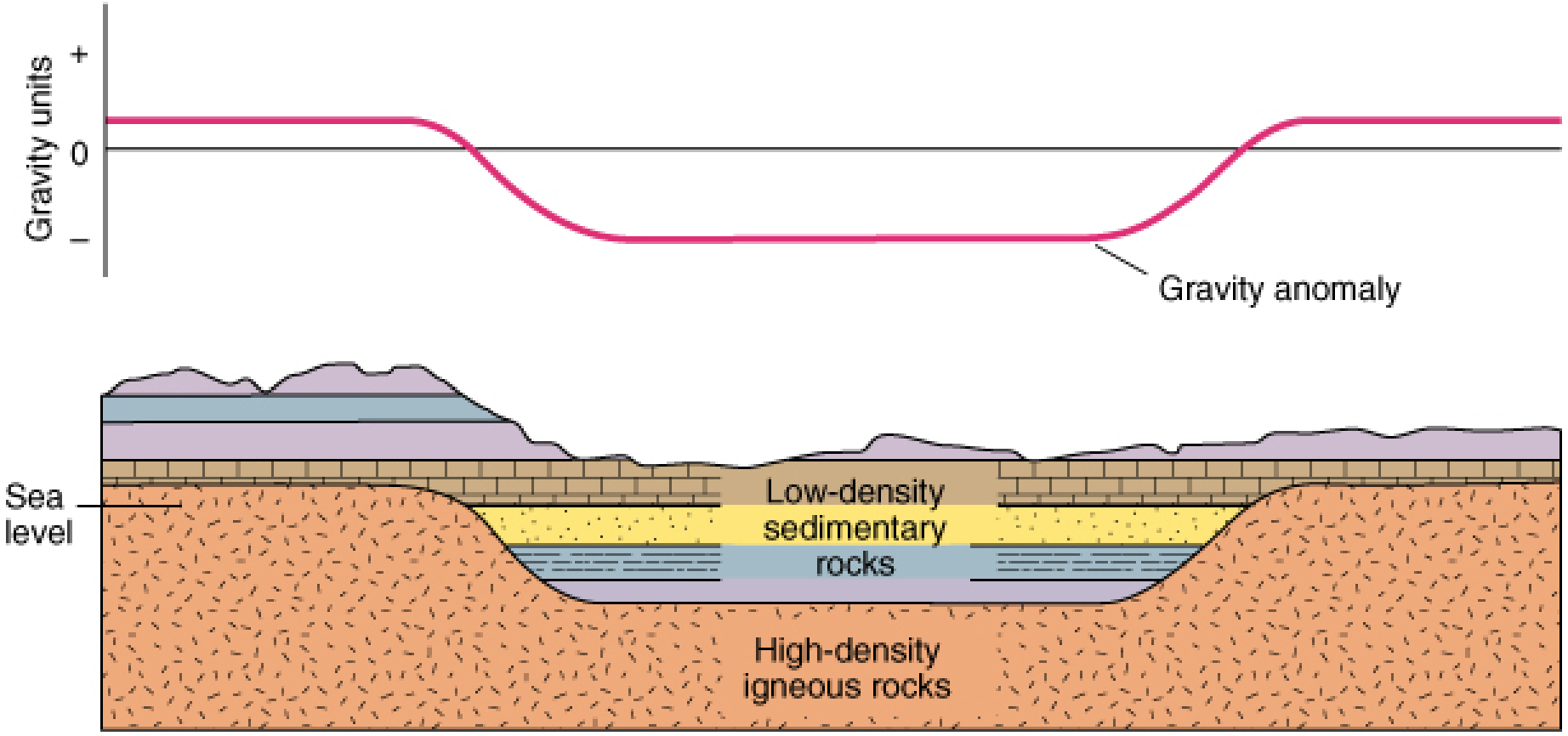


Measuring the pull of gravity

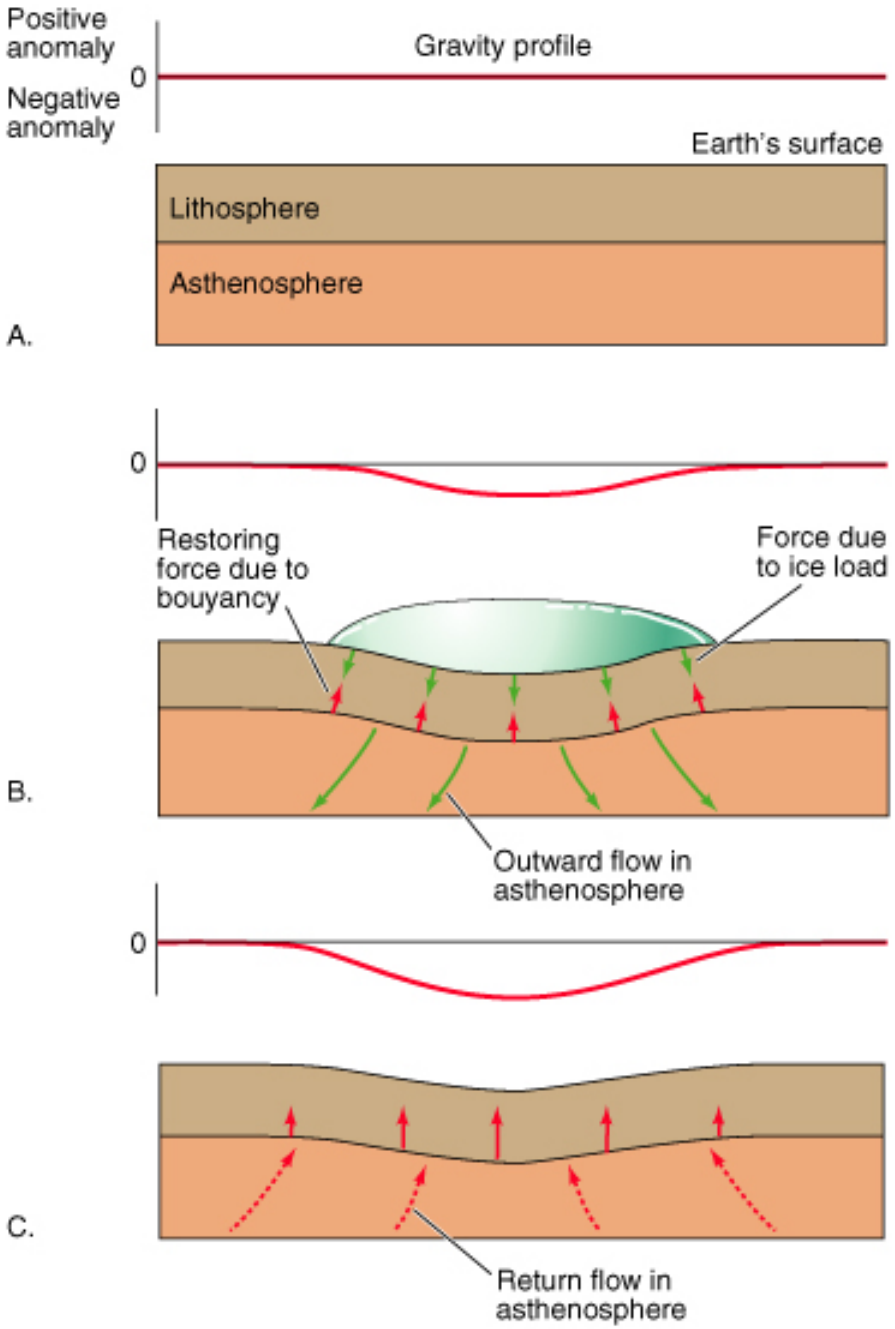


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Gravity anomaly over a sedimentary basin



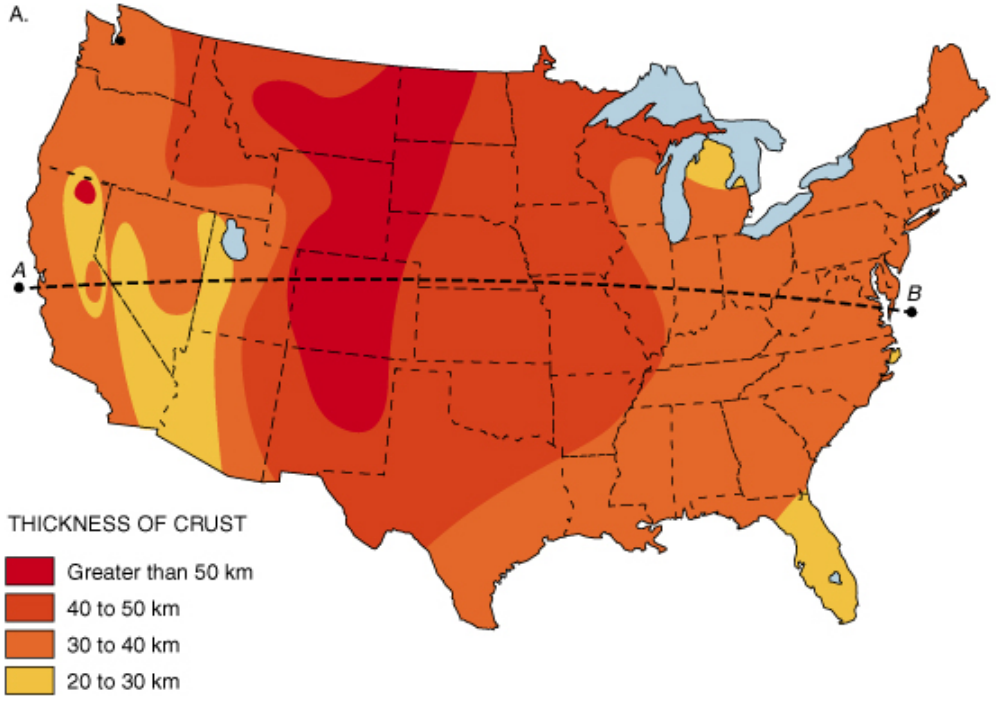
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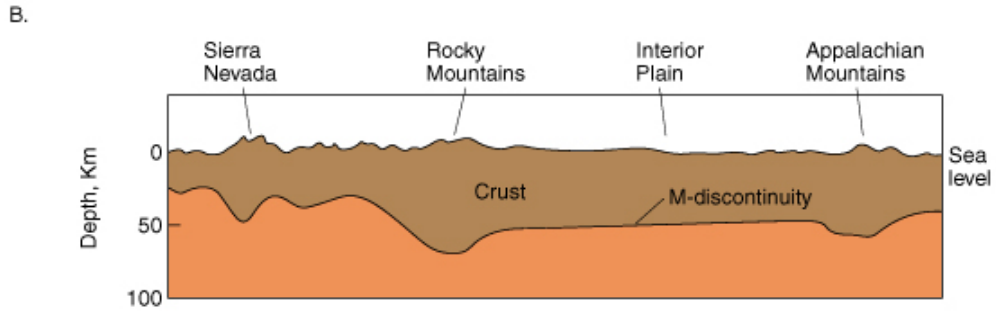


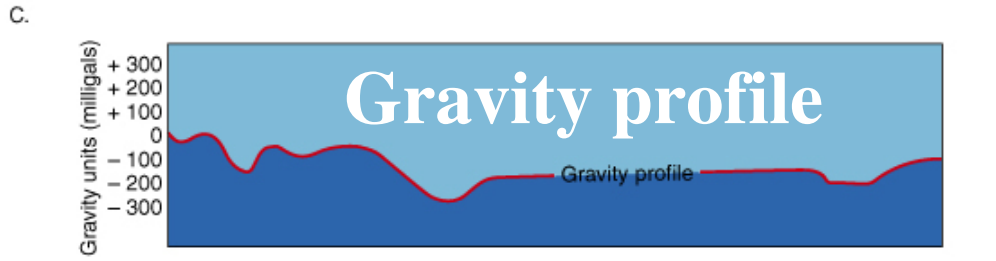
Formation of a negative gravity anomaly due to continental glaciation

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Crustal Thickness beneath the U.S.



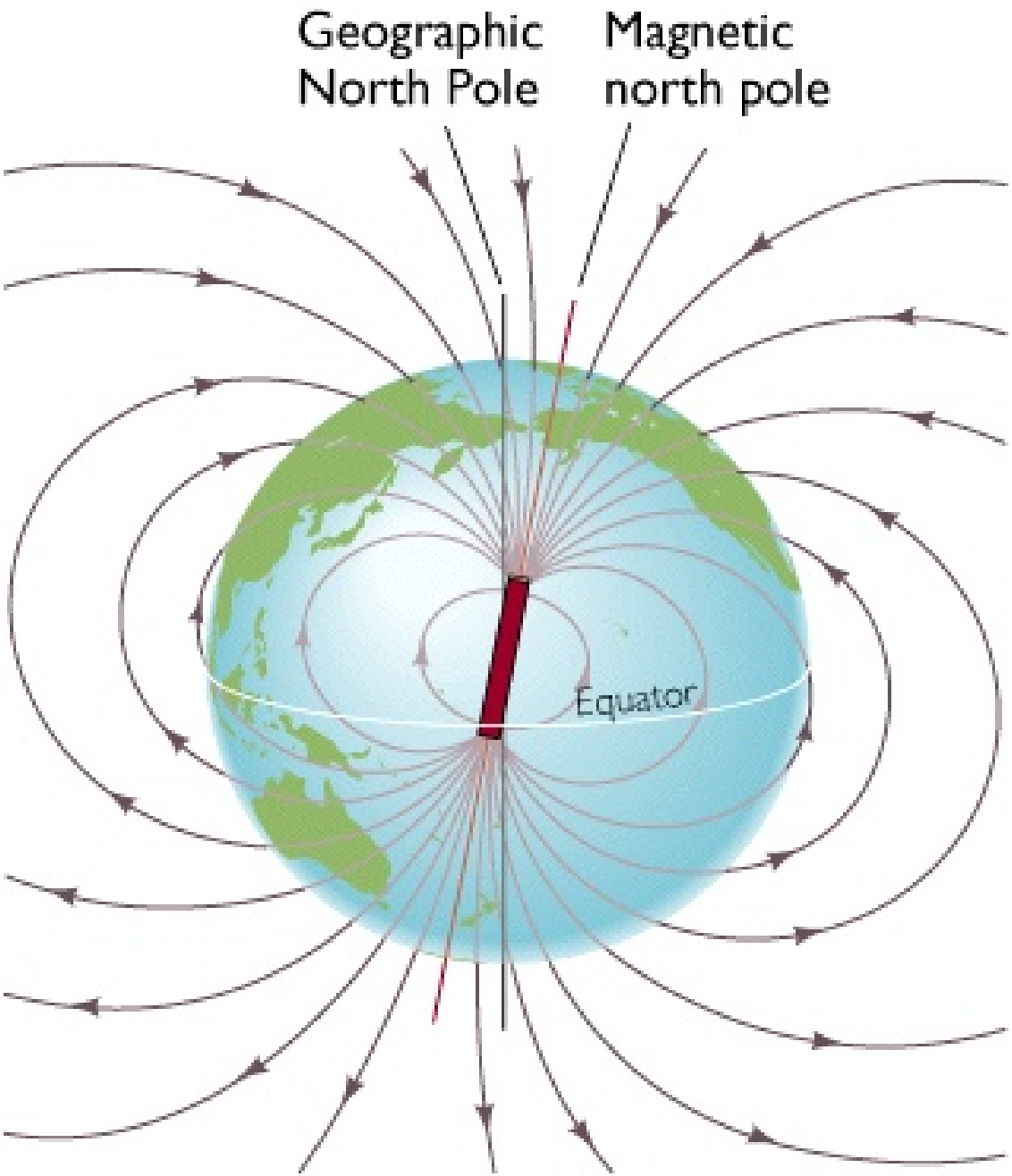




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Paleomagnetism

- Use the record of Earth's magnetic field to investigate past plate motions
- Permanent record of the direction of the Earth’s magnetic field at the time the rock was formed
- May not be the same as the present magnetic field

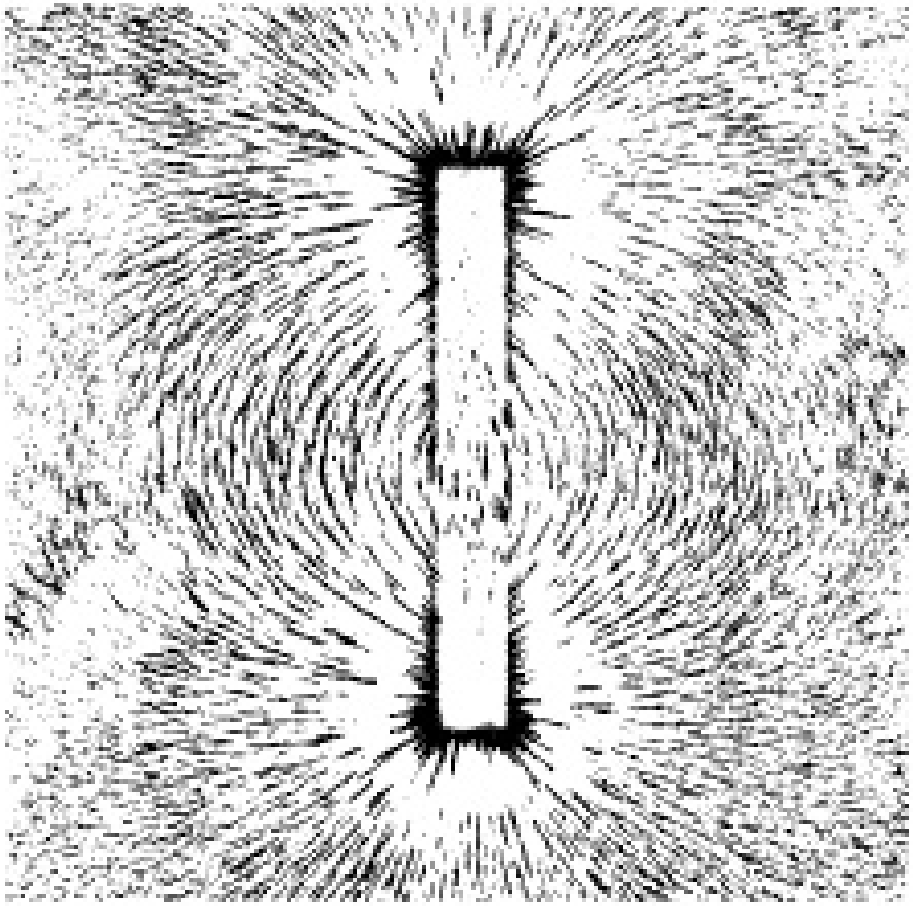


Present Magnetic Field of the Earth

Earth's magnetic field

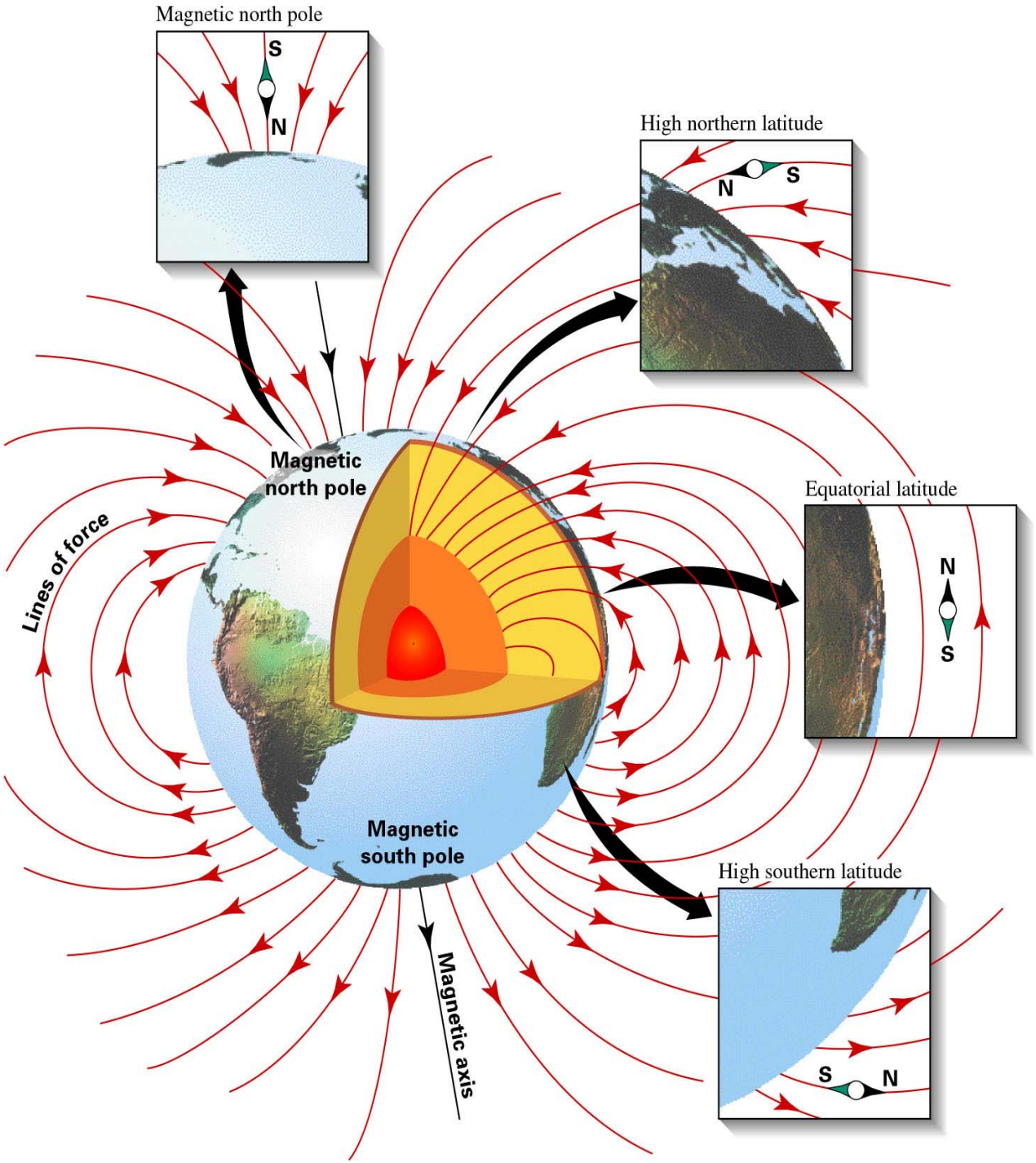
The Earth behaves as a magnet whose poles are nearly coincident with the spin axis (*i.e.*, the geographic poles).

Magnetic lines of force emanate from the magnetic poles such that a freely suspended magnet is inclined upward in the southern hemisphere, horizontal at the equator, and downward in the northern hemisphere



Magnetic Field of a Bar Magnet

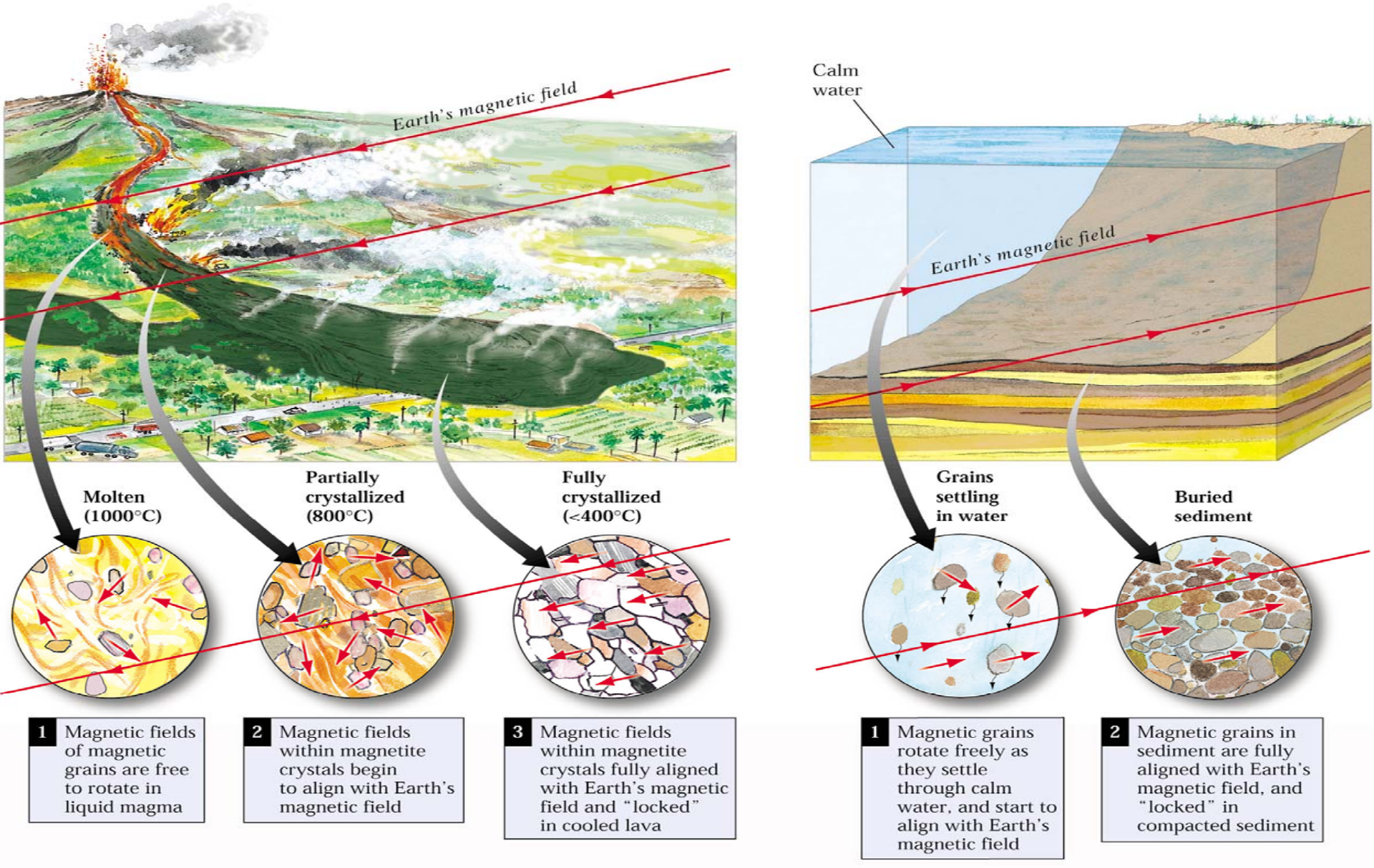
Prevailing magnetic field.



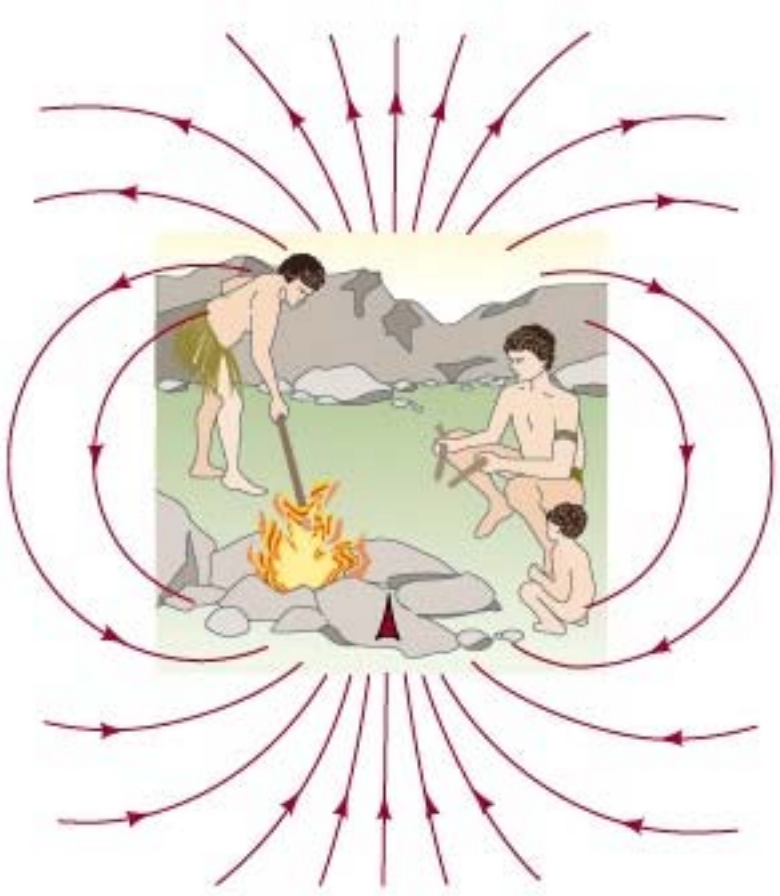
Use of magnetism in geology

The elements Fe, Mn, Cr, Co are effected by a magnetic field. If a mineral containing these elements cools below its Currie temperature (~500 deg. C) in the presence of a magnetic field, the minerals align in the direction of the north pole (also true for sediments).

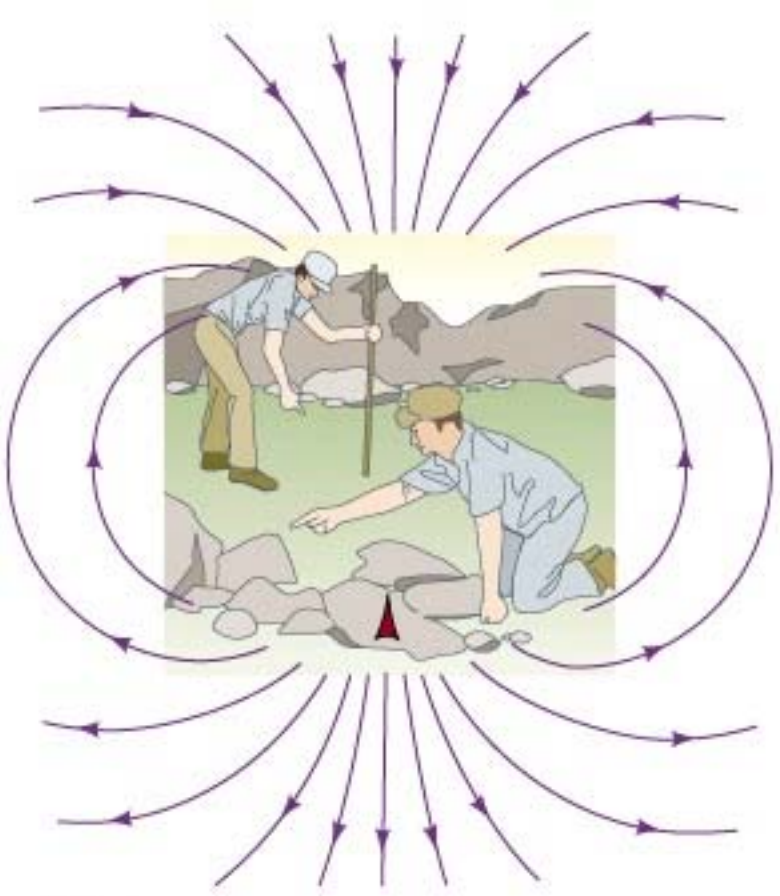
Magnetic-field polarity within magnetites.



Evidence of a Possible Reversal of the Earth's Magnetic field



30,000 years ago

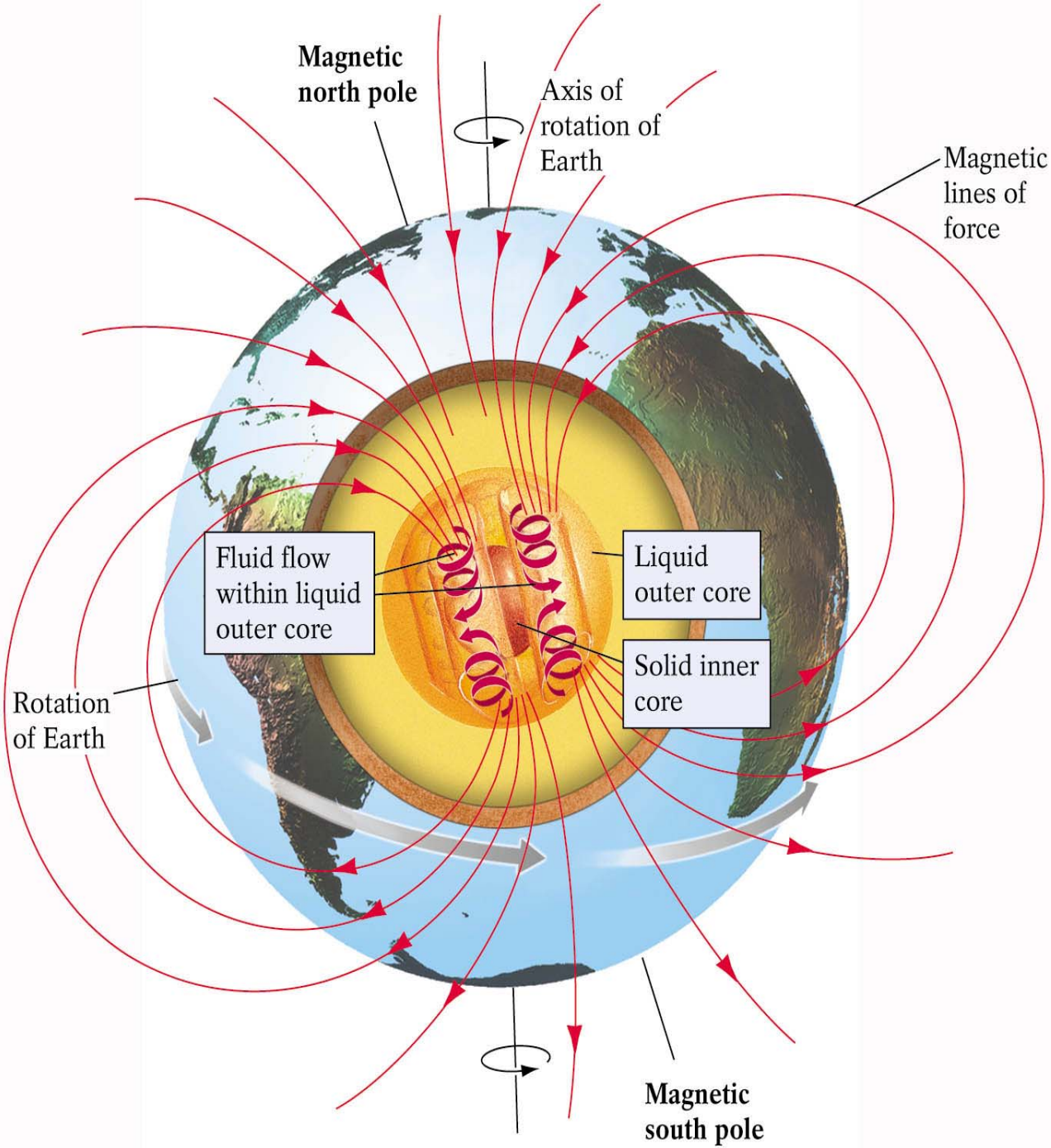


Today

How Does This Work?

Self-exciting dynamo theory - A dynamo produces electric current by moving a conductor in a magnetic field and *vise versa.* (*i.e.*, an electric current in a conductor produces a magnetic field.

Electrically conductive fluid.



Magnetic reversals

- The polarity of the Earth's magnetic field has changed thousands of times in the Phanerozoic (the last reversal was about 700,000 years ago).
- These reversals appear to be abrupt (takes about 1000 years or so).

Magnetic reversals

- A period of time in which magnetism is dominantly of one polarity is called a magnetic epoch.
- We call north polarity (the present field) *normal* and south polarity *reversed*.

Magnetic reversals

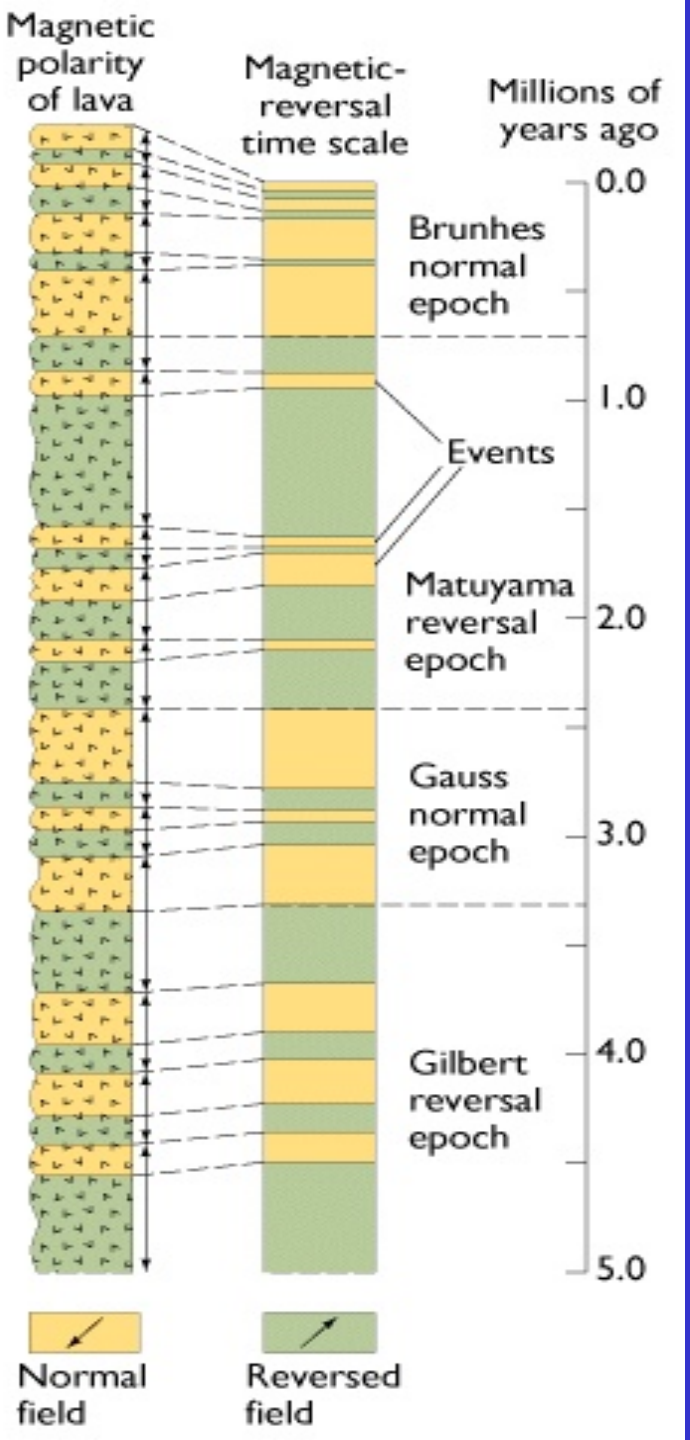
- Discovered by looking at magnetic signature of the seafloor as well as young (0-2 Ma) lavas in France, Iceland, Oregon and Japan.
- When first reported, these data were viewed with great skepticism

Self-reversal theory

- First suggested that it was the rocks that had changed, not the magnetic field
- By dating the age of the rocks (usually by K–Ar) it has been shown that *all* rocks of a particular age have the same magnetic signature.

Magnetic reversals

We can now use the magnetic properties of a sequence of rocks to determine their age.



The Geomagnetic Time Scale

Based on determining the magnetic characteristics of rocks of known age (from both the oceans and the continents).

We have a good record of geomagnetic reversals back to about 60 Ma.