Plate TECTONICS

or

"I feel the Earth move under my feet. . ."

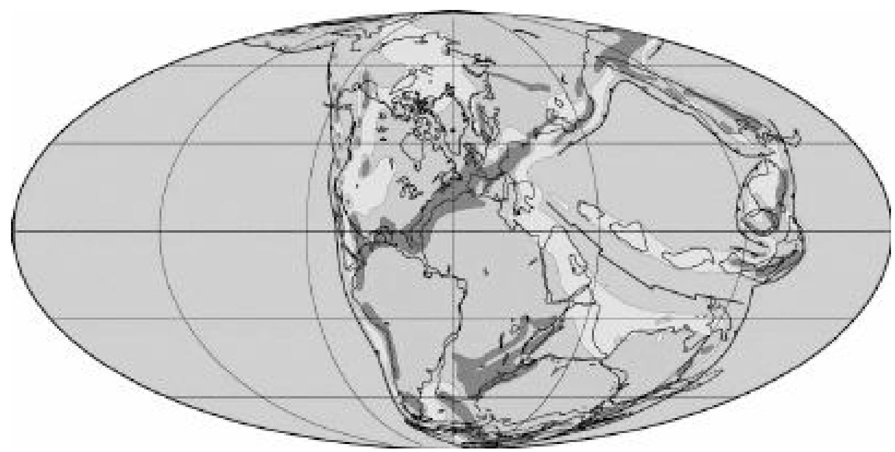
(and a tip o'the hat to Volcano World and the USGS for unwittingly providing images and information. . .)

OK. So we got rocks and minerals. *Now what?*

- *Why* are certain rocks and minerals found at certain places?
  - Some volcanoes produce only mafic rocks, others produce only felsic—none ever "switch-hit". *Why?*
  - Sedimentary rocks are sometimes found on high mountains—*how* did they get there?
  - Metamorphic rocks in some areas are formed by directional stress, and in others by non-directional stress—*why* do we get one or the other?
  - *How* does all this rock and mineral stuff tie in with everything else about the solid Earth?

Alfred Wegener (1880-1930)

A German meteorologist and geophysicist, Wegener became interested in "continental drift" while reading about the distribution of certain animal and plant fossils in far-flung places on the Earth.

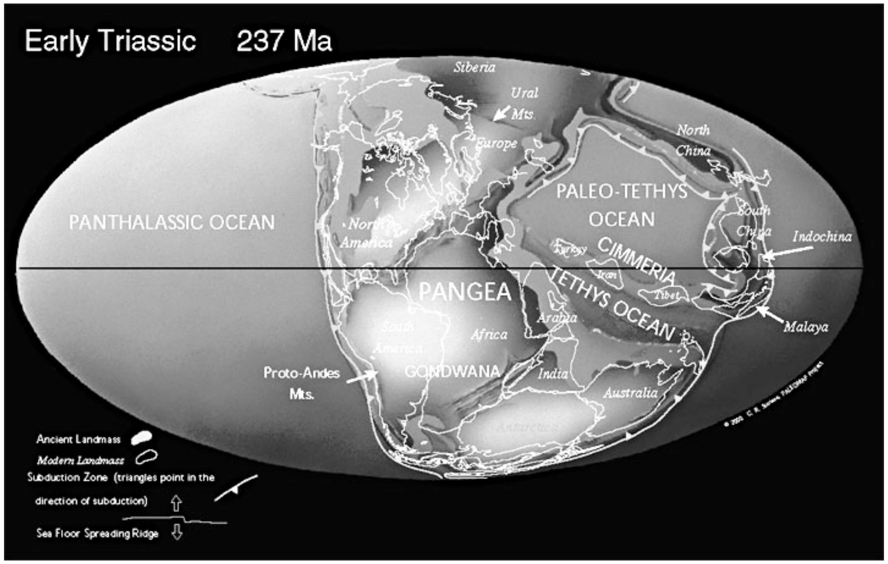


"the fundamental soundness of the idea seized my mind. . ."

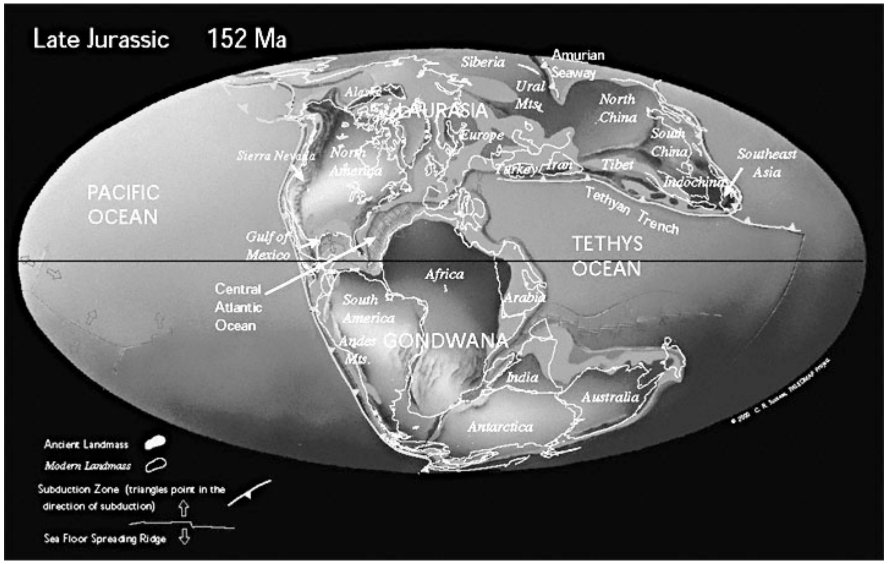
Pangaea

- ***Pangaea*** means "all the Earth"—name for a hypothetical *supercontinent*
- **formed** about 250 million years ago (before that, the continents were separate)
- began **breaking up** about 200 million years ago, forming:
  - a northern half, **Laurasia**
  - and a southern half, **Gondwana**
- Both halves then further fragmented to give rise to the continents we know today
  - The images on the next few slides appear courtesy of Chris Scotese, whose website is an awesome reference

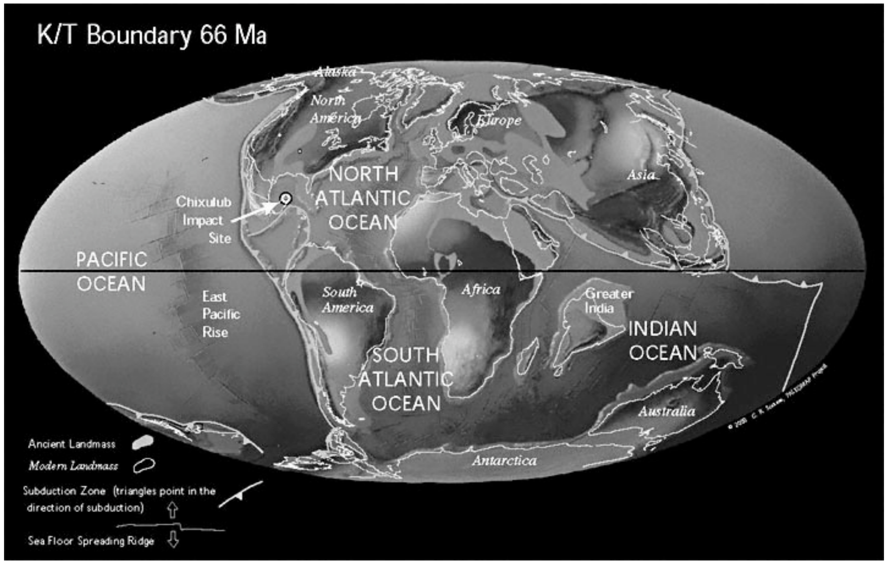
So here's what Pangaea looked like. . .



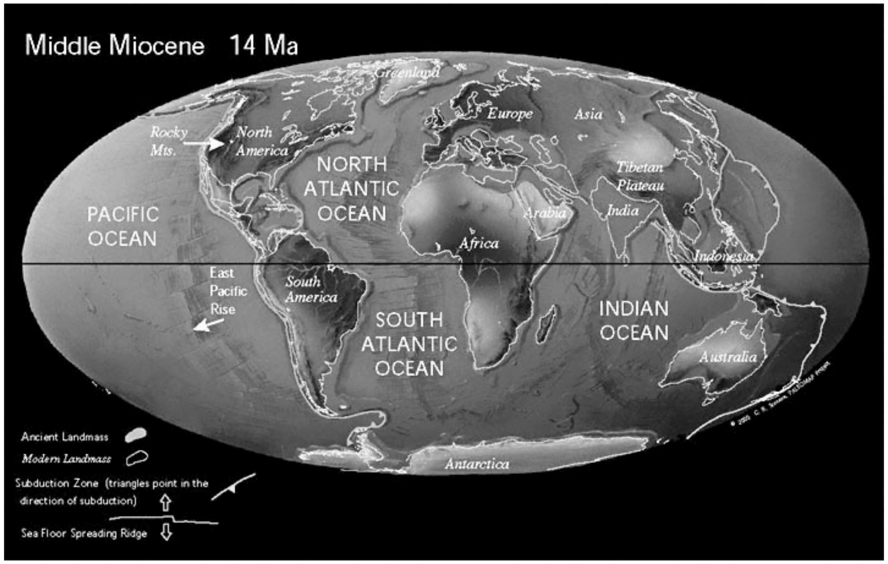
Laurasia and Gondwana have rifted from each other. . .

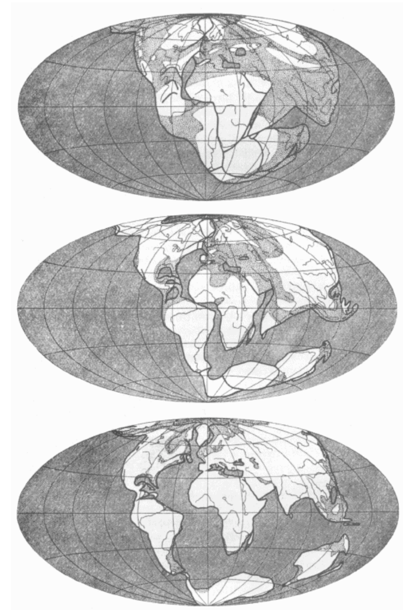


"Breakin' up is hard to do. . ."



By 14 million years ago, things look pretty familiar.

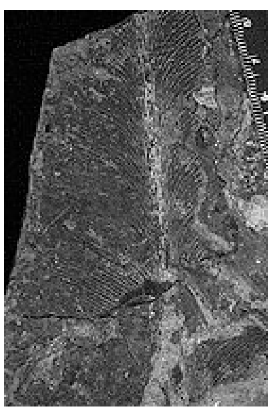




Wegener's lines of evidence:

- Distribution of fossils that pre-dated the breakup of Pangaea
- Distribution of living organisms
- Apparent Polar Wander (APW)
- Distribution of geological features

Consider *Glossopteris*. . .

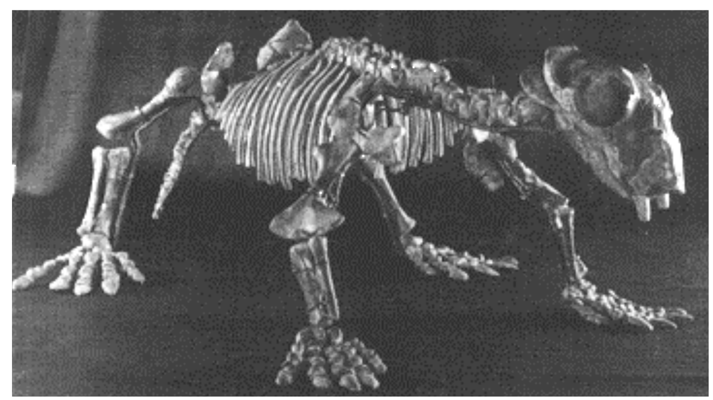


Antarctica

Australia

India

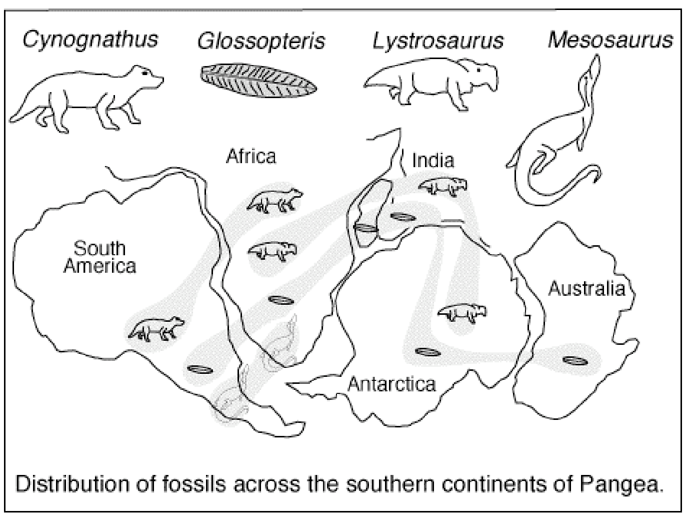
Consider *Lystrosaurus*. . .



Consider *Mesosaurus*. . .

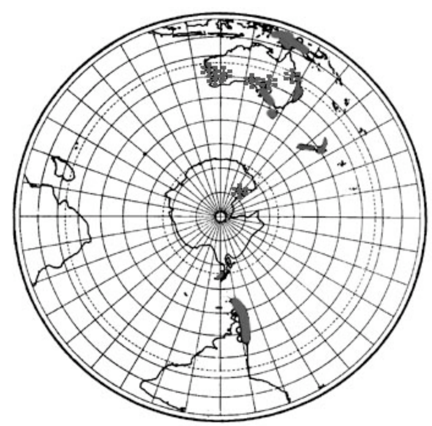
These and other fossils are important because:

- They are just a bit older than the inferred time of the breakup of Pangaea
- They are found on landmasses that are now separate but that were once close together in Pangaea
- They have the same pattern (or overlapping patterns) of distribution

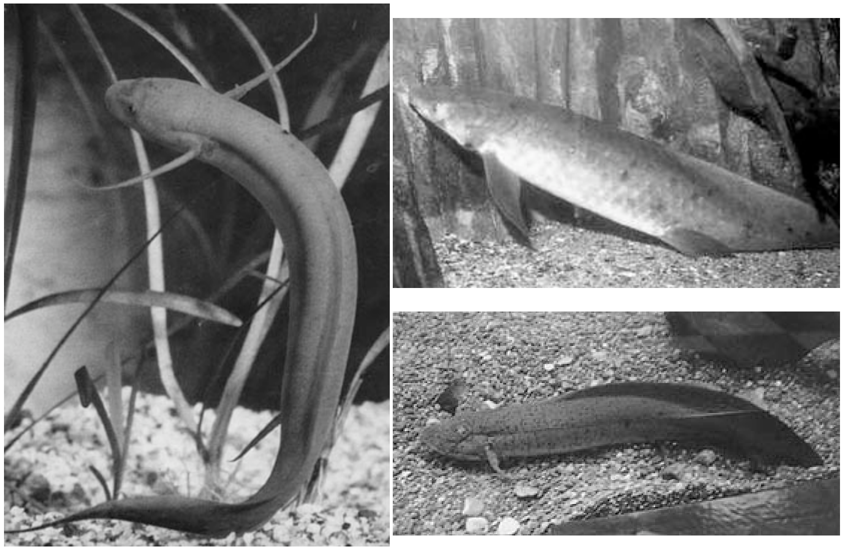


This map shows where these fossils have turned up, superimposed on a reconstruction of southern Pangaea

A number of living organisms are distributed in patterns that suggest that they were once unique to Laurentia or Gondwana



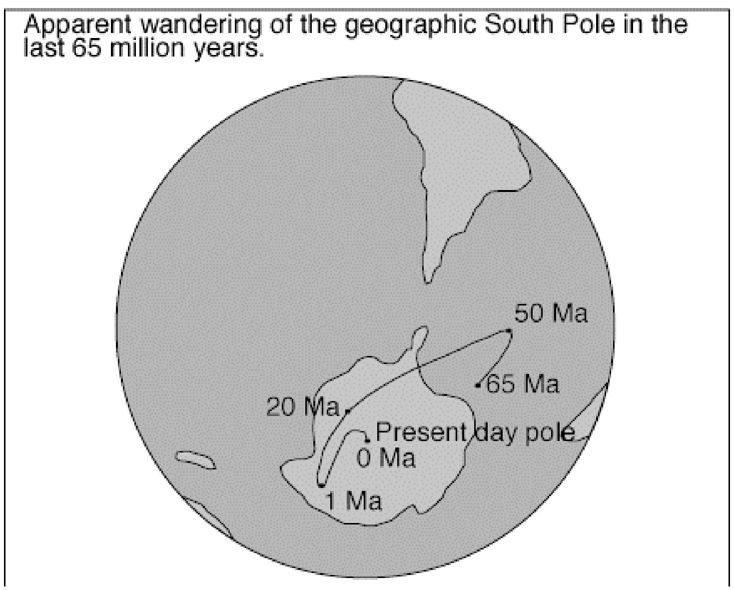
Nothofagus, the genus of "southern beech", and its distribution. Asterisks indicate where fossils have been found.



Lungfishes are another example of Gondwanan species.
(Left: African. Upper right: Australian. Lower right: South American.)

Apparent Polar Wander

- Many rocks contain records of Earth's magnetic field at the time they were formed
  - Molten rock loses all magnetic field. . .
  - When the rock cools below its *Curie temperature*, iron-containing minerals become magnetized in the same direction as the Earth's magnetic field at that point
- Such rocks act as "fossil compasses" that indicate the direction and distance to the magnetic poles
- At face value, the rock record would indicate that the magnetic poles have shifted all over the face of the Earth. . .



Apparent Polar Wander

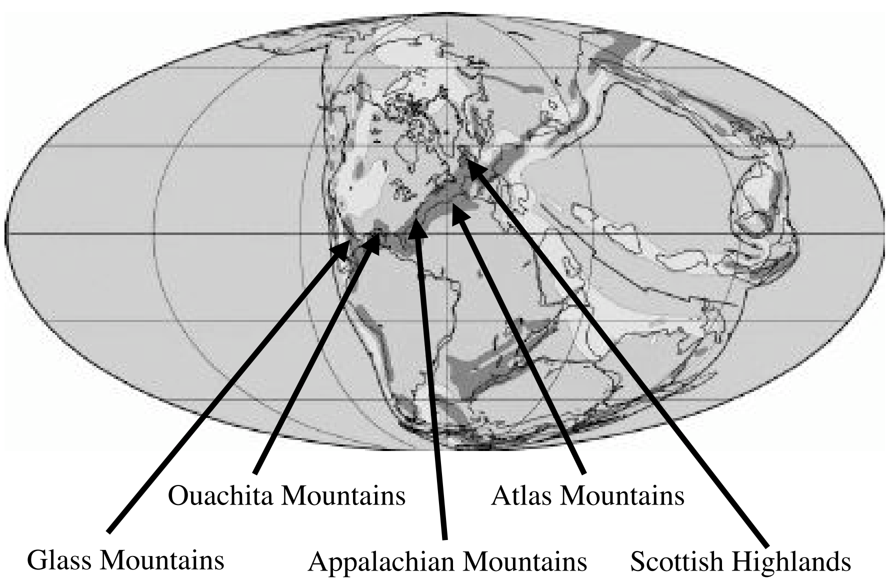
- In reality, the magnetic poles do move slightly (*true polar wander*). . .
- . . . but most of the effect is *apparent polar wander (APW),* resulting from the continent moving relative to the poles
- What's more: continents that were once joined together have parallel *APW paths*.

Geological Features

- Geological features such as mountain ranges and glacial deposits that are now on separate continents "match up"
- What are now separate features were once part of the same feature, now split by the rifted continents

Geological Features

- Other features are interpreted as having formed by continents colliding with each other
  - Examples include "fold-belt" mountain ranges: Ouachitas, Appalachians, Ural Mountains, Swiss Alps, Himalayas, etc.



Notice how these mountain ranges, now separate, fit together into one range on this reconstruction of Pangaea.

Wegener's ideas did not meet with acceptance at the time. . .

The theory of Wegener is to me a beautiful dream, the dream of a great poet. One tries to embrace it and finds that he has in his arms but a little vapor or smoke; it is at the same time both alluring and intangible.

-- H. Termier, French paleontologist

Wegener's ideas did not meet with acceptance at the time. . .

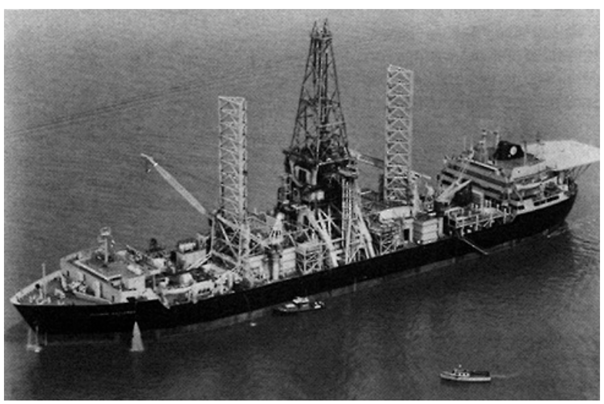
Whatever his own attitude may have been originally, in his book he is not seeking truth; he is advocating a cause and is blind to every fact and argument that tells against it.

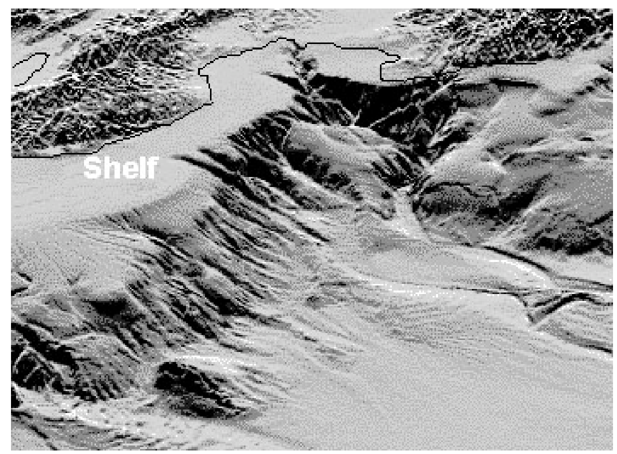
-- Philip Lake, American geologist

Problems with Wegener's ideas

- Wegener had no convincing explanation for what force was pushing the continents around
  - He originally thought it might be tidal forces (i.e. the gravity of the sun and moon)
  - Other calculations showed that tides strong enough to move continents would stop the Earth's rotation completely
- Wegener though thatt the continents might be "plowing through" the ocean floors, like icebreaker ships. . .

Exploration of the oceans (by ships like *Glomar Challenger*) led to the formation of modern plate tectonic theory by 1965

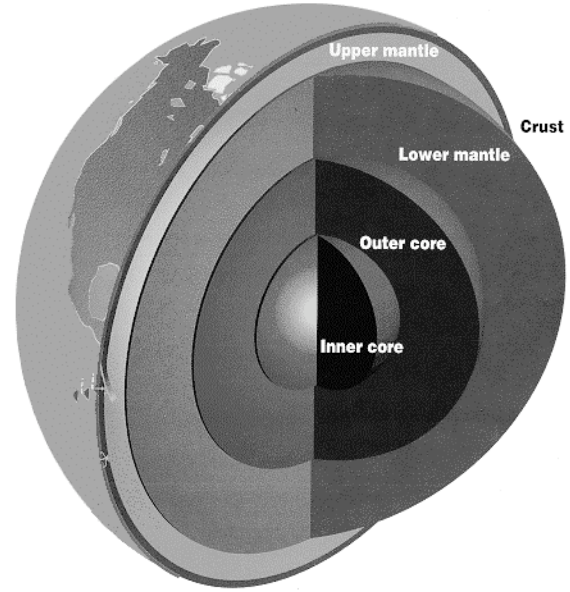




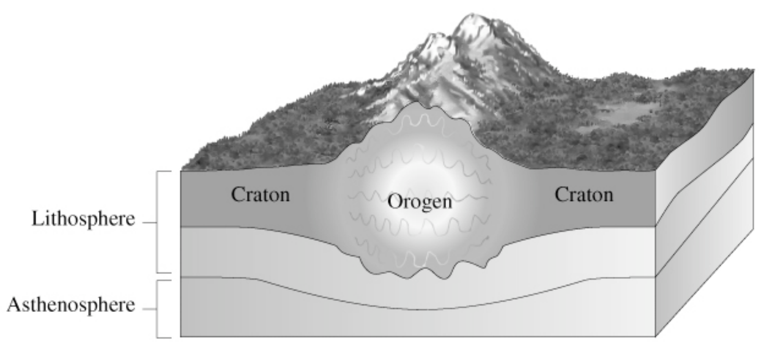
Structure of a continent: The *continental shelf* is a relatively flat region extending to the steeper *continental slope,* which marks the true edge of the continent.

Match up the outlines of the continental shelves, and you get an almost perfect fit. . . But what's moving them around?

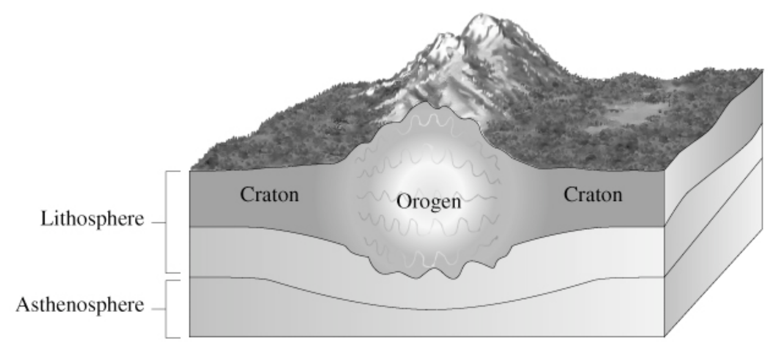
The Earth's structure consists of a solid outer *crust*, a *mantle* layer (thought to be mostly ultramafic rock), and an iron-nickel *outer core* and *inner core*.



Cross-section of a continent: The lighter *continental crust* (density about 2.6-2.7 g/cm^3) lies above the *oceanic crust* (density about 2.8 g/cm^3).



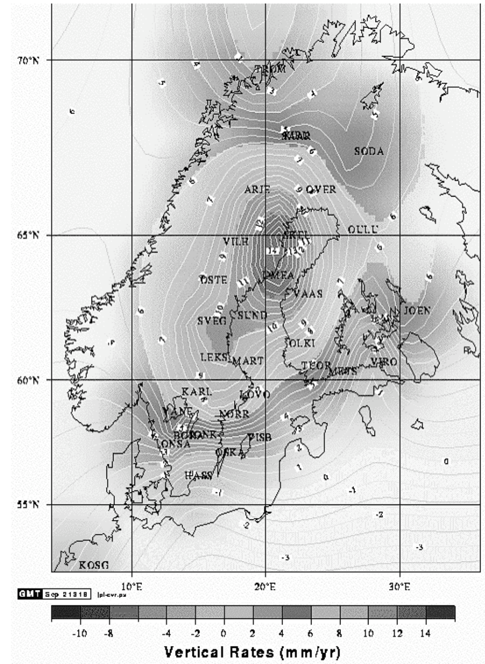
Continental and oceanic crust together make up *tectonic plates* that "float" on the solid but extremely viscous *asthenosphere* (a.k.a. the upper mantle).



It will take several lectures, but I promise: we'll eventually answer the question of *how* we know all this. . .

A continent can be pushed down into the asthenosphere, and then rise back up if the pressure is released. This adjustment to retain buoyancy is called *isostasy*.

Thanks to *glacioisostatic rebound,* these ancient sea cliffs are now hundreds of feet from the waterline. Hudson Bay, Canada.



Map of glacial rebound in Scandinavia, measured directly over a decade using GPS (Global Positioning System) satellite technology. The areas of fastest rebound (shown in red) are rising at over 14 mm per year.

(Map courtesy of the BIFROST project)