1/30/08

GEOL 117 Class 6 web notes

Scientific Revolutions
Brief Intro to Plate Tectonics
Continental Drift
Sea-floor Spreading
Paleomagnetism

Scientific Revolution: Replacement of reigning "paradigm" by a new paradigm -- greatly changes a field of science (Thomas Kuhn's idea)

1. "Normal" Science: Observations and theories form a coherent paradigm or "story" that explains almost everything- new observations are fit into it, observations that don't fit are questioned.
2. "Crisis": New observations don't fit but are correct and can't be discarded: Paradigm threatened
3. "Revolution": New paradigm developed and accepted
-- New paradigm generates new "testable hypotheses"
-- Old paradigm defended by many- healthy skepticism
-- Eventually, new paradigm found clearly superior

Failed revolutions: New paradigm NOT accepted, old paradigm "patched up" or modified or other wise defended and kept

Development of Plate Tectonics: Revolutionized Geology

1. "Normal" Science: 100 years ago, plausible theories explained things like...
- Why are ocean fossils found near the top of Mt. Everest and other mountain ranges?
- Why are mountain chains found where they are?
- Why are volcanoes found only in certain zones of the world

The idea that the continents move was not really considered- not really "needed"

2. "Crisis": New observations in the mid-1900's
Unanticipated discoveries in the ocean basins were key to this

3. "Revolution": Plate tectonic theory developed, 1960's
- New paradigm- gave a "big picture" of the earth in a new way
- Completely new way of looking at the earth- hard for many to accept
  - Explained many, many details about the earth
  - Old paradigm could not
- Old theories given up- but not without careful weighing of the competing theories
  Healthy skepticism is normal in science
- Eventually, the evidence FOR plate tectonics became overwhelming

In the end, a scientific revolution greatly advances science by developing a new, more accurate model with which to understand nature.

Note: Technology had advanced enough to put a person on the moon by 1968, and yet the most basic principle describing how the earth works was just gaining acceptance! This is partly because **much of the evidence was hidden in the ocean depths**, which were not explored until the mid-1900's.

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Brief Intro to Plate Tectonics- A major paradigm for geology

The earth's crust and the uppermost layer of the mantle move together (this package is the **Lithosphere**)

The lithosphere is **broken into plates** that slide past each other, collide, and slip under/over each other

Driving force for this: Convection; the mantle "turns over" because it is cooled at the top and heated within

Continental Drift- an early theory, one component of plate tectonics

Basic concept (Alfred Wegener, ca. 1912)

- Single supercontinent, "Pangea" ~250 m.y. ago
- Slow "drifting" to present position

Evidence for continental Drift

1. Fit of the continents across the Atlantic Ocean

Atlantic coastlines fit together like a jig-saw puzzle. This had been noticed by other hundreds of years before, but Wegener explored whether geologic features also matched-up in his reconstruction.

2. Distribution of mountains and rock sequences

Appalachian mts. and similar mountains in Europe connect up when continents are reconstructed. Distinctive types of rocks and patterns of folds on Africa and S. America match up well for a reconstructed Pangea

3. Distribution of sedimentary rocks reflecting paleoclimate (glacial evidence)

Rocks deposited at the Earth's surface (sedimentary rocks) reflect the climate (and hence latitude) where they form. For example, ancient coral reefs and coal swamps form in warm, humid, low latitudes. Glacial deposits should form at cold, high latitudes. Wegener found evidence for glaciated regions widely scattered in the Southern Hemisphere, and for coal deposits. His reassembled continent explains the paleoclimatic record in those sedimentary rocks.

Interesting side note: Some scientists suggested (as late as the 1960's) that the earth's rotational poles changed over time (for example, the earth might have rotated differently, so that the rotational pole was located in India). So there were ways of explaining glacial ice near the equator, other than continental drift. See wikipedia article, "Pole shift theory" if you are curious about this.

4. Distribution of fossils:

A number of identical fossils are found on widely separated continents.

- Cynognathus -- land reptile (couldn't swim at all) in S. Amer. & Africa
- Mesosaurus -- fresh water reptile (couldn't swim far and not in salt water) in S. Amer. & southern Africa
- Lystrosaurus - fat land reptile (not a swimmer) in Africa, India, Antarctica
- Glossopteris - fern with heavy seeds (couldn't be blown across the ocean)

The distribution of those organisms only makes sense for a reconstructed Pangea

Wegener's idea was not accepted at the time! It was even ridiculed. The reasons were:

1) Wegener didn't have a reasonable mechanism for movement of the continents.

He suggested that attractive forces of the moon caused continents to crash through the oceans (like a ship breaking through ice). Therefore, ocean crust should be deformed, but it isn't.

2) Wegener's geological evidence was mostly from observations in the Southern Hemisphere.

Northern Hemisphere geologists were unfamiliar with the observations so they discounted them. Prejudice based on ignorance (scientists are human).

This was **a "failed" scientific revolution-** a new paradigm did not gain ascendance and the community just continued on with "normal science".

But the theory was resurrected when detailed information about the sea floor was gathered and analyzed in the 1950's and l960's.

Sea-Floor Spreading, proposed by Harry Hess in 1962 based on his observations of sea-floor topography. The basic idea:
1) New ocean **crust is created at mid-oceanic ridges**, moves laterally ("spreads") away from ridges like a conveyer belt, and is destroyed at trenches, where it sinks into the mantle.
2) Convection currents in the mantle are the driving force of sea-floor spreading.

This theory created a scientific revolution. During the l960's, many research projects tested this new hypothesis. Many of these dealt with properties of the sea floor.

Plate tectonics is a larger paradigm, of which sea floor spreading is one part.

Additional Evidence (around the time Hess developed his hypothesis and a little later) that led to the theory of Plate Tectonics:

<u>Paleomagnetism (this is challenging material for most Geology 117 people)</u>
1) Apparent Polar wandering (idea began in the 1950's, developed through 1960's)

- When lava solidifies or sediments collect, resulting rocks are slightly magnetized
  …. Magnetic minerals tend to orient parallel to Earth's magnetic field
- This magnetic orientation remains for millions, maybe billions of years
- Points to the location of magnetic north pole AT THE TIME OF FORMATION
- Also gives the **latitude** of the rock's formation, relative to the magnetic pole
  How? The magnetic field is inclined:
  - Parallel to earth's surface at low latitude
  - Almost vertical at very high latitude
  so....Inclination ANGLE increases as latitude increases
  and… if you measure the inclination angle, this tells you your latitude

If continents and magnetic poles were stationary, one would expect that paleomagnetic directions would all match today's magnetic field- **THEY DO NOT!**

Original interpretation: The magnetic pole had wandered over time
But this didn't hold up- **DIFFERENT POLAR WANDER TRACKS are observed on DIFFERENT CONTINENTS!**

The only way to reconcile all the paleomagnetism data was to postulate that the continents drifted.

2) Magnetic reversals (Vine and Matthews, 1963)

- Earth's magnetic poles abruptly change places periodically ("north" becomes "south")
- We know when these reversals occurred
- Rocks formed during a time period of reverse polarity have magnetism the opposes Earth's present-day magnetic field
- Rocks formed during times of normal polarity have magnetism that reinforces the earth's magnetic field