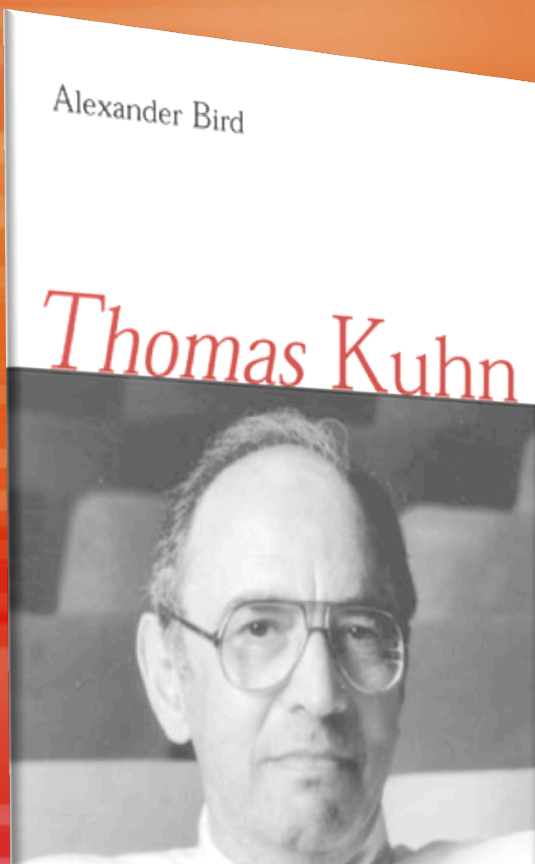


# Plate Tectonics I: Discovery

Paradigms and Scientific Revolutions  
Wegener and Continental Drift  
Sea Floor Spreading  
Plate Tectonics





Thomas Kuhn. 1962. *The Structure of Scientific Revolutions*, University of Chicago Press, 1962.



- 1922** born, Cincinnati, Ohio,
- 1949** Ph. D. (physics), *Harvard University*  
Assistant professor of general education and history of science, *Harvard University*
- 1956** Professor of history of science, *University of California—Berkeley*
- 1964** M. Taylor Pyne Professor of Philosophy and History of Science, *Princeton University*
- 1979** professor philosophy/history of science, *Massachusetts Institute of Technology*
- 1983** Laurence S. Rockefeller Professor of Philosophy, *MIT*.
- 1996** died

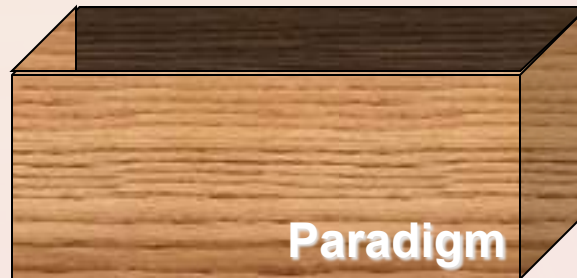
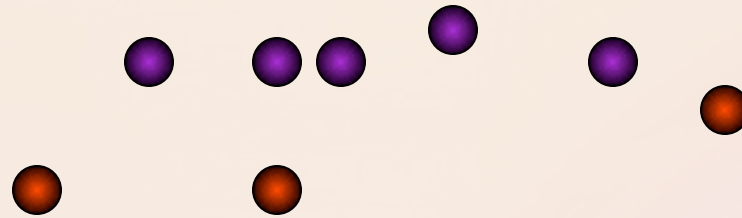
**Paradigm** - a philosophical and theoretical framework of a scientific school or discipline within which theories, laws, and generalizations and the experiments performed in support of them are formulated

*Paradigms help scientific communities to define the boundaries of their discipline in that they help to:*

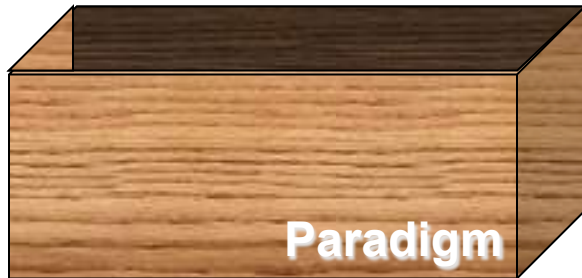
1. create avenues of inquiry.
2. formulate questions.
3. select methods with which to examine questions.
4. define areas of relevance

***Paradigms are essential to the functioning of science!***

# New Scientific Observations



*Anomalies* – new observations that do not fit



## Resolving Anomalies

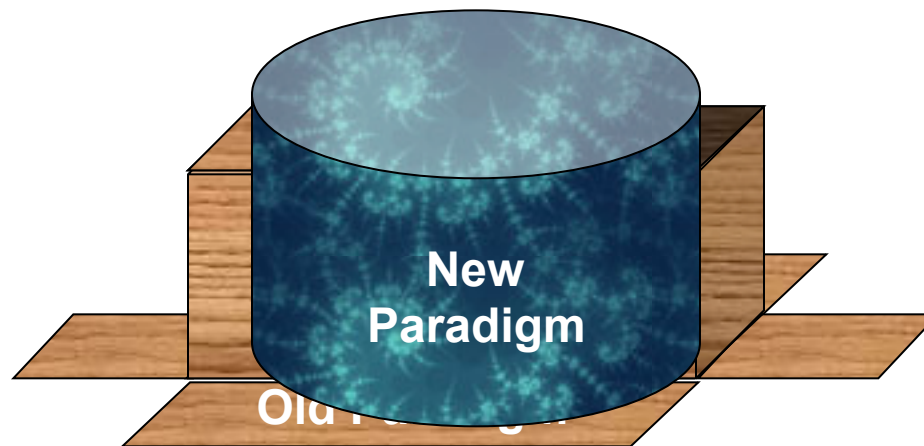
### Paradigm in Crisis

- 🕒 Crisis-provoking problem resolvable with current paradigm
- 🕒 The problem resists and is labeled, but it is perceived as resulting from the field's failure to possess the necessary tools with which to solve it, and so scientists set it aside for a future generation with more developed tools.
- 🕒 A new candidate paradigm emerges, and a battle over its acceptance ensues (*paradigm wars*)

# Scientific Revolution

Adoption of a new paradigm which both explains all the old observations, and incorporates the new.

The new paradigm replaces the old one completely, and our understanding of the science changes.





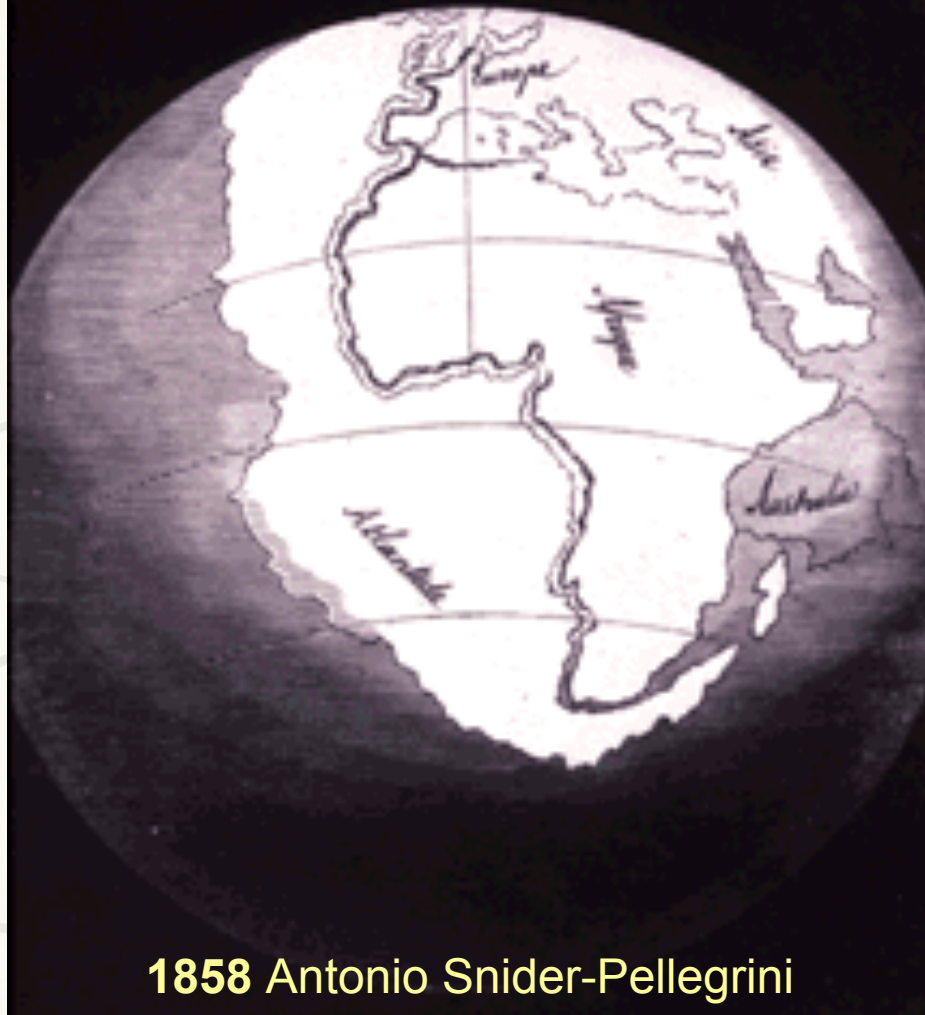
## Alfred Wegener (1880-1930)

1904 Ph.D. University of Berlin

- ⊕ Geophysics, meteorology and climatology researcher; pioneered use of weather balloons to track air circulation; extensive field research in Greenland.
- ⊕ Published *The Origins of Continents and Oceans*, which proposed that the continents move relative to each other

AVANT LA SEPARATION

(trans: before the separation)



**1858** Antonio Snider-Pellegrini

## The Fit of the Continents

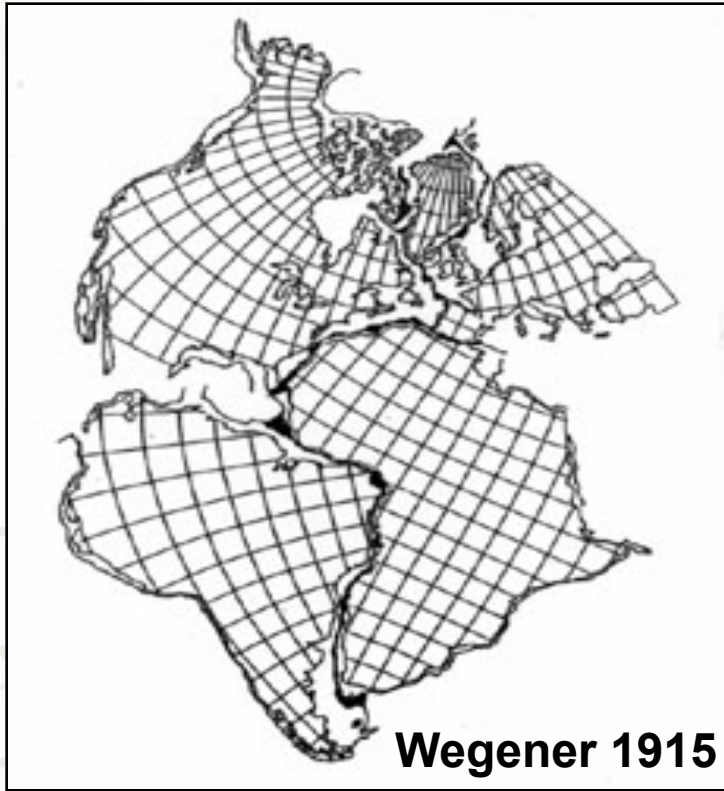
Earlier natural philosophers (e.g., Francis Bacon, Alexander Von Humbolt) had made the observation that the eastern shorelines of North and South America seemed a good fit to the western coasts of Africa and Europe.

Even with pretty bad maps (left) of the Americas, the fit does catch the eye.

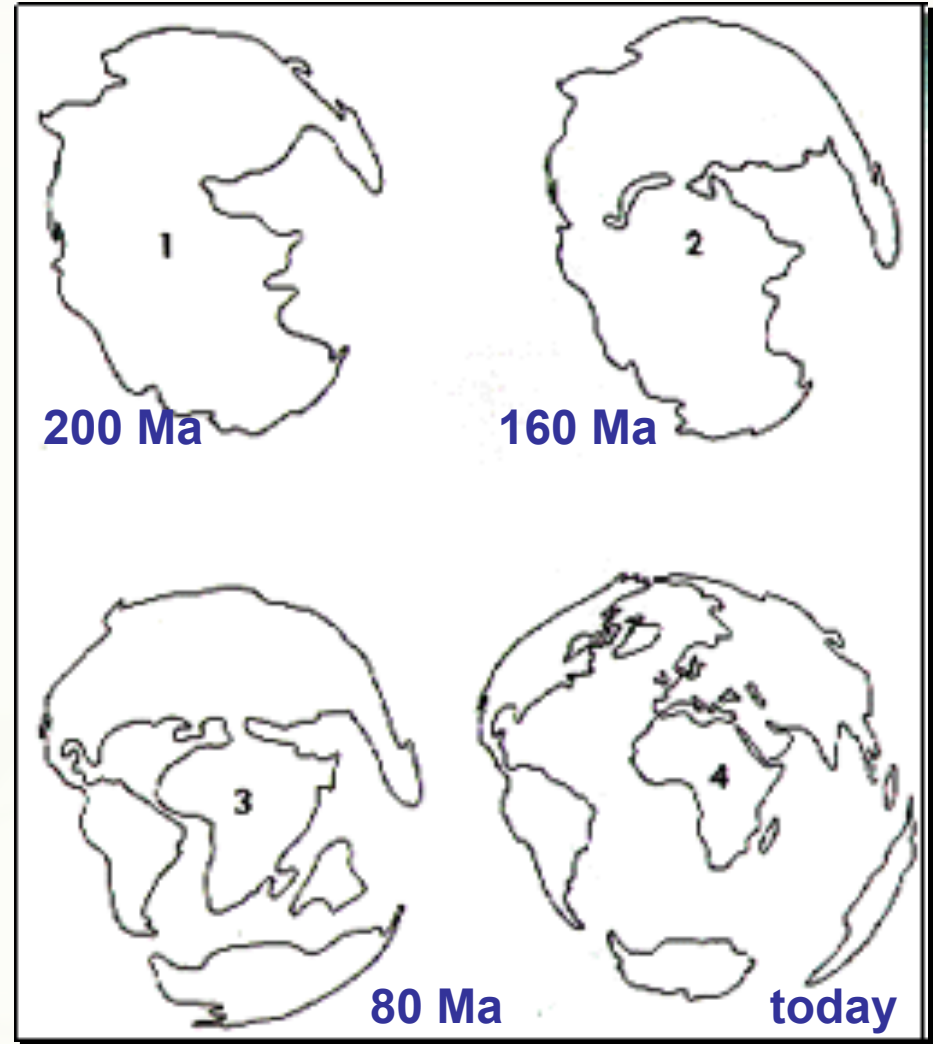
<http://pubs.usgs.gov>

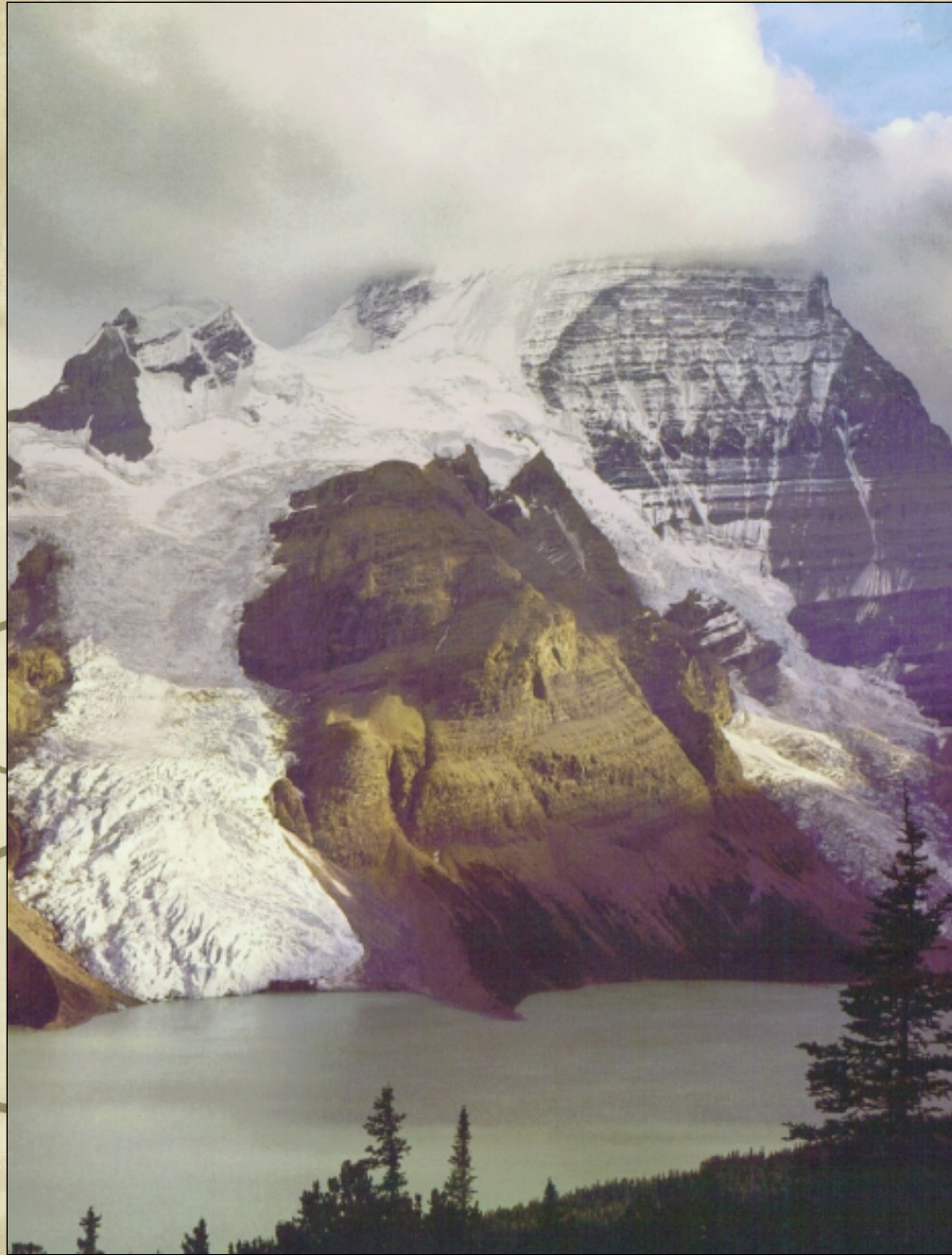


# The Fit of the Continents



With better maps, and new data, Wegener proposed that all the continents had been joined into one huge landmass 200 million years ago, and had since gone their separate ways.





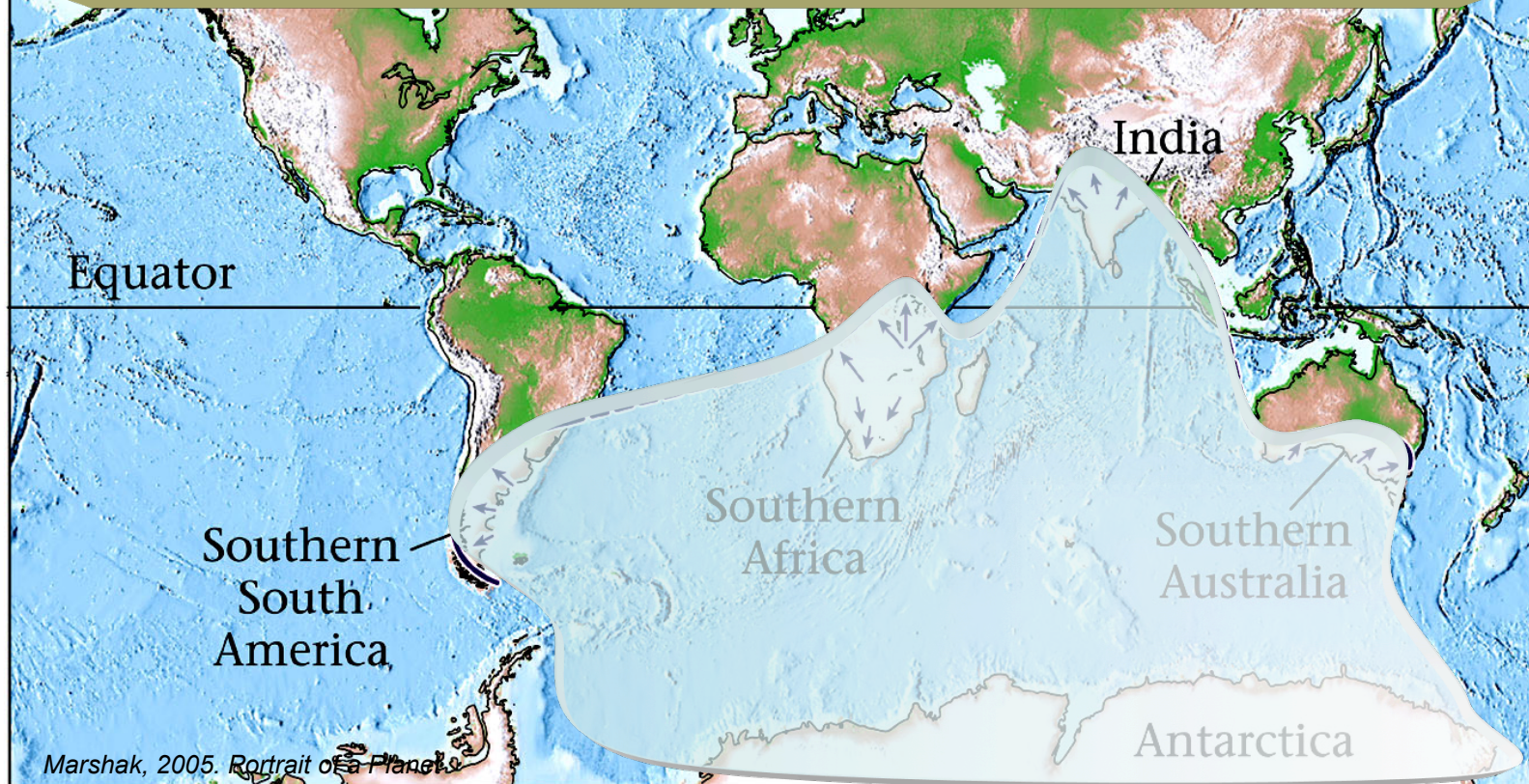
## Wegener's Evidence for Continental Movement

### Paleoclimatology

Abundant evidence for glaciers in the past in areas currently near equator.

Evidence for tropical conditions in the past in regions currently near poles

Clues in the sedimentary rock record (such as glacial deposits) indicated that there were once continental glaciers in places that are now near the equator.



Other data from the sedimentary rock record indicate that tropical environmental conditions once existed in areas near the poles today.

If the continents were at different latitudes in the past, these paleoenvironmental distributions make sense.

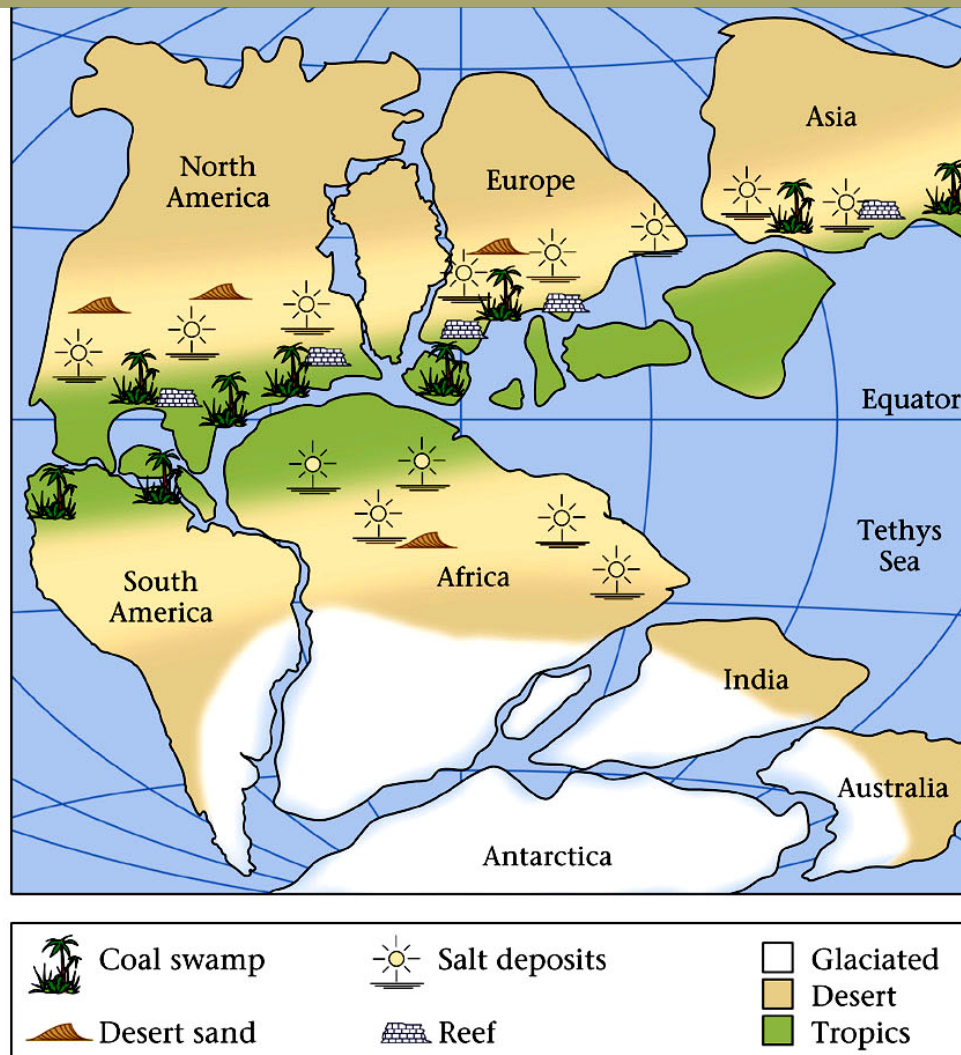


FIGURE 3.4

*Earth: Portrait of a Planet, 2nd Edition*  
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## Wegener's Evidence for Continental Movement



### Paleobiogeography

Fossils are the remains and traces of once living things.

When scientists looked at the distribution of fossil in modern rocks, many of the distributions were weird-looking, with the same kind of terrestrial animal or plant separated by oceans.

# Paleobiogeography

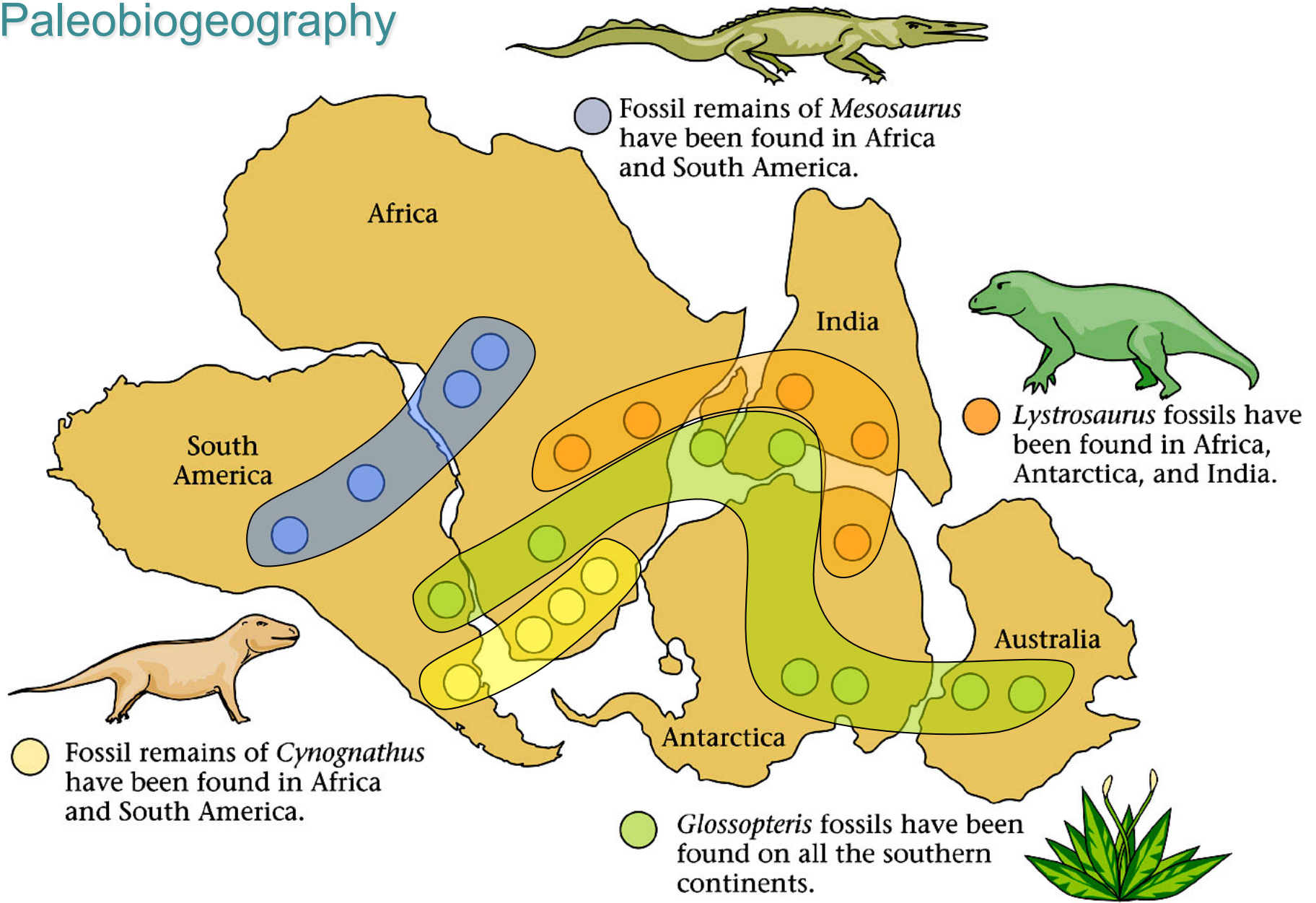
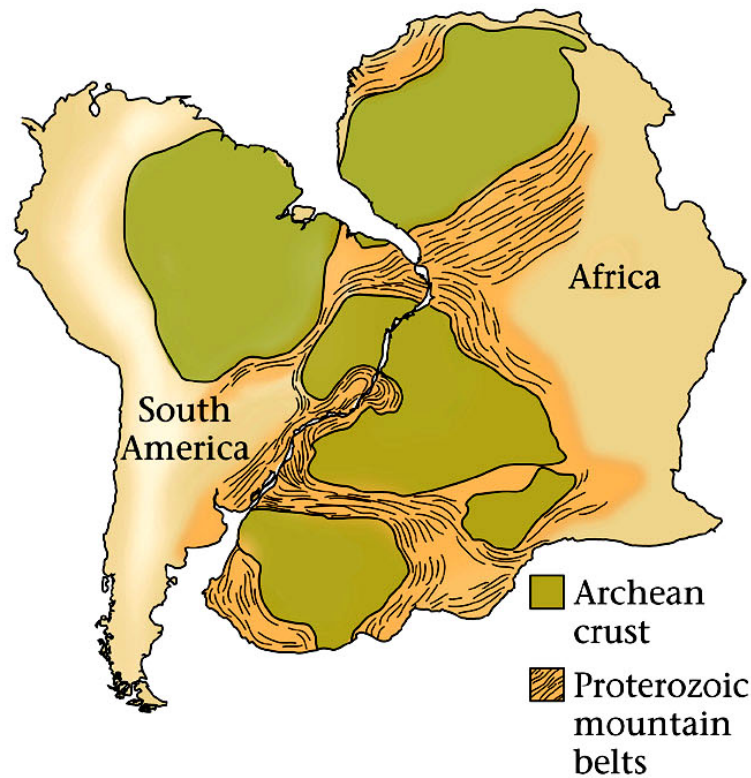


FIGURE 3.5

## Wegener's Evidence for Continental Movement



### Similarities in Regional Geology

As with paleobiogeography, some geologic features have clearly been “sliced and diced.”

The pieces can be reassembled, but only if the continents are moved.

# Wegener's Evidence for Continental Movement

## Truncated Mountain Ranges

As with paleobiogeography, some geologic features have clearly been “sliced and diced.”

The pieces can be reassembled, but only if the continents are moved.



(b)

*Earth: Portrait of a Planet, 2nd Edition*  
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**"A conviction of the fundamental soundness of the idea  
took root in my mind."**

## ***Continental Drift***

**The Earth's crust is composed of large,  
rigid plates, which move relative to each  
other throughout geologic time.**



Wegener made what was to be his last expedition to Greenland in 1930.

While returning from a rescue expedition leading a dogsled run that brought food to a party of his colleagues camped in the middle of the Greenland icecap, he died, a day or two after his fiftieth birthday.

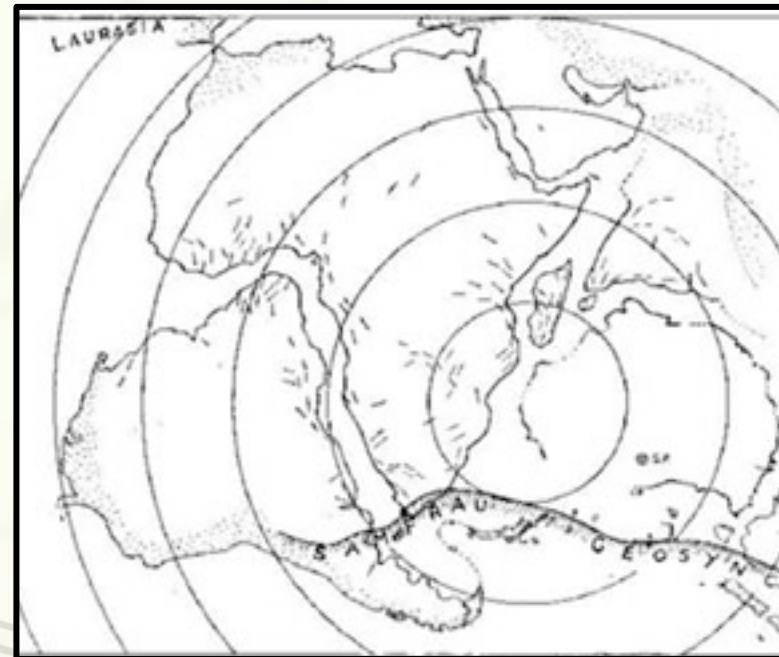


courtesy Geological Survey, Pretoria

## Alexander Du Toit

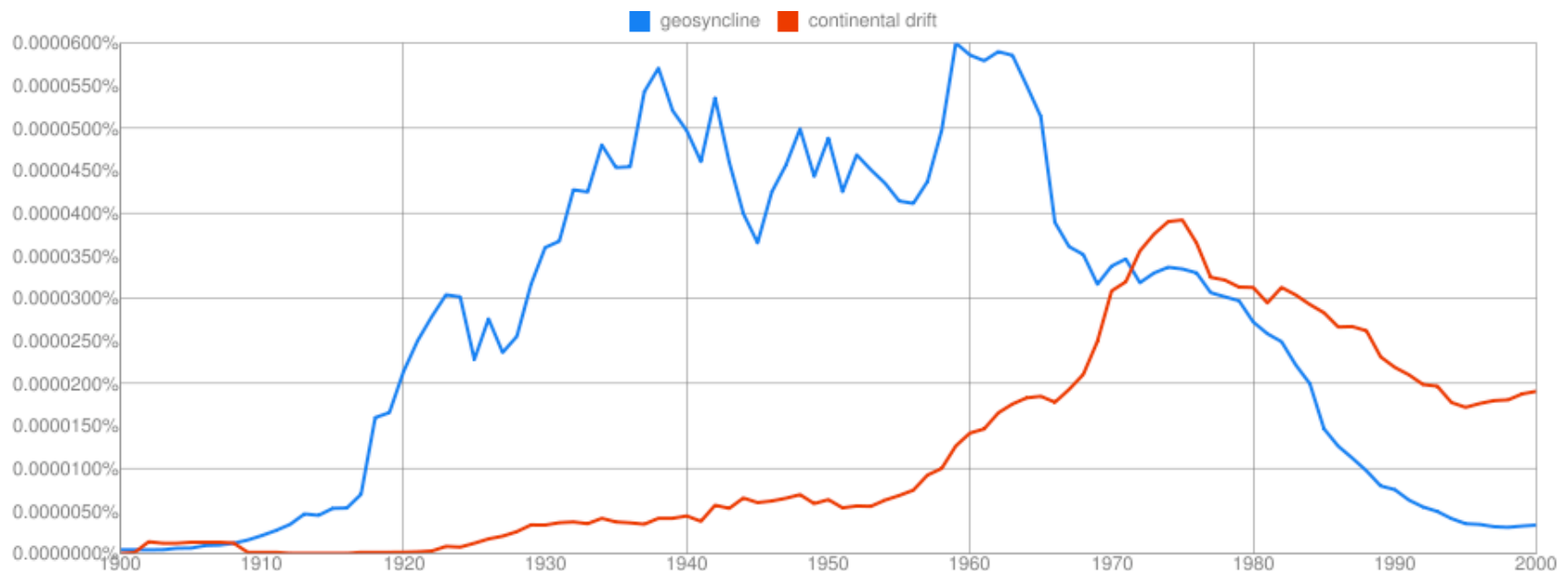
After Wegener's death, other scientists took up the theory of continental drift.

Most of these scientists lived on pieces of the former supercontinent Gondwanaland, where the regional geology supported the theory.



## The Failure of Continental Drift

The theory of continental drift never gained much popular support primarily because it was incomplete, lacking a mechanism. “Vertical tectonics” which postulated that blocks of crust popped up and down over time, creating mountains, was the dominant paradigm of the day.



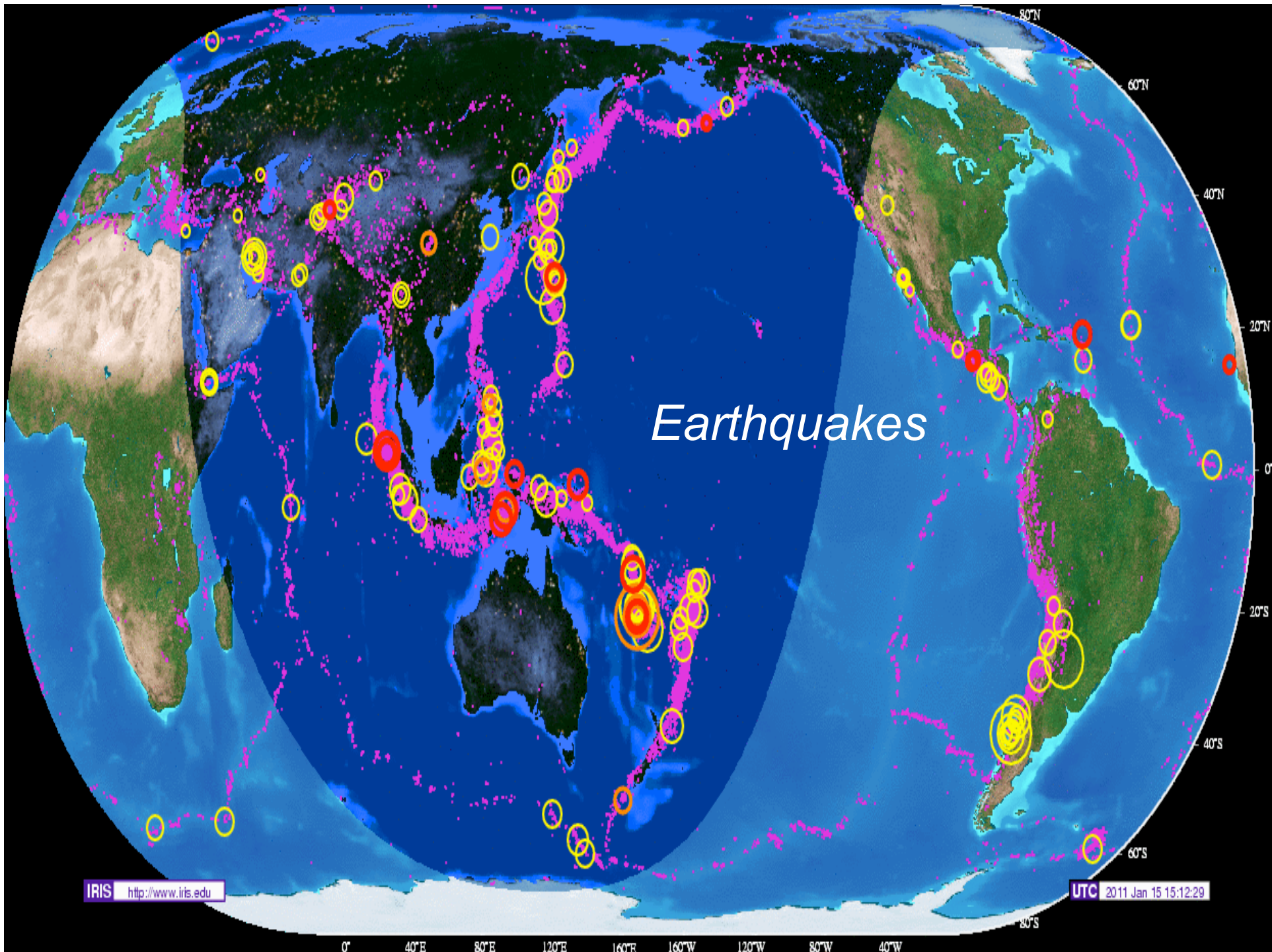
## New Data: Seismic Data

Earthquakes and volcanoes are not randomly distributed on the Earth, but concentrated in zones!



Earthquake and/or volcano-rich zones define the edges of the plates, where different plates are moving relative to each other, causing seismic upheaval.

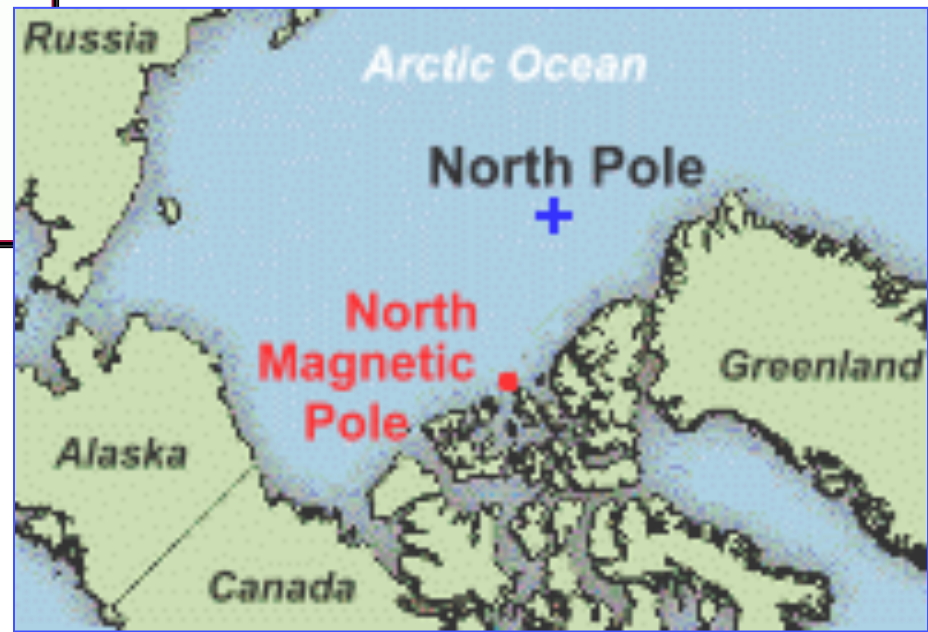
<http://www.worldatlas.com/>





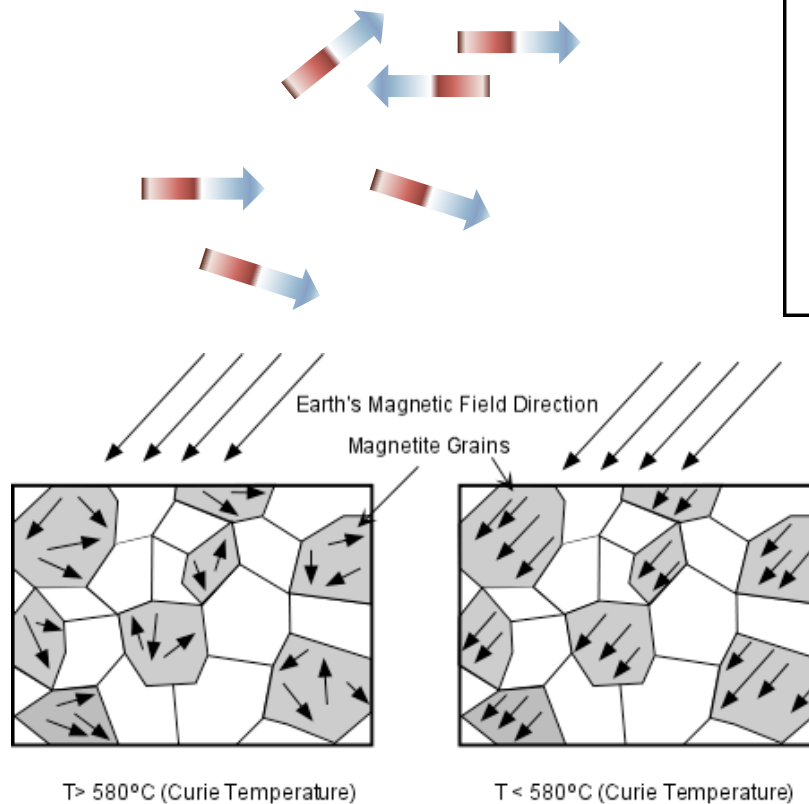
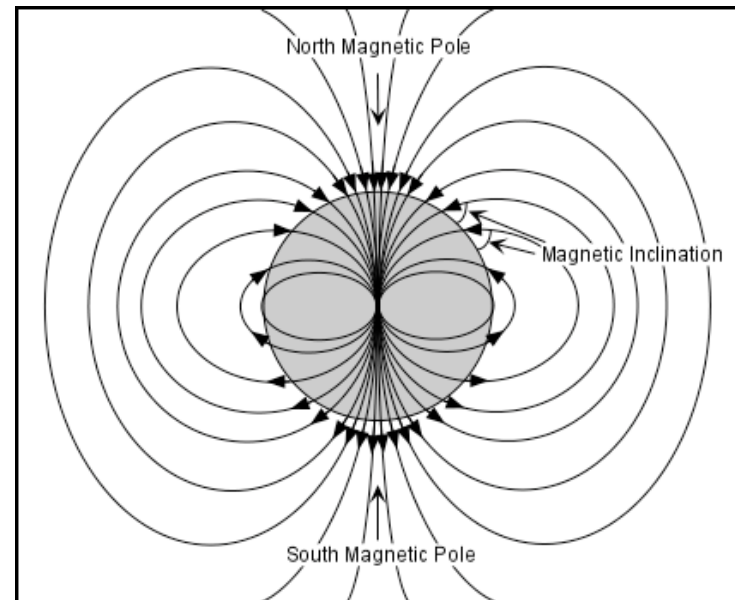
## More New Data

The Earth's core generates a magnetic field with magnetic poles near the rotational north and south poles.



# Paleomagnetism

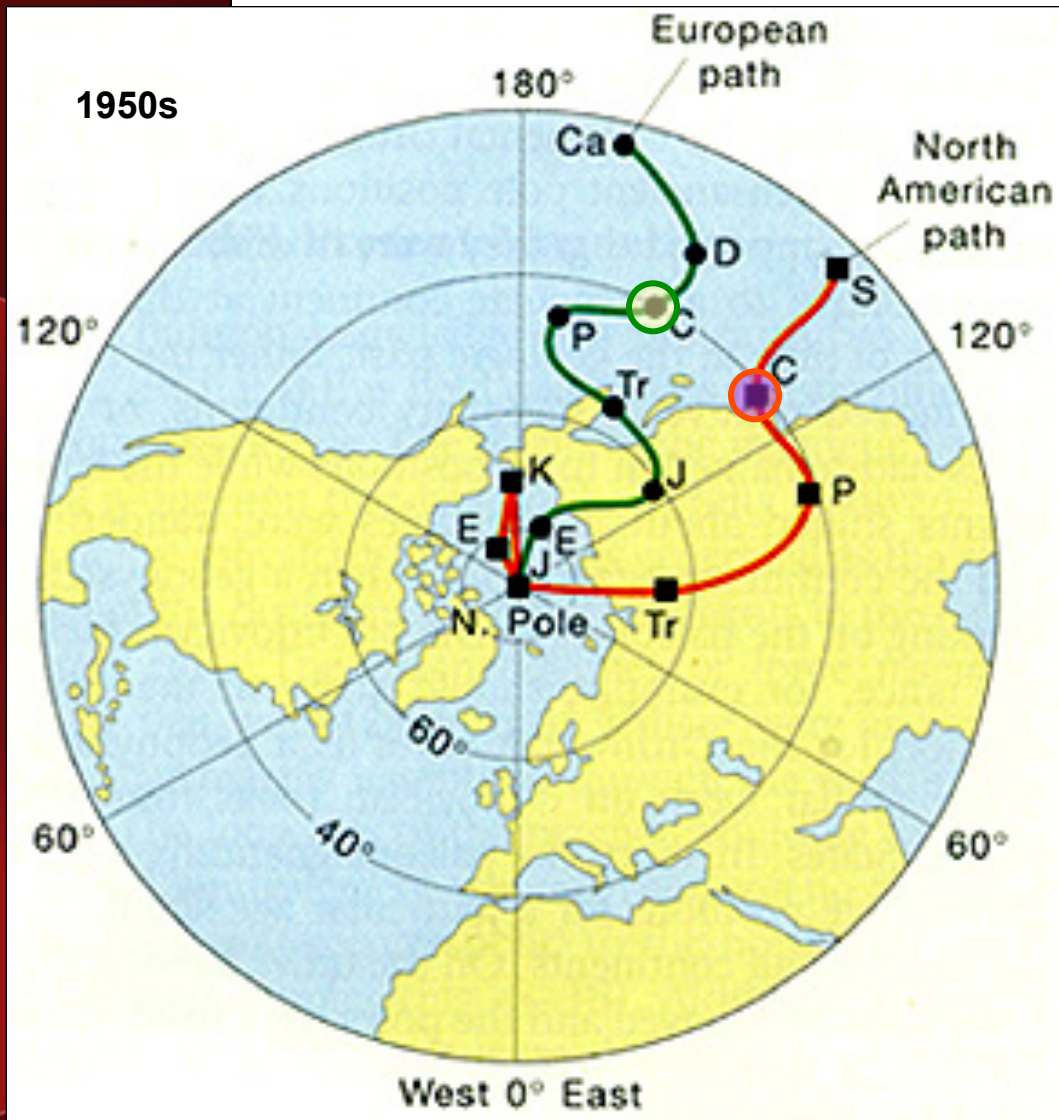
The magnetic field of the Earth is inclined relative to the surface of the Earth. This magnetic inclination correlates with latitude.



Magnetic minerals align to the local magnetic field. Therefore the latitude at which that mineral formed can be determined.



# Apparent Polar Wandering

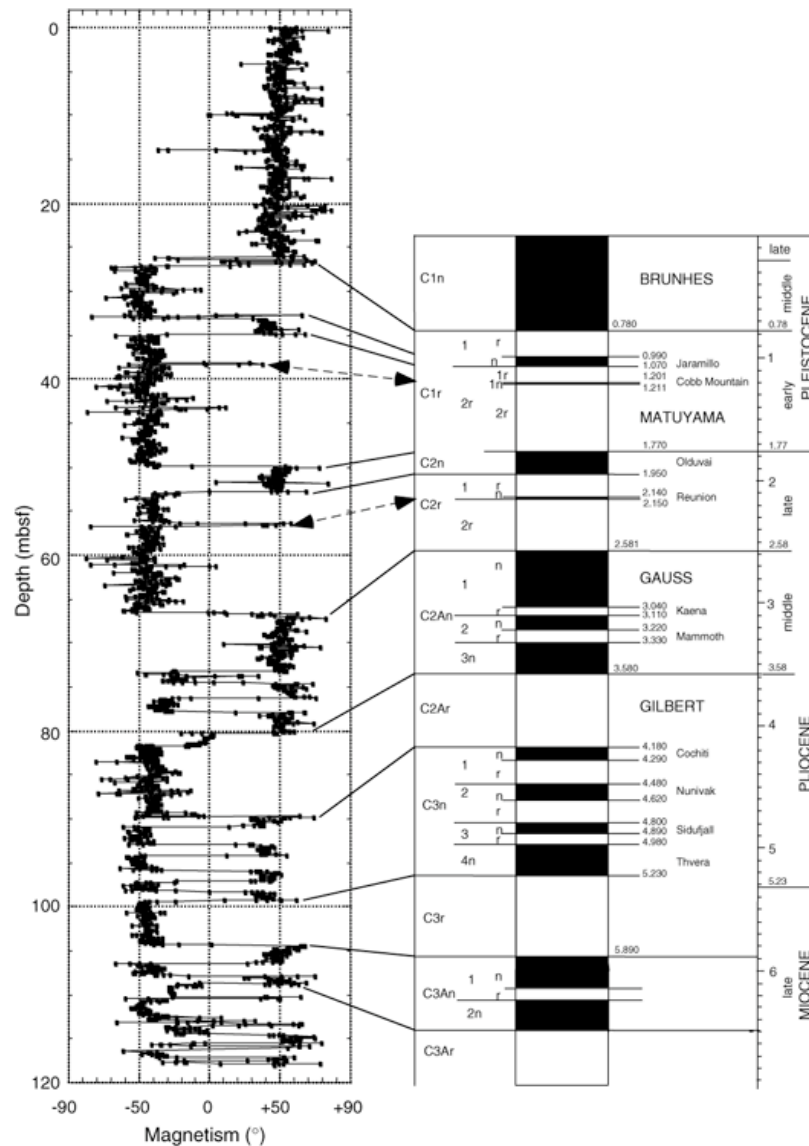


In the 1950s, scientists used paleomagnetism to map the position of the Magnetic North Pole in the past.

Not only were the past poles not near the present poles, but the actual position of the poles during any time period varied by location!

Clearly something was very wrong...

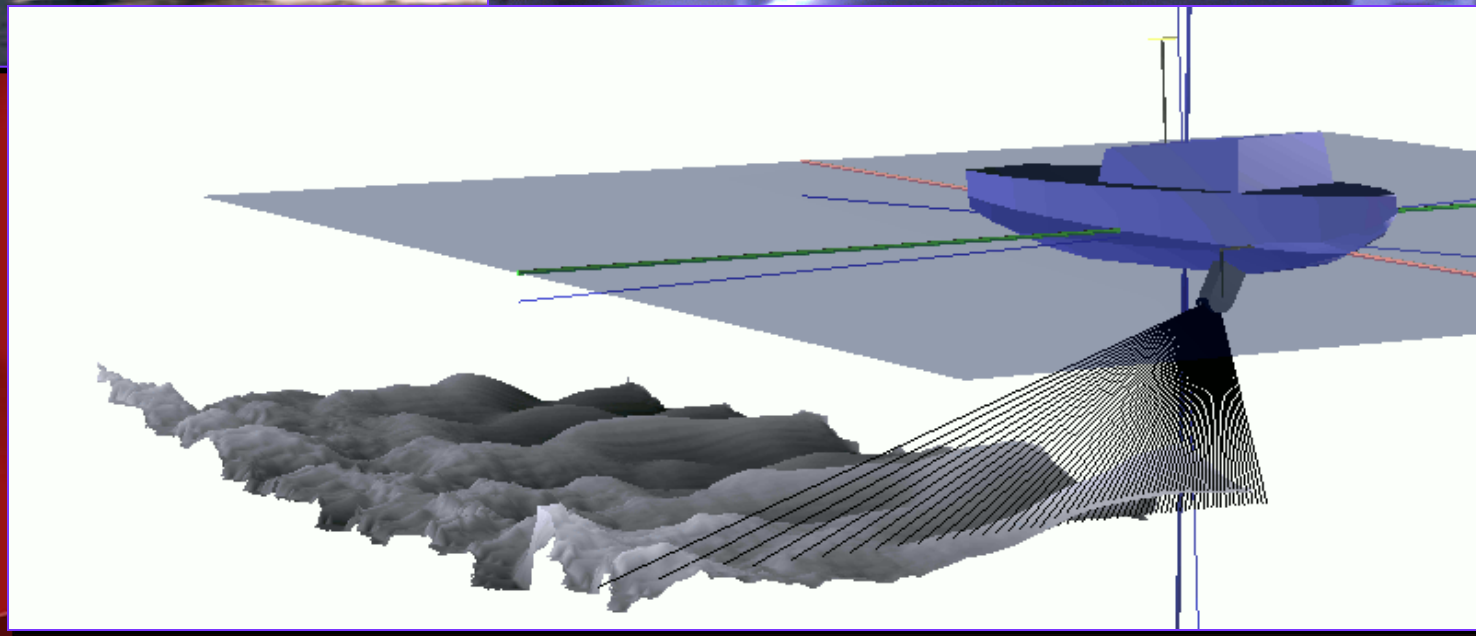
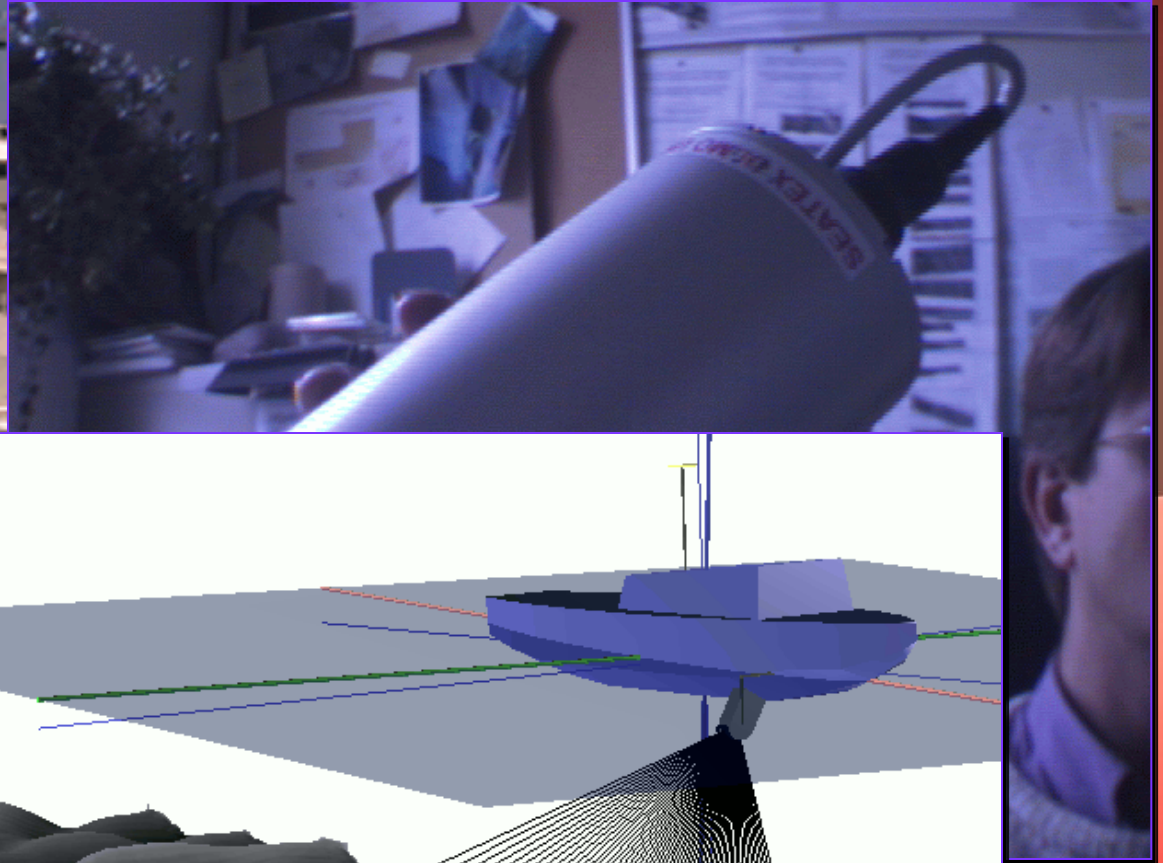
## More New Data



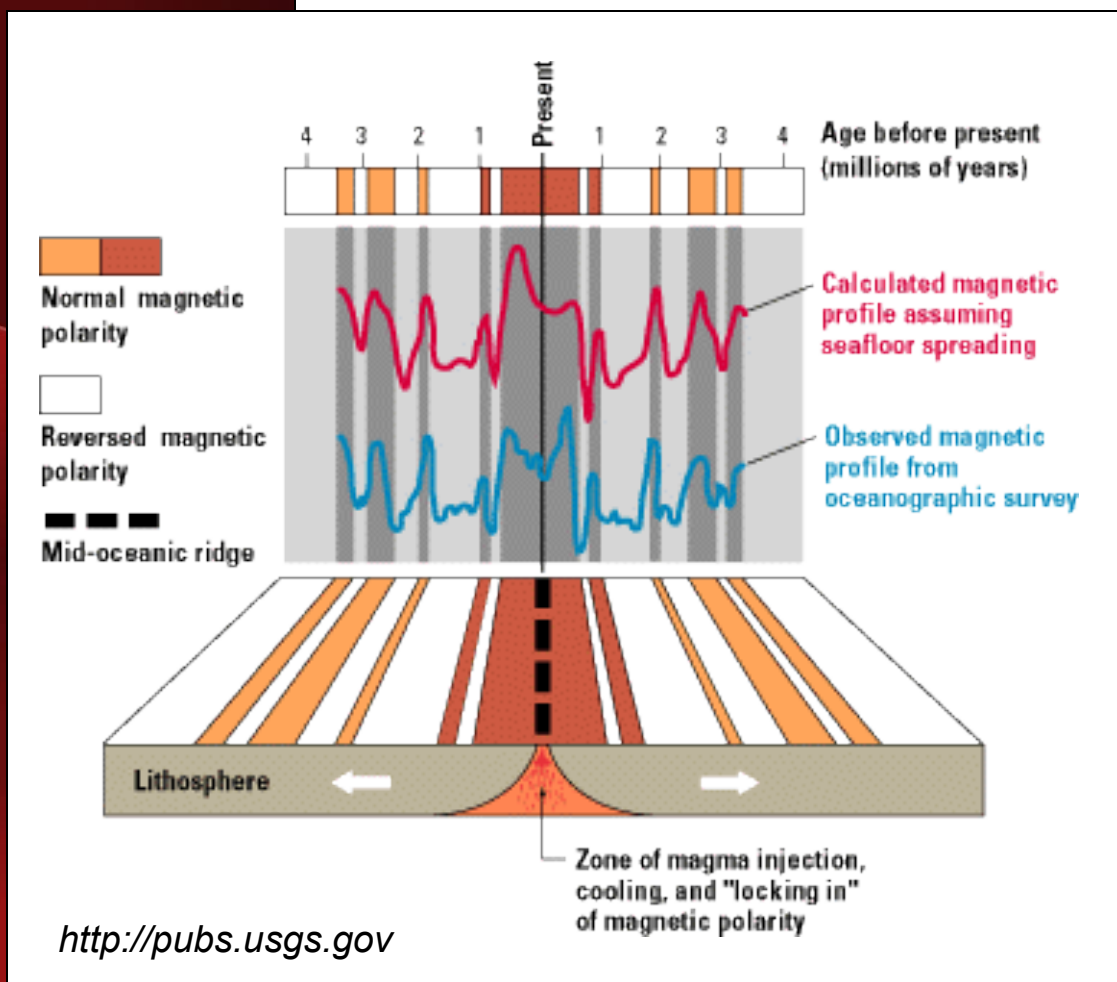
The north and south poles of Earth's magnetic field reverse from time to time. This switch is preserved in rocks with magnetic minerals.



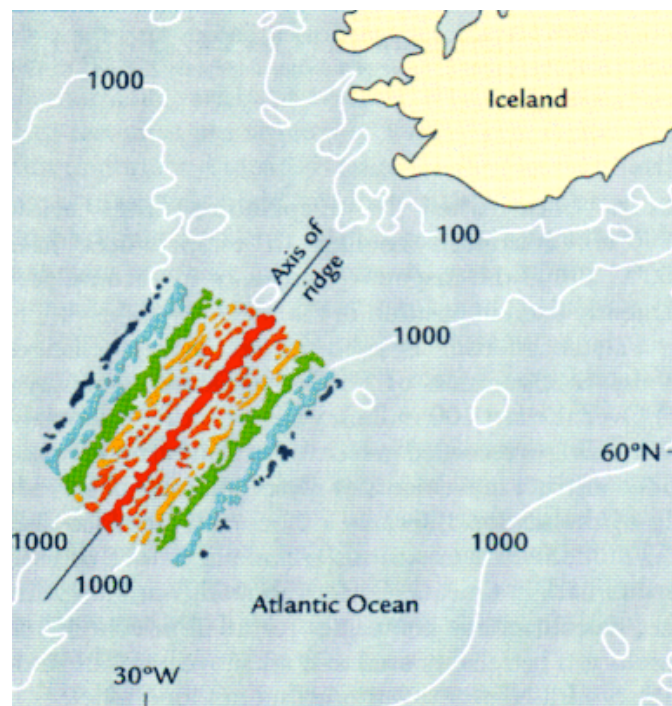
# Magnetic Polarity of Oceanic Basalts



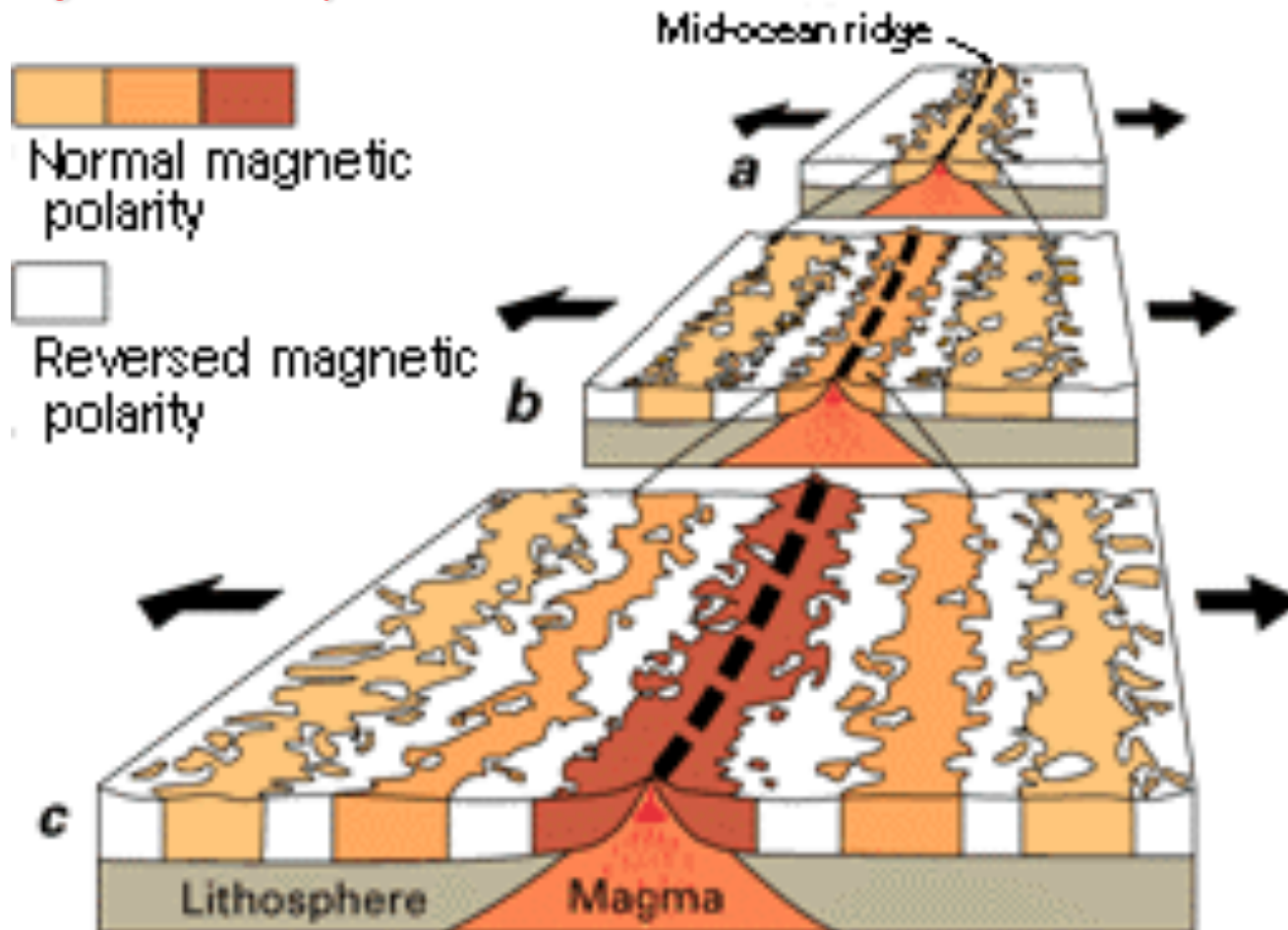
# Magnetic Polarity of Oceanic Basalts



When details of the seafloor became available, there were strips of normal and reverse magnetic basalt parallel to mid-ocean ridges.

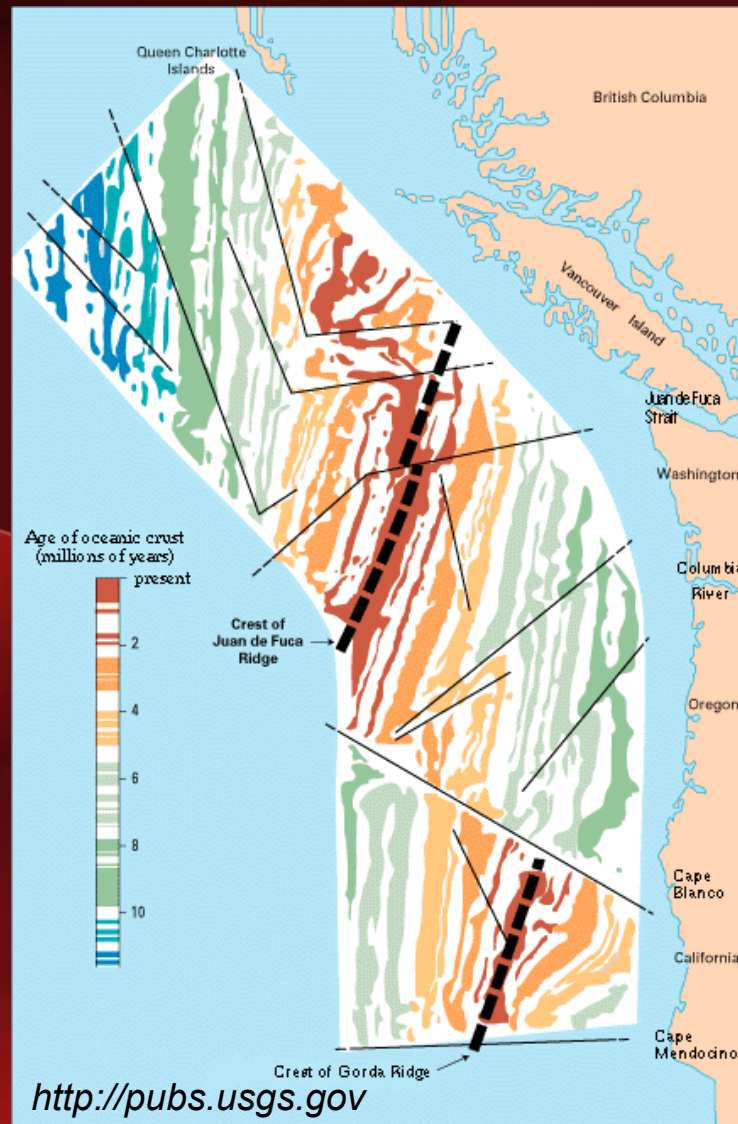


## Magnetic Polarity of Oceanic Basalts



<http://pubs.usgs.gov>

The two sides of the ridges were mirror images of each other.



## Seafloor Spreading

Radiometric dating confirms that the rocks are youngest near the ridge, and older farther away. In other words, the seafloor was spreading away from the mid-ocean ridges.

Seafloor spreading is a **mechanism** for continental drift!

**Seafloor Spreading + Continental Drift = PLATE TECTONICS!**

