Plate Tectonics: The observations

Early world maps

Early 18th century world map

Early 19th century world map

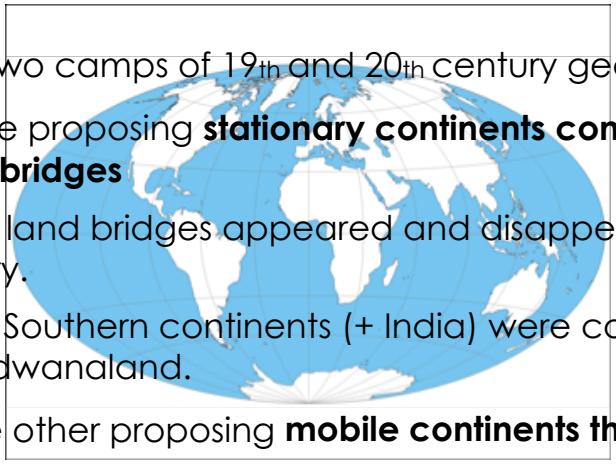
Early Observations

Late 19th century and early 20th century geologists noted:

- Similar outlines of Africa's west coast and South America's east coast.
- Evidence of glaciation, and similar and contemporaneous plant fossils in India,

Australia, South America, and southern Africa.

Early Hypotheses and Debates



The two camps of 19th and 20th century geologists:

• One proposing **stationary continents connected by ancient land bridges**

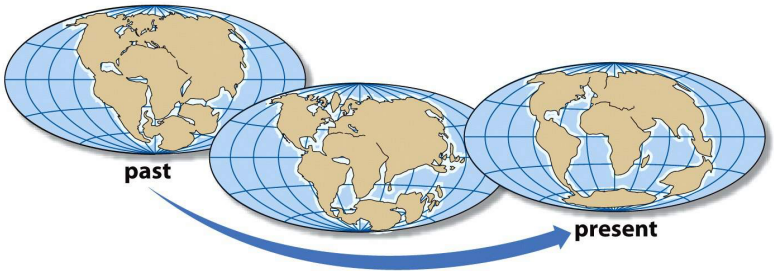
– the land bridges appeared and disappeared through Earth history.

- The Southern continents (+ India) were connected to form Gondwanaland.

• The other proposing **mobile continents that were once a single landmass that then broke up and the continents drifted apart to today's distribution**.

(1880 – 1930)

Alfred Wegener and Continental Drift



Germany, 1915,
The Origin of Continents and Oceans
Pangaea: The original supercontinent

Wegener's observation: geographic fit

Scientists and scholars had long noticed the *'jig-saw puzzle'*

like fit of the continental shorelines.

For Wegener this fit was

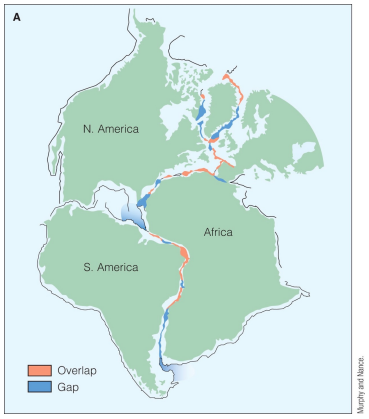
too good to be a coincidence.

Wegener's observations: **geographic fit**

The geographic fit is even better at the *continental slopes*.

Continental slopes are the

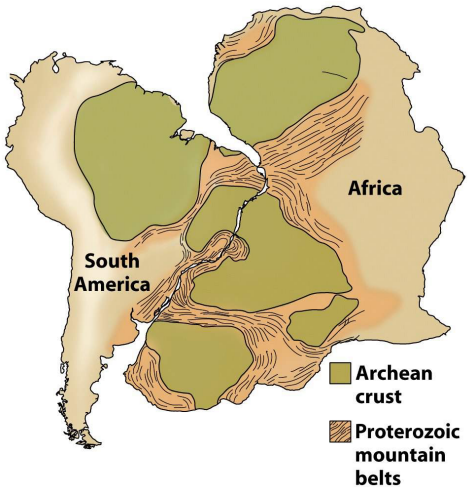
true edges of the continents.



Wegener's observations: **the geology**

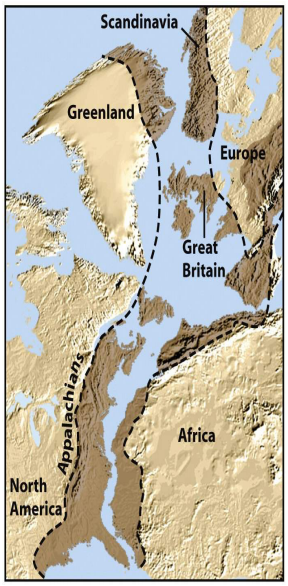
Geological formations across the Atlantic shorelines matched!

Wegener correlated the geology of South America and Africa

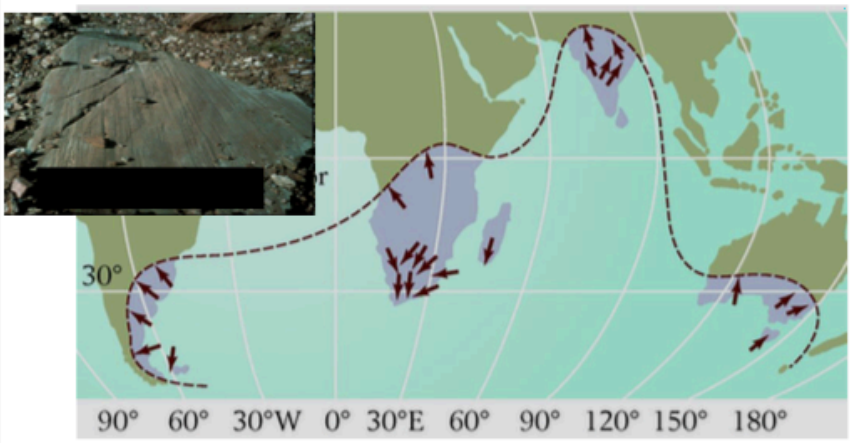


Wegener's observations: **the geology**

And the mountain belts
across the North Atlantic

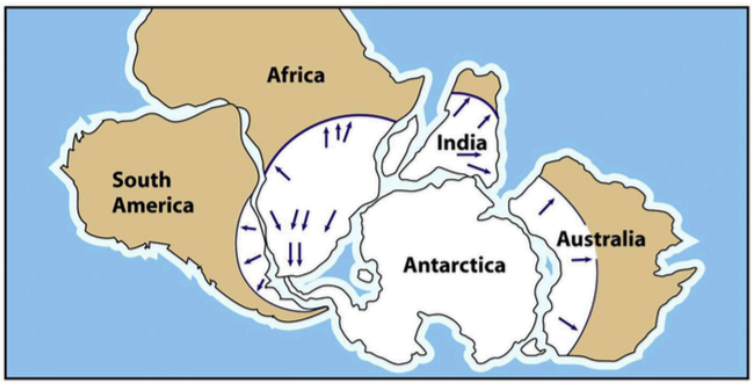


Wegener's observations:
glacial deposits



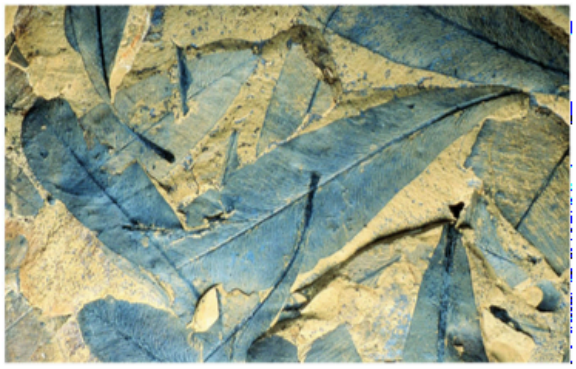
Contemporaneous glacial deposits on present day continents. The direction of glacial movement (interpreted from striations) is indicated by arrows.

Wegener's observations: glacial deposits



Wegener plotted the range of contemporaneous glacial deposits on each continent together on the southern part of Pangaea: They defined *an ancient polar ice cap!*

Wegener's observations: the fossils

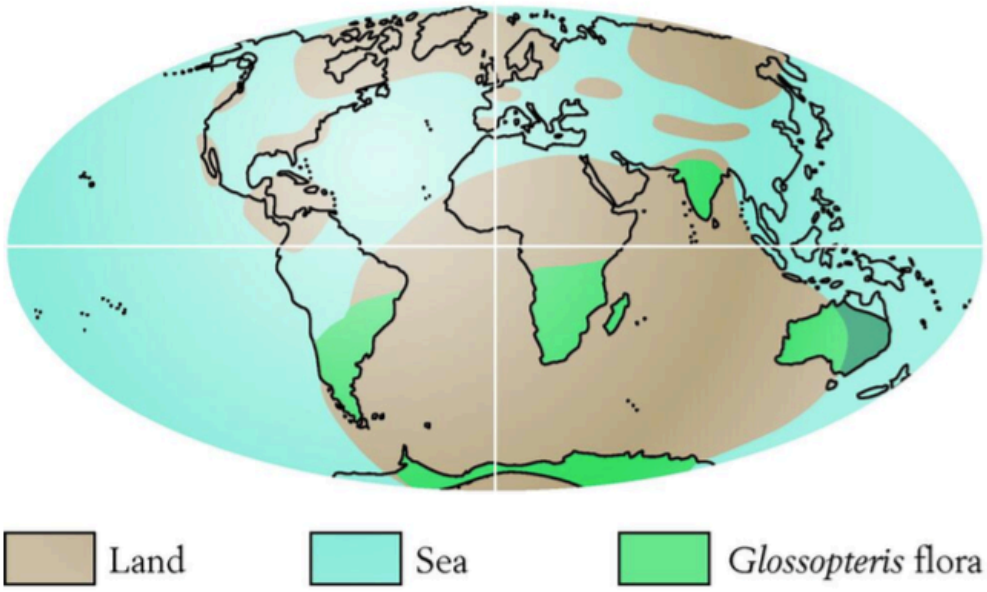


Glossopteris: A fossil plant

Lystrosaurus: A fossil reptile

Wegener's observations: **the fossils**

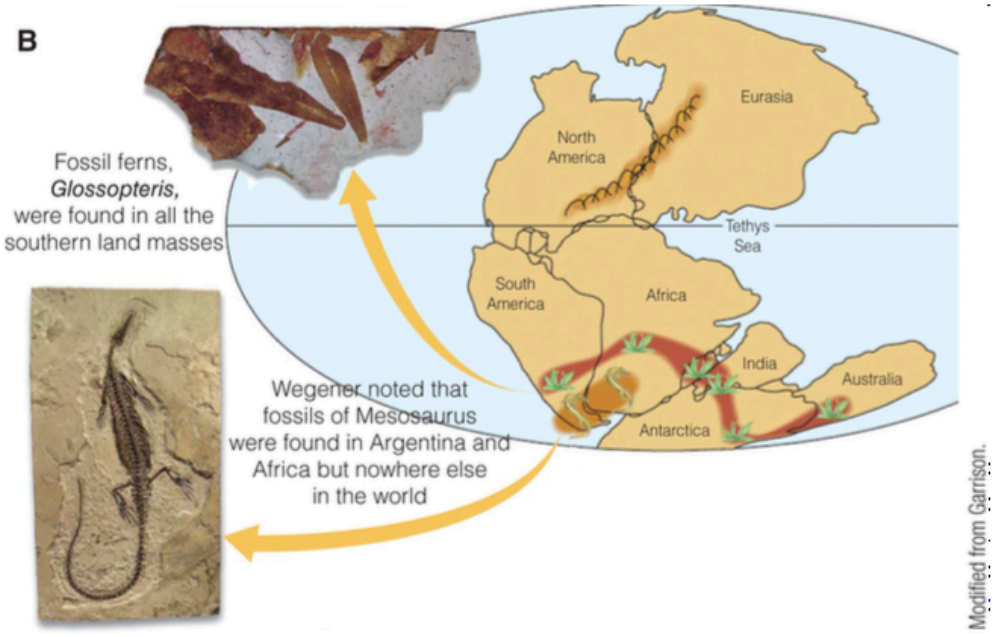
The distribution of fossils of *identical land and freshwater life forms* on the southern continents.



Interpretation one: Was there a large landmass connecting these continents?

Wegener's observations: the fossils

The distribution of fossils of *identical land and freshwater life forms* on the southern continents.



Interpretation two: Were these continents together as part of a supercontinent?

Wegener's observations: **the paleoclimate**

Paleo = ancient, prehistoric

Paleoclimate zones across Pangaea inferred from geology.

Evidence for location of the continents with respect to the equator and the poles.

Wegener's observations

- The geographic fit of continental shorelines.
- *Contemporaneous* glacial deposits from the southern continents that were Gondwanaland.
- The geological formations across continental shorelines match when all continents are put together.
- Distribution of *identical* and *contemporaneous* fossils on the southern continents.
- Inferred similar paleoclimate of the southern continents.

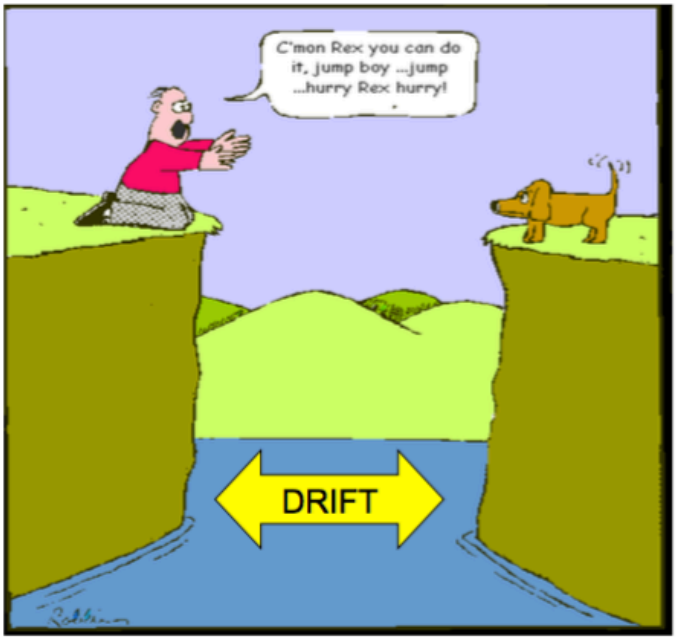
Wegener's model: Continental Drift

The break up of the supercontinent Pangaea around 250 Ma, set the present day continents adrift in the oceanic crust!

Wegener's model rejected!

Despite compelling supporting evidence, most early 20th century scientists dismissed Wegener's ideas due to lack of an adequate mechanism.

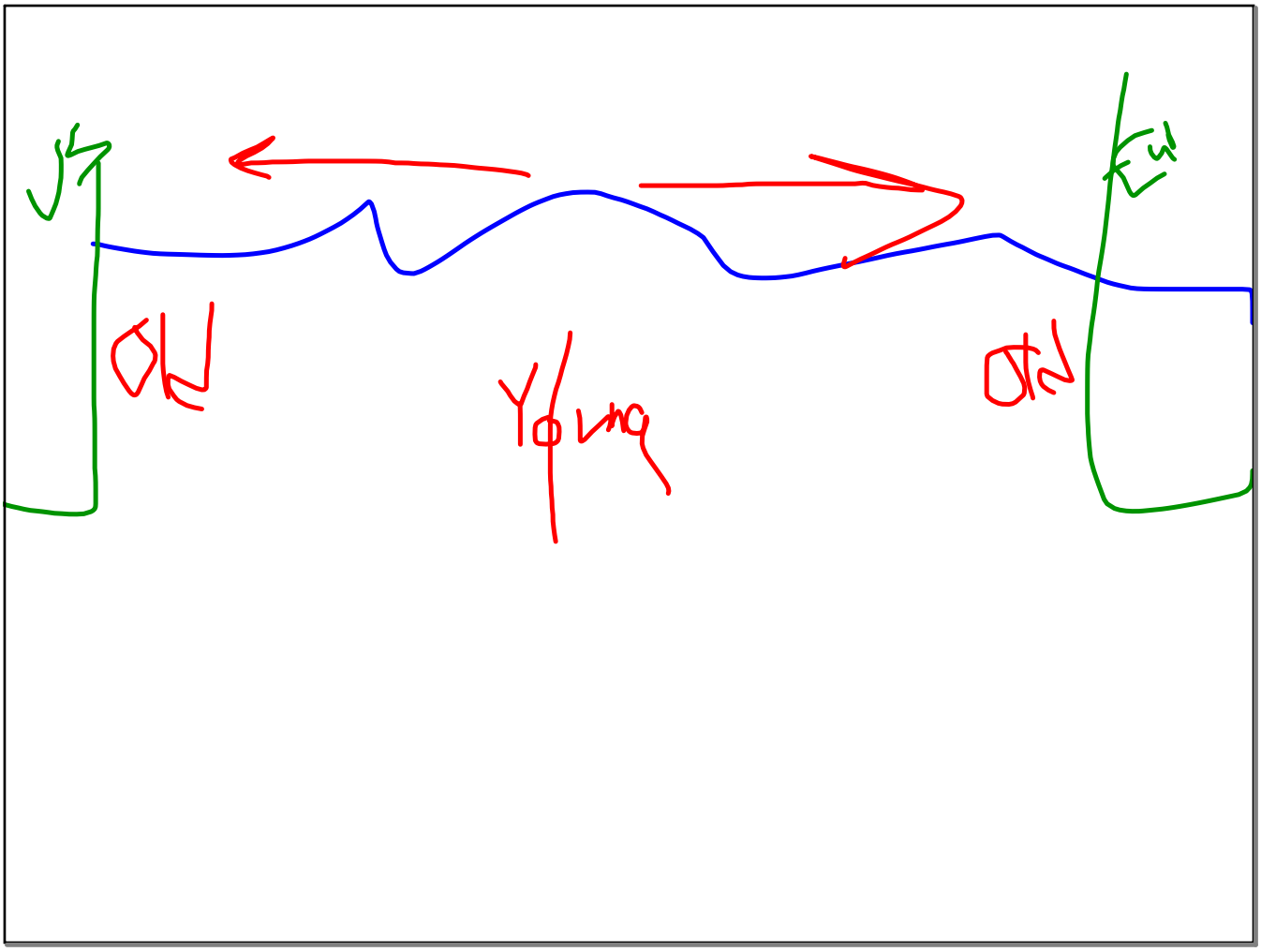
In 1930, Wegener died without vindication.



Wegener revisited

The 1950s and 60s brought new scientific discoveries:

- **Paleomagnetism** and **magnetic reversals**
- Exploration of the **ocean floor**

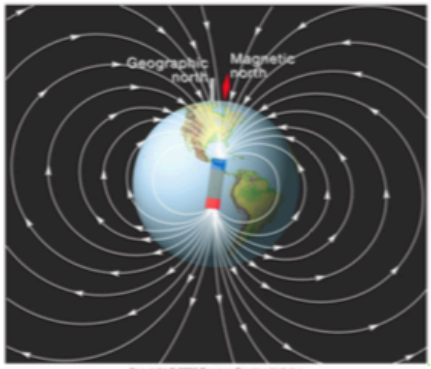


Paleomagnetism

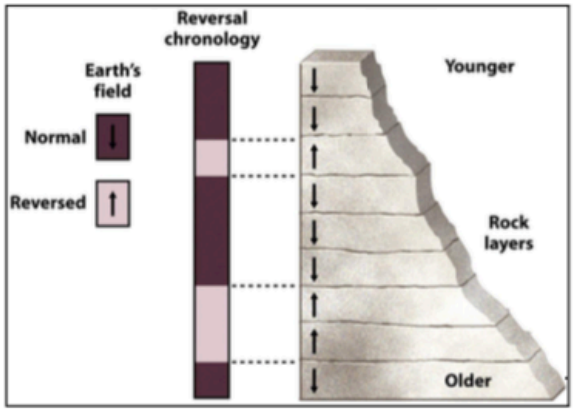
The direction of Earth's magnetic field is recorded in igneous rocks:

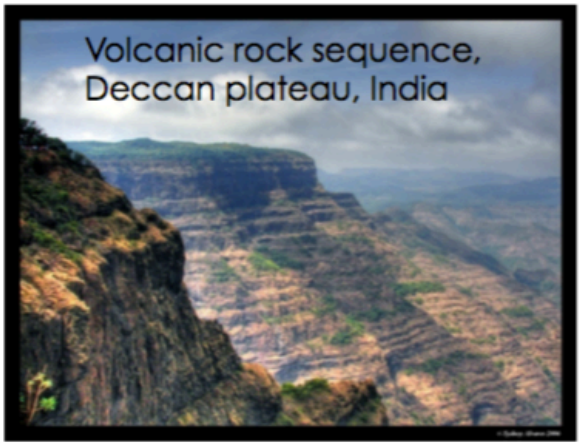
Fe-bearing minerals align themselves to the magnetic field as they crystallize.

Lava flows can then record the position of the magnetic pole when they were erupted.



Magnetic reversals!

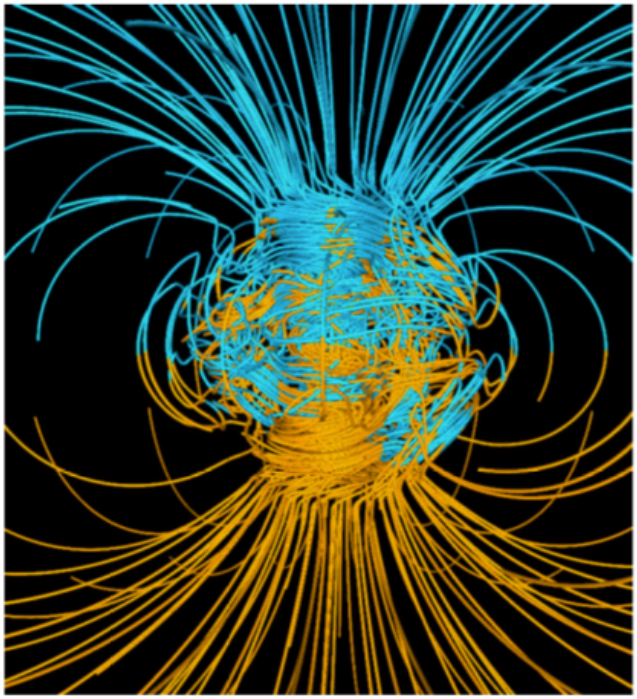




Paleomagnetic measurements of thick sequences of volcanic rocks revealed abrupt shifts in the magnetic pole directions through time.

Normal polarity: conforms with today's N-S orientation.
Reverse polarity: opposite S-N poles.

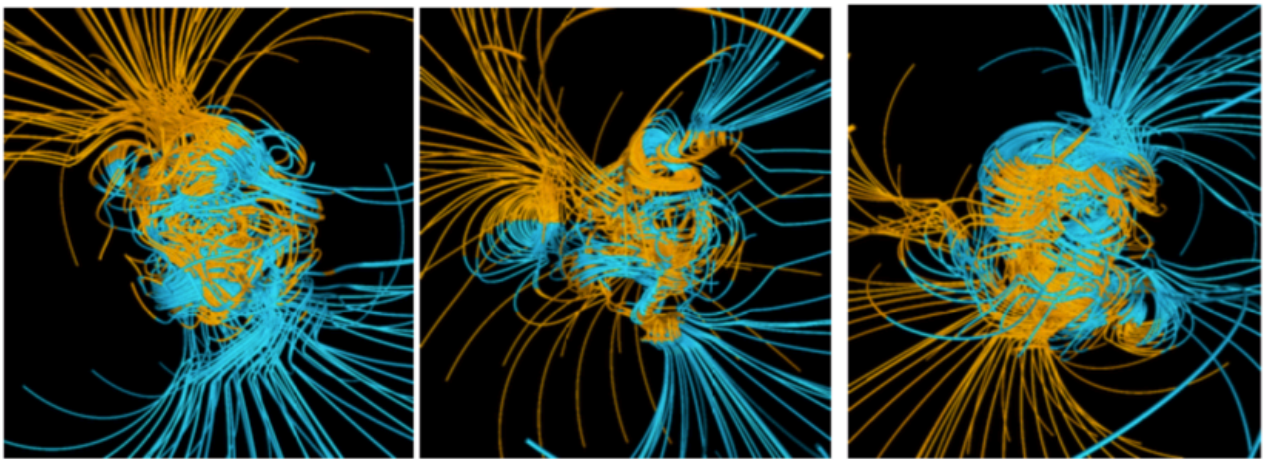
Magnetic Reversals



http://www.es.ucsc.edu/%7Eglatz/geodynamo.html

Computer simulation of Earth's current magnetic field

Magnetic Reversals



500 years before the middle of reversal

In the middle of reversal

500 years after the middle of reversal

http://www.es.ucsc.edu/%7Eglatz/geodynamo.html

On average, every 200,000 years, Earth's magnetic field reverses within 2000 years!

The sun reverses its polarity approximately every 11 years!
http://www.youtube.com/watch?v=B4UtVo7-yJA

Harry Hess: *Sea floor spreading*

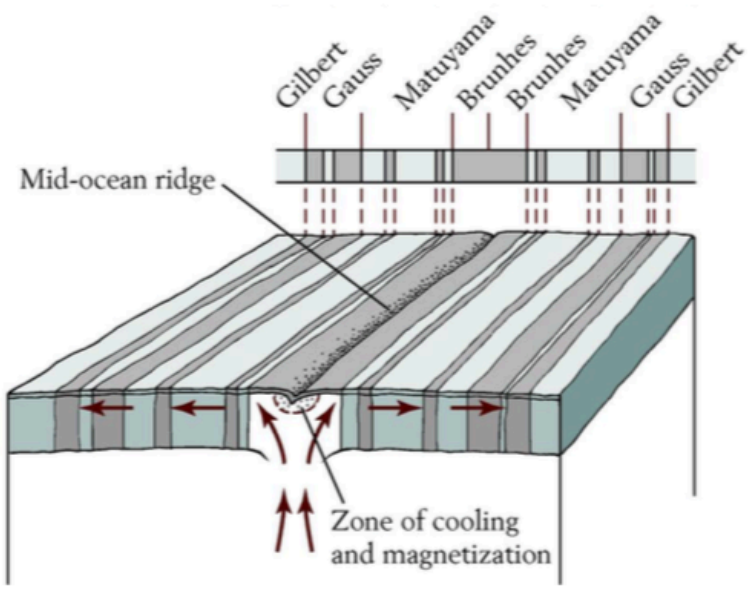
(1906 – 1969)

1940s and 50s: Naval officer and geologist, Harry Hess mapped parts of the Atlantic ocean floor.

Exploration of the ocean floor

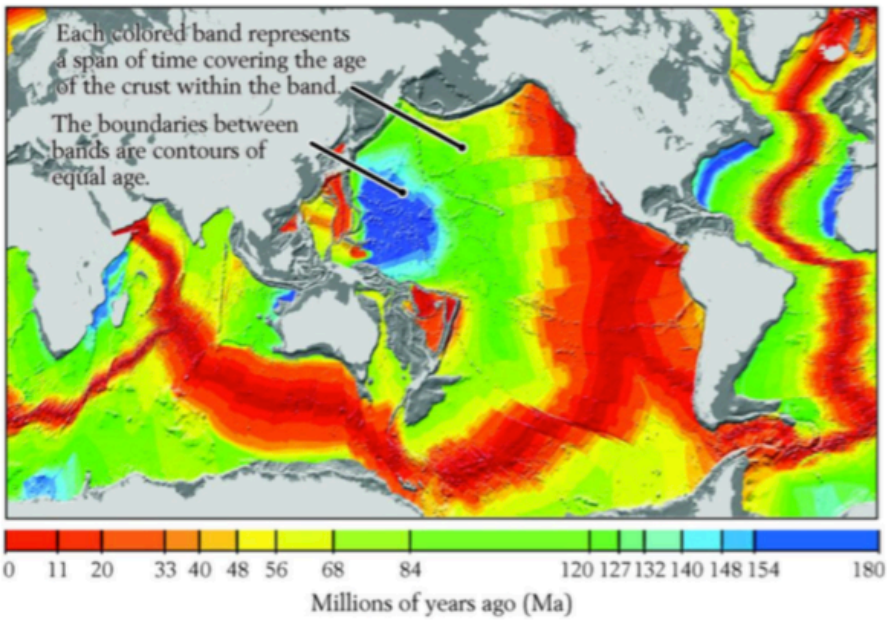
1960s: First maps of the ocean floor revealed a system of volcanic ridges running through the middle of most oceans.
1962: Harry Hess proposes '*Seafloor spreading*'.

Magnetic reversals in the ocean floor!



Symmetric pattern of magnetic reversals across the mid oceanic ridge axis!

Age of the ocean floor: Wegener vindicated!



The age of oceanic crust increases symmetrically across the ridge axis!

Decisive evidence that the ocean floor was created at ridge axis and spread apart!

A new theory is born!

After nearly 50 years since Wegener proposed and supported his Continental Drift hypothesis, new scientific developments led Harry Hess to finally unify all the observations and inferences into a new theory: **Plate Tectonics!**

The implications of Plate Tectonics revolutionized science of geology and shaped modern geological thought!