Paleomagnetism and Seafloor Spreading

Slides from lectures preceding Seaflor Spreading exercise

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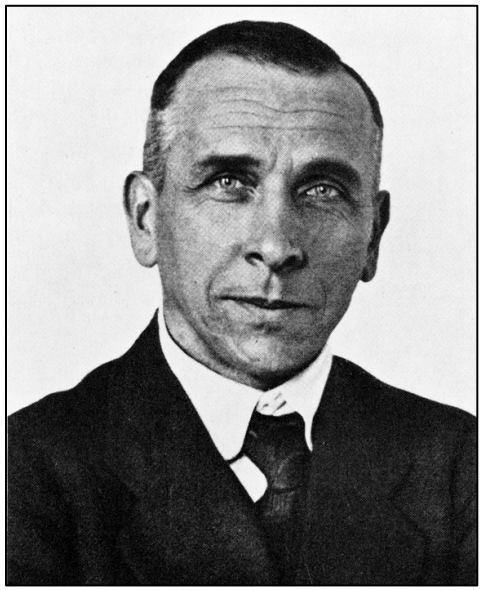
Alfred Wegener

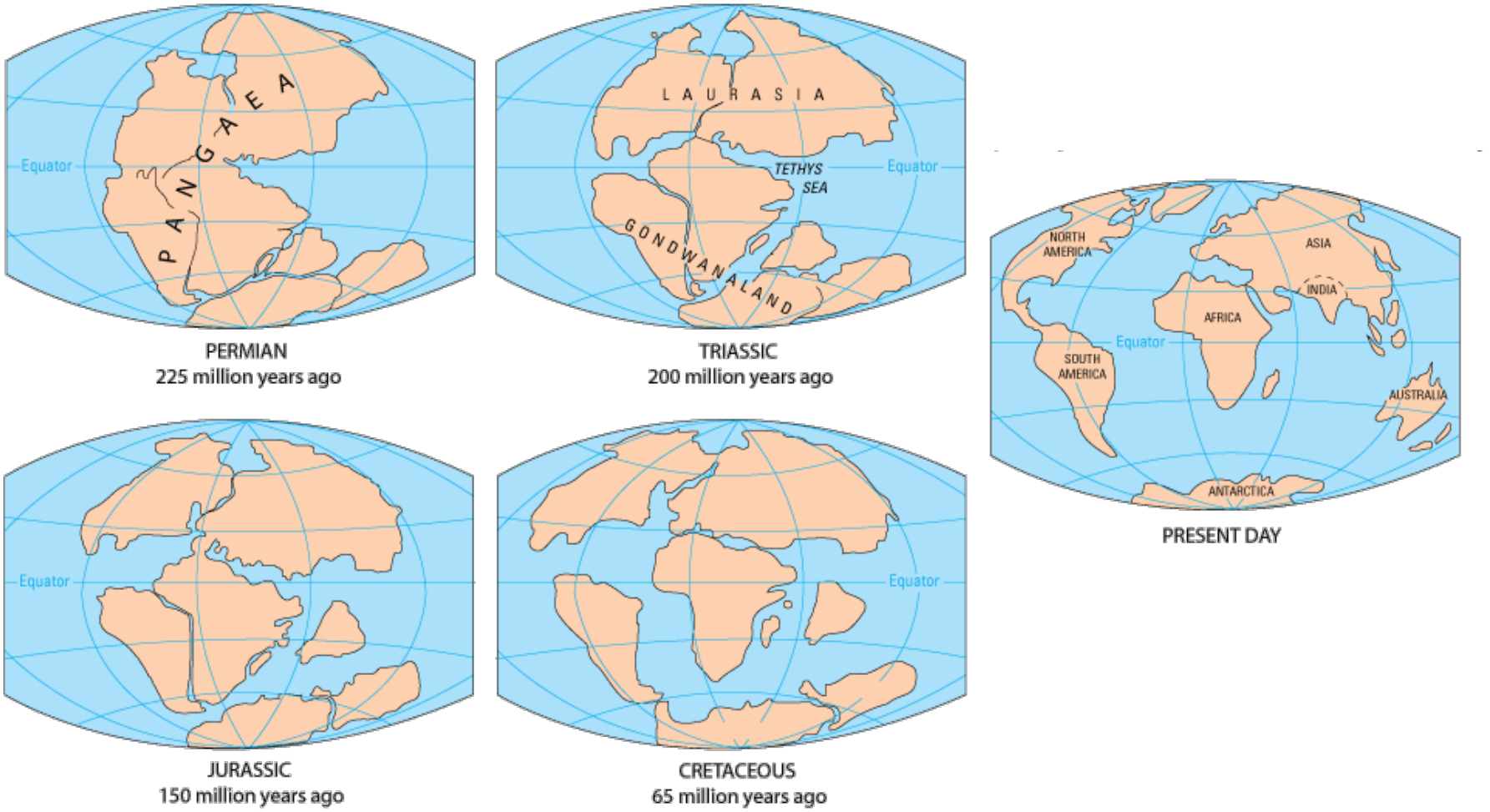
- **Who?**
  - **German meteorologist**
- **When?**
  - **Early 1900s**
- **What?**
  - **All land was once one large continent**
  - **Later, it broke apart, moved to present places**
- **Why?**
  - **Wegener had lots of data…**



https://commons.wikimedia.org/wiki/File:Alfred_Wegener_ca.1924-30.jpg

Continental Drift

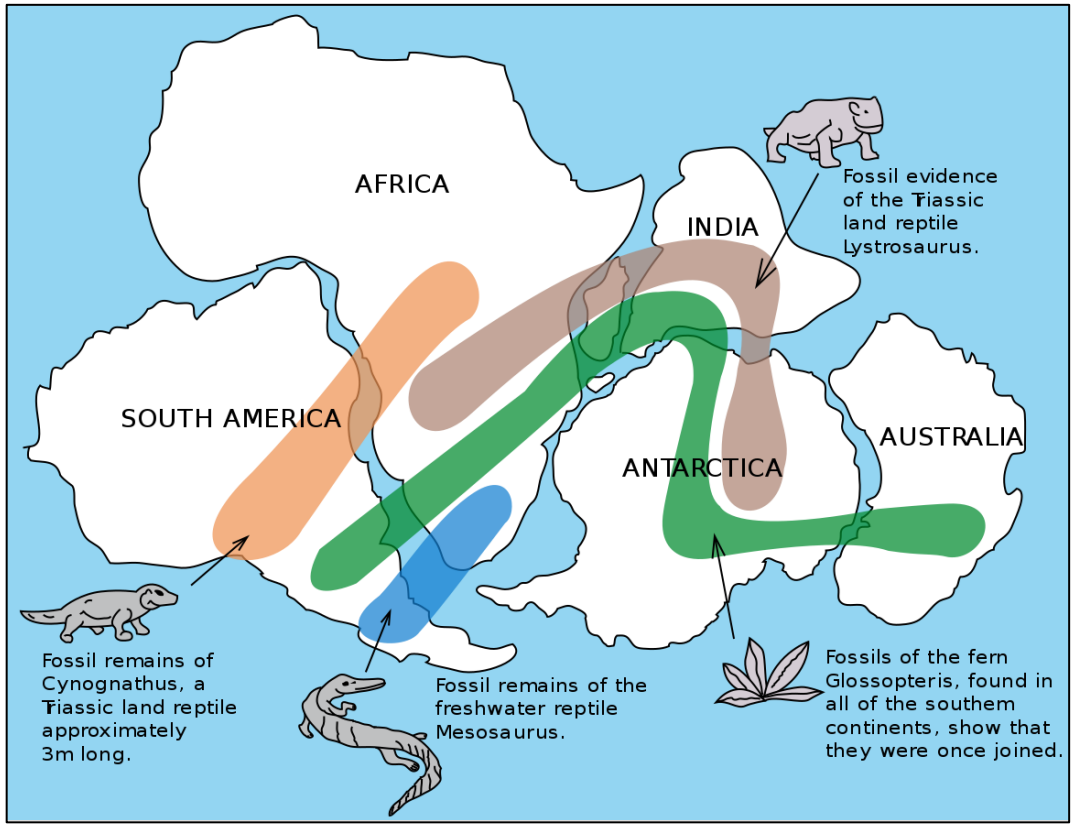
- "Pangaea" means "all lands"



https://commons.wikimedia.org/wiki/File:Pangaea_to_present.gif

Evidence From Fossils

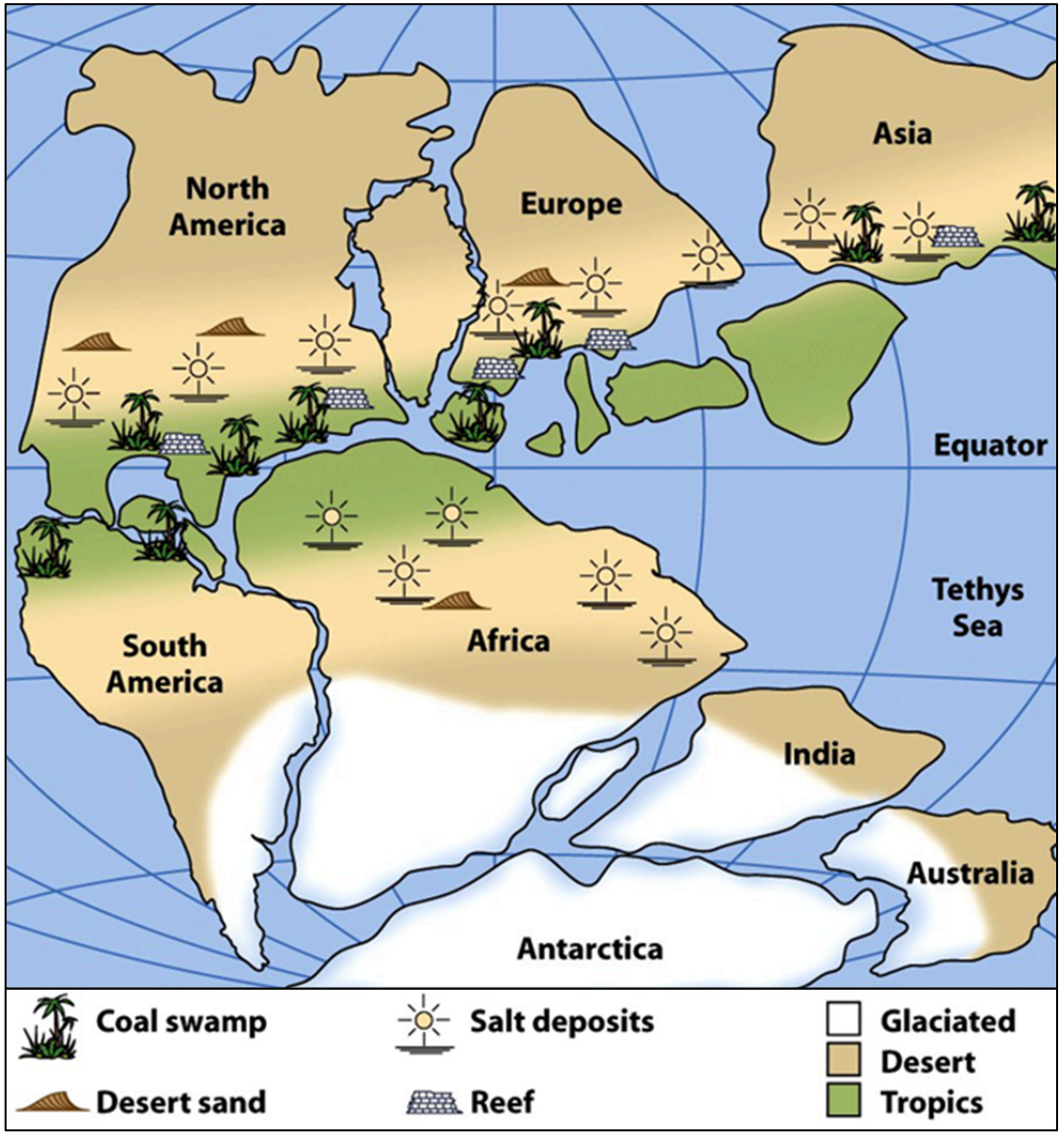
- **Found on different continents**
  - **Could not swim or float across oceans**
  - **How did they get there??**
- **With Pangaea, they could stay on land!**



https://commons.wikimedia.org/wiki/File:Snider-Pellegrini_Wegener_fossil_map.svg

Evidence from Paleoclimates

- Climate interpreted from rocks:
  - Limestone = tropical reefs
  - Rock salt = deserts
- Paleoclimates make sense with Pangaea



http://geophile.net/Lessons/PlateTectonics/PlateTectonics_03.html

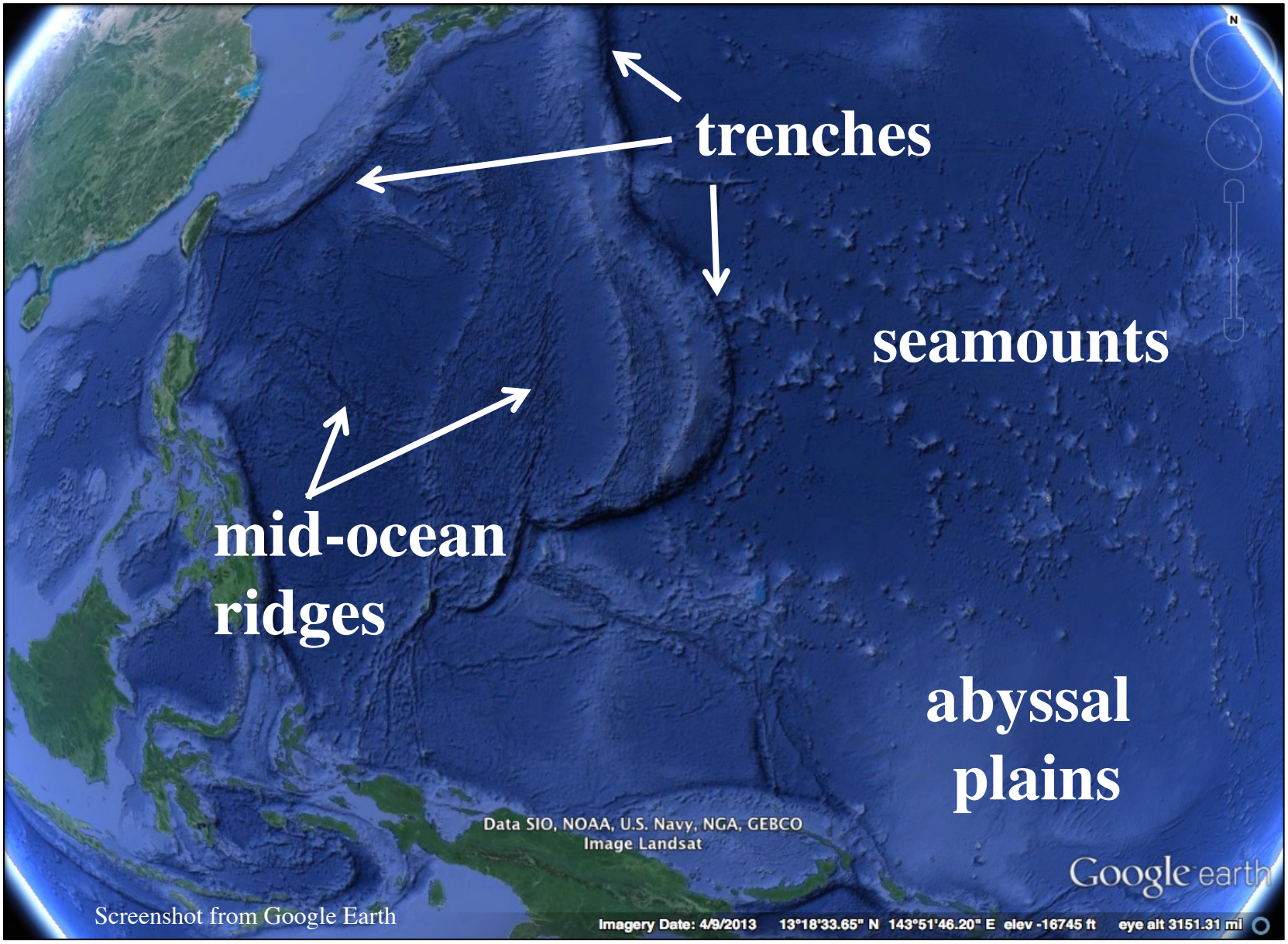
Reactions

- **Wegener thought his evidence was convincing.**
- **Others:**
  - **“Utter, damned rot!”**
    - president of American Philosophical Society
  - **It “befogs the minds of students” -**
    geologist B. Willis

After Wegener

- **Little work on drift for next 20 years**
- **1950s: new data were obtained**
  - **Details of sea floor topography = *bathymetry***
  - **Earthquake epicenters**
  - **Earth magnetism**

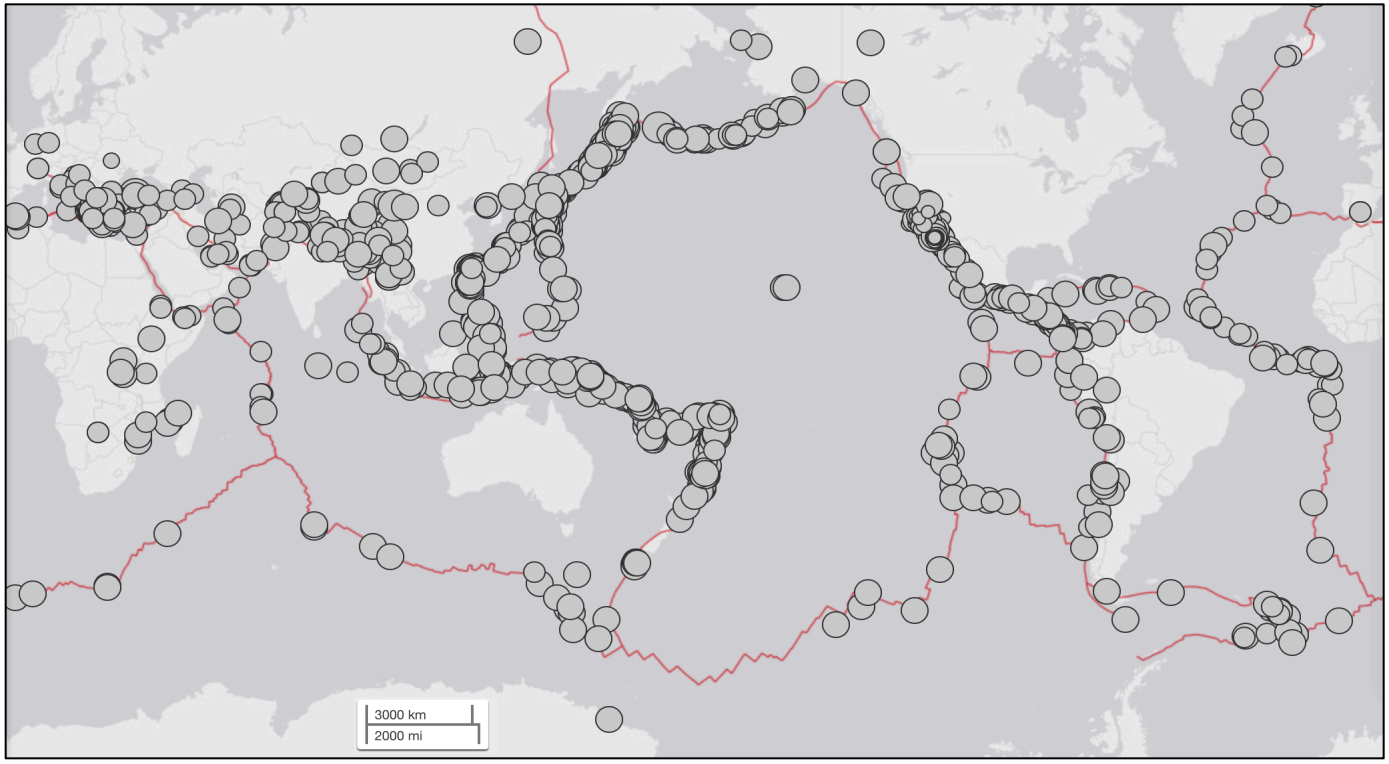
Bathymetry



Screenshot from Google Earth

Earthquakes

- More and better seismometers → more accurate epicenters
  - Patterns: EQs occur along ridges and trenches

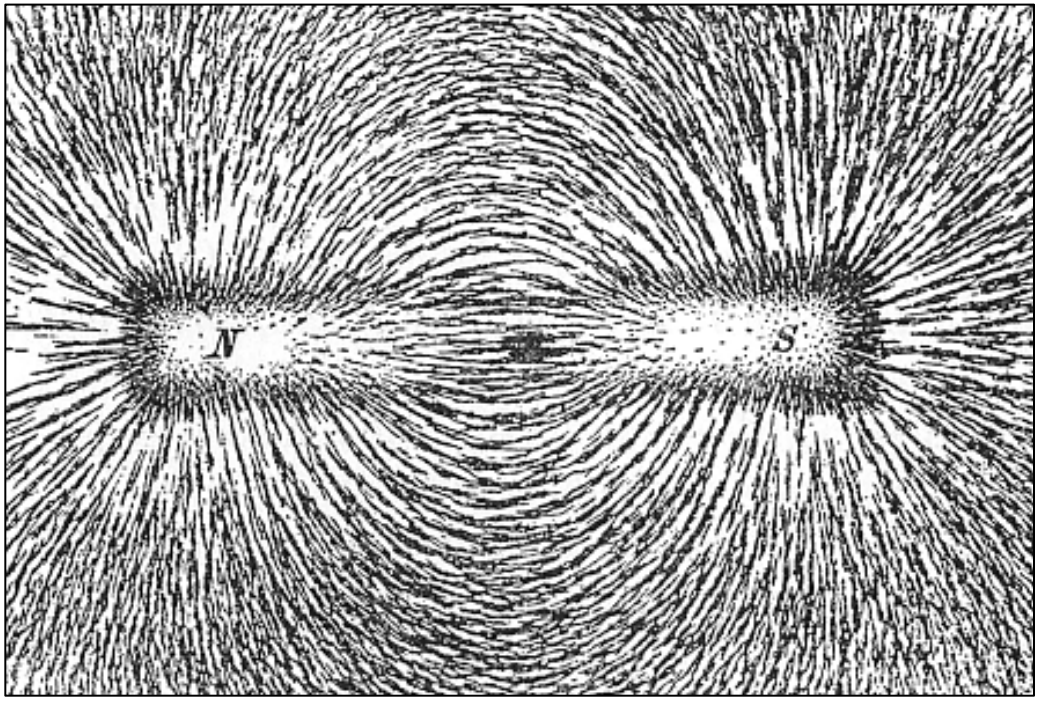


https://earthquake.usgs.gov/earthquakes/search/

Earth Magnetism

- **Geophysicists studied**
  1. **Magnetic rocks on land**
  2. **Magnetic field strength over oceans**

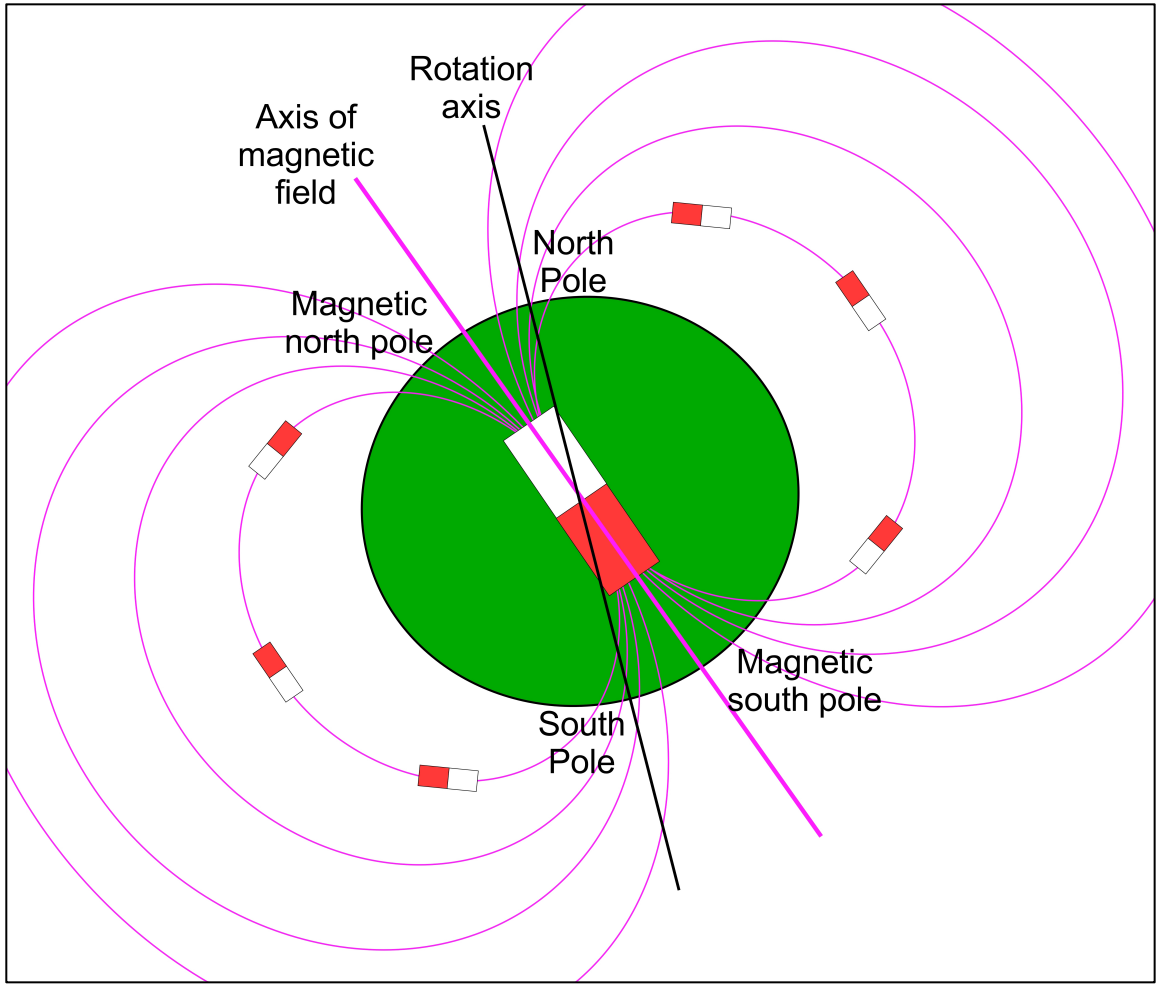
Iron filings outline magnetic field of a bar magnet.



https://commons.wikimedia.org/wiki/File:Magnet0873.png

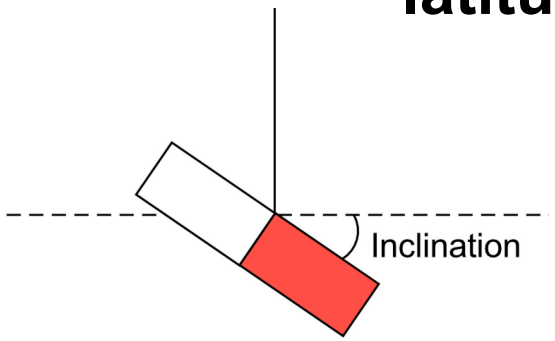
Earth's Magnetic Field

- **Generated in the liquid outer core**
  - **From flowing metal**
- **Behaves like the field of a bar magnet**



Detecting the Magnetic Field

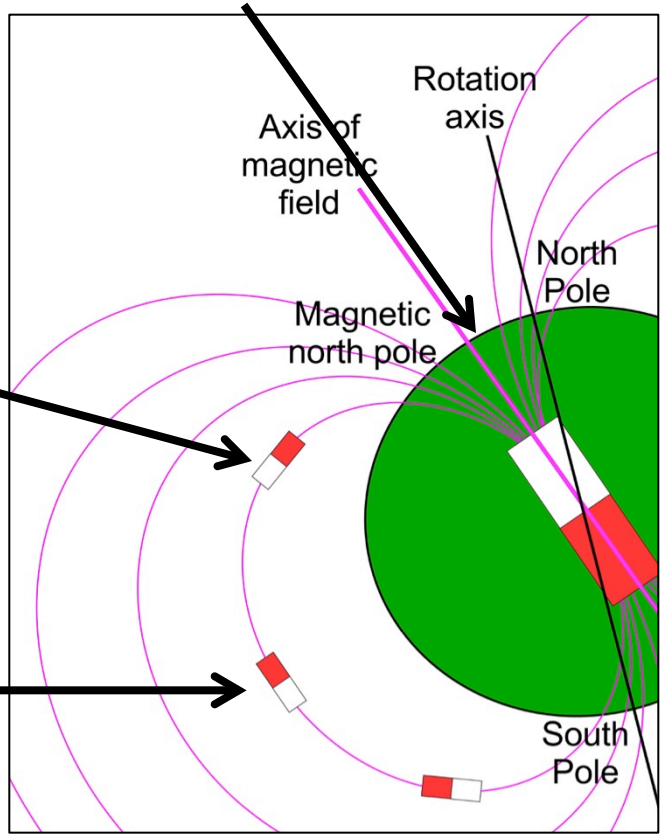
- **A freely-suspended magnet tilts:**
  - **Angle of tilt = *inclination***
  - **Varies with latitude (0° - 90°)**



Angle of inclination increases as latitude increases

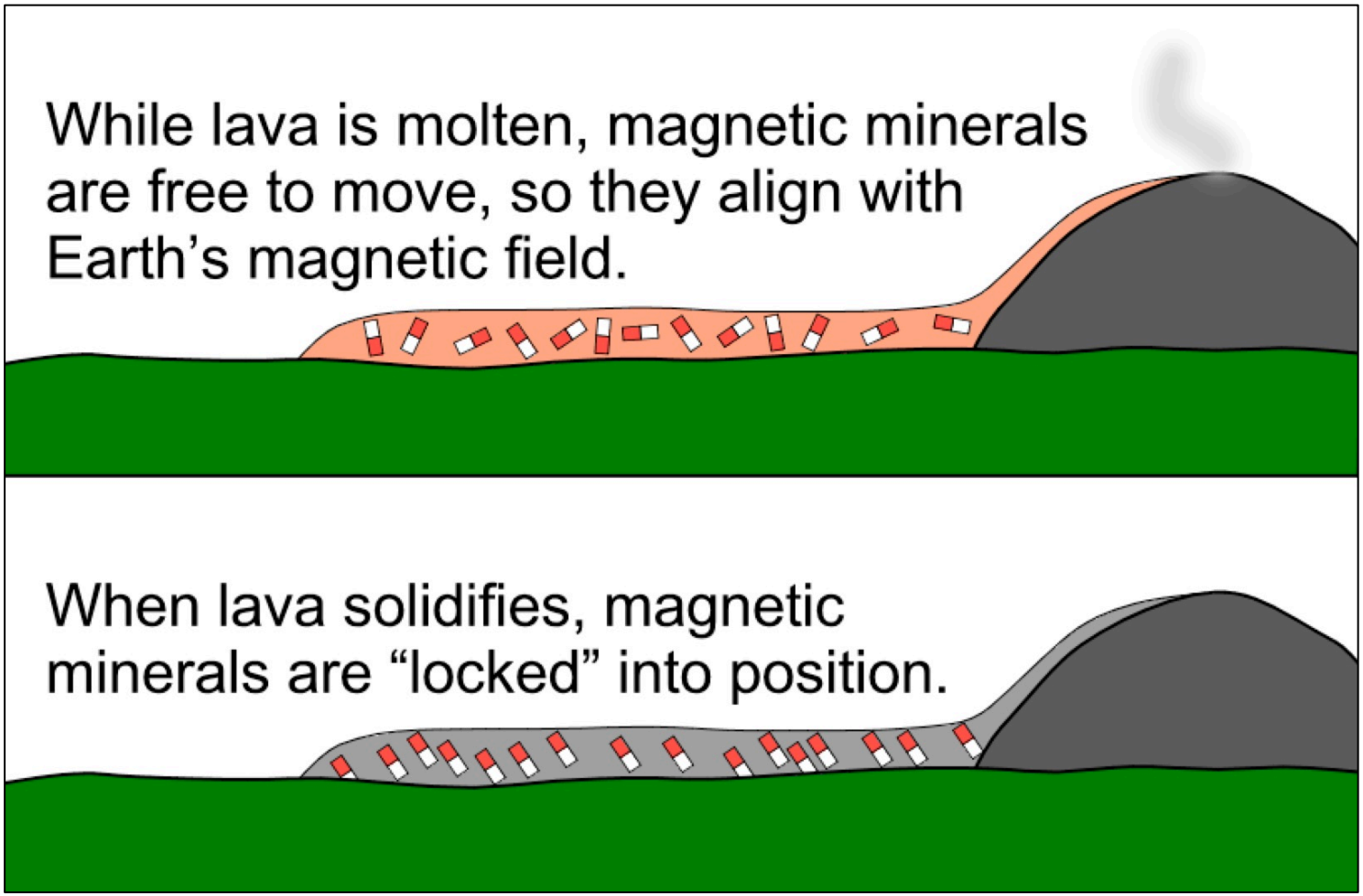
Horizontal at equator

Vertical at poles



Paleomagnetism

- **Magnetic minerals in some rocks, mainly igneous rocks, preserve magnetic field direction.**



A Discovery using Paleomagnetism

1. **Polar Wander Paths**

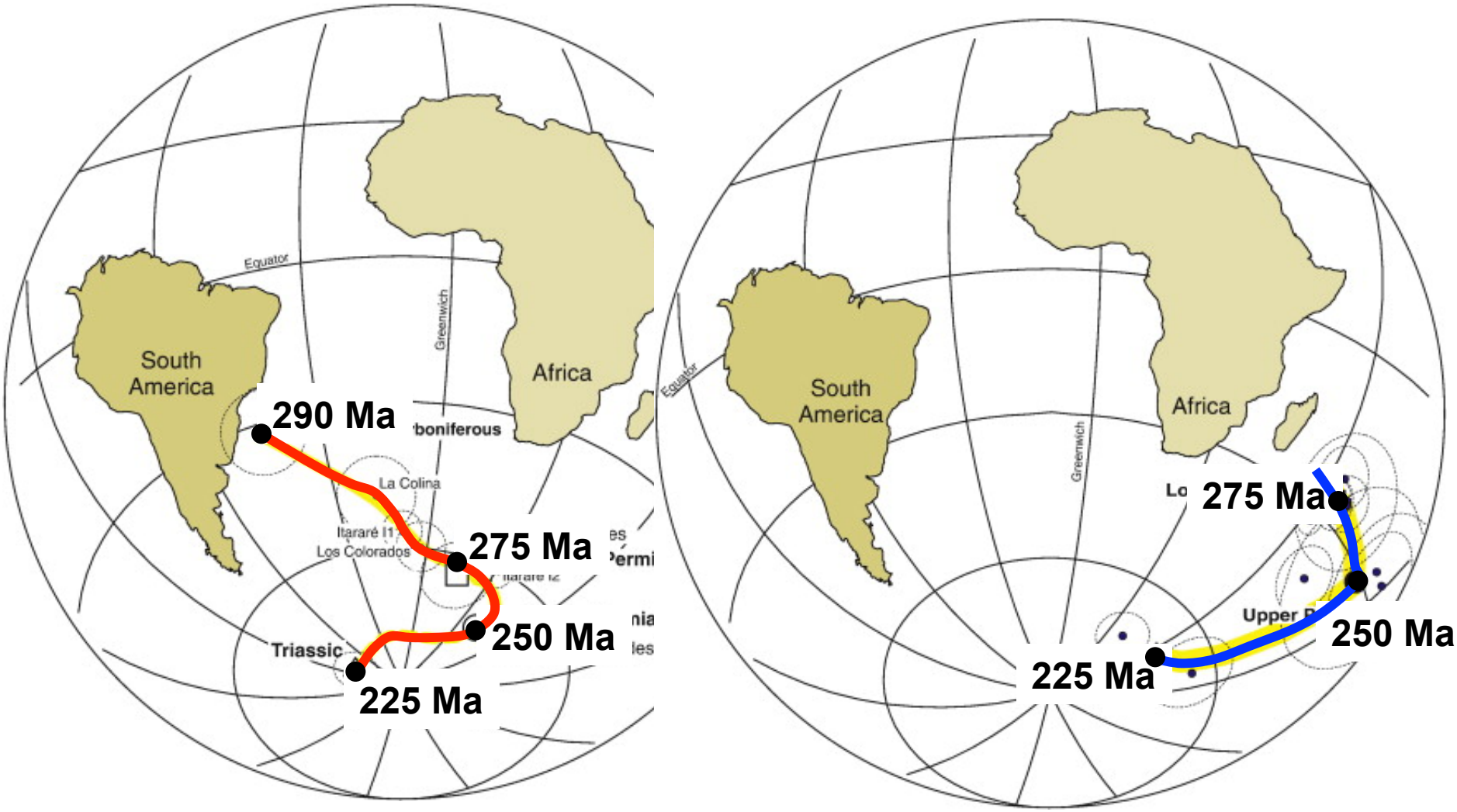
   - **Method uses igneous rocks on land:**

     - **Age (from radioactivity)**

     - **Direction of magnetic north pole (MNP) (from paleomagnetism)**

   - **Discovery: MNP moves!**

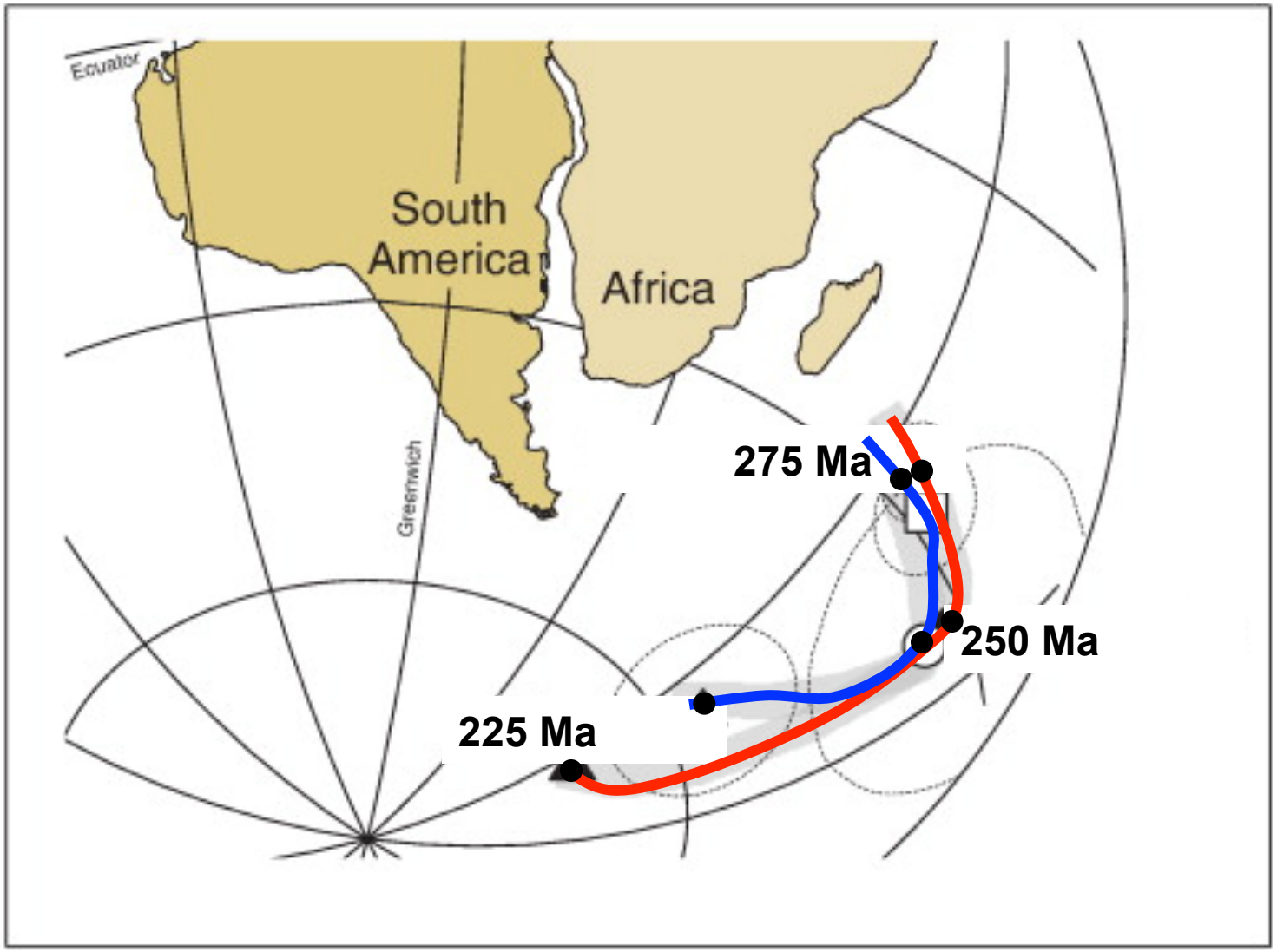
Polar Wander Paths for SA & AF



https://www.researchgate.net/publication/253282658

- **Implies 2 MNPs at the same time – impossible!**

Paths Coincide with Pangaea



https://www.researchgate.net/publication/253282658

Another Paleomagnetic Discovery

2. **Magnetic reversals**

- **Method: uses stacked lava flows on land**
  - **Age (from radioactivity)**
  - **NMP (from paleomagnetism)**
- **Discovery: field reverses!**

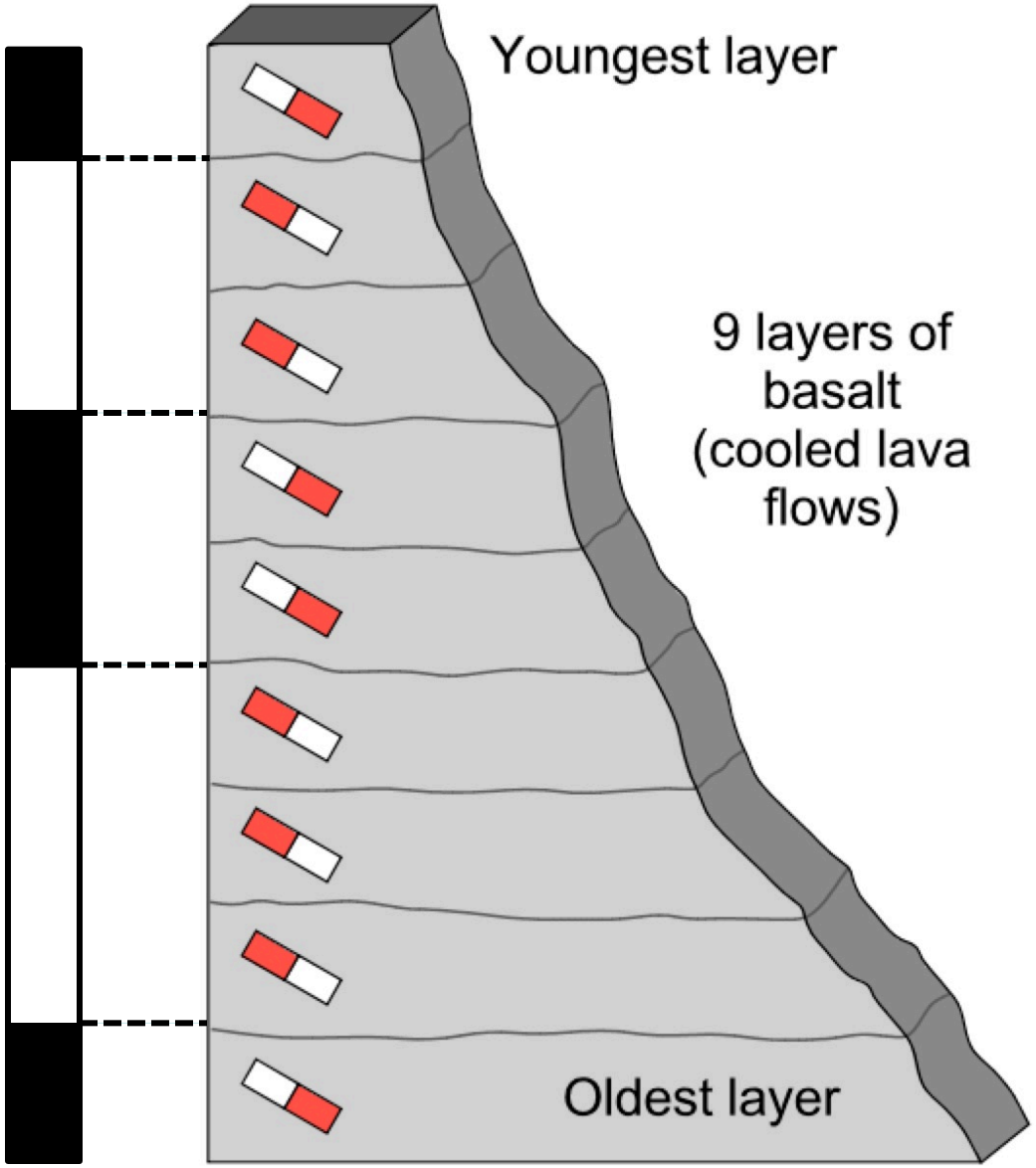
Magnetic Polarity

- *Normal* polarity

  - Compass points N

- *Reverse* polarity

  - Compass points S



One More Finding from Paleomagnetism

3. **Marine magnetic anomalies**

   - **Method: ship tows magnetometer**

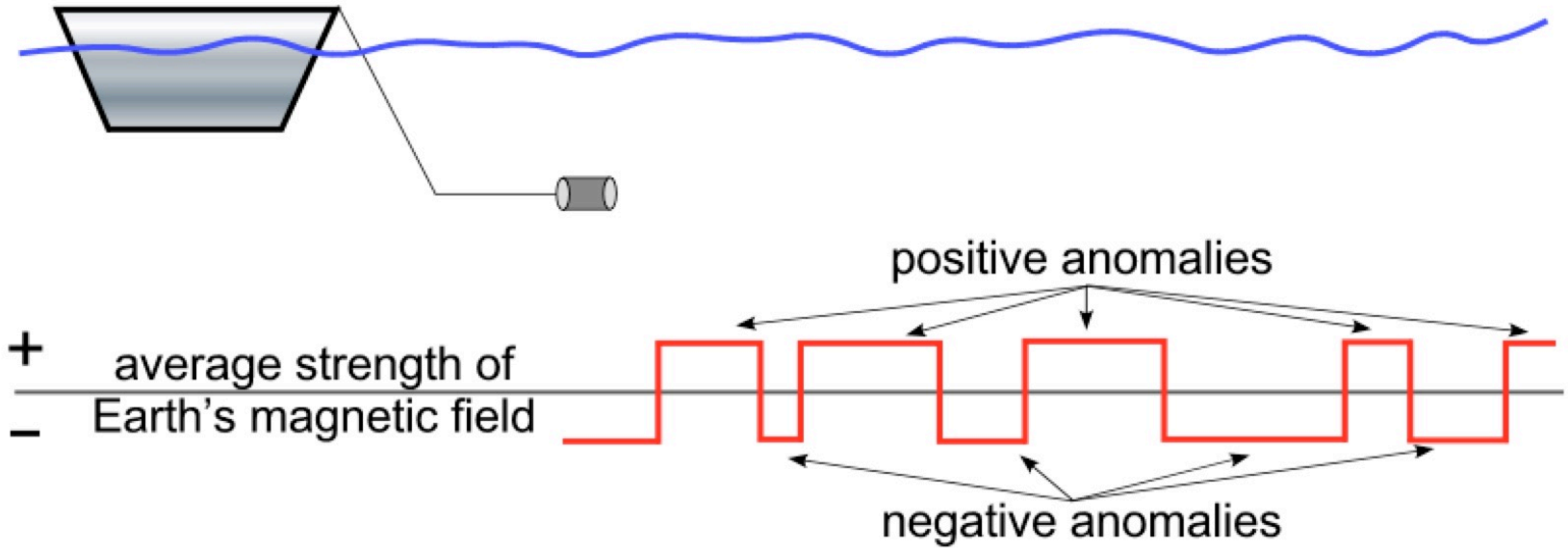
     - **Measures strength of field**

   - **Discovery: High / low strength**

     - ***Anomaly*: variation from expected value**

Terms for Anomalies

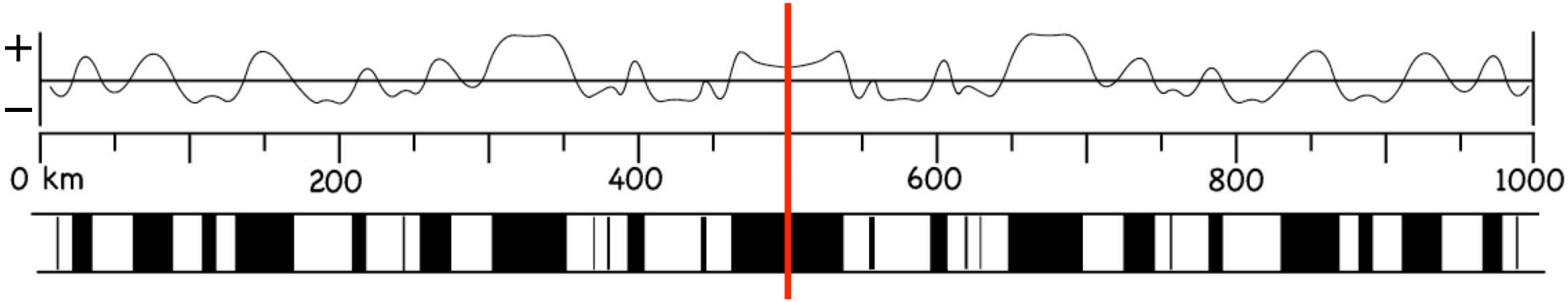
- **High strength = *positive anomaly***
- **Low strength = *negative anomaly***



- **Anomalies were a puzzle when first discovered!**

Marine Magnetic Anomalies

- **Alternating + and – anomalies**



- **Symmetric across mid-ocean ridges**
- **What causes these anomalies?**
  - **Positive over rocks with normal polarity**
  - **Negative over rocks with reverse polarity**

Seafloor Spreading

- **Harry Hess (1962)**
  - **Combined continental drift, bathymetry, EQs, magnetism**
- **Oceanic lithosphere:**
  - **Forms at mid-ocean ridges**

https://commons.wikimedia.org/wiki/File:Hess.gif

New minerals align with magnetic field!

  - **Moves away from ridge**

Explains symmetric anomalies!

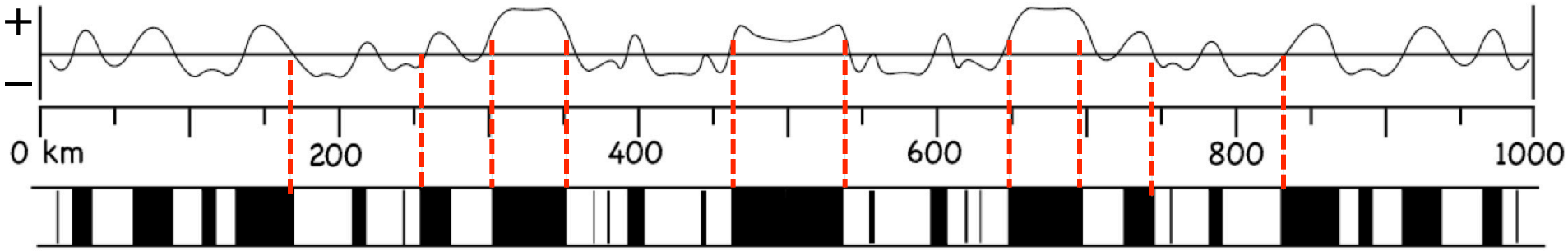
  - **Sinks down into mantle at trenches & is destroyed**

Provides a mechanism for continental drift!

Patterns Match

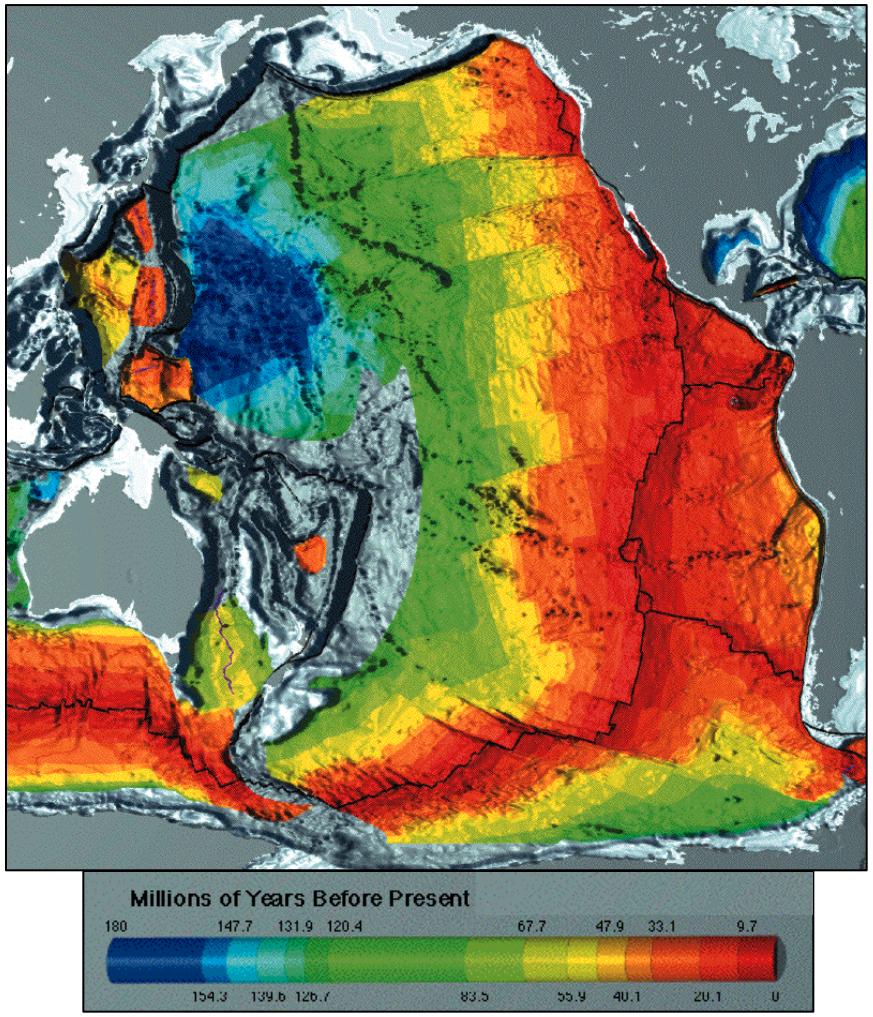
- **Seafloor spreading + reversals = anomalies**

Anomalies		Reversals
+ / –	⟶	Normal/reverse
Width	⟶	Duration



Testing the SFS Hypothesis

- **Predictions:**
  - **Youngest oceanic crust at mid-ocean ridges**
  - **Age increases with distance from MOR**
- **Tested on hundreds of rocks: confirmed**
- **Rates of spreading = 1 – 17 cm/yr**



https://commons.wikimedia.org/wiki/File:Pacific_seafloor_crust_age_2.gif

Teaching Notes and Tips

This exercise is divided into three complementary sections. The exercise may be completed in one extended laboratory period, or individual sections may be assigned as separate, shorter activities or as homework.

The Excel workbook file includes a worksheet that contains the key. The workbook given to students should have only the Sediments worksheet.

Note that students need access to a computer (Part III) and a printer (Part I) to complete this exercise. Alternatively, the instructor may print these materials as handouts.

Some students have difficulty entering formulas in Excel, so the instructor should review the process and keep track of progress.

Because computer software changes so rapidly, the instructions for accomplishing certain tasks with Excel might differ from those given in the student instructions. Thus, the instructor should be aware of possible difficulties using Excel.