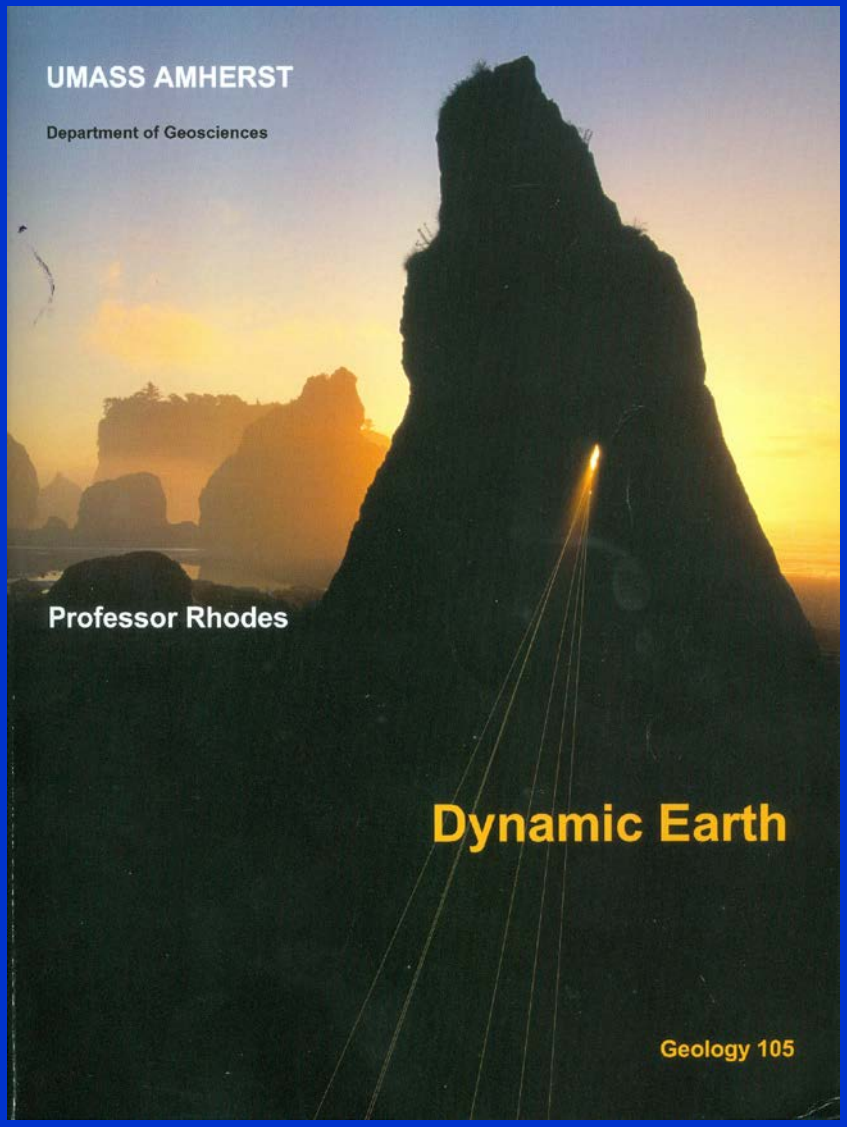
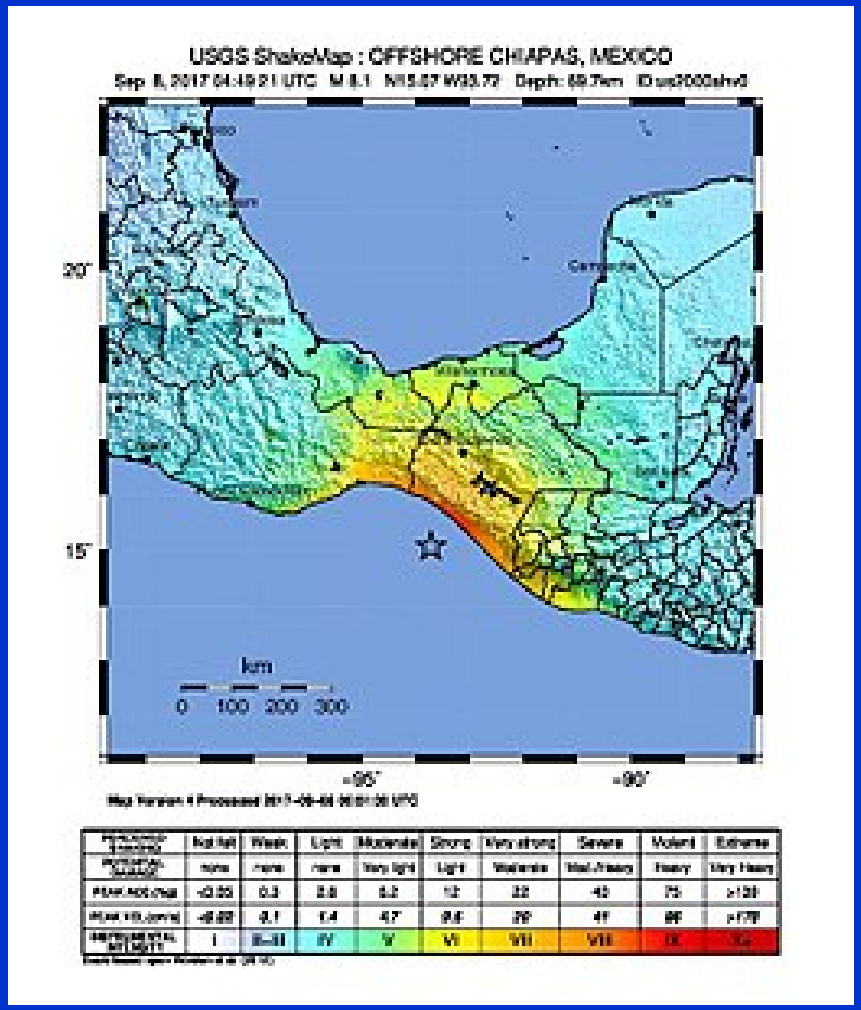
BOOK PROBLEM



Chiapas Earthquake, Mexico
Sept 7, 2017, M = 8



OFFICE HOURS

Mike Rhodes
Tuesday and Thursday 3:00 – 5:00 pm

Sumaya Hamdi, TA
Wednesday 9:30 – 11:30 am
Tuesday and Thursday 1:00 – 2:00 pm

CONTINENTAL DRIFT

SEA-FLOOR SPREADING

PLATE TECTONICS

The Theory of Continental Drift

Alfred Wegener (1912) proposed:-

- A large super-continent **PANGEA** split into smaller fragments about 200-300 million years ago. These then drifted apart to form the present arrangement of continents.

- He had no satisfactory mechanism to offer , but appealed to a less-dense continent “floating” and “drifting” over a more dense oceanic crust (like icebergs in the ocean).

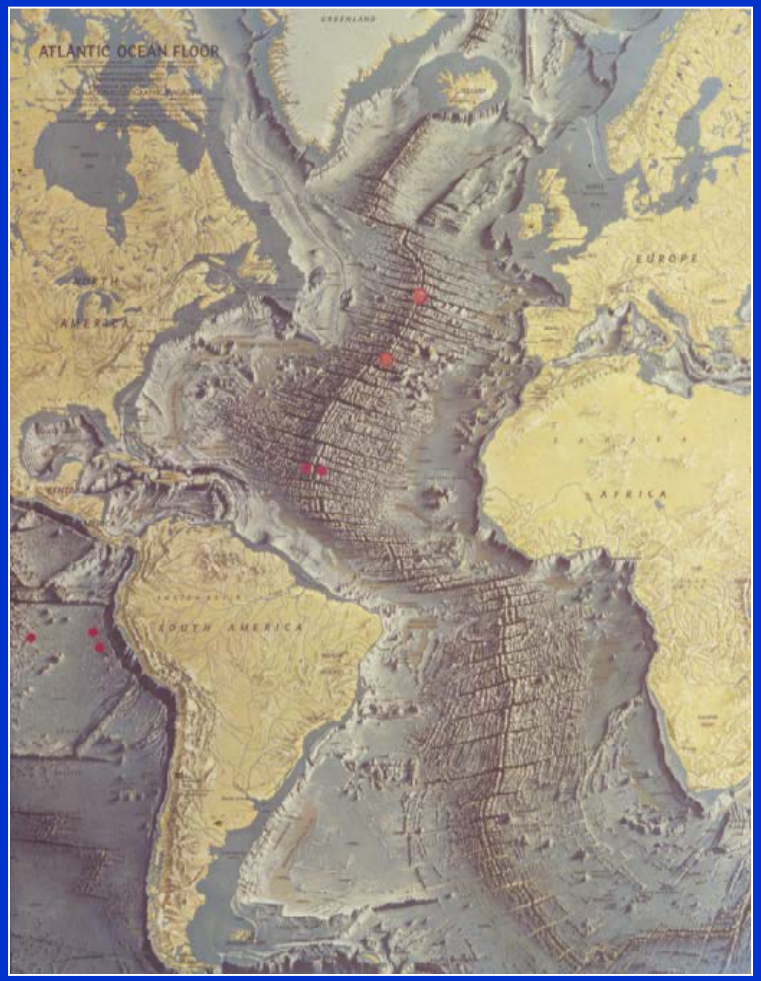
Most geologists were highly skeptical and the idea was NOT widely accepted.

This is what Wegener thought Pangea looked like 200-300 million years ago.

Can you spot the present continents?

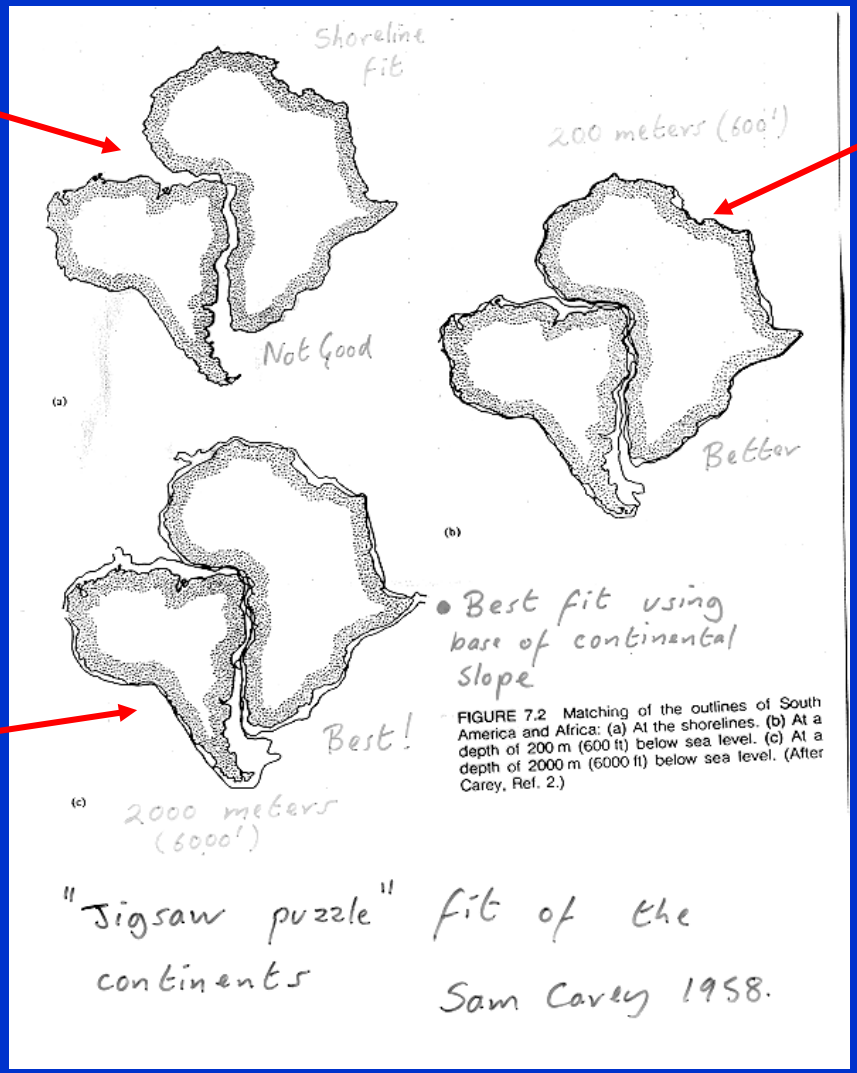
We will now review the evidence that led Wegener to propose his theory of **Continental Drift**.

Fit of Continents



Various attempts to fit Africa and South America

Shoreline fit (not great)

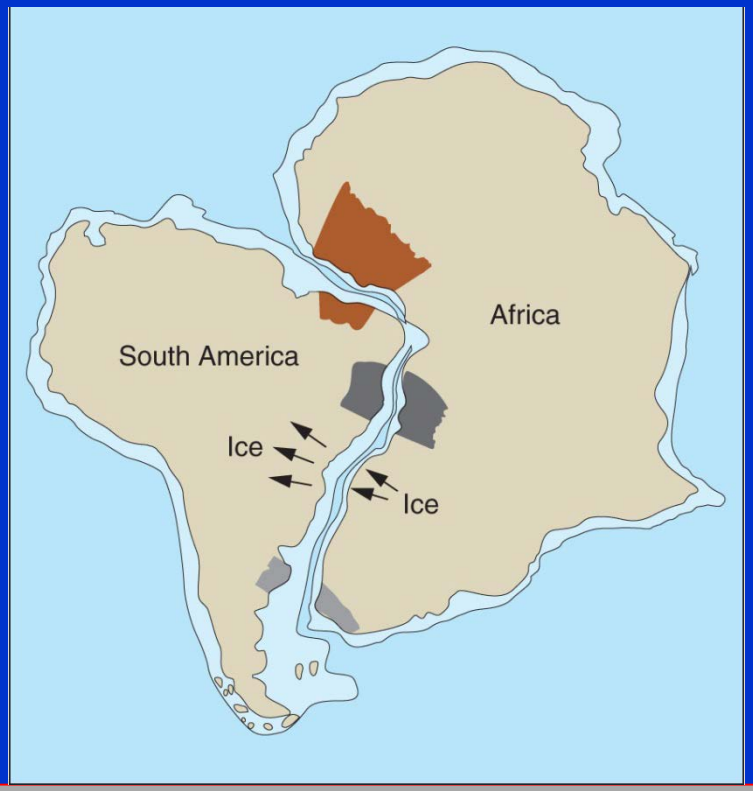


200 m. fit (better)

Continental Slope 2000 m (best)

Work done by Carey in 1958

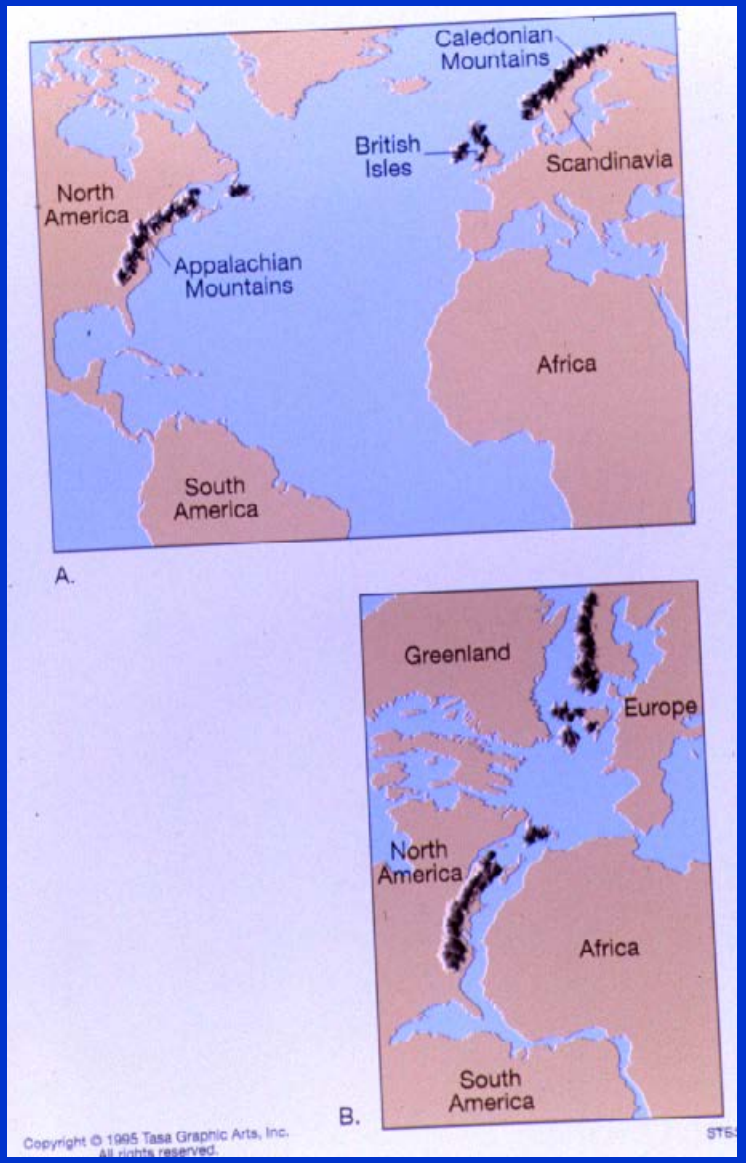
When we fit the continents of Africa and South America “back together again”, we find that:-



- Similar rock types extend from one continent to the other
- The rocks are also the same age.

CONCLUSION - perhaps the two continents were once part of a single larger continent?

Similar rock types extend across continents



Rocks in the Appalachians of North America and the Caledonides of Britain and Norway are very similar and are also similar in age.

When we fit Europe and North America together, we find that The Appalachians and Caledonides could form a single mountain chain.

Distribution of ice

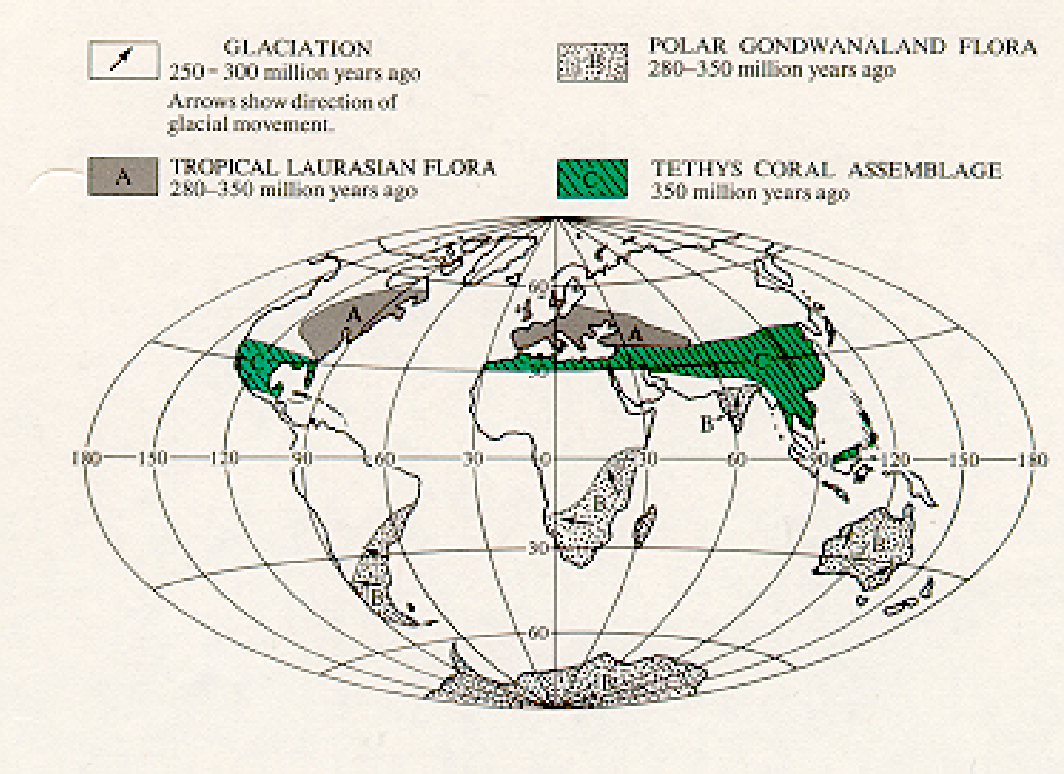
The white areas were covered by ice and tundra about 300 million years ago (arrows show the direction of ice movement).

PROBLEM: If the earth's orientation, relative to the sun, has remained constant - then these cold glaciated areas are in the wrong latitudes. They should be further south, where Antarctica is today!!

Wegener took the areas that had been covered by ice sheets and fitted them together around the south pole.

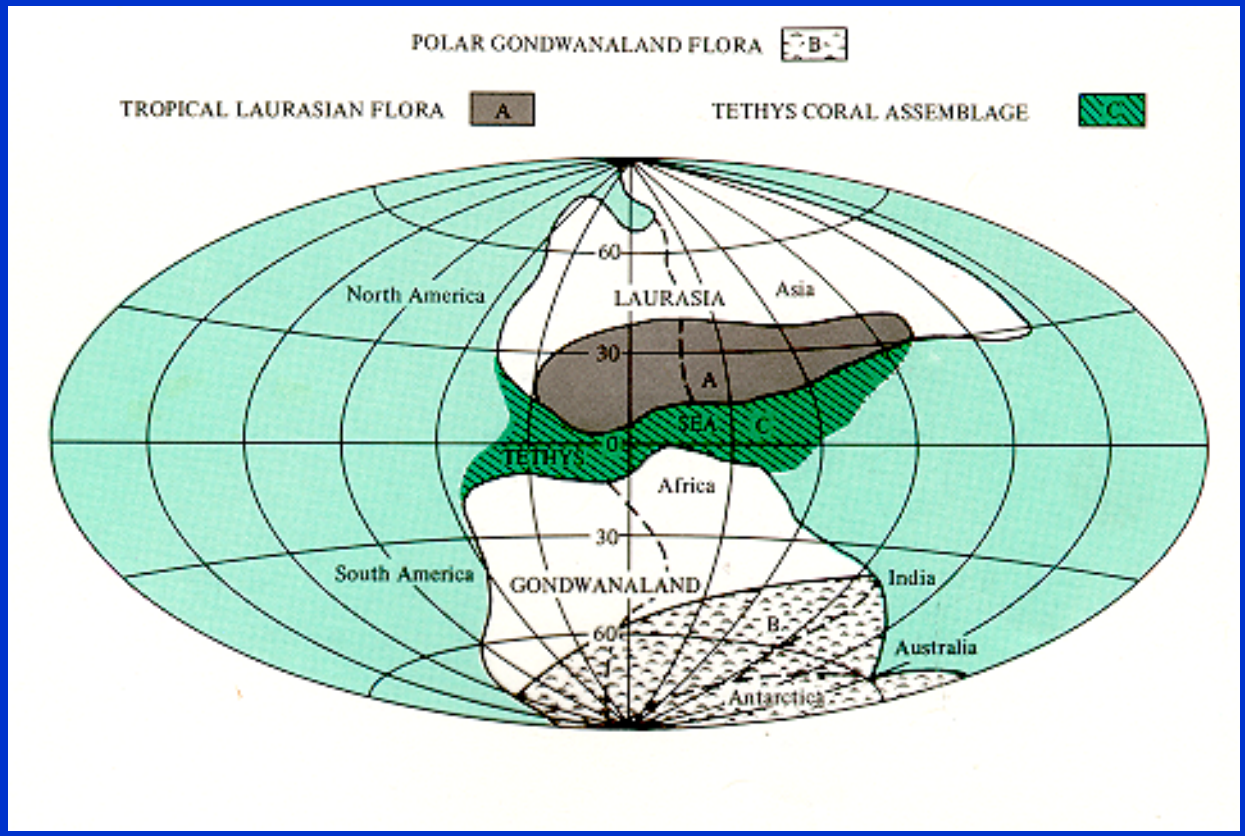
HIS CONCLUSION - the continents were once part of a single larger continent that then split apart, drifting to their present positions over the last 300 million years.

Distribution of corals and coal



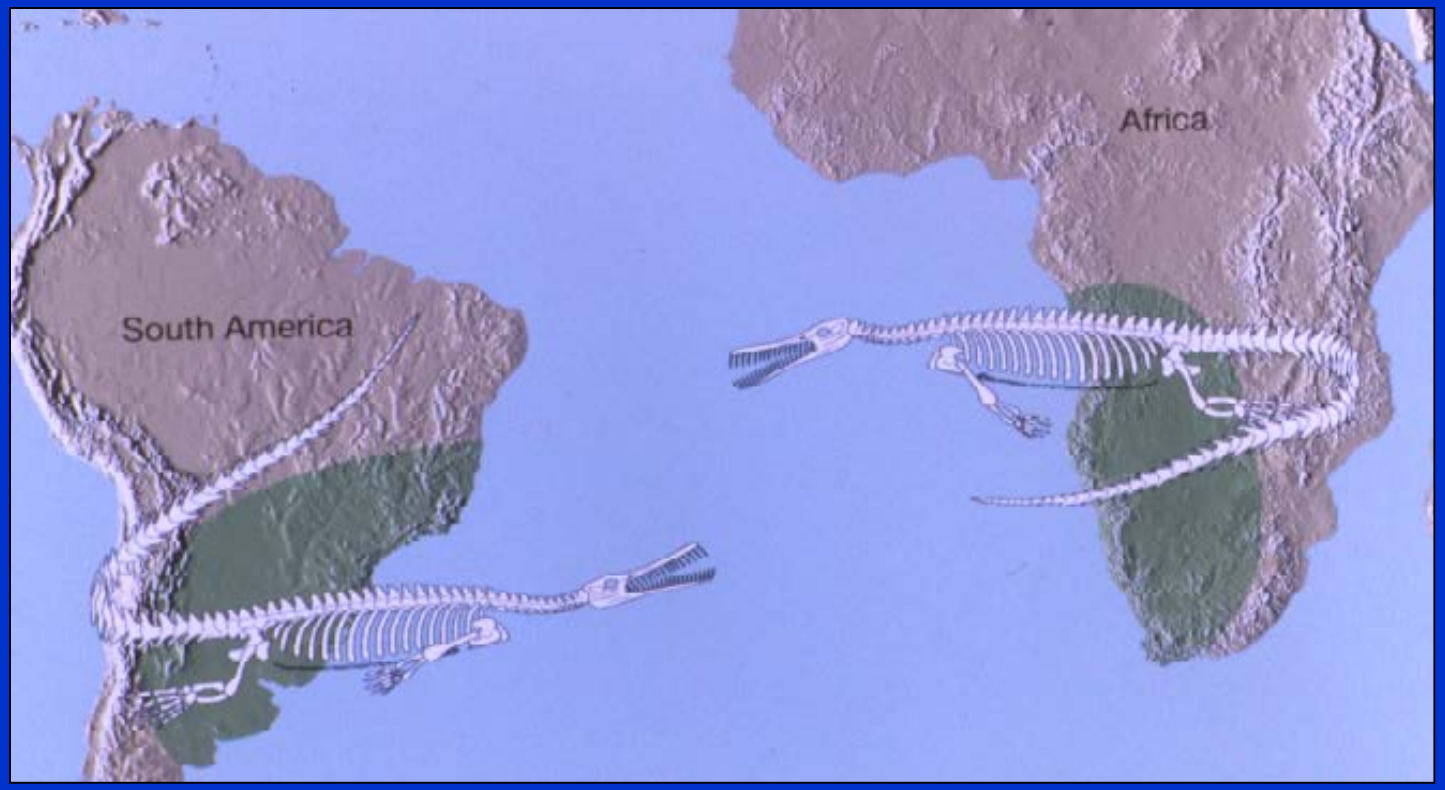
If we look at the distribution of 280-350 million year old rocks containing corals and coal (both formed in warm tropical conditions), we find that they are about 30^0 in latitude too far to the North!

Here is Wegener's interpretation:-



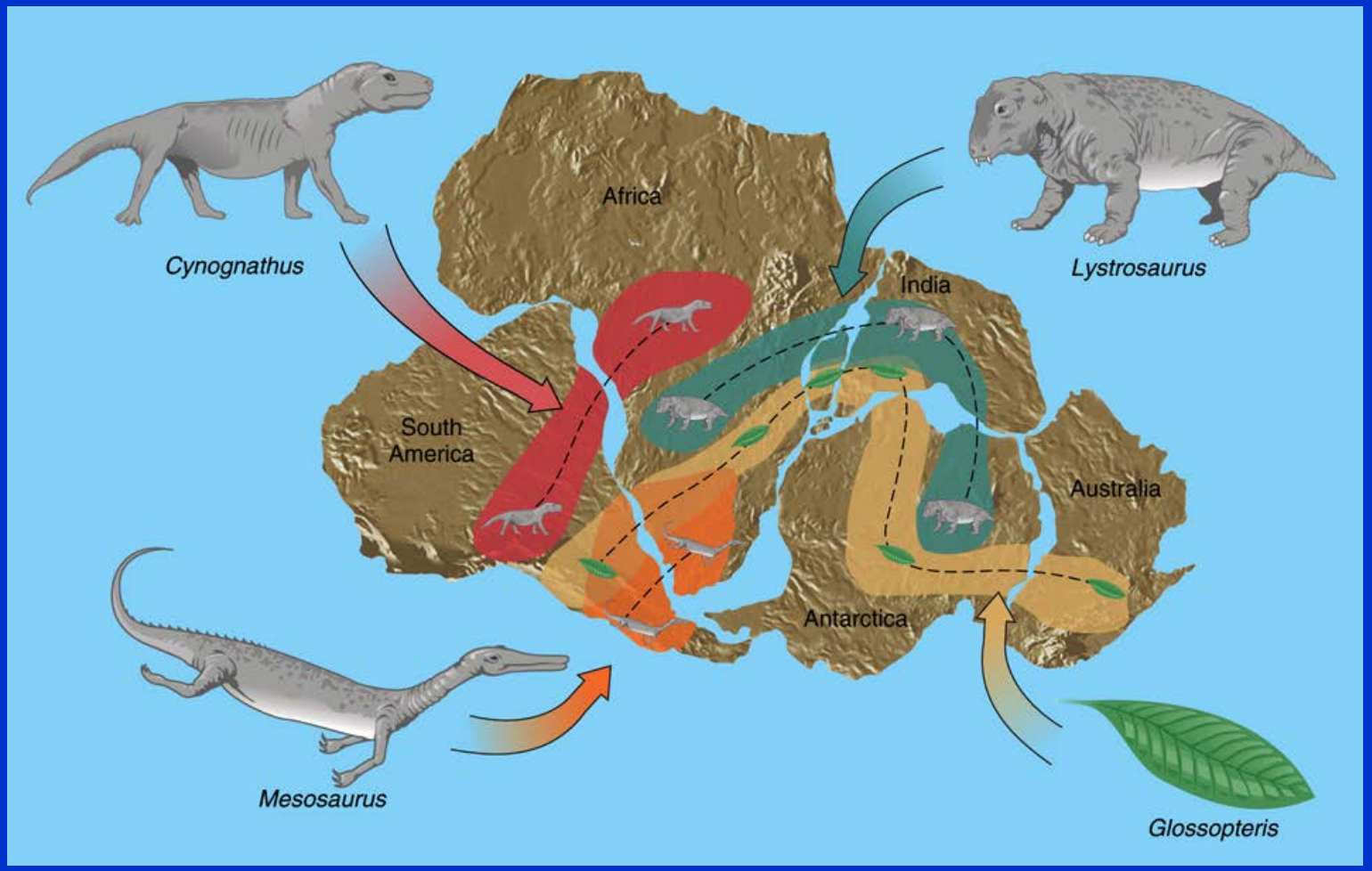
About 300 million years ago, the super-continent **Pangea** was much further south. It then broke up into two continental masses, **Laurasia** and **Gondwanaland** with a shallow tropical sea (**Tethys**) between them.

Distribution of Mesosausarus



Mesosaurus was a small reptile that lived about 250 million years ago. Fossils of Mesosaurus are found on both sides of the Atlantic in South America and Africa (green shaded areas).

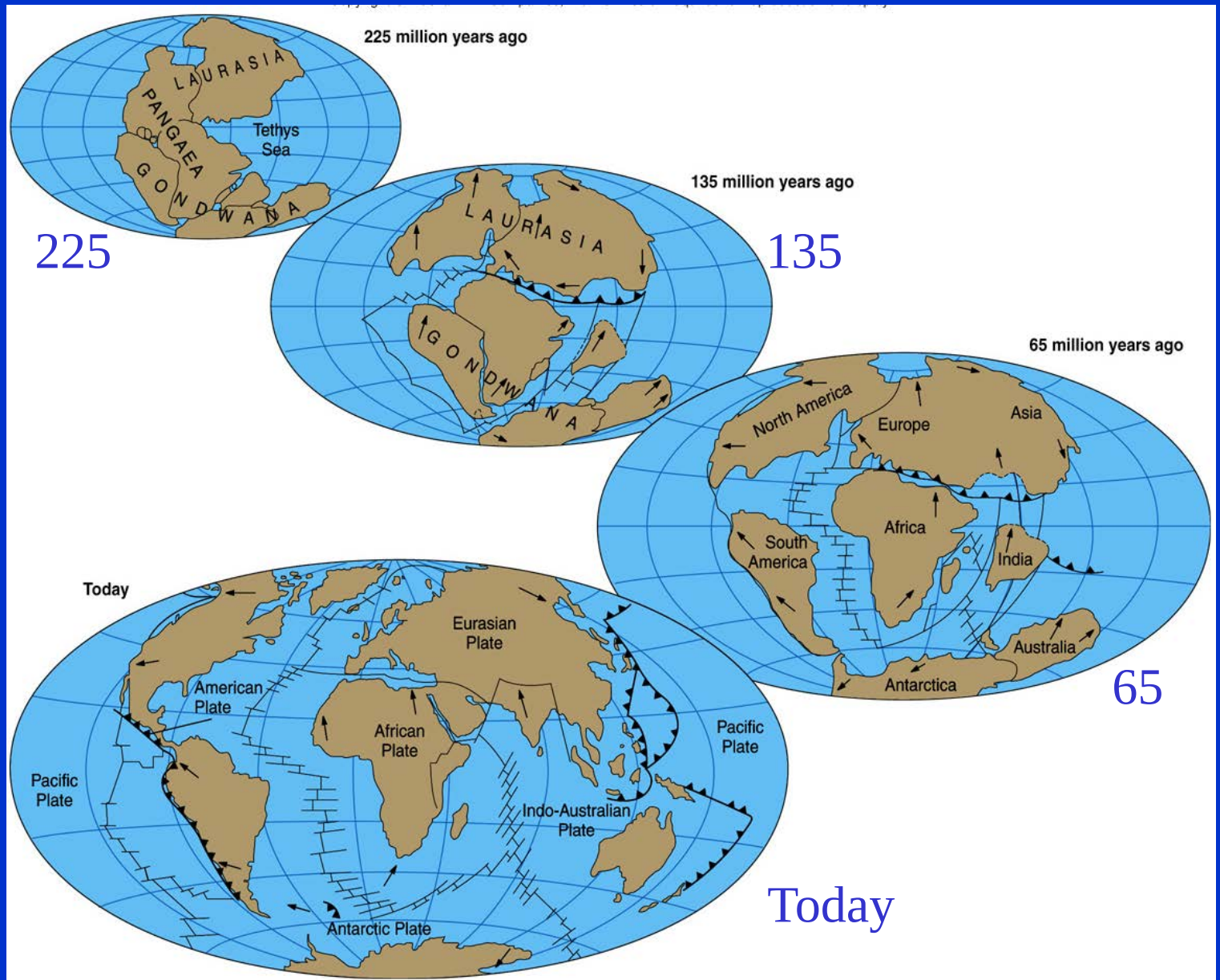
Distribution of other Reptiles and Plants



Similar fossils (reptiles and plants) are found on the different continents. How could they have crossed the oceans?

CONCLUSION - they didn't, the continents were part of the same landmass about 200-300 million years ago.

This is how Wegener thought the continents moved over the last 200 million years:-



Arguments Favoring Continental Drift

- Fit of continents
- Apparent discrepancy in inferred latitudes of ancient rocks
- Rocks of same age and similar characteristics on different continents
- Distribution of similar plants and animals on different continents (how did they cross the oceans?)

WEGENERS CONCLUSIONS:

The continents have drifted over the past 300 million years to their present positions!

(not a very popular idea at the time!!!)

Let's review the scientific method

I. Gather data (measurements or observations)

II. Think of a **hypothesis** to explain the data

III. Gather more data to test the hypothesis (try to prove it wrong!)

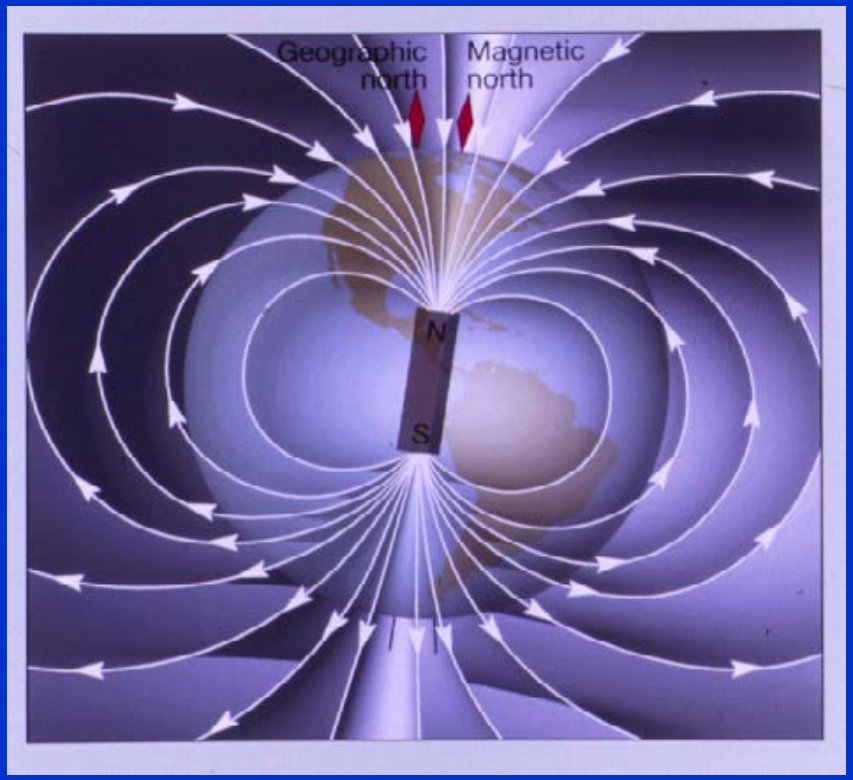
IV. If the hypothesis survives testing, refine the hypothesis to account for the new data

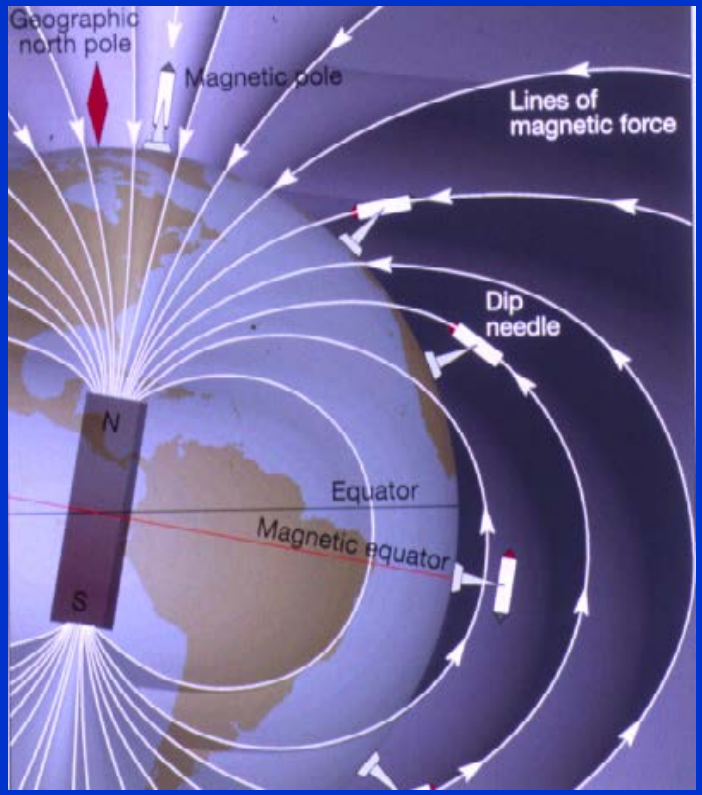
V. If the hypothesis continues to survives testing, eventually it becomes a **theory**.

Note - data should be capable of being repeated by others

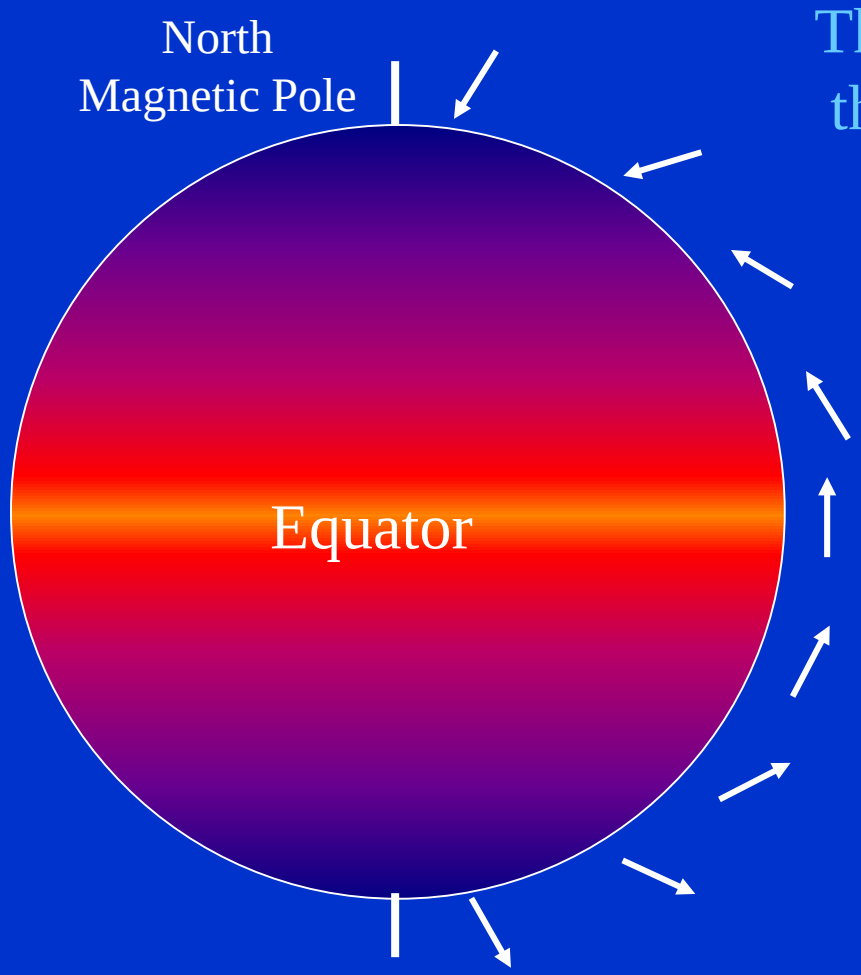
PALEOMAGNETISM

The next line of evidence came about 40 years later (1950's) from the study of the earth's magnetic properties





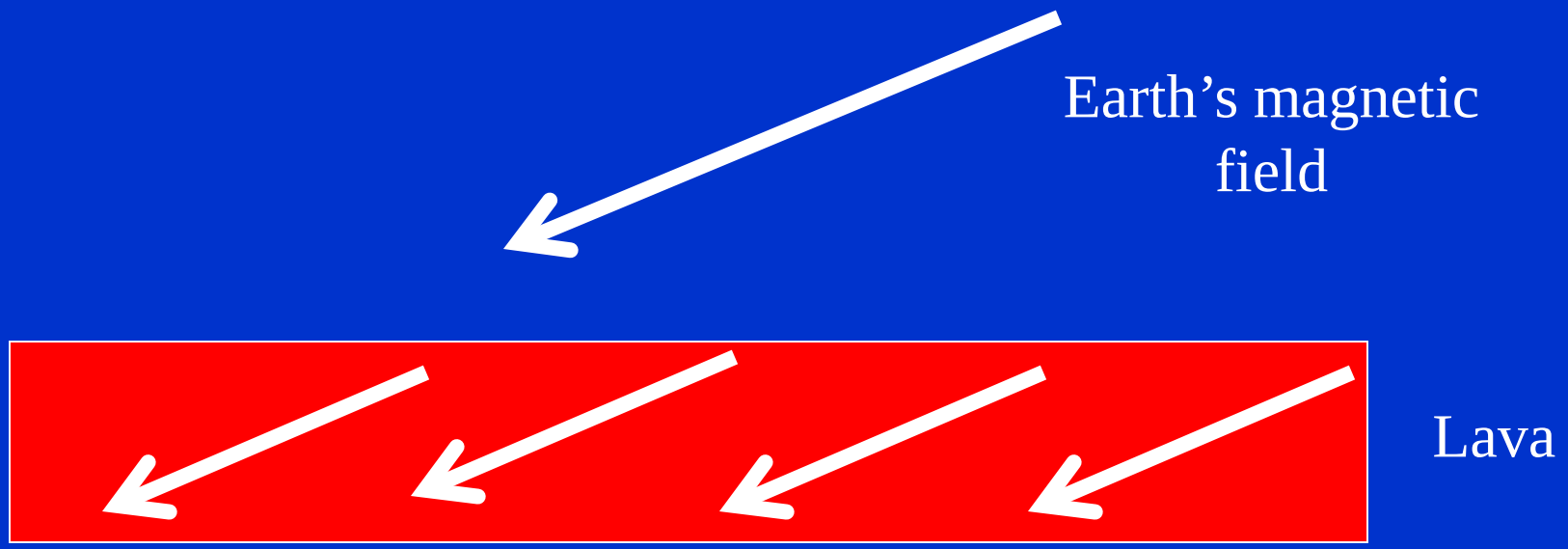
The direction and inclination in which a dip-needle points reflects the earth's magnetic field:-

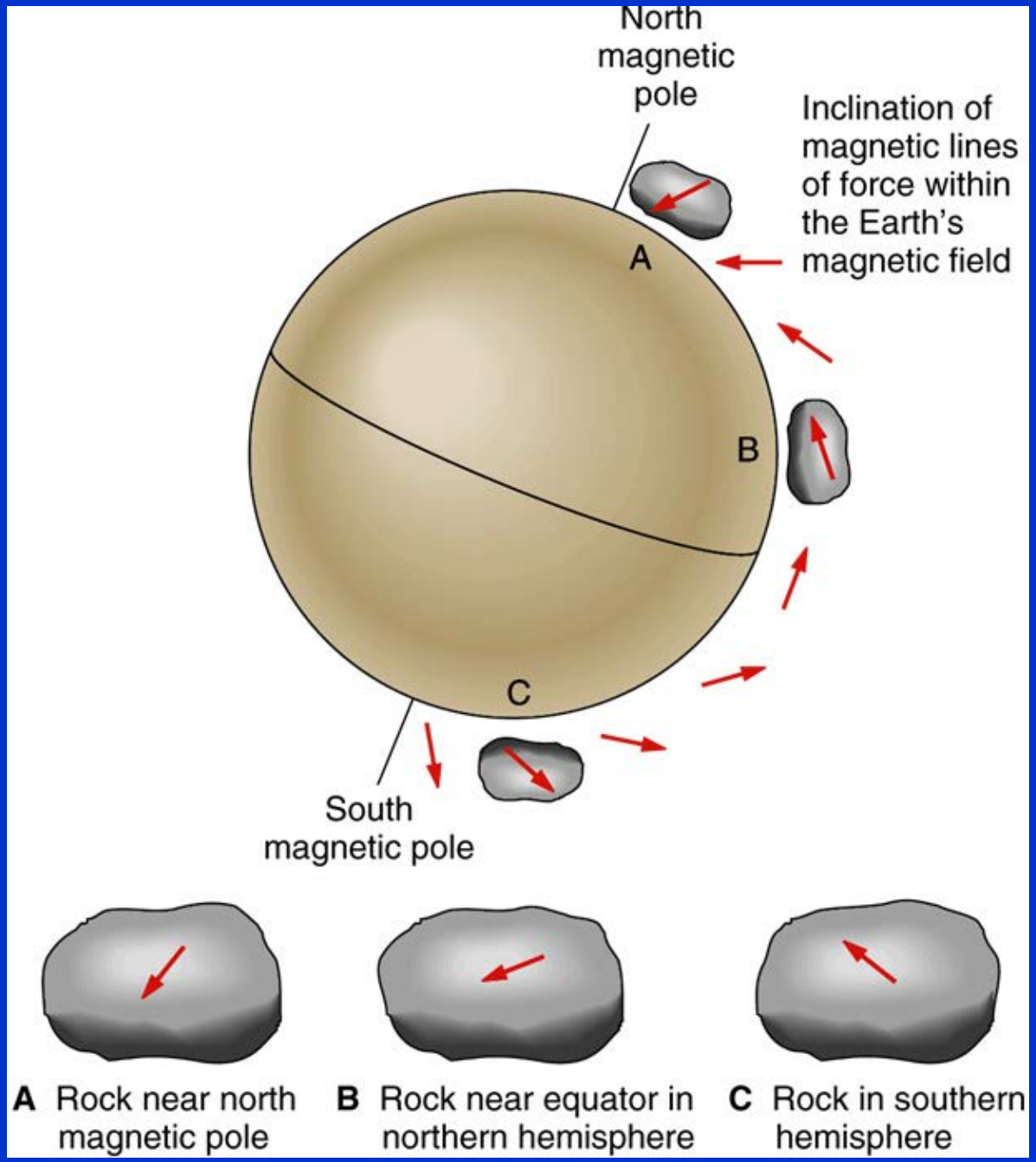


The higher the latitude, the steeper the inclination

Inclinations
Equator ~ 0 degrees
Hawaii ~ 20 degrees
Iceland ~ 60 degrees

Similarly, magnetic iron-bearing minerals crystallizing from molten lava align themselves with the earth's magnetic field - thus preserving a record of where the rocks formed relative to the earth's magnetic poles





If we collect rocks from different latitudes, their magnetic direction and inclination will reflect the earth's magnetic field where they were formed.

PALEOMAGNETISM

(The study of magnetic properties of old rocks)

The direction and inclination of magnetism of an iron-bearing mineral such as **magnetite** can tell us where that mineral (or rock) formed with respect to the magnetic pole.

Example - if basaltic lava that is 200 million years old has a flat magnetic inclination, then it cooled and crystallized near the equator about 200 million years ago.

Imagine the surprise in the 1950's when it was discovered that ancient rocks had magnetic directions and inclinations that did not correspond with the present magnetic pole position.

CONCLUSIONS

- Either the earth's axis of rotation has shifted significantly over the last 300 million years (not considered likely)
- Or, the rocks on the continents are no longer located where they were formed.

In other words, the paleomagnetic evidence appears to support the arguments for continental drift.

POLAR "WANDERING" CURVES

We have learned that rock samples containing magnetic minerals (commonly magnetite) provide information (direction and inclination) on where they were formed relative to the north magnetic pole.

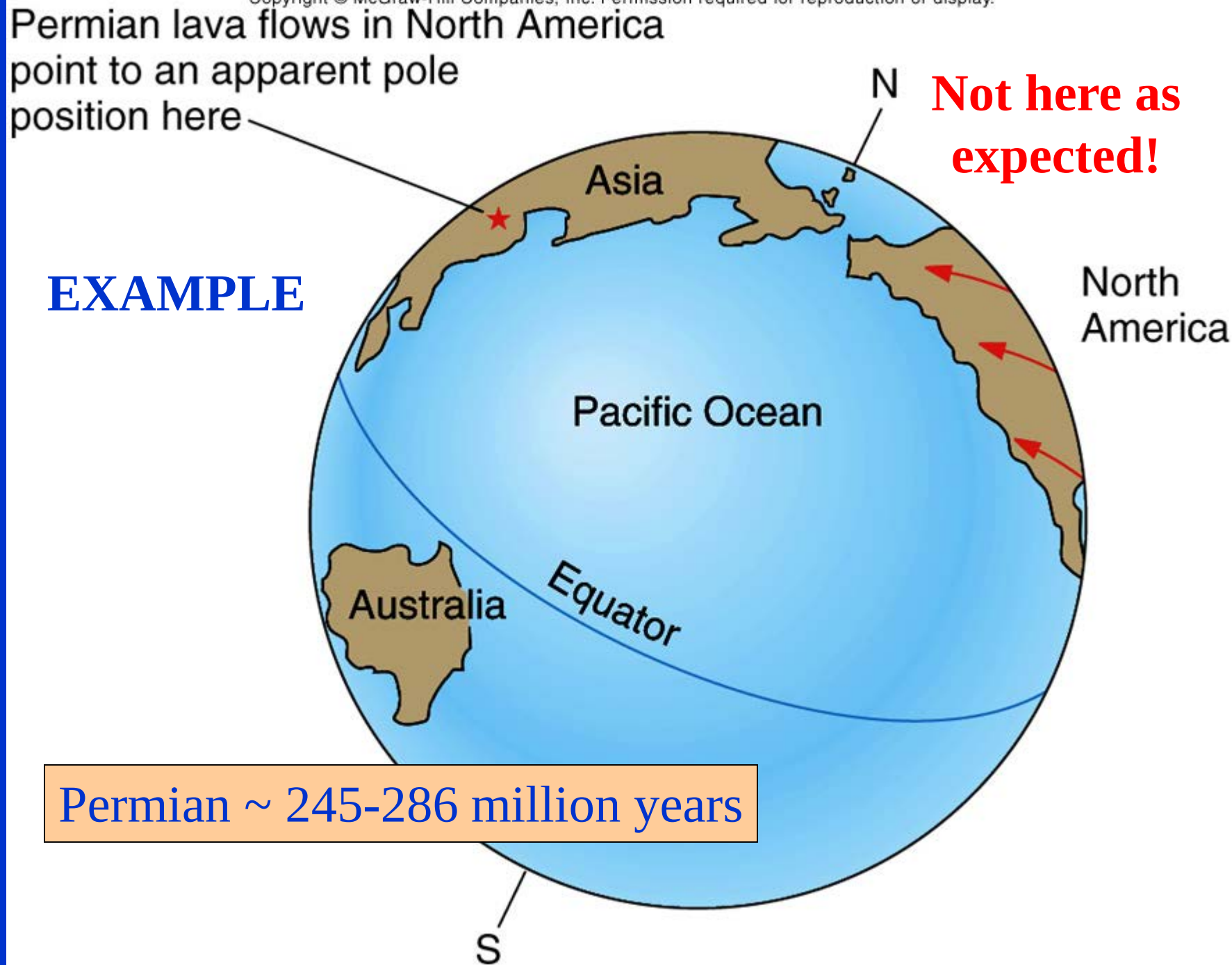
Turning this around – if we collect **recent** volcanic rocks from different places around the world, measurement of their **magnetic direction and inclination** will converge on the **present** magnetic north pole.

POLE POSITION ~ 90^0 - INCLINATION

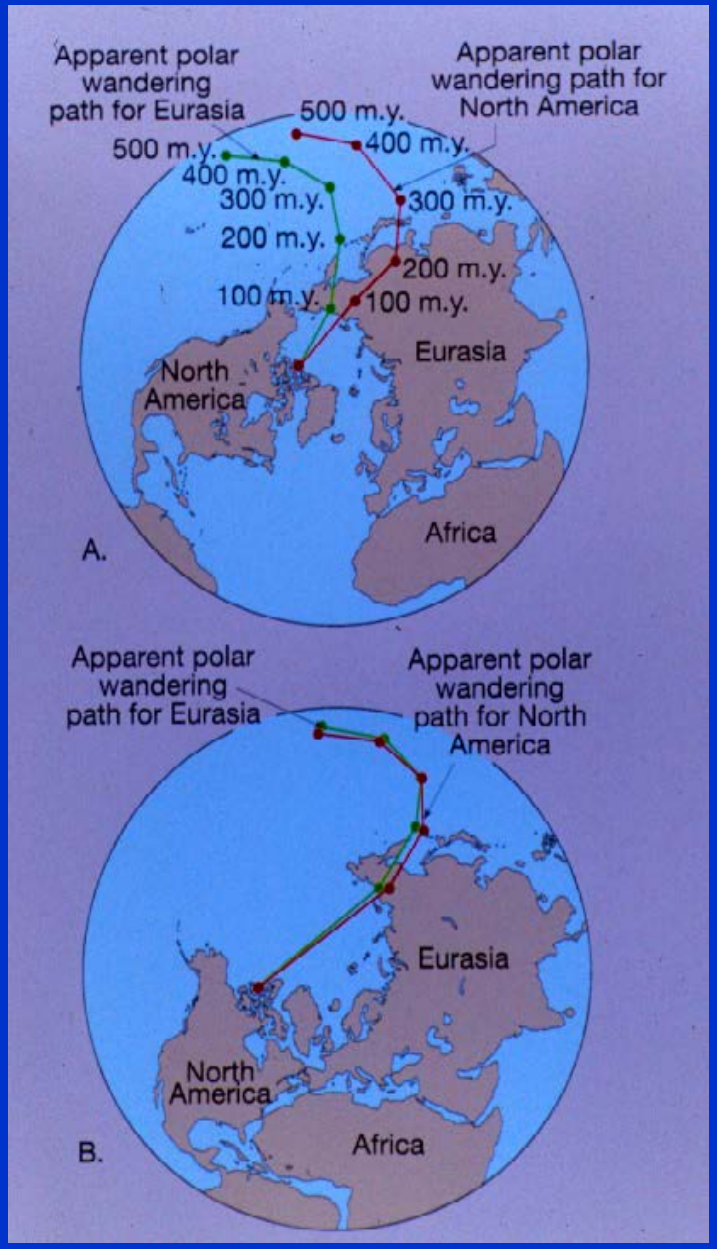
Does this happen with ancient rocks?

If we measure their magnetic inclination and direction, we might expect that rocks of the same age on different continents would give identical polar positions, which should correspond with the present polar position.

- Rocks of different ages give different polar positions
- Rocks of the same age but on different continents give different polar positions
- The older the rock the further the calculated polar position is from the present position



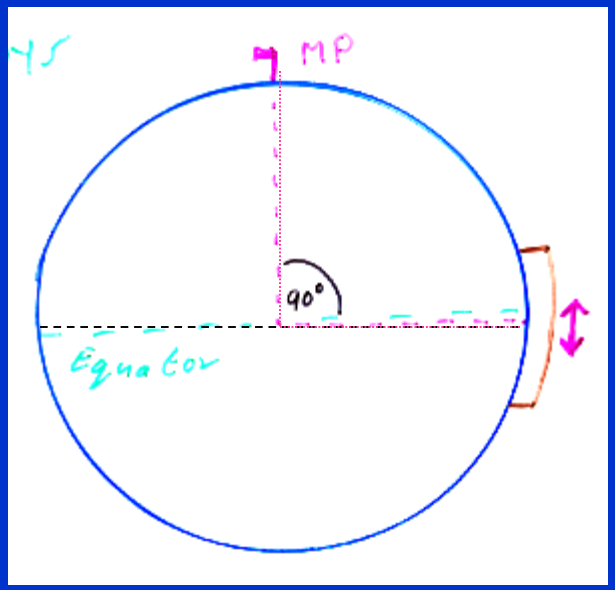
Examples of so-called “Polar Wandering Curves”



Plotting the apparent polar positions for rocks of different ages from North America and Eurasia produces two curves, the so-called “polar wandering curves”. Note that as the curves get younger they converge.

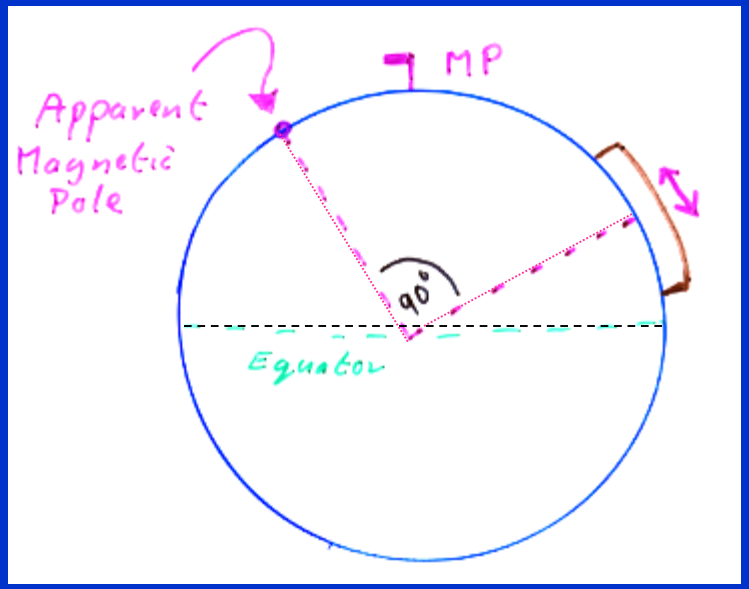
Fitting the continents back together results in a single curve. Nonetheless, the positions still do not correspond with the current magnetic position. To account for this, the continents would have had to move northwards as well.

Explanation of “Polar Wandering Curves”



300 million years ago

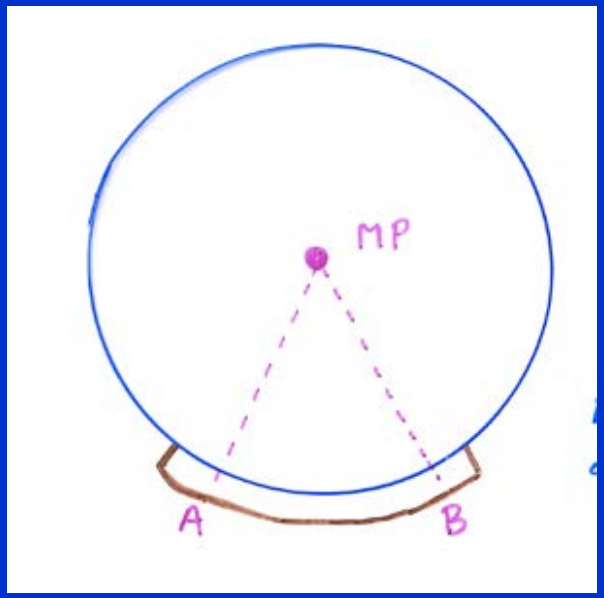
Sideways view of earth with continent astride the equator



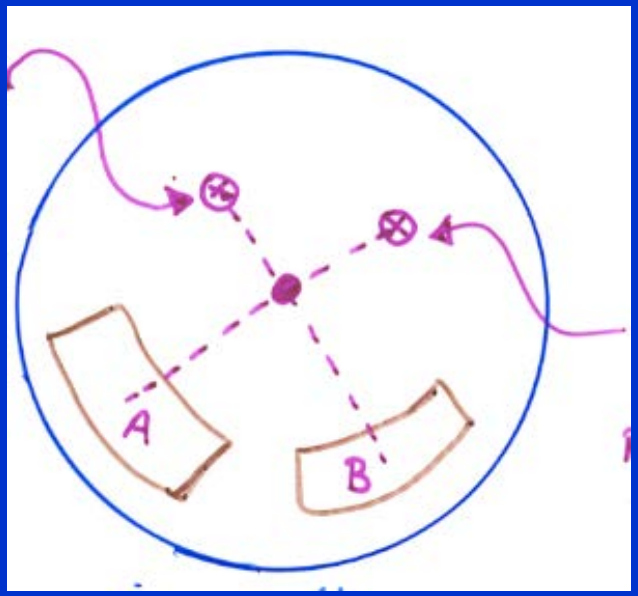
Today

Continent moves northwards resulting in an “apparent” magnetic pole that is displaced from the true pole

Another example - View looking down onto the magnetic pole



Apparent magnetic Pole for continent B



Apparent magnetic pole for continent A

300 million years ago

Two locations on large continent astride the equator

Today

Continent splits apart and moves to the north

In other words it is not the poles that “wander” as the name unfortunately suggests, but the continents!

CONCLUSION

- Paleomagnetic studies appear to provide support for Wegener's ideas of continental drift.
- The continents appear to have been joined over 200 million years ago.
- Paleomagnetic evidence also suggests the continents have moved northwards.