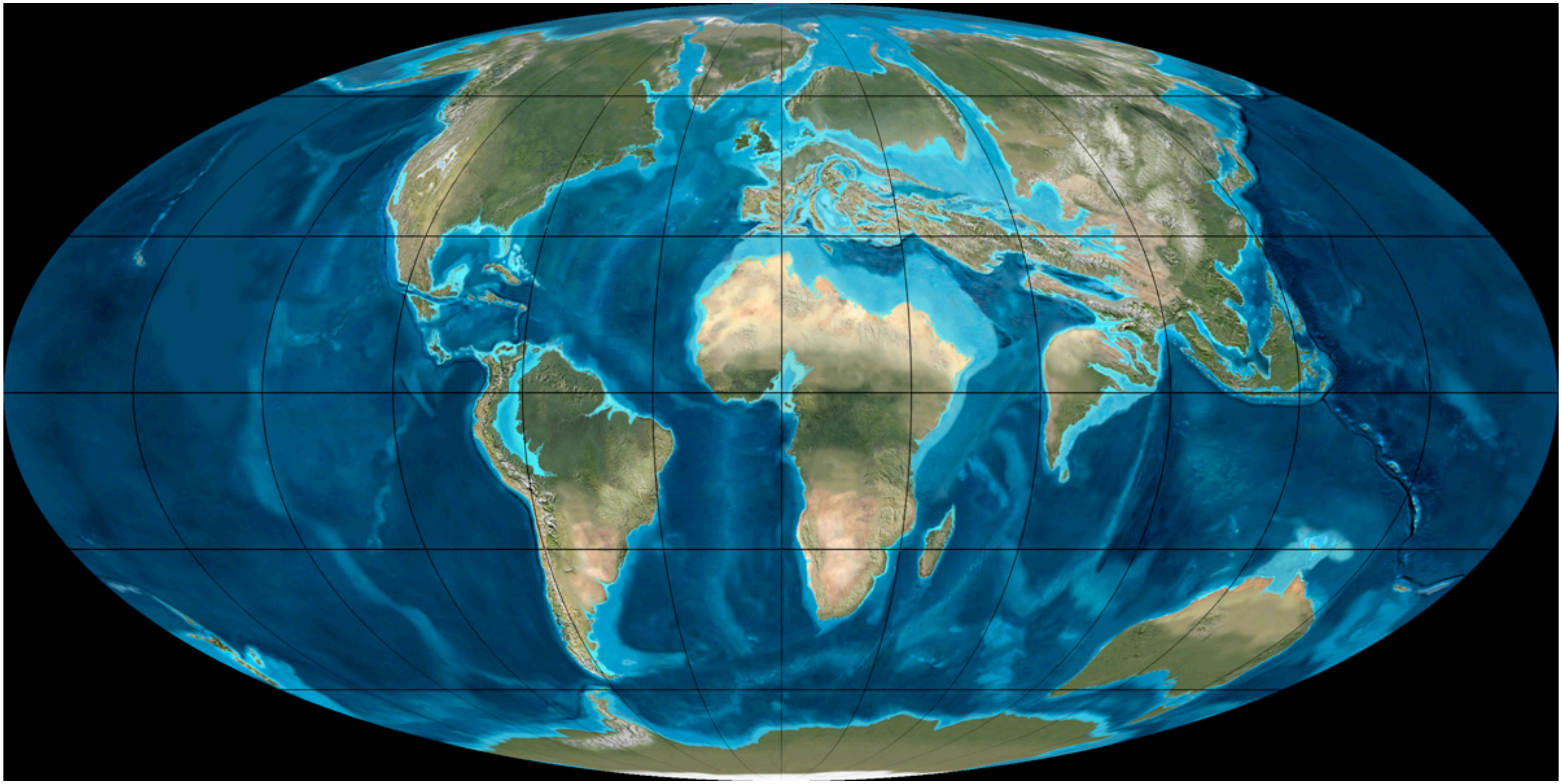
Reconstructions of the world through time

How are these maps generated?

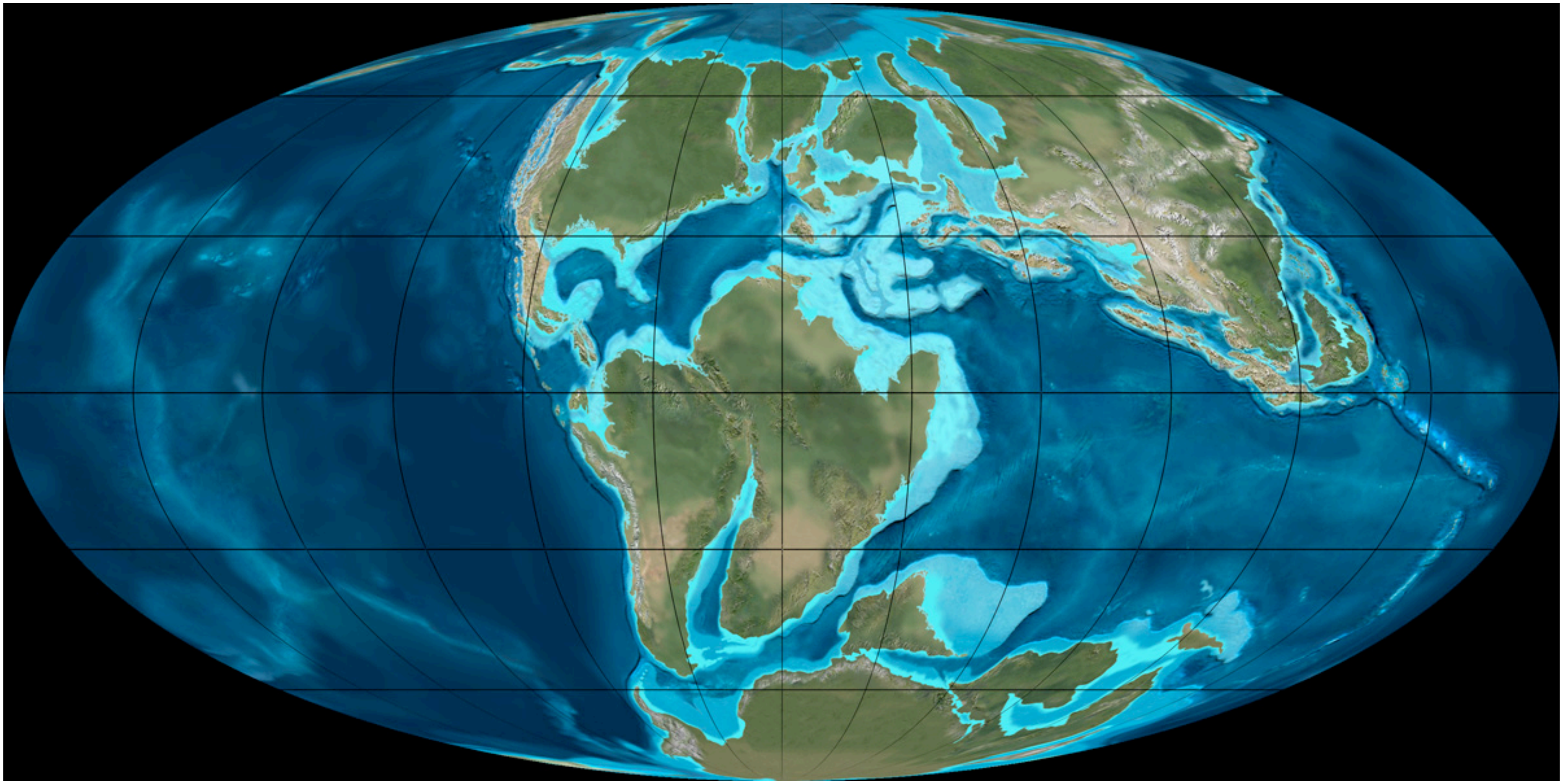
Images from:http://jan.ucc.nau.edu/~rcb7/globaltext2.html

50 Ma Eocene Period



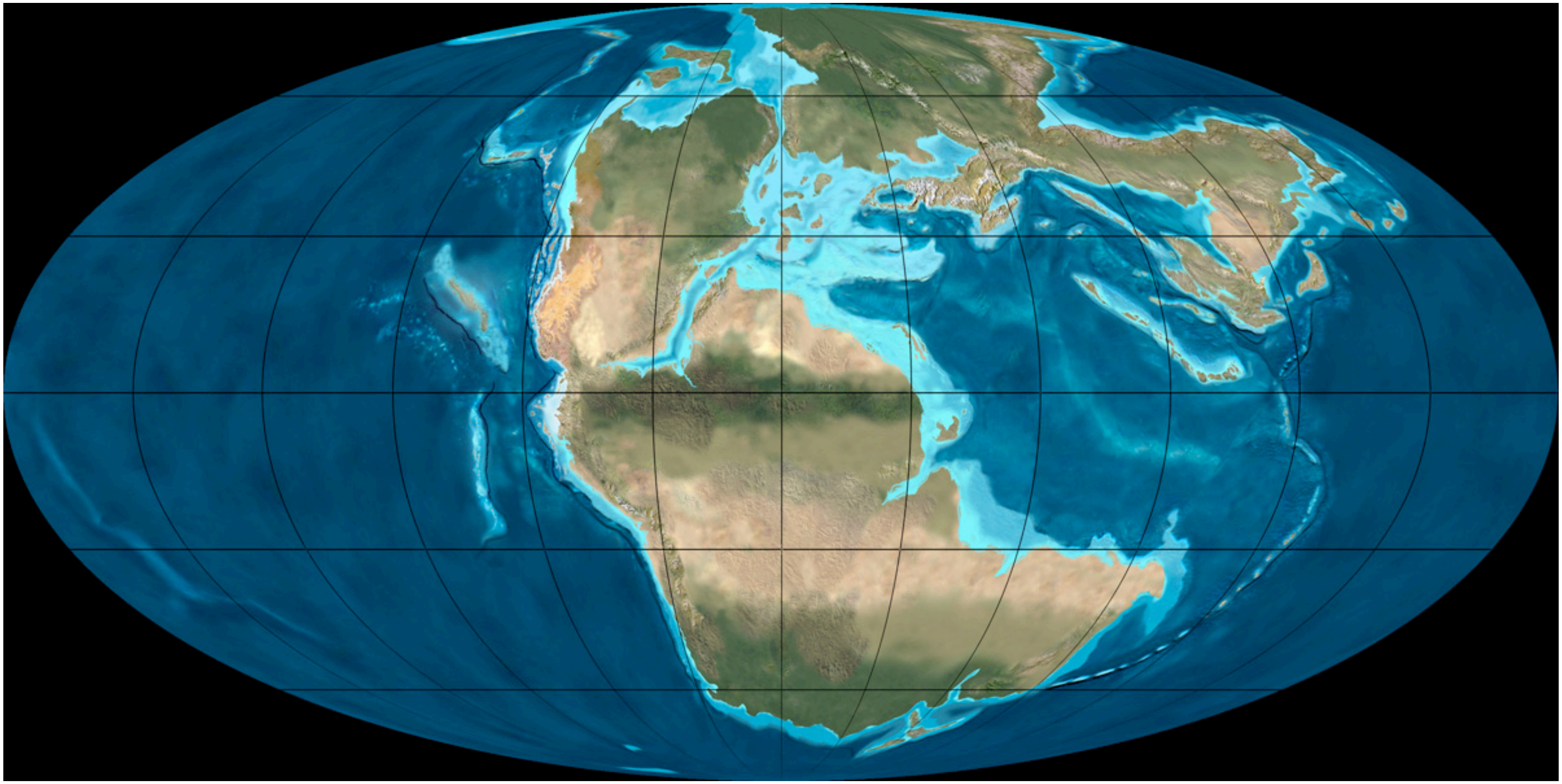
This map is for the (geologically) recent past. The plates are positioned based on the age of rocks in the ocean floor - we move the continents to the edge of 50 Ma year old ocean crust

120 Ma early Cretaceous Period



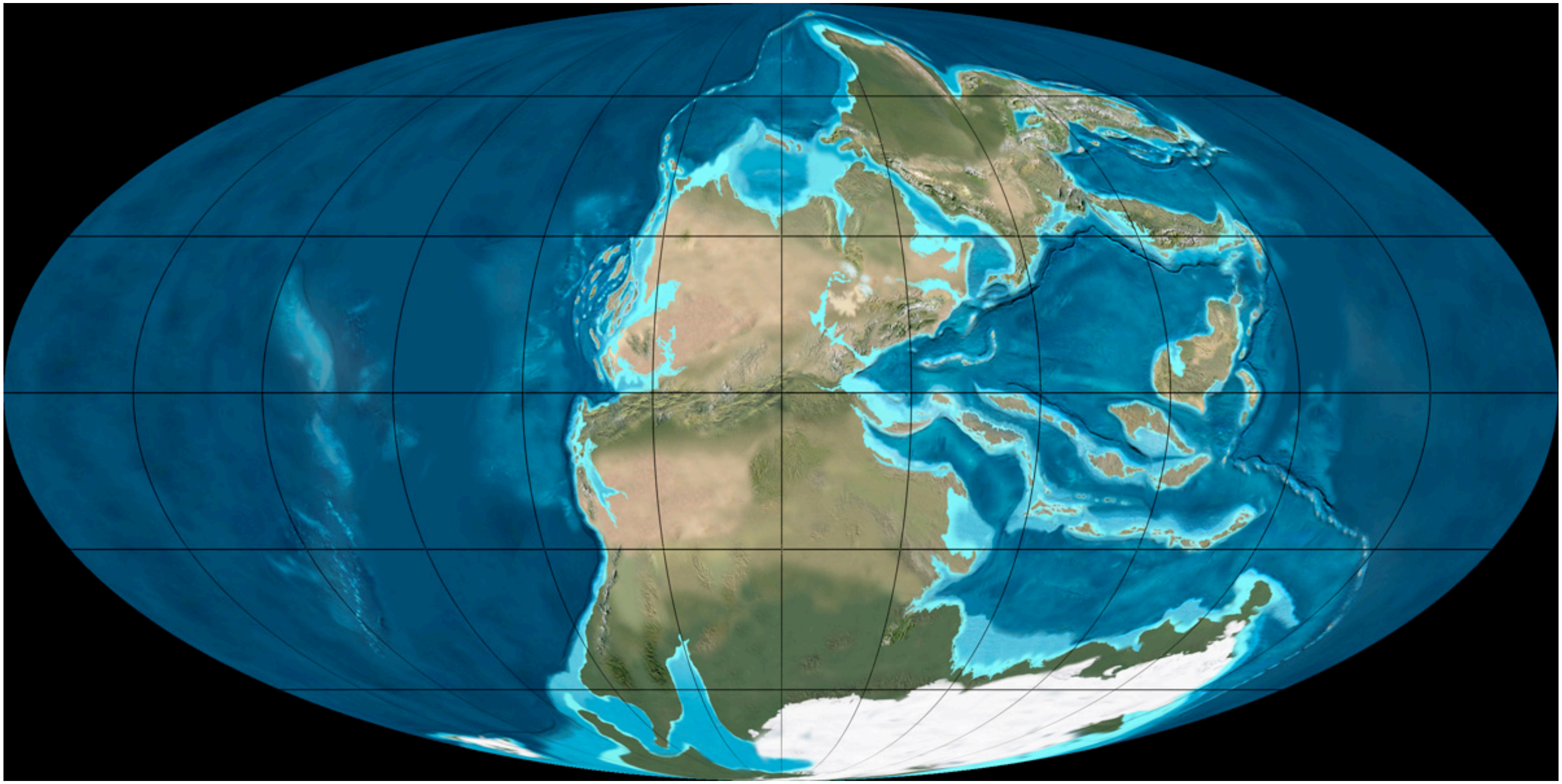
In order to make this map we can still use some of the ocean crust but there is very little of this age left in the world…starting in the Cretaceous we need to use another data set to position the plates: paleomagnetism

200 Ma early Jurassic Period



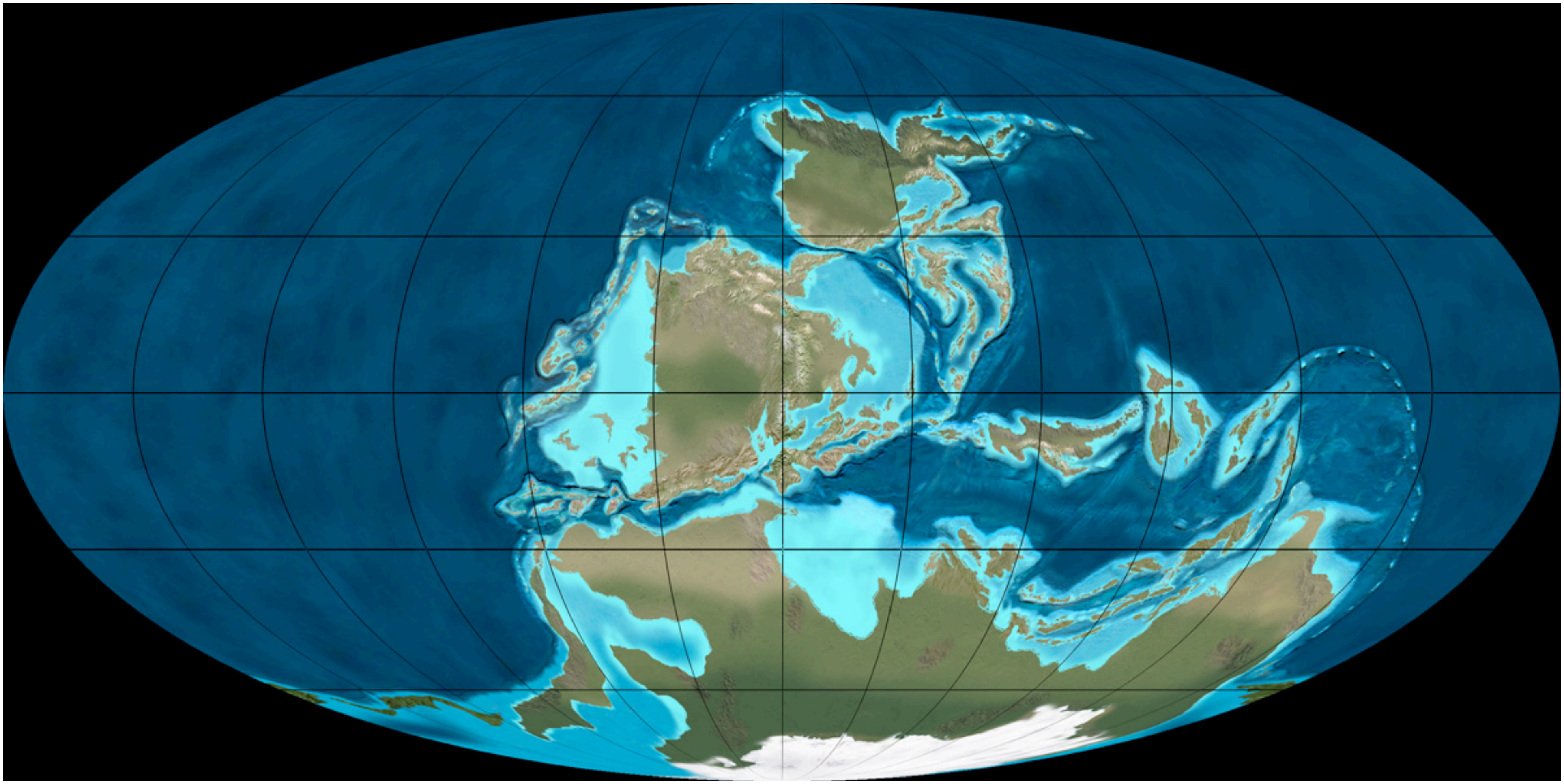
The Atlantic Ocean begins to open..Asia is not assembled yet.. Africa and South America are still joined to Australia, Antarctica and India..Europe is mostly submerged. The ocean crust off Nam is among the oldest ocean crust on Earth today

260 Ma late Permian Period



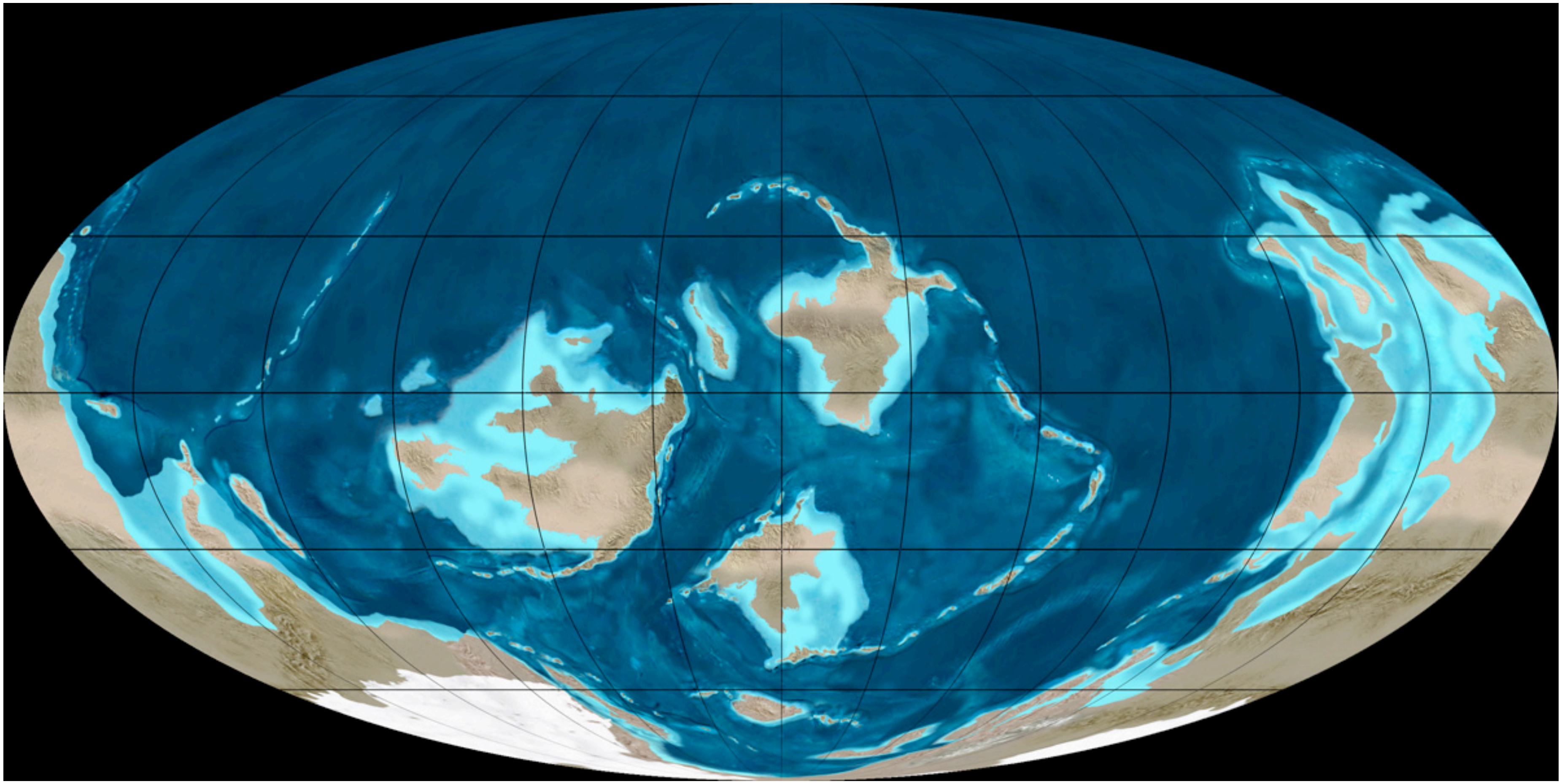
The supercontinent of Pangea…where the present day Indian Ocean is located is full of volcanic islands that ultimately will coalesce to form Asia

340 Ma Mississippian Period

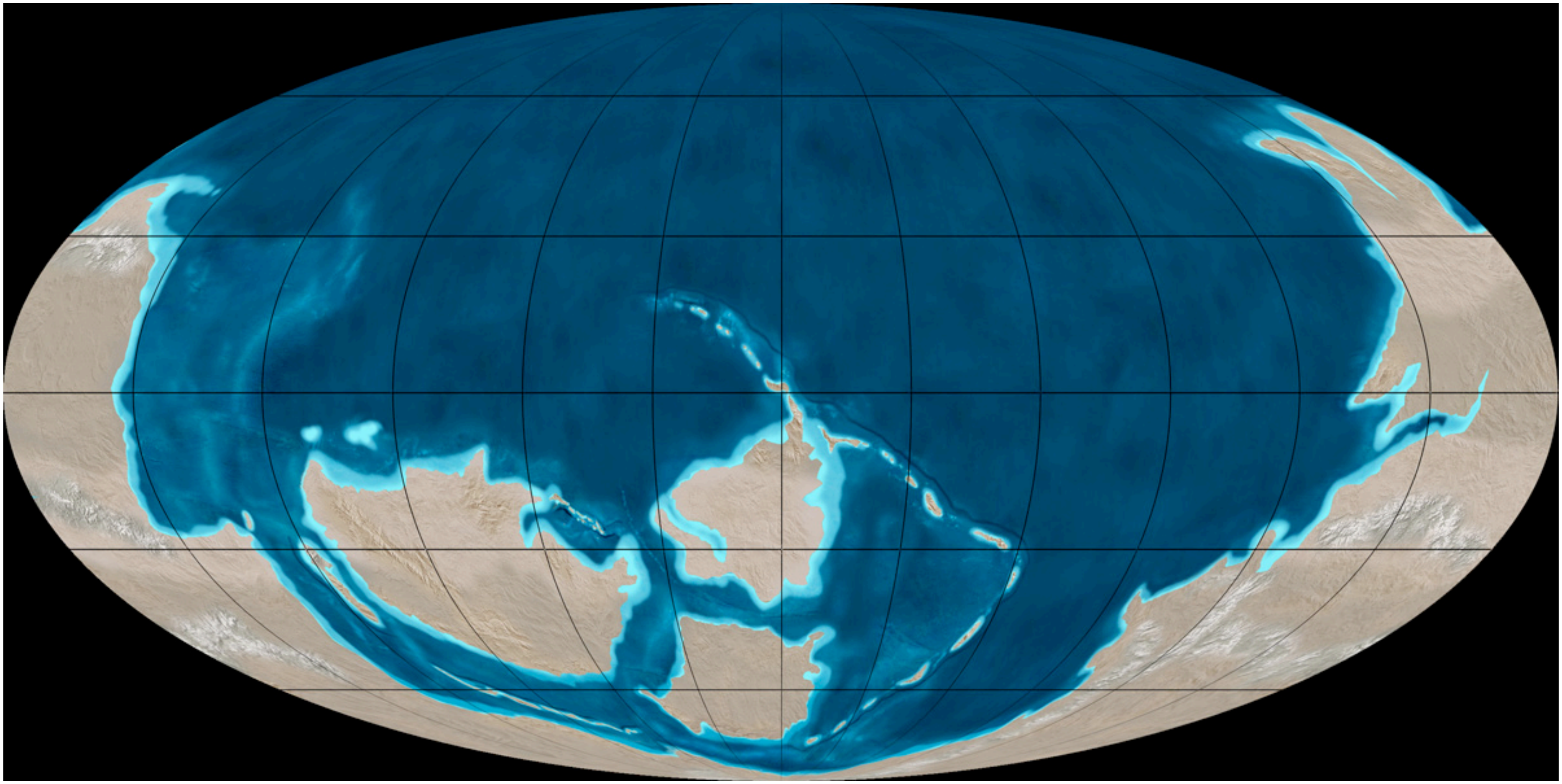


Pangea is assembling…the Iapetus Ocean (between N.Am and South America/Africa) is closing in advance of continent/continent collision

470 Ma early Devonian Period

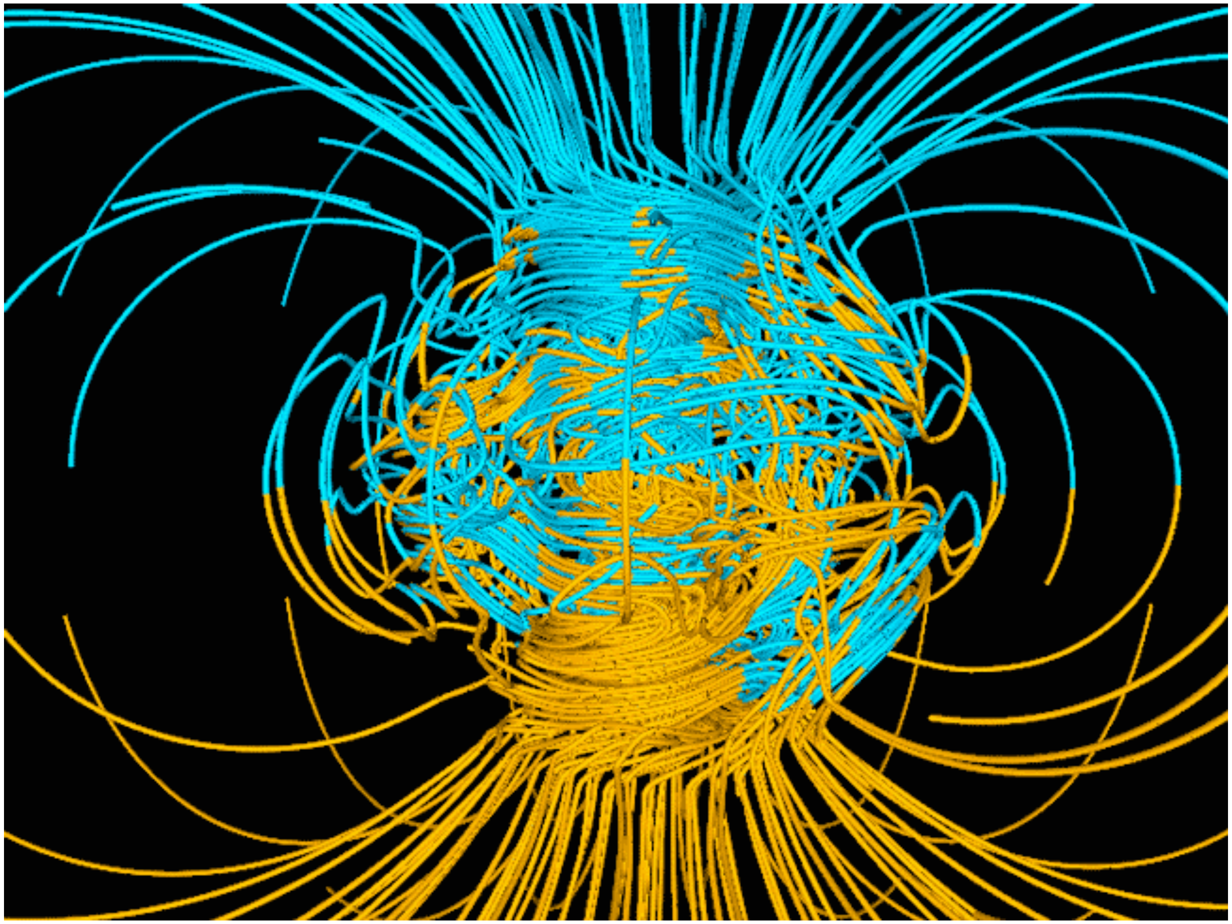


540 Ma early Cambrian Period



Most plates are clustered together into a supercontinent called Rodinia

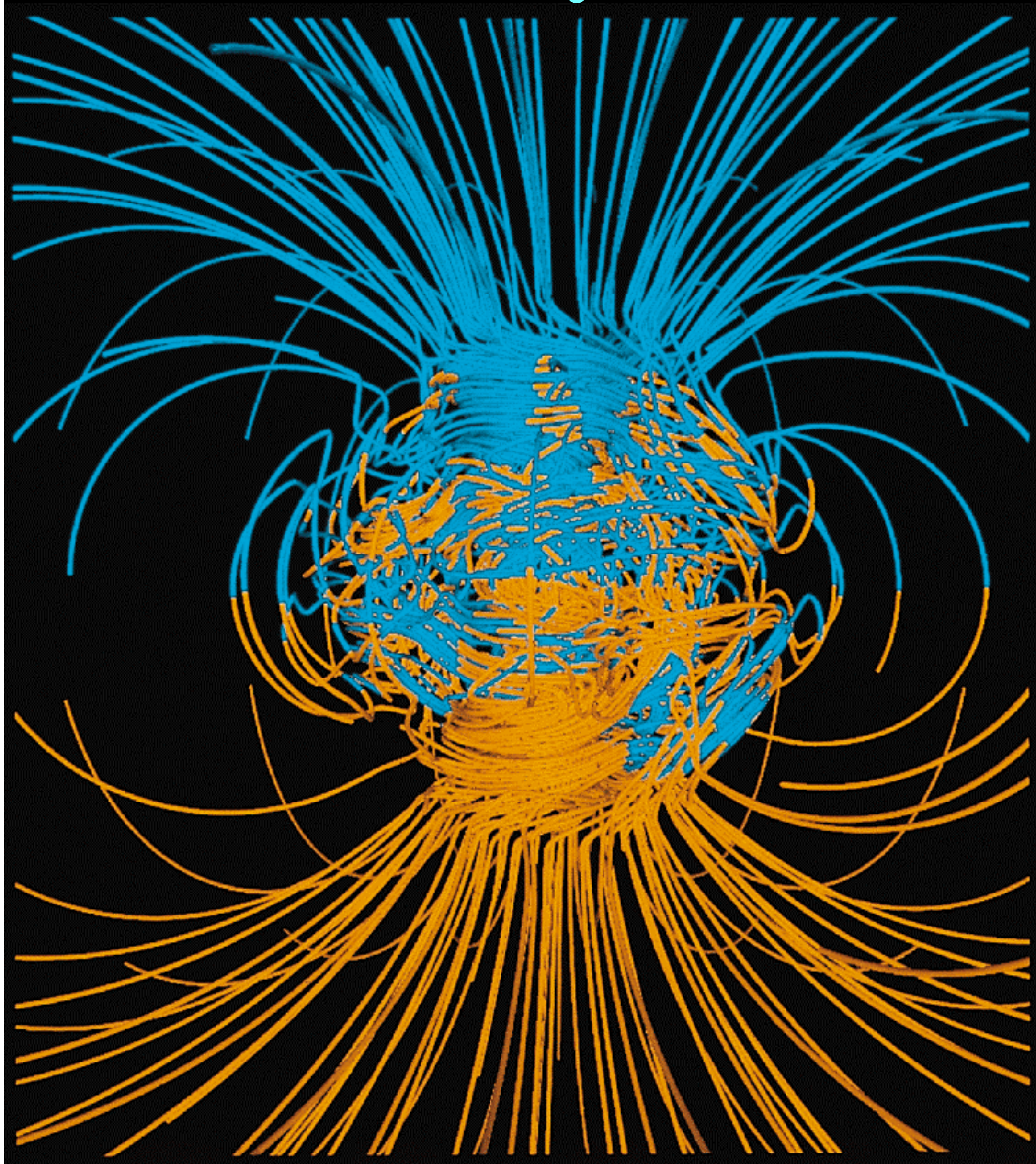
We need to understand the Earth's magnetic field and how it can be used to understand how the Earth's surface has changed over time…



The Earth's magnetic field is preserved in rocks

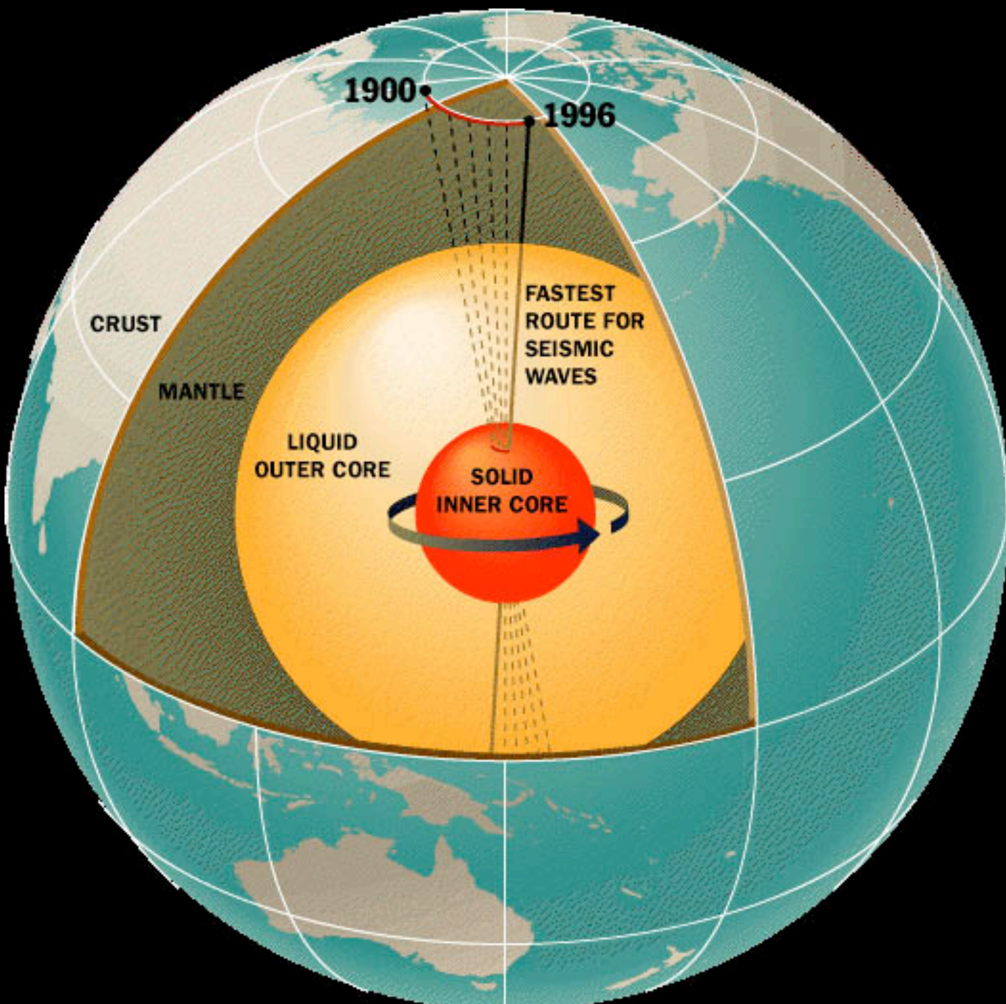
The Geodynamo

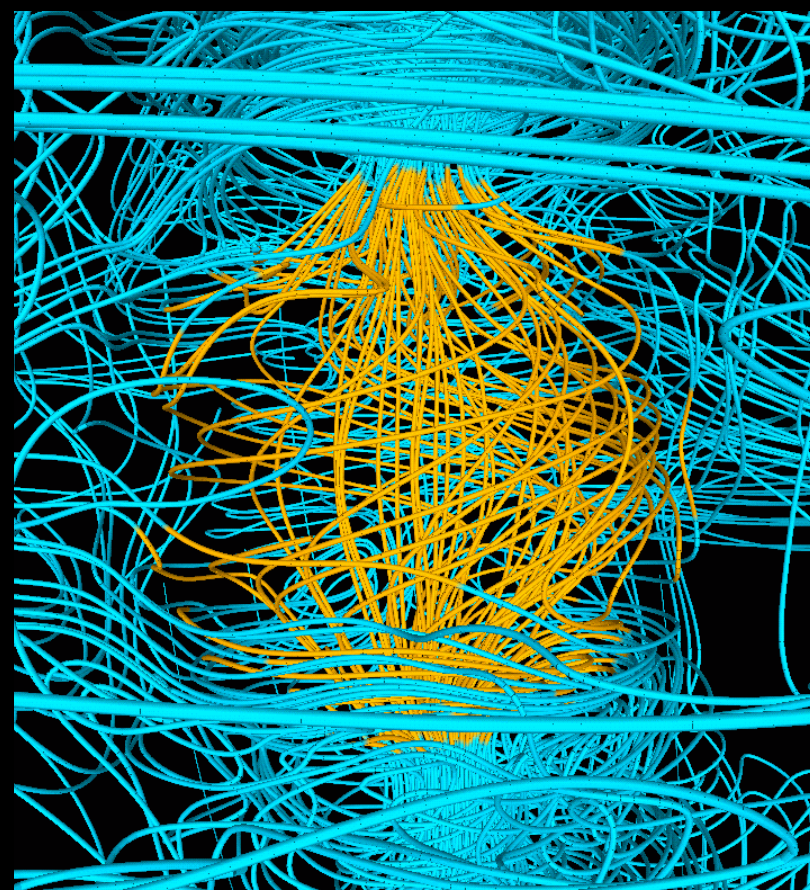
Gary Glatzmaier (Los Alamos)
Paul Roberts (UCLA)



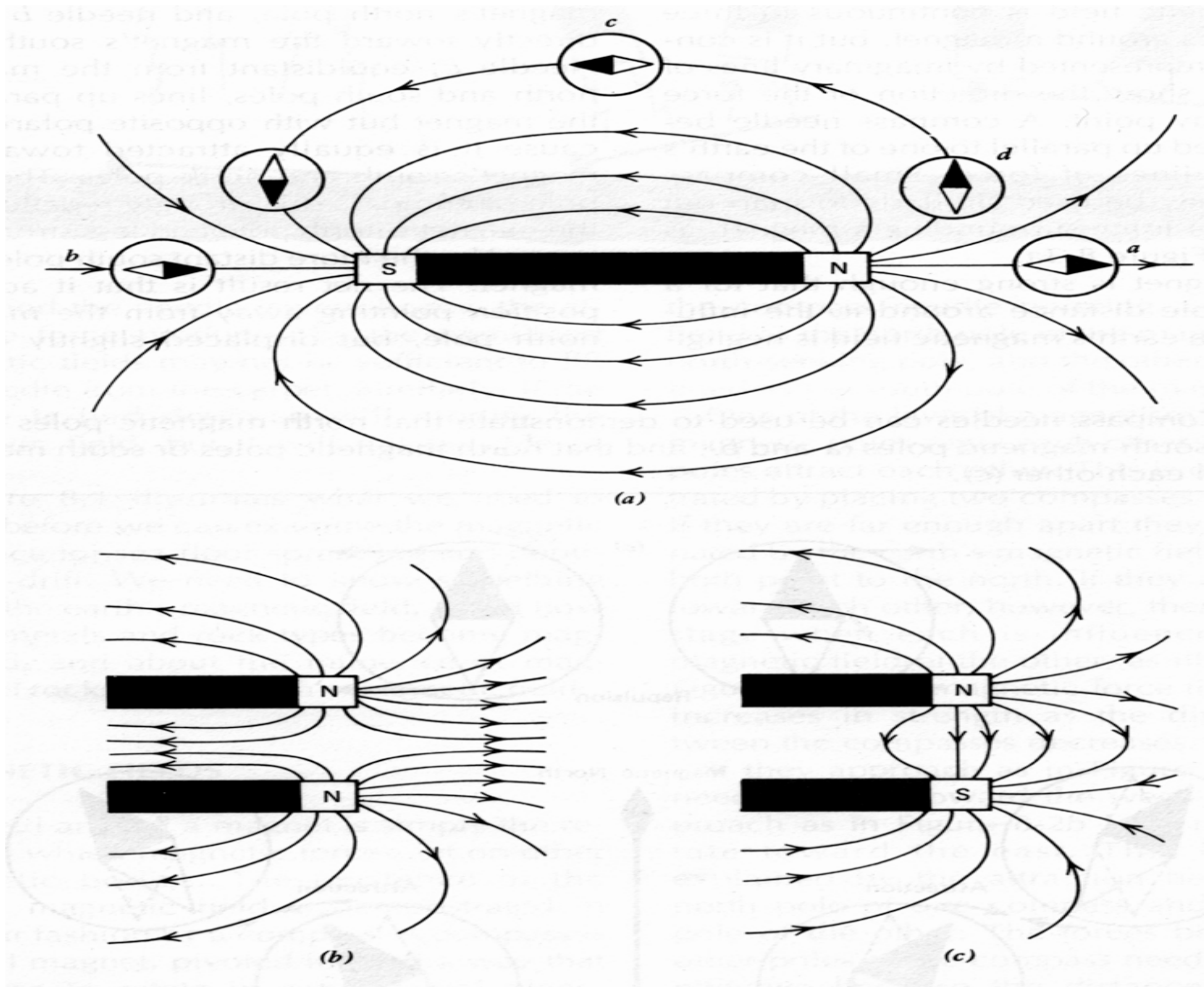
Simulated 3-D structure of Earth's magnetic field, with inward (blue) and outward (yellow) directed field lines. Field lines extend two Earth radii from the core. The location of the core-mantle boundary is evident where the structure becomes complex.

A snapshot of the simulated magnetic field structure within the core, with lines blue where outside the solid inner core and yellow where inside. The rotation axis is vertical

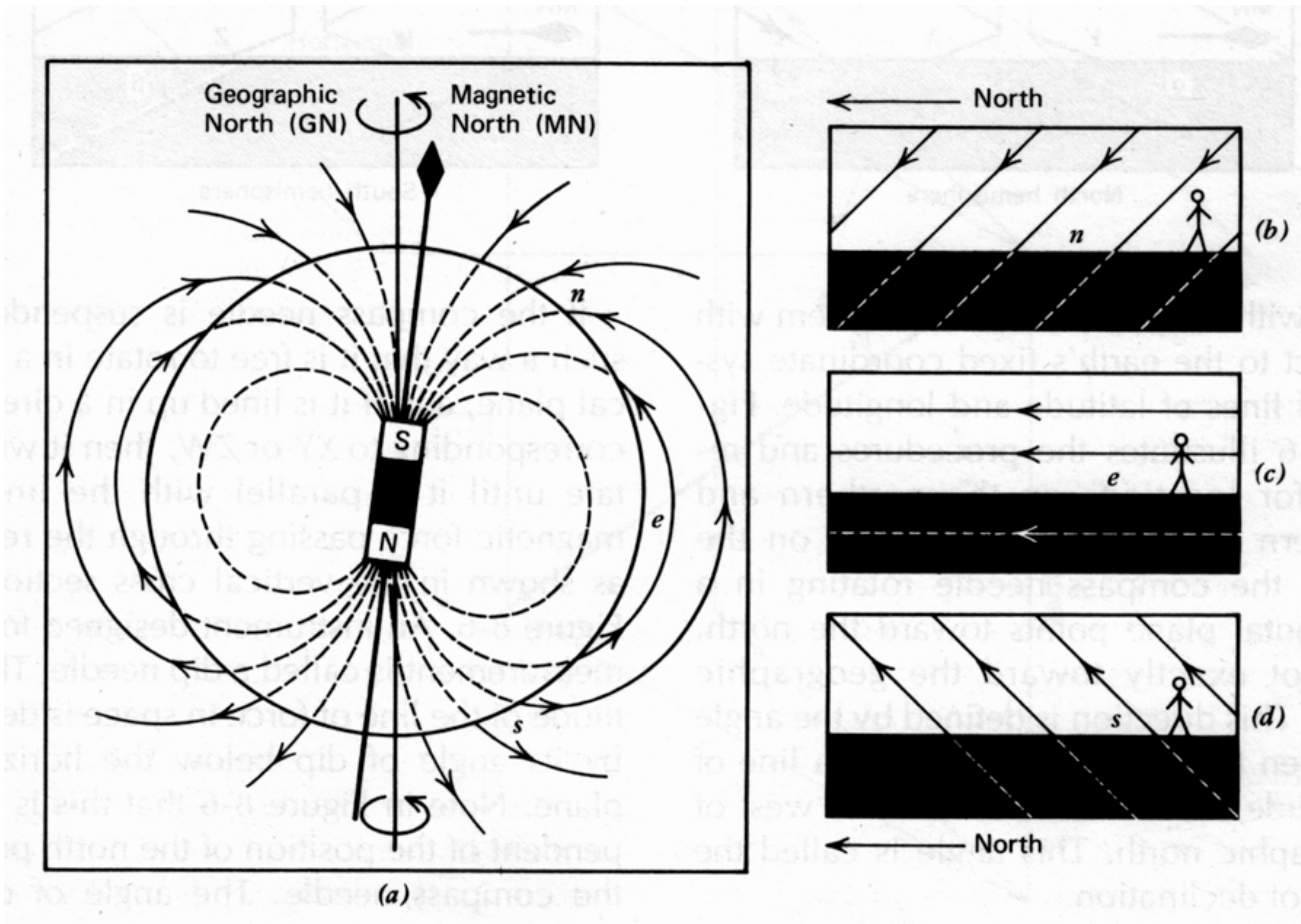




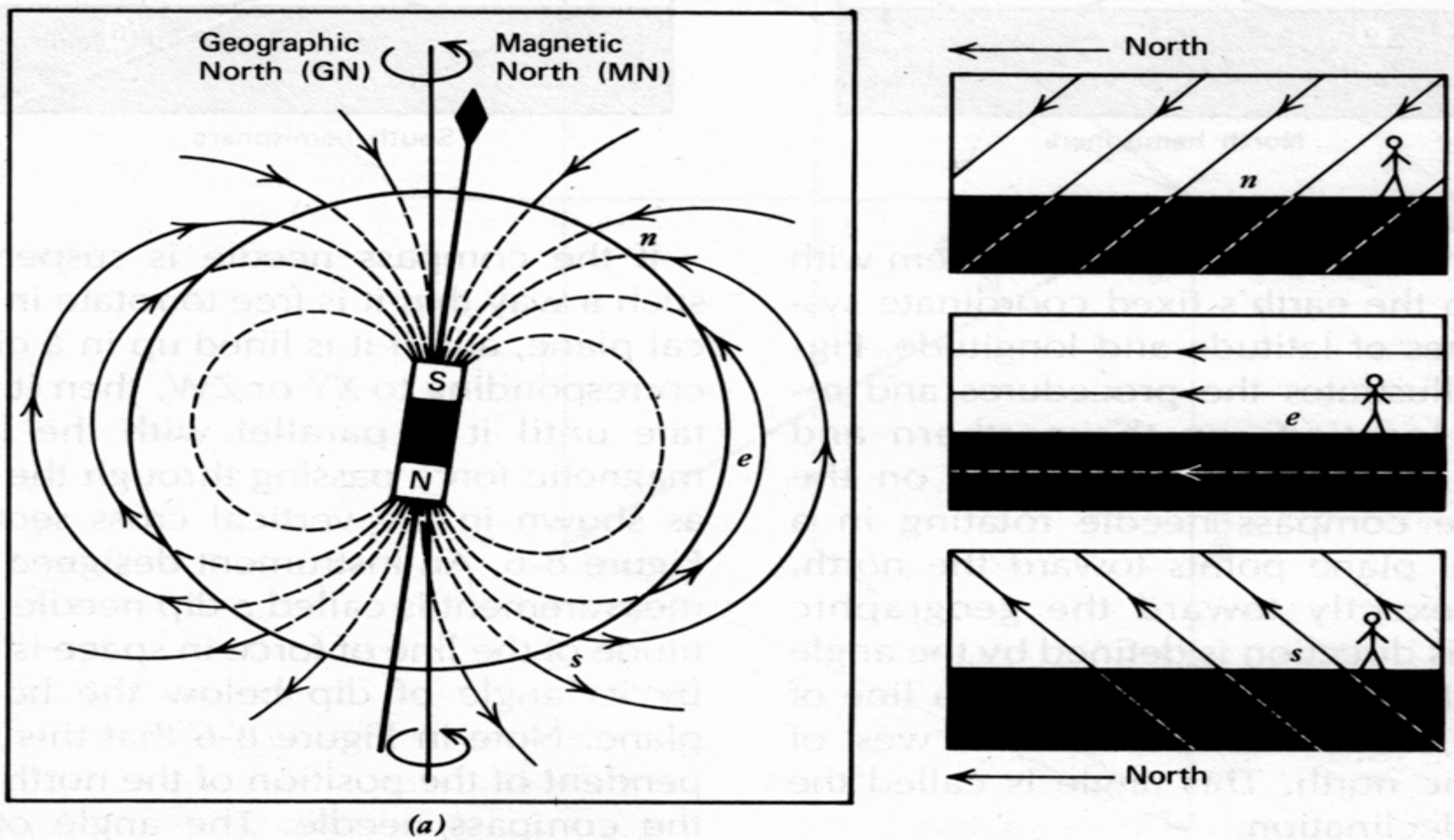
The earth’s magnetic field behaves like a dipole magnet



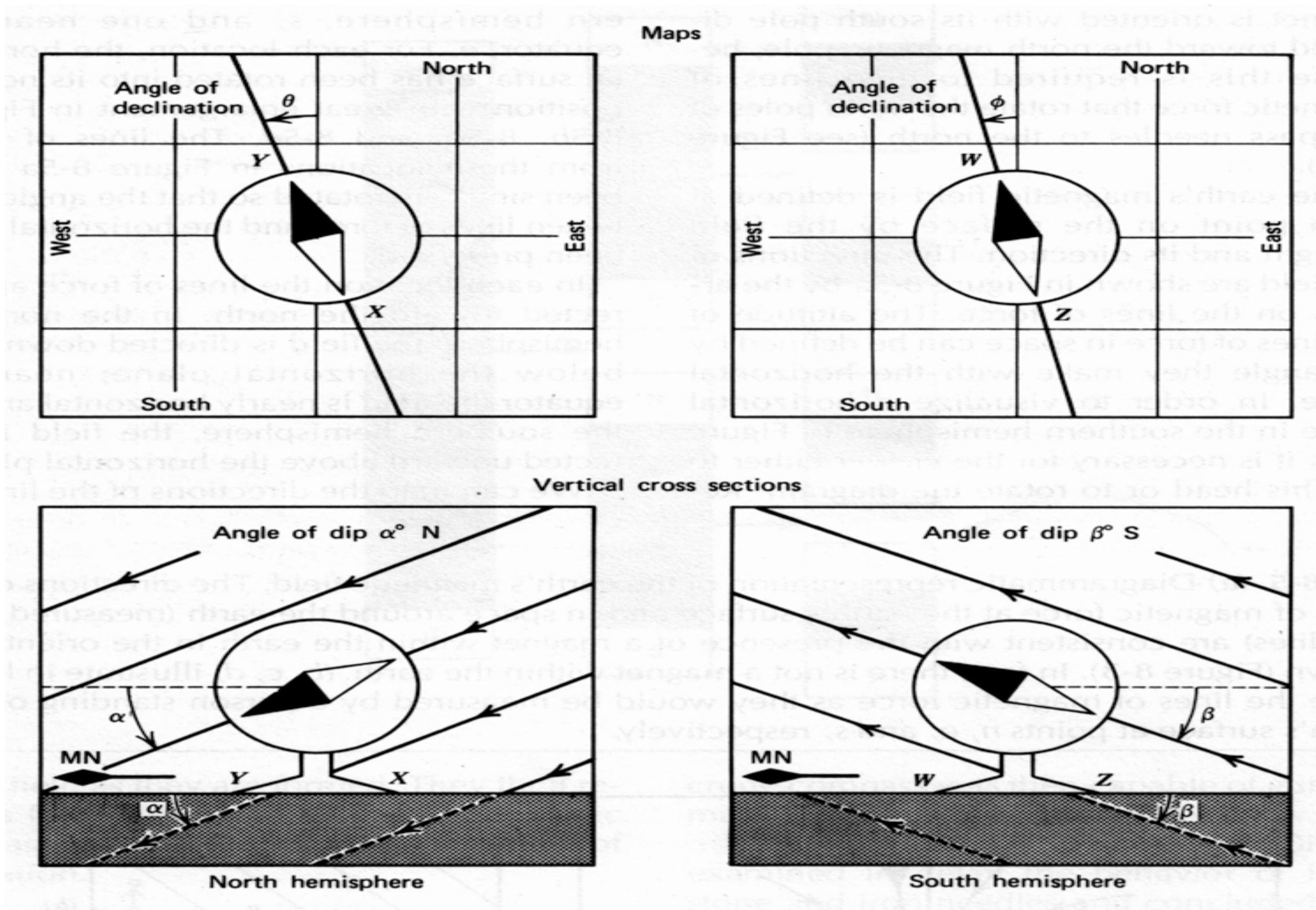
Magnetic field lines encircle the earth in 3D.
Field lines "come to closure" at the geographic north pole, which is why compasses point here. What does that say about the orientation of the earth's dipole in the core? Yes, the south end of the dipole is pointing north!



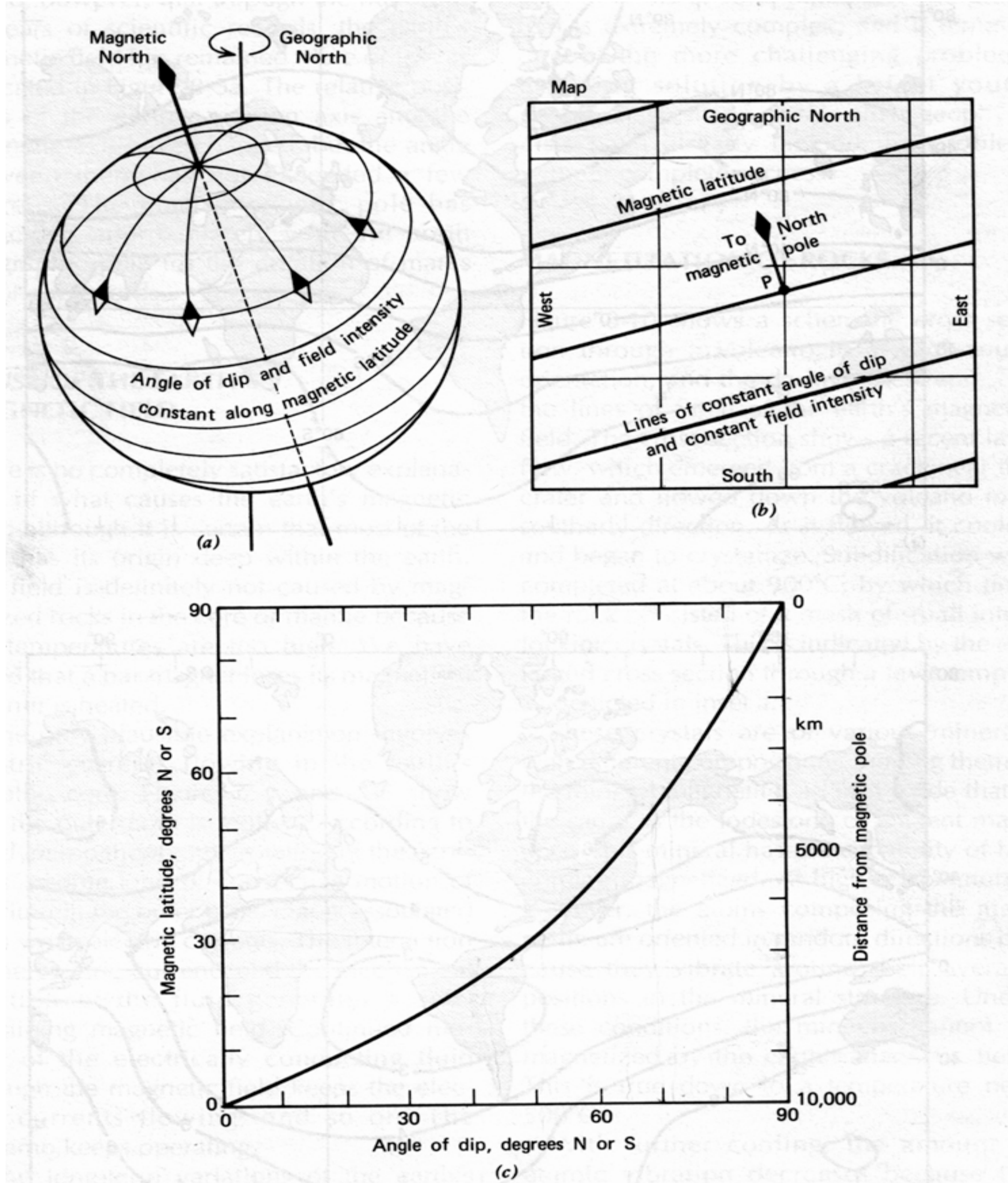
The 3D orientation of the earth’s magnetic field also means that field lines are oriented at different angles relative to the Earth’s surface; parallel at the equator, perpendicular at the poles, approx. 45 degrees at 45 degrees N or S latitude.



So a compass can rotate in two directions, towards closure at the South end of the dipole (our geographic North pole) AND vertically, parallel to the field orientation relative to the surface of the earth = **angle of inclination**

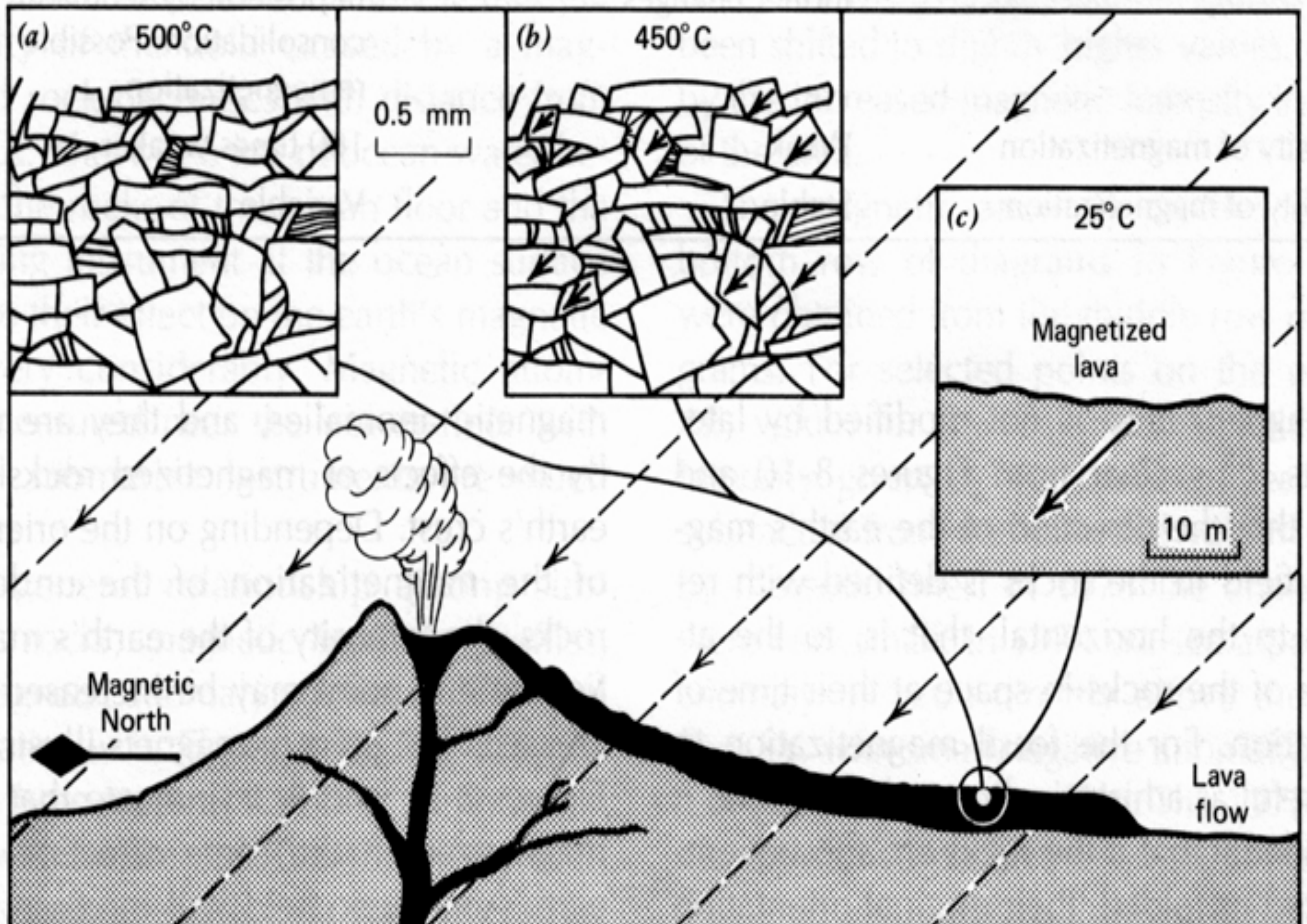


The relationship between latitude and angle of inclination:

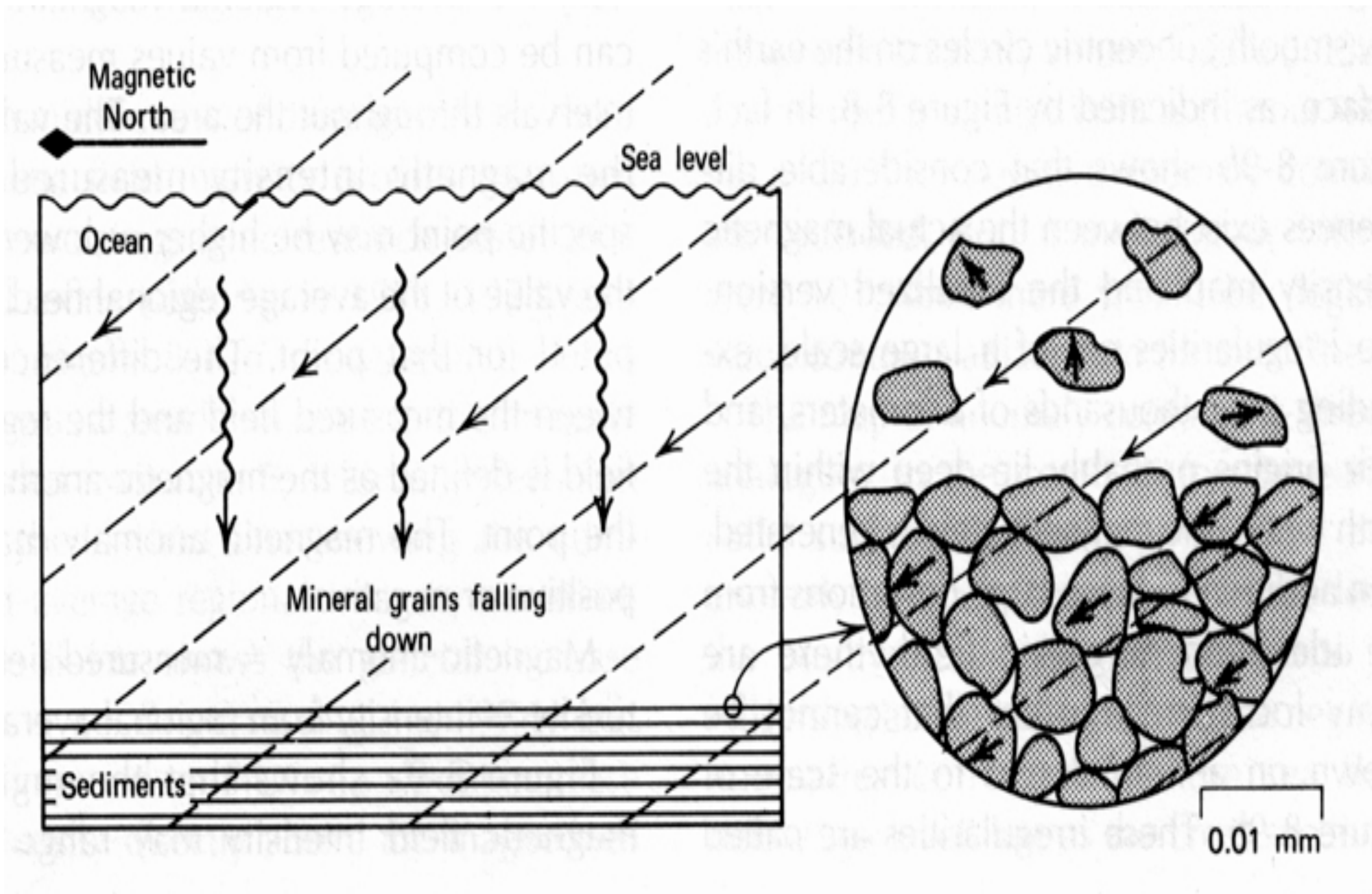


How rocks can record the earth’s magnetic field when they form. When magma cools the iron present in mafic minerals orient parallel to the field lines at that time and place

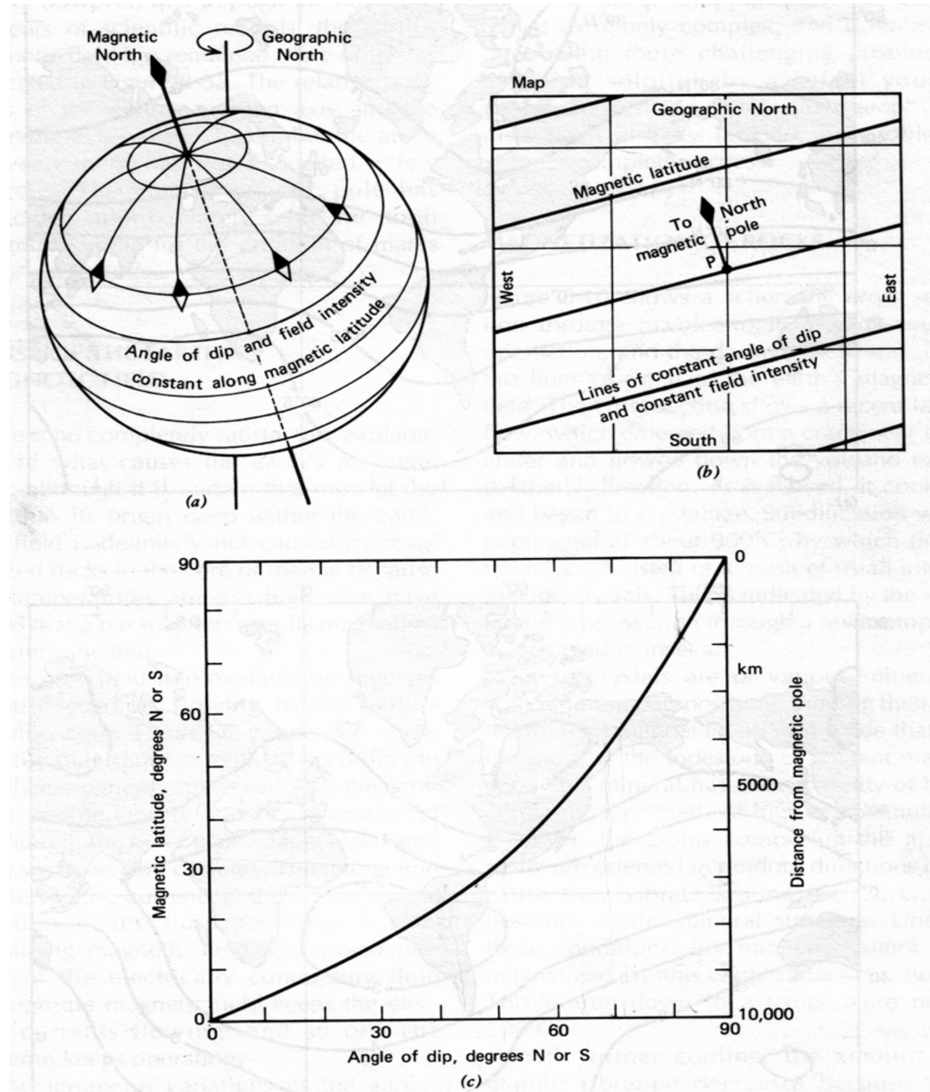
The Curie Point is the name for the temp. where the minerals “lock in” to this orientation; ~450-500º



How sedimentary rocks record the earth's magnetic field. When grains settle out of the water, if it is still/quiet water they will orient themselves parallel to the earth's magnetic field.



Because of the relationship between the angle of inclination and the latitude on the Earth's surface where an Fe-rich rock formed, we can use this information to determine the "paleo-latitude" for an iron-rich rock.



British geophysicists measured the angles of inclination of Fe-rich rocks in Great Britain that spanned a wide range of ages. What did they find?

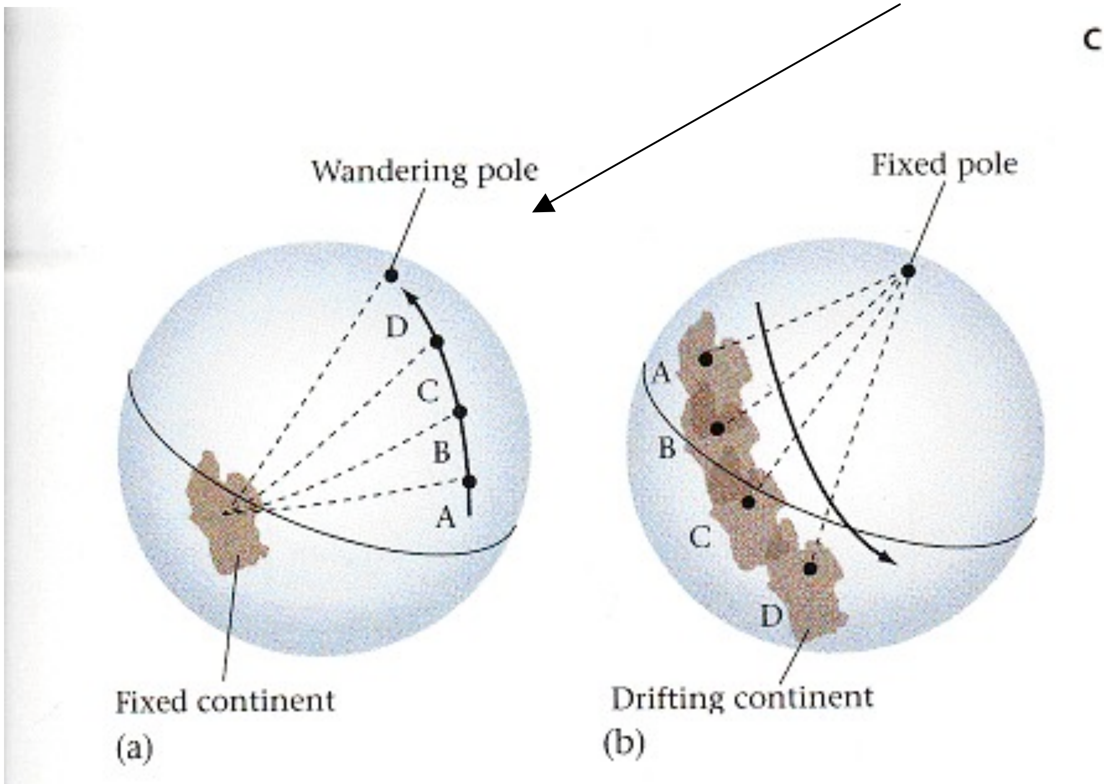
Each rock recorded a different angle of inclination!

How did they interpret this data:

they suggested that from one time period to another, the Earth's magnetic field moved. They called this phenomenon **Polar Wandering -** literally, the magnetic poles wandered around!

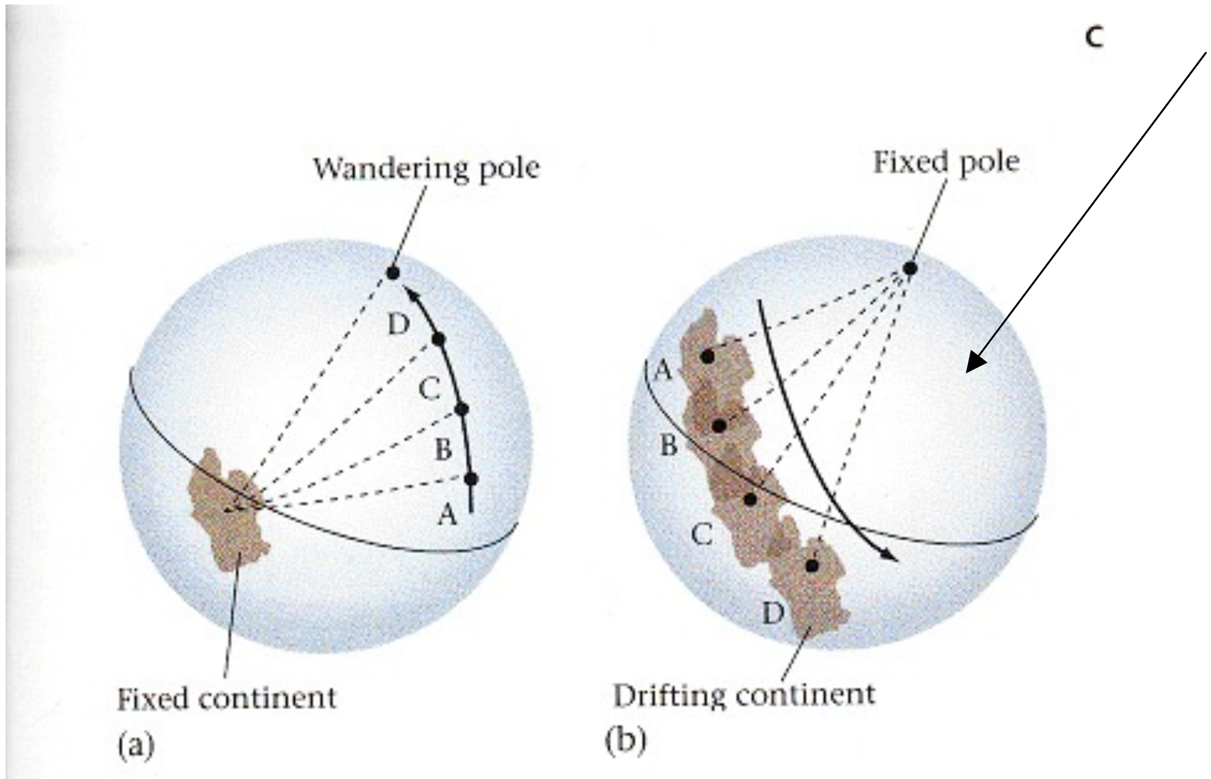
They constructed a series of **A**pparent **P**olar **W**andering (APW) curves that showed (they thought) that the poles moved around the Earth over time

An Apparent Polar Wandering (APW) curve showed how the magnetic pole moved, or wandered, over time (figure a below)



Of course, if the continents where you sampled the rocks are going to remain stationary, then the pole must be moving, or wandering

Alternatively, the pole could be stationary, and the continent moving (figure b below)



Which interpretation is correct? At the time when this research was being done, aside from Wegner's hypothesis that the continents DID drift, geologists thought that the Earth's surface was fixed in place, and apparent polar wandering was real.

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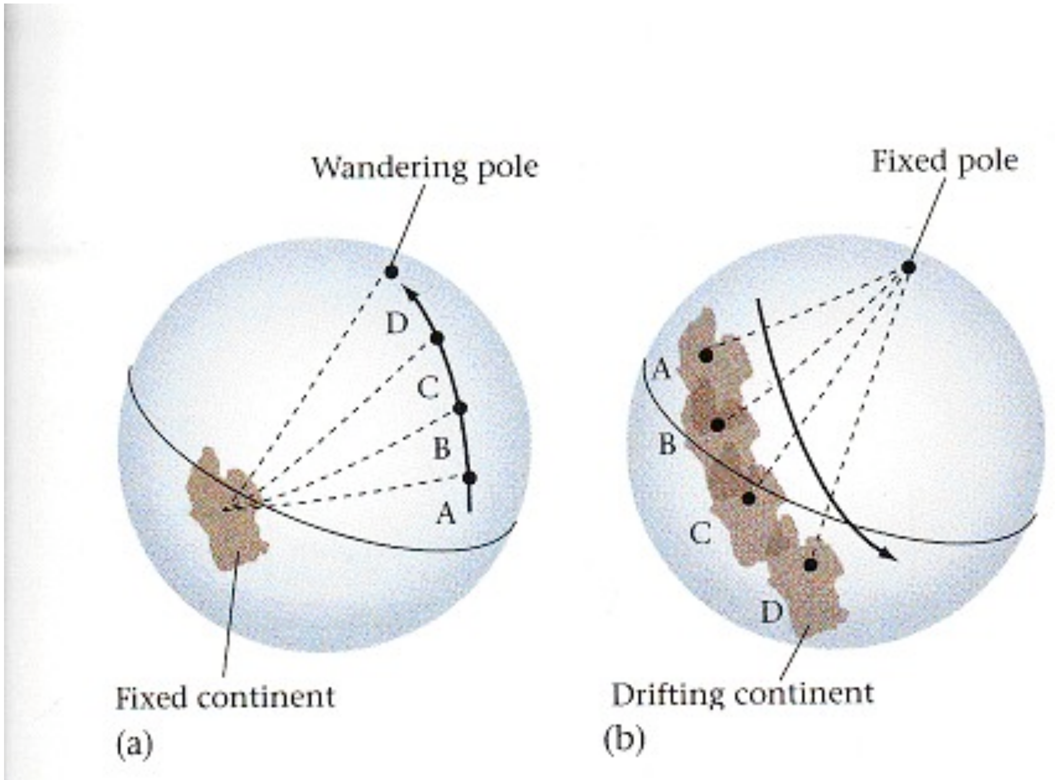
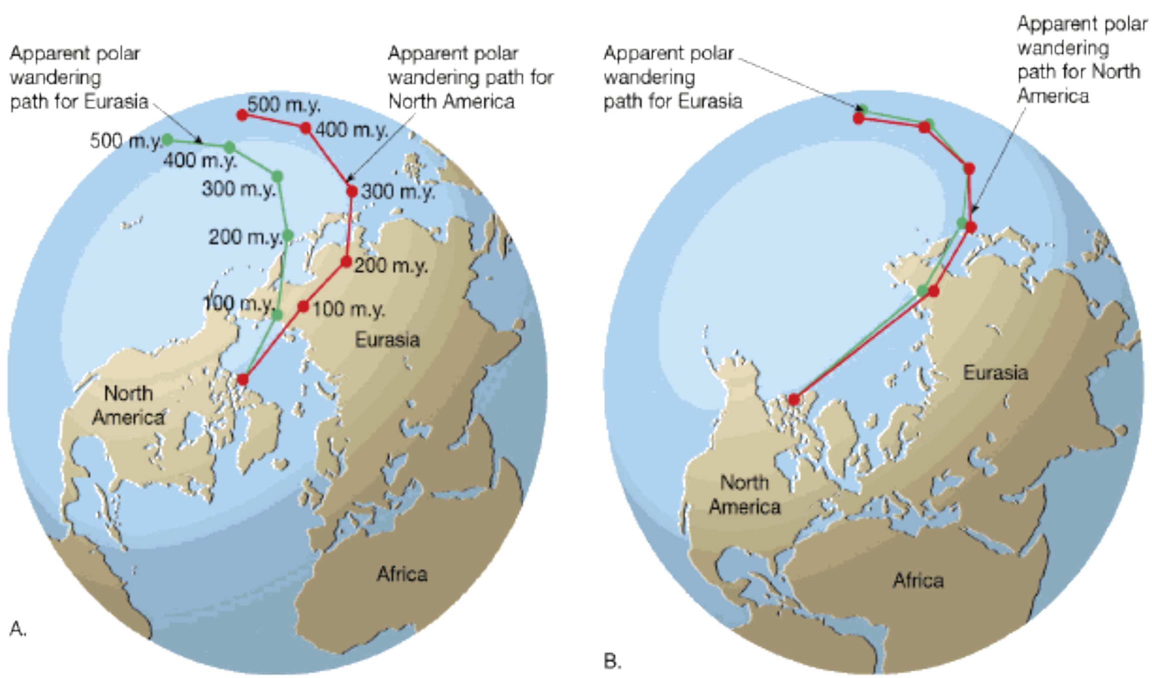


What finally convinced geologists that apparent polar wandering was NOT occurring was the observation that when you created an APW curve for a second continent, you got a different result!……

Rocks of the same age from different continents record two different magnetic poles! In green is shown data from Eurasia that indicates its APW curve, and in red is the APW curve from North America. Obviously, there is only 1 magnetic pole, so if you move the continents together, the lines tracing the location of the magnetic pole through time for these two continents coincide. Thus, it must be the continents that moved, not the poles!

Apparent polar-wandering paths for Eurasia and North America



How do we use paleomagnetism to locate a plate on the Earth's surface?

- You must know the age of the rock
- The rock must be Fe-rich, so you can determine the angle of inclination of the Earth's magnetic field at the time it formed
- You must know which plate you are on (that may seem overly obvious to you, but when bits and pieces of the Earth's surface have attached and detached from various plates, it's not always that straightforward!

Paleomagnetism helps with latitude only, not longitude

- Two plates can be at the same latitude, but be very far apart, or close together. How do we determine which?

(a) How similar are there geologic histories. For example, if in several million years they share an orogeny, or mountain-building event, then they must have been relatively close together

(b) Do they share similar marine animals? The ocean between them must have been relatively narrow; if they share terrestrial animals, then they were very close together!