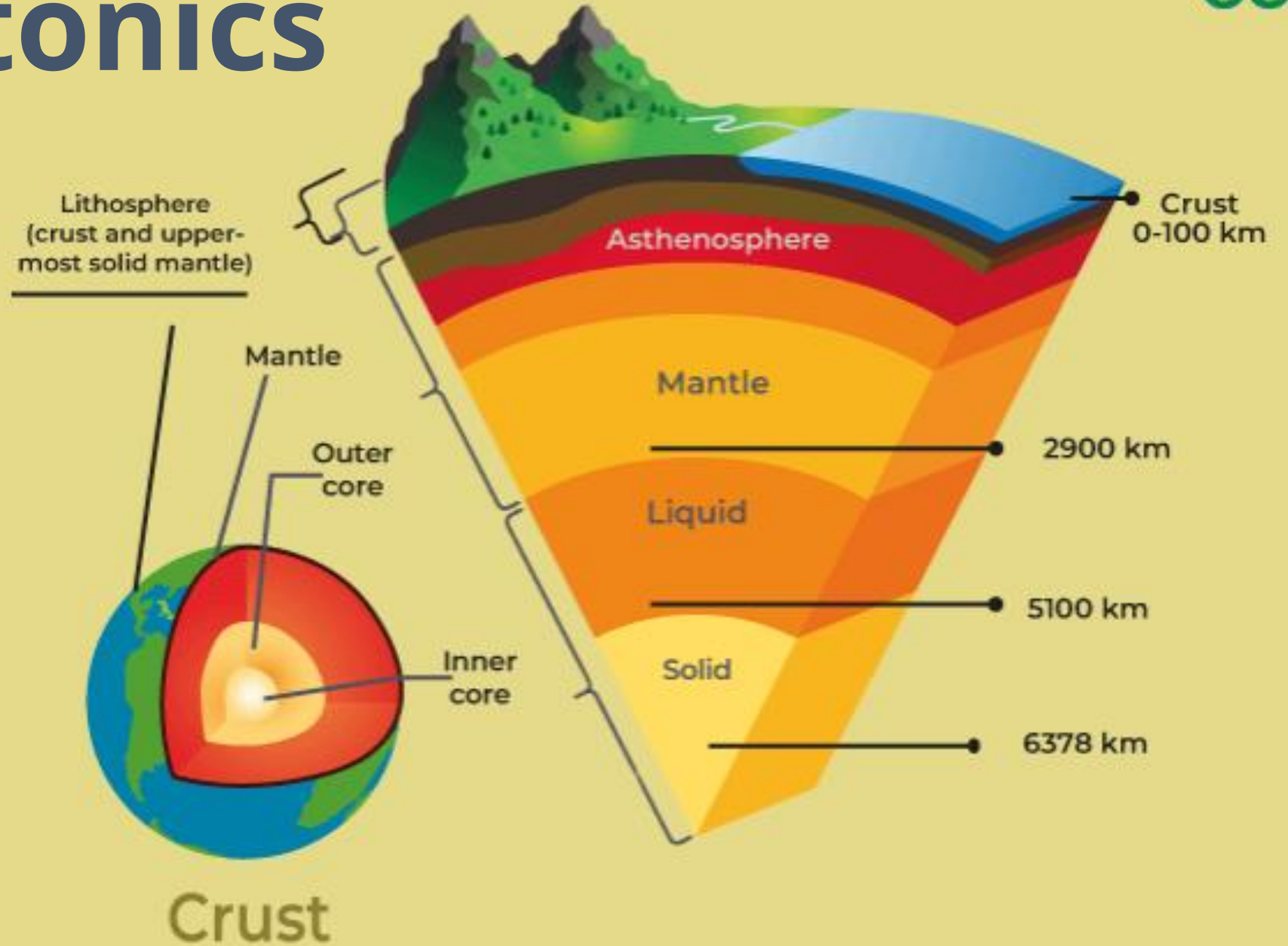




Plate Tectonics

Elizabeth M. Dowding
System Erde III
May, 2024





Elizabeth M. Dowding

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- Palaeobiogeography
- Spatial patterns of diversity
- Bioregionalisation
- Palaeogeography



Contents

1. Introduction to learning outcomes
2. History of the theory
3. Evidence for Plate Tectonics

Introduction to learning outcomes

- Session 1
 - Introduction to theory
- Session 2
 - Introduction to using GPlates
 - Practical guide to picking a plate reconstruction
- Session 3
 - Using a plate reconstruction
- Assignment
 - Group task

Schedule

Date	Length	Topic
May 8 Wednesday	(1h)	Introduction/Starting with GPlates
May 15 Wednesday	(1h)	GPlates: rotations
May 16 Thursday	(2h)	Raster data and single points

Technical Requirements

- You will need a computer with Win, Mac or GNU/Linux
 - IPAD, Chromebooks will not work.
- We will install GPlates together



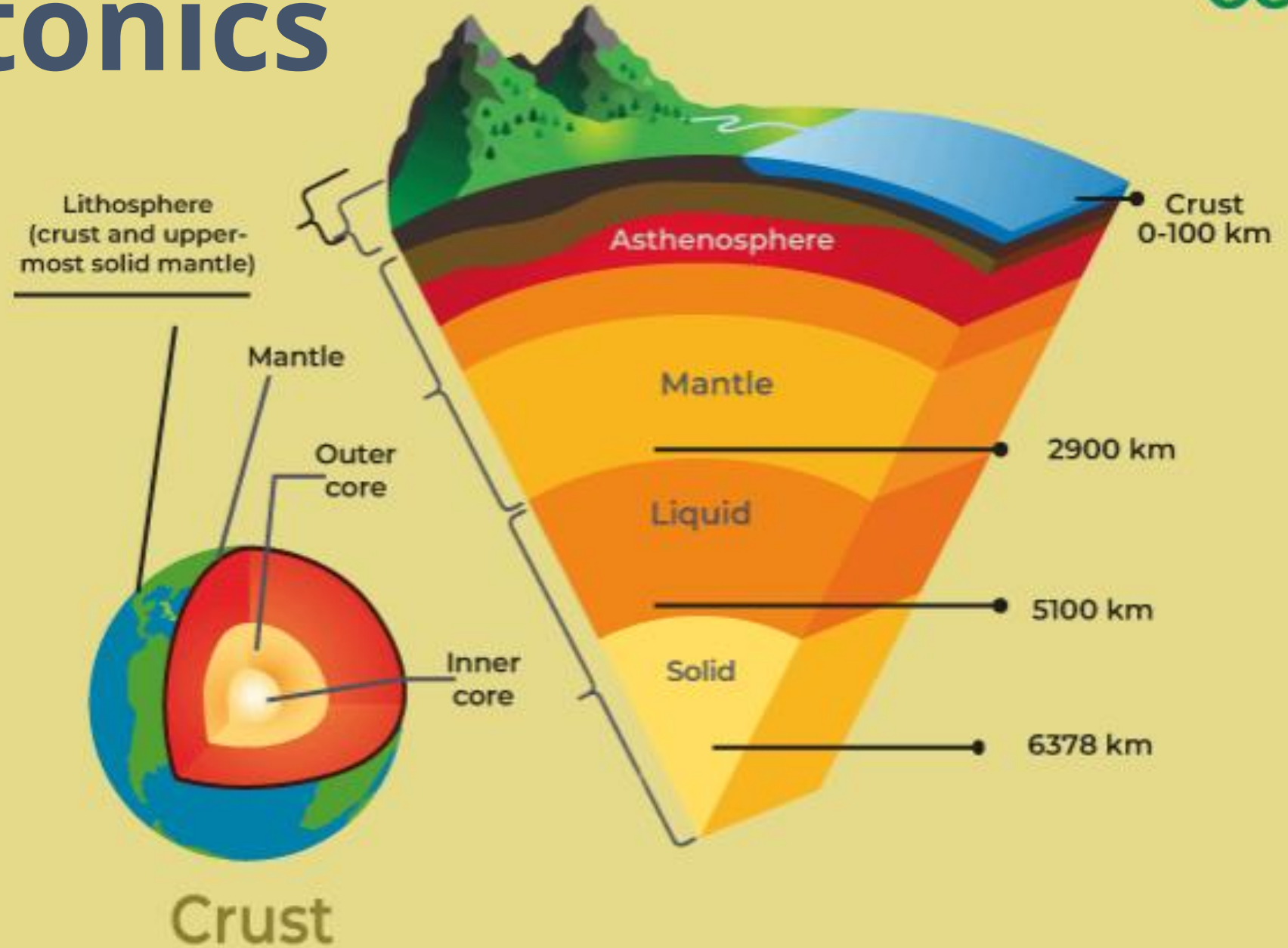
Assignment

Due 19 July

- Practical exercise with GPlates
- Short report (max. 3 A4 pages)
- Assignment can be written in German
- Due at the end of the lecture period (July 19) - necessary to pass the course



Plate Tectonics



Section 2: History of the theory

- What are the different theories about Earth History?
 - What is the evidence?
 - What do we use it for?
-
- 5 Mins.



Different theories about Earth History?

- Static Earth
- Land Bridge
- Expanding Earth
- **Continental Drift**
- Convection Current
- **Sea Floor Spreading**
- Polar Wander
- **Plate Tectonics**

- 1. Continental Drift**
- 2. Sea Floor Spreading**
- 3. Plate Tectonics**

Static earth? Geometric Fit!

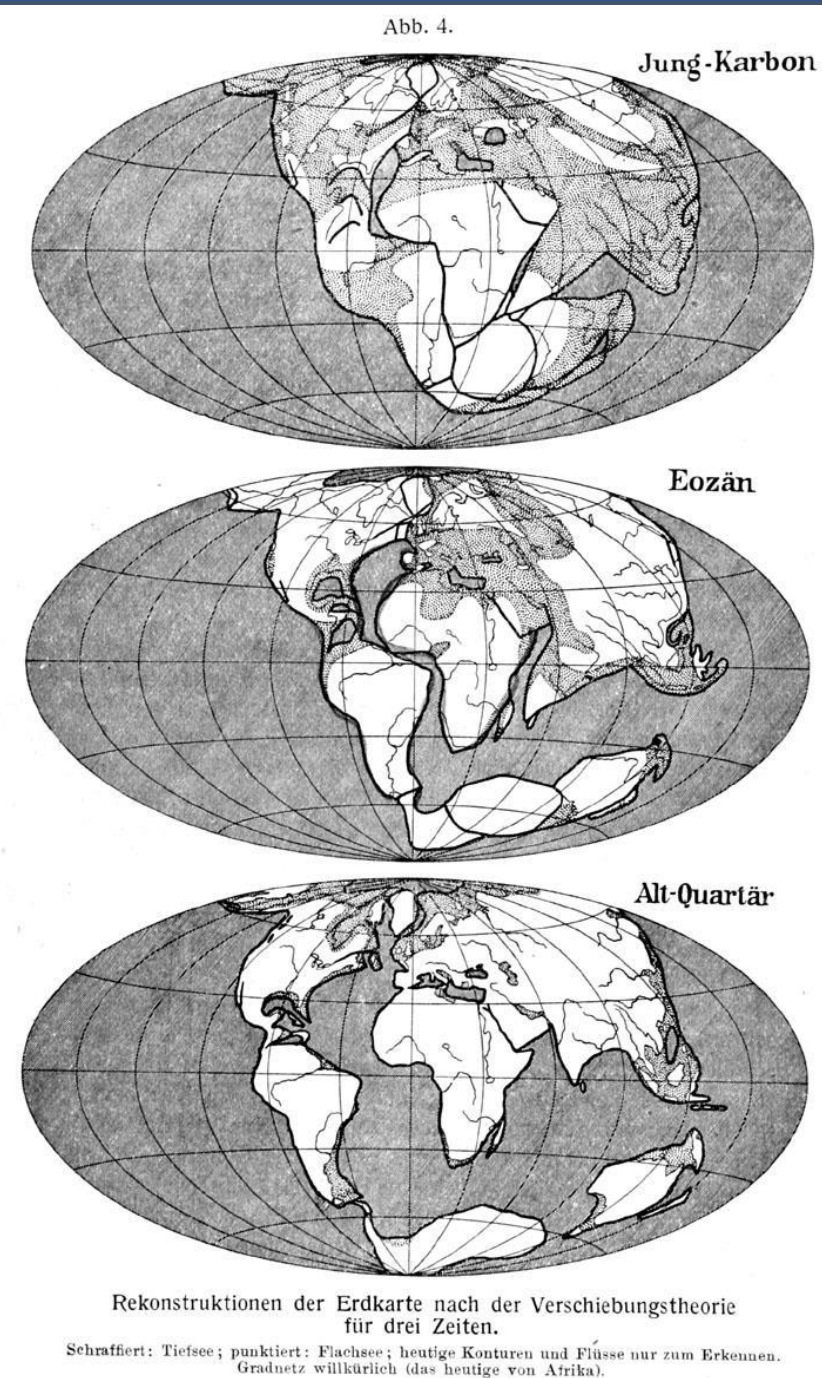
The continent outlines seem to match

- Jigsaw puzzle
- (Ortelius 1596): *Thesaurus Geographicus*
- Lilienthal, Humboldt, Snider-Pellegrinii, Kious etc.
- (Snider-Pellegrini 1858)



Alfred Wegener (1880-1930)

- 1912, Pangea
- *Die Entstehung der Kontinente* (Wegener 1912)
- Not fully accepted until 1970s



Why?

What do you need to know or assume before you develop continental drift theory (CDT)?

1. A good understanding of rock time
2. Good taxonomy
3. Good chronostratigraphy
4. Global scope (NO INTERNET! Invented in 1983)
5. **Something is making and letting the rocks move**

Other explanations?

- Expanding earth



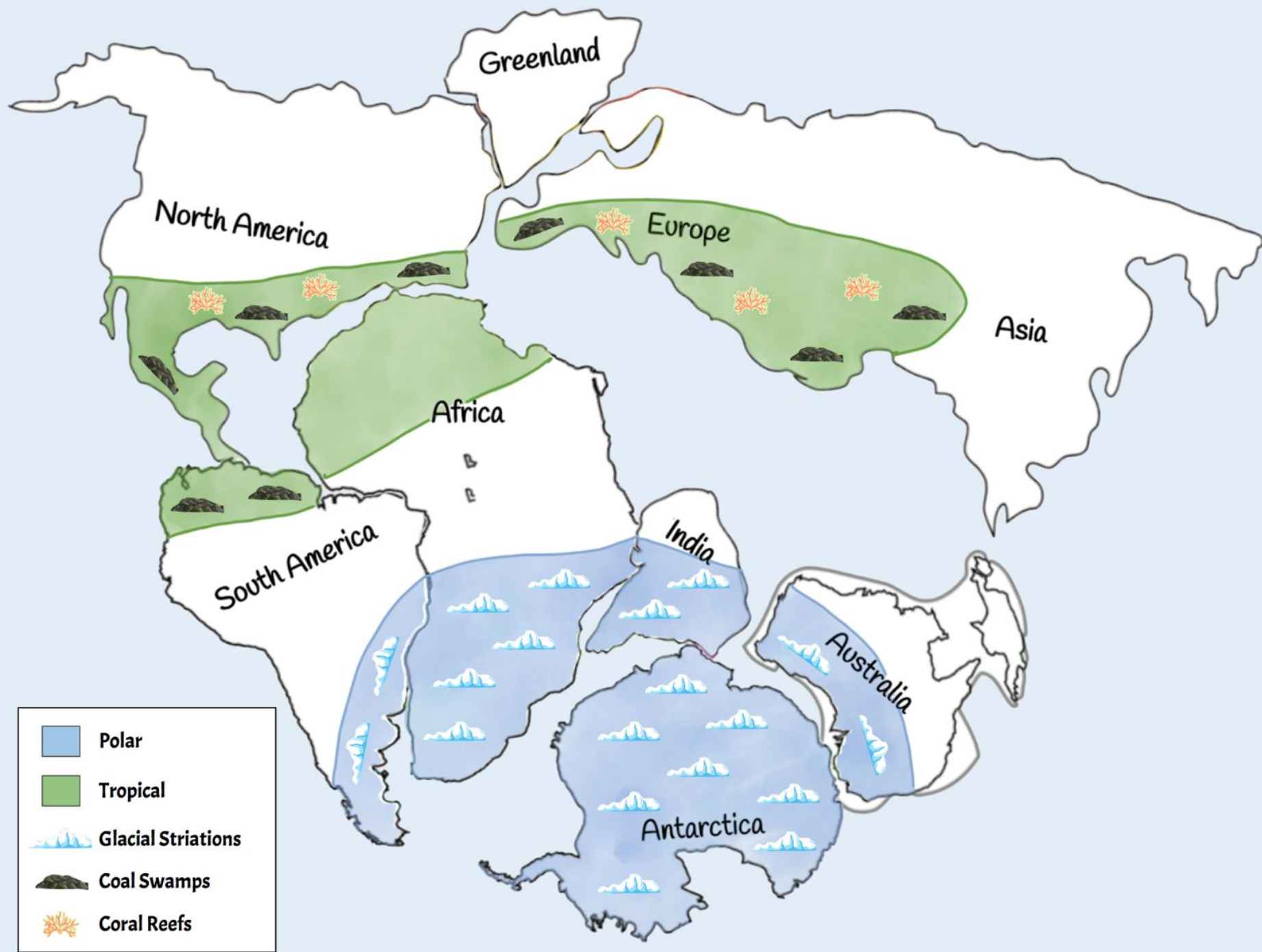
Other explanations?

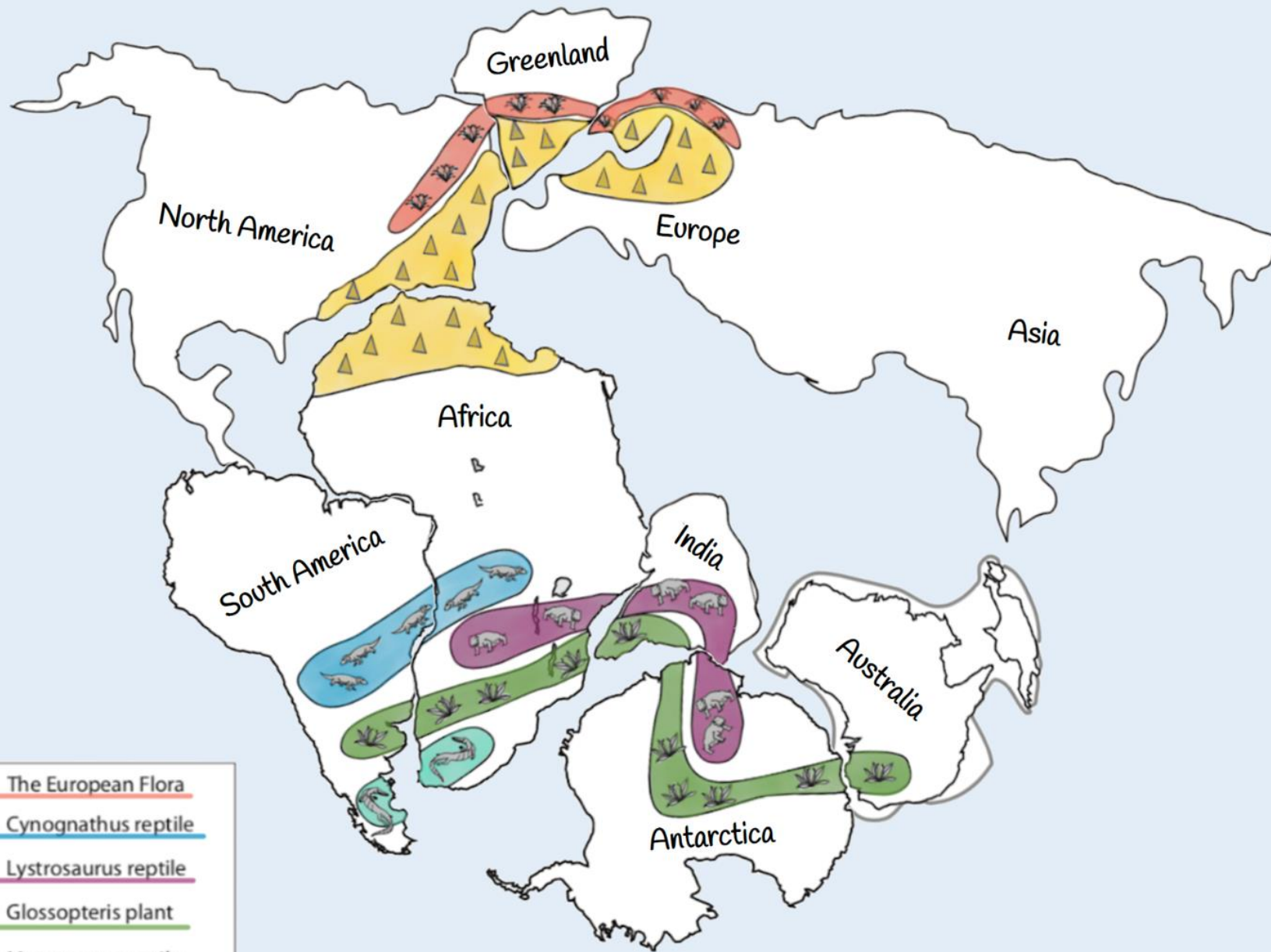
- Landbridges?



Continental Drift: What does it offer?







Greenland

North America

Europe

Asia







Africa

South America

India

Australia

Antarctica

-  The European Flora
-  Cynognathus reptile
-  Lystrosaurus reptile
-  Glossopteris plant
-  Mesosaurus reptile
-  Alpine Mountains

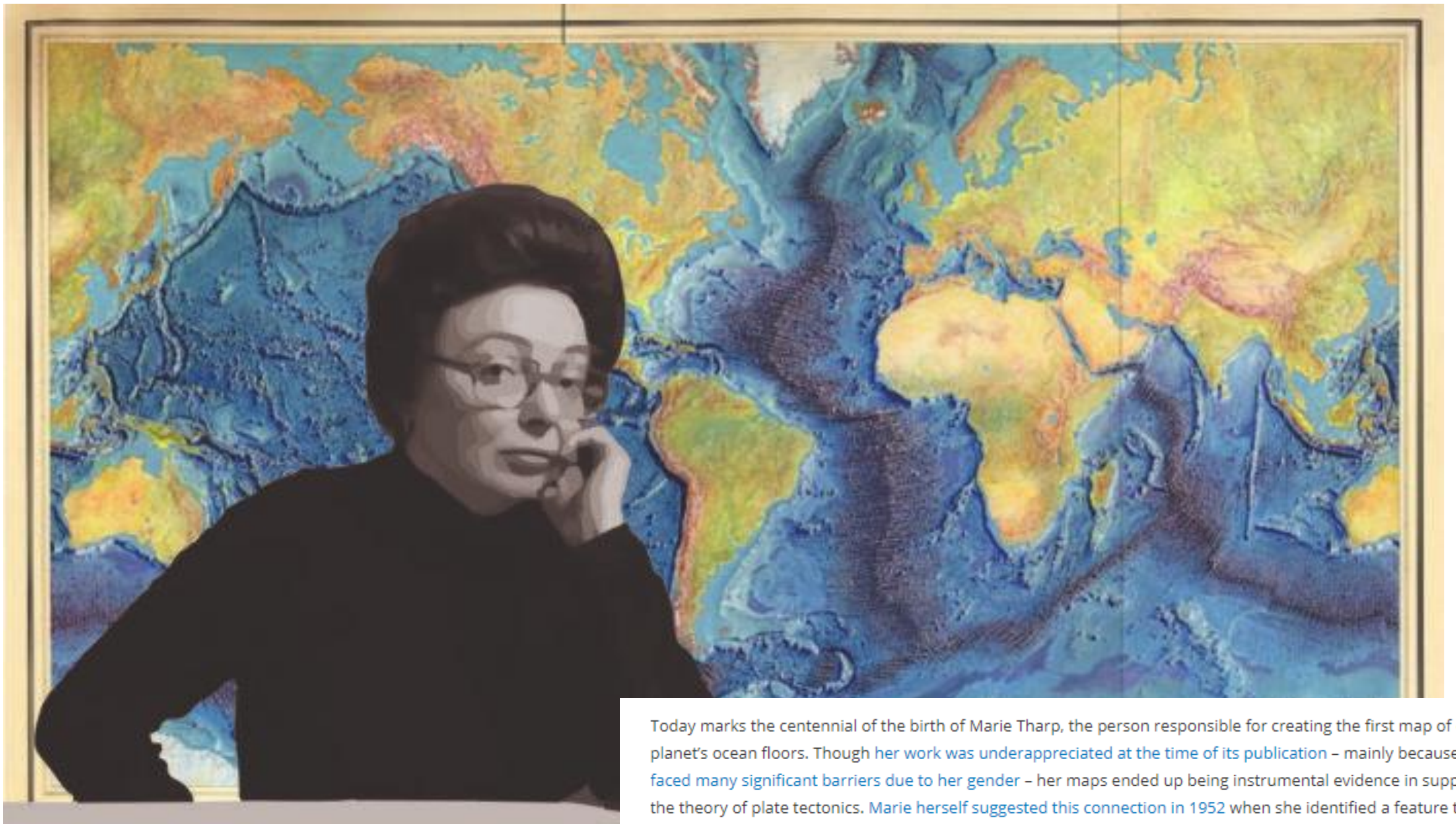
CDT: What does it NOT offer?



Mechanism!







Today marks the centennial of the birth of Marie Tharp, the person responsible for creating the first map of our planet's ocean floors. Though her work was underappreciated at the time of its publication – mainly because she faced many significant barriers due to her gender – her maps ended up being instrumental evidence in support of the theory of plate tectonics. Marie herself suggested this connection in 1952 when she identified a feature that split the Atlantic as a rift valley, but even her research partner Bruce Heezen dismissed her idea as 'girl-talk'.

Sea Floor Spreading : Harry Hess, 1960

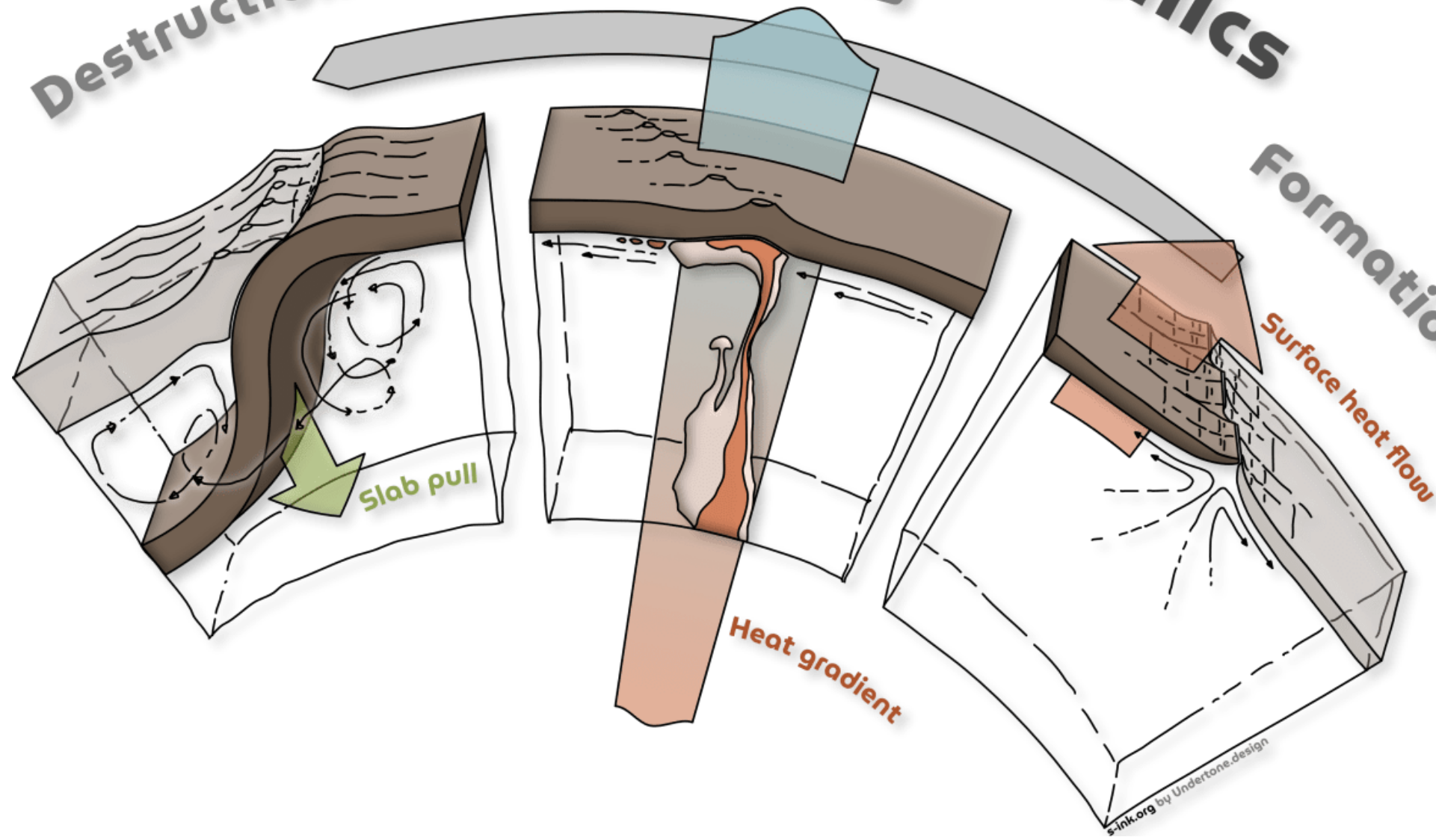
Seafloor spreading occurs at divergent plate boundaries. As tectonic plates slowly move away from each other, heat from the mantle's convection currents makes the crust more plastic and less dense. The less-dense material rises, often forming a mountain or elevated area of the seafloor.

Ocean-plate tectonics

Destruction

Cooling

Formation



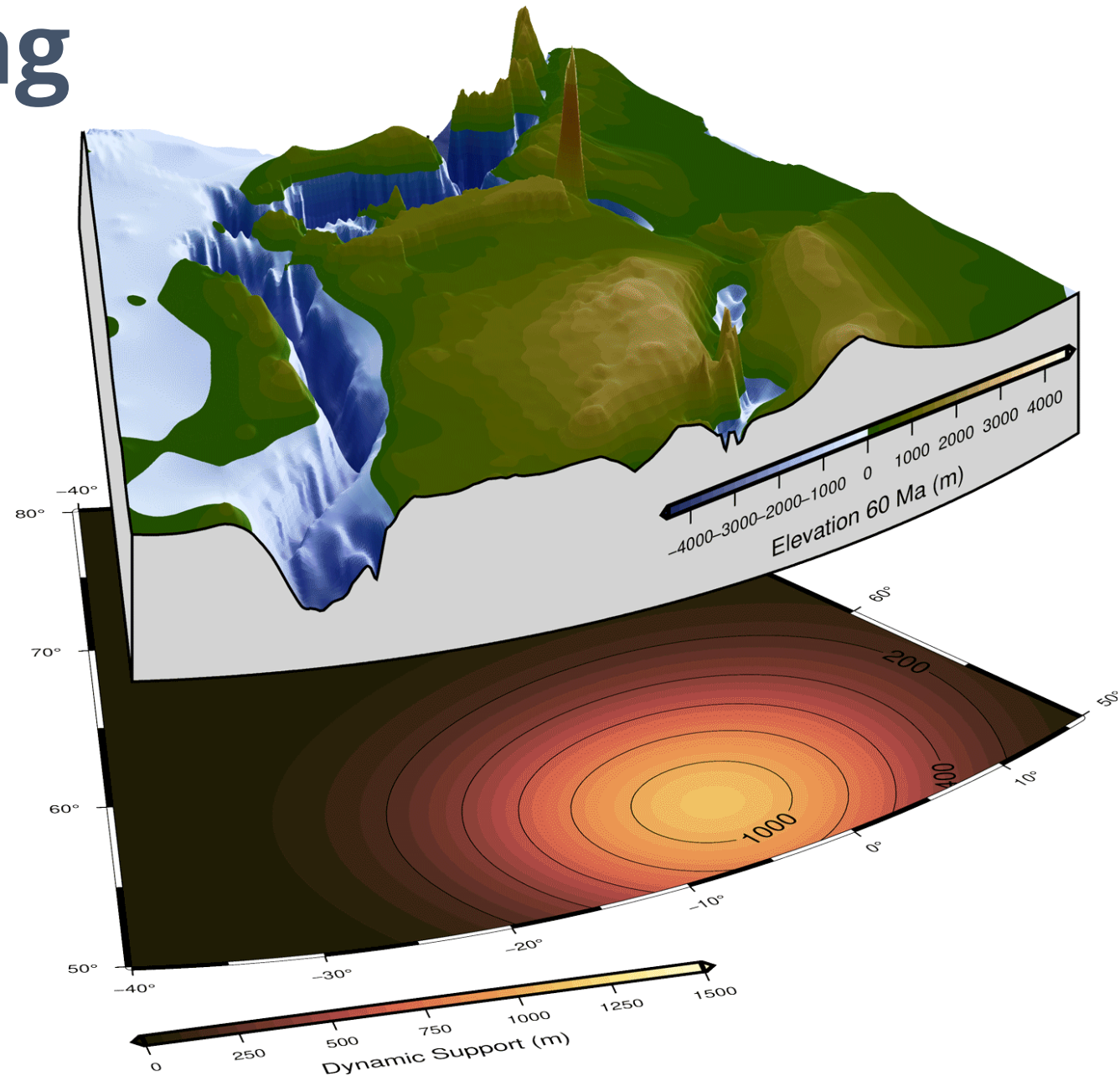
Slab pull

Heat gradient

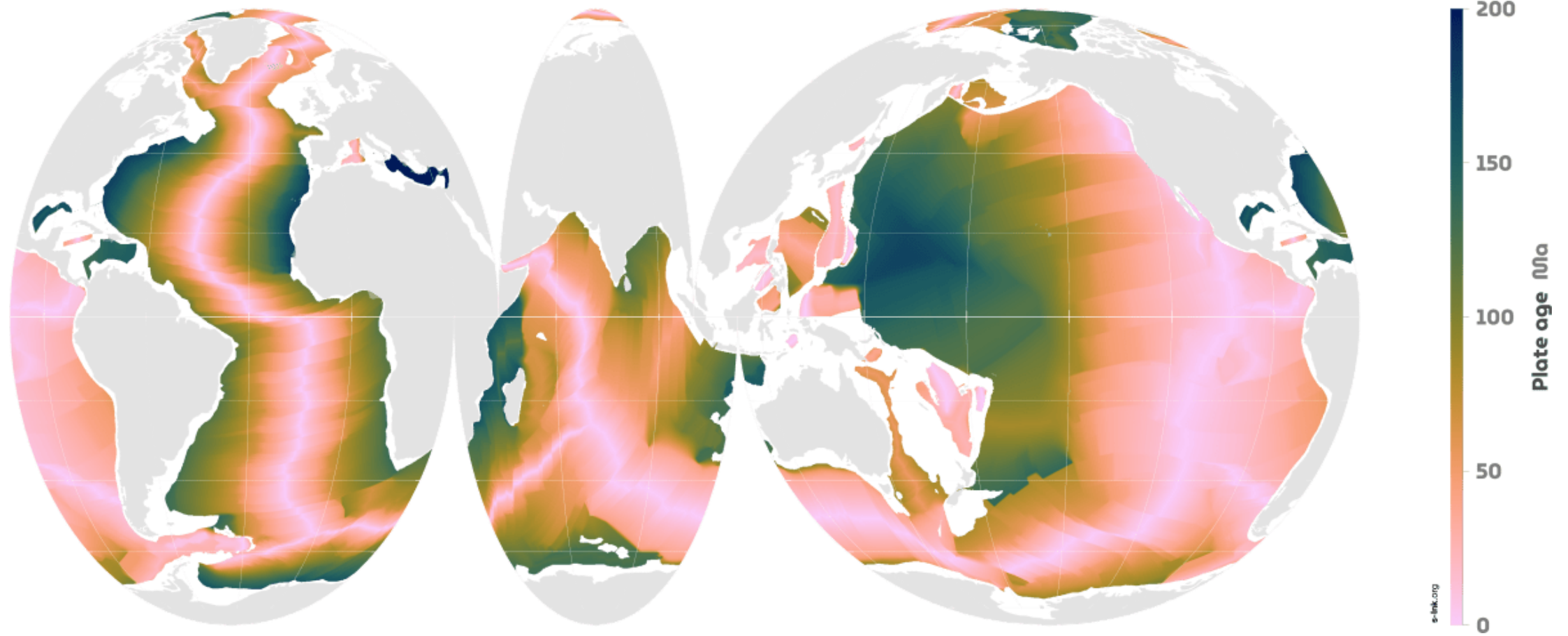
Surface heat flow

Sea Floor Spreading

North East Atlantic Ocean Evolution

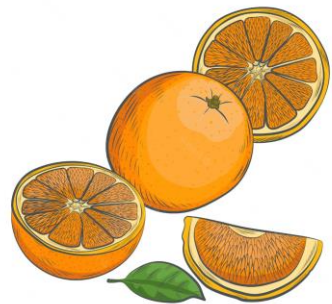


Ocean-plate age





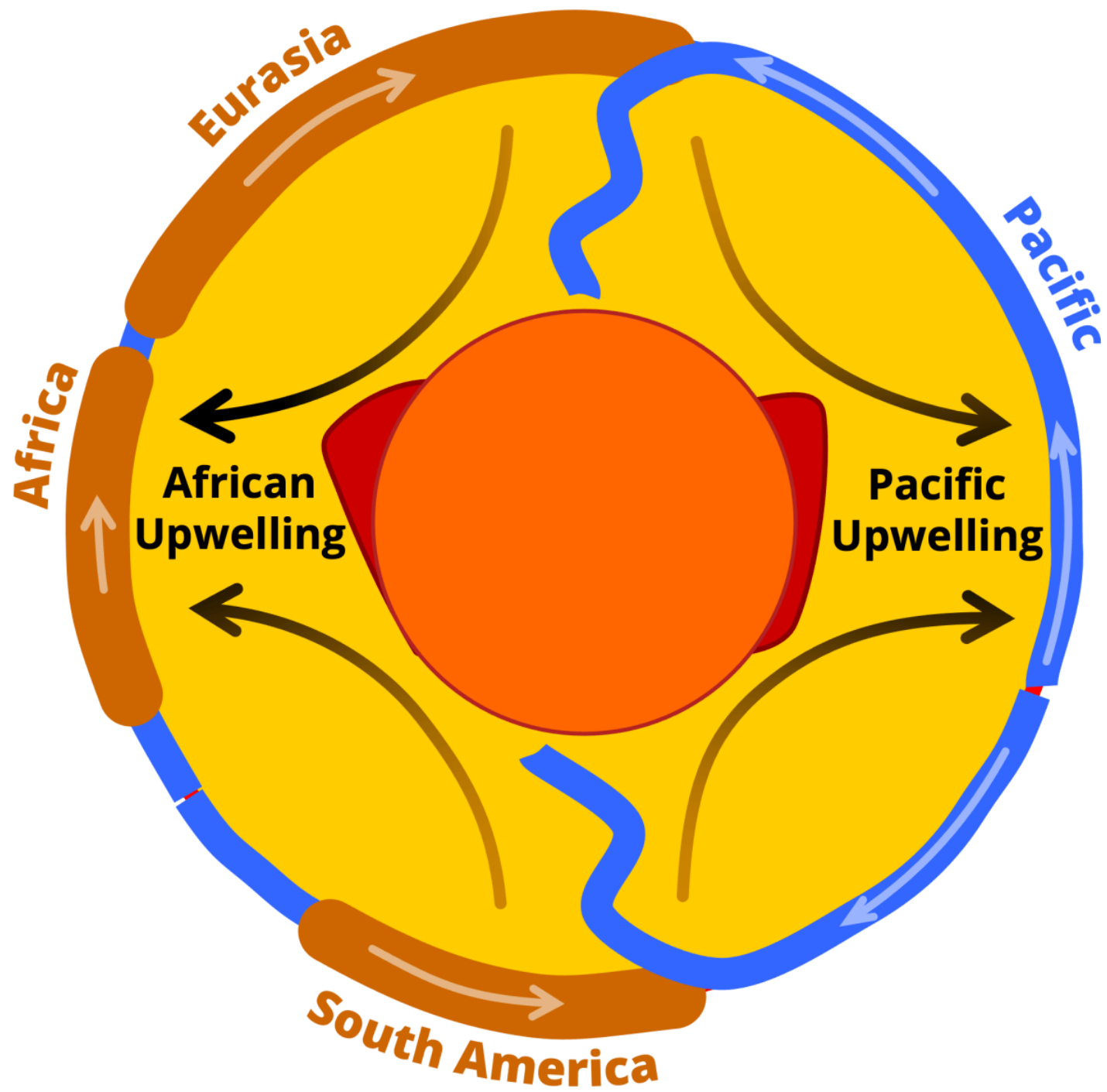
ORANGE PEEL PLATE TECTONICS



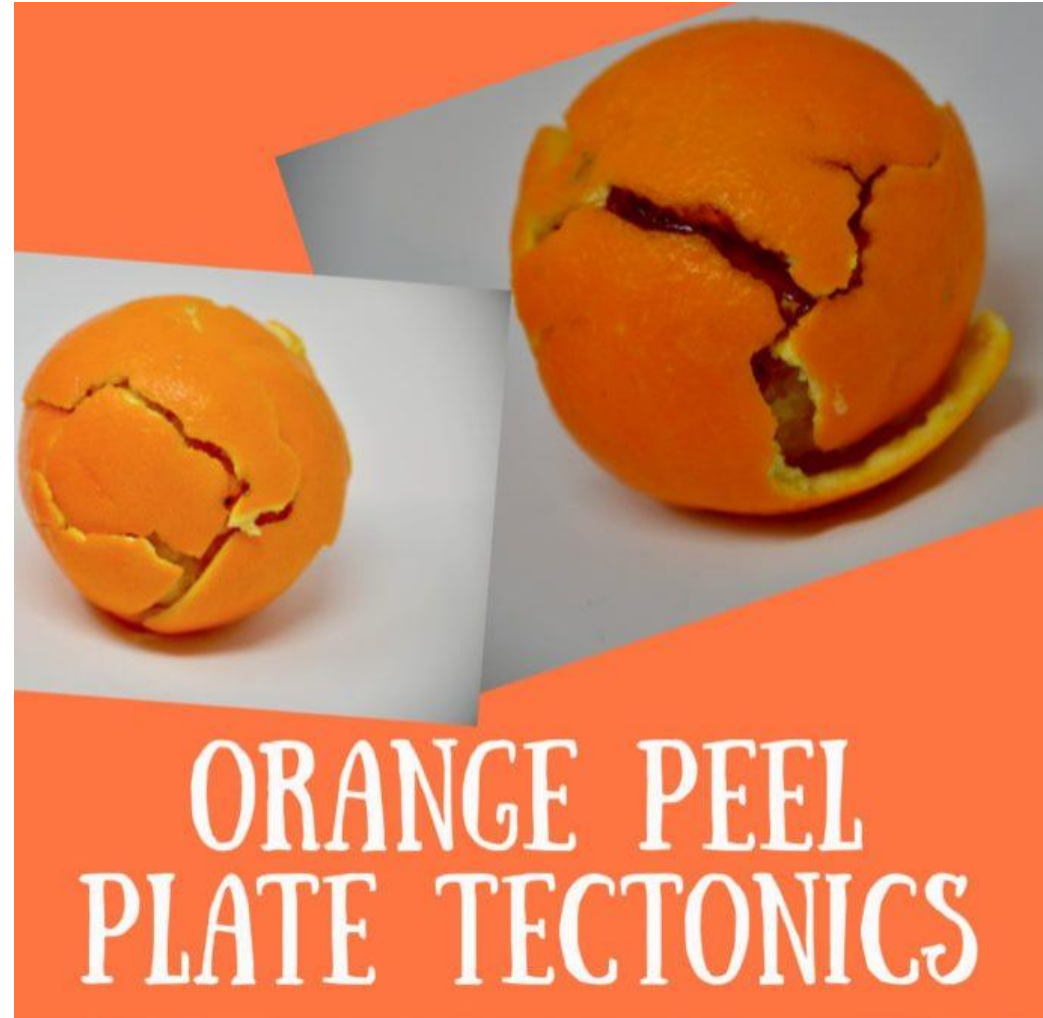
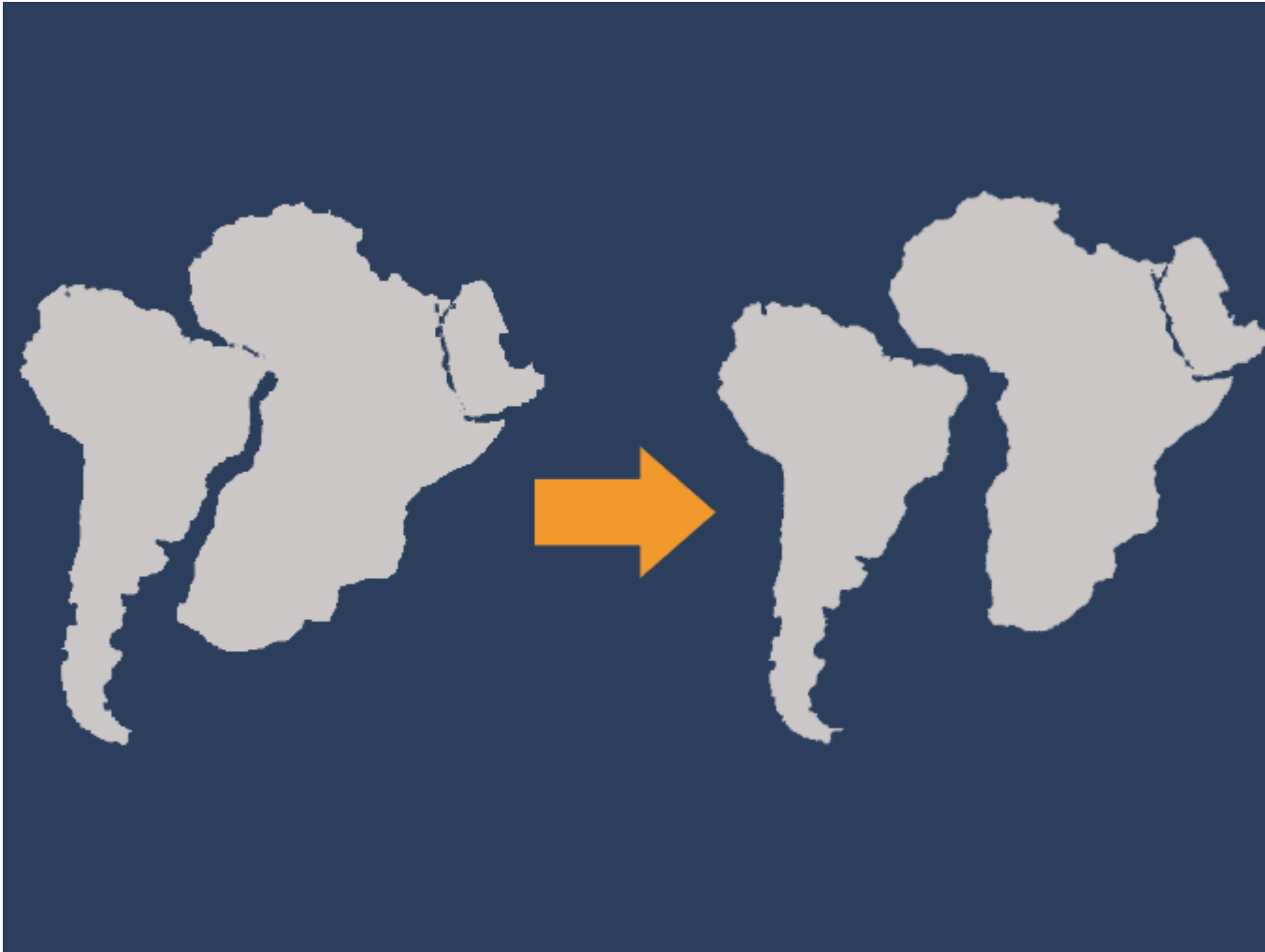
The Wilson Cycle

How to make and unmake Pangea



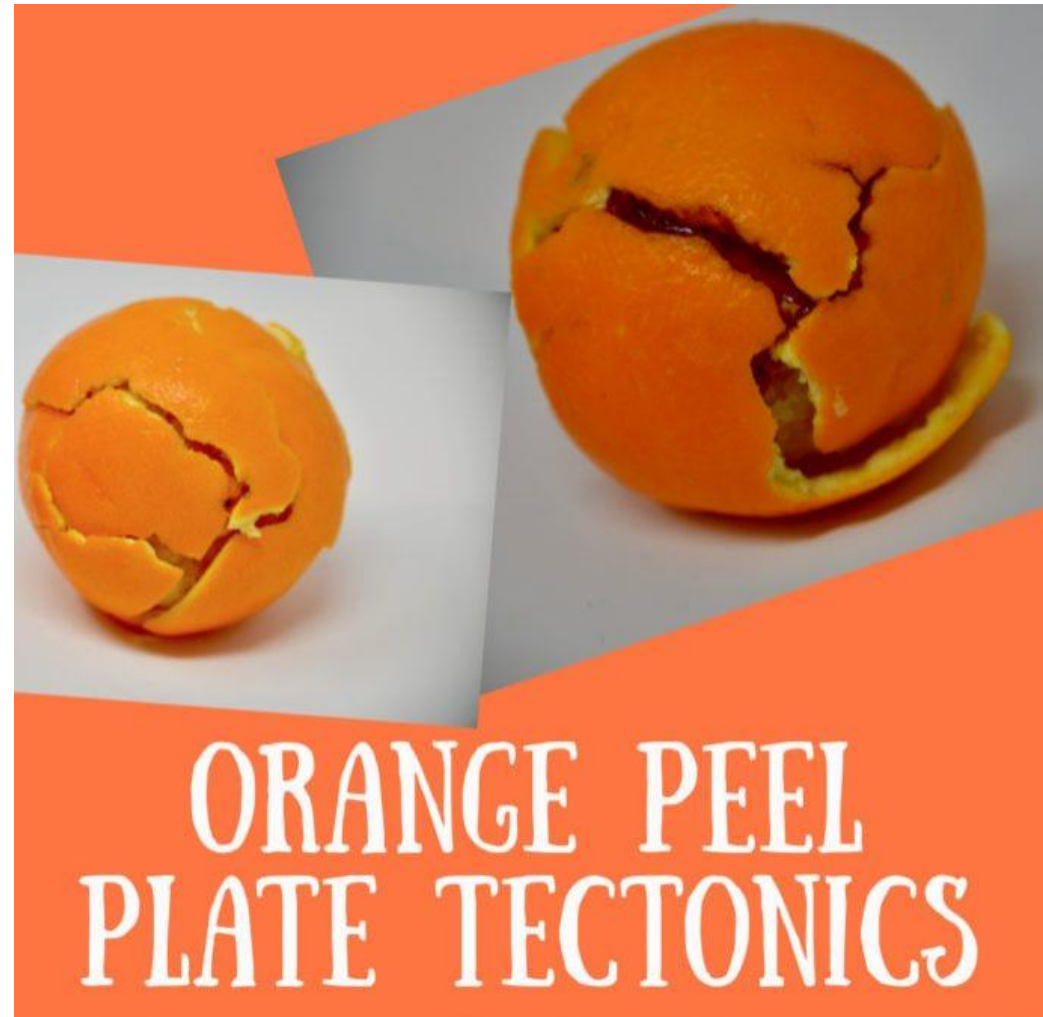


What is the Difference?



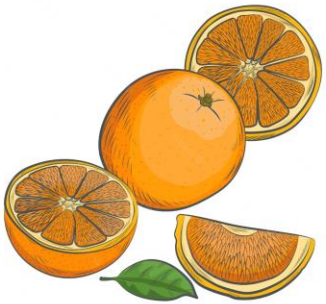
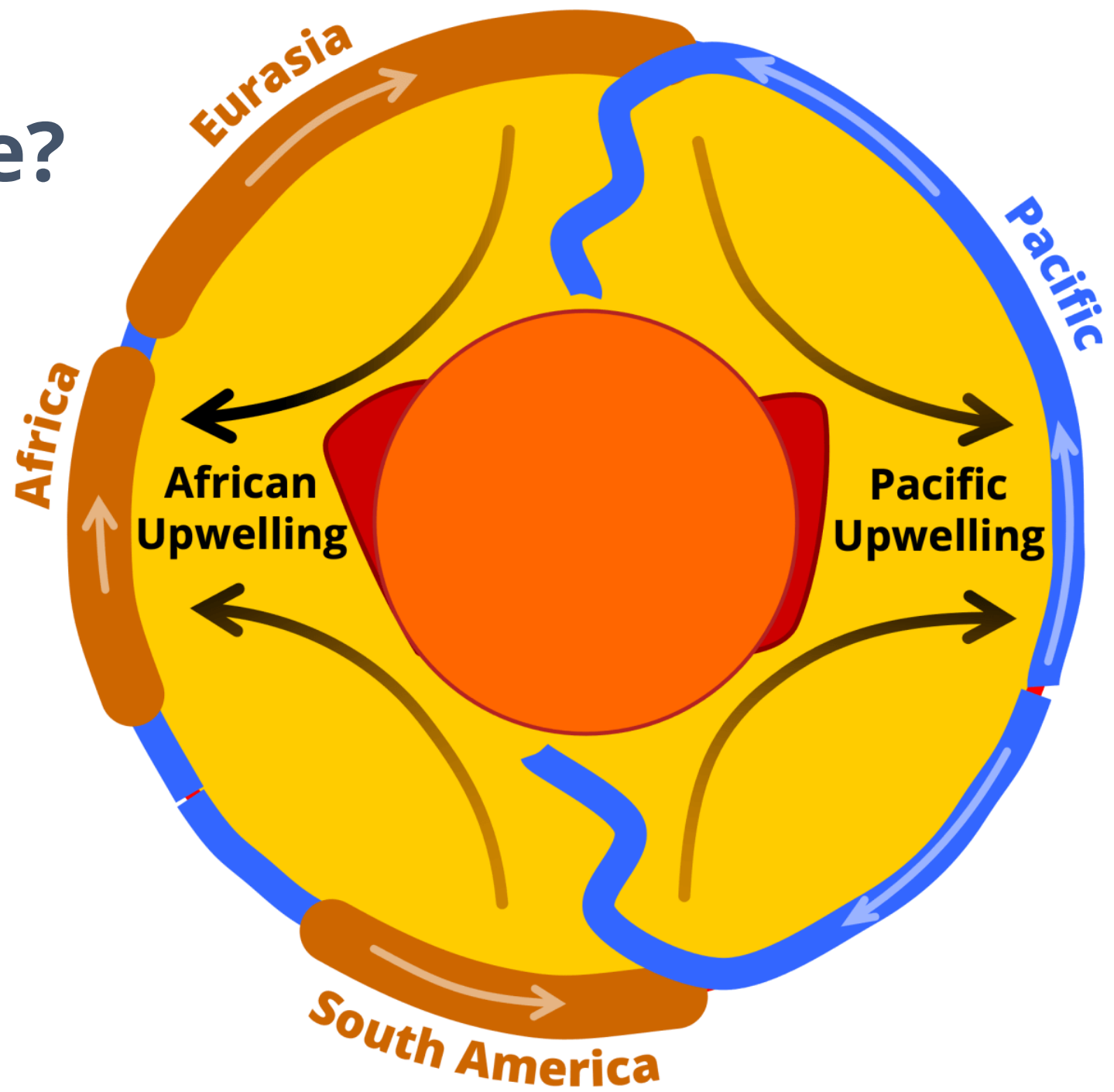
What is the Difference?

- Subduction
- Plate destruction
- Plate formation
- Sea floor spreading
- Geodynamics
 - Slab dynamics
- Mantle heterogeneity
- Core to Palaeomagnetic field inclusive

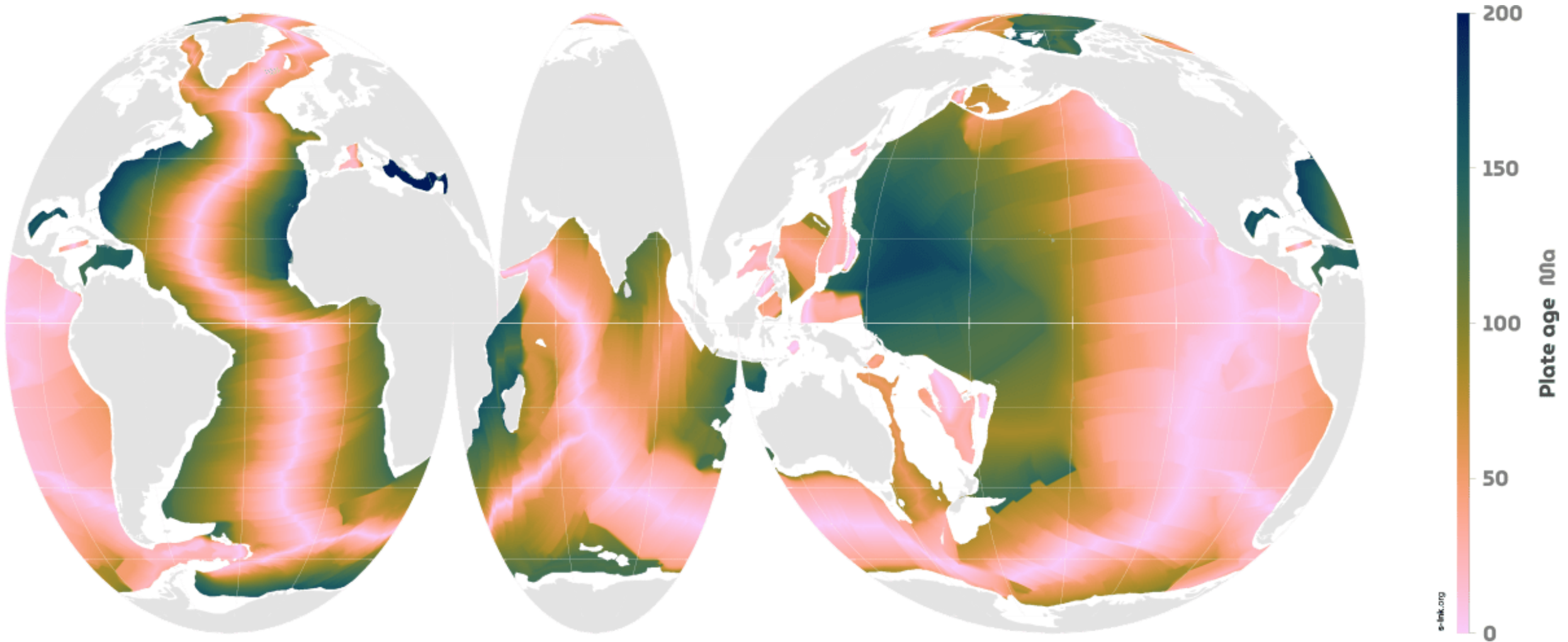


Part 3

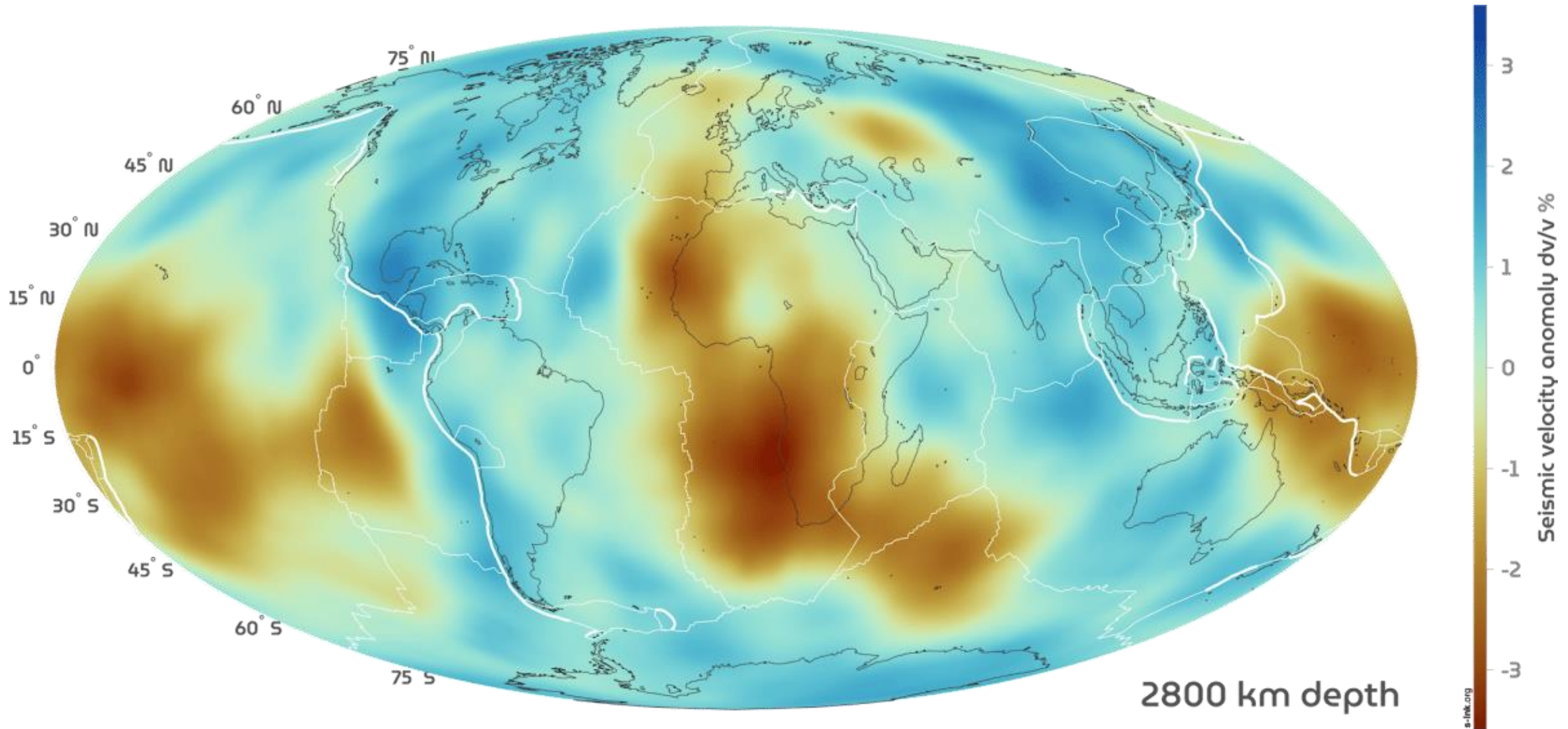
What is the Evidence?



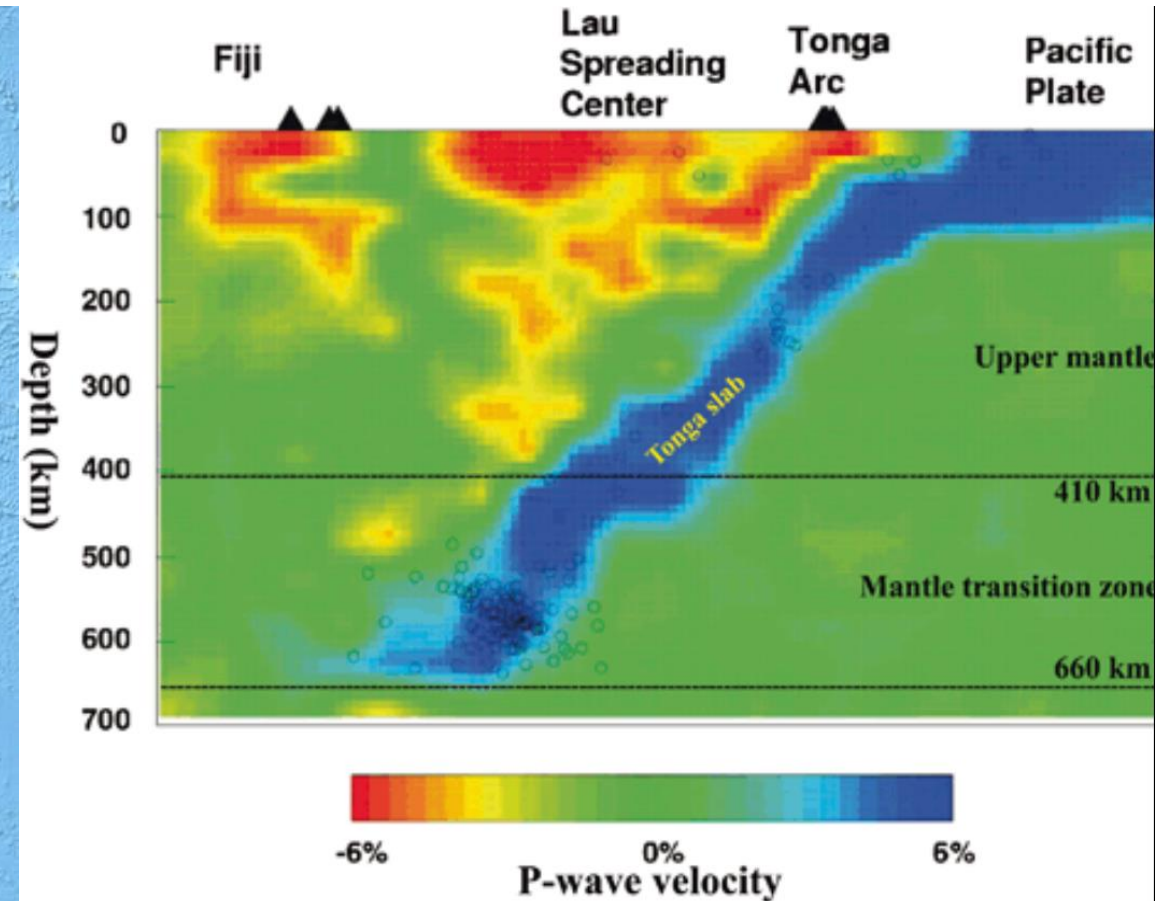
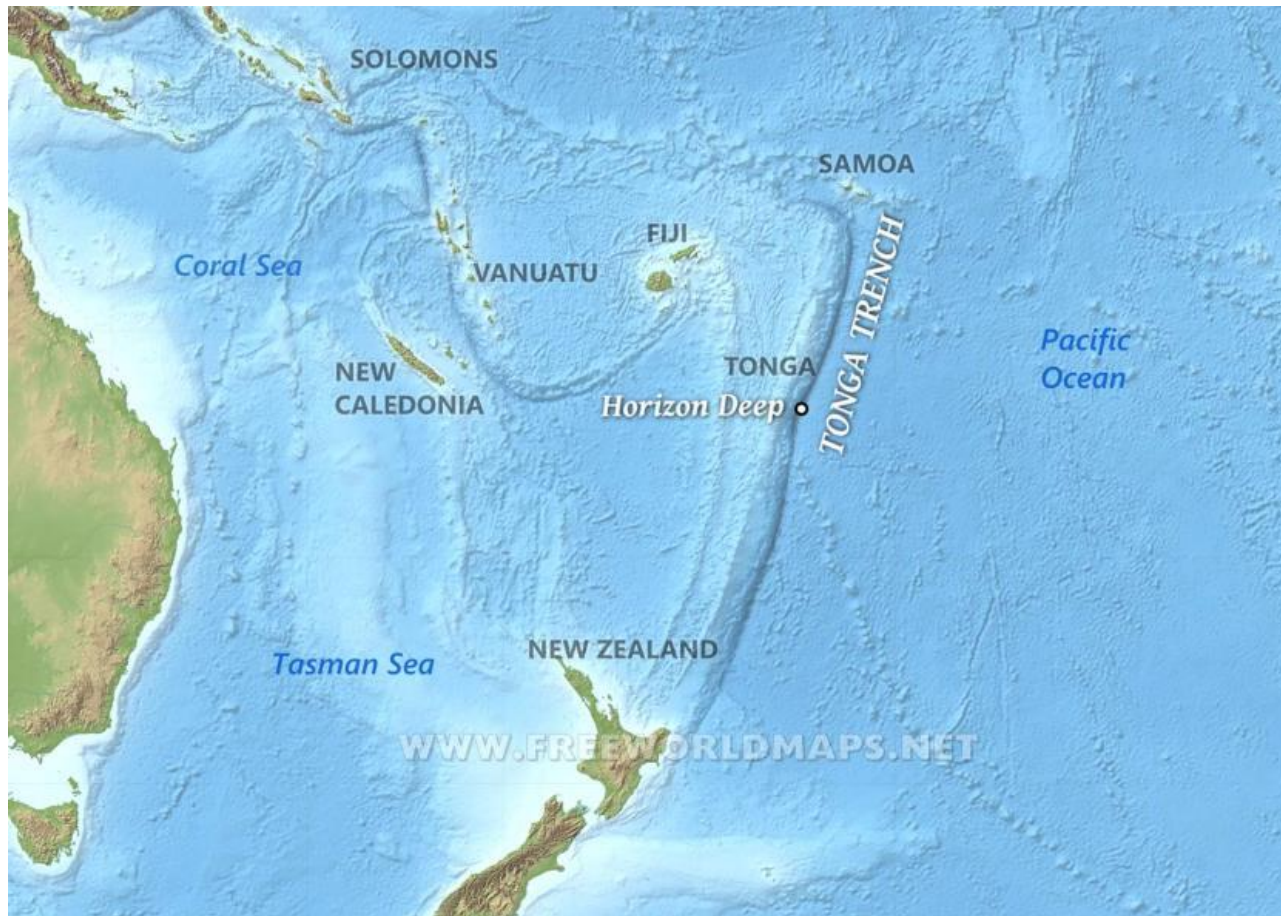
Wilson Cycle: Ocean floor age



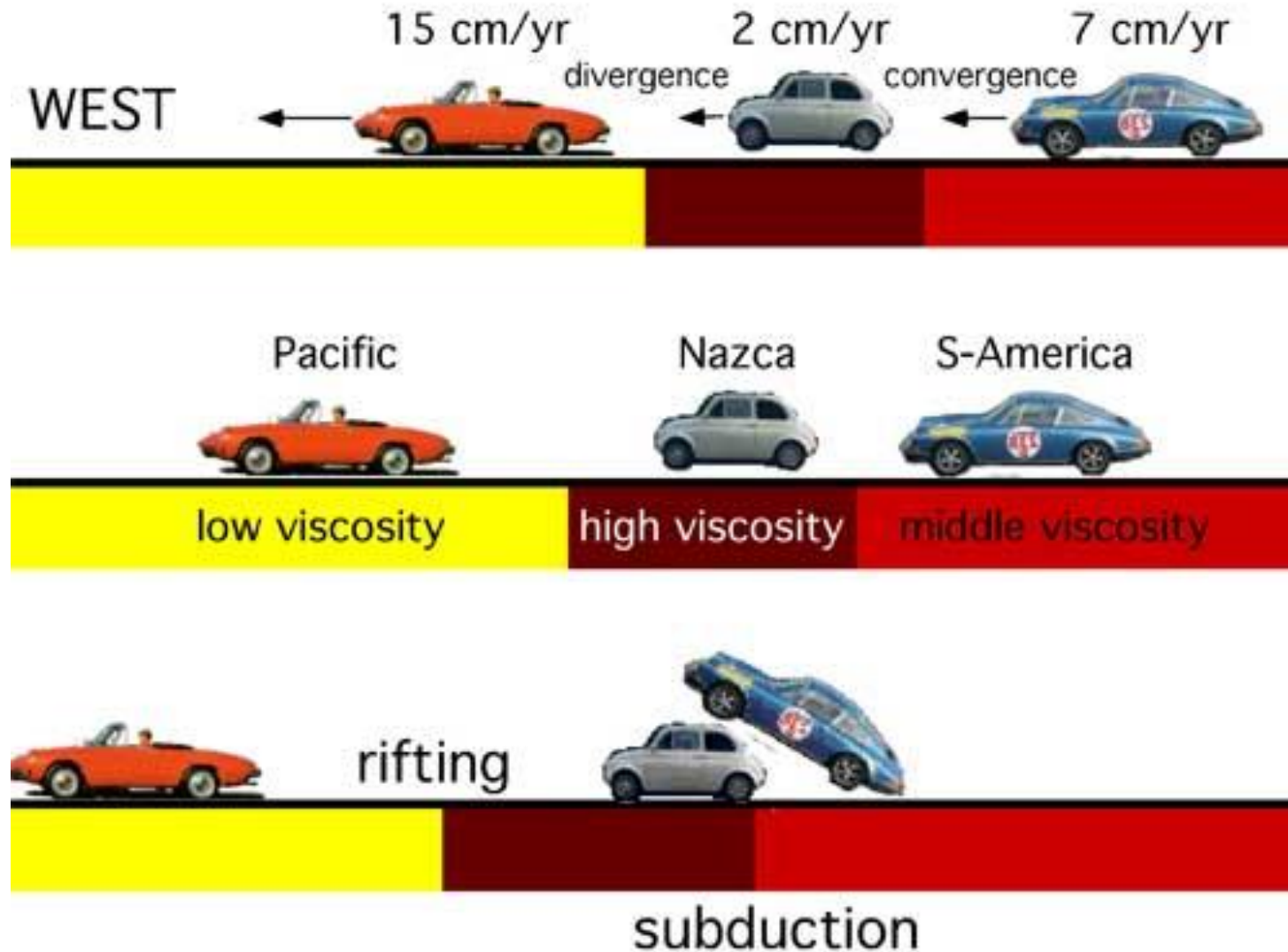
Seismic mantle tomography maps

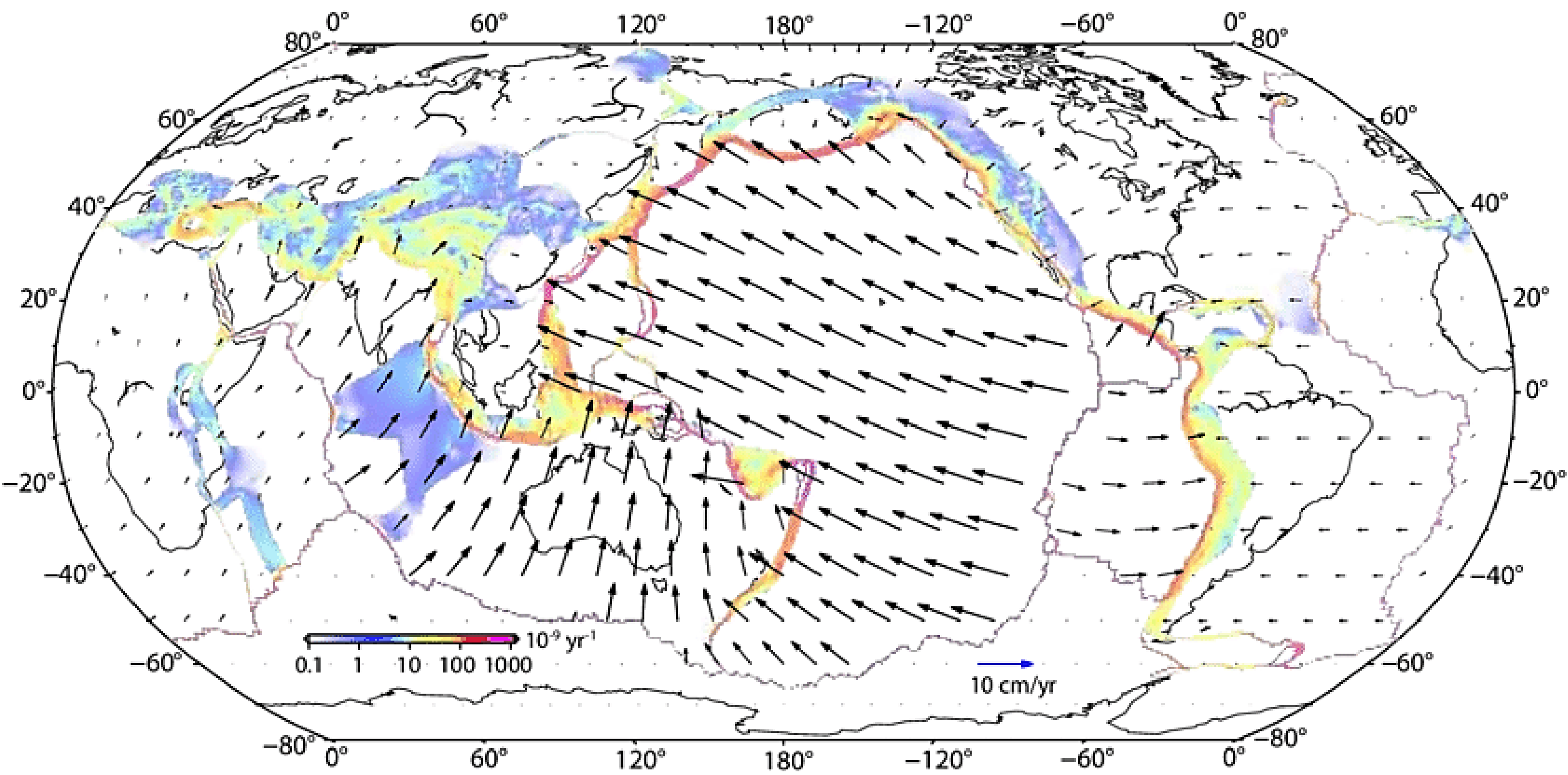


Tomography: Evidence for subduction

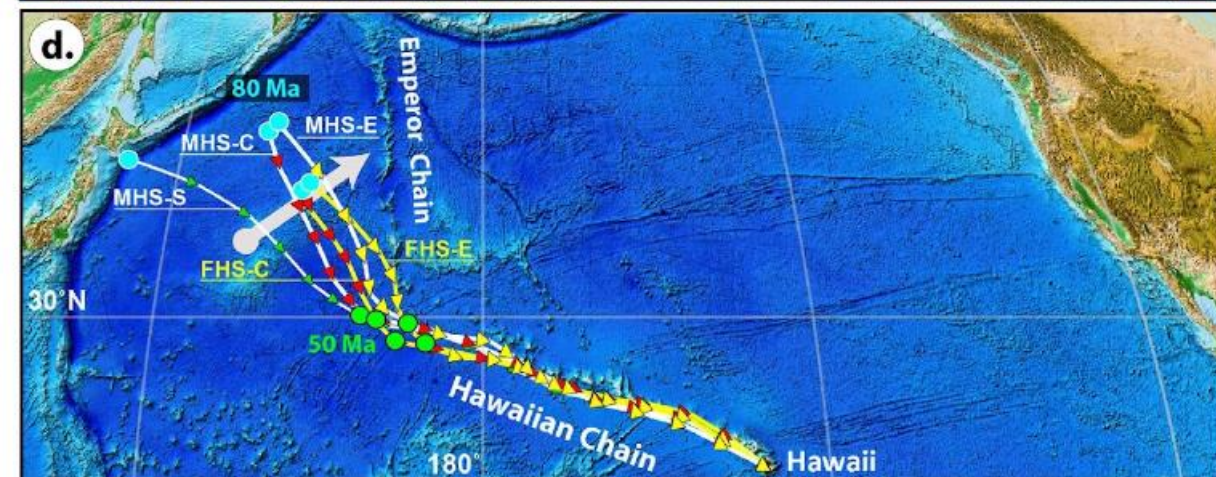
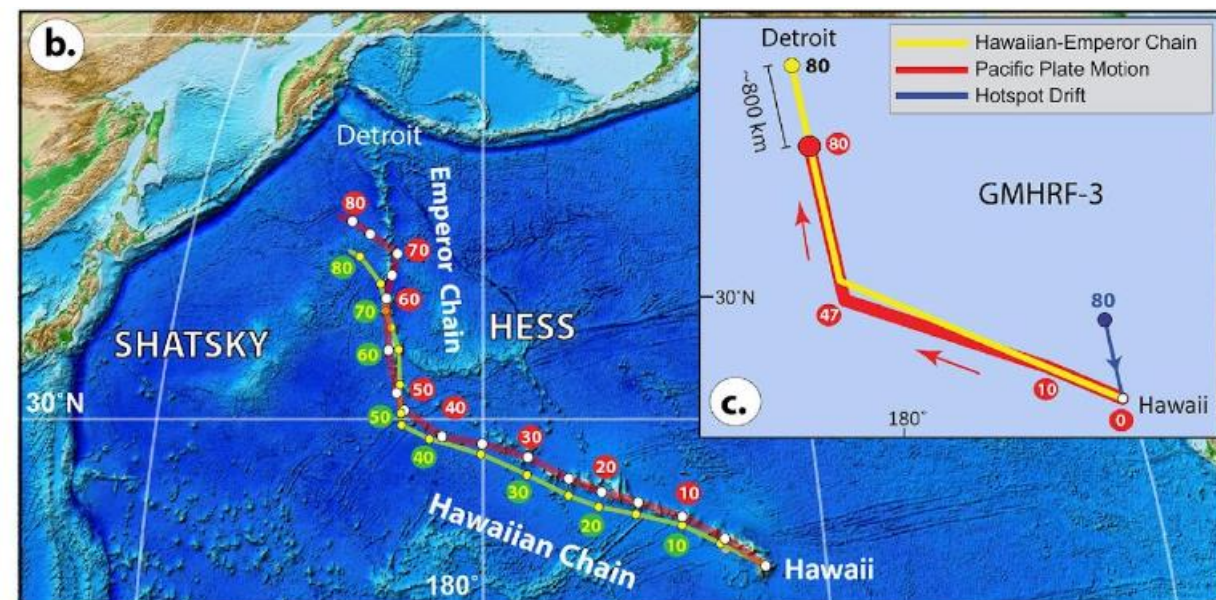
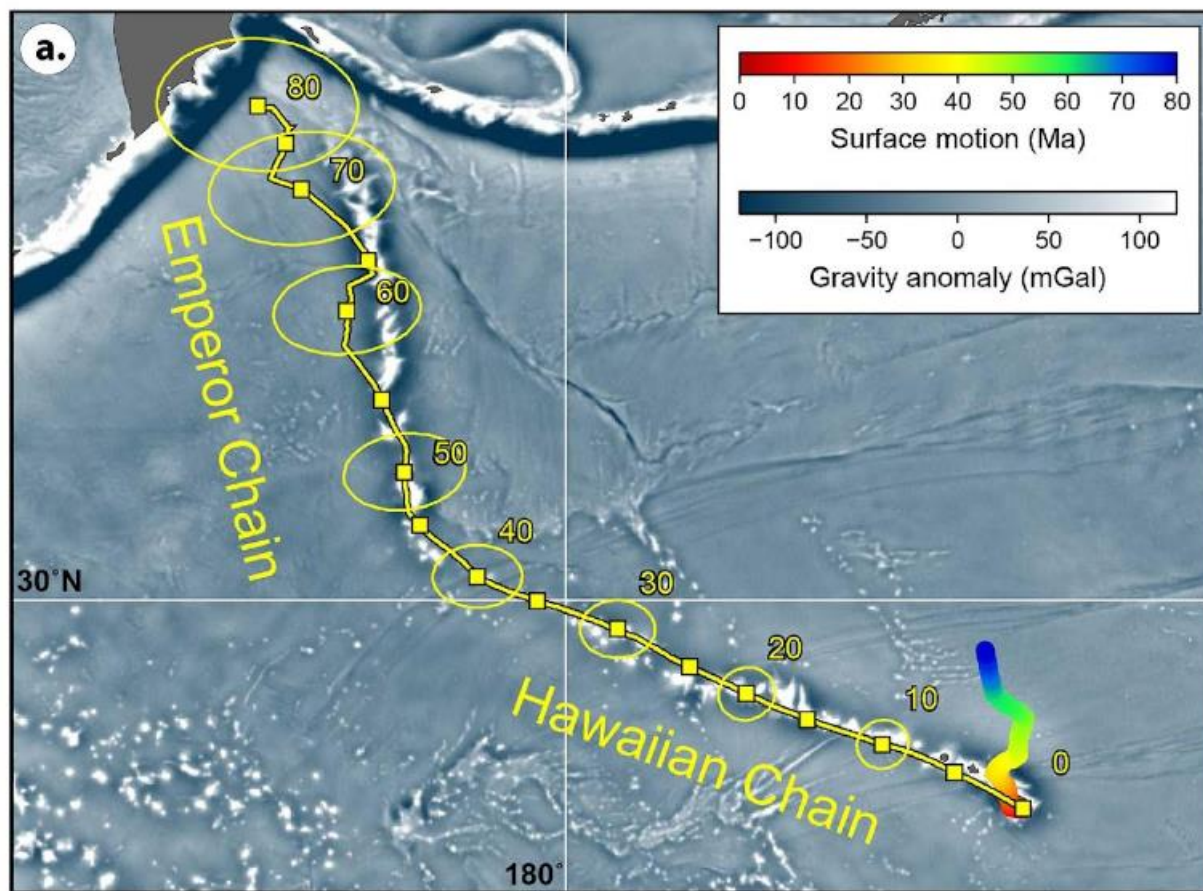


Relative plate velocities

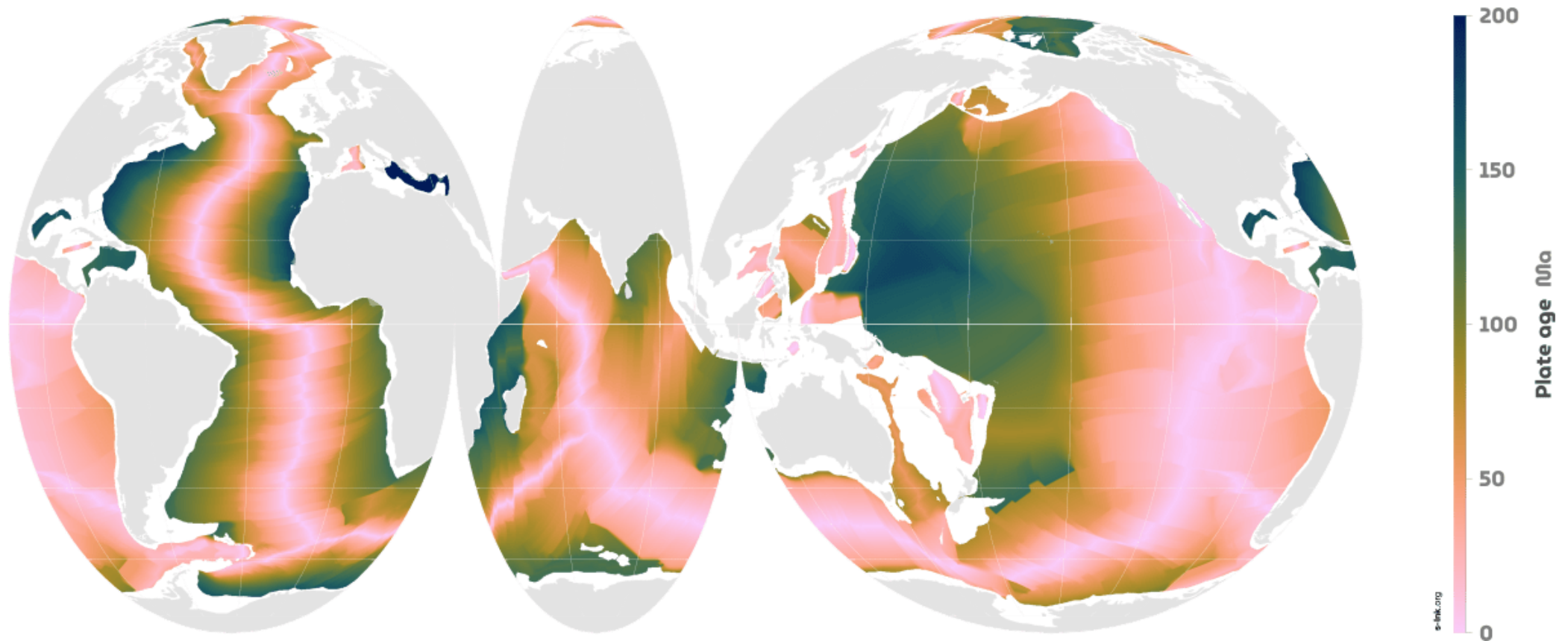




Plates move above a hotspot

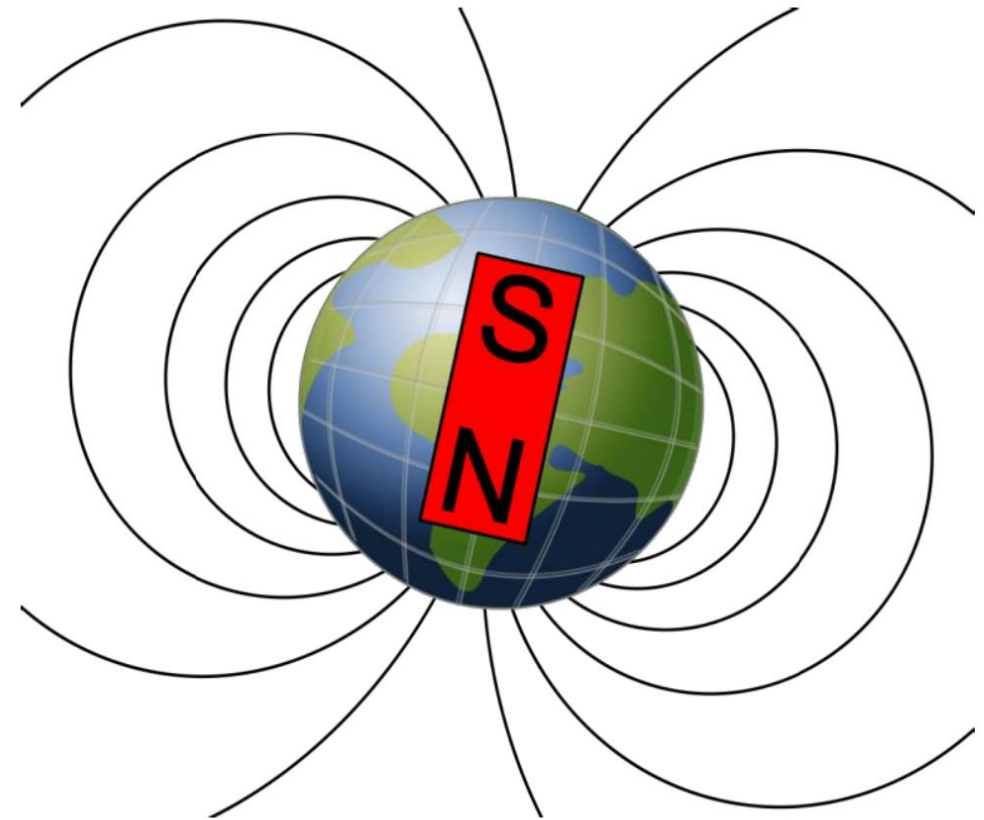
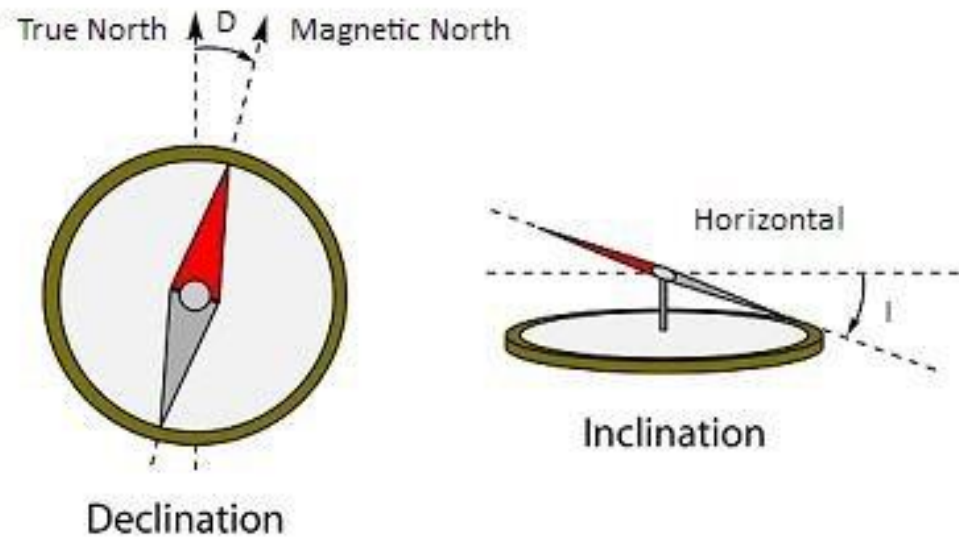


What if it's older than 220Ma?

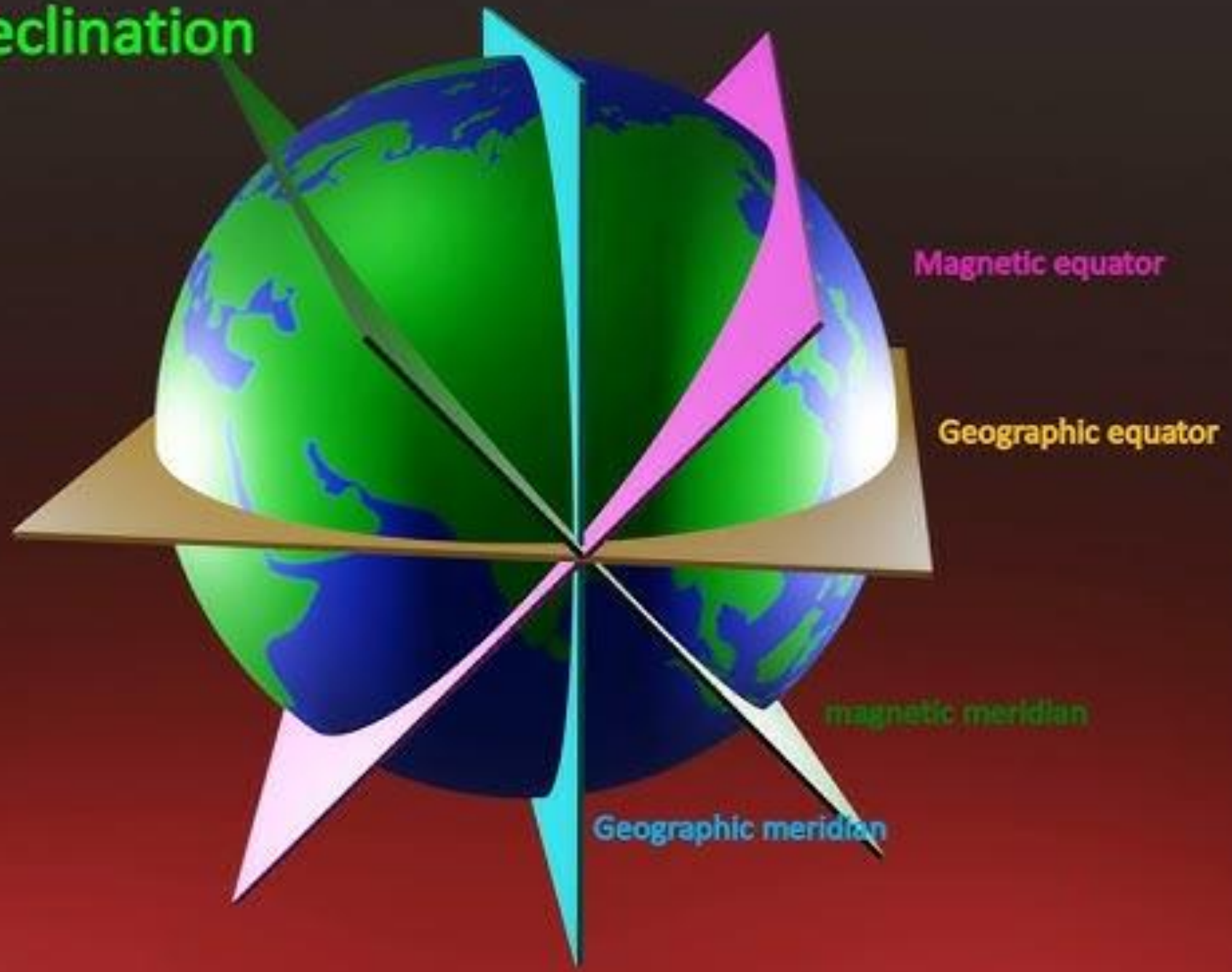


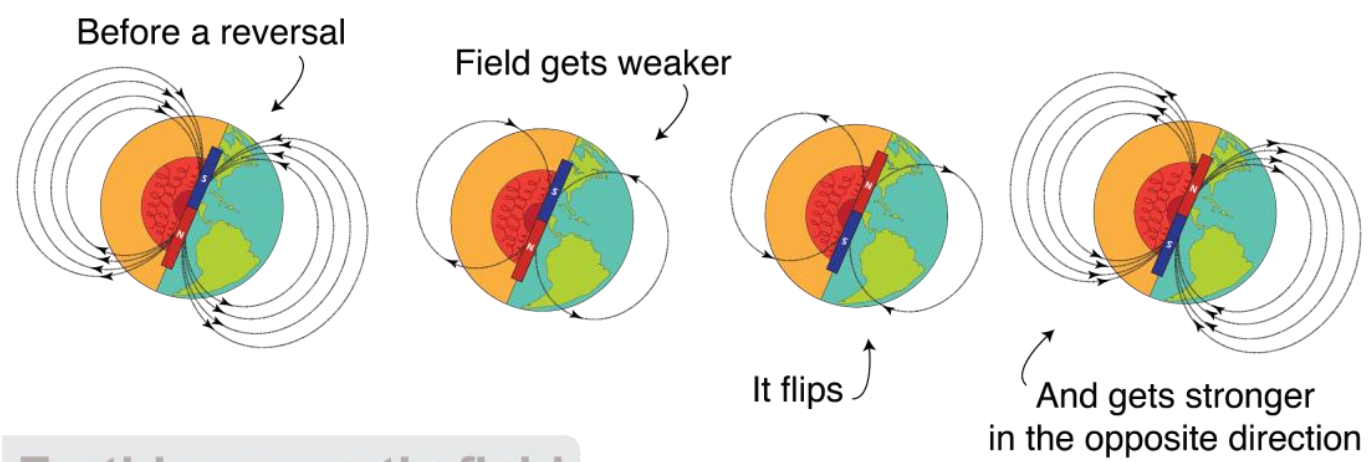
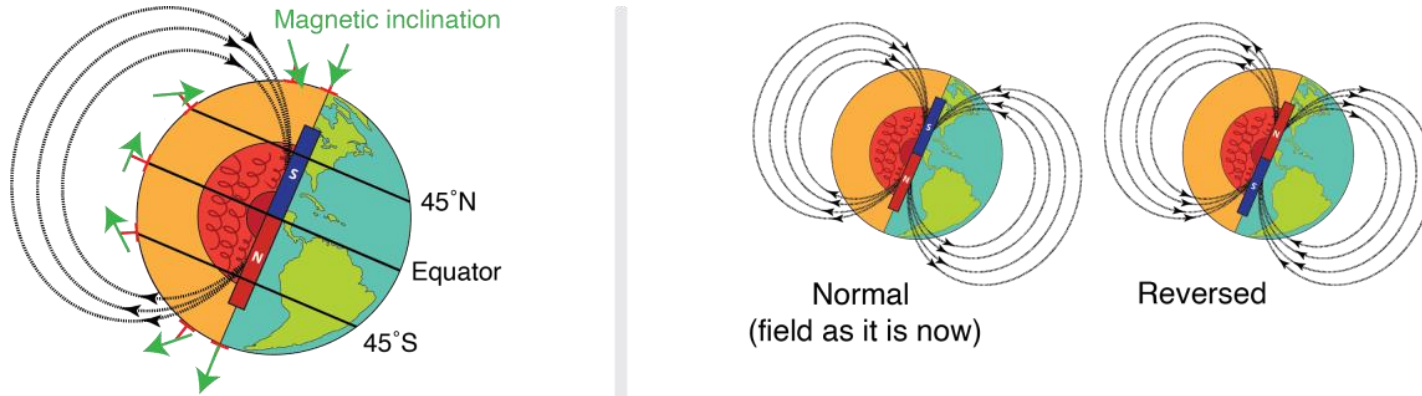
Geomagnetism and Palaeomagnetism

The Geocentric Axial Dipole (GAD)

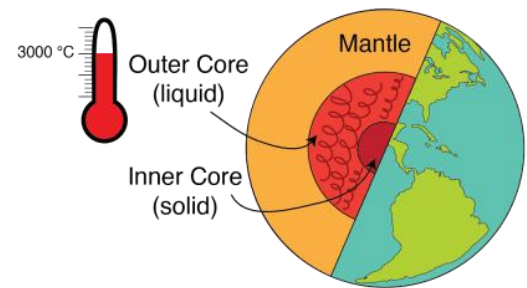
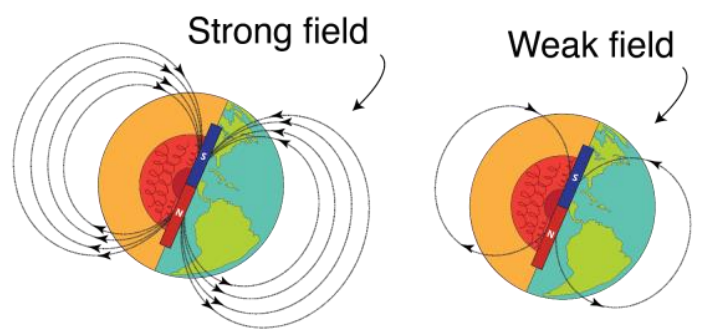


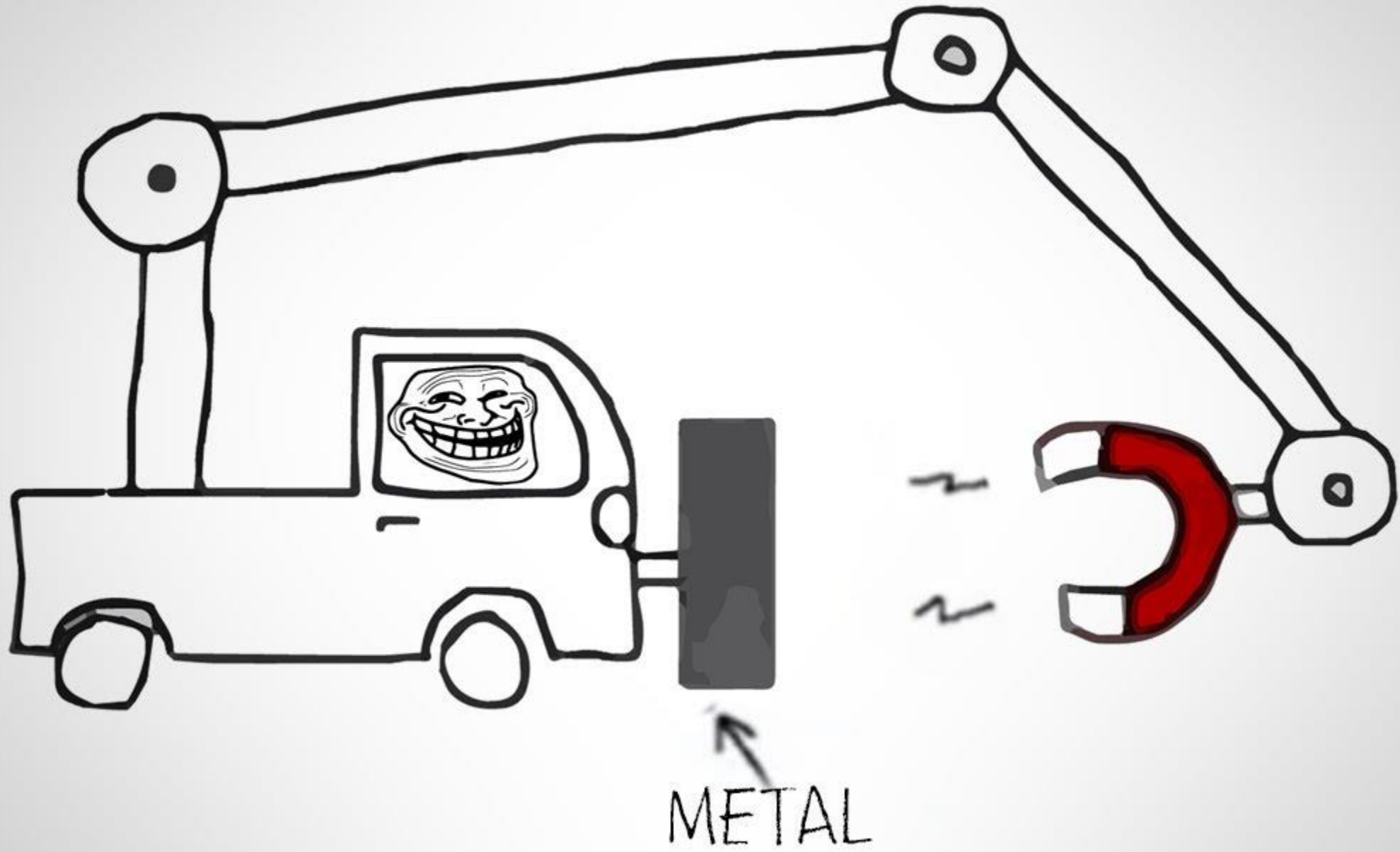
Magnetic declination





Earth's magnetic field
by Annique van der Boon via s-ink.org







But how?



METAL

The Geodynamo Hypothesis

The dynamo theory describes the process through which a rotating, convecting, and electrically conducting fluid can maintain a magnetic field over astronomical time scales

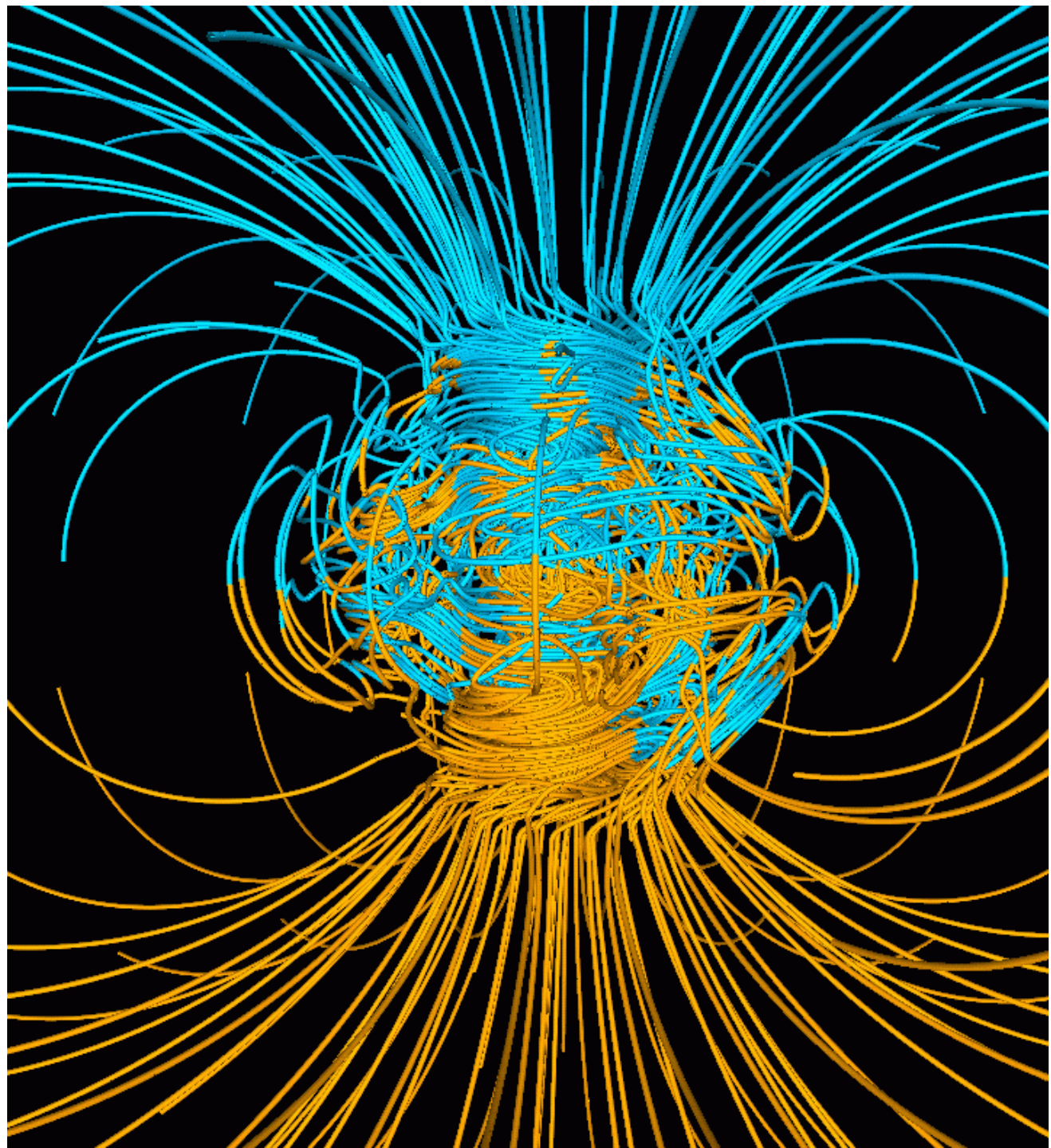
Proposed to have existed as early as 3Byr

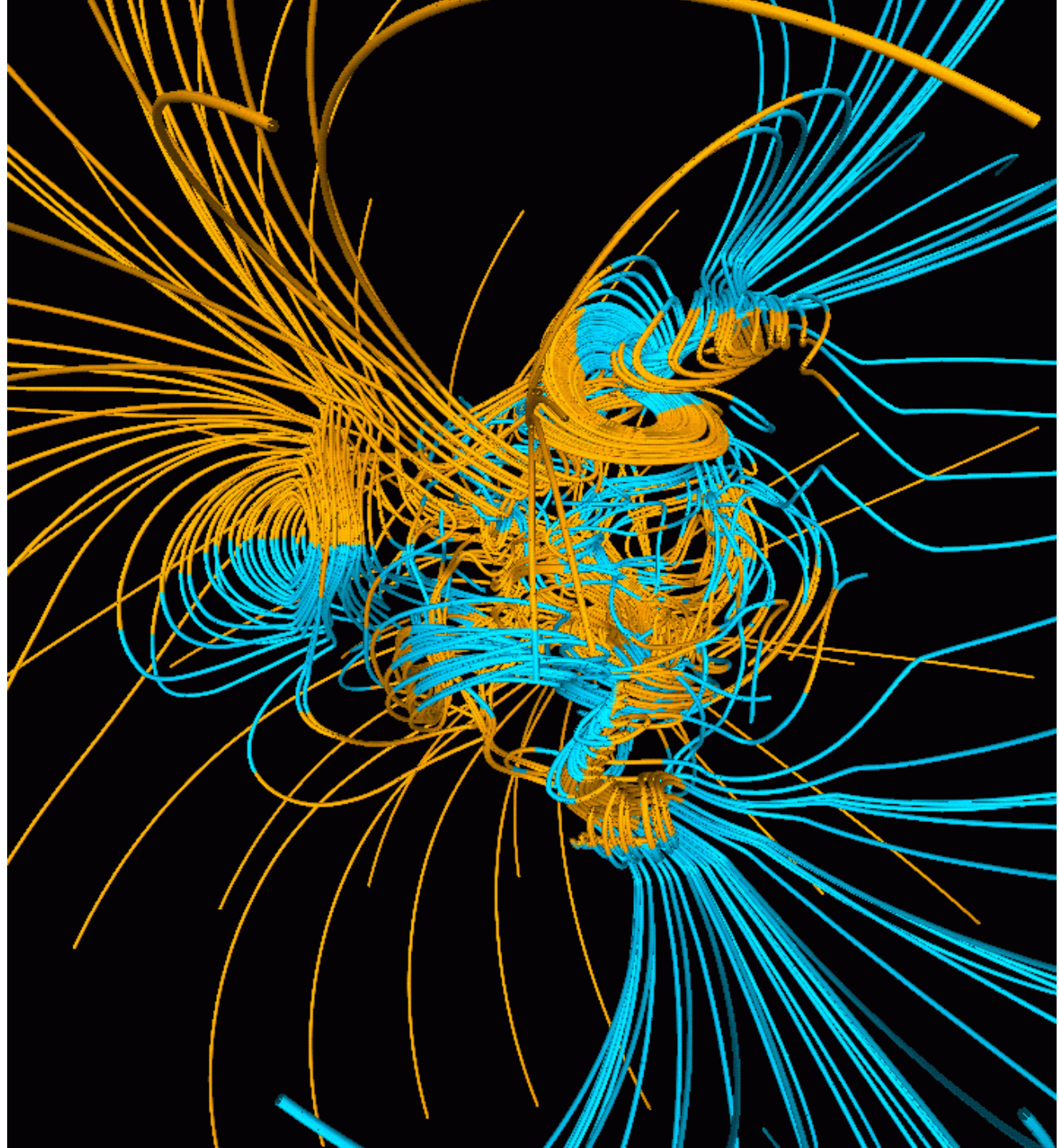
It results in the Earth's
GEOCENTRIC AXIAL DIPOLE

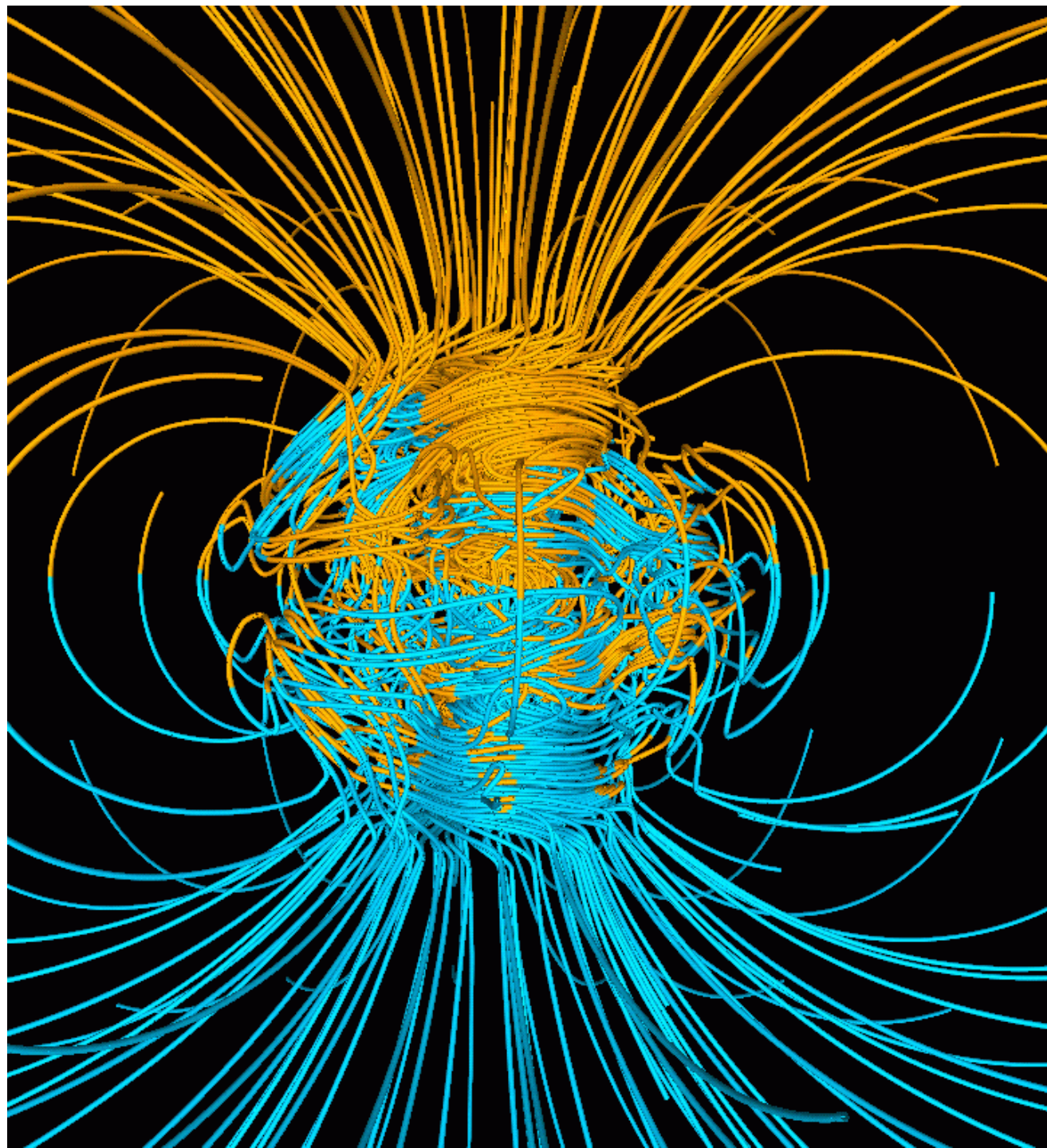
In GAD we trust

Reversals can happen within
1000 years

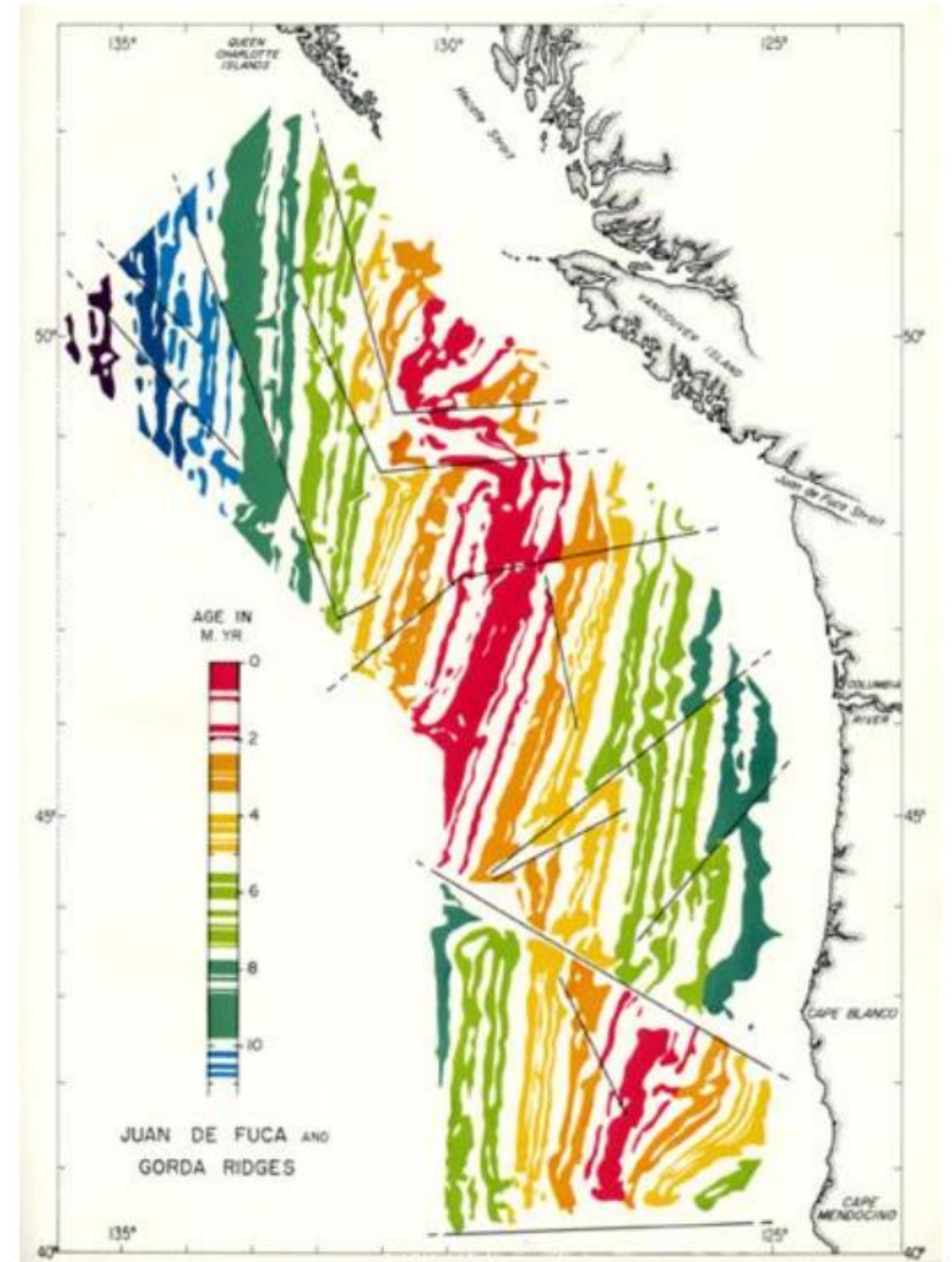
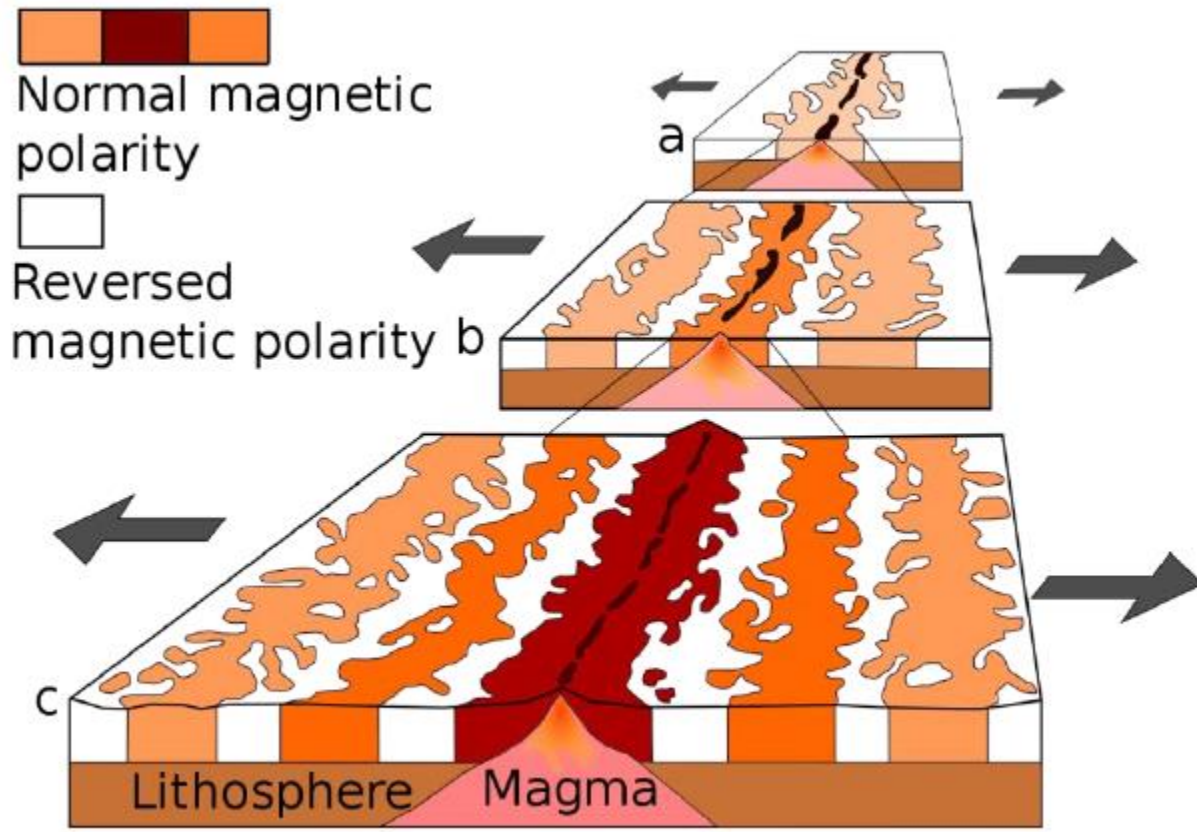
Currently observed every 20
000 years or so according to
the three-dimensional
numerical simulation of the
geodynamo, run at the
Pittsburgh Supercomputing
Center and the Los Alamos
National Laboratory







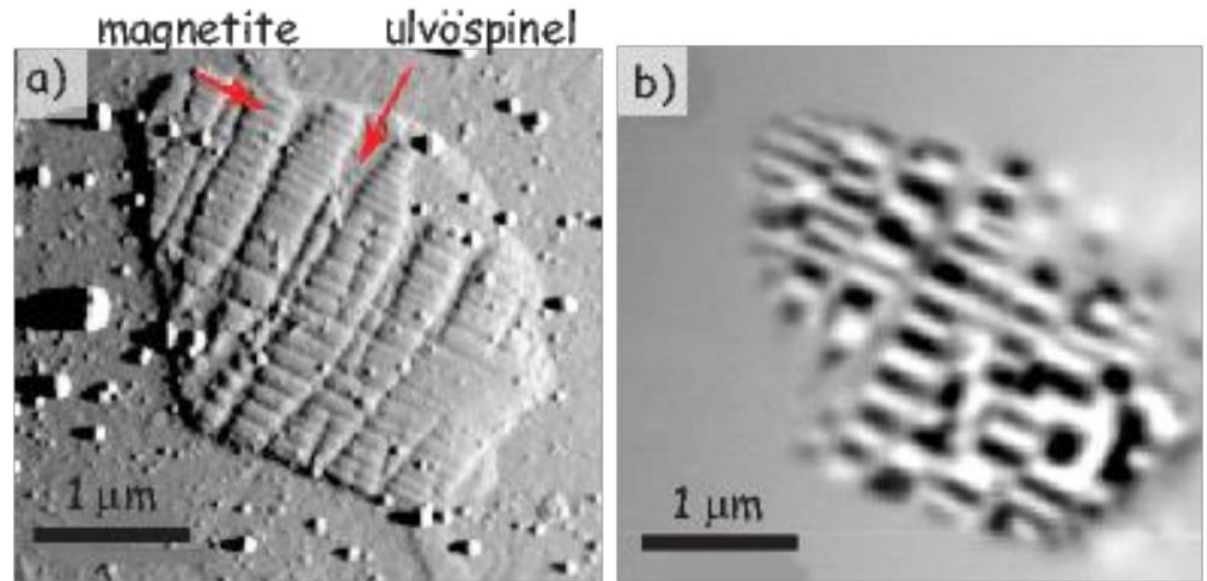
Palaeomagnetic stripes



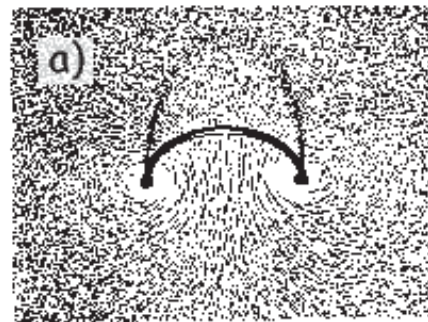
Where does the data come from?



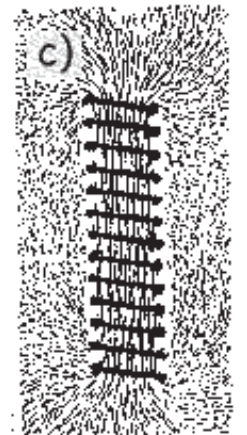
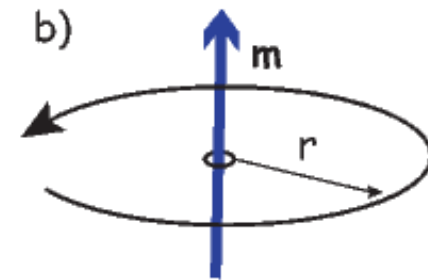
- Natural remanent magnetization
- Conserved fossil magnetic field
- Fe-Ti oxide minerals
- Captured at point of heating
- Can be reset



magnetic flux (magnetic moment), velocity, magnetic susceptibility



Iron Filings



Measurement?
Magnetometer!

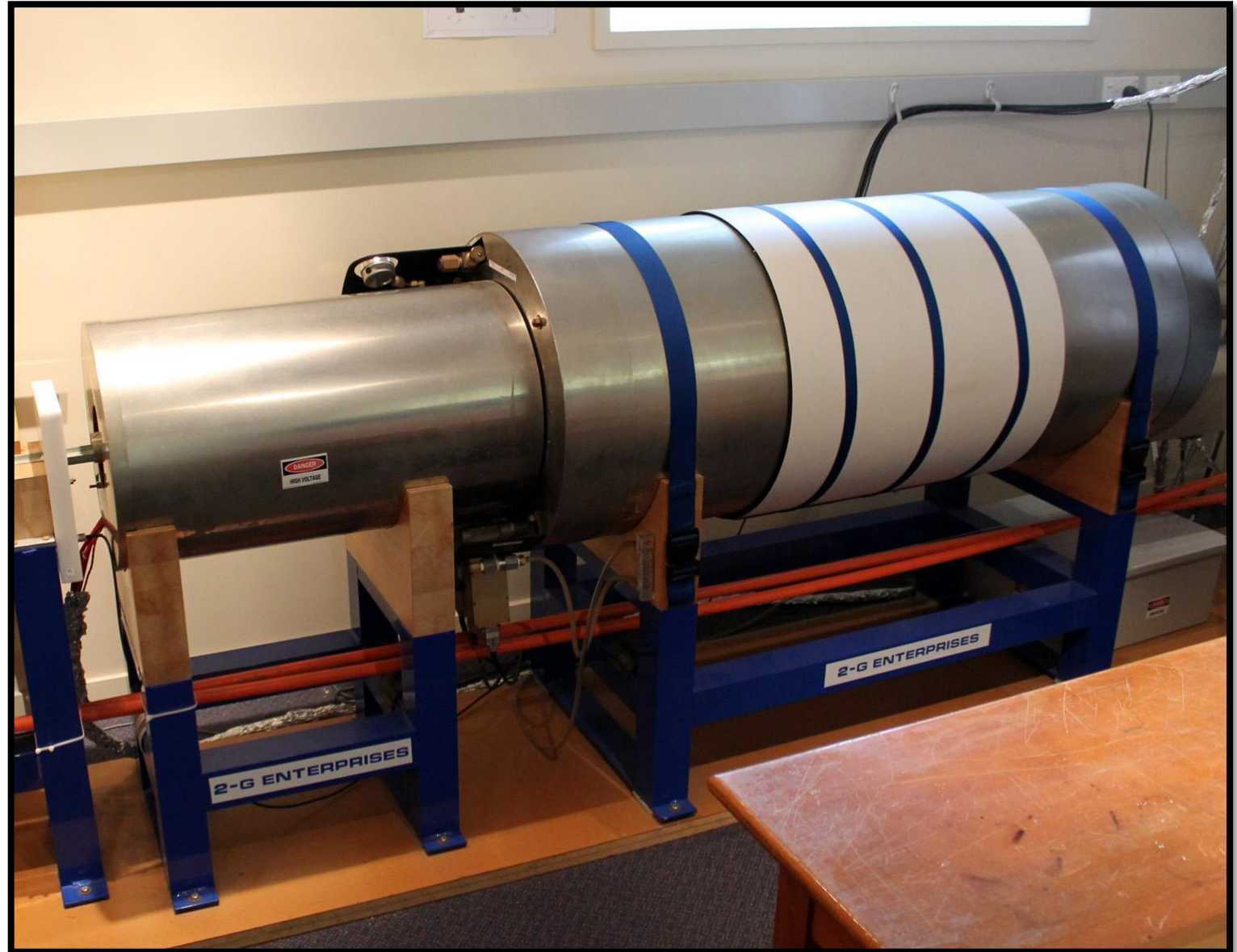


Plate Reconstruction for Palaeontologists

- Apparent Polar Wander
- True Polar wander
- Plate Rotations
- Reference Frames

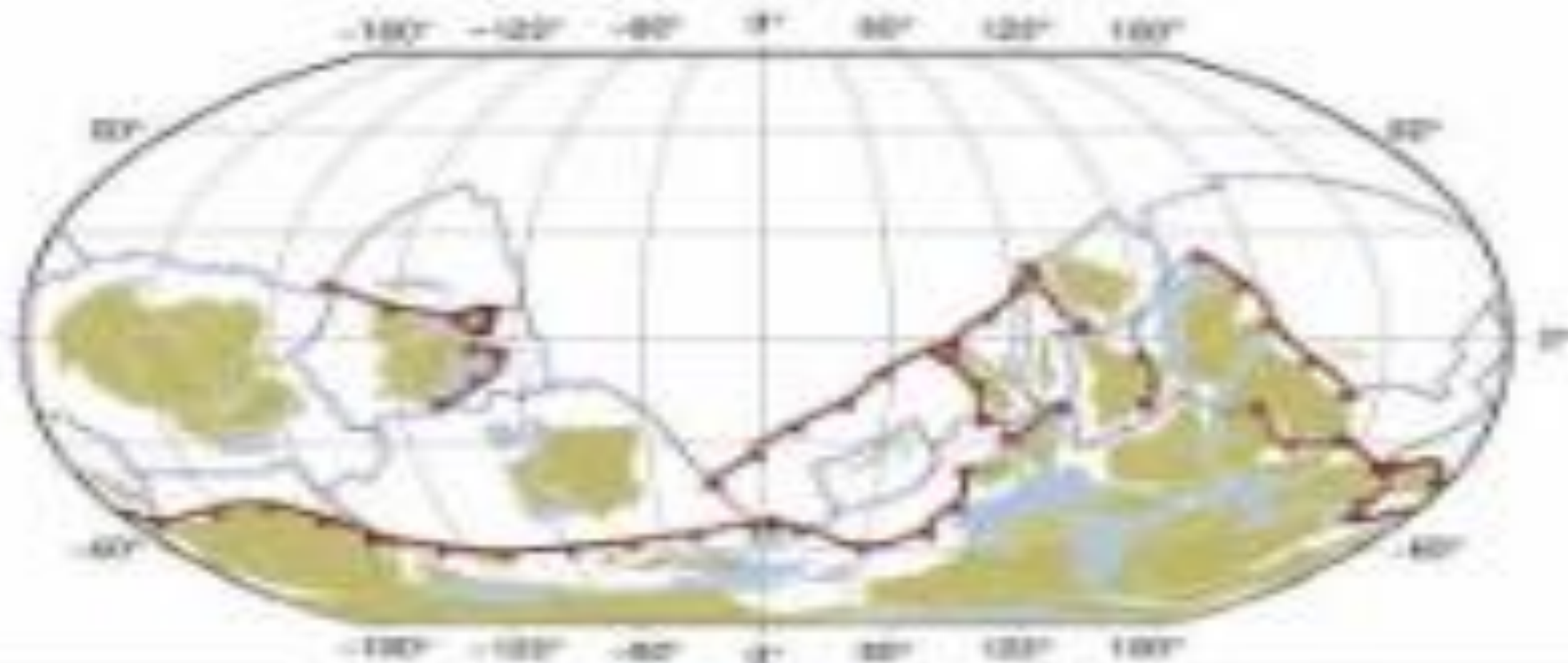
**Concepts to cover
next week**

But First



FOXADHD.COM

528 Ma



Extension Questions

- What is plate tectonics?
- When did plate tectonic start?
- Why would we look for plate tectonics on other planets, e.g. Mars?
- What data exists for palaeolongitude?
- What can we use plate reconstructions for?

Let's Download the program.

- [GPlates setup | GPlates for System Erde III. \(adamtkocsis.com\)](http://adamtkocsis.com)

References

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- Lu, G., Zhao, L., Chen, L., Wan, B. and Wu, F., 2021. Reviewing subduction initiation and the origin of plate tectonics: What do we learn from present-day Earth?. *Earth and Planetary Physics*, 5(2), pp.123-140.
- Merdith, A.S., Collins, A.S., Williams, S.E., Pisarevsky, S., Foden, J.D., Archibald, D.B., Blades, M.L., Alessio, B.L., Armistead, S., Plavsa, D. and Clark, C., 2017. A full-plate global reconstruction of the Neoproterozoic. *Gondwana Research*, 50, pp.84-134.
- Snider-Pellegrini, Antonio. 1858. *La Création Et Ses Mystères Dévoilés: Ouvrage Où l'on Expose Clairement La Nature de Tous Les Êtres, Les Éléments Dont Ils Sont Composés Et Leurs Rapports Avec Le Globe Et Les Astres, La Nature Et La Situation Du Feu Du Soleil, l'origine de l'Amérique, Et de Ses Habitants Primitifs, La Formation Forcée de Nouvelles Planètes, l'origine Des Langues Et Les Causes de La Variété Des Physionomies, Le Compte Courant de l'homme Avec La Terre, Etc.* Librairie A. Franck.
- Straume, E.O. , C. Gaina, S. Medvedev, and K.H. Nisancioglu (2020), Global Cenozoic Paleobathymetry with a focus on the Northern Hemisphere Oceanic Gateways, *Gondwana Research*, 86, 126-143. <https://doi.org/10.1016/j.gr.2020.05.011>
- Wegener, Alfred. 1912. "Die Entstehung Der Kontinente." *Geologische Rundschau* 3 (4): 276–92. <https://doi.org/10.1007/BF02202896>.