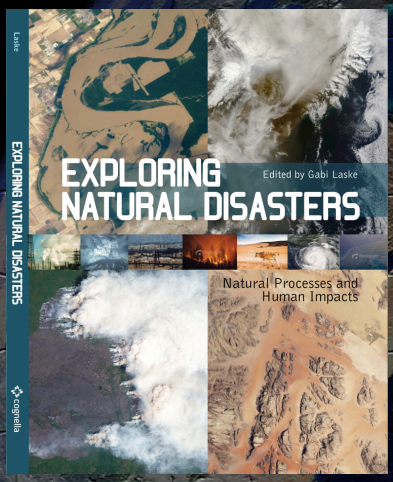
Topic 4: Plate Tectonics

https://geowiki.ucsd.edu/sio15



- all lectures will be recorded
- switch off your camera
- mute yourself
- submit questions through chat box

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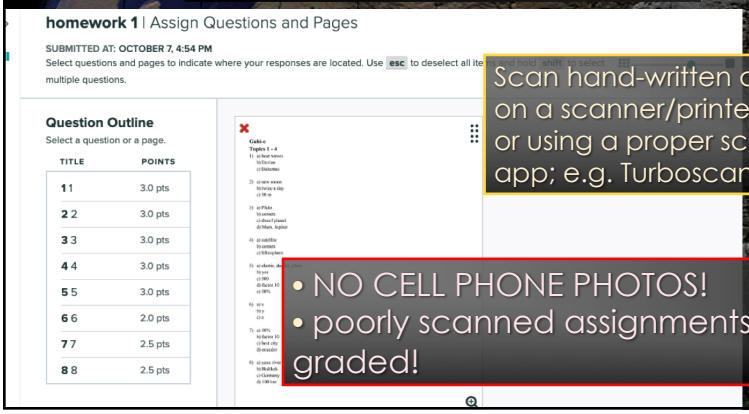
Homework 1- Gradescope

Watch additional homework video on homework submission!

- submit on Gradescope
- 1 single pdf
- assign location of answers before hitting submit button



Scan hand-written assignments on a scanner/printer, or using a proper scanning app; e.g. Turboscan

- NO CELL PHONE PHOTOS!
- poorly scanned assignments will not be graded!

For-Credit Test #1 - Canvas

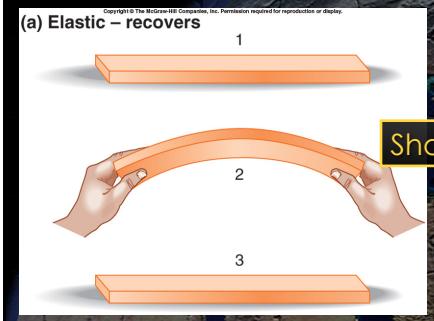
- You should have done this test by now!
- If not, contact Prof. Laske immediately

Future For-Credit Tests - Canvas

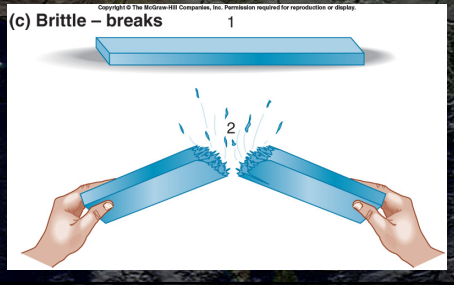
- On Mondays (open Sundays 11 pm); due 11:59 pm
- Late submissions without penalty by Tuesday 3 pm
- no need to have camera on during test
- no need to Zoom record your test
- do not 'screen shot' test questions (this is considered cheating)

Elastic, Ductile and Brittle Material

Fig 2.22



Short Video 4a



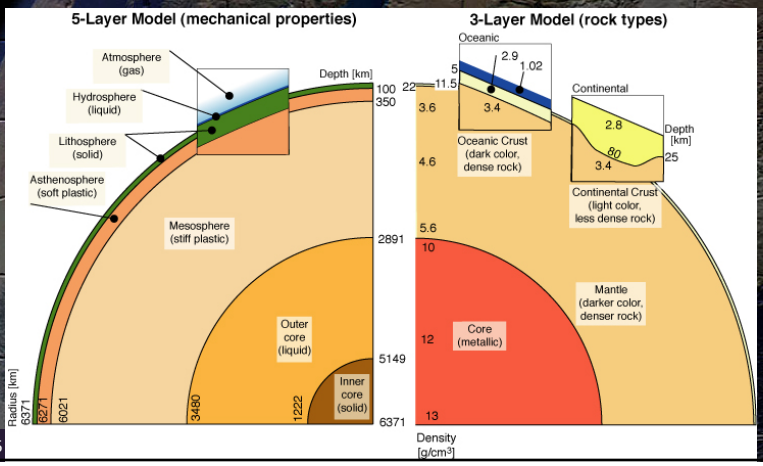
Response to Forces
- elastic: recovers
- ductile: deforms (e.g. under pressure/heat)
- brittle: breaks

The Layered Earth

Fig 3.27

- solid inner core (metallic)
- liquid outer core (metallic)
- viscous mantle (similar to stony meteorites)
- weak asthenosphere above 350km depth
- strong lithosphere above 120km (crust + uppermost mantle)

Short Video 4a



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Earth's Outermost Shells

Fig 3.28

Short Video 4b

Lithosphere

- cool and strong but brittle
- zone of Eqs/volcanoes

Asthenosphere

- warm, soft, ductile

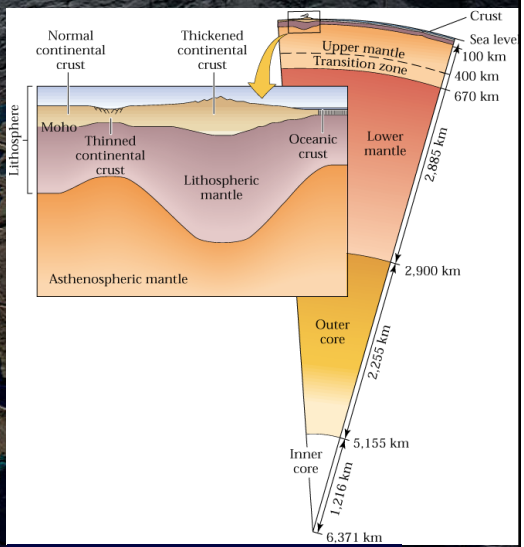

Image: S. Marshak "Earth, Portrait of a Planet"

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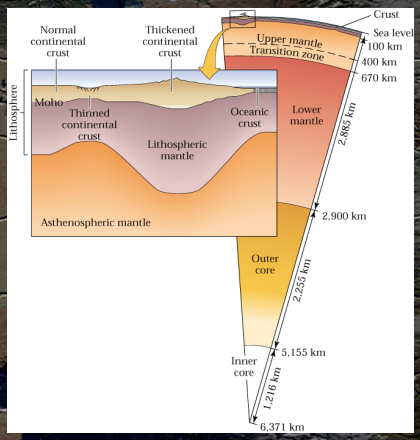
Plate Tectonics

Fig 3.28

Why do continents have roots?
What keeps the lithosphere afloat?

Short Video 4b



Poll – Q 1

Isostasy

Fig 3.29

2 counteracting forces

- gravity
- buoyancy

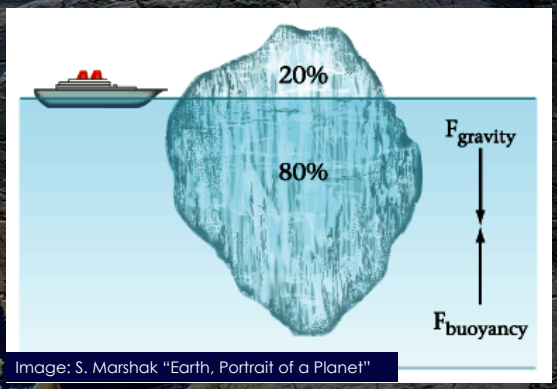


Image: S. Marshak "Earth, Portrait of a Planet"

isostatic equilibrium

- forces are balanced
- body floats

Short Video 4b

- rigid lithosphere floats on soft asthenosphere
- asthenosphere reacts to imbalance (flows)

postglacial rebound

Lithospheric Plates

Fig 4.19

- lithosphere is broken up into 12 major plates
- move about (a few cm per year)
- driven by mantle convection

Plate Boundaries

- divergent
- convergent
- transform

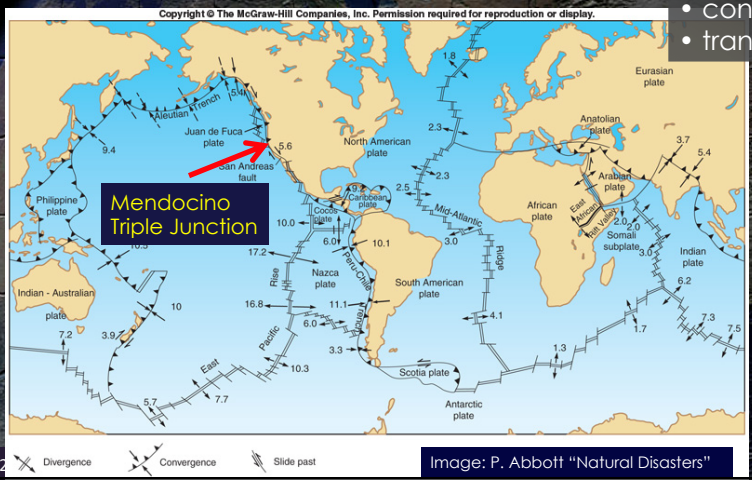
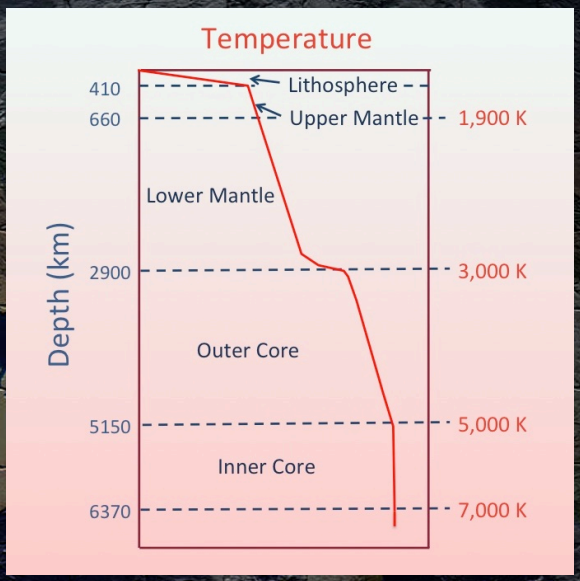


Image: P. Abbott "Natural Disasters"

The Layered Earth - Temperature

- ~ 3000 K near CMB
- ~ 7000 K near center

5000 K = 8540°F



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What Drives Plate Tectonics?

Topic 2: Earth's Internal Heat ->Mantle Convection

- mantle moves/convects over geologic times (a few cm/yr)
- -> plate tectonics on surface
- -> earthquakes, volcanoes, uplift and landslides

Fig 4.17

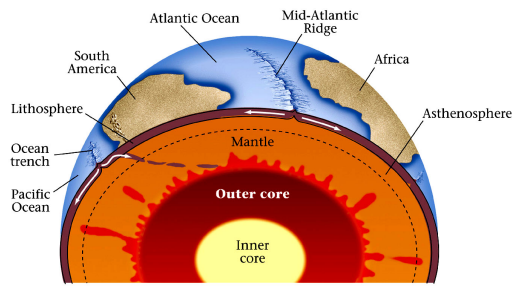

Image: S. Marshak "Earth, Portrait of a Planet"

a little bit like this

- ductile mantle (video 4a)
- viscosity: resistance to flow (Topic 2 notes)

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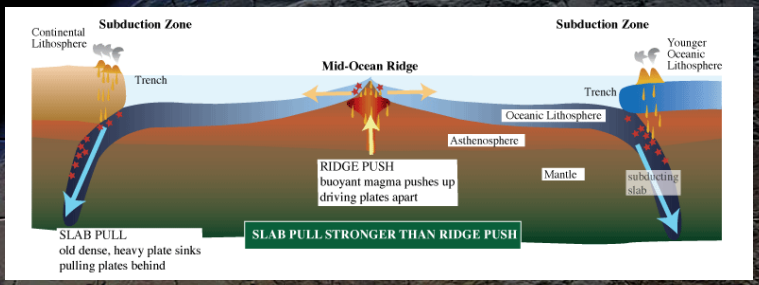
Poll – Q 2

Plate Tectonics - The Grand Unifying Theory

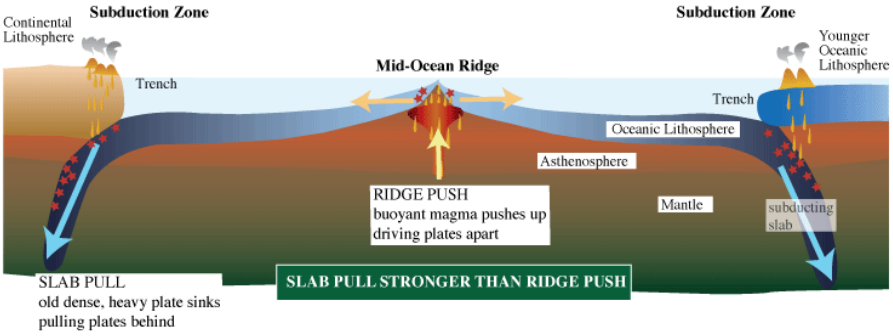
Fig 4.16



- lith. formed at MORs
- lith. consumed in subduction zones
- same rate
- plates move a few cm/yr
- earthquakes
- volcanism
- mountain building and other features on Earth's surface

The Two Forces that Drive Plate Motion

Fig 4.16



slab pull ridge push slab pull

slab pull more dominant

Short Video 4c

Continental Drift

How do we know that plates move sideways?

- Alfred Wegener, 1915
- continents like jigsaw puzzle
- fossil records match across oceans
- geologic units match across oceans
- apparent polar wander curves don't match

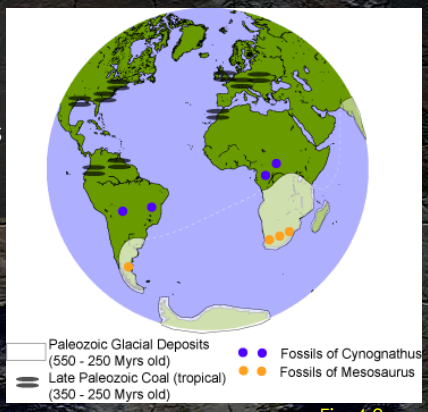
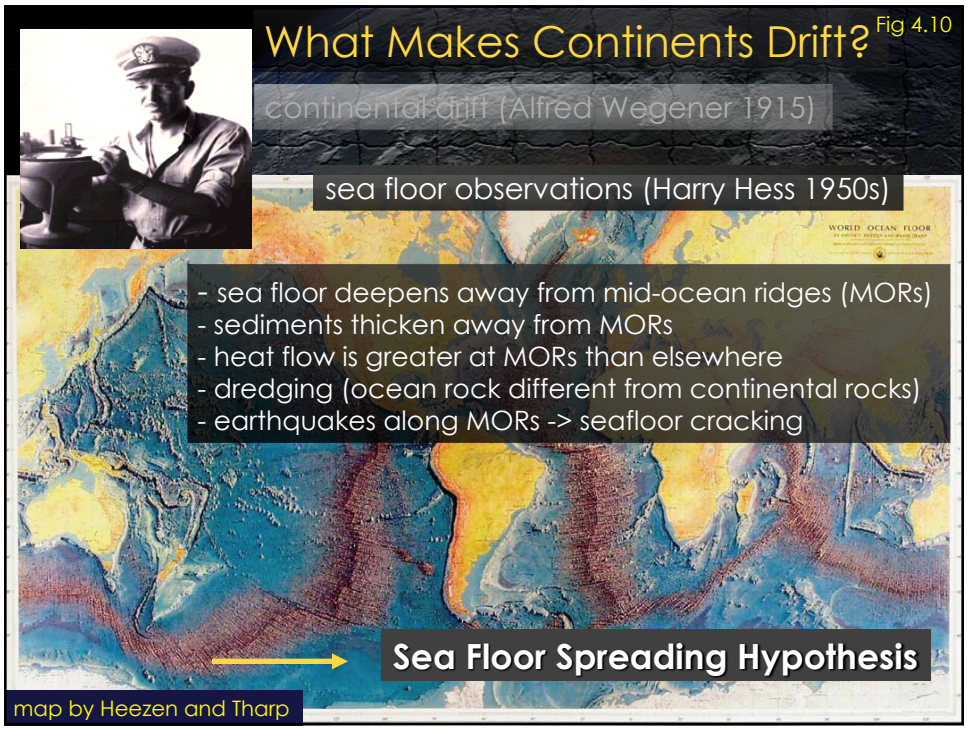


Fig 4.3

Fig 4.2

just like Big Bang theory, this was suggested early but not accepted until 1960s


What Makes Continents Drift?
Fig 4.10
continental drift (Alfred Wegener 1915)
sea floor observations (Harry Hess 1950s)
- sea floor deepens away from mid-ocean ridges (MORs)
- sediments thicken away from MORs
- heat flow is greater at MORs than elsewhere
- dredging (ocean rock different from continental rocks)
- earthquakes along MORs -> seafloor cracking
Sea Floor Spreading Hypothesis
map by Heezen and Tharp

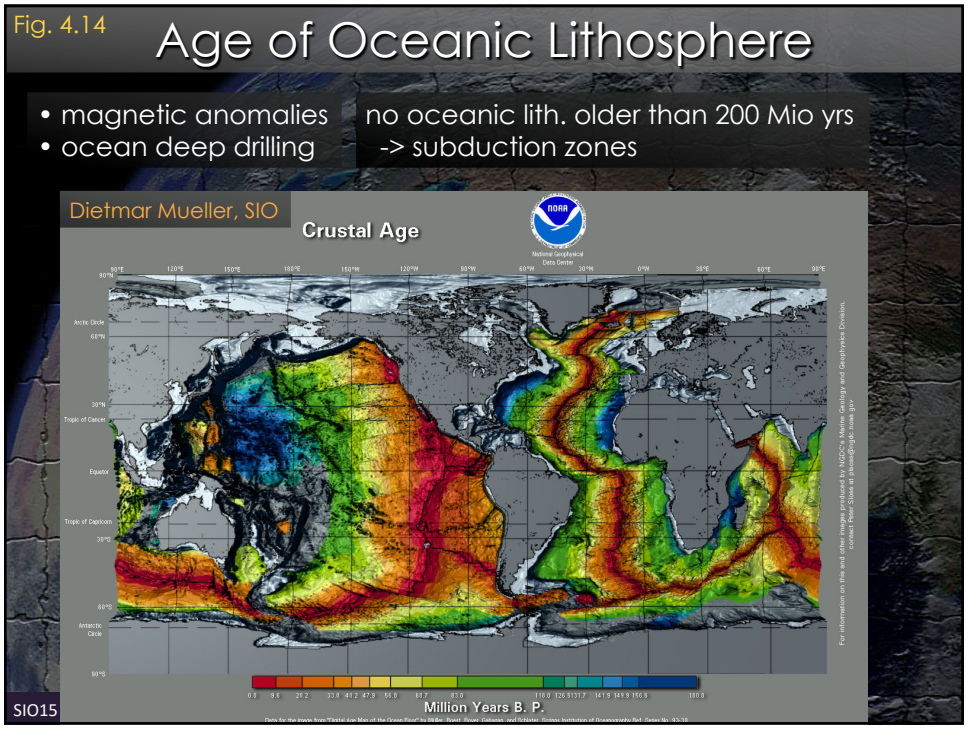


Fig. 4.14
Age of Oceanic Lithosphere
• magnetic anomalies
• ocean deep drilling
no oceanic lith. older than 200 Mio yrs
-> subduction zones
Dietmar Mueller, SIO
Crustal Age
Million Years B. P.
SIO15

Poll – Q 3

Short Video 4c

Earth's Magnetic Field

- magnetic north 2020 at: 86.5°N, 164.0°E

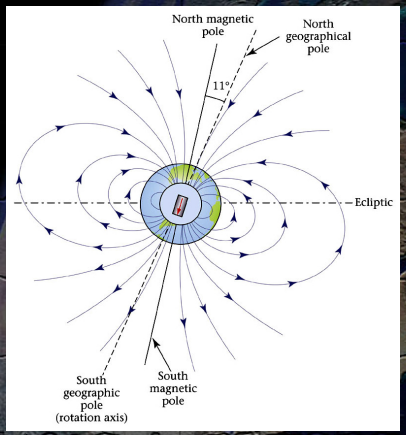


Fig 4.5

Shape:
like that of bar magnet (dipole)

Observables:
strength, declination, inclination

Origin:
currents in metallic liquid outer core
-> magnetic dynamo

Time Evolution:
changing field; reversals

- magnetic north 2000 at: 81.5°N, 111.4°W

Recording Earth's Magnetic Field

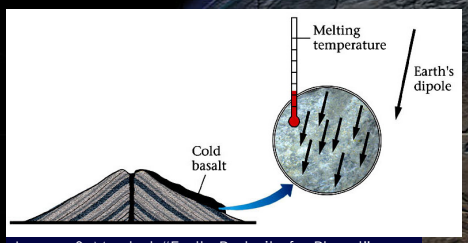


Image: S. Marshak "Earth, Portrait of a Planet"

Curie Temperature (~ 500°C)
above: domains align with mag. field
below: domains frozen

Fig 4.7

Source: Wikipedia

- rock freezing from magma record current field
- Earth's field/rock position change over time (record of magn. field)

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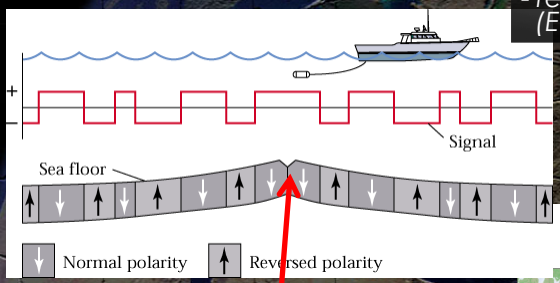
Fig. 4.13

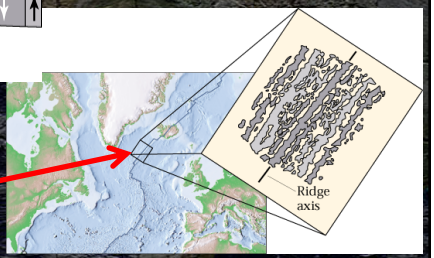
Seafloor Spreading

Short Video 4d

- mapping of magnetic anomalies (1960s)

- ship tows magnetometer
- records magnetic anomalies (Earth field+magnetized rock)





- new lava cools below Curie T
- current magnetic N frozen into rock
-rock moves away from ridge
- symmetric patterns

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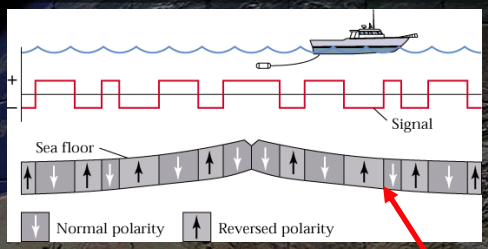
How fast does the Magnetic Field Reverse?

field direction maintained on the order of millions of years



SIO Professor Cathy Constable
(Photo: La Jolla Light)

Reversal:
anywhere between 100 and > 20,000 yrs
most say a few 1000 yrs

not related to mass extinctions!

Magnetic Field Reverse and Mass Extinctions

not related to mass extinctions!

Reversals:
anywhere between 100 and > 20,000 yrs
most say a few 1000 yrs

https://www.cnn.com/2021/02/19/world/magnetic-fields-earth-intl-scli-scn/index.html

CNN World Africa Americas Asia Australia China Europe India Middle East United Kingdom LIVE TV Edition

Reversal of Earth's magnetic poles may have triggered Neanderthal extinction -- and it could happen again

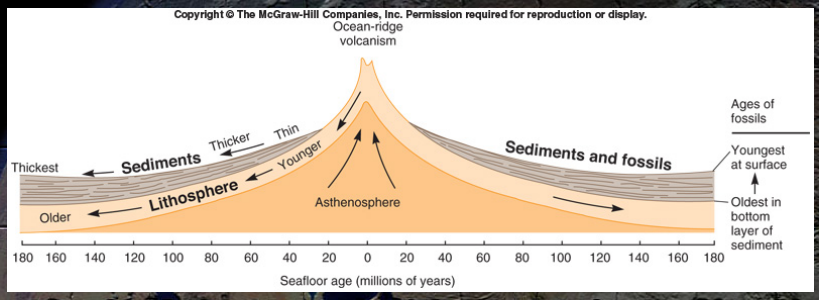
By Amy Woodyatt, CNN
Updated 10:49 AM ET, Fri February 19, 2021

- 42,000 years ago
- Temporary breakdown
- 800 years
- Laschamp Excursion
- "triggered dramatic climate shift"
- Why only Neanderthals?

Milankovitch cycles/supervolcano more like triggers for climate change!

- Changes in Earth's orbital parameters
  * Topic 21

Fig 4.12 The Cooling Oceanic Lithosphere



- New lithosphere at MOR pushes plates apart
- thickens, cools, gets dense
- loses buoyancy
- more likely to subduct
- sinking slabs pull rest of lithosphere behind it