Plate Tectonics Webinar Series

1. How Plate Tectonics Works

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Teacher Earth Science Education Programme Ltd

TESEP

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We wish to acknowledge the Traditional Owners of the land on which we meet today.

We also wish to pay our respects to Elders past, present and future.

All TESEP webinars are recorded

After each webinar episode you will be sent a link with:

- access to the slide set for that episode (including any embedded videos and links)
- access to a recording of that episode (YouTube)

After each episode you will also be sent:

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Please subscribe for news about forthcoming and new webinar series!

Australian Curriculum v.9 (F-10)

We will be following the Australian Curriculum v.9 (2022):

- Curriculum content for Years 7-10 only
- Focus on the Earth and Space science sub-strand
- Will follow as many other sub-strands as possible

Australian Curriculum v.9 (F-10)

Much of this webinar is dedicated to Year 8, "… continue to develop a view of Earth as a dynamic system, in which change occurs across a range of timescales".

Rocks and Minerals for the classroom, and Plate Tectonics webinars cover this fully.

This webinar Series will follow the following sub-strands:

Australian Curriculum v.9 (F-10)

Year 8

- Explain how new evidence or different perspectives can lead to changes in scientific knowledge (AC9S8H01) - **Covered in episodes 1, 2 and 5.**
- Investigate tectonic activity including the formation of geological features at divergent, convergent and transform plate boundaries and describe the scientific evidence for the theory of plate tectonics (AC9S8U03) - **Covered in episodes 3-6.**
- Develop investigable questions, reasoned predictions and hypotheses to explore scientific models, identify patterns and test relationships (AC9S8I01) - **All episodes**
- Describe the key processes of the rock cycle, including the timescales over which they occur, and examine how the properties of sedimentary, igneous and metamorphic rocks reflect their formation and influence their use (AC9S8U04**) - Covered in episode 3**

https://v9.australiancurriculum.edu.au/

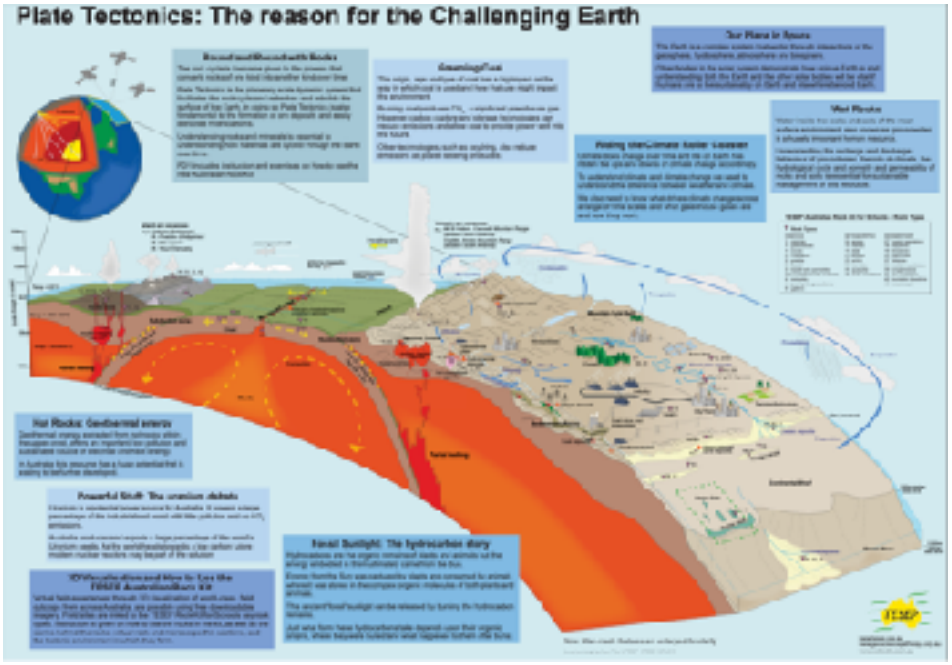
Australian Curriculum v.9 (F-10)

Episode 1 (AC9S8U03)

- modelling interactions at plate boundaries
- investigating the relative significance of different forces involved in tectonic plate movement including slab pull, ridge push and convection

https://v9.australiancurriculum.edu.au/

TESEP Rock Kit and Plate Tectonics Poster

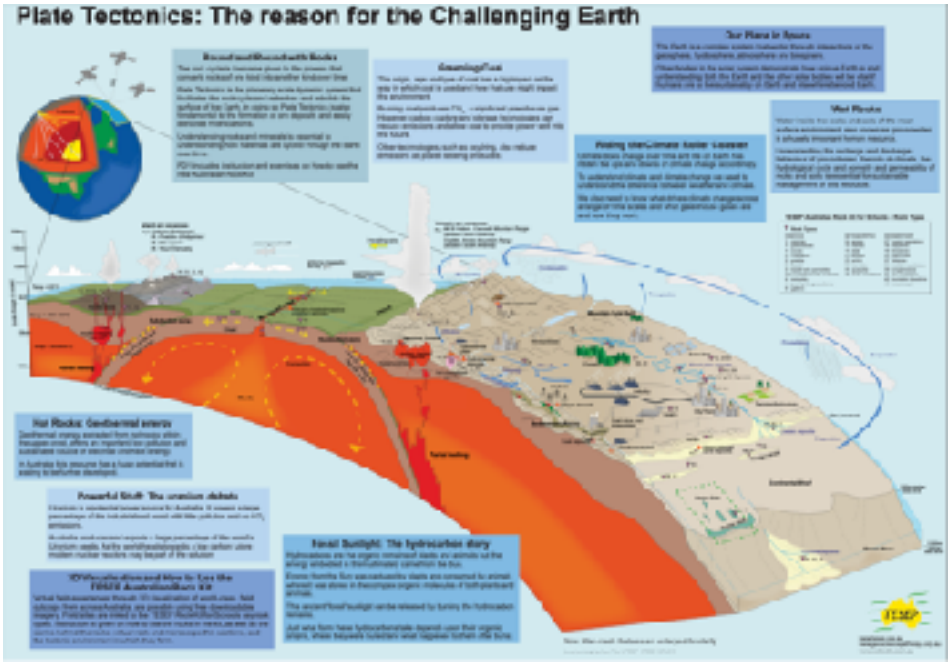


A great to teach where rocks form and the industries that extract and use them.

Get them from haines.com.au or host a PD at your school!

You can also get them as a bundle

TESEP Rock Kit and Plate Tectonics Poster



The rock kit (and rock numbers) will be referred to in each episode

Background

Plate tectonics is a fundamental process on Earth.

It explains the distribution of different rocks, minerals and fossils through geological time, the occurrence of natural hazards like volcanic eruptions and earthquakes, and landforms.

But how does it work?

How did we learn about it?

What are the impacts on life on Earth?

Critical Minerals PD overview

This PD has 6 episodes:

1. How plate tectonics work
2. History of the plate tectonic theory
3. Rocks, minerals and resources
4. Magmatism and volcanoes
5. Tectonics and landforms
6. Natural hazards

What is plate tectonics?

The term refers to how the Earth's surface is built of plates.

- In geology, a 'plate' is a large, rigid slab or rock.
- 'Tectonics' comes from the Greek work root 'to build.

The theory of plate tectonic states that the Earth's outermost layer is fragmented into a dozen or more large and small plates

- That are moving relative to one another as they ride atop hotter, more mobile material.

The 'theory of continental drift' was the forerunner to the theory of plate tectonics.

Source: *Historical perspective [This Dynamic Earth, USGS]*

Are there any new discoveries in Plate tectonics? Mantle Waves

BBC

Mystery behind major landforms solved, scientists say

8 August 2024

Share Save

Charlotte Andrews & PA Media
BBC News

Great escarpments can be found in southern Africa, India, Brazil and Australia

The mystery of how some of the Earth's most dramatic landforms came into being has been solved, scientists believe.

Researchers from the University of Southampton studied the creation of steep slopes called great escarpments.

It was previously not known how the giant plateaus found in southern Africa, India, Brazil and Australia, originated.

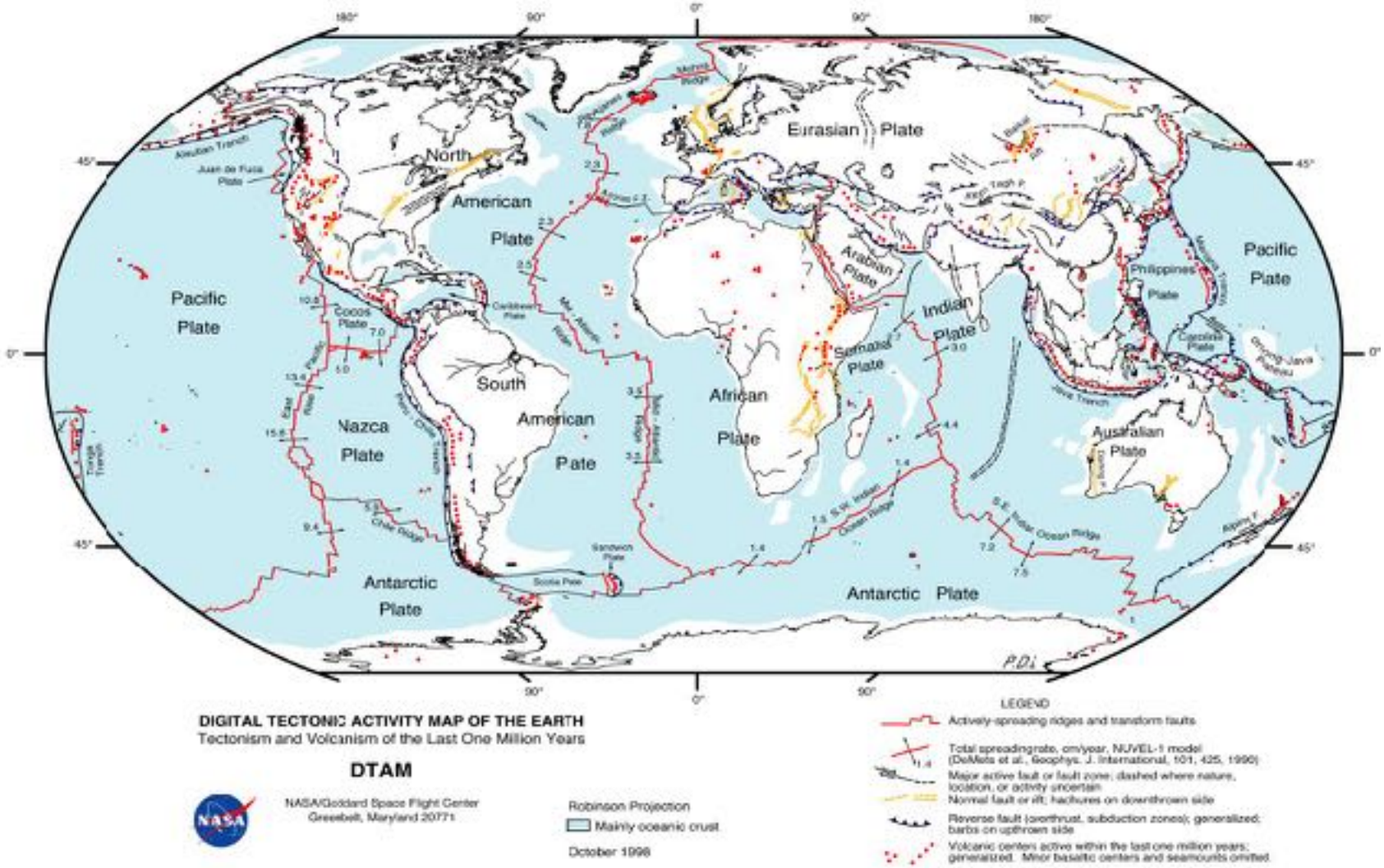
What is plate tectonics?

There is also some myth busting due to new models and evidence:

- What drives plate tectonics?
- Is the mantle a liquid or a solid?

We will cover these two questions in this episode.

What are plates?



Source: *phpaQCmzk.png (899×579) (cheggcdn.com)*

What are plates?

Continental Plates	Oceanic Plates
Granitic (Si, Na, K, Al)	Basaltic (Fe, Mg, Ca)
Average Density: 2.6g/cm^3	Average Density: 3.0g/cm^3
Average Thickness: 30km (0-75km)	Average Thickness: 6km (0-10km)
Age range: 0-4 Billion years	Age range: 0-340 Million years
Continental plates are lighter	Oceanic plates are denser

If they collide, what is likely to happen?

What are plates?

Continental Plate rocks

Granite TESEP No. 25

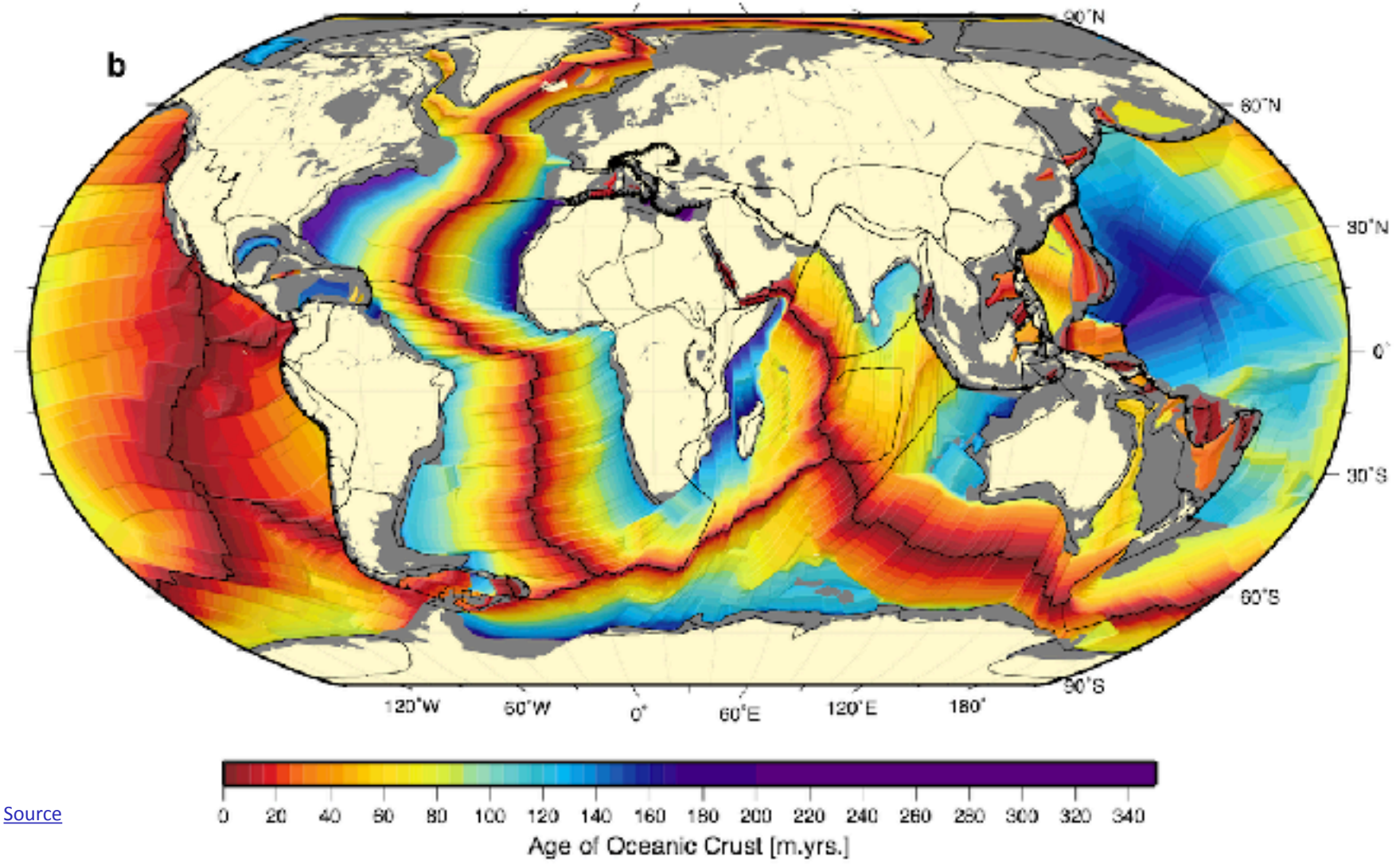
Source

Oceanic Plate rocks

Basalt TESEP No. 34

Source

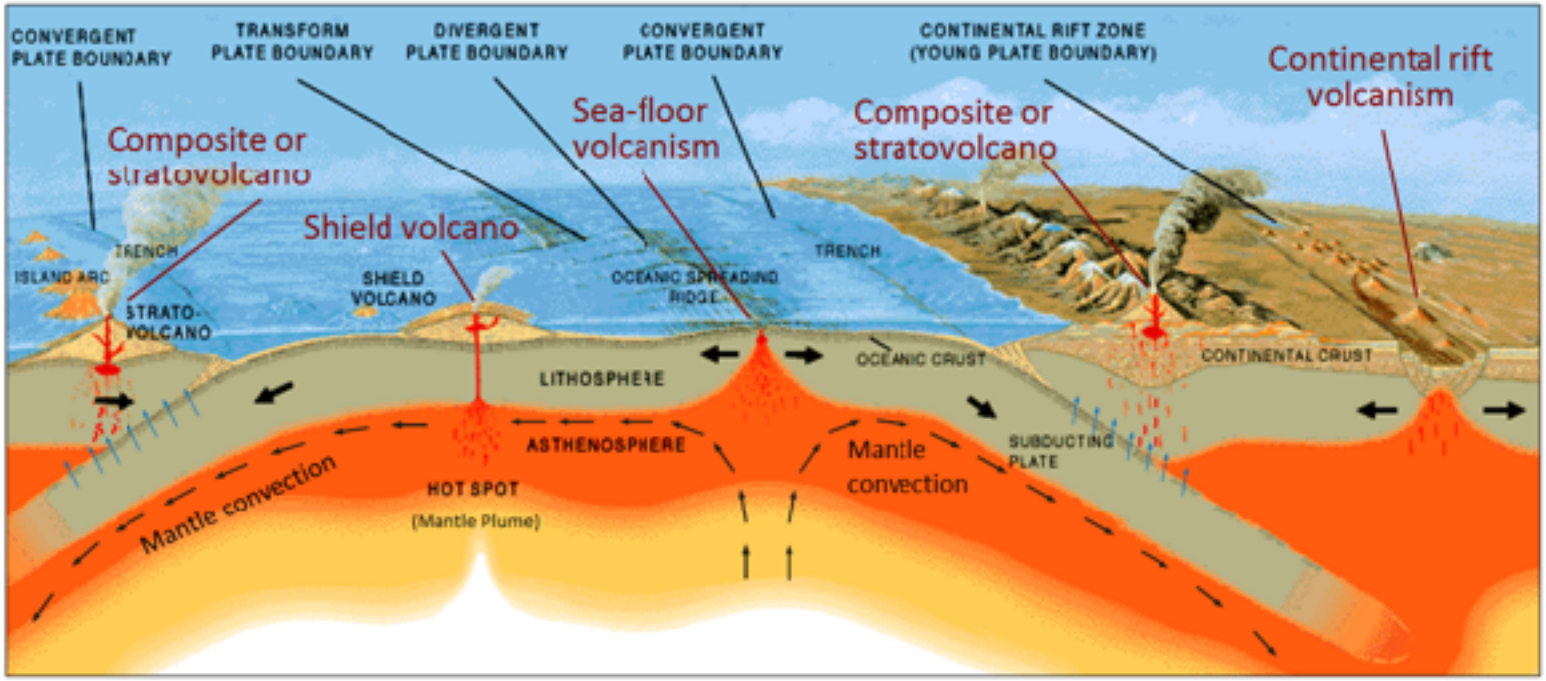
What are plates?



Source

Plate tectonics

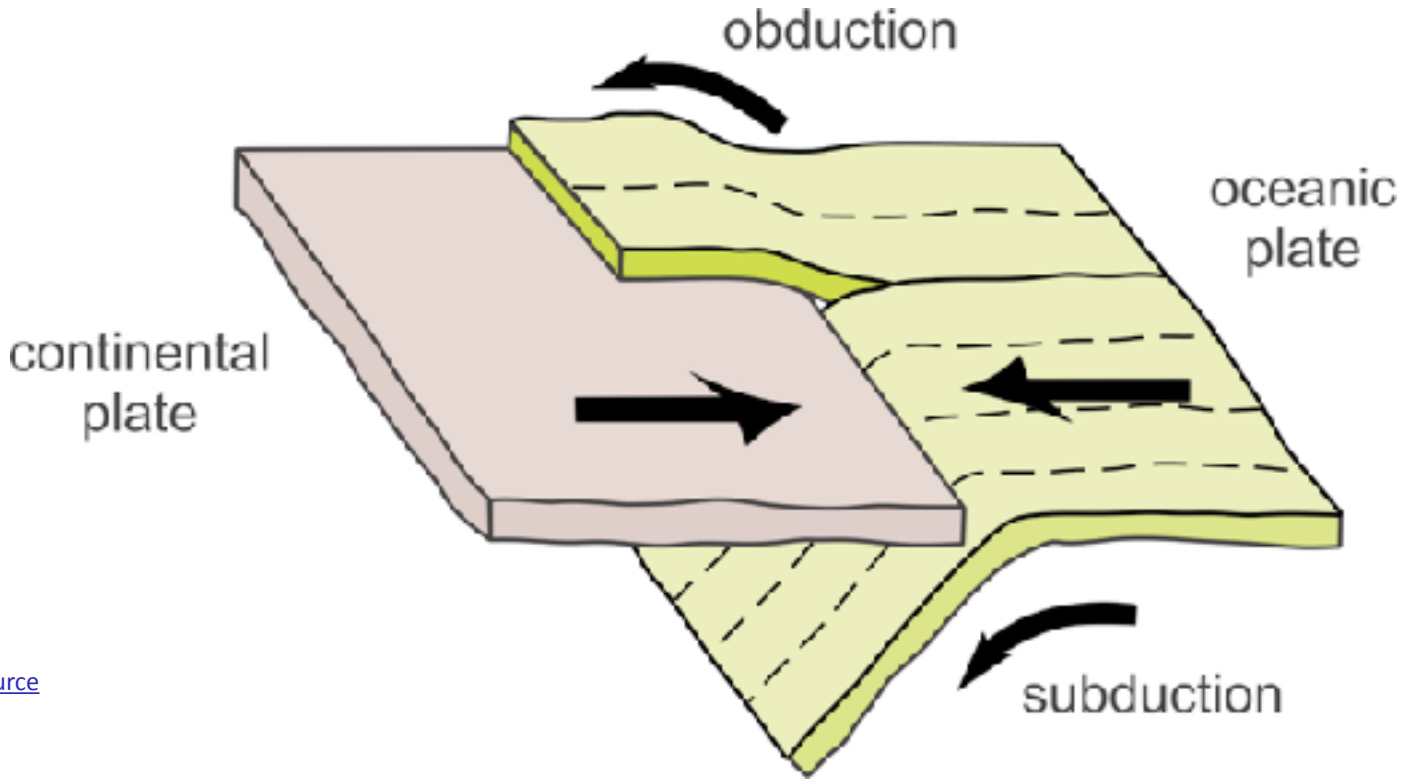
- The tectonic plates are the ‘outer skin’ of Earth – they interact in three ways:
  - Convergent* (come together) – volcanoes and earthquakes
  - Divergent (move away) – volcanoes and earthquakes
  - Transform (slide past) – earthquakes only.



Source: BC open textbooks

Plate tectonics

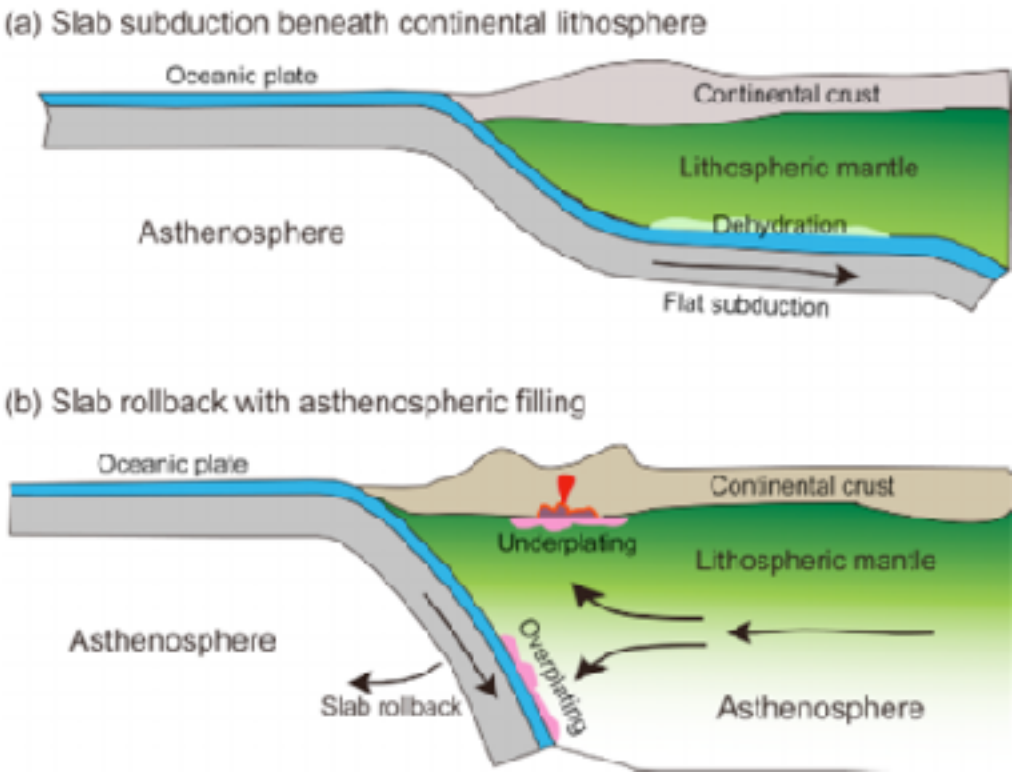
- The tectonic plates are the ‘outer skin’ of Earth – they interact in three ways:
  - There are two different types of convergent plate margins**
  - Part of the Pacific plate is obducting the Australian plate



Source

Plate tectonics

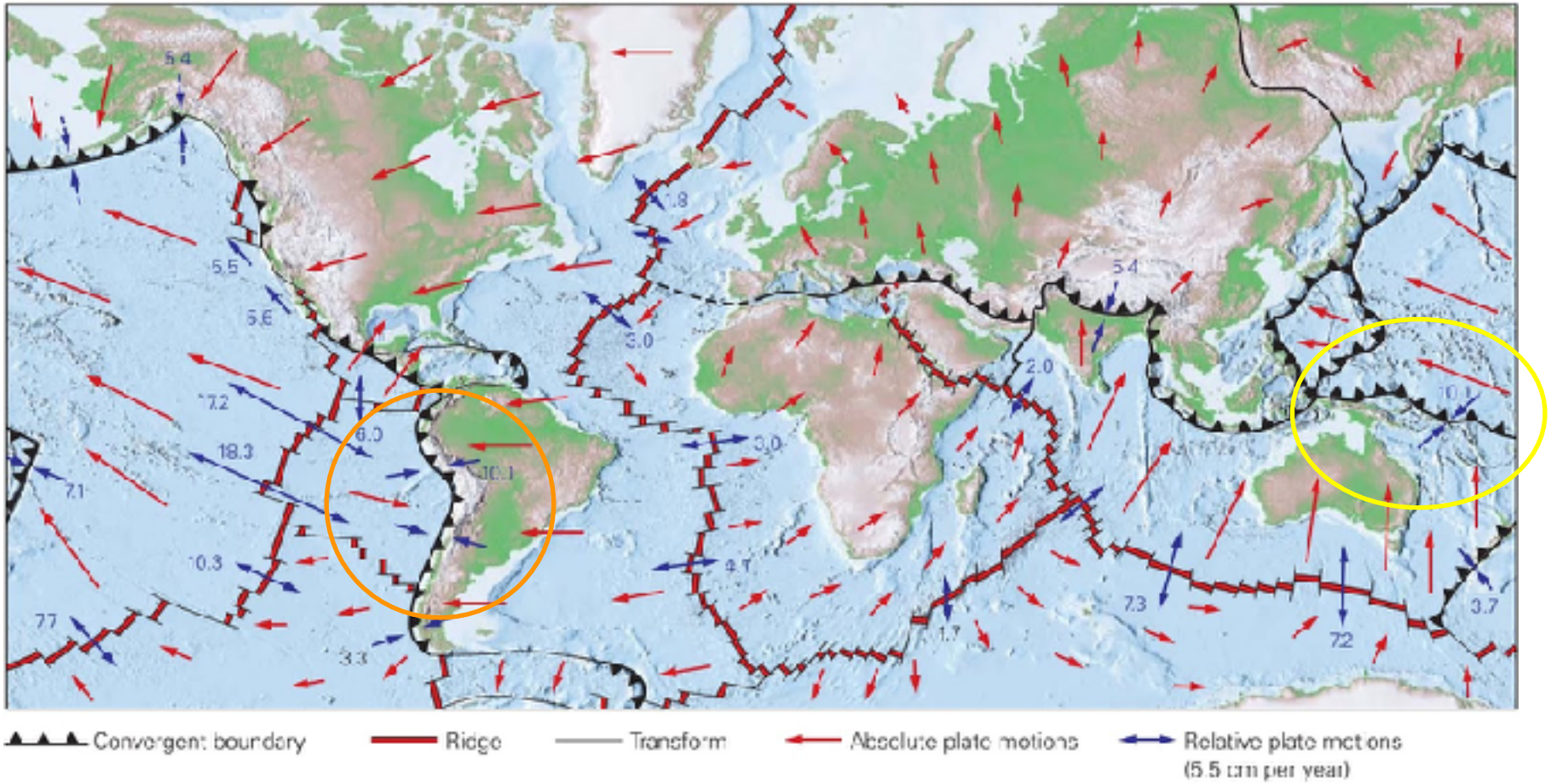
- The tectonic plates are the ‘outer skin’ of Earth – they interact in three ways:
  - Convergent margins have different types of subduction (e.g., flat-slab, oblique, etc.)
  - Flat-slab subductions do not result in roll-back or trench-suction/mantle wedge



Source

Plate tectonics

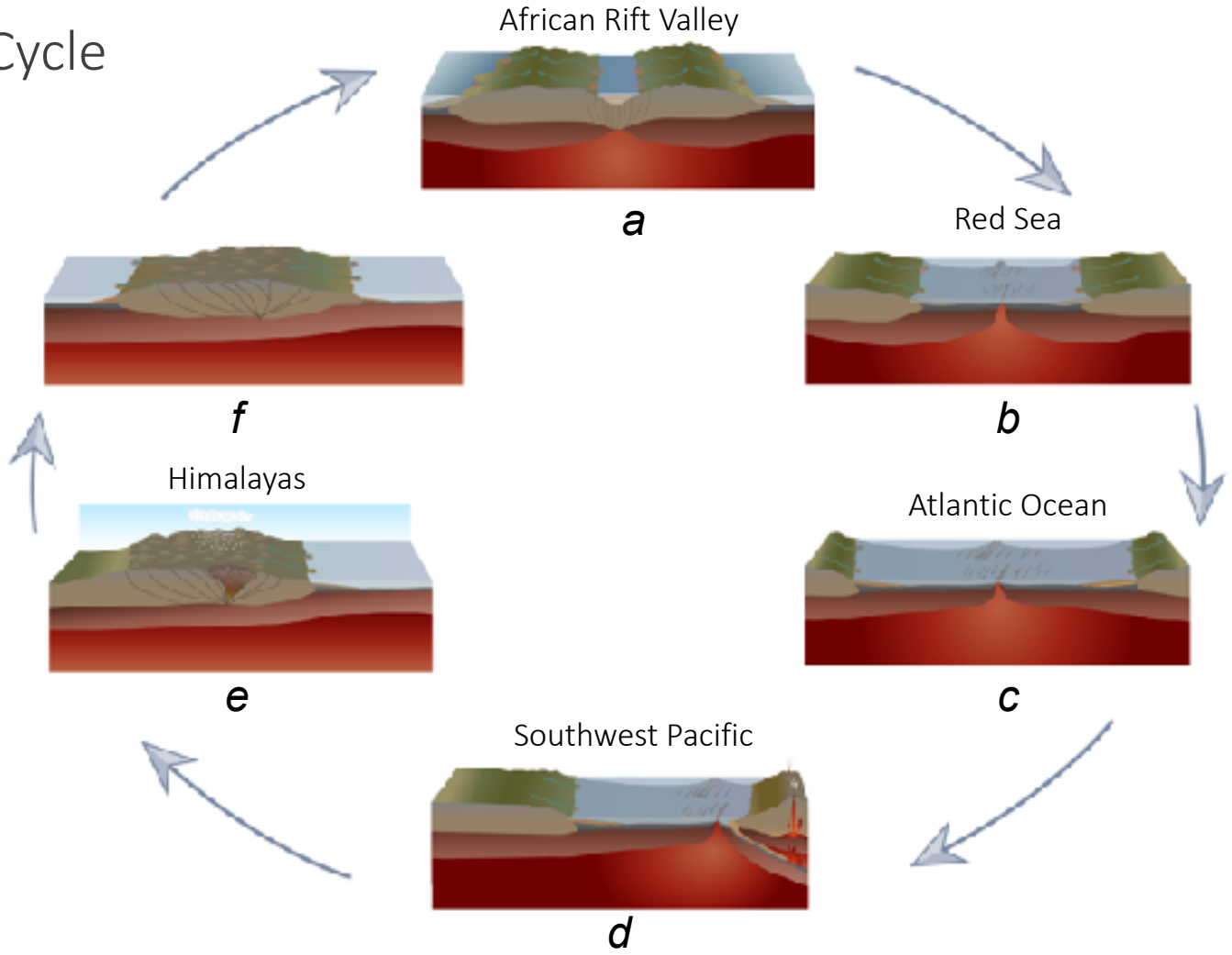
Rates of movement (cm)



Obduction highlighted in yellow; flat-slab subduction highlighted in orange

Source

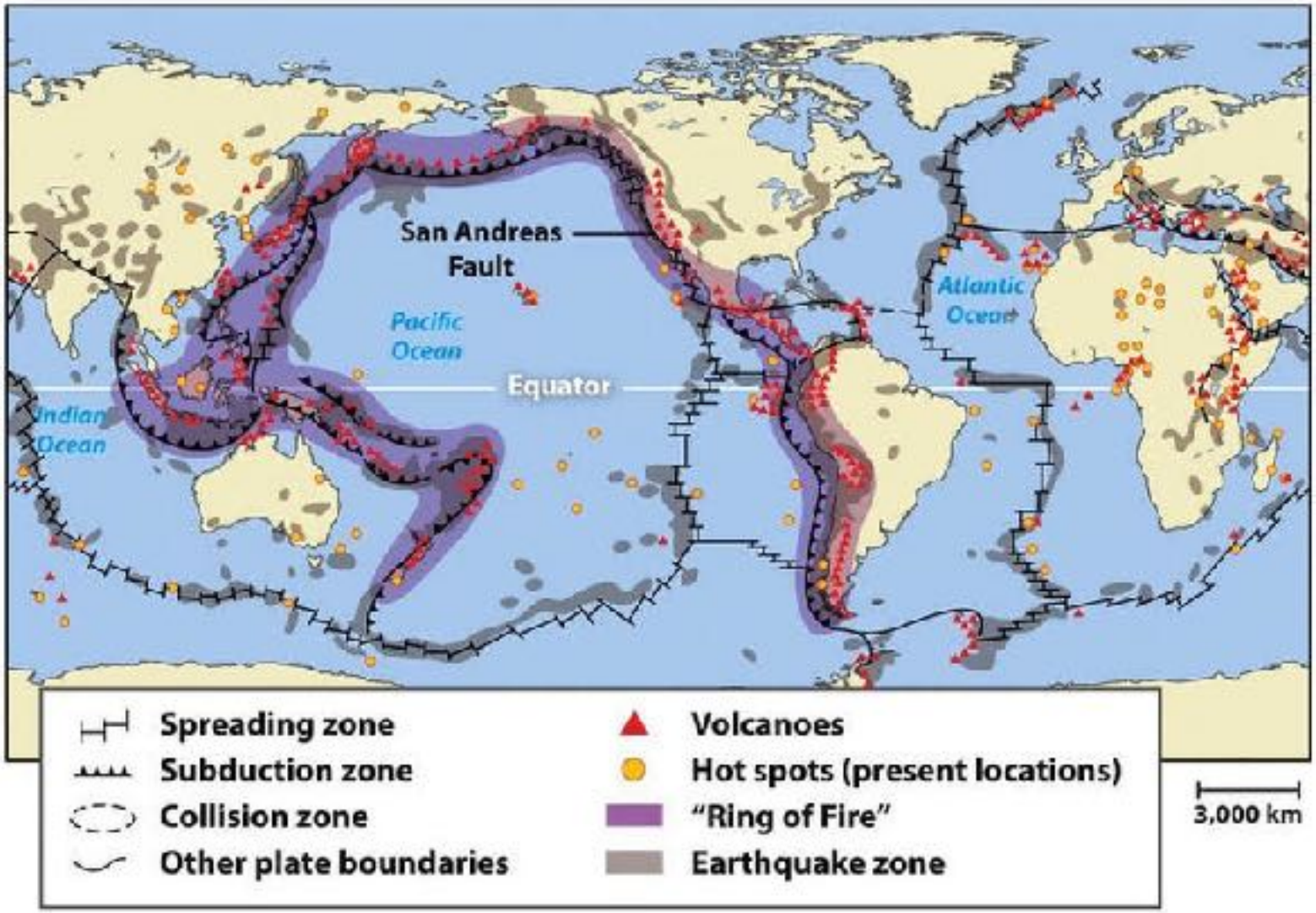
Wilson Cycle



a. Rift-to-drift phase, initial opening of an oceanic basin; b. Seafloor spreading; c. Widening of the basin; d. Subduction of oceanic plate, closure of the basin; e. Continent-continent collision; f. Continent erodes, thinning the crust

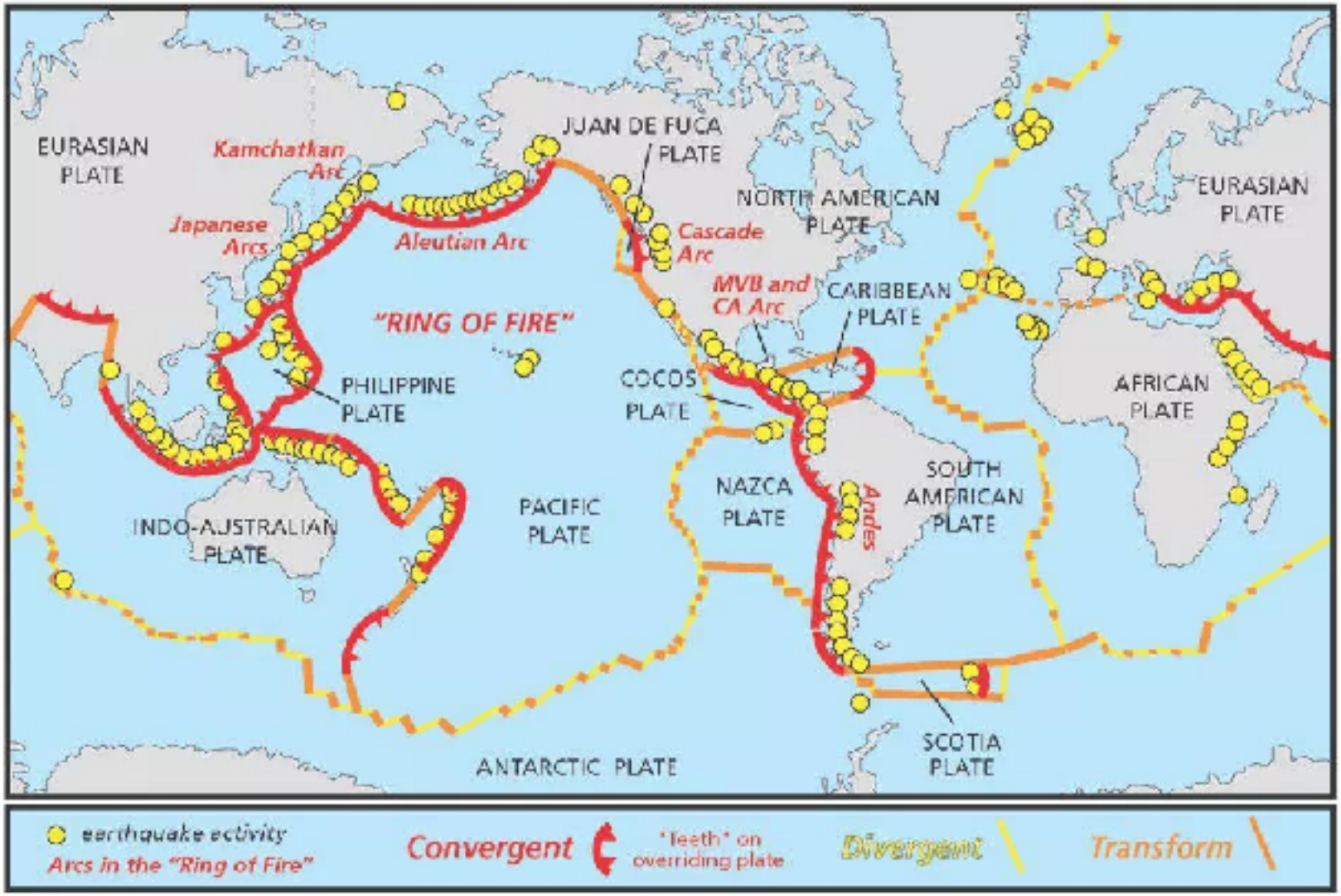
Source: : File:Rock cycle in Wilson Cycle.png - Wikimedia Commons

Volcanoes and plate margins



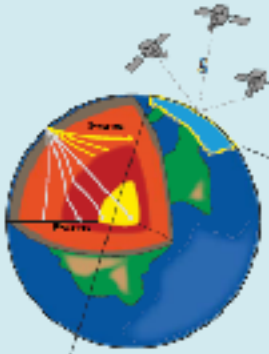
Source

Earthquakes and plate margins



Source

Plate Tectonics: The reason for the Challenging Earth



Round and Round with Rocks

The rock cycle is the name given to the process that converts rocks of one kind into another kind over time.

Plate Tectonics is the planetary scale dynamic system that [illegible] surface of the Earth. In doing so Plate Tectonics is also fundamental to the formation of ore deposits and usually extracted hydrocarbons.

[illegible] PDI includes [illegible] on Uranium and the new Geoscience Rock Kit.

Greening Coal

The origin, age and type of coal has a big impact on the way we mine it, and on how [illegible] might impact the environment.

[illegible] However, carbon capture and storage technologies are [illegible] the future.

Other technologies, such as oxyfiring, also reduce [illegible]

Our Place in Space

The Earth is a complex system that works through interactions of the geosphere, hydrosphere, atmosphere and biosphere.

Other bodies in the solar system [illegible] and understanding both the [illegible]

Riding the Climate Roller Coaster

Climate change [illegible] and the Earth has ridden the ups and downs of climate change accordingly.

To understand climate and climate change we need to understand the difference between weather and climate.

We also need to know what drives climate change across a range of [illegible] and how they work.

Wet Rocks

Water inside the rocks and soils of the near surface environment, also known as groundwater, is a hugely important human resource.

Understanding the [illegible] behaviour of groundwater, the role of climate, the hydrological cycle and porosity and permeability of rocks and soils, is essential for sustainable [illegible]

Hot Rocks: Geothermal energy

Geothermal energy, extracted from hot rocks within the upper crust, offers an important, low pollution and [illegible] waiting to be further developed.

Powerful Stuff: The uranium debate

Uranium is a potential power source for Australia. It powers a large [illegible] emissions.

[illegible] Australia's Uranium [illegible] nuclear reactors may be part of the solution.

3D Visualisation and How to Use the TESEP Australian Rock Kit

Virtual field experiences through 3D visualisation of world-class field outcrops from across Australia, are possible using fine-resolution imagery. Field sites are linked to the TESEP Rock Kit for Schools key rock [illegible] stories behind the rocks, virtual rock and microscope thin sections, and the tectonic environments in which they form.

Fossil Sunlight: The hydrocarbon story

Hydrocarbons are the organic remains of plants and animals and the [illegible]

Energy from the Sun was captured by plants and [illegible] where it was stored in the complex organic molecules of both plants and animals.

This ancient fossil sunlight can be released by burning the hydrocarbon [illegible]

Just what form these hydrocarbons take depends upon their organic origins, where they were buried and what happened to them after burial.

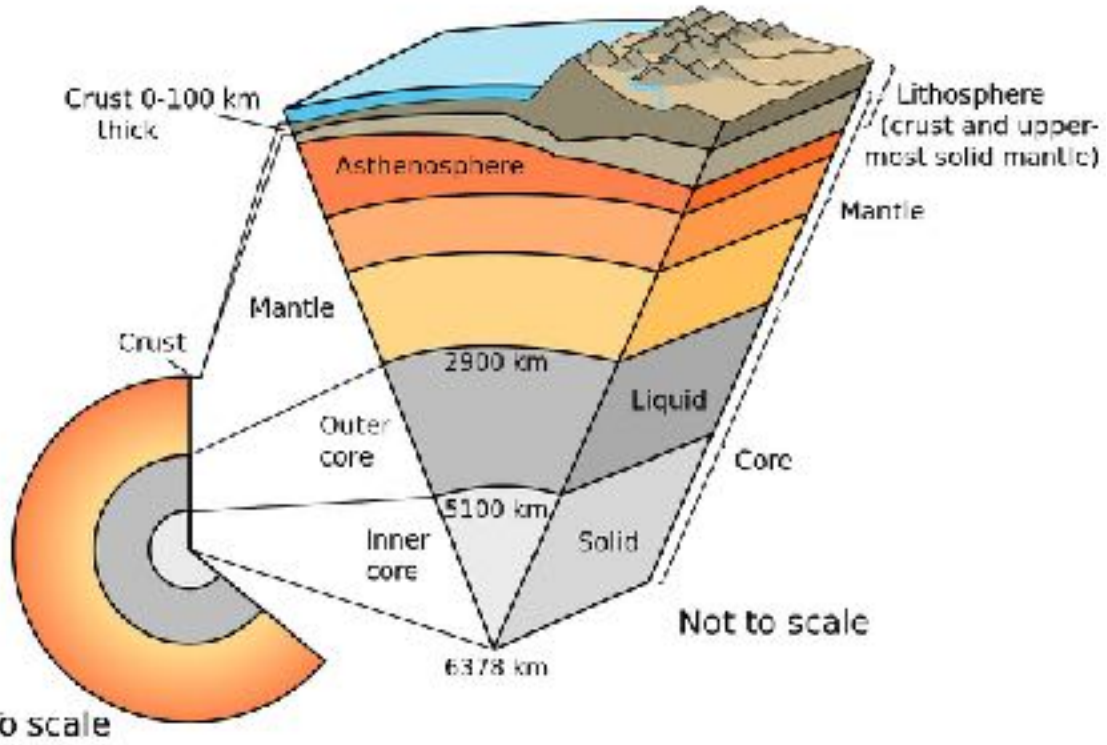
Note: Main inside features and colours for clarity

TESEP

What drives plate tectonics?

The mantle is below us for 3000km!

- The temperature and pressure of the mantle increase with depth.
- Temperature ranges from



Source: *mantle | National Geographic Society*

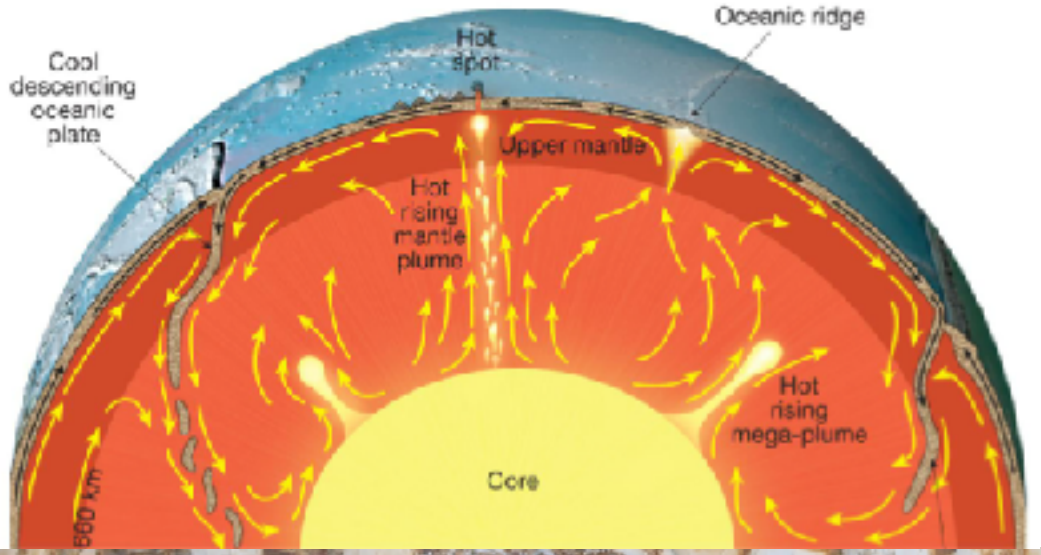
What drives plate tectonics?

Traditional theory is that convection cells in the mantle is the driver of plate tectonics

- Hot material rises and cold material sinks
- Debate over whole of mantle or layered convection.

However – this theory is now outdated but still commonly used.

Source: *main-qimg-2357448e0009ae25d18c27223114032f (549×328) (quoracdn.net)* *mantle | National Geographic Society* *eps_4375.jpg (2250×1500) (cloudinary.com)*

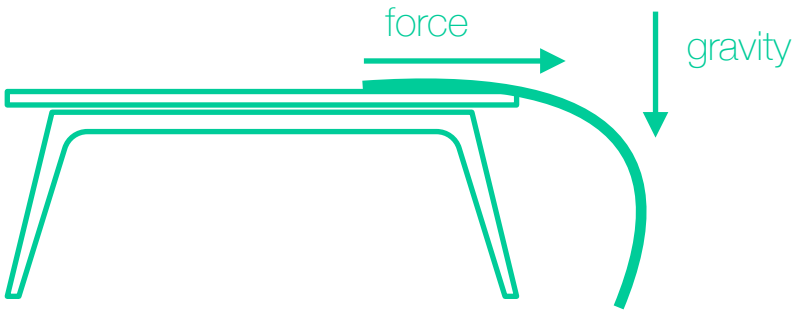


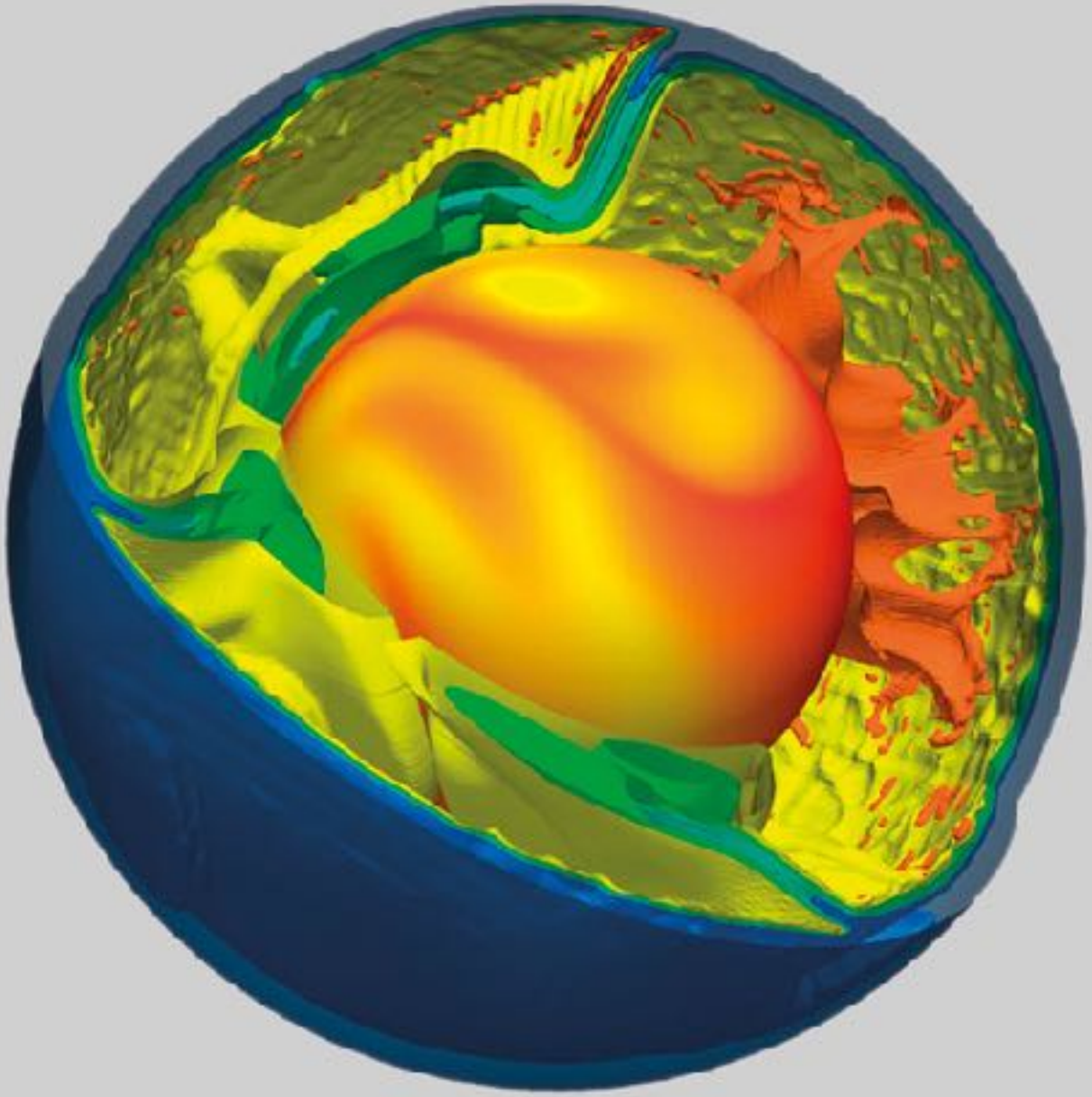
What drives plate tectonics?

Current models suggests a ***gravity-driven convection system*** drives plate tectonics. Plate motion is driven by a combination of 4 main forces, rather than convection alone.

- Why?
- Current models suggest that the tectonic plates move quicker than mantle convection
- What, then, is driving plate tectonics?

1. Think of a heavy tablecloth on a dinning room table …



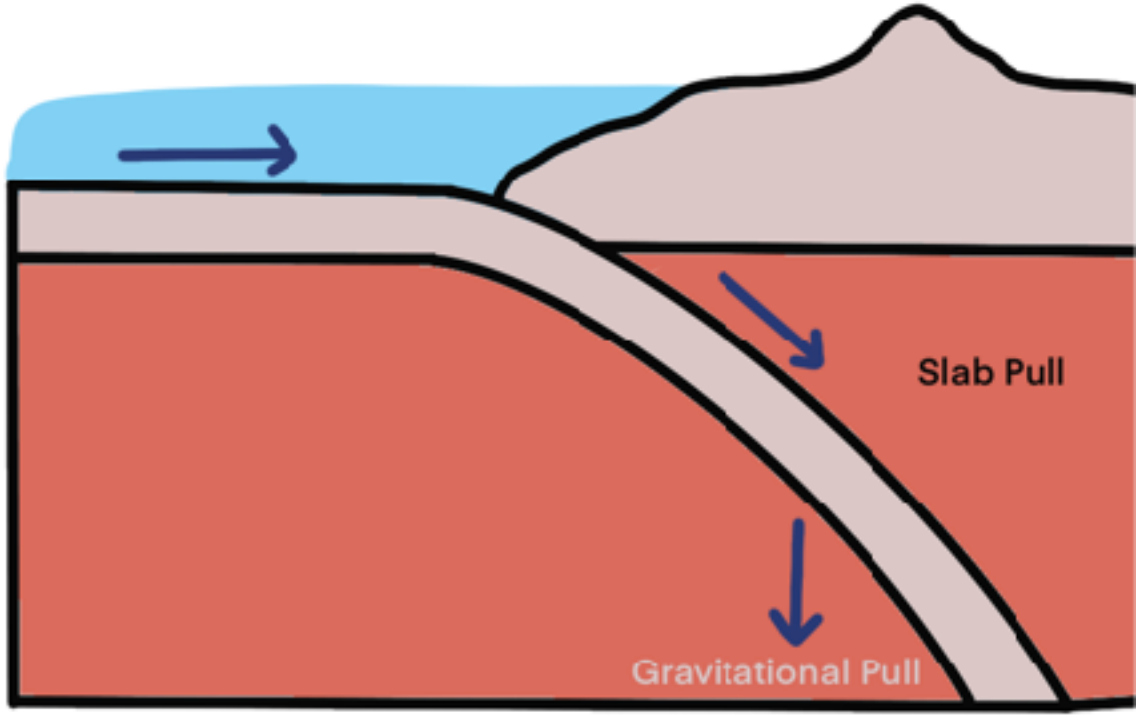


Source

What drives plate tectonics?

1. Slab pull

The slab (lithosphere) is denser than the underlying mantle (asthenosphere), which enough to pull the rest of the plate into the mantle via gravity

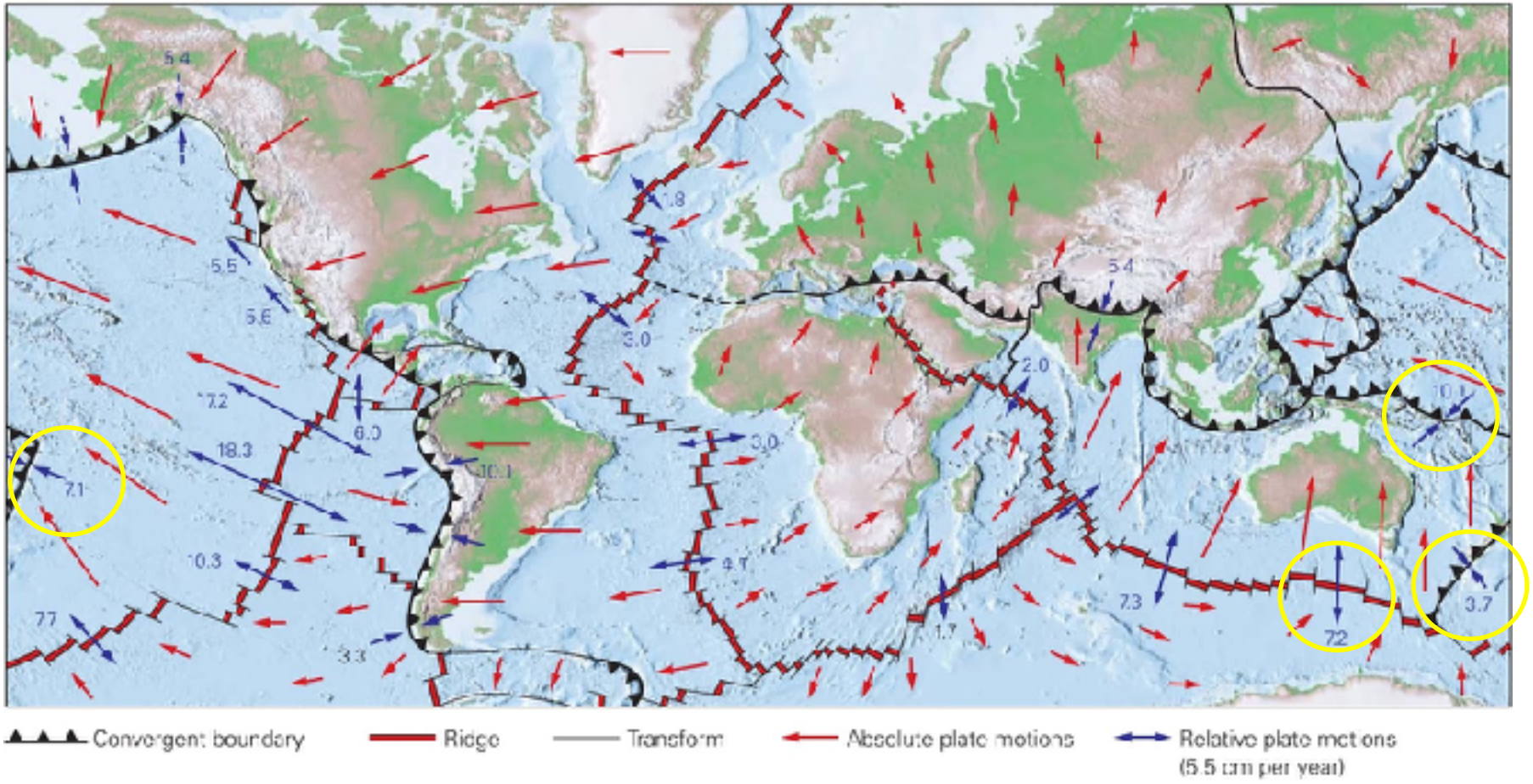


Simple model

Source

Plate tectonics

Rates of movement (cm)

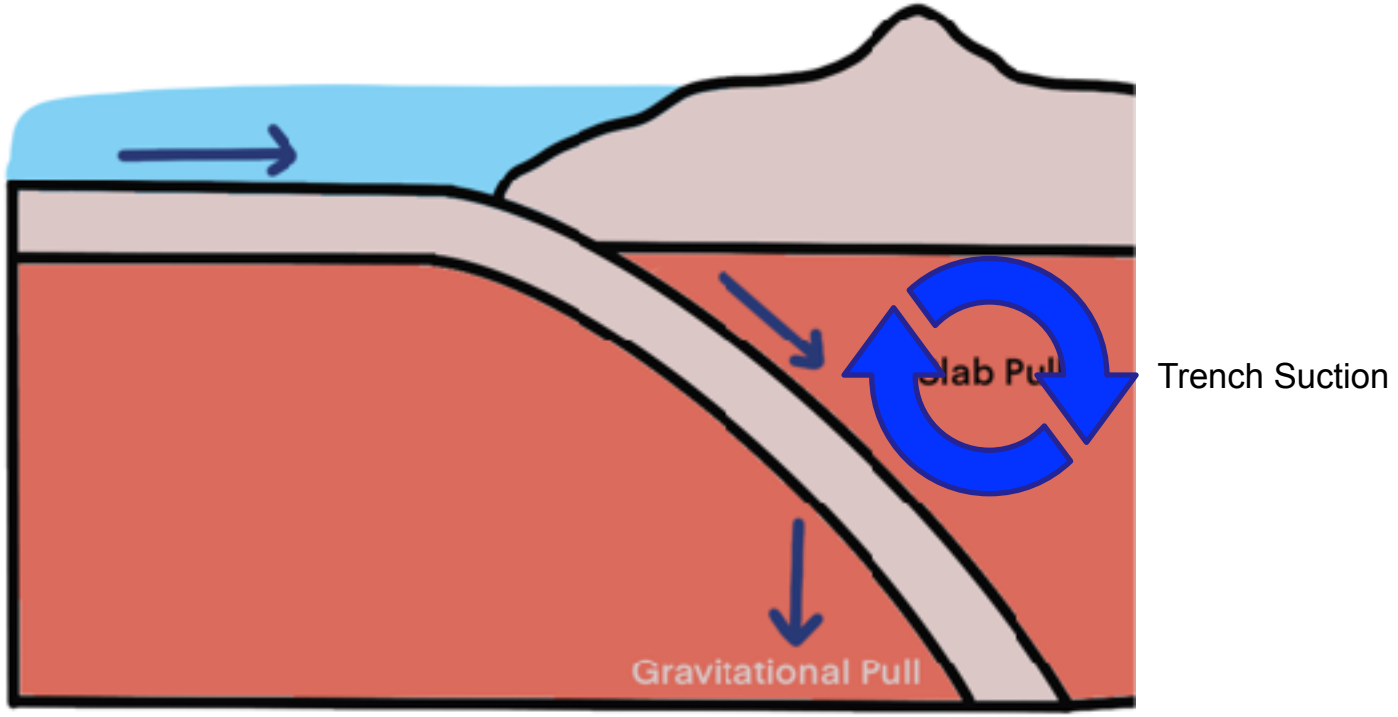


Source

What drives plate tectonics?

2. Trench (Slab) Suction

The subduction plate creates a small isolated convection cell in the mantle wedge. This creates an addition force and speed up subduction.



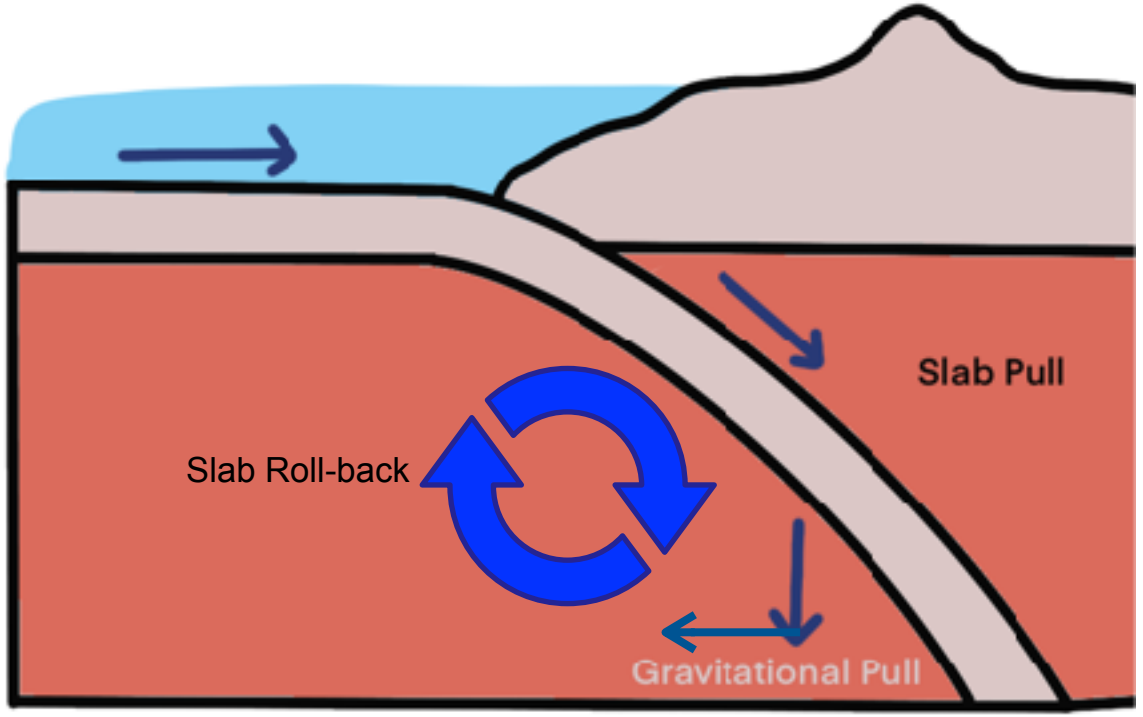
Simple model

Source

What drives plate tectonics?

3. Slab Roll-back

Subduction creates a small convection cell under the slab. This creates an addition force.



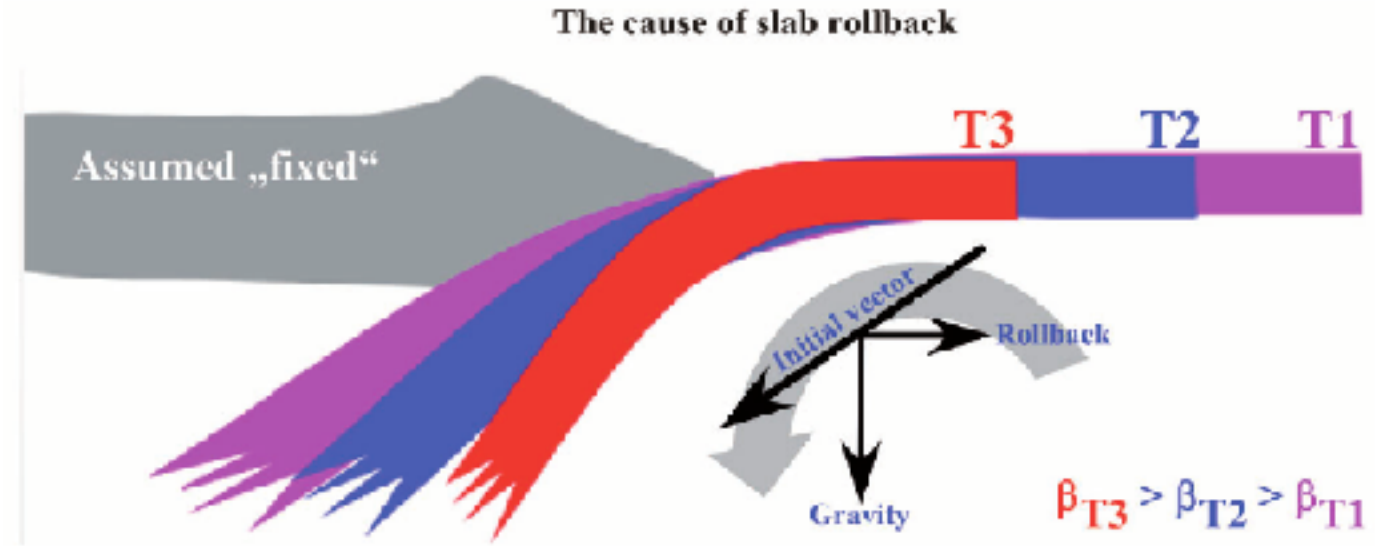
Simple model

Source

What drives plate tectonics?

3. Slab Roll-back

Subduction creates a small convection cell under the slab. This creates an addition force.



Simple model

Source

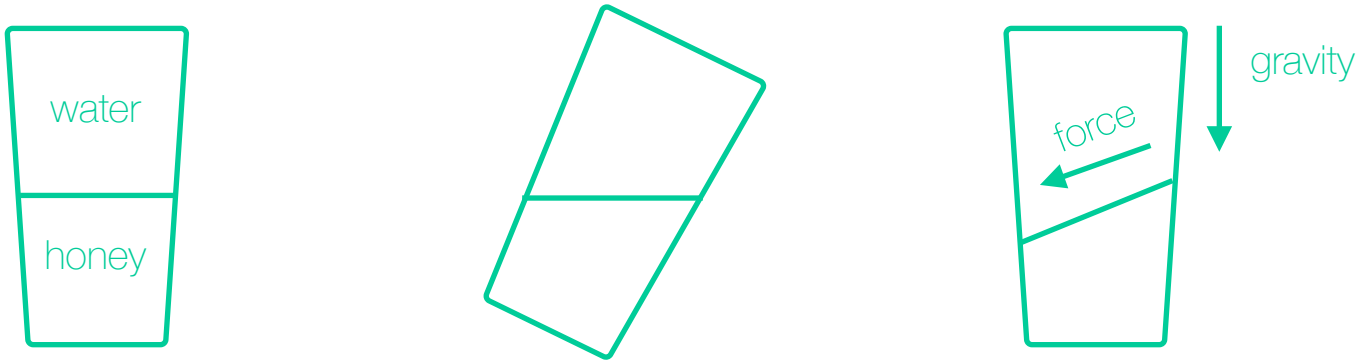
What drives plate tectonics?

Current models suggests a ***gravity-driven convection system*** drives plate tectonics

Facts

- The upward movement of the mantle pushes against the thin divergent plate margin
- The mid-oceanic ridge (and mantle) is higher than the surrounding oceanic plate

2. Think of glass filled with honey and water. Now tilt the glass so you get a wedge of honey on one side and place it back on the table again.

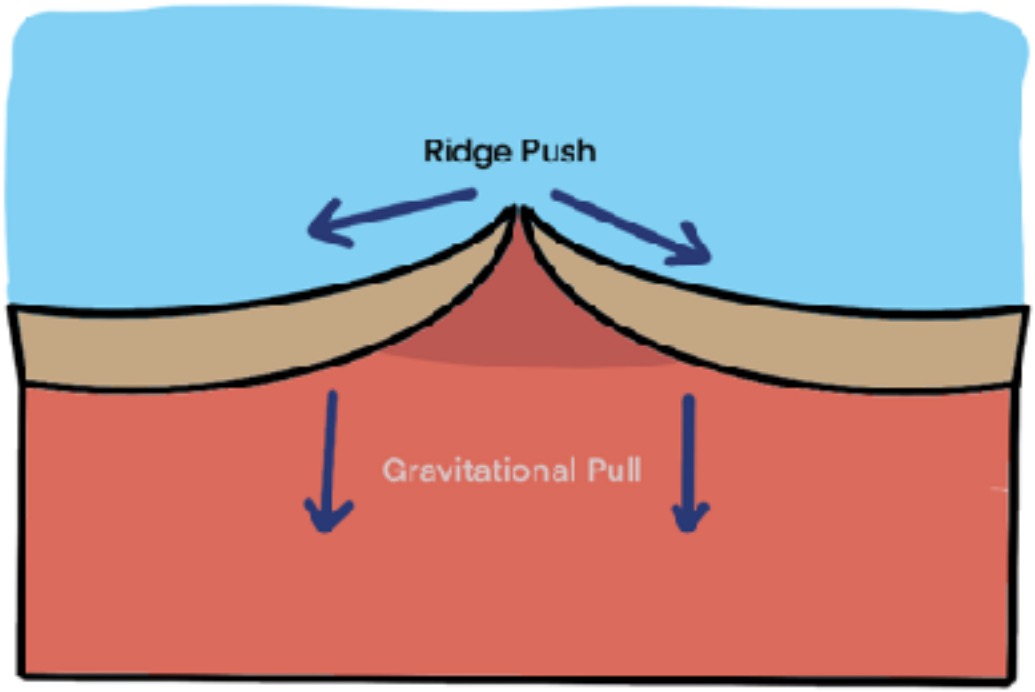


Source: *Earthquakes_and_plates.png (720×443) (usask.ca) Plate Tectonics—What Are the Forces that Drive Plate Tectonics?- Incorporated Research Institutions for Seismology (iris.edu)*

What drives plate tectonics?

4. Ridge push

The mantle (asthenosphere) is higher at the ridge, which enough to push the rest of the plate sideways via gravity.



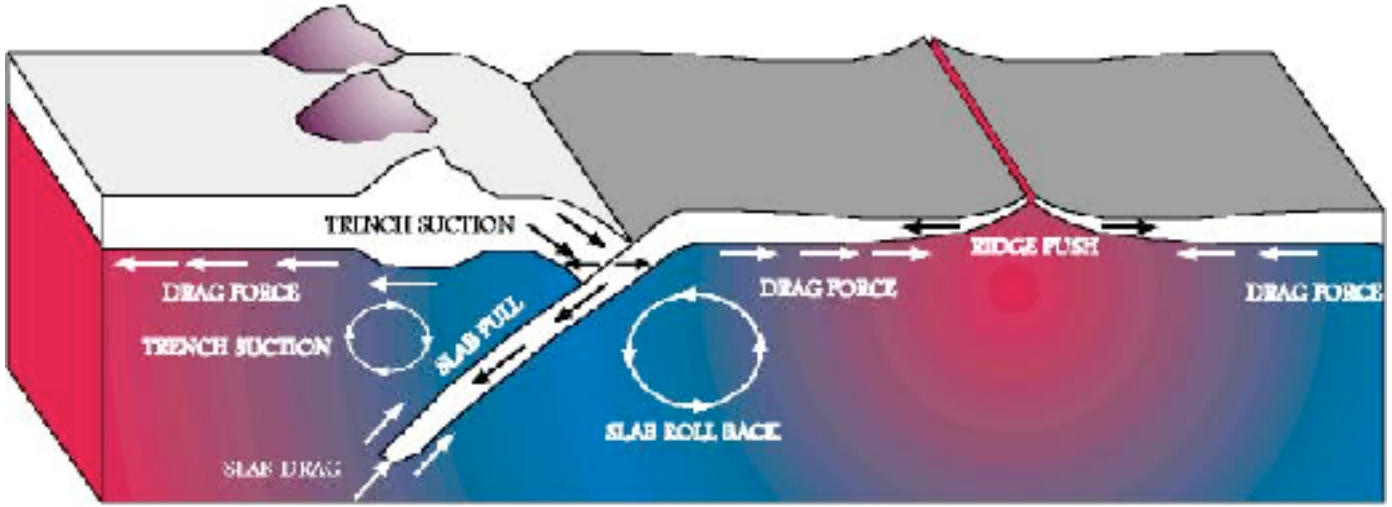
Simple model

Source

What drives plate tectonics?

Plate motion is driven by a combination of 4 main forces*, rather than convection alone

1. Slab Pull
2. Trench or Slab Suction (speed up subduction)
3. Plate Roll-back (speed up subduction)
4. Ridge Push



Source

Want more information?

What is the Mantle made of?

The Mantle

Peridotite (Fe, Mg rich, Si poor)

Dominantly olivine

Contains chromite, pyroxenes

Average Density: 3.2g/cm^3

Mantle is **solid** (under high P/T)

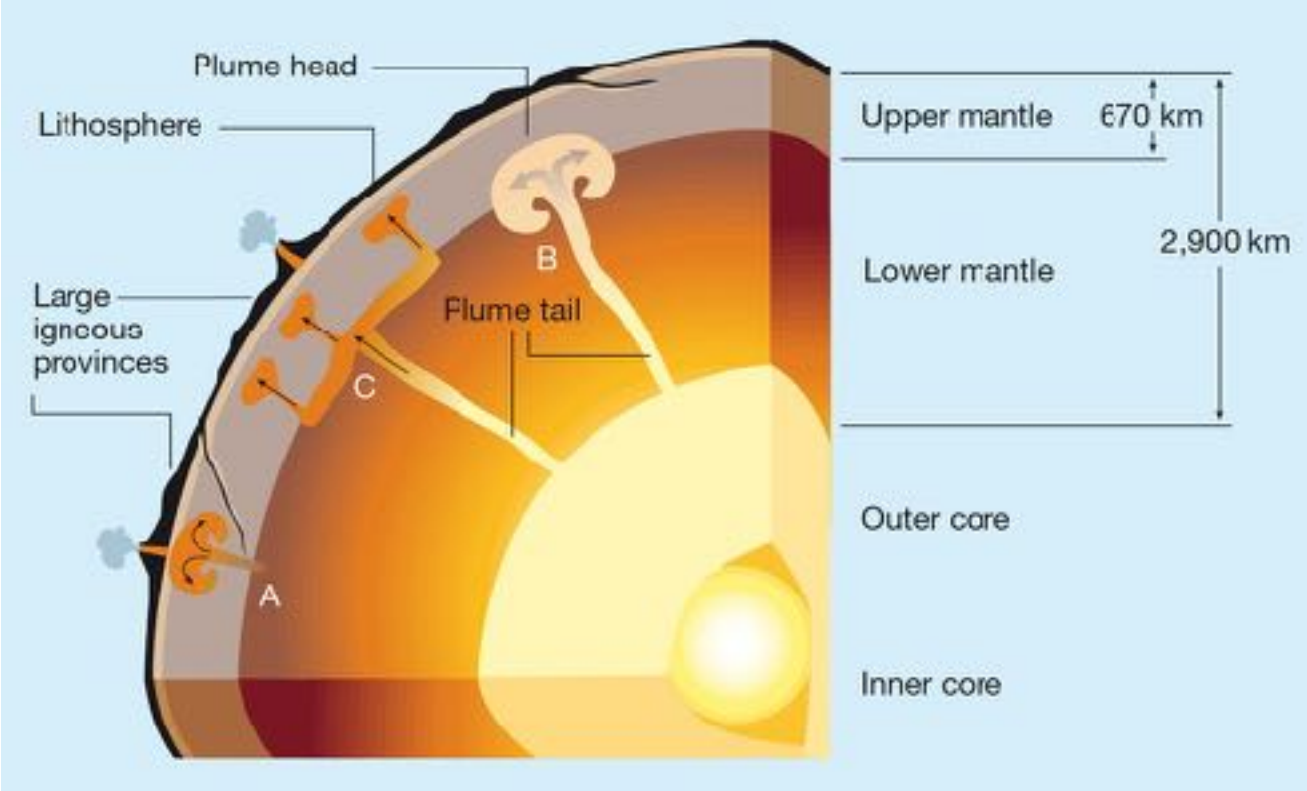
Mantle rocks

Peridotite TESEP No. 34

Source

Hot spots

Mantle plumes provide upwelling of magma to form hot spot volcanoes.

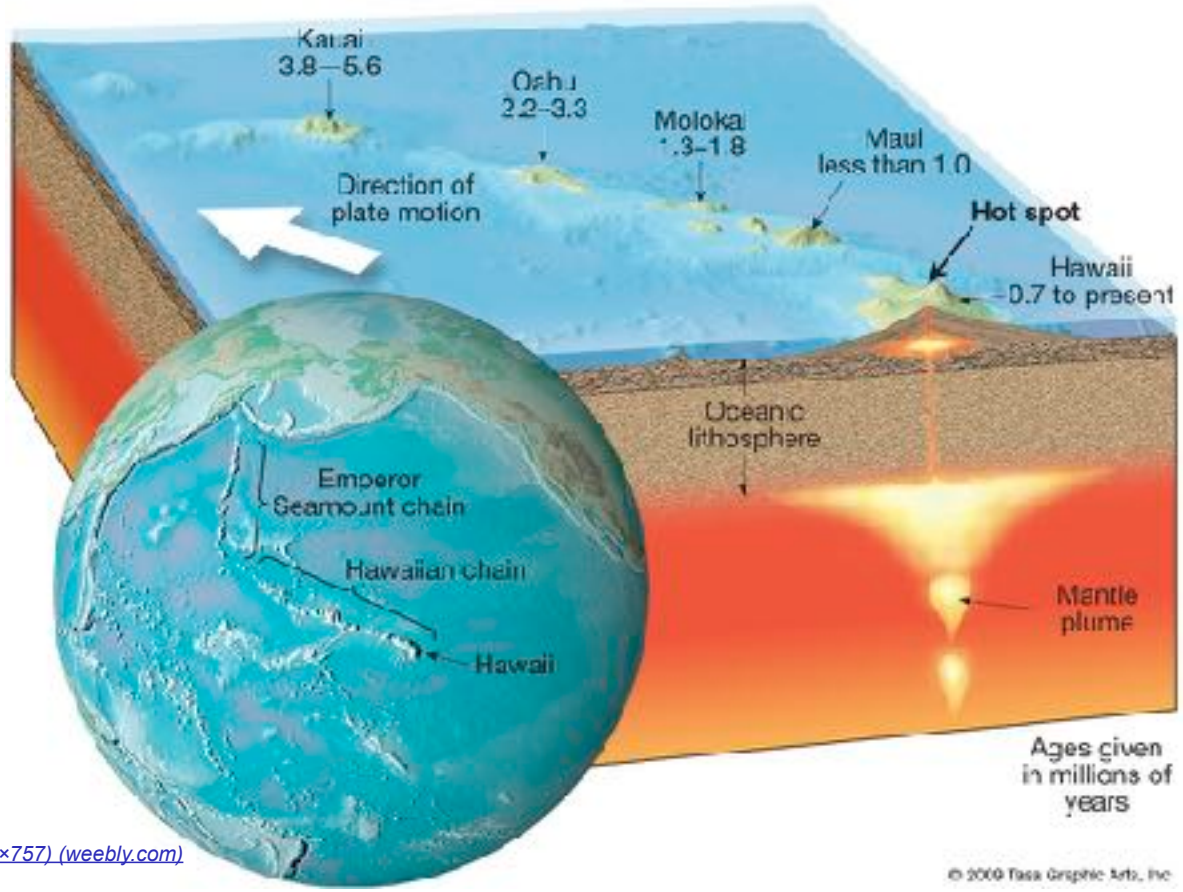


Source: f2c138e5-92d8-4fc3-a459-bea5600a4b88.jpg (1000×606) (nationalgeographic.org)

Hot spots

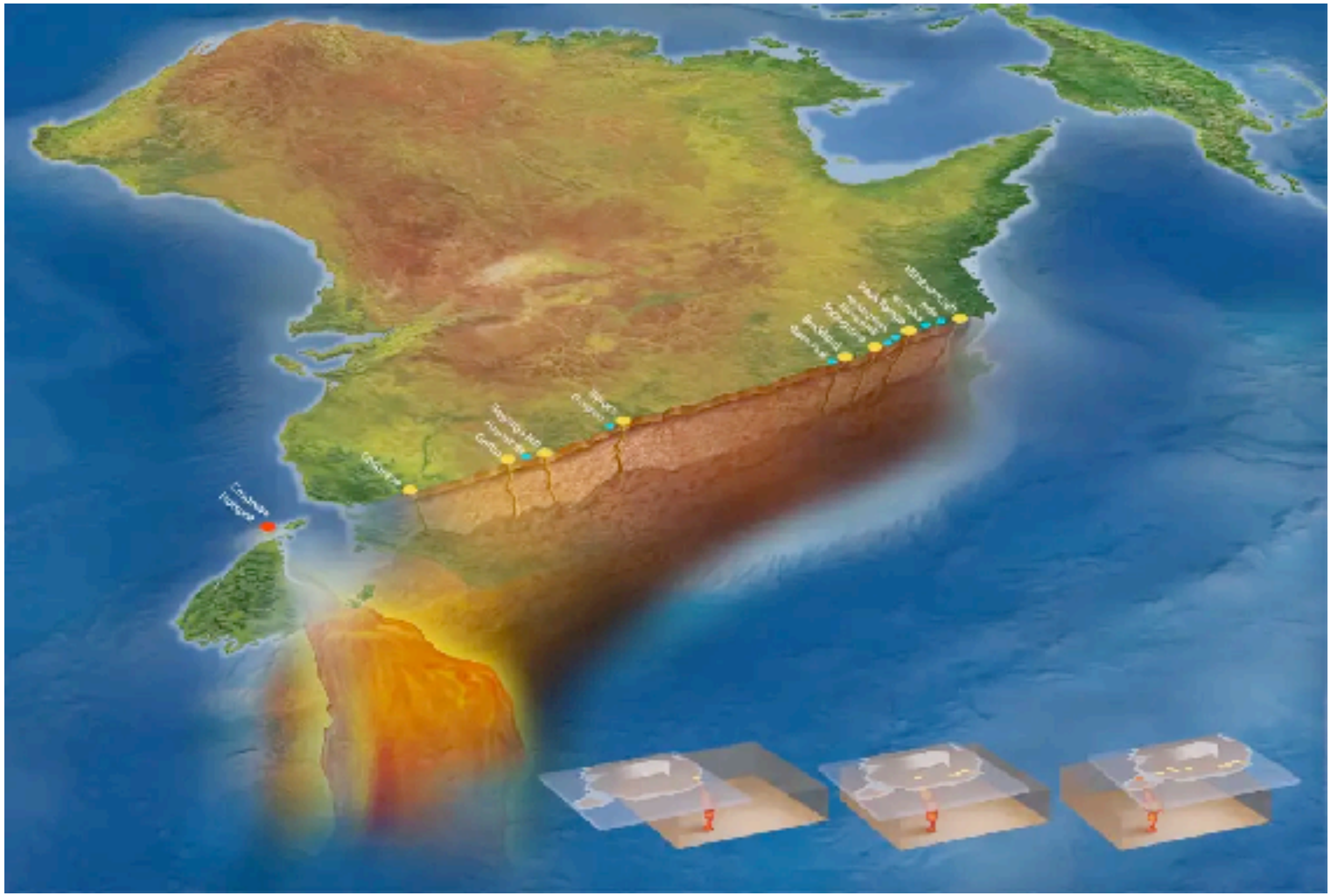
The mantle plume that forms the hot spot is stationary

- As a tectonic plate moves over the hot spot, a chain of volcanoes forms
  - e.g. Hawaii and …



Source: TASA Graphics Arts, inc [hawaiian-hotspot_orig.jpg (1000×757) (weebly.com)]

Hot spots



Source

Eastern Australian Hotspot is the longest in the world

How long has plate tectonics been happening?

Earth is ~4,600,000,000 years old

- 4.6 Ga (Ga = a billion years)

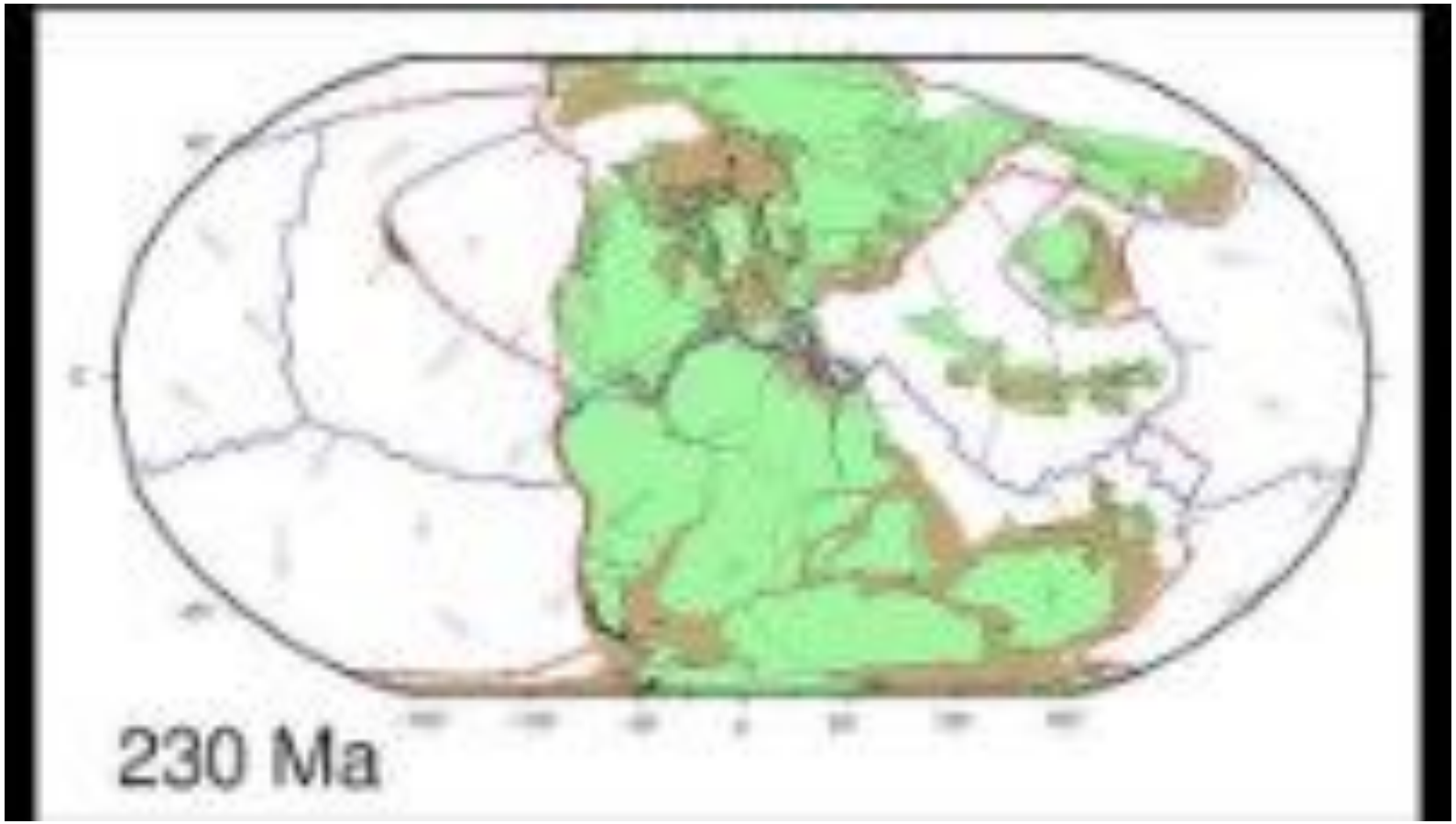
Plate tectonics can be demonstrated since ~2.2 Ga

A different tectonic mode before then as the mantle was much hotter

- The crust and upper mantle (the lithosphere) possibly formed a single unbroken plate.
- With time the lithosphere broke into plates.
- Denser material sank into the mantle, and the plates began to recycle by subduction.

Source: *When and how did plate tectonics begin on Earth? (earthmagazine.org)*
Brown et al. 2020 (Plate Tectonics and the Archean Earth | Annual Review of Earth and Planetary Sciences (annualreviews.org)

Plate tectonics: movements over the last 400 million years



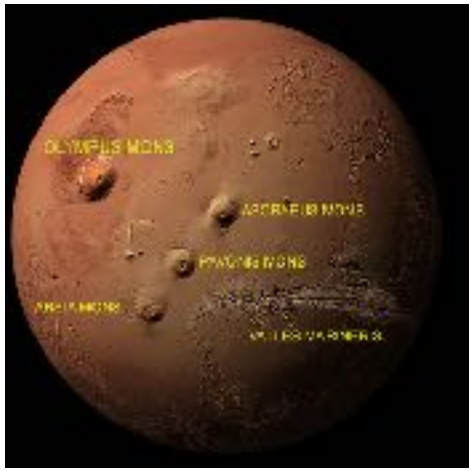
Source: *https://youtu.be/RyKWiEaBALk*

Plate tectonics: what about in another 250 million years?

Source: *https://youtu.be/hos7w8xrcEs*

Do volcanoes and earthquakes occur on other planets?

- Volcanoes on Mars are the result of mantle plumes
  - No evidence of plate tectonics
  - As a result, the volcanoes are huge.
  - Olympus Mons on Mars is the biggest volcano in the solar system
    - Three times higher than Mt Everest!
- 'Moonquakes' can be caused by tides (gravitational stress), meteorite impact or thermal energy (NASA).

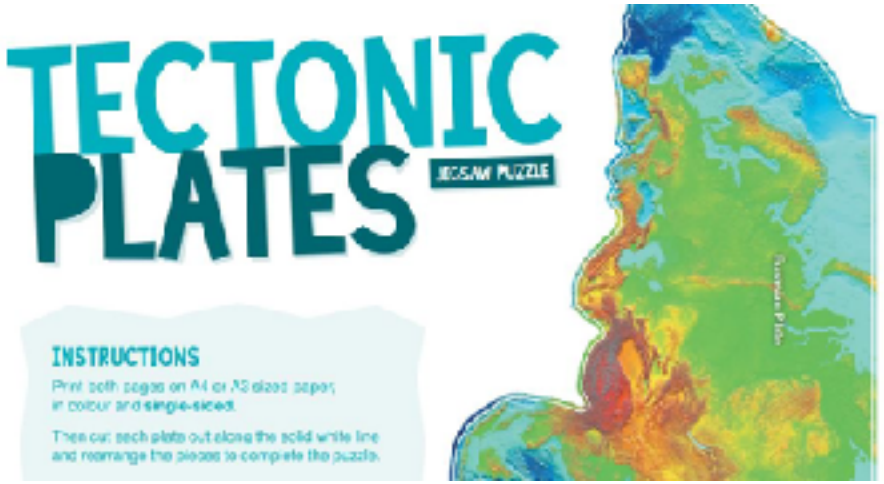


Source: *VALMONS2copy.jpg (768×768) (proseth.com)*
_apollo11_seismometer1.jpg (904×913) (smbhax.com)

Activity: plate tectonics

World elevation map that shows the shape of the major tectonic plates. Physical print in colour for giveaway. When completed the 'Tectonic Plates Jigsaw Puzzle' will fit on a desk. Suitable for primary Years 5-6 and secondary Years 7-12.

Help students visualise plate boundaries on a spherical Earth, rather than on a flat map. The model shows major plate boundaries, boundary types and highlights our own Indo-Australian plate. Ready to cut out and construct (tennis ball required). Assembly instructions included.
Suitable for primary Years 5-6 and secondary Years 7-12



Source: https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/140017 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/68913

Summary

The theory of plate tectonic states that the Earth's outermost layer is fragmented into a dozen or more large and small plates

- That are moving relative to one another as they ride atop hotter, more mobile material.

Gravity-driven convection systems (i.e., Slab Pull, Trench Suction, Plate Roll-back and Ridge Push) are the main drivers of plate tectonics (rather than mantle convection alone)

3 types of margins – convergent, divergent and transform

Volcanoes and earthquakes are more common along plate margins