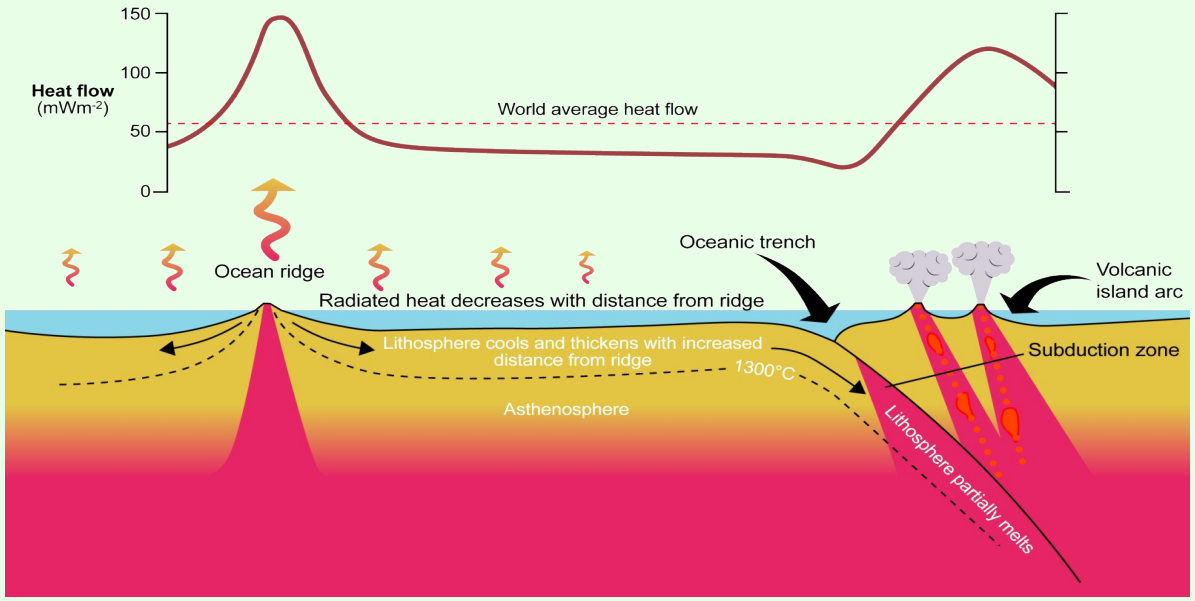
The plate tectonic story – online

Part 1

Earth Science for science and geography – video workshop



Developed from the Earth Science Education Unit 'The plate tectonic story' workshop, with permission

Earthlearningidea online video workshops

Purpose – ESEU background

- Most Earthlearningidea online video workshops are based, with permission, on workshops originally developed by the Earth Science Education Unit (ESEU)
- These were designed as interactive workshops for teachers and trainees, involving interaction, discussion and presentations by participants to others
- Global research into professional development workshops shows that these aspects are critical to success
- ESEU research shows that this workshop approach is highly successful in changing teaching in schools; evaluation feedback has also been very strong

Earthlearningidea online video workshops

Purpose – Earthlearningidea development

- The Earthlearningidea Team has developed the ESEU workshops into online video workshops for those unable to take part in face to face interactive workshops
- Each workshop is led by a PowerPoint presentation and has an accompanying booklet that contains all the activity background details, resource lists, risk assessments, etc.
- The individual workshop activities have been published for open access online at the website: https://www.earthlearningidea.com/
- Each workshop activity has a question script and a video keyed into CASE principles, that can be accessed through the PowerPoint hyperlinks
- The aim is to facilitate online Earth science learning

Earthlearningidea online video workshops

Teaching Earth science using the Cognitive Acceleration through Science (CASE) approach

- The activities in this workshop are keyed into the CASE approach – to develop thinking skills while teaching key Earth science material
- If you are unfamiliar with the case approach, you can access a video introduction at: https://www.earthlearningidea.com/Video/CASE.html
- An exemplar Earth science teaching activity with a question script using the CASE approach is at: https://www.earthlearningidea.com/Video/Atmosphere_ocean.html

Earthlearningidea online video workshops

Running Earthlearningidea online video workshops

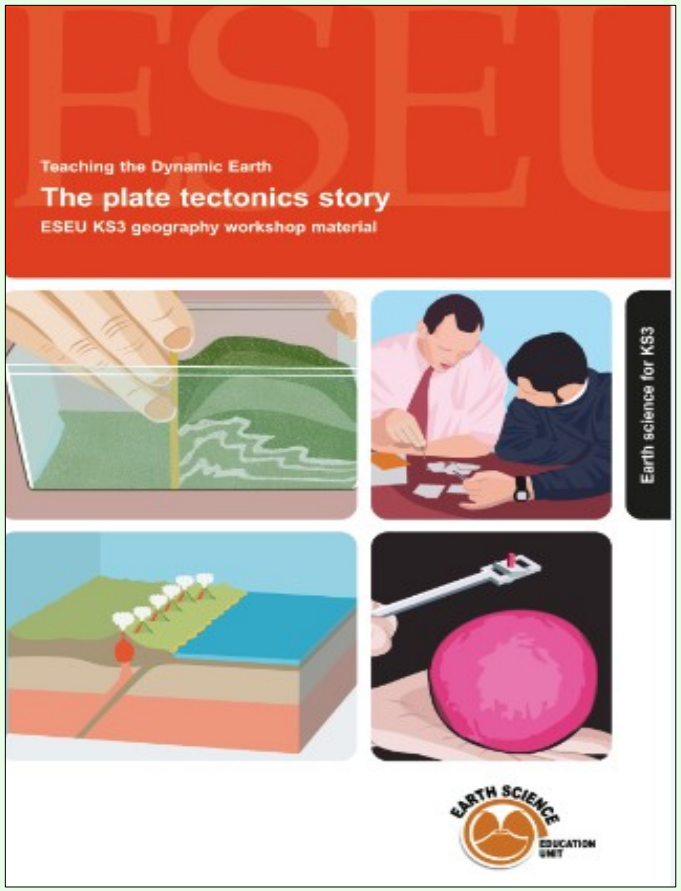
- Each workshop is led by a PowerPoint presentation
- Launch the PowerPoint
- Some slides contain hyperlinks to MP4 video files
- Run the hyperlinked files and then return to the PowerPoint, flick through any slides you have already seen, and continue
- The workshop is presented in this way so that the workshop itself, or individual videos, can be used in classroom teaching

The plate tectonic story

Workshop video run times		m	s	m	s
The plate tectonic story, part 1				38	30
Big picture, ‘facts’ earthquakes and plates	Big picture and ‘facts’	2	56	6	47
	Earthquake volcano earthquake evidence	3	06		
	China plate summary	0	45		
Seismic evidence and potty putty mantle	Seismic evidence	3	18	8	43
	Solids that flow	4	19		
	Skateboard summary	1	06		
What drives the plates?				4	27
The wax magnetic field and magnetic Earth	Frozen magnetism	2	08	13	18
	Magnetic Earth	6	30		
	Sponge ball	4	40		
Heat flow, age of ocean floor and plate speed	Heat flow evidence	2	17	5	15
	Age of ocean floor	2	58		

The plate tectonic story, part 2				37	56
Divergent margins	Divergent margins	2	03	4	32
	Faults in a Mars Bar	2	29		
Magnetic stripes				5	21
Convergent margins	Convergent margins	3	42	8	06
	Deformation	4	24		
Continental jigsaw puzzles				4	40
Brickquake				4	59
Party popper eruption				6	29
Plate plenary				3	49

The plate tectonic story – both parts together	76	26



The plate tectonic story

Earth science for science and geography

The workshop is based on this pdf booklet originally prepared by the Earth Science Education Unit and now available on the Earthlearningidea website. It contains a workshop summary, the outcomes, teacher guidance, risk assessments and resources lists – as in the following slides

The plate tectonic story

Summary

‘The plate tectonic story’ workshop gets to grips with the wide-ranging evidence for the theory that underpins our detailed modern understanding of our dynamic planet – the theory of **Plate Tectonics**.

The workshop begins with an introduction and progresses through a series of activities that are designed to help students develop their understanding. It uses several independent sources of evidence supporting the theory, including using rock and fossil evidence, seismic records, geothermal patterns, geomagnetism, and large-scale topographical features, both above and below sea-level.

The workshop concludes by investigating some of the Earth hazards linked to plate tectonics, and how we can reduce loss of life.

The plate tectonic story

Workshop outcomes

The workshop and its activities provide the following outcomes:

- an introduction to plate tectonics;
- distinction between the ‘facts’ of plate tectonics and the evidence used to support plate tectonic theory;
- a survey of some of the evidence supporting plate tectonic theory;
- explanation of some of the hazards caused by plate tectonic processes - earthquakes and eruptions;
- methods of teaching the abstract concepts of plate tectonics, using a wide range of teaching approaches, including practical and electronic simulations;
- approaches to activities designed to develop the thinking and investigational skills of students;
- an integrated overview of the concepts involved in teaching the processes of plate tectonics.

The plate tectonic story

Think through the processes using this wide range of activities:
Note: practical activities needing apparatus/materials are shown with a *

The plate tectonic story, part 1

- The big picture and the ‘facts’ of plate tectonics
- Earthquake and volcano distribution evidence*
- China plate summary*
- The seismic evidence
- Solids that flow*
- Skateboard summary
- What drives the plates?
- Frozen magnetism*
- Magnetic Earth*
- Magnetic Earth using a sponge ball globe*
- The heat flow evidence
- The age of ocean floor and plate speed

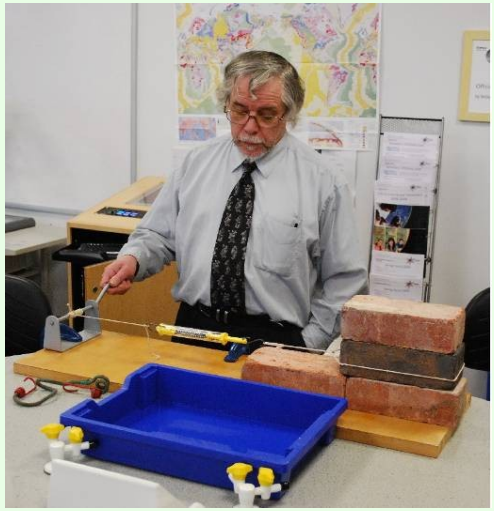
The plate tectonic story, part 2

- Divergent plate margins
- Faults in a Mars™ Bar*
- Magnetic stripes*
- Convergent margins*
- Continental jigsaw puzzles*
- Brickquake*
- Party popper eruption*
- Plate plenary

The plate tectonic story

Carry out risk assessments before the following activities:

Magnetic Earth
Magnetic stripes
‘Brickquake’ – can earthquakes be predicted?
How predictable are volcanic eruptions? - party popper simulation



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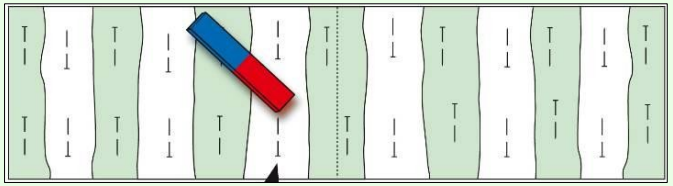

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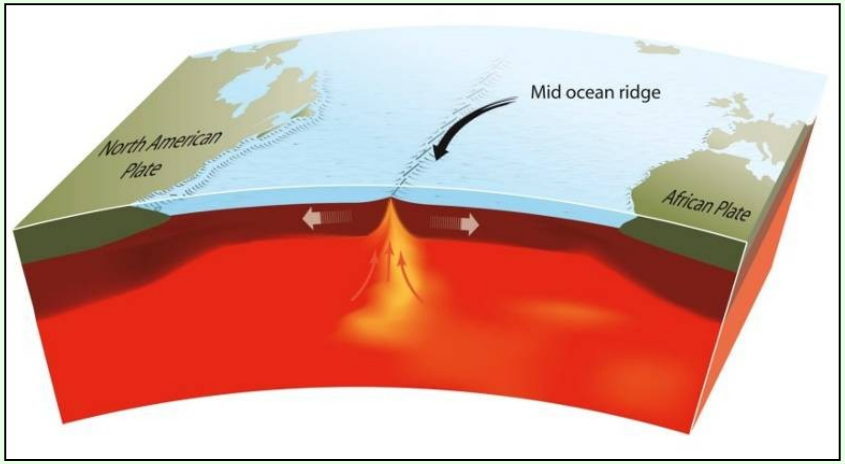
The plate tectonic story

- **The big picture and the ‘facts’ of plate tectonics**

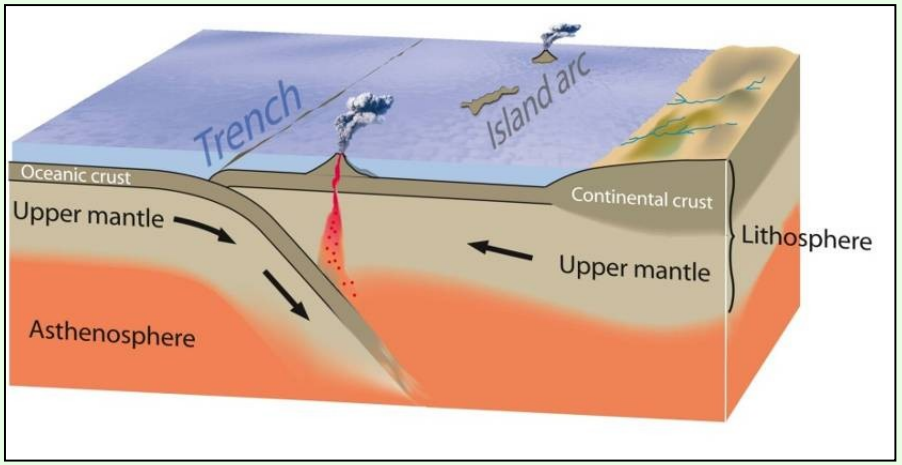
Go to: https://www.earthlearningidea.com/Video/V21_Big_picture.html hyperlink

The plate tectonic story

The big picture
and the ‘facts’ of plate tectonics



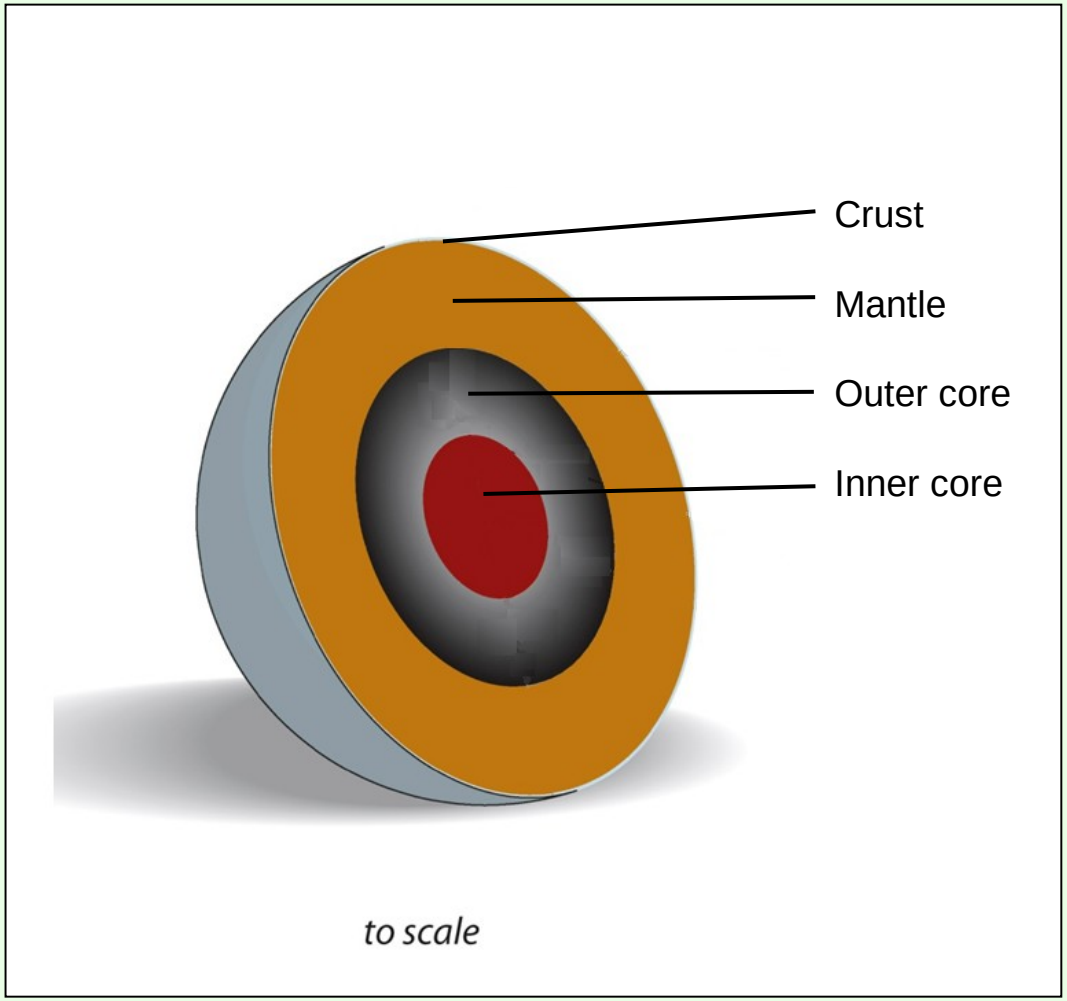
An oceanic ridge © Press & Siever, redrawn by ESEU



Continental plate collision zone. Reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

The Earth has a crust, mantle, outer and inner core

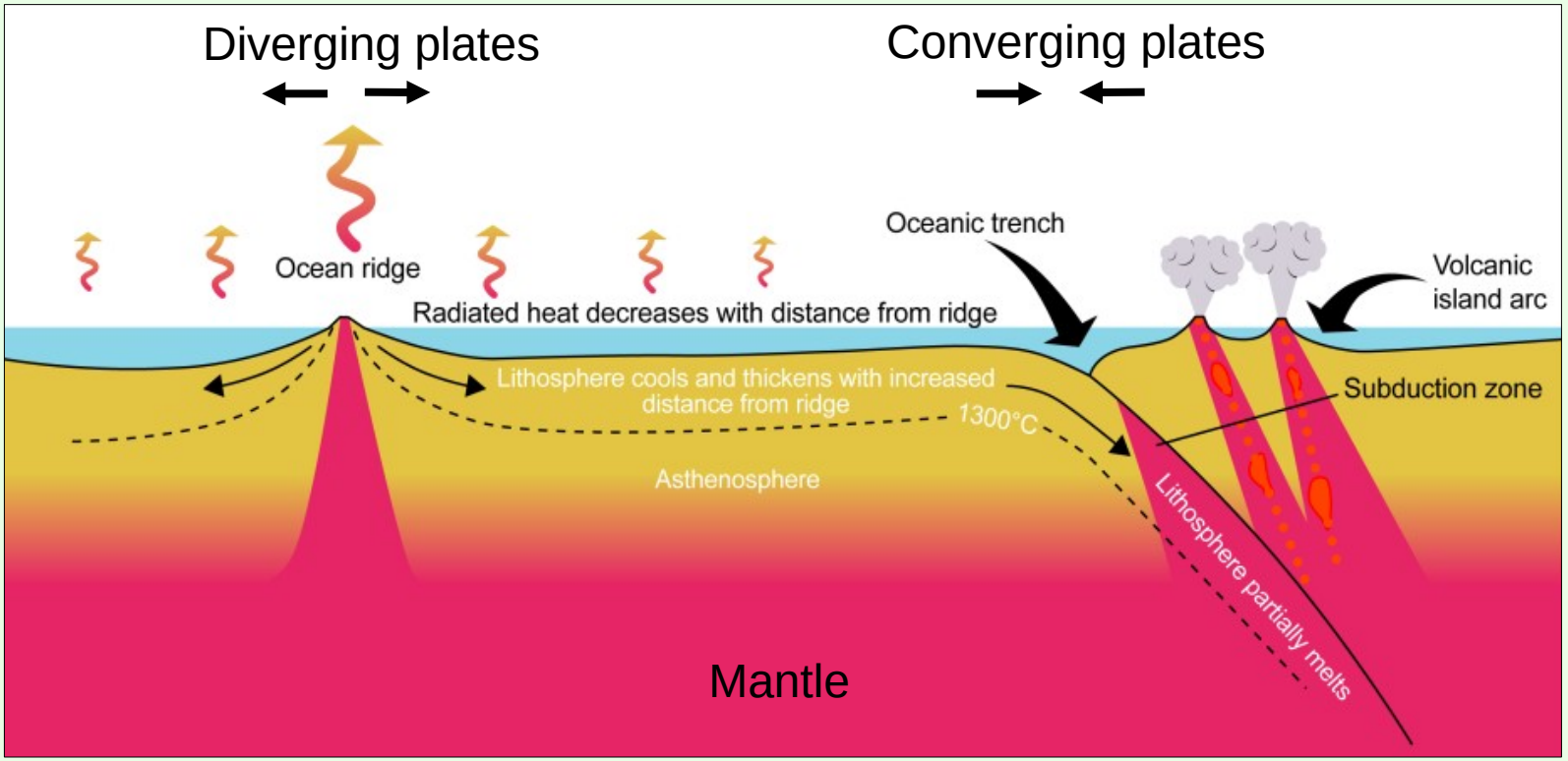


The Internal structure of the Earth - reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

The upper part of the mantle and the crust look like this

Over geological time the mantle can flow

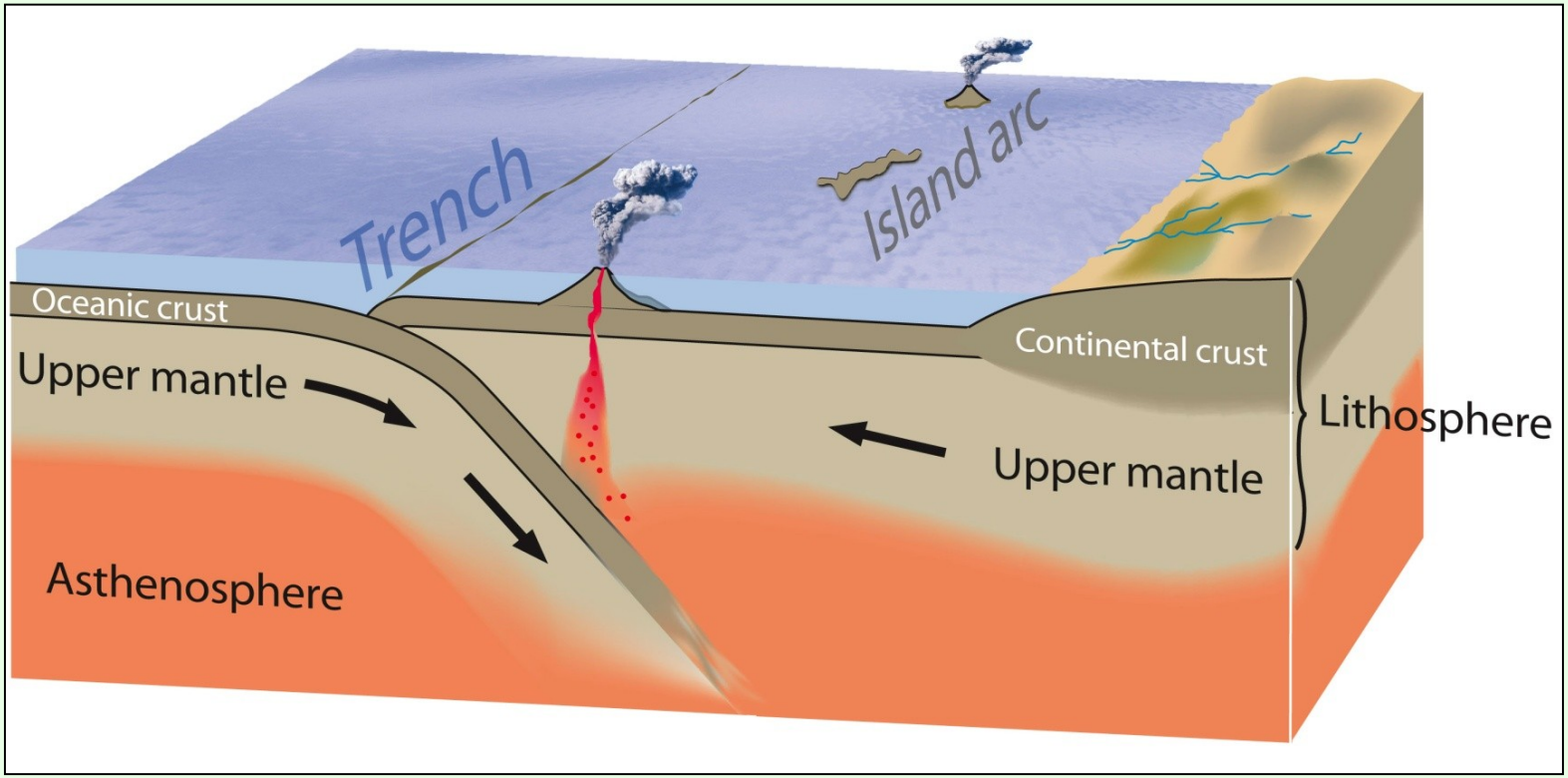


The upper part of the mantle and the crust © Chris King and Dee Edwards, redrawn by ESEU

The plate tectonic story

A subduction zone looks like this

When one plate goes down -
partial melting occurs and volcanoes are produced

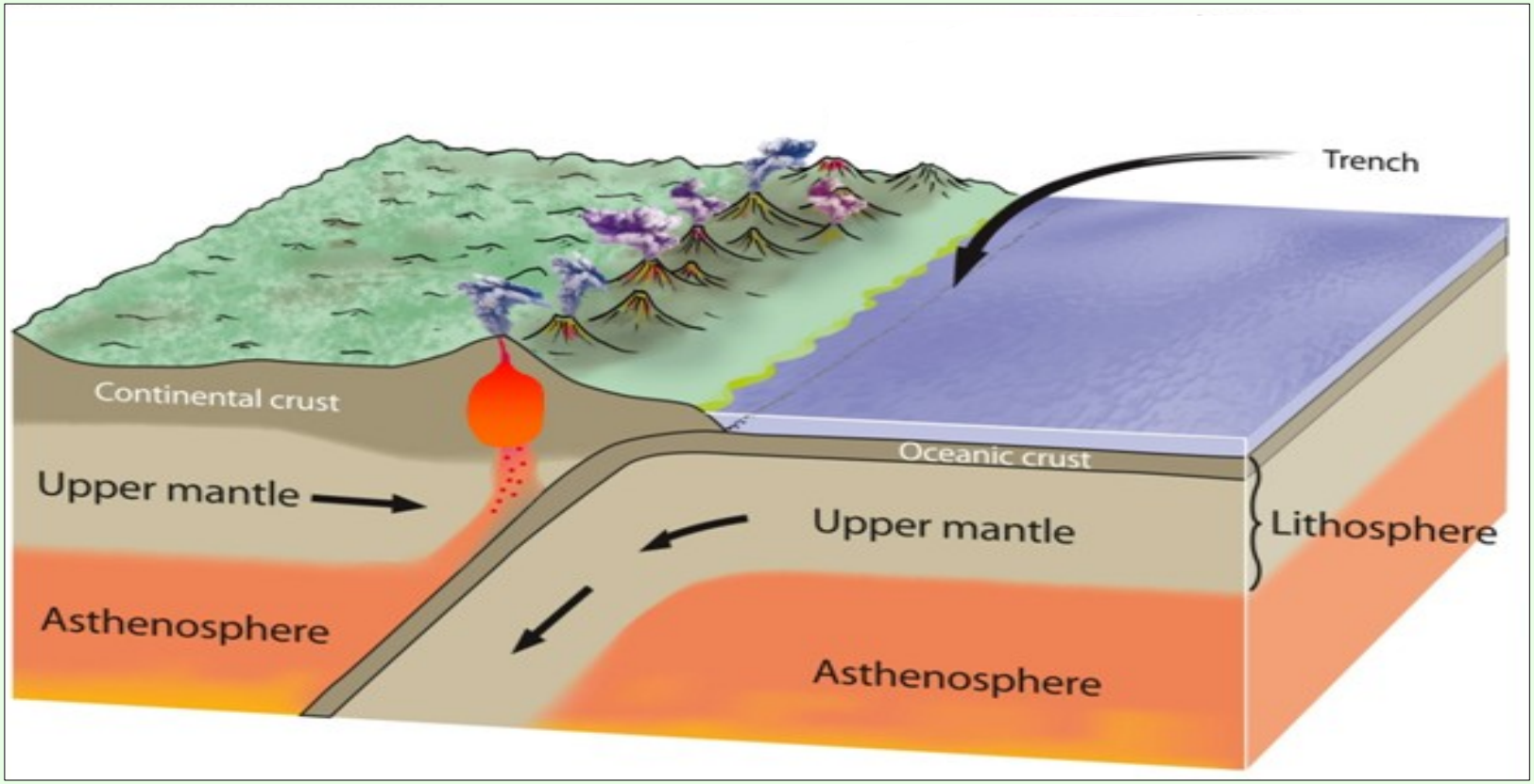


Subduction zone ('partially melts and volcanoes are produced' 'molten rock cools down below the surface')
- reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

A subduction zone with a continent on one plate

Sometimes the molten rock cools down below the surface

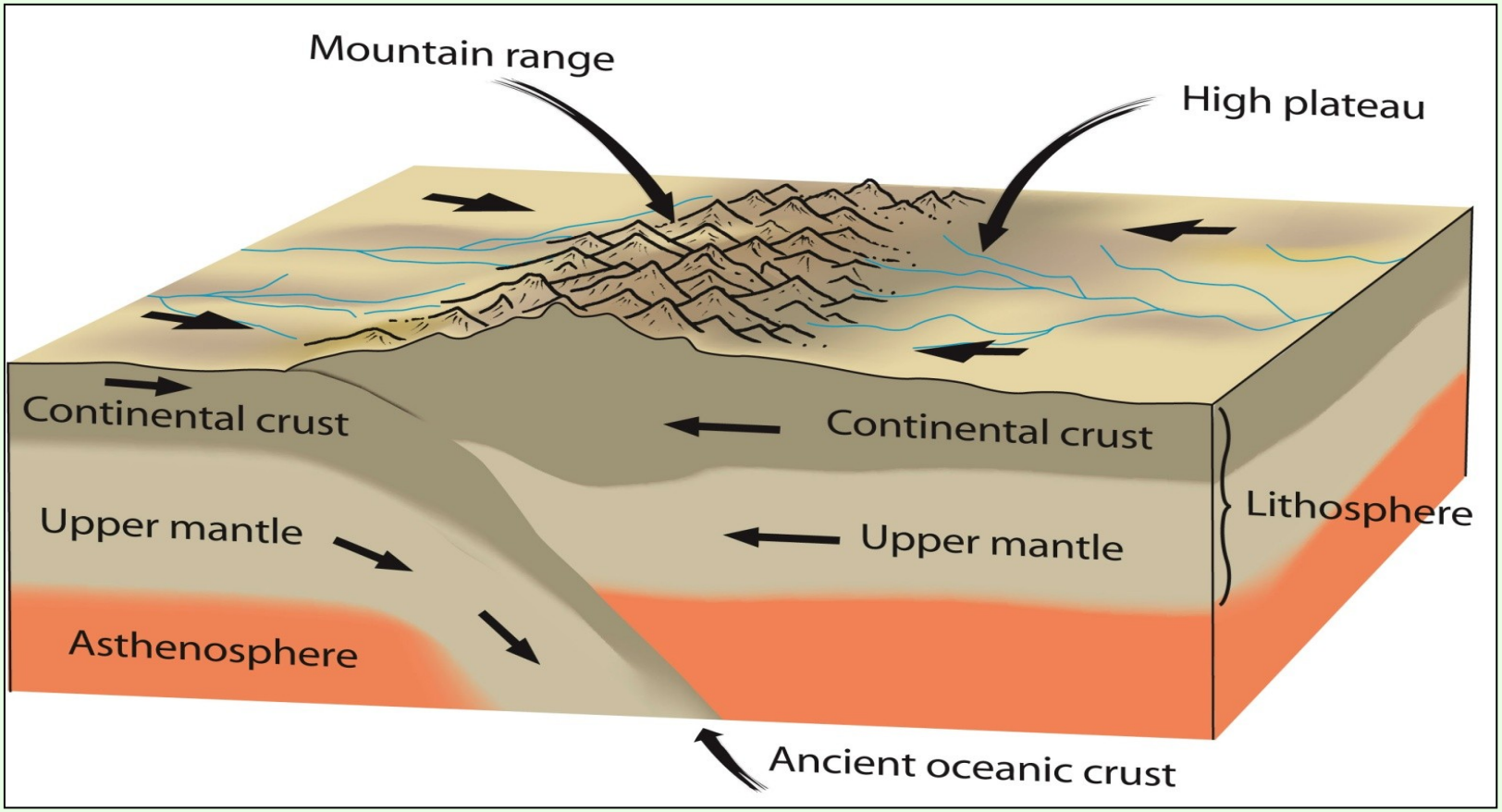


Subduction zone ('partially melts and volcanoes are produced' 'molten rock cools down below the surface') - reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

A subduction zone with continents on both plates

When two plates carrying continents collide – mountain chains are built

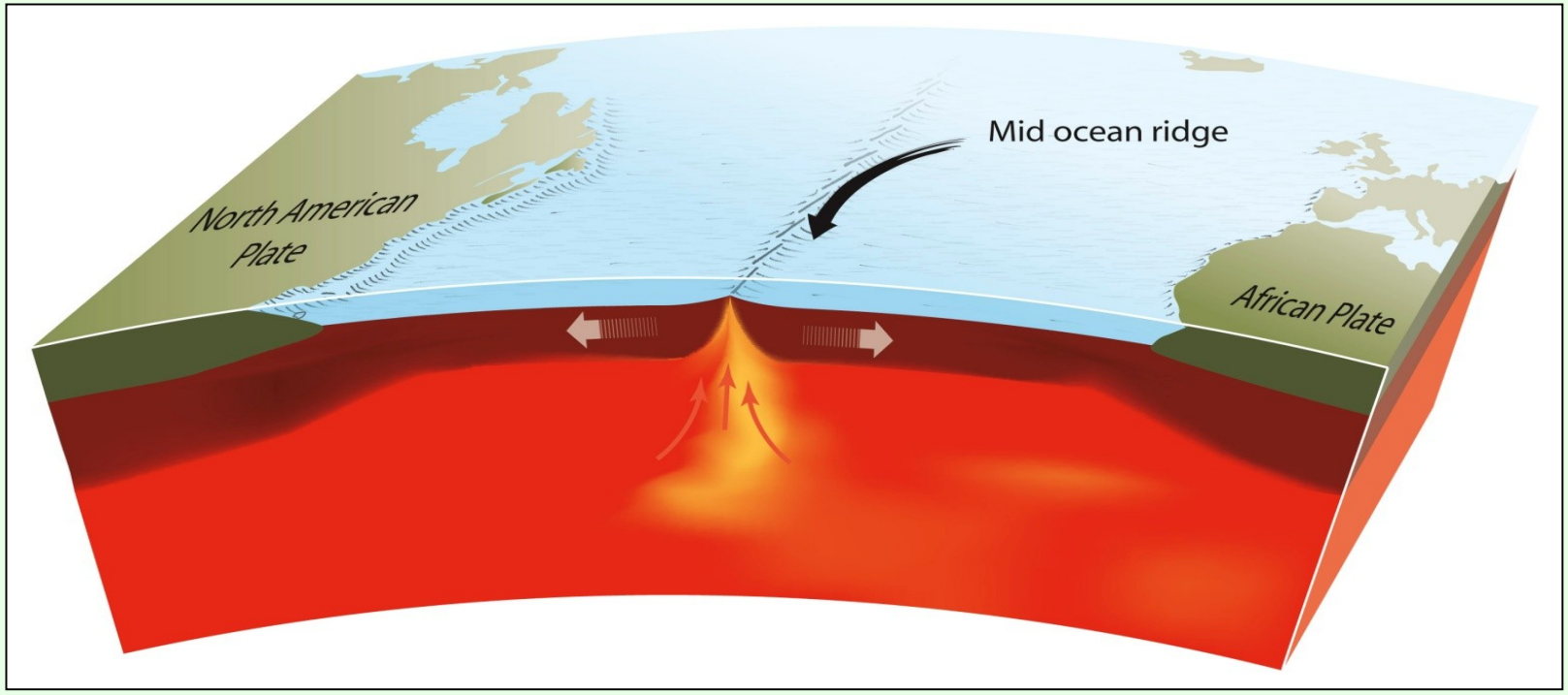


Continental plate collision zone. Reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

An oceanic ridge

If plates are converging, there must be somewhere on Earth where plates are moving apart, or diverging – where new plate material is being made

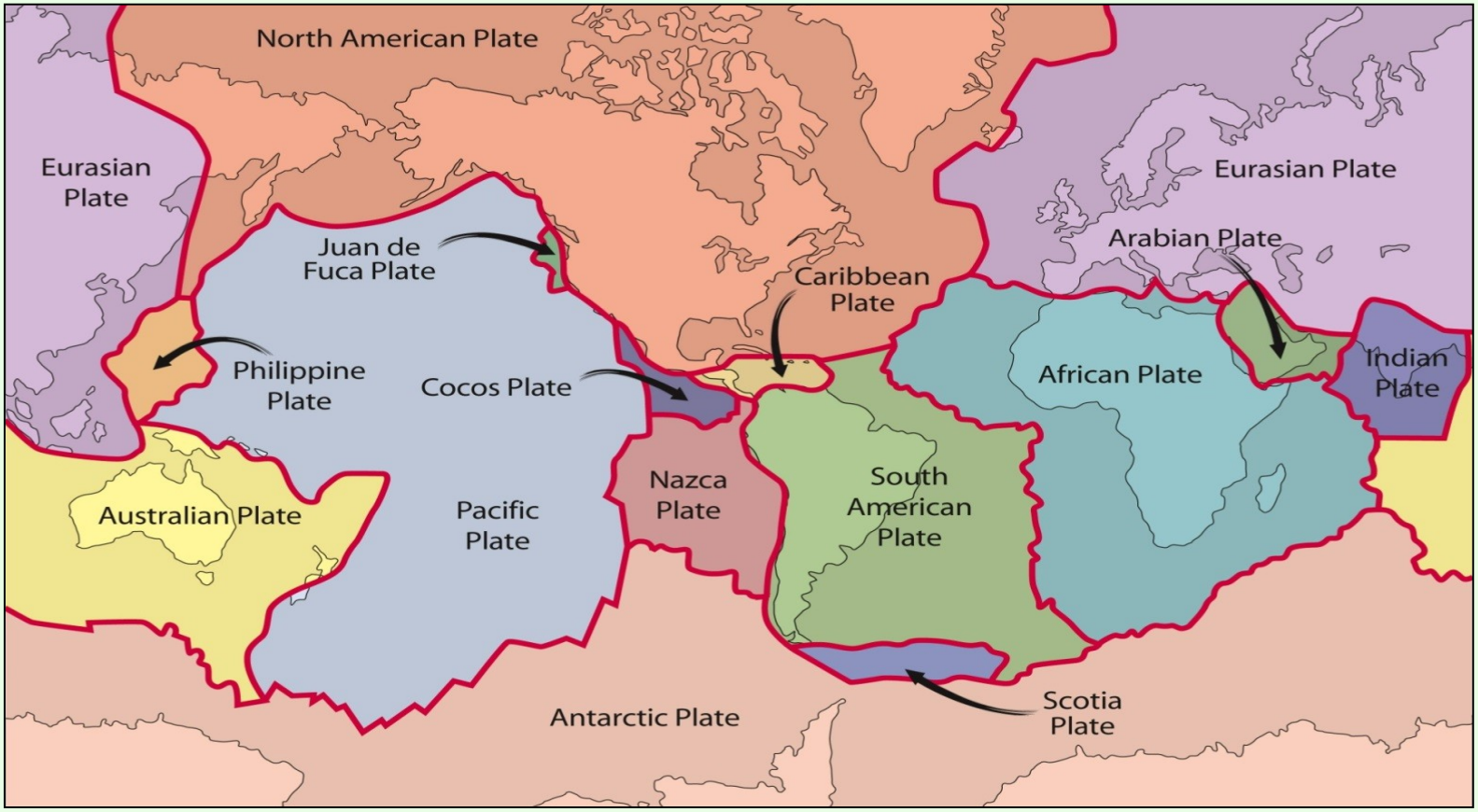


An oceanic ridge © Press & Siever, redrawn by ESEU

The plate tectonic story

Map of plates

The result is - the map of plate margins today



Map of plates - reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

- So – that is the ‘big picture’ of plate tectonics
- But plate tectonics is not a series of facts, as suggested in the story above, but is a theory supported by evidence
- But what is this evidence and how does it support the theory?

Note: The theory of plate tectonics is outlined in narrative form as the ‘Story for teachers: plate tectonics’ on an early page of the ‘The plate tectonic story’ booklet.

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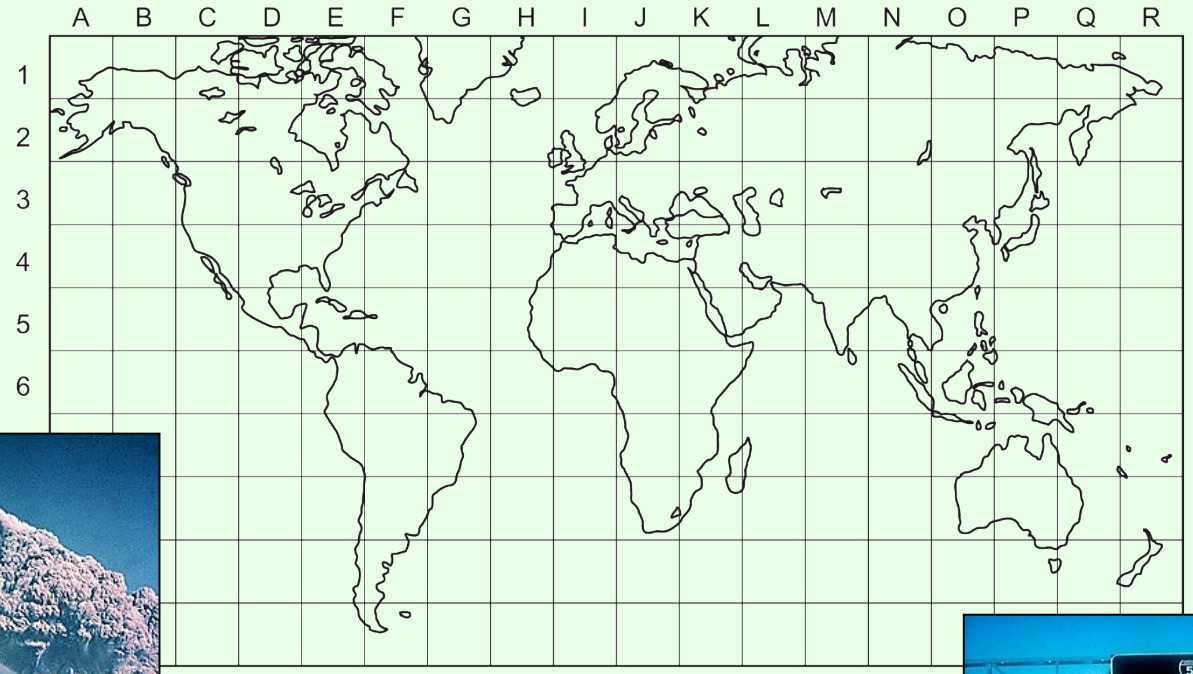
The plate tectonic story

- **Earthquake and volcano distribution evidence**

Go to: https://www.earthlearningidea.com/Video/V21_Equ_volc_evid.html
hyperlink

The plate tectonic story

Where on Earth are earthquakes and volcanoes?
- geobattleships



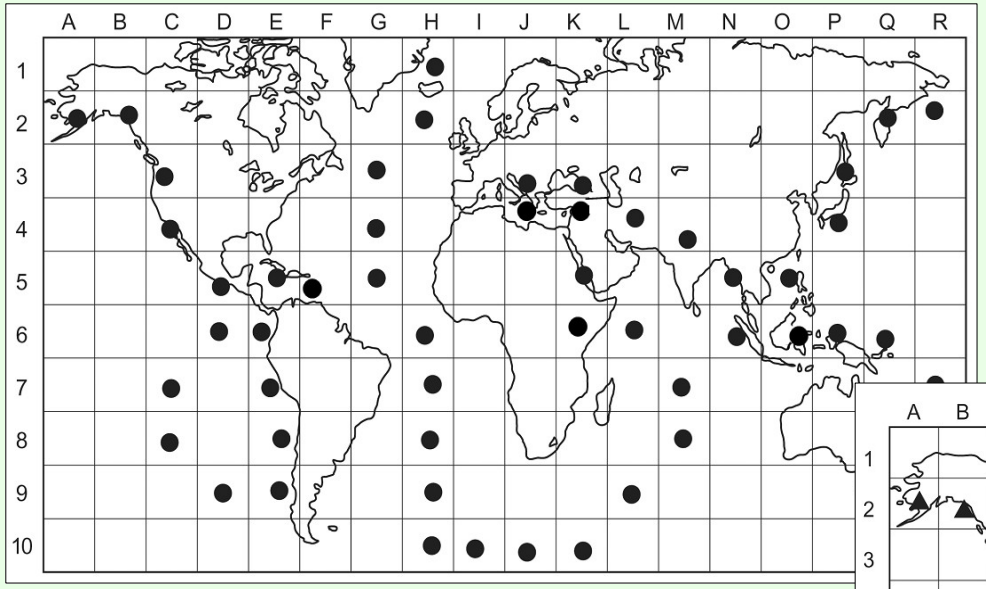
Battleship grid for Geobattleships © Dave Turner

Galunggung eruption by USGS, public domain

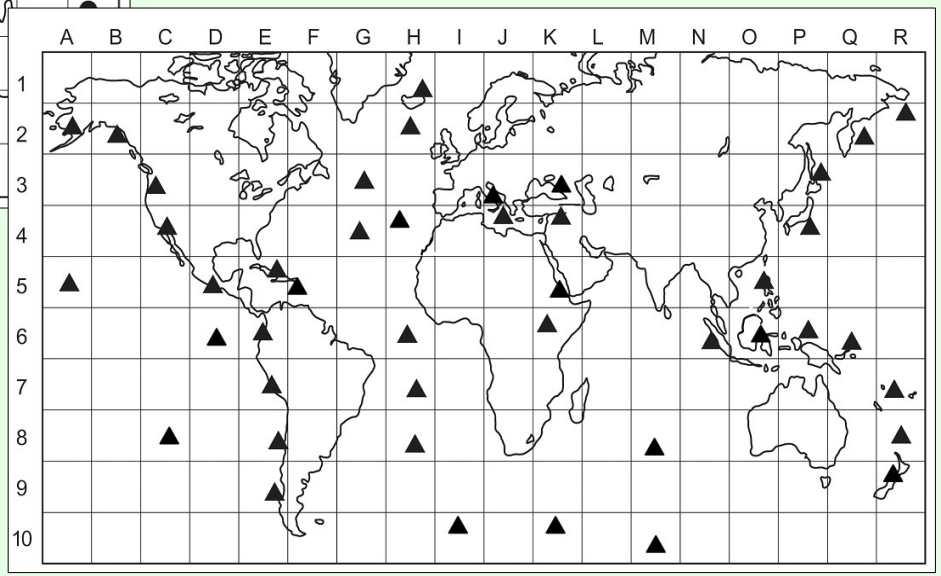
'North All Trucks' © USGS

The plate tectonic story

Where on Earth are earthquakes and volcanoes?
- geobattleships



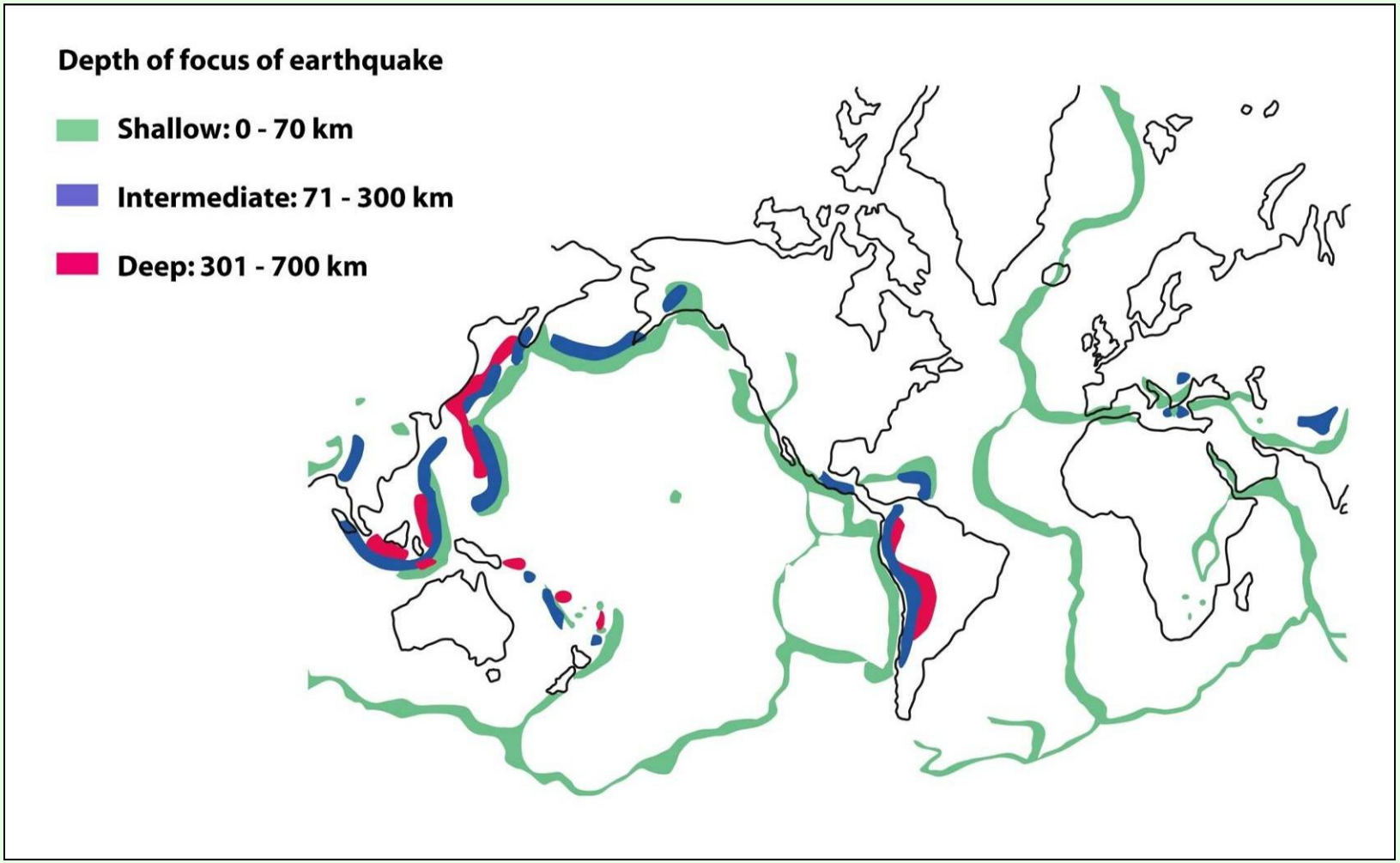
Earthquakes



Volcanoes

The plate tectonic story

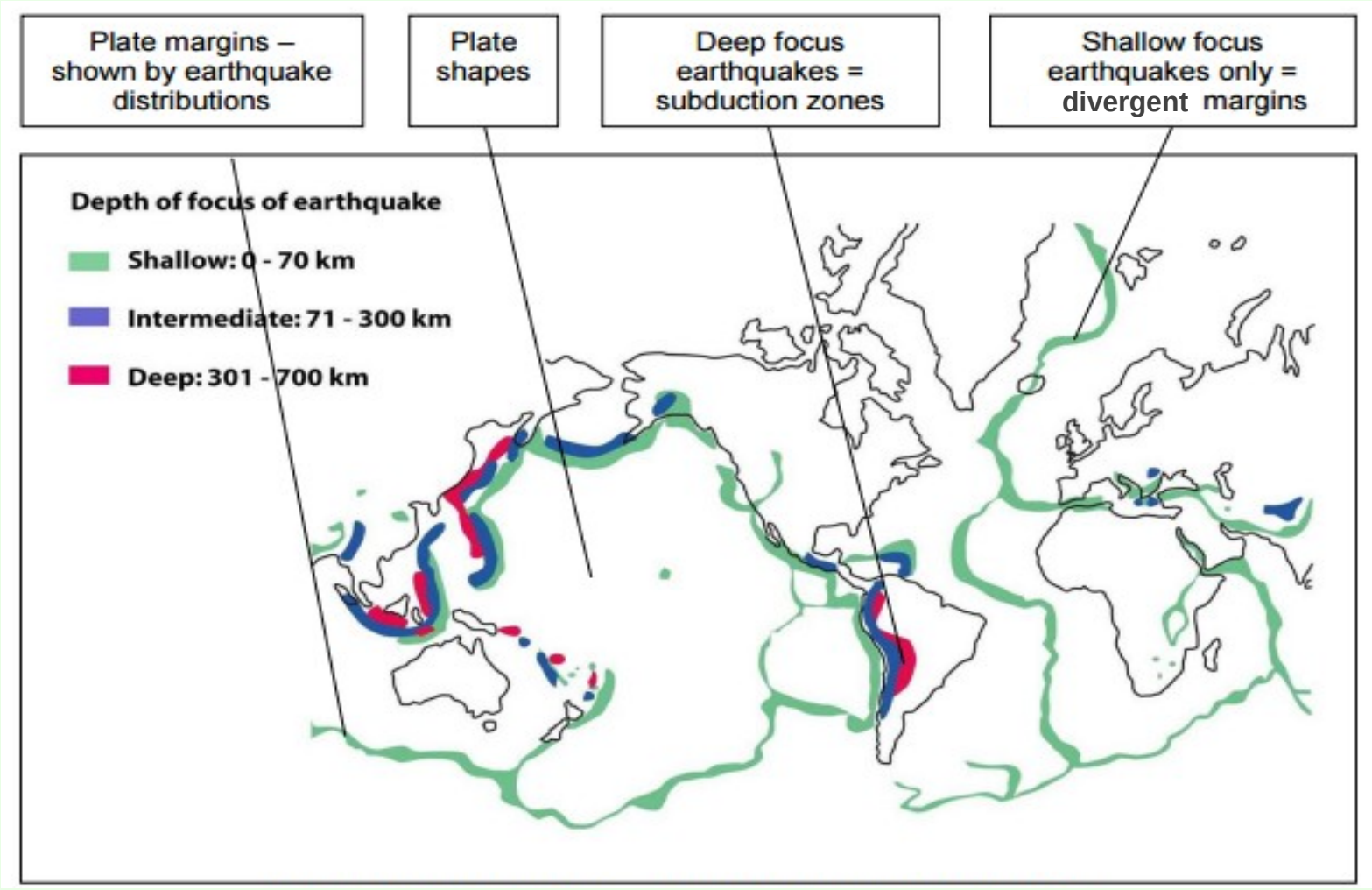
Distribution of earthquakes – what does the distribution show?



Distribution of earthquakes – source unknown, redrawn by ESEU

The plate tectonic story

Distribution of earthquakes – what does the distribution show?



Distribution of earthquakes – source unknown, redrawn by ESEU

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The plate tectonic story

- **China plate summary**

Go to: https://www.earthlearningidea.com/Video/V21_China_plate.html hyperlink

The plate tectonic story

Why are the Earth's tectonic plates called plates?

Picture of a plate © Peter Kennett

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The plate tectonic story

- **The seismic evidence**

Go to: https://www.earthlearningidea.com/Video/V26_Seismic_evidence.html
hyperlink

The plate tectonic story

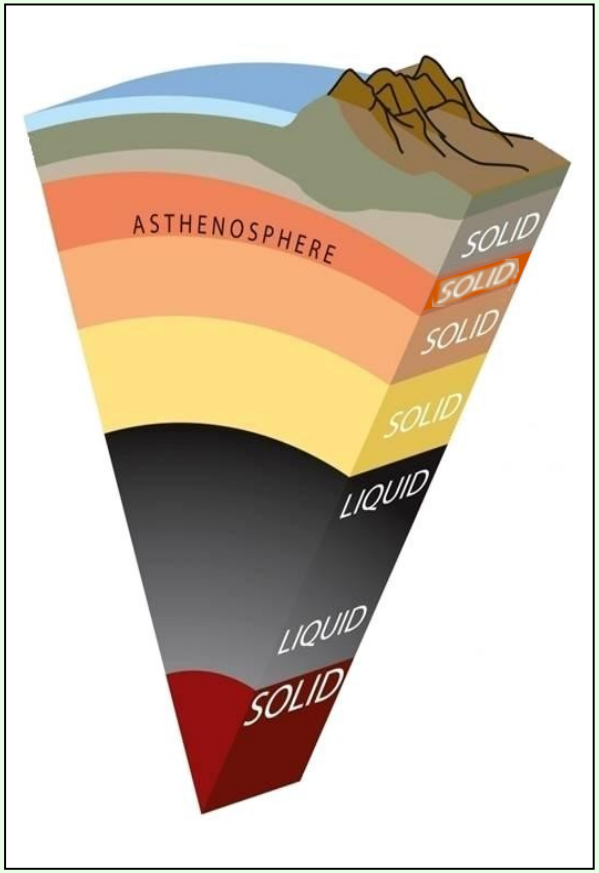
Seismic evidence

Seismic waves are shock waves that pass through and over the Earth

Seismic waves are generated naturally by earthquakes

There are three main types:

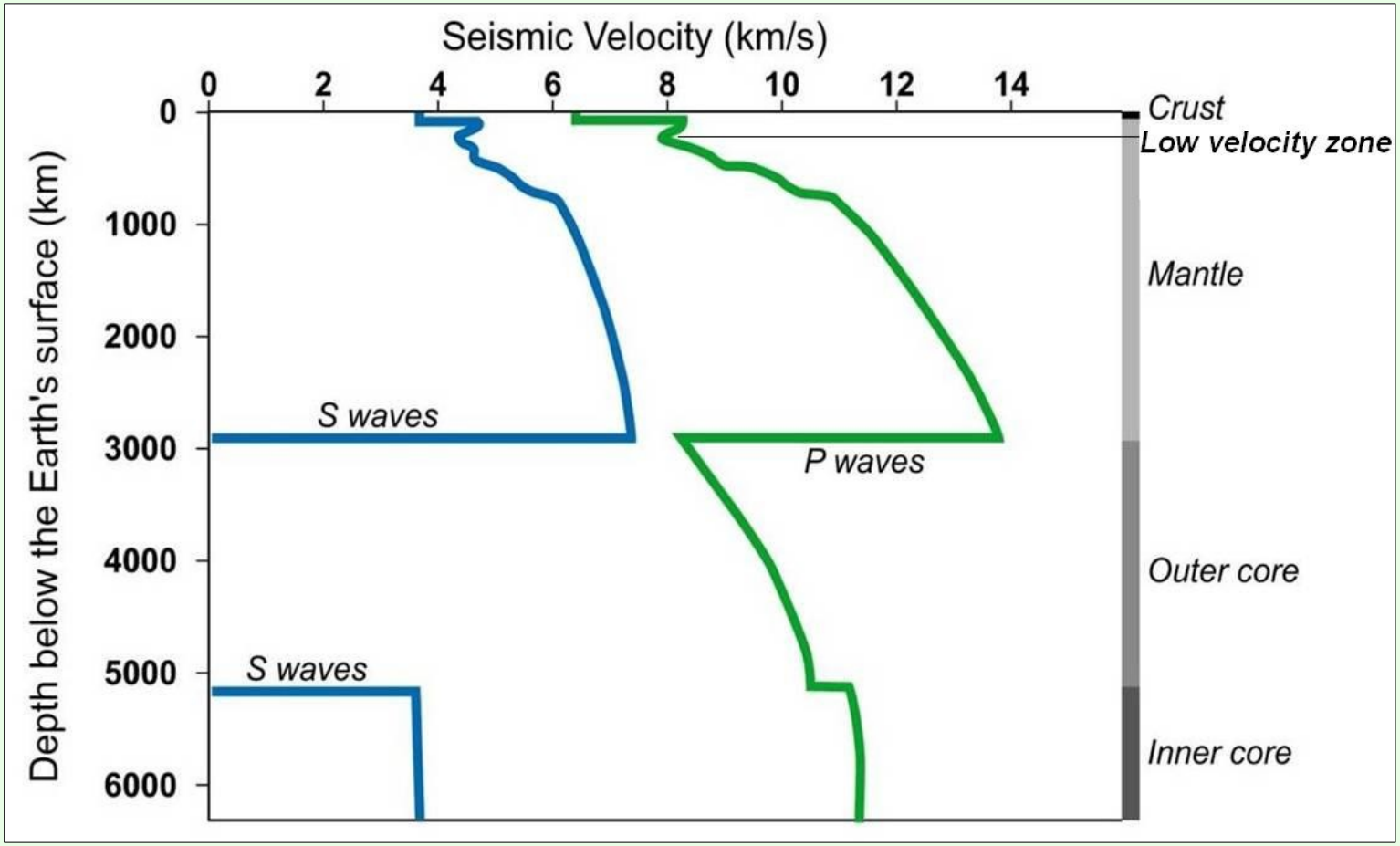
- P-waves – travel through solids and fluids (liquids and gases); pass through the Earth
- S-waves – travel only through solids (not fluids); pass through the Earth
- Surface waves – formed when P- and S-waves reach the Earth's surface; these cause most damage



The Structure of the Earth – from the seismic evidence – reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

Velocities of P- and S-waves as they travel into the Earth

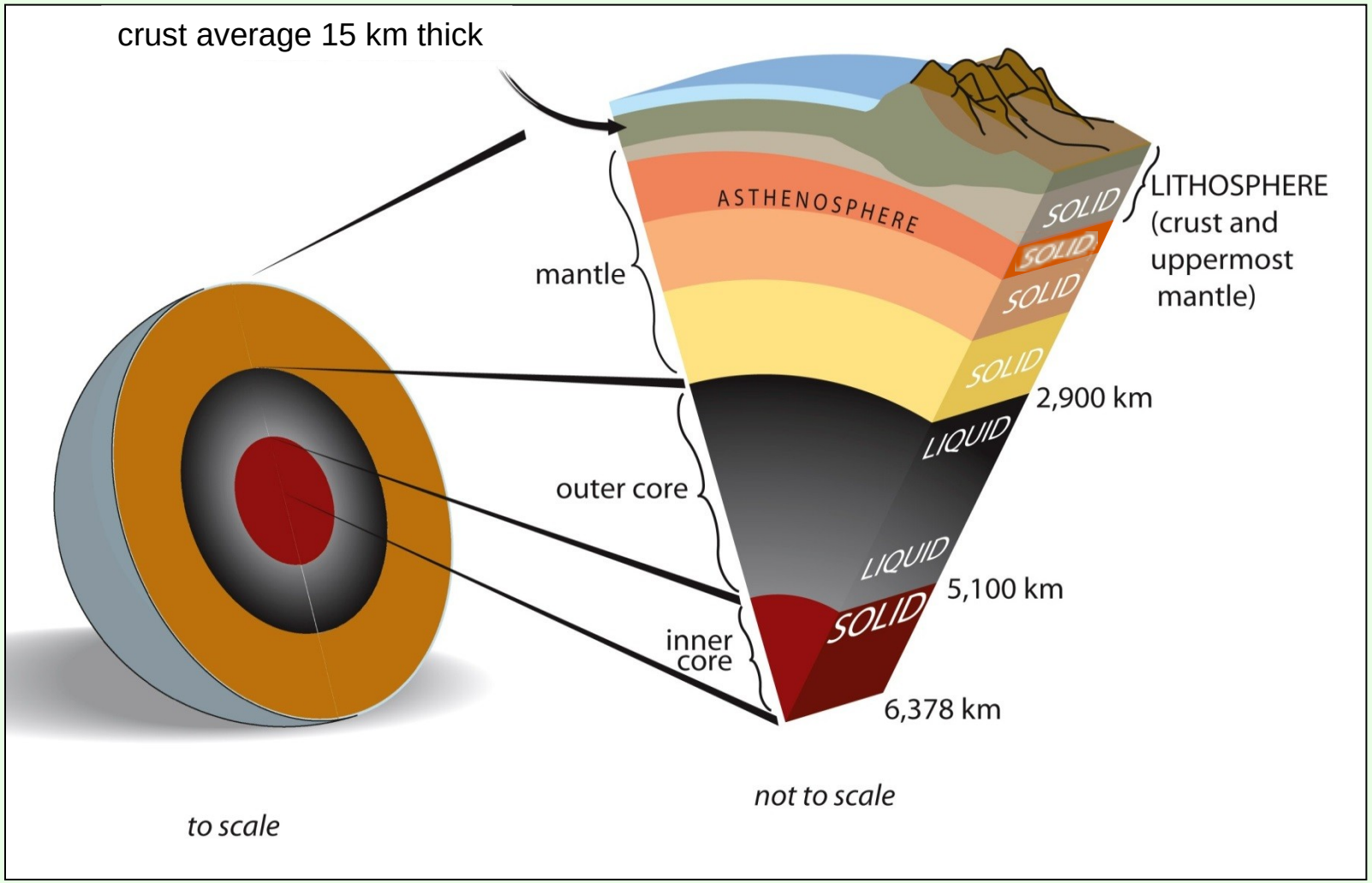


Graph of 'Velocities of P and S waves as they travel into the Earth © ESTA, redrawn by ESEU

- P-waves – travel through solids and fluids (liquids and gases)
- S-waves – travel only through solids (not fluids)

The plate tectonic story

The structure of the Earth – from the seismic evidence



The Internal structure of the Earth - reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

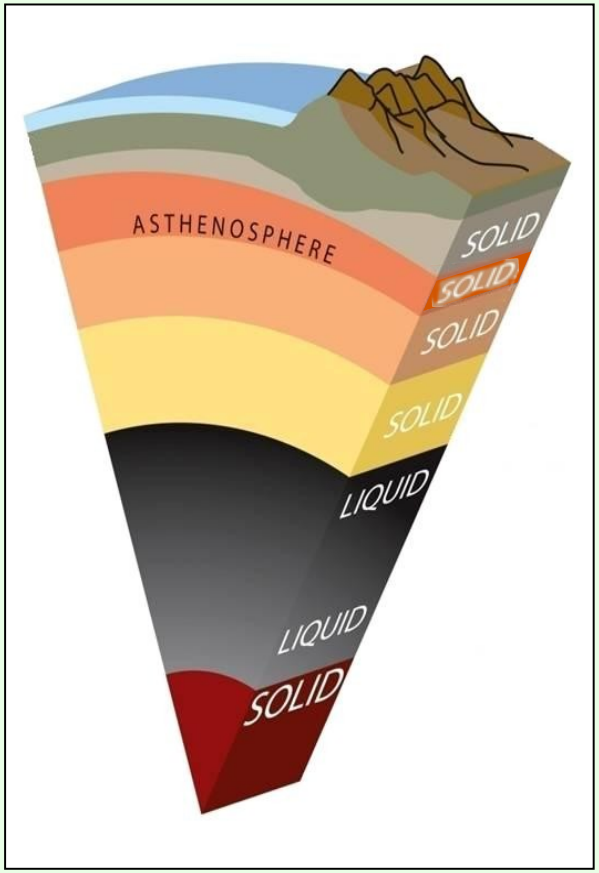
Seismic evidence – summary

The outer core is liquid (no S-waves transmitted)

The inner core is solid (transmits S-waves)

The rest of the Earth is also solid – the crust, the lithosphere, the asthenosphere and the rest of the mantle (transmits S-waves)

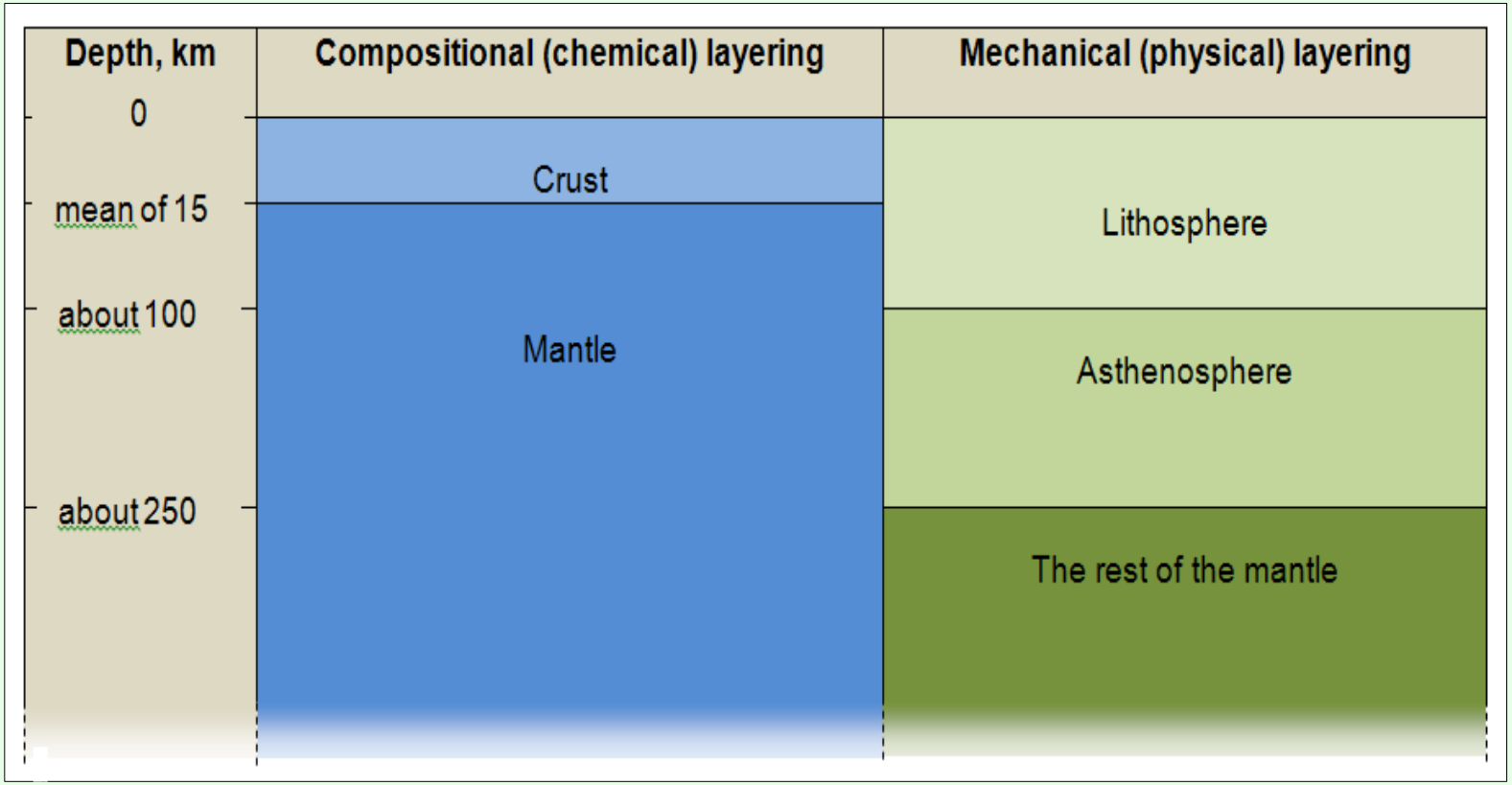
Seismic waves slow down in the asthenosphere (low velocity zone) because the solid asthenosphere, is near its melting point and so is plastic and can flow



The Structure of the Earth – from the seismic evidence – reproduced with kind permission of USGS, redrawn by ESEU

The plate tectonic story

The lithosphere, asthenosphere and below:



The lithosphere, asthenosphere and below © ESEU

Note 1. The crust has a mean thickness of 35 km beneath continents and 6 km beneath oceans giving an overall mean of about 15 km.

Note 2. The crust is too thin to form plates – plates are made of rigid lithosphere – around 100 km in thickness

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The plate tectonic story

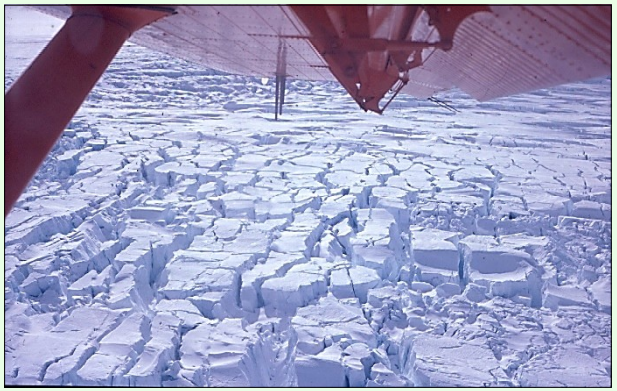
- **Solids that flow**

Go to: https://www.earthlearningidea.com/Video/V26_Potty_putty.html hyperlink

The plate tectonic story

Can solids flow?

- Can you think of a common solid that flows?
- Answer = ice
- Ice is solid – and can break (fracture)
- Ice is solid – but when near its melting point in a glacier on a mountainside – it flows
- It flows even in polar glaciers – which are frozen to the ground



Fractured ice – seen from a plane in Antarctica

A glacier flowing downhill in Norway

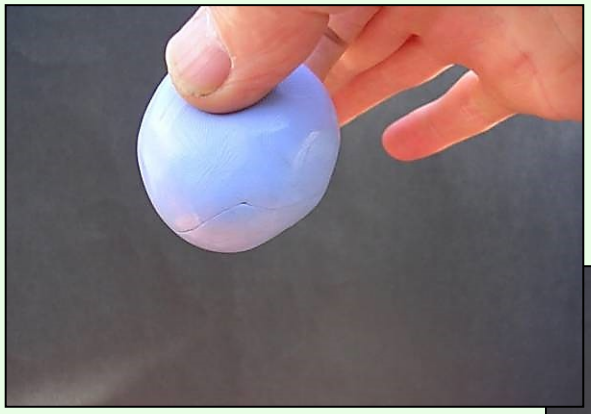
The plate tectonic story

Properties of the mantle – potty putty™
Showing how the solid mantle can flow

Student pulling Potty Putty™ © ESEU

The plate tectonic story

Modelling the mantle



The plate tectonic story

Modelling the mantle - summary

- How are ‘potty putty’ and the mantle similar?

Potty putty	The mantle
Breaks – brittle behaviour	Mantle in the lithosphere breaks – causing earthquakes
Bounces – elastic behaviour	Transmits earthquake (seismic) P- and S-waves
Bends, flows – plastic behaviour	Can flow (over geological time)

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The plate tectonic story

- **Skateboard summary**

Go to: https://www.earthlearningidea.com/Video/V26_Skateboard.html hyperlink

The plate tectonic story

Modelling the lithosphere and asthenosphere (?)

Skateboard © Peter Kennett, ESEU

The plate tectonic story

Modelling the lithosphere and asthenosphere (?)

The crust – trainers	The extreme upper mantle – skateboard	The asthenosphere - wheels

Skateboard © Peter Kennett, ESEU

The asthenosphere (wheels) flows, carrying the plate of lithosphere = trainers (crust) + extreme upper mantle (skateboard) along

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The plate tectonic story

- **What drives the plates?**

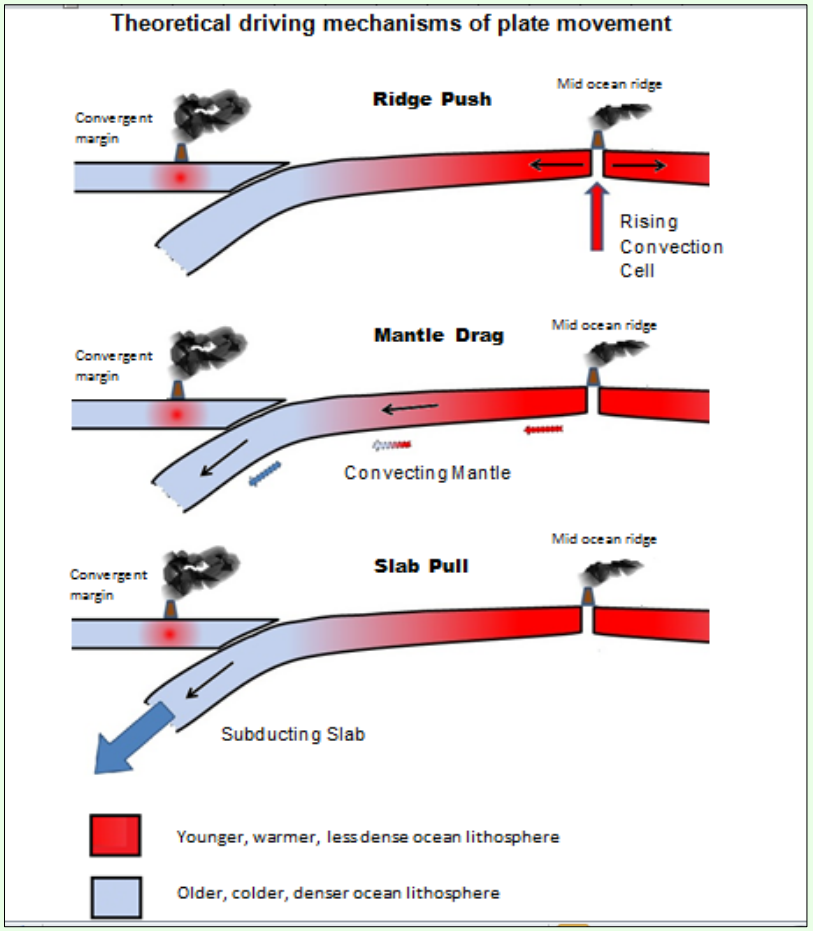
Go to: https://www.earthlearningidea.com/Video/V25_What_drives_plates.html
hyperlink

The plate tectonic story

What drives the plates? – different theories

- **Ridge push** – plates form on oceanic ridges, higher than the surrounding area – the plate slides off, pushing the plate along
- **Mantle drag** – the convection current theory – a convection current flowing in the mantle drags the plate above along
- **Slab pull** – the subducting plate material is more dense than the mantle beneath and so sinks and subducts, pulling the plate along

What does the evidence show is the best theory?



Theoretical driving mechanisms of plate movement © Pete Loader

The plate tectonic story

What drives the plates? – different theories

- **Ridge push** – plates form on oceanic ridges, higher than the surrounding area – the plate slides off, pushing the plate along
  - plates where divergent margins form the greatest percentage of a plate margin should be moving fastest
- **Mantle drag** – the convection current theory – a convection current flowing in the mantle drags the plate above along
  - plates on either side of diverging margins should be moving at the same speed
- **Slab pull** – the subducting plate material is more dense than the mantle beneath and so sinks and subducts, pulling the plate along
  - plates where subduction zones form the greatest percentage of a plate margin should be moving fastest

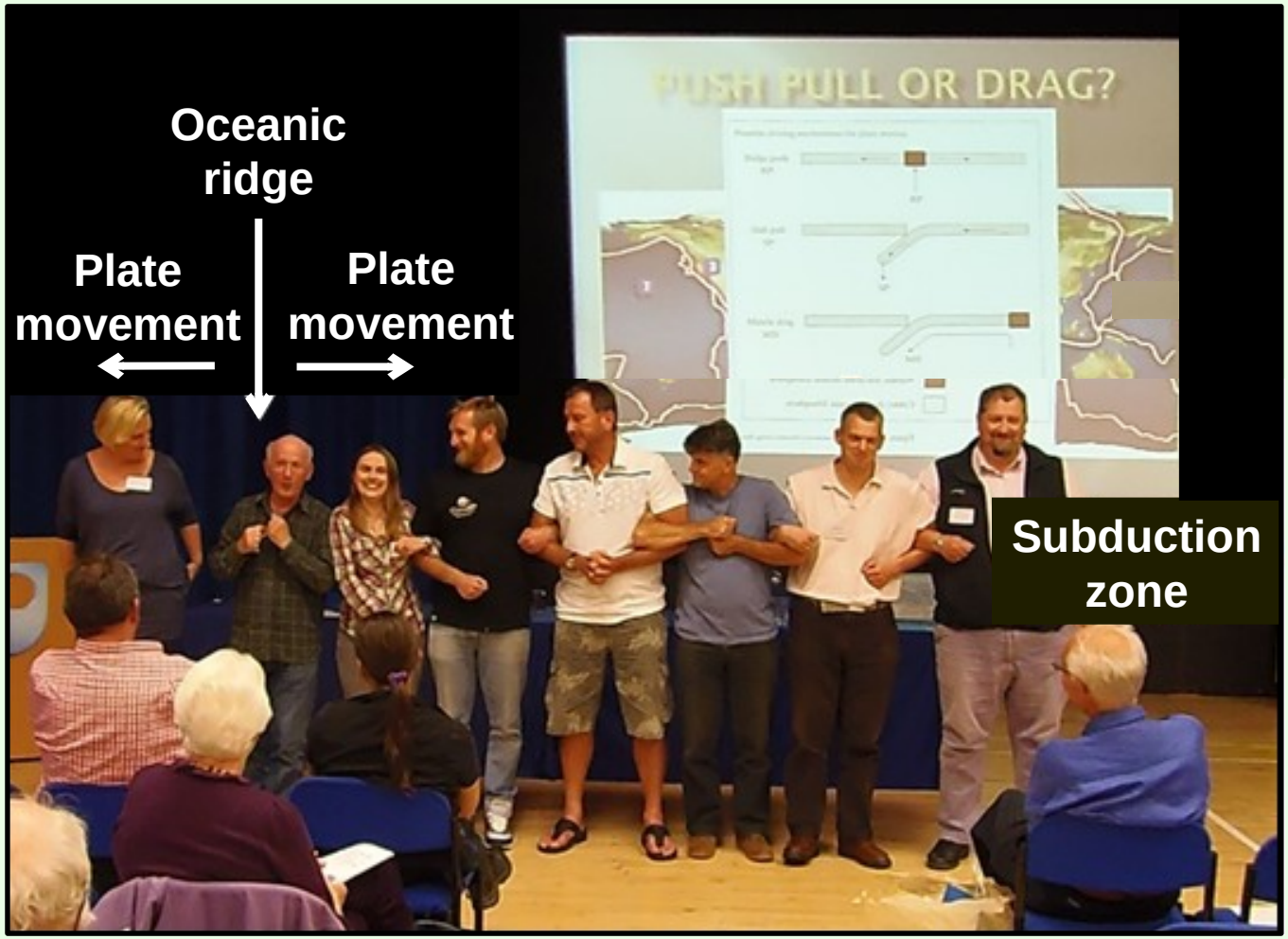
The plate tectonic story

What drives the plates? – different theories

- **Little correlation** – but this may be important for plates with little subduction
  - plates where divergent margins form the greatest percentage of a plate margin should be moving fastest
- **Different speeds** – plates on either side of divergent margins move at different speeds
  - plates on either side of diverging margins should be moving at the same speed
- **Strong correlation** – thought to be the main driving force for most plates
  - plates where subduction zones form the greatest percentage of a plate margin should be moving fastest
- The convection current model, as still shown by many diagrams, has no evidence – our thinking has moved on

The plate tectonic story

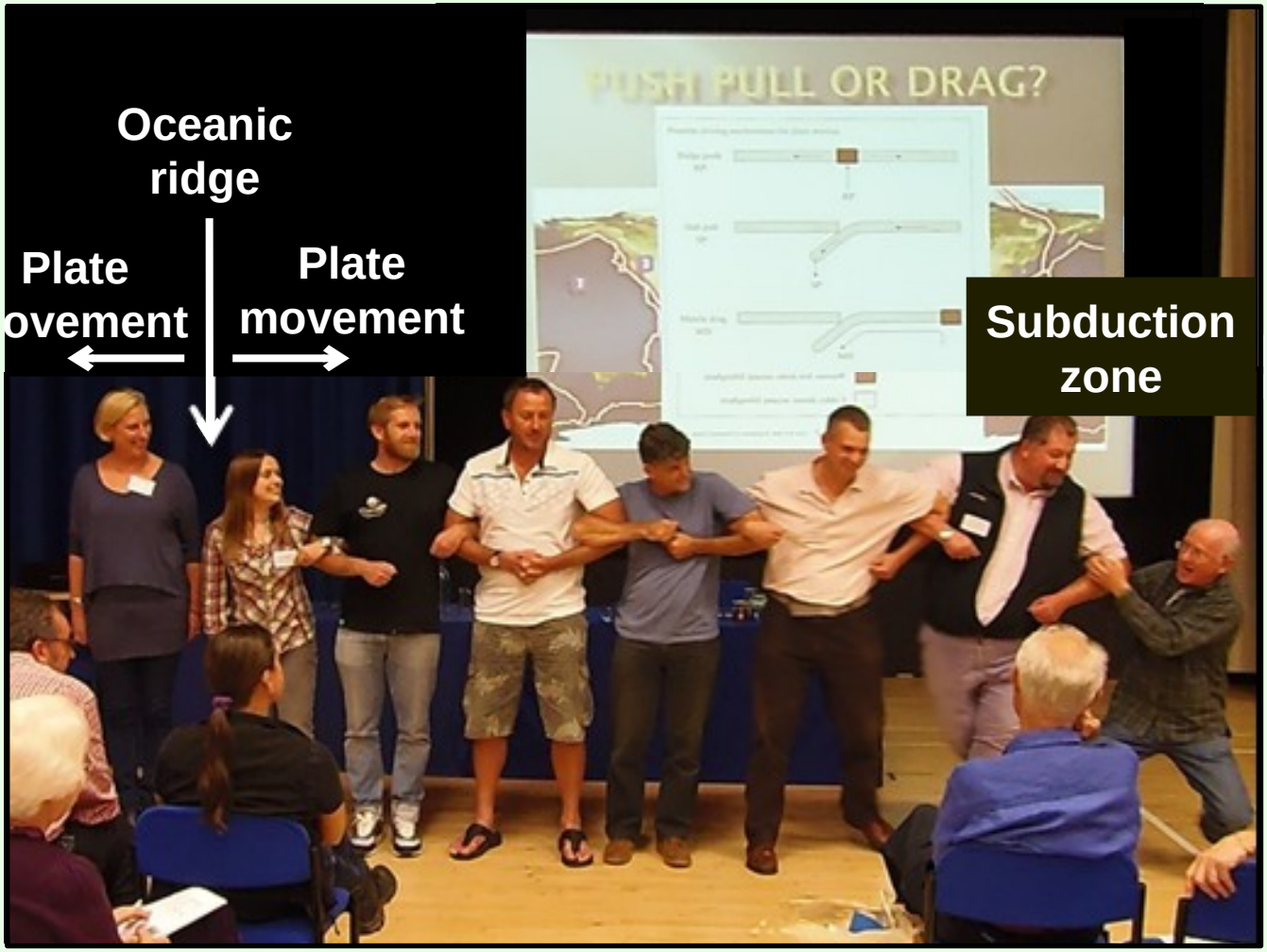
What drives the plates?



Stab pull © David Bailey

The plate tectonic story

What drives the plates?



Stab pull © David Bailey

For more information about these processes, consult the: 'All models are wrong – but some are really wrong: plate-driving mechanisms' Earthlearn-ingidea

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The plate tectonic story

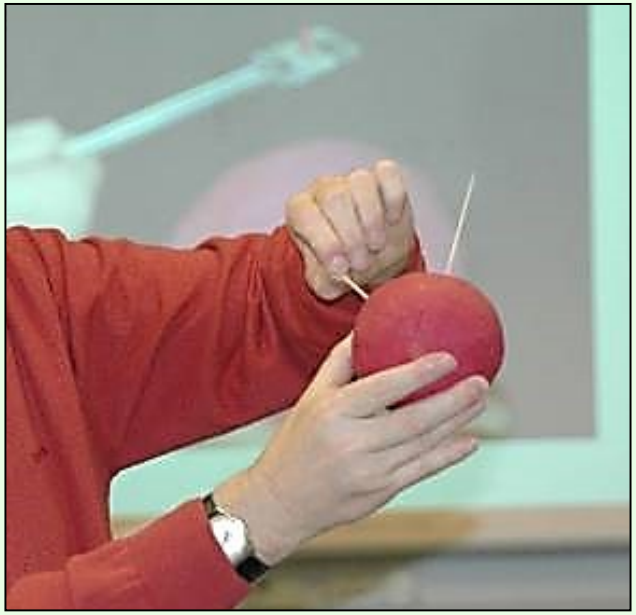
- **Frozen magnetism**

Go to: https://www.earthlearningidea.com/Video/V24_Magnetism1.html hyperlink

The plate tectonic story

The magnetic evidence
From magnetic globe to magnetic rock evidence

Petri-dish magnetic field preserved in iron filings in wax © Michèle Bourne, ESEU



Model magnetic Earth (ESEU)

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The plate tectonic story

- **Magnetic Earth**

Go to: https://www.earthlearningidea.com/Video/V24_Magnetism2.html hyperlink

The plate tectonic story

Model magnetic Earth

Model magnetic Earth (ESEU)

The plate tectonic story

Model magnetic Earth

- How many degrees does the magnet on the Magnaprobe™ rotate through as it is moved from one pole to the other?
- 360^{o} or back to the start = 0^{o}

The plate tectonic story

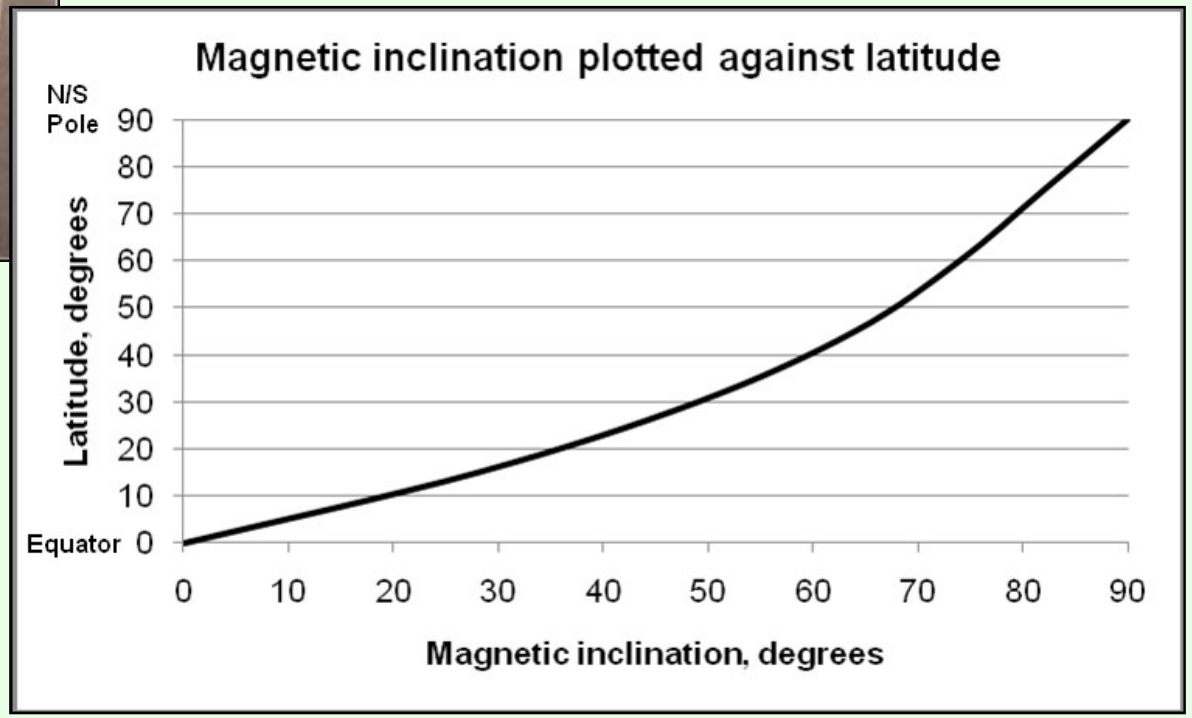
Model magnetic Earth

- If a volcano erupted at the North Pole, what angle (dip) would the magnetism recorded there have (the remanent magnetisation)?
- Vertical (90^o)
- If a volcano erupted at the South Pole, what dip would the remanent magnetisation there have?
- Also vertical (90^o)
- If a volcano erupted at the Equator, what dip would the remanent magnetisation there have?
- Horizontal (0^o)
- Some lavas of Carboniferous age in the UK have horizontal magnetisation. Where was the UK when the lavas erupted?
- On the Equator

The plate tectonic story

Preserving remanent magnetisation

Petri-dish magnetic field preserved in iron filings in wax © Michèle Bourne, ESEU



Magnetic inclination plotted against latitude (graph) © Chris King

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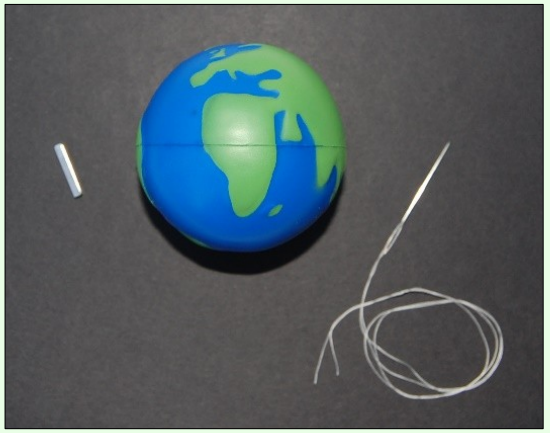
- **Magnetic Earth using a sponge ball globe**

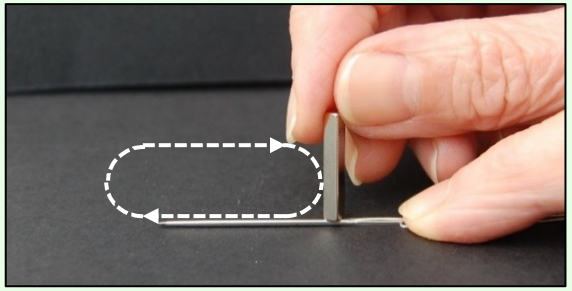
Go to: https://www.earthlearningidea.com/Video/V24_Magnetism3.html hyperlink

The plate tectonic story

Recipe for a magnetic Earth and a magnetic detector

- Collect a needle and thread, a small magnet and an ‘Earth’ stress ball.
- Thread the needle with the piece of thread.
- Make the needle into a magnet, by laying it flat on the table, holding a magnet upright, and stroking it in the same direction ten times, as in the photograph.
- Push a sharp pencil or pen into the North Pole of the stress ball until it reaches just over half way
- Remove the pencil/pen and push a small magnet into the same hole until it reaches half way
- You now have a model magnetic Earth and a magnetised needle ‘magnetic detector’

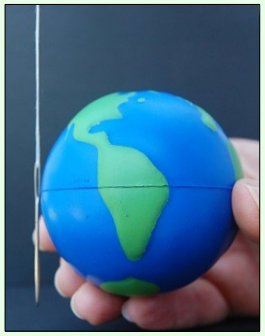




The plate tectonic story

Recipe for a magnetic Earth and a magnetic detector

- Find one of the magnetic poles of the Earth by hanging the needle from the thread, and finding where the needle is pulled straight down
- Find the pole on the other side of the model Earth, where the two magnets (the needle magnet and the one in the Earth) repel, so the needle is pushed away from the pole and circles around it at an angle
- Find the Equator, where the needle is upright beside the side of the Earth



Note: We need to teach pupils that Earth's magnetism is **NOT** caused by a bar magnet inside the Earth – the evidence is that it is caused by currents in the core. This is just a model of how Earth's magnetism works

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The plate tectonic story

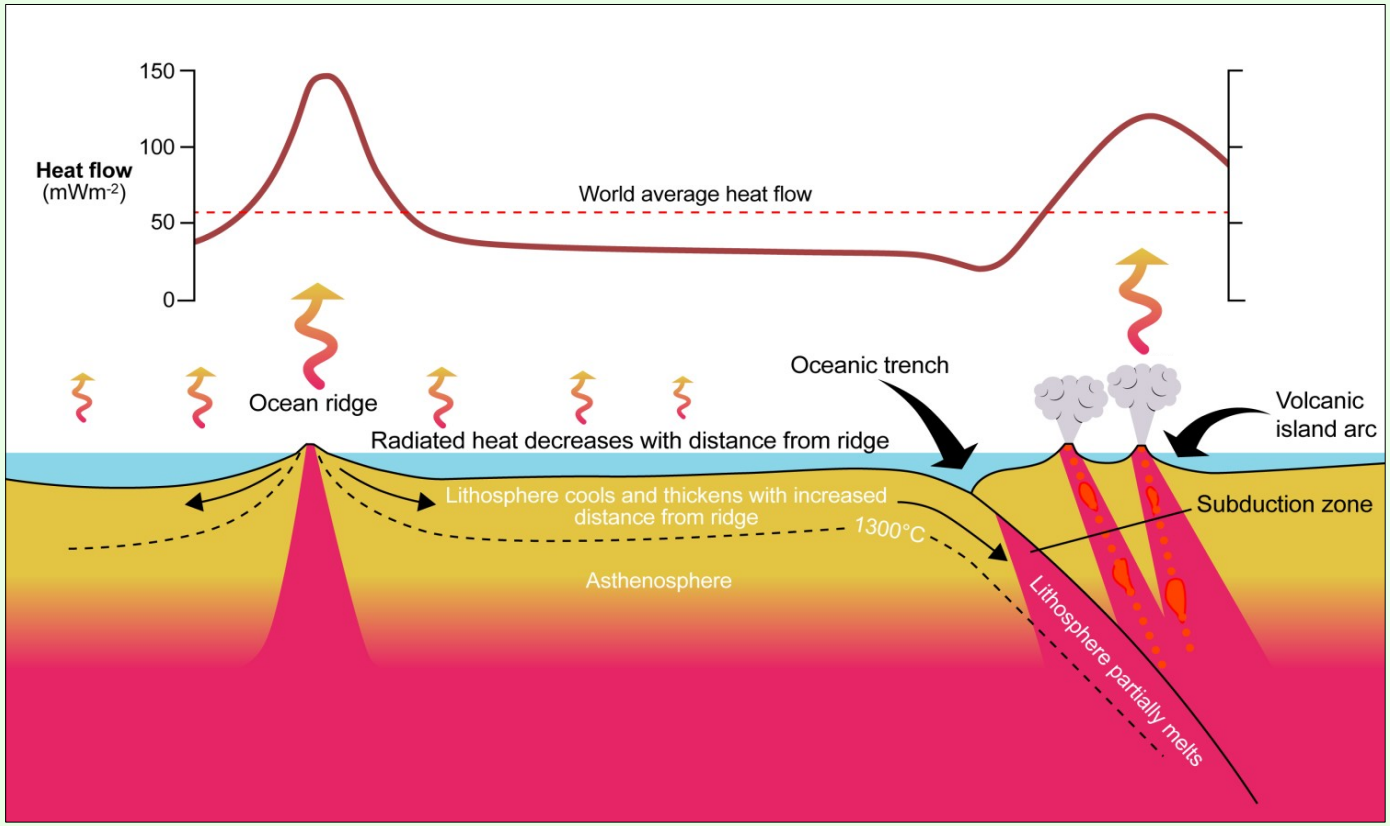
- **The heat flow evidence**

Go to: https://www.earthlearningidea.com/Video/V28_Heat_flow.html hyperlink

The plate tectonic story

The heat flow evidence

The pattern of heat flow from the Earth



The pattern of heat flow out of the ocean floor and the upper part of the mantle and the crust © Chris King and Dee Edwards, redrawn by ESEU

The plate tectonic story

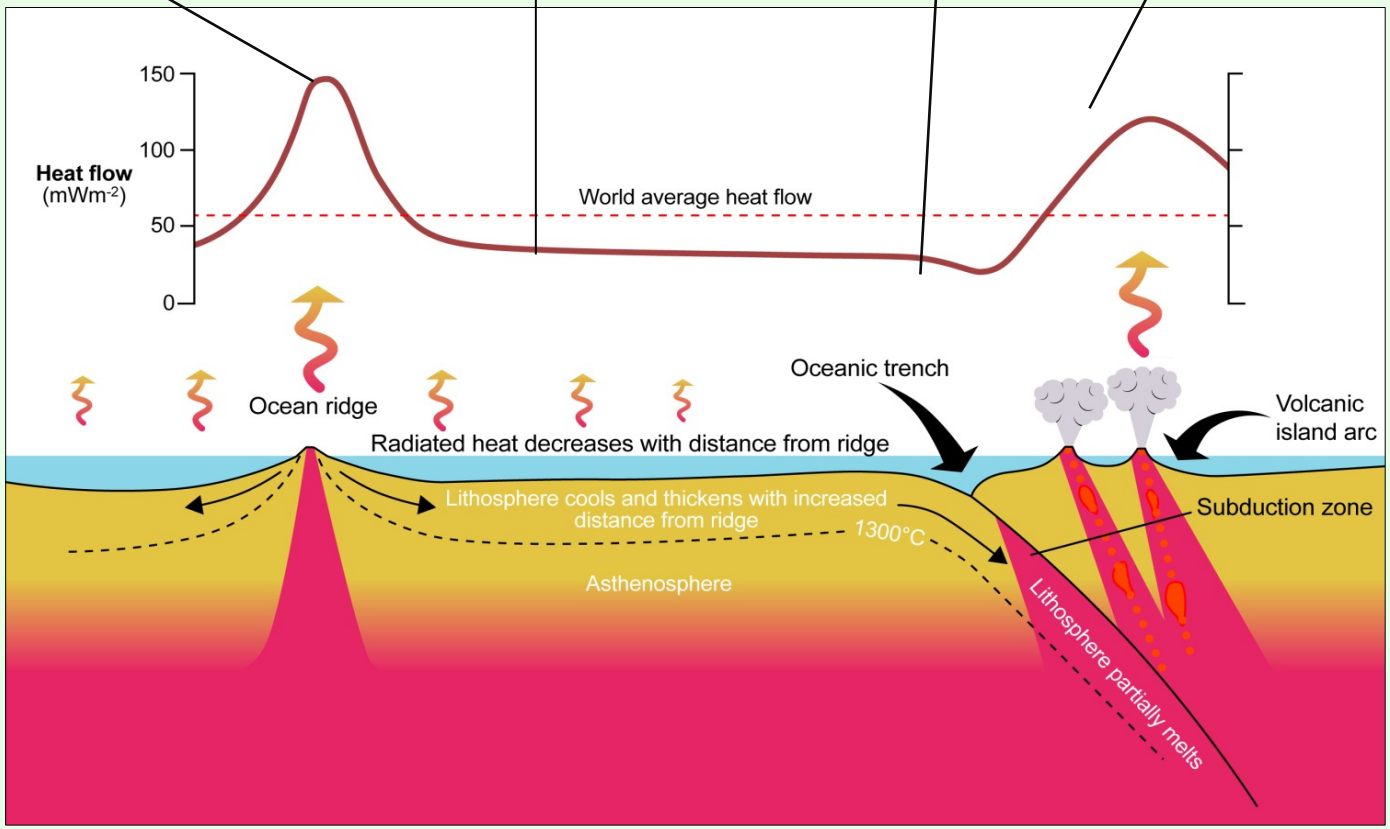
The pattern of heat flow from the Earth

High heat flow – from rising current at ridge

Heat flow reducing as plate cools

Lowest heat flow at trench

High heat flow from volcanicity



The pattern of heat flow out of the ocean floor and the upper part of the mantle and the crust © Chris King and Dee Edwards, redrawn by ESEU

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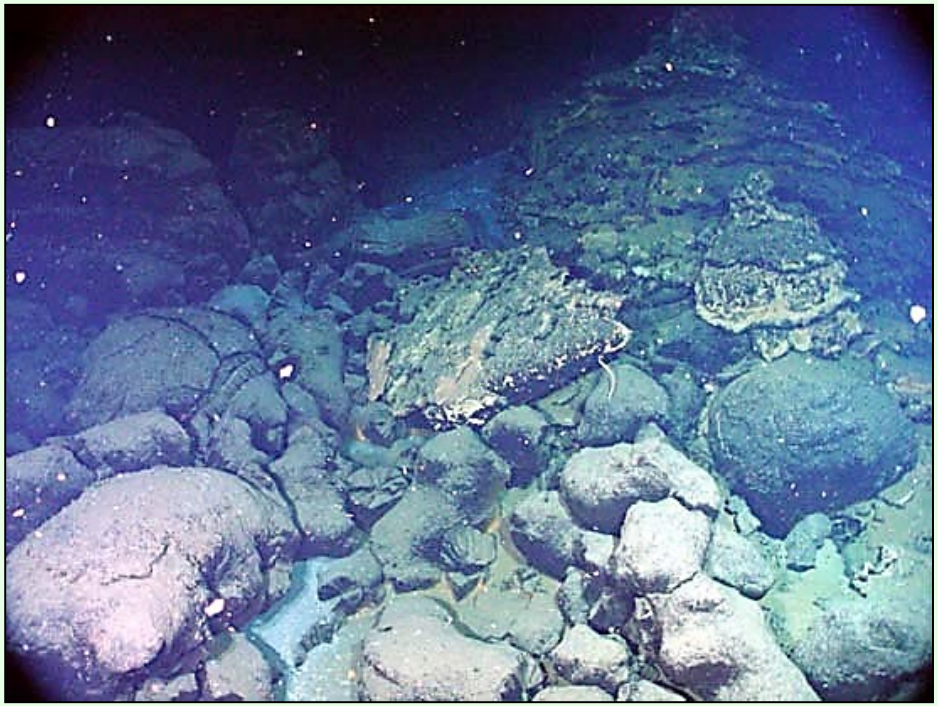
The plate tectonic story

- **The age of ocean floor and plate speed**

Go to: https://www.earthlearningidea.com/Video/V28_Age_ocean_floor.html
hyperlink

The plate tectonic story

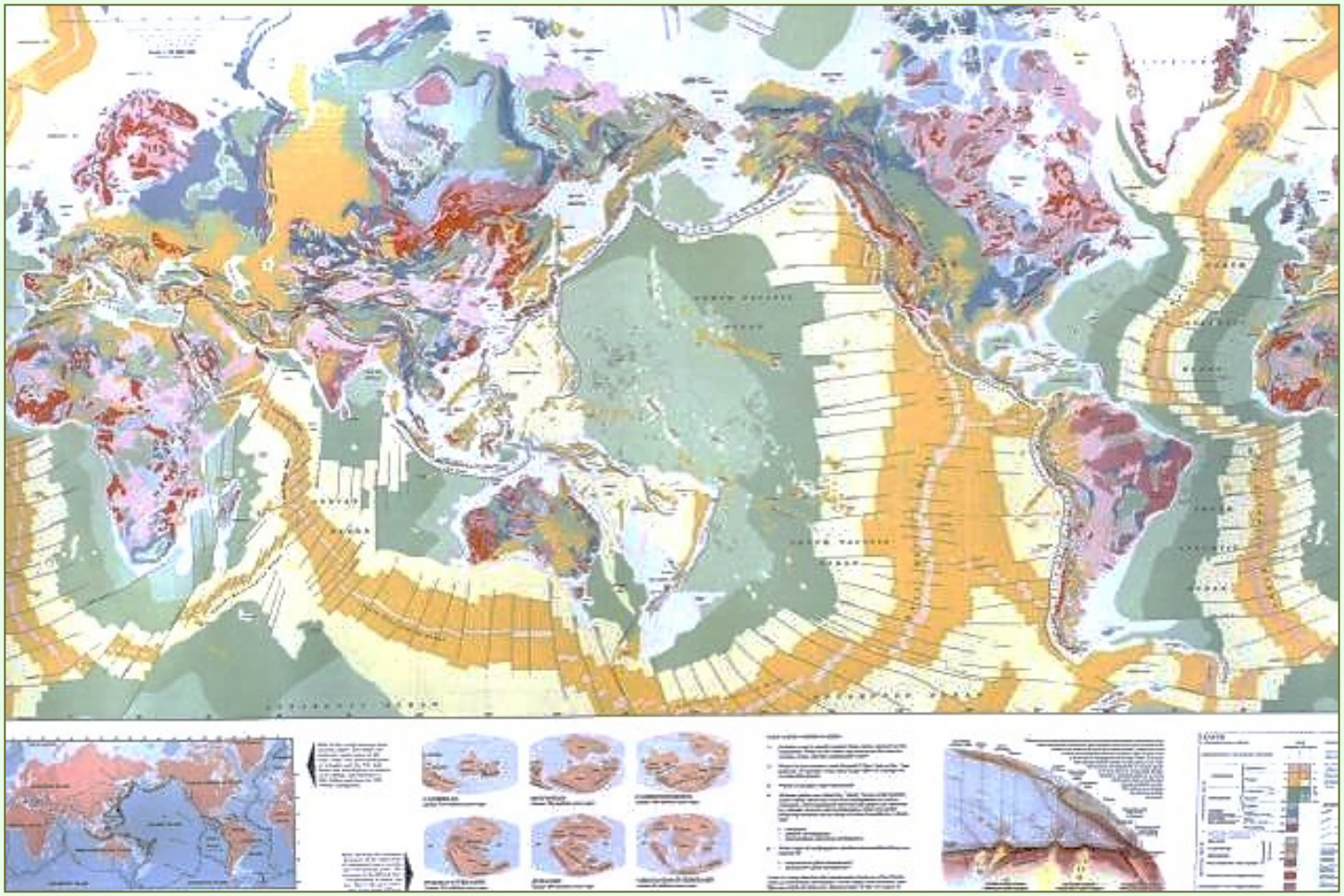
The age of the ocean floor evidence: ocean floors are young where new plate is being formed, becoming older outwards



‘Ancient pillow lava’ by US National Oceanic & Atmospheric Administration – image in the public domain

The plate tectonic story

Evidence from the age of the sea floor



Photograph of 'The Geological Map of the World'. © Open University

Age of the sea floor – youngest = dark yellow, oldest = pale green

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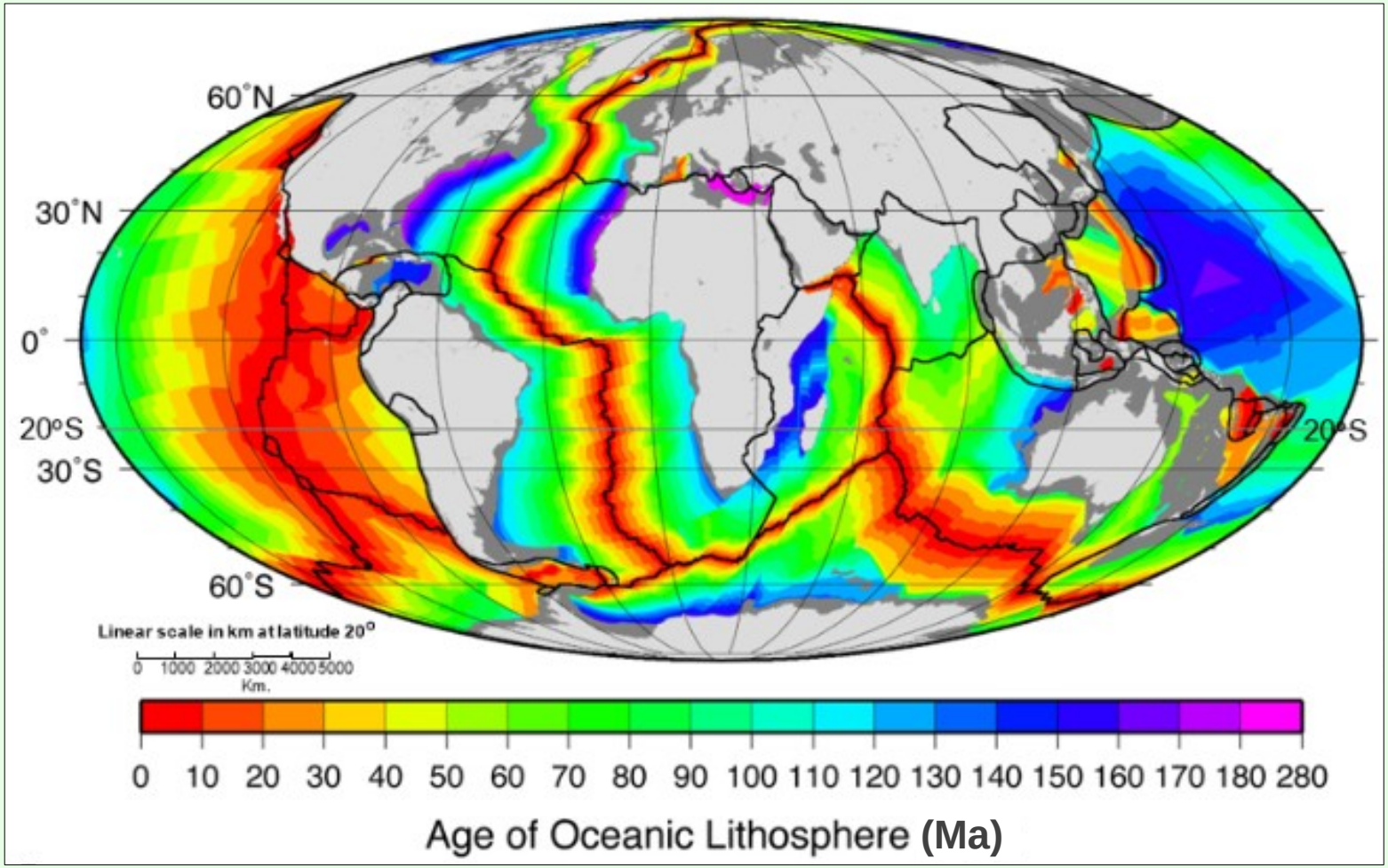
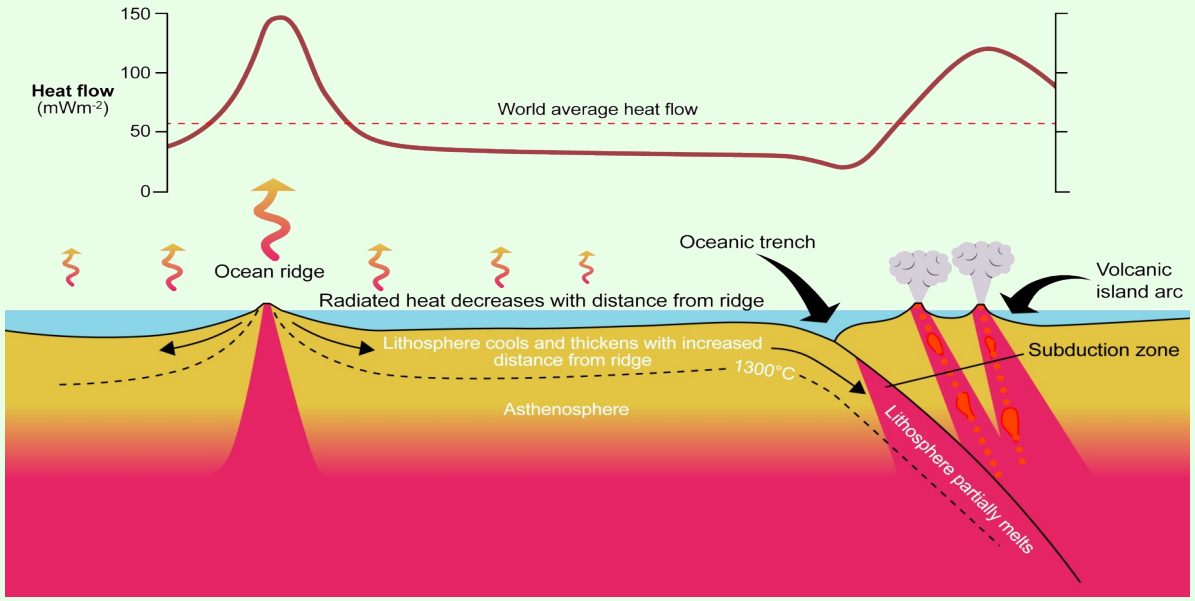
Which is the fastest-spreading oceanic ridge?



The plate tectonic story – online

End of Part 1

Earth Science for science and geography – video workshop



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