The plate tectonic story – online
Part 2
Earth Science for science and geography
– video workshop

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

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The plate tectonic story

• Divergent margins

Go to: https://www.earthlearningidea.com/Video/V29_DivergentMargins1.html

hyperlink
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Divergent plate margins - adding new plate material

Underwater basalt lava at a divergent margin in the public domain by Vintei
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Activity at an oceanic ridge – a divergent plate margin
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Mid-Atlantic ridge

http://maps.grida.no/go/graphic/world-ocean-bathymetric-map
(Hugo Ahlenius, UNEP/GRID-Arendal)
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Icelandic-type eruption
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Ancient pillow lavas
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Black smoker activity

Black Smoker’ by US National Oceanic & Atmospheric Administration (public domain)
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- Faults in a Mars™ bar

Go to: https://www.earthlearningidea.com/Video/V29_Divergent_margins2.html
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Faults in a Mars™ Bar
Modelling a divergent plate margin

Gap between the North American and Eurasian continental plates © Randomskk
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Faults in a Mars™ Bar
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Faults in a Mars™ Bar

central ‘rift valley’

rigid ‘lithosphere’ moving left

rigid ‘lithosphere’ moving right

ductile flowing ‘asthenosphere’

solid ‘mantle’
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A divergent margin rift valley on land
Iceland

Gap between the North American and Eurasian continental plates © Randomskk
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• Magnetic stripes

Go to: https://www.earthlearningidea.com/Video/V30_Magnetic_stripes.html
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The magnetic stripes evidence

Research ship used to tow magnetometer
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Magnetic anomalies over the Reykjanes Ridge

Black = positive anomaly
White = negative anomaly

The equipment used to show magnetic anomalies © Peter Kennett

Magnetic anomalies over the Reykjanes Ridge © Geoscience, redrawn by ESEU
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Magnetic evidence for ocean floor spreading

**Calculated** magnetic profile: assuming that seafloor spreading occurs, based on known reversals and dates from similar rocks on land.

**Observed** magnetic profile: measured above the East Pacific Rise by oceanographic survey.

Normal magnetic polarity: (yellow to red)

Reversed magnetic polarity: (light blue to dark blue)

Lithosphere

Zone of magma injection, followed by cooling which leads to the "locking in" of the magnetic polarity.
Meanwhile, it had been found from sequences of volcanic lava flows that the Earth’s magnetic field had ‘flipped’ many times in the geological past.

Magnetisation preserved in rocks – like the petri dish wax magnetic field – but reversed at intervals because of magnetic pole flips.
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Classroom demonstration of concepts associated with sea floor spreading

- Pin magnetised by stroking with magnet
- Fold
- Piece of card marked with symmetrical bands either side of the fold
- Card pulled to represent direction of plate movement
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Magnetic anomalies over the Reykjanes Ridge

Black = positive anomaly
White = negative anomaly

The equipment used to show magnetic anomalies © Peter Kennett

Magnetic anomalies over the Reykjanes Ridge © Geoscience, redrawn by ESEU
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The magnetic stripes are offset by transform faults – conservative or sliding plate margins
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• Convergent margins

Go to: https://www.earthlearningidea.com/Video/V31_ConvergentMargins.html
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Convergent plate margins - recycling material

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

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

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Convergent plate margins - recycling material

Ocean v ocean convergent plate margin
– one oceanic plate subducted beneath another

Ocean v continent convergent plate margin
– an oceanic plate subducted beneath a continental plate

 Continent v continent convergent plate margin
– two continental plates colliding
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Ocean-ocean convergence

Two oceanic plates meet in the open ocean. The denser plate is subducted into the mantle. Partial melting produces magma which rises to form an island arc.
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Convergent plate margins: where plate material is recycled

'A satellite view of the Aleutian Islands, Pacific Ocean' by NASA (public domain)
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Island arc volcanism

Zavodovski Island, South Sandwich Island, South Atlantic (Peter Kennett)
The dense oceanic plate descends below the lighter continental one. Partial melting of the basaltic rocks of the ocean floors produces magma which rises. It is richer in silica than basalt and erupts in a more violent way.
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Ocean-continent convergence: Mount St Helens
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Continent-continent convergence

When two continents are brought together at a converging plate boundary, the continental rocks are of too low density to be subducted. Instead they become folded and faulted, to form a mountain range.

Continental plate collision zone. Reproduced with kind permission of USGS, redrawn by ESEU
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Plates in motion – cardboard replica
A working model of how colliding continents produce mountain chains – like this one

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Continent-continent convergence

The rapid northward drift of the Indian plate (at 15-40cm per year) produced the Himalayas and Tibetan Plateau when it collided with the Eurasian plate.

Folds at Lhotse (Himalayas) by Michael Searle © University of Oxford

Eurasian Plate (India's movement) © This Dynamic Earth: the Story of Plate Tectonics, USGS, redrawn by ESEU
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Plates in motion:
cardboard replica plates in motion

Cardboard replica of plates in motion (photograph) © ESEU
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Plates in motion:
cardboard replica plates in motion

moveable wooden block attached to end of thin card
layers of paper serviettes clipped together onto the thin card strip
fixed wooden block taped to card base
thin card strip passes through slit in base
slit in heavy card base
PULL

Cardboard replica of plates in motion (diagram) © ESTA, redrawn by ESEU
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Plates in motion:
cardboard replica plates in motion

Photograph of plates in motion © Chris King
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• Deformation

Go to: https://www.earthlearningidea.com/Video/V31_Deformation2.html
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Deformation – make your own folds and faults

The Himalayas in 30s...
The plate tectonic story

Deformation – make your own folds and faults

The Himalayas in 30s
The plate tectonic story

Deformation – make your own folds and faults

The Himalayas in 30s
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• Continental jigsaw puzzles

Go to: https://www.earthlearningidea.com/Video/V32_Jigsaw_puzzles.html
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Continental jigsaw puzzles - the ‘matching’ evidence

Debating the reconstruction of the supercontinent of ‘Gondwana’ © Peter Kennett
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The continental jigsaw puzzles (the outlines of the Gondwana continents)
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The continental jigsaw puzzles (continental shelf match at 1000m depth below sea level)

At 1000 m below sea level, the continental rock types give way to oceanic ones. Using this depth for a reconstruction gives a better fit than the present coastlines. Areas of overlap are mostly where features such as deltas have added to the continental margins since break-up.
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The continental jigsaw puzzles \((\text{former distribution of ice across the Gondwana continents})\)

Areas covered by ice sheets 300-250 million years ago (rather conjectural for Antarctica because of modern ice cover!)

Direction of movement of ancient ice sheets

The continental jigsaw puzzles \((\text{former distribution of ice across the Gondwana continents})\) © Andrew McLeish in ‘Geological Science’
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The continental jigsaw puzzles (matching ancient rock distributions)

The distribution of ancient rocks across South America and Africa © Andrew McLeish in ‘Geological Science’

The distribution of younger rocks across South America and Africa up to the beginning of the continental split. Source unknown, redrawn by ESEU
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The continental jigsaw puzzles (distribution of land/freshwater animals and plants in the continents of ‘Gondwana’)

The continental jigsaw puzzles fossil distribution evidence, reproduced with kind permission of USGS
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Map of plates and continental distributions today

Map of plates © This Dynamic Earth: the Story of Plate Tectonics, USGS, redrawn by ESEU
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Brickquake

Go to: https://www.earthlearningidea.com/Video/V33_Brickquake.html
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Brickquake – can earthquakes be predicted?
How earthquakes work –
and how difficult they are to predict
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Brickquake – can earthquakes be predicted?
How earthquakes work –
and how difficult they are to predict
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Brickquake – can earthquakes be predicted?

How earthquakes work –
and how difficult they are to predict

Brickquake – can earthquakes be predicted (diagram) © ESEU
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Distribution of earthquakes

Depth of focus of earthquake
- Shallow: 0 - 70 km
- Intermediate: 71 - 300 km
- Deep: 301 - 700 km

‘Brickquake’ – can earthquakes be predicted?

Distribution of earthquakes – source unknown, redrawn by ESEU

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<th>Force (Newtons)</th>
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<td>4</td>
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</tbody>
</table>

‘Brickquake’ results

Brickquake (ESEU)
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Party popper eruption

Go to: https://www.earthlearningidea.com/Video/V34_Party_poppers.html
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How predictable are volcanic eruptions?
– party popper simulation

Set-up for the party popper activity © Peter Kennett, ESEU
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How predictable are volcanic eruptions? – party popper simulation – the result of 156 attempts
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How predictable are volcanic eruptions?
– party popper simulation

Volcano alert ‘Chance cards’ © David Turner
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- Plate plenary

Go to: https://www.earthlearningidea.com/Video/V35_Plate_plenary.html
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What am I doing?

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Plate-riding

Image of the Earth © Noldoaran

‘Surfer’ by United States Marine Corps (public domain)
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Plate-riding

‘How fast am I going?’

‘What is happening in front of me?’

‘In which direction am I travelling?’

‘How can I tell I’m moving?’

‘What is happening behind me?’
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Plate-riding

‘How fast am I going?’
(as fast as our fingernails grow)

‘In which direction am I travelling?’
(towards the East)

‘What is happening in front of me?’
(I’m heading towards the Japanese subduction zone, with its earthquakes, volcanoes and mountains)

‘What is happening behind me?’
(new plate material is being formed, as in Iceland)

‘How can I tell I’m moving?’
(GPS measurements over several years, magnetic stripe evidence, age of the sea floor evidence)
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Model the five different types of plate margin with your hands
Possible answers include:

- divergent margin
- ocean v ocean
- ocean v continent
- continent v continent
- conservative (transform)
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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.
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