

Discovery of 'magnetic stripes' forming patterns on the floor of the Atlantic, spreading from MAR, in pairs one each side. Formed as Earth's magnetic field underwent regular reversals.

Rate of sea-floor spreading: Atlantic widening about 3 cm each year, so at constant rate suggests began to open 180-250Ma BP. So back to Pangaea!

But if the ocean is widening, something else must be giving way to provide the space on the Earth's surface – unless the Earth itself is expanding!

Part 5 Welcome to the BIG IDEA!

1960's: sea-floor spreading + continental drift = moving plates!

Earth's outer layer as a set of rigid plates moving slowly on a less rigid mantle. The present jumble of plates is just a snapshot in Deep Time.

Plates: rigid, brittle, from 10 km to 200 km thick, up to several thousand kilometres across. Composition: essentially of basalt in young ocean basins (thinner), of granite in older continental parts of plates (much thicker)

When plates meet

Constructive margins/boundaries: mid-ocean ridges > sea-floor spreading > new material

Destructive margins/boundaries: plates collide and then...

- two continental plates may weld together (possibly with slow over-ride) – thick and of similar density, producing major mountain ranges. But note that such a collision will be preceded by the disappearance of an ocean plate by subduction – see below – and the remains of the ocean plate may be found in the debris.
e.g. India meets Eurasia about 45 Ma BP > Himalayas; Europe meets Asia about 220 Ma BP > Urals.
- ocean plate meets continental plate – denser ocean plate is over-ridden by less dense continental plate, goes down – **subduction** – producing crumple zone in form of mountain range.
e.g. Nazca plate meets South America – still continuing > Andes; Scotland (on continent of Laurentia) collides with England (on micro-continent of Avalonia) about 400 Ma BP > Scottish Highlands (Caledonides from Canada to Norway).
- two plates may slide jerkily past each other along a complex fault zone, producing major earthquake activity as each jerk takes place.
e.g. Pacific Plate rotates against the North American Plate along the San Andreas Fault Zone > major earthquake zone along Californian coast; the Moine Terrane slid past the Grampian Terrane along the Great Glen Fault, with major earthquakes in the distant past, and still giving frequent minor quakes today.

And finally a mechanism to explain plate movement

It was suggested from the 1960s onwards that the cause of plate movements was the circulation of slow convection currents in the hot mantle beneath (plastic flow, not fluid flow). In recent

years, evidence has emerged for such convection cells in the mantle, though the details of these have still to be determined.

However, although the drag of mantle convection currents against the underside of the plates is important, a major cause of plate movement is the drag caused by subducted plates diving down into the mantle, pulling the rest of the plate with them. This opens up the crust at the mid-ocean ridges, reducing pressure on the hotter material beneath, allowing it to melt and well up to fill the gap. This gives rise to sea-floor spreading.

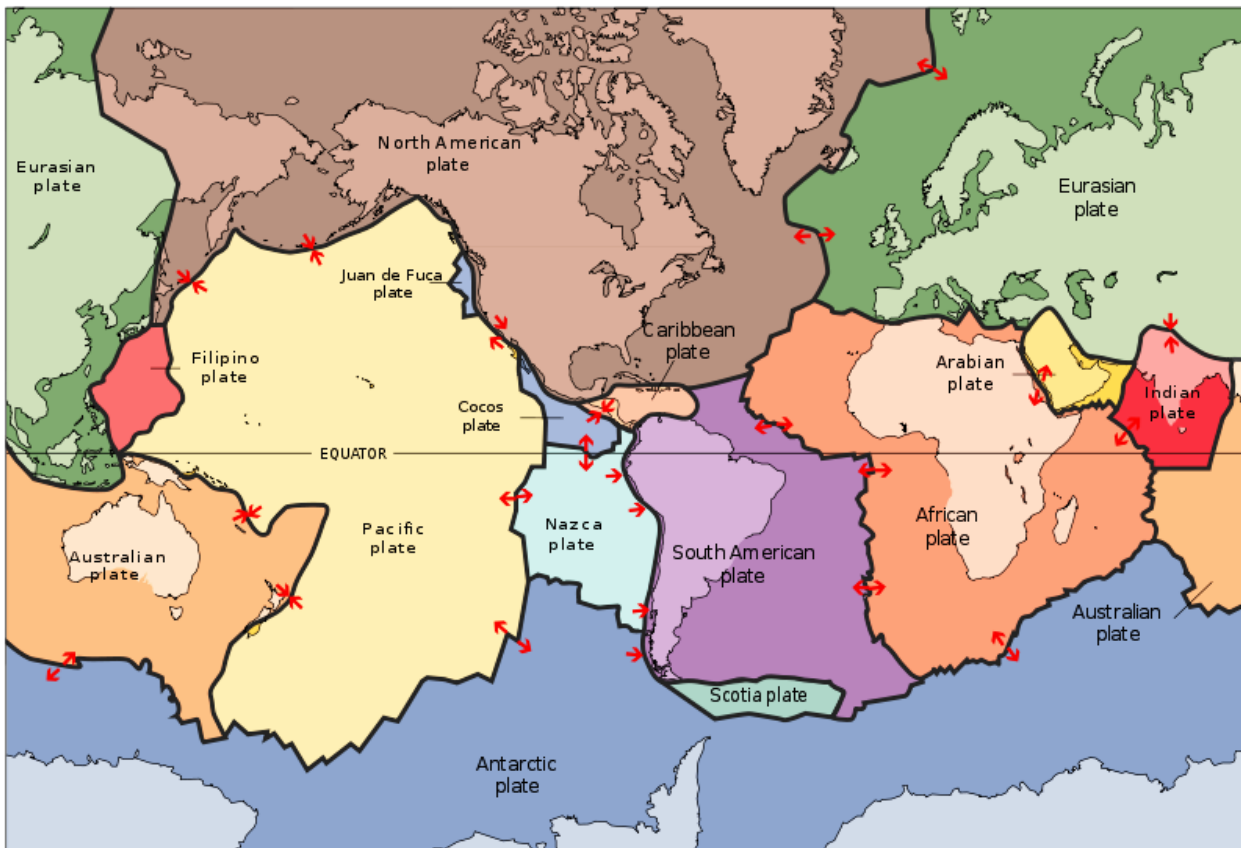
Eventually the descending section of the subducting plate breaks off and slowly sinks through the mantle, perhaps reaching the mantle-core boundary, where it is slowly absorbed into the mantle.

So the material of the lithosphere is slowly recycled from mid-ocean ridge to subduction zone – but mainly basaltic ocean plate material, with any sedimentary deposits that have become stuck to them. The central ancient cores of the continents, called **cratons**, do not become involved in tectonic recycling, and form hard resistant and essentially very ancient cores to every continent.

Epilogue

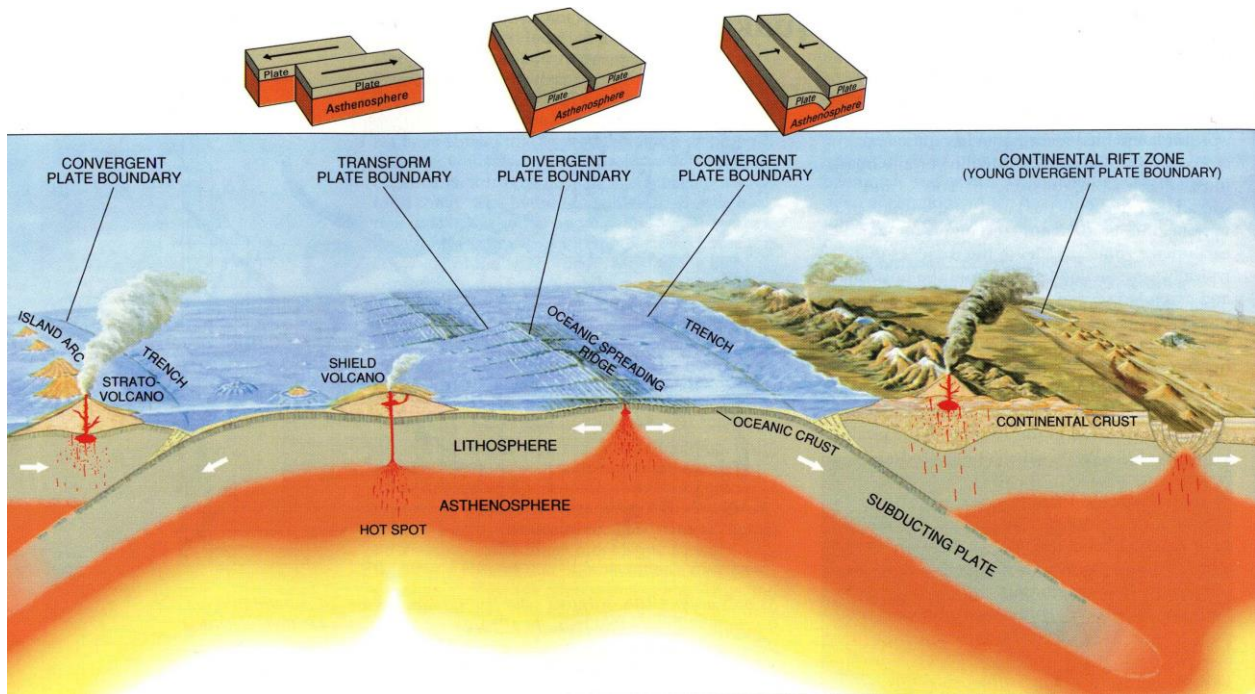
This session has been but a brief initial look at this vast topic. Much of importance has been omitted or skipped over, and will have to be taken up in later sessions. Volcanoes, earthquakes, large intrusions, folding, faulting, mountain building... we will come back!

The Present-Day Tectonic Plates



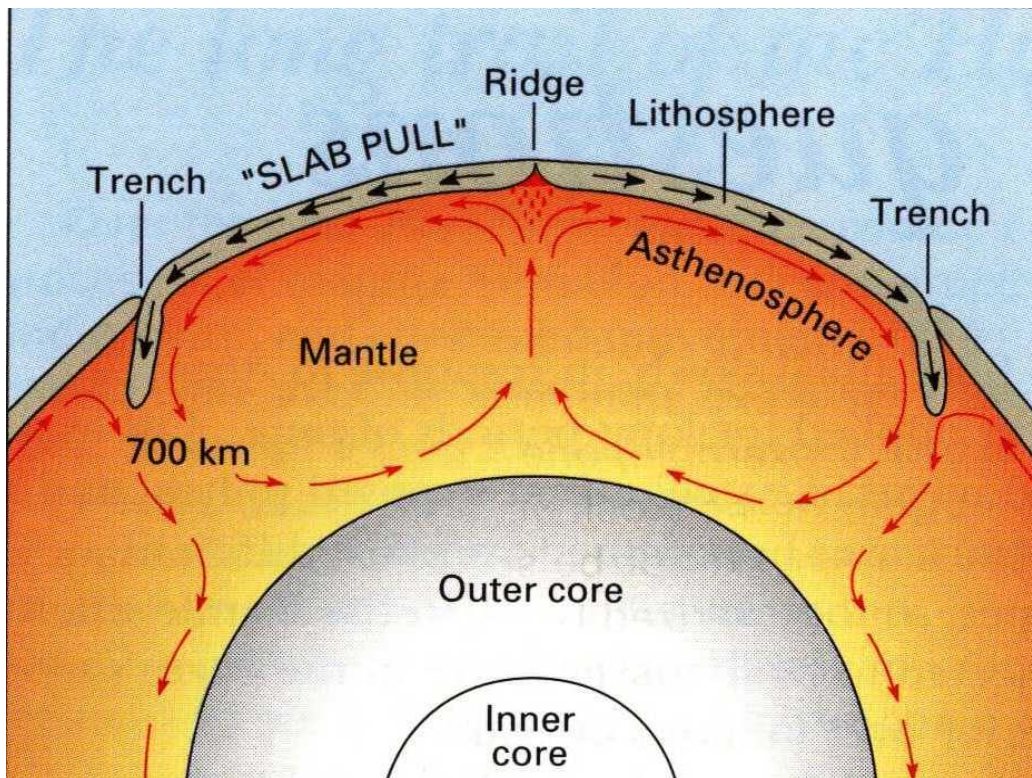
Source: US Geological Survey

Types of Plate Boundary



Source: US Geological Survey

How does it work?



Further reading

NB: Although many publishers give their popular science books on Earth topics only short lives as new books, they can often be found secondhand on Amazon and other secondhand book sources.

From the books listed in the Session 2 Summary, several have good sections with excellent illustrations on Plate Tectonics:

- Earth Story, by Simon Lamb and David Sington; BBC books
- Journeys from the Centre of the Earth, by Iain Stewart; Century
- Origins: The Evolution of Continents, Oceans and Life, by Ron Redfern; Cassell
- Earth: The Definitive Visual Guide, ed. James Luhr; Dorling Kindersley
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In addition the following may be of interest:

- The Viking Historical Atlas of the Earth, Roger Osborne & Don Tarling, ed Stephen Jay Gould; Viking Press
- The Tectonic Plates are Moving! Roy Livermore, Oxford UP, £17.99 (an up to date text on the subject in very readable language)
- Plate Tectonics: An Insider's History of the Modern Theory of the Earth, Naomi Oreskes; Westview Press (a series of essays written by scientists who were involved in the development of Plate Tectonics – a historical perspective)
- Supercontinent: 10 Billion Years in the Life of Our Planet, Ted Nield; Granta (a well-written overview, including the future!)

Websites

The Palaeomap Project, aiming to produce comprehensive maps of Earth past,

www.scotese.com/Default.htm

Now animated versions from the same project: https://www.youtube.com/watch?v=g_iEWvtKcuQ, and also with a peek into the future of the planet:

<https://www.youtube.com/watch?v=uLahVJNnoZ4> (and with more detail of the Africa/S America match)