THE CARBON CYCLE

The Geological Society

ATMOSPHERE
VERY FAST
TERRESTRIAL BIOSPHERE

ATMOSPHERE
FAST
OCEANS

ATMOSPHERE
SLOW
LITHOSPHERE

RESERVOIR	AMOUNT OF CARBON (GtC)	RESIDENCE TIME (YEARS)
ATMOSPHERE	830	5
TERRESTRIAL BIOSPHERE	2,400	10
SOILS	1,600	
VEGETATION	600	
OCEANS	38,000	400
SURFACE	1000	
DEEP	37,000	
LITHOSPHERE	>75,000,000	100 - 200,000,000
SEDIMENTARY ROCKS	>60,000,000	
HYDROCARBONS	15,000,000	

RAIN WATER REACTS WITH CO_2 TO FORM CARBONIC ACID (H_2CO_3)

$H_2O + CO_2 \longrightarrow H_2CO_3$

CHEMICAL WEATHERING OF SILICATE ROCKS BY CARBONIC ACID

$CaSiO_3 + 2CO_2 + H_2O \downarrow Ca^{2+} + 2HCO_3^- + SiO_2$

IONS TRANSPORTED TO OCEAN

CO_2 RELEASED FROM MID OCEAN RIDGES

CO_2 RELEASED FROM VOLCANOES

VOLCANOES PROVIDE FRESH SILICATE ROCK FOR WEATHERING

CONTINENTAL CRUST

CO_2 IN MAGMA

ACCRETIONARY WEDGE

OCEANIC CRUST

UPPERMOST MANTLE

LITHOSPHERE

ASTHENOSPHERE

1

CARBONATE SHELLS FORM SEA FLOOR CARBONATE ROCKS

CARBONATE ROCKS SUBDUCTED

PARTIAL MELTING & METAMORPHISM OF SUBDUCTED ROCKS RELEASES CO_2

$CaCO_3 + SiO_2 \downarrow CaSiO_3 + CO_2$

2

3

BURIED HYDROCARBONS

1

CO_2 IN ATMOSPHERE

$CO_2 + H_2O \rightleftharpoons H_2CO_3$

$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

$H^+ + CO_3^{2-} \rightleftharpoons HCO_3^-$

$Ca^{2+} + 2HCO_3^- \rightleftharpoons CaCO_3 + CO_2 + H_2O$

PHYTOPLANKTON GROWTH

ORGANISMS BUILD $CaCO_3$ SHELLS

PHOTIC ZONE

~200m

UPWELLING

DECOMPOSITION

SEDIMENTATION

SEDIMENTATION

DEEPWATER CIRCULATION

NUTRIENTS+ CO_2

ORGANIC SEDIMENTS

CARBONATE SEDIMENTS

2

CO_2 IN ATMOSPHERE

PHOTOSYNTHESIS

$6H_2O + 6CO_2 \rightleftharpoons C_6H_{12}O_6 + 6O_2$

RESPIRATION

RESPIRATION - ANIMALS, PLANTS & DECOMPOSERS

PHOTOSYNTHESIS

ORGANIC CARBON IN SOIL

3

CO_2 IN ATMOSPHERE

$C_xH_y + n(O_2) \downarrow x(CO_2) + \frac{y}{2}(H_2O)$

COMBUSTION

COMBUSTION

EXTRACTION

EXTRACTION

BURIAL

BURIAL

IMPERMEABLE SEAL

RESERVOIR

COAL SEAM

MIGRATION

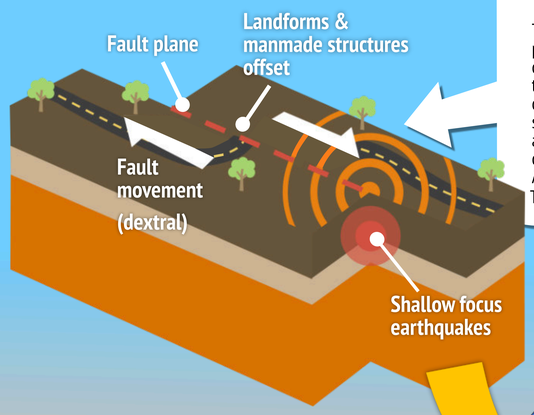
HYDROCARBON SOURCE ROCK C_xH_y

PLATE TECTONICS

FIND OUT MORE! ➡ www.geolsoc.org.uk/plate-tectonics
➡ www.geolsoc.org.uk/tectonicstories

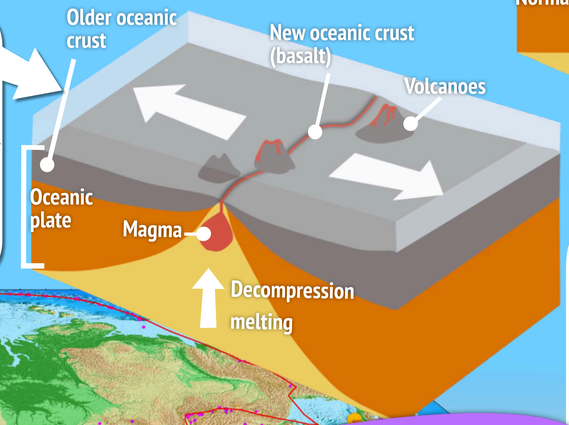
TRANSFORM BOUNDARY

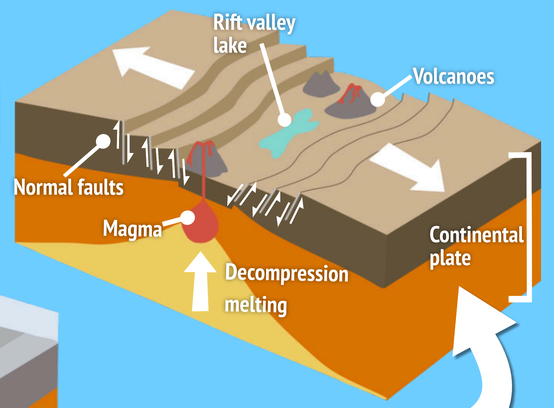
Transform plate boundaries occur between plates that are sliding past each other, either in opposite directions, or in the same direction but at different speeds. When the plates eventually slip, the **pressure** built up by **frictional forces** as they grind past each other is released as **seismic energy**, causing **shallow focus**, and sometimes devastating, earthquakes. Transform plate boundaries are most common in oceans between ridge segments, but also occur at continental margins or in continents, such as the San Andreas Fault between the Pacific and North American plates. Transform boundaries occur in oceanic and continental crust zones.



DIVERGENT BOUNDARY (MID OCEAN RIDGE)

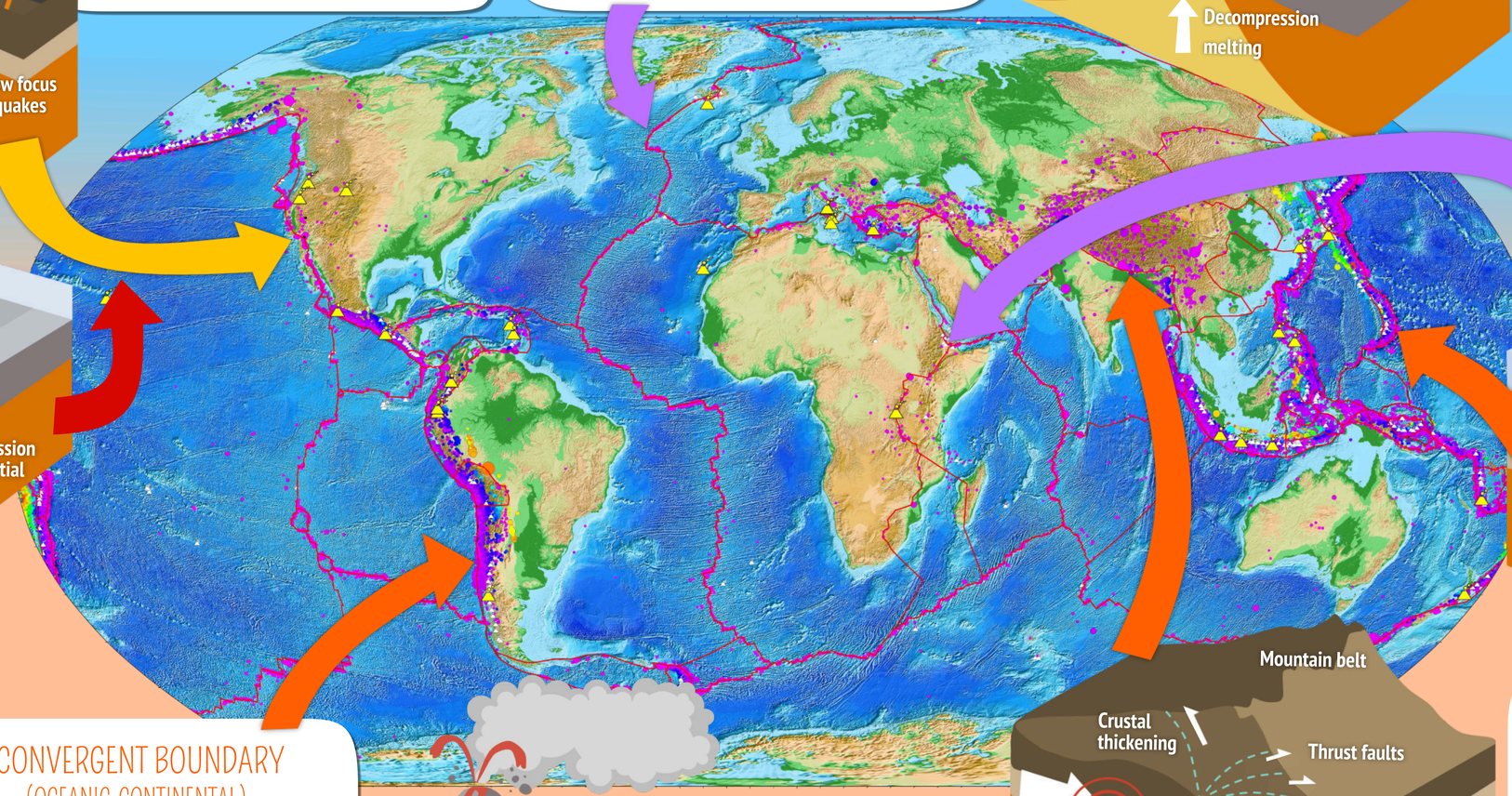
In oceans, divergent boundaries generate **mid-ocean ridge systems** as a result of **sea floor spreading**. Examples include the Mid-Atlantic Ridge (a slow spreading ridge) and the East Pacific Rise (a fast spreading ridge). As the plates pull apart the underlying hot mantle passively **up-wells** towards the surface. As it rises, the **pressure** acting upon the mantle rocks reduces and they start to partially melt in a process known as **decompression melting**. This produces basaltic magma which once cooled forms new oceanic crust.

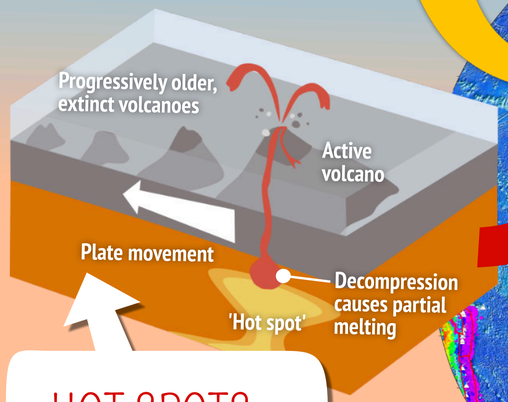




DIVERGENT BOUNDARY (CONTINENTAL RIFT VALLEY)

Within continents, divergent margins produce **continental rift** systems as a continental plate **stretches** and **thins** with the two sections moving away from each other. A series of elongate lowland valleys form bound by steeply dipping normal (extensional) **faults**, as in the East African Rift Valley. As extension continues the continental rift valleys sink lower, eventually allowing ocean waters to flood into the basin. If rifting continues, the continent may become separated into two plates with new **basaltic ocean lithosphere** forming along the centre of the rift producing a new narrow ocean basin with its own mid-ocean ridge (e.g. the Red Sea).





HOT SPOTS

Whilst most volcanic activity occurs at plate boundaries, volcanoes can erupt in the middle of plates; for example the Hawaiian Islands. These volcanoes, known as **intraplate volcanoes**, lie above **'hot spots'** and are thought to be associated with rising super-heated mantle material (mantle plumes) from deeper in the mantle. As these hot rocks rise, they partially melt **(decompression melting)** to form pockets of **basaltic magma**. This magma then up-wells and erupts on the sea floor as a **volcanic island**. As the plate gradually moves like a conveyor belt over the stationary mantle hot spot, a chain of volcanoes is formed recording the past movements of the plate.

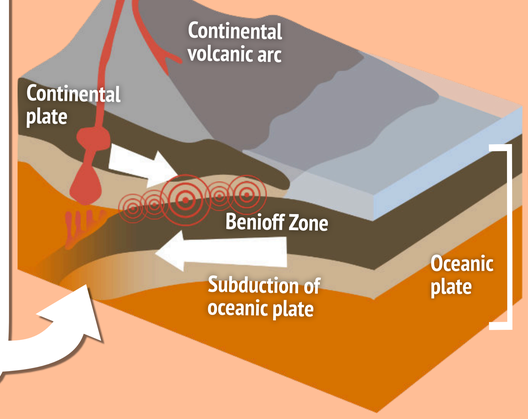
WHAT ARE THE DIFFERENT TYPES OF PLATE BOUNDARY?

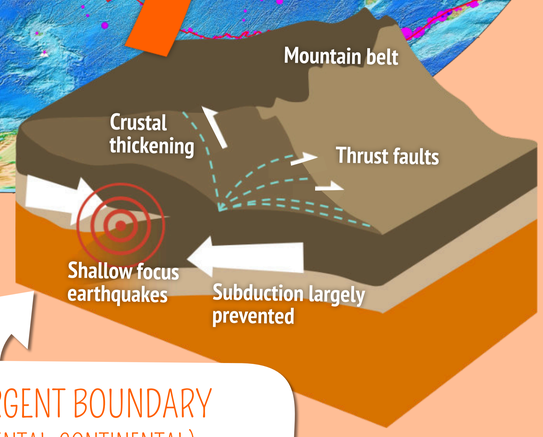
- DIVERGENT BOUNDARY: Plates are moving **away from** each other
- CONVERGENT BOUNDARY: Plates are moving **towards** each other
- TRANSFORM BOUNDARY: Plates are moving **past** each other or

CONVERGENT BOUNDARY (OCEANIC-CONTINENTAL)

When an oceanic plate is moving towards a continental plate the denser oceanic plate (~2.9 g/cm3), will sink beneath the buoyant continental plate (~2.7 g/cm3) in a process known as **subduction**. During subduction the descending oceanic plate drags against the overlying plate, causing both to fracture and deform. This results in frequent earthquakes that get deeper as the ocean plate descends further beneath the continental plate. This defines an inclined narrow zone of **earthquake foci** known as the **Benioff zone** which can extend to more than 600km in depth.

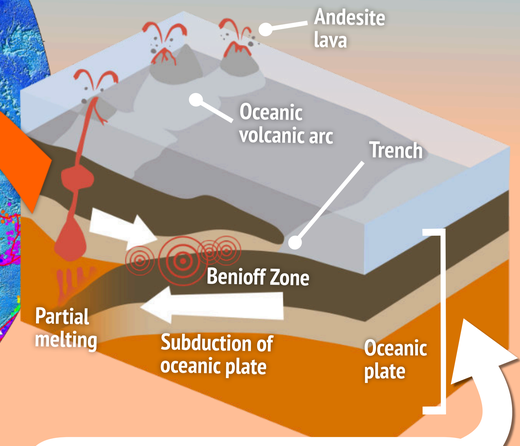
During subduction **hydrous minerals** (minerals containing water in their structures) in the oceanic plate are heated and release water into the mantle. This lowers the melting point of the mantle causing it to **partially melt** and generate pockets of molten magma. The hot magma (up to 1000°C) is more buoyant than the surrounding rocks so rises and typically erupts at the surface as **andesitic lava**, creating a **chain of continental volcanoes** above the subduction zone; for example the Andes in South America.





CONVERGENT BOUNDARY (CONTINENTAL-CONTINENTAL)

When two continental plates collide at a convergent boundary, they will ultimately form a wide **mountain belt** like the Himalaya. Because continental plates are buoyant in relation to the underlying mantle, subduction is largely prevented during continental collision. As the plates converge, fragments of ocean crust and sediments on the continental margin can become caught in the **collision zone** between the continents, forming a highly deformed zone of rock. **Compressional stresses** also cause extensive **folding** and **faulting** of rocks within the two colliding plates. This deformation causes the crust to **thicken** and can extend hundreds of kilometres into the plate interior, causing a broad zone of **shallow earthquakes**.



CONVERGENT BOUNDARY (OCEANIC-OCEANIC)

When two oceanic plates converge, generally, the older, cooler and denser oceanic plate is **subducted** beneath the younger, less dense plate forming a **subduction zone**. The descending oceanic lithosphere is heated and minerals in the crust dehydrate to release water into the mantle. This lowers the melting point of the mantle which **partially melts** to form magma. The hot, buoyant magma rises and erupts on the sea-floor to produce an arc of volcanic islands, typically made of the igneous rock **andesite**. Volcanic island arcs such as the Philippines, the Caribbean islands and the Aleutian Islands have all been formed at oceanic-oceanic convergent boundaries.

The Geological Society

Plate Tectonic Stories