.4 Plate margins and magma plumes

In this section you will learn about plate margins, magma plumes and landforms associated with plate tectonics

Plate margins

Constructive (divergent) plate margins

When two plates separate (diverge) they form a *constructive margin*. There are two types of divergence:

- in oceanic areas, sea-floor spreading occurs on either side of mid-ocean ridges (e.g. the Mid-Atlantic Ridge)
- in continental areas, stretching and collapsing of the crust creates rift valleys (e.g. the Great African Rift Valley).

It is at constructive plate margins that some of the youngest rocks on the Earth's surface are to be found. This is because new crust is being formed as the gap created by the spreading plates is filled by magma rising from the asthenosphere. As the magma cools, it solidifies to form dense new basaltic rock.

Mid-ocean ridges

Oceanic divergence forms chains of submarine mountain ridges that extend for thousands of kilometres across the ocean floor. If we could drain water from the oceans, the ridges would look like giant, bending spinal cords snaking along the constructive plate margins! Regular breaks called **transform faults** cut across the ridges – similar to the way our discs break up our spines.

These faults occur at right angles to the plate boundary, separating sections of the ridge. They may widen at different rates, which leads to frictional stresses building up, with shallow-focus earthquakes (those that occur at a depth of less than 70 km) releasing the tension (Figure **1**).

Mid-ocean ridges can rise up to 4000 m above the ocean floor. The middle of the ridges is marked by deep rift valleys in all but the most rapidly separating plate margins, which are found in the east Pacific. Over centuries, the rift valleys are widened by magma rising from the asthenosphere, which cools and solidifies to form new crust.

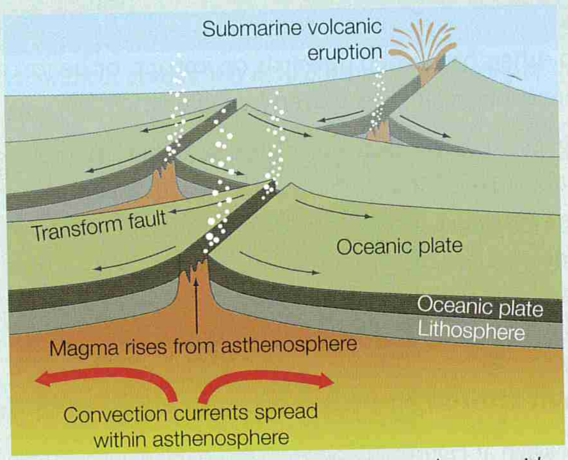

Figure 1 *Transform faults along a mid-ocean ridge*

Volcanic eruptions along the ridges can build **submarine volcanoes**. Over time these may grow to rise above sea level, creating volcanic islands such Ascension Island, Tristan da Cunha and Surtsey in the mid-Atlantic Ocean.

Rift valleys

Continental divergence forms massive rift valleys. These valleys are formed when the lithosphere stretches, causing it to fracture into sets of parallel faults. The land between these faults then collapses into deep, wide valleys that are separated by upright blocks of land called *horsts*. The Great African Rift Valley is especially interesting because it may eventually mark the formation of a new ocean as eastern Africa splits away from the rest of the continent.

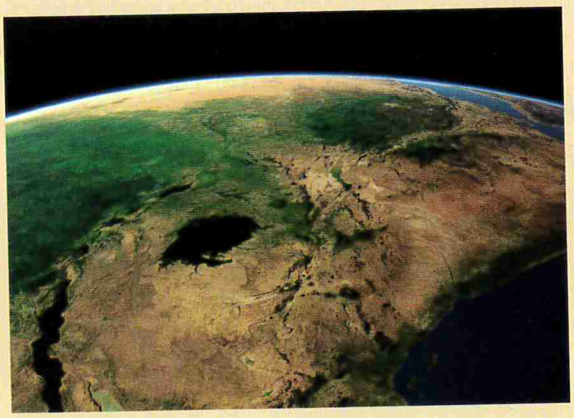

Figure 2 *East Africa's Great Rift Valley extending south from the Red Sea*

Destructive (convergent) plate margins

When two plates collide (converge) they form a destructive plate margin. Three types of convergence are possible:

- oceanic plate meeting continental plate, such as along the Pacific coast of South America
- oceanic plate meeting oceanic plate, such as along the Mariana Trench in the western Pacific
- continental plate meeting continental plate, such as the Himalayas.

Oceanic plate meets continental plate

The colliding of oceanic plate with continental plate is associated with **subduction**. This involves one plate diving beneath the other and being destroyed by melting.

Oceanic plate is denser than the lighter continental plate and so subducts underneath it. The exact point of collision is marked by bending of the oceanic plate to form a *deep ocean trench* such as the Peru–Chile trench along the Pacific coast of South America. As the two plates converge, the continental land mass is uplifted, compressed, buckled and folded into chains of *fold mountains* (Figure **3**) such as the Andes. As compression continues, simple folding can become asymmetrical, then overfolded (making a *recumbent* fold). Increasing the compression yet further would make the middle section so thin that it might break, creating a *nappe*.

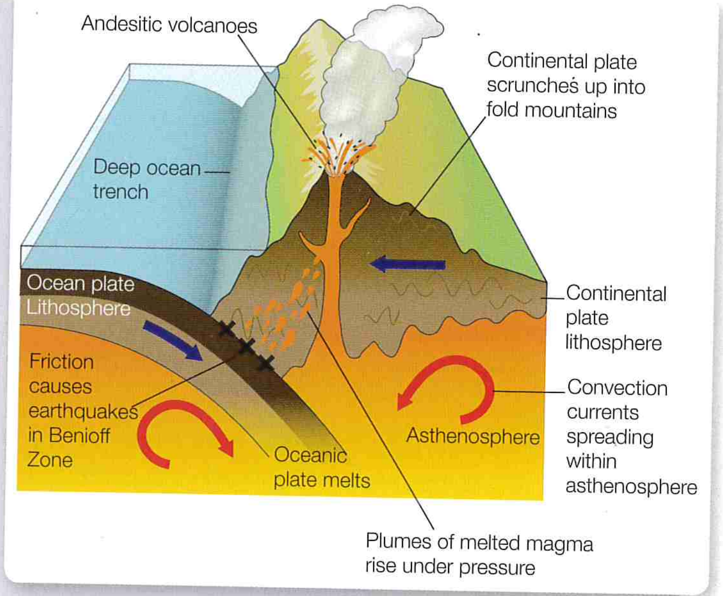

Figure 3 *Oceanic plate meets continental plate*

The descending oceanic plate starts to melt at depths beyond 100 km and is completely destroyed by 700 km. This zone of melting is called the *Benioff Zone*. Melting is caused by both increasing heat at depth and also friction. This friction may also lead to tension (stresses) building up, which may suddenly be released as intermediate (70–300 km deep) or deep-focus (300–700 km deep) earthquakes. The melted oceanic plate creates magma, which is less dense than the surrounding asthenosphere and, as a result, rises in great plumes. Passing through cracks (faults) in the buckled continental plate, the magma may eventually reach the surface to form explosive volcanic eruptions.

Oceanic plate meets oceanic plate

When two oceanic plates collide, one plate (the faster or denser) subducts beneath the other. This leads to the formation of a deep ocean trench and melting, as described previously. The resulting rising magma from the Benioff Zone forms crescents of submarine volcanoes along the plate margins which may grow to form *island arcs* (see 5.7). The Mariana Trench and the Marianas Islands in the western Pacific illustrate this particularly well.

Here the Pacific plate is being subducted beneath the smaller Philippine plate.

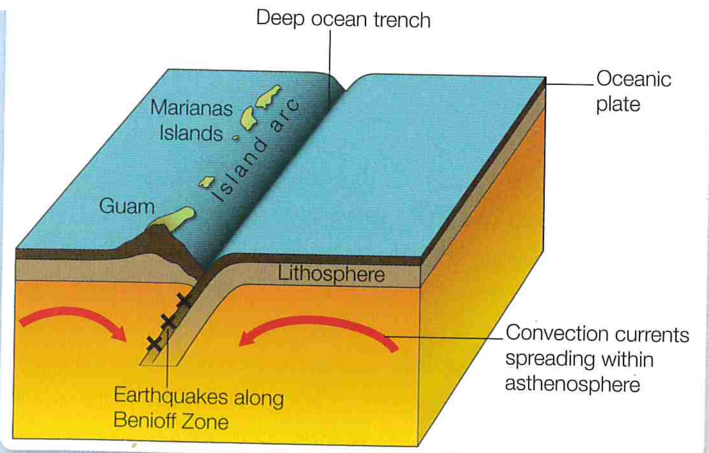

Figure 4 *Oceanic plate meets oceanic plate*

Continental plate meets continental plate

Continental plates are of lower density than the asthenosphere beneath them. This means that subduction does not occur. The colliding plates, and any sediments deposited between them, simply become uplifted and buckle to form high fold mountains such as the Himalayas (Figure **5**). Volcanic activity does not occur at these margins because there is no subduction, but shallow-focus earthquakes can be triggered. Young fold mountains, such as the Himalayas, are continually compressing and growing higher. Everest is growing 5 mm every year, so each climber to reach the summit really has climbed higher than any other person before!

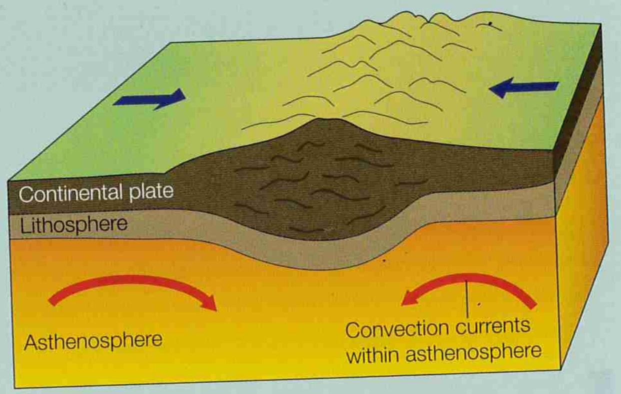

Figure 5 *Continental plate meets continental plate*

Conservative plate margins

When two plates slide past each other they form a conservative plate margin (Figure **6**). Along these margins crust is not being destroyed by subduction. There is no melting of rock and, therefore, no volcanic activity or formation of new crust. Despite the absence of volcanic activity, these margins are extremely active and are associated with powerful earthquakes.

Friction between the two moving plates leads to stresses building up whenever any 'sticking' occurs. These stresses may eventually be released suddenly as powerful shallow-focus earthquakes, such as in Los Angeles (1994) and San Francisco (1906 and 1989). These earthquakes occurred along California's infamous San Andreas fault system (Figure **7**, also Haiti, 5.12).

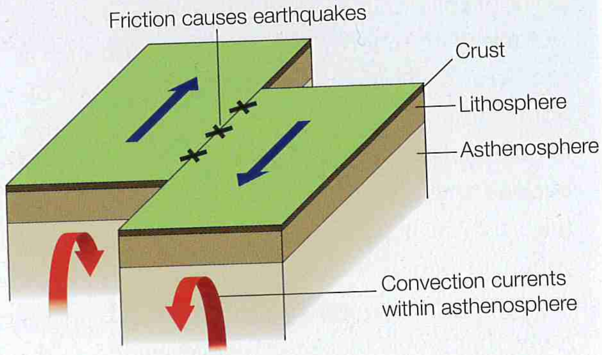

Figure 6 *Conservative plate margin*

Magma plumes

Look at Figure **1**, in section 5.10. Earth shaking (**seismicity**) and volcanic activity (**vulcanicity**) are strongly associated with plate tectonics. In fact 95 per cent of the world's earthquakes and most volcanoes are located along plate margins.

Even seemingly notable exceptions, such as the volcanic Hawaiian Islands, are explained in part by plate movements. As already described, radioactive decay within the Earth's core generates very hot temperatures. If the decay is concentrated, hot spots will form around the core. These hot spots heat the lower mantle creating localised thermal currents where **magma plumes** rise vertically. Although usually found close to plate margins, such as beneath Iceland, these plumes occasionally rise within the centre of plates and then 'burn' through the lithosphere to create volcanic activity on the surface. As the hot spot remains stationary, the movement of the overlying plate results in the formation of a chain of active and subsequently extinct volcanoes as the plate moves away from the hot spot. The Hawaiian Islands, near the centre of the Pacific Plate, are a classic example of this (see Figure **2**, page 279).

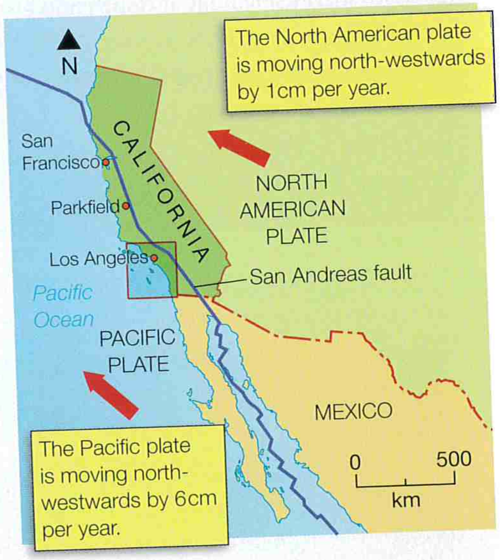

Figure 7 *The San Andreas fault system*

Figure 8 *The relationship between seismicity, vulcanicity and plate tectonics*

Type of plate margin	Processes	Geographical features and examples
Constructive margins	Plates diverge – move away from each other	• New oceanic crust is formed by basaltic magma rising from the asthenosphere • New basaltic rocks • Mid-ocean ridges broken up by transform faults (Mid-Atlantic Ridge) • Shallow-focus earthquakes • Basic volcanoes (Eyjafjallajökull, see 5.6) • Volcanic islands (Ascension Island, Tristan da Cunha and Surtsey) • Continental rift valleys (The Great African Rift Valley)
Destructive margins • Subduction zones • Collision zones	Plates converge – move towards each other	*Oceanic v. oceanic* • Oceanic crust is destroyed by subduction and melting at depth • Deep ocean trenches (Mariana Trench) • Island arcs (West Indies, Aleutian and Mariana Islands) • Shallow, intermediate (70–300 km deep) and deep-focus (300–700 km deep) earthquakes • Explosive, acid volcanoes (Krakatoa, Merapi, see 5.6 and Montserrat, see 5.7). *Oceanic v. continental* • Oceanic crust is destroyed by subduction and melting at depth • Deep ocean trenches (Peru–Chile Trench) • Continental land mass is uplifted, compressed and buckled into fold mountains (Andes) • Intermediate and deep-focus earthquakes • Explosive, acid volcanoes (Cotopaxi) *Continental v. continental* • Colliding plates, and any sediments between them, uplift and concertina into particularly high fold mountains (Himalayas) • Shallow-focus earthquakes • Continued compression and overfolding can result in fracture creating a thrust fault and nappe
Conservative margins	Plates move sideways past each other	• Shallow-focus earthquakes (Haiti, see 5.12 and the San Andreas fault system, Figure **7**)
Exceptions to plate margins	Hot spots near the centre of a plate	• Basaltic volcanoes (Mauna Loa, Kilaue (Hawaii) and Yellowstone)

ACTIVITIES

1 Study the information about the different types of plate margins.

- **a** Explain why submarine volcanoes are formed at constructive plate margins.
- **b** What is meant by subduction and why is it an important process at destructive plate margins?
- **c** Why is there no volcanic activity at a continental collision margin?

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- **d** Describe and explain the pattern of earthquakes at the different destructive margins. Use simple sketches to support your answer.

2 **a** Label Figure **9** with the names of specific tectonic plates. Use Figure **1** in section 5.10 and your own knowledge. Begin by locating New Zealand and the Andes on the map.

b Finish your diagram by adding annotations to the suggested boxes.

3 Explain the relationship between earthquakes, volcanic activity and plate margins. Be sure to use examples in your answer.

Figure 9 *Block diagram of tectonic plate margins*