

Contents

Introduction	iv
Chapter 1 Changing river environments	xx
Chapter 2 Changing coastal environments	xx
Chapter 3 Changing ecosystems	xx
Chapter 4 Tectonic hazards	xx
Chapter 5 Climate change	xx
Chapter 6 Changing populations	xx
Chapter 7 Changing towns and cities	xx
Chapter 8 Development	xx
Chapter 9 Changing economies	xx
Chapter 10 Resource provision	xx
Chapter 11 Geographical skills	xx
Chapter 12 Geographical investigations	xx
Chapter 13 Exam-style questions	xx
Glossary	xx
Index	xx

Sample pages

4

Tectonic hazards

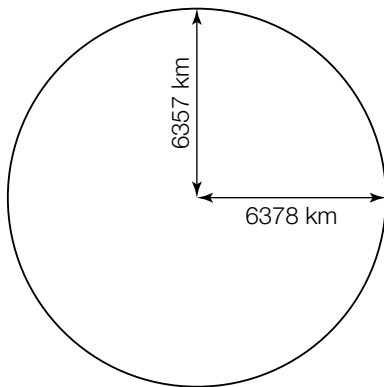
This chapter covers the Cambridge IGCSE® and O Level topic 4

In this chapter you will learn about:

- The structure of the Earth and plate tectonics
- Earthquakes and volcanoes
- The impacts of earthquakes and volcanoes on people's lives
- How earthquakes and volcanoes can be managed

The structure of the Earth

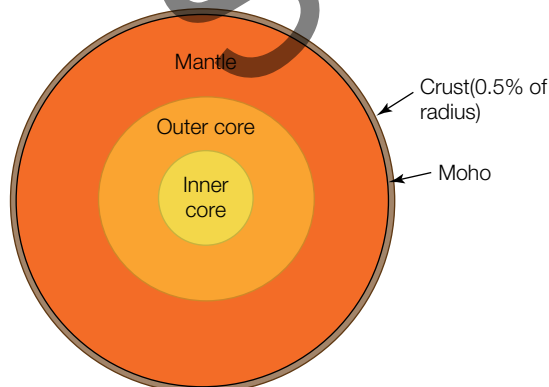
The shape of the Earth can be described as an oblate sphere—it is slightly flattened! The polar radius is 6,357 km and the equatorial radius is 6,378 km.



▲ Fig. 4.1 The shape of the Earth

The Earth has a concentric layered structure made up of:

- crust
- mantle
- outer core
- inner core.



▲ Fig. 4.2 The internal structure of the Earth

Crust

The crust is the thin outer skin of the Earth. More is known about the crust than any other layer because it can be directly sampled at the surface and by drilling

The crust can be divided into two types:

- continental crust
- oceanic crust.

The two types of crust have their own different characteristics:

Characteristic	Oceanic crust	Continental crust
Location	Beneath the oceans	Beneath the continents and continental shelves
Thickness	6 km	averages 25–40 km maximum 90 km under mountain ranges
Composition	Dark dense rocks	Lighter in colour and density
Density	3.0 g.cm ⁻³	2.7 g.cm ⁻³
Age	Oldest rocks 200 million years	Oldest rocks 4,000 million years

▲ Table 4.1 the differences between oceanic and continental crust

The boundary between the crust and the underlying mantle is known as the **Mohorovicic Discontinuity** or **Moho**. Its depth varies according to the thickness of the crust at that point.

Mantle

This lies beneath the crust and extends down to 2,900km. It is solid, although parts behave plastically and is made up of dark, very dense rocks.

Outer Core

This layer is liquid and has a composition rich in iron sulfide. The movement of the liquid is responsible for the Earth's magnetic field. It has a very high density.

Inner Core

This layer is solid and rich in iron and nickel with a density of approximately 12g.cm^{-3} .

Lithosphere

The **lithosphere** is the crust plus the outer part of the mantle down to depths of about 50 km. The name means 'rock sphere'. The rocks are cool and rigid unlike the hotter parts of the mantle below which can flow plastically. The lithosphere is the 'plates' described later in this chapter.

Learning Tip

The terms crust and lithosphere (plates) are sometimes confused. Do you know the difference?

Research

The boundary between the crust and the mantle is called the Moho. What is the boundary between the mantle and the core called?

Tectonic plates

A scientific revolution

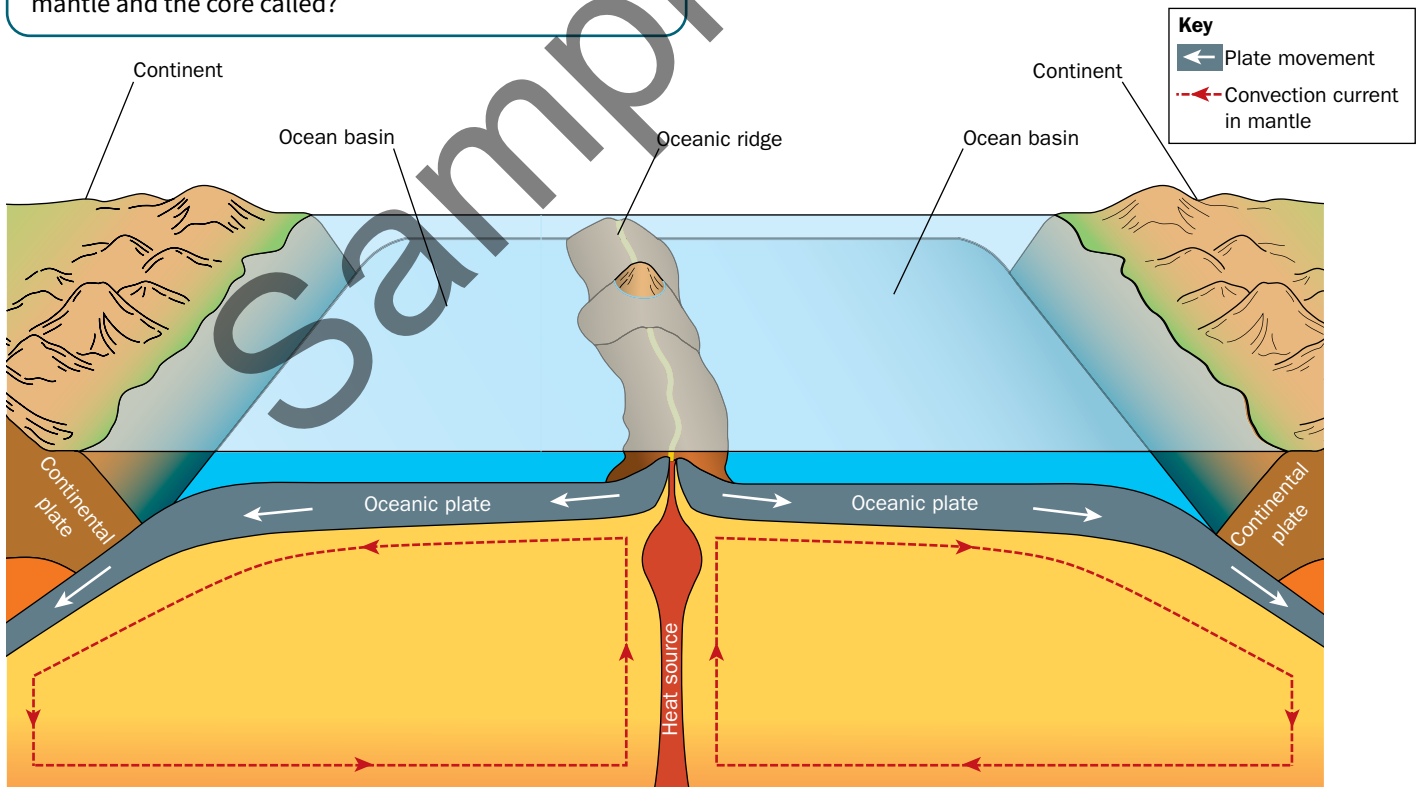
The idea that the continents have not always been in the same place, but have moved slowly over immense periods of time, has been around for about 100 years. However, it was never fully accepted.

Then, in the 1960s and 1970s, the theory of plate tectonics was developed. This theory quickly became accepted, and has completely changed our understanding of the Earth and how it works. A lot of supporting evidence for the theory was gathered around this time, as a result of the first surveys of the deep ocean floors. This evidence was very important in convincing other scientists about the new ideas.

No single scientist can claim to have invented the theory of plate tectonics. It was developed through a series of ideas by scientists at Princeton University in the USA and Cambridge University in the UK.

What is a plate?

The Earth's surface is made up of a series of sections, known as **plates**. On average, these plates are about 50 km thick. They include the Earth's crust and the upper part of the layer below (called the mantle). The plates



▲ Fig. 4.3 How convection currents in the mantle cause the plates to move

themselves are relatively cold and rigid. However, the rocks underneath them reach temperatures of more than 1300°C and behave plastically (in other words, they can flow rather like a jelly). The plates interlock—a bit like the panels that make up the outside of a football. However, unlike the panels on a football, the plates can move relative to each other—flowing over the hotter, more plastic, rocks below (that act like a lubricating layer).

Why do the plates move?

Deep within the Earth, heat is being produced by radioactivity. This heat is not evenly distributed, so there are hotter areas and colder areas. At the hotter areas, the plastic-like rocks in the Earth's mantle become lighter and rise, causing convection currents (see Fig. 4.3). These convection currents drag at the rigid plates sitting above them, causing them to move, typically at rates of between 1 and 10 cm a year. The plate movements can be measured using stars in the sky as reference points.

Learning Tip

Remember that 'the plates' and 'the crust' are not exactly the same thing. Make sure that you know the difference between the two.

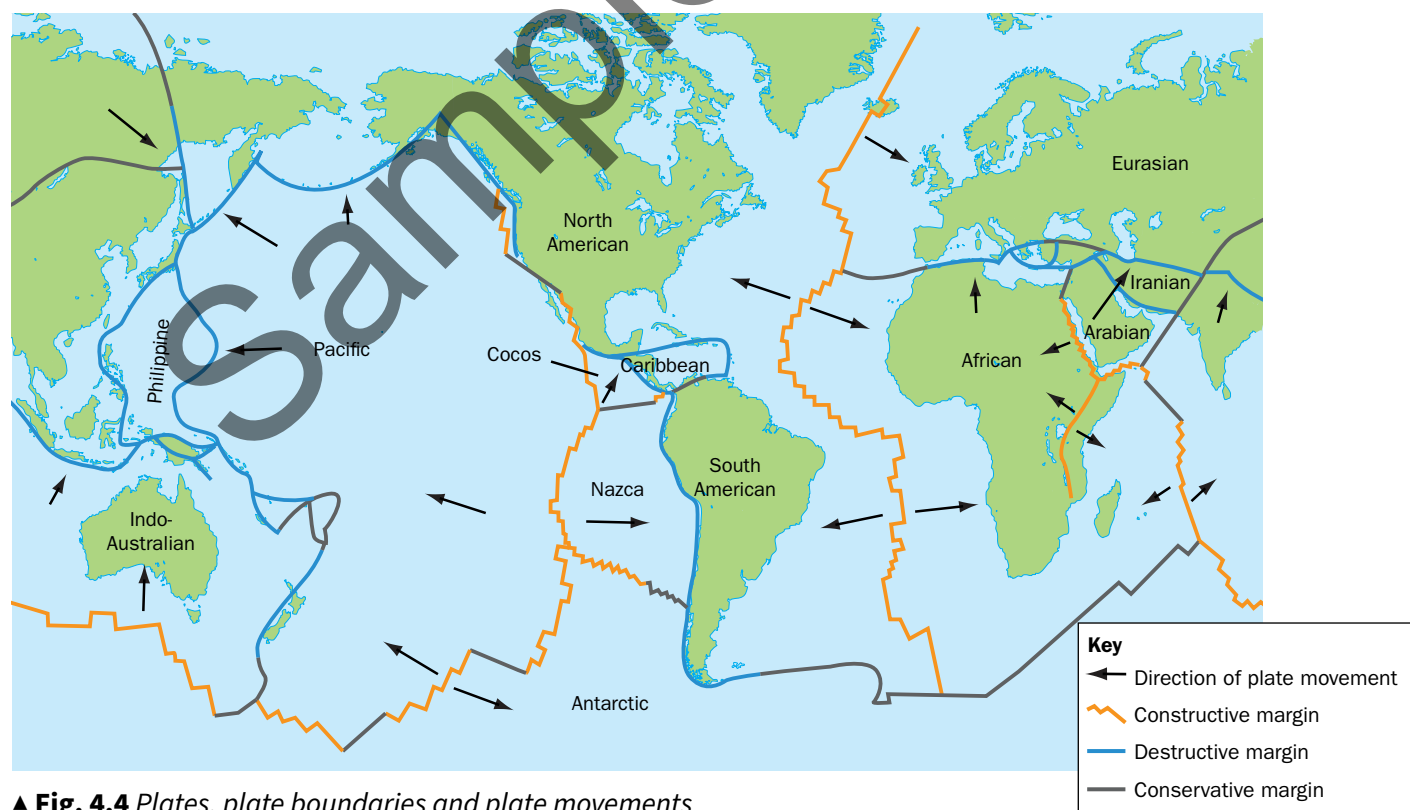
Plate boundaries

Do you live on a plate margin (**plate boundary**)? If you do, you will certainly experience large earthquakes from time to time. You might also be on a plate boundary where there is volcanic activity. And you might live in, or close to, high fold mountains.

If you live closer to the centre of a plate, any earthquakes near your home will be relatively small. There will also be no active volcanoes, and any mountain ranges will be smaller.

Discussion Point

Living near to a plate margin can be hazardous. There are examples in both MICs (e.g. New Zealand and the West Coast of the USA) and in LICs (e.g. the Philippines and Peru). Why do people live in these areas?



▲ Fig. 4.4 Plates, plate boundaries and plate movements



▲ **Fig. 4.5** The 2011 earthquake in Christchurch, New Zealand, brought down many buildings and killed 65 people

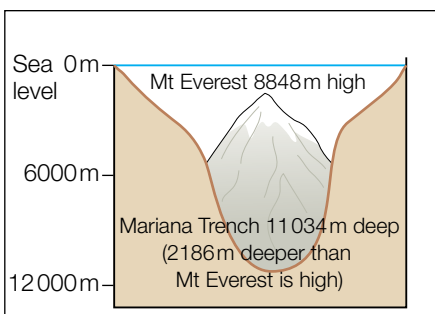
Convergent (destructive) plate margins

Convergent (destructive) margins are places where plates move towards each other (converge) and collide. They are also called destructive because oceanic plate is destroyed.

A good example is along the west coast of South America, beneath the Andes (see Fig. 4.6). Here, an oceanic plate (the Nazca Plate) collides with a continental plate (the South American Plate). Because the oceanic plate is denser, it is forced beneath the less dense and more buoyant continental plate at an angle of about 45°. This process is known as **subduction**. The ocean floor is dragged down by this process to form a long and relatively narrow, but deep, ocean trench (called the Peru-Chile Trench).

Ocean trenches are the deepest areas on the Earth's surface. The deep ocean floor is normally between 2,000 and 5,000 m below sea level, but the deepest point on the Earth's surface (the Mariana Trench in the Pacific Ocean) is 11,034 m deep. This is deeper than the highest mountain (Mount Everest) is high (Fig. 4.6).

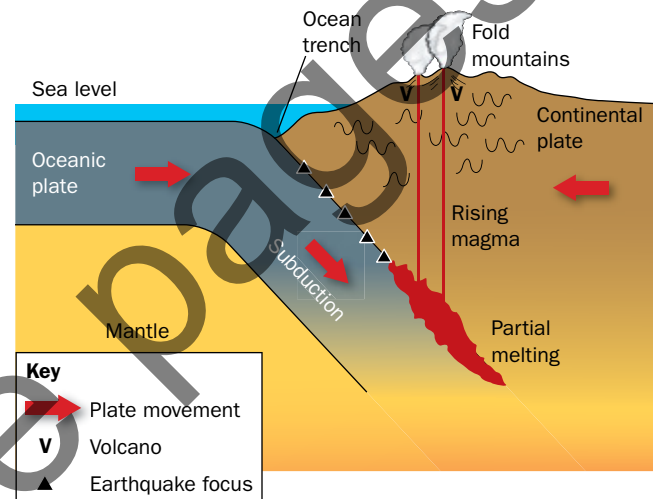
- As the oceanic plate is subducted beneath the continental plate, friction between the two plates



◀ **Fig. 4.6** The highest and lowest points on the surface of the Earth

Question

1. Refer to Fig. 4.4.
 - a. Name a plate which includes both part of a continent and part of an ocean.
 - b. Name a plate which contains just ocean floor and no part of a continent. (There are no very large plates which are just made up of a continent.)
 - c. Name a place where two plates are moving towards each other.
 - d. Name a place where two plates are moving away from each other.

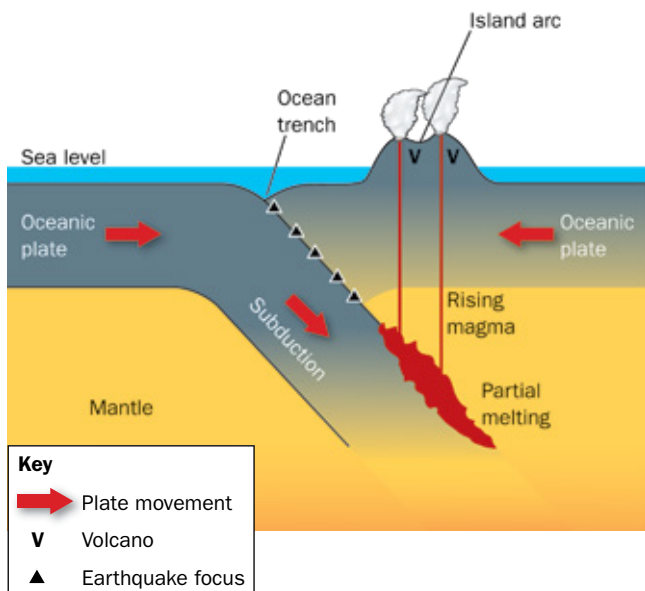


▲ **Fig. 4.7** A cross-section through the Andes, showing the destructive plate margin and the process of subduction

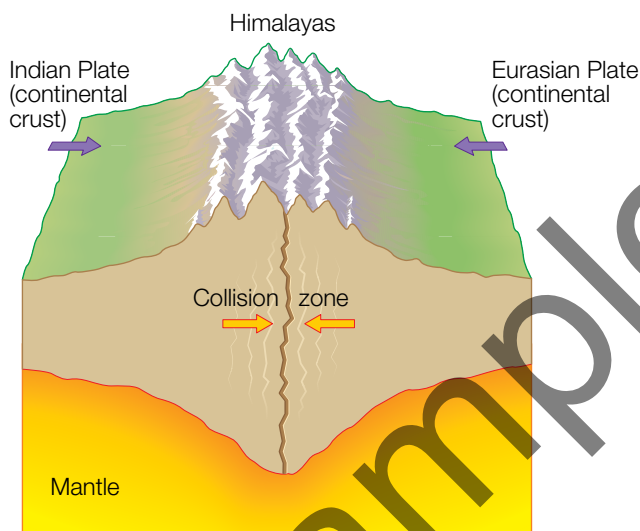
causes earthquakes. The earthquakes get deeper the further down the subduction zone they are. Shallow earthquakes occur beneath the Peru-Chile Trench but deeper earthquakes occur below the Andes.

- Eventually, the oceanic plate is forced so deep into the Earth that it becomes part of the mantle and is destroyed. Partial melting of the overlying mantle produces **magma** (molten rock), which rises to form the strato-volcanoes that occur in the Andes
- The powerful compression of the colliding plates also crumples the rocks of the continental plate and forces them up to form the fold mountain range of the Andes. This process continues today.

Other plate collisions involve two oceanic plates. One example is Japan. The features here are exactly the same as in the Andes, except that, because there is no continental plate, there are no fold mountains. Instead, the longer of the two oceanic plates is subducted. The rising magma then produces a chain of volcanic islands, known as an **island arc**.



▲ Fig. 4.8 A cross-section through Japan, showing a destructive margin involving two oceanic plates



▲ Fig. 4.9 A cross-section through the Himalayas

Question

2. Explain the meaning of the terms: subduction, magma, plate, plate margin, compression.

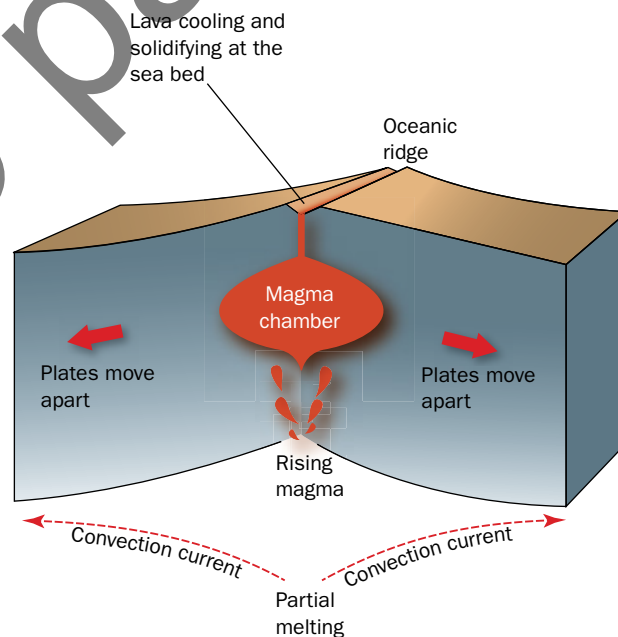
Convergent (collision) plate margins

In the case of the Himalayas (the highest mountains in the world), there is a collision between two continental plates that are converging (see Fig. 4.9)—a **convergent (collision) plate margin**. Fold mountains form and earthquakes occur, but there is no subduction of an oceanic plate, so there are no volcanoes in the Himalayas.

Divergent (constructive) plate margins

Divergent (constructive) plate margins are the places where new oceanic plate is created. Continental plate is neither created in the same way nor destroyed by subduction. At divergent plate margins, the stresses within the Earth are of tension (stretching) rather than compression (see Table 4.2).

The only divergent plate margins on the planet are the great **ocean ridge** systems (e.g. the Mid-Atlantic Ridge, the East Pacific Rise, and the Carlsberg Ridge in the Indian



▲ Fig. 4.10 A cross-section through a divergent plate margin

Tension	Compression	Shearing
Plates diverge. The Earth's surface is stretched and gets longer.	Plates converge. The Earth's surface is squashed and gets shorter.	Plates slide past each other sideways. The Earth's surface does not change in length.

▲ Table 4.2 Types of stress

Ocean). These ridges are huge submarine mountain ranges, which form some of the largest features on the Earth’s surface. They are mostly below sea level, but occasionally rise above it. One example of this is the volcanic island of Iceland in the North Atlantic Ocean.

Question

- Look at the oceans shown on Fig. 4.4 (noticing, in particular, the types of plate margin within them). Name one ocean that is getting bigger and one ocean that is getting smaller. Give reasons for your choices.

Learning Tip

If you are explaining how a volcano forms, tell the whole story—from the production of magma in the Earth’s mantle, all the way to the lava solidifying on the surface. Simple sketches can be very helpful with explanations.

Conservative (transform) plate margins

Conservative (transform) plate margins are so called because the plates are being conserved. In other words, they are neither being created nor destroyed. Shearing stress occurs at these margins (see Table 4.2), and the plates slide past each other sideways. Friction between the two plates causes earthquakes but volcanoes do not occur. The San Andreas Fault system in California (in the USA) is an example of a conservative plate margin. Although Fig. 4.11 shows both plates moving in the



▲ Fig. 4.11 California and the San Andreas Fault system

Learning Tip

Don’t confuse destructive and constructive margins! Some candidates get mixed up because fold mountains form at destructive margins. These plate margins are called destructive because plate is destroyed.

same direction, their speeds of movement are different. As a result, the Pacific Plate is moving past the North American Plate and shearing occurs.

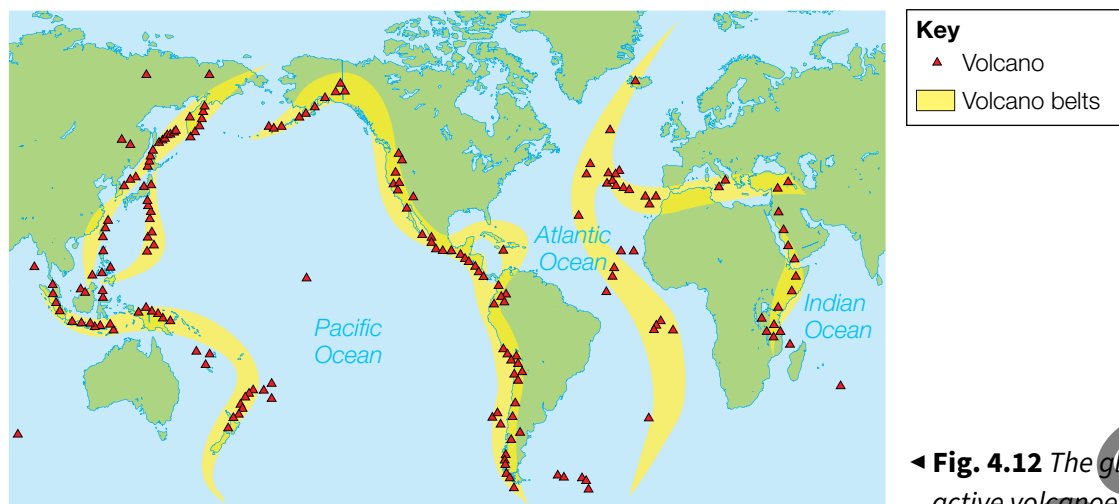
Type of plate margin	Examples	Type of stress	Features
Destructive with an oceanic plate and a continental plate	Andes	Compression	Earthquakes Fold mountains Volcanoes Ocean trenches
Destructive with two oceanic plates	Japan Philippines West Indies	Compression	Earthquakes Island arcs Volcanoes Ocean trenches
Convergent/collision	Himalayas	Compression	Earthquakes Fold mountains
Constructive	Mid-Atlantic Ridge East Pacific Rise Carlsberg Ridge	Tension	Earthquakes Ocean ridges Volcanoes
Conservative	San Andreas Fault	Shearing	Earthquakes

▲ Table 4.3 A summary of the features of plate margins

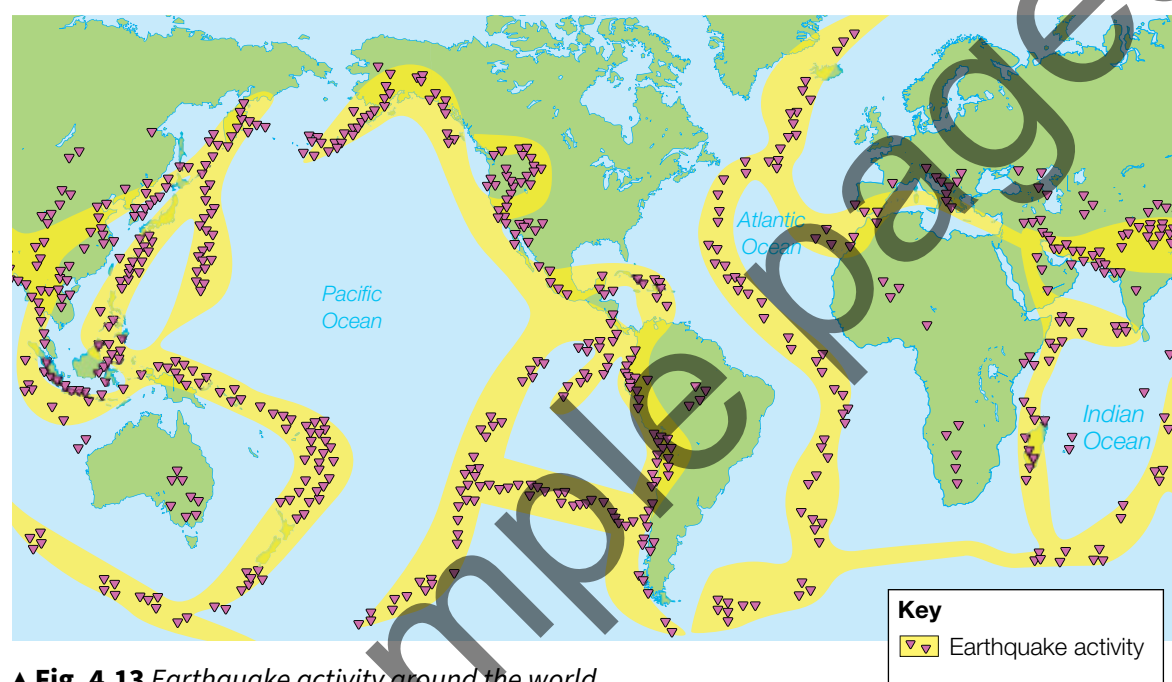
Earthquakes and volcanoes

Location of earthquakes and volcanoes

One definition of an **active** volcano is a volcano that has erupted in the current geological period of time—since the end of the last ice age about 11,650 years ago, or one that has the potential to erupt again in the



◀ **Fig. 4.12** The global distribution of active volcanoes



▲ **Fig. 4.13** Earthquake activity around the world

future. Fig. 4.12 shows their global distribution—there are about 540 of these. Other volcanoes are described as **dormant** (resting, but which may erupt again in the future), or **extinct** (dead and will not erupt again).

Notice how the active volcanoes form a series of relatively narrow belts around the planet. The Pacific Ring of Fire is the most famous of these belts, and it

goes all the way round the rim of the Pacific Ocean.

Fig. 4.13 shows the global distribution of earthquake activity. Earthquakes occur more frequently than volcanic eruptions.

What causes earthquakes?

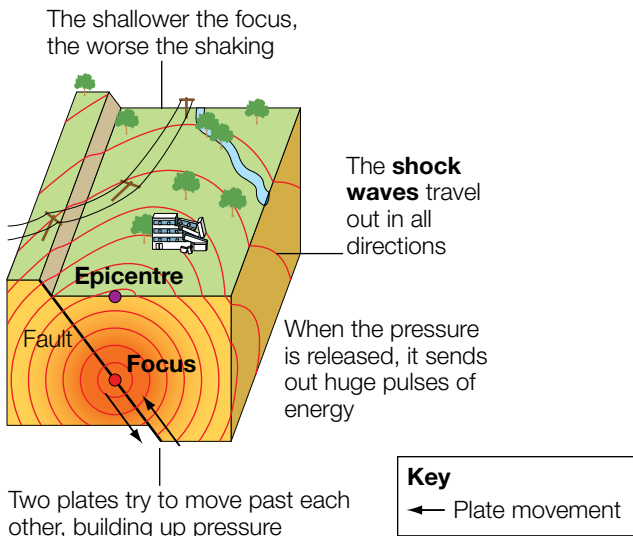
Fig. 4.4 shows the location and type of plate margins around the world. Strong earthquakes occur at all of these different plate margins, as shown in Fig. 4.13.

Earthquakes are caused by plate movements—either towards each other, away from each other or sliding past each other. The plates don't always move at a constant rate; they are often 'stuck' in one position. Stress and pressure build up as the plates try to move. Then there is

Question

4. Refer to Fig. 4.12 and Fig. 4.13.
 - a. What are the similarities between the two maps?
 - b. List the areas that have earthquakes but not volcanoes.

a sudden release of pressure when the plates break free (along a crack in the Earth called a **fault**). Huge amounts of energy are released and the shock waves or vibrations travel through the Earth as an earthquake wave or **seismic wave**. The point within the Earth where the earthquake originates is called the **focus**. The point on the Earth's surface directly above the focus is called the **epicentre**.



▲ **Fig. 4.14** How earthquakes occur

What causes volcanoes?

A volcano is a hole or crack in the ground through which gases, **lava** (liquid), and **pyroclastic** material (solid) are erupted. The vent is connected to a magma chamber beneath the ground.

As Figs. 4.12 and Fig. 4.4 show, most volcanoes occur at plate boundaries, although, as we have already seen, there are no volcanoes at collision boundaries like the Alps and Himalayas, because there is no subduction of an oceanic plate, and therefore no melting to produce magma.

These are places where, deep in the crust and upper mantle, temperatures of between 800°C and 1500°C cause the rocks to melt and produce molten rock (magma). The magma rises because it is less dense than the surrounding rocks and reaches the Earth's surface as lava.

The processes are slightly different at the different types of plate margin.

Divergent (constructive) plate margins See Fig. 4.10	Beneath the ocean ridges, deep in the Earth's mantle, there is a concentration of heat, which causes partial melting. Small pockets of magma slowly collect and rise towards the Earth's surface, where they cool and solidify to form new oceanic crust. This new rock forms below as well as on the surface. The lava often flows out from long cracks (fissures) building up gently sloping areas, rather than conical mountains. The oceanic crust cracks and diverges—pushed apart by the newly formed crust and dragged by the convection currents in the mantle.
Convergent (destructive) plate margins See Fig. 4.7 and Fig. 4.8	At these margins the process of subduction, described earlier, occurs. The denser oceanic plate is subducted and forced down to greater depths. The increase in temperature causes partial melting of the plate. The small pockets of magma merge together and rise to the surface and erupt as volcanoes.

▲ **Table 4.4** The processes that cause volcanoes

What comes out of a volcano?

Gases

The main gas to be emitted by volcanoes is water vapour (50–80 per cent), but there may also be emissions of sulfur dioxide, hydrogen sulfide, nitrogen, hydrogen, and carbon dioxide. Some of these gases are poisonous. These gases can become trapped in the viscous lava. This causes pressure to build up and lead to frothing of the magma and explosive eruptions.

Liquids

Magma is molten rock material below the Earth's surface. Lava is the flows of molten rock material which have erupted on to the Earth's surface.

Solids

These are known as pyroclastic material.

- Ash is made up of the smallest particles (less than 4 mm in size). However, blocks of the coarsest material are much larger.
- The smallest particles can be held in suspension in the air, as clouds, for months or even years.