

3 Living with natural hazards

3.1 The effects of earthquakes and volcanoes

Earthquakes and volcanoes are responsible for considerable loss of life, property and livelihoods (Table A). As they cannot be accurately predicted, the effects of earthquakes tend to be more destructive. However, on occasions volcanoes do erupt suddenly and with explosive force. They can send clouds of red-hot ash and dust hurtling down mountainsides at over 150 km/h. These pyroclastic flows are responsible for many of the deaths resulting from volcanic eruptions.

A Effects of volcanic eruptions and earthquakes

Volcanic eruptions	Earthquakes
Primary effects (caused directly by the volcanic)	Primary effects (caused by shaking and ground movement)
Buildings destroyed by fires, explosions, weight of ash; crops/livestock destroyed	Buildings collapse, roads crack, bridges collapse, glass shatters, gas pipes break, electricity pylons fall, water pipes break
Secondary effects	Secondary effects
Mudflows, changes in landscape/climate, food/water supply disrupted, homelessness, businesses forced to close, cost of insurance claims, unemployment	Fires, explosions, floods, homelessness, tsunamis, diseases, landslides, businesses forced to close, cost of insurance claims, unemployment

The following case studies show some of the damaging effects of volcanic eruptions and earthquakes.

Case study Tungurahua volcano in Ecuador erupts, August 2006

The Tungurahua volcano (Map B), whose name means 'throat of fire', blasted a 10 km high ash cloud into the sky (Photo C), along with larger pieces of rock called volcanic bombs. Huge flows of lava ran down the mountainside. The ash covered an area of 740 by 180 km with up to 5 cm of ash. Pyroclastic flows raced down the north-western slopes, destroying 7 villages and making 5,000 people homeless. Six people lost their lives and falling volcanic rocks injured many more. People tried to protect their heads by covering them with blankets and buckets, as they fled the area. Many suffered breathing difficulties due to the hot ash. The lava and ash covered the fertile farmlands, destroying the crops. Livestock were lost. Many farmers were left with nothing. Roads were impassable and rivers were clogged up with ash. The nearby hydroelectric plant was shut down, as were local airports.



B Location of the Tungurahua volcano



C Tungurahua volcano

In this section you will learn:

about the primary and secondary damage caused by earthquakes and volcanoes

some case studies of the damage caused by an earthquake and a volcanic eruption.

AQA Examiner's tip

Be clear as to the differences between primary and secondary effects of both earthquakes and volcanic activity. Learn at least three examples of each effect.

Key terms

Primary effects: those resulting directly from the event itself.

Secondary effects: those that result from the primary effects.

Tsunamis: large ocean waves caused by an underwater earthquake.

Richter scale: a measure of earthquake strength.

Aftershocks: smaller tremors occurring after an earthquake.

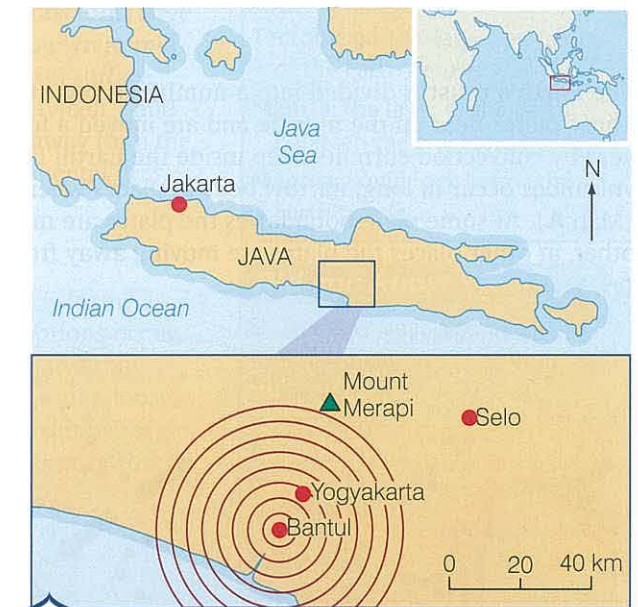
Earthquake hits Yogyakarta, Java (Indonesia), May 2006

An earthquake measuring 6.3 on the Richter scale caused a huge amount of damage to Yogyakarta near the coast of Java (Map D). Almost 6,000 people lost their lives and 37,000 were injured, with many having to be treated at the roadside or in temporary clinics, as hospitals were damaged.

About 154,000 houses were destroyed and many more were damaged, leaving 1.5 million people homeless. People were trapped under the rubble of collapsed buildings, many of which were smaller, older houses (Photo E). A worker for a non-governmental organisation said: 'I was shaken from my bed ... furniture was falling and concrete chunks started falling from my hotel room ... people were running out in panic, in their bedclothes.' They feared that the earthquake might cause a tsunami like the one that followed the 2004 earthquake. Luckily this did not happen, but the earthquake did cause an eruption of the nearby Merapi volcano, which sent debris 3.5 km into the air.

Aftershocks forced medics to move injured people outdoors, for fear of further building collapse. Many survivors had gathered a few belongings and were sleeping outside. Plastic tents were set up on a nearby football pitch.

The area is one of great cultural importance and a Hindu temple complex was badly damaged, as were ancient royal palaces. This has resulted in a loss of income from tourism. Many small businesses such as silver handicrafts, earthenware pottery and weaving, were destroyed, and 82,000 people lost their livelihoods. The overall cost of the damage was put at US \$3 billion.



D Location of the Yogyakarta earthquake



E Collapsed buildings in Yogyakarta

Activities

- Describe the location of the Tungurahua volcano in Ecuador.
 - Draw a table to show the primary and secondary effects of the Tungurahua volcanic eruption.
- Describe the location of the Yogyakarta earthquake.
 - Draw a table to show the primary and secondary effects of the Yogyakarta earthquake.

extension Conduct some research to investigate why the effects of earthquakes might be more damaging in a less developed country such as Indonesia.

Did you know ??????

The deadliest ever earthquake was in the Shaanxi Province of China in 1556. More than 830,000 people lost their lives. In recent times, the 2004 earthquake in Indonesia, which caused a tsunami in the Indian Ocean, claimed 283,100 lives.

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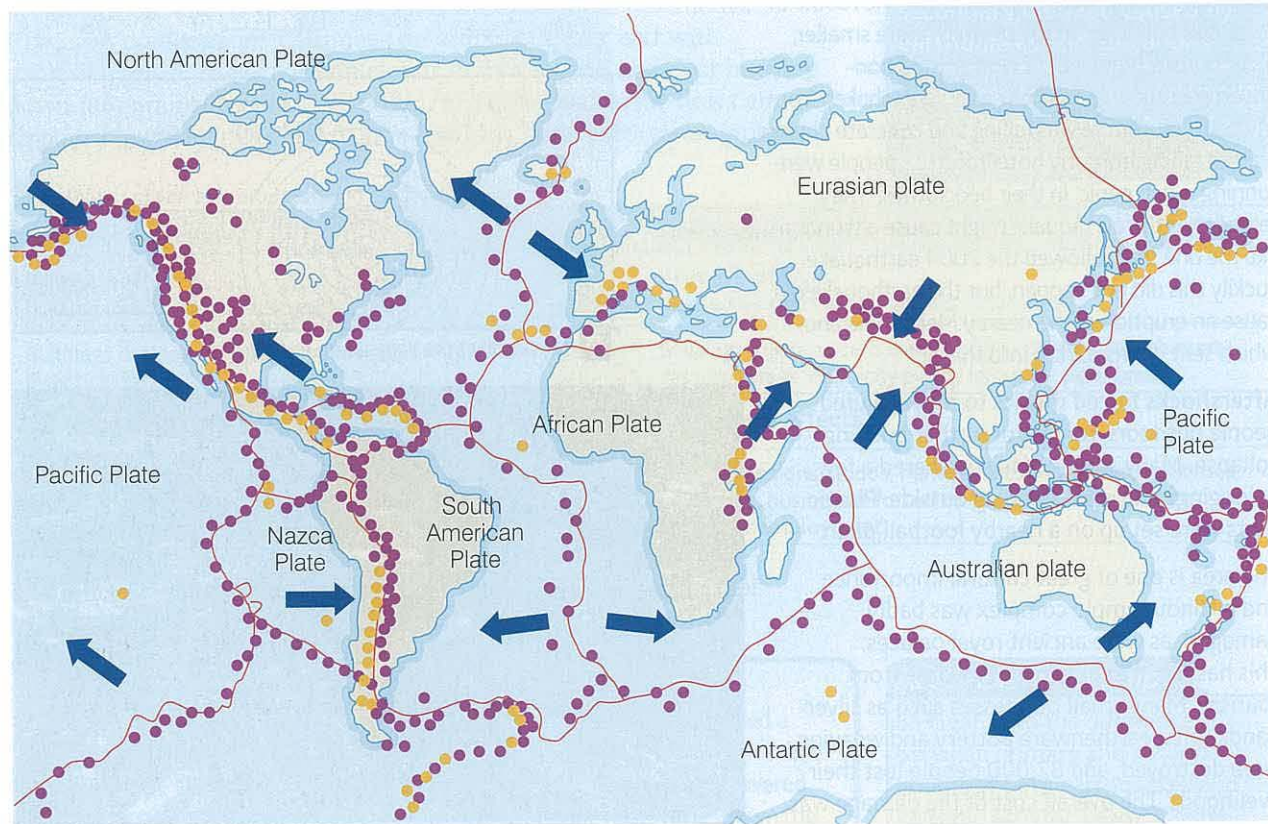
Learn more about earthquakes at www.earthquake.usgs.gov



3.2 The causes of earthquakes and volcanoes

The **Earth's crust** is divided into a number of **tectonic plates** (Map A). These plates float on the **mantle** and are moved a few centimetres each year by convection currents deep inside the Earth. Earthquakes and volcanoes occur in long, narrow belts at places where the plates meet (Map A). At some plate boundaries the plates are moving towards each other, at other places the plates are moving away from each other.

In this section you will learn:
 about the different types of plate boundary
 about the processes that cause earthquakes and volcanic eruptions.

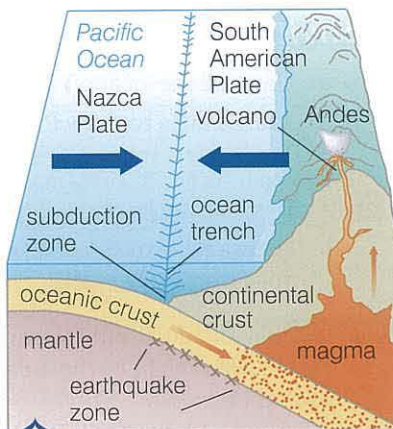


Key — plate boundary ← direction of plate movement ● volcano ● earthquake

A Global distribution of earthquakes, volcanoes and tectonic plates

What is a destructive plate boundary?

Where plates move towards each other, the thin oceanic crust is forced beneath the thicker continental crust to form a subduction zone. A deep ocean trench forms as the ocean floor is pulled downwards and the continental crust is buckled to form mountain ranges (Diagram B). As the oceanic crust is forced downwards, it starts to melt and form new **magma**. This is due to the friction between the moving plates and the intense heat in the mantle. The newly formed magma is less dense than that in the mantle and rises, reaching the surface through cracks in the crust and erupting to form volcanoes. Where the magma rises offshore, volcanic island arcs are formed. As the plates move against each other, pressure builds up. A sudden movement of the plate releases this pressure and the shockwaves cause earthquakes at the surface.



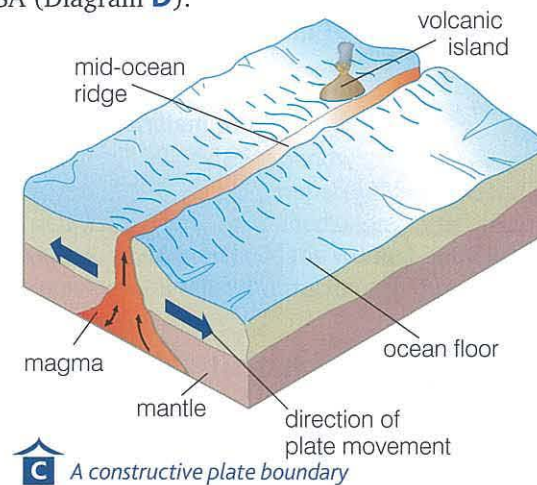
B A destructive plate boundary

What is a constructive plate boundary?

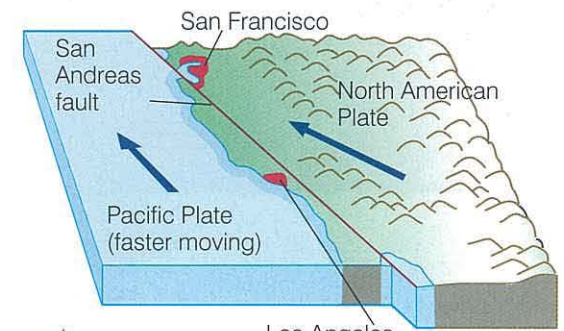
Where plates move away from each other, new crust is formed as magma rises from the mantle (Diagram C). Frequent volcanic eruptions form large ridges, up to 3,000 metres above the ocean floor. These are known as mid-ocean ridges, along which volcanic islands rise above the ocean surface. Along the Mid-Atlantic Ridge the seafloor is 'spreading' by between 1 and 5 cm each year. The Eurasian and African plates are moving away from the North and South American plates due to this process of continental drift.

What is a conservative plate boundary?

Where plates slide sideways past each other, no new crust is formed and no crust is destroyed. Therefore very few volcanic eruptions occur, but earthquakes are frequent and often very strong. The plates may lock together as they move and pressure builds up. As they snap loose, shockwaves cause violent earthquakes at the surface. An example of a conservative plate boundary can be seen on the western coast of the USA (Diagram D).



C A constructive plate boundary



D A conservative plate boundary

Activities

- 1 Describe the distribution of earthquakes and volcanic eruptions.
- 2 What is meant by the term 'continental drift'?
- 3 Copy and complete the table below.

Type of plate boundary	Plate movement	Type of hazard found	Examples of plate movement
Destructive			Nazca plate meets South American plate
Constructive		Earthquakes and volcanoes	
Conservative	Plates slide sideways past each other		

extension Explain the causes of the eruption of the Tungurahua volcano in Ecuador and the earthquake in Yogyakarta, Indonesia (see pages 62–3).

Key terms

- Earth's crust:** the solid, outer layer of the Earth.
- Tectonic plates:** large segments of the Earth's crust.
- Mantle:** the layer of the Earth between the crust and the core.
- Magma:** liquid rock below the Earth's surface.

Did you know

- The strongest recorded earthquake was magnitude 9.5 in Chile on 22 May 1960.
- 500,000 detectable earthquakes occur in the world each year. 100,000 of these can be felt, and 100 of them cause damage.

AQA Examiner's tip

Learn the diagram of a destructive plate boundary and ensure that you can add at least four labels to it.

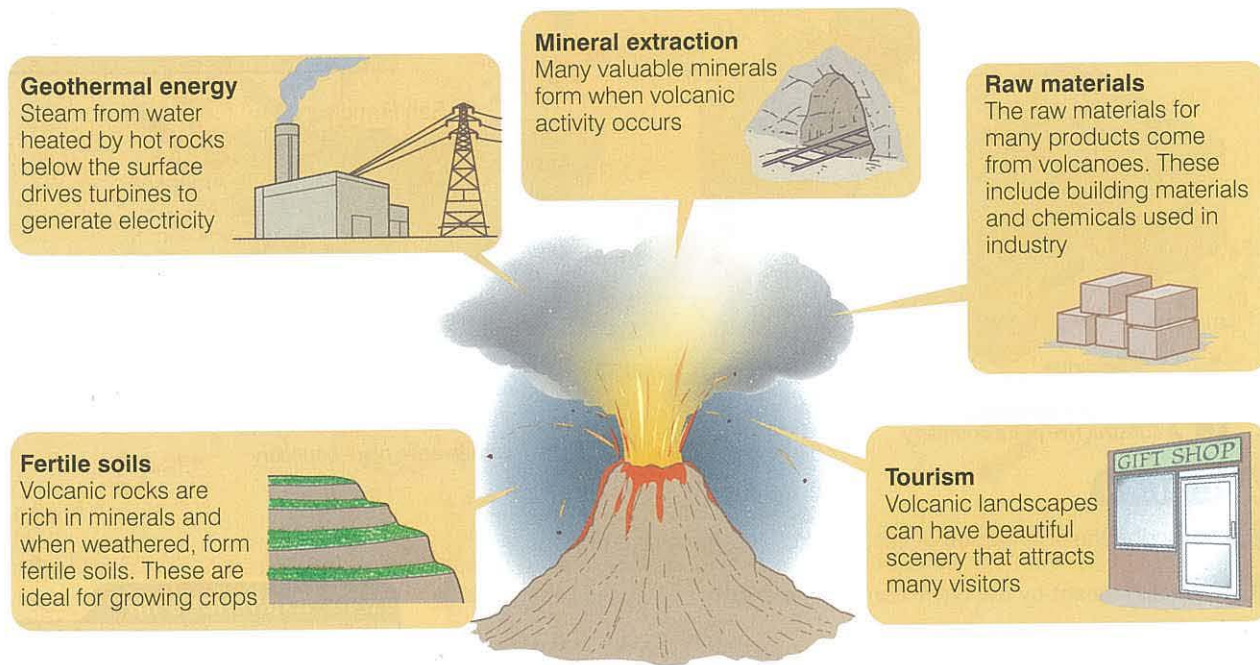
links

Learn more about plate boundaries at www.earthquake.usgs.gov/eqcenter/

3.3 Living with tectonic hazards

Despite the hazards, many people continue to live in earthquake zones or areas close to volcanoes. As tectonic hazards occur relatively infrequently, they might feel that a major volcanic eruption will never happen in their lifetime, or that an earthquake will never strike their particular location. It may also be a case of 'there's no place like home'. After living in the same area for many generations, families develop a strong sense of heritage. Family and friends live in the area and they do not want to move elsewhere. In many less developed countries people simply cannot afford to move away, or it may be that as population pressure increases, more people are forced to live in areas of risk. In some cities building regulations do not allow development on areas that are at risk of **liquefaction**, but illegal shacks are sometimes built in these areas.

Volcanic areas offer many economic advantages (Diagram A). Many people live in these areas because the benefits outweigh the possible risks.



A Benefits of volcanic areas

Geothermal power

Geothermal power is widely used in places such as New Zealand, Hawaii and the volcanic island of Iceland, where it provides 70 per cent of energy needs. The Geysers field in northern California (USA) is the largest geothermal development in the world and provides enough energy for the city of San Francisco and its 765,000 people.

Geothermal energy is a renewable energy source which is clean and sustainable. Geothermal power plants release less than 1 per cent of the CO₂ emissions of a fossil fuel power plant and the steam and water are constantly reused.

In this section you will learn:

the reasons why people live in earthquake zones and in areas close to volcanoes.

Key terms

Liquefaction: the loss of strength that can occur in the ground during earthquake shaking.

Tourism

Tourism is now an important activity in many volcanic areas. People get jobs in hotels and restaurants, in the making and selling of souvenirs, in transport and as tour guides. People flock to marvel at eruptions and there are trails, viewpoints and visitor centres provided for them. Other volcanic features also attract tourists; hot springs and mudbaths have long attracted people because of their health benefits. Geysers such as Old Faithful (Photo B) in Yellowstone National Park (USA) are major tourist attractions.

Agriculture

Lava breaks down quickly to form fertile soil, especially in a hot, wet climate. Hawaii produces crops such as sugar, coffee and pineapples on volcanic soils that have taken less than 100 years to form.

Minerals

In volcanic areas, heated groundwater concentrates traces of minerals such as copper, gold, silver, and tin into rich veins. These are mined, along with precious stones such as diamonds. Many worked-out goldmines have now become tourist attractions in their own right.

Is it worth the risk?

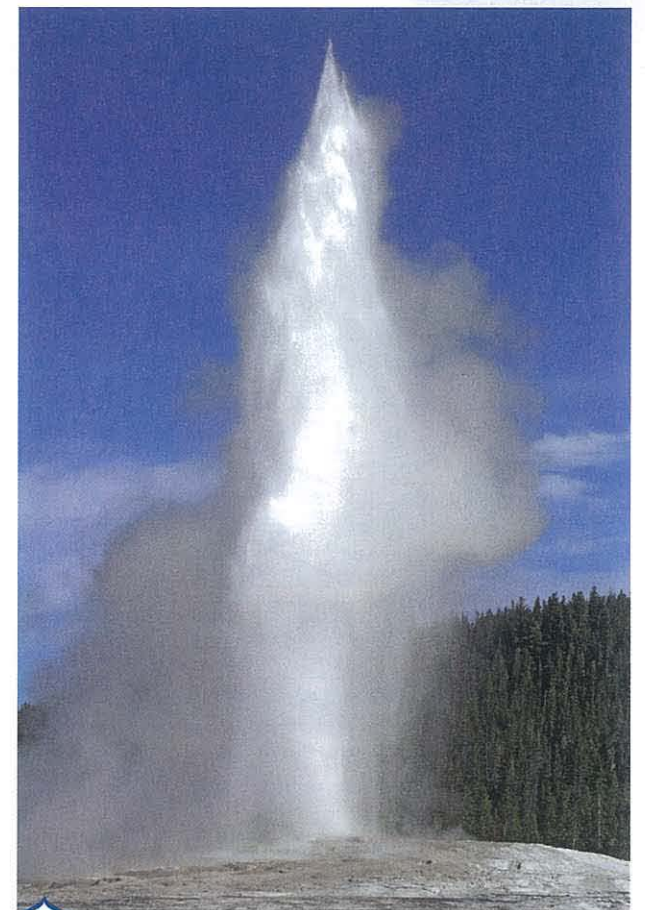
Many people living in areas of tectonic hazards believe that advances in science and technology will make life safer for them. Whilst many volcanoes are closely monitored and people are evacuated when there are signs of an eruption, it is still impossible to accurately predict when an earthquake will occur. Much research has been done on this subject – especially in Japan, where the entire population is at risk from earthquakes – but with little success. In California (USA), despite the history of earthquakes, increasing numbers of people want to live there. Attractions such as opportunities for well-paid jobs and a pleasant climate and lifestyle, make it worth the risk.

Activities

Write a paragraph to explain how each of the following might benefit local people.

- 1 Volcanic scenery.
- 2 Material erupted from a volcano.
- 3 Heat beneath a volcano.

extension Use the internet to find out more about the ways in which one volcano is of benefit to people, for example Vesuvius (Italy), Mount Merapi (Indonesia), Mount St Helens (USA).



B Old Faithful

AQA Examiner's tip

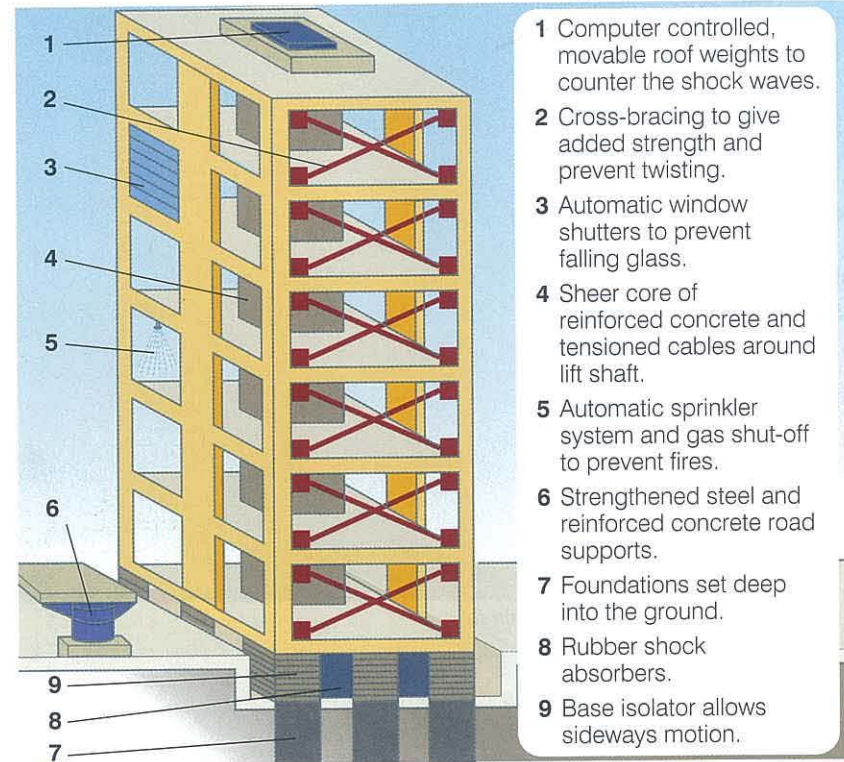
There are potential benefits of living in areas that experience tectonic hazards. Learn some of these benefits in relation to specific locations.

links

Learn more about particular volcanic features in the USA and Iceland at www.nps.gov/yell and www.energy.rochester.edu/is/reyk

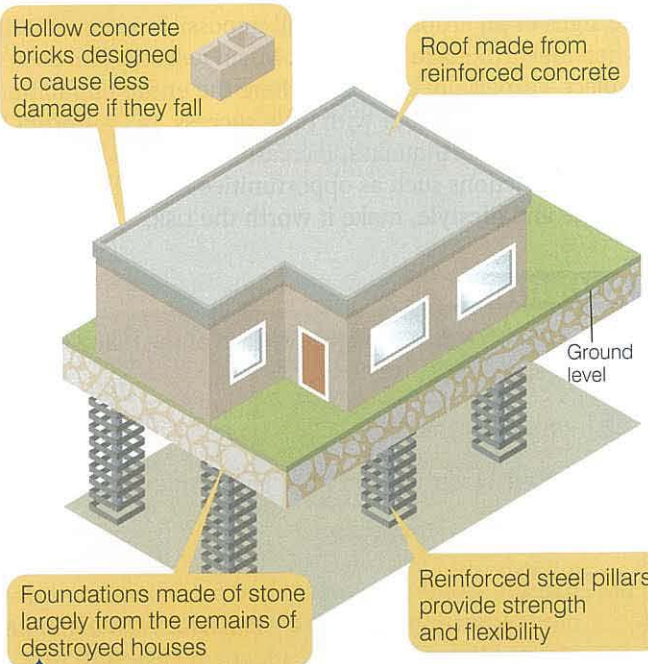
3.4 Reducing the effects of earthquakes

If people plan and prepare for earthquakes, then the risks can be reduced. Advances in building design means that many new buildings are 'earthquake proof' (Diagram A). Older buildings can be **retrofitted** to strengthen them in order to reduce the effects of earthquake shaking (Photo B).



A An earthquake-proof building

Earthquake proofing and retrofitting are very expensive and may not be affordable in some countries. However, the use of **appropriate technology** can protect people in less developed countries. Over 1 billion people around the world now live in bamboo houses. This is because bamboo is very strong, yet bends easily and has been proven to withstand much earthquake shaking. In Costa Rica (Central America) 70 hectares of bamboo plantation will build 1,000 houses: to grow the same amount of timber would require 600 hectares. Also, only a tiny proportion of the energy needed to make steel is needed to process the bamboo. When a strong earthquake hit Costa Rica in January 2009, all of the bamboo houses at its **epicentre** survived without damage. In Gujarat, India, basic houses designed to withstand earthquakes are being built from local and recycled materials (Diagram C).



C Earthquake-resistant house in Gujarat

In this section you will learn:

how people can plan and prepare for an earthquake

what actions people can take following an earthquake.



B The building in the background has been retrofitted

What is earthquake preparedness?

If people are aware of what actions to take before, during and after an earthquake, then the number of casualties can be reduced (Figure D). In many areas earthquake preparation is taught in schools and there are regular 'drills' involving local people and the emergency services. In Japan 'Disaster Prevention Day' is held each year on 1 September, the date on which the Great Kanto earthquake struck Tokyo in 1923. People are reminded of what to do in the event of an earthquake.

Earthquake shaking maps can help with planning and responding to emergencies and targeting aid. Computer-generated scenarios show the intensity of ground shaking at different locations (Map E). People can be made aware of the level of risk in the area where they live and put in place the necessary levels of protection. The maps also help the authorities draw up **building codes**. In areas of intense shake, or areas at risk from liquefaction, codes would specify a high level of 'earthquake proofing' on buildings.

Key terms

Retrofitting: the addition of new technology to older buildings.

Appropriate technology: technology designed with consideration of the community it is intended for.

Epicentre: the point on the Earth's surface directly above the focus of an earthquake.

Building code: regulations which state how a building should be constructed in order for it to be safe.

Activities

- 1 Describe four ways in which buildings can be made to withstand an earthquake.
- 2 Suggest why the building methods used in Costa Rica and Gujarat are appropriate and sustainable.
- 3 Design your own poster to promote earthquake preparedness.
- 4 Give two ways in which earthquake shaking maps can benefit people.

extension Suggest 10 items that you think should be included in an earthquake kit. (Page 76 may give you some ideas.) Explain why you chose each item.

links

Learn more about preparing for earthquakes at www.earthquake.usgs.gov and www.fema.gov/hazard/earthquake

EARTHQUAKE PREPAREDNESS

You CAN Survive an Earthquake!

By following these guidelines you will reduce the chances of injuries to you and your loved ones and lessen the likelihood of having household contents damaged or destroyed in an earthquake

1 Prepare your home
Secure all heavy, moveable items of furniture.

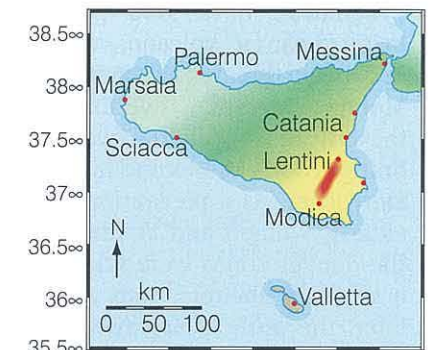
2 Create a disaster plan
Make sure everyone in the family knows what to do in an earthquake. Choose a safe place in every room. Prepare an earthquake kit.

3 Know what to do when the shaking begins
Practise your drill. Drop, cover and hold on! If outdoors, find a clear spot away from buildings, trees, and power lines.

2 After the shaking stops
Check for injuries. Listen to the radio for instructions.

April is earthquake preparedness month

D Earthquake preparedness poster



Shaking and damage
I II III IV V VI VII VIII IX X+
Low High

E Earthquake shaking map of Sicily

AQA Examiner's tip

Be able to explain how both more developed and less developed countries have attempted to reduce the impact of earthquakes.

3.5 Reducing the effects of volcanoes

A volcanic eruption cannot be prevented, but the immense power of the volcano can be closely monitored. This reduces the risk of living near a volcano. Scientists look for increases in **seismic activity**, releases of volcanic gases and changes in the temperature or mineral content of nearby springs. The most noticeable sign that an eruption could occur are changes to the shape of the volcano. By using tilt meters to measure the angle of the slope of the volcano, **laser ranging** and aerial photographs, any bulges in the mountain can be detected. Mount St Helens (USA) bulged by 137 metres before it erupted in 1980.

If it is clear that a volcanic eruption is likely, then a course of action has to be decided upon. Several options could be considered, including:

- Restricting access to the area.
- Evacuating the area (see the article on Java and Map C).
- Reducing the effects of the eruption (see the article on Mount Etna and Photo A).

Java Volcano Evacuation Ordered

In May 2006, Indonesia's president ordered the **evacuation** of 17,000 people living near a volcano, which had been threatening to erupt. Mount Merapi, overlooking the city of Yogyakarta, was on orange code – the second highest alert level. As a precaution, the elderly, women and children in the danger zones were taken to emergency shelters. Two weeks later, the authorities raised the alert to the highest level – the red

code – ordering the immediate evacuation of all residents on the mountain. In villages, horns were sounded to let people know they should leave. Army trucks were used to ferry thousands of people away from the danger zone. Some villagers did not want to leave their valuable farmland as they were worried about their property, cattle and crops being stolen. Most were eventually persuaded to evacuate.

Bulldozers move in on Mount Etna

Some 70 bulldozers have been used to build earth and rock walls to divert lava away from villages. Planes and helicopters have dropped water to cool the lava and slow it down, as they did in Iceland in 1983 when a lava flow threatened a nearby town. In the past the Italian authorities have used military bombing and dynamite to divert lava flows.



A Bulldozers move in on Mount Etna

In this section you will learn:

- how volcanoes can be monitored
- how people can plan and prepare for a volcanic eruption
- what actions people can take following an eruption.

Did you know

Ash clouds may be so dense that they turn the sky pitch black. Ash severely restricts visibility and deadens sound. Very fine ash particles can stay in the atmosphere for many years, and be spread around the world by winds. Following the Mount St Helens eruption, ash travelled around the world twice. In the year following the eruption, the average global temperature fell by 1°C.

Key terms

- Seismic activity:** movements in the Earth's crust.
- Laser ranging:** using laser beams and mirrors to detect minute changes in the shape of the land.
- Evacuation:** movement of people away from a place of danger to a place of safety.

AQA Examiner's tip

Learn case studies covering volcanic eruptions in both more and less developed countries.

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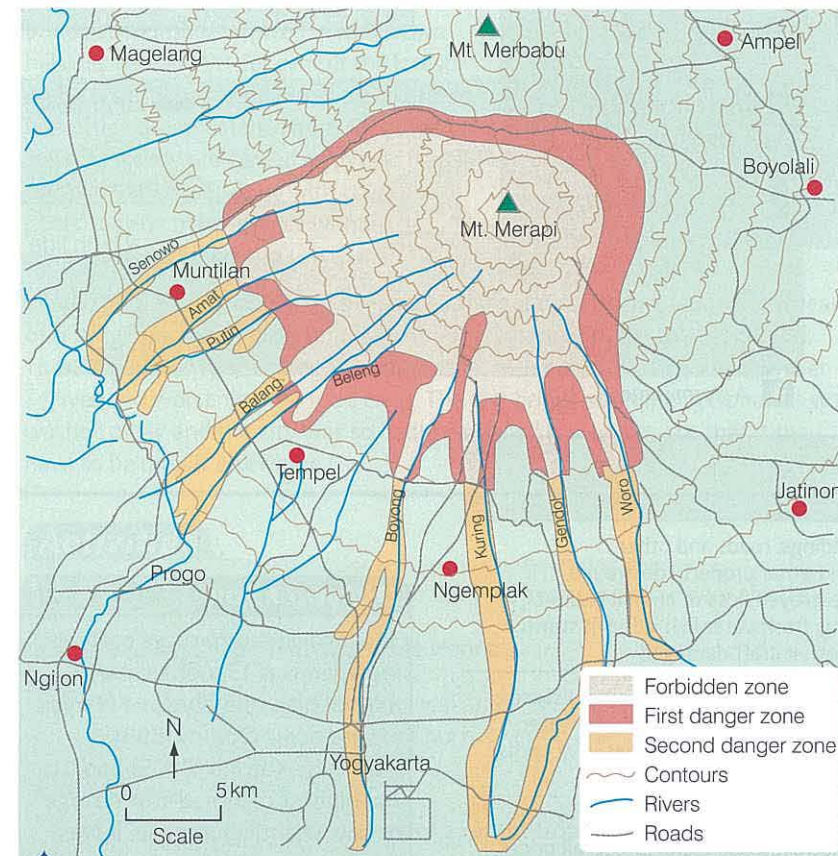
Learn more about Mount St Helens at www.fs.fed.us/gpnf/mshnvm

How can people prepare for a volcanic eruption?

In areas where volcanoes emit large amounts of ash, a major risk is from roof collapse due to the weight of the ash. Improved building design can help to reduce injuries and lessons have been learned from areas that receive heavy snowfall. Flat-roofed buildings are most at risk of collapse and should not be constructed in areas where ash fall is common. Sloping roofs that are reinforced and made of smooth materials such as metal and glass are more likely to shed volcanic ash. Ash also corrodes roofs and suitable plastic coverings have now been developed. It can also damage computer and electrical systems and filter systems are increasingly installed in many buildings. Simpler methods include sealing doors and windows.

Through campaigns aimed at increasing awareness about what to do during a volcanic eruption, people are encouraged to keep towels and tape in an emergency kit, which should also include a torch, bottled water, wind-up radio, goggles and disposable breathing mask.

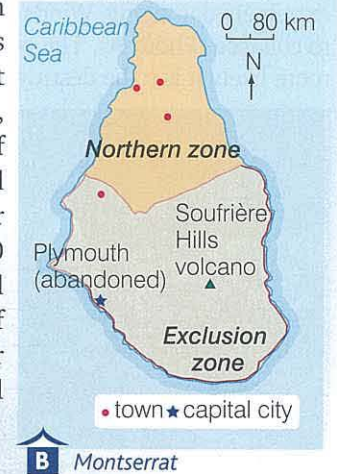
Volcanic hazard maps (Map C) have been developed and are often available to local people on the internet, or are displayed in public buildings. They show areas most likely to be at risk from ash falls, lava flows or mudflows, for a number of different eruption scenarios. They can be useful for planning possible evacuation routes or future building projects.



C Hazard map for Mount Merapi (Indonesia)

Thousands evacuated from danger zone

During the eruption of the Soufriere Hills volcano on Montserrat that began in 1995, access to the south of the island was restricted because of the danger (Map B). Around 5,000 people were evacuated to the northern part of the island and a further 7,000 left the island altogether.



Activities

- 1 Describe ways in which a volcano can be monitored.
- 2 Describe ways in which the actions taken by the authorities during the Mount Etna eruption differ from those taken during the Mount Merapi eruption.
- 3 a Suggest how each of the items included in the emergency kit might be of help to people in a volcanic eruption.
b Suggest two other items that might be included in the emergency kit.
- 4 Suggest how volcanic hazard maps might be useful.

extension Find out why different actions are appropriate for different eruptions.