1 Tectonic processes and hazards

Tectonic hazards are earthquakes and volcanic eruptions. Also included under the heading are secondary hazards, such as tsunamis.

Spatial variations in the tectonic hazard risk

The global distribution of tectonic hazards

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Key concepts

Plate boundaries are recognised by plate tectonic theory as being of three types:

- Convergent (destructive): occur where two tectonic plates are moving together. Where a dense oceanic plate collides with a less dense continental plate, the former is thrust underneath the latter, forming a subduction zone. Mountain building and volcanic eruptions are the outcomes.
- Divergent (constructive): the moving apart of the plates creates rifts filled with new crustal material from volcanic eruptions.
- Conservative (transform): here two crustal plates slide past each other. The friction often triggers earthquakes.
- Collision: two continental plates collide and crush against each other, pushing up mountains.

Earthquakes

The global distribution of tectonic hazards is far from random. The main earthquake zones occur along **plate boundaries**, particularly convergent and conservative ones (Figure 1.1). Occasionally earthquakes occur in the middle of tectonic plates (intra-plate earthquakes).

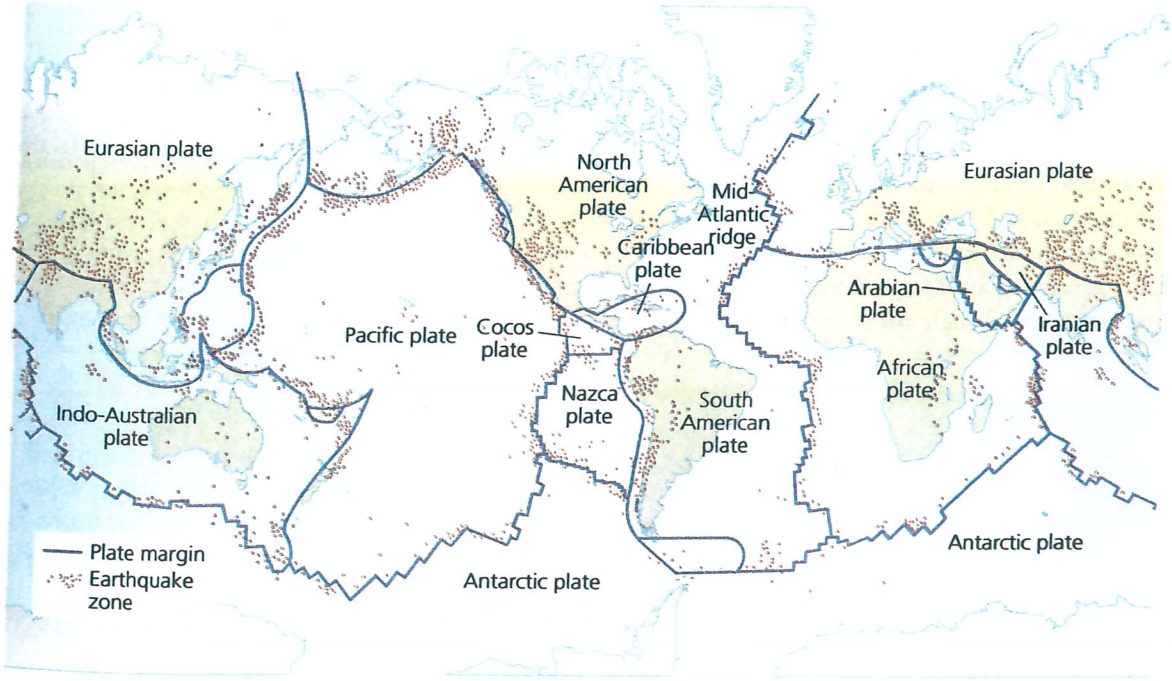
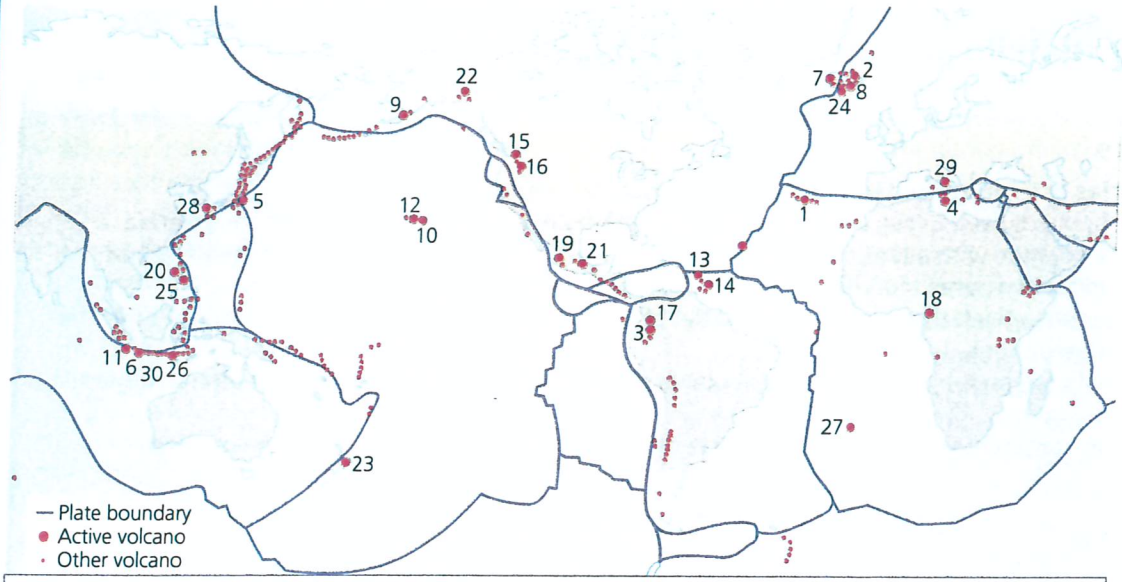


Figure 1.1 The global distribution of earthquakes

Volcanoes

There are about 500 active volcanoes around the world. Figure 1.2 shows that a significant number of these are located in the 'Ring of Fire' around the Pacific Ocean. Most volcanoes occur near plate boundaries, but there are also **hotspot volcanoes**.

Hotspot volcanoes: These are found in the middle of tectonic plates and are thought to be fed from the underlying mantle (a thick layer of high-density rocks lying between the Earth's crust and its molten core). These volcanoes occur where the mantle is unusually thin and hot. The summits of the Hawaiian islands are classic examples.



1 Azores	6 Galunggung	11 Krakatoa	16 Mt St Helens	21 Popocatapetl	26 Tambora
2 Bardarbunga	7 Grímsvötn	12 Mauna Loa	17 Nevado del Ruiz	22 Redoubt	27 Tristan da Cuhna
3 Cotopaxi	8 Haeimaey	13 Soufrière Hills	18 Nyos	23 Ruapehu	28 Unzen
4 Etna	9 Katmai	14 Mt Pelée	19 Parícutin	24 Surtsey	29 Vesuvius
5 Fujiyama	10 Kilauea	15 Mt Rainier	20 Pinatubo	25 Taal	30 Meru

Figure 1.2 **The global distribution of active volcanoes**

Tsunamis

Tsunamis are caused by submarine shock waves generated by earthquakes or volcanic eruptions, and have a wide global distribution (Figure 1.3). They are most commonly experienced around the coastlines of the Pacific Ocean. Tsunamis are are potentially most devastating where a gently sloping continental shelf allows them to build to great heights.

Revision activity

Make sure you know what happens at each of the four types of plate boundary and whether volcanoes, earthquakes or both occur.

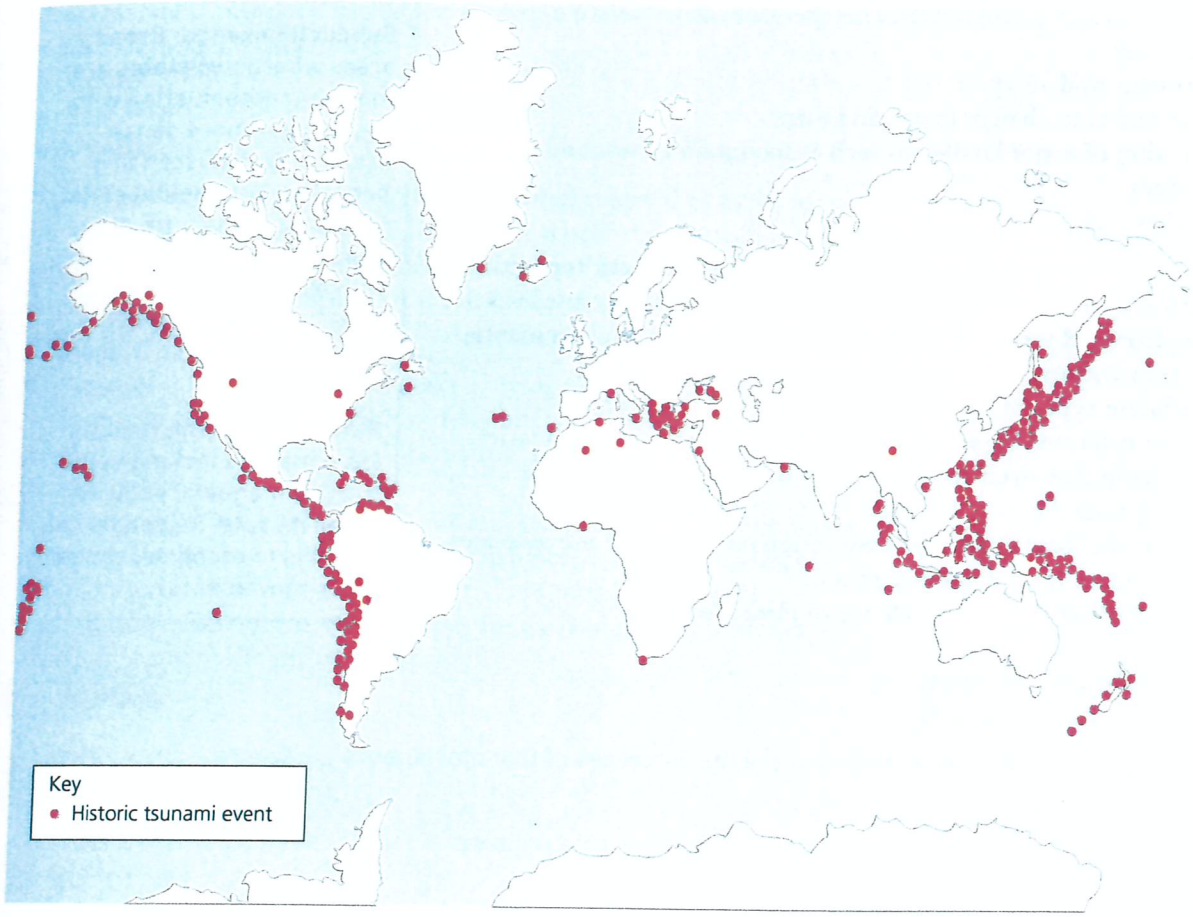


Figure 1.3 Notable tsunami events since 1900

Now test yourself

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1 Name two locations outside the Pacific Rim where there have been a number of notable tsunamis.

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Theoretical frameworks

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The theory

Key concept

Plate tectonics theory views the Earth's crust as consisting of a number of mobile yet rigid elements (plates). These plates are of two different types:

- thin crust underlying the ocean basins
- thicker crust underlying the continents.

The low density of the thick continental crust allows it to 'float' on the much higher-density mantle below. Heat derived from the Earth's molten core rises within the mantle to create convection currents which, in turn, move the tectonic plates.

Over a long period of geological time, as the plates move relative to each other, they cause:

- the continents to drift apart
- the ocean basins to change in size and form
- the formation of major landforms such as mountain chains and mid-ocean ridges
- earthquakes, volcanic eruptions and tsunamis.

The following are important elements in the theory of **plate tectonics**:

- The nature of the Earth's structure with a relatively thin crust broken up into plates and wrapped around a thick and largely molten mantle.
- Convection within the mantle causes crustal plates to move.
- Four different types of plate boundary are recognised (page 7).
- New crust is formed by sea-floor spreading at divergent boundaries.
- Crust is being destroyed and remoulded in **subduction zones** at convergent boundaries.
- Slab pull is the force created by convection currents that moves plates and drags them into subduction zones.
- **Paleomagnetism** provides evidence of plate movements.

Subduction zones: Broad areas where two plates are moving together, often with the thinner, more dense oceanic plate descending beneath a continental plate. Fold mountains form at the edge of the overriding plate, with associated volcanic activity. Stress between the two plates also triggers earthquakes.

Paleomagnetism: Results from magma locking in the Earth's magnetic polarity when it cools. Scientists can use this to reconstruct past plate movements.

Now test yourself

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2 How do tectonic plates move and what are the outcomes of that movement?

Answer on p. 215

The type and magnitude of event

The type of tectonic event is largely determined by the type of plate boundary. The convergent boundary is the most productive of both earthquakes and volcanic eruptions, followed by the divergent boundary. The conservative boundary produces only earthquakes.

Science has still to discover what determines the magnitude of a tectonic event. The Benioff zone is thought to be important in the case of some earthquakes. This is the boundary between an oceanic plate that is undergoing subduction and an overriding continental plate. It is a sloping plane and stresses are built up as the cold oceanic plate sinks into the hot mantle. The zone produces earthquakes, but why are some of those earthquakes more powerful than others?

Now test yourself

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3 Is event magnitude more important than event location? Give your reasons.

Answer on p. 215

Physical processes behind tectonic hazards

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Earthquakes

Earthquakes are caused by sudden movements of the Earth's crust relatively close to the surface, usually along a pre-existing fault. The movement is the outcome of a gradual build-up of tectonic pressure and

then its sudden release. The sudden movement creates vibrations (seismic waves) of three different kinds:

- P (fast)
- S (slower)
- L (surface).

The **hypocentre** of an earthquake, sometimes referred to as the focus, is the point of origin within the Earth's crust where the pressure is released – the point of rupture. The **epicentre** is the point on the Earth's surface directly above the hypocentre. It is the surface location where the shock waves are likely to be strongest.

The overall severity of an earthquake is determined by the amplitude and frequency of these waves. The S and L waves are more destructive than the P waves. They cause crustal fracturing, ground shaking and three secondary hazards:

- Liquefaction: this affects loose rock and sediment. The seismic waves trigger the ground to lose its load-bearing capacity, causing large buildings to settle into the ground, tilt and possibly collapse.
- Landslides: these occur where slopes are weakened by seismic waves and slide under the influence of gravity.
- Tsunamis (see below).

Now test yourself

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4 What are seismic waves? What is the difference between the hypocentre and the epicentre of an earthquake?

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Tsunamis

These waves are potentially the most lethal of the secondary earthquake hazards. Out at sea they do not represent a hazard since they are low in height and generally go unnoticed. It is only as they approach a coastline and the sea becomes shallower that they grow in height.

The impact of a tsunami depends on a number of physical and human factors:

- duration of the event
- wave amplitude and distance travelled
- depth and gradient of the offshore zone
- degree of coastal protection provided by mangroves and coral reefs
- timing of the event – night or day
- quality of early-warning systems
- density of population and degree of development close to the coastline.

Volcanoes

The primary hazards of a volcano are:

- Pyroclastic flows: the frothing of magma at the vent produces bubbles that burst explosively to eject hot and poisonous gases as well as hot, fine materials. Clouds formed of these gases and materials are most lethal when they roll down the sides of a volcano.
- Tephra (ash falls): these are rock fragments ejected into the atmosphere and ranging in size from 'bombs' to fine dust. The accumulation of tephra on roofs starts fires and causes buildings to collapse.

- Lava flows: these are flows of molten rock, often fast moving and lethal.
- Volcanic gases: these are mixed gases emitted during explosive eruptions. The carbon dioxide is particularly dangerous.

The secondary hazardous impacts of volcanoes are:

- lahars: mudflows created by the combination of heavy rain on slopes covered by fine volcanic material
- jokulhaups: catastrophic floods caused by volcanic eruptions beneath glaciers.

Exam tip

Remember that compared with other hazards, such as earthquakes and tsunamis, volcanoes have historically killed far fewer people. An important factor is that there is often some form of advanced warning of an eruption.

Revision activity

Make sure that you have a located, recent example of each of the three tectonic hazards, together with the date of the event and some indications of the scale of the human impact.

Now test yourself

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5 Which of the primary hazards of a volcanic eruption is potentially the most lethal? Give your reasons.

Answer on p. 215

Tectonic hazards become disasters

Vulnerability, risk, resilience and disaster

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Vulnerability and risk are key factors in turning hazards into disasters.

Key concepts

Vulnerability relates to the ability of a community to cope with the impacts of a hazard. That ability is determined by a range of factors, from the quality of warning systems and emergency responses to the level of development and settlement density. So it is argued that a developed country, with good governance and access to technology and relevant resources, is less vulnerable to the same hazard than a developing country. The likelihood of that hazard becoming a disaster is reduced.

Risk is the exposure of people to a hazardous event. It relates to the probability of a hazard leading to a loss of life and/or livelihoods. The assessment of risk is complicated by many factors, including:

- the perceptions of individuals and communities
- the unpredictability of hazards, with people being caught out by the timing or magnitude of a tectonic event
- the lack of alternatives – people continue to live in hazardous areas because they have no other options
- the fact that the benefits of hazardous location may outweigh risks involved in staying there
- acceptance of the risk that something might happen.

Hazards: These are natural events that threaten or actually cause injury and death, as well as damage and destruction to property.

Disasters: These occur when hazards have a significant impact on vulnerable populations. Officially, a hazard becomes a disaster when 100 or more people are killed and/or 100 or more people are affected.

Typical mistake

Tectonic events by themselves are not hazards. They become hazardous only when they adversely impact on people, their settlements and livelihoods.

Typical mistake

The terms hazard and disaster are often taken to mean the same thing. In fact, they mean very different things.