CHAPTER 4

Plate tectonics: the moving Earth

Learning focus

At the end of this chapter you will be able to:

- >> describe the interaction of human activities with natural systems
- >> explain the causes of major events in natural systems that impact on humans
- >> describe the impact of natural disasters on humans living in the region
- >> evaluate responses made by governments, non-government organisations and community groups to natural disasters
- >> propose strategies to deal with the impact of natural disasters in the future.

The structure of the Earth

> *Civilization exists by geologic consent, subject to change without notice.*
>
> Will Durant, US historian (1885–1981)

This chapter examines plate tectonics as one of Earth's major natural systems. The interaction between plate tectonics and human activities is investigated through studies of the natural disasters associated with plate tectonics. These disasters do not respect human borders and are a threat to all people.

Any explanation of plate tectonics requires a basic understanding of the internal structure of the Earth. Since the formation of the Earth about 4.6 billion years ago, the planet has cooled and separated into several different layers [4.1]. The solid inner core consists mostly of dense iron. A less dense layer of nickel and iron called the outer core surrounds the core. The next layer is the molten mantle, which has several distinct layers. The Earth's crust is the outermost layer surrounding the mantle. It is a thin layer of rocky material that is in a state of constant movement over time. Interactions between the two outer layers of the Earth determine the operation of plate tectonics.

What is plate tectonics?

lithosphere
the outermost layer of the Earth including the crust and the uppermost mantle

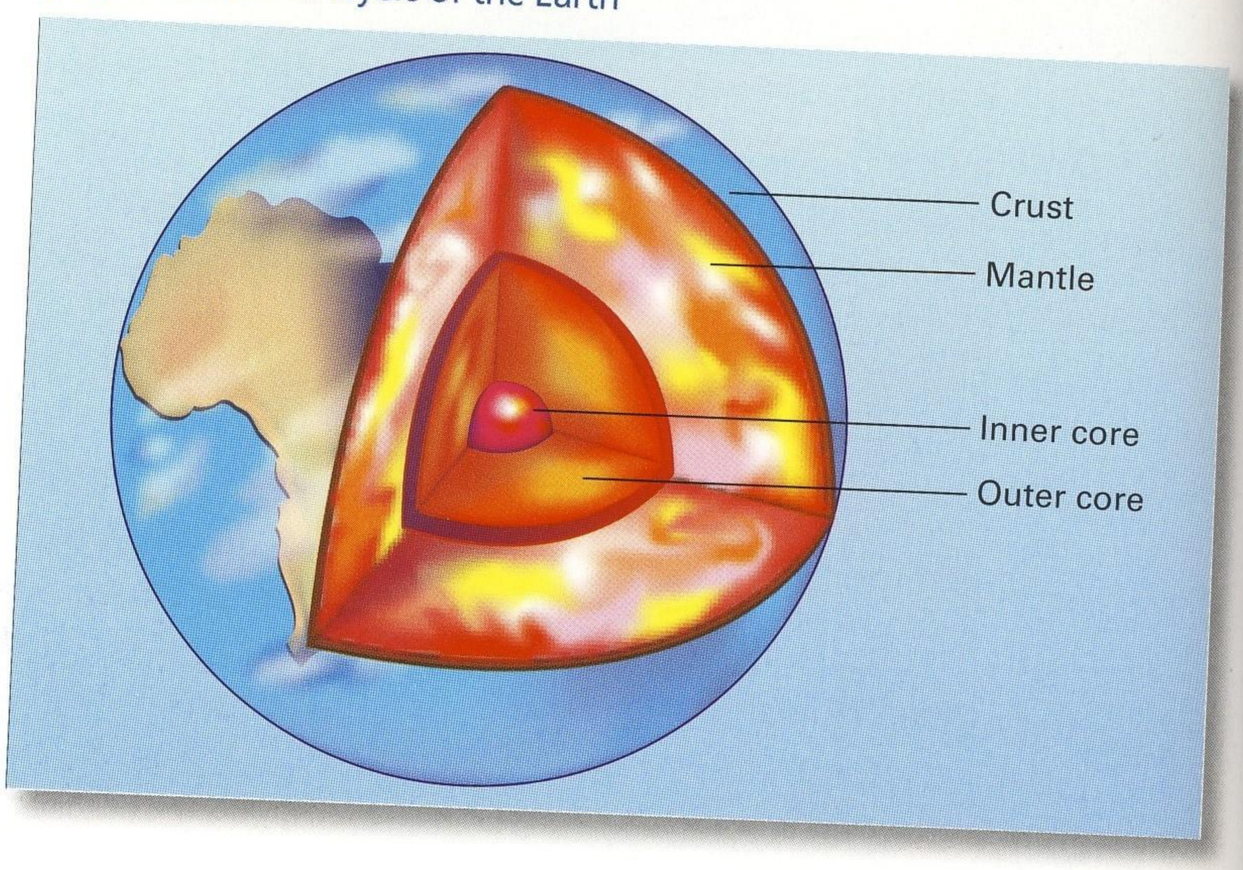
The theory of plate tectonics was developed in the late 1960s to explain the dynamic processes of the Earth. According to plate tectonics, the **lithosphere** of the Earth consists of thin, rigid segments or plates of crust and the uppermost mantle. These lithospheric plates float like rafts on the deeper, molten layer of the mantle. The theory of plate tectonics offers a reasonable explanation for the process of plate evolution—their formation, movement and destruction. It shows that the Earth's surface is not a static grouping of land and water bodies, but an integrated system driven by materials and processes from the Earth's interior. As plate tectonics operates over time, it slowly and continuously changes the sizes, shapes and locations of the world's continents and oceans.

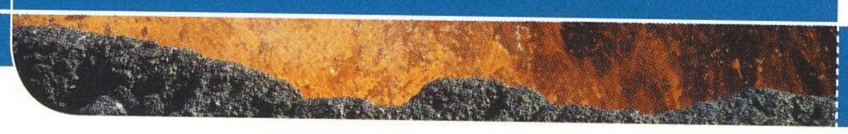
Plate tectonics only gained widespread acceptance in the late 1950s and early 1960s. Prior to this, the processes causing tectonic forces were unknown and subject to speculation. The development of the theory of plate tectonics and the important processes that underpin it are a necessary starting point to understand how this natural system operates.

did you know?

In geology, a *plate* is a large slab of solid rock. *Tectonics* comes from a Greek word meaning *to build*. So, *plate tectonics* refers to how the Earth's surface is built from plates.

[4.1] The internal layers of the Earth





Learning activities

4.1 Explain in your own words Will Durant's comments at the start of the chapter.
4.2 Describe the internal structure of the Earth.
4.3 What is the lithosphere?
4.4 What does the theory of plate tectonics tell us about the Earth's surface?

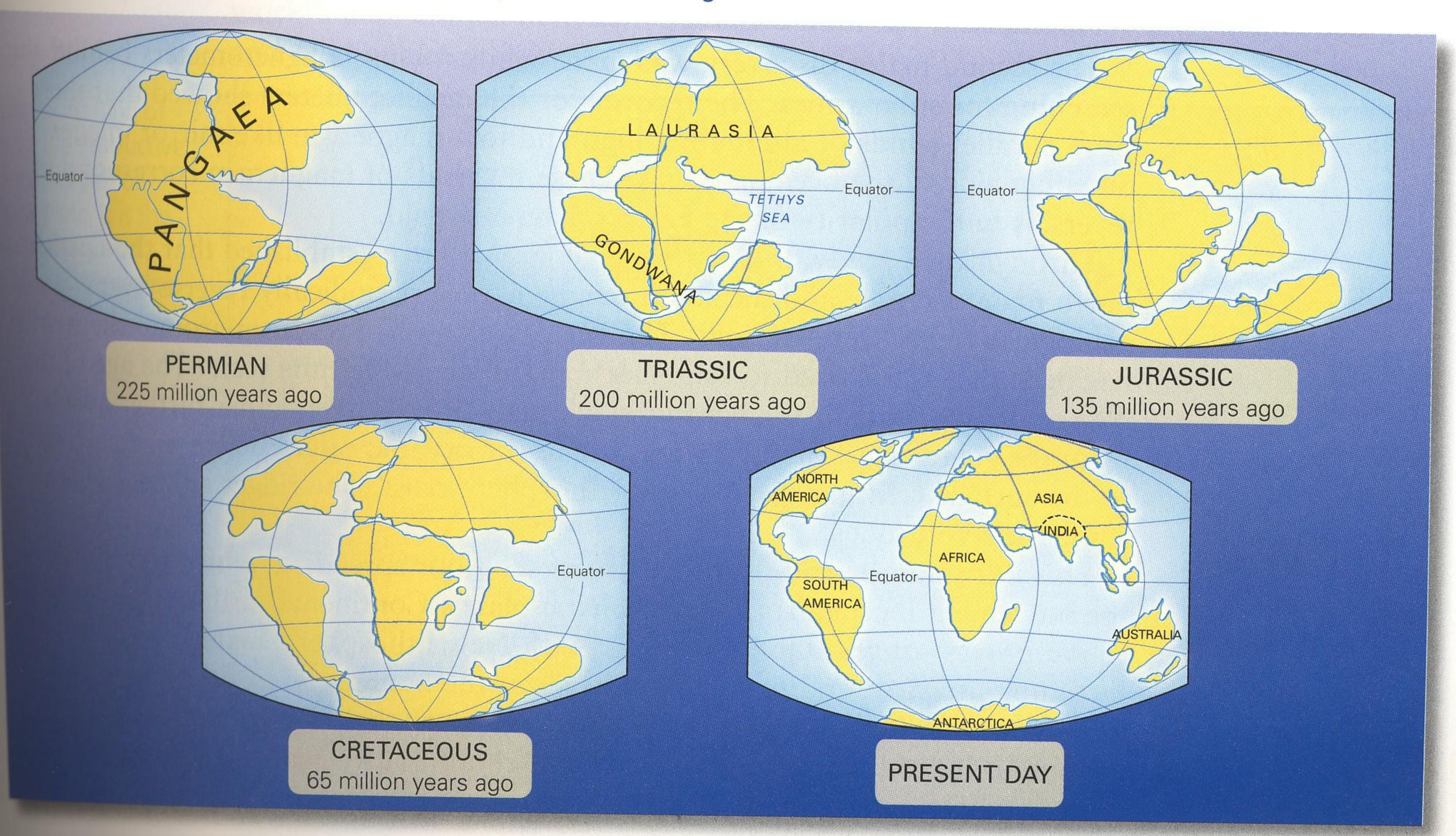
Evolution of the theory of plate tectonics

Since the early map makers of the 1400s and 1500s, many people had noticed that the shape of the continents fitted together like pieces in a giant super-continental jigsaw puzzle. The first modern scientist to propose that the continents had once been joined was Alfred Wegener, a German meteorologist.

The theory of continental drift

In 1912, Wegener presented a detailed theory of continental drift. He proposed that the continents had once been joined as a super-continent he called Pangaea [4.2]. Wegener's evidence included common ancient glaciations, similar mountain ranges, fold belts, rock types and fossils from places where continents on different sides of large oceans fitted together. He proposed that the continents had drifted apart by sliding over the ocean floor. However, geologists rejected Wegener's theory saying that the ocean crust was not strong enough to support the continents and there would be too much frictional resistance for any movement to occur. In spite of this, evidence to support continental drift gradually began to accumulate, first in the form of studies of the Earth's magnetic field.

[4.2] The evolution of the continents from the super-continent Pangaea



Palaeomagnetism

Palaeomagnetism is the history of the Earth's magnetic field. In the 1950s and 1960s, geologists discovered that when rocks cool and solidify, the alignment of magnetic minerals, such as magnetite, takes on the orientation of the magnetic field at the time the rock was cooling. Studies on rocks of various ages in Europe and North America showed that the magnetic pole had apparently moved through time. However, the path of the magnetic poles for Europe and North America were different, suggesting that the continents had moved relative to each other through time. This was confirmed by studies on other continents. The next step in the acceptance of the plate tectonics theory was the discovery of the mechanism for how the continents moved. This was to come from studying the sea bed.

Learning activities

4.5 What evidence did Wegener use to show that the continents had once been joined together?

4.6 What is Pangaea?

4.7 Why did geologists initially reject Wegener's theory?

4.8 How did palaeomagnetism help to prove that the continents had moved over time?

Sea-floor spreading

During World War II, geologists working for the United States military made some significant discoveries while studying the ocean floors looking for hiding places for submarines. They found two important topographic features on ocean floors:

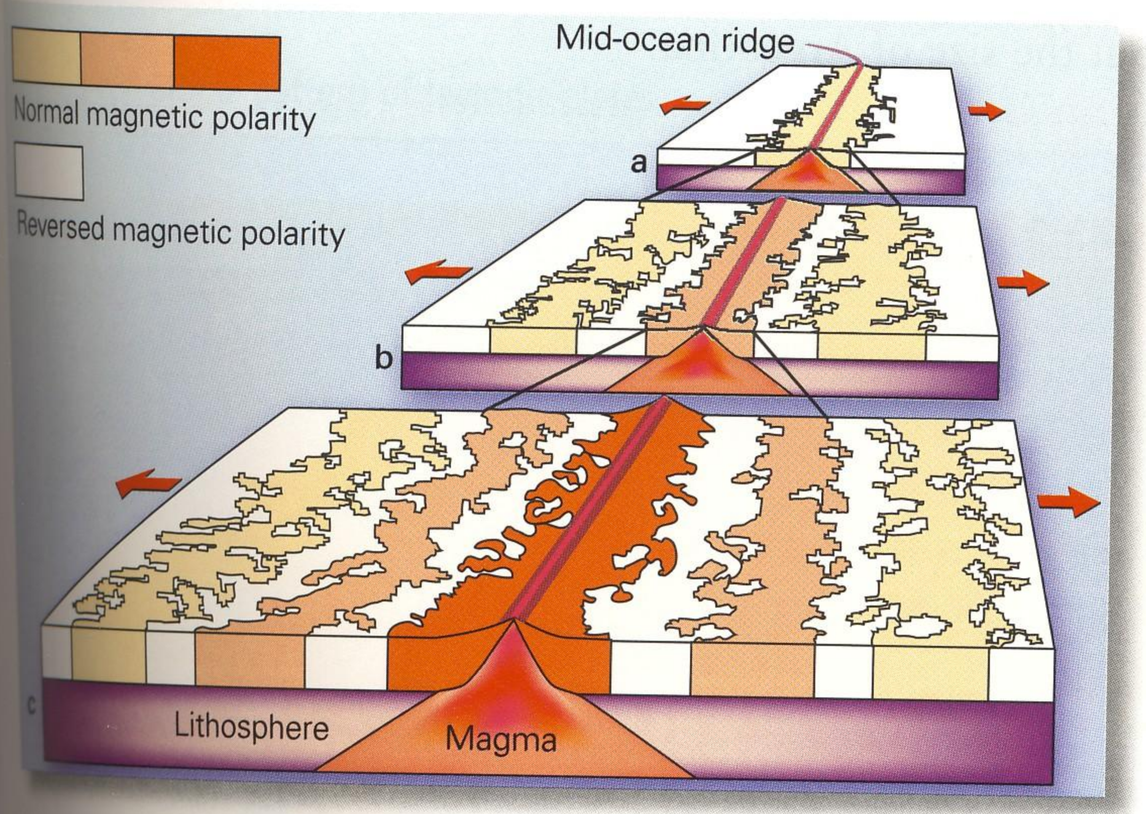
- oceanic ridges—these long ridges were found in the middle of the Atlantic Ocean and in the eastern part of the Pacific Ocean
- oceanic trenches—these deep trenches were found along the edges of continents, especially in the Pacific Ocean.

The second major discovery was made while towing magnetometers behind ships searching for submarines. The records for the magnetometers showed that there were parallel bands of alternating high and low magnetism like mirror images on either side of the oceanic ridges. These reversals of magnetism correspond to reversals in the polarity of the Earth's magnetic field.

Through their study of lava flows, geologists have established that the Earth's north magnetic pole and the south magnetic pole periodically reverse over geologically short time periods. The age of volcanic rocks from around the world has been dated and used to establish a global magnetic time scale. The age of the rocks on either side of the oceanic ridges gets progressively older further away from the ridge. The youngest rocks are at the oceanic ridges where magma rises to the surface creating new oceanic lithosphere crust. The ridges are in fact active submarine volcanoes.

This information lead to the theory of sea-floor spreading, which partly explains the movement mechanism of lithospheric plates. Continental drift appears to be due to the process of sea-floor spreading [4.3]. New lithospheric material is continually intruding upwards and pushing outwards at the boundaries of lithospheric plates like two super conveyor belt systems moving in opposite directions. Geologists proposed that if lithospheric material was continuously being created at the mid-oceanic ridges and moving outwards, then it must be continuously being destroyed at the edges of the lithospheric plates [4.4].

[4.3] A theoretical model of sea-floor spreading and magnetic striping at a mid-oceanic ridge: (a) a spreading ridge about 5 million years ago, (b) about 2 to 3 million years ago, and (c) present-day



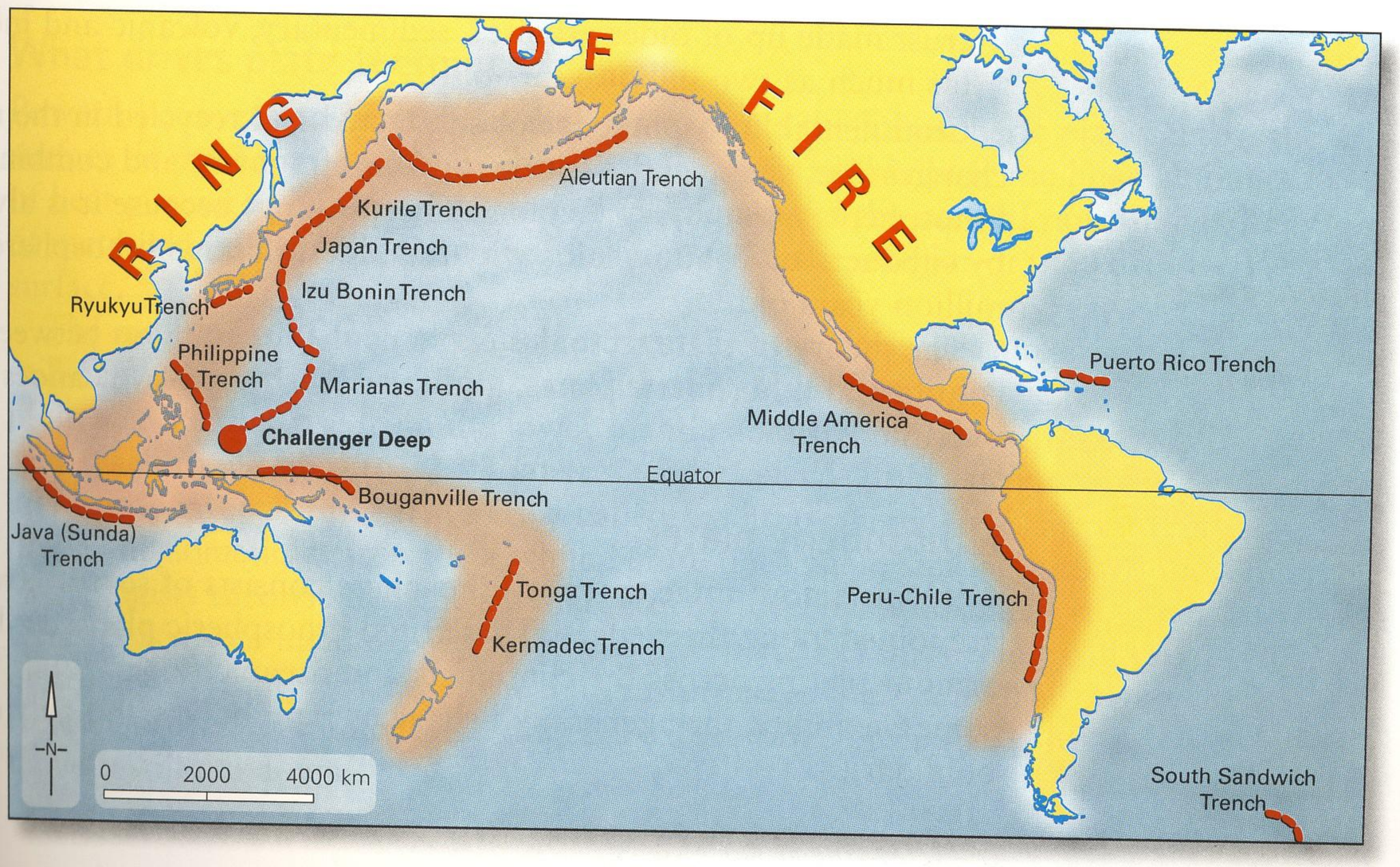
[4.4] New oceanic lithosphere is continuously created at the mid-oceanic ridges and spreads outwards over time

Destructive oceanic trenches

oceanic trenches
deep valleys in the ocean at the edges of tectonic plates where oceanic lithosphere subducts back into the mantle

While oceanic ridges continually create new material and expand the oceans, this cannot continue indefinitely. The oceanic lithosphere is ultimately destroyed and recycled into the mantle at the oceanic trenches. Here, the oceanic lithosphere subducts (slides downwards), fractures and produces progressively deeper and deeper earthquakes as it continues its slow descent into the molten mantle. As the material sinks and melts, plumes of magma rise up through fissures and fault lines in the overlying continental lithosphere to create chains of volcanoes parallel to the oceanic trenches. These tectonically unstable landforms are the visible product of the destructive margins of lithospheric plates. The Pacific Ring of Fire—one of the world's best-known destructive oceanic trenches—is marked by active volcanoes and earthquake activity [4.5].

[4.5] The Pacific Ring of Fire marks the destructive (recycling) margins of the Pacific plate. It is the most tectonically and volcanically active region in the world.



Think about this

The process of sea-floor spreading has created more than 50 000 kilometres of mid-oceanic ridges in the world. The ridges zigzag along the ocean floors following fault lines called fracture zones.

subduction zone
the boundary where one continental plate meets another plate and sinks below it

Subduction zones at the edge of tectonic plates are long, thin zones of concentrated tectonic activity. Typically, subduction zones are no more than 100 kilometres wide. The total length of the world's subduction zones is about 30 500 kilometres. The total global area of subduction zones is about 2.6 million square kilometres. This is about the size of Argentina.

Learning activities

4.9 a What are mid-oceanic ridges?
b How do they help explain how the lithospheric plates move?
4.10 a What are oceanic trenches?
b Describe what happens at oceanic trenches.
4.11 Explain how the theory of sea-floor spreading works.
4.12 Describe how the Pacific Ring of Fire got its name.

The theory of plate tectonics

The theory of plate tectonics builds upon the theory of continental drift, the theory of sea-floor spreading and information on earthquake and volcanic activity at subduction zones located at tectonic plate boundaries. Plate tectonics has revolutionised the study of the Earth as an integrated natural system.

Types of lithosphere

The Earth's lithospheric plates consist of two basic types of lithospheric building blocks:

- oceanic lithosphere (sima)—thin, (around 10 kilometres) dense crust made up of younger volcanic basalt (less than 300 million years old)
- continental lithosphere (sial)—thicker, (sometimes 20–80 kilometres) less dense crust made up of older granites, sedimentary, volcanic and metamorphic rocks (as much as two billion years old).

Continental lithosphere is not subducted and recycled in the mantle. It only changes size, shape and position, and can fragment and combine. Oceanic lithosphere is temporary (geologically speaking) because it is always destroyed by subduction. That explains why the oldest oceanic lithosphere is less than 300 million years old.

The theory of plate tectonics explains the interactions between ocean and continental lithospheric plates, and the occurrence of volcanoes and earthquakes over the Earth.

did you know?
Mid-oceanic ridge volcanoes that are made of oceanic lithosphere sometimes rise above the surface of the ocean like toothpaste squeezed from a tube. Examples include Iceland and the Australian territories of Heard and Macquarie Islands.

Lithospheric plates

Geologists now agree that the lithosphere consists of several irregular plates that are joined along their edges. These rigid lithospheric plates act like slow-moving armour plating across the continents and oceanic floors. While the plates have some flexibility, they generally behave as rigid bodies and only deform along plate boundaries.

It is worth remembering that the present pattern of tectonic plates shown in [4.6] is only the most recent pattern of tectonic plates since Pangaea formed about 300 to 500 million years ago. Geologists believe that there were probably many other combinations of lithospheric plates and continents before then.

[4.6] Global pattern of tectonic plates

did you know?

Six of the nine major tectonic plates are named after the continents found on them: Indo-Australian, Antarctic, North American, South American, African and Eurasian.

What drives plate tectonics?

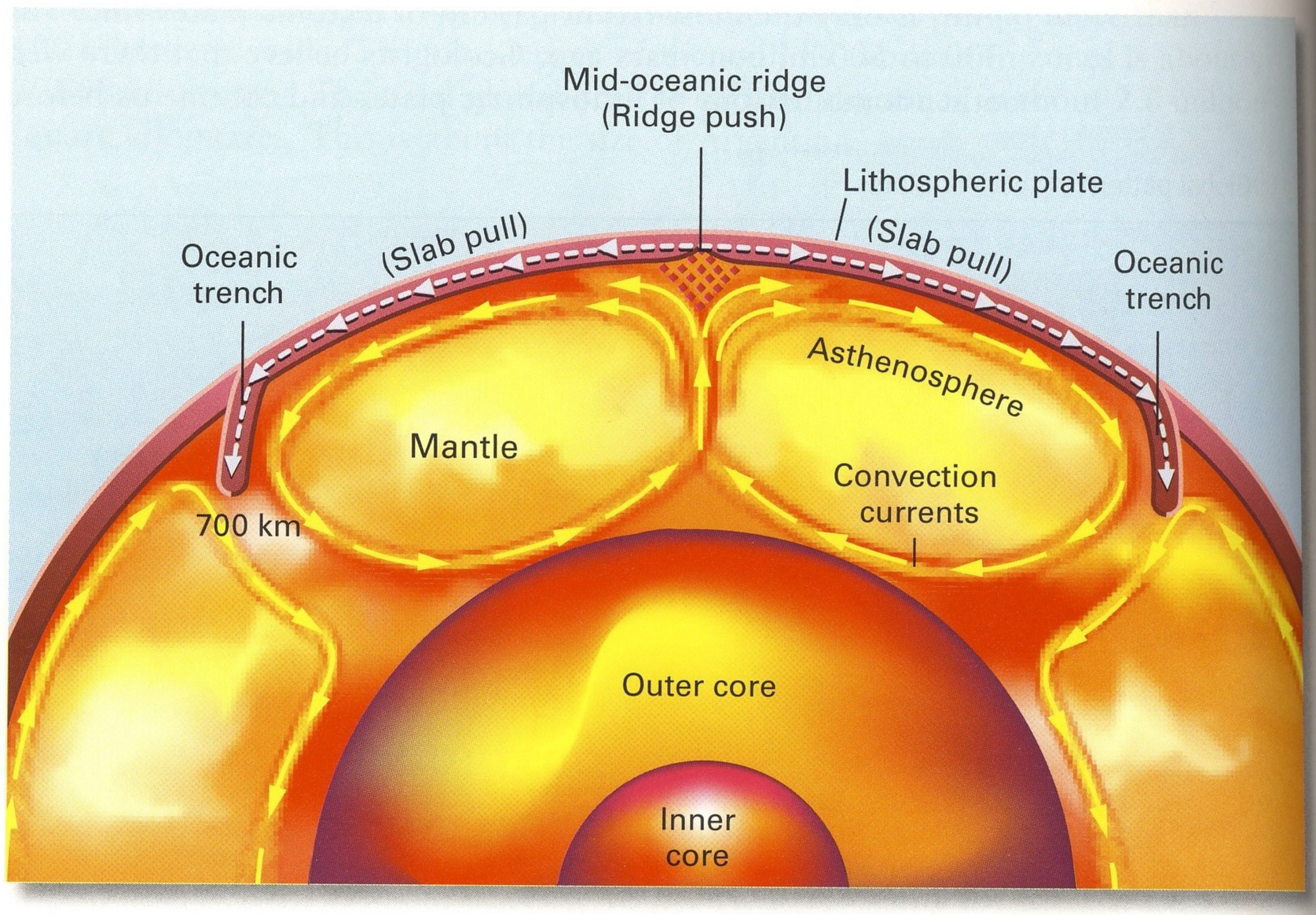
Powerful convection currents in the mantle move the lithospheric plates across the surface of the Earth. In the process, these currents redistribute the huge amounts of heat generated by the formation of the planet and the natural radioactive decay of materials, such as uranium and thorium, from the interior of the Earth to the surface.

The movement of the convection currents is very slow, measured in only millimetres per year. The currents consist of a soup of soft, plastic (easily moulded), molten rocks that rise from the lower mantle about 1600 kilometres down. When they reach to within 4 to 32 kilometres of the surface, they encounter the rigid and brittle layer of the Earth's crust called the lithosphere. Here, the currents slow down and sometimes stop for a while before once again sinking back to the depths.

Geologists theorise that the sinking of dense oceanic lithosphere at subduction trenches is also a main driving mechanism of plate tectonics. They call this destructive tectonic process at the margins of plates 'slab pull'. The creative tectonic process at mid-oceanic ridges is called 'ridge push' [4.7]. Just how plates move is still unknown.

asthenosphere
the zone beneath the relatively rigid lithosphere where fluid molten rock has maximum plasticity or flowing ability.

[4.7] Powerful convection currents drive plate tectonics as well as 'slab pull' and 'ridge push'



Learning activities

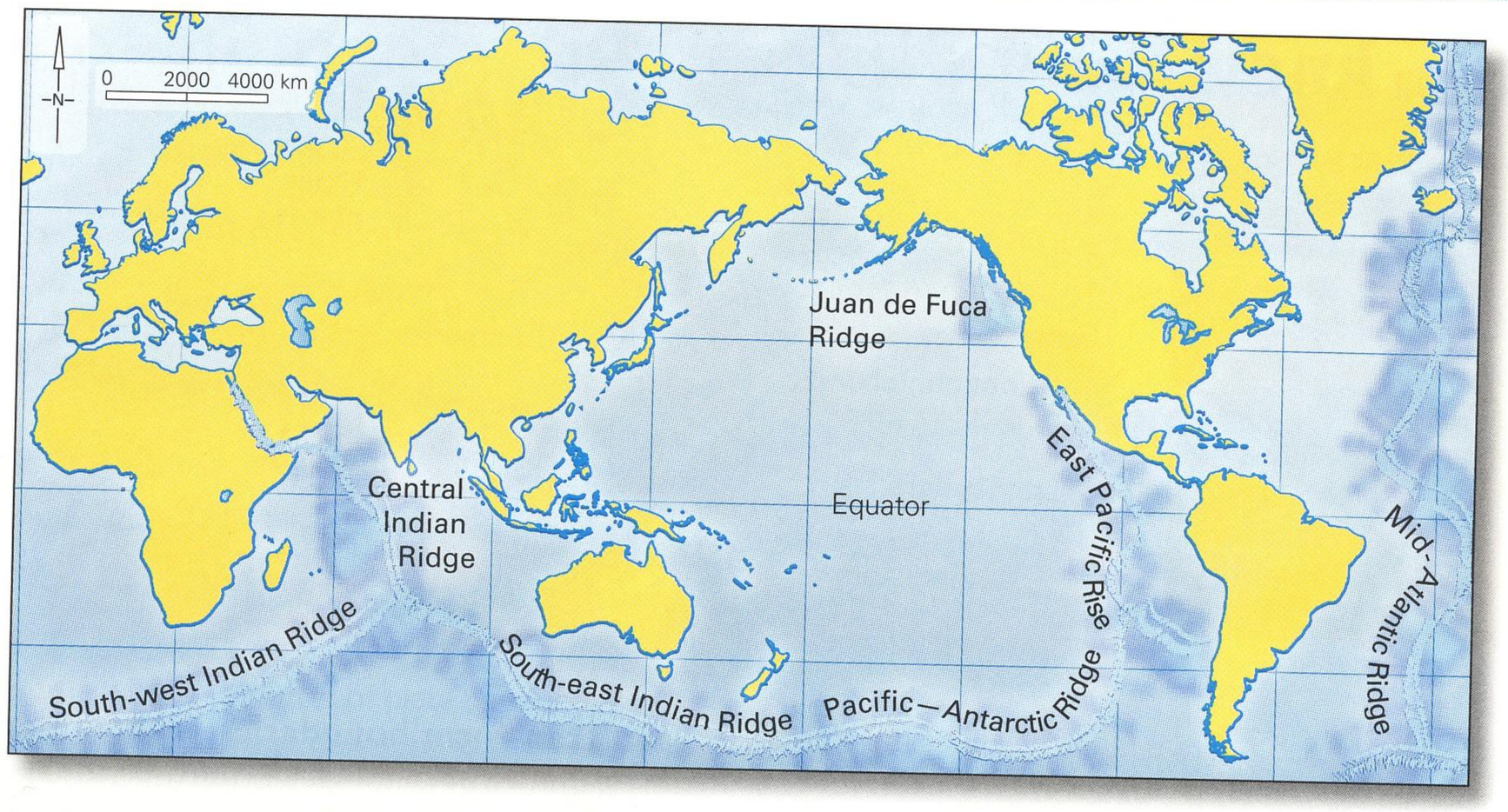
4.13 Why has plate tectonics revolutionised the study of the Earth?
4.14 Describe the two basic types of lithosphere.
4.15 Why is continental lithosphere regarded as geologically permanent while oceanic lithosphere is regarded as temporary?
4.16 List the major tectonic plates on which the continents are located.
4.17 Explain how convection currents result in the movement of lithospheric plates.
4.18 What is the asthenosphere?

did you know?
In 1993, scientists located the world's largest known concentration of active volcanoes. They found 1133 volcanoes on the sea floor in the South Pacific in an area about the size of Wales.

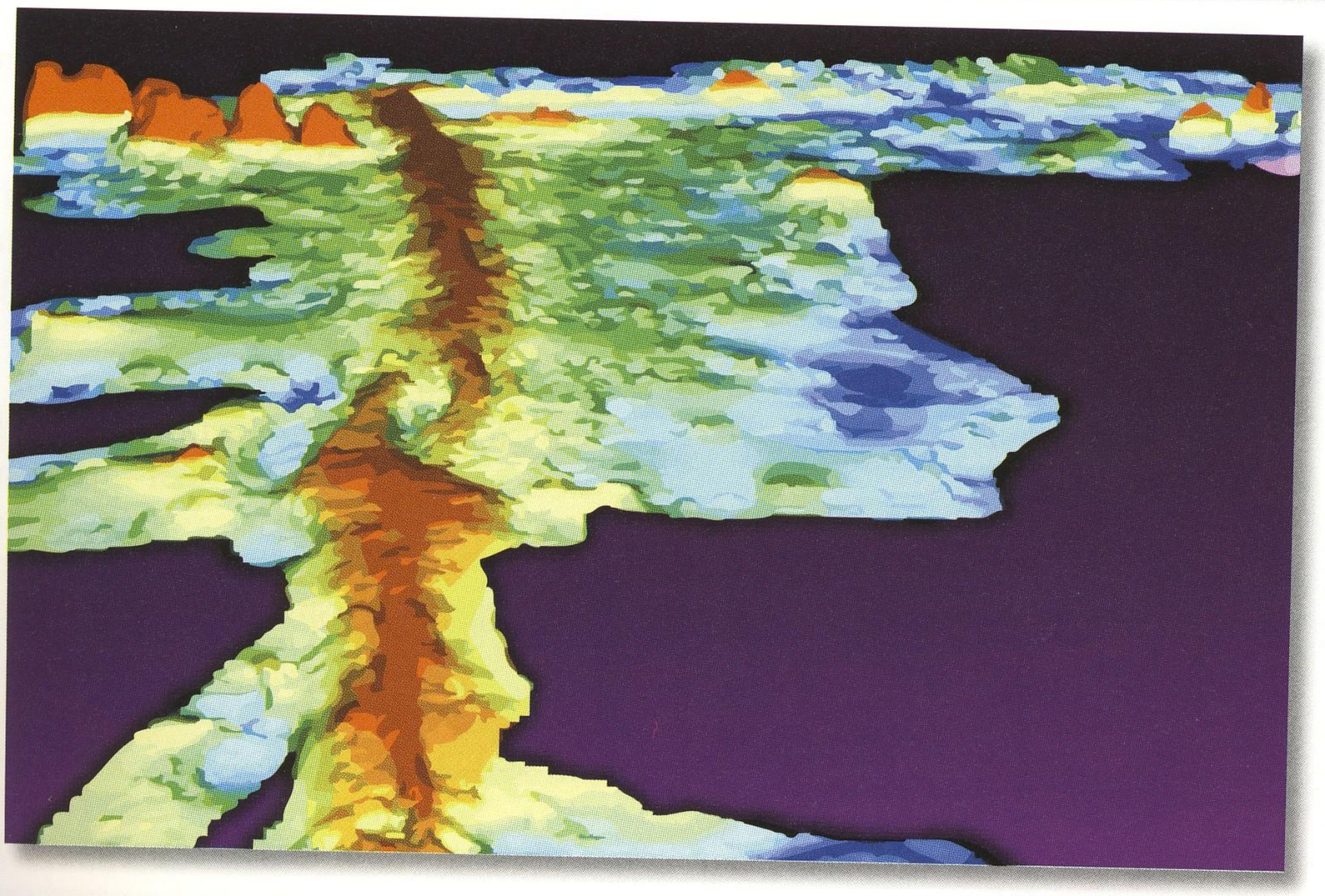
Plate boundaries

Tectonic plate boundaries were discovered by plotting volcanoes and earthquake activity on a world map. There are four types of plate boundaries based upon their relative movements. Plate movements occur in relatively narrow zones between plates where the tectonic forces with potential risks to humans are concentrated.

1 **Divergent boundaries**—where adjacent plates move away from each other as new oceanic lithosphere is created. The mid-oceanic ridges are spreading plate boundaries [4.8]. One of the best know divergent boundaries is the Mid-Atlantic Ridge, which spreads apart at a rate of about 2.5 centimetres per year or 25 kilometres per million years.
2 **Convergent boundaries**—where plates collide into each other and one plate is destroyed as it subducts under the other. There are three types of convergent boundaries, depending on the type of lithosphere involved. See [4.10], [4.11] and [4.12].

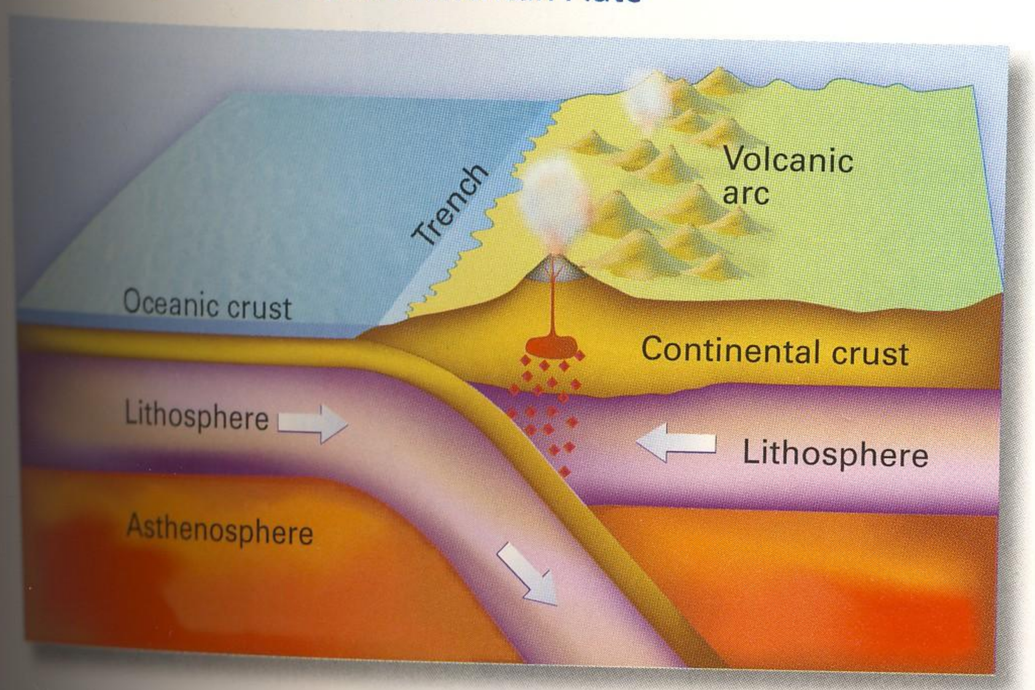


[4.8] The mid-oceanic ridges around the globe

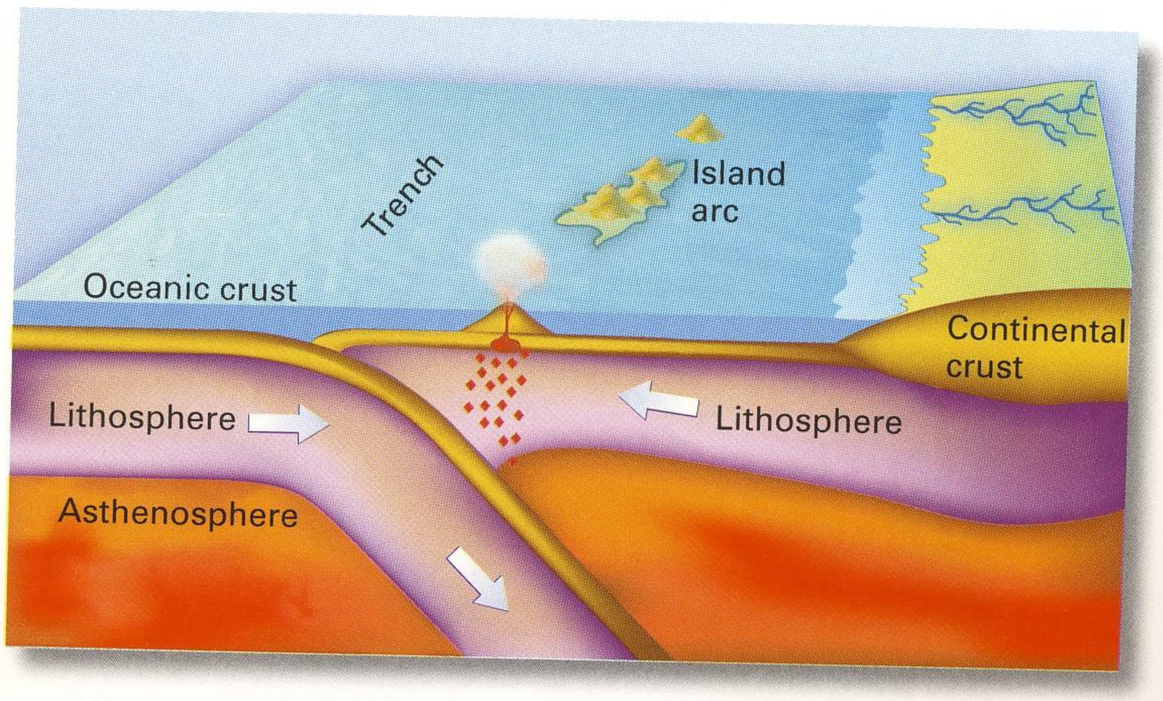


[4.9] Computer-generated detailed topographic map of a segment of the mid-oceanic ridge. 'Warm' colours (yellow to red) indicate the ridge rising above the sea floor, and the 'cool' colours (green to blue) represent lower elevations.

[4.10] Oceanic–continental convergence, e.g. the Nazca Plate subducting under the South American Plate

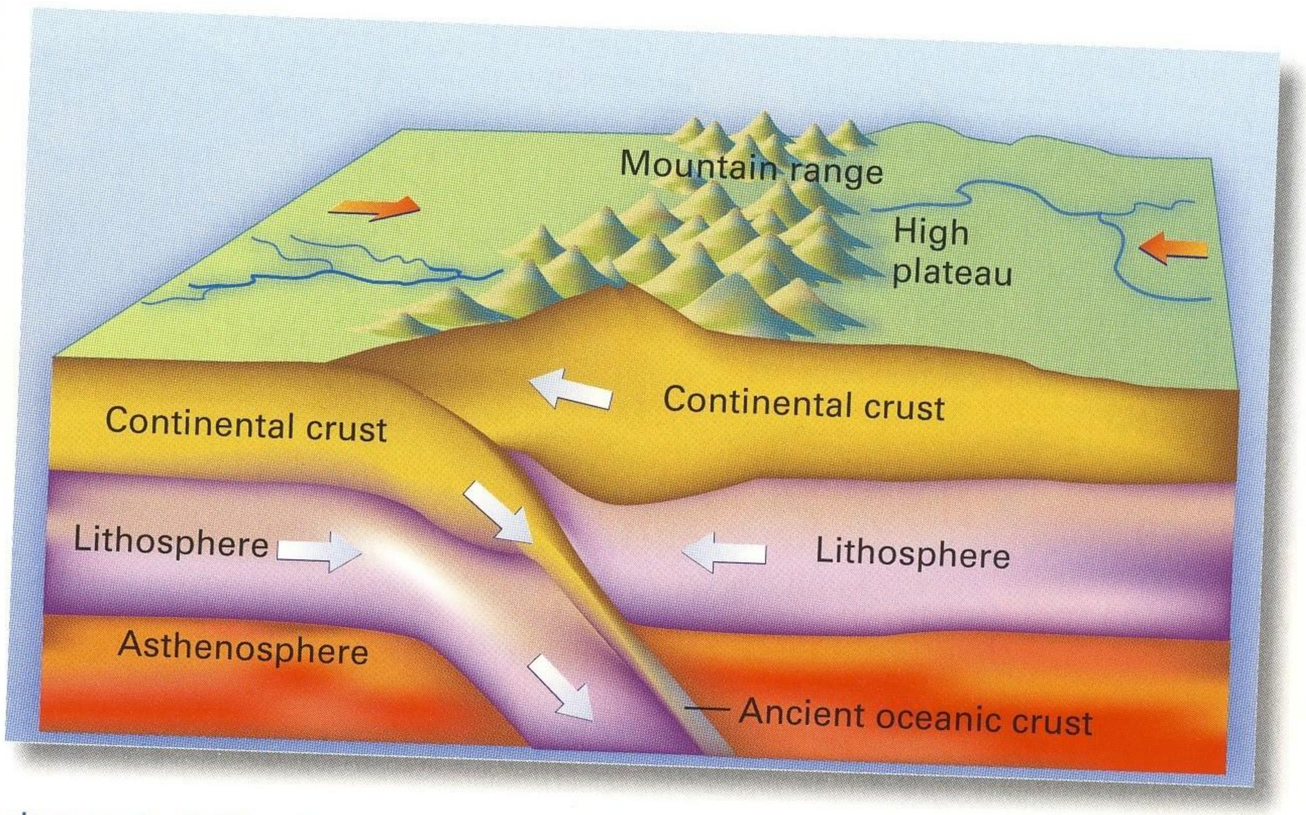


[4.11] Oceanic–oceanic convergence, e.g. the Pacific Plate subducting under the Philippine Plate



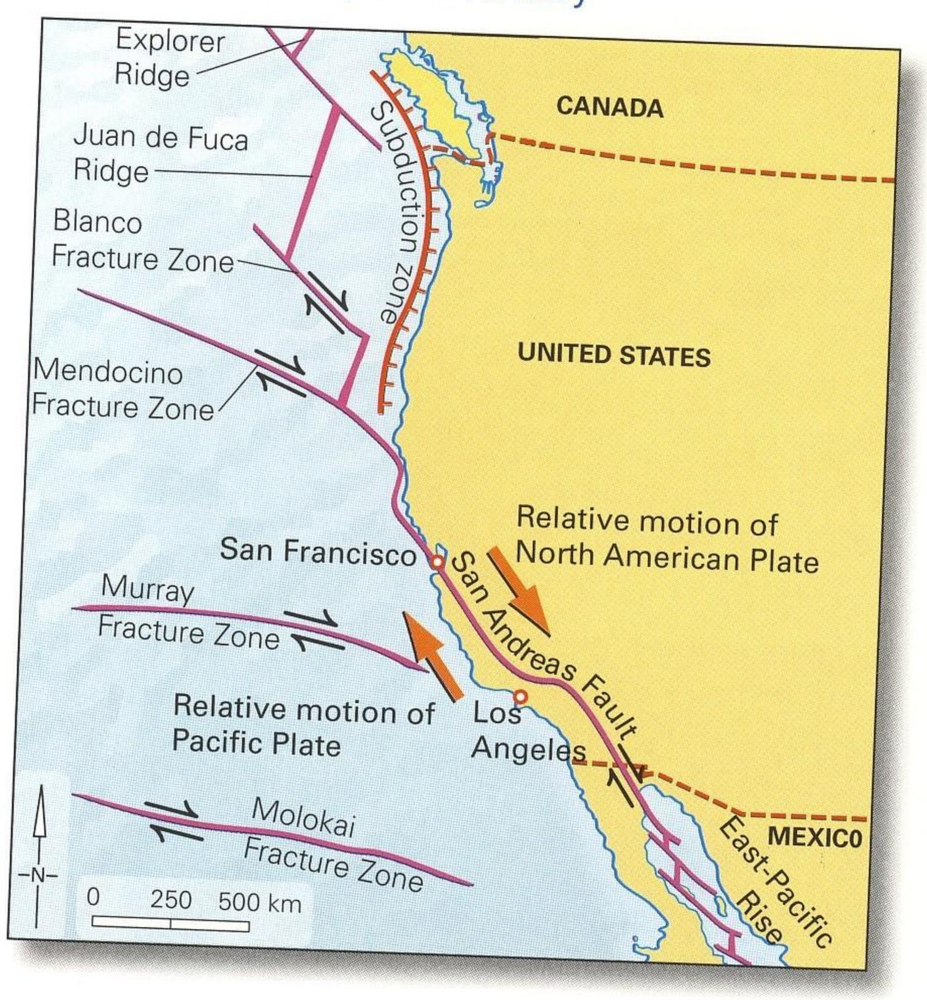
did you know?

Hot spots are relatively hotter zones in the mantle that rise up through the lithosphere to form volcanoes. As the lithospheric plate moves, the old volcanoes become extinct and the hot spots create younger volcanoes. The islands of Hawaii were created in this way.



[4.12] Continental–continental convergence, e.g. the Indo-Australian Plate colliding with the Eurasian Plate to form the Himalayas

[4.13] The San Andreas fault zone in California is a transform tectonic plate boundary



3 **Transform boundaries**—where the plates slide past each other, neither creating nor destroying the plates. Most transform boundaries are in the oceanic plates, where they are called fracture zones. The San Andreas fault zone in California is a rare example of a transform boundary on land [4.13]. Here, the North American Plate is sliding horizontally past the Pacific Plate at about 5 centimetres per year. It produces many shallow earthquakes that have destroyed property and taken many lives.

4 **Plate boundary zones**—where plate boundaries and interactions are uncertain because they extend over a wider area. An example of this is the region between the Eurasian and African plates where there are also several microplates. These zones tend to have more complicated geology and earthquake patterns.

Learning activities

4.19 How were tectonic plate boundaries found?
4.20 List the four main types of plate boundaries.
4.21 What type of boundary are mid-oceanic ridges?
4.22 Describe what happens at convergent plate boundaries.
4.23 Name the three types of convergent boundaries and give an example of each one.
4.24 Why are transform boundaries sometimes called conservative (rather than destructive) plate boundaries?
4.25 In what ways are plate boundary zones different from other types of plate boundaries?

Interaction of human activities with plate tectonics

Humans gain many long-term benefits from living near plate tectonic boundaries, but they also have to deal with occasional short-term natural hazards and disasters, such as volcanic eruptions, earthquakes and tsunamis.

Benefits of plate tectonics for human activities

Present and past tectonic plate boundaries have an abundance of natural resources, such as fertile soils, biodiversity, minerals and energy. Humans have long used these resources and concentrated human settlement in these areas.

[4.14] Natural resources of plate boundaries

Natural resources	Characteristics
Fertile soils	Volcanic soils break down to produce some of the most fertile soils on Earth, rich in iron and magnesium. Greater crop production leads to higher population densities in volcanic areas.
High biodiversity	Volcanic regions generally have a greater biodiversity than non-volcanic regions. The high altitude of many volcanoes also produces **orographic rainfall**. As a result, natural vegetation and crops grow quickly and support a wide variety of animal species.
Mineral deposits	Most valuable metallic mineral ores mined in the world are associated with past volcanic processes. Minerals such as gold, silver, copper, lead and zinc are concentrated by tectonic activity.
Fossil fuels	Coal, oil and natural gas are produced in geologic basins formed by plate tectonic processes.
Geothermal energy	Steam from active volcanic regions and underground rocks can be used to generate electricity and supply hot water and heating needs. More than 70 per cent of Iceland's homes are heated with **geothermal energy**.

orographic rainfall
rainfall produced by condensation around mountains

geothermal energy
energy extracted from the heat in underground rocks and fluids

Think about this

It is estimated that 10 per cent of the world's population live near active volcanoes or volcanoes that may become active. Indonesia, Japan, the Philippines, Mexico and Italy all have large populations living near volcanoes.

[4.15] New Zealand generates electricity from geothermal power.

Adverse impacts of plate tectonics for human activities

Plate tectonics are responsible for the following natural hazards:

- volcanic activity
- earthquakes
- tsunamis.

It is important to note that the effects of these individual natural hazards on humans occur over relatively short periods of time compared with the geological time scale of plate tectonics. Throughout human history, millions of people have been exposed to the effects of these natural hazards because they have chosen to live in close proximity to tectonic plate boundaries.

Volcanic activity

Think about this

Nine countries contain more than 90 per cent of the active volcanoes or volcanoes that have erupted in recent history—Indonesia, Japan, the United States of America, Russia, Chile, the Philippines, New Guinea, New Zealand and Nicaragua.

Since the year 1600 BCE (Before Common Era), nearly 300 000 people have been killed by volcanic eruptions. The Smithsonian Institute estimates that there are 1511 'active' volcanoes across the Earth, and many more dormant ones that could reactivate at any moment. Volcanoes cause problems for human activities in several ways:

- **Tephra** (from the Greek word for ash), the exploded material (hot ash, rocks and lumps of semi-solidified lava from a volcano), may aerially bombard human settlement and cause loss of life and property damage. In 79 CE, Mount Vesuvius buried the cities of Pompeii and Herculaneum.
- **Lava flows** may engulf settlements; smother crops and roads, start fires and trap people. Around Mount Etna in Sicily, bulldozers are sometimes used to channel small lava flows so they cause less damage. In Hawaii, lava flows from the Kilauea volcano regularly bury villages, roads and property.
- **Pyroclastic eruptions** are the fast-moving clouds of lava, ash and volcanic gases that may suffocate and incinerate people and animals as they bury everything in their path. In 1902, pyroclastic eruptions from Mount Pelée in Martinique killed

[4.16] An active volcano erupts

28 000 inhabitants of St Pierre. Pyroclastic eruptions and mudflows account for most deaths caused by volcanoes.

- **Mudflows** on the steep sides of volcanoes carry masses of water-loosened volcanic soil, mud and ash and may bury settlements and wash them away. The Javanese name 'lahars' is given to these natural disasters because they are common on the heavily populated and extremely volcanic Indonesian island.
- **Poisonous gases** such as carbon monoxide, sulphur dioxide, carbon dioxide and hydrochloric acid may be released during eruptions and suffocate and kill people and animals. In 1986, a minor disturbance in a volcanic crater lake called Lake Nyos in Cameroon, Africa, released about one cubic kilometre of carbon dioxide gas that killed 1700 people in nearby villages, thousands of cattle and even more wild birds and animals.
- **Erupting volcanoes** near glaciers may melt the ice and release floods of water and mud that may drown people. This happened in 1985 in Colombia where 23 000 people were killed in a village when the Nevada del Ruiz volcano melted a glacier. Volcanoes may also release water from crater lakes that may flood surrounding villages.

did you know?

The worst volcanic disaster in Japanese history occurred in 1792 when the Unzen volcano, 40 kilometres east of Nagasaki, erupted and killed more than 15 000 people. Unzen is one of 75 active volcanoes in Japan.

Predicting volcanic activity

Around the world, **vulcanologists** and **seismologists** study the **seismic** activities, gas emissions and chemical composition of rocks from many active volcanoes and fault zones close to human settlements. They aim to predict eruptions and earthquakes so that people can be evacuated and lives saved. However, at present, no reliable method for predicting volcanic eruptions and earthquakes has been developed. As a result, despite large advances in our knowledge of plate tectonics, it is not possible to ensure the safety of humans due to the unpredictability of tectonic processes.

vulcanologists
scientists who study volcanoes

Learning activities

4.26 What are three natural hazards associated with living near tectonic plate boundaries?

4.27 List five main benefits that arise from living near tectonic plate boundaries.

4.28 Outline the ways that volcanic activity can create natural hazards for humans.

4.29 How does a lava flow differ from a mudflow?

4.30 **a** Describe how scientists study earthquakes and volcanoes.

b Why do scientists want to predict volcanic eruptions and earthquakes?

seismologists
scientists who study earthquakes or earth vibrations

seismic
refers to anything related to earthquakes or earth vibrations

Earthquakes

Earthquakes are caused by a sudden release of built-up pressure in tectonic plates. When energy is released, seismic vibrations radiate outwards from the earthquake focus or rupture point. The point on the surface directly above the focus is the epicentre of the earthquake. The huge amounts of energy released by a major earthquake can cause damage up to thousands of kilometres away from the epicentre. Smaller aftershock vibrations can last for months as the tectonic plates readjust. Although scientists know how most earthquakes occur, they are uncertain about predicting when they will occur and how large they might be.

did you know?

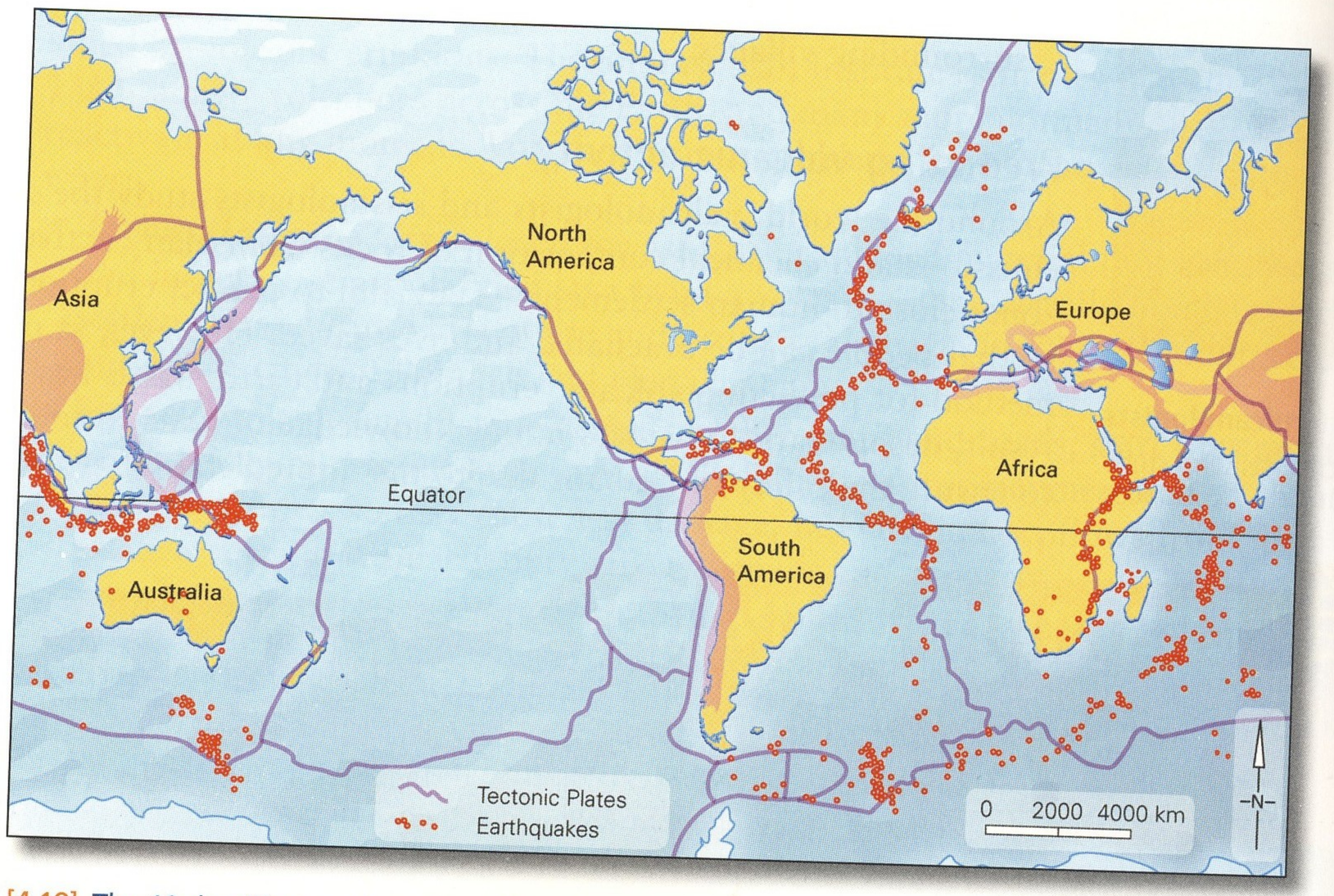
An earthquake at Bam, Iran, on 26 December 2003 resulted in the death of approximately 50 000 people and destroyed the medieval, mud-brick city.

Where do most earthquakes occur?

Most earthquake activity is concentrated at tectonic plate boundaries. About 80 per cent of earthquakes occur in the Pacific region, 15 per cent in the Mediterranean and Asian regions and only five per cent occur in the mid-oceanic ridges. While earthquake activity can also occur away from tectonic plate boundaries, especially along fault lines or weaker areas in the Earth's crust, it is generally less frequent and severe than at tectonic boundaries [4.17].

Earthquake disasters

Earthquakes have caused the world's greatest disasters. They flatten buildings and kill their occupants, rupture gas pipes, which in turn cause serious fires, and create widespread devastation. Earthquakes can also trigger dangerous tsunamis, landslides and volcanic activity. Table [4.18] shows the 10 deadliest earthquakes of the last 100 years.



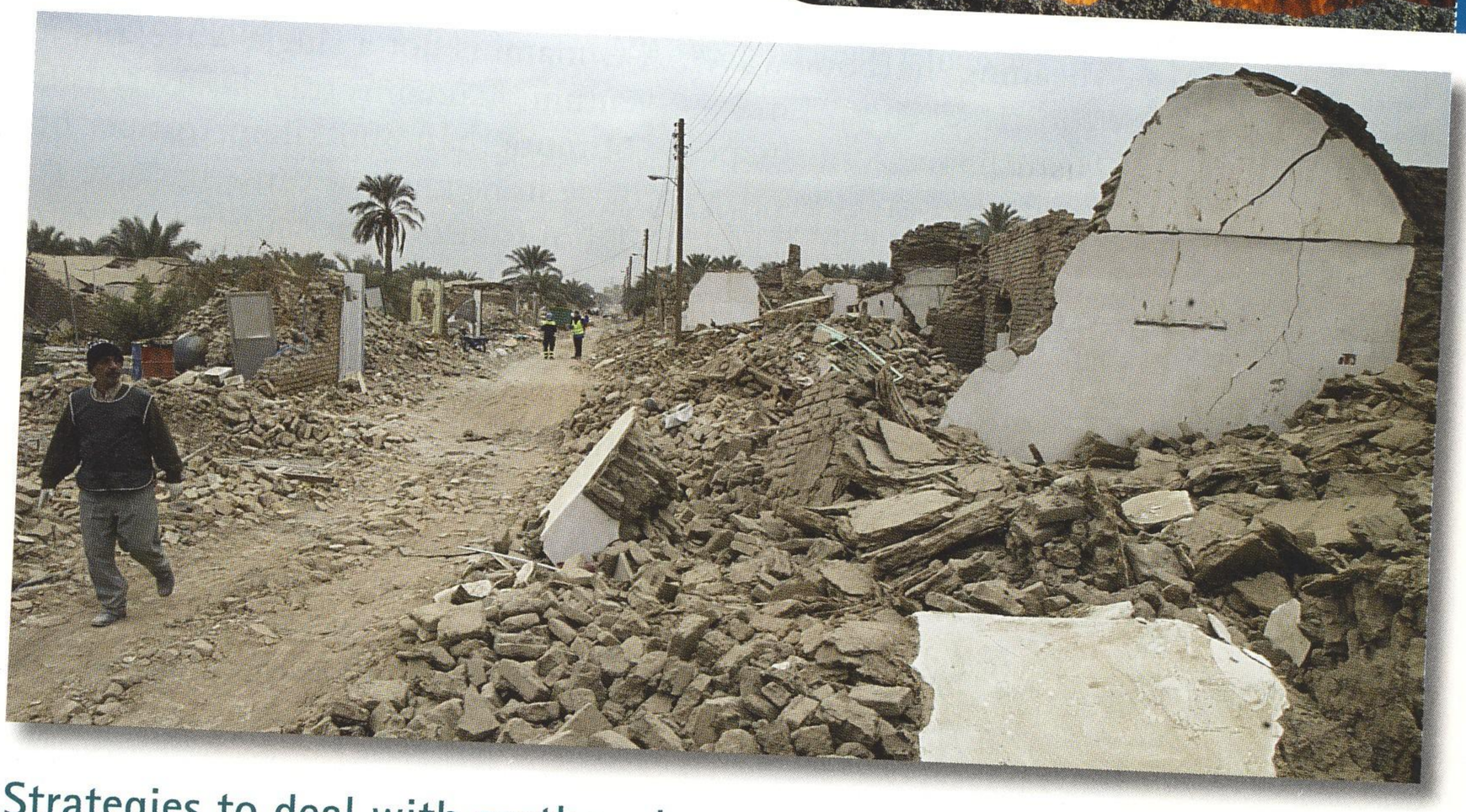
[4.17] Most earthquakes are concentrated into narrow, tectonically active zones

[4.18] The 10 deadliest earthquakes of the last 100 years

Date	Location	Fatalities	Magnitude
1976	China, Tangshan	255 000	7.5
2004	Indonesia, off Sumatra	232 010*	9.0
1927	China, near Xining	200 000	Not available
1920	China, Gansu	200 000	8.6
1923	Japan, Kanto	143 000**	Not available
1948	Turkmenistan	110 000	7.3
1908	Italy, Messina	70 000–100 000 (est.)	7.2
1932	China, Gansu	70 000	7.6
1970	Peru	66 000	7.9
1935	Pakistan, Quetta	30 000–60 000 (est.)	7.5

* This figure includes the number killed and missing in the tsunami triggered by the earthquake.

** Many thousands were killed in the Great Tokyo Fire caused by the earthquake.



[4.19] Devastation in Bam, Iran, caused by the 2003 earthquake

did you know?

The world's largest earthquake was a magnitude 9.5 earthquake in Chile in 1960. It caused the deaths of 5000 people.

Strategies to deal with earthquakes

In an attempt to minimise the risk of earthquake damage, many countries such as Japan and the United States have incorporated strict building codes that are designed to minimise earthquake damage. Large skyscrapers have earthquake-buffering devices that minimise the violent shaking motion that causes buildings to collapse. In some areas, constant seismic monitoring and sophisticated disaster warning systems are in place, but there is little anyone can do until early warning prediction systems are improved.

In 2006, the Japanese research ship *Chikyu* started drilling seven kilometres into the seabed in an area where tectonic plates overlap. One of the aims of the mission is to find out about the origin of earthquakes in the mantle. Scientists hope the research will provide Japan and East Asia with the first effective earthquake prediction system. If the system is successful, it may be tried in other regions.

Learning activities

4.31 What causes an earthquake?

4.32 What is the difference between the focus and the epicentre of an earthquake?

4.33 What are aftershocks?

4.34 Describe the global distribution of earthquakes and their spatial association with tectonic plate boundaries.

4.35 a Describe the different ways that earthquakes can kill people.

b Where was the deadliest earthquake in the last 100 years and how many people were killed?

4.36 a Describe how building strategies may reduce loss of life in earthquakes.

b Why is the Japanese research ship *Chikyu* drilling in the sea floor?

Tsunamis

Tsunamis or seismic sea waves are caused by disturbances of the ocean surface as a result of volcanic eruption, earthquakes, coastal or submarine landslides or asteroid/meteorite impacts. The word 'tsunami' comes from two Japanese words

did you know?

Tsunamis are sometimes mistakenly called 'tidal waves'. However, they have nothing to do with tides. Strictly speaking, a 'tidal wave' or 'tidal bore' is the small wave formed by an incoming tide as it travels up a river estuary against the direction of the current. The tidal wave or bore that occurs on the Qiantang River in China is up to nine metres high and travels at up to 40 kilometres per hour. Another well-known example occurs in the estuary of the Severn River in England.

meaning 'harbour wave'. A tsunami is not a single wave, but a series of waves with enormous energy and momentum. Tsunamis travel outwards from the original disturbance zone at speeds of more than 800 kilometres per hour. Upon reaching land, the waves greatly increase in height and cause massive destruction, loss of life and property. The landfall of transoceanic tsunami waves can be thousands of kilometres from the original disturbance, so they represent a disaster threat to distant coastal communities.

The Krakatau tsunami of 1883

The severe 1883 eruption of Krakatau volcano, located in the Sunda Straits between Java and Sumatra islands in Indonesia, created a series of tsunami waves up to 40 metres high. Almost all of the 36 417 people who died were killed by the tsunamis created as the volcano blew itself to pieces. The sound of the great Krakatau explosion was heard nearly 5000 kilometres away and the tsunami travelled across the Indian Ocean to India, Australia, Madagascar and Africa.

The Aitape, PNG tsunami of 1998

Earthquakes are the most common cause of tsunamis. They can also trigger landslides on land and underwater that in turn generate tsunamis. The Aitape tsunami hit the village of Aitape on the north coast region of Papua New Guinea (PNG) in 1998. The primary cause of this tsunami was a magnitude 7.0 earthquake that caused a submarine landslide. The landslide displaced the ocean surface and the resulting tsunami killed over 2000 people, destroyed houses and infrastructure, and altered the environment around the village [4.20].

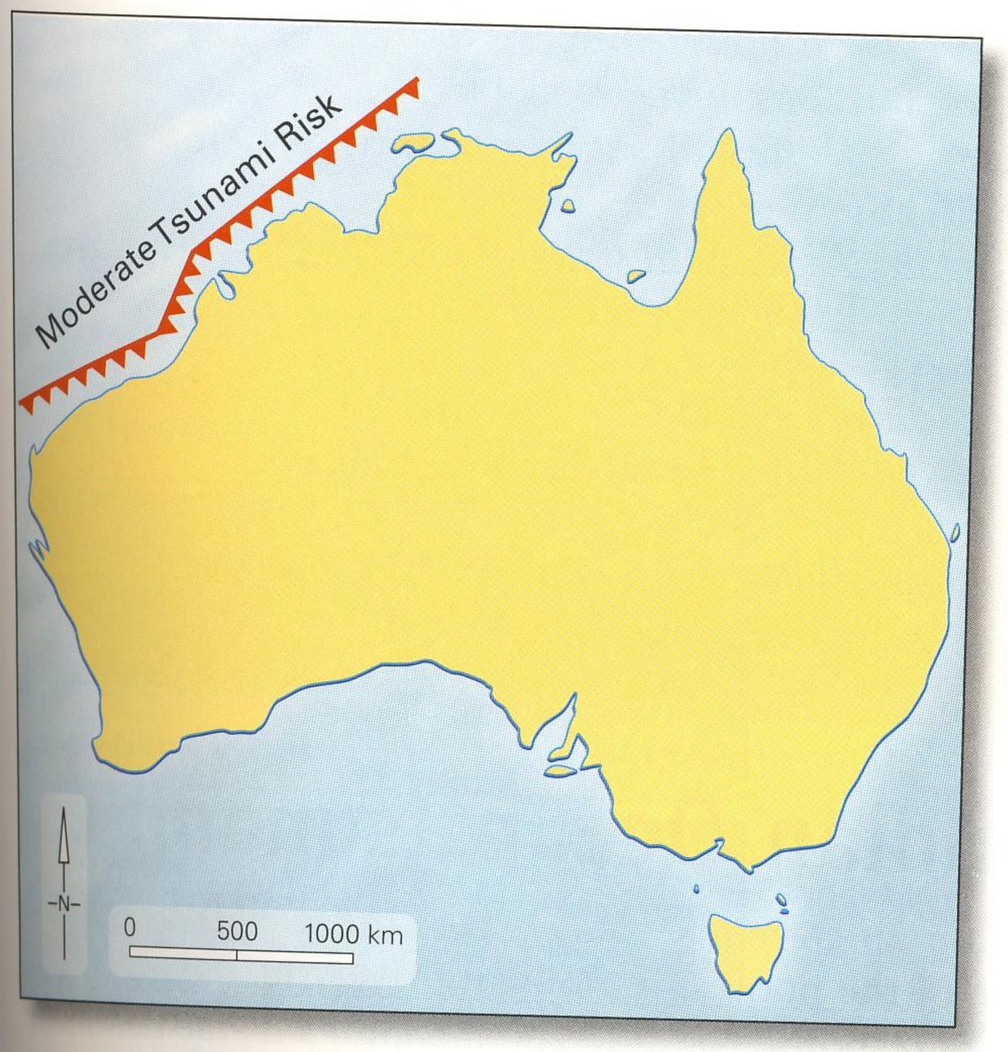
Tsunamis in Australia

According to Geoscience Australia, a tsunami affects the Australian coastline about once every two years. Fortunately, most are insignificant and are classified as low risk. However, Australia's north-west coastline has a moderate tsunami risk classification because of its proximity to the earthquake and volcanic activity resulting from the tectonic plate boundary lying across the Indonesian archipelago [4.21].

Evidence of large tsunamis that affected Australia in the past can be found in deposits of coastal materials 20–30 metres above the present sea level and many kilometres inland. The Great Barrier Reef off Queensland's coastline may offer some protection from tsunamis originating in the Pacific Ocean region. Similarly, the islands of New Zealand may also offer some protection from tsunamis originating off the South America coastline.

[4.20] Part of the village of Aitape destroyed by a tsunami in 1998

[4.21] Tsunami risk assessment map of Australia



[4.22] Tsunami warning information sign

did you know?

The tsunami from the 1883 eruption of Krakatau caused a six-metre tsunami on Australia's north-west coast.

Strategies to deal with tsunamis

The obvious strategy in dealing with tsunamis is to avoid them. In order to do this, people living in coastal areas need advance warning of when a tsunami is going to strike. Most tsunamis occur in the Pacific region because of the tectonically active Pacific Ring of Fire. As a result, the Pacific Ocean Tsunami Warning System (POTWS) was established in 1965. It has 26 member nations that rely upon seismic-monitoring stations and sea-level gauges located around the Pacific. These devices measure earthquakes and abnormal changes in sea levels. The headquarters in Hawaii issue warnings for potential tsunamis to nations in the Pacific Basin. Once a tsunami is detected, the path is calculated and arrival times are estimated using travel-time maps. The potentially vulnerable coastal areas are identified and warnings issued.

However, in order for a tsunami warning to be effective, a tsunami risk assessment for coastlines is needed. According to Geoscience Australia, the risk assessment looks at:

- the likelihood of an event that may cause a tsunami
- the expected location and size of an event
- the shape of the sea floor where an event may take place
- the shape of the coastal land that may be affected by a resulting tsunami
- the presence of any headlands or harbours in the region that may cause a tsunami to change direction.

This risk assessment information is used to predict the potential speed, direction, height and destructiveness of any tsunami that may affect an area. In Australia, information on tsunamis is first gathered by Geoscience Australia seismologists who immediately notify Emergency Management Australia (EMA) staff. The EMA notifies Australian authorities and Pacific island nations at risk of tsunami damage.

Learning activities

4.37 a What are tsunamis?
b What causes tsunamis?
4.38 Explain why tsunamis can threaten places far away from their source area.
4.39 Outline the differences between tsunamis and tidal waves.
4.40 Describe the Krakatau tsunami and its effects.
4.41 What happened with the Aitape tsunami in PNG?
4.42 Why does Australia's north-west coastline have a moderate tsunami risk classification?
4.43 Describe how the Pacific Ocean Tsumani Warning System (POTWS) operates.
4.44 What does a tsunami risk assessment for coastlines entail?

Sample study: the 2004 Indian Ocean tsunami

The 2004 Indian Ocean tsunami on 26 December was one of the world's greatest natural disasters. It affected some of the poorest nations in the world and prompted an unprecedented global response for aid. The tsunami was the deadliest in recorded history with more than 200 000 people killed. It also caused severe economic and environmental damage [4.23].

Richter scale
A logarithmic scale indicating the magnitude or strength of an earthquake. It was developed in 1935 by Charles Richter in collaboration with Beno Gutenberg, both of the California Institute of Technology.

[4.23] The Indian Ocean tsunami struck without warning and caused great loss of life and devastation

Factors contributing to the development of the tsunami

A severe 'megathrust' earthquake that measured 9.15 on the **Richter scale** triggered the 2004 Indian Ocean tsunami. The earthquake occurred in a fault line between the mobile Indo–Australian Plate and the stationary Eurasian Plate. See figure [4.6]. The epicentre of the earthquake was 250 kilometres off the north-western coast of Sumatra in Indonesia. The Indo–Australian Plate is constantly moving northwards and colliding with the Eurasian Plate at the rate your fingernails grow (around 5–6 centimetres per year). In addition, it is sliding along and subducting under the Eurasian Plate. This tectonic movement generates great forces in these two tectonic plates. Earthquakes in this area are common and they occur when pressure is released along the tectonic boundary.

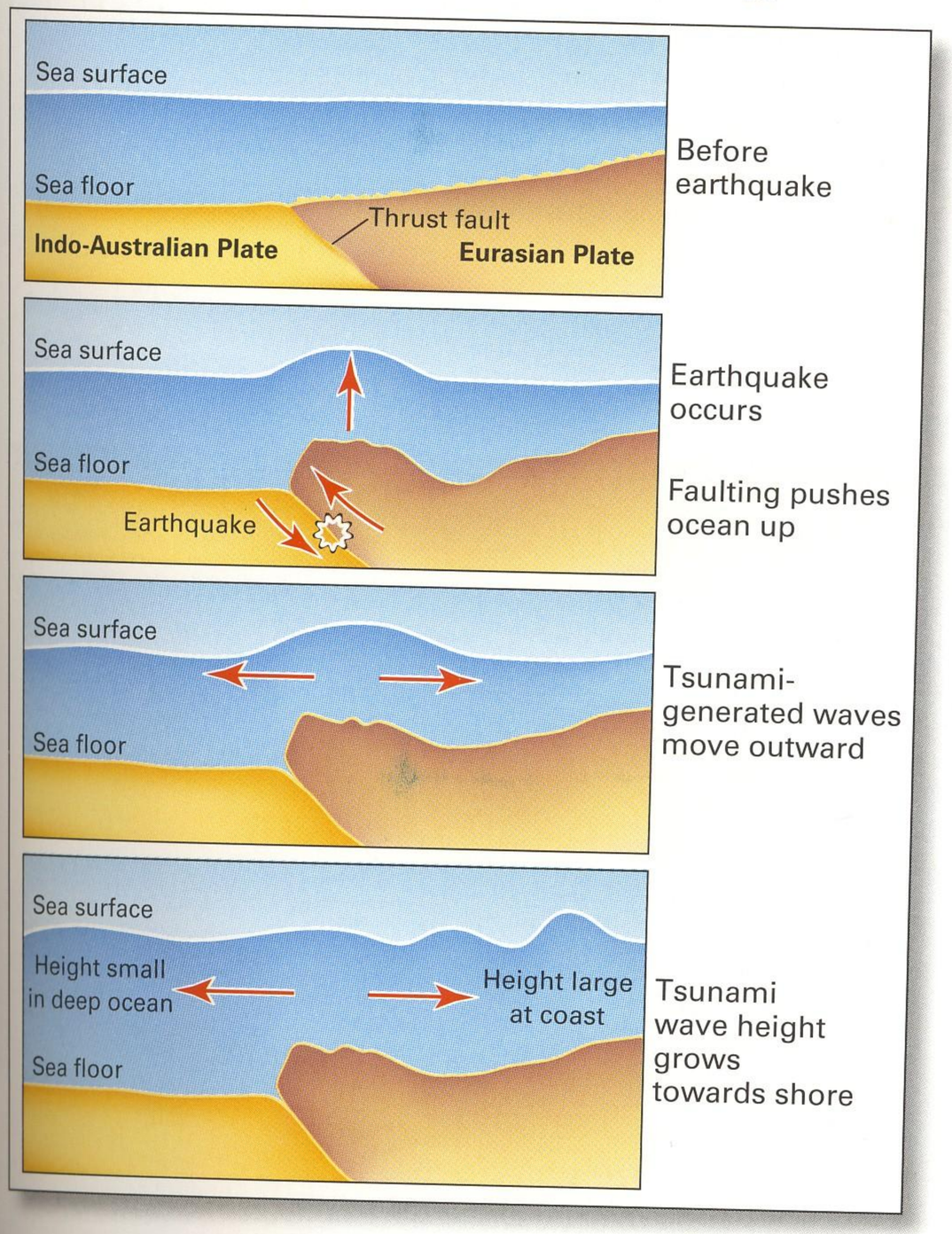
On 26 December 2004, a slab of the Earth's crust 960 kilometres long by 250 kilometres wide slipped between 8 and 15 metres. This rupturing of the sea floor generated the earthquake, and displaced millions of tonnes of water that created the tsunami [4.24].

The earthquake was the world's most severe in 40 years. The tsunami spread

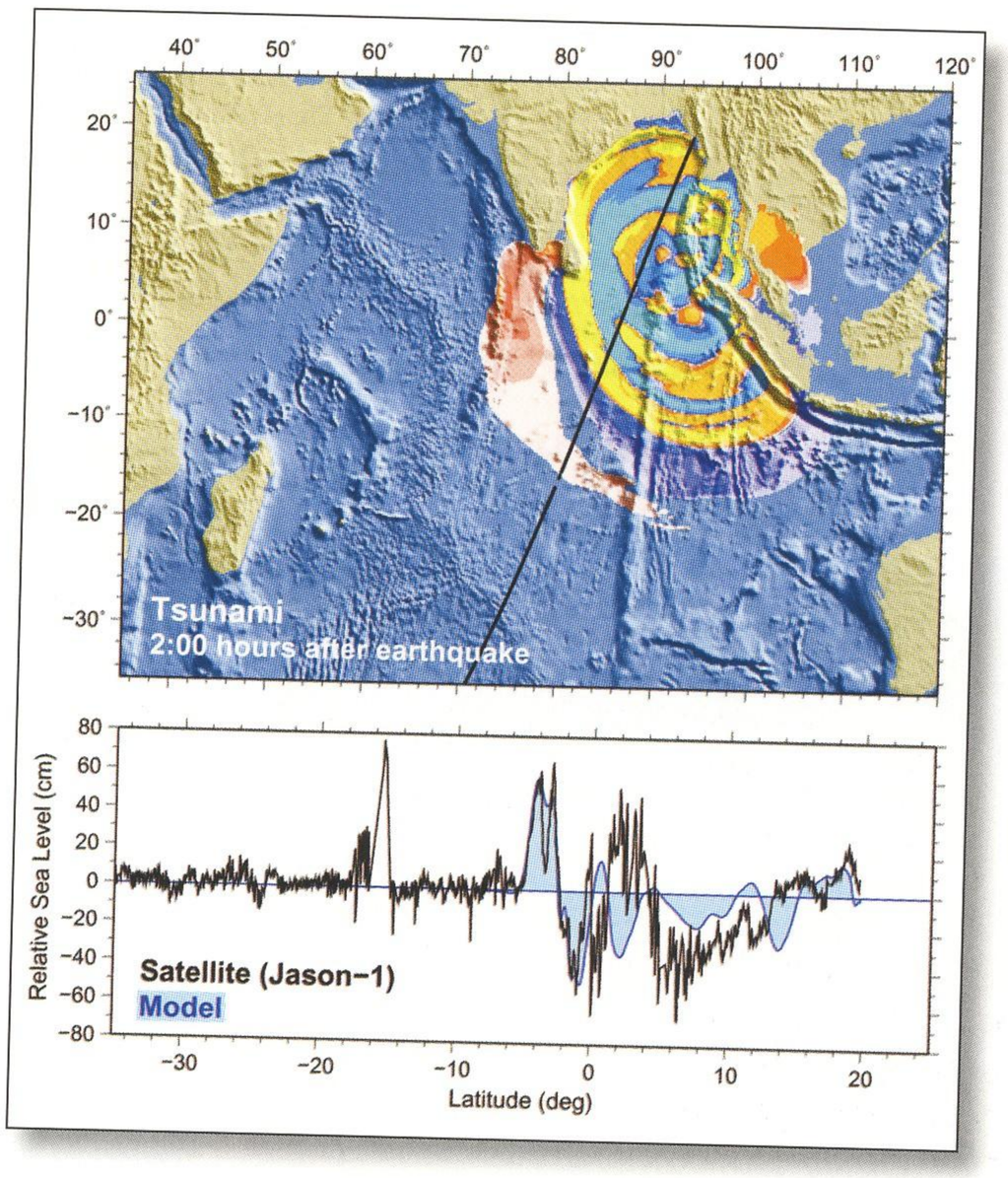
out as a series of long waves from the epicentre of the earthquake and caused severe devastation in Asia and as far away as Africa.

Once formed, the tsunami travelled at about 800 kilometres per hour and hit the coast of the Indonesian province of Aceh on the island of Sumatra 15 minutes later. It continued more than 4800 kilometres across the Indian Ocean and hit the coast of Somalia in Africa less than seven hours later. Waves and sea level increases of up to 30 metres were recorded in some places.

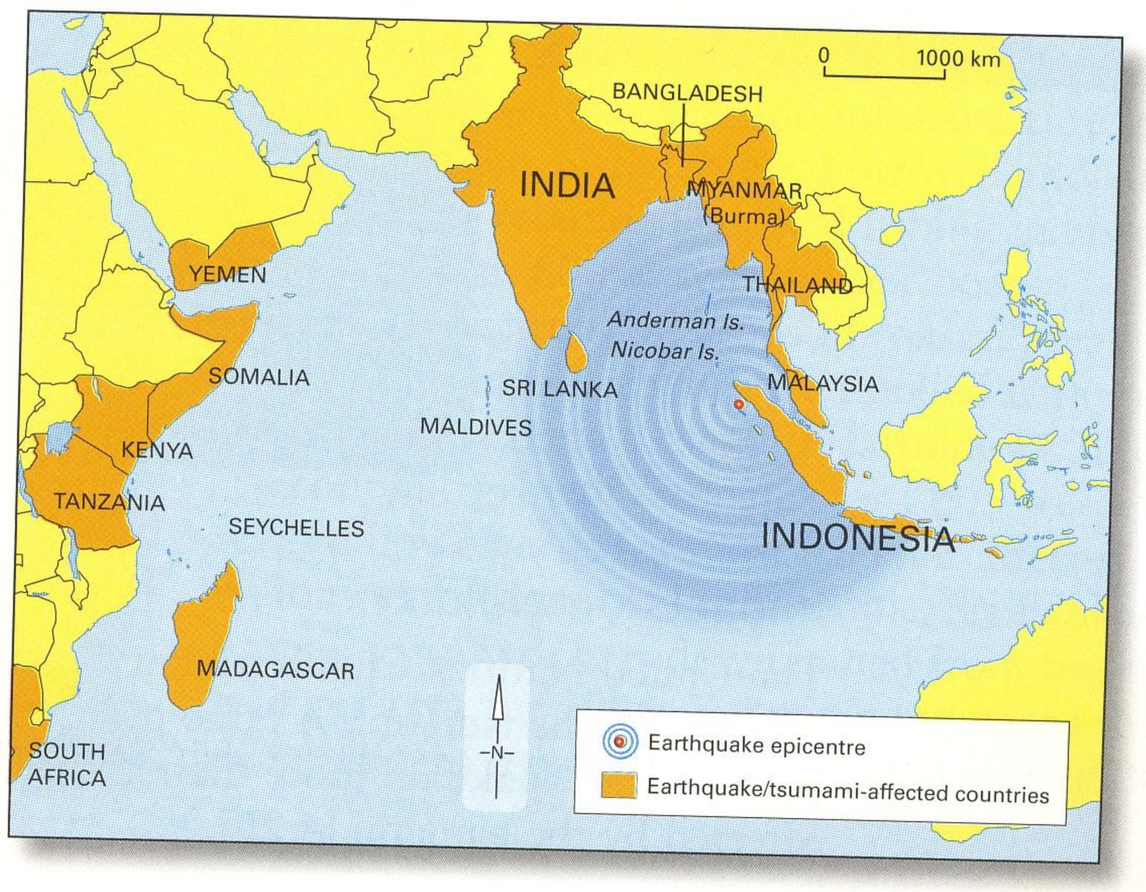
[4.24] How the 2004 Indian Ocean tsunami was formed



[4.25] Radar imaging of the tsunami two hours after the earthquake



[4.26] Countries affected by the 2004 Indian Ocean tsunami



Learning activities

4.45 Why was the 2004 Indian Ocean tsunami so significant as a natural disaster?
4.46 Explain what caused the earthquake that triggered the tsunami.
4.47 Which countries were affected by the tsunami?
4.48 Why were some countries in the Indian Ocean not affected by the tsunami?

Impacts of the 2004 Indian Ocean tsunami

Accurate estimates are impossible to obtain in some cases due to poor records and victims being washed out to sea. Citizens (mostly tourists) from more than 50 countries around the world were killed by the tsunami. Germany and Sweden lost more than 500 citizens in the disaster. Twenty-five Australians were killed and one was still unaccounted for six months later.

[4.28] Remnants of a town on the west coast of Aceh, Indonesia

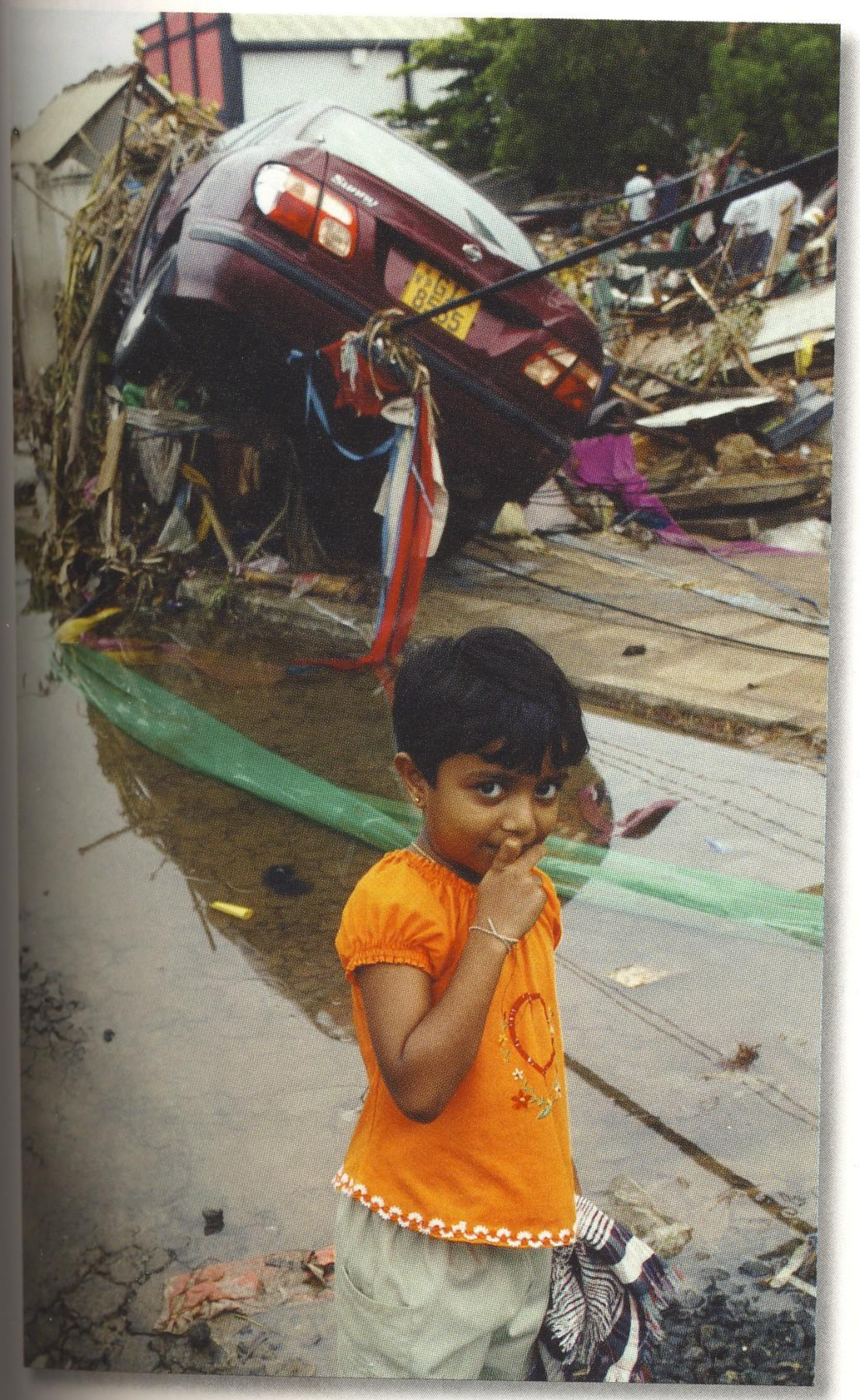
[4.27] Estimated human impacts

Country where deaths occured	Deaths	Missing	Displaced
Indonesia	>130 000	>37 000	>500 000
Sri Lanka	31 000	5 637	573 000
India	12 405	5 600	380 000
Thailand	5 399	3 000	–
Somalia	298	–	5 000
Maldives	82	26	22 000
Malaysia	68	–	–
Burma (Myanmar)	61	200	3 200
Tanzania	10	–	–
Seychelles	2	–	–
Bangladesh	2	–	–
South Africa	2	–	–
Kenya	1	–	–
Yemen	1	–	–
Madagascar	–	–	> 1 000
Total	>179 331	>51 426	>1 484 200

Impacts on children

The United Nations Children's Fund estimated that up to 1.5 million children were affected by the tsunami. A large percentage of the tsunami casualties were children because they make up more than a third of the population in the Asian countries affected by the tsunami [4.29].

[4.29] Many children lost parents in the tsunami



[4.30] Damaged coastal plain on the west coast of Aceh after the tsunami

More than 30 000 children lost one or both parents and many more children lost other family members. The Save the Children Fund estimated that more than 150 000 children were homeless and 2000 were separated from their parents in Aceh.

Many organisations expressed fears that criminals, such as child traffickers, could exploit orphaned and displaced children. Surviving children require ongoing help to cope with psychological and emotional trauma.

Environmental impacts

The tsunami's giant waves (some over 10 metres high) destroyed many coastal mangrove forests, which protect the coast from erosion. Twenty per cent of sea grass beds around Aceh were damaged. Mangroves and sea grass beds are vital fish habitats.

The tsunami damaged coral reefs in some areas by breaking off large pieces and smothering reefs in sediment and debris. Thirty per cent of coral reefs around Aceh were damaged. Coral reefs in the Asian region were already stressed by dynamite fishing and overfishing. Many fishermen depend on coral reefs for food.

Coastal farmland and water supplies were flooded by salt water and contaminated with pollution from sewage, industrial chemicals and dead bodies.

Asian rainforests were cleared to provide timber to rebuild houses and this led to increased run-off with silt carried into the ocean where it affected coral reefs.

Economic impacts

Houses, farms, industries and infrastructure in affected regions were largely destroyed and will take years to rebuild. The local fishing industries had more than 60 per cent of their boats destroyed. Agricultural crops in coastal areas were wiped out and rice fields were flooded with salt water making them useless for farming [4.30].

Economic growth estimates for 2005 were revised downwards for most tsunami-affected regions and countries. For example, Sri Lanka's economic growth was downgraded from five to four per cent for 2005. Indonesia requested that its external debt repayments be suspended until 2006.

Tourist earnings slumped after the tsunami as tourists feared staying at coastal resorts. The Maldives is more dependent on tourism revenue than any other tsunami-affected country with 42 per cent of its gross domestic product coming from tourism.

Economic impact on Indonesia

In January 2005, the Minister of State for National Development Planning in Indonesia announced preliminary figures of economic damages and losses in Indonesia totalling rupee 42.7 trillion (A$5.7 billion). The damage included:

- 1.3 million homes and buildings
- 8 ports
- 4 fuel depots
- 85 per cent of the water supply system
- 92 per cent of the sanitation system
- 120 kilometres of roads
- 18 bridges.

Since January 2005, the economic costs have increased as the full scale of the disaster became apparent. The infrastructure of Aceh will take many years to rebuild.

[4.31] Banda Aceh before and after images

[4.32] Fishing boat carried into a village street in Sri Lanka

[4.33] Banda Aceh was 'Ground Zero' for the 2004 Indian Ocean tsunami

Learning activities

4.49 Name the eight nations that suffered the most as a result of the tsunami.
4.50 Why are accurate estimates of casualties impossible to obtain in some cases?
4.51 Describe the impacts of the tsunami on children.
4.52 Outline the main environmental impacts of the tsunami.
4.53 What were the economic impacts of the tsunami?
4.54 Why is the economic impact of the tsunami upon Indonesia likely to take many years to repair?

Strategies in response to the tsunami

The sheer scale of the 2004 Indian Ocean tsunami disaster shocked and united the world in an effort to help the survivors. Graphic images of dead bodies, destroyed buildings, orphaned children and desperate human suffering from more than 10 countries lead to an unprecedented international aid response. United Nations' agencies, non-government organisations (NGOs), foreign governments and many other organisations started humanitarian and emergency relief operations in the devastated regions.

According to the US Agency for International Development, there are four phases in the provision of disaster relief. The first two phases occur immediately after a disaster. Phases 3 and 4 occur in the medium and longer term.

[4.34] Disaster relief phases

Phase 1—Emergency life saving

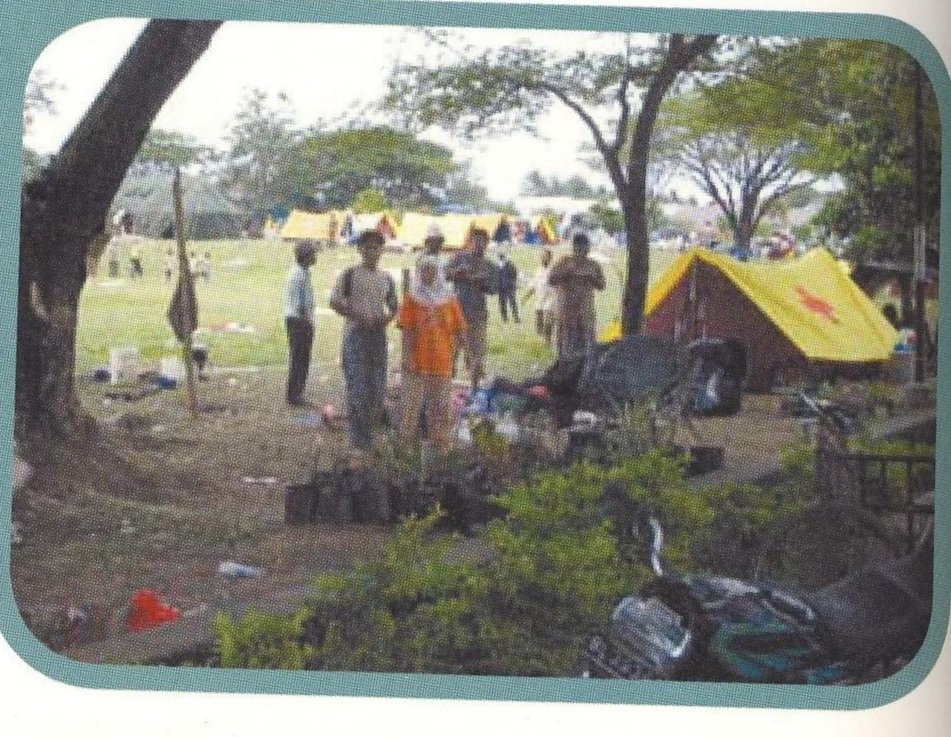
Local people, government officials, armed forces and volunteer relief workers from many nations searched for the missing, cared for the sick and injured and buried the dead, sometimes in mass graves. The task was urgent because the hot, tropical climate and the large numbers of victims increased the threat of diseases, such as cholera, striking the survivors. Emergency hospitals, first aid centres, supply lines and communications networks were established. The immediate needs of the survivors included supplying food, safe drinking water, clothing, shelter and medicine.

[4.35] Helicopters searched for survivors and provided emergency supplies in remote areas

Phase 2—Relief efforts

The survivors needed temporary shelter and a clean water supply to prevent disease outbreaks. Generators for electricity were set up and survivors were supplied with food, clothing and medical help. The huge cleanup operation began, often with the help of machinery.

[4.36] Tsunami survivors were housed in an emergency tent village



Phase 3—Rehabilitation

In this phase, temporary housing and schools need to be built. Utilities such as water, sewage and electricity need to be re-established. Local businesses and shopkeepers need help to start again.

[4.37] Rehabilitation of buildings damaged by the tsunami near Galle, Sri Lanka

Phase 4—Reconstruction

In this long-term phase, permanent houses, factories and businesses are rebuilt and services, such as hospitals and schools are restored. Infrastructure, such as roads, bridges, railways and airports, is also rebuilt and residents receive help to find permanent employment.

[4.38] Local and international governments combine to support the rebuilding of services in one of the worst affected areas in Sri Lanka

International aid response

Ninety-two countries sent aid to tsunami-affected nations. As the following newspaper article shows, the aid response was one of the best experienced.

[4.39]

Tsunami response was world's best—UN

Emma Batha
London, 19 December 2005 (Reuters)

As the world marks the first anniversary of the Indian Ocean tsunami, millions of people who dug into their pockets in an unprecedented outpouring of generosity will be wondering how their money has been spent.

Some may be surprised to discover that 12 months on the vast majority of the 1.8 million people who lost their homes in the Dec. 26 disaster are still in temporary accommodation.

But if the pace of reconstruction has been disappointing, the initial relief effort went far better. Basic needs were met promptly, helping prevent an epidemic that could have killed thousands in a second disaster.

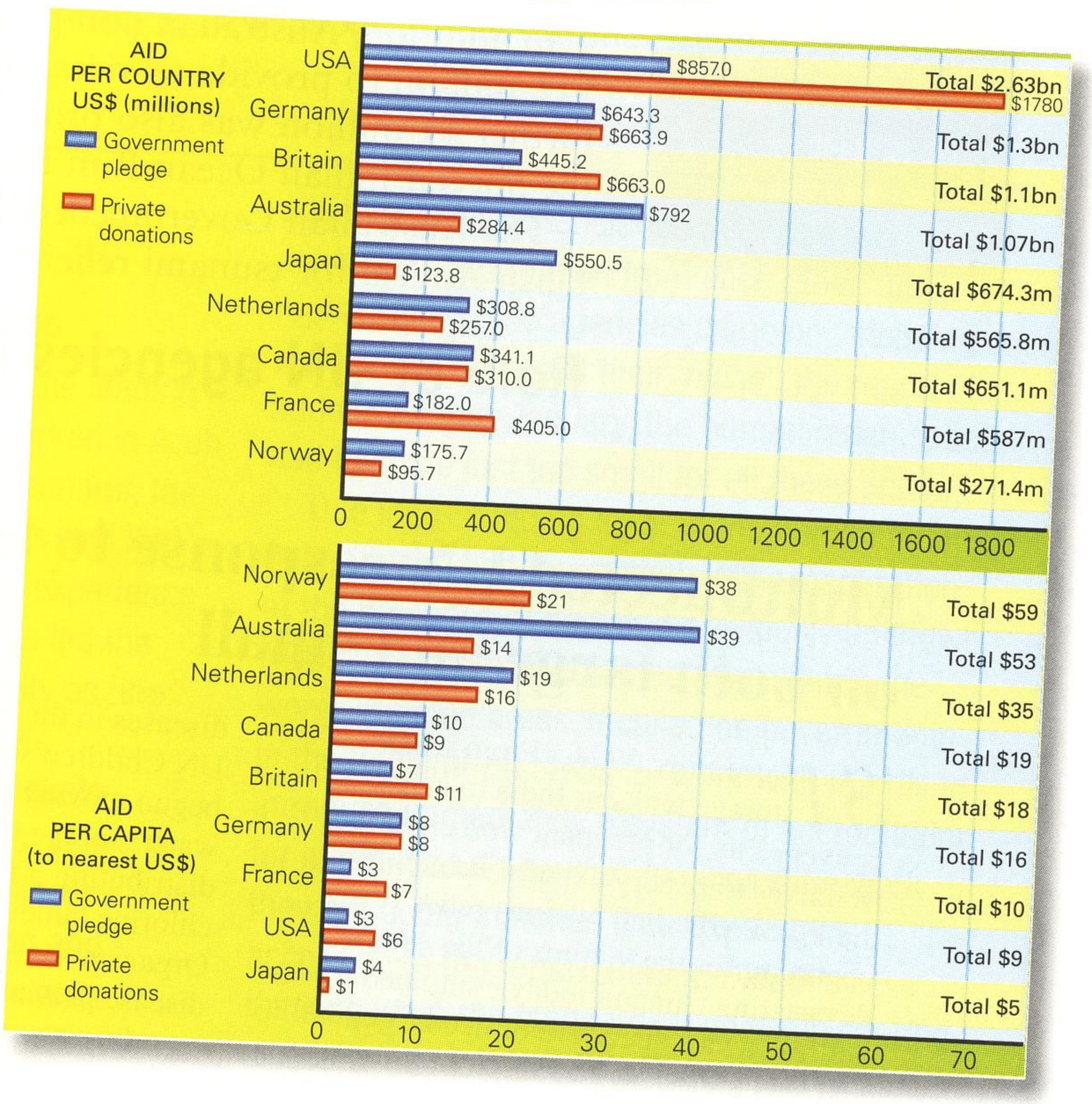
'The world's response to the tsunami was the best ever,' UN emergency coordinator Jan Egeland said. 'Governments, the private sector, and individuals around the world opened their hearts and their wallets. Private donations for the tsunami eclipsed anything seen before,' he told Reuters.

By comparison, Egeland said disasters like Hurricane Mitch which ravaged Central America in 1998 and the Bam earthquake in Iran in 2003 had only received half the money promised.

Dozens of governments, the World Bank and Asian Development Bank pledged more than $7 billion. They have so far allocated over $6 billion, according to Reuters research. The public donated another $5 billion plus.

Source: Reuters Foundation Alert Net

[4.40] Tsunami aid—the world's biggest donors



Learning activities

4.55 What are the four phases in the provision of disaster relief?

4.56 Why is it important to divide the provision of disaster relief into short-term and long-term phases?

4.57 Why did Jan Egeland, the UN emergency coordinator, say that 'The world's response to the tsunami was the best ever'?

4.58 Explain why there are differences between the aid per country and the aid per capita in figure [4.40].

Australian Government's tsunami aid response

Australia responded to the tsunami disaster quickly by sending teams and emergency relief supplies to tsunami-affected countries. The Australian Government committed $60 million for emergency humanitarian assistance. Australian aid efforts were coordinated and administered by the Australian Agency for International Development (AusAID). Australian assistance provided more than 80 000 people with shelter, water, food and sanitation services.

did you know?

WHO developed a successful surveillance system for epidemics in the tsunami-affected areas that included mass vaccinations for measles—a common cause of death in children after natural disasters.

Australia's foreign aid has a geopolitical basis. This means that most Australian aid goes to our immediate neighbours in the Asia–Pacific region to foster 'good neighbour' relations and to ensure stable government and economic development. The Australian Government's tsunami aid also had a geopolitical basis with a pledge of $33 million for Indonesia and $15 million for Sri Lanka, the Maldives, Seychelles, India and Thailand.

In addition, Australian non-government organisations (NGOs) received just over $12 million to provide services, supplies and support in tsunami-affected areas. A further $1 million was also provided to smaller NGOs for tsunami relief as part of the Special Indian Ocean Rim Disaster Fund.

The Australian Government also committed $23.5 million to the United Nations Flash Appeal for tsunami relief.

Role of UN agencies in tsunami relief

[4.41]

Multifaceted UN response to tsunami focuses on both large and small

31 December 2004—From water storage tanks in India to safe delivery kits for pregnant women in the Maldives to fishery experts in Indonesia, the massive United Nations relief operation for the victims of the Asia's devastating tsunami today continued to address a vast spectrum of needs, general and specific, giant and small.

In what is shaping up as the largest ever UN relief effort for a natural disaster, the world body has deployed five parallel operations to tend to the needs of nearly a dozen countries struck by the catastrophe, which killed at least 120 000 people, injured half a million more, displaced 1 million and deprived up to 5 million of basic services.

'The repercussions of this tragedy are so severe that communities are going to require massive international aid for many months to come,' UN World Food Programme (WFP) Executive Director James Morris said, noting that the latest carnage capped a year already marked by tragic humanitarian crises such as the conflict raging in the Darfur region of western Sudan.

The following is a country-by-country snapshot of some of the latest items in the UN's multifaceted response to the disaster:

- **India**: With contaminated water presenting the greatest threat of deadly diseases in the tsunami's aftermath, the UN Children's Fund (UNICEF) has begun moving nearly 2500 500-litre water storage tanks to relief camps and distributing 3 million water purification chlorine tablets. The UN World Health Organization (WHO) is planning disease prevention at district level, guarding against potential measles outbreaks and providing vitamin A and oral rehydration salts (ORS). The UN Food and Agriculture Organization (FAO) is monitoring fisheries.
- **Indonesia**: The UN High Commissioner for Refugees (UNHCR) is starting an airlift on Sunday of 400 tons of shelter and other emergency supplies for an initial 100 000 people in Aceh province, among the worst and most inaccessible disaster zones. A UN joint logistics centre will be set up at the central level and in Banda Aceh, the provincial capital and a FAO emergency coordinator and a fishery expert have been sent in.
- **Maldives**: The UN country team is focusing primarily on the provision of water, food, ORS and transport. The UN Population Fund (UNFPA) is procuring safe delivery kits for the 4000 expectant mothers while UNICEF is providing food, shelter and non-food items.
- **Sri Lanka**: UNFPA is carrying out reproductive health assessments. UNICEF continues to help ferry the wounded and dead to area hospitals while providing 10 000 bed sheets, towels, drinking water bottles, cooking utensils sets and mats to assist the displaced and stranded. UNHCR has been distributing non-food items.
- **Thailand**: UNFPA has deployed mobile clinics while UNICEF has begun assessing the needs of children. FAO is assisting the worst affected sectors of fisheries and agriculture. The UN Development Programme (UNDP) is sending 1000 body bags and 2000 kilos of formalin to the devastated holiday island of Phuket. The UN Educational, Scientific, and Cultural Organization (UNESCO) is focusing on education and their World Heritage Committee will assess damage to relevant areas. The UN International Labour Office (ILO) will focus on longer-term rehabilitation and employment.
- **Somalia**: FAO assessment teams have already been mobilized for a food security assessment in the field and the WFP has stockpiled 83 tons of food supplies for the worst affected areas.

Source: United Nations

Role of non-government organisations (NGOs)

About 300 NGOs were involved in providing tsunami relief to the Indonesian province of Aceh. Some of these were small NGOs that did not follow the humanitarian guidelines followed by the larger NGOs for providing disaster relief. One NGO vaccinated children in Aceh against measles and did not bother to maintain proper records. The following newspaper article outlines the nature of this problem.

[4.42]

NGOs can add to disasters

By Marwaan Macan-Markar
Inter Press Service, 5 October 2005

These NGOs … caused concern to the leading global humanitarian agency that worked in Aceh in the immediate aftermath of the tsunami, the International Federation of Red Cross and Red Crescent Societies (IFRC). The Aceh experience with the activities of some NGOs has led the IFRC to describe humanitarian activity as 'the world's largest unregulated industry'.

It is an unfortunate reality, says Bekele Geleta, head of the IFRC's South-east Asia office. '(These NGOs) stay in the business because there is no proper regulation and because there are no minimum standards'. Geleta made those comments Wednesday at the launch here of the IFRC's annual 'World Disaster Report', a 250-page document on the international response to the tsunami and other natural disasters during 2004.

Agencies did not follow standardised procedures and reports were not made available, according to the publication. 'In Aceh, there was so much competition between agencies over beneficiaries that they even concealed information from each other,' the report said. Some agencies came on 'shopping expeditions' to guard their 'niche', the report added. 'By mid-January, the humanitarian space had become just too small for all these actors'.

One long-standing actor in the humanitarian field, Oxfam, had responded with exasperation at the presence of new and previously unknown NGOs that had mushroomed overnight in the worst-affected areas. It called on governments in the tsunami-hit areas to 'work with the UN to introduce immediately a system of accreditation for international agencies to ensure the work they are doing matches their experience,' according to the report. Behind Oxfam's thinking were the standards it abides by during disasters, as do other established humanitarian agencies like the IFRC, Save the Children Fund and Médecins Sans Frontières. 'There are minimum standards all agencies that are seriously committed to providing humanitarian assistance have to be aware of and should aspire to follow,' Ashvin Dayal, regional director for Oxfam's East Asia office, told IPS.

Source: Global Policy Forum

did you know?

The Australian Council for International Development (ACFID), which monitors NGOs in Australia, calculates that the total tsunami aid donated by Australians to NGOs amounts to $366.4 million as of 30 September 2005.

Learning activities

4.59 Outline the ways in which the Australian government helped tsunami-affected countries.

4.60 Explain what this statement means: Australia's foreign aid has a geopolitical basis.

4.61 Explain why it was appropriate to call the UN's response to the tsunami multifaceted.

4.62 List the UN agencies that assisted with the tsunami relief operation and outline the types of support they provided.

4.63 **a** List the reasons why small NGOs might have wanted to help tsunami victims.

b List the reasons why large NGOs were concerned about the relief aid provided by smaller NGOs.

c Hold a class debate on the topic: 'Victims of a natural disaster should receive aid from any source willing to provide it.'

Reflection on tsunami disaster plans

Unlike the Pacific Basin, there was no early warning tsunami system in the Indian Ocean. This is because tsunamis in the Indian Ocean are relatively rare, compared with the Pacific. As a result, the Indian Ocean coastal communities had no advance warning of the danger of tsunamis. As the sea receded just before the tsunami hit, many people wandered out to gather the stranded fish instead of fleeing for their lives to higher ground.

[4.43] Provision of safe drinking water and temporary shelter were among the first priorities after the tsunami

Was the response appropriate?

According to the UN, the international response to the tsunami was the best ever response to a natural disaster. The international aid delivered compared with the amount promised was also very high compared with other disasters [4.43]. There were no outbreaks of disease or starvation among the survivors. The response to this disaster seems to have been appropriate given the sheer scale and magnitude of the tragedy. The fact that most of the affected countries were developing nations made their need for support even greater after the disaster.

What were the lessons learned?

According to the Australian Council for International Development (ACFID), Australian NGOs have learned lessons from their work during this tsunami response, which has built upon their experience during past international disasters. These include:

- the impact that can be achieved by leveraging off an international NGO network, where that is available
- the critical importance of a prior investment in NGO disaster preparedness and contingency planning in the communities with which NGOs operate
- the central role of healthy local partner relationships to enable quick mobilisation after a disaster
- the importance of the Sphere and Red Cross international standards to ensure sound NGO practice
- ensuring that NGO accountability mechanisms also reflect the views of affected communities.

The most important lesson from the tsunami was that there was an urgent need for an Indian Ocean Tsunami Warning System (IOTWS). The fact that the world's only tsunami warning system at the time was in the Pacific, where the wealthy nations, such as the United States, Canada, Japan, Australia and New Zealand are located, only serves to highlight the fact that poor nations do not have the resources to properly prepare themselves for disasters, such as tsunamis.

Update on progress in tsunami-affected regions

According to ACFID, the pace of tsunami reconstruction has been slow for several reasons:

- in Aceh, access to devastated areas has been severely hampered by lack of infrastructure, including roads and ports
- the destruction of many land title deeds and loss of some coastal land in Aceh, which has led to protracted negotiations at local level about the many thousands of claims to land ownership
- considerable delays in the publication of the Indonesian government's reconstruction plans, which set back the planning work of NGOs
- in Sri Lanka, the Government's decision to ban any rebuilding within 100 metres of the coast generated an exceptional challenge for community consultation and early stage planning
- in all countries, foreign NGOs must operate within the planning constraints and preferred timing of national, provincial and local government agencies
- the commitment of NGOs to full community consultation as part of their own planning processes was more challenging due to the large numbers of displaced and traumatised people, the number of renters and squatters involved and because many local officials and community leaders died in the tsunami
- once planning approvals are in place, there are still significant organisational challenges to be overcome before reconstruction can commence
- a lack of experience of mass shelter construction on this scale amongst NGOs, real problems in sourcing building materials and the tripling in the price of timber since the tsunami.

did you know?

Tsunami aid to NGOs in Australia was subject to unprecedented transparency checks to ensure there was no leakage and that the administration fees were minimised.

While the progress of reconstruction seems slow, and numerous political, cultural and logistic problems have been encountered, it is worth remembering that many of the projects are medium to longer term and therefore it is unreasonable, given the scale of the disaster, to expect faster progress. Most authorities say any assessment of reconstruction should be made after five years.

Strategies to address future tsunami threats in the Indian Ocean

Since the tsunami, Sri Lanka has set up a controversial Coastal Conservation Zone (CCZ) that extends 200 metres from the normal high tide in the north and the east, and 100 metres in the south and the west. Damaged structures within the CCZ cannot be repaired or rebuilt and no new development is permitted. The CCZ is meant to be a buffer zone against possible future tsunamis.

Since the fertile coastal zone of many Indian Ocean countries is densely populated, it is unlikely that other governments, such as India, Indonesia and Thailand, will enforce a buffer zone. Critics of Sri Lanka's CCZ have said that the system will be difficult to implement and is subject to corruption and exceptions. Many poor people who have not received compensation have already built their dwellings within this zone [4.44].

did you know?

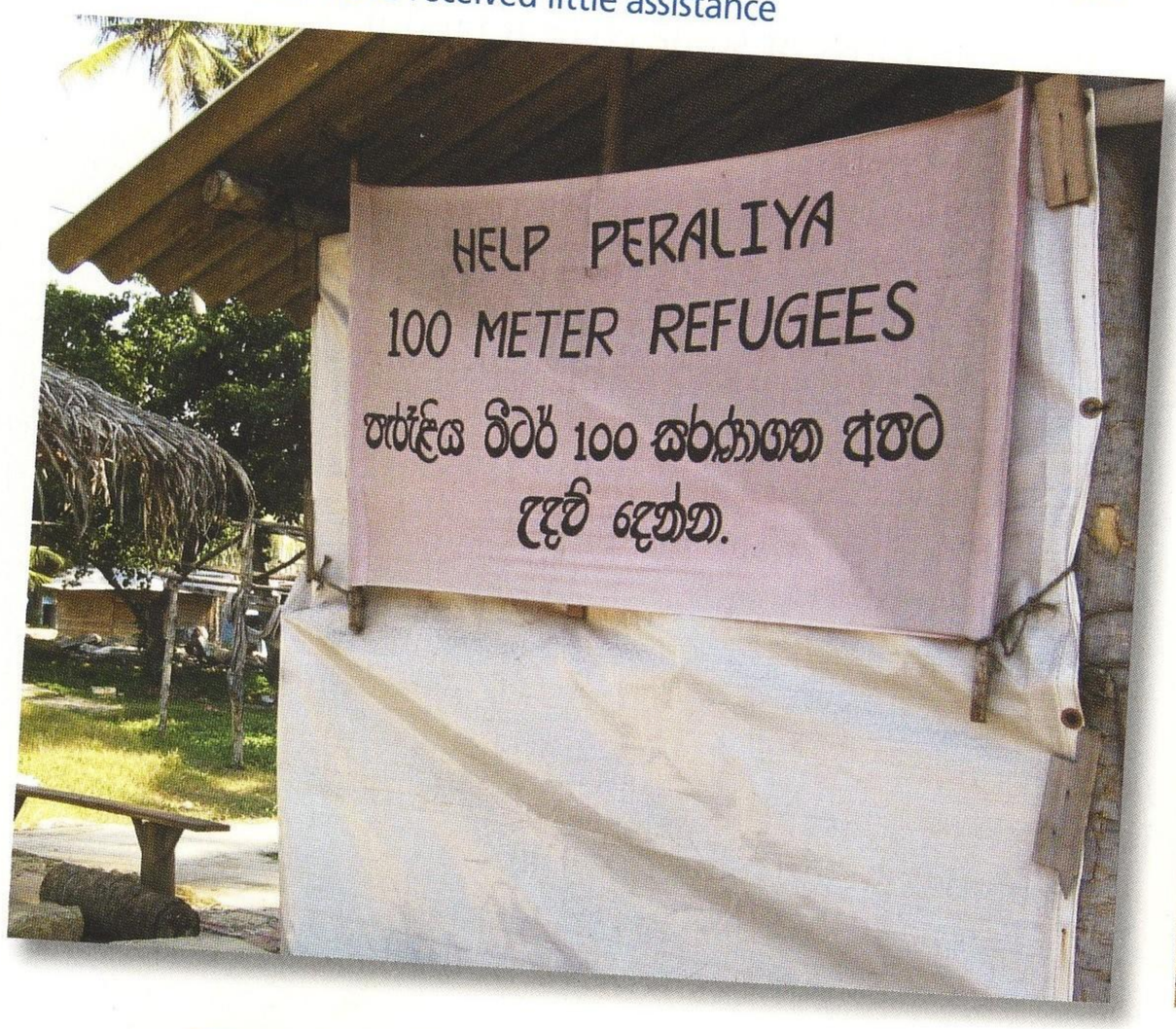
Several Australian seismologists had unsuccessfully called for an IOTWS prior to the 2004 tsunami. Perth will be a major monitoring centre for the new IOTWS.

Indian Ocean tsunami early warning system

In June 2005, international pressure lead the UNESCO Intergovernmental Oceanographic Commission (IOC) to establish the framework for four new tsunami warning and mitigation systems around the world including the Indian

Ocean. Sixteen countries bordering the Indian Ocean have since conducted national assessments to identify the requirements for the development of the Indian Ocean Tsunami Warning System (IOTWS) [4.45].

[4.44] Many poor people who lived within 100 metres of the coastline have received little assistance



[4.45] Early warning systems will assist local communities in the future

Learning activities

4.64 According to ACFID, what lessons have Australian NGOs learned from their work on the tsunami response?

4.65 What reasons does ACFID give to explain why the pace of tsunami reconstruction has been slow?

4.66 Why do most authorities say that any assessment of reconstruction should be made after five years?

4.67 **a** What is the Sri Lanka's Coastal Conservation Zone (CCZ)?

b Give reasons why the CCZ is controversial.

4.68 Describe what is happening with the implementation of an Indian Ocean tsunami early warning system.

Sample study: the 2005 Kashmir earthquake

The Kashmir earthquake occurred on 8 October 2005 in the Pakistan-administered region of Kashmir. The earthquake measured 7.6 on the Richter scale, making it a major earthquake. The epicentre of the earthquake was near the provincial capital city of Muzaffarabad. Hundreds of aftershocks occurred in the region after the first earthquake. The widespread destruction and loss of life that resulted from the earthquake and its aftershocks prompted a global aid response [4.46].

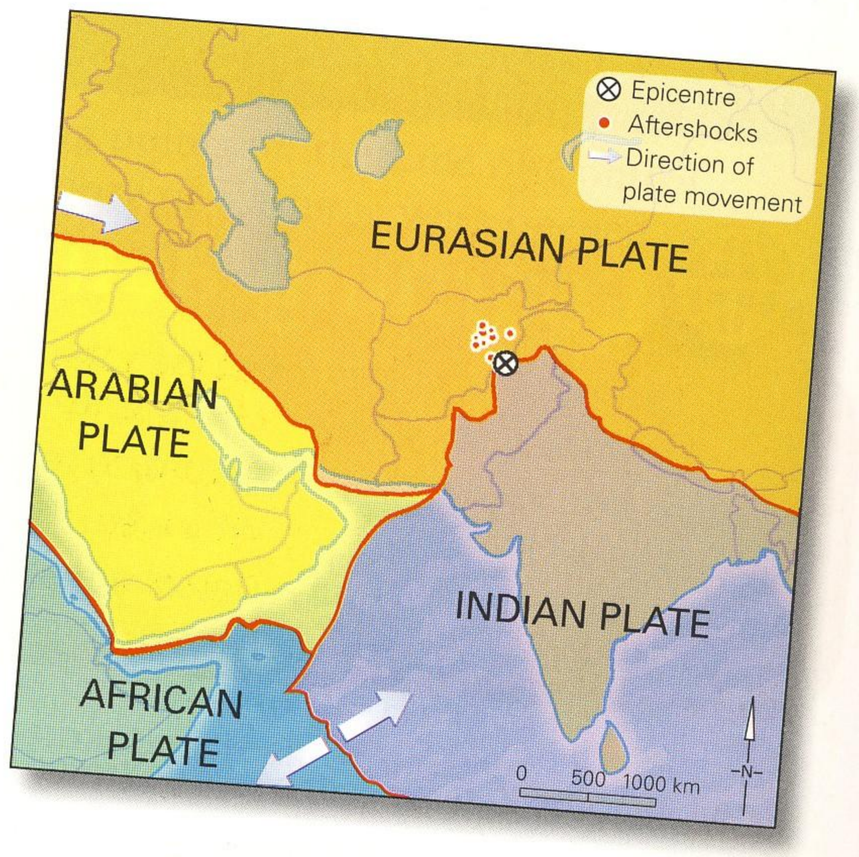
[4.46] Entire towns and villages were destroyed by the 2005 Kashmir earthquake

Factors contributing to the development of the earthquake

The cause of the 2005 Kashmir earthquake was the ongoing tectonic collision between the mobile Indo-Australian Plate and the stationary Eurasian Plate. The tectonic collision zone between the Indian subcontinent and the Eurasian Plate occurs in Pakistan and Kashmir [4.47]. Earthquake activity is common along this tectonic boundary.

The force of the collision between the two tectonic plates has created the Himalayas, which are a tectonic crumple zone. The world's highest mountain range was first uplifted about 50 million years ago. Today, it continues to rise by about 5 millimetres per year.

[4.47] The tectonic setting of the 2005 Kashmir earthquake



What happened?

Earthquakes are the vibrations that travel through the lithosphere in response to the readjustment of tectonic pressures in lithospheric plates. The 2005 Kashmir earthquake is a reminder of the constant tectonic forces that shape the lithosphere of the Earth and the great dangers these present to nearby human activities.

Learning activities

4.69 How did the magnitude of the Kashmir earthquake on 8 October 2005 compare to the earthquake that caused the Indian Ocean tsunami on 26 December 2004?

4.70 Describe the location of the epicentre of the earthquake.

4.71 Outline the cause of the Kashmir earthquake.

4.72 How is the formation of the Himalayas related to the Kashmir earthquake?

What were the impacts of the earthquake?

The worst affected areas were the remote mountainous region of Kashmir in northern Pakistan, Pakistan's North-West Frontier Province (NWFP) and parts of the Kashmir valley in Indian-administered Kashmir. Parts of the Pakistani

province of Punjab were also affected and the city of Karachi experienced a minor aftershock. Earthquake damage was also reported in northern India and Afghanistan.

Human impacts

Most people killed were in buildings that collapsed. More than 3.3 million people were left homeless in Pakistan. The UN reported that more than four million people were directly affected by the earthquake. There was great concern that many of the survivors would be at risk of dying from winter cold and the spread of disease.

[4.48] The human toll of the earthquake

Country where deaths occurred	Deaths	Injured
Pakistan (NWFP and Kashmir)	87 350	>100 000
India (Kashmir)	1360	6266
Afghanistan	3	–
Total	88 713	>106 266

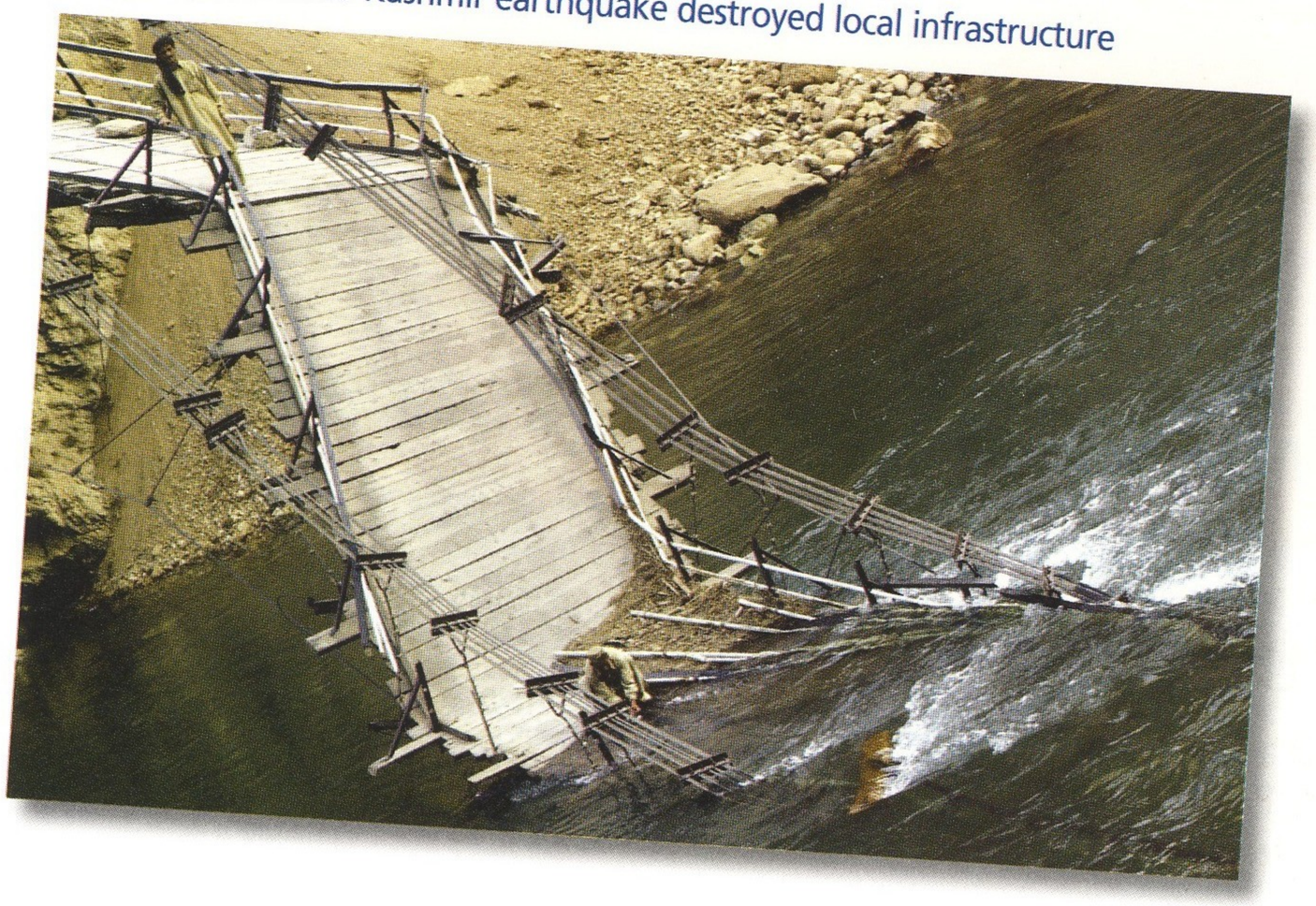
Economic impacts

Early estimates of the earthquake damage were put at more than $6.6 billion. Most buildings, roads and bridges in the affected areas were destroyed or severely damaged. Many livestock also perished. The earthquake and its aftershocks triggered many landslides that buried buildings, roads and bridges and even entire villages [4.49]. As these regions are poor, isolated and largely subsistent, the economic impact on the local economy was severe.

Learning activities

4.73 List the total number of deaths, injuries and homeless people as a result of the earthquake.
4.74 According to the UN, how many people were directly affected by the earthquake?
4.75 Why were the economic impacts of the earthquake severe?
4.76 Describe the environmental impacts of the earthquake.

[4.49] The 2005 Kashmir earthquake destroyed local infrastructure



Environmental impacts

The greatest environmental impact resulting from the earthquake was increased erosion. This resulted from the many landslides triggered by the earthquake and its aftershocks. Snowfall in winter also triggered mudslides on disturbed ground. A future environmental impact of the earthquake will be the clearing of forests to provide timber for new dwellings.

Response to the earthquake

The earthquake disaster prompted an urgent response from the two main affected nations and the international community.

National

The governments of Pakistan and India responded quickly to the disaster, directing their armed forces in search and rescue operations. However, there were many factors that made progress slow and frustrating:

- The sheer volume of rubble in collapsed buildings called for the use of heavy machinery that was in short supply.
- Roads, bridges and communications were knocked out in many areas, making access to affected areas difficult.
- Rescue efforts were hampered by the many aftershocks, which put the lives of the rescuers in danger.
- The onset of winter snows further threatened the survivors and made access to many of the affected areas difficult.
- Many of the 15 000 villages affected by the earthquake were in remote, inaccessible areas. Relief aid had to be airlifted into these areas.

The disputed border of Kashmir between the two nuclear-power neighbours, India and Pakistan, has been a political flashpoint for many years. In an unprecedented act of cooperation, five crossing points on the Line of Control (LoC) between India and Pakistan in the province of Kashmir were opened to allow for the flow of relief supplies and for families to meet their relatives.

The people of Pakistan and India responded generously to the disaster relief appeal. In the first few days after the earthquake, the most urgent need of the rescuers was to locate survivors under collapsed buildings before they died of injuries, dehydration and exposure [4.50]. Desperate people used picks and their bare hands in an often futile attempt to find their family and friends. The next priority was to provide water, food, medical supplies, tents and blankets for the survivors. Victims had to be buried as soon as possible in accordance with their religious beliefs. This also helped to prevent any possible outbreak of disease.

[4.50] Rescuers searching for survivors of the 2005 Kashmir earthquake

International

Two days after the earthquake, the United Nations warned that more than 2.5 million people were homeless. They urgently needed shelter, especially with winter approaching at these high altitudes. A UN appeal was launched for US$272 million (A$360 million) to aid the earthquake victims. The United States pledged an initial US$50 million (A$66 million). The United States was keen to show support for its political ally Pakistan and flew military aircraft and aid from operational bases in nearby Afghanistan.

Many countries sent helicopters to ferry supplies into inaccessible areas. The North Atlantic Treaty Organisation (NATO) airlifted 900 tonnes of aid from warehouses in Turkey. More than 20 countries sent rescue teams. Specially trained rescue dog teams from foreign nations were also used in the rescue operations. After a week, it became apparent that no more survivors would be found and rescuers turned their attention to providing relief for the homeless survivors. Most of the survivors were housed in tent villages. More than ten thousand tents were flown into the disaster area.

The Pakistani Foreign Minister, Khurshid Mahmud Kasuri, told reporters that the international response had been 'overwhelming' and 'transcends' religion and politics. Pakistan even accepted aid from its neighbour and nuclear rival, India. However, when comparisons were made with the international aid for Indian Ocean tsunami victims, a different picture emerges.

did you know?

Australia gave $10 million towards the Kashmir earthquake aid appeal. More than $60 million was donated for the Indian Ocean tsunami victims.

[4.51]

International response to Asian earthquake a disgrace

9 November 2005

One month on from the Asian earthquake, Save the Children is calling on the international community to dramatically scale up its response.

The earthquake has claimed nearly 80 000 lives and unless more is done to assist the reported 3.5 million homeless and 79 000 injured, thousands more could die from disease and exposure, the charity warns.

Executive Director of Save the Children New Zealand John Bowis says: 'Governments have been much slower to release funding than after the tsunami, despite the fact that there are over 50% more people displaced and we are racing against the harsh Himalayan winter. Every day, it is getting colder and people will not survive long in the open or in makeshift shelters. Young children are particularly vulnerable. Our teams on the ground urgently need additional funds now to reach these families before it is too late.'

One month on from the devastating earthquake less than a quarter of the US$550 m appealed for by the United Nations has been pledged, and nearly half of this figure (US$60 m) remains undelivered. Save the Children is spending US$6.9 m in the region but this will run out in another month, and thousands more may die unnecessarily unless further funds are secured.

The scale of the international response to the UN appeal is in stark contrast to that for the tsunami, when international donors pledged over US$700 m for immediate emergency relief in the first two weeks.

	Indian Ocean tsunami	Kashmir earthquake
Number of dead	>200 000	>75 000
Number of homeless	c. 2 million	>3.5 million
Initial UN appeal	US$977m	US$550m
Pledges to UN appeal, one month on	US$775m (79%)	US$131m (24%)
Average temperature at night, one month on	22°C and stable	0°C and falling

The earthquake destroyed 70% of the houses in the affected areas and damaged the remainder, leaving up to 3.5 million people in 15 000 villages homeless and in need of medical care, water and sanitation support.

'It is a disgrace that the international community has committed such a small proportion of what the UN has asked for—one month later—and with winter closing in,' says Toby Porter, Save the Children UK's Emergencies Director. 'Within days of the quake, the message from the UN was clear. The world needed to provide both an instant and a massive response. The challenges we are facing today were all predicted. The international community should collectively hang its head in shame.'

Source: Save the Children New Zealand

[4.52] Pakistani armed forces unload relief supplies from a United States Army helicopter in a remote area of northern Pakistan hit by the earthquake

Learning activities

4.77 List the main factors that slowed disaster relief reaching those people affected by the 2005 Kashmir earthquake.

4.78 Describe the types of cooperation that occurred between India and Pakistan immediately after the disaster.

4.79 Outline the international response to the Kashmir earthquake.

4.80 According to article [4.51], why was international aid for earthquake victims a 'disgrace'?

Role of non-government agencies in the earthquake disaster response

[4.53]

Non-Government Organizations (NGOs) play a pivotal role in relief, rehabilitation and reconstruction activities

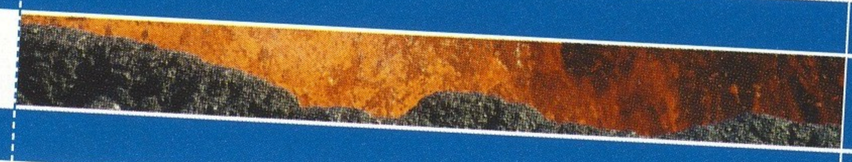
United Nations Development Programme—Pakistan, Islamabad, 25 January 2006

As the earthquake hit the northern regions of Pakistan and news started flooding in about the massive devastation that this natural disaster caused on October 8, 2005, international, national and local NGOs immediately focused all their efforts to provide aid, relief, and they are now working towards rehabilitation and reconstruction.

Although the various agencies of the United Nations, the army and the Government launched a variety of projects for the support of the people of these areas, the main role was and continues to be played by the NGOs. It is through their efforts and partnership that projects are being implemented throughout the earthquake affected areas.

'When we see a smile on the faces of these people, we forget our own hardships and get renewed energy to help these people,' says Shahnawaz Khan, who is working with Sungi Development Foundation (Sungi). 'When we provide someone with a blanket or a heating stove, the prayers we get are so much that we are humbled.'

It is through their hard work, that United Nations Development Programme (UNDP) is able to make ▶



a difference in the lives of thousands of families. In their partnership with UNDP the work started with the provision of winterized tents and kitchen sets. The main partner in this venture was International Organization for Migration (IOM). These tents were given to families based on a rapid assessment conducted with the help of local NGOs and local authorities.

To provide better protection against the extreme cold weather, UNDP launched its transitional shelter project. Islamic Relief, Sungi, the Citizen Foundation, Strengthening Participatory Organization (SPO), National Rural Support Programme, Taraqi Foundation, Human Resource Development Network (HRDN) and Heritage Foundation have partnered with UNDP to provide Corrugated Galvanized Iron (CGI) sheets and tool kits to over 32 000 families. Needs assessment were conducted in the snowbound areas of Mansehra, Batagram, Shangla, Kohistan, Muzafarabad, Neelam and Baagh by these agencies in their respective areas. They are now mobilizing the community for the distribution of material for transitional shelters. The organizations also provide support and recycled structure material for the homes.

A need was also identified for heating and cooking facilities. Taraqi Foundation and Sungi are the implementing partners for this project. The NGOs oversee the distribution and monitoring of heating stoves and construction of community kitchens and lungars. The NGOS conduct assessments to identify which communities would most benefit from this project and subsequently aid is provided to them. Under this project, the NGO partners also provide the communities with fire safety training.

'Without the support of NGOs and other implementing partners, we would never have been able to provide so much help and so quickly to the people of the northern areas of Pakistan,' says Haoliang Xu, Pakistan UNDP Country Director.

The role of NGOs is monumental in the wake of the earthquake and there is no doubt that they have been instrumental in saving thousands of lives.

Source: United Nations Development Programme—Pakistan

Learning activities

4.81 According to article [4.53], how important are the NGOs to the disaster relief operation?

4.82 Describe the work of the United Nations Development Programme in Pakistan.

4.83 List three types of things that were provided to help the earthquake victims.

Think about this

The earthquake may yet have a positive outcome. Cooperation between traditional rivals India and Pakistan could lead to a diplomatic thaw in their relationship and a new geopolitical reconciliation.

Role of UN agencies in the earthquake disaster response

As with the Indian Ocean tsunami disaster, the role of the UN agencies was to facilitate and coordinate the aid response in collaboration with the government authorities and the NGOs.

Reflection on earthquake disaster plans

In insurance terms, earthquakes are classified as 'Acts of God' and as such, they are nearly impossible to plan for. Most disaster plans are nearly always reactive rather than proactive. The governments of Pakistan and India responded quickly and enlisted international assistance for the disaster. The disaster plans helped to save many thousands of victims.

Was the response appropriate?

The response to the earthquake disaster stretched the ability of the international community to respond to disasters of this type. Concerns still exist about the levels of international aid compared with that given to Indian Ocean tsunami victims, but 2005 was a particularly disaster-filled year with the Indian Ocean tsunami, Hurricane Katrina and many smaller disasters. Many nations may have suffered from compassion fatigue. Despite killing fewer people than the tsunami, the Kashmir earthquake presented a greater challenge to aid relief because of the mountainous terrain; winter snows; poor, damaged and non-existent infrastructure; and the logistics of aerial delivery of food, medicines, water and supplies, especially tents and blankets to remote, inaccessible areas.

What were the lessons learned?

The earthquake caused more than 60 per cent of buildings around Muzaffarabad to collapse. Most of the deaths and injuries in the disaster occurred in collapsed buildings. An assessment by the Pesshawar University of Engineering and Technology showed that about 60 per cent of the buildings were constructed of unreinforced solid concrete masonary blocks. Each block was not tied in with the rest and this made the buildings more prone to earthquake damage. The partial solution to this problem would be to enforce a new building code. However, this would only protect the new buildings and may be difficult to enforce in remote areas in developing nations. In addition, any old buildings would still be as vulnerable to future earthquakes in the earthquake-prone region as those that collapsed in the 2005 earthquake.

Update on progress in earthquake-affected regions

Many of the mud-brick houses in remote areas affected by the earthquake were destroyed, along with much of livestock the people depend upon. Some 350 000 people in remote villages refused to come down to lower altitudes during the winter because they feared for the security of their land and their surviving animals. In early December 2005, another earthquake centered in Afghanistan caused landslides and make travel and communications even more difficult in the earthquake-affected area.

More than 200 000 people were housed in makeshift tents, many of which were not properly heated for winter. Sanitation became an issue and there were concerns about disease outbreaks after winter. Some aid workers also criticised the Pakistani government and the UN-led relief operation for not identifying the need for tools and building supplies, especially corrugated iron sheeting.

Strategies to address future earthquake threats in the region

The United Nations has said that they would like to make earthquake-proof buildings in the region a goal within 10 years. The logistics of getting aid by air to remote, inaccessible regions turned out to be a major problem and a coordinated strategy needs to be developed. The building of helicopter landing pads in remote areas may alleviate this problem somewhat.

Think about this

The UN identified a shortfall of 2.4 million blankets, 11.2 million quilts, 170 000 plastic sheets and 200 000 tarpaulins.

Need for new policies to deal with future quakes

Just after the Indian Ocean tsunami in December 2004, the United Nations convened a World Conference on Disaster Reduction in Kobe, Hyogo, Japan. The conference discussed progress in disaster risk reduction over the previous decade. Two of the main outcomes were the need for the development of a best practice response to disasters and the implementation of early warning systems to minimise the impacts of disasters. The following aspects of early warning systems for disasters could assist in formulating new policies to address future earthquake disasters in the Kashmir region and indeed around the world:

- prior knowledge and assessment of the risks faced by the community
- scientific monitoring and warning service for these risks
- dissemination of understandable warnings to communities at risk
- knowledge, public awareness and preparedness to act.

Learning activities

4.84 What is meant by the term 'compassion fatigue'? How might it relate to the level of aid provided to victims of the Kashmir earthquake?

4.85 Why did the Kashmir earthquake present a greater challenge to aid relief than the Indian Ocean tsunami?

4.86 Describe why buildings were so easily damaged in the Kashmir earthquake.

4.87 Divide the class into small groups. For example, the class might be divided into eight groups with three students in each group. Each group should assume the role of an Asian country represented at the World Conference on Disaster Reduction. The task of each group is to present a strategy plan that reflects the views of the country they represent. The strategy plan presented should address the following areas:

- planning for the early warning of natural disasters
- response immediately following a natural disaster
- support and rebuilding program over the longer term after the event.

Your strategy plan should consider responses appropriate to a range of major natural events that impact on humans, for example tsunamis, hurricanes, earthquakes and volcanic eruptions.