Answers to data response and decision making exercises

1. Examine the map below that shows the location of earthquakes and volcanoes around the Pacific Ocean. See Figure 6.3 in the Student Book for the colour version.

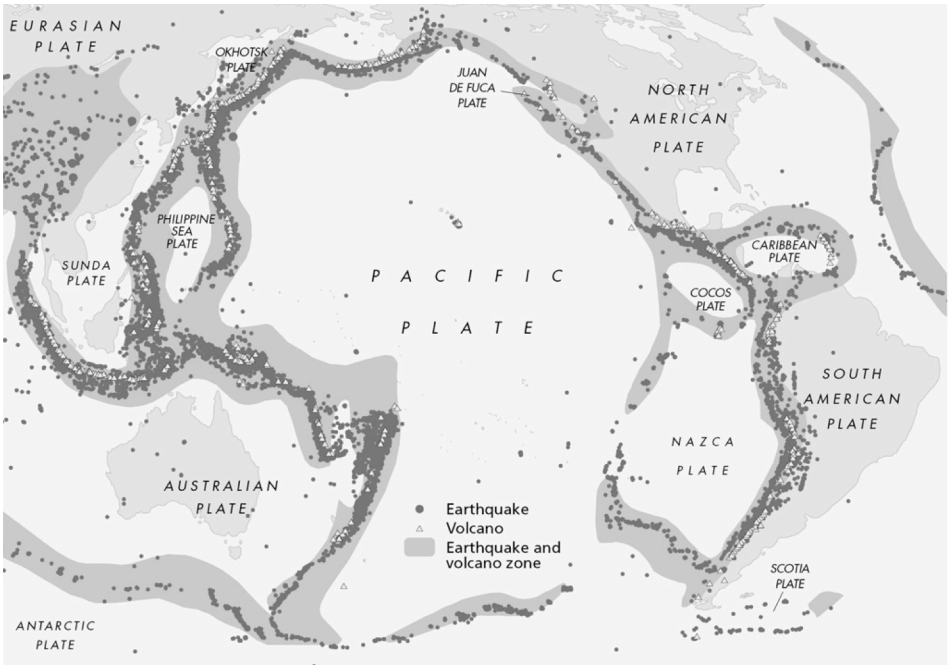


Fig. 6.15 Tectonic activity in the Pacific Ocean.

a) What is an earthquake?
An earthquake is a sudden violent shaking of the ground as a result of movements within the Earth's crust.

b) Define the key terms *focus* and *epicentre*.
Focus: The point within the Earth's crust where an earthquake originates.
Epicentre: Point on the Earth's surface directly above where an earthquake occurs.

c) Describe the distribution of earthquakes and volcanoes on the map.
Earthquakes and volcanoes are found in narrow belts, often but not always together. The main concentrations are located around the outside of the Pacific Ocean in a ring that extends northwards from New Zealand, then northeast to the Philippines. The belt then runs north to Japan and then east to North America before running south along the west coast of North and South America. Another band of earthquakes and volcanoes runs into the Pacific Ocean around the Nazca plate. There are some isolated volcanoes and earthquakes in the centre of the Pacific Ocean around the Hawaiian island chain.

d) Suggest reasons for this pattern of earthquakes and volcanoes.
The narrow bands of volcanoes and earthquakes are found along the edges of tectonic plates. Many of these are destructive plate boundaries where plates collide and cause volcanoes and earthquakes to become active. Isolated volcanoes could be caused by hot spots in the mantle.

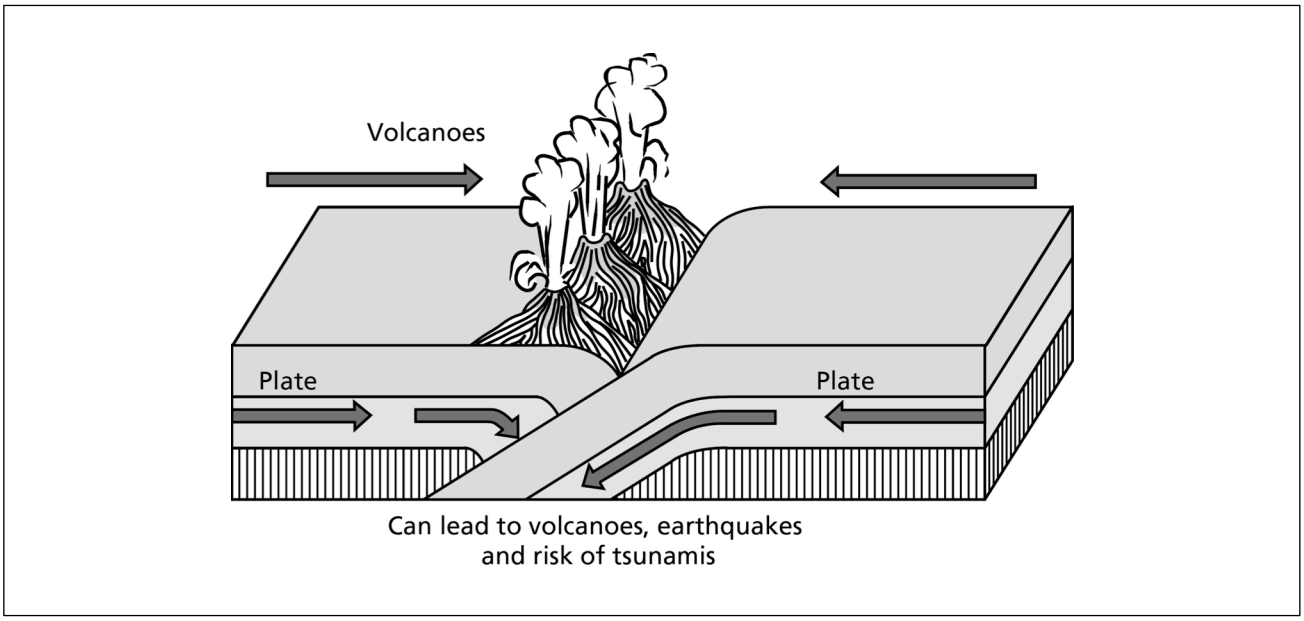
e) Describe the main types of plate boundary.

There are 3 main types of plate boundaries – conservative, constructive and destructive. Conservative plate boundaries are found where two continental tectonic plates are locked together. Land is neither created nor destroyed. A constructive plate boundary is where two tectonic plates are moving apart, creating new crust. A destructive plate boundary occurs when an oceanic plate collides with a continental plate. The oceanic plate is denser so sinks downwards or subducts and melts, leading to the formation of volcanoes.

f) Why do tectonic plates move?

In the mantle, super heated plumes of magma rise up to the crust, then move sideways against the crust before cooling and sinking. These convection currents drive the movement of plates.

g) Using diagrams, explain the formation of volcanoes at destructive plate boundaries.



2. The map below shows the plate tectonic setting of New Zealand.

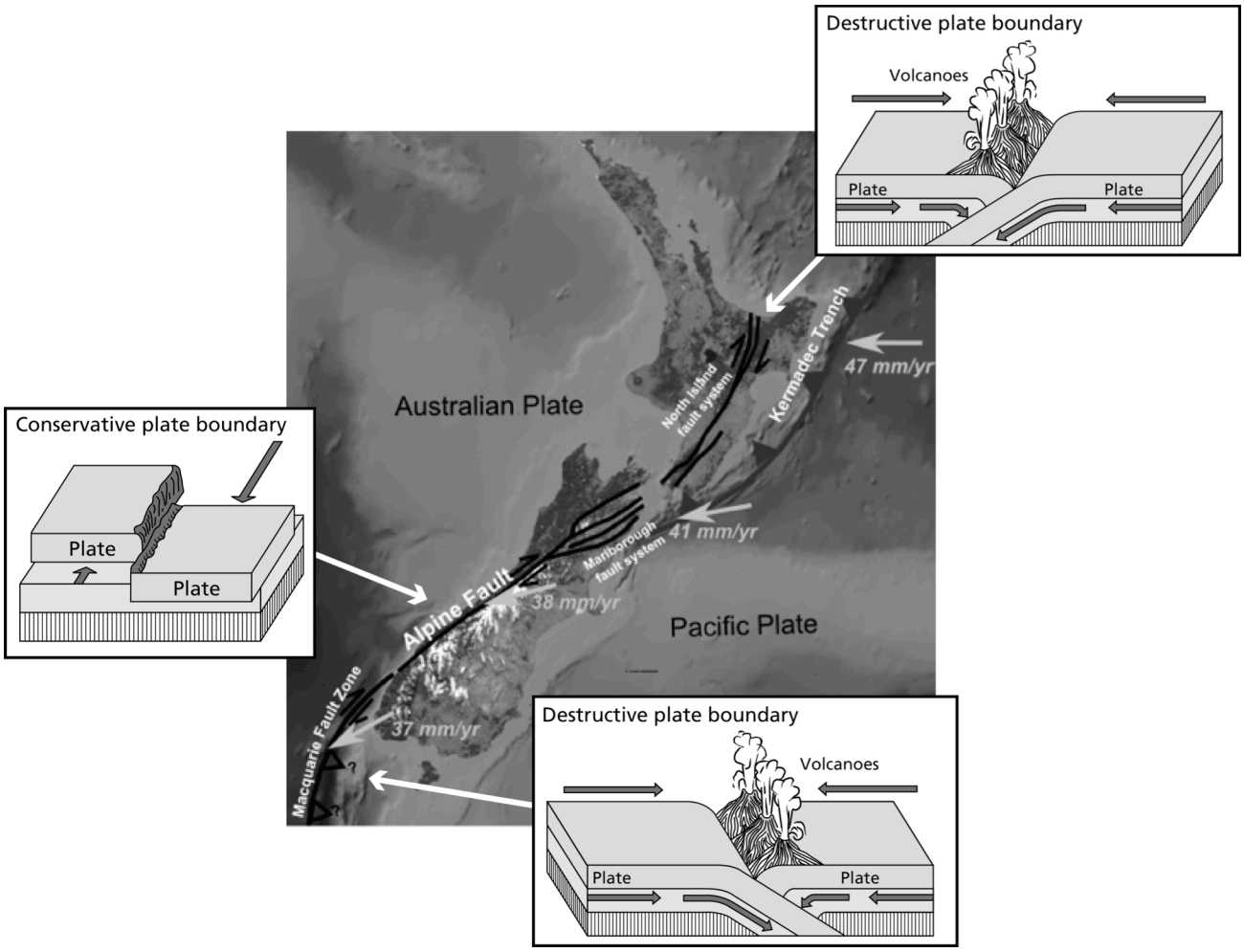


Fig. 6.16 The complex plate boundaries under New Zealand.

New Zealand is highly tectonically active and this creates a dynamic or constantly changing environment. From glaciers in the south to volcanic fields in the north, through dramatic mountains, fault lines and beautiful coastline, New Zealand contains some of the most outstanding landscapes on Earth. Geologically, New Zealand is one of the youngest countries on Earth. However, the plate tectonics that shape the dramatic and beautiful landscapes also create risk from a range of hazards. New Zealand sits on top of an active plate boundary where the Pacific and Australian Plates meet. The resulting geology is complex but developing an understanding of it will help you to explain some of the landscapes and hazards that occur.

a) Using your knowledge of plate boundaries, annotate the map above with diagrams to show the type of faults and plate boundaries occurring in New Zealand.
See annotated map above.

b) Suggest which tectonic hazards New Zealand is likely to experience and why.
New Zealand is likely to experience both volcanoes and earthquakes. This is because there is a destructive plate boundary under North Island and a conservative boundary on the South Island on the Alpine fault.

New Zealand has a comprehensive network of seismic monitoring stations. The maps below show the locations and depth of earthquakes in New Zealand over the past 10 years as well as the location of active volcanoes.

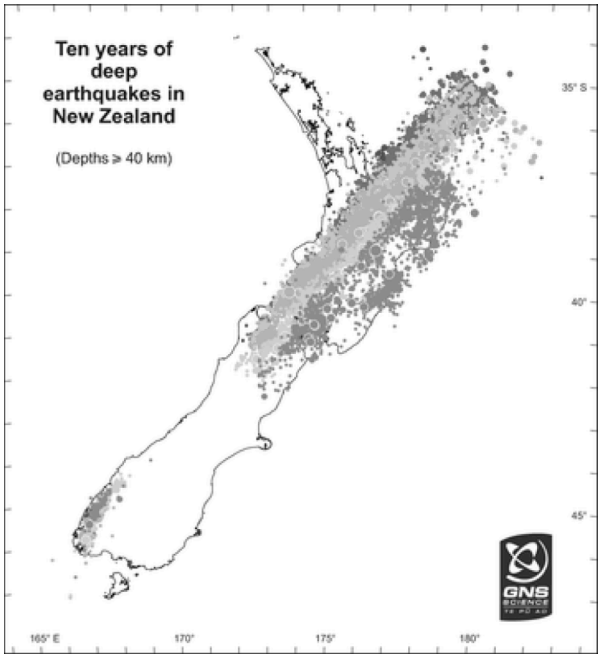


Fig. 6.17 Deep earthquakes in New Zealand.

Fig. 6.18 Shallow earthquakes in New Zealand.

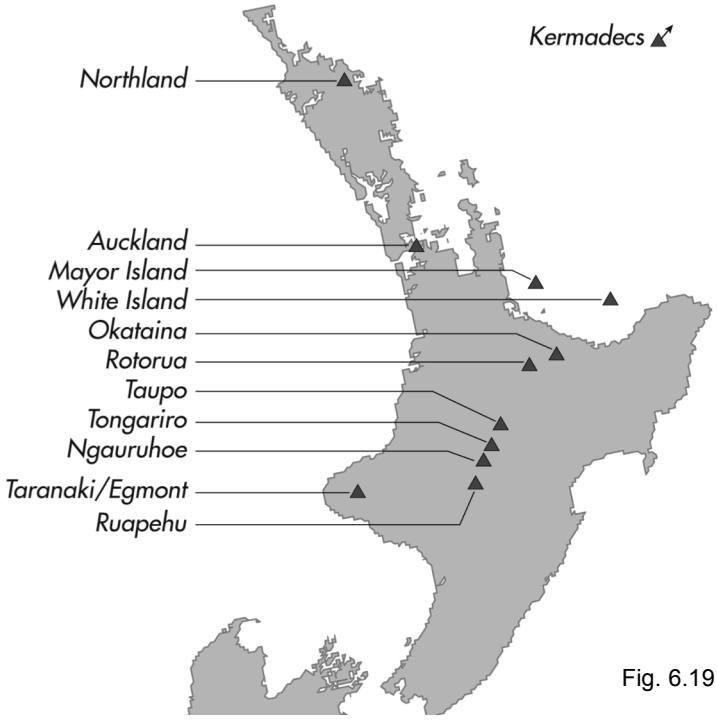


Fig. 6.19 Location of New Zealand's volcanic centres.

c) What is the pattern of deep earthquakes in New Zealand? How does the map in Figure 6.17 link to the plate boundary information?
The deep earthquakes follow a specific pattern that runs from east to west under North Island of New Zealand. The shallowest quakes are in the east and they get systematically deeper towards the west in bands that run northeast to southwest. This pattern is caused by the presence of a subduction zone, where the oceanic crust of the Pacific plate is subducting at an angle down under the Australian plate.

d) What is the pattern of shallow earthquakes in New Zealand? How does the map in Figure 6.18 differ from the map of deep earthquakes in Figure 6.17? Suggest reasons for the pattern.
Shallow earthquakes that are less than 40 km deep are more evenly distributed across New Zealand. There are no deep earthquakes on South Island as there is a conservative plate boundary here where the Pacific and Australian plates are locked together on the Alpine fault. The shallow earthquakes occur in a line that runs from the northeast to the southwest of New Zealand and are directly related to the plate boundaries here.

e) The volcano map in Figure 6.19 shows areas of volcanic activity, not just individual volcanoes. For example, The Auckland Volcanic Field is made up of over fifty separate volcanoes scattered across New Zealand's largest city. How does the information in the three maps in Figures 6.17-6.19 help to explain this pattern?
There is a subduction zone under North Island of New Zealand. As the Pacific plate subducts under the Australian plate at a speed of 47 mm per year, it creates an ocean trench. The subducting plate begins to melt in the mantle, which then causes magma to rise and form volcanoes on the surface of North Island.

3. Due to the complex tectonic setting, New Zealand is prone to damaging earthquakes. There are stringent building codes, evacuation plans and education in schools. Urban search and rescue teams practise drills regularly. These reduce the vulnerability of the population by decreasing risk and increasing the capacity to cope if a disaster does occur. This was clearly demonstrated in 2010 when an unknown fault line near Christchurch ruptured. The impact of this earthquake is shown below.

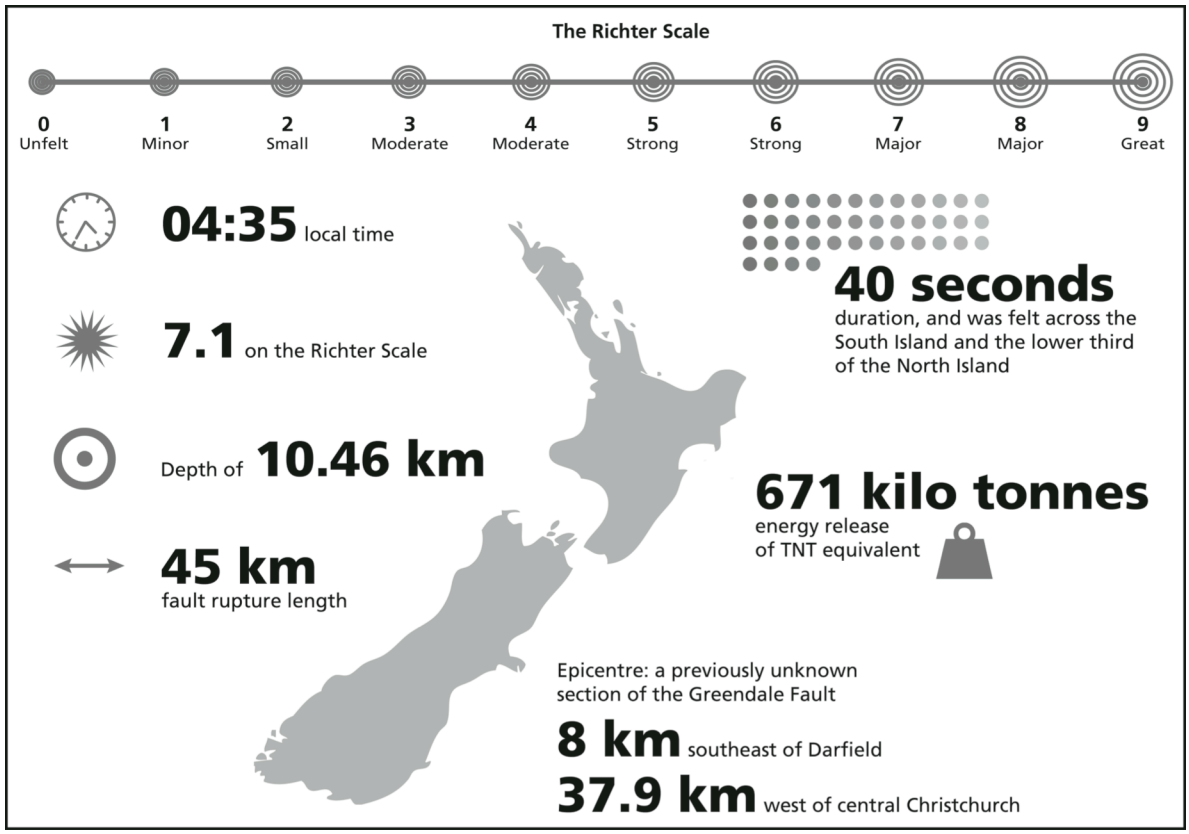


Fig. 6.20 The 2010 Darfield earthquake, 4 September 2010.

Effects of the earthquake

- Across the region, there was widespread damage to infrastructure and housing, and disruption to many businesses. A state of emergency was declared.
- Despite the tremendous damage and the constant aftershocks that made life very challenging, many people felt lucky that there was no loss of life.
- Railway lines buckled and had to be repaired.
- Soil liquefaction caused a lot of problems, with flooding damaging buried pipes and building foundations.
- Because this earthquake happened at night, when most people were in their beds, there were not many people injured by falling buildings or landslides.
- Two people were seriously injured, with approximately 100 injuries in total.

Despite the tremendous power of the quake, many New Zealanders – although shaken – cleaned up, repaired and carried on with life. The fact that there was no loss of life meant people were perhaps lulled into a sense of security about how well they were prepared for an earthquake. They didn't realise that this was to be the first of a sequence of powerful earthquakes over the coming months that would alter the future of the second biggest city in New Zealand. The Student Book contains detailed information on the more devastating February 2011 earthquake that struck closer to the city centre.

a) Using the Student Book, compare and contrast the September 2010 and February 2011 earthquakes.

The 2010 Darfield earthquake occurred earlier in the morning than the 2011 quake at a distance of 37.9 km west of Christchurch and at a depth of 10.46 km. This was deeper and further away from the CBD than the February 2011 quake. The 2010 earthquake was in fact stronger with a magnitude of 7.1 and a duration of 40 seconds in comparison to 6.3 magnitude for up to 25 seconds. The effects of the quakes were very different. The 2010 earthquake, whilst causing significant damage to property and infrastructure and injuring over 100 people, was less destructive than the 2011 earthquake. This killed 185 and injured 7000 people, alongside damaging 100 000 properties. The CBD of Christchurch was extensively damaged.

b) Suggest reasons why the second earthquake was more deadly than the first.

The second earthquake, although releasing less energy, was much shallower (5.95 km) and much closer to central Christchurch (6.7 km) than the first. The fault, which angled upward, ruptured under softer sedimentary rocks which magnified the effects of the shock waves and caused much greater ground motion. The softer rocks also liquefied which meant many buildings collapsed. The time of day was important as it occurred at lunchtime when the city centre was very busy. Finally, the first quake would have weakened the structure of some buildings that then collapsed in the second quake.

The map and graph below show the strength and location of the main shocks and huge number of aftershocks.

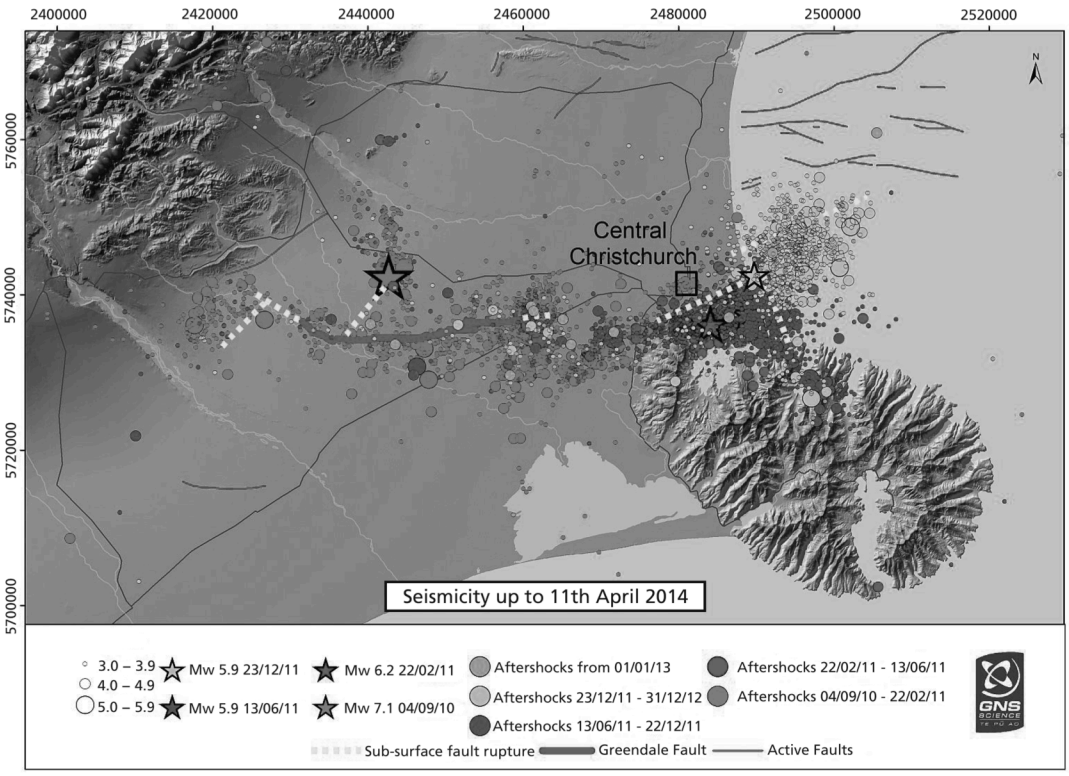


Fig. 6.21 Aftershocks of the Darfield earthquake.

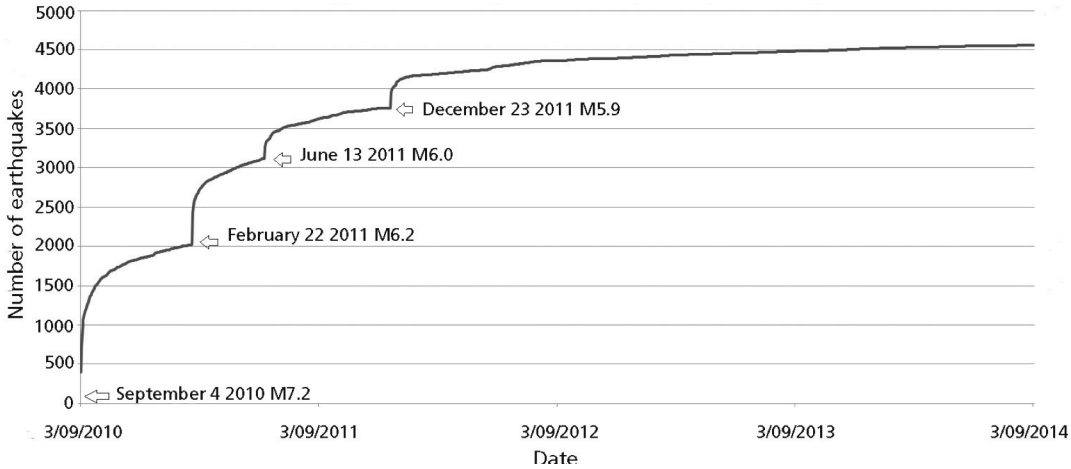


Fig. 6.22 Aftershocks following the Canterbury earthquake in New Zealand, September 2010.

c) Describe the location and strength of aftershocks around Christchurch. What happens to the number of aftershocks after each big quake?

The 2010 and 2011 major earthquakes and the associated aftershocks are located along a fault system that runs from west to east under central Christchurch and out to sea. There were 3 significant aftershocks from the September 2010 earthquake: the devastating February 2011 6.3 earthquake and the 2 further magnitude 5.9+ earthquakes in June and December 2011. After each of these bigger related earthquakes there are thousands of smaller aftershocks. For example, after the September 2010 earthquake, there were over 1100 smaller aftershocks in the days that followed. The number eventually decays, until there is another large quake which sees the pattern repeat, with fewer aftershocks each time. In total, there were over 4000 earthquakes in 16 months under Christchurch.

How people react to situations such as the quakes that unfolded in Christchurch will depend upon a range of factors. The diagram below helps us to understand how people might respond to hazards.

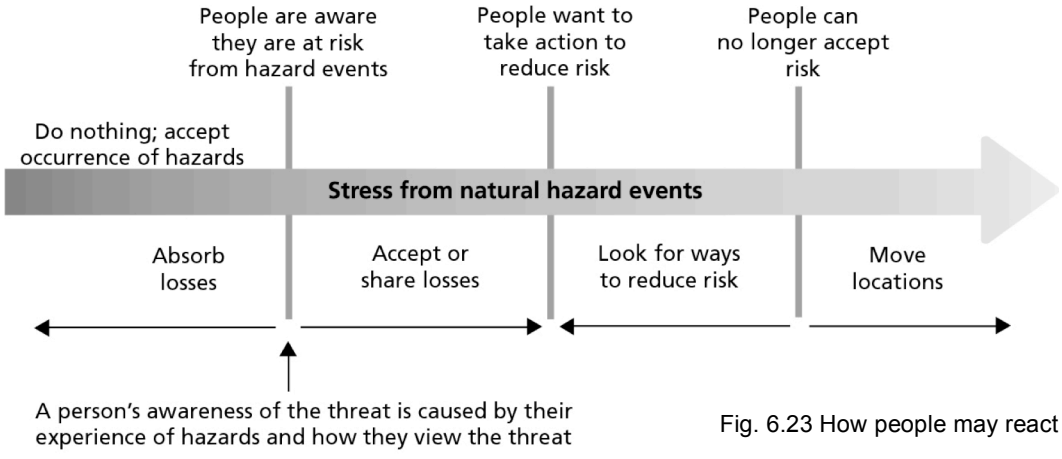


Fig. 6.23 How people may react to natural hazards.

d) Using Figure 6.23, as well as all the information on the two main earthquakes, the damage and the multiple aftershocks, describe how you feel you would react if you were a resident in the city.

How someone reacts to events such as these will be influenced by a complex range of factors such as age, prior experiences, whether you have children and how you were affected by each quake. For example, if you have children and your house was partially damaged in the September 2010 earthquake, but destroyed the following February, it is likely that you would consider moving away from Christchurch. Equally, if you were seriously injured in one of the quakes, then the trauma might cause you to want to leave the city. For many people, this was the reality in the 18 months after the first earthquake. People who had survived both major quakes and then lived in a city with damaged infrastructure were happy to rebuild. However, after other major aftershocks, they decided they had had enough and looked to move locations. For others, the extensive liquefaction meant large areas of Christchurch were no longer inhabitable. People were forced to move to other locations in the city and beyond.

However, not everyone chooses to leave. Many people will repair their houses with the insurance money and ensure they meet the latest safety standards. The earthquake provides new employment opportunities as well, which will encourage people to stay in the city.

4. Recovering from a serious earthquake requires significant planning and investment – there are several key stages. These stages are examples from the Christchurch earthquake:
   - The immediate search and rescue operation – hours and days following the earthquake.
   - The demolish, repair, patch-up and planning phase – September 2010 to December 2011.
   - Begin to rebuild, replace and reconstruct – 2012 to 2014.
   - Construct, restore and improve – 2015 to 2020 and beyond.

   A complex and comprehensive recovery plan has been put into place by organisations set up by the New Zealand government. They created CERA (Canterbury Earthquake Recovery Authority) and appointed an earthquake minister to the government to oversee the rebuild, replace and reconstruct phase. CERA has now been disestablished with a shift to more local governance over future projects. The central business district (CBD) of the city was devastated in the second earthquake, so rebuilding this key anchor has been an initial focus. Many of the projects are now constructed. Another significant challenge is what to do with the residential red zone in the city – an area of 6.3 sq km containing 7300 homes along the Avon river, which suffered severe liquefaction and where residential building is no longer allowed.

   New Zealand, like many countries, completes a regular census, so has been able to record the social and economic impact of the earthquake. Information on this can be found here: **http://www.stats.govt.nz/Census/2013-census/profile-and-summary-reports/2013-census-infographic-chch.aspx**

   Using the information above, the suggested links and your own research, comment in detail on the social and economic short- and medium-term effects of the earthquake, as well as the recovery efforts to date. You should focus on the developments in the CBD as well as the developing plans for the red zone. You might also want to suggest your own plans for the red zone.

After the September 2010 earthquake, the immediate short-term social and economic impacts were related to the immediate search and rescue operation in the hours and days following the earthquake, followed by the demolish, repair, patch-up and planning phase from September 2010 to December 2011. The obvious social impact in the short term was the loss of 185 lives and the 7000 people who were injured. Many more people were affected by damage to property with over 168 000 houses damaged. For over a year, thousands of people had to live in temporary accommodation. Many thousands more stayed in their homes as they were assessed by structural engineers. Residents had to contend with disrupted power, water and sanitation infrastructure – over 659 km of sewage pipes were destroyed. Many places of work in the CBD were destroyed, so businesses had to relocate. Some smaller businesses did not have the capacity to do this, so they closed. Other businesses chose to relocate to other cities in New Zealand, meaning people had to move or find alternative work. The number of businesses in the CBD declined from 5689 to 3758 in less than one year. The trauma of the earthquakes meant that some residents of the city chose to leave New Zealand altogether.
The damage to the CBD was significant so the New Zealand government raised a temporary tax on all citizens called an earthquake levy. This enabled the national government to pump money into the city in the short term to help deal with the financial cost of cleaning up the damage, demolishing buildings, repairing infrastructure and making vital plans for the future.
In the medium term, the planning phase gave way to the rebuilding, replacing and reconstruction of the CBD and residential areas. There were a number of key projects that enabled this. A mall made of shipping containers was constructed in the CBD to allow some shops to reopen. The Re:Start mall encouraged people back into the CBD, which was vital for other businesses. Construction began on major anchor projects as part of the urban regeneration. Projects such as the international cricket oval and new bus interchange have already been completed. Construction of major new health and innovation precincts are underway which will encourage major companies back to the city. Other major buildings such as the theatre and museum were reopened. The massive construction phase has had some interesting socio-economic effects. The population of Christchurch has increased by 2.6% – less than the national average. However, the number of children in the city declined by 4%. There are now more young males in the city than before, as well as a greater number of foreign born migrants. The number of unoccupied dwellings in the city rose by 81%. The city had a decline of 17% of jobs in manufacturing by 2013. However, jobs in construction rose by 59% in the same period. The number of workers in the CBD declined by nearly 20 000 with jobs moving west towards the airport. This has caused a 20% increase in the number of people driving a company vehicle.
The CBD red zone is now fully reopened and there are many plans in place for the residential red zones, where houses have been demolished and cannot be rebuilt in the future due to risk of liquefaction. The earthquakes have provided a significant opportunity for urban regeneration in Christchurch. Plans for sustainable buildings using the latest green technology are in place. There are to be more green spaces and amenities for the residents. Improved public transport will lower congestion and help to create a vibrant, prosperous 21st century city.