Geo Factsheet

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Tectonic hazards in New Zealand

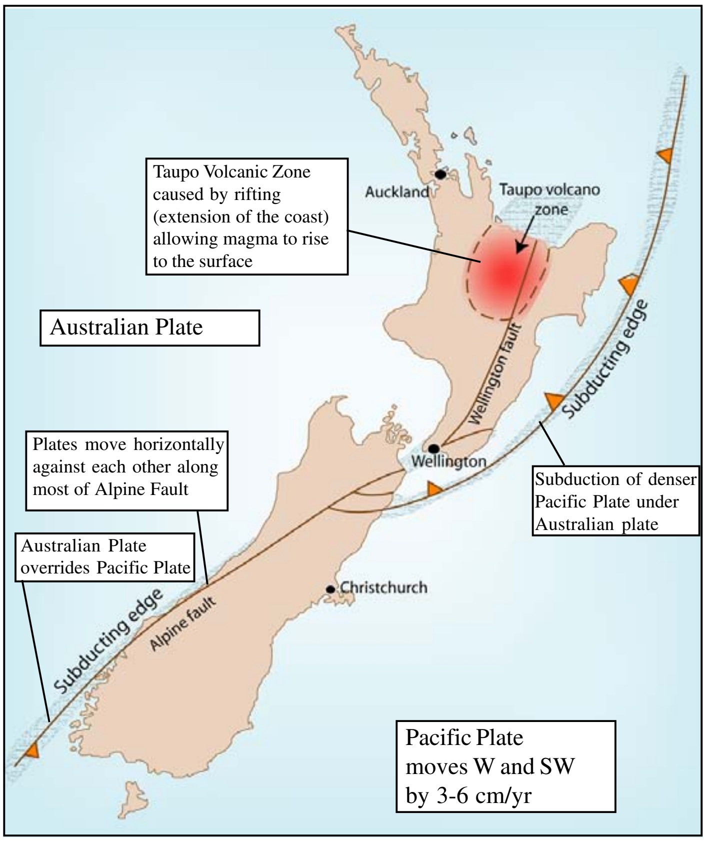
New Zealand sits astride the collision boundary of two of the world's major plates, the Pacific and Australian plates, resulting in a great range of tectonic hazards, namely:

- earthquakes
- volcanoes
- tsunamis
- secondary hazards - landslides, subsidence, liquefaction and flooding

Tectonic setting of New Zealand

Figure 1 shows the plate boundary and major fault systems in North and South Island, along with the most active volcanic zone.

Figure 1 Tectonic setting of New Zealand



Thousands of earthquakes are detected by seismographs each year, but only 100-150 can be felt. Between 1992-2007, New Zealand experienced >30 earthquakes with a magnitude greater than 6.0. Another measure of seismic activity is that Auckland moves relative to Christchurch by 5 cm/yr. Table 1 based on records dating from 1840, shows the expected frequency of earthquakes:

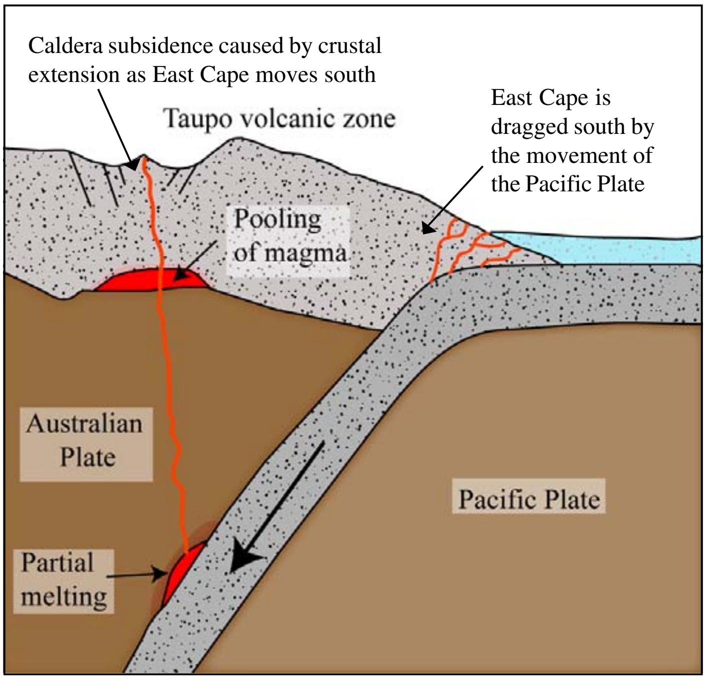
Table 1. Predicted frequency of earthquake events

Magnitude	Expected frequency
6.0	Several per year
7.0	1 in 10 years
8.0	1 in 100 years

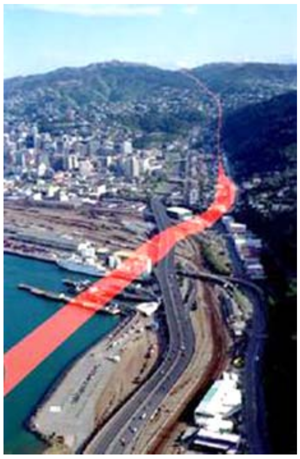
North Island

The Pacific Plate is being subducted along the east coast at a steep angle, underneath the relatively light continental crust of the Australian Plate (Figure 2). This is dragging the East Cape southwards, creating a rift zone further west, known as the Taupo Volcanic Zone, the area of most volcanic activity in New Zealand. Subduction occurs at a rate of up to 6cm/yr.

Figure 2 Pacific plate subduction



The most important fault system running through North Island is the Wellington Fault and New Zealand's capital city, Wellington, sits upon this very active zone. The subduction boundary is 25-30 km beneath Wellington. In 1855, New Zealand's largest historic earthquake occurred here, causing lateral movement of 15 m and 6 m vertical uplift.



The Wellington region was tilted to the west, raising the harbour area 1-1.5 m. It is predicted that the Wellington Fault will experience an 8.0 earthquake in the next 40 years and it will cause 4-6 m horizontal displacement and variable uplift and subsidence due to the complex buckling at the plate boundary.

Image. Wellington Fault (Source: GNS Science)

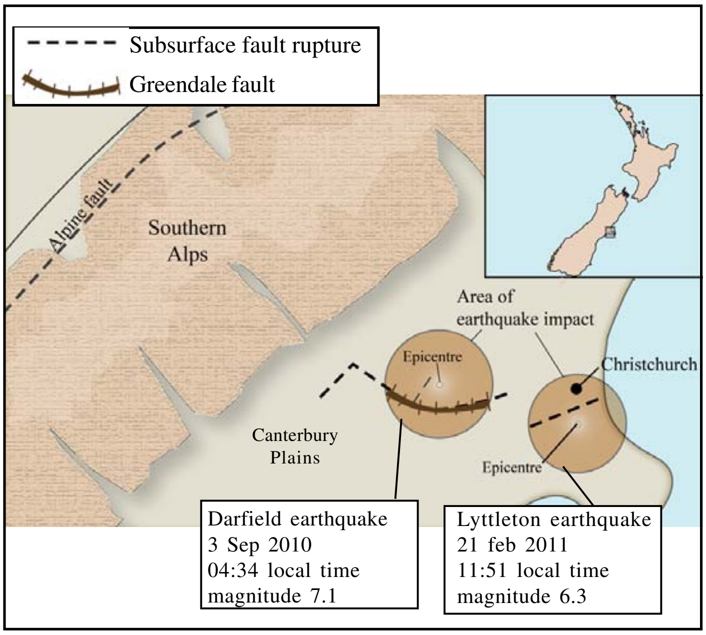
South Island

For most of its length, the Alpine Fault, 600 km long, is a conservative margin, marking the "on land" boundary, and here the Pacific and Australian plates move horizontally against each other. At the southern tip, the Australian plate is being subducted under the Pacific plate, so reversing the action to the north. This means that there are complex buckling motions along one of the world's major tectonic boundaries, which explains the high risk of tectonic hazards and resulting landscapes. Over the past 12 million years, the Southern Alps have been lifted up 20 km, although rapid erosion means that today's highest peaks are below 4000 m. A major rupture (magnitude 8.0) is predicted within 40 years.

The 2010 and 2011 Christchurch earthquakes

Two major earthquakes occurred within 6 months of each other, affecting Christchurch, South Island (Figure 3). Both quakes were along "strong" faults, meaning that the rocks are held together by friction, and the event was more powerful than if rock material had been less consolidated. The earthquake in February 2011 was an aftershock, as it is considered that it would not have happened without the earlier earthquake in 2010. However, neither earthquake in the Canterbury region affected the faulting system in North Island, although some ground shaking was reported.

Figure 3 Two Christchurch earthquakes 2010, 2011



Darfield earthquake, 4th September 2010

On 4th Sept 2010, at 04:34am local time, a magnitude 7.1 earthquake struck the Canterbury region, about 40 km west of Christchurch. It was caused by the rupturing of a previously unknown fault network 10 km below the Canterbury Plains. It created a surface tear of 24 km that was named the Greendale Fault. Not all ruptured faults made the surface but their energy was transmitted along the system underground, adding to magnitude of the event.

No-one had expected an earthquake this close to Christchurch. However, there were no fatalities and the impact was measured in economic damage to buildings and infrastructure. Some land moved 4m sideways in less than a second, and liquefaction was a major problem. There was a 5.1 shock four days later that caused more damage to already weakened buildings, and on Boxing Day, tremors were sufficient to close the main shopping mall.

Lyttleton aftershock, 22nd February 2011

The earthquake struck 5 km from Christchurch's CBD, on a buried fault running east-west through the city, creating a 15 km surface rupture. This earthquake has been named the Lyttleton aftershock.

After the Sept 2010 earthquake, a major aftershock was expected, around 6.0 magnitude, but because it was 6 months later, the probabilty of one occurring had reduced to 25%. At magnitude 6.3, it was less powerful but more destructive than the Darfield earthquake, for various reasons. It was faster than normal earthquakes of this magnitude, with acceleration rates up to four times greater than that of the Japanese 9.0 earthquake in March 2011. This was due to the original rupture being supplemented with new energy 1-2 seconds after the earthquake began, possibly from interconnecting fault systems. Despite monitoring after the Darfield earthquake, there was no evidence that a major aftershock would hit here.

***Exam Hint:-** Use the websites to keep up to date with the further aftershocks*

Factors affecting the impact

1. Intense ground shaking due to:

- the high energy levels released along the fault (x3-4 greater than in September 2010, and x6 greater in eastern suburbs)
- the direction in which the energy was released
- a "slapdown" or trampoline-like interaction between subsurface layers under the city
- the close proximity of the epicentre – 6 km from Christchurch's CBD, compared with 44 km west in Sept 2010
- the shallow depth of the earthquake's focus

2. Geology

The Canterbury Plains consist of loose sediment resting on harder rocks. As the seismic waves travelled along the fault, the upper layers moved further as they were unconsolidated. As the earthquake ended, and the material began to settle under gravity, they hit the harder rock still rising from below, resulting in "slapdown" or a trampoline effect. More energy was then transmitted to the surface, magnifying the event.

3. Liquefaction

As the upper and lower layers separated, the slapping effect released large amounts of subsurface soil water that was forced to the surface. (More discussion under Secondary Hazards; Figure 8). 200,000 tonnes of saturated silt upwelled to the surface, where it flowed as streams. It is estimated there is 9 m depth of liquefiable material under Christchurch and during the September event, past known areas of susceptibility were activated. In the February 2011 event, liquefaction was widespread but when vibrations stopped, solidity returned. Some areas in the eastern suburbs will not be used for rebuilding.

Impacts

The death toll was 182, covering 15 nationalities, due to the collapse of the TV station where an English language school was based; 94 bodies were recovered from this building. It was the second deadliest event after the Hawke's Bay earthquake in 1931. The focus was in the SE suburbs where the land was raised 50 cm. However, in the city centre there was subsidence caused by liquefaction as well as deformation after crustal fracture. 80% of the water and sewage systems were destroyed. A national state of emergency was issued, lasting 5 days. A full Emergency Plan was in action within two hours, coordinated by the National Crisis Management Centre in Wellington. In the immediate aftermath, rescue teams across the world arrived to help search for survivors, but the last person to be rescued alive was found just 24 hours after the event.

Post-earthquake response

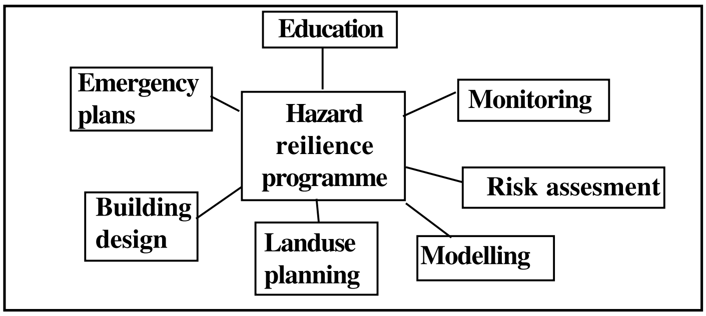
Rescue changed to response after a week. In March, the Canterbury Earthquake Recovery Authority (CERA) was set up for 5 years to oversee the reconstruction. The estimated cost of repairs is expected to reach £8 billion. The interest rate was cut to deal with damage and this led to a fall in the value of NZ dollar.

Despite following building codes for a 1 in 500-year event, 10,000 buildings needed to be demolished, and 100,000 repaired. (It was estimated the earthquake was more than a 1 in 2500-year event). Therefore medium term temporary housing units were set up on the Racecourse and the Agricultural Park. Schools and universities were disrupted but many children were re-enrolled in schools across the country, especially where families had second homes.

New Zealand, being a developed nation, has a well-developed hazard resilience programme, known as the Natural Hazards Platform, set up in 2009. The main players are GNS and NIWA, both leading research institutes, as well as several universities and consultants.

The data collected since September 2010 has been used to improve the many elements of this programme (Figure 4).

Figure 4 Components of a hazard resilience programme



Monitoring of aftershocks has enabled the hidden or "blind" faulting pattern to be mapped, so predictions as to the frequency, magnitude and spatial distribution of future earthquakes can be improved. This information will inform city planners as to the best areas for future development and other landuse decisions.

Volcanoes

As the subducting plate slides down into the earth's hot mantle, the crustal rocks are heated and water and other volatile elements are boiled off. The chemical effect of this water is to lower the melting point of rocks in the solid mantle above the subducting plate, allowing magma to form. This buoyant molten rock rises to the surface and erupts to form volcanoes.

Volcanic activity is confined mainly to North Island (Figure 5). This is due to rifting, or extension of the crust, where blocks of crust are forced apart by uprising magma, allowing volcanoes to form at the surface. The Taupo Volcanic Zone has been the most active zone in New Zealand for the last 1.6 million years and is one of the most active in the world. Hot springs are common in South Island but are not in any way connected to earthquake activity. Although the probability of an eruption affecting a large area is relatively low in any one year, historical records show that volcanic eruptions, as a hazard type, have caused most deaths.

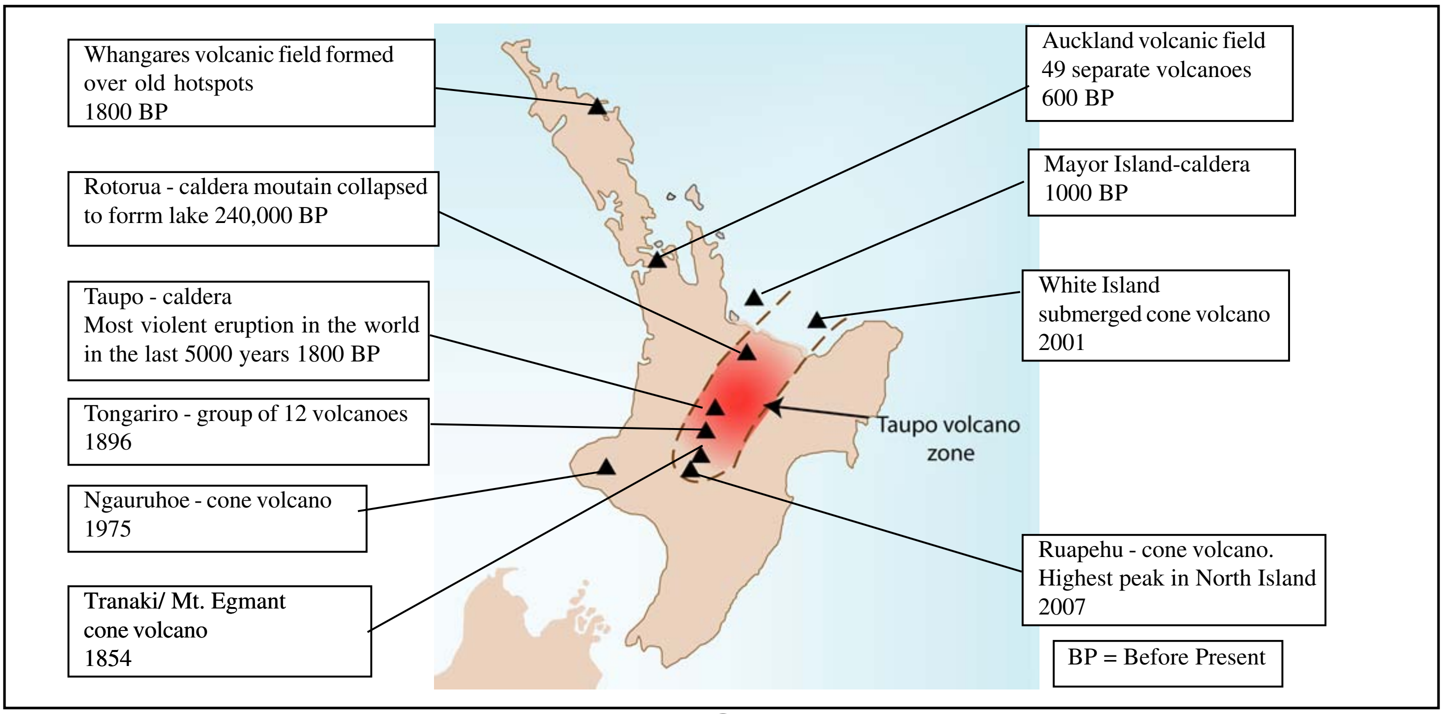
Three types of volcano can be found in New Zealand:

- Volcanic fields – these are areas of gentle, low-frequency eruptions, forming single volcanoes that never erupt again eg. Auckland Volcanic Field
- Cone volcanoes- also known as composite cones or stratovolcanoes - can erupt successively over time, building up lava deposits into a cone eg. Ruapehu, Taranaki
- Caldera volcanoes – these are the most violent type of eruption and when they occur, can create calderas 10-25 km wide and deposit ash and pumice over large areas.

Potential hazards associated with volcanic activity

- Ash falls
- Pyroclastic flows
- Lava flows
- Lahars
- Landslides
- Volcanic gas emissions
- Tsunamis
- Hydrothermal eruption
- Electrical storms

Figure 5 North Island volcanoes



Monitoring of volcanoes

Monitoring of volcanic activity is standard practice in developed countries such as New Zealand, based on the data supplied by fixed instrumentation.

- **Ground Deformation**
  As magma moves upwards and forces itself into crevices and pore spaces, it causes displacement that can be measured accurately with GPS.
- **Chemical analysis**
  Magma releases gases as it nears the surface, so samples are taken at fumaroles, where emissions occur. The % composition of gases gives vital information about the state of the magma below. Release of gas can set up volcanic tremors that are measured. If fumaroles occur on a lake-bed, then water samples are taken, such as at Ruapehu.
- **Seismic monitoring**
  Thousands of small earthquakes are detected each year using seismographs and there are extensive networks of instruments to detect tremors.

Tsunami

New Zealand is at risk from tsunamis, and they can occur due to several reasons:

- They require a shallow offshore earthquake (but within 100km of the coastline) with a magnitude greater than 7.5 and with vertical displacement.
- New Zealand has also experienced tsunamis created by large submarine or coastal landslides caused by earthquakes.
- Large earthquakes may cause waves on a lake, known as **seiches** that can flood lowlying lakeside areas, as well as travelling down rivers and causing flooding downstream; for example the1885 Wairarapa earthquake and flooding of Wellington harbour.

Whilst the coast is well-instrumented for recording such events, there is not a warning system for a tsunami created close to shore. Tsunami-risk from elsewhere in the Pacific is transmitted by the Pacific-wide international warning system.

Secondary hazards

Landslides

Table 2 Landslides within the Southern Alps, South Island

Event	Date	Impact
Green Lake landslide	13,000 B.P.	Possibly the world's greatest landslide. Rock slippage of 26 km^3 due to collapse of 10km of Southern Hunter mountain. It created a major lake which has since been infilled
Falling Mountain rock avalanche triggered by Arthur's Pass earthquake	1929	55 million m^3 rock moved 4.5km down valley
Abbotsford landslide	1979	Destroyed 63 houses in South Dunedin
Summit of Mt Cook	1991	12 million m^3 rockslide, lowering the summit by 10 m. Created a 3.9 earthquake.

New Zealand experiences a high frequency of landslides, the most dangerous being deep-seated ones, due to:

- its location on an active plate boundary
- easily eroded young (tertiary), soft sedimentary rocks
- steep slopes in mountainous areas
- high rainfall, often in storms
- glacial retreat, with many unconsolidated sediments.

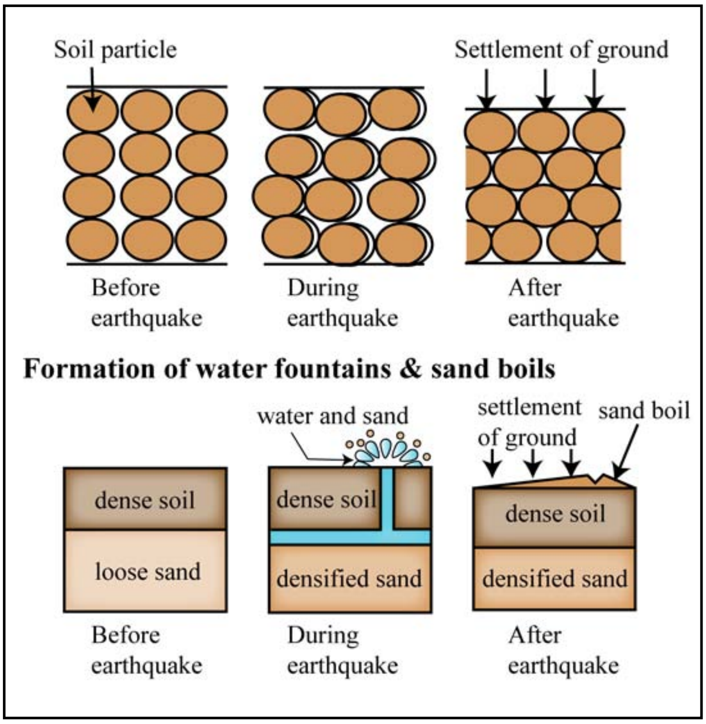
Subsidence

Subsidence occurs when tectonic activity causes downward vertical displacement of a block of land on one side of a fault, and can affect very large areas. Permanent flooding has occurred in the past in coastal areas. It is closely linked with liquefaction, where ground shaking causes loose sediments to settle or slump as subsoil water is released.

Liquefaction

Liquefaction occurs when soil particles are rearranged and pore spaces collapse, resulting in compaction and water is forced out and up to the surface (Figure 6). This creates surface features such as sand boils and surface cracks. Depending on the % water content and slope angle, liquid soil can begin to flow downhill, similar to river channels.

Figure 6. The process of liquefaction



This weakens the load-bearing capacity and buildings are undermined as their foundations become more fluid. They either sink or tilt, and underground pipes get forced upward and crack. It was a major factor in the Christchurch earthquakes because the city is built on an alluvial plain i.e. silts and clays deposited by rivers and containing a high water content.

Summary

Therefore New Zealand can continue to expect major earthquake and volcanic activity, along with associated geological hazards. The organised response to the recent earthquakes was described as the best ever. Whilst this increases the rescue, recover and mitigation capabilities, the forces of nature show that ultimately, the only way to avoid major catastrophes is to avoid known active tectonic zones.

References

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