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91191



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Mana Tohu Mātauranga o Aotearoa  
New Zealand Qualifications Authority

## Level 2 Earth and Space Science 2025

### 91191 Demonstrate understanding of the causes of extreme Earth events in New Zealand

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of the causes of extreme Earth events in New Zealand.	Demonstrate in-depth understanding of the causes of extreme Earth events in New Zealand.	Demonstrate comprehensive understanding of the causes of extreme Earth events in New Zealand.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

**You should attempt ALL the questions in this booklet.**

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

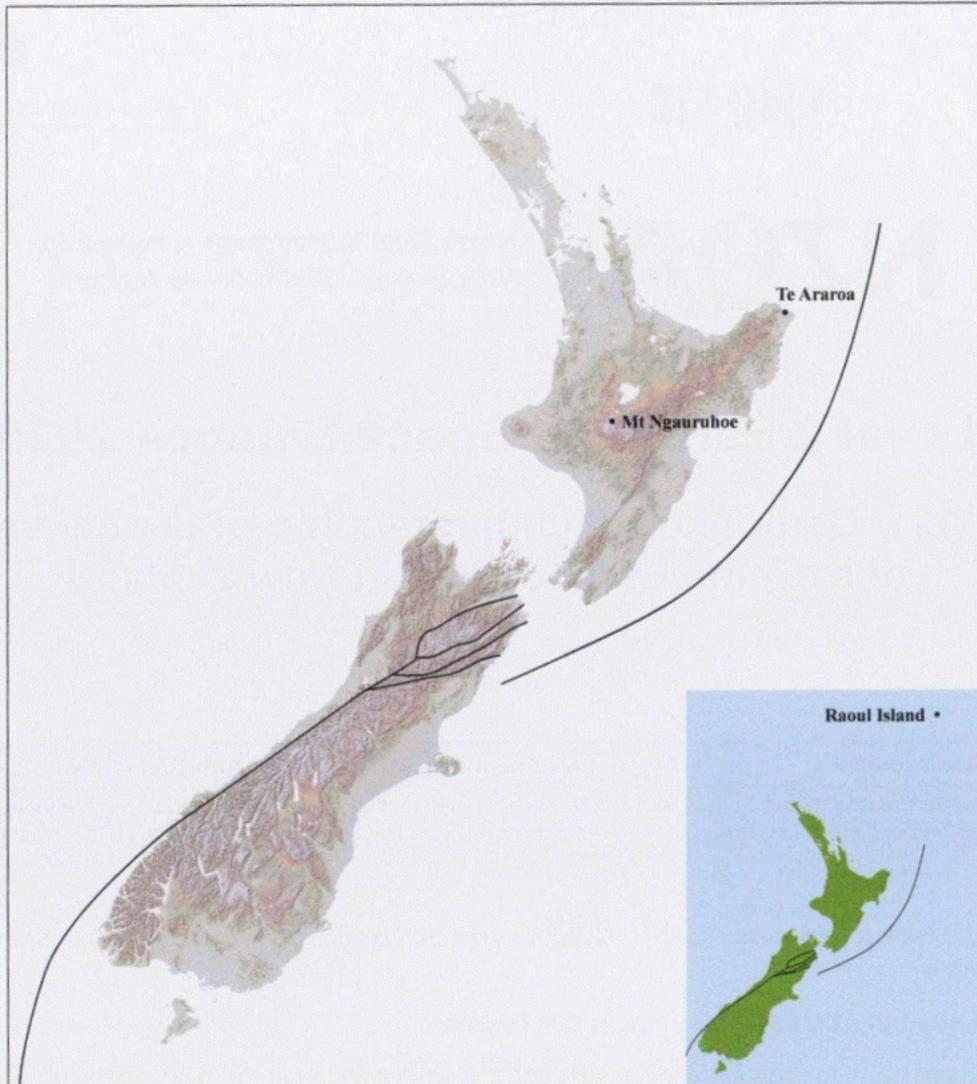
Do not write in any cross-hatched area (X/X). This area will be cut off when the booklet is marked.

**YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.**

Excellence

TOTAL 20

Regional map showing locations referred to in this paper



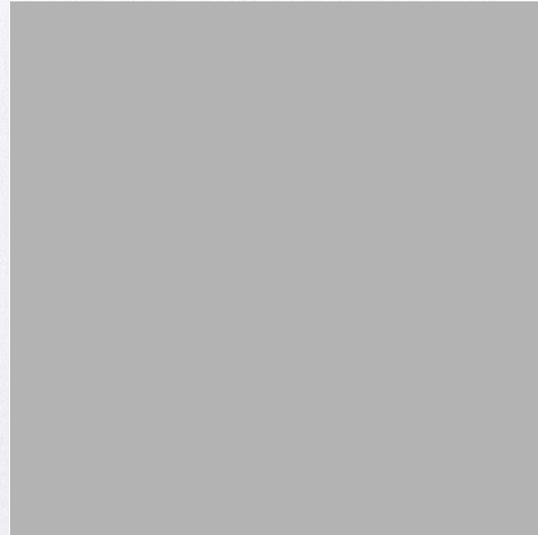
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The assessment begins on the following page.**

### QUESTION ONE: MT NGAURUHOE

Mt Ngauruhoe is the youngest, largest, and most active cone of the much larger Tongariro volcanic complex in the central North Island of New Zealand.

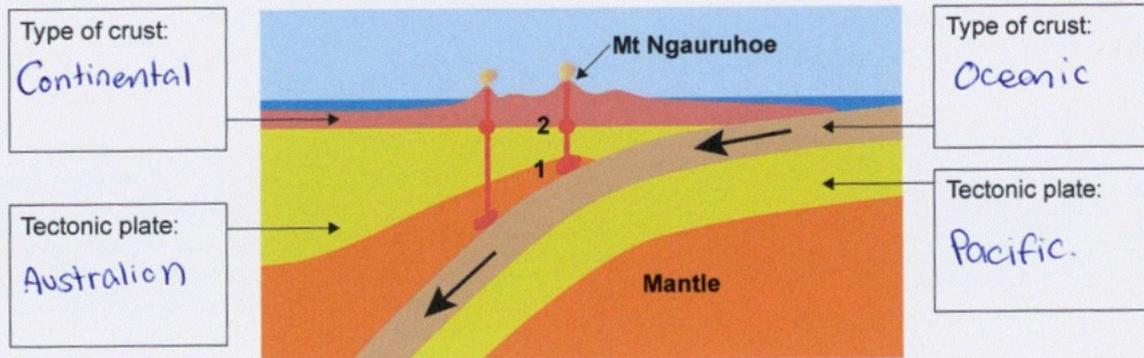
Mt Ngauruhoe formed approximately 7000 years ago, and is an andesitic stratovolcano.

More than 60 eruptions have been recorded since written records began in 1839; many of these were ash eruptions, while some have been lava flows, with the last occurring in 1975.



Source: [www.gns.cri.nz/assets/Our-Science/Subfiles/Natural-Hazards-and-Risks/Subfiles/Volcanoes/Volcano-Fact-Sheet-Ngauruhoe.pdf](http://www.gns.cri.nz/assets/Our-Science/Subfiles/Natural-Hazards-and-Risks/Subfiles/Volcanoes/Volcano-Fact-Sheet-Ngauruhoe.pdf)

- (a) Label the diagram to name the tectonic plates involved in this area of the North Island and identify the type of crust (continental or oceanic).



- (b) Explain, in detail, how tectonic processes led to the formation of andesitic magma.

In your answer you should consider:

- the map on page 2
- the labelled diagram in part (a)
- the key tectonic processes involved at 1 and 2 on the diagram above.

Tectonic plates are moved together by convection currents. Convection currents are when magma deep in the mantle is heated by the core - gaining kinetic energy which causes the <sup>particles</sup> to move faster and spread out - making the material less dense. This material then rises where it gets further

away from the heat source. There it cools - making the particles ~~less dense~~ <sup>slow down</sup> and clump together - which means the material becomes ~~less~~ denser so it sinks down again. This constant flow of magma in circular motions is what moves the tectonic plates together. In the north island - convection currents move the plates together (convergent boundary.) The denser pacific (oceanic crust) plate subducts under the less dense Australian (continental crust) plate. Once subducted, heat + pressure squeezes water out of the oceanic crust. This water lowers the melting point of surrounding magma in the mantle - causing ~~them~~ <sup>it</sup> to melt, becoming less dense than its surroundings, and rising towards the crust. Once risen, the hot basaltic magma then melts the continental crust above it and mixes in with this melted crust. As a result, Andesitic magma is formed.

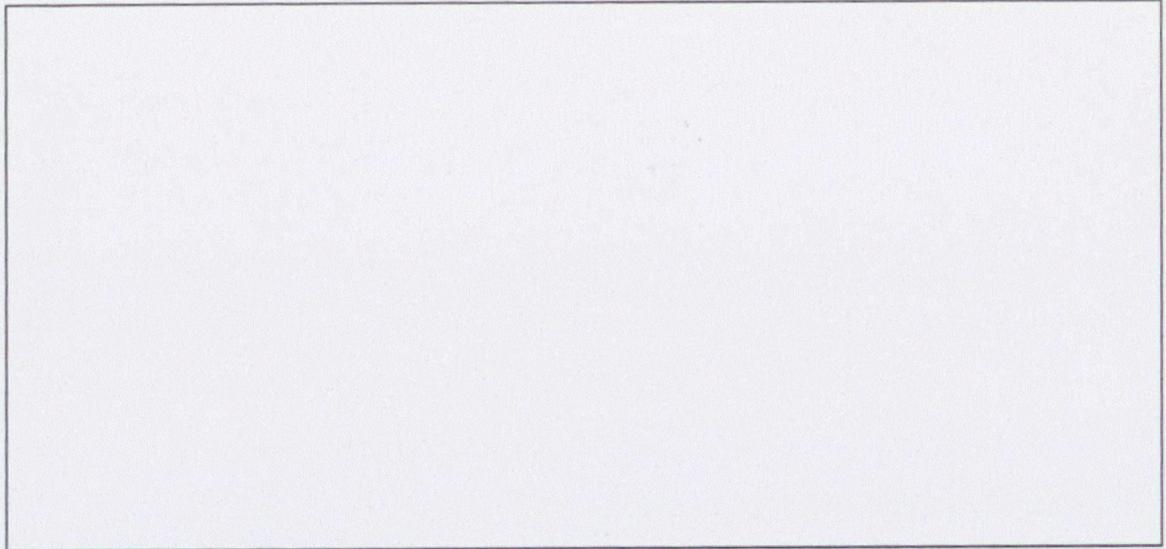
(c) Mt Ngauruhoe is an andesitic stratovolcano.

Explain, in detail, how andesitic magma leads to the formation of a stratovolcano.

In your answer you should consider:

- the characteristics of andesitic magma
- the type of eruptive products produced by Mt Ngauruhoe
- how layering and magma composition link to the shape of Mt Ngauruhoe.

*An annotated diagram may assist your answer.*



Andesitic magma ~~to~~ has an average silica content - leading it to be ~~an~~ averagely viscous (in between very runny and very thick) its silica content also means that it traps a medium amount of gas bubbles so it is <sup>reasonably</sup> explosive. Mt Ngauruhoe is an ~~andesitic~~ stratovolcano ~~am~~ which erupts andesitic magma. Stratovolcanoes can erupt multiple times. Each eruption, they leave behind ~~layers~~ <sup>of</sup> two layers which affect its shape. The first layer is the dried lava rock. Andesitic magma is not runny so it does not travel far before cooling like basaltic magma.

Instead, the lava rock cools <sup>it</sup>  
~~and~~ forms <sup>^</sup> a steep, cone like mountain shape.

The second layer is the leftover ash and debris from the eruption. One of the eruption ~~for~~ products of stratovolcanoes are pyroclastic flows, which are dense clouds <sup>come out of the volcano</sup> of ash and rock that rise ~~and~~ fall quickly <sup>during</sup> ~~and~~ after eruption. Pyroclastic flows are dense, so they are pulled back towards the ground <sup>by gravity</sup> quickly after an eruption. They cover the ~~lava~~ volcano in ash, leading to the second layer of the strato volcano being created.

These layers of hardened lava rock and leftover ash slowly build up ~~over~~ the course as the volcano erupts more.

This gives stratovolcanoes - like Mt Ngauruhoe their steep cone shape.

## QUESTION TWO: 2021 EAST CAPE EARTHQUAKE AND TSUNAMI

On 5 March 2021, a magnitude 7.2 earthquake at a depth of 33 km, struck 124 km east of Te Araroa, on the East Cape of the North Island.

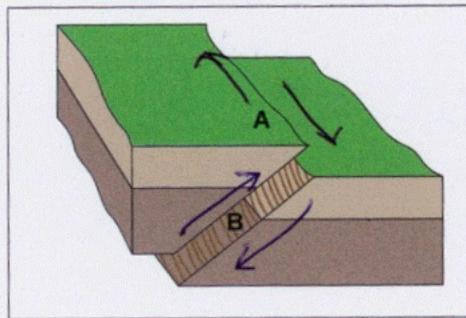
Large parts of the East Cape and Hawkes Bay were pushed 1 cm to the southwest.



- (a) An oblique reverse fault caused this earthquake.

Describe what a fault is AND add arrows to the diagram below to show the movement that occurred along the fault at positions A and B.

A = ~~Oblique~~ Strike-slip Fault  
 B = Reverse Fault.



- (b) The earthquake was reported as felt by over 52 000 people from across New Zealand, but no damage was reported.

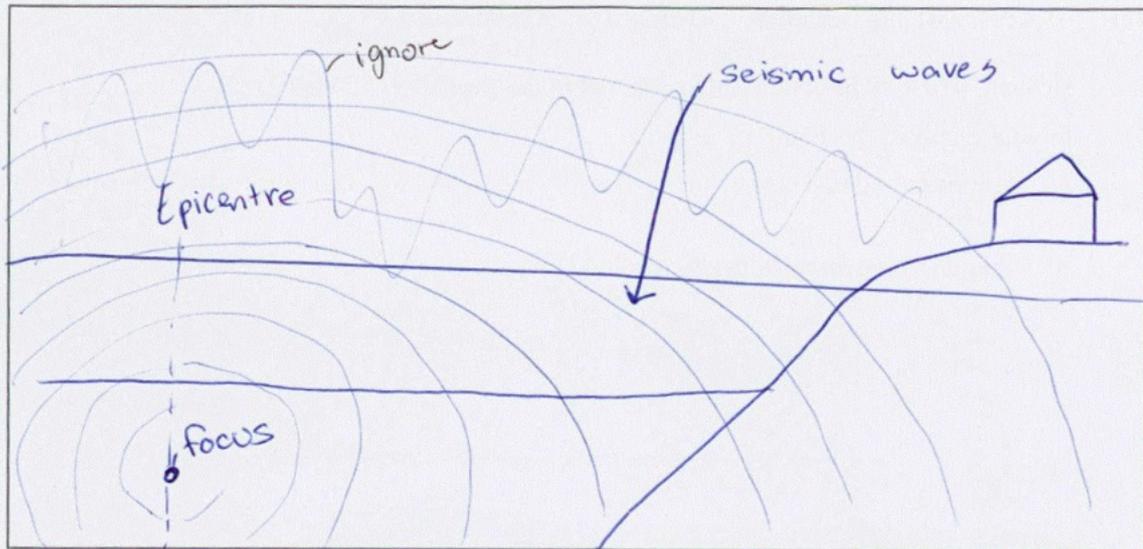
Explain, in detail, why this earthquake was felt by so many people across the whole country, yet no damage was reported.

In your answer you should:

- explain what is meant by the focus and epicentre of an earthquake
- describe seismic wave movement from the focus and epicentre
- explain the links between energy, seismic wave movement, and damage caused by an earthquake.

*An annotated diagram may assist your answer.*

Despite the East Cape earthquake being felt by many New Zealanders, it was not destructive. This is due to the focus and location of the epicentre. The focus of an



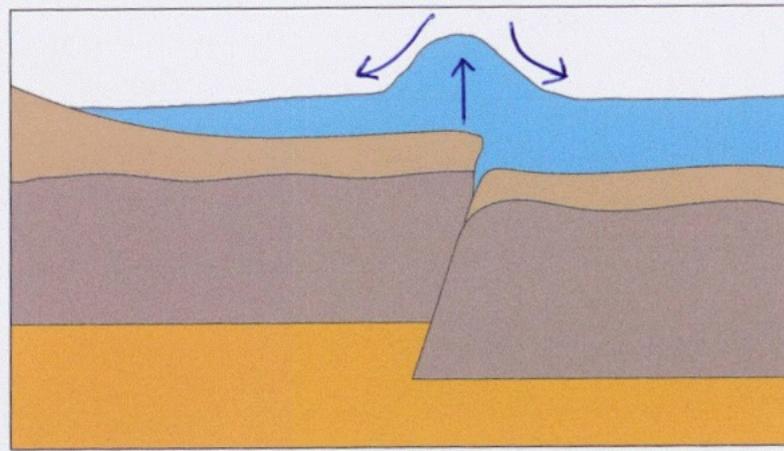
Earth quake is the exact point <sup>in the crust</sup> where the energy is released. In this case the <sup>deep</sup> focus of the Earthquake is 33km, which is neither deep nor shallow. Because of this, when the energy is suddenly released as seismic waves - there is a decent amount of energy ~~lost~~ <sup>from</sup> the waves lost to rock before reaching the surface. Aswell as this, the epicentre is also located 124 km away from the nearest town - Te Araroa. This means that the waves had to travel through lot's of rock before they reached civilisation - and by then a lot of energy had been lost. Despite these two reasons the magnitude of the earthquake was high which explains why the earthquake was felt throughout NZ. However the depth and faraway location of the epicentre means that when the waves reached town, they were not concentrated enough to cause damage.

(c) As a result of this earthquake, a tsunami was produced.

Explain, in detail, how this earthquake led to the formation of a tsunami.

In your answer you should:

- annotate and add arrows to the diagram below to show how the crustal movement caused a tsunami
- explain the energy transfers involved.



An earthquake is a sudden shaking of the ground due to a release of strain at a fault\*. In this case, <sup>Elastic potential</sup> energy was released <sup>as kinetic energy</sup> when the reverse oblique fault slipped. The fault occurred out on the coast, meaning that when it slipped - the reverse fault pushed upwards displacing the water above it. Kinetic energy ( $E_k$ ) was transferred from the fault to the water, causing it to jolt upwards. Gravity then pulled the water ~~back~~ back down causing ~~it~~ to ripple the energy to ripple out through the water in

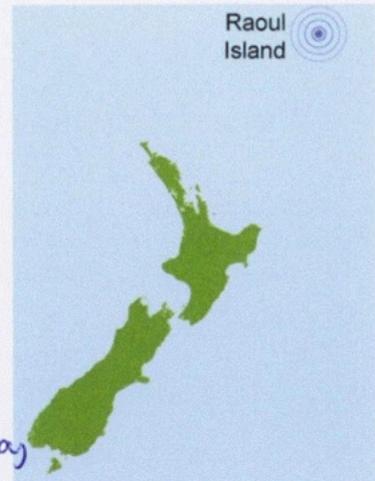
all directions at extreme speeds.

\* Adding on to the earthquake part:  
At a fault, rocks strain against each other due to their rocky, uneven surfaces. These surfaces have friction ~~that~~<sup>against</sup> one another meaning that instead of sliding past each other smoothly they stay in place and build up strain and elastic potential energy ( $E_p$ ). The elastic rebound theory states that as the rocks grind past each other, they will slowly deform in shape. However eventually the strain will overcome the friction and the ~~to~~  $E_p$  will be released as  $E_k$  quickly and the rocks will then ~~be~~ jolt forward before returning to their regular shape.

### QUESTION THREE: RAOUL ISLAND

On 5 March 2021, a few hours after the East Cape earthquake in New Zealand, two earthquakes occurred in the Raoul Island area, northeast of New Zealand; the first a magnitude 7.3, and the second a magnitude 8.1.

The magnitude 8.1 earthquake was the result of a megathrust earthquake along the subduction zone in the Kermadec trench.



- (a) Describe a tsunami wave.

In your answer you should consider the water column.

A tsunami is a giant wave due to a sudden displacement of a column of water caused by an underwater disturbance. E.g. volcanic eruption, earthquake or a landslide.

- (b) Both earthquakes led to tsunami warnings being issued throughout the Pacific.

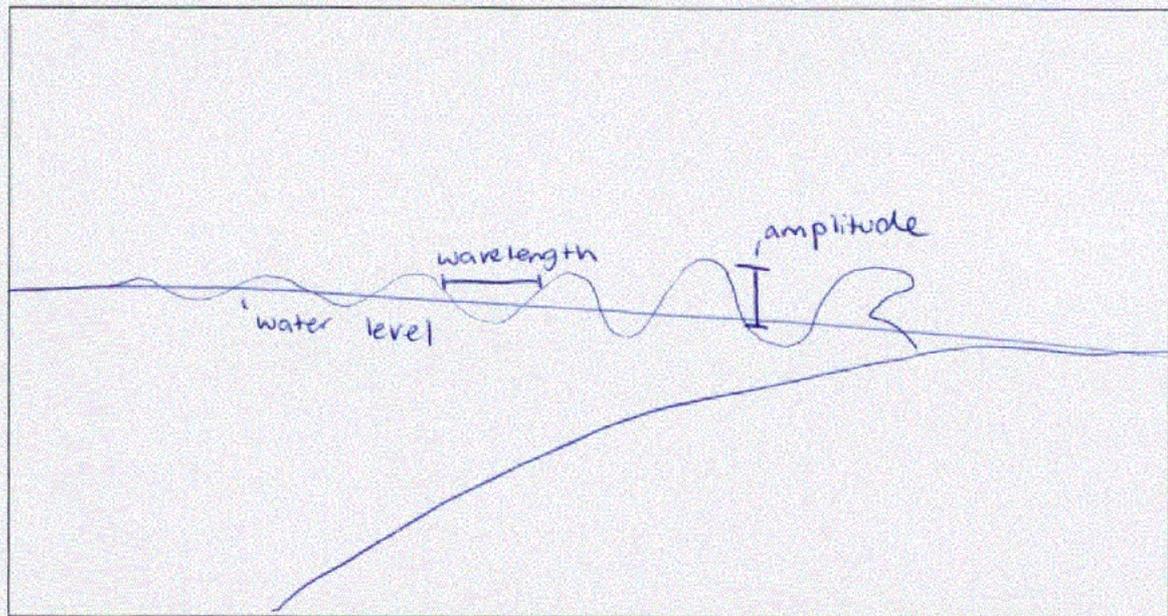
Explain, in detail, why this megathrust earthquake led to tsunami warnings being issued throughout the Pacific.

In your answer you should consider:

- how tsunami travel in open ocean
- changes to the height (amplitude), wavelength, and speed of the tsunami wave as it approached New Zealand's coastline, and the reasons for this.

An annotated diagram may assist your answer.

Initially when in the deep ocean, tsunamis travel at very high speeds (up to 800 km/h) with a small amplitude ~~height~~ and long wavelength. As the depth of the ocean gets shallower when the tsunami starts approaching land, the energy that is being transferred through the water is compressed. This causes the amplitude to increase significantly.



and the wavelength to decrease. The speed will also slow as it approaches shore. This makes tsunamis more of a threat to civilisations throughout the Pacific as the large amplitude means that the run-up height and inundation of the tsunami will be greater - imposing more of a threat to their ~~their~~ communities.

Question Three continues  
on the next page.

- (c) Raoul Island is the largest of the Kermadec Islands. The island is the summit of a mostly submerged volcano that has two caldera craters formed after previous eruptions.



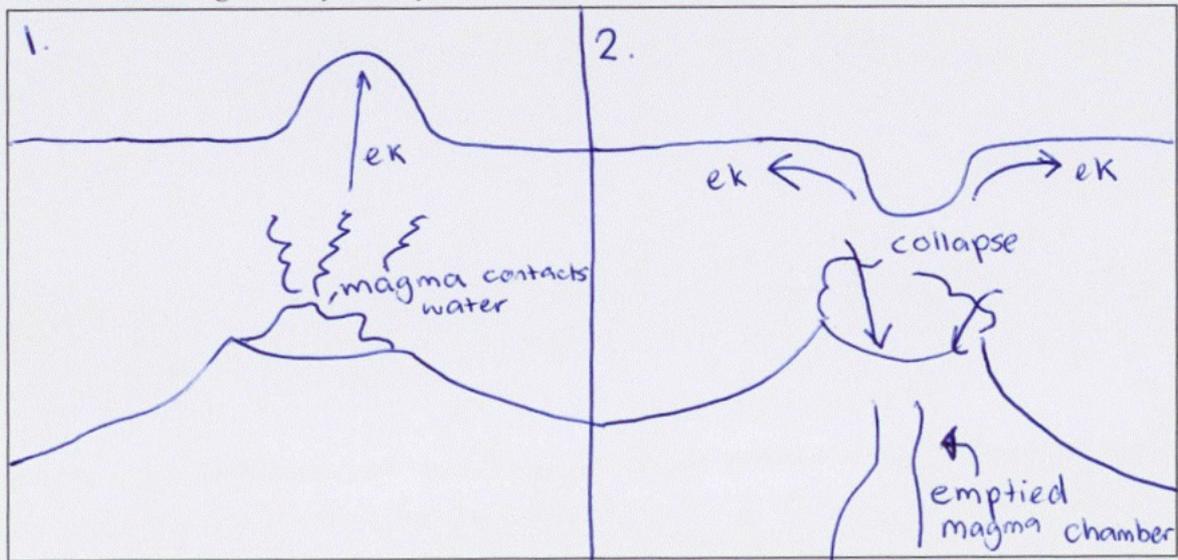
Adapted from: <https://www.geonet.org.nz/about/volcano/kermadecislands>

Explain, in detail, the tsunami risk associated with a caldera eruption from a volcano like Raoul Island in the Pacific Ocean.

In your answer you should consider:

- the stages of eruption for a typical submerged caldera volcano
- the different ways a caldera eruption can cause a tsunami.

An annotated diagram may assist your answer.



Caldera volcanoes erupt rhyolitic magma, which is high in silica and very viscous. Because this magma is viscous, it also traps a lot of gas bubbles, resulting in explosive eruptions. When the hot magma from the mantle contacts water, a reaction happens between them.

giving it Ek energy  
so the particles move  
apart

The magma instantly heats up the water, making it less dense so it rises quickly to the surface. This quick rise of water results in a displacement, which is <sup>then</sup> pulled down by gravity resulting in the energy being given off through the water in all directions - ultimately resulting in a tsunami. Another way that a caldera eruption can cause a tsunami is when it collapses in on itself. Once erupted, the thick magma ~~dries~~ does not travel far due to its viscosity. It dries in a blob on top of the emptied magma chamber. Because the magma chamber is empty there is nothing supporting the dried magma from underneath. As a result the <sup>heavy</sup> dried magma <sup>causes the volcano to</sup> collapses forming the large caldera crater. As the volcano collapses, water from above is displaced downwards. From there, energy is repelled out from that ~~displaced~~ displacement, once again causing a tsunami.



## Excellence

**Subject:** L2 Earth & Space Science

**Standard:** 91191

**Total score:** 20

Q	Grade score	Marker commentary
One	E7	The candidate was awarded an E7, as in part (c) they comprehensively explained the characteristics of Andesitic magma and how they influenced the formation of Mt Ngauruhoe. E.g. the medium viscosity magma trapped some gas, leading to a medium explosive eruption that produced alternating layers of ash and lava. Due to its medium silica content, which results in medium viscosity, the lava does not travel very far before it cools. Part (b) answer could be strengthened by linking friction to the melting of the crust and explaining that water lowers the melting point, which aids the melting of the crust. The candidate could also include the melting of the Australian plate, adding silica to the magma.
Two	E7	The candidate was awarded an E7, as in part (c), they comprehensively explained the transfer of energy from the plate (Elastic potential energy) to displace the water, which was brought down by gravity, and transferred to kinetic energy, moving water in all directions. To reach an E8, the candidate could have explained that very little energy is lost in the formed tsunami. Part (b) answer could be reinforced by clearly stating that energy from the earthquake moves in all directions and clarity around, if the earthquake was shallow or deep, or the type of seismic waves released.
Three	M6	The candidate was awarded an M6, as in part (b), they explained in-depth how the tsunami behaves in the shallows by the water slowing down, decreasing in wavelength and increasing in amplitude. However, in the deep ocean, the candidate has not indicated why the tsunami can reach high speed, long wavelengths and small amplitude, such as very little energy is lost. Part (c) alluded to a phreatomagmatic eruption, allowing for water to be displaced. Clarity that gas was produced or water was evaporated would reinforce the answer. Also, the candidate did state that the caldera collapses but not linked to the weight of water.