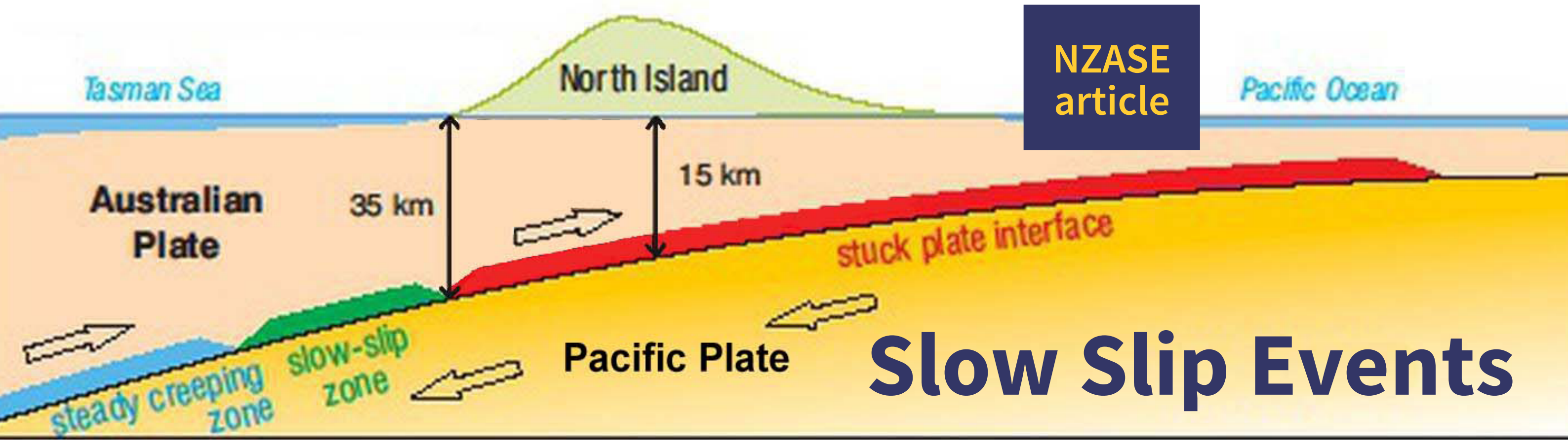


The interface of the Australian and Pacific plates beneath the southern North Island, viewed from Raukawa Moana/ Cook Strait. Image: Courtesy GNS.

NZASE article

Slow Slip Events

Aotearoa New Zealand sits on the boundary of two large tectonic plates, the Pacific and the Australian. Te Ika a Maui / the North Island sits on the Australian plate, with the Pacific plate meeting it and descending underneath. Over the last 20 years scientists have come to realise that where these two plates meet, instead of moving past each other, they are 'sticking' together. This can cause seismic events called Slow Slip Events or SSE.

Māori have stories and pūrākau related to historical events in Te Tai Rāwhiti/the East Coast. These, with evidence of tsunami occurring before the written record, build a picture of the pattern of seismic events in the area.

What are Slow Slip Events?

In a slow slip event (SSE) the plates become unstuck, causing tremors so tiny they are hard to detect, so-called 'silent earthquakes'. In an SSE the plate boundaries move past each other, millimetres at a time over weeks to months. The total movement would be the equivalent of a magnitude 6+ earthquake, but in SSE it happens over many weeks, not all at once.

These slow slip events tend to occur just below the area of the plate interface that is 'stuck', relieving some of that stress. Dozens have been detected in the country since 2002, typically occurring at least once or twice a year. We now know that they are part of the normal behaviour of our subduction zone.

Where do SSE occur?

The Pacific plate meets the Australian plate in the Hikurangi trench. Below this point the Pacific plate is descending into the mantle under the Australian plate – the Hikurangi Subduction Zone. This interface runs from one coast to the other under Te Ika a Maui. At the Hikurangi margin, SSE occur at a shallow depth (<10km), and last for two to six weeks. On the western side of the island, Manawatu-Kapiti SSE occur at 30-40km below the plate surface, and last one to two years.

These SSE are occurring at predictable intervals. SSE were recorded off the east coast near Pōrangahau in 2006, 2011 and 2016. Expecting another this year, scientists placed instruments to record it. A two-week event started on May 23, and sensors recorded the land moving 2cm eastward. The SSE also coincided with a series of small earthquakes around the region – the largest being a magnitude 4.2 shake on May 30.

While SSE occurred around every five years at Pōrangahau, further up the coast at Tūranga-nui-a-Kiwa/Gisborne, they happened every one to two years. An SSE also began near Gisborne this year on June 14 and caused 2cm of movement. A cluster of about 60 small earthquakes were recorded north of Gisborne, the largest being 4.2 on June 16.

The plate tectonic boundary, rate and direction of plate movement; red barbs show the area of subduction. University College, Cork, Ireland.

At the plate boundary further south, Kaikōura experienced a 7.8 magnitude earth-quake in 2016. This led to thousands of after-shocks, and also triggered three slow-slip events in the Hikurangi subduction zone, each lasting several weeks. In total they released energy equivalent to earthquakes of about M_w 7.1.

A house at Pouawa, just north of Gisborne, destroyed by a tsunami on March 26, 1947. Seaweed was left hanging in the power lines, top right. Photo: Harold J Dunstan, NZ Free Lance. PAColl- 0785-1-159-01, Alexander Turnbull Library.

Why are SSE important?

Stuck tectonic plates can cause huge earth-quakes if that tension is released all at once. Subduction zones where slow slip events occur are responsible for generating the world's largest earthquakes – mega-thrust earthquakes – which have a magnitude greater than 8. These earthquakes can produce tsunami with deadly consequences, such as in Japan in 2011 and Sumatra in 2004. We now know that SSE occurred in the same location a month before the 2011 tsunami in Japan (Ito et al., 2013).

The evidence suggests such a large earthquake is possible in the Hikurangi Subduction Zone. It would severely damage nearby areas and could produce a significant tsunami affecting much of the coast of Aotearoa, as well as our Pacific neighbours. We have already had at least one significant tsunami. In Gisborne in March 1947, an earthquake registering 5.9 on the Richter scale generated a large enough tsunami to destroy homes and a bridge, and leave seaweed in telegraph wires 12m above sea-level.

When Māori arrived in NZ, many iwi settled on the coast. Oral traditions talk of some of these coastal villages being swept away by huge waves, for example, at Taporapora at the Kaipara river mouth, on Rangitoto/D'Urville Island in the Marlborough Sounds, and on Motiti Island off Tauranga. Evidence of the types and placement of sediments in local rock strata suggest these three may have been tsunami.

Scientists are studying SSE in our waters. Dr Laura Wallace leads a group of seismologists from the USA, Japan, and New Zealand in the Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS), in the biggest experiment of its kind.

Laura Wallace says "understanding the timing and likely location of a large subduction zone earthquake can only happen by first solving the mystery of slow slip events. The more we know about SSE, the more we understand the subduction zone as a whole, and ultimately the better prepared we can be."

Finding out about SSE

The Hikurangi Subduction Zone, one of our largest geological hazards, is ideal for studying slow slip quakes, because they are shallow enough to be imaged at high resolution.

Movement caused by these SSE happens so slowly and over such small distances, that they are undetectable by both humans and seismographs. So to measure these tremors on land GNS uses positioning system (GPS) equipment installed across the country.

To detect vertical movement of the seafloor in millimetres, scientists use absolute pressure gauges. These measure the pressure water exerts on the seafloor below. If the sea floor goes down, there's more water above so pressure increases; if the seafloor rises, there's less water above so pressure decreases.

While they can't detect the tremors, seismometers can be used in a different way. A large array of seismometers off the southern Hawke's Bay coast enables scientists to create 3D pictures similar to CT scans. This seismic tomography imaging allows geoscientists to visualise the interface between the Pacific and Australian tectonic plates to help understand

A device including an ocean bottom seismometer and an absolute pressure gauge is checked before being dropped to the sea floor, as part of the HOBITSS experiment. Photo: Erin Todd.

what is happening underground. The results show how weak the fault has become and where pressure is being felt within the plate boundary.

Off the coast of Tūranga-nui-a-Kiwa/Gisborne, scientists have used marine electromagnetic methods (more like an MRI scan), to provide a different image of the seafloor. Differences in electrical conductivity shows that local seamounts (undersea volcanoes) store large amounts of water. As the seafloor dives under the trench, these seamounts are fed into the subduction zone. Subducting seamounts may be involved in SSE and were probably the cause of the 1947 Gisborne earthquake.

"Slow slip events are a great reminder that we live on a very active tectonic plate boundary in New Zealand," Wallace says.

Possible classroom activities

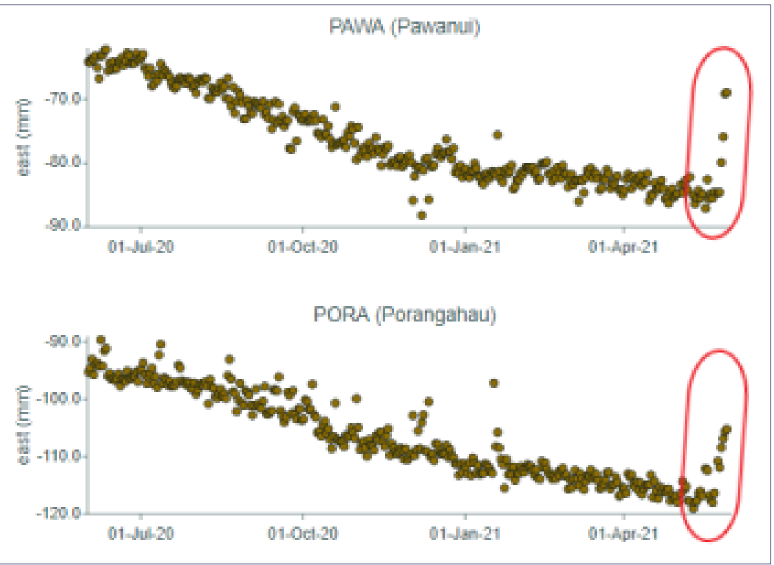
- Distinguish between the Hikurangi trough, Hikurangi Subduction Zone and Hikurangi margins.
- Why is it important for us to understand the Hikurangi Subduction Zone?
- Look at the whole plate boundary on the map. How does movement on the two subduction zones differ? What is between the two zones?
- Find out more about the marine electromagnetic methods and seismic tomography.
- What does Civil Defence advise about earthquakes and tsunami? How does everyone know this?
- Find out more about the March and May 1947 earthquakes in Gisborne.
- 5.9 is not a megathrust earthquake and yet it caused a large tsunami. Find out more about these so-called tsunami earthquakes.
- In some references the March 1947 Gisborne earthquake is recorded as 5.9 M_L. GNS record it as 7.2 M_W. Elsewhere it is given as 7.1 M_S. What do these all mean?
- Find out how the tsunami alert system works. How much warning could people in Gisborne expect?
- Watch a relevant video and make some conclusions, e.g.: GNS Science slow slip animation [4m]; NZs hidden megathrust fault [3m]; Tsunami hazard [3m]; Model of large Hikurangi earthquake [5m].
- If your school is near the coast work out/find out where the tsunami-safe zones are. In Wellington these are shown by blue stripes across the road. Where would those stripes go in your area? This Civil Defence info may help.
- In Wellington the Tsunami Ready app helps you find the nearest safe place. For other areas the Hazards – Red Cross app is helpful.
- Read an article about NZ earthquakes or tsunami; e.g., The tsunami that washed time away, *Connected* 3, 2014; or One city, two earthquakes, *School Journal,* 2011 Nov L3 (no link).
- Explore the 2014 LEARNZ virtual field trip: Geohazards – volcanoes, tsunamis, landslides, earthquakes and hydrothermal activity.
- Create a quizlet or Blooket set of 15 flashcards based on information in this article, and invite classmates to play a Blooket game or try the quizlet cards.

Ngā Kupu

Āinga whakararo - Subduction
Autōhiko - Electromagnetic
Te kaha (o te rū) - Earthquake magnitude
Nukuratarata - Mantle
Paenga papaneke - Plate boundary
Papaneke - Tectonic plate
Rū - Earthquake
Rūmuri - Aftershock
Rūpaku - Tremor
Tai āniwhaniwha - Tsunami

From Te Aka Maori Dictionary and *Paekupu*

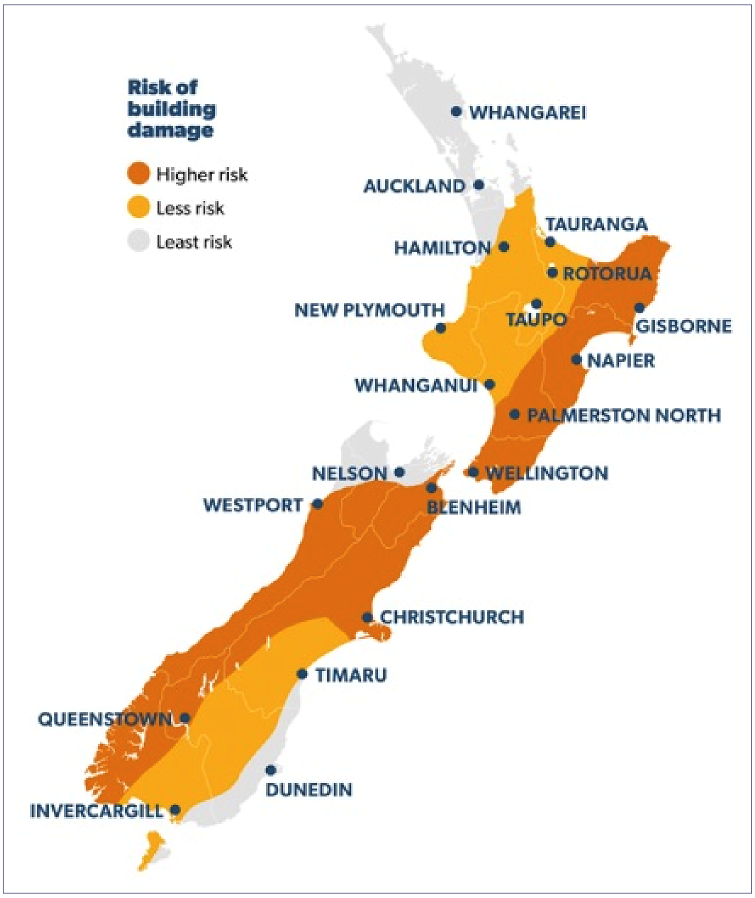
- The local kohanga want their tamariki to learn about natural hazards in their area. Write an illustrated pukapuka in te reo Māori that recounts a natural disaster that has been recorded in local iwi oral histories.
- Kōrero pūrakau often tell the Māori oral histories of geological events such as tsunami. Research Māori oral history surrounding such a tsunami or earthquake event. Compare it with any Pākehā record of that event. What important aspects of this event were reflected in the kōrero pūrakau? Why are such oral histories of these events so important to put into a kōrero pūrakau? Present your whakaaro in a poster. Appendix one, page 39 of this pdf recounts several pages of such events you can use as a starting point; or see New Zealand's tsunami history on Te Ara; or Darren King et al., 2018, Māori oral histories and the impact of tsunamis in Aotearoa New Zealand [26-page report with appendices].



Red ovals show a slow slip event in late May, 2021. An eastward displacement of about 20mm was measured by GNS at two GPS sites off the east coast near Pōrangahau.

This article was improved by suggestions from Mere Manning (Ngāti Kahungunu ki te Wairoa), and critique by Jenny Pollock (Pākehā).

Zones of earthquake risk to buildings; the higher risk zone is above or close to where the Australian and Pacific tectonic plates meet. Earthquake Commission.



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