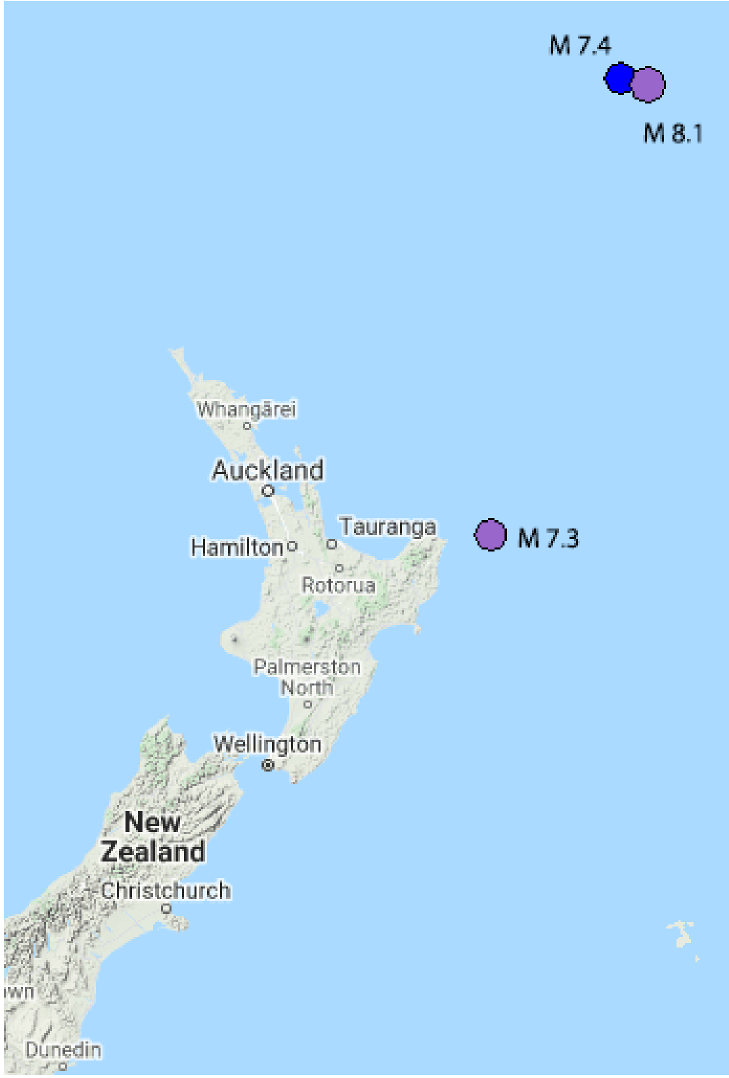
Magnitude 7.3 NEW ZEALAND
Magnitude 7.4 KERMADEC ISLANDS
Magnitude 8.1 KERMADEC ISLANDS
Thursday, March 4, 2021

Three large earthquakes occurred along the Kermadec Trench, north of New Zealand. The earliest and southern-most earthquake (M 7.3 at 13:27 UTC) occurred northeast of Gisborne, New Zealand at a depth of 20 km.

The M 7.4 and M 8.1 earthquakes occurred at 17:41 and 19:28 UTC respectively near the Kermadec Islands, New Zealand. Given the ~950 km distance from the M 7.3 to the two larger earthquakes, it is unlikely the M 7.3 triggered the two larger events.

NOAA released tsunami warnings for many islands in the southwest Pacific. There were no immediate reports of serious damage or casualties before the warning was downgraded.



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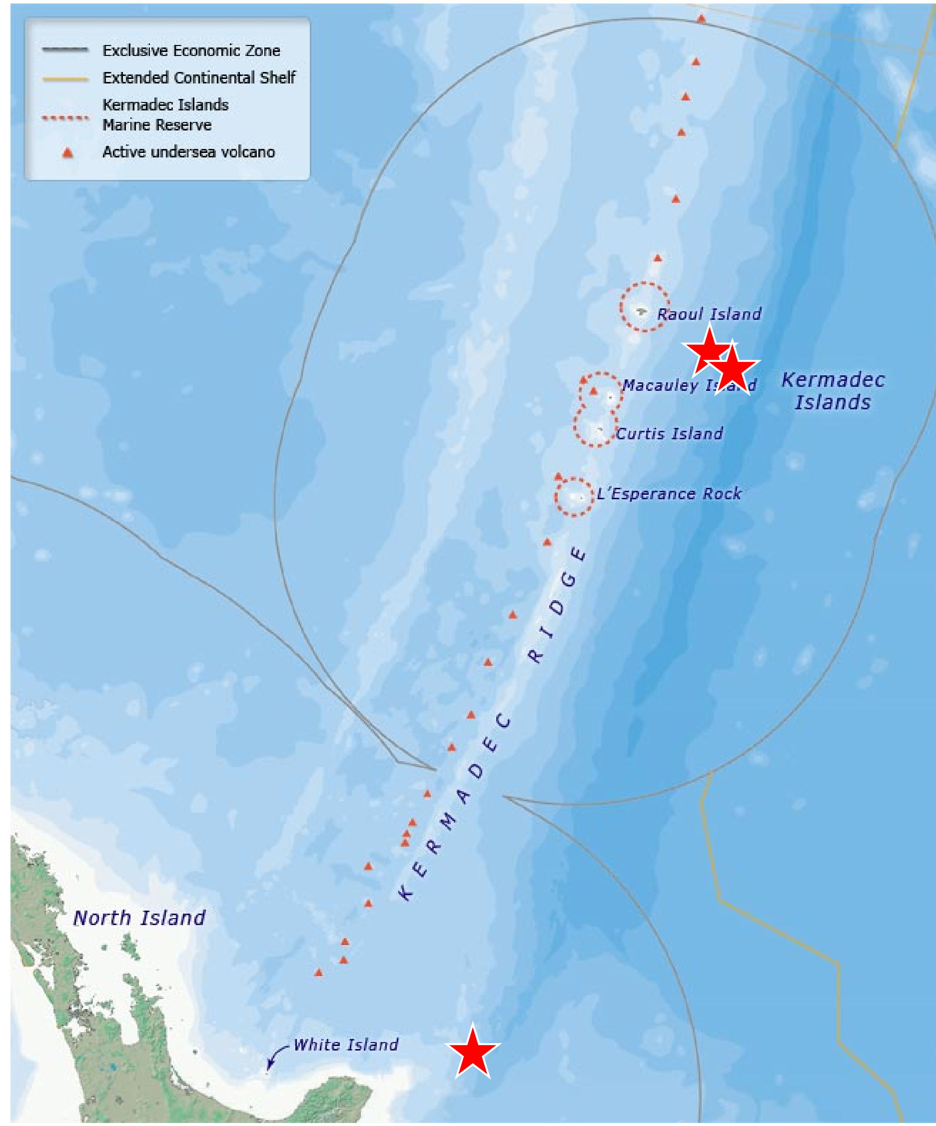
The Kermadec Islands are the tiny emergent part of a chain of submarine volcanoes that define the Kermadec Ridge. There are no permanent settlements on the islands.



In political terms, the Kermadecs are important for New Zealand as they define the northern extent of the Exclusive Economic Zone (EEZ) and the Extended Continental Shelf (ECS).

Image courtesy: Simon Nathan, 'Kermadec Islands - Geology and climate', Te Ara - the Encyclopedia of New Zealand

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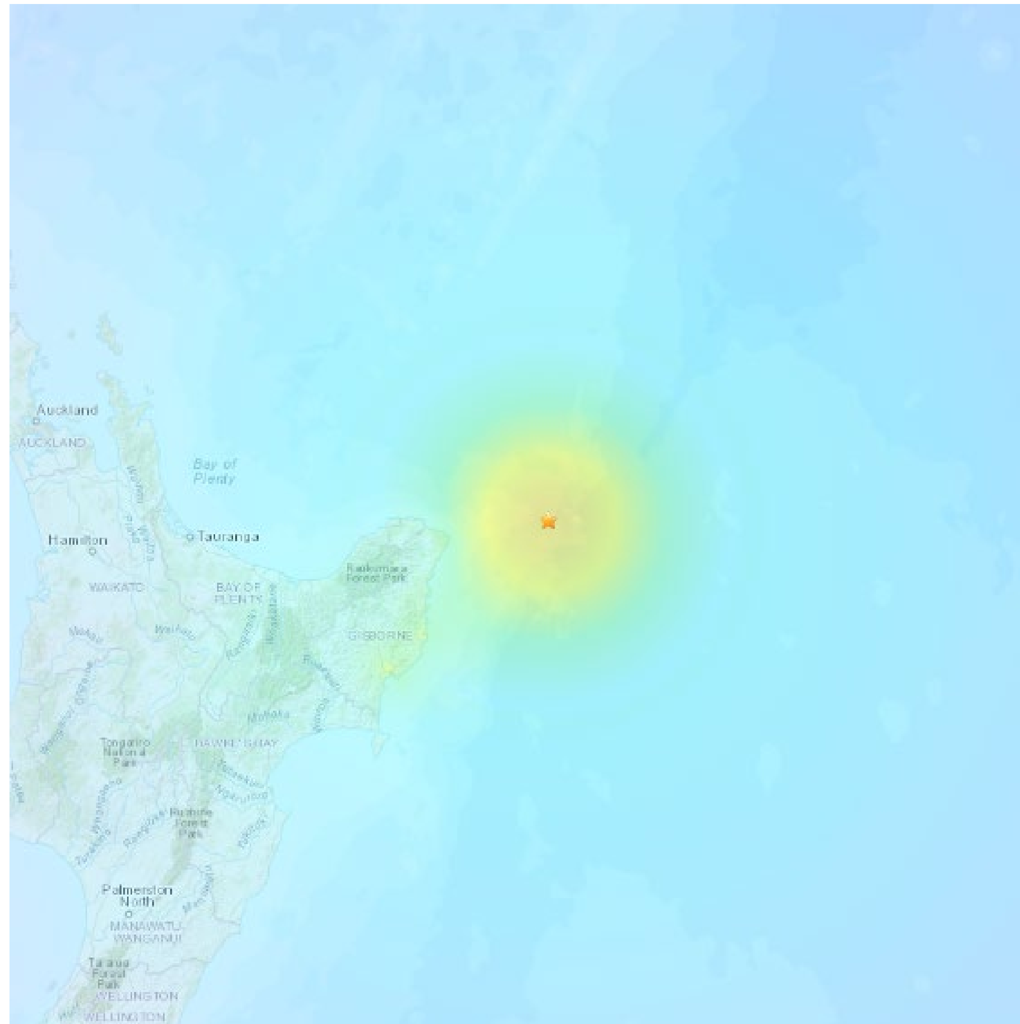
The Modified-Mercalli Intensity (MMI) scale is a ten-stage scale, from I to X, that indicates the severity of ground shaking.

The M 7.3 was felt across much of New Zealand.

MMI	Perceived Shaking
X	Extreme
IX	Violent
VIII	Severe
VII	Very Strong
VI	Strong
V	Moderate
IV	Light
II-III	Weak
I	Not Felt



USGS Estimated shaking Intensity from M 7.3 Earthquake

IRIS Teachable Moments

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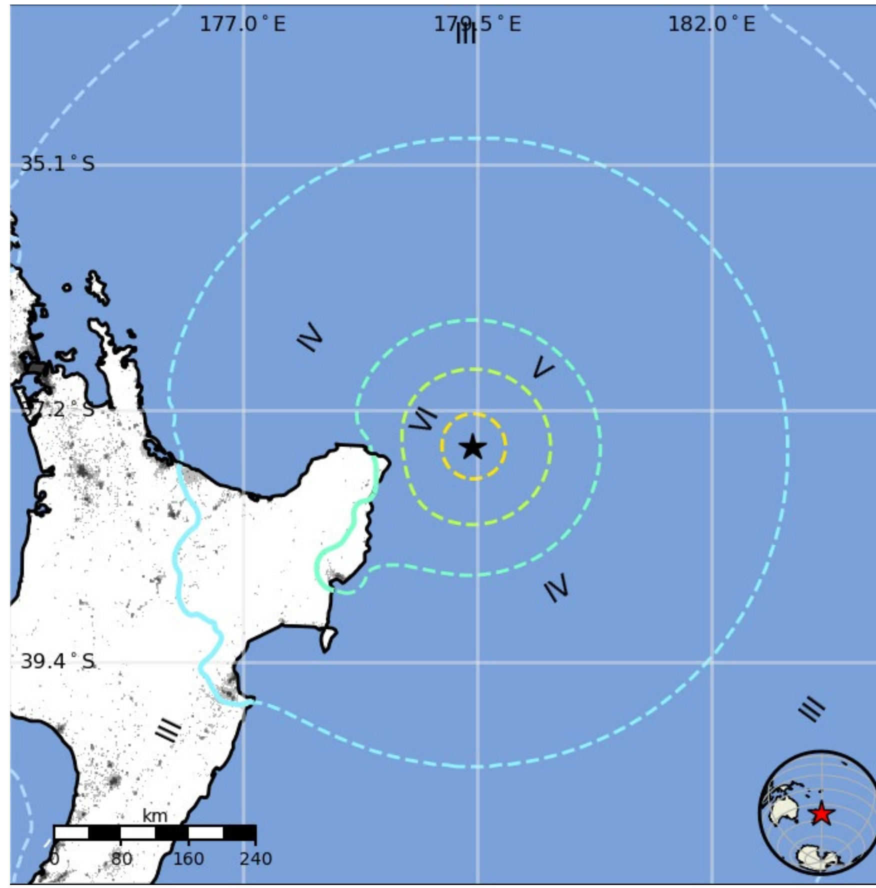
The USGS PAGER map shows the population exposed to different Modified Mercalli Intensity (MMI) levels.

Approximately 41,000 people felt moderate shaking from the M7.3 earthquake.

I	Not Felt	0 k*
II-III	Weak	2,719 k*
IV	Light	225 k
V	Moderate	41 k
VI	Strong	0 k
VII	Very Strong	0 k
VIII	Severe	0 k
IX	Violent	0 k
X	Extreme	0 k



The color coded contour lines outline regions of MMI intensity. The total population exposure to a given MMI value is obtained by summing the population between the contour lines. The estimated population exposure to each MMI Intensity is shown in the table.

Image courtesy of the US Geological Survey

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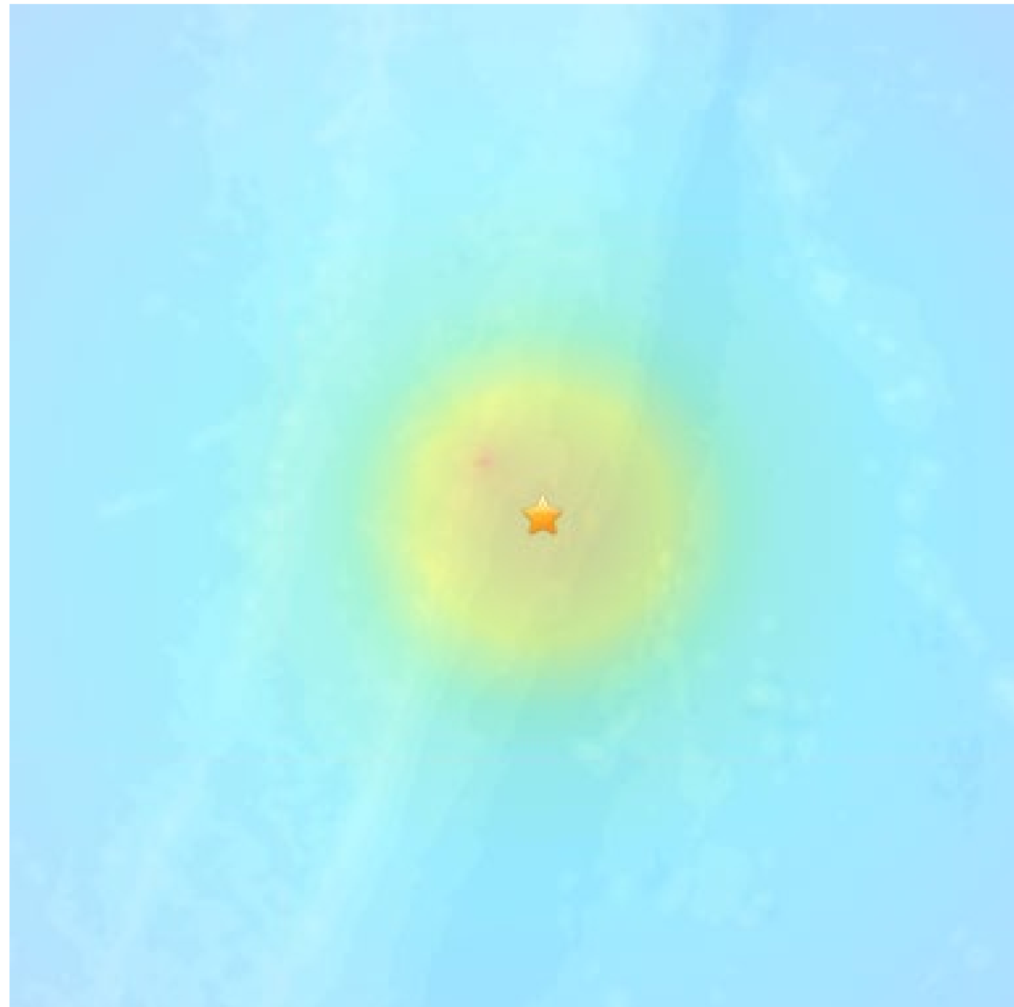
The Modified-Mercalli Intensity (MMI) scale is a ten-stage scale, from I to X, that indicates the severity of ground shaking.

Since the Kermadec Islands are uninhabited, the M 8.1 was likely not felt.

MMI	Perceived Shaking
X	Extreme
IX	Violent
VIII	Severe
VII	Very Strong
VI	Strong
V	Moderate
IV	Light
II-III	Weak
I	Not Felt



USGS Estimated shaking Intensity from M 8.1 Earthquake

Magnitude 7.3 NEW ZEALAND
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Magnitude 8.1 KERMADEC ISLANDS
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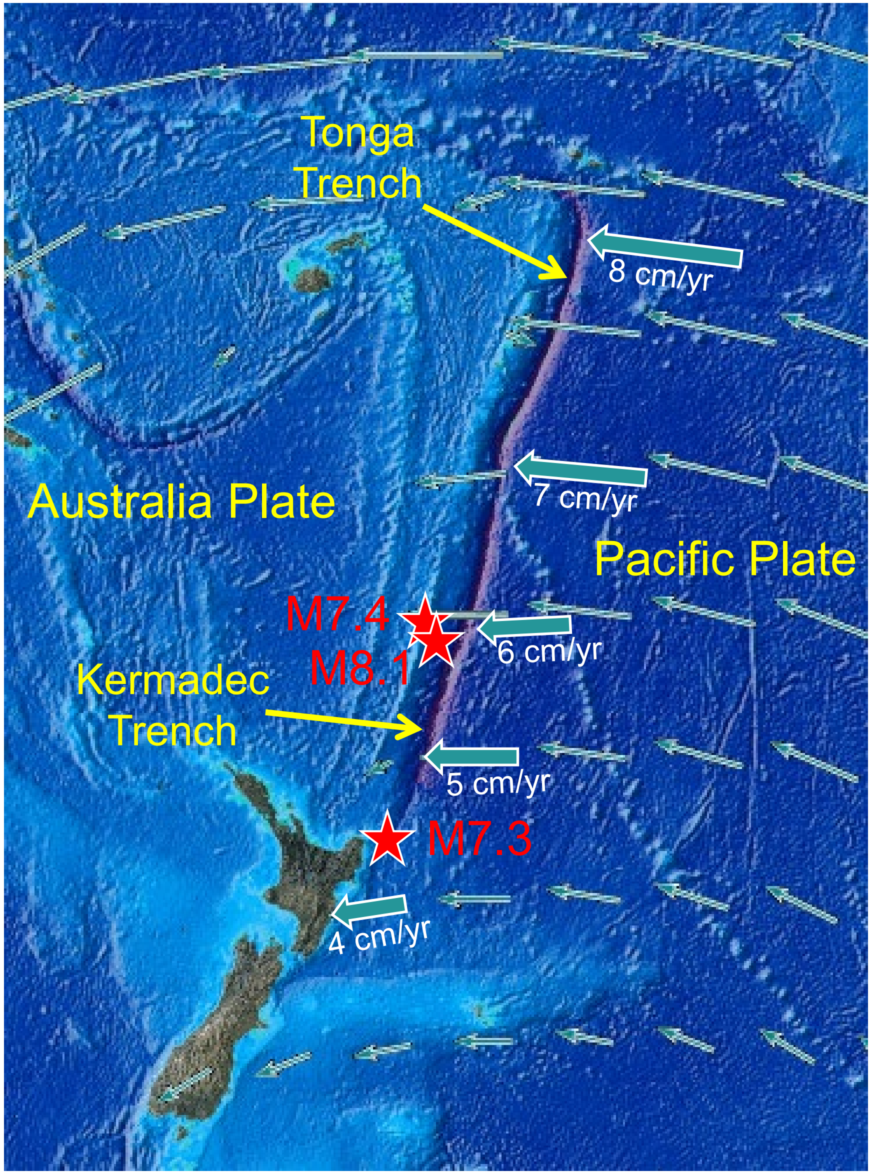

Blue arrows on this map show the motion of the Pacific Plate with respect to the Australia Plate. The epicenters of the three earthquakes are shown by the red stars. These earthquakes occurred along the Kermadec Trench where the Pacific Plate subducts beneath the Australia Plate.

Notice how the rates of subduction of the Pacific Plate change along the Kermadec and Tonga trenches from less than 5 cm/yr in the south to more than 8 cm/yr in the north. These changes in linear rates are a reminder that lithospheric plates are spherical shells, not flat plates. Plate motions are actually relative rotations of spherical shells rather than linear motions of flat plates. Because the Tonga – Kermadec convergent plate boundary is 2500 km (over 1500 miles) long, the importance of spherical geometry is quite clear in this region.

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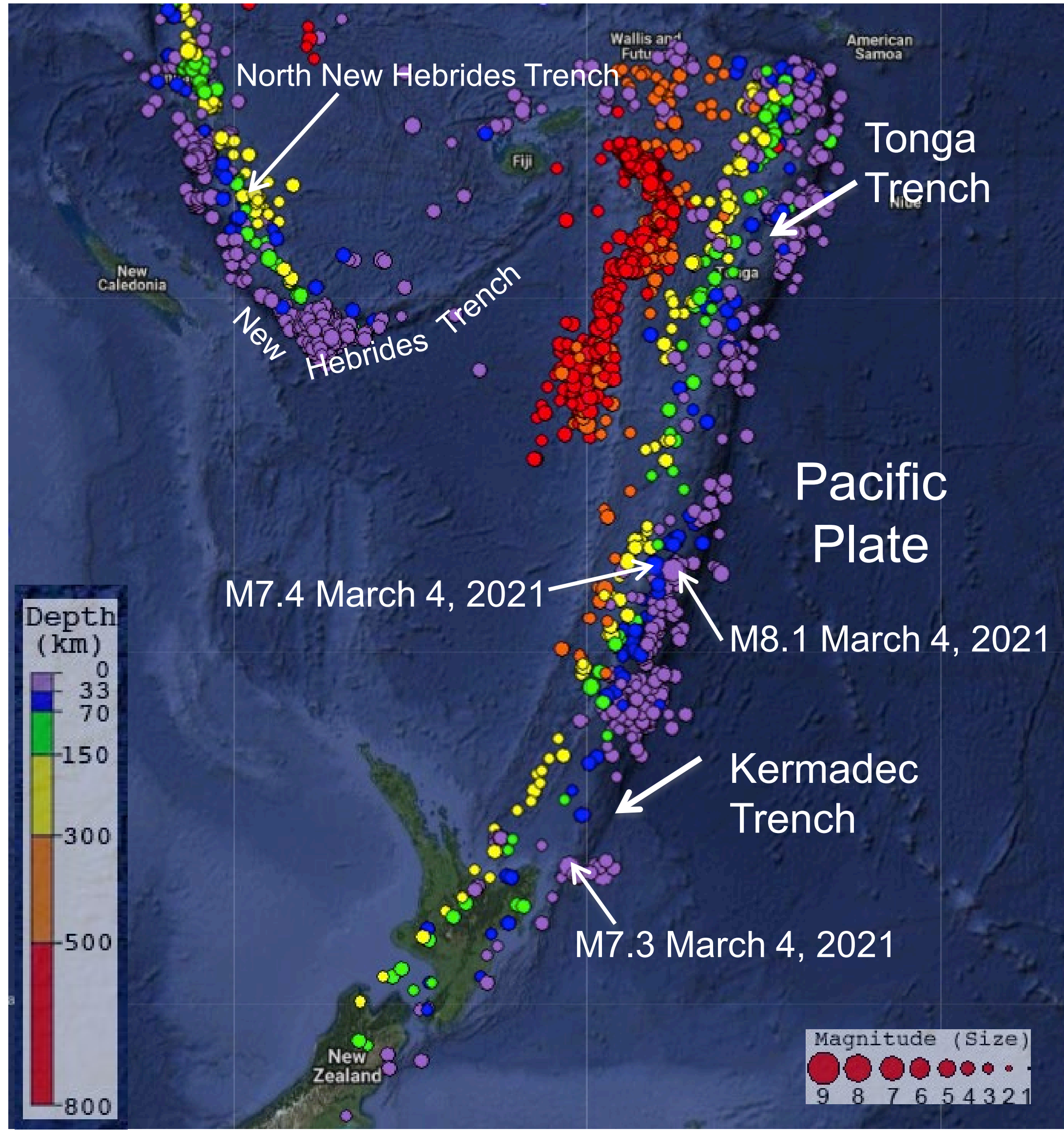
Map created with the IRIS Earthquake Browser

The earthquakes are labeled on this seismicity map showing the most recent 2000 magnitude 4 or larger earthquakes in this region of convergence between the Australia and Pacific Plates. Across the Kermadec and Tonga trenches, earthquake depths increase from east to west as the the Pacific Plate subducts beneath the Australia Plate.

As shown in the previous slide, the Pacific Plate subducts faster into the Tonga Trench than into the Kermadec Trench. So, it remains brittle and capable of generating deeper earthquakes in the northern part of the subduction zone. This seismicity map illustrates how the depths of the deepest earthquakes increase from south to north along the Kermadec and Tonga trenches.



Magnitude 7.3 NEW ZEALAND
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Animating ten years of seismicity in the region.

Animation created with the IRIS Earthquake Browser

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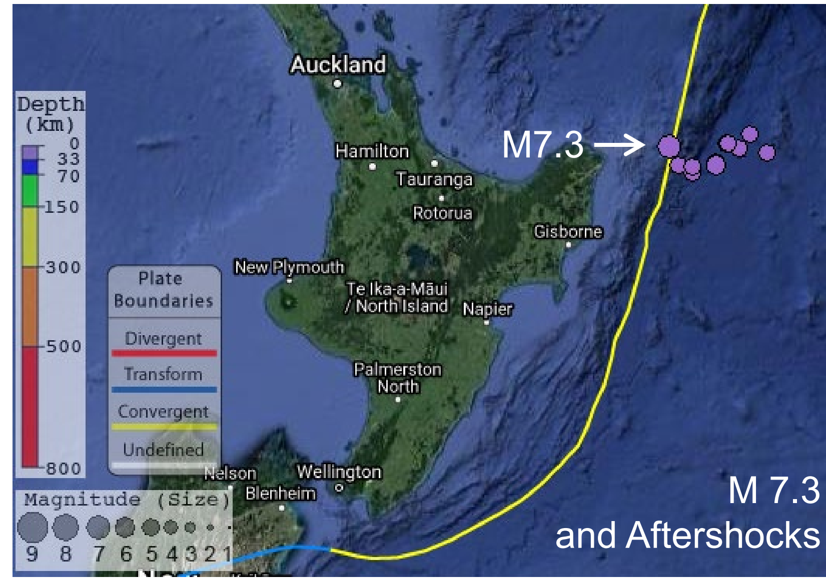
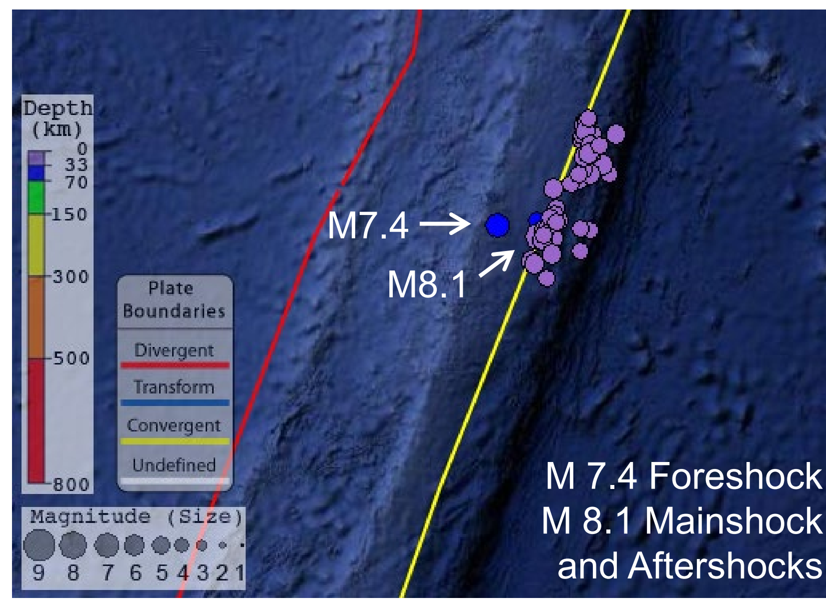
The first earthquake, a M 7.3 at 13:27 UTC was followed by at least 10 aftershocks from M 4.7 - M 5.6.

While a M 7.4 occurred later the same day to the north, due to the distance, it is unlikely to have been triggered by the earlier M 7.3.

However, the M 7.4 at 17:41 UTC turned out to be a foreshock to a M 8.1 that struck at 19:28 UTC.

The M 8.1 was followed by at least 38 aftershocks from M 4.9 – 6.2.





Maps created with the IRIS Earthquake Browser

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A **foreshock** is a smaller magnitude earthquake that precedes the mainshock.

There are no special characteristics of a foreshock that let us know it is a foreshock until the mainshock occurs.

A **mainshock** is largest magnitude earthquake during an earthquake sequence.

Aftershocks are smaller earthquakes occurring after a large earthquake as the fault adjusts to the new state of stress.

The graph shows how the number of aftershocks and the magnitude of aftershocks decay with increasing time since the main shock. The number of aftershocks also decreases with distance from the main shock.

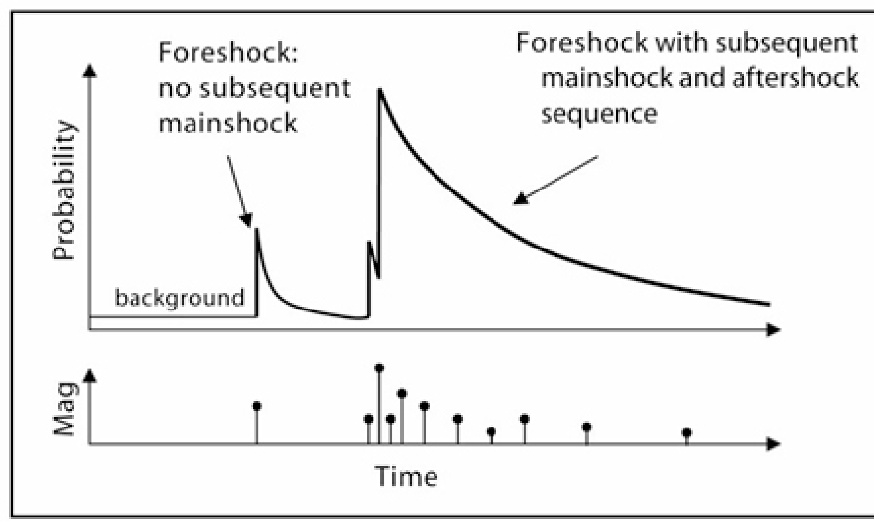

Image courtesy of the US Geological Survey

Magnitude 7.3 NEW ZEALAND
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The interaction between the Pacific and Australia Plates creates one of the most seismically active tectonic environments in the world.

This image labels notable shallow earthquakes on the North Island of New Zealand since 1848.

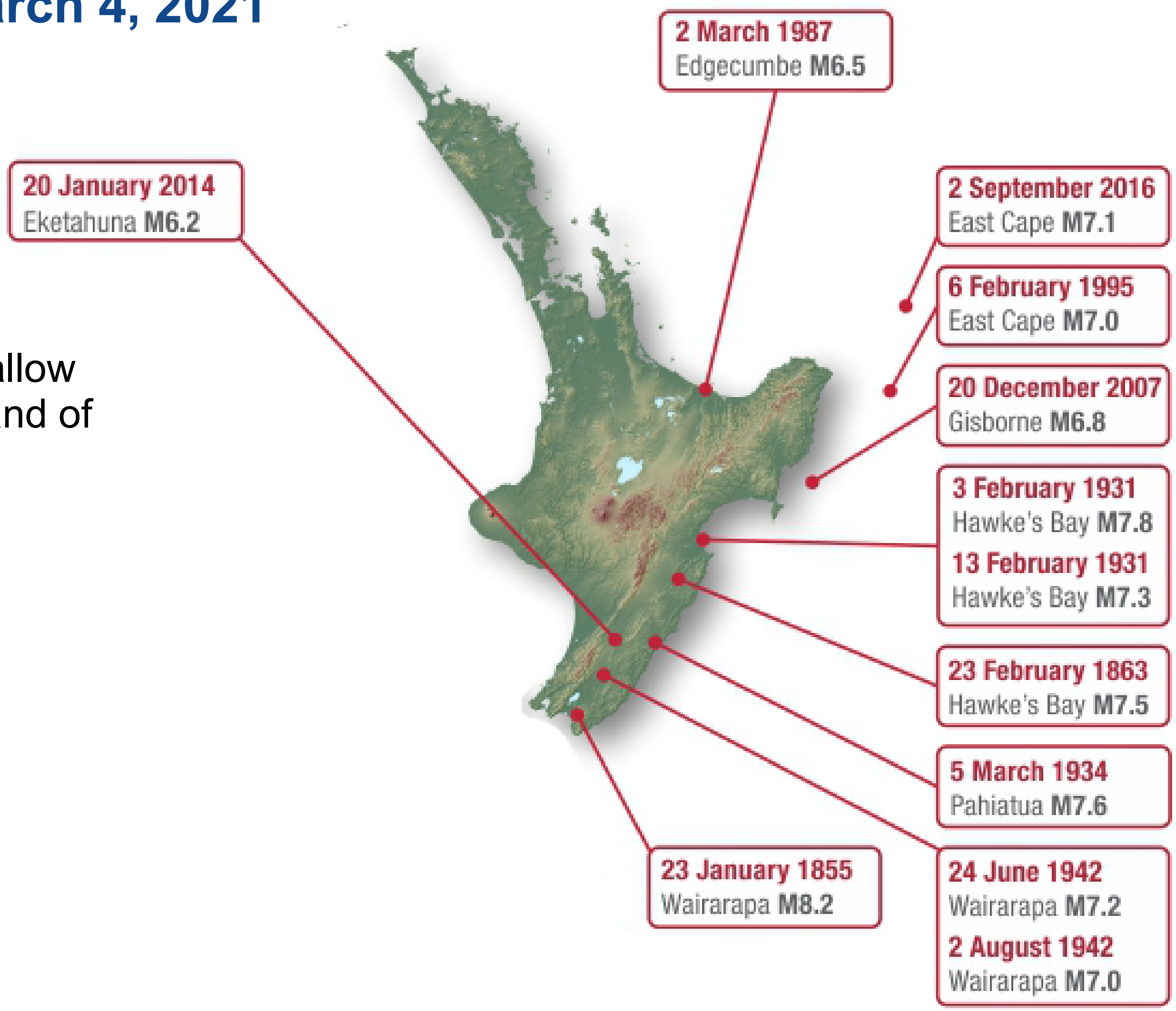

Image modified from GNS Science

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To help understand the seismic risk in New Zealand, GNS Science has been measuring the locations of Global Positioning System (GPS) sites since the early 1990s.

Over time these recordings have shown that the surface of the landscape is being deformed by tectonic movements as the Australia and Pacific Plates slowly converge.

This diagram illustrates rate of motion of GPS stations across the North Island. The eastern margin of the North Island is being pushed westward due to WSW motion of the Pacific Plate across a convergent plate boundary with high friction. As the North Island is compressed, it stores elastic energy that could be released during a future earthquake.

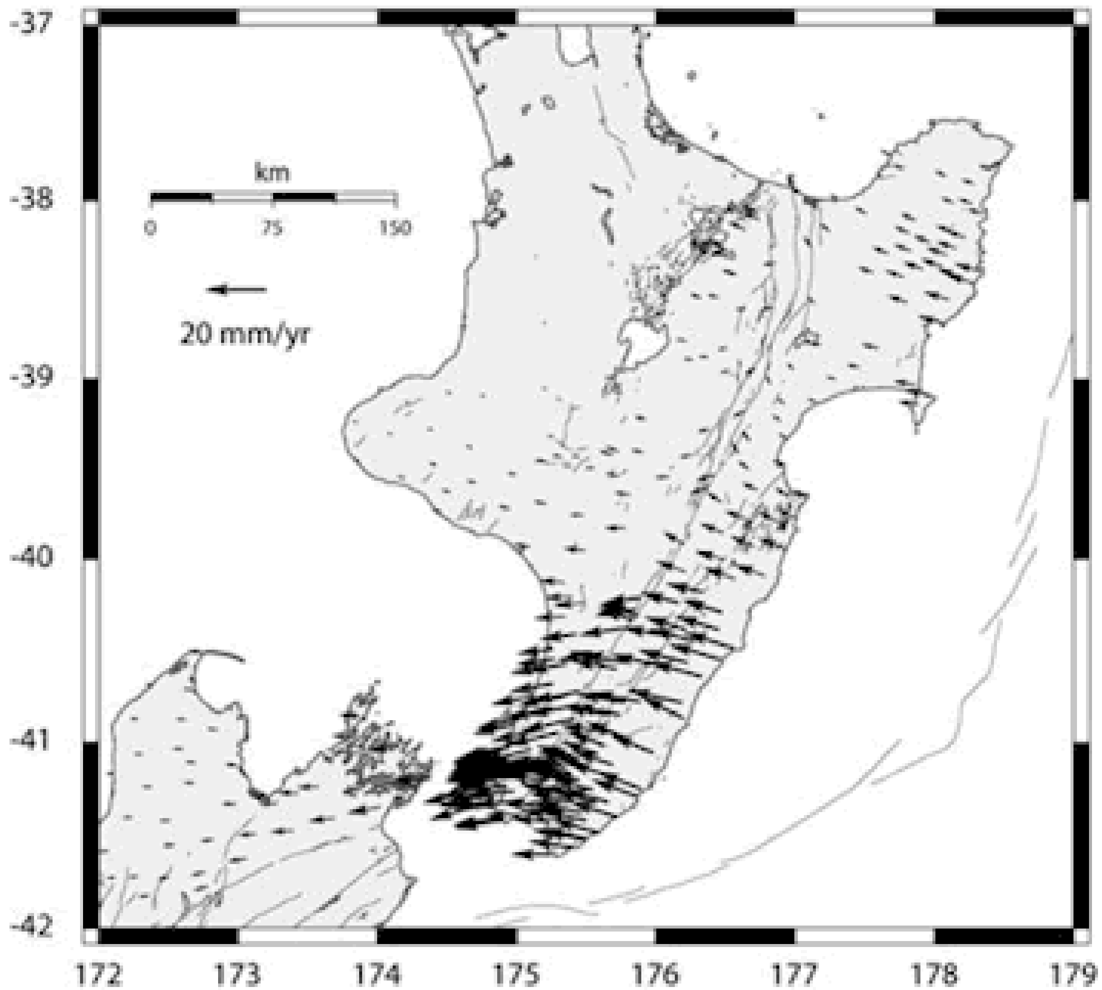

Image courtesy of GNS Science

Magnitude 7.3 NEW ZEALAND
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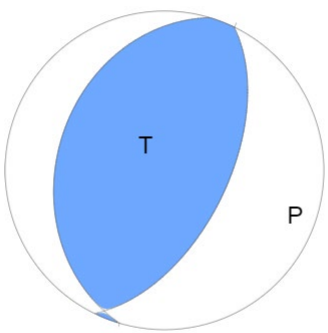
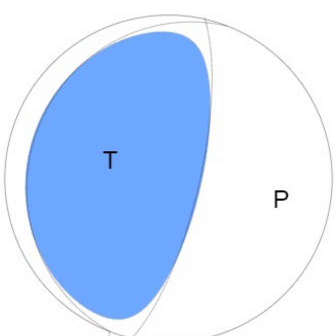
The focal mechanism is how seismologists plot the 3-D stress orientations of an earthquake. Because an earthquake occurs as slip on a fault, it generates primary (P) waves in quadrants where the first pulse is compressional (shaded) and quadrants where the first pulse is extensional (white). The orientation of these quadrants determined from recorded seismic waves determines the type of fault that produced the earthquake.



M 7.4

The M 7.3 earthquake had complex waveforms suggesting that potentially more than one fault was involved.

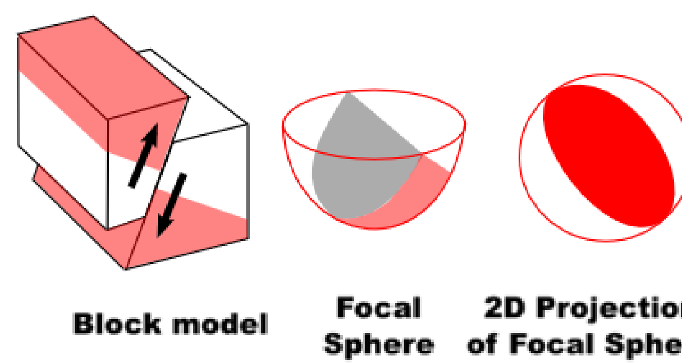
The M 7.4 foreshock and M 8.1 mainshock have similar focal mechanisms indicating these earthquakes occurred as the result of thrust faulting on or near the subducting plate interface.



M 8.1

The tension axis (T) reflects the minimum compressive stress direction. The pressure axis (P) reflects the maximum compressive stress direction.

Reverse/Thrust/Compression



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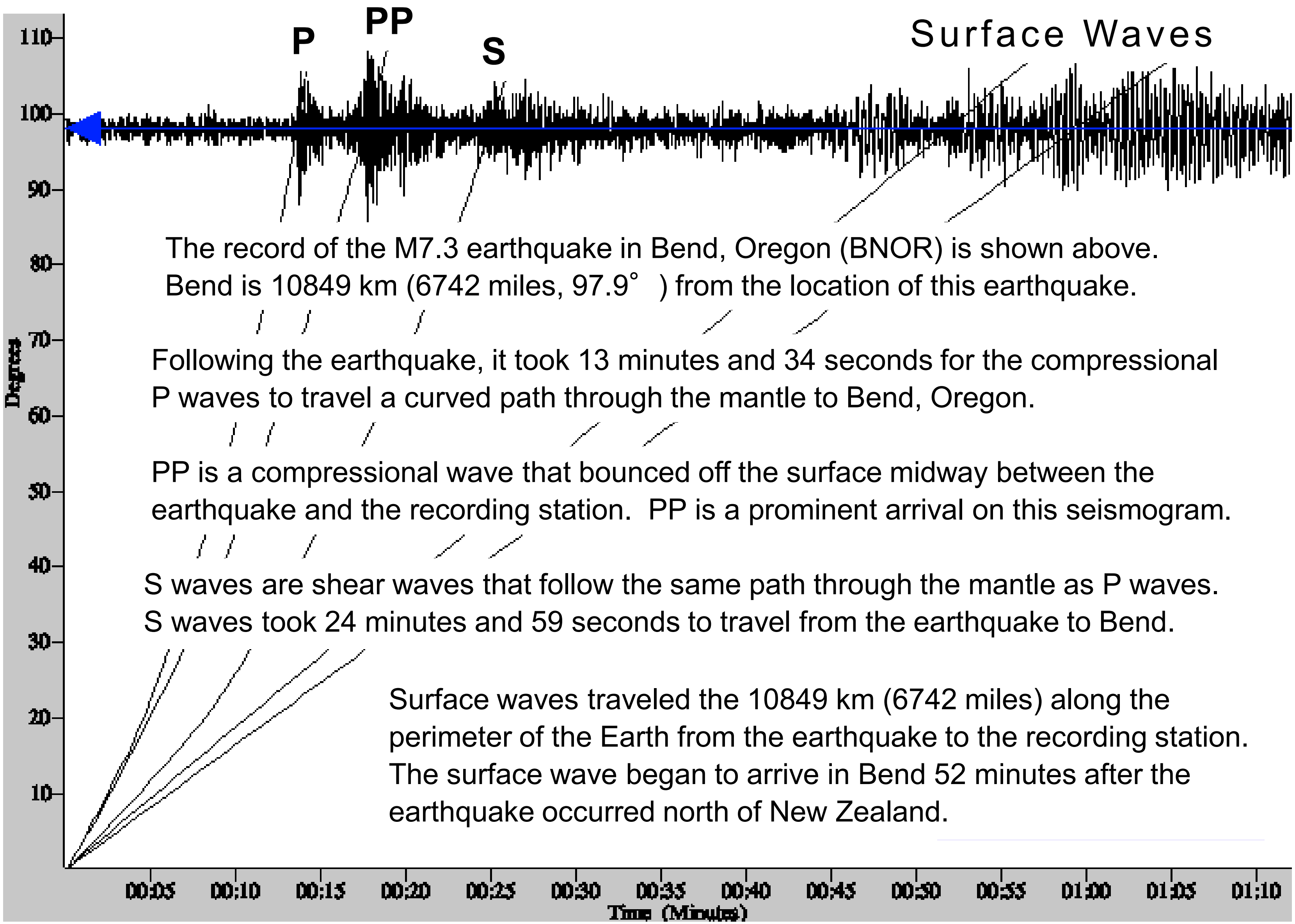
This animation explores the motion of a reverse fault, and how reverse faults are represented in a focal mechanism.

Focal mechanism solutions are estimated by an analysis of observed seismic waveforms, recorded after the earthquake, observing the pattern of "first motions", that is, whether the first arriving P waves push up or down.

Magnitude 7.3 NEW ZEALAND

Wednesday, March 4, 2021 at 13:27:36 UTC



The record of the M7.3 earthquake in Bend, Oregon (BNOR) is shown above. Bend is 10849 km (6742 miles, 97.9°) from the location of this earthquake.

Following the earthquake, it took 13 minutes and 34 seconds for the compressional P waves to travel a curved path through the mantle to Bend, Oregon.

PP is a compressional wave that bounced off the surface midway between the earthquake and the recording station. PP is a prominent arrival on this seismogram.

S waves are shear waves that follow the same path through the mantle as P waves. S waves took 24 minutes and 59 seconds to travel from the earthquake to Bend.

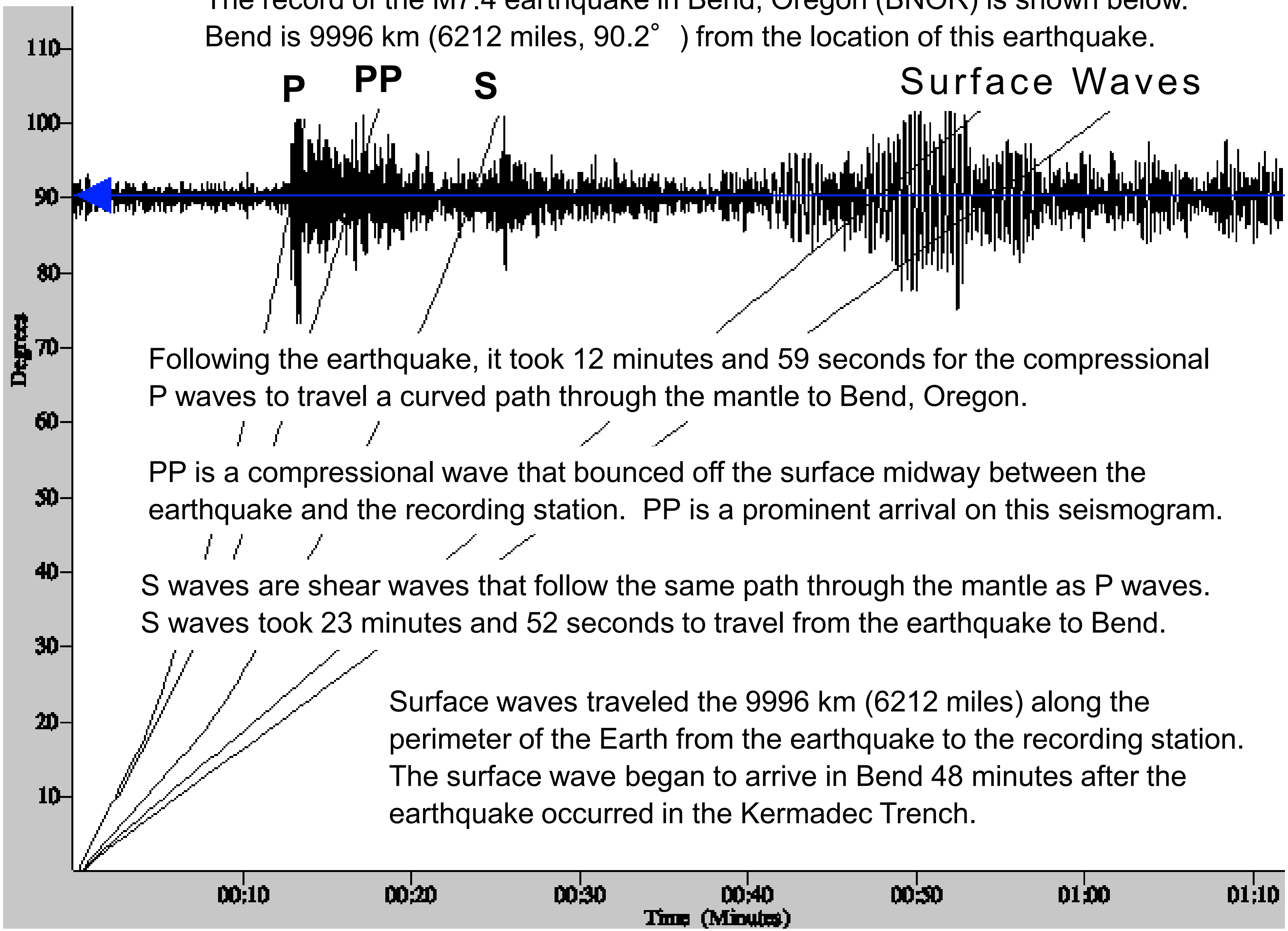
Surface waves traveled the 10849 km (6742 miles) along the perimeter of the Earth from the earthquake to the recording station. The surface wave began to arrive in Bend 52 minutes after the earthquake occurred north of New Zealand.

Magnitude 7.4 KERMADEC ISLANDS

Thursday, March 4, 2021 at 17:41:25 UTC

Teachable Moments

The record of the M7.4 earthquake in Bend, Oregon (BNOR) is shown below. Bend is 9996 km (6212 miles, 90.2°) from the location of this earthquake.



Following the earthquake, it took 12 minutes and 59 seconds for the compressional P waves to travel a curved path through the mantle to Bend, Oregon.

PP is a compressional wave that bounced off the surface midway between the earthquake and the recording station. PP is a prominent arrival on this seismogram.

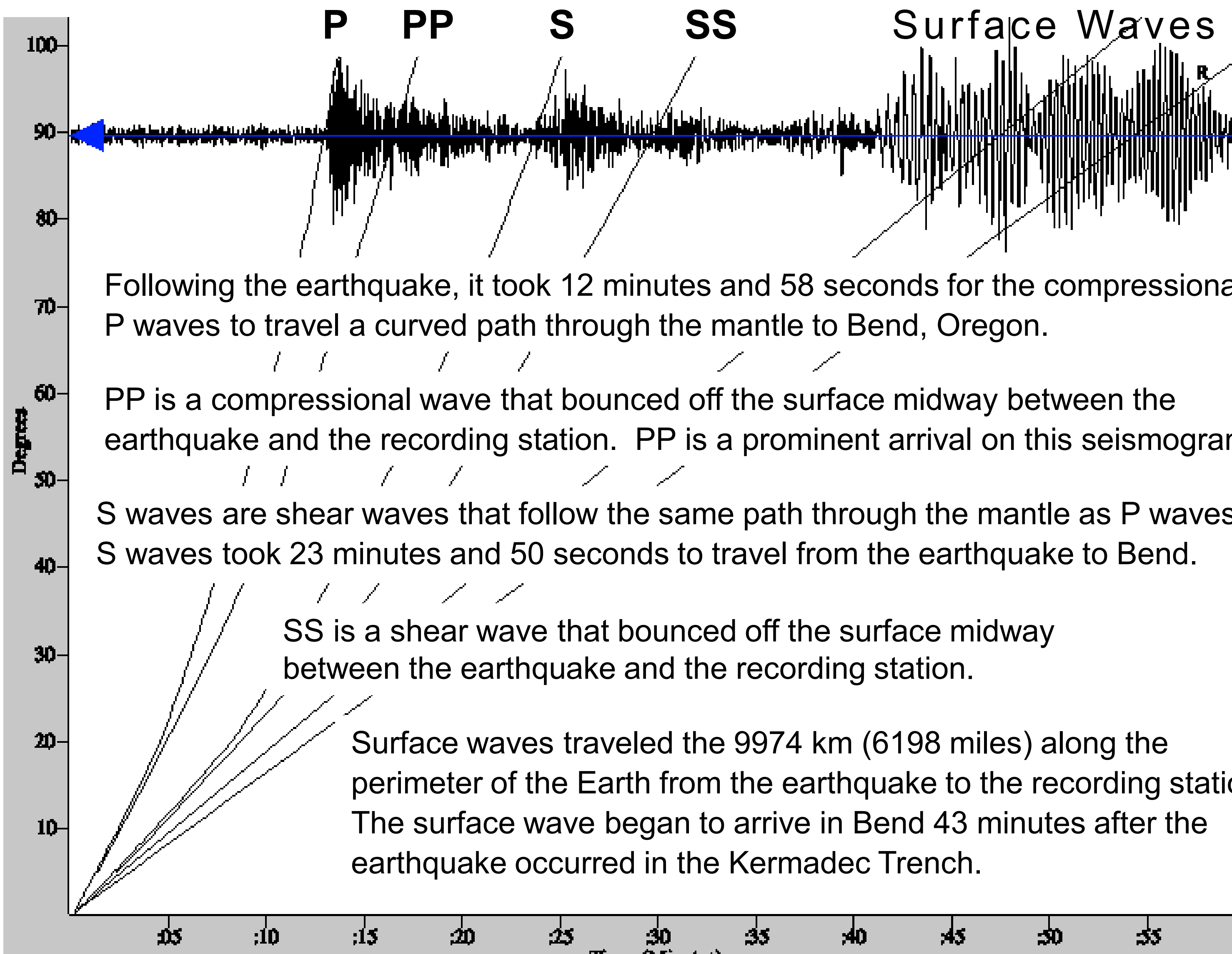
S waves are shear waves that follow the same path through the mantle as P waves. S waves took 23 minutes and 52 seconds to travel from the earthquake to Bend.

Surface waves traveled the 9996 km (6212 miles) along the perimeter of the Earth from the earthquake to the recording station. The surface wave began to arrive in Bend 48 minutes after the earthquake occurred in the Kermadec Trench.

Magnitude 8.1 KERMADEC ISLANDS

Thursday, March 4, 2021 at 19:28:31 UTC

The record of the M8.1 earthquake in Bend, Oregon (BNOR) is shown below. Bend is 9974 km (6198 miles, 90°) from the location of this earthquake.



Following the earthquake, it took 12 minutes and 58 seconds for the compressional P waves to travel a curved path through the mantle to Bend, Oregon.

PP is a compressional wave that bounced off the surface midway between the earthquake and the recording station. PP is a prominent arrival on this seismogram.

S waves are shear waves that follow the same path through the mantle as P waves. S waves took 23 minutes and 50 seconds to travel from the earthquake to Bend.

SS is a shear wave that bounced off the surface midway between the earthquake and the recording station.

Surface waves traveled the 9974 km (6198 miles) along the perimeter of the Earth from the earthquake to the recording station. The surface wave began to arrive in Bend 43 minutes after the earthquake occurred in the Kermadec Trench.

Teachable Moments are a service of

The Incorporated Research Institutions for Seismology
Education & Public Outreach
and
The University of Portland

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