

Seismicity of the Earth 1900–2010

Eastern Margin of the Australia Plate

Compiled by Harley Benz, Matthew Herman¹, Arthur C. Tarr, Gavin Hayes, Kevin Furlong¹, Antonio Villaseñor², Richard Dart, and Susan Rhea

¹Department of Geosciences, Pennsylvania State University, State College, PA 16802 USA
²Institute of Earth Sciences, CSIC, Spain

TECTONIC SUMMARY

The eastern margin of the Australia plate is one of the most seismically active areas of the world due to high rates of convergence between the Australia and Pacific plates. In the region of New Zealand, the 3000 km long Australia-Pacific plate boundary extends from south of Macquarie Island to the southern Kermadec Island chain. It includes an oceanic transform (the Macquarie Ridge), two oppositely verging subduction zones (Puysegur and Hikurangi), and a transpressive continental transform, the Alpine Fault through South Island, New Zealand.

Australia-Pacific relative velocity is approximately 35 mm/yr along the three plate boundary segments south of the Hikurangi subduction zone. The transpressive nature of the Alpine Fault leads to the rapid (>4 mm/yr) uplift of the Southern Alps. At the Puysegur subduction zone, starting in southwest New Zealand, the Australia plate descends obliquely to the northeast under South Island. To the east of North Island, subduction polarity is reversed at the Hikurangi trench, where the Pacific plate sinks to the west. The convergence rate at the Hikurangi subduction zone increases northward from 35 to 60 mm/yr.

Since 1900 there have been 15 M7.5+ earthquakes recorded since 1900 near New Zealand. Nine of these, and the four largest, occurred along or near the Macquarie Ridge, including the 1989 M8.2 event on the ridge itself, and the 2004 M8.1 event 200 km to the west of the plate boundary, reflecting intraplate deformation. The largest recorded earthquake in New Zealand itself was the 1931 M7.8 Hawke's Bay earthquake, which killed 256 people. The last M7.5+ earthquake along the Alpine Fault was 170 years ago; studies of the faults' strain accumulation suggest that similar events are likely to occur again.

North of New Zealand, the Australia-Pacific boundary stretches east of Tonga and Fiji to 250 km south of Samoa. For 2,200 km the trench is approximately linear, and includes two segments where old (>120 Myr) Pacific oceanic lithosphere rapidly subducts westward (Kermadec and Tonga). At the northern end of the Tonga trench, the boundary curves sharply westward and changes along a 700 km-long segment from trench-normal subduction, to oblique subduction, to a left lateral transform-like structure.

Australia-Pacific convergence rates increase northward from 60 mm/yr at the southern Kermadec trench to 90 mm/yr at the northern Tonga trench; however, significant back arc extension (or equivalently, slab rollback) causes the consumption rate of subducting Pacific lithosphere to be much faster. The spreading rate in the Havre trough, west of the Kermadec trench, increases northward from 8 to 20 mm/yr. The southern tip of this spreading center is propagating into the North Island of New Zealand, rifting it apart. In the southern Lau Basin, west of the Tonga trench, the spreading rate increases northward from 60 to 90 mm/yr, and in the northern Lau Basin, multiple spreading centers result in an extension rate as high as 160 mm/yr. The overall subduction velocity of the Pacific plate is the vector sum of Australia-Pacific velocity and back spreading velocity; thus it increases northward along the Kermadec trench from 70 to 100 mm/yr, and along the Tonga trench from 150 to 240 mm/yr.

The Kermadec-Tonga subduction zone generates many large earthquakes on the interface between the descending Pacific and overriding Australia plates, within the two plates themselves and, less frequently, near the outer rise of the Pacific plate east of the trench. Since 1900, 40 M7.5+ earthquakes have been recorded, mostly north of 30°S. However, it is unclear whether any of the few historic M8+ events that have occurred close to the plate boundary were underthrusting events on the plate interface, or were intraplate earthquakes. On September 29, 2009, one of the largest normal fault (outer rise) earthquakes ever recorded (M8.1) occurred south of Samoa, 40 km east of the Tonga trench, generating a tsunami that killed at least 180 people.

Across the North Fiji Basin and to the west of the Vanuatu Islands, the Australia plate again subducts eastwards beneath the Pacific, at the North New Hebrides trench. At the southern end of this trench, east of the Loyalty Islands, the plate boundary curves east into an oceanic transform-like structure analogous to the one north of Tonga.

Australia-Pacific convergence rates increase northward from 80 to 90 mm/yr along the North New Hebrides trench, but the Australia plate consumption rate is increased by extension in the back arc and in the North Fiji Basin. Back arc spreading occurs at a rate of 50 mm/yr along most of the subduction zone, except near 15°S, where the D'Entrecasteaux ridge intersects the trench and causes localized compression of 50 mm/yr in the back arc. Therefore, the Australia plate subduction velocity ranges from 120 mm/yr at the southern end of the North New Hebrides trench, to 40 mm/yr at the D'Entrecasteaux ridge-trench intersection, to 170 mm/yr at the northern end of the trench.

Large earthquakes are common along the North New Hebrides trench and have mechanisms associated with subduction tectonics, though occasional strike slip earthquakes occur near the subduction of the D'Entrecasteaux ridge. Within the subduction zone, 34 M7.5+ earthquakes have been recorded since 1900. On October 7, 2009, a large interplate thrust fault earthquake (M7.6) in the northern North New Hebrides subduction zone was followed 15 minutes later by an even larger interplate event (M7.8) 60 km to the north. It is likely that the first event triggered the second of the so-called earthquake "doublet".

DATA SOURCES

The earthquakes portrayed on the main map and the depth profiles are taken from two sources: (a) the Centennial earthquake catalog (Engdahl and Villaseñor, 2002) and annual supplements for the interval 1900–2007, where the magnitude floor is 5.5 globally, and (b) a catalog of earthquakes having high-quality depth determinations for the period 1964–2002 and a magnitude range of 5.0≤M≤5.4 (Engdahl, personal comm. 2003).

Major earthquakes (7.5≤M≤8.2) are labeled with the year of occurrence, while earthquakes (8.0≤M≤8.2) are labeled with the year of occurrence and also denoted by a white outline.

The Seismic Hazard and Relative Plate Motion panel displays the generalized seismic hazard of the region (Giardini and others, 1999) and representative relative plate motion vectors using the NUVEL-1A model (DeMets, et al., 1994.)

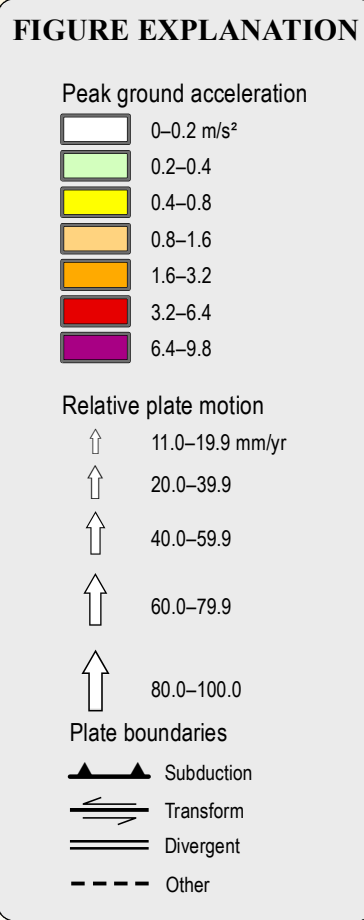
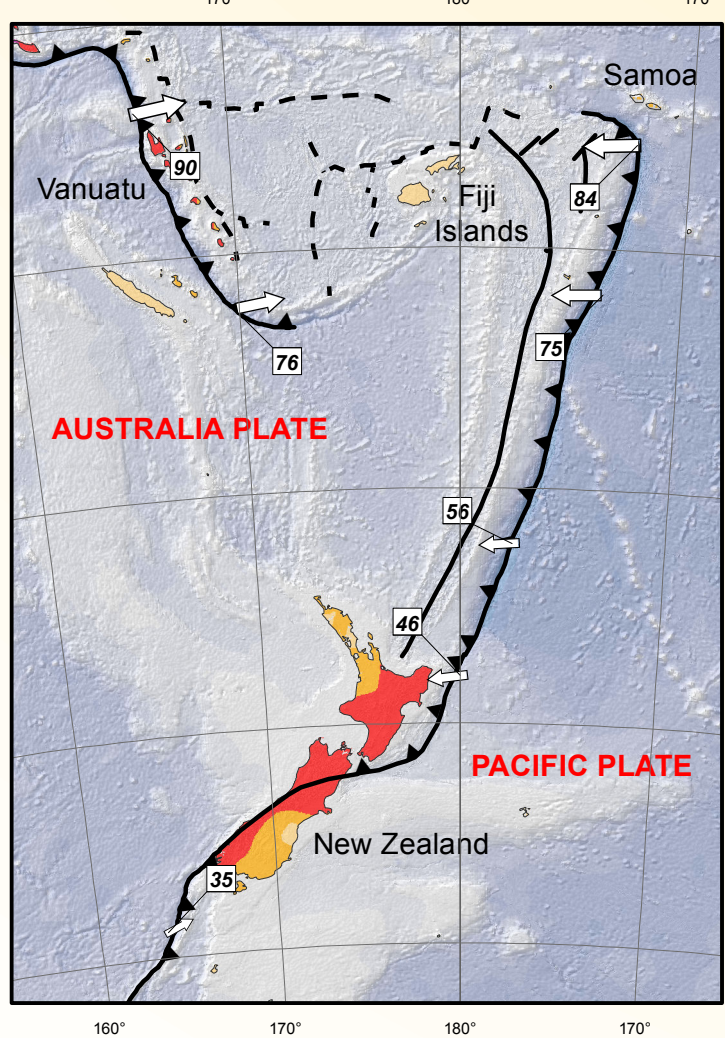
Pre-instrumental seismicity was obtained from the NOAA National Geophysical Data Center (2010) database of significant earthquakes; locations are approximate, based on macro-seismic reports and field investigations. We selected earthquakes with associated reports of moderate to major damage, 10 or more deaths, an estimated magnitude of 7.5 or greater (if known), Modified Mercalli Intensities X, or tsunami generation.

Base map data sources include GEBCO 2008. Volcanoes of the World dataset (Siebert and Simkin, 2002), plate boundaries (Bird, 2003), Digital Chart of the World, and ESRI. Slab contours are from Hayes and Wald (2010).

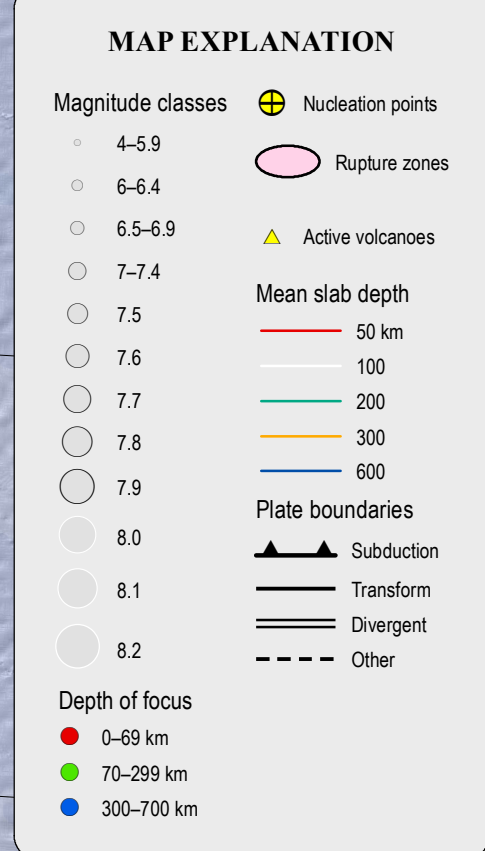
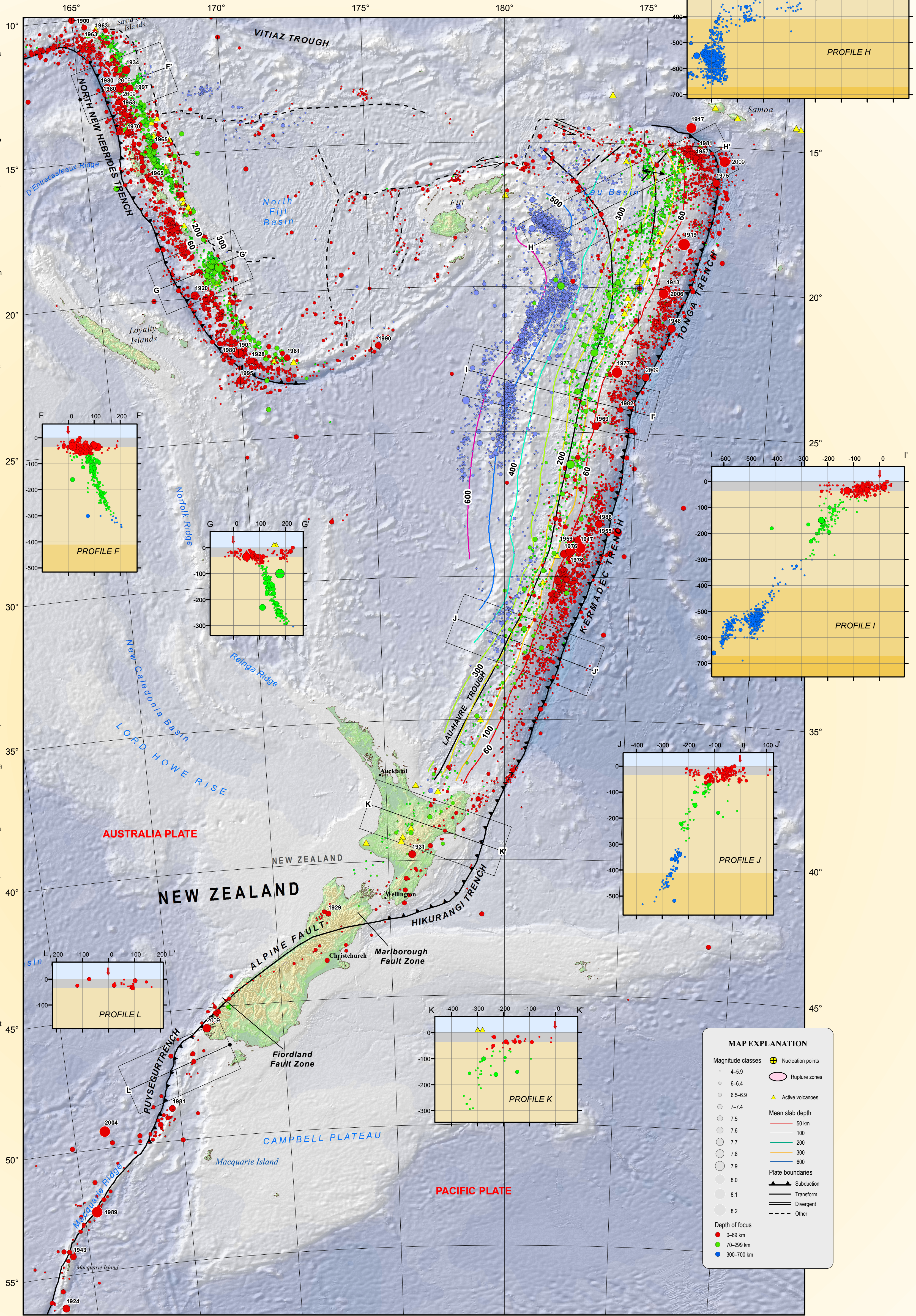
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SEISMIC HAZARD AND RELATIVE PLATE MOTION

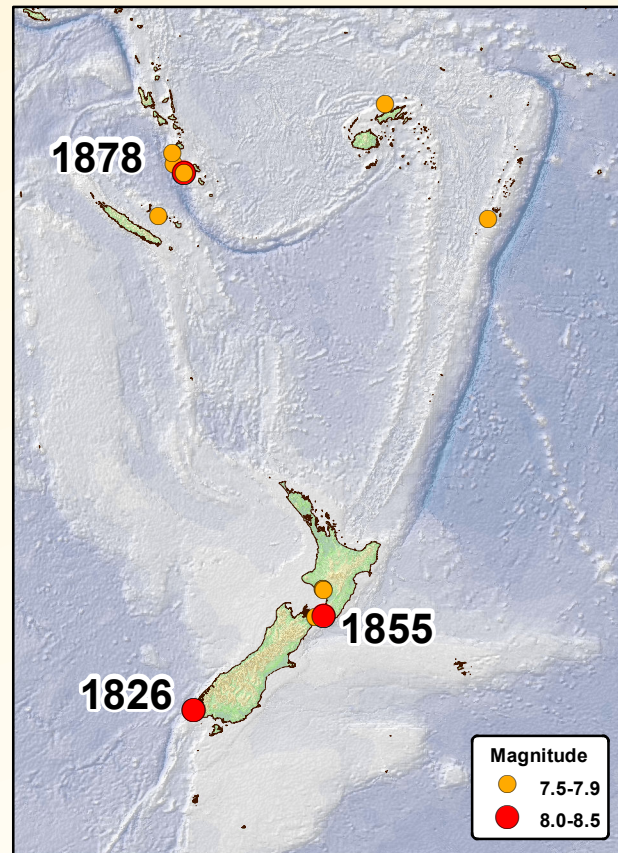


The vectors on this map show only the relative plate motion between the Pacific and Australia plates. "Back arc extension" adds significant rate of plate motion in this area. See text for details.



PRE-INSTRUMENTAL SEISMICITY 1500–1899

M ≥ 7.5, tsunami, or deaths



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This map was produced on request, directly from digital files, on an electronic plotter.

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