A Comparison of Transpressional Boundaries: What New Zealand Can Tell Us About Tectonics in New Guinea

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PENNSTATE GEODYNAMICS

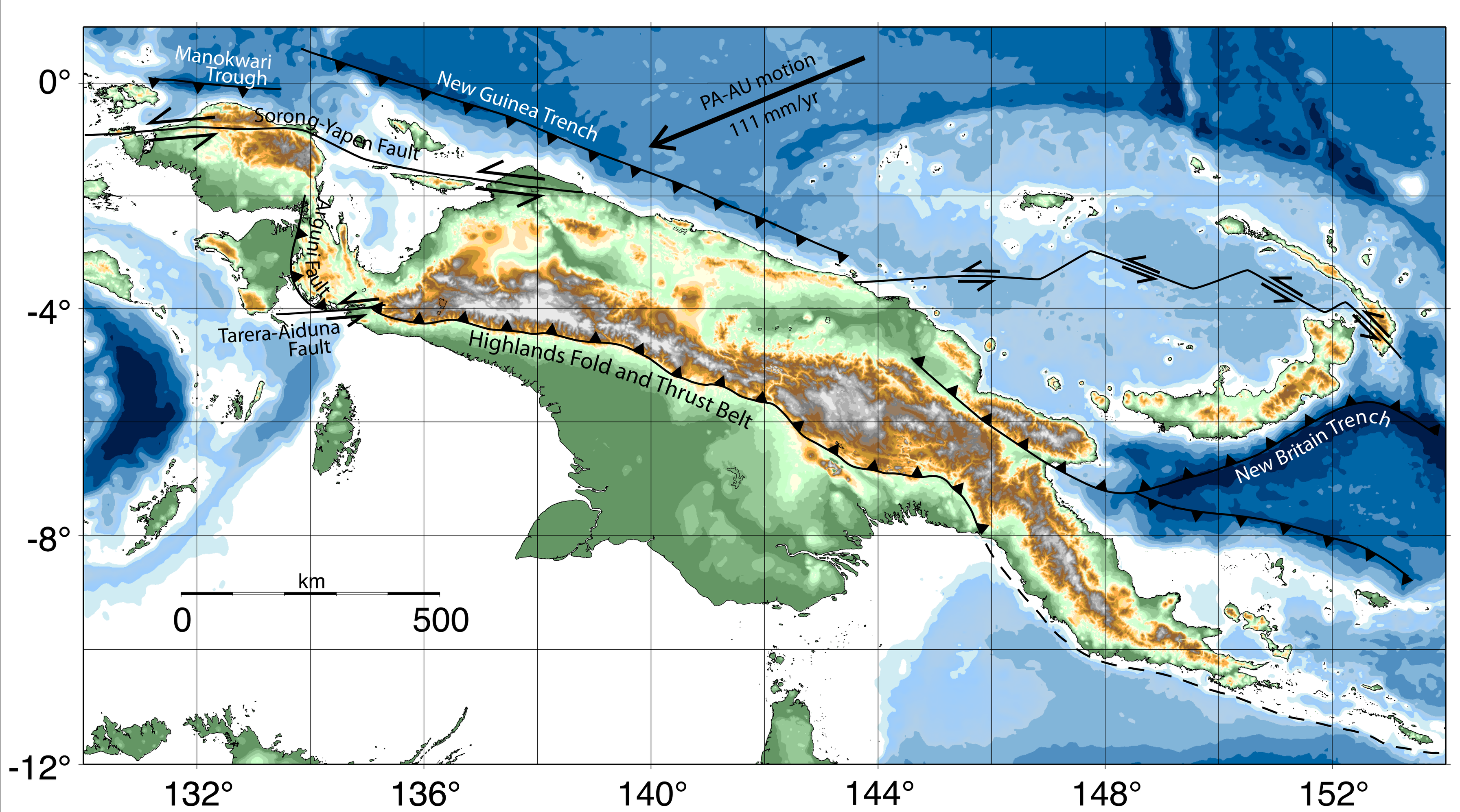
Introduction

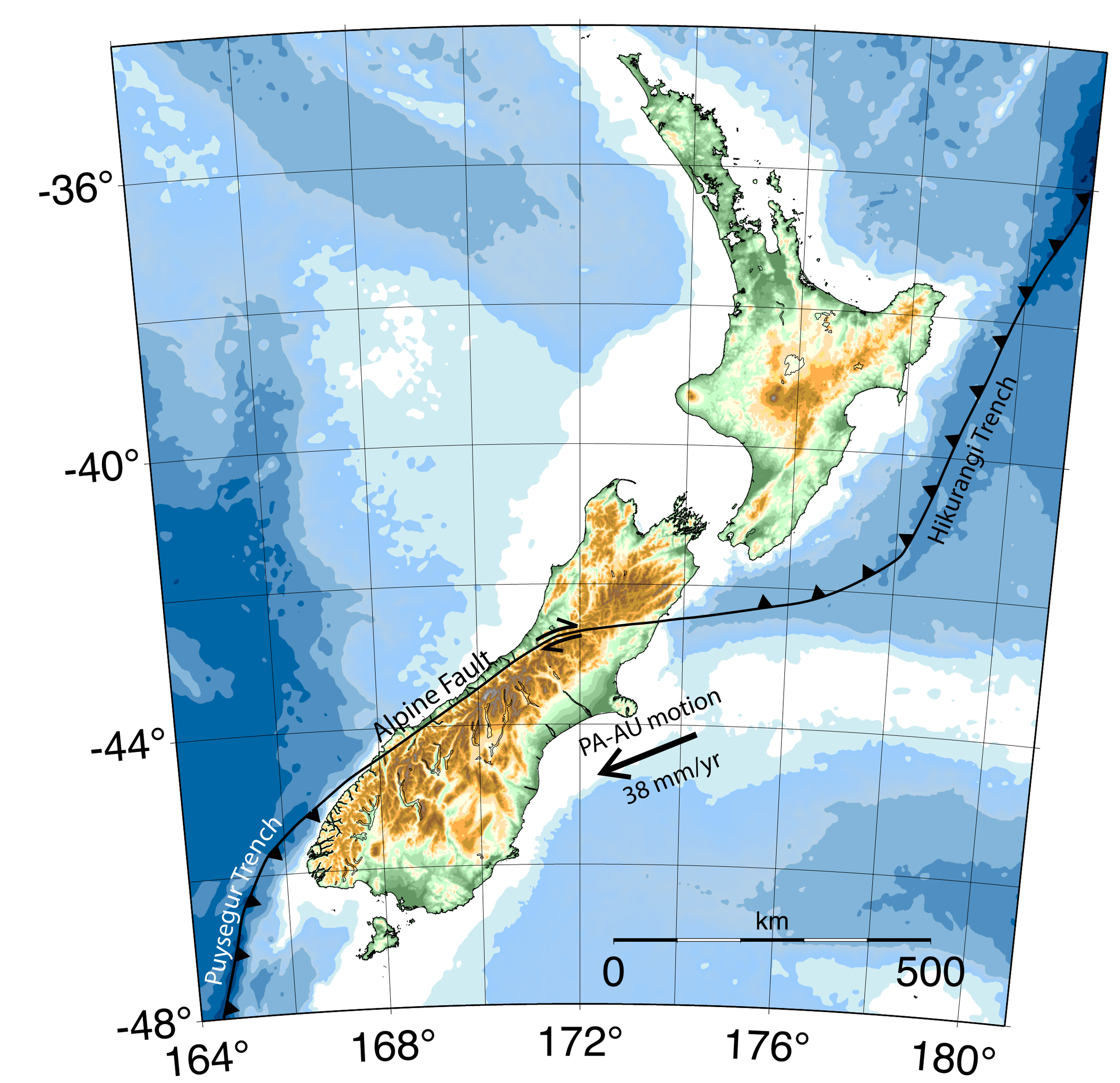
During orogenesis, mountain ranges rise and broaden. Various factors may contribute to the morphology of the orogen: size and geometry of colliding blocks, rheology, and/or kinematic factors such as the convergence angle and relative plate velocity. Here we focus on plate velocity. We might expect a mountain range formed by more rapid convergence to be a larger orogen, because more material is transported into the collision zone. Also, we might assume that seismicity would occur at a higher rate, reflecting greater deformation rates.

Tectonic Settings

The two orogens used for comparison are the Highlands fold and thrust belt in New Guinea and the Southern Alps in New Zealand. The tectonic setting for these two locations is similar: uplift is driven by oblique to transpressional convergence between the Pacific and Australia plates; the angle formed by the plate motion vector and the orientation of the range front is small; and the collisions, beginning in the Middle Miocene, transport material through the orogen on the order of 2-5 million years. Because the other kinematic variables are similar, these are good locations to observe the effect of plate velocity on the orogen. The Pacific-Australia velocity near New Guinea is 110-114 mm/yr, almost three times larger than the rate near New Zealand, 36-39 mm/yr.

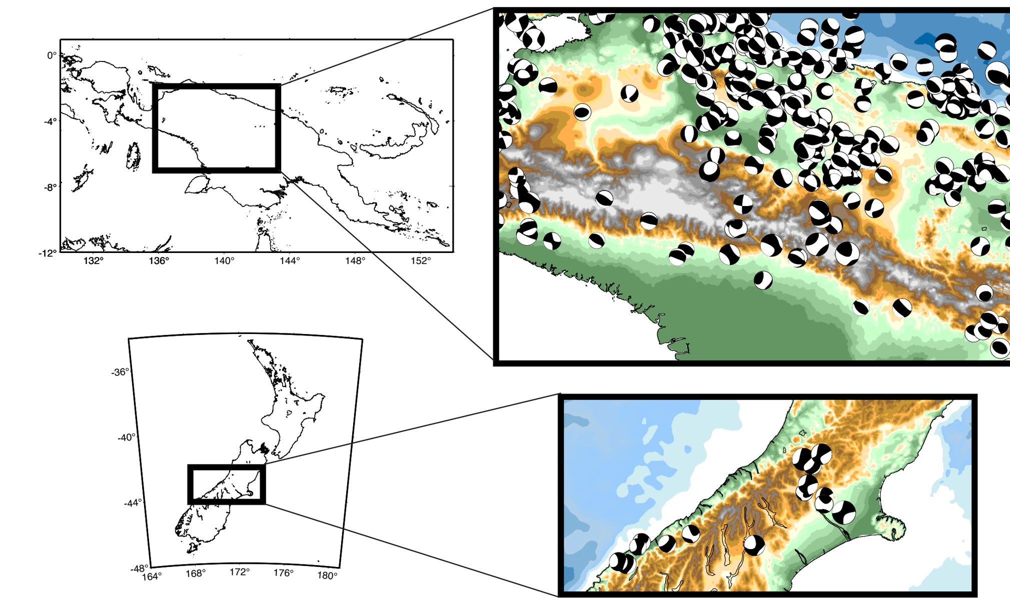
	New Guinea	New Zealand
Velocity Azimuth (Clockwise from N)	246°-248°	242°-250°
Velocity-Structure Angle	30°	15°-20°
Orogen Width	100-250 km	100-200 km
Plate Velocity	110-114 mm/yr	36-39 mm/yr
Maximum Height	4884 meters (Puncak Jaya)	3754 meters (Aoraki/Mt. Cook)





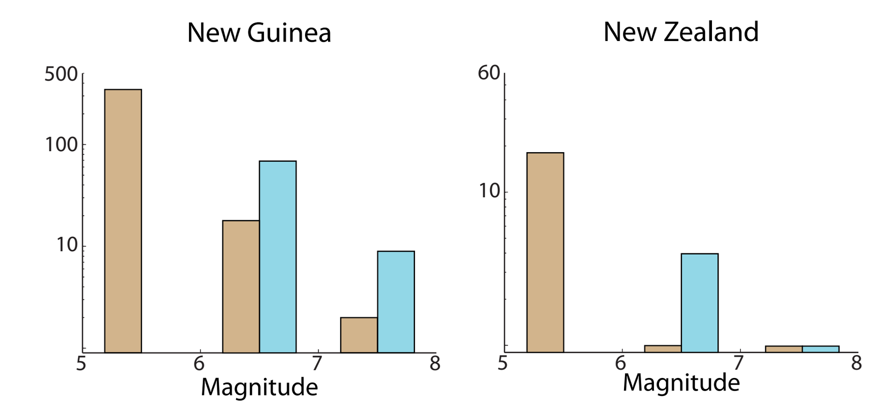
Seismicity

We picked regions for seismic analysis that are representative of the orogens and attempted to exclude subduction-related seismicity. New Guinea seismic data are from the Centennial (Engdahl and Villasenor, 2002) and USGS Catalogs for earthquakes from 1900-present. New Zealand seismic data are from the GeoNet Catalog for earthquakes from 1940-present. Focal mechanisms are from the Global Centroid Moment Tensor Catalog. A b-value analysis indicates that the catalogs are complete in the past 10 years to M5.0 and in the past 50 years to M6.0. Total moment release was calculated for selected regions (shown at right) over the past 10 and 50 years. The value was normalized to the surface area of each region. Moment release units are dyne•cm/km².



Seismic Moment Release

Time Interval	New Guinea	New Zealand (Including M7.0)	New Zealand (Excluding M7.0)	Moment Release Ratio (NG/NZ) (Including M7.0)	Moment Release Ratio (NG/NZ) (Excluding M7.0)
10 Years	2.92×10^{16}	4.15×10^{16}	4.63×10^{15}	0.7	6.3
50 Years	1.28×10^{17}	5.94×10^{16}	2.25×10^{16}	2.2	5.7

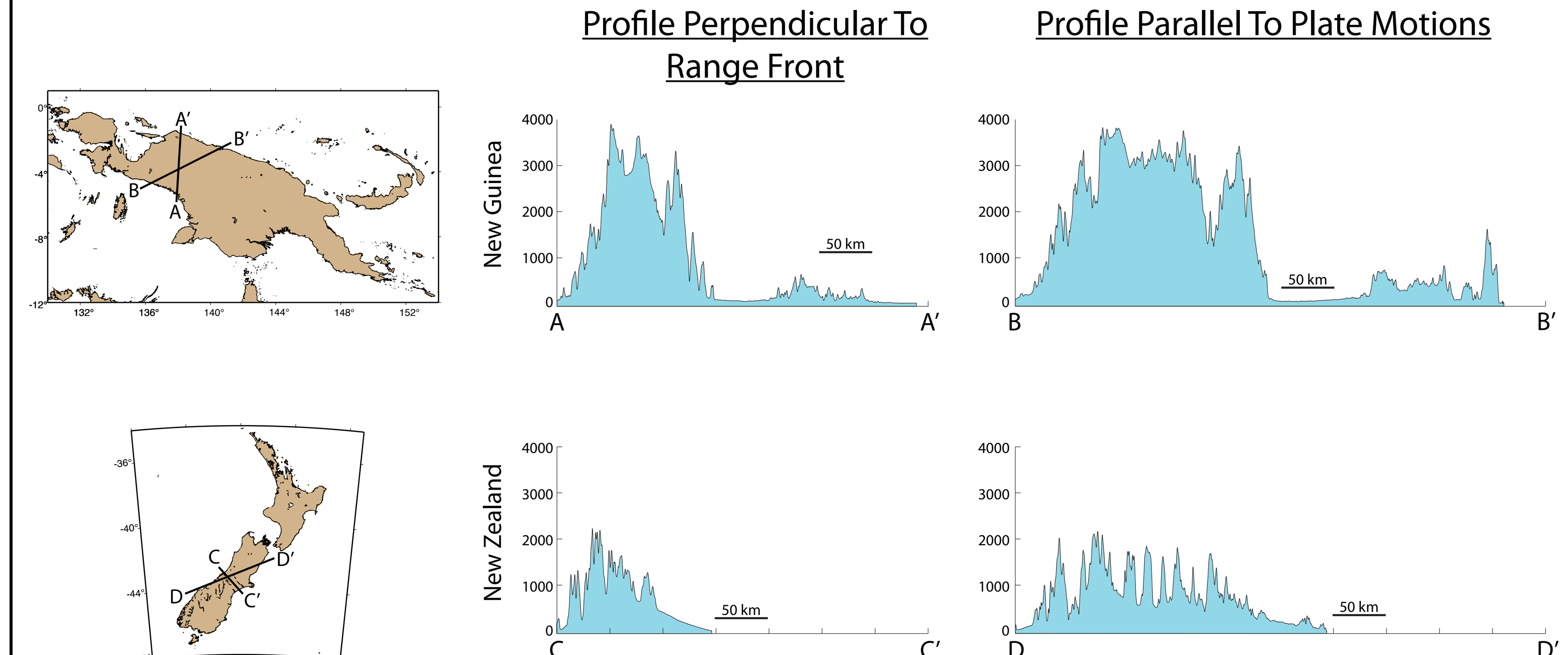


Moment release per km² in the New Zealand orogen (4.15×10^{16}) is greater than in the New Guinea orogen (2.92×10^{16}) over the past 10 years. By excluding the September M7.0 event, the moment release per km² in New Zealand decreases by a factor of 10 (4.63×10^{15}). In the past 50 years, moment release per km² is greater in New Guinea (1.28×10^{17}) than in New Zealand whether the M7.0 event is included (5.94×10^{16}) or not (2.25×10^{16}).

For "common" events, the number of earthquakes in 50 years should be five times the number of events in 10 years. This is the case up to the largest earthquakes (M7.0-7.9) in the New Guinea orogen. In New Zealand, this scaling occurs in the M6.0-6.9 interval; however, M7.0 and larger events are "rare" and do not scale from the 10 to 50 year interval.

Cross Sections

We have constructed profiles of the orogens using SRTM 90 meter resolution DEMs. Across each boundary, profiles were analyzed both perpendicular to the mountain range and parallel to the plate motion direction. The profiles were smoothed with an 11 point running average.



In both the perpendicular and parallel profiles, the New Guinea and New Zealand orogens are approximately the same width, whereas the New Guinea orogen is 2-3 times taller, thus the cross sectional area of the New Guinea orogen is 2.5-3.5 times that of the New Zealand orogen.

Regions for Comparison

We have chosen to compare tectonically straightforward segments of each orogen. In New Guinea, this includes the Highlands fold and thrust belt from 136°-144°, excluding complicating tectonic zones such as the triple junction west of the island and multiple subduction zones north and east of the island. In New Zealand, the segment includes most of the length of the Southern Alps and excludes the Hikurangi and Puysegur subduction zones that connect to the north and south ends of the Alpine Fault.

Discussion

- The 50 year area-normalized moment release rate is 2.2 times larger in the New Guinea orogen than in New Zealand, generally consistent with a plate velocity that is three times larger.
- Moment depends on the total fault area, not the surface area, which can be related to the depth extent of seismicity. In New Guinea, earthquakes regularly occur to 35 km deep, whereas in New Zealand, earthquakes are rarely deeper than 20 km.
- Focal mechanisms in the New Guinea orogen are evenly divided between thrust and strike slip mechanisms. In New Zealand, the mechanisms are dominantly strike slip.
- The New Guinea orogen has a 2-3 times larger cross sectional area than the New Zealand orogen, also consistent with a plate velocity that is three times larger.
- The Highlands fold and thrust belt has not become significantly wider than the Southern Alps, but has grown taller.
- Morphologically, the two orogens are similar and are symmetric both in the range perpendicular cross section and in the motion parallel cross section.