CAUSE OF RECENT EARTHQUAKES IN THE OTWAY AND STRZELECKI RANGES, VICTORIA

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BRIEFING NOTE 496

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An earthquake of magnitude 4.8 occurred 16 km WNW of Apollo Bay in the Otway Ranges of Victoria on October 21, 2023 (Figure 1, left panel). This was followed on February 8, 2024 by a magnitude 4.5 earthquake 1 km SSE of Leongatha in the Strzelecki Ranges in the Latrobe Valley (Figure 1, right panel). Neither earthquake caused significant damage because of their small magnitudes, but they highlight the activity of recent faulting in the Otway and Strzelecki Ranges (Figures 2 and 3). The faults in Figures 2 and 3 are mostly striking in a northeast-southwest direction, perpendicular to the direction of maximum horizonal compression shown in the earthquake focal mechanisms on the right of Figure 3.

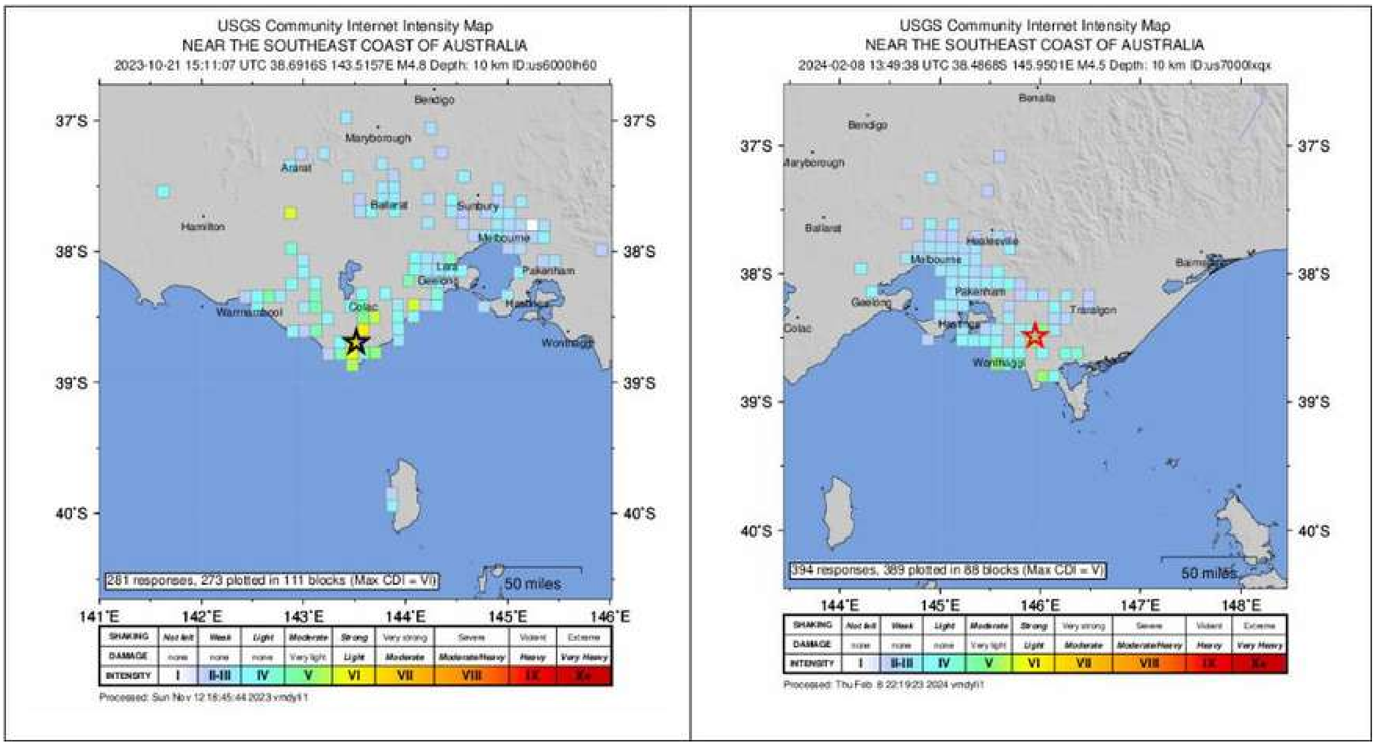


Figure 1. Shakemaps of the Apollo Bay (left) and Leongatha (right) earthquakes. Source: Geoscience Australia.

***Figure 2.**Faults in southern Victoria showing the locations of the Apollo Bay (left) and Leongatha earthquakes (right) as yellow stars. Source: Modified from Geoscience Australia (2023) Neotectonic Features Database.*

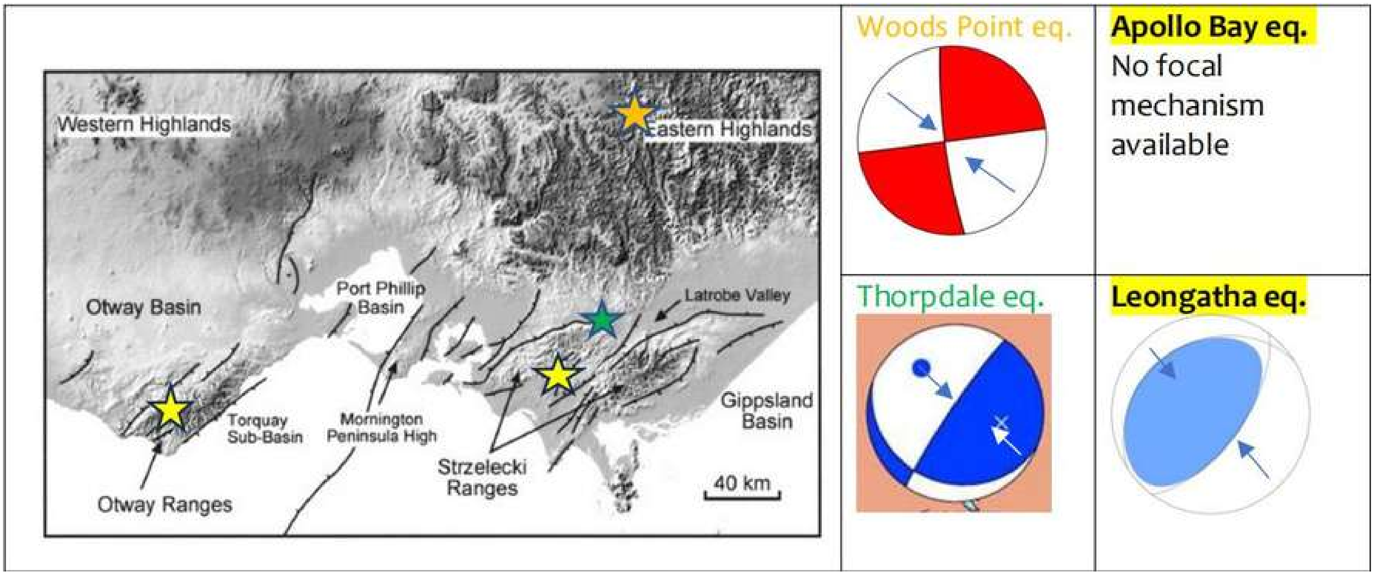
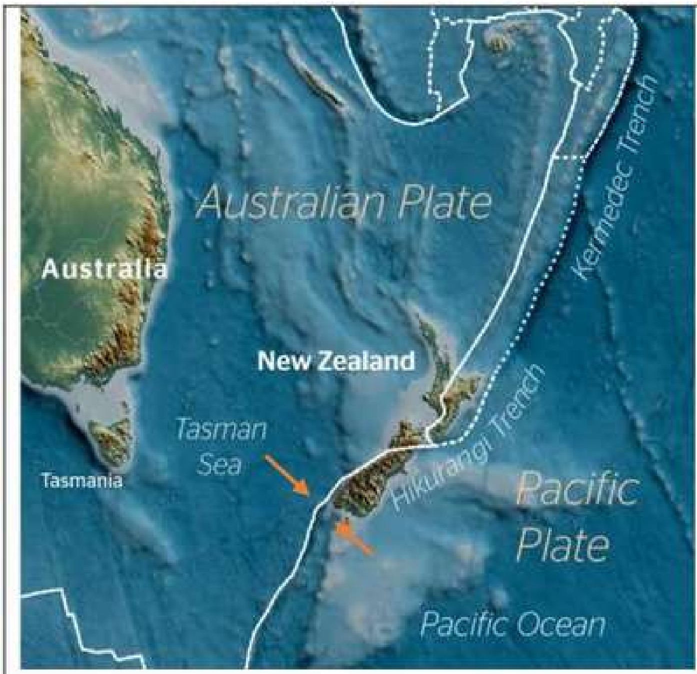


Figure 3.Left: Locations of the 2016 Thorpdale and 2021 Woods Point earthquakes (green and orange stars) and the Apollo Bay and Leongatha earthquakes (yellow stars), and their association with mapped faults of the Strzelecki and Otway Ranges. Right: Focal mechanisms with blue arrows showing the direction of maximum horizontal compressional stress, consistently oriented NW-SE, as also in the 2010 and 2011 Christchurch events (Figure 4).



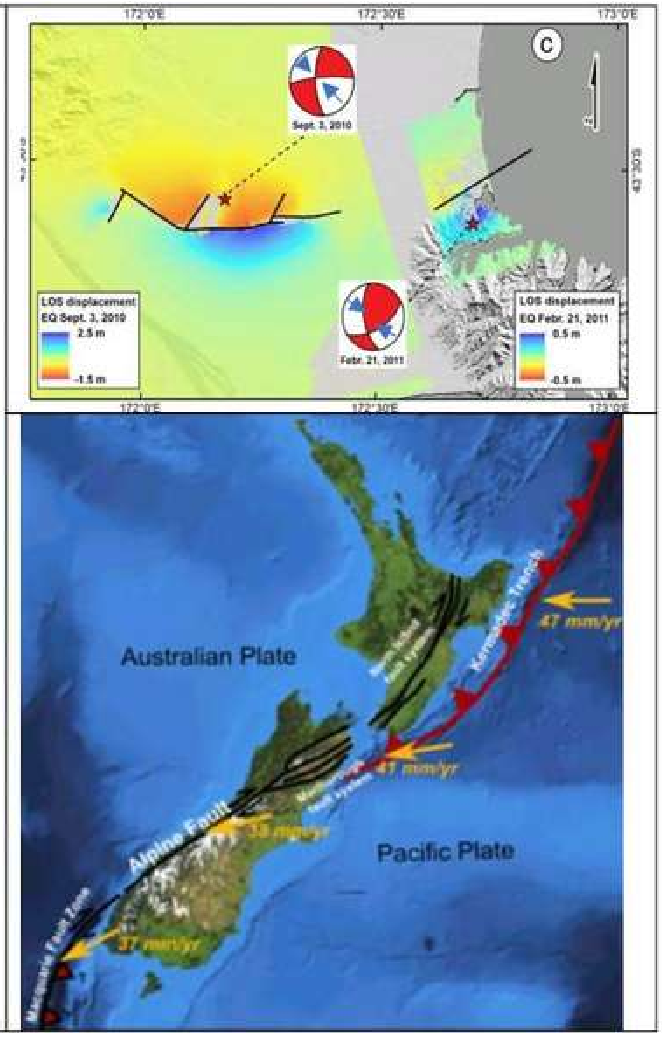


Figure 4. *Top: White line shows the boundary between the Pacific Plate and the Australian Plate. Lower right: The Pacific Plate is converging and colliding with the Australian Plate along the Alpine fault on the west coast of the South Island of New Zealand. Upper right: The arrows in the maps of the Christchurch earthquake focal mechanisms show the direction of maximum horizontal compression is consistently oriented NW - SE in both the SE Australia (Figure 3) and South Island NZ earthquakes, shown by orange arrows in the top panel.*

CAUSE OF THE RECENT EARTHQUAKES IN THE OTWAY AND STRZELECKI RANGES

As illustrated on the left side of Figure 4, the Pacific Plate is converging and colliding with the Australian Plate along the Alpine fault on the west coast of the South Island of New Zealand, as indicated by the orange arrows. The relative motion between these two plates generates strain elastic across their boundary, which is released periodically in earthquakes according to Reid's Elastic Rebound Theory (USGS, 2024), as shown schematically in the right panel of Figure 5. The part of the convergence that is parallel to the fault is accommodated by large strike-slip earthquakes (centre panel of Figure 5) on the Alpine Fault; there have been four major earthquakes (about Mw 8) on this fault in the past 900 years. The part of the convergence perpendicular to the fault is partly accommodated by earthquakes that cause crustal shortening on either side of the fault. In the past ten years, that shortening has occurred in both the Canterbury Plain in the 2010 Mw 7.0 Darfield and 2011 Mw 6.2 Christchurch earthquakes, and in southern Victoria in the 2016 Mw 4.9 Thorpdale, 2021 Mw 5.9 Woods Point, and 2023 Mw 4.8 Apollo Bay and Mw 4.5 Leongatha earthquakes. This crustal shortening is very gradually reducing the width of the Tasman Sea.

The fault planes of the 2016 Thorpdale and 2023 Leongatha earthquakes (Figure 3) and 2011 Christchurch earthquake (top right panel of Figure 4), all reverse faulting earthquakes (left panel of Figure 5), are all oriented northeast-southwest, causing shortening in the northwest-southeast direction. The fault planes of the 2021 Woods Point (Figure 3) and 2010 Darfield (Figure 4) earthquakes are both strike-slip earthquakes (centre panel of Figure 5) having roughly north-south and east-west strikes respectively, with shortening in the northwest-southeast diagonal direction in both cases.

HOW EARTHQUAKES CAUSE CRUSTAL SHORTENING

Reverse faulting on dipping fault planes directly reduces the distance between the two sides of the fault in the direction of fault motion, as illustrated on the left panel of Figure 5. Strike-slip faulting on vertical fault planes reduces the distance diagonally at 45 degrees in the northwest-southeast direction and increases the distance diagonally at 45 degrees in the northeast-southwest direction, as illustrated in the centre panel of Figure 5.

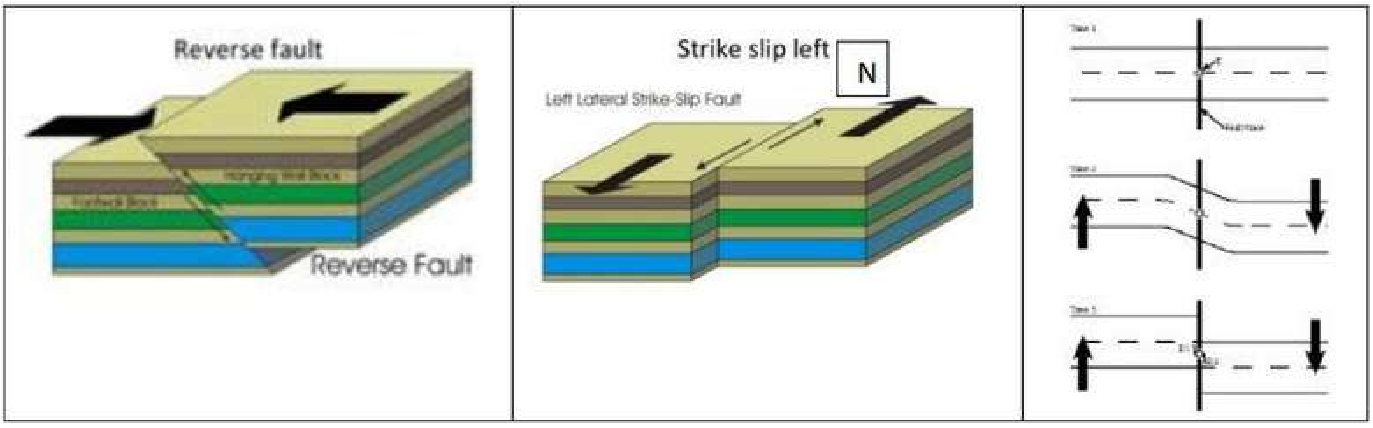


Figure 5. Mechanism of reverse faulting (left) and strike-slip faulting (centre). Right: Reid's elastic rebound theory of earthquakes applied to strike-slip faulting, showing map views of a fault (thick black line) crossing a road at top: undeformed state; centre: strained preseismic state; and bottom: unstrained postseismic state. Source: USGS (2023). Sudden motion of the fault in an earthquake transforms the centre map to the bottom map in a few seconds or tens of seconds.

The topographic map of southeastern Australia in Figure 6 shows the Flinders and Mt. Lofty Ranges of South Australia which, like the Otway and Strzelecki Ranges of Victoria (but unlike the Eastern Highlands), are in phases of active mountain building due to earthquakes occurring on the faults shown in Figures 2 and 3. This causes crustal shortening in a NW-SE direction across these mountain ranges.

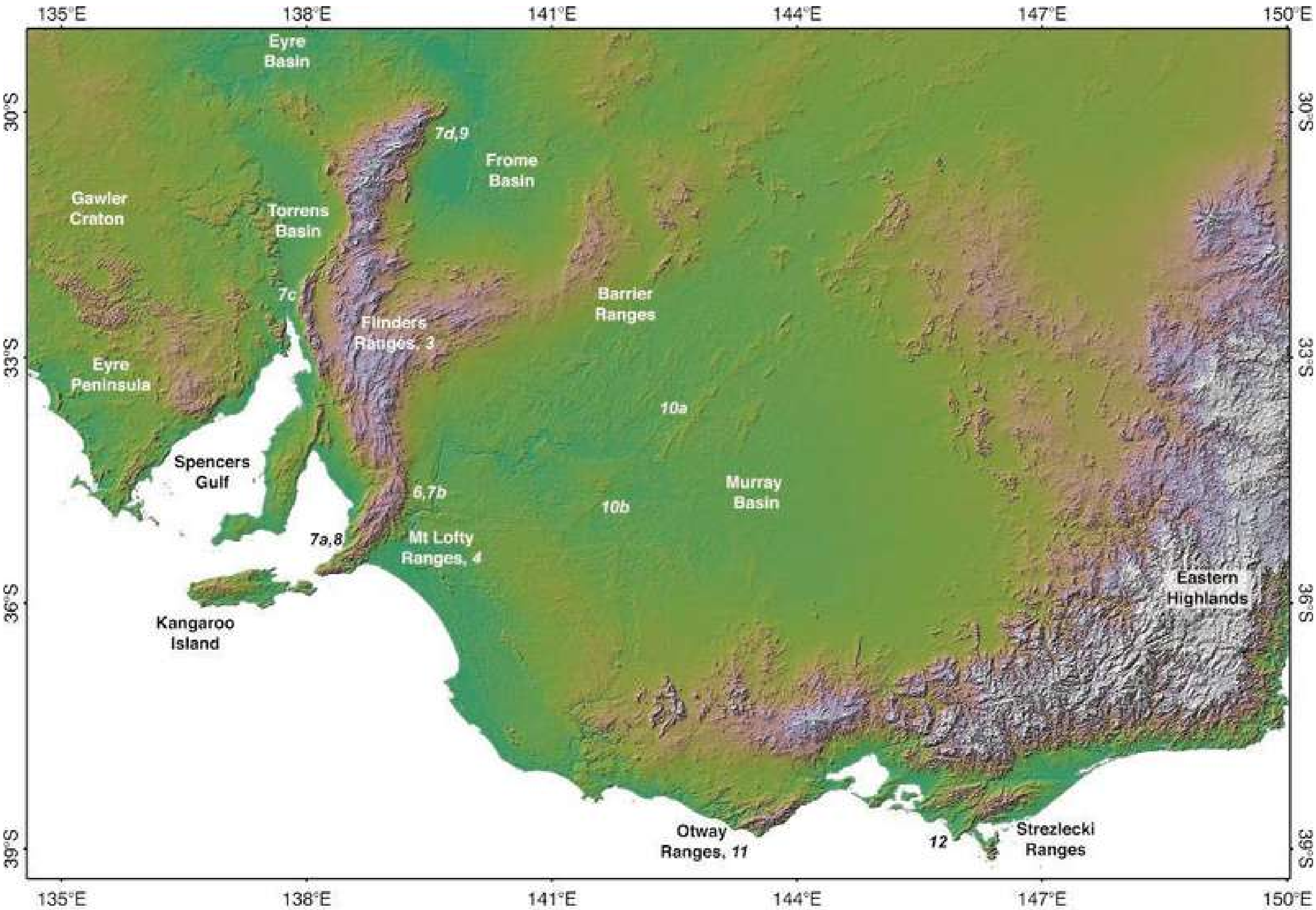


Figure 6. Topographic map of southeastern Australia showing the Flinders and Mt. Lofty Ranges, the Otway and Strzelecki Ranges, and the Eastern Highlands. Source: Sandiford (2003).

The contributions of the active faults of the Flinders and Mt. Lofty Ranges and the Otway and Strzelecki Ranges are evident in the historical seismicity of Australia (left side of Figure 7) and the probabilistic ground motion map (right side of Figure 7), especially in the recent activity in the Strzelecki Ranges.

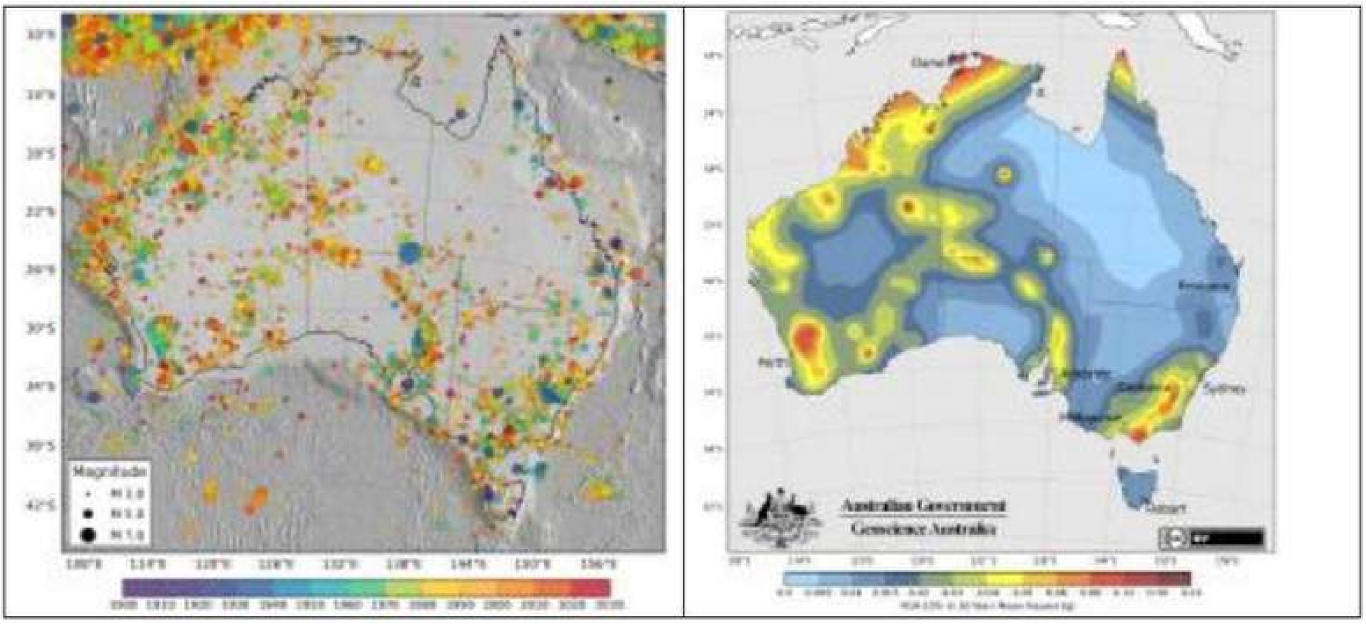


Figure 7. Historical seismicity (left, with dot colour showing recency of occurrence) and the probabilistic peak ground acceleration for an AEP of 1:500 for reference site conditions (Vs30 of 760 m/s). Source: Allen (2023).

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Paul is Chief Geoscientist at Risk Frontiers. He has a PhD in Geophysics, and has 45 years experience as an engineering seismologist, including 15 years with Risk Frontiers. He has had first hand experience of damaging earthquakes in California, Japan, Taiwan and New Zealand. **He works with Jacob Evans and Behnam Beheshtian in the development of QuakeAus and QuakeNZ.**