

# Presentation of September 4, 2010 Canterbury Earthquake

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# Introduction

- ▶ This presentation is on the 2010 Mw 7.1 Canterbury Earthquake. The earthquake occurred as I was traveling from San Francisco to Auckland, New Zealand to attend the IAEG Congress. Upon arrival I was asked to join the Geotechnical Extreme Events Reconnaissance (GEER) team to document damage from the event in the Christchurch area of the South Island. Little did I know that another smaller (Mw 6.2), yet deadlier earthquake would strike 5 months later in close to the same area.

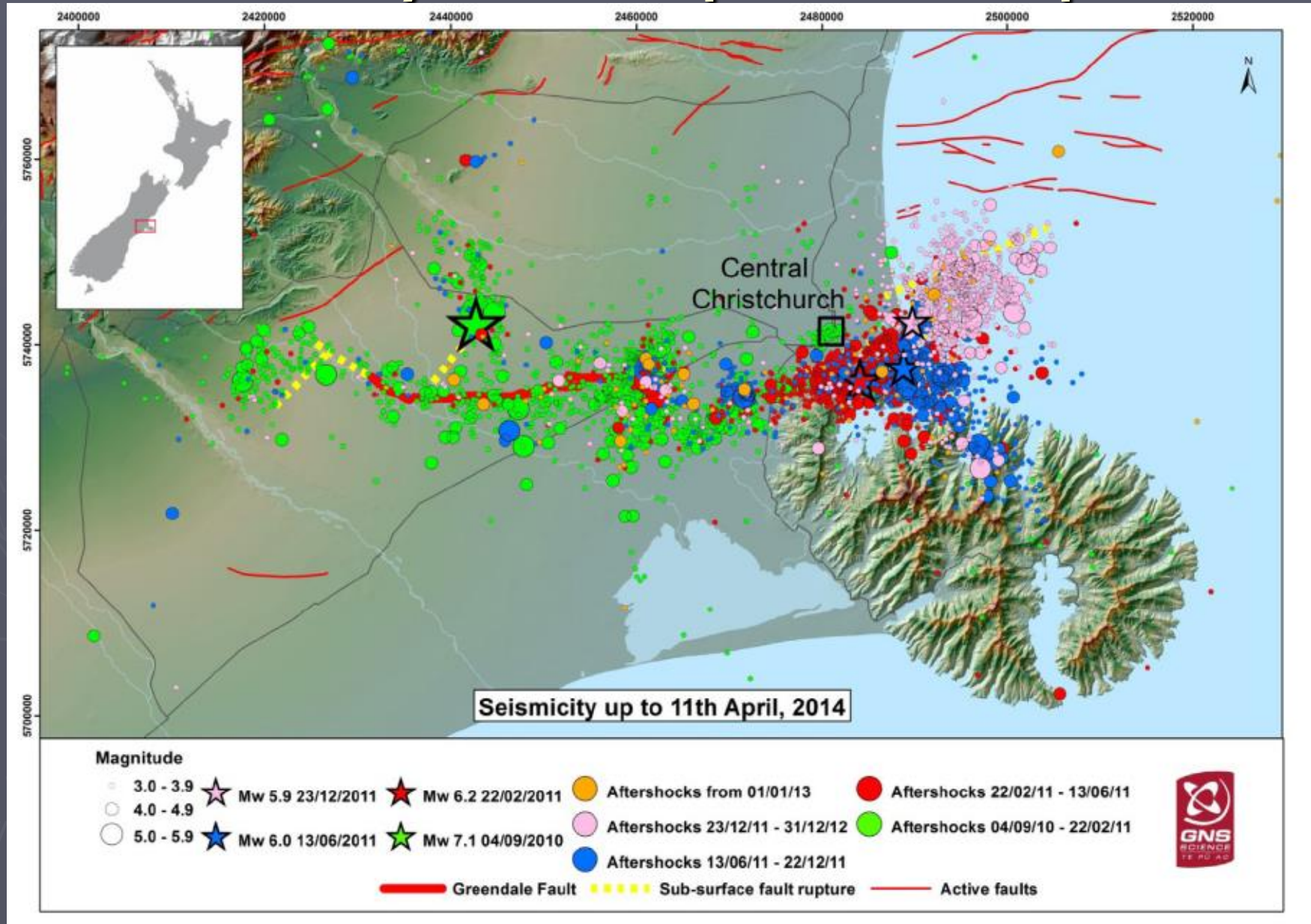
# Introduction

- ▶ The purpose of the GEER is to observe and record earthquake induced phenomena and impacts to infrastructure before evidence is removed or altered as part of cleanup efforts.
- ▶ The reconnaissance was conducted by a joint USA-NZ-Japan team with the main funding for the USA contingent coming from GEER and partial support from PEER and EERI.
- ▶ This presentation includes my photographs from Sept. 8-10 supplemented with a few photos and observations noted in the GEER report, Nov. 2010. I also describe other seismic events from 2011-16.

# Sept 4<sup>th</sup> Darfield Earthquake

- ▶ At 4:35 am on September 4th NZ Standard Time (16:35 Sept 3rd UTC) the rupture of a previously unrecognized strike-slip fault (Greendale Fault) beneath the Canterbury Plains of New Zealand's South Island produced a Mw 7.1 earthquake that caused widespread damage throughout the region. Surprisingly only two people were seriously injured, with approximately 100 total injuries. This compares with 185 deaths in the 2011 event

# Canterbury Earthquake Sequence



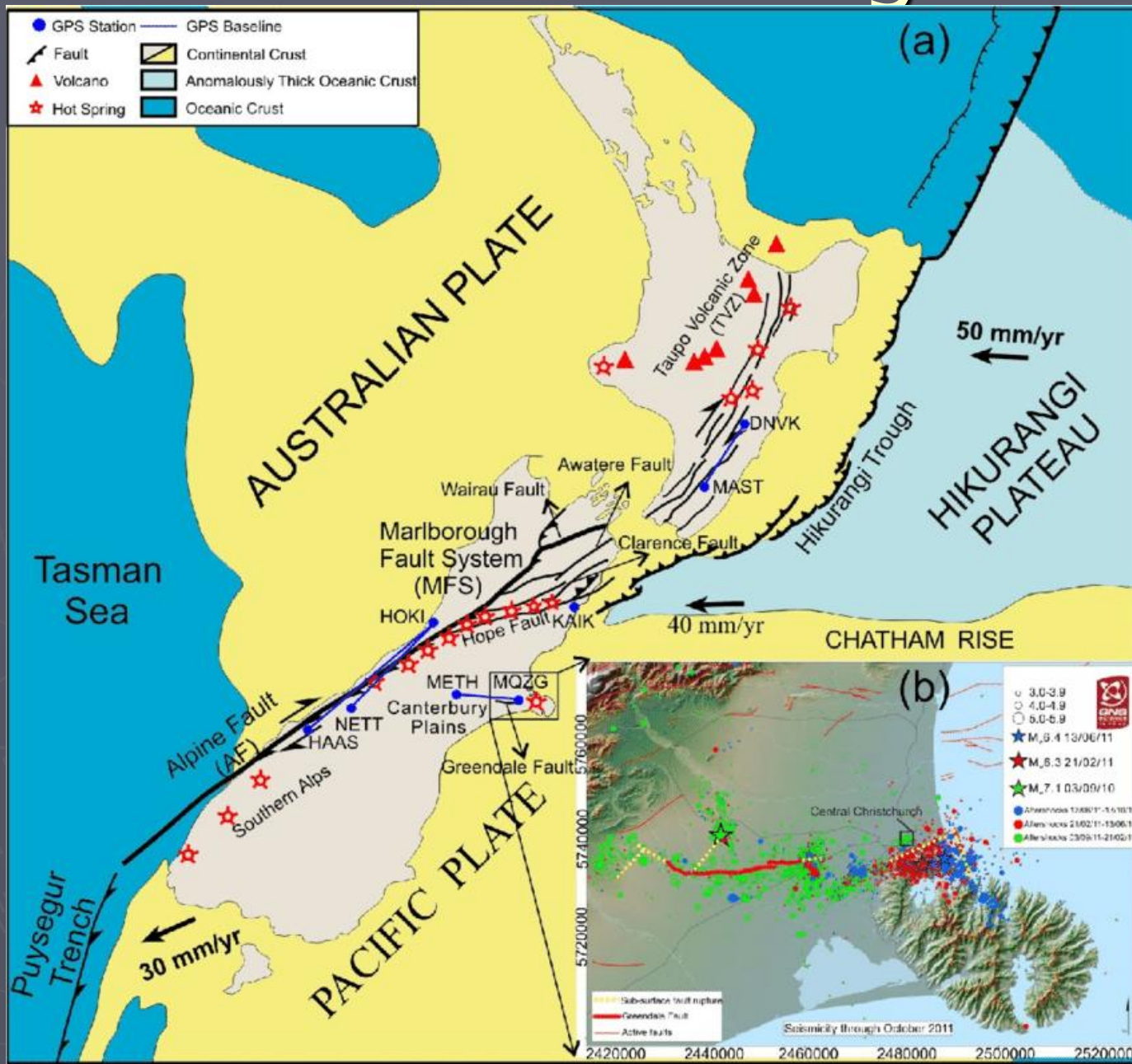
# Greendale Fault Rupture Characteristics

Surface Rupture Length	29 km
Average Surface Displacement	2.3 m
Maximum Surface Displacement	4.6 m
Subsurface Rupture Length*	45 km
Subsurface Rupture Width*	23 km
Rupture Area*	1035 km <sup>2</sup>

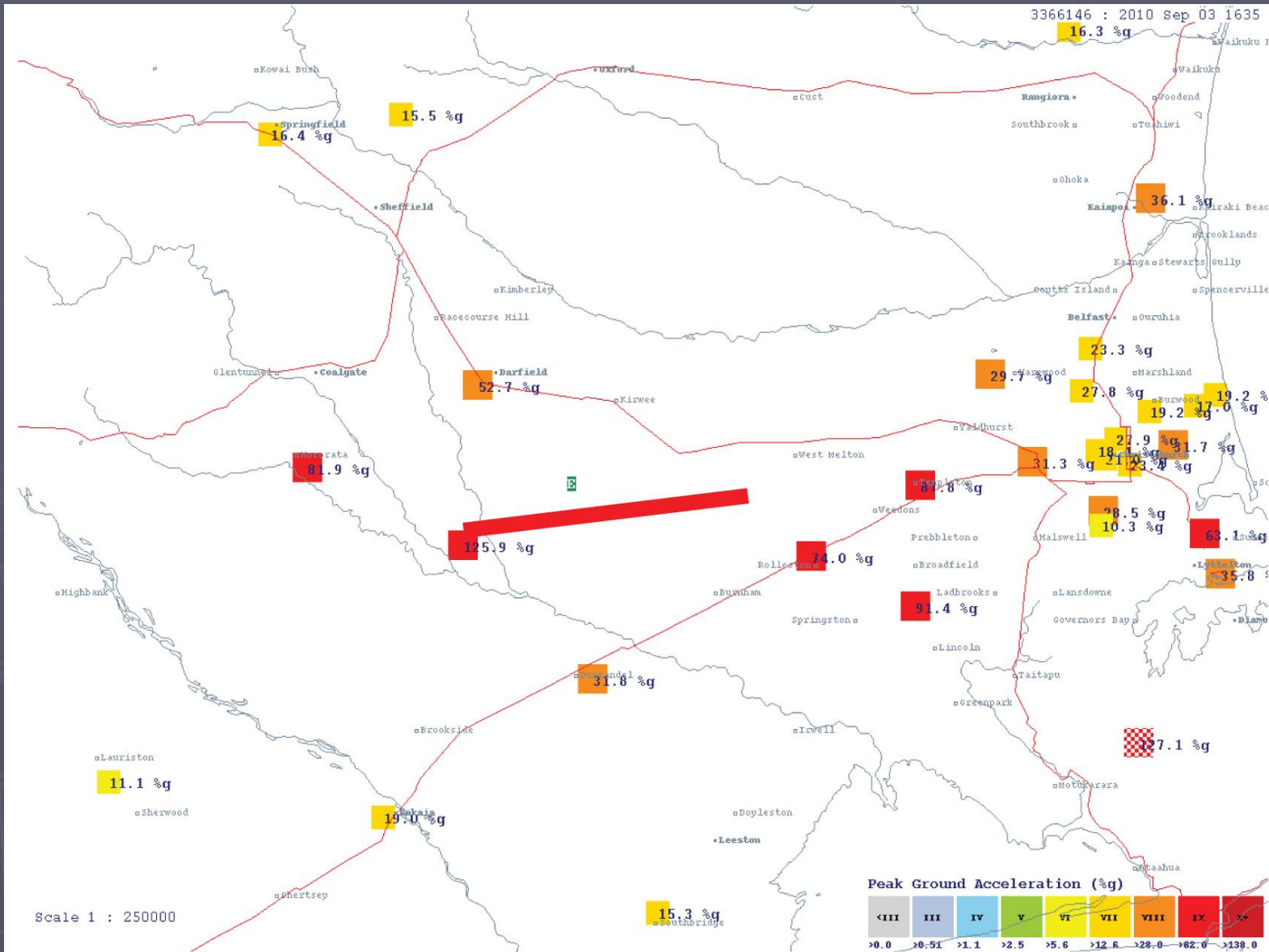
\*Estimated from preliminary interpretations of GPS and INSAR data

Epicenter (focal) depth: 10.8km

# Tectonic Setting

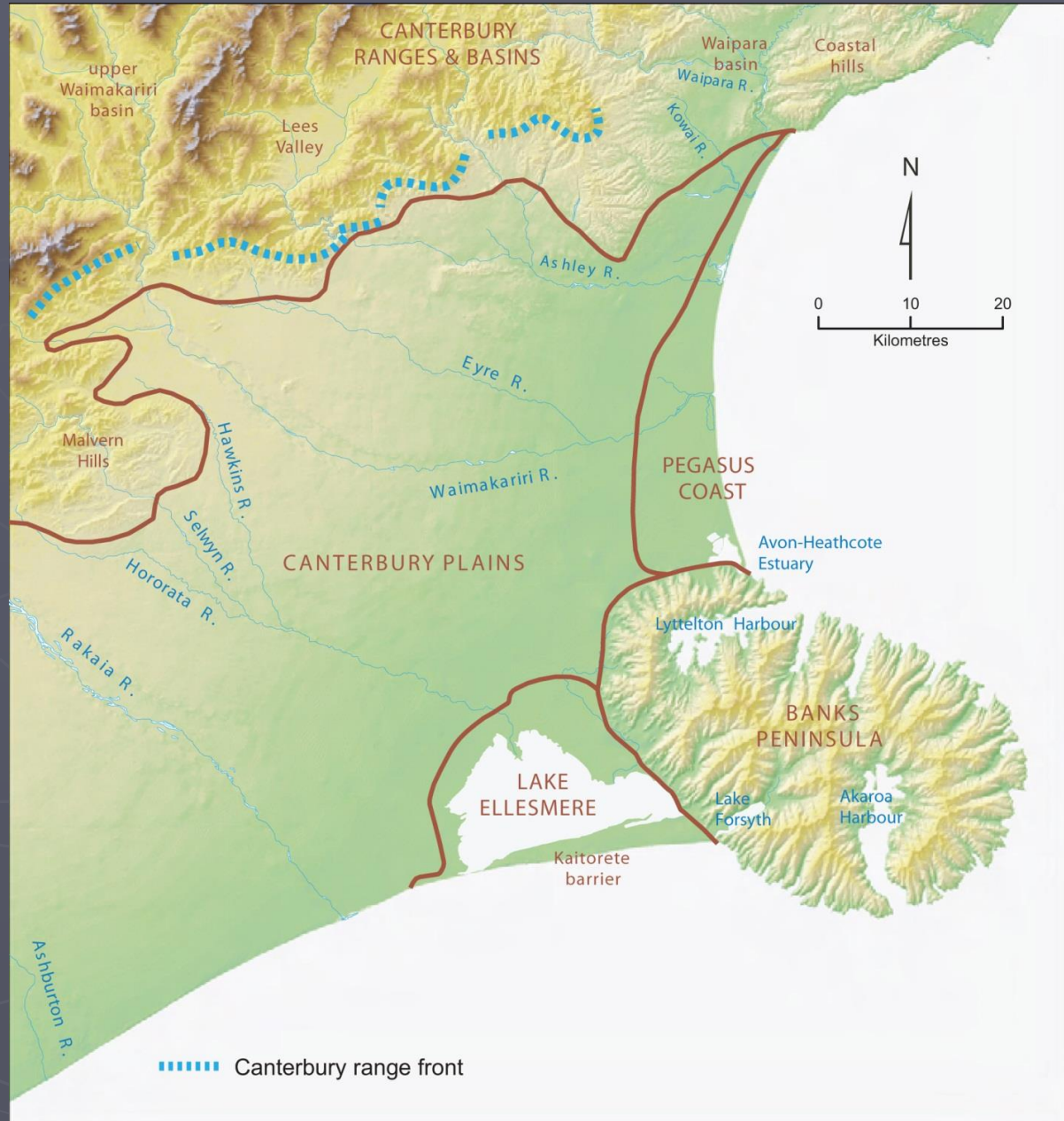


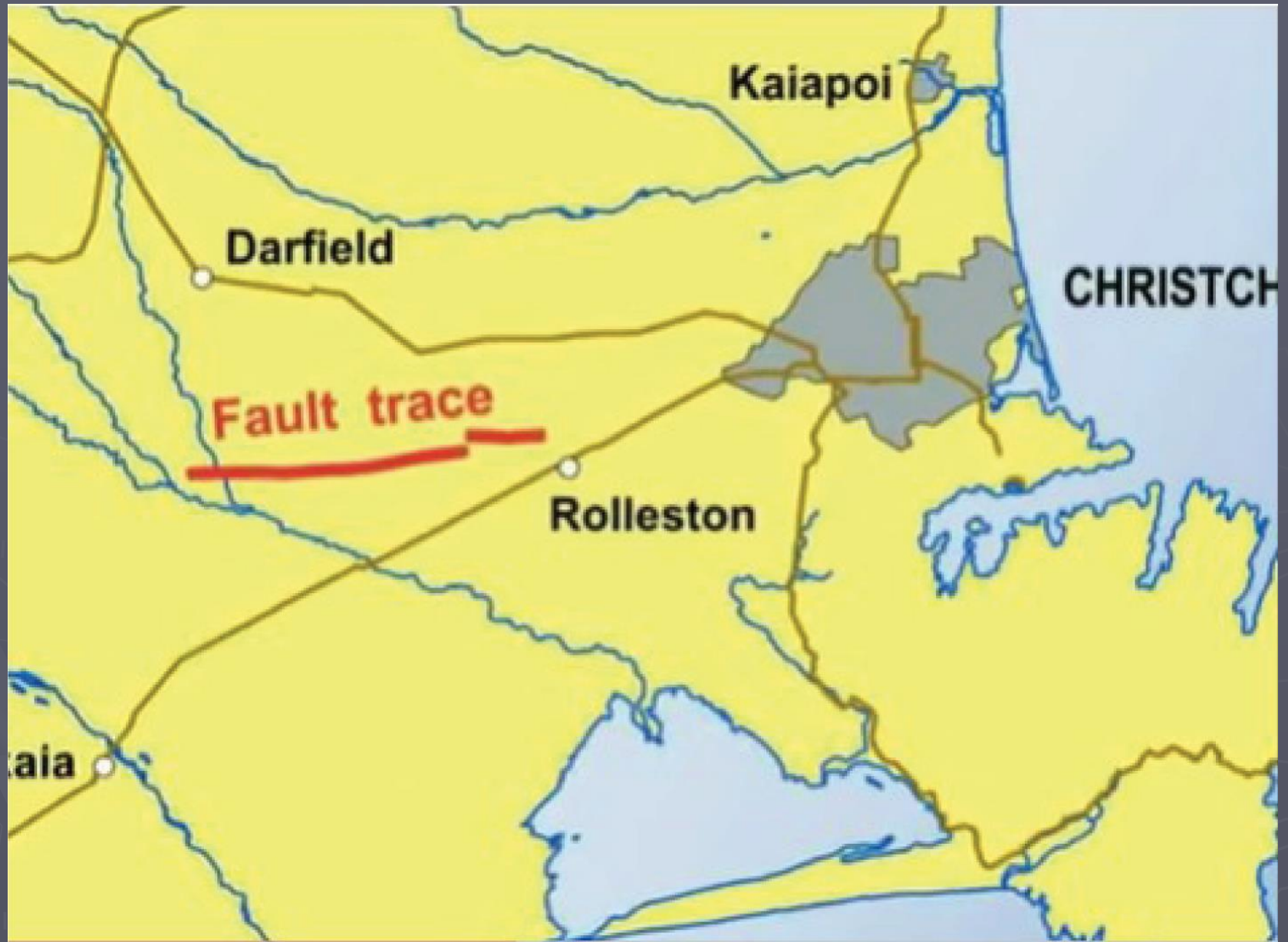
# Ground Motion (pga)





# Geographical Setting

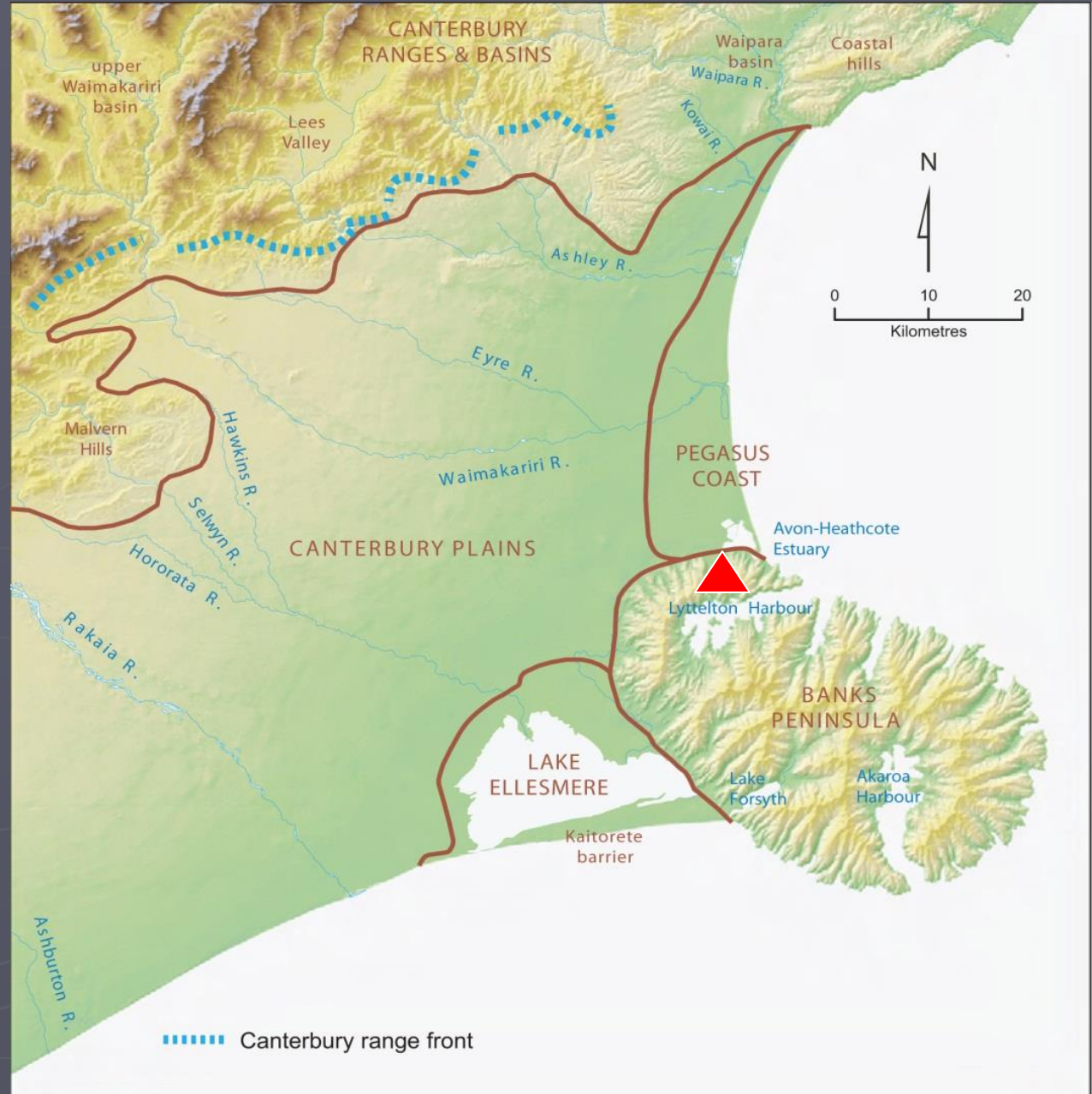




# Preliminary Observations

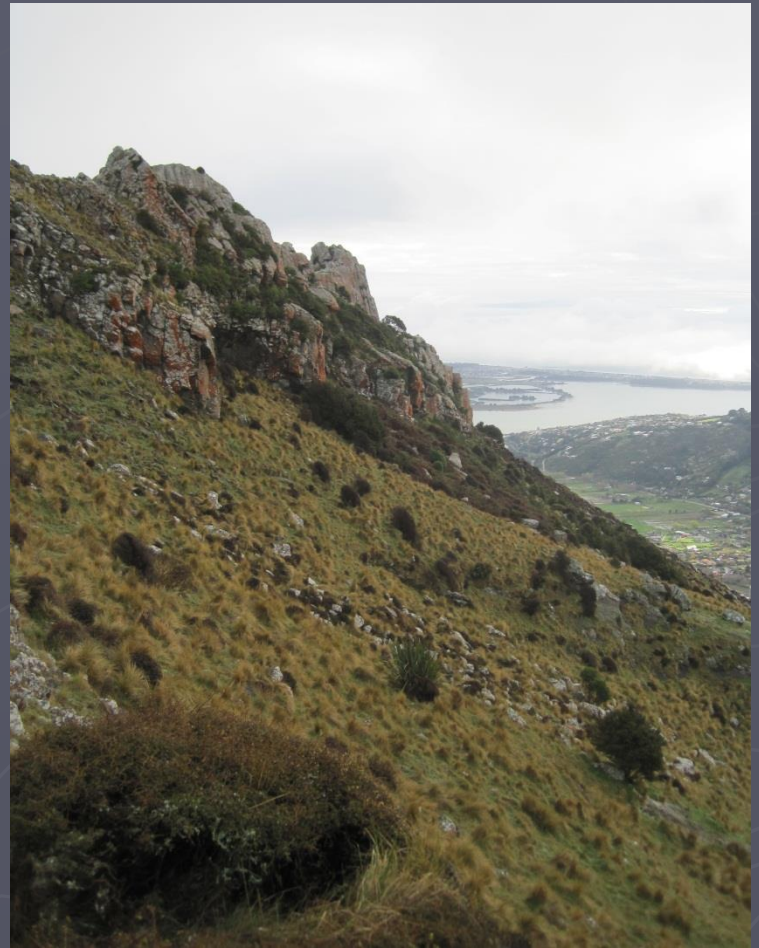
- ▶ Rock Avalanche, Castle Rock Reserve, Littleton, Christchurch
- ▶ Fault Offset, Telegraph Rd at Grange Rd.
- ▶ Fault Offset, Highfield Rd at Grange Rd
- ▶ Sand Boils, Christchurch
- ▶ Liquefaction features, Kalapoi
- ▶ Railroad deformation south of Kirwee
- ▶ Waimakariri River bridge near Sheffield
- ▶ Ashely Bridge crossing of Waimakariri River

# Rock Avalanche, Castle Scenic Reserve, Littleton, Christchurch









# Rock Avalanche



View upslope towards source



View down the chute towards tunnel portal



# Fault Offset, Highfield Rd south of Telegraph Rd





Photo by David Burrell, courtesy of GNS Science

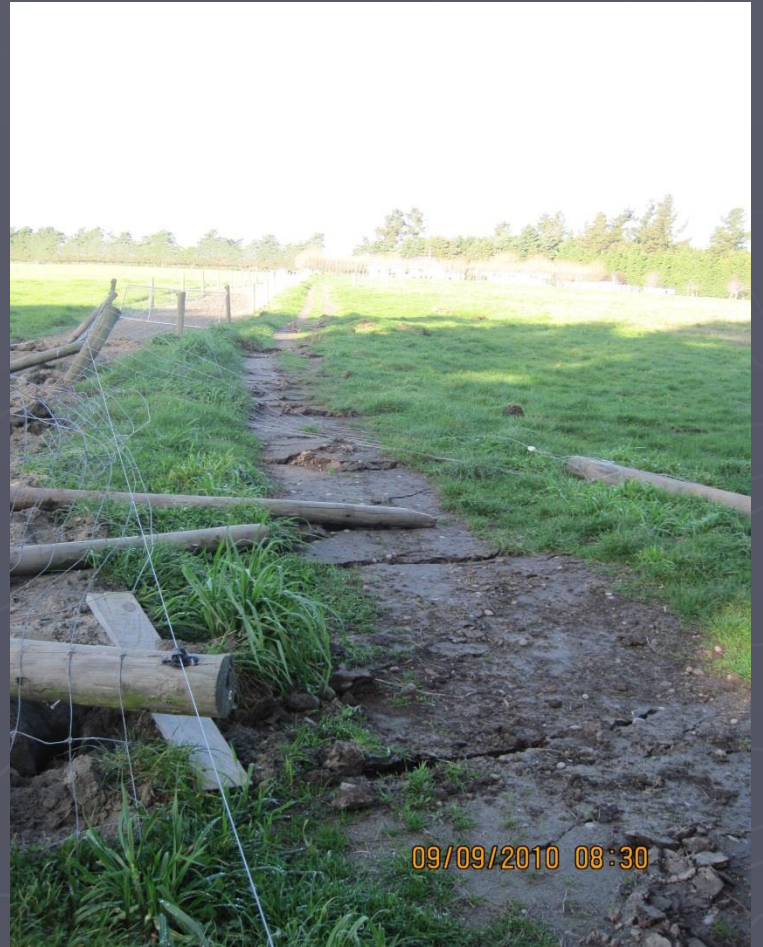




# Impacts to Structures



Christchurch



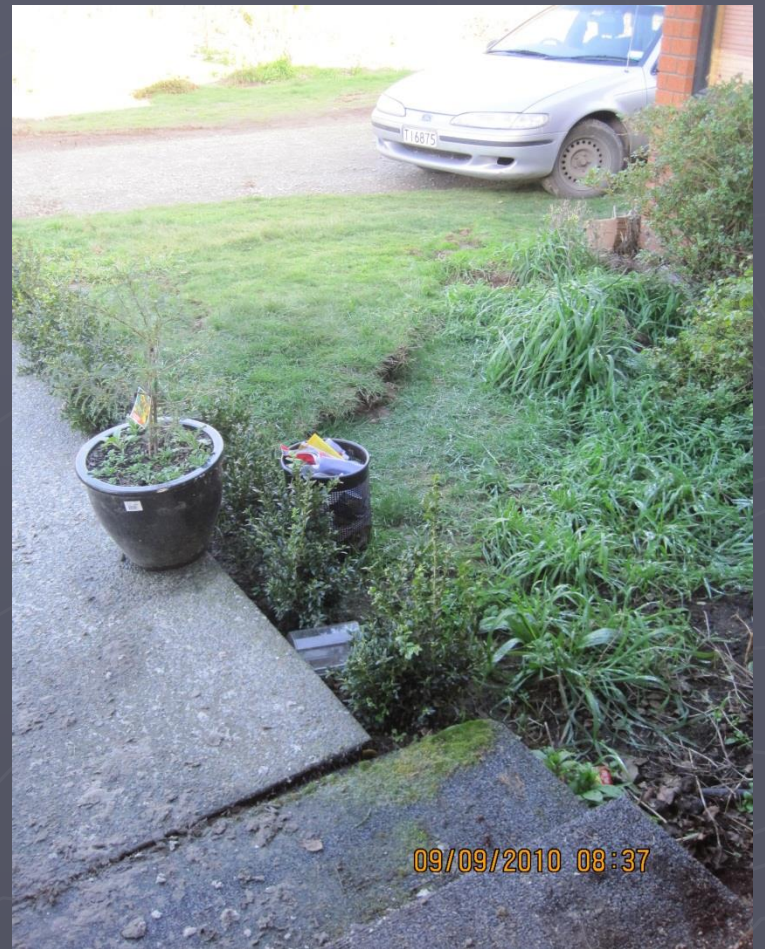






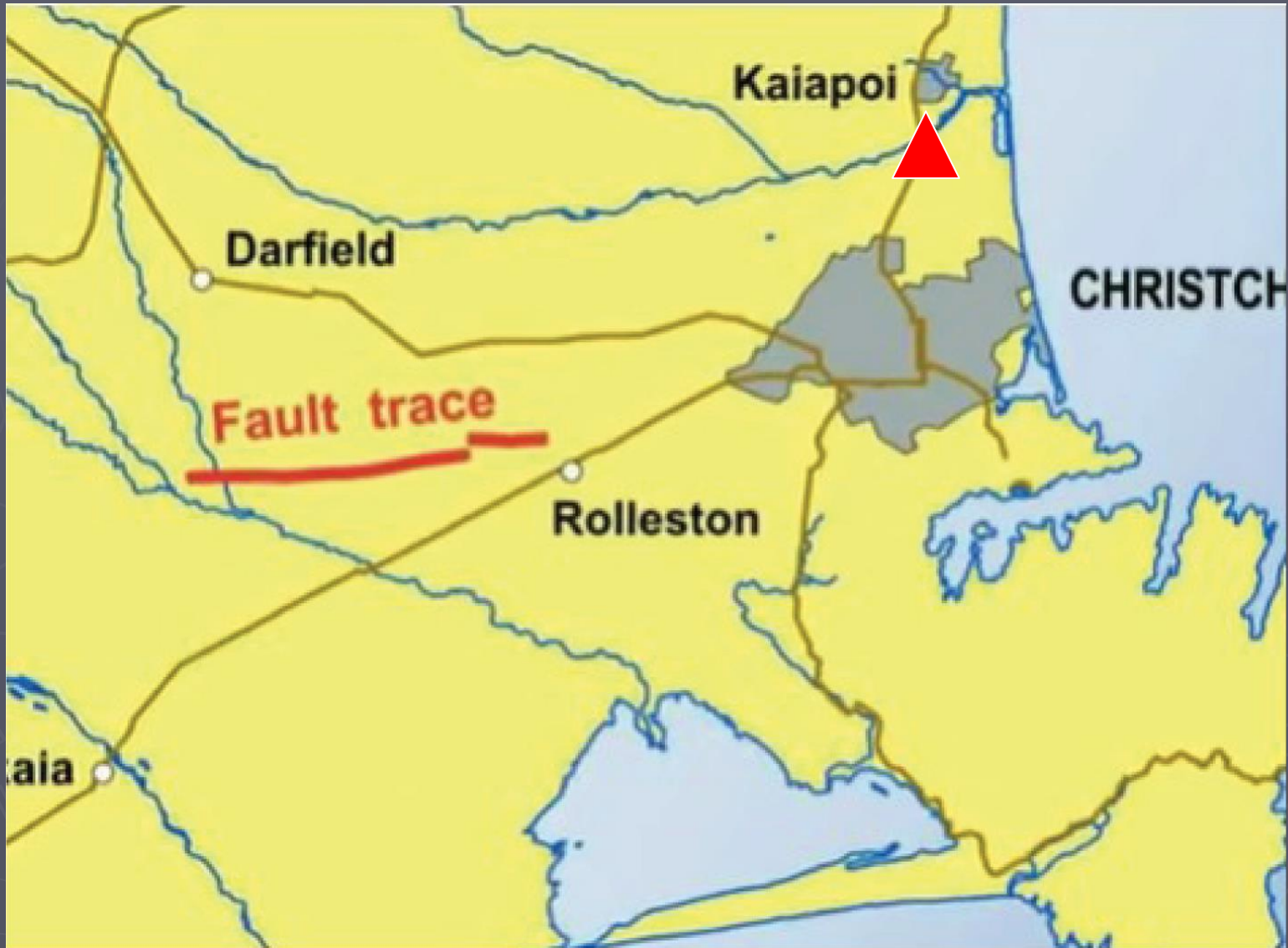






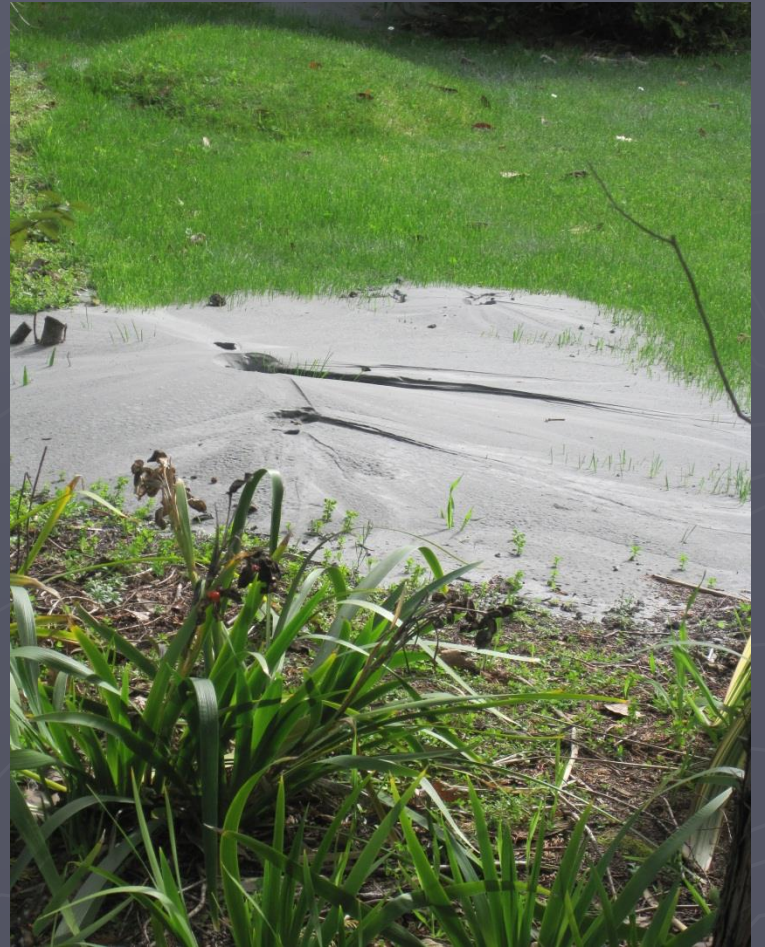


# Liquefaction Features



# Liquefaction features, Christchurch and Kaiapoi Area









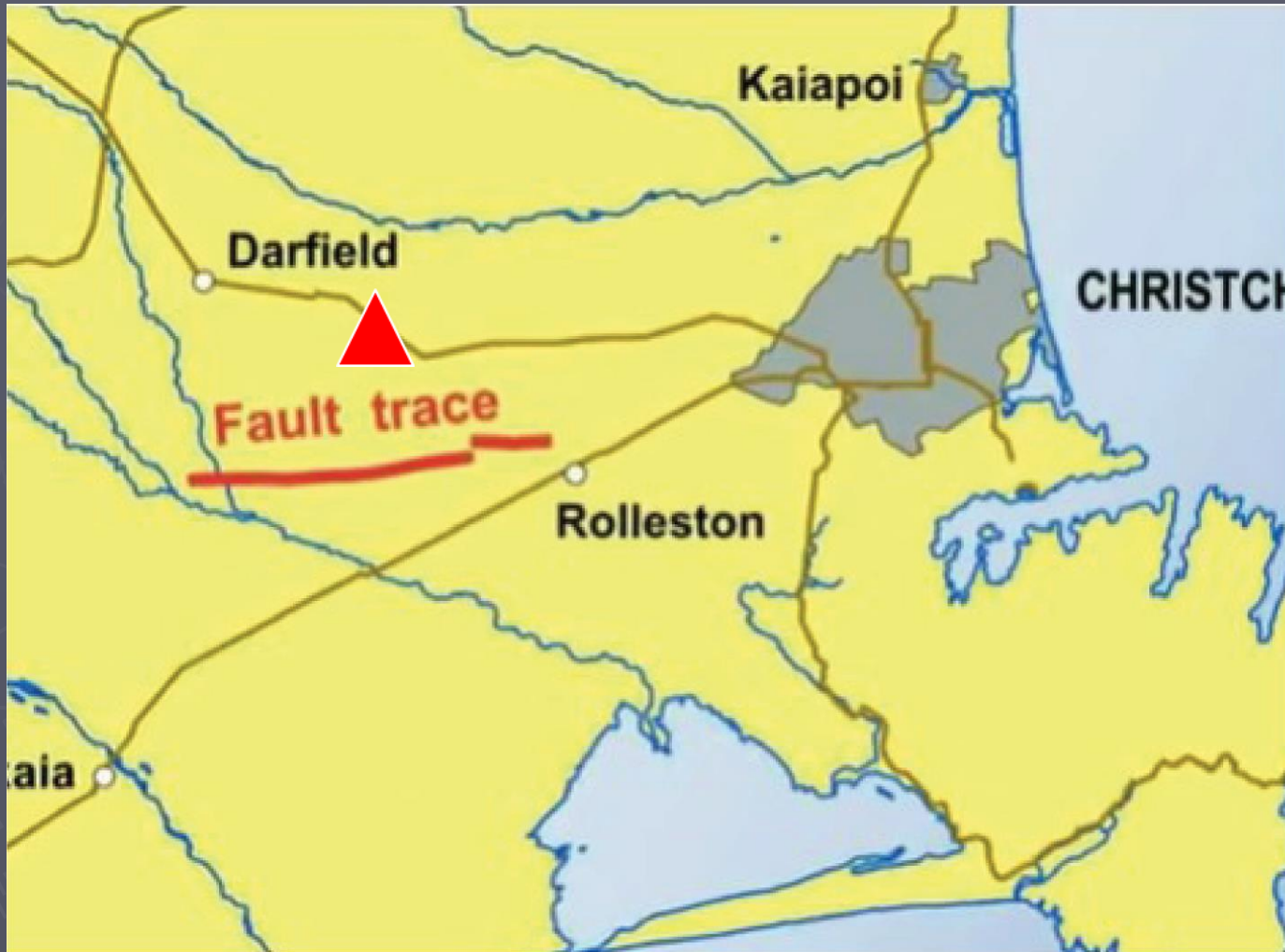


# Kaiapoi River lateral spreading





# Railroad damage



# Railroad deformation south of Kirwee





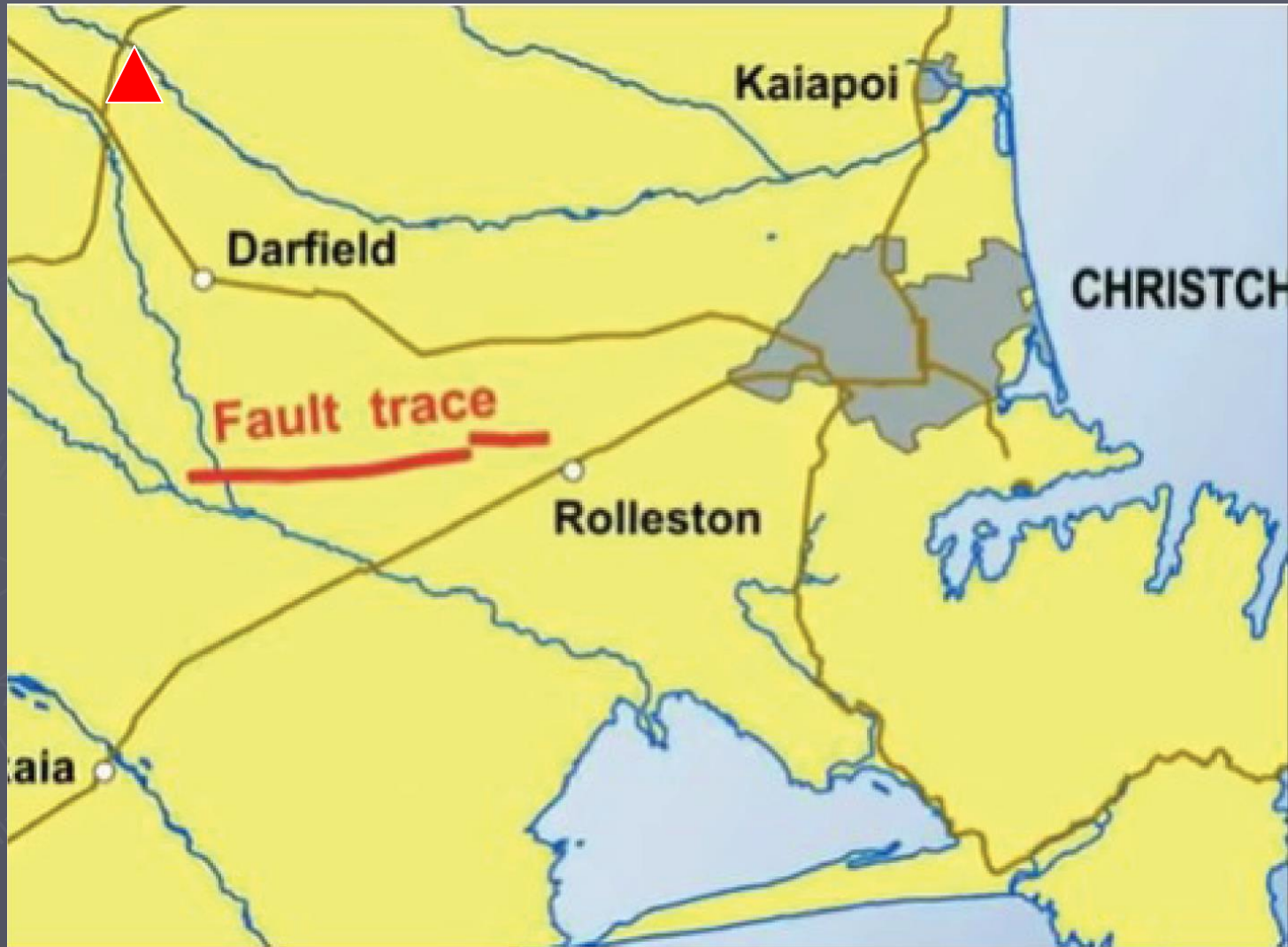
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# Railroad embankments



Rolleston (at left). Woodford Glen  
(top)

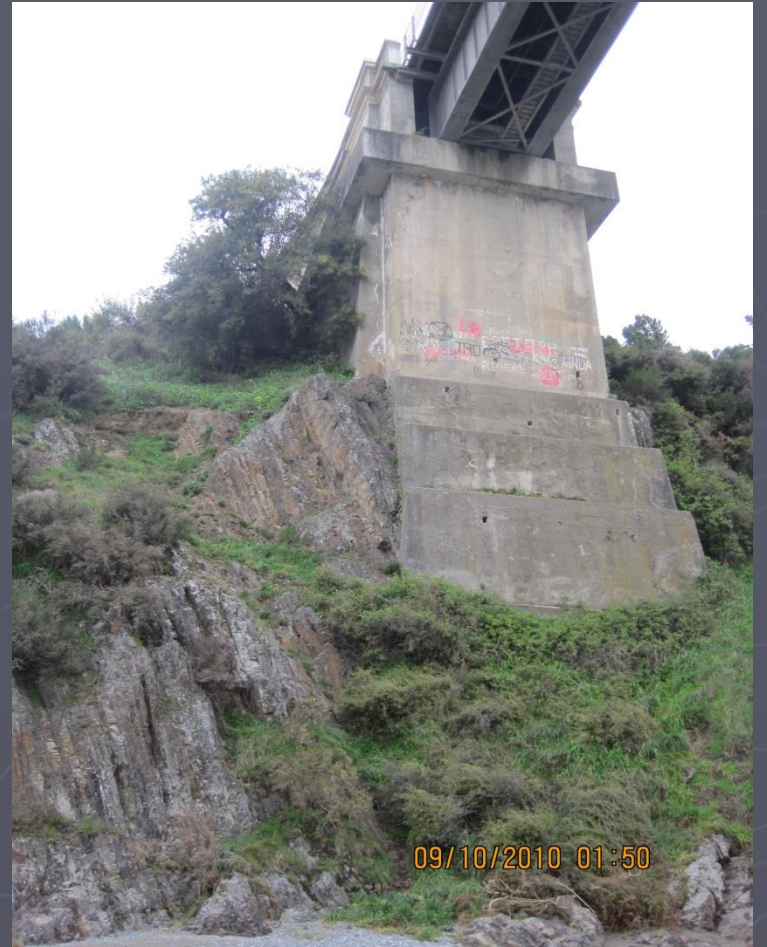
# Bridge Sites





# Waimakariri River bridge near Sheffield







# Ashely River Bridge Retrofit





# Darfield EQ References

- ▶ Bridges: Wotherspoon et al, 2011. Performance of Bridges during the 2010 Darfield and 2011 Christchurch Earthquakes. *Seismological Research Letters*; 82 (6): 950–964.
- ▶ Liquefaction: Beyzaei et al, 2018. Depositional environment effects on observed liquefaction performance in silt swamps during the Canterbury earthquake sequence, *Soil Dynamics and Earthquake Engineering*; 107 303–321
- ▶ Ground Motion: Seguo and Kalkan, 2011. Ground motion attenuation during M 7.1 Darfield and M 6.2 Christchurch, New Zealand, earthquakes and performance of global predictive models ; *Seismological Research Letters*; 82 (6): 866–874.
- ▶ Rockfall: Khajavi et al, 2012. Seismically induced boulder displacement in the Port Hills, New Zealand during the 2010 Darfield (Canterbury) earthquake; *New Zealand Journal of Geology and Geophysics* Volume 55, Issue 3 271-278
- ▶ GEER Report: Geotechnical Reconnaissance of the 2010 Darfield (New Zealand) Earthquake, Version 1 Report Nov. 2010 Editors: Russell A. Green - US Lead (Virginia Tech, Blacksburg, VA, USA), Misko Cubrinovski - NZ Lead (University of Canterbury, Christchurch, New Zealand), 172pp. doi:10.18118/G6D59F

# 2011 $M_w$ 6.3 Christchurch Earthquake

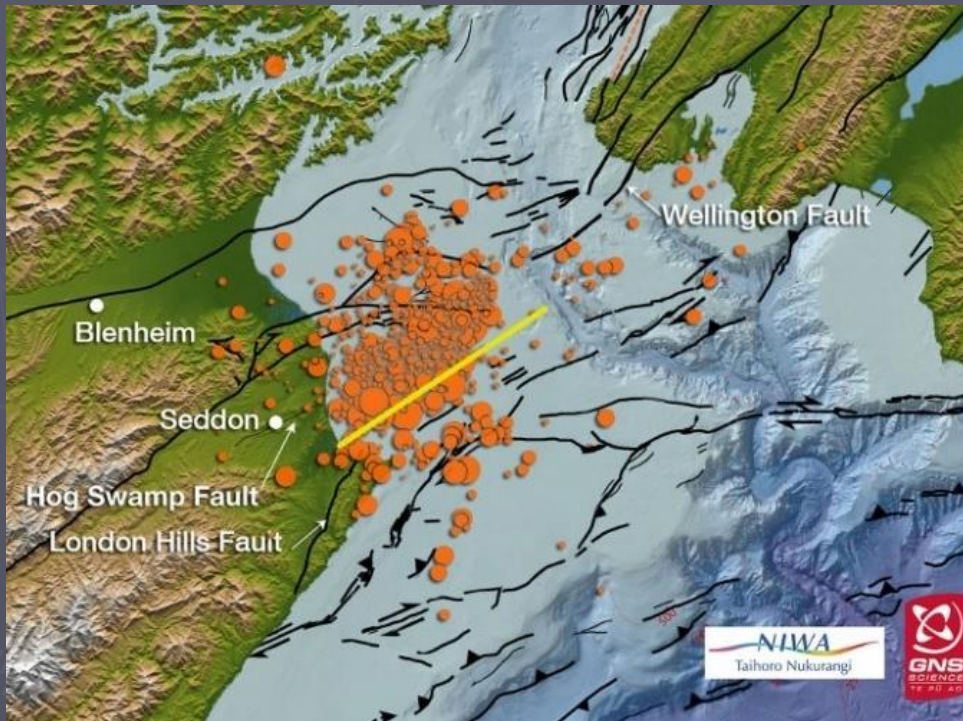
- On Tuesday 22 February 2011 at 12.51 p.m. Christchurch was badly damaged by a magnitude 6.3 earthquake, which killed 185 people and injured several thousand.
- The earthquake epicentre was near Lyttelton, just 10 kilometres south-east of Christchurch's central business district.
- 15-kilometre-long fault did not express surface rupture
- Predominantly reverse movement
- Peak ground accelerations of more than 2g



<https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Recent-Events/Canterbury-quake/Hidden-fault>

# Recent New Zealand Earthquakes

2013 Cook Strait earthquake  
 $M_w$  6.5. Unknown offshore fault  
Ground accelerations 1/10<sup>th</sup> that of similar magnitude Christchurch earthquake



2016 Kaikōura earthquake  
 $M_w$  7.8. The rupture lasted nearly 2 minutes  
ground was displaced, horizontally and vertically by up to 12 metres. 20 separate fault ruptured (world record)

