Comparison of the 1989 Newcastle and 2010 Kalgoorlie and Christchurch earthquakes

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Abstract

At first glance these three shallow earthquakes would appear to have little in common, one a near-plate boundary magnitude 7 earthquake, the others on either side of continental Australia quite distant from plate boundaries and both smaller than magnitude 6. The damage is the one thing they have in common, too high in Australia and surprisingly moderate in New Zealand, and reasons are sought to explain this.

Table 1 Summary of parameters relevant to earthquake damage

Earthquake	*Foundation*	*Nearest plate boundary km*	*Magnitude*	*Type of damage*	*Damage cost*
Newcastle NSW 1989	Sydney Basin sediments inter-bedded sandstone and coal	2000	ML 5.6	old URM buildings	$4billion
Kalgoorlie WA 2010	Archaean bedrock, the top 100m very weathered	2000	ML 5.0	old URM buildings	$4million
Christchurch NZ 2010	Pleistocene glacial gravels and pockets of saturated fine sands	100	Mw 7.0	old URM buildings	$4billion

Keywords: earthquake, damage, plate tectonics, focal mechanisms

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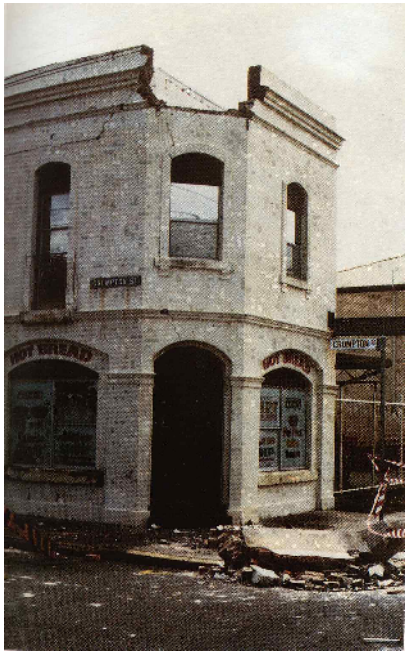
The earthquakes



Newcastle NSW 1989, magnitude 5.6 The 28 December 1989 Newcastle earthquake at 10:35am local time was, after that near Adelaide in 1954, only the 2nd earthquake to score a direct hit on an Australia city, fortunately it was only of moderate magnitude and lasted just a few seconds. In a city of about 300,000 people, the damage bill seemed to be rather large given the size of the earthquake and 13 people were killed as shop awnings and old un-reinforced masonry (URM) walls collapsed on them. Even so, given the damage, it was fortunate that schools and colleges were closed for the Christmas holidays and normal Bingo activities at the Workers Club cancelled to ready the building for a concert that night otherwise the death toll would have been much higher.

The earthquake ruptured a 2 km long thrust fault that initiated at a depth of about 12 to 13 km, well below the Sydney Basin sediments but still considered shallow. Faulting did not outcrop at the surface. We installed the first of 5 portable seismographs that night but recorded only one very small aftershock the following day.

There was minor lateral spreading of bridge abutments and in suburbs along the Hunter river where houses were built on hydraulic-fill but there were no sand boils or other evidence of liquefaction. Infrastructure was badly damaged, communications and power cutoff for hours.

Un-reinforced double brick masonry is a common building material though many of the older houses used timber frame and cladding

with a brick or stone chimney. The Workers Club was the only building that suffered partial collapse but many houses lost chimneys and some moved off their timber piles and suffered puncture failure. The latter type of damage was often not observable from a brief streetside inspection, the house still looked level, the chimney lying in the backyard. The only sign of a problem was the disconnect between the front steps and entrance.

Schools and colleges were badly damaged, 14 schools were closed and one of the colleges. Both hospitals were badly damaged, the old masonry Royal Newcastle Hospital slated for closure, never reopened.

There were no requirements to consider earthquakes in the design and construction of buildings in Newcastle prior to the earthquake and there were no strong motion recorders there to monitor the ground motion.

Kalgoorlie/Boulder WA 2010, magnitude 5.0 On the other side of the continent on 20th April 2010 at 08:17am local time, Kalgoorlie/Boulder WA was struck by a magnitude 5.0 'earthquake', the largest in a series of small earthquakes dating back to 1917 which are attributed to deep gold mining activities. All are induced seismic events. Rockbursts are not uncommon in deep mines in other mining countries and have caused the deaths of many miners over the years. There are fewer than 30,000 residents in kalgoorlie/Boulder..

Using arrival times from a small network of geophones around Kalgoorlie and the Australian National Seismograph network, ASC obtained a reasonable location 3 km SSW of the city and at a very shallow depth (see Table 2). It is interesting to compare this with the USGS epicenter, 30 km NE of the city and the GA location using the national network but not the local area network data. There were not sufficient station arrivals to do a focal mechanism for this event.

Table 2 Various estimates of the Kalgoorlie epicentre

Agency	*Origin Time UTC*	*Latitude ºS*	*Longitude ºE*	*Depth km*	*Place*
USGS	0017 08	30.530 ± 13.7 km	121.653 ± 13.7 km	10	30km NE Kalgoorlie
GA	0017 09	30.83	121.429	?	6km SSW Kalgoorlie
ASC	0017 09.6 ± 0.14	30.798 (±0.007)	121.485 (±0.010)	0G (±5)	3km SSW Kalgoorlie

Note: the USGS epicenter is well outside the quoted error bars from an epicenter in Boulder, SSW of Kalgoorlie.

There was one foreshock and hundreds of aftershocks, 8 of them large enough (magnitudes 2.4 to 2.9) to be located by GA using their regional network stations to the 10th of May (see www.ga.gov.au and Bathgate et al, this conference), all of them felt locally.

During the main event, residents of Kalgoorlie, Boulder and Coolgardie reported strong shaking for between 5 and 10 seconds. Damage was mainly confined to the Boulder area with five or six old hotels on Burt Street badly damaged including the Golden Eagle Hotel where the balcony collapsed into the street and the historic Lionel Street pub which had extensive roof and wall damage. About 40 public and commercial buildings in the area

were damaged including Boulder's historic town hall whose western wall had partially come away.

QuickTime™ and a
decompressor
are needed to see this picture.

Kalgoorlie School of the Air was closed after suffering significant structural damage. Students at Boulder Central School were evacuated and a ceiling collapsed at Boulder Primary School, the junior block at Kalgoorlie Primary School has been closed. Cracks appeared in the walls of North Kalgoorlie Primary School.

Workers were evacuated from the Super Pit open cut mine and the underground mine whilst a safety audit was undertaken.

In this part of WA earthquake hazard is not deemed sufficient to warrant strengthening buildings in Kalgoorlie/Boulder though they have been regularly shaken over the years by mine blasts and rock bursts. There were no publicly operated strong motion recorders in the vicinity of the town.

AEES member, Professor Hong Hao, drove to Kalgoorlie to investigate the damage. His report is available on the AEES website (www.aees.org.au).

Christchurch NZ 2010, magnitude 7.0 This shallow magnitude 7 earthquake in the South Island of New Zealand at 3:30 am NZST on 3 September 2010, was not on the plate boundary, neither on the uncomfortably quiet Alpine Fault that bisects the island nor the subduction zone off the southwest coast. Instead the earthquake ruptured a deeply buried, previously unknown fault striking eastwest at about 45° to the alpine fault and within the Pacific Plate.

Thousands of aftershocks were (and are occurring at time of writing) recorded by GNS Science on Geonet stations, seismographs, accelerographs and GPS stations. Those in the first few days delineated a 60km long complex fault zone about 25km west of Christchurch, a city of 300,000 people. The mainshock focal mechanism shows a right-lateral

strike-slip fault but aftershock mechanisms varied, some of the earlier larger events had thrust mechanisms and seemed to be en-echelon to the main eastwest zone.

Canterbury University's Professor John Berrill had fortuitously deployed a network of locally designed and built accelerographs in the region so the strong ground shaking was well measured.

Three AEES members joined the NZ reconnaissance teams, Professor Mike Griffith arrived in Christchurch within 30 hours of the earthquake and joined an assessment team focused on URM buildings. Shortly after he returned to Adelaide, the author arrived and examined strong motion sites, the fault zone, damaged buildings and liquefaction sites with Dr John Zhou from GNS Science. Dr Tim Mote arrived after McCue departed and joined the geotechnical investigation.

Old un-reinforced masonry buildings (photo above) showed similar damage to those in Newcastle and Kalgoorlie. Housing damage was particularly severe where there was substantial foundation failure, liquefaction and lateral spreading. In those areas sewerage and water pipes and underground electricity cables were broken. Many apparently undamaged wooden houses lost chimneys though not all, as seen in the accompanying photograph. The damage was only apparent because of the *porter loos* lining the streets (see photo). Reinforced old heritage masonry buildings seemed to be undamaged. Some URM buildings were damaged by pounding against adjacent structures of different height. Modern tall buildings suffered no structural damage.

Discussion

The level of damage was very similar in three very different seismic events in two different countries with different tectonic settings, focal mechanism and foundation conditions. No buildings collapsed, no well-engineered tall buildings suffered structural damage, un-reinforced masonry structures bore the brunt of the damage.

All three seismic events were shallow but those in Australia were relatively small at magnitudes 5.6 and 5.0 whereas the Christchurch NZ earthquake had a magnitude of 7.0, about 200 and 1000 times respectively greater energy release than the other two.

We attribute the difference to four effects. Firstly is the difference in the underlying foundations; high frequency waves were probably stronger in the two Australian settings compared with New Zealand because of the 1 to 2 km thick sequence of glacial sediments underlying Christchurch, despite the difference in magnitude (Unfortunately there is no strong motion data to confirm this). Secondly, difference in building styles, whereas rigid, un-reinforced, double-skinned masonry is common in Newcastle and Kalgoorlie it is rare in Christchurch, perhaps because of earlier earthquakes. Thirdly, suitable loading code provisions were enforced in the design and construction of most buildings in New Zealand whereas there was no thought given to earthquakes in the design and construction of buildings in Newcastle and Kalgoorlie. Lastly, pre-existing conditions meant that old un-reinforced masonry buildings in Australia were very vulnerable to lateral loads, there was a lack of ties and widespread prior damage due to settlement from mining under both Australian cities.

The Australian events highlight the need for more strong motion instruments to be deployed in Australia. The spectral amplitudes of ground motion cannot be compared when data are lacking. The damage bill in Newcastle was more than $4billion and in Kalgoorlie $5million, surely a few tens of thousands of dollars for instruments is good value for money.

Acknowledgment

Photos Damage photographs in Kalgoorlie, Professor Hong Hao UWA, those in Newcastle taken from the AEES website (www.aees.org.au), those in Christchurch taken by Kevin McCue.

We would like to thank our NZSEE hosts for including us on the Chilean earthquake visit and again for their generosity in Christchurch.