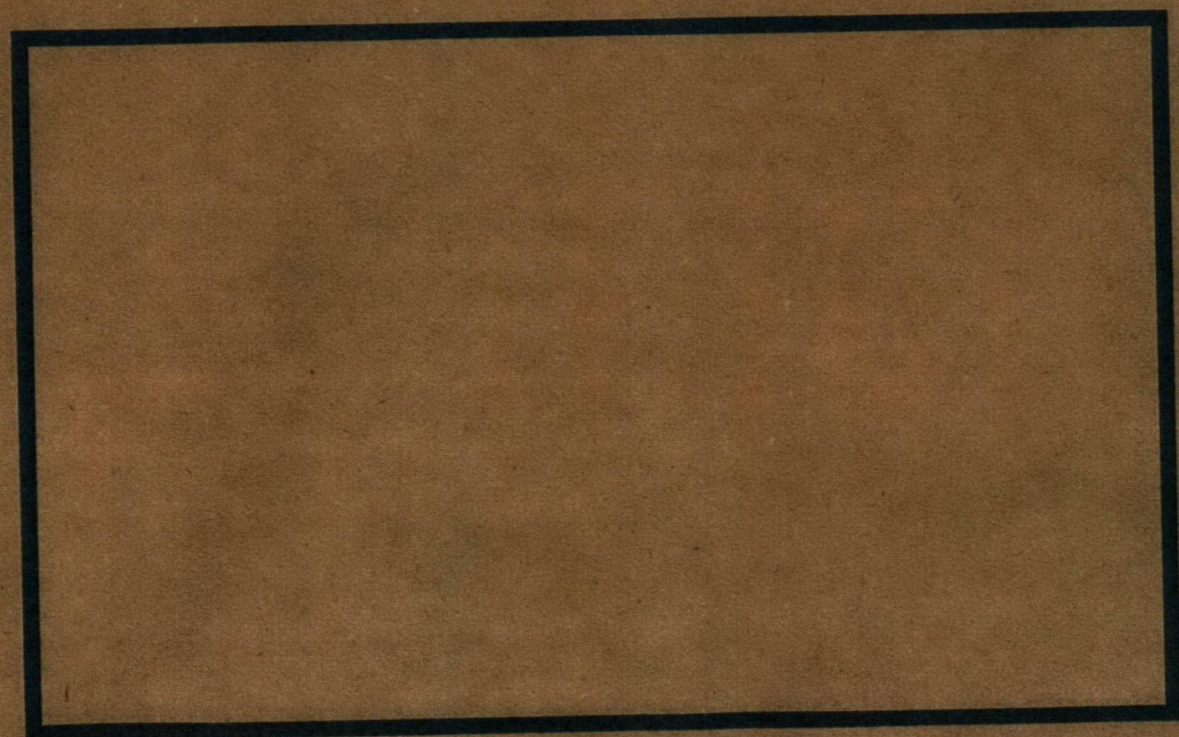
NZE 42-(EQC 2011/)

Focal mechanism analysis of Christchurch Boxing Day aftershocks

J Ristau, GNS Science



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J. Ristau

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BIBLIOGRAPHIC REFERENCE

Ristau, J. 2011. Focal mechanism analysis of Christchurch Boxing Day aftershocks, *GNS Science Consultancy Report* 2011/43 . 7 p.

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EXECUTIVE SUMMARY

On 26 September 2010 a series of shallow aftershocks to the moment magnitude (M_w) 7.1 Darfield earthquake occurred near the Christchurch city centre. The largest was local magnitude (M_L) 4.9 and cause significant damage in the city centre. Focal mechanisms derived from regional moment tensor analysis have been calculated for three events including the M_L 4.9. 16 first-motion focal mechanisms have also been calculated including the same three events for which moment tensor solutions have been calculated. The moment tensor solutions are right-lateral strike-slip mechanisms while the corresponding first-motion solutions show more reverse faulting. However, the *P*-axis orientation is consistent between the two methods. The remaining first-motion mechanisms show mainly reverse faulting with *P*-axes oriented NW-SE or E-W. All of the mechanisms are tightly clustered within ~ 2-3 km and do not show any spatial variability.

1.0 INTRODUCTION

The moment magnitude (M_w) 7.1 Darfield earthquake occurred on 3 September 2010 at 16:35 UTC (4 September 2010 04:35 NZST) approximately 40 km west of Christchurch. The earthquake caused extensive damage in Christchurch and the surrounding region and left a well-defined surface rupture which has been named the Greendale Fault. The mainshock was well recorded on the New Zealand seismograph and strong-motion accelerometer network (Petersen *et al.* 2011) and was felt as far away as Northland. More than 4000 aftershocks have been located by GeoNet with 15 being local magnitude (M_L) $\geq$ 5.0. Details on the mainshock and aftershock activity can be found in Gledhill *et al.* (2011).

2.0 BOXING DAY EARTHQUAKE SEQUENCE

On 26 December 2010 NZST a sequence of shallow aftershock activity took place near the Christchurch city centre (Figure 1). The largest event was M_L 4.9 and caused a significant amount of damage in the city centre. There are 20 events with $M_L \geq 3.0$ in the GeoNet earthquake catalogue for the Christchurch Boxing Day sequence with five having $M_L \geq 4.0$. Regional moment tensor solutions have been calculated for three events with $M_L \geq 4.0$ using code developed by Doug Dreger at the University of California, Berkeley Seismological Laboratory (*e.g.* Dreger and Helmberger 1993; Pasyanos *et al.* 1996). For details on the regional moment tensor method in New Zealand see Ristau (2008). The other two events occurred during the coda of an M_w 7.3 earthquake in Vanuatu; therefore, it was not possible to calculate a moment tensor solution for those events as the waveforms were obscured by the teleseism in the frequency band used to calculate moment tensor solutions.

Of the 20 events with $M_L \geq 3.0$ first-motion focal mechanisms have been calculated for 16 events using code developed by Robinson and Webb (1996). These include the same three events for which moment tensor solutions were calculated (Figure 1; Table 1; Table 2). The first-motion solutions in bold in Table 2 are the events for which a moment tensor solutions has been calculated (Table 1). The locations used to calculate the moment tensor and first-motion focal mechanisms were taken from the GeoNet catalogue. Bannister (2011) has relocated events from the Boxing Day sequence to obtain more precise locations; however, slight changes in the locations will not have a significant effect on the focal mechanisms.

The moment tensor focal mechanisms are consistent with one another showing strike-slip mechanisms with one E-W fault plane and one N-S fault plane, and the depths are all very shallow (2 – 4 km). The moment tensor focal mechanisms are similar to the strike-slip mechanism of the mainshock calculated using teleseismic methods but rotated ~ 15° counter clockwise. The first-motion focal mechanisms for the same three events show mainly reverse faulting (Figure 1). However, the *P*-axis is consistently near-horizontal and trending NW-SE in both the moment tensor and first-motion mechanisms (Figure1; Table 1; Table 2). The first-motion solutions tend to have a lack of station coverage in the NE quadrant which may explain the discrepancy between the first-motion and moment tensor solutions. The moment tensor solutions all appear to be quite well constrained as strike-slip mechanisms.

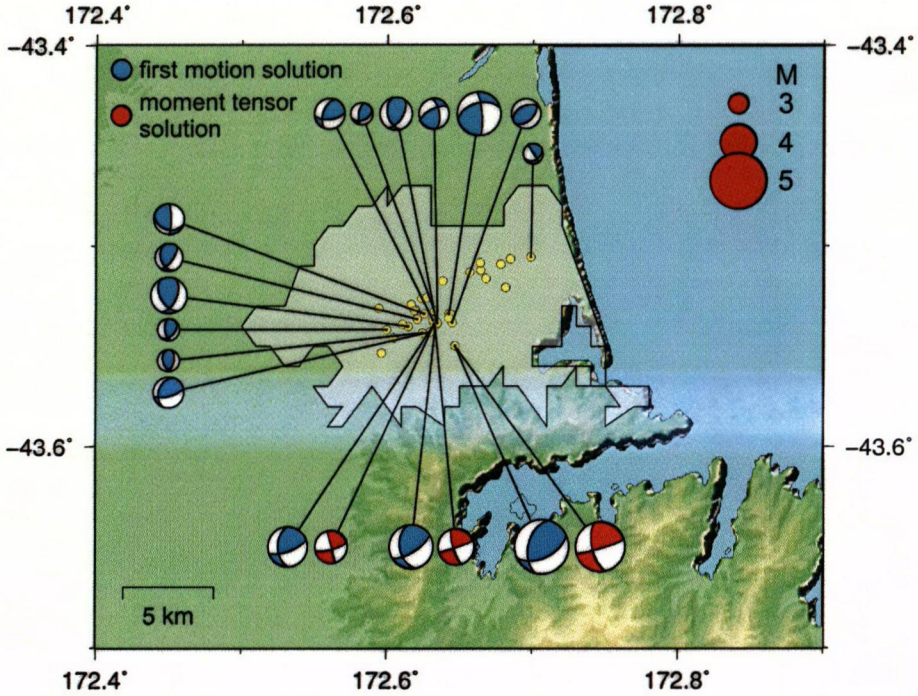

Figure 1 Moment tensor (*red*) and first motion (*blue*) focal mechanisms for events during the Christchurch Boxing Day earthquake sequence. All located events from 26-27 December 2010 are shown by the yellow dots. The moment tensor solutions are strike-slip faulting while the first motion solutions are mainly reverse faulting.

Table 1 Moment tensor solutions.

CUSP_ID	Date	Latitude	Longitude	NP1 S/D/R	NP2 S/D/R	Mw	Mo (Nm)	Depth (km)	P-axis pl/tr	T-axis pl/tr
3437085	201012251307	-43.5388	172.6325	345/88/-14	76/76/-178	3.8	5.84E+14	2	11/300	8/31
3437105	201012252130	-43.5498	172.6468	74/84/153	167/63/6	4.7	1.18E+16	2	14/123	23/27
3437366	201012261110	-43.5399	172.6333	72/87/166	163/76/3	4.0	1.11E+15	4	8/118	12/27

Date - YYYYMMDDHHMM; S/D/R - strike/dip/rake; pl/tr - plunge/trend; Mw - moment magnitude; Mo - moment

The remaining first-motion solutions are mechanisms which show mainly reverse faulting (Figure 1; Table 2). The *P*-axis direction varies between NW-SE and E-W but there does not appear to be any consistent spatial variation e.g. changing from NW-SE to E-W from west to east. All of the events for which focal mechanisms have been calculated are tightly clustered within ~ 2-3 km of one another except one event several kilometres to the northeast. Figure 2 shows focal mechanisms derived from moment tensor solutions for events near Christchurch other than the Boxing Day events in the Darfield aftershock sequence. The Boxing Day events are consistent with the mechanisms in Figure 2 and do not appear to be unusual.

Table 2 First motion solutions.

CUSP_ID	Date	Latitude	Longitude	ML	Depth (km)	NP1 S/D/R	NP2 S/D/R	P-axis pl/tr	T-axis pl/tr
3437085	**201012251307**	**-43.5388**	**172.6325**	**4.2**	**4.7**	**70/70/135**	**179/48/27**	**13/129**	**25/45**
3436949	201012251308	-43.5429	172.6295	3.7	7.5	200/35/40	76/68/118	19/145	57/24
3436954	201012251328	-43.5400	172.6146	4.0	6.2	150/50/50	23/54/128	2/87	60/353
3436956	201012251332	-43.5340	172.6427	4.4	4.0	255/50/165	355/79/41	18/119	37/223
3437061	201012251903	-43.5378	172.6339	3.8	2.4	30/55/120	165/45/55	6/99	35/357
3437105	**201012252130**	**-43.5498**	**172.6468**	**4.9**	**5.0**	**65/55/125**	**194/48/51**	**4/131**	**62/34**
3454006	201012252132	-43.5340	172.6257	3.7	5.0	360/80/120	107/32/19	28/66	46/302
3437107	201012252135	-43.5382	172.6449	3.6	5.0	245/45/105	44/47/76	1/144	79/240
3437133	201012252253	-43.5366	172.6209	3.5	5.0	35/65/120	161/38/43	15/104	59/348
3454452	201012252254	-43.5433	172.6244	3.1	5.4	165/45/70	12/48/109	2/89	76/352
3437148	201012252334	-43.5369	172.6315	3.7	5.0	200/55/40	84/58/138	2/143	51/50
3437153	201012252352	-43.5054	172.6986	3.0	5.0	60/35/-175	326/87/305	38/267	33/27
3437159	201012260012	-43.5383	172.6347	3.7	2.0	350/60/30	244/64/146	3/298	41/205
3437222	201012260329	-43.5325	172.6324	3.1	2.0	190/65/60	64/38/137	15/301	59/57
3437239	201012260426	-43.5417	172.5999	3.1	3.0	40/40/130	172/60/62	11/282	63/35
3437366	**201012261110**	**-43.5399**	**172.6333**	**4.4**	**3.6**	**170/45/30**	**58/69/131**	**14/119**	**49/12**

Date - YYYYMMDDHHMM; S/D/R - strike/dip/rake; pl/tr - plunge/trend

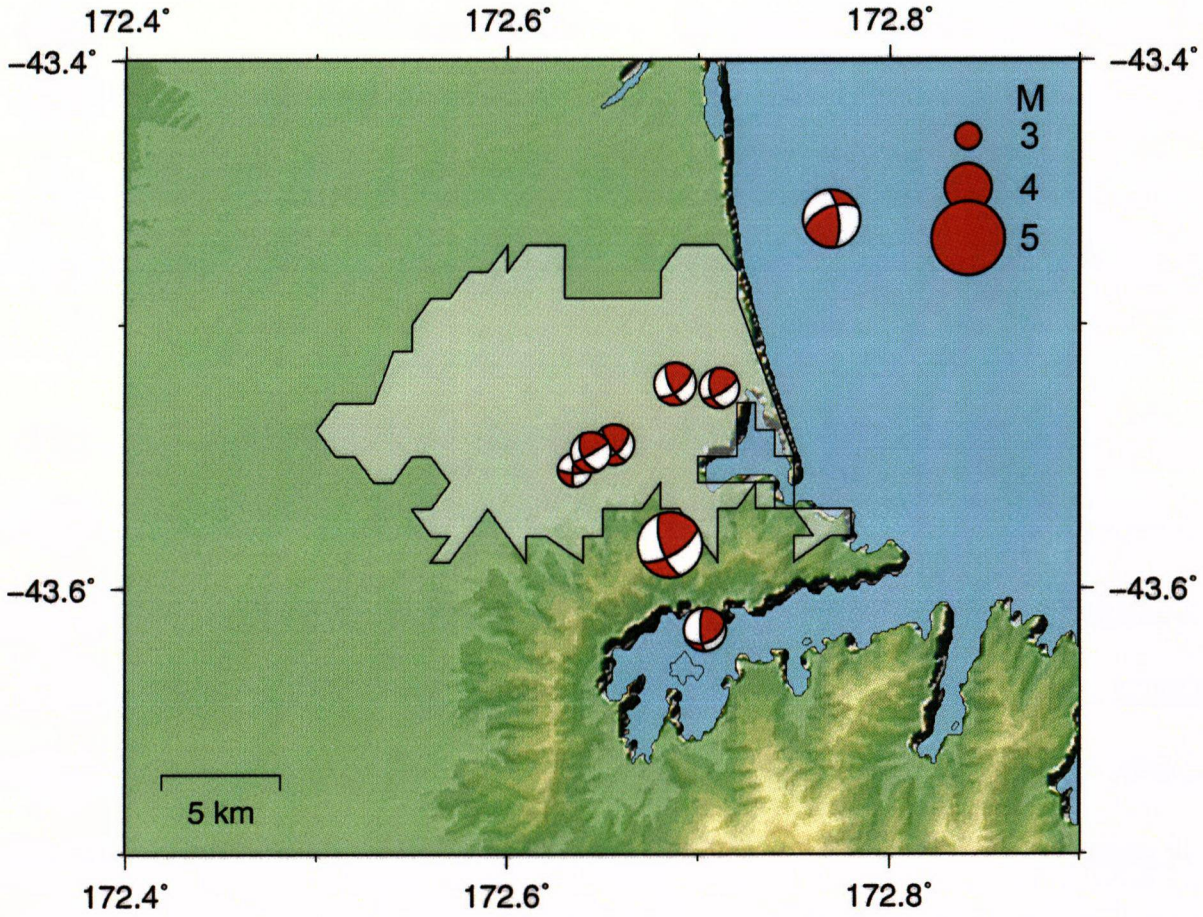

Figure 2 Focal mechanisms derived from regional moment tensor solutions for aftershocks in the Christchurch city region not including the Boxing Day sequence. The events are all reverse faulting with a significant strike-slip component and *P*-axes consistent with focal mechanisms derived from the Boxing Day sequence.

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www.gns.cri.nz

Principal Location

1 Fairway Drive
Avalon
Lower Hutt 5010
PO Box 30368
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4600

Other Locations

Dunedin Research Centre
764 Cumberland Street
Dunedin 9016
Private Bag 1930
Dunedin 9054
New Zealand
T +64-3-477 4050
F +64-3-477 5232

Wairakei Research Centre
114 Karetoto Road, Wairakei
Taupo 3377
Private Bag 2000
Taupo 3352
New Zealand
T +64-7-374 8211
F +64-7-374 8199

National Isotope Centre
30 Gracefield Road, Gracefield
Lower Hutt 5010
PO Box 31312
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4657