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Tectonic-seismology of the Mw 7.1 2010 Darfield (Canterbury NZ) Earthquake

Kevin P. Furlong (1), Gavin P. Hayes (2), Mark Quigley (3), and Harley Benz (2)

(1) Penn State University, Department of Geosciences, University Park, PA, United States (kevin@geodyn.psu.edu), (2) NEIC - U.S. Geologic Survey, Golden, CO United States, (3) Univ Canterbury, Dept. Geological Sciences, Christchurch, NZ

The September 3, 2010 (UTC) Mw 7.1 Darfield earthquake in central Canterbury, New Zealand provides an ideal opportunity to link detailed geological observations to seismological characteristics of the earthquake rupture. The high resolution mapping of surface rupture - its extent, attitude, magnitude, and kinematics - has been compared with determinations of on-fault co-seismic slip as imaged by finite fault models, analyses of rupture processes, and patterns of aftershock activity. The seismologically imaged fault extends approximately 50km with a central (about 30 km long) section modeled as having substantial near surface fault displacements. This correlates closely with the 30 km of observed right-lateral strike-slip surface rupture, with an average of over 2.5 meters of horizontal (more than 5 meters in some locations) and up to 1 meter of vertical displacement. This surface rupture has been well mapped and is a continuous, narrow (order 10-20 meters in width) fault system that can be separated into three major segments, a central and an eastern segment each near-vertical and striking almost due E-W, and a western segment trending more NW-SE, and apparently slightly more shallowly dipping. Although there is localized vertical deformation associated with some of the fault step-overs, the general pattern of vertical displacements observed along large sections of the surface rupture reflect a co-seismic slip vector that deviates as much as 20° or more from the horizontal on the near-vertical strike-slip fault. The sense of vertical displacement also changes between fault segments, with the easternmost segment showing south-side down while the two other segments are south-side up. These discrete changes in fault kinematics as seen in the surface morphology reflect discrete variations in rupture characteristics. Aftershocks and their regional moment tensors show a predominance of strike slip displacements, with a large fraction of aftershock moment release shallow, and located in the vicinity of the fault segment that did not rupture to the surface, in the seismological fault modeling (east of the easternmost surface rupture segment). Independently, the geologic and seismologic earthquake observations provide only a part of the earthquake story. The narrow surface expression of the rupture and its correlation with seismic rupture, in spite of the more than 300 m thickness of gravels that separate bedrock from the surface, implies a history of fault behavior that has localized deformation within this thick superficial gravel layer. Additionally the overall landscape evolution of the central Canterbury region may reflect the long-term but subtle effects of the displacement histories of this and other intra-block faults associated with but distant from the main Pacific-Australia plate boundary through New Zealand. For example, the present-day path of the Waimakariri River, deviates from the range-normal orientation of the other major rivers draining the east side of the Southern Alps in Canterbury. What drove this river reorientation is unclear, but a regional pattern of Darfield earthquake-like fault displacements, generally north-side down, is one possible mechanism to cause such a path deviation.