

EQC Project 08/547

Characterising the Seismic Potential of Compressional Inversion Structures, NW South Island

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January 29, 2010

TECHNICAL ABSTRACT

The NW South Island west of the Alpine Fault is an area of ongoing *compressional inversion* where a set of steep former normal faults trending predominantly NNE-SSW inherited from Late Cretaceous–Eocene crustal extension have, since the mid-Miocene, been reactivated to varying extents in a WNW-ESE shortening regime. Over the past century these inversion structures have given rise to a series of $6 < \mathbf{M} < 7.8$ damaging earthquakes resulting predominantly from reverse slip on basin-bounding fault systems. Seismic hazard from inversion fault structures is difficult to assess because of their structural complexity, the reversal of slip-sense across the structures with time, their progressive structural adaptation, and their concealment by young sedimentary cover along basin margins.

This project has employed a multifaceted approach to understanding and assessing the seismic hazard from inversion structures, employing: (i) tectonostratigraphic basin analyses to define the migration and changing level of activity on the inversion fault systems; (ii) combining structural-stratigraphic data from oil-industry marine seismic profiling with onshore geological and morphotectonic analyses; (iii) comparing compressional inversion fault systems in the NW South Island with those in NE Honshu, Japan, where basin-bounding inversion structures have given rise to several well-studied $6 < \mathbf{M} < 7$ earthquakes over the past decade; and (iv) investigating, in terms of frictional fault mechanics, the factors governing the competition between reverse-slip reactivation of the steep inherited faults (that are poorly oriented for reshear) and the development of new low-angle thrusts that are favourably oriented for reactivation in the compressional stress regime.

Key findings from this study are:

- 1) Categorisation of the structural characteristics of inversion fault systems at different stages of their evolution.
- 2) The demonstration that integration of offshore seismic profiling with onshore data is a powerful tool for the analysis of inversion structures.
- 3) Aftershock patterns following inversion earthquakes in NE Honshu reveal competition between reshear of steep inherited faults and formation of new low-dipping thrusts.
- 4) Seismological/electrical anomalies indicating fluid overpressuring in the lower seismogenic crust of NE Honshu (critical to the reactivation of poorly oriented faults) suggest that comparable geophysical anomalies may occur in the NW South Island.
- 5) As inversion structures evolve, down-dip segmentation of steep inversion faults by new-forming thrust faults becomes likely unless high fluid overpressures are maintained.
- 6) Recognition of a Late Neogene concentration of activity around the reverse-fault systems bounding the Wakamarama-Paparua structural high (a reverse-fault ‘pop-up’).
- 7) Identification of intense Pliocene-Holocene deformation localised along the coast-bounding Cape Foulwind Fault with important seismic hazard implications for the coastal towns of Westport, Greymouth, and Hokitika.
- 8) Recognition of possible Holocene fault activity along the Wakamarama range-front.
- 9) Initiation of a proposal for a collaborative microearthquake network centred in the Murchison Basin area involving researchers from DPRI in Kyoto and Tohoku Universities in Japan together with NZ researchers.