Ultrahigh-resolution seismic reflection imaging of the Alpine Fault, New Zealand

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[1] High-resolution seismic reflection surveys across active fault zones are capable of supplying key structural information required for assessments of seismic hazard and risk. We have recorded a 360 m long ultrahigh-resolution seismic reflection profile across the Alpine Fault in New Zealand. The Alpine Fault, a continental transform that juxtaposes major tectonic plates, is capable of generating large (M > 7.8) damaging earthquakes. Our seismic profile across a northern section of the fault targets fault zone structures in Holocene to late Pleistocene sediments and underlying Triassic and Paleozoic basement units from 3.5 to 150 m depth. Since ultrashallow seismic data are strongly influenced by near-surface heterogeneity and source-generated noise, an innovative processing sequence and nonstandard processing parameters are required to produce detailed information on the complex alluvial, glaciofluvial and glaciolacustrine sediments and shallow to steep dipping fault-related features. We present high-quality images of structures and deformation within the fault zone that extend and complement interpretations based on shallow paleoseismic and ground-penetrating radar studies. Our images demonstrate that the Alpine Fault dips 75°–80° to the southeast through the Quaternary sediments, and there is evidence that it continues to dip steeply between the shallow basement units. We interpret characteristic curved basement surfaces on either side of the Alpine Fault and deformation in the footwall as consequences of normal drag generated by the reverse-slip components of displacement on the fault. The fault dip and apparent ~35 m vertical offset of the late Pleistocene erosional basement surface across the Alpine Fault yield a provisional dip-slip rate of 2.0 ± 0.6 mm/yr. The more significant dextral-slip rate cannot be determined from our seismic profile.

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1. Introduction

[2] Knowledge of fault zone structure in the shallow subsurface is important for understanding seismic hazard and risk. Key physical properties of potentially active faults are usually determined or inferred from surface outcrops, geomorphology, shallow boreholes, and/or trenches. High-resolution geophysical imaging at greater depths can extend and enhance interpretations of fault zone structure and behavior.

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[3] The Alpine Fault is an example of a continental transform fault juxtaposing major tectonic plates. Similar in structure and tectonics to the well-known San Andreas Fault, it is a large transpressional strike-slip fault that accommodates much of the 36 mm/yr relative plate motion across the South Island of New Zealand. Although surface rupture of the fault has not been recorded in the ~200 years of European settlement, paleoseismic evidence suggests the fault is likely to rupture in large events (M > 7.8), posing a considerable seismic hazard in the region [*Sutherland et al.*, 2007].

[4] At our survey site along the northern section of the Alpine Fault (Figure 1), the fault trace emerges from dense bush and mountainous terrain to cross an open, relatively flat area known as Calf Paddock. Abandoned late Quaternary river terraces and stream channels formed by the Maruia River are offset vertically and horizontally across the main trace of the fault [*Wellman*, 1952], indicating ongoing displacement. Paleoseismic trenching suggests the last surface rupture at Calf Paddock occurred between 1530 and 1700 A.D. [*Yetton*, 2002]. Extensive 3D ground-