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Case History

Detailed images of the shallow Alpine Fault Zone, New Zealand, determined from narrow-azimuth 3D seismic reflection data

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ABSTRACT

Previous high-resolution seismic reflection investigations of active faults have been based on 2D profiles. Unfortunately, 2D data may be contaminated by out-of-the-plane reflections and diffractions that may be difficult to identify and eliminate. Although full 3D seismic reflection methods allow out-of-the-plane events to be recognized and provide superior resolution to 2D methods, they are only rarely applied in environmental and engineering studies because of high costs. A narrow-azimuth 3D acquisition and processing strategy is introduced to produce a high-resolution seismic reflection volume centered on the Alpine Fault Zone (New Zealand). The shallow 3D images reveal late Quaternary deformation structures associated with this major transpressional plate-boundary fault. The relatively inexpensive narrow-azimuth 3D acquisition pattern consisting of inline source and receiver lines was easily implemented in the field to provide 2- by 4-m CMP coverage over an approximately 500- by 200-m area. The narrow-azimuth acquisition strategy was well suited for resolving complex structures within the fault zone. Challenges in processing the data were amplified by the effects of strong velocity heterogeneity in the near surface and the presence of complex dipping, diffracted, and truncated events. A carefully tailored processing scheme including surface-consistent deconvolution, refraction static corrections, noise reduction, dip moveout (DMO) corrections, and 3D depth migration greatly improved the appearance of the final stacks. The 3D images reveal strong reflections from the faulted and folded late Pleistocene erosional basement surface. A steeply dipping planar main (dominant) fault strand can be inferred from the geometry and truncations of the overlying postglacial sediments. The 3D images reveal that the average apparent vertical displacement (20–30 m) of the basement surface across the dominant fault strand at this location is somewhat less than that estimated from a pilot 2D seismic reflection profile, suggesting that the provisional dip-slip rate based on the 2D data is a maximum.

INTRODUCTION

High-resolution seismic reflection profiling across active fault zones can be used to determine key fault properties such as dip, geometry, and slip rate (e.g., Treadway et al., 1988; Miller et al., 1990; Stephenson et al., 1993; Pratt et al., 1998; Improta and Bruno, 2007; Kaiser et al., 2009; Campbell et al., 2010; Dorn et al., 2010). The 2D profiling approach provides useful snapshots of fault zone structure. Relatively simple laterally continuous features can be interpolated between widely spaced profiles, but determination of more complex or subtle structural variations along fault strike requires the use of 3D seismic methods. Three-dimensional seismic reflection methods have two main advantages over 2D methods: (1) increased spatial resolution and (2) identification and correct migration of out-of-plane reflections and diffractions (Hart, 1999; Cartwright and Huuse, 2005). Furthermore, in strike-slip or oblique-slip tectonic regimes, lateral juxtaposition of different geological units within the fault zone complicates the interpretations of 2D profiles. In such set-

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