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Seismic reflection measurements behind the Hikurangi convergent margin, southern North Island, New Zealand.

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Summary. The active Australian-Pacific plate boundary passes through New Zealand. In the north, the Pacific plate subducts beneath the Australian plate with an accretionary wedge forming the eastern continental (Hikurangi) margin of the North Island. The structure of the region behind the Hikurangi margin changes from the extensional back-arc basin under central North Island to a postulated crustal downwarp under the southern North Island. A 100 km long multichannel seismic reflection profile was recorded across the region of crustal downwarp. The data show discontinuous coherent reflectors dipping westwards at the east end of the profile, and east dipping reflectors at the west end, from depths of 9 to 15 s two way time. Simple hand migration of these events indicate that the east dipping reflectors, interpreted as the base of the Australian plate crust, abut against the west dipping reflectors which are interpreted as marking the top of the subducted Pacific plate. Detailed earthquake hypocentre locations in the area show a dipping zone of high seismicity, the top of which coincides closely with the west dipping events, thus supporting this interpretation.

1. Introduction

New Zealand lies across the actively deforming Australian-Pacific plate boundary. Active oblique subduction of the oceanic Pacific plate westwards under the continental Australian plate (North Island) occurs at the Hikurangi Trough and extends as far south as northern South Island (42°S) where it changes to a transform zone with oblique convergence of continental lithosphere in central South Island. At the southwest end of South Island the direction of subduction changes with minor subduction of oceanic Australian plate under the South Island (Pacific plate). An accretionary wedge (Cole & Lewis 1981, Davey *et al.* 1986) forms the eastern margin of North Island (Fig. 1). The 'back-arc' region of this active margin changes in character from the back-arc basin in the north (the offshore Havre Trough and the onshore extensional back-arc rift of the Central Volcanic Region (CVR), Karig 1970) to the postulated crustal downwarp coincident with the South Wanganui Basin (Stern *et al.* 1986; Fig. 1). Thin (15 km) crust and low velocity (7.4 km/s) mantle (Fig. 1, profile AA') underlie the CVR which is also characterised by high heatflow, low gravity, crustal extension and voluminous, predominantly Quaternary, rhyolitic volcanics. The CVR appears to have opened asymmetrically during the past 4 Ma with the active volcanic front now lying along its eastern margin (Stern 1985). South of the CVR, gravity and seismicity data (Stern *et al.* 1986) indicate that the back-arc region coincides with a crustal downwarp and the overlying sediment-filled South Wanganui Basin (Fig. 1, profile BB'). This basin contains

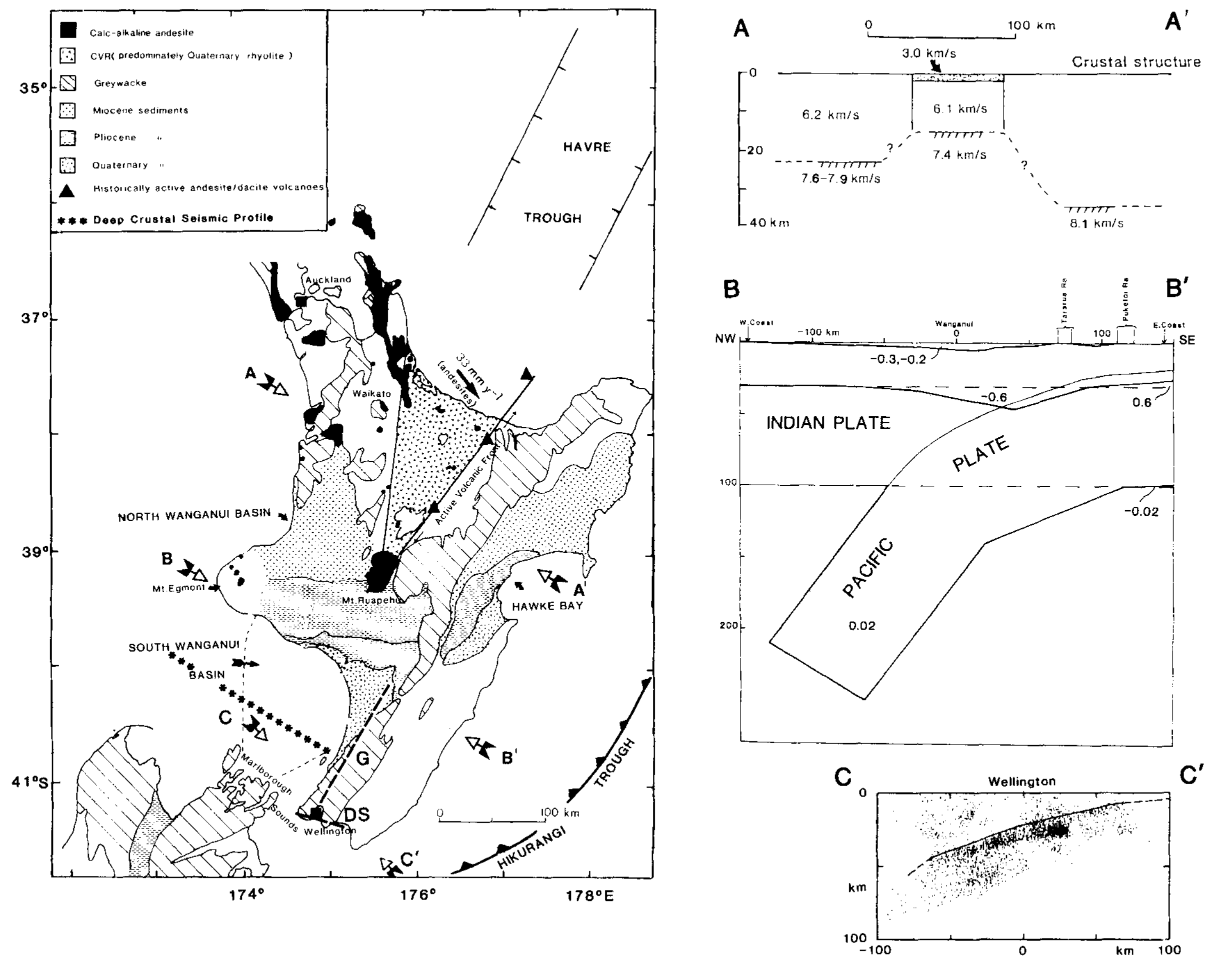

Figure 1 North Island, New Zealand, showing simplified geology, plate boundary (Hikurangi Trough), Central Volcanic Region (CVR), location of seismic profiles of Garrick (1968) - G, and Davey & Smith (1983) - DS. Location of profiles AA' across the CVR, BB' across the South Wanganui Basin, and CC' the seismicity profile of Robinson (1986).

sediments mainly of Pliocene and Pleistocene age overlying Mesozoic greywacke. The deposition centre for these sediments moved southwards and eastwards with time.

The seismic reflection profile discussed in this paper crosses the southern portion of this crustal downwarp. Earlier seismic refraction data to the east of the basin (Fig. 1, profile G) indicated a crustal thickness of about 36 km with crustal seismic velocities of 6.2-6.5 km/s overlying a mantle velocity of 8.1 km/s (Garrick 1968). At the south end of North Island, seismic reflection measurements (Fig. 1, profile DS) detected a strong reflector at a depth of about 25 km under Wellington, dipping to the west at about 15° (Davey & Smith 1983). This reflector coincides closely with the top of a zone of high seismicity (Robinson 1986) and was interpreted as being close to the top of the subducted Pacific plate (Fig. 1, profile CC').

2. Data

The profile presented forms the eastern part of a 220 km long multichannel seismic profile which crosses the South Wanganui Basin and extends towards the northwest (Fig. 1). Data were recorded in SEG-D demultiplexed format at a 2 ms sampling rate using a 240 channel, 3000 m streamer, configured to 120 channels. A 1530 cu in high pressure (3000 psi) airgun array was the sound source. Two sonobuoys were used to give refraction data. Data were recorded to 20 s two-way time at a shot interval of 80 m. Processing included reformatting (to SEG-Y format), gain recovery, CDP gather, predictive deconvolution, velocity analysis, stack (20-fold), 2-D filter, predictive deconvolution, post stack filter, trace amplitude balancing, adjacent trace sum, and display. Velocity analysis only applied to the sedimentary part of the section, basement velocity was derived from sonobuoy refraction measurements with deeper velocities based on the crustal refraction profile (Garrick 1968) to the east. The upper 6 s of the record have been migrated using wave equation migration. Deeper events have been restored to their approximate true position, assuming a two-dimensional structure, using simple hand migration of reflecting elements.

The preliminary section (Fig. 2) shows a very clear, well stratified sedimentary section up to 3 km thick overlying a very irregular basement horizon. Multiples from this horizon are strong. Several events with the appearance of diffractions are apparent in the mid-crustal section. Clear, but discontinuous, coherent reflections dipping westwards at the east end of the profile, and vice versa, occur at depths of 9 to 15 s two-way time with a cross-over occurring at about 13.5 s two-way time under shotpoint 300 (about 30 km offshore). Migration of the deeper reflecting elements (Fig. 2) separates out these reflecting elements and indicates eastward dipping reflectors abutting against the westward dipping reflectors. The deep events fade away to the west, under the shallower sedimentary section.

3. Discussion

The eastward dipping deeper events under the western portion of the profile are interpreted as coinciding with the base of the crust of the Australian plate. The westward dipping events at the eastern end of the profile coincide closely with the top of a westward dipping zone of high seismicity detected on a local microseismicity network (Fig. 1, profile CC'). This close correspondence supports the interpretation that the westward dipping reflectors coincide with the top of the subducted Pacific plate. A strong reflector occurs in a similar position to the south along a seismic reflection profile through Wellington (Davey & Smith 1983). The results also correspond closely with the model derived for the Wanganui Basin from gravity data (Stern *et al.* 1986). The data thus seem to be imaging the crustal downwarp which

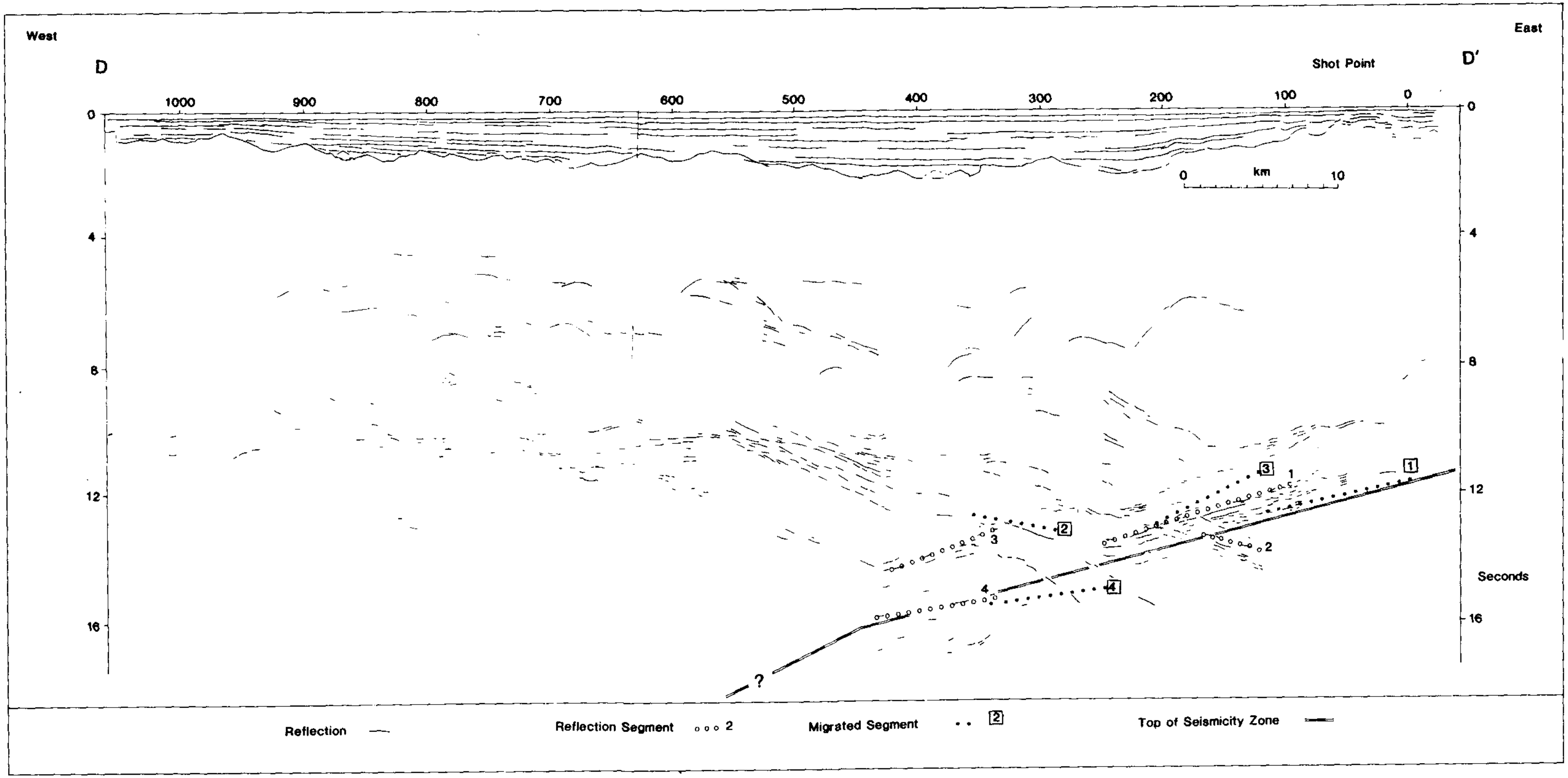

Figure 2. Line drawing of the deep seismic reflection proifile. Reflection segments corresponding to the major reflection events, their migrated positions and the location of the top the zone of high seismicity (Fig. 1, profile CC′) are shown.

overlies the sharp change in dip of the subducting Australian plate. Further processing is needed to clarify detail of the downwarp region.

Curved discontinuous events appearing in the middle crustal section were originally considered to arise from the effect of focussing and defocussing of seismic energy by the irregular basement topography. Wave equation modelling, using a method derived by A.J. Haines, of a planar interface beneath the irregular basement morphology could not reproduce the curvature on these events which probably arise from side swipe from basement topography. No explanation is proposed for the lack of deep energy under the western part of the profile.

The seismic profile succesfully images the top of the subducting Pacific plate to depths of about 15 s two-way time (45 km). It corresponds to the back arc region where the overlying lithosphere of the Australian plate is being downwarped rather than undergoing extensional tectonics, as occurs further north. The lithospheric downwarping over the 'back arc' region of a convergent margin may mark an early, pre-rift, tectonic regime occurring at the onset of subduction.

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