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Crustal seismic reflection measurements across the northern extension of the Taupo Volcanic Zone, North Island, New Zealand

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ABSTRACT

A crustal seismic reflection profile across the offshore Taupo Volcanic Zone (OTVZ) has been reprocessed to improve the lower crust–upper mantle image. The OTVZ is underlain by several strong sub-horizontal crustal reflections that may correspond to shear zones or mafic sills. A reflector interpreted to correspond to Moho lies at a depth of about 8–8.5 s twt (seconds two-way-traveltime) – about 20 km – under the western margin of the Raukumara Peninsula and rises to a depth of about 6 s twt (about 16 km) under the active, eastern part of the OTVZ and can be traced at about this depth across most of the OTVZ. Underlying this inferred Moho are two diffuse zones of discontinuous reflectivity, one underlying the active eastern OTVZ and a less well defined one underlying the landward extension of the Havre Trough. They extend from about 15 to 35 km depth, within the mantle wedge, and are inferred to be imaging a zone of depleted upper mantle associated with crustal extension. A localised zone of deep (30–50 km) reflectivity and seismicity occurs under the eastern OTVZ margin and may relate to fluid flow from the Hikurangi plateau being subducted further east.

1. Introduction

In North Island, New Zealand, the Pacific plate is subducting obliquely westwards under the Hikurangi margin, giving rise to a continental extensional back-arc basin, the Taupo Volcanic Zone (TVZ, Fig. 1). Intense shallow seismicity occurs along its eastern margin with northwest–southeast extension occurring at a rate of about 8–15 mm/yr (Darby et al., 2000; Wallace et al., 2004). The central part of the TVZ is characterised by extremely active and prolific silicic volcanism of late Quaternary age. Magma erupted at rate of 0.3 m3/s over the past 0.3 Myr, making it one of the most active rhyolitic systems on Earth (Wilson et al., 1995). The average heat flux from the central 6000 km^2 of the TVZ is very high at 700 mW m^{-2} (Bibby et al., 1995). To the NNE and SSW of this central rhyolitic domain, volcanicity is dominantly calc-alkaline concentrated along the eastern margin of the rift — e.g. at Mt Ruapehu to the south and White Island and the island arc volcanoes along the Kermadec ridge to the north. The TVZ has long been considered to be the southern continuation of the back-arc extension of the Havre Trough into continental lithosphere of New Zealand (e.g. Karig, 1970) with extensional features forming the outer Bay of Plenty (Davey, 1977). Details of the offshore back-arc region and its transition from oceanic to continental lithosphere are less well known (Wright, 1992, 1993; Gamble et al., 1993).

Detailed morphology and shallow seismic investigations document the asymmetric recent faulting across the coastal region, both onshore (Nairn and Beanland, 1989; Mouslopoulou et al., 2008; Begg and Mouslopoulou, 2010-this issue) and offshore (Davey et al., 1995; Lamarche et al., 2006 and references therein), and infer the extension of near-surface structures from the TVZ into the Havre Trough (Wright, 1993). The spreading axis of the Havre Trough is offset to the SE into the offshore extension of the active faulting of the TVZ over a broad transition zone (Wright, 1993). Gamble et al. (1993) infer a sharp continental/oceanic arc transition from geochemical signatures of volcanic rocks along the offset in spreading axis and extending to the continental shelf edges to the NW and SE.

Early seismic studies (Haines, 1979; Stern and Davey, 1987) of the crustal structure under the TVZ show a shallow Moho (15 km) underlain by anomalously low velocity upper mantle (7.4 km/s). More recent investigations across the North Island (Henrys et al., 2003), immediately north of Mt Ruapehu, give similar results in general but differ in detail and interpretation. Stratford and Stern (2006) interpret a crust 15 km thick (seismic velocity<6 km/s), underlain by a transition zone (seismic velocity 6.8–7.4 km/s) from 15 to 20 km depth. A conventional Moho does not exist and mantle with seismic velocity of 7.4 km/s occurs at 20 km increasing to 7.8 km/s at 80 km with a strong wide angle reflector at 35 km depth interpreted to be a melt layer. The transition zone is inferred to be new crust formed by underplating. Harrison and White (2006) model the data with a sediment layer up to 3 km thick underlain by a 13 km thick crustal layer with seismic velocity of 5–6.5 km/s. Under this is material with seismic velocities from 6.9 to 7.3 km/s to 30 km depth interpreted as

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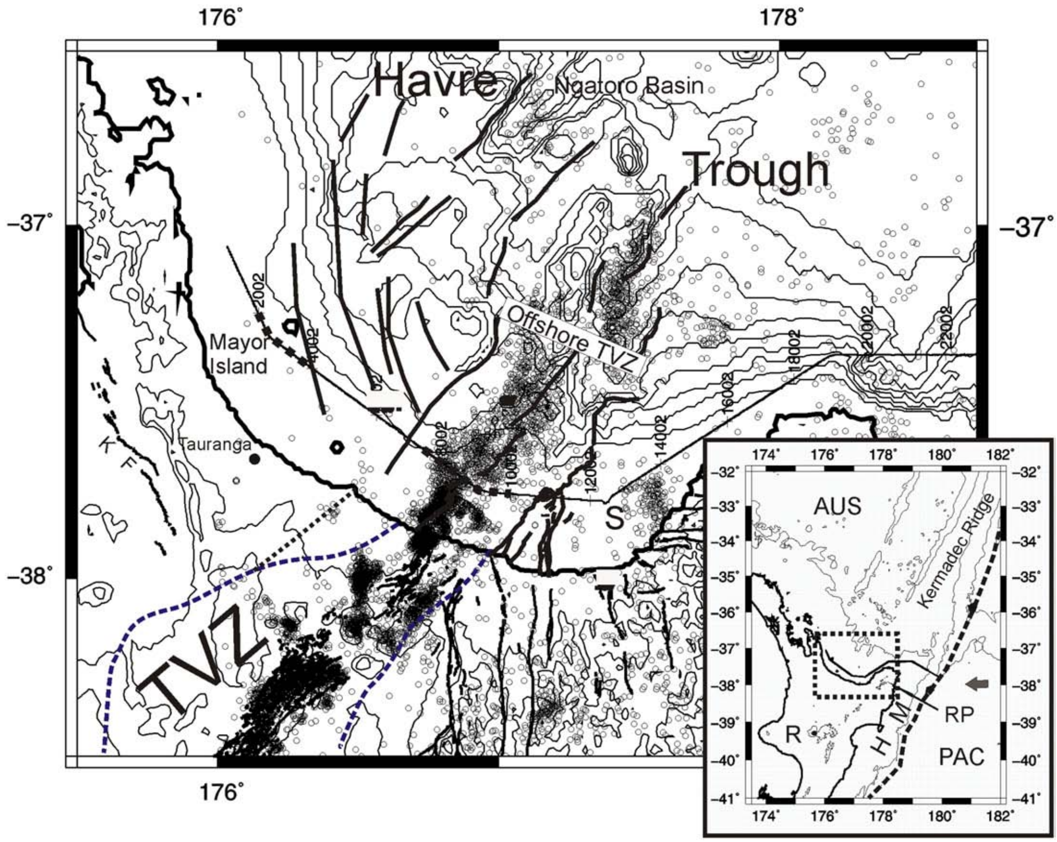

Fig. 1. Location of seismic profile shown in Figs. 3–6 (thin line, annotated with cdps 0–15000). Taupo Volcanic Zone – TVZ – delineated by dashed line, with older extent at the coast by dotted line (after Wilson et al., 1995). Seismicity (circles) and active faults on land (thick lines) from GEONET. Faults offshore (thick lines) after Wright (1992, 1993) and Lamarche et al. (2006). K — Kerepehi Fault. Dotted heavy line overlain on seismic profile track shows the extent along profile of the lower crustal/upper mantle discontinuous reflectivity (Figs. 4 and 5). S — zone of mantle wedge seismicity. Inset: location of Fig. 1 (dotted line). AUS — Australian plate, PAC — Pacific plate, thick dashed line — plate boundary, arrow — direction of plate convergence after DeMets et al. (1994), black dot labelled M — Mt Ruapehu, HM — Hikurangi margin, RP — Raukumara Peninsula (note it lies under the inset on main figure).

heavily intruded or underplated lower crust. They interpret the base of crust at 30 km depth under the TVZ, marked by a strong reflector, and underlain by mantle with seismic velocity of 7.4–7.8 km/s.

Crustal seismic reflection data were recorded in 1990 along the coast of the Bay of Plenty and the forearc region of the Hikurangi subduction zone (Davey and Lodolo 1995) and thus cross the offshore extension of the Taupo Volcanic Zone (OTVZ). Interpretation of the shallow part of the profile has been discussed by Davey et al. (1995, 1997). The location of the profile is shown in Figs. 1 and 2. These data have been reprocessed to improve the signal from the lower crust and upper mantle in order to try and understand the nature of the lower crust and upper mantle under the TVZ and its relationship to extension in the Havre Trough.

2. Data

The seismic data were recorded by R/V OGS Explora using a 60 channel 3000 m digital streamer and a 45 litre airgun array (Davey and Lodolo 1995). The data have been reprocessed to improve both the shallow and deeper section. Additional processing included more detailed velocity analysis (0.5 km intervals), source signature deconvolution, radon demultiple processing, and prestack time migration. The improved imaging of the deeper part of the section allows an interpretation of the mid-lower crust and uppermost mantle. Crustal data quality is variable across the section, partially due to geometrical effects of the sedimentary section, and continuity of reflectors is poor. However, some strong reflecting elements are recorded, particularly under the OTVC, for example the strong reflector at 5 s twt (seconds two-way-traveltime) under cdp 9000. Note the cdp number (the position along track) is common to all figures. This signal shows up as about 8 dB above background noise on the unprocessed shot records (Bannister et al., 2008) with deeper events 2–3 dB above background. This, and the dominant frequency of the signals (20 Hz), gives confidence that the events in the crust and upper mantle are not

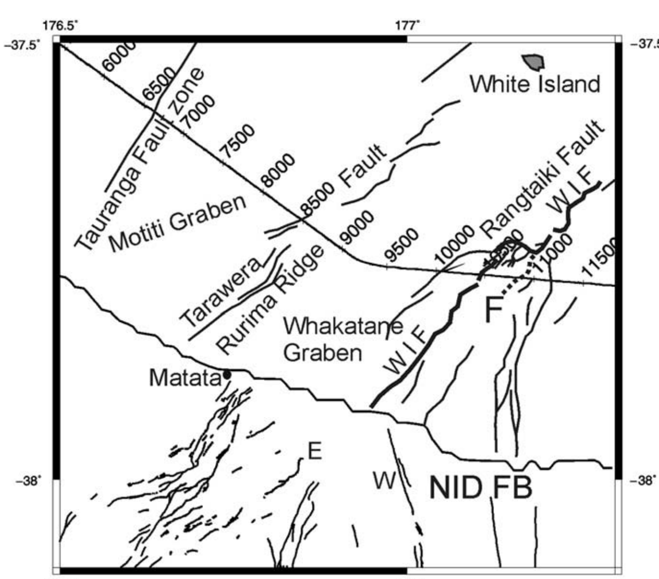

Fig. 2. Detailed location of the seismic profile across the OTVZ and the faults and structural features in the region. F — fault inferred to mark the eastern margin of the OTVZ (see text), WIF — White Island Fault, NIDFB — North Island Dextral Fault Belt, E — Edgecumbe Fault, W — Whakatane Fault.