Magnetotelluric imaging of upper-crustal convection plumes beneath the Taupo Volcanic Zone, New Zealand

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[1] Broadband MT (magnetotelluric) data were recorded that form an array of measurements at the south-eastern margin of the TVZ (Taupo Volcanic Zone), in the central North Island of New Zealand. These array data are used to investigate mechanisms by which the TVZ's extraordinarily high heat flux is transported to the surface. Taken together with seismological data, these MT data show compelling evidence that support a model of hydrothermal convection within the brittle (upper ∼6–7 km) part of the crust. Both 2-D and 3-D inversion models of these MT data show vertical low-resistivity zones that connect surface geothermal fields to an inferred magmatic heat source that lies below the brittle-ductile transition. **Citation:** Bertrand, E. A., et al. (2012), Magnetotelluric imaging of upper-crustal convection plumes beneath the Taupo Volcanic Zone, New Zealand, *Geophys. Res. Lett.*, *39*, L02304, doi:10.1029/2011GL050177.

1. Introduction

[2] The rhyolitic part of the Taupo Volcanic Zone (TVZ) in the central North Island of New Zealand discharges ∼4.2 GW of heat [*Bibby et al.*, 1995]. At upper crustal depths, *Bibby et al.* [1995] suggest that this heat flux is transported to the surface via convection in 23 high-temperature geothermal systems, each of which are marked by near-surface low-resistivity anomalies (Figure 1). The shallow (<3 km) geothermal fields are thought to represent the upper portion of rising, high-temperature convective plumes that extend down to depths of ∼8 km [*Bibby et al.*, 1995; *Kissling and Weir*, 2005; *McLellan et al.*, 2010]. However, much remains uncertain about the basement structure and mechanisms of heat transport at depths >3 km (the present maximum drilled depth).

[3] The geothermal fields in the TVZ provide ∼10% of New Zealand's electricity demand [*Bignall*, 2010], but development is currently limited to depths of 2–3 km. To maintain, or to increase this level of geothermal energy in the long term, production from depths >3 km will be required where temperatures may approach 400°C. The highest temperature yet encountered is 332°C at ∼3 km depth in the Rotokawa geothermal field [*Hunt and Harms*, 1990]. Seismicity recorded in the TVZ suggests that the brittle-ductile transition occurs at a depth of ∼6–7 km [*Bibby et al.*, 1995; *Bryan et al.*, 1999]. Therefore, basement rocks (greywacke and meta-sediments) between 3 and 7 km should be able to support fracture permeability and allow convective heat transport. However, no geophysical methods have yet imaged the proposed plumes that connect the surface geothermal systems to their underlying magmatic heat source.

[4] To investigate links between the deep magmatic heat source and the shallow hydrothermal systems, a research project that includes structural geology, experimental geochemistry, passive-seismic and magnetotelluric (MT) measurements was initiated in 2008 [*Bignall*, 2010]. The goal of the MT and passive-seismic surveys is to identify structures present within the basement rocks at depths between 3 and 7 km that advance our understanding of the processes that transport heat to the surface. This paper describes the MT data analysis and shows detailed 2-D and 3-D inverse resistivity models that image narrow, vertical zones of low-resistivity that may represent the convective plumes described by *Bibby et al.* [1995].

2. Data Collection and Analysis

[5] Previously, regional MT surveys of the central TVZ have imaged the crustal resistivity structure to depths of 30–40 km [*Ogawa et al.*, 1999; *Ingham*, 2005; *Heise et al.*, 2007, 2010]. In addition, closely-spaced MT and seismic surveys have been conducted locally at individual geothermal fields to investigate shallow structures (upper 3 km) motivated by commercial development [*Heise et al.*, 2008]. Here, we focus on detailed basement structure in the upper 10 km using a dense array of MT measurements.

[6] Using Phoenix MTU instruments, broadband (0.01–1000 s) MT data were recorded for 2 nights duration at 204 locations in the south-eastern TVZ during the spring months of 2009 and 2010. Measurements were made at ∼2 km intervals on a series of profiles forming a NW-SE rectangular array (25 × 35 km) that extends from the central rift axis to the south-eastern rift margin (Figure 1). These profiles are oriented perpendicular to the dominant geological and geoelectric strike directions of the TVZ (i.e. N45°E [*Heise et al.*, 2007]). Robust processing of the measured time-series data using a remote reference to reduce cultural EM noise [*Gamble et al.*, 1979] resulted in high-quality MT soundings at most sites occupied. Details regarding the complementary passive-seismic survey are included in the auxiliary material (Figure S1).[1]

[7] Prior to inversion modeling, the dimensionality of MT data must be assessed. The magnetotelluric phase tensor

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[1]Auxiliary materials are available in the HTML. doi:10.1029/2011GL050177.