2-D MAGNETOTELLURIC IMAGING OF THE ROTORUA AND WAIMANGU GEOTHERMAL FIELDS

Wiebke Heise[1], Ted Bertrand[1], T. Grant Caldwell[1], Graham Hill[1], Neville Palmer[1] and Stewart Bennie[1]

[1]GNS Science, PO Box 30368, Lower Hutt 4010, New Zealand

w.heise@gns.cri.nz

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ABSTRACT

2-D inverse modelling of magnetotelluric (MT) measurements at 101 locations in a 40 km by 10 km wide band crossing the Rotorua and Waimangu geothermal fields suggest that the geothermal fields are fed by up-flow zones that rise from the edge of a single electrically conductive body situated between the geothermal fields at about 6 km depth. The conductive body is interpreted to be a zone of silicic magma.

INTRODUCTION

The Taupo Volcanic Zone (TVZ) in the central North Island of New Zealand is a rifted-arc within continental lithosphere that has formed in response to the oblique subduction of the Pacific Plate beneath the Australian Plate. This region is characterised by young rhyolitic volcanism, rapid crustal extension, and is a region with exceptionally high geothermal heat flow (4200 MW) that is discharged through 23 high temperature (>200°C) convective hydrothermal systems. Figure 1 shows the location of the geothermal fields in the TVZ, which are associated with areas of low (< 30 Ωm) DC apparent resistivity. The low apparent resistivity areas map the near surface extent of the geothermal fields (Bibby et al., 1995; Stagpoole and Bibby, 1998). Here we report the results of a magnetotelluric (MT) survey in the Rotorua and Waimangu area designed to image the deeper structure of these geothermal systems.

1. MAGNETOTELLURIC DATA

MT data were recorded at a total of 76 locations in and around the Rotorua geothermal system. This survey was carried out for the Bay of Plenty Regional Council to gain improved information on the Rotorua geothermal system, in-particular the extent of the southern part of the Rotorua geothermal field at depths greater than those depicted in the 1:50,000 DC electrical resistivity maps of the area. An additional 25 magnetotelluric (MT) measurements were recorded for the Waikato Regional Council to help determine the deep structure of the Waimangu geothermal system (Figure 1). Figure 2 shows the location of the MT soundings and the profiles used for the 2-D inversions described later.

2. RESULTS

Mathematically, the phase information contained in the MT measurements is a tensor that can be represented graphically as an ellipse. Because the phase information in the MT response is not distorted by near surface conductivity heterogeneities, phase tensor ellipse maps provide a method of visualizing the MT data that allows the main features of the conductivity structure to be recognized prior to inversion modelling (Caldwell et al., 2004).

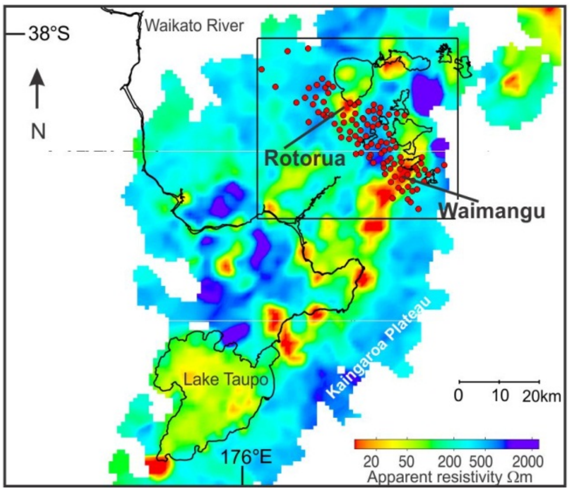

Figure 1: DC apparent resistivity map from Schlumberger array measurements made with an electrode spacing (AB/2) of 500 m. Conductive areas shown in red (<30 Ωm) mark the geothermal systems (Bibby et al., 1995). Inset shows Rotorua and Waimangu measurement area with MT sites (red dots).

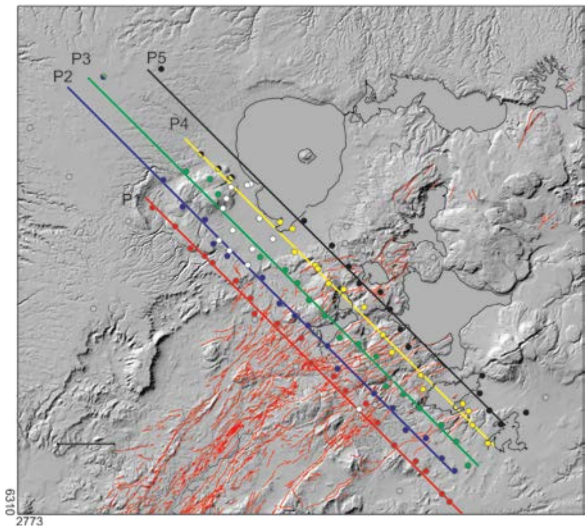

Figure 2: Locations of MT measurements and profiles used for 2-D inversion modelling. White dots show measurement locations that were too noisy to be used. Red lines show mapped active faults from the GNS active fault data-base.

The phase tensor skew angle (β) is a measure of the tensor's asymmetry and shows 3-D effects in the MT phase response. For 1-D and 2-D resistivity structures, which are mirror symmetric, β is zero. In general, a 3-D resistivity structure will not be mirror symmetric and thus the MT phase response will be asymmetric and β non-zero. As can be seen in Figure 3, south of Rotorua the skew angle is >5° and there is a systematic variation in the orientation of the ellipse axes showing that the influence of 3-D structure in this region is significant. Heise et al., (2010) also noted large skew angle values in the wider region south and west of Rotorua.

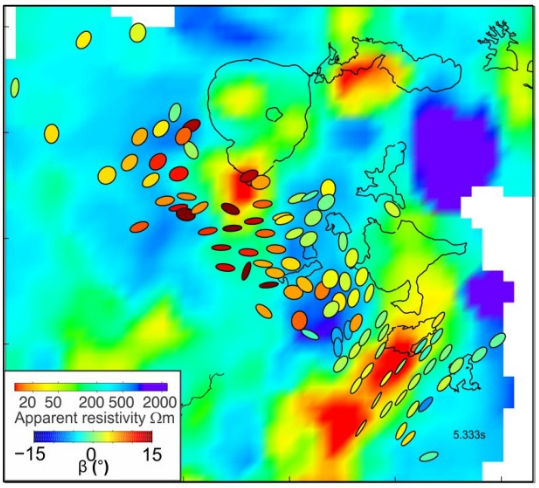

Figure 3: Phase tensor ellipses for phase tensor skew β at 5.33 s. Background colour is the DC apparent resistivity.

Phase tensors ellipses coloured by the geometric mean of the maximum and minimum phases (Φ_2) are shown in Figure 4. As can be seen in this figure, high phase values ($\Phi_2 > 45°$) are present in the region between the Rotorua and Waimangu geothermal fields indicating that an electrically conductive region is present in the mid-crust.

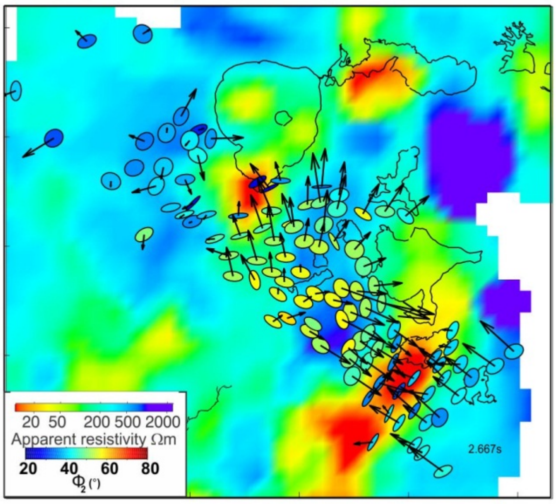

Figure 4: Phase tensor ellipses and real induction arrows at 2.6 s period superimposed on the DC apparent resistivity map. The ellipse colour shows the geometric mean of the maximum and minimum phase Φ_2.

3. 2-D INVERSION MODELLING

Here we report the results of 2-D inversion modelling, conducted as a first step in a more comprehensive analysis that will also utilize 3-D inversion modelling.

2-D modelling necessarily assumes that the strike direction of the resistivity structure is known. The so called geo-electric strike can be determined from the phase tensor and induction vector analysis or geologically. South-west of the survey area the zone of intense surface faulting shown in figure 2 suggests that the structural trend is ~N45°E. Further south-east in the Waimangu area the orientation of the phase tensor ellipses also suggest a N45°E strike; consistent with the overall strike of the south-east margin of the TVZ (Heise et al., 2007). 2-D resistivity inversion models were created for the five NW-SE profiles (1-5) shown in Figure 2. Modelling was carried out using the 2-D inverse modeling code described in Rodi and Mackie (2001) and implemented in WinGLink.

The 2-D resistivity images (not shown) suggest that the geothermal fields are fed by up-flow zones that rise from the edge of a single, large, electrically-conductive body situated between the geothermal fields at about 6 km depth. This conductive body is interpreted to be a zone of silicic magma.

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