ELECTRICAL STRUCTURE OF THE TOKAANU GEOTHERMAL FIELD

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SUMMARY - The structure of the Tokaanu geothermal field has been investigated using audiomagnetotelluric and magnetotelluric soundings. An initial interpretation of the electrical structure has been obtained from 1-dimensional modelling of the invariant apparent resistivity and phase at each measurement site. The spatial extent of low resistivities at 200m depth is in excellent agreement with the location of observed surface thermal features. To the northeast of Tokaanu Thermal Reserve the boundary of the field is probably located close to the Tongariro River. To the southeast it appears that there is a very sharp, near vertical, boundary which is approximately coincident with a southwest-northeast trending fault.

1. INTRODUCTION

The Tokaanu-Waihi geothermal field is situated on the southwest edge of Lake Taupo approximately 10km to the northwest of the town of Turangi. Although the thermal activity has been a focus of attention since the area was fist inhabited little appears to be known about the subsurface structure or extent of the field.

Two main areas of hydrothermal activity are apparent *(see* Fig. 1) - the Hipaua Thermal *Area* adjacent to the northeast to southwest trending Waihi Fault; and the Tokaanu Thermal Reserve behind Tokaanu township.

Other hot springs have been identified (Topping, 1974) within a very localised *area* bounded by the lake, the Tokaanu power station tailrace *canal* and the base of the Karakamea massif which rises to approximately 1300m in height to the southwest of State Highway 41. In addition there is a considerable seepage of hot water into Lake Taupo along the shoreline at Waihi village.

The main geological features of the area are indicated in Fig. 1. The Karakamea massif is comprised of the Karakamea and Pihanga Andesites whilst the lower, flatter terrain to the northeast is covered by the alluvial deposits of the Tongariro River. An additional feature is the

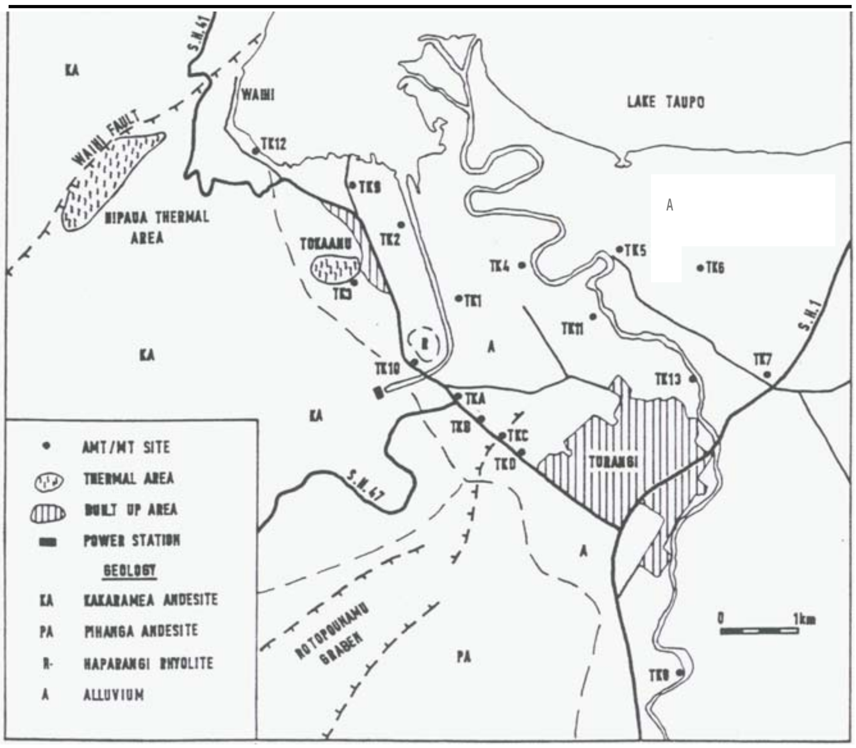

Figure 1. Thermal features, main geological features and the location of AMT/MT sites in the Tokaanu area.

rhyolite dome of Maunganamu which is estimated to be less than 2000 years old. The Waihi Fault is a major structural feature and is believed to extend through Lake Taupo (Grindley, 1960), branching to form the Whangumata, Whakaipo and Kaipo Faults to the north of the lake. Close to Waihi the rocks along the Fault have been hydrothermally altered. About 4km southeast of Tokaanu there is a second active fault scarp striking northeast and approximately marking the boundary between the Karakamea and Pihanga Andesites. It has been suggested by Hancox (1978) that this fault is actually comprised of two parallel faults, 2km apart, which join about 2km to the southwest of Highway 41. The western fault, when extended to the south, marks the northwestern boundary of Lake Rotoaira. The downthrust section between the faults is known as the Rotopounamu Graben.

2. AMT/MT MEASUREMENTS

To attempt to elucidate the structure of the geothermal field and its relationship to the geology of the area, audiomagnetotelluric (AMT) and magnetotelluric (MT) soundings have been made at a number of locations within and around the field. The locations of the AMT/MT sites are shown in Fig. 1. Lack of access into the immediate area of the Tongariro delta prevented more widespread coverage in this region, whilst the presence of Turangi, and its associated cultural noise, also reduces the number of suitable locations at which measurements can be made. The steep, bush covered hillsides of the Karakamea range are also unsuitable for measurements with the result that no information can be obtained concerning the extent of the field to the west and southwest.

At sites TK1 to TK13 measurements have been made of time variations in both the northward and eastward components of the horizontal magnetic and telluric (electric) fields. The basic frequency range covered by the data is from 1000-0.1Hz in three overlapping frequency bands. However at TK5 measurements were made at frequencies out to 0.01Hz whilst at some of the other sites the data covers only the range from 1000-1Hz. In all cases the frequency range covered is sufficient to be able to derive the electrical conductivity structure of the fist lkm in depth. Deeper information is obtained at those sites where lower frequency measurements were made.

In an attempt to obtain information on the variation of structure along State Highway 41, just outside Turangi, scalar AMT measurements were made in the frequency range 100-1Hz at four locations TKA to TKD. At these sites measurements were made only of the magnetic field variations in an orientation perpendicular to the road and telluric field variations parallel to the road. Such measurements do not yield as detailed structural information as is obtained by measurement of the full horizontal fields but can be used to give some guide to structural variations along the line of sites.

3. RESULTS

The data from sites TK1 to TK13 have been analysed in the manner outlined by Ingham (1991) and described in detail by Reeves (1991) to give, for each site, the impedance tensor as a function of period of variation. From the impedance tensor variation at each site the usual parameters used in AMT/MT analysis have been calculated - E-polarisation, H-polarisation and invariant apparent resistivity and phase curves, dimensionality indices and the orientation of the principal axes of the impedance tensor. These quantitites are presented in full by Reeves (1991).

Shown in Fig. 2 are pseudosections of the invariant apparent resistivity and phase (Ranganayaki, 1984) along a west-east line of sites. As discussed by Ingham (1989) such pseudosections can be used to give a qualitative indication of the variation in electrical conductivity structure along the section. The depth of penetration of the magnetic and electric field variations increases with increasing period of variation, and thus in the absence of static-shift the apparent resistivity pseudosection can be viewed as an approximation to a resistivity-depth pseudosection. Phase values of 45° indicate that the electrical conductivity is increasing with depth while, conversely, phases of less than 45° result from an increase in resistivity with depth. For example, site TK3 is immediately to the south of Tokaanu Thermal Reserve and exhibits apparent resistivities of less than 3 ohm-m at all periods below about 1s. At longer periods the apparent resistivity begins to increase. Compatible with this behaviour is that the phase, which remains close to 45° at short periods, falls to less than 30° shortly before the

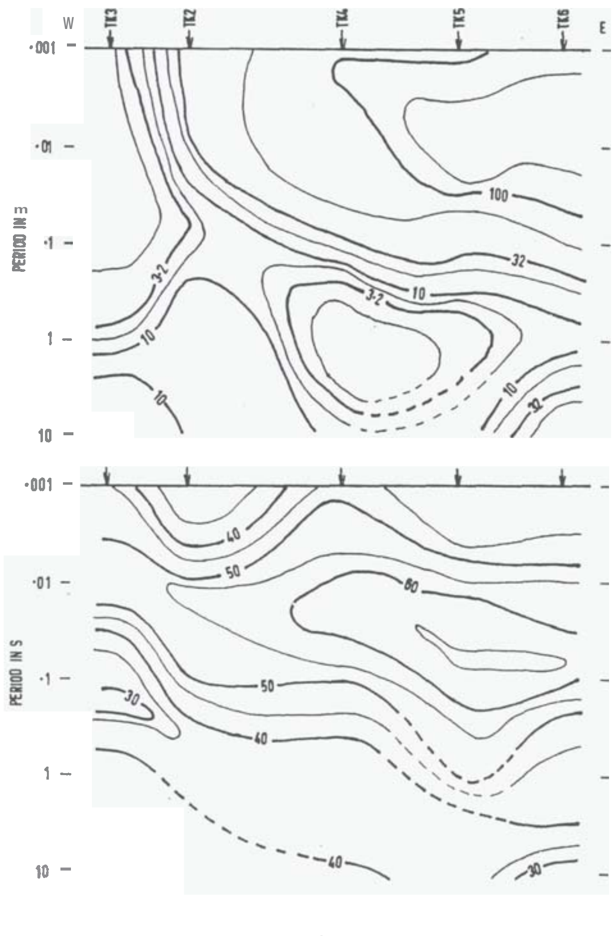

Figure 2. Pseudosections of the determinant apparent resistivity and phase along a W-E line through Tokaanu geothermal field.

apparent resistivity rises.

An initial interpretation of structure from Fig. 2 would thus be that low resistivities persist as far east as sites TK4 and TK5 (i.e. as far as the Tongariro River) but at considerably greater depth than beneath TK3. However, the very high phases in the period range 0.01-0.1s at TK5 and TK6 are a result of higher resistivity close to the surface rather than very low resistivity at greater depths.

A similar pseudosection for a line of sites approximately parallel to Highway 41 is shown in Fig. 3. In this case the apparent resistivities and phases shown are not the invariant values but those pertaining to an orientation of the impedance tensor axis parallel to the line of sites. This effectively corresponds to the H-polarisation orientation and allows inclusion of the results from the four sites at which scalar measurements were made in this orientation. Even so the results from these sites are still not strictly comparable to those from the full AMT/MT sites.

From Fig. 3 it is apparent that very low resistivity over the whole period range exists only at TK3 adjacent to the Thermal Reserve. To both the northwest (i.e. towards Waihi) and to the southeast the surface resistivities are higher and low resistivities occur at longer periods (greater depths). This is again compatible with the behaviour of the phase which has high values in the period range 0.01-0.1s at TK9 and TK10. To the southeast of TK10 the difference in the nature of the

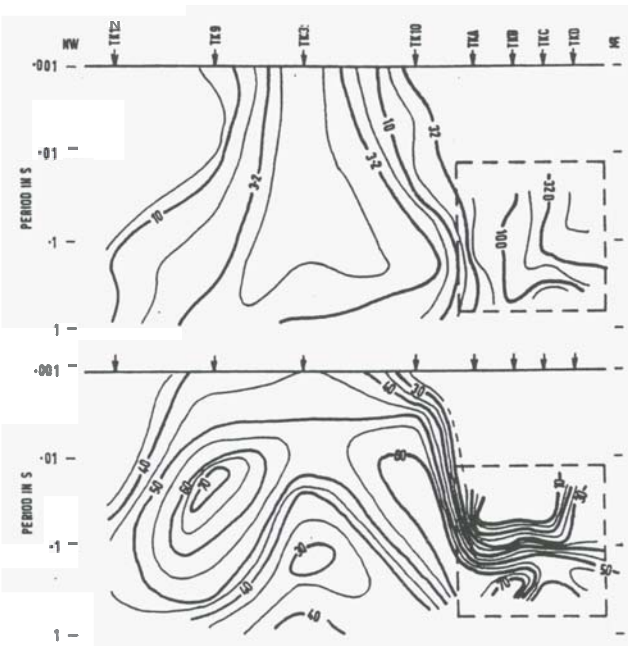

Figure 3. Pseudosections of H-polarisation apparent resistivity and phase along a NW-SE line through Tokaanu geothermal field.

measurements at TKA, TKB, TKC and TKD becomes crucial as there is an extremely sharp increase in apparent resistivity and the phase values have a completely different character. Should this be a real difference rather than simply a function of the different nature of the measurements, it argues for an extremely sharp boundary to the geothermal field immediately to the southeast of TK10.

A full quantitative interpretation of the electrical structure requires at least 2-dimensional numerical modelling of the E and H-polarisation apparent resistivities and phases along the lines of sites presented in Figs. 2 and 3. A preliminary interpretation can be obtained by 1-dimensional modelling of the invariant apparent resistivity and phase responses (i.e. calculation of a resistivity-depth variation beneath each site without regard to the effect of lateral variations). Such a 1-d interpretation should reveal the gross features of the true structure although at long periods in particular lateral structural variations may distort the interpretation.

One-dimensional modelling of the invariant responses has been carried out using the method of Fischer et. al. (1981) and Fischer and Le Quang (1981) to obtain 1-d resistivity structures which give the best fit to the apparent resistivity and phase data at each site. As modelling of AMT/MT data is non-unique a Monte-Carlo modelling program has subsequently been used to explore how far the resulting structures can be modified without significantly altering the fit to the data. From the modelling results contour plots have been constructed showing the inferred resistivity at various depths. These are shown in Fig. 4 for depths of 100, 200 and 500m. For the *scalar* sites the resistivity-depth variation has been obtained by a simple Bostick inversion (Bostick, 1977) of the scalar data.

4. DISCUSSION

The results presented in Fig. 4 suggest that the lateral extent of low resistivities, presumably associated with the geothermal reservoir, increases with depth within the first 500m. The principal observations which can be made concerning the results in Fig. 4 are as follows.

- At 100m depth only the region immediately surrounding the Tokaanu Thermal Reserve and extending southeast as far as the tailrace canal has resistivity values of less than 5-6 ohm-m.

- At 200m depth this area is extended to the northeast suggesting a dip of the geothermal reservoir in that direction of about 6°.

- At 500m depth low resistivities also occur at site TK4. Further to the east and northeast there is a sharp rise in resistivity.

- There is a very rapid increase in resistivity immediately to the southeast of TK10. The position of this increase does not change with depth possibly indicating an abrupt, near vertical, boundary to the geothermal field.

- No deductions can be made concerning the extent of low resistivities to the north and west.

Apart from the region around Waihi from which no measurements are available, the area enclosed by the 6 ohm-m contour at 200m depth is almost exactly that in which surface thermal features occur. It would seem

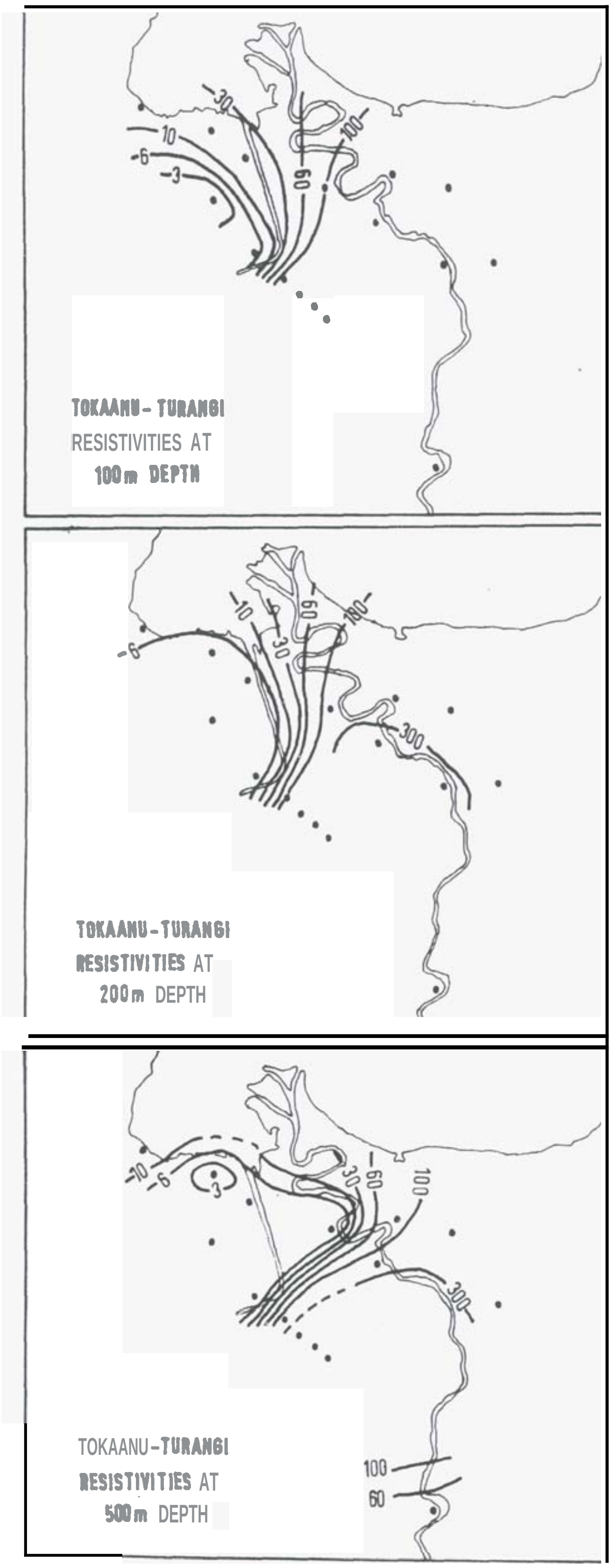

Figure 4. Contour plots of resistivity at different depths in and around Tokaanu geothermal field.

reasonable therefore to to deduce that this area does indeed represent the extent of the geothermal field at 200m depth. Clearly there is a suggestion that the reservoir may actually extend further to the northeast at greater depths. The true boundary of the field may thus be as far to the northeast as the Tongariro River. Beyond this point, beneath TK5 and TK6 for example, resistivities never fall below 15 ohm-m.

The apparent near vertical boundary of the field to the southeast of TK10 may well be the result of the different types of measurements made at TKA, TKB, TKC and TKD compared to TK10. However, there are three points which can be made which perhaps suggest that the sharp increase in resistivity is a real feature. Firstly, high resistivity also occurs at sites TK11 and TK13 (enclosed by the 300 ohm-m contour at 200m depth). Secondly, the boundary is coincident with the line beyond which no surface thermal features are found. Thirdly, and perhaps most interestingly, the location of the boundary is very nearly coincident with the fault marking the northern extension of the Rotopounamu Graben. It is tempting to suggest therefore that this fault marks the southeastern edge of the geothermal field. Confirmation of this might be obtainable should it prove possible to acquire full AMT/MT data from the region southeast of the fault.

As it is apparent from the activity at Waihi and the Hipaua Thermal Area that the reservoir extends as far to the northwest as the Waihi Fault, it may be the case that these two approximately parallel faults mark the northwestern and southeastern limits of the geothermal field. With the indications above that the northeastern boundary is close to the Tongariro River this would leave only the extent of the field to the southwest, beneath the **Karakamea** massif, in question.

5. ACKNOWLEDGEMENTS

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