INTERPRETATION OF MAGNETIC ANOMALIES OVER THE REPOROA GEOTHERMAL FIELD, TAUNO VOLCANIC ZONE, NEW ZEALAND

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SUMMARY—The Reporoa geothermal field is located in an area of the Taupo Volcanic Zone (TVZ) which exhibits a complex magnetic source pattern since hydrothermally demagnetised rocks occur together with younger normally magnetised and older reversely magnetised volcanic rocks. No distinct negative residual magnetic anomalies could be observed over the central part of the prospect during our aeromagnetic survey conducted at c. 760 m asl. However, when results of detailed geological studies and magnetic studies of cores are considered, it was found that the subdued magnetic anomalies over the Reporoa Field contain a small component reflecting demagnetised rocks which are surrounded, in part, by reversely magnetised rocks at the bottom of the Reporoa Caldera.

1. INTRODUCTION

Hydrothermal activity can cause partial or complete demagnetisation of volcanic host rocks since it alters the primary magnetic minerals (for example, magnetite) to almost non-magnetic minerals (i.e., pyrite). This is well established for geothermal systems in the Taupo Volcanic Zone (TVZ) where significant negative residual magnetic anomalies have been observed over at least ten geothermal fields which are associated with hydrothermal demagnetisation of the upper part of the reservoir (Hochstein and Soengkono, 1996).

An aeromagnetic survey of the eastern TVZ including the Reporoa area was made in May 1993. The survey was conducted along N-S oriented flight lines separated by about 1 km at a height of c. 760 m asl (300-400 m above mean ground). No distinctive negative anomalies were observed over the Reporoa geothermal field, and in an earlier interpretation (Soengkono and Hochstein, 1996) the effect of demagnetised rocks was neglected. Examinations of drillhole cores and cuttings from the deep Reporoa RP1 well (e.g., Lampoonsub, 1987; Bignall, 1990; Nairn et al., 1994; Wood, 1994), however, shows that intense hydrothermal alteration had affected most rocks encountered in this well. A revised magnetic model of the Reporoa area is presented in this paper which allows for hydrothermal demagnetisation in the RP1 well.

Figure 1. Location map of the study area in the eastern TVZ. Grid coordinates are in terms of NZ Map Grid (km).

2. GEOLOGY

The Reporoa geothermal field lies between the already explored geothermal fields of Ohaaki-Broadlands in the SSW and Waiotapu in the NNE (Fig. 1). A simplified geological-geophysical map of the greater Reporoa area is shown in Fig. 2. It shows the main features that are relevant for
The Reporoa geothermal field lies within the Reporoa Caldera which was only recently recognised after detailed geological investigations (Nairn et al., 1994). A major eruption from this caldera occurred about 0.24 Ma ago and produced the Kaingaroa Ignimbrites (c. 100 km$^3$) which are widespread along the eastern edge of the TVZ and which are characterised by a large content of andesitic rock fragments. The geothermal well RP1 was drilled to about 1340 m depth (Fig. 3). It penetrated 300 m of lacustrine sediments (Huka Falls Formation) consisting mainly of mudstones, underlain by a sequence of rhyolite lavas (−530 m thick) that represent at least two episodes of dome activity (Wood, 1994). Below the rhyolites, drilling encountered a sequence of tuffaceous sediments and tephras of the Waiora Formation (−450 m thick) which overlay a welded part of the Kaingaroa Ignimbrites near the bottom of the hole.

Magnetisation studies of cores (Lampoonsub, 1987) indicate that most cores are completely demagnetised although some magnetisation (0.9 A/m remanence) occurs in a core from about 880 m depth (see Fig. 3). A similar pattern has been observed at the Ohaaki-Broadlands geothermal field (Fig. 1) (Hochstein and Soengkono, 1996).

Figure 2. Simplified geological - geophysical map of Reporoa area (after Nairn et. al, 1994; Grindley et. al, 1994; Wood, 1994; and Bibby et.al., 1994).

Figure 3. Geological log (Wood, 1994) and magnetisation of cores (Lampoonsub, 1987) of drillhole RP1. The shaded area represent the range of the magnetisation magnitude of unaltered volcanic rocks in the TVZ (Hochstein and Soengkono, 1996).
3. GEOTHERMAL ACTIVITY

Small areas with active Surface manifestations (mainly thermal ground) occur over the Reporoa geothermal field (see Fig. 2). In addition, two low temperature springs (Golden Springs) occur 6 km to the SSW from the centre of the field. All Surface manifestations have a rather small total heat output of about 20 MW (Bibby et al., 1994a).

Resistivity surveys with fixed Schlumberger arrays (Bibby et al., 1994a,b) shows that the Reporoa field is associated with a low resistivity area (<10 ohm-m apparent resistivity for an array spacing of \( AB/2 = 500 \) and 1000 m). A discontinuity of apparent resistivity occurs to the east and west of the Reporoa resistivity low, but not towards the Waiotapu field in the north-east. Healy and Hochstein (1973) suggested that the thermal activity at Reporoa is caused by a concealed outflow from the Waiotapu geothermal field which lies upstream in the Reporoa-Waiotapu catchment. Although the temperature profile in well RP1 shows a temperature inversion below 500 m depth and the well has lower temperatures than those measured, for example, in well WT7 (Waiotapu) at similar depths, these features do not necessarily support an outflow model since significant downflow of cooler fluids has been observed in the RP1 well. A chloride flux study gave no evidence for any concealed outflow of fluids from the Reporoa field into the Waikato River (Hochstein et al., 1992). From the pattern of resistivity data (Schlumberger traversing and vertical electrical sounding surveys) across the Reporoa and Waiotapu areas, Bibby et al. (1994a,b) inferred that the Reporoa field is a separate and independent geothermal field.

4. RESIDUAL MAGNETIC ANOMALIES

The residual magnetic anomalies (Soengkono, 1992) over the Reporoa area obtained from our 1993 aeromagnetic survey are shown in Fig. 4. The uplifted Paoera Fault Block in the north-western part of Fig. 4 is associated with distinct SW-NE trending, positive residual magnetic anomalies whereas significant negative anomalies occur over the Te Kopia geothermal field along the same fault zone. No distinctive magnetic anomalies are associated with the two dacite domes in the northern part of the figure (the Maungaongaonga Dome in the west and the Maungakakaramea or Rainbow Mountain in the east), indicating that these features have been demagnetised by hydrothermal alteration during past activities of the Waiotapu geothermal system.

Negative residual magnetic anomalies near the north-western margin of the Reporoa Caldera are clearly associated with exposed, reversely magnetised rocks. Subdued negative residual magnetic anomalies also occur over the Waiotapu geothermal field to the northeast of Reporoa although only a small portion of these anomalies is shown in Fig. 4. The rhyolite dome to the west of the Waiotapu bore field (Trig. 8566) is associated with a positive anomaly, indicating that the dome has not been affected by demagnetisation. Pronounced negative residual anomalies near the eastern and north-eastern edge of the Reporoa Caldera were interpreted to be caused by remnants of a large, buried andesite volcano (Soengkono and Hochstein, 1996) whose existence is indicated by lithic fragments of andesitic rocks found in the Kaingaroa Ignimbrites (Nairn et al., 1994).

Negative residual magnetic anomalies cannot be recognised over the low resistivity structure of the Reporoa field. An area with positive residual anomalies occurs towards the south-west, straddling the inferred boundary of the Reporoa Caldera near the Kairuru Dome in Fig. 4; they extend towards the Reporoa resistivity low. The eastern extension of these positive anomalies can also be recognised in the pattern of a map of Bibby et al. (1994a,b) showing detailed, low level (60 m above ground) aeromagnetic data in that area. The Kairuru rhyolite dome occurs in the south-eastern part of the area with positive anomalies. It has been suggested by Bibby et al. (1994a,b) that the magnetic high is caused by buried rhyolite domes which can be correlated with the sequence of rhyolites encountered in well RP1 and at the Kairuru Dome.

5. INTERPRETATION OF MAGNETIC ANOMALIES

The Reporoa geothermal reservoir lies in an area with a complex magnetic source pattern because hydrothermally demagnetised rocks occur together with normally and reversely magnetised volcanic rocks. A preliminary interpretation of the Reporoa magnetic anomalies has been presented by Soengkono and Hochstein (1996) who also gave a preliminary interpretation for the magnetic anomalies over the Waiotapu, Waimangu and Waikite fields. Possible effects resulting from concealed, demagnetised rocks at Reporoa were neglected in the earlier study because of the lack of a distinct negative magnetic signature over the Reporoa field.
A reinterpretation of the residual magnetic data over the Reporoa area was therefore attempted. It was conducted following the method outlined by Soengkono (1992) and using all constraints given by available surface geological investigations, the geological log of RP1, and the magnetic measurements of cores from that well. We assumed that the average total magnetisation of normally magnetised volcanic rocks in the study area outside the geothermal reservoirs is of the same order of magnitude as that of unaltered rocks in the greater TVZ which is c. 1.7 A/m (Soengkono, 1995). The shaded vertical band shown in Fig. 3 represents the range of the magnitude of magnetisation (median values) of unaltered volcanic rocks in the TVZ, taken from Hochstein and Soengkono (1996).

The reinterpretation started with the 3-D model constructed by Soengkono and Hochstein (1996) which already included normally magnetised bodies representing the north-eastern part of the concealed rhyolite dome complex south-east of Reporoa (magnetisation 2.5 A/m), reversely magnetised andesite bodies concealed beneath the western and north-western part of the Reporoa Caldera (total magnetisation of -1.8 A/m), a shallow infill (upper 300 m) of the Reporoa Caldera representing the...
mudstones of the Huka Falls Formation (with a total magnetisation of 0.5 A/m), and hydrothermally demagnetised rocks of the upper part of the Waiotapu reservoir near the northern rim of the Reporoa Caldera. New magnetic bodies were added to that model representing the reversely magnetised rocks north-west of the Reporoa Caldera and the normally magnetised rhyolite dome (at Trig. 8566). The model was further modified by assessing the effect of demagnetised rocks as observed in the RP1 well.

**Our** best fit 3-D model is shown in Fig. 5 and the magnetic effects computed from that model are presented in Fig. 6. We found that the representative total magnetisation for the body representing the buried dome complex south-west of Reporoa had to be increased to about 3.0 A/m. More significantly, we also found that this magnetic body **has** to be terminated south-west of RP1 in order to obtain a good fit between the computed magnetic effects and the observed residual magnetic anomalies in the central part of the Reporoa field.

**Figure 6.** Magnetic anomalies computed from the model shown in Fig. 5. Contour interval is 100 nT.

**Figure 7.** 3-D magnetic interpretation profile along line A-A'. The computed magnetic anomalies shown in the upper section are from the model with the rhyolite body terminated south-west of RP1 (1), and with the rhyolite body extending to the northeast of RP1 (2).
(see Fig. 7). The comparison shows that the sequence of rhyolite lavas penetrated by well RP1 is part of the same rhyolite dome complex that has been hydrothermally demagnetised. Our magnetic interpretation is therefore consistent with intense hydrothermal alteration of rocks found in this well from examinations of cores and cuttings (e.g., Bignall, 1990; Nairn et al., 1994; Wood, 1994), supported by results (see Fig. 3) of magnetic measurements of cores (Lampoonsub, 1987).

6. SUMMARY AND DISCUSSION

Our reinterpretation of magnetic anomalies over the Reporoa Caldera has shown that some hydrothermally demagnetised rocks occur at depth in the central part of the Reporoa geothermal reservoir. The magnetic signature of this effect is masked by strong positive magnetic anomalies caused by a large, concealed rhyolite dome complex beneath the south-western part of the Reporoa Caldera, and also by negative anomalies caused by remnants of an older, buried, reversely magnetised andesite volcano beneath the eastern and north-eastern part of the caldera. In comparison with the magnetic structures of other high temperature reservoirs in the TVZ which have been studied in detail (summarised recently, for example, by Hochstein and Soengkono, 1996), the structure of the Reporoa system is unusual since the extent of the demagnetised rocks at depth is significantly smaller than the extent of near-surface rocks with low resistivity.

If the north-eastern part of the rhyolite dome complex has been hydrothermally demagnetised by fluid/rock interaction in the Reporoa geothermal reservoir, it can be inferred from our model that hydrothermal demagnetisation has only affected a rather limited portion of the northern edge of the dome complex, which appears to cover less than, say, 5 km$^2$ at 800 m depth. The low resistivity rocks in the upper 300 m cover an area of at least 15 km$^2$. If the deeper reservoir were of smaller extent, this could explain the rather small natural heat output of the prospect. It is also possible that a cold water inflow from the south-east, as has been suggested by Wood (1994), has prevented demagnetisation to expand.

REFERENCES


