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MAGNETIC STUDY OF THE MOKAI GEOTHERMAL FIELD

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ABSTRACT

A low level airborne magnetic survey (altitude 760m a.s.l., mean nominal height above terrain: 300 m) over the Mokai geothermal field and the surrounding area has delineated an area of relatively low total force magnetic anomaly associated with the geothermal field. This low magnetic anomaly appears to be the effect of a hydrothermally demagnetized body of volcanic rocks within the Mokai reservoir at depths of about 0 to -500 m a.s.l.

The Pukemoremore rhyolite dome lying directly to the east of the Mokai geothermal field is also demagnetized. It is possible that part of the Mokai reservoir extends further to the east beneath the Pukemoremore dome.

INTRODUCTION

The Mokai geothermal field lies about 25 km north-west of Taupo (Map 1) in the central volcanic region of North Island. New Zealand. Although the occurence of surface thermal manifestations in this area (the location shown in Map 1) had been reported in 1937 (Grange, 1937). interest in the geothermal prospect was revived only in 1977 following the results of a multipole-quadrupole resistivity survey by Geophysics Division DSIR (Bibby. 1977: Bibby et al., 1984). Following this survey. more detailed surveys including Schlumberger resistivity mapping (Bibby et al., 1984), geological mapping (Lloyd, 1978) and chemical studies of the surface manifestations (Henley and Glover. 1980) were conducted.

Since 1980, six deep exploratory holes have been drilled in the Mokai geothermal field (Map 1) and one of the wells. MK5. was found to be the most productive exploration well ever drilled in New Zealand (mass flow of about 700 tonnes/hour: equivalent to about 25 MW electrical power).

GEOLOGY

The Mokai geothermal field is situated between the rhyolite dome complex of the Maroa volcanic centre and a western belt of smaller rhyolite. domes (known as the Mokai Ring Complex (Healy, 1962)). see Map 1. The Maroa volcanic centre is one of the six known major volcanic centres of the Taupo Volcanic Zone and has been active for the last 230 thousand years (Wilson et al.. 1984).

The rhyolite domes of the Maroa centre and the western dome belt are surrounded by ignimbrite flows (see Map 1). Apart from these products of rhyolitic volcanic activity, which. according to Lloyd (1978) and supported by drillhole data (Wood, 1982a and b: 1983a.b and c: 1984), has been dominant in this area for more than 300 thousand years. small outcrops of basaltic lava and scoria can also be found in some places around the Maroa volcanic centre (Healy et al.. 1964: Wilson et al., 1984).

MAGNETIC SURVEY

Hydrothermal processes have been known to alter ferrimagnetic minerals like magnetite and/or titanomagnetite to non-magnetic minerals such as hematite. pyrite. leucoxene or sphene (Browne. 1982). This causes the reservoir rocks to become partially or completely demagnetized. Results of ground magnetic surveys over Kawerau (Studt, 1958: Macdonald and Muffler. 1972) and Broadlands (Hochstein and Hunt, 1970) geothermal fields in New Zealand show significant low magnetic anomalies which were interpreted as the effect of hydrothermally demagnetized volcanic rocks. Similar anomalies have also been observed over some Icelandic geothermal fields as shown from airborne magnetic surveys over Reykjanes (Bjornsson et al., 1970) and Hengill (Bjornsson and Hersir, 1981).

A low level airborne magnetic survey (altitude 760 m a.s.l.) covering the Mokai geothermal field and the surrounding area was conducted on the 21st of March 1984 (Soengkono., 1985).The residual total-force magnetic anomalies observed in this survey are shown in Map 3. One of the most interesting features on this map is the region of relatively low magnetic anomaly that coincides with the geothermal field as defined by the low resistivity anomaly (Bibby et al. 1984). The centre of this magnetic anomaly, hereafter referred to as the Mokai magnetic low. lies slightly to the north of the centre of the low resistivity region. suggesting that the source of the magnetic anomaly lies within the low resistivity region.

A less pronounced area of relatively low magnetic anomaly is also present near Ongaroto where a small low resistivity region had been mapped and interpreted to be associated with a lateral outflow of geothermal water from Mokai towards the Waikato river (Bibby et al., 1984).

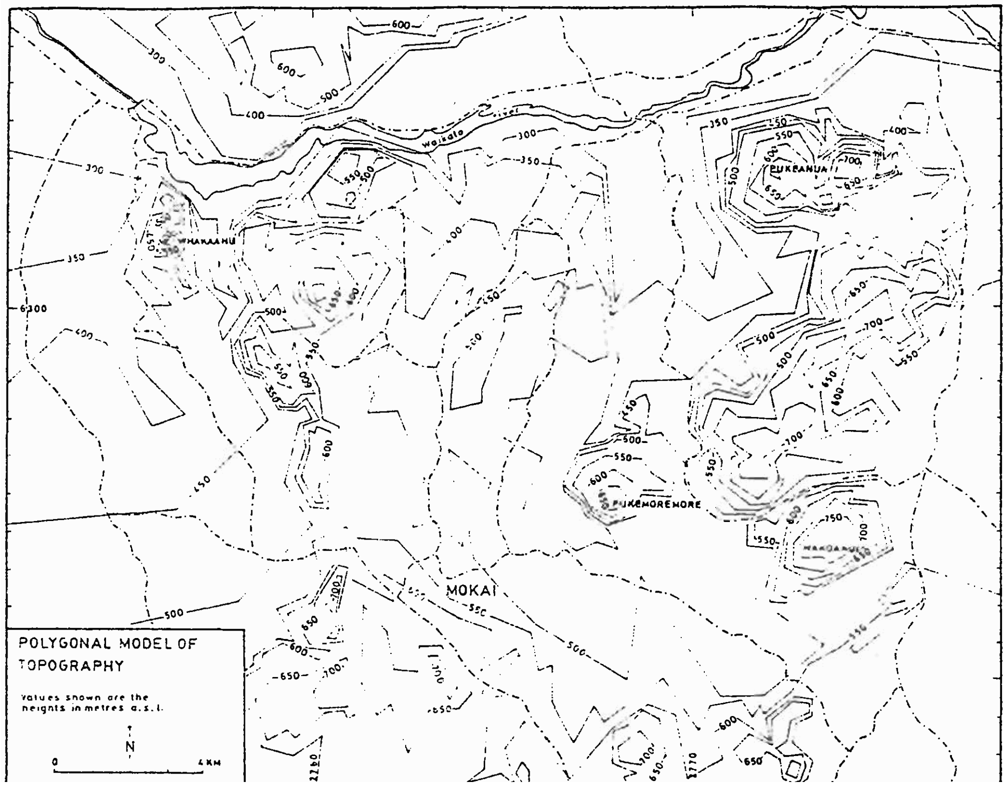

Figure 1.

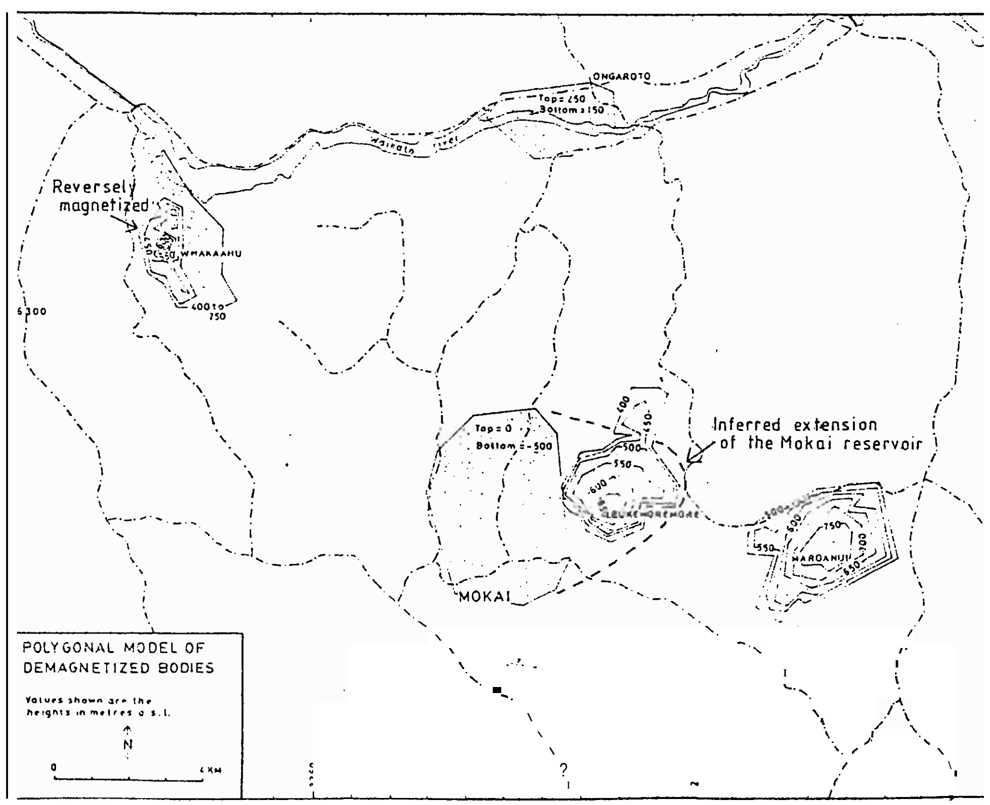

Figure 2.

INTERPRETATION OF THE MAGNETIC DATA

MAGNETIC MODELLING

It has been known that steep topography of volcanic terrain may give rise to magnetic anomalies (Parasnis, 1979). In case of the magnetic data in Map 3, this phenomenon is indicated by the correlation between positive magnetic anomaly centres with exposed rhyolite domes which form the hills around the Mokai geothermal field. To investigate the possibility wether the Mokai magnetic low is controlled by topography, magnetic effect of the topography was computed using 3-D modelling. The polygonal terrain model is shown in figure 1. The magnetization was assumed to be normal and having a magnitude of 2.5 A/m, using values of Modriniak and Studt (1958), Hochstein and Hunt (1970) and Rogan (1982).

The theoretical topographical effect, which was computed for a 1000 m grid, is presented in Map 2. This map does not show any low magnetic anomaly near the Mokai geothermal field nor at Ongaroto and thus confirms that the Mokai magnetic low and the low magnetic anomaly near Ongaroto are not caused by effects of the surrounding (magnetic) topography.

Thirteen core samples were taken from the Mokai drillhole: these exhibit a very low magnetic susceptibility and low remanent magnetization. Figure 3 shows that the magnetization of the samples taken from 0 to -500 m a.s.l. levels is less than 0.2 A/m compared to about 2.5 A/m for volcanic rocks outside the Mokai reservoir. This result already indicates that the Mokai magnetic low is caused by demagnetized rocks within the Mokai reservoir.

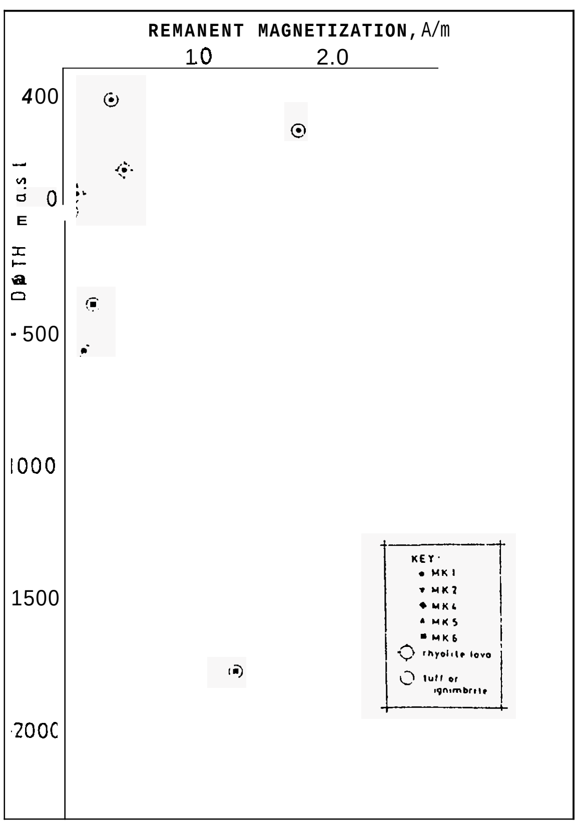

Figure 3. Plot of remanent magnetization against depth, Mokai geothermal field.

There is a significant difference between the computed (Map 2) and observed (Map 3) anomalies over the Pukemoremore and Maroanui domes in the Maroa volcanic centre and the Whakaahu dome to the west of the western dome belt. The fact that the observed magnetic anomalies at Pukemoremore and Maroanui are almost featureless (see Map 3) indicates that the rhyolites forming the domes are non-magnetic. At Whakaahu, the observed magnetic anomalies are strongly negative which suggests that the rhyolites are reversely magnetized and thus predate the Brunnes-Matuyama polarity epoch (730 thousand years ago).

A second 3D-magnetic model was then constructed which allows for the topographic effects of the model shown in figure 1 and includes demagnetized masses beneath the Mokai field, the Ongaroto area, the Pukemoremore and Maroanui domes and which also allows for a reversed magnetization of the Whakaahu dome. The polygonal model for the latter effects is shown in figure 2; the computed anomalies are presented in Map 4. As can be seen in map 4, the new magnetic model reproduces the broad region of low magnetic anomaly in the areas of the Mokai geothermal field and Ongaroto, the featureless anomaly at Pukemoremore and Maroanui and the negative anomaly at Whakaahu.

DISCUSSION

It has been shown that the volcanic rocks inside the Mokai reservoir have been demagnetized and that the effect of this demagnetization can be observed by the measurement of magnetic field at 760 m a.s.l. (about 300 m above the ground surface). Magnetization measurements of drillhole samples and modelling of the observed magnetic anomaly suggest that the demagnetization of rocks occured mainly at 0 to -500 m levels. Demagnetized rocks could extend to greater depths since the computed anomalies are not much affected by the actual level of the lower boundary, the same holds for the computed effect of the demagnetized Pukemoremore body. Results of petrography and XRD analyses of cores and cuttings from Mokai drillholes (Wood, 1982 a and b; 1983 a, b and c; 1984) indicate that the hydrothermal alteration at depths below 0 m is quite intense and that alteration minerals pyrite and sphene are common. Thus, the demagnetization of the volcanic rocks inside the Mokai reservoir is clearly associated with hydrothermal processes, i.e. activity of the Mokai geothermal field has caused hydrothermal demagnetization.

The Pukemoremore rhyolite dome lying directly to the east of the Mokai geothermal field is also non-magnetic. It is possible that hydrothermal activity in the past also demagnetized this rhyolite dome and that escape of steam to the surface has been controlled in the past by a yet unknown E-W trending fracture zone. Schlumberger traversing data (Bibby et al., 1984) show that around Pukemoremore, the apparent resistivity drops rapidly from about 700 ohm-m for AB/2=600 m to about 150 ohm-m for AB/2=1200 m, suggesting low resistivity at depth. Also, the contrast between inferred maximum and minimum apparent resistivity derived from the multipole-quadrupole data (Bibby et al., 1984) beneath the Pukemoremore dome is not as high as that directly outside the geothermal field to the south and west. It is thus possible that the Mokai reservoir actually extends to the east of the mapped resistivity boundary. An inferred extension of the geothermal field based on these arguments is shown in iiuure 2.

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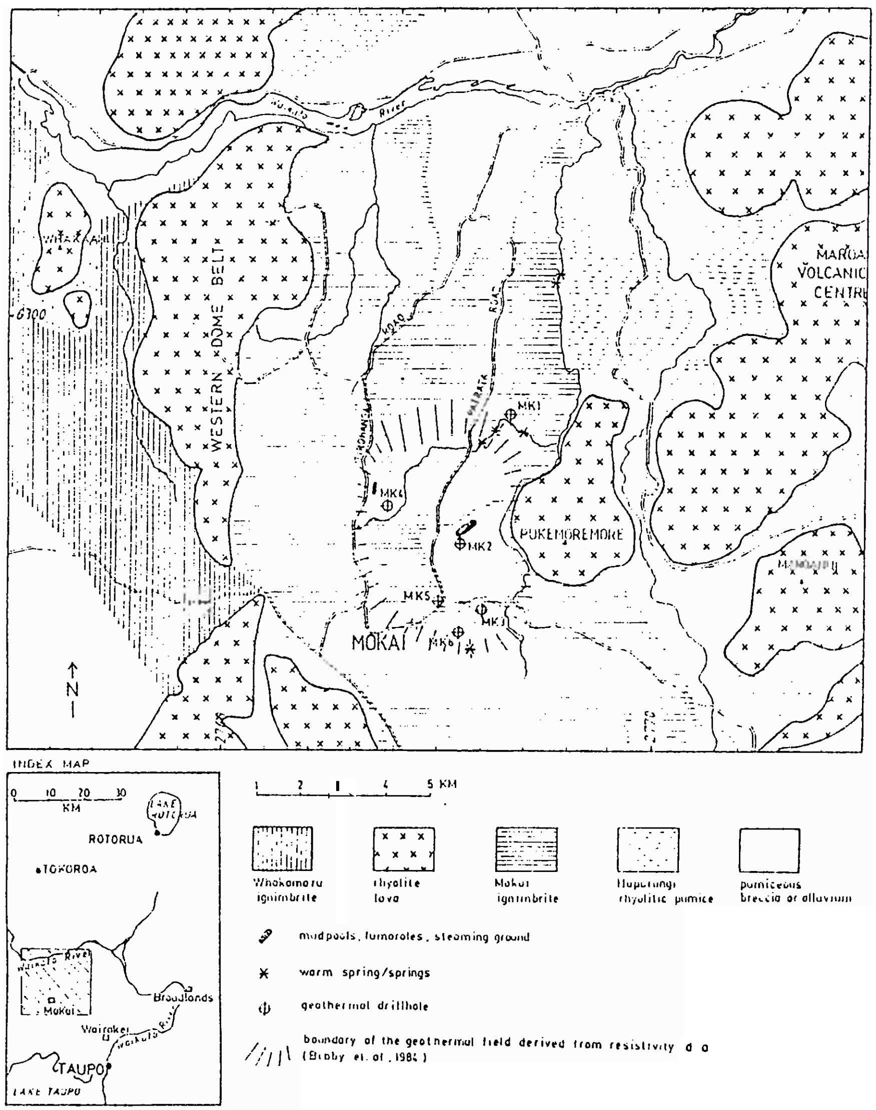
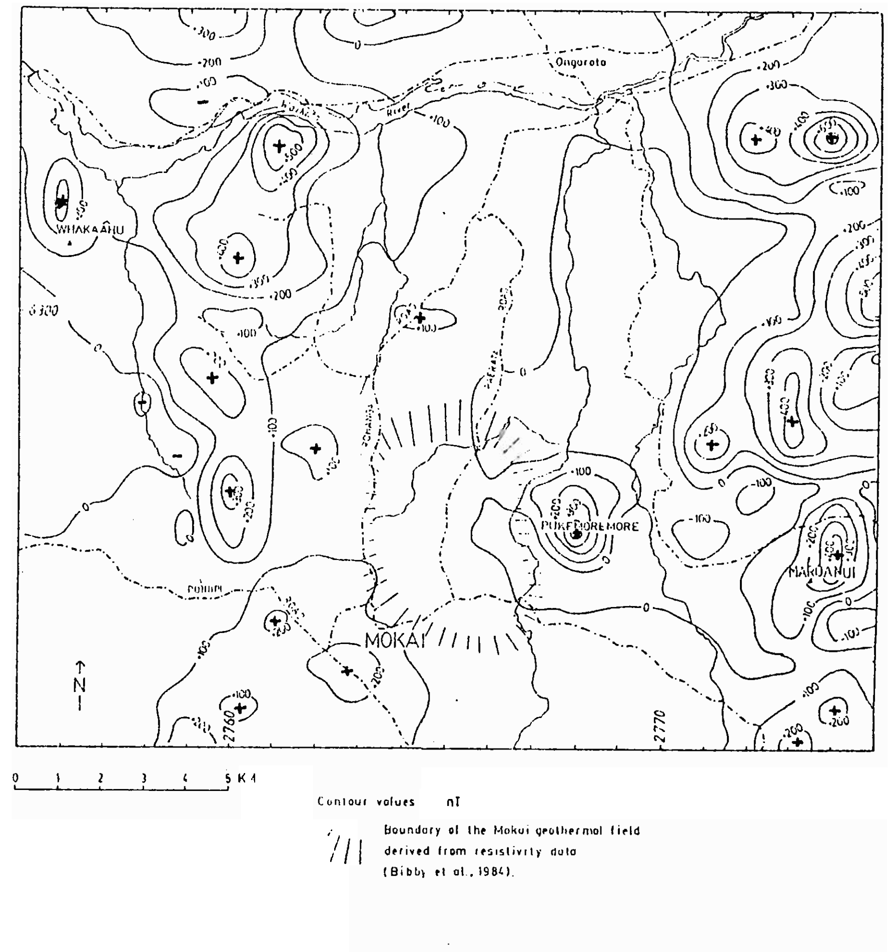
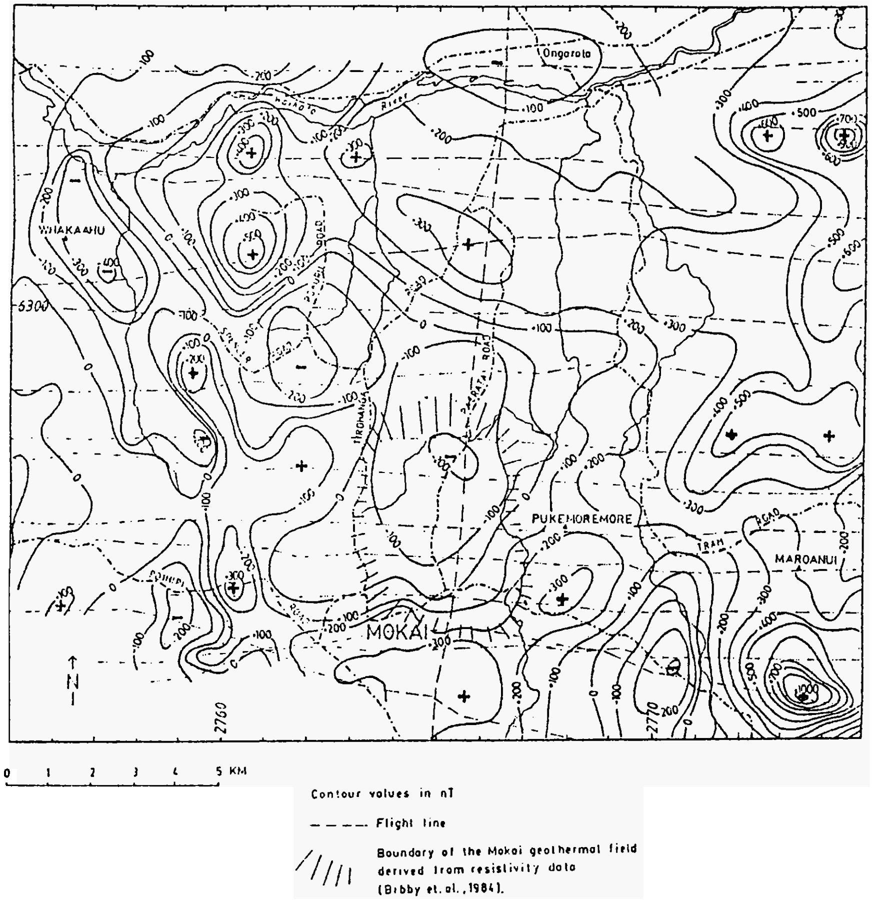


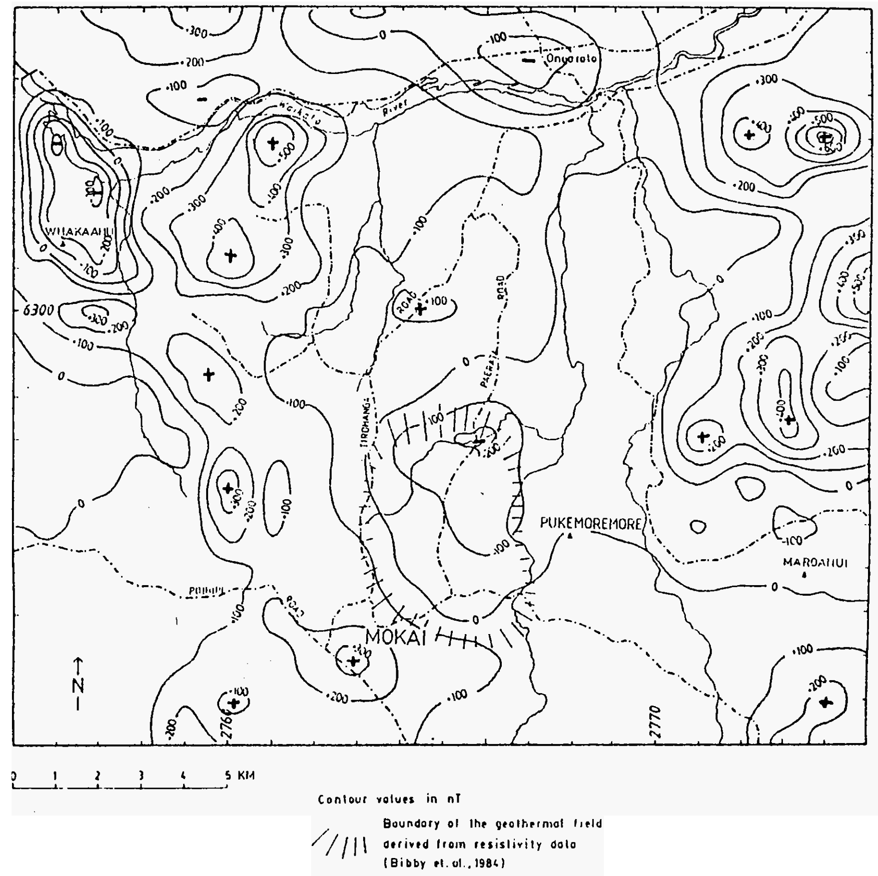
Map 1. Simplified geology of the Mokai area



Map 2 Theoretical (computed) total-force magnetic anomaly showing the effect of topography at 760 m a.s.l.



Map 3 Observed residual total force magnetic anomaly at 760 m a.s.l.



Map 4. Theoretical (computed) total-force magnetic anomaly showing the effects of topography, demagnetized bodies at Mokai, Ongaroto, Pukemoremore and Maroanui and reversely magnetized body at Whakaahu.