RESISTIVITY RECONNAISSANCE SURVEY OF THE KAITOKE VALLEY GEOTHERMAL PROSPECT, GREAT BARRIER ISLAND (NEW ZEALAND)

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ABSTRACT

A small resistivity survey of the Kaitoke Valley geothermal prospect on Great Barrier Island has shown that the thermal springs in this valley are located over a shallow, concealed outflow of thermal water. The source region is still unknown but it is likely that deeper thermal waters ascend to about sealevel in the direct vicinity of the Mt. Hobson Caldera, a recently detected rhyolitic volcanic centre of inferred Pliocene age. No economic reservoir exists directly beneath the thermal springs.

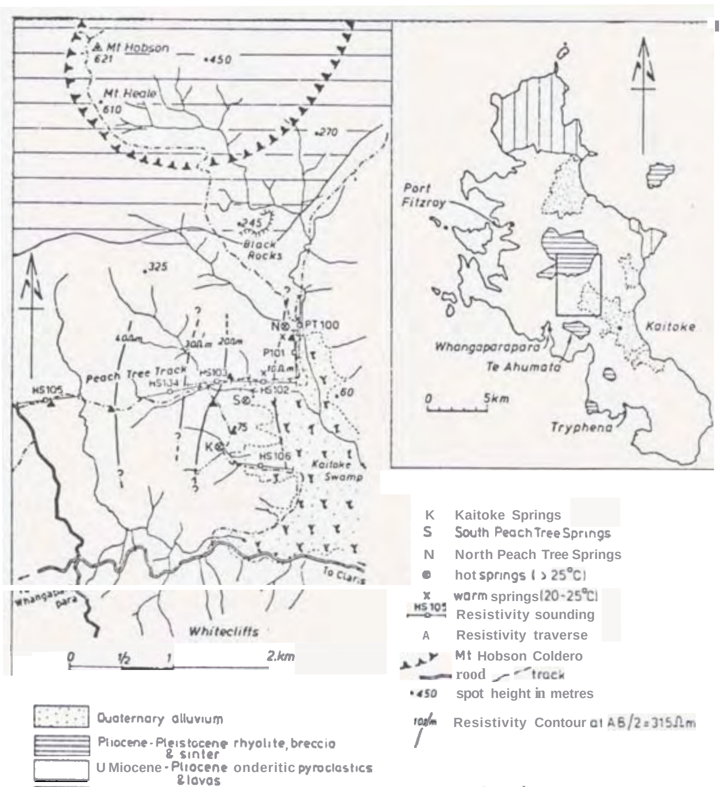

FIG. 1.

INTRODUCTION

Minor hot and warm springs occur in the Kaitoke Valley on Great Barrier Island. The springs are well known and the more prominent ones have been described by Hochstetter **(1867)**, Hutton **(1868)**, Winkelmann **(1886)** and Herbert **(1921)**. A coherent description of all springs can be found in Wilson *et al*, (1973). The springs occur over a distance of about **1.5** km at about the same elevation (**10** to **15** m above sealevel) and discharge neutral NaCl type water along the western boundary of the Kaitoke Swamp (see Fig. 1). The total natural heat loss is small (< **0.3 MW**). The springs appear to be aligned (NNE trending direction); the southernmost springs (Kaitoke Springs, K in Fig. 1) show the highest temperature (≃ **84**°C). The springs exhibit almost constant molecular ratios (Cl/B, Na/K) which indicates that all springs are fed by the same body of shallow, hot water (Wilson *et ai,* **1973**). The chemistry of the thermal springs is indicative for a deep seated hot watgr system with temperatures in excess of 212 C, as given by the Na-K-Ca geothermometer. The overall chemical composition differs not significantly from that of thermal waters discharged over hot water systems in the Taupo Volcanic Zone except that the total solids of the least diluted springs in the Kaitoke Valley are significantly higher (total solids about **12** 9/11) and that the SiO_2 content is rather low (about **150** mg/ℓ). A detailed description of the chemistry of the springs has been given by Wilson *et ai,* **(1973)**.

Fig. 1. Geological map of the Kaitoke Valley geothermal prospect (Great Barrier Island) showing the location of thermal springs and the location of the resistivity survey described in this paper; apparent resistivity contours based on data obtained with a spacing of AB/2 = **315** m are also shown. (The base map for this figure was taken from Wilson *et ai,* **1973**).

Prior to this study not much information was available which could be used to argue for or against the occurrence of a deeper hot water system beneath the Kaitoke Valley. The apparent NNE alignment of the thermal springs can be used to infer that thermal waters ascend vertically along a NNE trending fracture zone, although the apparent alignment can equally be explained by a horizontal flow of hot water originating anywhere in the W, NW, or N sector if these fluids would drain at shallow depths into the Kaitoke Swamp (Wilson *et ai,* 1973). We investigated the resistivity structure of the Kaitoke Valley prospect in 1981/82 as part of a geophysical reconnaissance survey of Great Barrier Island (Henrys, 1982). Our study of the Kaitoke prospect was also motivated by the reasoning that any, albeit indirect, proof for the existence of an economic geothermal reservoir beneath the Kaitoke Valley might affect the development of electric power on the island which lacks other indigeneous energy resources and where at present electricity is being produced by a number of small, expensive diesel generating plants.

RESISTIVITY SURVEY

The Kaitoke Valley geothermal prospect is only accessible by a few tracks, the higher ground is inacessible. This setting limited the extent of the resistivity survey during which a total of 7 soundings with the Schlumberger array (maximum spacing AB/2 = 315 m and 465 m) were made along existing tracks; the survey was augmented by a resistivity traverse (AB/2 = 315 m). The location of the resistivity stations is shown in Fig. 1; the survey was started in November 1980 and completed in March 1981.

Apparent resistivity contours based on data obtained with a spacing of AB/2 = 315 m are shown in Fig. 1. These contours indicate that low resistivity rocks occur dominantly in the axial, N-S trending strip of the Kaitoke Valley although the eastern margin of this structure is still unknown.

The low resistivity structure was further investigated by resistivity soundings which were interpreted using the method described by Ghosh (1971). Examples of two soundings obtained at the southern and northern end of the N-S trending axial resistivity low are shown in Fig.2. Interpretation of these soundings gave clear evidence that low resistivity rocks with true resistivities between 2 to 5Ωm. are confined to a rather thin (15 to 25m) layer within Miocene andesitic pyroclastics and lavas. This low resistivity layer comes to within 10m to the surface near the Kaitoke Hot Springs at the southern end of the prospect (see sounding HS 106 in Fig. 2a) whereas it occurs at about 80m depth in the northern part near the North Peach Tree Hot Springs (see sounding PT 100 in Fig. 2b). The same layer was also found in the central part between 20 to 50m depth beneath stations HS 102 and HS 103. The shallow low resistivity layer extends therefore beneath the axial region of the prospect but disappears between stations HS 103 and HS 104 (see Fig. 1).

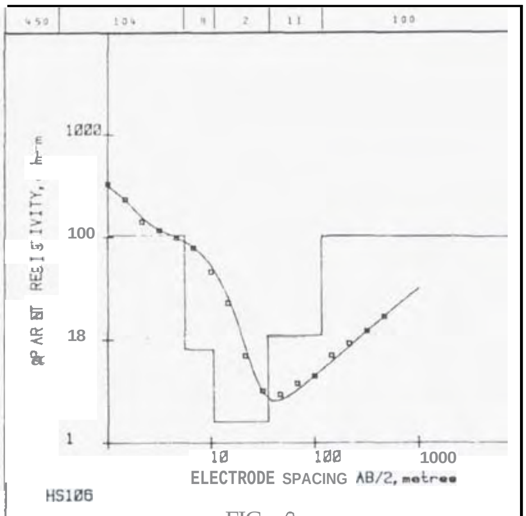

FIG. 2a.

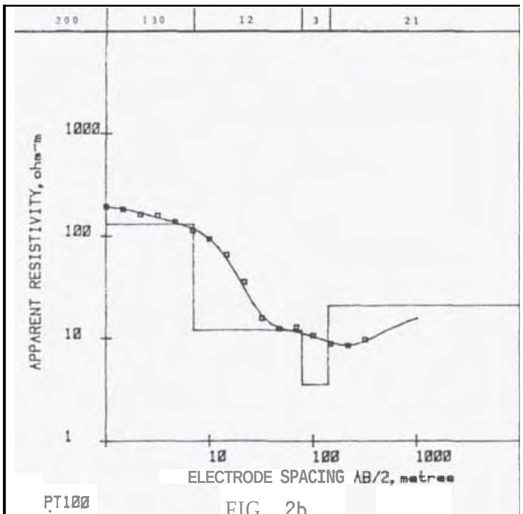

FIG. 2b.

Fig. 2. Resistivity sounding curves from the Kaitoke Valley prospect, Great Barrier Island. The sounding HS 106 (left hand side) was taken south of the Kaitoke Hot Springs, the sounding PT 100 (right hand side) was taken near the North Peach Tree Springs; for locality see Fig. 1. The step function indicates the true resistivity versus depth function.

If one considers the high salinity of the thermal fluids (i.e. ~ 12 g/ℓ) and takes into account the hydrological setting of the prospect, the low resistivity layer can readily be identified with a lateral outflow structure which must be recharged by a body of hot water lying to the north of the North Peach Tree Hot Springs (i.e. N of station PT 100). Such concealed outflows are typical for thermal systems in mountainous terrain. The high temperatures of the Kaitoke Hot Springs can now be explained because the outflow comes nearest to the surface near these springs. The high temperatures (i.e.- 84°C) of some of the Kaitoke Hot Springs also indicate that the outflow structure is thermally well insulated; it is, therefore, possible that a significant amount of hot water is discharged in the Kaitoke Swamp.

GEOLOGICAL STRUCTURE OF THE PROSPECT

Although the source area of the hot water could not be delineated by the resistivity survey, a recently completed geophysical reconnaissance study of Great Barrier Island (Henrys, 1982) has provided some important information about the overall geological setting of the Great Barrier Island thermal system. Interpretation of gravity anomalies, for example, indicates that in the prospect area a thick (1 to 1.5 km) sequence of easterly dipping andesitic flows and pyroclastics (Coromandel Group Volcanics) of Miocene age unconformably overly greywacke basement rocks which outcrop about 5 km to the NE (see insert in Fig. 1). Glassy rhyolites of Pliocene age (Whitianga Group Volcanics of Thompson, 1960) cover Coromandel Group Volcanics around Mt. Hobson. The gravity data also show that the rhyolitic volcanics to the east of Mt. Hobson are confined to a deep seated volcanic centre (about 2.5 km. deep) which is most likely a collapsed caldera. The southern boundary of the Mt. Hobson Caldera, which can also be recognised in LANDSAT images, is shown in Fig. 1. Remnants of rhyolitic pyroclastic flows of similar age occur in other parts of the island; nearest to the prospect area are the pyroclastics at Mt. Te Ahumata for which a radiometric age of 4.6 x 10^6 yr has been cited (Leach *et al*, 1981). It has been inferred that these pyroclastics formed originally a much wider, coherent cover which has been eroded and that the widespread rhyolitic pyroclastics originated from the Mt. Hobson Caldera which subsequently was filled by glassy rhyolites (Henrys, 1982). No convincing evidence for younger volcanism has been found yet.

DISCUSSION

The small resistivity reconnaissance survey of the Kaitoke Valley geothermal prospect on Great Barrier Island has shown that the thermal waters discharged by a number of small springs are derived from a shallow, almost horizontal concealed outflow of hot water. These fluids move laterally into the upper reaches of the Kaitoke Valley from a yet unknown source lying further north in the direction towards the Mt. Hobson Caldera. It is possible that the source is associated with the caldera, a rhyolitic volcanic centre of Pliocene age.

Since there is no clear evidence that younger (i.e. < 4 x 10^6 yr) volcanism has occurred near the prospect, it is unlikely that the heat source for the Kaitoke Valley prospect can be associated with a younger cooling pluton of, say, late Pliocene age, beneath the Mt. Hobson Caldera. Model studies by Norton and Knight (1977), for example, have shown that most of the anomalous heat of such an intrusion (with a cross-sectional area similar to that of the Mt. Hobson Caldera) would have been dissipitated by convective heat transfer during a period of less than 0.5 x 10^6 year.

It is, however, possible that high temperatures of about 200 C could occur near the bottom of the Mt. Hobson Caldera (i.e. at 2.5 km. depth) if an anomalously high temperature gradient about 70 to 100°C/km exists beneath the island. Anomously high temperatures have indeed been observed in many shallow wells in the Northland Area and in the Coromandel Region and are probably caused by an anomalous terrestrial heat flux resulting from high standing, hot upper mantle rocks (Hochstein, 1978). High temperatures have also been observed on Great Barrier Island further away from the prospect, for example, at Tryphena where a temperature of 34.5°C was observed at the bottom of a 207 m hole (refer to Wilson *et al*, 1973). Since it is likely that the permeability and porosity of rhyolites at the bottom of the Mt. Hobson Caldera are greater than those at the same level in the greywacke basement rocks, it is possible that a convective transfer cell can establish itself in the bottom part of the caldera and that some fluids reach the surface by ascending along ring fractures near the southern caldera rim from where they could flow laterally into the Kaitoke Valley. The chemistry of the fluids would then be caused by leaching of the rhyolites at the bottom of the caldera.

The studies summarized in this paper indicate that an economic (i.e. economically exploitable) reservoir of hot water does not exist beneath the thermal springs in the Kaitoke Valley. Such a reservoir might occur in the bottom portion of the Mt. Hobson Caldera which unfortunately lies at great depths.

ACKNOWLEDGMENT

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