Rotokawa Geology and Geophysics

A Rae

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EXECUTIVE SUMMARY

This report on the Rotokawa Geothermal Field summarises the:

- geological setting;
- stratigraphy and fault structure;
- hydrothermal alteration;
- geophysical structure;
- permeability.

The following conceptual (hydrogeological) model of the geothermal reservoir, which is based on a review of previous deep drilling and numerous geoscientific studies in the area, supports a Resource Consent Application by Rotokawa Joint Venture Ltd for expansion of electric power generation at Rotokawa.

The Rotokawa Geothermal Field is located about 10 km north-east of Taupo Township in the eastern part of the Taupo Volcanic Zone (TVZ). The field extends over an area of ~17 to 28 km^2, and is comparable in size to other successfully exploited New Zealand geothermal fields (such as Mokai, 18 to 26 km^2).

The surface geology at Rotokawa is dominated by rhyolite domes, pumice alluvium, Wairakei breccia and hydrothermal eruption breccias. Structural lineaments within the thermal area are defined by the NE-alignment of hydrothermal eruption vents (including Lake Rotokawa). Acid sulphate-style surface alteration occurs on the northern shore of the lake, and includes native sulphur, kaolinite, smectite, silica residue, alunite and other sulphates, cinnabar and arsenic precipitates. At least 2.6 Mt of native sulphur has accumulated in the upper 20 m beneath and adjacent to the lake. Areas of extinct neutral chloride-style surface alteration (silicification and silica sinter float) occur along both banks of the Waikato River.

The volcano-stratigraphy at Rotokawa is summarised in Figure 2. The greywacke basement has been intersected by only two Rotokawa geothermal wells (RK4, RK16). A 870 m elevation difference between the two wells, and absence of greywacke in other deep wells, confirms the basement surface is deeper to the northwest, as a result of NE-SW block faulting. Directly overlying the basement is Rotokawa Andesite, a thick (2,100 m) sequence of flow-banded, porphyritic andesite lava. Above the Rotokawa Andesite, the volcano-sedimentary sequence consists of Reporoa Group (Tahorakuri Formation, Waikora Formation), Wairakei Ignimbrite, rhyolite lavas and domes, Waiora Formation and Huka Falls Formation, and hydrothermal eruption breccias of the Parariki Breccia. Drilling of RK17 defined a normal fault that has downthrown Rotokawa Andesite to the south-southeast by >690 m.

Evidence from drilling confirms the Rotokawa Geothermal Field is situated above a NE-SW trending structural trough, or graben, which has block faulted the greywacke basement and Rotokawa Andesite. The trough has subsequently been infilled by Reporoa Group sediments and Wairakei Ignimbrite. Faulting of the post-Wairakei Ignimbrite strata has not been recognised, and elevation differences at the base of the Wairakei Ignimbrite suggest only minor reactivation, if any, of the deep graben faults.

Extensive acid alteration, caused by interaction with steam heated acid sulphate waters, is largely restricted to shallow levels (<200 m drilled depth), although sporadic zones of acid alteration active now and/or in the past also occur at greater depth (to 590 m in RK14, and 1600 m in RK16). These deep zones are well documented and indicate sulphate-rich and CO_2-rich acid waters have permeated to depth from shallow aquifers. Beneath the zone of acid alteration, a propylitic-style hydrothermal mineral assemblage (of quartz, wairakite, epidote, clinozoisite, illite, chlorite, adularia, albite and calcite) indicates deposition from near neutral pH, chloride waters. Intensity and style of hydrothermal alteration indicate fracture controlled permeability at depth. Measured well temperatures, and the propylitic-style alteration mineral assemblage, indicates either relatively low permeabilities at depth, and/or a young geothermal system that has yet to equilibrate with prevailing (high) subsurface temperatures.

Median porosities of ~10% in the rhyolite, ignimbrite, andesite and sediments at Rotokawa are typical of TVZ geothermal systems. Higher porosities (~25%) are found in shallow and deep aquifers. In the deep reservoir at Rotokawa, faulting is the predominant control on fluid flow through the greywacke basement and Rotokawa Andesite. In the southwest, the fault intersected by RK17 influences the shape of the deep isotherms, suggesting the fault is a major conduit for upflow and defines the western geothermal reservoir boundary. At shallow depths, primary permeability dominates in the Waiora Formation, rhyolite lavas and breccias. Horizontal permeability in the rhyolite lava provides access for cool water inflows from the west, north and south.

Best estimates of total natural heat loss from Rotokawa thermal features range between ~210 MW_t and 240 MW_t. Modelling of apparent resistivity (Schlumberger traversing, soundings, and bipole-dipole array) data from Rotokawa is consistent with a geothermal system dominated by fracture permeability at depth. The surveys reveal a shallow low resistivity anomaly, defining an area of ~17 to 28 km^2. A low resistivity layer (1-3 Ωm) at shallow depths (250-400 m below surface) represents porous aquifers and intense hydrothermal clay alteration at the top of the geothermal system (<200° C). Beneath the shallow layer, a resistivity of ~20 Ωm represents a transition to higher temperature alteration clays (>200° C) such as illite and chlorite. The resistivity increases at deeper levels (>1.2 km) to ~35 Ωm, as porosity reduces and the intensity of alteration in the andesite decreases.

Data gained from numerous geophysical and chemical surveys at Rotokawa, and detailed geoscientific investigations associated with past deep drilling, has provided a sound understanding of the geology and structure of the Rotokawa geothermal system, and reliable information upon which to base future resource development.

INTRODUCTION

Geoscientific information from the Rotokawa geothermal field (Figure 1), namely geological setting, stratigraphy, hydrothermal alteration, structure, geophysics and permeability, is summarised and discussed in relation to the conceptual model for the geothermal reservoir. The sixteen geothermal wells drilled at Rotokawa have provided a sound understanding of the sub-surface geology, structure, hydrothermal alteration and permeability of the geothermal field. This discussion has implications for any geothermal development, with respect to reservoir permeability, resource size and sustainability, and any observed hydrological changes resulting from a decade of steam production from the Rotokawa field.

SURFACE GEOLOGY

The surface geology at Rotokawa has been described by Grindley et al. (1985). The northern margin of the geothermal system is dominated by the twin rhyolite domes of Oruahineawe and Kaimanawa (Figure 1). These domes are surrounded by fragmental pumice breccias that formed during dome emplacement. To the east, Rolles Peak is a volcano remnant of andesite (710,000 years old). To the west, rhyolite lavas are exposed at the Aratiatia Dam and in the bed of the Waikato River at Aratiatia Rapids. Alluvium derived from products of the Taupo eruption (181 AD Taupo Pumice) form a low river terrace near the Waikato River, while 26,500 year old Wairakei breccia (Oruanui ignimbrite) is exposed between the river and Lake Rotokawa. In the immediate vicinity of the lake, successive hydrothermal eruption breccias dominate surface cover.

Aerial photographs reveal structural lineaments to be common within the thermal area, particularly in the alignment of hydrothermal eruption vents (Collar and Browne, 1985). The craters of the large hydrothermal eruptions are oriented along a north-easterly trend, suggesting a structural control. Surface expressions of the northeast-trending faults of the Aratiatia Fault zone are to the north and north-west (Figure 1).

The evidence for late Quaternary hydrothermal eruption activity includes Lake Rotokawa itself and many smaller craters and eruption deposits. At least 25 small (10-30 m diameter) explosion craters have formed in an area north of the lake since deposition of the 1800 year old Taupo Pumice. In addition to these, there have been at least eight large hydrothermal eruptions in the last 20,000 years, the most recent being about 3,700 years ago. They formed craters with diameters up to several hundred metres. Blocks of up to 2 m in diameter were erupted from depths as great as 450 m (Collar and Browne, 1985). These deposits, known collectively as the Parariki breccia, partially cover an area up to 15 km^2 in the southern part of the field, with individual deposits of up to 11 m in thickness.

Extensive areas of hydrothermally altered ground occur adjacent to the northern shore of the lake alongside acid sulphate-chloride springs. The acid sulphate-style of surface alteration includes native sulphur, kaolinite, smectite, silica residue, alunite and other sulphates, cinnabar and arsenic precipitates. Large deposits of native sulphur have accumulated, at least 2.6 million tonnes in the upper 20 m in an area underneath and adjacent to the lake.

Areas of extinct neutral chloride-style surface alteration, including silicification and silica sinter float, occur along both banks of the Waikato River. In addition, extinct acid-sulphate alteration occurs northwest of RK6. Alteration associated with a NE trending linear zone of steaming ground is found west of RK8.

Clasts in the hydrothermal eruption breccias commonly exhibit pre-eruption alteration states, with both acid sulphate and neutral pH mineral assemblages present. The neutral pH assemblage is overprinted in some clasts by acid sulphate minerals, suggesting a progressive change from neutral to acid conditions at the depth of origin. This change in the depth extent of acid fluids may be related to a period when changes occurred in the local shallow hydrology. Based on the evidence of fossil sinters, some neutral-pH chloride waters once discharged from vents in the Lake Rotokawa vicinity.

SUBSURFACE GEOLOGY

Stratigraphy

Rotokawa is located near the south-eastern boundary of the Taupo Volcanic Zone (TVZ) where deep basement structure is dominated by regionally-extensive northeast-trending, normal fault systems. Post-basement, volcano-stratigraphic sequences for the Rotokawa geothermal field are summarised in Table 1 and, along with isotherms, illustrated by schematic cross-sections A-A' and B-B' (Figure 2). The following description has been summarised from Bromley et al. (2002) and geological reports from the Rotokawa wells drilled since (Rosenberg and Kilgour, 2003; 2005; Rosenberg et al., 2005).

Greywacke basement has been intersected in only two Rotokawa geothermal wells, at -1850 mRL in RK4 and -2720 mRL in RK16. This 870 m elevation difference and the absence of greywacke in five other deep wells (RK5, TD: -2461 mRL; RK6, TD: -2109 mRL; RK8, TD: -2288 mRL; RK13, TD: -2135 mRL; RK14, TD: -2114 mRL), confirms that the basement surface becomes increasingly deeper to the northwest. This is probably a result of block faulting by a series of NE-SW striking normal faults.

Directly overlying greywacke basement is the Rotokawa Andesite lava, a dark grey to green, variably massive or slightly flow banded porphyritic lava with phenocrysts of plagioclase feldspar and two pyroxenes. The formation is very thick, up to 2,100 m has been intersected in RK16, and likely consists of a series of multiple lava flows.

Situated above the Rotokawa Andesite is a volcano-sedimentary sequence variably consisting of the Reporoa Group, Wairakei Ignimbrite, rhyolite lavas and domes, Waiora Formation and Huka Falls Formation. The Reporoa Group (Gravely et al., 2006) consists of the Tahorakuri Formation, a crystal-lithic vitric tuff, or ignimbrite, of variable thickness (up to 250 m thick) and the Waikora Formation a greywacke sandstone and argillite siltstone pebble conglomerate (up to 250 m thick). The Reporoa Group is absent in RK4, and Tahorakuri Formation is absent in wells RK14, and RK9.

The Wairakei Ignimbrite, a member of the Whakamaru group of ignimbrites, is a welded crystal-rich, pumice vitric tuff with characteristic corroded and embayed quartz crystals. It has uniform thickness, ranging between 200-390 m thick, and relatively low vertical permeability.

Above the Wairakei Ignimbrite is the Waiora Formation, a mixture of pumice, lithic, crystal tuffs, ashes and breccias that occur between 290 mRL and -810 mRL. Haparangi rhyolite lavas, domes and breccias occur within the Waiora Formation (Figure 2), and those intersected at shallow levels, between 400 m and -400 mRL, in northern and western wells (RK6, RK8, RK16-18) are possibly related to the Oruahineawe-Kaimanawa dome complex. Wells drilled in the central and southern part of the field (i.e., the vicinity of RK5, RK9 and RK2-4) intersected older and deeper rhyolites, between -100 m and ~-600 mRL. The Waiora Formation and the rhyolitic lavas and breccias have high permeability and host the shallow high temperature aquifers situated at the Waiora Formation/rhyolite contact that were intersected by such wells as RK5, RK6, RK11, RK13 and RK16 (Figure 2).

At shallowest levels, the volcanosedimentary strata are capped by finely laminated mudstones, siltstones and sandstones of the Huka Falls Formation. On the southern side of the Waikato River, these are intercalated with the highly variable hydrothermal eruption breccias of the Parariki Breccia.

Most recent drilling of wells RK16 and RK18, in the southwestern part of the reservoir (Figure 1), have revealed the deepest post-Rotokawa Andesite lithologies (i.e., Wairakei Ignimbrite, Reporoa Group) to be missing from the stratigraphic sequence, as well as significant elevation differences of the Rotokawa Andesite between the west and central regions of the field (Figure 2, B-B'). Drilling of RK17 clearly defined a normal fault that has downthrown the Rotokawa Andesite to the south-southeast by more than 690 m (Rosenberg et al., 2005). This fault is part of a graben structure that has been in-filled by Reporoa Group sediments and the Wairakei Ignimbrite, confining these lithologies to the central and eastern regions of the system (Figure 2, B-B').

Table 1 Generalised stratigraphy of Rotokawa geothermal field.

Formation Name	Thickness Range	Lithology
SUPERFICIAL (incl. Oruanui Formation)	10 to 30 m	Unaltered and thermally oxidised pumice tuff, rhyolite lava lithic clasts and unaltered quartz and feldspar crystals
HUKA FALLS FORMATION	15 to 150 m	Fine sandstone and siltstone with some pumice-rich subunits.
PARARIKI BRECCIA	20 to 220 m	Strongly altered, quartz-feldspar rich tuffaceous breccia with a silty-clay matrix
WAIORA FORMATION	90 to 550 m	Crystal-rich, hornblende bearing vitric tuff
RHYOLITE LAVA AND BRECCIA	110 to 660 m	Crystal-poor, rhyolite lava and breccia
WAIRAKEI IGNIMBRITE	200 to 390 m	White, crystal-rich, non to densely welded ignimbrite. Large quartz crystals are often heavily embayed
WAIKORA FORMATION	10 to 250 m	Rounded to sub-rounded greywacke and argillite gravels.
TAHORAKURI FORMATION	20 to 250 m	White, crystal-vitric-lithic tuff
ROTOKAWA ANDESITE	865 to 2190 m	Mottled, pale green and reddish purple, pyroxene-bearing andesite lava.
GREYWACKE BASEMENT	-	Dark to pale grey, weakly metamorphosed argillite and fine silty sandstone

Structure

Evidence from drilling confirms that the Rotokawa geothermal field is situated above a NE-SW trending structural trough, or graben, that has block faulted the greywacke basement and Rotokawa Andesite lava (Figure 3). The trough has subsequently been infilled by Reporoa Group sediments and Wairakei Ignimbrite (Figure 2, B-B').

A normal block fault-controlled graben structure that affects the basement and pre-Wairakei Ignimbrite sediments at Rotokawa is well documented in published papers (Grindley et al., 1985; Krupp and Seward, 1987) and un-published GNS Science geological well reports (e.g., Rosenberg and Kilgour, 2003; 2005; Rosenberg et al., 2005). However direct evidence for normal-faulting has only come from wells drilled in the western part of the field (RK16-18). These wells showed that the Rotokawa Andesite is approximately 450 m shallower than in RK4. The shallow stratigraphy of RK17 is similar to RK16 and RK18, but at -1057 mRL RK17 drilled out of Rotokawa Andesite into Reporoa Group sediments and then back into Rotokawa Andesite at -1228 mRL. This sequence is best explained by the path of RK17 intersecting a normal fault and drilling from upthrown into downthrown blocks (Figure 2, B-B'; Rosenberg et al., 2005).

Faulting of the post-Wairakei Ignimbrite strata has not been recognised and elevation differences at the base of the Wairakei Ignimbrite, which are within 50 m of each other (Rosenberg et al., 2005), suggests that there has been only minor reactivation, if any, of the deep graben faults. Lineations of the Aratiatia Fault zone have been mapped at surface to the north of the field (Figure 3), but with the exception of hydothermal eruption crater alignment (Collar and Browne, 1985), there are no surface fault traces in the centre of the field that might correlate with the deep graben structures.

HYDROTHERMAL ALTERATION

The extensive surface acid alteration in the vicinity of Lake Rotokawa, caused by interaction with steam heated acid sulphate waters, is largely restricted to the shallow stratigraphy in nearby wells (i.e., <200 m depth). Deeper acid alteration zones either active presently or in the past occur at greater depths, with anhydrite as deep as 535 m (RK4), alunite between 480-590 m depth (RK14) and sporadic occurrences of kaolinite to 1600 m (RK16) and 470 m (RK9). These deep zones indicate that sulphate-rich and CO_2-rich acid waters have permeated to depth from shallow aquifers and are thought to have been responsible for casing failures in RK2, RK4 and RK9. The acid zones are well documented and future well-siting and design can take into account their location.

Beneath the zone of acid alteration, a propylitic hydrothermal mineral assemblage that can include mordenite, wairakite, epidote, clinozoisite, quartz, illite, chlorite, adularia, albite and calcite, indicates deposition from near neutral pH, chloride waters. Deep core samples and cuttings from Rotokawa wells seldom display intense hydrothermal alteration, which reflects the relatively low permeability in many of the units. The style of alteration, particularly in the deep andesites, indicates that much of the permeability is fracture controlled.

The temperatures indicated by the propylitic alteration mineral assemblages are commonly lower than measured temperatures. This may be a result of the relatively low permeabilities and/or a relatively young geothermal system with an alteration assemblage that has not yet equilibrated to higher prevailing temperatures. This can be inferred by the lack of high temperature alteration minerals (e.g., actinolite-tremolite which forms >300° C) in intervals in excess of 300° C. Clay mineralogy and fluid inclusion studies of samples from RK4 and RK5 suggest that the southern part of the Rotokawa geothermal system has heated up by 30° to 60° C. Some fluid inclusions show evidence of crystals that formed during an early phase of cooler temperature fluids, then becoming intergrown with crystals whose inclusions are close to present temperatures (Hedenquist et al., 1988).

POROSITY

Effective porosities and permeabilities of rock formations are important variables used to formulate and calibrate hydrological and mathematical models of the geothermal reservoir. Measured porosities of core samples from Rotokawa range from 5% to 33%. A median value of about 10% applies to the rhyolites, ignimbrites, andesites and sediments, which is typical of TVZ geothermal systems hosted by such rocks. The greywacke basement generally has a low matrix porosity (<5%). However, much higher porosities (~25%) are found in the shallow (Waiora Formation tuff breccias) and deep aquifers (Rotokawa andesite tuffs and breccias).

PERMEABILITY

Permeability within the reservoir is essentially controlled by three factors:

1) distribution of primary permeable zones that are related to the texture and mode of formation of the geological unit (e.g., low permeability mudstones or high permeability breccias);

2) distribution of secondary permeable zones that are related to brittle faulting and fractures generated by earthquakes, thermal stresses and/or regional strain;

3) distribution of secondary permeable zones that are related to effects of prolonged hydrothermal alteration causing either dissolution of fluid pathways and/or mineral deposition.

At Rotokawa primary permeability and that related to fault structures are the most dominant in controlling fluid flow. In the deep reservoir, faulting appears to be the predominant control on fluid flow through the greywacke basement and Rotokawa andesite lavas (Figure 2). Primary permeability in the Rotokawa Andesite is also likely to be important for providing vertical and horizontal fluid flow along lava flow interfaces, breccias and cooling joints. To the southwest of the reservoir, the fault intersected by RK17 appears to influence the shape of the deeper isotherms, in particular the 330° C isotherm (Figure 2), suggesting that this fault is a major conduit for an upflow zone and possibly defines the western boundary to the geothermal reservoir (Figure 2).

At shallow depths, the Waiora Formation and the rhyolite lavas and breccias influence vertical and horizontal permeability. Hot water aquifers at the boundary between the Waiora

Formation and the rhyolite lava have been intersected by wells RK5, RK6, RK11, RK13 and RK16 (Figure 2). Horizontal permeability in the rhyolite lava also provides access for cool water inflows from the west, north and south, affecting the shallow temperature inversions present in RK16-18, RK6, RK8, RK5 and RK14 (Figure 2).

GEOPHYSICS

Resistivity

Electrical resistivity surveys at Rotokawa, using a variety of methods (Schlumberger traversing, soundings, and bipole-dipole array) reveal a shallow low resistivity anomaly that is enclosed by a boundary transition zone (Figure 1), implying a field area of between about 17 and 28 km^2 (Risk, 2000). Modelling of the measured apparent resistivity data shows a typical resistivity structure for a TVZ geothermal system, which is dominated by a very low resistivity layer (1 to 3 Ωm) at shallow depths (between 250 m and 400 m below surface). This represents the top of the geothermal system, consisting of hot fluids (<200° C), porous aquifers, and intense hydrothermal clay alteration (kaolinite, smectite). Below this shallow low-resistivity layer, the resistivity increases to about 20 Ωm. This represents a transition to higher temperature alteration clays (>200° C) such as illite and chlorite. At even deeper levels (>1.2 km), porosity reduces further and the intensity of alteration in the andesite decreases. The resistivity increases accordingly to about 35 Ωm, despite the presence of very high-temperature chloride fluids. This supports the model of the system being dominated by fracture permeability at depth.

The background resistivity structure that surrounds the Rotokawa anomaly consists of different cold formations with values ranging between about 35 Ωm and 250 Ωm. These variations are caused by large changes in clay content and porosity; relatively young unaltered rhyolites to the northwest have higher resistivities, while clay-rich mudstones and weathered tuffs have lower resistivities. The width of the boundary zone reflects both the width of the transition zone between hot and cold conditions in the upper 1 km, and some uncertainty of the interpretation, taking into account measurement density.

Within this overall model, there are local variations in resistivity observed in soundings and traversing data (Risk, 2000). Along the Parariki Stream, northeast of Lake Rotokawa, there is a ‘corridor’ of relatively low apparent resistivity consistent with the presence of intense acid alteration in the upper 200 m from near-surface acid condensate waters.

Heat loss assessments

The best estimates of total natural heat loss from Rotokawa thermal features range between about 210 MW and 240 MW thermal (Fisher, 1965; Lynne, 1983). These are subject to considerable uncertainty however, because of large natural variability in the factors that affect natural discharge of heat. An attempt to measure the heat flow into the Waikato River shows that the net heat flow and chloride flux were insufficient to be adequately determined (Bromley and Graham, 1997). A best estimate of 2 MW (thermal) has been deduced (Khabar et al, 1986; Fisher, 1965).

One of the biggest uncertainties in calculating the total natural heat loss from Rotokawa is the evaporative loss from the surface of the lake. Lynne (1983) calculated the heat loss from Lake Rotokawa surface to be 68 MW (thermal).

The area of the lake is 62 hectares and its catchment 862 ha (Forsyth, 1977). Using an average annual rainfall of 1 m/yr, then the contribution of rainfall to the lake amounts to 20 l/s. Numerous cold water springs on the edge of the lake are fed by groundwater from the surrounding catchment. Assuming net infiltration rates of 5% these could amount to about 70 l/s. Most of this surface water input is lost, however, through evaporation. Evaporation rates vary with air velocity, surface temperature and humidity. Based on a semi-empirical formula given in Dawson (1964) and using an average wind speed of 2.8 m/s at Lake Rotokawa, the rate of additional evaporation in summer, when surface temperatures are about 4° C above normal (relative to cold water lakes), is about 55 kg/s or 135 MW (thermal). During winter the surface temperature is only about 0.5° C above normal, hence relative evaporative losses are much lower (4 kg/s, 10 MW). Taking a mean of these summer and winter values results in an estimated average anomalous heat loss from the surface of Lake Rotokawa of about 70 MW thermal, which is similar to Lynne's 1983 value.

CONCLUSION

The areal extent of the Rotokawa geothermal field is of comparable size to other successfully exploited New Zealand geothermal fields. A sound understanding of the geology and structure of the geothermal field shows that the geothermal field is situated above a NE-SW trending structural basement trough that is infilled and overlain by volcaniclastic sedimentary rocks that are typical to many Taupo Volcanic Zone geothermal fields. The rank and styles of hydrothermal alteration imply that permeability in the deep reservoir is largely fracture controlled with faulting being the dominant control of fluid flow pathways in the greywacke basement and overlying andesite. At shallow levels however, formation permeability in the Waiora Formation and rhyolite lavas and breccias, is a major control on aquifer location.

The detailed scientific data gained from numerous geophysical and chemical surveys and intensive geoscientific investigations of material from past geothermal drilling has provided a sound understanding of the geology, structure, alteration and hydrology of the Rotokawa geothermal system. This has provided reliable and sound information for which to base any future resource development.

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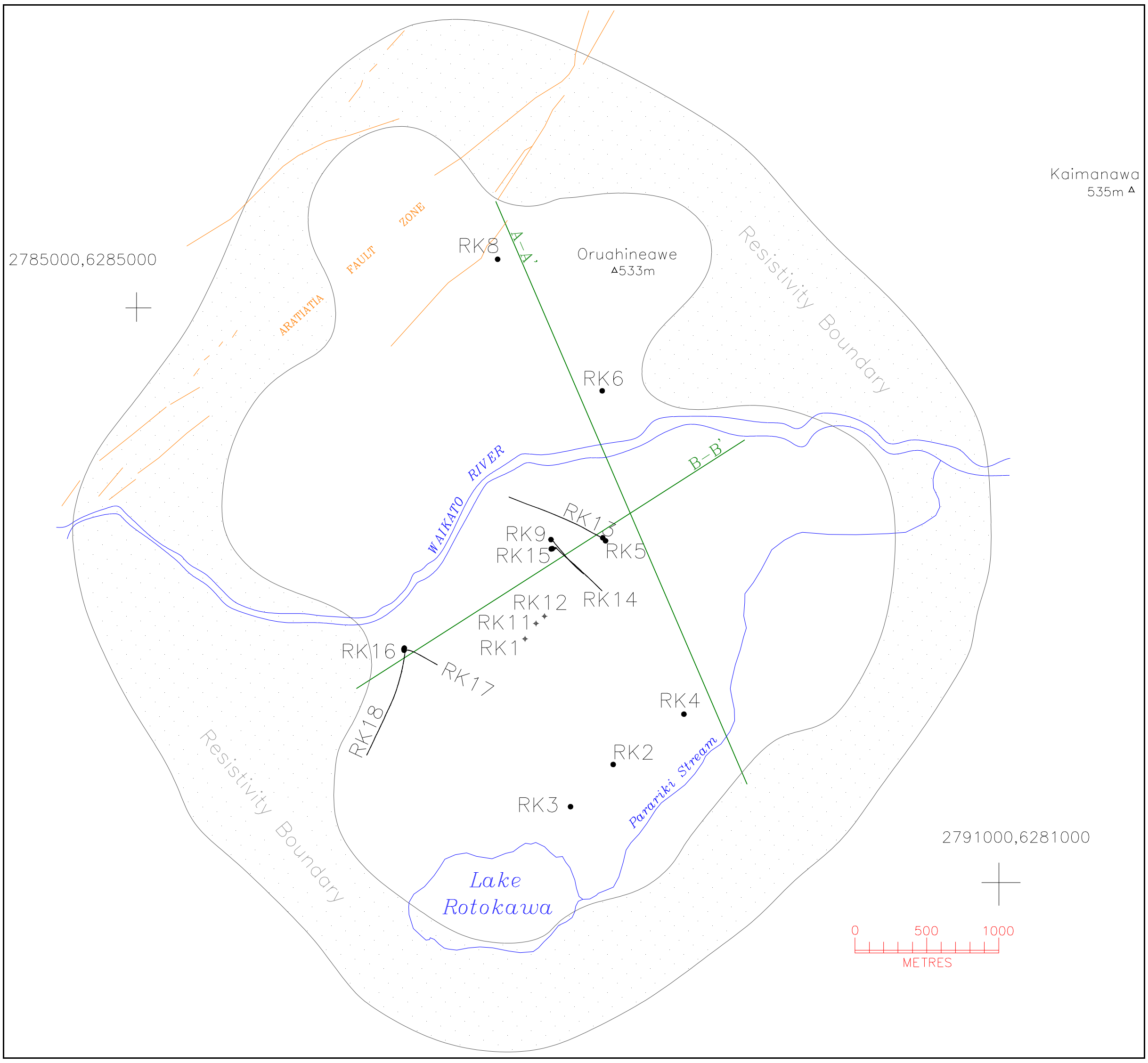

Figure 1 Rotokawa geothermal field showing well locations, the surface expressions of NE-SW-striking faults in the Aratiatia Fault zone, lines of cross section for A-A' and B-B' (Figure 2). The hatched resistivity boundary zone is from Risk (2000)

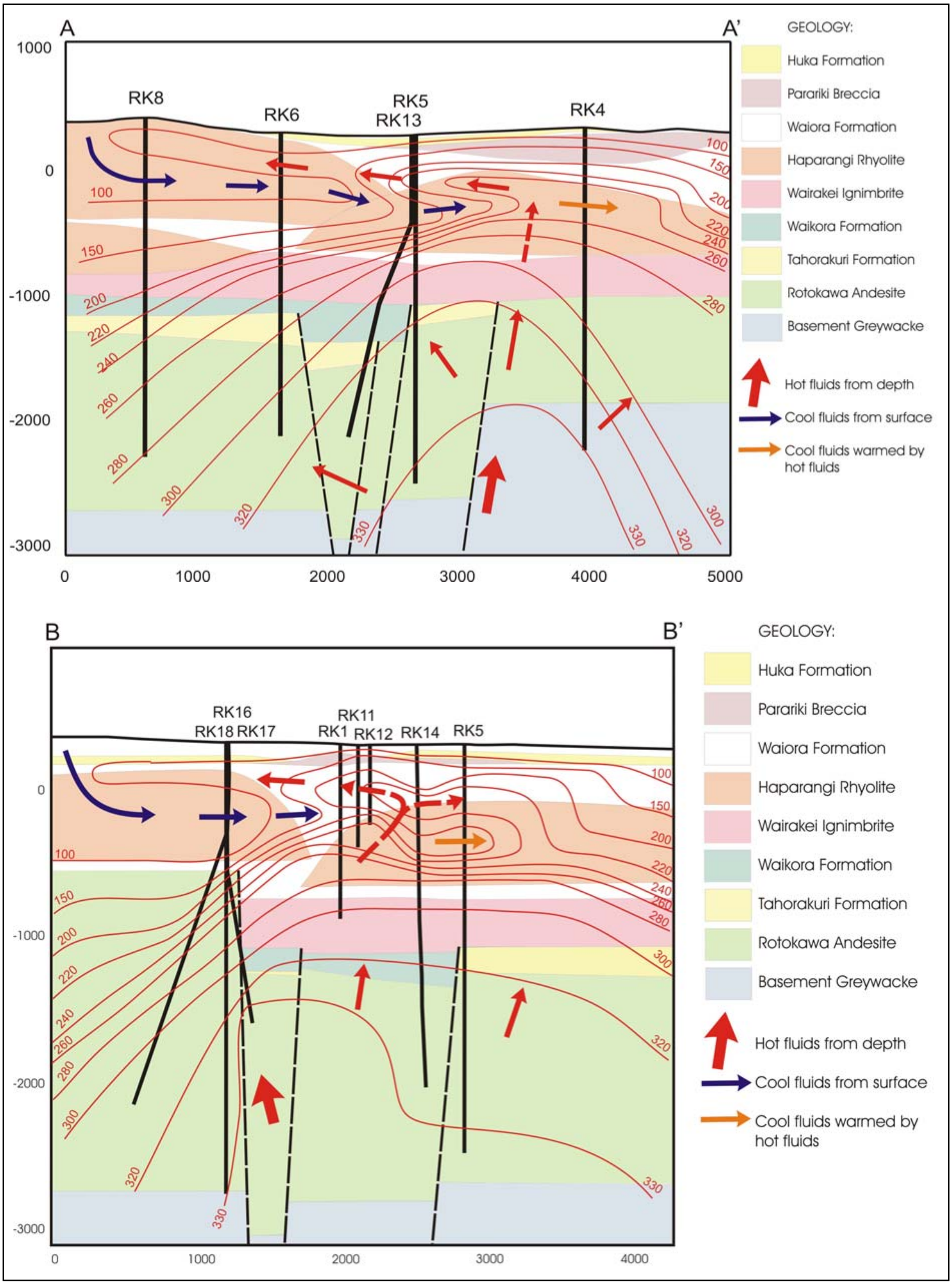

Figure 2 NW-SE (A-A') and SW-NE (B-B') cross-sections through the Rotokawa geothermal field illustrate the known stratigraphy, inferred fault locations, isotherms and hydrology.

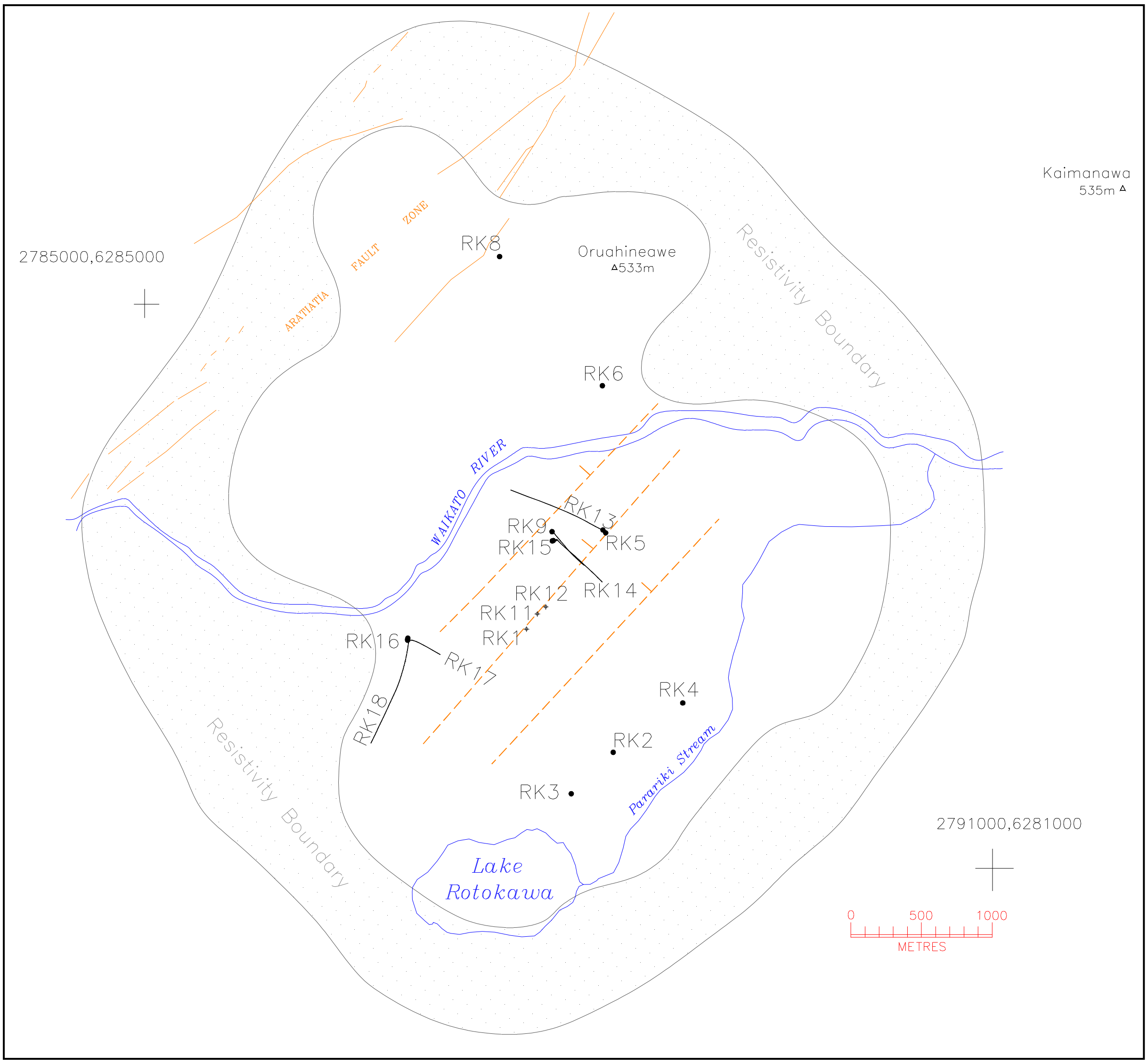

Figure 3 Map of the Rotokawa geothermal field showing the deep normal faults, projected to surface (dashed orange lines), and the location of a graben or structural trough that has been infilled by Reporoa Group sediments and Wairakei Ignimbrite. The hatched resistivity boundary zone is from Risk (2000).

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