DEEP EXPLORATION OF THE OHAAKI GEOTHERMAL FIELD

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ABSTRACT

The Ohaaki geothermal field is typical of those in the Taupo Volcanic Zone in New Zealand, having high permeability and relatively high temperatures at shallow depths. The wells drilled at Ohaaki from the mid 1960's to the mid 1980's, produced 240-280°C geothermal fluid from volcanic-derived formations between 400 and 1000 m depth. Production-induced pressure drawdown since the Ohaaki Power Station was commissioned in 1988 has resulted in an influx of cool water into the shallowest production zones, and decline in steam production. In 1995 three exploration wells were drilled to investigate the production potential of the greywacke sediments that were known to be present below the volcanic formations. Permeable zones were not found within the hot greywacke. Target zones for deeper production from 280-300°C fluid were identified towards the bottom of the volcanic sequence and BR15 and BR49 are presently producing about 12 MWe from these zones.

INTRODUCTION

The first exploration wells at Ohaaki were completed in the mid 1960's. The depth of these wells was effectively limited to about 1500 m by the capacity of the National T12 rig that was available to drill them. Three deeper wells, BR15, BR24 and BR34 were drilled, but none of these encounter good permeability.

The successful wells produced 5-10 MWe with the main feed zones at a depth of 400 to 1000 m. During the extended field test from 1968-71 a steam zone developed at the top of this interval. Towards the end of the test period an influx of cooler shallow fluids was evident through the changes in enthalpy of the produced fluid, the fluid chemistry and the downhole surveys. The full significance of this influx of cooler fluids was not recognised at the time.

Production for the 114 MWe Ohaaki power station commenced in 1988. Dilution and cooling of the shallow-feeding wells in the western part of the field became apparent almost immediately and dilution has followed in some of the wells in the eastern field. By 1996 two wells had failed through cooling and the feed water temperature for several others had declined from 240 to approximately 200°C.

While wells with shallow feed zones have been affected by the influx of cooler fluids, wells with deeper feed zones, below 600 m depth, generally showed a slower decline in potential (little change in feed water characteristics based on chemistry and physical data). Up until the end of 1995 the bulk of fluid produced from the Ohaaki reservoir was derived from the volcanic formations at 400-1000 m depth.

It became evident that deeper exploration of the Ohaaki reservoir was needed to investigate the possibility of producing hotter fluid that was less affected by the shallow diluting fluids. In the nearby Rotokawa and Ngatamariki geothermal fields, potential production had been proven from depths down to 2.5 km within volcanic-derived formations. Formation temperatures below 1000 m at

Ohaaki were known to be in the range 290-310°C. Reliable production could be expected if suitable permeability could be located

Prior to undertaking the 1995 deep drilling at Ohaaki the results of recent deep (>2.5 km) exploration programmes world-wide were reviewed together with the production potential of the deeper formations and structures throughout the Taupo Volcanic Zone.

Based on this review it was decided to investigate the deeper resource at Ohaaki by drilling three deviated wells with nominal drilled depths of 3 km and deviation angles of 45° from the vertical. These wells were programmed to be drilled to cross the regional structural trend, seeking to locate permeable fractures and zones within the greywacke below the volcanic formations.

DRILLING

The locations of the three wells are shown on figure 1.

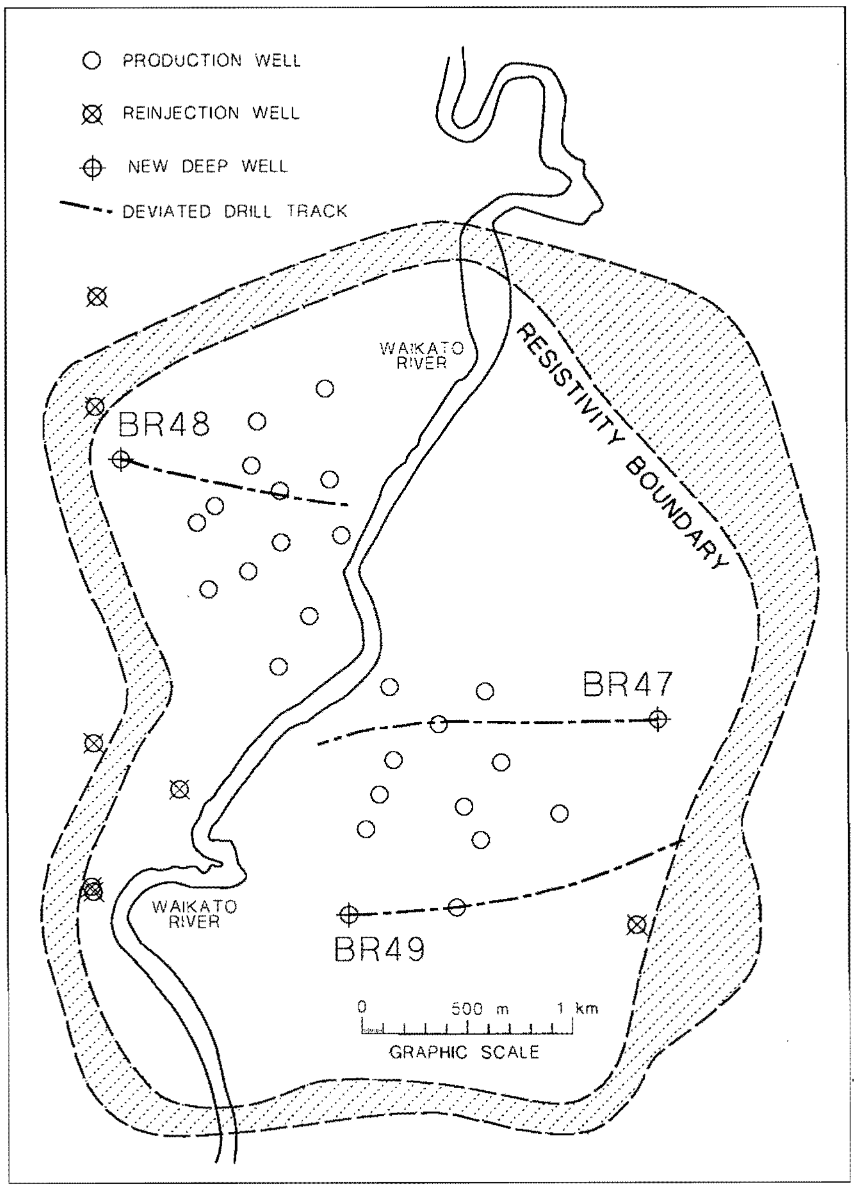

Figure 1 - Map of the Ohaaki Geothermal field showing the well tracks of BR47,48 and 49. Other production and reinjection wells are also shown.

Figure 2 is an indicative geological cross section along the BR49 well track. The well deviation is also shown in figure 2. The kick-off point was at 300 m, with build-up rates of up to 8°/100 metres, reaching full deviation of about 45° at approximately 970 m depth. The 9-5/8" production casing was originally programmed to be set into the greywacke at 1200-1300 m but this was pulled back to 1100m. The well was drilled to 2.8 km.. The bottom part of the production casing and the open hole were essentially in the tangent section of the hole. Because of the deviation angles, two of the wellheads were able to be located outside the hotter surface area of the Ohaaki field and the wells drilled through the "field boundary" in order to reach the target zones. This provided an advantage in that down to about 500 m depth the wells were effectively in non-geothermal conditions which reduced the likely difficulties associated with gas, steam and unstable surface conditions that are sometimes encountered.

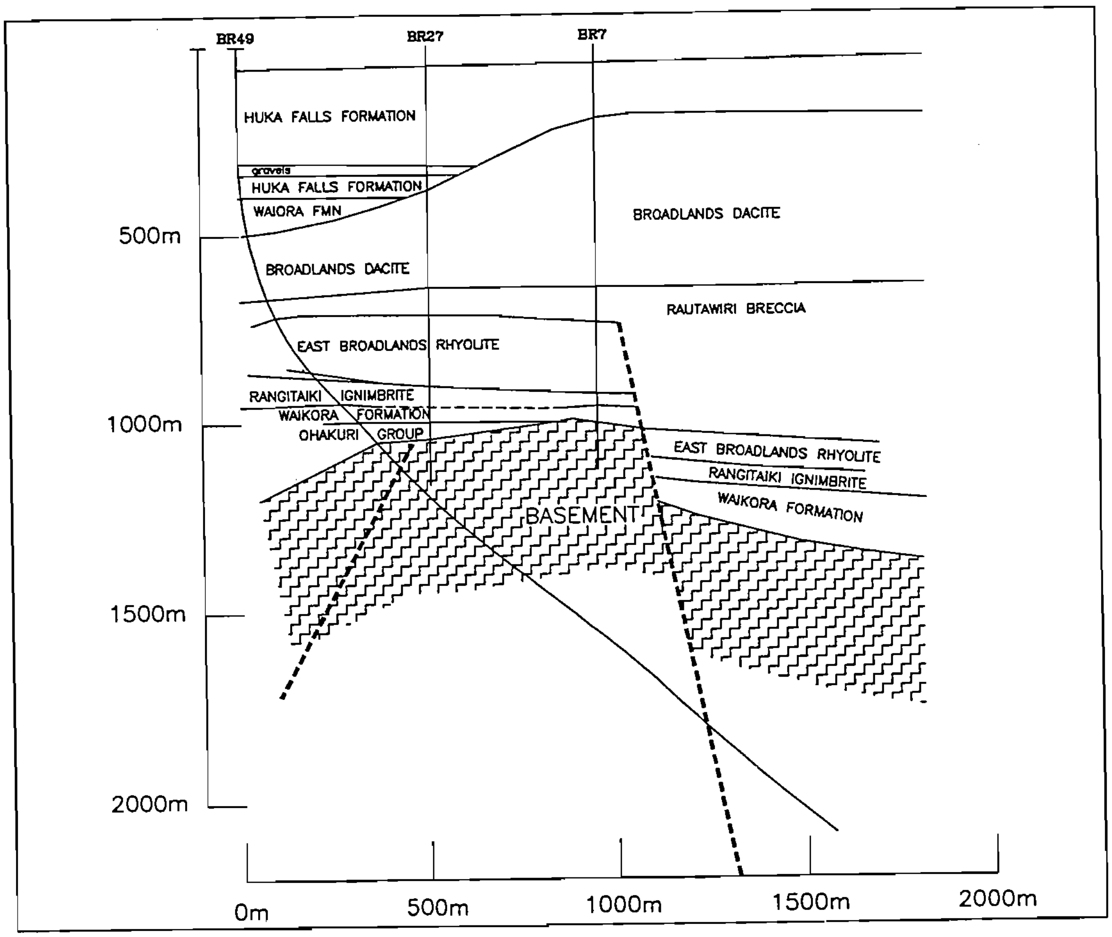

Figure 2 - Cross section along the BR49 well track

The wells were drilled using Parker Drilling Company's Rig 228. The rig was mobilised from Singapore to New Zealand to undertake the work. The rig has a maximum hook load of 500 tonnes and was fitted with a TESCO hydraulic top drive unit for the Ohaaki contract. Well bore direction and deviation were continuously controlled using retrievable MWD instruments.

DRILLING RESULTS

The well details are documented in Table 1 below. Drilling commenced in January 1995 and the three wells were completed by late June 1995. The first well took 49 days to drill, that being the longest time of the three. Some of this time being attributed to establishing the operation and the rig crew becoming familiar with the rig and the top drive unit.

Table 1 - Drilling Data For Ohaaki Deviated Wells Drilled During 1995

Well	BR47	BR48	BR49
Casing depth (m)	1300	1137	1094
Total drilled depth (m)	2983	2243	2798
Average deviation of open hole section (°)	50	47	50
Vertical depth (m)	2336	1858	2080
Horizontal throw (m)	1604	1086	1610
Days drilling	49	39	41
Maximum Measured Temp (°C)	302	295	290
Permeability - kh - (dm)	0.05	3.3	1

WELL LOGGING

An important objective of the programme was to determine the characteristics of fracture zones and in particular the fluid producing fractures and zones intersected by the well bore. To achieve this it was planned to log the wells, where possible, using fracture logging (Schlumberger microresistivity-based FMS supported by calliper, sonic, density and porosity logs) to determine fracture orientation, in conjunction with spinner / flowmeter logs to identify which fractures accepted and / or produced fluid. Additional logging methods such as vertical seismic were considered and tested while drilling BR47, but were not used for the later wells.

To successfully run the more sophisticated fracture logs required that the well bore was stable (ie unlikely to collapse) and could be cooled to less than about 100°C to with in the limitations of the logging cable and downhole instrumentation. For wells drilled into high temperature formations - in this case greater than 290°C - this means that there must be permeability (fracture zones) towards the bottom of the well which will accept cool water injected from the surface. With deep permeable zones present the well bore temperature should be able to be kept cool enough to run the logs. If permeable fractures are not found it may be possible to cool the well by pumping under high pressure, but this would cause the formation to be stimulated and logging would not reflect the natural fracture conditions.

Conventional completion tests were also undertaken on the wells.

RESULTS

The three wells were designed primarily as exploration wells to find out more information about the resource. The geological interpretation of the deep exploration programme is covered in more detail by Wood (1996).

BR47 was cased into the greywacke. It found no fracture permeability with the overall injectivity in the order of 1 t/h/b.. A rhyolite dyke was found within the greywacke formation, but there was no permeability associated with this feature. Temperatures were greater than 290°C throughout most of the open hole section. No fracture logs were run as there was no indication of significant permeability and the well temperatures precluded running the tool.

BR48 was drilled below 1500 m with complete lost circulation. A temperature log made on completion of the drilling showed it was cool enough to run the fracture logging suite of tools. Sonic, porosity and density logs were successfully completed but the FMS logs were abandoned after the tool string became stuck at 2000 m due to hole conditions. The tools were subsequently fished by the rig and recovered.

The programmed production casing shoe depth for BR49 was changed to ensure that it was above the likely volcanic-greywacke contact. This was to improve the probability of locating some permeability in this well. The major permeable zone in BR49 was found subsequently within the volcanics and close to the contact zone with the greywacke but little if any permeability deeper within the greywacke. While preparing to run the FMS logs there were problems with a temperature log run in the open hole. This required another fishing operation to recover the logging tools and the subsequent fracture logs were not run because of the likelihood of the tool string becoming stuck .

Preliminary tests on BR48 and BR49 indicated production potential. Given the success that was achieved, with two out of the three wells drilled being suitable for production, it was decided to undertake a review of the existing wells with the view to rentering and redrilling. BR15 and BR42 were re-entered and redrilled with deviated well paths to new locations in November and December 1995. Redrilling BR15 was successful but BR42 resulted in little change in its productivity. Production testing of the new wells showed than an additional 20 MWe potential was immediately available from the new wells drilled and the old wells reentered. BR15 and BR49 are connected to the production system and are producing about 12 Mwe. BR48 is expected to be connected into the system later in 1997.

BR15, BR48 and BR49 have feed zones in the volcanic formations above the greywacke, temperatures encountered are up 300 ^{0}C. At the time of writing the chemistry of BR48 has not stabilised with the influence of drilling fluids evident. BR15 and BR49 are connected to the production system and are producing alkali chloride waters of the following composition.

BR	DATE	WHP	H	MASS	Na	Ca	Cl	SO4	HCO3	Cl (RES)	TQTZ	TNK	TNKC	CO2 TD	CO2/H 2S
		b.g.	kJ/kg	t/hr		mg/kg				ppm	°C	°C	°C	wt%	
15	Aug-96	19.7	1338	302	947	2.2	1613	2.6	183	1014	282	291	295	1.53	62
49	Dec-96	14	1066	144	958	0.5	1028	21.6	489	731	248	247	283		

DISCUSSION

The present production depths at Ohaaki are relatively shallow and subsurface temperature data shows that there is a substantial heat reserve at greater depths. The 1995 deep exploration programme was successful in locating new production zones below the present producing levels.

- Good production potential and additional reserves are located deeper in the volcanic formations and near the contact zone between greywacke and overlying volcanics.

- No significant permeability was found to be present in the greywacke sediments which were drilled during the 1995 exploration programme.

Production from wells BR 15 and BR 49 are currently adding some 12 MWe to the output of the Ohaaki power station.

BR48 is programmed for further testing in early 1997. Connection into the production system is anticipated during 1997.

There is energy available in the reservoir and drilling additional wells will enable some of the production decline caused by dilution and cooling in the shallower depths of the reservoir to be made up with production from deeper hotter fluids. Additional wells need to be drilled into the zones identified from the 1995 drilling programme to assist in making up for the decline that is occurring.

ACKNOWLEDGEMENT

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REFERENCES

Wood, C P. (1996). Basement Geology and Structure of TVZ Geothermal Fields, New Zealand. Proc. 18th NZ Geothermal Workshop, p157ff.