Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Rationale for Targeting Fault Versus Formation-Hosted Permeability in High-Temperature Geothermal Systems of the Taupo Volcanic Zone, New Zealand

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Keywords: Faulting, formation permeability, ignimbrite, geothermal systems, Mokai, Taupo Volcanic Zone

ABSTRACT

Finding permeability is an essential aspect of production or injection well targeting during exploration, resource delineation and production stages of geothermal field development. In the past, production well targeting at New Zealand's Wairakei and Kawerau geothermal fields was often "fault-biased", with major faults (determined by mapping, inferred from stratigraphic displacement in wells, and more recently by microseismic techniques) assumed to provide the primary fluid pathways/well inflows. In many cases, we have found that this approach is warranted, but success in New Zealand targeting fault structures has varied within fields, and from field to field. PTS logs of many recently drilled production and injection wells in Ohaaki, Mokai, and Rotokawa geothermal systems, demonstrate primary formation-hosted permeability, rather than being a secondary target, actually provides the major producing (permeable) inflow zones. In these fields, permeable zones are commonly hosted by ignimbrite and fractured lava (rhyolite or andesite) units, even though basement faults are likely to provide deep structural control on the primary fluid upflow, with lateral and/or vertical permeability controlled by contrasts in rock density and porosity, and spacing and inter-connection of fractures providing excellent production permeability (and in some developments, injection targets). In our paper, we highlight production drilling successes at Ohaaki, Mokai, Wairakei and elsewhere, and suggest for geothermal systems where fault-zone permeability is clearly demonstrated that a structure-based rationale for geothermal well targeting should be followed. However, if a fault-zone feed-zone link is equivocal (as is more often the case), a facies approach targeting auto-brecciated or jointed lava or welded pyroclastic units, or formations with intrinsic primary permeability, should be given equal consideration.

1. INTRODUCTION

In many geothermal fields, production well drilling focuses on targeting known (or inferred) structurally-controlled permeability, and the early days of geothermal exploration in New Zealand followed a similarly reasoned approach. Indeed, in some fields targeting fault/fracture zones is still recommended, as the production reservoir may be hosted in lavas (e.g. andesite, at Rotokawa), metasediments (e.g. greywacke, at Kawerau and Rotokawa) or other rock types with very low inherent permeability. In some ignimbrite-dominated geothermal systems in New Zealand, however, such as Wairakei-Tauhara, Mangakino and Mokai, formation-hosted permeability may have the greater importance in providing pathways for production fluids.

In this paper we focus on geological results of geothermal drilling at the Mokai Geothermal Field (TVZ) in 2003-2008, where Mighty River Power Ltd. (MRP) investigated a variety of formation-hosted permeability and fault targets. From 2003 to 2005 well targeting advice was given by GNS Science, in collaboration with geo-engineering specialists from MAGAK, Sinclair Knight Merz and GCNZL, for 5 wells in the southern part of the field (MK10 - MK15; Figure 1). Subsequently, GNS Science provided well services and undertook post-drilling science on a further 7 deep geothermal wells for MRP (MK7A, MK16-MK21).

The first well in the 2003-2005 drilling phase was MK10, which was a deviated well, designed to intersect an inferred fault zone. However, drilling and completion test data show production zones in MK10 was not associated with any unequivocally defined fault/fracture, but rather with a formation boundary and within an ignimbrite. As the MK10-MK15 programme progressed, drilling results and completion test data encouraged a revision of permeability targets, with *intra*-formational fractures and bulk-rock permeability, and *inter*-formational contacts increasingly favoured, although the science team were mindful unknown fault-structures intersected by drilling (i.e. without any surface expression) might also be productive.

A second phase of drilling occurred in late 2006 - early 2007, with MK7A (a deviated production well drilled as a replacement for MK7) and MK16 drilled in the main production area, and MK17 drilled to test additional deep fluid injection capacity in the NW part of the field. Later (March - August, 2008), MK18 and MK19 were drilled as exploration wells in the eastern part of the Mokai Geothermal Field, and two injection wells (MK20 and MK21) were drilled in western and northern parts of the field for waste fluid management resulting from expansion of power generation.

2. STRATIGRAPHY

All Mokai wells drilled in 2003-2004 exceeded the 1245 mVD (vertical depth) drilled by MK12, with the deepest wells (i.e., MK11, MK14 and MK15) being >2000 mVD Subsequently, 5 of the later wells (MK7, to 1994 mVD; MK17 to 2403 mVD; MK19 to 2271 mVD; MK20 to 1990 mVD; and MK21 to 2622 mVD) drilled below -1500 mRL.

A study of cuttings and drillcore from each of the wells was carried out by GNS Science, summarized in Table 1, which built on the understanding of the stratigraphy and inferred structure of the Mokai Geothermal Field from previous DSIR and IGNS studies, particularly of MK3 (Wood, 1983a), MK5 (Wood, 1983b), MK6 (Wood, 1984) and MK7 (Wood & Rosenberg, 1998).

At Mokai, the stratigraphy is dominated by a sequence of variably welded ignimbrite sheets, several rhyolite lava units, pumiceous fall deposits of variable distribution and thickness, and volcaniclastic sediments (Kilgour et al., 2007), as summarised in Figure 2 and Table 1.

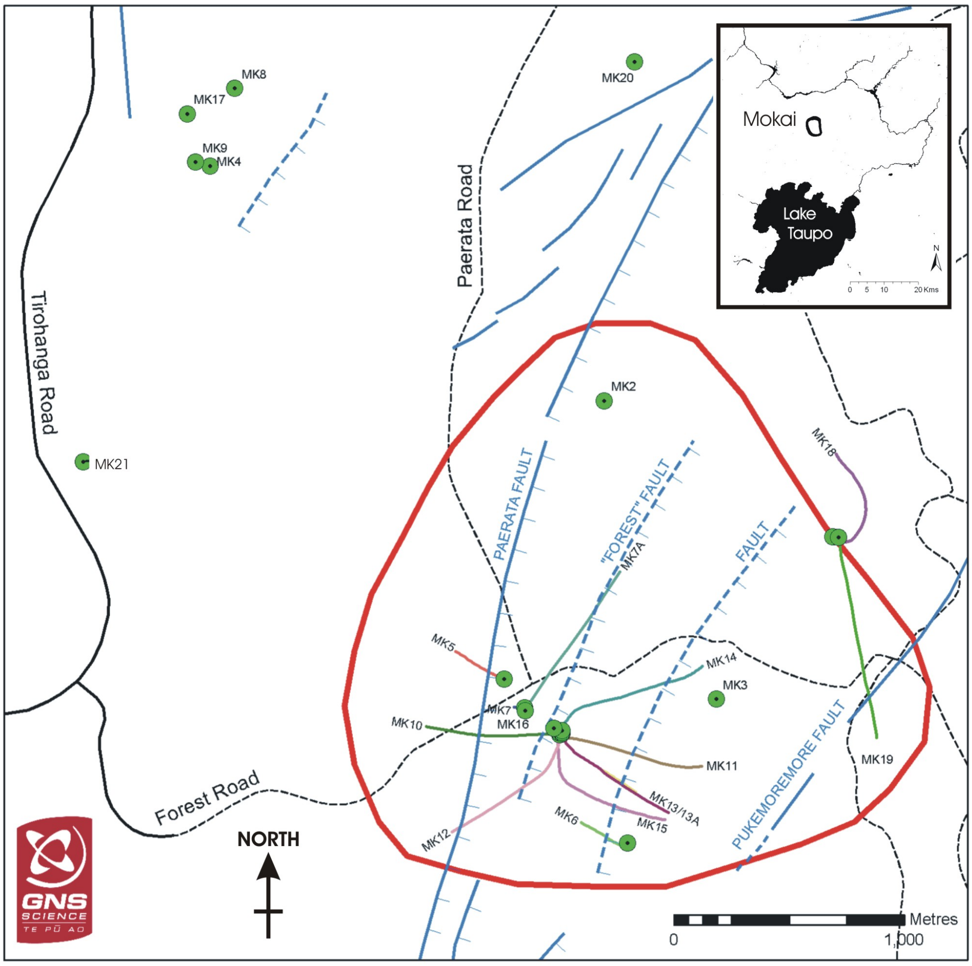

Figure 1: Location map of the Mokai Geothermal Field, showing well tracks, known/inferred faults and field boundary.

Table 1: Stratigraphy encountered by drilling at Mokai Geothermal Field.

Formation	Thickness	Description
Surficial deposits	~ 25 m	Tephra, sands and gravels
Mokai Ignimbrite	< 200 m	Crystal-rich, non-welded upper ignimbrite (up to 130 m thick); welded basal ignimbrite.
Tuff / silicified breccia	< 65 m	Crystal-lithic tuff, with spherulitic rhyolite and polymictic volcanic breccia lithics
Mokai Rhyolite	< 165 m	Pale grey rhyolite. Upper glassy-perlitic texture, with spherulitic/flow banded base.
Volcaniclastic Sediments	< 150 m	Volcaniclastic silts, sands and sediments, with gravelly horizons.
Pumice vitric-lapilli tuff	< 100 m	Pale grey, crystal-poor lithic tuff, with pumice, tuff, banded rhyolite clasts in tuff matrix.
Rhyolite B (and tuffs)	< 200 m	Upper part brecciated and spherulitic, grades to flow banded, sparsely porphyritic lava.
Ignimbrite B	0 - 125 m	Lithic crystal tuff, with silicified tuff, banded rhyolite, pumice and crystals in fine matrix.
Pumice tuff / breccia	< 80 m	Grey lithic tuff, with pumice, rhyolite, silicified tuff and sparse crystals in an ash matrix.
Rhyolite C	0 - 230 m	Weakly porphyritic rhyolite lava
Ignimbrite C	150 - 300 m	Partially welded ignimbrite, with rhyolite, tuff and minor pumice clasts, and crystals.
Ignimbrite D	140 - 300 m	Partially welded, crystal-rich ignimbrite, with rare lithic clasts in a fine ash matrix.
Whakamaru Ignimbrite	340 - 900 m	Partially welded, crystal-rich ignimbrite, with embayed quartz, minor pumice and lithics.
Pumice tuff / breccia	< 50 m	Lithic poor, welded pumice ignimbrite with of quartz, plagioclase and mafic crystals.
Rhyolite D	0 - 365 m	Pumiceous rhyolite lava, variably spherulitic, flow-foliated and/or porphyritic.
Volcaniclastic Sediments	0 - >360 m	Volcaniclastic crystal tuff, with quartz crystals, rare feldspar and mafics in an ash matrix.
Vitric tuff / breccia	< 130 m	Poorly sorted volcaniclastic breccia, with rhyolite, pumice, siltstone, quartz and feldspar.
Ignimbrite F	< 150 m	Welded ignimbrite with pumice fiamme, spherulitic rhyolite, andesite and crystals.
Volcaniclastic Sediments	0 - >130 m	Volcaniclastic crystal tuff, with quartz, rare feldspar, mafic crystals in a fine matrix
Rhyolite E	< 480 m	Porphyritic, flow banded rhyolite, with glassy, spherulitic and brecciated intervals .
Mokai Dacite	< 200 m	Porphyritic dacite, with plagioclase, ortho/clinopyroxene and magnetite phenocrysts.
Ignimbrite	0 - >325 m	White/mottled, partially welded ignimbrite.

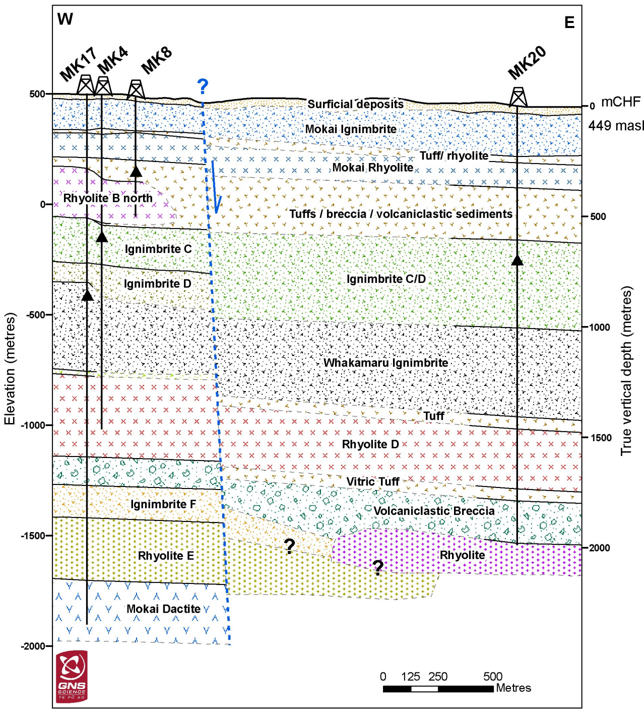

Figure 2: Representative west-east geological cross-section (MK17-MK4-MK8-MK20) of the Mokai Geothermal Field, showing the stratigraphic units encountered by production-injection drilling.

As geothermal drilling has continued at Mokai, production zones have been found at the Rhyolite C/Ignimbrite C and Ignimbrite C/D stratigraphic contacts, within Ignimbrite D, at the Ignimbrite D/Whakamaru Ignimbrite contact, within Whakamaru Ignimbrite, and at the contact between volcaniclastic units and Ignimbrite F (Kilgour et al., 2007).

Ignimbrite D is a weakly welded, pumice-rich, crystal- and lithic-poor ignimbrite (Figure 2). It has been identified only at Mokai, where it is >250 m thick. The absolute age of Ignimbrite D is unknown, and its stratigraphic position affords only a relative age of <320 ka (Wilson et al., 1995). It is crystal-poor, with its crystal fraction dominated by feldspar, with subordinate partially resorbed quartz. Lithic fragments include rhyolite lava and rare granitoid rock.

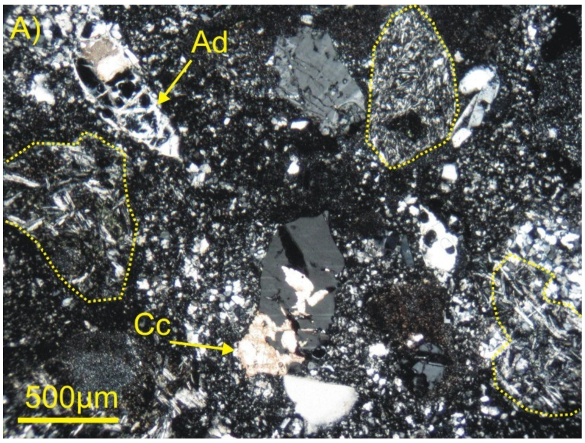

Figure 3: Representative thin section photograph of Ignimbrite D (MK21: 730 mRF), showing lithic and crystal fragments in a fine grained matrix.

The Whakamaru-Group (Figure 3) is a regionally extensive series of ignimbrite sheets, which occur in surface outcrop, and in all explored geothermal fields in the central TVZ. At Mokai, the Whakamaru Ignimbrite underlies Ignimbrite D, and has two welding zones: 1) an upper ~250 m porous, non-welded unit; and 2) a dense, strongly welded basal unit, at least ~350 m thick. The ignimbrites are ~340-320 ka, and have >1000 km^3 cumulative volume (Wilson et al., 1995).

Indurated volcaniclastic sandstone and siltstone occurs below Whakamaru Ignimbrite. The unit is poorly permeable, and may provide a permeability contrast with over- and underlying ignimbrites to focus lateral fluid flow.

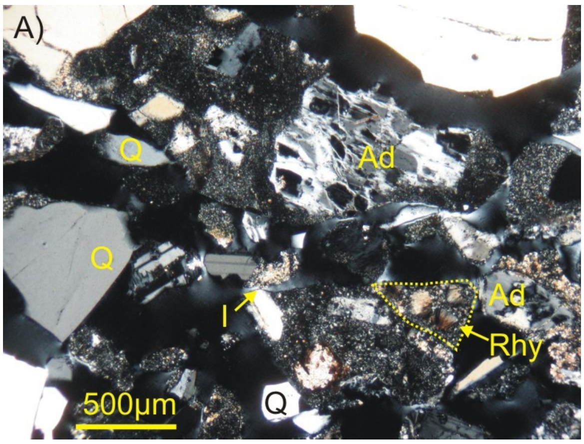

Figure 4: Representative thin section photograph of Whakamaru Ignimbrite (MK21: 1000 mRF), showing quartz and altered plagioclase crystals (pseudomorphed by adularia and minor illite), and rhyolite lithics in an altered matrix.

Ignimbrite F was encountered in the deepest Mokai wells (i.e., MK14-17, MK21, and possibly MK11 and MK14). The rock is a hard, dense, welded ignimbrite, with a lenticular fabric, low crystal content and common greywacke, mafic lava and rhyolite lava lithics. High rock strength and hardness make fracture dominated permeability likely, although evidence from MK14 and MK15 favours at least some inter-formational feed zones.

3. STRUCTURE

Two major faults have been delineated in the Mokai production area (Figure 1), based on surface fault traces and thermal feature lineaments mapped by Lloyd (1978), and air-photo interpretation: (i) Paerata Fault, which has a N-S orientation through the Mokai borefield, dipping to the west; and (ii) Pukemoremore Fault, which marks the eastern boundary fault of the Mokai geothermal area.

Numerous scarp-like features have been mapped in the vicinity of MK6 and the Mokai power station, although the lack of evidence of displacement means their interpretation as faults is questionable. In contrast, displacement of lava on the Pukemoremore dome and post-26,000 y volcanic deposits, is coincident with the Pukemoremore Fault Zone. The western margin of the zone was delineated a “fault” by Lloyd (1978), but it could be an erosional feature.

At Mokai, there is no direct evidence (i.e. well data, or unequivocal stratigraphic correlations between drillholes) of large scale deep faulting. Downhole stratigraphic correlations are uniformly flat (particularly in the shallow parts of the field), whilst variations in formation thicknesses could be explained by topographic features (e.g. lava dome/flow margins, erosion, or infilling valleys or depressions). It is possible to infer differences in the elevation of the deeper units as fault displacements, but the evidence is only provided by relatively widely-spaced wells, and any “fault” should only be regarded as a possibility – indeed, a tilted or sloping orientation could account for the apparent discrepancy in the depth at which some ignimbrite units are first encountered in some wells.

Certainly, if there is strong evidence for a fault, then that (depth) zone should be a high priority drilling target, but as it stands, permeability at Mokai is most likely controlled by the physical properties and hydrological parameters within the formations, rather than large structural features.

4. HYDROTHERMAL ALTERATION

A study of hydrothermal mineral occurrences, fluid inclusion thermometry and well data can reveal differences between mineral stability conditions, and past/present temperature-chemical conditions in the geothermal system.

Several clay and silicate mineral phases have narrow (or minimum) temperature stability ranges, which are useful for resolving the thermal evolution of a geothermal system (e.g. smectite <140^{o}C; interlayered illite-smectite, marked by increasing crystallinity 140-230^{o}C; and illite >230^{o}C), whilst epidote and other calc-silicate phases are important indicators of elevated temperature. Hydrothermal mineral phases can also provide an indication of fluid chemistry (e.g. alunite indicates pH<3, whereas an assemblage of quartz, adularia and illite points to neutral pH conditions) and reservoir permeability (i.e. plagioclase is progressively replaced by albite, then albite+adularia, and finally adularia (Figure 5), with enhanced formation permeability).

Examination of the hydrothermal minerals at Mokai, particular in the southern part of the geothermal field, reveals an argillic alteration assemblage (of smectite, illite-smectite, hematite, calcite and quartz), indicative of low permeability conditions, overlying a higher rank propylitic mineral assemblage (chlorite, quartz, illite, calcite and epidote, with variable adularia and/or albite, wairakite, titanite, leucoxene, trace clinozoisite and rare hydrothermal amphibole). In most wells, the transition between the two alteration types occurs at ~500 m depth (i.e., close to the boundary between undifferentiated tuffs, and Ignimbrite B).

In the production parts of the Mokai geothermal system, zones of intense propylitic alteration are coincident with host rocks comprising non-welded to partially welded ignimbrite (e.g. Ignimbrite D, non-welded Whakamaru Ignimbrite, Ignimbrite F). Zones of intense hydrothermal alteration are typically characterised by common chlorite and epidote, sporadic illite, calcite and quartz.

Measured well temperatures (exceeding 300° C in several wells) and completion test data (Grant, 2004) are in good agreement. Solute geothermometry indicates reservoir conditions are ~300^{o}C, yet epidote is not abundant, and it is possible its absence in places may be due to zones of poor permeability, where hydrothermal mineral equilibrium is yet to be achieved. The occurrence and habit of epidote typically implies formation temperatures >260°C (Browne and Ellis, 1970). At Mokai, the deep reservoir fluids are inferred to move along formation boundaries or intra-formational pathways, and vertically via fracture networks, and the hot hydrothermal fluids may only recently have penetrated some parts of the reservoir, which may not have thermally stabilised.

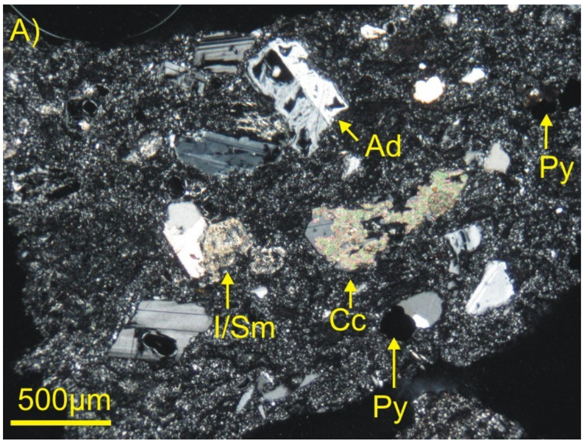

Figure 5: Ignimbrite C (MK21: 500 mRF), with primary plagioclase phenocrysts and groundmass replaced by adularia (Ad), quartz, calcite (Cc), illite-smectite (I/Sm) and pyrite (Py).

5. FEEDZONE LOCATIONS

Kilgour et al. (2007) showed, based on geological logging of cuttings and core, and completion test data (Grant, 2004) that the location of major feedzones in Mokai wells are able to be correlated with Ignimbrite D, the contact between Ignimbrites C/D, the contact between Rhyolite C/Ignimbrite C, within the Whakamaru Ignimbrite and Ignimbrite F, and the boundaries between these rock units. Using MWD survey data, Kilgour et al. (2007) plotted the 3-D location of feedzones in MK10-MK15 in order to demonstrate a common, large-scale fault plane could be discounted as the major source of feedzones in those wells.

As the drilling programme at Mokai progressed, greater understanding of the location of feedzones in the wells demonstrated the importance of formation permeability as a primary target, at Mokai and other high-temperature, ignimbrite-dominated geothermal systems of the TVZ (e.g. Ohaaki, Wairakei-Tauhara), as shown in Figures 6 and 7. It is important to note, although permeability at appears to be formation-controlled, that there is inherent diversity within the productive rock units due to the degree of primary welding and secondary effects (such as fracturing resulting from thermal cooling, intensity of hydrothermal alteration and local faulting), such that the production wells have encountered mixed successes (as measured by mass flow).

Feedzones occur throughout Ignimbrite D, and physical rock property testing shows the ignimbrite has significant bulk permeability, with high (25 – 30%) apparent porosity (Kilgour and Rosenberg, 2004). Where intersected by drilling, the ignimbrite has no indication of major hydrothermal veining, whilst the generally pervasive nature of hydrothermal alteration points to the rock matrix being very permeable.

Completion well testing, combined with cuttings and core examination and core property testing, show the Whakamaru Ignimbrite has two zones of contrasting permeability character. The non-welded upper zone is pervasively altered, with feedzones reflecting its high bulk porosity. In contrast, the lower, densely welded zone of the Whakamaru Ignimbrite is weakly altered, due to its relatively impermeable matrix. Examination of joint patterns in surface outcrops of Whakamaru Ignimbrite point to well feedzones in the welded zone being most likely restricted to zones of discrete, sub-vertical joint sets, created during post-emplacement cooling. Both the non-welded and welded zones of the ignimbrite provide feedzones to MK10, MK13, MK15, whilst only the non-welded zone contributes fluid in MK12 (and previously in MK7), and the welded zone in MK5 and MK14.

A package of volcaniclastic sediments immediately below the Whakamaru Ignimbrite is moderately consolidated, and in places silicified. The bulk porosity of the sediments is relatively low, with no evidence of (hydraulic, or other) fractures to account for enhanced permeability within the upper few tens of metres of this formation in MK15. It is likely the fluid flow path in MK15 is related to the contact between the sediments and the overlying ignimbrite, rather than inherent permeability of the sediments themselves.

Ignimbrite F is a densely welded ignimbrite (>270 m in MK14) that, unlike the Whakamaru-Group ignimbrites, does not exhibit variations in welding over its drilled depth. Ignimbrite F commonly hosts sub-vertical, chlorite + epidote filled veins. The width of the veins (c.f., fractures) ranges from <1 mm up to 3 mm wide which, given the low bulk porosity of the ignimbrite, is strong evidence for reservoir fluid being channeled through these fractures.

6. DISCUSSION

The results of geothermal well drilling at Mokai, combined with examination of cuttings and cores from the wells, has afforded an opportunity to obtain insights into the lithological controls on permeability in the ignimbrite-dominated, high-temperature TVZ geothermal fields. Prior to the 2003-05 Mokai drilling programme, well MK5 was widely considered to derive its main production from feeds in the Paerata Fault (Wood, 1983b). Indeed, Soengkono (2000) provided an assessment of the fault structure at Mokai, and suggested there were three main faults, oriented NW, N and NE (Figure 7) that provided the main upflow for thermal fluids in the geothermal field.

Vertical and particularly horizontal permeability within the Mokai reservoir is generally good (Grant, 2004). It is widely accepted that there is a major upflow zone in the southern part of the geothermal field, possibly facilitated at depth by the Pukemoremore Fault, which flows in a north to north-westerly direction (Bibby et al., 1984). The major controls on fluid flow, however, particularly in the upper part of the Mokai system (above ~3 km depth) is not well defined, as it involves a combination of structural and hydrological barriers – i.e., fracture controlled permeability of the Whakamaru Ignimbrite, and minor splinter faults which are difficult to recognised in drill cuttings. For the most part, it is evidence provided by loss circulation records during drilling; pressure, temperature and flow spinner (PTS) completion testing; stratigraphic logging and the intensity and style of hydrothermal alteration which points to physical and hydrological parameters of certain strata (particularly Ignimbrite D and Whakamaru Ignimbrite) and stratigraphic contacts (e.g. Rhyolite C/Ignimbrite C; and Ignimbrite C / D) providing the dominant permeability control on fluid flow in the Mokai geothermal system.

Production, injection and exploration well drilling at Mokai has shown that not all wells targeting postulated faults (inferred from aerial photograph interpretation of surface lineations, and apparent stratigraphic displacements between adjacent or nearby Mokai wells) have intersected production zones clearly coincident with fault structures.

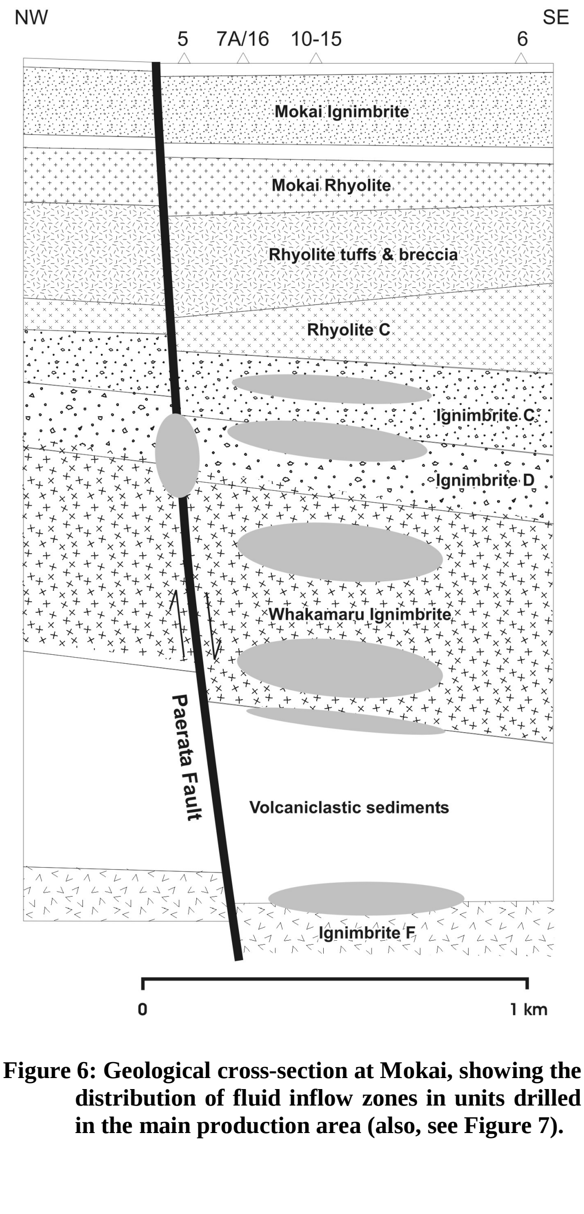

Figure 6: Geological cross-section at Mokai, showing the distribution of fluid inflow zones in units drilled in the main production area (also, see Figure 7).

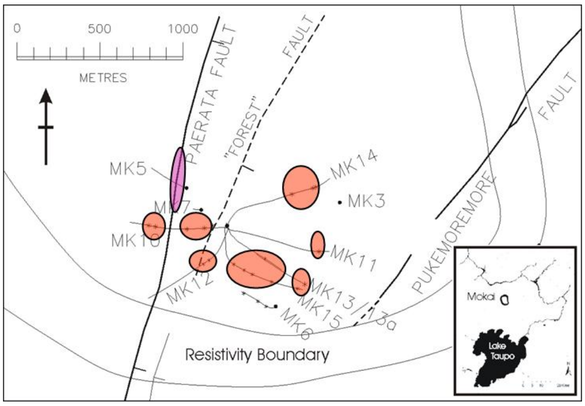

Figure 7: Distribution of inflow zones in wells located in the Mokai production area. Inflows are not coincident with major faults (indicated fault traces are mapped surface features - the dip of respective fault planes is unknown).

In the case of MK10, completion test data showed permeability is coincident with bulk rock permeability in the ignimbrite, rather than associated with a major fault structure. Of course, in MK10 and elsewhere at Mokai, it could be argued that the inferred fault does occur at the location inferred by geological mapping and other evidence, but is structurally inactive, or mineral-sealed.

Most of the feedzones encountered at Mokai during the 2003-2008 drilling were associated with formation hosted permeability in ignimbrite and other pyroclastic units. Consequently, understanding the potential for common lithological characteristics and/or the location of feedzones at similar stratigraphic positions within each ignimbrite is important. The lithological character of Ignimbrite D at Mokai is similar in all wells, i.e., there are no alteration and/or lithological differences to account for any variation in feedzone potential. Indeed, the results from Ignimbrite D indicate that feedzones are randomly distributed throughout the ignimbrite. For example, feedzones in MK7 were located throughout the ~300 m thick Ignimbrite D; in MK10 and MK12 feedzones are limited to the upper part of the ignimbrite; whilst in MK13-MK15 feedzones are located throughout the ignimbrite, but overall make negligible contribution to well flow. In MK5, feedzones occur in a narrow interval within Ignimbrite D that may be associated with the Paerata Fault (Figure 7; Wood, 1983b).

Formation-hosted permeability within the Whakamaru Ignimbrite is two types, reflecting rheological differences within the unit. Due its non-welded nature, fluid flow in the upper part of the ignimbrite is inferred to be relatively uniform. Indeed, the high bulk porosity measured for cores from this stratigraphic level suggest continuous flow conditions, assuming limited mineralisation. In contrast, the sub-vertically fractured, lower welded zone is more likely to provide fluid flow along fracture/joint spaces. Based on our present understanding, there is no compelling evidence to suggest feedzones located in either welding zone are related to the Pukemoremore Fault, which cuts across the southern part of Mokai Geothermal Field (Figures 1, 7).

During the 2003-08 drilling programme, several wells were drilled deep enough to intersect Ignimbrite F, including MK15, MK16, MK17 and MK21, and possibly MK11 and MK14. Previously, MK6 had intersected feedzones in Ignimbrite F. The welded ignimbrite is intensely fractured, with sub-vertical to sub-horizontal fractures, and rheology similar to the densely welded zone of the Whakamaru Ignimbrite. Like the Whakamaru Ignimbrite, Ignimbrite F is likely to promote relatively rapid vertical flow, with limited horizontal flow. Ignimbrite F is at least 150 m thick, based on MK21 drilling, which intersected the unit between -1085 and -1235 mRL. Underlying Ignimbrite F in MK21 is a tuff/non-welded ignimbrite, Rhyolite E and an unnamed ignimbrite (-1790 to -2117 mRL, TD), which represent the oldest pyroclastic rocks at Mokai area.

Injection and production well drilling at Mokai since 2005 has benefited from the information gained from previous drilling, particularly concerning the targeting formation-hosted permeability. Results from the MK10-MK15 drilling programme showed it was possible to refine targets based on lithology and alteration mineralogy, complemented by completion test data. Indeed, acquired completion test data provides a good estimate of the production potential for each well. Wells MK10-MK15 were all moderate to very good producers, ranging from 100 to 300 t/h steam capacity (albeit less potential output than MK5, ~450 t/h).

Although Mokai production wells have encountered feedzones related to formation permeability and the contact between some formations, there is no indication recent wells have intersected fault structures coinciding with major producing feedzones, even though petrological evidence indicates wells having intersected fractures (in places filled by hydrothermal minerals, to form veins) or reactivated faults and/or fracture networks (i.e., evidence from sheared veins). Some productive zones are common between wells, but others differ, possibly due to local lithological conditions, mineral sealing etc.

Another aspect of drilling MK10-17, was the strategy by Mighty River Power Ltd. to design a drilling programme with wellpad(s) accommodating several deviated wells. Their strategy enabled a number of targets to be explored, whilst still intersecting consistently productive formations, such as Ignimbrite D and Whakamaru Ignimbrite.

7. SUMMARY

The 2003-2008 drilling programme at Mokai has resulted in the completion of eight new production wells (MK7A, MK10-MK16) in the southern part of the geothermal field, and five other injector/exploration wells distal to the main production area, to a maximum depth of -2117 mRL (2622 m drilled depth, in MK21).

Geothermal well drilling has provided new information on the location and character of formation-hosted permeability in the ignimbrite-dominated Mokai Geothermal Field. At Mokai, permeability is inferred to be controlled by the physical character of Ignimbrite D, Whakamaru Ignimbrite and Ignimbrite F, and hydrological interconnectivity within those strata, rather than major faults. Although fault traces have been mapped in the area, there is no unequivocal evidence for large faults within the Mokai Geothermal Field providing a dominant control on fluid flow.

Results show, whilst targeting known or inferred fault structures during the exploration/production stages of geothermal field development may be justified, formation-hosted permeability may be more prospective, and/or with fault-related permeability providing secondary targets.

8. ACKNOWLEDGEMENTS

The authors would like to thank Mighty River Power Ltd., (MRP) and Tuaropaki Trust for allowing us to present this paper. We also acknowledge input from GNS colleagues, particularly Geoff Kilgour and Ernesto Ramirez, and MRP staff during the Mokai drilling programme.

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