GEOTHERMAL DRILLING AT BROADLANDS ANC NGAWHA

COMPARISONS AND CONTRASTS

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Production Drilling at Broadlands (Figures 1, 2)

The geology structure and performance of the Broadlands field was summarised two years ago in the Broadlands Investigation Report of June 1977. Drilling has since followed recommendations made in that report to drill stepout wells on two major inferred subsurface faults in the southeast part of the field to identify fracture zone permeability and so add to the overall resources of the field. Both wells (BR 35 and BR 36) were sited to intersect these faults at or near the top of the greywacke basement and both were highly successful in intersecting fissures near the anticipated depths and so producing reliable well discharges. The two wells averaged 70 tonnes/hour steam at WHP. 16 bars, effectively doubling the resources east of the Waikato River to a present total of 300 t./hour. Deepening of three non-productive wells (BR 24, BR 14 and BR 30) was also recomnended and the G.C. 350 rig deepened BR 24 in late 1977. Unfortunately, the well strayed off line in the wrong direction (to the northwest by about 10°) from below-1200 m and was abandoned when drillpipe became stuck. The well is now being redrilled and deviated to the southeast to search for a possible downdip continuation of one of the steep NW-dipping faults in the basement greywacke. A further well (Br 26) was Jrllled in the northeast lobe of the resistivity anomaly 400 m SW of BR 1 in an area of known high temperatures and low primary permeability. The well intersected greywacke at 1500 m without encountering any significant losses of circulation; once more underlining the importance of locating subsurface fault-determined fissures for successful production in the Broadlands Field.

Reinjection Drilling at Broadlands

Disposal of waste hot water by reinjection into the field is a necessity at Broadlands and experiments have been conducted to determine the most suitable sites. The waste water from BR 27 was successfully injected into BR 7 for several months at temperatures ranging from 100° - 150°C at flow rates of 25 - 32 t./hr. The waste water was not exposed to the atmosphere and silica deposition was insignificant. In another experiment, water from BR 11 was reinjected at 80°C into the Ohaki Rhyolite at BR 33 after allowing silica polymerisation to take place in a holding pond; some silica build-up In pipes was noted. It is not now considered desirable to reinject above production levels in a permeable faulted region such as Ohakl because of likely adverse effects on producing wells.

A further reinjection well (BR 34) was drilled on the SW margin of the field in 1978 to 600 m and tests conducted in monitor wells to determine passage times of reinjection water towards the field. In 1979 BR 34 was deepened to over 2800 m in an effort to locate deep permeability in the basement, although geological interpretation indicated this was unlikely to be found. The well drilled basement greywacke below 1600 m and found no significant permeability except just below the casing at 800 - 900 m where a fault may have been intersected. The well discharged briefly from this zone, until the slotted casing became detached and slid to the well bottom. The well filled with debris so that it is no longer useable in the deeper levels. Efforts may be made in the future to improve permeability by hydraulic fracturing.

In a recent report by NZED many wells unsuitable for production because of insufficient permeability or temperature have been suggested as potential reinjection wells. These are mainly of moderate depth (900 - 1200 m), have long lengths of open hole and are situated towards the margins of the production field; Reinjection rates per well of 40 - 100 t./hour are anticipated depending on known downhole permeabilities, although two wells close to the Waikato River (BR 13 and BR 23) are expected to take up to 300 t./hour. These wells are, of course, perfectly good production wells and could be used as such in the future. Further reinjection well sites have been suggested in this area.

Investigation Drilling at Ngawha, Northland (Figure 3)

Since 1977, five wells (N 2, N 5, N 7, N 4, N 9) have been drilled at Ngawha to determine the productive potential of the 30 km^2 field as outlined by resistivity surveys. As anticipated from the results obtained from a 600 m failing hole (N 1) in 1965, the primary permeability of the field is very low compared with even the worst in the Taupo Volcanic Zone. In all drillholes, a thick (500 - 600 m) impermeable sequence of allochthonous late Cretaceous - early Tertiary marine sediments, emplaced by large-scale slumping, overlies basement greywacke (Waipapa Group). The overlying sediments have a complex structure because of their mode of emplacement, but contain discrete rafts of relatively unsheared claystone, limestone and greensand that can be correlated between some wells. A basal conglomerate of Eocene age is present locally and supplies some permeability, although generally cased off. The productive potential lies mainly within the basement greywacke, and is entirely dependant on intersecting fissures.

Of the six wells drilled to date, only two (N 4 and N 9) have intersected significant basement permeability. Both wells were sited near the centre of the resistivity anomaly close to hot-springs alignments and close to a conspicuous topographic lineament bisecting the field in a north-south direction. both wells struck permeability at two different levels within the basement, these levels being confirmed by downhole spinner tests, which showed downflows of 230°C water between the two permeable levels. All the other wells drilled have proved quite impermeable, so that the nature of the permeable fissures in N 4 and N 9 is a matter of some importance. The levels at which fissures were encountered (-630 m and -950 m in N 4; -410 m and -710 m in N 9) differ appreciably signifying that they are not horizontal features. However, data are insufficient to determine if extensions of surface faults were encountered.

Tectonic Model for Ngawha (and Broadlands?)

The north-south orientation of the Ngawha resistivity anomaly is probably a direct reflection of the thermal anomaly in relatively impermeable rocks, where lateral outflows in near-surface aquifers can be neglected, For example, at Broadlands the thermal and resistivity anomalies are both oriented in a NNW direction across the structural grain of the Taupo Volcanic Zone. Thus the resistivity anomaly trend is likely to reflect the heat source at depth. Both at Ngawha and Broadlands the surface escape of thermal fluids is controlled by NE distensional fissures or faults, presumably parallel to the regional horizontal stress direction. The movement of large crustal plates determines the regional stress field which conforms to a simple pattern of NE compression and NW extension over northern NZ.

Since the NE faults trend at an oblique angle (400 - 60°) to the thermal anomalies, it is likely that either:

a. The thermal anomalies are related to distensional fissures produced in an earlier stress field or

b. The thermal anomalies are related to shear fractures produced by the same stress field.

Since both fields are associated with late Quaternary volcanism (< 3 x 10^5 years) significant rotation of the regional stress field is unlikely. A model involving thermal heating along fundamental shear faults in the basement is, therefore, proposed. This heating may have been accomplished by magmatic intrusion and/or hydrothermal convection in fissure systems.

In the case of Ngawha, the north-south lineament through the field lines up with volcanic centres to the north and south (Tauanui cone) as well as a small volcanic vent within the field (N 5 area). The lineament may continue southward across Northland to the west coast near Dargaville (Landsat Photo, D. Skinner and P. Oliver pers. comm.

From consideration of the Quaternary regional stress field in Northland, the NE directed principle horizontal stress direction (P.H.S.) would produce dextral transcurrent displacement on a north-south fault. Late Tertiary analogies exist in the Coromandel Peninsula (Waihi and Te Aroha fissure vein systems) where Wellman (1354) and Wodricki and Weissburg (1970) have described NE hydrothermal vein systems intersected by north-south dextral transcurrent faults that have also been the locus of hydrothermal vein deposition. If Broadlands is a structural analogue, the NNW thermal anomaly may mark a deep-seated dextral. strike-slip fault controlling the ascent of magmas and hydrothermal fluids in the basement and opening up NE trending tensional faults in the near-surface racks.

References

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Figure Captions

Figure 1 Broadlands Geothemal Field showing relation of isotherms to faults and resistivity contours.

Figure 2 Cross section of Broadlands Geothermal Field from BR 4 to BR 16.

Figure 3 Ngawha Geothermal Field showing relation of faults to resistivity contours and volcanic centres.

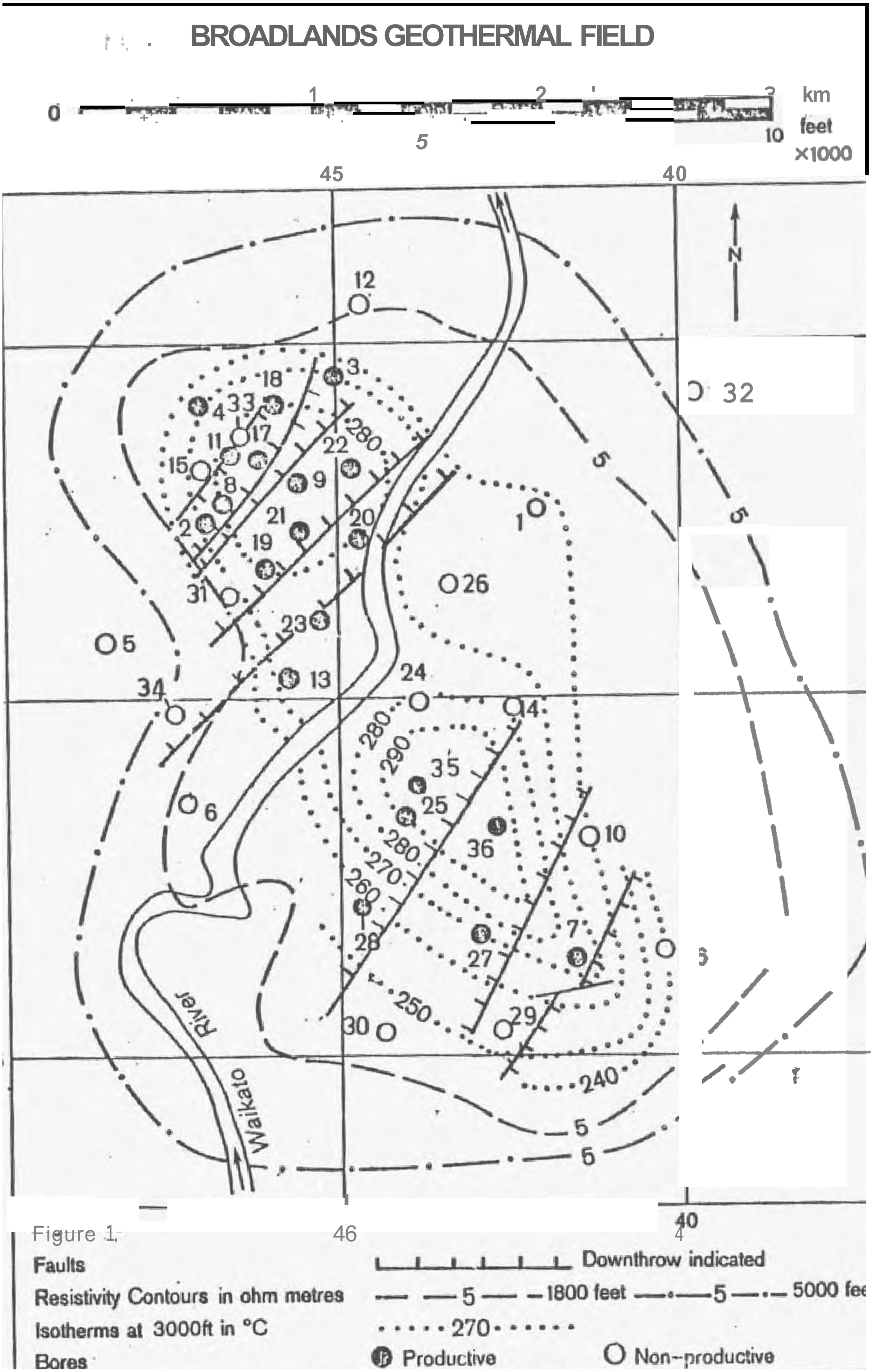
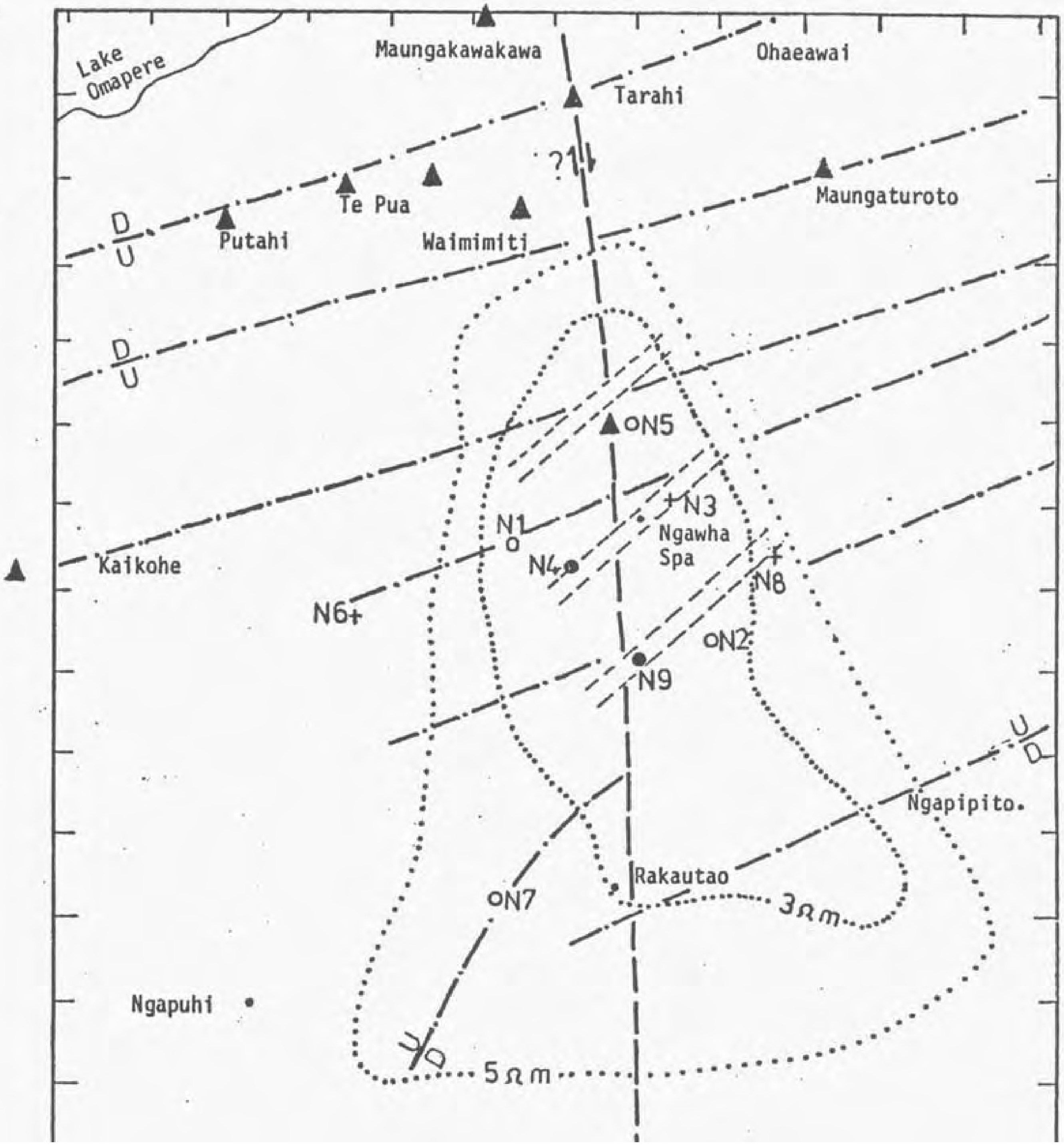

BROADLANDS GEOTHERMAL FIELD
0 1 2 3 km
5 10 feet ×1000
45
40
N
75
80
85
46
40
12
3
18
4
33
17
11
15
8
22
280
9
2
21
20
1
19
26
31
23
5
34
13
24
14
280
290
35
25
6
36
10
280
270
260
28
7
27
30
29
250
240
5
River
Waikato
Faults
Downthrow indicated
Resistivity Contours in ohm metres
5 1800 feet
5 5000 fee
Isotherms at 3000ft in °C
270
Bores
Productive
Non-productive

Figure 1.


Lake Omapere
Maungakawakawa
Ohaeawai
Tarahi
Maungaturoto
Te Pua
Putahi
Waimimiti
Kaikohe
Ngawha Spa
Ngapipito.
Rakautao
Ngapuhi
N1
N2
N3
N4
N5
N6
N7
N8
N9
3Ωm
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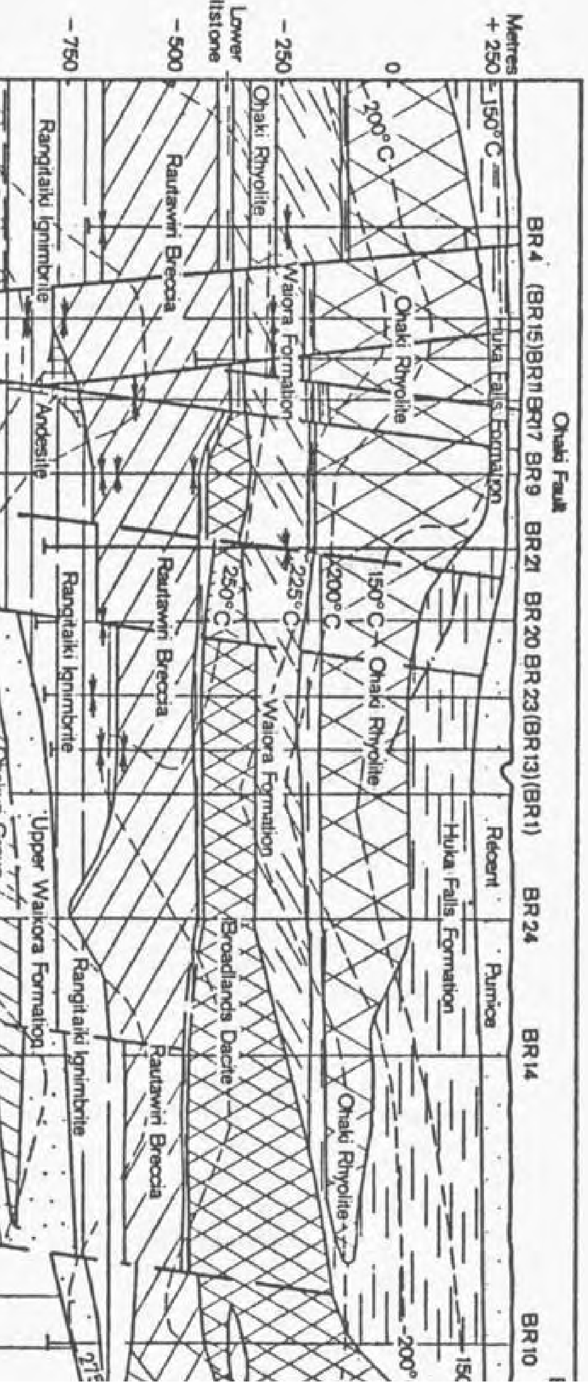
7


Ohaki Fault
BR4
(BR15)BR11BR17
BR9
BR21
BR20
BR23
(BR13)(BR1)
BR24
BR14
BR10
Metres
+ 250
0
- 250
- 500
- 750
Lower Siltstone
150°C
200°C
225°C
250°C
Recent
Pumice
Huka Falls Formation
Ohaki Rhyolite
Waiora Formation
Broadlands Dacite
Rautawiri Breccia
Rangitaiki Ignimbrite
Andesite
Upper Waikora Formation