GEOTHERMAL RESOURCES IN NEW ZEALAND AN OVERVIEW

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TYPES OF GEOTHERMAL SYSTEMS

In many parts of New Zealand, the rocks at shallow depth (< 1 km) have high porosity and may contain up to 30% (by volume) of water. Usually, the pores and fractures are connected so that the water in the rock can move in response to pressure changes. Fractures have high permeability and allow water to move quickly from place to place.

The Resource Management Act (1991) differentiates between geothermal water and cold groundwater on the basis of temperature: water greater than 30°C is geothermal, that below 30°C is groundwater. This distinction has no scientific foundation–it is based solely on the concept that water above this arbitrary temperature is an energy resource–it is not possible to clearly separate geothermal water from cold groundwater on the basis of temperature alone.

New Zealand's geothermal waters can generally be separated (but not always), on the basis of their temperature, geological location and chemistry, into two main groups:

- ***Low-Temperature Waters*** with temperatures of between about 20°C (ambient) and about 100°C, associated with active faults.

- ***High-Temperature Waters*** with temperatures greater than 100°C, associated with areas of active volcanism.

These waters form convective, hydrological systems within the upper part of the crust which are driven by the heat sources. In both cases, in their natural state, these are dynamic systems–the hot water is continually being lost at the surface to rivers and being replaced from deeper in the earth.

LOW-TEMPERATURE TECTONIC GEOTHERMAL SYSTEMS

Low-temperature springs occur mainly in the northern half of the North Island and in a band through the central part of the South Island (Figure 1). In the North Island, low-temperature springs are found mainly in areas of recent tectonic activity (such as the East Coast), and in areas of extinct volcanism (such as the Waikato and Coromandel). In the South Island, low-temperature springs are found mainly near the Alpine and Hope Faults, and appear to be associated with greater than normal temperatures (up to 200°C) at shallow depth (<2 km) which result from recent tectonic uplift.

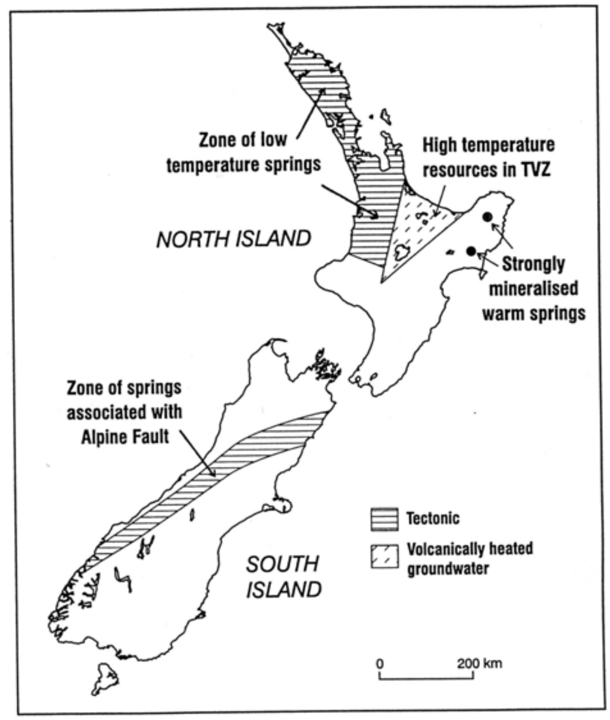

Figure 1. **Distribution of geothermal waters in New Zealand.**

Chemistry

The chemical composition of low-temperature tectonic geothermal waters is influenced mainly by the chemistry of the rocks the water has come into contact with, and the temperatures to which the water has been raised. Despite the relatively low discharge temperatures of South Island springs (40 - 60°C), their chemistry indicates that some of the waters have reached temperatures of over 100°C. The fluids within rocks with which the water interacts will also influence the chemistry. For example, the waters from Te Puia and Morere Springs on the East Coast of the North Island are highly mineralized. They contain high concentrations of sodium (Na) and chloride (Cl); probably, the result of mixing with fossil sea water from the underlying marine sediments.

Exploration and Use

There has been no systematic exploration for low-temperature systems in New Zealand. Those not already known to the Maoris before the arrival of Europeans have

Table 1. Some Examples of Direct Uses of Low-Temperature Geothermal Resources in New Zealand.

Location	Temperature ºC	Flow Rate (L/s)	Use
North Island			
Ngawha	40-50s	2	Bathing - commercial, mercury extraction in past
Kamo	up to 25s	<1	Bathing - past use by sanitarium and hospital
Waiwera	45-52s	-	Bathing - public, commercial, private pools
Parakai	up to 65s, d	12d	Bathing - 3 pool complexes, 4 motels, 5 private pools
Te Maire (Naike)	52-93s	10	Bathing
Hot Water Beach	54-63s	<2	Bathing - public and baths at Motor Camp
Te Aroha	59	<1	Bathing
Waingaro	37-54s	6	Bathing - public pool
Miranda	56s, 64d	7s	Bathing - commercial pool complex
Okauia	40d, 47s	<2	Bathing - commercial pool
Kawerau	up to 100	-	Industrial processing, greenhouse heating, electricity generation (binary plant), space heating
Awakeri	58-69s, 49-70d	50d	Bathing - commercial pools
Lake Rotokawa	45-52s, 29-99d		Space heating (motel, school, greenhouse)
Tikitere	30-99s	<1	Bathing , space heating, heating for greenhouses
Rotorua	up to 100s, d	-	Bathing (commercial pools and residential), space heating (domestic and industrial), timber drying, soil sterilization
Waikite	up to 99	1.5-3.5s	Bathing (commercial pools)
Golden Springs	40-50	9-40s	Bathing
Ohaaki	25-95	<20	Lucerne drying, heating of greenhouses (past)
Waiotapu			Timber drying
Wairakei	up to 100	-	Bathing, fish farming, space heating
Taupo-Tauhara	40-98s	20s	Bathing, heating greenhouses, domestic space heating
Tokaanu	19-98s	1-15s	Bathing (commercial and domestic pools), domestic heating
Morere	up to 62s		Bathing (commercial pool)
Te Puia	59-70s		Bathing (commercial pool - now defunct)
South Island			
Hammer Springs	32-43s, 50d	8d	Bathing (commercial pool)
Maruia Springs	up to 60s	2-5s	Bathing (commercial pool)

s = spring, d = drillhole. Data from Mongillo & Clelland (1984).

generally been found accidently by explorers, mineral prospectors, farmers, and trampers. It is unlikely that any new low-temperature geothermal springs of significant size or flow rate will be discovered; but, it is probable that additional localized areas of warm groundwater will be found.

At present, the main use of low-temperature waters in New Zealand is for bathing (Table 1). Public baths operate at Kamo, Waiwera, Parakai, Miranda, Te Maire, Waingaro, Hot Water Beach, Okauia (Matamata), Te Aroha, Tauranga, Awakeri, Te Puia, Morere, Hammer, and Maruia. A history of the use of some of these springs is given in the book ***Taking the Waters - Early Spas in New Zealand*** by Ian Rockel (1986).

HIGH-TEMPERATURE VOLCANIC GEOTHERMAL SYSTEMS

Only the upper parts of volcanic geothermal systems have been investigated by drilling. The deeper parts have been probed by geophysical techniques and their behavior is deduced theoretically from mathematical models or from scale models in the laboratory. A conceptual model of a volcanic geothermal system is that meteoric waters percolate down from the surface to depths of 5 - 10 km where they become heated by hot (up to 800°C) volcanic rock, such as a magma body. Although such shallow bodies are believed to be the prime source of heat for high-temperature geothermal waters, no such body has yet been positively identified beneath any of the known volcanic geothermal systems in New Zealand, and their shape, size, depth and chemistry remain largely speculative. The waters become heated and interact chemically with the volcanic rock; then, being of lower density than the surrounding water, they rise in a plume, towards the surface through pores and fractures in the overlying rocks.

Once established, this plume is remarkably stable and the water rises vertically, seeking permeable paths to the surface. Although the temperatures may be several hundred degrees, the pressures at depth are such that the water does not boil. As the water rises, cooler water from the adjacent rocks may be entrained in the plume, reducing the temperature and diluting the concentrations of dissolved salts. Near the surface, a number of factors can complicate the flow: reduced pressures can cause local boiling, the geological structures in the rocks can channel flow, and surface waters can infiltrate the system.

Maori tradition has a different origin for the volcanic geothermal systems. Their legend is that when Ngatoroirangi (chief of the Te Arawa tribe) and Ngauruhoe (his slave), were exploring the Taupo Volcanic Zone they climbed the slopes of Mount Tongariro and were close to dying from the cold. Ngatoroirangi called to his sisters, Kuiwai and Haungaroa, in Hawaiki across the Pacific Ocean, to send heat to resuscitate them. The sisters heard his cry for help, and with the fire gods Pupu and Te Hoata, set out underground to bring heat. In the search for their brother, they stopped and came to the surface to look for him at places on the way. Their route led from Whakaari (White Island), puia Moutohora (Whale Island), Okakaru, Rotoehu, Rotoiti, Tarawera, Paeroa (Waikite), Orakeikorako, Taupo, and Tokaanu, to Tongariro. Where they stopped, the heat burst out as thermal activity, and remains as ngawha (overflowing pools), puia (volcanoes, hot springs), and wairiki (hot springs).

At the surface, the volcanic geothermal systems are characterized by groups of thermal features within an area of 5 to 15 km^2. The natural discharge of energy from these features can be considerable. Before exploitation, Wairakei Geothermal Area discharged more than 600 megawatts (MW) of heat, with one feature alone (Karapiti Blowhole) discharging 12 MW.

High-temperature waters are associated only with active volcanism and in New Zealand are confined to the northern and central parts of the North Island (Figure 2). A list of the larger, known volcanic geothermal systems is give in Table 2.

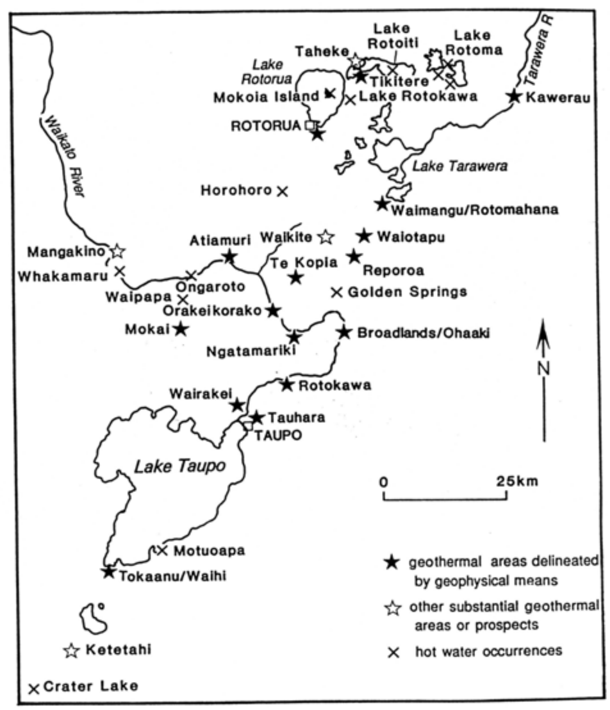

Figure 2. Map of the central part of the North Island showing the location of the known high-temperature volcanic geothermal systems (Hunt & Bibby, 1992; Mongillo & Clelland, 1984).

Age of the Volcanic Geothermal System

Measurements of heavy isotopes of hydrogen (deuterium and tritium) present in geothermal waters suggest that the circulation time for high-temperature geothermal waters in New Zealand is longer than 100 years, but less than 12,000 years. Cooling of the source body eventually causes the system to decay and die, and geological evidence suggests that individual systems may exist for up to half a million

Table 2. New Zealand's High-Temperature Volcanic Geothermal Systems (Allis and Speden, 1991; Lawless, et al., 1981).

System	Approx. Area (km^2)	Temp. ^{O}C	Status	No. of Drillholes	Available Energy (PJ)
Horoboro	5	220	f	1	400
Keteahi	?		u	-	?
Kawerau	10	250	c	32	1 300
Mangakino	5	220	f	1	400
Mokai	15	280	f	6	2 700
Ngatamariki	10	260	f	4	1 400
Ngawha	15	230	f	15	1 400
Ohaaki	10	260	c	46	1 400
Orakeikorako	5	260	p	4	?
Reporoa	5	230	u	1	500
Rotorua	5	220	u	-	400
Rotokawa	15	280	c	10	2 700
Taheke	5	230	u	-	500
Tauhara	15	240	f	5	1 900
Te Kopia	5	240	f	2	500
Tikitere	10	230	p	-	900
Tokaanu	10	250	u	-	1 300
Waikite	5	230	u	-	500
Waimangu	10		p	-	?
Wairakei	15	230	c	135	1 400
Waiotapu	10		p	7	?

Temperature: Inferred average temperature over 3 km depth range.

Status: p = protected for tourist use; c = commercial exploited
u = un-investigated; f = some feasibility studies made

PJ = Petajoule = 10^{15} joules

years. Epithermal mineral deposits, such as found at Ohakuri and in the Coromandel region, are the fossil remnants of previously active volcanic geothermal systems.

Relation to Cold Groundwater

Hot geothermal fluid may mix with and warm the cold groundwater, and if this occurs in a topographically high area where the groundwater is flowing naturally towards a topographic low, the resultant warm water or *outflow* may be carried a considerable distance from the area of the geothermal system. At Mokai, hot geothermal water rising from the Mokai geothermal system meets and mixes with the groundwater flowing down slope, and the resulting warm water is carried laterally about 10 km to emerge in the bed of the Waikato River as the Ongaroto Springs (39°C). Outflows are sometimes very large and hot, and have been mistakenly though to indicate the presence of a geothermal systems below the place where they emerge, until drilling or geophysical measurements show that only a thin layer of hot water is flowing near the top of a zone of cold groundwater.

USE OF GEOTHERMAL RESOURCES

There are several ways in which geothermal energy is used in New Zealand:

1. Direct use - the heat is used directly (e.g., space heating, heating of swimming pools, drying and processing agricultural products.

2. Conversion to another form of energy (e.g., production of electricity).

3. Recovery of minerals (e.g., recovery of silica, lithium, boron, etc., from the waters).

The greatest use of geothermal water in New Zealand is for generating electricity. When a deep geothermal well is discharged, the emerging fluid is a mixture of liquid water (about 80% by mass) and steam. The steam is separated and piped to the power station. The water, together with condensed steam from the power station, is disposed of either by putting it into a nearby river or by pumping it back into the ground.

Figure 3. Geyser, Whakarewarewa, Rotorua.

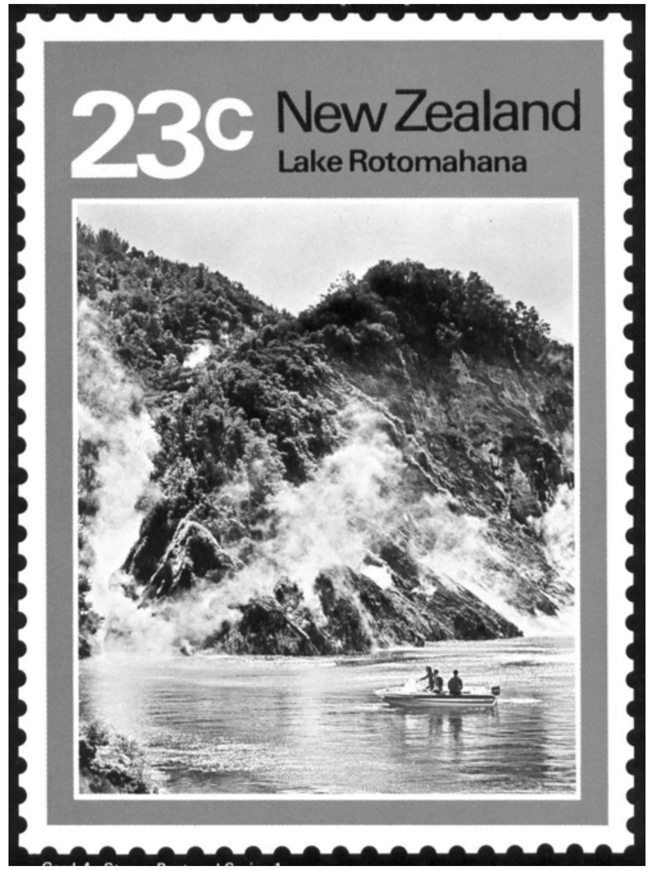

Figure 4. Lake Rotomahana (from Post Office Philatelic Bureau Stamp).

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