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THERMAL SPRINGS AT HOT WATER BEACH (COROMANDEL PENINSULA, NZ)

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ABSTRACT: The thermal seepages at Hot Water Beach discharge an uncontaminated, neutral pH NaCl-type water (TDS c. 4g/kg) at a max. temperature of 64°C (estimated heat discharge is between 0.3 and 1 MW). The reservoir is contained within a NNE trending fracture zone of unknown width. Cation geothermometers point to deep fluid temperatures of up to 170°C; cooling upper crustal rocks are the likely heat source and temperatures in deep wells indicate a sweep depth of up to 2 km for any advective flow which feeds the discharge. The springs have close affinity with other hot spring systems on Coromandel and Great Barrier Island.

1. INTRODUCTION

The thermal springs at Hot Water Beach (East Coast, Coromandel Peninsula) are a well-known tourist attraction. They have been described briefly in earlier regional studies (Fraser and Adams, 1907) but a detailed study of the manifestations was only made 20 years ago by Ovens (1976). A few results of that study have been cited recently by Skinner (1995) in his explanatory report of the 1 : 50,000 geological map of Mercury Bay Area. The thermal springs were also studied by Lyon and Giggenbach (1992) when they investigated the isotopic composition of various hot spring prospects in the Hauraki-Coromandel area. Apart from these studies, no detailed description of the attractive manifestations and their unique setting has been given yet. This short paper is an attempt to fill this gap.

2. GEOLOGICAL SETTING

The geological setting of the thermal manifestations is shown in Fig.1, taken from the geological map (Mercury Bay Area) published by Skinner (1995). The oldest outcropping volcanic rocks are the Tapuaetahi Andesites (ap) which form a coherent coastal block between Hot Water Beach and Tairua (c. 13 km to the south). The andesites are c. 9 Myr old (Skinner, 1995) and originated from several, ill defined centres. They are overlain by Wharepapa Ignimbrite which consists of several flow members including the Hot Water Beach (wrh) Flow Member (Skinner, 1995), which incorporates the unwelded Taiwawe ash-flow member of Ovens (1976)) outcropping at the beach. The pyroclastic flows originated from the Kapowai Caldera (centre c. 15 km to the SW) and have a radiometric age of c. 8 Myr, cited in Skinner (1995). The contact between the pyroclastic flows and the andesites occurs at c. 20 m depth in a drillhole which is close to thermal springs in the Taiwawe Stream (see Fig.2).

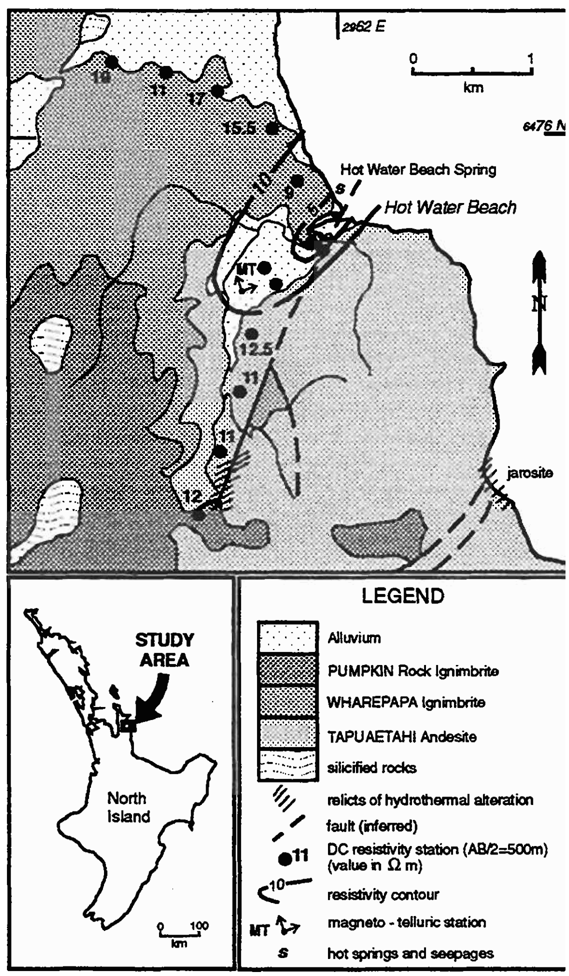

Fig.1 Geological setting of the Hot Water Beach thermal manifestations; the locality of DC- resistivity traverse stations and a MT- sounding site are also shown.

TABLE 1: Hot Water Beach Thermal Waters (Analyses)

(all concentrations in mg/kg)

	Beach seepage (s4)		Old Bore	New Bore	Groundwater Bore
Date	(<1907) 1)	(1975) 2)	(1975) 2)	(1995) 3)	(1995) 4)
T (°C)	n.d.	64	55	57	21
pH	n.d.	8.0	(7.5)	(7.5)	6.3
Na	1130	1390	1250	n.d.	40.3
K	55	60	52 (70)*	n.d.	3.7
Ca	190	174	136	128	16.2
Mg	7	18	4	4	6.5
Cl	2000	2180	1985	n.d.	51
SO_4	n.d.	98	4	8	11
HCO_3	240	(c.400)**	(c.400)**	n.d.	n.d.
SiO_2	78	73	76	78	71
F	n.d.	2	2	n.d.	0.1
TDS	n.d.	4420	3920	n.d.	n.d.

Comments:
1. Analysis cited by Fraser and Adams (1907); data converted to mg/kg
2. Analyses cited in Ovens (1976); analyst T. Wilson (Geol. Dept., Univ. of Auckland)
3. Partial analysis by L. Ling (Geol. Dept., Univ. of Auckland)
4. Analysis by Environment Waikato (D. Jenkinson, pers. comm., July 1996)

* later correction, cited by Ovens (1976)
** inferred from TDS, approx. value only.

The Hot Water Beach Ignimbrite flow (wrh) is overlain, in turn, by a younger rhyolitic pyroclastic flow, the Pumpkin Rock Ignimbrite (wp), which originated either from the Whitianga Harbour estuary (Ovens, 1976) or the southern edge of the Kapowai Caldera (Skinner, 1995). Remnants of this flow also occur in pockets on top of the eroded Tapuaetahi Andesites (Fig. 1). These ignimbrites represent the youngest volcanic sequence in the area; their radiometric ages are between 5 and 6 Myr (Skinner, 1995).

Heat transfer from Late Miocene to early Pliocene crustal intrusions beneath the greater Kapowai Caldera and the Whitianga volcanic centre involved several convective systems resulting in widespread deposition of silica sinter and hydrothermal alteration of shallow reservoir rocks. One of these systems was located to the west of Hot Water Beach as indicated by extensive silicified host rocks (near left margin of Fig. 1). Acid condensates probably moved to the east and were discharged near the present coast line where jarosite has been deposited (Fig. 1). Concealed outflows of neutral pH fluids probably caused more intense hydrothermal alteration of Tapuaetahi Andesites along a fracture, c. 2.5 km SSW from the present day thermal springs (see Fig. 1). Parallel bands of kaolinite and montmorillonite in that locality have been described by Ovens (1976).

3. THERMAL MANIFESTATIONS AND HEAT OUTPUT

The surface discharge features consist of seepages occurring in five localities (s1 to s5 in Fig. 2), aligned at 018 ° over a distance of c. 0.5 km. The northern-most seepage (s5) is always covered by the sea, but seepage s4 (the 'beach springs') lies between high and low tide level and discharges hot water (T_{max} = 64 "C in 1975) by numerous seeps over a distance of c. 15 m at a rate of c. 0.15 to 0.25 Vsec. Three other seepages occur on the bottom of the Taiwawe Stream which has tidal flow up to a road bridge near the southernmost seepage s1. The location of these seepages is indicated by gas bubbles and warm patches at the bottom of the stream (at 1.5 to 2 m waterdepth).

Several shallow (12 to 30 m) bores drilled on the south bank of the stream, opposite seepage locality s3, have been described by Ovens (1976); all had artesian flow. A few years ago a new thermal bore (B in Fig. 2) was drilled to 30 m depth; in December 1995 it produced an artesian flow of c. 0.5 l/s with a well head temperature of 57°C. This bore (water right 2262; coordinates: T 11; 618 753) supplies hot water for bathing. All thermal bores were drilled within 10 m along an E-W trending line and showed increasing temperatures at the andesite - ignimbrite contact going to the east. shallow (7.7 m) well nearby produces a very diluted thermal water with T = 19 to 21°C.

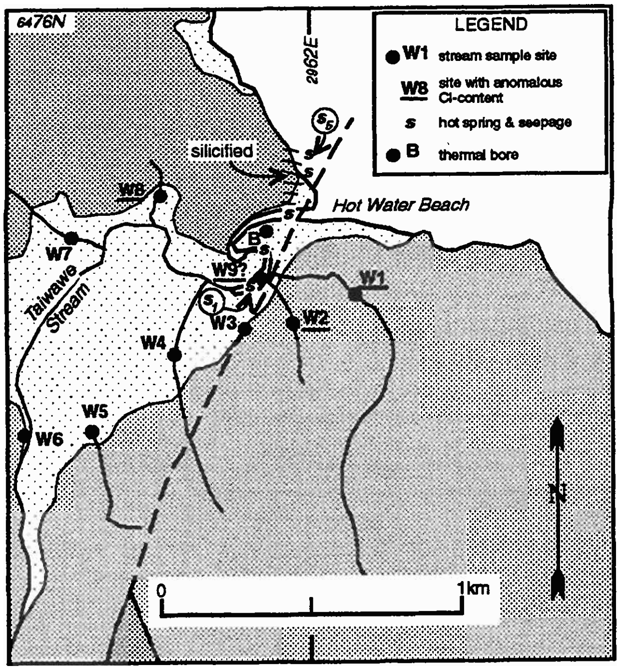

Fig.2 Location of thermal seepages and stream sampling sites in Hot Water Beach area.

Minor discharges of diluted thermal water also occur in a few small creeks lying to the east and to the west of the inferred fracture. Some of these show up with minor patches of steam close to the ground on cold mornings (Ovens, 1976). One area is close to stream sampling site W8, c. 0.35 km to the W of the thermal bore (Fig.2). Another lies in a pine plantation drained by two small creeks which were sampled at sites W1 and W2, c. 0.25 km to the east of seepage s5 (Fig. 2). Minor discharge of warm water also occurred in the past near the Taiwawe Stream at site W7 near an old sawmill. This spring stopped flowing when drainage of the swampy alluvial valley lowered the watertable at the turn of the century (cited in Ovens, 1976).

The hydrological setting of the natural discharges is complex. It is unlikely that the hot water at the andesite - ignimbrite contact moves to the west, say, towards site W8, since the hydrological gradient is to the east and temperatures in older thermal wells decrease rapidly to the west at the contact (gradient c. -2.5°C/m). It is therefore likely that thermal water ascends in a wider fracture zone which contains an axial, permeable fracture which feeds the aligned seepages s1 to s5. This points to a fracture zone reservoir, a common reservoir type of low and intermediate temperature systems known from Asian countries (Hochstein, 1988).

Only an order of magnitude estimate can be given for the heat output of the Hot Water Beach discharges. Flowrate and temperature data of minor discharges in creeks point to about 0.1 to 0.2 MW; that of the major seepage s4 is c. 0.15 MW. Assuming that the long-term discharge rate of 5 Vsec of pumped thermal wells is close to the natural thermal recharge, a maximum output of c. 1.1 MW is indicated. It is therefore likely that the total heat discharge is of the order of 0.3 to 1 MW. Such a rate is similar to that of another hot water prospect at the western margin of Coromandel Peninsula, the Te Aroha thermal area, with a natural heat output of c. 0.5 MW (Michels et al., 1993). The thermal output of the Kaitoke Hot Springs on Great Barrier Island to the N of Coromandel Peninsula is of the same magnitude (Henrys and Hochstein, 1982).

4. GEOCHEMISTRY OF THE THERMAL WATER

Only a few analyses of the thermal water have been made (see Table 1). The oldest analysis is that cited by Fraser and Adams (1907). Analyses of thermal water from the beach seepage (s4) and a thermal well which discharged in 1975 are listed in Oven's thesis. In December 1995 a sample was taken from the new thermal bore and analysed for constituents indicative of shallow mixing (i.e. Mg, SO_4). The constituents of water from the shallow well (7.7 m) were monitored from 1992 to 1995 by Environment Waikato . Although the ionic balance of the old analyses is of intermediate quality and the error of the bicarbonate and potassium values of the 1975 samples is uncertain, the quality of the analyses is adequate for the following discussion.

A comparison of the two analyses made in 1975 shows that the sample from the beach (s4 site) has a slightly higher mineralisation; Ovens explained this by a seawater contamination (1%) of the sample from the last high tide. The more representative sample is therefore that taken from the thermal bore which shows that the thermal water is a neutral pH sodium chloride water containing only a small amount of Mg and S04. This indicates that no seawater has contaminated the thermal water in the well and that practically no mixing with groundwater has occurred at shallow depths.

The ratios of Na, K, and Ca were used by Ovens to assess deeper cation equilibrium temperatures (see Henley et al., 1984). Unfortunately, that assessment contains a numerical error since a deep equilibrium temperature of 235°C was quoted whereas the correct value is 153°C and 168°C for K-values of 52 and 70 mgkg respectively. Intermediate temperatures at greater depths are also indicated by other geothermometers. The quartz geothermometer for slowly ascending fluids (no mixing) gives a minimum value of 122°C and the Na-K geothermometer of Giggenbach (1986) gives a value of 170°C. If the thermal fluids were heated by deep sweeps of meteoric waters which infiltrated the higher terrain along the axial region of the peninsula, it is likely that they penetrate to depths where temperatures between 150 and 170°C prevail.

This inference is confirmed by the results of isotope studies which show that no significant oxygen $(\partial^{18}O)$ shift has affected these waters (Lyon and Giggenbach, 1992). Since the approximate temperature gradient of crustal rocks beneath the E coast of Coromandel

Peninsula is known, the depth of the heat sweep can be estimated from the cation equilibrium temperatures (to be shown later)

5. SEEPAGE STUDIES

A small stream sampling programme was conducted in 1975 ; the sampling sites are shown in Fig.2. Only chloride and SiO_2 constituents were analysed. The results are listed in Table 2 (taken from Ovens, 1976). Background values were assessed for three creeks draining the Tapuaetahi Andesites c. 10 km south; their average "normal" values are listed also in Table 2. Allowing for an uncertainty given by two standard deviations of the background samples, it can be inferred that traces of thermal water enter the creeks at sites W1, W2, W8, and the shallow groundwater bore close to the thermal bore.

TABLE 2: Sampling of Creeks in Hot Water Beach Area

(constituents in mg/kg)

Site	Chloride	SiO_2
W 10, 11, 12, (1)	30 ± 5	10 ± 2
W1	49	14
W2	56	15
w3	39	15
w4	33	14
w5	35	15
W6	30	13
W7	29	15
W8	62	16
W9(2)	476	17
7.7 m bore (3)	40-50	60-70

Comments: (1). Mean background values from 3 creeks in Pumpkin Hill area (c.10 km south)
(2.) Taiwawe Stream near roadbridge and southernmost seepage (s1)
(3.) The range of data given represents seasonal changes during 1992 to 1995.

6. RESISTIVITY SURVEYS

A DC - resistivity survey using a Schlumberger array (AB/2 = 500 m) was made in 1975 to assess the lateral extent of thermally altered ground. Low apparent resistivity values between 5 and 19 ohm-m were observed (see Fig.1); the average resistivity was 12.5 ohm-m (neglecting the result of 2 stations closest to the hot springs). A similar survey over Tapuaetahi Andesites c. 10 km south gave average values of 50 to

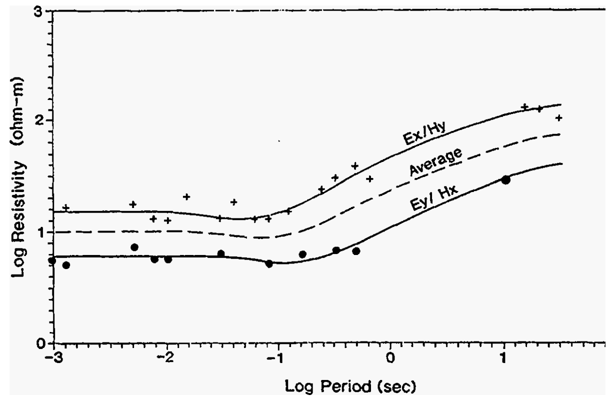

Fig.3 Magneto-telluric sounding curves (Ex dipole orientation was 080°, that of Ey was 350°).

60 ohm-m for these rocks (Ovens, 1976). Although the resistivity value of unaltered rocks is highly variable, hydrothermally altered rocks tend to show up. with significantly less scatter since the dominant conductance mechanism is via the rock matrix containing clay minerals. Altered volcanic rocks on Great Barrier Island near the Kaitoke Hot Springs also show up with true resistivity values between 10 and 20 ohm-m in the upper few hundred meters (Henrys and Hochstein, 1982). The now extinct Ohakuri geothermal system in the Taupo Volcanic Zone which stands in cold, hydrothermally altered rhyolitic rocks exhibits resistivity values similar to those at Hot Water Beach (Ignacio, 1985).

The vertical extent of the low resistivity rocks was assessed in December 1995 by a magneto-telluric (MT) sounding. The location of the MT - array with 50 m long orthogonal dipoles is shown in Fig.1. A 5 -channel ZONGE GDP-32 digital receiver unit was used to record electric and magnetic signals. The phase coherency of signals from one dipole was poor; only scalar apparent resistivities could be computed which are shown in Fig.3. The two curves are separated by a frequency-independent galvanic distortion (static shift); the average of the curves matches the measured apparent DC-resistivity. The average curve can be interpreted in terms of a simple 2-layer structure with $\rho 1$ = 10 ohm-m, h1 = 500 m; $\rho 2$ = 100 ohm-m. This structure can be explained in terms of a 500 m thick layer of hydrothermally altered rocks (presumably reflecting older hydrothermal activity) and a substratum of unaltered rocks.

7. HEAT SOURCE CHARACTERISTICS

Two deep wells have been drilled in the greater Whitianga area since 1989 which indicate anomalously high temperatures in the upper km. The following data were taken from open file reports lodged with Environment Waikato (Hamilton).

The first deep well was drilled c. 12.5 km to the NW of Hot Water Beach in Whitianga township (grid reference: T 11; 515822) in 1989; it was drilled to a depth of 625 m and produces warm water with T up to

44°C from 470 m depth indicating a vertical gradient of c. 0.06°C/m (also cited in Skinner, 1995). The second well was drilled c. 15 km S at Pauanui (grid reference: T 12; 645593) to a depth of 1100 m in 1993 and encountered a bottom temperature of c. 110°C. A few temperature measurements at intermediate depths indicate a gradient of c. 0.065°C/m to 450 m depth and c. 0.1°C/m down to the bottom. The data indicate that the upper crust between Pauanui and Whitianga is still anomalously hot, reflecting a cooling crust heated by volcanic intrusions 5 to 9 Myr ago. It can be inferred that rocks beneath Hot Water Beach, and probably also beneath the Kapowai Caldera now exhibit temperatures between 80 to 100°C at c. 1 km depth. This implies a sweep depth of the order of 1.5 to 2 km for advective flows which attain equilibrium temperatures between 150 to 170°C.

8. SUMMARY

The hot springs at Hot Water Beach discharge mineralised (TDS c. 4g/kg), neutral pH sodium chloride water which is not contaminated by seawater or surface water. Cation geothermometers point to equilibrium temperatures of up to 170°C at greater depth. All springs are strictly seepages which are aligned in NNE direction for a distance of c. 0.5 km. The prospect can be classified as an intermediate temperature thermal system confined within a fracture zone of yet unknown width. The natural heat discharge is of the order of 0.3 to 1 MW, similar to that of other major hot spring systems at Coromandel and on Great Barrier Island. The heat source for these systems appears to be cooling crustal rocks which in the greater area around Hot Water Beach have temperatures as high as 80 to 100°C at c. 1 km depth.

It is likely that heat is swept from these deeper hot rocks to the surface by secular advective flow; geothermometers point to a maximum sweep depth of c. 2 km. An unusual feature of the hot spring systems on Coromandel Peninsula and on Great Barrier Island is the high mineralisation of these waters (between 4 and 11 g/kg TDS); other hot spring systems occurring further west over the Hauraki Rift have a significantly lower mineral content (c. one order of magnitude lower, see Hochstein and Nixon, 1979).

One can explain this important difference by assuming that a large volume of paleo- thermal fluids from extinct high temperature geothermal systems still occurs at upper crustal levels beneath Coromandel and Great Barrier Island which are now slowly flushed to the surface by advective systems.

The Hot Water Beach system is an old thermal system as indicated by the silicification of the ignimbrite flow member exposed in the cliffs near the beach springs. However, it is unlikely that the widespread hydrothermal alteration of the ignimbrites and andesites as indicated by resistivity surveys is the result of hot fluid - rock interaction involving fluids from the present day fracture zone system. It is more likely that the widespread - and deep reaching - alteration is the relict of older geothermal systems which might have become extinct during the Pliocene.

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