SPRING CHEMISTRY OF THE WAIKITE-PUAKOHUREA THERMAL AREA

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SUMMARY

The chemical characteristics of the Waikite-Puakohurea spring waters have been used to determine the relationship of the different groups of springs to each other and to the deeper aquifer. The composition and temperature of the deep water is deduced. Comparisons are drawn between these fluids and those found at Te Kopia and Orakeikorako which are also located on the NW down-thrown side of the Paeroa Fault, and with Waiotapu waters.

1. LOCATION OF FEATURES AND NOMENCLATURE

The Waikite-Puakohurea thermal springs are located north of the Waikite Valley road, west of Waiotapu. The largest group of springs are situated at NZMS 260 U16 990143, near the foot of the Paeroa *Scarp*, but include springs and fumaroles extending 4 km north-east along the scarp.

Confusion has surrounded the allocation of names, "Waikite Springs" and "Paukohurea Springs". Maps exist (NZMS 1,N85 and NZMS 260, U16), in which these features appear geographically transposed. Moreover, "Paukohurea" sometimes attracts the alternative spelling of "Puakohurea" at which point speculation must arise as to whether the original name may have been "Puiakohurea". More surprising is that no map seems to dedicate the name "Waikite Springs" to the overwhelmingly dominant hydrothermal feature of the region: i.e. the concentration of numerous, and often extremely vigorous, springs from which the bath complex derives its hot water supply. These are mostly dismissed as "Thermal *Area*" while "Waikite Springs" is applied to either one of two markedly smaller features.

Cody (1992), in conjunction with Klyen, has systematically numbered the features from north to south. These numbers and names have been adopted in this report. In order to distinguish the springs supplying the baths complex and the total springs in the general area covered by the survey, the former is termed "Waikite Springs" and the latter the Waikite-Puakohurea area. All groups of Springs at Waikite-Puakohurea, and selected Te Kopia and Orakeikorako features are shown in Fig.1.

2. PREVIOUS WORK

2.1 Geology (Healy,1952; Nairn,1973)

The Paeroa Fault Scarp, the largest in the district strikes north east across the area. At Waikite the downthrow is 125m to the northwest. Two kilometres to the north-east it splits into 3 and the surface expression dies out. The locations of the springs are fault controlled. Paeroa Ignimbrite overlain by pumiceous pyroclastics of the Waiora Formation are exposed by the Paeroa Fault at Waikite. Part of the top of the *scarp* and the downthrown block on the north-west are covered by Earthquake Flat Breccia, a pumiceous pyroclastic flow erupted c42000 years B.P. Fluviatile deposits of the Hinuera Formation and Taupo Pumice Alluvium cover the floor of the valley along the foot of the *scarp*.

2.2 Geophysics

Regional aeromagnetic and gravity surveys were reported by Modriniak and Studt (1959). Resistivity soundings and regional traversing measurements (nominal AB/2 spacings of 500m and 1000m) have been collected throughout the Waikite, Te Kopia and Orakeikorako area, and the results (MacDonald, 1965 and Geophysics Division, 1985) suggested that there was no connection between Waikite and Te Kopia fields, However a low level aeromagnetic survey conducted by Geometrics in 1986 suggested that there might be a broad corridor of demagnetised rock, possibly due to hydrothermal alteration, linking the two fields along the base of the Paeroa Fault Scarp. Bromley (1992) measured closely spaced tensor CSAMT soundings along three traverses perpendicular to the Paeroa Fault *scarp;* i.e. NW-

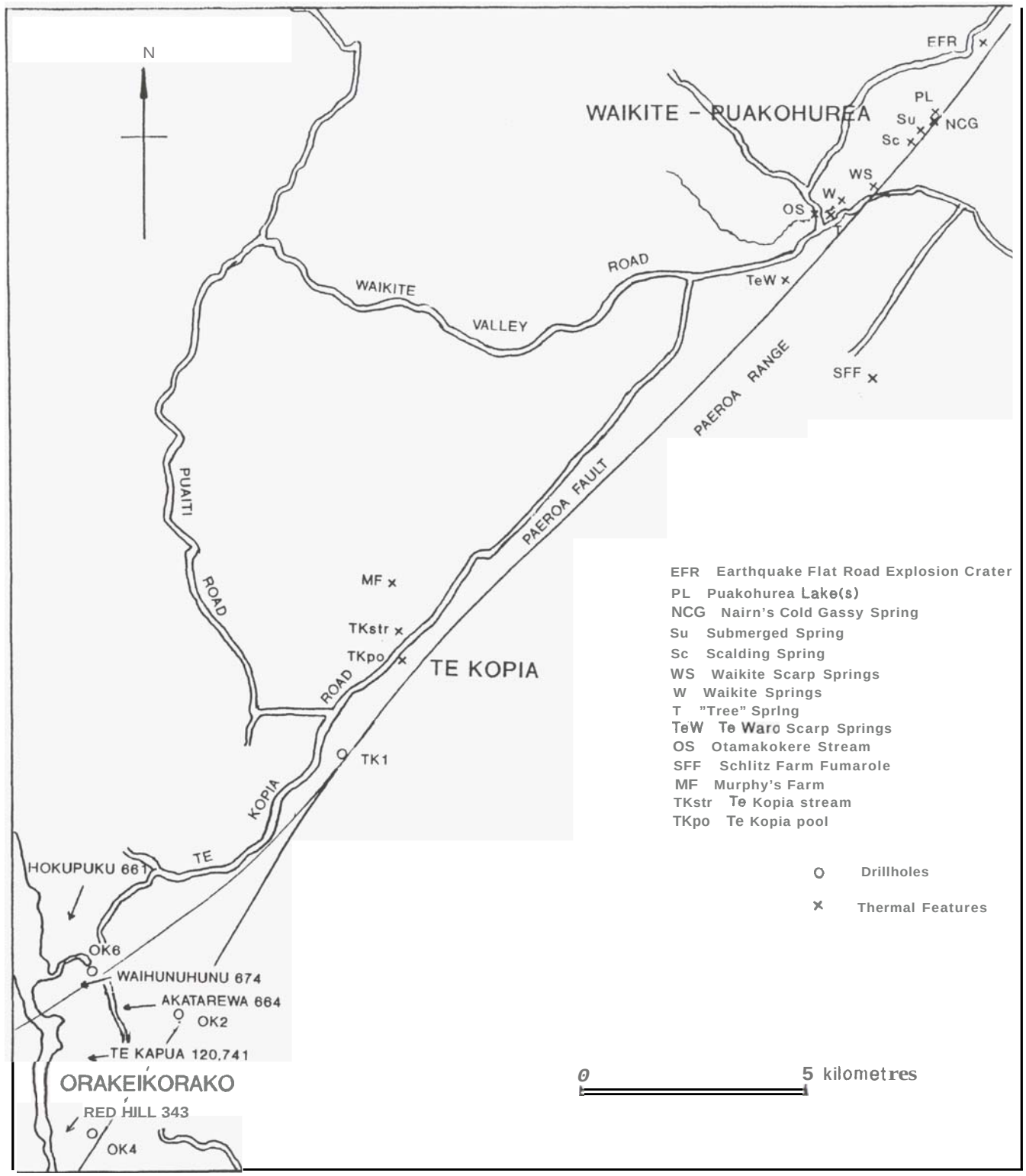


Figure 1: Location of Waikite-Puakohurea, Te Kopia, and Orakeikorako Thermal Features and Drillholes.

SE. These data support the existence of a broad corridor of low resistivity at 600m depth. At this depth it was invisible to the previous resistivity surveys. Bromley also conducted Schlumberger array DC resistivity measurements at selected sites using nominal AB/2 spacings ranging from 600m to 2400m. These data supported the presence of the low resistivity layer of 5 to 10 ohm-m at about 600m (Bromley, 1992).

23 Chemistry

Mahon (1965) reported the results of a chemical survey carried out in April 1964. He used Cl/B ratio data to show that the hot waters at Waiotapu, Waikite, Paukohurea (sic), Te Kopia and Orakeikorako were of a similar chemical type. However chemical data given (Na/Li) indicate that he did not sample at Puakohurea. Sheppard and Robinson (1981)

reported on a chemical and isotope survey of Waiotapu, Reporoa and Waikite hydrothermal discharges. Boron concentrations were listed as less than 2 ppm and thus Cl/B ratios were not obtained for the Waikite waters. Their paper concentrates on Waiotapu with less attention to the Waikite Puakohurea area. N.B. "Paukohurea" in Sheppard and Robinson is probably the Wailcite Scarp group. Although they raise the question of a connection between Waikite and Waiotapu they give no opinion on it.

3. PRESENT WORK

Forty three features were sampled between July 1991 and April 1992. Descriptions of the features together with brief comments of the chemistry were reported by Glover et al (1992). A more rigorous delineation of the various groups within the "Waikite Thermal Area" has been used than hitherto. From north to south the groups are:-

Earthquake Flat Road Explosion Crater [EFR]
This crater is probably the result of several, linearly located, phreatic eruptions. The feature, within a narrow valley, contains several lakelets and a small low-grade hydrothermal area with gas discharges at the base of an eastern spur. A footnote of speculative interest is the existence of photographic evidence, albeit tenuous, of a phreatic eruption here post-Tarawera eruption of 1886 (R.Keam, pers com).

Puakohurea Lake(s) [PL]
This consists of one or more lakes or ponds, depending upon the rainfall. The out flow of two main groups of hot springs, which issue from the foot of perpendicular bluffs to the east, and a cold stream enter the lake(s) system.

Nairn's Cold Gassy Spring [NCG]
This is a gassy spring located within a small basin perched above a white fan on the hillside.

Submerged Spring [Su]
The "Submerged Spring" is a spring with a submerged sinter perimeter and rising gas bubbles located at the foot of the transverse bench filling the head of the Waikite Valley. The flat valley floor exhibits much evidence of old and abandoned sintered waterways.

Scalding Spring [Sc]
Enclosed by a fence this spring is situated on the valley floor.

Waikite Scarp Springs [WS]
Located either close to or directly beneath the high tension transmission lines spanning the Waikite valley is a complex of fumaroles, hot springs and hot streams. Steaming ground, and steaming gas vents are found immediately below the scarp crest and on an intermediate platform and the valley floor. Between this platform and the valley floor are two areas of hot spring activity, the northerly is a particularly fine and energetic feature with sintered surround and discharge channel. Numerous small hot inflows to an extensive swamp are found on the valley floor.

Waikite Springs [W]
This name is applied to the dominant hydrothermal feature in the area containing the water source for the bath complex. This is a fine group of springs and also the most hazardous. Water temperatures are in excess of 90°C whilst fragile surface and stream-bed crusts overlie hot sediments, with the hydrothermal features and precipitous and unstable banks often obscured by steam and vegetation. All "sinter" in this area is calcareous not siliceous.

Tree Spring [T]
The Tree Spring is a warm flowing spring in a shallow gully.

Te Waro Scarp Springs [TeW]
These warm outflows emerge from the foot of the Paeroa Scarp and provide a major tributary to the Te Waro stream.

Otamakokore Stream at Corbett Road bridge [OS]
The Otamakokore stream which drain most of the above areas is gauged at this point.

Schiltz Farm Fumarole [SFF]
Two steam vents are located at this solfatara south of the Waikite Valley Road. One, not sampled, is confined within a vertical concrete pipe.

4. CHEMISTRY OF THE "WAIKITE-PUAKOHUREA" SPRINGS [W-P]

4.1 Results

Chemical data from all the features sampled in 1991-92 are reported by Glover et al (1992). Table 1 lists chemical concentrations of lithium, sodium, potassium, calcium, rubidium, caesium, chloride, sulphate, total boron, total silica, and total carbonic species expressed as bicarbonate, in mg/litre, and the pH value. Table 2 shows the more significant mole ratios together with some geotemperatures calculated from the analytical data.

4.2 General chemical description

The majority of the discharges from Waikite-Puakohurea are near neutral chloride-bicarbonatewaters with bicarbonate the dominant anion present. Compared with other New Zealand natural geothermal waters these features discharge some of the most dilute waters. The Waikite Springs (W) group have chloride concentrations of 140-150 mg/litre, whilst the highest concentration (237 mg/litre) is found in the Scalding Spring (Sc) which has a flow of up to 2.0 litres/sec. Cl/HCO_3 mole ratios mainly lie between 0.1 and 0.9.

TABLE 1: Waikite, Te Kopia, Orakeikorako and Waiotapu Water Analyses

Source No.	CT °C	pH	Li	Na	K	Ca	Mg	Rb	Cs	Cl	SO4	B	Tot siO2	Tot HCO3
Earthquake Flat Road Explosion Crater														
S 5669	26.2	6.35	.06	29	3.2	2.8	1.1	<.05	<.05	7.9	19	.11	117	111
S 5613	95	5.95	.04	22	15.9	1.8	2.5	.07	<.05	6.0	199	.08	312	35
S 5617	49.4	6.45	.10	38	11.9	1.7	1.5	<.05	<.05	8.7	131	.09	171	173
Pwkohurea Lake														
S 5640	7.7	7.40	<.01	7.7	3.9	1.9	.83	<.05	<.05	7.2	8	<.02	53	11
S 5638	47.5	6.10	.07	51	8.6	3.1	1.6	<.05	<.05	21.7	14	.17	138	352
S 5641	31.2	7.65	.06	49	8.9	3.0	1.6	<.05	<.05	21.0	15	.17	136	107
Nairn's Cold Gassy Spring														
S 5646	15.9	2.75	<.05	11	5.6	3.2	.73	<.05	<.05	6	174	.04	106	
Submerged Spring														
S 5632	41.2	7.6	.38	75	9.3	2.8	1.4	<.05	<.05	40	16	.33	143	142
Scalding Spring														
S 5644	89.2	7.95	2.9	322	19.7	.49	.09	.13	.18	237	45	2.23	304	454
Waikite *Scarp* Spring.														
S 5651	98.4	8.10	3.0	290	16.2	.92	.03	.14	.26	199	46	1.79	277	432
S 5670	72.4	8.75	2.0	211	14.9	.52	.05	.05	.08	139	34	1.34	258	275
S 5671	48.8	8.50	2.0	220	16.0	.87	.12	.06	.08	136	34	1.32	243	313
Waikitr Springs														
S 5576	19.4	7.10	.60	67	11	4.4	1.2	<.05	.05	47	16	.57	129	122
S 5577	33.4	7.05	.75	a5	12.6	4.9	1.3	<.05	.07	58	16	.60	144	161
S 5580	97.5	7.90	2.4	230	9.3	8.7	.19	.12	.35	150	39	1.54	183	361
S 5585	98.9	8.90	2.4	224	9.0	1.6	.13	.12	.32	146	38	1.51	174	300
S 5586	99.5	7.80	2.2	215	8.8	7.8	.22	.11	.31	145	39	1.46	167	338
S 5587	94.5	7.35	2.0	199	7.8	7.5	.28	.08	.25	132	37	1.42	141	302
S 5598	98.6	7.85	2.0	202	6.9	7.1	.20	.08	.29	140	38	1.40	150	278
Tree Spring														
S 5567	50.2	7.65	.90	112	10.5	1.7	.12	<.05	.07	73	24	.7	184	152
Te Waro Scarp Springs														
S 5557	36.6	7.00	.29	59	3.8	4.2	1.6	<.05	<.05	33	7	.26	113	143
S 5555	37.1	6.85	.31	63	4.1	4.8	2.1	<.05	<.05	36	6	.30	114	170
S 5551	34.9	7.00	.29	56	3.9	4.6	1.8	<.05	<.05	32	8	.28	112	107
Otamakokore Stream at Corbett Rd. bridge														
S 5566	53.8	8.55	1.4	172	10.0	5.6	5	.07	.18	114	31	1.08	162	252
Te Kopia														
MF	61.5	7.5	.41	86	3.4	3.7			.096	89	18	.9	140	56
TKstr	81	4.1	.12	47	30.4	9	2.2	.21	.215	40	132	.42	277	19
TKpo	54	2.4	.38	27	20.7	6.6	.89	.15	.094	32.5	308	.51	259	
TK 1	99	9.5	3.1	254	40.2	1				301	64	3.6	546	70
Orakeikorako														
OK 2	99	9.2	3.1	300	35	1.3				319	61	4.17	410	252
OK 4	99	9.2	3.1	550	54					546	142	7.78	480	405
OK 6	99	8.75	2	257	19.3	12.1				142	20	1.53	250	490
OK 6	99	8.85	4.3	430	49	3.9				383	42	4.07	480	546
Spr661	50	7.2	.8	155	6	5.7	1.1			50	9	.54	110	378
Spr674	79.5	7.9	1.2	180	8	4	2			106	16	1.09	130	271
Spr664	64	8.2	1.2	135	10	4.6	0.6			78	12	1.09	150	201
Spr120	94	8.7	4.11	322	48.6	1.7	.05	.53	.67	339	99	3.6	376	207
Spr741	98.5	7.7	4.64	368	54.9	2.2	.02	.56	.71	364	102	3.7	428	298
Spr343	100	8.6	3.1	320	38	2.2				355	95	4.05	310	185
Waiotapu														
LKG	98	7	4.2	581	85	4.4	.50	.59	.48	911	151	12	432	34
CP	75	5.6	8.04	1079	143	32.6	.04	1.41	1.27	1820	65	25	435	170
Wt-3	100	9.1	4	535	38	11.5				673	83	7.2	254	37
Wt-4	100	7.5	8.3	965	135	22.5				1600	48	16.7	450	
Wt-6	100	8.8	5.5	587	104	8.8	.06			1121	73	9.6	363	112
Wt-7	100	8.7	5.7	836	106	9				1285	86.5	13.5	356	53

4.3 Chloride/Boron ratios

Chloride and boron are two of the more conservative species and once in solution are not readily lost. The exceptions to this are some loss of boron into the steam phase which is only significant at high temperatures, and some uptake of boron into illites. The higher chloride discharges (Sc, WS, and W) have relatively constant Cl/B ratios of 28 to 33, consistent with their confinement in a rhyolite aquifer. The more dilute and lower temperature spring waters (T, Su, TeW, PL, and NCG) have higher Cl/B ratios suggesting that dilution is occurring by low chloride zero boron water. An exception to this appears to be the EFR features which have very low boron concentrations and hence less precision in the data.

4.4 Chloride/Bicarbonate ratios

The high bicarbonate concentrations are derived from the reaction of CO_2 rich waters with the country rock. The diluting fluid in most cases increases the bicarbonate relative to the chloride; i.e this fluid has low chloride and high

TABLE 2: Waikite, Te Kopia, Orakeikorako and Waiotapu Waters Molecular Ratios and Geothermometers

Source No.	Cl/B	Cl/SO_4	Cl/HCO_3	Na/Li	Na/K	TQtz °C	TCH °C	TNa/K °C	TNaKCa °C	TRCor °C	CT °C
Earthquake Flat Road Explosion Crater											
S 5609	21.9	1.1	0.12	145	15.4			226	172	60	26.2
S 5613	22.9	.1	0.29	165	2.4			476	296	87	95.0
S 5617	29.5	.2	0.09	115	5.4			339	246	91	49.4
Pwkohurea Lake											
S 5640		2.4	1.13		3.4			411	241	79	7.7
S 5638	39.0	4.2	0.11	220	10.1			266	205	72	47.5
S 5641	37.7	3.8	0.34	250	9.4			274	209	75	31.2
Nairn's Cold Gassy Spring											
S 5646	45.8	.1		330	3.3			412	244	124	15.9
Submerged Spring											
S 5632	36.9	6.8	0.48	59.6	13.7			236	196	80	41.2
Scalding Spring											
S 5644	32.5	14.3	0.90	33.5	27.8	194	180	178	200	200	89.2
Waikite Scarp Spring.											
S 5651	34.0	11.7	0.79	29.2	30.4	187	173	172	186	186	98.4
S 5670	31.7	11.1	0.87	31.9	24.1			189	199	199	72.4
S 5671	31.5	10.8	0.75	33.2	23.4			191	197	197	48.8
Waikite Springs											
S 5576	25.2	8.0	0.66	33.7	10.4			264	206	116	19.4
S 5577	29.3	9.8	0.62	34.2	11.5			253	203	113	33.4
S 5580	29.8	10.4	0.71	28.9	42.0	163	145	150	147	147	97.5
S 5585	29.5	10.4	0.84	28.2	42.3	161	142	150	160	160	98.9
S 5586	30.3	10.1	0.74	29.5	41.5	158	140	151	147	147	99.5
S 5587	28.4	9.7	0.75	30.0	43.4	150	129	148	145	148	94.5
S 5598	30.5	10.0	0.87	30.5	49.8	133	132	139	139	139	98.6
Tree Spring											
S 5567	31.9	8.2	0.83	37.6	18.1			212	192	188	50.2
Te Waro Scarp Springs											
S 5557	38.2	12.6	0.40	61.4	26.4			182	153	57	36.6
S 5555	36.7	16.3	0.36	61.3	26.1			183	154	48	37.1
S 5551	34.9	10.8	0.51	58.3	24.4			188	156	41	34.9
Otamakokore Stream at Corbett Rd. bridge											
S 5566	32.2	10.0	0.78	37.1	25.2			175	163	145	53.8
Te Kopia											
MF	30.2	13.4	2.7	63.3	43.0			149	138	138	61.5
TKstr	29.1	0.82	3.6	118	2.6			455	286	165	81.0
Tkpo	19.5	0.29		21.4	2.2			489	289	214	54.0
TK1	25.5	12.7	7.4	24.7	10.7	232		260	249	249	99.0
Orakeikorako											
OK2	23.4	14.2	2.2	29.2	14.6	212		231	228	228	99.0
OK4	21.4	10.4	2.3	53.6	17.3	223		215			99.0
OK6	28.3	19.2	0.50	38.8	22.6	181	166	194	177	177	99.0
OK6	28.7	24.7	1.2	30.2	14.9	223		228	223	223	99.0
Spr 661	28.3	15.1	0.23	58.5	43.9			147	142	95	50.0
Spr 674	29.7	18.0	0.67	45.3	38.3			156	154	60	79.5
Spr 664	21.9	17.6	0.67	34.0	23.0			193	173	140	64.0
Spr 120	28.8	9.3	2.8	23.7	11.3	206		255	245		94.0
Spr 741	30.0	9.7	2.1	24.0	11.4	215		254	244		98.5
Spr 343	26.8	10.1	3.3	31.2	14.3	194	182	232			100.0
Waiotapu											
LKG	23.2	16.3	46	41.8	11.6	216		252	245		98.0
CP	22.2	76	18	40.5	12.8			242	230		75.0
Wt-3	28.6	22.0	31	40.4	23.9	182		189	188		100.0
Wt-4	29.3	90		35.1	12.2	218		248	235		100.0
Wt-6	35.7	42	17	32.2	9.6	204		271	251		100.0
Wt-7	29.1	40	42	44.3	13.4	203		238	235		100.0

Geothermometer Sources:

TQtz Quartz-maximum steam loss Fournier & Rowe (1966)
TCH Chalcedony Solubility - Fournier (1973) adapted for maximum steam loss
TNa/K Sodium/Potassium Ratio - Fournier (1983)
Na/K-Ca Sodium/Potassium Ratio with Calcium - Fournier & Truesdell (1973)
TRCor " " " " " corrected for Magnesium - Fournier & Potter (1979)
CT - collection temperature

bicarbonate. Groups Sc, WS and W have the highest chloride and Cl/HCO_3 ratio supporting them being most representative of the deep fluid.

4 5 Chloride/Sulphate ratios

The high sulphate low Cl/SO_4 waters are produced by oxidation of the H_2S carried in the steam, being dissolved and oxidised to sulphate in the near surface waters. This is most evident in the northerly features, particularly at EFR and NCG. Features with these chemical characteristics are usually stagnant or semi stagnant as the sulphate produced accumulates. The hot water pits (S 5613) and hot sediments (S 5617) at EFR, and the NCG certainly fit this description having little or no visible outflow. TeW springs, although diluted, show similar Cl/SO_4 ratios to the less diluted springs. Their moderate flows of up to 0.5 litres/sec preclude the build-up of sulphate.

4.6 Sodium/Lithium ratios

This ratio has been used as a geothermometer (Fouillac and Michard). However, as sodium bearing diluting ground water with zero lithium *can* affect the ratio, the geothermometer has not been applied to the Waikite-Puakohurea waters. However evidence of dilution with non-geothermal waters is seen in the more dilute waters. The Na/Li ratio in the less dilute waters (WS, W, Sc) is 28 to 33. Dilution increases the ratio to 38 (T), 60 (Su), 115-165 (EFR), 240 (PL), and 330 (NCG).

4.7 What is the deep fluid like?

The evidence fiom the differences in chloride concentrations, Cl/HCO_3, Cl/SO_4, Cl/B, and Na/Li point to the central groups of springs; i.e. Sc, WS, and W, being the most representative of the deep fluids. However there is no clear evidence to indicate how much dilution and modification to the deep water has occurred in these discharges. Comparison between spring and bore discharge chemistry at Orakeikorako, which is situated at the SW end of the Paeroa Scarp Fault, suggests that the more highly mineralised springs there are not too dissimilar to the deep fluid. If similar conditions exist at Waikite-Puakohurea then the deep fluid composition can best be correlated with that of Sc, WS and W waters. Assuming that adiabatic boiling has occurred as the waters ascended to their point of discharge the bores would discharge water of similar composition to the springs:-

Cl	= 200-300 mg/l;	Cl/B	= 25-30;
Cl/SO_4	≥ 15;	Na/Li	= 25-30.

However, the chloride concentrations could be somewhat higher as the high resistivity layer down to 600m discovered by Bromley (1992) to exist between Wailcite-Puakohurea and Te Kopia could be downwards flowing cold water. If so the Wailcite-Puakohurea waters may all be diluted with respect to the deep water.

5. EVIDENCE FROM GEOTHERMOMETERS

Table 2 includes some calculated geotemperatures derived from silica and alkali concentrations. For most of the features there is a large spread between the minimum and maximum indicated temperatures. Some of the calculated temperatures are nonsensical (e.g. very high TNa/K values for S 5640, S 5646, which are cold waters and for the stagnant waters of S 5613 and S 5617). These are included in Table 2 to illustrate the care which has to be taken when applying formulae. By and large, data from less than boiling discharges should not be used.

5.1 Silica Geothermometers

The silica concentration of geothermal aquifers is usually controlled by the solubility of quartz at the aquifer temperature. When sampling well discharges it is assumed that the water looses steam adiabatically as it moves up the well and pressure is reduced. The SiO_2 concentration at 100°C is then easily related to the temperature of the water supplying the well (Mahon (1966), Fournier and Rowe (1966) etc). Greater difficulty is encountered when relating the SiO_2 in spring waters to deep temperatures. As the water moves towards the surface a number of processes can alter the SiO_2 concentration. Steam loss increases the SiO_2 concentration. Loss of temperature, caused by steam loss, by dilution with a cooler water or, less commonly, by conductive heat loss, tends to lower the SiO_2 concentration as it adjusts to a lower solubility. This may in part be offset by another more soluble form of silica controlling the solubility at lower temperatures; e.g. the change from *Quartz* to Chalcedony occurs between 200°C and 180°C. It is especially difficult to interpret those surface waters that are stagnant, semi-stagnant, and or have below boiling temperatures. Thus for the Waikite-Puakohurea waters only flowing and boiling or near boiling springs are used (see Table 2). For these, the Waikite Springs indicate up to 145°C, Waikite Scarp Spring gives 173°C to 187°C and the Scalding Spring 180°C to 194°C. The less diluted water gives the higher calculated temperature.

5.2 Sodium/Potassium geothermometers

Base exchange reactions between Na and K in alkali feldspars proceed very slowly at temperatures below 300°C and where reservoir temperatures are changing in response to production or as waters flow towards the surface. Therefore the tendency is to use the Na/K geothermometer to estimate possible higher temperatures and the other geothermometers to assess the lower temperature of the shallower reservoirs in which the waters reside for a relatively short period of time. This may be appropriate for wells but is fraught with danger if *applied* to spring waters. There is no single universally best Na/K geothermometer because the ratio at a particular temperature depends on the particular mined assemblage and structural states of the minerals with which the water equilibrates.

At the Waikite-Puakohurea area this is complicated by the dilution that has probably occurred and the high HCO_3 formed by CO_2 reaction with the rocks which will also have changed the alkali concentrations and their ratio.

The Na/K-Ca geothermometer (Fournier and Truesdell, 1973) takes account of reactions involving exchange of Na^+, K^+, and Ca^{2+} with mineral solid solutions. This is entirely empirical and precipitation of calcite gives estimated temperatures that are too high. Fournier and Potter (1979) noted that waters with high magnesium contents gave erroneously high temperatures and devised a correction for this. An examination of the data in Table 2 shows that the low temperature springs (EFR, PL, SuS, and TeWSS) have all adjusted to below 100°C when the magnesium in taken into account. Those springs that show dilution of the dominant water in a particular group, e.g. S 5576 and S 5577 in the Waikite group, have a lower Na/K and hence higher calculated temperature than the less diluted waters. This indicates that the diluting fluid has a lower Na/K than the deeper water and that the high geotemperatures exhibited by the dilute waters are unreliable.

Probably the most reliable indicator is the least diluted water, Sc, which indicates 180°C to 200°C, although W features appear to be discharging from a 145°C to 160°C aquifer.

6. TRIANGULAR GRAPHS

6.1 $Cl\text{-}SO_4\text{-}HCO_3$

Figure 2 shows the different types of waters encountered in the Waikite-Puakohurea Springs. None of them lie in the "mature" field as defined by Giggenbach (1991). The NCG and two of the EFR features are in the steam heated waters field, as are the Te Kopia acid surface waters. The rest are termed peripheral waters and are less mature than any of the spring waters from Orakeikorako, Murphy's Farm, and Waiotapu. Among the W-P waters the different groups are distinguishable, e.g the PL features S 5638 and S 5641 being close to the HCO, apex and the TeW, WS, W, and Sc features trending away from the HCO, apex towards the Cl apex. This is in line with the trend of decreasing dilution and confirms that the Sc, WS and W features will gives the best indicators of deeper conditions although their position in the Peripheral field suggests that all extrapolations to depth should be treated cautiously.

6.2 Li-Rb-Cs

Figure 3 shows the relative proportions of lithium, rubidium and caesium in the waters. Dissolution of rhyolite would give a composition denoted by the triangle in the Rb comer. At high temperatures (>300°C) Rb is taken up in illite and the composition of the water moves away from the Rb apex. The position of the Waiotapu and Orakeikorako waters closer to the Rb apex than the W-P waters confirms that the latter are less mature than the former. Among the W-P features themselves WS waters appear closest to the upflow whilst the WS and Sc are further down an outflow path where Cs is taken up in zeolites. The apparent difference between this scenario and that indicated by the $Cl\text{-}SO_4\text{-}HCO_3$ diagram and the dilution pattern can be resolved. The $Cl\text{-}SO_4\text{-}HCO_3$ plot show where HCO, rich diluting water is affecting the features and the Li-Rb-Cs plot show removal of alkalis by formation of mineral alteration products.

7. COMPARISON WITH TE KOPIA, ORAKEIKORAKO AND WAIOTAPU WATERS

Te Kopia features are mainly steam heated pools and are classified as acid-sulphate waters (Sheppard and Klyen, 1992). The spring at Murphy's Farm is the sole neutral chloride water. TK1 is a 945 m drillhole which discharges neutral, 300 mg/litre, chloride water similar to the Orakeikorako boiling springs. Waikite and Waikite Scarp waters contain only 50% of the chloride concentration of the Orakeikorako waters, i.e. are much more dilute, Figure 2 shows that the Orakeikorako wells discharge the same type of water as the nearby springs (c.f. Tables 1 and 2). As the wells are up to 1350 m deep, this suggests that the low chloride water is not an artefact of shallow dilution, but represents the deep reservoir. If a similar situation exists at Waikite-Puakohurea, then the deep aquifer will have a composition similar to that of the dominant Waikite Springs, i.e. bicarbonate waters of not more than 200°C.

The Waiotapu waters are east of the Paeroa Range and are more typical of the high chloride near neutral geothermal waters of the Taupo Volcanic Zone and are quite dissimilar to the Paeroa Fault Scarp waters.

8. GAS DISCHARGES

Glover et al(1992) reported gas analyses from six features in the W-P area. Giggenbach's formulae for the H_2/Ar and CO_2/Ar geothermometers (Giggenbach, 1991)) were applied to the data. According to him the H_2/Ar temperature is usually quite close to the measured discharge temperatures, and the CO_2/Ar temperature possibly reflects a deeper temperature. As most geothermal gas contains much larger amounts of CO, involved in any equilibration process, as compared to H_2, the former will be slower to adjust to changing temperatures. The main features of each analysis are given below.

EFR - S 5610. The gas from this lake contained 24 to 68 mole% air (two samples). TH_2/Ar = 65°C - 86°C; TCO_2/Ar = 199°C - 209°C.

EFR - S 5618. Although the discharge temperature was 98°C the air content was 78.4 mole%. TH_2/Ar=154°C; TCO_2/Ar=198°C.

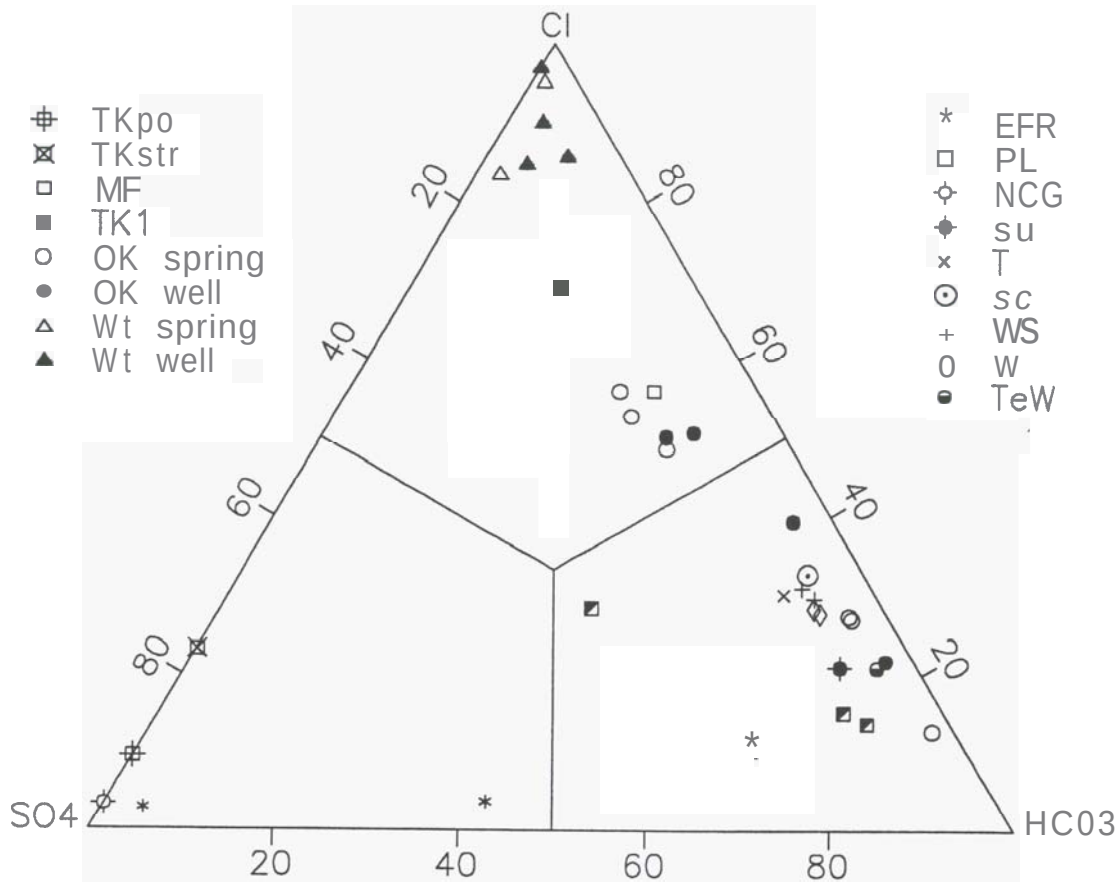


Figure 2: Relative Cl, SO, and True HCO, contents of waters on weight basis,

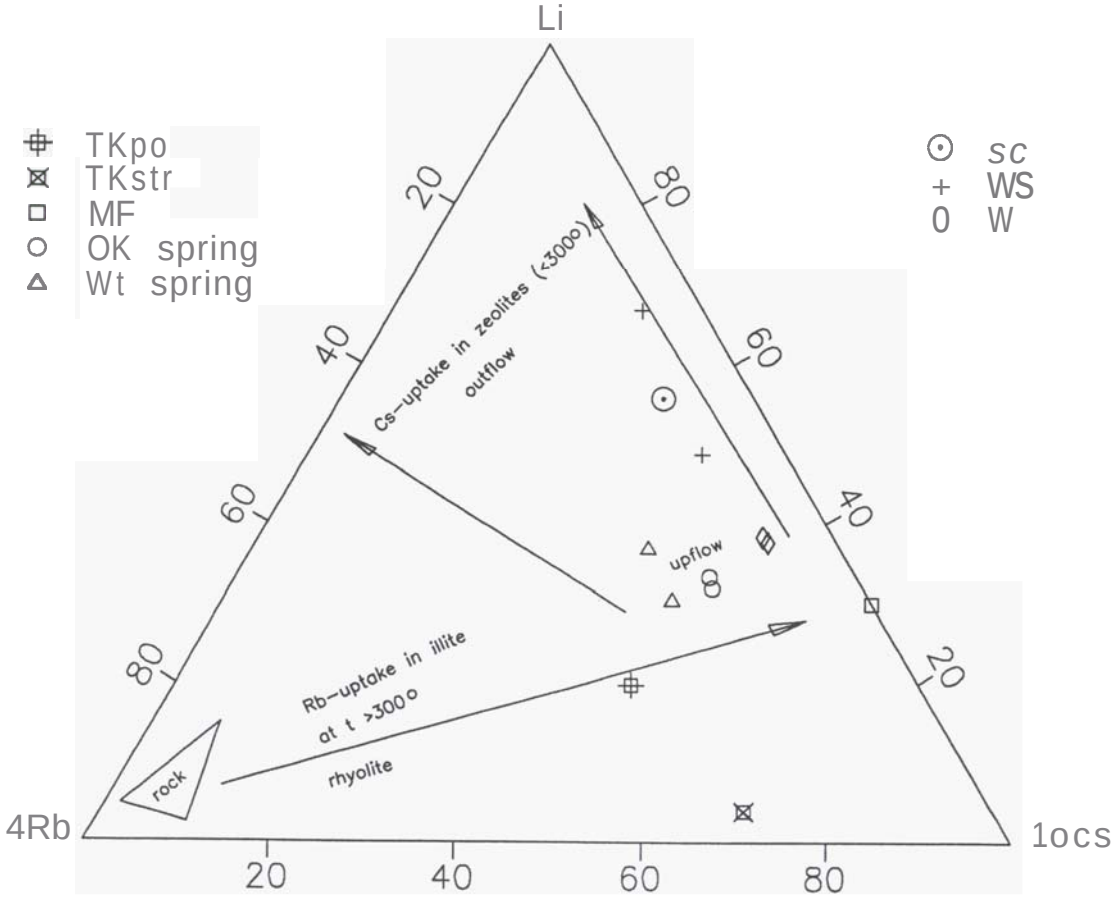


Figure 3: Relative Li, Rb and Cs contents of the waters on weight basis.

NCG = S 5646. This sample collected at 16.3°C was virtually air free. CO_2/H_2S =1040 and CO_2/H_2 = 820000, both these indicate that the gas has come a long way from its source. The low H_2S content agrees with the high SO, in the spring water (see earlier). TH_2/Ar = 14°C, close to the discharge temperature, whilst TCO_2/Ar = 265°C.

Waikite Scarp Fumaroles, S 5664 and S 5660. The former, discharging at 88°C, was mainly air (91%). The latter at 98°C, had only 3% air and TH_2/Ar and TCO_2/Ar of 131°C and 259°C respectively.

Schiltz Farm Fumarole, S 5505. Located east of the Paeroa Scarp, this air free discharge had more characteristics of a geothermal fumarole close to a geothermal aquifer than any of the features sampled. CO_2/H_2S = 14; CO_2/H_2 = 160. The hydrogen and carbon dioxide temperatures were in close agreement, 274°C and 265°C respectively.

In summary the gas data indicates that the northern features, EFR and NCG are further away from the upflow than the WSS fumarole. Temperatures at depth are likely over 200°C but the steam has travelled far from a source of that temperature. The Schiltz Farm fumarole is closer to a hot source, but this may be different to that supplying the W-P area.

9. HEAT FLOW

The Otamakokore Stream drains all Waikite features sampled with the exception of Te Waro Scarp springs, and possibly the EFR features. The heat flow (above 12°C) is 43 MW (c.f. 46 MW measured by Healy (1952)). This is similar to the heat flow into the Puarenga stream at Whakarewarewa. However the Chloride flux of ca. 30 g/sec. is about half the Whakarewarewa flow.

These data are in accordance with the lower chloride in the aquifer at Waikite-Puakohurea.

10. CONCLUSIONS

1. A bicarbonate-chloride reservoir underlies the Waikite-Puakohurea springs and calcite deposition could be a problem if drilling was undertaken.

2. Deep water temperatures are probably not much above 200°C.

3. Scalding Spring, Waikite Scarp and Waikite Springs are closer to an upflow zone.

4. The waters are similar to but more dilute and cooler than the Te Kopia and Orakeikorako waters.

5. Heat flow in the Otamakokore Stream is 43 MW, similar to that from Whakarewarewa.

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