# CHEMISTRY OF THE WELL DISCHARGES AT NGAWHA

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## ABSTRACT

Discharge and downhole water and gas samples from four of the six deep wells drilled at Ngawha, namely NG1, NG2, NG4 and NG9, have been analysed. The last two of these tapped a reservoir calculated to be of total discharge composition of 1240 ppm $Cl^-$, 410 ppm silica, 870 ppm boron and about 190 ppm bicarbonate. The gases are about 1.14 wt % of the total discharge, about twice that of Broadlands, and ten times that of Wairakei.

Geothermometers indicate two reservoirs, one at about 230°C, and one at >400°C. Other indicators show that the system is old, sealed, and in proximity to a magma body.

Six deep geothermal wells, NG1, NG2, NG4, NG5, NG7 and NG9 have been drilled since 1964.

NG1 was discharged in 1965 and analyses of the discharge have been reported by Ellis and Mahon (1966). The discharge was extremely unstable, gassy (up to 50 wt % gas) and of variable composition Downhole samples from NG2 were collected in February 1978, bleed samples in April 1978 and discharge samples in June of that year. Unfortunately this well was discharged vertically in an uncontrolled manner and so physical data from which discharge enthalpy could be calculated cculd not be collected. The well eventually went dry.

NG4 and NG9 were both discharged in November 1979, although NG4 had had downhole samples taken in March. Both of these wells had a prodigious output - 350 and 540 tonnes per hour respectively, and at an enthalpy varying between 950 to 1000 J/g. The production of such a large volume of water with a high boron content in an area with no major watercourses - located, in fact, on the east-west dividing watershed, limits the disposal volume of discharge into the local watercourses, and for this reason the discharges had to be of limited duration.

The chemical results reported here are for NG2, NG4 and NG9 only. NG1 discharges have been reported and discussed by Ellis and Mahon (1965) and Giggenbach and Lyon (1977).

The chemical composition of more than seventy water and twenty five steam samples from these three wells have been presented by Giggenbach and Sheppard (1980). Table 1 gives typical analyses for Ngawha well discharges. The decision to take the large number of discharge samples from NG4 and NG9 was based on the experience with NG1 where fluid compositions changed markedly with variations in discharge conditions. This proved to be unnecessarily pessimistic.

Downhole samples are usually collected ahead of major discharge periods in order that a concentration profile for the well may be determined, perhaps allowing major feed zones to be detected. This is rarely the case, and at Ngawha, in NG4 and NG9, the presence of a strong interzonal downward flow below 700m precludes the presence of a deeper fluid.

Figure 1 condenses the information obtained from the downhole and bleed samples in terms of chloride and depth or volume discharged. The observed patterns for NG4 and NG9 closely correspond to those expected., In NG2 the decrease in chloride content from around 1000 ppm at 550 m and 930 m during February 1978 to <500 ppm in April may reflect the low permeability conditions for this well allowing drilling and well testing fluid to remain in the vicinity of the well and to even dilute the fluid at depth. The increase in chloride to 1130 ppm at 1100 m after a short period of discharge (on 21.6.80) during which the well ran almost dry, suggest the thermal fluid

**WATER**

| Well | Date | WHP b,a | H J/g | ST °C | $X_w$ | pH | Li | Na | K | Rb | Cs | Mg | Ca | $NH_3$ | $SiO_2$ | B | Cl | $SO_4$ | $HCO_3$ | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NG 1 | 6.65 | 12.9 | 958 | 100 | .76 | 7.6 | 10.3 | 820 | 70 | - | - | - | 23* | 56 | 480 | 1004 | 1360 | 16 | 295 | 0.7 |
| NG 2 | 20.6.78 | 14.1 | - | - | - | 6.5 | 10.7 | 861 | 80 | .23 | .48 | 0.6 | 16.0 | 74 | 426 | 816 | 1162 | 42 | 590 | 1.2 |
| NG 4 | 21.11.79 | 14.6 | 1023 | 161 | .83 | 7.6 | 13.5 | 1025 | 90 | .32 | .76 | .11 | 2.9 | 44 | 464 | 1080 | 1475 | 27 | 298 | 2.1 |
| NG 9 | 27.11.79 | 16.4 | 1000 | 170 | .86 | 7.5 | 12.9 | 1011 | 90 | .32 | .72 | .10 | 2.9 | 47 | 471 | 1060 | 1437 | 35 | 486 | 2.0 |

**STEAM**

| Well | Date | WHP b,a | H J/g | ST °C | Ys | Xg | $CO_2$ | $H_2S$ | $NH_3$ | He | $H_2$ | Ar | $O_2$ | $N_2$ | $CH_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NG 2 | 20.6.78 | - | - | - | - | 172 | 927 | 5.30 | 2.31 | .013 | 5.70 | .009 | .004 | 5.1 | 54.1 |
| Ng 4 | 21.11.79 | 14.7 | 1023 | 161 | .165 | 25.1 | 945 | 11.2 | 8.3 | .004 | 3.04 | .002 | .005 | 2.3 | 29.9 |
| NG 9 | 27.11.79 | 16.0 | 100 | 170 | .137 | 29.8 | 948 | 11.8 | 11.4 | .004 | 2.55 | .007 | .027 | 2.6 | 24.0 |

* Ca + Mg

TABLE 1. A selection of typical water and steam discharge compositions for the four Ngawha wells sampled. All solutes in ppm, steam fraction, Ys in mol/mol, gas fractions Xg and the Xi in mmol/mol, water free. Data from Giggenbach and Sheppard, 1980, and Ellis and Mahon, 1965.

feeding **NG2** to be similar to that produced from **NG4** and **NG9.**

The pattern of increase in solute content with bleed discharge time may be used to complement downhole samples and to obtain additional information on variations in solute content within the shut-in drillhole. Taking account of the discharge rate and diameter of the drillhole, assuming a uniform rise in the fluid column, composite solute/depth and solute/time curves can be derived, as is shown by the dotted lines in Figure 2 for **NG4** and **NG9.** In both of these wells, the fluid occupying the solidly cased part of the well is affected by dilution with low chloride waters, perhaps from condensation. The close to uniform compositions derived from within the slotted casing corresponds to that of the water entering the wells below 600 m, and produced during subsequent full discharges.

*An* analysis of the silica-chloride relationship in the full discharge samples is shown in Figure **2.** Since chloride is largely inert in geothermal fluids, but silica is affected by chemical dissolution or precipitation, the effects of various processes for **NG2** and NG4 and **9** can be determined from such a plot.

Correction for steam loss in the samples gives an average chloride content of 1240 ppm and silica content of 410 ppm. The plotting of this point in Figure **2** further gives an indication of the processes affecting the samples of all types.

**NG2** initial downhole and bleed sample compositions fall well above the simple dilution lines, indicating equilibration of diluted waters with high temperature rocks. Subsequently collected full discharge samples suggest steam loss from waters of low chloride content, rather than the deep waters found in **NG4** and **NG9.** Such behaviour is explained by taking into account the low permeability conditions of **NG2** causing the discharge tb intermittently run dry, with the discharge produced likely to represent a partly evaporated mixture of deep thermal water and residual drilling and condensate fluids.

The first three bleed samples for **NG4** occupy positions beneath the dilution line and alos far from the dashed curve representing the position of data points for the deep thermal waters after dilution **by** surface water followed by complete silica requilibration. The trend of the data points, however, suggest the gradual transition from a **900** ppm chloride water with a low silica content to a water closely resembling the typical deep water. The'only possible process giving rise to the observed low $SiO_2$ contents at still high chloride contents is conductive cooling of the waters accompanied 'by silica-deposition. Points above the total discharge composition represent steam loss from the deep water.

The evaluation of the temperature of the deep fluids by the use of chemical

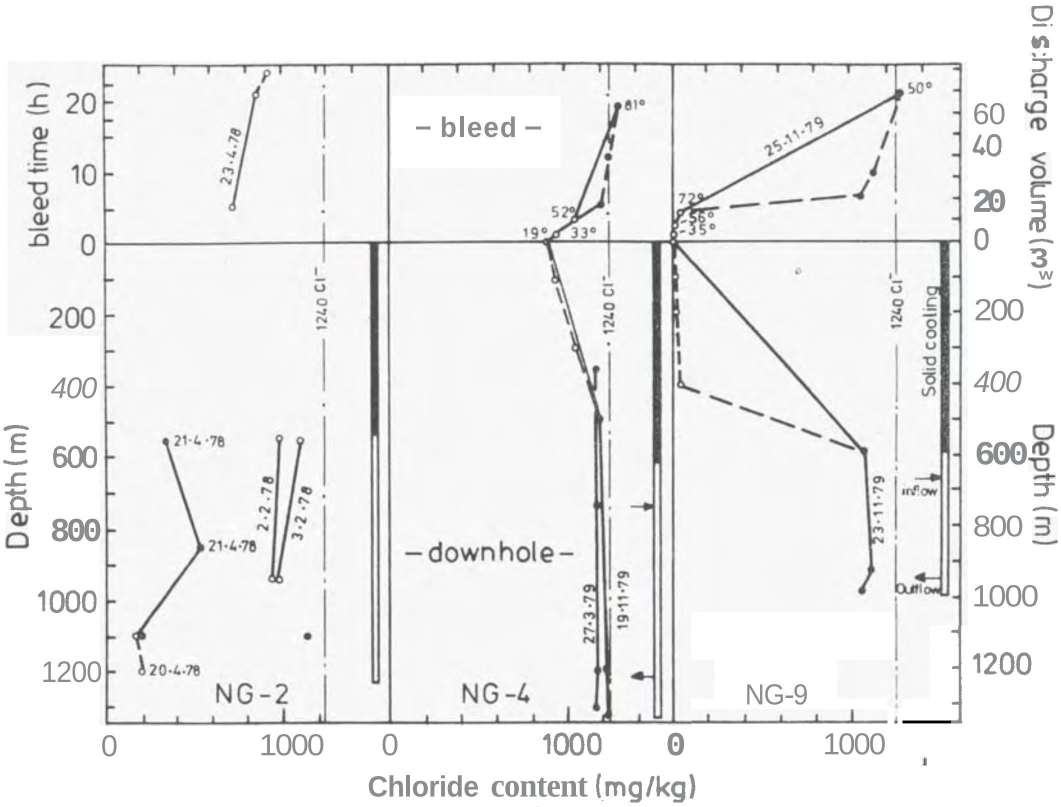


FIGURE 1. Variation in chloride contents for Ngawha wells with depth (downhole samples) and time during bleed, at 1 $ls^{-1}$. From Giggenbach and Sheppard, 1980.

geothermometers gives quite consistent results about 230°C. Gas geothermometers, on the other hand, and gas isotope geothermometers indicated equilibration temperatures above 400°C. This is interpreted to indicate that initial equilibration of the various chemical components has occurred in a high temperature reservoir >400°C, but that a long residence time for waters in a 230°C reservoir has allowed reequilibration to this temperature for aqueous but not gaseous species.

The Figure 3 illustrates a total nitrogen-helium-argon plot, with the characteristic location of most New Zealand geothermal and some non-geothermal gases. The Ngawha springs lie on a tie line linking high helium ("crustal") systems, typified by Morere, Te Puia and Hanmer Springs, and high nitrogen ("magmatic") systems, characterised by Ngauruhoe and White Island. The initial high helium in bleed and gassy samples suggests the accumulation of gas, and the high nitrogen content in NG4 and NG9 is thought to indicate the proximity of a degassing "magma".

The large $\delta^{18}O$ shift of the water to high values is held to be evidence of prolonged interaction with the host rock in the area (Blattner and Bunting, 1980), and also that there has only been a small throughput of water in the whole history of the geothermal system. Preliminary argon isotope measurements indicate an enrichment in radiogenic argon - a sure indicator that there is little input of meteoric water into the system.

## REFERENCES


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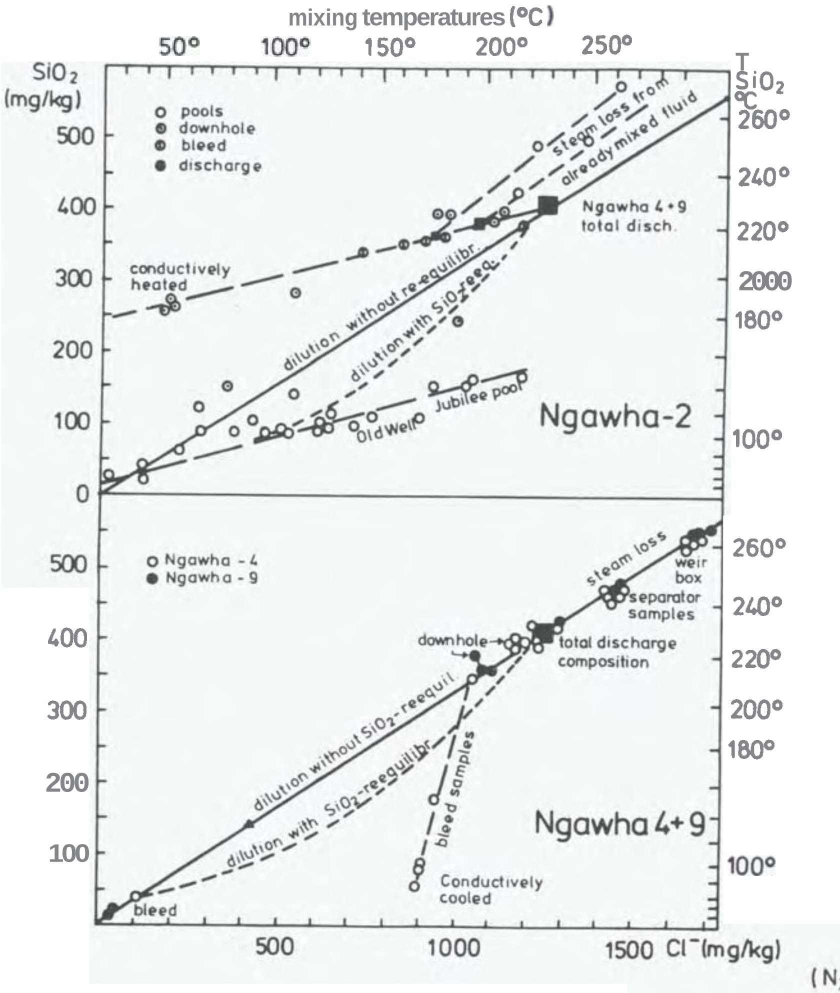


FIGURE 2. Plot illustrating dilution, steam loss, and conductive heat transfer processes affecting Ngawha well (and pool) discharges. From Giggenbach and Sheppard, 1980.

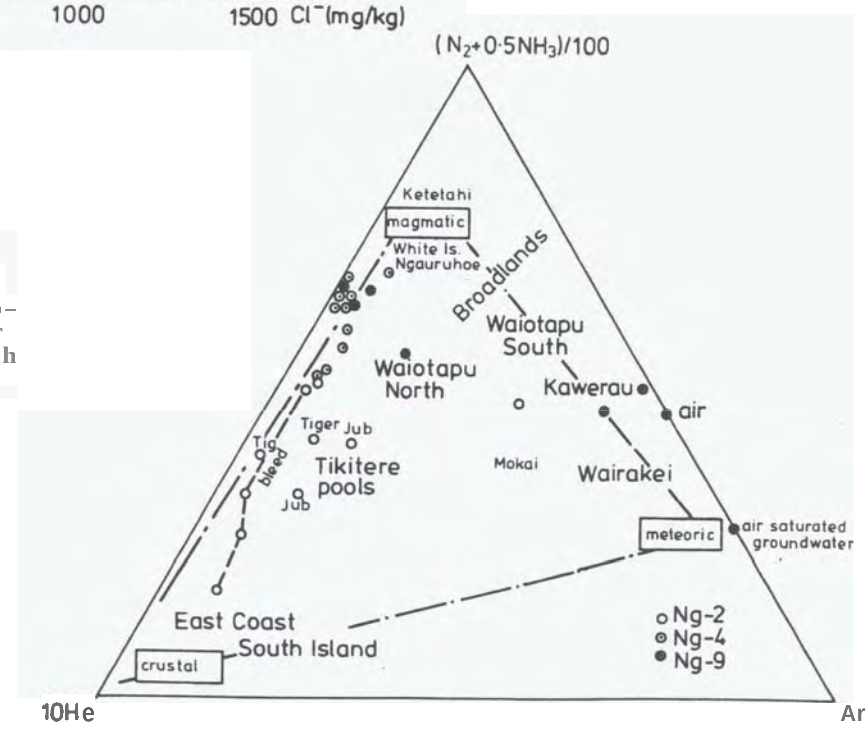


FIGURE 3. Relative total Nitrogen, Helium and Argon contents of New Zealand geo- thermal, volcanic and other discharges. From Giggenbach and Sheppard, 1980.

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