CONCENTRATION OF BORON IN SOILS AROUND DRILLPADS IN THE NGAWHA GEOTHERMAL FIELD, NORTHLAND, NEW ZEALAND

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SUMMARY - Boron concentrations of 156 soil samples near the drillpad of Ngawha drillwell Ng 13 average 41 µg/g. In 1983 this well discharged 88,000 tons of alkali chloride water (B content = 1150 µg/g), derived form the greywacke reservoir. By contrast 62 soils near the drillpad of Ng 15 had average boron concentrations of 2.09 µg/g. Since drillhole Ng 15 has never been discharged, these results show that boron carried by the Ngawha thermal fluids becomes readily fixed in soils in the area of discharge.

1. INTRODUCTION

The Ngawha geothermal field is **located** about 5km east of Kaikohe, in Northland, New **Zealand (fig** 1). It is being considered for power development **and** potential environmental impacts of this are now **being assessed.**

The geothermal waters in the **deep reservoir contain** high concentrations (up to **1230** µg/g) of boron which is toxic in very **small** doses to **plants, and** also **has** toxic effects **on** animals at higher concentrations. Discharge of boron-rich **fluids from** wells at Ngawha thus presents a potential environmental **hazard.**

An investigation of soils **was undertaken** to assess their **boron** retention nine years after surface discharge of thermal waters occured.

The results of **this** study are presented in this paper.

2 INVESTIGATION HISTORY

The earliest phase of geothermal exploration at Ngawha concluded in **1964 with one** deep bore **being** drilled. From **1981** to **1983 furthur** exploration and development continued with nine more wells **being** drilled. The **deepest** well drilled was completed to 2333 m (Ng 13).

In 1991 a Joint **Venture** Company was **formed** with the **intention** of developing the **resource** for electricity generation, and at present statutory approvals required (under the Resource Management Act) to **allow** development to **proceed** are **being** considered **by** the Northland Regional **Council** (KRTA, 1992). The only present **use** of the resource is for **bathing.**

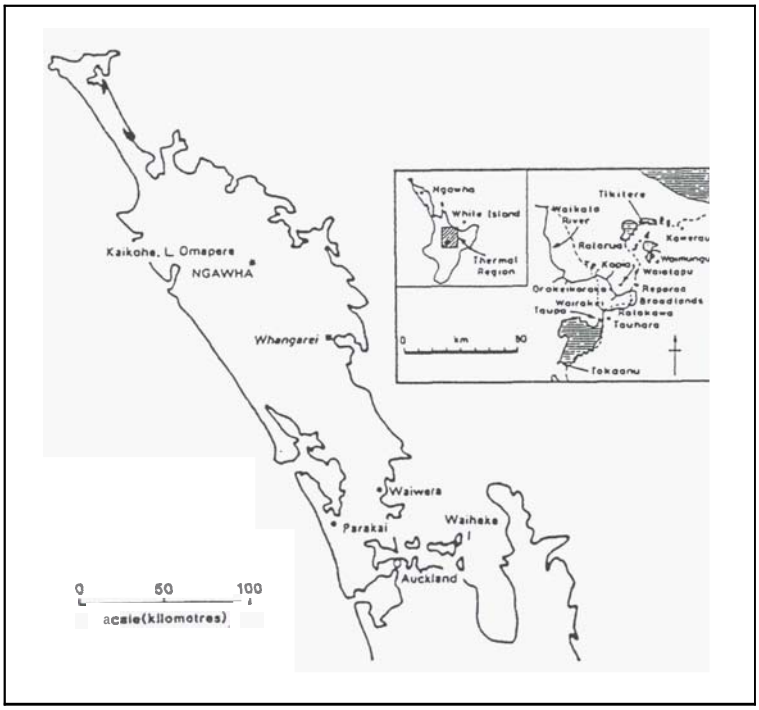


FIGURE 1. Location **of** the Ngawha geothermal field in Northland, New Zealand.

3. THE NGAWHA GEOTHERMAL RESOURCE

The Ngawha region lies within a Holocene-Quaternary volcanic area (Cox, 1985) known as the Kaikohe Basalt Field (Skinner, 1981), which is formationally included in the Kerikeri Volcanic Group (Kear et al. 1961). The geothermal field is covered by a 500-700 m thickness of Cretaceo-Tertiary sedimentary rocks of marine origin known as the Northland Allochthon (Ballance and Sporli, 1972). These sedimentary rocks are comprised of a high proportion of clays and silts, and as a result, have low intrinsic permeability. The sediments are underlain and overlapped by Permo-Jurassic metagreywackes and meta-argillites of the Waipapa Group which form the regional basement. Overlying the major formations in the Ngawha area are thin layers of recent basalts and lake sediments (KRTA, 1992).

The Ngawha geothermal field lies within a small topographic basin and is centred on the Ngawha Springs Village. The bulk of the surface expression of the geothennal system consists of hot water springs and gas seepages, that are associated with mercury, sulphur and trace amounts of other metals (KRTA, 1985).

The productive Ngawha reservoir consists of the permeable volume within the greywacke basement (DSIR, 1985) whose thickness is thought to be in excess of 1000m (KRTA, 1992). The low permeability Cretaceo-Tertiary sediments act as an aquitard to the geothermal fluids upwelling from the greywacke reservoir. The temperatures near the base of the aquitard are about 210°C to 230°C, and the highest temperature (300°C) attained is in the deepest well (Ng 13).

4. ENVIRONMENTAL CONSIDERATIONS

A number of constituents of environmental concern are present in the Ngawha thermal waters, including : Na, Cl, As, F, B, Hg, Li, CO_2, H_2S, NH_3 and Rn-222 (DSIR, 1985).

The average concentrations of B, Cl and Hg in the deep reservoir fluid (as total discharge) are given in Table 1, and are compared to data for the same constituents in the Broadlands and Wairakei systems. As a consequence of the composition of the Ngawha fluids, discharge of some of the thermal fluids at the surface, either to waterways or ground soakage, will be prohibited (KRTA, 1992). Thus the most likely option for disposal of separated water from a development at Ngawha is by reinjecting the fluids. Constituents that are carried over in the steam phase could be dispersed by a cooling tower (DSIR, 1985).

5. SCOPE OF THE STUDY

The aims of this study were achieved by firstly measuring the boron levels in soils around a well that had been discharged (Ng 13), in 1983. Boron levels around well Ng 15 were also measured to act as a control site, as this well was never discharged.

Bore Ng 13 was completed in 1983 to a depth of 2333m and bore Ng 15 was completed in 1982 to a depth of 431m.

Boron was also measured in separate soil components (eg, drilling chips, plant material), and in surface fluids, pine needles, and soils distal to the bore sites.

Table 1 : Concentrations of boron, chlorine and mercury in Broadlands, Wairakei and Ngawha Deep Reservoir (total discharge) fluids (in mg/kg).
(From DSIR, 1985).

WELL	BROADLANDS 11	WAIRAKEI 72	NGAWHA *
Cl	1213	1280	1199
B	33	23	873
Hg	0.00 16	0.0008	0.028

* Average concentrations for wells NG 2, 3, 4, 8, 9, 11, 12, 13, and 18 (DSIR, 1985)

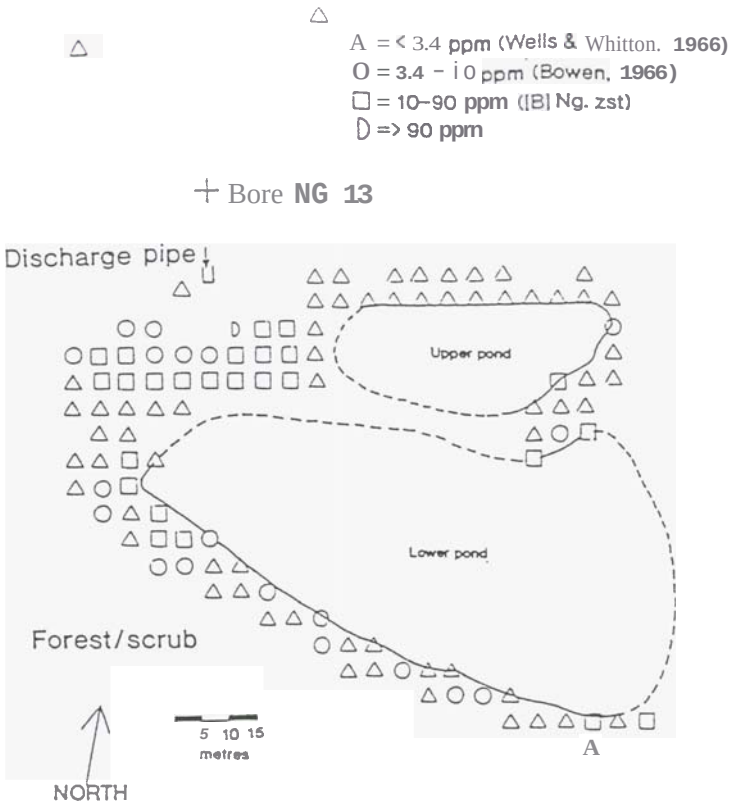
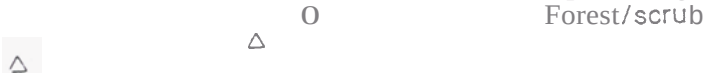


Figure 2 : Boron concentrations in soils at 3 cm depth at Ng 13



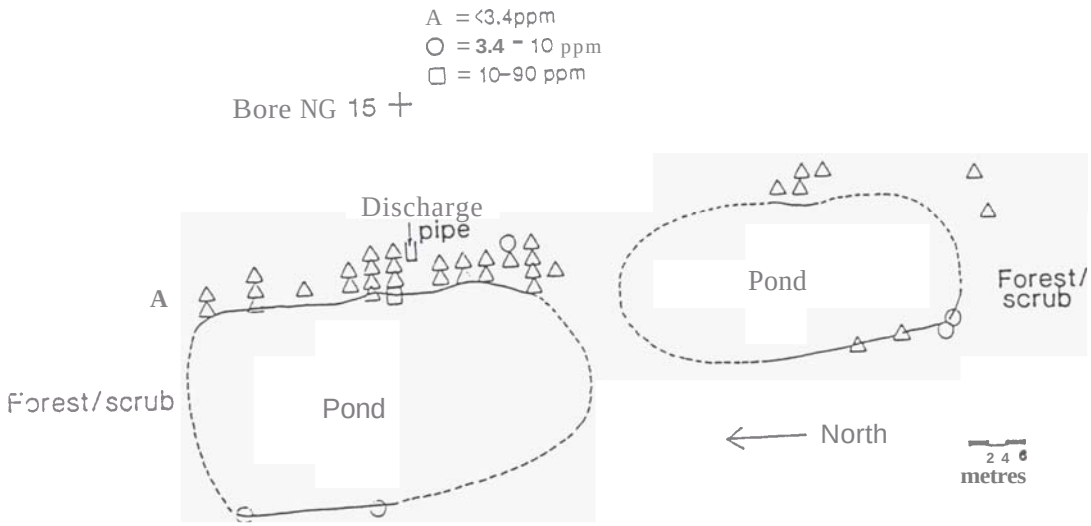


Figure 3 : Boron concentrations in soils at 3 cm depth at Ng 15

Note : The boron concentration of average New Zealand soils = 3.4 ug/g (Wells **and** Whitton, 1966).
The boron concentration of soils worldwide = 10 ug/g (Bowen, 1966).
The boron concentration of the Ngataturi siltstone (a common surface outcrop) = 90 ug/g (Ellis **and Sewell,** 1985)

The distances of both bores from Ngawha Springs (the nearest area of natural surface discharge) is 500 m away, too far for the springs to have added boron to the soils at these two bore sites.
Bore Ng 13 and Ng 15 are 370 m apart, and this is also a great enough distance for the discharge from bore Ng 13 to not have affected Ng 15 soils.
The clay mineralogy of these soils was studied to look for possible relationships between boron levels and clay type.

6. METHODS

Soils were sampled on a grid pattern at evenly spaced intervals around the wellhead and holding ponds (Figures 2 and 3). All samples were taken at 3 cm depth. At some sites samples were taken down to 60 cm depth. Within some of the holes dug for multiple depth sampling, the water table was encountered. After allowing a period of 24 hours for the water level to stabilise, filtered water samples were taken for boron analysis and the water level measured. Needles from pine trees (which have grown near the bores since well pad construction) were also sampled and analysed for boron.

Soil samples were dried at < 30°C , then split and sieved (to between 2.80 mm and 1.0 mm). Following this the soils were leached in ultrapure water for five hours in a boiling water bath and the filtered leachate was analysed by ICPAES. Pine needles were ashed at 500°C, then leached in the same way as the soils. Fluid samples taken in the field were filtered before analysis by ICPAES.

7. RESULTS

The boron concentrations of soils around bores Ng 13 and Ng 15 are presented in Figures 2 and 3. Bore Ng 13 was discharged to the south, thus samples that were taken to the north of the wellhead were assumed to be unaffected by direct discharge of fluids from the bore, and were thus considered local background samples. Boron concentrations in the soils around Ng 13 (mean average = 41 µg/g) are generally a lot higher than at Ng 15 (mean average = 6.5 µg/g), with a concentration of higher B soils present in the area of direct discharge (Figures 2 and 3).
For bore Ng 13, 87 out of 156 samples had boron concentrations higher than that of the average New Zealand soil, and 98 out of 156 had concentrations higher than the greatest local background samples (2.09 µg/g). For bore Ng 15, 10 out of 62 samples had boron concentrations exceeding the average New Zealand soil. The boron concentrations of soils increases with depth at the Ng 13 site with values ranging from < 1 µg/g to 520 µg/g.

The clay mineralogy of samples from bores Ng 13 and Ng 15 is dominated by illite, smectite and the kaolin group. The adsorption capacities of these clay types for boron varies, with illite having greater boron adsorption capacity than kaolinite, and kaolinite greater than smectite (Hingston, 1963). This variation in adsorption capacity does not appear to be a controlling factor in the levels of boron found in the soils measured. Two samples taken ten metres apart, in the area of direct discharge at Ng 13, contained 167 µg/g (sample 35) and 107 µg/g (sample 37), with the clay mineralogy of the higher boron soil (35) comprising only smectite, whereas the other comprised illite and kaolinite.

The boron concentrations of near surface fluids at Ng 13 are between 0.23 - 2.8 µg/g which is higher than at Ng 15 (.06 - .09µg/g). Some Ng 13 waters exceeded the World Health Organisation recommended limit for the boron concentration of irrigation waters (1.0 µg/g).

As part of this study experimental work has been undertaken to assess the capacity for soils to adsorb boron. This work involved saturation of soils with a fluid similar to the discharge from bore Ng 13 (B=1150 µg/g, Cl=1680 µg/g).
Preliminary results show that the capacity for these soils (that previously had low boron concentrations) to adsorb boron is high. Increases of 480 to > 700 times that presently in the soils indicates that they are well below their saturation capacity for boron.

8. CONCLUSIONS

It appears from a comparison of the boron concentrations in soils and near surface fluids at Ng 13 and Ng 15, that release of geothermal fluids from Ng 13 has increased the boron content of soils over which the fluid was discharged. The soils at Ng 13 are at present below their maximum boron adsorption potential, as determined from experiments.

9. ACKNOWLEDGEMENTS

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9. REFERENCES

Bowen, H.J.M **(1966) :** Trace elements in biochemistry. Academic Press, London.

Ballance, P. F. and Sporli, B.K. **(1972)** : Northland Allochthon. J. Royal Soc. NZ 9:259-275

Cox, M.E. **(1985)** : Geochemical examination of the active hydrothermal system at Ngawha, Northland, NZ : Hydrochemical model, element distribution and geological setting. D Phil thesis, University of Auckland.

Cox, M.E. and Browne, P.R.L. **(1991)** : Geochemistry of groundwater and thermal waters in the Ngawha area and elsewhere. Proc. 13th Geothermal Workshop 1991, Auckland University.

DSIR Geothermal Coordination Group **(1985) :** The Ngawha Geothermal Field : new and updated scientific investigations. DSIR Geothermal Report No. 8

Ellis, A.J. and Sewell, J.R. **(1985) :** Boron in waters and rocks of New Zealand hydrothermal areas. NZ Journal Science 6:589-606

Hingston, FJ. **(1963)** : Reactions between boron and clays. Aust. J. Soil Res., 2:83-95

Kear, D. et. al **(1961)** : Sheet 1, North Cape **(1st** Ed.). Geological Map of New Zealand 1:250,000 M.Z. Geol. *Surv.*, DSIR, NZ 1p

KRTA Ltd **(1985)** : Direct use of the Ngawha Geothermal Resource. NZ Energy Research and Development Committee Report no. 109

KRTA Ltd **(1986) :** Investigation of factors controlling boron concentrations in groundwaters of the Auckland region. Auckland Regional Water Board Technical Publication 34

KRTA Ltd **(1992)** : Assessment of Environmental Effects. Relating to proposals to develop the Ngawha geothermal resource.

Schmidt, R.E. and Whitton, J.S. **(1975)** : Note on boron toxicity in a stand of Radiata pine in Hawkes Bay. NZ Journal Science 18:109-113

Wells, N. and Whitton, J.S. **(1966) :** The influence of hydrothermal activity on the element content of soils and plants. NZ Journal Science 9: 982-91