THE USE OF VOLATILE CONSTITUENTS IN GEOTHERMAL FLUIDS FOR ASSESSING THE TYPE, POTENTIAL AND NEAR SURFACE PERMEABILITY OF A GEOTHERMAL SYSTEM : THE BROADLANDS GEOTHERMAL AREA, N. Z.

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ABSTRACT

Volatile constituents surveys were conducted to evalute the suitability as geochemical indicators in a gassy system; Broadlands, New Zealand. Samples were collected from many places across the system for soil Hg, soil air Hg, CO_2, and Rn and Tn, respectively. The distribution map was compared with the local structure including fault localities and stratigraphy. Comparison was also made with the physical conditions in the aquifer including near surface temperatures and 300 and 600 m isotherms.

Zones of high concentrations of volatile components on the western side of the system appeared to correspond with distinctive geological and physical structures and anomalies, but not so obvious on the eastern side except Hg in soil air. This may result from the thick sequence of low porosity and permeability lacustrine sandstone and siltstone beds (Huka Falls Formation) which occur in the east.

INTRODUCTION

The concentrations and distributions of volatile components, such as mercury, carbon dioxide, radon, helium, hydrogen, etc., which can migrate from deep geothermal fluids to the surface, are sometimes useful for assessing the type, potential and near surface permeability of a geothermal system. In order to evaluate the suitability of these components as geochemical indicators it is necessary to investigate their distributions and concentrations in an area which is well known physically (Temperature), structually, stratigraphically and petrologically.

Recently, mercury in soil and soil air, or carbon dioxide in soil air surveys have been utilized successfully as a geothermal exploration technique by several workers especially in USA and Japan. These geochemical survey, however, were done mainly in an early stage of geothermal exploration in a new field, and is few in the area where is well known in other scientific investigations including drilling survey. This survey compares geological and geophysical data at depth available with the geochemical results at Broadlands geothermal area, N.Z., where is well defined by exploratory drilling.

OUTLINE OF BROADLANDS GEOTHERMAL AREA

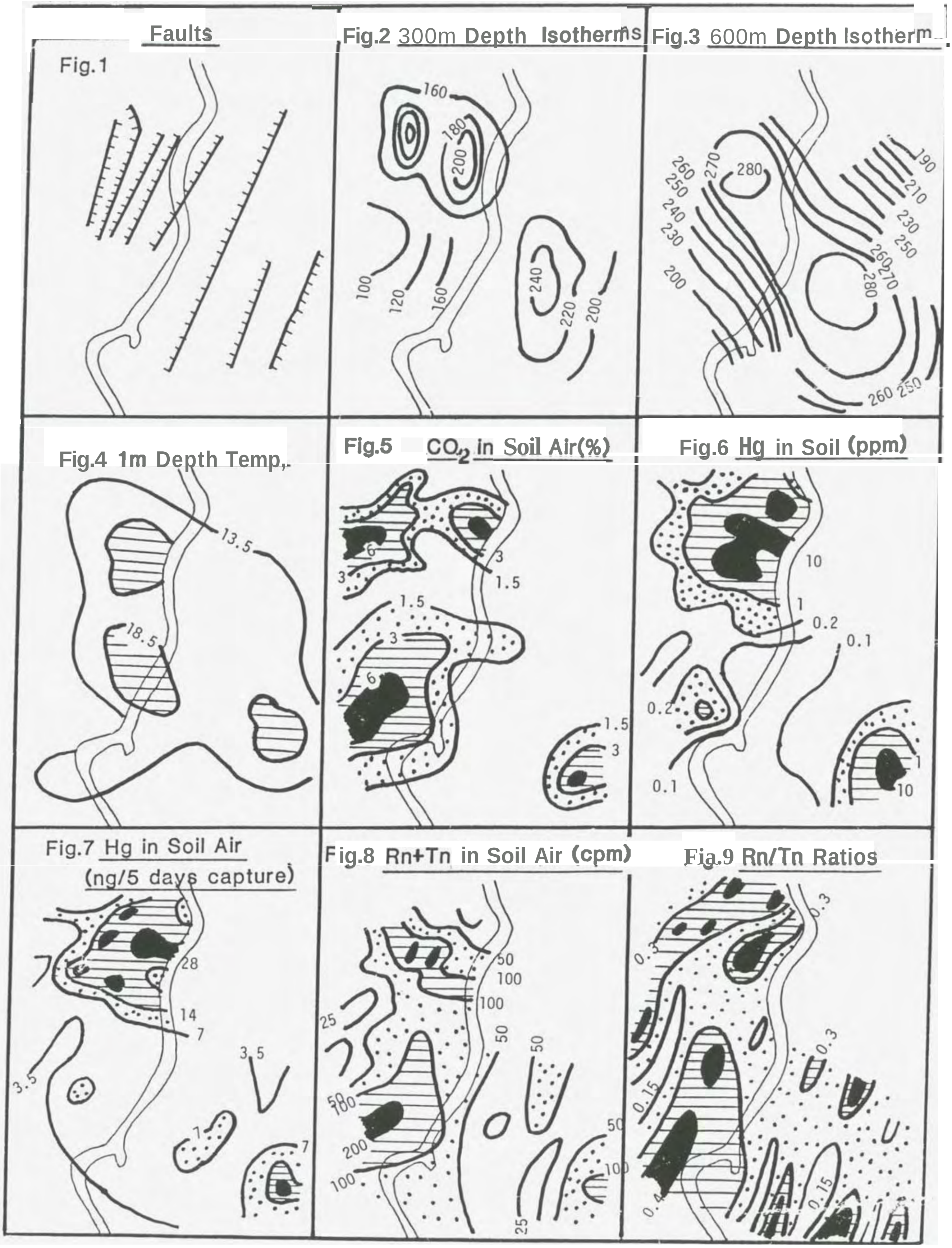
Broadlands, located approximately 22 km northeast of Wairakei, has limited surface thermal activity but was developed to near full production prior to building an electric power station of proposed output of about 100 MW, in a geothermal system of around 9 KM^2 in area. Scientific investigations and subsequent large scale drilling have demonstrated that the area of the deep hot water system is comparable to that at Wairakei.

The Broadlands system has been studied in details (New Zealand Ministry of Works and Development Report 1977). According to the report, the summary is as follows; the surface activity is concentrated in two areas; one is the Ohaki area consisted of a few hot springs, steaming grounds, mud pools and hot water seepages into the Waikato river, another is the small Broadlands thermal area limited to a few warm springs, gas discharge and patches of steaming ground. The subsurface structure of the area is dominated by buried Ohaki rhyolite and Broadlands dacite flows, which have an important control on the hydrology of the field, and by the Mesozoic greywackes and argillites that form the basement. Huka mudstone and recent pumice cover at the near surface. Several recent fault traces are shown by the alignment of hot springs and lineations on air photographs. Most strike north-east but some strike in a more easterly direction. Geophysical measurements were also carried out in details ; near surface temperature measurements, electrical resistivity surveys , gravity , magnetic, seismic refraction measurements, etc.

Water and steam chemistry of the wells suggest that the waters could be derived from a single deep body of hot water. Variation at different sites appear to result from variations in subsurface geology and different physical processes (dilution, boiling). Gas concentrations are ten times higher than found at Wairakei. This appears to be related to the basement greywackes and argillites.

VOLATILE CONSTITUENTS CONCENTRATIONS IN BROADLANDS GEOTHERMAL AREA

Seventy-two sampling stations were set up across the system (show appendix figure) and samples were collected for soil mercury, soil air mercury, carbon dioxide and radon and thoron, respectively. The


Faults
Fig.1
Fig.2 300m Depth Isotherms
160
180
200
100
120
160
240
220
200
Fig.3 600m Depth Isotherm
260
250
240
230
200
270
280
190
210
230
250
260
270
280
260 250
Fig.4 1m Depth Temp.
13.5
18.5
Fig.5 CO2 in Soil Air(%)
6
3
1.5
3
1.5
3
6
1.5
3
Fig.6 Hg in Soil (ppm)
10
1
0.2
0.1
0.2
0.1
1
10
Fig.7 Hg in Soil Air
(ng/5 days capture)
28
14
7
3.5
3.5
7
7
Fig.8 Rn+Tn in Soil Air (cpm)
50
100
100
25
50
50
50
100
200
100
50
100
25
Fig.9 Rn/Tn Ratios
0.3
0.3
0.3
0.15
0.4
0.15

soil mercury concentrations range from 0.02 to 171 ppm. Frequency distribution calculation indicates a background value of 0.2 ppm. The soil air mercury was measured using gold needles to capture mercury vapor degassing from the ground. The concentrations range from 0.7 to 76 ng/5 days capture with the background value of 8 ng. Carbon dioxide was 0.1 - 34 % with background value 1.5 %, and radon and thoron range 13 - 1510 cpm with 30 cpm background, respectively. The distribution maps of the components were compared with the local structure including fault localities and stratigraphy. Comparison was also made with the physical conditions in the aquifer including near surface temperatures (surface geothermal manifestations) and 300 and 600 m isotherms. They are given in figures 1 to 9.

At Broadlands the gas content of the steam is moderately high (3 - 8 %) and mainly carbon dioxide. Gas concentrations in the eastern wells were higher than those present in the west. This is contrary to the surface discharge (Fig. 5). Radon was also same tendency to carbon dioxide (for example, well 28 in the eastern area was the highest value in radon). Anyway, zones of high concentrations of volatile components on the western side of the system appeared to correspond with distinctive geological and physical structures and anomalies. This was, however, not so obvious on the eastern side although there did appear to be a relationship between the high concentrations of mercury in the soil air and the temperatures at depth. This probably represents and demonstrates high diffusivity of this element from the fluid at depth. According to the results of many surveys, soil mercury and soil air mercury are not always in good correspondence because soil mercury shows the geothermal history up to the date while soil air mercury shows just present geothermal activity. Broadlands may be one of the exceptional cases , and must be a promising geothermal area. Rn/Tn ratios in fumaroles or wells are usually low in relatively high thermal activity due to the shallow source of radon and thoron, but it is interesting that those in soil air appear to be in good coincidence with fault localities (Fig. 9).

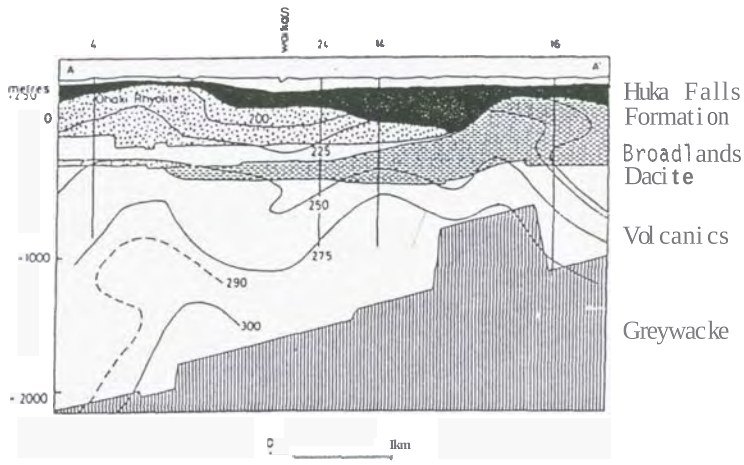


Fig. 10; Vertical section showing isotherms and some of the geological formation at Broadlands Area

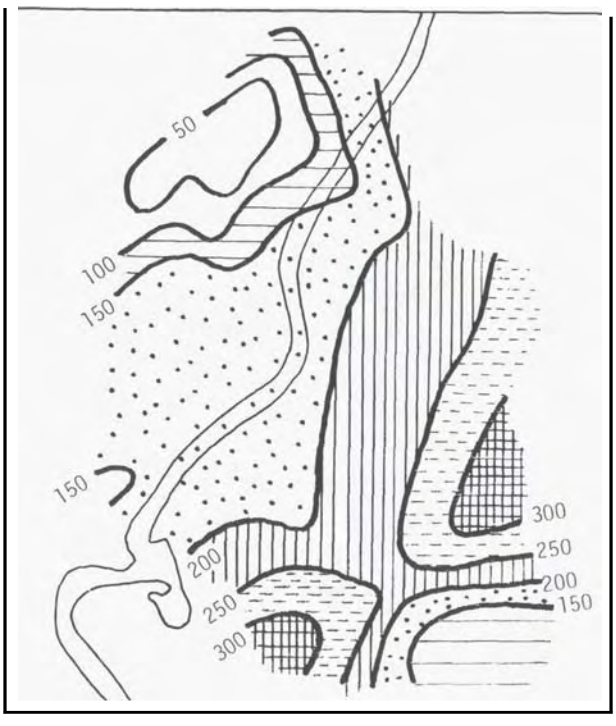


Fig. 11; Isopaches of Huka Falls Formations at Broadlands geothermal area (meter)

The general lack of any definition or correspondence between volatiles and structure in east Broadlands may result from the thick sequence of low porosity and permeability lacustrine sandstone and siltstone beds (Huka Falls Formation) which occur in this area (Fig. 10). Similarly, there are no surface expressions of faults in this area. Figure 11 gives the isopaches of the Huka Falls Formation in Broadlands, which were estimated from the geologic colums of the well cores. It seems possible that major upflow in the east is diverted towards the west as a result of the Huka Formation. This formation is only less than 50 m thick in the west and may not have the same hydrological control in this area. Inversely, Fig. 11 may show the extent of buried Ohaki Rhyolite and Broadlands Dacite flows, which are related to the heat source, showing the similar figure as volatiles distribution maps.

SUMMARY

The Broadlands volatiles anomalies directly overlay the near surface temperature anomaly. The difference between 300 or 600 m depth isotherms and volatiles anomalies occured in the eastern side of the system. This could be explain as a result of

the thick Huka Falls Formation, which consists of low porosity and permeability lacustrine sandstone and siltstone beds.

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Appendix Figure : Location map of Boreholes and Sampling Points at Broadlands