INVESTIGATIONS ON HYDROTHERMAL ACTIVITIES USING FLUID INCLUSION GEOTHERMOMETRY IN THE OTAKE AND HATCHOBARU GEOTHERMAL FIELDS

TAKAGI, H., West Japan Engineering Consultants, Inc., Watanabe-dori, Fukuoka, Japan
FUJINO, T., West Japan Engineering Consultants, Inc., Watanabe-dori, Fukuoka, Japan
KUROKAWA, K., Kyushu Electric Power Co., Inc., Watanabe-dori, Fukuoka, Japan

1. ABSTRACT

The homogenization temperatures of fluid inclusions in hydrothermal minerals such as quartz, anhydrite and calcite from wells in the Otake and Hatchobaru geothermal fields have been measured.

The fluid inclusion temperatures from wells drilled in the producing zone distribute along a narrow range a little inside of the boiling point curve. The lowest value of the fluid inclusion temperatures at each depth is quite close to the present temperature of fluid conduits and reservoirs.

The reservoir temperature in the Otake geothermal field is estimated to be 190 - 200°C at the producing level (300 - 500 m below surface) and 250 - 280°C at the producing level (1,000 - 1,500 m below surface) in the Hatchobaru geothermal field. The distribution of fluid inclusion temperatures from wells drilled in the reinjecting zone has a wide range and show a bimodal distribution. The lowest value of the low temperature peak agrees well with the present temperature, whereas the value of the higher temperature peak appears to be equal to the original reservoir temperature.

The temperature contour map at the producing level in the Otake geothermal field obtained from the fluid inclusion geothermometry shows that the geothermal fluid comes up from the south at a steep angle and forms a reservoir with temperature of 190 - 220°C. In the Hatchobaru geothermal field, the temperature contour map reveals that a high temperature zone above 270°C strikes east to west and breaks towards the north at southeast of the power plant.

2. INTRODUCTION

The geothermal development of the Otake and Hatchobaru fields has been carried out by Kyushu Electric Power Company, Inc. since 1950's. The Otake power plant (12.5 MW) which was completed in 1967 has been operating for 21 years. The Hatchobaru power plant (55 MW) was constructed in 1977. A total of 105 exploration, production and reinjection wells have been drilled to date in the fields.

The subsurface temperature which is one of the most important factor for the investigation of hydrothermal activity has been measured in these wells. In the early stage of developments, however, the temperature logging was carried out using mercury maximum thermometers and Kuster thermometer. Detailed temperature of the subsurface could not be obtained. It is difficult to determine the subsurface temperature before drilling even using a themister thermometer, because most borehole temperatures are measured a few hours or a few days after drilling. The measured temperatures must have been lowered varying degrees by the drilling. The degree of cooling caused by the drilling depends on various factors which include the permeability of the formation, the amount of circulation loss of drilling mud water, and the drilling conditions. For this reason, the thermal structure has not been precisely determined.

As a result of the study on fluid in geothermal field using fluid inclusion (Taguchi etal, 1985, 1986, Fujino etal 1985), it has become clear that fluid inclusions can reveal not only the past subsurface temperature but also the present reservoir temperature.

Fluid inclusion geothermometry has been applied to the investigation of the Otake and Hatchobaru geothermal fields.

3. GEOLOGY

The Otake and Hatchobaru geothermal fields are situated 6 km north-west of Mt. Kuju. The geological map of the fields is shown in Fig. 1. The geology consists of Palaeozoic - Mesozoic basement rocks, the Miocene Use group, the early Pleistocene Hohi volcanic rocks and the middle-late Pleistocene Kuju volcanic rocks (Table-1). The heat source of the geothermal activity is thought to be derived from the post volcanism of the late Kuju volcano, which started about 0.2 Ma. The tectonic structure in the fields dominated by northwest-southeast trending faults.

The fracture zones associated with the faults in the Usa group and Hohi volcanic rocks reserve the termal fluids mainly. The depth of the reservoir is thought to be 300 m - 500 m below the surface in the Otake field and 1,000 m - 1,500 m in the Hatchobaru field.

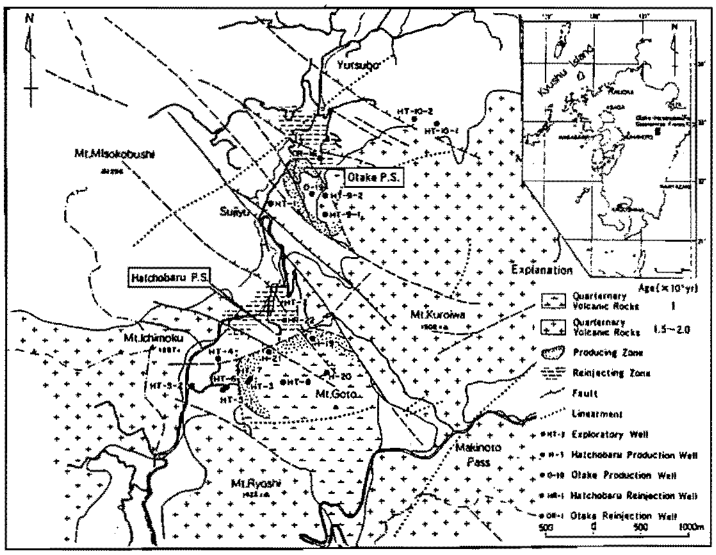

Figure 1. Generalized geologic map of the Otake-Hatchobaru geothermal field, showing faults and wells.

Age			Formation	Rock
Cenozoic	Quaternary	Holocene	Alluvium Volcanic Fan Deposit	Gravel, Sand
		Pleistocene	Kuju Volcanic Rocks Gotozan Lava Kuroiwa-yama Lava Sensuizan Lava Ryoshidake Lava Handa Pyroclastic Flow Deposit Ichimoku-yama Lava Misokobushi-yama Lava (0.1~0.5 Ma)	Hornblend Andesite Pyroclastic Flow Deposit
			Hohi Volcanic Rocks (0.7~1.7 Ma)	Pyroxene Andesite Tuff Breccia
	Tertiary	Miocene	Usa group (24 Ma)	Pyroxene Hornblende Dacite
Mesozoic ~Palaeozoic			Basement Rocks	Granitic Rocks (80 Ma) Metamorphic Rocks

Table. 1. Geologic successin of the Otake and Hatchyobaru geothermal field

4. RESULTS AND INTERPRETATIONS

The application of the fluid inclusion geothermometry in the production and reinjection wells is explained as follows.

Well H-21 was drilled at the northern edge of the producing zone at Hatchobaru. Homogenization temperatures were obtained at depth intervals of 100 m. As shown in Fig. 2, the ranges of homogenization temperatures are relatively wide at shallower depths levels and are relatively narrow at deeper depths. It is thought that the subsurface temperature at shallow depth is changeable because the hot water from depth mixes with the shallow cold water.

The plot of lowest homogenization temperatures at levels deeper than 1,200 m is almost parallel to the measured well temperatures. The lowest homogenization temperatures at lost circulation depths of 1,190 m and 1,700 - 1,800 m are 250°C and 290°C respectively. They shows good agreement with the measured temperatures. The veins filled with anhydrite and quartz at 1,332 m and 1,602 m are sealed; hence they are not conduits for thermal fluids. The lowest temperatures of fluid inclusions at deep levels are slightly lower than the measured temperature

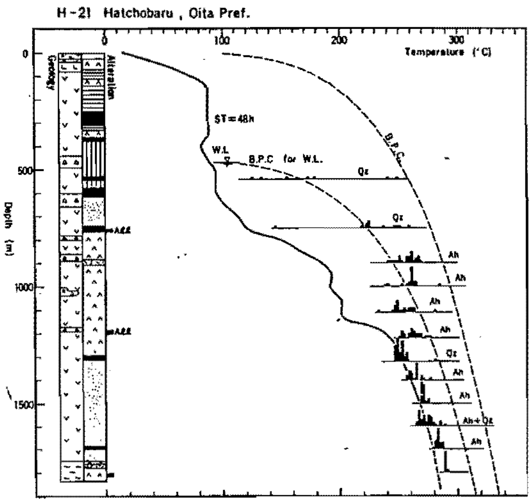

Figure 2. Homogenization and measured temperatures with geologic and alteration columns of well H-21.

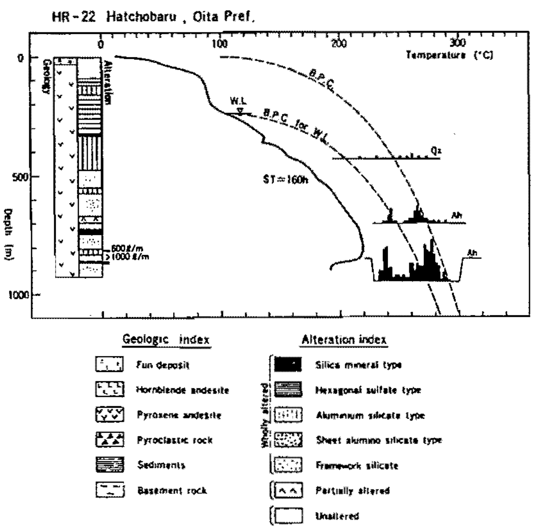

Figure 3. Homogenization and measured temperatures with geologic and alteration columns of well HR-22.

except at lost circulation depths. In active geothermal fields, the measured temperature often found to be slightly higher than the lowest temperature of fluid inclusions in less permeable zones.

Well HR-22 was drilled in the Hatchobaru reinjecting zone. The fluid inclusion temperatures have two distinct peaks of 239 and 273°C, and have a wide range of about 65°C (Fig. 3).

The minimum temperature is about 230°C which indicates the reservoir temperature. The high temperature peak (273°C) is similar to the reservoir temperature, indicating the original reservoir temperature before development. Many reinjection wells have been drilled around well HR-22 and much hot water of about 90°C has been reinjected. It is assumed that the temperature difference between the two peaks of fluid inclusion temperature was caused by the mixing of the reinjected water.

Fig. 4 and Fig. 5 show the temperature distribution at the producing level (Otake: about 500 m below surface, Hatchobaru: about 1,000 m below surface) and sections which cross the main producing area. These were drawn using the minimum homogenization temperatures.

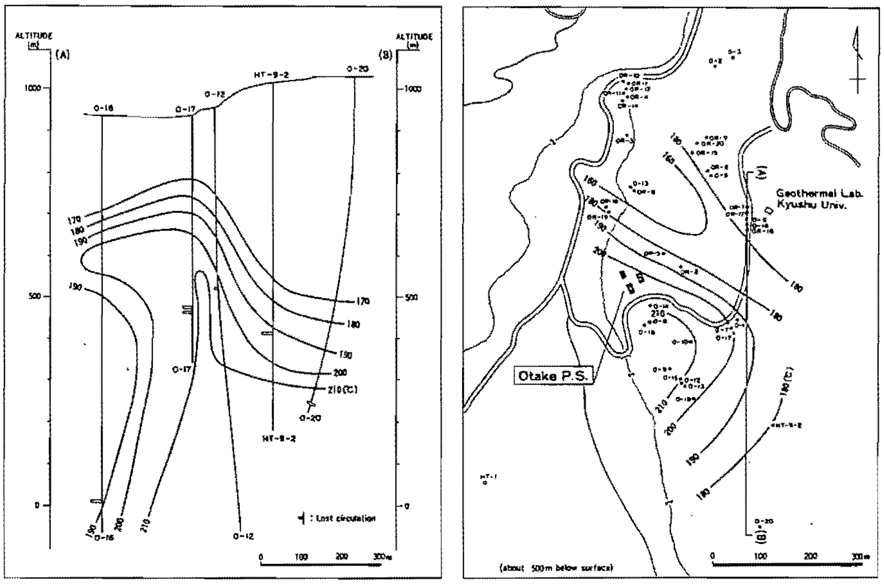

Figure. 4 Section and distribution map of subsurface temperature made by the minimum homogenization temperature in the Otake geothermal field.

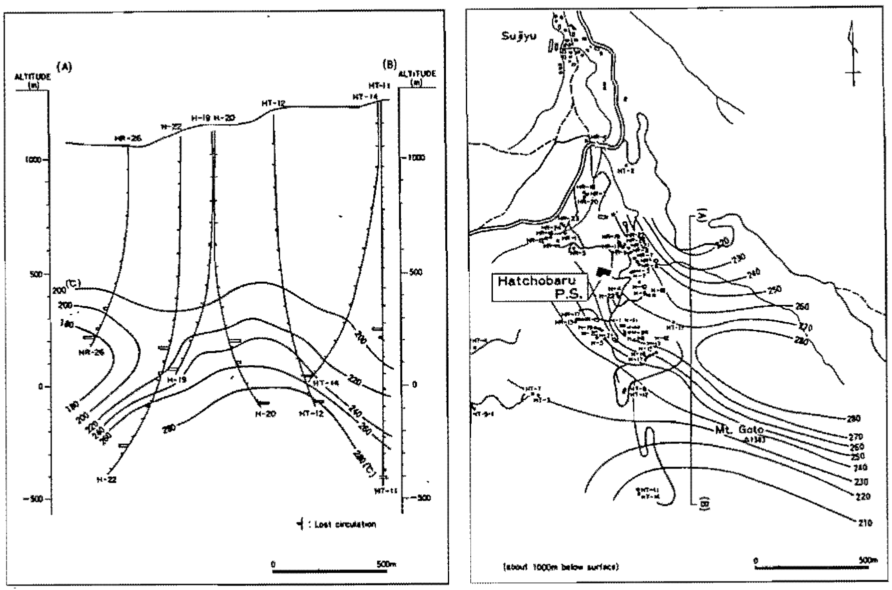

Figure. 5 Section and distribution map of subsurface temperature made by the minimum homogenization temperature in the Hatchyobaru geothermal field.

Fig. 6 and Fig. 7 show the temperature distributions in the Otake and Hatchobaru reservoir determined using a sillica thermometer. The contour maps from fluid inclusion thermometry are in harmony with the contour maps obtained from sillica thermometer.

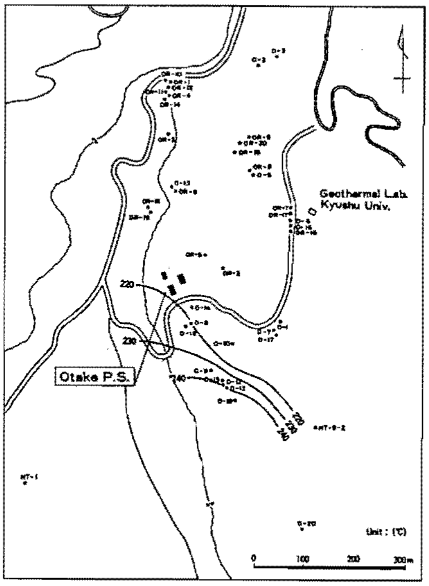

Figure. 6 Temperature distribution of the Otake reservoir, calculated by sillica thermometer (1985)

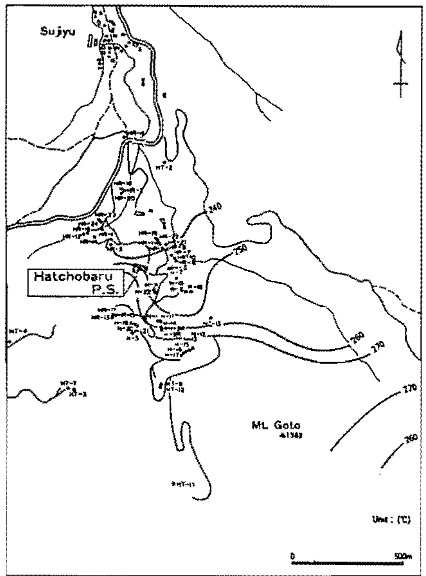

Figure. 7 Temperature distribution of the Hatchyobaru reservoir, calculated by silica thermometer (1986)

The contour map of the Otake geothermal field (Fig. 4) indicates that the geothermal fluid rises from the south at a steep angle. After that it forms a horizontal reservoir at a depth of about 500 m below surface. The temperature of the reservoir is estimated to be 200 - 220°C. In the Hatchobaru geothermal field (Fig. 5), the high temperature zone above 270°C is over 1,200 m long and 300 m wide. This high temperature zone strikes east to west and breaks towards north at southeast of the power plant.

5. CONCLUSION

The investigations on hydrothermal activity using fluid inclusion geothermometry in the Otake and Hatchobaru geothermal fields lead to the following results.

1) The lowest value of homogenization temperatures is quite close to the present temperature of permeable zones such as fluid conduits and reservoirs.
2) In inpermeable zones, the lowest value of homogenization temperatures is slightly lower than the measured well temperature. The facts is useful to define the sealing zone.
3) Fluid inclusion temperatures from the reinjecting zone show a bimodal distribution. The minimum value of the low temperature peak agrees with the present temperature, whereas the value of the higher temperature peak appears to be equal to the original reservoir temperature.
4) The thermal structure of the Otake geothermal field is determined with the aid of the fluid inclusion geothermometry. The structure shows that the geothermal fluid comes up form the south froms a reservoir of 200 - 220°C at the level of 500 m below surface.
5) In the hatchobaru geothermal field, a high temperature zone more than 270°C estimated by the fluid inclusion geothermometry at a producing depth of about 1,000 m, strikes east to west and breaks toward the north.

6. REFERENCES

Taguchi, S., Irie, A., Hayashi, M. and Takagi, H. (1985) Subsurface Thermal Structure Revealed by Fluid Inclusion Thermometer at the Otake Geothermal Field, Kyushu. Journal of the Geothermal Research Society of Japan, Vol. 7, No. 4, p.401 - p.413.

Fujino, T. and Yamasaki, T. (1985) The Use of Fluid Inclusion Geothermometry as an Indicator of Reservoir Temperature and Thermal History in the Hatchobaru Geothermal Field, Japan. Geothermal Resources Council, Transactions, Vol. 9 - Part 1.

Taguchi, S., Nakamura, M., Takagi, H. and Hayashi, M. (1986) Fracture Control of Fluid Flow Revealed by Fluid Inclusions at the Hatchobaru Geothermal Field. Geothermal Resources Council, Transactions, Vol. 10.