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APPLICATION OF NEDO'S CORE-ANALYSIS SYSTEM TO THE WASABIZAWA GEOTHERMAL DEVELOPMENT FIELD IN NORTHEAST JAPAN

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Abstract

Secondary quartz and calcite minerals in cores and cutting samples from the Wasabizawa geothermal field, Akita Prefecture, Japan, were used for the fluid inclusion measurements, homogenization temperature measurement, melting point of ice measurement and Laser Raman analysis. Among homogenization temperatures at each depth in a well, the lowest value of quartz is nearly the same as the formation temperature estimated by temperature logging. On the other hand, homogenization temperatures of calcite are lower than the formation temperature. This is probably resulted from fact that formation temperature in the past was lower than the present temperature. From this, formation temperature in the present time can be easily estimated, applying homogenization temperature measurement of fluid inclusion in quartz from the Wasabizawa field. Moreover, there is a possibility that information about thermal history can be obtained, combining the measured data from some different kinds of minerals. The melting point of ice measurement indicates that salinity of fluid inclusions in quartz from the western part of the field is higher than that from the eastern part. This trend is just similar to that of chloride concentration of geothermal brine.

1. Introduction

It is essential for a survey of geothermal development to measure homogenization temperatures of fluid inclusions, because they can be collected directly from the underground during drilling and are useful for planning of drilling. Fluid inclusions reflect physical conditions and chemical composition of hot water at the time of fluid trapping.

The New Energy and Industrial Technology Development Organization of Japan (NEDO) funded a project for exploring fractured-type geothermal reservoirs (Horikoshi et al., 1996). This project included a study of the core-analysis system. In the part of studying this system, we established three items, natural remanent magnetization measurement, the measurement of fluid inclusions and zircon morphology analysis methods. These items aimed to determine the structure of fractured-type geothermal reservoirs by measurement of core and cuttings. The usefulness of these items were confirmed by application to the Yutubo geothermal field, Kakkonda geothermal field and Ogiri geothermal field. In the "Development of Technology for Reservoir Mass and Heat flow Characterization" (Horikoshi and Ide, 1998), this core-analysis system is applying to some geothermal fields. In this paper, the results of the application of this system to the Wasabizawa geothermal field during the 1998 Fiscal Year are presented.

2. Sample selection

Nine boleholes were drilled in the Wasabizawa geothermal field as part of the program for promoting geothermal developments (NEDO, 1998). Six wells were successful for production. Six wells from N5-WZ-1 to N7-WZ-6 were drilled for obtaining cores and the other three were dilled for sampling cuttings. Quartz was sampled from cores and cuttings in all wells, and calcite minerals were sampled from N6-WZ-3 and N8-WZ-9. These hydrothermal minerals were cut and polished for the core-analysis system. In addition to these hydrothermal minerals, quartz was also collected from granitic host rocks.

3. Homogenization temperature and melting point of ice

The range of homogenization temperatures (Th) of fluid inclusions sampled from the hydrothermal minerals are shown in Figs.1 and 2. A solid bar represents the range of Th in quartz and a open bar represents the range of Th in calcite. Th values of quartz are higher than Th in calcite at the same depths of N6-WZ-3 and N8-WZ-9. A curved line represents an equilibrium temperature which was calculated by temperature logging in N5-WZ-1, N5-WZ-2, N6-WZ-3 N6-WZ-4, N7-WZ-6, N7-WZ-7 and N8-WZ-9. In addition to the equilibrium temperature, the surface boi1ing point curve (SBPC) and the water level boiling point curve (WBPC) are represented by a dashed and single-dotted curved line and a dashed and double-dotted curved line, respectively. Most of Th are lower than the SBPC and a part of Th exceeds the SBPC.

The following relations are observed between the lowest values of Th of quartz in core samples and the equilibrium temperatures at sampling depths. The lowest Th values of hydrothermal quartz are consistent with the equilibrium temperature at depths: 650m in N7-WZ-6, 909.5m in N5-WZ-1 and 1,054.85m in N6-WZ-3.

The lowest Th values of quartz in host rocks are also consistent with the equilibrium temperature (NEDO,1999). The lowest Th values of quartz from other wells are 70°C lower than the equilibrium temperature. However, the lowest Th values of quartz at a depth of 1,312.3m in N6-WZ-4 are 70°C lower than the equilibrium temperature. The lowest Th values of quartz in cutting samples from N7-WZ-7 and N8-WZ-9 are within 30°C from the equilibrium temperature. The lowest Th values at a shallower depths are higher than the equilibrium temperature, while those a deeper depth are lower than the equilibrium temperature. The lowest Th values of quartz in cutting samples are not closer compared with core samples, because cutting samples are a mixture of different depth samples.

A cap rock consisted of alteration zones is distributed from 300m to –100m above sea level. Most Th values of quartz at depths of 141.8m in N5-WZ-1 and 411.8m in N6-WZ-3 where locate around the boundary between an upper zone of formation and cap rock, are higher than the equilibrium temperature. Especially, Th values of quartz at shallows in N5-WZ-1, N6-WZ-3 and N7-WZ-5 are higher than the SBPC and the WBPC, and rages of homogenization temperature distribution of quartz become wider as depth decreases. These facts suggest that the geothermal water is up-flowing from greater depths and evaporating to form two phases.

Homogenization temperatures of fluid inclusions of calcite were measured for samples from N6-WZ-3 and N8-WZ-9. Most fluid inclusions in quartz and calcite measuring Th are secondary. The lowest Th values of calcite tend to be almost lower than those of quartz. The reason to this might be the thermal history that the formation temperature in the past was lower than the present temperature and/or might be the stretching effect of fragile mineral, calcite.

Figure 3 depicts the relationship between homogenization temperatures and ice melting temperatures of fluid inclusions. The right side axis of the figure represents salinity given in wt.% NaCl equivalent. Fluid inclusions with the ice melting temperatures to be at about zero degree centigrade exist in almost all the wells. Fluid inclusions with lower ice melting temperatures at negative degree centigrade also exist in almost all wells. These distributions and the lowest value of ice melting are affected by the difference composition of hot water.

4. Laser Raman analysis

Figure 4 shows the results of measuring the partial pressure of the gas content in samples from wells using Laser Raman analysis. Gases of CO_2, N_2 and CH_4 were detected in most samples from the wells in the Wasabizawa field, though H_2S gas was not detected. It is considered that N_2 and CH_4 gases are derived from sedimentary origin materials in metamorphic rocks surrounding the geothermal reservoir. The partial gas pressures become higher as depth increases in several wells except for the N8-WZ-9.

5. Discussion

Among the homogenization temperature data, the lowest value from quartz grains is nearly the same as the formation temperature estimated by temperature logging. From this, it is useful to measure the homogenization temperature of fluid inclusion in quartz for estimating the formation temperature in the Wasabizawa geothermal field. Figure 5 depicts the highest temperature between homogenization temperatures and temperatures obtained by logging in each well. In addition, average values of salinity in each well are plotted (Fig. 5). The average melting points of ice in N5-WZ-1, N7-WZ-5 and N7-WZ-6 drilled in the western part of the Wasabizawa geothermal field are from –0.2 degrees centigrade to –0.5 degrees centigrade, and show the lower salinity value from 3,400 to 8,500 ppm in the field. The average melting points of ice in N5-WZ-2, N6-WZ-3, N6-WZ-4, N7-WZ-7, N7-WZ-8 and N8-WZ-9 drilled in the western part are from –0.6 degrees centigrade to –1.6 degrees centigrade, and salinity values from 10,000 to 27,000 ppm are higher than those of the eastern part. This trend is just similar to that of chloride concentration of geothermal brine.

6. Conclusions

1. It is useful to measure the homogenization temperature of fluid inclusions in quartz for estimating the formation temperature in the Wasabizawa geothermal field.
2. The homogenization temperatures of calcite are lower than those of quartz in the field. It is considered that formation temperature in the past was lower than the present temperature.
3. The melting point of ice measurement indicates that salinity of fluid inclusions in quartz from the western part of the field are higher than that from the eastern part. This trend is just similar to that of chloride concentration of geothermal brine.

Acknowledgments

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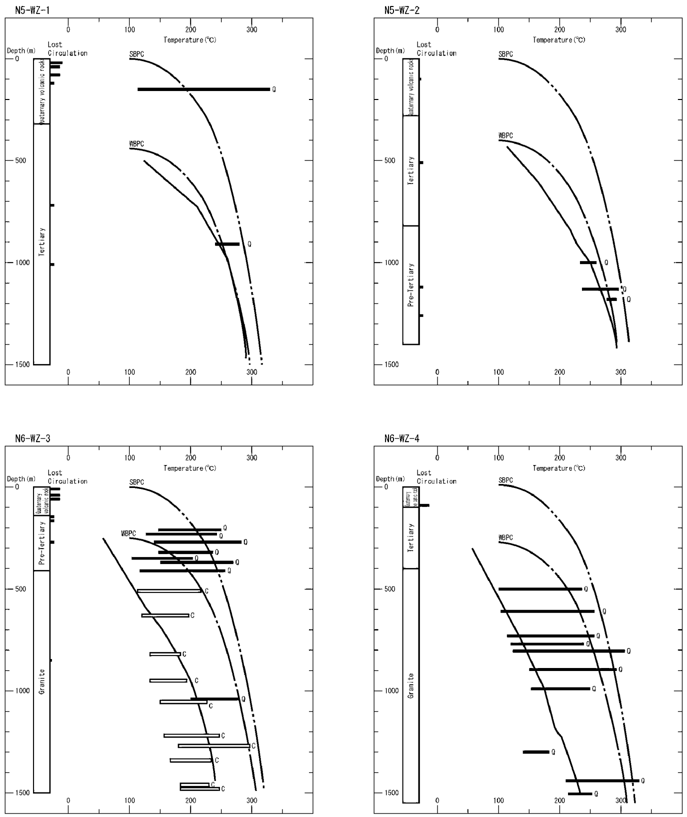


Fig.1 Range of measured homogenization temperature of fluid inclusions in quartz(Q) and calcite(C) from wells N5-WZ-1, N5-WZ-2, N6-WZ-3 and N6-WZ-4

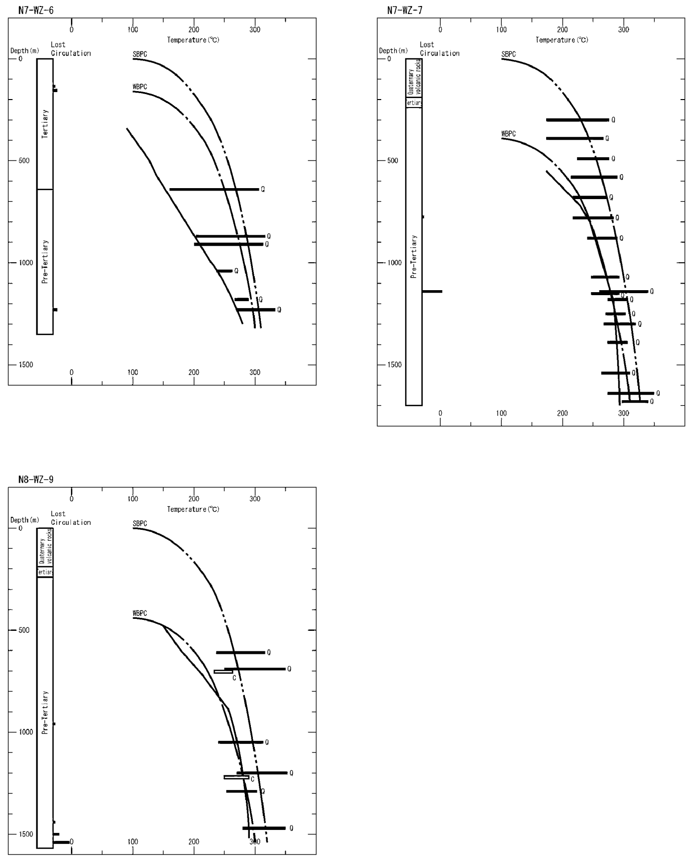


Fig.2 Measured homogenization temperature of fluid inclusions in quartz(Q) and calcite(C) from wells N7-WZ-6, N7-WZ-7 and N8-WZ-9

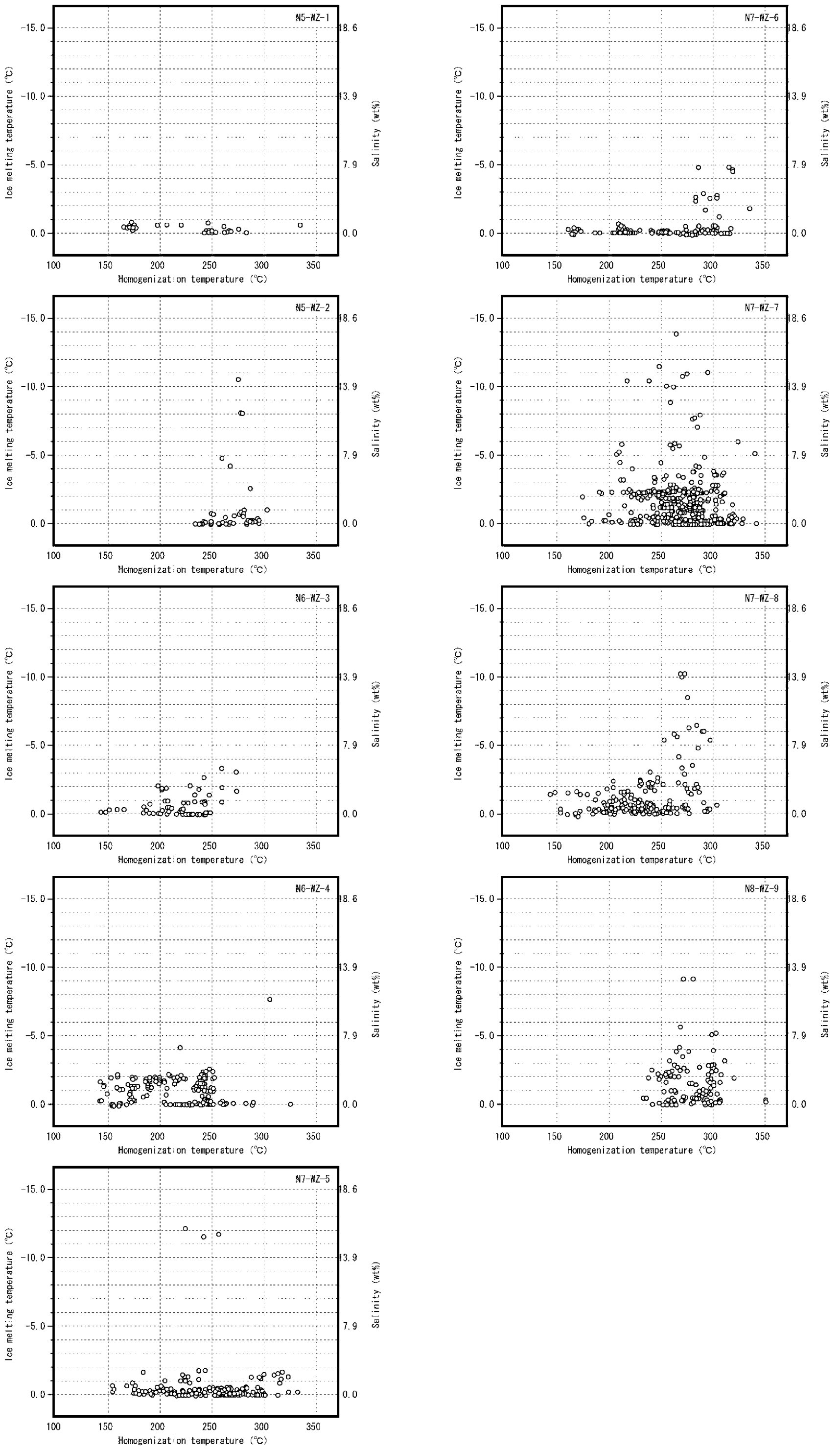


Fig.3 Homogenization temperature vs. melting point of ice of fluid inclusions from wells N5-WZ-1, N5-WZ-2, N6-WZ-3, N6-WZ-4, N7-WZ-5, N7-WZ-6, N7-WZ-7, N7-WZ-8 and N8-WZ-9

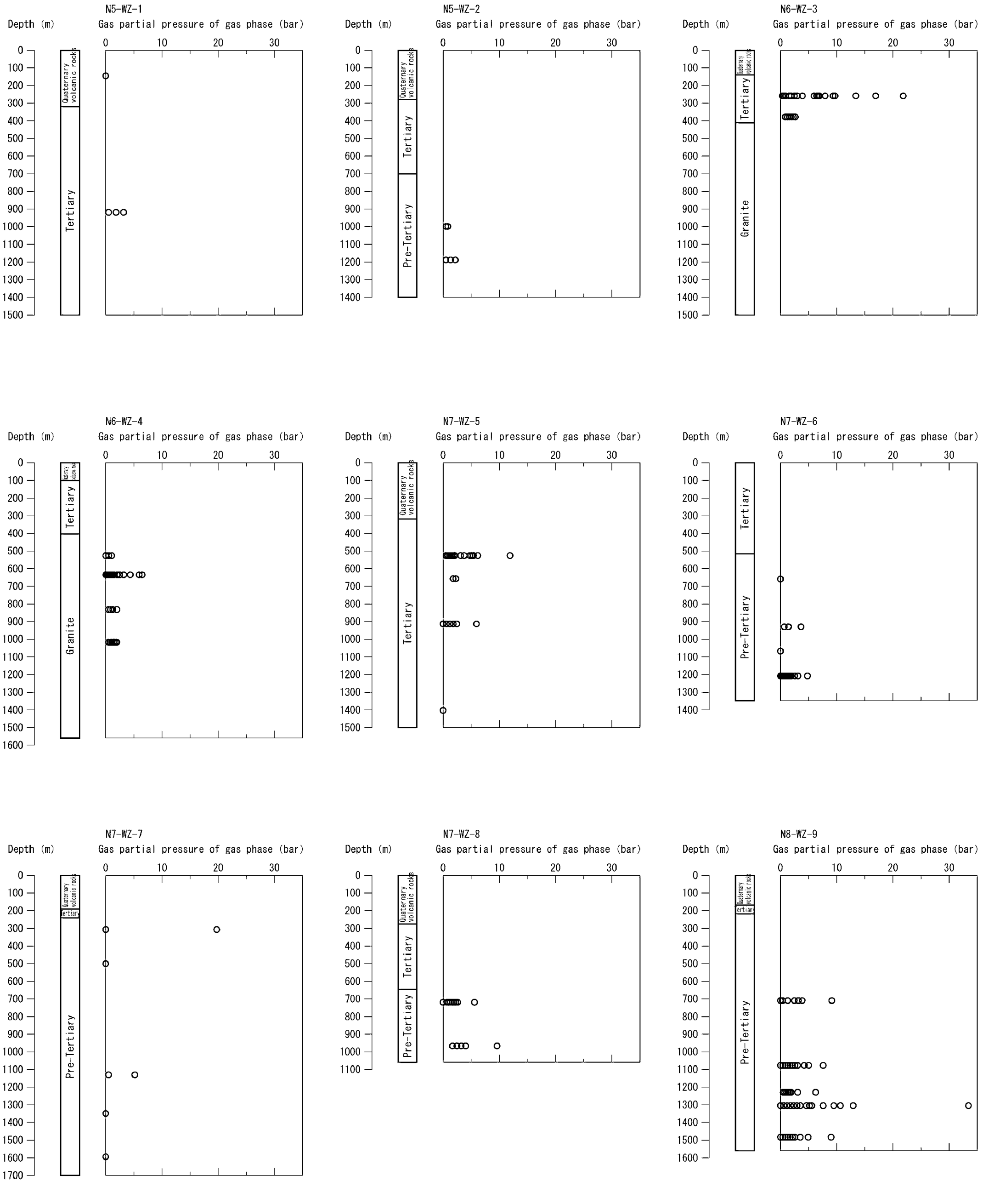
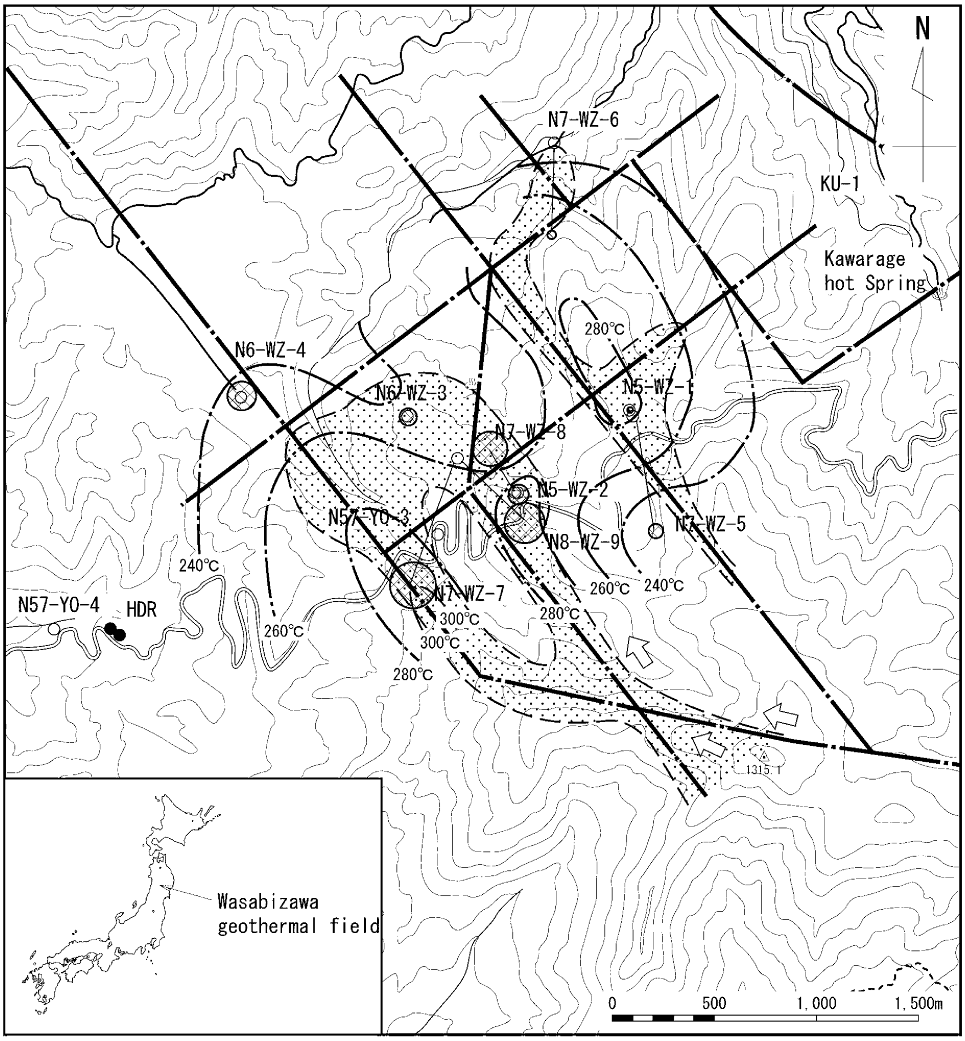


Fig.4 Gas partial pressure of detected gases in fluid inclusions from wells N5-WZ-1, N5-WZ-2, N6-WZ-3, N6-WZ-4, N7-WZ-5, N7-WZ-6, N7-WZ-7, N7-WZ-8 and N8-WZ-9



Legend

Well point
Open circles and latticed circles represent top and bottom of well respectively.
A size of grid circle shows degree of a salinity detected by ice melting temperature of inclusions.

200℃
Temperature contour determined by highest measured temperature and homogenization temperature of fluid inclusions.

Fault
Reservoir
Fluid flow
} from NEDO(1998)

Fig.5 Iso-thermal contour map showing salinity of fluid inclusions in the Wasabizawa geothermal field