# DEVELOPMENT OF CORE ANALYSIS SYSTEM - GEOLOGY *AND* GEOCHEMICAL TECHNIQUES TO SUPPORT MODELLING OF A GEOTHERMAL RESERVOIR

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**SUMMARY** - To detect the geological and geochemical changes of a geothermal reservoir, fluid inclusions fiom the Akinomiya geothermal field in Japan have been measured as part of a NEDO project. Results of this study suggest that several geothermal fluids have been active in the Akinomiya area and the thermal history of this area can be estimated fiom the apparent salinity and homogenization temperatures. This paper outlines the application and possibilities of NEDO's core-analysis system.

## 1. INTRODUCTION

For geological and geochemical field data, fluid inclusions in hydrothermal minerals have been examined regarding homogenization temperature (*Th*), final ice-melting temperature (*Tmi*), and gas composition analysis, as they reflect the physical conditions and chemical composition of hot water at the time of fluid trapping. The usefulness of fluid inclusions has been exemplified through application to several geothermal fields (e.g. Maeda et al., 2000). Under MITI's New Sunshine Program, NEDO has conducted a project involving the development of technology for reservoir mass and heat flow characterization since 1997, aiming to establish a technology for reservoir characterization and management (Horikoshi et al., 1998). This paper describes the results of NEDO's core-analysis system application in the Akhomiya geothermal field in Japan. One of six themes of our project, it focuses on the establishment of technologies for obtaining geological and geochemical information that will assist in the construction of a reservoir model. In this theme, we will establish methods for measuring *Th* and for determining the fluid and gas composition of fluid inclusions. This method was named NEDO's Core-analysis System and was developed in a previous NEDO project named "Development of Exploration Methods for Fracture-type Geothermal Reservoirs" (Horikoshi et al., 1996). Also in this theme, we are developing a rock-dating technique using thermoluminescence and chemical analysis of trace elements using ICP-MS to obtain the geological and geochemical information about the geothermal reservoir. Through the utilization of the compiled data, reservoir changes and the connection of fractures between wells will be clarified and NEDO's core-analysis system will be utilized in the construction of a reservoir model.

## 2. SURVEY AREA

The Akinomiya geothermal field is located in southern Akita Prefecture, northeast Japan (Fig. 1). In this study, cores were sampled fiom five wells (N8-AY-1, N8-AY-2, N9-AY-4, N9-AY-5 and N58-YO-8). In the neighborhood of the Akinomiya geothermal field, there are the Wasabizawa and the Uenotai geothermal fields. These fields form a geothermal zone in the NE-SW direction and the relationships of each geothermal reservoir situated in these fields is being surveyed. The Akinomiya geothermal field is being surveyed in order to promote geothermal development by NEDO. Since 1996, eight boreholes have been drilled in the Akinomiya field. Previous geothermal development was carried out from 1982 to 1984 in the Akinomiya area (NEDO, 1985).

## 3. EXPERIMENTAL METHODS

The *Th*s and *Tmi*s of fluid inclusions were measured by a Linkam TH-6OOPS and an USGS-type gas-flow heating/freezing stage, respectively. The partial gas pressures of fluid inclusions were measured by a Jobin-Yvon RAMANOR T64000, following the procedure of Maeda et al. (1998). All fluid inclusions have been described and their origin determined according to Roedder's criteria (Roedder, 1984).

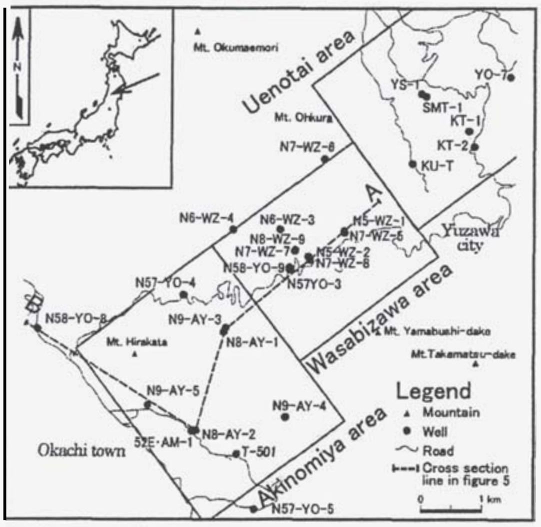


**Fig.l Location of Akinomiya geothermal field**

## 4. RESULT

### 4.1 Homogenization temperature

Figure 2 shows the range of homogenization temperatures of fluid inclusions according to depth. A solid curved line represents the equilibrium temperature, calculated by temperature logging in each well. In addition, the surface boiling point curve (SBPC) and the water level boiling point curve (WBPC) are represented by a dash and single-dotted curved lines and a dash and double-dotted curved lines, respectively.

The lowest values of Th of quartz sampled from the host rock in N8-AY-2 are consistent with the equilibrium temperature. This result in the Akinomiya area agrees with that of the Wasabizawa area (Maeda et al. 2000). The lowest values of *Th* of quartz sampled from the veins of hydrothermal minerals in N8-AY-1 and N8-AY-2 are lower than the equilibrium temperature curve. This suggests that the quartz trapped fluids with temperatures lower than the present underground temperatures.

### 4.2 Ice melting temperature (*Tmi*)

Figure 3 shows the *Tmi* values of fluid inclusions in five wells. Fluid inclusions with *Tmis* of about zero degrees centigrade are present in nearly all of the wells. Fluid inclusions with *Tmis* under zero degrees centigrade were also found in most wells, especially in the pre-Tertiary rocks in N8-AY-1 and N8-AY-2. Though the frequency of lower *Tmi* fluid inclusions with *Tmis* under zero degrees centigrade is less than those of zero *Tmis* with *Tmi* around zero degrees centigrade, ratios between the colder and zero *Tmi* fluid inclusions vary in each well and in each layer. This suggests that several *Tmi* fluids have been acting in certain stages.

### 4.3 Partial gas pressure

Figure 4 shows the partial pressures of the gas content of fluid inclusions in five wells. $CO_2$, $N_2$ and $CH_4$ were detected in most samples from all of the wells except N9-AY-4. $CO_2$ and $N_2$ were detected and $CH_4$ was scarcely detected in the samples from N8-AY-1. Only $CO_2$ was detected in samples from N58-YO-8. No difference was found concerning gas composition between Tertiary rocks and pre-Tertiary rocks.

Partial gas pressure has a tendency to increase as depth increases in the Akinomiya area.

## 5. DISCUSSION

***Differences in apparent salinity***

Figure 3 shows the relationship between *Th* and *Tmi*. The data of N9-AY-4, N9-AY-5 and N58-YO-8 plot around zero degrees centigrade. On the other hand, some of the results from N8-AY-1 and N8-AY-2 are under zero degrees centigrade. Looking at it from a geological point of view, almost all of the *Tmis* of fluid inclusions in Tertiary rocks are near zero degrees centigrade in the Akinomiya area. On the other hand, the *Tmis* of fluid inclusions in pre-Tertiary rocks has a wide range and the *Tmis* of some inclusions are under zero degrees centigrade. Evidently, the apparent salinities of the trapped geothermal fluids are different in each layer. Considering the fact that minimum *Th* values of fluid inclusions with high apparent salinity are lower than the equilibrium temperature in pre-Tertiary rocks, some geothermal fluids with high salinity and low hot water temperature were probably active in the past.

From the chemical composition of present geothermal fluids from production wells in the Akinomiya area, concentrations of chloride in such geothermal fluids are under 2,000 ppm (NEDO, 1998). Therefore, if the fluid inclusions were formed relatively recently, their *Tmis* should be near zero degrees centigrade. To put it in different terms, the apparent salinities of fluid inclusions in Tertiary rocks and those of present geothermal fluids are almost equal. The timing of hydrothermal activity involving high salinity fluids has yet to be determined.

***Relationship between Th and equilibrium temperature***

Some relationships are reported between *Th* and equilibrium temperature (e.g. Fujino and Yamasaki, 1985, Takenouchi, 1988). Comparing the equilibrium temperature with the distribution of *Th*, Muramatsu (1993) suggested that equilibrium temperatures and the *Ths* of fluid inclusions have relationship patterns associated with the thermal history of each geothermal area.

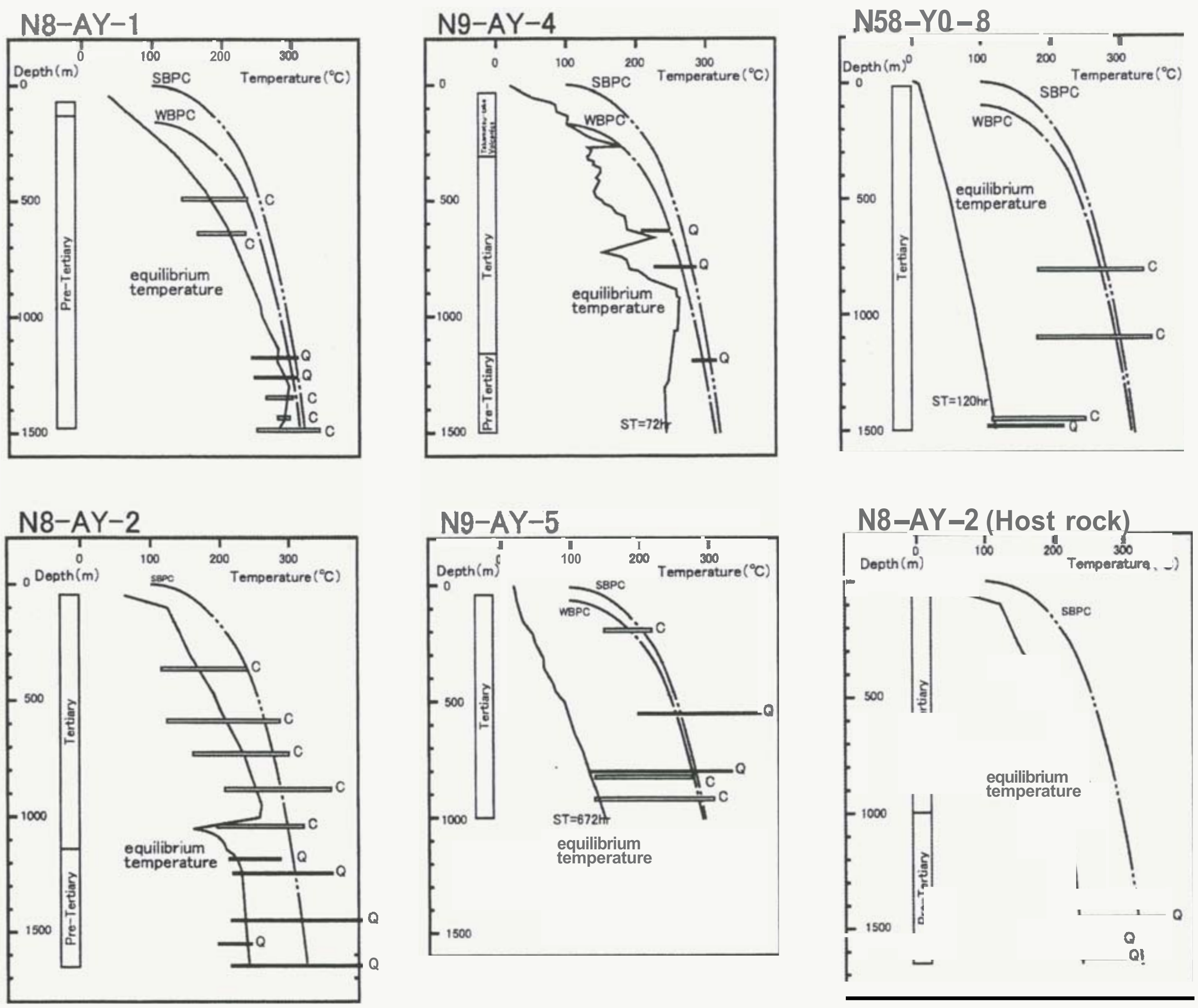


Fig.2 Range of measured homogenization temperature of fluid inclusions in quartz(Q) and calcite(C) from wells N8-AY-1, N8-AY-2, N9-AY-4, N9-AY-5, N58-YO-8 and N8-AY-2 (Host rock).

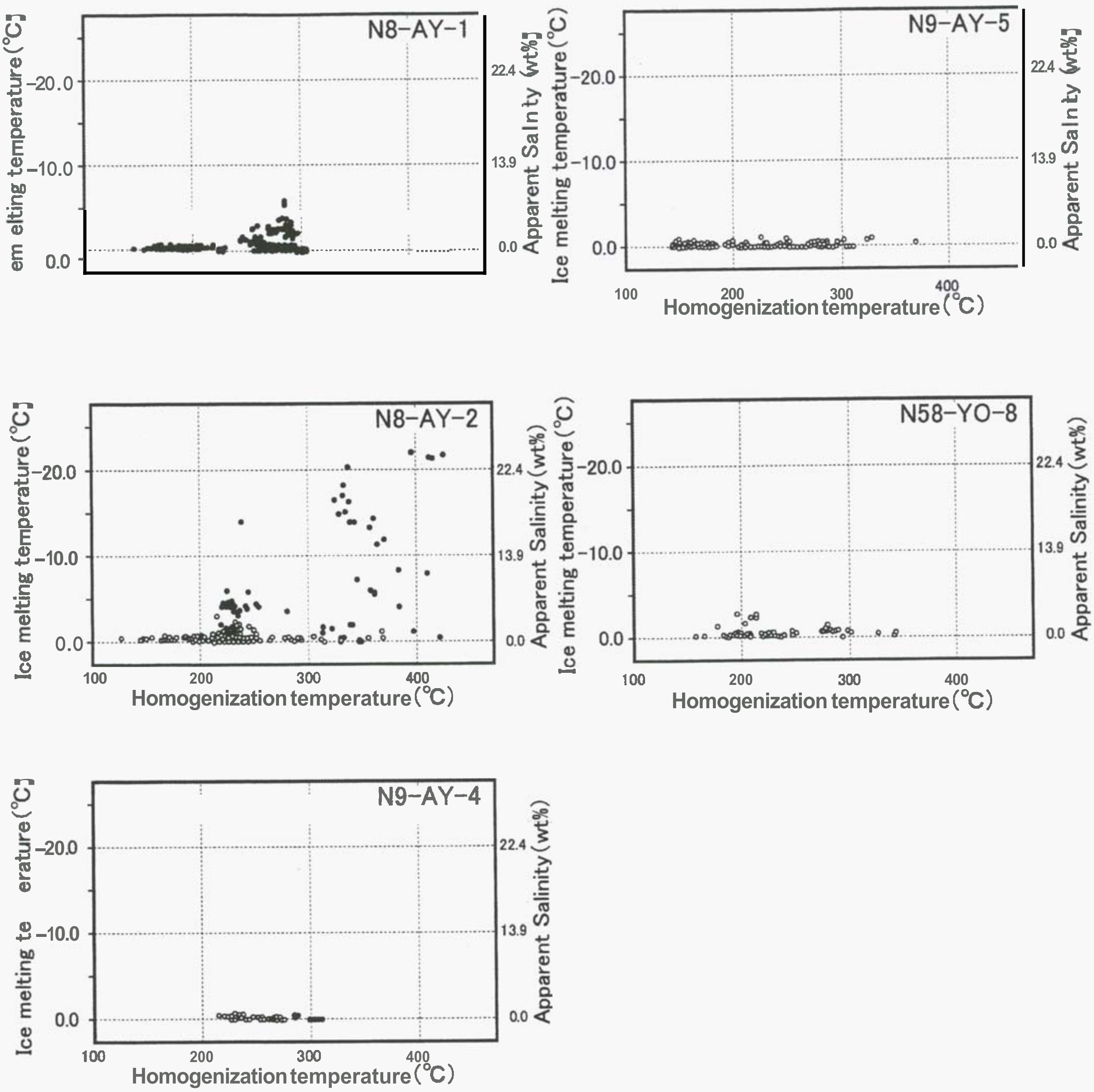


Fig.3 Homogenizatian temperature vs. melting point of ice of fluid inclusions from wells N8-AY-1, N8-AY-2, N9-AY-4, N9-AY-5 and N58-YO-8.
Solid circles represent sampling from the Pre-Tertiary.
Open circles represent sampling from the Tertiary.

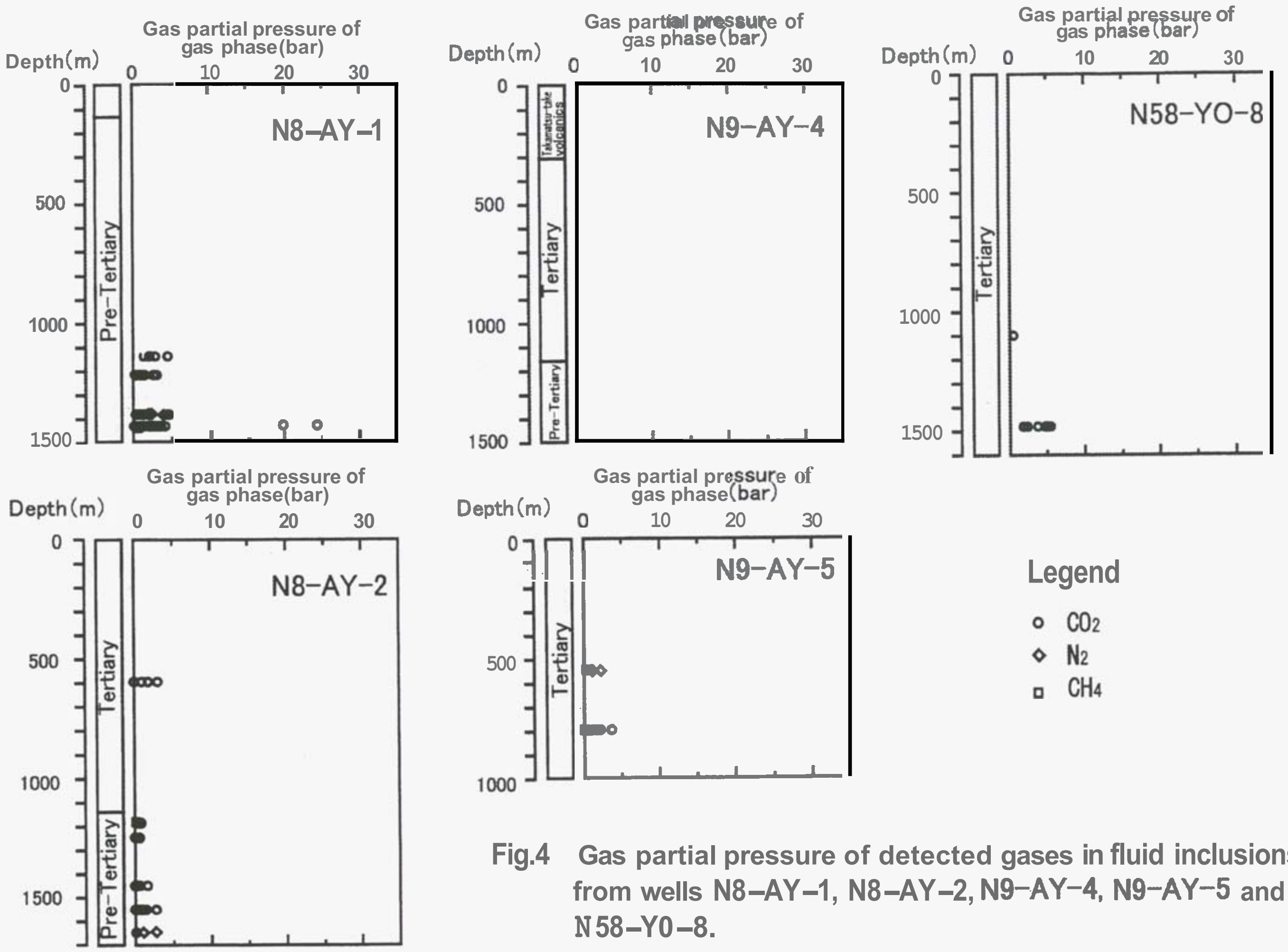


Fig.4 Gas partial pressure of detected gases in fluid inclusions from wells N8-AY-1, N8-AY-2, N9-AY-4, N9-AY-5 and N58-YO-8.

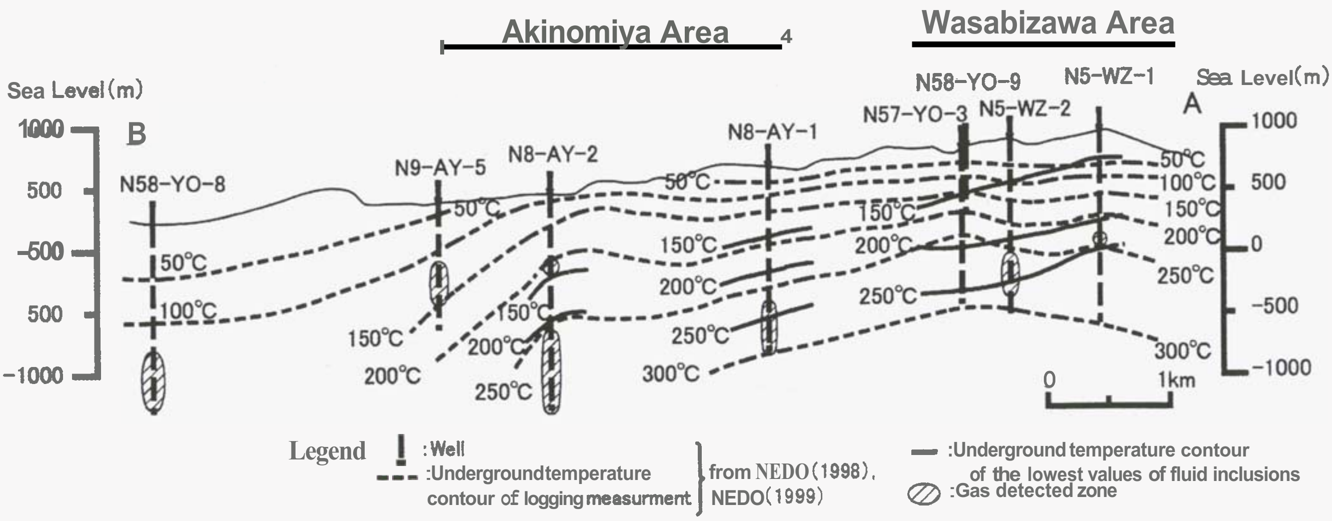


Fig.5 Compiled cross section of the study area

He further indicated that geothermal activity was more vigorous when the equilibrium temperature was higher than the minimum value of *Th* in fluid inclusions in a geothermal area.

Figure 5 shows a cross section of the Akinomiya and the Wasabizawa areas with two isothermal lines drawn for equilibrium temperature and minimum value of *Th*, respectively. The fact that equilibrium temperatures are higher than the minimum values of *Th* implies vigorous geothermal activity in the Akinomiya area. On the other hand, the equilibrium temperatures and minimum value of *Ths* are relatively similar in the Wasabizawa area. Geothermal activity in the Wasabizawa area appears to have been stable since fluid inclusion trapping (NEDO, 2000).

## 6. CONCLUSIONS

The aim of this study is to establish technologies to obtain geological and geochemical information that will assist in the construction of a reservoir model. The conclusions of this project are summarized as follows:

The *Ths, Tmis* and partial gas pressures of fluid inclusions in quartz from the Akinomiya area were measured. Some geothermal fluids were active in the past at a lower temperature than the present underground temperature with salinity higher than the present geothermal fluid. The geothermal fluids in the Akinomiya area decreased in salinity and increased in temperature. Several geothermal fluids in the Akinomiya area have been active. By comparing equilibrium temperature and *Th*, we can conclude that geothermal activity is becoming more vigorous in the Akinomiya area.

## 7. ACKNOWLEDGMENTS

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