Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

GEOTHERMAL DEVELOPMENT PROMOTION SURVEY PROJECT IN JAPAN

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Key Words: geothermal , Promotion Survey Project, Shibetsu, Ashiro, Akinomiya, Wasabizawa

ABSTRACT

For enhancement of geothermal power development by private sectors in Japan, NEDO (New Energy and Industrial Technology Development Organization) has been performing a program of "Promotion Survey Projects". In the Survey Projects, geoscientific studies and surveys—geological and geochemical studies, a geophysical survey, well-drilling, well-test and reservoir evaluations—have been carried out as NEDO projects sponsored by the Japanese government. So far, more than 50 geothermal areas in Japan have been studied using this program.

In Japanese geothermal power development, the program of these Survey Projects has been believed effective to encourage private sector development and technology support. Development in the some geothermal fields where the Survey Projects had been applied was continued and construction and operation of power plants were conducted. The survey project program is divided into three kinds of surveys at present, namely Surveys A, B and C. Depending on area and study content, an appropriate survey is applied to the selected geothermal area.

In this paper, the project program and the recent survey results are introduced. Positive indications on the potential of geothermal resources have been obtained in the survey projects at Shibetsu-dake, Ashiro, Wasabizawa and Akinomiya.

In the Shibetsu-dake area, where the project was conducted as Survey A with relatively large area, regional geological and geothermal structures were clarified using geoscientific data mainly obtained by surface studies and surveys. A high temperature zone (above 260 deg. C) was detected by well-drilling. Geothermal potential in this area is judged to be enough to perform the succeeding detailed survey. Existence of geothermal fluid at depths in the Ashiro area where the project was conducted—as Survey B—was confirmed by a well-discharge test. Further studies are necessary to realize power generation in the field. In the Wasabizawa area and the Akinomiya area where the projects were conducted as Survey C, geothermal reservoirs of high potential (higher than 270 deg. C), which are enough to be utilized for power generation, were confirmed using several exploratory wells. Near-future construction of power stations in these areas is expected.

Besides the above areas, NEDO is carrying out 5 promotion survey projects for finding geothermal resources of high potential simultaneously at present (1999). The activities of NEDO are expected to be useful for the private sector's geothermal development in Japan.

1. INTRODUCTION

Geothermal energy is regarded as the most promising oil-alternative energy in Japan and is expected to beneficial to the local society through multipurpose utilization. However, will-power of private sectors for geothermal power development is not always strong in Japan recently, due mainly to severe economic conditions. Furthermore, promising geothermal fields being located in national park areas and near hot spas—sometimes geothermal development is claimed not to perform by the Environmental Agency and hot spring owners. In these cases, some compromises with them are required for the coexistence of geothermal development with hot spas or national parks. That is, developing geothermal resources is regarded to be a risky and bothersome venture in Japan. Considering aspects of the development risks and social and economical conditions for geothermal power development, some assistance by the government is considered to be necessary for geothermal development by private sectors in Japan, using a government subsidy.

In order to reduce the risks involved in the initial investment of geothermal development, the Japanese government has made serious efforts to increase domestic geothermal power generation for the past two decades. Leading geothermal power developments in Japan with a firm step, NEDO, which is a semi-governmental organization under the ministry of International Trade and Industry (MITI) in fields related to technological development in Japan, started the revised-development promotion program on geothermal surveys in FY 1992. The program must be used for the benefit of the private sectors that intend to start geothermal power development in Japan. Using the program, they are supposed to be able to reduce the risk in the resource development.

The promotion survey program has been applied effectively to some geothermal areas, which were selected based on geothermally important factors such as heat sources, subsurface temperature, geothermal manifestations, geothermal structure etc. The projects at Shibetsu-dake, Ashiro, Wasabizawa and Akinomiya, which are introduced in this paper, are successful examples of the "Promotion Survey Projects" (Hattori A. et al., 1998).

2. PROGRAM OF GEOTHERMAL PROMOTION SURVEY PROJECTS

The promotion survey projects are regarded as a pre-feasibility study or resource feasibility study in general procedure of geothermal development. Performing the promotion survey projects is a major job of the Geothermal Energy Center of NEDO, and a great part of the budget of the center has been prepared for the Promotion Survey Projects. Over 3,000 to 4,000 million yen/year of the budget has been used for the promotion survey projects from 1980 to the present.

Before 1991, the promotion survey project was conducted with fixed survey specifications and constant area (about 50 to 70 km^2). The program was improved in 1992, thinking over the results of the past about 10-year projects. An epoch-making program that private companies—i.e. resource developers—were entrusted with the whole promotion study as Survey C

(described later) was introduced into the program for supporting private sector development directly. Not only surface geoscientific surveys and studies but also several exploration wells drilled of production-size were included in the survey. Therefore, the private company that intends to do field operations after the complementary promotion project can purchase the successfully discharged geothermal wells during the Survey C project at a reasonable cost. In addition, prerequisites for selecting survey areas for all kinds of surveys were made clear in the improved program. Regarding Survey C, minor changes of the program were conducted in 1999, but the basic specifications and concepts were not changed.

Under the scheme of this program, three kinds of survey projects, namely Survey A, Survey B and Survey C have been designated, differing in content and area. The surveys are classified as follows.
1) Survey A is the regional survey of 100 to 300 km^2, to detect subsurface high-temperature zones.
2) Survey B is the district survey of 50 to 70 km^2, to verify the presence of geothermal reservoirs of high potential.
3) Survey C is the pre-feasibility study of 5 to 10 km^2, to extract geothermally promising zones and evaluate potential of geothermal resources.

Details of the each Survey are described as follows.

2.1 Survey A

Objectives
In a geothermal area where prospective geothermal resources are considered to possibly exist but where there are few geoscientific data, geoscientific surface surveys and studies are mainly carried out for detecting high temperature zones during 3 years. Based on collected geoscientific data, the potentials of geothermal resources are judged for the next survey steps, i.e. Survey B or C. The area for Survey B or C is regionally extracted using the survey results, provided the geothermal potential in the area is high enough to conduct the following detailed surveys .

Contents
i) Collection of existing data
ii) Survey on geological structure
*Image analysis of remote sensing data
*Geological study and mapping, gravity survey, etc.
iii) Survey on subsurface temperature and heat sources
*Heat source surveys (distribution/age of volcanic rocks)
*Hydrothermal alteration study
*Fluid geochemical study
*Slim-hole survey (9 wells of 400-1,000 m depth)
iv) Integrated interpretation
*Delineating subsurface high temperature zone and hydro-thermal system.
*Extraction of prospective area based on geothermal structure.

2.2 Survey B

Objectives
In the geothermal area where promising geothermal resources are considered to possibly exist but geothermal surveys are not advanced mainly due to relatively high risks, geoscientific surveys and studies and exploratory well surveys are carried out for detecting geothermal reservoirs and modeling geothermal systems during 3 years. Based on collected geoscientific data, the potentials of geothermal resources are judged for Survey C. The area for Survey C is extracted from the survey results, provided the geothermal potential in the area is high enough to conduct the following detailed surveys.

Contents
i) Survey on geothermal resources
*Surface survey (Geological survey, Fluid-geochemical study, Geochemical survey and Geophysical surveys)
*Well survey (Heat holes and exploratory wells)
*Environmental study (Hot springs, etc.)
ii) Integrated interpretation
*Judgment on existence of geothermal reservoirs of high enthalpy.
*Modeling of geothermal system and reservoir.
*Extraction of promising area based on geothermal structure.

2.3 Survey C

Objectives
In the geothermal area where promising geothermal resources of high enthalpy are known to exist, geoscientific surveys and studies and exploratory well surveys are carried out for delineating geothermal reservoirs and modeling geothermal systems, during 4 years. Based on collected geoscientific data, potentials of geothermal resources are judged for leading private sectors to power development with low risks.

Contents
i) Survey for geothermal resources evaluation
*Detailed survey (Geological survey, Fluid-geochemical study, Geochemical survey and Geophysical surveys)
*Well survey (Exploratory wells, Production wells, Reinjection wells, Well log, Well discharge test, etc.)
*Geothermal resources evaluation (Long-term production test and Reservoir evaluation)
ii) Environmental study (Air, Water , Hot springs, etc.)
iii) Integrated interpretation
*Modeling of geothermal system and reservoir.
*Estimation of electric generating capacity of geothermal resources.

Fifteen projects have been conducted as "Geothermal Development Promotion Survey Projects" and Survey C projects have been promoted eagerly. So far, the two projects of Survey C at Wasabizawa and Akinomiya in the Tohoku district are believed to contribute to realizing power development by private sectors, in the near future.

3. RECENT SURVEY RESULTS

As the projects in which successful results were obtained, Shibetsudake Project (Survey A), Ashiro Project (Survey B), Wasabizawa Project and Akinomiya Project (Survey C) are introduced (NEDO, 1995, 1997, 1998a and 1998b). These survey areas are shown in Figure 1.

3.1 The Shibetsudake Project (Survey A)

The Shibetsudake area is located in the eastern part of Hokkaido, the northernmost island of Japan. The survey area is almost 300 km^2, extending 30 km in a NE-SW direction. Surveys and studies of Survey A described previously were applied to this area.

Three hot springs exist in the area, showing promising geothermal potential. More than 10 shallow thermal-gradient wells had been drilled before the promotion survey. Based on results of the geological and geochemical studies and geophysical survey, the locations were selected for three gradient wells and two deep exploratory wells. These wells subsequently recorded a maximum temperature of 264 deg. C at a depth of 1,734m for well SB-1. The geothermal structure was clarified conceptually using geoscientific study data and the high temperature zone was extracted. Survey results are summarized in Figure 2.

The high temperature zone of above 200 deg.C is recognized in the northeastern part of the survey area. Provided that the high temperature zone is related to geothermal fluid of high enthalpy, several faults in and around the high temperature zone (which were confirmed and assumed) possibly control behavior and distribution of the geothermal fluid. Since a high temperature zone was confirmed in the area, "Survey B" is now ongoing within the Shibetsudake area, and is named as the Musadake Area.

3.2 The Ashiro Project (Survey B)

The Ashiro project area is situated about 40 km north-northwest of Morioka city, Iwate Prefecture. The area is a part of the Hachimantai geothermal field where several known geothermal power plants are situated, i.e. Matsukawa (22 MWe), Onuma (10 MWe), Sumikawa (50 MWe) and Kakkonda (80 MWe). The survey area is located in the northern part of Hachimantai, measuring 15 km^2.

An exploration well, HT-1, drilled in 1980 near the Kusanoyu hot-spring, showed a maximum temperature of 185.6 deg. C at a depth of 802 m—indicating a high heat-flow of 15 HFU ($628mW/m^2$). Hydrothermal alteration zones composed of pyrophyllite and kaolinite zones were observed near the Kusanoyu and Appi hot springs. These were situated along the southern margin of an assumed collapsed basin with WNW-ESE trending fractures. Geothermal fluid discharging at the hot-springs is believed to derive from the deep level.

Several surface surveys were carried out and two deep exploratory wells (AR-1 and -2) of 2,000 m depth were drilled to confirm the geothermal potential of the area. Well AR-1 recorded a maximum temperature of 269 deg. C at a depth of 1,774 m, and AR-2, 283.4 deg. C at 1,715m. A higher temperature zone is assumed to extend towards the south. A low resistivity layer is situated between 500m and 1,000m deep, and was proved by drilling in altered pyroclastic flow deposits and dacitic pyroclastics of the upper Ainai formation of Pliocene-Pleistocene. The lowest resistivity layer (under 5 ohm-meter) consists of altered zones of montmorillonite and sericite. Figure 3 shows the conceptual model of geothermal reservoir in this area. This area was judged to deserve Survey C application.

3.3 The Wasabizawa Project (Survey C)

The Wasabizawa area is situated in the southern part of Akita Prefecture. The Uenotai geothermal power plant is only 2 km east of the survey area. Since 1995, systematic exploration surveys have been carried out in the area of about 8 km^2 . The survey program for Survey C previously described was applied to the objective area. The surveys consisted of geological, geochemical, and geophysical techniques (gravity and CSAMT surveys). The project was completed in 1998.

Using the integrated analysis results from these surveys, targets of exploratory wells were decided. Nine deep production wells, with depths ranging from 1,069 to 1,702m (the majority of the wells were drilled to depth of 1,500m), were drilled to confirm the reservoir extent. All the wells recorded over 200 deg. C with four wells exceeding 280 deg.C. The maximum temperature recorded was 299 deg.C. A high temperature zone is situated in the southeast, extending towards the northwest. The geological structures consist of NE-SW and NW-SE striking faults and fracture zones and a large-scale collapsed structure found southeast of this area. Distribution of the main geothermal reservoir must be controlled by the NW-SE trending structure along the margin of the collapsed structure. Figure 4 shows a conceptual model of geothermal reservoir in the area. Since May 1997, long term production tests were carried out; three months for the well WZ-9, and two months for the well WZ-7. At the same time, chemical analyses of brines and a pressure monitoring were made. Based on the results of these studies, a numerical simulation using 3-D block model and an economic analysis were conducted.

3.4 The Akinomiya Project (Survey C)

The Akinomiya area of approximately 10 km^2 is situated in the southern part of Akita Prefecture and the northeast boundary is adjacent to the Wasabizawa area. The project was started in 1997 and the survey program for Survey C previously described has been applied to the objective area. The surveys consisted of geological and geochemical studies, a geophysical survey and exploratory well study.

Faults estimated by the surface geological study and tectonic lines inferred from the resistivity map and the gravity map are believed to control geothermal fluid behavior as shown in Figure 5. For clarification of geological structure related to geothermal reservoir, studies using exploratory wells are continuing.

By FY1998, five deep exploratory wells had been drilled, with depths ranging from 1,001.51m to 1,651.5m. Most of the wells recorded temperatures over 240 deg.C and three wells discharged geothermal fluid successfully. In particular, the well AY-3 discharged about 70 ton/h steam and 130 ton/h water at the well head pressure of 15 kg/cm^2 and its reservoir temperature was recorded at 277 deg.C. The distinguished reservoir in the granitic rocks was found by drilling the well. A high temperature zone is situated in the eastern half of the area and then a high enthalpy fluid reservoir seems to extend to the boundary of the Wasabizawa area. Regarding the relationship between the reservoirs at Akinomiya and Wasabizawa, more detailed studies are necessary. Figure 4 shows a conceptual model of a geothermal reservoir and subsurface fluid behavior in the area. A numerical simulation using a 3-D block model and an economic analysis are being conducted and the feasibility of geothermal power development in this area is being judged at the final stage of the project.

4. FUTURE ACTIVITIES IN THE PROMOTION PROGRAM

Helped by these promotion surveys, the total geothermal

generation capacity in Japan exceeded 533 MW in 1999. However, since further development surveys are greatly restrained by the national park, and because of existing hot-springs reservations and economical conditions (including cost-competition with other types of power generation, such as nuclear, thermal, and hydro-power), only one new geothermal power plant is now under construction on Kyushu Island, i.e. the Oguni PP (20 MW) in Kumamoto Prefecture.

No one expects a huge surge in geothermal generation capacity right away because of the "Geothermal Promotion Survey Projects". However, NEDO has to effort to support private sector development. If private companies hop on the bandwagon, the development could be positioned for a big rebound when social and economic conditions change in the near future.

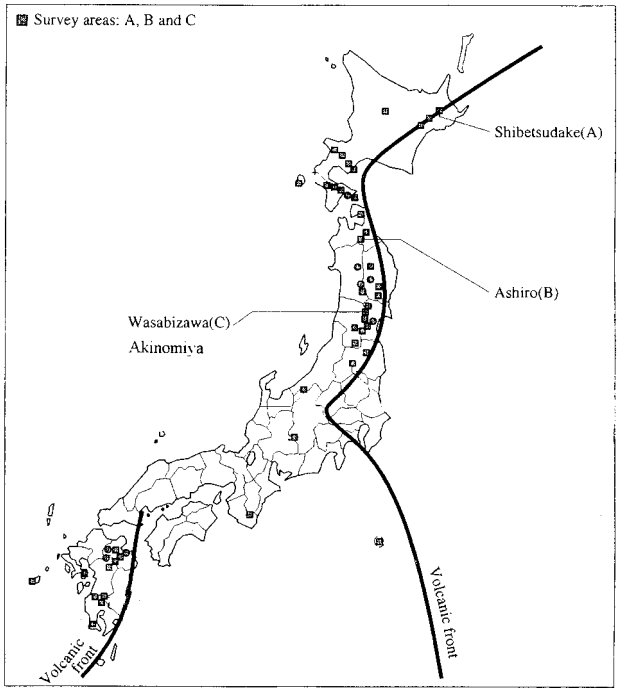

Figure 1. Areas for Geothermal Development Promotion Survey Projects

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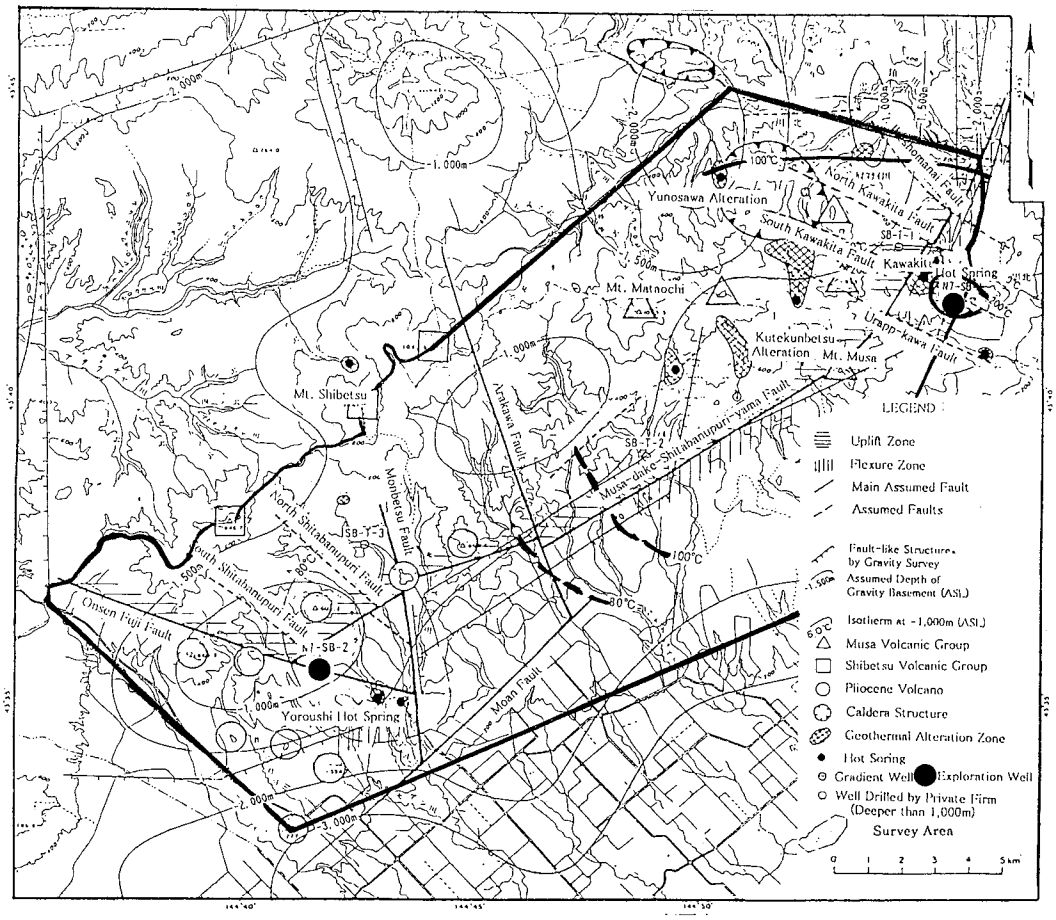

Figure 2. Survey Results in the Shibestudake Area

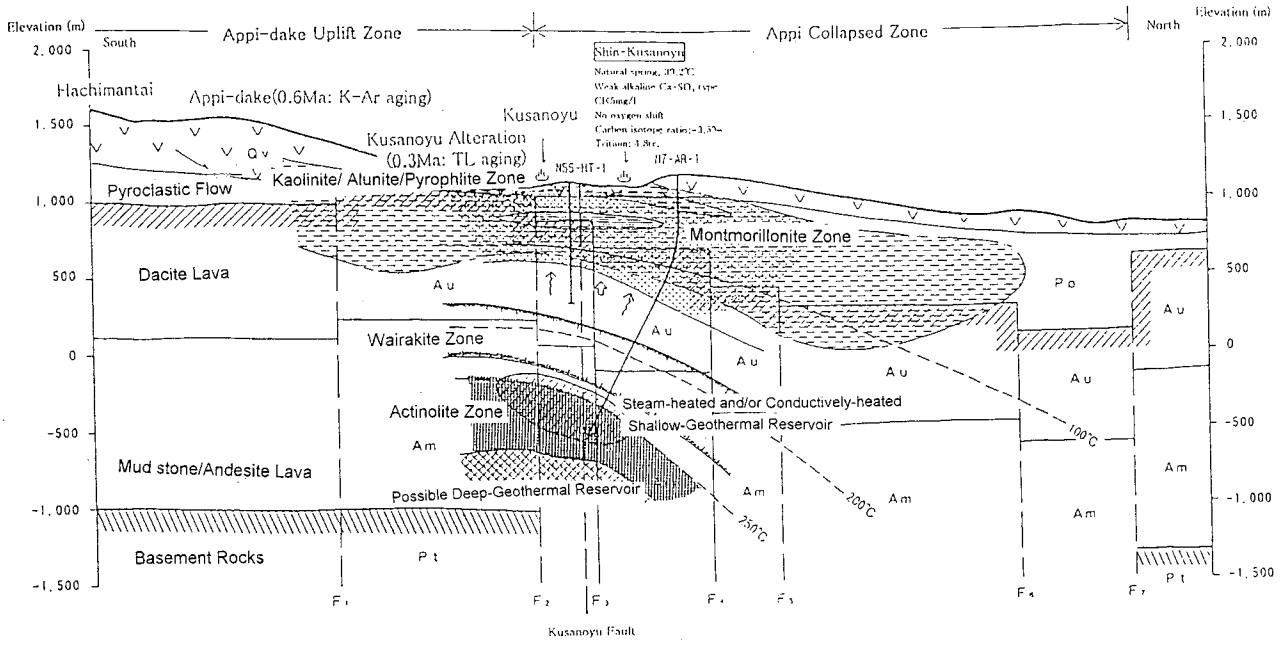

Figure 3. Geothermal Model of the Ashiro Geothermal Area

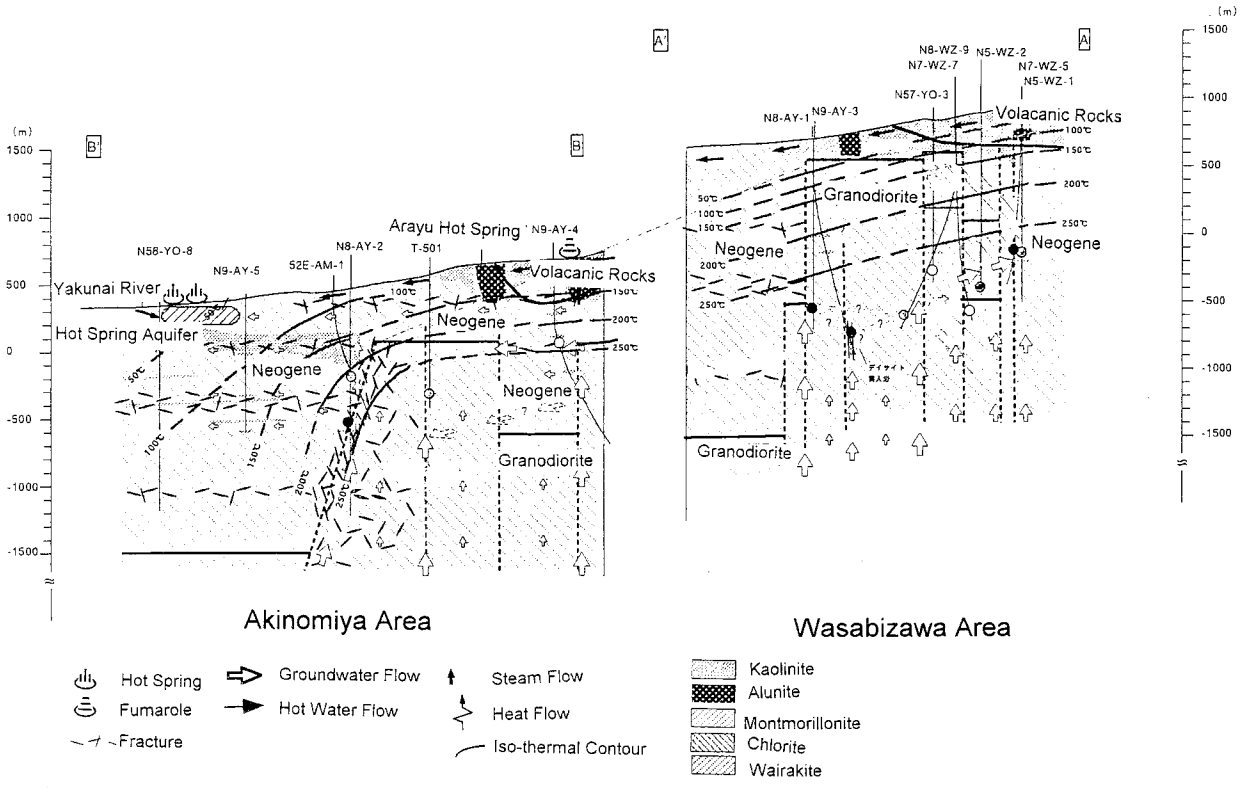

Figure 4. Geothermal Model of the Wasabiza and Akinomiya Areas

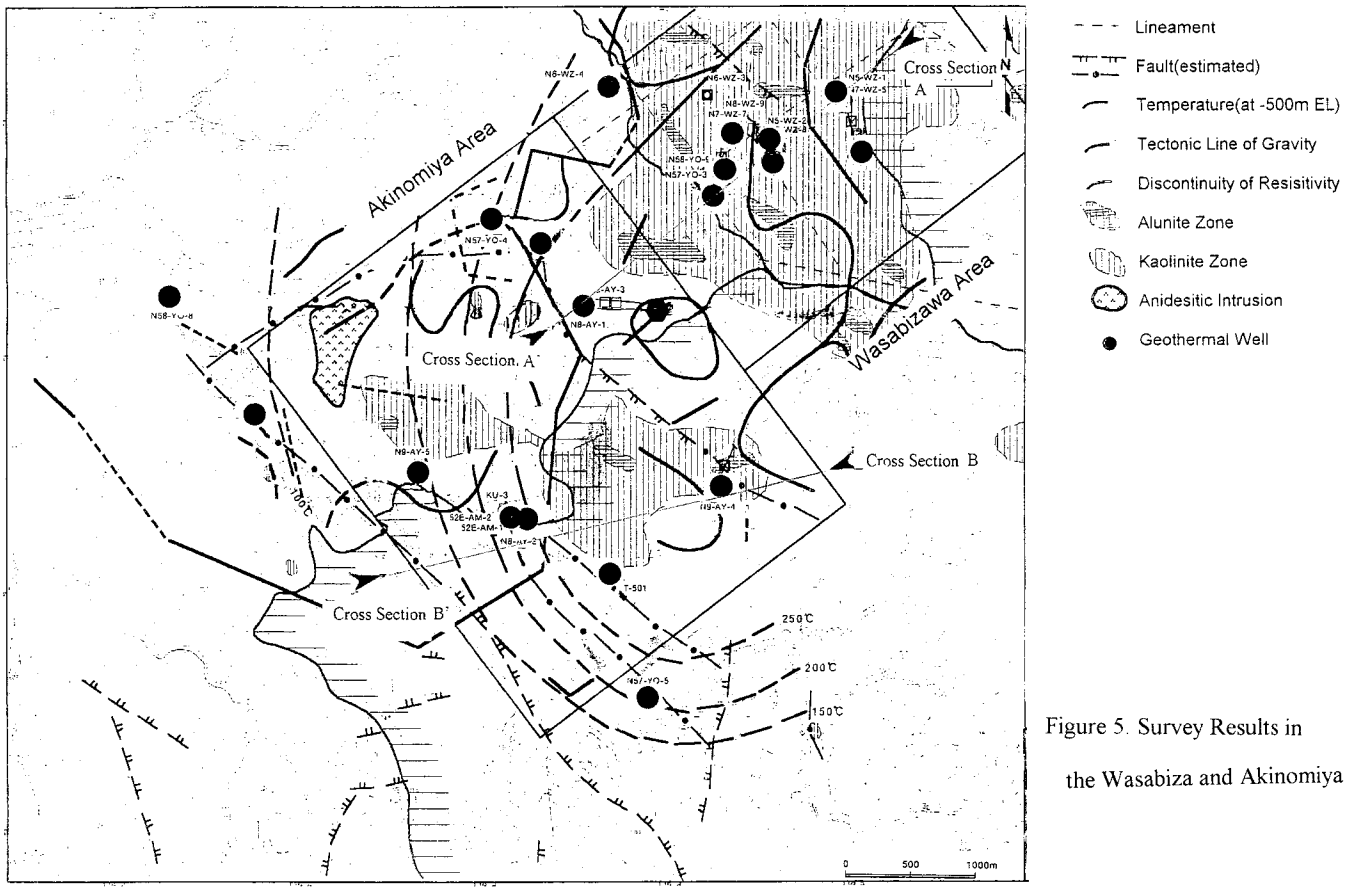

Figure 5. Survey Results in the Wasabiza and Akinomiya Areas