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The Research and Development for the Geothermal Energy in JOGMEC, JAPAN

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ABSTRACT

Until the year of 2003, the technology development for the geothermal energy had been conducted by NEDO under the METI's Sunshine and New-Sunshine promotions. The development supported by the government was, however, suspended due to the political decision. Other budget of the geothermal development became to be shrinking. After the electricity failure by the Tsunami disaster in 2011, the geothermal energy came under the spotlight and the technology development was restarted. The underground technologies around the reservoir are conducted by JOGMEC such as potential evaluation, exploration, drilling and so on.

Three projects concerned with the geothermal technology development are being carried out by JOGMEC, some of which are used the results of the NEDO projects. One is the exploration project of the precise detection of the fractures by the reflection seismic technique. The seismic method is considered to be hard to conduct in the geothermal field because of the complex geological setting but it has highly developed in the oil and natural gas field exploration. We have applied the recent technique to the seismic reflection data which were already collected in the geothermal fields and obtained reasonable results, which shows the major fault of the geothermal reservoir. The resistivity exploration using the TEM method survey with the SQUID magnetometer was also carried out. The last one is the technology for maintaining the reservoir pressure by recharging water into the reservoir.

1. INTRODUCTION

The Matsukawa Power Plant, the first geothermal power plant in Japan, commenced to operate in 1966. Since then geothermal energy is being exploited with the technology development and 17 power plants with 20 units are currently working with the installed capacity of 537 MW (as of March 2012; Thermal Nuclear Power Engineer Society, 2013). However, no power plant has been constructed since the Hachijo-jima power plant started to operate in 1999.

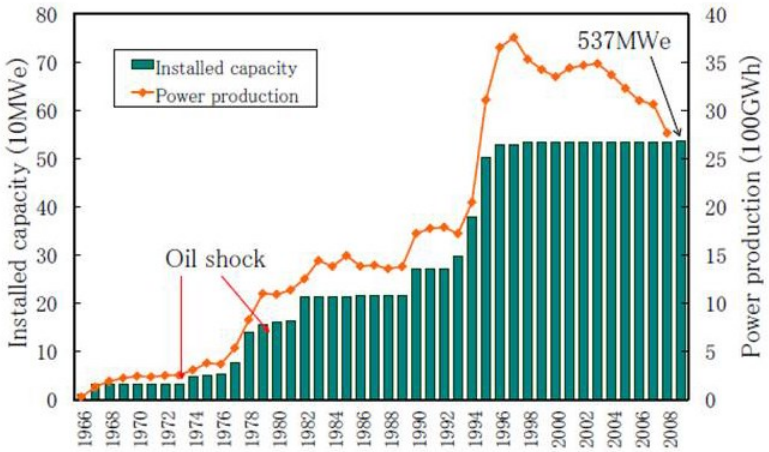

Figure 1: Geothermal power in Japan (Installed capacity and power production)

The R&D projects for the technology of the geothermal energy were firstly conducted by MITI (Ministry of International Trade and Industry, at present METI; Ministry of Economy, Trade and Industry) in 1974. The projects contained exploration and production technologies, material science and the HDR (Hot Dry Rock) system. The projects were transferred to NEDO (New Energy Development Organization in original and New Energy and Industrial Technology Development Organization at present) after its establishment in 1980. NEDO was founded in order to promote the research and development of new energies such as Solar PV, coal liquidation, wind power, geothermal energy and so on. The promotion survey program and financial subsidy for the geothermal energy development had also been conducted by NEDO under the promotion by MITI. The R&D project in NEDO was suspended in 2003 and no national project with government budget has been conducted since then.

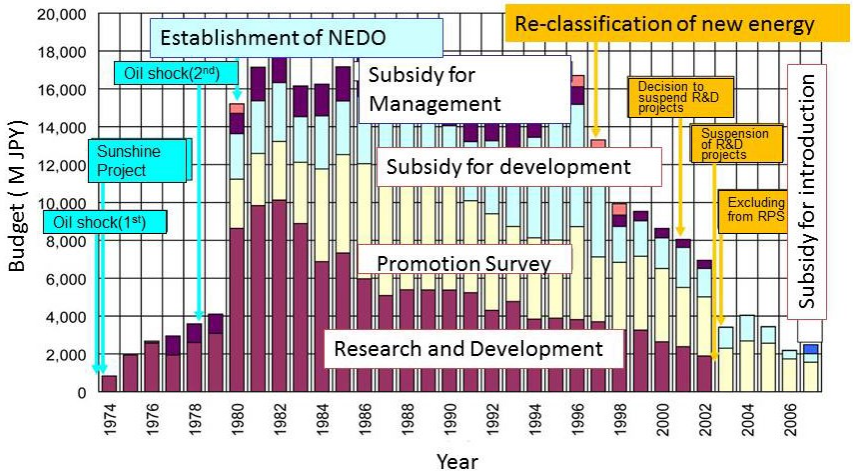

Figure 2: Budget for the geothermal energy development in Japan

In September 2012, JOGMEC (Japan Oil, Gas and Metals National Corporation) started programs for the geothermal energy development. The program includes not only survey and financial support like subsidy but also technology development. The technology development cannot be fully recovered after the suspension of the NEDO project but some results have been included in new JOGMEC projects. This paper we will review the technology developments conducted in NEDO and introduce the present projects in JOGMEC.

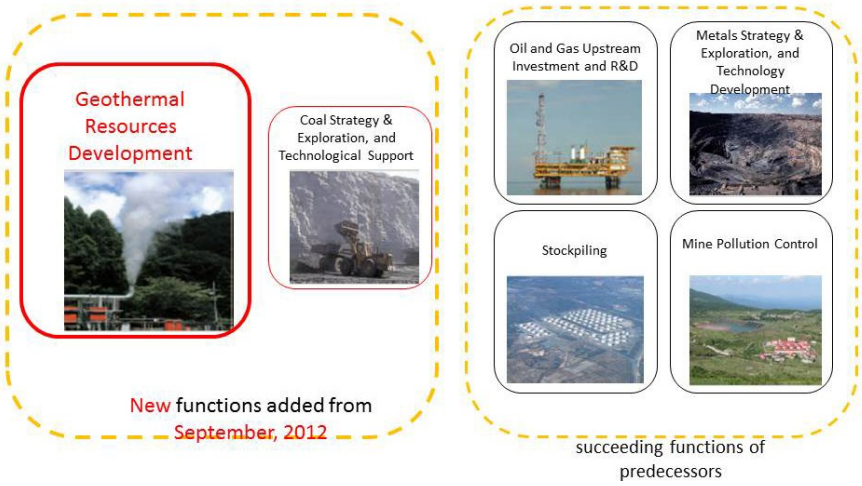

Figure 3: Functions in JOGMEC

2. TECHNOLOGY DEVELOPMENT IN NEDO

Technological developments funded by the government budgets had been conducted by NEDO and several national institutes under the umbrella of MITI. The national institutes like Geological Survey of Japan carried out basic R&D projects such as the physical property measurement of the rock in the geothermal reservoir, analysis method using the inversion technology and so on. NEDO, on the contrary, had a roll to apply fundamental technologies to the actual geothermal fields. Six projects were running when the decision of the suspension for all geothermal R&D was made. The title of six projects are as follows; Development of the technology for reservoir mass and heat flow characterization, Deep-seated geothermal resources survey, Development of drilling and production technology for deep-seated geothermal resources, Development of MWD system for geothermal wells, Development of binary cycle power generation technology, and Development of a hot dry rock (HDR) power generation system. The contents and results are briefly being reviewed for two important projects in this session.

2.1 Development of the technology for reservoir mass and heat flow characterization

Technology is required to identify the physical and hydrological changes which occur in the reservoir during production of geothermal fluid. Such technology could contribute to both minimizing the decrease in power generating output which often occurs during production, and increasing overall power generating output by indicating the location of fluids in surrounding areas.

NEDO launched a new R&D project aiming to characterize and forecast the mass and the flow in the geothermal reservoir in 1997. In this project, the equipment and methods were developed to measure the flow rate and monitor the movement of fluid. Gravity, SP (Self-Potential), microearthquake monitoring methods were adopted in the project. The project was suspended before the integration of all monitoring methods and performance test in a geothermal field. The computer program which calculates the variation of geophysical measurements such as gravity and resistivity on the surface from the output of the fluid flow simulator was developed in this project. The program is useful to compare the monitoring data and the computed results. If the data obtained in

the monitoring are far away from computed results, we have to adjust the reservoir parameters of the simulation. The computer code is widely used in the research projects not only for the geothermal exploitation but also for other subjects such as the CO_2 geological storage.

2.2 Development of a hot dry rock (HDR) power generation system

The conventional geothermal power generation method cannot utilise underground heat if little or no natural steam or hot water exists with it. Hot dry rock power generation, however, needs no natural steam or water. Its innovative concept enables the use of a type of geothermal energy which was never utilized before.

Fractures is artificially created by the hydro-fracture technique in the basement rock, where high temperature is expected. The location of these fractures is determined using seismic monitoring technology. A production well is then drilled in a location where it will be connected to the injection well through the artificial fractures. Water injected into the injection well flows through the artificial fractures, absorbs heat from the hot dry rock, and returns to the surface through the production well. Japan has abundant hot dry rock resources of about 2,900MWh (NEDO, 1994), which are estimated to contain an enormous quantity of thermal energy.

In the HDR project, we have succeeded to create two artificial reservoirs, upper and lower reservoirs and to produce the electricity of 50kW using steam of the flow rate of 1.5t/h. The project, however, remained several challenges, one of which is the short circuit created in the artificial fracture, resulting in the temperature decrease of the produced fluid (NEDO, 2003).

3. CURRENT AND FEATURE WORKS

Geothermal department in JOGMEC was established in September 2012 after the revision of the JOGMEC law, where geothermal energy will accelerate to develop. JOGMEC conducts financial support, survey by helicopter and technology development,

There are several options for the financial support. One of the supports is the granting subsidy, which supports up to 75% of the cost for the initial surface survey when the private company applies the subsidy. In the case of the application by the local company including the local government, the cost is fully assisted by JOGMEC. Survey using an investigation well is also supported by the subsidy though the percentage of the subsidy is decreased. Other financial supports are equity capital and liability guarantee. JOGMEC can invest up to 50% of the equity capital of the company for the drilling of investigation wells and discharge test using the wells. At the stage of building power plant huge amount of the cost is necessary to drill sufficient number of wells and JOGMEC supports the development by the liability guarantee, where up to 80% of the expenses are guaranteed. Nakashima et al. (2015) discuss on the several financial supports conducted by JOGMEC.

To evaluate the geothermal potential airborne survey using the gravity gradiometer installed in a helicopter were conducted at two areas in Kyushu. The investigation covers about 500km^2 in Kujyu and 200km^2 in Kirishima areas. Shimada et al. (2015) presented the survey results and discuss on the interpretation for the geothermal structure in the investigation areas.

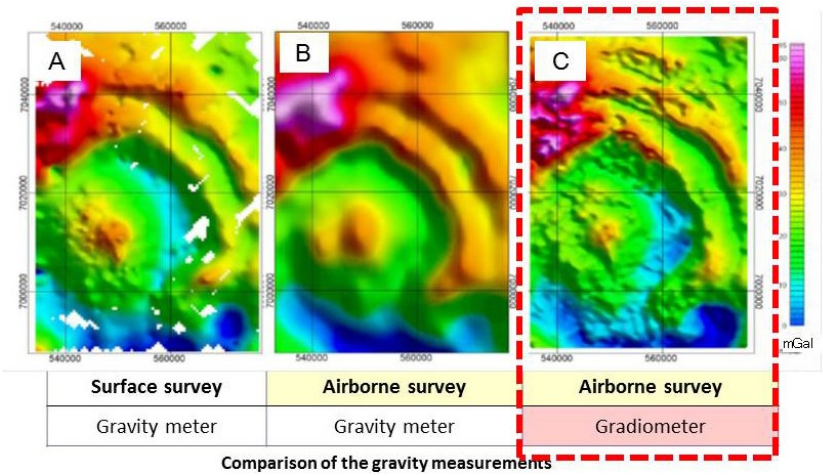

Figure 4: Survey by gravity meter and gradimeter

No geothermal technology development by the government project has been carried out since the government decided the suspension of the development because of the policy determination in 2003 except the development conducted by private companies and universities with small budgets. Three projects for geothermal technology development are being conducted by taking the NEDO's projects into account.

3.1 Seismic reflective analysis

Seismic reflection is one of the most precise methods to detect geological structure. The reflection survey is commonly adapted to find out anticline structure for oil and gas exploration. Seismic reflection data were collected at several geothermal fields in order to detect fractures associated with geothermal resources in Japan. However, faults were not always detected clearly by the reflection data.

The survey line should be designed as straight as possible for the 2D reflection analysis. However, most of the geothermal field in Japan are located in a mountain area and it is hard to set a survey line along a straight line. Recently Mizutani (2012) re-analysed 2D seismic data and showed fractures in a geothermal field in Japan. The success of the analysis was partly due to the reason that the recent technology developments makes the performance of the computer becomes much better and the complex calculation

faster. We selected four geothermal areas in Japan where seismic reflection data are available and applied a modern analysis technique, which has recently developed. Figure 5a shows the 2D survey line in the Ogiri geothermal field, Kyushu Island.

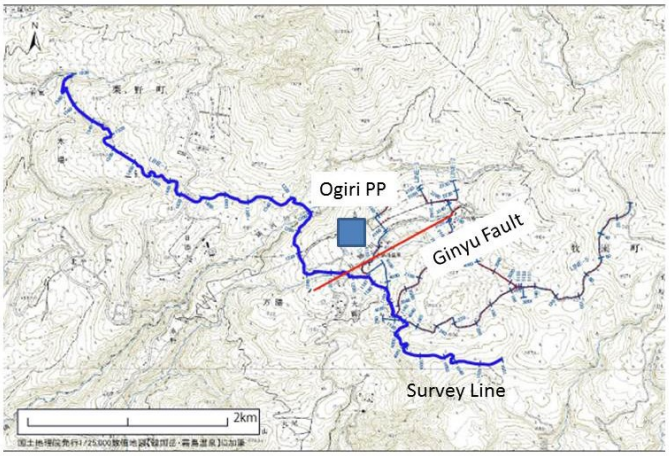

Figure 5a: Survey line for the seismic reflective method in Ogiri area

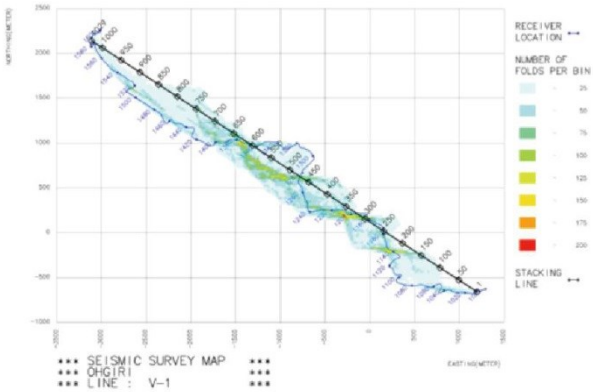

Figure 5b: Distribution of reflection points and a vertial survey line

The survey line was about 7.5km in length. The length was enough to calculate the geological structure at the reservoir depth of about 2km but the line was out of straight. The data were collected in 1998. Hypothetical survey line was assumed and all data were projected on the line. Fig 6 showed the seismic image analysed by the method in 1998.The Ginyu fault, the major fault associated to the geothermal fluid production indicated by arrows was identified at the shallow sections but unclear at the deep. On the contract to the analysis in 1998, the recent technique for suppression of noises can reveal the feature of the fault in the seismic reflection. There still remains uncertainty due to the bending survey line (Fig. 6b).

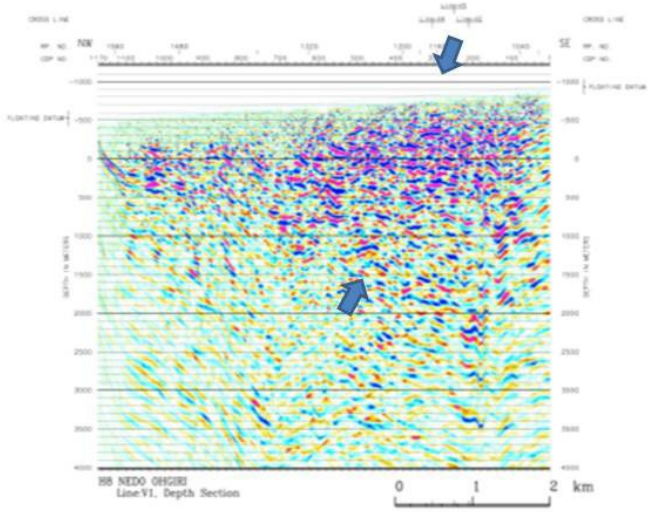

Figure 6: Seismic reflection record analysed by the method in 1998

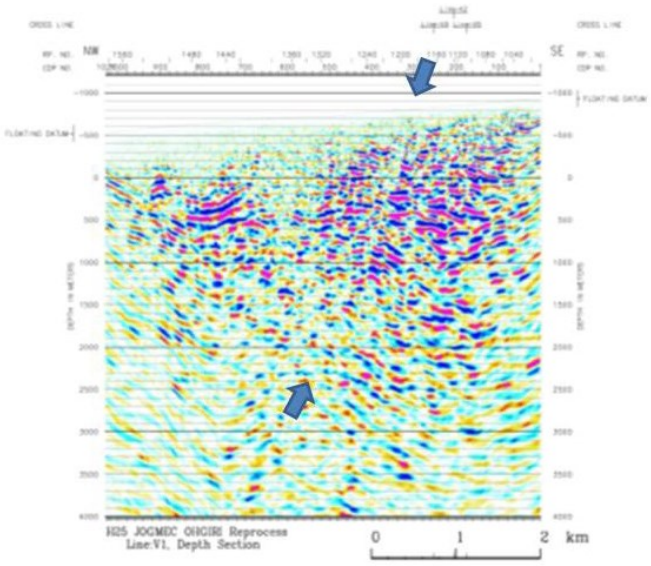

Figure 7: Seismic reflection record through the suppression of noises

A 3D acquisition with 2D configuration of receiver and vibrator for the seismic analysis becomes common in the petroleum industry. The application to the detection of geothermal reservoir, however, is somewhat difficult because of the topological condition. A acquisition configuration of the areal distribution of receivers with a line vibration source should be a possible layout to get precise reflection profile in a mountain geothermal field.

3.2 Electromagnetic survey

JOGMEC has developed a TEM (transient or time-domain electromagnetic) survey system using High-Temperature SQUID (superconducting interference device) magnetometer to intensify the exploration depth of the measurement (Arai et al., 2002). The system is named SQUITEM and was originally developed to the survey for the subsurface metal resources. SQUITEM system was applied to metal exploration in Australia and found a low resistivity distribution was found out which was failed to detect accurately by a conventional TEM survey system (Arai et al., 2006). In the SQUITEM system, the magnetic field (B) is measured in this system though the time-derivation of the magnetic field (dB/dt) is observed in a conventional TEM system used an induction coil receiver. Therefore the SQUITEM system is essentially more detectable and accurate in the response from the deep layer than the conventional system. The system has not been operated at the geothermal field.

In order to pick up the issue to operate the SQUITEM system and to solve it, we had a plan to conduct the system in a geothermal field where resistivity structure is well described. A survey using the SQUITEM system was carried out at the Ogiri geothermal field, where electromagnetic surveys by CSMT and MT methods were carried out in the survey project (Takakura et al, 2001). Fukuda et al. (2015) showed the detail of the survey.

3.3 Management technology in geothermal reservoir characteristics

Some geothermal fields are facing difficulty in producing steam needed to operate stably due to the depletion of the geothermal fluid, which results in the vaporization, cooling, and acidification of the reservoir. The depletion of the fluid makes sometimes a severe damage of the operation as the pressure at the inlet of the turbine becomes lower than the limitation. To address this challenge, JOGMEC make a R&D project to stabilize the production of subsurface geothermal steam and hot water by not only improving accuracy in evaluation of behavior of the geothermal fluid, but recharging water to the geothermal reservoir. Technology for the computer simulation and for the hydro-fracture stimulation developed in “Development of the technology for reservoir mass and heat flow characterization” and “Development of a hot dry rock (HDR) power generation system”, NEDO projects suspended in 2003, is used. Okabe et al (2015) showed the detail of the project and discussed.

4. CONCLUSIVE REMARKS

JOGMEC was established in 29 February 2004 as a government enterprise and has many experiments to exploit subsurface resources such as oil and metals. A function of geothermal resource development was newly added in JOGMEC in September 2012. The function includes potential survey and technology development as well as financial supports. Most functions are those transferred from NEDO but the procedures for the financial supports have been different. As to the survey program NEDO conducted the promoting survey where the surface survey was mainly conducted. The airborne survey by a helicopter is carried out in JOGMEC with the airborne gravity gradiometric method and the TEM method. This airborne survey method has an advantage in uniform investigation in a wide area. The investigation areas of 300 to 500 km^2 were selected around the geothermal power plants.

Three projects are being conducted for the technology development. The fracture mapping technique using the seismic reflection method was examined to the data obtained by the NEDO project. The recent analysis technique make the reflection image became clearer in the deeper part of the profile and enable to identify the fractures and the faults. The seismic survey is a powerful method to explore the geothermal resources even in a mountain area. It is worthwhile to make proper configuration in the application of the seismic survey technology in the Japanese geothermal field. The technology will help to exploit the resources but the difficulty in the cost is still remained.

Electromagnetic survey was also conducted using the SQUITEM system, developed survey equipment in JOGMEC to improve the signal accuracy corresponding to the sound in deep layer. A geothermal field was selected for the survey where the resistivity data collected in the previous NEDO project and the airborne data operated by JOGMEC were available. The management technology to recover the depleted reservoir pressure by artificial water injection into the reservoir is being developed. Some technologies developed in this project are transferred from that in NEDO.

Table 1 shows the list of the technology development in Geothermal Resources. JOGMEC already start the development for some technologies but there are lots of technologies the industrial wishes to develop. We will make progress for the development not only by ourselves but also by international collaborative works.

Table 1: Subsurface technologies for developing geothermal energy

Survey	Gravity Survey, Geological survey, Geochemical survey, Thermal alteration survey, Surveys in airplane, satellites
Exploration	Geophysical explorations using electric, magnetic, and seismic methods Surface exploration and exploration in wells
Performance Prediction	Geological and hydrological modeling, Fluid flow simulation technology
Drilling	Directional, Highly deviated, and Horizontal well drilling MWD (Measurement While Drilling) and DHM (Down Hole Motor) technologies
Evaluation/assessment	Resource, Environment evaluation Economy, Risk assessments,
Production	Well stimulation, Scale inhibitor, Steam production from acid geothermal fluid Cultivation
Monitoring	Seismic monitoring, Environmental monitoring, Land elevation monitoring

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