Political and Environmental Necessity of Japanese Projects on Geothermal Research and Development

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Key Words

governmental policy, environmental aspect, fracture-type, deep-seated reservoir, **HDR.** *binary* **cycle**

INTRODUCTION

In Japan. geothermal power was first successfully generated when a mere 1.12 kWe of power was produced in 1966 at Matsukawa in the Tohoku district. A great achievement can be seen in the current total 380 MWe capacity of Japan's thirteen power stations (Figure 1. and the 530 MWe capacity including plants which are under construction. However, such capacity levels are still very low compared to the overall geothermal energy potential existing in Japan

The major reasons for this are (1) a long lead time. (2) high risk and (3) high cost for development of geothermal fields The National Park Law restricts exploration or exploitation in national parks. where most promising geothermal areas are located. And what is worse. the recent low price of petroleum oil discourages Japanese geothermal developers from further investment. Therefore. if will be difficult to accomplish a national scheme to have 2,800 MWe of geothermal power generation by 2010

On the other hand. global environmental protection has recently became a very subject around the world. Energy consumption and environmental protection are ambivalent. It is quite impontant to develop environment-friendly energy resources economically. Thus. the duty of AIST in supporting the projects by New Energy And Industrial Technology Development Organization (NEDO) is becoming more important considering- the current situation

GOVERNMENTAL POLICY FOR DEVELOPMENT OF GEOTHERMAL ENERGY

Japan's national scheme after the oil crisis in 1973 was to develop geothermal power plants with a capacity of 2,100 MWe by 1990. As was mentioned above, Japan currently has only thirteen geothermal power plants with a total capacity of 380 MWe. Haven't we seen fruitful results from investment despite spending 80-100 billion yen for basic exploration and technology development? The answer is "No." We cannot expect to get petroleum oil at a low price forever Fossil energies in particular will he exhausted in the future. From the viewpoint of short-term strategy for energy security, we need continuous technology developments to reduce the production cost of new energy resources to be economically competitive with conventional ones. Even though geothermal energy has already been utilized for many years. for further development, more advanced technologies *are* required to utilize new types of geothermal reservoirs such as deep-seated and hot dry rock systems andlor tu obtain higher recovery from low-temperature systems

Funhermore, we must protect the global environment from the massive absorption of fossil fuel consumption by industrial countries. Although current energy consumption in developing countries is relatively low, it will increase rapidly with improvement of the quality of life Without countermeasures to restrict pollution on a global scale. severe environmental problems will occur sooner or later. One of the measures for reducing environmental damage without harming economic activity is a "breakthrough" in technology development.

The Japanese government has a proposal lor a strategy to develop C02 solidification technologies with the cooperation of developed countries. An international meeting was held in Tokyo in October 1993 to discuss abaut this proposal A resolution to start cooperative work was accepted by all participants at the meeting and the OECD Secretariat is going to prepare a draft proposal by this spring

Although most new energies and renewable energies emit only a little pollution to the environment, the strongest point of geothermal resources is that they can produce condensed energy constantly. while

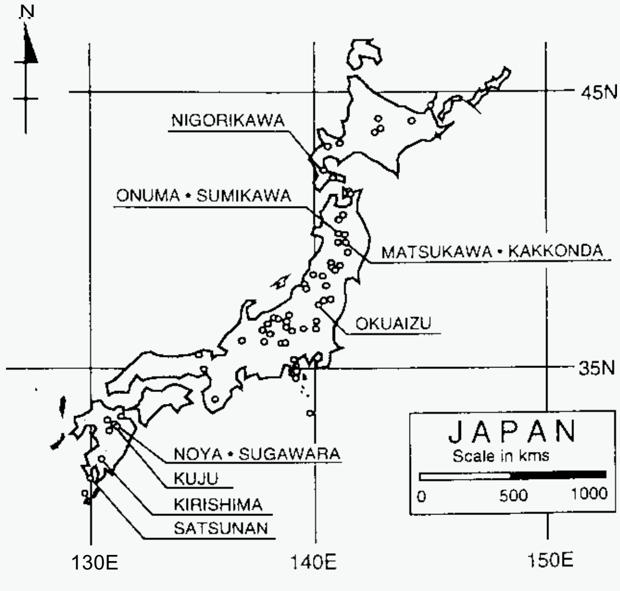

Figure 1. Map of prospected geothermal areas in Japan

°°° prospected geothermal areas

NAME existing geothermal power plants

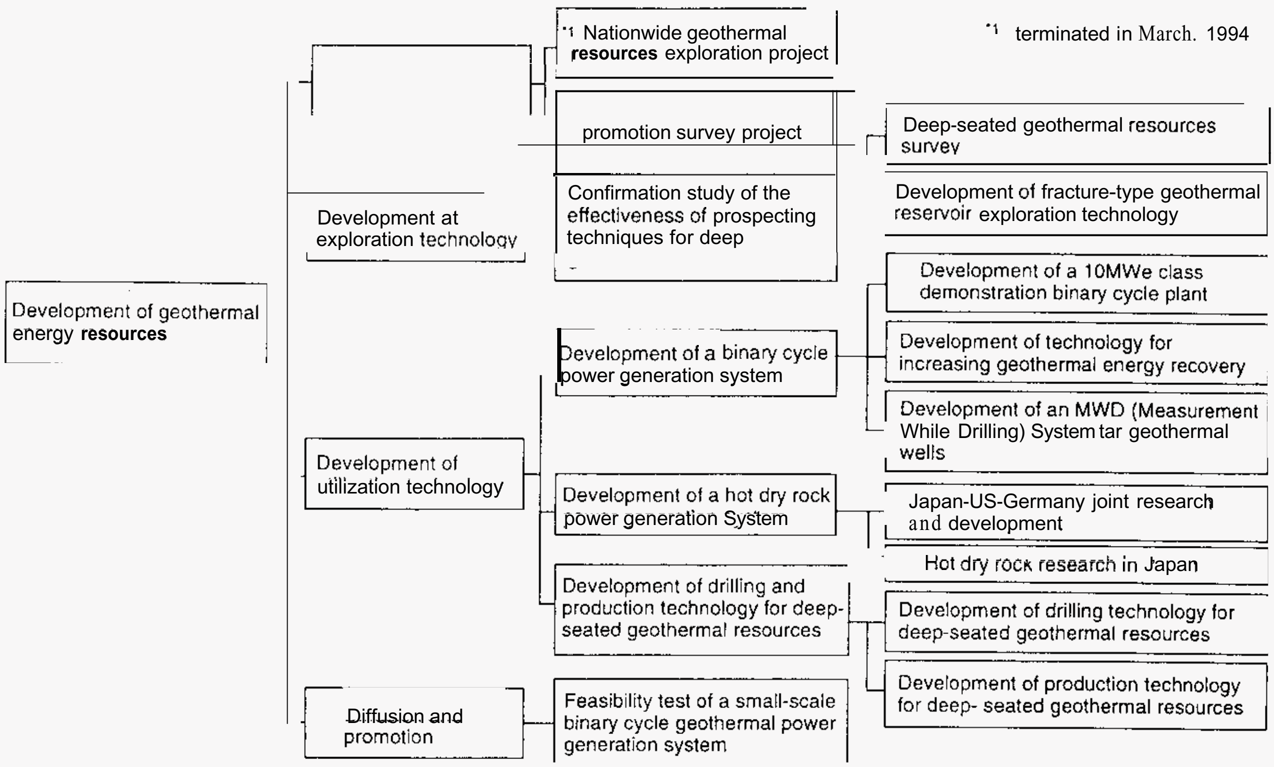

Figure 2. NEDO projects for development of geothermal energy resources

most other new energies can produce only low density and/or unstable energy. Those of us who are involved in the development of geothermal energy have to publicize how geothermal energy can greatly contribute to save the global environment Further utilization of geothermal energy reduces CO_2 discharge without discouraging economic activity As geothermal energy resources exist only in limited parts of the world. we should utilize them as much as possible where such resources are available. Thus, the Japanese government recognizes that efforts for further geothermal energy development have become more imponant than ever More.

NEDO PROJECTS FOR DEVELOPMENT OF GEOTHERMAL ENERGY RESOURCES

Since 1980, NEDO has been working to promote geothermal energy resources development by means of four tasks: surveys of resources. development of exploration technology. development of utilization technology. and diffusion and promotion The overall framework of current NEDO projects in the field of geothermal resources development is shown in Figure 2 Each of the projects is introduced in the following sections.

Survey of Resources

Nationwide Geothermal Resources Exploration Project

The purpose of this project was to identify the distribution of geothermal resourccs systematically for the promotion of efficient utilization of geothermal resources in Japan. The whole project was conducted from FY1980 to FY1992 in three phases.

In the first phase (1980-1983), NEDO analyzed nationwide geothermal data. applying the latest data, such as radar imagery data, Curie Point data and gravity data throughout Japan. Many prospective georhermal areas were thus identified. Based on the results of the first phase, four types of prospective geothermal fields were selected for further investigation: a possible high temperature system and three different types of volcano-related hydrothermal convection systems. A variety of ground-surface surveys were conducted at these fields and their geothermal structures (heat source. hydrothermal fluid, and reservoir structure) were analyzed in the second phase (1984- 1986).

In the third phase (1987-1992), a computer system called GEMS (The Geothermal Expert Modeling System) for heat source evaluation was developed and the potential of each geothermal area was thus evaluated Methods for various survey. analysis, and evaluation were standardized for this computer system Airborne electro-magnetic and magnetic, and satellite (JERS-1) surveys *were* also conducted in a several geothermal areas employing optic sensors (OPS). The results show that OPS are quits useful for regional geothermal resource exploration over large and distant districts.

Geothermal Development Promotion **Survey**

This survey project. composed of surveys **A.** B and C. has begun in 1980. Survey **A** is a regional survey of 100-300 km^2 area searching far high subsurface temperature zones. B **is** a district investigation of 50-70 km^2 area to verify the presence of geothermal reservoirs. C is a pre-feasibility study of 5-10 km^2 area extracted as a promising geothermal area. Survey C includes drilling of production-size exploration wells for a long-term production test and other surveys to estimate the potential of the reservoir. Survey B has already been finished in 38 areas, resulting in the discovery of 24 areas in which the maximum temperature in drillholes **are** over 200°C. In districts which were identified as promising geothermal areas, further investigation will be conducted by private companies

Development of Exploration Technology

Deep-Seafed Geothermal Resources Project

For an expansion of geothermal power generation, development of deep-seated geothermal resources which underlie shallower reservoirs that have already been developed must have the fastest effect. The estimated volume of deep-seated geothermal resources in Japan is more than 40,000 MW, which is twice that of shallow resources. However, the high cost and high risk of deep geothermal development obstructs further development. NEDO began a six-year research project, the Deep-seated Geothermal Resources Survey, in FY 1992. The goal of the project is to designate directions for the deep geothermal resources development for practical use.

The Kakkonda geothermal field where a 50 MW power plant had already been in operation was selected for this project. Drilling of an exploration well WD-1 (Well for Deep Geothermal Evaluation) which will be the deepest (–4,000 m) and hottest (350-400°C) geothermal well in Japan has been under way since 1994. Various kinds of well logging and several new investigation methods for deep geothermal reservoirs are being conducted. Some new drilling techniques such as top-drive drilling system and measurement-while-drilling (MWD) system are also introduced to be evaluated in their efficiency for deep geothermal drilling throughout the project.

Flow tests are scheduled at two different depths when the drillhole hits deep reservoirs. Temperature and pressure monitoring, tracer tests, and casing corrosion and erosion tests will be conducted during flow tests. The profile of deep-seated geothermal reservoir would be thus revealed (Figure 3) and criteria for deep exploration will be indicated in the end.

Development of Fracture-type Geothermal Reservoir Exploration Technology

Since 1980, NEDO has been engaged in the development of new techniques to delineate fracture zones which mainly control the geothermal fluid flow systems. Development of application technologies for geothermal exploration using electro-magnetic waves, seismic waves, and micro-earthquakes are thus being conducted.

As an electromagnetic method, array controlled source magnetotelluric (CSMT) method is being studied in this project for an improvement of accuracy of the CSMT method. Lighter and smaller CSMT equipment was designed and manufactured to be suitable for rough geothermal fields. Joint inversion analysis of MT and CSMT methods are proved to be effective.

As for seismic methods, high-resolution seismic reflection surveys, vertical seismic profiling (VSP), and seismic tomography are being studied. Several improvements of the borehole experiment tools especially against high temperature were made for field experiments. Correlation between fracture zones and hydrological characteristics in a geothermal field is being investigated by combination analysis of various well tests, geological survey and seismic surveys.

For micro-earthquake analysis, Micro-earthquake Data Processing and Analysis System (MEPAS) was developed for geothermal exploration and monitoring. Micro-earthquakes often occur

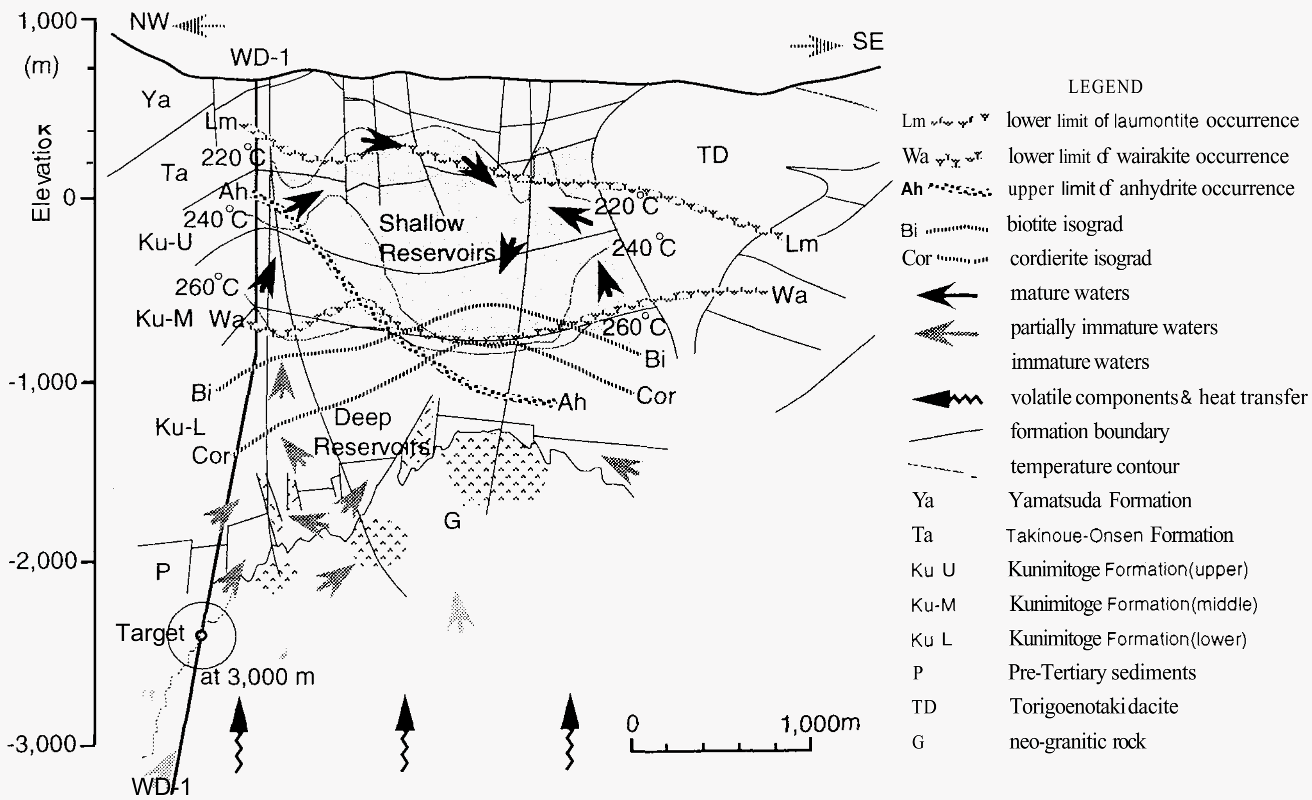

Figure 3. Prospected geological section in the Kakkonda geothermal field, Iwate Prefecture (updated by data from WD-1 to a depth of 1,500m)

in geothermal areas because of movements of geothermal fluid. MEPAS automatically processes and analyzes data acquired by seismometers distributed in a geothermal field so that this systein can he easily used by engineers who are not earthquake analysis experts. MEPAS can also be used for further analysis by combining of micro-earthquake data with other geothennal exploration data.

Development of Utilization Technology

Development of a Binary Cycle Power Generation System

NEDO is endeavoring to establish technology for binary cycle electric power generation which enables the econoinic utilization of geotherrnal hot water. As it is a closed systern, it is an ideal system from the environmental aspect. Development of binary cycle power generation systems will encourage the expansion of geothermal power generation releasing the power of moderate temperature liquid-dominated geothermal resources (150-200°C)

By 1979, NEDO had succeeded in constructing and operating two different types of one MW pilot binary power plants, one for hot water and another combining hot water and steam. At the present time. development of basic techniques for enhancement of the performance level of the main plant components is the major task of this project.

Development of Technology for Increasing Geothermal Energy Recovery

Technology development for enlargement of energy recovery is being directed toward creation of artificial fractures by hydraulic fracturing or activation of existing fractures in order to increase productivity. Conceptual models of hydraulic stimulations for different types of reservoirs are shown in Figure 4. Establishment of this technology would rrduce the cost of geotherinal power generation.

Development of a MWD (measurement-while-drilling) System for Geothermal Wells

The drilling cost for a geothermal well occupies a large percentage of the total geotherinal investment. In geotherrnal drillings, severe problems, such as lost circulation, sloughing and sticking easily occurs resulting in the damage of drilling tools and/or well. On the other hand, because of cnviroiiinental regulations, the directional drilling technology is required to drill multiple wells from a single drilling station. Under these conditions, NEDO began a project, Development of a MWD System for Geothermal Wells in 1991 The project features the development of real time detection equipment for simultaneous acquisition, transference, calculation and analysis of bottom hole information under a high temperature (~200°C).

Development of a Hot Dry Rock Power Generation System

NEDO participated in the Fenton Hill hot dry i-ock project to conduct various research activities from 1980 to 1986. Since 1985, NEDO has been conducting a research project to develop eleinentary techniques for HDR geothermal power gencratioii at Hijiori test site in Akita Prefecture. A successful circulation test was madc for three months at a 1,800 in deep reservoir in 1992. Water loss during the circulation was less than 20 %, and the thermal energy of the produced

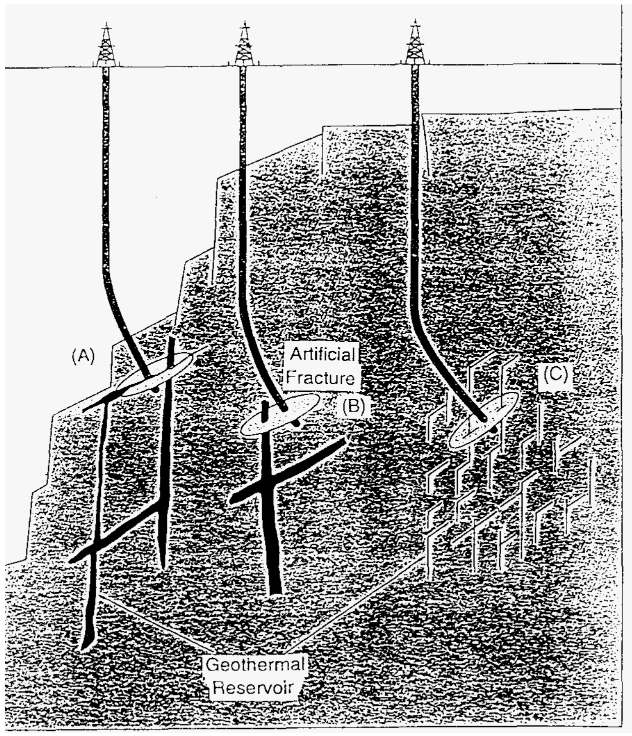

Figure 4.
Concepts of hydraulic stimulation for different types of reservoir
[A) Widening of weakly connected fractures
(B) Creation of new fractures
(C) Accumulation of fluid from small fractures

fluid was 8MW Then the wells were deepened to create 2,200 m deep reservoir below the existing reservoir to evaluate the energy volume and the lifetime of the artificial deep reservoir

Development of Drilling and Production Technology for Deep Seated Geothermal Resources

As is discussed above, the high cost and high risk in deep drilling prevents developers from exploiting deep-seated geothermal resources. Therefore, NEDO is performing a project, Development of Drilling and Production Technology for Deep-Seated Geotherinal Resources especially for high temperature conditions. As drilling technologies, special drilling bit, drilling mud, cement slurry, down-hole motor (DHM) against high temperature are being developed Similarly as production technologies, special PTSD logging tools and monitoring tools for PTC (Pressure, Temperature. and Chemical components), scale, tracer and surface and borehole gravity are being developed in this project.

Diffusion And Promotion

For sinall-scale energy resources. a seven-year project Demonstration Test of a Sinall-scale Binary Cycle Generating Plant has been conducted since FY1991 In a feasibility study for diffusion of a binary power generation systein, an economic evaluation of the generation system was made based on the distribution of resources and energy demands. Then a 100kWe class binary cycle power plant was constructed. Based on the results of an operation test in FY1994, the design of its system will be evaluated and modified to be suitable for a low-temperature geothermal system. Finally a 500kWe class binary cycle generating plant will be constructed and an operation test will be held.

CONCLUSIONS

Recent social concern about environmental problems encourages the promotion of geothermal energy development. Nevertheless, it is quite important to minimize environmental impacts by development of geothermal resources. NEDO has been carrying out its geothermal projects in consideration of landscape preservation and avoiding adverse effects on nature.

Geothermal projects other than those introduced above have also been conducted by NEDO and finished with fruitful results in the past. Some of the projects such as the Deep-seated Geothermal Resources Survey are being watched with the keenest interest internationally. It is our pleasure that the new technology and concepts developed by NEDO will be diffused abroad.