APPENDIX

CURRENT SITUATION OF GEOTHERMAL DEVELOPMENT AND GEOTHERMAL TECHNOLOGY DEVELOPMENT IN JAPAN

1. Geothermal Development in Japan: Current Situation and Issues

Located on the circum-Pacific volcanic belt, Japan is blessed with abundant geothermal resources. Trial calculations indicate that ten percent of the geothermal energy in the earth's crust is released in the Japanese archipelago and neighboring areas. Japan has geothermal energy power generation operations in sixteen locations, facilities with a total capacity of approximately 530 megawatts (Table 1 & Figure 1). Japan ranks fifth in geothermal power generation in the world; however, compared to 2,850 megawatts in the U.S. and 1,400 megawatts in the Philippines, it must be said that the capacity in Japan still remains at a relatively low level. This is due to the following circumstances in Japan:

(1) Most areas with available geothermal energy are located in natural parks. Due to the particular concern regarding influences on hot springs, much time is needed for the adjustments required to locate industries, including geothermal power generation plants. (2) Since effective survey techniques are not fully established, the development risks are large. (3) The development lead times are long, i.e. from the start of investigations to the construction of power generation plant(s). (4) As a result, the total power generation cost is higher than for other resources. In addition, Japanese geothermal energy developers have had to restrain development due to the low and stable prices of crude oil in recent years.

In the long-range energy outlook for Japan formulated in June 1994, the production targets for geothermal energy development are 600 megawatts in total for the year 2000, and 2,800 megawatts for the year 2010. Although the objective for the year 2000 is attainable, the objective for the year 2010 requires a further increase of 2,200 megawatts of power generation capacity. Considering that the Matsukawa power generation plant, the first in Japan, started operation in 1966 and that Japan has finally reached a total of 530 megawatts after thirty years of operations, extraordinary efforts will be required to reach the objective.

2. Geothermal Technology Development

On the occasion of the outbreak of the fourth Mideast War and the subsequent oil crisis in 1973, Japan embarked on efforts to promote the exploitation of alternative energy sources to replace oil. In 1974, the Sunshine Project Promotion Division was established at the Agency of Industrial Science and Technology, Ministry of International Trade and Industry; and in

1980, the New Energy Development Organization(NEDO) was established. Since this time , Japan has endeavored to develop new energy sources.

It is important to promote technology development from an integrated standpoint, particularly when faced with existing global environment issues, in order to carry forward a single package of balanced measures that combine the three goals of economic growth, assurance of stable energy supplies, and environmental conservation. Furthermore, from a technology standpoint, it is necessary to accelerate the development of energy and environmental technology in an efficient way. The New Sunshine Project was inaugurated, from this point of view, with the aim of maintaining sustainable growth and solving energy and environment issues at the same time. Japan is at the starting point of this innovative technological development.

National research institutes are at the core of geothermal technology development in Japan, and include , the Geological Survey Bureau, the Integrated Research Institute for Resource and Environmental Technology, and the Tohoku Agency of Industrial Science and Technology, among others. In order to promote geothermal energy development, the following will be necessary: (1) increased exploring of deeper parts of the earth and areas in close proximity to existing development regions which have less restrictions on the location of industry; (2) reduction of development risk through development of new probing technology; (3) reduction of excavation costs and shortening of lead times with improved excavation techniques; and (4) more rapid development of application technologies for yet untapped geothermal energy resources such as hot dry rock resources and medium-and high-temperature hot water resources.

At NEDO, geothermal energy development has been promoted in line with the following objectives: resource surveys, development of survey and excavation technologies, development of application technology, and the diffusion and promotion of related technologies.

RESOURCE SURVEY

With the 1973 Oil Crisis as a turning point, the Japanese government commenced a broad range of geothermal resource surveys in an organized manner. In order to reduce geothermal development risks, boost private firms' drive for development, and seek improvements in economic efficiency by reducing construction periods, NEDO embarked on a broad program of geothermal development promotion surveys in order to determine the amount of available geothermal energy and to increase the accuracy of such surveys themselves (Figure 2). The promotion surveys are conducted at three stages. "A Surveys" (covering an area of 100 - 300 square kilometers) are "wide-range surveys" to confirm the existence of high-temperature zones in areas with scarce data. "B Surveys" (covering an area of 50 - 70 square kilometers) are at the "rough survey stage" to filter out, from regions with available geothermal energy, areas of extraordinarily high temperature which are suitable for geothermal energy power generation, and then to confirm the geothermal reservoir(s) by mine well excavation. "C Surveys" (covering an area of 5 - 10 square kilometers) are at the "precise survey stage", intended to provide a grasp of the amount of geothermal resources by the implementation of mine well investigations in areas where geothermal reservoirs have been discovered. The mine well investigations include long-term eruption experiments .

In addition, the New Sunshine Project also includes technology development programs for NEDO to address various problems related to geothermal energy development (Figure 3).

DEVELOPMENT OF SURVEY TECHNOLOGY

In the development stage surveys, to more accurately probe the structures and features of fissure and fissure groups which form geothermal reservoirs, the development of the following technologies is implemented as part of the "Method for Surveying Fissure Type Geothermal Reservoirs Project": (1) seismic probing method; reflection methods (vertical seismic profiling using wells and seismic wave tomography); (2) electromagnetic waves; (3) physical survey methods with the aid of micro earthquakes.

It is gradually becoming clear that in the lower portions of existing reservoirs there are additional reservoirs. Compared to the resources existing in the shallow portions, the deep-seated resources are high in both temperature and pressure. If these resources can be exploited without restrictions on the location of industry, it will be possible to increase the power generation capacity.

However, since there are many risky factors unknown points about the scientific properties of hot water and the structures of geothermal reservoirs, a lack of adequate survey and application technologies and high temperatures in the deep underground, the current situation is that geothermal developers are not able to commence exploitation promptly. Therefore, during a survey of deep-seated geothermal resources being carried out by NEDO in the Kakkonda area of Iwate Prefecture, a 4,000 meter deep mine well is being excavated and geological investigations conducted. So far the investigation has confirmed a temperature of 500℃ at a depth of 3,730 meters.

DEVELOPMENT OF EXCAVATION TECHNOLOGY

In collaboration with the deep-seated resources survey project referred to above, the development of deep seated geothermal resource extraction technology is being conducted. The development consists of two areas: deep-seated resources excavation technology and deep-seated resources production technology. Deep-seated geothermal resource excavation technology includes the development of heat-resistant, pressure-resistant excavators (using bits, liquid mud, cement slurry), while deep-seated resources production technology includes development of production management machinery (PTSD detection, sampling devices).

A detection system for information at the bottom of geothermal wells (MWD system) is under development, aiming at improvements in excavation efficiency and accuracy by obtaining real time information at the bottom of geothermal well during excavation. Although an MWD system has already been used for oil excavation, the development of a system resistant to 200℃ heat and suitable for geothermal wells is still under way. The new system is expected to increase excavation efficiency, avoid problems during excavation, and reduce excavation time overall to reduce cost.

DEVELOPMENT OF APPLICATION TECHNOLOGY

In Japan the chief method of geothermal electric power generation is steam power generation, utilizing self erupting steam. However, medium- and high-temperature hot water that fails to erupt automatically due to the low temperature(s) in geothermal reservoirs is not utilized. Binary cycle power generation technology, which draws the unused hot water with downhole pumps (DHP) and then exchanges heat with a low boiling-point medium to create high pressure steam to drive a turbine, is under development.

The development of the downhole pump has been completed thus far. A 10 megawatt capacity pilot plant is under construction in the Sugawara area of Kyujucho in Oita Prefecture. Binary plants have already been put into practical use in the U.S. with 1 megawatt modular type units serving in the mainstream; however, there are no 10 megawatt capacity units yet. In addition, the DHP has been a line shaft type. The technology of Japan's underwater motor type DHP is resistant to 200℃ temperatures, the first of its kind in the world.

Hot dry rock, although possessing a significant amount of thermal energy, does not produce hot water and steam. Therefore a hot dry rock power generation system is designed so as to generate electric power by creating artificial reservoirs in hot dry rock and extracting thermal energy through water injection and circulation. An experimental field has been established in Hijiori, Okuramura of Yamagata Prefecture to implement related research and development. In 1991, a ninety-day artificial reservoir circulation experiment was conducted at a shallow portion (1,800 meter depth) and thermal energy and steam (thermal energy of approximately 8.5 MW) were recovered successfully. In 1995, a preliminary circulation experiment was conducted in a deep seated artificial reservoir (2,200m depth). The current target is to implement a two-year term circulation experiment to assess the potential of hot dry rock power generation.

Following the closing of the Fenton Hill experimental field in the U.S., hot dry rock experiment fields in Sort in Europe and in Hijiori and Ogachi of Japan are the only remaining ones in the world. The Hijiori experimental field is attracting attention from many countries.

As mentioned before, in order for Japan to attain a geothermal power generation capacity of 2,800 MW in the year 2010, the utilization of unused geothermal resources is indispensable. It is our hope that we will put geothermal energy into practical use in the foreseeable future.

Table 1. Geothermal Power Plants in Japan

	Name of power plant	Power generator	Steam supplier	Approved output capacity (kW)	Start of operation
For public use	Mori	Hokkaido Electric Power Co.,Inc.	Donan Geothermal Energy Co., Ltd.	50,000	1982/11/26
	Sumikawa	Tohoku Electric power Co.,Inc.	Mitsubishi Materials Corp.	50,000	1995/3/2
	Kakkonda No.1	Tohoku Electric power Co.,Inc.	Japan Metals &Chemicals Co., Ltd.	50,000	1978/5/26
	Kakkonda No.2	Tohoku Electric power Co.,Inc.	Tohoku Geothermal Enargy Co., Ltd.	30,000	1996/3/1
	Uenotai	Tohoku Electric power Co.,Inc.	Akita Geothermal Enargy Co., Ltd.	27,500	1994/3/4
	Onikobe	Electric Power Development Co., Ltd.	Electric Power Development Co., Ltd.	12,500	1975/3/19
	Yanaizu nishiyama	Tohoku Electric power Co.,Inc.	Okuaizu Geothermal Co., Ltd.	65,000	1995/5/25
	Otake	Kyushu Electric Power Co.,Inc.	Kyushu Electric Power Co.,Inc.	12,500	1967/8/12
	Hatchobaru No.1	Kyushu Electric Power Co.,Inc.	Kyushu Electric Power Co.,Inc.	55,000	1977/6/24
	Hatchobaru No.2	Kyushu Electric Power Co.,Inc.	Kyushu Electric Power Co.,Inc.	55,000	1990/6/22
	Ogiri	Kyushu Electric Power Co.,Inc.	Nittetsu Kagoshima Geothermal Co., Ltd.	30,000	1996/3/1
	Yamagawa	Kyushu Electric Power Co.,Inc.	Japex Geothermal Kyushu Co., Ltd.	30,000	1995/3/1
	Takigami	Kyushu Electric Power Co.,Inc.	Idemitu Oita Geothrmal Co., Ltd.	25,000	1996/11/1
For private	Onuma	Mitsubishi Materials Corp.	Mitsubishi Materials Corp.	9,500	1974/6/17
	Matsukawa	Japan Metals &Chemecals Co., Ltd.	Japan Metals &Chemicals Co., Ltd.	23,500	1966/10/8
	Suginoi Hotel	Suginoi Hotel Co., Ltd.	Suginoi Hotel Co., Ltd.	3,000	1981/3/6
	Kirishima Kokusai Hotel	Daiwabo Kanko Co., Ltd.	Daiwabo Kanko Co., Ltd.	100	1984/2/23
	Takenoyu chinetsu	Hirose Trading Co., Ltd.	Hirose Trading Co., Ltd.	105	1991/10/19
	Otake Binary Cycle Generating Plant	Kyushu Electric Power Co.,Inc.	Kyushu Electric Power Co.,Inc.	122	1995/1/20
Total				528,827	

Following 2 power plants are under planning.

Districts	Power generater	Steam supplier	Planning output capacity (kW)	Start of operation plan
Hachijojima	Tokyo Electric Power Co.,Inc.	Tokyo Electric Power Co.,Inc.	3,000	1998
Oguni	Electric Power Development Co., Ltd.	Electric Power Development Co., Ltd.	20,000	2000

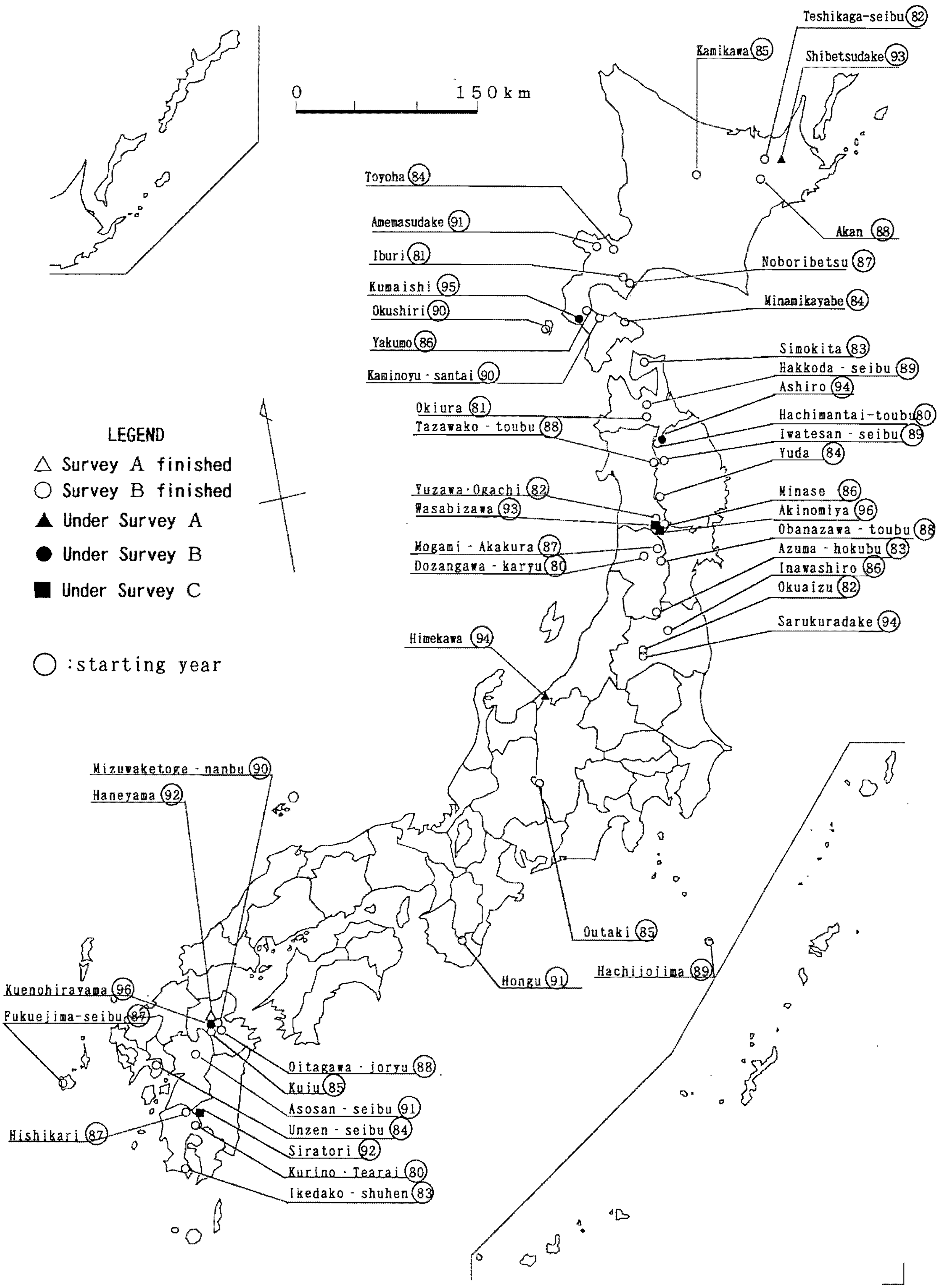

Figure 2. Location of Geothermal Surveys Carried Out by NEDO

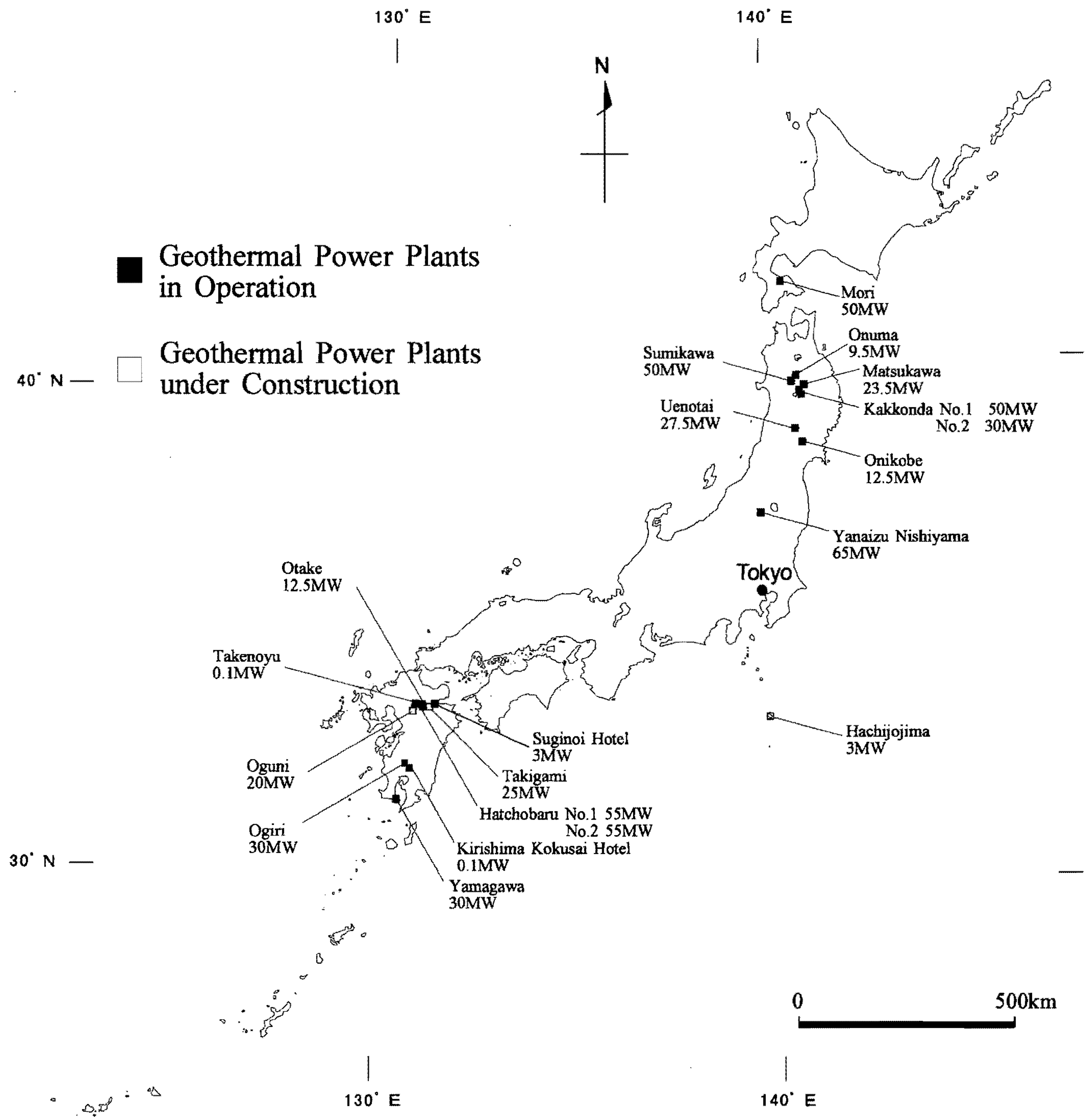

Figure 1. Geothermal Power Plants in Japan

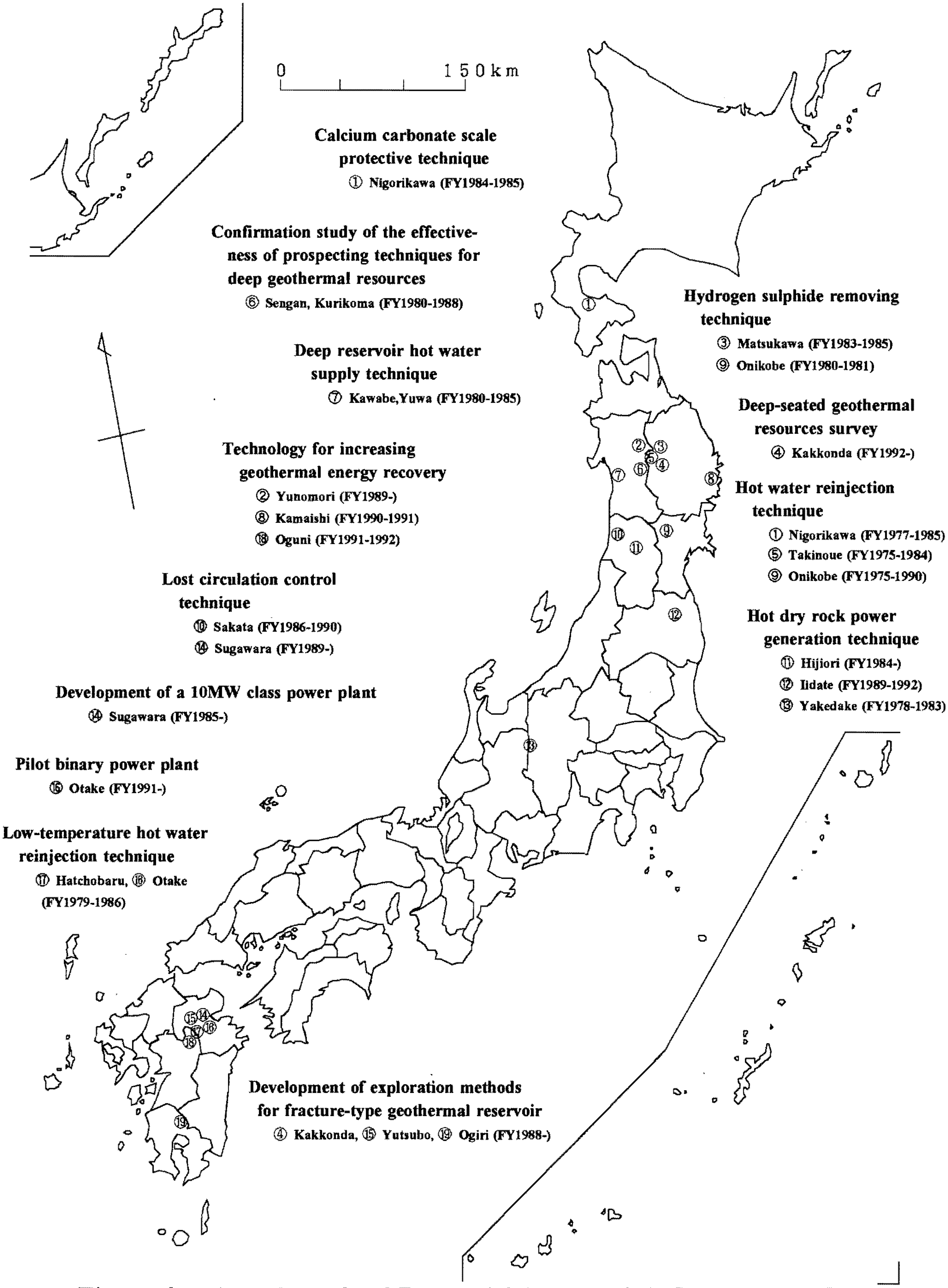

Figure 3. Location of R&D Test Fields Carried Out by NEDO