GEOTHERMAL DEVELOPMENT IN HACHIJOJIMA

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ABSTRACT

Since 1984, Tokyo Electric Power Co. (TEPCO) has carried out geothermal exploration in Hachijojima. TEPCO selected the southern part of the Higashiyama **as** a promising geothermal area In 1995, TEPCO drilled three explorations wells in northern part of Nakanogo, with well tests and flow tests, and confirmed high temperature and high-pressure vapor dominated geothermal resources, which are sealed by hydrothermaly altered cap rock.

Assessment shows the reservoir has enough potential for power generation of approximately 10 MWe. Now TEPCO is constructing the **3.3MW** geothermal power plant to be commercialized in March 1999 using one of these three well:

1. INTRODUCTION

Hachijojima is an island approximately 70km^2 in area and located **300 km** south from Tokyo, it has a population of about 10,000. This island consists of two volcanoes. Nishiyama is a 854m high stratovolcano, and Higashiyama is a dissected complex volcano which summit is 701m high (Fig. 1.)

Geothermal exploration in Hachijojima started in 1984 by Tokyo Electric Power Co. (TEPCO). As a result of geological survey, geophysical exploration and geochemical exploration over the island, South Higashiyama area was chosen **as a** promising area. From 1989 and 1991, New Energy and Industrial Technology Development Organization (NEDO) carried out geothermal development promotion survey. NEDO confirmed high temperature zone more than 300°C under southern part of Higashiyama area.

In 1993, advanced exploration was done by TEPCO, and an outline of the geothermal reservoir was obtained.

TEPCO also did the environmental impact survey in 1993, and chose the northern part of Nakanogo in south Higashiyama area for exploitation. Two production wells and one reinjection well were drilled in 1995. TEPCO confirmed steam dominated geothermal resource and is constructing **3.3 MW** geothermal power plant.

Tokyo Electric Power Services Co. (TEPSCO) has supported this TEPCO's geothermal exploration **as** main Consultant Company.

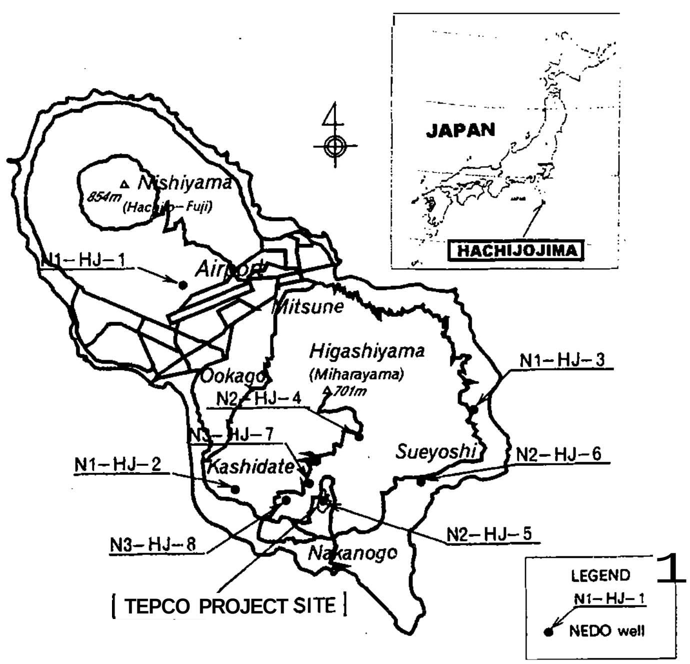

Fig.1 Distribution of wells

2. GEOLOGY

Hachijojima is located in the volcanic front formed by subduction of the Pacific Plate under Philippine Plate. **A** geothermal structure of the southern part of Higashiyama is shown in Fig. 2. Higashiyama is a complex volcano that is consists of andesitic to basaltic rocks, which formed in the Quaternary. Formations underlying these Quaternary rocks are not found in the surface, but drilling by NEDO shows the existence Neogene formation consists of andesitic to basaltic volcanic rocks. A geological cross section of the southern part of Higashiyama area is shown in Fig.3. The upper contact of the Neogene formation is near sealevel. Accompanying this are fractures that store and transmit geothermal fluid.

Hydrothermal alterations related to volcanic activities are only shown on a small scale around the summit of Mt. Higashiyama According to the results of drilling, clay minerals occur in five sub zones; montmorillonite zone; interstratified chlorite and montmorillonite zone; chlorite zone; kaolinite zone; and alunite zone. On the other hand, zeolites occur in 3 sub zones: clinoptilolite zone; mordenite zone; and the wairakite zone. Epidote is only found in Neogene formations. In N3-HJ-7, actinolite that is formed under high temperature and high-pressure occurs in deeper part. Alunite and kaolinite are found in Quaternary formations in N2-HJ-4, N2-HJ-5, and N3-HJ-7 where temperature is high. Clinoptilolite and mordenite are confirmed in many wells and they are distributed near the boundary between montmorillonite and chlorite. Wairakite occurs in the Neogene formation in N2-HJ-5, N3-HJ-7 and N3-HJ-8, where temperature is high.

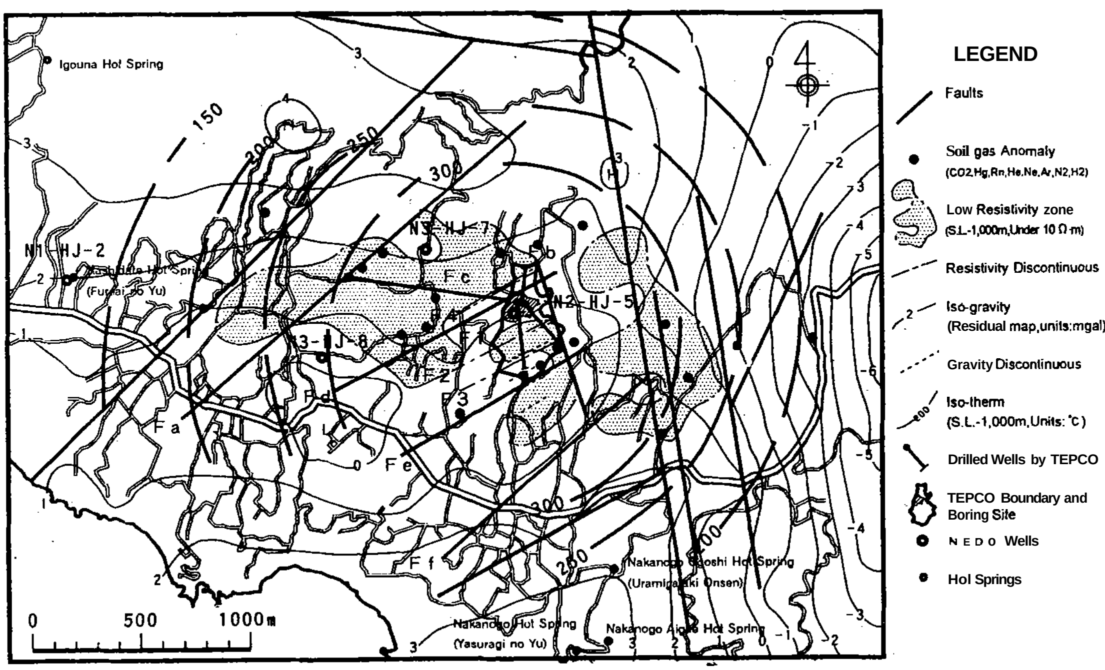

Fig.2 GEOTHERMAL STRUCTURE

3. GEOPHYSICS

To clarify the geothermal structure of the southern part of Hachijojima, TEPCO carried out gravity, CSAMT and MT surveys.

The gravity survey shows a positive anomaly around the southern part of Higashiyama, including the project site, and this implies high-density rock under this area.

The CSAMT survey and the MT survey show a low-resistivity area in the southern part of Higashiyama Vertically, the high resistivity zones correspond to distribution of Quaternary volcanic rocks and the low resistivity zones correspond to montmorillonite zone below. Middle to low-resistivity zone that is discontinuous in the horizontal direction lies under the low-resistivity zone corresponds to a fracture zone. These fractures are vertical and trend NE-SW direction (Fig.2). These fractures probably occur in Neogene formations and act as conduits for the geothermal fluids.

4. GEOCHEMISTRY

Three hot springs are locating near the coastline in the southern pari of Higashiyama. They are mixtures of seawater and meteoric water in the approximate ratio of 1 to 2.

Soil gas surveys shows anomalies of CO_2 and Hg around the **NE-SW** trending fractures (Fig.2).

Steam is produced in each production well obtained while flow test periods. Predominant element of steam is CO, while other elements scarcely occur, and volcanic gases are not detected.

5. WELL MEASUREMEMT

Fig.4 and 5 show the results of temperature logs in exploration wells drilled by **NEDO.** These are high temperature, particularly **N2-HJ-5, N3-HJ-7** and **N3-HJ-8** which plot close to the boiling point curve. Temperature increases sharply below 250m to 400m depth rising to 300℃ at depth pf 1000 m (fig.5). This indicates a cap rock may exist at this depth, separateing shallow ground water from deep high temperature geothermal fluid. The vertical pressure gradient above the cap rock depends on hydraulic pressure, and is different from the pressure gradient under the cap rock.

Flow test was done after drilling and well completion from October 1995 to February 1996. Steam flow rate is approximately equal to 3 MW power generarion. Table 1 shows result of flow test.

	HT-1	HT-2	HT-3
Sampling date	95/10/29	95/11/13	96/2/3
Well head pressure	0.3MPa	0 1MPa	0 18Mpa
Well head temp(C)	141 7	166 0	1550
Steam flow rate(t/h)	33	23	32
Water flow rate(t/h)	0 4	0	0
Water/gas ratio			
H_2O	99 301	99413	98.733
Gas	0 699	0 587	1267
Condensed water(pH)	4 3	3.6	3 7

6. GEOTHERMAL MODEL

We synthesized all results and made geothermal model as follows

Heat *source:* The horizontal temperature gradient has a radial distribution which is centerd on the caldera. The temperature is more than 300℃ at 1000 m depth.

Geological *structure*: This area is an uplift zone. Hydrothermal alteration zone forms near the boundary of Quaternary and Tertiary formations. It formes cap rock that is caused by self sealing.

Fluid flow system: Geothermal fluid flows.from deeper part to shallower part along vertical fractures. Chemical analysis of hot water from the exploration well indicates the mixture of sea water and meteoric water is in the approximately ratio of 1 to 2.

We show the geothermal model of Hachijojima in Fig. 7. In this model, cap rock formed by alteration zone separates shallower fluid flow system from deeper fluid flow system that makes a high temperature hydrothermal convection system passing by permeable zone as fractures in the Neogene formations. Outside this cap rock, Groundwater is mixture of sea water and meteoric waters heated *with* thermal conduction and form hot springs in the surface.

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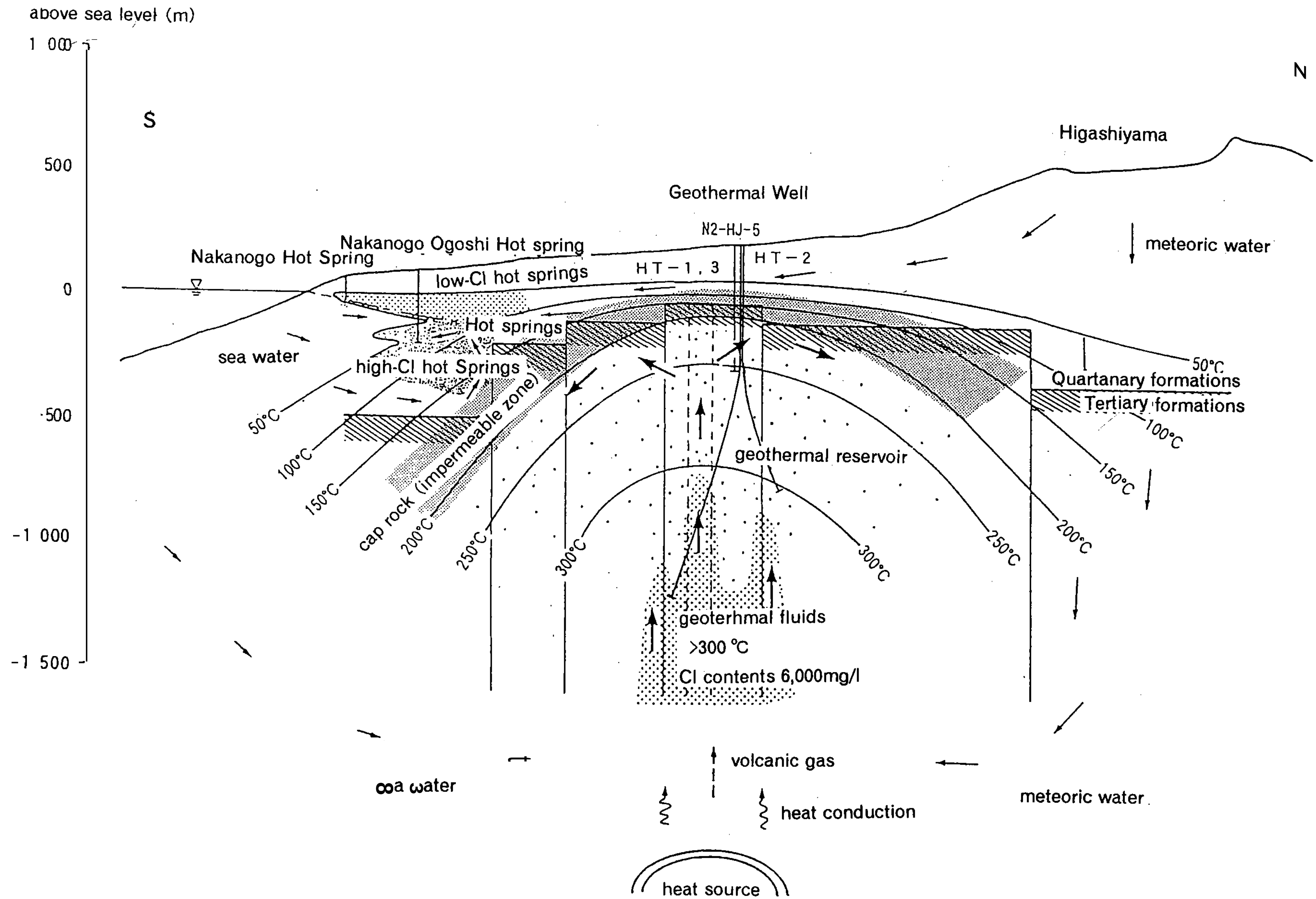


Fig.3 Geological cross section in southern Higashiyama

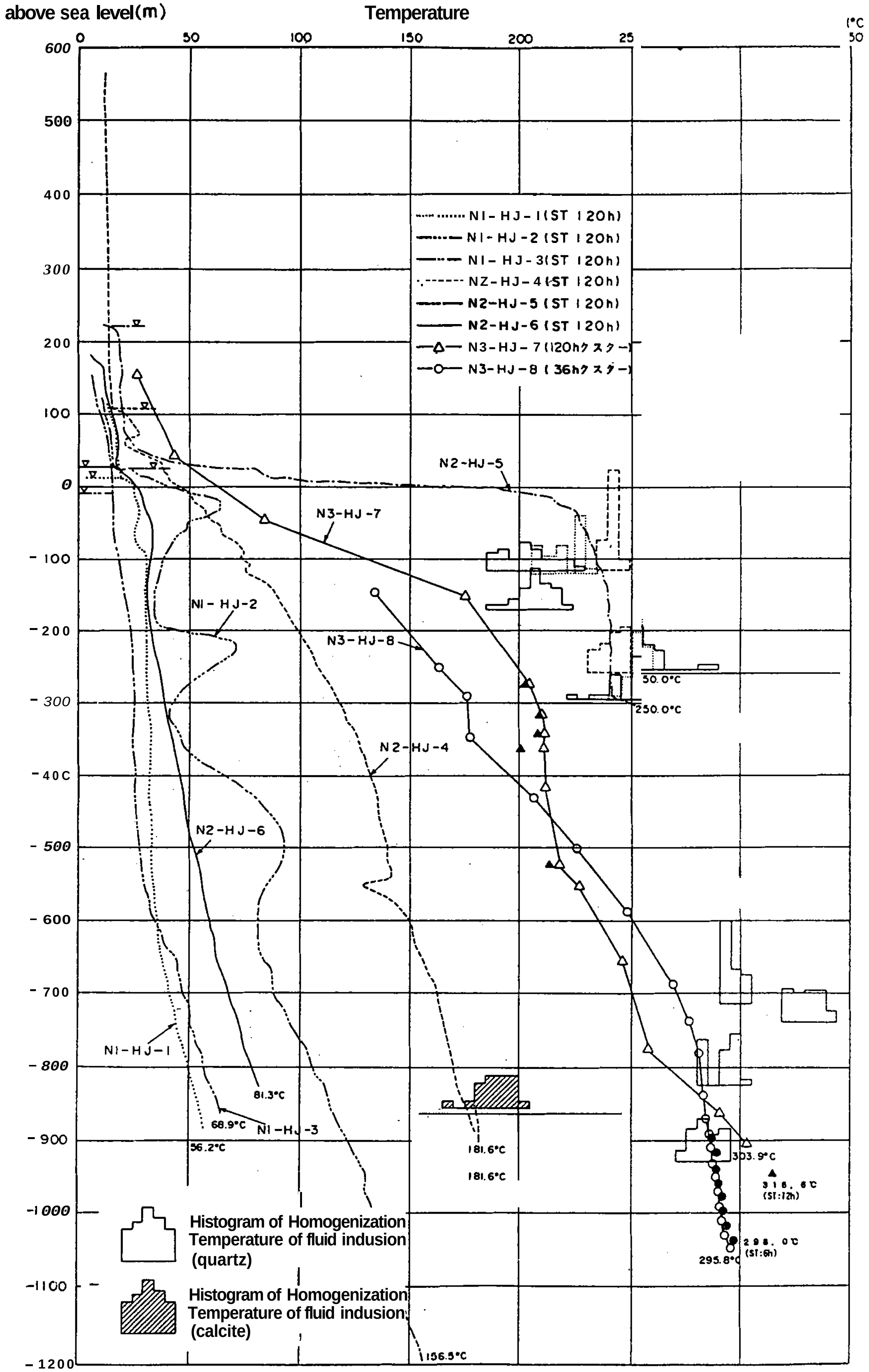
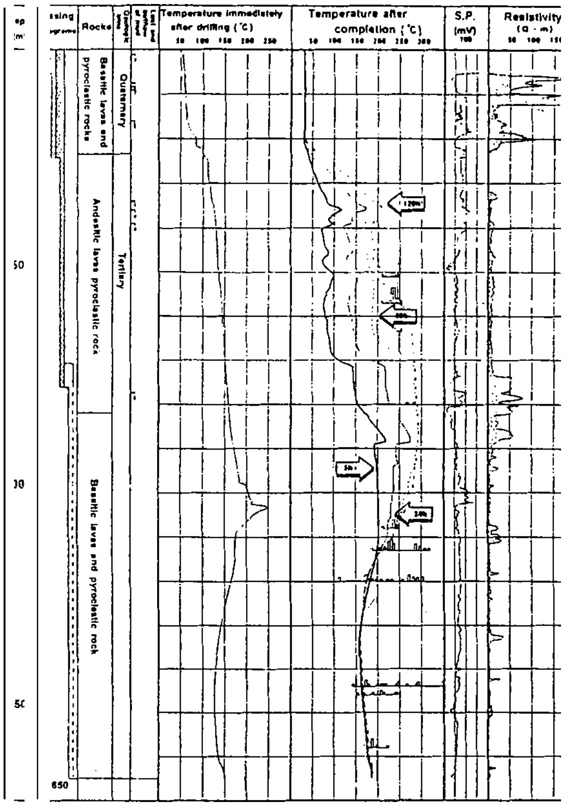


Fig.4 Temperature log in NEDO well



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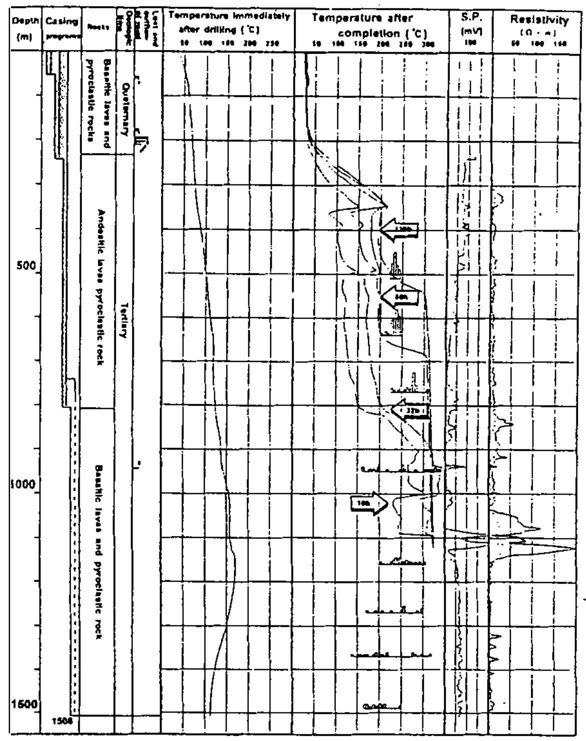

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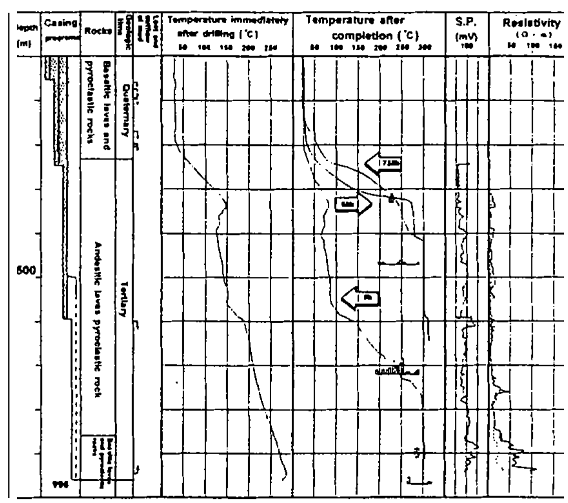

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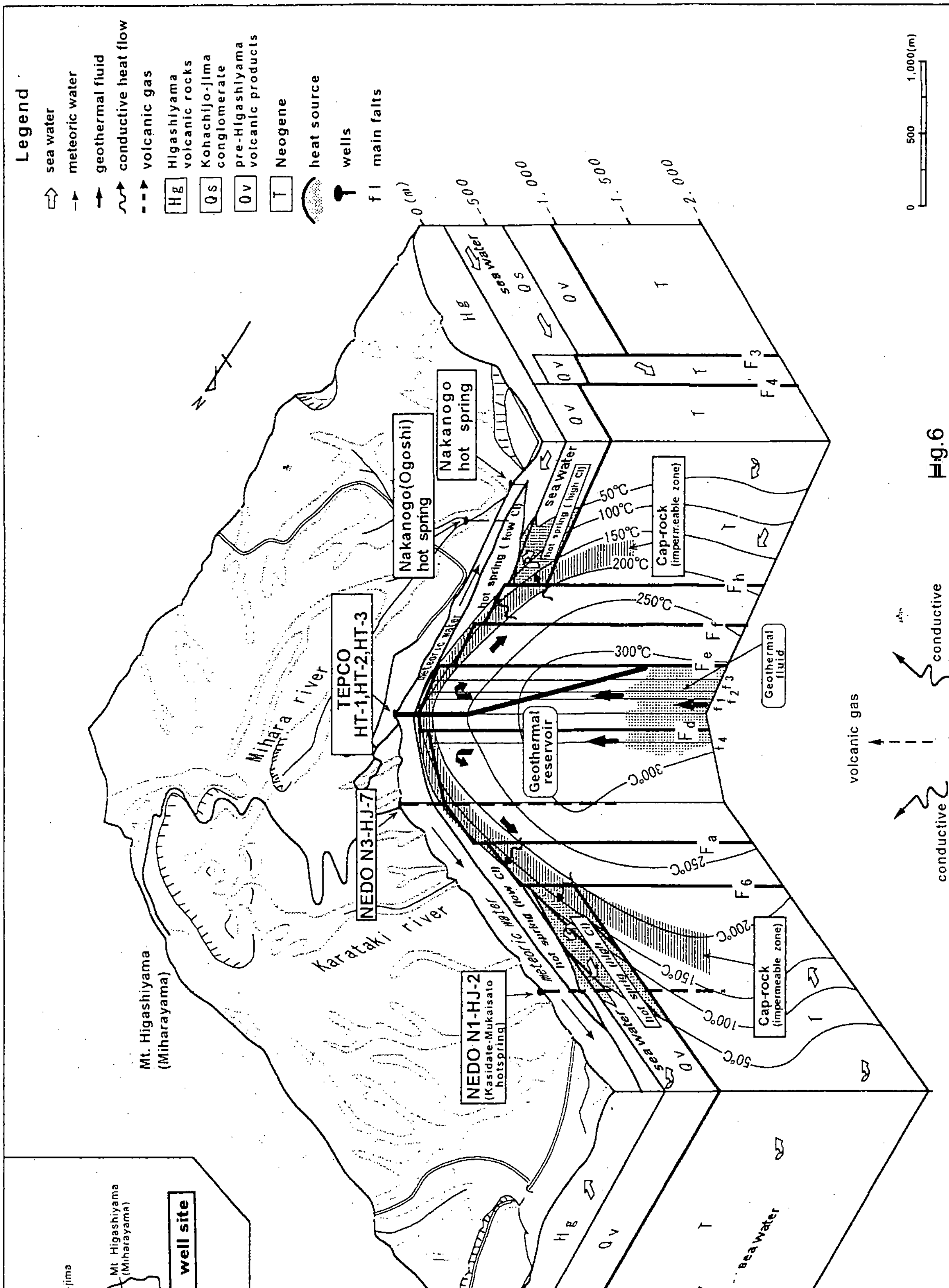

Fig.6 Geothermal model of Hachijo-jima field (bird's-eye view)