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THE PRODUCTIVE PERFORMANCE PREDICTION OF SOME WELLS IN HACHIJOJIMA HYDROTHERMAL FIELD,JAPAN.

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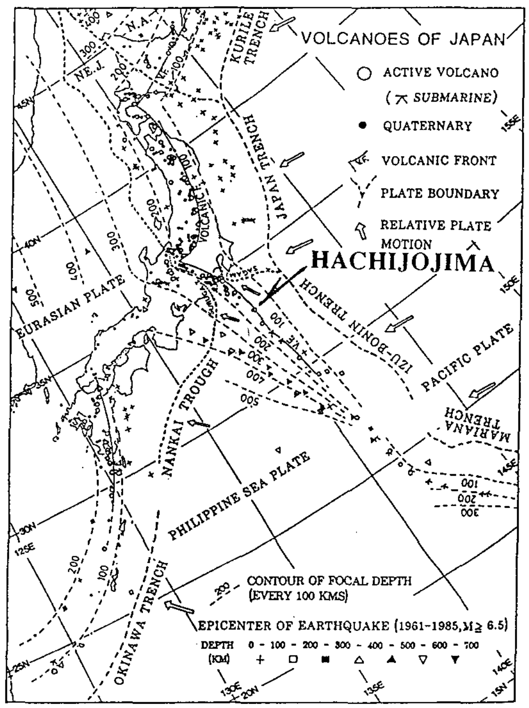
ABSTRACT
New Energy and Industrial Technology Development Organization (NEDO) did "Geothermal Development Promotion Survey" in the Hachijojima Island which is a volcanic island with $70km^2$ located in the Izu-Mariana Island Arc. In that national project, NEDO drilled 8 wells in the field and the maximum temperature of the field was 317°C at 1200m depth of a well. Of these survey NEDO confirmed the existence of geothermal reservoir,and using a well named HJ-5, NEDO did short time discharge test. The authors calculated borehole temperature and pressure under production the of the well in comparison with the measured data. The authors also calculated productive performance of another well named HJ-8.

INTRODUCTION
New Energy and Industrial Technology Development Organization (NEDO) was established as a governmental agency in October 1980 after the Second Oil Crisis. Its purpose is to act as an implementing agency of the Japanese Government in fields related to technological development. One of the most important activities is to develop and promote of new energies, such as geothermal energy.
In fields of geothermal energy, NEDO is working to research and development of technology for example hot dry rock technology (e.g. Hirakawa et al (1989)). Not only such kind of R/D projects, but NEDO is also working to promote geothermal resource development for private corporations, and in order to facilitate such development. It is implementing the "Geothermal Development Promotion Survey" project sponsored by Ministry of International Trade and Industry (MITI). Since 1980, surveys have been conducted in 40 areas across Japan to prospect geothermal resources in this project. Of these, surveys of 32 areas have been completed by the end of 1992. NEDO selects two or three new areas for this project each year, and each area is surveyed for two to four years.
In 1989 NEDO selected Hachijojima area as one of those new areas for this project, and started surveys. The island is one of the volcanic islands in the Izu-Mariana Island Arc. The main surface survey methods are geological surveys, geochemical surveys, geophysical surveys. As drilling survey NEDO drilled 8 slimholes named HJ-1 to HJ-8, and measured borehole temperature, physical properties of their boring core and did injection test. The minimum depth of these wells is 500m and the maximum depth is 1500m. The maximum borehole temperature measured in those wells is 317°C at 1200m depth of well HJ-7.
In 1990 NEDO drilled one of those wells named HJ-5 which was planned with 1000m depth, but NEDO gave up to continue drilling when it arrived 500m depth because of its difficulties to prevent loss circulation and too high formation temperature. Its borehole temperature arrived about 250°C at 200m depth. After completion of this well with 511m depth, in 1991 NEDO tried short time discharge test using this well. During this discharge test NEDO measured borehole temperature and pressure distribution during discharge. Before this discharge test the authors tried to predict the productive performance of this well. But there were much differences between the prediction and measured data. After discharge test the authors kept trying to calculate one to match with measured data. The authors introduce those calculated borehole temperature and pressure distribution during discharge compared with measured data.
NEDO drilled another well named HJ-8 with 1200m depth in 1991 which recorded 305°C at 1200m depth. The authors tried the productive performance of this well. But unfortunately because of casing damage NEDO gave up to do discharge test using this well, so it is impossible to compare the calculated results with measured data.

GEOLOGICAL STUDY
Hachijojima Island is one of the volcanic islands in the Izu-Mariana Island Arc in the northwestern Pacific Ocean and about 300km

south of Tokyo. Fig.1 shows the location of this island. The shape of the island is as like as a cocoon and its area is about $70km^2$ with 14km x 7.5km of width. Fig.2 shows the topographic map of this island and location of wells.



N. A.: North American Plate, NE J.: NE Japan Micro Plate

Fig.1 INDEX MAP OF THE HACHIJOJIMA

There are two Quaternary strato-volcanoes named Nishiyama(mean Western Mountain) and Higashiyama(mean Eastern Mountain) with many parasitic cones (Isshiki (1959)). They have another name "Hachijo-Fuji" and "Miharayama." Volcanic eruption were recorded at Nishiyama Volcano in the 17th century but there are no volcanic eruption record at Higashiyama Volcano.

These Quaternary volcanic rocks lie on the basement of Neogene volcanic rocks and Pleistocene sedimentary and volcanic rocks. Those basement rocks do not crop out in this island but they are identified in boring core.

The volcanic activity at Higashiyama Volcano was prior to Nishiyama Volcano. Its volcanic activity was from about 400,000 years BP to 4,000 years BP. The volcanic activity at the Nishiyama Volcano began after one of the Higashiyama Volcano and its activity continued on into present.

There are several hot springs on the seaside of the Higashiyama Volcano in the southern to eastern part of the island. For example at the southern seaside of the Volcano, there are several hot springs with temperature of 50 to 70°C at the surface. These hot water contains much Na and Cl contents, so it is regarded as heated up sea water. Except these hot springs, there are no hydrothermal manifestations all around the island.

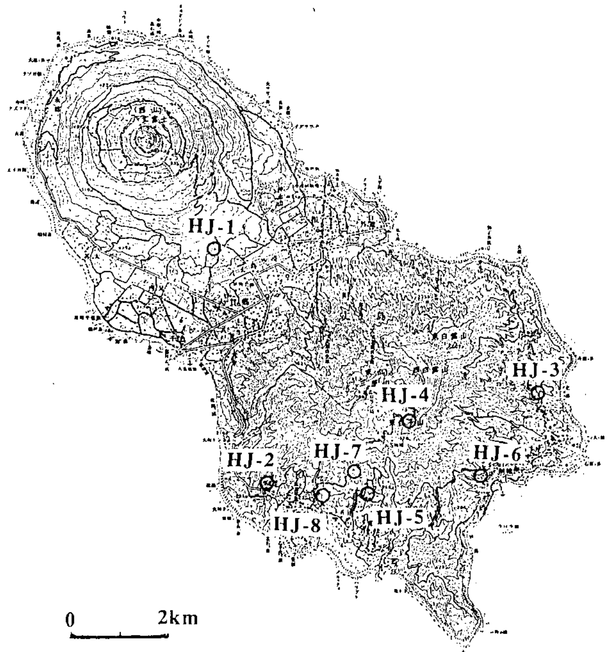


Fig.2 TOPOGARAPHIC MAP OF THE HACHIJOJIMA ISLAND

PROSPECTING METHOD OF THE SURFACE SURVEY

The prospecting method of surface survey which were implemented by NEDO are geological survey, fluid geochemical survey, soil gas geochemical survey, gravity and airborne magnetic survey(analysis only), electromagnetic survey (TDEM method), seismic survey (reflection method using Vibroseis on the land and air gun offshore), and so on.

As results of these surface prospecting, much information and knowledge were got in reference to the geological structure in and around this island especially for basement structure. And they suggest that the southern part of Higashiyama Volcano is the area which has the largest possibility in this island that geothermal reservoir is existence. But they do not suggest no more information about the reservoir, for example its distribution, depth, permeability, temperature, pressure or chemical composition of the geothermal fluid.

UNDERGROUND SURVEY

Specification of drilling and measurement of wells

NEDO drilled 8 wells named HJ-1 to HJ-8 with 500m to 1500m depth in this project. These wells were specified to have their diameters of final drilling step as 98mm or 76mm. These diameters are small in comparison with normal size of geothermal production wells or reinjection wells drilled at geothermal power plant.

Wells named HJ-1 to HJ-3 were drilled in 1989, wells named HJ-4 to HJ-6 were drilled in 1990 and wells named HJ-7 and HJ-8 were drilled in 1991. Of all these wells, only well HJ-1 were located in Nishiyama Volcano area, other 7 wells were located in Higashiyama Volcano area. Well HJ-4 were located the summit part of the volcano, well HJ-3 and HJ-6 were located in the eastern side of the volcanic body, and well HJ-2, HJ-5, HJ-7 and HJ-8 were located in the southern side of the volcanic body. Fig.2 shows the locations of these wells.

Standard program of measuring data using these wells were well logging (temperature, resistivity and so on) injection test and measuring physical properties using boring cores.

Fig.3 shows the borehole temperature distribution of all wells with elevation in meters ASL VS temperature in degrees in Celsius. These temperature distribution suggested formation temperature near the wells. In the wells HJ-1 to HJ-4, the maximum measured temperature was 182°C at 1500m depth in well HJ-4 and it had not yet confirmed existence of geothermal reservoir.So until this time it had been said that there were no manifestation that suggested geothermal reservoir with high temperature and geothermal fluid.

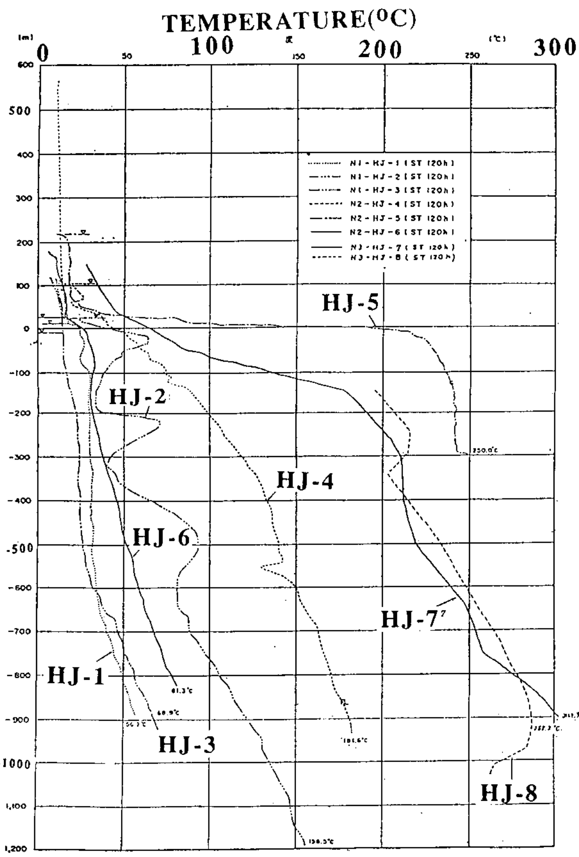


Fig.3 BOREHOLE TEMPERATURE DISTRIBUTION IN THE HACHIJOJIMA AREA

Well HJ-5 were planned with 1000m depth and small diameter. Fig.4 shows the planned cross section of this well. During drilling it was very difficult to continue drilling because of frequently and large lost circulation, over flow and high borehole temperature. At the end NEDO gave up to continue drilling at 511m depth. Fig.4 also shows the completed cross section of this well. From well head to 203m depth casing pipe were set with cement, and from 203m depth to bottom of the well slotted liner were set without cement.

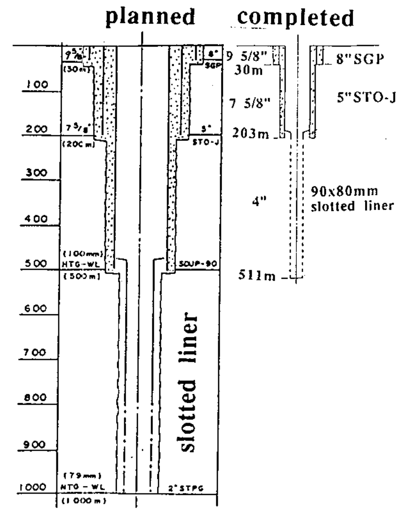


Fig.4 PLANNED AND COMPLETED CROSS SECTION OF WELL HJ-5

<u>Discharge Test of Well HJ-5</u>

After well completion of well HJ-5, NEDO logged borehole temperature and pressure in static condition. Fig.4 shows the borehole temperature and pressure distribution VS depth in m. in static condition. This temperature profile is characterized by a sharp boundary of the formation temperature at 250m depth. The shallower part of this boundary the formation is characterized by very low formation temperature which is lower than 30°C, it results from penetration of meteoric water with low temperature. The deeper part of this boundary is characterized by high formation temperature which is about 250°C cased of existence of up flow of geothermal fluid. At this time they presumed the condition of the reservoir as vapor dominated condition or mixture of vapor and liquid water because of high temperature and relatively lower pressure. During drilling many lost circulation or over flow zone were identified,but it is recognized that important point as feed points are two points with 204m and 346m depth. But it was impossible to identify which is more important for feed point.

From the result of injection test, permeability are presumed as 0.6 to 3.0 darcy-m using type curve matching method or semi-log plot method. But it is supposed that this test were influenced by the skin effect of near the well and blow of gas during drilling, so there were much inaccuracy of this value of permeability. In 1991 NEDO tried discharge test of this well. Unfortunately lack of reinjection well and of other reason the period of this test was limited very short as 4days. Fig.5 shows the productive performance of well HJ-5 and Fig.6 shows the borehole temperature and pressure distribution in production condition VS depth in meters.

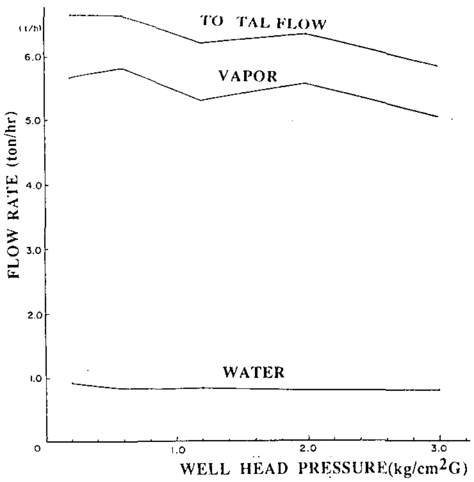


Fig.5 PRODUCTIVE PERFORMANCE OF WELL HJ-5

It is indicated that the phase of fluid in the reservoir is liquid in static condition, and during production the reservoir fluid began flashing in the formation so the borehole temperature and pressure are much lower than those of static condition.
Table1 shows the chemical composition of gas, condensed water and water discharged from well HJ-5. Even though it is feared that there remained influence of injected surface water and mud used during drilling, it is possible to say that the water is not such kind of influenced water nor condensed water of vapor after flashing. The chemical and isotopic composition of those fluid suggest that the origin of fluid water in the reservoir is meteoric water penetrated from the surface of the volcano not ocean water.

BOREHOLE CALCULATION OF WELL HJ-5

The authors had tried to predict the productive performance of HJ-5 prior to the discharge test. But there were much differences between the calculated results and the measured data.
After the discharge test the authors tried to calculate borehole temperature and pressure under production matching with measured data. Fig.6 shows the calculated borehole temperature and pressure distribution VS depth in meters compared with measured data under production. The final term of its calculation is to fix the pressure at the hypothetical production point and well head pressure.There are 4 cases of the calculation. In the case 1 and 2, the vapor/water ratio of the fluid inflow at the production zone are fixed as 0.797. In the case 3 and 4, the temperature at the hypothetical production point as 171.4°C. In the case 1 and 3, we use the heat transfer coefficient as 25 W/m^2°C and in the case 2 and 4, as 0 W/m^2°C. Other parameters are shown below.

production zone : 360m depth
formation temperature

20°C	0 to 160 m depth
110°C	160 to 200 m depth
230°C	200 to 360 m depth

Table 1 CHEMICAL AND ISOTOPIC COMPOSITION OF GAS, CONDENSED WATER AND HOT WATER DISCHARGED FROM WELL HJ-5

VAPOR		H_2O	vol.%	97.64
		Gas	vol.%	2.36
		H_2S	vol.%	4.2
		CO_2	vol.%	92.5
		R	vol.%	3.3
		H_2	vol.%	85.1
		N_2	vol.%	12.5
		CH_4	vol.%	2.4
	$\delta^{13}C$ (CO_2)		‰	-1.8
	$\delta^{34}S$ (H_2S)		‰	+6.0
CONDENSED WATER	pH		–	4.3
	Na		mg/ℓ	0.18
	Cℓ		mg/ℓ	0.15
	SO_4		mg/ℓ	2.64
	As		mg/ℓ	0.011
	Hg		ppb	5.5
	δD		‰	-26.6
	$\delta^{18}O$		‰	-1.1
WATER	pH		–	8.5
	SiO_2		mg/ℓ	575
	Cℓ		mg/ℓ	138
	SO_4		mg/ℓ	518
	Na		mg/ℓ	461
	K		mg/ℓ	30.4
	Ca		mg/ℓ	7.15
	Mg		mg/ℓ	0.21
	Fe		mg/ℓ	0.33
	Aℓ		mg/ℓ	1.18
	As		mg/ℓ	0.06
	B		mg/ℓ	114
	Hg		ppb	1.9
	HCO_3		mg/ℓ	319
	CO_3		mg/ℓ	8
	H_2S		mg/ℓ	18.9
	EC		μS/cm	2.190
	δD		‰	+7.8
	$\delta^{18}O$		‰	+4.7
	$\delta^{13}C$ (CO_2)		‰	+1.5
	$\delta^{34}S$ (SO_4)		‰	+10.0
	Tritium		TR	0.31±0.10

PRODUCTIVE PERFORMANCE PREDICTION OF WELL HJ-8

In 1991 NEDO drilled well HJ-8 with 1200m depth which located 1000m west of well HJ-5. After completing the well, temperature logging recorded 305°C at 1200m depth. Injection test showed its permeability is 0.59darcy-m, but as same as well HJ-5 this value has much inaccuracy. Fig.7 shows the cross section of this well.

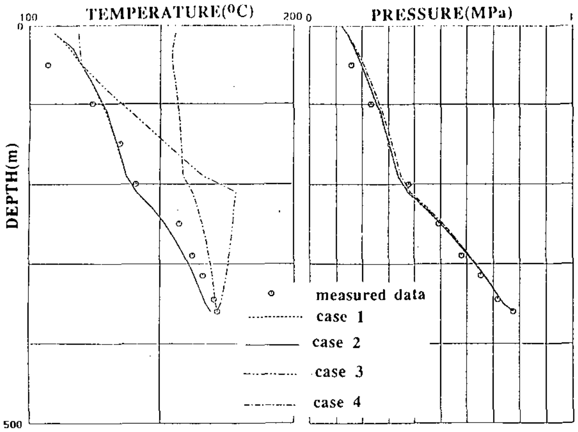


Fig.6 CALCULATED AND MEASURED BOREHOLE TEMPERATURE AND PRESSURE UNDER PRODUCTION OF WELL HJ-5

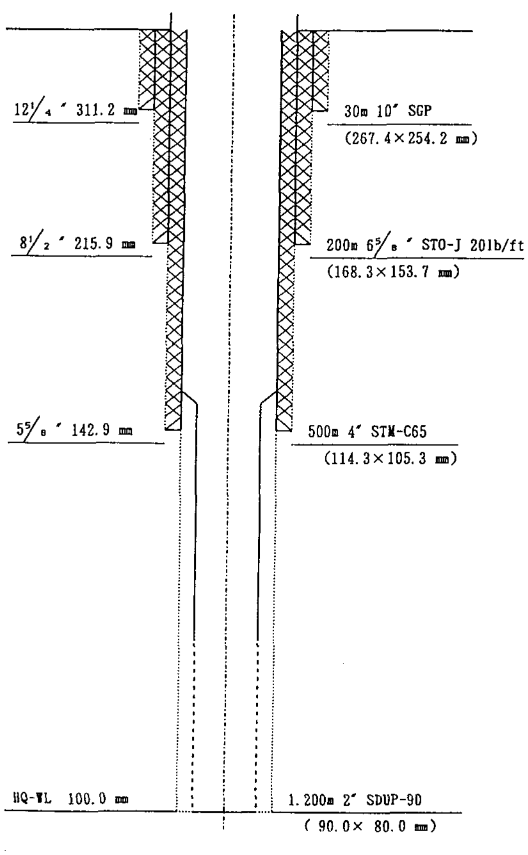


Fig.7 CROSS SECTION OF WELL HJ-8

The authors predicted the productive performance of well HJ-7. Fig.8 shows the calculation result of the relationship of well head pressure and flow rate as productive performance. The parameters of this calculation

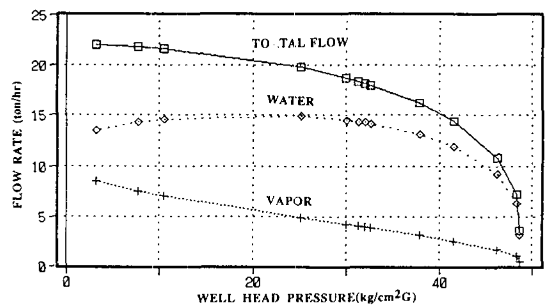


Fig.8 RELATIONSHIP OF WELL HEAD PRESSURE AND FLOW RATE DISCHARGED FROM WELL HJ-8

are shown below.
feed point : 1020m depth
temperature at feed point under static condition : 285°C
pressure at feed point under static condition : 92.96kg/cm²G
In the case 1 and 3, we use the heat transfer coefficient : 0 W/m²°C
Unfortunately NEDO gave up discharge test of this well because of casing damage and fear of blowing out caused too high formation temperature and pressure to preserve the well for such kind of slimhole. To prevent blowout NEDO completely plugged this well after injection test.
So it is impossible to compare this calculation with measured data

CONCLUSION

Through these survey and analysis of their datum clarified some knowledge about the geothermal reservoir showed below.
1)a geothermal reservoir exists in the southern part of Higashiyama Volcano.
2)the depth of the reservoir are 200 to 1500m in depth, but no information about detail distribution and shape
3)the temperature of the reservoir is 250 to 300°C
4)the phase of geothermal fluid in the reservoir is liquid with formation flashing under production or mixture of liquid and vapor water in reservoir.
5)quality of geothermal resource is enough for geothermal generation but its quantity is unknown.
6)more investigation is needed especially to get more information about distribution of permeability

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