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RECENT PROGRESS IN HOT DRY ROCK PROJECT AT HIJIORI, JAPAN

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ABSTRACT

This paper presents a report of the progress of the Hijiori project in FY 1989. In FY 1989, a third well, named HDR-2 was drilled to the depth of 1910m. An interference test revealed a connection between a injection well, SKG-2, and HDR-2. A 29-days circulation test was conducted to characterized reservoir performance between SKG-2 and two production wells. Several results obtained during the circulation test are summarized in this paper. Future plan in Hijiori test site is also mentioned.

INTRODUCTION

The New Energy and Industrial Technology Organization, NEDO, has been concentrating research efforts on developing hot dry rock (HDR) geothermal energy from FY 1985 under a renewable energy development program, named the Sunshine project. The project is under the administration of the Ministry of International Trade and Industry, MITI.

Field experiments have been carried out at Hijiori in the northern part of Honshu island, Japan. The objective of the Hijiori project is to investigate the possibility of exploitating HDR and developing a heat extracting system under practical temperature and depth conditions. The experimental program intends to investigate and confirm: (1) the creation of artificial reservoirs, (2)the detection fracture location (fracture mapping), (3)efficient extraction of heat, and (4) demonstration of environmental monitoring. NEDO and four contractors are conducting the work with the support of the National Research Institute for Pollution and Resources.

Several papers report the results before FY 1988 (Kobayashi et al., 1987; Hirakawa et al., 1989), and this report will focus on the results obtained in FY 1989 as well as a brief history and future plan of the Hijiori project.

PAST PROGRESS IN JAPANESE HDR PROJECT

The field experiments within the Japanese HDR development program has began in 1978 at a side near Mt. Yakedake in Gifu prefecture. The technologies of hydraulic stimulation, fracture mapping, well logging and reservoir evaluation were advanced during the experiments. The work used several wells in sedimentary formations with a depths of 300m and temperatures of about 60°C.

In 1984, the project entered a new stage following the encouraging results of the Yakedake experiment. The technical advances at Fenton Hill in the United States also provided a basis for a new research plan. The experiments site moved from Yakedake to a larger site at Hijiori for deeper, higher temperature testing.

The Hijiori test site is located inside the southern edge of a small caldera which was formed around 9000 years ago(Fig.1). The area has been target of geothermal exploration by a private company who drilled several exploration wells in the caldera. The boreholes encountered high temperatures, but the project was cancelled due to inadequate production of hot water and steam. Two wells, SKG-1 and SKG-2, remained from the commercial project.

In 1985, well SKG-2, located at the southern fringe of the Hijiori caldera, was selected for hydraulic fracturing stimulation. This well is 1802 m deep, and the bottom hole temperature is about 250°C. A 7" casing pipe was installed from the wellhead down to a depth of 1788m, leaving 14 m at the bottom open hole.

In October 1986, a total 1,080 m^3 of water was injected into the open hole portion of SKG-2 at rates up to 6 m^3/min. Approximately 35% of injected water returned as a mixture of hot water and steam during venting.

During the hydraulic fracturing test, the microseismic activity was monitored by two systems:(1) a downhole tri-axial geophone sonde set in well SKG-1 and (2) a surface net of eight stations around the test site. The hypocenter locations by the surface net defined as E-W, vertical zone at the south side of the injection well. The results obtained from three-axial geophone showed nearly the same tendency, but with a northward dip.

Two fracture types were detected by a borehole televiewer(BHTV) observation conducted at the openhole section in well SKG-2. An inclined fracture system *crossed* wellbore with strike of N159°E and dip of 60°NE. A vertical fracture system ran parallel to well axis and extended nearly in E-W direction.

In 1987, we drilled a new well, HDR-1 to intersect the hydraulically stimulated fracture. The well was drilled to the south side of SKG-2 where microseismicity were concentrated. HDR-1 has an open hole section for 300 m between a depth of 1500 m and the bottom at 1800 m. Connection between SKG-2 and HDR-1 was confirmed by an interference test. The temperature log from well HDR-1 showed anomalies at 1743 m and 1786 m depth, which appear to be the hydraulic connections.

In August 1988, we ran a stimulation test by injecting of around 2000 m^3 water from SKG-2. Then, we ran a circulation test for about two w ks. The injection rate was kept constant at about 0.5 m /min for 10.5 days and thereafter 1.0 m^3/min. A total of 13,430 m of water was injected in this circulation test. The intermittent pruduction of steam and water from well HDR-1 complicated our evaluation of reservoir performance. Nonetheless, the total recovery was estimated as about 34% from measured volume of hot water and calculated steam volume based on pressure and temperature conditions at the HDR-1 wellhead.

It was shown from both pressure-temperature-spinner (PTS) surveys in HDR-I and a simulation study by using WELBORE code that the intermittent production was caused by flushing in the wellbore and was not a reflection of reservoir hydrodynamics.

More than 100 microseismic events were detected with the surface net during the stimulation test. Of these, about 70 events had interpretable hypocenters. The hypocenter distribution was the same as that obtained during the hydraulic fracturing in 1986. A fault plane solution of microseismic waveforms showed a typical normal fault type mechanism with the vertical compression axis and a NE-SW dilatation axis.

For the future development of a deeper reservoir, well HDR-1 was deepened by about 400m from 1802m to

2200m after the circulation test. A cemented liner with a polished borehole receptacle (PBR) was set for future hydraulic fracturing operation in the depth interval between 1367 and 2159m.

During the drilling HDR-1, core samples were obtained by oriented corings and one normal coring. From the analysis of fractures in the oriented cores of HDR-1, we discovered an open fracture striking E-W and dipping 70° to the north.

PROGRESS IN 1989

For FY 1989, the following major objectives of the HDR program were planned: (1) drilling a new well HDR-2 to improve productivity from the reservoir around 1800 m depth, (2) conducting a injection test to evaluate flow connections between SKG-2 to HDR-1 and HDR-2, (3) designing and installing a surface system, (4)conducting a 30 days circulation test, (4)developing a borehole radar, a acoustic caliper tool, and a open-hole packer, and (5) continuing environmental monitoring around the Hijiori test site. The circulation test will include geochemical studies of circulating fluid, tracer tests, well loggings and microseismic observations to characterize and evaluate the reservoir.

We chose the location and orientation of HDR-2 according to distribution of microseismic events during the stimulation test in 1988, fracture orientation data obtained from the analysis of HDR-1 oriented core and BHTV observations in SKG-2 and HDR-1, and results of well logging. The target of well HDR-2 was decided as a point about 45 m to the SW of the bottom of well SKG-2. HDR-2 penetrated into basement rock at the depth of 1480 m. After 9 5/8" casing was set down to 1504 m, HDR-2 was drilled with 8 1/2" bit to the depth of 1910 m. Fig. 2 shows the trajectory of the well passing through the target zone.

A total of about 14m of core was recovered from granitic basement rock by 9 coring operations. Although no oriented core was obtained, some cores could be oriented by comparing the directions of distinctive fracture types occurring in the two holes One type is vertical and open with quartz veins and the other type consists of conjugated shear fractures with chlorite veins.

Cuttings from drill hole HDR-2 were analyzed to provide information on the distribution of alteration and geologic units. Several alteration zones were revealed at the depths of 1580, 1655, and 1760m. The alteration is typified by sericite and Mn. These zones correspond with the anomalies recognized by geophysical logging.

The completion of HDR-2 drilling was followed by a interference test among the three wells. A quick response occurred in the HDR-2 during the test showed a good connection between SKG-2 and HDR-2.

A circulation test was carried out for 29 days between October 19th and November 17th, 1989. The injection flow rate of 1 m^3/min. was kept constant throughout the test, except for three short periods at 2 m^3/min. A high pressure valve installed at the wellhead prevented flashing inside the well. This measure allowed the continuous and stable production of hot water and steam. As shown in Fig.3, the production temperature at HDR-1 wellhead increased gradually throughout the test. On the other hand, temperature at HDR-2 wellhead increased up to around 175° in several days and then decreased slightly during the latter part of the circulation test. Energy in the range of 4.5 MWt could be produced from the both production wells together. The total recovery was about 16000 tons, including steam and hot water, and the recovery rate was around 35%.

More than 400 microseismic events were detected by the surface net. The microseismic activity increased clearly when the injection rate was increased up to 2 m^3/min. The hypocenters of the events define a zone extending in ENE-WSW direction. Although this orientation trend is almost the same as that of the stimulation test in 1988, the hypocenters lay deeper and more to the east. Observations by a tri-axial geophone sonde also show the same result.

PTS logging was conducted ten times in wells HDR-1 and HDR-2 to evaluate feed points and to obtain temperature profiles during the circulation test. Temperature profiles along HDR-1 , surveyed through the PBR liner show that no cooling occur at the reservoir zone during the test. The temperature profiles of HDR-2 obtained during the test are shown in Fig. 4. The temperature anomalies indicated by arrows were observed at 1570m, 1660m, 1760m and 1770m. These points can be considered the feedpoints. These profiles also indicate that a portion of reservoir between well SKG-2 and well HDR-2 cooled down during the test. From the spinner survey, it is estimated that the four feedpoints listed above provided 11% , 16%, 31% and 42% of the total respectively.

BHTV observation .data obtained in a open hole section of HDR-2, depths 1510 to 1910 m, show three types of fracture system. One type seems to related borehole breakouts. These fractures extended along one side of wellbore only. An E-W striking, vertical fracture system was observed in the well. The other crossed the wellbore. These results are consistent with the BHTV observation data in HDR-1(Ito and Barton, 1990).

The geochemical composition of the production fluids from HDR-1 and HDR-2 shows that original reservoir fluid had the same Na/Cl ratio of sea water and was diluted by injected water. The concentration changes of several ions in production water at the initial stages of circulation indicate that there are significant differences between the flow paths from SKG-2 to HDR-1 and from SKG-2 to HDR-2; the flow path connecting SKG-2 and HDR-1 has a greater diffusivity than the path between SKG-2 and HDR-2. The results of two tracer tests are consist with this result.

FUTURE PLAN AT HIJIORI

In this fiscal year, a third well, HDR-3, is now being drilling at Hijiori to access the portion of the reservoir on the opposite side of SKG-2 (injection well) from the HDR-1. After completion of HDR-3, a two to three months circulation test will be carried out further characterize the existing reservoir.

In our current plan, SKG-2 either will be abandoned or used only for a monitoring well. We will develop a deeper reservoir by fracturing the open zone at the bottom of HDR-1 and deepening the production wells, HDR-2 and HDR-3. Fracturing from well HDR-1 and additional drilling is scheduled for 1992. A three-well system will be created with a central and two production wells on opposite sides of the reservoir from the injection well. Long term flow testing of the three-well system is scheduled for 1993-1994.

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REFERENCES

Hirakawa, S., Tomita, T, Kuriyagawa, M., and Sueyoshi, T. 1989: A trend of NEDO's hot *dry* rock project. Proc. Camborne School Mines International Hot Dry Rock Conf; 180-189.

Ito, H. and Barton, C. A. 1990: Stress interpretation from borehole breakouts at Hijiori hot *dry* rock experiment field, Yamagata, Japan. Tran. AGU; 71, 946.

Kobayashi, H., Kuriyagawa, M., and Sasaki, S. 1987: Hydraulic fracturing test to make geothermal reservoir for hot *dry* rock development at Hijiori, Japan. Trans. Geotherm. Res. Council; 11, 553-558.

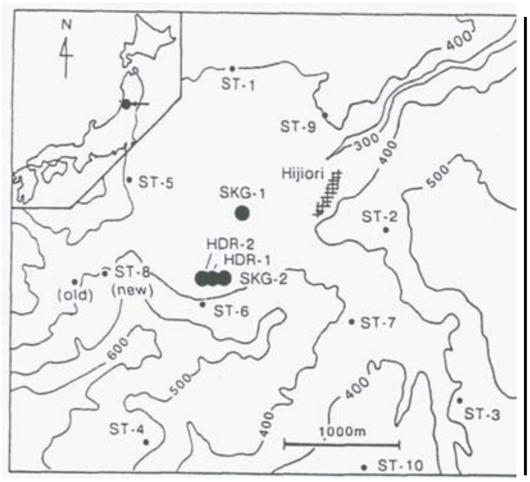

Figure 1. Location of wells and microseismic stations at Hijiori test site.

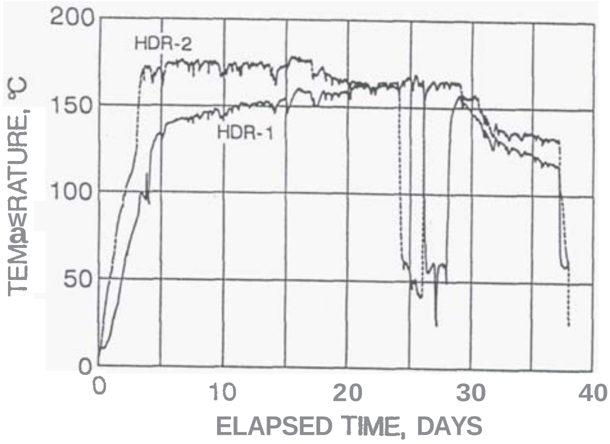

Figure 3. Wellhead production temperature during the circulation test.

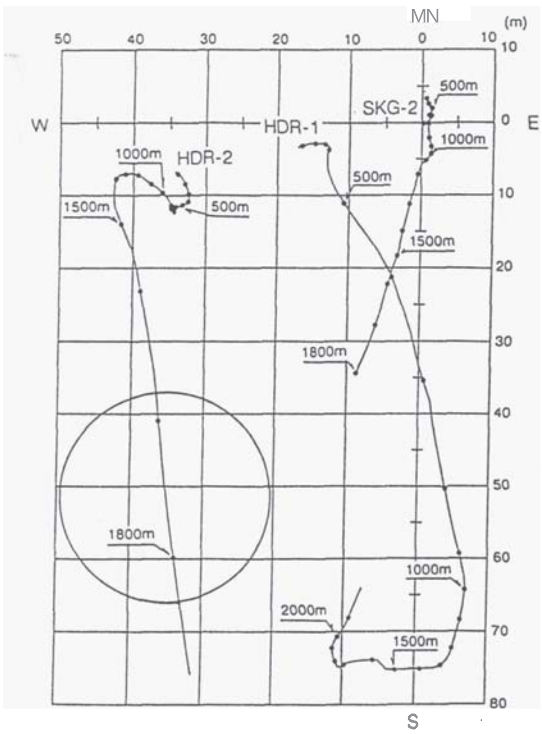

Figure 2. Trajectries of SKG-2, HDR-1, HDR-2. Circle shows the target zone of HDR-2 at the depth of 1750m (Plane view).

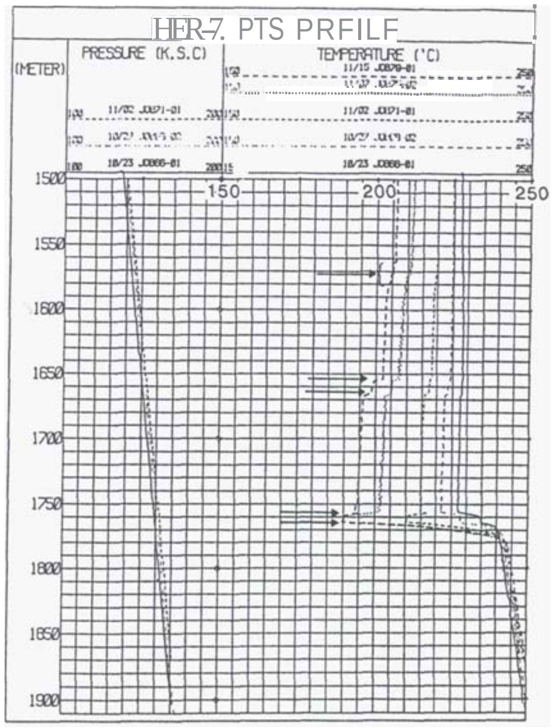

Figure 4. Temperature profiles of HDR-2 during the circulation test.