DEVELOPMENT OF AN ADVANCED GEOTHERMAL RESERVOIR MANAGEMENT SYSTEM FOR THE HARMONIOUS UTILIZATION WITH HOT SPRING RESOURCES

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ABSTRACT

A three-year research project has begun in 2010 to develop an integrated geothermal reservoir operation system for adequately controlled utilization and to prove that geothermal exploitations can be performed without interference to nearby hot springs. The project consists of three parts: Geothermal system modeling and integration of a reservoir operation system, Development of monitoring techniques, and Estimation of reservoir change by numerical simulation. In the first year of the project, the Hachijo island geothermal area was chosen as a model field and various field surveys and monitoring were conducted. The final goal of the project is to construct an integrated system that enables evaluation of the effects on hot springs by a geothermal development that may contribute to promote geothermal exploitation in Japan.

Keywords: geothermal system, hot springs, interference, monitoring, simulation, system integration

1. INTRODUCTION

Geothermal energy should play an important role as an environmentally friendly and stable base power. Understandings and agreements of local residents are essential for new geothermal exploitations. However, in some cases, geothermal projects have been delayed or stopped due to the concerns of local hot spring owners that their springs would be interfered or ruined by geothermal exploitation. Thus in Japan, it is quite difficult to exploit geothermal energy without cooperation with hot spring owners. Logically there should not be a problem if the amounts of natural heat and fluid recharges and utilization are well balanced or there exists a caprock between hot spring and geothermal reservoirs. In order to prove this logic, a three-year research project has been begun since fiscal year 2010 (FY2010). The purposes of the project are to develop an integrated geothermal reservoir operation system for adequately controlled utilization.

The procedures to evaluate effects of geothermal development on local hot springs are compiled by NEF (1999). This manual shows how the reservoir model should be made and which parameters should be monitored. It also describes that it is considered as no interference being unless some monitoring parameters change beyond 95% of confidential interval in their natural state. However, the manual has not been used effectively and natural fluctuation ranges of these parameters have not known yet. Therefore in this project, we will measure these parameters in model fields by simple conventional monitoring methods then compare the results with those by new monitoring technologies. Modeling and simulation of these fields will also be conducted. Finally a simple evaluation system will be produced with application examples to actual fields.

The project consists of three parts as follows: 1) Modeling of a geothermal system and integration of a reservoir operation system, 2) Development of monitoring techniques, and 3) Estimation of reservoir change by numerical simulation. In FY2010, we chose the Hachijo island geothermal area, Tokyo, where the Hachijojima geothermal power plant has been in operation since 1995, as a model field and newly conducted various field surveys and monitoring. The followings are the summary of the studies carried out in FY2010.

2. GEOTHERMAL SYSTEM MODELING AND INTEGRATION OF RESERVOIR OPERATION SYSTEM

"Geothermal system modeling" team constructed an initial conceptual model of the Hachijo island geothermal system as shown in Fig. 1. It includes a new observation well and existing wells, ground water flow system, a shallow hot spring reservoir and a deep geothermal reservoir being used for power generation. This team also conducted a resistivity survey of the field. Fig. 2 shows a three dimensional resistivity model as a result of three dimensional inversion of MT and AMT data.

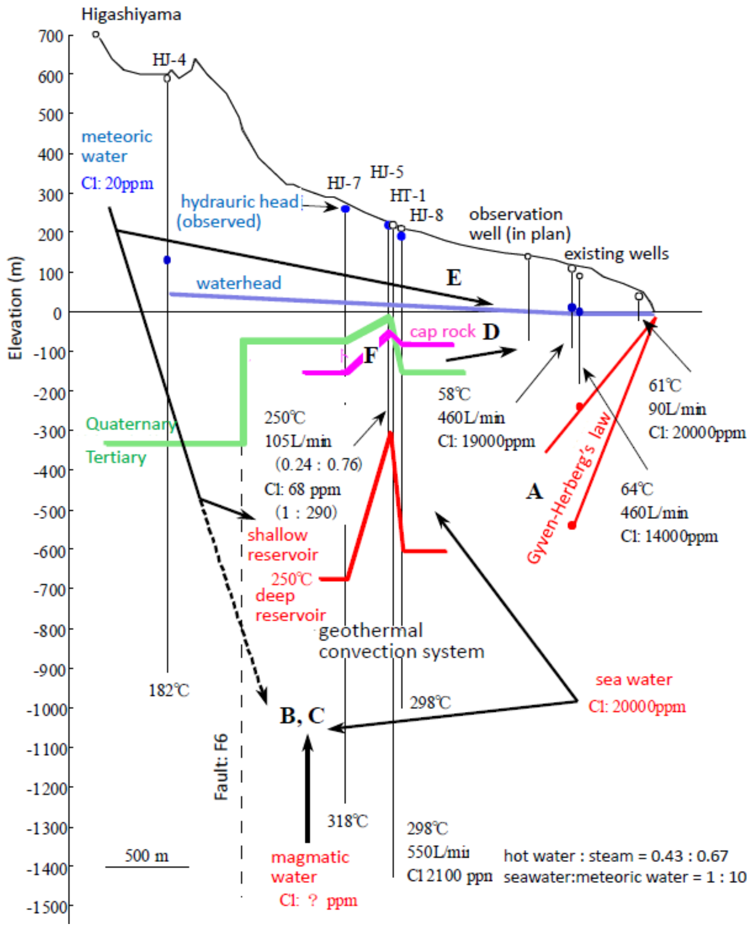

Fig. 1 Conceptual model of the geothermal system in Hachijo island, Japan (AIST, 2011)

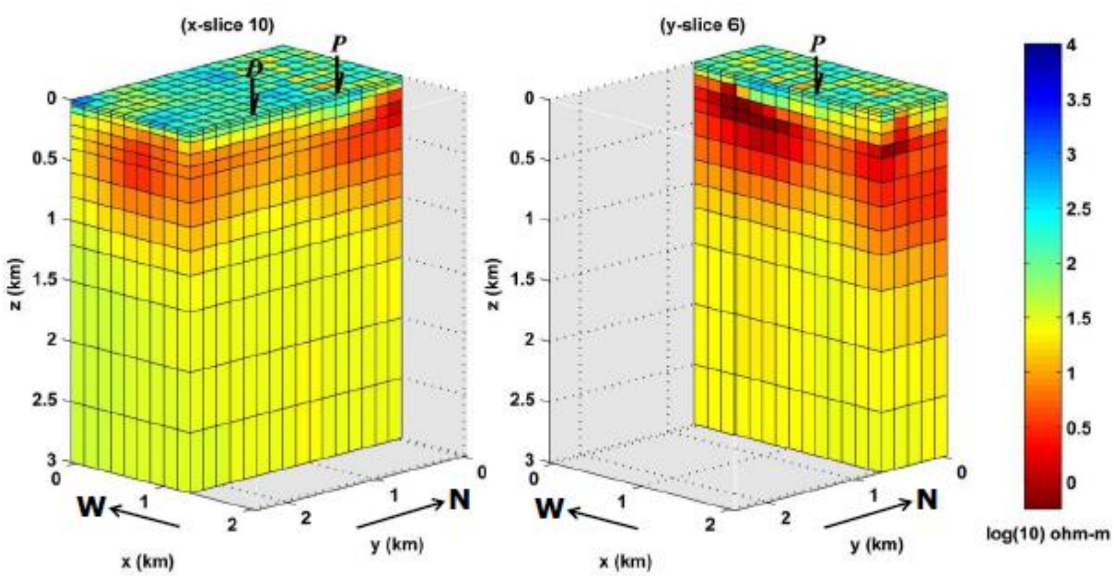

Fig. 2 Result of 3D inversion of MT and AMT data taken at the Hachijo geothermal area (AIST, 2011)
"P" in both slices indicates the geothermal power plant while "D" in x-slice (left) does the observation well.

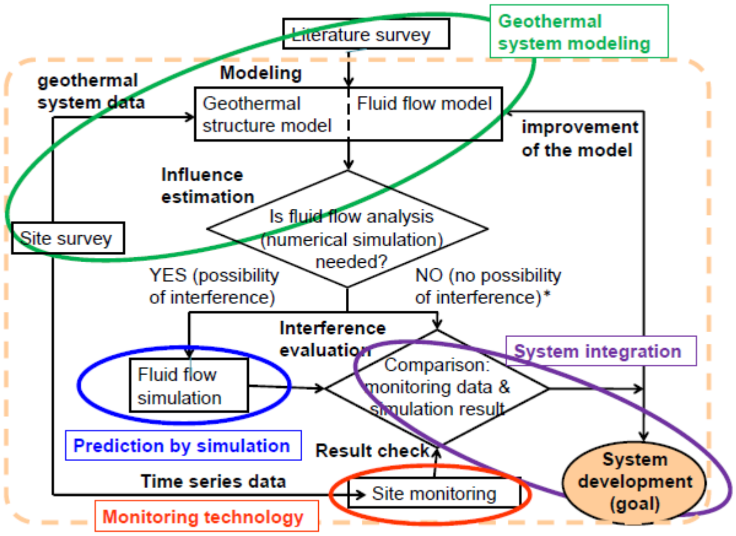

Fig. 3 Flow diagram of the integration system (AIST, 2011)

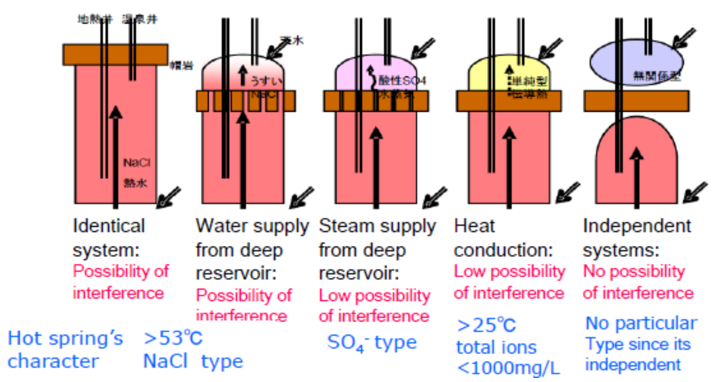

Fig. 4 Five types of relations between shallow hot springs and deep geothermal system (GRSJ, 2010)
Such types may be identified by temperature, hydraulic head, chemical components of the hot spring water.

The "Integration of a reservoir operation system" team conducted a conceptual designing of the integration system as shown in Fig. 3. The "interference evaluation" in Fig. 3 will be performed by categorization of the system into five conceptual models mainly based on fluid chemistry of the hot spring(s) as shown in Fig. 4. If the shallow hot spring reservoir is independent from the deep geothermal reservoir (type 5), there is no need to conduct numerical fluid flow modeling ("NO" in Fig. 3). However in this project, although the system in Hachijo is considered to be type 5, fluid flow simulation is conducted to show the necessary processes for any other fields.

The final goal is to construct an integrated system that enables evaluation of the effects on hot springs by a geothermal development. The integrated system will contain the latest technologies of exploration and monitoring methods. The system will be used for real geothermal and hot spring areas in Japan in this project to examine the applicability of the system. The results of monitoring and analysis will be opened to public as well.

3. DEVELOPMENT OF MONITORING TECHNIQUES

For geothermal monitoring, although each observation method needs continuous improvements, most of the monitoring methods have been already well developed except for micro-gravity method. In this situation, to design a combined monitoring system in consideration with local characteristic of a region is a new challenge to be completed. On the other hand, for micro-gravity method, a monitoring system with the latest high-resolution gravimeter for a continuous observation has not been developed yet. Therefore in FY2010, we drilled an observation well and conducted a production test at Hachijo island. This well will be used in the following year to monitor the water level, temperature and electrical conductivity. For micro-gravity monitoring, we checked stable operation of high-resolution gravimeters for continuous measurements and evaluated the baseline of the gravity distribution around the observation well. We also installed the necessary monitoring tools in boreholes at the existing power plant and hot springs, checked their operational performance, and started the continuous data logging.. For self-potential method, we conducted re-analysis of the existing data to make an observation plan for FY2011.

The final goal is to develop a reliable monitoring system that can detect small effects on a hot spring caused by geothermal exploitation. We aim to detect a change in groundwater and hot spring water level with a resolution of 10 cm by a continuous gravity monitoring..

4. ESTIMATION OF RESERVOIR CHANGE BY NUMERICAL SIMULATION

Generally, the existing geothermal simulation models are formed to evaluate the changes of geothermal reservoir under the cap rock, and do not include the shallower hot spring resources overlying the cap rock. Thus, the detailed simulation of the shallower hot spring resources after the exploitation of the deeper geothermal reservoir has not been done yet. Therefore, in FY2010, based on an existing geothermal reservoir model that had been created for reservoir operation of the Hachijojima geothermal power plant, a new numerical model was designed. Fig. 4 shows the extension of the calculation range and re-gridding of shallow part of the Hachijo island geothermal reservoir model for this purpose. We will carry out a detailed simulation for shallower hot spring resources in FY2011.

The final goal is to establish a standard procedure to construct a simulation model, which has flexibility with respect to the characteristic of the region, quantity and quality of the available data, etc. We particularly intend to make it possible to evaluate the change of shallow resources on/above the cap rock, which is approximately 100 m deep or shallower in the case of the Hachijo island geothermal area.

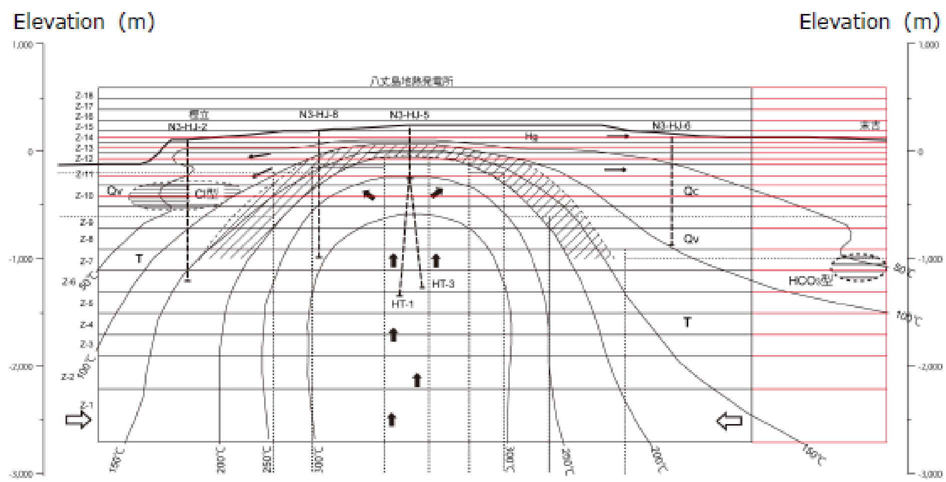

Fig. 4 Extension of the calculation range and re-gridding of shallow part of the Hachijo island geothermal reservoir model (AIST, 2011)

Black: original geothermal reservoir model, Red: newly added grids for interference simulation with hot springs

5. FUTURE PLANS OF THE PROJECT

A new observation well of 500 m is to be drilled to conduct production test, etc., at another model field, Minamiizu, Shizuoka prefecture this year. The Minamiizu region has several natural hot springs but hasn't been explored yet for power generation while the Hachijo area has been already developed for geothermal power generation. Therefor it is a new challenge to apply our reservoir management system for this Minamiizu area. The final product of the project will be software that helps to develop an integrated geothermal reservoir operation system for adequately controlled utilization, with appendix of application examples at model fields.

For mutual understanding of hot spring owners and geothermal developers and for sustainable use of the both hot springs and geothermal reservoirs, scientific investigation of the whole system is essential. We hope that the products of this project would be used effectively. However at the same time, we emphasize that the product (software) may be used to judge if there is a possibility of interference or not, but the final judgment if there exists an interference or not should be done by specialists in neutral positions.

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