SUSTAINABLE DEVELOPMENT OF GEOTHERMAL ENERGY -A CASE STUDY OF HATCHOBARU GEOTHERMAL FIELD, CENTRAL KYUSHU, JAPAN-

Sachio EHARA[1] and Jun NISHIJIMA[1]

[1]Laboratory of Geothermics, Faculty of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

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SUMMARY - Geothermal energy is renewable but its sustainability is not self-evident. Therefore the management of geothermal reservoirs is important to maintain the sustainable production of geothermal energy. We estimated the mass balance in the geothermal reservoir during exploitation at Hatchobaru geothermal field, central Kyushu, Japan based on the changes in gravity and Gauss's theorem. Combining the estimated mass change and the rates of production and re-injected geothermal fluids, we calculated the rate of natural recharge to the geothermal reservoir from outside. As a result, we estimated that the rate of natural recharge is nearly same as the rate of steam released to the atmosphere from the cooling towers. This result is consistent with the mass balance estimated from numerical modelling. Therefore we conclude that the sustainable production of geothermal energy is realized at Hatchobaru Geothermal Power Station.

1. INTRODUCTION

Geothermal energy is a renewable energy and its contribution to power generation in Japan is much larger than that of solar energy or wind energy, although the installed capacity of geothermal energy is much smaller than either that of solar or wind energy. The above fact shows that geothermal power generation is much more stable than that of other renewable energy sources. However geothermal energy is renewable but its sustainability is not self-evident. Rybach and Mongillo(2006) mentioned that there is still a clear need for significantly more research and studies of geothermal production sustainability

2. HATCHOBARU GEOTHERMAL FIELD

Hatchobaru geothermal field in central Kyushu, Japan is 5km northwest of Kuju volcano and its shows a liquid dominated fracture type geothermal reservoir. No1 unit(55MW) was completed in June, 1977 and No.2 unit(55MW) was completed in June, 1990. We started repeat gravity measurements in May 1990 just before the commencement of the operation of the No.2 unit in order to verify the sustainable development of geothermal energy.

The production zone is in the southeastern part of the field and the re-

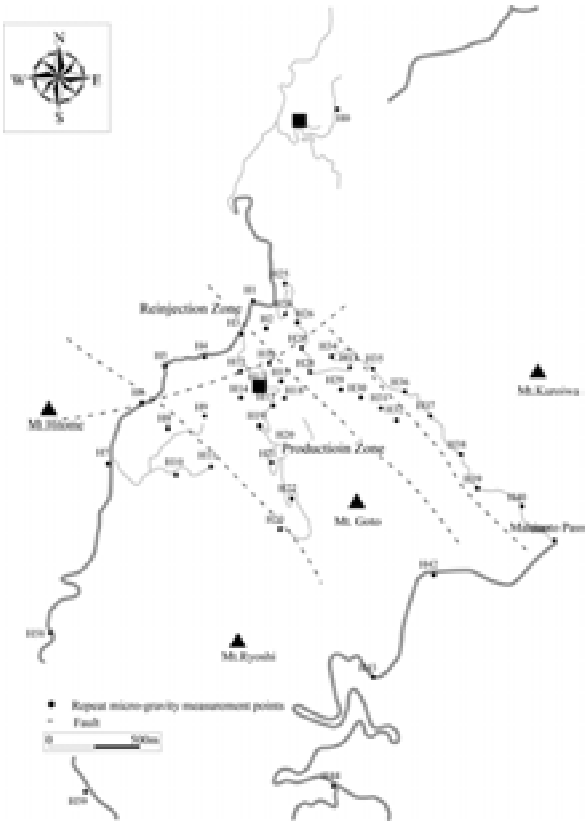

Fig.1: Location map of repeat gravity measurement at Hatchobaru geothermal field. Small solid circles show gravity stations. The solid square shows the location of geothermal power plant. Broken lines show main fracture zones. Solid triangles show volcanoes of the Kuju volcanic group.

injection zone is in the northwestern part as shown in Fig.1 Most production is from about 1000m to 2500m depth and most re-injection is from 1000m to 1500m depth. The deep geothermal fluids rise along fractures in the southeastern part of the field and flow laterally towards northwest.

3 REPEAT GRAVITY MEASUREMENT

The stations for repeat gravity measurements are also shown in Fig.1. Representative examples of gravity change in the production and re-injection zones are shown in Fig.2. The gravity in the production zone changed as follows; the gravity in the production zone increased a little in a limited area of the production zone just after the commencement of deep fluid production and after that, it decreased rapidly up to about 200 microgal in the whole production zone. After that, the gravity in the production zone became stable. The pattern of gravity change in the production zone is very similar to the change in reservoir pressure (Tagomori et al., 1996). The levelling surveys clarified that the ground movements ranged from -15mm to +35mm from August 1990 to March 1996 in the field, which corresponds to about -10 to +5 microgal in

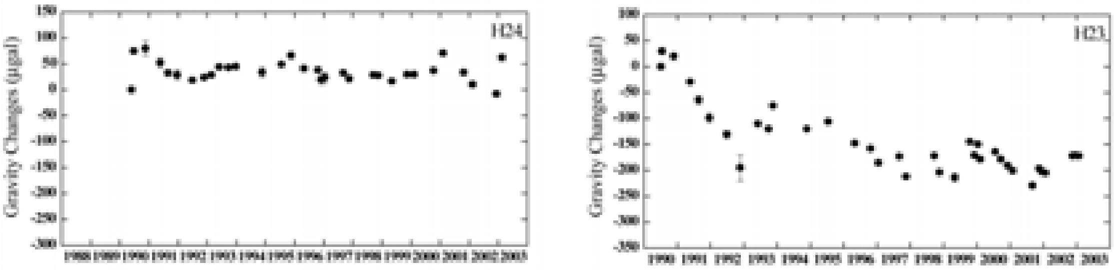

Fig.2: Examples of gravity change after the commencement of power generation in Hatchobaru geothermal field. Left: Gravity change at the station H24 in the reinjection zone. Right: Gravity change at the station H23 in the production zone.

gravity change. These values show that the effect of vertical ground movements is negligible on the observed gravity changes.

On the other hand, gravity change at the re-injection zone shows a different pattern from that in the production zone. The gravity increased up to several tens of microgal after the commencement of re-injection. After that, it decreased and became stable gradually. The temporal change of re-injected fluid is also very similar to the pattern of gravity change in the re-injection zone (Tagomori et al., 1996).

Fig.3: Gravity change at Hatchobaru geothermal field. Left: from June 1990 to June 1992, Right: from October 2000 to October 2001.

Contour maps of gravity change from June 1990 to June 1992 and from October 2000 to October 2001 are shown in Fig.3 The gravity change from June 1990 to June 1992 is much more rapid than that from October 2000 to October 2001, that is, the gravity change was becoming stable. The gravity change in the later stage of exploitation is limited in the narrower area.

We estimated the mass balance in the geothermal reservoir based on the changes in gravity and Gauss's theorem (La Fehr, 1965). Combining the estimated mass change and the rate of produced and re-injected geothermal fluids, we estimated the mass balance as shown in Fig.4 for different periods. The values in Fig.4 are estimated assuming that all the re-injected fluids were supplied to the reservoir. However, if we assume that 75% of the re-injected fluids were supplied to the reservoir, we have a good correspondence between the observed and calculated mass balance (Tokita et al., 2006).

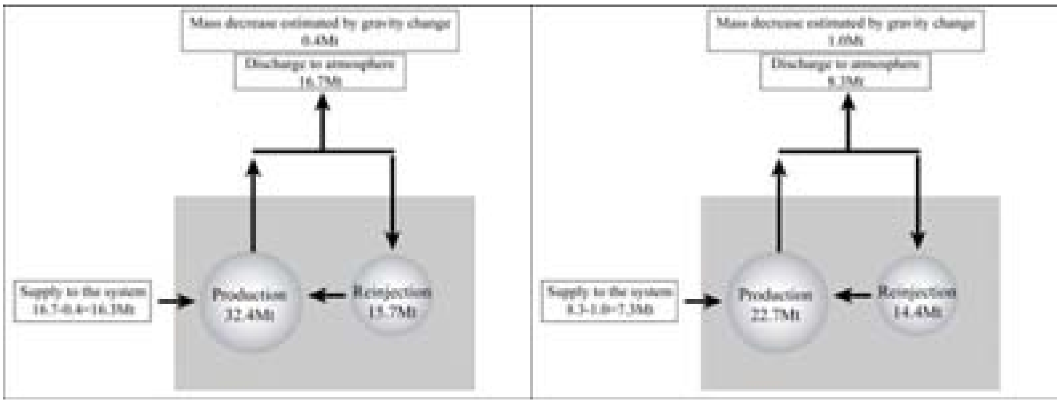

Fig. 4: Mass balance at Hatchobaru geothermal field estimated from rates of produced and re-injected fluids and gravity measurements. It is assumed that all the re-injected fluids are supplied to the reservoir. Left: from August 1991 to May 1993. Right: from October 2000 to October 2001.

4. CONCLUSIONS

We estimated the mass balance in the geothermal reservoir based on the changes in gravity and Gauss's theorem. Combining the estimated mass change and the rates of produced and re-injected geothermal fluids, we calculated the rate of natural recharge to the geothermal reservoir from outside. As a result, we estimated that the rate of natural recharge is nearly same as the rate of steam discharged to the atmosphere from the cooling towers. Therefore we conclude that sustainable production of geothermal energy is realized at Hatchobaru Geothermal Power Station.

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