GEOPHYSICAL MONITORING IN THE SENGAN (HAHIMANTAI) THERMAL AREA, NORTHEASET JAPAN

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ABSTRUCT

Microearthquakes monitoring has been carried out in the Kakkonda geothermal field, which is one of the most active geothermal field in Sengan thermal area. Comparing seismicity in the geothermal field, number of earthquakes, especially those in the reinjection field, has decreased. The decrease of events and change of distribution of earthquake suggests the change of characteristics of reservoir in the Kakkonda geothermal field.

Another geophysical monitoring is the precision gravity survey in the Sumikawa geothermal field, where a new geothermal power plant began operation in 1995. The increase in gravity was detected in the reinjection field, which was predicted by computer reservoir simulation.

INTRODUCTION

Geological Survey of Japan (GSJ) has been carrying out geophysical monitorings at two geothermal fields in the Sengan thermal area. One is microearthquake monitoring in Kakkonda and the other is gravity monitoring in Sumikawa. In both geothermal field repeated self-potential surveys have been also performed for several years. Some of studies in the Sengan thermal area are reviewed in this paper.

Sengan thermal area is located between Morioka and Akita prefectures and is one of the most well known thermal area. There are four geothermal power plants, Kakkonda, Matsukawa, Sumikawa and Onuma, and many hot springs in it. Late Tertiary and Quaternary volcanism is dominant in the thermal area overlying Miocene and pre-Tertiary sedimentary rocks. Geological and geophysical features on the Sengan area are studied under one of Japan's sunshine projects, which focused on geological and geophysical surveys over wide thermal area in Sengan and the other area.

MICROEARTHQUAKE MONITORING

The Kakkonda geothermal fields (Fig. 1) is well investigated by Japan Metal and Chemical Ltd. (JMC), the developers of the field, as well as the sunshine project. Various geological, geochemical and geophysical surveys have been performed on the field by JMC and GSJ. Recently a new project promoted by NEDO (New Energy and Industrial Technology Development Organization), deep-seated geothermal resources, has been started and intensive surveys have been done. The seismic monitoring commenced in 1982 with four seismometers by GSJ and other four seismometers were installed in the following 6 years. The aim of the monitoring is to study characteristics of microearthquakes in the geothermal field and to utilise them in a geothermal investigation. NEDO continued microearthquake monitoring and added two seismometers in the west of the geothermal field, where the investigation well WD-1 drilled to explore deep-seated geothermal resources.

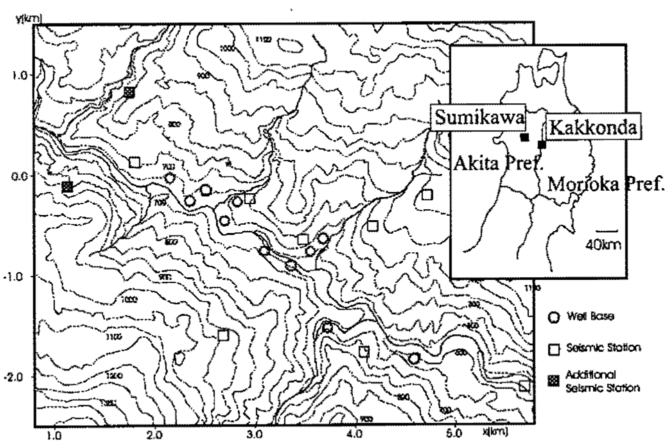

Fig. 1 Map showing the location and the topography of the Kakkonda geothermal field. Each topographic contour is drawn at a 50 m interval. Location of Kakkonda and Sumikawa geothermal field also shown in the right map.

Fig. 2 shows numbers of daily events in the NEDO network after Takahashi et al., (1995) during 23 December, 1994 and 20 June, 1995. Though there was period when data were under analysis at that moment, daily seismicity are less than 10. Fig. 3 shows daily seismicity recorded by the GSJ network in 1988. A daily average of seismicity is about 10 but there are several swarms in some of which more than 100 events occurred in a day. There were 6 swarms in 1988 indicated in Fig. 3. One occurred in January and the others happened in February, May, June, August and October. The number of earthquakes in the NEDO network decreased apparently. Lower seismicity is presented in the Matsukawa geothermal field than that in Kakkonda. The Matsukawa geothermal field is one of the vapour-dominated geothermal fields in Japan and located c. 5km north to Kakkonda. Hanano and Takanohashi (1993) pointed out that Matsukawa

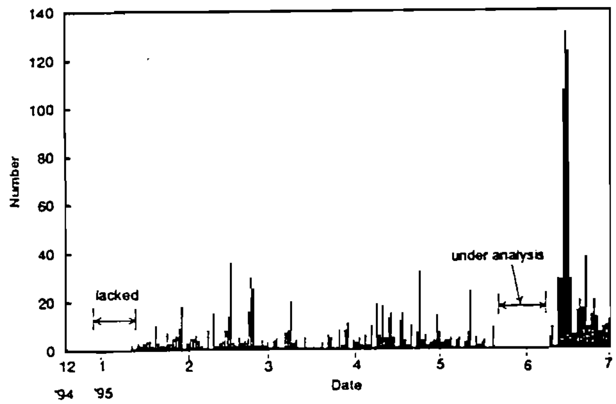

Fig. 2 Daily seisicity in December, 1994 to July, 1995 afer Takahashi et al., 1995

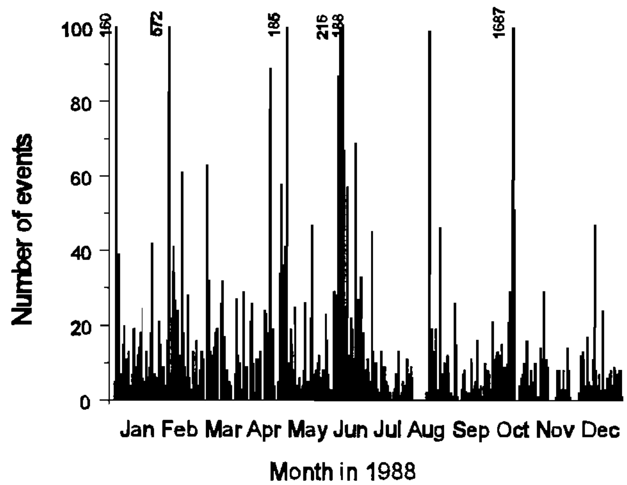

Fig. 3 Daily seisicity in 1988 after Tosha et al. (1995)

used to be a liquid-dominated geothermal field and has changed to a vapour-dominated one. Decrease of seismicity might be a sign the change of characteristics of the Kakkonda reservoirs though we need to monitor for a long period.

There were many earthquakes occurred in the southeast area of the geothermal field, where reinjection wells are located. Epicentres of swarms except in June are also plotted in the area in 1988. Hypocentres in 1995 are shown by Uchida et al. (1996), where are still hypocentres in the reinjection area but the numbers of them were lower than in 1988. No hypocentres are detected associated with the deep-seated

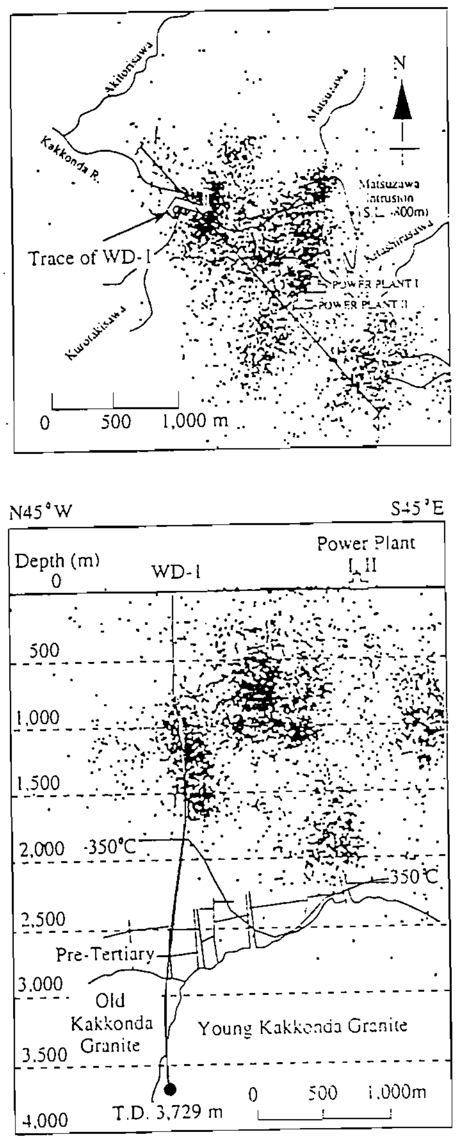

Fig. 4 Hypocentres in 1995, (Top)Hoizontal projection and (Bottom) cross-section after Uchida et al. (1996)

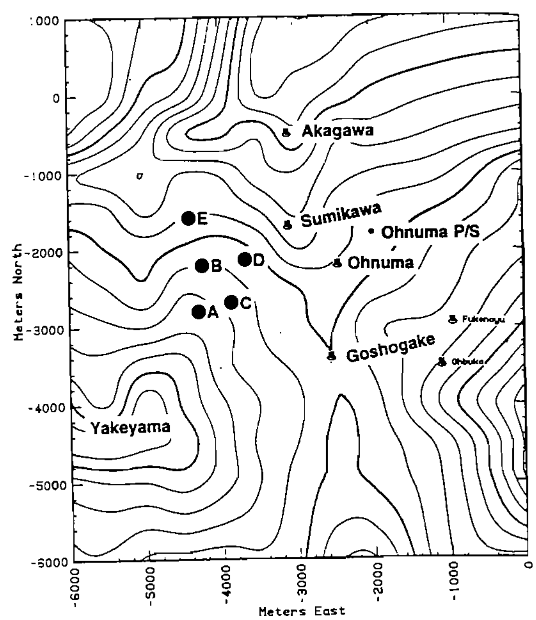

Fig. 5 Location of Sumikawa and Ohnuma area. Each topographic contour is drawn at a 50 m interval. Well bases are also shown by closed circles (after Ishido et al., 1995)

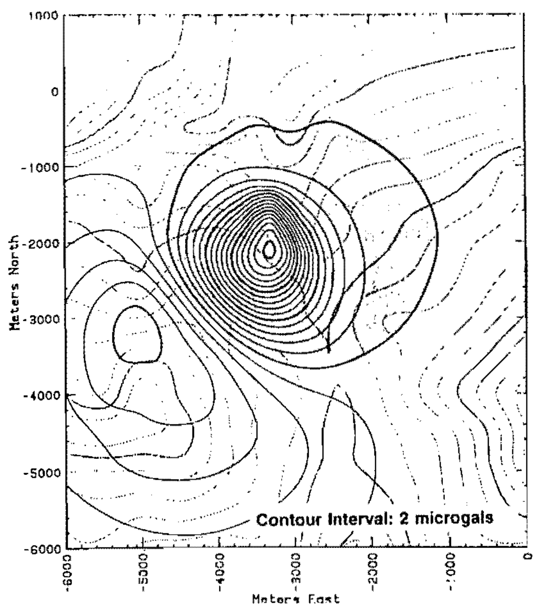

Fig. 6 Computed gravity change between 0 and 1 year. Upper right anomaly is positive. Contour interval is 2 micro-gal (20 nN/kg) after Ishido et al. (1995)

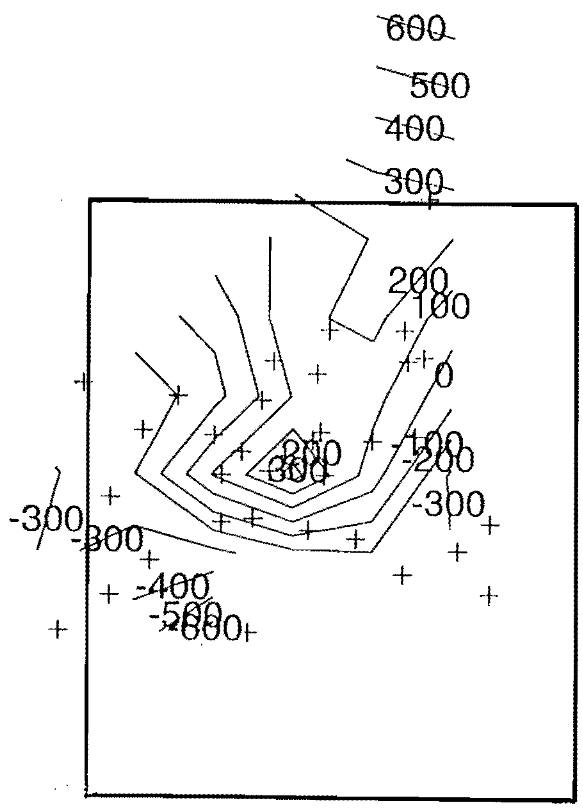

Fig. 7 Gravity change between 1994 and 1995. Square in the figure is the area in Figs 5 and 6. Cross symbols represent gravity survey points. Positive anomaly of about 30 micro-gal (300 nN/kg) is shown.

geothermal resources in the western area, where the trend of hypocentres toward to deep was recognized in 1988. The low seismicity in 1995 might be decrease of earthquakes in the injection area and defferent pattern of hypocentres might suggest the change of reservoir.

GRAVITY MONITORING

The Sumikawa geothermal field is located in the Hachimantai zolcanic zone of the Sengan thermal area, which is northwestward to the Kakkonda geothermal field. Exploratory studies have been made at Sumikawa since 1981 by Mitsubishi Material Coroiration (MMC) and Mitsubishi GasChemical Corporation (MGC). Fig. 5 shows the Sumikawa and the adjacent geothermal field, the Ohnuma; the Sumikawa field lies in the western part of the area and regarded as centred around drilling well bases A, B, C, D and E shown in the figure. Sumikawa geothermal power plant with a 50 MW generator was constructed and began to generate electricity in 1995. The Ohnuma geothermal plant in the east of the figure has been producing about 10 MW of electricity for several years.

Gravity survey has been used as one of the geophysical survey methods prior to large-scale development to assess the gravity anomaly distribution in the natural state. Repeated surveys are carried out to detect and characterize changes in the distribution in and around the field as exploitation proceeds.

Ishido et al. (1995) used the STAR geothermal simulator (eg. Pritchett, 1994) to perform a 30-year forecast of the consequences of production and injection in the Sumikawa geothermal field. They also presented a areal map of synthetic gravity anomaly change corresponding to the changes in the underground conditions calculated by a postprocessor for the STAR code. Fig. 6 shows a result of their calculation of the gravity change after one year of field operation. The increase in gravity due to the reinjection of geothermal fluid is dominant in the early stage of the operation as the fluid reinjects into the shallow levels. They predicted that the gravity increase of 30 micro-gal associated with the reinjection would be possible to detect even after only one year of operation.

The gravity change before and after the operation of power plant is shown in Fig. 7. A square in the figure is corresponded to the area of Figs. 4 and 5. Numbers in the figure are the gravity change in nN/kg (nano-m/sec^2), which is equal to 0.1 micro-gal. The gravity increase was detected at the reinjection zone of c. 300 nN/kg, which is the same amount of increase predected by Ishido et al. (1995). However, the contours less than 100 nN/kg are not closed. That seems to due to regional gravity overlying the gravity change caused by reinjection. For the production zone, the numerical calculation suggests the small amount of the decease in gravity (10 micro-gal) but no reliable contours were obtained in the survey. That is partly due to less survey points in the mountain area.

CONCLUDING REMARKS

Number of microearthquakes decreased in 1995 and less earthquakes occurred in the reinjetion field, comparing with microearthquakes in 1988. The decrease of seismicity and hypocentre distribution change suggests changes of the characteristics of reservoir. Gravity increased in the reinjection field as the same amount as the computer simulation expected. The combination of precision gravity survey with reservoir numerical simulation is useful.

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