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Geodetic Monitoring of Volcanic and Geothermal Activity Around Mt. Iwate

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ABSTRACT

Surface deformation due to reservoir depletion in Matsukawa geothermal field was detected from the leveling data which were acquired for monitoring and predicting volcanic activity. The local subsidence was observed during the inflation phase whose source was determined to be 8 km in depth.

Introduction

Ground deformation has long been used as a tool for monitoring and predicting volcanic activity (Dvorak & Dzurisin, 1997; Murray, et al., 2000). Surface deformation due to reservoir depletion may occur as a result of geothermal exploitation (Carnec & Fabriol, 1999; Mossop & Segall, 1999). If a geothermal power plant is near an active volcano both of the effects can be observed simultaneously. We show such a case study.

Geodetic Monitoring at Iwate Volcanic Group

Iwate volcanic group is situated at the southeastern portion of Hachimantai and surrounding volcanic clusters, northeastern Japan. It consists of several volcanic bodies extending in E-W direction, parallel to the maximum horizontal compressional axis of the tectonic stress in this region (Nakagawa, 1987). Matsukawa geothermal power plant and Kakkonda geothermal plant are deployed on the north and south base of Iwate volcanic group respectively (Figure 1).

Active seismicity has been observed since February 1998 at Mt. Iwate volcanic group. Half a year later, images derived from repeat-pass spaceborne interferometric synthetic aperture radar (SAR) showed conspicuous inflation centered on Mt. Mitsuishi, the westernmost volcanic body of the Iwate volcanic group (GSI, 1999). The other geodetic data, leveling data on the south base of Iwate Volcanic group and GPS, agreed with the SAR data.

As a result of this measurement, we started a repeat leveling survey at the northern base of Iwate volcano. The initial leveling survey took place in November 1998. The locations of the leveling survey points are shown in Figure 1. It consists of a line stretching some 20 km from the nearest accessible point to

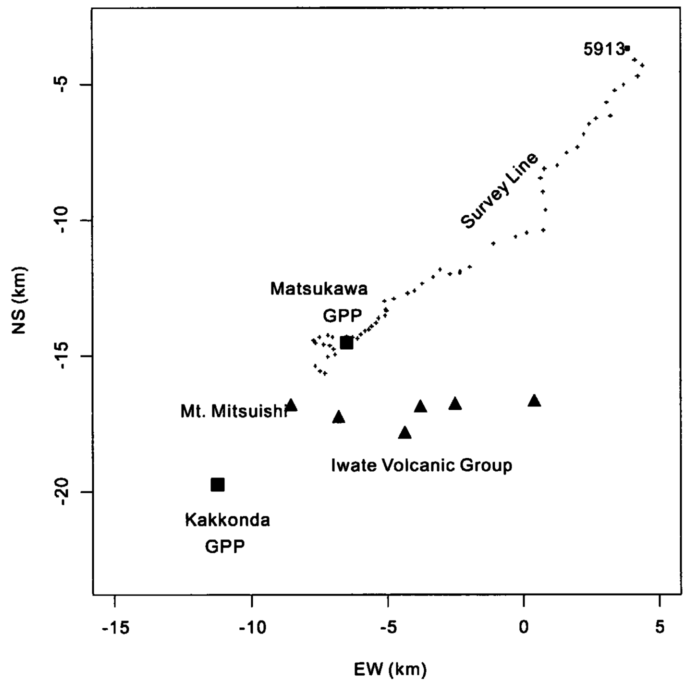

Figure 1. Location map of the Iwate volcanic group and geothermal power plants.

Mt. Mitsuishi to the northeast, terminating at the reference monument 5913, which is part of the nationwide leveling network. All leveling surveys were carried out to first-order specifications, with a nominal error of 2 mm per square root kilometer of level line. The second leveling survey measured elevations at the same survey markers in October 1999. The fixed reference monument for each survey was the monument 5913.

Results of Leveling Survey

The differences of ground-leveling data along a SW-NE profile (noted AB in Figure 3) between 1998 and 1999 are presented in Figure 2, together with the ground deformation profile estimated from GPS data of Geographical Survey Institute (GSI, 1999). GSI deployed GPS stations around Iwate volcanic group in addition to the nationwide GPS network (Miyazaki et al., 1997). Figure 3 shows the differences of GPS data during the same period (GSI, in prep). Modeling of the ground deformation was carried out assuming elastic deformation in a half-space from a simple point source (Mogi, 1958). Thus, the difference between the observed leveling data and the estimated deformation profile indicate in Figure 2 the local components of ground deformation (Figure 4).

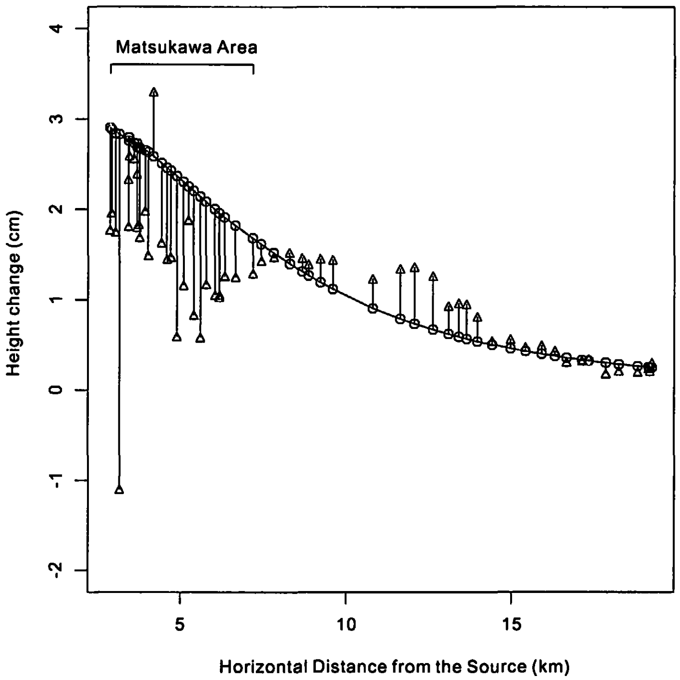

Figure 2. Results of the leveling survey.

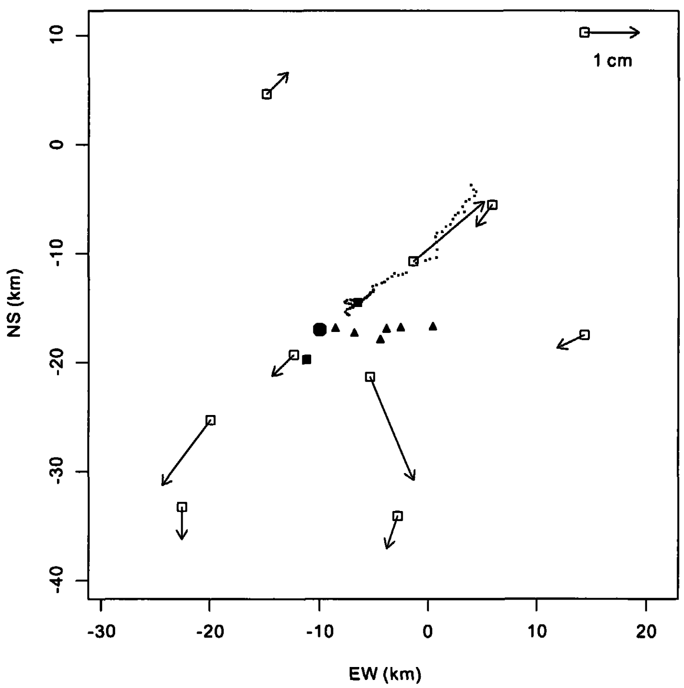

Figure 3. Horizontal grand deformation deduced from repeat GPS measurements by GSI. A solid circle indicates the location of the Mogi source which best fit to the data.

Discussion

Matsukawa was the first geothermal power station in Japan, starting power production in 1966, and it is a vapor-dominated geothermal field in which most of the wells currently produce dry superheated steam. Continued pressure buildup tests since 1986 have revealed that there is a lateral frow from southwest to northeast in the Matsukawa vapor-dominated reservoir, and most of the steam is supplied from southwest of the development area (Hanano, et al., 1993). Figure 5 shows the shut-in pressure distribution in 1988, from which a low-permeability barrier is inferred at least both at the top and sides of the reservoir (Hanano, et al., 1991). Without this low-permeability barrier,

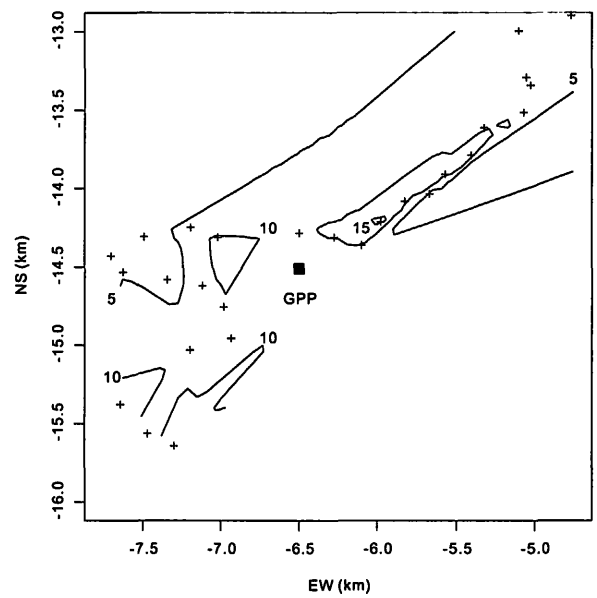

Figure 4. Contour map of local ground deformation around Matsukawa geothermal field. Contour interval is 5 mm/yr.

such a low reservoir pressure as shown in Figure 5 cannot exist stably at a depth of 800-1300 m.

Comparing Figure 4 with Figure 5 we recognize the center of subsidence is northeastmost of the reservoir, where the lowest shut-in pressure was observed in 1988. Since 1988, reinjection experiments have been conducted to sustain reservoir pressure and steam production and to extract the remaining heat energy in the superheated reservoir (Hanano, et al., 1991, 1993). Therefore, shut-in pressure distribution at present may

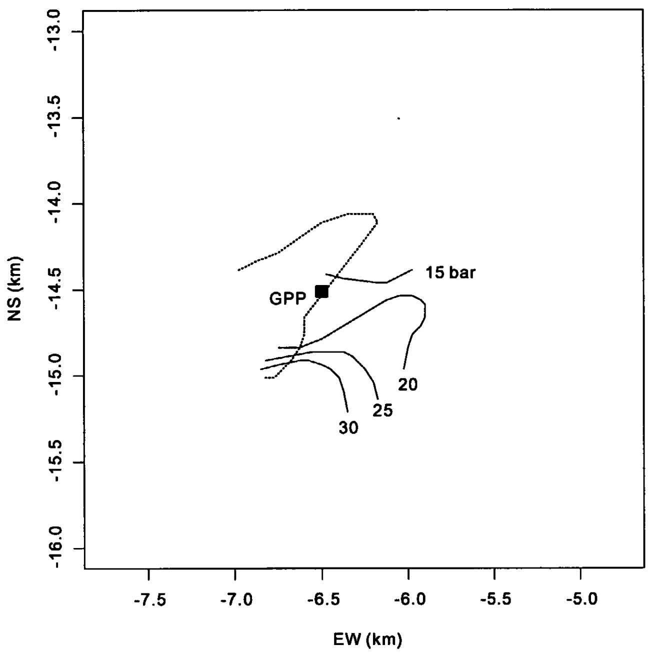

Figure 5. Shut-in pressure distribution at feed points in October 1988 (Hanano, et al., 1991), and location of intrusive rock (broken line).

be different from Figure 5 especially in the northeast part of the reservoir, where reinjection wells exist. The reinjection experiment has been successful, however, the reinjection rate in the experiment was not always large enough. Thus, it has been planned to continue the series of experiments and collect data for the coming full-scale field-wide reinjection test (Hanano et al., 1991). The observed ground deformation can provide important field-wide data.

The regional component of ground deformation, which can be seen as an inflation trend in Figure 2, was attributed to the point source whose depth is 8 km. The true character of the source still remains unknown. However, it can be a heat source, which activates or creates another geothermal reservoir as it was in Matsukawa and Kakkonda geothermal field.

Concluding Remarks

We recognized surface deformation due to reservoir depletion in Matsukawa Geothermal field, but have not analyzed it quantitatively yet, because the data is insufficient to do that. We started other geodetic surveys, gravity monitoring and continuous GPS measurements, around this area in 1999. In autumn 2000 we can evaluate such data. By combining the ground deformation monitoring with gravity monitoring, it becomes a more powerful and rigorous indicator of subsurface processes. As pointed out by Murray et al. (2000), each technique alone can produce results which are misleading or ambiguous, but by integrating data sets, many of the ambiguities are resolved.

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