Self-Potential Measurements in Ogiri and Shiramizugoe Geothermal Fields, Japan

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Keywords

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ABSTRACT

Self-Potential observation was carried out at Ogiri-Siramizigoe geothermal area, where NEDO had promoted a long-term production test using investigation wells for the survey of the geothermal area. The concordant SP change to the production of the geothermal fluid was not clear because of the shortened period of the production and because of the noise due to a magnetic storm at the start time of the production test. However, the tidal wave correction reveals that the SP change was recorded in accord with the geothermal reservoir change induced by the long-term production test.

Introduction

Self-Potential (SP) observation has been carried out around the Ogiri geothermal area in northwest of the Kagoshima Prefecture, the western regions of the Kirishima-mountains, since the commencement of the operation at the geothermal power plant. At the first SP survey, the positive abnormalities in potential were found centering on the area that became the production area of the power plant (eg. Ishido et al., 1997). New Energy and Industrial Technology Development Organization (NEDO) started the Development of the Technology for Reservoir Mass and Heat Flow Characterization, which aimed at efficient geothermal development, in 1997. Ogiri area was selected in this R&D project to determine the change of the geothermal reservoir using electricity and electromagnetic phenomena such as Self-Potential. As mentioned above, since SP data before a plant operation start was left behind, the comparison of the data obtained at the R&D project could be made with the previous data in the Ogiri area. To monitor of the SP change in the project, an SP observation network was laid consisting of 56 electrodes around the Ogiri area.

In response to the suspend of geothermal research and development projects, which was determined by political evaluation of the Ministry of Economy, Trade and Industry (METI) in March, 2002, SP observation by NEDO in the Ogiri area will be ended. SP observation in the Ogiri area has been continued by the Advanced Institutes of Science and Technology (AIST reconstructed from GSJ and other governmental institutes) using the network NEDO laid. Since the production examination at the investigation wells was planned in the Shiramizugoe area, which adjoins to Ogiri area, according to the promotion investigation enterprise of NEDO in August, 2003, SP observation in Ogiri and Shiramizugoe area was carried out by expanding the SP observation network in the Ogiri area.

Self-Potential Anomalies

SP anomalies in a geothermal area are thought to be based on the electro-kinetic phenomenon accompanying a flow of geothermal fluid in pore and crack of rocks (eg. Ishido et al., 1997). Electric charges separated by the electric double layer produced at the rock surface interfaced by the geothermal fluid causes the potential anomalies. The zeta (ζ) potential, which expresses the size of the electric double layer, is indispensable to a quantitive estimate. Although there was no experiment results of the reliable zeta potential data in a water-rock system at high temperature, the experimental measurement using granite and brine water was recently reported (Tosha et al, 2003). According the report, zeta potential takes a negative value at high temperature and a positive electric charge should be carried along with a geothermal flow. The result of the report is not contradictory to the expression of relations about the zeta potential at the room temperature (Ishido and Mizutani, 1981), which is used in the SP post processor, and can explain quantitatively the positive anomalies at the production zones in the geothermal area.

Self-Potential Observation

The SP observation network in the Ogiri and Shiramizugoe areas is illustrated in Figure 1, overleaf. Six electrodes were added to the network in order to monitor the long-term production test at the Shiramizugoe area. The additional survey points, which are

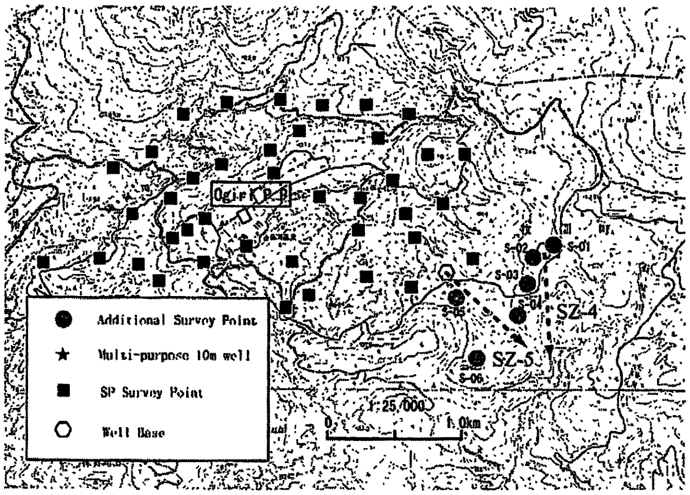

Figure 1. Map of the survey stations for the SP monitoring.

marked in circle symbols in Figure 1, were located along the road which passes close to the wellheads of SZ-4 and SZ-5, production wells for the long-term production test.

Electrodes were installed late in July, 2002, which are the product made from Phoenix of the same specification as used them in the Ogiri area. This electrode adopts Pb-PbCl for the sensor, and is possible to use stably without polarization in a sensor over a long period of time. The potential signal from each survey point was transmitted by the cable, and was recorded on the empty channel of the same recording system as used in the Ogiri observation network. This recording system takes in the data for 50 survey points to PC, connected to a 50 channel scanner, and it is designed so that various kinds of processing may be performed. Data is saved also in PC while it is forwarded at once on a day using an NTT telephone line.

In the Ogiri area, although continuous observation had been carried out over about three years, breakage of the scanner by thunder often happened. The breakage is seemed to be due to the high-pressure voltage excited by the electromagnetic effect and guided along the SP survey cable and/or the surge current transmitted in the commercial power supply. The damage of the recording system by thunder has continued in spite of installation of the surge element to guidance voltage. The strong current induced by thunder has damaged the pre-amplifiers of the multi-channel scanner of the survey system, meaning there is no available record data for a long time. For this reason, as a policy to minimize damage when generating of thunder is expected, the power supply is disconnected from the survey system, resulting in less continuous data recorded in the system.

Production Test Data

Figures 2 and 3 show total geothermal fluid production per hour at the Shiramizugoe investigation wells SZ-5 and SZ-4, respectively. Two wells were used in the long-term production test at the Shiramizugoe geothermal area. As shown in Figure 2, the production test was started at 12:10 on August 1, 2002, and was continued till 6:00 on August 6 in the well SZ-5. After the production test using the well SZ-5, the test using the well SZ-4 followed. The production test at the well SZ-4 was performed

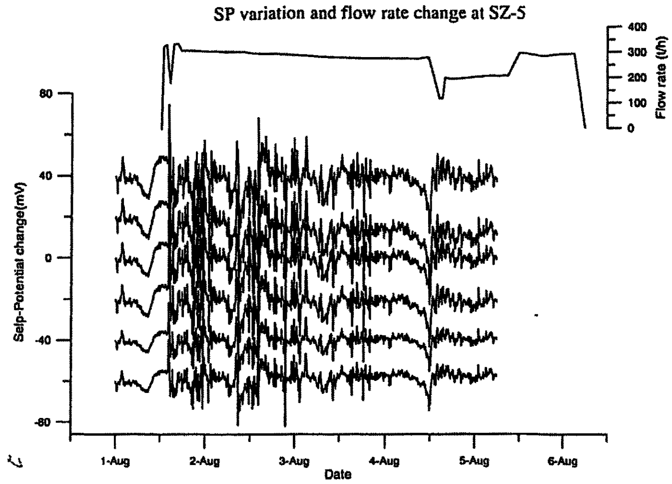

Figure 2. Self-Potential change and the amount of dischange at the investigation well of SZ-5.

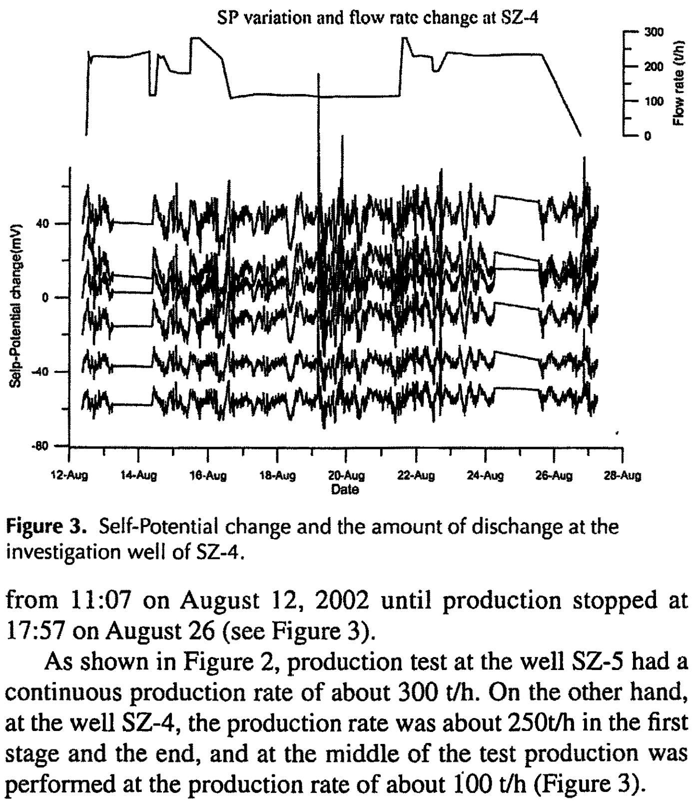

Figure 3. Self-Potential change and the amount of dischange at the investigation well of SZ-4.

from 11:07 on August 12, 2002 until production stopped at 17:57 on August 26 (see Figure 3).

As shown in Figure 2, production test at the well SZ-5 had a continuous production rate of about 300 t/h. On the other hand, at the well SZ-4, the production rate was about 250t/h in the first stage and the end, and at the middle of the test production was performed at the production rate of about 100 t/h (Figure 3).

SP Change During the Production Test at SZ-5

The bottom figure of Figure 2 shows SP change detected by electrodes close to the production wells during the production examination of SZ-5. The SP changes in the figure are shown in S-01, S-02, S-06 from top to bottom. The above Figure 2 shows the temporal changes of the amount of production fluid (steam and brine) at SZ-5. In the SP measurement the potential change is based on the electrode at the Ogiri area which is distant from the Shiramizugoe area

A big SP change that had large amplitude with a higher frequency was apparently observed at each trace on August 1, when the production test was started, shown in Figure 2. The SP, however, changed at about 2 hours after the production test started, and the similar SP changes are widely recorded in the Ogiri area distant from the investigation well. It was therefore possible that those signals are due to telluric current caused by a magnetic storm. Although SP decreased with reduction of the amount of the production on August 4, the decrease was possibly caused by other than the production of the geothermal fluid such as the telluric current since this decrease was also recorded in the Ogiri area. As mentioned above, since the SP record was interrupted before August 6, when the first production test using the well SZ-5 ended, in order to avoid the destructive influence on the observation system by thunder, SP change has not been recorded at the time of the end of the first production test.

SP Change During the Production Test at SZ-4

SP change during the production examination using the well of SZ-4 is shown at the bottom of Figure 3. SP data recorded at S-01, S-02, .., S-06 are shown from the top to the bottom as the same as in Figure 2, and the temporal production rate at the well is also shown at the above figure of Figure 3. The base potential for the SP records was selected at the same electrode as in Figure 2. In order to detect the change caused by the commencement of the production, the background of SP at each survey station is important. The SP record system had, however, been suspended due to the prevention of the thunder damage and the background level was not recorded enough to judge to SP change owing to the production start at the well of SZ-4.

The production rate was decreased in the middle of the production test at SZ-4 (from about 250 t/h to about 100 t/h), and the amplitude of SP was also decreased during the corresponding period. The production rate at SZ-4 returned to its start rate (about 250 t/h) and the SP values seemed to be increased when the production rate was changed. However, the clear recovery of the SP amplitude could not be found out due to the noise originated in the magnetic storm on the afternoon of 19 August. More works are necessary to compare SP records close to well of SZ-4 to those at the Ogiri area where the influence of the SP change due to the production is not expected.

Analysis by BAYTAP-G

The computational code of BAYTAP-G (Bayesian Tide Analysis Program – Grouping Model) aims at presumption of tidal components from observation data (Ishiguro et al., 1985; Tamura et al, 1991). The code has other useful functions such as presumption of a trend, a response with atmospheric pressure, and interpolation of missing observation. A Bayesian model and the theory to minimize ABIC (Akaike, 1980) are applied to estimate the trend of the observation. The code is, therefore, a powerful tool in analyzing the time series data. In this analysis tool, even when time series data are discontinuous, it is possible to separate periodic ingredients, such as a tide, from the other ingredients. It is also possible to interpolate the change after the removal of the periodic component. An example of the analysis using BAYTAP-G is shown in Figure 4. As shown in this figure, the original SP data were discontinuous and contained many periodic noises.

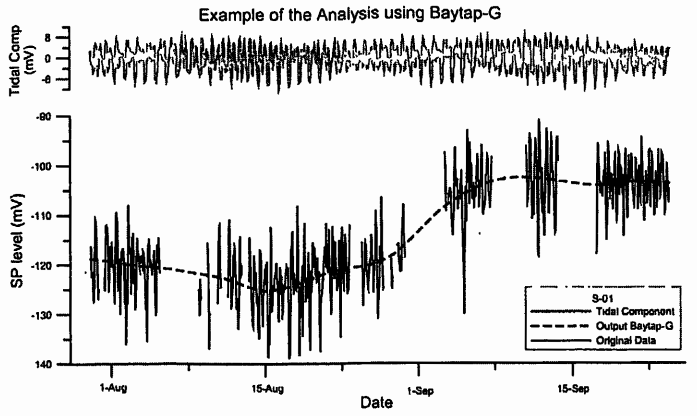

Figure 4. An example of analysis of Self-Potential change using BAYTAP-G.

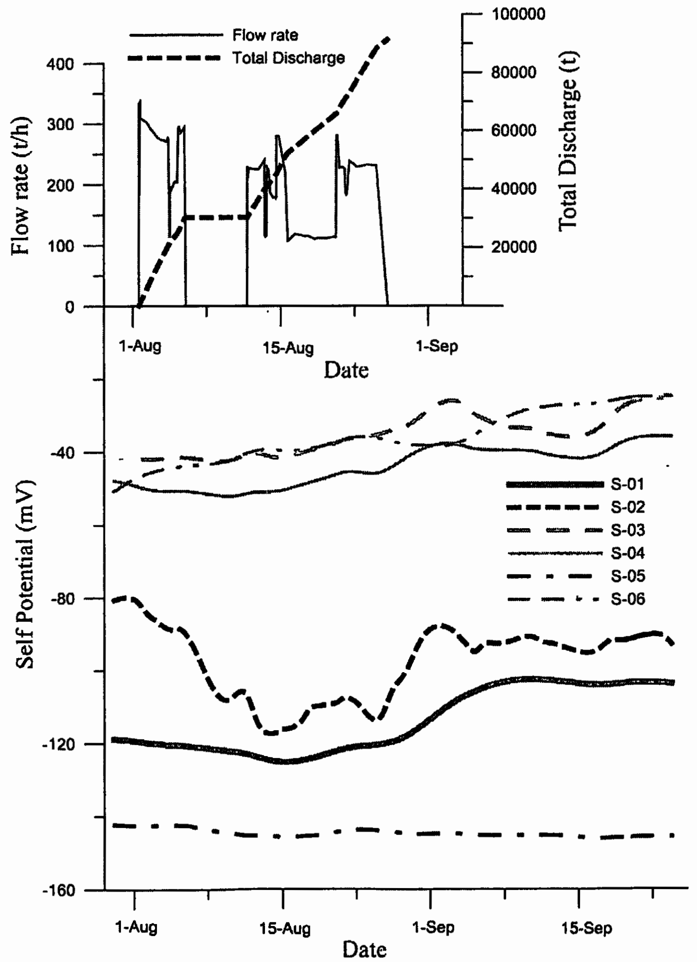

Figure 5. Self-Potential change after the removal of the tidal component.

After the reduction of the tidal component from the original data, SP change was estimated and is shown by the dashed line, inferring that SP kept almost constant during August and went up by about 20mV in September. Although the Ogiri geothermal field is located distantly from the coastline (about 20km), SP records are overlapped by the tidal signals. The mixture of the tidal signal to SP record is often observed at the survey in an island. We don't have a reasonable explanation why the tidal signal is recorded in the Ogiri field till present.

The SP changes in August and September are shown in Figure 5 after removing the tidal component by BAYTAP-G. The production rate and total amount of the production at wells SZ-4 and SZ-5 are also shown in the top figure of Figure 5. At the most of observation stations (S-01, 03, 04, 06), the SP seemed to be increasing gradually, or almost constant in August but were increasing in September (Figure 5). It was almost constant at the S-05 station.

On the other hand, at the observation station of S-02, SP began to decrease after the start of the production test at SZ-5, and it returned to the same SP level as at the other stations after the production test. As shown in Figure 1, the observation station of S-02 is located close to the SZ-4 well but the SP at that station changed during the production test at the SZ-5 well. As the feed points of SZ-4 and SZ-5 are very close to each other, it might be possible that production at SZ-5 caused the SP change near SZ-4 and that change was observed at the surface station S-02. The SP at S-01, where is close to the station S-02, was changed by the production at SZ-4 and was increased for about 20mV after the end of the test. The SP change observed at S-02 was similar to that at S-01 after the production test by SZ-4. The change was, however, unstable after the removal of the tidal component. The reason of this instability at S-02 might be the drift of the electrode and/or small potential change at the subsurface transmitted through the casing pipe of the SZ-4

Conclusions

After removing the tidal component and interpolating the missing data using a bayesian model, Self-Potential change of 40 mV or more was observed during the long-term production test. An underground change caused by geothermal fluid flow might be transmitted through the casing pipe of the production well and observed on the surface.

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