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SELF-POTENTIAL SURVEY IN HACHIJOJIMA

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ABSTRACT

Self-potential survey was carried out around Hachijojima geothermal power station.
The regional self-potential distribution indicates that the power plant is located near the northeastern margin of the central part of a NW-SE trending high-potential zone, which presumably originated in an up-current of hydrothermal solutions.
The continuous monitoring of self-potential indicates that a potential-fall zone formed some 200 m southeast of the power plant after the beginning of steam production. The change in self-potential probably resulted from a change in reservoir related to the steam production.
Periodical surveys on the self-potential will be carried out in the future to study how to extract and analyze self-potential fluctuations caused by a change in reservoirs.

1. INTRODUCTION

Hachijojima is an island located about 300 km south of Tokyo (Fig.1). It is approximately 70km^2 in area and has a population of about 9,500. This island has two large volcanoes, Mt. Nishiyama and Mt. Higashiyama.
Since 1992, TEPCO has continued geothermal exploration, obtaining an outline of the scale of the geothermal reservoir, with the exploitation site chosen to be the northern part of Nakanogo in the south Higashiyama area. Three wells (HT-1, HT-2, HT-3) were drilled at this site in 1995, and a steam-dominated geothermal resource was confirmed by subsequent flow tests. At present a 3.3 MW geothermal power plant is operating from March 1999.
Self-potential survey around the Hachijojima geothermal power station was carried out in October 1998 and from January 1999 to May 1999. This paper summarizes results of these self-potential survey.

2. GEOTHERMAL MODEL

The high-temperature geothermal resource in the south Higashiyama area exists in fractures of the Tertiary formation, as deduced from gravity discontinuities and the pattern of resistivity anomalies. These fractures serve as conduits for the ascent of geothermal fluid, and act as a geothermal reservoir.
The heat source of the geothermal fluid is likely the magma chamber associated with the volcanic rocks and parasitic volcanoes found in south Higashiyama. Ring structures occur in these areas and parasitic volcanoes exist on top of these structures. Moreover, the largest uplift of the Tertiary formation occurs inside these ring structures. These fractures channel the upflow of geothermal fluid.
Although Hachijojima is surrounded by the Pacific Ocean, the geothermal resource maintains a high temperature, indicating impermeable zones prevent the direct penetration of seawater into the deep geothermal system (Fig.2). Temperature profiles of wells in the project site increase steeply from the top of the Tertiary formation with increasing depth. In conjunction with a pressure discontinuity, this indicates the existence of a low-permeability cap rock covering the Tertiary formation. This cap rock domes over the uplift of Tertiary rocks directly beneath the project site. The cap rock also prevents the penetration of seawater and ground water into geothermal system.

3. REGIONAL SELF-POTENTIAL DISTRIBUTION

3.1 Outline of survey

Period of survey: Oct. 3 to 9, 1998
Area: about 2 km^2
Length of traverse: about 7.5 km
Station interval : 50 m
Potential meter: Memory High Coder 8804 (Hioki Electric Co. Ltd.)
Electrode: Silver-silver chloride electrode (Gochild Co. Ltd.)

3.2 Results of measurement

The obtained self-potential distribution is shown in Fig. 3, in which the place marked ◎ is adopted as a reference point (potential of 0 mV).
A NW-SE trending high-potential zone is found in the central part of the survey area, of which the northeastern and southwestern sides are characterized by low-potentials. The power station is located to the northeast of the central part of the high-potential zone. The high-potential part exceeding 40 mV is characterized by a comparatively flat potential distribution, while the boundaries with the neighboring low-potential parts on the northeastern and southwestern sides are

marked by a high potential gradient, indicating an abrupt drop to about 0 mV.

While the self-potential distribution in the survey area is characterized by a NW-SE trend, there is also recognized a NE-SW trending alternation of ridges and valleys of self-potential, which crosses the main trend at right angles. The northwestern margin of the high-potential zone in the southeastern part of the survey area also shows a similar trend of NE-SW.

With the exception of a high-potential zone in the eastern area, the above-mentioned self-potential distribution indicates that the high- and low-potential zones are coincident with up- and down-current areas of hydrothermal solution, respectively.

4. CONTINUOUS MONITORING OF SELF-POTENTIAL

4.1 Outline of surveys

Period of survey: Jan. 31 to May 31, 1999
Area: about 0.35 km^2
Number of measurement points: 40 + reference point (Fig. 4)
Recorder: Hybrid recorder RD3500U (NEC San-ei Co. Ltd.)
Recording interval: 15 minutes
Electrode: Silver-silver chloride electrode

4.2 Fluctuations of self-potential

Fluctuations of self-potential include daily changes, artificial noises, rainfall effects, and so on. Out of the daily changes, most conspicuous is what are presumably caused by tidal change with a period of some 12 and 24 hours. As a rainfall effect, a rapid change in self-potential was observed at many stations during a heavy rain that recorded a precipitation of as much as 150 mm between the evening and the midnight of May 7th, 1999. Fluctuations of self-potential in the survey area are divided into three types according to their patterns. The upper graphs in Fig. 5 show moving averages of representative observational data of the respective types. The type I, II, and III are represented by the station No. 4, No. 27, and No. 39, respectively. The bar chart and the line graph in the lower figure show the daily precipitation observed by Hachijojima meteorological observatory and the power output of the geothermal power plant, respectively.

The three types of potential fluctuation have the following characteristics:

① Type I: The self-potential shoots up with the heavy rain on March 7th, then followed by an identical level or a gradual increase associated with an minor drop around the beginning of May;

② Type II: The self-potential shoots up with the heavy rain on March 7th, followed by a gradual decrease and a subsequent increase after the beginning of May;

③ Type III: The self-potential rapidly drops with the heavy rain on March 7th, followed by a slow decrease and a subsequent increase after the beginning of May.

The comparison between the graphs of self-potential, rainfall, and power output indicates that a self-potential drop in type II and III during the period between the beginning of April and the beginning of May is coincident with an increase in steam production and precipitation. Further, a slow increase in self-potential observed at many measuring points after the beginning of May coincides with the period with a suspension of steam production and a low precipitation.

4.3 Change in self-potential distribution

Figures 6 to 8 show the self-potential distributions on February 4th just after the beginning of measurement, on March 13th immediately after the heavy rain, and on May 5th when low potentials were recorded at many measuring points, respectively. The values of self-potential used for the respective points are represented by two-day-and-a-half moving averages before and after the given days.

Self-potential distribution on February 4th

The self-potential distribution on February 4th is shown in Fig. 6. This shows a natural state of self-potential distribution before the commencement of steam production.

The regional self-potential distribution (Fig. 3) indicates that the survey area undergoing a continuous monitoring has a NW-SE trending high-potential zone and a low-potential zone on the northeastern side, between which there is found a rapid change zone.

Figure 6 indicates the formation of a remarkable low-potential zone with the center to the north of the power plant. This area belonged to a small northeast projection of the high-potential zone when the regional self-potential distribution was investigated, so that a great change in self-potential distribution must have occurred up to the present survey.

Though the cause of the change is unknown at the moment, a shallow-seated low resistivity zone confirmed by CSAMT prospecting in this area and construction works and edifices of the power plant might have affected the self-potential distribution.

Self-potential distribution on March 13th

The self-potential distribution on March 13th is shown in Fig. 7. Compared with the distribution on February 4th (Fig. 6), a remarkable change is found in the central part . While a NW-SE trending high-potential zone is recognized in the vicinity of measuring points 18 and 19 in Fig. 6, the area forms a low-potential zone in Fig. 7.

The low-potential zone, which had the center near the northern margin of the power station in Fig. 6, tends to expand to the east.

Self-potential distribution on May 5th

The self-potential distribution on May 5th is shown in Fig. 8. Compared with the self-potential distribution on March 13th (Fig. 7), there is found no remarkable change in the distribution pattern with the exception of a general lowering of the potential.

4.4 Distribution of changes in self-potential

Change in self-potential before and after the heavy rain

The change in self-potential from March 3rd to March 17th, between which a heavy rain occurred on March 7th, is shown in

Fig. 9. A rise in self-potential occurred in a belt that extends from the southeastern corner of the survey area to the north through the central part.

Change in self-potential from March 13th to May 5th

The change in self-potential from March 13th to May 5th is shown in Fig. 10. There is found a potential-fall zone with the center about 200 m southeast of the power plant, which tends to extend from WSW to ENE.
This period is coincident with steam production and heavy rainfall. The potential-fall zone is presumed to result from a reservoir change associated with steam production for the following reasons: ① it greatly differs from the change in self-potential before and after the heavy rain on March 7th and ② there is an ENE-WSW trending fracture system, a probable steam production zone, right under the potential-fall zone.

5. CONCLUSIONS

① The regional self-potential distribution indicates that the power plant is located near the northeastern margin of the central part of a NW-SE trending high-potential zone, which presumably originated in an up-current of hydrothermal solutions.
② The continuous monitoring of self-potential indicates that a potential-fall zone formed some 200 m southeast of the power plant after the beginning of steam production. The change in self-potential probably resulted from a change in reservoir related to the steam production.
③ Periodical surveys on the self-potential will be carried out in the future to study how to extract and analyze self-potential fluctuations caused by a change in reservoirs.

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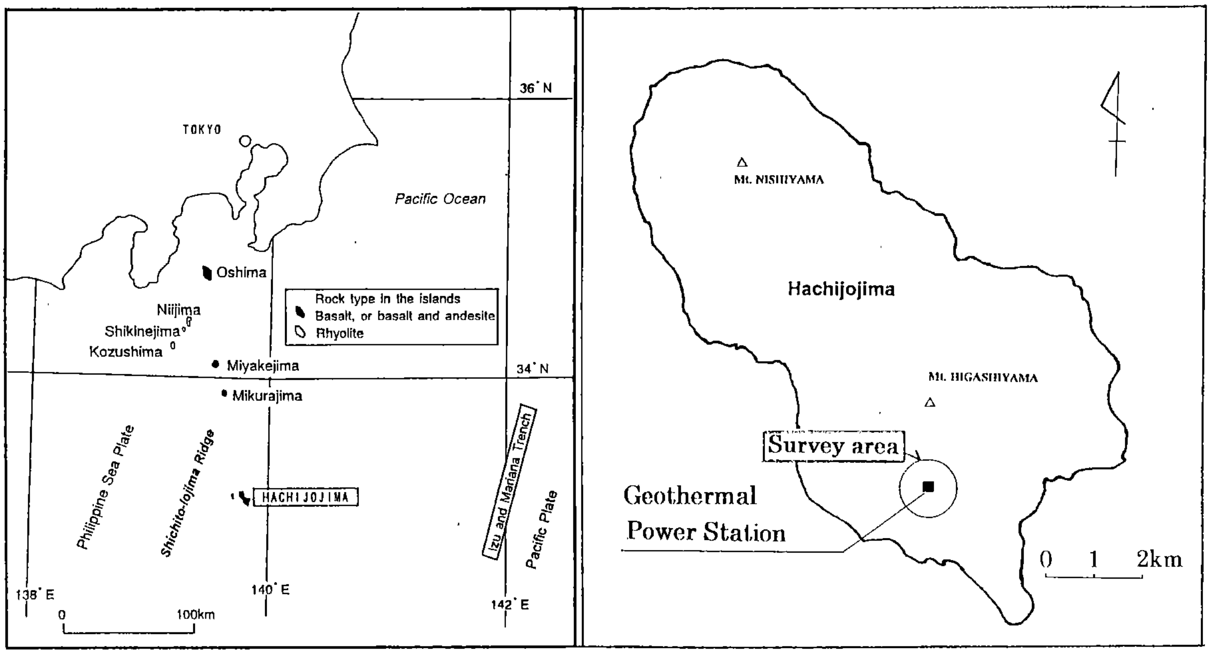


Figure 1. Location of survey area

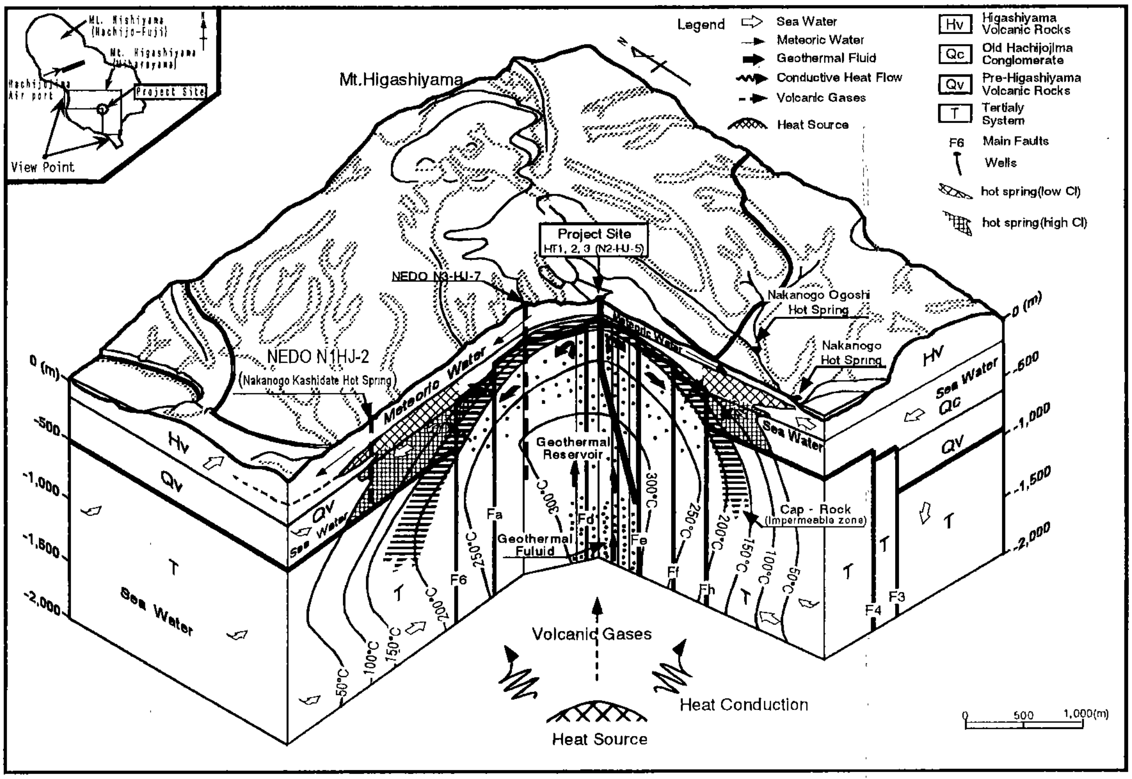


Figure 2. Geothermal model of south Higashiyama in Hachijojima

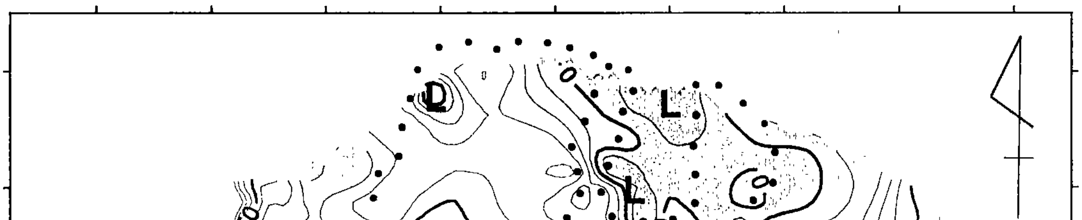


Figure 3. Regional self-potential distibution

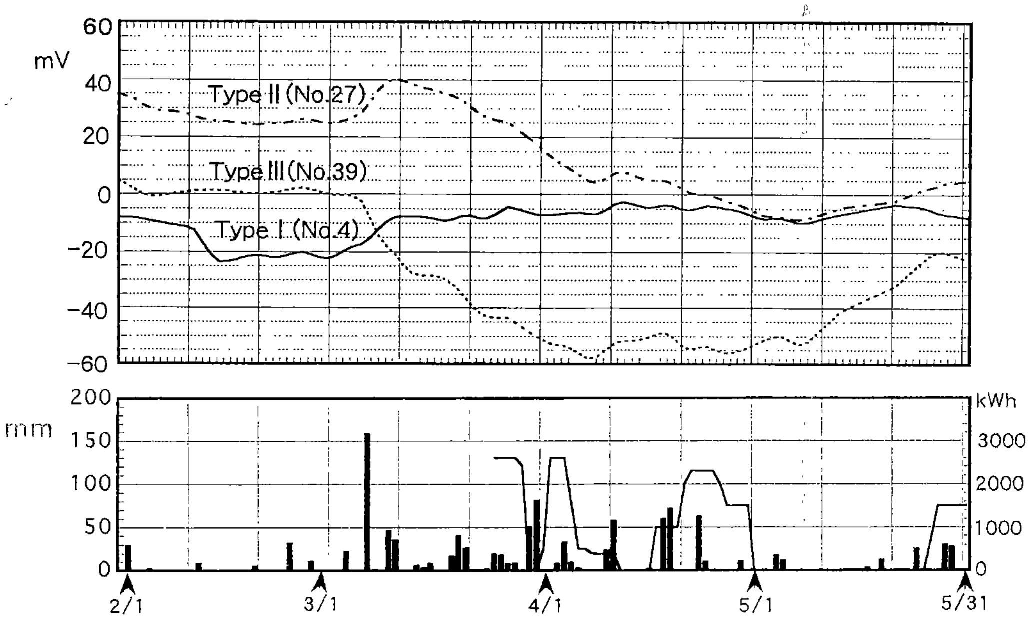


Figure 5. Fluctuations patterns of self-potential, rain fall and power output of the power station

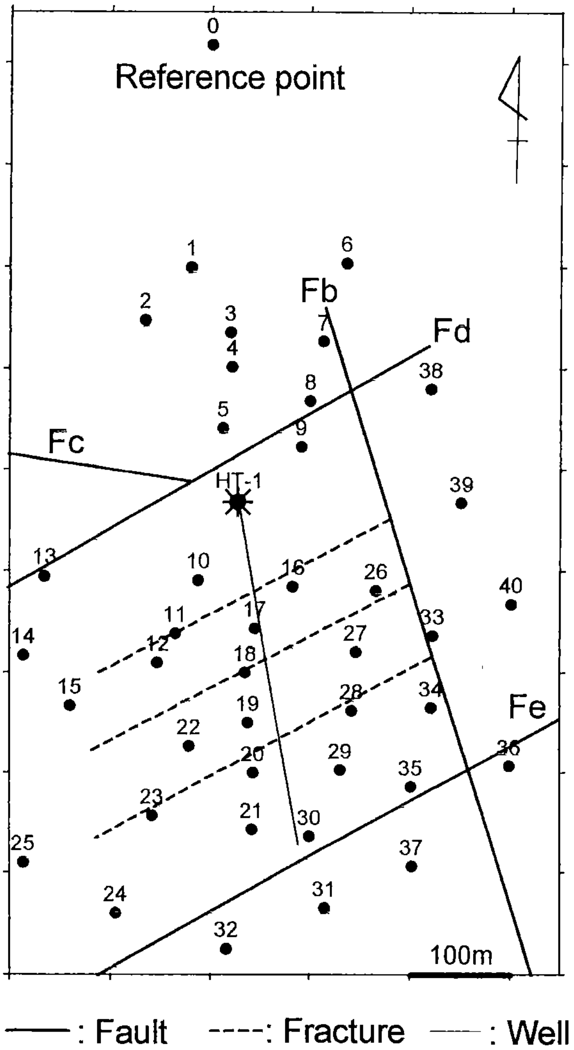


Figure 4. Stations , faults, fracture and well

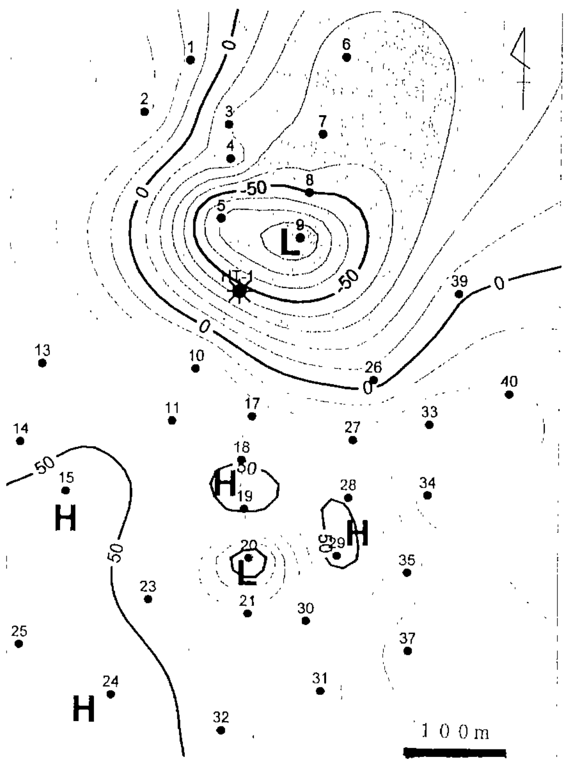
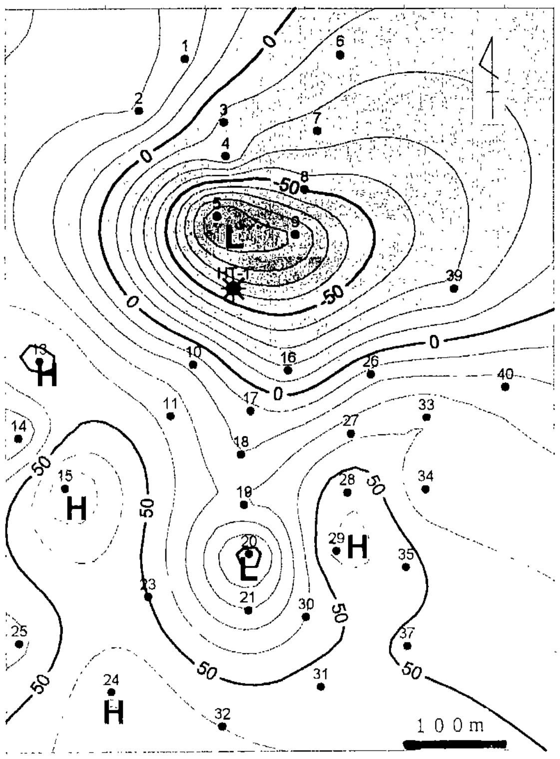
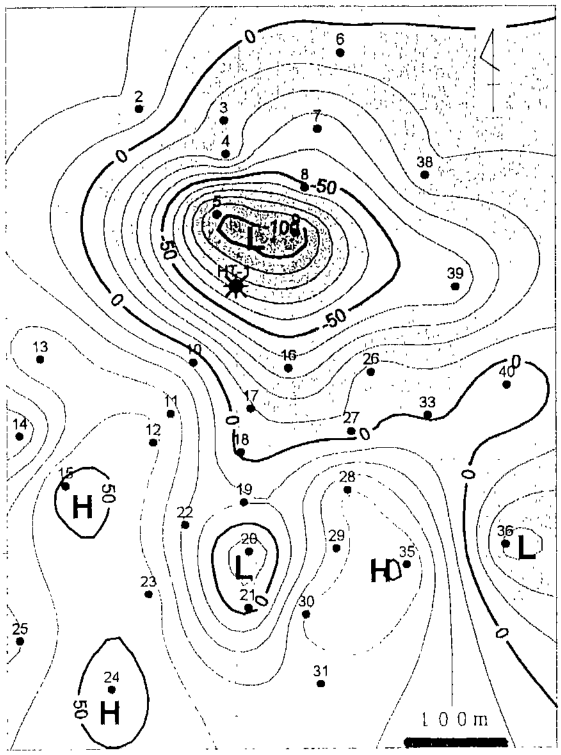


Figure 6. Self-potential distribution on February 4th



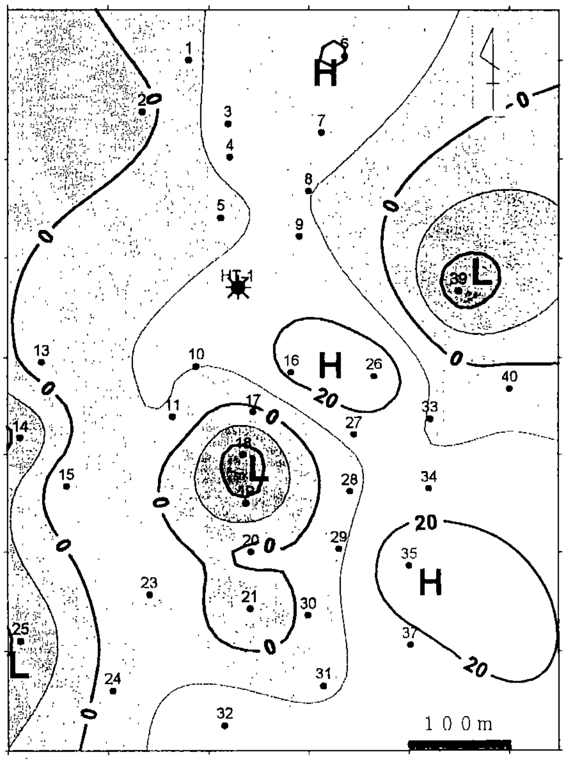
Contour interval : 10 mV

Figure 7. Self-potential distribution on March 13th



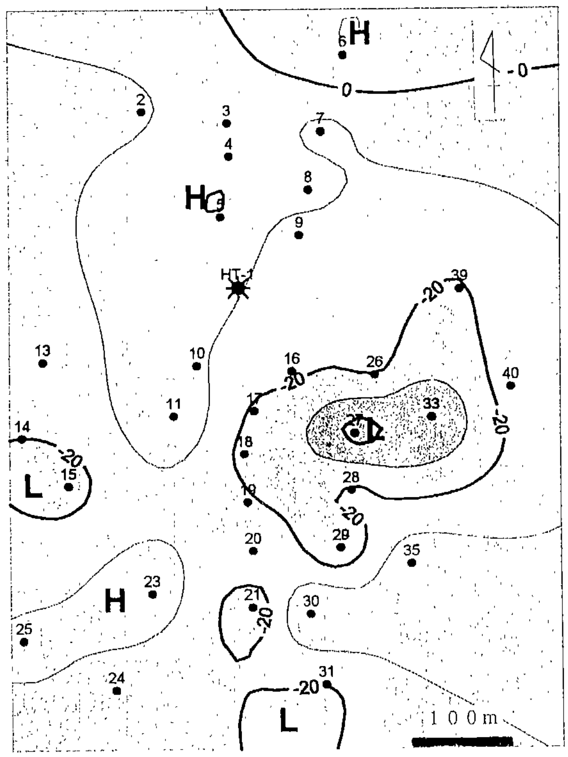
Contour interval . 10 mV

Figure 8. Self-potential distribution on May 5th



Contour interval : 10 mV

Figure 9. The change in self-potential from March 3rd to March 17th



Contour interval . 10 mV

Figure 10. The change in self-potential from March 13th to May 5th