DIRECT DETECTION OF GEOTHERMAL RESERVOIR AT HATCHOBARU GEOTHERMAL FIELD BY THE MISE-A-LA-MASSE MEASUREMENT

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ABSTRACT

The mise-a-la-masse survey was carried out in 1983 at Hatchobaru geothermal field using the HT-8 exploratory well which is located near the known production zone of geothermal resources.

The resulting residual maps clearly indicated the four promising low resistivity zones including the present geothermal reservoir which supplies the mixture of steam and hot water to the 55 MW power plant.

It was found that the measurement gave rise to the sharply contoured residual anomalies because of the high contrast in true resistivity between rocks and the geothermal reservoir at Hatchobaru geothermal field.

It was concluded that the strike of faults that regulate the upstream of the geothermal fluid and the lateral distribution of the geothermal reservoir could be directly detected by the mise-a-la-masse measurement at Hatchobaru geothermal field.

INTRODUCTION

In order to delineate the geothermal reservoir at Hatchobaru geothermal field, the mise-a-la-masse survey was carried out using the exploratory well HT-8 which is located near the present production wells. The HT-8 well is directional and cased to the full 1276m.

The generalized geologic succession at Hatchobaru geothermal field is as follows.

The Kujyu volcanic complex is characterized by relatively viscous lavas, which have formed many lava domes. The Hohi volcanic complex, extruded by the Kujyu complex, is comprized of about 800 m of very widespread pyroxene andesite lava flows and their pyroclastics. The upper and lower Hohi formations consist mainly of lavas. Underlying the Hohi complex at Hatchobaru deep wells (about 1100 to 1500 m deep) are propylites, more than 300 m thick, correlated with the Usa group. Their upper part, below the unconformity at the base of the Hohi complex, may be presumed to be the geothermal reservoir at Hatchobaru area.

Figure 1 shows the typical geoelectric structure of geothermal reservoir at Hatchobaru field on the basis of the joint inversion of Schlumberger and MT surveys. It is recognized that the electrical discontinuity between B-12 and C-15 roughly corresponds to the distribution of the lost circulation zone. In addition, the resistivity of low resistivity zone (marked by the square) shows the lowest value at station B-12. This may indicate that the degree of hydrothermal alteration is very strong and a promising reservoir exists around B-12. Thus, it is found that the geothermal reservoir could be delineated to some extent by the indirect geoelectrical methods such as DC and MT.

However, if the geothermal reservoir is charged electrically by the use of casing, the shape of the equipotential lines will reflect the geometry of the reservoir directly and would be expected to yield some informations concerning the shape, size, dip of the fault and other geometrical parameters.

It is observed that the geothermal fluid has a quite low resistivity such as 1 ohm-m,then the geothermal reservoir itself can be considered as a subsurface conductor like an ore body.

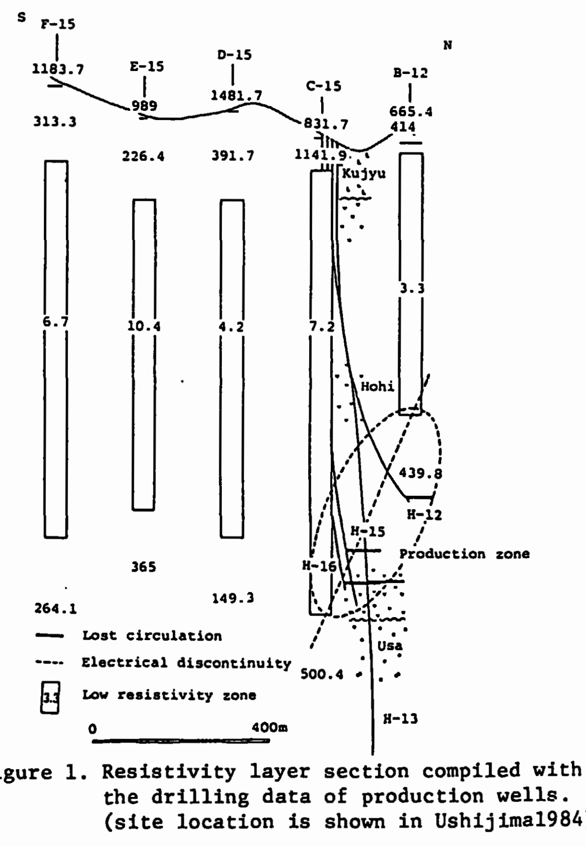


Figure 1. Resistivity layer section compiled with the drilling data of production wells. (site location is shown in Ushijima1984)

FIELD SURVEY

Figure 2 shows the electrode arrangements, C1, connected to the anchor casing of HT-8 well, is earthed into the conducting formation under investigation so that in fact the formation is acting as a current electrode. The distant earthing C2 is taken far from the surveyed area, apart 6 km distance from the C1 electrode.

The fixed potential electrode P2, the position of which is located by trial measurements, is also set far from the surveyed area and situated near the top of the Mt.Ichimoku.

The potential electrode P1 is moved radially from the C1 electrode with 100 - 150 m separation.

A commutated electric current, which has a frequency of 0.05 Hz is introduced and the resulting voltages on the ground surface are mapped at stations by means of a voltmeter with respect to the base station P2. The specific voltage at each station is derived from the recording of repeated measurements.

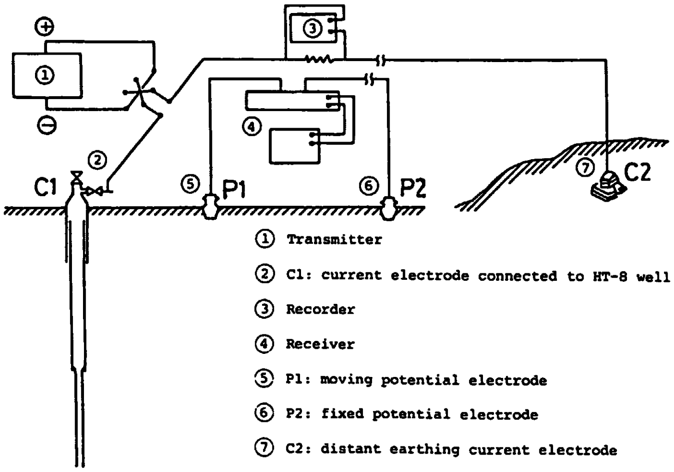


Figure 2. Electrode configuration in the mise-a-la-masse survey.

FIELD DATA

Figure 3 shows the distribution of the observed potentials.

Here, it is found that the equipotentials are distorted due to the existence of subsurface conducting body. In general, a horizontally layered earth or a symmetric body about the well would generate a pattern of circular contours centered on the well. Therefore, the distorsion suggests that the local structure of the subsurface is at least two-dimensional resistivity changes.

THEORETICAL COMPUTATION

The potential due to a point current electrode at a distance r is

$$V = \frac{\rho I}{2\pi} \cdot \frac{1}{r} \qquad (1)$$

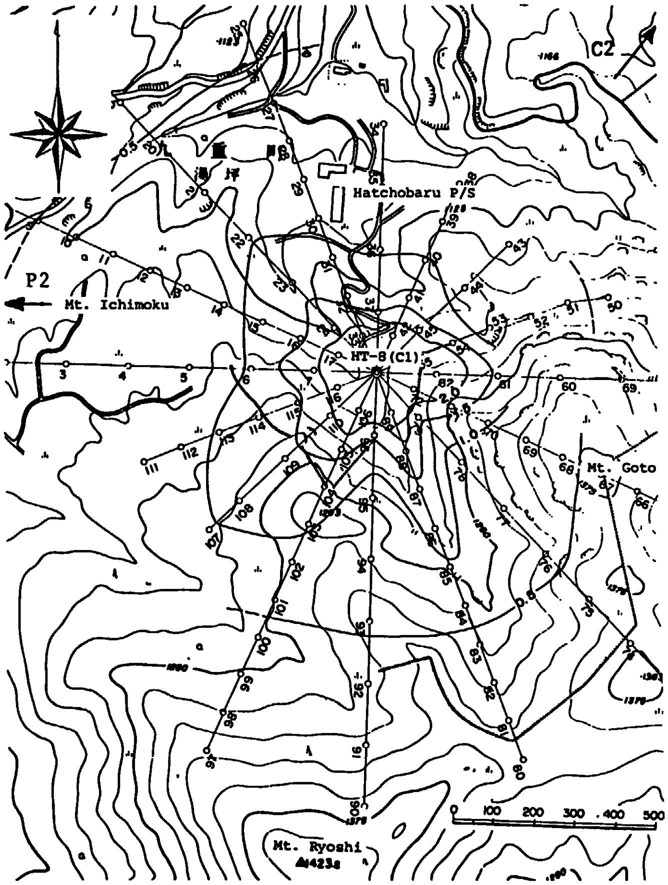


Figure 3. Normalized potential distribution at Hatchobaru geothermal field (mV/A).

if the potential at an infinite distance is assumed to be zero.

The potential of a line-source electrode has been introduced by Kauahikaua et al.(1980). The formula can be derived by a process of integration starting from the potential of a point electrode:

$$V = \frac{\rho I}{2\pi} \cdot \frac{1}{\ell} \cdot \ln\left(\frac{\ell + \sqrt{\ell^2 + r^2}}{r}\right) \qquad (2)$$

Therefore, the expression for the apparent resistivity for the four electrode configuration shown in Figure 2 is expressed as

$$\rho_a = K \cdot \frac{V}{I} \qquad (3)$$

where K is called a geometric factor and defined by the following equations:

$$K = 2\pi \cdot \left(\frac{1}{\ell} \ln \frac{\overline{p_2c_1}\,(\ell + \sqrt{\ell^2 + \overline{p_1c_1}^2})}{\overline{p_1c_1}\,(\ell + \sqrt{\ell^2 + \overline{p_2c_1}^2})} - \frac{1}{\overline{p_1c_2}} + \frac{1}{\overline{p_2c_2}}\right)^{-1} \qquad (4)$$

Topographic effects are also taken into account for the calculation of the geometric factor.

The theoretical equipotentials in a homogeneous isotropic earth is shown in Figure 4.

The equipotential surfaces approach spherical form in the neighbourhood of the electrode C1. However, the contour lines are distorted near Mt. Goto because of a steep topography.

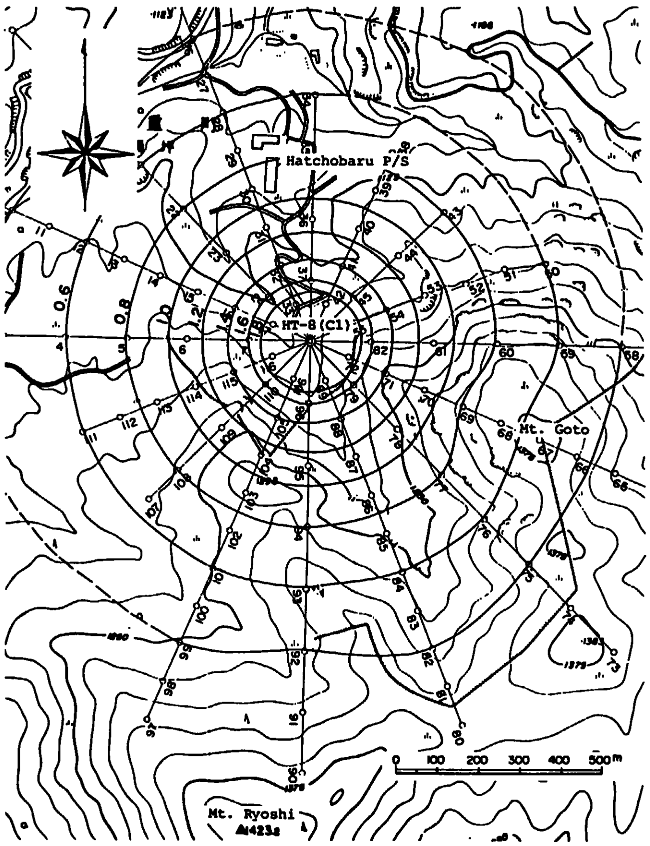


Figure 4. Theoretical equipotentials around C1 electrode in a homogeneous isotropic earth (x 10^{-3}. m^{-1})

INTERPRETATION

Potential anomalies with regard to a regional effect are determined by the data processing, and their possible causes are investigated according to the flow diagram shown in Figure 5.

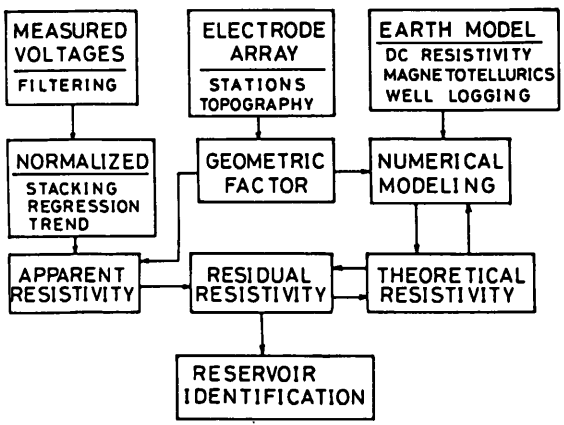


Figure 5. Flow diagram of interpretation for the mise-a-la-masse measurement.

The actual voltage V measured at each station are transformed into apparent resistivity by eq.(3) and compared with a theoretical apparent resistivity in order to get a residual anomaly.

The method used to simulate the local geological section are either two-dimensional or three-dimensional earth model based on the finite difference method.

Figure 6 shows the maps of residual anomalies obtained in Hatchobaru area.

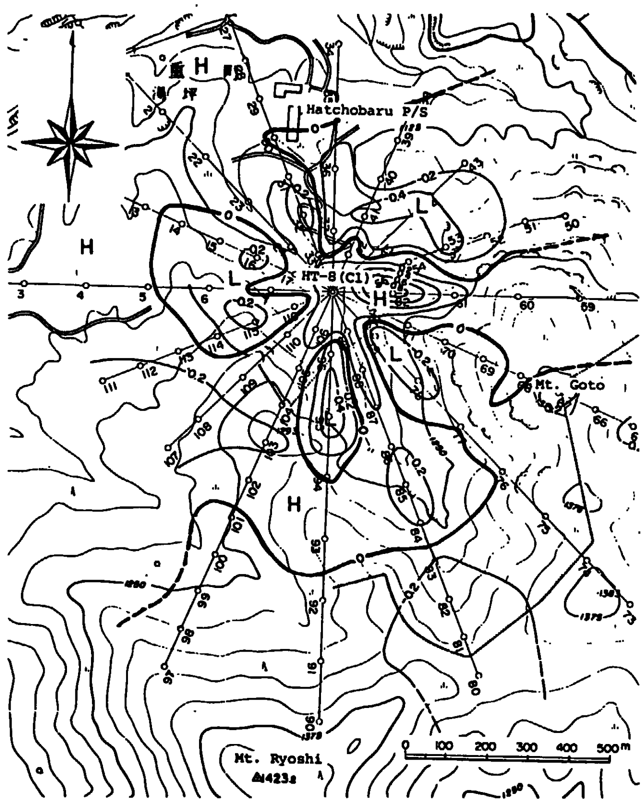


Figure 6. Residual map at Hatchobaru geothermal field (mV/A).

As shown in this figure, the mise-a-la-masse survey indicated four anomalously low resistivity zones including the present production zone.

The zone of north-eastern part marked L corresponds to the known geothermal area which supplies steam to the 55 MW geothermal power plant at Hatchobaru.

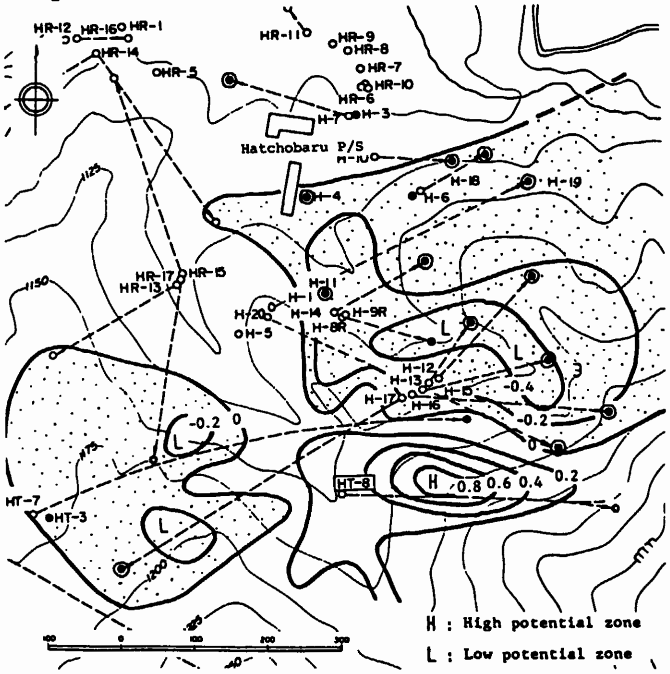
The another zone of north-western part is also confirmed that the reservoir temperature is high, 240 °C.

Two zones located in a southern part are not developed yet, but the zone of a southeastern part is planned to develop within this year.

Figure 7 shows the detailed residual map around the HT-8 well. From this data, the HT-8 well is situated within a region that is apparently more resistive zone than the surrounding formations.

The almost all of productive wells at Hatchobaru power station are located within a region marked with a letter L that is anomalously low resistivity zones and the contours are elongated in the north-west direction.

This direction coincide with the strike of fault that is considered as the geothermal reservoir at Hatchobaru field.



H- : Production wells HT- : Exploratory wells
HR-: Reinjection wells ● : Unused wells
◉ : Under production
H- R: Reinjection wells converted from production wells

Figure 7. Detailed residual map around the HT-8 well at Hatchobaru field (mV/A).

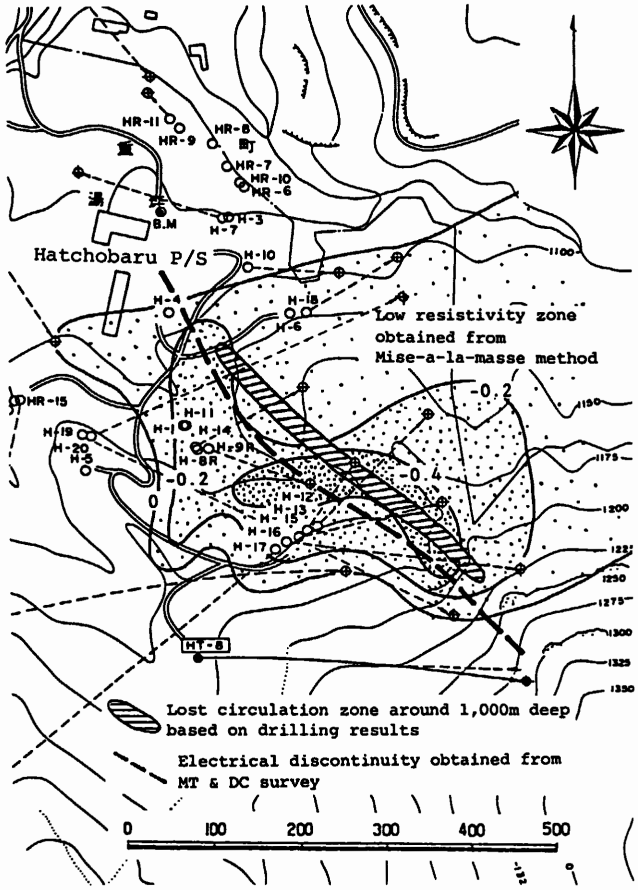


Figure 8. The enlarged residual map arround the present geothermal reservoir at Hatchobaru field (mV/A).

Figure 8 shows the enlarged residual map corresponding to the present geothermal reservoir. The map is compiled with the drilling results and electrical discontinuity obtained from the previous geophysical surveys. It is found that the shape of the low resistivity zone clearly reflects the geometry of the reservoir which distributes along the fault.

The most interesting fact is that the wells located within a negative center of the low resistivity zone have the largest producing capacity of steam and hotwater.

CONCLUSION

The mise-a-la-masse survey indicated four anomalously low resistivity zones.

The zone of north-eastern part corresponds to the present geothermal reservoir that supplies the mixtures of steam and hotwater to the 55 MW geothermal power plant at Hatchobaru. It was found that the distribution of potentials clearly reflect the geometry of the geothermal reservoir itself.

In conclusion, the strike of fault that regulate the upstream of the geothermal fluid is directly detected by the elongation of the voltage contours at Hatchobaru area.

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