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GEOELECTRICAL STRUCTURE OF THE HATCHOBARU GEOTHERMAL FIELD AND THE ADAPTABILITY OF ELECTRICAL METHODS FOR ITS UNDERSTANDINGS

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ABSTRACT

Electrical and Electromagnetic methods such as MT, CSAMT and Mise-a-la-masse methods have been applied in the Hatchobaru geothermal field, and are proved to be effective not only for understanding geothermal structure but also for the selection of drilling target. These methods were carried out by wellaeshed points and lines which were installed mostly at the interval of 100m to 200m in the area.

This paper describes the features of geoelectric structure in and around geothermal reservoir in Hatchobaru on the basis of comparison results obtained from drilling data and these geoelectrical data. In addition, the adaptability of each method for geothermal exploration will be discussed in relation to the structure of the Hatchobaru geothermal field.

INTRODUCTIOK

The geothermal power plants in Japan are being operated at 9 areas (total rated output: 270 MW) consisting of 4 industry-owned plants (35 MW) and 5 electric utility plants (235 MW) including Otake (12.5 MW) and Hatchobaru Unit 1 and Unit 2 (110 MW: 55 MW x 2) which were constructed by Kyushu Electric Power Co. (KEPCO). The capacity (122.5 MW) generated by KEPCO occupies about 45 percent for the total capacity of the geothermal power plants in Japan at present. KEPCG in conjunction with WEST JEC is the unique power company which develops geothermal energy from exploration to construction consistently, and under this organizatior. the plants are generating the rated output in quite stable conditions after the construction,

For geothermal development and maintaining power plants, the drilling must be one of important factors. In recent years, the production wells in Hatchobaru have been drilled in the rate of 100% successfully even in complex geology of volcanic area. This is based on that the subsurface structure was almost clarified from various explorations, especially electrical and electromagnetic methods. Fig. 1 shows the survey points and lines for those survevs.

GEOELECTRICAL STRUCTURE

In most of geothermal fields in the world where electrical or electromagnetic methods have been applied, the low resistivity zone can be detected showing less than 10 ohm-m. There are two view points regarding the judgement of low resistivity zone. One is that the low resistivity is the phenomena reflecting the geothermal reservoir itself which contains hot water with lots of dissolved chemicals in it. The

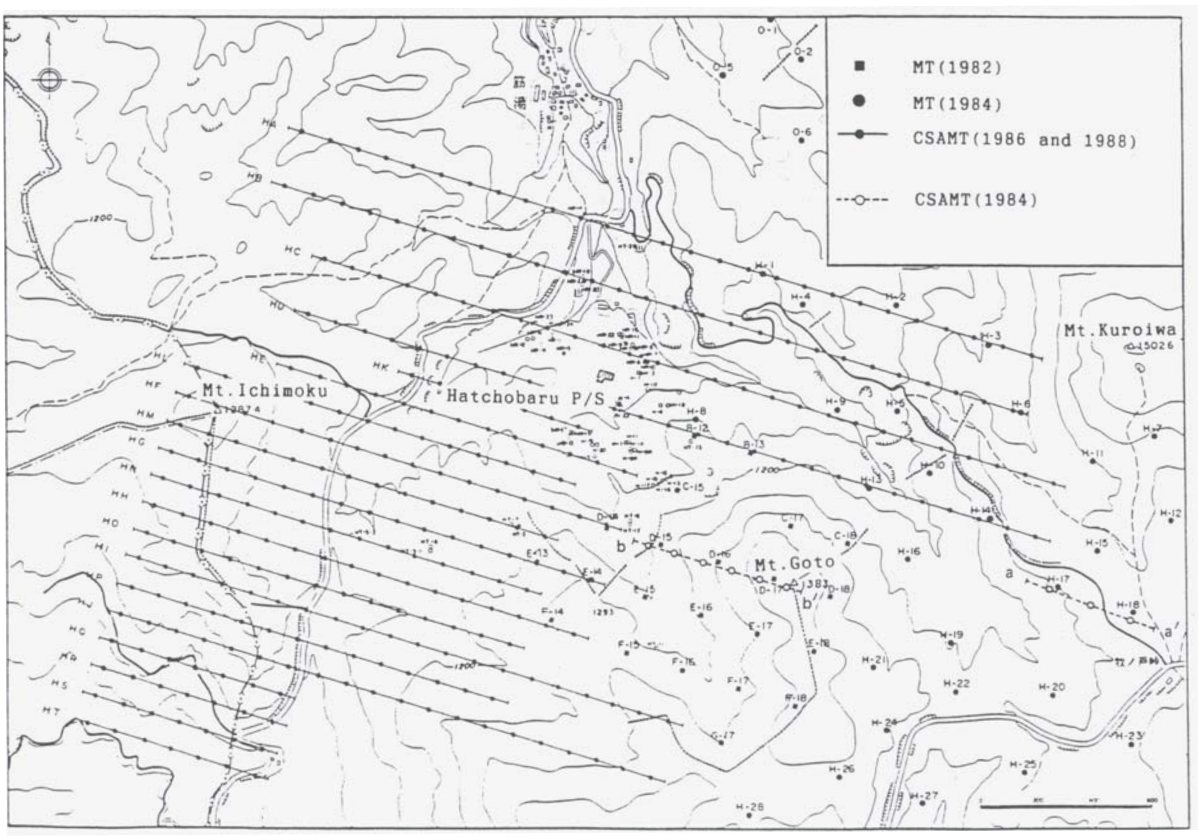

Fig.1 Survey points and lines for MT and CSAMT

other is that the low resistivity zone is not regarded as the phenomena reflecting the geothermal reservoir, but reflecting hydrothermal altered zone which is formed mostly over the geothermal reservoir by the movement of geothermal water from the deep to shallower parts near the surface.

The difference between these' two ways of interpretation results in a fundamental difference of conclusion when the drilling target must be decided on the basis of the electrical structure. In the former case, because the low resistivity zone itself is the final target, the drilling points and depths can be easily decided. On the contrary, in the latter case, the low resistivity zone is just one of the necessary factors for the selection of drilling points. In other words, the drilling point must be decided by not only the information of the low resistivity zone but also the information of the electrical basement considering geothermal structure such as fault system, and other geological and hydrological information.

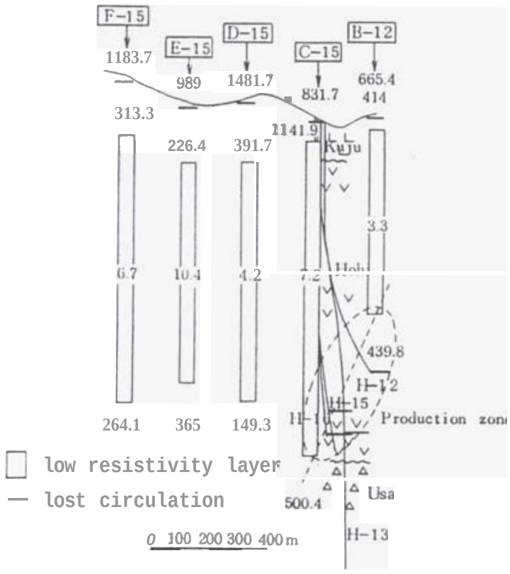

Fig.2 Electrical section with well logs from production wells

Fig. 2 shows one of examples of the resistivity structure obtained from MT with drilling data. Fig. 3 shows the model of geoelectrical structure in the Hatchobaru geothermal reservoir based on the idea described above and Fig. 2. From these figures, the resistivity structure of the area can be mainly divided into three layers such as resistive overburden, low resistivity layer and electrical basement. And the following features can be recognized in and around the reservoir.

a. The remarkable electrical discontinuity formed by the depth difference of the electrical basement can be recognized as shown in Fig. 2.

b. Resistivities of the low resistivity zones near or over the electrical discontinuity show minimum. (ρ_α: in Fig. 3) This means that the hydrothermal alteration is very intense because of upflows of deep geothermal hot water which is controlled by fault system and makes hydrothermal alteration like mushroom shape. In addition to this, because of the water flow along fault system, the low resistivity anomalv can be detected by contouring as a belt-like distribution.

c. Due to "masking effect" of shallow low resistivities, the reservoir cannot be detected as a signal of low resistivity but high resistivity in the electrical basement. The depth of reservoir roughlv corresponds to the top of electrical basement of deeper side of the electrical discontinuity.

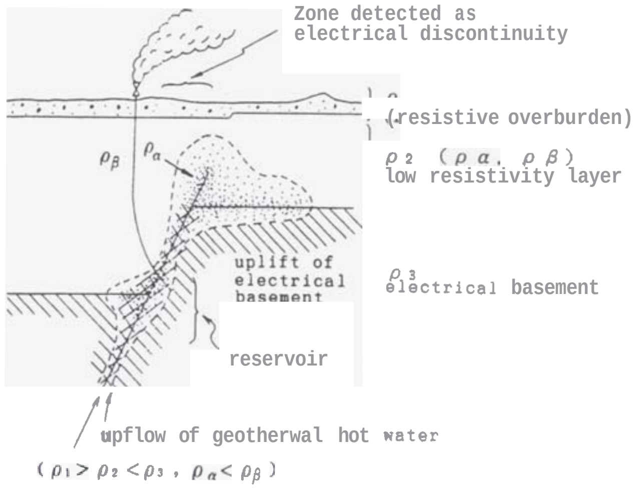

Fig.3 Geoelectrical structure of the Hatchobaru geotherwal field

d. Resistivity values of the electrical basement are in the range from 50 to 1,000 ohm-m. The resistivity of volcanic rocks is in general in the range fron 3,000 to 5,000 ohm-m, while the electrical basement, as geothermal reservoir, shows resistivity less than 1,000 ohm-m because the rocks are filled with hot water which contains lots of dissolved chemicals.

In the Batchobaru geothermal field, in order to detect above geoelectric features, the points and lines for geoelectric surveys must be installed at the interval of 100m to 200m. In other words, if the points are installed at the interval of longer than 500m, it may be difficult to detect electrical discontinuity resulting in impossibility of the selection of irilling target.

GEOLOGICAL IXTERPRETATION

Fig. 4 shows the acidic type hydrothermal alteration zone based on well data (upper part) and the low resistivity layers obtained from Schlumberger and MT. From this figure, the distribution of low resistivities roughly correspond to that of hydrothermal alteration zone, and lost circulation zones marked by square concentrate around the electrical discontinuities (dashed lines). Therefore, as mentioned previously, the low resistivity zones detected in the area are considered to be strongly affected by the acidic alteration (Alunite and Kaolin Pyrophyrite), and the electrical discontinuities reflect the faults because the alteration thickness changes between the both sides of the faults. That is, the informaticn of electrical discontinuity is very effective for locating the promising fault as geothermal reservoir.

Fig. 5 shows a plot of thickness vs resistivity of the resistivity layer from MT. As shown in the figure, it can be seen two groups which were carried out the measurement near the Komatsuike Sub-fault and the Hatchobaru fault. The thickness near the Komatsuike Sub-fault shows thinner than that of the Hatchobaru faults. This supposes that the remarkable electrical discontinuity is formed by the Komatsuike Sub-fault system and the hydrothermal alteration is very intense. The actual driiling data coincide with the tendency of the plot, especially the thickness of the acidic alteration zone coincide with it.

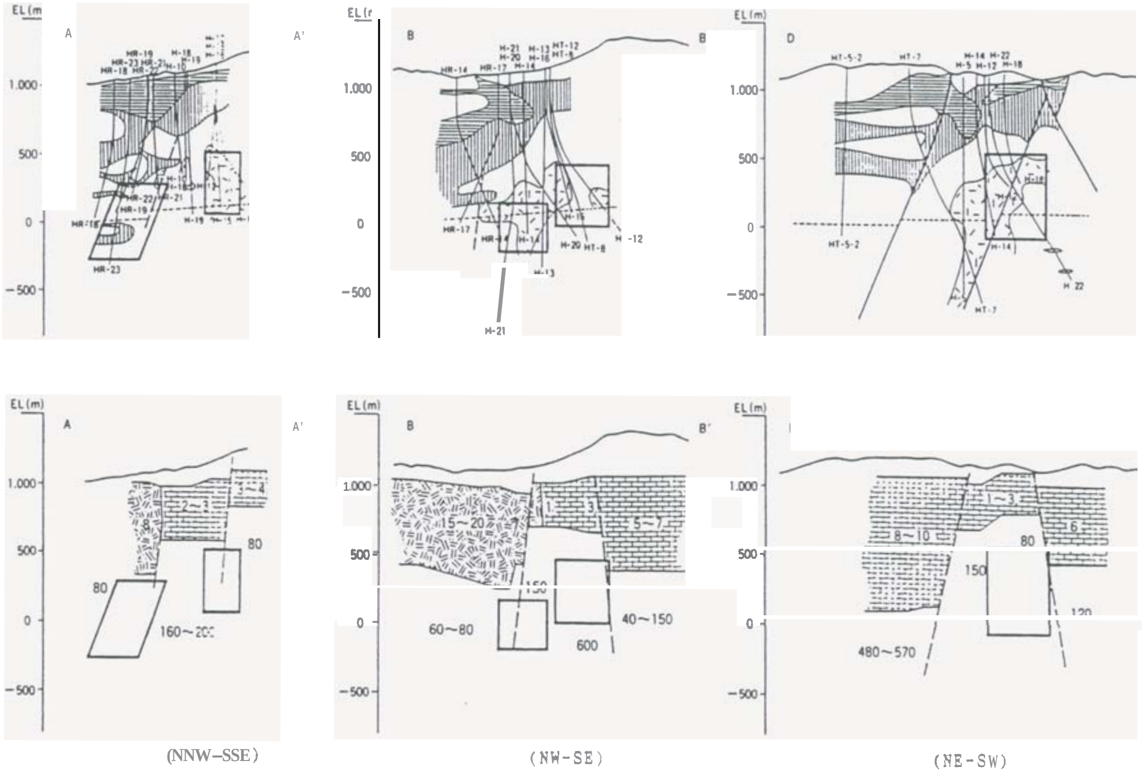

Fig.4 Sections of Hydrothermal alteration zones and corresponding resistivity layers

: lost circulation zone
: low resistivity layer from MT
: low resistivity layer from schlumberger

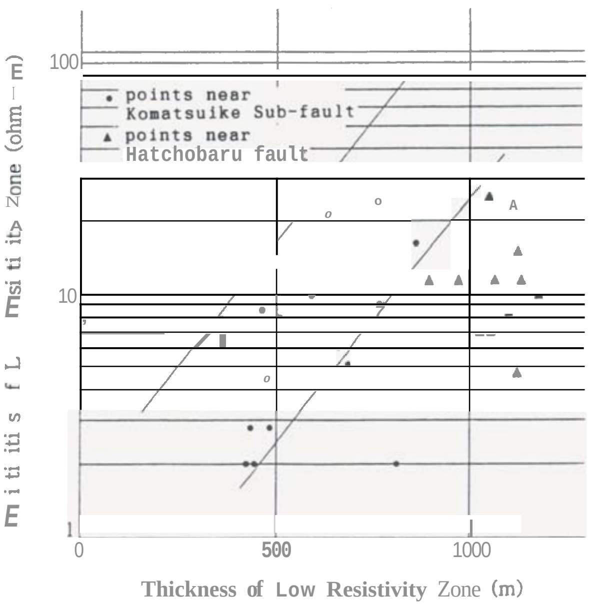

Fig.5 Resistivities vs thickness of low Resistivity zone

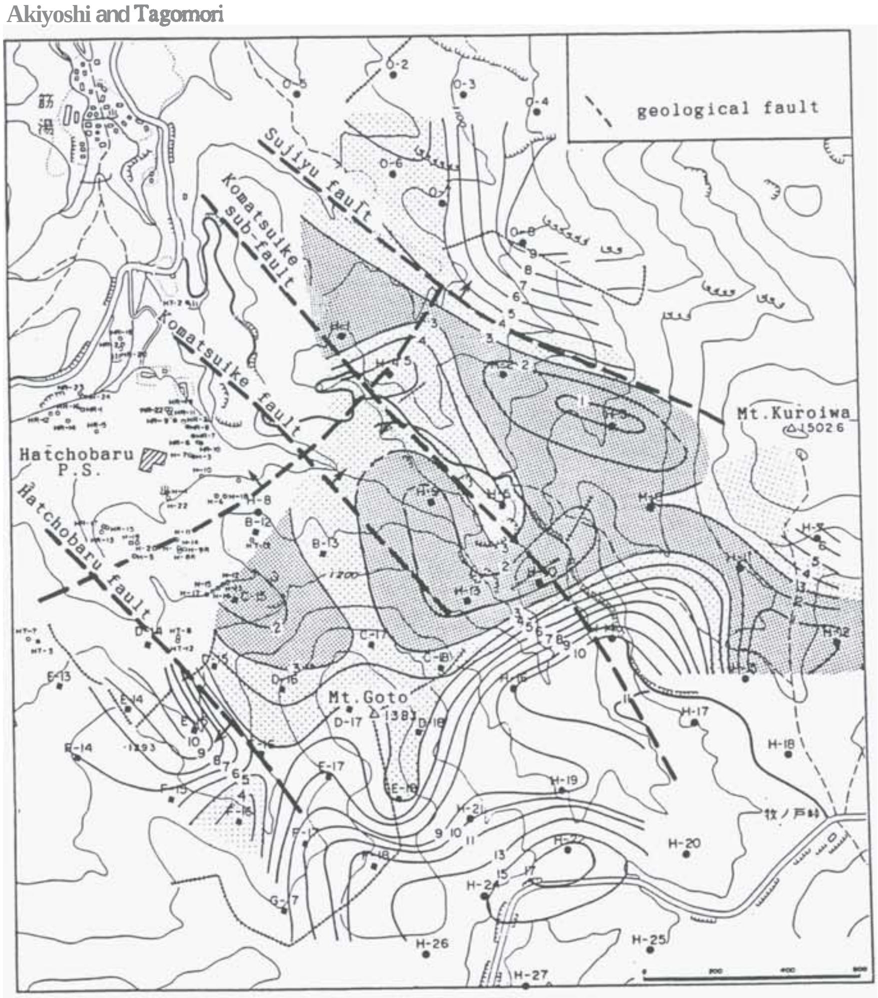

Fig.6 Iso-resistivity map of low resistivity layer from MT (ohm-m)

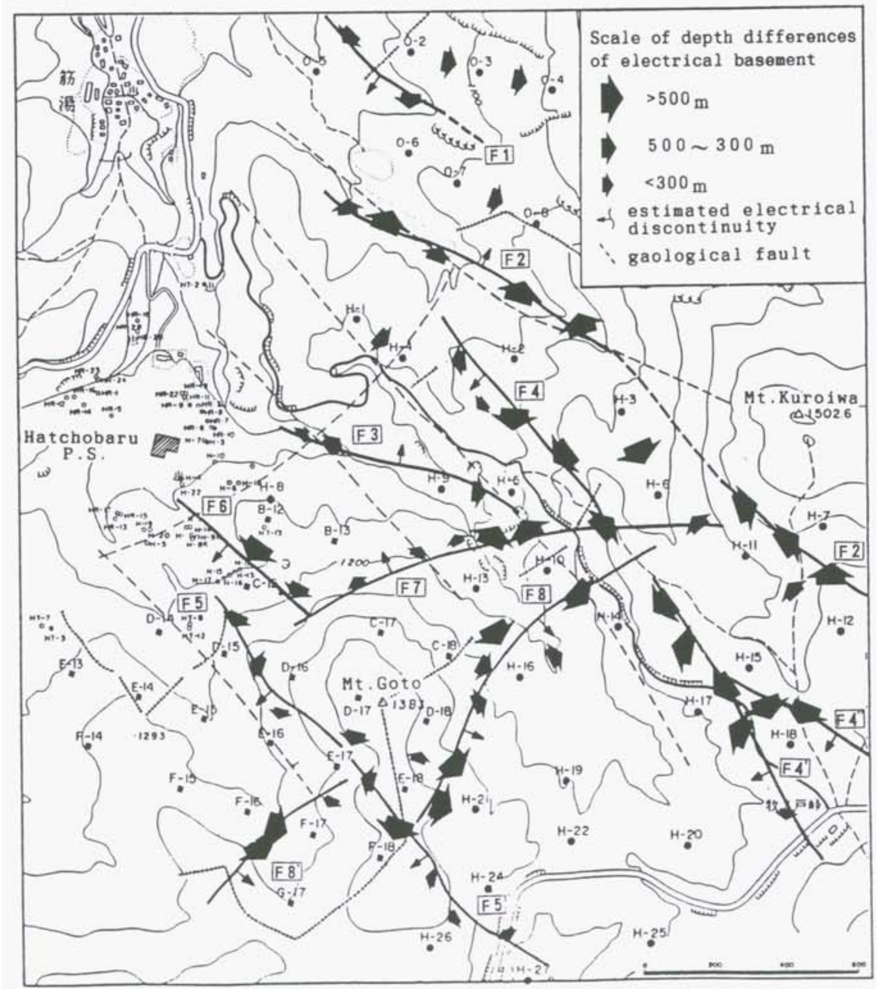

Fig.7 Estimated electrical discontinuities (F1～F8)

MAGNETOTELLURICS (MT)

MT was carried out in 1981, 1982 and 1984 in order to understand detailed geoelectrical structure of the eastern part of Hatchobaru at the interval about 200m. (Fig. 1)

Even in the MT method, the area covered near the surface with very low resistivity layer such as thermally altered rocks or mud stones, it was very difficult to detect the deep resistivity distribution in spite of sounding from high frequency to low frequency.

This is the resolution problems by masking effect, principle of equivalence, 3D-effect and so on. Therefore, in the conditions of difficulty to detect the deep resistivity distribution, MT was carried out for the objectives described below.

a. to delineate the belt-like anomaly of low resistivities distributed along faults

b. to detect the electrical discontinuities closely associated with fault system by setting well-meshed points.

Fig. 6 and Fig. 7 shows the iso-resistivity map of low resistivity layer and the estimated electrical discontinuities, respectively, As shown in these figures, the extremely low resistivity belt-like anomaly could be delineated at the eastern part of the Hatchobaru Power Plant tending NW-SE and NE-SW.

A noteworthy point is that the belt-like anomalies distribute almost corresponding with geological faults. Especially, the faults trending NW-SE are estimated to be promising structure as geothermal system. The detected electrical discontinuities have also same tendency with geological faults except F7 and F8. The arrows in Fig. 7 show the scale and direction of electrical discontinuities between neighbouring two points. F7 and F8 were also considered to be reflecting fault system and actually they were proved by exploratory wells from the results of large amounts of steam production.

CSAMT

CSAMT survey was carried out at the west and the west-southern part of the field in 1986, 1988 instead of MT because of its low cost and measurement easiness.

The CSAMT technique applied at that time was the simultaneous measurement of seven electric field values, which offers excellent lateral resolution in resistivities, and it helps to detect the belt-like alteration extent developed along faults. That is, CSAMT is a good tool not only for the detection of vertical resistivity changes bud also for the detection of horizontal resistivity changes.

Fig. 8 shows the iso-resistivity map of the low resistivity zone. The features of this figure are summarized as follows.

a. The eastern part of the Hatchobaru power plant shows very low resistivities less than 5 ohm-m, and it extends from NW to SE showing same distribution with MT.

b. On the contrary, the western part shows high resistivities extending from Mt. Ichimoku to NE direction. Hydrothermal alteration of this zone is estimated to be not so intense, and promising fault is not recognized even it can be found the electrical discontinuity.

c. The resistivities from the Hatchobaru Power Plant to the east are changed steeply suggesting NW-SE fault system controls the resistivity distribution. In actual, the fault trending NW-SE is one of major reservoir for the Hatchobaru Power Plant Unit 1.

CSAMT survey was carried out with the interval of 100m in the area and gave us detailed geoelectrical structure. The drilling plan is at present based on the information from CSAMT mostly.

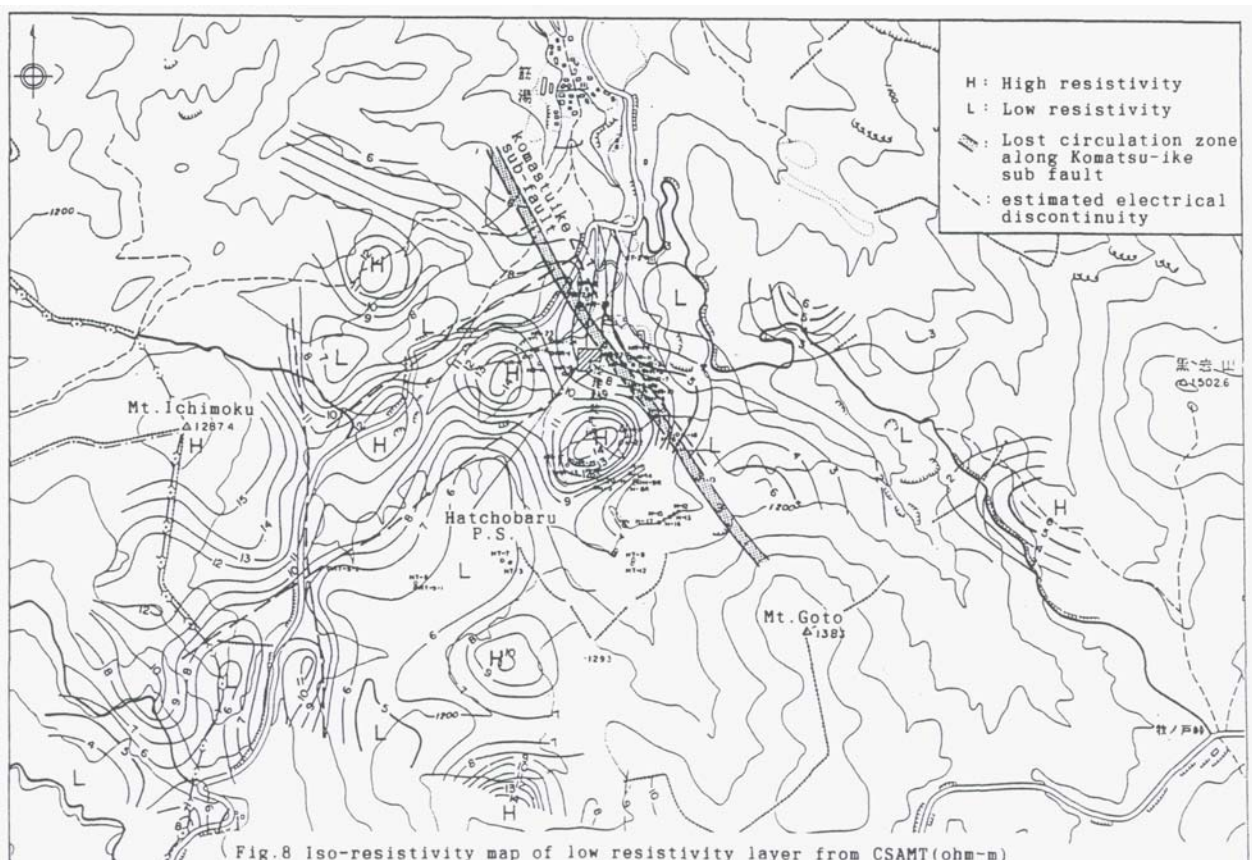

Fig.8 Iso-resistivity map of low resistivity layer from CSAMT(ohm-m)

MISE-A-LA-MASSE

This method was applied to geothermal well for the first time in Japan by KEPCO. And WEST JEC applied the method to eighteen geothermal wells to find its adaptability for geothermal exploration. Fig. 9 shows one of results which obtained in Hatchobaru using HT-8 exploratory well. The result is found the shape of low potential zone clearly reflects the geometry of the Hatchobaru Unit 1 reservoir which distributes along the fault.

Some of important points when this method applied to geotnermal wells are considered as follows.

a. The distortion of potential map is affected not only by the shape of geothermal reservoir but also by steep resistivity change which occurs in and around faults.

b. The distortion occurs more clearly when resistivity changes from High to low than low to high.

c. When a well is located in the center of low resistivity zone, the calculated apparent resistivity map gives us some ghost anomalies of high resistivities in the vicinity of the well.

The interpretation of the result by this method is very difficult, while the field work is relatively easy compared with other electrical and electromagnetic methods. Therefore, the interpretation should be carried out combining with other electrical surveyed data if it's possible. Further, this methods doesn't offer the depth information. However, even in this disadvantages, this method is very effective because resistivity change can be clearly detected in and around the faults. In Hatchobaru, the anomaly of low potential zone (residual potential) which coincides with the location of the electrical discontinuity is the most promising zone of geothermal fluids.

CONCLUSION

In the Hatchobaru geothermal field, the electrical and electromagnetic techniques are most effective tools for understanding the reservoir structure. The results of these methods contributed the construction of the Hatchobaru Power Plant Unit 2 because the most wells selected by the results produced a large quantity of steam and hot water.

Considering that most of geothermal reservoirs in volcanic areas are of the fractured type and are controlled by fault system, the geoelectrical structure presented in the paper may be regarded as a typical model of the reservoir. In that case, the electrical and electromagnetic techniques are expected to be applied by taking each adaptability which is discussed in this paper into account.

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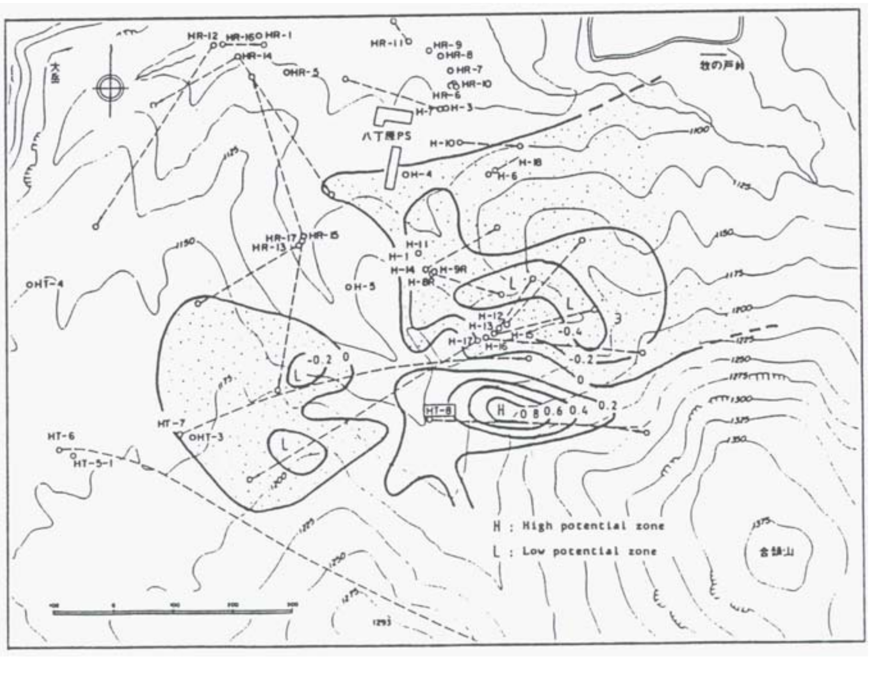

Fig.9 Residual potential map around the HT-8 well at the Hatcbobaru geotherwal field(MV/A)