SOME FIELD TEST RESULTS OF A HIGH ACCURACY MT SYSTEM

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1. Introduction

The "Development of A High Accuracy Magnetotelluric (MT) Method Exploration Technology" delegated by the New Energy Development Organization (NEDO), has been carried out by Geothermal Energy Research & Development Co., Ltd. (GERD) and Meisei Electric Co., Ltd. (MEC) as part of the "Confirmation study of the effectiveness of prospecting techniques for deep geothermal resources," one of the MITI's Sunshine projects, under a 5-year plan from FY 1984. It aims at the development and verification of portable, real time 4-point triple-reference processing MT method exploration techniques that make possible to estimate accurate conductivity of the earth's interior even in the geothermal fields of Japan that are mountainous and noisy for MT survey. This paper will report the portable, real time 4-point triple-reference processing MT method exploration techniques that has been developed until FY 1987.

2. Outline of development objectives and research results of MT method exploration techniques

2.1 Development objectives

In a series of surveys and studies being conducted by the NEDO, including the "Nation-wide geothermal resources exploration project," the "Survey of deep geothermal resources in the Hohi area, Kyushu," and the "Confirmation study of the effectiveness of geothermal prospecting techniques for deep geothermal resources," etc., foreign-made measuring systems are in use to carry out MT method exploration. It has been aware that the MT method is a highly effective exploration technique for looking into the deep conductivity of the earth's interior. However, in Japan it has been forced to apply the foreign techniques of the United States, Canada, France, etc., due to its under-development of MT method exploration systems and techniques. In this MT R & D project, therefore, development targets have been decided concerning MT method exploration technological elements and measuring systems as well as analysis techniques, which are required to be solved from the standpoint of the characteristics of the Japanese geothermal fields.

2.2 Research results

Fig. 1 shows a system composition of the 4-point triple-reference processing MT method. This measuring system is composed of data observation points (DOP) and a data processing/recording section (DPU), all of which are linked by optical fiber cables. The number of data observation points has been made four, two points more than last year, making 4-point simultaneous observation possible. The composition of equipment at each observation point is the same as last year.

The data processing/recording section also has been built up in order to realize 4-point simultaneous measurements. The MT method data processing/data acquisition program, developed on the basic system of a super-minicomputer (HP-9000), can real time process 4-point data being acquired and check them for quality, etc.

It is also possible to acquire synchronous data from two measuring system (DPU), using of time data from a quartz clock. Then, we made tests of long distance remote-reference MT method.

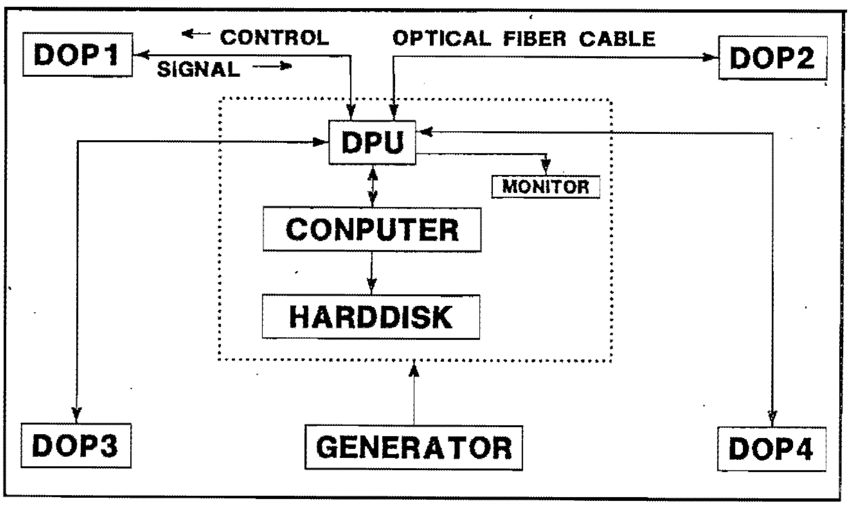


Fig. 1 Schema of measuring system

3. Field test

3.1 Outline of field test

The tests, subsequent to FY 1985 and 1986, were carried out in a district located from Kushino, Kokonoe Town, Kusu County, Oita Prefecture, to Kitazato, Oguni Town, Aso County, Kumamoto Prefecture, central-north Kyushu as shown in Fig. 2, covering an area of about 15 square kilometers.

Most of the test district is covered by Quaternary volcanic rocks. In the center of the district exist the Takenoyu and Hagenoyu hot springs. Also many geothermal boreholes have been drilled by the NEDO, the Electric Power Development Company, etc.

In the 1987 year's field test, measurements were made at 59 conventional MT method points (of which 24 were spaced 100 meters apart in a straight line for dense coverage of the surface electromagnetic field) and 212 super high frequency band MT (SHFMT) method points. As for the SHFMT method, the number is greater since measurements were carried out also at the points that were measured in 1985 and 1986. In the analysis, the data from all the points were used which have been measured in this district to date. Further field test was made of the long distance remote reference MT method.

3.2 Effects of triple-reference processing

In remote reference processing, the removal of noise is impossible in principle when the reference points are polluted by coherent noises involved in the observation points.

Through the field test it has been confirmed that the triple-reference processing can be expected to eject noise more efficiently, for the reference points locates spaciously and thus the chance of being polluted by coherent noises is less compared with dual-reference processing.

There being other potential algorisms of triple-reference processing than the developed method in FY 1987, we will continue studies on them.

3.3 Effects of long distance remote-reference MT method

In the field test district, it was found an inclination of the apparent resistivity curve was over 45 degrees from 1 second to 10 second, due to a regional noise at almost all of the observation points. It was confirmed the long distance remote-reference MT method was very effective to eject a regional noise (Fig. 3).

3.4 Expansion of frequency band for data processing

With introduction of the SHFMT method and of the digital filtering on low frequency time series data, the frequency band was expanded to make data processing possible in the frequency range of 20 kHz to 1,000 seconds.

This SHFMT method system has been accomplished with field magnetic sensors for making measurements into the high-frequency band, and a different algorism from the conventional MT method has been introduced in spectrum analysis so as to meet high frequency band requirements. Nevertheless, the system is the same as the conventional MT method in that it seeks a cross power to finally obtain 6 kinds of impedance tensor, Zij. Therefore, SHFMT data is possible to superimpose on the data processing results from the conventional MT system.

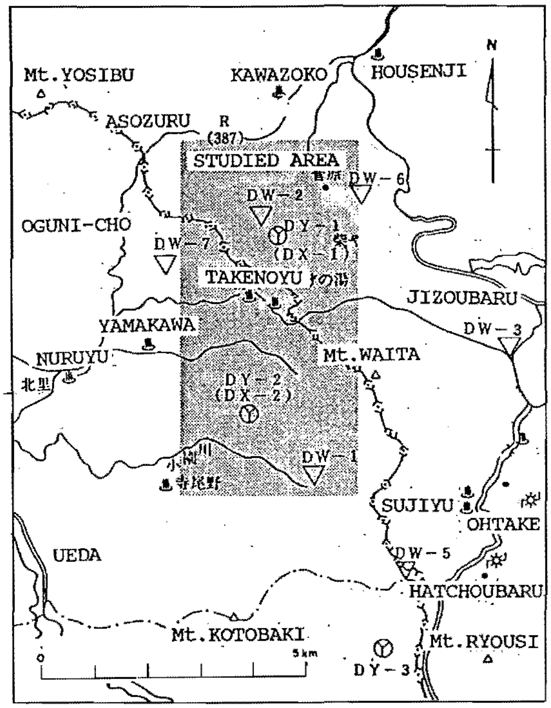


Fig. 2 Field test district

Fig. 4 shows an example of an apparent resistivity curve upon synthesizing SHF and super low frequency (SLF) SLF data with HF, MF, and LF data. Thus, very significant is the fact that the acquisition of wide-range of seven decade MT data has become possible; not only analysis become possible from shallower to greater depths than ever before, but analysis accuracy can be expected to improve.

3.5 Effects of continuous dense coverage measurement along the line

In order to make high-accuracy analysis, there has been pointed out the importance of making measurements with a shorter spacing of the observation points for accurate survey.

In the field test, therefore, continuous dense coverage measurements along the line were performed with a shorter spacing of the observation points in a straight line.

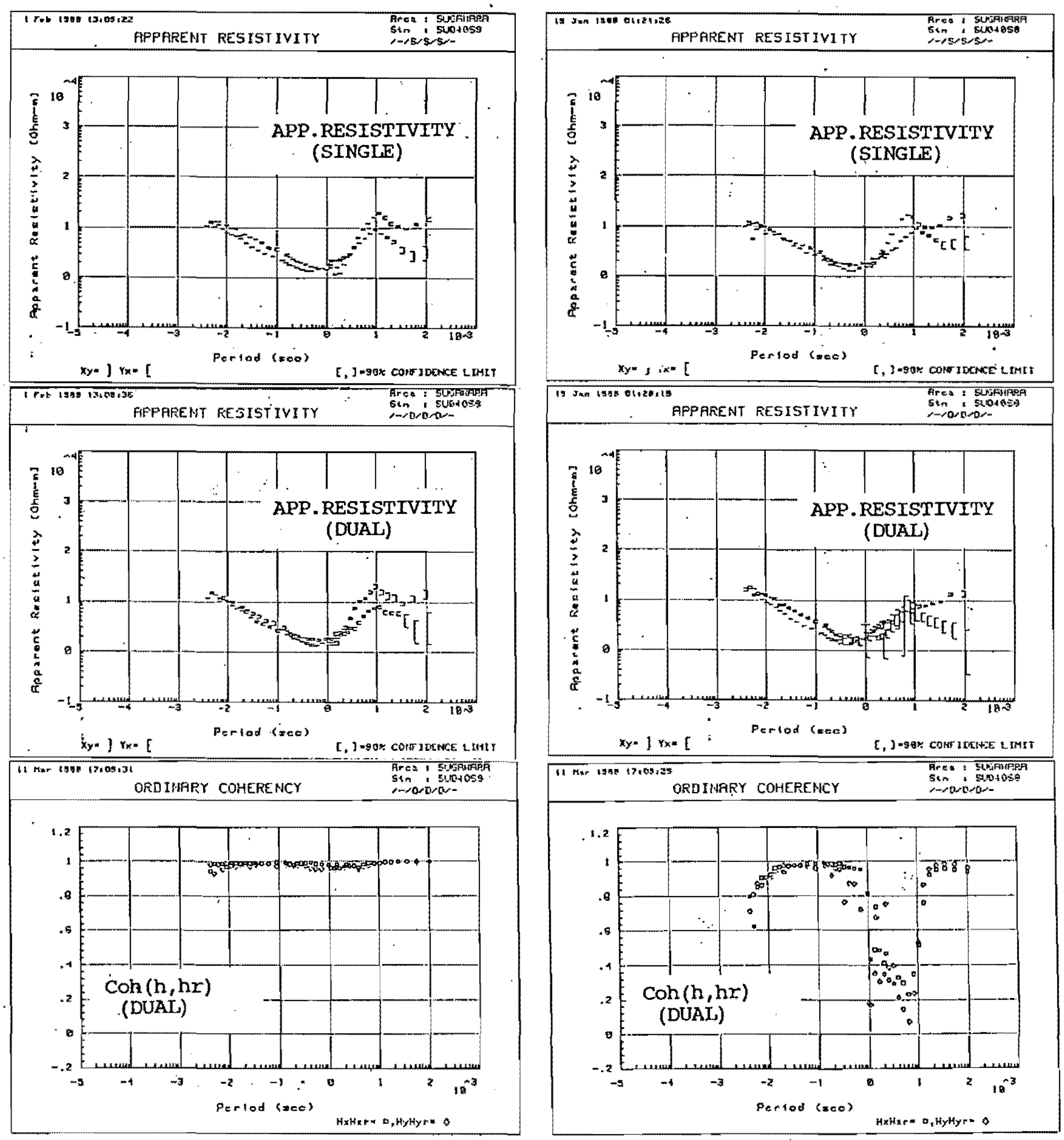
Fig. 5 shows the observation points where continuous measurements were made. As illustrated, the observation points were set in the north-south straight line, taking continuous Ey telluric line in the same direction.

In the MT method the telluric line is 100 meters long, while in the SHFMT method 30 meters, so that measurements were made at 24 and 80 observation points, respectively along the line.

The data of continuous measurements were analyzed in terms of one-dimensional model (Fig. 6, line D') and the results therefrom were compared with those (Fig. 6, line D) at ordinary observation point spacing (500 meters).

On survey traverse line D, there only exists a low resistivity range of gentle upward concave shape at location F1.

In contrast, continuous measurements made with additional points interposed between the observation points of survey traverse line D show that on observation line D' the downward convexity of this low resistivity is delimited more sharply in the



SHORT DISTANCE REMOTE REFERENCE

LONG DISTANCE REMOTE REFERENCE

Fig. 3 Effects of long distance remote-reference MT method (short distance remote-reference, long distance remote-reference) neighborhood of observation point 5 (F1).

Moreover, a resistivity discontinuity zone, F2, that had not been found on observation line D was detected.

4. Conclusion

It has been ascertained that the technological development of the 4-point MT method up to the last fiscal year has progressed successfully as initially planned. This suggests that we have caught up with the world level or surpassed it in some respects.

In the coming years, we are planning to undertake surveys in the field where actually promising geothermal wells exist to prove that the systems we have developed so far are valid as geothermal prospecting methods. That is, we would like to carry out proving tests to examine whether the geothermal reservoirs detected by existing wells can be confirmed by analyzing the data acquired in those systems.

Also, not limited to the attainment of high-accuracy measurements and analyses, we are scheduled to grasp the measuring costs involved and make sure of their economics.

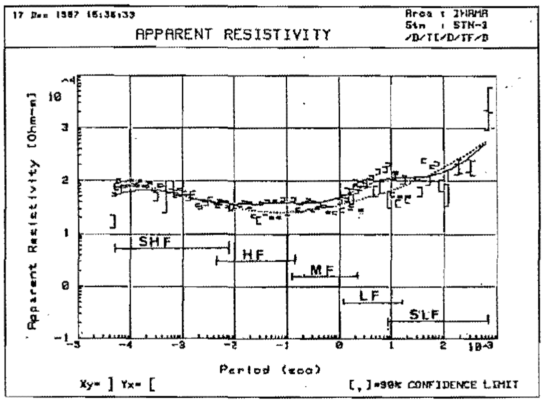


Fig. 4 Example of an apparent resistivity curve upon synthesizing SHF data with HF, MF and LF data

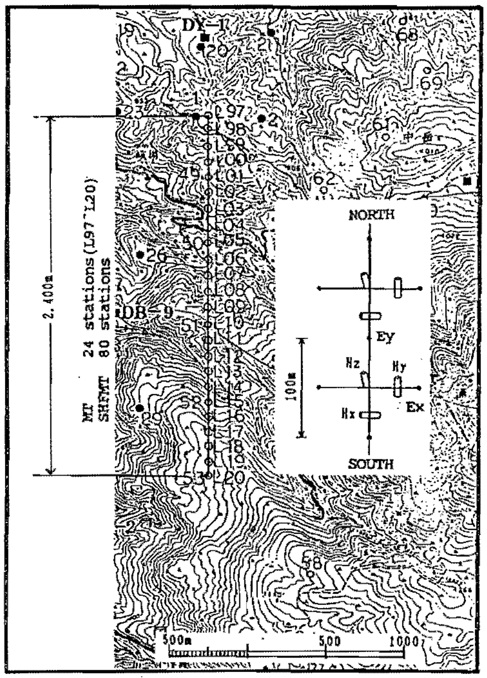


Fig. 5 Location and layout of observation points in continuous measurement

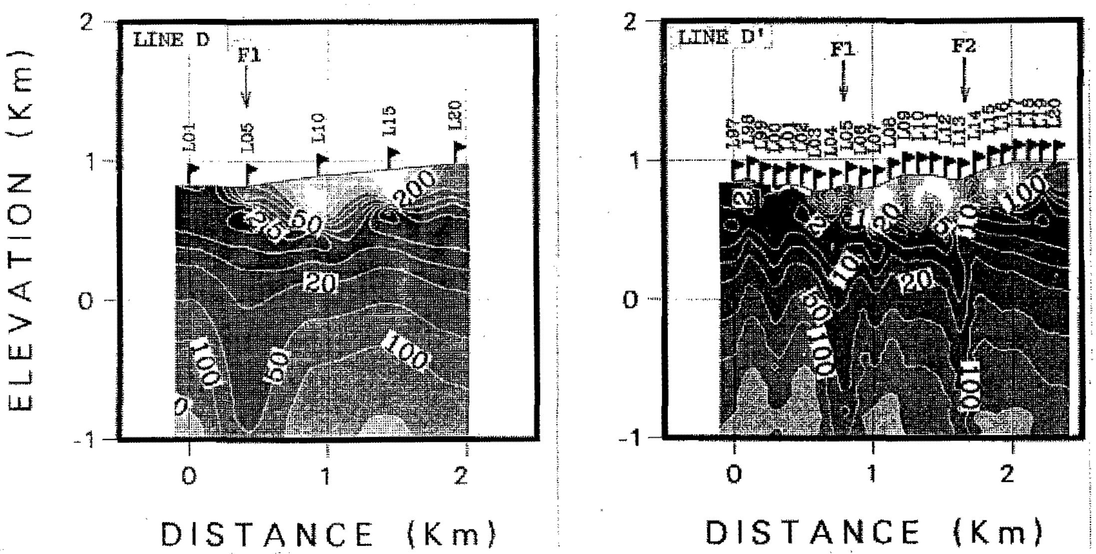


Fig. 6 Comparison of resistivity cross sections (survey traverse line D, observation point spacing 500 m; survey traverse line D', observation point spacing 100 m)