Introduction A New Geophysical Exploration Tool - Array CSMT/MT Method

Case history at Shibetsu-dake area. Hokkaido, Japan

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Abstract

Japan is well known as one of the most active volcanic countries in the world, arid it is well endowed with geothermal energy like as the Philippines.
As of November 1996, there are IS geothermal power plants in operation with a total generating capacity of 530 MW. According to the electricity supply target announced by the Government, geothermal generation at the end of the year 2000 should he 600MW (0.2% of total generation).

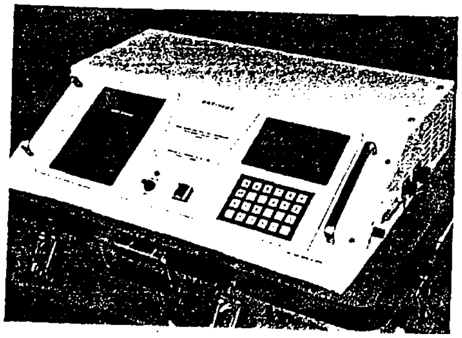
In order to approach this target. and to investigate deep seated geothermal reservoirs, it is required to investigate and to identify fractures related to geothermal resources at depth.
The New Energy and Industrial Technology Development Organization (NEDO) has been promoting the "Analysis and Evaluation on Exploration Methods for Fractured Type Geothermal Reservoirs". In addition a new Electro-magnetic Exploration Method, --Array CSMT atid its development--has been studied since 1990, as one of the new geophysical exploration technologies.

In September 1994, on the completion of this technology, the New Energy Foundation (NEF) introduced arid adopted this method for a geothermal promotion survey in Shibetsu-dake, Hokkaido, aid also in ashiro area. Iwate Pref. in 1995.

Despite the steep topography, the results of 2-D analysis in these survey areas, revealed clearly the hidden faults arid alteration at depth, and the exploration drillings based on the results of this survey successfully hit the high temperature reservoir at the depth.

1.0 ARRAY INSTRUMENTS

1.0 1 Transmitter/Generator



Transmitter PGT-50

a) Engine ------- Wisconsin, Max 62HP

b) Generator --- ZMG30, ZONGE Max 30KVA, 115V,
400Hz, 3 phase

c) Transmitter --- PGT-50, CHIBA *Max* 1200v, 50A,
20KVA, DC-8192Hz high power transistor
Programmable automatic transmission, 320x200 dot LCD

d) Transmitter Controller --- XMT-32, ZONGE 0.001-8192Hz

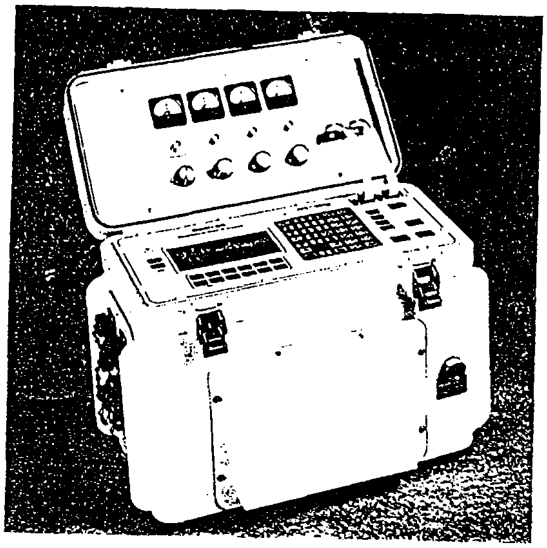
1.02 Receiver

a) Receiver --- GDP-32NJ, ZONGE
   16 channel, 0.25-8192Hz,
   80386SXL 16MHz
   2.5 inch 60MB hard disc,
   automatic receiving,
   MT processing

b) Coil --- ANT/1 for CSMT, ZONGE
   1/8-8192Hz, 0.5mV/Hz
   BF-4 for MT, EMI
   0.001-10KHz, 0.3V/Hz

c) Signal Conditioner --- SC-8, ZONGE
   8 channel with 3 band

d) Multi-conductor cable --- Shielded eight conductors cable



Receiver GDP-32NJ

2.0 SYSTEM

The Array CSMT system consists of 15 electric pots with boosters and connecting multi-conductor cables, with a magnetic coil at the center of the array Two multi-conductor cables are connected to the GDP-32NJ receiver through contact resistance boxes and a terminal box. The electric field pots spacing was 100m, with a total of 1500m. being covered by one layout

After completion of array CSMT data acquisition, the same array can be used for array MT measurement The electric field spacings are changed to 300m, a switching box can select every three electrodes, and the signals are amplified and filtered through a signal conditioner A total of five electric fields and one magnetic field can be measured, as array MT, by this configuration

3.0 SURVEY AREA and LINE SETTING in SHIBETSU-DAKE, HOKKAIDO

The Shibetsu-dake area is located in the eastern part of the island of Hokkaido. Based on the first phase of the survey, which consisted of geological, geochemical and a gravity survey, two areas were selected as possible sites within an area of 300 Km^2.

Several assumed faults which are considered to be related with the deep geothermal resources are drawn in the consolidated map, as shown in Fig.2 A total of ten survey lines were planned to cut across the assumed faults, having a total length of 49.5 Km.

Individual survey line lengths were 4.5 Km or 6 Km, with one array being 1.5 Km in length.

The electrode spacing along the lines were 100 m. for an array CSMT survey, and 300 m. for an array MT. In other words, one array can cover 1,500 m, with 15 electric dipoles and one perpendicular magnetic field for CSMT, using the same array for five electric fields for array MT.

4. Configuration

As shown in Fig.3, all fifteen electric pots are connected with signal boosters and multi-conductor shielded cables with 8 conductors of 0.18mm^2 size. These signal boosters decrease the contact resistant significantly, which makes it possible to detect the weak high frequency signals being sent through the long cables The measured ground resistance at the center of the array, coming from 16 electrode pots were all less than 30 ohm-m.

After the completion of the CSMT data acquisition, MT data can be taken by the same configuration by installing a switching box to skip every three stations. At the same time, in order to avoid cross talk with the electrodes and the receiver. the signal boosters were turned off and directly connected to the pots from the remote resistivity switching box, which is located at the center when MT signals are measured.

The general configurations for the array CSMT and array MT are shown in the figure.

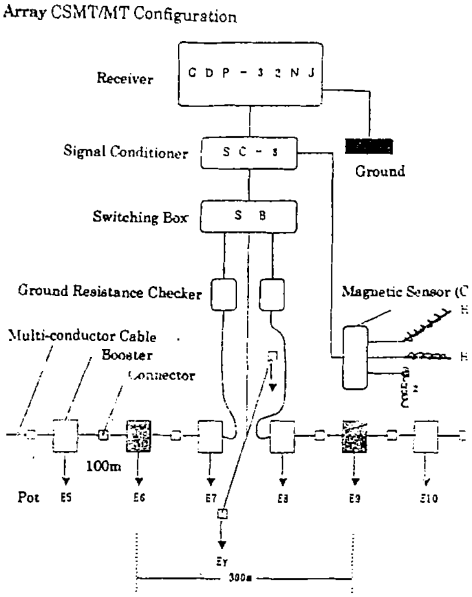


Figure 1. Array CSMT/MT Configuratio

5. GENERAL INFORMATION

Survey Area:	300 Km^2
Survey Lines:	10 Lines, 49.5 kilo meters
Array:	33 Arrays with 150 meter length each
Stations	495 Array CSMT, 165 Array MT and 33 MT
Spacing:	100 meters for array CSMT 300 meters for array MT Current Dipole: 4 locations
MT	5 component MT were measured at the center of each array (33 stations)
Consultants	Bishimetal Exploration Co., Ltd.

6. Results of Analysis

Using 3-D analysis software developed by Dr.Uchida of the GSJ, each profile were divided into 25 to 500m segments in vertical direction to a depth of 2500m, and 50 to 100m segments in the horizontal direction.

After several iterations, the **final** matching resistivity values are plotted in each segment and the contours are drawn, with the center of each segment **as** their representative value.

The resistivity map structure is separated into three groups; the Upper, Middle and Lower groups.

The Upper layer mainly corresponds to the Musa-pyroclastics, the Middle **layer** to sandstone, siltstone and mudstone, and the lower group *to* andestic pyroclastics

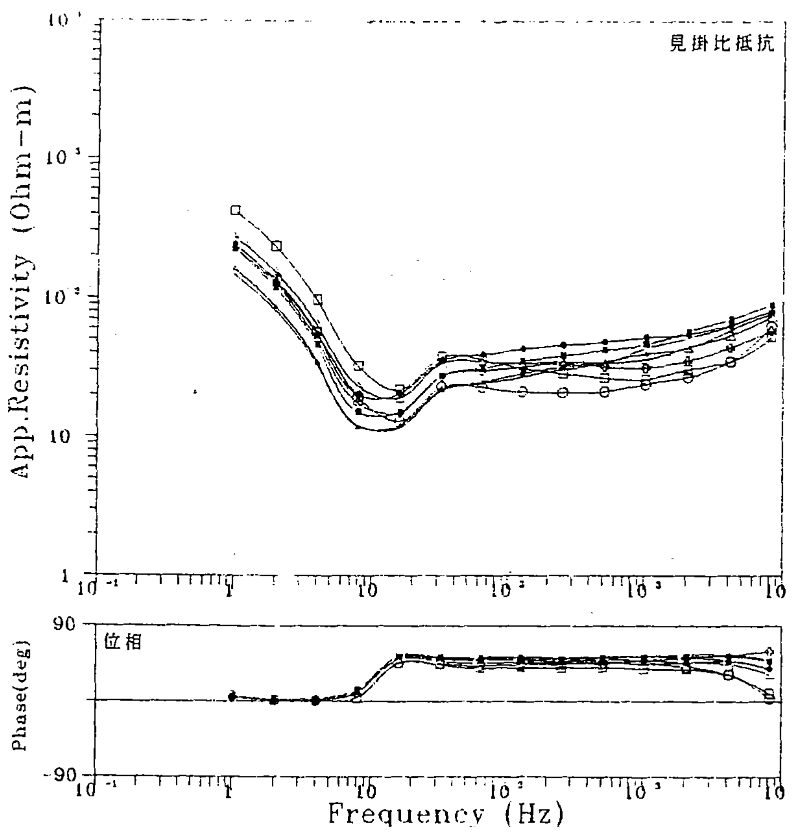


Figure **2.** Array CSMT Apparent Resistivity Curves

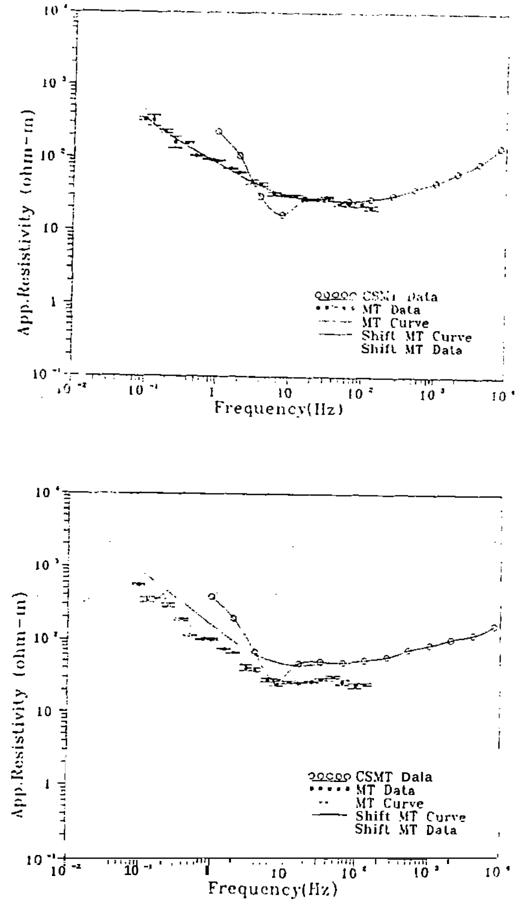


Figure 3. Merge of MT curve with CSMT curve

7. Example of Interpreted cross-sections

7.01 Line-M1

This line runs parallel to the dominant fault in the area, the Musa-Shitabanupuri fault, which is thought to control the geothermal activity in the area. While four assumed faults cut across the line, which are expected to bring the geothermal heat to the near surface.

One gradient hole **SB-T-1,** with **a** depth of 800m **was** drilled **near** station No.55 on this line.

The upper layer values are **all** resistive, with the layer becoming thicker in the center, around stations

No.31 and No.41, and towards the north from station No.61. The conductive middle layer thickens towards the south, with the depth of the lower formation corresponding well with the gravity data change. showing deeper towards the south. In the lower group, two resistive bodies are analysed, showing an uplift structure around station No.60.

A shallow resistivity boundary is seen around station No.16, while two deep boundaries are seen near station Nos.23 and 45. The shallow one seems to correspond to the Urappe fault and the deeper one, near station No.45, corresponds to the Kawakita south fault.

Figure V-1-2 shows the plot of resistivity log and 2-D analysis. The resistivity structure changes from 20 to 100 ohm-m towards the depth, and corresponds well with the 2-D analysis, shown in solid lines.

The low resistivity is probably due to white argilization which is seen at the depth of 70-300m. in borehole

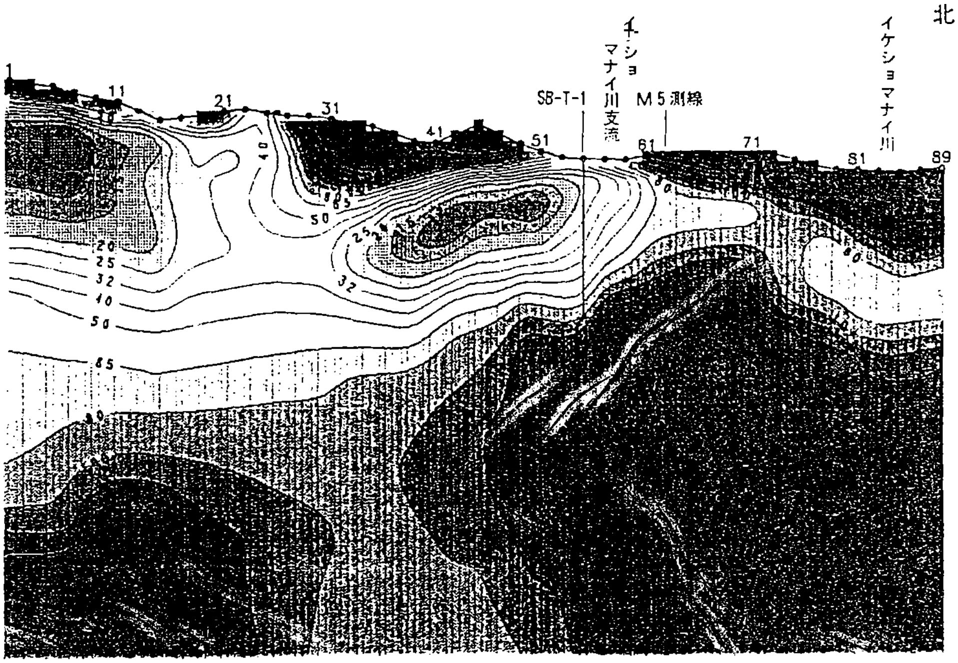


Figure 4. 2D Resistivity Model of Line-M1

7.02 Line-M5

This line runs in the north-eastern part of the survey area in NW-SE direction cutting across the dominant fault, the Kawakita-Sitabanupuri fault, at around station Nos.57-63.

North-west of station No.57 shows a higher resistivity than 100 ohm-m with high gravity anomaly, and the south-east shows less than 50 ohm-m changing quickly to a low gravity anomaly.

The fact that the Kawakita spa is located between the north Kawakita and south Kawakita faults along this high gradient gravity zone suggests that this low resistivity is due to geothermal alterations. The resistivity structure clearly corresponds well with the geological and gravity structure.

From a depth of 1600 m. ASL, the resistivity value increase towards the depths to the northwest of station No.57, while a wide and deep low resistivity is seen in the southeastern side of the line.

At depth of -300 m. ASL, the resisitivity show the minimum of 10 ohm-m, gradually increasing towards the depths.

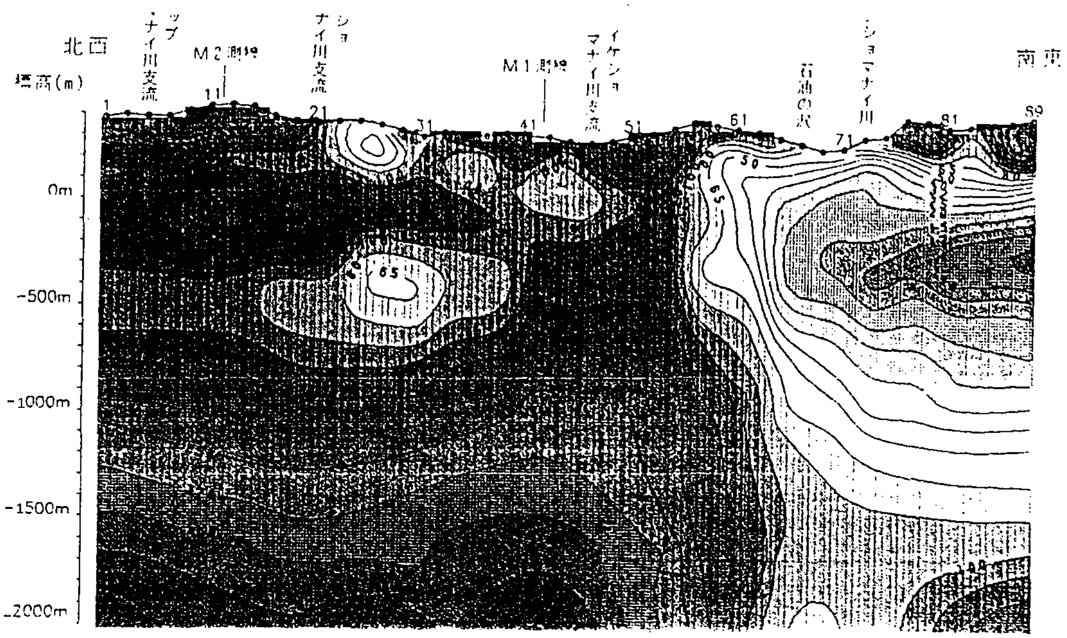


Figure 5. 2D Resistivity Model of Line **M5**

8. Conclusion

Despite the steep topography and poor access roads, 10 survey lines with a total line length of 59.5 km clarified a high density resistivity structure from the surface io the depth of 2,500 m.

The first trial to combine CSMT data with MT data are successful in making a joint inversion, with the stations 300 m apart

The number of the CSMT data along the array with a separation of 100 m. are 595 stations and array MT are 185 stations

The main fault structure which controls the geothermal activity in this area showed an excellent resistivity contrast, suggesting geothermal alteration at depth.

In order to trace the perpendicular faults, several lines cut across the assumed faults, showing the location of hidden faults and the assumed caldera structure by the gravity survey.

The resistivity structure can be separated into three groups. The shallow conductive overburden, which corresponds to Quaternary pyroclastic rocks overlain by conductive altered andesite to dacite of the Okusibetsu formation, and deep andestic rocks of the Chuurui formation.

In this **area,** the resistivity structure is not always horizontal but is clearly controlled by fault structure in the vertical direction.

The conductive zone with a strong resistivity contrast along the fault is deemed to be the most promising zone in this area.

The decent 2-D analysis after several iterations will be the key of the interpretation. In this case. the software was developed by Dr.Uchida of the GSJ.

It is also interesting to know that three gradient holes were drilled along the array CSMT/MT lines in the same year, showing good correlation between the 2-D resistivity structure and the resistivity logging in each hole.

It is important to note that in the planning stage, the proper direction of lines should be selected to cut the assumed structure perpendicular and also taking into consideration the location of the transmitter current dipoles.

From an economical point of view, this method is by far cheaper than the conventional MT and CSAMT, and the cleared brush lines can be used for access by other methods, such as geochemical survev.

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