MAGNETOTELLURIC STUDY OF THE GEOTHERMAL SYSTEM IN KUJU VOLCANO

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Kuju Volcano area, in the central part of Kyushu island, Southwest Japan, is one of the most active geothermal area in Japan (Fig.1). Kuju-Iwoyama, located northeastern part of the Mt.Hosshou, is an explosive crater of volcano and shows the most intense geothermal activity in this area. There are many active fumaroles, hot springs, and alteration zones. The purpose of this study is to make clear the subsurface structure of the volcano area where shows such intense geothermal manifestation by using geoelectromagnetic method.

We performed ELF-magnetotelluric sounding using Schumann resonance natural noise (8 to 40 Hz) to investigate the geoelectrical structure in this area. The survey was carried out at 133 points as shown in Fig.2. In this survey, two components of electric fields and two components of magnetic fields were recorded simultaneously by analogue data recorder for about fifteen minutes. In addition , the artificial electromagnetic wave from military VLF transmitter station at 17400 Hz was also observed in order to detect the shallow structure.

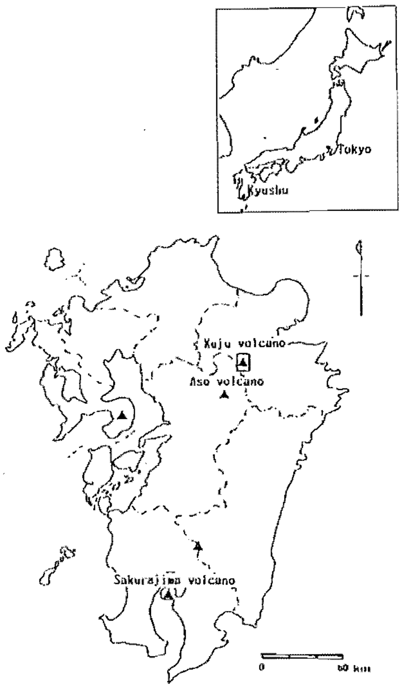

Fig.1. Map of Kyushu island

Four components of electric and magnetic fields were processed with the flow chart shown in Fig.3 by the personal computer. In this study, five times stacked power-spectrum and cross-spectrum of each components were regarded as a data set. For each data set, if the multiple coherency between the electric and magnetic components was less than 0.5 or the coherency of magnetic components was more than 0.5, then the data set was rejected as noisy data. Tensor impedance was calculated by the least square method for the smoothed spectrum.

Generally, the tensor impedance depends on the measuring direction of fields and the polarization of incident wave. Therefore, it is necessary to diagonalized the impedance matrix for obtaining the intrinsic impedance. For the case of the two dimensional resistivity structure, the impedance matrix can be diagonalized by the transformation of the coordinate axes. For the case of the three dimensional structure, however, it must be diagonalized by eigen state formulation. In this study, the intrinsic impedance was obtained by Eggers' eigen state formulation method (Eggers,1982). The formulation of this method is shown as follows.

$$\rho^{\pm} = \frac{1}{\omega\mu}|\lambda^{\pm}|^2 \qquad (1)$$

$$\lambda^{\pm} = Z_1 \pm \sqrt{Z_1^2 - \det[Z]} \qquad (2)$$

where

$$Z = \begin{bmatrix} Zxx & Zxy \\ Zyx & Zyy \end{bmatrix} \qquad (3)$$

$$Z_1 = (Zxy - Zyx)/2 \qquad (4)$$

In this case, the two principal axes of the tensor impedance are defined as the principal direction for the polarization ellipses of the electric fields.

$$\tan 2\psi^{\pm} = \frac{2\mathrm{Re}\langle Ex^{\pm} \cdot Ey^{\pm} \rangle}{|Ex^{\pm}|^2 - |Ey^{\pm}|^2} \qquad (5)$$

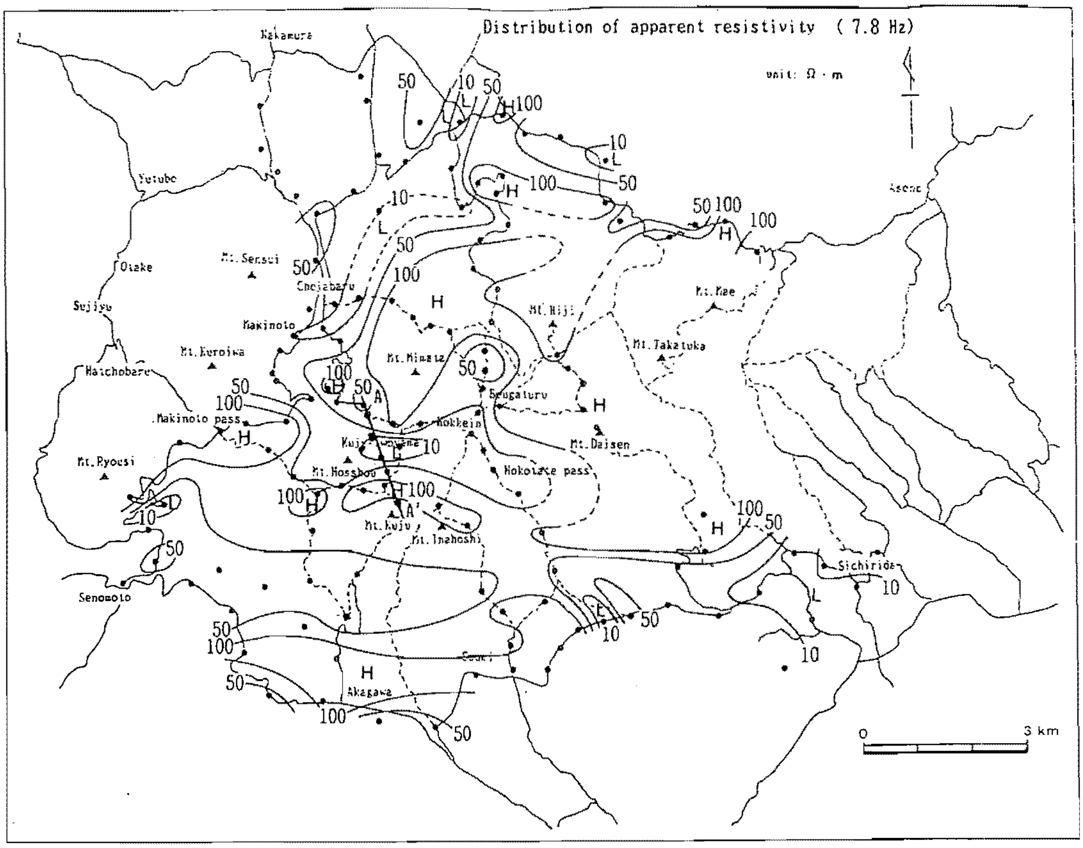

Fig.2. Survey sutes and apparent resistivity distribution (7.8Hz).

The intrinsic apparent resistivity map which was obtained in the way described above is superimposed on Fig.2. The apparent resistivity values in this map are the geometric mean of two intrinsic resistivity values at 7.8 Hz. This figure shows the extremely low resistivity zone, less than 10 ohm-m, exists at Kuju-Iwoyama area. This low resistivity zone located at the cross point of the two low resistivity belts which extend along the direction of NE-SW and NW-SE respectively. Moreover, the low resistivity zones also exist at the foot of the volcano. These low resistivity zones probably correspond to the fracture zone along the fault.

The two dimensional inversion was performed by the finite element modeling technique for the section along A-A' line shown in Fig.2. In this inversion, the one dimensional model was used as the initial model. In this survey only four frequencies were measured so that it is meaningless to construct the complicated multi layer model. The subsurface structure was assumed to be the simple two or three layer structure in this study. Fig.4 shows the result of the two dimensional inversion. According to this figure, the first layer has 50 to 300 ohm-m and its thickness is 40 to 200m. The resistivity values of the second layer vary at each site, but they are less than these of the first and third layer. The third layer has the about 300 ohm-m resistivity, except the Kuju-Iwoyama area.

We interpreted this resistivity structure as follows. The low resistivity zones, less than 5 ohm-m, in the second layer at the Kuju-Iwoyama area correspond to the existence of the mineralized hot water in these zones. And the fact that the resistivity of the first layer in this area is less than that of any other site shows that the rocks in the overburden layer has been altered because of the geothermal activity.

The extent of the second layer of the very low resistivity zone (1 ohm-m) found in Kuju-Iwoyama can not be determined by only ELF-magnetotelluric method. Because the depth of investigation is insufficient. From the result of ULF-magnetotelluric sounding, the bottom of this low resistivity zone is defined at 800 to 1500m depth. According to Ehara and Bito 1988, it is estimated that the hot water convective zone extends to 1500m depth by observation of micro-earthquake activity. Based on these results, the low resistivity zone below the Kuju-Iwoyama area is interpreted as the hot water convective zone.

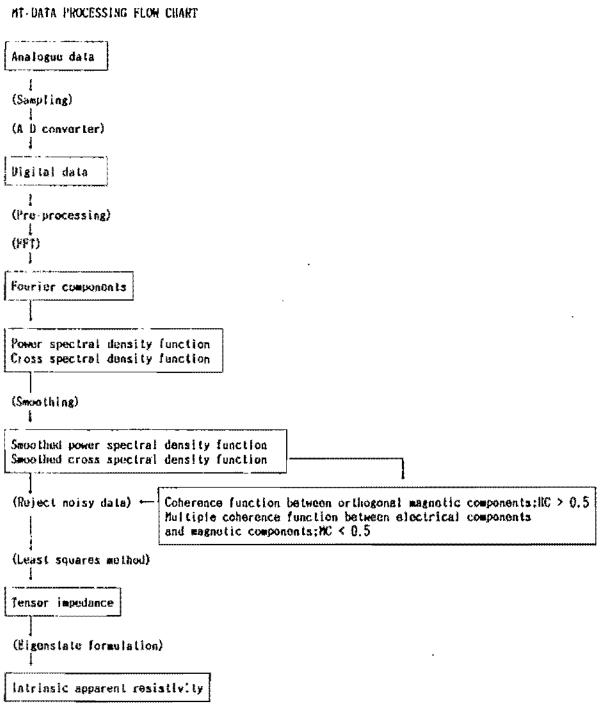

Fig.3. Flow chart of data processing

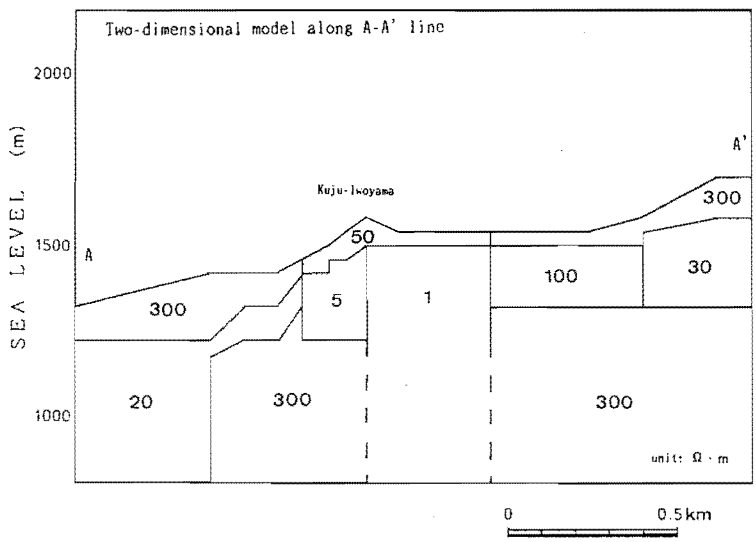

Fig.4 Two-dimensional resistivity model for the Kuju-Iwoyama area.

(Notations)

ω ; Angular frequency
μ ; Permeability
Z ; Tensor impedance
$\rho^{\pm}$; Intrinsic apparent resistivity values
$\lambda^{\pm}$; Eigen values of Z
$E^{\pm}$; Eigen vectors of the electric field
$\psi^{\pm}$; Principal direction of Z

(References)

Eggers, D. E., 1982, An eigenstate formulation of the magnetotelluric impedance tensor; Geophysics, v.47, P.1204-1214.

Ehara, s. and Bito, T., 1988, Seismic activity and underground structure of Kuju-Iwoyama (in Japanese); Rept. for the sci. res. fund from the Ministry of Education, No.61460194, P.1-23.