GEOTHERMAL STRUCTURE OF KUROBE HOT DRY ROCKS, CENTRAL JAPAN

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INTRODUCTION

In the middle reaches of the Kurobe River, Central Japan, there is a well-known geothermal area. During the construction of the tunnel of Kurobe Jobu Railway between Sennin-dani and Azohara Spa, the temperature in the tunnel increased and at last reached over 160°C of wall rock temperature (Matsui and Yoshida, 1962). There were not so many hot springs and fumaroles in the tunnel, therefore, the rock body is considered to be so-called "hot dry rocks". Temperatures of the wall surface show 98°C at maximum even now, and their high values correspond to a fracture zone of the rock body.

MT SURVEY

To clarify the geothermal structure of Kurobe hot dry rocks, the ELF- and VLF-MT soundings were carried out at 55 sites which lay near the hot-spring and geothermal area (Fig. 1). The geologic framwork of the Kurobe granitic body is characterized by granitic lith-facies (Ogata et al., 1983). The rock facies are distinguished as granodiorite, quartz diorite and porphyritic fine granodiorite. The Kurobe River flows through the central portion of the granitic body. The river bed and its western mountain slopes are underlain by granodiorites, while the eastern slopes are underlain by granodiorites and quartz-diorites. The Kurobe geothermal area is situated in the eastern marginal zone of granodiorites.

ELF-MT method measures natural electromagnetic waves at three frequencies in the Schumann resonant frequency band from 7.8 to 20.4 Hz, and also measures the VLF band at 17.4 kHz. The surveyed area is shown in Fig. 1.

The ELF-MT system used in the present study is almost the same as used by Handa and Sumitomo (1985), and consists of a magnetometer, a telluric amplifire and voltagemeter. Telluric and magnetic fields are amplified and selected waves are taken out by band-pass filters which hace peak responses at frequencies of 7.8. 14.0, 20.4 Hz and also 17.4 kHz.

H-polarization or TM mode (i.e. telluric field is perpendicular to the strike of the resistivity discontinuity) and E-poralization or TE mode (i.e. telluric compornent is pararell to the strike of the discontinuity) was not clear in this survey, and so the E-W telluric and N-S magnetic fields, and also the N-S telluric and E-W magnetic fields are observed.

The procedure for interpretation of the resitivity structure is shown in Fig. 2. An interpretation is made through two steps as usual. In the first step, assuming a two- or three-layered model, one-dimensional resistivity dustribution is obtained by inversion of the observed apparent resistivity result for each sounding. For this purpose, resistivity and thickness of the

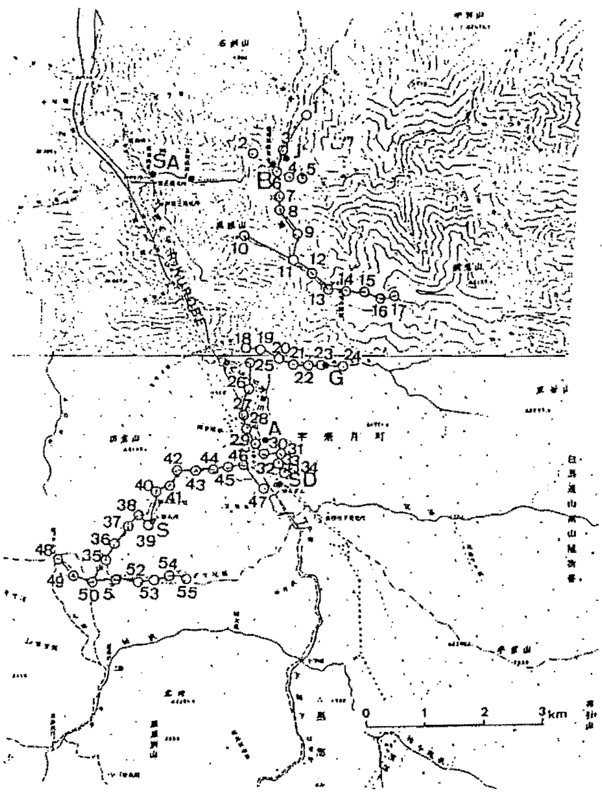

Fig. 1. Location of the MT sounding sites in Kurobe geothermal area. SA: Sarutobi Spa; B: Babadani Spa; J: Jijidani Spa; G: Gakidani Spa; A: Azohara Spa; S: Sennin Spa.

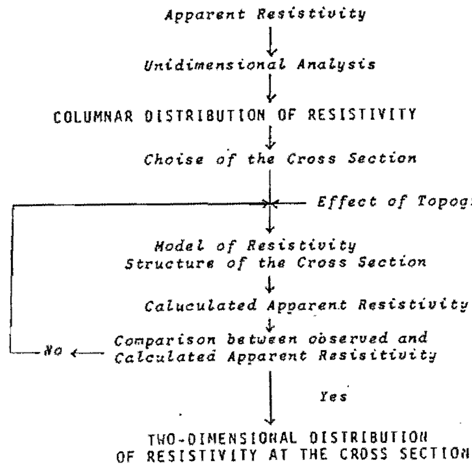

Fig. 2. The procedure of calculation of two-dimensional resistivity model.

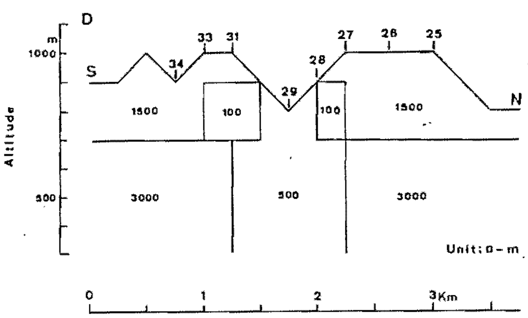

Fig. 3. The resistivity structure along Section D.

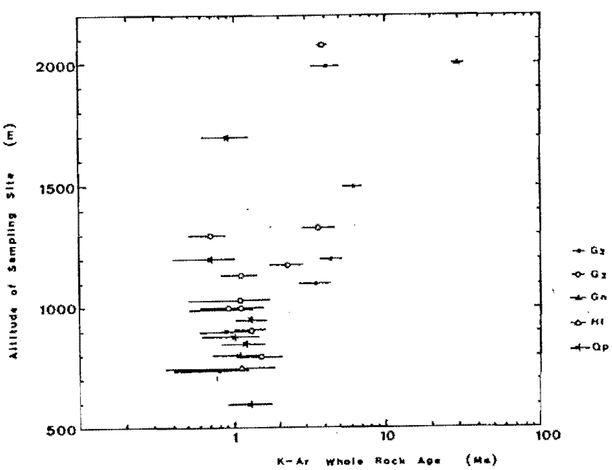

Fig. 4. The relation between radiometric ages and altitude of sampling sites. G_2: Granodiorite; G_3: Quartz diorite; Qp: Quartz porphyry; Hf: Hornfels; Gn: Gneiss.

topmost layer obtained by the an additional 17.4 kHz sounding. Determining the values of the topmost layer is also useful because the H-poralization response is greatly influenced by near-surface variations.

In the second step, a two-dimensional inversion process is performed. An initial two-dimensional model is constructed from the one-dimensional models obtained for each site in the first step.

The two-dimensional model for typical section D is obtained as shown in Fig. 3. Section A shows that the low resistivity zone is located at the Babadani Spa which is the junction of Babadani and Jijidani. The low resistivity in Section B is located along the quartz diorite. The low resistivity part in Section C is extended from the steam valve tower at Gakidani to upper reaches of this valley. This zone has about 1 km width and is situated at altitudes between 600 to 900 m. In the Section D (Fig. 3), a low resistivity prism is observed at Azohara showing more low resistivity in shallow parts. At Sennin Spa, the shallow low resistivity part is found. The narrow low resistivity part at the Section F is also observed.

The resistivity areas are found around hydrothermal reservoir and alteration part in geothermal area (Onodera, 1976). The character of geology of hydrothermal reservoir around geothermal area is accompanied by high temperature, porous layers filled up with ionic hydrothermal water and clay minerals originated from hydrothermal alteration. But in this region, only granitic rock bodies are observed and clay mineral are not so much.

In the Kurobe geothermal area, the resistivity of rocks are 50-200 ohm-m which indicates that the porosity of bodies are about 10% with few hydrothermal alteration, and thus low resistivity layers are very shallow and like sheets under the surface.

COOLING HISTORY

To clarify the heat source of this geothermal area, isotopic cooling curve for Kurobe granitic body was investigated. The study has resolved the thermal history of the Kurobe granitic body.

The granitic body emplaced into Hida gneiss. At the northern outer part of this body, the K-Ar whole-rock age is 50 Ma (Nozawa, 1975). The ages of these granitic rocks are given in Fig. 4. The oldest age in the surveyed area obtained for the granodiorite is 30 Ma at Kuranosukedani. On the other hand, the K-Ar whole-rock ages of quartz porphyry dike ate 0.7-1.3 Ma. The K-Ar whole-rock ages for granitic rocks range from 0.7 to 1.Ma, as shown in Fig. 4.

Hornblende and biotite K-Ar ages of granodiorite samples at Sennindani determined are nearly concordant at 5.7 ± 1.4 and 5.0 ± 0.8 Ma, respectively (Ogata et al., 1983). The whole-rock K-Ar ages of the granodiorite are concordant around 1 Ma. Beside the age of the granodiorite, a wide range of ages between 0.3 to 6.1 Ma are related to the altitudes of sampling sites, as shown in Fig. 4. Especially, the ages of granodiorite samples around the geothermal area have a close relation to the altitude of sampling sites (Fig. 5).

The relation between K-Ar whole-rock ages of these samples and altitudes of sampling sites around Sennindani are shown in Fig. 5. In this figure, the thermal history of Kurobe geothermal area approximates the cooling history of infinite tabular pluton without differential uplift.

CONCLUSIONS

Combining these studies several conclusions can be drawn as follows:

(1) Low resistivity layers are found at depths of less than 300 m beneath the surface.

(2) Some hot-springs are found along the Kurobe River and these resorviors are shallow, having sheet-like structures.

(3) The chemical geothermal results obtained from the hot-springs give the temperature of about 160-180°C at the source. From these results, the temperature of the central part of the Kurobe granitic body is estimated as around 200-250°C.

(4) The K-Ar ages of the granitic rocks around the Kurobe geothermal area have a close relation to the altitudes of the sampling sites. From mathematical interpretation of this relation, the cooling history of this granitic body can be inferred.

These facts that the high temperature of the central part of the Kurobe rock body is resulted from the residual heat of the central part of this body; therefor, the Kurobe geothermal area is so-called "hot dry rocks".

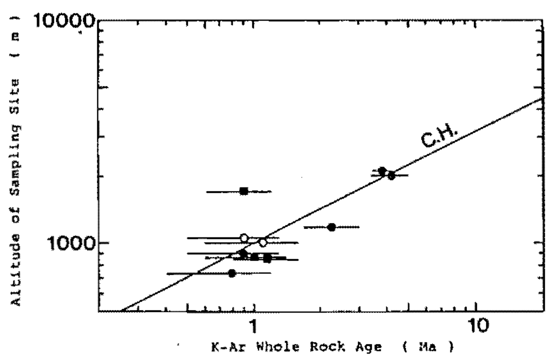

Fig. 5. The relation between K-Ar whole-rock ages and altitude of sampling site along Sennin-dani, near Kurobe geothermal area.
Solid circle: Granodiorite; Open circle: Quartz diorite;
Solid square: Quartz porphyry; C.H.: Theoretical cooling history indicated by infinite tabular pluton without differential uplift.