THERMAL HISTORY OF THE AKINOMIYA-OYASU GEOTHERMAL FIELD, NORTHEAST JAPAN

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ABSTRACT

The age of hydrothermal activity is rarely identified because the method for such alteration dating are limited. However, recent **progress** in the thermoluminescence (TL) dating method can easily get the time of alteration events. It is considered that the ages give **us** new ideas about geothermal activity that can be used for geothermal exploration.

Fifty-six alteration ages are obtained by TL method for the Akinomiya-Oyasu geothermal area. The age range of alteration is 0.004 to 4.26Ma. The north part of study area is characterized by old alteration ages and not attractive for geothermal exploration. Many young alteration halos are developed in southern part. However, the youngest alteration age do not coincide with the highest temperature reservoir area. The reason for this disagreement is the effect of shallow fluid flow.

The area has regionally developed Tertiary alteration zones and locally developed Quaternary ones. Underground temperature can be estimated by surface alteration age data. At 1000m depth, expected temperatures are 160°C, 130°C and 90°C for surface alteration ages of 0.2Ma, 0.5Ma and 0.8Ma, respectively. This temperature estimation is affected by the intrusion of a new heat source at around 0.25Ma. A depth of around 5km is expected for the top of the new heat source based on the age of intrusive rock and conductive heat transfer.

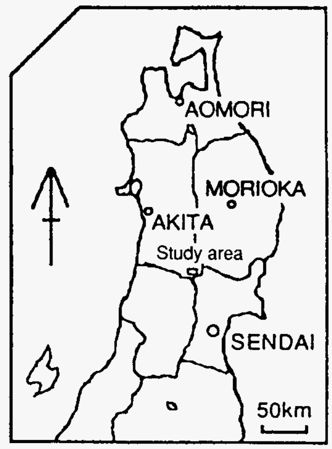

Fig. 1 Location of study area.

1. INTRODUCTION

Alteration halos play an important role in geothermal exploration and are intensely studied by mineralogical methods. However, mineral data can not give us any information about the time of hydrothermal events. Thermoluminescence (TL) dating of altered rocks gives **us** the time markers for hydrothermal activity.

In this paper, the relation between alteration age and underground temperature is discussed. Then the long range thermal history of the area is inferred. Akinomiya-Oyasu (Fig. 1) is one of the best places for such study because the area is intensely surveyed for the development of geothermal power plants and many data can be used for reference.

2. OUTLINE OF GEOLOGY AND GEOTHERMAL ACTIVITY

The area is located in the Ogachi caldera which formed in Late Pliocene (Takeno, 1988). Surface distribution of Pre-Tertiary basement limited to only the southwest part of the area but basement is widely dismbuted at -500m sea level.

A conceptual model of geothermal geology is shown in Fig. 2 which was presented by NEDO (1990). It summarizes many data for geothermal exploration such as geological survey, gravity analyses, resistivity survey, well logging and *so* on. As Fig. 2 shows, the area is characterized by horst-graben type geologic structure. The geology of south upheaval zone is Pre-Tertiary granite, gneiss and schist, Tertiary volcaniclastics and Quaternary dacite lavas with an age around 0.2Ma . The geology the of north subsidence zone is Tertiary volcanicrastics, Tertiary lacustrine deposit and Quaternary dacite domes/pyroclastics with an age of about 1-2Ma. Fractures of N-S, NW-SE and NE-SW directions are predominant, and N-S fractures were formed by the oldest movement.

Many thermal manifestations are recognized in this area, known as one of biggest geothermal areas in Japan. Presently, one 27.5MW geothermal power plant **is** operating at Uenotai, and, Hot Dry **Rock** experiment is going on northeast of Akinomiya. Heat sources are expected south of the area and the most prospective area is located in transitional zone between the horst and graben. The Uenotai geothermal power plant is located in such transitional zone.

3. DATING PROCEDURE AND RESULTS

Basic age data for historical consideration were obtained by TL dating method which is applied both volcanic rocks and alteration minerals. TL dating is an application of dosimetry using natural minerals. Minerals in the field absorb radiation from surrounding radioactive materials and cosmic rays at a fixed rate (annual dose is denoted by AD) and exhibit TL due to a total dose over geologic time, known as an equivalent dose (ED). The AD was calculated from the chemical data of radiogenic elements (U, Th, K) and cosmic ray evaluation. The **ED** was determined from the TL glow curves obtained from both natural and artificially irradiated samples. The TL age (t) is calculated by the simple equation, t=ED/AD. Figure 3 is the schematic explanation of TL dating method.

The experimental procedure of TL dating was described by Takashima and Honda (1988). Accordingly, their procedure is roughly explained. Mineral used for dating is quartz because it gives reliable age data. Samples are collected from unearthed and uniform areas. Such samples are dried at room temperature in the dark. Then 320-400g of the sample was crushed by a stainless mortal and/or ball mill, and sieved to pass 20 mesh. Then 290g of it was put in a plastic container for counting in a gamma ray spectrometer. **A** part of the 20 mesh sample was again crushed to get 80-200 mesh grains. After water washing, the grains were separated into magnetic and non magnetic portions by **an** isodynamic separator. The non-magnetic grains were treated by both 24% HF solution and HCl(1:1) for about 20 min. at 50°C each. The weight of sample was 10-50g in average, which was adjusted so as the final products becomes 0.5-1g. It is desirable to use aluminum sheets to keep the separated sample from exposure to light.

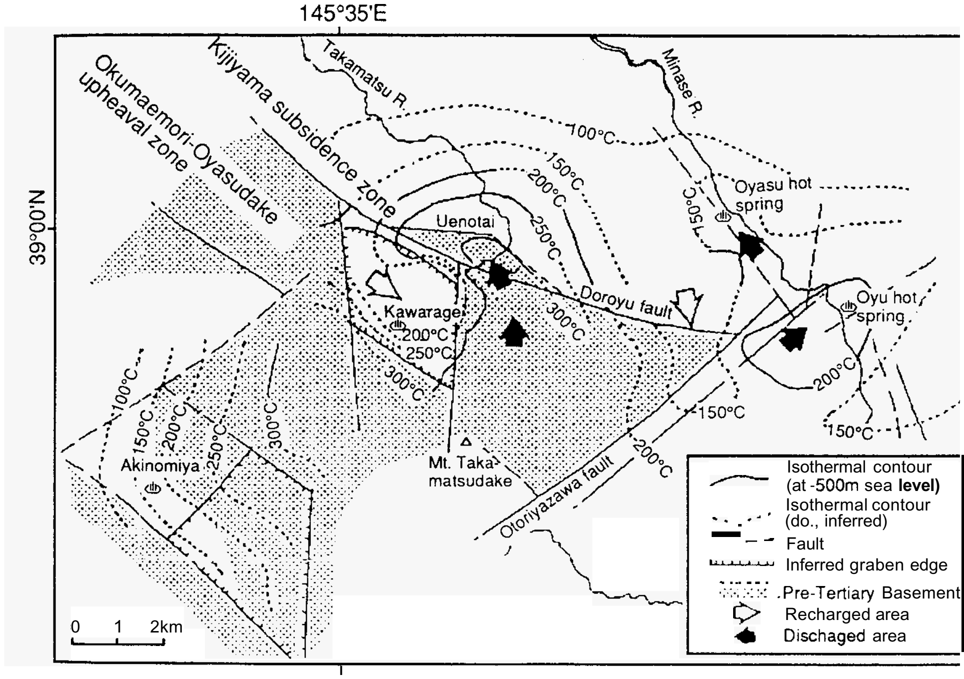

Fig. 2 Idealized model of geothermal geology at Akinomiya-Oyasu area (after NEDO, 1990).

The TL emission was measured by using the Kyokko 2500 TLD Dosimeter with the heating rate of 200°C/min. Twenty milligrams of the sample was set in the molybdenum heater with 10mm diameter pit. Two filter systems were used. One was infrared filter (Toshiba IRA-10) only and the other was infrared filter plus long wave pass filter (ESCO Products OG-590). Receiving wavelength of the former was 300-700nm and that of latter was 590-700nm. Basically, the latter filter system is used in measurement because the red color signal is high temperature and stable (Hashimoto *et al.*, 1987). The former filter system is used for the samples which only have blue light emission. Measurements were carried out for natural and gamma ray irradiated samples. Figure **4** is an example of TL glows of natural and gamma ray irradiated samples. Based on these data, equivalent dose (ED) is calculated. The average number of measurements for each sample is three and an error in equivalent dose was 10 to **20%.**

Chemical analyses were done by gamma ray spectrometry. The detector is a 76x76mm NaI scintillator crystal. Error **of** U and Th measurements is less than 10%and that of **K** is less than 3% in 24h operation and using NBS standards. Annual dose was calculated from the data proposed by Bell (1979) and water calibration introduced by Aitken (1985, p.75). Beta dose attenuation is roughly done for all samples with the data of Mejdahl (1979). Contribution **of** cosmic ray is neglected because the sample was buried in deep part at almost all geologic time and it received very low cosmic ray.

In this paper, 56 altered samples collected east part of Akinomiya-Oyasu area are used for TL dating. All data are plotted on Fig 5. The estimated TL errors are about 20-40%.

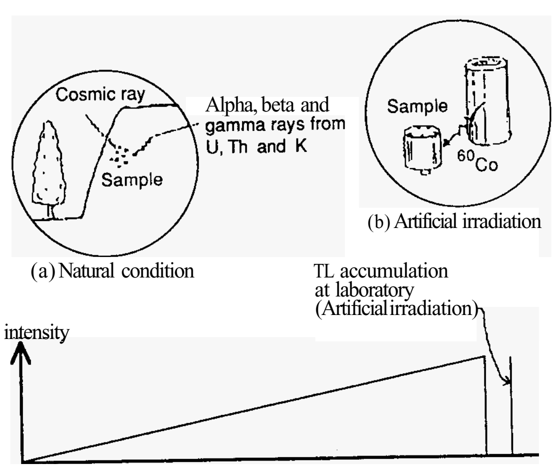

Fig. **3** Schematic explanation of TL dating.

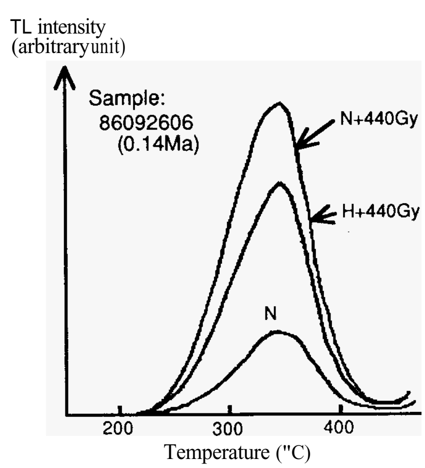

Fig. **4** TL glow curves of quartz separated from altered rocks.

4. DISCUSSION

4.1. Distribution of alteration zones and their ages

Alteration of this area is characterized by widely developed green colored zones and locally developed white colored zones (NEDO, 1988;Kimbara, 1985; Nakata and Takashima, 1992). Most of green colored alteration occurred in Tertiary time and has not been affected by Quaternary volcanic rocks. Accordingly, most of samples are collected from east part of the area because west part is covered by Quaternary volcanic rocks. Only few samples are collected from white colored alteration halos in that area.

Figure **5** is a distribution map of all TL age data of altered rocks. Clear discrimination found in Fig. **5** between the distribution of old TL ages in northern part and young TL ages in southern part. It is clear that the alteration ended around 0.6Ma **or** more in the northern part. The youngest alteration age is 0.56Ma for sample No.2. It corresponds to low underground temperature measured in MS-1 (78.5°C at 1000m depth; **NEDO,** 1990).

Even in the southern part, all TL ages are not young. For example, old TL age of 0.71Ma (sample No.50) is found near very young sample No.48 (0.009Ma). It indicates that the young alteration zones found in the south were not formed regionally but due to local hydrothermal activity. One such local fluid flow is traced along upper stream of the Minase river, southeast of study area. Relatively young TL ages are also found along the big fault crossing the southern part with the direction of WNW-ESE. The age of 0.18Ma for sample No.16 must be the effected by fluid flow through that fault.

It is not **so** easy to decide reservoir locations by this TL age distribution only. Based on the TL age distribution, southeast part is identified as the most hopeful area. However, drilling defined the an actual reservoir of the highest temperature in the west part of the young TL age concentration area. Of course, few young TL ages are recognized such area, but it is difficult to point out prospective zones by TL age data only. One reason causing this result are luck of samples because such area **is** covered by Quaternary volcanic rocks. **As** a conclusion, TL age data must be used carefully with combination to other exploration results.

4.2 Thermal history

This area is characterized by a combination of regional hydrothermal activity in Tertiary time and local recent fluid flow. These two different thermal effects can be traced by the relation between subsurface temperature profiles obtained by exploration wells and alteration ages of surface rocks at the drilling points. In this study, only three exploration wells, MS-5, MS-7 and YO-1, have such data.

Figure 6 is the relation between bore hole temperature of different depths and alteration ages at the surface of the drilling sites. In case of regional alteration, subsurface temperatures are in accordance with surface alteration age **of** drilling **points** (Takashima and Honda, 1988). In this area, temperatures at the 1000m depth are estimated to be 160°C, 130°C and 90°C **for** MS-5, MS-7 and **YO-1** points, respectively. It is also recognized that the MS-7 temperature profile up to 1200m is different from those at 500m or 100m depth (The differences in 700m and 800m are considered to be caused by the local fluid flow). This means that the subsurface temperature of MS-7 is boosted by new heat source. As Fig. **4** shows, MS-7 is located at the margin of high temperature zone. This corresponds to such assumption.

Figure 7 is the idealized model of thermal history of this area. The heat source causing regional alteration is considered to be dacitic magma of Tertiary age that heated the whole area uniformly because the area was self-sealed by alteration and conduction heat transfer became predominant. The center of the heat source must be located beneath the MS-5 site because the TL age is the youngest of the three points (Fig. 7-a). Cooling rate must be different at place to place based on the distance from heat source. The YO-7 point was first cooled down to 50°C which is the start of TL age counting (Takashima and Reyes, 1988). The time for such cooling at YO-7 was around 0.8Ma (Fig. 7-b). Then the MS-7 and MS-5 points became 50°C around 0.5Ma and 0.2Ma, respectively (Fig. 7-c, d). A new heat source came up beneath the west of MS-7 well site (Fig. 7-e). That heat source has changed the underground temperature profiles.

An age of around 0.25Ma is inferred for intrusion of a new heat source because TL dates of the newest volcanic **rocks** are 0.21-0.26Ma (Takashima et al., unpublished data). Based on the equation of Lachenbruch and Sass (1977), conduction length is calculated as

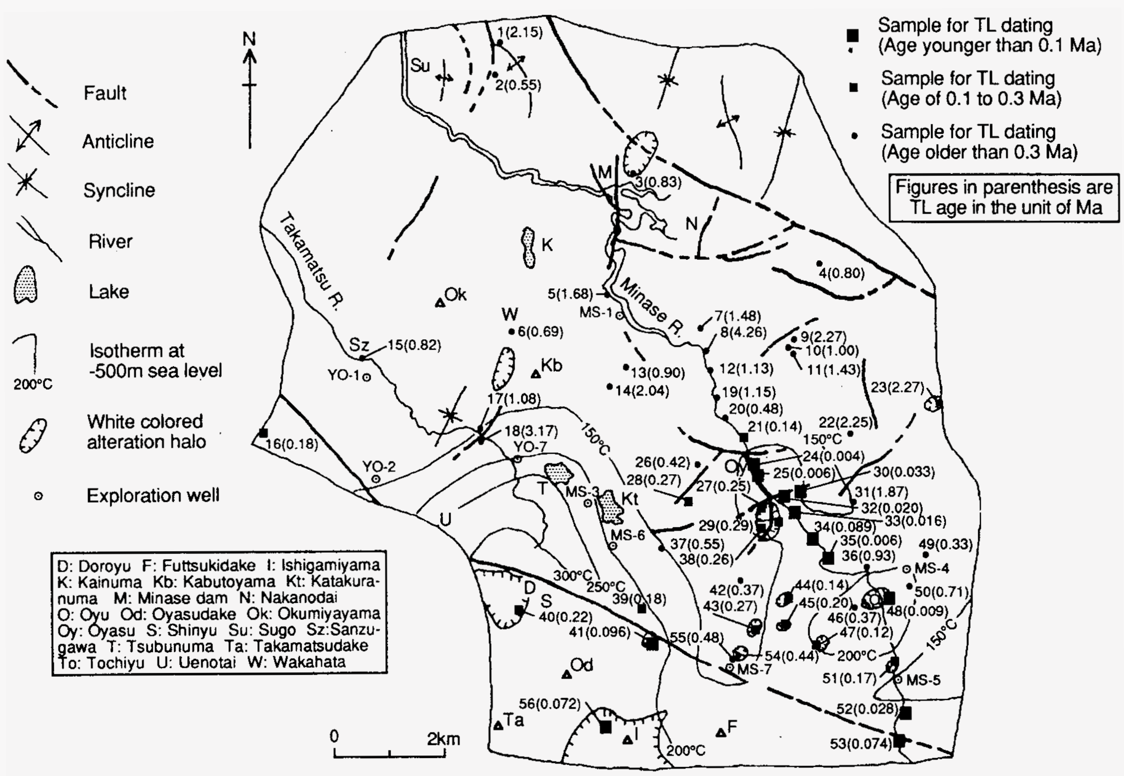

Fig. 5 TL age data with geological and geothermal data.

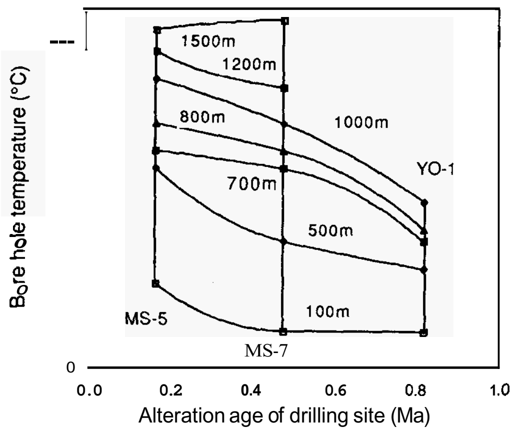

Fig. 6 Relation between surface alteratin age and subsurface temperature.

4km from the 1200m depth of MS-7 well (heat dispersion coefficient is assumed to $7x10^{-7}m^2/s$). Accordingly, the depth of the top of new magma is roughly estimated around 5km. The intrusion of new magma is also expected by the fluid inclusion study of bore hole cores (Takenouchi and Okada, 1984). In such fluid inclusion measurements, the highest temperatures are lower than measured bore hole temperature. It may indicate that the area is presently in the process of heating.

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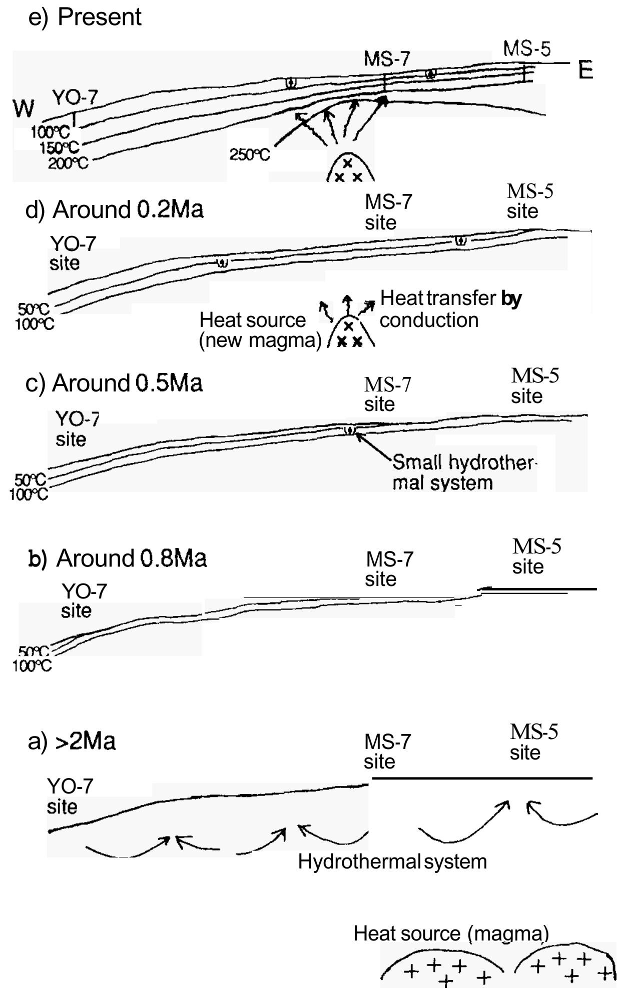

Fig. 7 Model of thermal history of Akinomiya -Oyasu area.

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*in Japanese with English abstract.