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Preliminary study on the thermoluminescence dating of altered rocks in the San Kamphaeng geothermal field, northern Thailand

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Abstract: Ages for six altered samples from the San Kamphaeng geothermal field were obtained by a thermoluminescence (TL) dating method. This is the first report on the determination of alteration age of Thai geothermal fields (because of low closing temperature in TL dating, obtained ages indicate those of alteration).

Obtained ages range from 0.11±0.03 to 0.84±0.25 Ma for six samples collected in and around the thermal manifestation area of the San Kamphaeng geothermal field. The youngest two samples are located around GTE-2 well which shows very high temperature in shallow part (about 85°C at the depth of 10 m). A possibility is posturated for the continuous hydrothermal activity for over 1 Ma, because the source of Thai geothermal fields is considered to be a deep circulating hydrothermal system and as eliminating sporadic igneous activities.

1. Introduction

Thermoluminescence (TL) is an unique technique for age determination. This method has been applied to many samples such as volcanic rocks, loesses, meteorites, fault fillings, altered rocks etc. (MAY, 1977; LI et al., 1977; SEARS and DURANI, 1980; TAKASHIMA, 1985).

In the case of geothermal fields, TL dating has many advantages in the range of dating (a few thousands to about one million years) and easy sample selection (quartz phenocrysts or secondary quartz in volcanic and altered rocks). From the age data of altered rocks, hopeful area can be selected and longevity of hydrothermal activity can be evaluated.

In this paper, duration and character of hydrothermal activity of the San Kamphaeng area (Fig. 1) is discussed based on the TL age data of altered rocks.

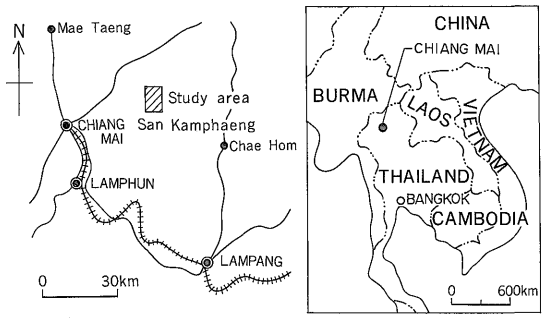

Fig. 1 Location of the San Kamphaeng geothermal field.

2. Basic theory and experimental method

The basic theory of TL dating is explained in Fig. 2. The TL age is determined by the equations shown in Fig. 2. The equation (1) in Fig. 2 means that the unit TL intensities of natural sample ($r \cdot t/a$) and artificially irradiated sample ($R \cdot T/A$) are the same. Then equation (2) in Fig. 2 is obtained. However, TL intensity measured for natural sample is not theoretical but reduced by fading. If the rate of (a/a') in Fig. 2 equals (k), then TL age (t) is calculated by the following equation:

$$t=(R \cdot T \cdot a' \cdot k)/(r \cdot A).$$

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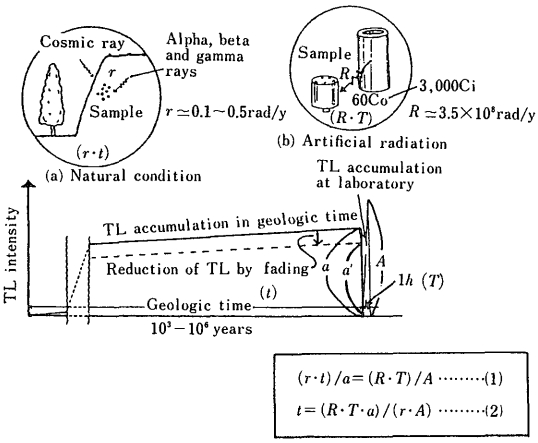

Fig. 2 Schematic diagram of TL dating.
(After TAKASHIMA and HONDA, 1985)

Where, (r) and (R) are the intensities of radioactivity in the rocks and in the laboratory (artificial irradiation), (a') and (A) are the measured TL peak heights of natural and artificially irradiated samples, respectively, and (T) is the time of artificial irradiation.

The value of (k) is determined by using standard samples for ages. Obtained (k) value is 2.3 (TAKASHIMA and HONDA, 1985) and all TL ages are calculated using this figure and the equation mentioned above.

As the procedure of TL dating has been already reported (TAKASHIMA, 1985), only the basic process is described below.

(1) About 0.2 g of 100–200 mesh quartz were selected.
(2) TL glow were measured for three kind of samples (natural, artificial and gamma-ray added).
(3) Annual dose rate is calculated by the data of chemical analyses of U, Th and K_2O.
(4) TL ages can be determined by the equation mentioned above with (k) value of 2.3.

A range of error is roughly estimated as about ±30% which include the whole processes of TL dating.

3. Sample collection and description

As shown in Fig. 3, all samples are collected in and around the thermal manifestation area which is identified to be the highest grade of alteration zone (K 1 zone) (CHUAVIROJ et al., 1987) except one sample (S–14) which is collected from SH 1 alteration zone.

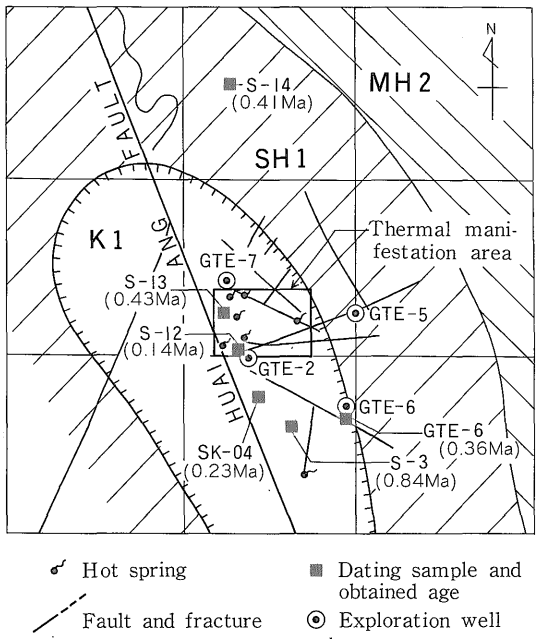

Fig. 3 Sampling location of TL dating.
Major alteration minerals of K 1 zone are kaolinite, quartz and sericite, SH 1 zone are sericite, halloysite and quartz, and MH 2 zone are montmorillonite and halloysite (refer to CHUAVIROJ et al. (1987) for details of alteration).

Sample No. 1 (GTE-6) was taken from GTE-6 well at the depth of 0 to 10 m. This sample is strongly altered and composed of quartz, sericite and kaolinite as the secondary minerals. The original rock is tuffaceous shale of Permian age.

Sample No. 2 (SK-04) was collected from altered part of Permian sandstone. Strongly altered part is restricted along the bedding planes (Fig. 4). The mineral paragenesis of this sample is quartz, kaolinite, sericite and feldspar.

All of the samples Nos. 3 (S-3), 4 (S-12), 5 (S-13) and 6 (S-14) are strongly altered rocks. The mineral paragenesis of these samples is quartz, sericite and kaolinite (S-3, S-12, S-13), and quartz, sericite and halloysite (S-14), respectively. In addition, minor amount of feldspar and montmorillonite is recognized in S-12 sample. The original rocks of these

Fig. 4 Occurrence of altered sandstone (SK-04) for TL dating.

samples are tuffaceous shale of Permian age.

4. Results

Table 1 is the summary of TL dating of six samples. Chemical analyses of radiogenic elements were carried out by the X-ray fluorescence method. The analytical error of K_2O is ±5%, and that of U and Th is ±30%. The ±30% error in U and Th do not affect too much to the final ages obtained, because the contribution of these two elements to total (annual) radiation dose calculation is small (BELL, 1979). The (T) in Table 1 is (r) in Fig. 2 normarized to one year. The (R·T) in Fig. 2 is fixed to 40 krad in this experiment.

Fig. 5 is the glow patterns of selected two samples. Exsistence of high temperature peak of 420°C and similarity of peak patterns among natural, gamma-ray added and artificially irradiated samples indicate high reliability of the measurement as described in previous paper (TAKASHIMA and HONDA, 1985).

All samples show TL saturation. In order to evaluate this effect, a graphycal technique is applied (Fig. 6). The accuracy of this method is not so high because the data points are limited. However, the ages without inequality can be obtained.

All ages in Table 1 indicate the time of the end of hydrothermal activities, because the TL of them had been discharged by the heat of alteration and started to accumulate new TL after alteration. The reset temperature of TL is function of TL peak temperature and preserved one. For the studied samples (TL peaks are around 420°C), reset temperatures are roughly estimated about 100°C, if the 600 years duration of hydrothermal activity is considered. All samples might have suffered higher temperature and activity of longer duration mentioned above.

As shown in Fig. 3, the youngest alteration ages (0.11±0.03 Ma for S-12 and 0.23±0.07 Ma for SK-04) are obtained for the samples collected near GTE-2 well which shows very high temperature (about 85°C at the depth of 10 m) in shallow part (RAMINGWONG and PRASERDVIGAI, 1984). Ages of other samples are older than 0.36±0.11 Ma. Three of them are concentrated in the range from 0.36±0.11 to 0.43±0.13 Ma and the oldest age is 0.84±0.25 Ma for S-3 sample.

Table 1 Summary of TL dating of altered rocks

No.	Sample No.	U (ppm)	Th (ppm)	K_2O (%)	(T) (rad/y)	TL glow height (cm) Original (A)	Gamma-ray added (B)	Artificial (C)	Saturation (B-A)/C	Specific TL A/C/T	TL Age (Ma)	Saturation corrected TL Age (Ma)
1	GTE-6	1	10	5.72	0.6386	0.90	1.01	0.40	0.27	3.57 > 0.31		0.36 ± 0.11
2	SK-04	2	15	4.33	0.5802	2.52	3.19	2.04	0.33	2.14 > 0.19		0.23 ± 0.07
3	S-3	2	6	1.86	0.2869	1.20	1.38	0.51	0.35	8.20 > 0.72		0.84 ± 0.25
4	S-12	2	6	1.29	0.2358	0.28	0.80	0.71	0.72	1.67 < 0.15		0.11 ± 0.03
5	S-13	4	11	3.82	0.5547	1.09	1.32	0.42	0.55	4.68 > 0.41		0.43 ± 0.13
6	S-14	3	8	2.88	0.4203	0.43	0.48	0.32	0.16	3.19 > 0.28		0.41 ± 0.12

T : Total radiation dose in calculated by the data of BELL (1979) as the contribution of alhpa radiation equals zero and 0.02 rad/year of cosmic ray.

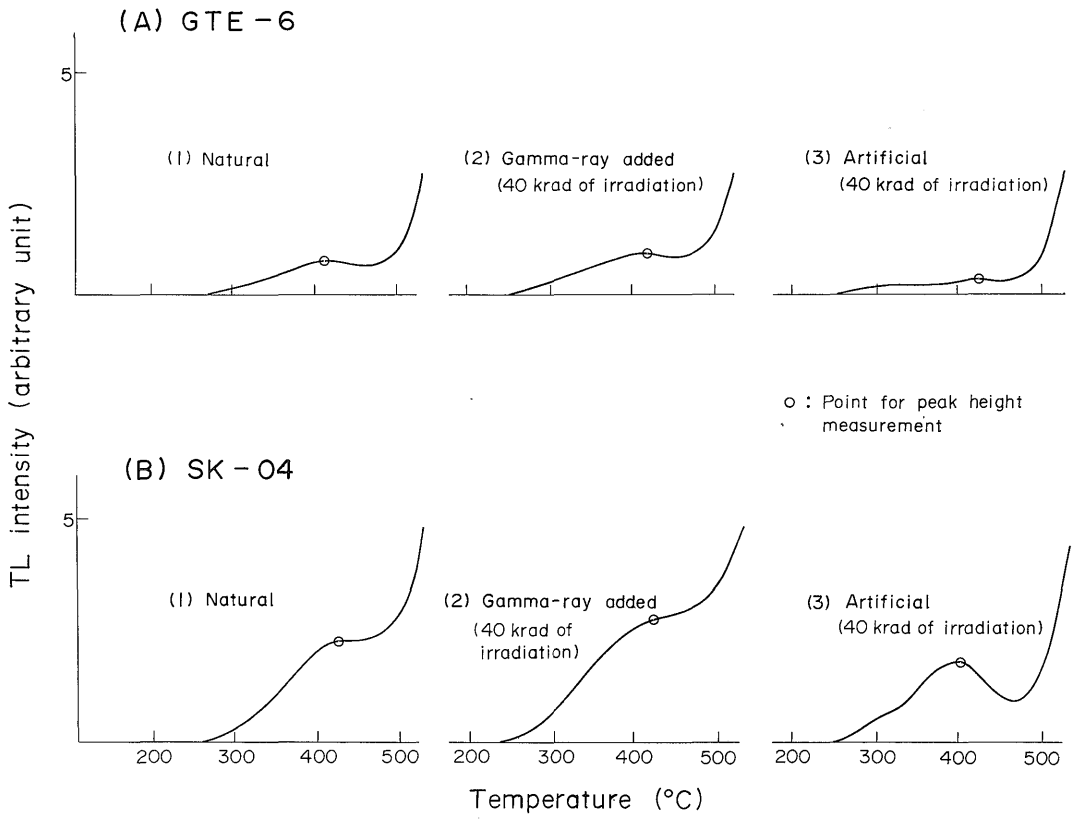

Fig. 5 TL glow curves of two altered samples.
Mineral for measurement is separated quartz with minor amount of sericite as an impurity.

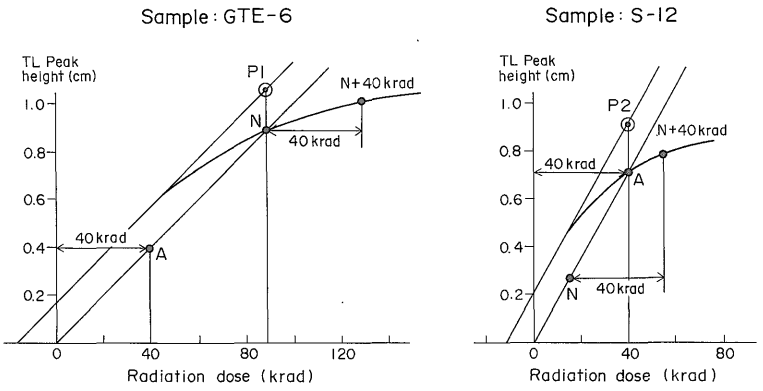

Fig. 6 Graphical correction of TL Saturation.
A : Artificially irradiated sample N : Natural sample
P1 : Saturation corrected TL peak height for natural sample
P2 : Saturation corrected TL peak height for Artificially irradiated sample

5. Discussion

Present data is the first but preliminary one of alteration age in the San Kamphaeng area. It is difficult to go into further detailed discussion based on only six age data. However, a few interesting points are inffered.

It is estimated that an intense hydrothermal activity around 0.40 Ma ago and that the hydrothermal activity in this area had started at more than 1 Ma ago. There is no answer for the activity between measured TL ages and the present thermal activity. In the volcanic-type geothermal areas, sporadic hydrothermal activities are recorded. For example, at least two different activities, that is, older than 1 Ma and present time are recognized in the Matsukawa and Kakkonda areas, Northeast Japan (TAKASHIMA and HONDA, 1986). However, hydrothermal system of the San Kamphaeng area is considered as a deep circulating non-volcanic type and may not be related to sporadic heat source. Accordingly, a possibility is posturated for the continuous hydrothermal activity from about 1 Ma to present.

The TL ages may become a tool for the geothermal exploration because the locations of the youngest two samples (S-12 and SK-04) correspond to the area where the highest temperature well (GTE-2) is located.

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タイ北部サンカンペン地熱地域の変質岩の熱ルミネッセンス年代測定に関する予察的研究

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要　旨

地熱活動の開始あるいは継続期間を求めるため，サンカンペン地域の地熱変質岩6個の年代測定を行った．得られた年代値は0.11から0.84 Ma（TL飽和補正値で，TL年代測定法の原理から変質年代を示す）である．

11万年あるいは23万年という比較的新しい年代値を示す試料は，本地域で掘削された最も高温の調査井の近くから得られており，変質岩のTL年代が地熱探査に有効であることを示している．

古い年代値としては84万年（1試料）及び40万年前後（3試料）が得られ，それらの時代にも地熱活動のあったことが確かめられた．これらの活動が連続していたものか，あるいは単発的に生じたものかの区別は今回のような少数のデータから求めることは困難である．しかし，この地域の地熱は火山のような単発性熱源を必要としない深部循環型非火山性地熱と考えられており，その特徴として長期間の連続活動が推定される．

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