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Soil gas and alteration of the San Kamphaeng geothermal field, northern Thailand

Saengathit CHUAVIROJ*, Khanpong CHINGCHIT* and Isao TAKASHIMA**

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Abstract: First soil gas survey of radon (Rn), carbon dioxide (CO_2) and mercury (Hg), and alteration study for a Thai geothermal field were carried out in the San Kamphaeng area. High anomalous zones of all soil gases except CO_2 were concentrated in the thermal manifestation area and along a major fault in this area. In a case of alteration, kaolinite 1 (Kl) zone (mineral paraganesis is kaolinite, sericite and quartz) overlaps to the high anomalous zones of soil gas survey. From these data, it is concluded the soil gas survey and alteration study are applicable for non-volcanic Thai geothermal fields.

1. Introduction

San Kamphaeng (Fig. 1) is one of the most hopeful geothermal areas in Thailand and JICA (Japan International Cooperation Agency) project is conducting (RAMINGWONG and PRASERDVIGAI, 1984). Accordingly, many studies such as geological mapping, chemical analyses of hot spring waters, resisitivity and seismic survey etc. were carried out (CHUAVIROJ et al., 1980; THIENPRASERT and RAKSASKULWONG, 1980; RAMINGWONG et al., 1980). Recently, some exploration wells up to 1500 m were drilled (JIVACATE, 1985). However, no soil gas survey have been done in the San Kamphaeng and other geothermal fields in northern Thailand.

Rock alteration is also an usefull tool for geothermal exploration and was applied to this field (SOPONPONGPIPAT et al., 1984). However, no detailed discussion on the mineral paragenesis and application to geothermal exploration have been done.

In this paper, the data of above studies (most of them are first application to the Thai geothermal field) are described and the results were discussed with reference to other exploration data.

*Geological Survey Division, Department of Mineral Resources, Thailand
**Research Institute of Natural Resources, Mining College, Akita University, Japan

2. Methods

2.1 CO_2 survey

Carbon dioxide contents of 84 points were measured around the thermal manifestation area of the San Kamphaeng field (7×8 km). Schematic profile of sampling pit of CO_2 survey is shown in Fig. 2(a). The procedure of CO_2 measurement is as follows:

(1) After setting polyvinyl chloride pipe, inhale filling air of about 1 litter with an injector.

(2) Clip the rubber pipe and keep on over 24 hours.

(3) After 24 hours or more, take off the clip and inhale the gas in the pipe (about 100 ml) with an injector.

(4) Immediately after the completion of above procedure, CO_2 content is measured

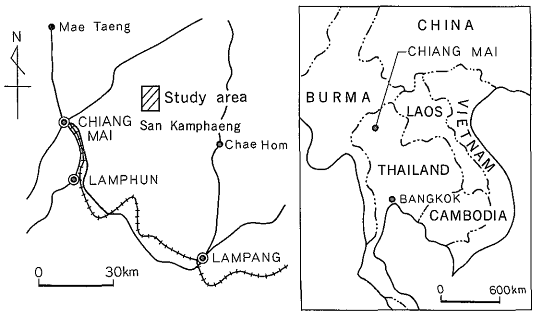

Fig. 1 Location of studied area.

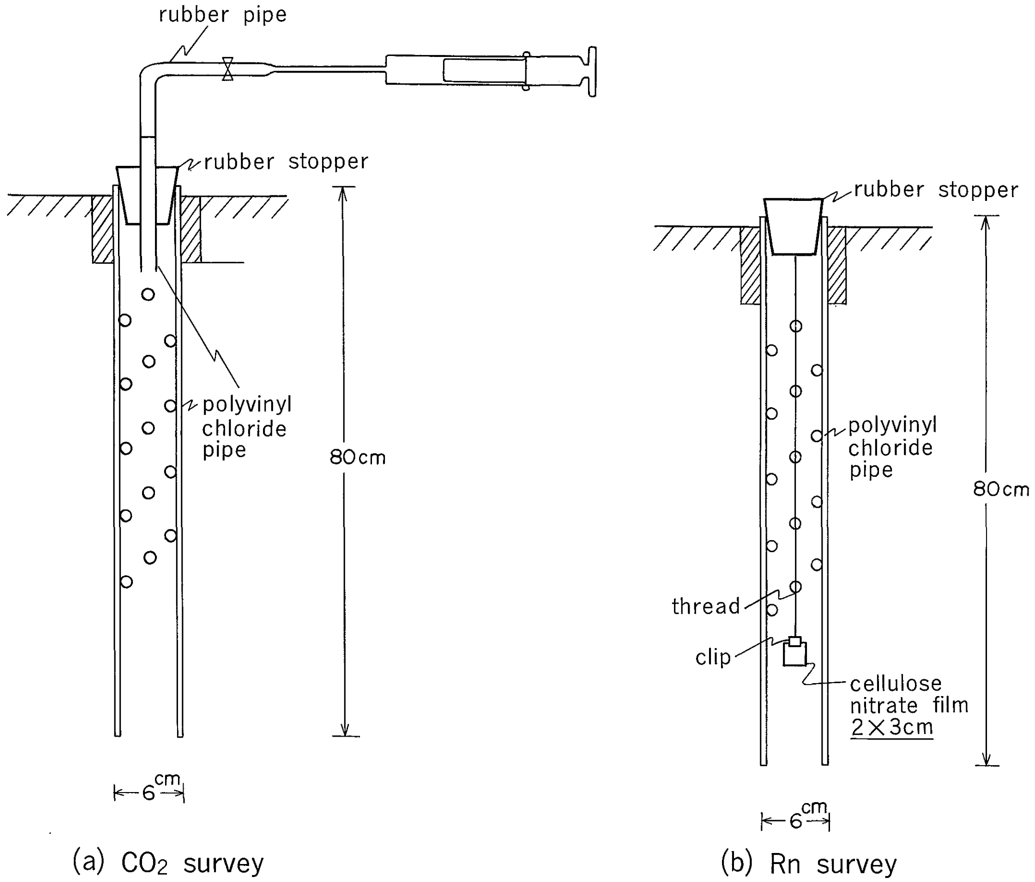

Fig. 2 Schematic profile of the sampling pit.

with Kitagawa type gas detector.

(5) If the concentration of CO_2 is not enough to detect, repeat the procedure (4) a few times. Obtained value must be devided by the number of sampling procedure for recieving CO_2 content.

2.2 Rn survey

Rn content is measured with alpha track detecting film method. The same sampling pit for CO_2 measurement is used in this survey. The system of measurement is shown in Fig. 2(b). The procedure of Rn survey is as follows:

(1) Set the film in the sampling pit as shown in Fig. 2(b). In this case, do not put the film into the pit filled with water or steam.

(2) Keep on the film in the pit for about 1 month. Then take off the film from the pit.

(3) Etch the film in 10% solution of sodium hydroxide on the water bath at 60℃ for 90 minutes, where a separator must be used for keeping etched film apart.

(4) After etching, the film is taken off from the separator and put it into water pool at the temperature of 40 to 50℃ and cool to room temperature. Then pour few amounts of water continuously for about 30 minutes and wash the film with distilled water and air-dried in a clean room.

(5) Count the track under the grating micrometer attached to microscope with the magnification of 100. Counting was carried out for about 10 grids of 1×1 mm size.

(6) Numbers of tracks observed (To) must be normalized to numbers / mm^2 / day based on exposure time (T days) and observed area (A). The equation for normalized track (NT) is as follows:

NT=(To/A)/T (tracks/mm^2/day)

2.3 Hg survey

Soils for Hg measurement were also collected from the same holes for Rn and CO_2 survey. In priciple, sampling layer for Hg measurement was the bottom of Al zone of soil strata. Hg is analyzed with atomic absorption spectrometry.

The measurement of Hg in this paper is limited only 42 samples collected along the

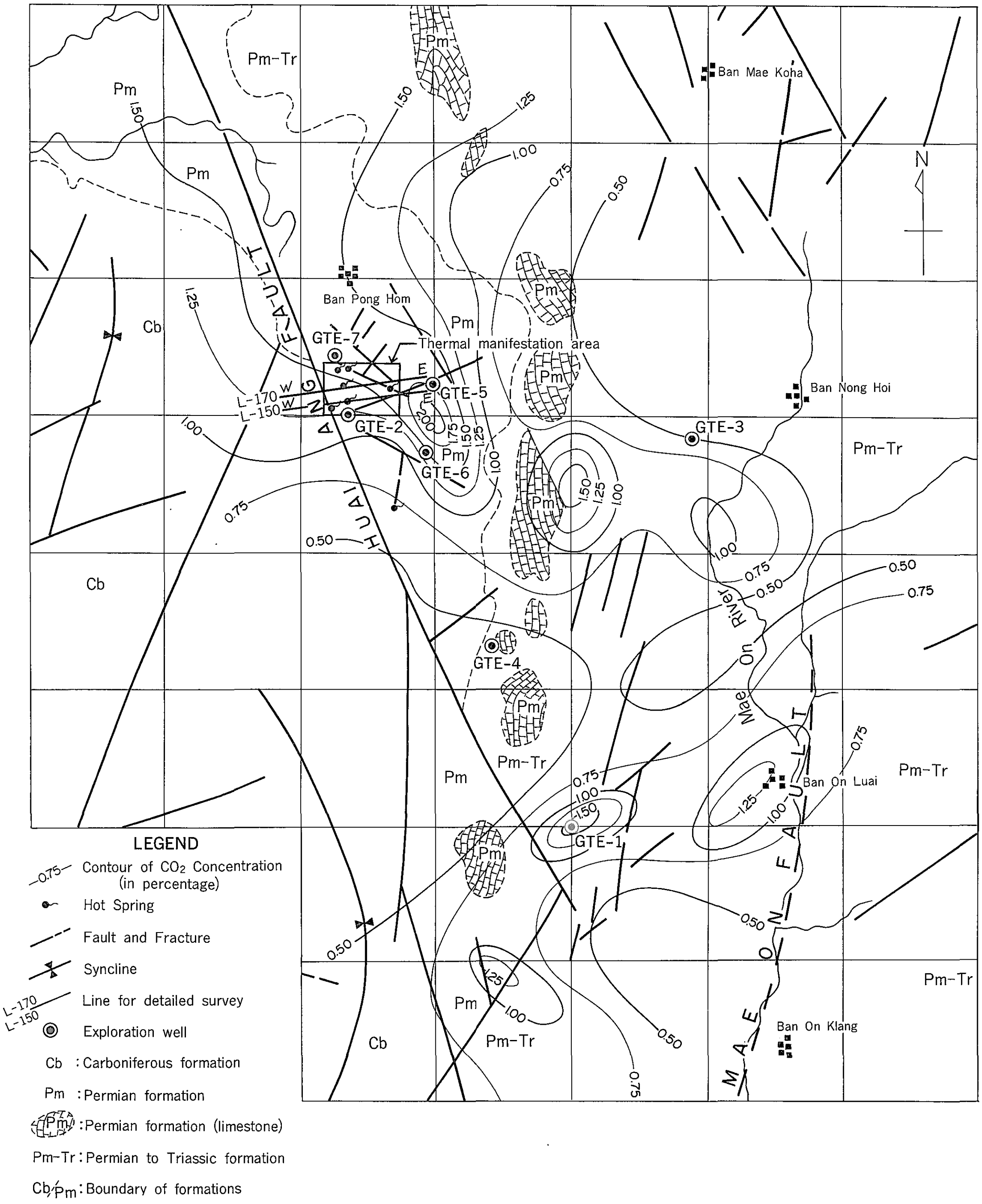

Fig. 3 Contour map of CO_2 concentration (interval of grid is 1 km).
(Geologic data from Chuaviroj et al., 1980)

two lines acrossing the thermal manifestation area in E-W direction.

2.4 Alteration study

Fourty-one alteration samples are collected from the San Kamphaeng area and its vicinity. The sampling points are distributed around hot spring area and Huai Ang Fault zone covering the area of about 5×5 km. The original rocks of altered samples are silicified shale, shale, sandstone, chert and basalt.

All samples are identified by X-ray diffraction method. Main constituent minerals are identified by power diffraction method. Then clay fractions less than 2 microns were separated by water dispersion method. They were used for detailed identification of clay minerals by X-ray diffraction of oriented samples before and after treatments with

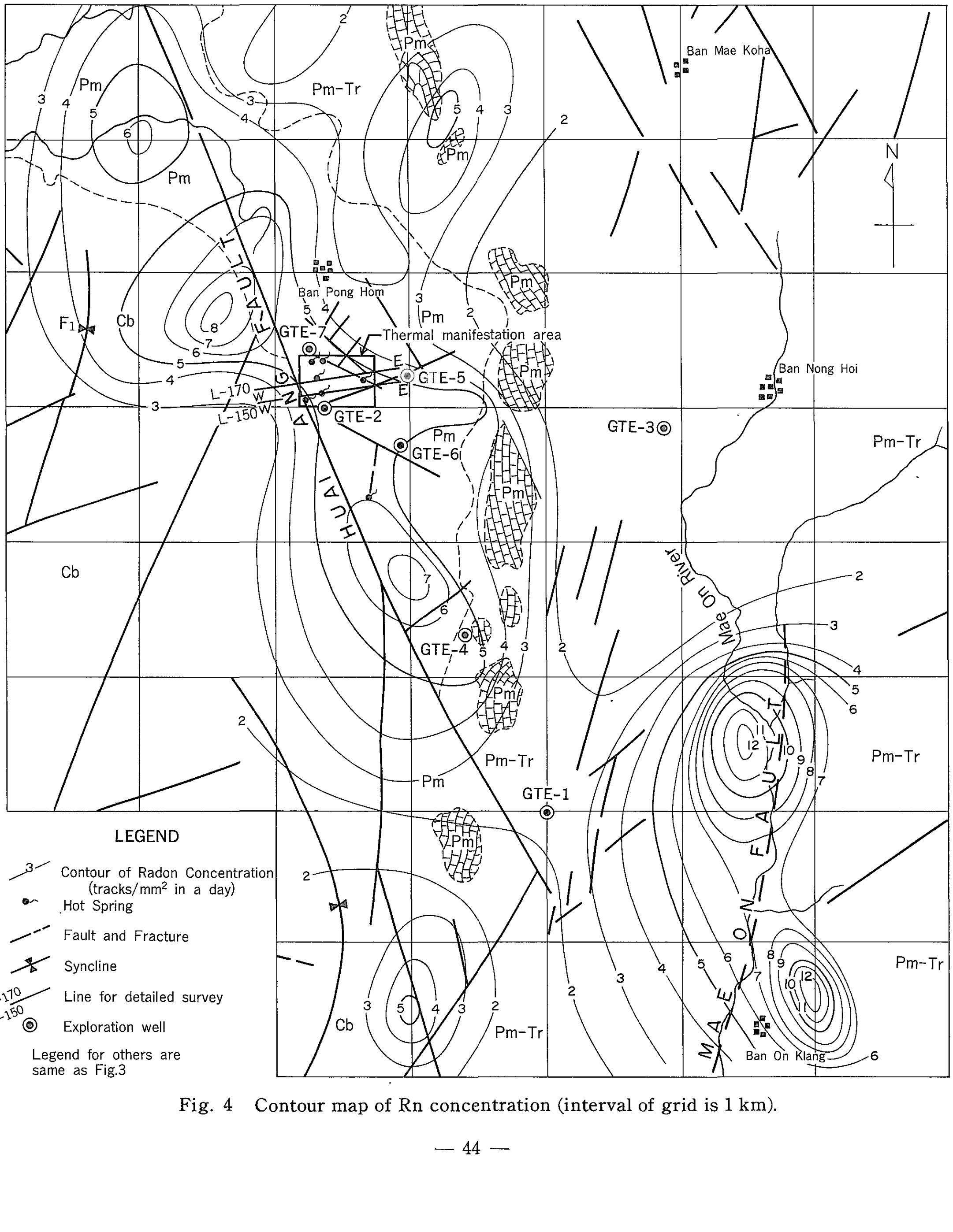

Fig. 4 Contour map of Rn concentration (interval of grid is 1 km).

ethylene glycol and hydrochloric acid.

3. Results and discussion

3.1 CO_2 survey

The concentration of CO_2 are plotted on the map form the contours of 0.25% interval (Fig. 3). The highest value of CO_2 is observed in the southeast of thermal manifestation area where CO_2 in soil air is over 2%. Another highly anomalous areas are about 1.5 km southeast of thermal manifestation area and the area around GTE-1 drilling site. Most of highly anomalous areas distributed along Huai Ang Fault and other faults but they tend to shift to limestone body which is streching N-S derection in the central part of studied area.

It may indicate that some CO_2 originated from limestone body. Accordingly, CO_2 data must be used with the combination of distribution of carbonaceous rocks.

3.2 Rn survey

Figure 4 is the contour map of Rn concentration. The highly anomalous areas of Rn concentration coincide with that of CO_2 except the area along Mae On Fault in which is the highest anomaly zone (over 12 tracks/ mm^2/day).

The Mae On Falut which shows the highest anomalies of Rn may reach to a deep sheeted granite body.

3.3 Hg survey

The Hg survey is carried out along two lines shown in Figs. 3 and 4. The purpose of Hg survey is to examine the results of CO_2 and Rn surveys. The results of analyses are plotted on the lines of L-150 and L-170 (Fig. 5).

In general, highly anomalous zones are coincide with fault zones. However, one unusually high peak zone is found in the

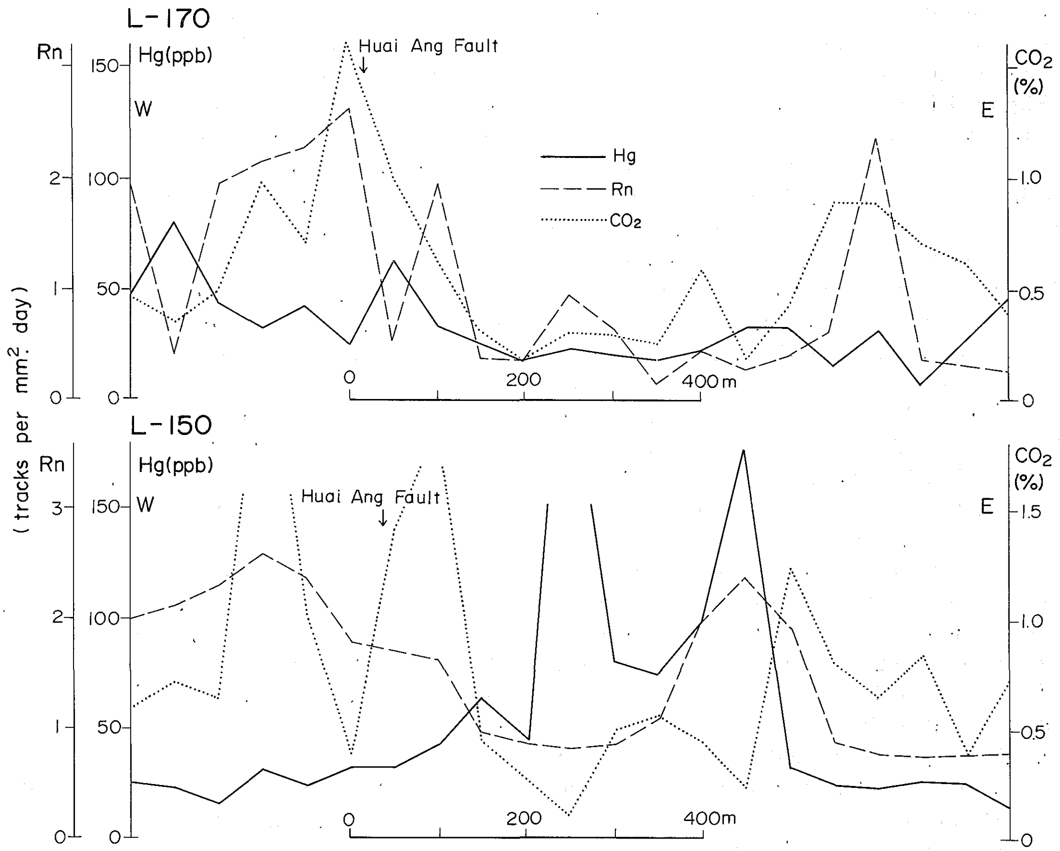

Fig. 5 The relation between Hg, Rn and CO_2 measurements.

Table 1 Mineral paragenesis of alteration zones

Mineral \ Zone	Sericite-Halloysite 1 (SH1)	Sericite-Halloysite 2 (SH2)	Kaolinite 1 (K1)	Kaolinite 2 (K2)	(S/M)	Mont.-Halloysite 1 (MH1)	Mont.-Halloysite 2 (MH2)	Chlorite (Ch)
Quartz	—		—		—	—		—
Chlorite								—
Talc								—
Sericite	—	—	—					
Kaolinite			—	—	—			
Halloysite	—	—			—	—	—	
Mont.					—	—	—	
S/M					—			
Calcite								—

Mont. : Montmorillonite S/M : Sericite /Montmorillonite mixed layer minerals

central part and no concentration zone is found in the western part of L–150 line.

3.4 Alteration study

The minerals identified are quartz, feldspar, hornblende, calcite, chlorite, talc, mica (sericite), kaolinite, halloysite, montmorillonite and sericite/montmorillonite mixed-layer minerals. The alteration area is divided into eight zones based on the mineral paragenesis shown in Table 1.

Figure 6 is the distribution map of above alteration zones. Zones of sericite-halloysite 1 (SH 1), sericite-halloysite 2 (SH 2) and montmorillonite-halloysite 2 (MH 2) are regionally distributed and they may be strongly affected by the weathering and mineral composition of original rock. Zones of kaolinite 1 (K 1), kaolinite 2 (K 2) and sericite/montmorillonite mixed-layer minerals (S/M) may be affected by hydrothermal activity. Among them, K 1 zone is the highest grade of alteration. Minerals of montmorillonite-halloysite 1 (MH 1) zone are considered to be formed by weathering but contribution of hydrothermal fluids is expected because of the presence of secondary quartz which was formed at the temperature higher than 80–100°C. Based on the mineral paragenesis, chlorite (Ch) zone is considered to be the relic of metamorphic basalt. As shown in Fig. 6, zones (K 1, K 2 and S/M) related to hydrothermal activity are located along the Huai Ang Fault. In addition, the highest grade K1 zone is distributed around the thermal manifestation area.

In conclusion, rock alteration is a good indicator for hydrothermal activity in the San Kamphaeng geothermal areas.

4. Summary and conclusions

This is the first report for application of soil gas and rock alteration surveys to the Thai geothermal field. The highly anomalous zones of soil gas and the highly altered zone are concentrated in the thermal manifestation area and along the Huai Ang Fault which is a major fault of this area and expected as an ascending pass of thermal fluids (Fig. 7). However, in the case of CO_2 survey, a few highly anomalous zones are observed in the east side of the above fault. They may be caused by carbonaceous rocks distributed in the central part of survey area (see Fig. 3). In conclusion, areas where all data show high anomaly will become candidates for exploratory drilling sites.

Figure 7 is the summary of above data and isothermal contour of 400 m depth based on the data of 6 exploration wells (GTE–1 to 7 but except GTE–3, modified from JIVACATE, 1985). Figure 7 shows that the thermal manifestation area is the best place for further exploration. Another target area selected is around Ban On Luai where high CO_2 and Rn anomalies and relatively high grade alteration are recognized in the Mae On Fault zone.

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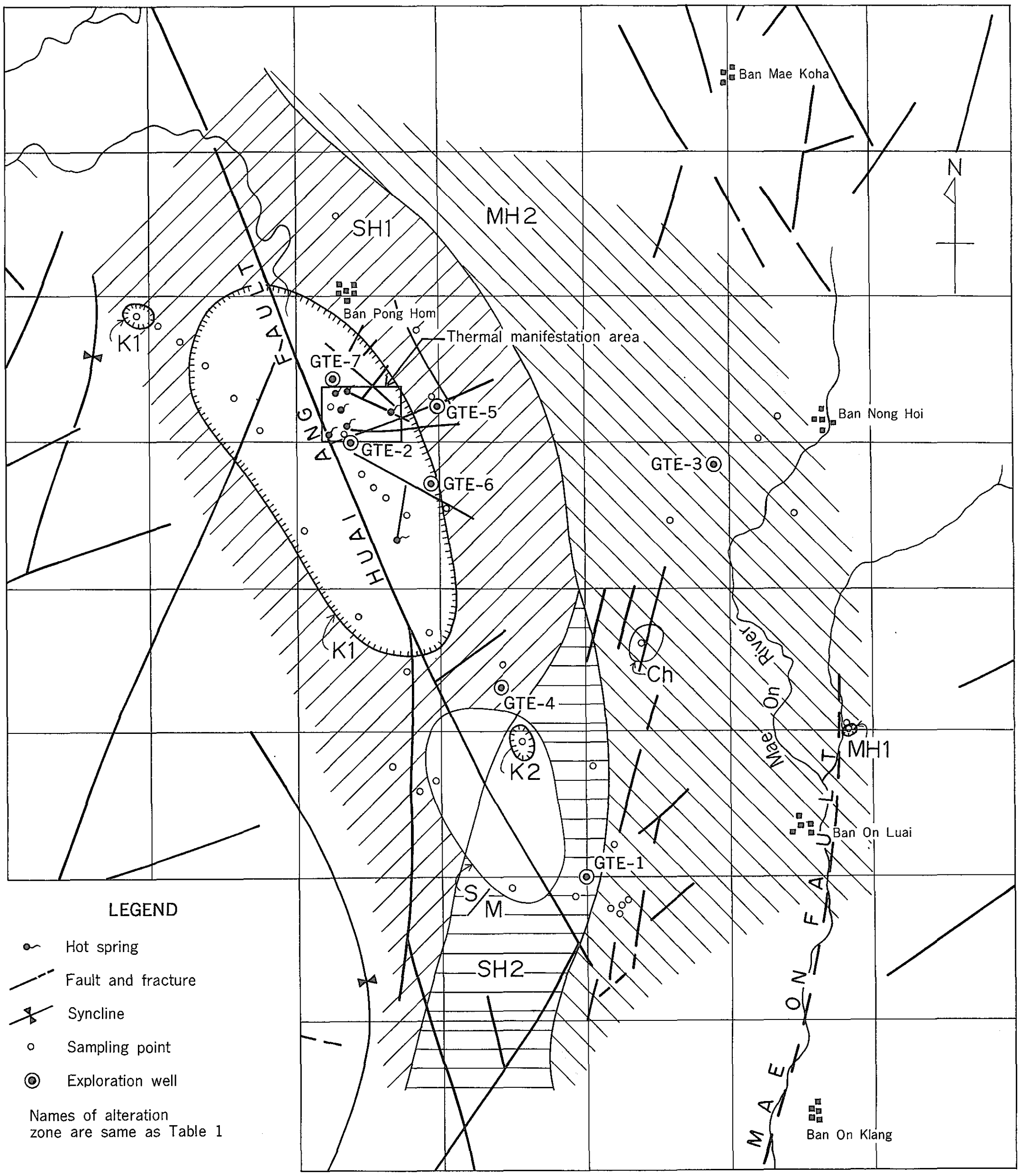

Fig. 6 Distribution of alteration zone (interval of grid is 1 km).
SH 1, SH 2 and MH2 zones are widely distributed alteration halos whereas other alteration zones are sporadically distributed.

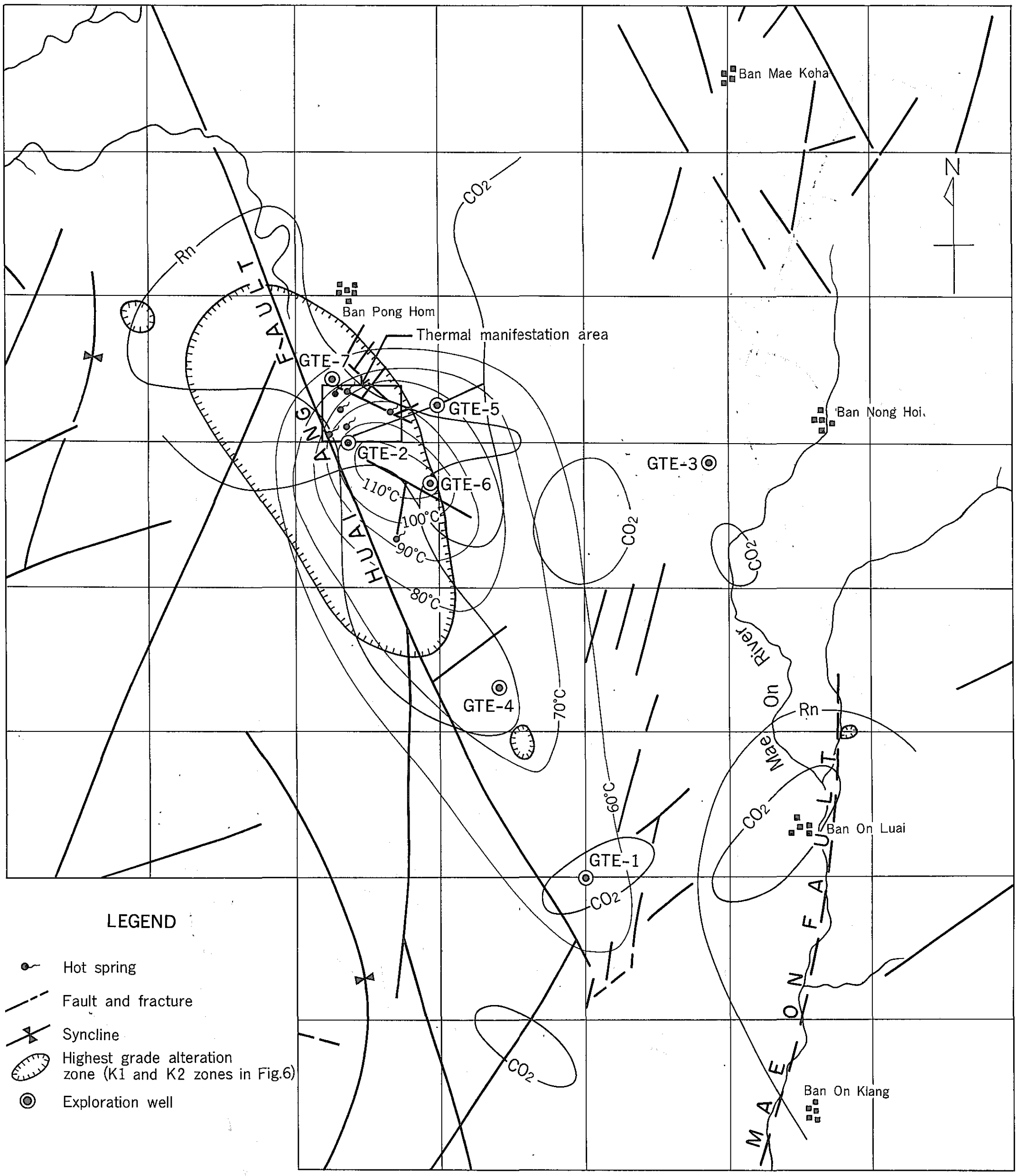

Fig. 7 Summary of soil gas survey, alteration study and subsurface temperature (interval of grid is 1 km). Contours of CO_2 and Rn are 1% and 5 tracks/mm^2/day, respectively.

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タイ北部サンカンペン地熱地域の変質と土壌ガス探査

S.チャビロイ・K.チングチット・高島　勲

要　旨

タイの地熱としては始めてのラドン（フィルム法），炭酸ガス（検知管法），水銀（土壌分析法）による地化学探査及び変質帯の細分がサンカンペン地域で行われた．対象地域の広さは温泉湧出地を含む約 7×8 km の範囲である（水銀のみ温泉湧出地を通る延長 1 km の 2 測線）．

ラドン，炭酸ガス各 84 点の測定から，前者で 5 tracks/mm^2/day，後者で 1% 以上の地域を異常地として抽出した．両者が一致し，かつ広い異常地として認められるのは，温泉湧出地を中心としてほぼ西北西-東南東に延びる断層上である（炭酸ガス異常地は石灰岩の岩体の分布の影響を受け，分布のずれが認められる）．

水銀は前述の 2 測線上 42 点のみの結果であるが，ラドン，炭酸ガスの異常地の分布と調和しており，断層上で特に高い濃度が記録されている．

変質についても地化学探査の結果とよく調和し，41 試料の X 線分析から，最も強い変質帯（構成鉱物はカオリナイト，セリサイト，石英）が温泉湧出地と断層沿いに広く分布することが確認された．

すべての異常地が広く，かつ一致して分布する上記以外の地域でも，やや弱い異常が狭い範囲に認められる部分が抽出されており，地化学探査及び変質帯調査が非火山性のタイの地熱地域にも適用できる可能性が高いことが示唆された．

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