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Isotope geochemistry of six geothermal fields in northern Thailand

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Abstract : Oxygen and hydrogen isotopic ratios ($^{18}O/^{16}O$ and D/H) were measured for 42 hot spring and meteoric water samples from six geothermal fields (San Kamphaeng, Fang, Mae Chaem, Mae Chan, Doi Saket and Pa Pae areas) and surrounding areas. The range of isotopic ratios of meteoric waters was defined in the δD–$\delta^{18}O$ diagram as the area confined by $\delta D = 8\delta^{18}O + 2.6$, $\delta D = 8\delta^{18}O - 1.4$, $\delta D = -55$ and $\delta D = -68$. Very small or no $\delta^{18}O$ shift of thermal waters from the San Kamphaeng and Fang areas indicates that water-rock interaction is not significant. One possibility is that the waters circulate through wall rocks which have already reacted with preceding circulating waters and have no potentiality of further exchange.

Tritium was also analyzed for 18 samples collected from the same areas. The water circulation time is estimated to be over 30 years for the hot spring waters and 10–30 years for the ground waters, respectively. In the San Kamphaeng and Fang areas, models of slow circulating water in channel like reservoir are postulated by the combination of tritium data and no $\delta^{18}O$ shift.

1. Introduction

Geothermal waters of northern Thailand are considered as non-volcanic origin and characterized by high temperature and low concentrations of disolved chemical species (TAKASHIMA and KAWADA, 1981). The water circulation system and heat exchange mechanism to form such geothermal waters are problems to be soluved.

In this paper, the origin of the geothermal waters and their circulation system are discussed on the basis of oxygen and hydrogen isotope data including tritium contents of waters. For hot spring and meteoric waters in Thailand, only few unpublished data are found in KRTA report (1977).

2. Samples and analyses

Twentyeight hot spring waters and 14 river and ground waters were collected from six geothermal fields (San Kamphaeng, Fang, Mae Chaem, Mae Chan, Doi Saket and Pa Pae areas) and surround areas in northern Thailand (Fig. 1). The samples from 10 areas are listed in Tables 1 to 3. Among them, the San Kamphaeng and Fang areas are characterized by predominent thermal manifestations of over 50 hot springs flowing out along a river side plain. The size of geothermal area of the San Kamphaeng area is 200×400 m and that of the Fang area is 200×300 m, respectively.

The ^{18}O and D analyses were done by Teledyne Isotopes Co. (U. S. A.). Fourteen samples were selected for the tritium analysis at Gakushuin University (Japan). No pretreatments were done for the samples.

3. Results

The results of D, ^{18}O and tritium analyses are shown in Tables 1 to 3 together with the data of temperature, TDS, pH, altitude, date of sample collection and type of waters.

All the data are plotted on the δD–$\delta^{18}O$ diagram (Fig. 2). The shaded area in Fig. 2 indicates the range of isotopic compositions of meteoric waters in northern Thailand,

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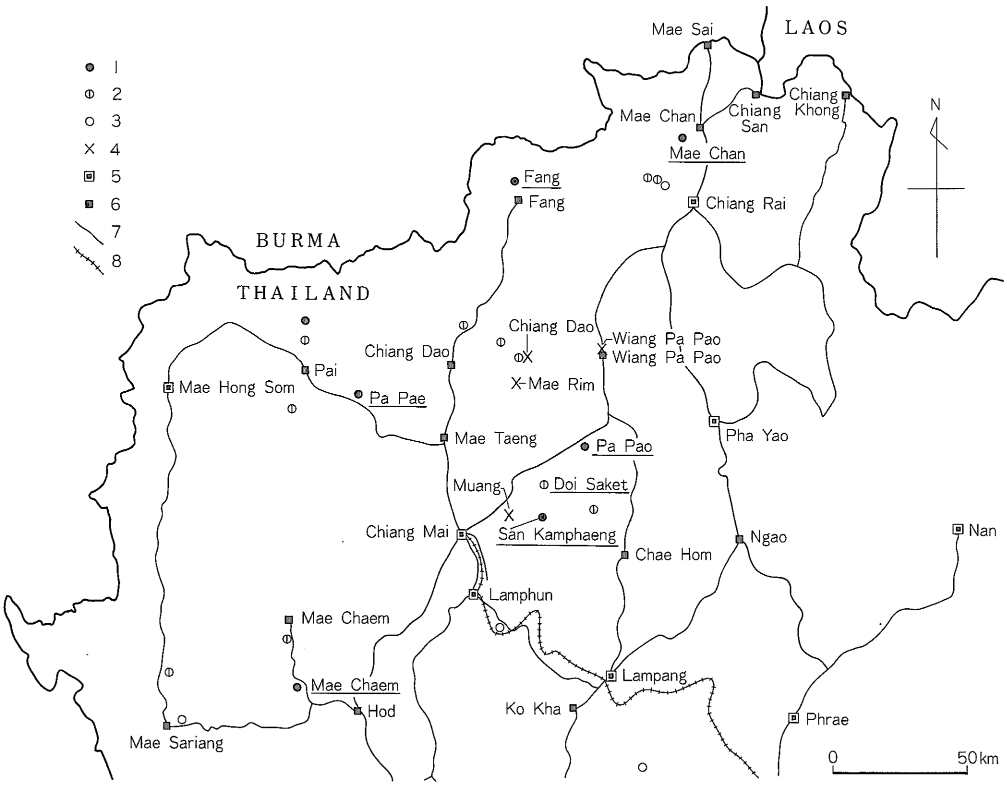

Fig. 1 Location of geothermal areas in northern Thailand. (Sampling localities are underlined)
1 : Hot spring (over 90°C) 2 : Hot spring (70–90°C) 3 : Hot spring (below 70°C)
4 : Meteoric water sample 5 : City 6 : Town 7 : Main road 8 : Railroad

Table 1 Isotope data of waters from the San Kamphaeng area

No.	Sample No.	Tw (°C)	TDS (mg/1)	pH	δD SMOW (‰)	δ^{18}O SMOW (‰)	T/U (T.U.)	Altitude(m)	Date of sample collection	Remarks
1	CM1−A	95.0	580	8.3	−60 ± 1	−7.51 ± 0.03		350	Dec. 09, 1981	Thermal water
2	CM1−B	96.0	577	8.0	−61 ± 1	−7.71 ± 0.03	< 0.12	350	Dec. 09, 1981	do.
3	CM1−C	92.0	561	8.1	−61 ± 1	−7.70 ± 0.08		350	Dec. 09, 1981	do.
4	CM1−E	84.0	533	8.0	−62 ± 1	−7.80 ± 0.06		350	Dec. 09, 1981	do.
5	CM1−G	98.0	580	8.1	−60 ± 1	−7.39 ± 0.03		350	Dec. 09, 1981	do.
6	CM1−H	99.5	604	8.9	−61 ± 1	−7.53 ± 0.06		350	Dec. 09, 1981	do.
7	CM1−I	99.0	607	8.5	−60 ± 1	−7.31 ± 0.03		350	Dec. 09, 1981	do.
8	CM1−M	90.0	539	8.0	−62 ± 1	−7.80 ± 0.05		350	Dec. 09, 1981	do.
9	CM1−F	93.0			−60 ± 1	−7.36 ± 0.08		350	Dec. 09, 1981	do.
10	TH−12				−58 ± 1	−7.34 ± 0.04	0.77 ± 0.14	350	Dec. 02, 1981	do.
11	TH−13				−61 ± 1	−7.73 ± 0.04	2.08 ± 0.27	350	Dec. 02, 1981	do.
12	TH−14				−60 ± 1	−7.52 ± 0.06	2.63 ± 0.34	350	Dec. 02, 1981	do.
13	GW−1	27.7	363	8.9	−59 ± 1	−7.50 ± 0.04		350	Dec. 09, 1981	Ground water
14	RVW−1				−66 ± 1	−7.98 ± 0.04		370	Aug. 21, 1980	River water
15	TH−4						8.60 ± 1.11	400	Oct. 02, 1981	Ground water
16	TH−5						12.2 ± 1.6	400	Oct. 02, 1981	do.
17	TH−11				−58 ± 1	−7.48 ± 0.03	14.5 ± 1.7	560	Dec. 02, 1981	do.

(Analyzed by Teledyne Isotopes (D and ^{18}O) and Gakushuin University (Tritium))

Table 2 Isotope data of waters from the Fang area

No.	Sample No.	Tw (°C)	TDS (mg/1)	pH	δD SMOW (‰)	δ^{18}O SMOW (‰)	T/U (T.U.)	Altitude(m)	Date of sample collection	Remarks
1	CM3–A	93.0	518	9.0	−69 ± 1	−8.31 ± 0.02		550	Dec. 14, 1981	Thermal water
2	CM3–B	95.0	523	9.3	−67 ± 1	−8.44 ± 0.06		550	Dec. 14, 1981	do.
3	CM3–C	96.0	513	9.5	−68 ± 1	−8.60 ± 0.03		550	Dec. 14, 1981	do.
4	CM3–D	90.0	516	9.5	−67 ± 1	−8.42 ± 0.03		550	Dec. 14, 1981	do.
5	CM3–E	90.0	487	9.3	−67 ± 1	−8.44 ± 0.02		550	Dec. 14, 1981	do.
6	CM3–F	94.0	503	9.4	−66 ± 1	−8.59 ± 0.05		550	Dec. 14, 1981	do.
7	TH–8				−65 ± 1	−8.38 ± 0.03	2.68 ± 0.35	550	Nov. 02, 1981	Ground water
8	TH–9						4.20 ± 0.53	550	Nov. 02, 1981	do.
9	TH–10				−67 ± 1	−8.48 ± 0.06	1.30 ± 0.19	550	Nov. 02, 1981	Thermal water
10	F MINE	40	342	7.9	−62 ± 1	−7.96 ± 0.06		550	Dec. 15, 1981	do.

(Analyzed by the same institutes as shown in Table 1))

Table 3 Isotope data of other hot springs and meteoric waters in northern Thailand

No.	Sample No.	Tw (°C)	TDS (mg/1)	pH	δO SMOW (‰)	δ^{18}O SMOW (‰)	T/U (T.U.)	Altitude(m)	Date of sample collection	Remarks
	Mae Chaem, Chiang Mai									
1	CM7–A	89.0	421	8.3	−58 ± 1	−7.06 ± 0.03			Dec. 16, 1981	Thermal water
2	CM7–I	96.0	418	8.6	−57 ± 1	−7.10 ± 0.03			Dec. 16, 1981	do.
3	CM7–J	91.0	411	8.6	−58 ± 1	−7.44 ± 0.02			Dec. 16, 1981	do.
4	STR–D	71.0	425	8.3	−57 ± 1	−6.61 ± 0.04			Dec. 16, 1981	Thermal water separate steam
5	RVW–1				−55 ± 1	−7.11 ± 0.04			Aug. 24, 1980	River water
	Mae Chan, Chiang Rai									
1	CP–1	99.0		8.6	−64 ± 1	−7.79 ± 0.03	2.55 ± 0.35	400	Aug. 23, 1980	Thermal water
2	GW–1				−68 ± 1	−8.52 ± 0.04		400	Aug. 23, 1980	Ground water
3	RVW–1				−68 ± 1	−8.30 ± 0.08		400	Aug. 23, 1980	River water
	Doi Saket, Chiang Mai									
1	CM2–A	82.0	442	7.5	−63 ± 1	−7.98 ± 0.04			Dec. 12, 1981	Thermal water
2	CM2–B	77.0	469	8.4	−61 ± 1	−7.49 ± 0.03			Dec. 12, 1981	do.
3	TH–3				−62 ± 1	−7.70 ± 0.08	12.5 ± 1.6	820	Oct. 02, 1981	Ground water
	Pa Pae, Chiang Mai									
1	PP–2	99.0		9.1	−64 ± 1	−8.03 ± 0.03	0.13 ± 0.09		Aug. 25, 1980	Thermal water
2	RVW–1				−61 ± 1	−7.84 ± 0.02			Aug. 23, 1980	River water
	Wiang Pa Pae, Chiang Rai									
1	TH–1				−57 ± 1	−7.54 ± 0.02	16.2 ± 1.9	640	Oct. 02, 1981	Ground water
2	TH–2				−62 ± 1	−7.94 ± 0.06	27.2 ± 3.3	1040	Oct 02, 1981	do.
	Mae Rim, Chiang Mai									
1	TH–6				−61 ± 1	−7.76 ± 0.04	12.9 ± 1.6	340	Nov. 02, 1981	Ground water
	Chiang Dao, Chiang Mai									
1	TH–7				−64 ± 1	−8.24 ± 0.05	14.6 ± 1.8	450	Nov. 02, 1981	Ground water
	Muang, Chiang Mai									
1	TH–15				−58 ± 1	−7.36 ± 0.04	8.8 ± 1.10	305	Dec. 02, 1981	Ground water

(Analyzed by the same institutes as shown in Table 1)

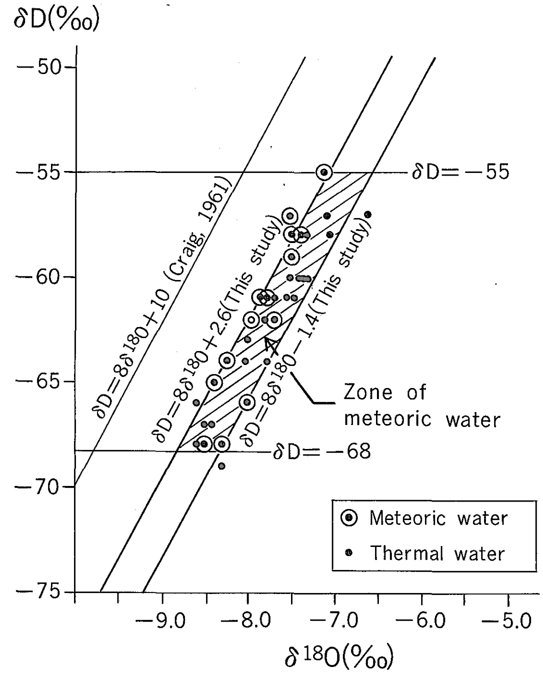

Fig. 2 Diagram of δD-$\delta^{18}O$ for the whole studied samples.

which is defined by the equations of $\delta D = 8\delta^{18}O + 2.6$ and $\delta D = 8\delta^{18}O - 1.4$, and the δD values of −55 and −68‰. The equations were derived by assuming the slope 8 for precipitation (CRAIG, 1961).

Tritium contents of hot spring and meteoric waters from nine areas are also shown in Tables 1 to 3. The ages of waters corresponding to tritium contents ((Tritium/Hydrogen)$\times 10^{-18} = 1$ T.U.) are estimated as follows:

(1) Older than 30 years—less than 3 T.U.
(2) 10 to 30 years—3 to 20 T.U.
(3) Younger than 10 years—over 20 T.U.

Based on the above estimation, the ages of all hot spring waters from the San Kamphaeng (Samples of CM1-B, TH-12, TH-13, TH-13), Fang (TH-10), Mae Chan (CP-1) and Pa Pae (PP-2) areas are evaluated older than 30 years. The ground waters show ages of 10 to 30 years except for TH-8 and TH-9 from the Fang area with relatively older ages of around 30 years. The TH-8 and TH-9 waters may have mixed with hot spring waters at shallow part. Relatively old ages of the ground waters indicate a small circulation rate even for shallow waters in the studied areas.

4. Discussion

4.1 San Kamphaeng area

Figure 3 is the δD-$\delta^{18}O$ diagram for the San Kamphaeng area in which 12 hot spring and 3 meteoric waters are plotted. Isotope ratios of meteoric waters of this area are represented by the samples of GW-1 and TH-11 in Table 1. Most of the hot spring waters have slightly low δD values compared to the above 2 samples.

The δD and $\delta^{18}O$ values of meteoric waters are controlled by isotopic fractionation in precipitation, decreasing (being depleted in ^{18}O and D) toward high latitude or high altitude areas. In this area, the effect of altitude is negligible because of the relatively flat land.

Therefore, the relatively low δD values of the hot spring waters indicate that the recharge zone of the geothermal system of this area is in further north. The δD value of −62‰ for TH-3 sample of the Doi Saket area (about 10

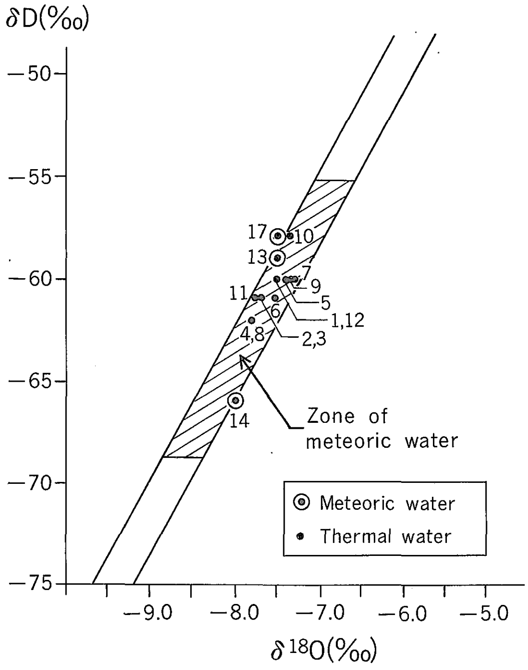

Fig. 3 Diagram of δD-$\delta^{18}O$ of waters from the San Kamphaeng area.
The zone of meteoric waters was transferred from Fig. 2.

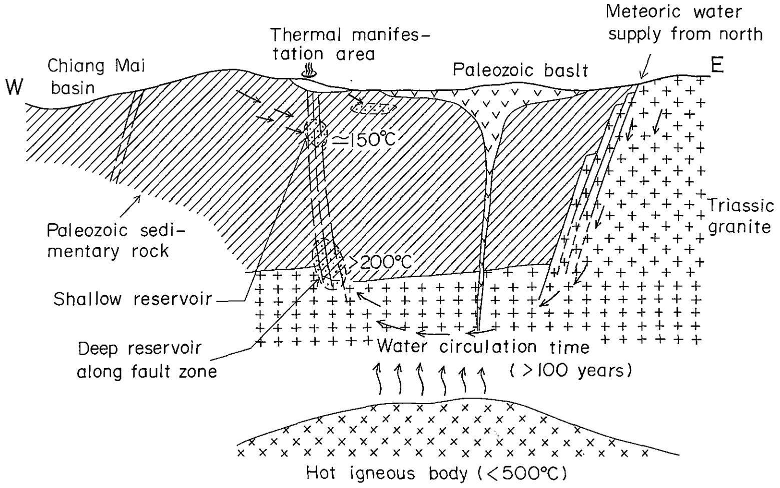

Fig. 4 Idealized reservoir model of the San Kamphaeng area (Modified from TAKASHIMA and KAWADA (1981)).
Distance between the E and W ends is about 20 km and no fixed scale for depth.

km north of the San Kamphaeng area) is almost identical to that of the hot spring waters in the San Kamphaeng area. Accordingly, the Doi Saket area is considered as a possible recharge area of the San Kamphaeng geothermal system.

No oxygen isotope shift is observed for the hot spring waters of the San Kamphaeng area. This no ^{18}O shift and low concentration of dissolved materials in the hot spring waters (HIRUKAWA et al., 1987) suggest a weak interaction of waters with rocks. Alternative is that the waters circulate through wall rocks in which alteration and isotope exchange have advanced and no potentiality of futher exchange is remained.

The δD value of RVW-1 sample is lower than usual meteoric and hot spring waters of the San Kamphaeng area. This sample was collected from a river flowing north, and indicate the supply of water from further north area.

Figure 4 is an idealized model for the circulating water system in the San Kamphaeng area slightly modified from TAKASHIMA and KAWADA (1981). In this new model, the reservoir size was reduced, the term of water circulation was modified from 30 years to over 100 years, and the recharge zone was postulated to the north.

4.2 Fang area

Figure 5 is the δD-$\delta^{18}O$ daiagram of the Fang area in which 8 hot spring and one meteoric waters are plotted. Isotope ratios of

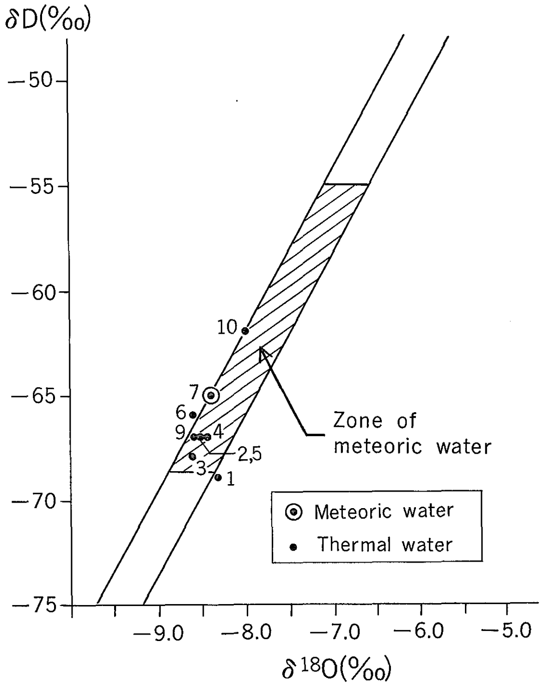

Fig. 5 Diagram of δD-$\delta^{18}O$ of waters from the Fang area.
The zone of meteoric waters was transferred from Fig. 2.

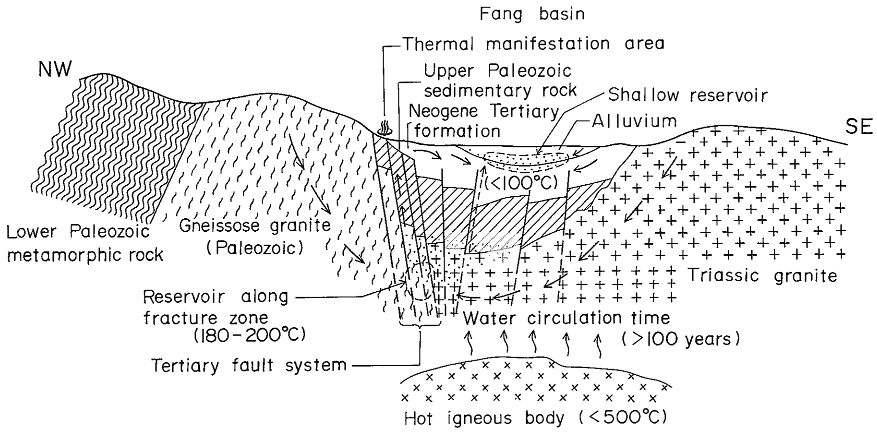

Fig. 6 Idealized reservoir model of the Fang area (Modified from TAKASHIMA and KAWADA (1981)). Distance between the SE and NE ends is about 20 km and no fixed scale for depth.

meteoric waters in this area are represented by the sample No. 7 (TH-8) in Table 2. As seen in the San Kamphaeng area, the δD values of hot spring waters in this area are lower than the value of meteoric waters (TH-8) collected in the same area. Accordingly, the recharge area is also postulated in northern part of the Fang area. Since there are no δD date for north of the Fang area, it is difficult to evaluate quantitatively how far the recharge area is. However, since the magnitude of difference in δD values between meteoric and thermal waters is similar to that of the San Kamphaeng area, the size of the water circulating system would also be similar in the two areas.

No oxygen shift is observed for hot spring waters of the Fang area except for CM3-A sample in Table 2. Detectable amount of oxygen shift of this sample may be caused by the reaction with carbonaceous materials because the content of HCO_3 of this sample is higher than the contents of another samples with similar temperature and pH conditions collected from same area (chemical data are taken from HIRUKAWA et al., 1987).

Sample No. 10 (F MINE) is a hot spring water from a fluorite mine which is located about 500 m south of the Fang geothermal area. The δD and $\delta^{18}O$ values of this water is different from the major hot spring waters, indicating that the recharge area of this water is different from that of the other hot spring waters of the Fang area.

Figure 6 is an idealized model for the circulating water system in the Fang area slightly modified from TAKASHIMA and KAWADA (1981). In this new model, the reservoir size was reduced and the term of water circulation was modified from 5 years to over 100

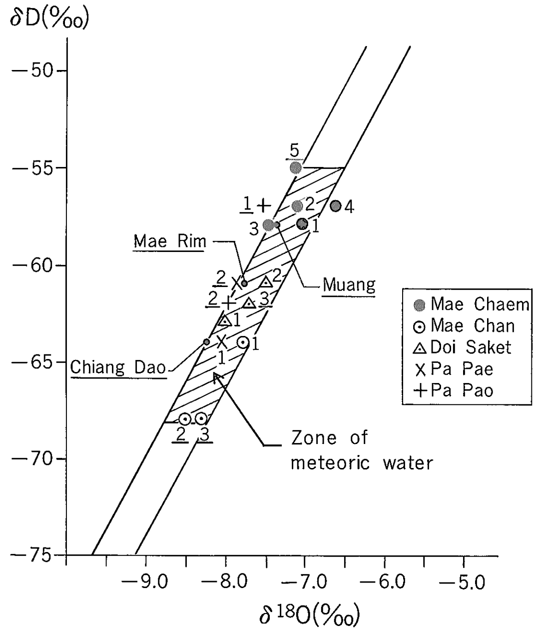

Fig. 7 Diagram of δD-$\delta^{18}O$ for waters from eight areas in northern Thailand.
Underlined numbers and locality names indicate meteoric waters.

years.

4.3 Other areas

Although the data of other areas are limited, the following two pionts are inferred from the δD-$\delta^{18}O$ diagram (Fig. 7):

(1) A detectable amount of $\delta^{18}O$ shift of Mae Chaem area is assigned to the interaction with limestone which is widely distributed around the thermal manifestation area. The evapolation may also cause a $\delta^{18}O$ shift but there are no hydrological evidences for it.

(2) A very clear relation is observed between the isotropic ratios of meteoric waters and the longitude of localities. The δD and $\delta^{18}O$ values gradually decrease from Muang through Mae Rim to Chiang Dao, from south to north.

5. Summary and conclusions

Based on the isotope analyses of the hot spring and meteoric waters of northern Thailand, followings are concluded:

(1) The range of isotopic compositions meteoric waters from northern Thailand is defined in the δD-$\delta^{18}O$ diagram as the area confined by $\delta D = 8\delta^{18}O + 2.6$, $\delta D = 8\delta^{18}O - 1.4$, $\delta D = -55$ and $\delta D = -68$.

(2) Virtually no oxygen isotope shift (except the waters which supposedly interacted with limestone) indicates that water-rock interaction is not significant in the studied areas. It is possible that the waters circulate through wall rocks which have already reacted with preceding circulating waters and have no potentiality of further exchange.

(3) Circulation time of water is long enough (expected to be over 100 years) to receive heat from deep hot rocks in the San Kamphaeng and Fang areas.

As a conclusion, large-scale reservoirs may not exist in either area but the reservoirs may be of channel like shape. A long term water circulation through the channels provides a large cumulative water-to-rock ratio, and advanced water-rock interaction may prevent further changes of chemical and isotopic compositions of the thermal waters. The chemical and isotopic analyses of deep hot waters in future may help understanding the reservoir characteristics.

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北部タイの温泉及び天水の同位体組成

高島　勲・W. ジャラチ

要　旨

タイ北部の6カ所の地熱地域（サンカンペン，ファン，メチャム，メチャン，ドイサァケット及びパパエ）及び周辺地域の温泉水と天水の合計42試料の重水素（D）と酸素18（^{18}O）の分析を行い，δD-δ^{18}O図表中の天水が$\delta D=8\delta^{18}O+2.6$，$\delta D=\delta^{18}O-1.4$，$\delta D=-55$，$\delta D=-68$の各式で囲まれる範囲にあることを明らかにした．

データ量の多いサンカンペン及びファン両地域については熱水系の解析を行い，δ^{18}Oのシフトがほとんどみられないことから，熱水と反応する母岩が熱水と接触する面積が少ないか，あるいは溶脱の進んだ母岩である可能性が高いことを指摘した．この結果を地熱モデルにあてはめれば，溶脱の進んだ脈状通路を流れる熱水系が推定される．

各地域から選ばれた18試料についてはトリチウムの分析も行われ，地下水であっても一部では10-30年という遅い流動期間が求められた．サンカンペン及びファン両地域ではそれよりも長期間の循環速度が予想され，トリチウム濃度から直接求めることはできないが，100年を超すものと考えられる．

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