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Preliminary study on the geochemical characters of major geothermal fields in northern Thailand

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Abstract : Chemical analysis of 30 hot spring waters from five geothermal areas (San Kamphaeng, Fang, Doi Saket, Mae Chaem and Pa Pae) and 11 gases from four areas (same as above except Pa Pae) has been carried out. The hot springs are identified as Na-HCO_3 type characterized by low contents of total dissolved materials. The subsurface temperatures of these areas are estimated to range from about 180°C to over 200°C based on Na-K-Ca geothermometer. A local difference is recongnized in chemical compositions although the type of hot spring is similar. Gases are N_2 and CO_2 types. Evaluated reservoir condition from gas analysis is the best in the San Kamphaeng area.

1. Introduction

There are many hot springs in northern Thailand which are characterized by relatively uniform chemical composition and some of them have high temperature up to boiling point. In order to elucidate the geochemical nature of hydrothermal system and water-rock interaction occurred in the system, we collected and chemically analyzed the hot spring water samples and gases from five geothermal fields shown in Fig. 1.

In this study, chemical character of the above mentioned five geothermal fields are summarized and the origin of hot springs are discussed from the view point of water-rock interaction and gas properties.

2. Sampling and method of analysis

Thirty three water samples (30 of hot spring waters and three of river and ground waters) and eleven gas samples were collected from five and four geothermal areas, respectively (Fig. 1).

Water sample was collected in three bottles which have the capacity of 1000, 500 and 300 m*l* each. To the 300 m*l* bottle, 3 m*l* of HCl (1+1) was added and the sample was used for the analysis of SiO_2, K, Na, Ca, Mg, Fe and Mn.

Free gas emanated from hot springs was collected by the displacing method as shown in Fig. 2. The volume of a glass sampling tube is about 50 m*l*.

The method of analysis for water and gas samples are summarized in Tables 1 and 2.

3. Results of analysis

3.1 Hot spring and other waters

The results of chemical analysis of the waters are shown in Tables 3 to 7. All hot spring waters are classified into the Na-HCO_3 type and characterized by relatively high fluorine contents and low chlorine contents. The pH values generally range from 7.5 to 9.7 (weakly alkaline) and relatively high values are observed in the Fang area. Ground water in the San Kamphaeng area (GW-1 sample) has similar chemical composition to hot spring waters except high contents of Mg and

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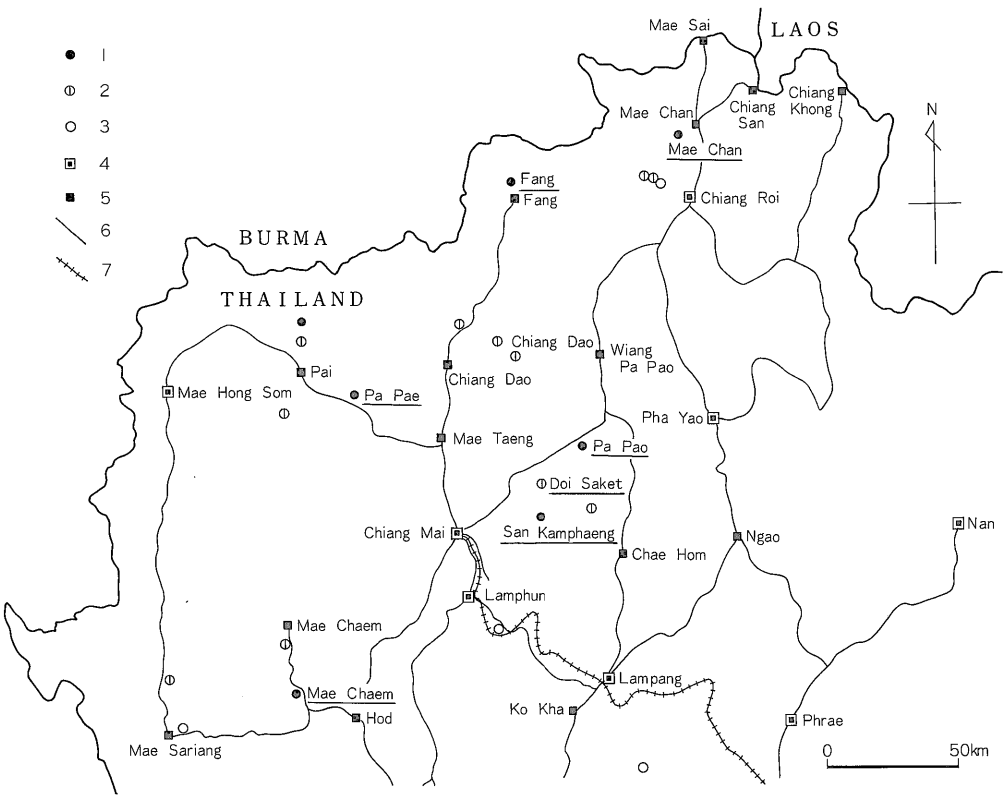

Fig. 1 Location of hot springs in northern Thailand.
1 : Hot spring (over 90°C) 2 : Hot spring (70–90°C)
3 : Hot spring (below 70°C) 4 : City
5 : Town 6 : Main road
7 : Rail road
Underlined names refer to the studied areas.

Table 1 Analytical method of hot water

Treatment	Element	Method
—	Tw	direct measurement by Hg thermometer
—	pH	direct measurement by colorimetry
Untreated	pH	pH meter in laboratory (other time sampling)
dito	TDS	gravimetry : dry 110°C
dito	Total alkalinity	titration by HCl standard soln.
dito	CL	titration by $AgNO_3$ standard soln.
dito	F	selective ion electrode potentiometry
dito	SO_4	gravimetry as $BaSO_4$
dito	K, Na, Ca, Mg	atomic absorption spectrophotometry
Acidified	K, Na, Ca, Mg, Fe, Mn	dito
dito	SiO_2	gravimetry

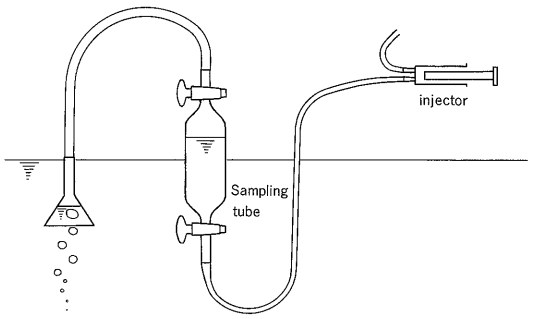

Fig. 2 Gas sampling Apparatus.

Table 2 Analytical method of gas by Gas chromatograph

Element	packed material in column	carrier gas
He, O_2, N_2, CH_4	Molecular Sieve 5A	Ar
Ar	dito	O_2
CO_2, C_2H_6	Active carbon	He

Fe whereas river water (STR-U sample) has quite different chemical compositions.

3.2 Gases

The results of gas analysis are shown in Table 8. Some data are corrected for probable air contamination by the method described by TEZUKA et al. (1983). The variation of gas components is remarkable. High He and H_2 contents are observed in the San Kamphaeng area and C_2H_6 is only observed in the San Kamphaeng and Fang areas. Carbon dioxide is quite variable even in the same geothermal field.

4. Discussion

4.1 Estimation of subsurface temperature

Based on the chemical analyses, subsurface temperatures of five geothermal areas are estimated. The maximum temperature obtained by silica geothermometer (TRUESDELL, 1975) is 166°C in the Fang area (Table 4) and that of Na-K-Ca geothermometer (FOURNIER and TRUESDELL, 1973) is 204°C at the San Kamphaeng area (Table 3).

Average temperature of Na-K-Ca geothermometer of four areas, San Kamphaeng, Fang, Pa Pae and Doi Saket, exceed 180°C or slightly lower than that value. Temperatures obtained by silica geothermometer are lower than those obtained by Na-K-Ca geothermometer. It may indicate the mixing of surface water to high temperature fluid occures during the ascending pass. Temperature differences of the above two estimations are greater in San Kamphaeng (46.7°C) and Doi Saket (36.3°C) than in Mae Chaem (11.3 °C) and Fang (18.2°C) areas. It may reflect the difference of the reservoir conditions. TAKASHIMA and KAWADA (1981) considered the existence of two reservoirs in the San Kamphaeng area as a probable cause of the temperature discrepancy estimated by the above two different geothermometers.

4.2 Chemical character of geothermal water

Hot spring waters of studied area are chemically characterized by 1) low total content of dissolved materials (less than 610 mg/*l* of TDS), 2) low Cl (less than 32 mg/*l*) and high F (up to 21 mg/*l*) contents, 3) low Ca (less than 5.8 mg/*l*) and Mg (less than 0.6 mg/*l*) contents, and 4) Na-HCO_3 type composition (Figs. 3 to 5). These characters are commonly found in almost all hot spring waters in northern Thailand (Department of Mineral Resources of Thailand, 1984).

The reason for the above mentioned chemical character and/or geochemical uniformity of the spring waters in the northern Thailand is not clear, whereas it was postulated from the isotopic analyses of the water that the main constituents of the water were leached out from the wall rocks by the reaction of water and rocks (TAKASHIMA and JARACH, 1986).

More detailed classification were carried out for the studied areas although basic character is not changed.

There are no clear relation between temperature and TDS as shown in Fig. 6. However, TDS values of each area have limited ranges but not overlap with other areas. It may not indicate simple mixture of ground waters with hot springs at shallow depth.

Two kinds of hot waters are identified from the diagram of TDS-Total alkalinity. One is high TDS group and the other is low TDS group. Both are proportionally increased their TDS values corresponding with their total

Table 3 Chemical compositions of hot springs in the San Kamphaeng area

No.	Sample No.	Tw (°C)	TDS (mg/l)	pH	T.A. (mg/l)	Cl (mg/l)	F (mg/l)	SO_4 (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	SiO_2 (mg/l)	T(SiO_2) (°C)	T(Na-K-Ca) (°C)
1	CM 1-A	95.0	580	8.3	359	19.6	17.5	19.7	14.9	158	2.98	0.38	0.078	142	151	194
2	CM 1-B	96.0	577	8.0	330	24.3	17.1	34.0	15.1	157	2.86	0.12	0.020	137	149	195
3	CM 1-M	90.0	539	8.0	320	29.5	16.2	27.8	13.6	151	4.39	0.36	0.140	112	139	186
4	CM 1-C	92.0	561	8.1	332	25.9	16.8	34.5	14.5	155	3.45	0.15	0.038	130	147	191
5	CM 1-E	93.0	533	8.0	337	21.9	16.2	17.0	13.4	150	4.21	0.27	0.110	112	139	186
6	CM 1-G	84.0	580	8.1	340	21.7	17.7	31.4	14.6	159	1.79	0.23	0.038	134	148	197
7	CM 1-H	93.0	604	8.9	350	19.8	18.1	34.1	15.2	162	1.05	0.13	0.144	153	155	204
8	CM 1-I	98.0	607	8.5	342	17.6	17.9	26.2	14.8	161	1.86	0.52	0.262	145	152	197
9	CM 1-J	99.5	561	8.6	309	31.0	17.7	65.5	15.2	162	1.40	0.47	0.080	136	149	201
10	CM 1-L	99.0	580	8.6	313	31.6	17.7	67.0	14.6	164	1.26	0.14	0.022	150	154	199
11	GW-1	27.7	363	8.9	248	13.7	12.0	2.47	3.63	101	2.20	2.72	2.190	80.4		
12	STR-U	24.0	335	8.0	315	3.75	0.20	6.71	0.83	7.61	41.5	32.4	0.038	39.0		
13	STR-D	36.5	385	8.1	298	4.74	6.70	35.1	5.85	61.6	35.2	17.3	0.360	63.3		

Table 4 Chemical compositions of hot springs in the Fang area

No.	Sample No.	Tw (°C)	TDS (mg/l)	pH	T.A. (mg/l)	Cl (mg/l)	F (mg/l)	SO_4 (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	SiO_2 (mg/l)	T(SiO_2) (°C)	T(Na-K-Ca) (°C)
1	CM 3-A	93.0	518	9.0	263	17.5	20.9	18.8	9.04	125	1.64	0.04	0.090	178	163	180
2	CM 3-B	95.0	523	9.3	255	18.0	21.5	18.6	9.25	125	1.69	0.05	0.100	182	164	181
3	CM 3-C	96.0	513	9.45	237	27.5	21.5	44.1	9.10	128	1.45	0.04	0.100	180	164	181
4	CM 3-D	90.0	516	9.45	235	26.7	21.7	45.9	9.22	131	1.10	0.05	0.124	188	166	183
5	CM 3-E	90.0	487	9.3	240	18.4	20.0	19.7	8.61	121	1.58	0.10	0.156	169	160	179
6	CM 3-F	94.0	503	9.4	246	17.7	21.3	32.7	9.13	126	1.20	0.01	0.074	179	163	183
7	FANG-1	99.0	510	9.0	245	18.0	—	22.5	8.68	120	1.41	0.05	0.277	176	162	181
8	FGTE-3	98.5	499	8.9	247	17.0	—	19.4	8.84	120	1.88	0.10	0.351	169	160	179
9	FGTE-5	99.0	519	9.1	255	18.4	—	20.3	8.98	126	1.23	0.07	0.083	180	163	182
10	F MINE	40.0	342	7.9	181	3.63	5.10	96.6	8.56	54.3	28.4	13.6	0.250	50.6	164	

Table 5 Chemical compositions of hot springs in the Pa Pae area

No.	Sample No.	Tw (°C)	TDS (mg/l)	pH	T.A. (mg/l)	Cl (mg/l)	F (mg/l)	SO_4 (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	SiO_2 (mg/l)	T(SiO_2) (°C)	T(Na-K-Ca) (°C)
1	CR 6 A−1	93.0	430	8.51	248	13.8	—	12.5	9.96	104	3.03	0.23	0.251	147	153	186
2	CR 6 A−2	89.0	441	8.29	246	9.84	—	25.6	9.18	105	2.63	0.93	4.05	162	158	183

Table 6 Chemical compositions of hot springs in the Doi Saket area

No.	Sample No.	Tw (°C)	TDS (mg/l)	pH	T.A. (mg/l)	Cl (mg/l)	F (mg/l)	SO_4 (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	SiO_2 (mg/l)	T(SiO_2) (°C)	T(Na-K-Ca) (°C)
1	CM 2−A	82.0	442	7.5	291	12.3	8.90	20.6	9.30	119	4.54	0.42	0.340	111	139	174
2	CM 2−B	77.0	469	8.4	320	11.3	9.50	20.3	10.5	130	3.36	0.15	0.038	128	146	180
3	CM 2 A−1	84.0	461	8.35	304	18.6	—	38.7	11.1	131	3.58	0.17	0.472	127	145	182
4	CM 2 A−2	82.0	439	8.23	285	12.8	—	21.5	10.3	120	5.79	0.44	0.092	110	138	177

Table 7 Chemical compositions of hot springs in the Mae Chaem area

No.	Sample No.	Tw (°C)	TDS (mg/l)	pH	T.A. (mg/l)	Cl (mg/l)	F (mg/l)	SO_4 (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	SiO_2 (mg/l)	T(SiO_2) (°C)	T(Na-K-Ca) (°C)
1	CM 7−A	89.0	421	8.3	259	13.9	17.9	12.1	6.30	119	3.67	0.01	0.020	132	147	156
2	CM 7−I	96.0	418	8.6	255	18.7	18.1	13.6	6.21	119	2.49	0.01	0.050	132	147	159
3	CM 7−J	91.0	411	8.6	253	13.4	17.5	11.9	5.90	115	2.18	0.01	0.050	127	145	158
4	STR−D	71.0	425	8.3	257	19.3	18.5	15.0	6.17	123	1.95	0.01	0.100	133	148	159

Tw : Temperature of hot spring T.A. : Total alkalinity (as HCO_3) Analysed by T.Hirukawa (Geological Survey of Japan) (include other areas)

Table 8 Gas analysis of some hot spring areas in northern Thailand

No.	Sample No.	Tw (°C)	He (V.%)	H_2 (V.%)	O_2 (V.%)	M_2 (V.%)	Ar (V.%)	CO_2 (V.%)	CH_4 (V.%)	C_2H_6 (V.%)	Total (V.%)	N_2/Ar	CH_4/H_2
1	CM 1−B*	96	0.080	0.000	0.11	84.00	2.59	8.95	4.26	0.012	100.002	32.4	—
2	CM 1−M	90	0.112	0.000	0.13	92.36	1.72	2.56	3.12	0.000	100.002	53.7	—
3	CM 1−C*	92	0.107	0.000	0.10	91.24	1.74	3.30	3.51	0.000	99.997	52.4	—
4	CM 1−H	93	0.021	5.491	0.10	58.62	1.37	33.18	1.22	0.000	100.002	42.8	0.22
5	CM 1−L	99	0.088	6.990	0.14	78.25	1.78	9.81	2.94	0.000	99.998	44.0	0.42
6	CM 1−1		0.039	4.698	0.11	38.36	1.10	54.20	1.50	0.000	100.007	34.9	0.32
7	CM 2−A*	82	0.015	0.000	0.29	91.40	1.46	6.84	0.00	0.000	100.005	62.6	—
8	CM 2−C*		0.053	0.000	0.12	93.14	1.44	3.00	2.25	0.000	100.003	64.7	—
9	CM 3−D*	90	0.064	0.000	0.10	55.18	1.82	28.93	13.88	0.030	100.004	30.3	—
10	CM 7−A*	89	0.080	0.212	0.10	31.53	0.90	66.86	0.32	0.000	100.002	35.0	1.51
11	CM 7−I*	96	0.011	0.215	0.09	32.50	0.85	65.36	0.98	0.000	100.006	38.2	4.56

No. 1−6 : San Kamphaeng area No. 7−8 : Doi Saket area No. 9 : Fang area No. 10−11 : Mae Chaem area

* Corrected value for probable air contamination

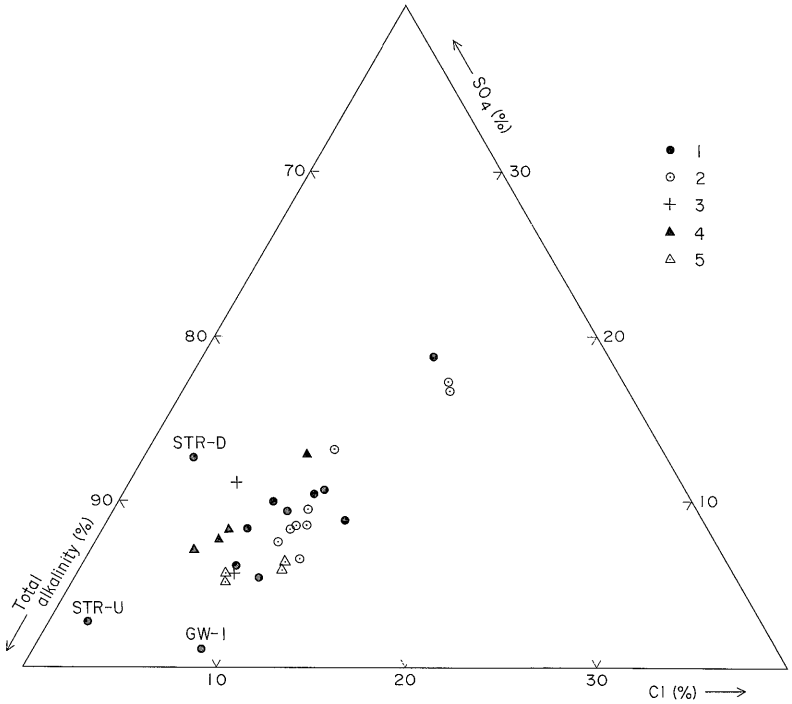

Fig. 3 Triangular diagram of hot springs.
1 : San Kamphaeng area 2 : Fang area
3 : Pa Pae area 4 : Doi Saket area
5 : Mae Chaem area

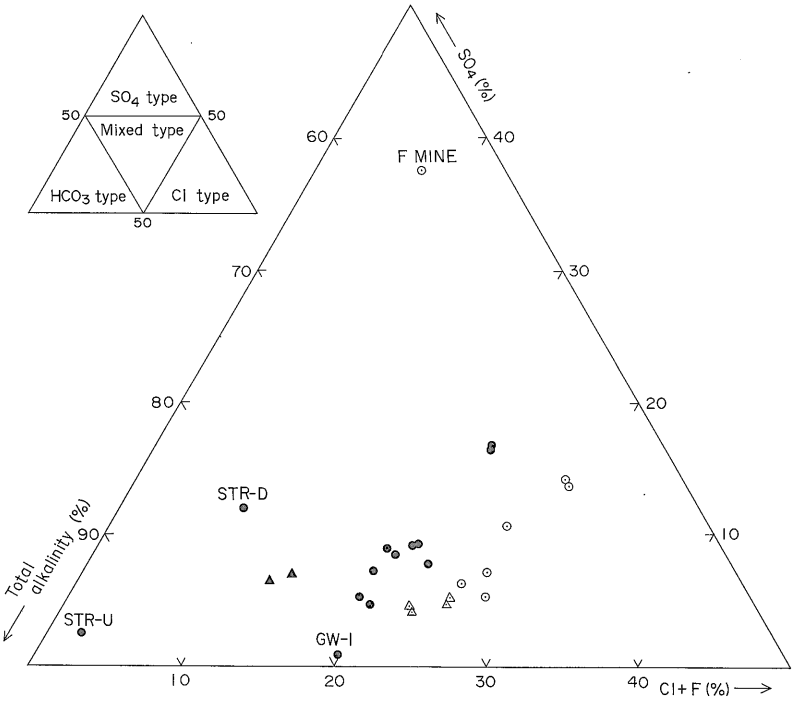

Fig. 4 Triangular diagram of anion composition.

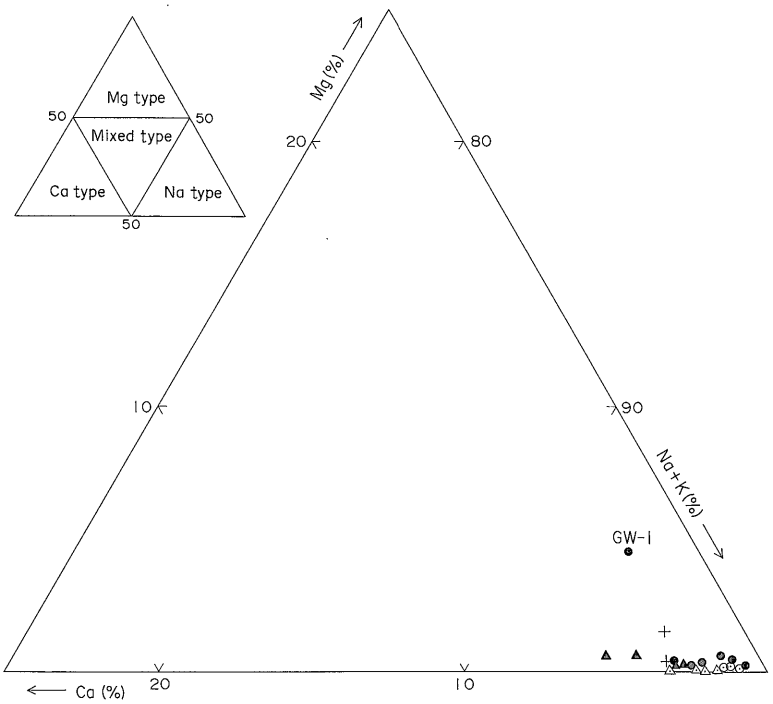

Fig. 5 Triangular diagram of cation composition.

alkalinity (Fig. 7). The difference between lines A and B in Fig. 7 may be attributed to the geologic conditions of each area although the details of them are unknown.

A reciprocal proportion is clearly observed in F and Ca contents for the hot spring waters of San Kamphaeng area (Fig. 8). For other areas, such relation is ambiguous and the reason for the above phenomena is not clear.

4.3 Character of gases

Main compositions of gases are plotted in both N_2 type (eight samples) and CO_2 type (three samples) regions of trianglular diagram (Fig. 9).

As shown in Table 8, H_2 is only detected in the San Kamphaeng and Mae Chaem areas. Presence of H_2 sometimes indicates the existence of active fault (WAKITA et al., 1980). Accordingly these two areas have some possibilities of existence of the fault whick has similar character to an active fault.

The low ratio of CH_4/H_2 indicates the good reservoir conditions (AKENO, 1978). In this study, CH_4/H_2 ratio can be calculated only for two areas (Table 8). Even so, good reservoir condition is posturated in the San Kamphaeng area by the low values of the ratio.

The N_2/Ar ratios similar to that for air dissolution to pure water at room temperature (the value is 40.2 at 25°C) indicate the high air contamination in all studied areas (Table 8).

Very high CO_2 contents in the San Kamphaeng, Fang and Mae Chaem areas correspond to the presence of limestone around the hot springs.

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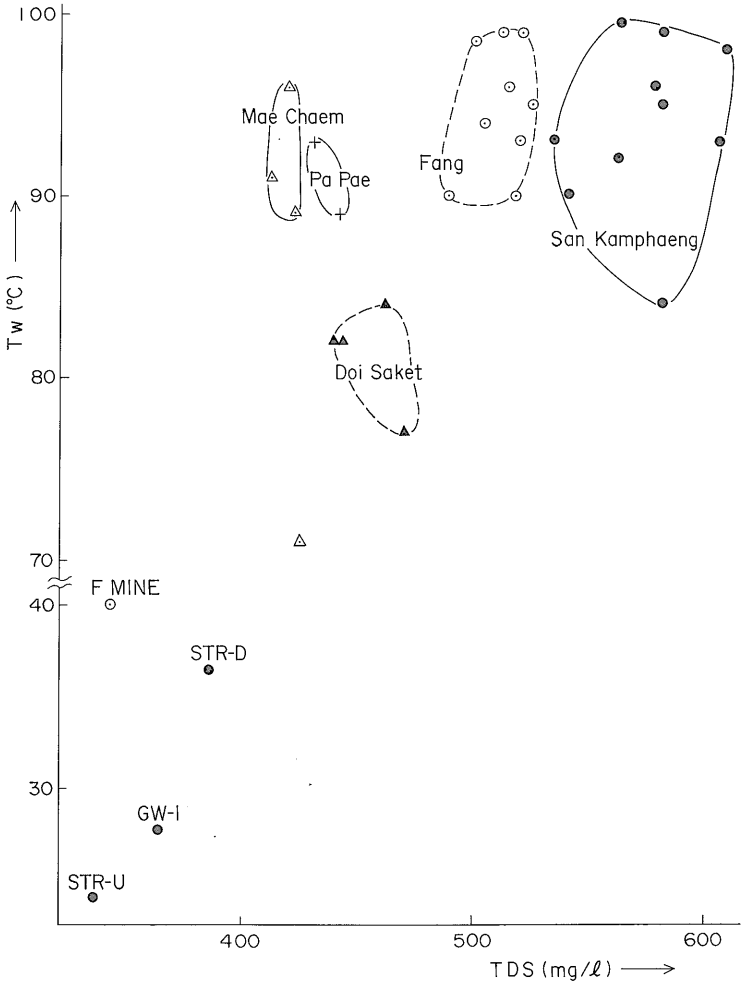

Fig. 6 Relationship between Tw and TDS.

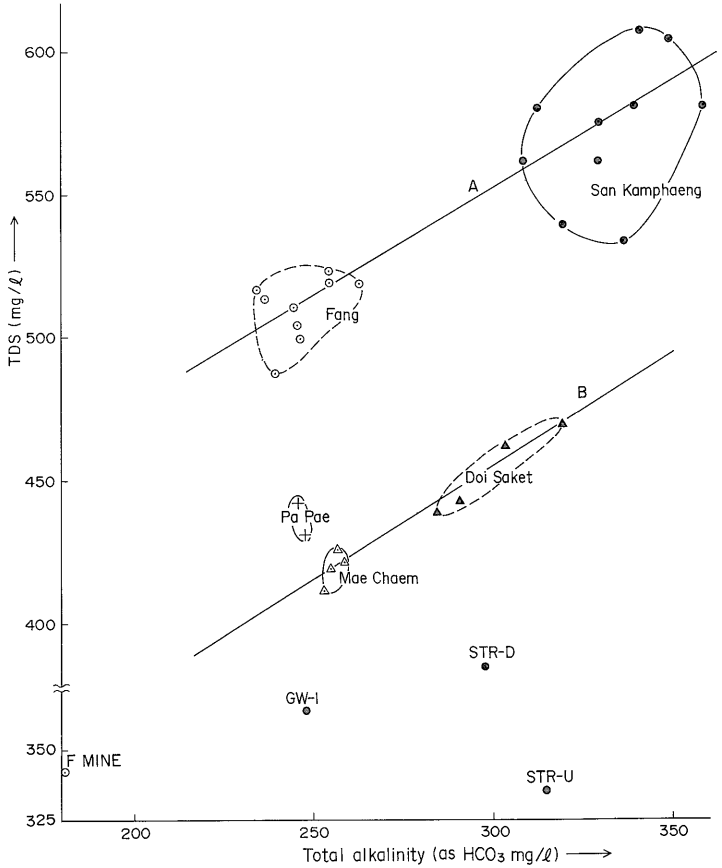

Fig. 7 Relationship between TDS and Total alkalinity.

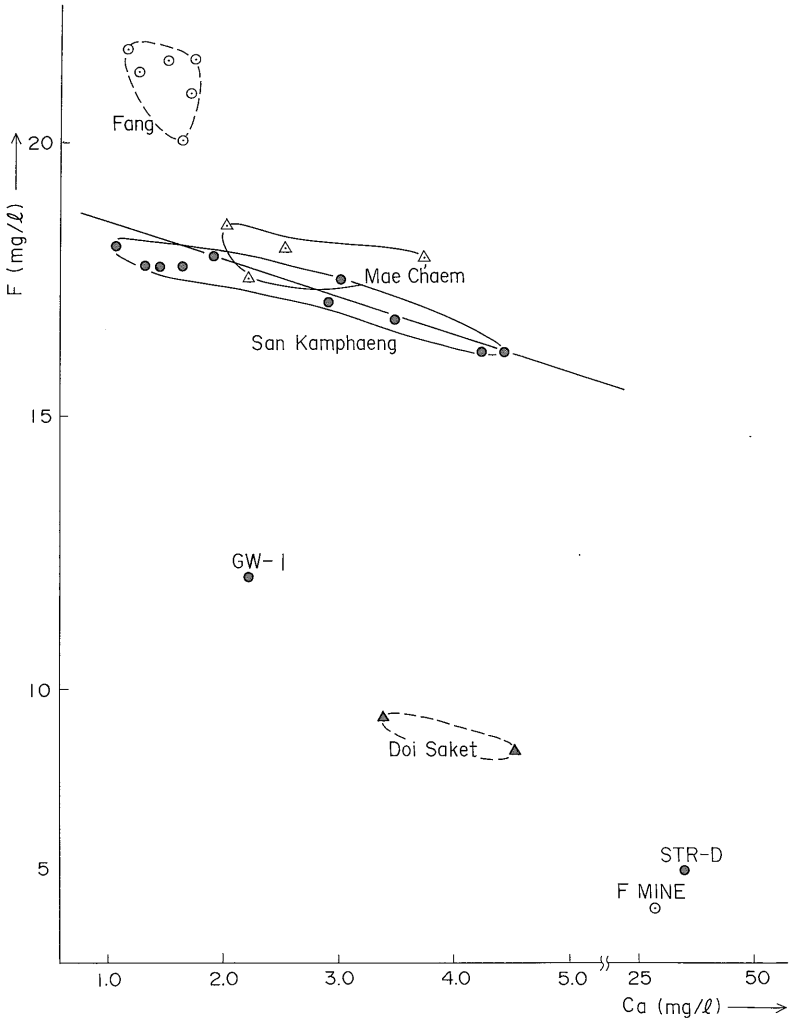

Fig. 8 Relationship between F and Ca.

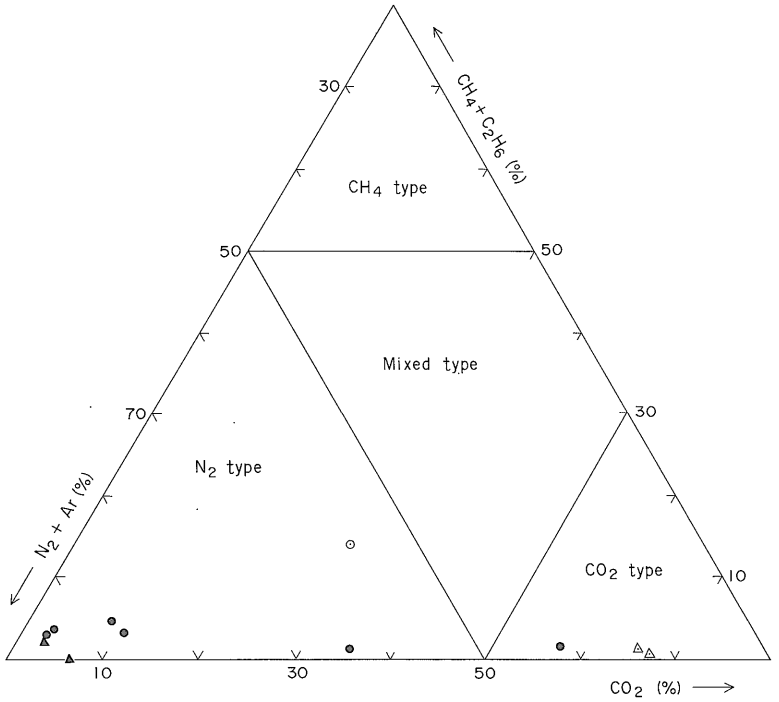

Fig. 9 Triangular diagram of gas composition.

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北部タイ主要地熱地域における熱水及びガスの地球化学

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要　旨

北部タイ地域に分布する温泉は比較的類似した化学組成を示し，70°C 以上の高温泉が広い範囲に分布している．これらの温泉に由来する熱流体（熱水及びガス）を地球化学の面から研究するためサンカンペン，フアン，パ・パエ，ドイサケット及びメチャムの 5 地域について熱水及びガスを採取し，測定・分析を行った．

研究を行った 5 地域の熱水は，高温（Tw＞71°C），弱アルカリ性（pH＝7.5－9.5），低溶存物（TDS＜610 mg/*l*），Cl＜F（当量値），低 Ca 濃度（5.8 mg/*l* 以下，ほぼ F 濃度と逆相関）及び低 Mg 濃度（0.6 mg/*l* 以下）の特徴を示し，Na-HCO_3 型の水質組成を示す．

熱水の化学組成から求めた貯留層の推定温度は，Na-K-Ca 法により 180–200°C，SiO_2 法により 140–165°C となり，熱水の上昇時における地表水との混合が推定される．

ガスの主要成分は N_2 8 試料及び CO_2 3 試料であり，サンカンペン及びメチャム地域においては，0.*n* % 以上の H_2 が検出され，活断層類似の断層の存在が推定された．また CH_4/H_2 比の値による貯留層の推定温度（サンカンペン及びメチャム以外の地域においては，H_2 が検出されない）は，サンカンペン地域で高い．

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