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GEOLOGY AND GEOTHERMAL RESOURCES OF PAI DISTRICT, MAE HONGSON PROVINCE, NORTHERN THAILAND

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ABSTRACT

About 300 square kilometers of Pai district is occupied by large pluton of granite which is predominantly coarse grained biotite granite of Triassic age. The main joint patterns of granitic body lie in NNE, NE, EW and NNW trending, having the appropriate permeability for hot fluid ascending to the surface in some geothermial areas i.e. Ban Pong Mai (MH_4), Ban Muang Rae (MH_6) and Huai Muang Paeng (MH_8). The other thermal areas i.e. Pong Sak (MH_3), Pong Pa (MH_5), Ban Mae Na (MH_7), Ban Mae He (MH_{10}) and Pong Jaja (MH_{14}) are associated with semimentary rock and low-grade metamorphic rock of Paleozoic Era. These Paleozoic rocks which exposed around the granitic batholith are composed of Cambrian quartzite; Ordovician limestone; low-grade metamorphic rocks of Silurian-Devonian age; conglomerate, sandstone, siltstone and shale in Carboniferous and Permian limestone. Tertiary beds exposed locally along the edge of Pai Basin which is also filled by Quaternary sediments. Old basic volcanic rock locally distributes and mostly found underlain the Permian limestone. Joint systems of the geothermal areas found in Paleozoic rock are resemble with those found in Triassic granite.

Most of the geothermal systems in Pai district can be defined as warm and hot water systems (Hochstein, 1985). The fluids are generally clear, low chemical and gas constituents, and slightly alkaline with pH = 7.8 - 8.7.

The surface temperature and total heat discharged ranges from 40 - 91°C and 0.1 - 9 MW respectively. Superficial alterations around the hot spring areas are dominantly calcite, silica, clay minerals and sodium fluosulphate. Heat sources may be effected by anomalously high heat flow from high heat generating capacity of granites.

INTRODUCTION

Pai district of Mae Hongscn province, is one Of the top north district of Thailand. It is located about 137 km NNW of Chiangmai province. Most of the area is covered by high mountainous ranges with the highest peak of Doi Chik Chong (about 1,972 m above MSL). The. low terrain of Pai basin occupies about 35 sq. km with the average altitude of 550 m above MSL. The drainage patterns are generally dendritic to sub-dendritic and sub-parallel systems which are dominantly fault controlled. The major drainage is Pai river which flows southward through Pai district and turns to the west near Ban Muang Rae. Several hot springs i.e. Ban Muang Rae, Pong Jaja, Pong Sak, and Pong Pa appear along the bank of this river as hot pools and seep types.

The average rainfall is of 1,253 mm per year (data during 1951-1975, taken from Mae Hongson station, Meteorological Department, Ministry of Communications, Bangkok) and the mean maximum rainfall is of 262.8 mm in August. The mean evaporation is 662.2 mm per year. The hottest period is in April with the mean maximum temperature of 37.7°C and the coldest period is in January with the mean maximum temperature of 14.0°C while the average annual temperature is of 25.4°C.

The investigations of Pai district are aimed at geological and geochemical work. Besides, the geophysical survey might have been conducted in the future.

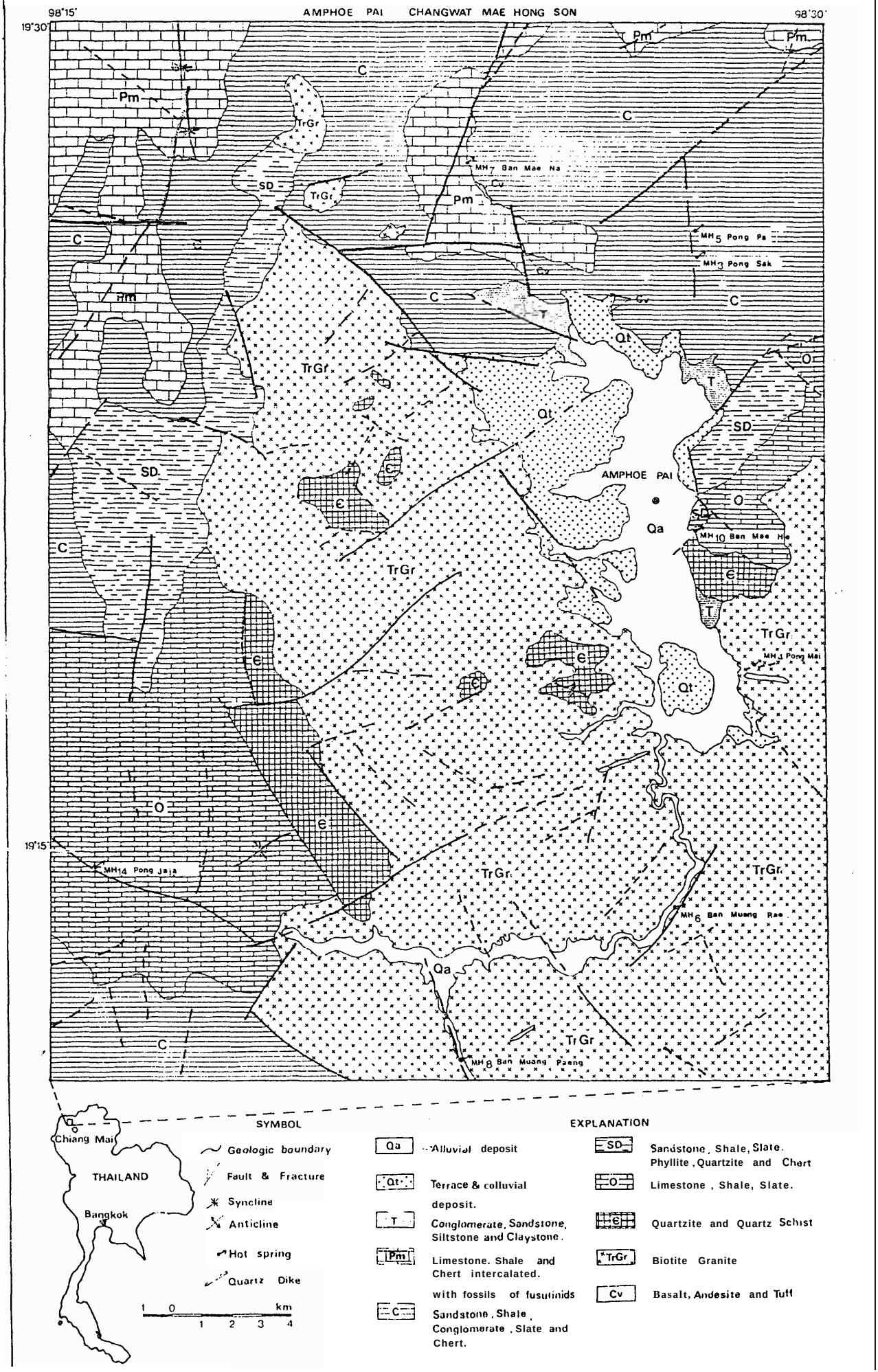
GEOLOGY OF PAI DISTRICT

The geological map of Pai district (Fig. 1) displays a wide distribution of various rock types in different ages. Stratigraphically, the Pai district exposed the thick sequence of sedimentary and low grade metamorphic rocks ranging in ages from Cambrian to Quaternary. The Cambrian rocks consisting of gray quartzite, quartz schist and locally skarn rock are distributed at the east and west margin of granitic pluton and partly formed as the roof pendants in granite. The foliation of these rocks obviously lie in the NS trendings. The Ordovician rocks are composed chiefly of massive to thin bedded limestone with argillaceans bands, slate and shale interbedded,, overlying conformably the Cambrian sequences. The Silurian Devonian rocks expose on the western and eastern parts of the area. They are characterized by the low-grade metamorphic rocks i.e. quartzite, phyllite and slate with occasionally limestone and chert intercalated. The Carboniferous rocks are widely distributed in the north of the investigated area. The sequences are mainly clastic sediments of conglomerate, sandstone, siltstone, shale with partly laminated limestone chert and slate intercalated. The Permian rocks are predominantly bedded to massive limestone with locally sandstone, shale and chert interbedded. Most of them are exposed in the northeastern part of the area and lie conformably on the Carboniferous rocks. The Tertiary sediments are locally exhibited along the edge of Pai basin. The sequences are made of conglomerate, sandstone, siltstone, and claystone. The Quaternary terraces and alluvium are developed in Pai basin, and mostly lie unconformably over the older rocks.

The igneous rocks which are mainly biotite granite of Triassic age are formed as the batholith in the central part of the area and distributed to the south. Besides, the minor hornblende biotite granite, leucocratic granite and quartz dykes are also found scattering in this batholith. The old basic volcanic rock, forming as fissure eruption, locally found underlain the Permian limestone. But some of them are associated with the Carboniferous rocks.

Structurally, the main normal fault patterns lie in NNE, NNW, NE and NS trendings while the major joint systems are predominantly in NNW and ENE direction (Udomratn et al., 1985) and the other joint patterns lie in NW NNE and WNW direction. All of the hot

FIG. 1


GEOLOGICAL MAP OF
AMPHOE PAI CHANGWAT MAE HONG SON
98°15'
98°30'
19°30'
19°15'
Pm
C
TrGr
SD
MH7 Ban Mae Na
Cv
MH5 Pong Pa
MH3 Pong Sak
T
Qt
O
AMPHOE PAI
Qa
MH10 Ban Mae Hie
MH1 Pong Mai
MH14 Pong Jaja
MH6 Ban Muang Rae
MH8 Ban Muang Paeng
Chiang Mai
THAILAND
Bangkok
SYMBOL
Geologic boundary
Fault & Fracture
Syncline
Anticline
Hot spring
Quartz Dike
1 0 1 2 3 4 km
EXPLANATION
Qa Alluvial deposit
Qt Terrace & colluvial deposit.
T Conglomerate, Sandstone, Siltstone and Claystone.
Pm Limestone. Shale and Chert intercalated.
C Sandstone, Shale, Conglomerate, Slate and Chert. with fossils of fusulinids
SD Sandstone, Shale, Slate. Phyllite, Quartzite and Chert
O Limestone, Shale, Slate.
Є Quartzite and Quartz Schist
TrGr Biotite Granite
Cv Basalt, Andesite and Tuff

springs are associated with these sets of faultings and fracturing which probably occurred in post-Tertiary period.

GEOTHERMAL RESOURCES

Eight thermal springs that manifest on the ground surface of Pai area, can be classified into two groups due to the associated rocks. The first group i.e. Ban Pong Mai (MH_4), Ban Muang Rae (MH_6) and Huai Muang Paeng (MH_8) occur in the Triassic granitic terrain. The other group i.e. Pong Sak (MH_3), Pong Pa (MH_5), Ban Mae Na (MH_7), Ban Mae He (MH_{10}) and Pong Jaja (MH_{14}), are associated with sedimentary rock and low-grade metamorphic rock of Paleozoic Era. The major joint systems of the rocks exposed in both group lie in the direction of NNE, NE, EW and NNW trendings. Most of the geothermal systems can be defined as warm and hot water systems. The surface discharged features are clear hot pool, warm pool and seep types. The chemistry of the warm and hot water systems described in this paper has been summarized in Table 1. Most of the thermal fluids are clear, low chemical and gas constituents, and slightly alkaline with pH = 7.8 - 8.7. The surface temperature ranges from 40 - 91°C and the total heat discharged lies within the range of 0.1 - 9 MW (Table 1).

The two most impressive out of the eight thermal areas in Pai district are Huai Muang Paeng and Pong Mai. At Huai Muang Paeng, the thermal area covers about 100 x 30 sq. m, and most of the surface activities are clear hot pool and seep types with the maximum temperature = 91°C. Gases discharge continuously, and large amount of steam separation can be observed. The superficial alterations are amorphous silica, sodium-fluosulphate, clay minerals and carbonate which formed as the travertine terrace, cf. Fig. 2.

Fig. 2: The typical silica and travertine terrace form at Huai Muang Paeng (MH_8)

Boulders of porphyritic, biotite granite can be found around the thermal area.

For Pong mai hot spring, it covers an area of 150 x 35 sq. m and the thermal characteristics are similar to Huai Muang Paeng hot spring. (Fig. 3) The maximum temperature is 78°C. Gases are present in intermitten discharge and large amount of steam separation can also be observed. The superficial alterations are silica and carbonate. Outcrop of porphyritic, biotite'granite are exposed near the thermal area.

	MH_3	MH_4	MH_5	MH_6	MH_7	MH_8	MH_{10}	MH_{14}
Flow	16	63.6	7.9	seep	seep	85.6	seep	seep
T(°c)	85	78	88	75	40	91	37	43
pH	8.7	8.3	8.6	8.5	7.8	8.3	8.2	8.1
SiO_2	83.4	152	90	95	52.1	90	40	64.2
Fe	nd	nd	nd	2.5	nd	0.53	nd	nd
Mn	nd	nd	nd	nd	nd	nd	0.06	0.04
Ca	6.5	3.8	5.3	6.0	70.0	5.6	29.8	38.9
Mg	0.13	0.04	0.13	0.12	8.33	0.04	9.7	8.9
Na	98	80	96	169	30.8	121	97.2	114.1
K	4.8	3.2	4.6	18.8	3.9	5.0	12.8	6.9
HCO_3^-	197	194	198	444	310	236	376	406
SO_4	22	15	32	19	21	24	36.8	40
F	nd	nd	nd	6.0	1.0	nd	6.0	6.3
Br	nd	nd	nd	0.6	nd	nd	nd	nd
THD(MWt)	1.8	9.3	1.1	<0.1	<0.1	7.4	<0.1	<0.1
Na/k	20	25	21	9	8	24	8	17
T(°c) qtz no steam loss	127	162	131	134	104	131	92	114
T(°c) qtz max. steam loss	124	153	128	130	104	128	94	113
T(°c) Na-K	163	149	161	226	238	151	242	177
T(°c) Na-K-Ca	145	137	145	198	153	142	182	143

Table 1 Chemical analyses of waters from thermal spring in Pai district, constituents in mg L^{-1}, flow in L sec^{-1}; nd = not determined, THD = Total heat discharged, MH_3 = Pong Sak; MH_4 = Pong Mai; MH_5 = Pong Pa; MH_6 = Ban Muang Rae; MH_7 = Ban Mae Na; MH_8 = Huai Muang Paeng; MH_{10} = Ban Mae He; MH_{14} = Pong Jaja. T(°c) geothermometer refer to the equation from Fournier (1981).

Fig. 3: The ground surface manifestation of Pong Mai (MH_4)

CONCLUSION

Hot spring systems in Pai district are associated with Triassic granite and the Paleozoic rocks. Most of them are fault controlled and likely to be formed as the fracture reservoir. Heat sources of these thermal systems may be effected by the anomalous high heat flow from high heat generating capacity of granite. The chemistry of the thermal waters are quite similar and most of them have low total dissolved solids. The ratio of Na:k, about 21:1, reveals that most of the hot water may come from the same sources except at MH_6, **MH7** and MH_{10} which may be effected by the mixing process. In addition, the subsurface temperature calculated by various geothermometer fall within the range of 130" - 180°C. The natural heat discharge of the thermal areas in Pai district lies within the range of 0.1 - 9 MWt (not including heat transfer by evaporation and conduction). The low total dissolved solid and low natural heat output may support the figure that the heat flow within the granite likely to be the heat source of those thermal systems.

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