Northern Thailand Geothermal Resources and Development— A Review and 2012 Update

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ABSTRACT

Northern Thailand has 16 hot spring systems with surface temperatures near or greater than 80°C with potential for binary plant power generation. Presently only Fang system generates power from wells flowing a total of 8.3 1/s of 116°C water to a 300 kW single module Ormat binary plant. Current production is 150-250 KW, which potentially can be increased by constructing new wells and increasing flow by pumping. Of the other 15 systems, 4 are in national parks and not considered for development. Several of the hot springs systems have silica geothermometry >130°C suggesting significant undeveloped resources exist in northern Thailand. Certainly the San Kamphaeng hot springs have the greatest known potential (estimated ~5MW) but like most of the systems it is associated with high-angle faulting and drilling has yet to find permeable zones yielding high flows (>11 l/s). The current project of the Thailand Department of Energy Development and Efficiency (DEDE) will survey these prospects with the intention of installing a small plant of 2-10 MW.

Introduction

In Northern Thailand, 16 hot spring systems (surface temperature >80ºC) are identified with potential for binary-plant geothermal power generation (Fig. 1, Table 1). Five of these locations within national parks are not being considered for development. The hot-spring systems are generally located on high-angle fault systems within Paleozoic and Mesozoic plutonic rock, Paleozoic metavolcanic rocks, or along the edges of Cenozoic basin sediments faulted against pre-Cenozoic rock. Much of the region is covered by dense vegetation and deeply weathered rock; however geologic maps are available for some of the areas.

At the present time, the only electrical generating facility is at Fang. In 1989 the Fang system was explored by drilling 4 wells that encountered fracture systems in granite at 268-417-m depth. The highest downhole temperature was 130ºC and combined flow was 36 t/h (~ 8.3 l/s) (Ramingwong et al., 2000; Korjedee, 2002). The 1989 installed single-module ORMAT binary 300 kWe plant generates 150-250 kWe that varies with season. Supply is now from shallow wells flowing a total of 8.3 l/s of 116ºC (1.1-1.3 bars wellhead pressure) water. One well is reamed and cleaned on a two week cycle to remove scale, while production is drawn from the other three wells. Estimated power cost is 6.3-8.6 US cents/kWh. The exhaust hot water from the power plant is used for a demonstration crop dryer with air-conditioning, and cold storage (Korjedee, 2002).

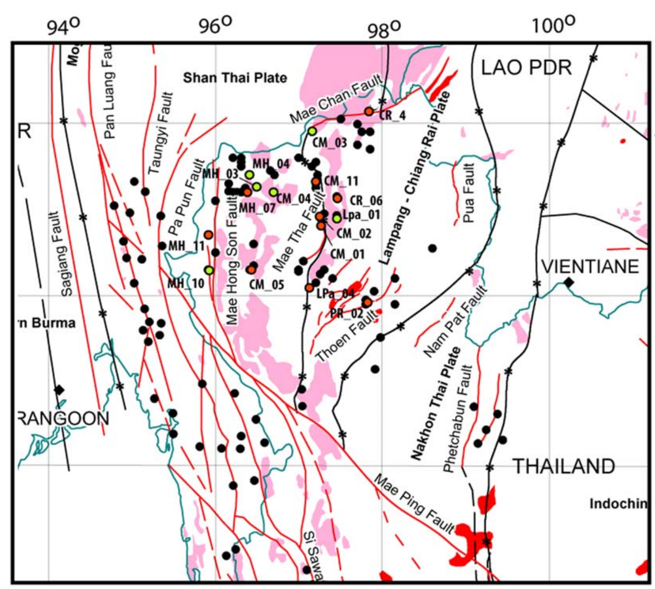

Figure 1. Location of hot springs in northern Thailand and adjacent Lao PDR and Myanmar. Geothermal areas(>80ºC) (Table 1) considered in this report are shown by a red infill dot, and labeled CR_04, etc., green infilled dots are locations of geothermal systems within national park areas. Pink areas are plutonic rocks, red areas are late Cenozoic basalt fields. Black lines with crosses are Mesozoic suture zones bounding sub-plates of continental Indochina. Red lines are active faults. Map is from Chulalongkorn University (2012).

Table 1. List of hot spring systems with surface temperatures near or greater than 80°C. Locations shown in Fig.1.

*Code	Name	UTM East	UTM North	Surface Temp. (°C)	Flow Rate (l/s)	Deposits Noted
CR_04	Mae Chan	583900	2225400	93.0	1.10 & 5.55	[2]silica encrustations, [3]silica muds
CR_06	Sop Pong (Lao River), Wiang Pa Pao District	548711	2113505	79.3	0.44	[2]sulfur, quartz?
CM_01	San Kamphaeng	524021	2080391	[6]42	[6]72	[5]alunite-kaolinite alteration
CM_02	Ban Pong Kum, Doi Saket District	525934	2090905	96.3	0.26	[2]sulfides, sulfur, salts?
*CM_03	Fang	516113	2207650	98.1	1.56	[4]siliceous sinter
*CM_04	Pong Duet (Mae Sae), Mae Taeng District	467017	2128036	95.0		[1,4]silica, sinter
CM_05	Tep Pha Nom (Om Khut), Mae Chaem District	436179	2020292	98.9	1.65	[2,4]silica, [1]calcite, banded sinter
CM_11	Ban Pong, Phrao District	518234	2141998	75.0	1.19	[2]gypsum, thenardite
*MH_03	Tha Pai, Pai District	444954	2134882	78.9	1.44	
*MH_04	Pong Pa, Pai District	442804	2149255	87.4	0.23	
MH_07	Mueng Paeng, Pai District	434450	2121998	96.0		[3]evaporates & calcareous cement
*MH_10	Mae Oom Luang, Mae Sariang District	394290	2013422	78.8	0.19	
MH_11	Ban Nong Haeng, Khun Yuam District	388689	2063150	81.1	3.00	
*LPa_01	Chae Son (Nam Mae Mon), Chae Hom District	549691	2082792	83.7	1.10	
Lpa_04	Ban Pong Nam Ron, Serm Ngam District	511283	2006176	78.0		
PR_02	Ban Mae Chok, Wang Chin District	567485	1987932	80.5	0.05	[2]thenardite, calcite, quartz

*indicates systems within national park areas. Code Names refer to provinces:
CR=Chiang Rai, CM=Chiang Mai, MH=Mae Hong Son, LPa=Lampang, PR=Phrae.

Additional data from other studies:
[1]Nathan (1976),
[2]Geotermica Italiana (1984),
[3]L. Owens, unpublished data,
[4]Barr et al. (1979),
[5]JICA(1984),
[6]Stream flow from more than 70 hot springs at CM_02 measured by Nathan (1976). JICA (1984) reports a max. surface temperature, 98°C.

In the discussion that follows we consider each system as it was known in its undeveloped state, in order to evaluate and compare the known potential of each area. The maximum temperatures and flows in these older reports differ in places from those taken more recently and indicated in Table 1. We then follow with a review of exploration results to date including additional fluid sampling and geothermometer calculations (Table 2). Mineral equilibria models are provided for higher temperature prospects using reconstruction of boiling fluids by WATCH (Arnórsson et al, 1982; Iceland Water Chemistry Group, 2010) and saturation indices calculations in WATCH and Geochemist's Workbench.

Known Geothermal Systems (T>80°C)

Alpha-Numeric Labeling of Hot Springs Systems

The numbering of each hot springs system refers to a geothermal database obtained by F. Singharajwarapan and the Thailand Department of Alternative Energy and Efficiency (DEDE) in 2006. The prefix refers to the province in which the hot springs are located as indicated in the Figure 1 caption. Maybe there should be a link to the website here.

Figure 2. Hot water (94 ºC) spouting from a 56-m borehole at Mae Chan Hot Springs (CR_04).

CR_04: Mae Chan (Ban Pong Nam Ron)

The hot springs occur over a 2.4 hectare area next to the Mae Chan River. The springs are located along the active Mae

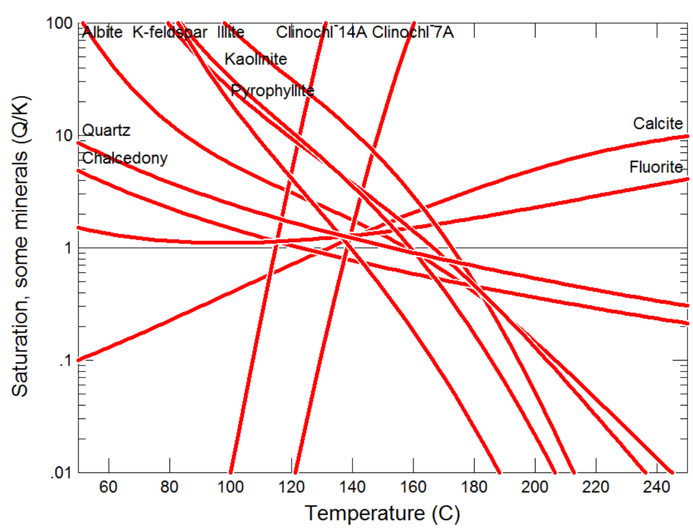

Figure 3. Mae Chan Bubbling Rock Pool (CR_04) illustrating disequilibrium between shallow conductive cooling fluids (110ºC) and possible deeper low flow recharge. Shallow equilibrium temperatures of ~110 ºC as predicted by equilibrium Saturation Index (SI) of Chalcedony and chlorite agree well with observed downhole temperatures identified in Mae Chan shallow well (112ºC).

Table 2. New Chemistry and calculated geothermometry from selected geothermal waters collected by L. Owens.

Number	Sample Name	Date	EC µS/cm	SiO2 (mg/l)	Ca (mg/l)	K (mg/l)	Na (mg/l)	Mg (mg/l)	Chalc.* (c.c) °C	Quartz (c.c.)* °C	Quartz (a./m.s.l.)* °C	Na-K-Ca (Mg c.)* °C	Na/K** °C	K/Mg [1] °C
CR_04	Mae Chan Well 1	9/10/11	620	120	1.5	7.9	120	<0.10	122	148	141	175	146	133
CR_04	Mae Chan Rock Pool	9/10/11	620	130	1.9	8.4	120	<0.10	127	153	145	176	152	135
CR_06	Sop Pong HS 1	9/9/11	460	140	2.1	7.8	100	<0.10	133	157	149	178	162	133
CM_01	SK-1	9/6/11	740	140	2.2	16	160	<0.10	133	157	149	200	188	157
CM_01	SK-W2	9/6/11	720	140	1.4	16	160	<0.10	133	157	149	204	188	157
CM_01	SK-W6	9/6/11	680	140	1	14	140	<0.10	133	157	149	205	188	153
CM_01	KP-3 Well 1	9/6/11	710	140	1.3	15	150	<0.10	133	157	149	204	188	155
CM_02	Doi Saket 1	9/9/11	550	110	4	15	110	<0.10	116	143	137	205	224	155
CM_03	FGTE-15	9/5/11	540	170	1.7	8.6	120	<0.10	146	170	159	178	154	136
CM_03	FGTE-14	9/5/11	550	170	1.5	8.2	110	<0.10	146	170	159	180	158	134
CM_03	FX-2	9/5/11	550	170	1.1	8.4	120	<0.10	146	170	159	181	152	135
CM_04	Dued HS_ bubbling pool	9/8/11	370	190	1.6	6.1	83	<0.10	155	177	165	174	157	125
CM_04	Dued HS Geyser 1	9/8/11	380	190	1.7	6.4	88	<0.10	155	177	165	174	156	126
MH_03	Tha Pai HS 1	9/8/11	350	67	2.2	2.9	77	<0.10	87	116	115	138	102	103
MH_07	Mueng Pang HS	9/8/11	490	88	2.6	4.6	100	<0.10	103	130	127	150	117	116

(c.c.) = (conductive cooling), (a./m.s.l.) = (adiabatic/max steam loss), (Mg.c.) =(Mg corrected)
*Fournier, 1981
**Truesdell, 1976: equation from Henley et al, 1984.
[1]Giggenbach et al, 1983: equation from Henley et al 1984.

Chan, left-lateral strike-slip fault, a prominent lineament through northernmost Thailand (Fenton et al, 2003). Flow from the springs was estimated to be no more than 3 l/s and the highest surface temperature was 99.5ºC. The springs seep out of joints in the exposed granitic rock (Nathan, 1976).

Highest temperature logged in a 100-m deep well is 122ºC (Ramingwong et al., 2000). In 2004, a 56-m borehole was drilled based on resistivity surveys, and produced 5.6 l/s of 94ºC water

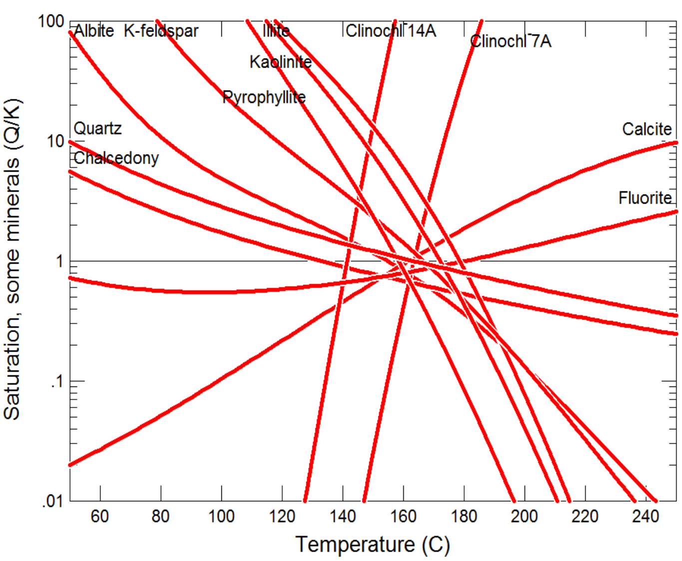

Figure 4. Saturation indices for Sop Pong well waters (CR_06) indicating a shallow equilibria resource temperature of near 130°C and a possible deeper resource at higher temperatures.

spouting 20 m into the air (Fig. 2). The well was used for a demonstration agro-products cold-storage (ammonia-water absorption refrigeration system) and drying facility DEDE (2005). Chalcedony and fast K-Mg geothermometry from a surface bubbling spring indicate approximately 122-127 ºC in agreement with the maximum observed temperature in these shallow wells (Table 2 and Fig. 3).

CR_06: Ban Sop Pong, Wiang Pa Pao District

Two groups of hot springs, 65 km northeast of Chiang Mai, in the Wiang Pa Poa basin, along Nam Mae Lao (river) once flowed at 2.5 l/s with a maximum surface temperature of 98ºC (Geotermica Italiana, 1984). Owing to their location on the popular Highway 118 tourist route, the original springs have been altered and piped to a tourist area. The original pools now flow at maximum temperatures of 73.1 C. Chalcedony geothermometry indicates approximately 133 °C. Higher temperatures are indicated by mineral equilibria models (Figure. 4), but additional investigation of the system is necessary to evaluate the extent of the resource.

CM_01: San Kamphaeng

The natural hot springs are distributed over a 12 hectare area associated with inferred branches the Huai Pong high-angle-reverse fault system. Highest surface temperature of the springs is 98°C (JICA, 1984). Total collective stream flow from more than 70 hot springs was estimated to be 72 l/s of 42°C water (Nathan, 1976). A number of exploratory wells identified the flow coming from fractures in Permian volcanic rocks (Barr et al., 1979; Ramingwong and Praserdvigai, 1984; Praserdvigai, 1986). A 1300-m exploration well (GTE-8) in 1989 encountered fractures from 330-920-m depth, and only the deepest fracture discharged 40 t/h (~11.1 l/s) of water at 125°C. (Ramingwong et al., 2000). GTE-2 measured 120 °C at 450m with promising temperature gradients at depth. Water chemistry was sampled from 4 flowing wells and identified a maximum geothermometry of 133°C (Table 2).

CM_02: Doi Saket (Ban Pong Kum)

The spring system is at the east side of the Chiang Mai basin a few km north of San Kamphaeng. In 1984 the hot water came from 3 groups of pools with a combined flow of 8.1 l/s with the highest surface temperature of 95.9°C (Geotermica Italiana, 1994), but now flow with a maximum temperature of 76°C, altering shallow soils to carboniferous clays. New geothermometry indicates near surface and likely exploitable temperature of 116 °C (Table 2).

CM_03: Fang (Now Considered to be Partly in the Mae Fang National Park)

The natural hot spring system at Fang emanates from several springs distributed over a 9 hectare area, along a normal-fault system at the edge of the Cenozoic Fang basin and the Paleozoic granitic rocks of the mountains to the west. Estimate of the total flow of the springs was 30 l/s, the hottest spring measured 99.5° at the surface (Nathan, 1976). The system is now developed for power generation (discussed above) with four production wells flowing 8.3 l/s each of 116-122ºC water. Fang produces relatively high flow rates from shallow fractured bedrock at temperatures near those predicted by fast-equilibrating geothermometry, similar to most other systems in Thailand. Fang is a demonstration of the productivity possible from shallow geothermal systems in these geologic settings.

CM_04: Pong Duet Geyser (Mae Sae (River)), Ban Pa Pae, Mae Taeng District (Partly Within Huai Nam Dang National Park)

The thermal area was thought to lie on a roughly semi-circular structure, approximately 1.5 km in diameter seen on air photos. The thermal features are over a 0.45 hectare area and consist of a pulsating geyser with an outflow of 1.5 l/s, at 100 °C and several larger pools (94.5-100 °C). Estimated total flow from the system was 17.5 l/s (Nathan, 1976). The site was visited in 2011, and consisted of several geysers boiling (91.6 °C) vigorously with active silica precipitation and argillic alteration. Fluids appear to be emanating from N-NE-trending fractures correlating with the regional structural trend. Water chemistry indicates mineral-equilibria relationships converging at 160 °C (Figure 5).

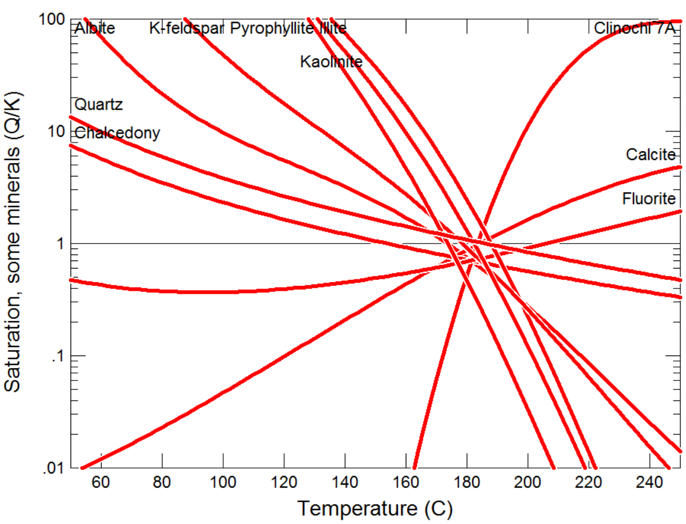

Figure 5. Saturation indices for Pong Duet geysering hot springs (CM_04) indicating mineral equilibria relationships converging at 160°C. Surface temperatures measured at near boiling for elevation (91-99C).

CM_05: Thep Pra Nom (Om Khut, Mae Chaem District).

The thermal features occur over an area of about 0.5 hectare, consisting of several groups of small individual hot pools and two plains with small seepages. Maximum termperature was 99 °C and flow estimated at 8.4 l/s of boiling water and an addition 6 l/s of hot water. Silica, calcite and alluvial deposits are cut by a N 10 E/ fault with a throw of 2-3 m (Geotermica Italiana, 1984). Banded silica deposits upwards of 2-m thick are reported as are lower flows (0.2 l/s). The waters have promising calculated geothermometer values of 153 °C (185 ppm silica; Barr et al, 1979) and the area deserves further investigation.

CM_11: Ban Pong, Phrao District

Ban Pong Hot springs issue into a marshy area ~100 m^2 along the west side of the Phrao basin. Five km north of Ban Pong is another hot springs area at Ban Nong Khrok. The springs are seepage over a 50-m^2 area that has been channeled into pools. Maximum temperature was 72.0 °C and flow estimated at 12.5 l/s. Sulfides are observed in the spring area and crystalline sulfur is present on some stones (Geotermica Italiana, 1984). The geologic setting is described by Surinkum et al. (1986).

MH_03: Tha Pai (in National Park)

The hot springs cover an area of over 1 km^2 including several high-temperature (74-77.6 °C) pools to the east and a few isolated bubbling pools (72.6 °C) to the west. Total flow estimated at 12.6 l/s. Geothermometry calculations indicate exploitable resource temperatures of only 87-103 °C (Table 2).

MH_04: Pong Pa, Pai (in National Park)

No information available on this site, at time of writing, except as indicated in Table 1.

MH_07: Ban Muang Paeng, Pai

The Pai geothermal system (Ban Muang Paeng) was not described by the early studies. The springs occupy an area of about 50 hectare within granitic mountainous terrain. The system was studied by Asnachinda et al. (1994), and although we have not seen the study, Ramingwong and Lertsrimongkol (1994) quote their paper for a surface temperature of 95°C. Korjedee (2002) reports on a resistivity survey at Ban Muang Paeng. Three exploratory wells to 250-m depth flowed hot water, and one had a bottom hole temperature of 94°C. Combined flow rate was 25 l/s at more or less atmospheric pressure (Ramingwong et al., 2000). The spring was observed in 2011 to be rapidly bubbling 95 °C water from a single source. Calculated silica (88 mg/l) geothermometers predict a resource of 103-130 °C (Table 2).

Korjedee (2002) reports on resistivity surveys of the nearby Ban Muang Rae geothermal area, and the results of three 200-m deep exploratory wells – which were not productive. Highest temperature at a depth of 170 m was 96°C.

MH_10: Mae Oom Luang, Mae Sariang (in National Park)

No information was available on this site, at time of writing, except as indicated in Table 1.

MH_11: Nong Haeng, Khun Yuam

No information was available on this site, at time of writing, except as indicated in Table 1.

PR_02: Phrae, Ban Mae Chok

The springs are limited to two pools and minor seeps located on both sides of a road. Maximum temperature was 79.4 °C, and flow estimated at 9.3 l/s (Geotermica Italiana, 1984).

LPa_01: Chae Son, Mueang (in National Park)

The hot springs system comprises various seepages covering a circular flat area of 0.4 hectare, west of the Nam Mae Mon River. Maximum temperature was 80.8 °C, and the flow estimated at 14.7 l/s (Geotermica Italiana, 1984).

LPa_04: Pog Nam Ron, Serm Ngam

No information was available on this site, at time of writing, except as indicated in Table 1.

Discussion

The Fang, San Kamphaeng, and Mae Chan and Pai geothermal areas have been explored using geochemical indicators in the waters, surface geophysical surveys, and drilling to depths of several hundred meters, and in the case of San Kamphaeng, 1300 m. The other systems were inventoried by Geotermica Italiana (1984), and Nathan (1974) but have not been intensively explored, or have been eliminated from consideration owing to their location in national parks. Reconassaince exploration of several of these other systems was performed by L. Owens in 2011 (Table 2). According to Ramingwong et al., 2000) the San Kamphaeng system has the greatest known potential (estimated 5 MWe), but utilization was not considered feasible at the time due to lack of available cooling water in the area. Results from previous exploration and study of the San Kamphaeng system suggest that deeper wells are needed to identify predicted 133 °C fluids at depth; however, permeability may be poor based on existing borehole profiles. It is likely that the Fang site can be upgraded from 0.3MWe to 2.8 MWe by increasing the flow from pumping new wells with improved construction. All of the geothermal prospects are likely to be associated with narrow fracture reservoirs associated with steeply dipping faults so that conventional vertical drilling has a high risk of missing the target (Ramingwong et al., 2000; Korjedee, 2002). Deep cutting vertical faults feed more permeable shallow fractured reservoirs allowing for re-equilibration of geothermal fluids. The current project will review the geology, geochemistry, and geophysics of the geothermal sites, and probably employ shallower geophysical techniques such as CSAMT to define a promising site for drilling. The current project of Thailand Department of Alternative Energy Development and Efficiency (DEDE) will survey these northern Thailand prospects with the intention of installing a small plant with a capacity of 2-10 MW.

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