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Development of San Kamphaeng Geothermal Energy Project, Thailand

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Abstract: Taking into account the relevant geological and sociological information, San Kamphaeng Geothermal Field, northern Thailand has been selected as a case study for an exploration drilling programme. The first ever geothermal exploration well in Thailand, GTE-1, was commenced at the end of 1981. Up to the present time, six geothermal exploration wells, GTE-1 to GTE-6, with an average maximum depth of 500 m., have been drilled. Two wells encountered hot water while the rest are dry. GTE-2 is now discharging hot water of 85°C with a very small discharge. GTE-6 encountered hot water of 120°C at the depth of 489 m. and is now discharging hot water of 104°C, 3.6 bar pressure and approximately 4 l/s at the well head. A number of shallow wells, less than 50 m. depth, were drilled in the thermal manifestation area and where resistivity survey showed relatively low values at shallow depth, suggesting possible zone of thermal water accumulation. Five shallow wells encountered hot water with temperatures ranging from 100°–130°C. Reservoir model of San Kamphaeng geothermal system is proposed. Under the joint technical programme between the governments of Thailand and Japan, a deep exploration well, to the depth of at least 1,500 m., is scheduled to start in July 1984.

INTRODUCTION

San Kamphaeng geothermal field is located in the northeastern part of Chiang Mai city (Fig. 1). Systematic studies to assess its energy resources started in late 1977, with the cooperation of personnel from the Department of Chiang Mai University (DMR), Electricity Generating Authority of Thailand (EGAT) and conditions, San Kamphaeng geothermal field was, therefore, chosen as a first case study and for an exploration drilling programme (Ramingwong, *et al.,* 1980). Relevant geologic data has, since then, been progressively made available (Ramingwong, 1981; Ramingwong *et al.,* 1982). Consequently, in 1982, the Technical Co-operation Project entitled 'Pre-Feasibility Study in the San Kamphaeng Geothermal Development Project' between Japan International Co-operation Agency (JICA) and Electricity Generating Authority of Thailand, representing the Thai working group, was then formulated and established. The project is scheduled for three years, 1982–1984 (JICA, 1983).

This paper presents a summary of the up-to-date information on the development of the San Kamphaeng Geothermal Development Project.

GEOLOGICAL SETTING

On a regional scale, hot springs of northern Thailand are related to the margins of Cenozoic basins. These basins are generally bounded by faults which follow older tectonic pattern and which were rejuvenated during Cenozoic times, as indicated by faults affecting terraces of late Tertiary or Pleistocene ages (Fig. 2). Some other hot springs are associated with the margins of Mesozoic or older granite batholiths, or with major fault zones. A Tertiary igneous event has been postulated to explain the Tertiary

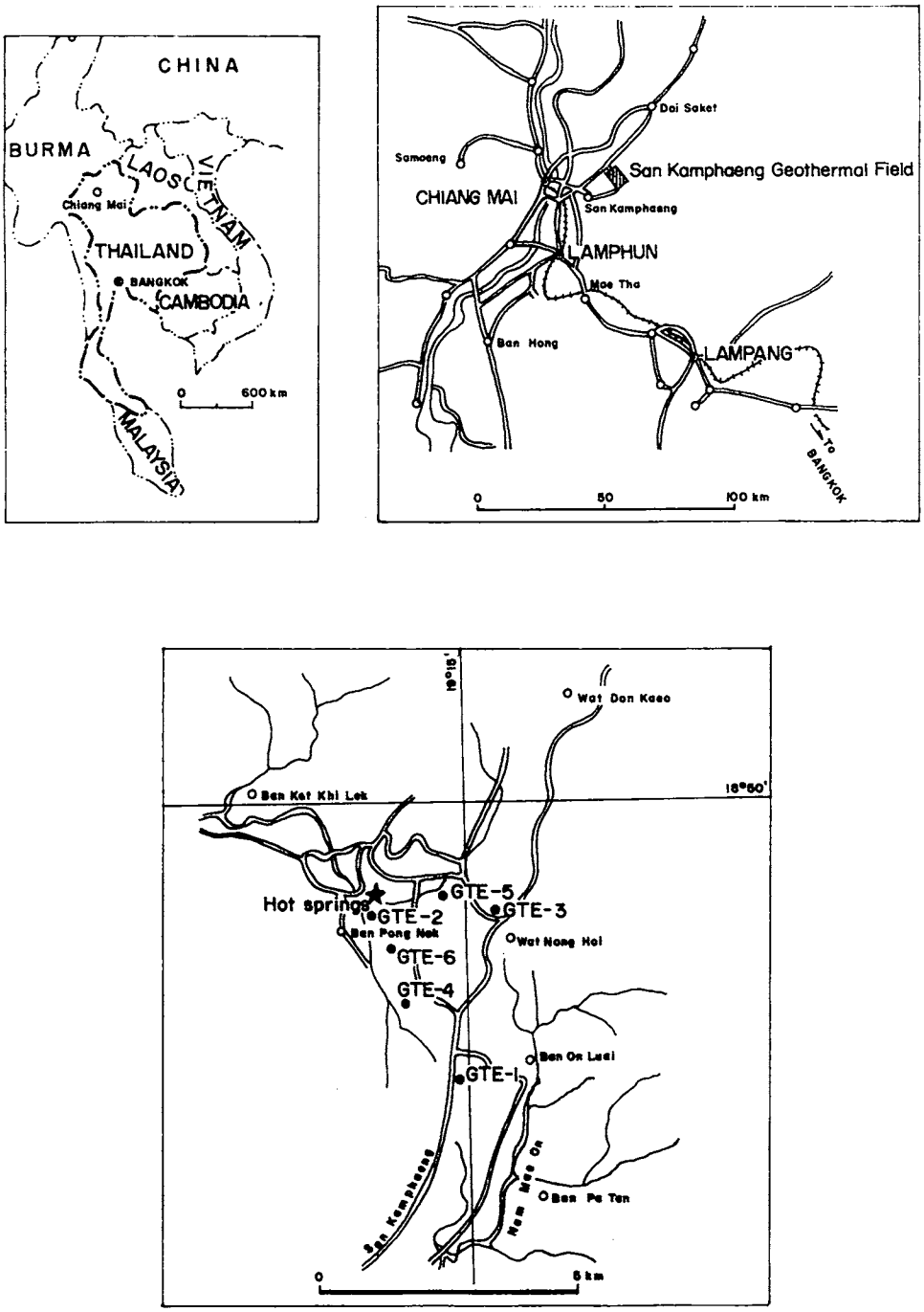

Fig. 1. Location Map of San Kamphaeng Geothermal System.

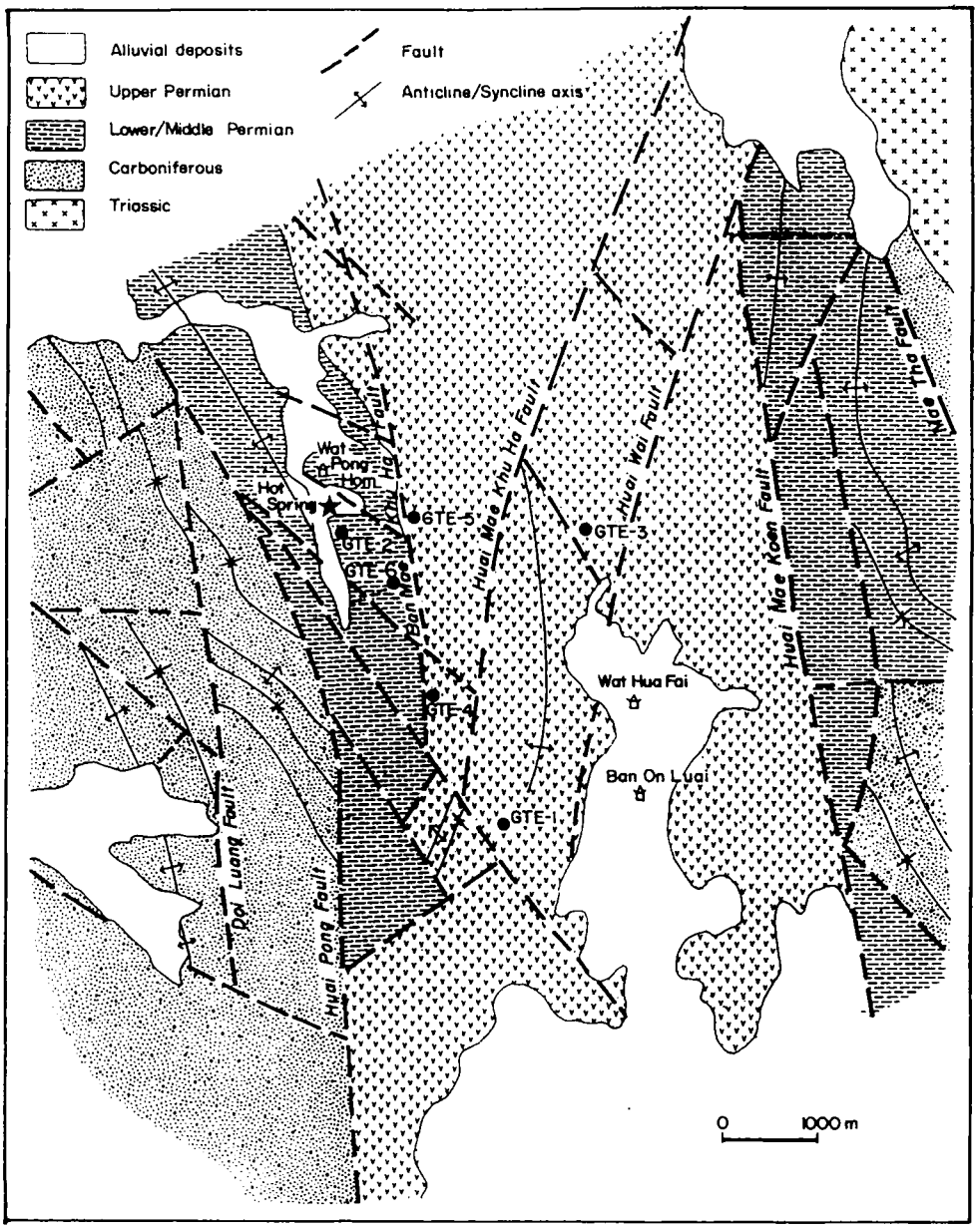

Fig. 2. Generalized geologic map of San Kamphaeng geothermal Field (modified after JICA, 1983)

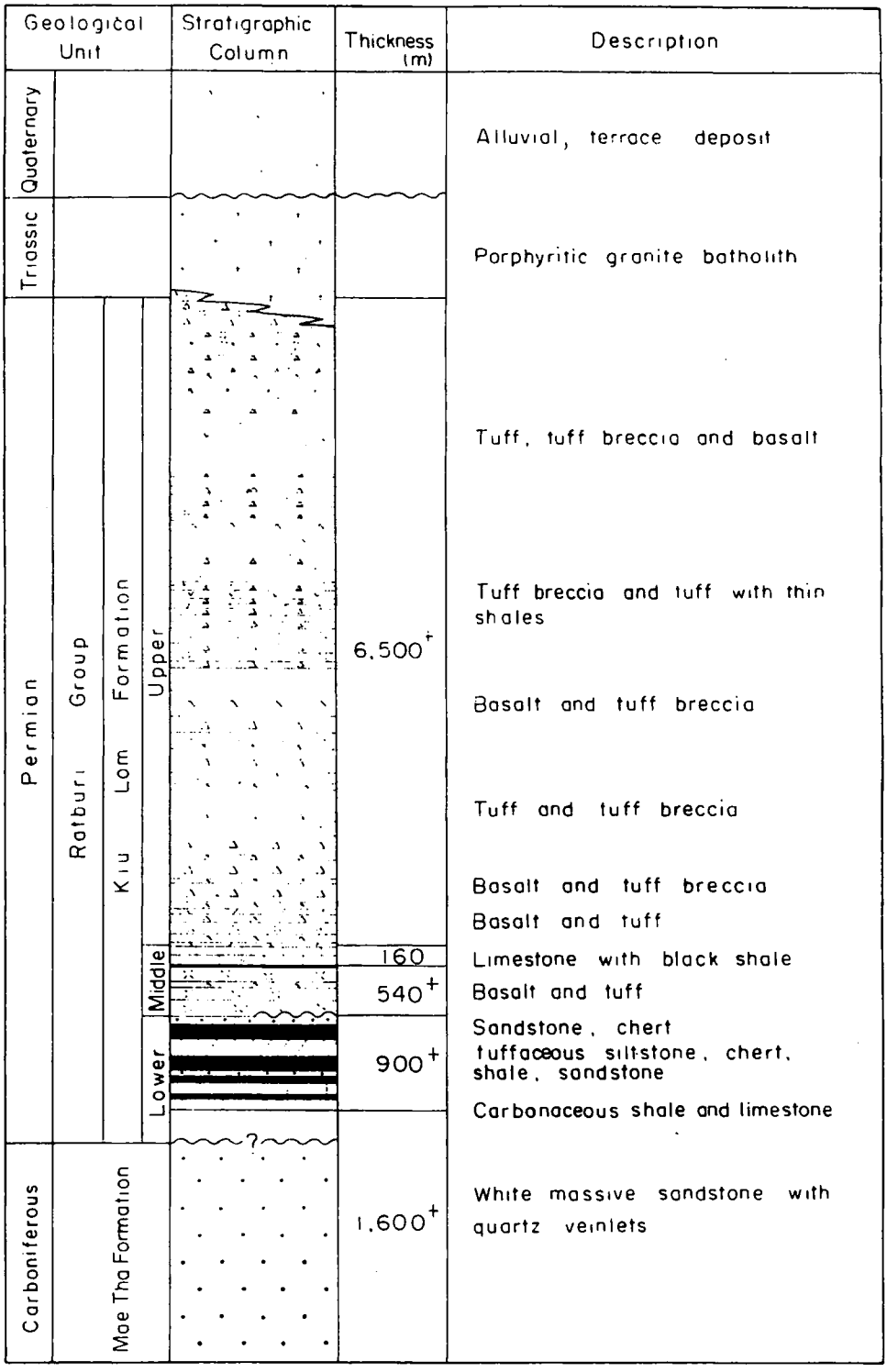

Fig. 3. Geological Column of San Kamphaeng Area (after JICA, 1983)

age obtained by radiometric dating of the crystalline basement complex west of Chiang Mai basin.

The San Kamphaeng geothermal field is underlain by Carboniferous sedimentary sequence which consists of hard and compact white massive sandstone and thin-bedded black shale with numerous quartz veinlets. This formation forms a folded structure which is considered to be the basement of the study area. It is in contact with Permian rocks which occupy the central part of the area. The Permian rocks can be divided into lower sedimentary rocks and upper volcanic rocks. The lower sedimentary rocks are distributed at the western side while the upper volcanic rocks occupy the central part and the eastern side of survey area. The lower sedimentary rocks consist of the following subzones; limestone and shale subzone, siltstone, chert, sandstone and tuffaceous siltstone subzone, chert subzone and sandstone subzone in ascending order. The upper volcanic rocks consist of basaltic lava flow, tuff breccia, agglomerate and tuff interbedded with limestone, sandstone and shale (JICA, 1983). Geologic column of the study area is presented in Fig. 3. Triassic rocks, porphyritic granite, expose in the north-eastern part of the study area.

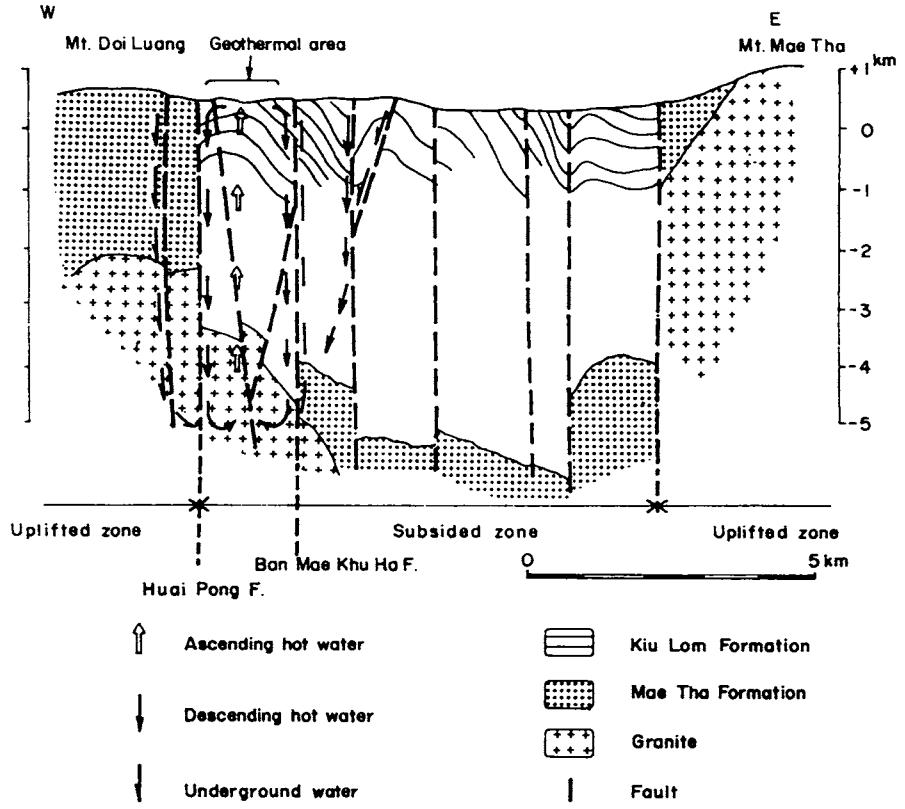

Fig. 4. Generalized geologic section and geothermal system of San Kamphaeng (after JICA, 1983)

Geological structure is characterized by a depression structure existing between two major faults trending from NNW to SSE. Other faults trending from NW to SE and from NE to SW are also observed in the depression area. A generalized geologic section of the study area is shown in Fig. 4.

EXPLORATION DRILLING WORK

The first ever geothermal exploration well was commenced at the end of 1981. Up to the present time six geothermal exploration wells (GTE-1 to GTE-6), with target depths of less than 500 m. and with the objective of subsurface geological confirmation and to examine the distribution of heat flow, were drilled in the San Kamphaeng geothermal area (Fig. 2). Long Year model 44 drilling machine is used for this purpose (Plate 1).

GTE-1, GTE-2, GTE-4, GTE-5 and GTE-6 reached 500 metre depth while GTE-3 was abandoned at 150 metre depth because of unfavourable geology and geothermal gradient. GTE-1 and GTE-3 were drilled in the upper volcanic rocks of Permian age while GTE-2, GTE-4, GTE-5 and GTE-6 were drilled in the lower sedimentary rocks of Permian age. Average geothermal gradient of GTE-3 shows normal 30°C/km gradient while GTE-2 is disturbed by hot water flow into the well. For GTE-6, from depth 0–290 m., temperature gradient as high as 200°C/km was observed. Nevertheless, GTE-6 encountered hot water at 120°C at 489 m. depth, therefore, the well was disturbed by the upflowing hot water making it impossible to obtain the temperature gradient at depths greater than 290 m. (Plate 2).

Apart from the above mentioned drilled holes, a number of shallow wells less than 50 metres depth, were also drilled in the hotspring area where the resistivity survey showed relatively low values at shallow depths, suggesting a possible zone of thermal water accumulation. Five of them, GTE (S-1), (S-12), (S-13), (S-18) and (S-22) produced hot bubbling and geysering waters, with temperatures ranging from 100–130°C (Plate 3 and 4). Technical data of GTE-1 to GTE-6 and some outstanding shallow wells are tabulated in Table 1.

SAN KAMPHAENG GEOTHERMAL RESERVOIR MODEL

The subsurface heat in the San Kamphaeng area is thought to have been derived mainly from the granitic body presumably seated at the depth of the Doi Luang uplifted zone and the Ban Pong Hom subsided zone, although some more additional heat would be brought about by the upflow of thermal fluid along large-scale faults as well as by part of the regional heat flow (JICA, 1983). The depth of the surface of the granitic body is estimated to be approximately 3.5 km. in the area where the geothermal indications are distributed. It is thought that the rain water, which penetrates down to the surface of the granite to the depth estimated above, would be changed to geothermal fluid, when heated while circulating in the granite body. The temperature of the fluid when heated would be approximately 190°C to 210°C, as is estimated by the Na-K-Ca thermometer(Ramingwong *et al.*, 1980), using the results of analysis of the chemical composition contained in the hydrothermal solution.

Plate 1. Long Year 44 Drilling Rig.

Plate 2. Hot water discharging from GTE-6

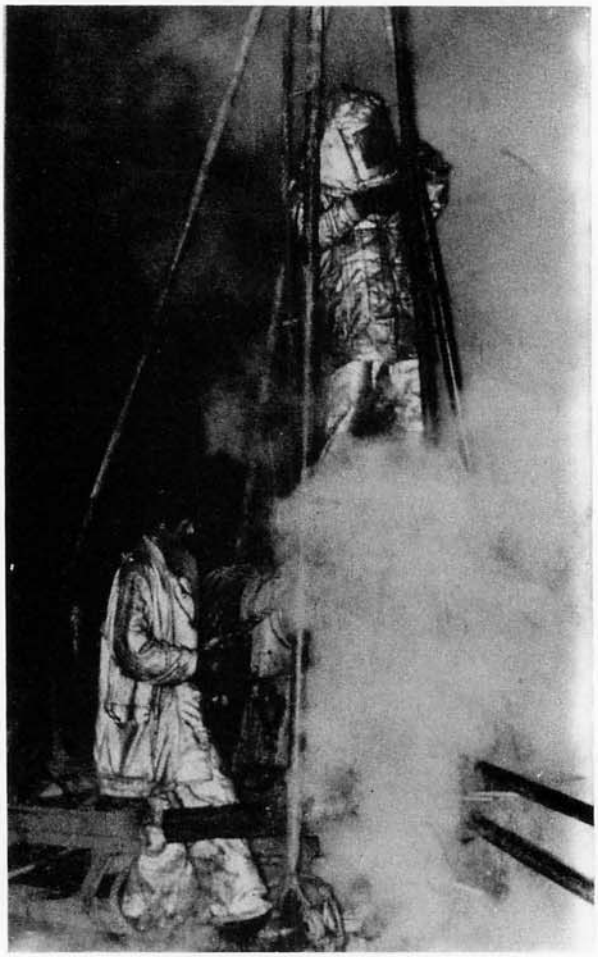

Plate 3. Drilling of shallow well (less than 50 m.)

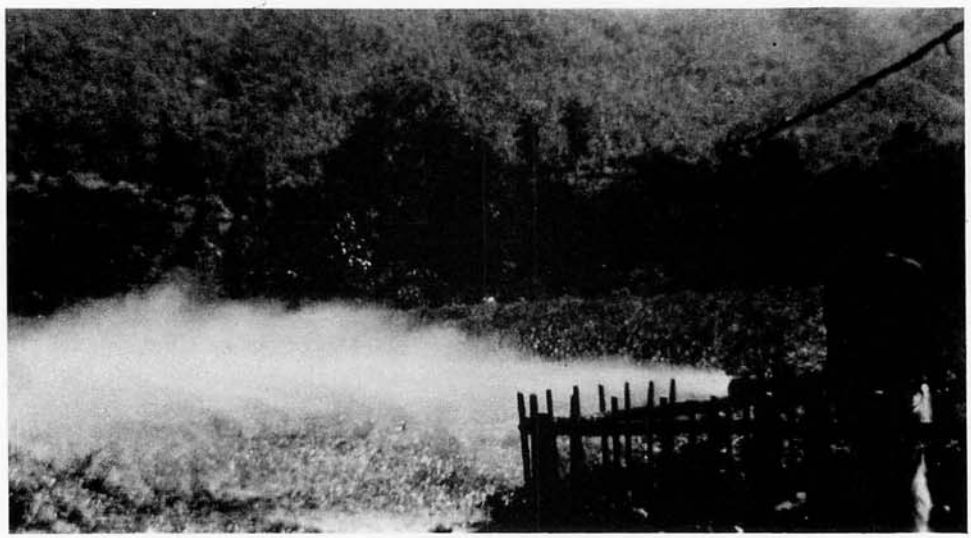

Plate 4. Hot water discharging from shallow well GTE (S-13)

TABLE 1

TECHNICAL DATA ON GEOTHERMAL EXPLORATION WELLS,
SAN KAMPHAENG GEOTHERMAL SYSTEM, CHIANG MAI, THAILAND

GTE : Geothermal Exploration Well with target depth less than 500 m.
GTE (S) : Shallow Test Well with target depth less than 50 m.

GTE-1

Date started:	September 25, 1981
Date completed:	December 23, 1981
Total depth:	500 m.
Drilling machine:	Long Year 44
Casing and hole diameter:	
	Hole 6.75 in. from 0–100 m 4.89 in. from 100–226 m 3.78 in. from 226–425 m 2.98 in. from 425–500 m
	Casing 5.5 in. casing cemented from surface to 100 m. 2.0 in. water pipe from surface to bottom hole, cementing is from 100 m. depth downward. The bottom is closed with screwed valve.
Temperature:	80.4°C to 462 m. depth.
Flow rate:	The well was installed by water pipe casing and cemented in order to prevent inflow of water. However after one month of installation, inflow of water was observed causing the well to be silted up to the depth of 462 m. Water is under pressure and slowly overflows at the surface. Overflow water is cold. The well will be used for long term temperature and heat flow measurements.
Lithology:	Greyish green basaltic tuff and agglomerate successions.

GTE-2

Date started:	January 7, 1982
Date completed:	March 25, 1982
Total depth:	500 m.
Drilling machine:	Long Year 44
Casing and hole diameter:	
	Hole 6.75 in. from 0–51 m 4.89 in. from 51–118 m 3.78 in. from 118–500 m
	Casing 5.0 in. casing cemented from surface to 100 m. 2.0 in. water pipe from surface to bottom hole.
Temperature:	Bottom hole temperature was recorded as 102.5°C and 105.4°C after drilling was completed.
Flow rate:	The well was installed by water pipe casing with some perforate at high fracture depth. The hot water, 85°C, flows out through the water pipe at the rate about 1 l/s.
Lithology:	Siltstone sandstone shale and limestone successions. Abundant pyrite crystals and white waxy minerals at top 30 m.

GTE-3

Date started:	August 5, 1982
Date completed:	September 7, 1982
Total depth:	150 m.
Drilling machine:	Long Year 44
Casing and hole diameter:	
	Hole 6.75 in. all through 150 m., open hole to total depth.
Temperature:	34°C at the depth of 150 m.
Lithology:	Basaltic tuff and agglomerate successions.

TABLE 1 (contd.)

GTE-4

Date started:	October 28, 1982
Date completed:	December 30, 1982
Total depth:	500 m.
Drilling machine:	Long Year 44
Casing and hole diameter:	
	Hole 6.75 in. from 0–62 m. 4.89 in. from 62–187.5 m. 3.78 in. from 187.5–500 m.
	Casing 5.0 in. casing cemented from surface to 60 m. 2.0 in. water pipe from surface to 210 m. cementing to fix the water pipe. The bottom is closed with screwed value.
Temperature:	82.2°C at 440 m. depth. Measurement was taken 9 days after drilling stopped while drilling mud was still in the well.
Lithology:	Basaltic tuff interlayered with sandstone and shale some thin layers of tuff breccia and chert. From the depth 302.5 metres downward basaltic tuff is absent. Abundant pyrite especially in shale layers.

GTE-5

Date started:	March 25, 1983
Date completed:	July 14, 1983
Total depth:	500 m.
Drilling machine:	Long Year 44
Casing and hole diameter:	
	Hole 6.75 in. from 0–61 m. 4.89 in. from 61–258 m. 3.78 in. from 258–500 m.
	Casing 5.0 in. casing cemented from surface to 60 m. 2.0 in. water pipe from surface to bottom hole, cementing to fix the water pipe. The bottom is closed with screwed valve.
Temperature:	97.1°C at 500 m. depth. Measurement was taken 36 hr. after drilling stopped while drilling mud was still in the well.
Lithology:	Basaltic tuff interlayered with sandstone, shale and chert. From the depth of 233.5 m. andesitic tuff is absent, and from 239 m. downward sandstone interbedded with siliceous shale and abundant pyrite.

GTE-6

Date started:	August 29, 1983
Date completed:	2 December, 1983
Total depth:	490 m.
Drilling machine:	Long Year 44
Casing and hole diameter:	
	Hole 6.75 in. from 0–105 Casing 5.0 in. casing cemented from surface 60 m. Opened hole 3.78 in. diameter
Temperature:	Encountered hot water of 120°C at the depth of 489 m., now discharges hot water of 104°C, 3.6 bar pressure with approximately 4 l/s discharge at well head.
Lithology:	Basaltic tuff interlayered with sandstone and shale.

TABLE 1 (contd.)

GTE (S-2)

Date completed:	Jan 11, 1982
Total depth:	12.50 m.
Drilling machine:	MBD, rotary rock-bit
Casing:	Open
Hole diameter:	2.98 in. size, diameter widened to 1.5 m. at ground surface
Temperature:	99°C at ground surface
Flow rate:	4.5 l/s, shooting and bubbling to 0.5 m. above ground surface (shooting height was 2–3 m. when drilling was newly completed)
Lithology:	Grey chert, highly weathered at top. Lower parts are sandstone with abundant pyrite crystals and white waxy minerals (clay minerals)

GTE (S-12)

Date completed:	Jan 27, 1982
Total depth:	10.50 m.
Drilling machine:	MBD, rotary rock-bit
Casing/hole diameter:	3.78 in. casing, cemented to 6 m. depth, open hole to total depth.
Temperature:	105.5°C at 3 m. depth. 99.0°C at top of casing (60 cm. above ground surface)
Flow rate:	Geysering for 5 min. at an intervals of 5 min. with flow rate of 3–5 l/s. Geysering height was 10 m.
Lithology:	As GTE (S-2)

GTE (S-13)

Date completed:	Feb 5, 1982
Total depth:	31.5 m.
Drilling machine:	MBD, rotary rock-bit
Casing/hole diameter:	3.78 in. casing, cemented to 9 m. depth, open hole to total depth.
Temperature:	99.5°C at top to casing (60 cm. above ground). At depth 21 m. measured temperature was 130°C. Hot water shooting to 12–15 m. above ground surface, water to steam ratio is estimated to be 2 : 1
Flow rate:	Greater than 10 l/s
Lithology:	Interbedded sandstone and shale with abundant pyrite crystals and white waxy minerals (clay minerals)

GTE (S-22)

Date completed:	Apr. 12, 1983
Total depth:	47.0 m.
Drilling machine:	Alker diamond core-bit
Casing/hole diameter:	3.78 in. casing cemented to 6 m. depth, open hole to total depth.
Temperature:	116.5°C at ground surface level and 130°C was recorded at 47.0 m. Hot water shooting to 12–15 m. above ground surface water to stream ratio is about 2 : 1
Flow rate:	Greater than 10 l/s
Lithology:	Interbedded sandstone and shale with abundant pyrite crystals and white waxy minerals (clay minerals)

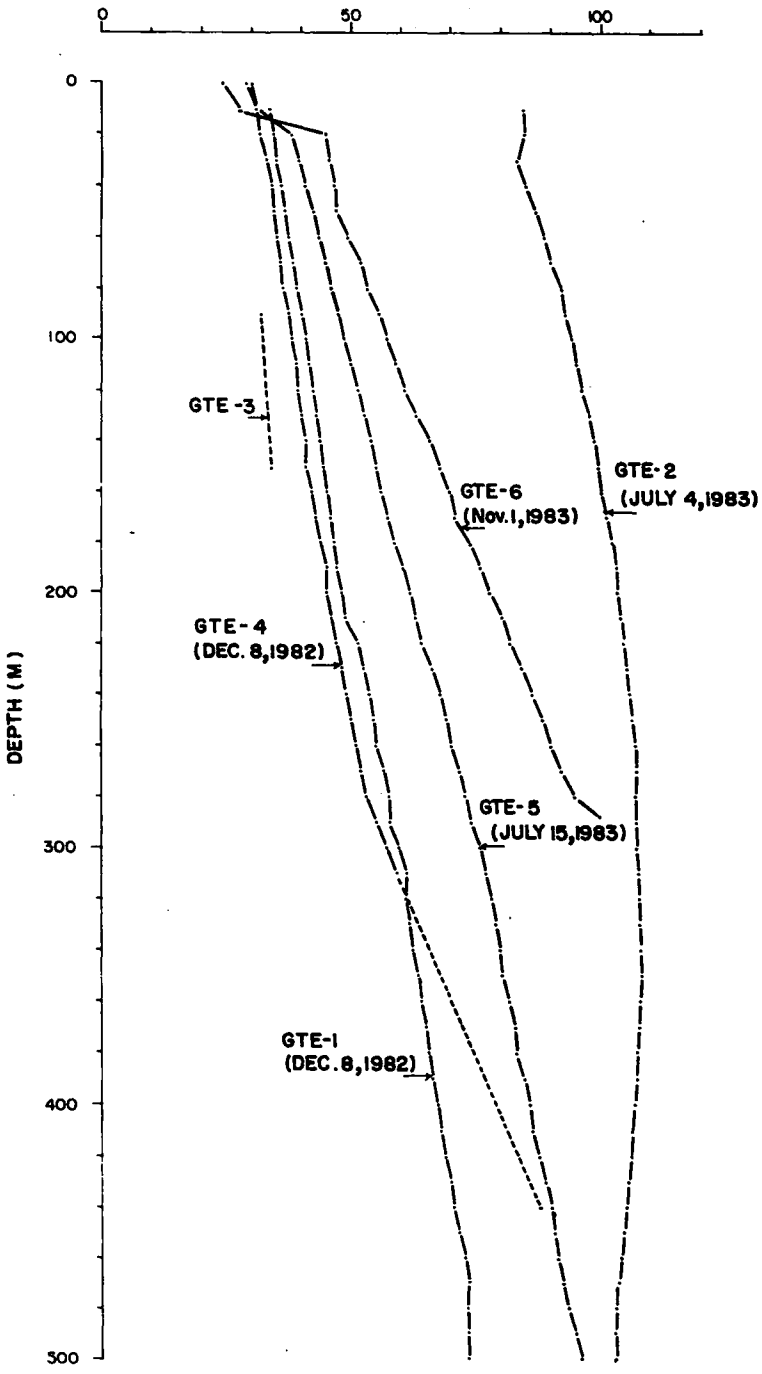

Fig. 5. Temperature profiles of San Kamphaeng exploration wells.

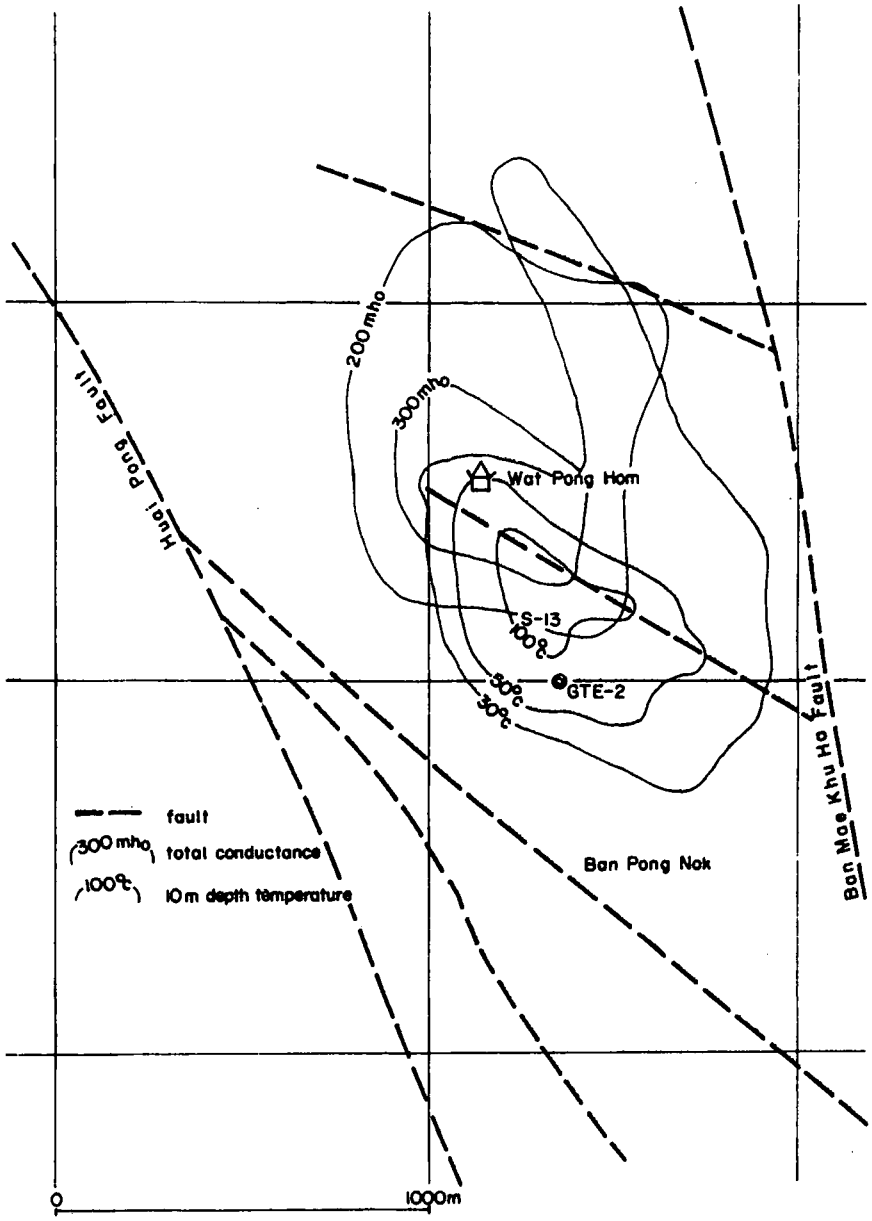

Fig. 6. Total conductance and isothermal contour map of San Kamphaeng Area.

The geothermal fluid formed in this way is thought to be flowing up along the Huai Pong fault, along the faults branching from it or along the Ban Mae Khu Ha fault. It is thought that the principal geothermal reservoirs are formed along such steep angled faults. Also, as the geothermal fluid would have diffused and been mixed with the underground water in the process of upflow, lateral reservoirs could have possibly been formed along the bedding planes. Horizontal fractures are well developed in chert and shale which are easily fractured lithologically, in limestones corroded by hydrothermal solutions, along the unconformity between the Mae Tha Formation and the Kiu Lom Formation, and also along the intrusive boundary of the granite. It is possible that these comprise favourable geothermal reservoirs (Fig. 4). The geothermal fluid is cooled down mainly conductively during upflow, but in the shallow part, the cooling occurs by direct admixture with the underground water. As the chemical composition in the fluids varies, the admixture of the underground water would occur at shallower depth. From the distribution of the low resistivity layers obtained by the deep electric survey, the depth of the admixture of the underground water is thought to be less than 500 metres. The temperature is thought to be approximately 160°C, as is indicated by the silica thermometer.

It is inferred that the geothermal fluid has moved up through some narrow pass to the central part of the area where the geothermal indications are distributed (around shallow hole, S-13) Fig. 6, and that is has diffused laterally in the alluvial deposits which are composed of sands, pebbles and muds as well as in the thick weathered fracture zones, where aquifers for the thermal water have been formed.

From the deep electric survey, low resistivity zones have been detected at a depth of less than 500 metres (first conductive layer) and at the depth of 1,000–3,000 metres (second conductive layer), in the area between the Huai Pong fault and the Ban Mae Khu Ha fault. This result is in good harmony with the result obtained by the seismic survey. Accordingly, it is possible to divide the San Kamphaeng geothermal area into two sub-areas of shallow and deep geothermal reservoirs (JICA, 1983).

FUTURE WORK PLAN

Under the JICA-EGAT Technical Cooperation Project, it has been agreed to drill an exploratory well in early 1984, in the potential area where the geothermal reservoir is expected. This would target the low resistivity layers at the depth of 1,000–1,500 m. Confirmation of the existence of the geothermal fluid and its temperature are the prime objectives of the drilling. Final evaluation on the potential of San Kamphaeng geothermal resources, for power generation, will only then be carried out.

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