Geophysical Investigation in the Pong Kum Hot Spring, Doi Saket, Chiang Mai, Thailand

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ABSTRACT

Resistivity, magnetic, and seismic surveys were carried out in the Pong Kum hot spring area. The survey area is along the northwest-trending Mae Tha fault in Ban Pong Kum, Doi Saket District, Chiang Mai Province. Resistivity data indicate low resistivity zones about 100 meters below the surface that represent basement geothermal reservoirs. These are potential targets for exploration. Two-dimensional seismic profiles indicate a shallow basement and fault zone near the Pong Kum hot spring. Two-dimensional total field magnetic data have a low magnetic susceptibility zone that may represent channels of upward moving geothermal water.

KEYWORDS: Pong Kum hot spring, resistivity survey, magnetic surveys, seismic survey

INTRODUCTION

Pong Kum hot spring is located at Ban Pong Kum, Doi Saket District in Chiang Mai Province in the northern part of Thailand (Figure 1). This hot spring is in the northern part of the Mea Tha fault, which trends northwest and dips west and northwest. This study investigated the link between the physical characteristic of a hydrothermal system and the alternative energy of geothermal power. The hot spring may be a geothermal power deposit only if four factors occur at the same place simultaneously. These four factors are:

1. A source of natural heat of great output, such as from a cooling magma body,
2. An adequate water supply,
3. An aquifer or permeable reservoir,
4. An impermeable cap rock (Ozguler and others, 1983).

Geothermal reservoirs and their environments have certain specific physical characteristics that are susceptible to detection and mapping by geophysical methods. This report discusses resistivity, magnetic, and seismic geophysical survey methods used in geothermal exploration. These three methods all provide information concerning geothermal reservoirs. Following the positive result achieved in the Pong Kum hot spring, geophysical data were used to identify new specific target areas and to provide data for future assessments of geothermal energy in the Pong Kum area.

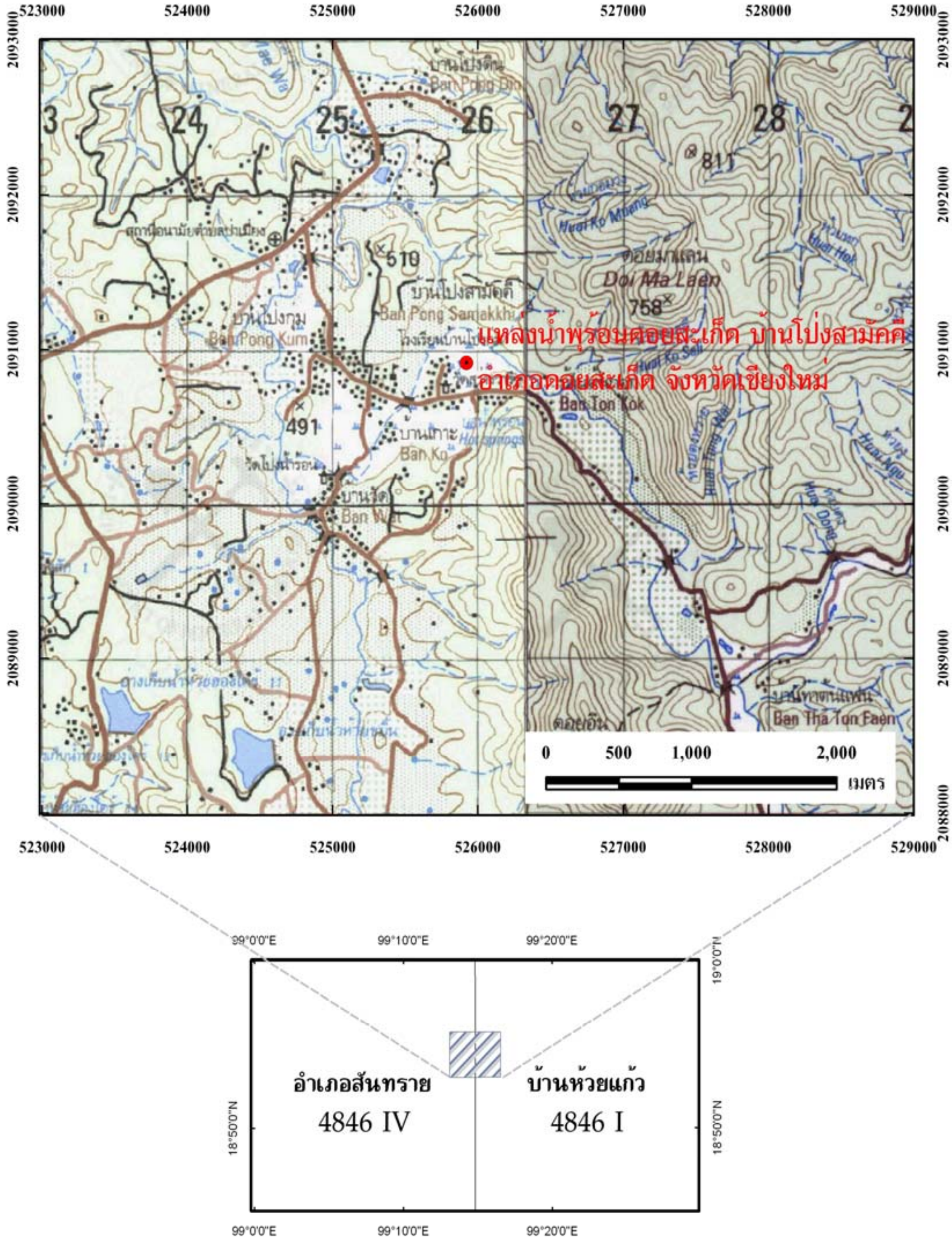


Figure 1. Location map of Pong Kum hot spring, Doi Saket District, Chiang Mai Province

GEOLOGY

Pong Kum geothermal field area is located in a Quaternary sediment-filled basin that is surrounded by topographically high terrain. Figure 2 shows the older lithologic units that surround and underlie the Pong Kum hot spring basin. These older units are: Silurian-Devonian Don Chai Group phyllite, quartzite, and quartzitic sandstone; Carboniferous Mae Tha Group sandstone that has shale interbeds; Permian-Triassic basalt, tuff, and agglomerate; Triassic biotite granite that is intruded into Ma Tha and Don Chai rocks. Quaternary sediments that overlie these older rock units are alluvium and terrace sand, silt, clay, and gravel (Pitrakun and Kulasingha, 1979).

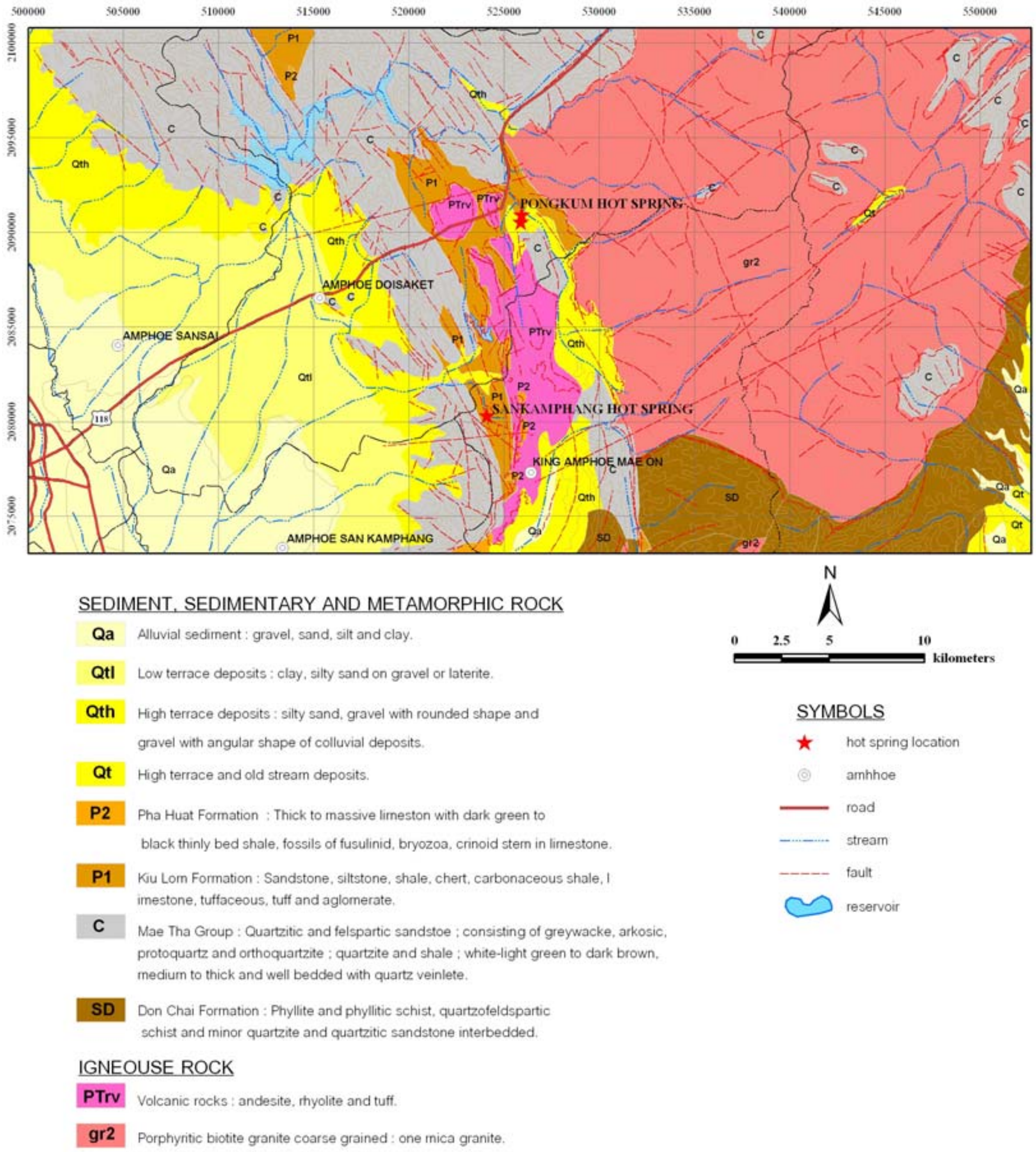


Figure 2. Geological map of the study area

The present structure of the Pong Kum hot spring area resulted from uplift, folding, and faulting of Don Chai Group rocks. The Mae Tha fault resulted from this deformation by tensional forces and granite intrusion and is the locus for geothermal fields. The fault trends northwest-southeast and is the major structure in the area.

GEOPHYSICAL INVESTIGATIONS

Geophysical surveys were made to construct the deep geological structure, condition and thickness of cap rock, and the regional and local thermal situation. A geothermal reservoir has certain specific physical characteristics that are susceptible to detection and mapping by geophysical methods.

Geophysical surveys made in the Pong Kum area were resistivity, magnetic, and seismic. The surveys were run along 12 lines oriented northeast-southwest. Line spacing was 50 meters (Figure3).

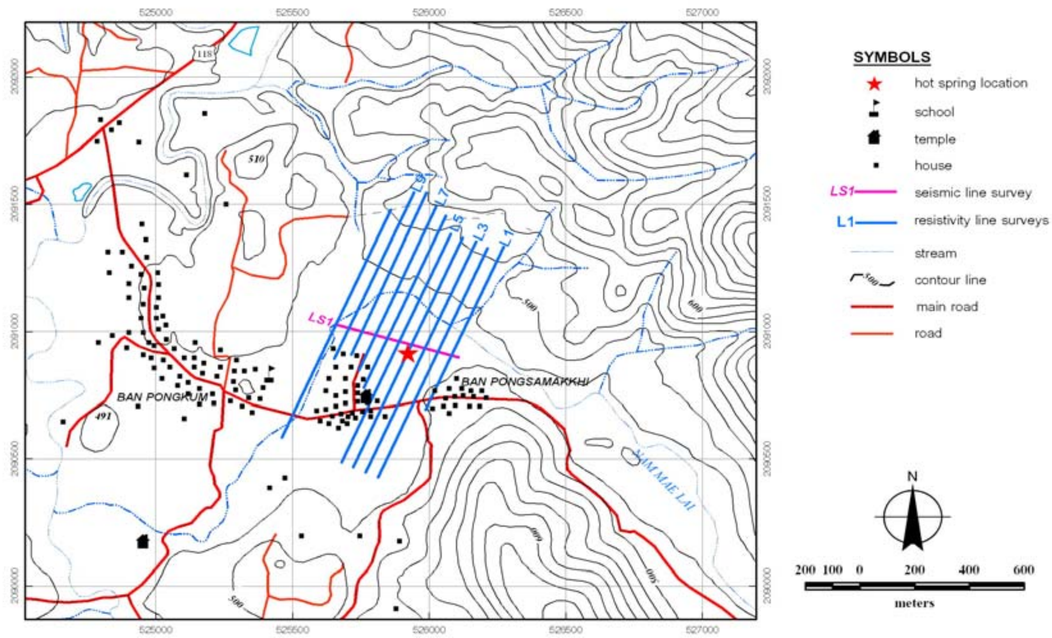


Figure 3. Location map of geophysical survey lines.

Resistivity survey

The most important technique in geothermal energy exploration is the resistivity method because it gives a strong response to the physical properties that vary in geothermal fields. These physical properties are temperature, fluid salinity, and porosity. For example, the hot water zone within an area can be located by a decrease of resistivity. This decrease results from an increase of both temperature and salt concentration in a geothermal reservoir. Resistivity surveys have also provided data for the detection and mapping of geothermal systems and for subsurface geological and structural interpretation.

Resistivity surveys were done with an automated multi-electrode switching system. The dipole-dipole array was used because in previous work it showed good resolution of fractures and caves (Roth and others, 1999; Labuda and Baxter, 2001). The survey used 48 electrode positions with a dipole spacing of 15 meters. The raw apparent resistivity dipole-dipole data were inverted and interpreted using the rapid two-dimensional resistivity inversion least squares method. The program used was RES2DINV, version 3.3 (Loke, 1998) to acquire a two-dimensional true earth resistivity inversion solution.

Resistivity depth sounding was made using the Schlumberger electrode configuration. Resistivity sounding curves were interpreted by curve matching using albums of theoretical curves and an auxiliary point diagram. The graphical interpretations were checked for accuracy by computer modeling.

Figure 4 shows resistivity cross sections of traverse lines 3, 4, and 5. Three different resistivity layers occur on these cross sections. These layers are:

1. A 100- to 400-ohm.meter resistivity layer that corresponds to alluvial sand and gravel.

2. A 2- to 40-ohm.meter resistivity layer that corresponds to clay and water. Resistivity values less than 10 ohm.meters correlate to heated or hot water-bearing rocks that occur just above geothermal reservoirs at a depth of approximately 80 meters. This 80-meter depth corresponds to the results of resistivity sounding shown in Figure 5.

3. A 200- to 500-ohm.meter resistivity layer that corresponds to the Paleozoic phyllite, quartzite, sandstone, and shale basement complex. This layer is at the bottom of the cross sections, below the depth of 80 meters

The structure of faulted basement and the overlying Quaternary sediments can be seen on these cross sections. The low resistivity around the faulted basement may represent a drop in resistivity caused by superheated geothermal fluid in the reservoir. These zones were classified as geothermal anomalies for future exploration drilling.

Magnetic survey

The magnetic survey was done using a geometric magnetometer. Total magnetic field data were collected with 20-meter station spacing along a northeast line direction. Regional total magnetic field was removed from the raw data, resulting in a residual that has a good correlation with the location of the Pong Kum hot spring

Figure 6 shows magnetic intensity map of the study area. Average total magnetic field intensity is 44,000 nanotesla. The high magnetic intensity zones occur in the middle part of the survey area and have a northeast-southwest trend. Northwest-trending faults are clearly indicated by the displacement and non-continuation of high magnetic intensity areas. These faults may represent the channels for upward moving geothermal water. Circular low magnetic intensities areas may represent the locations of hot water below the surface.

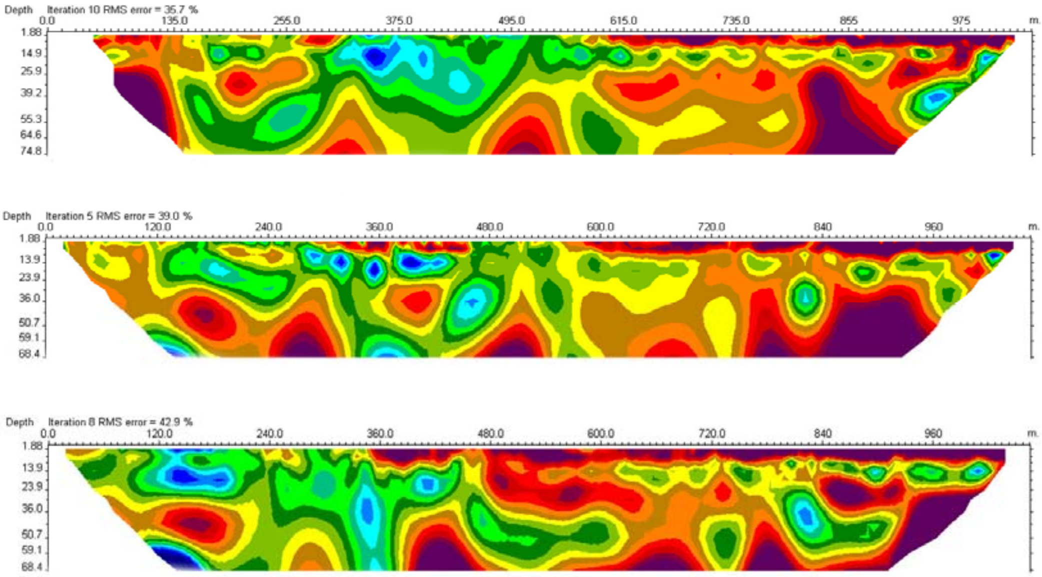
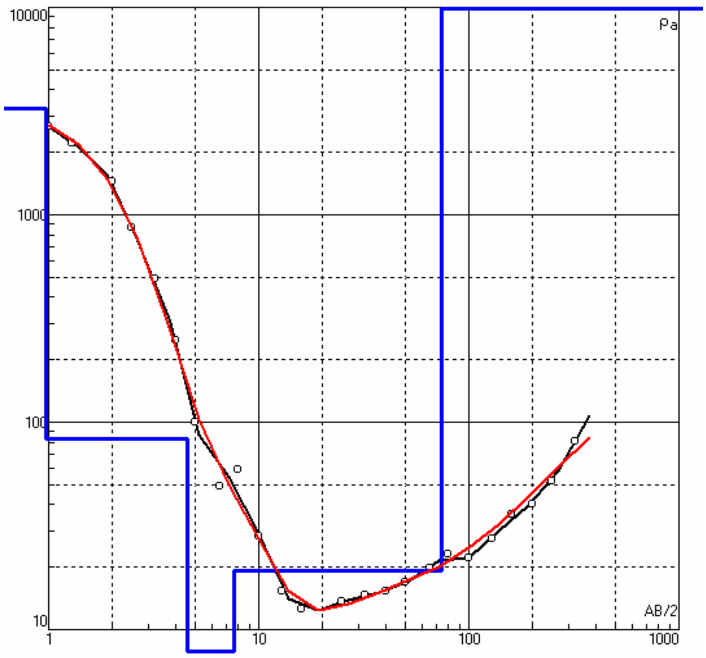


Figure 4. Resistivity survey results of lines 3, 4, and 5.



N	ρ	h	d	Alt
1	3236	0.97	0.97	-0.9703
2	82.7	3.6	4.57	-4.571
3	3.49	3.1	7.67	-7.674
4	19.2	66.4	74.1	-74.05
5	13228			

Figure 5. Resistivity sounding of line 4, station 360.

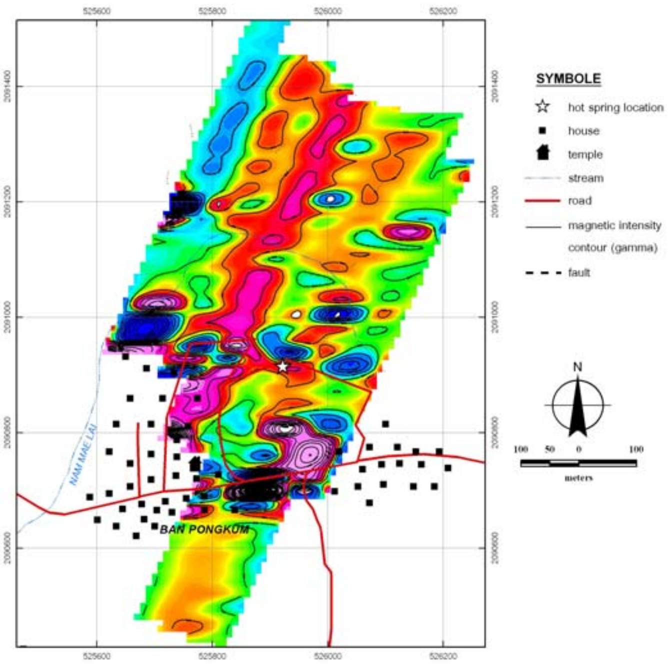


Figure 6. Magnetic survey results

The magnetic data were inverted to determine the three-dimensional magnetic susceptibility distribution for the survey area. The predicted data from the model agreed well with the observed data, given the noise assumption of 5 nanotesla**.** The model inversion of magnetic data shows tabular structures (Figure 7) that start at a depth of 80 meters and continue up to the surface. These tabular structures are the magnetic susceptibility zones that may represent the conduits for upward moving geothermal water. The zones of low magnetic susceptibility correlate with the location of the hot springs, suggesting the validity of the magnetic inversion.

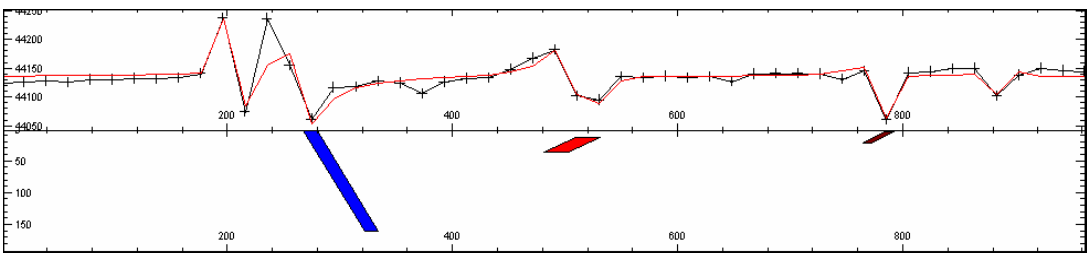


Figure 7. Magnetic model of line 5, showing the geometry of fault structures.

Seismic survey

The seismic survey location was approximate 100 meters north of the Pong Kum hot spring. The data acquisition system was a 48-channel seismograph with 288 28-hertz geophones, six geophones per group. Line 1 and line 4 were oriented northwest-southeast and northeast-southwest, respectively. The maximum in-line offset was 60 meters and receiver spacing was 5 meters.

Line 1 (Figure 8) is 475 meters long. On the basis of velocity change with depth, the line has three zones. The average velocity of the top zone is 750 meters per second and the zone is approximately 3 meters thick. It is the top soil that consists of sand, silt, and clay. The middle zone has an average velocity of 1500 meters per second and corresponds to weathered zones of highly varying thicknesses that are controlled by faults. The bottom zone has a velocity of more than 3000 meters per second and represents the basement rock. This zone has discontinuous thickness because it was cross-cut by many faults, especially in the middle part of the survey line.

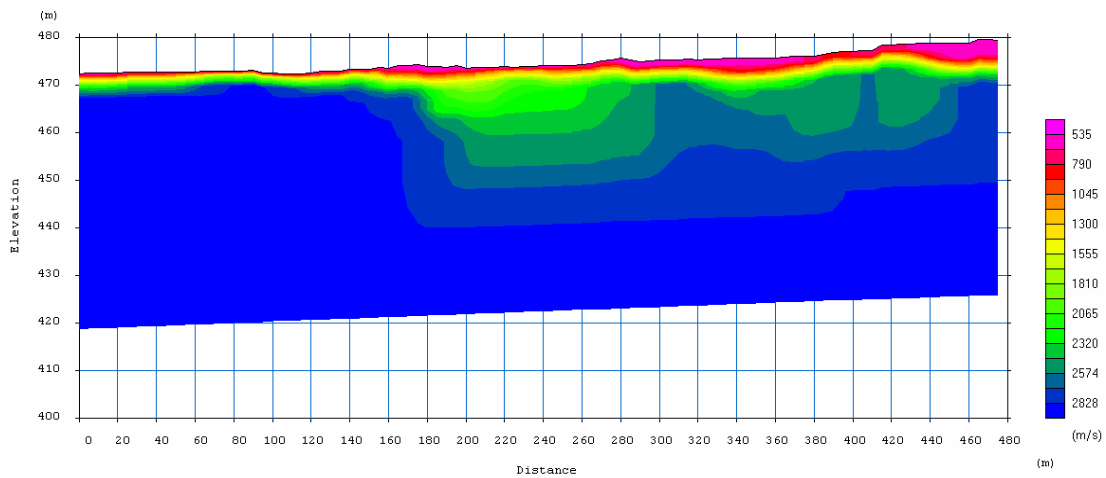


Figure 8. Seismic survey result across the hot spring area Figure 8. Seismic survey result across the hot spring area

CONCLUSION

All geological survey results can construct the model of the study area as shown in Figure 9. On this cross section, the basement corresponds to granite that intrudes near the study area. Normal and strike-slip faults were developed and formed as channels for down flowing cool water and for up flowing hot water. The geothermal reservoir on Figure 9 may be trapped by an impermeable layer, such as shale of Mae Tha Group.

Geophysical surveys are very important relative to the setting and extension of geothermal reservoirs in the Pong Kum hot spring area. The geothermal anomaly in the area is closely associated with the major fault and fracture system near the surface hot spring. However, geophysical exploration techniques have been limited due to their low effective penetration depth and the masking effects of shallow groundwater circulation.

Exploration drilling over the geothermal anomaly, thermal gradient measurement, and heat flow determinations are suggested for future work in order to study the main factors of the specific reservoir for developing the hot spring in this area.

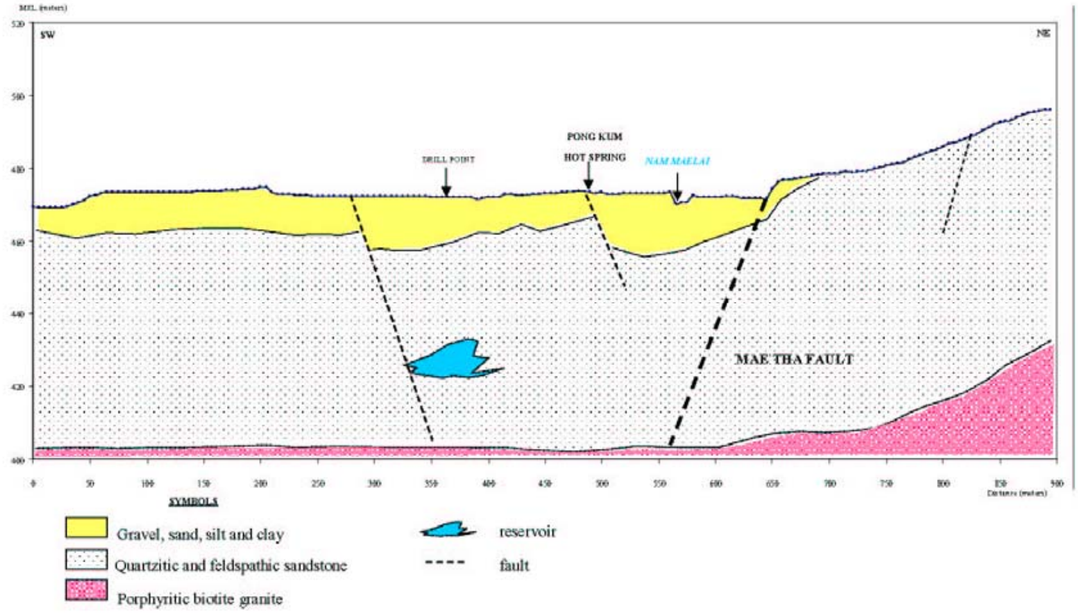


Figure 9. Interpreted geological model of the study area derived from geophysical surveys

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