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Physical Characteristic of Pong Kum Hot Spring, Chiang Mai, Thailand, Using Ground Geophysical Investigation

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ABSTRACT

Resistivity, magnetic and seismic surveys were carried out in the Pong Kum hot spring area in Chiang Mai, northern Thailand. The resistivity survey was conducted using dipole-dipole configuration with an electrode separation of 15 m. Interpretation of resistivity data using model curves indicated low resistivity zones (geothermal anomaly) representing the basement geothermal reservoirs. This target exploration zone is located about 150 m southwest of the hot spring surface and is approximately 80 m deep. Results from 2D seismic profiles indicated a shallow basement and fault zone near the surface of the hot spring. 2D total-field magnetic data show a low magnetic susceptibility zone in the NE-SW trending fault, which may represent channels for up-flowing geothermal water.

1. INTRODUCTION

Energy consumption seems to be increasing every year. This leads to the uses of alternative energy sources to reduce the import of petroleum. Coal is one possibility, but it has a very significant environmental impact. Geothermal energy is a good alternative energy source that is environmentally sound. Because it is a renewable resource, the demand for this resource is essentially increased. Thailand had some geothermal development in the past, particularly in the north. As stated by Ozguler *et al.* (1983), there are 4 major factors involved in geothermal energy prospecting: namely a source of natural heat, adequate water supply, a permeable reservoir, and impermeable caprock.

The hot spring studied is located at Ban Pong Kum, Doi Saket District in the Chiang Mai Province in northern Thailand, as illustrated in Figure 1.

It is now apparent that geothermal reservoirs and their environments have certain specific physical characteristics which are susceptible to detection and mapping by geophysical methods. Therefore, results from various geophysical surveys conducted in the Pong Kum geothermal hot spring are documented in this report including resistivity, magnetic, and seismic methods. Following the positive result achieved in the Pong Kum hot spring, geophysical data were extended to identify new specific target areas and form the basis of future assessments of geothermal resources in this area.

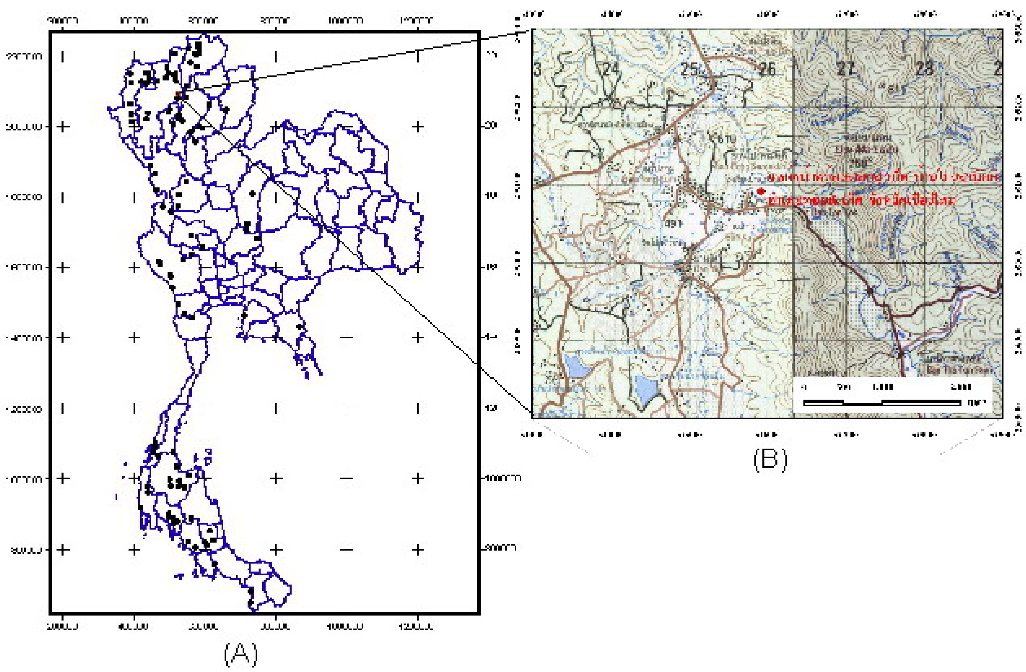

Figure 1: (A) Distribution of hot springs in Thailand
(B) Topographic map of the studied Pong Kum area showing hot spring location.

2. GEOLOGICAL SETTING

The Pong Kum geothermal field area is located in the Quaternary alluvial filled basin, and it is surrounded by high topographic terrain and underlain by Carboniferous clastic rocks and the biotite granite that intruded the clastic host rocks. (Pitrakun and Kulasingha, 1979)

After the deposition of the sediment during Late Paleozoic, compression tectonics with subsequent intrusion may have developed, and the rocks under the study area were uplifted, folded and faulted (particularly after the Triassic Period). Extension tectonics may have caused several sets of faults to develop in the late Tertiary, and movement along the faults caused the development of the Cenozoic basin. Fault movement is considered to still be active (Charusiri et al. 2000, Wiwegwin et al 2008). Structurally, the hot spring is located in the northern part of the NW trending Mea Tha Fault, which dips to the west and northwest directions.

3. GEOLPHYSICAL INVESTIGATIONS

All geothermal reservoirs have specific physical characteristics, so they are susceptible to detection and mapping by geophysical methods. In this study, geophysical surveys were applied to model the deep geological structure, conditions, and caprock thickness as well as the regional and local thermal situations.

Resistivity, magnetic and seismic methods of geophysical surveying were used in this area. The surveys were carried out on 12 survey lines in the northeast-southwest direction with a line spacing of 50 m, as shown in Figure 2.

3.1 Resistivity Survey

The most important technique in geothermal energy exploration is the resistivity method (Loke and Barker, 1996), because it always has strong responses to physical properties that vary in geothermal fields, including temperature, fluid salinity and porosity. For example, a hot water zone can be located within an area by a decrease in resistivity as a result of an increase in temperatures and salt concentrations in a geothermal reservoir. In addition, resistivity surveys can provide data for subsurface geological and structural interpretation, which can be used to detect and map geothermal systems,.

In this study, a resistivity survey was performed with an automated multi-electrode switching system (IRIS syscal R1 plus). The dipole-dipole array was chosen based on previous work that showed good resolution of fractures and caves with this configuration (Roth *et al.*, 1999; Labuda and Baxter, 2001). The survey employed a total of 48 electrode positions with a dipole spacing of 15 m. The raw apparent resistivity dipole-dipole data were inverted and interpreted using the rapid two-dimensional (2D) resistivity inversion least squares method. The program RES2DINV, Ver. 3.3 developed by Loke, (1998) was used to acquire a 2D “true” earth resistivity inversion solution in a color grid.

The results of the resistivity survey were displayed as apparent vertical resistivity cross-sections along traverse lines 3, 4 and 5. The results pointed to the existence of geothermal anomalies, as illustrated in Figure 3. Three layers of different resistivities were determined (from top to bottom):

1. A resistant cover (100-400 Ohm.m): This layer includes an alluvial sand bed, and coarse grained sediments represent thin (10 m) caprocks on the surface.

2. A conductive complex (2-40 Ohm.m): This layer is composed of clay and water. The zone with less than 10 Ohm.m is herein considered as the hot water bearing zone, which lies over geothermal reservoirs. This zone is located at a depth of approximately 80 m.

3. A resistant layer (200-500 Ohm.m) was interpreted as a basement of Paleozoic complexes. This layer is at the bottom of the cross section below a depth of 80 m.

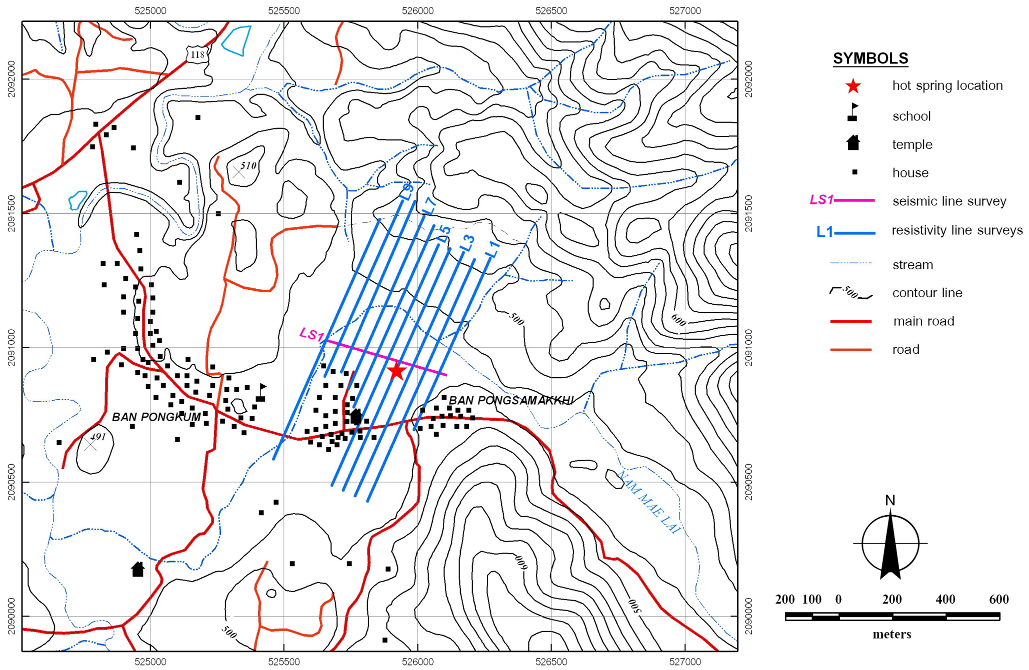

Figure 2: Topographic map of the Pong Kum hot spring area showing geophysical line surveys.

The structure of the fractured/faulted basement with Quaternary sedimentary cover can be seen on these sections, as shown in Figure 3 The low resistivity around the faulted basement is believed to be caused by superheated geothermal fluid in the reservoir. These zones were classified as geothermal anomalies for exploration drilling.

3.2 Magnetic Survey

The magnetic survey was collected using a Geometric 856G magnetometer. A total magnetic field with 20 m station spacings was collected along the northeast trending line. The regional total magnetic field was removed from the raw data, and the residual showed a good correlation with the location of the hot spring.

A magnetic intensity map of the Pong Kum study area with an average total magnetic field intensity of 44,000 nT is shown in Figure 4. The high magnetic intensity zones (shown in red) are located in the center of the northeast-southwest trending survey area. The zone in the northeast-southwest direction is inferred as the faults clearly observed using the displacement and non-continuation of high magnetic intensities. These faults may represent the channels for geothermal water flow to the surface. Circular areas with low magnetic intensities (shown in blue) may represent the location of hot water sites beneath the surface.

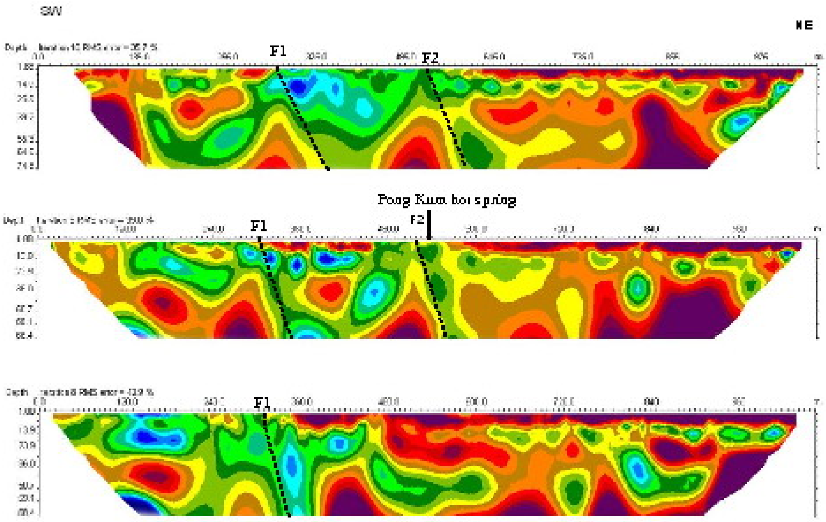

Figure 3: Results of resistivity survey profiles of line 3 (top), 4 (middle) and 5 (bottom) in the Pong Kum area of Chiang Mai.

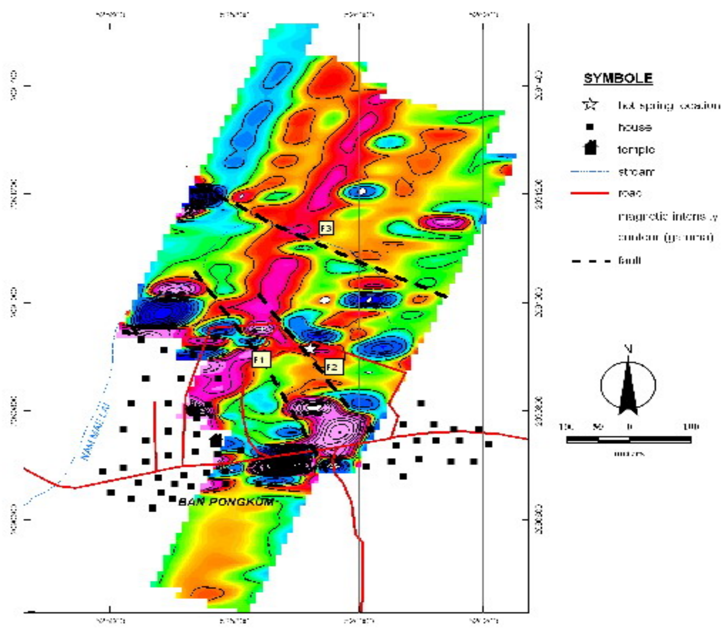

Figure 4: Result of the magnetic survey showing the orientation of the fault zones in the northeast-southwest direction.

3.3 Seismic Survey

The seismic survey was set up to the north of Pong Kum hot spring, as shown in Figure 2. The data acquisition system used was a 48 channel Geometrics Seismograph with 288 geophones (6 geophones for one group) and a 28 Hz receiver. The receiver and shot lines at line 1 and line 4 were oriented in northwest-southeast and northeast-southwest directions, respectively. The maximum in-line offset was 60 m, and the receiver spacing was 5 m.

The seismic profile approximately in the east-west direction shown in Figure 5 has a total length of 475 m. The velocity-depth relationship revealed three distinct layers that are controlled by fault structure. The average velocity of the top layer is 750 m/s and is considered to be the 3 m thick top soil consisting of sand silt and clay. The middle layer has an average velocity of 1500 m/s and is considered to be the weathering zones with high variation in thickness. The bottom layer is characterized by a high velocity of more than 3000 m/s and is considered to be the rock basement. This layer has discontinuous thickness, because it is cross-cut by many fault structures, especially in the middle part of the survey line.

4. Discussion and Conclusion

A geologic model of the Pong Kum studied hot spring area was visualized according to the overall results of the ground geophysical surveys and is shown in Figure 6. It is inferred that the basement corresponds with granite intrusion occurring near the study area, as reported by Wiwegwin et al. (2008). The intrusion was cut by faults, which act as channels for down- and up- flowing of cool and hot water, respectively. The geothermal reservoir was found to be capped by impermeable rocks, such as shale or fine-grained clastic rocks.

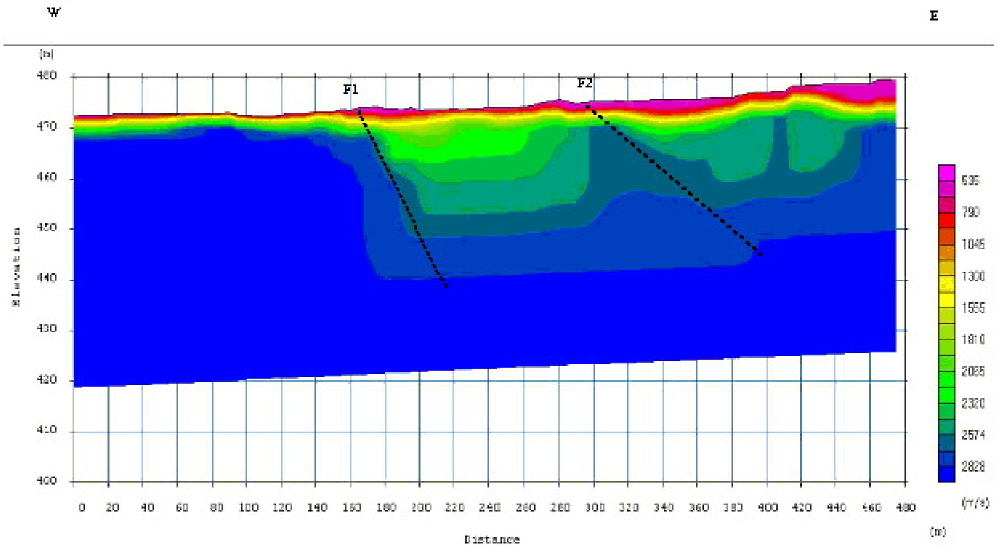

Figure 5: Seismic line survey section across the Pong Kum hot spring area

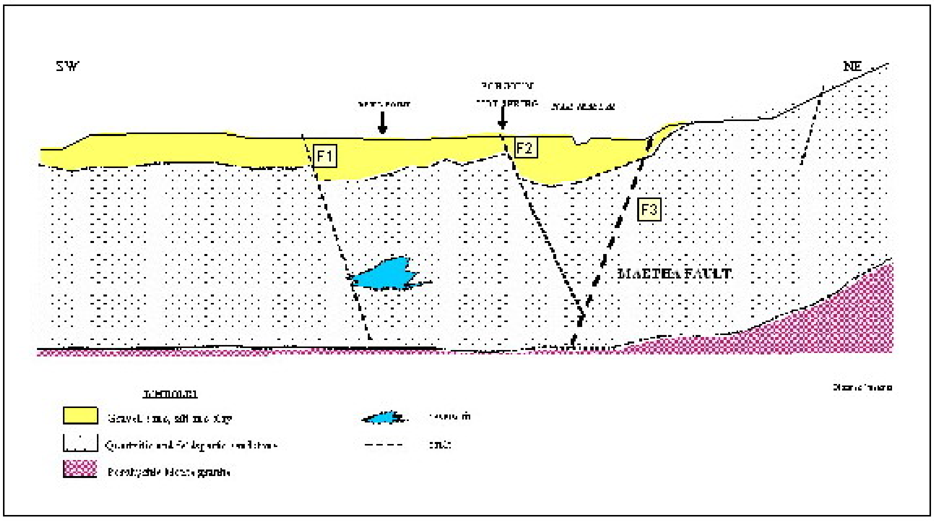

Figure 6: Geological model of the Pong Kum study area based on ground geophysical interpretation. Note that F1 & F2 are antithetic faults and F3 is a synthetic fault.

Geophysical surveys were very informative concerning the setting and extension of the geothermal reservoir in the Pong Kum hot spring. The observed geothermal anomaly is closely associated with the major fault and fracture system near the surface hot spring. However, the geophysical exploration techniques were limited by the 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 visualize the main factors of the reservoir for geothermal development in this area.

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