Geophysical Anomalies of Kaochaison Hotspring in Pattalung Province

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ABSTRACT

Geophysical measurements were made in the Kaochaison hot spring area in southern Thailand. to determine the subsurface geological structures related to the hot spring. Ninety-five gravity points and 37 resistivity soundings were measured. A positive gravity anomaly occurs in the same area as high resistive bedrock over the Kaochaison hot spring. Both gravity anomaly and the high resistive bedrock have an elongated shape and trend slightly west of north. A shallow Permian limestone about 1,000 meters thick was modelled to explain the positive gravity anomaly. This limestone is likely a part of horst and graben structures and is the pathway of hot water from a deep heat source.

KEYWORDS: Kaochaison, gravity anomaly, resistivity sounding, geological structure, horst and graben structures

Introduction

The Kaochaison hot spring is in Ban Kaochaison, Kaochaison district of Phattalung Province, and is about 840 kilometers south of Bangkok and about 25 kilometers southeast of Phattalung city. In Phattalung Province, there are four hot spring sites, the PL01 Kaochaison hot spring in Kaochaison district, with a surface temperature of about 57° C, the PL02 Ban Lo Chan Kra hot spring in Tamod district, with a surface temperature of about 46° C, the PL03 Ban Na Thung Pho hot spring in Kongra district, with a surface temperature of about 50° C, and the PL04 Ban Ra Wang Khua hot spring in KhuanKhanun district, with a surface temperature of about 42° C.

The general geology of Kaochaison hot spring and its vicinity is shown in Figure 1. The rocks exposed in the study area range from Cambrian to Quaternary. The Cambrian rocks of the Tarutao Group are white to light gray fine-grained sandstone and quartzite. The Ordovician rocks of the Thung Song Group are mainly gray, finely crystalline to coarse-grained limestone. The Silurian-Devonian rocks of the Pa-Samed Formation are black shale and mudstone. The Carboniferous Khuan Klang Formation includes gray mudstone, siliceous mudstone, shale, chert, and sandstone. The Ratburi Group Permian rocks are mainly white limestone and dolomitic limestone that form isolated hills in the eastern part of study area. The Jurassic-Cretaceous rocks of the Lam Thap Formation are arkosic sandstone, siltstone, and conglomerate. The Quaternary sediment includes gravel, sand, silt, and clay. Intrusive igneous rocks are Triassic in age. They are mainly biotite-muscovite granite and porphyritic granite and occur in a large area as isolated hills in the western part of Phattalung Province. They form a north-south belt and they may be heat sources of the geothermal system in the study area (Department of Mineral Resources, 2007).

The major structures in the study area are the northeast-southwest and northwest-southeast-trending faults and fractures in the Ordovician and Silurian-Devonian rocks and in the Triassic granite (Department of Mineral Resources, 2007)

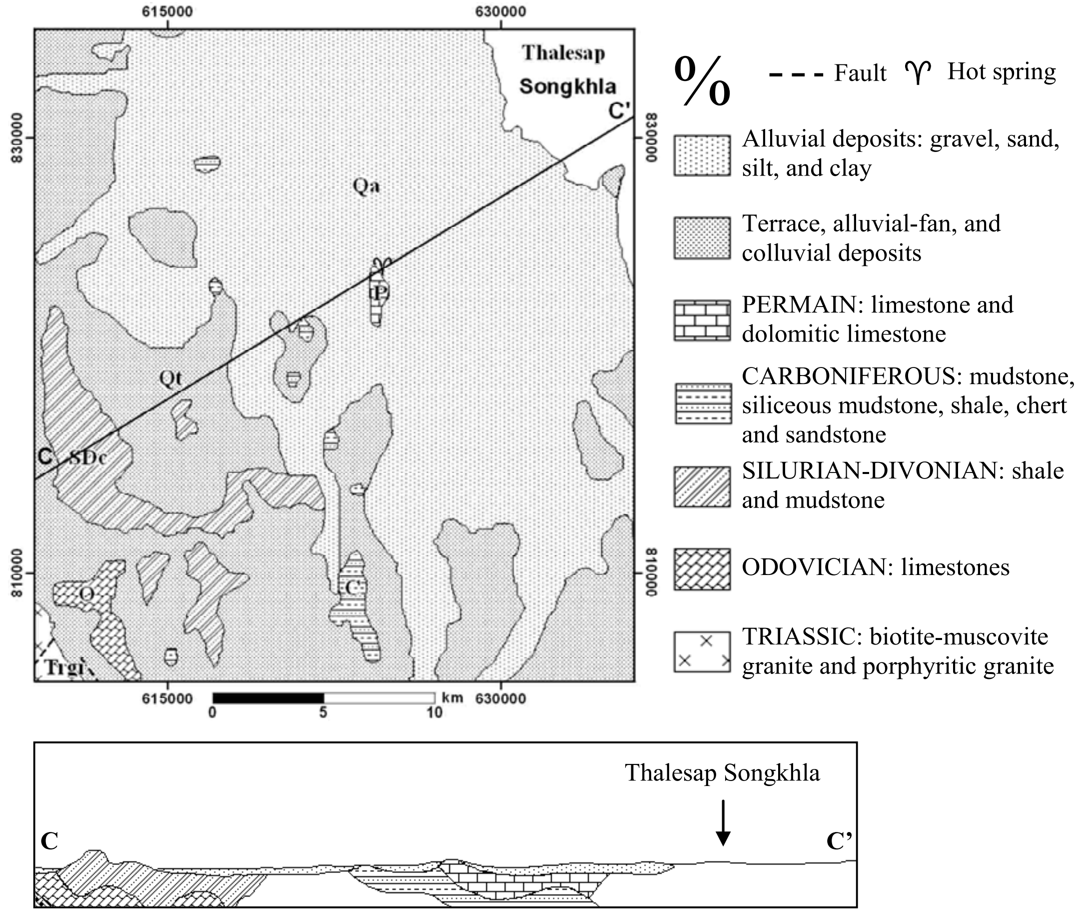


Figure 1. Geological map and cross section of the study area

Sawata and others (1983) conducted Quaternary geological studies in southern Thailand and concluded that the north-south-trending basin, located between east longitudes 100°15′ and 100°30′ and extending from the coast east of Nakhon Si Thamarat to the Thai-Malaysian border, is a graben. The hill range and the neighboring small basins east of the graben are parts of a horst. This graben and horst structure may be a southern extension of a geological structure formed by block faulting that has trapped some oil and natural gas under the Gulf of Thailand.

Raksaskulwong and Theinprasert (1995) suggested that hot springs in Thailand may be associated with granitic rocks that are heated by the decay of an abnormally high content of radioactive elements or because they occur at active fault zones that are leakage points for deep and hot zones. Charusiri and others (2003) suggested that the most probable heat source of Chantaburi hot spring is near-surface active rift-related magmatism. Such magmatism could have been the source of past basalt and may be responsible for hot spring development as a result of active intra-plate mantle melting through the major fault.

The objective of this research work was to determine the subsurface geological structure related to the Kaochaison hot spring using gravity and vertical electrical sounding methods.

Previous gravity and vertical electrical sounding measurements conducted in order to delineate subsurface plutons and fault systems are Majumdar and others (2001), Donnell and others (2001), Khawdee and others (2007), and Khawtawan and others, (2004).

METHODOLOGY

Gravity measurements investigate the subsurface geology by measuring variations in the Earth's gravitational field generated by density differences between subsurface rocks (Kearey and Brooks, 1991). The resistivity method investigates the subsurface by measuring the potential differences of electric currents that are introduced into the ground. The measured potential difference depends on the size, shape, location, and electrical resistivity of subsurface layers or bodies. In this study, vertical electrical sounding measurement was used in determining horizontal or near-horizontal interfaces.

Gravity measurement

The gravity value of each point was measured with a LaCoste and Romberge gravimeter, model G-565. Ninety-five measuring points were placed along roads in the study area. The spacing between measuring points was 2 kilometers. Gravity measurement was conducted in leap-frog loops with a period of 2 to 3 hours for each closing loop. The location of measuring points was determined with a Trimble Pathfinder basic-plus geographic positioning system instrument. The elevation of gravity points was measured with an American Paulin altimeter.

The measured gravity values were corrected for the effects of instrumental drift and tides, latitude, elevation, and surrounding terrain (Telford and others, 1998). The data were corrected to give gravity anomalies at mean sea level, these being Bouger anomalies. A Bouguer anomaly map was drawn and used for qualitative and quantitative interpretation in order to determine the geological structure at depth.

Vertical electrical sounding

Thirty-seven electrical resistivity soundings in the Schlumberger electrode configuration were conducted in the study area. The maximum spacing between current electrodes was 700 meters. The ground resistance was measured with an ABEM Terrameter SAS-1000 and the Resist program (Velpen, 1988) was used for one-dimensional modelling of sounding data.

Density of rock samples

Two to ten hand specimens of six rock-types exposed in the study area and the vicinity of study area were collected from seven sites. Sample weight did not exceed 3 kilograms. The densities of these samples were determined in the Prince of Songkla University geophysics laboratory and were used as constraints in gravity modellling for determining subsurface geological structures.

RESULTS AND DISCUSSION

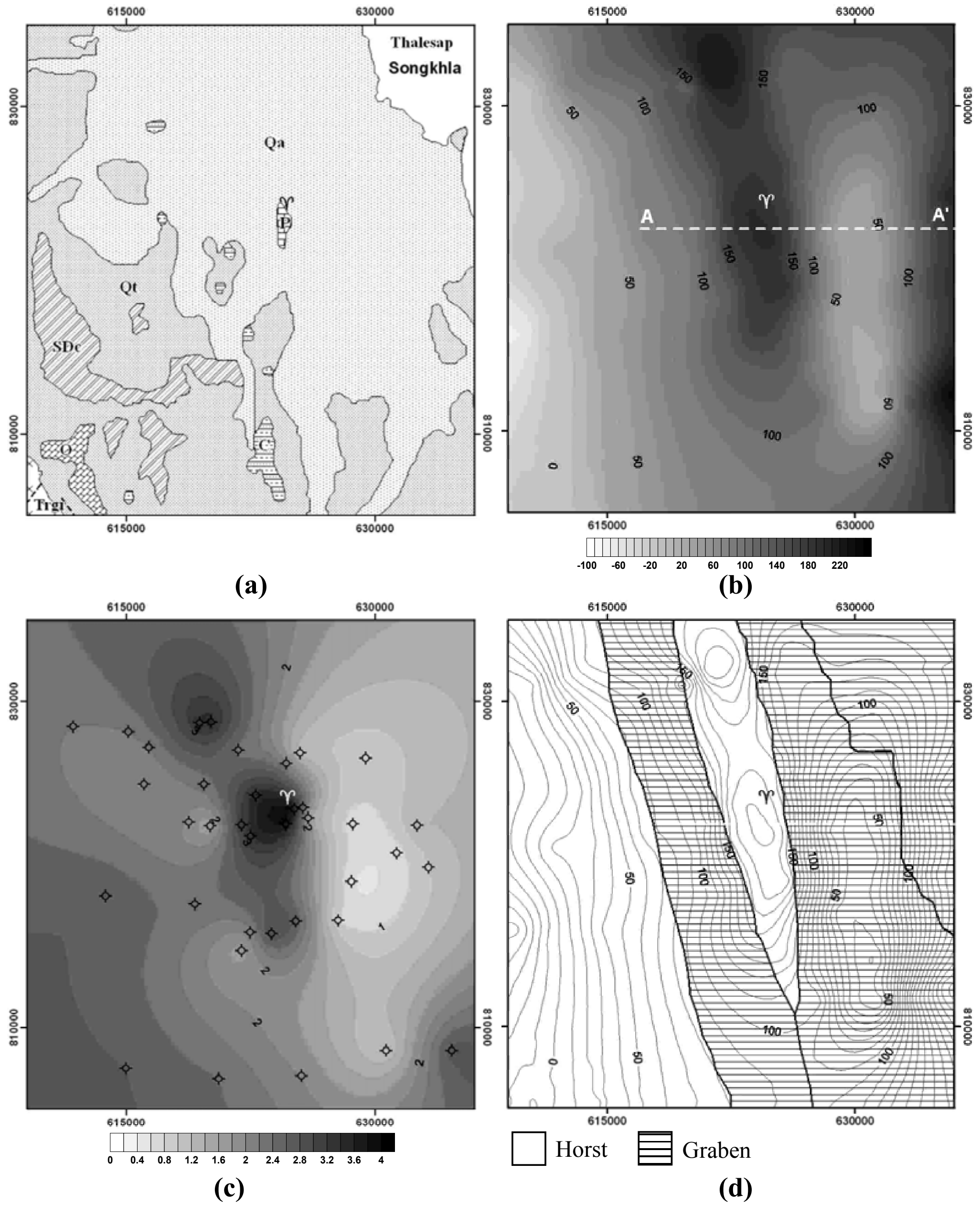
Gravity and vertical electrical sounding results

A Bouguer anomaly contour map superimposed on the geological map of study area is shown in Figure 2(b). There are three prominent Bouguer anomalies on the Bouger map. One is an area of very low Bouguer values, -60 to 20 gravity units, near granitic outcrops in the western part of study area. A second is an area of medium Bouguer values, 20 to 110 gravity units, in Carboniferous sandstone and Silurian-Devonian mudstone in the southern part of the study area and those covered by Quaternary sediments. A third is an area of high Bouguer values, 110 to 220 gravity units, with northwesterly-trending elongated shape in Permian limestone and Quaternary sediments in the northern and eastern parts of the study area.

Figure 2(c) is a true resistivity map at a depth of 75 meters. An area of high resistivity is in the central part of the study area and coincides with the high Bouguer anomaly. An area of low resistivity occurs in the eastern part of study area and coincides with the low Bouguer anomaly. These coincidences indicate that the causative body, considered to be Permian limestone, in the central part of the study area possesses higher density and resistivity than surrounding areas, particularly that of low Bouguer anomaly and low resistivity to the east. Hot spring PL01 is located exactly on the contact between the high and low anomalies. The high Bouguer anomaly area in the central part of the study area and the low Bouguer anomaly in the eastern part of the study area correspond with the horst and graben structures proposed by Sawata and others (1983).

Quantitative interpretation of Bouguer anomalies was done with forward gravity modelling on profile AA’ in Figure 2b to determine subsurface geological structures in the vicinity of hot spring PL01. Surface geological information, ground resistivity models obtained from the electrical sounding, and measured densities of rocks samples obtained from the present and a previous study

(Phethuayluk, 1996) were used as constraints in the gravity modelling. These constraints were 2,580 kilograms per cubic meter for Carboniferous sandstone, 2,770 kilograms per cubic meter for Permian limestone, 2,250 kilograms per cubic meter for Jurassic-Triassic sandstone, and 2,000 kilograms per cubic meter for Quaternary sediment.



Profile AA', + gravity point, ✧ resistivity point, ♈ hot spring

Figure 2. (a) Geological map of the study area; (b) Bouguer anomaly map, contour interval 10 gravity units; (c) modeled resistivity map at 75 meters depth; (d) Bouguer anomaly map superimposed on horst and graben structure map (Sawata and others, 1983).

Two possible geological structures around hot spring PL01 in profile AA' obtained from the present gravity modelling are shown in Figures 3 and 4. Profile AA' is about 20 kilometers long and crosses thermal spring PL01 (Figure 2b). The regional gravity anomaly in the study area increases eastward with a gradient of 9.8 gravity units per kilometer. This was removed from the Bouguer anomaly of profile AA'. A high residual anomaly of about 51 gravity units occurs at a distance of 6.5 kilometers and a low residual anomaly of about 122 gravity units is 13 kilometers distant (Figure 3a).

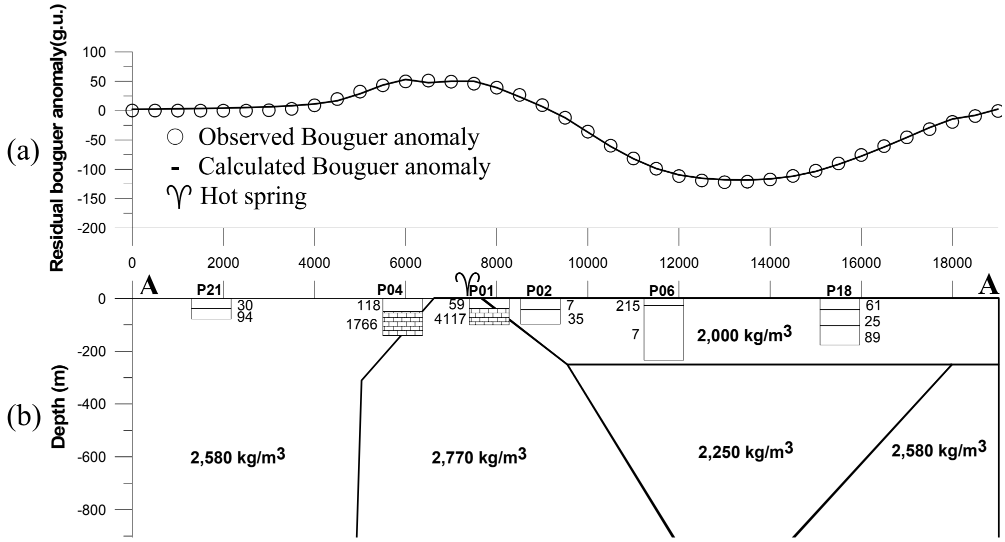


Figure 3. The first gravity model of profile AA'

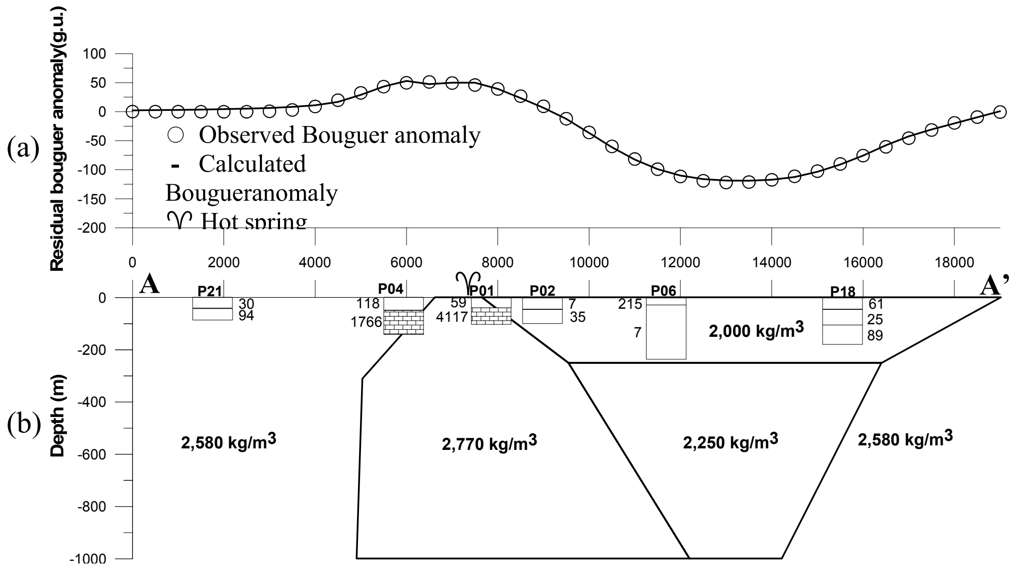


Figure 4. The second gravity model of profile AA'

In both gravity models, Carboniferous rock of 2,580 kilograms per cubic meter was used as the surrounding rock. Permian limestone, about 1,000 meters thick, was modelled to explain the high residual anomaly at a distance of 6.5 kilometers. Jurassic-Cretaceous rock 800 meters thick, and overlain by 200 meters of Quaternary sediment, was modelled to explain the low residual anomaly at a distance of 13 kilometers (Figure 3b). For the easternmost residual anomaly on profile AA', Permian limestone about 800 meters thick, and overlain by 200 meters of Quaternary sediment in the first gravity model (Figure 3b) and Jurassic-Cretaceous rock about 1,000 meters thick in the second gravity model (Figure 4b) were modelled to explain the anomaly.

The depth to the modelled Permian limestone at distance 6.5 kilometers agrees with the depth to high resistive substratum obtained from the resistivity sounding. In addition, the 100- to 225-meter thickness of the 7 to 25 ohm-meter low resistivity layer at points P06 and P18 in the eastern part of profile is in good agreement with the thickness of the Quaternary sediments obtained from gravity modelling (Figures 3b and 4b).

CONCLUSION

Subsurface geological structures of the PL01 hot spring area in Phattalung Province were determined from gravity and resistivity sounding measurements. A shallow Permian limestone about 1000 meters thick and trending north 10^{o} west underlying the PL01 hot spring was modelled to explain the high gravity anomaly in the central part of study area. Jurassic-Cretaceous rocks about 800 meters thick underlying 200 meters of Quaternary sediment were modelled to explain the low gravity anomaly to the east of the high gravity anomaly. The locations of the shallow modelled Permian limestone and thick modelled Jurassic-Cretaceous rocks correspond very well with the locations of the proposed horst and graben structures in the study area. These horst and graben structures are the westward extension of the horst and graben structures in the Gulf of Thailand (Sawata and others, 1983). It is likely that faults that bound the horst and graben structures in the study area and fractures in the Permian limestone serve as pathways of hot water from a deep heat source.

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