CHAPTER 1

INTRODUCTION

The present energy resources are mostly from sources, such as fuel oil, coal, and natural gas. Meanwhile the price of fuel oil is increasing, man being have been searching for alternative green energies to replace fuel oil. Green energies, namely, biodiesel, wind energy, solar energy, and geothermal energy would affect our way of lives in the near future.

The geothermal energy can be used for generating electricity such as Fang geothermal area in Chiang Mai, Thailand and Nesjavellir geothermal area in Iceland. In Thailand, over 90 geothermal resources have been recorded. There are many geothermal resources in provinces of southern Thailand namely; Yala, Songkhla, Phattalung, Krabi, Ranong, and Surat Thani. The aim of research is study geothermal resources in Phunphin and Ban Na Doem District, in Surat Thani Province because Surat Thani is one of most highly growing economic province in Thailand. The need for electric energy will be high in the future. Geothermal energy is the source of green energy that can be used to replace and save fuel oil in electric production.

In order to utilize geothermal resource, one must understand the basic geological structure related to hot spring. Measurement of gravity and resistivity would be helpful for providing us more information about geological structure related to hot spring. The study employed geophysics method to determine geological structures of hot springs in Phunphin and Ban Na Doem District, Surat Thani Province.

1.1 Review of Literatures

1.1.1 Study area and physiography

Surat Thani province is located in the southern part of Thailand (Figure 1.1), about 550 km south of Bangkok. The province covers an area of 12,891.4 km^2. The studied area (Figure 1.2) is confined to the southern portion of the Surat Thani Province, bounded by latitude 8° 33′ 28″ to 9° 19′ 35″ N (946000 to 1031000 N

UTM) and longitude 99° 7′ 38″ to 99° 42′ 34″ E (514000 to 578000 E UTM). All UTM data are WGS-84 basemap Zone 47. It covers Phunphin and Ban Na Doem hot-spring (SR7, SR8) an area of around 5,440 km^2.

The topography of the study area can be divided into four parts, coastal plane, alluvial plane, upland area, and high-mountain area. The high-mountain area is in the southwestern part of study, namely "Kao Luong" mountain. The mountain is about 1,200 m high. The upland area consists of undulating landform and isolated hills. The undulating area, which covers the largest part of study area, has an elevation between 20 and 100 meter above mean sea level. It is mostly covered by rubber tree plantations. The coastal area is composed of delta and beach sand. It is broad and flat with elevations little higher than the sea level, in some cases even lower and extend up to 5 km from the coastline to the inland area. Sand beaches are situated along the northern and eastern seaside. The river delta in the west of Surat Thani city is built up by the Tapee River. The present-day main river mouth is located northeast of Surat Thani city. The delta is formed in the shape of a bird's foot. The elevation of this area is fairly low, between -1 and +5 meter (Tatong, 2001).

Surface water flows are mainly directed from southwest to northeast. There are two main rivers and a number of smaller rivers, called khlongs by local people. The Tapee River is the biggest river in the area and flows from south to north. It joins with the Phum Duang River, the second largest river, at Phun Phin District and then flows to the sea at Pak Nam Tapee. There are a lot of khlongs, which are very large by size due to tidal influence, for example Khlong Tha Thong, Khlong Phun Phin, Khlong Bang Kluai, Khlong Tha Kup, Khlong Tha Chang and Khlong Yai Phum Riang (Margane, 2001).

1.1.2 Climate

The study area is situated on peninsular Thailand with the Gulf of Thailand on its eastern side and Andaman Sea on its western side. It is influenced by southwest and northeast monsoons. The summer season lasts from January to April. The highest average temperature in April is up to 31° C. The annual average temperature is 26° C. The monsoon season begins in May and ends in December. It can be divided into two periods. The first period is between May and October. During this time the area is influenced by southwest monsoon bringing high humidity from its passage over India Ocean before reaching land. The second wet period is between November and December when the area is influenced by the northeast monsoon, which passes Gulf of Thailand (Pantanahiran, 2001).

1.1.3 Regional Geology

The geological map in Figure 1.4 shows that sedimentary rocks and sediments dominate the study area. Igneous rocks, mainly granites were also observed in the study area. The area was affected by tectonic movements during various periods. In the tectonic evolution, Thailand consisted of two continental terrains, the Shan-Thai and Indochina terrains (Figure 1.5). They were welded together by a collision that occurred in the Triassic or Permian period. The Shan-Thai became the western, northern and southern parts and Indochina became the northeastern and eastern parts of Thailand (Bunopas, 1992; Mantajit, 1997). The welded zone was called Nan-Chanthaburi suture-zone trending in north-south direction. Granitic rocks were also generated at the time of the collision of both terrains. After that the Thai block seemed to be stable until the Cenozoic era. During the Cenozoic, Thailand was affected by the India-Eurasia collision. Consequently strike-slip faults and extensional basins were created. A major fault, created by this event, was the Klong Marui fault zone, which accompanied the eastern escarpment of the western mountain range and crosses the study area roughly between Thap Put and Khiri Rattanikhom District in a NNE-SSW direction. Due to the high rainfall and temperature, the rocks were highly weathered near the surface. Hence both, weathering and tectonic processes influenced present landforms. The lithostratigraphic classifications of rocks in Surat Thani are shown in Table 1.1.

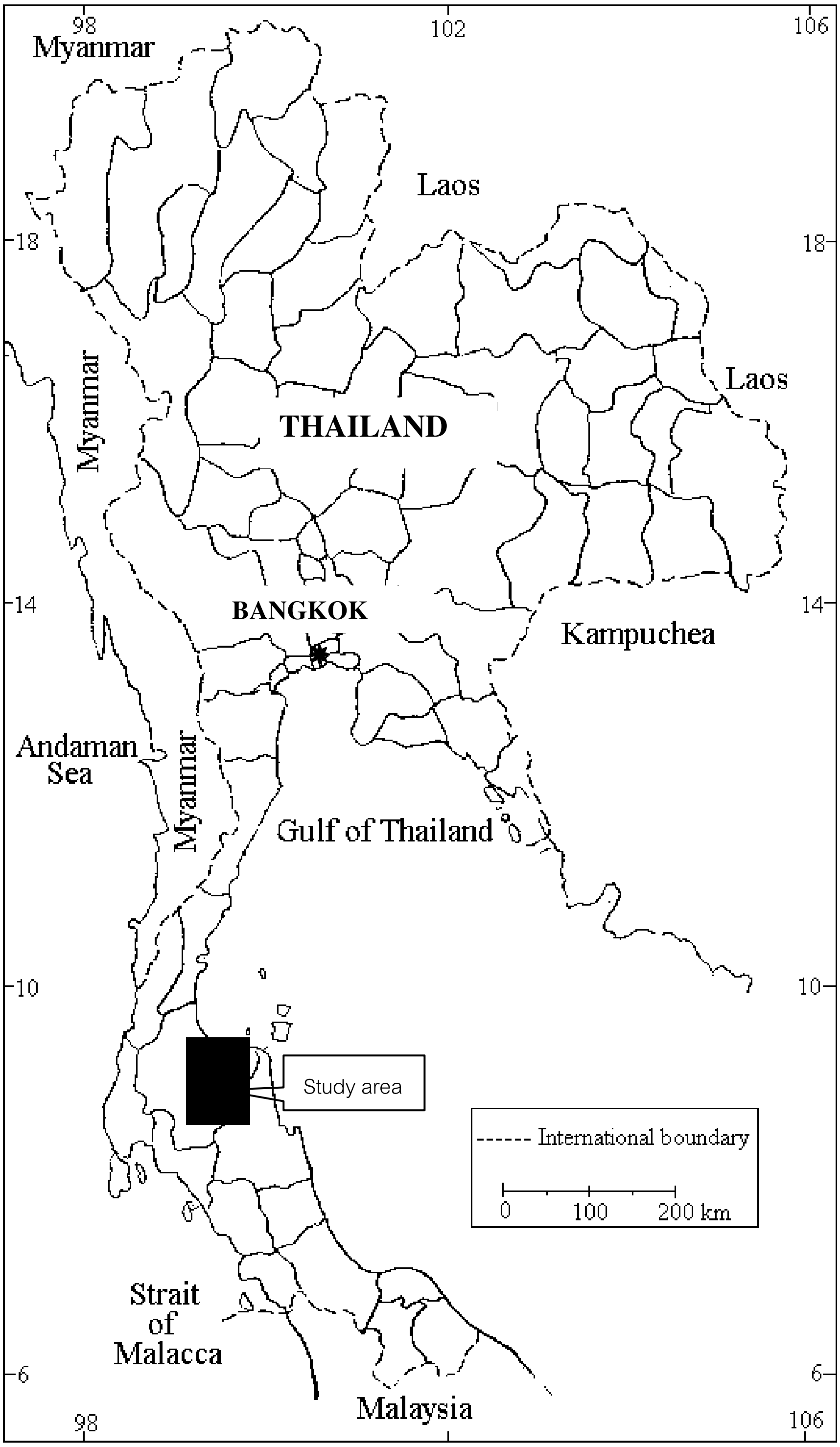


Figure 1.1 Location of the study area. Available from: <http://www.nectec.or.th /users/htk/graphic/1998.html>atlas571.jpg, [Accessed 6 July 2007]

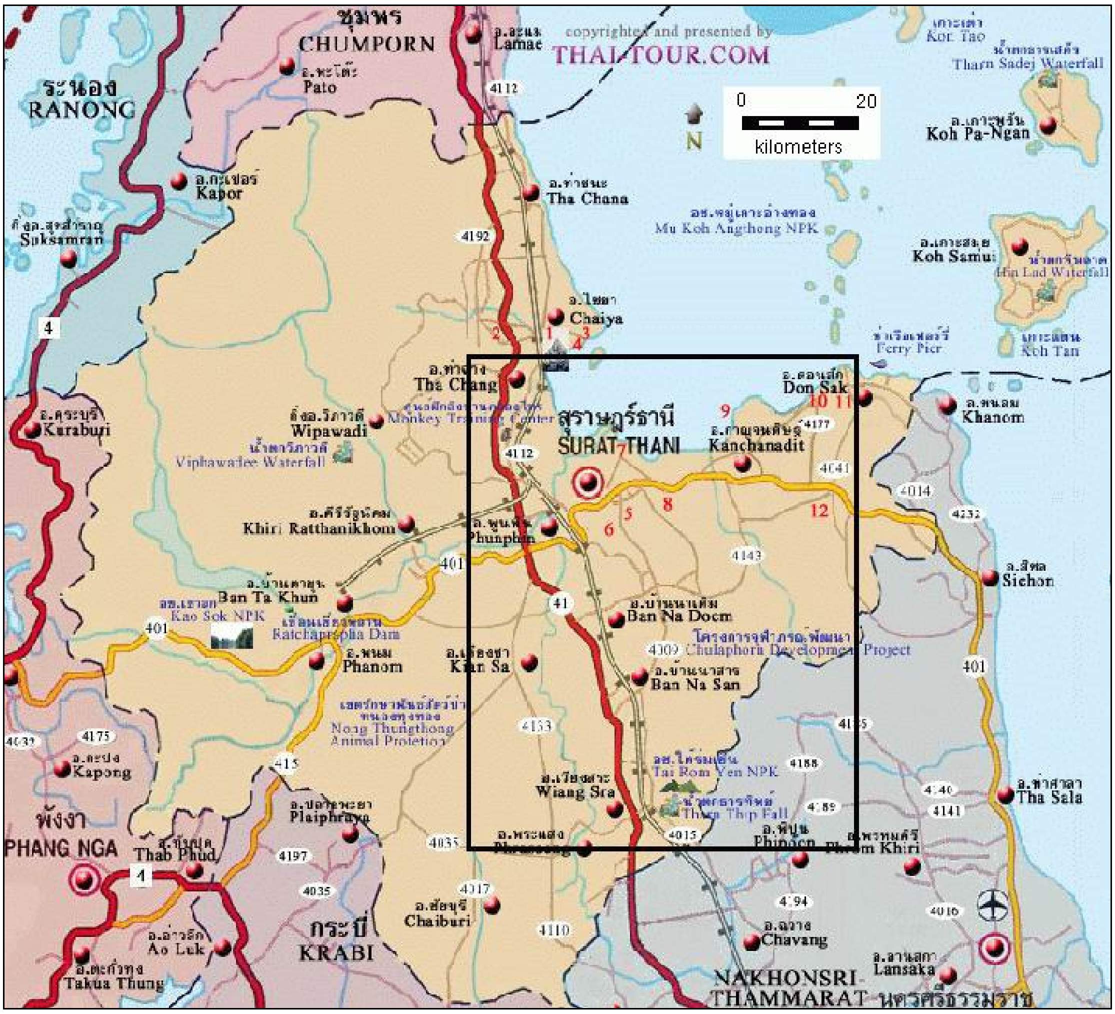
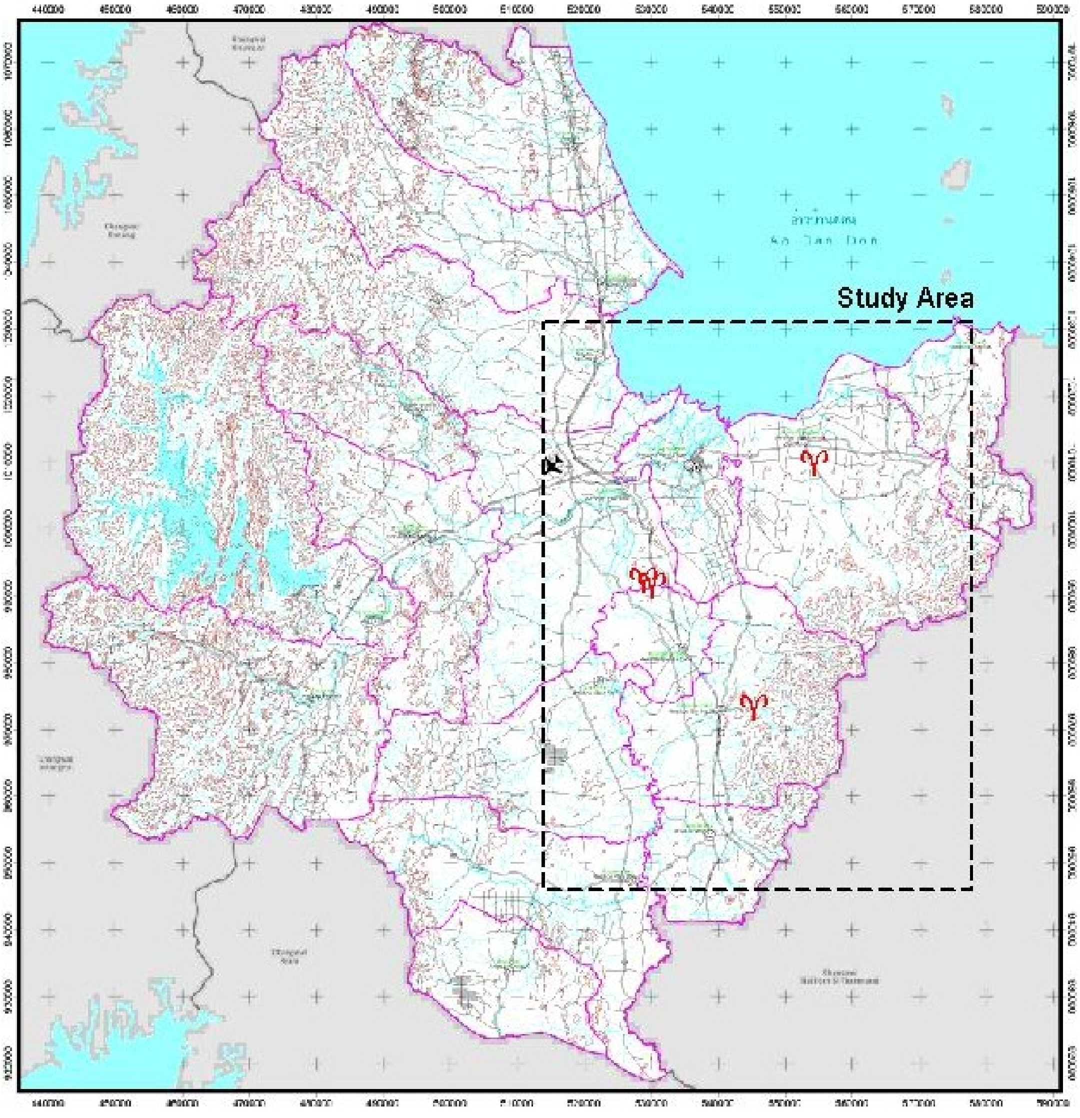


Figure 1.2 Location of the study area – regional overview. Available from: <http://www.thai-tour.com/thai-tour/South/> Suratthani/data/map.htm, [Accessed 9 July 2007].



EXPLANATION

The Information displayed in the map refers to the Royal Thai survey Topographic Base Maps (1:50,000)
4626 I, 4627 I,II, 4725 I, 4726 I, II, III, IV, 4727 I, II, III, IV, 4728 II, III, 4825 I, IV, 4826 I, II, III, IV, 4827 III, IV, 4828 III, 4926 III, IV, 4927 II, III, IV.
Additional information on roads and settlements is based on Landsat satellite imagery dated January 1999.

LEGEND

— River — Amphoe boundary
— Road — Level Contour
♈ Hot spring ✈ Airport

% 0 20
Kilometers

Figure 1.3 Location and topographical features of study area in Surat Thani Province. Available from: <http://www.dmr.go.th/eng/tgp/Project-HTML> /SRT-maps/Maps%20-%20Surat%20Thani%20-%20City.htm, [Accessed 9 July 2007].

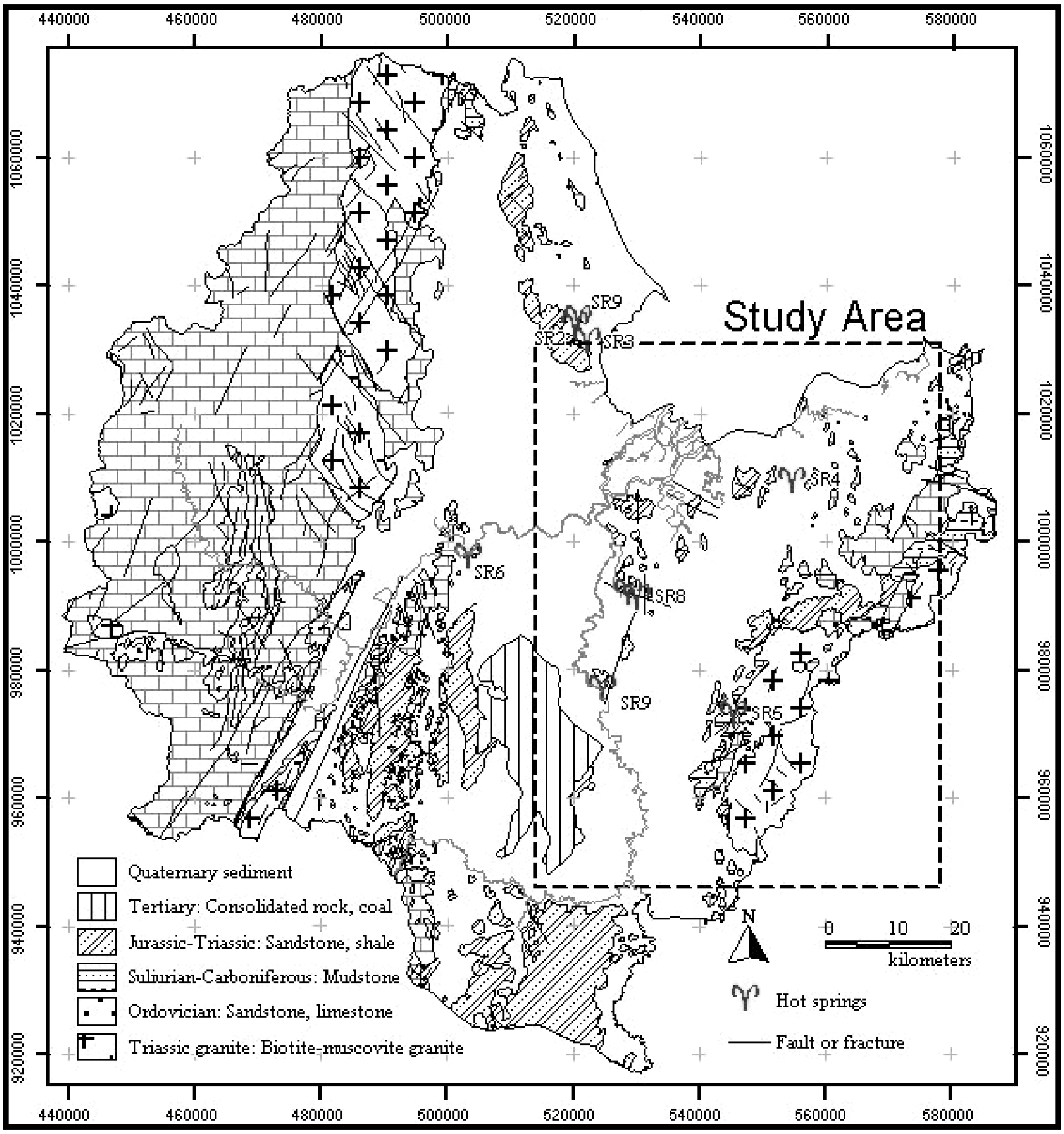


Figure 1.4 The geological map of the study area in Surat Thani Province (Department of Mineral Resources, 2004)

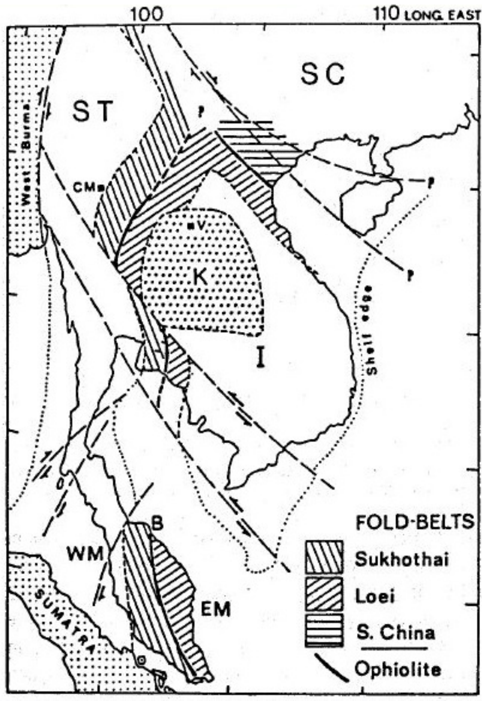


Figure 1.5 The Indochina (I) and Shan Thai (ST) terrains including fold belts and major fault zones (Mantajit, 1997)

Table 1.1: Lithostratigraphic classifications of rocks in Surat Thani.

Age		**Rock Name**	**Lithology**
Quaternary			Sand, Clay and Gravel
Cenozoic	Tertiary	Krabi Formation	Mudstone, Siltstone, Sandstone, Marl, Lignite and Gypsum
Mesozoic	Cretaceous	Phunphin Formation	Arkosic Sandstone
	Jurassic	Lam Thap Formation	Arkosic Sandstone and Siltstone
	Triassic	Saibon Formation	Sandstone, Siltstone, Limestone and Conglomerate
Permian		Ratburi Group	Limestone, Dolomitic Limestone and Chert
Carboniferous		Huai Prick Formation	Sandstone, Mudstone, Slate, Quartzite, Schist and Phyllitic Shale
Devonian			
Silurian			
Ordovician		Thung Song	Sandstone, Limestone, Shale, and Quartzite

Ordovician rocks alternatively called of Thung Song Formation. It is found in a very small area close to the granite body in the north-west of Surat Thani and south-east of study area. Thus rocks were partly metamorphosed by the granitic intrusion. The rocks are also strongly folded and faulted. These rocks are closely associated with and lie unconformably above the Pre-Cambrian high-grade metamorphic rocks in Shan-Thai Terrane. The Thung Song Formation is a thick sequence of tropical limestone dolomites and calcareous shale (Geological Survey Division, 2002).

Silurian-Devonian-Carboniferous rocks alternatively called of Huai Phrick Formation. It is found in a small area nearby the granite body in the southeastern part of the study area. Thus rocks were partly metamorphosed by the granitic intrusion. The formation is composed of sandstone, mudstone, slate, quartzite, schist and phyllitic shale. Limestone lenses can be found in this formation. The rocks have thin to thick beds of light brown to greening gray color. Some tentaculite, criniod and gastropod fossils have been found which indicate an age ranging from Devonian to Permo – Carboniferous (Chaimanee, 2001).

Permian rocks also know as Ratburi limestone or Ratburi Group. The Permian rocks occur as isolated hills in the southwestern and eastern part of the study area. The rocks are composed of limestone and dolomitic limestone. They are gray to dark gray in color and usually appear in thick to massive beds. In some areas, especially near faults, the limestone was transformed to dolomite. The rocks are intercalated with dark gray shale.

Triassic rocks also named Saibon Formation. It has been found in a cluster of hills in the south of Amphoe Phunphin. The rocks contain sandstone, siltstone, limestone lenses and conglomerate. The sandstone is maroon to brownish-red in color and medium to coarse grained. The rocks generally appear in thick to massive beds with cross bedding in some parts. The siltstone is yellowish-brown in color. It is thinly bedded and contains carbonaceous layers. The light gray limestone lenses have a thickness of around 3 to 5 m. Bivalves and foraminifers have been found in this rock. The conglomerate contains pebbles of limestone in a matrix of red sand.

Jurassic rocks also named Lam Thap Formation (Trang Group; Therarungsikul, 1999). The rocks occur in a large area between Chaiya and Tha Chang district as isolated hills in the southeastern part of the study area. They contain arkosic sandstone and siltstone. The sandstone is fine to coarse grained and thick-bedded showing small-scale trough cross-bedding. The rock is alternated conglomerate and quartzitic sandstone and is light gray to light brown in color.

Jurassic-Cretaceous rocks also named Phunphin Formation (Trang Group). The rocks comprise mainly arkosic sandstone. They were found in a small area near Amphoe Phunphin. The arkosic sandstone is red to purple in color, fine to medium grained containing mica. The rocks are poorly cemented and their beds are 0.5 to 2 m thick. They are intercalated with thinly bedded shale, which is purple in color. Cross-bedding, which was formed in troughs, has been observed in this rock unit.

Tertiary rocks also known as Krabi Group has been identified in an undulating area in the western part of the study area. They are generally composed of semi-consolidated mudstone, siltstone, sandstone, marlstone and fossiliferous and argillaceous limestone. Lignite and gypsum are often found. The lignite is usually interbedded with clay, called ‘lignitic zone’. The lignitic zone varies greatly in thickness from 6.2 to 43.3 m. The lignite within the zone generally consists of multiple seams. Each seam has a thickness ranging from 0.15 to 4.20 m (Knuden, 1987).

Quaternary sediments consist of terrace sequence (Qt) and alluvial floodplain sequence (Qa). They cover large areas especially along the main rivers. The terrace sequence (Qt) consists of clayey sand and gravel layers, friable to loose and white in color with abundant mottles and concretions. The sand layers consist of very coarse-grained sand, which is poorly sorted. The sequence occurs in middle and northeastern part of study area. The alluvial floodplain sequence (Qa) consists of silty clay layers, which are alternated by sand layers. The clay is stiff to friable and poorly sorted. The sequence is white to light gray in color with abundant mottles. It is found in along the main rivers and the shoreline.

Igneous rocks are found in a large area, in the southeastern part of the study area, and in the northern part of study area. The granite consists of porphyritic muscovite-biotite granite, which is medium to coarse–grained, light gray to pinkish brown in color and of equigranular texture. The rocks comprise essential minerals, potassium feldspar, plagioclase, quartz and biotite-muscovite.

In addition, rhyolite is in the Phrasang Distict southwestern part of study area (Dill et al., 2003). Figure 1.6 showed distribution of granites in Thailand. Among them, granites are the most common constituents whereas, intrusive rocks of intermediate, mafic, ultramafic composition and volcanic rocks are subordinate. Granites in Thailand are lineated in three major belts, from east to west, the Eastern Belt Granites (EBG), The Central Belt Granites (CBG) and the Western Belt Granites (WBG). The EBG show strong correlation with the I-Type granites or Magnetite Series whereas, the CBG show S-type or ilmenite Series affinities, Majorty of the WBG are S-Type with minor amounts of the I-Type or ilmenite Series granites. Emplacement ages of these granites, in a broad sense, appear to decrease westward from Lower Triassic in the east to Late Cretaceous in the west (Putthapiban, 2002). The area of study was bounded the central belt in the southeast and western belt in the northwestern.

According to the geology of Ban Tha Sathon hot spring (SR7) and Ban Khao Phlu hot spring (SR8), the lowest Formation is Sai Bon Formation of Triassic age. It is overlain by Lam Thap Formation of Jurassic age, and Phun Phin Formation of Jurassic-Cretaceous age, respectively. The upper sequences are terrace deposits (Chaturongkawanich, 2001).

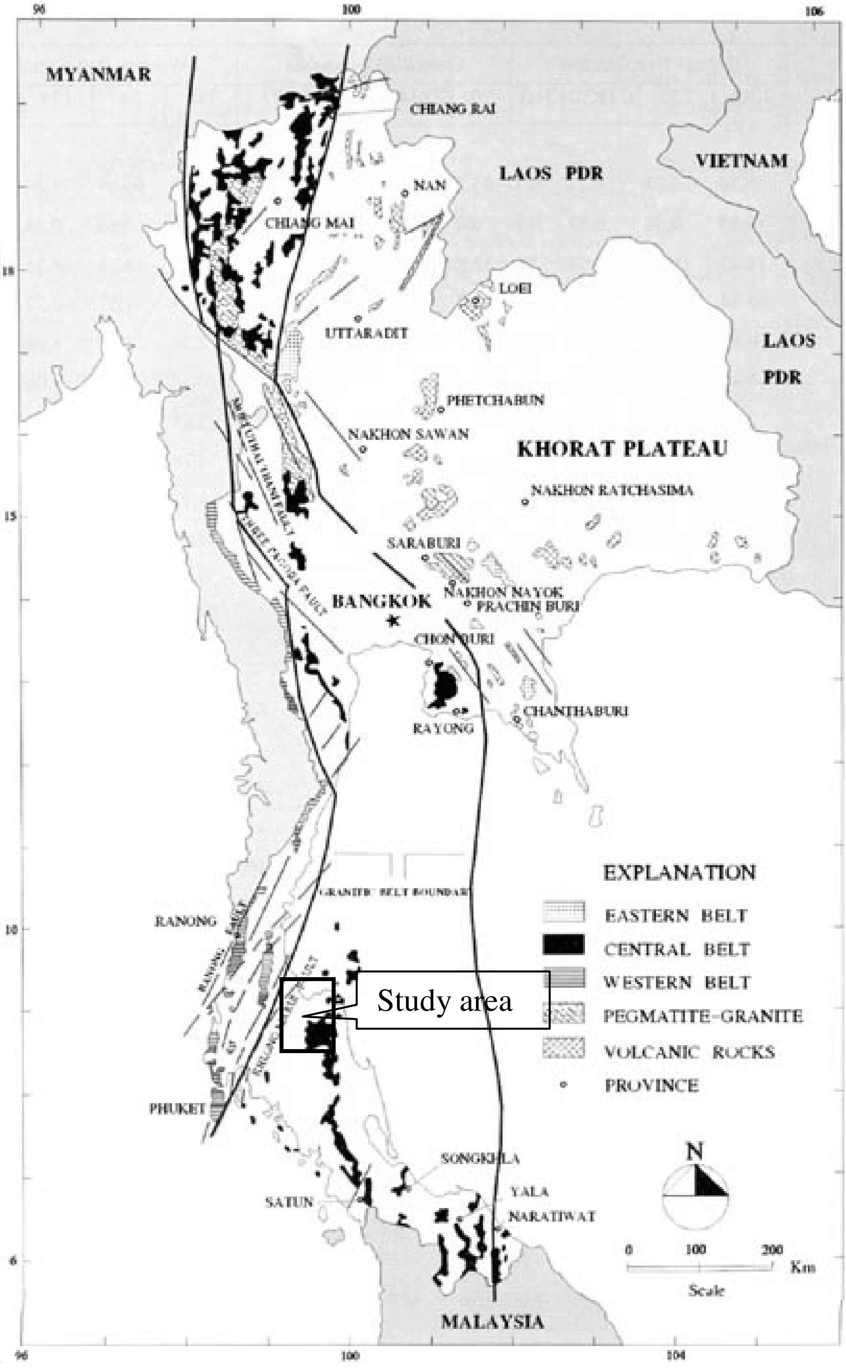
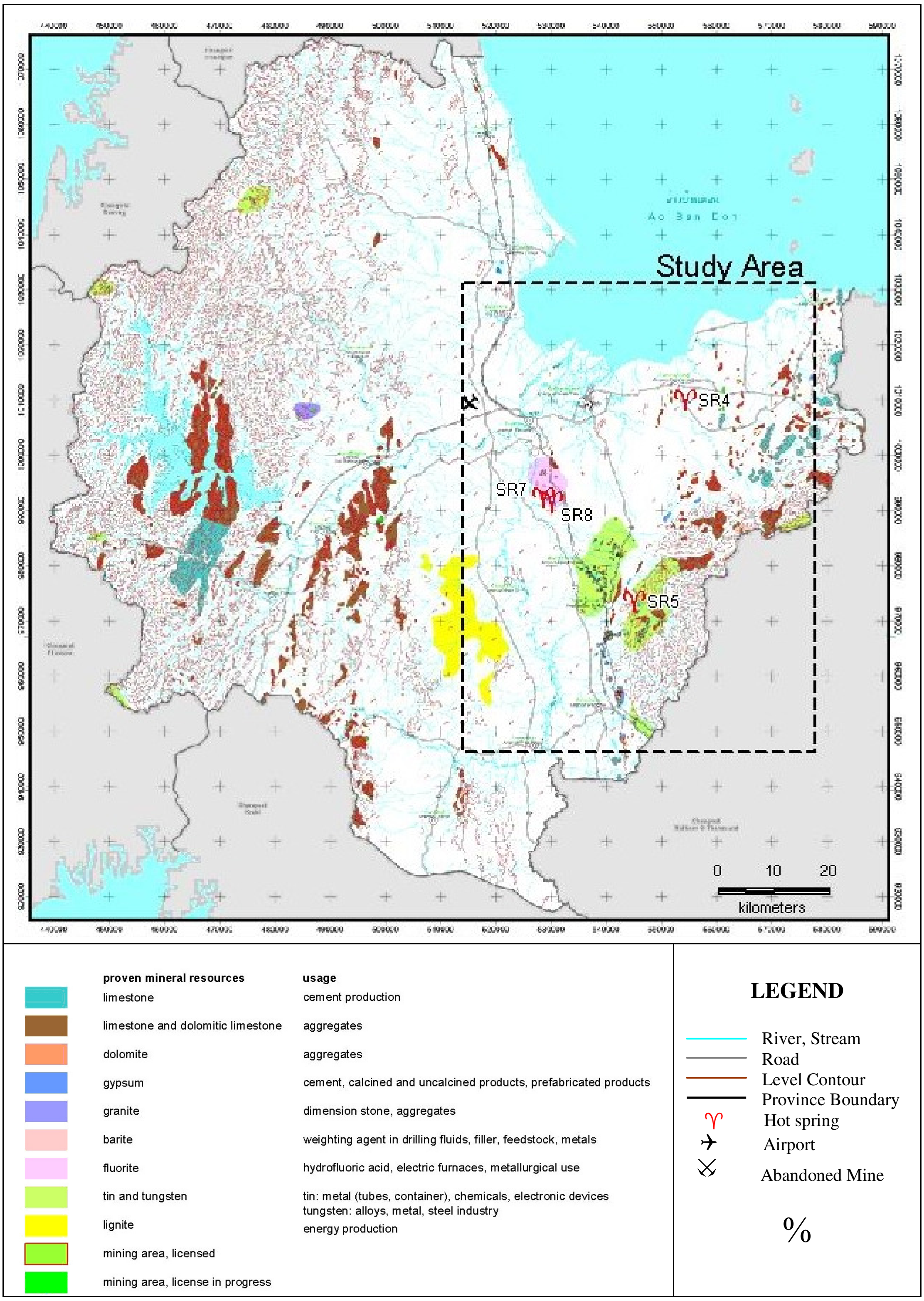


Figure 1.6 Distribution patterns of granites in Thailand (Putthapiban, 2002). The dash line denoted the fault zones.



	proven mineral resources	usage
🟦	limestone	cement production
🟫	limestone and dolomitic limestone	aggregates
🟧	dolomite	aggregates
🟦	gypsum	cement, calcined and uncalcined products, prefabricated products
🟪	granite	dimension stone, aggregates
▢	barite	weighting agent in drilling fluids, filler, feedstock, metals
▢	fluorite	hydrofluoric acid, electric furnaces, metallurgical use
🟩	tin and tungsten	tin: metal (tubes, container), chemicals, electronic devices tungsten: alloys, metal, steel industry
🟨	lignite	energy production
🟩	mining area, licensed	
🟩	mining area, license in progress	

Figure 1.7 Mineral resources map of Surat Thani Province. Available from: <http://www.dmr.go.th> [Accessed 5 September 2007].

1.1.4 Mineral resources

The most economic mineral in Surat Thani Province is limestone and dolomitic limestone. It appears on the surface in the western, southwestern, and eastern of study area and the small area close to SR7 and SR8 hot-springs. In vicinity of the SR7 and SR8 hot-springs, there are fluorite, the tin and tungsten deposits. Lignite deposits were found in the southwestern of SR7 and SR8 hot spring. In addition, on western margins of the granite mountain, there are gypsum mines.

1.1.5 Geologic structures

Tectonic movements, during Middle Triassic, when Shan-Thai Continent collided with the Indochina Continent, affected the study area, like in other areas of Thailand (Bunopas, 1981). This event created a structurally complex area, the Thai-Malay mobile belt extending from northern Thailand through the Gulf of Thailand (Figure 1.8). Due to this event, fold belts with N-S trending synclines were formed. The Triassic granite was also generated at this time. After the Shan-Thai-Indochina collision, the southern part of Thailand seems to have been stable until the Cenozoic era when the Indian continent collided with the Eurasian continent. Most tectonic features in this area result from this event, including NW-SE and NNE-SSW trending strike slip faults. The geometrical relationships of strike-slip and extensional faults together with the evidence of clockwise rotation of crustal blocks and recent earthquake analyses can be related to the strain ellipsoid of dextral simple shear (see Figure 1.9) (Polachan and Sattayarak, 1989). The major fault zone, the Khlong Marui fault zone (Figure 1.10), located in the western part of the study area, also occurred from this event. Also in connection with this collision, basins (mainly N-S trending half-grabens or grabens) were opened as pull-apart structures during the Tertiary (Polachan and Sattayarak, 1989; Talong et al., 2001).

Late Cenozoic basalts are widespread in Southeast Asia, in particular in southern and central Vietnam, southern Laos and Kampuchea, but they also occur locally in Thailand along the north, southern and western margins of the Khorat Plateau and Chantaburi area. Their presence is an indication of intraplate mantle melting at depth which is probably still active (Hoke and Cambell, 1995).

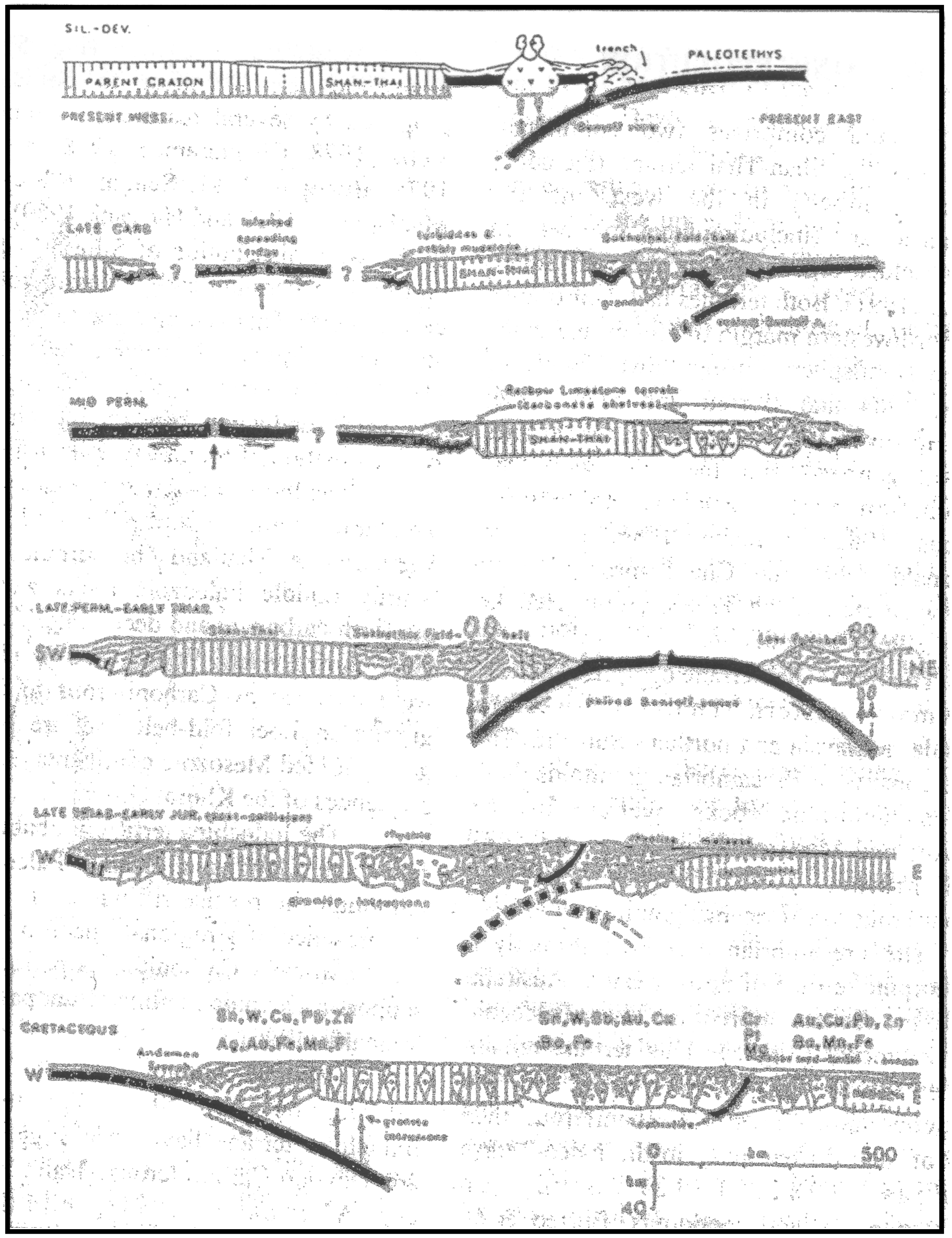


Figure 1.8 Plate tectonic history of Thailand, showing Shan-Thai (west) and Indochina (east) (Bunopas, 1981)

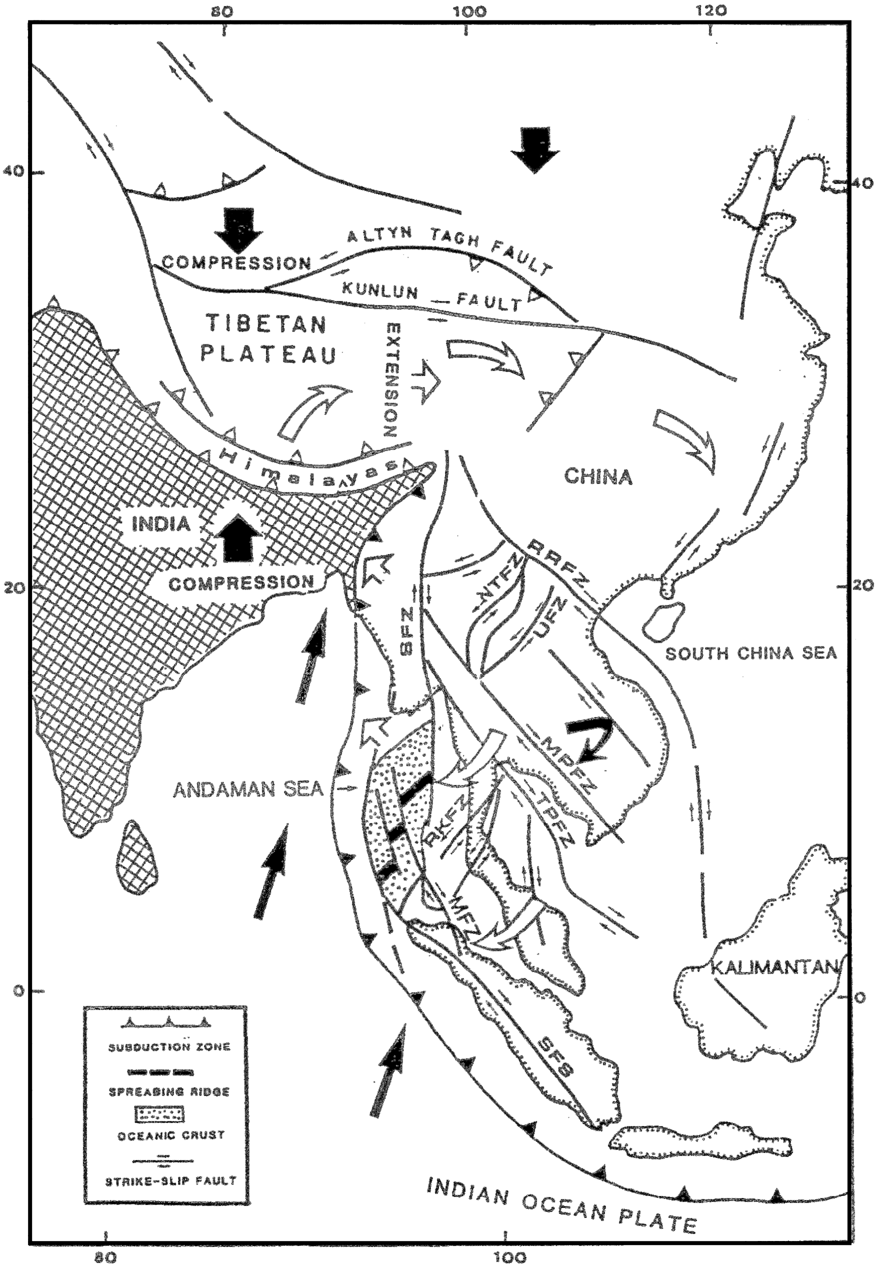


Figure 1.9 The tectonic maps of S.E Asia and South Chaina showing main fault patterns and relative movement of crustal blocks in response to the collision of India with Asia. SFS (Sumatran Fault System); MFZ (Mergui Fault Zone); SFZ (Sagaing Fault Zone); RKFZ (Ranong and Klong Marui Fault Zone); TPFZ (Tree Pagodas Fault Zone); MPFZ (Mae Ping Fault Zone); UFZ (Uttaradit Fault Zone); NTFZ (Northern Thailand Fault Zone) and RRFZ (Red River Fault Zone) (Polachan and Sattayarak, 1989).

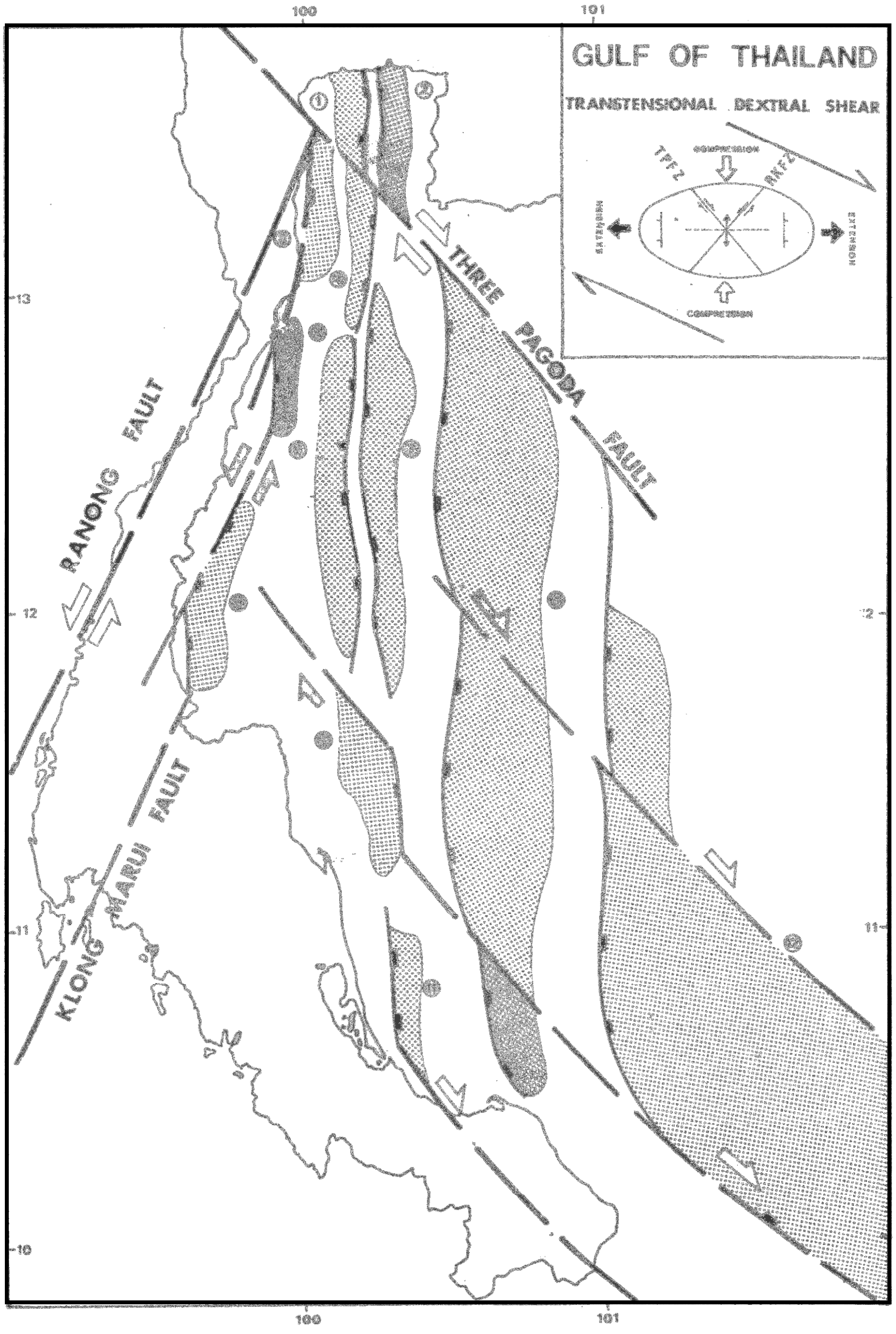


Figure 1.10 Structural map of Gulf of Thailand, showing relationship between conjugate strike-slip faults and the development of N-S trending pull apart basins. 1. Sakhon; 2. Paknam; 3. Hua Hin; 4. N.Western; 5. Prachuap; 6. Western; 7. Kra; 8. Pattani; 9.Chumpon; 10. Nakhon; 11 Songkla and 12. Malay (Polachan and Sattayarak, 1989).

The tectonic fault zones are marked by a number of hot springs. The hot spring areas, SR7 and SR8, are controlled by faults or fractures (Chaturongkawanich, 2001). In addition, the study of Raksaskulwong and Thienprasert (1995) found that zones of high heat flow, greater than 100 mW/m^2, coincide with N-S and NNW-SSE trending basins in the Gulf of Thailand.

The course of the Tapee river and partly also the Phum Duang river seem to be influenced by vertical tectonic movements. This becomes obvious especially in the southern part, where Triassic rocks are found next to Tertiary rocks, overlain further to the west by Quaternary sediments. According to oil well Khian Sa-1, drilled by Gopher Oil in 1988, the thickness of the Quaternary and Tertiary sequence is reported to be around 1,420 m so that the central part of Surat Thani basin seems to be considerably down-faulted. Unfortunately there are no interpreted seismic data from the area, which could yield a more detailed picture about the deeper structure of this basin, show in Figure 1.11 (Talong et al., 2001).

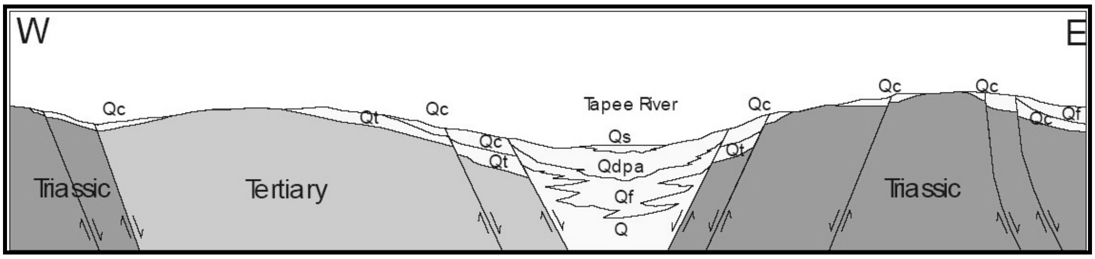


Figure 1.11 Schematic geological cross section though the southern part of the study area (taken from Talong, et al., 2001).

1.1.6 Geothermal resources

The geothermal were come from two words, geo means earth and thermal means heat, totally its mean the heat derived from of the earth’s core.

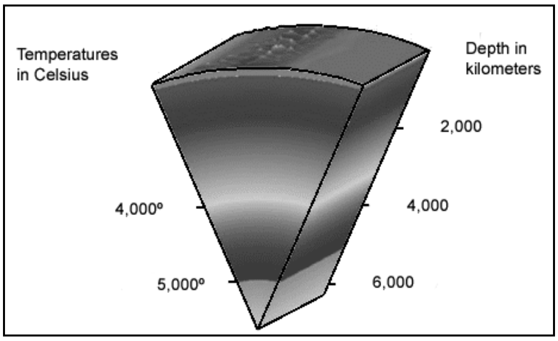


Figure 1.12 Temperatures in the Earth. Available from: <http://www.ist.cmu.ac.th /riseat/teenet/sci/documents.php> [Accessed 12 July 2007].

For geothermal resources, understanding geothermal energy begins with an understanding of the source of this energy-the earth's internal heat. The Earth's temperature increases with depth, with the temperature at the center reaching more than 4200 °C or 7600 °F as shown in Figure 1.12. A portion of this heat is a relic of the planet's formation about 4.5 billion years ago, and a portion is generated by the continuing decay of radioactive isotopes. Heat naturally moves from hotter to cooler regions, so Earth's heat flows from its interior toward the surface. The cause of geologic processes known as plate tectonics, the Earth's crust has been broken into 15 huge plates that move apart or push together at a rate of millimeters per year (Figure 1.13). Where two plates collide, one plate can thrust below the other, producing extraordinary phenomena such as ocean trenches or strong earthquakes. At great depth, just above the down going plate, temperatures become high enough to melt rock, forming magma (Figure 1.14). And because magma is less dense than surrounding rocks, it moves up toward the earth's crust and carries heat from below. Sometimes magma rises to the surface through thin or fractured crust as lava (Figure 1.14). However, most magma remains below earth's crust and heats the surrounding rocks and subterranean water. Some of this water comes all the way up to the surface through faults and cracks in the earth as hot springs or geysers. When this rising hot water and steam is trapped in permeable rocks under a layer of impermeable rocks (Figure 1.15), it is called a geothermal reservoir (Shibaki, 2003).

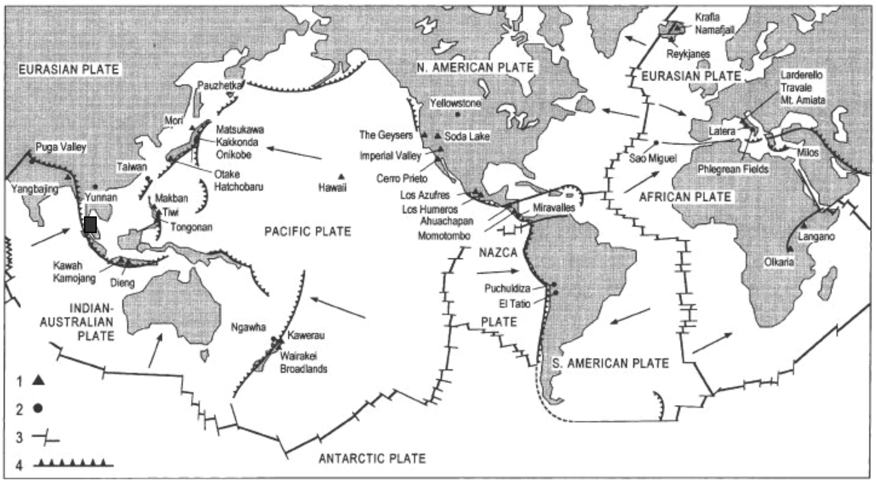


Figure 1.13 World pattern of plates, oceanic ridges, oceanic trenches, subduction zones, and geothermal fields that currently generate electricity. Arrows show the direction of movement of the plates towards the subduction zones. 1) Geothermal fields under exploitation; 2) Fields not yet exploited; 3) Mid-oceanic ridges crossed by transform faults (long transversal fractures); 4) Subduction zones, where the subducting plate bends downwards and melts in the asthenosphere (Barbier, 2002). The rectangular denoted the study area.

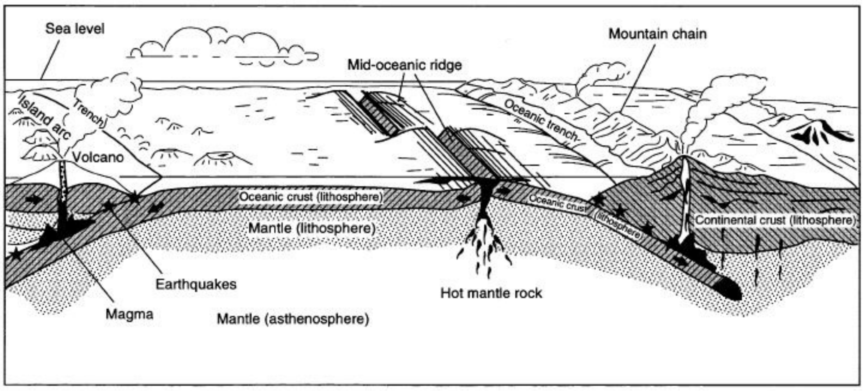


Figure 1.14 The basic concept of plate tectonics. Plates of rigid lithosphere (which include the oceanic or the continental crust, and the uppermost mantle), 70-125 km thick, overlie a layer of relatively low strength called asthenosphere. Mantle material rises between diverging plate boundaries (oceanic ridges), and plate material descends into the mantle at converging plate boundaries (oceanic trenches) (Barbier, 2002).

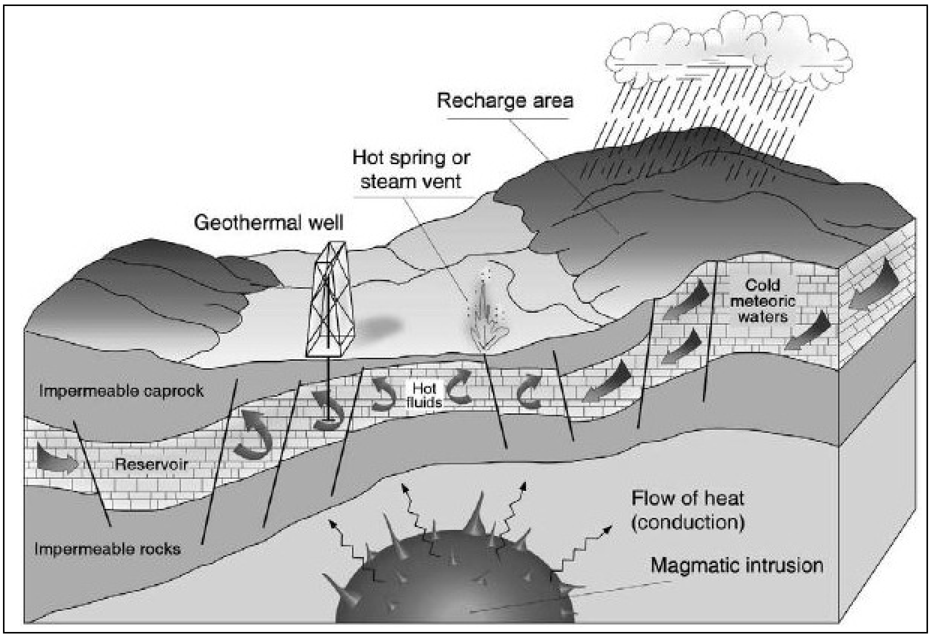


Figure 1.15 A geothermal steam field with its elements: recharge area, impermeable cover, reservoir, and heat source (Barbier, 2002).

1.1.7 Hot springs in Thailand

There are more than 90 hot springs in Thailand with surface temperatures ranging from 40° to 100°C (Raksaskulwong and Thienprasert, 1991) as shown in figure 1.16. At least five hot spring in northern Thailand considered have been as high energy potential for possible electric generation (Ramingwong et al., 1980).

Raksaskulwong and Thienprasert (1995) suggested that hot springs in Thailand may be associated with granitic rocks which are heated by the decay of the anomalously high content of radioactive elements in them or at the active fault zones which accumulate heat due to leakage and circulation of heat from deeper and hotter zones. Charusiri (2003) consider that the most probable heat source of Chantaburi hot-springs is near-surface active rift-related magmatism, which could give rise to the existence of basalts in the past and may be responsible for the hot–spring development by an active intraplate mantle melting though the major fault.

According to geothermal waters of Thailand that were of non-volcanic origin, characterized by high sodium, high bicarbonate, and low concentrations of dissolved chemical species (Takashima and Kawada, 1981).

According to the geology and geochemical study of eight hot springs (Appendix E) in Surat Thani (Chaturongkawanich, 2001), the hot springs are controlled by faults or fractures. They are NW-SE, NE-SW, almost N-S, and almost E-W trending and associated with dolomitic limestone or clastic sedimentary rocks of sandstone and shale. Heat source of these thermal systems may be high heat flow from high heat capacity granite or radiogenetic heat from granitic rocks. In addition, the study of Raksaskulwong and Thienprasert (1995) found that zones of high heat flow, greater than 100 mW/m^2, coincide with N-S and NNW-SSE trending basins in the Gulf of Thailand.

1.1.8 Previous geophysical studies in determination of the geological structure of geothermal areas

A gravity survey was conducted in order to determine the structure and boundary of Chaiya geothermal area in Chaiya and Tha Chang Districts of Surat Thani Province. A positive gravity anomaly of about 130 g.u. was observed over the hot springs area (Khawtawan, 2004). The gravity survey was employed to delineate the boundary of reservoir where high porosity and low density rocks gravity anomaly in the Ban Phong Gum hot-spring in Doi Saket District, Chiang Mai Province (Thienprasert, 1981). The interpretations of a gravity low centered in the area between Clear Lake and The Geysers by Stanley and Blakely, 1994 suggested that a large magma chamber existed at depths starting at about 7 km. In addition Corinne et al. (1999) observed a complex negative residual anomaly of about -50 g.u. which in a region of greywacke basement of Puhipuhi geothermal area in New Zealand.

In addition, the negative Bouguer anomalies (140 to -60 g.u.) was observed over granitic areas in Songkhla, Phattalung and Trang Province (Phethuayluk, 1997) and about -100 g.u. of granitic observed in Satun Province (Kaew-on, 1997).

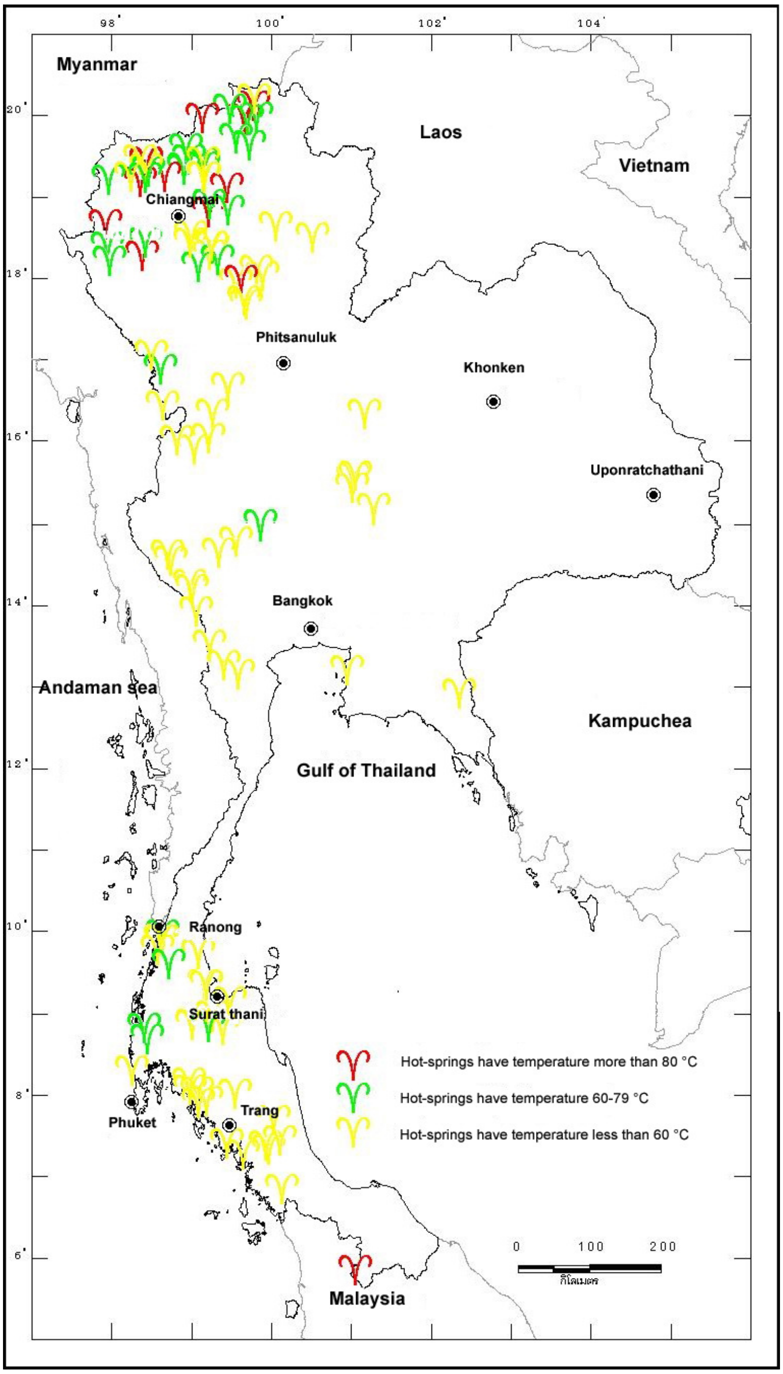


Figure 1.16 Hot springs in Thailand. Available from: <http://www.dmr.go.th /HOTSPRING> /LOCATION, [Accessed 11 October 2005].

A region of low apparent resistivity, less than 120 ohm-m, in Ban Phong Gum hot-spring spring, Doi Saket District, Chiang Mai Province suggested was increasing temperature and conduction of liquid in porosity fault or fracture (Tongchit and Tammavittawat, 1983). In addition, observed low resistivity in the middle of hot-spring basin of Ban Ngong Krong and Ban Phong geothermal area in Doi Saket District and Ban Mae Jok geothermal area in Wang Chin District Phrae Province related to fault or fractures (Chaturat, 1985). Moreover, Schlumberger vertical electrical sounding was conducted in Göynük geothermal area, northwest Anatolia, Turkey, to determine its geological structures (Çağlar and İşseven, 2004). Vertical electrical sounding conducted in low–temperature geothermal field of Hisar, western Turkey along the valley in an E-W direction suggests that the is characterized by low-resistivity values, which positive related to hot-fluid carrying fault/fracture zone that forms one of the boundaries of the valley (Özürlan and Şahin, 2005).

Airborne magnetic data of Sankamphaeng and Surat Thani were studied by Wisedsind (1997). He observed magnetic anomaly on active faults in vicinity of Sankampaeng hot spring, whereas in Surat Thani the observed magnetic anomaly is not directly on hot springs but may be related to heat sources of the hot spring.

The new $^{40}Ar/^{39}Ar$ dating information reveals that the average age of basalts in Ban Pong Nam Ron District, Chantaburi Province is about 1 Ma and the airborne magnetic results, together with previous studies, indicate the close genetic relationship of hot-springs and basalt (Charusiri, 2003). A negative magnetic anomaly (about -100 nT) over the Waimangu field, New Zealand was interpreted as near-surface hydrothermal demagnetization of rhyolitic host rocks (Soengkono, 2000).

1.2 Objective

The objective of this study is to utilize contrasts in physical properties in delineating subsurface geological structures of the study area, which might be related to possible sources and pathways of the geothermal waters. The main geophysical methods used in this study were gravity method for deeper subsurface and vertical electrical sounding method for shallower subsurface.