CHAPTER 1

INTRODUCTION

1.1 Introduction

Mapping the physical properties of the subsurface is very important in developing hydrocarbon reservoirs. These properties, P-wave velocity, density, porosity, and permeability, can be measured directly at well locations using well logging tools or core samples. However, the geological model developed by three-dimensional interpolation of those measurements often can not meet the need of the development planner. This because of a small number of wells or poor well locations or geologic complexities.

Three-dimensional seismic surveys provide more complete coverage of a target area. Seismic data are the complex response of such things as lithology, fluids, bed stacking pattern, and bed thickness. As such, seismic data are incredibly rich in amplitude, frequency, phase, geometry, and texture information. The purpose of seismic interpretation is to find stratigraphic units that have favorable reservoir properties. The only guide to what favorable reservoir properties are in seismic data is the well dataset. The link between these two sets of data is seismic attribute analysis.

A seismic attribute is a quantitative measure of a seismic characteristic. Seismic attributes are routinely used for predicting the qualitative or quantitative distribution of rock properties. Seismic attribute analysis of three-dimensional data can greatly increase the understanding of a reservoir model, including spatial distribution of important petrophysical and geological parameters, such as porosity. Well logs provide porosity information only at one location, and conventional seismic interpretation does not infer any information concerning porosity distribution away from the well location. Seismic attribute analysis provides a solution whereby seismic data are used as a guide to a more thorough interpolation between, and extrapolation beyond, well locations. The advantage of seismic attribute analysis is that attributes can highlight properties that are not visible to the interpreter using only seismic data.

Most gas and oil produced in Thailand comes from offshore Tertiary basins in the Gulf of Thailand. The Pattani basin is one of these basins and is a prolific gas and oil basin. Reservoirs in this basin are non-marine, mainly fluvio-lacustrine Oligocene and Miocene sandstone. Most of the gas fields are distributed in the central part of the Pattani basin, whereas oil fields are along the shallower basin margin. Knowledge of the porosity distribution of potential reservoir rocks in the Pattani basin is important for precisely locating development wells.

1.2 Objectives and scope

The main objective of this study was to predict and map the porosity distribution of some selected formations within the study area using seismic attribute analysis and interpretation. One cube of three-dimensional post-stack migrated seismic data volume and geophysical logs from seven wells were used in this study. The result of this study should help reduce the risk of drilling wells into sandstone beds that have low porosity.

1.3 Location and data set of the study area

The study area is located in the Pattani basin in the Gulf of Thailand. Data sets were provided by Unocal Thailand Limited. These sets consist of a three-dimensional post-stack seismic volume and geophysical logs from seven wells (Figure 1.1). The three-dimensional seismic volume, which covers 47 square kilometers, consists of 216 inlines oriented east-west and 471 crosslines oriented north-south. The northeast corner of the survey area is at inline 136 and crossline 1189 and the southwest corner is at inline 351 and crossline 719. The seismic data were recorded up to 5 seconds and processed with a 4-millisecond sample rate. For the purposes of the extracting seismic attributes, it is very critical to ensure that the amplitude spectra are preserved at each stage of the data processing. Unfortunately, the pre-stack data were not available and it was assumed that minor distortion of amplitude spectra took place during processing of field data.

The seven wells in the study area are deviated wells, all drilled from the same platform. Sonic, gamma ray, neutron, density, and resistivity logs were run in each well.

1.4 Software used

Hampson-Russell eLOG®, GEOVIEW®, STRATA®, and EMERGE® software programs were used. The eLOG® program was used to help manually correlate the well logs to the seismic data. The GEOVIEW® program was used to input the well logs. The STRATA® program (Figure 1.2) was used to generate an acoustic impedance volume, which was later used in the EMERGE® program as an external attribute. This EMERGE® program (Figure 1.3) was used to integrate well log and seismic data in order to estimate porosity by using multi-attribute analysis.

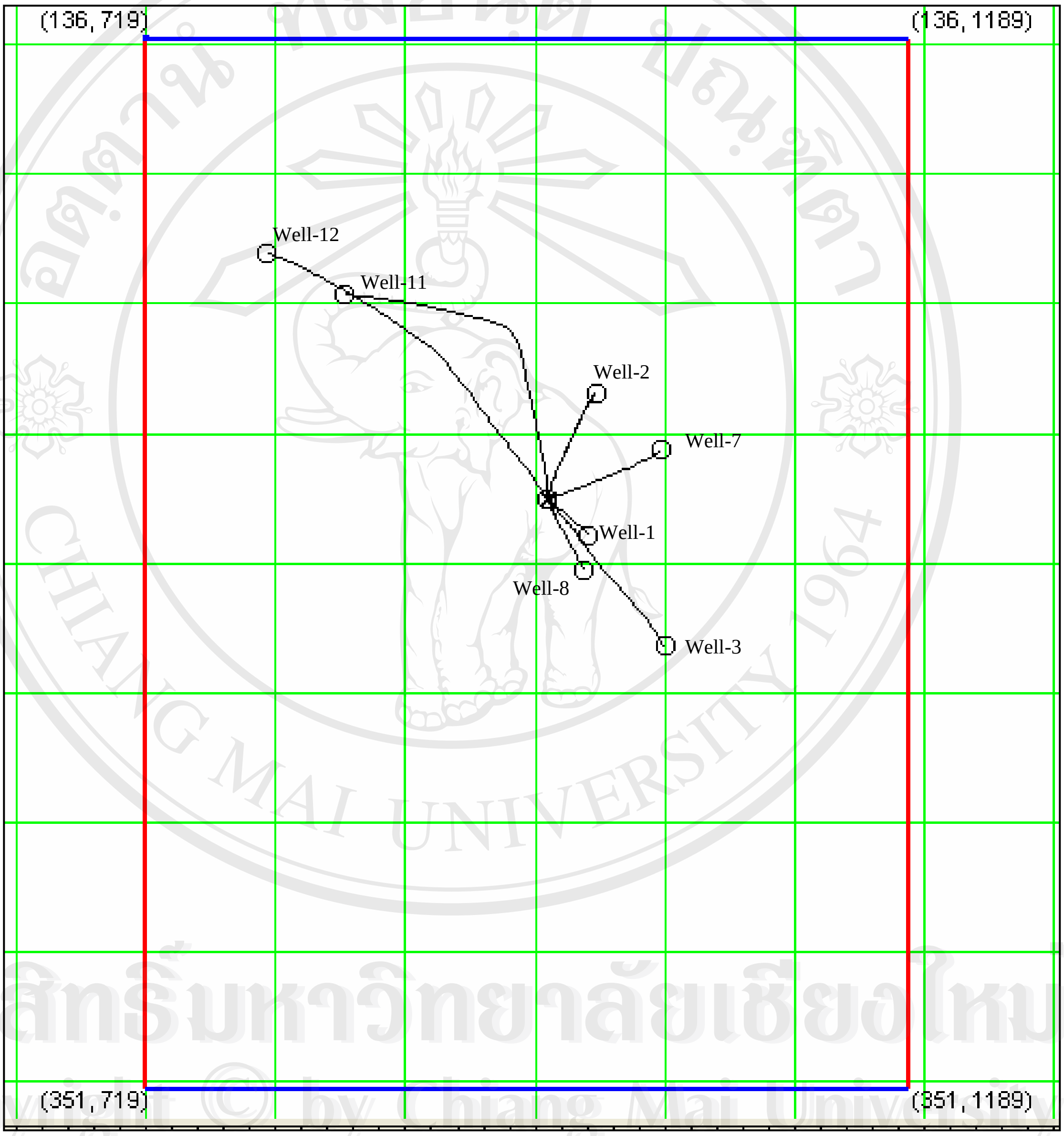

Figure 1.1: Base map showing the location of the three-dimensional seismic data set, east-west inlines 136 to 351 and north-south crosslines 719 to 1189, and deviated well locations.

Figure 1.2: The STRATA® software version and other program information.

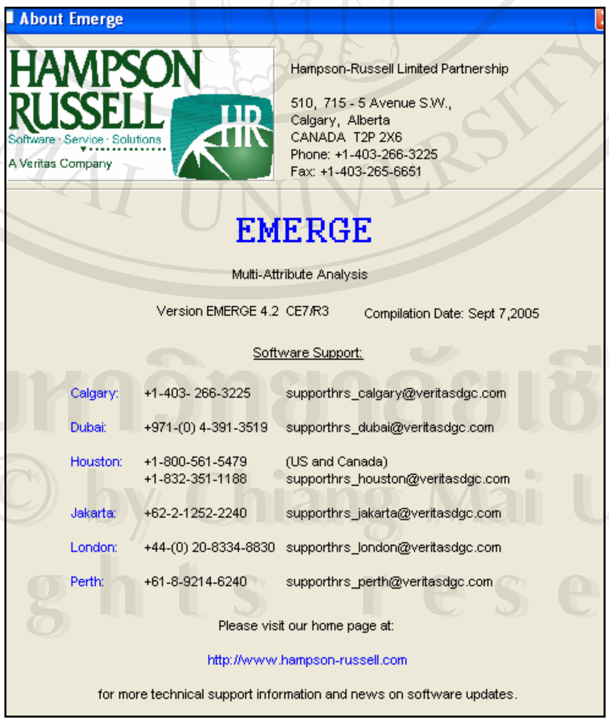

Figure 1.3: The EMERGE® software versions and other program information.

1.5 Literature Review

1.5.1 Geology of the northern part of the Gulf of Thailand

Several Tertiary basins are situated (Figure 1.4) in the northern part of the Gulf of Thailand. From north to south, these are the Sakhon, Pak Nam, Hua Hin, North Prachuap basins and the north-eastern part of the Pattani and Chumphon basins. Prадidtan and Dook (1992) summarized the stratigraphy, structure, and petroleum geology of the northern part of the Gulf of Thailand. According to them, the Tertiary basins in the area are intracratonic rift basins. The initiation of extensional rifting in the Gulf of Thailand was probably related to the Eocene collision of India with the Asian mainland, the subsequent extrusion, the rotation of Indochina, and the movement of strike-slip faults since the Oligocene. Therefore, these rift initiated basins were formed prior to Oligocene time.

A strike-slip tectonic model of Tertiary basins in Thailand was proposed by Polachan and Sattayarak (1989). Since Oligocene time, Tertiary basins in Thailand have developed mainly as north-south trending half-grabens or grabens (Figure 1.5). The Tertiary basin development in this region was attributed to the northwards progressive collision of the Indian craton with southern Asia. Penetration of India into Asia caused clockwise rotation of Southeast Asia, resulting in increasingly oblique subduction of the Indian Ocean plate beneath the western edge of Southeast Asia. This led to movement on strike-slip faults, with the associated development of trans-tensional basins in this region. In the northern part of the Gulf of Thailand, these basins are extensional intracratonic rift features, generally controlled by north-south striking extensional faults. The initiation of these faults was probably related to the northwest-southeast dextral shear and the north-south trending pre-Tertiary structural grain. The Tertiary strata of these basins are almost entirely non-marine.

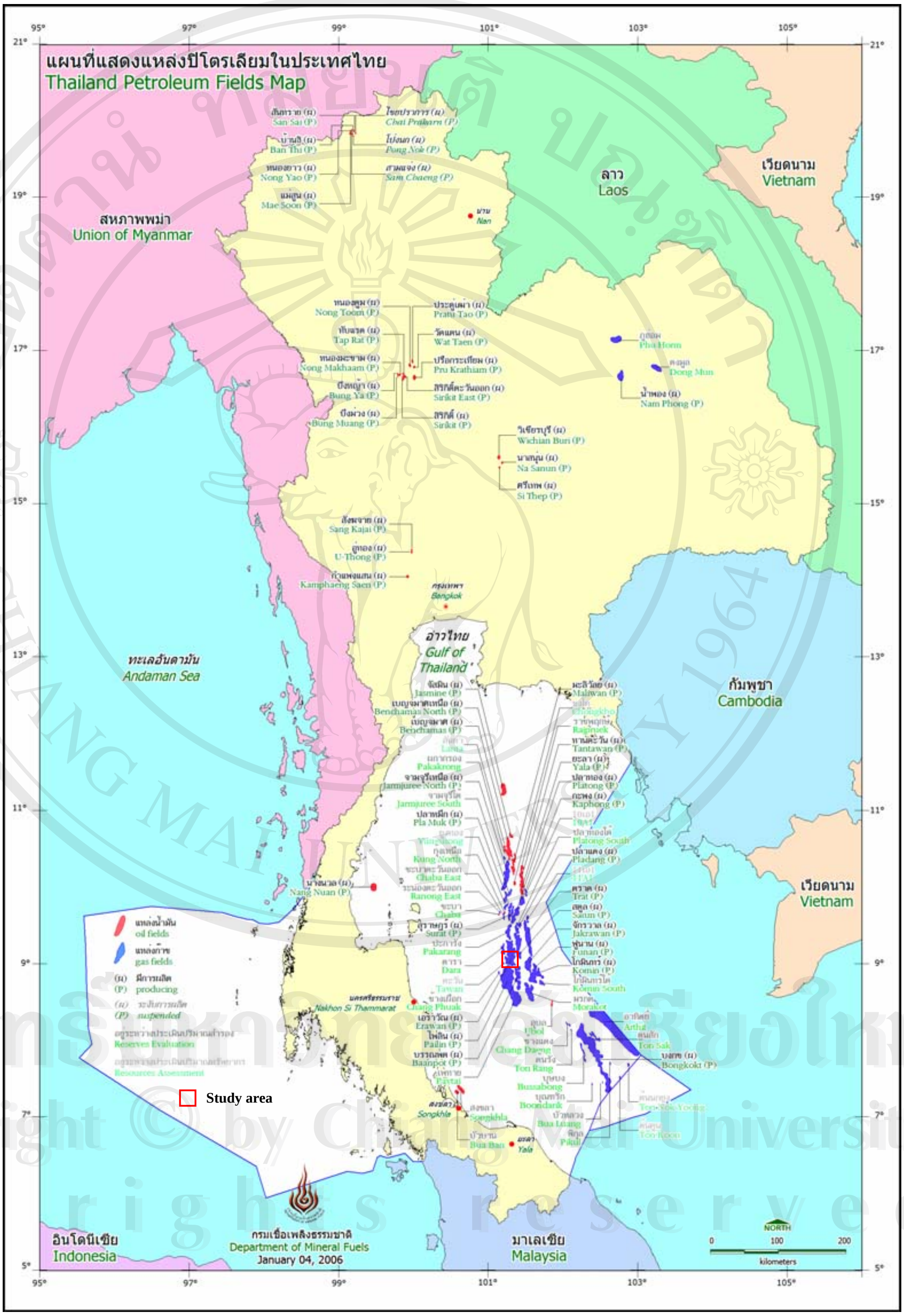

Figure 1.4: Petroleum fields of Thailand (Department of Mineral Fuels, Annual Report 2005).

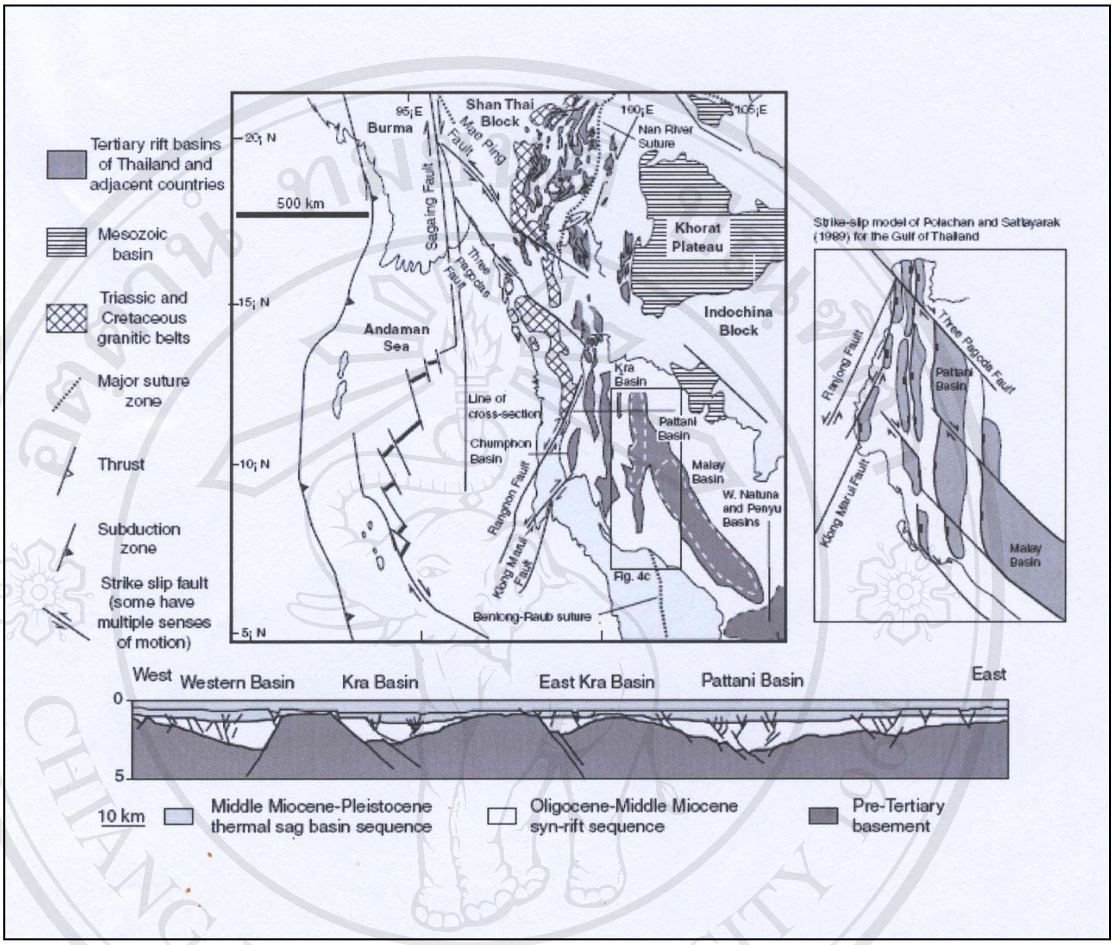

Figure 1.5: Regional tectonic map of western Southeast Asia and Tertiary basins in the Gulf of Thailand, modified from Packham (1996) and Leloup and others (1995). Cross section through the northern Gulf of Thailand from Oudom-Ugsorn and others (1986). Strike-slip model for Tertiary basin formation in the Gulf of Thailand after Polachan and Sattayarak (1989).

The petroleum potential of Thailand's Cenozoic intermontane basins, including the Gulf of Thailand, was analyzed by Chinbunchorn and others (1989). According to them, almost of these basins developed during the Tertiary as non-marine depositional systems. Sedimentary deposits at least 8 kilometers thick are preserved in the deepest part of the Pattani, Malay, and Phitsanulok basins. These sedimentary deposits are mainly a thick lower syn-rift sequence and less thick post-rift upper sequence. Chinbunchorn and others (1989) concluded that the syn-rift sequences of the Phitsanulok, Pattani, and Chumphon basins contain excellent oil and gas potential source rocks and good reservoirs and seals.

Source rocks in the Gulf of Thailand are primarily Oligocene and Miocene strata. The Oligocene source rocks are lacustrine deposits that contain type I kerogen and tend to yield oil rather than gas. The Miocene source rocks are fluvial flood plain and delta plain strata that contain type III kerogen and tend to yield gas (Chinbunchorn and others, 1989).

According to Prapidtan and Dook (1992), Tertiary syn-rift strata and pre-Tertiary carbonate strata are two prime reservoir sequences in the basins of the northern part of the Gulf of Thailand. The sandstone beds are immature and were deposited by small and weak river systems in fluvial and lacustrine deltaic environments. The deltaic sandstone beds are thin but laterally extensive and most contain lithic grains. These sandstone beds have good porosity and are at depths of less than 2500 meters. However, porosity decreases significantly with depth and below 2500 meters this creates a problem with reservoir quality.

1.5.2 Geology of the Pattani basin

The Pattani basin is a Tertiary intracratonal basin in the central part of the Gulf of Thailand (Figure 1.5). The basin is the most prolific hydrocarbon basin in Thailand and has an areal extent of about 10,000 square kilometers. It contains a succession of up to 10 kilometers of coarse- to fine-grained clastic rocks. The basin reflects the extensional tectonic regime of continental Southeast Asia. East-west extension resulting from the northward collision of India with Eurasia since the Early Tertiary resulted in the formation of a series of north-south trending sedimentary basins, including the Pattani basin.

The Pattani basin and other Tertiary basins in Thailand have striking similarities of sedimentation and structural style (Burri, 1989). These basins are characterized by normal faults and horsts and graben structures that probably were initiated by continental rifting and lithospheric stretching (Bunopas and Vella, 1983; Hellinger and Sclater, 1983).

Bustin and Chonchawalit (1995) proposed subdividing the Cenozoic sequence in the Pattani basin into six stratigraphic units (Figure 1.6). According to them, the sedimentary succession in the basin is divisible into syn-rift and post-rift sequences. Deposition of syn-rift sequence accompanied rifting and extension with episodic block faulting and rapid subsidence. The syn-rift sequence has three stratigraphic units. These are an Upper Eocene to Lower Oligocene alluvial fan, braided river, and flood plain sequence, an Upper Oligocene to Lower Miocene flood plain and channel sequence, and a Lower Miocene regressive sequence of marine to non-marine strata. The post-rift phase is characterized by slower subsidence and decreased sediment influx. The post-rift succession includes a Lower to Middle Miocene regressive sequence of shallow marine to flood plain and channel deposits, an upper Lower Miocene transgressive sequence, and an Upper Miocene to Pleistocene transgressive sequence.

	Unit	Subunit	Depositional environment	Sedimentary character	Lithology
POST-RIFT	6	Upper	Shallow marine	Fine-grained	Not available
		Middle	Interdistributary bay and/or crevasse splay	Generally fine-grained	Dark grey claystone
		Lower	Distributary channel in a coastal plain	Fining-upward sequences	Reddish brown claystone and sst
	5	Upper	Brackish swamp and marginal marine	Fine-grained with some fining-upward sequences	Brownish grey claystone and sst
		Lower	Distributary channels and flood plain	Fining-upward sequences and fine-grained	Sandstone and claystone
	4	Upper	Non-marine meandering channel	Fining-upward sequence and fine-grained	Sandstone and some claystone
		Middle	Distributary mouth bar and beach-ridge complex	Coarsening-upward sequences	Sandstone and claystone
		Lower	Pro-delta, shallow marine	Generally fine-grained	Clastone and some sandsone
SYN-RIFT	3	Upper	Upper delta plain and flood plain	Fine-grained with fining-upward sequences	Claystone and sandstone
		Middle	Distributary mouth-bar and beach-ridge complex	Coarsening-upward sequences	White sandstone and some claystone
		Lower	Pro-delta and shallow marine	Generally fine-grained	Brownish claystone
	2	Upper	Non-marine meandering channels	Fining-upward sequences	Brownish sandstone
		Lower	Meandering channel and flood plain	Fine-grained and fining-upward sequences	Red claystone and sandstone
	1	Upper	Flood plain and channel	Fine-grained and fining-upward sequences	Sandstone and grayish brown clst.
		Lower	Alluvial fan and braided stream	Coarse-grained and poorly sorted	Conglomerate and coarse sandstone

Figure 1.6: Stratigraphy and depositional environments of Tertiary syn-rift and post-rift strata in the Pattani basin (modified from Bustin and Chonchawalit, 1995).