UNDISCOVERED HYDROCARBON RESOURCES OF CHONNABOT PROSPECT, NORTHEAST THAILAND

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Received: Jan 14, 2011; Revised: Apr 4, 21, 2011; Accepted: Apr 4, 2011

Abstract

The objective of this research is to assess the undiscovered hydrocarbon resources in the Chonnabot prospect, an important Permian carbonate hydrocarbon source and reservoir rock of northeast Thailand. The study area covers the area of Chonnabot, Waeng Yai, and Waeng Noi districts, Khon Kaen province in the southwestern part of northeastern region of Thailand. The assessment of undiscovered hydrocarbon resources in the Chonnabot prospect was performed by using play analysis, probability theory approach, and FASPU computer program. The resulting mean estimates are 15.02 MMbbl of undiscovered oil and 657.53 Bcf of undiscovered non-associated gas.

Keywords: **Undiscovered hydrocarbon resources, petroleum potential assessment, play analysis, Chonnabot prospect, northeast Thailand**

Introduction

Exploration and production of petroleum in the northeast of Thailand has been going on for more than four decades, and today only two natural gas fields named Nam Phong and Sinphuhorm are on production. The petroleum provinces in the northeast still have a high potential for exploration and development (Atop, 2006; GMT 1999). The reservoir rocks in this vast region are mainly Permian carbonates which contain anticlines resulting from transversing fault lines, creating fractures, and adding porosity to the carbonates. Results from 30 wells confirmed the potentials of petroleum in the northeast and Permian carbonate reservoir rocks became a good candidate for petroleum reservoir.

The Chonnabot prospect is chosen for this assessment since there is some gas found in Connabot-1 well (Esso, 1982) and have Permian carbonates rock like in the Nam Phong and the Sinphuhorm gas fields (Chantong, 2007). This project covers the area of Chonnabot, Waeng Yai, and Waeng Noi districts, Khon Kaen province in the southwestern part of northeastern region of Thailand between latitudes 15°45´ to 16°15´ North and longitudes 102°15´ to 102°45´ East (Figure 1).

Play analysis, probability theory approach, and FASPU computer program are used for estimating undiscovered hydrocarbon at a

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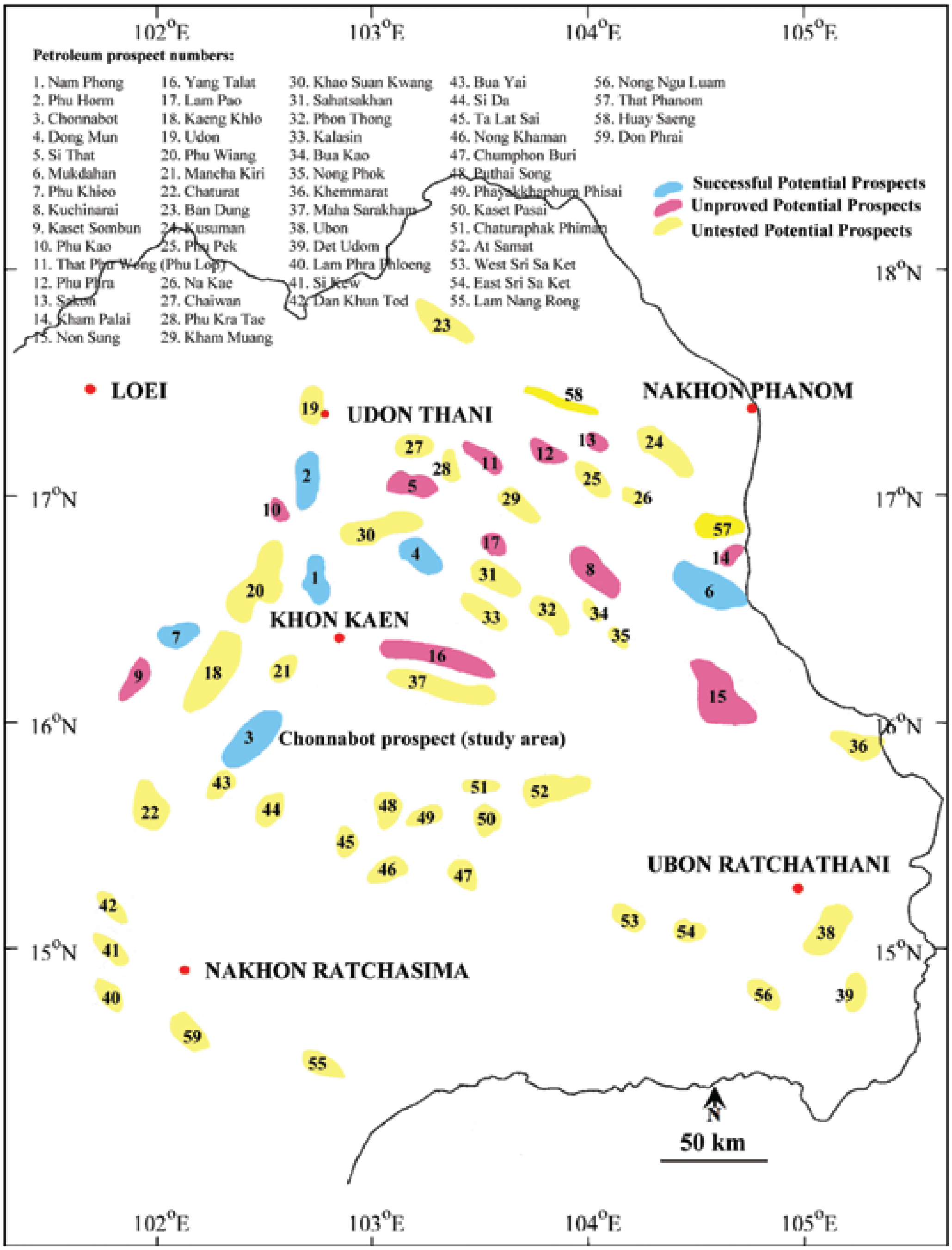

Figure 1. Map of northeastern region of Thailand showing the petroleum prospects (Chantong, 2007)

play scale within this prospect (CCOP, 1990; Charpentier *et al.*, 1994).

Materials and Methods

Materials

Required data for the undiscovered hydrocarbon assessment consist of two major parameters, which are petroleum geology parameters and petroleum engineering parameters. Petroleum geology parameters can be divided into three parts: play attributes, prospect attributes, and hydrocarbon volume attributes. The first play attribute consists of the probability of the existence of hydrocarbon source, timing, migration, and potential reservoir facies. The second prospects attribute consist of probability of favorability for trapping mechanism, effective porosity, and hydrocarbon accumulation. The last, hydrocarbon volume attributes consist of area of closure, reservoir thickness/vertical closure, effective porosity, trap fill, reservoir depth, hydrocarbon saturation, and number of drillable prospects.

Petroleum engineering attributes consist of some essential parameters for the quantity of hydrocarbon calculated by volume metric equation. These parameters are original reservoir pressure (psi), reservoir temperature (^{o}R), gas-oil ratio (Mcf/bbl), oil formation volume factor, gas compressibility factor, oil floor depth, oil recovery factor, and gas recovery factor.

All of required data for this assessment were compiled, reviewed, summarized, and documented from relevant literatures. These data were provided by the Department of Mineral Fuel (DMF), Ministry of Energy.

Methods

The geostochastic system for undiscovered hydrocarbon resources estimation in this study was performed by using Fast Appraisal System for Petroleum Universal (FASPU) computer program. The FASPU program is a prototype package of programs designed to assess the resource potential of undiscovered oil and gas resources using a play analysis method. A resource appraisal system is designed for play analysis using a reservoir engineering geologic model and an analytic probabilistic methodology. The geological model is a particular type of probability model using reservoir engineering equations. The probabilistic methodology is an analytic method derived from probability theory. A detailed discussion of the FASPU program is given by Crovelli and Balay (1994 and 1986).

Play Analysis Approach

Play analysis is a quantitative approach for estimating undiscovered hydrocarbon resource at a play scale. A play is a set of pools or prospects which are conceived as having similar geologic characteristics and sharing common geologic elements. Most of the input parameters used in the model are expressed in a probability form that is either as a probability of occurrence or as a probability distribution. This allows the uncertainty about the input parameters to be expressed quantitatively. Likewise, the resulting resource estimates are expressed as probability distributions in order to show the uncertainty of the estimates.

Play analysis approach can be divided into two groups of parameter. In the first group, estimates are made of the favorability for resource in the play as a whole, as well as in a random prospect in the play. In the second group, estimates are made of the number of prospect and the size of the possible accumulation.

In the first group of parameter, the probability of favorability for resource in the play as a whole (play attribute or marginal play probability) is estimated by judging the probabilities of existence of the subsidiary attributes of hydrocarbon source, timing, migration, and potential reservoir facies. The play can contain resources only if all four of these attributes exist. The play risk, the probability that the play contains no resource, is 1.0 minus the marginal play probability.

Next, the prospect attribute or conditional deposit probability, the probability of occurrence of an accumulation in a random prospect (conditioned on the play attributes being favorable), is estimated by judging the probabilities of existence of the subsidiary attributes of trapping mechanism, effective porosity, and hydrocarbon accumulation. The prospect risk, the probability that a prospect contains no resource (again conditioned on the play attributes being favorable), is 1.0 minus the conditional deposit probability.

In the second group of parameter, estimates are made of the number of prospect and also of various parameters which deal with the size of accumulations. Many of these variables are input as seven fractiles describing a probability distribution. Thus, the uncertainty about number of prospects is expressed by the seven fractiles for number of drillable prospects. The accumulation volumes are analytically calculated from the variables: area of closure (acre), reservoir thickness/ vertical closure (feet), effective porosity (percent), trap fill (percent), reservoir depth (feet), and hydrocarbon saturation (percent). Also used in this calculation are such engineering parameters as original reservoir pressure (psi), reservoir temperature (^{o}R), gas-oil ratio (Mcf/bbl), oil formation volume factor, gas compressibility factor, oil floor depth (feet), oil recovery factor (percent), and gas recovery factor (percent).

The probabilities determined in the first group are used with the distributions of prospect number and accumulation size to estimate resource amounts. These resource appraisal estimates are calculated using an analytic probabilistic methodology. The details of how the calculations are performed can be found in Crovelli and Balay (1994 and 1986).

Results and Discussions

The results of the study of geological, geophysical, geochemical, and petroleum reservoir engineering can define the attribute and the probability for each attribute.

The play attribute determination and analysis are mainly involved with the presence or absence of regional characteristics. The attribute determines whether conditions underlying the play are favorable for occurrence and accumulation of the hydrocarbon in the play level. The probability for each attribute is also shown in Table 1.

Play type of the Chonnabot prospect is defined as carbonate reservoir rock of Permian age (Chantong, 2007) (Figure 2). According to a previous work, the possible source rock is the Pha Nok Khao Formation of the Saraburi Group which has a fair to excellent organic richness, and the thermal maturity of source rocks indicated a late to overmature stage (Thongboonruang, 2008). In this assessment, the probability of the existence of hydrocarbon source is given to 1.00 and the probability of favorable timing for migration of hydrocarbon from source to reservoir is given to 1.00. The probability of the existence of potential migration path is given to 0.90. This is due to the fractured carbonate reservoir. The probability of existence of potential reservoir facies is given to 0.90. This is due to the influence of numerous tectonically induced fractures and microfractures were partly filled with calcite. It is common and accounted for the majority of the porosity and permeability. The dolomitization of limestone also provides the secondary porosity which enhances reservoir quality (Chinoroje and Cole, 1995). Therefore, the marginal play probability for this prospect, the product of the probability of hydrocarbon source, timing, migration and the potential reservoir facies, is equal to 0.81.

The prospect attribute determination and analysis within a play are mainly involved with the presence or absence of local characteristics. The attribute is generally favorable in a randomly selected prospect within the play area. The probability for each attribute is also shown in Table 1.

The probability of existence of trapping mechanism is given to 1.0 because the seismic profile shown angular unconformity between

Table 1. Input data for hydrocarbon resource assessment by the FASPU program of the Chonnabot prospect, Carbonate Play

INPUT	Attribute		Probability of favorable
Play attributes	Hydrocarbon source		1.00
	Timing		1.00
	Migration		0.90
	Potential reservoir facies		0.90
	Marginal play probability		0.81
Prospect attributes	Trapping mechanism		1.00
	Effective porosity (>3%)		0.80
	Hydrocarbon accumulation		1.00
	Conditional deposit probability		0.80
Hydrocarbon volume parameter	Reservoir lithology	Sand	--
		Carbonate	X
	Hydrocarbon type	Gas	0.95
		Oil	0.05

Attribute	Probability of equal to or greater than						
	100	**95**	**75**	**50**	**25**	**5**	**0**
Area of closure (1,000 acres)	1.01	1.66	4.06	7.07	10.07	12.47	13.07
Reservoir thickness (feet)	100	120	205	234	256	323	340
Effective porosity (%)	3.00	3.14	3.71	4.61	7.00	13.10	18.00
Trap fill (%)	30	35	40	45	50	70	80
Reservoir depth (1,000 feet)	11.40	11.65	12.65	13.90	15.15	16.15	16.40
HC saturation (%)	60	64	72	82	86	89	90
No. of drillable prospects	5	5	5	6	7	8	9

Note:

Original reservoir pressure (psi)	=	*(0.7166 x Depth) + 14.5038*
Reservoir temperature (°R)	=	*(0.0267 x Depth) + 538.00 (from 0-2,300 feet)*
	=	*(0.0068 x Depth) + 579.00 (from 2,300-5,500 feet)*
	=	*(0.0115 x Depth) + 537.00 (below 5,500 feet)*
Gas-oil ratio (Mcf/bbl)	=	*0.0056146*
Oil formation volume factor	=	*1.00*
Gas compressibility factor	=	*(0.00001 x Depth) + 1.02384*
Oil floor depth		*14,870 feet*
Oil and gas recovery factor		*Oil 5.00*
		Free gas 90.00

the Permian carbonate rock and the Triassic Huai Hin Lat Group (GMT 1999; Atop 2006). The probability of effective porosity is given to 0.80 because data from drilled-well in the study area (Esso, 1982) indicated that this carbonate reservoir rock has high average porosity. The probability of hydrocarbon accumulation is given to 1.00 since both reservoir and source rocks are the Permian carbonate (Figure 2). So, the chance of petroleum migration from source rock to its nearby trap rock is high. Therefore, the conditional deposit probability for the prospect level, the product of the probability of trapping mechanism, effective porosity and hydrocarbon accumulation, is equal to 0.80.

The probability distribution for hydrocarbon volume attributes can be calculated from the plot of data and the observation of a complementary cumulative distribution function. Then, the favorable value at the fractile of 100th, 95th, 75th, 50th, 25th, 5th, and 0th of each attribute, including area of closure, reservoir thickness/vertical closure, effective porosity, trap fill, reservoir depth, and hydrocarbon saturation, are

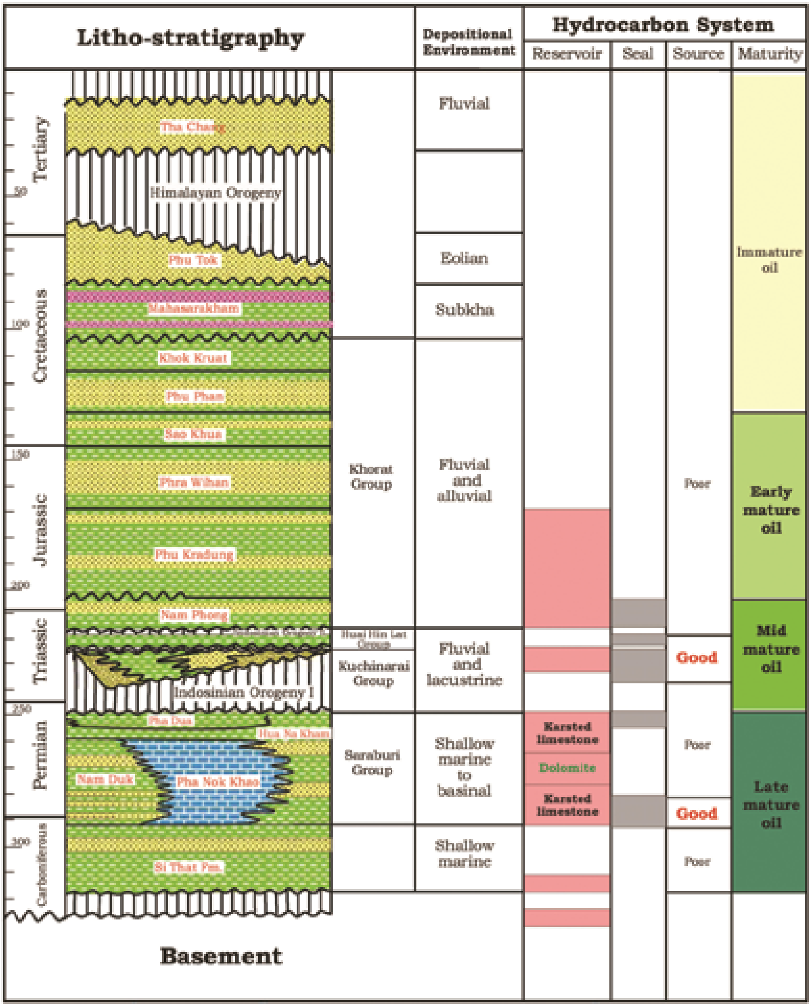

Figure 2. Lithostratigraphy and petroleum system of northeastern region of Thailand (Chantong, 2007)

estimated. In the play analysis approaching, the seven fractiles are estimated for all six of the hydrocarbon volume attributes. The probability for each attribute is also shown in Table 1.

The reservoir engineering parameters consist of original reservoir pressure (psi), reservoir temperature (^{o}R), gas-oil ratio (Mcf/bbl), oil formation volume factor, gas compressibility factor, oil floor depth (feet), and oil and gas recovery factor (percent). For the Chonnabot prospect, the probability theory is used as in the hydrocarbon approaching. As a result, the relationship between pressure and depth, temperature and depth, and other essential reservoir engineering parameters are summarized and shown in the lower part of Table 1.

The estimates of the total undiscovered recoverable quantities of hydrocarbon in the Chonnabot prospect are presented in the form of complementary cumulative probability as shown in Table 2. These distributions summarize the range of estimates generated by the FASPU program as a single probability curve in a "greater than" format. The assessments are reported at the mean and the level of confidence to 5 levels as follows;

- Very high confidence at the fractile of 95 (95^{th});
- High confidence at the fractile of 75 (75^{th});
- Medium confidence (most likely) at the fractile of 50 (50^{th});
- Low confidence at the fractile of 25 (25^{th}); and
- Very low confidence at the fractile of 5 (5^{th}).

As a result, oil in place resource within the Permian play of the Chonnabot prospect is estimated to 41.184 MMbbl from 1 oil accumulation at only 5 percent chance of discovery.

Based on geochemical study of the Permian carbonate source rock in the study area, it indicates that the possible natural gas generated in the Chonnabot prospect could be only non-associated gas. The accumulation size of these non-associated gas resources can be summarized as follows; 1) at 95 percent chance of discovery, the accumulation size is 122.43 billion cubic feet (from 2 accumulations), 2) at 75 percent chance of discovery, the accumulation size is 270.90 billion cubic feet (from 4 accumulations), 3) at 50 percent chance of discovery, the accumulation size is 470.44 billion cubic feet (from 4 accumulations), 4) at 25 percent

Table 2. Results of hydrocarbon resource assessment by the FASPU program of the Chonnabot prospect, Carbonate Play

Result	Mean	F95	F75	F50	F25	F05
Oil resource (MMbbl)						
Number of accumulations	0.161	0	0	0	0	1
Accumulation size	15.015	2.815	6.212	10.768	18.664	41.184
Unconditional play potential	1.958	0	0	0	0	13.877
Non-associated gas resource (Bcf)						
Number of accumulations	4.479	3	4	4	5	7
Accumulation size	657.53	122.43	270.90	470.44	816.99	1,807.66
Unconditional play potential	2,345.50	0	1,250.23	2,232.27	3,337.20	5,644.70

Note: F = fractile
Mean = arithmetic mean

chance of discovery, the accumulation size is 816.99 billion cubic feet (from 5 accumulations), and 5) at 5 percent chance of discovery, the accumulation size is 1,807.66 billion cubic feet (from 6 accumulations), respectively.

Conclusions and Recommendations

Results from the estimation of the total undiscovered oil and gas resources in the Permian carbonate of the Chonnabot prospect from this study can be summarized as follows;

1) The quantities of oil resource is 41.18 MMbbl but the chance of discovery is only 5 percent (F05). Therefore, there is a low or no chance to find an oil field within this prospect (Table 2).

2) The quantities of gas resources vary from 122.43 Bcf at very high confidence (F95), 270.90 Bcf at high confidence (F75), 470.44 Bcf at medium confidence (F50), 816.99 Bcf at low confidence (F25), and 1,807.66 Bcf at very low confidence (F05), respectively (Table 2).

However, the reliability of petroleum prospect assessment depends mainly on the accuracy of the input parameters and the proposed geological model. The results of the assessment may be different if the new information on this play type is available. The undiscovered petroleum resources assessed by FASPU program can be used for decision making in the investment of petroleum exploration and production in the nearby prospect of northeastern Thailand. It is also useful in the prediction of the future petroleum business in this region.

Acknowledgement

The research work presented in this paper was supported by Suranaree University of Technology. The permission of the Department of Mineral Fuel, Ministry of Energy, to use required data for undiscovered hydrocarbon assessment is also greatly appreciated. The authors would like to thank Assoc. Prof. Kriangkrai Trisarn for his valuable suggestions.

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