

Trapping Mechanisms along North Similan and Lanta Trends, Pattani Basin, Gulf of Thailand

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Abstract

Nine exploration wells along the Surin, Lanta, and North Similan structural trends in the northern Pattani Basin show significant variations in pay. To try to understand these variations in pay, analysis of the variations in the petroleum system elements in the area was studied with particular emphasis on trapping mechanisms. 3D seismic data, wireline logs and geochemistry data were used for this study. In the Pattani Basin, the first critical factor of the petroleum system is the structural trap. Wells should be drilled within structural closures to encounter hydrocarbon pays. However, pay count numbers vary considerably even in wells drilled on closed structures. For these wells fault sealing capacity was determined in this study to be the next critical factor that controls variations in hydrocarbon pays. Wells that have high sand- shale juxtapositions tend to have high pay count numbers whereas wells that have high sand- sand juxtapositions tend to have low pay count numbers. The third critical factor was determined to be the length of migration pathway or the distance from mature source rocks. The wells located near mature source rock tend to have higher pay counts on the east side where source rocks have higher maturation based on 1D maturity modeling. Sand distribution does not appear to be a factor in influencing the hydrocarbon pay count. From this integrated analysis, the best area for high pay potential is the eastern basinward side of the study area.

Keywords: Trapping Mechanisms, North Similan, Lanta, Surin, Pattani Basin, Gulf of Thailand

1. Introduction

Nine exploration wells along the Surin, Lanta, and North Similan structural trends show significant variations in pay, even though these wells are located along similar trends in similar structural positions. Some of these wells were unsuccessful which suggests a lack of complete petroleum system elements in some areas. To try to understand these, analysis of the different petroleum

system elements in the area was carried out with particular emphasis on trapping mechanisms as these have been thought to be the problem in the past. The seismic data, wireline logs and geochemistry data were used in this research to study the petroleum systems in the area, focusing on trapping mechanisms.

2. Methods

Various methodologies were used to assess each of the petroleum system elements. First, sands, shales, coals and hydrocarbon signatures were interpreted from well log data. Next, key markers were correlated from well to well for sand mapping, horizon interpretation and maturity model analysis. Then, net to gross of sand in each interval were calculated. These well log analyses and the net to gross sand analysis helped to indicate the reservoir quality potential. After that, the thickness of sandstone in each well was calculated and posted as net to gross percentage on a base map to generate the sand (reservoir) distribution map within Sequence 4 and Sequence 5 to see the trend and areal extent of the potential reservoirs. Next, all 9 wells were used to generate the 1D- maturity models. After that the 1D- maturity map can be generated to see the trend of mature source rocks. Detailed mapping of the top sands in every key well were mapped to see the potential structural closure areas that hydrocarbons could be trapped in. Next, the juxtaposition analysis or Allan diagram was analyzed. Structural maps and seismic cross sections were analyzed to find the possible migration pathways from source kitchen to trap.

3. Results

SAND DISTRIBUTION ANALYSIS

One of the critical variables in the petroleum system is reservoir distribution. To investigate this, net to gross sand percentages in every sequence were calculated from well logs. The net to gross percentages of Sequence 4 and Sequence 5 the main reservoirs, were posted on the base map to see the sand distribution compared to pay. The two sand net to gross maps show that reservoir sands are more abundant basinward and decrease on the flank of the basin. Also, sands tend to have higher proportions in the north area compared to the south area.

1D- BASIN MODELING ANALYSIS

Another key element in the petroleum system is the source kitchen. Basin modeling analysis in the study area was done. Thickness and lithologies of each rock formation were derived from well log data. In cases where the wells did not penetrate the whole section, seismic data were used to estimate the top of formation depths. Time depth conversions were calculated from check shot information. The beginning ages came from the regional stratigraphy in the Pattani Basin (Bustin et. al., 2003). All maturity levels (%Ro) calculated at the base of Sequence 1 -3 from 1D maturity models of nine wells were plotted on the base map to see the trend of the kitchen area, the mature source rock zone. This maturity map shows that source rocks generally reached high maturity basinward (east) and tend to be more immature along the flank of the basin. The well data also show gas pay (gas has higher maturation than oil) in wells which are located in the basinward area which supports this maturity mapping.

STRUCTURAL MAPPING ANALYSIS

A key element and dominant feature of the petroleum systems in the Pattani Basin is the fault trap, which has two main components; structural dip closure, and fault seal. As a result, structural maps of key horizons were mapped to determine whether wells were drilled within structural closures. The example of the well which was drilled in the structural closure is shown in Figure 1. There is only one well from 9 wells that was drilled outside the structural closure.

SEAL ANALYSIS

The other critical component to the hydrocarbon trap is fault seal capacity. The amount of hydrocarbon pay in the Pattani Basin might be significantly controlled by fault sealing capacity (Kachi et. al., 2005). To evaluate fault seals, juxtaposition diagrams or Allan diagrams (Allan, 1989) along the fault planes associated with 9 structurally trapped

hydrocarbon accumulations were generated from well log data (sand and shale stratigraphies) and seismic data adjacent to the fault planes. The seismic data was used to determine the elevations for each shot point along the fault planes.

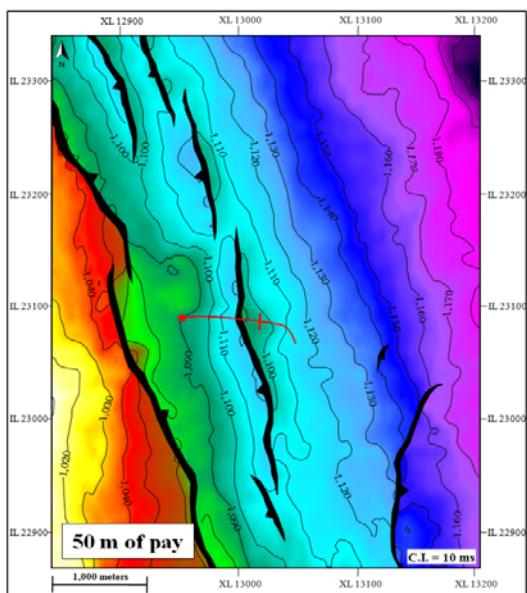


Figure 1. The structural time map of horizon at the example well shows that the well was drilled within structural closure. Intersection of well with this horizon is shown.

FAULT

The Allan diagram of Sequence 4 near the example well (Figure 2) shows quite a good correlation between actual and calculated pay zones. Pay counts from well log data are matched with sand-shale juxtaposition zones. The reason that this sequence has high amount of hydrocarbon accumulations might be that there are thick sands overlain and interbedded with thick shales which are good for sealing capacity.

There was a 47% correlation from the 9 wells which is a quite good result. Some intervals have no pay (especially in the upper section of Sequence 5), even though the Allan diagrams showed the possibility that they should have. Other factors, such as lack of migration or changing structural closure with depth also need to be considered.

The thickness of shale intervals is the main factor for good sealing capacity. There are many cases supported by this analysis which show that the sands below thick shale intervals have hydrocarbon pay because they have high chances for sand-shale juxtapositions. Evaluation of fault sealing capacity using Allan diagrams is useful, but it still has uncertainty.

MIGRATION PATHWAY ANALYSIS

The final element of the petroleum system to evaluate was the access that the potential fault traps had to mature source rock. That is, what are the migration pathways along the structural trends being studied. Sequence 4 and Sequence 5 are the main reservoir targets in the area. Thus, top Sequence 4 structural map was chosen to represent the reservoir structure for the lateral migration pathway analysis in map view (Figure 3). The top Sequence 4 structural map was overlain by maturity levels calculated at the base of Sequences 1 – 3 the main source rock interval. The main generation (high maturation) was basinward of the study area. Accordingly, hydrocarbon is interpreted to have migrated from east to west (up-dip) and typically moved perpendicular to structural contours. There are higher possibilities of hydrocarbon charging in the area that is close to the mature source rock.

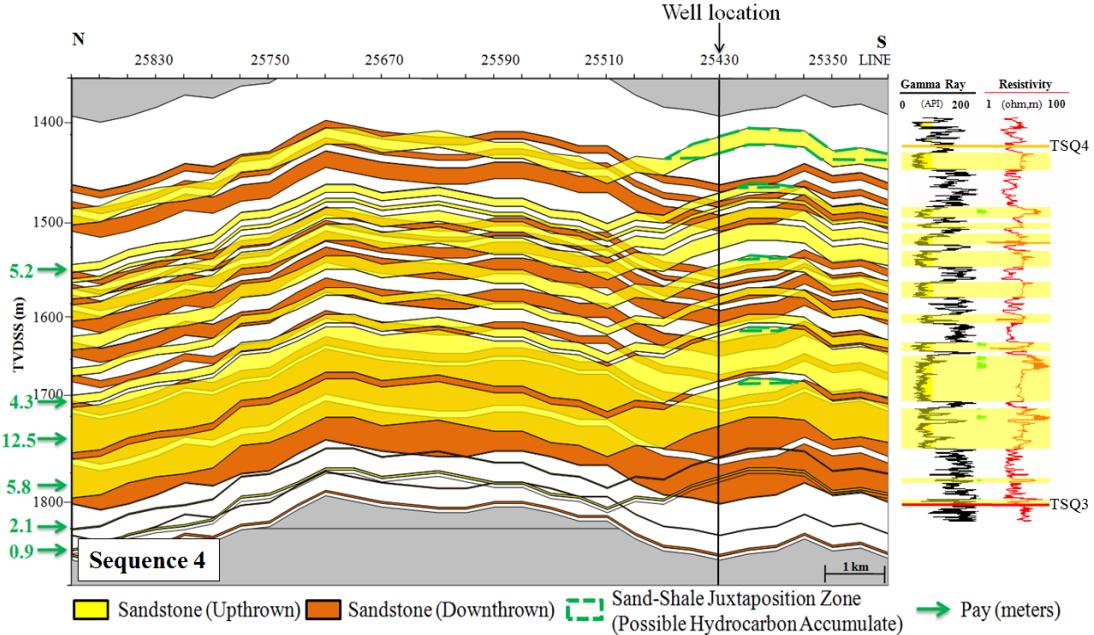


Figure 2. Allan diagram of Sequence 4 and near the example well showing the possible hydrocarbon accumulation (green dash lines). Green arrows with numbers show actual pay in meters.

Next, the vertical migration pathways were analyzed using seismic cross-sections. Interpreted sequences in seismic cross-sections show the primary source rock interval (Sequence 1 to Sequence 3) overlain by maturation. Hydrocarbon can move upwards along faults and can be trapped if there is shale juxtaposition. The example of cross-section is shown in Figure 4. Lateral migrations in the reservoir intervals are more difficult because of discontinuity of fluvial sand body geometries. Vertical migration is most dominant in this system, because there are many faults which are typical in the Pattani Basin. During fault movement, hydrocarbons can migrate through faults to up-dip positions where sands are juxtaposed with sands. Also fault movement can change shale gouge ratio and shale smear factors.

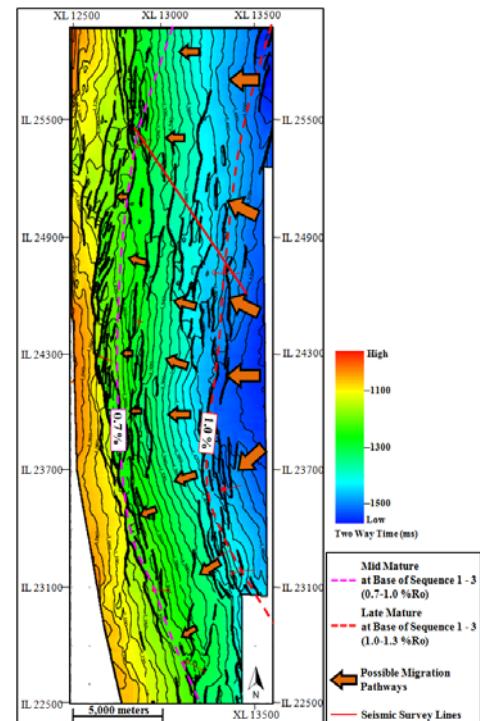


Figure 3. Top Sequence 4 structural map, which is overlain by maturation level, shows migration pathways as orange arrows.

4. Discussion

In the Pattani Basin, the first critical factor of the petroleum system which influences hydrocarbon accumulations is the structural trap. Wells drilled outside structural closures have low probability of any hydrocarbon pay whereas wells drilled within structural closures have high probability of hydrocarbon accumulations but their pay counts may vary.

The second critical factor of the petroleum system in this area is the fault sealing capacity. Most of the wells that have high pay counts also show good fault sealing capacity. In contrast, wells that have low pay

counts show poor fault sealing capacity. However, the fault seal analysis from this study shows that there is an uncertainty, about 47%, between actual and calculated fault sealing pay. The third critical factor is the migration pathway or the distance from mature source rocks. Wells that are located further from the source kitchen tend to have lower pay counts than wells that are located near mature source rocks. Sand distribution does not appear to be a factor in influencing the hydrocarbon pay count. Some areas have high sand net to gross percentages which should suggest good reservoir potential, but there is no economic pay there.

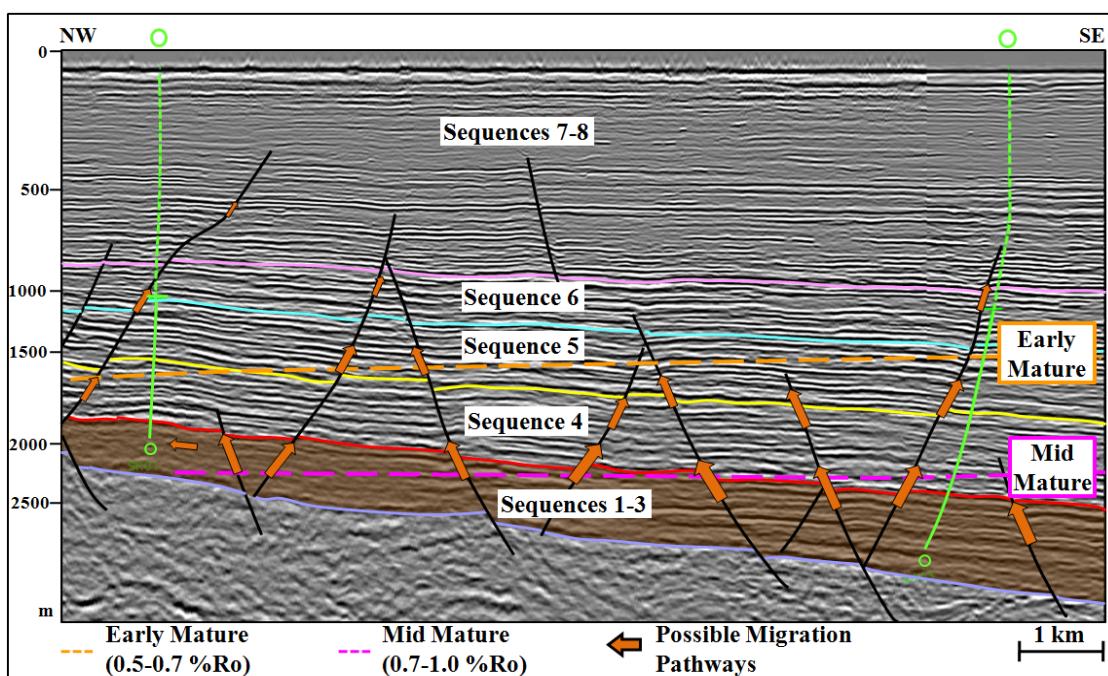


Figure 4. Cross section shows migration pathway analysis. Location is shown in Figure 3.

A previous study of fault seal analysis summarized that fault seals in this area were good, and that hydrocarbons cannot migrate through faults and this controlled the little to no hydrocarbon charge on the basin flank. However, the Allan diagrams in this

study show that most sands in wells that have low pay counts were juxtaposed with sands. Consequently, fault sealing capacity at these wells is not as good as the previous study reported. The previous study of the source rock maturation showed that source rocks reached maturity at the basinward side

of the area. This result is confirmed by the 1D-maturity analysis of this study.

5. Conclusions

The factors that affect the significant variations in pay between 9 wells drilled along similar structural trends is due to variations in the petroleum system elements. These are explained as follows:

1. Sand percentage increases basinward to the east side of the study area but are generally high, so the presence of reservoirs is not a critical factor in controlling pay counts in this area.

2. Source rock maturation shows that the area to the east has higher maturity than the west of the study area. Also the well data shows that wells located near the mature source rock have higher chances for hydrocarbon pay.

3. Wells should be drilled in the structural closures to encounter hydrocarbon pays. However, pay count numbers can vary in each well based on other factors.

4. Fault sealing capacity is the most critical factor that controls variations in hydrocarbon pays in the study area. Wells that have high sand-shale juxtapositions tend to have high pay count numbers whereas wells that have high sand-sand juxtapositions tend to have low pay count numbers.

5. Migration pathways are also important. The wells located near mature source rock tend to have higher pay counts on the east side where source rocks have higher

maturation. Lateral migration is limited and is a factor in limiting pay count in wells on the basin flank to the west.

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7. References

Allan, U. S., 1989, Model for Hydrocarbon Migration and Entrapment within Faulted Structures: The American Association of Petroleum Geologists Bulletin, v. 73, No. 7 (July 1989), p. 803-811.

Bustin R., Chonchawalit A., 2003, Petroleum Source Rock Potential and Evolution of Tertiary Strata, Pattani Basin, Gulf of Thailand: The American Association of Petroleum Geologists Bulletin, v.81, no. 12 (December 1997), p. 2000-2023.

Kachi, T., Yamada H., Yasuhara K., Fujimoto M., Hasegawa S., Iwanaga S., and Sorkhabi R., 2005, Fault-seal analysis applied to the Erawan gas-condensate field in the Gulf of Thailand: AAPG Memoir 85, p. 59 – 78.