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Depositional Environment and Reservoir Properties of Shallow Oil in Plamuk Area, Pattani Basin, Gulf of Thailand

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Abstract

The distribution of oil in the shallow section (approximately 900 to 1500 m deep and near the mid-Miocene Unconformity (MMU)) in the Plamuk area, offshore Thailand was investigated using conventional core and wireline data. Four fluvial lithofacies were interpreted from a core collected in the Plamuk G-4 well, including stacked channel sands that correspond to a blocky, low gamma ray log signature. Stacked channel sands were identified and correlated in 226 wells across the Plamuk area and their distribution was compared to the occurrence of oil in the same stratigraphic intervals. The comparison indicates that the abundance and connectivity of stacked channel sands is one of the main controls on oil distribution and it is recommended that the distribution of stacked channel sands is integrated into future exploration and development scenarios. However, the correlation between oil occurrence and stacked channel sand distribution is not good enough to discount other factors (e.g. trapping and sealing mechanisms and migration pathways) as being equally important controls on oil distribution.

Keywords: MMU, Stacked channel sand, oil distribution

1. Introduction

Most of pay reservoirs in the Plamuk field are below the mid–Miocene unconformity (MMU). Due to low compaction close to the shallow MMU, the potential for trap and seal decreases and this interval has not been a drilling target. However, some exploration and horizontal wells reveal hydrocarbon potential in this section (between approximately (3,000 feet (914 m) and 5,000 feet (1,524 m)). Therefore, there is a need to understand the reservoir in this shallow section in terms of depositional environment and reservoir sand distribution.

The main purpose of this study is to understand the depositional environment by using core data. Moreover, using well log data to study the reservoir properties, in term of relationship between quantities of sand and oil to find their association and to understand the factors that control oil distribution in this region.

2. Methods

In this study, depositional environments in the conventional core were interpreted first. Secondly, wireline data were correlated to identify the B, MMU and C

markers. The first is B marker represents by low gammaray coal, high resistivity and very high neutron response. Then, MMU is difficult to identify from log signature, however in this study, the MMU marker can be distinguish by absence in change in compaction of rocks and low gamma ray coal. At last, C marker defined by low resistivity shale bed and high gammaray signature After correlating the markers across the whole area, all interesting sands were correlated using gamma ray log signature, neutron-density log, pressure data and hydrocarbon data to check fluid connection between sands. The initial was focus on nearby wells in the same fault block first, then across the fault blocks. After correlating all the wells in the area, the pay sand summary report was used to find the distribution of oil between B and C markers. To find the relationship between reservoir sand and the amount of oil, sand distribution maps were compared to the oil distribution maps and structural maps.

3. Results

Core Description

Four main lithofacies were described and interpreted from two conventional cores from Plamuk G-04 well with a total of 59.25 feet (18.06 m), above the mid-Miocene Unconformity (MMU).

Unit 1: Very fine-grained sandstone interlaminated with clayey siltstone.

Unit 2: Thick bedded Mudstone with three subunits described as subunit 2.1, non-laminated, gray mudstone. Subunit 2.2, Poor laminated gray mudstone with roots and burrows. Subunit 2.3 laminated gray mudstone with roots and burrows.

Unit 3: Muddy sandstone with laminated clayey siltstone

Unit 4: Very Course to Fine-grained cross-stratified sandstone.

All litho facies interpreted as fluvial environment.

Well Log Analysis

Plamuk G-04 cored was tied to well logs. Log response of the cored interval is similar to log responses in similar lithologies from other cored intervals in the Pattani Basin. To start the correlation, the B, MMU and C markers were picked then identified a sand in one well by focusing on stacked sands. Thin-bedded sandstones containing oil also are interesting and uses for finding oil distribution. The Plamuk area was separated into three parts, northern, central and southern. Wells in the same fault block were correlated first then correlated to another fault block. Some log intervals, especially between the B and MMU markers, were run behind casing were yielded unreliable and inconsistent log response.

Sand and Oil Distribution

Percentage of oil distribution

The stacked sand distribution map is the net stacked sand thickness relative to the total thickness of the interval. Stacked sands were defined from wireline log responses generally use in the Plamuk area. The values were 0-100 API of GRCOMP, 1.93-2.58 gm/cc of RHOBCOMP and 0.06-0.28 of NPHICOMP. The stacked sands relate to a fluvial environment; bell shaped, blocky and funnel shaped of gamma ray log responses occur in most wells in this area and the thickness cut-off a gamma ray logs is 25 to 30 feet (7.6-9.1m) based on channel sand/bar deposits of Unit 1 in the Plamuk G-04 core.

The gross thickness in this study is the measured gross interval between B marker to MMU marker, MMU marker to MMU-5 marker (MMU-5 is half of total depth interval between MMU and C markers) and MMU-5 to C marker.

The percentage of net stacked to gross sand was calculated and separated for

each well individually then plotted on the B and MMU structural maps.

After plotting all the percentages of stacked sand to gross interval from each interval on the B and MMU structural maps, the percentage of stacked sand in the B to MMU interval was plotted on the B structural map. This map has a high stacked sand distributed in the center of northern Plamuk and central Plamuk area. However, these stacked sands are poorly connected. The other parts have fewer stacked sands and low stacked sand distributions, especially in the southern part. Many wells in the southern part were set in the casing, thus the southern part of this map may unreliable.

The middle interval is the MMU-MMU5 markers, high stacked sand distributed in northeastern and center of northern side. The other parts have a moderate number of stacked sands that decreases in the southern to the most southern part. Sands are connected across the same fault block and across fault blocks except in the southern part where sands are disconnected across the fault blocks, cannot be correlated laterally and the number of sands is less than in other areas. The lowest interval, MMU5-C has high stacked sand in the northwestern and center side. The other parts have a moderate number of stacked sands and decrease in the southern part. Sands are both connected between the same fault block and across fault blocks except in the west-central and southern part. lateral sand connection and the number of sands is less than in other areas.

Percentage of oil distribution

The oil distribution maps were created for the purpose of comparing the stacked sand distribution and oil distribution. The depth interval of oil is the same as the stacked sand interval. Each interval was calculated and separated for each well individually for B to MMU, MMU to MMU-5 and MMU-5 to C interval.

The percentage of net oil to gross interval was described by three maps. Firstly, the shallowest map is the B-MMU map that has a high amount of oil in the center graben area. However, it is scattered over a large area. The B to MMU interval was set in casing and is unreliable in the southern part.

The middle interval is the MMU-MMU5 marker, which has high oil in the southwestern part of northern Plamuk and center graben area. There is less oil in the southern part and no oil in the north-west of Plamuk area.

The lowest interval is MMU5-C, where oil is abundant in the southwestern part of northern and central Plamuk area. Different from the west-central area, there is no oil in this interval. Little oil occurs in the southern part.4. Discussion

The percentage of net oil to gross interval maps were compared with the percentage of net stacked sand to gross interval maps. In the B to MMU interval (Figure 1) the distribution of oil is probably relates to the amount of stacked sand. The graben center area has a high amount of stacked sand and a large amount of oil also is located in this graben center. However, the southern and northeastern part has some stacked sand but oil is not present in the southern area and less in the northeastern part. Moreover, a major problem in this interval is that many wells were set in casing.

The relationship between stacked sands and oil distribution in the MMU to MMU-5 interval (Figure 2) reveals a close match of stacked sands and oil, except in the northwestern area where no oil.

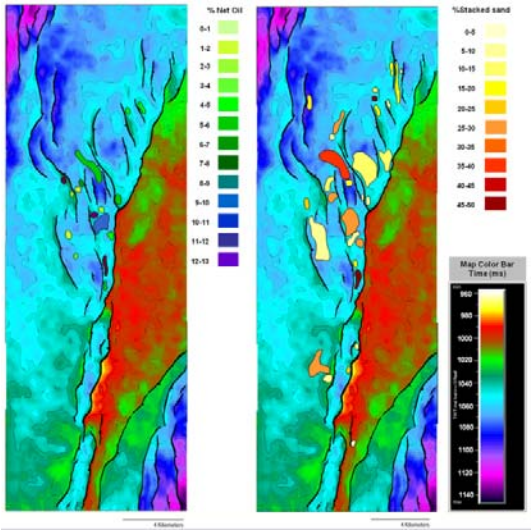

Figure 1. Comparison between the percentage of net oil to gross interval and the percentage of net stacked sand to gross interval in the B-MMU interval on the B structural map.

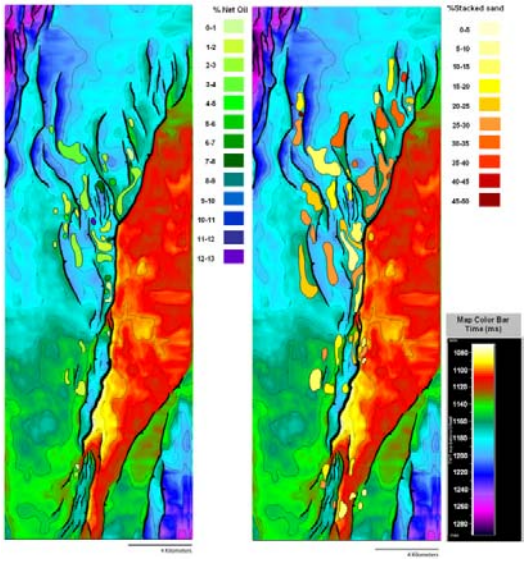

Figure 2. Comparison between the percentage of net oil to gross interval and the percentage of net stacked sand to gross interval in the MMU-MMU5 interval on the B structural map.

In the MMU-5 to C interval (Figure 3), the stacked sand and oil distribution matches. However, the western part that has some stacked sands without oil.

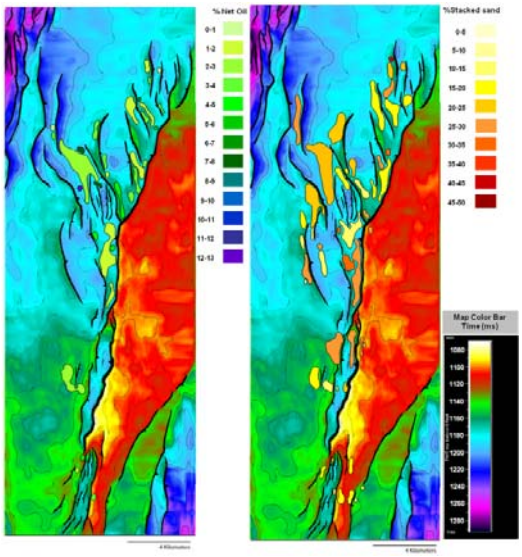

Figure 3. Comparison between the percentage of net oil to gross interval and the percentage of net stacked sand to gross interval in the MMU5-C interval on the B structural map.

One of the main controls of oil distribution in this area is the amount of stacked sand. Oil also appeared behind the fault blocks where higher structure on the upthrown side is more suitable to trap than on downthrown side. Moreover, the high oil content area is mostly in the central Plamuk area, which is higher than the northwestern part. However, they are exceptions such as the high area in southern Plamuk with little oil.

Therefore, it may be other factors controlling oil distribution such as migration pathway and seals.

Oil in the lower part may be unable to migrate to the upper part in the northeastern part of this area, due to a high amount of

shale that obstructed vertical migration from the lowest and less well connected sands in this interval. There may be little oil in the southern part despite its higher structure because oil may be obstructed by lateral shale seal and sands are not well connected.

Finally, even though other factors control oil distribution in this area, the results of this study indicates that where there are more stacked sands there is more possibility of finding oil. Therefore, plotting the percentage of stacked sands on the structural maps is very useful information that can be used for future development plans.

5. Conclusions

1. The Plamuk area was deposited in a fluvial environment from core stratigraphy and depositional environment, and includes four lithofacies; Unit 1: Very fine-grained sandstone interlaminated with clayey siltstone. Unit 2: Thick bedded Mudstone with three subunits described as subunit 2.1, non-laminated, gray mudstone. Subunit 2.2, Poor laminated gray mudstone with roots and burrows. Subunit 2.3 laminated gray mudstone with roots and burrows. Unit 3: Muddy sandstone with laminated clayey siltstone and Unit 4: Very coarse to Fine-grained cross-stratified sandstone.

2. Stacked channel sands correlated from 226 wells using the B, MMU and C regional markers found that most stacked sands are abundant in the same fault block and across fault block except in the southern Plamuk area.

3. The percentage of stacked sand to gross interval maps varies. The shallowest map is the B-MMU interval that has abundant stacked sand at the center of northern Plamuk and central Plamuk area (45-50%). The middle interval is between the MMU-MMU5 markers and there are abundant stacked sands in the northeast side of the area (25-35%). The basal interval, MMU5-C, has abundant stacked sand in the north-west and in the east-central side (25-30%).

4. Three percentage of oil to gross interval maps were created, the B-MMU map has a high amount of oil in the center graben area (9-10%). However, the data may unreliable due to casing affectes. MMU-MMU5, has abundant oil in the southwestern part of northern Plamuk (8-13%) and in the center graben area (4-8%). The lowest interval, MMU5-C, has abundant oil in the southwestern part of northern Plamuk (8-13%) and in the central Plamuk area (4-6%).

5. The percentage of net oil to gross interval maps and the percentage of net stacked sand to gross interval maps mostly match. Therefore, one of the main controls on oil distribution in this area is the amount of stacked sand. However, other factors are important such as lateral and vertical seal, stratigraphic and structural traps and migration pathway.

The results of this study indicate that matching the percentage of stacked sand with oil distribution is valuable information for future development plans.

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