

# BETTER EXPLORATION PROSPECTIVITY UNDERSTANDING THROUGH THE USE OF ADVANCED 3D BROADBAND SEISMIC

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## Summary

Nam Con Son basin is one of the most prolific oil and gas rich basins in Vietnam. Oil and gas is produced in a number of fields, i.e. Dai Hung, Hai Thach/Moc Tinh, Lan Tay/Lan Do, Dua/Chim Sao and Rong Doi/Rong Doi Tay. Despite many successful wells, there are opportunities to improve exploration CoS (chance of success) in a basin by better prediction of trap definition, reservoir and seal risks. This paper presents the use of advanced 3D broadband data to help better understanding the exploration prospectivity in the centre of the Nam Con Son basin.

3D broadband seismic was acquired and processed in 2013 - 2014, and conventional and special seismic interpretation techniques (Amplitude Versus Offset - AVO) were conducted to provide a better geological understanding of the prospectivity. In particular: i) traps were well defined in both structural and stratigraphic plays, ii) reservoir was better predicted through a combination of sequence stratigraphy and special seismic studies, iii) seal potential across major faults was determined by combination of conventional geological methods and using the seismic character response across the faults.

The presented results may be helpful for geoscientists exploring in the Nam Con Son basin and other areas of the Vietnam shelf.

**Key words:** 3D broadband seismic, AVO, Nam Con Son basin.

## 1. Introduction

Block 05-3/11 operated by Rosneft Vietnam is located at the centre of the Nam Con Son basin, offshore Vietnam, approximately 330km to the South-East from Vung Tau city (Figure 1). In 2013, 1,179.81km<sup>2</sup> of 3D broadband seismic data and 75.8km of 2D were acquired; the data was processed to both pre-stack time migration (PSTM) and pre-stack depth migration (PSDM) and was completed in 2014. Conventional and special seismic interpretation has defined a number of prospects including both structural (Middle Miocene) and stratigraphic traps (Upper Miocene). The understanding of prospect potential was significantly improved by a number of studies including: i) regional geological integrated analysis, ii) regional structure and tectonic activity evaluation, iii) 3D petroleum system basin modelling, iv) seismic sequence stratigraphic interpretation, and v) fault/top seal analysis based on the new 3D broadband seismic data.

## 2. Trap understanding

The 2013 3D broadband was acquired and processed by CGG (Figure 2). Eight horizons from T100 to T30 have been interpreted. In addition to the conventional interpretation, AVO and inversion studies were also undertaken, which helped to define two trap styles on the Block 05-3/11. These include the following:

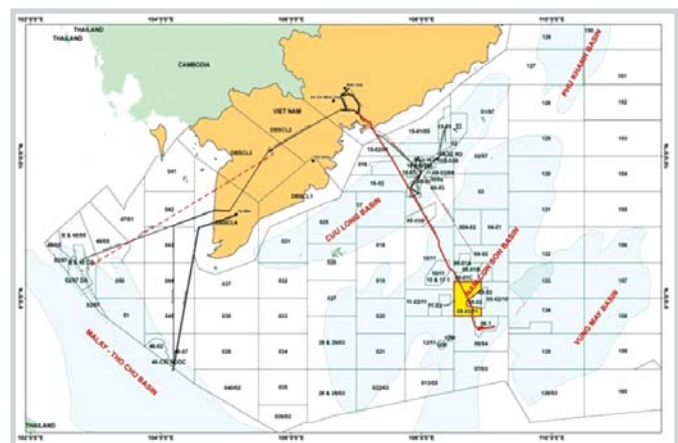


Figure 1. Block 05-3/11 location map

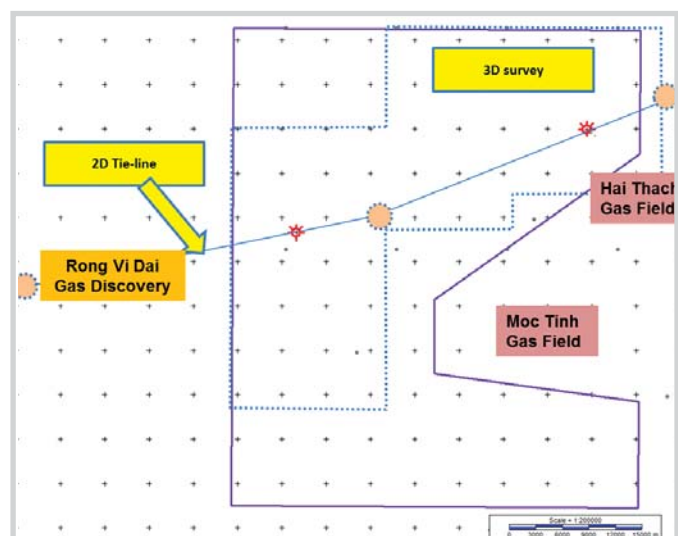


Figure 2. 3D broadband seismic area

- Upper Miocene stratigraphic traps

They were defined as i) seismic AVO Fluid Factor (ABFF) anomalies, and ii) conventional PSDM amplitude extractions that show greater chaotic character (Figure 3). The AVO anomalies are not conforming to structure interpretation. The ABFF data is used to highlight areas with good potential gas and reservoir characteristics that also show strong negative ABFF amplitudes. Reduced ABFF

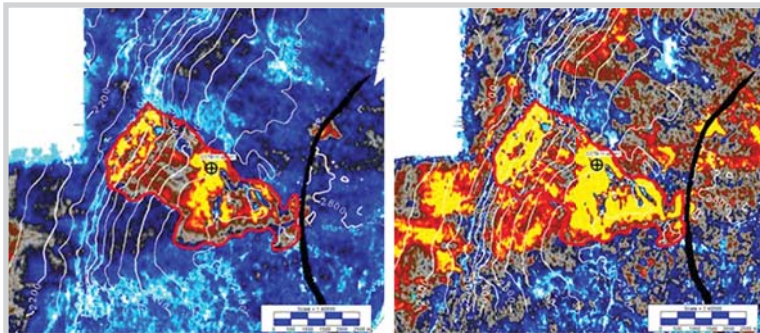


Figure 3. ABFF amplitude anomaly (left) vs. Conventional PSDM amplitude extraction (right)

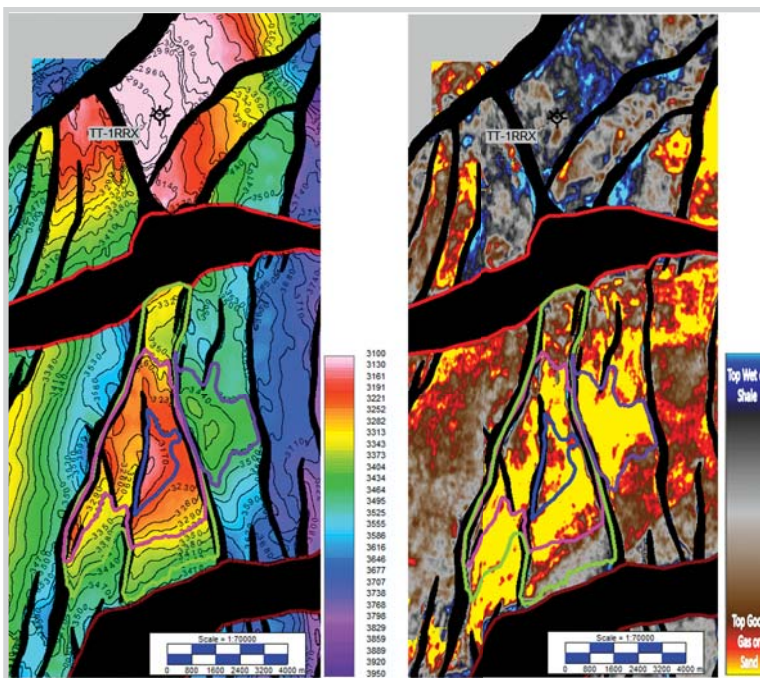


Figure 4. Top depth structure map (left) and good sand with high gas saturation predicted by AVO Fluid Factor attributes (right)

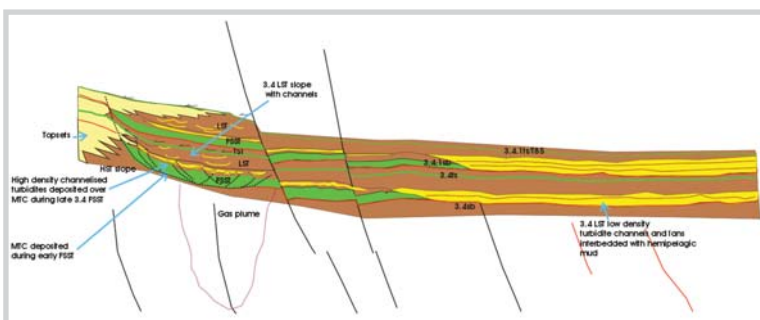


Figure 5. Schematic diagram of reservoir in Upper Miocene

amplitudes are interpreted as possible increase in sub-seismic resolution scale faulting, small shale partitioning, decrease in gas saturation, or poorer reservoir quality (i.e. net to gross, porosity, permeability). Sedimentary environmental studies suggest that these seismic facies represent slump/turbidities and/or ponded and amalgamated channels feature deposited in shelf/slope and deep marine environment. Seismic sequence stratigraphy analysis of the 3D data suggests these channels have their provenance to the west of the Block.

- Middle Miocene structural traps

They are 2-way or 3-way fault-bounded structures that have been defined on the high quality 3D data. The majority of the faults are oriented in a NE-SW or N-S direction and demonstrate large fault throws, and a lesser number are oriented in NW-SE direction with smaller fault throws (Figure 4). The orientation and magnitude of the faults are consistent with this regional stress regime in the Nam Con Son basin. There are complex imaging issues associated with the larger faults, which increases the potential risk for defining accurate fault geometries and trap definition.

3. Reservoir understanding

Clastic reservoirs are formed in both Middle and Upper Miocene sections:

- Upper Miocene reservoirs constitute deep marine slope/turbidite sands. Sandstone is present at depth 2,500 - 3,500m with porosity from 18 - 30%, average 20 - 22%. Reservoir thickness varies from 20 - 80m, average thickness of 40 - 50m from adjacent wells data. Seismic sequence stratigraphy study shows Upper Miocene reservoir in the Block has been identified as a combination of a slump deposit in the early falling stage systems tract (FSST) overlain by turbidite channel sands of the late FSST and lowstand systems tract (LST) (Figure 5). Seismic amplitude mapping identifies slump/turbidite and ponding of amalgamated channel facies. These illustrate chaotic geometry indicating variable reservoir

or partially cohesive mass flow deposits covered by high density turbidite channels. The slump/turbidite channel feature is limited down-dip by significant N-S faults that are surrounded to the north, south and east by marine shale deposits. From the AVO analysis, we observe that the PSDM intercept polarity changes whilst the gradient polarity remains unchanged, suggesting the possible gas water contact (GWC) indicator (Figure 6). Sand thickness evaluation is also supported by AVO derived isopach vs. drilled well thickness analyses.

- Middle Miocene reservoirs are shelfal, synrift turbidite sands, or were deposited in a slope or deep marine environment. These reservoirs are present at depth range of 3,000 - 5,000m with average porosity of 13 - 16% deduced from adjacent wells. Seismic sequence stratigraphy shows there is the possibility of widely deposited sands within stacked sand units with average thickness of each reservoir of between 15 - 20m. It is interpreted that these shelfal sand packages were flanked by incised valleys formed during FSST, thereafter these were filled during LST, transgressive systems tract (TST) and highstand systems tract (HST) with a range of paralic facies associations and later blanketed by marine flooding shale to form an effective top seal (Figure 7). Within this sequence, there are several interspersed high-amplitude seismic events that may represent carbonate facies that were deposited during HST transgression. There is a higher prevalence of seismic amplitudes within this section suggesting higher number of sands within the southern structure. The T60 and T58 reservoirs in Tho Tinh Nam prospect have fair to good AVO lithology indicators that are reasonably conformable with the structure. We believe the AVO lithology response is better than that seen at the TT-1RRX well, suggesting the possibility of similar to better quality sands. Below T50, the AVO response is dim and is interpreted as tight sand with low gas saturation. Sand thickness is supported by AVO amplitude and wavelength analysis using TT-1RRX as a constraint.

**4. Seal understanding**

Seal evaluation includes both top and lateral (side) seal evaluation. While top seal is proven within the Nam Con Son basin with a thick marine shale of up to 300m within the Upper Miocene and 140m in Middle Miocene, the lateral seal remains the key risk

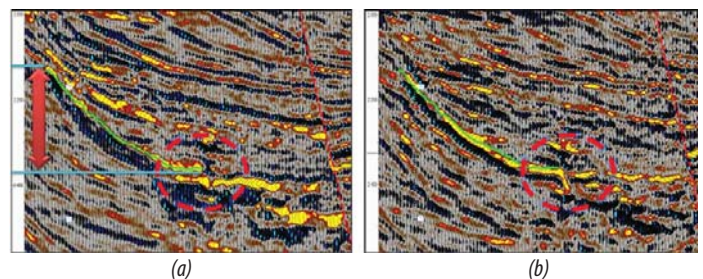


Figure 6. PSDM Intercept Polarity (a) changes while Gradient Polarity (b) remains unchanged at the bottom, suggesting the potential GWC indicator

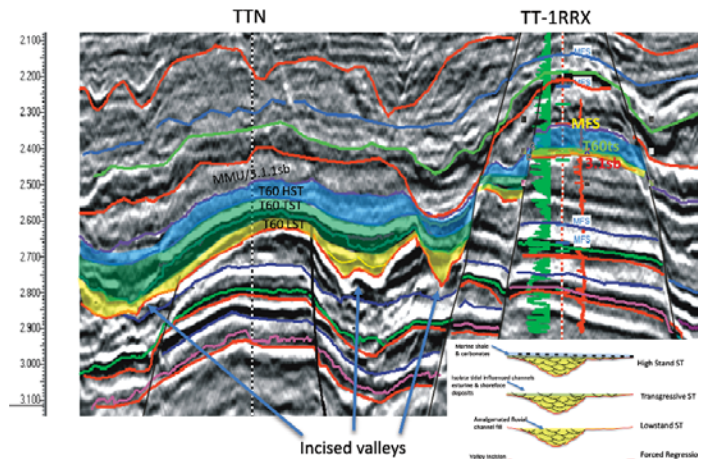


Figure 7. Middle Miocene reservoir predicted from seismic stratigraphy

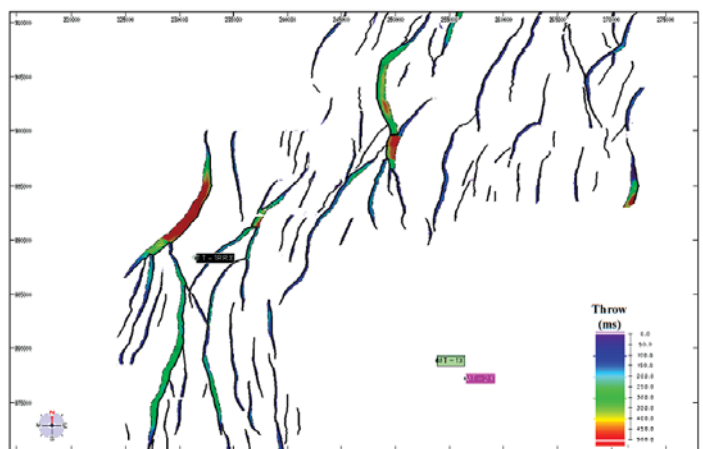


Figure 8. Block 05-3/11 fault throw in Middle Miocene

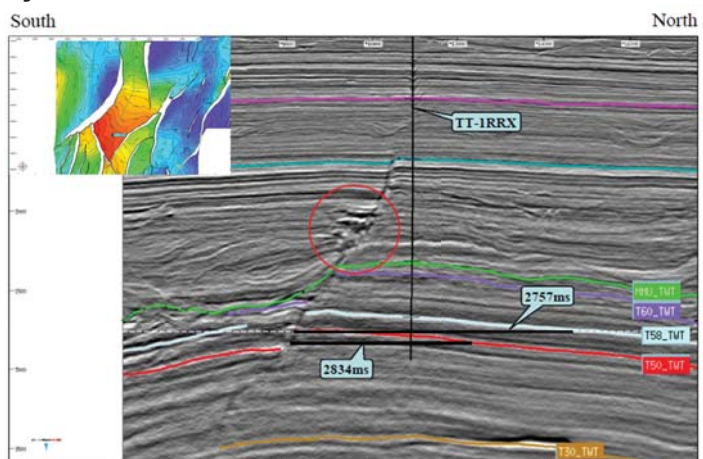


Figure 9. Evidence of gas leaking along fault in TT-1RRX

for several prospects in this area. The sealing potential across major faults is better determined by combination of conventional geological methods and using the seismic response across the faults.

Conventional fault seal study includes modelling of the fault throw, Allan diagrams, calculation of the Shale Gouge Ratio and prediction of the hydrocarbon height. Most of faults in the Block have fault throw of more than 100m within sections of abundant shale where there is more chance of sand against shale. Calculated shale gouge ratio is mostly higher than 50% and max hydrocarbon height supported by fault seal is up to 180 - 210m (Figure 8).

Conventional method shows all the faults are sealing, however the question is raised why the TT-1RRX well failed. Detailed investigation was undertaken using new broadband seismic data where we believe there is possible "seal damage" arising from complex fault linkages and the intersection of several faults bounding the Tho Tinh prospect, in particular the faults defining the SW and NW edge of the prospect where high amplitude anomalies are located close to and abut against the fault traces (Figure 9). These suggest that beside conventional interpretational methods, we need to carefully investigate the seismic image above the fault for any evidence of gas leaking, especially where there are complex fault intersections where effective seal could be damaged. A prospect with simple fault geometry with no fault linkages or confluences and no evidence of gas leaking up dip along fault is a much preferable drilling candidate.

## 5. Conclusions

Prospectivity understanding of the prospects in the Nam Con Son basin and Block 05-3/11 was significantly improved with the help from 3D broadband seismic:

- The structural traps were better defined, and the new seismic data helped better define the stratigraphic trap within the Upper Miocene section. These traps are believed to be formed by slump/turbidite and ponded amalgamated channel features in the shelf/slope and deep marine environment that are supported by good AVO characteristics.

- Reservoir risks are mitigated by an understanding of the sedimentary environment through seismic sequence stratigraphy studies, by AVO analysis, and with analog and well data correlation.

- Sealing potential has been identified using both conventional and detailed investigation of seismic image along and up dip of mapped faults. Structures with no fault confluences and no evidence of gas leaking up dip along fault are likely to be the best drilling candidates.

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