Integrating Various Methodologies For Thin Reservoir Characterization To Extend Life Of Ravva Field

Uday Mishra, Arnab Ghosh, Harshvardhan, Monosvita Chaliha, Prakash Bajpai, Shashank Singh, K Kaladhar Sharma, Cairn Oil & Gas, Vedanta Limited*
uday.mishra@cairnindia.com

Keywords

Ravva, Development, Spectral Decomposition, Geobody, AVO, Fluid Factor, Amplitude Detuning, Volumetrics

Summary

Ravva is a mature oil and gas field in K-G Basin, discovered in 1987 and brought into production in 1993. Ravva field is being developed under waterflood, which has undergone various drilling phases and has achieved a recovery factor of 50% over a span of 24 years. The Middle Miocene (MM) sands form the key reservoir has been thoroughly exploited. These MM sands were deposited in shoreface to deltaic settings and are represented by thick connected sands. MM sands are later eroded by a major unconformity LLMSB (Lower Late Miocene Sequence Boundary) following which a deep sea environment was followed during which some canyon cuts and slope channel complexes are deciphered. LLM sands are deposited during this time encased within thick LLM shale sequence and ranges in thickness between 3-15m, charging of these sands are through faults and sealing of reservoir (both top and lateral seal) are through shale boundaries. All the development/infill wells drilled till date have been optimized for exploiting MM sands, however some have encountered hydrocarbons at shallower LLM stratigraphic levels.
Recently, one of the wells was completed to access these thin LLM sands. The derived in-place estimates based on production data (currently under depletion drive) technically warranted the exploitation of these pools under waterflood. In light of this, thin LLM (Lower Late Miocene) sands lying above MM (Middle Miocene) sands were studied in detail using various geophysical technologies and integrated with Modeling and Reservoir engineering disciplines. This helped in sound Field Development Plan proposal for further exploitation of these LLM pools and extending Ravva field life.

LLM sands ranges in thickness between 3-15m and the seismic frequency at this level is ~28Hz only so these sands are not resolved in seismic and are detectable upto ~7-8m, owing to class 2 AVO response which increases the detectability. This poses a challenge in LLM sands mapping and delineating their geometries and connectivity using seismic data.
Various useful geophysical technologies were used and integrated for delineating LLM sands fairway, reservoir characterization and volumetric estimation:

- CWT (continuous wavelet transform) spectral decomposition and RGB (Red Green Blue) blending for delineating sand fairway and understanding depositional environment.
- Geobody picking using attributes for extracting sand geometries and input to modeling & volumetrics
- Seismic Net pay thickness estimation for subsequent volumetrics and well planning purposes

Following this the volumetrics were also validated with the material balance (MBAL) estimates to gain confidence and bring out the development plan for these LLM sands. This resulted into proposal for resource addition to declining Ravva field and future drilling campaign to exploit LLM sands, which have not been penetrated by any of the existing wells.

Introduction

The Ravva field (Figure 1) is located in the shallow offshore area of the Krishna Godavari Basin on the eastern coast of India (PKGM-1 block). The field is operated by Cairn Oil & Gas, Vedanta Ltd. (22.5%) on behalf of its JV partners ONGC (40%), Videocon (25%) and Ravva oil Singapore (12.5%). Oil production from Ravva was increased in two steps to reach a plateau of ~ 50,000 bopd by 1999, with water injection providing pressure maintenance. The oil production plateau rate continued for 9 years until 2007, after which the field started declining. The field is currently producing ~17000 bopd.

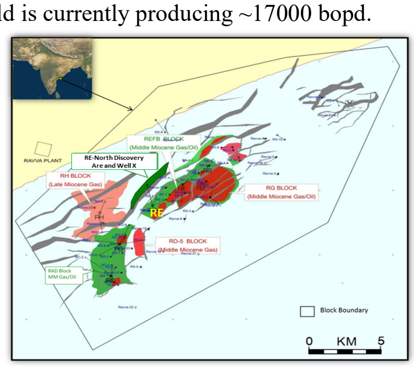

Figure.1: Ravva map showing main producing areas.

Integrating Various Methodologies For Thin Reservoir Characterization To Extend Life Of Ravva Field

Main Ravva producing reservoirs comprises of two areas separated by a shale filled erosional unconformity- RAD & REFB and LLM pools are distributed across whole field. During the drilling of wells for MM sands as primary target, wells were optimized to encounter LLM sands wherever possible which was later perforated in some of the wells after the production ceased from MM sands, this has shown mixed results with good productivity from some wells. As the crestal wells are currently producing at high water cut from MM sands, there is a need to look at shallower LLM sands (refer Figure 2) in detail and characterize them properly to bring out the development plan of LLM pools for optimum recovery.

A detailed study integrating geophysical, geological and Reservoir engineering data was conducted to come up with the comprehensive development plan for these LLM pools.

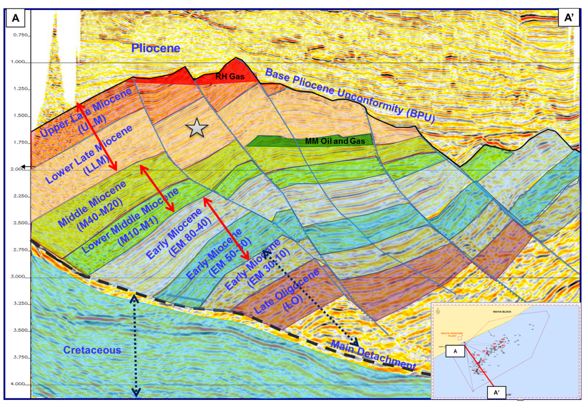

Figure.2: Ravva seismic dip section showing various stratigraphy levels and LLM highlighted with star mark.

Methodology and Workflow:

The methodology and workflow shown in Figure 2 was followed in order to identify LLM pool opportunities (*refer Varad Sabharwal et. al. 2016.*), integrate all studies and firm the development plan & well planning of these pools.

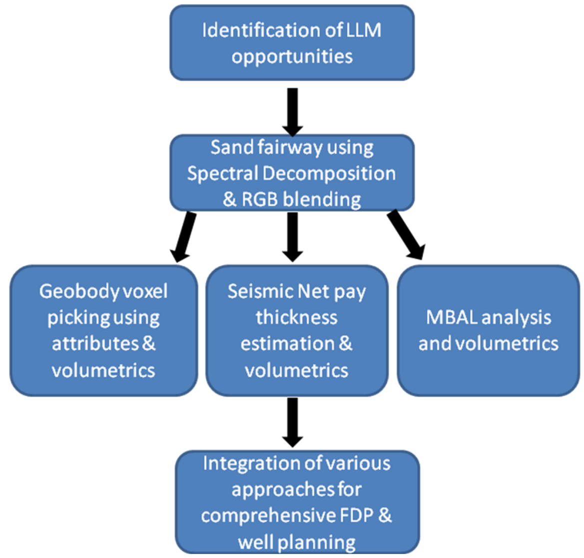

Figure.3: Methodology and workflow

Reservoir fairway and depositional environment using Spectral Decomposition (CWT) and RGB blending:

LLM sands are slope channel sands deposited in deep marine conditions, showing a typical seismic signature of bright amplitude (Soft) encased within transparent shale background. Ravva seismic data is AVO friendly and shows class 2/3 seismic signature with top of the sand represented by trough which is bright in hydrocarbon filled areas.
To get the fairway of these channel sands an advanced spectral decomposition technology. CWT technology was applied to greater success, which divides continuous-time function into wavelets and possesses the ability to construct a time-frequency representation of a signal that offers very good time and frequency localization.

From amplitude spectrum analysis three frequencies were selected mainly on the higher frequency side considering LLM sands thickness which is mostly in the range of 3-15m, prior this frequency volumes were generated using CWT technology. RGB blending & visualization technology was used to blend the three frequency volumes (Red- 25Hz, Green- 30Hz, Blue-35Hz) and a suitable time thickness slab was selected which was then panned to get the proper image representing LLM sands and their fairway (refer Figure 4).

Integrating Various Methodologies For Thin Reservoir Characterization To Extend Life Of Ravva Field

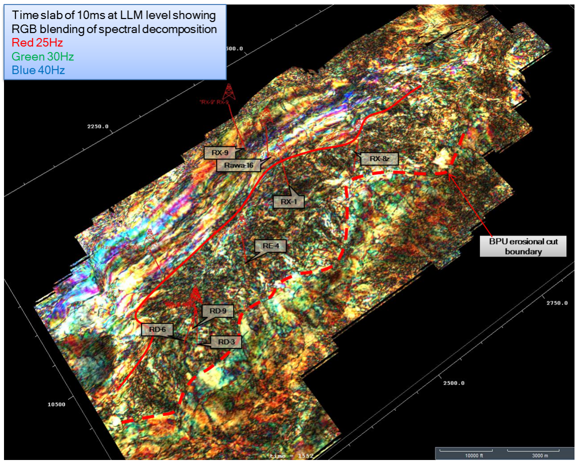

Figure.4: CWT & RGB blending showing major LLM sand fairway in NW-SE direction in the middle section.

This analysis clearly indicates that LLM sands channel orientation is NW-SE (refer Figure 4); this helps in building the geological model of these sands and opens up opportunity to identify similar undrilled channels.

Geobody extraction using attributes and modeling for volumetric estimation:

Reflectivity inversion study has given insights into generation of Rp & Rs as output volumes and further using them has helped in generating Fluid Factor attribute volume, which based on validation at several well locations, has proven to be an excellent hydrocarbon indicator across the producing field (*refer Rajan Kumar et. al. 2008*).

This fluid factor volume has also shown better detectability compared to other inversion outputs like Vp/Vs and AI volumes and has been helpful in detecting LLM sands, due to these advantages fluid factor volume was used to extract geobodies using advanced voxel picking & visualization technique.

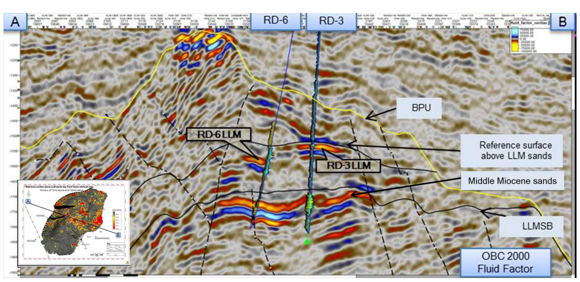

Figure.5: Fluid Factor dip section showing prominent signature at some of the LLM pools.

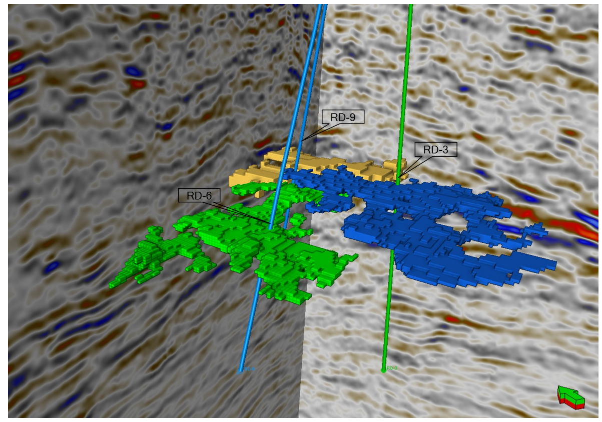

Figure.6: Geobody picking using fluid factor attribute for LLM pools and corresponding wells.

The picked geobodies (refer Figure 6) were taken to the modeling workflow and well log properties were populated into model for volumetrics.

Validation of volumetrics using Seismic Net pay thickness estimation after detuning amplitudes:

As LLM sands are thin and there are challenges pertaining to frequency content of the data, these sands are not clearly resolved in seismic so advanced workflow like seismic net pay thickness estimation was required instead of classical approach of sand body mapping. In this study Alistair Brown's (1986) (*Tuning effects, lithological effects and depositional effects in the seismic response of gas reservoirs)*, methodology was used and step by step approach from Rob Simm- 2009, *(Simple net pay estimation from seismic: a modelling study)* was followed with following workflow:

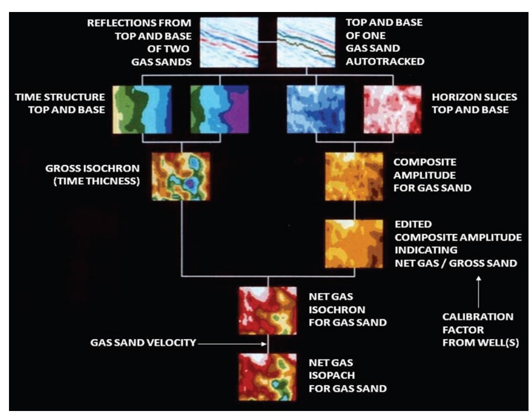

Figure.7: Workflow for Net pay estimation using seismic amplitude detuning.

Integrating Various Methodologies For Thin Reservoir Characterization To Extend Life Of Ravva Field

Wedge modeling suggests that 18ms is the tuning thickness and below this tuning effect can be seen on amplitude. These amplitudes were detuned by generating a scalar using modeled curve (Forward model to understand sands of similar nature using existing well as shown in Figure 8 below) and baseline curve. Net pay map was generated using detuned amplitude map which has helped in identifying areas with high pay. This map is then used to get volumetrics for these pools and further validation with other approaches is followed.

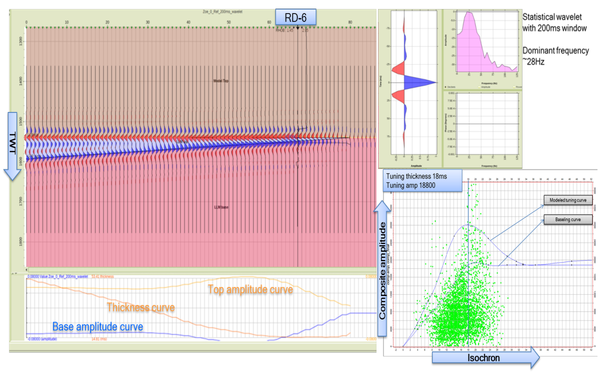

Figure.8: Wedge modeling section and plot showing modeled tuning curve and baseline curve.

MBAL estimation

As these thin LLM sands are not clearly resolved in seismic, and there are uncertainties in mapping of these sands, an independent estimate for volumetric is essential to gain confidence.
Material balance provides a good estimate of the in-place volume for these small LLM pools. The major uncertainty in material balance estimate is the PVT data as no hydrocarbon samples were acquired in LLM sands. The estimate for bubble point is based on produced GOR trends and reservoir pressures which have been recorded at regular intervals. Formation volume factor and compressibility were derived using different correlations taking into account the fluid/formation properties at MM level.
Based on these estimates, a range of in-place volumes were calculated which were then compared with the volumetric estimates based on other approaches.

Integration of various approaches for comprehensive FDP and well planning:

After getting the sand fairways from spectral decomposition, sand geometries using geobody picking, net pay maps from seismic detuning work and further volumetrics MBAL estimation in some pools, it was critical to integrate all these results to propose a robust development plan for LLM pools. As we understood that geobody picking on fluid factor volume has potential of overestimating volumes as the thickness component from geobody may not be the true reservoir thickness indicator.
At the same time volumetric estimation from the seismic amplitude detuned net pay map was lower compared to geobody approach and provided better illustration of high pay areas. MBAL volumetrics estimation was on higher side which indicated that seismic methods were underestimating the volumetrics for these thin LLM sands. This integration of various methodologies was able to provide a fair estimate of volumetric ranges and highlight areas with maximum pay for optimal well placement.

Conclusions

LLM sands in Ravva has not been on development portfolio for long time due to higher production from MM sands but recently as the MM sands are depleted in some wells, it's the right time for considering LLM sands for development. Due to thin reservoirs at LLM compared to MM and their deposition as channel sands, encased in shale, these sands are isolated individual pools and definitely innovative Geophysical approach was needed to ascertain their pool boundaries and come up with comprehensive volumetrics validated by various methodologies and dynamic data. For these thin LLM sands the above approach of integrating various methodologies has been fruitful in providing us range of volumetrics and higher confidence on these pools. Hence a comprehensive field development plan based on integrated studies is underway which will certainly extend the life of Ravva field once executed.

References

Varad Sabharwal 2016. What's hiding behind your pipe? PetroTech 2016*
Rajan Kumar, V. Ravichandran, Damian Kelly, 2008. Reservoir Characterization and Structural Correlation Using Shear Seismic and Pressure Data Integration in Ravva Field: An Innovative Technique, 2008 Indian Oil and Gas Technical Conference and Exhibition, Mumbai, India, SPE 113140

Acknowledgements

The authors gratefully acknowledge the valuable suggestions of the Ravva Field JV partners, Oil and Natural Gas Corporation, Videocon Limited and Ravva Oil (Singapore).