Delineation of Reservoir Geometry of Thin TS-4 Sands using Seismic Inversion in Rudrasagar Field, Assam & Assam Arakan Basin

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Summary

North Assam Shelf area of the Assam & Assam Arakan Basin has been extensively explored in last five decades and 17 oil & gas fields are producing from Paleocene to Miocene reservoirs (Fig.1). The Tipam Group of reservoirs of Miocene age (TS-1 to TS-6) are producing oil mainly from structural prospects. All Tipam pays except TS-4 are extensively explored, however, thrust on exploration of TS-4 play has not been adequately given in the past. TS-4 sands are sandwiched between the claystones of the Lower Clay Marker (LCM). The overall characteristics of the LCM-TS-4 pack indicate that the sandstones were deposited as isolated lenticular sand bodies and larger channel complexes in meandering fluvial channels. To chase the lead obtained from recently drilled well W-A, a study has been carried out in Rudrasagar and adjoining areas.

Absence of reservoir facies in LCM-TS-4 pack may be due to pinching out and or facies deterioration. This brings out a stratigraphic aspect in exploration of TS-4 along with the structural component. The thickness of TS-4 sand varies from 0m to 22 m in the study area. The occurrence of such intervening thin clastic reservoirs can form excellent hydrocarbon pools in fault associated structural prospects.

In this study, seismic attribute analysis along with post stack inversion has been attempted for deliniation of these reservoirs. Occurance of TS-4 sands is represented by low amplitude on seismic data due to destrctive interference. The integrated interpretation of attribute maps derived from Acoustic Impedance volume, validated by well data, has successfully depicted reservoir geometry patterns.

Introduction

Major tectonic elements of the Assam and Assam Arakan basin are: Assam Shelf, Naga Schuppen belt and Assam-Arakan Fold belt. The basin is bounded on the north and west by the Brahmaputra River and on the south and east by the Indo-Burma Ranges (Fig. 2). Assam Shelf is located between the Eastern Himalayan foothills and the Assam-Arakan thrust belt. The Assam Shelf exhibits a complex structural pattern mostly concealed by huge recent alluvial cover. The area is divided into two distinct Blocks viz. North Assam Shelf (Upper Assam) and South Assam Shelf (Dhansiri Valley) on the basis of structural style, and hydrocarbon plays. The North Assam Shelf (NAS) is separated from South Assam Shelf (SAS) by East-West trending Jorhat wrench fault system. The presences of Hydrocarbons have been established in Upper Assam way back to 1890, when oil was discovered in Digboi by Burma Oil Company. Later on ONGC & OIL started extensive exploratory efforts in area that resulted in number of discoveries of small and large oil fields in the Upper Assam area.

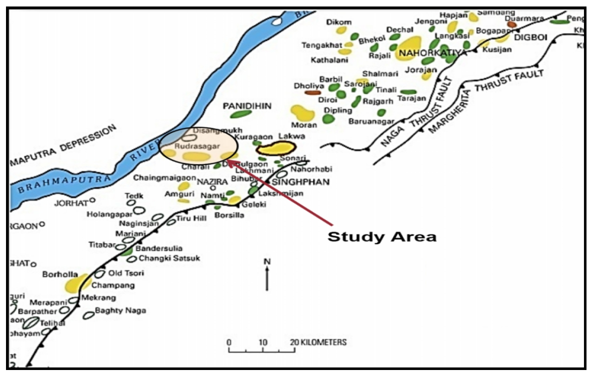

Figure 1- Study Area

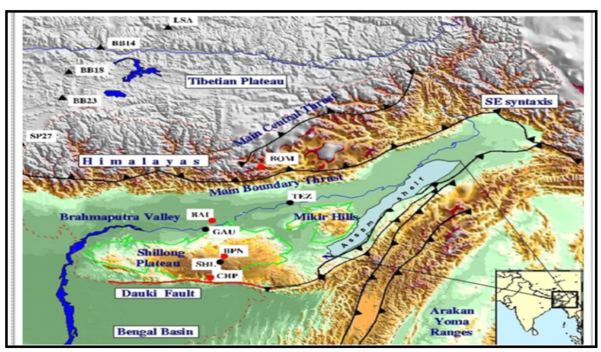

Figure: 2 Tectonic Map of Assam and Assam Arakan Basin

Rudra Sagar field is situated in Upper Assam shelf (Fig. 3). It is under commercial production since 1966. So far 80 exploratory and 113 development wells have been drilled to explore and exploit Barail Main Sand which is the principal pay in this area. Most of the inplace hydrocarbon reserves have been established in oil bearing BMS-BCS-I pays, apart from these, small gas pools in BCS-VIII and oil pool in TS-4 have also been established.

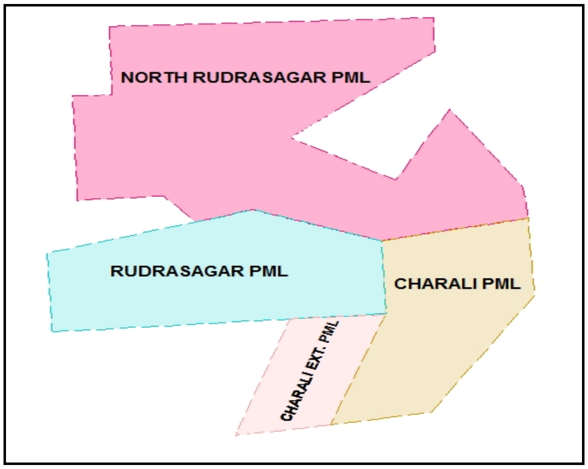

Figure: 3 Rudrasagar PML Area

Depositional Environment of TS-4

The TS-4 reservoirs are deposited as a channel fills within LCM (Lower Clay Marker) flood plain deposits. The individual TS-4 channel sands are thin to moderately bedded and are classically encased within otherwise the thick LCM clay/claystone sediments in entire North Assam Shelf area. However, the intensity of channel activity was lesser with shorter duration within LCM compared to its overlying and underlying multi-storied sand units. The prevalence of an overall low energy system, at places leads to total absence of reservoir facies due to pinching out and or facies deterioration of TS-4. This brings out a stratigraphic aspect in exploration of TS-4 along with the structural component. The geological occurrence of such intervening thin clastic reservoirs provide excellent trap for hydrocarbon pools in fault associated structural ridges.

The LCM-TS-4 pack play targeted in the present study, is a low resistivity shale-sandstone marker sandwiched between the thick braided sandstones of TS-3 and TS-5. This unit can be correlated over the entire North Assam Shelf area with significant variation in thickness. Two correlatable sand packs (TS-4A and TS-4B) and some smaller sand units (TS-4C) have been identified so far. Thickness of LCM-TS-4 pack ranges from 30m to 45m in Rudrasagar area. In log motifs, the sands show fining up cycles in channel margins and box-type pattern along channel axes. In these units of sands TS-4B is the most prominent. One east-west log correlation profile of wells W-A, W-M, W-F, W-D & W-D has been shown (Fig. 4 & 5).

The main characteristics of this type of depositional system are:

- Lower rate of subsidence with finer fore-deep facies
- Low energy system
- Lower gradient, less sediment supply
- High sinuosity channel systems
- Presence of small scale, diversified channel network & other flood plain features
- Dominance of finer clastics
- Formation of point bars & flood plain environment deposits, viz. Crevasse Splay, Overbank deposits etc.
- Resultant sand bodies are laterally discontinuous with varied orientation & facies variation

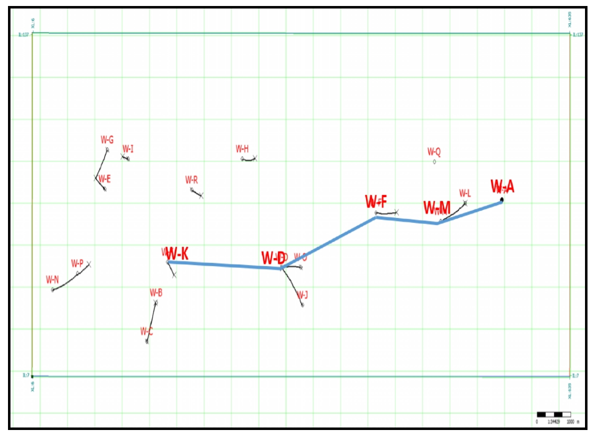

Figure:4 Basemap

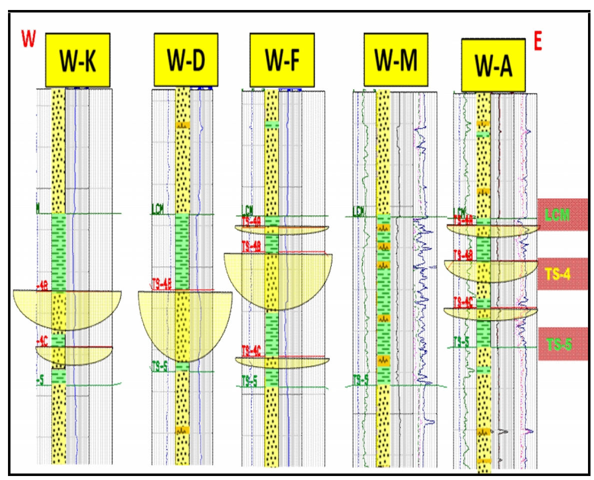

Figure:5 depositional Pattrern of TS-4

Net Sand iso-lith map of TS-4 has been prepared in study area summing up all sand packs within LCM and TS-5. In study area TS-4 sand thickness ranges from 0-22m (Fig. 6).

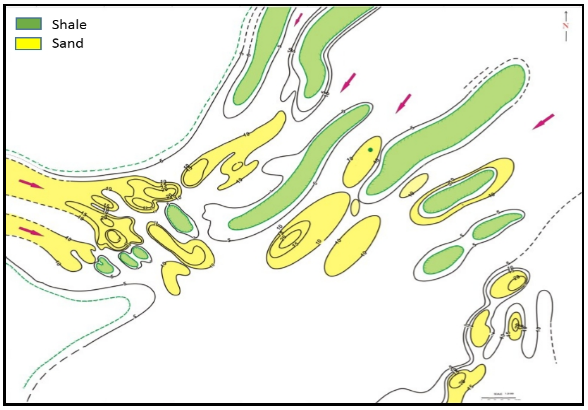

Figure: 6 Isolith map of TS-4 Sand

Challenges

The challenges of finding hydrocarbons in this type of reservoir facies are:

1. Capturing of reservoir distribution, or channel network identification
2. Better chance of strati-structural entrapment of hydrocarbons.

As reservior sands are thin and discrete, we have attempted seismic attribute analysis along with post stack seimic inversion for better deliniation of reservior facies.

Methodology

Data used

The study area is covered with 3D seismic data. Seismic volume has been processed at 2ms sample interval having grid geometry of 25m X 25m. Eighteen wells have been used in the study (Figure 4).

Theory

LCM pack is sandwiched between TS-5A sand below and TS-3 sand at top. TS4 sands of Middle Miocene age are developed within LCM (Lower Clay Marker) shale pack as thin & discrete sands. LCM shale is having character of low impedance whereas TS3, TS4 & TS5 sands are high impedance sands. Seismic response of TS-4 sands is embedded in trough generated at LCM top. Presence of TS4 sands create low amplitude anomalies in LCM top seismic response due to destructive interference *(Anoop Singh et al. 2015)*. These low amplitude anomalies are good indicator of presence of TS4 sands within LCM shale. This phenomena is explained in Fig. 7. Lowering of amplitude due to presence of TS-4 sands can be observed in seismic section shown in Fig. 8.

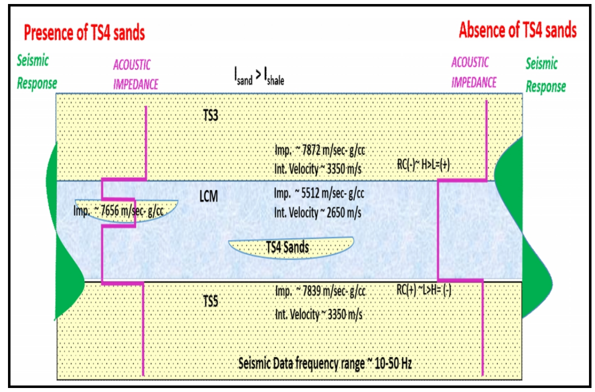

Figure: 7 Low Amplitude Anomaly Model

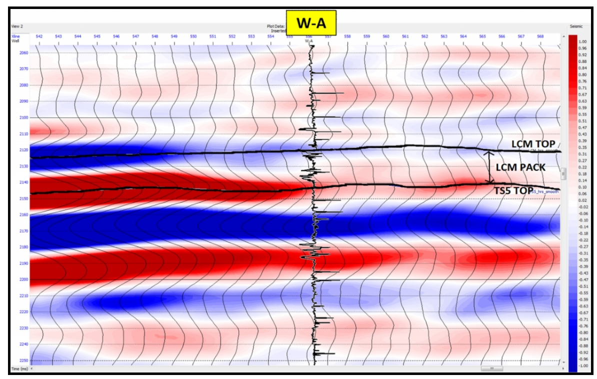

Figure: 8 Seismic Section

Discussion

Window based seismic attribute map, were generated. RMS amplitude has been extracted along LCM top horizon (+/- 8ms) for identification / differentiation of facies (Fig. 9). Low amplitude values are indicating presence of channel sand. Channels are entering into the study area from north and are conforming to regional thickness variation distribution patterns observed in interval map of TS-5 top & LCM top derived from seismic data.

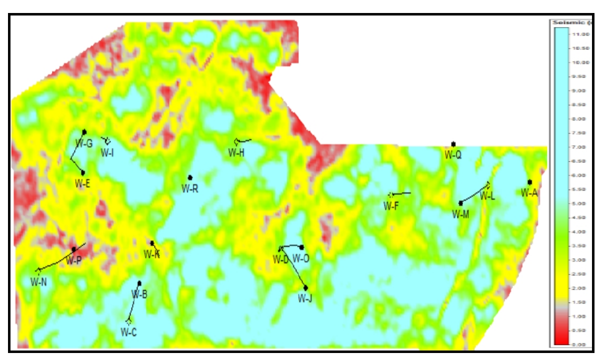

Figure: 9 RMS Amplitude

TS-4 sands are high in acoustic impedance to incasing shales. When AI logs cross plotted with gamma ray it has been observed that presence of TS-4 sands can be distinguished on the basis of its high AI property. Sand shale saparation has been observed in crossplot as sand is showing character of high impedance and low gama ray count (Fig.10). On basis of this, post stack seismic inversion has been attempted for better delineation of sand geometry.

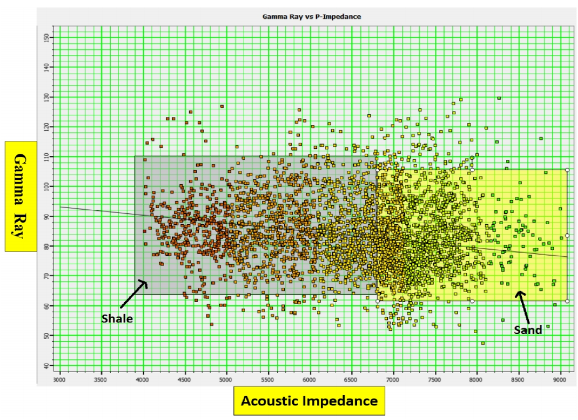

Figure: 10 Cross Plot of P-impedance Vs. Gamma Ray in LCM Pack

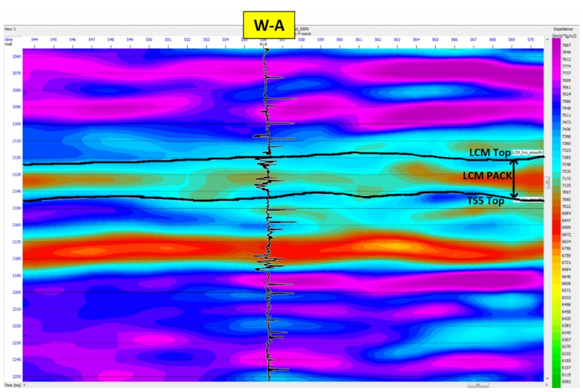

Figure: 11 Acoustic Impedance Section

Results and validation

Acoustic Impedance volume has been generated through post stack seismic inversion technique (Fig. 11). Absolute integrated amplitude map from inverted impedance volume has been generated using window of LCM Top & TS5 Top (Fig. 12). In this map red is indicating high AI representing channel sands and blue is indicating low AI representing shale. Zoomed part is also shown in Fig.12. In Rudrasagar field discontinuous meandering channels are clearly visible. In left part of Rudrasagar field, presence of TS-4 sands in LCM pack is more because of high rate of shifting of channels.

To validate our results, sand isolith map prepared from well data was overlaid on impedance map. It is observed that isolith map is very well matching with of acoustic impedance map (Fig.13).

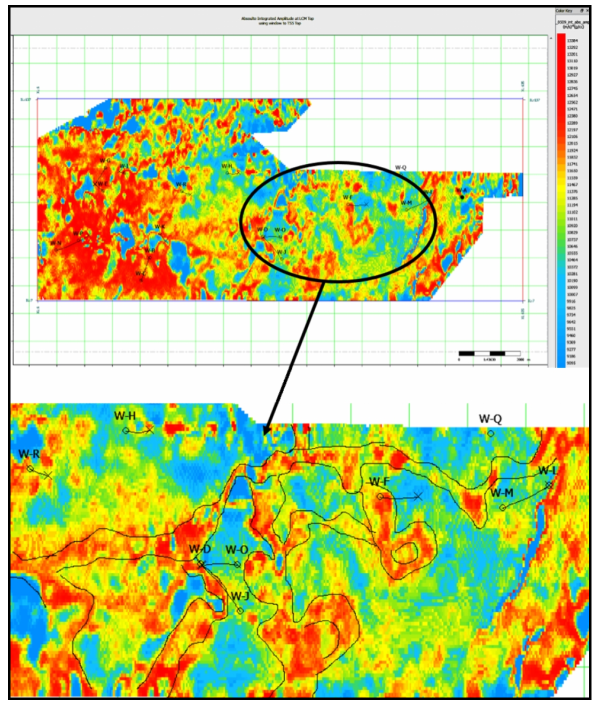

Figure: 12 Acoustic impedance map (Absolute integrated amplitude, Window: TS-5 top to LCM top) from inverted impedance volume and its zoomed portion

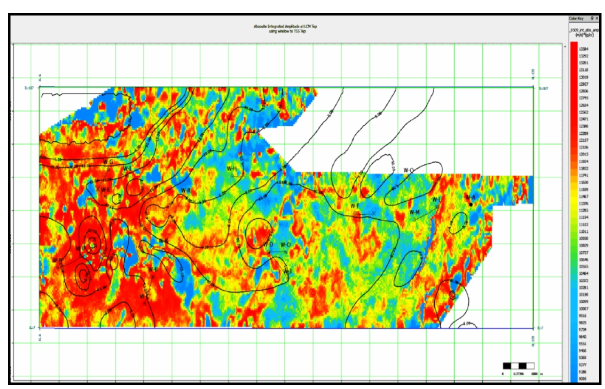

Figure: 13 Acoustic impedance map (Absolute integrated amplitude, Window: TS-5 top to LCM top) from inverted impedance volume overlaid with sand isolith map

Cross plot has been generated between TS-4 sand thickness at drilled well locations vs. computed impedance value generated from inversion at particular well location. We found that prediction of sand thickness is possible when it is more than 10m thick and corresponding impedance values are more than 7000 m/s*g/cc (Fig.14).

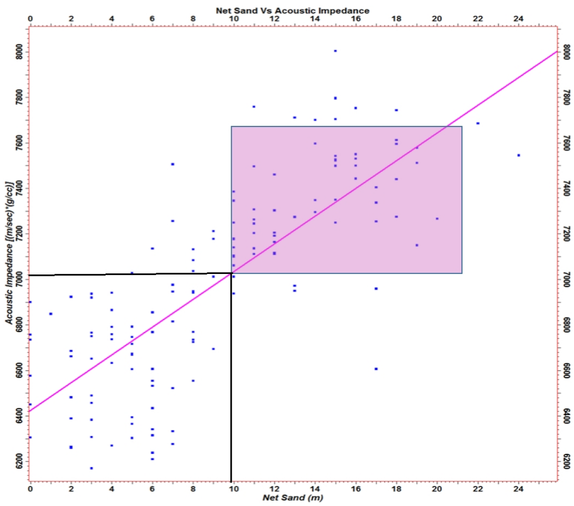

Figure: 14 Cross Plot- Net sand Thickness Vs. Acoustic Impedance

Conclusion

To obtain few plausible solutions to identify the reservoir geometry of thin and discrete TS-4 sands, Post Stack Seismic Inversion has emerged as an excellent tool. The combined interpretation of various inverted sections and window based attribute maps helped in identification and mapping of channels systems. In most of the cases, the emerged reservoir geometry is in tune with well data.

Seismic inversion results are showing better delineation of reservoir facies than RMS amplitude generated from seismic data. In inverted results, channel geometry is distinct and honouring well data.

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