P 036

Integrated "Modified Inversion" approach to improve Litho-Facies mapping in clastic reservoirs in Kalol reservoirs, Cambay basin

*Surajit Gorain**

Summary

With major oil and gas discoveries diminishing in number, industry is turning its attention to redevelop fields with poor reservoirs like silts which have otherwise been accorded lower priority earlier. It has always been a challenge to identify the locales with better reservoir facies development in un-drilled areas of a field and most often many development wells either go dry or turn out to be poor producers, significantly increasing the cost of production from a given field. "Kalol Field in Cambay Basin is a several decades old discovery with a significant number of development wells. However the oil recovery remained hardly around 25% (approx.). Most often, the contributing factor for this low recovery factor is poor reservoir facies (tight silts) within the major producing sequences like Kalol IX and Kalol X. Identifying areas of better reservoir facies remained a challenging task before the geo-scientists.

"Seismic Inversion" (through Sonic Log) has been in vogue for many years now as a litho-facies prediction tool , it is often observed that Sonic Log alone is not fully effective in resolving the subtle differences between clastic facies like Silty Sand, (which often turns out to be productive in Kalol Field) and Silty Shale etc. Conventional seismic inversion has been modified through an integrated approach to overcome this challenge of facies mapping in Kalol IX & X.

It is known that Gamma Ray Log is very effective in differentiating subtle vertical variations in clastic lithofacies in wells. Keeping this in view, an attempt is made to integrate the GR(Gamma Ray), RT(True Resistivity) and DT(Sonic) values against the reservoir section in Kalol Pay in a Cambay Basin with seismic character and develop a "Modified Inversion" method to identify the areas of better reservoir facies within the productive sequences in the field." This innovative and integrated approach to locate the areas of better reservoir facies in a field through seismic data greatly helps in improving the success rate, fluid recovery from the field and finally the economics of the investments.

Keywords: *Seismic Inversion, Reservoir Characterization, Modified Inversion, Structural Modeling, Log Correlation etc.*

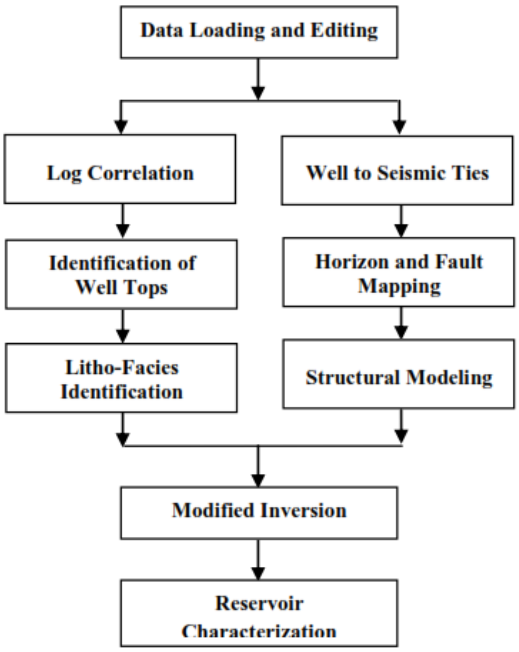
Approach

In Kalol Field of Cambay Basin a series of thin clasti reservoir are sandwiched between Kalol-IX and Kalol-X.These multi-pay sands are very thin and exhibited several lateral lithological variation. Seismically these layers difficult to resolve because of following reasons

- The reservoirs are very thin(~ 2 to-8 m),whichare beyond seismic resolution.
- Overlying and underlying coals mask the seismic wave leading to lowering in seismic frequency.
- The log property of the reservoirs sandwitched between coals are also effected because of coal property.

A Integrated “Modified Inversion” approach has be edeveloped to map the Litho-facies variation with-in th Kalol reservoir. The workflow adopted is shown below-

(Prize Petroleum Company Limited,New Delhi (A wholly owned Company of HPCL))
Email: sgorain@gmail.com



Case Study

To validate the workflow a small marginal field in Cambay Basin is identified and the above approach is adopted to identify the areas of better reservoir facies within the productive sequences in the field to enhance the productivity.

Data Loading and Editing

The field considered here have full coverage of 3D PSTM seismic data and 5 wells.Gamma Ray (GR) and Resistivity Logs (RT) are available for all the five wells,but Sonic Log(DT) and Density Log are available only for three wells (Well-A, Well-B & Well-C).Out of the five wells, only "Well-A" gives oil production of the order of 10-15 M3 /d whereas other wells produce at very low rates(1-1.5 M3/d).

To enhance the S/N ratio the seismic data the seismic cube is processed through Structural Smoothing. Despiking and 1st order Smoothing is done to overcome the effect of one point anomaly in the log data.

Well Correlation and Identification of Well Tops

Detailed Log correlation has been carried out based on the Log charateristic and Mud log data.Three Well Tops(K-IX Base, With-in IX-Xand K-X Top) are marked within the reservoir sequence.

Litho-facies identification

Major litho-facies units (like Good Reservoir, Moderate Reservoir, Non Reservoir and Coal)are identified and a Litho-facies log has been mapped for each well in the Reservoire sequence. Figure 1 depicts the worked-out Litho-facies for all the five wells. The Silty-sand layers within Kalol formation, namely Kalol-IX and Kalol-X (Middle to Upper Eocene age) are the main hydrocarbon bearing reservoirs

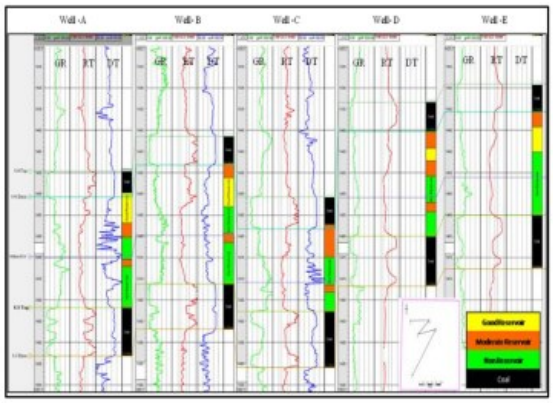


Fig.1: Well Correlation and Facies Log

Well to Seismic Tie

Utilizing the available DT, Density logs and correlated well tops well-to-seismic tie has been carried out and the corelated well tops are placed in the seismic to map the seismic horizons namely (K-IX Base, With-in IX-X and KX Top).

It is evident from the seismic section that it is difficult to map the reservoir between Kalol-IX and Kalol-X only from seismic because of vertical resolution limit.

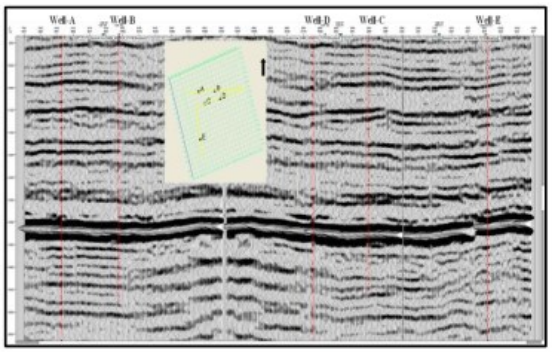


Fig.2: Unintepreted Arbitrary Seismic Line passes through wells.

Horizon and Fault Mapping

Horizons and faults are tracked through out the volume and Time Structure maps of each hozions are generated.

Structural Modeling

Using mapped horizon and faults, Pillar Gridding and Fault Modeling is done. RMS velocity cube is used for Velocity Modeling. Based on the log signature 10 and 8 layers are incorporated between K-X Base & With-in IX-X and Within IX-X & K-X-Top respectively. Finally depth converted Structural Modeling done using Velocity Modeling.

It is observed that the Well-E located in the southern part of the field is structurally highest at Kalol level and the remaining four wells in the northern part of the field are relatively at a lower level, with Well-C as the deepest at Kalol level.

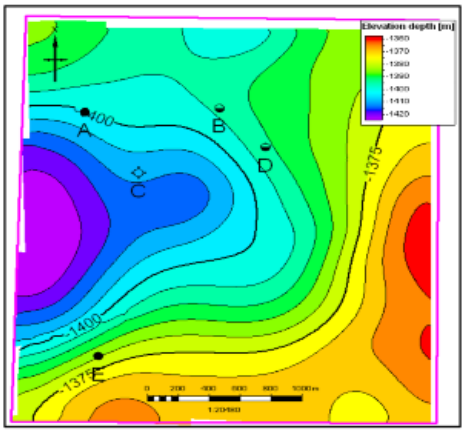


Fig.3: Depth Structure Map of K-IX Level

Modified Seismic Inversion

"Modified Seismic Inversion" is an integrated approach where Seismic character is correlated with log property to calculate the 3D attributes volume through Genetic Inversion algorithm (available in Petrel Software in Volume attribute Module). In the above workflow Seismic amplitude is cross-correlated with GR, RT and DT log and 3D attribute volume of GR, RT and DT is calculated using Genetic Inversion algorithm. As an output of the process it gives a 3D Attribute volume and a synthetic curve of the log property (GR, RT and DT). This is an iterative process. To overcome the effect of overlying and underlying coal layers in the synthetic logs GR,RT and DT these are cropped within the reservoir sequence and the above process is repeated until a good matching is observed between the actual and the synthetic logs. Using the Velocity model Depth conversion of the final calculated 3D attribute volume (GR, RT and DT) is done. Finally Seismic resampling is done to distribute the attribute property (GR, RT and DT) in the Structural grid and hence an Inverted Cube of GR,RT and DT is generated.

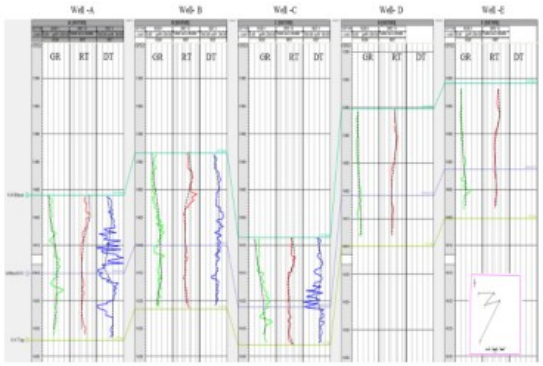


Fig.4: Comparison with the actual/synthetic curves.

The black dotted curves are the synthetic curves generated from the Modified Inversion.

Segmentation

It is observed that GR value ranges from 65 to 85 API units in Well-A, Well-B& Well-C wells; it ranges between 45 and 55 API unit in Well-D&Well-E wells. Generally GR does indicate some characteristics of the provenance from which the sediment is derived. Thus it is surmised that there is a possibility of two different streams bringing in the sediment from two proximal but distinct provenances.

Thus for the purpose of mapping the litho- facies within the target sequences through "Modified Inversion Approach", the Block has been considered in two separate segments, the Southern part comprising Well-D & Well-E and the Northern part comprising Well-A, Well-B & Well-C wells. It is to be noted that this segmentation has no tectonic significance and it is only for the purpose of litho-facies mapping.

Reservoir Characterization

Based on "Modified Inversion" approach as depicted in the above workflow the reservoir and non reservoir is classified mathematically using the Inverted cube(GR, RT and DT). The following logic have been applied to map the reservoir and non-reservoir-

Reservoir in the Northern Segments
RE north=if ((GR<=85) and RT>=10), Reservoir, otherwise Non Reservoir)

Similarly

Reservoir in the Southern Segments
RE south=if ((GR<=60) and RT>=4), Reservoir, otherwise Non Reservoir)

Point to be noted that the cut of value of the different logs are identified based on the value range of the available wells. This will vary from field to field.

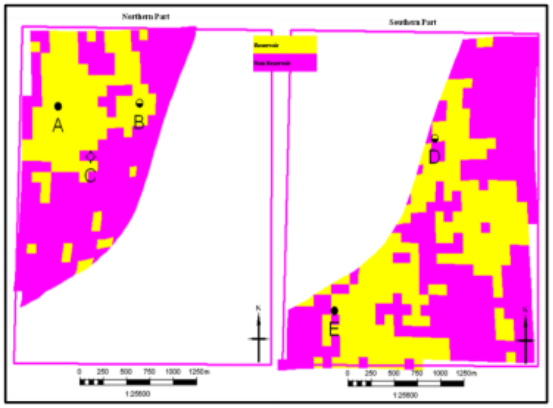


Fig.5: Reservoir distribution Map for Northern and Southern Part

The figures above show two different sets of clusters of reservoir exist within the area which are genetically different as per their property.

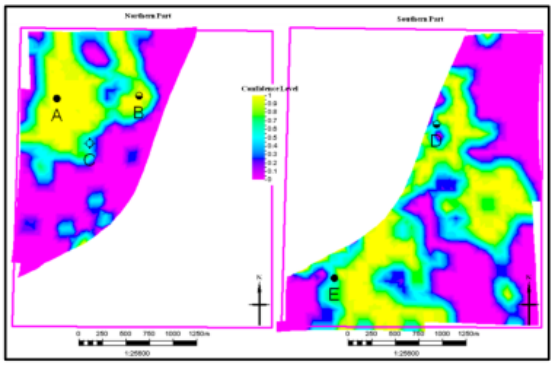


Fig.6: Probability distribution map of Reservoir and Non-Reservoir along the Kalol-IX base.

The figure above shows the reservoir distribution the Kalol IX Base level with degree of certainty. The yellow color represents the most certain reservoir and pink is non reservoir.

Conclusion

"Modified Inversion" approach gives a way to delineate the thin reservoir beyond seismic resolution.

Using this approach it is possible to generate 3D volume of GR, RT, DT and other conventional well logs of the study area and thereafter those inverted 3D volume can be used for Reservoir Characterization.

"Modified Inversion" approach gives a probability distribution map of Reservoir/Non Reservoir which may indirectly give the reservoir limits and may help in planning future drilling locations.

This innovative and integrated approach to locate the areas of better reservoir facies in a field through seismic data greatly helps in improving the success rate, fluid recovery from the field and finally the economics of the investments.

Acknowledgements

Author is grateful to Prize Petroleum (a wholly owned company of HPCL) for providing the necessary information and infrastructure facilities to carry out this work.

Author acknowledges his sincere thanks to Mr. Syam Sundar Yalamarty advisor Prize Petroleum for his valuable guidance & Mr. M K Surana, CEO Prize Petroleum for according permission to publish this work.

References

Bose, A.,Singh, V., Tandon, A.K., Josyulu, B.S. & Chandra, Manish, 2004, Stratigraphic and Lithologic Interpretation of Thin Reservoir through an Integrated Approach: A Case Study, PP 742-751, Expanded abstract, 5th Conference & Exposition on Petroleum Geophysics, Hyderabad-2004, India.

Chandra, Mahesh, Srivastava, A. K., Singh, V., Tiwari, D.N., Painuly, P.K., 2003, Litho-stratigraphic Interpretation of Seismic data for reservoir Characterization: Expanded abstract, APPG international conference Barcelona, Spain, Sep 21-24, 2003.