The objective of building a model with necessary details to characterize vertical and lateral heterogeneity at the well, multi-well, and field scale, required the model to be finely layered with relatively small XY cell dimensions. Accordingly a 192498120 million cell model was built having 570 layers of 1.5 m average thickness and a grid dimension of 100 x 100 m the small XY-cell dimensions facilitated extraction of portions of the model for local reservoir simulation. Next, the well logs were upscaled using appropriate averaging methods to assign values to cells in the 3D grid penetrated by the wells. Due to lack of sufficient well data the upscaled facies logs alone could not be used to create the facies model. Hence building a more realistic facies model necessitated the use of densely sampled seismic attribute data for better propagation of facies in the inter-well areas. Seismic impedance volume was generated by inversion of the available 3D seismic data. Since no correlation could be obtained between seismic impedance and petrophysical attributes at known well locations it could not be used directly as an input to modeling. Hence it was decided to incorporate seismic attribute maps as soft constraints to guide the distribution of facies spatially within the facies model while the vertical variability is defined by the well logs and vertical-variogram models.

Accordingly average seismic impedance maps were extracted from the seismic-impedance volume over required depth intervals (Fig. 5).

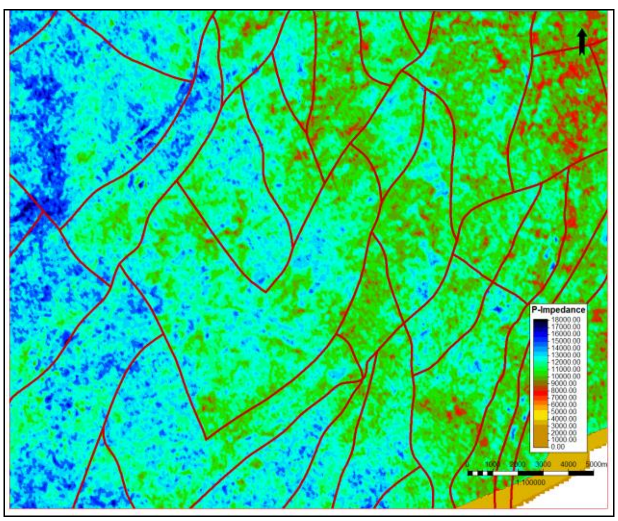

Figure 5: Average seismic impedance map

These averaged seismic impedance maps were converted to facies probability maps. These maps show relatively high probability at the well locations where good reservoir facies are present and low probability in case of absence of reservoir facies and honor the areal distribution of the facies (Figure 6).

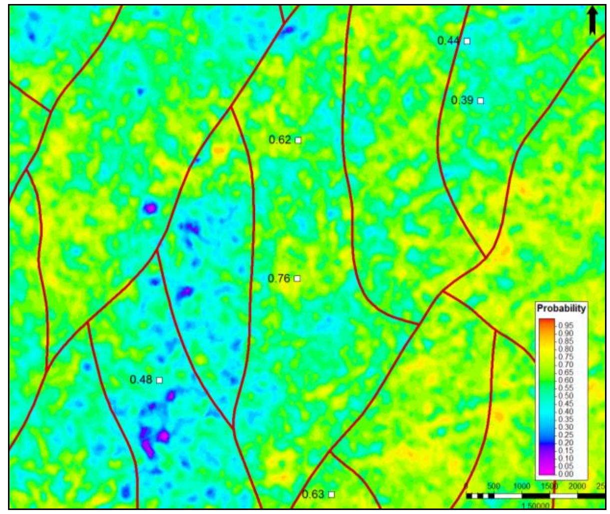

Figure 6: Facies probability maps showing areas of high and low facies probabilities

However in order to capture the vertical variation in facies these maps were integrated with well log data and Vertical variogram models (Figure 7) using stochastic facies modeling technique known as sequential indicator simulation (SIS) available in PETREL software.

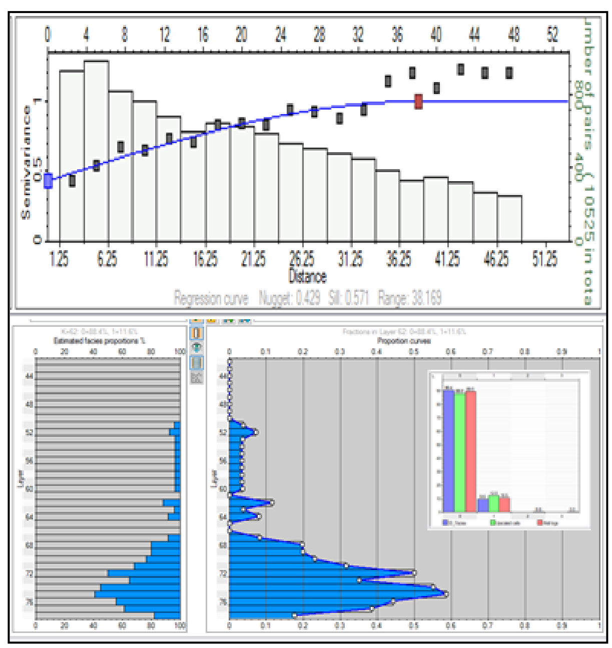

Figure 7: Vertical Variogram, Vertical Proportion Curve and Histogram showing distribution of Upscaled and log data.

Some variations may have been introduced as a result of difference in scale of seismic and well log data. This facies model was then used as a constraint for guiding the properties in the petrophysical modeling workflow available in PETREL software. Seismic constrained model provides a more detailed and accurate distribution of reservoir properties as compared to the well-based model (Figure 8).

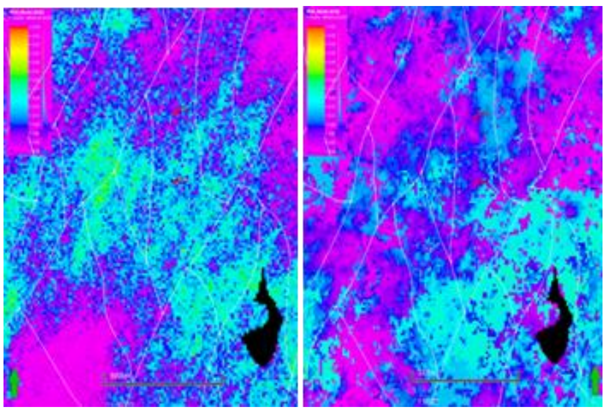

Figure 8 Distribution of reservoir properties of well-based model compared with Seismic constrained model

Subsequently the resulting multiple equiprobable models of reservoir properties were subjected to reservoir simulation studies without upscaling in either vertical or horizontal direction.

Reservoir Simulation

Available SCAL and PVT data was used to initialize the model. While the well test data was utilized for generating the permeability transform which was further scaled up to match the production behavior. The reservoir simulation studies produced a good history match with the use of minimum modifiers validating the distribution of properties within the model and generated ample confidence in planning future development strategy for optimized production. Subsequently, development scheme was formulated by targeting the good hydrocarbon saturation locales left at the end of history match in the model and well inputs from the existing platforms were identified for targeting Panvel, Mukta and Basal Clastic reservoir with additional facilities.

Examples

Structural uncertainties may be introduced in the structural geological model due to input data quality or insufficient geological or geophysical information. These structural uncertainties may have a direct impact on exploration, development, and production, and in well placement decisions. Presented here is the case of structure B-10 where the acquisition of 3D seismic broadband data resulted in addressing the structural uncertainty and helped in planning well locations for developing the structure (Figure 9).

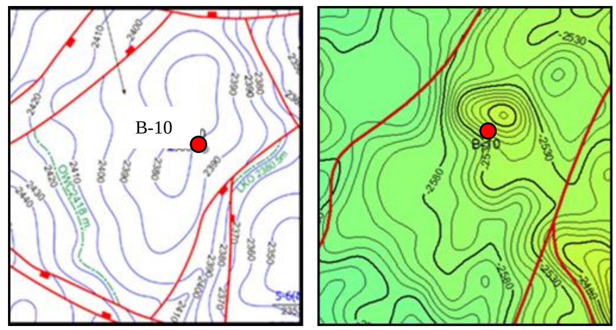

Figure 9: Structure contour maps of B-10 structure showing variation in structural configuration.

As per the earlier seismic data the geological model prepared showed the B-10 structure to be extending in the N-S direction and covering almost the entire fault block but when the new 3D seismic broadband data was used the structure was restricted to a very small area towards NW of well B-10 this also resulted in significant reduction of estimated volumes. The new structural model not only reduced the risk by addressing the structural uncertainty but also helped in preparation of an optimized development plan with better placement of wells.

Another example from B-1 structure demonstrates how integration of seismic data has led to significantly improved accuracy of reservoir model and helped to reduce uncertainties in predictions away from wells. The seismic attribute maps at different pay levels show the distribution of better impedance in the southern and western part of the structure which is also reflected in the facies model as seen from the average facies maps extracted at different pay zones (Figure-10)

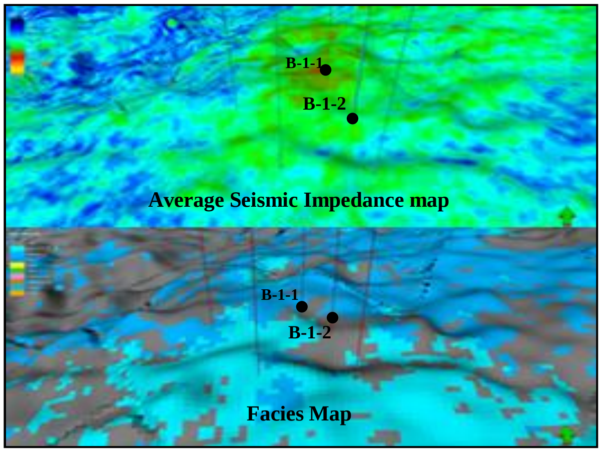

Figure 10: Average Seismic impedance map and average facies map showing spatial distribution.

Production performance of the wells B-1-1 and B-1-2 further corroborates the fact that facies in this part of the reservoir is poor. Facies architecture across the B-1 field obtained from the seismically constrained model serves as an excellent guide in firming up the development locations and also for better reservoir management.

In structure B-5 the seismic broadband data was again able to reduce the structural uncertainty and demonstrated the structural configuration which was different as compared to the earlier interpretation thereby giving more realistic estimates of the in-place oil and better control in well placement (Figure-11).

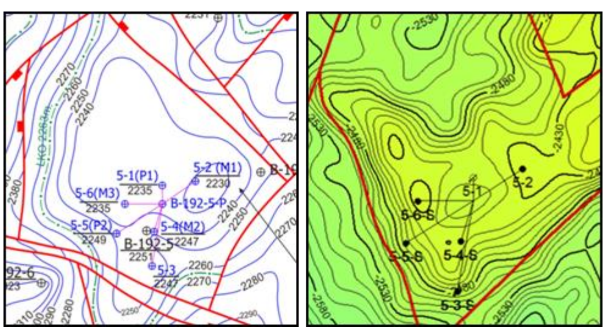

Figure 11: Structure contour maps of B-5 structure showing variation in structural configuration.

Apart from addressing the structural uncertainty the average seismic impedance map indicated distribution of moderate to good impedance values towards Northwest of the platform B-5. Keeping this in mind one location B-A has been proposed between B-5 platform and well B-10 which once drilled will add more confidence to the present geological model. Also moderate to good impedance values were observed in the South and East of B-5 platform in Lower Bassein pays hitherto not very promising in this block (Figure-12).

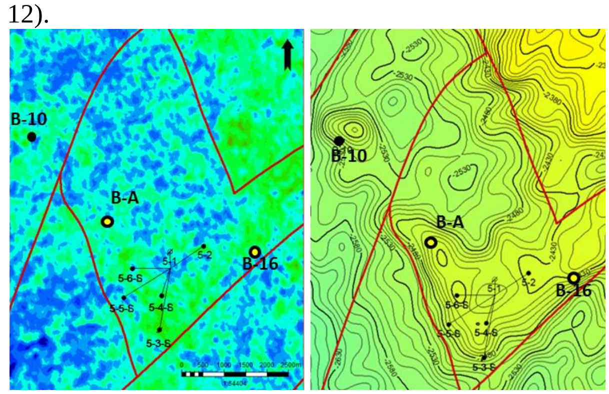

Figure 12: Average Seismic impedance and structure contour maps of B-5 structure showing Location B-A & B-16.

Subsequently an exploratory well B-16 was drilled in this part for exploring the lower pays and encountered very good development of Bassein pay as anticipated by the average impedance map. This pay was tested and produced about 3000 BPD oil authenticating the distribution of properties as envisaged. This further validated the use of seismic constrained static model for predicting well locations for preparing the future development plan.

Conclusions

In early stages of field development, inadequate petrophysical data makes it difficult to reasonably assess the actual reservoir properties. However, assimilation of additional constraints, such as 3D seismic data and geological concepts, can significantly improve the accuracy of reservoir models and help reduce uncertainties in predicting the spatial distribution of petrophysical properties within heterogeneous reservoirs.

An integrated approach for incorporation of 3D seismic information in the geological model of a carbonate, oil reservoir is demonstrated resulting in a model capable of estimating reliably the in place volume, their distribution and predicting the flow dynamics of the reservoirs.

Integration of seismic data not only reduces the uncertainty in spatial distribution of properties but also provides better control on structural configuration minimizing the associated risks.

Significantly improved reservoir description based on seismically constrained models can considerably improve the quality of the reservoir simulation and enhance its reliability to predict reservoir performance and make optimized development plans.

References

Sheldon B. Gorell,* Western Atlas Software, Creating 3-D Reservoir Models Using Areal Geostatistical Techniques Combined with Vertical Well Data, SPE 29670

Tingting Yao, Integrating Seismic Data for Lithofacies Modeling: A Comparison of Sequential Indicator Simulation Algorithms, *Mathematical Geology, Vol. 34, No. 4, May 2002*

R.A. Behrens, SPE, M.K. MacLeod, T.T. Tran, SPE, Chevron Petroleum Technology Co., and A.O. Alimi, SPE, Chevron Nigeria Ltd,. *SPE Reservoir Evaluation & Engineering, April 1998*

H. H. Haldorsen and E. Damsleth, "Challenges in Reservoir Characterization," *AAPG Bulletin*, Vol. 77, No. 4, 1993, pp. 541-551.

Internal unpublished reports of ONGC, (2015-2018)

Acknowledgments

The authors thank the management of ONGC for giving permission to submit this paper in SPG international conference -2020. Authors do acknowledge the management of Institute of Reservoir Studies, ONGC, Ahmedabad for providing the opportunity and all necessary facilities during the course of the study.