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Research Article

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Integration of Geological Process Modeling (Gpm) For Achieving Realistic History Matching Scenarios for An Eocene Carbonate Field in The Middle Indus Basin

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Abstract
The field of interest lies within the Middle Indus Basin of Pakistan and is Southeast of the Sulaiman foredeep area. The Field is currently producing mainly from the Eocene Limestone, which represents a prolific play within the area. The Eocene Limestone represents in the region represents several carbonate buildups of different nature ranging from Reefal Buildups to Isolated Lagoonal Patchy Reef Buildups on the platform. It is important to mention here that in this case we were dealing with a Frontal Reefal Buildup. The Eocene Limestone also represents a mixed environment of open and closed systems with open systems showing some areas of carbonate buildups followed by restricted platform settings.

Keywords: Matching Scenarios, Basin, Carbonate Field, Realistic

Introduction

In this study, we are highlighting the importance of creating sequence stratigraphic frameworks and their integration with predictive Forward Stratigraphic Modeling. (Figure 1).

The Field represents a classical Reefal buildup of Eocene Limestone along with its platform settings towards the Southern Side. A geological model was prepared by integrating Post Stack Simultaneous Inversion which helped in capturing some of the reservoir quality trends of the Main Buildup facies and the platform facies however, the Seismic Inversion results could not give a valuable insight into the smaller parasequences and higher resolution details on the architecture and morphology of the Reefal buildup as observed on the well data and the indications of discontinuous facies across the Field between the multiple carbonate buildups in the vicinity as indicated from the dynamic data.

Workflow & Methodology

To solve this challenge a Two-Step Approach was used: Step 1 is where a detailed sequence stratigraphic framework was constructed using the available well data and seismic data along with the results of the seismic inversion. In Step 2 Integration of the Sequence Stratigraphic Framework with the predictive forward stratigraphic modeling approach was used to build a more representative forward model.

Based on the Sequence Stratigraphic approach 6 different parasequences were interpreted and correlated with the seismic data. The parasequences revealed the existence of better Reservoir Quality (RQ) and more importantly the connectivity of these good RQ facies around the frontal Reefal buildup for which the reservoir simulation was to be performed.

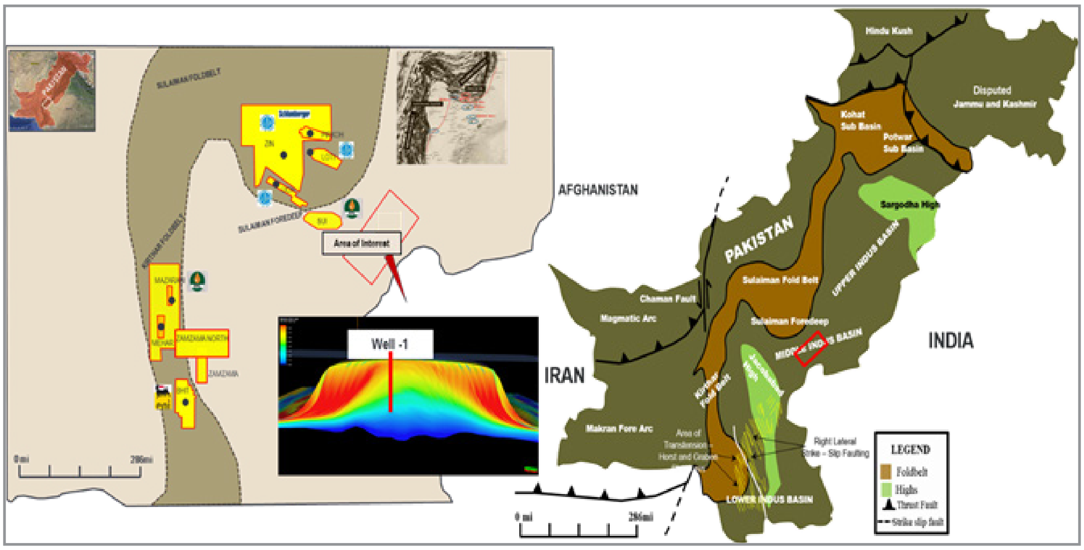

Figure 1: Location map of the Study Area highlighting the study area of the carbonate buildup on which the forward stratigraphic modeling workflow has been implemented. The forward modeled carbonate buildup is also shown with Well 1 used to calibrate the forward stratigraphic model.

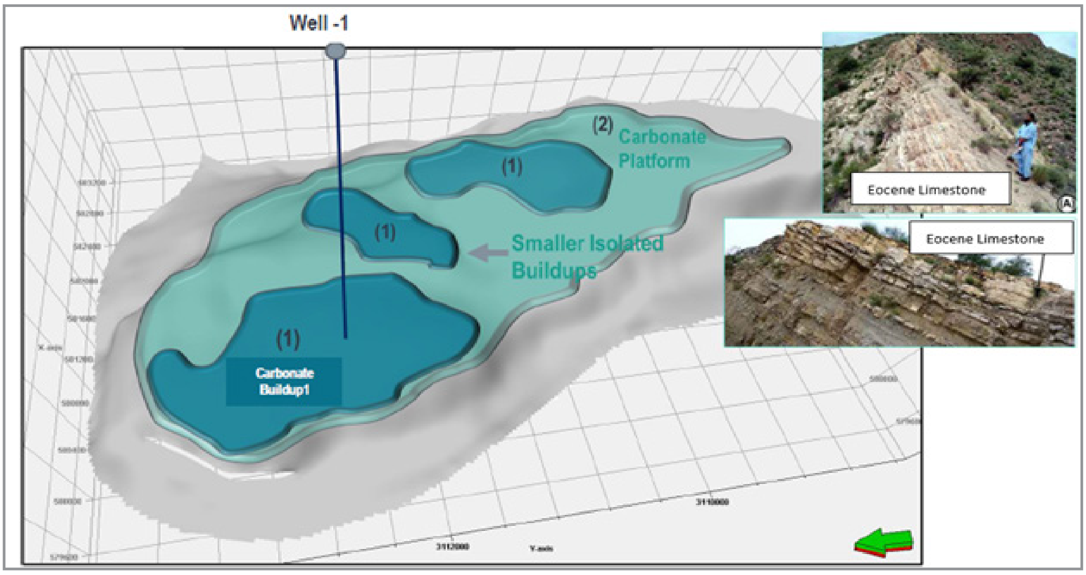

Figure 2: Conceptual framework of the Carbonate buildup which shows the main buildup for which the stratigraphic modeling was carried out using the Geological Process Modeling workflow. The main buildup is observed not to be connected with the smaller isolated buildups.

Geological Process Workflow

The Geological Process Modeling predicted the distribution of the Carbonate (Best Reservoir Quality Rock) distributed near the main buildup where the first well is drilled and is currently producing. The GPM model also predicted the Southern Build-up within the D&P lease which pointed toward the presence of another possible area for future Field Development. The main challenge during the reservoir simulation was to confirm if any connected Gas volumes are being contributed from the near vicinity carbonate buildup number 2 towards the main Reefal Buildup from which the well is currently producing. The initial history matching showed the presence of dynamic Gas support for the producing well and hence this “X” volume of Gas was to be connected to the producing well to achieve a realistic history match scenario [1].

Several attempts were made during the history matching work-flow where Reservoir Connectivity was improved by introducing High Permeability Streaks, Higher Net to Gross Connectivity, Increasing the Pore Volume multiplier, and adding extreme end Perm Multipliers on the region to reproduce a reasonable history for the producing well. With all the editions a History Match was obtained on the Geostatiscal driven model which was integrated with seismic inversion results but at the cost of adding pseudo variables. This was a point of challenge where without adding pseudo dynamic adjustments a reasonable History Matching was not obtained.

Forward Stratigraphic Model Prediction

At this point, a Geological Processing Modeling simulation was performed which showed two remarkable differences to the previous geological model. The first difference was that the GPM simulation predicted a higher connected volume around the Frontal producing buildup and the second difference was it showed the presence of good quality facies mainly the core Reefal part around the producing well compared to high RQ variation from the seismic inversion results. As a result, the dynamic simulation was performed on the GPM driven model this time and it not only helped in achieving a realistic history match but also did not require any pseudo dynamic variable changes which hence improved the confidence in the model predictability.

The carbonate buildup evolution shows three critical stages where in the early phases of the buildup there is slight and subtle vertical relief of the buildup whereas it progresses into more vertical evolution in the later stages which leads towards the development of zone 3, 2 and 1.

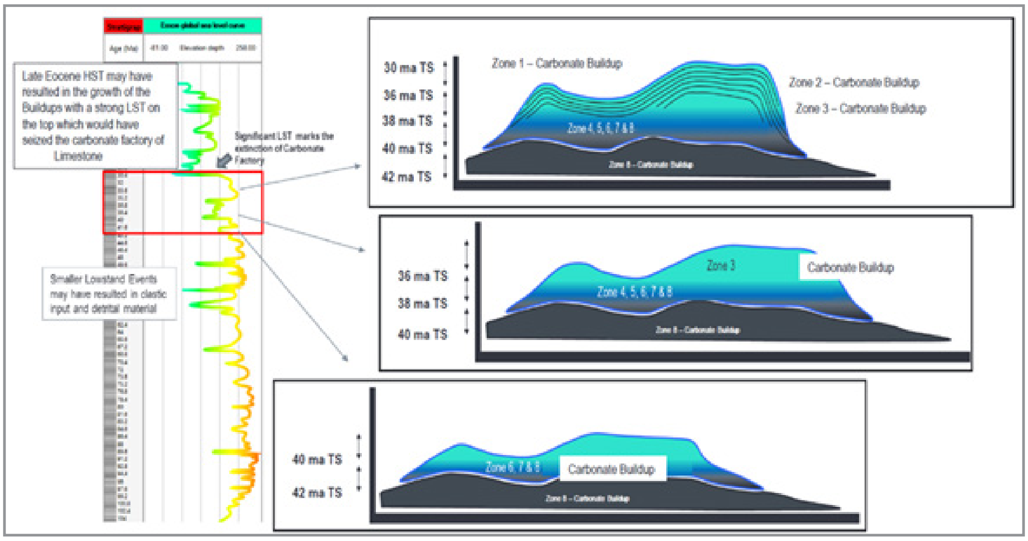

Figure 3: The carbonate factory evolution of the Main Carbonate Buildup shows the three key stages. In Stage 1 there is subtle carbonate buildup with the associated platform which is then followed by stage 2 and 3 developments which show the later carbonate favorable conditions which lead towards the vertical relief development of the carbonate.

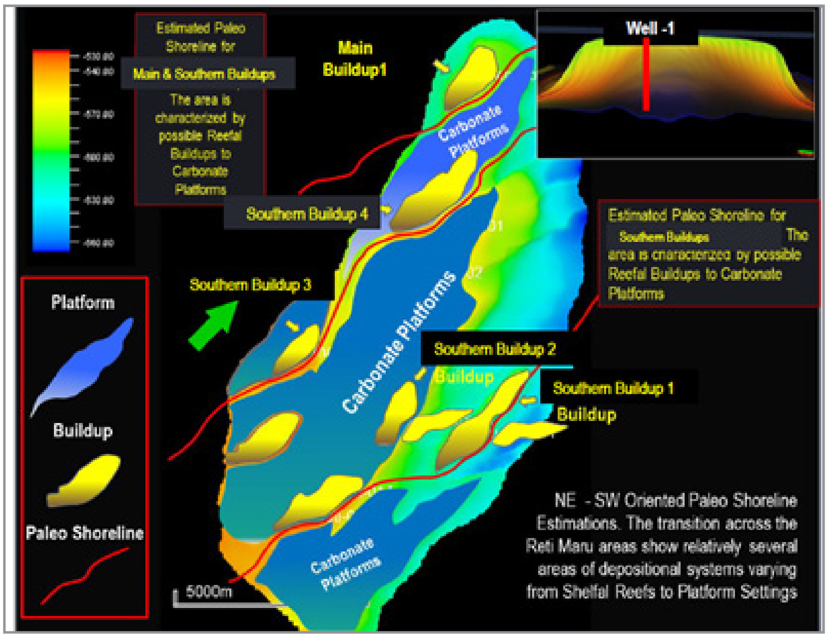

Figure 4: The carbonate factory evolution of the Main Carbonate Buildups and other smaller buildups within the platform region of the study area. It is also worth to note the isolation of the buildups where most of these are not connected.

Seismic Inversion Integration

The forward stratigraphic modeling workflow was also conditioned from the seismic inversion dataset which was used to make inferences on the forward stratigraphic model however it was observed that the seismic inversion datasets helped to a great extent in delineating the top of the carbonate buildup facies which predicted very good reservoir quality and high porosity zones within the buildup. However, the challenge which was proved to be difficult to be delineated through the seismic inversion solution was the prediction on the reservoir connectivity which was resolved through the forward stratigraphic model and hence proved by the dynamic modeling during the history matching workflow.

Connectivity was improved by introducing High Permeability Streaks, Higher Net to Gross Connectivity, Increasing the Pore Volume multiplier, and adding extreme end Perm Multipliers on the region to reproduce a reasonable history for the producing well. With all the editions a History Match was obtained on the Geostatiscal driven model which was integrated with seismic inversion results but at the cost of adding pseudo variables. This was a point of challenge where without adding pseudo dynamic adjustments a reasonable History Matching was not obtained [2].

Forward Model Physical Process

The workflow used for modeling the carbonate facies through the forward stratigraphic modeling integrated several geological physical processes which include diffusion, wave energy and carbonate modeling. It is also important to mention here that the Exxon global eustacy sea level curves was used to calibrate the forward stratigraphic model. It is important to highlight that several modifications were made to calibrate and condition the stratigraphic model.

Reservoir Connectivity

The Geological Process Modeling predicted the distribution of the Carbonate (Best Reservoir Quality Rock) distributed near the main buildup where the first well is drilled and is currently producing. The GPM model also predicted the Southern Buildup within the D&P lease which pointed toward the presence of another possible area for future Field Development. The main challenge during the reservoir simulation was to confirm if any connected Gas volumes are being contributed from the near vicinity carbonate buildup number 2 towards the main Reefal Buildup from which the well is currently producing. The initial history matching showed the presence of dynamic Gas support for the producing well and hence this "X" volume of Gas was to be connected to the producing well to achieve a realistic history match scenario.

History Matching Results

Several attempts were made during the history matching workflow where Reservoir Connectivity was improved by introducing High Permeability Streaks, Higher Net to Gross Connectivity, Increasing the Pore Volume multiplier, and adding extreme end Perm Multipliers on the region to reproduce a reasonable history for the producing well. With all the editions a History Match was obtained on the Geostatiscal driven model which was integrated with seismic inversion results but at the cost of adding pseudo variables. This was a point of challenge where without adding pseudo dynamic adjustments a reasonable History Matching was not obtained [3].

Conclusion

At this point, a Geological Processing Modeling simulation was performed which showed two remarkable differences to the previous geological model. The first difference was that the GPM simulation predicted a higher connected volume around the Frontal producing buildup and the second difference was it showed the presence of good quality facies mainly the core Reefal part around the producing well compared to high RQ variation from the seismic inversion results. As a result, the dynamic simulation was performed on the GPM driven model this time and it not only helped in achieving a realistic history match but also did not require any pseudo dynamic variable changes which hence improved the confidence in the model predictability. Therefore, the GPM model showed excellent insights on how predictive models can be used to capture subsurface heterogeneity on a more realistic scale as compared to the extensive usage of geostatistical driven models.

Acknowledgements

We would like to thank OGDCL management for giving permission for this publication allowing technical community to benefit from the forward stratigraphic modeling workflows.

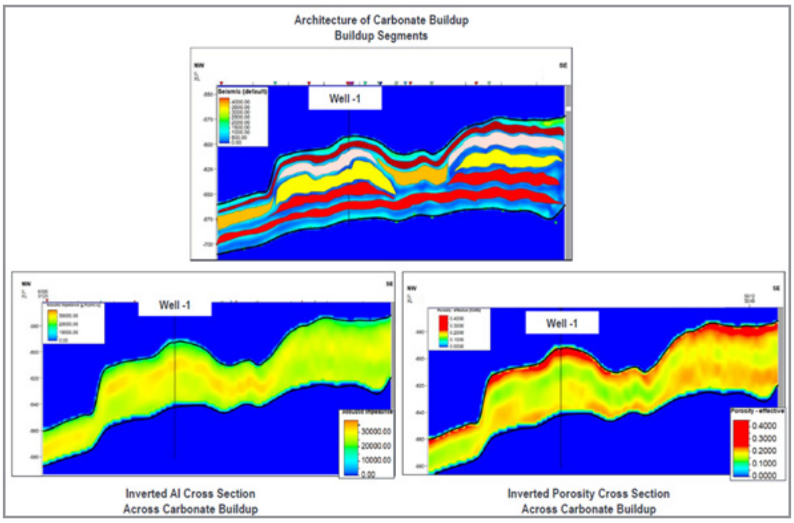

Figure 6: Seismic cross sections showing the inverted acoustic impedance and inverted seismic porosity which shows very good reservoir quality for the carbonate buildup in the upper sections whereas the seismic inversion conditioned dataset was not predictive enough to delineate the reservoir connectivity which was solved through the forward stratigraphic modeling

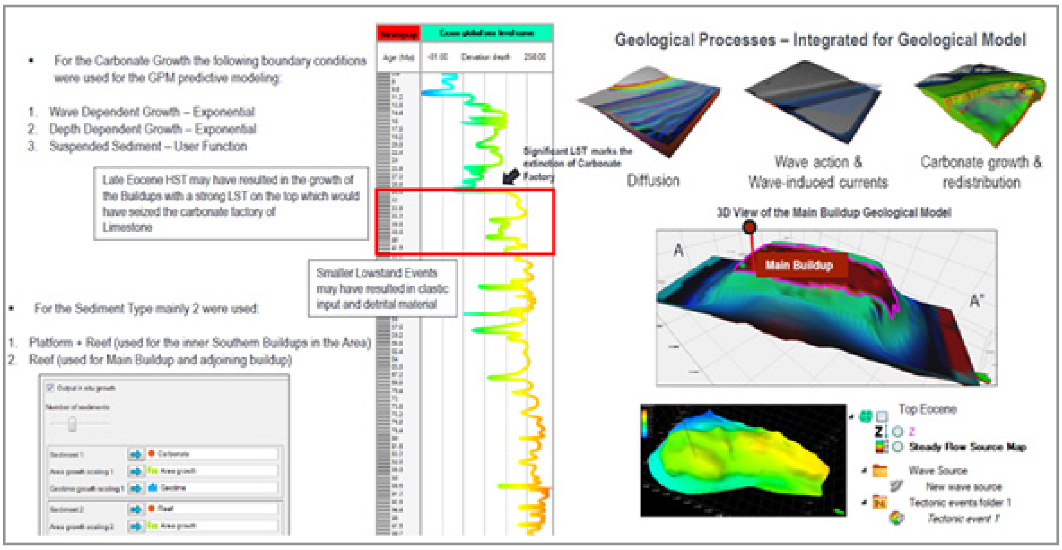

Figure 7: The forward stratigraphic modeling workflow which was used to predict the carbonate facies along with the connectivity of the reservoir facies which was modeled through diffusion, wave actions and carbonate growth and redistribution.

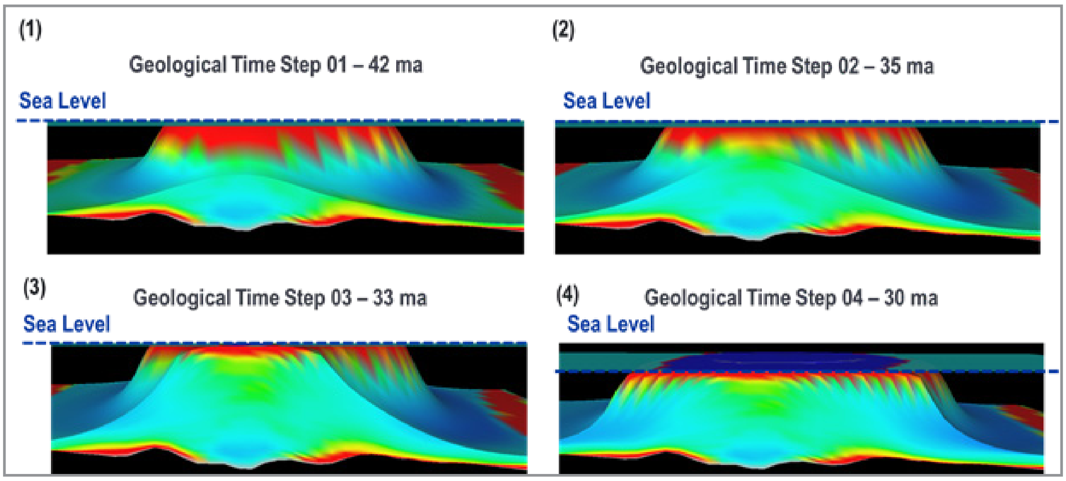

Figure 8: The forward stratigraphic modeling workflow which was used to predict the carbonate facies along with the connectivity of the reservoir facies which was modeled through diffusion, wave actions and carbonate growth and redistribution.

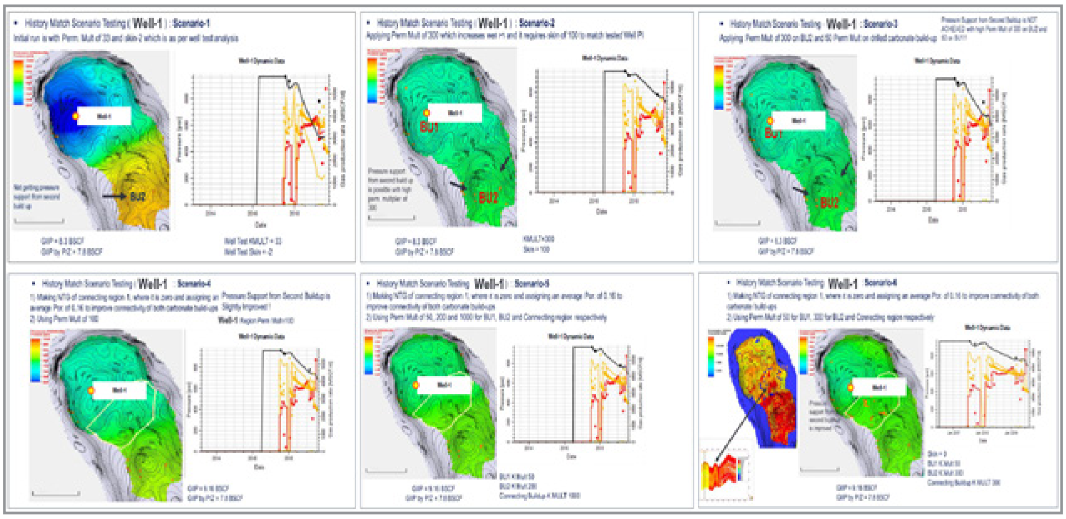

Figure 9: The history matching scenarios for the carbonate buildup shows the effects of changing dynamic variables where the history match exercise was not achieved through realistic iterations, or a history match was obtained but through several iterations on the dynamic variables leading towards very significant changes on the static properties.

About the Authors

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- **Nasir Hamim:** I am 15 years experienced Reservoir Geologist, with broad technical and commercial vision of field development and operations, having strong background in computing. The principal activities include reservoir modeling for field development, well planning, interpretation, reservoir description, reservoir characterization and petrophysical analysis. The work at Kirthar Range, Sulaiman Range and Middle and Lower Indus Basin is helping me to utilize all the concepts learned during these passed years with a better understanding of reservoir planning and development for both oil and gas fields.
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