PS Integrating Sedimentology and Quantitative Rock Physics for Reservoir Characterization and Modeling in Field Development: A Case Study of an Onshore Field in Niger Delta, Nigeria*

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Abstract

Most of the fields in the onshore Niger Delta are undeveloped several years after discovery. Among the numerous challenges that have hindered optimal development of these fields include geological uncertainties such as complex reservoir geometry, spatial and temporal variation of reservoir fluid. Hence, this study is aimed at improving the geological understanding of the reservoir systems by integrating sedimentology and quantitative rock physics for optimal field development. The objectives of this study include: to reconstruct the depositional environment of the reservoir sands, investigate the presence of stratigraphic barriers to lateral fluid variation, construct predictive reservoir model for simulation, and finally define optimal field development strategy. Analogs, core, logs, seismic, and production data were integrated in the study. The methodology and workflow for the study have combined simultaneous amplitude variation with offset (AVO) inversion, seismic geomorphology, static modeling, and dynamic simulation. Segmentation of the AVO inversion attributes including: shear impedance, lambda-rho and mu-rho into discrete facies classes revealed macro-scale sedimentary features such as barrier mouth bar and braided channel systems with crosscutting relationship on horizon slices. Evidence from core interpretation supports a bay/lagoon marginal marine environment with characteristic layer cake and labyrinthine sand geometry. The conceptualization of the sedimentary environment and the sand geometry defined from the inversion attribute characterization, formed input for constructing a predictive reservoir model. The dynamic simulation of forty years production from the reservoir model gave a match of less than 10% difference between the simulated and historical production of oil and water respectively. Consequently, a three horizontal wells case with 4-1/2 inch tubing size and 1500 inch drain length, have been selected as the most realistic option for optimal field development and oil production at 1500 barrel per day rate using gas lift recovery mechanism. Finally, the integration of simultaneous AVO inversion, attribute segmentation, and sedimentology has reduced the geological uncertainty that had hindered optimal development in the field. This integrated methodology and workflow will serve as analog in solving complex geological problems and the associated development challenges in similar reservoir systems.

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http://www.searchanddiscovery.com/documents/2013/10513yu/ndx_yu.pdf

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ABSTRACT

Most of the fields in the onshore Niger Delta are undeveloped several years after discovery. Among the numerous challenges that have hindered optimal development of these fields include geological uncertainties such as complex reservoir geometry, spatial and temporal variation of reservoir fluid. Hence, this study is aimed at improving the geological understanding of the reservoir systems by integrating sedimentology and quantitative rock physics for optimal field development. The objectives of this study include: to reconstruct the depositional environment of the reservoir sands, investigate the presence of stratigraphic barriers to lateral fluid variation, construct predictive reservoir model for simulation, and finally define optimal field development strategy. Analogs, core, logs, seismic, and production data were integrated in the study. The methodology and workflow for the study have combined simultaneous amplitude variation with offset (AVO) inversion, geomorphology, static modeling, and dynamic simulation. Segmentation of the AVO inversion attributes including: shear impedance, lambda-rho and mu-rho into discrete facies classes revealed macro-scale sedimentary features such as barrier mouth bar and braided channel systems with cross-cutting relationship on horizon slices. Evidence from core interpretation supports a bay/lagoon marginal marine environment with characteristic layer cake and labyrinthine sand geometry. The conceptual understanding of the sedimentary environment and the sand geometry defined from the inversion attribute characterization formed major input for constructing a predictive reservoir model. The dynamic simulation of forty years production from the reservoir model gave a good match within 10% difference between the simulated and historical production of oil and water respectively. Consequently, a 3 horizontal wells case with 3-1/2 inch tubing size and 1500 inch drain length, have been selected as the most realistic option for optimal field development and oil production at 1500 barrel per day rate using gas lift recovery mechanism. This development strategy will increase oil recovery factor from 7% to 35%.Finally, the integration of simultaneous AVO inversion, attribute segmentation, and sedimentology has reduced the geological uncertainty that has hindered optimal development in the field. This integrated methodology and workflow will serve as analog in solving complex geological problems and the associated development challenges in similar reservoir systems.

INTRODUCTION

Most Onshore fields in the Niger Delta are associated with development challenges, drilling and business risk (Egboga, 2011). Hence, geological uncertainties including: facies heterogeneity, complex reservoir architecture and sand connectivity, as well as lateral fluid variation have been the major challenge in characterizing fluvial and deltaic reservoirs for field development (Posamentier, 2002). Typical fluvio-deltaic reservoirs exhibit complex geometry including: layer-cake, jigsaw puzzle, shingle, and labyrinth (Yu et al., 2013). Hence, the conventional reservoir characterization method for facies heterogeneity using the simple layer-cake correlation could be unrealistic in fluvial and delta dominated environments.

OBJECTIVES

- To reconstruct the depositional environments of the reservoirs;
- To define sand geometry and correlation techniques in the study area;
- To investigate the presence of stratigraphic barriers to lateral fluid variation and;
- To build a predictive geological model for dynamic simulation and optimize field development planning.

DEVELOPMENT CHALLENGES

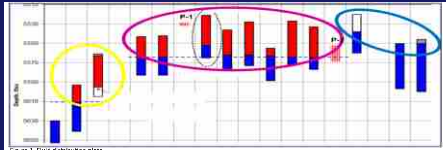

Figure 1. Fluid distribution plots

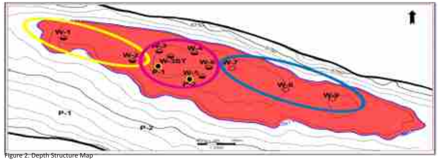

Figure 2. Depth Structure Map

*Optimal full field development was not possible after 40 years of oil discovery due to poor understanding of subsurface geology and trapping mechanism as shown in Figures 1 & 2

INTEGRATED WORKFLOW AND METHODOLOGY

1. Sedimentological analysis & Environment of Deposition

2. Rock Physics/Prestack AVO Inversion & Seismic Facies Segmentation

3. Static/Dynamic Reservoir Modeling & Field Development Scenarios

* Core description, biofacies analysis & log analysis (Environment of deposition)
* AVO inversion and rock physics analysis (Lambda-rho, Mu-rho, Shear impedance attributes)
* Principal component analysis/seismic facies segmentation and geomorphology
* Hierarchical facies/petrophysical modeling & volume estimation
* Dynamic modeling and history matching
* Prediction/production forecast and development scenarios testing

RESULTS & INTERPRETATION

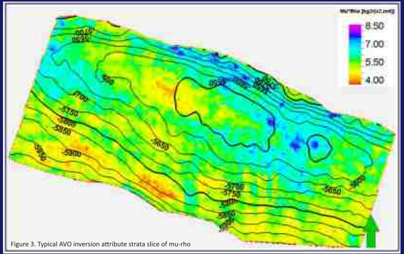

Figure 3. Typical AVO inversion attribute strata slice of mu-rho

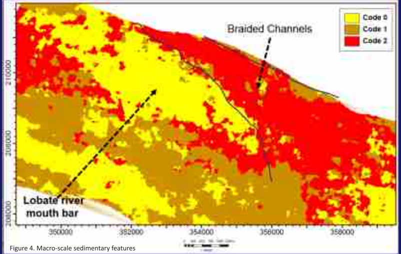

Figure 4. Macro-scale sedimentary features

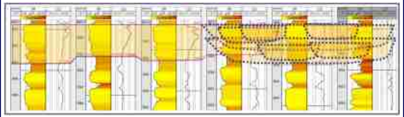

Figure 5. Combined layer-cake & labyrinth sand correlation

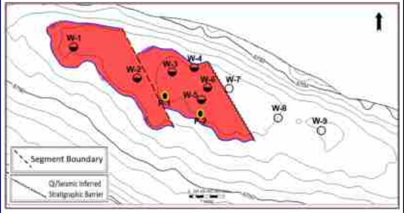

Figure 6. Reservoir depth map

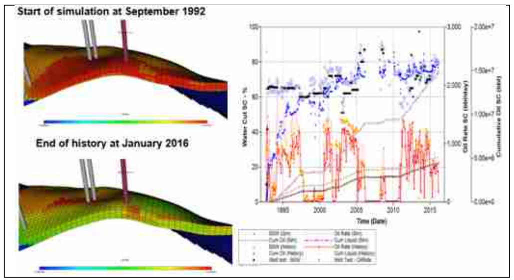

Figure 7. Reservoir Model & History match

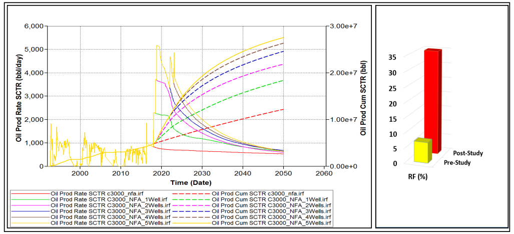

Figure 8. Development options & production forecast

CONCLUSIONS

1.The reservoir sand is deposited in bay/lagoon environment as river mouth bar and braided channel deposits

2.The reservoir geometry is a combination of simple layer-cake & labyrinth geometry

3.The reservoir has combined structural and stratigraphic trapping to oil accumulation with the channel forming stratigraphic barrier to flow

4.The optimized reservoir model shows that the 3 additional horizontal wells on gas lift recovery mechanism will increase the recovery factor from 7% to 35%

SELECTED REFERENCES

Egbogah. E. O. (2011). "Onshore/Marginal Field Developments: Challenges, Opportunities and Prospects for the Future". SPE Annual Oloibiri Lecture And Energy Forum

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