Reducing the Uncertainty of Static Reservoir Model in a Carbonate Platform, through the Implementation of an Integrated Workflow: Case A-Field, Abu Dhabi, UAE*

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Abstract

Predicting the spatial distribution of petrophysical properties within heterogeneous reservoirs is affected by significant uncertainties when based only on well information. However, integrating additional constraints, such as 3D seismic data and sedimentary concepts, can significantly improve the accuracy of reservoir models and help reduce uncertainties on predictions away from wells.

The aim of this study is to build a reliable 3D geological static model using petrographic and sedimentary reports and current understanding of the sedimentary conceptual model for the field. These core interpretations provide a clear description of the facies architecture across the A-Field, serve as excellent reference during seismic stratigraphy interpretations, and lead into a more geological distribution of the petrophysical properties in the reservoir through the facies models.

In the area of interest, Reservoir 1 is dominated by skeletal peloidal packstone with common thin, interbedded good-reservoir-quality rudstone and algal unit in the upper part of the reservoir. Reservoir 2, on the other hand is dominated by foraminiferal algal peloidal packstones with thin units of floatstone.

An integrated approach for facies modeling was implemented in order to generate stochastic models of the facies associations capable of reproducing the natural transition through the sequences. This method was adopted to model the high-resolution...
prograding pulses in the carbonate platform that were interpreted through cores description and facies association for both reservoirs.

The final 3D sedimentary-stratigraphic architecture is used as the main constraint to model the petrophysical properties for each reservoir. Under this approach, these models can account for the varying spatial continuity of reservoir properties honoring the different sedimentary facies. Facies-based property models preserve the facies-specific statistical distribution of the property, as well as its depositional direction. The facies-based, 3D petrophysical models provide an improved prediction of petrophysical properties distribution and reservoir heterogeneity. The permeability simulation based on facies and the cloud transform between porosity and permeability allows better control across the reservoir of spatial connectivity patterns that could be used for improved reservoir performance prediction as carried out in the present static model.
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Presentation Outline

1. Objective
2. Definition of Geological and Geophysical Uncertainties
3. Geological Static Model (Base Case)
   a. Structural Framework
   b. Facies Modeling
   c. Petrophysical Modeling
4. Modeling Uncertainties in Realizations
5. Sensitivity Analysis
6. Conclusions
1. Objective

- Implementation of an Integrated Workflow in order to reduce the Uncertainty of Static Reservoir Model in a Carbonate Platform.
Overview

Field A

Slightly elongated low-relief structure with a NNE-SSW trend located between two giant fields.

- Ø (%): R1: 18 - 27
  R2: 15 - 18
- K (mD): R1: 25 - 70
  R2: 5 - 10
- Thick (ft.): R1: 150
  R2: 20

Development area of 8.5 x 4 km
2. Definition of geological and geophysical uncertainties

Fishbone Diagram

- Structural Framework
  - Petrophysical Interpretation
    - Fluid Contact
      - MDT
    - Velocity Model
    - Seismic Picks
- Porosity Modeling
  - Probability Distribution
    - Geostatistic Analysis
    - CCA
- Saturation Modeling
  - Geostatistic Analysis
    - Variogram Ranges
    - Anisotropy
    - Azimuth
- Uncertainty
  - Probability Distribution
    - Geostatistic Analysis
    - CCA
    - Facies Association
    - Facies Proportion
    - Permeability Modeling
    - Facies Modeling
      - Depositional Association
      - Well Test
      - Probability Distribution
      - Azimuth
      - Variogram Ranges
      - Anisotropy
3. Geological Static Model

Workflow

1. Well Core Data
2. Structural Model
3. Sedimentological & Stratigraphic Study
4. Facies Model
5. Porosity Model
6. Permeability Model
7. RRT Model
8. Sw Model

Country: United Arab Emirates
Model name: 2014 BQ Geomodel
Block: Bida Al Qemzan
Scale: 1:50000
License: ADCO
Date: 02/02/2015
3.1. Structural Uncertainty

Surfaces (Uncertainty during seismic Interpretation)

Stochastic Gaussian Map

- Zero value in wells (mean = 0 and std = 1)
- Variance smoothly decreases with increasing distance from the well positions
- Variations depend on the quality of seismic data
  - Velocity Model
  - Interpretation Pick
  - Isochore Thickness

Step II:
- Run a certain number of realizations, adding the residual Gaussian map with the base case map in each equi-probable realization.
3.a. Structural Uncertainty

Structural Closures and Fluid Contacts

Log and MDT Interpretation showed FWL which was also supported by fluid sampling.
Through Seismic Interpretation lateral uncertainty was reduced and vertically through petrophysical and well test evaluations.
3.b. Facies Modeling

Facies, Facies Association, Depositional Environment

- The depositional trend.
- Boundary of facies.
- Estimate and propose fluid flow trend.
- As a guidance to define layer cake / clinoform structures, etc.

Depositional sedimentary trend is used as guidance during 3D modeling.
Histogram shows good relationship between upscaled and log data. Variograms were defined to know the spatial relationship between wells. VPC avoids vertical stationary distribution.

3.b. Facies Modeling

3D Model Algorithm - Intersection

Vertical Proportion Curve

- Progradation 1
- Progradation 2
- Progradation 3

Variograms were defined to know the spatial relationship between wells. Truncated Gaussian with Trends
3.d. Petrophysical Modeling

Porosity Model

There are two important sources of porosity uncertainty. The first is related to logging tool measurement, processing and interpretation. The second is related to upscaling from logs to 3D model.

Understand how to perform data analysis to prepare the input for petrophysical modeling.
3.e. Petrophysical Modeling
Permeability Model

1. Neural Network Estimation Model

2. Calibration 3D Permeability Model from Well Testing

Two main objectives:
1. Reduce uncertainty through the calibration of the Permeability log, using two different sources.
2. Involve more wells as input data before K modeling (15 wells instead of 6 cored wells).

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Logs used during Train Estimation Model:
- Resistivity
- Sonic
- Gamma Ray
- Neutron Porosity
- Density

High values achieved

Permeability (Well Test)

Permeability (RCA)
3.f. Petrophysical Modeling

**RRT Model**

**Symbol legend**

- Phie vs. CKH vs. TZ_PG_B_G (Upscaled)
- R35 = 28
- R35 = 7
- R35 = 4
- R35 = 2
- NA

**Country**

United Arab Emirates

**Model name**

2014 BQ Geomodel

**Block**

Bida Al Qemzan

**Scale**

1:50000

**License**

ADCO

**Date**

02/02/2015

**Best and Worst PGs**

- PGs

**Z-values**

TZ_PG_B_G

**Kh vs Phie**
Good continuity of best RRT in the upper section and poor RRT in the lower section.

Transverse section shows how the best RRT is being degraded from RRT1 to RRT2 or 4 (consistent with sedimentological interpretation and petrophysical evaluations).
PC property assigned to Transverse section shows how the best RRT are being degraded from RRT1.
### 4. Modeling Uncertainties in Realizations

**Uncertainty Variables, Distribution and Monte Carlo Simulation**

95 variables were defined to run uncertainty model in:

- Structural Framework
- Facies
- Porosity
- Permeability
- RRT
- Sw Models.

**500 realizations**

Reservoirs 1 & 2 – STOOIP (MM STB)

- P90: 0.8 X
- P50: X
- P10: 1.3 X
Finally, OWC and SW Model mainly in Reservoir 1 has more influence in the changes of the volume.

Sw ranges are between:
- $0.88X$ – $1.15X$ MMSTB

OWC in R-1 ranges are between:
- $0.9X$ – $1.1X$ MMSTB

Phie Model ranges are between:
- $0.98X$ – $1.02X$ MMSTB
6. Conclusions

• The main variables which interfere during each step were identified.
• The uncertainty was modeled using the variables directly related to the construction of the static model.
• Analysis was very well represented due to higher density of wells at the crest of anticline.
• Additional seismic information was included in order to reduce the uncertainty and find spill point and structural closure in the northern and southern area of the field.
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