Hydrocarbon reservoir modeling: comparison between theoretical and real petrophysical properties from the Namorado Field (Brazil) case study.

Marcos Deguti Hashimoto (74817)
CMRP - Modeling of Petroleum Reservoirs Center
Scientific Internship (5 months)
Synthetic hydrocarbon reservoir modelization: a case-study of Namorado Field, located in Bacia de Campos, Brazil.

CMRP - Modeling of Petroleum Reservoirs Center
Master Dissertation (6 months)
Validate the ‘internship’ synthetic reservoir results employing real data provided by ANP (Brazilian Oil and Gas Agency).
Why study synthetic reservoirs?

Survey and Information Acquisiton are high-cost operations due to:

- Displacement of equipment;
- Hostile environments;
- Limited footprint;
- Among others.

Solutions have come-out to try to avoid and minimize operation’s cost:

- Synthetic reservoirs have become a option to study and model hydrocarbons reservoir employing none or minimum amount of information.
Internship Goals

- Designing and modeling a synthetic reservoir selecting a real analogue reservoir according to the following characteristics:
  - Sand channels contents;
  - Anticline geometry;
- Real analogue reservoir chosen is Namorado Field located in Bacia de Campos, Brazil.

Internship Stages

- Structural and facies model construction;
- Porosity simulation through DSS algorithm;
- Permeability/porosity co-simulation through Co-DSS algorithm;
- Density, compressional and shear velocity (Vp and Vs) calculation;
- Seismic attributes calculation;
- Synthetic seismic generation.

Softwares employed:
- Petrel by Schlumberger and MATLAB.

* DSS - Direct Sequential Simulation
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Structural and Facies Model

- Anticline Geometry
  - Siliciclastic channels (sand) [yellow]
  - Shale formation [grey]

- 9,105,300 cells (151 x 201 x 300)

- 3775m x 5025m x 300m (25m x 25m x 1m)

Porosity Model


- Porosity simulated through the DSS (Direct Sequential Simulation)
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Permeability Model

- Calculation with Kozeni-Carman (permeability-porosity) relationship:

\[ K = \frac{1}{72} \frac{\Phi^3}{(1 - \Phi)^2 \tau} d^2 \]

- Permeability simulated through the Co-DSS (Direct Sequential co-Simulation with Joint Probability Distributions).

Density Model

- Density model calculated with the following formula:

\[ \rho = \Phi \cdot \rho_{fluid} + (1 - \Phi) \cdot \rho_{matrix} \]

- Gassmann Fluid Substitution algorithm applied to oil-saturated zones;
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Compressional Velocity Model

- Sand Vp calculated with Dvorkin and Nur (1996),

Constant Cement Model:
  - Firstly 100% brine saturation, then Gassmann Fluid Substitution algorithm applied to oil-saturated zones;
- Shale Vp calculated with Oliveira (2004) empirical relationship:
  
  \[ V_p = -0.0582 \cdot \varphi - 0.0145 \cdot V_{arg} + 4.7634 \ (Km/s) \]

Shear Velocity Model

- Sand Vs calculated with the following physical formula:
  \[ V_s^2 = \frac{G}{\rho} \]
- Shale Vp calculated with Castagna (1985) empirical Vp/Vs relationship (mudrock line):
  \[ V_s = 0.862 \cdot V_p - 1.172 \ (Km/s) \]
Seismic Attributes 1/3

The calculated seismic calculated attributes are the following:

- Acoustic Impedance
- S-wave Impedance
- Elastic Impedance (10°, 20°, 30° and 40°)

\[
SI = \rho \cdot V_s
\]

\[
IE = \frac{V_p}{V_s}^{1+\tan^2 \theta} \cdot V_s^{-8\left(\frac{V_s}{V_p}\right)^2 \cdot \sin^2 \theta} \cdot \frac{1-4\left(\frac{V_s}{V_p}\right)^2 \cdot \sin^2 \theta}{\rho}
\]

\[
IA = \rho \cdot V_p
\]
Seismic Attributes 2/3

The calculated seismic calculated attributes are the following:

- Lame Coefficients
  - $\mu$ and $\lambda$
- Poisson Coefficient

\[
\mu = \rho \cdot V_s^2
\]

\[
\lambda = \rho \cdot V_p^2 - 2 \cdot \mu
\]

\[
v = \frac{V_p^2 - 2 \cdot V_s^2}{2 \cdot (V_p^2 - V_s^2)}
\]
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Seismic Attributes 3/3

The calculated seismic calculated attributes are:

- **AVO Intercept vs Gradient**

  \[ A = \frac{1}{2} \left( \frac{\Delta V_p}{V_p} + \frac{\Delta \rho}{\rho} \right) \]

  \[ B = \frac{1}{2} \left( \frac{\Delta V_p}{V_p} \right) - 2 \left( \frac{\Delta V_s}{V_p} \right)^2 \cdot \left( 2 \cdot \frac{\Delta V_s}{V_s} + \frac{\Delta \rho}{\rho} \right) \]

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Synthetic Seismic

The synthetic seismic is generated by the convolution between the reflection coefficient and wavelet (0°-40°).

The seismic wiggle was stacked in four ways:

- Full Stack .................................................. 0° to 40°
- Partial Stack (Near) ................................. 0° to 20°
- Partial Stack (Middle) ......................... 10° to 30°
- Partial Stack (Far) .................................. 20° to 40°
Moving forward

The ‘intership’ synthetic reservoir was concepted in a theoretical approach by using several related papers, thesis, books and handbooks.

However, is this synthetic reservoir usable?

Is it reliable?

So, it is time to validate all previous work.

Briefly, this Master Dissertation will evaluate the ‘intership’ reservoir results comparing it to the reality.
Objectives

The main Master Dissertation objectives is to:

• Validate the ‘internship’ reservoir results, comparing it step-by-step to a new real-approached synthetic reservoir.
  – Modelization of a new synthetic reservoir with real approach;
  – Comparison of all its stages;
• The real data will be required and provided by ANP.

Data Set

The dataset contains:

• Loggins data from six wells in Namorado Field
  – NPHI, GR and RHOB;
• Each well (geologic) reports.

* The National Agency of Petroleum, Natural Gas and Biofuels (ANP) is the regulatory body for activities that integrate the oil, natural gas and biofuels industry in Brazil. ANP is also a reference center for data and information on the oil & gas industry.
# Master Dissertation Project

## Dissertation Roadmap

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<th>Modeling</th>
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<tr>
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<tr>
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## Technical Workflow

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Partial Results 1/2

Structural Model

- Grid: 9.105.300 cells (151 x 201 x 300)
  - (3775m x 5025m x 300m (25m x 25m x 1m)

Facies Model

- Anticline Geometry
  - Siliciclastic channels (sand) [yellow]
  - Shale formation [grey]

Bulk Volume X profile:

Bulk Volume Y profile:
Partial Results 2/2

Porosity Model

Permeability Model
Main Bibliography

- Horta, A. e Soares, A. (2010), Direct Sequential Co-simulation with Joint Probability Distributions;
Thank you for your attention!

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