Static Reservoir Modelling of a Discovery Area in Interior Basin, Gabon

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Abstract

The reservoir modelling and resource estimation are pre-requisite for making investment decisions in the petroleum industry. Present study focused on the static reservoir modelling and estimation of reserve potential of a discovery area in Interior Basin, located in north-eastern part of oil rich country Gabon. Using the 2D seismic data, three exploration wells were drilled out of which one turned out to be discovery. Further two appraisal wells were drilled for confirmation of the extent of the reservoir. In continuation, Static reservoir modelling was carried out to quantify the reserve potential associated with geological uncertainty parameters.

The proposed workflow comprises the following - (1) Construction of the Geometrical model - using depositional sequences and major faults delineated using 2D seismic data and depth markers measured along the 3 wells; (2) Construction of the Facies model - facies were interpreted using log motif methodology; and facies model was populated with Sequential Indicator Simulation algorithm; (3) Population of the geological model with petrophysical properties - Sequential Gaussian Simulation was used to populate grid cells with porosity and water-saturation models. The potential reserve was estimated by incorporating various reservoir parameters.

Keywords

Geometrical Modelling, Facies Modelling, Pertophysical Modelling, Reservoir Modelling etc.

Data Sum Up

The study area, lies in the Eastern part of the Interior Basin of Gabon. This area (3761 sq.km) includes 1039 LKM of vintage 2D Seismic Data, about 850 LKM recently acquired 2D Seismic Data, 140 sq km recently acquired 3D seismic data, 26 wells drilled between 1950 and 1982 and 5 wells drilled between the year 2012-2014.

Introduction

Based on the interpretation of both 2D and 3D seismic data 3 exploratory wells (K-1, B-1 and L-1) were drilled in the area during 2012-13 with a hydrocarbon discovery in 3rd well L-1. To appraise the discovery and further exploration the consortium drilled two appraisal wells namely L-2 and L-3, during 2014. In well L-2, crude oil was observed during reverse circulation. In well L-3, based on the log data and MDT sample results, it was observed that all zones were water bearing and well was suspended without any DST testing.

The objective of the present work was to construct Static model for the N'Dombo Formation (which is the reservoir formation) through geometrical and property modelling.

Geology

The Interior Basin of Gabon resulted from the breakup of Gondwana Land that began in the Permo-Carboniferous and Triassic by reactivation of pre-existing zones of lithospheric weakness (Guiraud et al., 1992).

The Gabon Margin is segmented by NE–SW trending strike-slip faults defining zones with partly different tectonic and stratigraphic histories. These faults (which are major strike-slip in nature) extend to off shore area and are resulting into opening of the Atlantic. In the Interior Basin, normal faults trending N60^0E offset the Axial Fault (Teisserenc and Villemin, 1990).

Source: The major source present in the area is Schists (Brown Schists and Black Schists Source Rocks) series which contain potential source rocks corresponding to lacustrine bituminous claystones. The Kékélé (Early to Mid Neocomian) & Agoula series (Permian) also acts as source rocks.

Reservoirs: Good quality reservoir sands are present in the M'Vone, N'Dombo/Kékélé, Fourou-Plage and Gamba formations within the Interior basin. The secondary reservoirs are the M'Vone sandstones (Jurassic), and the Fourou Plage sandstones (Neocomian).

Seals: The Ezanga evaporites form good seal for the Gamba reservoirs in the western part of the basin. Elsewhere in the basin the seal above this reservoir is likely to be poor. The Fourou-Plage reservoir sands are expected to be sealed by the surrounding Lobe shale. The main source intervals in the block viz., the Kango, Bokoue and Bikoume shales are the potential seal for the deeper M'Vone and N'Dombo/Kékélé reservoirs.

Methodology

1. Rock Typing & Facies Interpretation

Rock typing was carried out with the help of Train Estimation Model module in Petrel which is a Neural Network Technique, using GR, PHIE, Sw, RHOB, Vshale

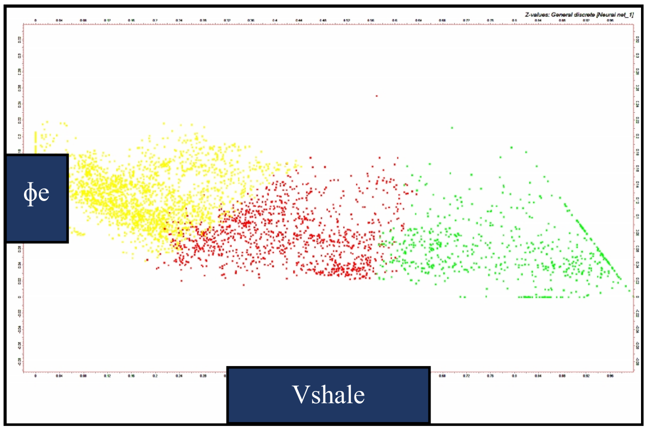

Figure-1 Lithology classification using Neural network

2. Seismic facies classification

Seismic facies analysis is a tool to describe depositional environments using seismic data. Channel feature was observed in the reservoir Formation (Fig. 2).

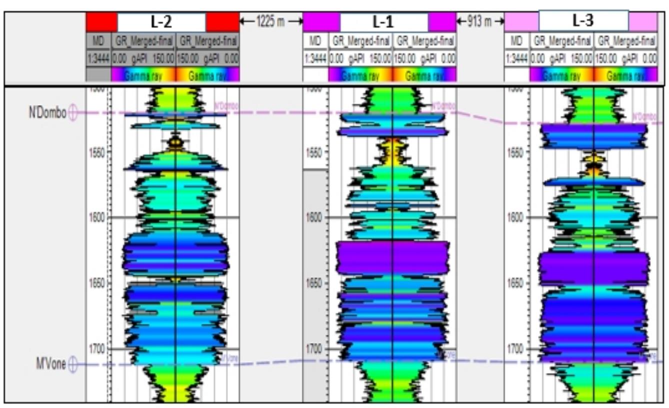

Figure-2 Facies interpretation

3. Corner Point Gridding

Fault Modeling

The Fault model was constructed in depth domain using the seismically interpreted faults that were picked

Logs as an input for the lithology group identification. Three lithology groups have been identified (Fig. 1) using an unsupervised classification method which has been further checked with individual logs in Well Correlation panel. Facies logs generated by unsupervised classication have been further edited manually in all three wells located in discovery area.

from the 2D seismic data in time domain and then depth converted using the available velocity model. The modelled faults were tied to the fault sticks from seismic as a quality check for the fault paths whilst building the fault framework of the field. The modelled faults were limited to the N'Dombo level.

Pillar Gridding

The geo-cellular model of the 3D grid is mainly based on the top, middle and base skeleton that are constructed within this process. The 3D grid was created with "I "and "J" increment 100x100 m including the modelled faults. The grid boundary was created with reference to the selected area boundary considered in velocity modelling. The "I" and "J" directions were assigned parallel and perpendicular to the faults created in the fault model. The model was segmented to three segments in order to ease control of various reservoir simulation phases. Modelled Faults have been used mainly as segment boundary. However I/J Trend also been used in the area where fault is not present to define the segment.

Make Horizon

The Make horizons process is the first step in defining the vertical layering of the 3D grid. Horizon modeling was used to define the main vertical architecture of the reservoir model. When introducing these horizons to the set of pillars generated in the Pillar gridding process, all intersections between the pillars and the horizons become nodes in the 3D grid. During this process well adjustment was done to ensure that the well tops link and control the horizons generated by the Make horizon process.

Layering

Layering process was performed to create small divisions within the modeled zones to capture the reservoir properties whilst the Facies and Petrophysical logs upscaling processes. The layer thickness is the cell thickness in the Z dimension. The high-resolution layering was performed to capture the various lithology and Petrophysical log properties details, as possible, for the well log data.

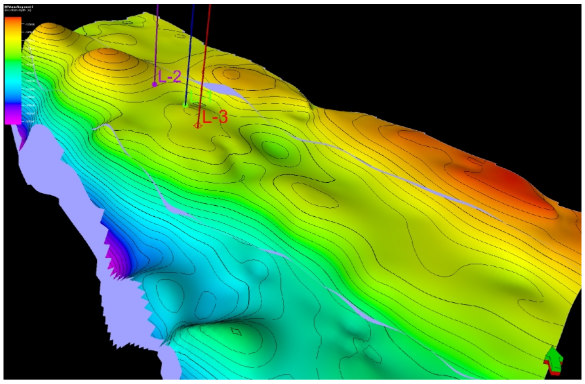

Figure-3 Horizon model with layering for the N'Dombo Formation

Geometrical Modeling

3D Grid QC was carried out using Geometrical Modeling method. Cell Volume property was generated via Geometrical Modeling process. This calculates the bulk volume of each cell in the 3D grid. Corrective actions were taken in Fault Modeling/Pillar Gridding process for areas with negative cell volume and finally to ensure there should be no cells with negative volume. Further quality check was done using Cell Angle and Cell Inside Out Property.

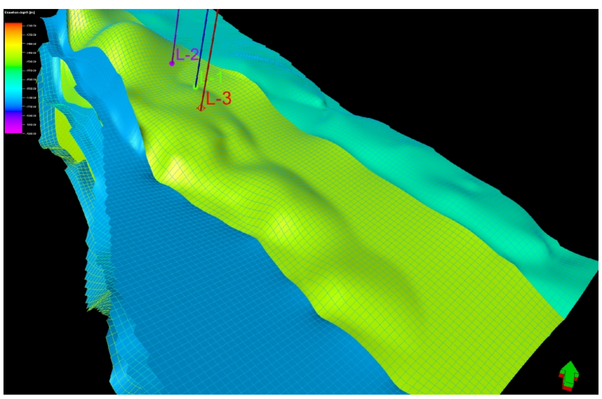

Figure-4 Skeleton for the static model

4. Facies Modeling

Facies modeling was carried out using Sequential Indicator Simulation to populate facies.

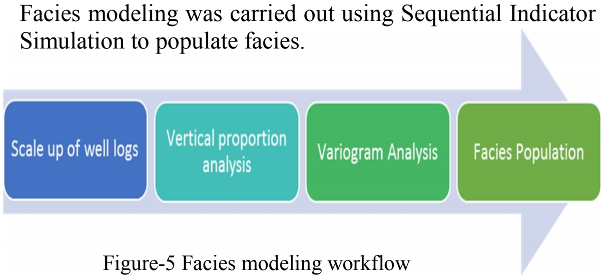

Figure-5 Facies modeling workflow

Scale up of well logs

In this process interpreted Facies log was resampled into the 3D grid along the well path (Fig. 6).

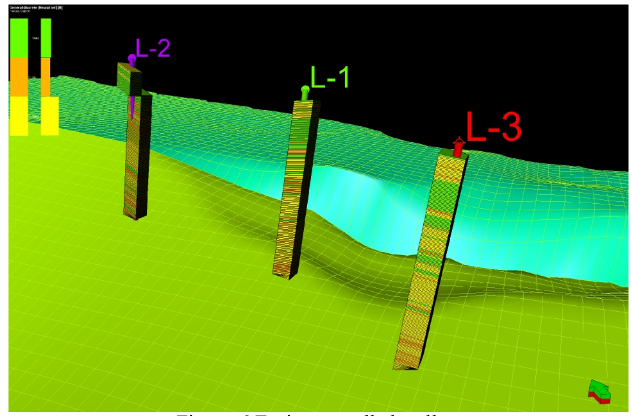

Figure-6 Facies upscalled wells

Vertical proportion curves

A vertical proportion curve shows the probability of populating the facies in different layers.

Variogram analysis

Variogram analysis has been performed using the upscale facies data to infer the variation in major, minor & vertical direction. Based on histogram analysis and log correlation profile the different facies distribution were inferred and applied in the facies model.

Facies Population

A seismic guided Facies Model using the upscale well data was prepared for the area of study. Geo statistical analysis was done on the upscale well data to estimate the variogram parameters useful for population of facies from the wells in the area. Sequential Indicator Simulation (SIS) technique which is a kriging based stochastic method of facies modeling in Petrel was used for the population of facies from the wells.

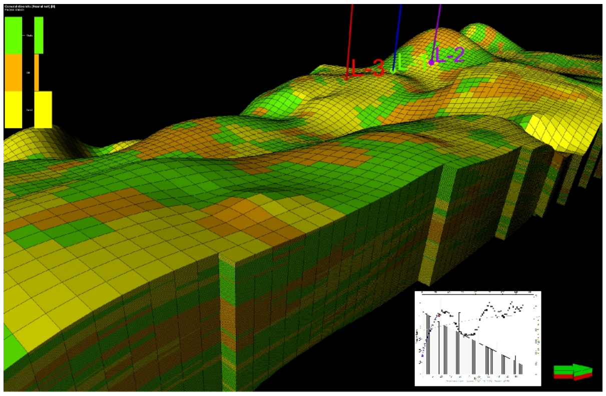

Figure-7 Distribution of facies in the model

5. Petrophysical Modeling

Petrophysical parameters like porosity & water saturations were also modelled.

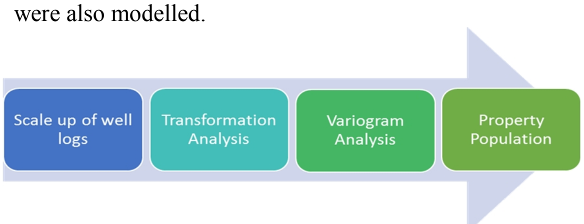

Figure-8 Petrophysical modeling workflow

Porosity Modeling

Effective Porosity log derived from Quanti-Elan analysis was used for three wells in the area. This Effective Porosity log was resampled into the 3D grid along the well path using scale up well logs process after biasing it with the already upscale Facies Log. Gaussian random function simulation technique which is a stochastic method for Petrophysical modeling in Petrel was used for the population of porosity property from the wells.

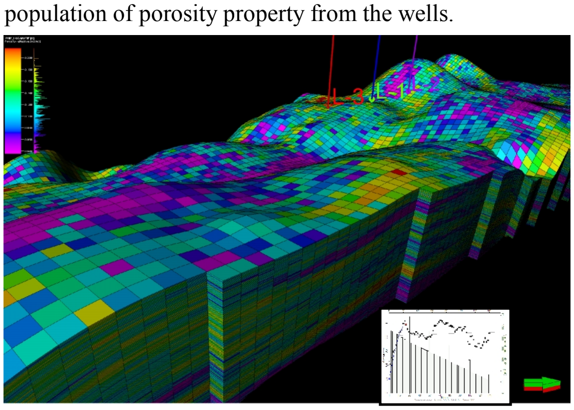

Figure-9 Distribution of effective porosity in the model

Water Saturation Modeling

Water Saturation log derived from Quanti-Elan was used for three wells in the area. This Water Saturation log was resampled into the 3D grid along the well path using scale up well logs process after biasing it with the already upscale Facies Log. Kriging algorithm has been used for Water Saturation modeling using the upscaled water saturation logs from the wells. In this process already modeled correlated Porosity property has been used as secondary variable in the Co-kriging together with the use of a geometrical property as a trend to model the Water Saturation.

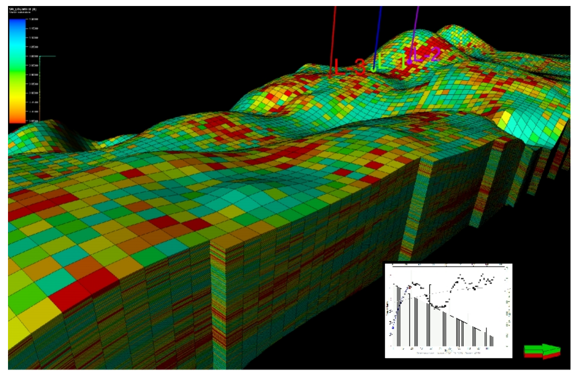

Figure-10 Distribution of water saturation in the model

6. Defining Contacts

Oil water contact (OWC) information was considered from existing drilling data and has been defined for entire model across all faulted segments. A 3D contact property was also generated.

Summary and Conclusions

Three dimensional reservoir modeling plays an important role in the exploration and development phases. The integration of all available data allowed team to better understand the spatial distribution of lithofacies and associated reservoir parameters. Feedbacks from geological, geophysical, petrophysical and drill data were instrumental in the reservoir model improvements during the project. The learnings from the project will help to plan and optimize delineation well programs of the projects in the earlier stages of field development.

Qunti-Elan study carried out for discovey & appraisal wells for the calculation of petrophysical parameters (ϕe, Sw and NTG) and results are in good agreement with core data in respect of saturation and porosity.

Static model for the reservoir zone has been generated and accordingly volumetric reserves (In Place) were estimated which is worth going for development.

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