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Capturing Reservoir heterogeneity through 3-D Modelling- A case study from Nandej field,Cambay Basin

Abstract

Geo cellular modelling (GCM) needs synergistic approach to render a realistic image of the reservoir heterogeneity by unearthing relationship between geology, seismic study, reservoir study analysis & petro-physical analysis. Constructing reservoir model has become a significant step in resource development as reservoir modeling provides a spot to integrate all available data and geologic concept.

The present GCM study aimed to capture adequate detail in order to characterize vertical and lateral heterogeneity of the two pays viz K-A & K-B sand of Middle to Late Eocene age which are the most significant producers in the Nandej field.

In this study, facies trend maps were generated, using litho-type proportion map (LPM) and vertical proportion curves (VPC), to capture the geological inhomogeneity. The robustness of the model was validated with core analysis incorporated to create permeability model. The reservoirs behavior and log analysis suggest that the K-A reservoir is extensive and is better developed than K-B pay. The reservoirs are tight and hydro-fracture is mostly essential for production. The integration of a stochastic geological model and petrophysical reservoir characteristics has led to realistic model and identification of areas for exploration & development

Introduction

The Nandej field (Fig:-1) lies in Mehsana-Ahmedabad block. Kalol-A and Kalol-B are the main pays Sertha Member of Kalol Formation and 3D modeling to capture heterogeneity have been attempted.

Fig-1: Location Map

Fig-2: General stratigraphy of the field

Geological Setting and stratigraphy

The Cambay basin came into existence due to rifting along N-S to NNW-SSE Dharwarian trend in the Early Cretaceous (Biswas, 1987). This basin is bounded by step-faults in the Eastern & Western margins. The major cross- trends have divided this basin into five tectonic blocks from south to north viz. i) Narmada-Tapti Block, ii) Jambusar-Broach Block, iii) Cambay-Tarapur Block, iv) Ahmedabad-Mehsana Block, v) Patan-Tharad-Sanchor Block. The study area falls in Ahmedabad-Mehsana Block in Northern part of Cambay Basin. Generalized stratigraphy of the area is given in fig:2.

Methodology & workflow

This paper presents one synergistic workflow to build 3D geological model. On the basis of sample data and under the control of structure frameworks and sedimentary facies, statistical analysis of every sedimentary facies to describing anisotropy in geological body. Finally petrophysical model is prepared that are reflecting

anisotropy of geological body. Finally validating at blind wells and results of independently created permeability maps. Basic workflow of 3D geological modeling is shown in fig-3.

Fig-3: Methodology and work flow

Facies composition and depositional setting

The complexity and diversity of geological conditions controlling spatial shape of geological body must be understood to control facies modeling. In the present study, the pay K-A &B para-sequence is marked by coarsening up sequence below regionally persisting coal. The K-A reservoir facies is present almost all the wells suggesting tidal flat / tidal creek environment of deposition. It seems to be deposited in low energy regime and shows better facies development towards north western part of the field and in south-eastern part of the field. The sediment input direction appears from NE direction (Fig-4).

Fig: 4- Isolith map of K-A & K-B

To understand the distribution of poor reservoir characteristic; the low density pack was analyzed to understand the distribution pattern of low density facies (coal). The pack becomes more carbonaceous as we move towards western part of the field (Fig-5) with NE-SW trending carbonaceous patch in the north central area of the field. The central part of the field has relatively poor production performance which supports the above observation.

Fig-5 Carbonaceous patches in K-A pay

The reservoir isolith map and previous study indicated that the sediment input direction is from northeast. The coal beds were deposited in the swampy/marshy environment. So establishing high precision geological body model must consider the following influences of three geological conditions i.e tectonic condition, sedimentary environment and anisotropy in geological body. Thus to capture this complexity following methodology was adopted to create geo-cellular models.

Fault Framework

The primary fault model has been deciphered from basin seismic interpretation. The model incorporates the fault/flow baffle consisting of seismic faults, faults observed on well logs and flow barriers observed on the basis of reservoir analysis. The two attributes namely dip angle and azimuth were run to capture the heterogeneity of the fault plane and on the basis of these two attributes the fault sticks and planes were readjusted maintaining the throw of the faults.

During the course of Electrolog correlation missing sections were observed in two wells of K-A pack is missing and in seven wells were K-B upper coal is missing. This data also have been justified in the fault mapping.

The Pillar gridding process was used generate a corner point 3D grid from the fault model. Pillar Gridding is a unique concept where the faults in the fault model are used as a basis for generating the 3D grid. Once the fault framework is created, the input surfaces were inserted honouring the faults (Fig-6).

Fig-6: Fault Framework

Facies Modeling

Facies log was created for each well and were used for construction of a detailed facies architecture model in which the size, shape and spatial position is preserved. These facies are interpreted based on the log signatures in individual wells, then facies logs were upscaled to around 1+0.5 m into the model and data analysis was applied to the upscaled facies logs. Data analysis was carried out by system analysis, quality checking input data, and for better understanding of the Horizontal and vertical flow, anisotropy along with its associated trends. Facies modelling of K-A and K-B reservoir were carried out using trend from maps (probability maps), vertical proportional curve (VPC) and variogram analysis through sequential indicator simulation technique (Fig:7).

Facies probability maps for each facies code i.e. Shale, Sand, Silt and Coal was prepared. Additionally, to honor continuity as well as heterogeneity of the reservoir these probability maps were corroborated with geobody and used as a final trend maps with different weigh percentage of probability maps to populate facies in the each pays. These modelled Geobodies were used to model the spatial distribution of different reservoir facies, separated by non reservoir facies.

Petro-physical modeling of K-A & K-B

The log data was processed for quantitative evaluation after building ELAN Plus mineral model based on laboratory data. This information was the main input for petrophysical modeling.

Upscaled porosity and saturation were used for data analysis with normal score transformation and biased to individua Fig-7: Data analysis; vertical proportional curve, variogram analysis & probability map lection of the technique, frequency distribution function was taken as guiding parameter.

Porosity Modeling

The porosity logs were analyzed with normal score transformation and biased with individual facies code. The facies distribution acts as guiding rails for porosity modelling for K-A and K-B using sequential Gaussian random simulation for each facies individually.

Saturation Modeling

Water saturation (Sw) modelling in almost all the reservoir is a bit complex due to chaotic mineralogy and heterogeneity of texture. During present study, even after using ELAN processed data, there are instances where the saturation and porosity computed are not in perfect harmony of hydrocarbon production.

As these pays are depletion drive, thus for the propagation of hydrocarbon properties of sequential Gaussian random simulation was used for K-A and K-B.

In the study, the normal score transform of Sw_i was carried out to achieve Gaussian distribution. After the transformation, data analysis and geo-statistical simulation is performed in the transformed space. Finally the data is back transformed into the original data space to get spatial distribution of saturation in reservoir model. Input truncation was used to remove the anomalous data in the zones prior to statistical analysis.

Validation

Special core study analysis were used to create permeability transform to create permeability modeling. The porosity permeability transforms were used for creating permeability at wells.

The results of permeability model was compared with the phi-He-So map and reservoir distribution with production performance. The validating the strength of the Geocellular model (Fig-8a &b).

Fig-8a: Permeability map & reservoir thickness map

Fig-8b: Phi-He-So Map

Fig-9: Validation of model with blind wells

The model was validated by checking the petro-physical properties on the blind wells (Fig-9) not used in the modeling process and were found satisfactory.

Conclusions

Reservoir characterization has become a significant step in resource exploitation as reservoir modeling provides a spot to integrate and compile all available data and geologic concept.

Synergistic integration of geological & seismic attributes, well and reservoir data led to identification of barriers and finalizing the structural framework.

K-A reservoir is better developed throughout the field and has better reservoir property while K-B is poor in nature. The modelled petrophysical property indicates better areas which are in line with the production behavior of the field. K-A reservoir is getting poor in the western part due to increase in carbonaceous content.

Downscaled Geocellular Model (GCM) has been prepared for Kalol pay sands of Nandej field using refined 3D seismic fault pattern, ELAN processed logs, geological and reservoir data.

Based on the study potential areas for development & exploration of K-A &K-B pay delineated. Based on study four development locations were released.

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