Geo-Cellular Modelling of a Brownfield: A Case Study from North Kadi, Cambay Basin

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Keywords

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Summary

Cambay basin is an intra-cratonic, NNW-SSE trending narrow, elongated, rift basin located in the NW margin of Indian Precambrian Shield. North Kadi field is located at southern tip of Mehsana High in the Ahmedabad-Mehsana tectonic block of Cambay Basin and has been under production since 1969. The sands encountered within the Kalol Formation of Middle to Late Eocene age are amongst the most significant producers in the field followed by the Mehsana, Mandhali and Linch Sands of Early Eocene age. The modeling of North Kadi field aimed to capture adequate detail in order to characterize vertical and lateral heterogeneity at the well and the field scale to use as input to simulation and contribute to better reservoir management. Approximately 280 SKM of 3D seismic data in addition to 2D seismic data was interpreted. Six horizon tops were mapped using depth converted seismic interpretation combined with well data. Fault mapping and correlation was done on every 20th Inline and Trace line. A total of 483 wells were taken up for study of the field. Structural model was constructed by inputting fault sticks, well tops and seismic horizons to the relevant Petrel modules. A three dimensional grid was prepared by Pillar gridding. Selected wells were processed to arrive at effective porosity and water saturation values. Effective porosity obtained from ELAN plus processing was propagated to each cell of the three dimensional grid after processed data was scaled up to the grid dimensions and analyzed in detail. Saturation modeling was carried put after relationship between bulk volume of water (BVW) and height above free water level (FWL) was determined for different payzones in different blocks of the field. The effort resulted in a model with 50m X 50m lateral resolution and average cell thickness of 1.2 m with each 3d cell having discrete values for petrophysical parameters.

Introduction

North Kadi field is located 25 Km southwest of Mehsana Town in the Ahmedabad-Mehsana Tectonic Block of Cambay Basin and covers an area of more than 72 square km. Ahmedabad-Mehsana tectonic block is demarcated by Nandasan fault in the north and Vatrak fault in the south The field was discovered in 1968 and is under production since 1969 from Kalol sandstone reservoirs of Eocene age. Subsequent exploration and development efforts of the field indicated presence of hydrocarbons in Linch, Mandhali, Mehsana, Chhatral, Balol and Miocene pay sands. Most of the oil has been established within Kalol sands which are the main contributors to production. Linch and Mehsana pay zones are undersaturated reservoirs whereas Kalol and Chhatral pays are saturated reservoirs. Overlying sands of Balol pay of Oligocene age and Miocene sands are gas bearing in this field. This fine-scale geo-cellular model will be simulated for firming up the future investment plan for holistic field development.

Structurally, North Kadi is a NW-SE double plunging, faulted anticline formed over a paleo-high. The field is North Kadi field is located at southern tip of Mehsana High. And is flanked by Mehsana Horst in the north and Warosan Low in the east. Sediment thicknesses gradually decrease from the low in the east towards west & northwest. The generalized stratigraphy of Ahmedabad-Mehsana tectonic block of Cambay Basin is appended in figure-1 below.

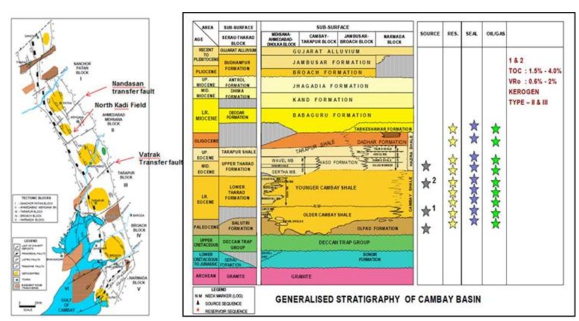


Figure-1

Workflow

The workflow used is described below.

Seismic Interpretation:

- 3D seismic data from three volumes was interpreted for mapping.
- 2D seismic data from five 2D campaigns was used in the western part of the field to ensure that the entire mature field is covered (Figure-2) and to extend the fault framework to the western part of the field.

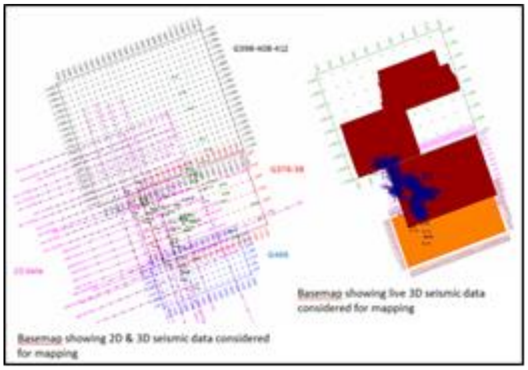


Figure-2

- Time–Depth functions were generated by making synthetic seismograms (Figure-3) for wells sampled to cover entire area of study.

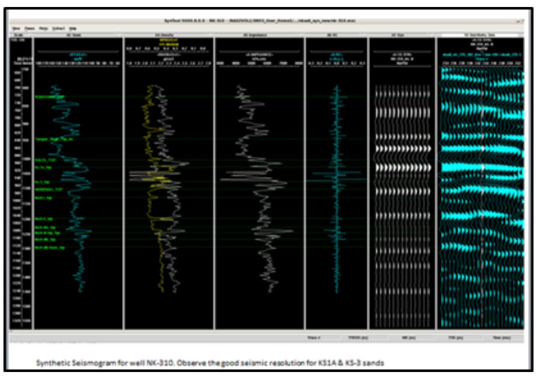
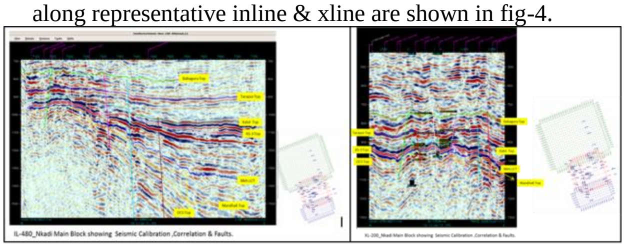


Figure-3

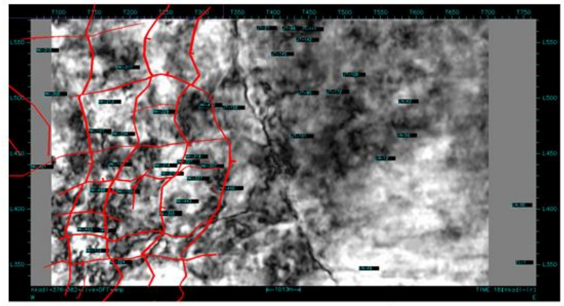
- VSP data, wherever available, was used to validate synthetic time-depth tables.
- Velocity modeling was carried out for converting time maps to depth maps by using Landmark‟s "Depth Team Express software‟.
- Six horizon tops were mapped using depth converted seismic interpretation combined with well data.
- Fault mapping and correlation was done on every 20th Inline and Trace line. AnHorizon and Fault correlation along representative inline & xline are shown in fig-4.



IL & XL showing Seismic Calibration, Correlation & Faults

Figure-4

- Seismic attribute volumes (i) ESP, (ii) Curvature, (iii) Dip, (iv) Dip-Azimuth and (v) Difference were generated and analyzed both on standalone volumes and flattened volumes at the mapped levels.
- Spectral decomposition was carried out to map finer lineaments (Figure-5).



Amplitude Time slice at 16Hz from DFT SPECDCOMP volume of Main Nkadi Block. (Mapped faults at Kalol superposed.)

Figure-5

- Fault trends, especially minor ones were substantiated with the help of ant tracked volume.

Well Log Correlation:

- A total of 483 wells were taken up for study of North Kadi field.
- Well locations, raw logs and perforations were loaded in Petrel^{TM} software of M/s Schlumberger.
- The log correlation (Figure-6) of different units for all the wells was carried out using log correlation module of Petrel^{TM}.

Electrolog Correlation Profile EW-2

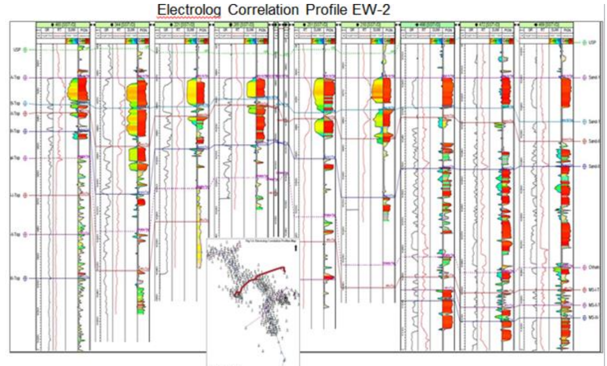


Figure-6

Structural Modelling:

- Structural model was constructed by inputting fault sticks, well tops and seismic horizons to Petrel's modules meant for Fault, Horizon and Zone Modeling and a three dimensional grid was prepared by Pillar gridding.
- Layering process created geological layers within each zone and defined the dimension of the cell in the Z

direction. The layers were created proportionally to capture the fine vertical variations in log data. Each zone was divided into fine layers required in the subsequent processes of property modeling.

- The pillar grid was finalized after repeated iterations during which fault pillars were successively refined and any discrepancies in the input data were removed to satisfy field observations. Figure-7 shows the pillar gridded skeleton of the field and the structure contour map of Kalol Sand 1A beside it.

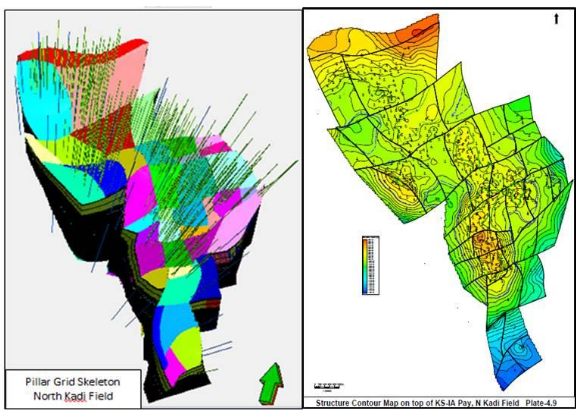


Figure-7

Petrophysical Interpretation:

- After loading the raw log data, depth matching and environmental corrections were carried out.
- The depth matched and environmentally corrected data was used to prepare cross-plots for identifying clay types, minerals and matrix density.
- The wells drilled during and subsequent to 1981 were processed to arrive at effective porosity and water saturation values as raw logs of approximately 140 wells drilled before 1981 have only unfocussed resistivity logs and no porosity logs.
- The log data was processed for quantitative evaluation after building ELAN Plus mineral model based on laboratory data. (Figure-8)

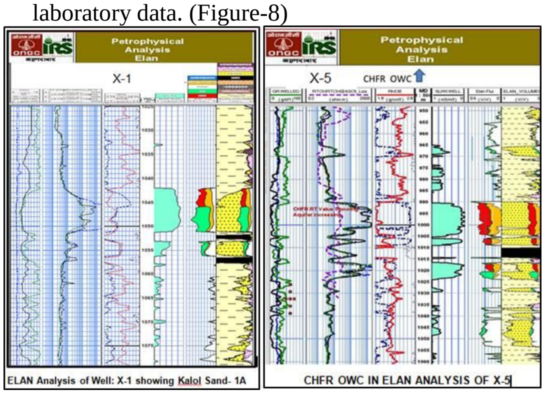


Figure-8

- Following Indonesian equation was used for computing water saturation in the unflushed zone (Sw) and in the invaded zone (Sxo).

$$Sw^{-n/2} = \left[\left(Vcl^{(1-Vcl/2)} / \sqrt{Rclay}\right) + \left(\phi^{m/2} / \sqrt{(a \times Rw)}\right)\right] \times \sqrt{Rt}$$

Property Modelling:

- Effective porosity obtained from Elan plus processing was scaled up to the grid dimensions.
- Scaled up as well as raw log data was analyzed in detail and variogram analysis was carried out to determine the statistical parameters for propagation.
- Scaled up effective porosity was propagated to each cell of the three dimensional grid.
- Saturation modeling was carried out after relationship between bulk volume of water (BVW) and height above free water level (FWL) was determined for different payzones in different blocks of the field. Water saturation was propagated from processed well log data for zones where initial fluid contact is not evident.

Figure-9 shows a relation between bulk volume of water (BVW) and height above free water level (FWL) established for Kalol Sand 1A.

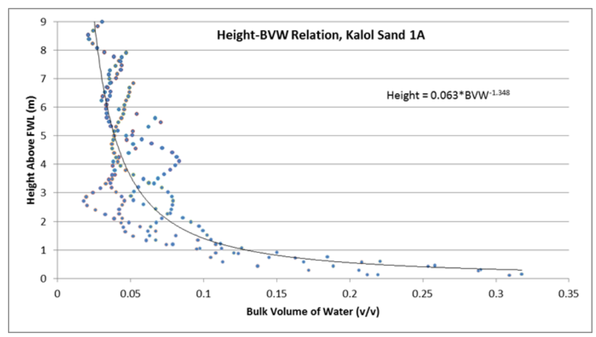


Figure-9

Figure-10 shows distribution of effective porosity and water saturation near top of Kalol sand 1A

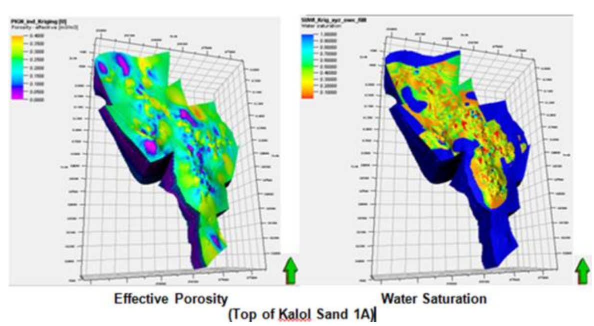
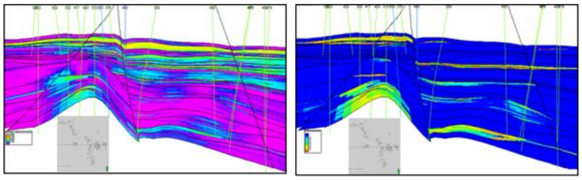


Figure-10

Figure-11 shows the distribution of effective porosity and water saturation in section.



Intersections showing effective porosity (left) and water saturation

Figure-11

Conclusions

Integrated Geocellular Model (GCM) has been prepared for all 26 pay sands of North Kadi using refined 3D seismic fault pattern, ELAN processed logs, geological and reservoir data. The fault frame work for the horizons mapped has been brought out by integrating all available seismic data. Structure maps indicate that the main field is trending NW-SE. On the basis of fault configuration, North Kadi field is divided into forty segments. Some of these segments are not in communication; faults are considered sealing in nature in such cases. A total of 483 wells, covering all the sands were used to prepare the geo cellular model which has 50m X 50m lateral resolution and average cell thickness of 1.2 m with each three dimensional cell having a discrete value for petrophysical parameters.
In preparation of GCM, 30 surfaces, 52 faults, 40 segments, 29 zones, 858 layers and 53,539,200 cells were made to characterize horizontal and vertical distribution of porosity and saturation for all twenty six pay-sands.
The results of the study are in line with expectations and the model is anticipated to contribute to more effective and efficient reservoir management in North Kadi field.

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