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An Integrated approach for modeling naturally fractured reservoirs of Borholla field of Assam basin by DFN approach using 3D seismic data, log data and dynamic data

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Summary

Fractured basement (igneous / metamorphic / trap) are emerging as potential hydrocarbon reservoirs worldwide. Significant volume of the world's proven reserves have been found in naturally fractured reservoirs. In some 370 fields world over, natural fractures are important for production and a significant proportions of it are in basement settings. In about 30 different, commercial hydrocarbon reserves have been reported from the fractured basement. In India, almost all the major petroliferous basins have recorded occurrence of hydrocarbons within the fractured basement / trap. Presently, four basins in the Indian context, i.e. Assam & Assam-Arakan, Krishna Godavari, Cauvery and Cambay are on commercial production from fractured Basement.

In spite of these, fractured basement has probably not received the attention it deserved so far. One reason could be due to the lack of technology in mapping the fractures and their network spatially and characterize the basement. With the advent of computational hardware and software becoming cheap and their availability, the task of mapping the fracture framework started at seismic data acquisition/Imaging stage it self. It is established now that the travel time delays between the fast and the slow S-waves and their polarization azimuths are now exploited from the mode converted split shear waves in mapping the fractures. The present paper deals with leveraging the available technologies/software to model the naturally fractured reservoirs from seismic to simulation.

Introduction

Mapping of the fracture network and estimation of the fracture porosity constitute two major steps in static model preparation of a naturally fractured reservoir. Institute of Reservoir Studies (IRS), ONGC has taken up an ambitious program of preparing a fracture model, for the fractured basement of Borholla field in Assam and match the results with the pressure transient test analysis. This involved usage of the recent soft wares available in the industry. The process involves preparation of 3D grid cell (geo cellular model) with up scaled reservoir properties. Then the fracture modeling is carried out using the static as well as dynamic data goes in for which takes a host of geological data, out crop data, production data, petro physical data and reservoir data.

A comprehensive fault and fracture modeling Fracture network mapping and estimating its porosity constitute two major steps in static model preparation of naturally fractured reservoirs. Additionally the permeability of such reservoirs is controlled by parameters such as fracture length, density, orientation, aperture and single fracture connectivity. A detailed fracture description is thus crucial for proper modeling of fractures for reservoir simulation. The fracture properties of the calibrated fracture model were up scaled to the whole grid by Analytical up scaling using the single media option. A discrete fracture network (DFN) is generated for a small zone of interest in the grid by using a fracture density driver (probability map) to constrain the DFN generation. (Fig.15). This is calibrated based on well test interpretation data (KH value), using genetic algorithm. Once the statistic parameters are calibrated, the equivalent

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parameters are up scaled to the entire field. This fracture model is then incorporated in the simulation model of a naturally fractured reservoir.

In the Indian sub-basin context, Borholla – Champang field (Fig.1) in Upper Assam was the first field of ONGC from where production of hydrocarbon from fractured Granite basement has been commercially established. The Basement is partially weathered. Nearly 74 wells have been drilled to the basement so far in the area, of which 39 oil & 4 are gas bearing. The basement zone is on production since March 1981.

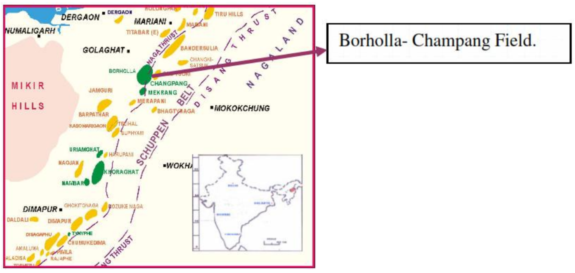


Fig.1 Location Map

Modeling of this naturally fractured reservoir was taken up using DFN (Discrete Fracture Network) technique on standard commercial software. (PP Deo, PVidya Sagar et al 2009))

Seismic Attribute Analysis

The 3D seismic data acquired (Fig.2) with basement as target reflector has been used for mapping. Fig:3. shows the depth structure map with faults that have been picked and mapped on the basic seismic data.

Various seismic structure related attributes have been used in this study with an objective to delineate and map the fault and fracture network. For best results it is suggested to filter the seismic data for any incoherent/back ground noisy events particularly near the basements as we generally do not see stratification down below. Fig: 2 and 4 amply demonstrates this fact. Representative basement correlation (yellow color) done on an In line and Trace line is shown in Fig.2.

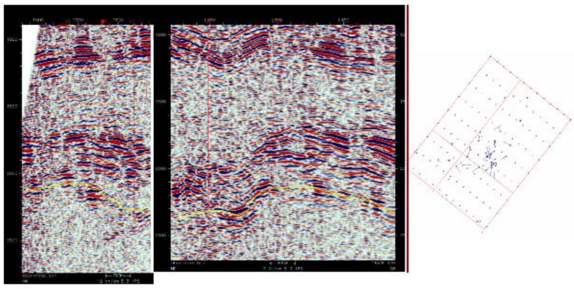


Fig.2 Seismic In Line & Trace Line Showing basement correlation

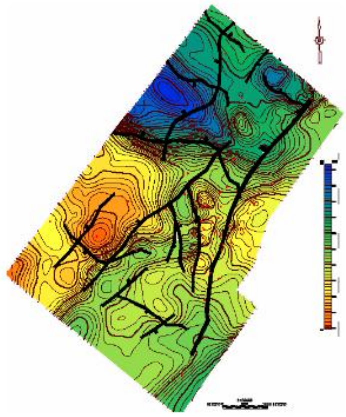


Fig:3.Depth structure map showing the faults

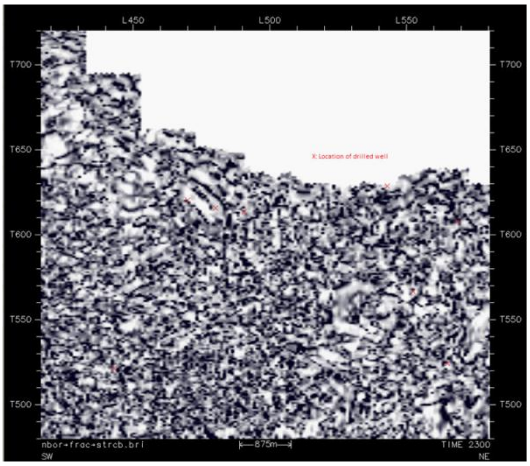


Fig.4 Coherency slice from structure cube Attribute

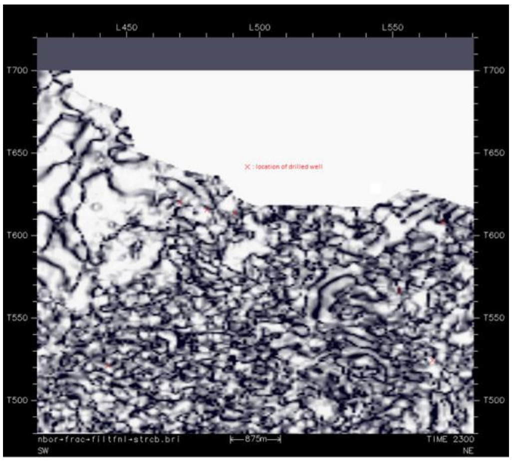


Fig.5 Coherency slice from structure cube Attribute after band pass filtering of input seismic data

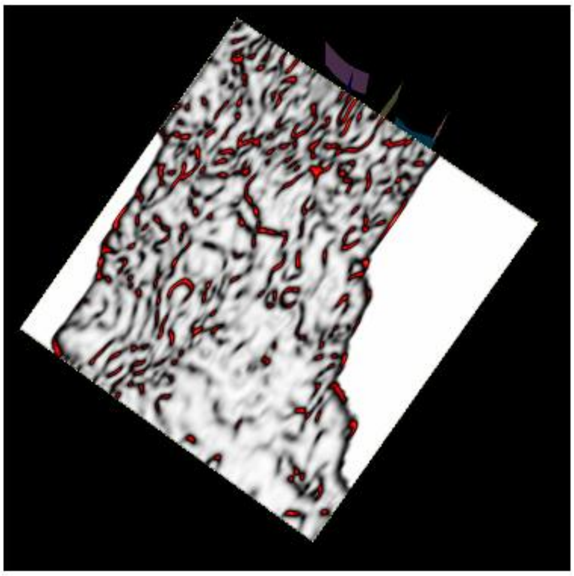


Fig:6. Slice from variance cube

The event similarity prediction studies for mapping seismic discontinuities has been carried out on the basic seismic volume and on the conditioned seismic volume. The coherency slice data from the conditioned data provided better results with detailed fault framework (Fig:5).

Further, Advanced 'Ant Track Capability' of standard commercial software has been used to generate sub seismic faults. Even this process also involves prior data smoothening/conditioning in the form of structure smoothing of the input seismic volume and computation of variance cube.(Fig:6) This variance cube was subsequently used to generate the Ant Track Volume. The Ant Track results have clearly brought out the presence and distribution of sub seismic faults (Fig.7).

All the slices shown in Fig.4 to 7 have been taken from basement and below.

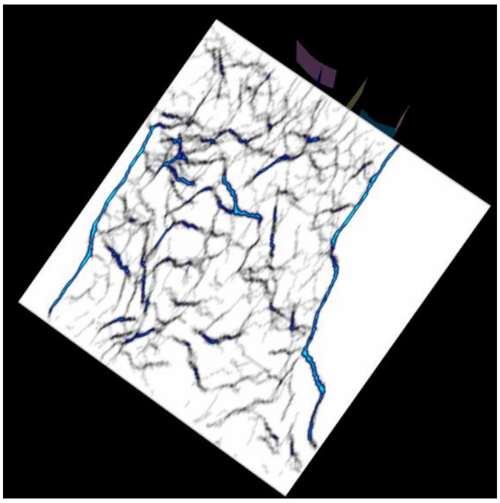


Fig:7 Ant Tracked Volume showing sub seismic lineaments

Well Log Attributes

Well log attributes such as resistivity contrast on LLD-LLS, hole rugosity, hole breakouts, abrupt change in density, longer sonic travel time, radioactive anomalies (high Gamma Ray peak) etc., have been used to identify fractured zones (Fig.8). On the basis of these petrophysical attribute studies in the basement section two facies type have been generated. These have been classified as fractured and non-fractured facies (Fig.9). These classified facies have been upscaled in the software and distributed and populated in the 3D volume using appropriate variograms (Fig.10). The distribution of these two facies within the 3D volume is very well brought out in the generated profiles (Fig. 11). This was discussed in detail under 3D reservoir grid section.

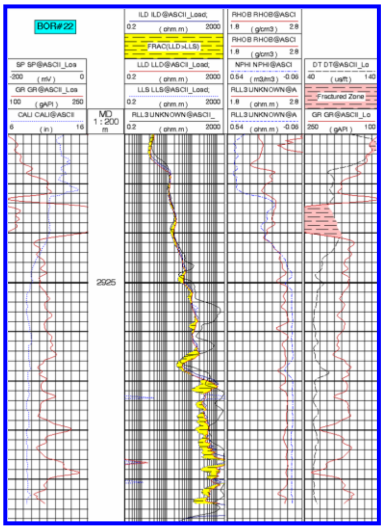


Fig.8 Fracture identification from conventional logs

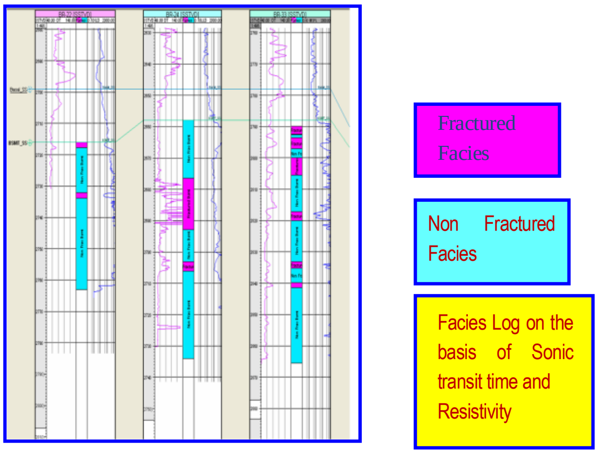


Fig.9 Facies classification from logs

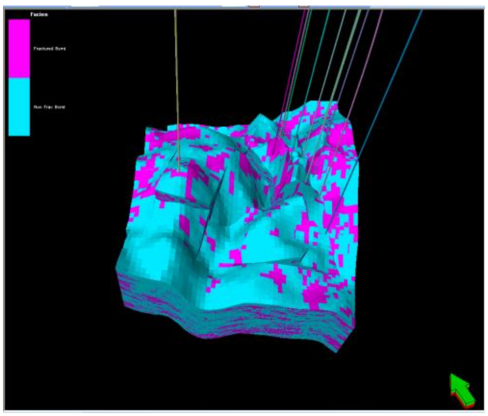


Fig.10 3D view of Facies Distribution

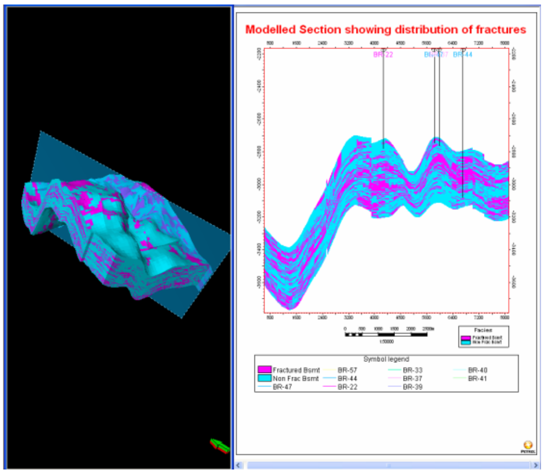


Fig.11 North-South section of facies model

3D Reservoir grid

Using the commercial modeling software Geo-cellular model was prepared with key interpretation output of the major fault network, depth surfaces corresponding to basement top and basal clastics. A mathematical surface was generated at 350m below basement top to define the lower bound of the model. 350 m was considered to cover substantial part of the basement and to have sufficient depth to provide the aquifer support needed for simulation.

Fault model prepared after adjusting the model top and lower bounds governed by basal clastics top and basement +350m.Thus, the three surfaces along with the faults loaded as fault sticks provided the structural framework of the model

Subsequent to scale up of facies logs, there was the need to propagate the scaled up facies from the well location to the grid cells geo statistically assigning a value into the grid node. Data analysis provides the geo statistical means like Kriging, Variogram etc, to control the facies propagation and analyze the geological uncertainties thereof. Of these, Variogram method was used to compute the fracture facies / non fractured facies propagation. With the result of the data analysis the fractured and non-fractured facies were propagated in 3D space and time within the gridded volume in the facies modeling process.

Fracture Model

A comprehensive fracture modeling was carried out in the commercial software where in a detailed fault and fracture analysis shall be done before modeling. The 3D grid, facies, faults, surfaces; available KH values of wells have been imported in to the software. Structural study through Curvature analysis technique has been used to pick the sub seismic faults. Curvature is a measure of the deviation of a surface from a plane. The more a surface is structurally flexed, folded or faulted, the larger its curvature. The input data for computing/mapping additional fault lineaments is Interpreted horizon data after duly cleaning up. In the present study, the structure map at basement level (Fig. 3) is the input. Location, orientation, and dip of the sub seismic faults were determined by automatic gathering and grouping of different sets (Fig.12 and Fig.13).

Fault and fracture modeling was performed for populating not only the sub seismic faults (Fig.13 and Fig.14) but also used for generating the diffused fractures in the reservoir grid by defining the dip angle, azimuth, length, aspect ratio, aperture, conductivity, fractal dimension and density of the sub seismic faults and diffused fractures (Fig.15). The fracture model so prepared was validated with the KH data from the actual well test data.

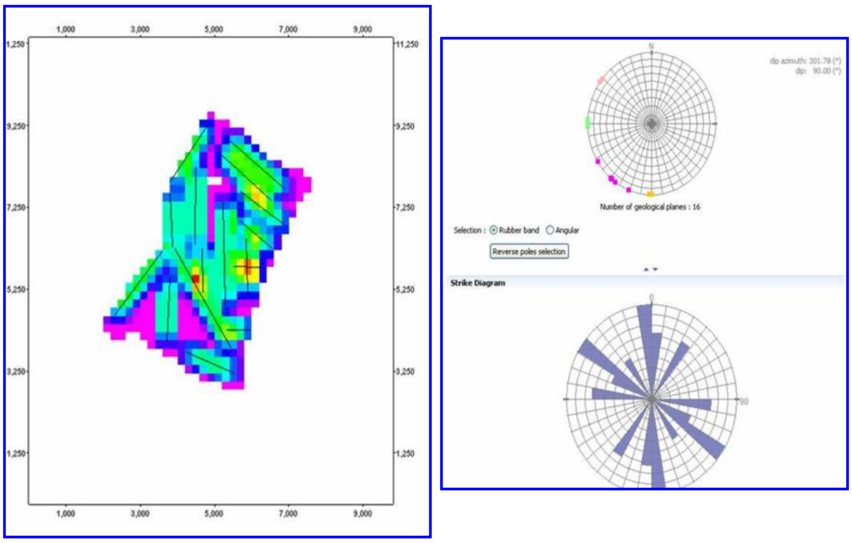


Fig.12 Sub seismic fault mapping through curvature analysis.

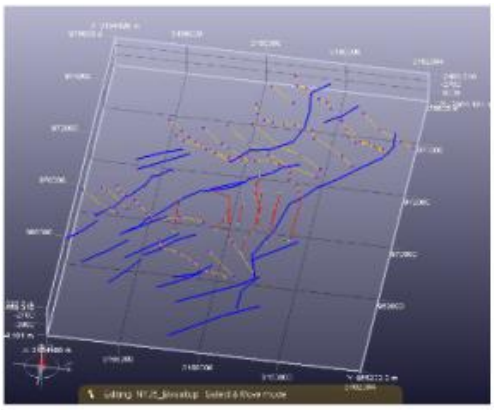
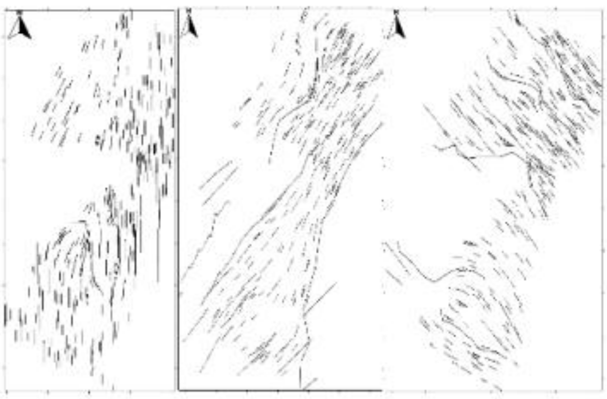


Fig:13 Sub seismic faults



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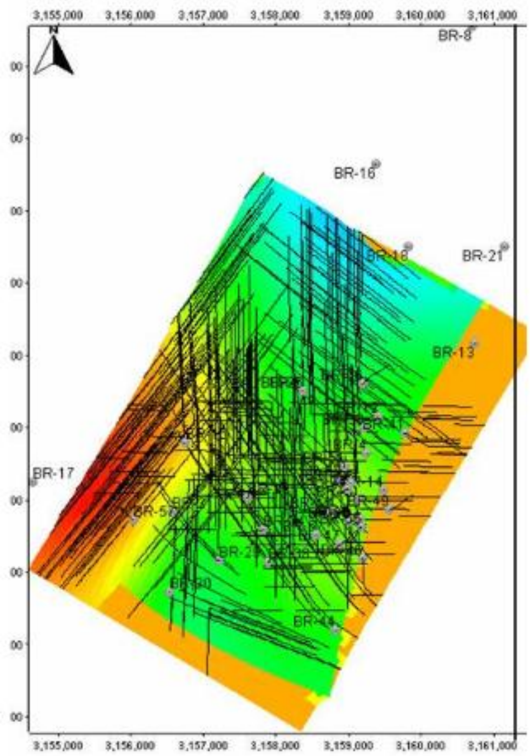

Fig.14 Map view of modeled Sub seismic faults.

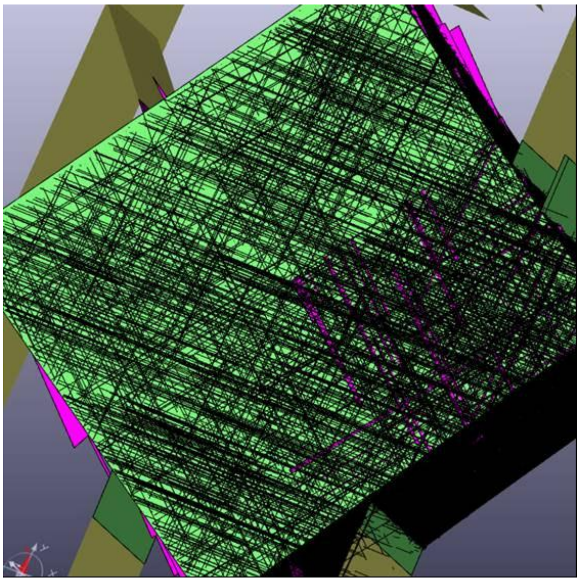

Fig15: Modeled diffused fractures around a well in a defined Zone of Interest

The fracture properties of the calibrated fracture model were up scaled to the whole grid and properties viz. fracture porosity and fracture permeability distribution was obtained (Fig.16).

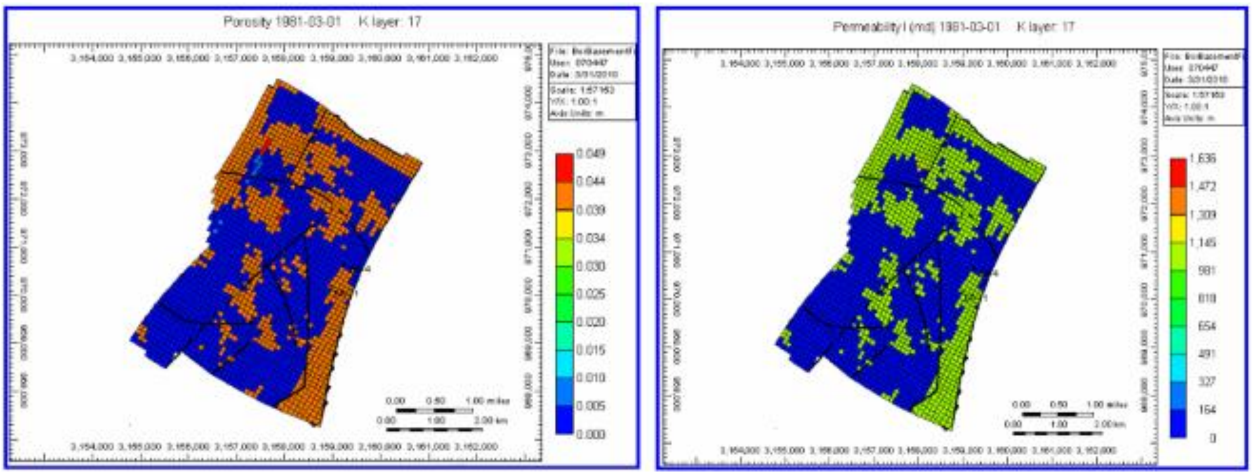

Fig.16 Map view of modeled porosity and permeability

Conclusions

- Integrated fracture model of basement section of Borholla field of Upper Assam has been prepared.
- Advanced features such as structure cube attributes, ant tracking and curvature analysis have been used in delineating faults and sub seismic faults.
- Various log attributes have been used in identifying fractured zones and generating the facies type.
- Curvature based fracture density maps were used in propagating the sub seismic faults and diffused fractures.
- The fracture model was validated with the KH data from the actual well test data.
- The Up-scaled fracture porosity and permeability distribution have been propagated in to the gridded area.

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