

Innovative Approach to Capture Heterogeneous Thin Pay Sands through Seismic Guided Stochastic Reservoir Modeling Processes. A Case study from Tapti Daman Sector, Western Offshore Basin, India

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Keywords

Tapti Daman, Clastic Reservoir, Tidal Influence, Poisson Impedance, P-Impedance, Sand Dispersal, Geo-Cellular Model, Thin Pay Sand.

Summary

Tapti Daman Sector is located in the Northern part of Western Offshore Basin, India. This sector is the amalgamations of various small structures like B-12/C-26, C-2, C-23/C-24 and C-39 etc. having commercial hydrocarbon accumulation, mainly gas in Mahuva and Daman Formation of Early Oligocene and Late Oligocene age respectively. This paper deals with the characterization and Geo-Cellular Modeling of clastic reservoirs of Daman Formation in B-12/C-26 area. Daman Formation in the study area represents the transitional environment between clastics of Cambay Basin in North East and carbonate of Mumbai Offshore Basin in South West.

Late Oligocene (Daman Formation) witnessed a global transgression, whereas sands within Daman are the result of High Frequency-Low Order sea level fall. Daman Formation is characterized by multi-stacked sands with thin shale interbeds and occasional limestone deposition in tide influenced deltaic environment. The primary gas bearing sands in study area are S-40 and S-30 having thickness range maximum up to 30 m, restricting its temporal resolution within single seismic cycle. Primary challenge in this area is the delineation of the sands owing to discrete nature, sub-seismic resolution and lithological variation vertically as well as laterally. Thus standalone seismic driven approach is not amenable to characterize the reservoir. Therefore to characterize such thin pay sands, an innovative workflow integrating seismic and stochastic well based algorithm has been adopted to prepare robust Geo-Cellular Model that is able to justify the sand dispersal pattern and hydrocarbon distribution in the area. Poisson Impedance combining with P-Impedance and S-Impedance from Pre-Stack Inversion results is used as the guiding factor for preparing facies model, where P-Impedance is used for propagating porosity in the model. This paper brings out methodology for effective delineation of heterogeneous thin gas sand reservoirs integrating seismic results and well based stochastic modeling.

Introduction

B-12/C-26 field part of Tapti Daman Sector is considered to be the southern extension of Cambay Basin located in Gulf of Cambay. Field is situated at distance of about 160 km WNW of Mumbai and 80 km north of Mumbai high field with an average water depth 30m (Fig.1).



Fig.1: Location Map of B12/C26 field in Tapti Daman.

The clastics reservoirs of Daman Formation (Late Oligocene) and Mahuva Formation (Early Oligocene) are the main hydrocarbon bearing zones in Tapti-Daman Sector. Daman Formation comprised of multi-stacked sands deposited in fluvio-deltaic environment. The basin forms a broad syncline rising against the ENE-WSW trending marginal faults towards the north, against the NNW-SSE trending basin margin in the east and in the south against the E-W trending Diu fault. The western limit of the Tapti-Daman block is represented by the Diu arch. The initial extension regime during basin formation was obliterated by the younger tectonics resulting in the combination of high and low as present day

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structural setup in the area. The transtensional regime during Miocene, most pronounced in the Late Oligocene & younger sequences, has given rise to a number of structures. Geologically it forms a major tectonic depression (Surat Depression) flanked by Saurashtra Homocline to the west/northwest, Eastern Homocline to the east, Diu Fault to the south and Diu arch to the west (Fig.2). Over the time, approximately 6000m thick Tertiary sediments have been deposited in the depression. Sediment deposition is represented by layers of shale/claystone, sandstone, siltstone with occasional carbonate and coal/carbonaceous matter.

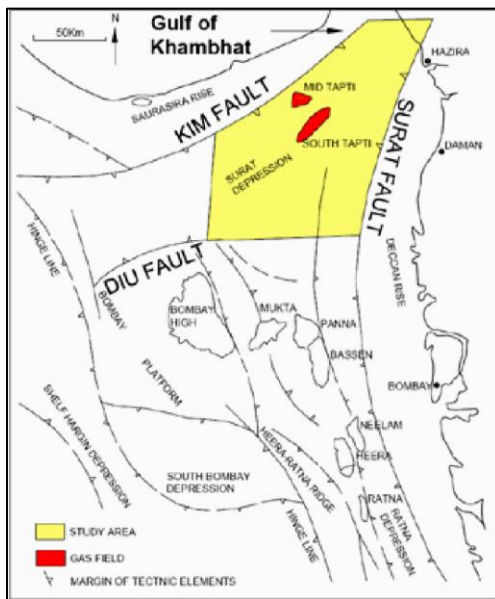


Fig.2: Tectonic map of Western Offshore Basin.

Proto Narmada and proto Tapti are the major river systems responsible for clastics supply to the basin. Heavy minerals suite and nature of detritus of sediments of Tertiary suggest major influx is from North East direction.

Initiation of sedimentation in Tapti Daman Sector started with deposition of Paleocene to Early Eocene Panna Formation above the Deccan Traps of Upper Cretaceous age. Subsequently, Belapur, Diu, Mahuva and Daman Formations were unconformably deposited in the entire area. Daman Formation (Late Oligocene) is a coarser clastics rich sequence and major gas bearing formation within this area, which is overlain by Mahim, Tapti and Chinchini formations of dominant shale. The generalized stratigraphy is shown in the Fig.3.

AGE	FORMATION	LITHOLOGY	PETROLEUM SYSTEM
POST MIOCENE	CHINCHINI		
MIOCENE	LATE		
	MIDDLE	TAPTI	
	EARLY	MAHIM	Panna-Mahim (MBS)
OLIGOCENE	LATE	DAMAN	Panna-Daman
	FEARLY	MAHUVA	Panna-Mahuva
	EOCENE	DIU BELAPUR	Panna-Belapur
PALEOCENE	PANNA		Panna-Panna
CRETACEOUS			

Fig.3: Generalized stratigraphy of the Tapti Daman.

Methodology adopted

Extensive pre-stack inversion feasibility study was carried out to effectively characterize such complex and heterogeneous thin intercalated shale-sand reservoir and delineate sand dispersal pattern. It is observed that the PSTM gathers were reasonably flat up to 36° within zone of interest (Daman-Mahuva) and suitable for pre-stack inversion. Four angle stacks with angle ranges 4°-12°, 12°-20°, 20°-28° and 28°-36° have been generated for inversion. Rock physics modeled logs crossplots of P-impedance and Vp/Vs was able to discriminate the pay and non-pay zones to a certain extent, whereas filtered to seismic frequency crossplots showed some overlap between gas bearing and water bearing sands. Therefore, Pre-Stack Inversion Poisson Impedance volume was generated by combining inverted P-Impedance (Zp) and S-Impedance (Zs) using following equation,

$$\text{Poisson Impedance (PI)} = Z_p - c * Z_s$$

$$c = 1/0.715 = 1.398$$

Where, c is the inverse of the slope of the litho-fluid trends of P-Impedance and S-Impedance cross-plot, which optimizes the rotation. This volume was able to characterize the facies and used secondary variable for stochastic reservoir modeling (Fig. 4a and 4b).

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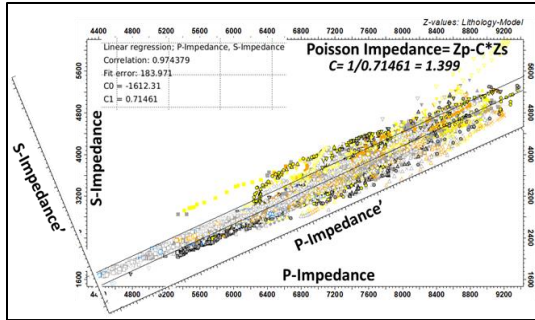


Fig.4a: Relation to create Poisson impedance volume

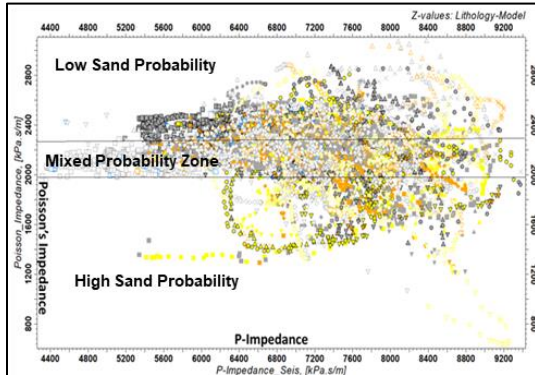


Fig.4b: Probability of facies delineation with respect to Poisson Impedance.

Poisson Impedance was used as prime guide for facies delineation in GCM. Other petrophysical properties like porosity and saturation followed after the facies model. The workflow adopted to model the thin pay sand is given in figure 5.

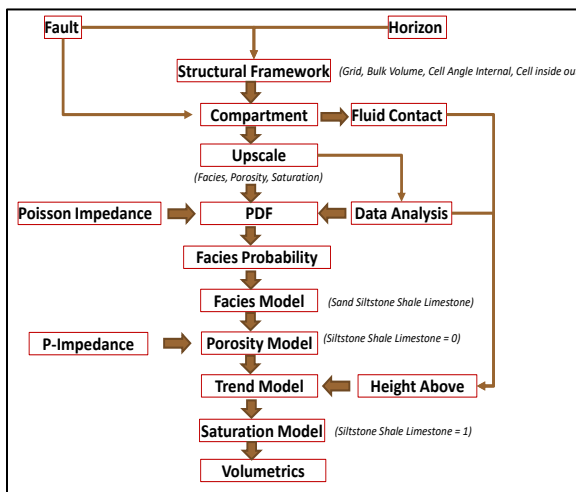


Fig.5: Workflow adopted for GCM preparation.

Model Preparation

Seismically, mapped horizons equivalent to Mahuva, Sand-30 and Daman Formation and correlated faults have been used to prepare the structural framework of the area. Structural model was built using horizons/surfaces bounding the reservoir intervals, faults and the inter-relationship between surfaces and faults by CPG method, which is the primary inputs. Grid construction was performed keeping increment (in i and j direction) as 100 m and 100 m for the vertical zonation 0.5 m main hydrocarbon bearing zones. With this configuration total cells generated were 63306960 (508*372*335).

Initiation of property modelling was carried out after quality checking of the grid, where cell internal angle remain less (8°), no cell inside out and bulk cell volume was positive which showed the robustness of the grid (Fig.6). Geometric properties like Zones, Segments and ABOVE CONTACT were created to limit the vertical propagation of facies and petrophysical properties in model.

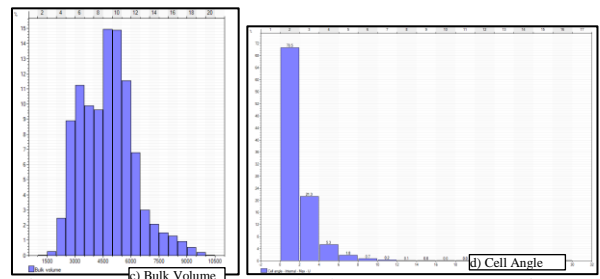
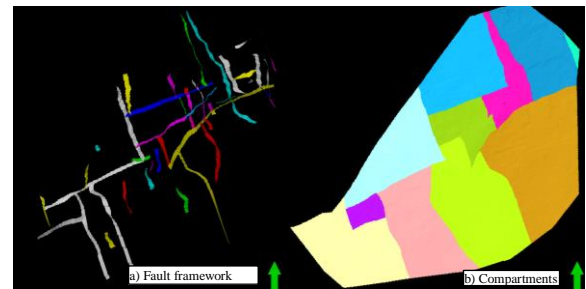


Fig.6: a) Fault Framework, b) compartments in B-12/C-26 area, c) Bulk volume histogram and d) Internal cell angle histogram

Contact definition of thin pay sands and hydrocarbon distribution within Daman formation were mapped based on normal suites of logs, ELAN processed logs and Rock Physics Modelling output data. The contacts of sands in B-12/C-26 area is taken as

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mostly lowest known gas (LKG) where GWC only in well B-12-W for S30 at -2457m and GWC at -2276m (B-12-I) for S40 was present (Fig.7).

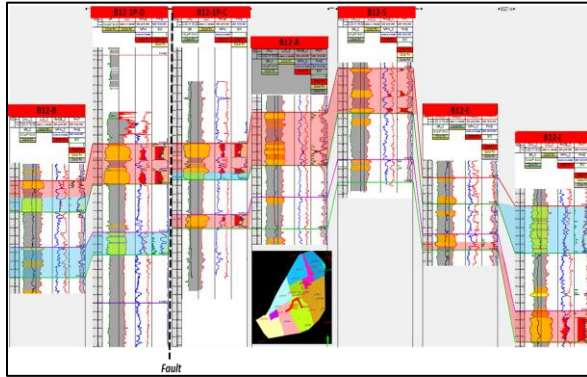


Fig.7: Well Correlation profile showing hydrocarbon distribution.

Probabilistic approach has been adopted for Facies model. Lithofacies for each pay sands of Daman Formation were populated stochastically. Pay sand wise Posterior Probability Distribution Function (PDF) of all facies with secondary variable of Poisson Impedance was generated (Fig.8). Sand isolith maps for the each pay extracted from facies model were inconformity with the envisaged geological understanding and justified the wells (Fig.9). Facies model thus generated served as the bias for the petrophysical properties population. The outcome of sand lithofacies is overlain by well based isolith maps, which define the similar sand geometry.

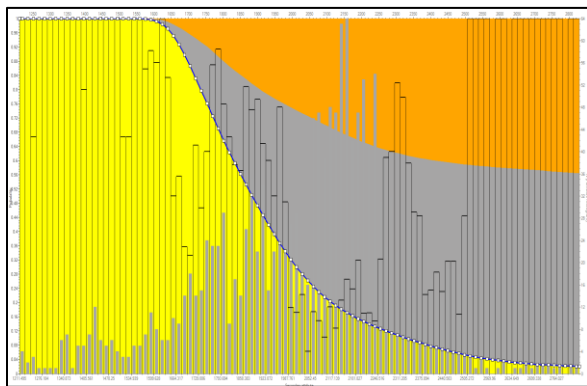


Fig.8: Posterior probability distribution function (PDF) for all facies of S30.

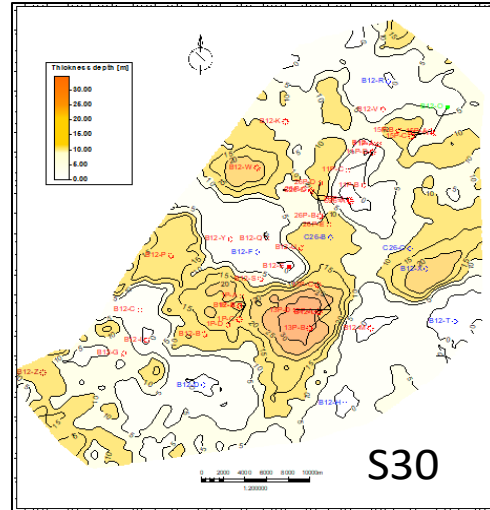


Fig.9a: Sand isolith map of pay S30 extracted from facies model

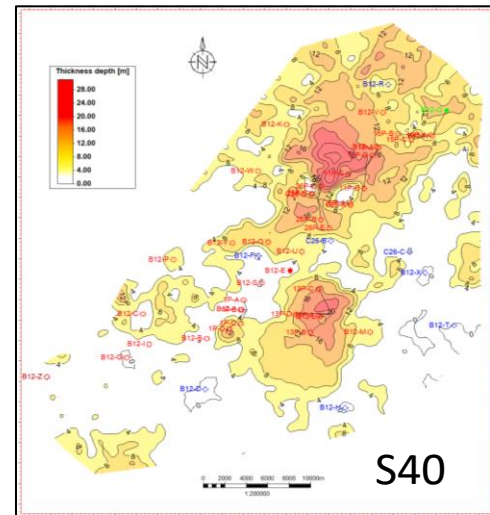


Fig.9b: Sand isolith map of pay S40 extracted from facies model

Properties such as porosity and saturation have been populated throughout the reservoir/model, based on the input data, knowledge of their trends, distributions and the same was performed stochastically. The Porosity model was conditioned to seismic data using collocated co-kriging since P-impedance shows linear and inverse relationship with effective porosity (PHIE) in sands (Fig.10). Gaussian Random Function Simulation (GRFS) using collocated co-kriging was performed taking P-Impedance as the secondary variable. The average porosity map filter to facies and zone was extracted

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which showed the variation of porosity in the area (Fig.11.)

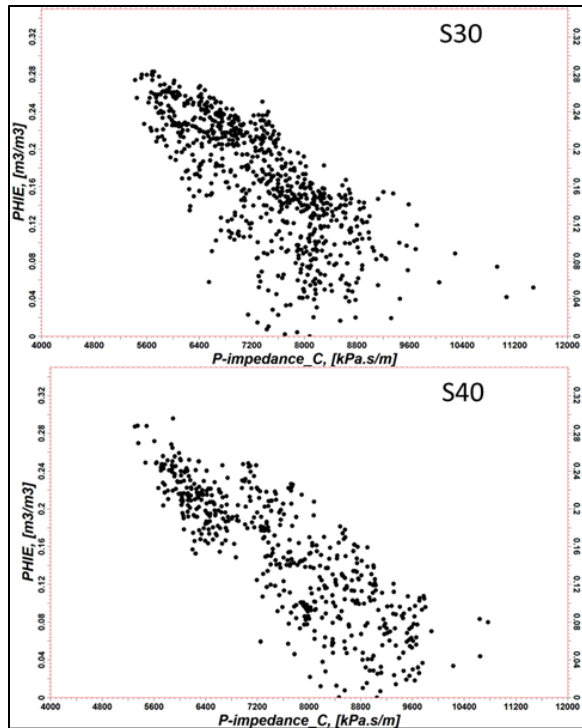


Fig.10. Relationship between P-impedance and PHIE for S30 & S40.

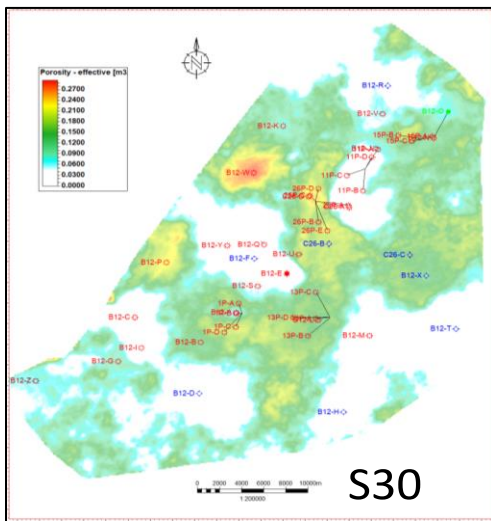


Fig.11a: Average porosity map of pay S30 extracted from porosity model

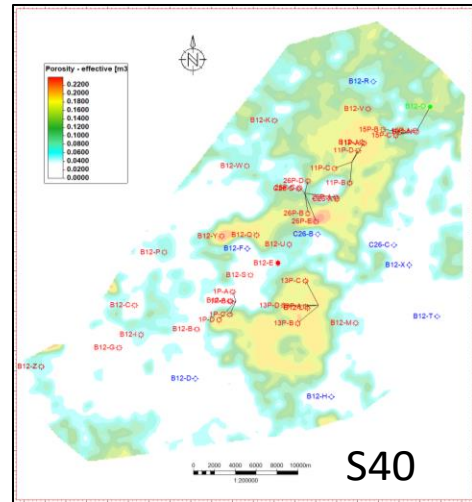


Fig.11b: Average porosity map of pay S40 extracted from porosity model

There was inverse relation observed between Sw and effective porosity in upscaled logs. Therefore regression function was taken as guiding trend for Saturation modeling (Fig.12).

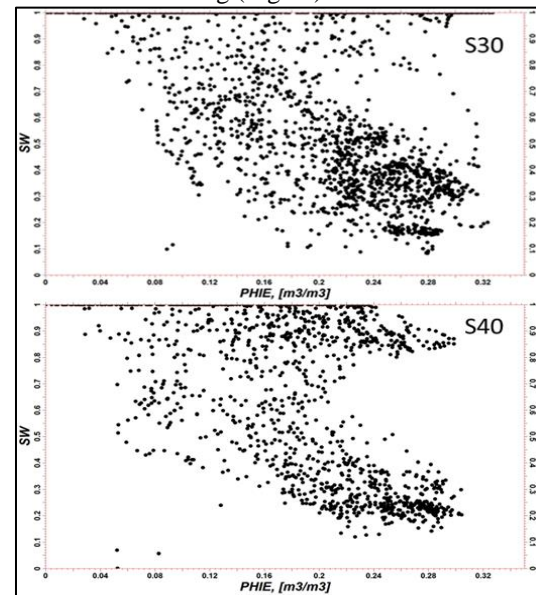


Fig.12. Relationship between PHIE and Sw for S30 & S40.

This was performed parallel (XYZ) to height above contact and biased with porosity model using krigging algorithm. The average saturation maps were extracted for QC and found to be satisfactory at all wells (Fig. 13).

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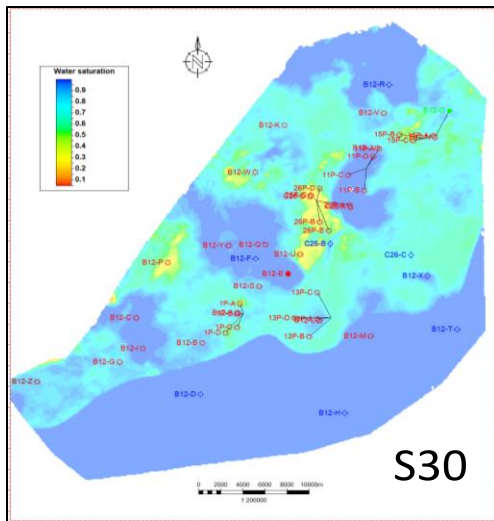


Fig.13b: Average Saturation map of pay S30 extracted from saturation model

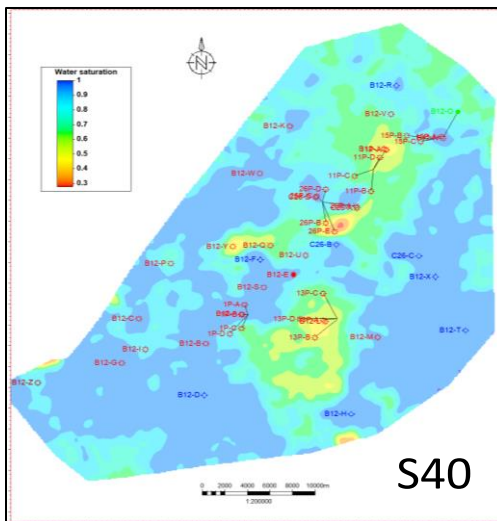


Fig.13b: Average Saturation map of pay S40 extracted from saturation model

Conclusions

The methodology adopted here has focused on delineation of thin pay sand reservoirs through integration of pre-stack inversion results, well based data and reservoir data using stochastic Geo-cellular-Modeling. This workflow could effectively delineate the sand geometry, whereas standalone seismic guided attributes were not able to discriminate the reservoir facies and hydrocarbon distribution.

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N.B: The views expressed in the paper are those of the authors only.

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