

Depositional model and delineation of reservoir fairways of Basal Clastics of Mumbai High field, Western Offshore Basin, India

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Keywords

Basal Clastics, Geological model, Reservoir fairways, Basement, Wedge out, P-impedance, Characterization

Summary

Mumbai High field located in the western offshore of India, is a giant structure, established hydrocarbon in Miocene carbonates of L-III, L-II & L-I and Basal Clastics as a secondary reservoir. Commercial quantities of hydrocarbon were discovered from Basal Clastics first in 1976, subsequently 97 wells have penetrated into the Basal Clastics, out of which 59 wells proved to be hydrocarbon bearing. Presently 15 wells are producing from Basal Clastics with cumulative production of 8000 BOPD.

Basal Clastics sands are deposited over a long period ranging from Pre-Cambrian to Oligocene, which suffered several cycles of erosion and re-deposition. Deposition of Basal Clastics sand and fluid distribution therein is heavily governed by the Basement architecture and its lithology, giving rise to several compartmentalized occurrence of hydrocarbon.

The earlier sand models were prepared based on well input only which lead to surprises during development phase. To overcome the shortcoming of well based model, present model is prepared integrating Basement architecture, Basement relief, production/testing of wells data, seismic attribute and earlier studies.

Basement lithology was characterized into three major groups: Granite/Granite Gneiss, Phyllite/Schist and Basalt. Primary source for the clastics are Granite/Granite gneiss, whereas it became shaly or absent in the Basalt province. Basal Clastics reservoir is hydrocarbon bearing in the Basement lows, whereas absent in Basement high. The wedge out areas of the Basal Clastics against the Basement highs mapped precisely in the seismic data.

This study effectively brings out the deposition model and reservoir fairways, which explained the hydrocarbon distribution in the field.

Introduction

Mumbai High field is located off the western coast of India in Arabian Sea about 160 kilometers north-west of Mumbai (Fig.1).

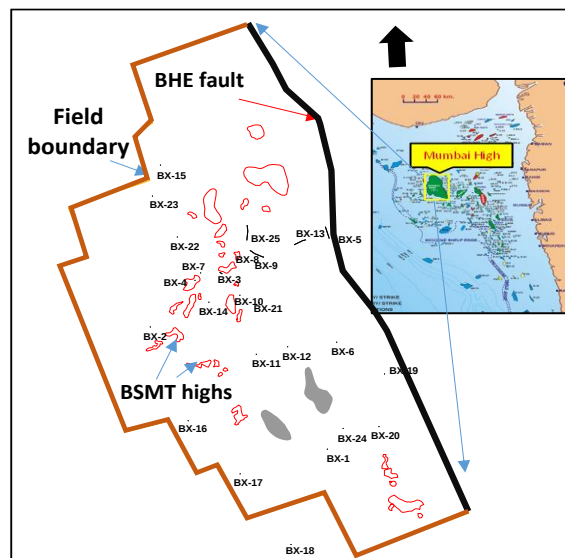


Fig.1 Location Map Mumbai High field.

In Mumbai high field, the sedimentary sequence can be grouped broadly into three major units: Basal unit of clastics varying thickness upto 30m resting over igneous (Granitic/Basaltic) and metamorphic (Granite gneiss/schist/ quartzite) Basement, middle unit of predominantly of limestone and shale of 1000-1100m thick, upper unit of limestone, shale and claystone of 800-900m thickness. The upper part of middle unit (Bombay Formation) is most productive (Fig.2).

Oil in Basal Clastics was first discovered in year 1976 in the well BX-1 which was tested and oil rate found to be about 1000 bbls/day. As on date 97 wells have penetrated through Basal Clastics, out of which 59 wells proved to be hydrocarbon bearing.

Reservoir Modelling: Seismic to Simulation

Hydrocarbon distribution shows oil, free gas and gas cap gas accumulation over the field in the Basal Clastics formation.

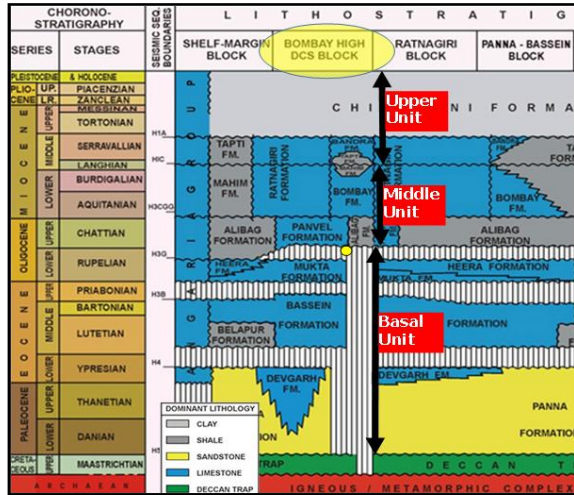


Fig.2 Generalised stratigraphy of the Mumbai high field

Role of Basement in Basal Clastics depositional pattern

Basal Clastics which is the product of Basement eroded material, is the first clastics sequence deposited over Basement, since the Basement remained as an isolated high from Precambrian to Oligocene age. The provenances for Basal Clastics are mainly from granitic, metamorphic and basaltic Basement. To understand the Basal Clastics depositional pattern, composition of Basement was analyzed by integrating the log responses, side wall core (SWC), Conventional Core (CC) and cuttings data and a Basement composition distribution map was prepared (Fig.3).

A generalized sedimentary succession, based on the core studied in well BX-14, shows that the sequence was deposited with a coarse conglomerate at the bottom followed successively by a gritty sandstone, massive sandstone, fine grain sandstone and at the top by a siltstone or shale (Fig.4). The Basal Clastics sands are deposited in a continental, fluvial to transitional regime from Pre-Cambrian to Late Oligocene age and suffered several cycles of erosion and re-deposition due to long hiatus. Post Oligocene entire Mumbai high was inundated by sea depositing thick carbonates in Panvel and Bombay formations.

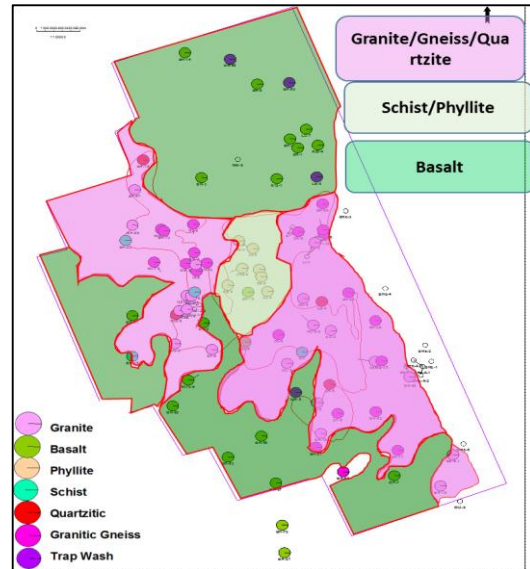


Fig.3: Mumbai High Basement composition map.

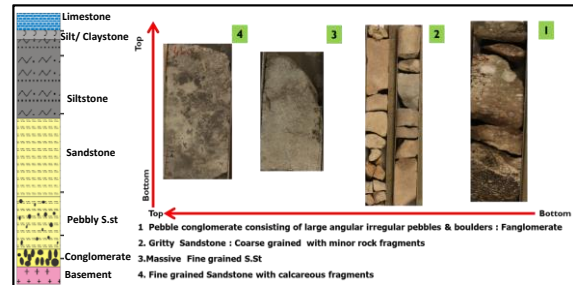


Fig.4 Generalized sequence of Basal Clastics observed in core of BX-14.

Structural Setting

The tectonic fabric of Basement and Basal Clastics is interpreted using various attribute. A representative time slice at 1720ms extracted from dip magnitude volume attribute (Fig.5), shows a major NNW-SSE strike slip fault (BHE fault). Another seen major fault, trending from WNW-ESE is dividing the Bombay High structure into Mumbai High North (MHN) and Mumbai High South (MHS) part. Apart from these, a number of N-S faults parallel to Bombay High Eastern margin fault were mapped. These faults are dissected by E-W cross trends. In the southern part of area NNE-SSW and NNW-SSE fault trends are mapped.

Reservoir Modelling: Seismic to Simulation

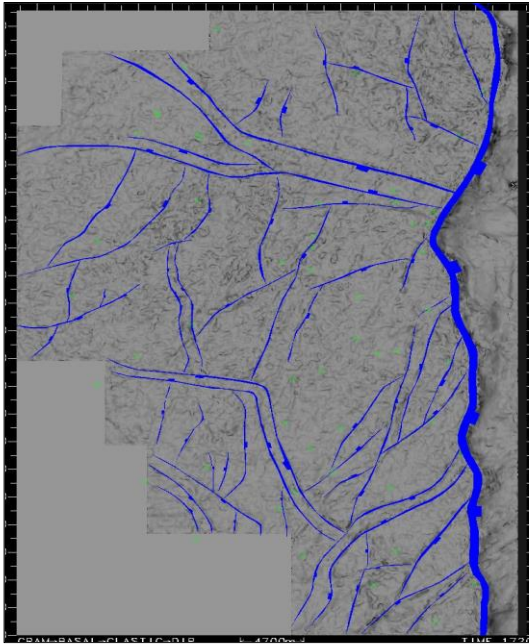


Fig.5: Time Slice at 1720ms extracted from Dip Magnitude Volume, showing the faults trends

Characterization of Basal Clastics

Higher thickness (upto 30m) of Basal Clastics is observed in Basement low areas and it is absent wherever prominent Basement highs are present. In the recently drilled well BX-4, the Basal Clastics is not present as it has encountered the Basement high, which turned out to be shallowest Basement in MHS field. Basal Clastics surface wedging out against the Basement were mapped precisely on the CRAM processed seismic data, as shown in arbitrary seismic section (Fig.6). Basal Clastics surface draped on Basement horizon is clearly depicting the Basement inliers (Fig.7).

The deposition of Basal Clastics sands are mainly controlled by underlying Basement lithology, paleo-relief, and fluvial drainage pattern. The hydrocarbon bearing clastics are observed on the top of granite/granite gneiss/phyllite/schist/quartzite Basement type, which are mainly restricted in the Mumbai High South (MHS) area.

The log motifs of Basal Clastics overlying granite/granite gneiss Basement are representing thick and good sand development. Wells in the northern part of MHS, are showing thick weathered Basement,

which is probably the result of long time exposure and in-situ weathering of the Basement rock. Wells in the western part are showing high GR response against the sands occurring just above the Basement. These sands are derived from adjoining granitic/granitic gneissic high and deposited in the intervening lows with very less distance transportation (Fig.8).

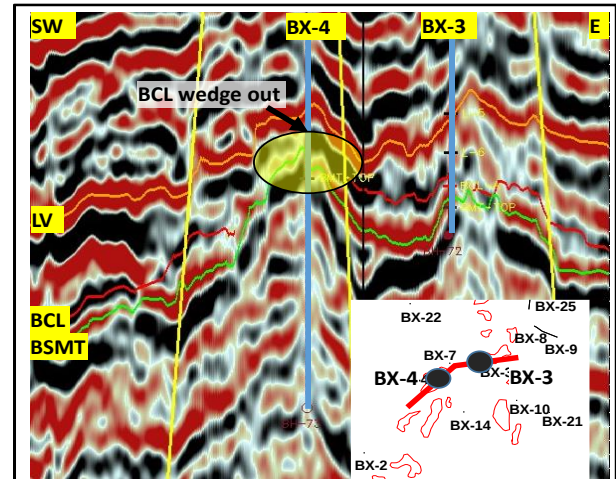


Fig.6 Arbitrary seismic section depicting basal clastics (BCL) formation wedge out against Basement.

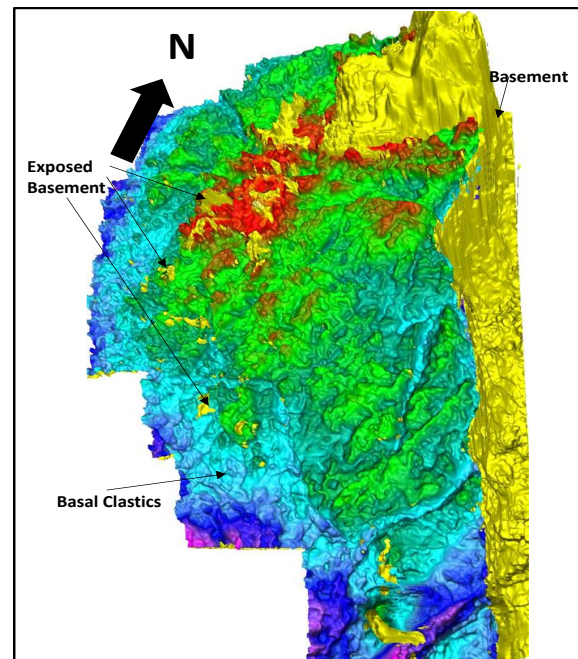


Fig.7 Basal Clastics Surface Draped on Basement depicting Basement highs and wedge out limits.

Reservoir Modelling: Seismic to Simulation

Basal Clastics overlying phyllite /schist /quartzite Basement are showing relatively less thickness, except in well BX-6 and BX-8. These wells have penetrated the relatively low Basement topography and are surrounded by granitic Basement, which led to good sand deposition (Fig.9).

Clastics derived from Basalt provenance are mostly shale in the MH field or absent as observed in MHN area. The southern part of the field is dominantly shale with thin sand and silt layers. These thin sand and silt layers are probably transported from up dip granitic/granitic gneiss Basement erosion (Fig.10).

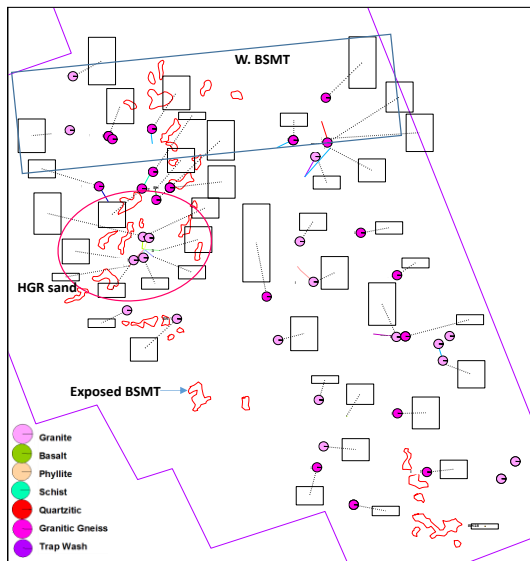


Fig.8 Log motifs of Basal Clastics on Granitic/Granitic gneiss Basement.

The grain size parameters and the plots of CM pattern help to distinguish between the sediments of different environments of fluvial to deltaic deposits. Based on CM pattern, Chug et al. carried out study in 1985, for wells BX-7, BX-9, BX-10 and BX-11, which suggested that sand in well BX-7 deposited under gravity flow and dumped near site, while the wells BX-9, BX-10 and BX-11 indicated fluvial deposition with multi-channels system. The C-M Pattern (Fig.11) of sands of well BX-7 belong to NO and OP regions, suggested predominance of high energy rolling, while samples of the wells BX-9, BX-10 and BX-11 in PQ-QR regions, suggested transportation by rolling and graded suspension with comparatively moderate energy condition.

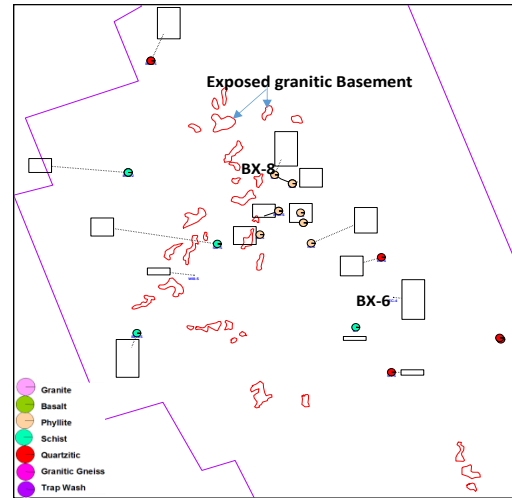


Fig.9 Log motifs of Basal Clastics on metamorphosed Basement (Phyllite/Schist/Quartzite).

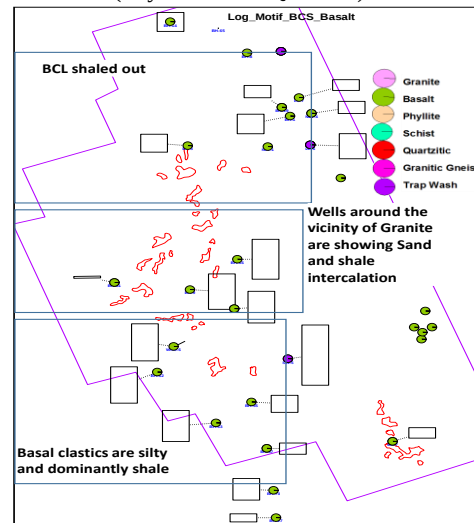


Fig.10 Log motifs of Basal Clastics on Basalt Basement.

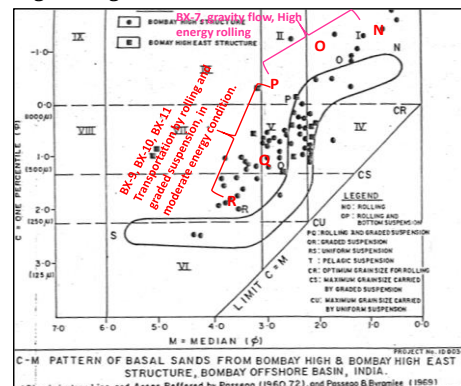


Fig.11 C-M pattern of Basal Sands.

Reservoir Modelling: Seismic to Simulation

Depositional Model of Basal clastics

A depositional model for Basal Clastics is prepared using Basement type, Basement topography, cross plots, seismic attributes and integrating earlier studies. A Cross plot between PHIE vs. P-IMPEDANCE for BX-6 and BX-12 depicts two distinct hydrocarbon windows (Fig.12), where the impedance is ranging from 7300-9500 for BX-6 and 9500-10550 for BX-12. The variation in impedance range clearly indicates the presence of different reservoir facies. The acoustic impedance attribute and multi attribute facies average response map with in a window of plus 4ms to minus 20ms w.r.t. Basement horizon extracted are showing distinct NE-SW trends (Fig.13).

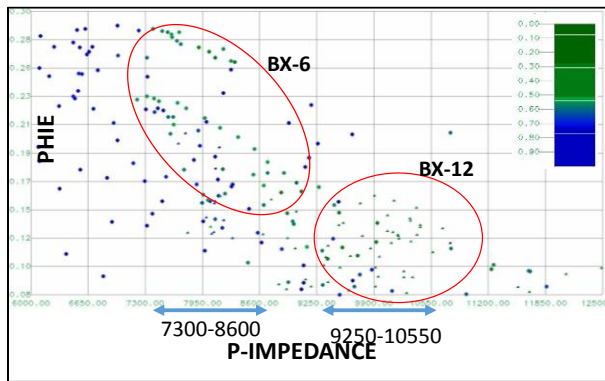


Fig.12 Cross-Plot Between PHIE and P-Impedance with Sw.

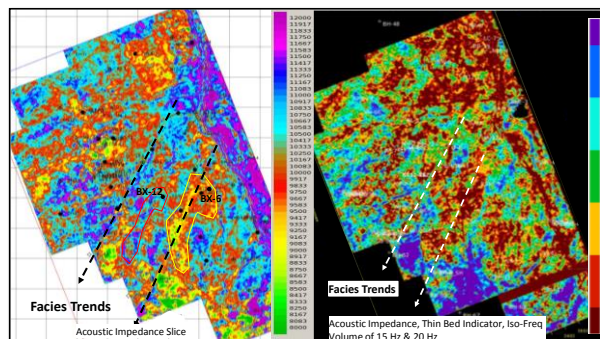


Fig.13 Acoustic impedance and Multi-Attribute Facies Map (Basement p4-m20ms) - Average Response (Acoustic Impedance, Thin Bed Indicator, Iso-Freq Volume of 15 Hz & 20 Hz) showing NE-SW trends.

Based on the seismic attribute analysis, Basement structure and granulometry study, a NE-SW trend is inferred and incorporating all wells data, isopach map of Basal Clastics was prepared. The Basal Clastics

depositional trends are mainly controlled by the underneath Basement topography, which was further validated by draping the isopach map contour on Basement structure map (Fig.14).

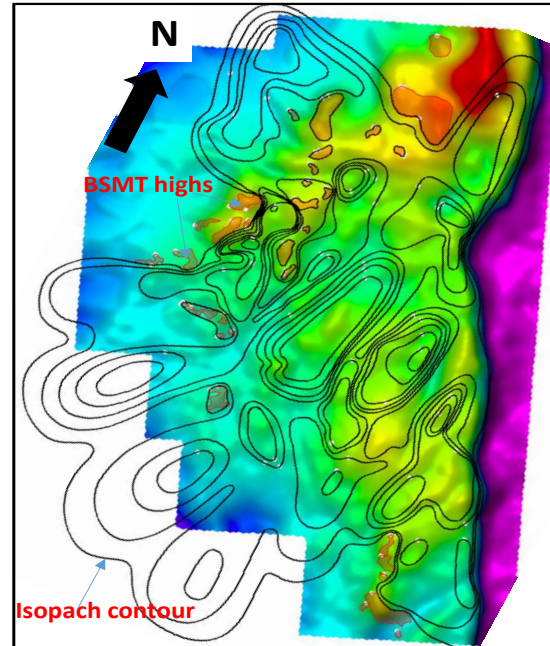


Fig.14: Isopach map contour draped on Basement Map.

Hydrocarbon distribution in Basal Clastics Formation is well explained in the section W-E along the wells BX-4, BX-3, BX-9, BX-13 and BX-5 (Fig.15). Many wells are drilled in the area falling in between BX-4 and BX-3, which is characterized by high GR sand producing excellently in the field. Well BX-13 and BX-5 is drilled in graben area are showing good thickness of sand and oil presence in Basal Clastics.

Basal Clastics reservoir is divided into different blocks based on production history and sand deposition models, where Block-A, B and C are good producers. The pressure data of wells also suggest that these blocks are isolated. The gas oil contacts (GOC) are different in the field, as in Block-A, GOC is at 1827.5m and in Block-D it is at 1885m, whereas Block-F has Gas Shale Contact (GSC). The recorded pressure data of producing wells indicated marginal decline in pressure even after production for a longer time. This suggests either the in-place volume is more with reservoir being aurally extensive or all the blocks are supported by same aquifer through fractures evidently seen in the Basement

Reservoir Modelling: Seismic to Simulation

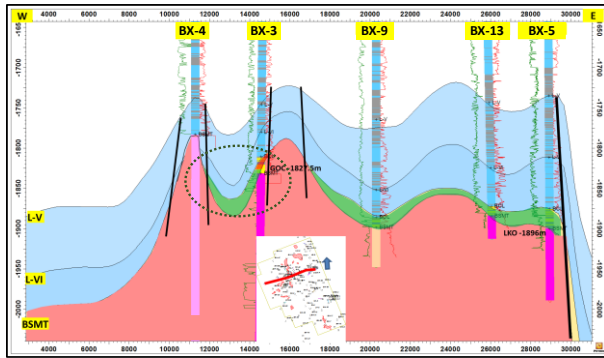


Fig15: W-E geological section along the wells BX-4, BX-3, BX-9, BX-13 and BX-5 showing hydrocarbon distribution.

Based on the integrated study a deposition model for Basal Clastics was prepared, which depicts the sand dispersal pattern and major reservoir fairways trends as given in 3D schematic block diagram (Fig.16).

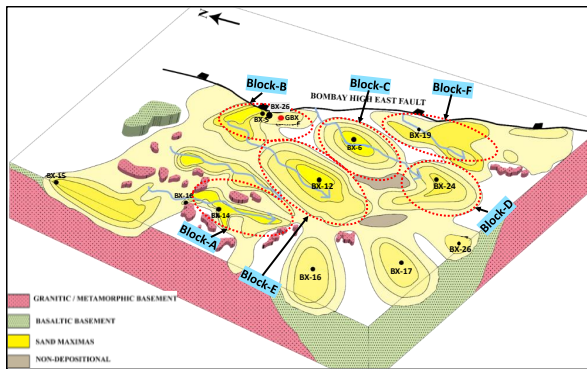


Fig16: 3D schematic depositional model and reservoir fairways of Basal Clastics and different reservoir blocks

Based on the model a development well, BX-26 has been drilled in Basal Clastics in Block B and is producing oil 769 BPD without water cut.

Conclusions

- Basal Clastics sands are deposited in a continental, fluvial to transitional regime from Pre-Cambrian to late Oligocene period and suffered several cycles of erosion and re-deposition.
- Basement lithology and relief had influence on Basal Clastics deposition.
- The wedge out areas of the Basal Clastics against the Basement highs mapped precisely in the seismic data.

- Depositional model for Basal Clastics and reservoir fairway trend is prepared using well data, Basement relief, seismic attributes and integrating earlier studies clearly explained the compartmentalization.
- Basal Clastics is producing mainly from Block-A, B and C. The pressure data suggest that these blocks are isolated and marginal decline in pressure even after production for a longer time. This suggest either the in-place volume is more with reservoir being aerially extensive or all the three blocks are supported by same aquifer through fractures evidently seen in Basement.
- Development well BX-26 drilled in Block-B on the basis of model is producing oil 769 BPD, thereby validating the model.

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