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Major Pay Sand Delineation through Inversion Study from the Mid to Northern Cambay Basin Field, India

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Summary

The Cambay Basin is situated in the western part of Indian and it is divided into five major tectonic blocks from north to south. During depositional activity the major pay formations have been changed with tectonic activity from south to north. The main three formations named Kalol, Kadi and Intra Cambay considered as reservoir formation that developed in the late rift to early post rift stages of basin development. These were deposited within fluvio - deltaic system – the lower to middle Eocene Kadi and Kalol formation in the north Cambay Basin, while late paleocene Intra-Cambay formation within OCS was deposited as regressive sand bodies. Other than these formations somewhere Deccan also has made hydrcarobon production. The different pay sands contains in these formation have been analysed here.

Introduction

The Cambay Basin, a prolific hydrocarbon producing basin in which many producing field is located. The NNE-SSW trending Tertiary rift basin located in the western part of India. The basin is juxtaposed with Mumbai Offshore Basin with many giant oil and fields in the south and Rajasthan Shelf, a basin with increasing exploration interest in the north. The reservoir in Cambay Basin is sandstone reservoir. But in full stack seismic data shows limited contrast between sandstone reservoirs and other lithologies. It is common in for reservoir sands to have similar P-impedance with the intra-formation shales. As both lithologies are concurrent in depth, interpretation mistake are easily made. This will result in ambiguous seismic amplitude extractions, which does not always represent the true reservoir distribution. However, where P-impedance alone cannot characterize the reservoir, for instance coupling the P-impedance with shear information through S-impedance can gives us more close information regarding reservoir and it's pay sand lithology.

Methodology

a) 3-D Model Assumption

The seismic inversion result has been used here to convert the seismic reflection data in to impedance log at each and every point. It is required to attach geophysical constraints to the inversion of the seismic reflection data then these constraints can be attached with particular facies and very closely with structure (Pendrel et al., 1998). The some inversion result below seismic band frequency gives some ambiguous information. Here the suitable geological model has been used for considering the closely correlated frequency. For low frequency model the sonic and density log has been taken in consideration.

b) Wavelet Analysis for Inversion (Dufour et al., 1998)

Wavelet Analysis is an important step to run the seismic inversion. The main goal of this analysis is that match the wavelet as per best option to the well log reflection coefficient to the input seismic data at well location. The wavelet which is corresponds to the seismic amplitude is utilized to seismic inversion purpose. In inversion study two waves are much more important P-P and P-S wave; for this two wavelets corresponding to the mentioned waves must be determined. It is very much often that in seismic inversion there is a query that "At each CMP, which reflection coefficient series, when convolved with the wavelet produces a synthetic which replicates the input seismic data?" (Pendrel et al., 1998). The solution is found by minimizing a combination of L1 and L2 norms, subject to set of constraints (Debeye and Van Riel, 1990).

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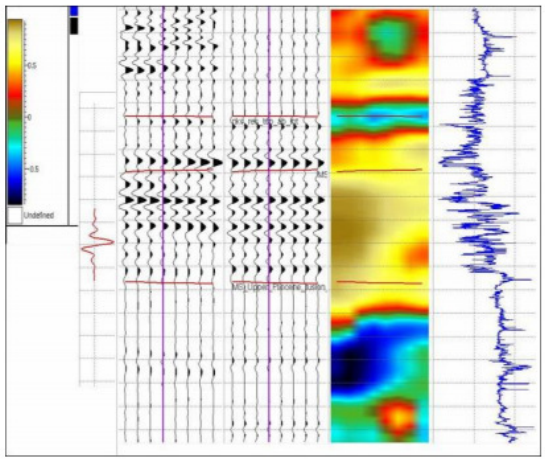

Fig1: The wavelet which is used to run in seismic inversion

c) Determination of Vp/Vs

After getting the result the seismic inversion in both conditional wave P-P and P-S, the Vp/Vs ratio estimation is required for analyzing the inversion result. This Vp/Vs ratio can be estimated very accurately in depth domain and also make fine interpretation over the geological formation. The ratio estimation procedure is listed by given formula,

$$Vp/Vs \sim Vpp / Vps * 1 + \Delta P - P + \Delta P - s$$

(1) (Pendrel et al., 1998)

In equation (1) ΔP – P represents the effects of P wave stacking and for ΔP – s , S wave stacking represents. The both inversion is consists of low and high frequency components.

$$Vp/Vs \sim Zpp / Zps \sim \{ Zpp (low) + Zpp (high) \} / \{ Zps (low) + Zps (high) \}$$

(2) (Pendrel et al., 1998)

Where Zpp and Zps represents impedances.

$$Vp/Vs \sim \{ Lpp + dzpp (x, y, t) \} / \{ Lps + dzps (x, y) \}$$

(3) (Pendrel et al., 1998)

Where Lpp and Lps are the low frequency contents and dzpp and dzps relative inversion.

The different layers which are estimated in geological model, maps can be defined from the average Vp/Vs for thin layers with conformable major horizon (Pendrel et al., 1998 and Margrave et al., 1998).

Reservoir Study

a) Reservoir-Kalol and EP-IV:

The Kalol formation displays an overall regressive – transgressive – regressive nature with which the three component members correspond. The regressive depositional system is comprised of sandstone, siltstone, carbonaceous shale and coal. In general thickest, dominant sandstones occur in the northern areas (e.g. Mehsana area), which grade southward into sandstones and inter-bedded siltstone, carbonaceous shale and coals. During deposition we have got result that high frequency regressive – transgressive episodes (parasequences) which result in almost cyclic sedimentary patterns within the depositional system.

The EP-IV formation – named as Eocene pay formation has multiple band but in between these EP-III and EP-IV (mainly) considered as the main reservoir formation. The formation is situated just below the Kalol formation and above the thick Cambay Shale. The formation consists with sandstone, siltstone and shale. The reservoir is developed within distributary channels, distributary mouth bars and tidal sand bars are often good in quality. The sandstones are featured in the well log section (white marker).

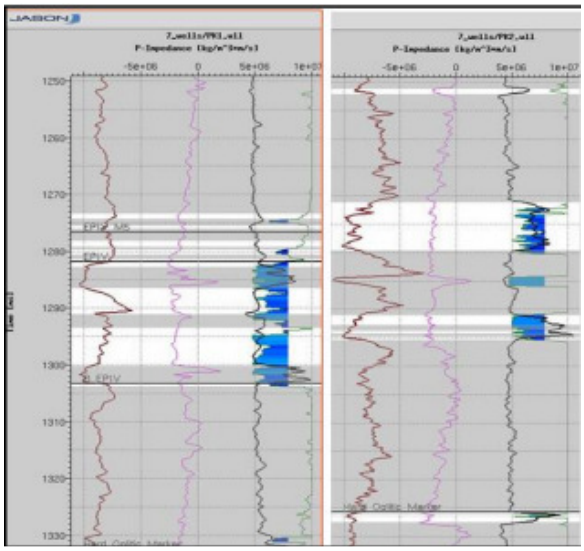

Fig2: The well log correlation for reservoir delineation

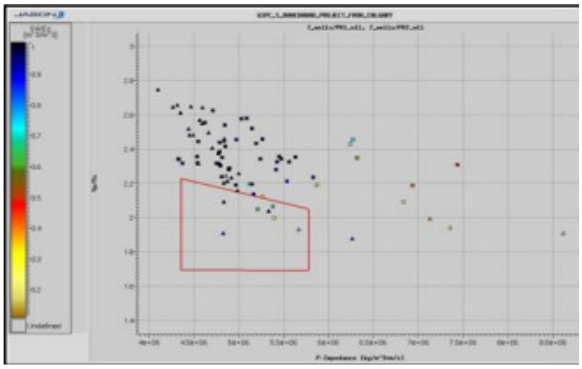

Fig3: The cross plot is showing the delineation of the reservoir of the Northern Cambay Basin field.

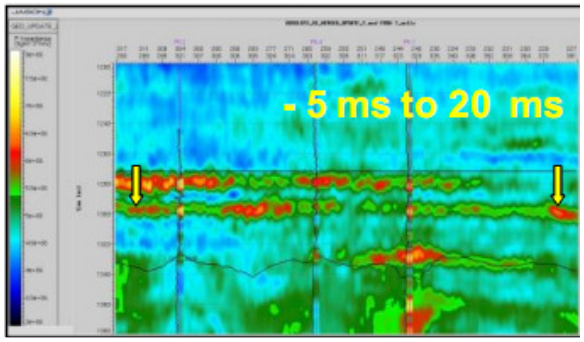

Fig4: Reservoir Analysis in-between -5ms to 20ms time interval

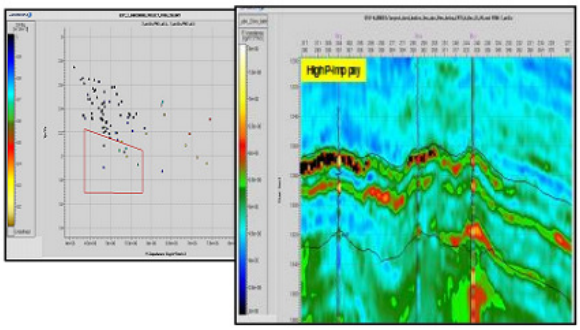

Fig5: The formation named Kalol is analysed in-between -5ms to 20ms has been over high P-impedance volume

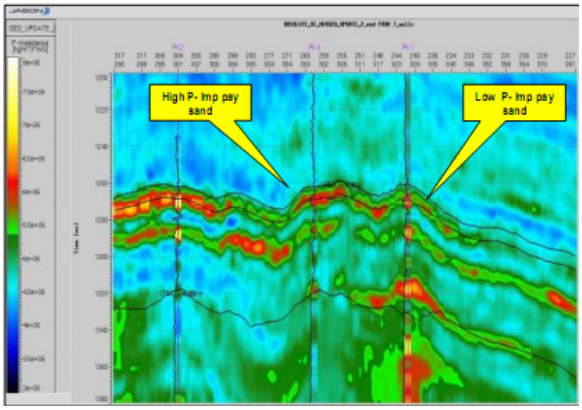

Fig6: The high and low P-impedance Sand contrast over EP-IVformation

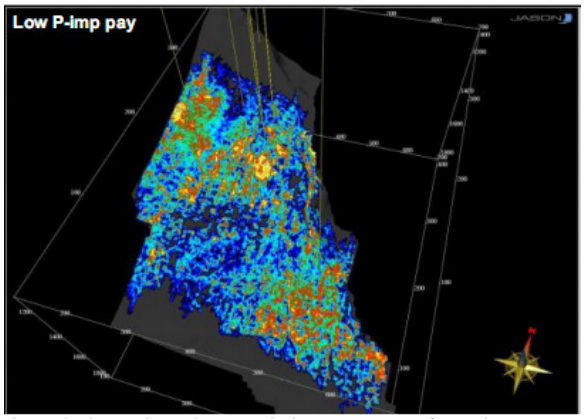

Fig7: The low P-impedance variation over EP-IV formation; some well produced from this formation (well path shows)

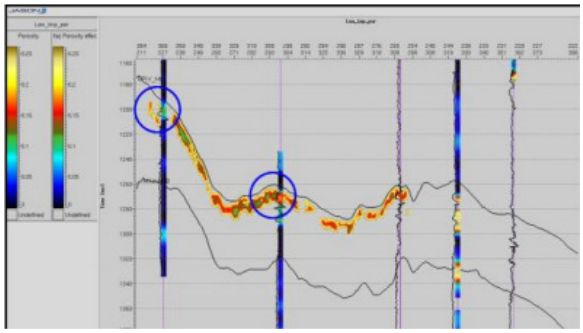

Fig8: The figure shows high P-impedance variation over the Kalol to EP-IV formation

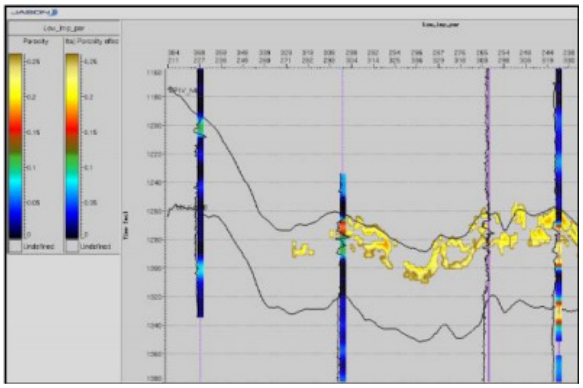

Fig9: Low P-impedance variation is showing through this figure over the EP-IV formation

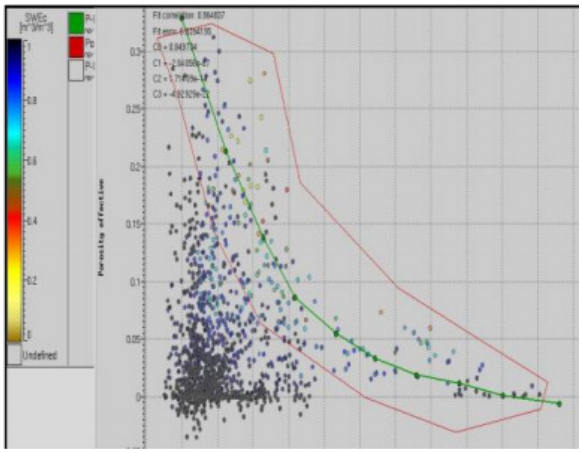

Fig10: The figure is showing the variation of porosity with Pimpedance over EP-IV formation

The combination P-impedance and Vp/Vs ratio can be used to delineate the pay sand. For follow the particular procedure for delineate pay sand the high and low P-impedances have been separated out by two polygons (Fig9). By which we can map the distribution of pay sand.

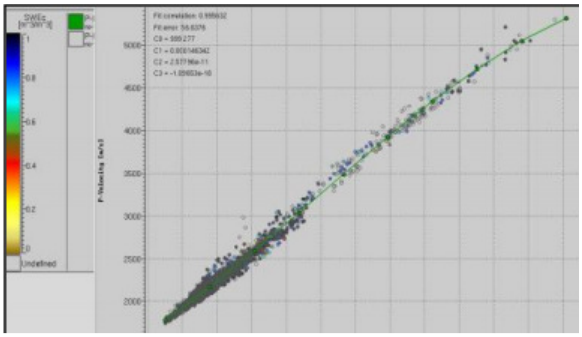

Fig11: P-impedance; velocity distribution for Vp/Vs study

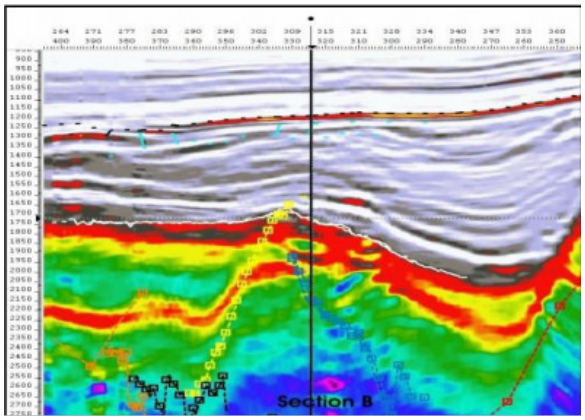

Fig12: The cross line section is showing along the well path through pay formation

b) Reservoir-Deccan Trap:

Deccan Trap which is considered as basement in Cambay Basin. The Basement is acting as fractured reservoir. Trap consists of multiples layer of flood basalt that together are more than 2000m thick. The reservoir has both type of porosity; matrix and fracture. In mid Cambay Basin some fields are producing hydrocarbon (e.g. Ingoli area).

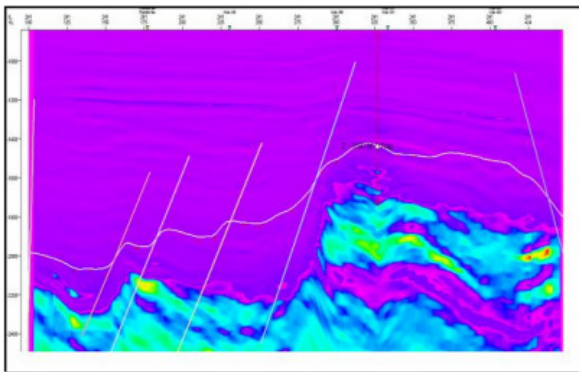

Fig13: Deccan Trap formation with fault on RAI volume

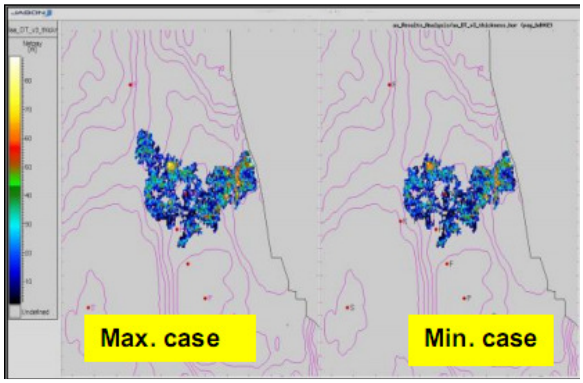

Fig14: The figure is showing the reservoir thickness map over Deccan Trap (probabilistic distribution)

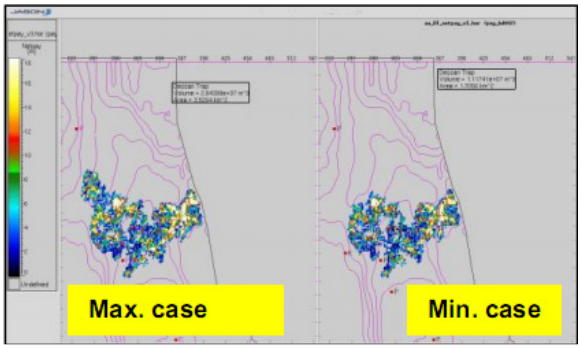

Fig15: The figure is showing the (thickness * porosity) mapdistribution (probabilistic) over the Deccan Trap

C) Reservoir-Dholka Mid Pay:

The Dholka mid pay sand is one of the prolific producers of hydrocarbon of the mentioned area in Cambay Basin. The formation consists with sandstone, siltstone and occasionally coal. The formation in AhmedabadMehsana tectonic block was the resultant of major longitudinal delta in Ahmedabad-Mehsana region. The formation with good reservoir rock hosts the bulk of Cambay Basin oil and gas reserve at favourable structures in all the tectonic blocks.

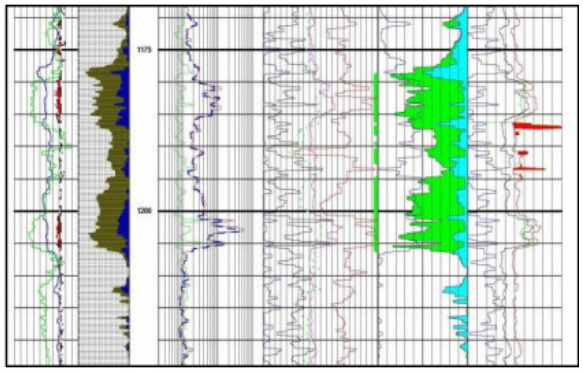

Fig16: ELAN response over Dholka pay region in discovery well.

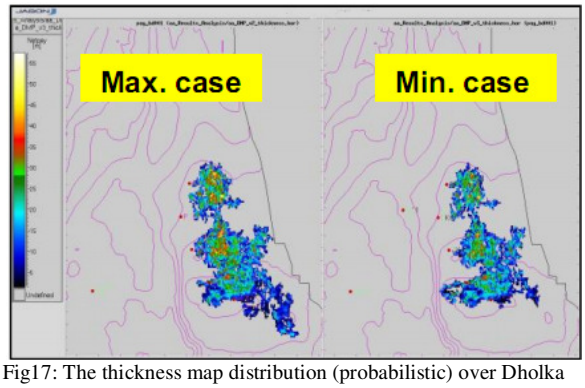

Fig17: The thickness map distribution (probabilistic) over Dholka pay

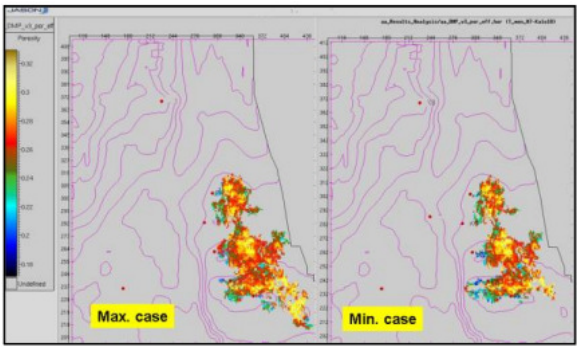

Fig18: The porosity map distribution in both cases over Dholka pay

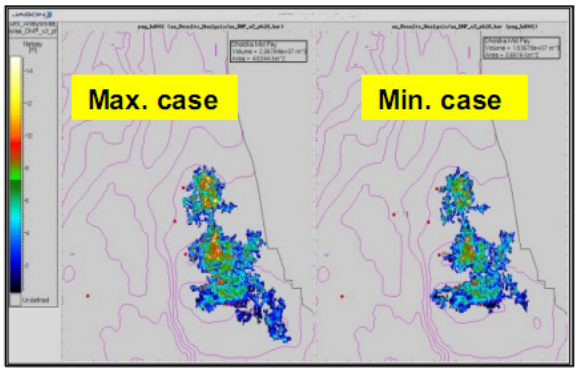

Fig19: The figure is showing the (thickness * porosity) map distribution in both cases (min. & max) over Dholka pay

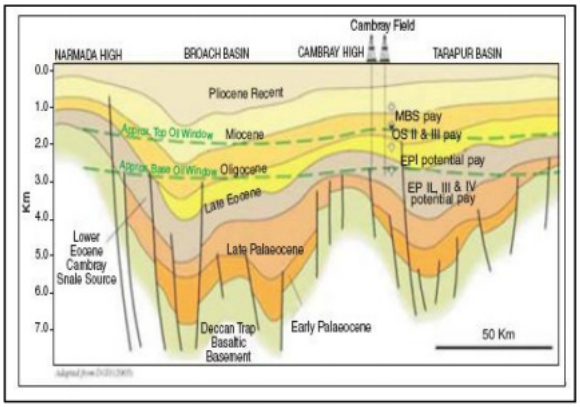

Fig20: N-S geological section in Cambay Basin (Bhowmik and Mishra, 2008)

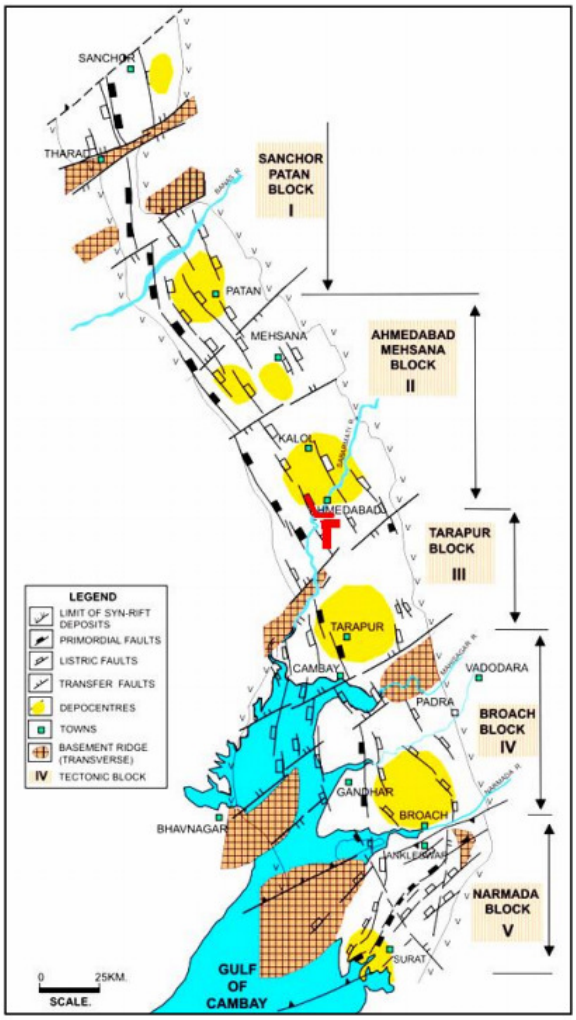

Fig21: N-S tectonic block in Cambay Basin (Bhowmik and Mishra, 2008)

Conclusion:

The Cambay Basin is a commercial petroleum producer from Tertiary sediments resting on Deccan trap. Reservoir constitutes sandstone/siltstone deposits within Kalol and Cambay Shale along with trapwash derivatives within the Olpad formation. The source rock in the Cambay Basin ranges from Early Paleocene to Oligocene. These units consist of lagoonal to shallow marine shale in the Older Cambay shale and deltaic to shallow marine shale in the Younger Cambay Shale. The Paleocene Olpad formation also forms a source rock. It is believed that lateral migration in the basin is very limited and preferred migration path is vertical, resulting in short and effective migration pathways into the traps. In the basis of different data analysis (geological and geophysical), it is concluded that the major fields which are situated in between mid to northern Cambay Basin have mainly three pay sand; Kalol pay; Dholka pay; EPIV pay and Deccan Trap pay. There is another formation in Cambay Basin, named as Kadi formation which is converted from Cambay Shale from southern Cambay to Northern Cambay. These pays are the prolific producer of hydrocarbon.

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Reference

Bhowmik, P.K., and Mishra, R., 2008, Indian Oil and Gas Potential, KDMIPE, Dehradun p.220-223; Glimpses of Geoscience Research in India : Indian Report to IUGS 2004-2008.

Debeye, H.W.J. and Van Riel, P., 1990, Lp-norm deconvolution: Geophys. Prosp. V.38. p.381.

Dufour, J., Shook, I., Edmunds, A., and Squires, S., 1998, Blackfoot 3C-3D, a new interpretation of the compressional and converted wave data: Geo-Triad'98 Abstracts, The Joint Convention of the Canadian Society of Exploration Geophysicist p.225.

Margrave, G.F., Lawton, D.C., and Stewart, R. R., 1998, Interpreting channel sands with 3C-3D seismic data: The Leading Edge, p.509.

Pendrel, J., Stewart, R.R., and Van Riel, P., 1998 Interpreting Sand Channel from 3C-3D Seismic Inversion, New Orleans, Louisiana.