

Insights on Olpad Formation: -Assessment of Hydrocarbon Play Types in North Cambay Basin, India

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Summary

North Cambay Basin had undulating basin floor topography with a number of highs and lows of varying amplitudes at the beginning of Palaeocene. The fault controlled negative areas were seats for subsequent deposition. Olpad Formation comprising of thick synrift sediments derived from Deccan Trap escarpments were deposited concomitant to subsidence and thus intrabasinal irregularities were reduced. The sequence represents dominantly a period of lacustrine conditions of sedimentation. The oil bearing sands within Olpad sequence indicated in the recently drilled deep well in Santhal field has rejuvenated the pursuit for hydrocarbons in synrift sediments. The comprehension of depositional and palaeo-structural conditions therefore is imperative to locate prospective areas. The prevalence of three distinct play types in Olpad Formation discerned by assimilation of available geoscientific data defines the hydrocarbon prospectivity which at this juncture appears subtle and is characterized by moderate risk-moderate gain.

Introduction

The intra-cratonic aborted Cambay Basin is bordered by Radhanpur-Barmer Arch and Kathiawar uplift on the west and the Aravalli belt in the east (Fig-1a)

Exploration in North Cambay Basin hitherto was mostly confined to post rift stage sequences. The exploratory efforts so far were attuned to structural elements and have met with considerable success in finding hydrocarbons. Exploration today has reached a mature stage and is focused on subtle traps and small amplitude entrapment situations. Continued efforts spread over the last four decades could establish two-thirds of the prognosticated reserves. The balance resource is yet to be converted into in place reserves and is the major task ahead.

The basin came into existence during rifting along N-S to NNW-SSE trend in Late Jurassic to Early Cretaceous. The two dominant NW-SSE and ENE-WSW directions correlate well with the intra-basinal horsts and grabens (Fig-1b).

The tectonic grain transverse to the basinal trend is suggestive of the subsurface continuation of the Aravalli swell. M/s Cairn Energy has located commercial oil bearing sands in synrift sediments in contiguous Barmer Basin further north reviving interest in synrift exploration in North Cambay Basin .

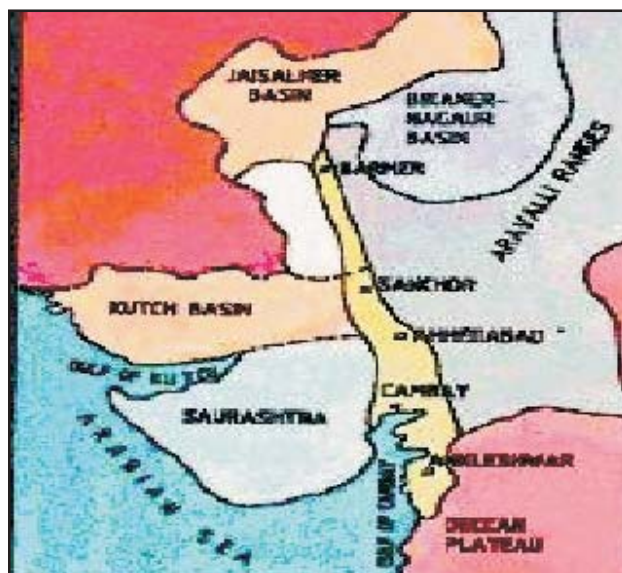


Fig.1a: Sedimentary Basins of Western India.

Olpad Formation has once again assumed significance after oil has been indicated in a deep exploratory well in Santhal field on the eastern border of Mehsana Horst (Fig-2). A large number of wells have been drilled in this part of Cambay Basin confined to Post rift prospects and investigations of Olpad Formation have been insignificant restricted only to a few wells. The present day exploration trend shows tapering down of size and number of discoveries. Yet to find hydrocarbons are now believed to be mainly confined to stratigraphic and subtle plays. Hence

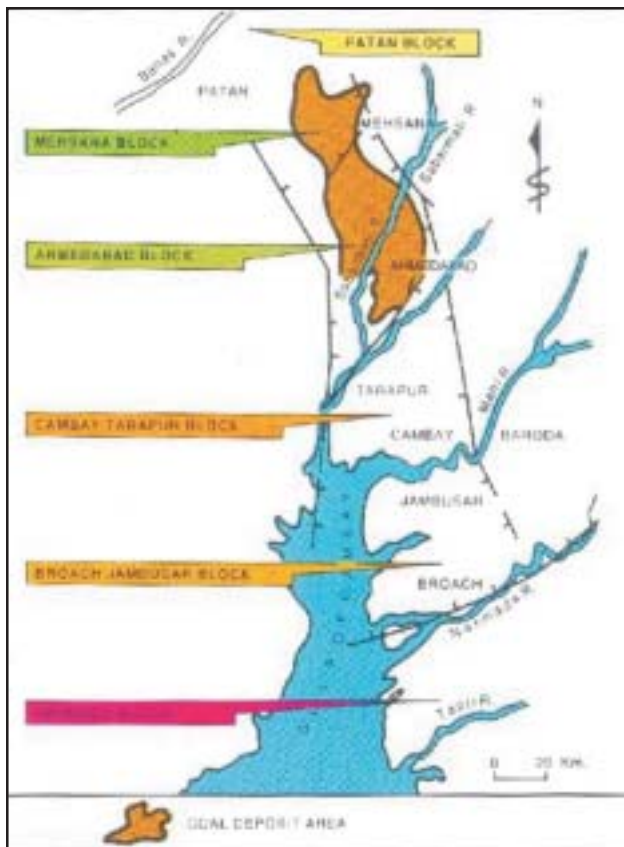


Fig.1b: Tectonic map of Cambay Basin

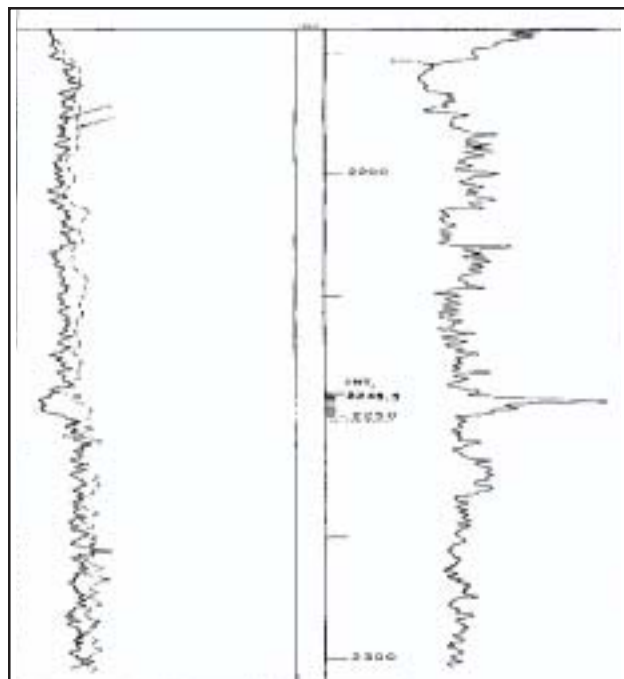


Fig. 2 : Rift Fill sands in Santhal Half Graben.

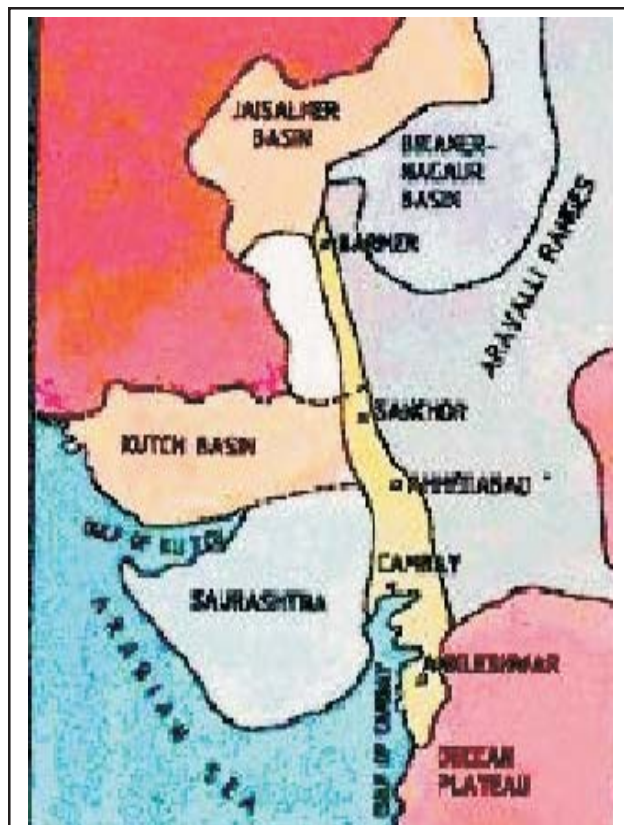


Fig. 3: Lithostratigraphy of Mehsana block

emphasis has to shift to exploration of these plays at deeper levels in the synrift sequence.

Lithostratigraphy

Olpad Formation comprises of thick synrift sediments derived from Trap escarpments. Grabens /Half-grabens accumulated trap wash, trap conglomerate, reddish brown claystones and siltstones which unconformably overlie Deccan Trap. The sequence comprising of volcanoclastic claystones, siltstones and shales deposited during synrift phase of basin evolution was a period of lacustrine conditions. Claystones, the main constituents are varied in colour and texture with distinct vertico-lateral variations. Red claystones and laminated claystones that mainly constitute Olpad Formation are fluvatile and lacustrine deposits (Fig-3).

Organic rich portions are characterized by calcitic, dolomitic and sideritic concretions. Cherts dirty white, cryptocrystalline and thinly bedded are reported from Olpad Formation suggestive of lacustrine environment under low

energy conditions. The detritus in general is composed dominantly of sediments that were texturally and compositionally immature. The overall association of sandstone, siltstone, claystone, shale and volcanicwacke or trapwacke indicates lacustrine origin.

Depositional History

The basin came into existence probably in Late Jurassic evidenced by the presence of 700m Upper Jurassic Dhrangdhra Sandstones. During Mesozoics genetically the basin was related to Kutch and Saurashtra Basins to the west. Extrusion of Deccan Trap was contemporaneous with the rifting of Seychelles from Western India close to K/T boundary obliterating the Mesozoic topography. Deccan Trap has been encountered over Mehsana Horst. The primordial lineaments were reactivated and gradually the rift became the depocentre of subsequent Tertiary sedimentation. The basin had undulating basin floor with a number of highs and lows of varying amplitudes at the beginning of Palaeocene (Fig-4).



Fig.4: Isochron map of top of Deccan Trap (In Exploration Strategy of Cambay Basin Document, 1990)

The fault controlled negative areas were seats for deposition of thick sediments called Olpad Formation derived from Trap escarpments (Fig-5). The sediments of Olpad Formation appear to have different provenances at different places in North Cambay Basin. The first marine transgression into the basin took place sometime during Upper Palaeocene. Continued subsidence along marginal faults with uniform deposition resulted in reduction of intra basinal irregularities. The connection with the sea was lost and lakes with euxinic conditions prevailed. Periodic minor

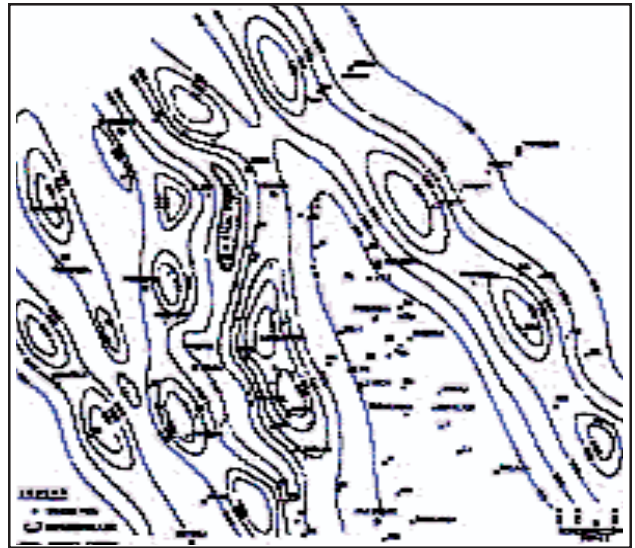


Fig. 5: Isopach map of Olpad Formation (After Mehsana Project)

fault movements occurred during these times and in the later part of Lower Eocene, the connection with the sea was restored with large rivers depositing deltas. Further in the beginning of Middle Eocene the sea retreated resulting in fluvial deposition. A major transgression set in during Late Eocene, which was followed by complete retreat of sea towards late Oligocene. Miocene period witnessed tectonic upheavals that led to structurations of tremendous significance in petroleum exploration.

Critique

The basin shows a mosaic of en-echelon grabens which acted as depocentres during early synrift stage. The complex geology and sporadic occurrence of heterogeneous reservoir facies render the exploratory efforts in synrift sediments challenging. However, the occurrence of mature source rock in a few wells and tested presence of oil at few widespread locations on either flanks of Mehsana Horst bear testimony to the excellent potential of this Formation to accumulate hydrocarbons at suitable locales.

The synrift sediments had indicated oil at the top of Olpad Formation on Khambel-Kamboi high in the Western Depression. Oil has been indicated at the top of Olpad Formation in the southern culmination of North Kadi High (Fig-6). In the western flank of Mehsana Horst reservoir facies and presence of thick oil was established as early as late sixties. Further in the eastern flank of Mehsana Horst, Santhal well too has indicated oil with in Olpad Formation. Commercial production is ongoing from one of the wells in Linch field in Jakasana area from reservoirs occurring within Olpad Formation (Fig-7).

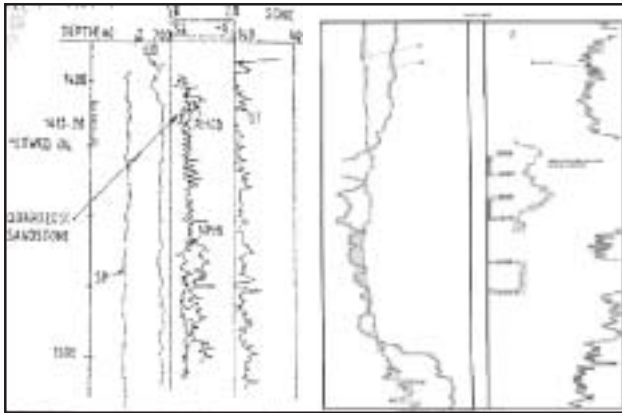


Fig.6: Synchronous sands on Kamboi High & North Kadi High.

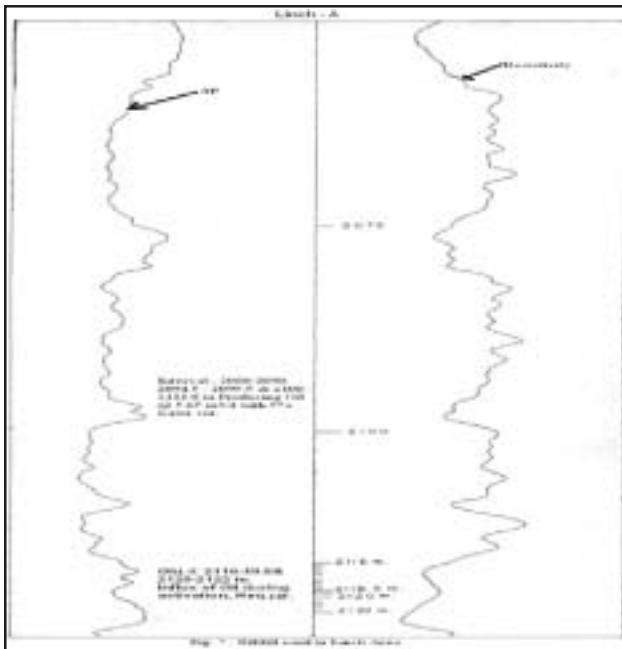


Fig.7: Rift fill sands in Linch area.

These sporadic occurrences need to be comprehended in proper geological perspective. The structural style and reservoir facies in Kamboi and North Kadi differ considerably from that of Linch and Santhal accumulations. The North Kadi and Kamboi reservoirs occur on Basement related highs while those of Linch and Santhal occur within ENE-WSW cross trends. The oil shows on either flanks of Mehsana Horst constitute another occurrence. This clearly indicates the prevalence of three distinct plays for Olpad Formation in Mehsana Block (Fig-8).

The comprehension of depositional and palaeostructural conditions is critical to unravel areas meriting future exploration.

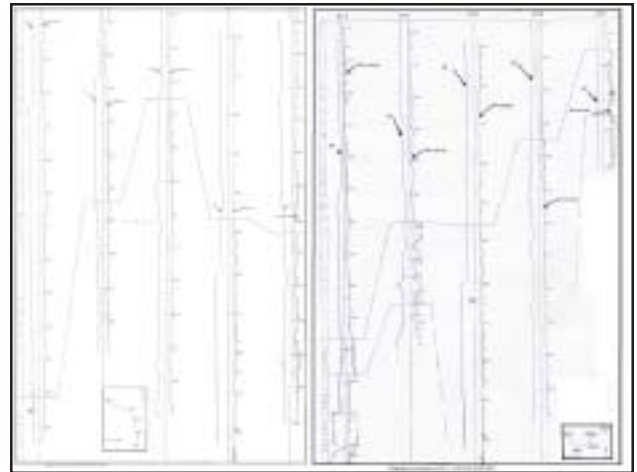


Fig. 8: Stratigraphic correlations across and along Mehsana Block

Play Characteristics:

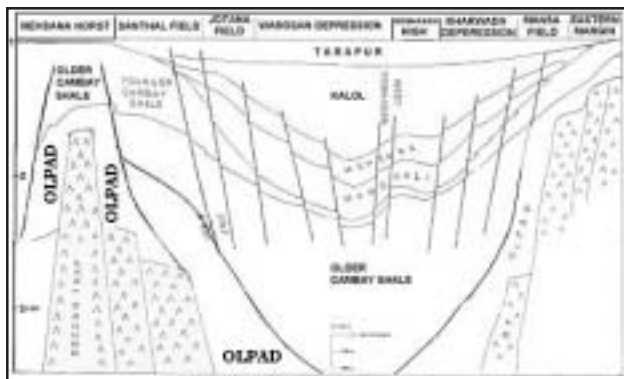
Geological thought centres on notion of processes that shaped the environment of deposition through time and space continuum. Three play types have been interpreted in Mehsana block:

- Synchronous sands on structural highs
- Rift fill sediments in the fault blocks on the cross trends (transfer zones)
- Faglomerates adjoining highs

These plays constitute palaeogeomorphic traps caused by geomorphic processes through erosion of ancient relief and consequent deposition followed by burial with younger sediments. The features are indeed subtle although structural movements did trigger their deposition. However, it was the final Miocene structural inversion that culminated in setting up the entrapment condition for hydrocarbon accumulation. The horst blocks as well as the tilted blocks could form drape anticlines after differential compaction of the sediments.

Synchronous sands on structural highs

The sediments of Olpad Formation have different provenances at different places in North Cambay Basin. The occurrence of Olpads on highs can be explained by conceiving a depositional model of an alluvial fan subjected to insitu weathering and leaching resulted in the synchronous deposition of the sands that gave rise to the development of wash out sands. Such a deposition exhibits the occurrence of conglomerate and gritty sands on the crest and the immediate slopes of the highs grading into clays, further



downwards. The sediments on the North Kadi High have exhibited these characteristics. The heterogeneous sediments on the North Kadi High have its counterpart on Kamboi High which has proved to be oil productive. These occurrences could also be termed as depositional remnants.

Rift fill sediments in the fault blocks within cross trends (transfer zones)

Transfer faults are associated with lows and faults associated with highs. Sediments eroded from the footwall of faults fall into the transfer zones. Hence, transfer zones are considered as proximal areas to sediment source. Drainage occurs from uplifted hanging wall into half grabens. The cross trends also affect the axial slope of the basin resulting in distinct changes in the sediment dispersal pattern in comparison to distal areas from the transfer zones. A mosaic of en-echelon half grabens and grabens acted as depocentres during early synrift stage (Fig-9).

The sediment influx consisted of detritus from Deccan Trap escarpments and axial palaeodrainage system that transported sediments from the NW as a major longitudinal river system to the SE. Rapid erosion accompanied by rapid infilling by coarse detritus occurred. The trunk channel remained consistently confined to the axis of the basin getting deflected at the Mehsana Horst into two distributaries. In the transfer zone structural inversion of pronounced negative expression have spawn highs within lows. The seismic expressions of both western and eastern depressions clearly show major faults hading in the same direction resulting in asymmetrical half grabens interspersed with palaeohighs (Figs-10a, b&c).

The end of synrift is marked by a prominent angular unconformity. Episodic block rotation resulted in en-echelon

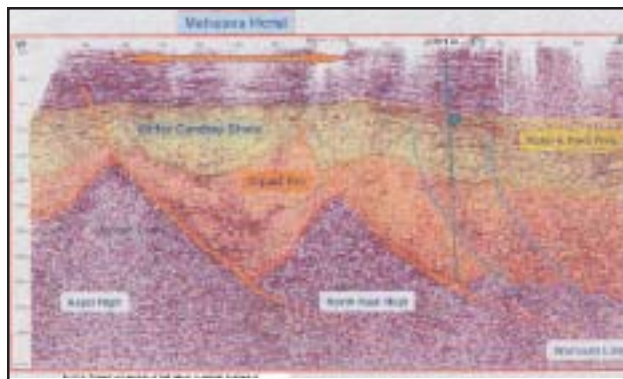


Fig.10a: Seismic expression of Half Graben in Eastern depression.
(Source – Basin Group, 2004)



Fig.10b: Seismic expression of Half Graben in Western Depression

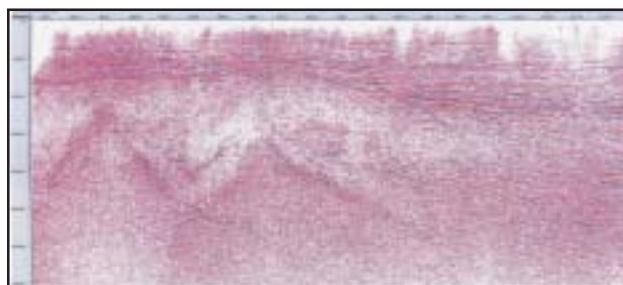


Fig.10c: Synrift sediments in Northern part of Sobhasan area (Source – 3D Atlas, 2005)

structures as envisaged on the basis of steeply dipping reflectors overlying gently dipping reflectors at some places and presence of parallel sets of high angle normal faults. When deformation accompanies strike-slip movement, fault blocks get rotated into orientation parallel to the principal displacement zone. The rotation of blocks resulted in en echelon structures juxtaposing Olpad Formation against Older Cambay Shale at places. The accompanying tectonic displacement by transverse faults entailed accommodation space at different times to adjust the stress and lacustrine conditions thus prevailed. The intersection of faults has entrapped oil in Linch and Santhal fields while faults away from transfer zones like that in North Jotana did not provide entrapment conditions as indicated by the drilling results.

In the cross trend down south in Ahmedabad block productive oil has been proved in better reservoir facies within Olpad Formation of Nawagam field in the sixties itself.

Fanglomerates adjoining highs

Seismic expression reveals clear evidences for the presence of erosional carving of Deccan Trap at places in the eastern side of Mehsana Horst and the flattening of the top of the horst. The dumping of weathered and eroded material from top of the horst in the eastern and western flanks is evident from the seismic data which might have wrought reservoir facies within Older Cambay Shale/ Olpad Formations corroborated by well data (Fig-11).

These facies are represented by high amplitude seismic events. The near fan area deposits bordering fault scarps comprise of coarse sediments. The deposition of claystone facies took place in lacustrine environment at the distal ends. The wedge shaped geometry recognized is suggestive of accompanying tilting with fan progradation.

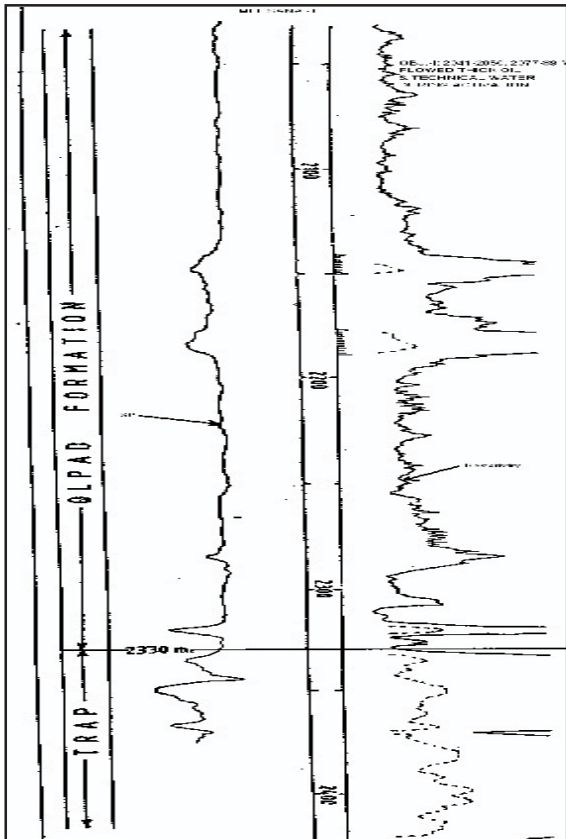


Fig.11: Fanglomerate sands in Western Flank of Mehsana Horst

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During the synrift stage of tectonic evolution, grabens and half grabens evolved in North Cambay Basin. Geochemical studies by Banerjee et al reveal that Olpad Formation with potential source rocks has generated appreciable amounts of hydrocarbons in North Cambay Basin. The primary conditions for hydrocarbon entrapment will depend on whether the area falls within the potential source bed or falls in the vicinity of faults. The rift fill sands in Olpad Formation of contiguous Barmer Depression have produced hydrocarbons. Older Cambay Shale represents post rift sedimentation and with considerable thickness abuts palaeohighs and accommodation zones. The rift fills could have been charged with insitu generated hydrocarbons after short distance migration and through preferred pathways provided by faults that juxtapose even Older Cambay Shale against reservoir facies of Olpad Formation (Fig-12).

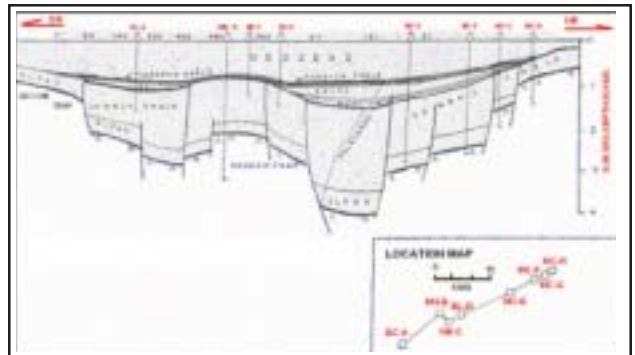


Fig.12 : Seismogeological Transect of Mehsana Block

The transfer zones being an intersection of fault sets play an important role in fluid migration. Olpad sequence made up of heterogeneous sediments has seals and vertico-lateral variation is common. Vertically drained high impedance petroleum system is expected in the identified play types of Olpad Formation. The possibility of the three play types getting charged and accumulating oil is therefore plausible and proved at North Kadi, Kamboi, Linch and Santhal fields (Fig-13).

Therefore, analogous areas in the Becharaji-Mehsana City,Kadi-Nandasana-Langhnaj cross trends, palaeohighs around Unawa, Sobhasan, on Mehsana Horst, either flanks of Mehsana Horst ,and both the basin margins offer scope for exploration of Olpad plays (Fig-14).

Assessment of Plays

Different plays have different risks that can affect

