Exploration Potential of Syn-rift Olpad Play in the western rising flank of Warosan low, Mehsana Tectonic Block, North Cambay Basin.

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Summary

Mehsana area of North Cambay Basin has got well established oil fields which are producing for last four decades from multiple plays at different stratigraphic levels from Older Cambay shale to Kalol. The basin is in a very mature state of exploration and of late it is observed that though the success rate is good but sizes of the discoveries are small. Hence there is need to shift focus of exploration to deeper plays below Older Cambay Shale (OCS) and in this respect exploration of Syn-rift Olpad Formation is important. The encouraging result from recently drilled exploratory well in the eastern basin margin in the North-Mansa area, which is producing oil from Olpad on self at a sustained rate of 190 barrels/day with no drop in reservoir pressure, has rejuvenated the pursuit for hydrocarbons in the synrift sediments in north Cambay Basin. The present study is an effort assimilate this success and to look for similar setup in other parts of the Mehsana area. The eastern margin success of Olpad has occurred in a setup where the Cambay shale, which is the proven Source rock, is in juxtaposition with Olpad Formation. The authors are of the view that similar setup exists in the western rising flank of Warosan low also.

Keywords: North Cambay Basin

Introduction

Cambay Basin is a narrow elongated (NNW - SSE) extensional basin located on the western margin of Indian plate (Fig. 1). Precambrian rocks of Aravalli System are exposed in the northeast. Deccan Trap of late Cretaceous to early Tertiary age with underlying Mesozoic strata is exposed on the eastern and western flanks of the basin. This Cenozoic extensional basin is a typical “intra cratonic aborted rift” which evolved due to rifting along Dharwarian orogenic trend during the northward migration of the Indian plate after its break up from Gondwanaland in Late Mesozoic and the Basin came into existence during Early Cretaceous. The rift-drift transition phase of Indian plate witnessed volcanic events in the western India during which huge thickness of traps are deposited in Cambay Basin.

The extensional architecture of the basin is defined by two types of faults viz., 'listric normal faults', striking N-S to NNW-SSE and 'transfer faults', trending ENE-WSW to NE-SW. The listric faults mostly run sub parallel to the rift - border faults. Transfer faults frequently offset the listric faults. During Late Miocene, few areas in the basin experienced inversion tectonics related to Himalayan Orogeny. Thus basin architecture is defined by an enechelon arrangement of asymmetric half grabens.

Fig.1 Geological map showing Cambay Basin
bordered by listric normal faults oblique to the rift axis and are separated by transfer fault zones/accommodation zones and basement highs. A thick sequence of sedimentary rocks ranging in the age from Paleocene to Recent overlies the Deccan Trap, which is considered as technical basement in Cambay Basin. A total of about 6 km thick sedimentary sequence is expected in the deepest part of the Cambay Basin. A complex network of these faults compartmentalizes the basin into distinct tectonosedimentary blocks bordered by major transfer faults (Fig 2). Based on major basement faults the Cambay Basin is subdivided into five major tectonic blocks, which were based on structural elements and have met with considerable success in finding hydrocarbons from multiple stratigraphic levels (Fig.3). The major oil fields (Fig.4) in this area are Lanwa-Santal-Balol producing exclusively from Kalol Formation. Jotana, North-Kadi, Sobhasan, Linch and Nandasan produce from multiple plays ranging from Older Cambay shale to Kadi and Kalol Formations. Exploration has reached a mature stage and at present it is focused on subtle traps and small amplitude entrapment situations in the areas bordering established fields.

Huge thicknesses of Paleocene synrift sediments (Olpads) in Mehsana area of Cambay Basin has escaped focused exploration over the years due to the successes from younger plays. Though Small oil pools in Olpad are already established on Khambel-Kamboi and West Patan area to the west of Mehsana Horst, success was so far elusive in the eastern depression and eastern margin.

Fig.2 Tectonic map of Cambay Basin.

Fig.3 Generalized Stratigraphy of Cambay Basin.

Fig.4 TWT Relief Map on horizon within Younger Cambay Shale.
Reservoir characteristics & Play types

In the early stages of rift the primodial lineaments reactivated; subsequent rift & drift lead to creation of undulating Basin floors with highs and Lows providing depocentres for huge thickness of sediments i.e. Olpads derived from erosion of Deccan traps.

The common lithofacies of Olpad comprises trap conglomerate with pebbles of varying sizes (Fig.5), trap wacke, trap wash, siltstone & claystones. Trap conglomerates and trap wacke differ in size of pebbles and trap fragments generally embedded in clayey matrix. The finer volcanic particles known as trap-wash (Fig.6) comprise clay and siltstones. Claystones are often laminated, varying in colour from dark grey, blackish grey to red. Thinly bedded crypto crystalline dirty white layers are also reported from Olpad Formation suggestive of deposition under low energy conditions. Bioclastic trapwacke comprising sub rounded basalt clasts along with shell fragments embedded in chloritic matrix (fig.7) suggestive of fluvial/lacustrine condition are reported in wells in Charada area in eastern margin.

Olpad play can be broadly divided into two major categories based on their occurrences and genetics; A. Sediments on Basin margin, structural highs and their flanks in narrow half grabens. B. Rift fills sediments in depressions. Olpads on Basin margin, on Horsts blocks and its flanks can be explained by insitu weathering and leaching of traps and transport of these huge volumes by alluvial fans towards nearest depocentres/depressions.

The resultant deposits exhibit the occurrence trap conglomerates gritty sands at proximal part of alluvial fans, trapwacke on the crest and immediate slopes and finally grading into trapwash comprising clays, siltstone facies further downward in depression. Major depressions both west and east of Mehsana Horst has accommodated huge thickness of Olpad sediments as they became more pronounced with rifting till major marine transgression during which Older Cambay shale was deposited in the entire Basin. In the depressions however these Olpad sediments might have been affected by axial drainage resulting in development of good reservoir facies at places.
Fig. 7 Photomicrograph of SWC in a well in Charada with Basalt clasts & shell fragments (Bioclastic trapwacke) embedded in a chloritic matrix.

Discussion

So far, success in synrift Olpad sediments was limited to west of Mehsana Horst i.e, in Khambel-Kamboi high and West Patan area. Two wells in Khambel-Kamboi and one well in West Patan (Fig. 8) have produced oil in commercial quantity.

Fig. 8 Seismic section through Well WP-A which produced oil from Olpad.

Many more structures were drilled in the similar horst-graben set up in the areas west of Mehsana Horst, the results were not encouraging. The possible reasons for this may be insufficient quantum of hydrocarbon generation due to the fact that sedimentary thickness is not much in these grabens and shallow burial depth of source rock facies. So far exploration activity for Olpads in east of Mehsana Horst is sparse and success is limited to eastern margin. In the recent past thick oil zones in Olpad were established at shallow depths in three wells B, C &D (Fig.4) in Charada area in the eastern margin of the basin. The wells drilled Charada area have encountered conglomeratic Olpad overlying the Trap (Fig. 9). Due to highly viscous nature of the oil, these wells are yet to be put under production, awaiting suitable and reliable technology for exploitation.

The latest success from Olpad has come from a well A in North-Mansa area (Fig. 4 & 10) again in the eastern margin which is producing oil on self at a sustained rate of 190 barrels/day with no drop in reservoir pressure, indicating very good lateral extent of reservoir. The log motif of the pay zone is shown in fig. 11. This success has rejuvenated the pursuit for hydrocarbons in syn-rift sediments in the east of Mehsana Horst. The present study is an effort to
assimilate this success and to look for similar setup in western rising flank of Warosan Low. We can understand from the regional relief map (Fig.4) of the reflector within younger cambay shale (Mandhali) that Warosan Low is actually the northern extension of Nardipur Low. The rising flanks of this composite Warosan-Nardipur Low is important because of the fact that this depression has got huge thickness of cambay shale, which is the established source rock in the north Cambay Basin and we have major oil fields producing from shallower Formations. Unlike the areas falling in the west of Mehsana Horst, this low might have generated enormous amount of hydrocarbon to charge the reservoirs at multiple stratigraphic plays in the east of Mehsana Horst area. Jotana Fault (Fig 4 & 12) with significant throw is a prominent listric Fault east of Mehsan Horst.

Fig.11 Composite log motif & processed log of Olpad pay zone of a Well-A in North Mansa area.

Fig.12 Coherency slice at 1100 ms clearly brings out Jotana fault.

Thickness of sediment layers/Formations gradually increases eastward towards Warosan depression. At all stratigraphic level, the sedimentary layers forms anticlinal structure along the downthrown side of the Jotana fault due to drag effect.

Fig.13 Regional E-W Seismic transect connecting Jotana field and Well-A of Mansa Field.
All along the length of this fault hydrocarbon accumulations in OCS, Mandhali, Mehsana & Kalol have been established and currently being exploited in Jotana field, adjoining western rising flank of Warosan Low & northern part of Linch field.

As discussed earlier, Mehsana Horst being the prominent structural element, uplifted to considerable height during rifting stage must have contributed enormous amount of trap derived sediments/Olpads during upheavals to the west as well into Warosan depression in the east. Jotana Fault being the nearest major listric fault to the east of Mehsana Horst, thick sequence of Olpads in the form of trap conglomerate, trap wacke are likely to be encountered in the western rising flank of Warosan Low and forming entrapment against this major fault as well as in the upthrown block bordering eastern flank of Mehsana Horst where Olpad is in juxtaposition with Cambay shale which is the established source rock. In the similar set up oil has been encountered in well A which is evident in seismic section (Fig. 10). It can also be seen from the seismic transect (Fig.13) that similar setup do exists in the western rising flank of Waosan low. It is well established fact that Jotana main fault is providing the entrapment condition at multiple younger stratigraphic levels. Till now the exploration success along this fault was mainly from post rift sequences. No well has penetrated Olpad Formation in the immediate downthrown side of this major fault. Few wells were drilled up to Olpad in the upthrown block of this fault. Well E drilled in northern part of Linch field has encountered good reservoir facies in Olpad. Well-F in Santhal field in upthrown side of Jotana fault has been tested in Olpad and gave indications of oil. Western rising flank of Warosan depression where Olpad Formation is in juxtaposition with Older Cambay shale is likely to be the ideal locale for reservoir development where Olpad Formation is in juxtaposition with Cambay shale. Further eastward, towards basin axial Olpad Formation is likely to be dominated by trapwash and finer clastics being away from source. Well-G was drilled to a depth of 5006m in the above settings and encountered about 2000m of Olpad sequence, however the reservoir facies were poor.

**Introspection**

In the available seismic data, resolution of deeper events are very poor and are also masked by first orders multiples of Kalol formation, hence impression of Jotana fault is not very clear in the deeper section. Energy penetration beyond Kadi formation is a problem in the area due to presence of thick coal in Kalol and Kadi formations. Hence getting proper seismic expression from Olpad formation which is expected beyond a depth of about 2700 mts is a challenge and recent efforts to acquire data by focusing this objective was not very successful. Special reprocessing with focus to enhance the deeper events may help in interpretation. It can be concluded that the recent success in Olpad Formation in the eastern margin, can be replicated in the western rising flank of Nardipur-Warosan low also where we find Cambay shale is in juxtaposition with Olpad. In this part there is added advantage of the presence of major Jotana fault which offers a proved entrapment situation. Here the Olpad reservoirs is expected at a deeper depth in comparison to eastern margin, hence quality of the oil should be better.

**Conclusion**

Mosaic of en-echelon half grabens and grabens acted as depocentres during early synrift stage in north Cambay Basin. Synrift sediments of Olpad Formation comprising trap conglomerate, trap wacke, trap wash, siltstone & claystone derived from weathering and leaching of Deccan Traps were deposited in fluvial and lacustrine environment. Warosan-Nardipur Low, the prominent depression in the Mehsana area received enormous thickness of synrift sediments from west as well as from eastern Basin margin. Significant hydrocarbon finds in Olpad sediment in the eastern margin in Charada & Mansa area led us to believe that areas in the western rising flank of Warosan depression, in proximity to Mehsana horst are ideal locale for exploration of Olpads.

**Acknowledements**

The authors are thankful to the ONGC management for granting permission to publish the paper and use the data and the findings of various projects. We are also grateful to Mr. S. K. Das ED-Basin Manager, Western Onshore Basin, ONGC, Vadodara for the guidance and encouragement. The views expressed in the paper are solely of the authors and not necessarily of the organization in which they are working.

**References**

Lithostratigraphy of Indian Petroliferous Basins, by J. Pandey etal; ONGC,1993; unpublished report

Identification of Preferred Reservoir Development In Olpad Formation For The Exploration Of Deeper Prospects


Developing a suitable methodology for the evaluation of payzones for effective reservoir characterization of Olpad in Charada-Mansa area in Cambay Basin by B.K. Saikia, Rajesh Chandra, CEWELL. ONGC, June, 2010; unpublished report