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Chasing Mid-Miocene and Younger Clastic plays in Mumbai Offshore Basin

Abstract

Mumbai Offshore Basin is the best known hydrocarbon province of India and is the main producer of oil& gas in the country. Among the hydrocarbon plays, the Middle Miocene clastic play,known as S1 sand is a commercial producer only in the Mumbai High Field. Elsewhere, the S1 sand or it's equivalents are grouped in Tapti Formation. In Tapti-Daman Sector generally, little is known about the origin, genesis and areal spread of the S1 sand although a good amount of drilling data has been collected over the years. The present study is undertaken to understand the S1 sand equivalents in terms of it's depositional pattern and as possible prospective hydrocarbon play. The analysis on the basis of horizon slices, taken across various 3D volumes, gives a braided coeval channel complex in Mumbai Offshore depicting its entry from Gulf of Cambay and spreading over Mumbai High in flood plain environment. Further Integration of G&G data indicate that clastics input is mainly due to the episodic upliftment of himalayas (HOM-II and HOM-III) during Middle Miocene and younger times and concurrent withdrawal of sea due to glaciation in Antarctica and Greenland. A few areas are identified for exploration of this play.

Introduction

Western Offshore Basin is a well-established hydrocarbon basin which produces oil and gas from reservoirs in the fractured Basement of Pre Cambrian age to shallowest reservoir of Middle to Late Miocene age (Tapti Formation). The S1 sand belongs to Mid Miocene age and is prolific hydrocarbon reservoir over Mumbai high. The effort in the present work is to delineate the channel geometry in Tapti Daman sector and connecting it to Mumbai High, to establish the direction of sediment supply and evaluate the characteristics of sand present in younger level (Mid Miocene ad Younger).

Exploration history

CFP (France) carried out the preliminary study of S1 sand in the year 1979 and concluded that the unit had been deposited in a regressive phase during the Miocene age. Rao and Talukdar (1979) has indicated this pay as shoe string sand deposited above the wave base and transported by longshore current. Basu et.al (1982) opined that shallowing of sea during Middle Miocene with development of lagoonal and marginal marine deposition regime have resulted in the deposition of S1 pay. Kale et.al (1984) has done sedimentological evaluation and depicted shallow marine environment for S1 pay comprising a phase followed by regressive and again a transgressive phase under fluctuating and low energy conditions (S1 deposited in shallow marine condition in multiple regressive and transgressive phases). They have attributed sand silt deposition to brief period of moderate energy associated with wave action and silt-shale deposition as suspect on deposit. Mishra et. al (1984) suggested a tidal flat regime of sedimentation associated with tidal channels. Sharma et. al (IRS, 1987) studied S1 sequence for designing the technological scheme. They have proposed a depositional model consisting of tidal channel separated by inter-tidal areas and associated tidal deltas (Model of S1: Tidal channel separated by intertidal areas). The study carried out by Bhosale et al in Jan 1997 considered data from 450 wells where S1 unit had been encountered. The report deals with the reservoir facies identification, depositional environment and reservoir potential of S1 sand. A study was also carried out by B.L. Lohar et al in March' 1999. Most recently IRS in 2006 has again taken up the S1 sand evaluation and prepared a geo-cellular model and suggested upside of hydrocarbon volume (Done geocellular modeling and gave the upside of S1 sands). However all above studies were concentrated to Bombay High only and no regional model was prepared. Wells drilled beyond Bombay High have very poor data availability for S1 pays. Occurrence of hydrocarbon in S1 pay over Bombay high is an established fact but hydrocarbon occurrence beyond the structure towards Tapti Daman Sector was not documented. Drilling of well XXX-1 in Panna JV, as well as the hydrocarbon occurrence in the well BXX-1 to the east of Mumbai High Fault encouraged a re-look of the data in rest of Mumbai Offshore. A task force was constituted to study the hydrocarbon prospectivity of S1 sand in HPB block to the east of Mumbai High Field. Well A1 drilled on the basis of this study turned out to be hydrocarbon bearing from S1 sand. More recently a couple of prospects were generated by WOB to test the hydrocarbon potential of S1 sand in the area south of B-XX (Fig A).

A1

Fig. A Recent work to understand hydrocarbon prospectively of S1 Sand

Depositional Environment and Tectonic setting

The clastic supply during Middle Miocene (Post Serravallian) time in western offshore basin is due to intense Himalayan tectonism when the collision between Indian plate and Eurasian plate is well-established. Post Serravallian changed the sedimentation pattern of Mumbai high from Carbonate to clastics due to heavy supply of sediments from NE side. In Tapti Daman area, there was huge thickness of sediments deposited at the end of Serravallian and in Central graben and HPB platform; pro-delta shale/Clays were deposited. The lithological contrast across the Mumbai High fault persists during Middle Miocene too, signifying that the fault was active and exerted a control over the spread of the clastics. A singularly significant event to have taken place during Mid Miocene is the deposition of S-1 Sand**.** Multiple trangressive and regressive phases due to episodic glaciation of Antarctica and Greenland allowed the clastic influx to be transported up to Mumbai High area through Gulf of Cambay. The clastics are deposited in a fluvial setting where subsequently the sands were reworked due to tidal influence.

A modern day analogue (Fig. B) depicting the similar depositional pattern in Gulf of Cambay corroborates the Middle Miocene deposition of S1 and Younger channel system in Mumbai Offshore (Fig. C).The Gulf of Khambhat acquired the present configuration in the last few thousand years since the Pleistocene sea-level lowstand (last glacial maximum, ~18 ka) when the entire continental shelf was subaerially exposed and rivers down-cut into the coastal plain. With increasing sea-level rise, the exposed shelf was drowned, flooding parts of the Modern western Indian Peninsula, and large tidal sand ridgs formed in the outer gulf. After the fall of sea-level at 2 ka, the Gulf acquired the Modern configuration (Fig.B) with multiple estuaries on both coastlines, rivers supplied the embayment with sandy sediments, and tidal sand bars formed in the modern estuaries. Where the tidal currents are reworked transportation and re-deposited large amount of sands due to fluctuating the sea-level changes Integration of G&G data led to interpretation that clastic input from Himalayas during the episodic upliftment of Himalayas (HOM-II and HOM-III) during Middle Miocene and younger times and concurrent withdrawal of sea due to glaciation of Antarctica and Greenland Glaciation. Clastic influx got transported upto Mumbai High area through Gulf of Cambay in fluvial environment and subsequently got tidally reworked during multiple phases of withdrawal and inundation of sea.

Fig. B Inferred Geological Evolution and Depositional System in Gulf of Cambay

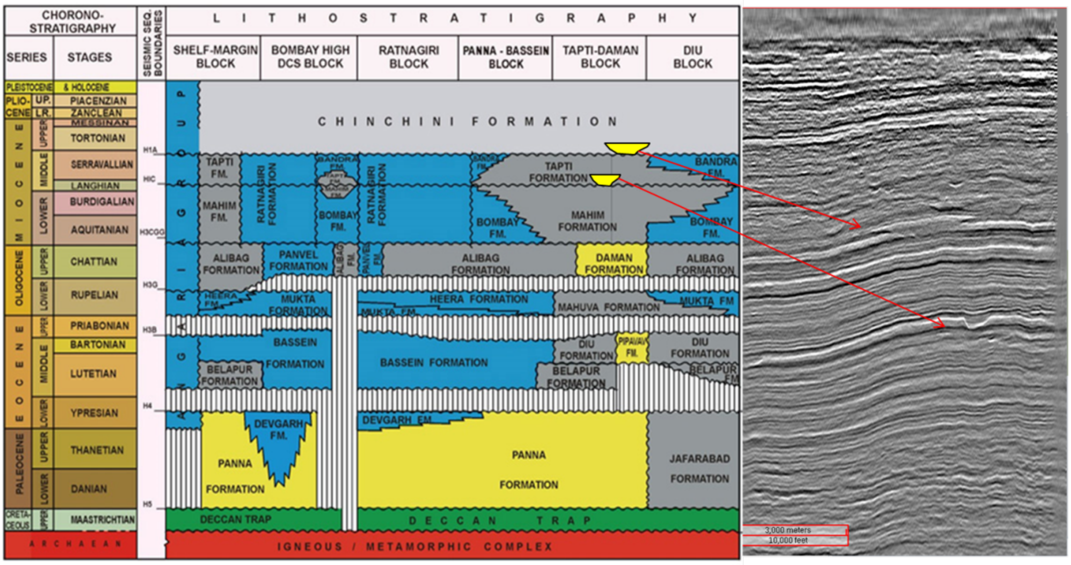


Fig. C S1 and Younger channel sands placed against Generalized Stratigraphy of Mumbai Offshore

Approach to delineate the depositional pattern of S1

To understand the depositional pattern and hydrocarbon potential of S1 sand a study in Tapti Daman Sector was undertaken. Seismic data from north of North Tapti to Mumbai High Field was analysed to understand geological depositional environment in Mumbai Offshore. Channel cuts and fill close to Mahim Top were well evident (Fig. D) starting from northern most part of study area.

Fig. D S1 Channel cuts in Northern most part of study Area

Methodology

These cuts and fill did not exhibit any seismic amplitude anomaly; therefore it wasn't possible to get any pattern for these channels on the basis of attributes from seismic data. However, one strategy to map depositional systems with high resolution is to change the emphasis of seismic interpretation from vertical sections to horizontal sections. For that a perfectly migrated 3-D seismic data set, horizontal resolution is the same as vertical resolution. Outcrop and subsurface studies show depositional bodies have horizontal dimensions greater than their vertical dimensions. As a result, small depositional bodies often can be resolved in plain view even if they can only be detected in vertical view. Although most of these depositional elements are less than 10 meters thick -- and thus below vertical seismic resolution -- they are well resolved in the horizontal dimension. To implement horizontal-view seismic interpretation, we must pick geologic-time surfaces (or stratal surfaces) from 3-D seismic volumes so that the horizon slices made certain window (±100) by across these fixed-geologic-time surfaces(Mahim & Tapti) for can be analyzed in terms of depositional systems. Time slices and horizon slices are the horizontal-section views most commonly used by seismic interpreters. Depositional geometry started to become evident once horizon slices along Mahim & taptiTops surface was generated (Fig E,F, G &H).

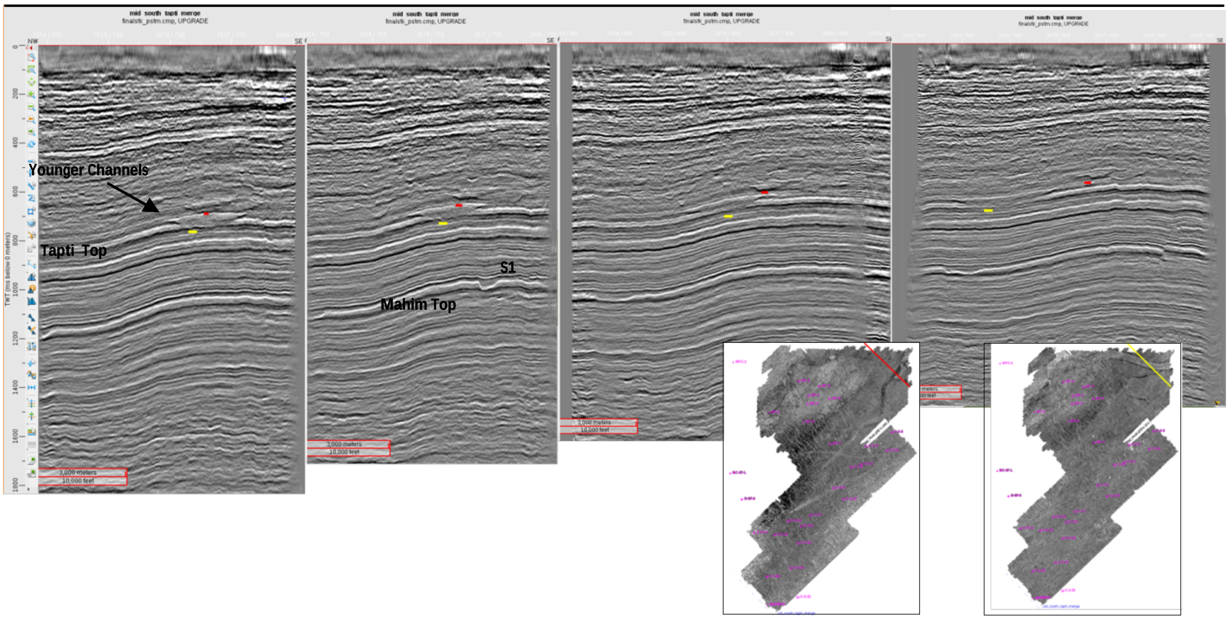


Fig. E Younger Channels in Mid Tapti Area

Fig. F Mid-Miocene Channels in Umrat Area

Fig. G Areal Spread of Younger Channels in Ambe, Mid Tapti / Umrat Area

ger channel

More importantly a younger channel complex (Fig. E & G) close to Top of Tapti Formation was captured while scanning through the data. On horizon slices this complex seems to be present in Ambe, Umrat, Mid and South Tapti area (Fig. G). Evidently sands equivalent to this younger channel complex are present even on Mumbai high field close to L-I limestones (Fig.H)

Fig. H Seismic section and horizon slice exhibiting younger channel complex over Mumbai High Field

However, this system needs to be brought out in majority of C-series, B170 and Central graben area to get a comprehensive picture of depositional geometry of this channel complex. Depositional pattern for S1 sand working on the basis of horizon slices close to Mahim Top through various 3D volume (Fig. I & J) gives a Braided Co-eval channel complex (Fig. K) in Mumbai Offshore depicting its entry from Gulf of cambay and spreading over Mumbai High in flood plain environment .

Fig. I S1 Channel cuts in Ambe Area

Fig. J S1 Channel cuts in C39 Area

Spectral Decomposition

In C39 area spectral decomposition was carried out using horizon guided approach for centralized window of 100 ms individually for Mahim and Tapti Top level. For S1 level variable thickness could be observed from tuning frequencies ranging from 8 Hz to 32 Hz. For younger channel system Tuning frequencies range from 16 Hz to 48 Hz. Above mentioned tuning frequencies demonstrate that these channel feature range from 10 to 40 m considering the interval velocities at the targeted objects in the range of 1800 to 2000 m/s. The present study brought out the unambiguous channel system in the area (Fig F& G.). A number of wells have also been drilled through these channels without S1 being the primary target objective for hydrocarbon exploration. Therefore, geological and geophysical evaluation of these channel sands has not been done conclusively, primarily because of absence of geological data during drilling and petro-physical data (electro-log etc.) after drilling.

Characteristics of S1 and shallower sands

Sands deposited in middle Miocene time are in the form of channel system and reworked by tidal current. In Tapti-Daman area, all the drilled wells were studied to know the character of sand. The sand present in that level are basically siltysand with high gamma count. Most of the wells have gas shows during drilling close to that level so there is a chance that the prospectivity of sands in Tapti Daman area is not well understood as the Tapti-Daman area is the input direction for sands of the same level which are hydrocarbon producer in Bombay high region (Fig. K). These sands are mainly low resistive sands; resistivity varies from 1-2 ohm.m which is comparable with the hydrocarbon producing wells (A1). In most of the wells, either logs are not available for that level or log quality is not good as recorded in a larger hole size.

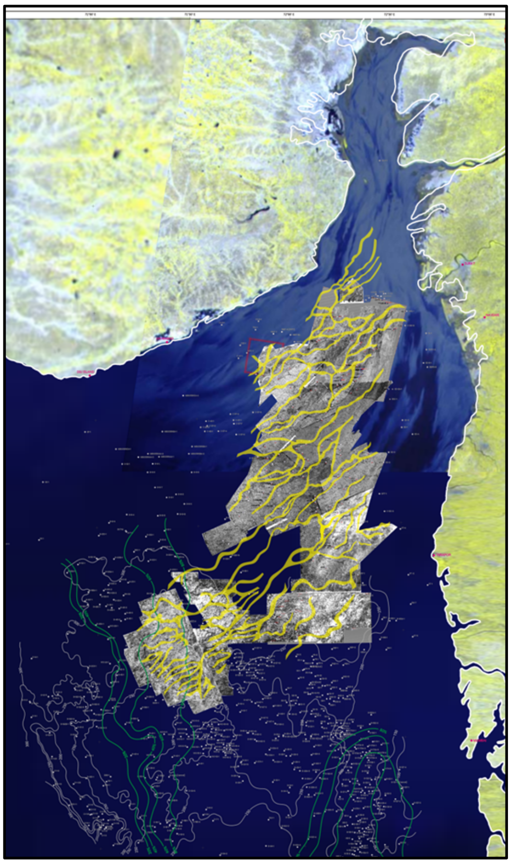
In North-Tapti field, most of the wells have considerable thickness of silty-sand in Miocene level, where B-1-2A and B-1-3 have hydrocarbon shows (TG.1-2.9%, moderate to faint cut) while drilling. In C39 area, fine to silty sands/siltstone of maximum thickness 30m is present. UK-1 and UK-2 have gas shows in S1 level and have encountered sands in Miocene level (TG-8%, V. Faint cut). Towards the southern part of Tapti-Daman area in B12 and C-24 field, log signature indicates silty sand with maximum thickness of 20m where total gas of 1-3.68% were reported while drilling in some of the wells (X-13, X-14, X-8, and C-8). The log signature remain similar from north to south in Tapti-Daman area, but channel cuts are more prominent towards the northern part (North-Tapti, Ambe, C-39 and South –Tapti field) whereas towards the southern part (B12, C-24, C-23, B-170), the channels are less visible in seismic and are thin in nature.

One well NB-4A, a side tracked well from well NB-4 was targeted to explore the hydrocarbon potential of S1 equivalent Middle Miocene Sands. The well had a large horizontal drift of about 720m to target this sand at a TVDSS of 1200m. The well, at targeted depth, encountered poor silty facies. As per the present study, the well was terminated just outside the envisaged S1 Channel sand.

Some of the hydrocarbon producing wells from Mumbai high is compared with the wells from Tapti-Daman area (Fig k) which indicate that the log signature is comparable in both the area.

Y-1 **R-3** **A-1** **NB-4-A**

Fig. K Log motif of some of the wells



Comprehensive Mosaic of S1 Channel

Conclusion

Present study indicates the sand fairway is fairly well defined from Gulf of Cambay in northernmost part of Mumbai Offshore to Mumbai High Field.

A few startistructual traps are identified and under consideration for exploratory drilling. Additionally, few other identified locales which are available, will open up areas for future exploration.

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