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# Delineation of up-side potential of a Barail channel sand for optimizing production in an Upper Assam oilfield

## Abstract

The Makum Field in Upper Assam Basin is entering an early declining phase in oil production after plateauing during the period 2012-15. However, recent discovery of oil from the higher-up Extra Sand promises sustainability of oil production in the field. This thin-bedded stratigraphic reservoir has been observed as high amplitude reflections in seismic within the impervious matrix of Barail Argillaceous Unit which was further reviewed by detailed seismic attribute studies including spectral decomposition and geobody extraction. Results of the study indicates the anomaly to be an isolated meandering channel-like geometry. Key challenges of developing this new reservoir is the difficulty to assess their oil potentiality based on seismic signature alone, as petrophysical and drilling evidences of only few wells drilled through these channels in other parts of the field has indicated it to be hydrocarbon bearing. Considering the Barail Extra Sand oil potential of the discovery well and better economics, future development locations in the field can be placed in areas targeting both the lower prolific oil producer of Barail Arenaceous reservoir with better saturation level and the higher-up Extra Sand channels. The study confirms that multi-attribute analysis has the power to unlock the covariant information embedded in seismic data in collaboration with well evidence in brown fields and may lead to discovery of new upside potential.

## Introduction

A field is said to be mature once its production has reached its peak followed by decline. Makum Field which has been taken as a case study in this paper, is located within OIL's operational area in Upper Assam Basin (Figure 1). The Field is in its early declining oil production phase after plateauing during 2012-15 with peak production of about 27500 bopd, achieved during 2014. Thereafter, oil production from the field is showing a decreasing trend with increasing water cut. The main producing reservoir of this field is the Barail Arenaceous of Oligocene age. Since the discovery of oil in 1993, the field has been developed with both vertical and horizontal wells for the single pool Barail Arenaceous reservoir.

To sustain oil production from the field through zone transfer, few wells have been tested in the higher-up Barail Argillaceous and Tipam sands (Early Miocene) but the results were not commercially encouraging. Few wells were also drilled to probe the deeper Eocene/Lower Paleocene reservoirs leading to few discoveries but production results were not consistent for a comprehensive field development. A breakthrough oil discovery in the higher-up Barail Extra Sand within Barail Argillaceous Unit was made in Well-X, drilled in the western part of the Makum fields producing about 150 bopd, opening up further scope for sustaining and/or enhancing oil production in the field from this new stratigraphic reservoir.

This paper focuses on (a) delineation of this new oil potential (i.e., the thin-bedded Barail Extra Sand reservoir) in the Makum field through integrating geophysical and wells data, and (b) field development planning through optimal integration of G&G, reservoir and production data. Using various 3D seismic attributes along with well logs, hydrocarbon prospects within the Argillaceous Unit has been associated with fluvial channels which is not considered earlier as traditional reservoir in the study area.

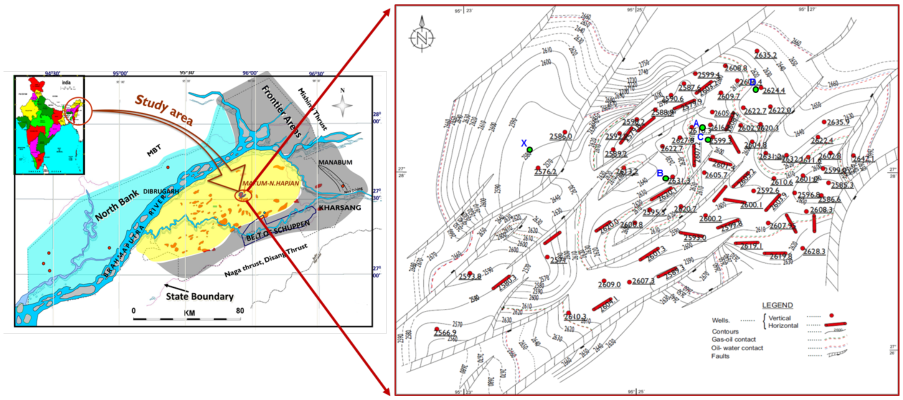


Figure 1: Index Map showing the wells drilled in the Study Area

## The Barails Stratigraphic Unit

Stratigraphically, the Barails Formation (of Oligocene age) has been divided in this area into two units (*i.e. Barail Arenaceous overlain by the Argillaceous Unit*). The Barail Arenaceous Unit is mainly sandstones with minor shale/mudstone beds whereas the higher-up Barail Argillaceous consists mainly of shale, mudstone, carbonaceous shale, coal with sandstone. The Barail Arenaceous Unit is interpreted as a progradational distributary mouth bar deposits and observed as an extensive blanket sand in the area. Petrophysical and geophysical analysis indicates that this reservoir is an amalgamation of individual sand bodies separated by thin shales/mudstone with an average thickness of about 90 m in the study area.

The higher-up Barail Argillaceous Unit, on the other hand, is a low energy delta plain channel deposits composed of mudstone/shale with coalbeds deposited during Early Oligocene Period. This unit served as effective seal for the lower prolific oil producing Barail Arenaceous Sand reservoir. The Extra Sands within the Argillaceous unit occurs as isolated low sinuosity channels with thickness varying between 8 m to 15 m in drilled wells. A comparison on lateral extension of the sand of the above two units as shown in Figure 2 indicates that the higher-up Extra Sand reservoir of Barail Argillaceous Unit is defined as pinched out sand bodies developed only in certain part of the field.

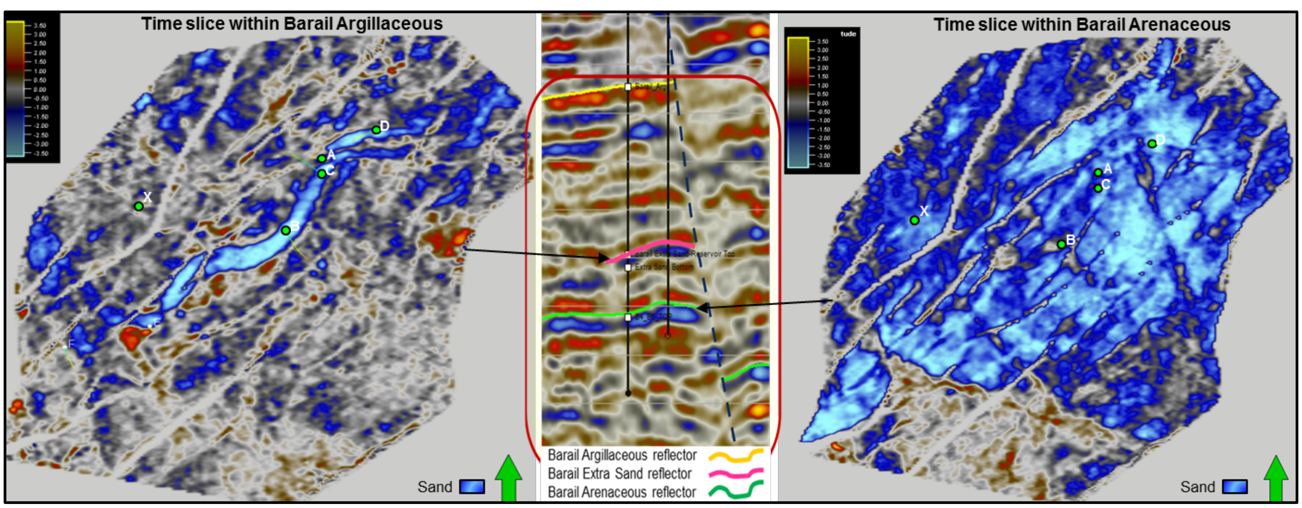


Figure 2: Horizon slice of amplitude volume showing extensive delta distributaries channel Sand of Barail Arenaceous (main producing reservoir) and isolated channel within Barail Argillaceous with low sinuosity

The main objective of the study is to identify and trace prominent seismic features similar to the discovery extra sand of Well-X within the Barail Argillaceous to other areas in the Makum Field. Out of the 90 wells drilled so far in the field, it has been observed that only few wells have penetrated through similar sand bodies. The key challenges of developing this new oil potential, however, is the difficulty to identify hydrocarbon bearing channel sands based on seismic signature alone as petrophysical and drilling evidences of only few wells drilled through these channels in other parts of the field has indicated it to be hydrocarbon bearing.

## Methodology

In recent years, a wide variety of geophysical techniques have been developed to image plan views of the depositional environment and other geologic features extracted from 3D seismic volumes which is known as seismic geomorphology that has also become an important tool for oil and gas exploration (Davies et al., 2007). Stratal and horizon slices from 3D volumes can be studied using different seismic attributes that highlights lateral seismic facies variations within the 3D seismic cube. Combining well-logs with seismic response of these stratigraphic features provide important tools in identifying reservoir geomorphology, facies and other properties as well as hydrocarbon potential especially for the non-traditional stratigraphic reservoir in the area.

In order to know the extent of Barail Extra Sand of Well-X and distribution of similar channels in the entire Makum Field for further field development plan, firstly, well data were reviewed with regional seismic. Following work-flow has been adopted for the present study.

a) Seismic-to-well tie
b) Time slice in flatten volume of Amplitude and Sweetness
c) Spectral decomposition with CMY blending
d) Calibration of channel feature with well logs in the Field
e) Log correlation of wells drilled through similar channels in the Field
f) Geo-body extraction
g) Field development plan

## Seismic signature

Seismic attributes are one quantitative measure inherent in the amplitude, frequency and phase content of reflection data. Detection of structural and stratigraphic information based on seismic attributes and spectral decomposition is one of the fundamental workflows when it comes to interpreting subsurface geological features. When seismic amplitude changes associated with the features of interest are not noticeable on vertical sections, time or horizon slices often yield distinctive patterns that are easily recognizable. Although there are lots of seismic attributes that are in common use today, for the present study we are using only few attributes like amplitude, sweetness and spectral decomposition with CMY blending.

As the main objective of the study is to identify and trace prominent seismic features similar to the discovery extra sand of Well-X, time slices within Barail Argillaceous of flatten amplitude (Figure 2) and spectral decomposition volume (Figure 3) was generated revealing other channel features throughout the Makum Field. One such channel identified in the central part of the Makum Field is oriented in NE-SW direction with minor sinuosity, having maximum width of about 400 m. The channel appears to be disconnected towards the southwestern part of the field.

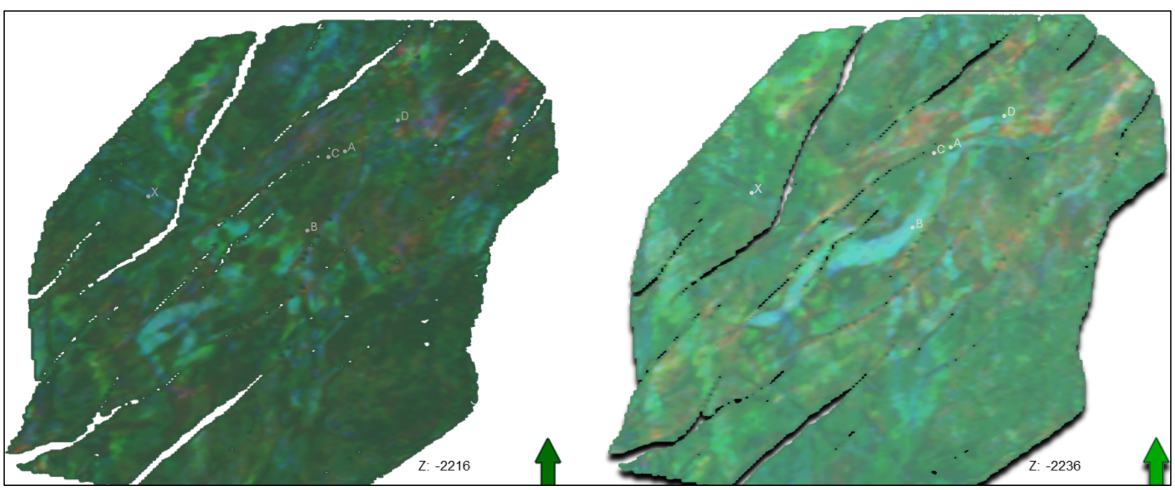

Figure 3: CMY blend of three frequency volume showing the higher-up extra sand of Well-X and other channels in the Study area at lower level

Sweetness attribute extracted over the strata slice near the channel clearly depict the channel geometry as shown in Figure 4 with very good contrast between the channel body and its surrounding shale /mudstone. Spectral decomposition can be used to detect thinner channels within wider channel belt complexes and thus facilitates the prediction of sand distribution, preservation of abandonment channel facies, and development of scrolls. It is a common geophysical method for imaging and mapping bed thickness and geologic discontinuities in 3D seismic volumes (Partyka et al., 1999). This process is based on the conversion of seismic data to the frequency domain; the amplitude response at different frequencies tunes in to a specific bed thickness, which helps highlight stratigraphic features such as channels and complex faulted areas. Three frequency volumes (i.e. 10, 25 & 45 hz) has been generated based on seismic frequency spectrum and further used for making CMY blend for visualization. CMY (cyan-magenta-yellow) color blending distinctly depicts the channel configuration along the proportionate stratal slice as shown in Figure-3. The channel is clearly visible in 25 hz band (magenta colour) showing the horizontal extent of the channel further towards the SW with feeble response.

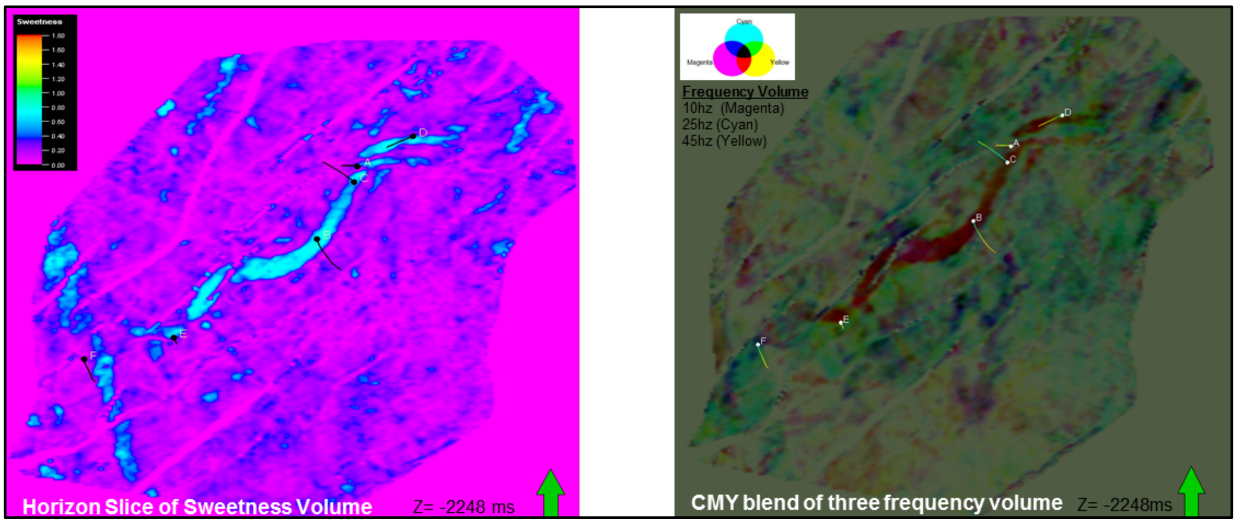


Figure 4: Horizon slice of sweetness volume and CMY blend of three frequency volume

The above channel as seen in 3D seismic is corroborated with well log of Well-B (Figure 5) for sand development and hydrocarbon prospect in the field. Combined evidence from drilling, well logs and cores of this well drilled in the central part of the channel suggest this sand to be hydrocarbon bearing. The channel is around 41 m above the Barail Arenaceous Sand reservoir.

Three wells of Makum fields are found to be drilled through this channel. Logs from these wells has been correlated for channel top and bottom along with its petrophysical interpretation (Figure-5). All the three wells showed good sand development in the channel part (average effective porosity = 20%) as well as reasonable hydrocarbon saturation (average Sw = 60%). The maximum thickness of 13 m is observed at Well-B and minimum thickness of 8 m observed at Well-C which may be located towards the channel edge. The blocky gamma log motif suggests a distributary channel fill. No visible fluid contact has been observed in these wells. So far, none of the wells drilled in the field has been tested for this sand.

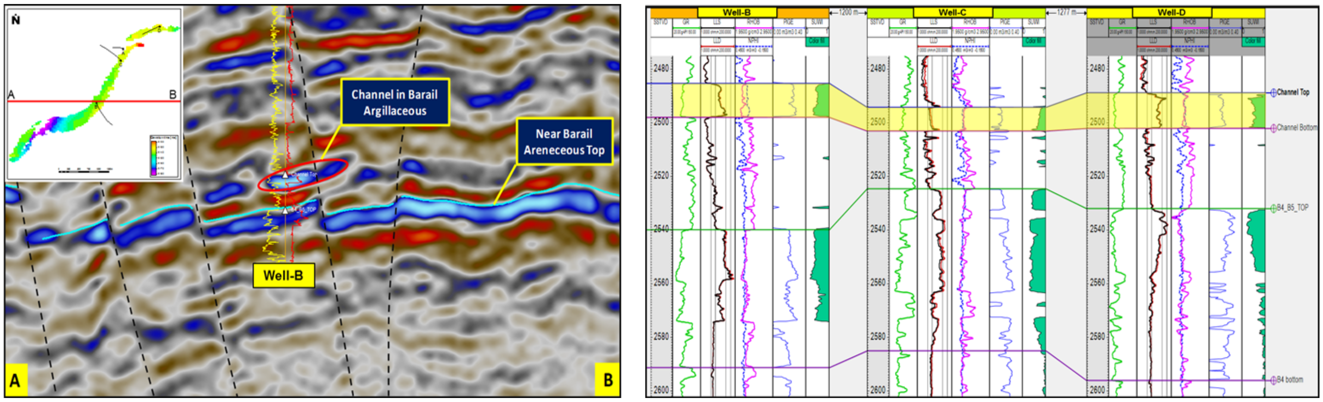


Figure 5: Cross line along Well-B showing the amplitude anomaly against the channel and structural log correlation along wells drilled through the channel

To map distribution of the channel sand in 3D space and to find its areal extent, 3D visualization techniques has been used by extracting Geo-body of the channel. Geo-body tool is used for mapping the geo-body by using amplitude anomaly of the channel as seed. The three dimensional view of the channel body and top surface (TWT) of the channel is extracted as shown in Figure 6.

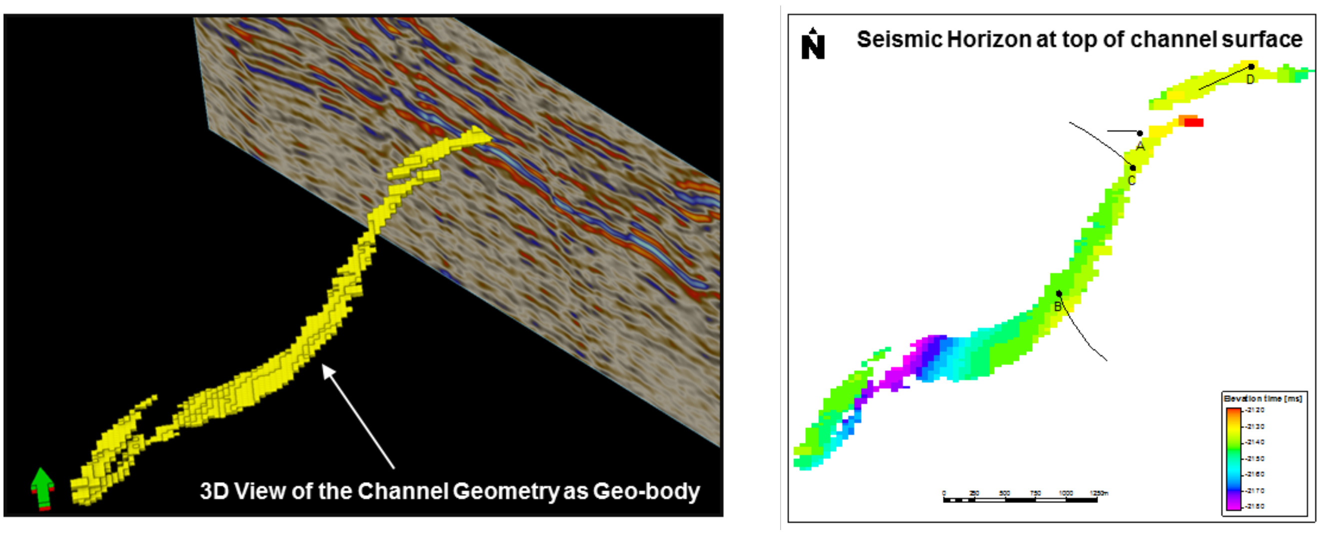


Figure 6: Cross line along Well-B showing the amplitude anomaly against the channel and structural log correlation along wells drilled through the channel

## Field Development Plan

Till date, Field Development Plan in the Makum field was carried out targeting the prolific oil producing Barail Arenaceous reservoir through drilling of extension/delineation, development and infill wells to augment oil production and recovery from the reservoir. Considering this development plan and oil potential of the Barail Extra Sand discovery in Well-X with 150 bopd, it is felt prudent to drill development wells in the field targeting both the Barail Arenaceous and Barail Extra Sand for better economic at well level. Taking this into account, the interpreted Barail Extra Sand channel map is superimposed on the simulated model saturation map at the end of history match for placement of locations in the field targeting both the reservoir (Figure 7). Production from the Barail Extra Sand reservoir in the field can be carried out through zone transfer from existing wells after draining out of oil from the lower Barail Arenaceous reservoir. Additional wells in the field can be placed in areas with better saturation level at Barail Arenaceous reservoir level penetrating through higher-up Barail Extra Sand channels.

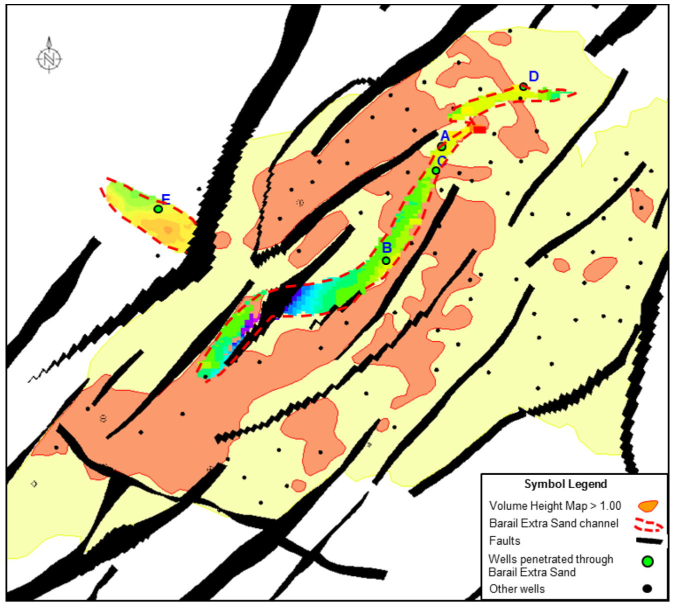


Figure 7: Barail Extra Sand channel map superimposed on the simulated model saturation map at EOH

## Discussions

Channels filled with porous rocks and surrounded by impervious matrix may have considerable aerial extent trapping substantial hydrocarbon. A three dimensional visualization of such features using 3D seismic volume and corroborated with well logs provides an accurate perspective of potential hydrocarbon reservoirs in areas like Upper Assam with a well-established petroleum system. The present study suggest possibility of presence of such reservoir within traditionally non reservoir section like Barail Argillaceous, hence, open up future potential for detail study of such stratigraphic features. The methodology implies that channel identification using 3D seismic can similarly be carried out to nearby fields in identifying upside potential of ageing field. Future development locations in the field can be placed in areas with better saturation level at Barail Arenaceous reservoir level penetrating through higher-up Barail Extra Sand channels, considering present potential of the channel sands and better well economics.


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