

Use of seismic attributes & Post-stack Seismic Inversion for understanding subsurface geological features & mitigation of risk: A case study from Upper Assam Basin, India

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Summary

Seismic Interpretation involves a methodological integrated approach of various disciplines with additional application of advanced studies such as seismic attributes, spectral decomposition etc for improved stratigraphic interpretative approach.

Subtle changes in the stratigraphy are often captured by seismic attributes which show changes in waveform shape and are termed as stratigraphically significant attributes. The principal objective of the seismic attributes is to provide accurate and detailed information to the interpreter on structural, stratigraphic and lithological parameters of the prospect. Similarly, spectral decomposition is a unique method of utilizing seismic data and the discrete Fourier transform for imaging and mapping temporal bed thickness and geological discontinuities over 3D seismic covered areas. A variety of analytical techniques is employed to image and visualize depositional elements and other geologically significant features.

In the present paper, an integrated application of stratigraphically significant attribute i.e. integrated seismic amplitude magnitude attribute, reflection strength attribute and post stack seismic inversion attributes were judiciously applied to an area for mitigation of risk of drilling dry wells. Optimal use of such advanced studies, as part of seismic interpretation aided in identification of stratigraphic prospects.

Introduction

The study area is located in South-western part of OIL's operational area in Upper Assam Shelf Basin, at the southern bank of Brahmaputra River, in north-eastern part of India is shown in **Figure-1**. The Upper Assam Shelf part is predominantly a Tertiary Basin, the relative basin stratigraphy is shown in **Figure-2**. Sediments of Palaeocene/ Eocene age were deposited in shallow marine to marine environment in this basin. Regional tilt/uplift prompted widespread marine regressions with an increase in the supply of sediments to this part of the basin during Oligocene. This is reflected by predominance of deltaic facies in arenaceous sequence of Barail formations. On the other hand, argillaceous sequence of Barail Formation (Mainly of Lower Oligocene age), seem to belong to coastal plain (especially carbonaceous shales and coal). The upper sequence is embedded with a number of fluvial channel sands. During Miocene, sediments were deposited under fluvial and lacustrine environment. In the 3D seismic data processing phase the above objectives were

taken care of and the processed post stack time migrated seismic data in the block is of good quality with good mappability of continuous reflectors at target formations. The frequency content of the data varies from 10 Hz to 70 Hz range with a dominant frequency of about 22-38 Hz.

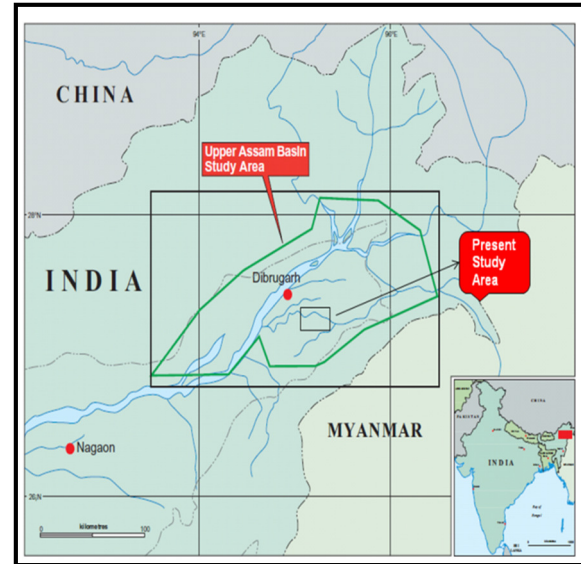


Fig 1: Index Map of the Study Area

Geology of the study Area

The Assam-Arakan sedimentary Basin is a shelf-slope-basinal system. The shelf part of the basin spreads over the Brahmaputra valley and the Dhansiri valley, and the area of study is lying between the Naga thrust and Sinyang thrust. The shelf-to-basinal slope, i.e., the hinge zone lies below the Naga Schuppen belt. The basinal (geosynclinal) part is occupied by the Naga Schuppen belt.

The shelf part rests on Precambrian granitic basement, whereas the basinal part lies on transitional to oceanic crust. The area within the Upper Assam shelf, having high petroleum potential, measures approximately 56000 sq km and contains about 7000m thick sediments of mostly Tertiary period, and the area in the basinal part with moderate to high hydrocarbon potential measures about 60,000 sq km and contains more than 10,000m thick sediments of mostly Tertiary period.

The Upper Assam Shelf of the Assam-Arakan Basin lies mostly below alluvial cover of the mighty Brahmaputra

Integrated Interpretation of Thrust belt area based on Seismic and Surface Geologic Mapping- A case study from Upper Assam Basin, India

River and its tributaries. Towards south and southwest, the shelf extends to the Dhansiri valley, lying between the Mikir hills in the west and the Naga foothills in the east to southeast, and then continues westward to North Cachar hills and southern slope of Shillong Plateau. The general elevation of the Dhansiri and Brahmaputra valleys ranges between 85m and 90m above mean sea level (MSL).

The hill ranges of western Nagaland, aligned roughly in NNE-SSW direction and exposing Tertiary sediments which are involved in a complex system of imbricate thrusts, lie on the southeastern side of the Upper Assam Shelf.

The selected study area lies in Assam-Arakan basin which is polycyclic basin located in the North-Eastern part of India. The shelf part of the basin spreads over the Brahmaputra and Dhansiri valley, shelf to basinal slope part lies below the Naga Thrust and the basinal (geosynclinal) part is occupied by the Naga Schuppen belt and the Cachar-Tripura Mizoram-Manipur fold belts. This is a proven petroliferous basin covering about 116,000 sq km. About 7 kms thick sediments ranging in age from Paleocene to Recent are present in the shelf part and a huge thickness of more than 10 kms sediments ranging in age from Upper Cretaceous to Recent is present in the fold and thrust belt. Eocene-Pliocene sequences contain potential source, reservoir and cap rocks. Around 115 oil and gas fields have been discovered in the basin. The Upper Assam Shelf part is predominantly a Tertiary Basin. Sediments of Palaeocene/ Eocene age were deposited in shallow marine to marine environment in this basin. Regional tilt/uplift prompted widespread marine regressions with an increase in the supply of sediments to this part of the basin during Oligocene. This is reflected by predominance of deltaic facies in arenaceous sequence of Barail formations. On the other hand, argillaceous sequence of Barail Formation (Mainly of Lower Oligocene age), seem to belong to coastal plain (especially carbonaceous shales and coal). The upper sequence is embedded with a number of fluvial channel sands. The regional stratigraphy is presented below as Fig-2.

Methodology:

During the conventional seismic data interpretation, reflectors were mapped on seismic data conformable with geological sequence boundary in the study area. The reflectors were finalized according to the continuous formations in the OIL's operational area of Upper Assam basin. As an initial reconnaissance step after completion of structural interpretation of seismic data, the data was re-looked and scanned to derive stratigraphic insights and anomalous seismic features from 3D seismic data. On review of Amplitude Horizon slices close to upper Barail

formation channel like features observed in the study area (Figure-3).

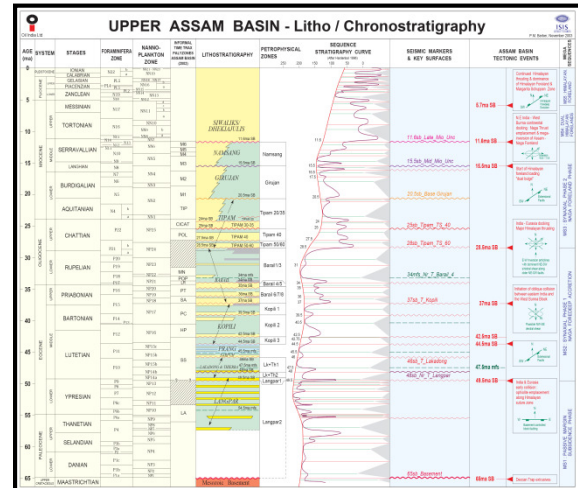


Fig 2: Regional stratigraphy of the study area

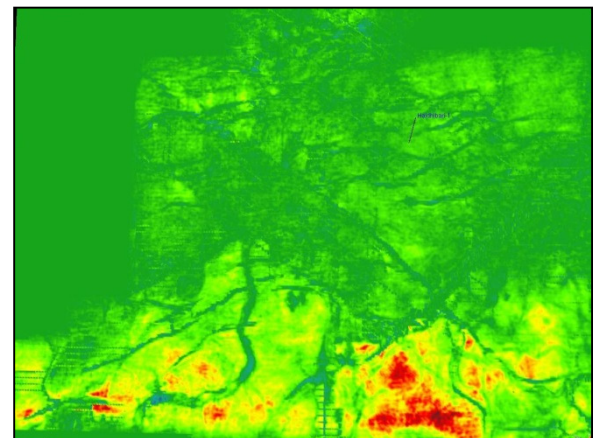


Figure. 3: Amplitude Horizon slice close to Upper Barail formation

Above findings were further augmented with seismic attribute analysis by optimal number of seismic attributes viz. integrated reflection strength, integrated seismic amplitude, coherency and energy. All the attributes maps were not shown as they are coherent with the shown maps in terms of features. These attribute maps were generated close to Barail formation with varying volume windows to discern geological features of interest. While analyzing the result of attribute maps, some spatially discontinuous features were observed which may be possibly channel geometries spreading from north to south in integrated reflection strength (Figure-4) attribute maps.

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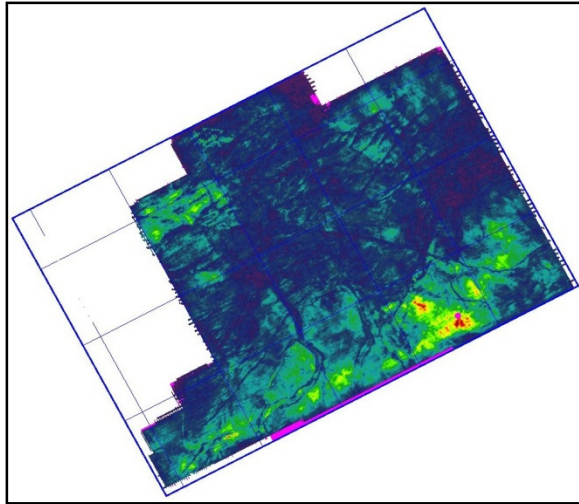


Figure.4: Integrated reflection strength attribute map close to upper Barail formation.

Subsequently, a post stack inversion has been carried out in the study area to mitigate the risk and also to understand the qualitative estimate of the reservoir. Seismic inversion transforms the spiked seismic reflectivity at geological boundaries (caused by changes in the lithology or physical state) into meaningful **elastic** properties (impedances). Since impedance, the inversion output is the product of density and acoustic velocity; it offers direct correlation with rock properties. By contrast to seismic reflectivity, which occurs at the contacts of contrasting strata, impedance takes on constant values within rock layers, allowing a straightforward and intuitive correlation with geology and stratigraphy. Therefore, transformation to impedance simplifies the lithological and stratigraphic interpretation and plays an important role in seismic interpretation.

Model-based Post-stack inversion study has been carried out on 3D seismic data. Model-based inversion starts with an initial model (constructed by interpolating acoustic impedance derived from well log information and interpreted seismic horizons to guide the structural information) of the earth's geology and perturbs this model until the derived synthetic seismic section best fits the observed seismic data. This method is intuitively very appealing since it avoids the direct inversion of the seismic data itself. Model based inversion algorithm has been preferred for the project with intent to arrive at a desired high resolution (both spatial and temporal) acoustic impedance volume in order to delineate both the Barails & Eocene sands. This algorithm has been selected over other inversion modules with lowest inversion error. Post stack inversion study has been used to integrate Acoustic

impedance of the established hydrocarbon bearing formations to derive estimates of the potential distribution of sands possibly containing hydrocarbon in integration with the computed AI attribute through well data and other relevant log informations.

Acoustic impedance is a layer property. Post-stack inversion is used to better map extent and thickness of reservoirs and to give a qualitative estimate of reservoir quality. The resulting impedance volume can be used to predict reservoir sand facies away from well control. The computed impedance (product of RHOB & DT) at each of the well locations are correlated and deliberated with the acoustic impedance volume generated through Post stack inversion study. Figure 4 through 6 shows the acoustic inversion result for wells

The impedance values emerged to be in good accordance and hence establish the authenticity of the study and the impedance volume. Inversion results have also been authenticated with well testing results of the producing wells.

A comprehensive analysis of the Acoustic Impedance (AI) volume in integration with the log information has been carried out and the AI attribute distribution at the locations proposed. In this Post Stack Inversion study, significant impedance anomalies have been observed at all the proposed location both at Barail (Oligocene) and Eocene levels. These locations appear to penetrate various sand levels both in Barail & Eocene and also help in redefining the sand distribution in the study area. The impedance distribution suggests convincing reservoir sand facies development.

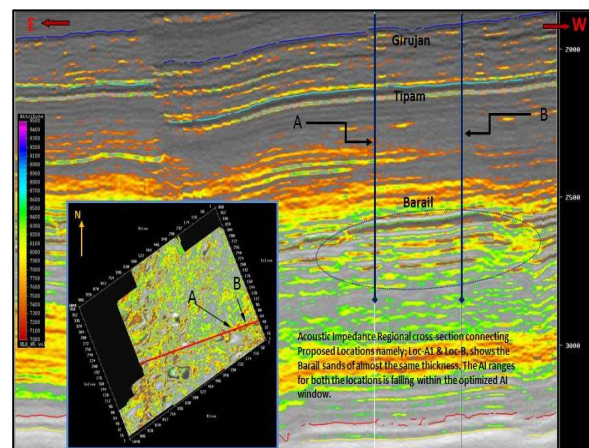


Figure 5: Showing optimized Acoustic Impedance values at the Proposed locations

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Location-A and Loc-B, shows three (3) set of sand at different levels within Barail, below near Top Barail supplementing the impedance range and offers good lateral sand facies development. The sand shows an encouraging lateral continuity for the locations. The encircled zone (& zoomed) in the **Figures-5** showing the lateral & vertical distribution of the multiple sands falling within the optimized Acoustic Impedance value range at the proposed location within Barail.

Similar to the analysis carried out at the Barail level, oil bearing wells has been thoroughly scrutinized at the Eocene levels. Arbitrary lines (sections) were drawn connecting producing wells. The impedance sections along the wells are found to be in conformity with the impedance from the well logs, however, is slightly towards the higher side but falling within the optimized range for the sands at the Eocene level. All the wells having producing sands falling within the optimized impedance range. On closely scrutinizing the impedance at the Eocene level it may however be seen that the impedance to the south is slightly lower than that of the north and has been found to be the general behavior for the Eocene sands within the block. The **Figure-6** shows that location C fall within the optimized acoustic impedance value range.

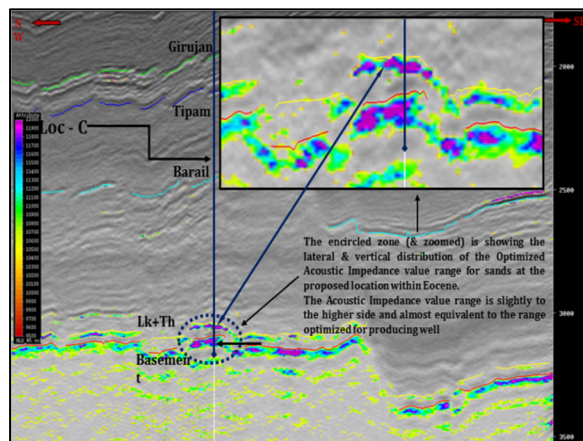


Figure 6: Showing optimized Acoustic Impedance values at the Proposed locations

Conclusion

From Integrated analysis of Seismic attributes and post stack seismic inversion in the study area, helped to delineate channels like patterns running from N-S and NNE-SSW in upper Barail sequence as well as helps in increased confidence in further future proposed locations.

This study has helped the interpreters to find the possible stratigraphic prospects with a different outlook. Such integrated studies will possibly help in minimizing the exploration risk and to define better hydrocarbon drillable prospects. Horizon slice, Attribute analysis & spectral decomposition tools in combination provided the whole subsurface picture to understand the paleo-geomorphology close to Barail formation.

Inclusion of post stack seismic attributes has helped in delineating the prospect and reducing the risk of drilling dry well by optimizing acoustic impedance range within the periphery of the well having similar geologic setup.

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