Seismic Attribute Analysis for Identification of Strati-Structural Prospects:  
A Case Study from Upper Assam Basin

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Summary

Oil exploration in Upper Assam Basin commenced with the discovery of the Digboi oilfield more than 100 years ago, when based on surface oil spill a well was drilled on an exposed anticlines. As most of the structures have been already drilled, the need of the hour is to probe smaller structures and stratigraphic traps. In this perspective, Seismic attributes had got wide acceptability and use in oil exploration and production business ranging from identification of prospects to reservoir characterization. Anomalous features on attribute maps have proven to be useful in finding new structural and stratigraphic traps and sometimes good indicators of the reservoir quality. This study scrutinizes how attributes can be used to map strati-structural traps, prospect evaluation and risk mitigation.

An amplitude preserved processed 3D Seismic time and depth migrated data is used in the present paper for case study to show the use of combination of seismic attribute in prospect evaluation. The present study is primarily focused on use of different seismic attributes at different reservoir level and how these attributes can help in generating new leads and reducing risks.

Introduction

i) Study Area

The Block lies in the western part of the Upper Assam Shelf Basin of OIL’s operational area in NE India (Figure-1) and overlies on a basement highs that are developed along the Brahmaputra Basement Arch. The Namsang and Girujan Formations thin over the basement high. The Eocene shelf margin roughly parallels the axes of the Brahmaputra Arch. The available seismic data belongs to foreland part of Upper Assam Basin is of good seismic resolution. Approximately, 145 Sq. Km. of data was acquired by Oil India Limited during the period 2007-2008. Some wells are already drilled in the study area before acquisition based on 2D and narrow azimuth 3D seismic data of different vintages. SW part of the block produces from Barail whereas NE from Eocene level. The wide azimuth 3D survey has been planned, identifying Strati-Structural prospects and reservoir distribution pattern from Tertiary and Pre-Cretaceous sequences. Considerable efforts were made during processing to preserve the amplitude and enhance the frequency content of the data as much as possible. The frequency content in the data is up to 60Hz to 70Hz range with a dominant frequency of about 30-40 Hz. The primary structural and stratigraphic features of this petroleum system are associated with plate movements that occurred from the latest Paleozoic to the present.
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ii) Geological Background of study Area

The selected study area lies in Assam-Arakan basin which is a polyhistory basin located in the North-Eastern part of India. The block falls within the Tura-Sylhet-Kopili-Barail-Tipam composite petroleum system of the Assam-Arakan Basin. The Upper Assam Shelf part is mainly a Tertiary Basin. The Assam-Arakan sedimentary Basin is a Shelf-Slope-Basinal system. The shelf part of the basin spread over the Brahmaputra valley and the Dhansiri Valley, the later lying between the Mikir Hills and The Naga foothills. The basinal (geosynclinal) part is occupied by the Cachar, Tripura, Mizoram and Manipur fold belts. The shelf part rests on the Precambrian granitic basement, whereas the basinal part lies on transitional 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 60000 Sq. Km. and contains more than 8000 m thick sediments of mostly tertiary period. The Brahmaputra Arch run along the southeastern side of the Brahmaputra river. The southeastern slope of the Upper Assam Shelf towards southeast of the Brahmaputra Arch, having local structural highs and lows, upto the Naga thrust, and extending 8-10 km beneath the Naga Schuppen belt. This part contains most of the oil fields of the Upper Assam Shelf. Sediments of Eocene age were deposited in shallow marine to open marine condition during marine transgression. Kopili shale are the main source rock sequence for hydrocarbon generation in the area. The succeeding Barail Group, was deposited under deltaic environment and are divided into two litho units in the Upper Assam Basin namely Argillaceous and Arnaceous Sequence. The Argillaceous sequence is made up of mainly shales, Carbonaceous shale, coal beds etc. This sequence seems to be deposited in coastal plain conditions whereas the arnaceous sequence consists of fine grained sandstones and subordinate shale. The upper sequence is embedded with a number of fluvial channel sands. Miocene sediments were deposited under fluvial and lacustrine environment whereas the Girujan sediments were deposited under flood plain conditions (Figure-2).

Methodology

i) Variance Cube: Variance Cube facilitates identification of lateral changes in the seismic response caused by variation in structure, Stratigraphy, lithology, porosity, and the presence of hydrocarbons. Semblance & Manhattan distance are used to predict similarity between two adjacent data point. It is extracted to enhance the visualization of subtle faults and fractures, which has assist us to track faults and fractures more quickly and accurately in the block (Figure-3). It also helps us to identify the drainage pattern of the reservoir.
ii) Integrated Amplitude: It is employed to describe the waveform shape and gives the total energy at any given instant along a seismic trace of study area. High reflection strength is associated with major lithologic changes between adjacent rock layers. It is used for identifying bright spot, dim spot and flat spot. The initial signatures of the geomorphologic features like channels were spotted by Integrated Amplitude (Figure 4).

iii) Instantaneous phase: It’s a physical attribute and describes the phase angle at any instant along the complex trace. It is independent of reflection strength, and therefore used to find the continuity of the event within the block. It is used to find out depositional patterns, discontinuities, pinch outs, angular unconformities and zones of thickening (Figures 5).

iii) Instantaneous frequency: It describes the rate of change of phase of a complex trace with respect to time. Changes in instantaneous frequency can help to identify fracture zones; bed thickness and hydrocarbon indicator as hydrocarbon reservoir often cause a drop of high frequency components (Figure 6a and 6b).

Figure-3: Time slice at 2500 ms in a variance cube generated for the study area showing faults and fractures.

Figure-4: Amplitude map over reflector Barail Coal Shale depicting some channel deposits in east and south-east portion. Major faults in the western part of the block along with a no. of criss-cross fault are also visible; at the same time in the northern part of the block sedimentary deposition can be observed clearly which also validates the depositional history for Barail formation within the study area.

Figure-5: Instantaneous phase calculated over a BCS showing depositional patterns and zones of thickening.
iv) **Dip/Azimuth Attributes:** Dip uses a refinement grid to calculate dip changes from trace to trace and azimuth attribute indicates the direction of dip orientation. Extraction of these attributes designates the subtle faults and flexures. This helps to identify the drainage pattern of the reservoir.

Figure-6.a: Shows an integrated instantaneous frequency map for Barail Coal Shale, illustrating some channels in the east and southeastern part of the block.

Figure-6.b: Integrated instantaneous frequency calculated for Lakwa formation which depicts some depositional evidence in the northern part of the block whereas some channels like features is also visible in the southern and eastern part of the block.

Figure-7.a: Dip calculated over a BCS showing dip associated with particular horizon.

Figure-7.b: Azimuth calculated over a BCS showing subtle flexures over a horizon.
v) Spectral Decomposition (CCT): Spectral decomposition used to extract a detailed stratigraphic pattern which in turn helps in refining the interpretation of the seismic data to a great extent. The concept behind spectral decomposition is that a reflection from a thin bed has a characteristic expression in the frequency domain that is indicative of temporal bed thickness. If further said, higher frequencies image thinner beds, and lower frequencies image thicker beds.

Spectral decomposition analysis was taken up around the zone of interest i.e. close to the mapped horizon. In order to restore confidence on channels and sand bars observed on different set of attributes different frequency slices were generated for time window of ±16ms to ±52ms from mapped horizon, over a wide array of frequencies ranging from12Hz to 55 Hz. On carefully examining these set of frequencies it was found that the seismic anomalies are best resolved on 21 Hz and 45 Hz because thicker sands were best resolved at lower frequencies and the thinner sands were best resolved at higher frequencies (Figure 8).

Conclusion

A Seismic attribute analyses has been carried out to locate and define subtle stratigraphic characteristic, geomorphic features and structural features. The aims of comprehensive attribute analysis are to delineate potential reservoir as well as non reservoir litho-facies particularly within the mapped reservoir units. Attributes calculated from seismic amplitude data were used in conjunction with horizontal time slices and vertical sections to identify and delineate potential hydrocarbon reservoir zones and channel sand bar. These attributes were qualitatively analyzed for patterns or trends that have provided insight to the facies distribution. The results of seismic attributes alone can be inconclusive, but this interpretation in conjunction with conventional seismic interpretation can give great insight of the prospective sands as shown in Figure 8. In this paper seismic attributes were used for marking horizons and faults along with mapping of sedimentological features were done, which facilitates interpretation of seismic data faster and accurately. Seismic attributes are very useful in extracting structural and stratigraphic information from seismic data. It is a very persuasive technique which can be used for identification of possible leads and prospects and it also minimizes the exploration risk substantially by facilitating us in understanding depositional environment, subsurface structural features and reservoir properties.

Figure-8: Spectral decomposition image with 21Hz (above) and 45Hz (below) frequency of 32 ms volume window showing many Paleo-fluvial channels at Barail sequence.

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