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Application of Spectral Decomposition for identification of Channel Sand Body in OIL's operational area in Upper Assam Shelf Basin, India - A Case study

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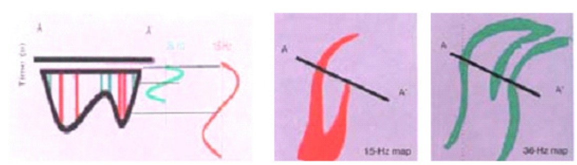
Summary

Spectral decomposition provides 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. When seismic data is transformed into frequency domain using discrete Fourier transform, the amplitude spectra delineate temporal bed thickness variability, while the phase spectra indicate lateral geologic discontinuities. This signal analysis approach may be used successfully to delineate geobody in 3D seismic data such as channel sands and structural settings involving complex fault systems .

A 3D-seismic data set processed & conditioned pertains to Upper Assam shelf Basin is used in the present paper for case study to detect & reveal thin beds primarily buried stream channels and other thin sand prone deposits in the main producing. The spectral decomposition (i.e. decomposing the data into its spectral components) analysis within a seismic data window along the interpretated horizon of interest has revealed the stratigraphic information – buried channel sands, possibly charged with hydrocarbons.

Introduction

Spectral decomposition may be used to extract detailed stratigraphic patterns 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 **(Figure 1)**. If further said, higher frequencies image thinner beds, and lower frequencies image thicker beds. The concept is similar to the remote sensing technique utilizing contiguous bands of frequencies to map & identify the land use at the earth's surface. As in remote sensing, it is very important to dynamically observe the response of the reservoir to different frequency bands **(Figure 2).**



(a) (b) (c)

Figure-1: Diagram showing the interrelationship between thin bed tuning and the amplitude of spectral components through an idealized channel. (a) Vertical cross-section (b) Spectral component at higher frequency (c) at low frequency

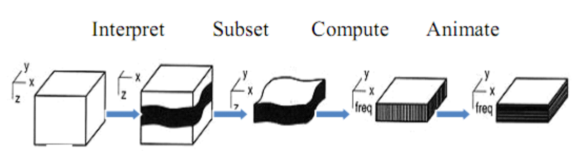


Figure-2 : Brief Workflow of Spectral Decomposition

The key is to create a set of data cubes or maps, each corresponding to a different spectral frequency, which can

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be viewed through animation to reveal spatial changes in stratigraphic thickness. The successive Spectral decomposition images reveal different parts of a reservoir with varying thickness in an area; Partyka et al, (1999 & 2003). In this paper Spectral Decomposition is being used for observing & discerning the response of the gas bearing channel sands to optimize the development plan in the study area.

Geological Background

Assam-Arakan basin is a 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. During Miocene, sediments were deposited under fluvial and lacustrine environment.

Study Area

The study area is located in central part of OIL's operational area in Upper Assam Shelf Basin, at the southern bank of Brahmaputra River, in north-eastern part of India **(Figure- 3).**

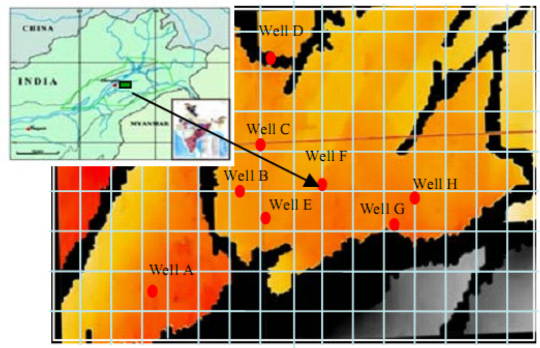

Figure-3: Location map showing study area along with well locations and line of cross section

Acquisition & Processing

Oil India has acquired approx. 500 sq.km. 3D- seismic data in and around the study area during 2002-03 & 2004-06. Before the acquisition of these surveys, several wells were drilled on the basis of 2D-seismic data interpretation in the area. The 3D surveys had primary objectives of detailed mapping of Paleocene/Eocene formation to identify additional drillable prospects, reasons for failure in some of the wells in the area. For the present study around 60 sq.km. 3D data was used. The data quality is good with a dominant frequency of about 30-40 Hz and up to 60-70 Hz present in the data. The processing flow consisted of the following steps – input data & reformatting, trace editing, spherical divergence correction, refraction statics, surface consistent deconvolution, band pass filter, surface consistent amplitude scaling, velocity analysis, residual statics, PSTM, 3D stack .

Interpretation

(a) Reasons for taking up study

As per the well log data, Within Oligocene sequence, Barail channel sands are fining upward sand bodies, deposited under fluvial condition. Initially, the channel sand bodies were considered to be continuous through out the structural extent in the study area. On basis of structural interpretation eight wells were drilled, out of which two wells (wells B & C) were on gas production in the sands pertaining to Barail formation of Oligocene sequence, four other wells (wells A, E, G & H) producing from a deeper formation, showed evidence of hydrocarbons from well logs in the Barail sands, whereas two other wells i.e. well-D and well-F encountered shaley sands in this formation. As per the geological section **(Figure 4)** these gas bearing sands are found to be structurally discontinuous and fining upwards, quite contrary to the initial structural interpretation. All these challenges involved the use of some additional interpretational techniques; hence spectral decomposition along with other seismic attributes was extracted to delineate this geological anomaly charged with gas.

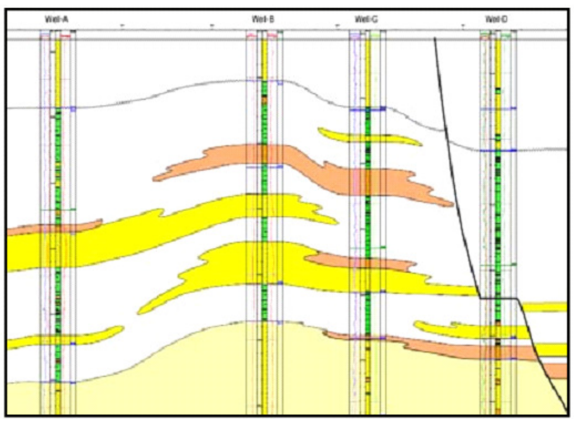

Figure 4: Geological section through wells A, B, C and D showing fluvial channel sand in Barail Sequence

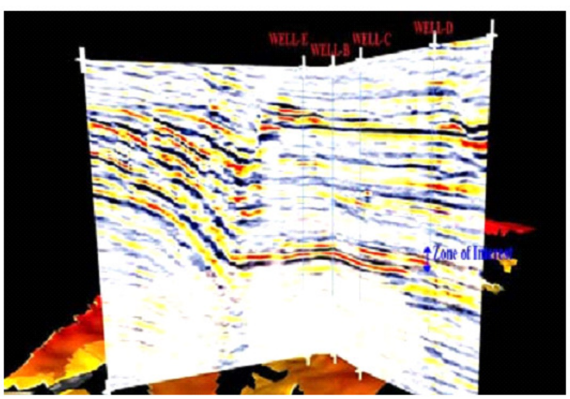

Figure 5: Seismic section passing through the wells-D, C, B and E showing zone of interest

(b) Method

Initially mapping was done on two reflectors in this study; one on an unconformity surface between Miocene and Lower Oligocene which can be mapped regionally in the area and the other close to the producing sands (zone of interest). It may be noted that reflections between these two surfaces are not continuous (**Figure 5**). Well to seismic tie was established in all the well locations.

Seismic attribute analyses viz. coherency, energy, instantaneous amplitude attribute were carried out within the two mapped horizons to supplement the geologic interpretation. Some channel like sand body anomaly was observed in coherency map **(Figure 6)**, however, inspite of changing various parameters the sand body could not be mapped with confidence. Similar anomaly was also observed in energy as well as instantaneous amplitude attribute but with lot of uncertainty and the definition of channels was not very clear in these attribute maps **(Figure 7)** & **(Figure 8)** respectively.

After limited success of conventional seismic attributes in discerning the possible channel like sand bodies, spectral decomposition analysis was taken up around the zone of interest i.e. close to the mapped horizon. The frequency slices were generated through a time window of ±12ms to ±36ms from mapped horizon, over a wide array of frequencies ranging from 8 Hz to 60 Hz. Animating through these frequencies, the best definition of the seismic anomaly was observed at 10Hz and 25Hz over a time window ±16ms. A number of channel bodies could be observed over the frequency range 10-50 Hz (**Figure 9a, 9b,9c & 9d)**, however, the best output of spectral decomposition anomaly was observed after blending of 10Hz and 25Hz extracted maps**(Figure 9e)**, because the thicker channel sand zones were tuned by lower frequencies and the thinner sand zones by higher frequencies. The interpreted possible channel is shown in **Figure 9 (f)**. The width of fluvial channel is of the order of 400-600 m. The mapped sand thickness also validates the observed best tuning frequency.

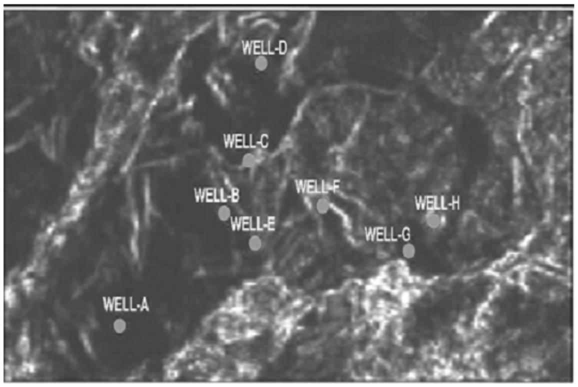

Figure 6: Coherency map (±16ms volume) at mapped horizon close to reservoir

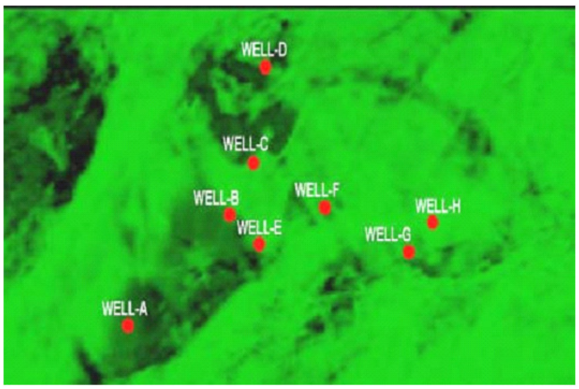

Figure 7: Energy anomaly map (±16ms volume) at mapped horizon close to reservoir

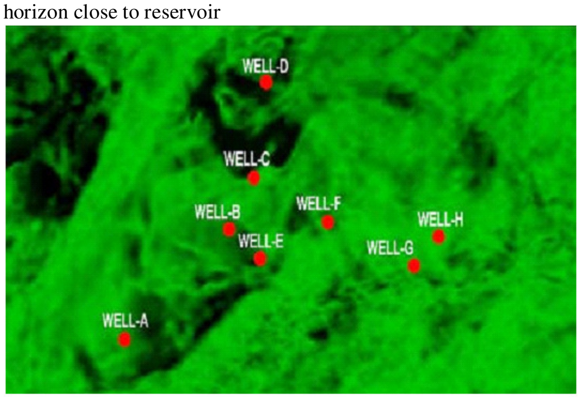

Figure 8: Amplitude anomaly map (±16ms volume) at mapped horizon close to reservoir

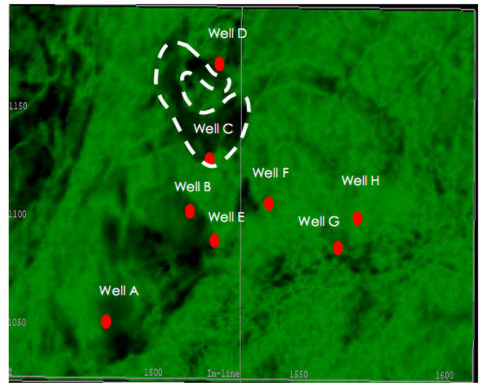

Figure 9 (a) Spectral decomposition Images at 10Hz amplitude and

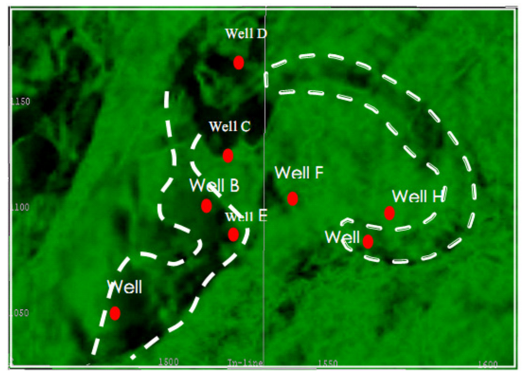

Figure 9 (b) 25 Hz amplitude in ±16ms volume showing Paleo-fluvial channel at Barail sequence; showing outline of possible sand bodies.

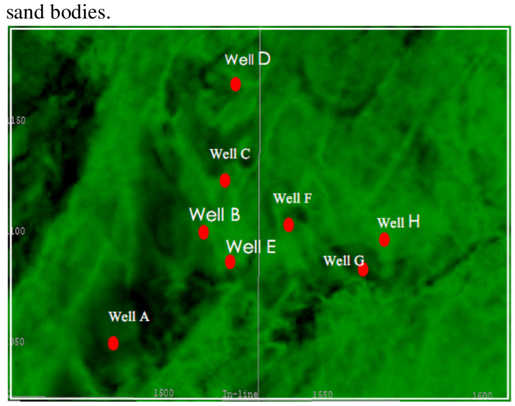

Figure 9 (c) Spectral decomposition image at 40Hz amplitude and

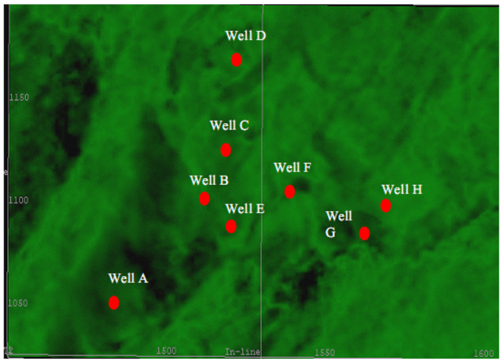

Figure 9 (d) 50 Hz amplitude in ±16ms volume showing Paleo-fluvial channel at Barail sequence; very faint images of sand bodies, difficult to interpret

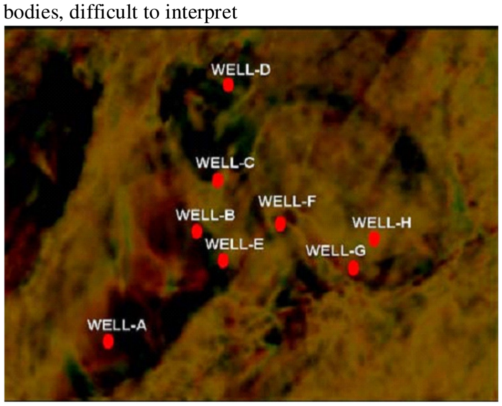

Figure 9 (e) : Spectral decomposition image blended with 10Hz (green colour) and 25 Hz (red colour) in ±16ms volume showing Paleo-fluvial channel at Barail sequence

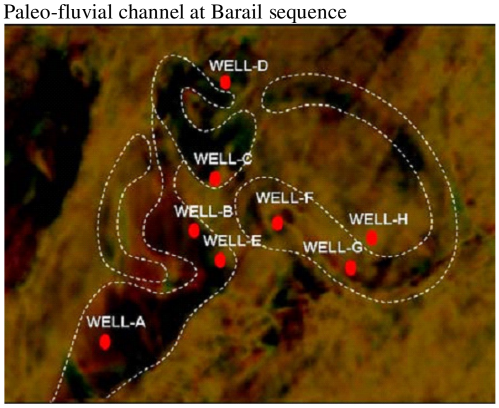

Figure 9 (f) : Spectral decomposition image showing outline of possible fluvial channel sand bodies encountered in the wells

(c) Results

The observed channels were validated with well evidences. It was observed that the wells which intersect the channels encountered cleaner channel sands and therefore, were found to be productive. On the other hand, the other wells, drilled even just outside the channels encountered sands which were more shaly or very thin in nature and were not so productive. The results of the study are expected to be used to lower down the risk of continued development of reservoir and to support & locate additional prospects in the area.

Conclusion

Spectral decomposition has become a useful and important technique & tool for extracting stratigraphic information from seismic data. In this paper, a case study is presented, where spectral decomposition is being used successfully to image & map the channel sands and established reasoning of success and failure of different wells in a study area in Upper Assam, India.

Acknowledgements

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