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Application of Continuous Wavelet Transformation (CWT) and Time Frequency Wavelet Transformation (TFCWT) for improved temporal resolution of thin beds- A Case study

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Introduction

The CB/OS-2 block is situated in the Cambay Graben and straddles the transition zone between the Surat Depression and the western end of the Narmada Rift in the north-west India offshore region, north of Mumbai (Figure 1). The main producing formations from top to bottom are Babaguru and Tarkeshwar formations of middle Miocene age. Except the bottom 75m interval of Tarkeshwar, which contains the thin and multiple oil sands, rest of the interval contain thick gas sands. Good quality and high resolution 3D seismic was acquired over the field that is rich in high frequency content. Inadequate contrast in rock properties of oil sands and masking effect of overlying high amplitude gas sands pose difficulties to map these oil sands. Seismic inversion based interpretations were unsuccessful in prediction of lithology and fluids. Spectral Decomposition techniques have been applied in this context to map the sand fairways and depositional geometries.

Latest advances in spectral decomposition of seismic data like Continuous Wavelet Transformation (CWT) and Time Frequency Continuous Wavelet Transformation (TFCWT) enable to achieve higher resolution over the widely used Short Time Fourier Transform method (STFT). STFT requires a minimum time window and the defined spectral attributes refer to the combined response of stacked layers (within the time window) and is effective for mapping sand fairways.

In this background, Continuous Wavelet Transformation (CWT) and Time Frequency Continuous Wavelet Transformation (TFCWT) techniques were tested to resolve and map thin layers within the sand fairways.

CWT is a narrow band spectral analysis method. It extracts the power of given frequency by using a wavelet which dilates and translates along the zone of interest. The output is a spectral power map for a given frequency within a narrow time interval.

TFCWT is another approach wherein it displays spectral power of a given frequency in TWT time for any event and this can be seen against seismic background. Unlike CWT, whose response includes a range of up to 5Hz around the central frequency, TFCWT gives a deterministic response to a single frequency.

Figure 1: Location map showing Lakshmi Field in CB-OS/2 block

Spectral Decomposition (STFT)

There are up to 5 oil sands (thickness vary 3-18m in drilled wells) embedded in a 75m thick shale unit. Model studies for tuning frequency response with thickness variations were carried out for sands using rock properties observed in the wells. This helped to assess the relation between tuning frequency and corresponding layer thickness. Seismic data was analyzed for bandwidth and amplitude levels in order to aid interpretation of tuning frequencies of those derived from seismic data. Spectral decomposition was run on a 100 Sq. km 3D PSTM volume for the time window covering the oil sands (Figure-2) using Schlumberger’s spectral decomposition software module. A tuning cube was generated and tested for tuning frequency amplitudes at well penetrations. It was observed that thick sand areas are illuminated at lower frequencies and thin sands at higher frequencies.
Good linear relation was seen between gross sand thickness (as seen at wells) and tuning frequency which was subsequently used to predict gross sand from tuning frequencies in the given area. Thus two distinct sand fairways were identified (Figure-3) and tested successfully by drilling, shown in figure 3 as well 7 (11m sand) and well 8 (18m sand).

Though STFT successfully revealed sand fairways, it is not effective in detailing individual sand geometries within those sand fairways. Thus STFT has limitations in resolving the issues relevant to reservoir sand continuity and its geometry.

Recent approaches like CWT, TFCWT to enhance temporal resolution over the STFT have been attempted and the results are discussed in this paper.

Figure 2: Seismic section passing though wells and showing zone of interest (Logs: Sw on right and Porosity on left)

Continuous Wavelet Transform (CWT)

Continuous Wavelet transform (CWT) is a narrow band spectral analysis method, which does not require pre-selecting a window length and uses dilation and translation of wavelet to produce a time-scale map. The scale includes a band of frequencies and is inversely proportional to the time support of the dilated wavelet. (Sinha et al, 2005).

CWT overcomes the limitations of the fixed window approach of conventional spectral decomposition technique by automatically changing the window size with frequency.

Lower Tarkeshwar interval encountered few sand units that are seen as discontinuous amplitudes in vertical seismic sections. CWT was run using OpendTect software, on seismic volume at different frequencies and results were analyzed. The CWT response at 50Hz frequency enabled the delineation of sand 1 at platform 1 area (Figure 4). There are two sand fairways that are separated by shale units. The distribution of the sand 1 was calibrated in wells 2 and 2z as shown in figure 5. New sand fairway is identified south of Platform 1 that was not seen in the STFT displays. By using the deduced relationship between tuning frequency and the corresponding layer thickness, this sand is predicted to have thickness of about 12-13m. A prospective area is identified (highlighted by blue polygon) for future development. Based on the well results the CWT tool will be used to assess other sands observed in different locations in the field.

CWT delinates sand 1 in zone of interest

Figure 3: Map showing sand fairways

Figure 4: Channel geometry defined by CWT (50Hz) response
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**Time Frequency Continuous Wavelet Transform (TFCWT)**

TFCWT method uses a moving window approach and does not average neighboring frequencies like that in CWT. TFCWT generates a time-frequency map instead of time-scale that displays the precise frequency of the event. The TFCWT method has shown response of sands in the zone of interest. Figure 6 shows delineation of Sand 2 in Well 4, which was not seen in CWT and STFT. This technique has ability to evaluate the data with greater temporal resolution compared to CWT and STFT methods.

TFCWT has been applied on a small area for testing its strength and applicability in the field. As results of the technique are encouraging, a full scale study is envisaged for delineation of thin sand in the field area.

**Summary**

The application of spectral decomposition methods in Lakshmi field helped to resolve the channel morphology and prediction of gross sand thickness in the zone of interest, where amplitude methods were unsuccessful.

Preliminary understanding of Time Frequency Continuous Wavelet Transform (TFCWT) method appears to be more promising to resolve thin beds. Its response can be seen in the background of seismic section in time. These studies have improved the understanding of the oil sands within the Lower Tarkeshwar Formation and provided key inputs to the infill development drilling decisions in the Lakshmi field. Details derived by the application of Continuous Wavelet Transform (CWT) when integrated with TFCWT, STFT and other subsurface data mitigate the risks associated with development drilling.

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References


Janice Liwanag, Dr. Rongfeng Zhang, Karl Mirochnik (2006) Enhancing Reservoir Visualization with Spectral Decomposition. Dew Vol.15 No.09