An Approach to Net Thickness Estimation Using Spectral Decomposition

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Introduction

Many methods have been applied to seismic data in the reservoir characterization domain to produce images that can reduce the uncertainties associated to the geological interpretation process, litho-stratigraphic interpretation and fluid contents[1]. Spectral decomposition of seismic traces into frequency domain is an established and popular technique for stratigraphic analysis from seismic reflection data. Apart from the qualitative nature of interpretation, spectral decomposition can also provide quantitative information about bed thickness and visualizing subtle seismic tuning effects and delineating phase.

The power of the Discrete Fourier transformation (DFT) to transform seismic data into frequency domain have been used for reservoir characterization[2] and is known for long time now. In the present study we have used a computer program – GeoFrame™ Spectral Decomposition[#] for estimating Net Thickness. After running spectral decomposition on 3D Seismic Volume, the result is a frequency volume where instead of the samples being 4 ms, 8 ms, 12 ms, the samples are subdivided into 5 Hz, 10 Hz, 15 Hz, etc. (Fig. 1). These frequency slices provide valuable information about the reservoir and may indicate potential traps for hydrocarbons. The power of spectral decomposition is that it can reveal the same features as in geology which helps geoscientists to analyze and map seismic features as a function of spatial position, traveltime, frequency, amplitude and phase and allows them to visualize, interpret, and quantify the seismic response to an extent that was previously unattainable.

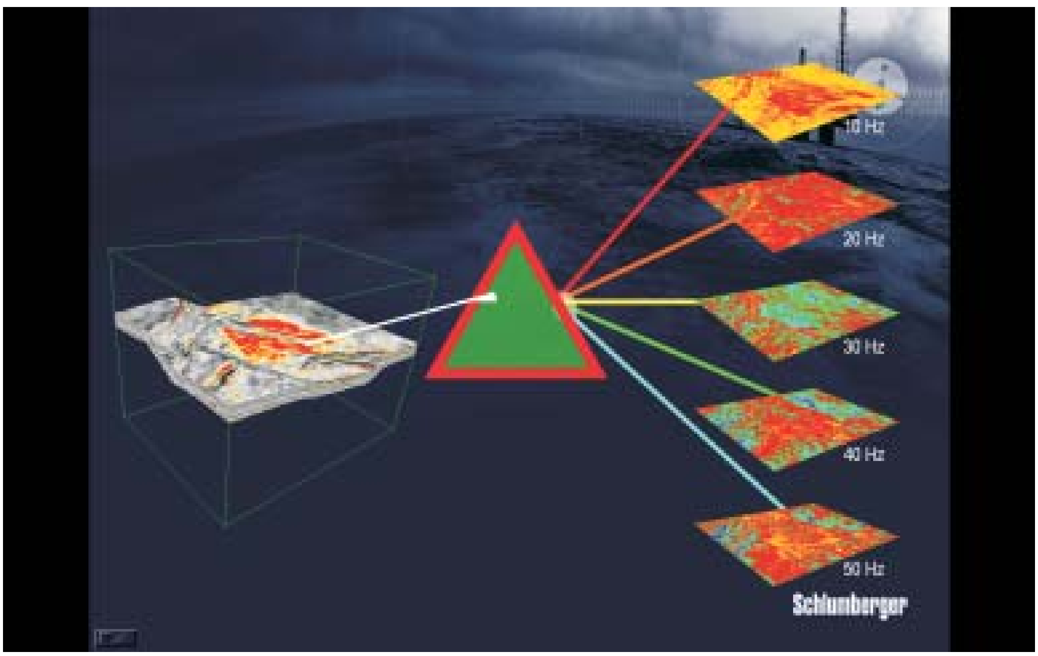

Fig.1: A Schematic diagram depicting transformation of Seismic data into various frequency domains

Understanding DFT and basic assumptions

A time series can be completely represented by amplitude and phase spectra. For a large temporal window, geology can be considered to be random and the amplitude spectra represent more the wavelet amplitude spectrum (Fig. 2a). But for a short time window statistics can be considered non-stationary and geology is less random. The amplitude spectrum is now wavelet amplitude spectrum plus geology (Fig. 2b). For such short temporal windows, geology now acts as a filter, attenuates the spectra of the source wavelet and provide valuable information about the geology.

This is achieved by decomposing the seismic signal into discrete frequency components in a nonstationary sense i.e. over a short temporal window. Local geology tends to tune the wavelet's spectra, through constructive and destructive interference of spectral components.

Methodology

In the present study Spectral Decomposition has been used in combination with well data to prepare the net thickness map. The workflow shown in Fig. 3 depicts the combination of well data and spectral decomposition results to create net thickness maps. Consequent results have been used to propose ideal locations for new wells. The workflow suggested is for clastic environment, but is equally applicable in many other situations.

a. Marker Interpretation

The first step in the geological interpretation is to interpret

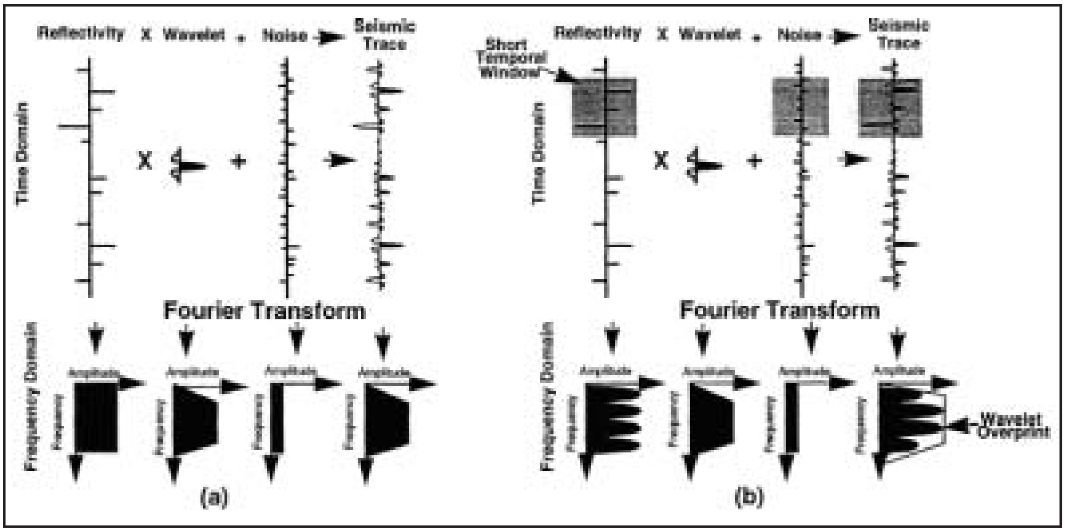

Fig.2 : (a) The convolutional model and Fourier transform for a long temporal window (random geology, stationary statistics). (b) The convolutional model and Fourier transform for a short temporal window (nonrandom geology, nonstationary statistics)

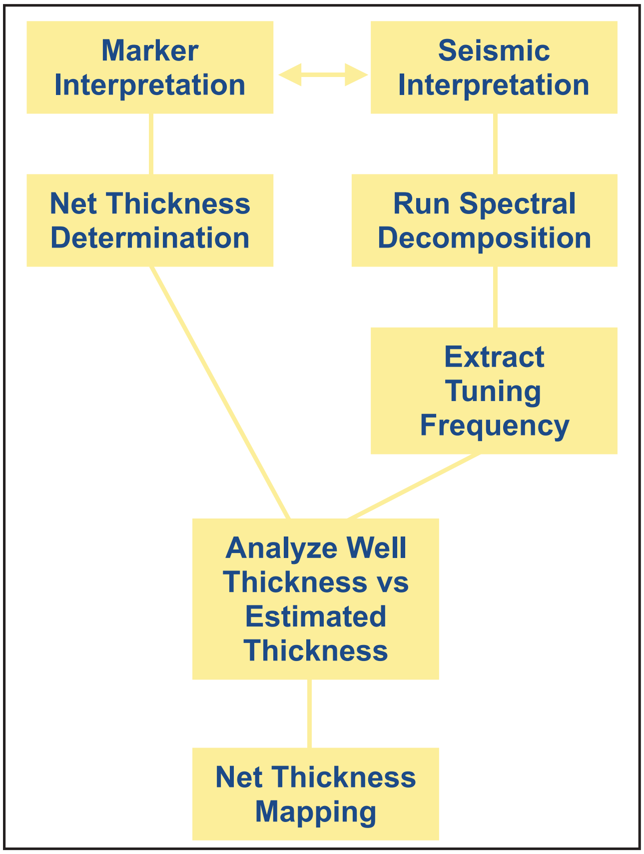

Fig. 3 : A schematic flowchart of Net Thickness Mapping using well data and spectral decomposition.

c. Seismic Interpretation

When the geologists are working with well log well markers. In the present study, log correlations based on the SP logs were used to pick stratigraphical markers (Fig. 4). It is observed that Well W-12 has consi-derably higher net thickness than the W-9 well.

b. Net Thickness Determination

A cutoff value on the VCLAY, SW, PHIE and PERM log was used to determine net thickness value for the sand unit and calculate other reservoir zone properties. The bubble map below shows net thickness values for various wells in the field. Notice that well W-4 has the highest net thickness for this particular sand unit (Fig. 5). The contour map shows two way time values interpreted in a 3D survey by the geophysicist for the seismic event corresponding to the sand unit.

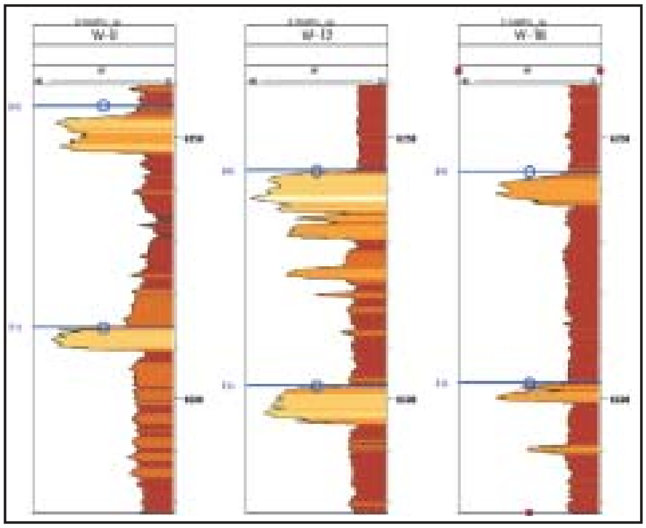

Fig.4: Log Correlation between Wells W-9, W-12 & W-18 based on SP curve has been used to pick Stratigraphical markers.

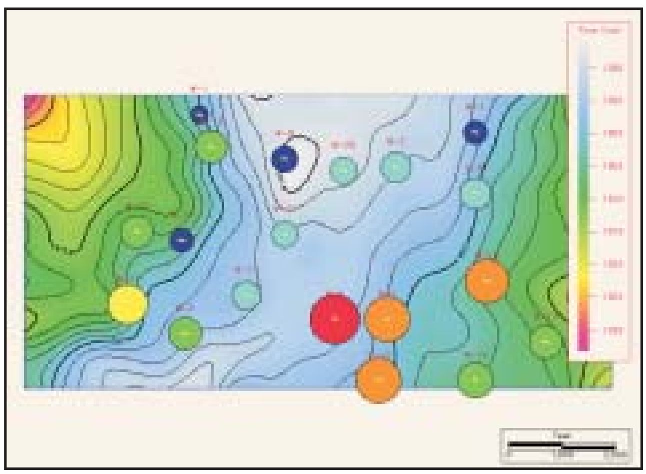

Fig.5 : Bubble Map showing Net Thickness estimation for various wells.

correlations, the geophysicist can be interpreting the 3D seismic data. Working together in the same project minimizes the risk of making any mistakes as they are combining their knowledge and not wasting time doing unnecessary input and output of data. The geophysicist in this example interpreted the reflector corresponding to the base of the sand as it has a higher acoustic impedance contrast and is therefore easier to follow (Fig. 6).

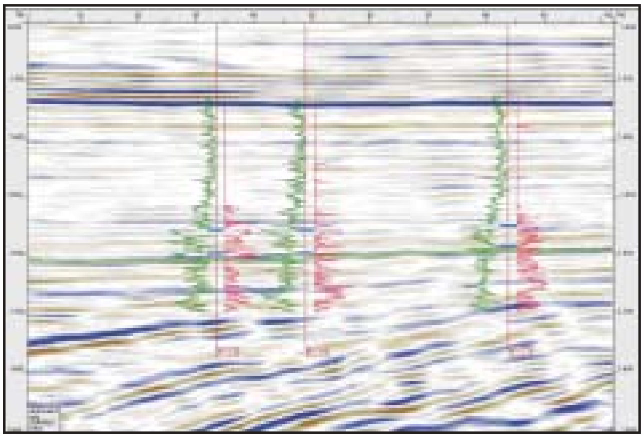

Fig.6: A Seismic Section depicting wells W-12, W-18 and W-11 with markers, logs and interpreted horizon

d. Spectral Decomposition

After doing Seismic Interpretation and Log Correlation, finally spectral decomposition is carried on a time window above the horizon of interest. After running spectral decomposition, the seismic volume is decomposed and now it is frequency indexed. (Fig. 7)

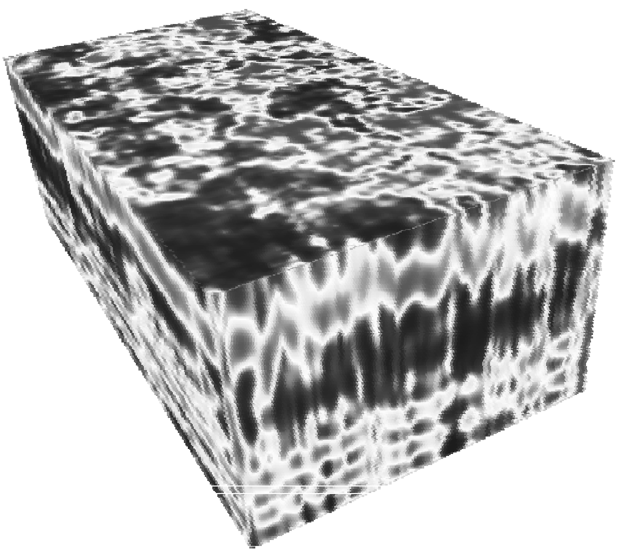

Fig.7: A Frequency Indexed Seismic Volume after Spectral Decomposition

e. Extract Tuning Frequency

The first peak amplitude of this frequency cube is what is known as the tuning frequency. Theory predicts that the tuning frequency extracted from spectral decomposition frequency cubes is inversely proportional to reservoir thickness. Practical observations from well data have confirmed what the theory predicts. This knowledge can be used to combine well data and spectral decomposition results. Prior to doing this, the tuning frequency event must be interpreted. Special attributes such as "Time at maximum amplitude" or "Time at first peak" can be used to accelerate this task. The resulting horizon is then smoothed to remove any spikes. (Fig. 8)

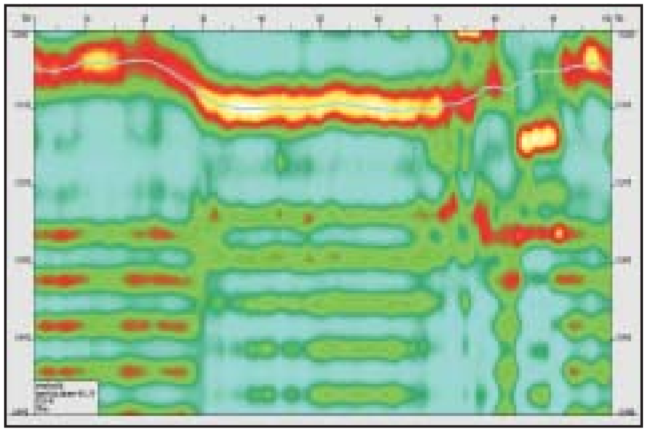

Fig.8: Window depicting smoothened horizon.

f. Analysis of Net Thickness at Wells vs Response Frequency

The relationship between response frequency and net thickness at well locations can be evaluated and studied using log property distribution and mapping (Fig. 9). The crossplot below shows an inverse relationship between response frequency and net thickness determined from

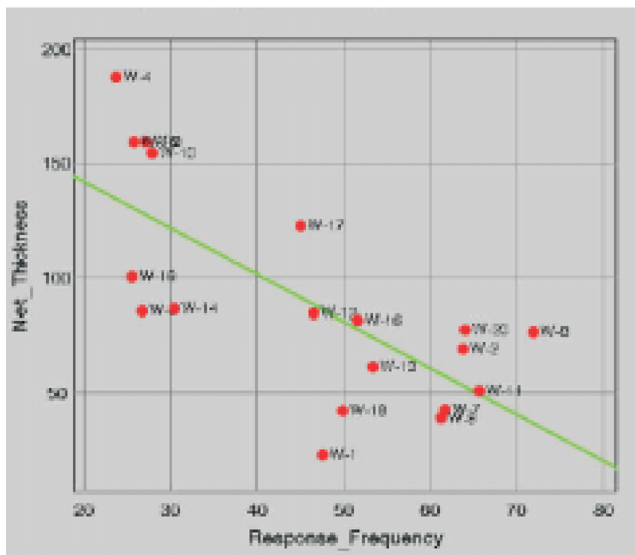

Fig.9 : Cross plot between Net Thickness Vs Response Frequency for various wells.

geological well marker correlation. The estimated net thickness values predicted by the frequency cube (green line) does not correspond exactly with the actual net thickness values at the wells (red dots), but the correlation is quite good. Using geo-statistical algorithms such as collocated co-krigging we can make sure that well data is honored exactly. The well data combined with the estimated net thickness values from the frequency cube predict net thickness values more accurately away from the wells.

g. Net Thickness Mapping

The final result is a net thickness map that uses both well data and the results from spectral decomposition. This map now has a lot more detail than a map that would result from well data only. As there is a good correlation between the two, the map reveals valuable information to plan wells that involve less risk and penetrate more sand.

The red area predicts the highest net pay thickness values in the field and helps you determine ideal locations for new well proposals.

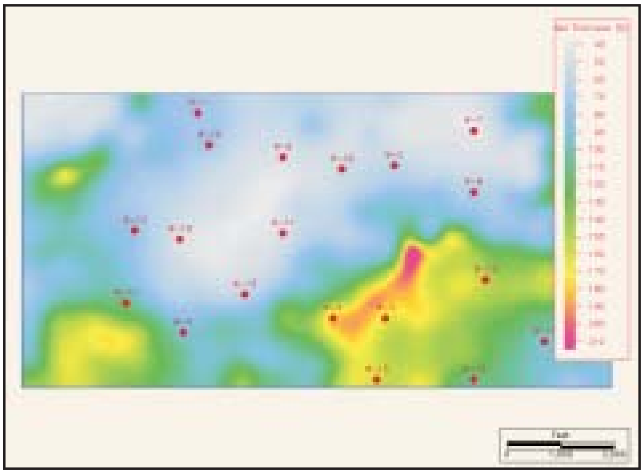

Fig.10 : Net Thickness Map for the area of study showing locations of various wells

Summary and Conclusions

Spectral decomposition can be powerful aid to imaging and mapping of bed thickness and geological discontinuities. Transforming seismic data (Time domain) into frequency domain with the help of computer programs, *viz.*,. GeoFrame™ Spectral Decomposition# has greatly reduced the efforts required by the explorationists to understand the reservoir, seismic modeling and volume estimation technique and quickly and effectively quantify various stratigraphical parameters like Net Bed thickness.

References

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