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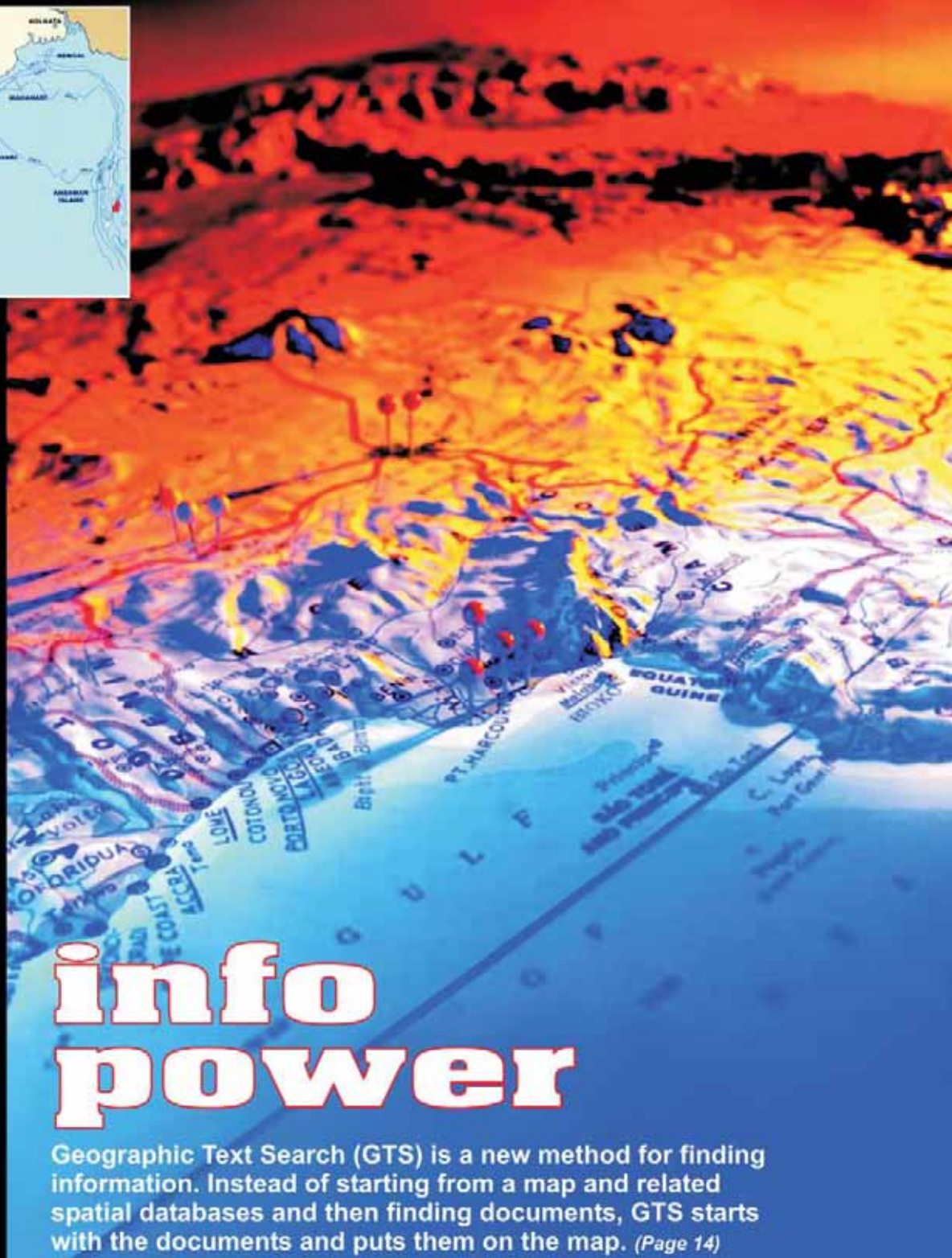
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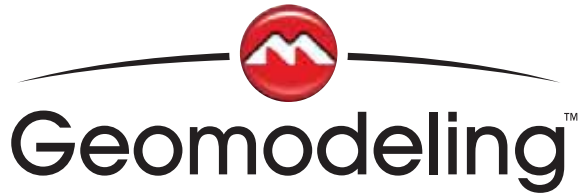
## Gas Hydrates presence established in KG Basin, East Coast of India

India has met with significant success in establishing the presence of sizeable reserves of good quality gas hydrates. Results from the Krishna Godavari basin are particularly remarkable. These have shown the presence of a 128m thick gas hydrate layer.



## info power

Geographic Text Search (GTS) is a new method for finding information. Instead of starting from a map and related spatial databases and then finding documents, GTS starts with the documents and puts them on the map. (Page 14)



# 'Enhancing Reservoir Visualization with Spectral Decomposition'

**Spectral decomposition adds value to visualization and interpretation workflows by revealing details normally overlooked in full bandwidth seismic displays.**

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**W**ith the increasing demand for improved oil recovery worldwide, geophysicists require more rigorous seismic interpretation methods to get the most information from their data. Canada-based Geomodeling Technology Corp. has been meeting industry demand by incorporating the latest spectral analysis methods into VisualVoxAt seismic interpreta-

tion software since 1996. The windows-based technology is now equipped with four different spectral decomposition methods, enabling interpreters to evaluate their data with greater resolution than offered by conventional seismic analysis techniques. Four spectral decomposition methods were applied to the Blackfoot field in southern Alberta, Canada, where producing oil and gas reservoirs are hosted by channel sands. The study demonstrates that running multiple spectral decomposition techniques can help to visualize different aspects of the reservoir morphology and can greatly improve understanding of reservoir potential.

## Spectral Decomposition: An Introduction

First introduced to industry in the late 90's, spectral decomposition is now becoming a valuable post-processing technique for investigating complex hydrocarbon plays. Typically used in thin bed analysis, spectral decomposition is based on the concept that a thin bed reflection has a unique spectral response in the frequency domain. Spectral decomposition algorithms (such as a Fourier transform) are applied to seismic reflection data to break down the seismic signal into its frequency components. The output is a tuning cube, or a series of amplitude or phase maps tuned to

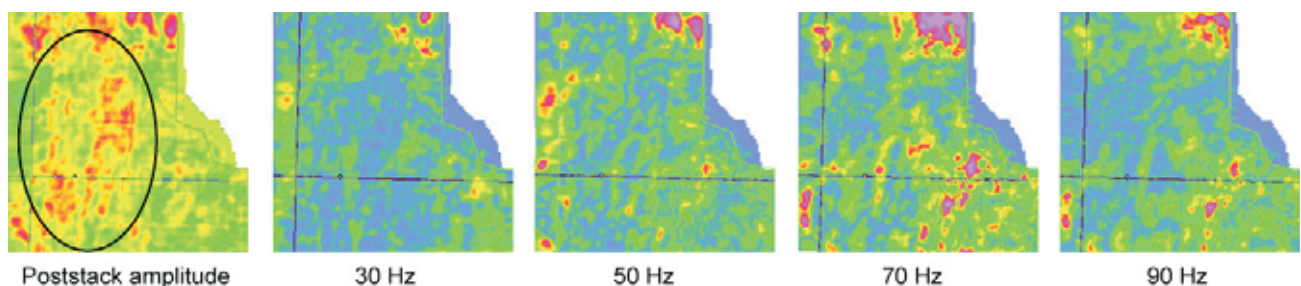


Figure 1. Time Frequency Continuous Wavelet Transform is applied to an interval derived from poststack amplitude to generate a tuning cube consisting of frequency slices. High amplitudes are pink; low amplitudes in grey. Scrolling through the frequency domain reveals channel morphology at 70 Hz.

specific frequencies. The resulting amplitude spectra can be used to calculate bed thicknesses in the time domain, while phase spectra help to define lateral stratigraphic discontinuities. By examining the amplitude and phase maps at various frequencies (i.e. by scrolling through the tuning cube), the interpreter can identify subtle events and anomalies that are not readily visible in the poststack data (Figure 1).

## Comparison of Spectral Decomposition Methods

VisualVoxAt users can choose from four different spectral decomposition methods to enhance their interpretations:

- Short Time Fourier Transform (STFT)
- Continuous Wavelet Transform (CWT)
- Time Frequency Continuous Wavelet Transform (TFCWT)
- S-Transform (ST)

Frequency gathers generated from each method reveal the distribution of frequency on a single trace and demonstrate the differences in frequency resolution among the four techniques (Figure 2).

STFT is a subset of Discrete Fourier Transform, a widely used algorithm that uses a fixed window approach to spectral decomposition. In the STFT method, the user specifies the length of a time window, in which the signal is transformed to represent the acoustic properties and bed thicknesses within the window. Selecting shorter window lengths can help resolve high frequency events and separate events with similar or closely-spaced dominant frequencies. However, the use of these shorter windows can overlook events at lower frequency and compromise map resolution. Selecting longer window lengths will sample a wider range of data and may produce a better statistical

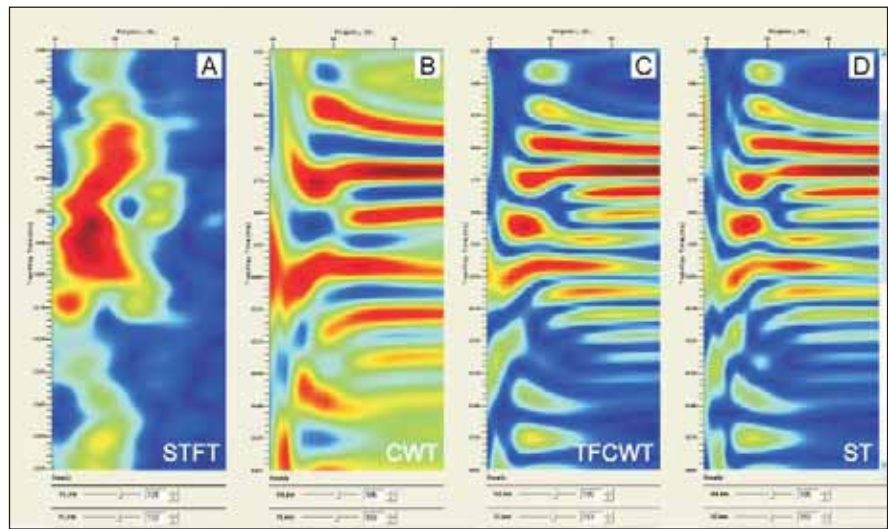


Figure 2. Frequency gathers from VisualVoxAt's four spectral decomposition methods reveal the distribution of frequency on a single trace from a zone of interest. STFT = Short Time Fourier Transform, CWT = Continuous Wavelet Transform, TFCWT = Time Frequency Continuous Wavelet Transform, ST = S-transform.

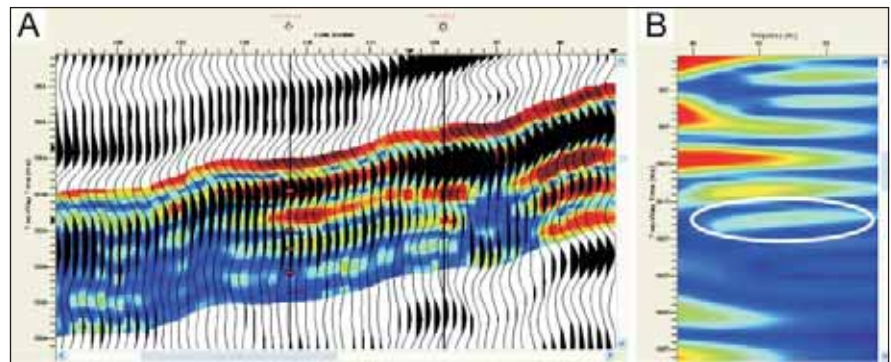


Figure 3. a) Spectral decomposition via Time Frequency Continuous Wavelet Transform (TFCWT) is applied to a strata-grid and overlain on seismic section. Channel events occur between 1020 and 1025 ms. b) Frequency gather of a single trace at a location close to the high-amplitude spectrum of the channel. The gather reveals a high energy anomaly between 50 and 90 Hz.

representation of the acoustic properties. The downside of this approach is that fine-scale events will not be resolved if the window length is too long. Figure 2a shows an example of a frequency gather generated from the STFT method.

CWT samples the seismic signal using a moving, scalable time window. In this method, the window size automatically changes with frequency and allows for adaptive sampling of the seismic trace. The resulting spectral maps provide higher temporal resolution at higher frequencies in comparison to STFT. The CWT frequency gather in Figure 2b shows that CWT is far superior in preserving reflection events than the STFT method for higher frequencies. At lower frequencies, however, CWT cannot adequately resolve events that are closely-spaced in the time domain.

TFCWT overcomes this issue by generating a time-frequency map that displays the exact frequency for any event. CWT and STFT methods, on the other hand, output maps at a central frequency within a given time window. For example, a CWT spectral decomposition map at 70 Hz displays the average amplitude response from around 65 to 75 Hz. However, a TFCWT map at 70 Hz shows the amplitudes at exactly 70 Hz. Like CWT, the TFCWT spectral decomposition method uses a moving window approach, but it does not average neighbouring frequencies in the same way as previously mentioned methods. Therefore, TFCWT maps provide higher time-frequency resolution than STFT or CWT (Figure 2c). Both CWT and TFCWT methods provide high-frequency resolution at low frequencies and high temporal

resolution at high frequencies. One disadvantage of TFCWT is that it is computationally intensive, and generating spectral decomposition maps with this method can be time-consuming.

Like TFCWT, S-Transform generates a real time-frequency map and samples the seismic signal with a moving time window. However, the size of the window in the S-Transform method is frequency-dependent. Because the transform has a more rigorous relationship with the spectra, it can produce spectral decomposition maps with fairly high resolution. S-Transform is faster to calculate than TFCWT but typically gives similar results (Figure 2d).

### Resolving a Channelized Reservoir

In Alberta's Blackfoot field, the oil- and gas-producing Lower Cretaceous Glauconite Member contains shales and quartz sands of lacustrine and channel origin. The hydrocarbon reservoirs typically occur where the porous sands pinch out against impermeable sands or shales. Three channel phases have deposited sands with up to 18% porosity. However, the channel sands can be difficult to differentiate from the adjacent low-permeability strata because the lithotypes share similar P-wave impedances. To better visualize the channel facies in the Blackfoot data, we

implemented a workflow combining VisualVoxAt's strata-grid module with the software's spectral decomposition capabilities.

Spectral decomposition can be applied directly to poststack amplitude data and its attributes. However, we recommend first applying a 'strata-grid' calculation to the poststack interval of interest. A strata-grid is essentially a sample volume that has been extracted from the original seismic volume, but the poststack data in a strata-grid is reorganized into proportional slices. The calculation removes structural bias and allows visualization of paleo-surfaces.

We generated a strata-grid from two stable horizons outlined in previously published reports from the Blackfoot survey area. We then applied the TFCWT spectral decomposition algorithm to the strata-grid to generate a tuning cube. The strata-grid spectral decomposition results (Figure 3a) reveal high amplitude channel sands between 1020 and 1025 ms. We then generated a frequency gather (Figure 3b) to see the distribution of frequency on a trace from the high amplitude horizon. High energy signals in the frequency gather correspond to frequencies where we may expect to visualize channel sands in the tuning cube. In this case, the channel will tune in between 50 and 90 Hz. Scrolling through the resulting frequency slices revealed distinct channel morphology at about 70 Hz (Figure 1). After determining the optimal frequency for visualizing the channel sands, we narrowed down

the zone of interest for further investigation with all four of VisualVoxAt's spectral decomposition techniques (STFT, CWT, TFCWT, ST). By running the algorithms on a smaller volume, we reduced the time required to generate tuning cubes.

### Results

All four spectral decomposition methods provided better resolution of the channel morphology in comparison to the poststack amplitude map, but each offered a different spectral response at 70 Hz (Figure 4).

Figure 4b shows spectral decomposition result via STFT with a window size of 30 ms. Longer window size results are not considered here because structures of interest are only seen at higher frequencies in this case, based on the frequency gather analysis (Figure 3b) and the other spectral decomposition maps in Figure 4. By sampling the seismic signal with a short window size, we can avoid the averaging affects inherent in the fixed window method and obtain better frequency resolution.

Figures 4c and 4d demonstrate that the moving window approaches of CWT and TFCWT provide improved time-frequency resolution in comparison to STFT. However, the TFCWT map does a better job in differentiating relative thicknesses within the channel (Figure 4d).

The S-Transform map produced similar results to TFCWT, with only slightly less resolution (Figure 4e). Overall, the TFCWT map resolves the channel morphology with greater detail in comparison to all other methods. A review of all four spectral decomposition maps shows that the results are consistent with the frequency gather analysis in Figure 2.

### A Closer Look

Generally speaking, thin events appear as high amplitudes at certain higher frequencies in spectral

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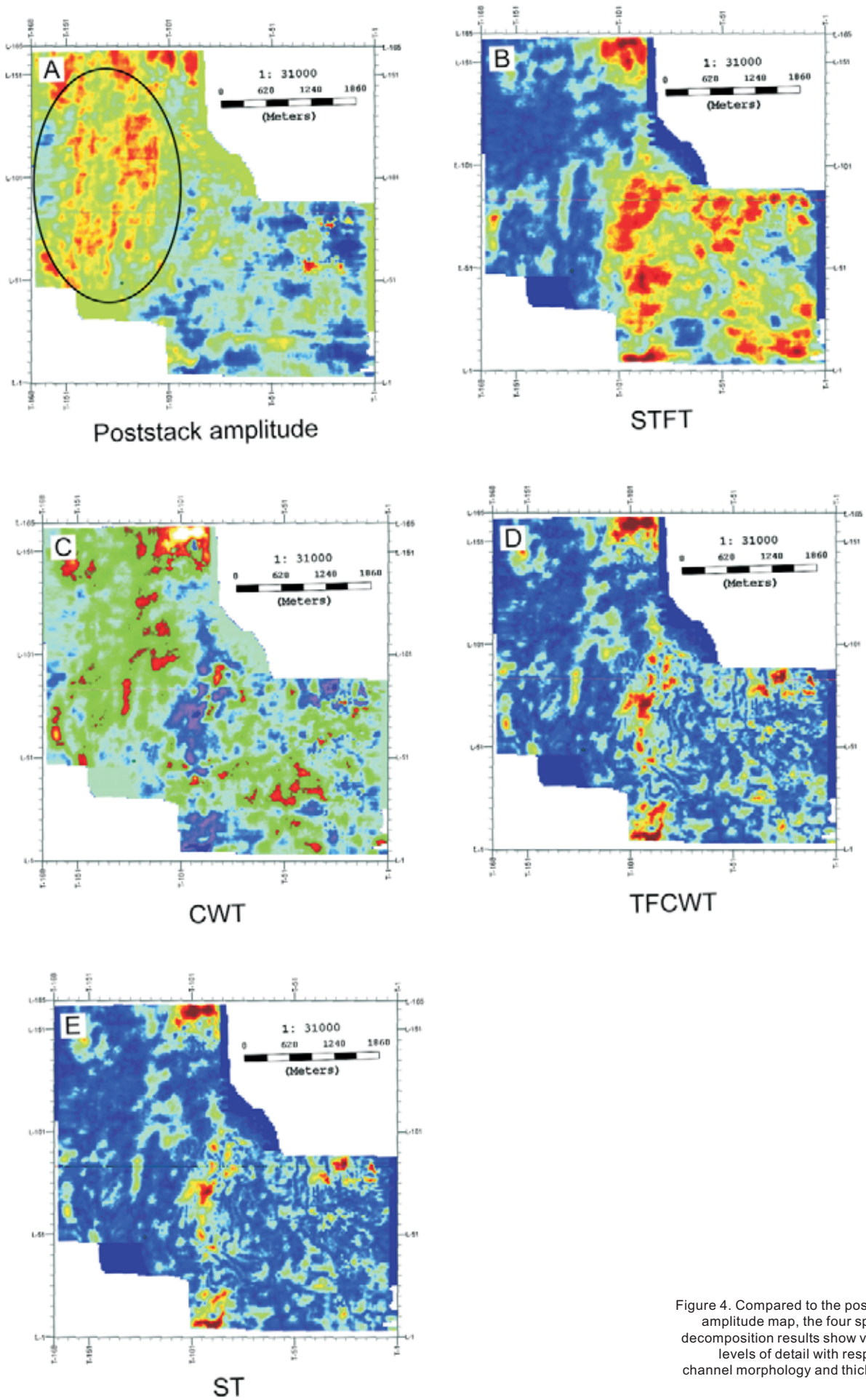


Figure 4. Compared to the poststack amplitude map, the four spectral decomposition results show varying levels of detail with respect to channel morphology and thickness.

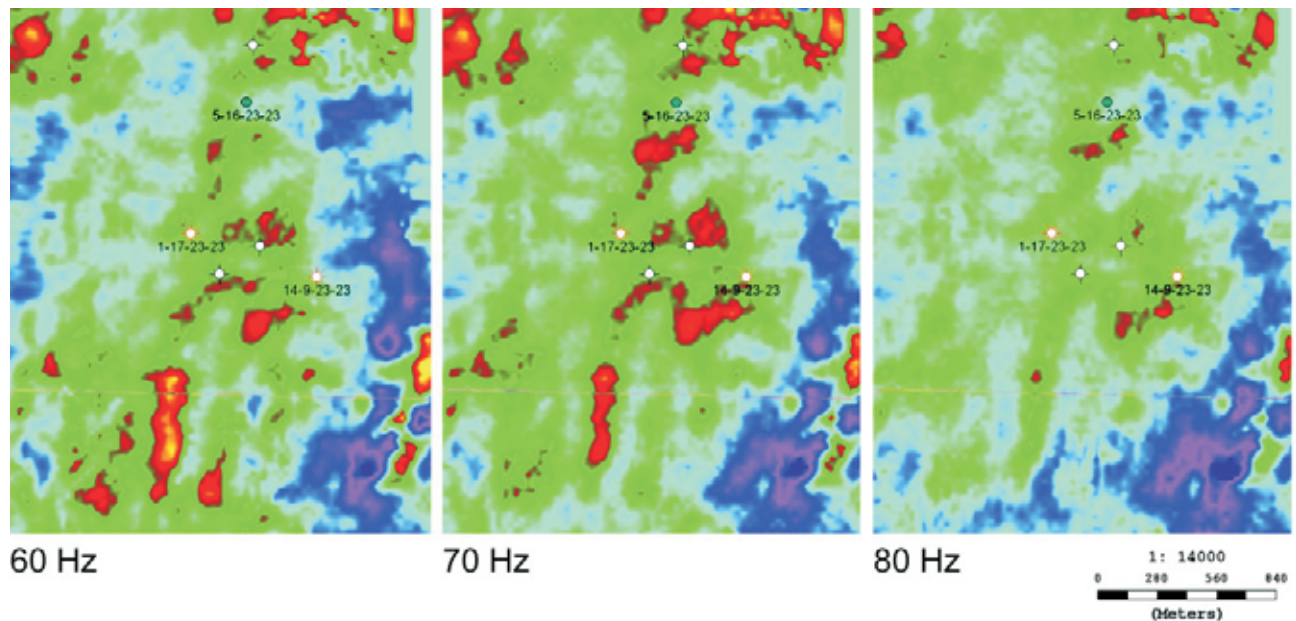


Figure 5. Scrolling through Continuous Wavelet Transform spectral decomposition maps shows that well 14-9-23-23 occurs on the c channel's edge (i.e. where the channel tunes in at higher frequencies, but tunes out at lower frequencies).

decomposition maps. So it is possible to observe the spatial variation of the target by viewing spectral maps in succession within the tuning cubes. Sometimes, if channel or bed thickness increases or decreases spatially, it can be observed by scrolling through the frequency slices. Figure 5 shows a CWT map detailing the Glauconite channel and the wells in the area. Scrolling from 60 to 70 to 80 Hz reveals that well 14-9-23-23 occurs on the edges of the channel, based on

the amplitude change in the frequency slices.

### Conclusions

In imaging the Glauconite channel sands, running multiple spectral decomposition methods helped to resolve the channel morphology and bed thickness relationships within the channel facies. While TFCWT spectral decomposition provided the best resolution of all the methods, it also took the longest time to calculate. The S-Transform maps provided similar results to TFCWT and were faster to generate, making

the S-Transform method the most efficient technique for resolving the channels in this particular study.

Spectral decomposition can greatly improve visualization and interpretation workflows by revealing thin beds, lateral discontinuities and subtle anomalies not readily identified in poststack data. By correlating the spectral maps back to well logs and attribute relationships, the technique can help the interpreter to better understand complex reservoir plays and plan drilling strategies with greater confidence. **DEW**