The use of spectral decomposition to QC seismic data

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Summary

Evaluating the quality of seismic data based on the amplitude spectrum alone can be misleading, especially when comparing independently acquired and processed datasets. To determine which dataset has better frequency content we use spectral decomposition and coherency to compare stratigraphic and structural details as a function of frequency. We applied this workflow to two 3D seismic datasets (2011 Legacy and 2015 Broadband) from the Chinook Field in the Gulf of Mexico. Although the legacy and the broadband data have the same peak frequency and high frequency cutoff, the isofrequency volumes from the continuous wavelet transform and frequency-dependent coherency attributes show that the broadband data has better geological interpretability at high frequency.

Introduction

The quality control (QC) of seismic data is one of the most important steps that takes place prior to quantitative seismic analysis. In the interest of increasing resolution, there is always the question of how high a frequency can be utilized as deconvolution will boost both signal and noise. If too much noise at high frequency is allowed to pass through data processing, this can introduce unacceptable levels of error into inversion and multi-attribute predictions leading to costly reservoir characterization errors. A common processing QC step is to bandpass filter the data and to qualitatively assess data quality within different frequency bands. Spectral decomposition followed by generation of coherency attributes is a convenient means of doing this with great detail at the interpretation stage.

In this study we present a workflow based on the use of the continuous wavelet transform (CWT), to perform the seismic data QC. We apply this workflow to two different datasets with different acquisition parameters but the same bandwidth and peak frequency acquired over the Chinook Field in the Gulf of Mexico to compare the data quality.

Study area: Chinook Field, Gulf of Mexico

Chinook Field is located in the Walker Ridge protraction area of the Ultra-Deepwater of the Gulf of Mexico (>8,000 ft. below sea-level), whose reservoirs are part of the Lower Tertiary Wilcox Trend oil fields, starting at 25,000 ft. (Figure 1). Chinook reservoirs are characterized by fine-to-very-fine-grained, high pressure (~18700 psi), normal temperature (240 ^{o}F), with good porosity (12-24%) and low permeability (10-50 mD) Paleogene sands. Rock-physics studies, based on the well logs, demonstrate that lithology discrimination is feasible (Figure 2). However the correlation of these properties with seismic data has not been successful due to the quality of the legacy seismic (a speculative 3D NAZ, from 1998-1999, which was later reprocessed in 2005 and 2011). The geological model for the area has been based on a statistical model that used as input only well information (Watkins et al., 2015). So far, the seismic volumes had been used only for the structural interpretation, since the low resolution didn't allow for a multi-attribute reservoir characterization.

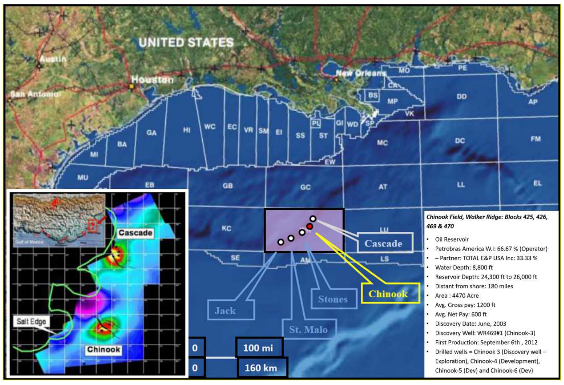

Figure 1: Map location of Chinook field (and other deep water Wilcox fields) in the Gulf of Mexico, along with basic field information (Watkins et al., 2015).

Methodology

The CWT is a commonly-used wavelet transform that utilizes orthogonal basis wavelets to decompose the seismic trace into individual frequency components. The CWT is essentially equivalent to a narrow-band filtering of the data in the temporal domain. We apply the CWT to seismic traces using a Morlet dictionary (e.g., Puryear et al., 2008). When applied to seismic data, the CWT generates isofrequency volumes that can be used for a variety of applications including layer thickness determination (Partyka et al, 1999), stratigraphic visualization (Marfurt and Kirlin, 2001), and direct hydrocarbon detection (Castagna et al., 2003; Sinha et al., 2005).

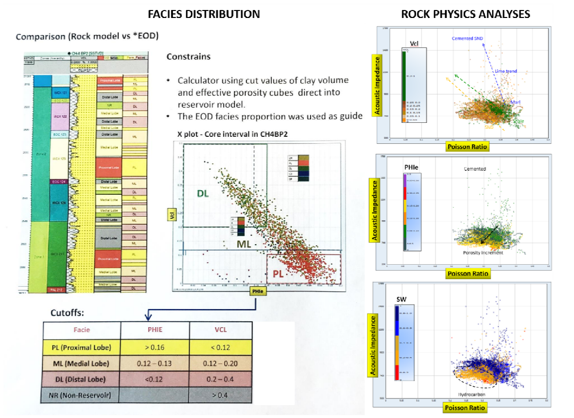

Figure 2: Rock properties and facies distribution on Chinook well logs. The left side shows the facies interpretation for one of the wells, well C, and their discriminations through the Vcl and PHIe. The right side shows a cross plot of Acoustic Impedance and Poisson's ratio used to discriminate the following rock properties: Vcl (top), PHIe (middle) and SW (bottom).

The isofrequency volumes obtained from CWT can also be used for structural interpretation when associated with geometrical attributes, such as coherency (Li and Lu, 2014). Coherency is a seismic attribute that measures changes in waveform and provides a quantitative of geologic discontinuities, such as faults, channels or other discontinuous features (Bahorich and Farmer, 1995; Marfurt et al., 1998; Gerstzenkorn and Marfurt, 1999; Lu et al., 2005). In general, most interpreters apply coherency to the final processed, broadband data (Chopra and Marfurt, 2007).

In this study, we use the CWT as a tool to compare and QC different seismic datasets in terms of stratigraphic and structural features (Figure 3).

Results

In 2014-2015, a high-density broadband proprietary 3D NAZ seismic data were acquired and processed (PSDM). Despite the data being broadband, which would imply a better resolution compared to the legacy survey, there are still difficulties in correlating the new seismic data with rock properties, to perform quantitative studies (Figures 4 and 5).

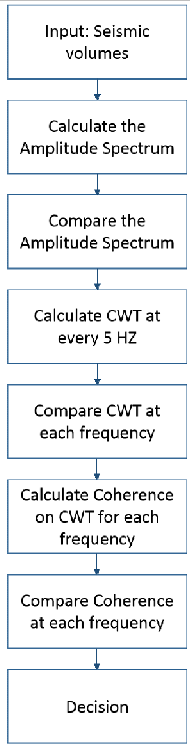

Figure 3: Workflow solution applied to compare and QC the different seismic data.

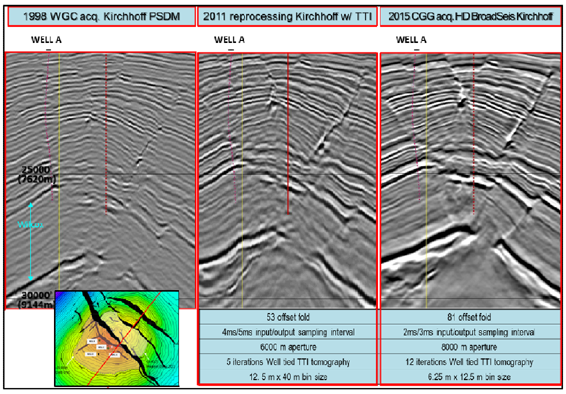

Figure 4: Arbitrary line through well A comparing the legacy seismic data and the broad band data at Chinook field.

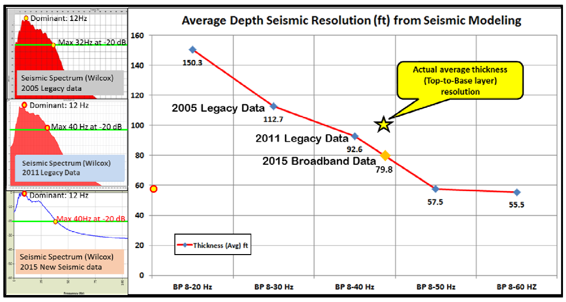

Figure 5: Graphic showing the improvement of vertical resolution for Chinook Field, since the first 3D acquired (1998-1999) to the new broadband 3D seismic Volume (2014-2015). On the left side, we compare the Seismic Amplitude Spectrum for the reprocessed Legacy Data (2005 and 2011) and for the 2015 Broadband Data.

As we can see in the amplitude spectrum for the target area, the Wilcox Formation (Figure 5), the low-frequency part of the spectrum that was recovered for the 2015 Broadband data (3-5 Hz) is improved relative to the 2011 Legacy survey. However, the other end of the spectrum remains pretty much the same when compared to the 2011 legacy data. An initial interpretation of the data showed that the 2015 Broadband data had better resolution at the target zone (80 ft thickness on average) when compared to the same area on the 2011 Legacy data (90 ft thickness on average) (Figure 5). Note that, the increase of the higher frequency content showed by the 2011 Legacy data was achieved through new techniques of processing data that enhance the amplitude of the higher frequencies, while the broadband data we are using for comparison is the raw data, where no enhancement technique was applied during the data processing.

To investigate the image resolution for both surveys, spectral decomposition using a CWT was performed. In Figure 6, we compare the CWT result for the 2011 Legacy data and the 2015 Broadband data. To assess quality, one cannot simply compare the overall amplitude as a given frequency, as wavelet shaping can produce any desired amplitude. What is important is how geologically reasonable the image is and what details can be interpreted. This is a subjective process and not as simple as just measuring cross-power. Overall, at 31 Hz, the 2015 Broadband data is more interpetable with finer detail. The improved detail and sharpness of the image is particularly evident on coherency attributes (Figure 7). There is better definition of the faults across the frequency band when compared with the 2011 Legacy data, corroborating the previous CWT quality assessment.

Conclusions

In this work we showed how we can use spectral decomposition to do seismic data QC, evaluating the signal-to-noise, resolution, and fault detectability at each frequency, thereby determining the true bandwidth of the data. The amplitude spectrum of the data itself is not enough to address the real limits of resolution of the data, and a more detailed analysis, using spectral decomposition is useful.

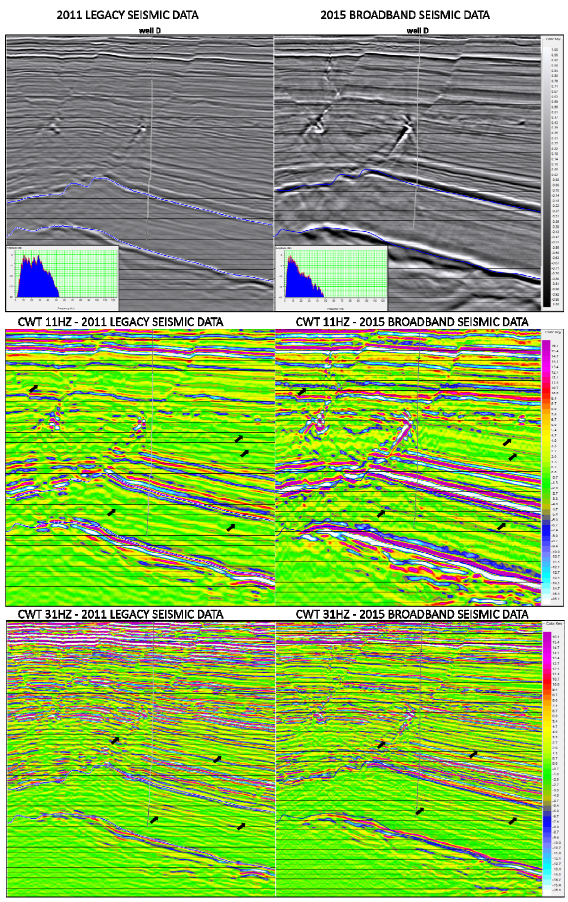

Figure 6: Arbitrary line through well D comparing the results of the CWT at peak frequency (11 Hz) and at 31 HZ for the legacy and the broadband data at Chinook field. The black arrows highlight the discrepancies between both datasets.

The comparison of the 2011 Legacy data and the 2015 Broadband data in terms of the CWT isofrequencies and the coherency showed the superiority of the 2015 Broadband data in terms of the geology revealed. The CWT revealed not just more continuity of the layers, but also better resolution of them in a given frequency band. The coherency attribute showed better localization of the faults on the 2015 Broadband data, helping improve structural interpretation of the area.

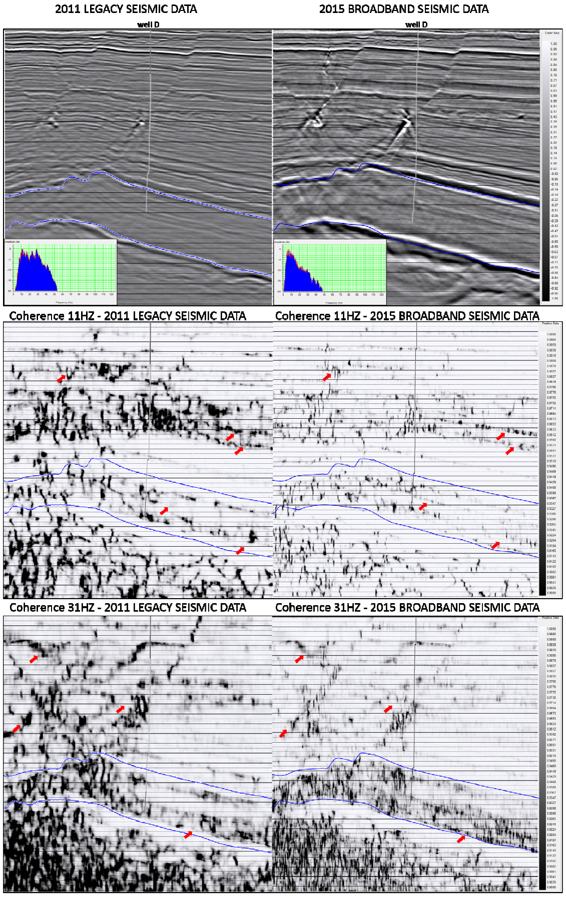

Figure 7: Arbitrary line through well D comparing the results of the Coherency at peak frequency (11 Hz) and at 31 HZ for the legacy and the broadband data at Chinook field. The red arrows highlight the discrepancies between both datasets.

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EDITED REFERENCES

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