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Spectral Signatures of the Tubridgi Field: Onshore Carnarvon Basin, Western Australia

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This case history describes the application of spectral analysis to measure the attenuation of seismic frequencies beneath a hydrocarbon accumulation.

Introduction:

The Tubridgi Gas Field is located 30 km west-southwest of Onslow W.A. in the onshore portion of the Carnarvon Basin in Production Licence L9 (Figure 1) . The hydrocarbons are entrapped in a northeast-trending anticlinal structure with broad, low relief evident only by depth mapping of seismic two-way-times. The commercial hydrocarbons are trapped in the Cretaceous and Triassic Sandstone reservoirs and are sealed by the Cretaceous Muderong shale. The stratigraphic section at the Tubridgi gas field is shown in Figure 2. Note that a secondary non-commercial gas accumulation within the poor reservoir quality Gearle Siltstone is the likely cause of distortions in the T.W.T structure across the field. The field was discovered in 1981 with the drilling of the Tubridgi-1 well by Pan Pacific Petroleum NL. Ten years later the Tubridgi Gas Field became the first commercial hydrocarbon accumulation to be developed onshore Carnarvon Basin (Thompson[i]).

Background:

While attenuation zones ("dim-spots") have been visually noted on seismic sections associated with some hydrocarbon accumulations for almost twenty years (Taner and Sheriff[ii], Anstey[iii], Dobrin[iv] and Sengbush[v]), early attempts at measuring attenuation in the laboratory and from seismic data have had limited success. During the mid eighties, work by Terry Jones[vi] discussing a frequency dependent attenuation model, and experimental work by Bourbie et. al[vii] demonstrating that gas in rock pores attenuates more P wave energy than water, helped set the stage for the further investigation and development of these ideas.

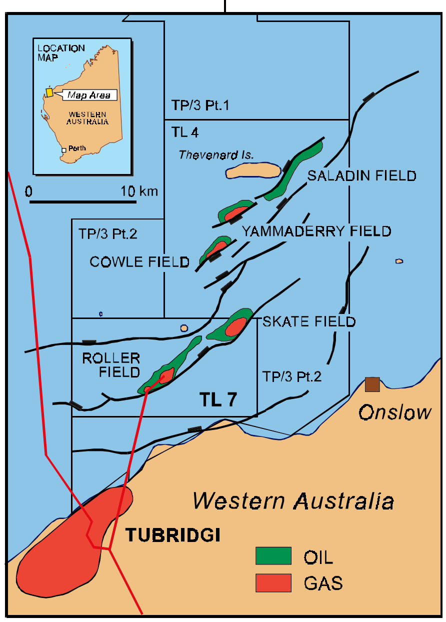

Figure 1 Location Map

This study utilises recently developed techniques for spectral and attenuation analysis[viii]. The technique contains several proprietary algorithms that have overcome some of the limitations of previous methods used to measure attenuation from stacked seismic data.

The factors affecting the spectral character of the seismic data generally fit into two categories (Dilay and Eastwood)[ix]:

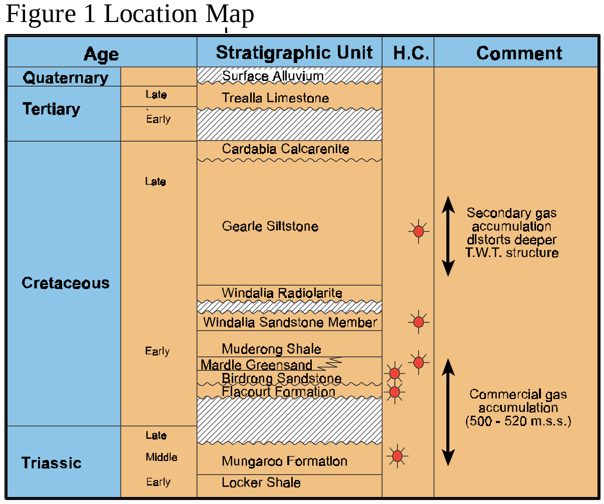

Figure 2 Stratigraphic Section: Tubridgi Field

Lithological

The spectral character changes in response to time-thickness variations within a formation or a group of formations. Usually, these variations can be associated with changes in velocity within the formation, stratigraphic pinch-ins pinch-outs, changes in sand/shale ratio, and lateral changes in the impedance of the reservoir.

Petrophysical
Spectral attributes can also be used to estimate the attenuation characteristics of a certain formation. It has been experimentally established that fluid-bearing porous rock formations attenuate seismic waves preferentially (ie. higher frequencies within the seismic band are more severely attenuated than lower frequencies). Generally, gas attenuates more than oil and oil more than water. Klimentos[x] discusses a well logging example and Eastwood and Dilay[xi] document a case history using attenuation as measured by the same proprietary technology used in this study.
This case history deals with spectral analysis designed to minimise the lithological effects, thereby isolating the petrophysical effects, namely attenuation.

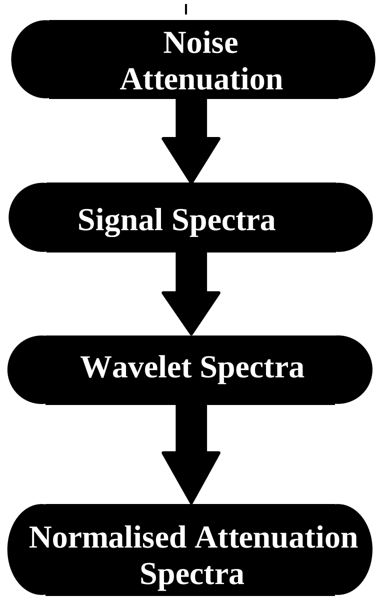

Figure 3
Spectral Processing Flow

Procedure:

In this study the stacked seismic data was analysed for evidence of attenuation beneath the Tubridgi hydrocarbon accumulation. The line analysed was an NW-SE oriented seismic line (J84A-19) located through the central portion of the field. The seismic data was not reprocessed pre-stack for the spectral analysis. However, the post-stack spectral processing flow followed is shown in Figure 3. The first step was to apply a noise attenuation technique to reduce the levels of coherent and random noise in the data and thus improve the Signal-to-Noise-Ratio (SNR). In this example a localised principal component analysis technique was utilised. Next, the signal spectrum was estimated for each trace from a horizon consistent time window (280 msec), both above and below the zone of interest. These spectra are further processed to estimate attenuation spectra.

Estimated Signal and Wavelet Spectra
The estimated signal and wavelet spectra from the window above the zone of interest are shown in Figure 4. The upper panel shows the seismic with the analysis window highlighted in red. The location of the Tubridgi-8 and Tubridgi-10 gas wells are shown. The middle and lower panels show the estimated signal and wavelet spectra. Note that the vertical axes on the spectral displays represent frequency. The black areas provide an indication of the presence and strength of spectral frequencies in the window of

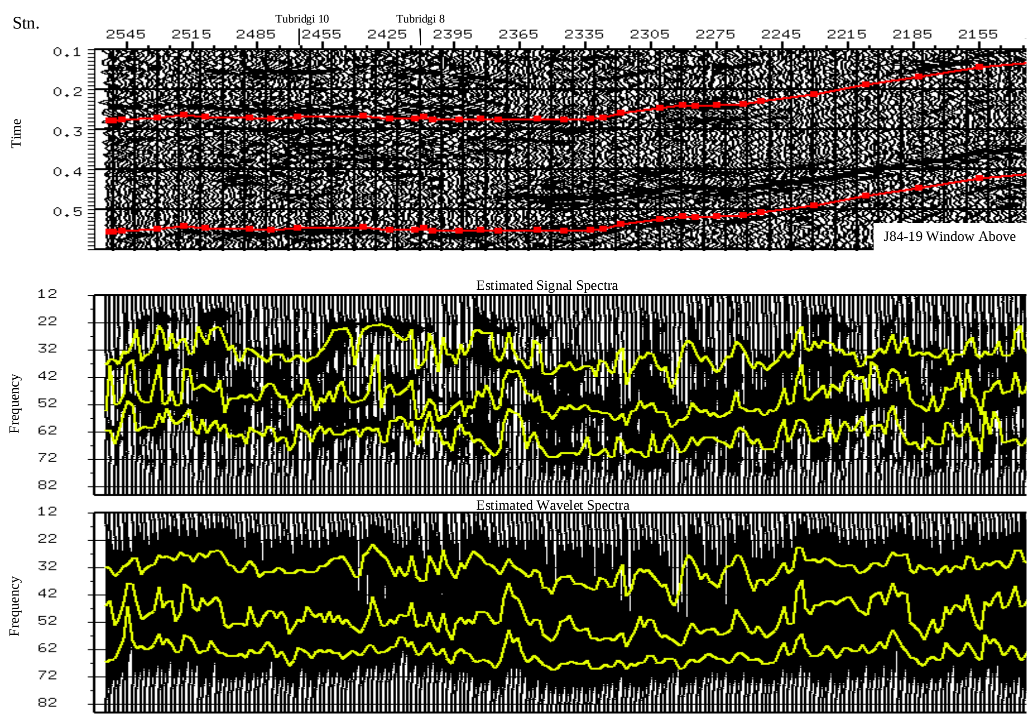

Figure 4 Estimated Signal and Wavelet Spectra: Window Above

analysis. In this study the window of analysis used was 280 milliseconds to help limit the effects of non-stationarity of the wavelet spectra. The effects of reflectivity are further minimised in determining the estimated wavelet spectra. The 15th, 50th, and 85th percentile frequencies are highlighted in yellow on the estimated signal and wavelet spectra panels to quantify the spectral changes.

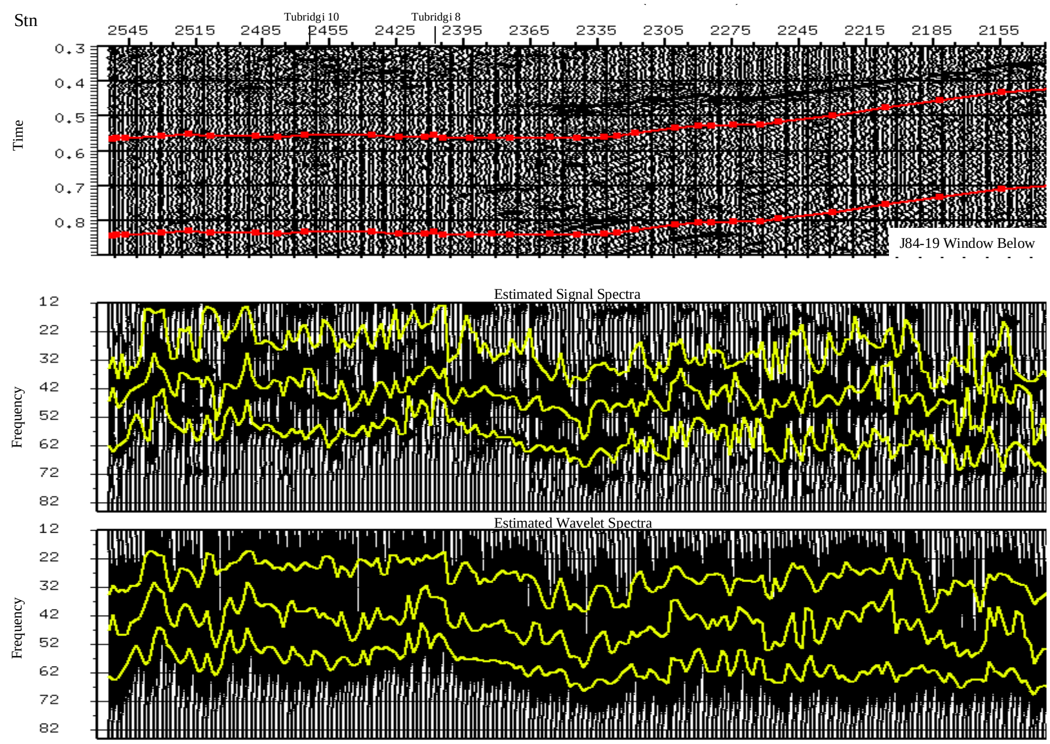

Figure 5 Estimated Signal and Wavelet Spectra: Window Below

Figure 5 shows the estimated spectra from the window below the zone of interest. Examination of the estimated wavelet spectra from the window below shows a subtle shift in the percentile frequencies towards lower frequencies. Comparison of the wavelet spectra from the window above to the wavelet spectra from the window below suggests a loss of higher seismic frequencies below the Tubridgi gas field.

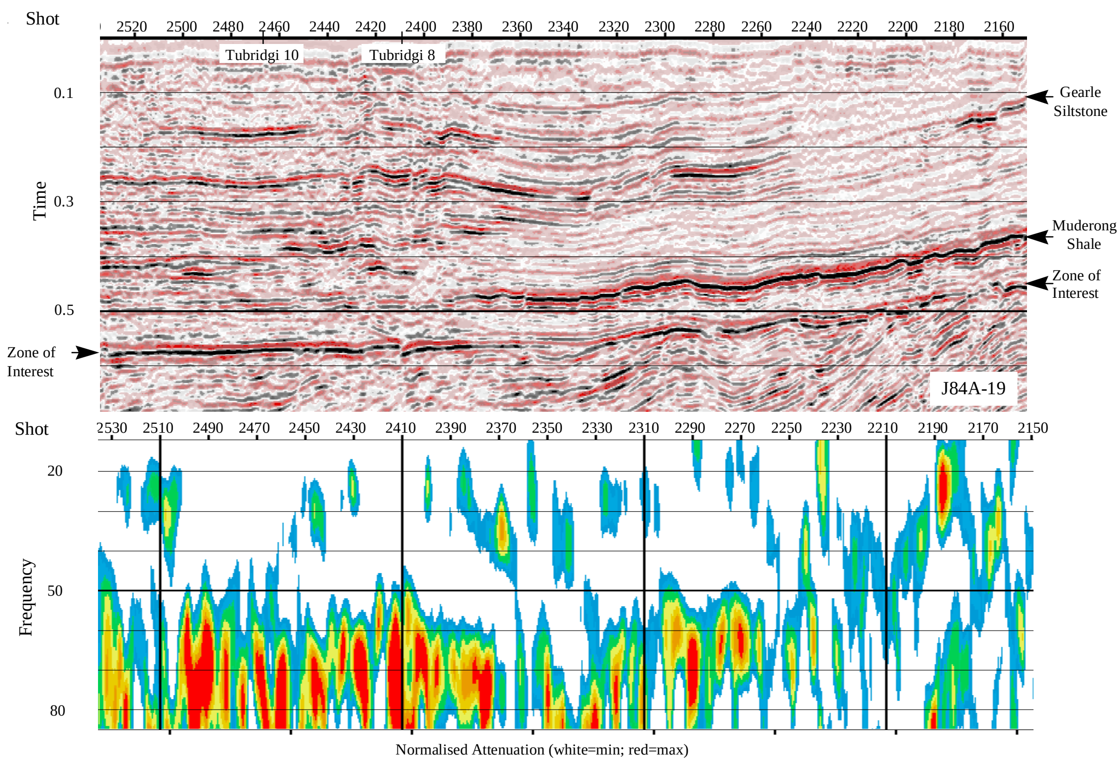

Figure 6 Normalised Attenuation Spectra

Normalised Attenuation Spectra

The normalised attenuation spectra were then determined using the estimated wavelet spectra from the window above and the window below the zone of interest. The normalised attenuation display is shown below the seismic panel in Figure 6. The normalised attenuation spectra show the attenuation plotted using a dB scale with white representing minimum and red representing maximum attenuation. In this example the normalised attenuation spectra shows that there has been a loss of seismic frequencies (50-80 Hz.) from the window of analysis beneath the Tubridgi gas field compared to the window of analysis above the reservoir. The line shown demonstrates the tie with two of the gas wells in the field. With this information an explorationist may conclude that other wells in the area with similar spectral signatures would also contain hydrocarbons. However, when interpreting relationships between any seismic attributes and reservoir properties, caution should be exercised when forming conclusions about the presence and strength of these apparent relationships. Since all geophysical attributes and their interpretation contain elements of non-uniqueness, the explorationist must make allowances for these problems in the assessment and management of risk. Moreover, the explorationist must decide whether the apparent relationship observed at just two wells, in this case, the measured spectral attenuation from the seismic and the presence of commercial hydrocarbons encountered in the wells, is statistically adequate to be useful as a discriminating attribute in development of the asset. Obviously, with additional well calibration points further confirmation and validation of the spectral technique becomes easier (Figure 7).

The composite display of Figure 7 shows the estimated wavelet and normalised attenuation spectra from forty traces centred on the sixteen wells templated in the study. The seismic data analysed was from two different seismic vintages without any match filtering. Note that the majority of gas wells have attenuation anomalies which show predominantly attenuation of seismic frequencies between 50 to 80 Hz. while the dry wells demonstrate for the most part different spectral signature. In this case study, the use of additional wells as calibration points has confirmed and helped to refine our initial observation that there is measurable attenuation of seismic frequencies below the Tubridgi Hydrocarbon accumulation. While the use of so many calibration points was not essential to demonstrate the potential of the spectral attributes as a direct hydrocarbon indicator, the additional wells certainly helped to establish some of the data and attribute limitations. Moreover, with the additional calibration points, the explorationist can better establish the resolution and accuracy of the spectral attributes in predicting the outcome of future wells in the area.

Summary and Conclusions:

The presence of gas in the Cretaceous and Mungaroo Sandstone reservoirs at the Tubridgi field appears to have caused measurable attenuation of higher seismic frequencies. Since the attenuation measurement was made from geophysical archived stacked seismic data and the analysis is independent of phase, this type of spectral analysis may provide a rapid means of extracting useful seismic attributes. Validation of the spectral signatures with well control helps the explorationist to determine the reliability of the spectral content in the processed seismic data and the suitability of the spectral method applied. The integration of these spectral attributes into

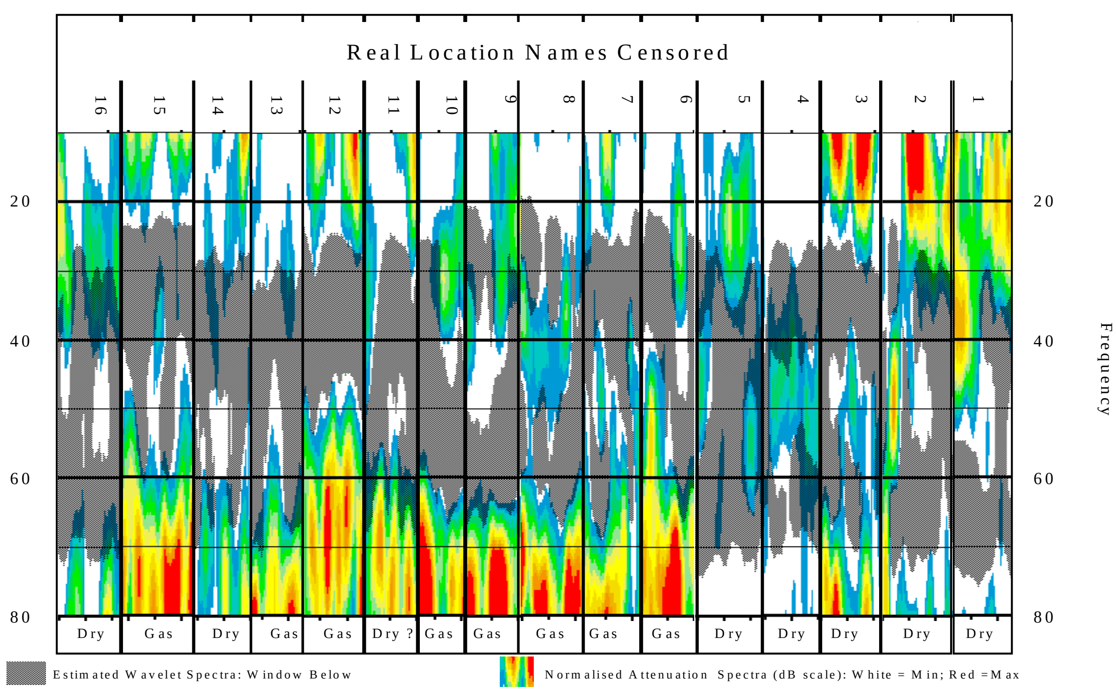

Figure 7 Composite of Wavelet and Normalised Attenuation Spectra showing ties with sixteen wells from the Tubridgi field area

current corporate workflows may make a significant contribution in exploration, appraisal and exploitation of new and existing hydrocarbon reserves.

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