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Seismic Window

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Wavelets, sandy beds and spectral decomposition

In the exploration business there are times when a well discovers hydrocarbons but the reservoir quality is poor. As a result the initial euphoria in the office turns to a more sombre mood as press releases are rewritten and resource estimates revised. So is it possible to predict good quality blocky sands with sharp contacts from ratty, fining upwards beds and avoid the potential let down?

We could put together a sequence stratigraphy story to predict where to expect good quality sands or we could process the data some more and produce a veritable array of different inversion products, but this takes time and money, which is quite scarce these days. Can we use the regular seismic data to help? It is easy to model the seismic signature of different depositional patterns and to identify the response associated with the preferred geology. Figure 1 shows some simple models and seismic responses for a blocky bed with sharp contacts above and below, a fining upwards bed with a sharp base and a coarsening up bed. All the modelled beds are 20 m thick. As can be seen, all the models have a distinctive seismic response which should be easy to discern (Table 1). Of course we have to deal with noise including interference from surrounding reflectors but still it should be possible for a good interpreter.

One trick is to apply a –90 degree phase rotation to the seismic data. This is often used as a quick approximation of an inversion and the troughs between zero crossings now mimic the depositional motif as seen in Figure 2. Of course, not being a true inversion, the side lobes of the wavelet remain and distort the picture somewhat but the essentials are there. That's all fine, but is real data as neat as the models? The real data examples show some wiggles over the more common colour display with a gamma log overlay at a well location. Figure 3 shows a thin blocky sand with some minor fining up in the well. To the right the seismic waveform is symmetric suggesting a clean blocky sand while to the left the waveform becomes asymmetric as the trailing peak strengthens. One possible interpretation is that the reservoir to the left has coarsened at the base. Figure 4 shows a blocky bed with the gamma log suggesting shale content is increasing downwards. To the left the pattern is similar to the trace at the well intersection but to the right it appears the basal contact becomes more gradational resulting in weak trailing reflection.

Spectral decomposition is another tool that is available on workstations and may be some help in determining the reservoir quality. Put simply, a sharp boundary can be considered to have a broad frequency content while a gradational contact is relatively low frequency so, if we display the frequency spectrum at each boundary, it should be possible to identify the type of boundary present (Figure 5). The high amplitude sharp contacts do indeed have a broad frequency content peaking at

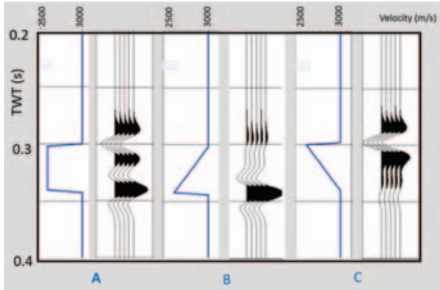

Figure 1. *Models and synthetic seismogram signature of: A – blocky bed, B – fining up bed and C – coarsening up bed. Each bed is 20 m thick and a 30 Hz Ricker wavelet was used. This wavelet has relatively strong sidelobes.*

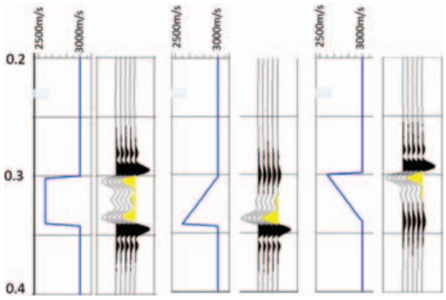

Figure 2. *Models with –90 degree phase rotation applied to wavelet that results in an approximation to inversion. An Ormsby filter was used to minimise sidelobes.*

about 35 Hz, while the gradational contacts are represented by a weak, low frequency anomaly. Expanding on this, we could create an attribute that measures the amplitude difference between high and low frequency components, say the 20 Hz and 40 Hz components (Table 2). A map of this attribute calculated along a seismic reflection could delineate areas of

Table 1. Characteristics of seismic waveform associated with various models

Model	Top	Bottom	Waveform
A. Blocky	Sharp	Sharp	Symmetric
B. Fining up	Gradational	Sharp	Asymmetric – trailing peak
C. Coarsening up	Sharp	Gradational	Asymmetric – leading peak

Table 2. Example calculation for attribute to discriminate sharp from gradational contacts. Method 1 uses spectral decomposition. Method 2 uses high and low cut filters on data

	Method 1 – Spectral decomposition			Method 2 – Band pass filtering		
	20 Hz Amplitude	40 Hz Amplitude	Difference Amp(20) – Amp(40)	Low pass 30 Hz Amp	High pass 30 Hz Amp	Difference Low-High
Sharp	0.7	0.9	–0.2	–370	–520	+150
Gradational	0.3	0	+0.3	–66	–31	–35

sharp or gradational boundaries. (A similar attribute can be created by applying a low pass and high pass filter to the seismic data and measuring the difference in amplitude of a reflector).*

Finally, a word on wavelets. The modelled synthetic seismograms in Figure 1 were calculated using a 30 Hz Ricker wavelet which is a fairly standard wavelet used by most interpreters even though it is not well understood by them. In fact most would have trouble describing the frequency content of a Ricker wavelet. Other wavelets can and should be used and some are shown in Figure 6. The Ricker, Butterworth and Klauder wavelets yield similar results. Also shown is a selection of Ormsby wavelets, which tend to have smaller side lobes, and a minimum phase wavelet that is just ugly. Interestingly, at the recent February ASEG meeting in Perth the speaker suggested the frequency content of a recent broadband processed survey contained useful frequency content as low as 2 Hz and as high as 160 Hz (like the high frequency Ormsby wavelet second from the right) which requires processing at a 2 ms sample rate to avoid aliasing. Notice how this wavelet produces a waveform that is getting close to the reflection coefficient display – which was the ultimate goal when I started working in the seismic industry.

*If you try this let me know how it went.

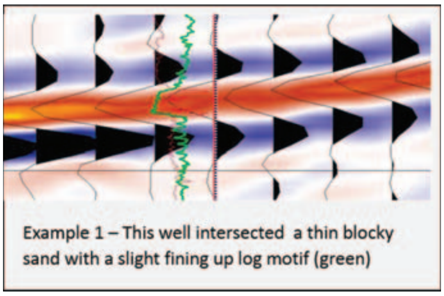

Figure 3. *Real data example with interpreted blocky bed to the right and more gradational top to the left. Good choice for the well location!*

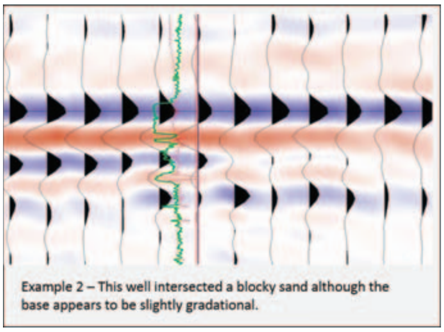

Figure 4. *Another example with the well between a blocky bed to the left with the base becoming more shaley to the right. Another good choice of location!!*

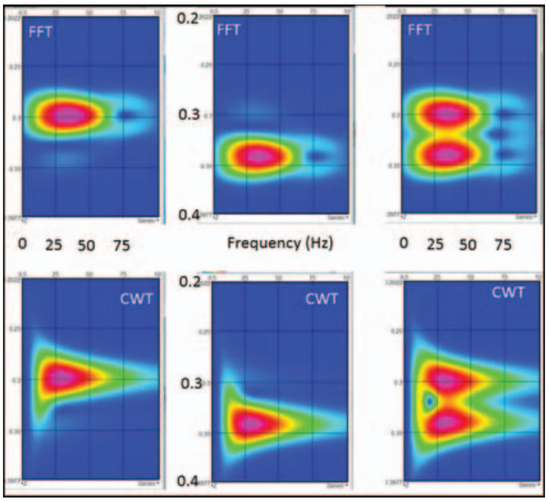

Figure 5. *Spectral decomposition display of the 3 models of Figure 1. Top is FFT version while bottom uses CWT. Horizontal axis is frequency, vertical axis is TWT. Contact attribute Amp (20 Hz) – Amp (40 Hz) = 0.8 – 0.9 = –0.1 at sharp contact and 0.3 – 0 = +0.3 at gradational contact.*

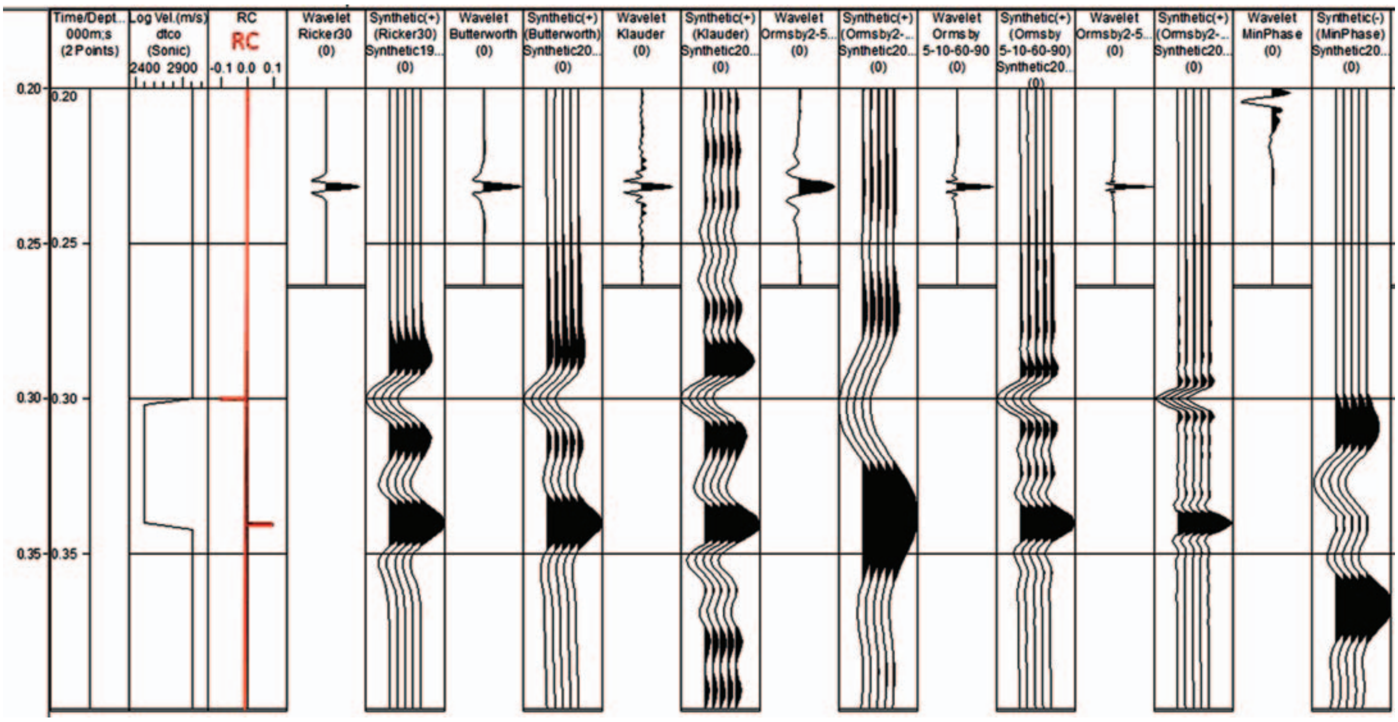

Figure 6. *A comparison of different wavelets and the resulting seismic signature of the blocky model. Left to right: 30 Hz Ricker, 10–60 Hz Butterworth, 5–60 Hz Klauder, Ormsby a) 2-5-20-30, b) 5-10-60-90, c) 2-5-100-160 and a minimum phase wavelet.*