Interpretational Aspects of Internal Multiples from Australia to West Texas

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Abstract

One-D synthetics with all internal multiples generate subtle and major interference patterns with pay-zone reflections beneath layers of large impedance contrasts. Different sampling rates and frequency bands on the synthetics assist in the evaluation of the effects of multiple properties from these high-contrast zones. The influence on pay zones from a single large impedance contrast is best documented by a stratigraphic profile built from local well logs. Subtle interference patterns from multiples on the pay-zone reflection are evaluated by comparing stratigraphic synthetics with and without multiples.

Motivation

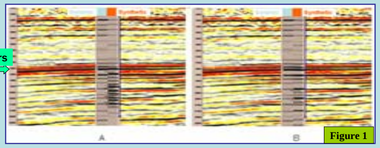

Figure 1

In the middle of Figure 1A, the traces on the left are from the seismic field data, while the traces on the right are conventional synthetic seismograms. Below the strong coal bed reflections, the synthetic does not adequately tie the seismic data. Figure 1A is repeated in 1B with the exception that all internal multiples are included in the synthetic. Now we have an excellent well tie. In order to understand the influence that the coal beds have on the seismic, the following study was developed.

Wave Propagation in Layered Media

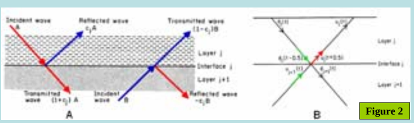

Figure 2

Following Robinson, Figure 2A illustrates vertical raypaths displaced horizontally in time to illustrate multiple reflections. Horizontal axis represents time arrival. The downgoing waveform reflects from interface *j* with amplitude of c_jA, and transmits through interface *j* with amplitude of $(1+c_j)A$. The reflection coefficient of interface *j* is c_j when wave is going down. Correspondingly, when the upgoing wave with amplitude B hits interface *j*, the reflected wave has amplitude of $-c_jB$, and the transmitted wave has amplitude of $(1-c_j)B$. We assume that there is no absorption in the media. As shown in figure 2B, the traveling waveform will be the same waveform delayed or advanced certain time. Therefore, the downgoing waveform $d_{j+l}(t)$ is,

$$d_{j+1}(t) = (1+c_j)d_j(t-0.5) - c_ju_{j+1}(t)$$

and upgoing waveform $u_j(t+0.5)$ is

$$u_j(t+0.5) = c_jd_j(t-0.5) + (1-c_j)u_{j+1}(t)$$

If the downgoing waveform $d_0(t)$ in half-space 0 is imposed on a layered system, and there is no upgoing wave from u_{j+1} in half-s pace of $k+1$,

$$\begin{bmatrix} D_{k+1}(z) \\ 0 \end{bmatrix} = \frac{z^{-k/2}}{(1-c_k)\cdots(1-c_2)(1-c_1)(1-c_0)} N_k \cdots N_2N_1N_0 \begin{bmatrix} D_0(z) \\ U_0(z) \end{bmatrix}$$

Where, $N_0 = \begin{bmatrix} 1 & -c_0 \\ -c_0 & 1 \end{bmatrix}$, $N_j = \begin{bmatrix} z & -c_j \\ -c_jz & 1 \end{bmatrix}$

1D Model

Figure 3 illustrates the density and sonic log curves for a 1D model. In this study, 4 1D models were used. They represent changes in the coal-bed properties and the number of layers.

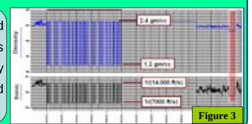

Figure 3

1D Modeling Results

1. Sampling rate effect

In this study, a Ricker wavelet and sampling rates of 1ms, 2ms and 4ms are used. Figure 4 contains synthetics generated with different sampling rates and with and without internal multiples. Figure 4A is sampled at 4ms, while Figure 4B at 1ms. The sonic and density curves in Figure 4B have the same shape as the original depth curves. Figure 4C illustrates the 1D-synthetics at different sampling rates. At the bottom is the 1D-synthetic without multiples. The length of the time delay due to the multiples increases from 4ms to 1ms sampling rates, but if the sampling rate increases to 0.5ms or 0.25ms, the delay time will essentially be the same as 1ms. That constant delay time occurs because the sampling rate adequately defines the extremes of the impedance contrasts in the sonic and density logs. The synthetics generated without multiples are essentially the same for 1ms or 4 ms sampling.

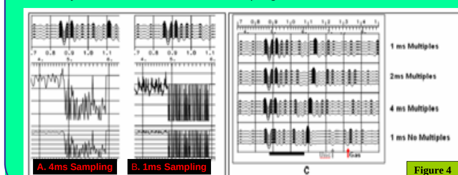

Figure 4

2. Frequency effect

I generated 1D-synthetic seismographs using different wavelets for 1ms sampling. The results are shown in Figure 5. On the 5-8-35-45 Hz synthetics with and without internal multiples, we can recognize the unconformity and gas zone beneath the coals beds. However on the 5-8-55-60Hz and 5-8-70-90Hz synthetics with all internal multiples, it is difficult to detect the unconformity or gas zone. In essence, all internal multiples have a preferred frequency band. This shows that as frequency increases, the vertical resolution increase, but the identification ability decreases.

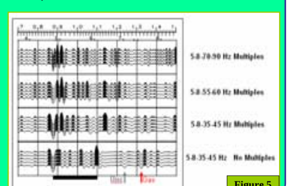

Figure 5

3. Lithology and the number of layers effect

Suppose we already have the knowledge of seismic responses from lignite coal layers. How can we apply this experience to a different area where the properties and number of coal layers change? Figure 6 illustrates the seismic synthetics which demonstrated this consideration. As shown in figure 6A, the upper two 1D-synthetics are from 30 layers lignite (velocity 7000ft/sec and density 1.2 gm/cc) model. The lower two 1D-synthetics are from 30 layers bituminous (velocity 14000ft/sec and density 1.48 gm/cc) model. As the background formation has velocity 14000ft/sec and density 2.4 gm/cc, the transmission loss at the interface between lignite and background is almost twice that between bituminous and the background. The length of delay time from the lignite model is two times larger than the bituminous model. Figure 6B repeats figure 6A except that the upper two 1D-synthetics are generated from the 15 layer lignite model. The delay time from the lignite model in Figure 6B is nearly the same as the bituminous model. These two examples indicate that the delay time occurs with the changes in both lithology and the number of layers.

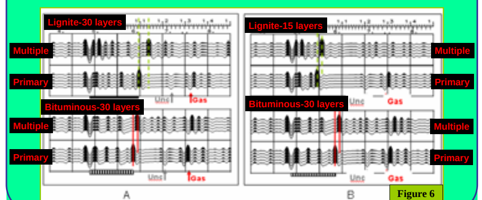

Figure 6

2D Stratigraphic Profile

In Figure 7A, two well-log curves from the Central Basin Platform are shown. The wells have a large velocity contrast due to the low-velocity Woodford shale. Beneath the shale is the 31-Formation which is the gas pay interval in this area. A 2D geologic model (Figure 7B) was built based on these two wells. Two gas-charged reservoirs are shown beneath the low velocity shale with a gap between them.

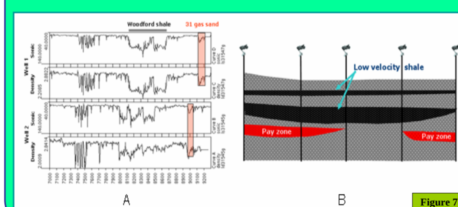

Figure 7

2D Stratigraphic Synthetic

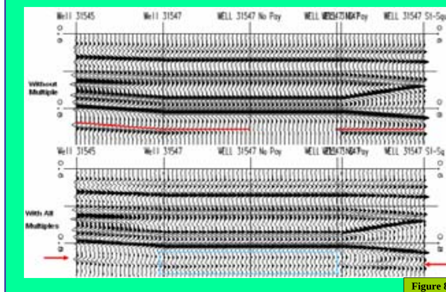

Figure 8

Figure 8 contains two stratigraphic synthetics. The upper synthetic was generated with primaries only. The reflection events from the low velocity shale are very clear. The left gas reservoir reflection event disappears with the sand tapering out, and the right gas reservoir reflection shows up with the sand presence. In the lower synthetic, multiples are included. The gas reservoir reflections are interfered by multiples. The two gas sand reflections become connected. If we interpret the lower synthetic, we expect a continuous sand reservoir from left to right, an erroneous interpretation.

Conclusions

- When numerous large impedance contrasts are present, events beneath the abnormal impedance layers will have a time delay due to the influence of all internal multiples;
- When the impedance contrast and number of the layers change, the delay time will change also;
- When the wavelet's frequency increases, the ability to differentiate lower events decreases because internal multiples create a preferred pass band; and,
- For subtle (small amplitude) stratigraphic targets, the events beneath a high-contrast impedance layer can make the interpretation more difficult and suspect.

Reference

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Acknowledgements

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