The effects of reservoir thickness, fluid and Q to seismic amplitudes

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Summary

The effects of the reservoir thickness, fluid and Q to seismic amplitudes are important to seismic interpretation, rock property inversion and reservoir characterization. This abstract studied these effects by using wedge models. The changes of fluids affect the tuning amplitude curves as well the horizon times of the tops and bases. The change of Q affects the amplitude of the base reflector – this implies that rock property inversion would be in error without incorporating the Q. The spectra of the synthetic data are mostly affected by the velocity changes of the sandstones.

Introduction

It has been known for long that predicting reservoir thickness is one of the challenges in reservoir exploration. (Widess, 1970). Thickness of hydrocarbon reservoirs is often significantly less than a half wavelength of dominant frequency. Without knowing reservoir thickness we cannot decompose thin bed interference out from primary reflected amplitude. Any attempt to link seismic attributes (amplitude, frequencies and AVO) to reservoir rock and fluid properties (DHI) can be jeopardized easily by the thin bed interference. We apply a wedge model with realistic reservoir properties to search how reflected amplitude is affected by thin beds and different fluid saturations.

Models

Table 1 shows a three-layer model (two shales and one gas sand in the middle) estimated from well logs. We manually blocked the well logs into a few layers. The velocities and densities are the averages of each blocked layers. We then replaced the gas in the sandstone by three fluids and make three additional sandstones with new properties as shown in **Table 2**: a) brine; b) low-saturated gas under normal shallow water environment, called 'shallow_fizz' and c) low-saturated gas under deep water environment, called 'deep_fizz'. The Q values are taken from Taner and Treitel's paper (2003) with some modifications.

	Density g/cc	Vp km/s	Vs km/s	Q	Vp/Vs
Shale	2.2500	2.3980	1.0916	60	2.1967
Sand	1.9580	1.7009	1.1848	22	1.4356
Shale	2.2137	2.2856	1.0203	70	2.2403

Table 1: Model parameters used to build wedge models. The velocities and densities were estimated from the corresponding well logs. Q information were based on Taner and Treitel (2003).

	Density	Vp	Vs	Q	Vp/Vs
Wet_sand	2.0860	2.3500	1.1965	31	1.9641
Shallow_fizz	2.0705	1.7379	1.2010	11	1.4471
Deep_fizz	2.0752	2.1236	1.1996	18	1.7702

Table 2: Properties of the sandstone in Table 1 after three fluid substitutions. The four sandstones in these two tables and the upper and lower shales are combined to make the four wedge models used to generate the synthetics in Figure 1.

Four wedge models were built based on the rock properties in Table 1 and 2 with different sandstones. The wedge thickness varies from 0 to 60 meters. The dominant frequency of the wavelet at the first interface is about 20hz. The 1/8 wavelength thin-beds defined by Widess (1970) are about 10.6, 10.9, 13.3, 14.7 meters for gas, shallow_fizz, deep_fizz, and wet sandstones respectively.

Synthetics

Figure 1 shows the zero-offset synthetic seismic data and the attributes of snapped horizons for the four wedge models. The method to generate the synthetics is based on Aki and Richards (2nd edition, 2002). Note that the reverse polarity was used in the models, so that a negative reflection coefficient corresponds to positive seismic amplitude. Following are some analyses..

Fluid effect

Changing reservoir fluids clearly affects the magnitude of seismic amplitudes. We can also see some changes on the tuning amplitude curves in Figure 1 and these changes are compared in Figure 4.

Horizon times

Picked horizon times are off their real traveltimes to the two interfaces due to the wavelet interference. The absorption to the seismic wavelets also affects the traveltimes but it is small in this experience. These differences are shown in **Figures 2 and 3** for the upper and lower interfaces respectively. They show as a push-down and pull-up on the horizons. The travetimes are about 5ms faster for the thin layers and about 2ms slower at about 22m thickness.

Amplitude versus reservoir thickness and Q

Figure 4 shows seismic amplitude at the snapped top and base horizons, shown in Figure 1. In order to understand the effect of Q, we compared synthetics for the same wedge model but with Q=60 for the sandstone in all four cases. The picked amplitude are shown in red dotted lines. In comparison with realistic Q values for different fluid saturation as shown in Table 1 and 2, the Q causes significant variation of amplitude on base reflectors. This implies that the Q should be considered for fluid prediction.

Interpretation of sand thickness

Figure 5 shows that simply snapping minima and maxima do not yield the correct thickness of the sandstone bed. Apparent thickness is consistent with model for wavelength longer than quarter wavelength, but significantly overestimates as model thickness decreases less than quarter wavelength (**Figure 5**). The curves show that the same time interval can be interpreted as two different thicknesses, one greater and one smaller than the 1/8 wavelengths. This non-uniqueness can be solved by comparing the differences in the waveforms, horizon time push-down and pull-up (see previous sections), and time-frequency information (Discussed in the next section).

Time-frequency analysis

The Fourier spectra show clear changes when thickness varies, as shown in **Figure 6.** With or without the realistic Q in case do not have clear effect on the spectral changes as indicated by **Figures 7 and 8**. This information can be used to estimate thin bed thickness and its rock properties. However, for field data, the Fourier transform is not suitable for the localized events. The localized transforms such as wavelet transform can be used to reveal some of the information (Li and Ulrych, 1996). The spectral decomposition has shown some successful applications in helping reservoir characterization (Castagna et al, 2003). We are currently working on modeling studies to improve the understanding of the spectra changes in the time and frequency domain.

Conclusions

We have shown effects of the thickness, fluids and Q to seismic amplitudes through wedge modeling. The changes of fluids affect the tuning amplitude curves as well the horizon times of the tops and bases. The change of Q affects the amplitude of the base reflector – this implies that rock property inversion would be in error without incorporating the Q during the forward modeling. The spectra of the synthetic data are most affected by the velocity changes of the sandstones.

Acknowledgments

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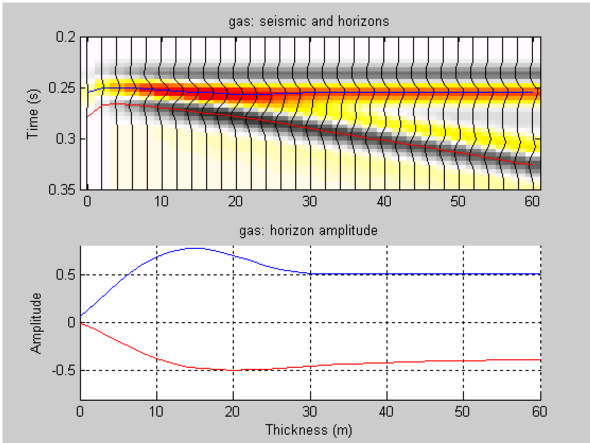
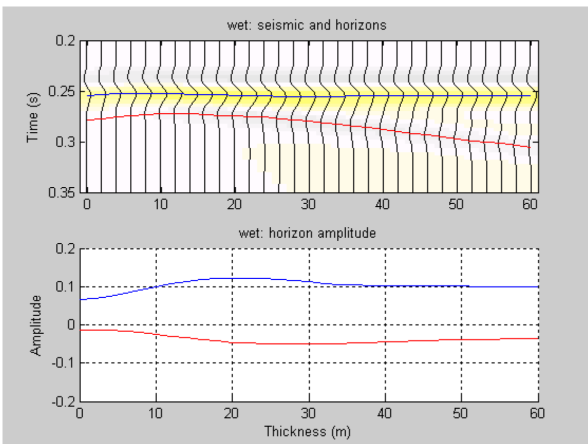


(a)



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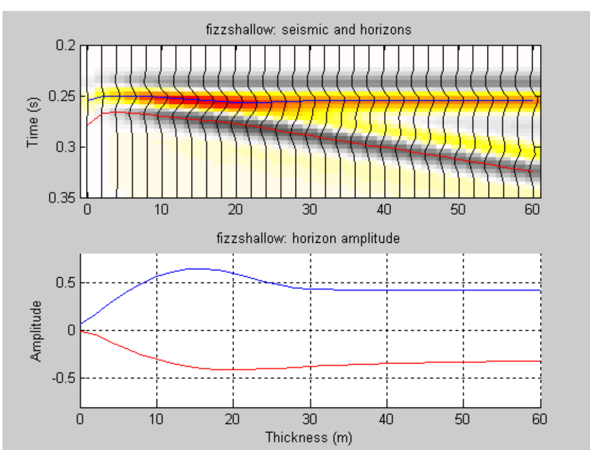

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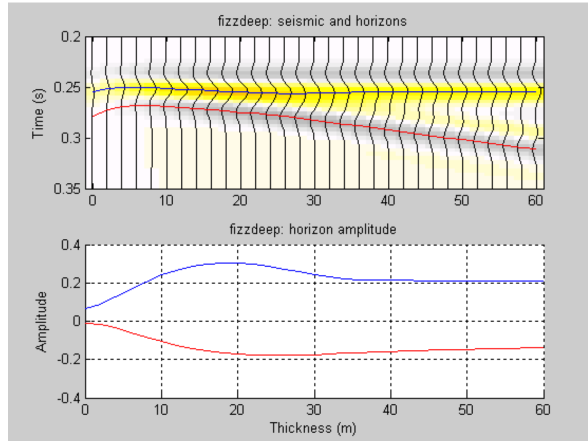

(d)

Figure 1: Synthetic seismic sections horizon information for the wedge models in Tables 1 and 2. (a) Gas case: Upper - seismic and auto picked horizons of top and base of the sandstone; Bottom - seismic amplitudes. (b) Wet sandstones; (c) for sandstones with fizz water under normal (shallower) water case; (d) for sandstones with fizz water under deep water condition. The seismic images are displayed at the same energy level. Picked horizons are snaped into the maxima and minima.

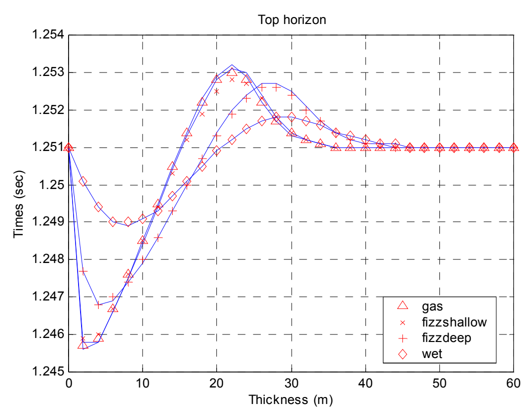

Figure 2. Picked top horizon times for the four wedge models. The blue lines are with Q=60 for all models and discrete points are from the models in Tables 1 and 2.

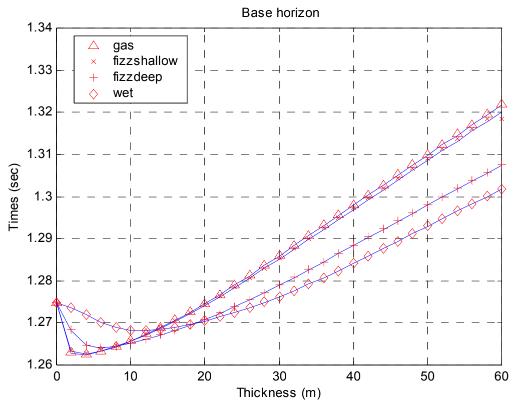

Figure 3. Same as in Figure 2 but for base horizon times.

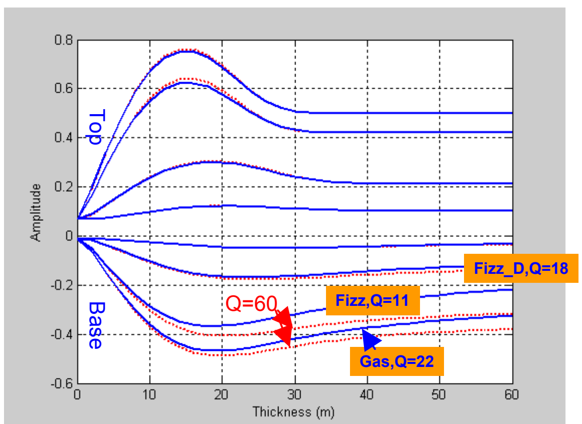

Figure 4. The amplitudes picked at the tops and bases for the four wedges. Red dotted lines are with Q=60 for all models and blues are for the models in Tables 1 and 2.

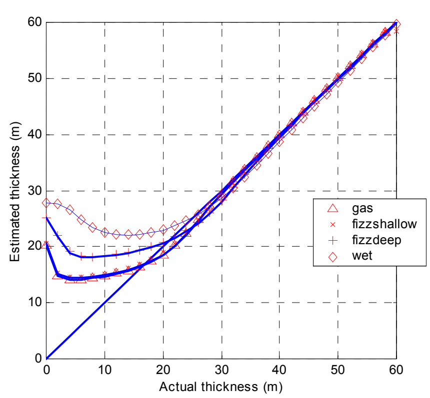

Figure 5. Estimated reservoir thickness change with wedge thickness for the four wedge models. The symbols are for the models in Tables 1 and 2 and blue lines are with Q=60 for all models.

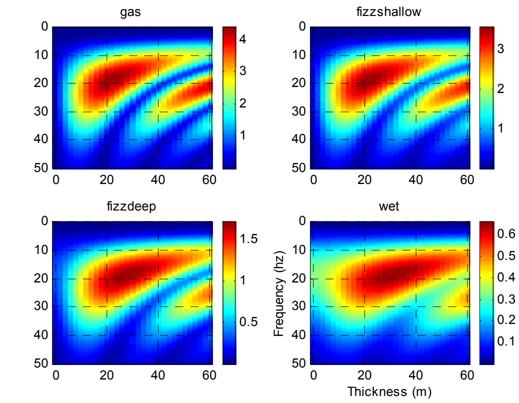

Figure 6. The Fourier spectra of the seismic data. Shifting of the peaks is obvious due to the fluid changes. Note the change of the energy level is indicated by the color bar on the left of each image. The combined frequencies of the two interfaces are clearly changing with the thickness.

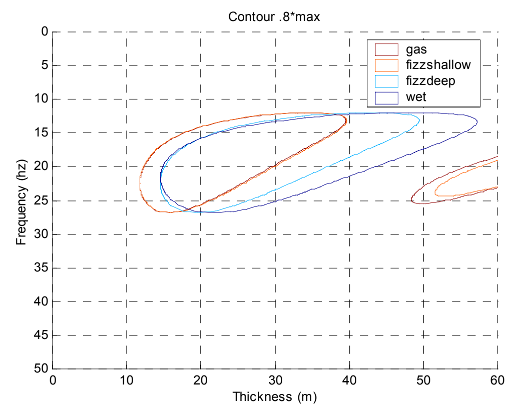

Figure 7. Contours at 60% of the peak amplitudes in Figure 6. The gas and fizz water in this case are almost identical but both have a clear shifts from the rest of the two fluids.

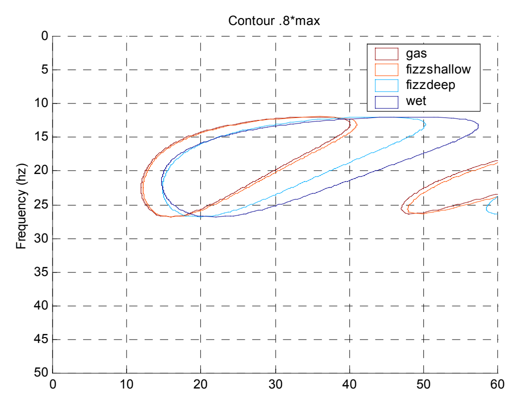

Figure 8. Same as in Figure 7 but with Q=60 for the sandstones in all four wedges.