Thin beds, tuning, and AVO

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This is the sixth installment of this bimonthly column. Fittingly, it's an excellent one. I'm thrilled that we've been able to maintain our goal of 100% open data, open code, and fully reproducible figures. With the open-access license that SEG applies to the column itself, I hope all students of geophysics (as far as I'm concerned, that's all of us!) are enjoying the experience of being able to follow along and share the contents of the tutorials freely with classmates and colleagues. Thank you for reading! If you have suggestions for future topics or would like to contribute one yourself, please drop me a line: matt@agilegeoscience.com. I'd love to hear from you.

In this tutorial, we will explore two topics that are particularly relevant to quantitative seismic interpretation — thin-bed tuning and AVO analysis. Specifically, we will examine the impact of thin beds on prestack seismic amplitudes and subsequent effects on AVO attribute values.

The code used to generate results and figures presented in this tutorial can be found in two Python scripts at *http://github.com/seg*. Each script is self-contained and allows the user to investigate the impact of layer and wavelet properties on poststack and prestack seismic amplitudes.

Tuning refers to the modulation of seismic amplitudes because of constructive and destructive interference from overlapping seismic reflections. This phenomenon commonly occurs when a downgoing wave is reflected from multiple closely spaced interfaces. If the resultant upgoing reflections overlap, the reflected seismic energy will interfere and alter the amplitude response of the true geology.

Let's examine this phenomenon using a zero-offset synthetic wedge model created using the script *tuning_wedge.py* (Figure 1). This model is generated using a 30-Hz Ricker wavelet and varying the thickness of layer 2. For thicknesses greater than 40 m, we see that the amplitude response of the wedge is a constant value. This indicates that there are discrete reflections from the top and base of the wedge with no interference.

Below a thickness of 40 m, the effects of constructively interfering wavelet side lobes become apparent (i.e., amplitude increase resulting from tuning). Below a thickness of approximately 17 m, we start to see destructive interference from overlap of the central wavelet lobes. Interpreting the geologic meaning of these tuned seismic amplitudes is clearly more complex than the case of nonoverlapping seismic reflections.

The wedge model is a standard tool in the interpreter's ar-senal. It is used routinely to gain insight into the geologic meaning of seismic amplitudes below the tuning thickness of a particular reservoir. The same tuning phenomenon that impacts zero-offset seismic data also affects prestack seismic amplitudes and prestack analysis techniques such as AVO.

Let's reconsider our initial wedge model. Instead of examining only the zero-offset case, we now investigate a synthetic angle gather to assess the impact of thin-bed tuning on angle-dependent reflectivity.

Figure 2 is created using the script *tuning_prestack.py*. This figure shows a synthetic angle gather and associated amplitude-versus-angle-of-incidence curves corresponding to the 17-m-thick trace from our wedge model. Notice in this figure that there are two amplitude curves for the upper-interface reflectivity, one corresponding to the convolved amplitude and the other corresponding to the exact Zoeppritz P-to-P reflectivity. Explicitly, one is what we expect to record in the field (i.e., convolved amplitudes), and the other is what we theoretically anticipate for a given V_P, V_S, and density model (i.e., Zoeppritz reflectivities).

Quite clearly, there are differences in the reflectivities computed using Zoeppritz equations and the convolved synthetic. As previously discussed for the zero-offset case, a

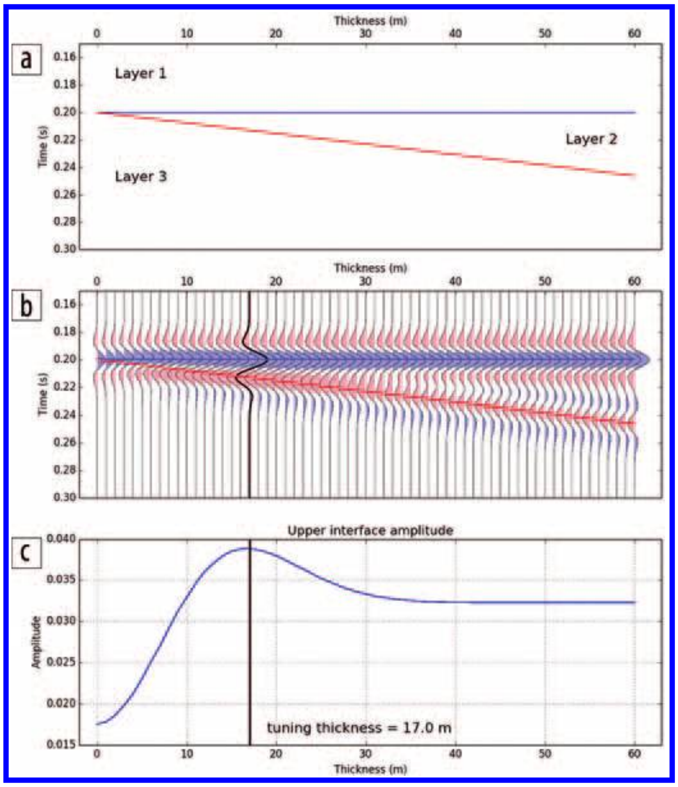

Figure 1. (a) A three-layer wedge model. (b) Zero-offset synthetic seismogram displayed in normal polarity. (c) Amplitude of the synthetic extracted along the top of layer 2.

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model 17 m thick will result in constructive interference along the upper interface. As expected, the convolved amplitudes are larger than the exact Zoeppritz reflectivities, but only for angles of incidence less than 27°. For angles of incidence larger than 27°, the convolved amplitudes become smaller than the exact Zoeppritz reflectivities (i.e., destructive interference). This indicates that tuning resulting from thin beds is also dependent on incidence angle.

Let us now consider the impact of thin-bed tuning on the AVO attributes, normal-incidence reflectivity (R_0), and gradient (G) calculated for the top of our wedge. We calculate R_0 and G attributes by fitting Shuey's equation,

$$R(\theta) = R_0 + G\sin^2\theta, \qquad (1)$$

to the amplitude values for the upper interface. Table 1 summarizes those attribute values.

For our 17-m-thick wedge, there is a significant difference between R_0 and G values computed from the convolved synthetic and exact Zoeppritz amplitudes. Because AVO is an amplitude-based analysis technique, tuning caused by thin beds will manifest similar errors when we invert for other AVO attributes.

In summary, thin-bed tuning affects poststack and prestack seismic amplitudes. Simple synthetic-model-ing tools such as those presented in this tutorial allow you to gauge the impact of thin-bed tuning on seismic-amplitude interpretation and analysis techniques. TLE

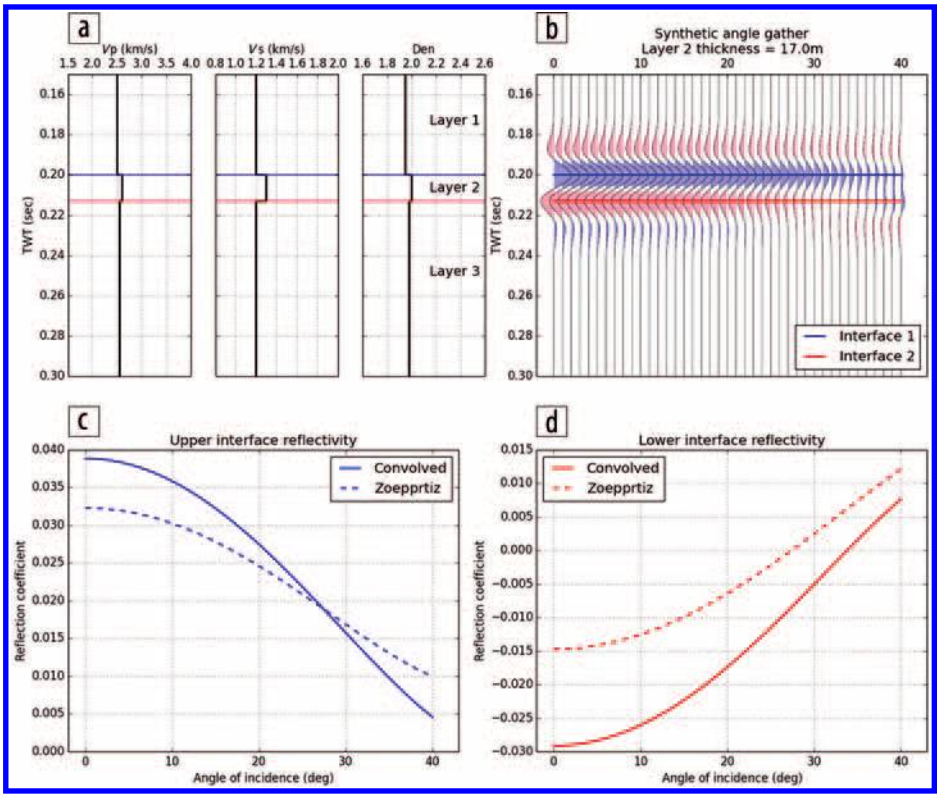

Figure 2. (a) Input properties for synthetic model. (b) Synthetic angle gather for the three-layer model, displayed in normal polarity. (c) Amplitude extracted along the upper interface. (d) Amplitude extracted along the lower interface.

Table 1. AVO inversion of convolved and exact Zoeppritz reflectivities from the wedge-model upper interface produce significant AVO attribute values.

Reflectivity curve	R_0	G
Zoeppritz	0.03168	−0.05671
Convolved	0.03797	−0.08555

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Suggested reading

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