Geophysical Tutorial: Thin Beds, Tuning, and AVO

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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 errors in AVO attribute values.

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

Tuning refers to the modulation of seismic amplitudes due to 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 phenomnon using a zero-offset synthetic wedge model created with the *tuning_wedge.py* script (Figure 1). This model was generated using a 30Hz Ricker wavelet and varying the thickness of Layer 2. For thicknesses greater than 40m, we see that the amplitude response of the wedge is a constant value indicating that there are discrete reflections from the top and base of the wedge with no interference.

Below a thickness of 40m, we start to see the effects of constructively interfering wavelet side lobes (i.e. amplitude increase due to tuning). Below approximately 18m thickness we start to see destructive interference from overlap of the central wavelet lobes. Interpreting the geological meaning of these tuned seismic amplitudes is clearly more complex than the case of non-overlapping seismic reflections.

The wedge model is a standard tool in the interpreter's arsenal. It is routinely used to gain insight to the geological 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 will investigate a synthetic angle gather to assess the impact of thin bed tuning on angle-dependent reflectivity.

Figure 2 was created with the *tuning_prestack.py* script. This figure shows a synthetic angle gather and associated amplitude versus angle of incidence curves corresponding to the 18m 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 another coresponding to the exact Zoeppritz P-to-P reflectivity. Explicitly, one is what we expect to record in the field (convolved) and one is what we theoretically anticipate for a given
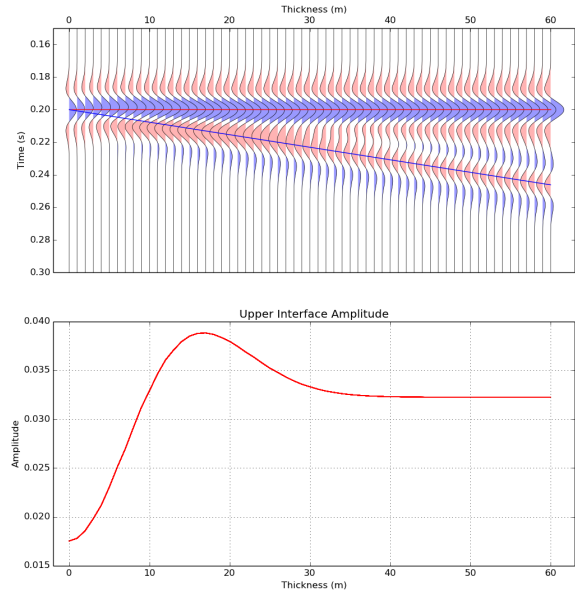

Figure 1: (top) Zero-offset synthetic seismogram for a 3-layer wedge model, displayed in normal polarity; (bottom) amplitude of wedge model extracted along top of layer 2

V_P, V_S, and density model (Zoeppritz).

Quite clearly there are differences in the reflectivities computed using Zoeppritz equations and the convolved synthetic. As previously discussed for the zero-offset case, an 18m thick model 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 (destructive interference). This indicates that tuning due to thin beds is also dependent on incidence angle.

Let's now consider the impact of thin bed tuning on the AVO attributes, normal incidence reflectivity (NI) and gradient (GRAD) calculated for the top of our wedge.

We calculate NI and GRAD attributes by fitting Shuey's equation,

$$R(\theta) = NI + GRAD \sin^2 \theta, \tag{1}$$

to the amplitude values for the upper interface. These attributes are summarized in Table 1.

For our 18m thick wedge there is a significant difference between NI and GRAD values computed from the convolved

synthetic and exact Zoeppritz amplitudes. As AVO is an amplitude based analysis technique, tuning due to thin beds will cause similar errors when inverting for other AVO attributes.

In summary, thin bed tuning affects both poststack and prestack seismic amplitudes. Simple synthetic modeling 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.

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

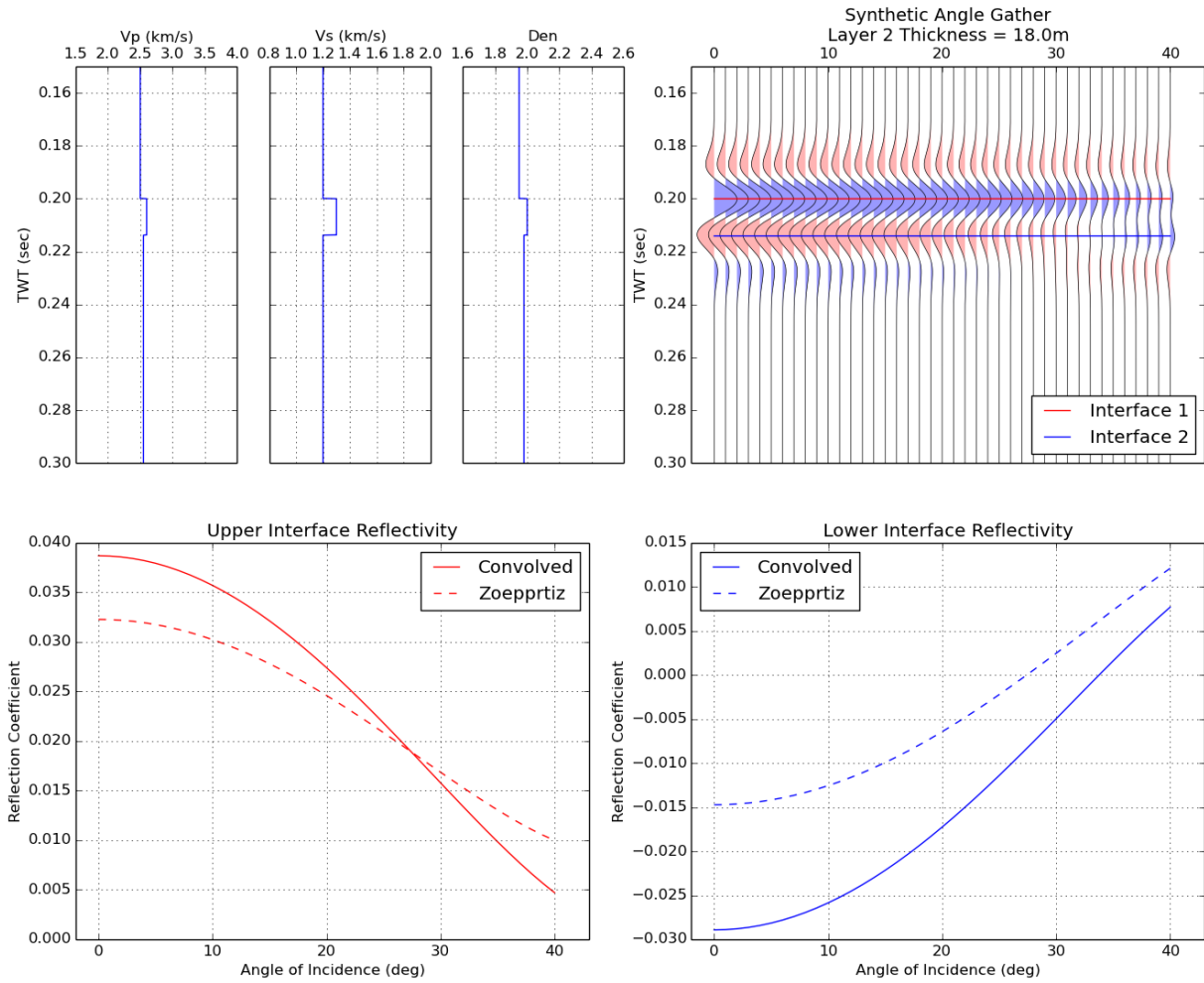| Reflectivity Curve	NI	GRAD
Zoeppritz	0.03168	-0.05671
Convolved	0.03797	-0.08555

Figure 2: (top left) Input properties for synthetic model; (top right) synthetic angle gather for the 3-layer model, displayed in normal polarity; (bottom left) reflectivity amplitudes extracted along upper interface; (bottom right) amplitude of wedge model extracted along lower interface.

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