What is a P-S zero-offset section?

Robert R. Stewart, Henry C. Bland, and Chuandong Xu

ABSTRACT

Converted-wave reflectivity is zero at normal incidence (zero offset), but has a sinusoidal-type dependence on offset. Conventional NMO and stacking correct the P-S events to zero-offset traveltime and then sum the offset-variant reflections. Thus, the P-S zero-offset section is an average of the P-S AVO response across the set of source-receiver offsets. Variable offsets in the stack, from location to location, may lead to amplitude variations in the sections. Thus, in survey design we should try to have not just smooth fold but a consistent offset distribution. Weighting the offset P-S data in attempt to produce a zero-offset, pure-shear value is another approach to try to smooth out offset variability. Synthetic and field examples from the Blackfoot 3C-3D survey indicate that there is significant variation in the P-S reflectivity with offset.

P-S REFLECTION ANALYSIS

The converted-wave reflection coefficient is zero at normal incidence to an elastic interface. Or, with flat layers, there is no conversion at zero offset. But, we make zero-offset or stacked sections routinely with P-S data. Thus the question arises, “What exactly is a zero-offset P-S section?” We can take a simple interface model and use the Zoeppritz equations to calculate the converted-wave reflectivity as a function of angle of incidence. Figure 1 shows an example for the case outlined in Table 1. We observe a sinusoidal type dependence of reflectivity with offset. If we only had certain angle or offset ranges, Figure 1 also indicates the average value across that offset range. The heavy dashed line shows the average value across the whole range.

	P- velocity (m/s)	**S- velocity (m/s)**	**Density (g/cc)**
Layer 1	3562	1837	2.512
Layer 2	3862	2011	2.528

Table 1. Elastic constants for a two-layer model.

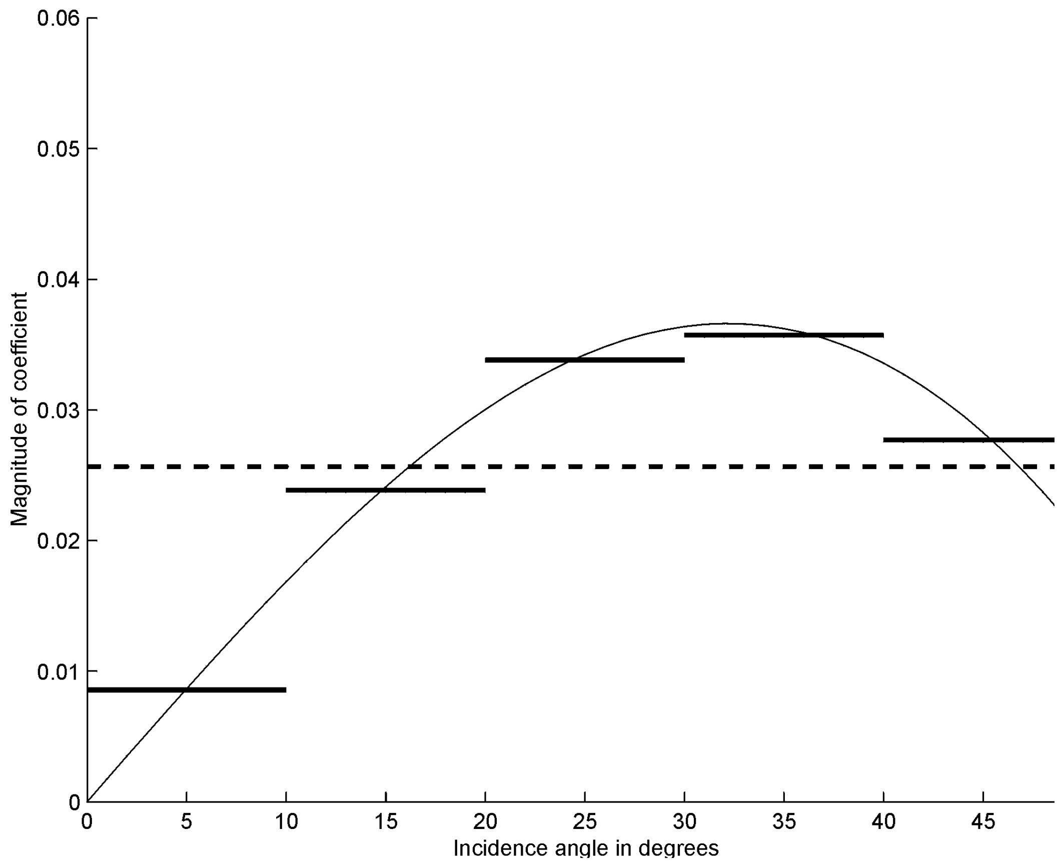

Figure 1. Converted-wave reflectivity versus incidence angle for the two-layer model in Table 1. Solid lines indicate the average value across the 10°-angle ranges. The broken line provides the average value across the whole 50° range.

The zero-offset section is just the NMO-corrected and stacked set of traces. That is, the average reflectivity (which is not zero) across the set of source-receiver offsets for each common conversion point. We note that this is no different than the result for conventional P-P data, where the zero-offset trace is also a stack of the reflectivity across the recording aperture at each common reflection point. However, the P-wave reflectivity is usually not zero at normal incidence and often only varies a small amount with moderate offsets.

Survey design considerations

Most 2-D and 3-D survey designs will attempt to have even fold across the target regions. This helps reduce the ultimate "footprint" or signature that the survey leaves on the final seismic image. Even if we have uniform fold though, we might have considerably different offsets contributing to it. In this case, the stacked amplitudes could also be quite different depending on the offsets involved. Thus, it would be useful to view the near, middle, and far offset folds and design to make them similar.

Blackfoot 3C-3D survey

The Blackfoot 3C-3D seismic survey was conducted in November, 1995 near Strathmore, Alberta. To investigate the offset-dependent variations, we use offset-limited migrated volumes from this survey. From these volumes, we have extracted a north-south line. The amplitudes of five offset-limited sections are shown in Figure 2. Each overlapping offset range is about 500m wide Generally, the near-offset amplitudes (x) are small, but the magnitudes increase with increasing offset until the far offsets (o). We do note, however, that due to other likely effects of offset (e.g., NMO stretch, attenuation, etc.), the offset variation is neither smooth nor even monotonic.

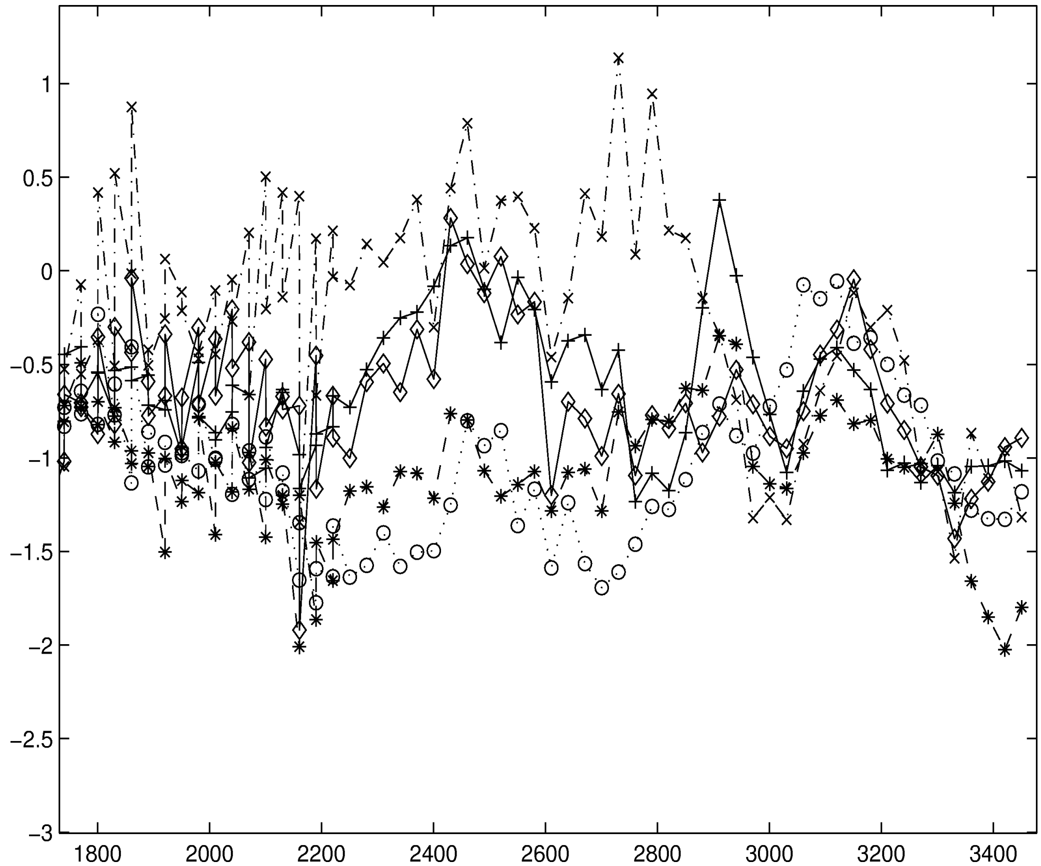

Figure 2. P-S amplitudes of five offset groups extracted from the Blackfoot 3C-3D survey. Near offsets (x), near-mid offsets (+), mid offsets (◊), mid-far offsets (*), and far offsets (o) generally grow from small to large.

HOW TO FIX VARIATIONS

If the offset distributions are similar for all bins, then there shouldn't be a direct AVO problem. However, if there is variation in the offsets involved then we might do best to weight the traces that go into the stack. This can be accomplished using weights as outlined in Stewart and Bland (1997). The weights defined there are from the relationship between the pure-shear reflectivity and converted-wave reflectivity:

$R^{ss}(0) \approx \frac{\alpha}{4\beta} \csc\theta \, R^{ps}(\theta)$, where α, β are the average P-velocity, S-velocity across the interface; θ is the angle of incidence. We would like to produce a zero-offset shear reflectivity because this will generally be non-zero and can be immediately inverted for S velocity using conventional P-wave techniques. Pre-stack migration is another approach to the problem if the correct amplitude weights have been used.

CONCLUSIONS

Converted-wave reflectivity varies sinusoidally with offset. The zero-offset stack is an average of the NMO-corrected reflectivity across the range of offsets in the stack. Thus it can vary, from location to location, if it is composed of dissimilar offset ranges. In designing a P-S survey, it is prudent to have consistent offset ranges as well as even fold. An example from the Blackfoot 3C-3D survey indicates that there is significant and somewhat predictable variation in reflectivity with offset in various offset-limited sections.

REFERENCES

Aki, K. and Richards, P.G., 1980, Quantitative seismology: Theory and methods: W. H. Freeman and Co., v.1.

Stewart, R.R. and Bland, H., 1997, An approximate relationship between R^{ps} and R^{ss}: CREWES Research Report, ch. 12, v. 9.