Bandlimited Survey Design and CCP Stacking of P-S Data

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The fact that P-S rays generally do not reflect at the source-receiver midpoint for flat-lying reflectors in v(z) media is perhaps the most basic difference to take into account in the design and processing of P-S data compared to P-P data. However, the asymmetry of the P-S raypath can sometimes appear to cause more problems than it actually does. For example, subsurface fold calculations for CCP stacking of P-S data can appear to be very sensitive to Vp/Vs and CCP bin size in situations where P-P data yield fairly uniform subsurface fold. Figure 1 shows the CDP and asymptotic CCP fold (Vp/Vs = 2.0 and 2.1) at the center of an orthogonal 3D, 4C OBS survey with source and receiver intervals of 50 m, source line spacing of 100 m, and receiver line spacing of 300 m. Fold has been calculated in the usual fashion here, with nearest neighbor interpolation of reflection points to the center of the nearest 25 x 25 m CDP bin. The asymptotic CCP fold appears to be very sensitive to Vp/Vs: there are lines of zero fold for Vp/Vs = 2.0, but the fold is fairly uniform for Vp/Vs = 2.1. This result seems suspicious because the subsurface reflection points do not actually move very much when Vp/Vs is changed by such a small amount.

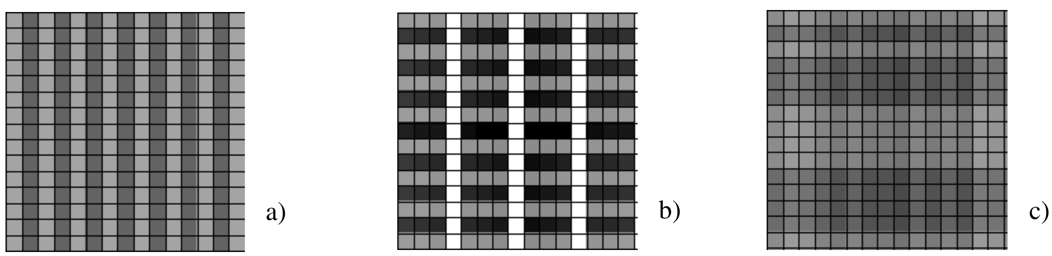

Figure 1. Nearest-neighbor fold maps (white = zero fold, black = 450 fold). a) CDP fold b) CCP fold, Vp/Vs = 2.0 c) CCP fold, Vp/Vs = 2.1

The apparent sensitivity of the asymptotic CCP fold to Vp/Vs in this example is more an indication of the inaccuracy of nearest-neighbor interpolation than of true changes in subsurface coverage. Nearest-neighbor interpolation assumes that each trace contributes to only one output bin, and therefore is essentially infinite in spatial bandwidth (like a delta function). True seismic wavefields are always bandlimited, and therefore do not behave this way. The NMO-corrected wavefield should be interpolated with a bandlimited delta function (i.e. a sinc function). Normally the CDP bin width determines the distance between the zero-crossings of the spatial sinc-function since this has been chosen as the Nyquist sample rate at the survey design stage. It is important not to misinterpret bandlimited interpolation as an arbitrary type of “mix” of the data across bins. Sinc-function interpolation makes the weakest reasonable physical assumption about the wavefield in order to interpolate between irregular sample points.

Figure 2 shows the same subsurface fold maps as in Figure 1, but now calculated with sinc-function interpolation. We not only see that the fold is more uniform than before, but that the asymptotic CCP fold is much less sensitive to Vp/Vs than crude nearest-neighbor interpolation would indicate. We therefore see that P-S survey design, as well as basic processing steps such as CCP stack, ideally should take the spatial bandlimits of the seismic wavefield into account in order to avoid false indications of fold sensitivity to Vp/Vs and to acquisition geometry.

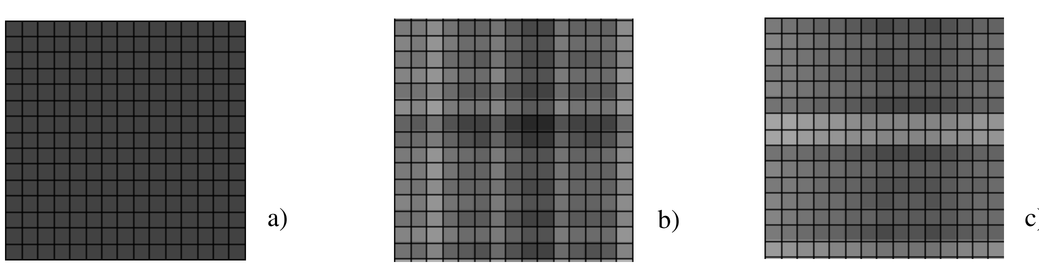

Figure 2. Bandlimited (sinc-function) fold maps a) CDP fold b) CCP fold, Vp/Vs = 2.0 c) CCP fold, Vp/Vs = 2.1