Case history: 3-D shear-wave processing and interpretation in radial-transverse (SV-SH) coordinates

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Summary

A 9-C 3-D seismic reflection data set from Clark County, Kansas is processed to produce SH and SV data volumes. Data processing is quite straightforward; rotation of the data from field coordinates to radial-transverse coordinates, static corrections (elevation, shot, and receiver) derived from the SH data, NMO correction with a single velocity function, inside-trace mute, and stack.

Super gathers monitor the convergence of the shear-wave statistics, which are found to be relatively small (+/- 40 ms), and simple to estimate from the dominantly 12 Hz SH data. Single velocity function NMO (velocities derived from SH) show the SV data to be slightly overcorrected, suggesting the presence of vertical transverse isotropy. An inside-trace mute eliminates the surface-wave noise cone. Dominant reflections in the stacked data are from the top and base of the Morrow clastic interval. Reflection signal quality is superior on the SH data.

Introduction

Nine-component 3-D seismic reflection data is typically processed in field coordinates (Simmons and Backus, 1999) and large shear-wave statics are generally found. Rotation of the prestack data to radial-transverse coordinates produces SH data from which statics are more easily estimated.

Three 9-C 3-D data sets are available that target Morrow channel sands which are overlain by a thick carbonate interval. The data sets differ in the severity of the near-surface conditions and signal-to-noise ratio.

Preliminary results from a 9-C 3-D survey in Clark County, Kansas shows that data processing (and interpretation) is simplified in radial-transverse (SV-SH) coordinates.

Super gathers, statics, and vertical transverse isotropy

Super gathers are produced after applying an azimuth-based rotation to the four-component prestack shear-wave data (orthogonal shear-wave sources, orthogonal horizontal geophones). Traces are sorted by offset and then stacked into 100 ft offset bins. Super gathers are defensible since geologic structure is minimal in this area, and give an indication as to the severity of shear-wave statics.

SH (transverse source, transverse receiver) and SV (radial source, radial receiver) super gathers are shown in Figures 1 and 2. Each panel shows the gather produced after applying additional static corrections to each prestack trace; no statics (raw), elevation statics (elevation), shot statics (SP), and receiver statics (RP). Common shotpoint stacks are created from the SH data and shot statics are estimated by crosscorrelation with a pilot trace. The shot statics are applied (+SP), and receiver statics are then estimated from common receiver-location stacks and applied to the data (+RP). This process is then repeated for a second pass (+SP+RP).

Note the enhancement of the reflection signal (2.0-2.5 s at the near offsets) as the statics converge. SH signal quality is superior to that of SV. The statics are based on the alignment of the strong low-frequency SH reflection package at the Morrow level. These statics clearly improve the alignment of the SH head waves, the SH reflections, the SV head waves, and the SV-P-SV head waves. The complexity of the head waves on SV contrasts with the simple SH first arrivals. It is easy to see how refraction-based statics operating on the data in field coordinates will be elusive.

Shot and receiver statics are shown in map view, and as histograms, in Figures 3 and 4. Low-frequency components are apparent in the first pass of shot statics since the datum velocity used for the elevation statics is imperfect (2500 ft/s).

The final static-corrected P, SV, and SH super gathers are shown after NMO correction in Figure 5. The shear-wave velocity function is derived from SH, and applied to SV as well. Note the superior reflection signal on SH, and the slight over-correction of the data on SV. This suggests the presence of vertical transverse isotropy.

The near-offset noise cone at the target reflection time (~2.0 s) extends to twice the offset in the shear-wave data as it does on the P-wave data. The optimum reflection signal window is larger and broader for SH than it is for P.

Brute stacks: SH and SV

A north-south line (inline) from the processed SH volume is shown in Figure 6. The static corrections that have been applied to this line are noted. The target zone reflections (2.0-2.5 s) are apparent after just elevation statics, and increase in amplitude and continuity as passes of shot (SP) and receiver (RP) statics are added.

A comparison of SH and SV sections with elevation statics, and with final statics, is shown in Figure 7. Note the superior
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Signal quality of the SH data. This observation is consistent for all lines in the data set. A true rotation to SV would also include the time-variant vertical-radial plane rotation, although this can probably be neglected.

Conclusions

Shear-wave data processing is simplified in radial-transverse coordinates. We will present the final processing results of this data set, and also investigate the extent to which our observations generalize to other 9-C 3-D data sets recorded in north Texas and southeast Colorado.

References


Figure 1: SH super gathers as a function of applied static corrections.

Figure 2: SV super gathers as a function of applied static corrections.
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Figure 3: Maps of shot and receiver statics. Map dimensions, 15700 ft N–S, 11400 ft E–W. Units are ms.

Figure 4: Histograms of shotpoint (SP) and receiver point (RP) statics.

Figure 5: Super gathers, statics applied, nmo corrected. The shear–wave velocity function is obtained from SH.
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Figure 6: Inline (N–S) from processed and stacked SH volume as a function of applied static corrections.

Figure 7: Inline (N–S) from processed and stacked SH and SV volumes with initial (elevation) and final (elevation + two passes SP and RP) static corrections.