Data Conditioning of a Modern Midcontintent Data Volume using POCS Five-Dimensional Interpolation

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Summary

We present a 5D interpolation case study based on a well-sampled Mississippi Lime survey acquired in NW Oklahoma, USA, where the objective was to map the impedance anomalies and subtle faults that may cause a horizontal well to leave the target zone.The original data provide good fault images but suffer from acquisition footprint and other noise. We use a commercial Fourier transform based interpolation technique Projection onto Convex Sets (POCS) to construct an interpolated 800-fold data volume and find footprint to be suppressed and lateral continuity of prestack inversion images improved. However, fault and karst edges at the target Mississippian horizon and a channel at the shallower Marmaton horizon have been significantly attenuated.

A Simple Model of Specular and Nonspecular events

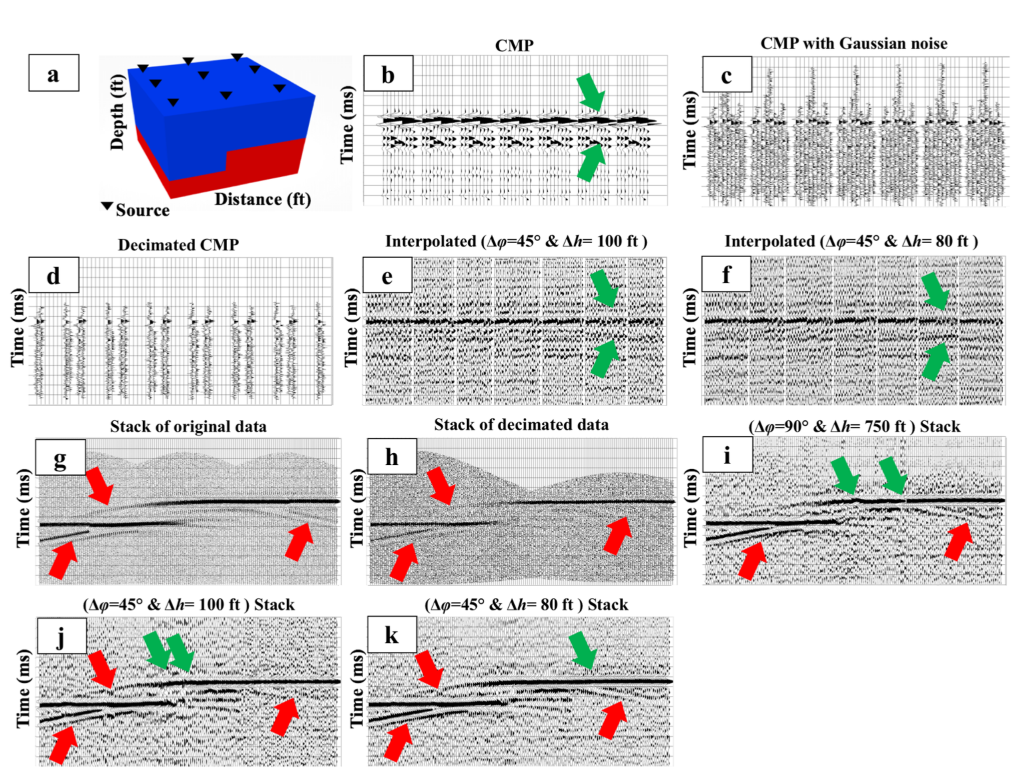

Figure 1: (a) Model of a faulted reflector in depth. (b) 7 CMPs after NMO correction using the correct velocity. Red arrows indicate unfocussed diffraction events. (c) same CPDs in (b) after adding gaussian noise 10% of the amplitude. (d) CMPs in (c) after decimation. We muted 4 out of the possible 9 sources in the modeled data. (e) CMPs after POCS interpolation using the annulus sectors bins measuring $\Delta\ \Phi$=45° and Δh= 80 ft (g) and $\Delta\ \Phi$=45° and Δh=80 ft (h). The number of traces per CMP depends on the annulus sector bin size. To better illustrate the effect of interpolation, we show the stacks due to of the original data (g), deciemated (h), different annulus binning in (i) $\Delta\ \Phi$=90° and Δh= 750 ft (j)$\Delta\ \Phi$=45° and Δ h= 80 ft (k) $\Delta\ \Phi$=45° and Δh= 80 ft. The specular reflection energy is not properly constructed in (i) and (j) due to the in appropriate annulus sector binning (green arrows). (k) give the best result to enhance the specular reflection.

Seismic Data Acquisition and Processing

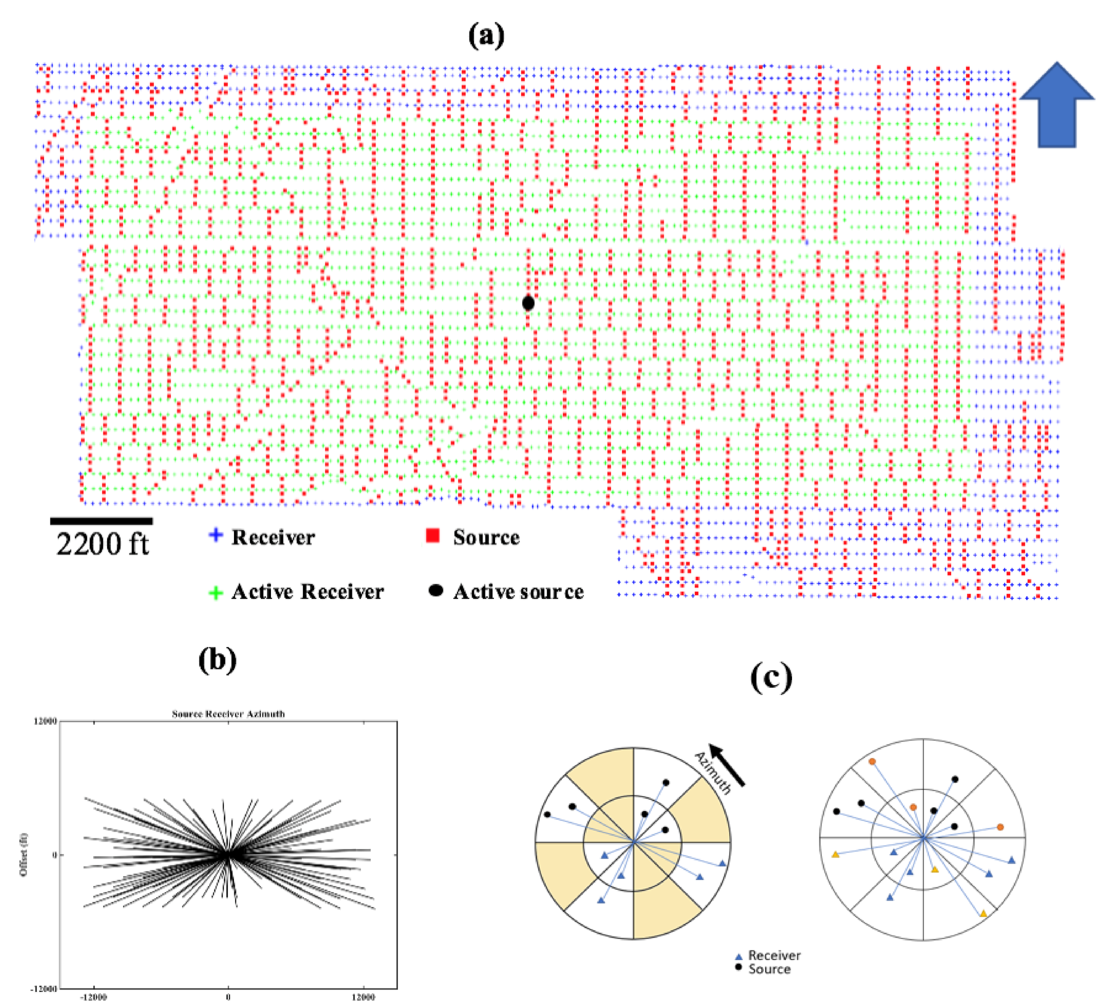

Figure 2: (a) A map showing the survey acquisition geometry. (b) Spider diagram for a common midpoint gather. Notice the survey has longer offsets in the E-W direction than in the N-S direction and hence is a narrow azimuth. (c) cartoon showing the annulus sector binning of a common midpoint gather with two offset and four azimuthal sector bins for (left) data before and (right) after 5D interpolation.

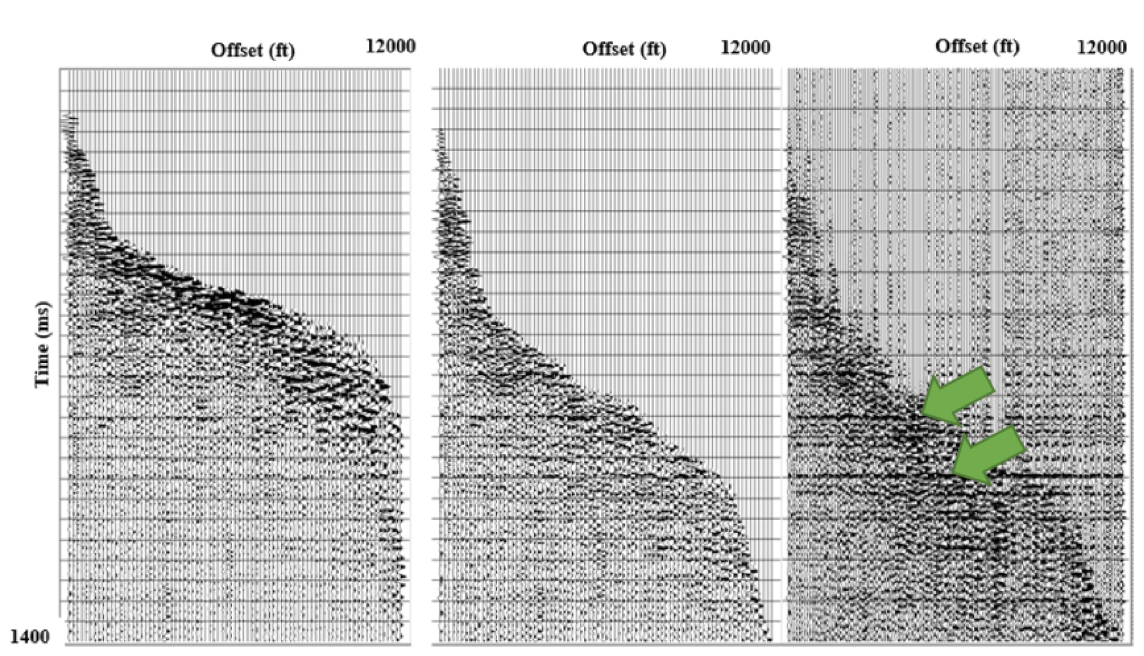

Figure 3: Original CMP without (a) and with (b) mute. CMP after POCS interpolation using $\Delta\ \Phi$=45° and Δh= 660 ft(c). The three CMPS are plotted against absolute offset. Note we have more traces per CMP after interpolation and that results in stronger and more contineous reflections(green arrows). A pitfall of any Fast Fourier technique is that we extrapolate data beyond the mute. The extrapolated data if used in the PSTM could stress the far offset amplitude on the the final stack and create in approperiate amplitude signiture. We re-apply the same mute in figure b prior to migraiton to prevente the extrapolated traces leaking into the data.

Effect on Migration and Geometric Attributes

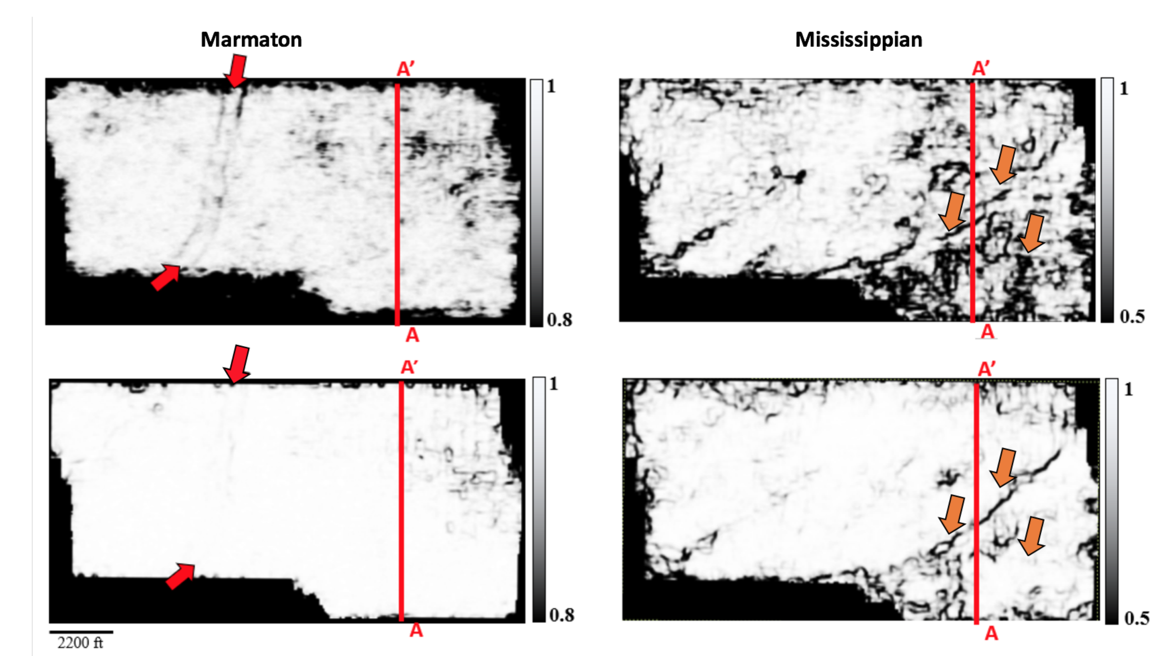

Figure 4: A horizon slice along the top of the Marmaton pand top Mississippian through coherence volumes computed from on the data before (Top) and after 5D interpolation. Note the channel running north-south on the Marmaton slice, indicated by red arrows. In the Mississippian image note what appear to be en echelon faults (orange arrow) and elliptical karst collapse features, some of which were identified by Cook (2016) on horizontal image logs. In both slices, the N-S and E-W acquisition design results in a rectangular footprint pattern that fades in and out across the survey that is directly linked to the deployment of sources and receivers. Most of the footprint artifacts have been eliminated. Unfortunately, the channel edges seen in top right figure have been lost after 5D interpolation. The NE-SW trending fault that appeared to be en echelon in the top two figures appears to be more continuous after 5D interpolation rather than as an en echelon fault in top left figure. Karst collapse features in the Mississippian identified by Cook (2016) also appear to have been suppressed.

Effect on P- Impedance

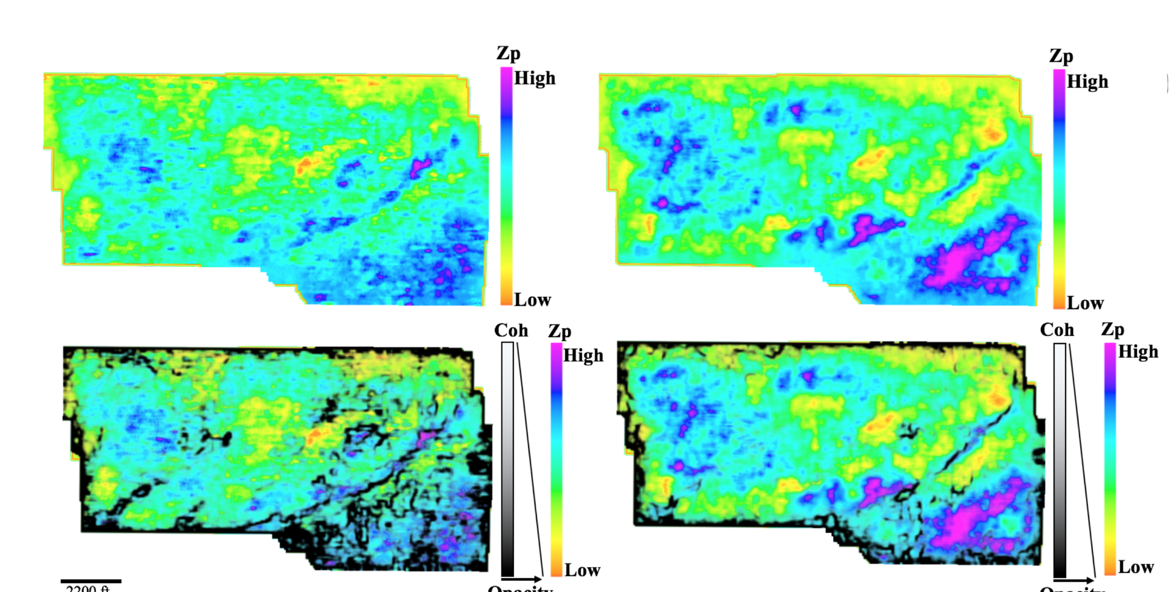

Figure 5: Top: Horizon slice along the top of the Mississippian through the P-wave impedance volumes obtained by prestack inversion of the original (left) and 5D interpolated data (right). Bottom: the same horizon slices through acoustic impedance co-rendered with coherence (a) before and (b) 5D interpolation.

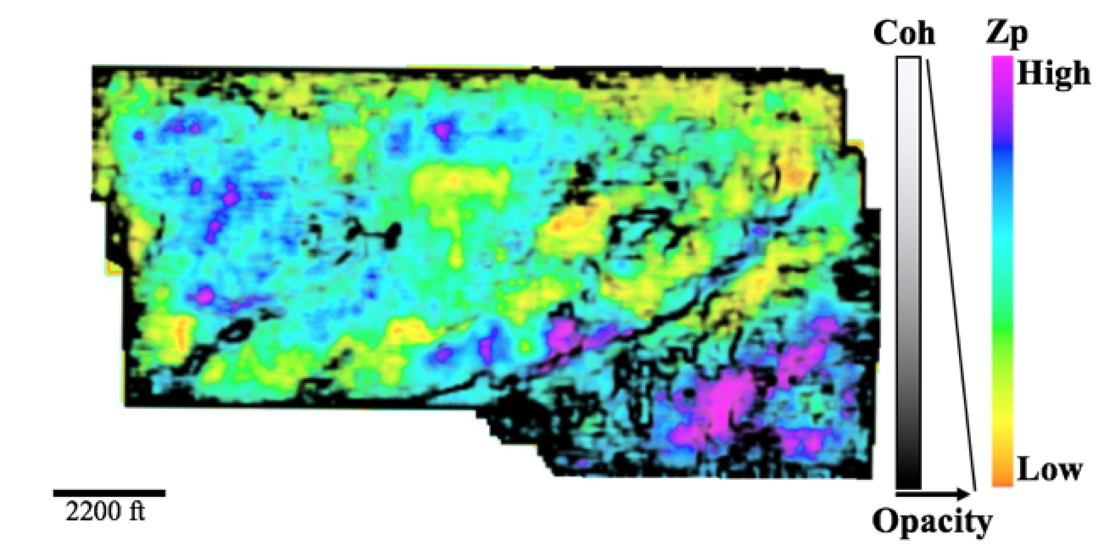

Figure 6: The impedance computed on 5D interpolated data co-rendered with the coherence computed on the original data. Note the coherence anomaly seems to delineate the high impedance (magenta) anomaly in the SE part of the image.

Conclusions

In the midcontinent of the USA, 5D interpolation methods have become a well-accepted part of the seismic processing workflow that helps suppress acquisition footprint and improves specular reflections for impedance inversion. Although regularized seismic data yields a better signal-to-noise ratio and better AVO analysis, one must be aware of the inherent limitations of the method due to parameters settings and the nature of the features being interpolated. We have demonstrated using POSC algorithm on an Oklahoma dataset that subtle features can be damaged at the expense of improving the amplitude analysis. We attribute the loss to the error introduced due to the annulus sector binning, and inherent NMO correction. In our analysis we found that computing geometrical attributes on original interpolated seismic data gives better results whereas impedance is better computed on 5D interpolated data. We recommend that interpreters request data volumes with and without interpolation to construct a more detailed image of the subsurface.

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