Challenges in AVO Compliant Processing of Multiple Surveys

Greg Cameron, Josef Heim*
WesternGeco/Schlumberger, Calgary, Canada
gcameron@calgary.westerngeco.slb.com
and
Frederik Horn, Andy Dyke
WesternGeco/Schlumberger, Calgary, Canada

Summary

Extracting rock properties from seismic data requires a careful, AVO compliant approach to processing. Variations in acquisition geometry, overlaps, and signal and noise content can cause problems for AVO inversion, as demonstrated through data examples from the Western Canadian Sedimentary Basin. Seismic data processing can improve an inversion for rock properties – or degrade the result; depending on the parameters and algorithms chosen throughout the processing flow. This is illustrated with several examples of noise attenuation, amplitude weighting for migration, and compensation for residual moveout post migration.

Introduction

Variations in acquisition geometry, overlaps between surveys, and different noise content must be compensated for if seismic data are to be merged with the ultimate goal to invert for rock properties. Surveys are typically acquired with different recording instruments, geophones, sources (dynamite, vibroseis, air-guns, etc.) and exhibit characteristic coherent noise trends.

Furthermore the random noise of each survey depends on environmental conditions and ambient noise at the recording time in the area. In many cases the surveys to be merged were designed with different geometries, fold and offset distribution, and merging the data with other data from the area is typically an afterthought.

All this leads to problems in processing to merge these data: The source wavelet is different between surveys as well as the noise content; leading to phase changes across survey boundaries if not corrected for. Different geometries and overlap between vintage surveys lead to fold variations and gaps in offset planes causing migration artifacts.

Even if differences between surveys are compensated for there are many more challenges preparing a data set for pre-stack inversion; for example residual moveout.

The Phase Challenge

A typical processing workflow involves removing as much noise in various stages as possible – without damaging the source wavelet. Figure 1 shows typical shot records with significant coherent and ambient noise: Groundroll, airblast, and some guided wave energy are clearly visible next to some localized noise trends.

A Surface Consistent Deconvolution tends to stabilize the wavelet and phase significantly better than a trace-by trace process. However, there are still problems: Rapidly changing noise content, as observed across survey merge boundaries will impact the computation of deconvolution operators and can cause phase distortions in the merge area. This leads to phase variations when tracking from one survey into the next across the merge zone.

Careful noise attenuation prior to computing the deconvolution operators can minimize this problem and will lead to a more stable wavelet – a prerequisite for a successful pre- or post stack inversion.

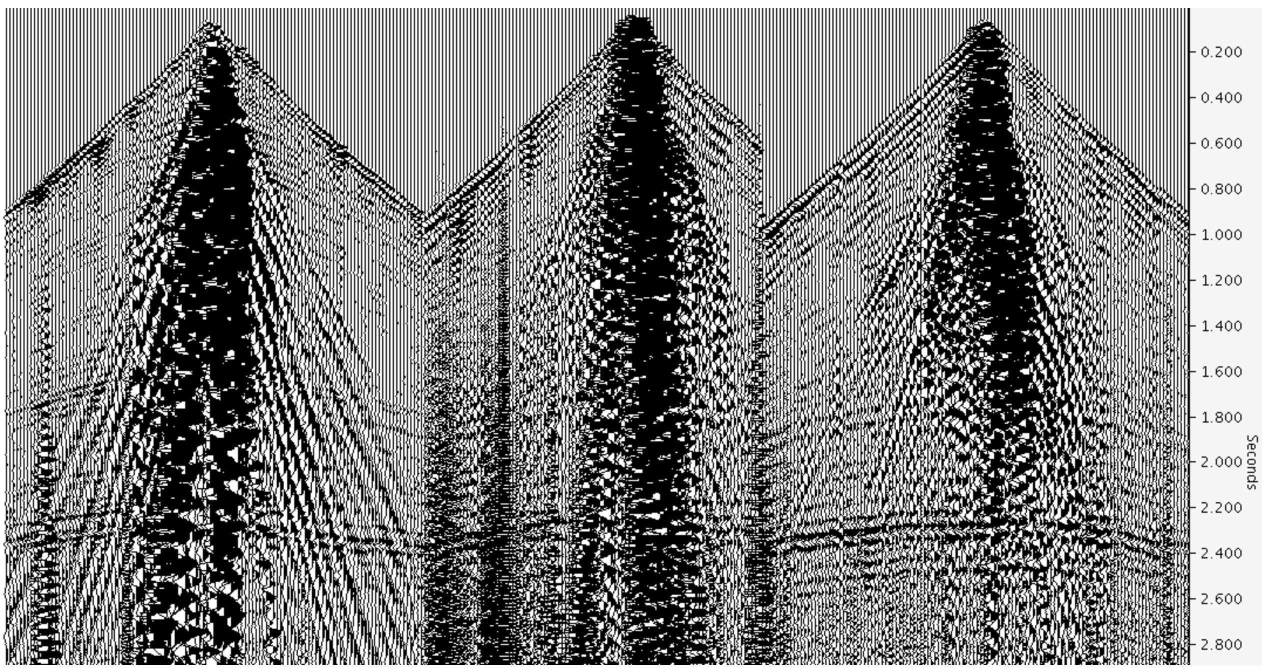

Figure 1 shows a selection of shots from a single survey. The variable noise content will affect the stability of the deconvolution operators.

The Fold Challenge

Seismic surveys are typically designed to achieve even fold, azimuth and offset distribution – with environmental constraints, cost limitations, and access problems causing sparseness and irregularities. Merging surveys adds another factor into this mix – typically they were not designed to be merged. Bin size, geometries, and grid orientations are different. All this leads to fold irregularities in overlap areas between surveys.

Many algorithms used in seismic data processing require regular spatial sampling; or at least perform better if applied to regularly sampled data. A common offset Kirchhoff Pre-Stack Time Migration doesn't require regularly sampled input data; but will show more footprint and amplitude artefacts if there are significant fold variations in the individual offset planes.

Figure 2(a)

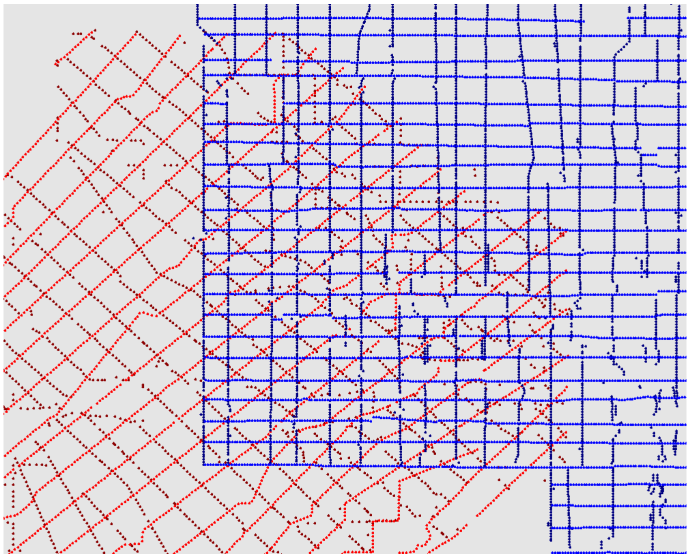

Figure 2(b)

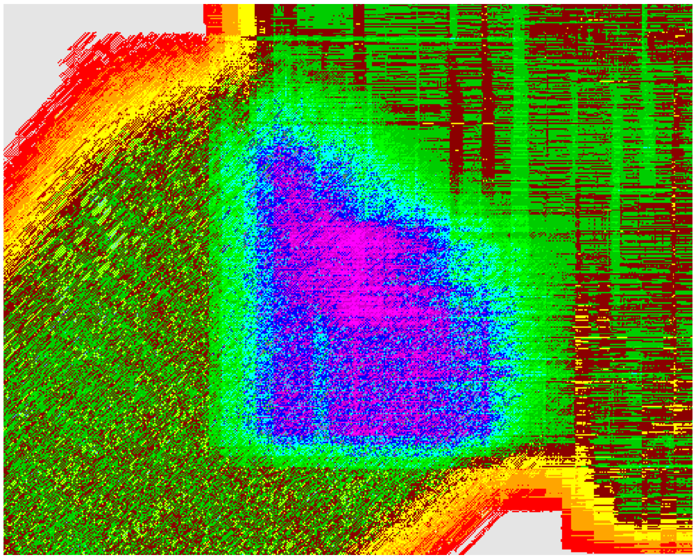

Figure 2(a) shows a shot and receiver map for two overlapping surveys in Alberta. The different acquisition azimuth results in different fold characteristics when gridded on a common grid as shown in Figure 2(b). These geometry variations will impact the amplitude of the migrated data, affecting the inversion result.

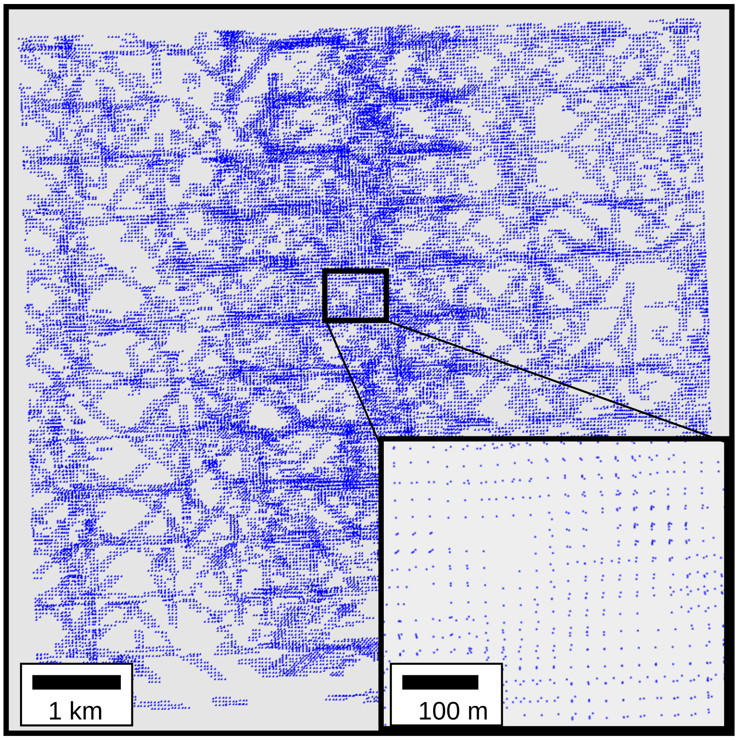

Figure 3: Midpoint coordinates in an overlap zone between two 3D seismic surveys with offsets ranging from 1200 – 1350 m. The irregular sampling needs to be considered in order to minimize artifacts in a Kirchhoff migration pre-stack-time migration.

An effective way of stabilizing the output amplitudes spatially and across offsets in a Kirchhoff PSTM is to compensate for irregular spatial sampling. This can be achieved by applying weighting schemes prior to migration and / or spatial interpolation if required.

The Moveout Challenge

Residual moveout on gathers can degrade the stack response, but typically velocities and mutes are adjusted accordingly and a full stack is not significantly compromised. This can be different for Pre-stack AVO inversion because it requires events to be flattened to all angles considered in the inversion. Hyperbolic moveout corrections will not always flatten gathers across all offsets – it is therefore very common to apply higher order corrections, include ray bending effects in traveltime computations, and apply anisotropic algorithms if necessary.

Many times this is not sufficient to flatten gathers across all offsets / angles. Left over residual moveout that is obvious in the gather domain (see figure 4) might be not be as clear in the angle stack domain and can be interpreted as an AVO response. The results of a subsequent pre stack inversion could then be contaminated as well. A gather flattening algorithm can compensate for this residual moveout without compromising real amplitude variations with offsets.

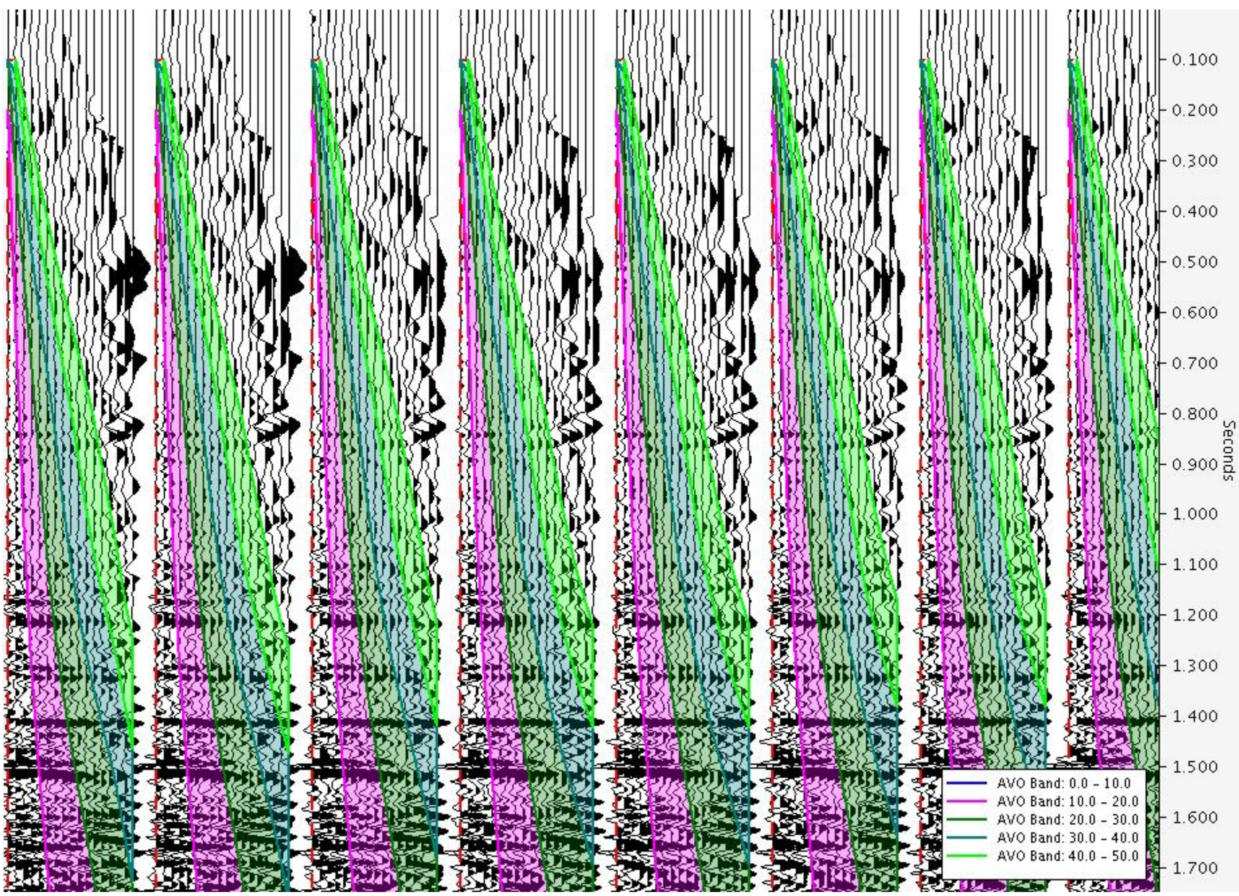

Figure 3 shows migrated gathers with angles overlaid. Residual flattening of the gathers is necessary in order to successfully invert the data.

Conclusions

This abstract has outlined the challenges encountered in processing when merging vintage surveys. This is especially important for pre-conditioning of AVO post- or pre-stack inversion.

Key challenges are signal noise variations and resulting phase distortions; fold variations causing imaging problems, and residual moveout compromising AVO inversion of angle stacks or gathers.

Acknowledgements

We would like to acknowledge WesternGeco Multiclient for the permission to use the data shown in this abstract.

References

Jaramillo, H., 2005, Practical aspects of Voronoi-based area weights for Kirchhoff migration: SEG Expanded Abstracts 24, 1886

Kirchheimer, F., Ferber R. "Robust surface consistent deconvolution with noise suppression" 71th Ann. Meetg. SEG, San Antonio 2001

Nickel, M., Sønneland, L., 1999, Non-Rigid matching of migrated time-lapse seismic; SEG Annual Meeting.