Analysis of a Repeat Crosswell Tomography Dataset with Microseismic:

Fracture and Fluid Placement by Hydraulic Fracturing

David Rampton* , Robert M. Dilmore , Richard Hammack, Tom Daley

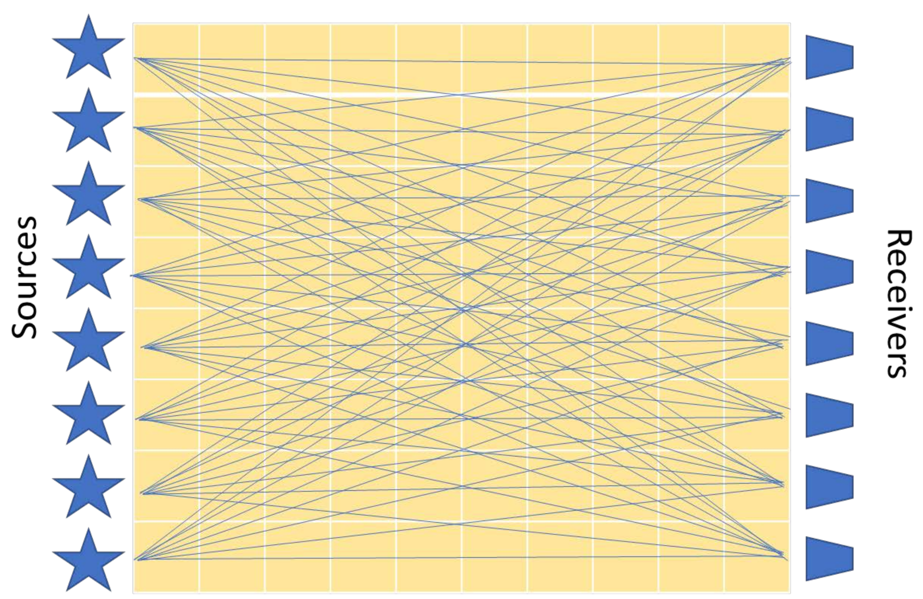
ORISE at National Energy Technology Laboratory, Pittsburgh, PA and Carnegie Mellon University

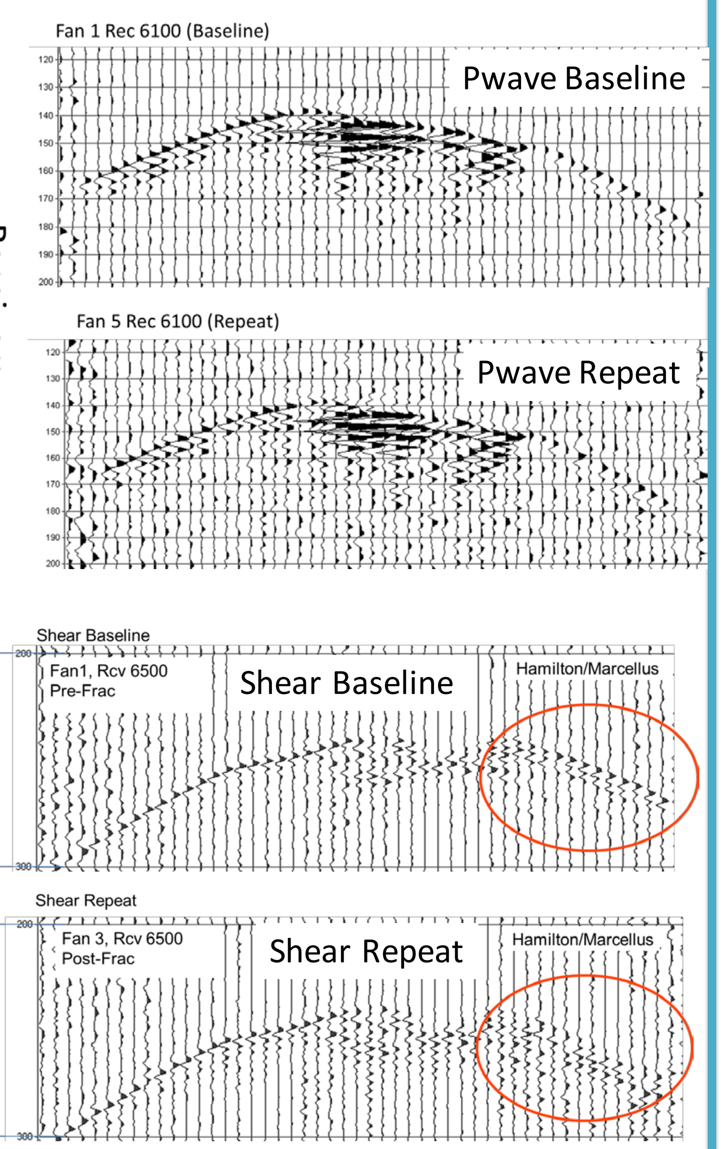
* (david.rampton@netl.doe.gov)

Research & Innovation Center

NATIONAL ENERGY TECHNOLOGY LABORATORY

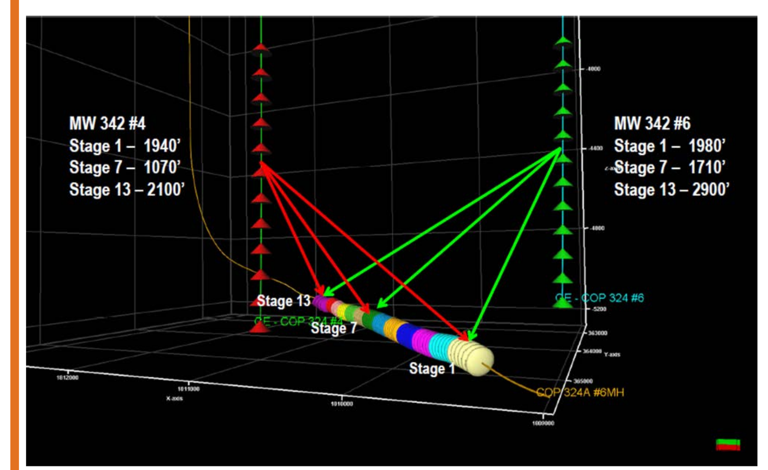
Crosswell Seismic Acquisition



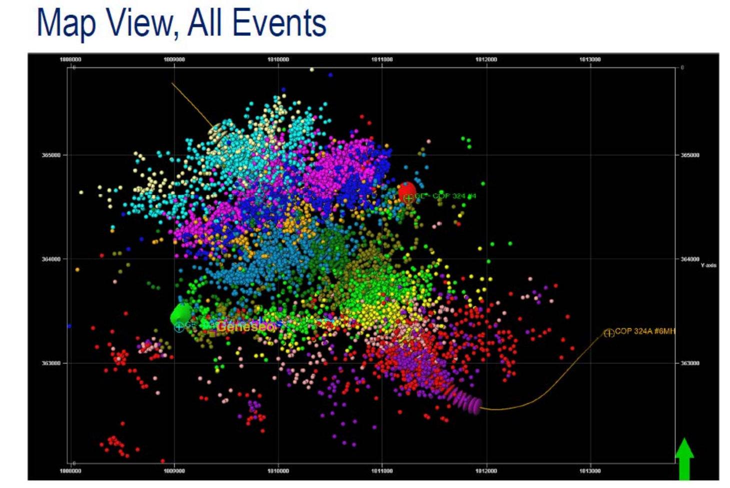


Crosswell seismic is just as the name implies: seismic sources are placed in one well, receivers in an adjacent well, and waveforms are recorded across all interwell shot-receiver combinations to infer subsurface velocities and properties. By repeating the acquisition, changes in the subsurface can be evaluated.

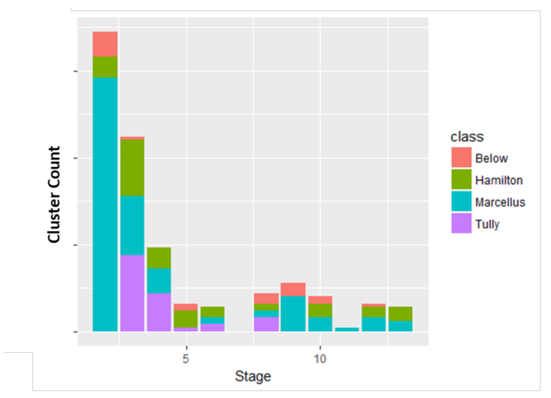
Microseismic Survey

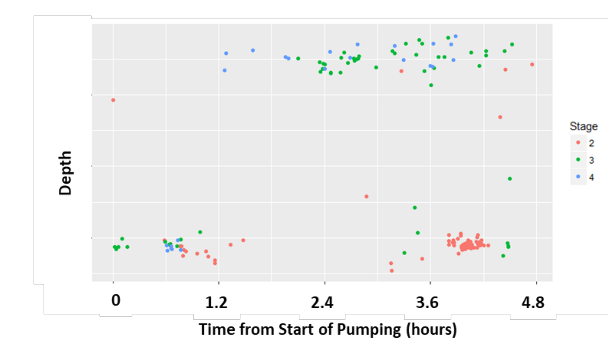


Map View, All Events



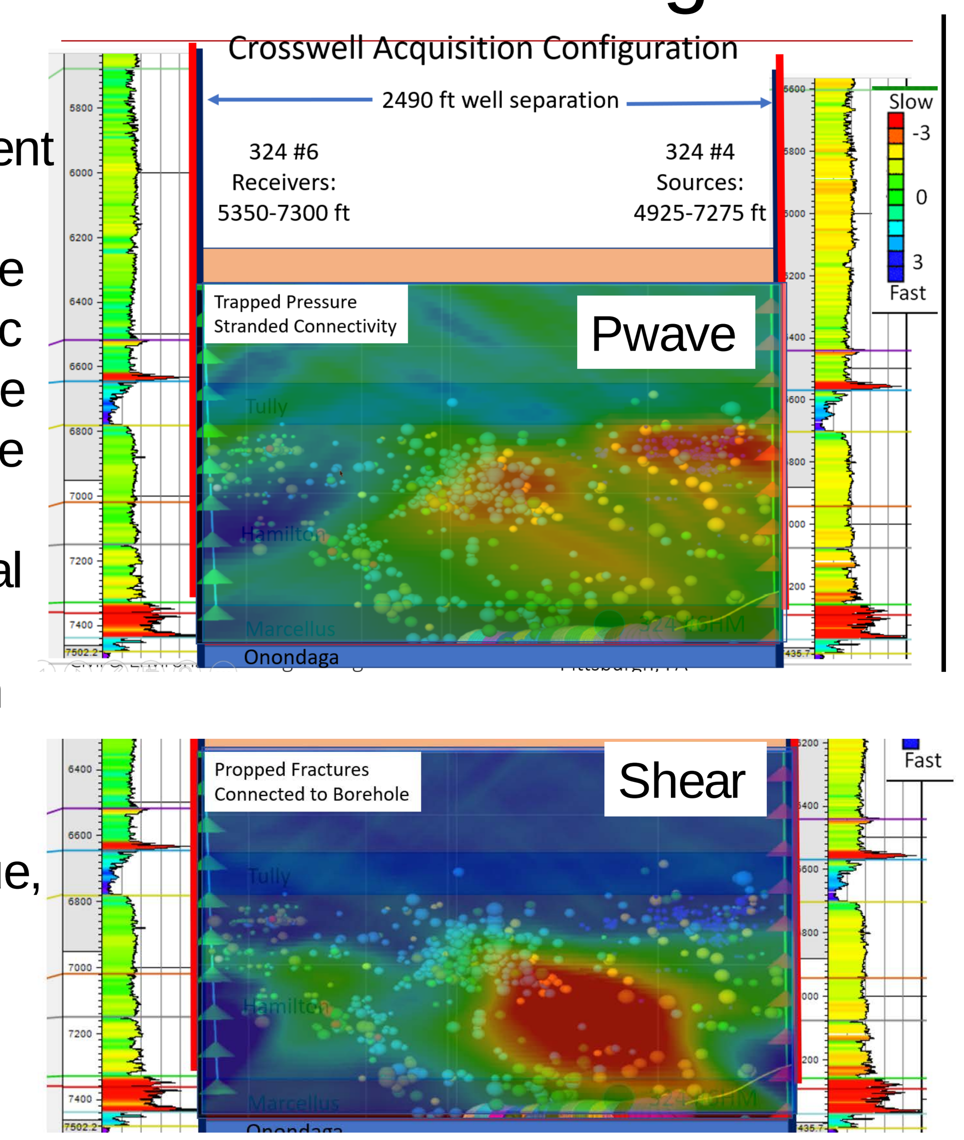
Microseismic surveys involve passive recording of seismic energy to “listen” for seismic events that can be interpreted as fracture creation or strain release on existing natural fractures. Since the environment created by hydraulic fracturing already has significant noise, separating signal from noise for proper event location and characterization is often difficult. Most microseismic events from a Marcellus completion tend to be out of zone – fractures or strain relief?





Interpretation of Contractor Processing

Contractor processing showed smooth results that differ from current processing. The pwave response shows velocity slowdown high in the section coincident with microseismic event locations. The shear response is also a slow down but closer to the borehole and not in the same location as the pwave change. Initial interpretation is that the pwave response is due to fracture creation with trapped pressure, while the shear response is a location where propped fractures exist. If this is true, then hydraulic fractures will have breached the Tully formation, implying loss of seal integrity. This can be explained by the bedding-plane slip model of Rutledge, 2015.

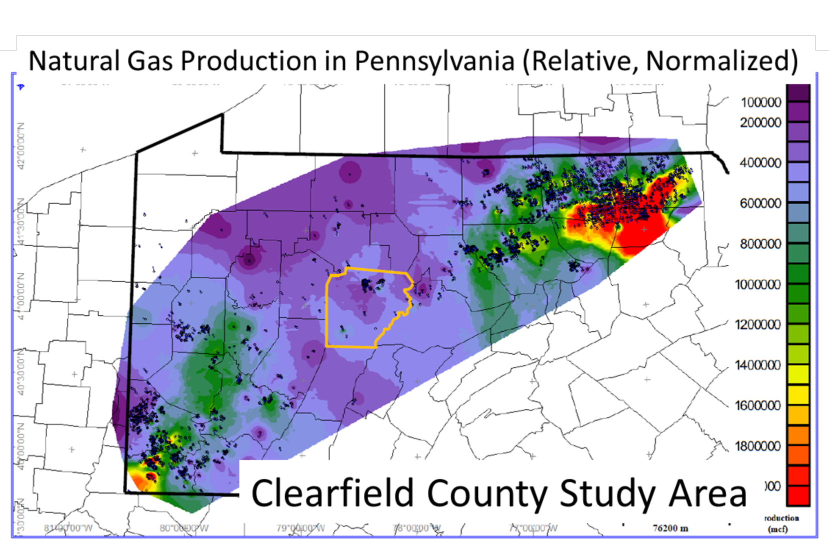


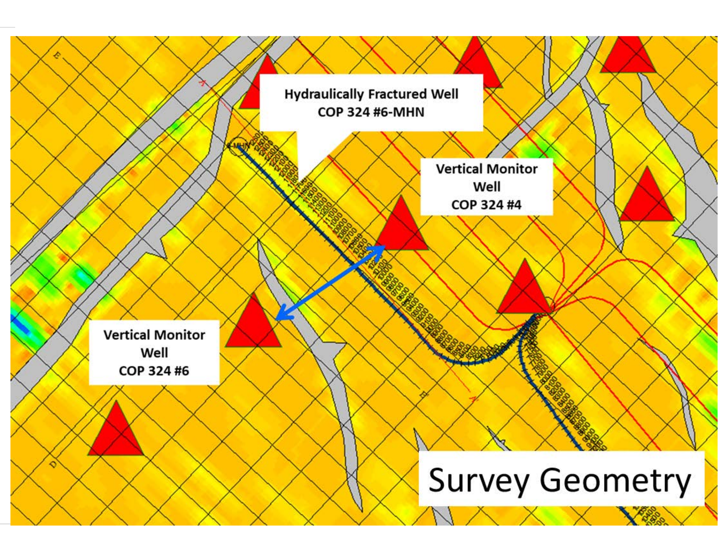
Rampton, Hammack, Fracture Detection using repeat crosswell seismic in a Marcellus reservoir, SEG Extended Abstracts, 2018.

The Clearfield Survey

In July, 2013 NETL acquired a repeat crosswell survey in Clearfield County, Pennsylvania before and after hydraulic fracturing a horizontal well in the Marcellus formation. The dataset is unique and involved a number of firsts:

- First Crosswell Seismic Project for NETL, URS and ECA
- First Crosswell Seismic Project in Pennsylvania
- First use of VSI Receiver String for Crosswell Seismic for full waveform analysis
- Ztrac Source used – capable of generating orthogonally oriented shear data that can be used for polarization studies.
- Repeat tomography performed within three days of hydraulic fracturing; hopeful to capture production effects.





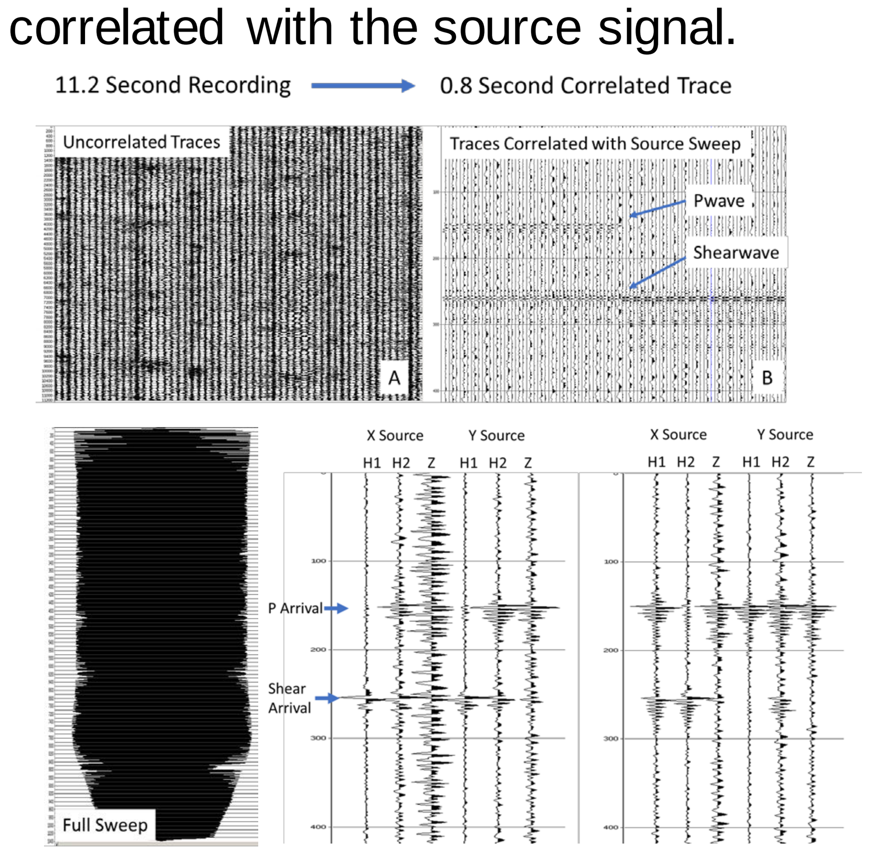
Map from Cole Bowers' masters thesis, WVU, 2014.

Hydraulic fracturing was also accompanied by passive seismic recording for microseismic analysis. The data were acquired and processed by Schlumberger, but are being re-analyzed in depth for this study.

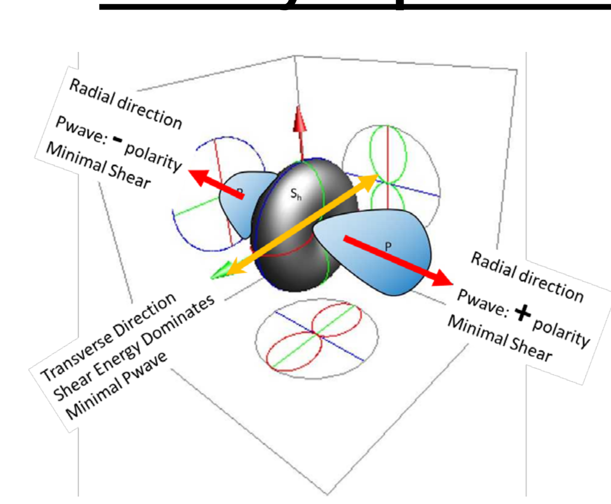
Analysis

Geometry + Noise Reduction

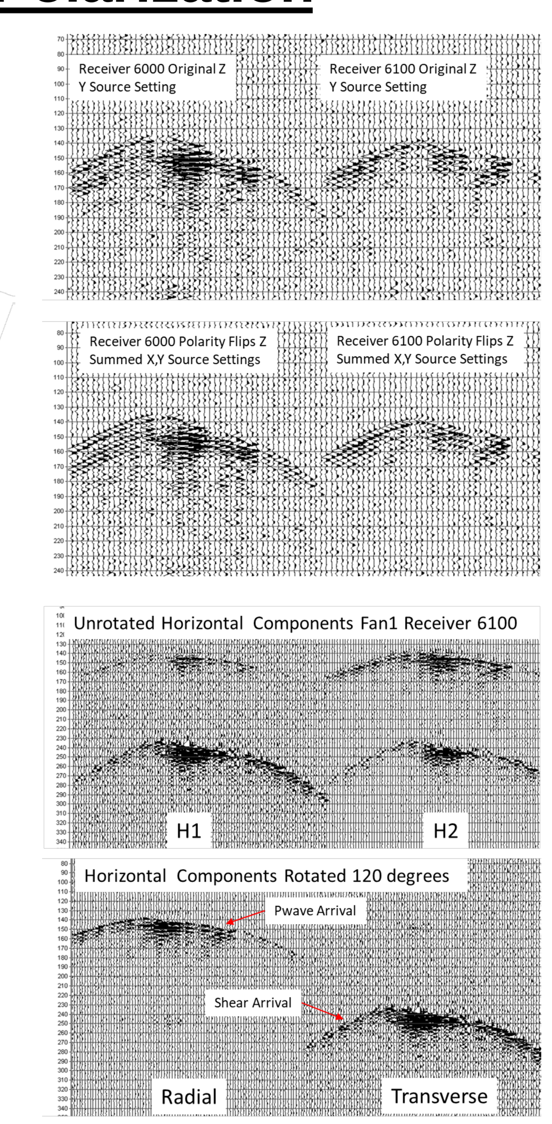
Source introduces a 10.2 second frequency sweep from 30-400 Hz and 11.2 seconds of data are recorded. Output is basically noise until cross-correlated with the source signal.



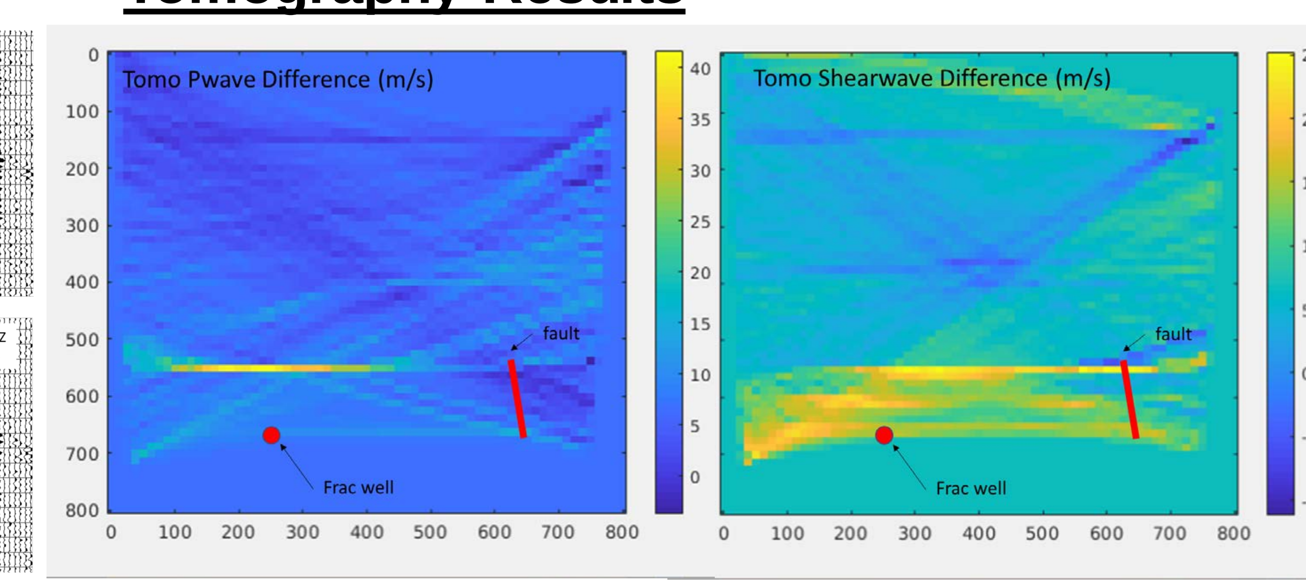
Polarity Flips and Polarization



Source radiation pattern and receiver geometries require trace inspection for polarity flips and rotation from inline/xline (raw) to radial/transverse. Pwave energy is optimized on the radial component, shear on the transverse.



Tomography Results



Inversion requires adjustments for both raybending and anisotropy. Though further refinement is necessary, the results show a dramatic change at the bounding seal interface as well as impact at the interpreted fault. The shear response is much more significant than the pwave response. These results highlight flaws in the contractor processing and show the benefit of focused effort.

Acknowledgements

- This work is funded by the National Energy Technology Laboratory through the Field Monitoring Team and the National Risk Assessment Partnership.
- Grateful appreciation goes out to the Oak Ridge Institute for Science and Education for program support.
- Matlab code and mentoring provided by the Lawrence Berkeley National Lab, particularly Jonathan Ajo-Franklin, Tom Daley, and Pierpaolo Marchesini.
- Extensive use is made of utilities from Seismic Unix, the creation of the Colorado School of Mines and now supported by John Stockwell.