

# Monitoring CO<sub>2</sub> Injection Using Direct and Converted P- and S-Waves Obtained by 3D VSP

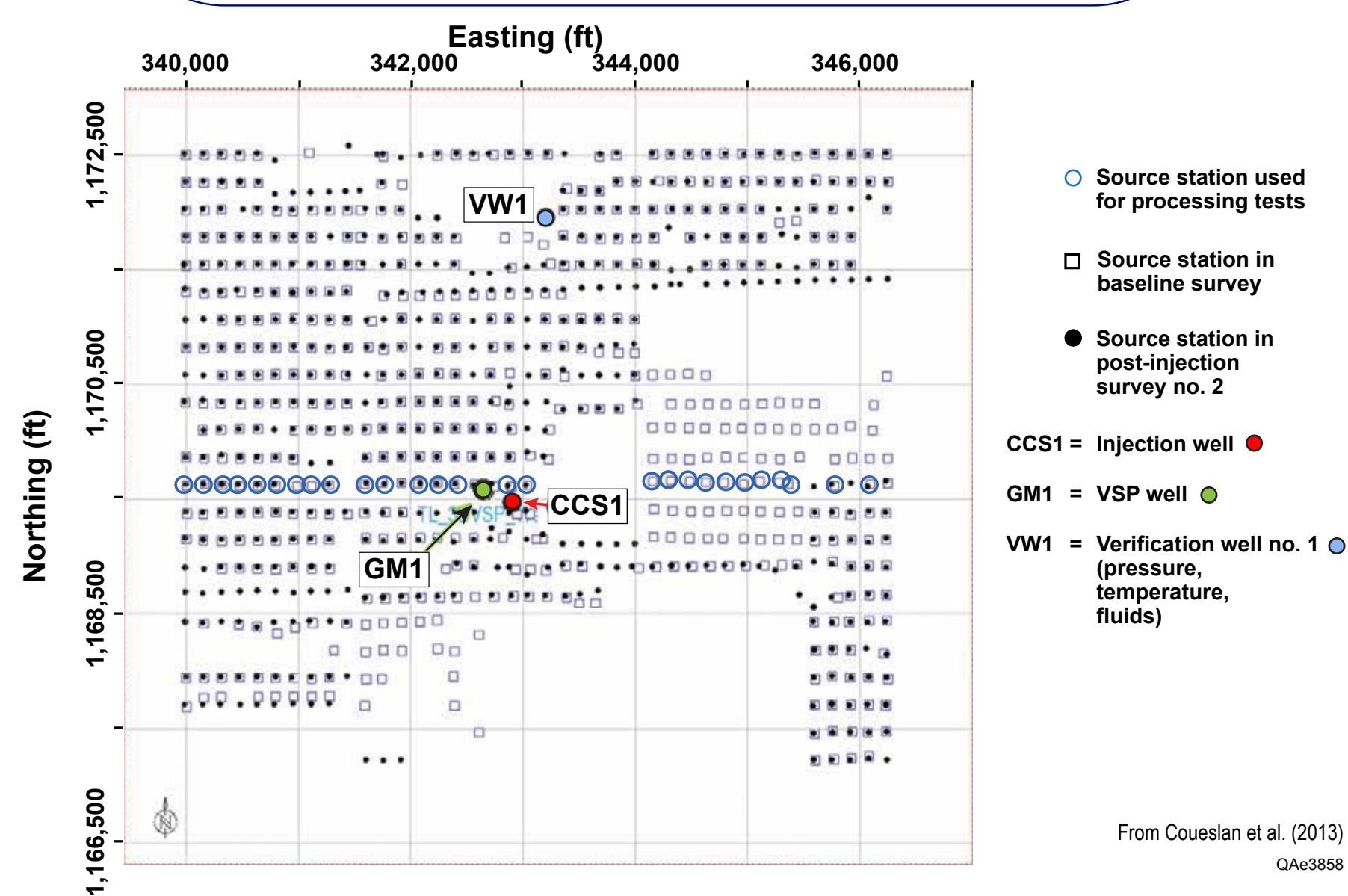
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## Abstract

Seismic wavefields contain different waves and modes. Each of these modes interacts with the subsurface in its own way and often carries information about different features of the strata. A joint analysis of all available seismic wavefield modes yields a deeper understanding of the subsurface and helps constrain subsequent interpretation.

Vertical Seismic Profiling (VSP) traditionally uses three-component receivers. This allows recording of all seismic wavefield components and their separation from each other. In this study, we work with 3D VSP data sets acquired at The Illinois Basin–Decatur Project (IBDP) site and investigate how different seismic wavefield components react to CO<sub>2</sub> saturation. We developed processing strategies for optimal extraction of P-P, P-SV, P-SH, SV-SV, and SV-P components. The first three modes are relatively strong, robust components that are produced by direct compressional waves and are traditional for VSP processing and interpretation. The SV-SV and SV-P components, in turn, are produced by direct S-waves, which are also generated by a vertical vibrator. These components are often ignored, despite the fact that they possess unique characteristics and provide information not available from the traditional components. We analyze all five VSP data components, obtain a seismic image for the strata around the injection well for each of these components, and discuss their features.

## Seismic Survey Design



## Status August 2015

- A technology that allows accurate extraction of SV-P and SV-SV modes from vertical seismic profiling data has been developed
- SV-P and SV-SV seismic images obtained are robust and consistent with conventional P-P, P-SV, and P-SH seismic images
- Integration of five different seismic data modes provides more robust seismic analysis of the gas storage site
- Independent modes indicate a possible dislocation at the top of reservoir; this feature requires a detailed study involving a full 3D VSP data volume and 3D surface data
- CO<sub>2</sub> injection changes seismic properties of the reservoir that is detectable by P-P and SV-P images
- P-SV, P-SH, and SV-SV appear too noisy to be used for time-lapse analysis; development of the technology should be aimed at elimination of these noises

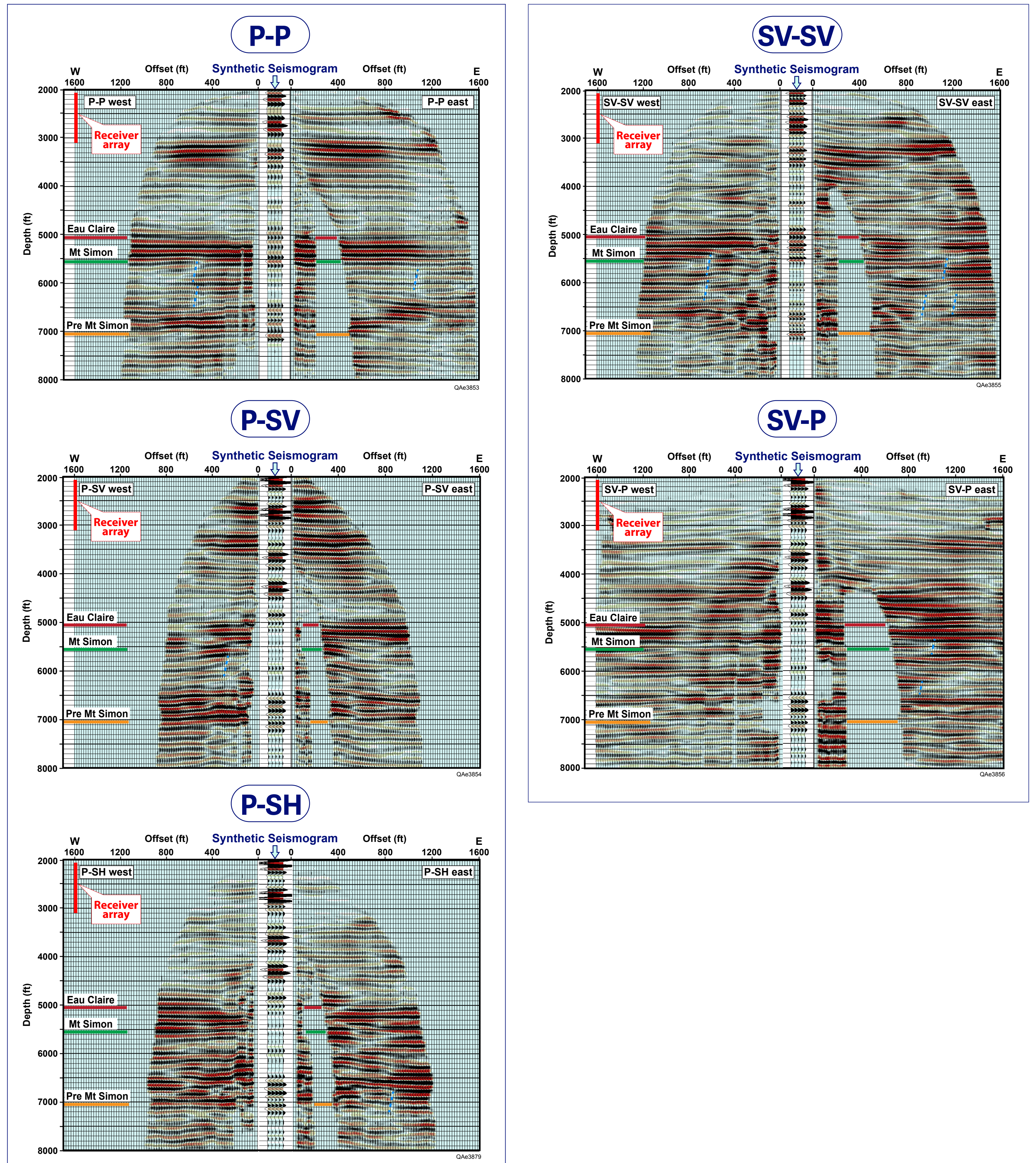
## Acknowledgments

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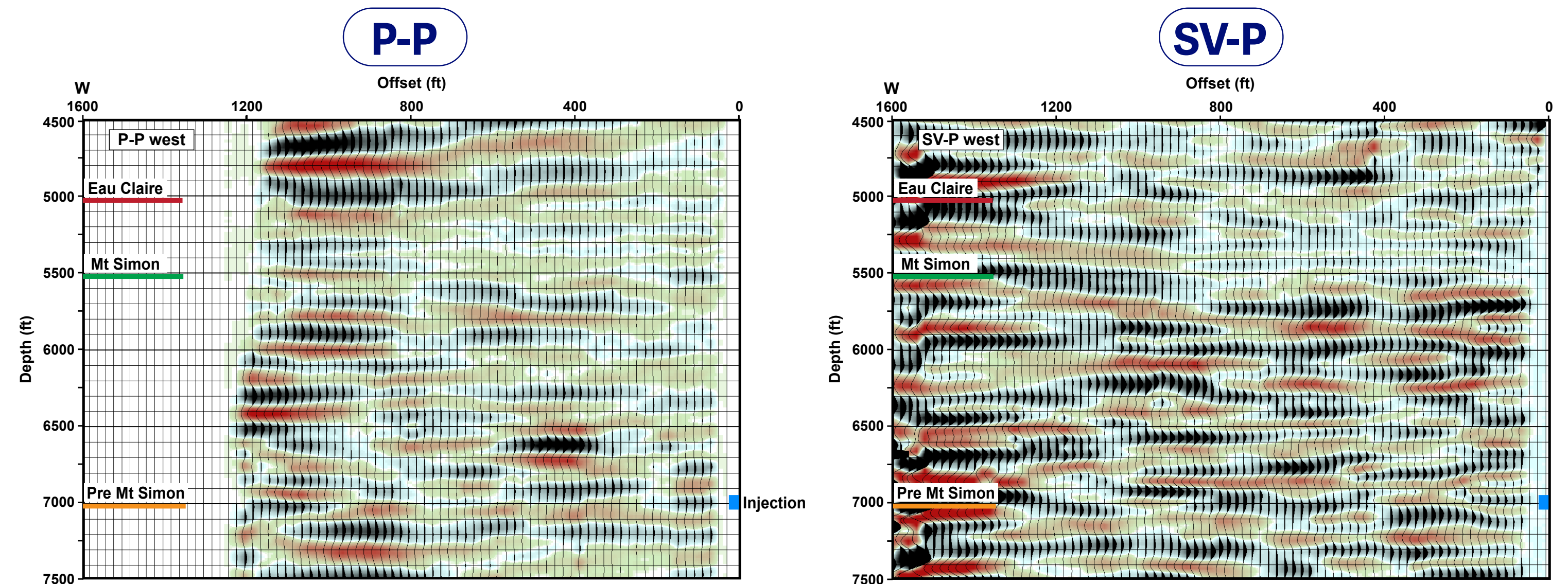
## Integrated Seismic Monitoring

### Basement 2 Survey



## CO<sub>2</sub> Plume Monitoring

### Monitor 3 / Basement 2 Difference



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