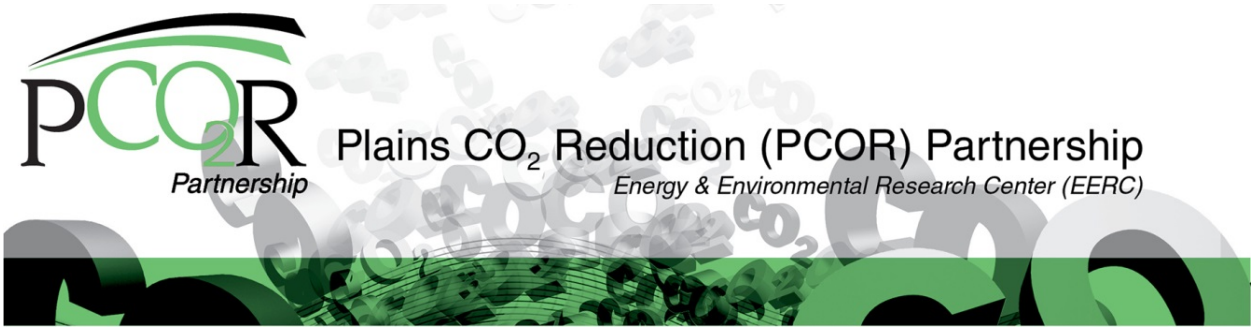

INITIAL ANALYSIS OF EXPANDED SEISMIC CAMPAIGN DATA COMPLETED

Plains CO_2 Reduction (PCOR) Partnership Phase III
Task 9 – Milestone M64

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Cooperative Agreement No. DE-FC26-05NT42592

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June 2017
2017-EERC-06-13
Approved

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ACKNOWLEDGMENT

This material is based upon work supported by DOE NETL under Award Number DE-FC26-05NT42592.

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BACKGROUND

The Plains CO_2 Reduction Partnership (PCOR) Partnership, led by the Energy & Environmental Research Center (EERC), is working with Denbury Resources Inc. (Denbury) to study carbon dioxide (CO_2) storage associated with a commercial enhanced oil recovery (EOR) project at the Bell Creek oil field located in southeastern Montana, which is operated by Denbury Onshore LLC. Denbury is managing all injection, production, and recycle activities as part of its commercial CO_2 EOR operation. The EERC, through the PCOR Partnership, is studying the behavior of reservoir fluids and injected CO_2 to demonstrate safe and effective CO_2 storage associated with a commercial EOR project. The PCOR Partnership is developing practices and technologies that will allow future commercial-scale CO_2 storage projects to make informed decisions regarding site selection, injection programs, operations, and monitoring strategies that improve storage efficiency and effective storage capacity in clastic geologic formations.

A significant contributor to this effort has been the acquisition and interpretation of multiple overlapping three-dimensional (3-D) surface seismic surveys over the field. A baseline survey, acquired in 2012 prior to the start of CO_2 injection, provided detailed information to enhance the characterization of the reservoir and served as a benchmark comparison to subsequent time-lapse data when it was acquired. When the baseline survey was paired together with overlapping 3-D surface seismic surveys acquired after injection had progressed, the changes occurring between the two surveys constituted a direct indication of where the injected CO_2 had migrated within the reservoir at the time of the survey. This provided additional information on permeability barriers and flow channels that were then used to refine the characterization, update the geologic models to improve subsequent predictive simulations, and help determine the ultimate fate of injected CO_2. At Bell Creek, two 3-D surveys were acquired subsequent to the baseline, in 2014 and 2015, respectively, that have been used to track injected CO_2 and provide updated information for geologic and simulation models.

INITIAL ANALYSIS OF EXPANDED SEISMIC CAMPAIGN DATA COMPLETED

The expanded seismic campaign consists of acquisition, processing, and interpretation of multiple time-lapse seismic data sets including 2-D surface seismic data, 3-D surface seismic data, vertical seismic profile (VSP) data, and passive seismic data. Figure 1 shows a time line of the geophysical studies that were a part of the PCOR Partnership project's expanded seismic program at Bell Creek. Initial analysis of the expanded seismic campaign consisted of interpretation and refined processing of these data. Details on the results of the initial analysis of the expanded seismic

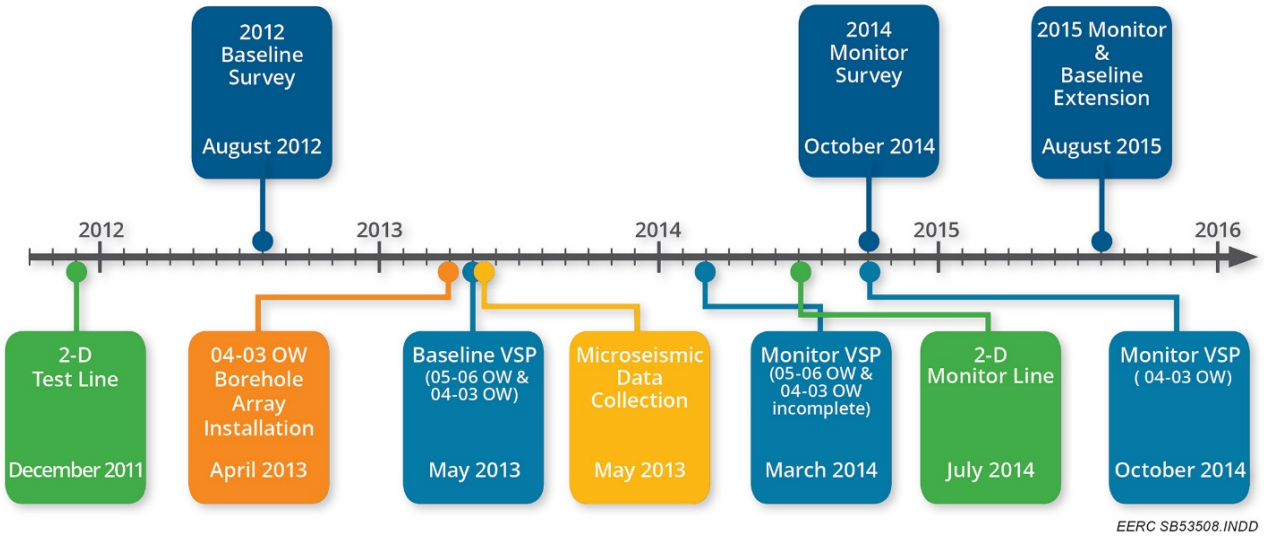

Figure 1. Time line showing the different components of the expanded seismic campaign.

campaign data will be reported in the topical report Deliverable 104 "Bell Creek Test Site – Analysis of Expanded Seismic Campaign," which will be submitted to DOE by the end of June 2017.

Some highlights from this initial analysis include the interpretation of the 2-D time-lapse seismic surface data, which established the applicability of time-lapse seismic to monitoring injected CO_2 at Bell Creek and led to the acquisition of time-lapse 3-D surface seismic surveys. Time-lapse differencing of these pre- and postinjection 3-D data sets (4-D data sets) has refined the geologic model and given insight into the reservoir response to various stages of phase development, including water and CO_2 injection. Examples of the interpretation of the 4-D data sets are shown in Figure 2. These interpretations include:

- Delineation of the permeability barrier boundaries that could not be resolved with 3-D baseline data.
- Indication of updip migration of CO_2 in the south–east direction.
- Apparent accumulation of CO_2 around the closures formed by the permeability barrier, which may be preventing further CO_2 movement.
- Illumination of a permeable pathway allowing for fluid and pressure communication between Development Phases 1 and 2, which transects the permeability barrier.
- Observation of higher amplitude signal in Development Phase 2 compared to Phase 1, contradictory to expected amplitudes based on the amount of CO_2 injected in each phase, which may be attributed to increased pressure in Phase 2 due to water curtain injection wells.

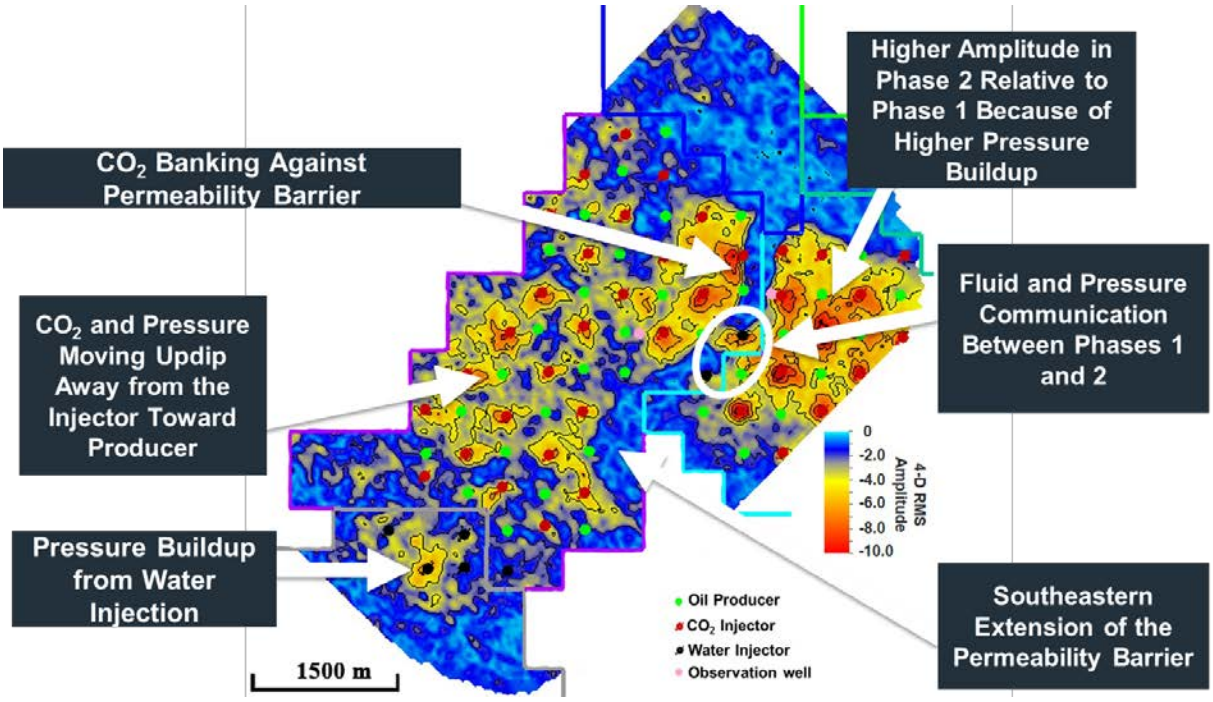

Figure 2. Summary of 2014–2012 overlapping 4-D amplitude difference map interpretation at Phases 1 and 2.

Analysis of the expanded seismic campaign will continue with in-house processing and interpretation of pre- and postinjection passive data to better understand changes in reservoir conditions associated with phase development. Additionally, pre- and poststack inversion of 3-D surface seismic data will be performed to gain more information about reservoir compartmentalization to help further refine the geologic model for use in simulations. Thus far, initial analysis of the expanded seismic campaign has enhanced the characterization of the reservoir at Bell Creek, leading to refined geologic models and improved predictive simulations. This analysis has also led to a greater understanding of monitoring best practices, which will be reported in best practices manual D51 "Monitoring for CO_2 Storage and CO_2 EOR," due to DOE by the end of October 2017.