Time-lapse seismic imaging for carbon capture, utilization and storage (CCUS) in thin, stacked coals

Ellen Gilliland, Nino Ripepi, Michael Karmis
Virginia Center for Coal and Energy Research (VCCER), Virginia Tech, Blacksburg, VA 24061-0411, USA
elleng@vt.edu, nino.ripepi@vt.edu, mkarmis@vt.edu

A small-scale carbon capture, utilization and storage (CCUS) project in southwest Virginia will incorporate time-lapse seismic imaging as one part of its monitoring, verification, and accounting (MVA) program to assess the injected CO_2 plume. The DOE-sponsored study is designed to test the injection and storage potential of unconventional reservoirs and will involve injecting 20,000 tonnes of CO_2 into a series of thin, unmineable coal seams. The study site is located in an active coalbed methane (CBM) field in Buchanan County, Virginia. An additional goal of the study is to assess the effect of CO_2 injection on enhanced coalbed methane (ECBM) recovery at offset wells. Up to three CBM production wells will be converted for use as injection wells, and a number of new wells will be drilled for monitoring and collecting time-lapse seismic data.

The project objectives require the use of a time-lapse seismic method, either vertical seismic profile (VSP) or crosswell seismic, to try to image the injected CO_2 plume. However, several factors will complicate the ability to successfully image the plume. The target reservoir is a series of 15-20 coal seams, averaging 1.0 foot in thickness and distributed over approximately 900 feet of section. This unusual geometry will be a challenge to resolve, even with advanced seismic methods. It is unknown whether injected CO_2 will be in a supercritical state within the formation and for how long. At a nearby CCUS site in Russell County, Virginia, CO_2 injected at high pressure was supercritical in seams deeper than 1600 feet (Ripepi, 2009). At the Buchanan County site, the deepest seams are just over 2100 feet, but the injection pressure could be lower, resulting in the CO_2 being in gas phase. Gaseous CO_2 will not contrast with pre-existing methane, and the ability to image the CO_2 plume would depend on the presence and amount of water in the formation. Water is produced from three candidate injection wells at a rate of approximately 45 barrels per month. Additionally, analyzing and understanding the change observed between repeated surveys will require the ability to isolate the effects of multiple processes, including the spread of CO_2, swelling of the coal matrix and resultant changes in permeability, and seasonal or other natural variation in the seismic properties of the formation.

Time-lapse seismic imaging is included in the project plan as a feasibility study where the advancement is the application, not the technology used. Crosswell and VSP methods are already established, effective tools for assessing the spread of CO_2 in CCUS projects (Daley et al., 2007; Hoversten et al., 2002). However, most target formations used in CCS projects resemble conventional reservoirs—thick sedimentary formations with high porosity and permeability, often filled with brine or oil, which create a strong acoustic contrast to the injected CO_2. Some coals, such as the Fruitland coals of the San Juan Basin and the Fort Union Group lignite of the Williston Basin, have been used for injection studies, but these cases are not analogous because the seam thicknesses, often tens of feet, make them easier targets to resolve with seismic imaging (Wilson, Wells, and Koperna, 2009; Nelson, Steadman, and Harju, 2005). The challenges of this study lie in the ability to detect subtle change in thin, dispersed beds and to distinguish the contributions of multiple reservoir processes to the observed change.

The foremost research question posed by this study is whether time-lapse seismic methods are meaningful for the application of CCUS in thin coals—are the results useful enough to justify the cost compared to other MVA techniques? If the method successfully captures change in the seismic properties of the reservoir, it will be important to learn whether the effects of different reservoir processes can be distinguished within the results and to what degree. Also, it will be important to assess any correlation between seismic observations, other monitoring and geophysical data, and ECBM recovery and to determine the relationships between seismic observations, injection processes, and the shape and nature of the true plume. Finally, an optimal survey design needs to be determined, accounting for the anticipated reservoir geometry, while considering successful designs at other CCUS sites. The results can be used to improve design for potential future studies of CCUS in thin coals.

References

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