Seismic monitoring of CO₂ injection into a depleted gas reservoir – Otway Basin Project

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Abstract

Within the Stage I of the Otway Basin Project, of the Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC), approximately 65,000 tons of CO₂/CH₄ mix in the ratio of 80/20 was injected into the Waarre C formation (depleted Naylor gas reservoir) over the last two years. The CO₂ was produced and transported from a nearby natural accumulation, via pipeline and injected into a sandstone reservoir.

The use of depleted gas fields for CO₂ storage as well as CO₂-based enhanced gas recovery are of global importance. Thus, the CO2CRC Otway Basin Pilot Project provides important experience in establishing whether such scenarios can be monitored by geophysical techniques, in particular seismic time-lapse methodology. Indeed injection of CO₂ into a depleted gas reservoir (within residual gas saturation window) does not present favourable conditions for the application of geophysical monitoring techniques. Numerical simulation of the CO₂ injection process at Otway show that changes in elasticity of the reservoir rock will be quite small and difficult to monitor even with the most powerful time-lapse (TL) seismic methodologies. Consequently, the design and implementation of the monitoring program had to address these issues. The monitoring program had two objectives: (1) to ensure detection of possible gas leakages out of the reservoir into other formations and (2) to attempt to detect changes of seismic response due to CO₂ injection into the reservoir.

To increase the sensitivity of TL seismic we combined 3D VSP with 3D surface seismic. For a land seismic case, we achieved excellent repeatability with 3D time lapse surveys, which at the reservoir level produced normalised RMS difference values of about 20% for surface seismic and 10% for 3D VSP, respectively. The location of the time-lapse anomaly detected at the reservoir level is broadly consistent with CO₂ flow simulations. However borehole seismic measurements showed that time-lapse is very small to be reliably evaluated from repeated surface seismic measurements as the anomaly is of a similar magnitude to noise, making its unique attribution to the CO₂ plume difficult.

One of the important outcomes of these studies is evaluation of land time-lapse seismic capabilities. New understanding and new methodologies for assessment of 3D seismic data repeatability were developed during Otway Basin tests. This helped us understand and validate time-lapse signal from the reservoir. It also enabled us to demonstrate that quality of time-lapse land surveys can be high enough to be able to detect very small, up to five thousand tonnes, leakages which is of essential importance to any monitoring program as it provides possibility for rapid mitigation.