# Security of Storage in Carbon Dioxide Enhanced Oil Recovery

R Jamie Stewart,[1] Gareth Johnson,[1] Stuart Haszeldine,[1] Peter Olden,[2] Eric Mackay,[2] Bernhard Mayer,[3] Maurice Shevalier,[3] Michael Nightingale[3]

[1]University of Edinburgh, School of Geosciences, Edinburgh.EH9 3FE
[2]Heriot-Watt University, Institute of Petroleum Engineering, EH14 4AS
[3]University of Calgary, Department of Geoscience, Calgary, Alberta, Canada T2N 1N4

Preliminary studies from Carbon Dioxide Enhanced Oil Recovery ($CO_2$-EOR) in Canada have suggested that, in $CO_2$-EOR settings, solubility trapping takes place within both aqueous and hydrocarbon phases. As such it is postulated that $CO_2$-EOR may have the potential to securely store a greater quantity of $CO_2$ than a purely non-EOR storage operation. This study's principal objective was to quantify how much solubility trapping takes place within both aqueous and hydrocarbon phases in $CO_2$-EOR settings.

The fate of $CO_2$ is an important consideration when injecting $CO_2$ into the geological subsurface. $CO_2$ can be trapped structurally and stratigraphically, by residual trapping, solubility trapping, and by mineral trapping (IPCC 2005). Although in a well selected storage complex a combination of each of these trapping mechanisms should lead to extremely high confidence in storage security, certain geological risks will always exist (Worden & Smith 2004). What is known however is that the highest geological storage risks exist when $CO_2$ is in free phase and is reliant on structural and stratigraphic trapping. Increased security of $CO_2$ storage will be achieved if the storage mechanism migrates from structural and stratigraphic trapping to solubility trapping in the time frame of the $CO_2$ storage operation.

The Pembina Cardium $CO_2$ Monitoring Pilot Project was used as a test site to determine the relative roles of solubility trapping. The Pembina Cardium $CO_2$ Monitoring Pilot site is located near the town of Drayton Valley, west of Edmonton (Alberta, Canada), in the Pembina Field (Fig. 1). The Pembina oilfield is the largest individual (Owen, 1975) and one of the oldest onshore oilfields in Canada. The pilot consisted of two five-spot injection patterns, with two of the production wells being shared by the two injector wells. This resulted in two $CO_2$ injectors with six surrounding producers (Fig. 1). These wells were completed in the middle of the Pembina field in an area that has been water flooded since 1962 (Dashtgard et al. 2008). $CO_2$ injection started in 2005 with approximately 75,000 tons of truck delivered liquid $CO_2$ being injected between March 2005 and March 2008. Between March 2005 and March 2007 $CO_2$ was continuously injected through the two injection wells. After this period the pilot switched to WAG injection with injected $CO_2$ being periodically alternated with water injection (Hitchon, 2009).

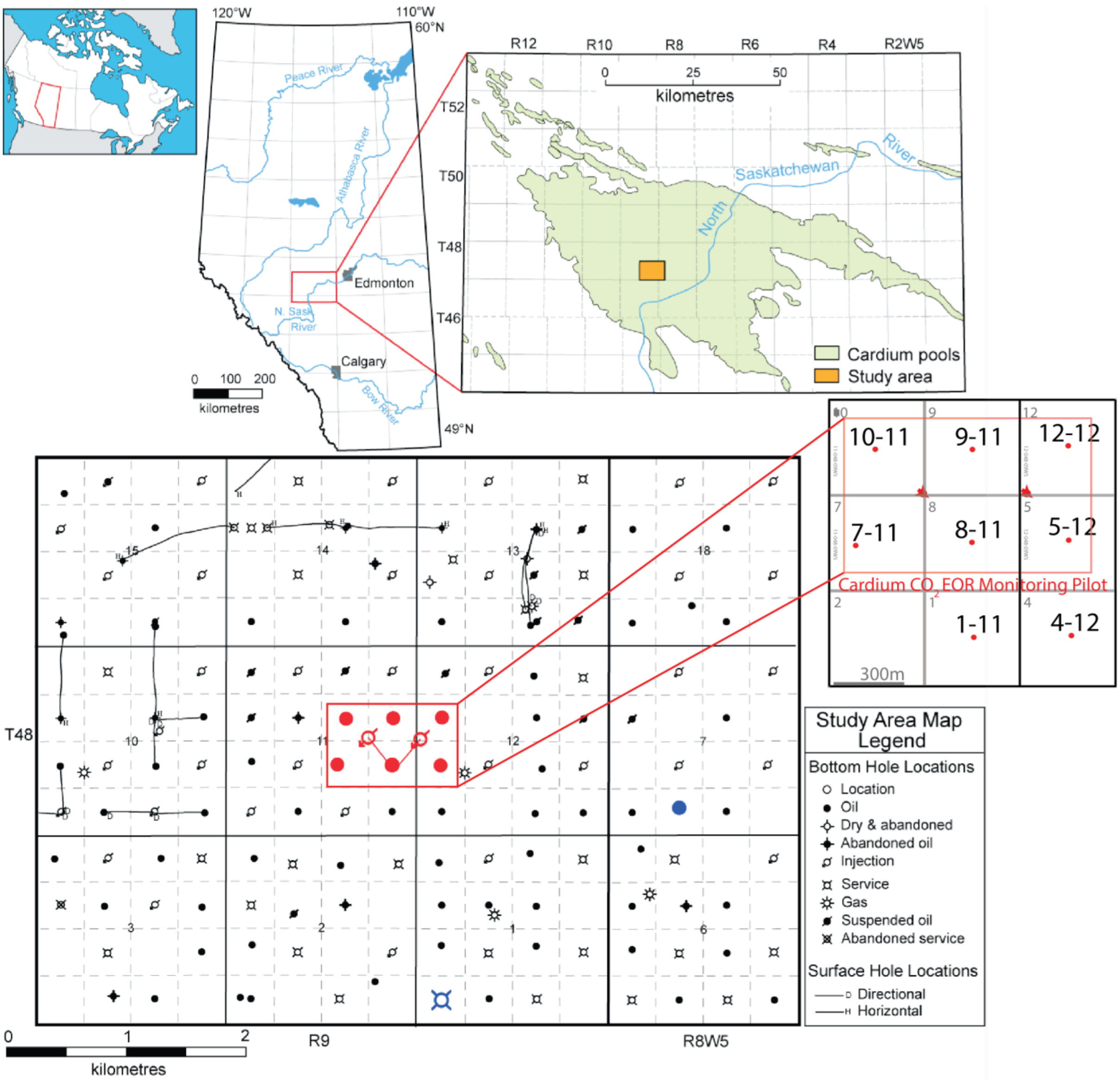


*Figure 1 – Location Map of the Cardium pool, Pembina Field, adapted from* (Dashtgard et al. 2008). *The lower map illustrates the location of the wells within the study area. Wells 10-11, 9-11, 7-11 and 8-11 are production wells in the classic 5 spot pattern with a CO2 injector in the middle. Using wells 9-11 and 8-11wells 12-12 and 5-12 form a second 5 spot pattern with another CO2 injector in the middle. Wells 1-11 and 4-12 are also production wells, which sit further to the South.*

Firstly two geochemical approaches, based on the work of Johnson et al. (2011), using empirical data from the site (gas geochemistry, production volumes and water isotope geochemistry) were used to determine the phase distribution of $CO_2$ (dissolved or free phase) at a number of production wells that were sampled monthly during the two-year $CO_2$ injection pilot. In addition a simplified reservoir simulation was performed to use as a test-bed to investigate various $CO_2$ injection scenarios with the model having some of the salient features of the pilot project. In particular the model was used to test the observations of the role of solubility trapping, both in oil and aqueous phases, versus free-phase $CO_2$ trapping.

The two geochemical methods show that the distribution of $CO_2$ in the reservoir, and hence the relative role of the trapping mechanisms, is closely matched where conditions permit both methods to work. The initial reservoir simulation model also closely matches the average $CO_2$ distribution and relative trapping contributions derived from the geochemical approaches giving extra confidence in both the methods using the empirical data and the reservoir model itself.

Subsequently the reservoir model was used to model a number of alternative scenarios including; continuous $CO_2$ injection, WAG, injection into a depleted oil field and injection into a saline aquifer. Results show that additional $CO_2$ storage by solubility trapping is achieved when an oil phase is present relative to a saline aquifer, hence increasing $CO_2$ security by reducing the proportion of injected $CO_2$ that remains as a buoyant free phase.

References

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