The CO_2 Storage Potential of the Canterbury-Otago Region, New Zealand

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Search and Discovery Article #80086 (2010)
Posted May 14, 2010

*Adapted for extended abstract prepared for presentation at AAPG/SEG/SPE Hedberg Conference, "Geological Carbon Sequestration: Prediction and Verification," Vancouver, BC, Canada, August 16-19, 2009

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Introduction

Geological storage of CO_2 has been identified as a viable means of reducing greenhouse gas emissions to the atmosphere. This study evaluates the CO_2 storage potential of the onshore Canterbury-Otago region of the South Island, New Zealand. The impetus for the study is that North Otago currently hosts a lime works which may soon be joined by a coal-fired cement works. The combined CO_2 emissions generated could be ~0.95 Mt per annum.

The early Canterbury Basin (Figure 1) developed as a passive margin following Late Cretaceous seafloor spreading in the Tasman Sea. Transpression between Australian and Pacific tectonic plates then reversed subsidence onshore and deformed existing Tertiary strata. Uplift of the Southern Alps since the Mid-Late Miocene has resulted in rapid sedimentation east of the foothills. These events have produced reservoir-seal pairs suitable for CO_2 storage and containment. Investigation of some of these reservoir units has resulted in only sub-commercial hydrocarbon discoveries. However, three structural closures were identified that have the potential to trap CO_2.

Onshore Canterbury Basin Stratigraphy

Three suitable reservoir units have become buried sufficiently since the Miocene (Bennett et al., 2000) to store supercritical CO_2. The oldest reservoir comprises Upper Cretaceous to Paleocene fluvial, estuarine, and marine sandstones of the Broken River Formation (BRF) and Conway Formation (CF) (Field and Browne, 1989). The BRF is a fine- to medium-grained, porous sandstone up to ~200 m thick that hosts a regionally patchy coal interval (Field and Browne, 1989).

Reservoir sands within the BRF (Figure 2) are either hard or friable, and are interbedded with the thin coal seams and associated mud baffles of the main coal interval (Field and Browne, 1989; Bennett et al., 2000). The formation "youngs" to Paleocene in the south, where its facies become paralic (Field and Browne et al., 1989; King et al., 1999). The CF (Figure 2) is a muddy, massive, fine sandstone to siltstone in outcrop, is up to ~135 m thick and occurs only in the north of the region (Field and Browne, 1989; King et al., 1999).

The second reservoir is Paleocene in age and comprises the Charteris Bay Sandstone (CBS) and the Waipara Greensand (WG) (Figure 2). The CBS has good porosity and permeability (poroperm) characteristics and is up to ~300 m thick where it occurs in the north. The WG is muddier and glauconitic, occurs up to ~90 m thick, and has pervasive concretionary intraformational baffle zones that result in locally large lateral variations in poroperm (Bennett et al., 2000).

The final reservoir is the Homebush Sandstone (HS) (Figure 2), a mature shelfal sand with locally excellent poroperm properties (Bennett et al., 2000). The HS is up to ~250 m thick in the north (Field and Browne, 1989). In the south, a muddier, glauconitic equivalent, the Waihao Greensand, occurs up to ~100 m thick (Field and Browne, 1989).

Storage would rely on regional mudstones, siltstones, and carbonates within the marine sequence, and fluvial or lacustrine siltstones and mudstones within the terrestrial sequence for sealing (e.g., Field and Browne, 1989). Detailed sealing potential has not been studied and most sealing lithologies are not distributed extensively within the more proximal sequence onshore (Bennett et al., 2000). Nominally, the BRF & CF reservoir is sealed by the Paleocene Loburn Mudstone (LM) formation (e.g., Field and Browne, 1989; Bennett et al., 2000). The CBS-WG and HS reservoirs are commonly sealed onshore by the Eocene Ashley Mudstone (AM), Oligocene limestones, and Miocene mudstones (King et al., 1999; Bennett et al., 2000). These are thicker and more widespread than the LM. In some areas they occur above a stack of all three reservoirs sitting in possible communication (e.g., King et al., 1999).

Stratigraphic Modelling and the Approach to Calculating CO_2 Storage Capacity

The spatial distribution of reservoir and seal strata was used to adapt an earlier age-layered model of Cretaceous-Cenozoic basin fill arising from seismic and measured stratigraphic information (Field and Browne, 1989). An interpolated geotherm was used to calculate a critical surface below which CO_2 can be sustained in a supercritical phase state necessary for storage under hydrostatic conditions. The criteria defining the critical surface are: temperature of 31.1°C; hydrostatic overburden pressure of 7.38 MPa (CO2CRC, 2008).

The new reservoirs and seals model (NRSM) was queried using the distribution of the critical surface. The total reservoir pore space occurring below the critical surface constitutes the Total Pore Volume (TPV) for saline formation storage (CO2CRC, 2008). CO_2 may be retained by any mechanism possible; e.g., hydrodynamic trapping, formation water-flow-rate trapping, dissolution trapping, conventional-buoyancy trapping beneath an impermeable seal lithology or, over longer timescales, mineral-precipitation trapping (CO2CRC, 2008).

The three structural closures identified were used to constrain reservoir zones of greatest storage potential by conventional-buoyancy trapping. Repeating the previous exercise using closure distributions made it possible to calculate the TPV storage capacity for each reservoir within each closure. Trap geometries relied on seismic data interpreted as part of original exploration studies. Reservoir thicknesses from the NRSM were used to estimate trap-geometry-correction factors. To test the influence of utilising such relatively low-resolutionthickness information at this scale, control calculations were performed with well strata thicknesses assumed to extend trap-wide and having a constant trap-geometry correction factor of 0.5.

Figure 3 shows seal (a), reservoir (b), and supercritical reservoir (c) distributions.

TPV CO_2 Storage Capacities

Table 1 summarises TPV for CO_2 storage within saline formations by reservoir. The BRF-CF reservoir is the most voluminous and possesses significantly greater TPV; the CBS-WG reservoir has a relatively low net-to-gross ratio; the HS reservoir has a similarly low net-to-gross ratio but is more widespread; this counteracts the relatively high proportion occurring above the critical surface (Figure 3, layers (c)).

Many of the storage capacities (TPV's) calculated using trap geometries derived from the NRSM agree well with those arising from the control calculations using well data. The higher calculated capacities correlate with the models having a greater trap-geometry correction factor. This highlights the importance of correctly defining the geometry of reservoir closure for more accurate predictions of CO_2 storage capacity.

Conclusions

Preliminary results indicate that reservoirs identified within three structural closures of the onshore Canterbury Basin may provide a combined capacity to store 96 Mt of CO_2 when sequestered with an efficiency of 1% TPV. This would provide sufficient capacity to store all CO_2 emissions from the lime and proposed cement works in North Otago for ~101 years, assuming 100% efficiency of CO_2 emissions capture. Additional storage capacity may also be available for CO_2 captured from future thermal power generation should commercial gas discoveries be made offshore.

Some Tertiary formations of Otago may have limited potential, but these mostly occur shallower than 800 m and where sealing would be a major risk. Shallow coals occur in both Canterbury and Otago, but underground workings, lack of good seal ideologies, and conflict with possible future use of these coals as a resource downgrade their potential for CO_2 storage.

References

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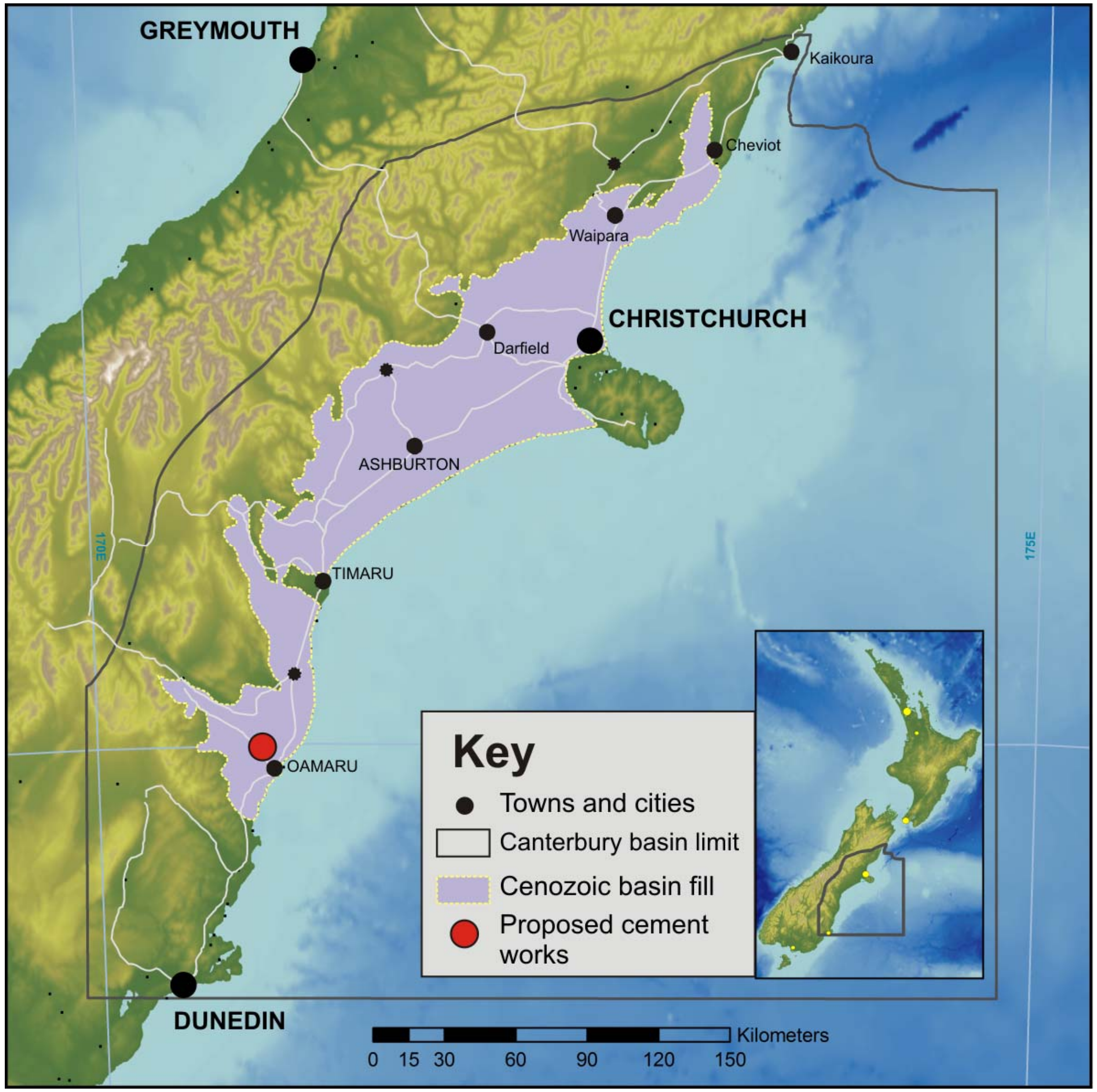

Figure 1: Location of the Canterbury Basin.

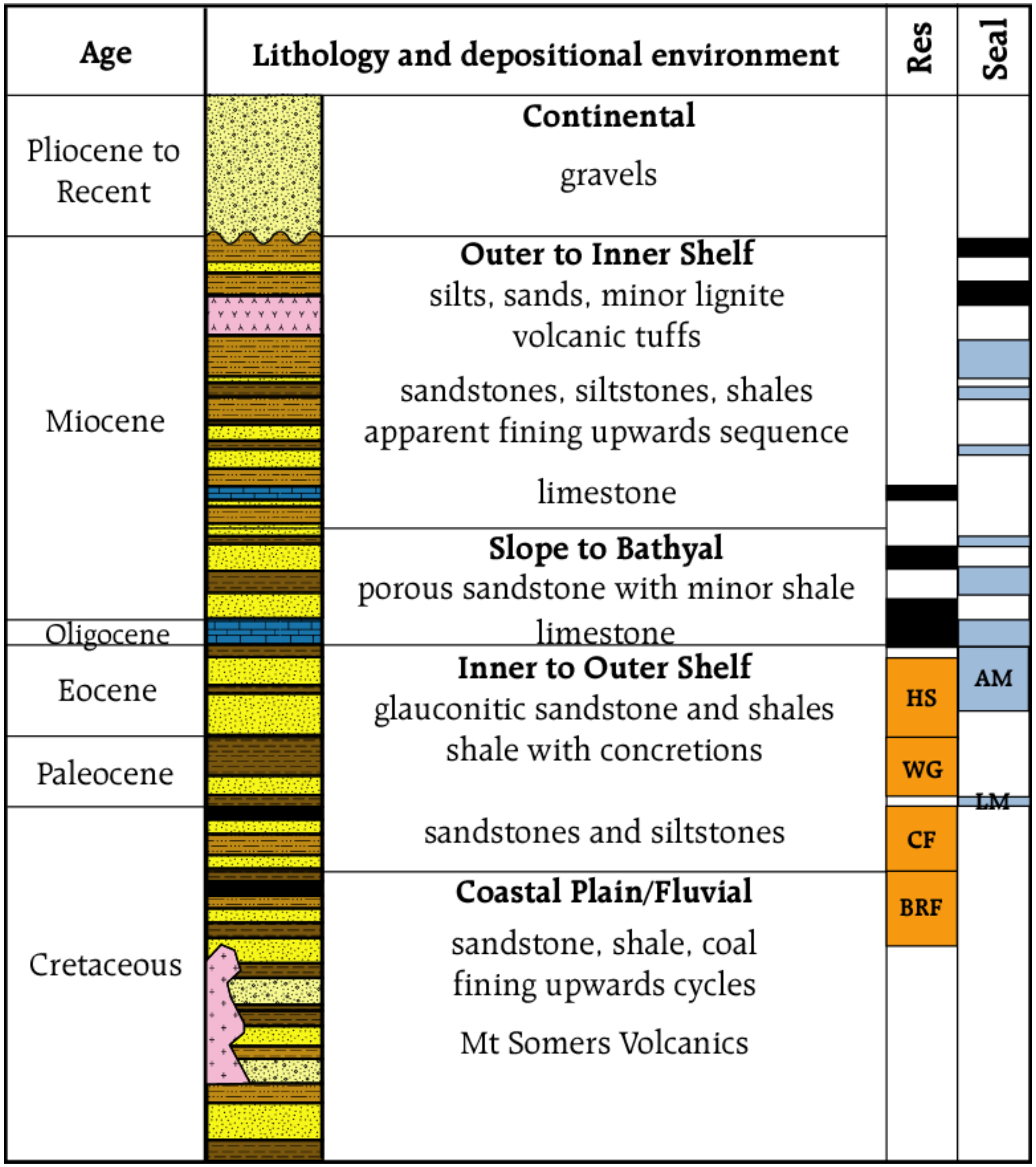

Figure 2: Summary of onshore stratigraphy.

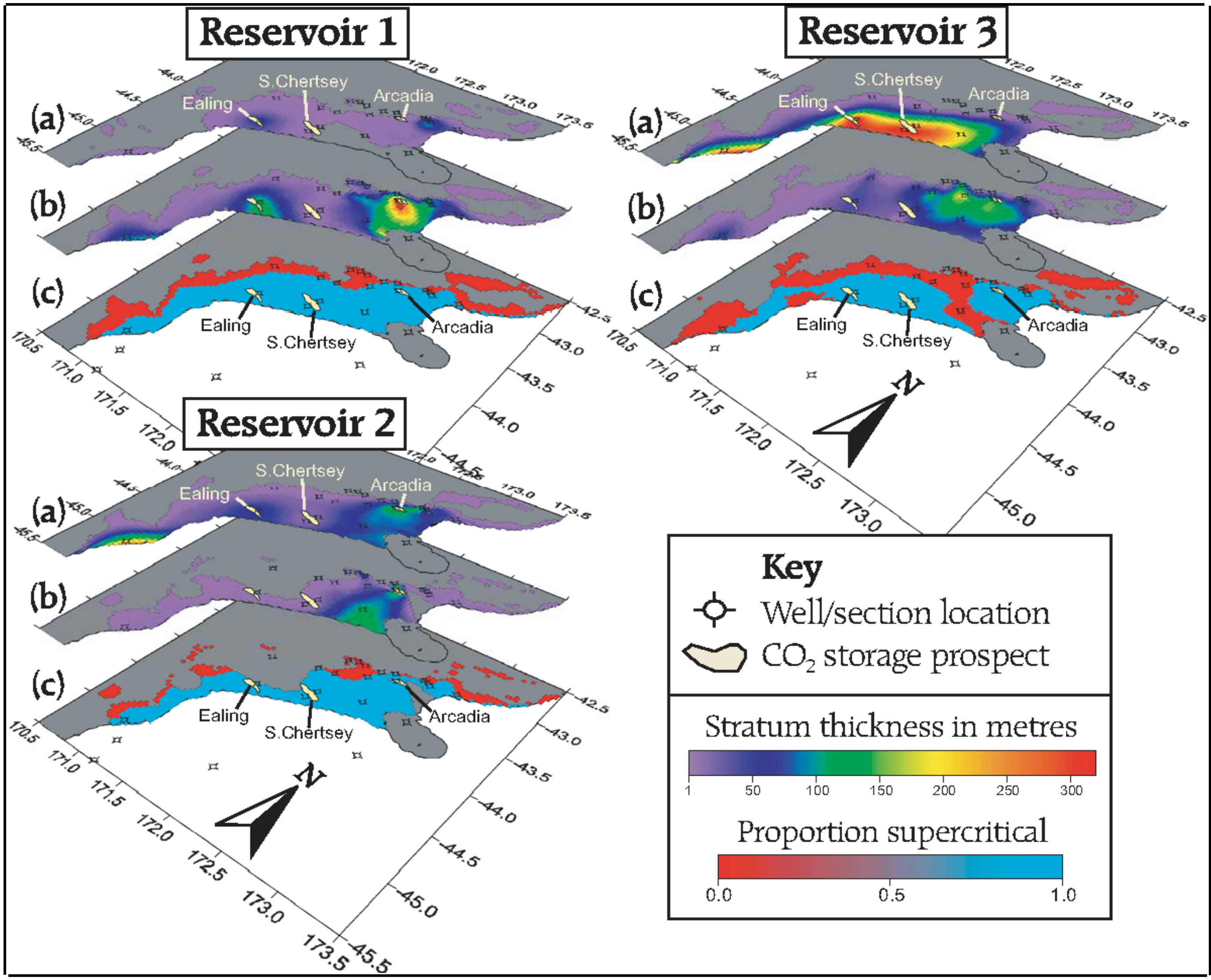

Figure 3: Distributions of reservoirs and seals of the NRSM: BRF&CF (Reservoir 1), CBS&WG (Reservoir 2) and HS (Reservoir 3). Layers (b) show the distributions of reservoir strata. Layers (a) show distributions of the associated seals. These layers correspond to the greyscale of stratum thickness. Layers (c) show the distributions of the reservoirs below (light) and above (dark) the critical surface (second greyscale). Layers feature 3 structural closures: Ealing, South Chertsey, and Arcadia.

Reservoir (Age)	Porosity	Bulk Rock Volume[1] (m^3)	TPV (m^3)	Mean Depth (m)	CO_2 Density (kg/m^3)	CO_2 Equivalent TPV (Gt)	Capacity at 1% Efficiency (Gt)
HS (Eocene)	0.33[2]	3.82E+11	1.25E+11	1071	646	81	**0.81**
WGCBS (Pal.)	0.35	2.24E+11	7.94E+10	1174	647	51	**0.51**
BRCF (Cret–Pal.)	0.31	5.71E+11	1.77E+11	1272	648	115	**1.15**

[1] Volume deeper than minimum depth for supercritical CO_2 storage.

[2] Arithmetic mean of core porosity measurements from 8 stratigraphic drill holes (mean of 33%) and log derived porosity at Ealing-1 and Kowai-1 (32%).

Table 1: Storage capacities for regional, deep saline formations.