PS Suitability of the Dryland Fluvial-Aeolian Sediments and Its Depositional System for CO_2 Sequestration, Analogues Study from Umbum Creek, Lake Eyre, Central Australia*

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Search and Discovery Article #80050 (2009)
Posted May 20, 2009

*Adapted from poster session at AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, 2009

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Abstract

The efficiency of CO_2 geological storage is determined by the depositional system of the sedimentary basins, in which the storage reservoir qualities of subsurface reservoir rocks are primarily controlled by their composition, texture and grain size. The ability to quantifiably predict such porosity and permeability is a significant factor in storage reservoir quality forward modeling.

The degree of reaction, reaction rates and mineralogical storage of CO_2 are dependent on mineral assemblage, concentration of CO_2 in the gas and CO_2-water ratios. Immediately after injection, the CO_2 will be stored as a free phase within the host rock. Over time, it will dissolve into the local formation water and initiate a variety of geochemical reactions.

Sediments from the modern dryland fluvial-aeolian Umbum Creek, western Lake Eyre Basin, Central Australia reflect the nature of the hinterland region, drainage basin and depositional environment. Initial rock compositions such as mineralogy, texture and grain size are the main influence on geochemical processes to become permanently trapped in the sedimentary basin by 'ionic' or 'mineral' trapping.

In the case of the Umbum Creek sands, the medium to coarse grain size, 88-92% of quartz, less than 2% of feldspar and less than 10% of lithic fragments, together with subrounded to rounded grains, moderately well sorting and very little in clay content, leads to a suitable candidate for good storage reservoir quality, if buried. However, the high evaporation conditions in the terminal splay complex environment lead to the growth of gypsum, anhydrite and salt in the sands. A similar analysis of a sedimentary basin could lead to a better assessment of CO_2 geological storage quality prior to sequestration.

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ABSTRACT/SUMMARY

The efficiency of CO_2 geological storage is determined by the depositional system of the sedimentary basins, in which the storage reservoir qualities of subsurface reservoir rocks are primarily controlled by their composition, texture and grain size. The ability to quantifiably predict such porosity and permeability is a significant factor in storage reservoir quality forward modeling.

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1 INTRODUCTION

Carbon dioxide (CO_2) capture and geological storage can contribute to reduce emissions of greenhouse gas provided it is implemented on a large scale. Several types of storage reservoir may provide storage capacities of this magnitude. Conventional geological constraints on finding the right place to store CO_2 include having a porous and permeable reservoir rock (e.g. sandstone) to allow injection and storage of the CO_2, overlain by an impermeable seal rock (e.g. claystone) to retain the injected CO_2 in the geological subsurface (Fig.1) (Bachu et al., 1994).

The injection and storage of carbon dioxide (CO_2) in subsurface reservoirs results in chemical interaction between CO_2, the formation waters and the rock itself. However, in order to understand the behaviour of CO_2 migration and long term safe storage of CO_2 such as residual, mineral and solubility trapping in the subsurface, a petrological assessment of the reservoir and seal rocks with respect to the depositional system will be undertaken. The objective of this poster is to provide a comprehensive review of the site characterisation and reservoir quality for CO_2 storage with respect to dryland fluvial-aeolian sediments and its depositional setting. For this purpose, an analogue study was conducted of the dryland fluvial-aeolian depositional settings of western Lake Eyre Basin, Central Australia.

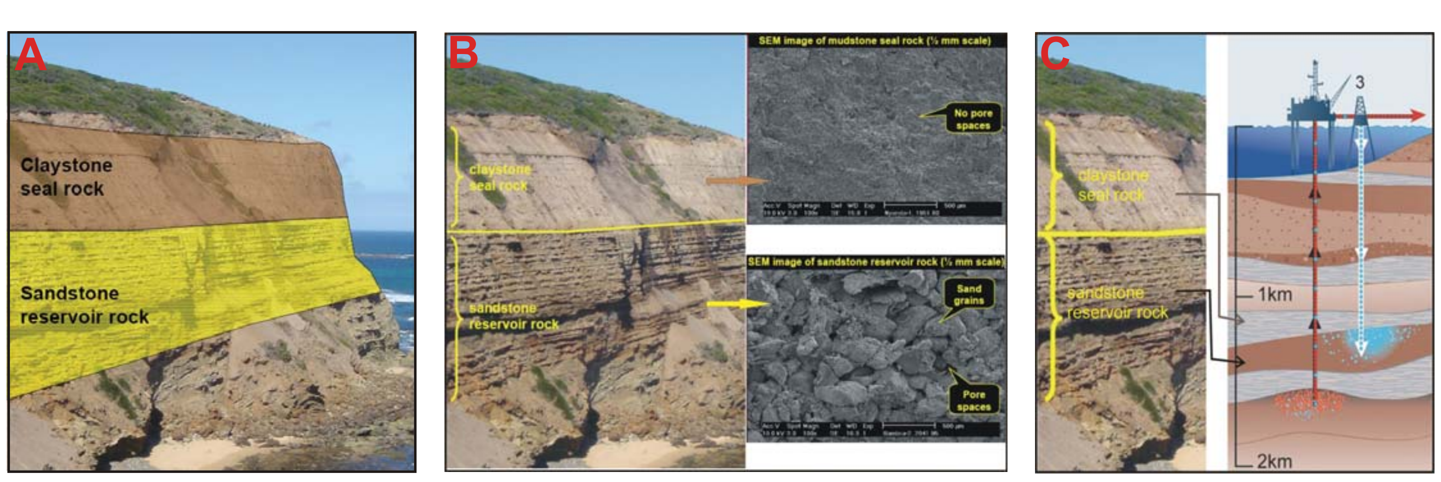


Figure 1. Illustrating the various steps involved in geological storage of CO_2. A. Site identification, B. Site characterisation and C. Injection and storing CO_2.

2 GEOLOGICAL STORAGE

CO_2 can be stored geologically by a variety of different options (Fig. 2). Of these, the three main alternatives are: saline formations; oil and gas fields (once depleted or in conjunction with enhanced oil or gas recovery); and coal seams (deep unmineable or in conjunction with enhanced coal seam methane) (Bachu & Gunter, 1999; Cook et al., 2000).

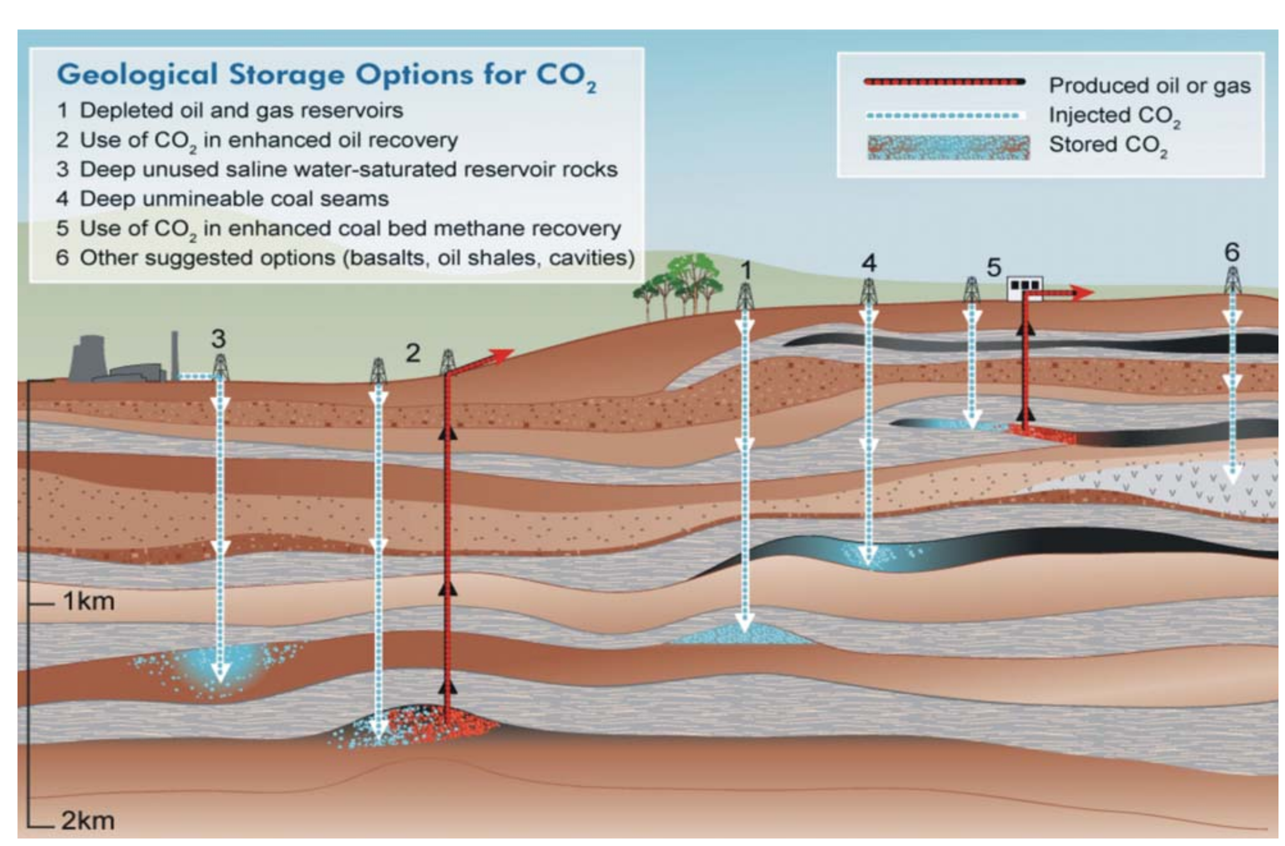


Figure 2. Options for the geological storage of carbon dioxide (CO_2)

3 PROPERTIES OF CO_2

The physical state of CO_2 varies with temperature and pressure as shown in Figure 3a & b. At low temperatures CO_2 is a solid; on warming, (if the pressure is below 5.1 bar) the solid will sublime directly into the vapour state. At intermediate temperatures (between −56.5°C and 31.1°C), CO_2 may be turned from a vapour into a liquid by compressing it to the corresponding liquefaction pressure (and removing the heat produced). At temperatures higher than 31.1°C (if the pressure >7.38MPa (73.9 bar), the pressure at the critical point), CO_2 is said to be in a supercritical state where it behaves as a gas. Indeed under high pressure, the density of the gas can be high, approaching or even exceeding the density of liquid water. This is an important aspect of CO_2's behaviour and is particularly relevant for its storage.

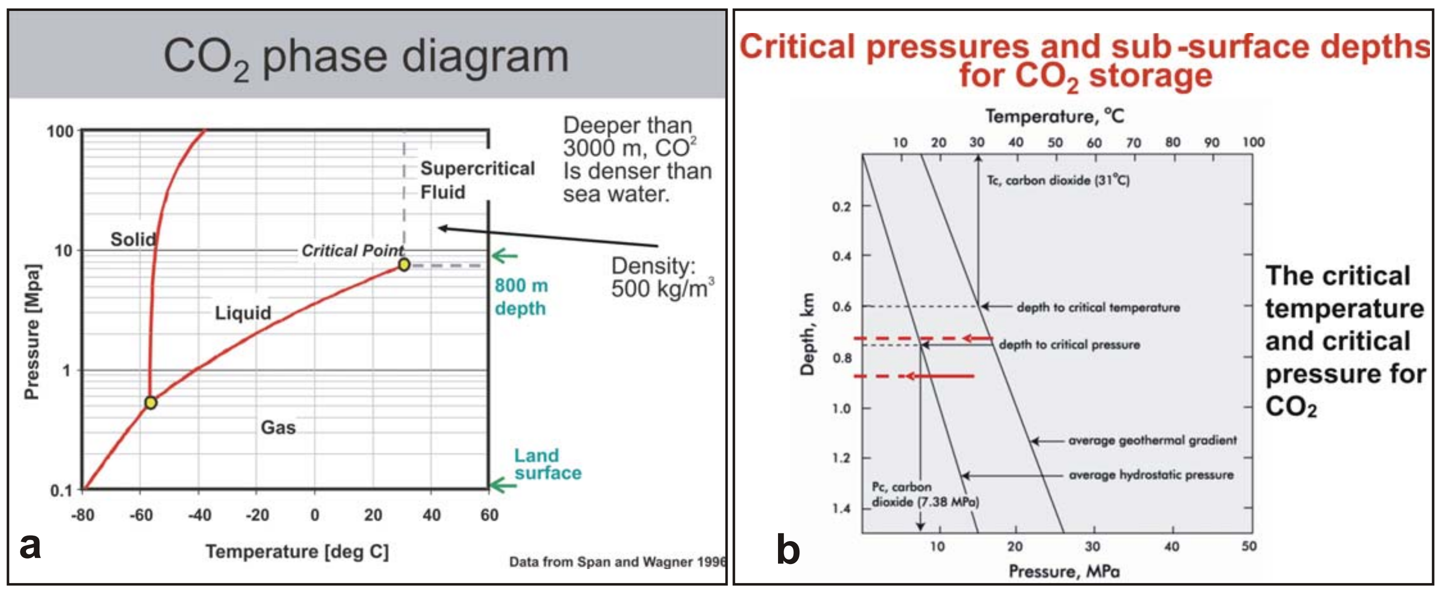


Figure 3. (a) CO_2 phase diagram (after Bachu, 2000). (B) Critical temperature and pressure for CO_2 sequestration

The dissolution of CO_2 in water (this may be seawater, or the saline water in geological formations) involves a number of chemical reactions between gaseous and dissolved carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^{2-}) which can be represented as follows:

$$CO_{2\,(g)} \rightleftharpoons CO_{2\,(aq)} \quad (1)$$

$$CO_{2\,(aq)} + H_2O \rightleftharpoons H_2CO_{3\,(aq)} \quad (2)$$

$$H_2CO_{3\,(aq)} \rightleftharpoons H^+_{(aq)} + HCO^-_{3\,(aq)} \quad (3)$$

$$HCO^-_{3\,(aq)} \rightleftharpoons H^+_{(aq)} + CO^{2-}_{3\,(aq)} \quad (4)$$

Addition of CO_2 to water initially leads to an increase in the amount of dissolved CO_2 (1). The dissolved CO_2 reacts with water to form carbonic acid (2). Carbonic acid dissociates to form bicarbonate ions (3), which can further dissociate into carbonate ions (4). The net effect of dissolving anthropogenic CO_2 in water is the removal of carbonate ions and production of bicarbonate ions, with a lowering in *p*H.

The depth of CO_2 injection and density of CO_2 are important parameters to consider for intermediate storage of carbon dioxide. For ease of transport and greater storage capacity, CO_2 is best injected as a dense, supercritical fluid. The critical point where CO_2 enters the supercritical phase is defined as 31.1°C and 7.38 MPa (Fig. 3a) (Holloway & Savage, 1993; Bachu, 2000). Based on worldwide average geothermal and hydrostatic pressure conditions, this equates to an approximate minimum subsurface depth of about 800 m (Fig. 3c) (Holloway & Savage, 1993). Below this depth (under normal sedimentary basin conditions) supercritical CO_2 is 30–40% less dense than a typical saline formation water under the same conditions (Ennis-King & Paterson, 2001, 2002). Lighter CO_2 will naturally rise upwards by buoyancy through the reservoir rock until trapped by various physical, hydrodynamic or geochemical trapping mechanisms (although in the longer term storage, CO_2 saturated brine may sink under the right conditions [Ennis-King & Paterson, 2005]).

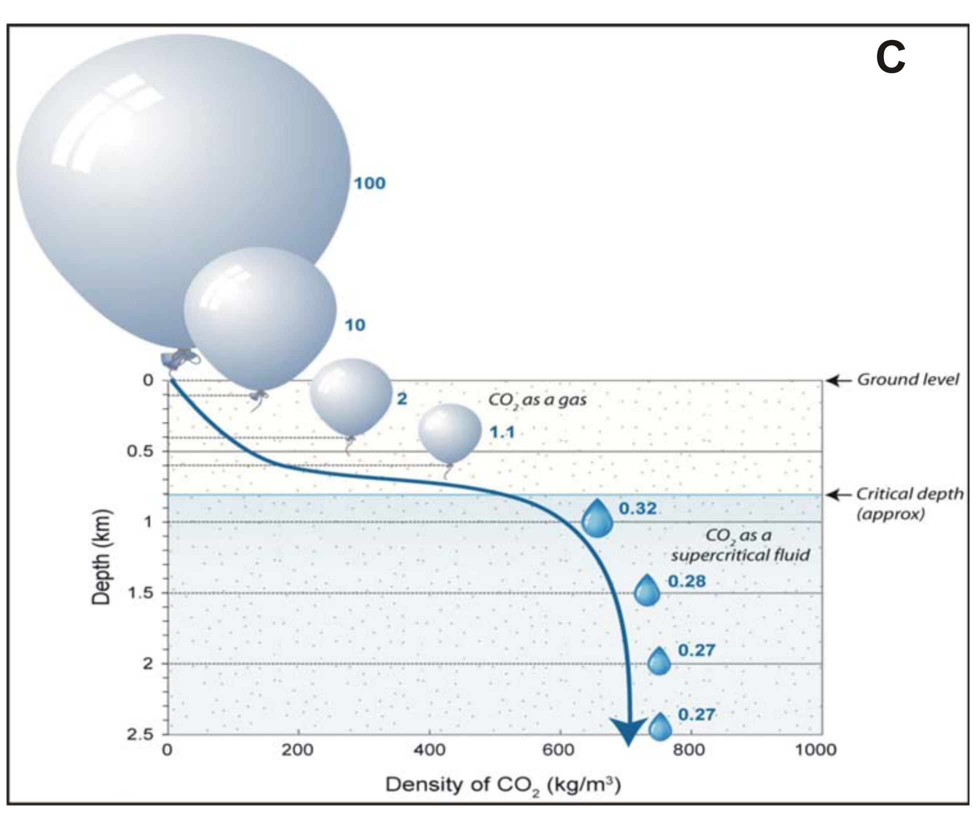


Figure 3c. Variation of density with depth (assuming hydrostatic pressure, geothermal gradient of 25°C/km and surface temperature of 15°C).

The efficiency of CO_2 storage in geological media, defined as the amount of CO_2 stored per unit volume (Brennan and Burruss, 2003), increases with increasing CO_2 density. Storage safety also increases with increasing density, because buoyancy, which drives upward migration, is stronger for a lighter fluid. Density increases significantly with depth while CO_2 is in gaseous phase, increases only slightly or levels off after passing from the gaseous phase into the dense phase and may even decrease with a further increase in depth, depending on the temperature gradient (Ennis- King and Paterson, 2001; Bachu, 2003).

4 CO_2 FLOW & TRANSPORT PROCESSES

Once injected into the formation, the primary flow and transport mechanisms that control the spread of CO_2 include:

Fluid flow (migration) in response to pressure gradients created by the injection processes;

Fluid flow in response to natural hydraulic gradient;

Buoyancy caused by the density differences between CO_2 and the formation fluids;

Diffusion;

Dispersion and fingering caused by the formation heterogeneities and mobility contrast between CO_2 and formation fluid;

Dissolution into the formation fluid;

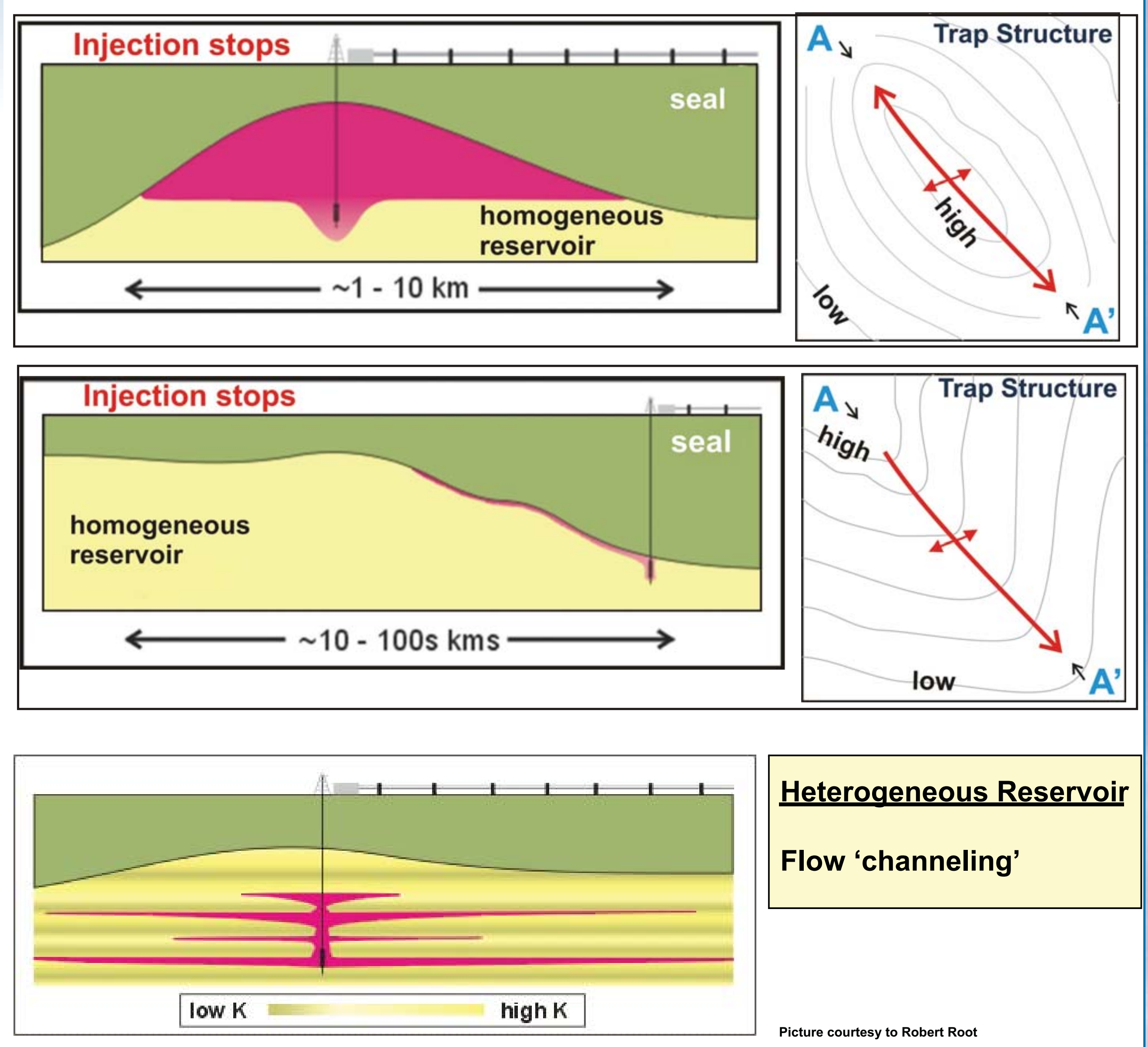
Mineralization;

Pore space (relative permeability) trapping;

Adsorption of CO_2 onto organic material.

5 CONCEPTUAL CO_2 STORAGE SCENARIO

The storage mechanism known as physical trapping of CO_2 below low permeability seals (caprocks), such as very low- permeability shale or salt beds, is the principal means to store CO_2 in geological formations. Sedimentary basins have such closed, physically bound traps or structures, which are occupied mainly by saline water, oil and gas. Structural traps include those formed by folded or fractured rocks. Stratigraphic traps are formed by changes in rock type caused by variation in the setting where the rocks were deposited.



Amount of CO_2 geologically stored influenced by:

- Rate of CO_2 migration
- Style of multiphase flow
- Rate of CO_2 dissolution
- Rate of chemical reaction with minerals

Controlled by many variables, including:

- Reservoir and seal structure
- Stratigraphic architecture
- Reservoir heterogeneity
- Faults/fractures
- Pressure/temperature conditions
- Hydrodynamics and chemistry of *in situ* formation fluids

Figure 4. Illustrates the conceptual CO_2 storage in homogenous and heterogeneous reservoirs

Reservoir heterogeneity also affects CO_2 storage efficiency and hence intermediate storage. The density difference between the lighter CO_2 and the reservoir oil and/or saline water leads to movement of the CO_2 to the top of the reservoir; particularly, if the reservoir is relatively homogeneous and has high permeability, it is well suited for intermediate storage of CO_2. This negatively affects the CO_2 storage and oil recovery. Consequently, reservoir heterogeneity may have a positive effect, slowing down the rise of CO_2 to the top of the reservoir and forcing it to spread laterally, giving more complete invasion of the formation and greater storage potential (Flett et al., 2005).

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6 TRAPPING MECHANISMS

In any geological storage site, the injected CO_2 will ultimately be trapped by a number of the mechanisms. The type of trapping, if and when it occurs, is dependent on the dynamic flow behaviour of the CO_2 and the time-scale involved. With increasing time, the dominant storage mechanism will change and typically the storage security also increases. Figure 5 is a simple representation of CO_2 storage and how the trapping mechanism alters over time. Because of multiple storage mechanisms working at multiple length and time scale, the shallow crust should attenuate mobile free-phase CO_2 plumes, trap them residually, & ultimately dissolve them. This means that over time risk decreases and permanent trapping increases. For example, the initial storage mechanism will dominantly be physical structural and stratigraphic trapping of the immiscible-phase CO_2. With increasing time and migration, more CO_2 is trapped residually in the pore space and is dissolved in the formation water to increase the storage security. Finally, mineral trapping may occur by precipitation of new carbonate minerals after reaction of the dissolved CO_2 with the host rock mineralogy, thus permanently trapping the CO_2 (IPCC, 2005).

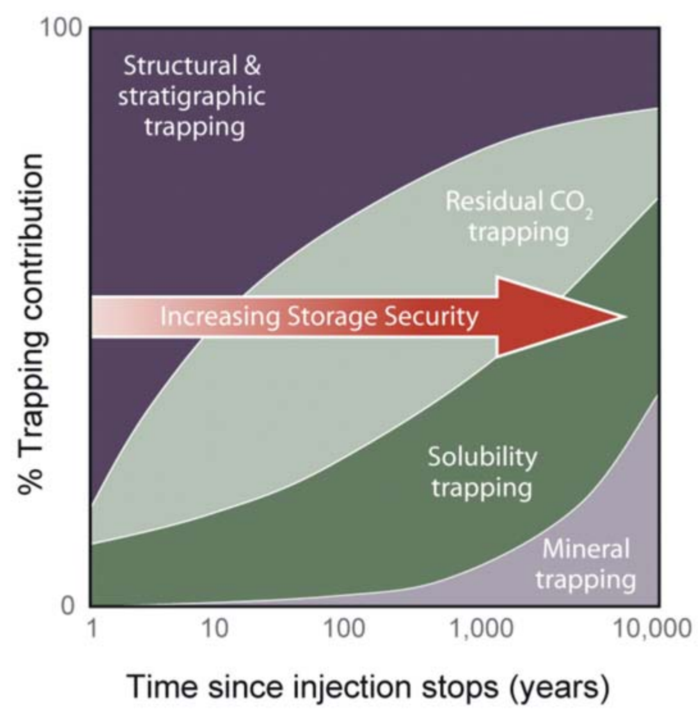


Figure 5. Schematic representation of the change of dominant trapping mechanisms and increasing CO_2 storage security with time (IPCC, 2005).

7 STRUCTURAL/STRATIGRAPHIC TRAPPING

Structural/stratigraphic trapping relates to the free-phase (immiscible) CO_2 that is not dissolved in formation water. When supercritical CO_2 rises upwards by buoyancy it can be physically trapped in a structural or stratigraphic trap (as a result of the CO_2 being the non-wetting phase). The nature of the physical trap depends on the geometric arrangement of the reservoir and seal units. Common structural traps include anticlinal folds or tilted fault blocks (Fig 6a) and typical stratigraphic traps include those created by a lateral change in facies up-dip or a depositional pinch-out (Fig 6b). There are numerous variations of structural and stratigraphic traps (Fig 7A-D), plus combinations of both structural and stratigraphic elements that can provide physical traps for geological storage of CO_2 (Kaldi & Gibson-Poole, 2008).

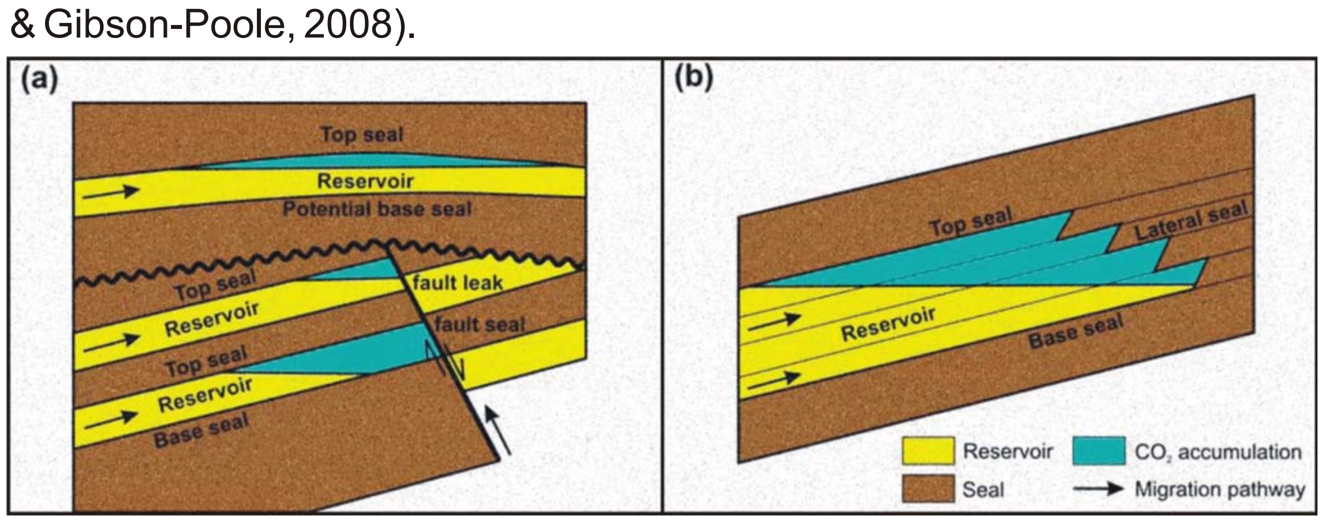


Figure 6. Examples of (a) structural and (b) stratigraphic physical traps for CO_2 (modified from Biddle & Wielchowsky, 1994).

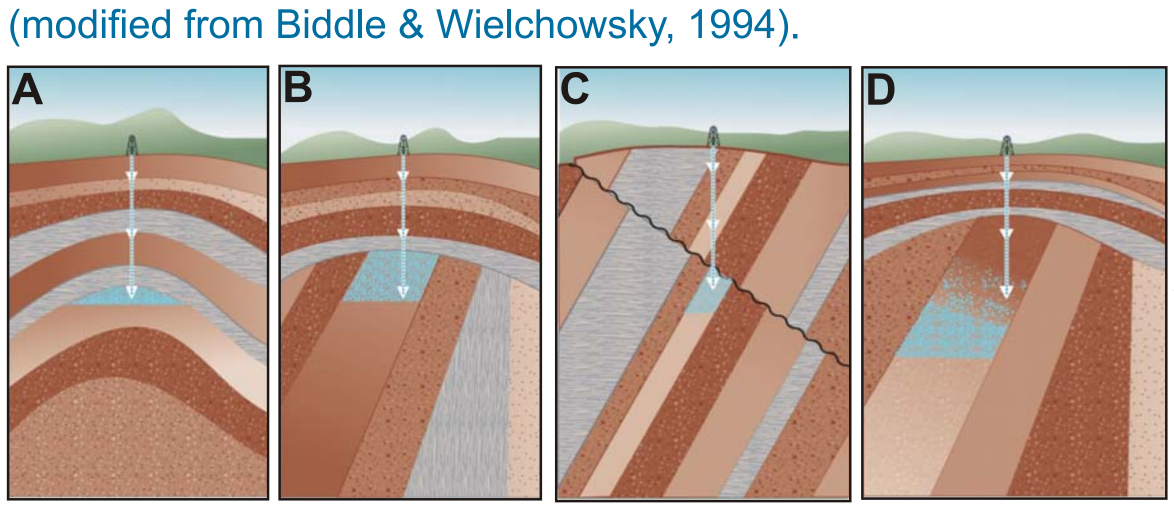


Figure 7. Showing examples of structural and stratigraphic trapping
A. Anticline trapping
B. Unconformity trapping
C. Fault trapping
D. Facies change trapping

In hydrodynamic trapping the flow of the injected freephase CO_2 is dependent on the dip of the sealing horizon and the flow velocity and direction of the *in situ* formation water. In horizontal or gently dipping reservoirs, this can lead to very long residence times (thousands to millions of years) (Fig 8) (Bachu et al., 1994).

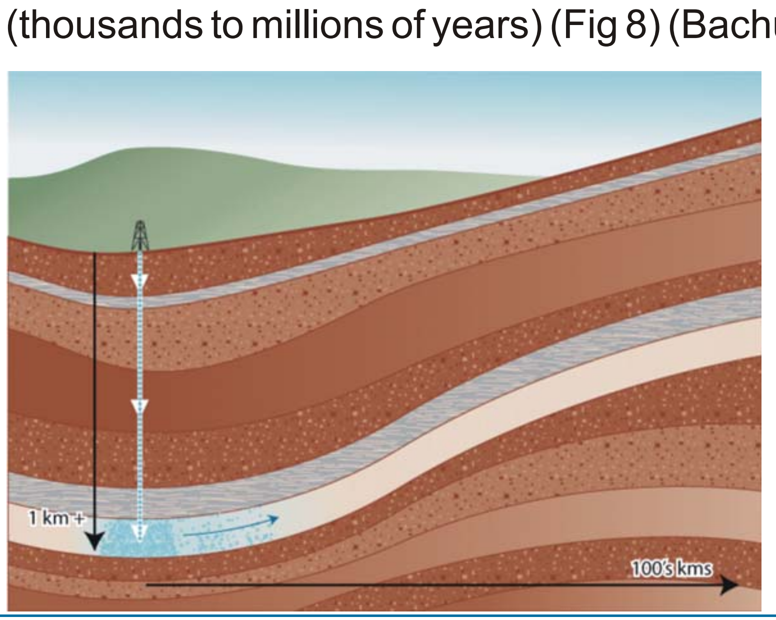
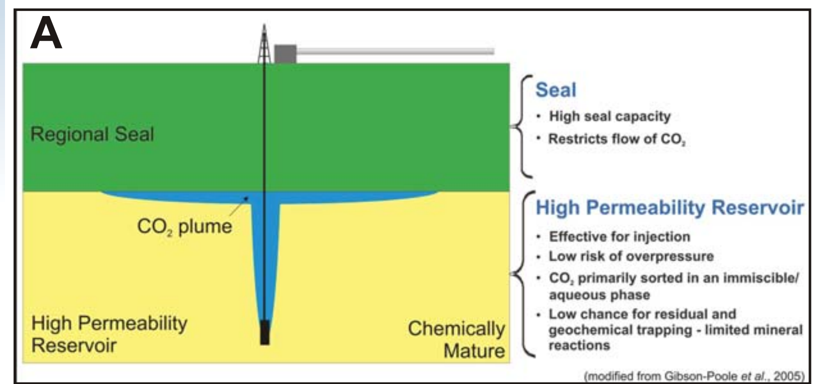


Figure 8. Hydrodynamic trapping of CO_2, where the CO_2 migration pathway is 10s to 100s km long allowing for a long residence time (Bachu et al., 1994; Kaldi & Gibson-Poole, 2008).

8 MINERAL TRAPPING

Mineral trapping is quite variable from formation to formation and thus needs to be examined as part of the site characterisation process for storage site selection. Mineral trapping is a function of the mineralogy of the reservoir rock, the chemical composition of the formation water and the formation temperature and pressure. In addition, potential reactions depend on the contact surface (interface) between the mineral grains and the formation water containing dissolved CO_2, and on the flow rate of fluids through the rock (Gunter et al., 2004).



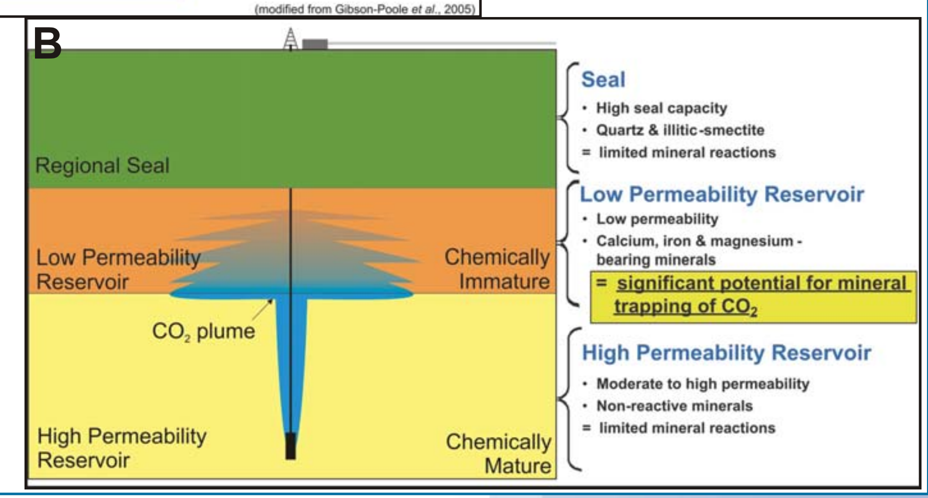


Figure 9. Illustrates the CO_2 storage through mineral trapping in an ideal reservoir. A. High permeability reservoir scenario B. Combination of high permeability and low permeability reservoir rocks.

9 RESIDUAL TRAPPING

Residual trapping occurs when the CO_2 becomes trapped in the pore space as a residual immobile phase by capillary forces (Fig 10) (Ennis-King & Paterson, 2001; Flett et al., 2005). At the tail of the migrating CO_2 plume, imbibition processes are dominant as the formation water (wetting-phase) imbibes behind the migrating CO_2 (non-wetting phase). When the concentration of the CO_2 falls below a certain level, it becomes trapped by capillary pressure forces and ceases to flow (Ennis-King & Paterson, 2001; Flett et al., 2005). Therefore, a trail of residual, immobile CO_2 is left behind the plume as it migrates upward (Juanes et al., 2006). Residual CO_2 saturation values vary between 5–30 % based on typical relative permeability curves (Ennis-King & Paterson, 2001). Over time, the residually trapped CO_2 dissolves into the formation water (Ennis-King & Paterson, 2001; Flett et al., 2005).

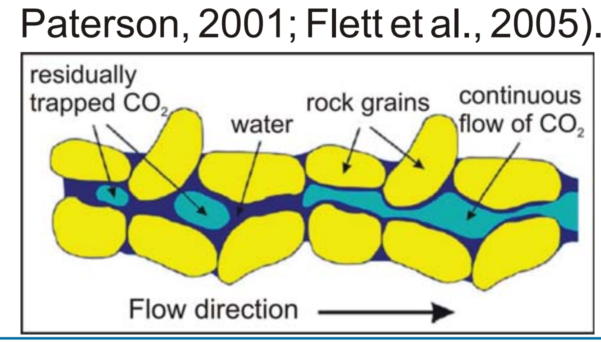
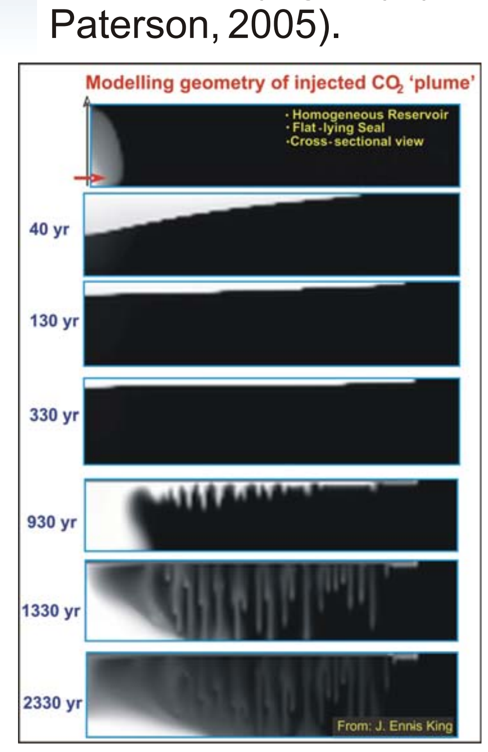


Figure 10. Residual trapping of Co_2

10 SOLUBILITY TRAPPING

Solubility trapping relates to the CO_2 dissolved into the formation water (Koide et al., 1992). Carbon dioxide solubility increases with increasing pressure and decreases with increasing temperature and water salinity. Carbon dioxide may mix with, and then dissolve in, formation water through the processes of diffusion, dispersion and convection. The density of the CO_2-saturated water increases to become about 1 % more than that of the unsaturated water. The dense CO_2-saturated water overlying less dense unsaturated water creates a density instability and plume of CO_2-rich water flow downward (Fig 11) (Ennis-King & Paterson, 2002; Ennis-King & Paterson, 2005).



Stratigraphic heterogeneities also improve solubility trapping, as they increase the tortuosity of the CO_2 migration path, and accordingly the CO_2 contacts larger volumes of formation water into which it can dissolve (Flett et al., 2005). The time-scale for complete dissolution is critically dependent on the vertical permeability.

Figure 11. Solubility trapping simulation showing the high-density Co_2-saturated brine (grey colours) sinking into the brine column below (white colour) (Ennis-King & Patterson, 2005).

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11 ANALOGUE STUDY: UMBUM CREEK, WESTERN LAKE EYRE BASIN, AUSTRALIA.

Introduction: The Lake Eyre Basin is a wide shallow, low gradient intracratonic basin which records a complex history of alluvial, lacustrine and aeolian, reflecting several tens of millions years of environmental change. Lake Eyre is the fourth largest terminal playa lake in the world. It is a vast downwarped area of low relief and internal drainage of 1,140,00 km^2. The Umbum Creek catchment area drains the Davenport Ranges, covering approximately 200 km^2 of Palaeo-Proterozoic metasediments and volcanics, Neo-proterozoic metasediments and Mesozoic and Cainozoic sedimentary rocks of the Eromanga Basin. Additionally, there is reworking of Neogene gibber plains, aeolian sand dunes, and fluvial sands at the base of the Davenport Ranges. Umbum Creek flows into a modern ephemeral braid-delta/terminal splay complex build into the arid Lake Eyre playa.

The analogue study of the Umbum Creek fluvio-aeolian-dominated terminal splays associated with dryland depositional environments are significant in determining the site characteristics for CO_2 storage in intracratonic reservoirs in many subsurface basins around the world. Potential reservoirs include the Permian Upper Rotliegend Group of northern Europe; the Jurassic Norphlet Formation sandstone reservoirs in Mobile Bay, Alabama, USA; and the Mesozoic Etjo Sandstone Formation, northwest Namibia.

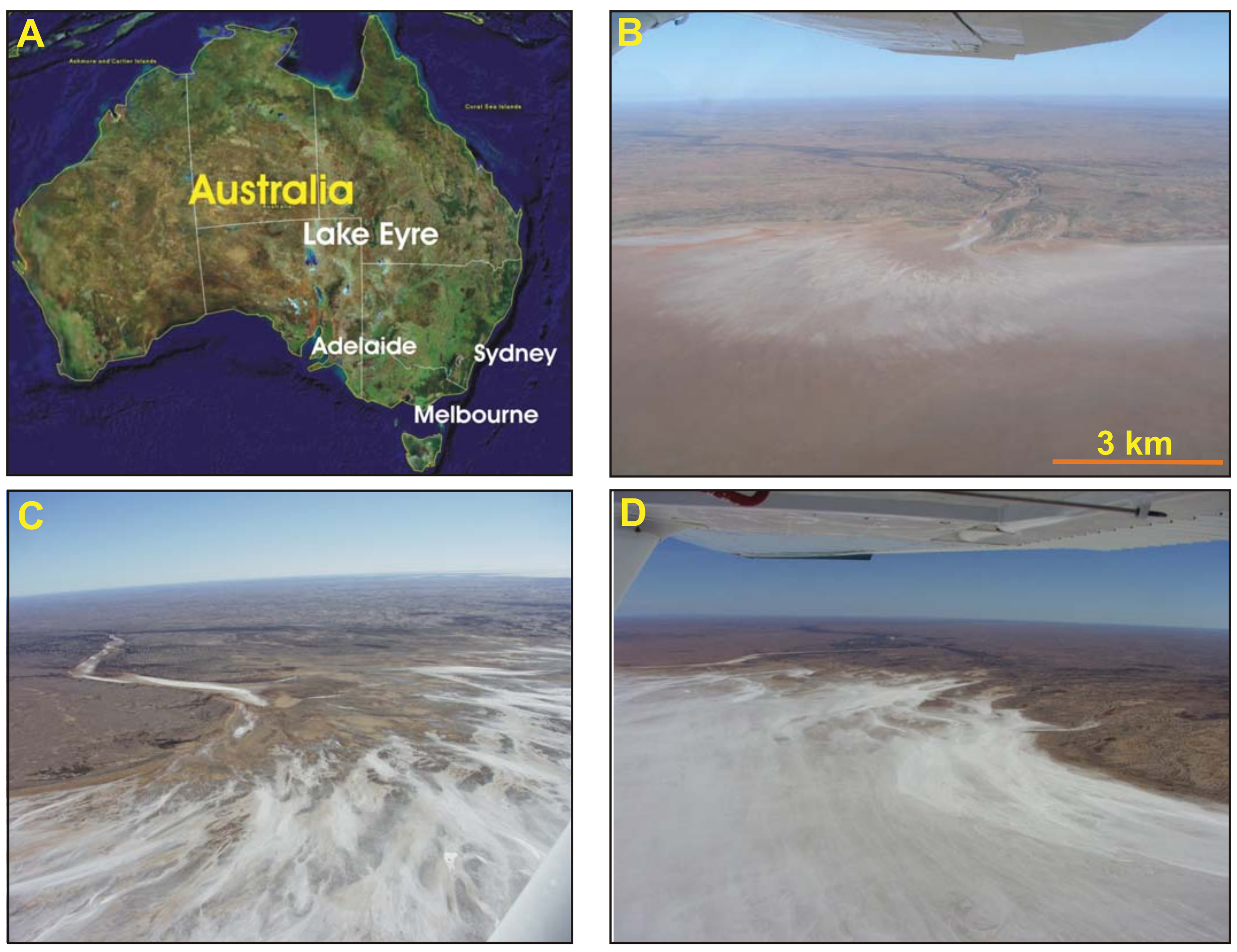


Figure 12. A. Location map. B, C and D. Aerial view of Umbum Creek Terminal splay

12 SEDIMENTOLOGY & ARCHITECTURE OF THE UMBUM CREEK TERMINAL SPLAY

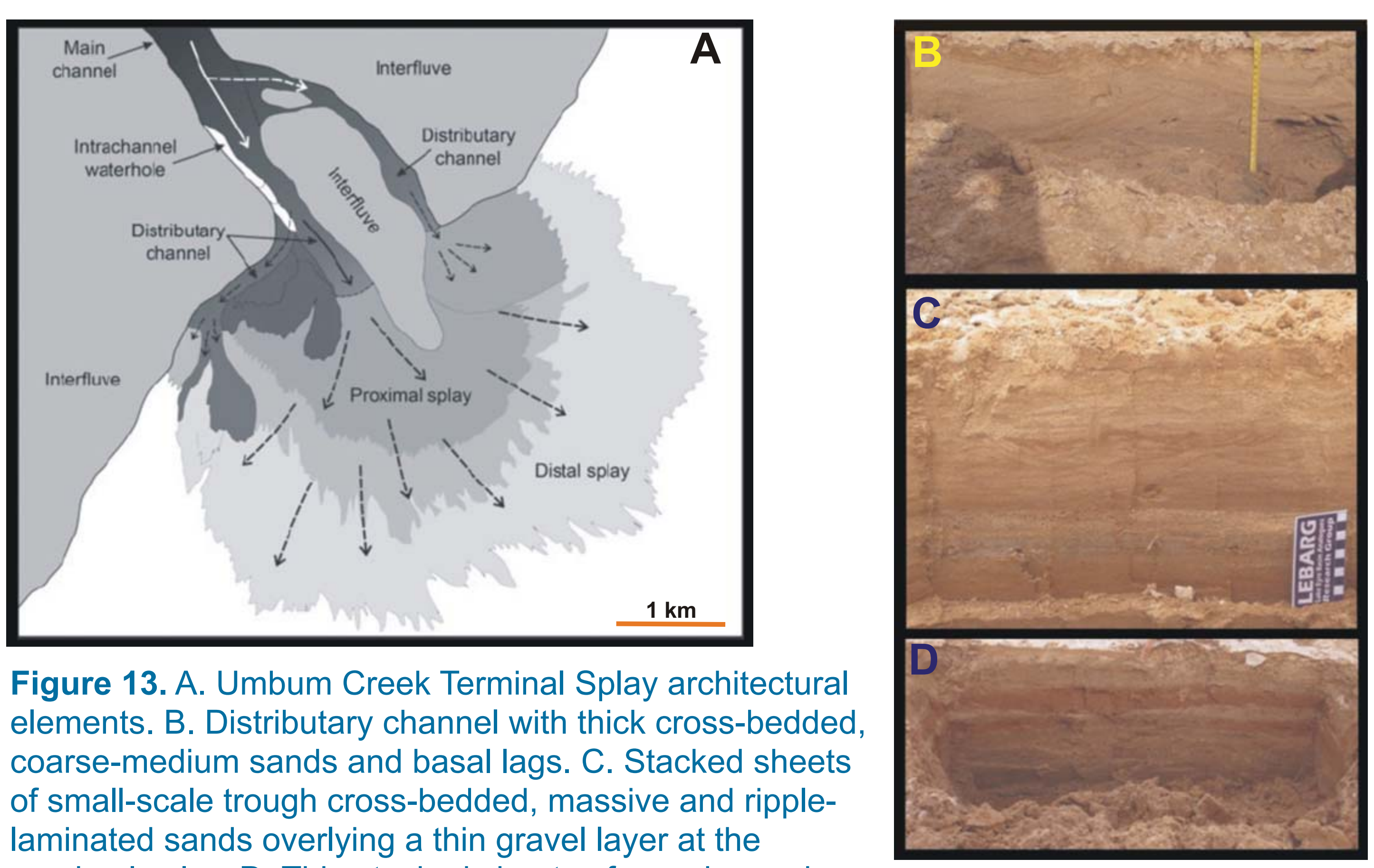


Figure 13. A. Umbum Creek Terminal Splay architectural elements. B. Distributary channel with thick cross-bedded, coarse-medium sands and basal lags. C. Stacked sheets of small-scale trough cross-bedded, massive and ripple-laminated sands overlying a thin gravel layer at the proximal splay. D. Thin stacked sheets of massive and ripple-laminated fine sands, interlayering of silt and clay as seen in the distal splay.

Variability in splay morphology and architecture reflects the influence of different depositional processes operating to build the splay complexes. Multiple factors are thought to influence splay development, including catchment size, discharge, vegetation, grain-size distribution and composition of fluvial-aeolian transported sediment, as well as the influence of successive lake filling events which may result in a change from sheetflood to deltaic processes.

Three primary facies associations have been identified which subdivide the Umbum Creek terminus into distributary channel, proximal and distal splay sections. Proximal splay sediments are characterized by erosionally based, relatively thick (> 100 mm), stacked sheets of coarse-medium sand, which commonly display trough & planar cross-bedding. The distal splay is characterized by thin (generally < 50 mm) massive beds of very fine sand, silt and clay.

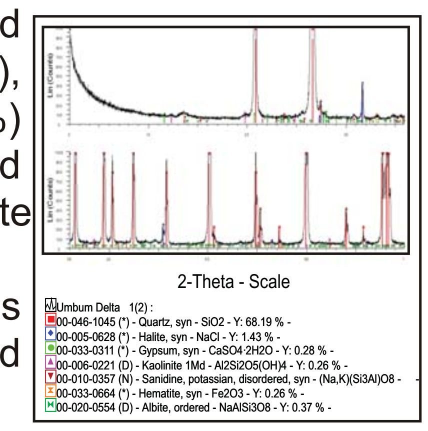
13 KEY OBSERVATIONS

The Umbum Creek terminal splay complex covers an area approximately 300 km^2.

Grain Size: Grain-size estimates were taken qualitatively from logging trenches in the field and measured quantitatively from twenty four samples which were dried and sieved in the laboratory.

The proximal splay has an average grain-size distribution of medium-coarse-grained sand. The distal splay sediments have an average grain size of silt to medium-grained sand. Sorting improves with increasing distance from the feeder channel. The grains are subrounded to well rounded. This is indicative of the fluvio-aeolian influence on the sediments.

Significance: This results in moderate to low compaction, which preserves porosity and permeability for CO_2 injection and migration.



Mineralogy (composition): The modern sand composition is monocrystalline quartz (60-70%), polycrystalline quartz (10-20%), lithics (<15%) and feldspar (<5%). The clay fraction is dominated by quartz. However, clay minerals, feldspar, halite and gypsum comprise approximately 30% of the clay fraction. Sediment provenance comprises granitic, volcanic, metasediments and sedimentary rocks.

Significance: The high quartz content provides high mechanical and chemical stability, thus preserving porosity and permeability for CO_2 migration .

Grain coating: The shape of the grains in the terminal splay complex is angular to well rounded. Grain angularity promotes formation of cements and grain coatings. Early grain coating is aluminium silicates, titanium oxide and clay minerals. Quartz, halite and gypsum are the other cements identified within the terminal splay complex.

Significance: Cementation destroys porosity. However, late diagenesis (dissolution) creates secondary porosity and permeability, which increases CO_2 migration and later mineralization trapping.

Arrows showing the percussion marks (A & C) and roundness of the aeolian grains(B)

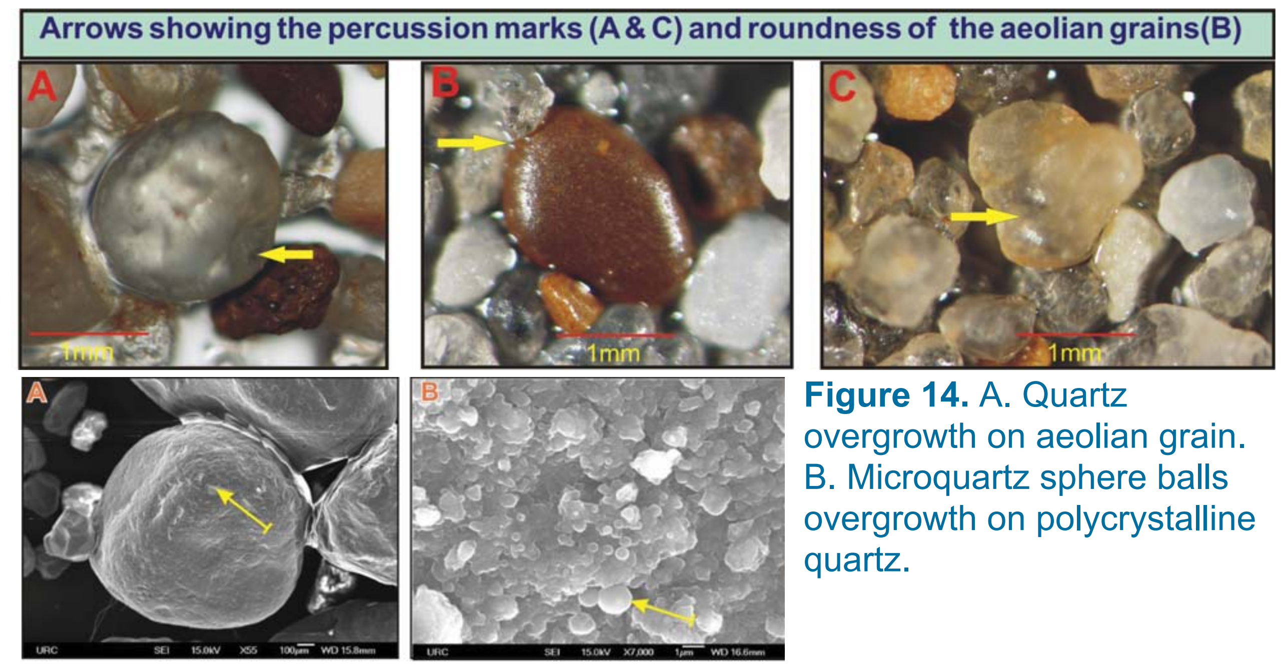


Figure 14. A. Quartz overgrowth on aeolian grain. B. Microquartz sphere balls overgrowth on polycrystalline quartz.

Sedimentary structures (bed forms): The main characteristic features are thin beds (0.1 to 0.3m) which comprise coarse-medium sands with gravel layers, trough cross-bedded, thinly stacked sheets of ripple-laminated fine sands alternating with layers of silt and clay. The predominance of horizontal laminations, widespread presence of mud drapes and mud intraclasts are associated with aeolian sand beds and cemented with silica, halite and gypsum.

Significance: CO_2 migration in the less porous and permeable distal splay deposits is slow due to reservoir heterogeneity, thus creating new mineralization. Subsequently, reservoir heterogeneity has a positive effect in slowing down the rise of CO_2 to the top of the reservoir.

Figure 15. A. Cross-beds, laminations. B. Association of aeolian sediments. C. Laminations of fine silt and clay layers.

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14 RESERVOIR CHARACTERIZATION OF UMBUM TERMINAL SPLAY FOR CO2 SEQUESTRATION

Storage Potential: Storage site requirements depend on trapping mechanisms and geological depositional setting. The reservoir characteristics are the major criteria for selecting sites for long or intermediate term storage of CO_2. Umbum Creek terminal splay deposits (of western Lake Eyre Basin) have the potential to be used as analogues for geological storage of CO_2.

Reservoir Heterogeneity: Reservoir heterogeneity affects CO_2 storage efficiency and hence long or intermediate term storage. The density (buoyancy) difference between the supercritical CO_2 and the reservoir oil and/or saline water leads to movement of the CO_2 along the top of the reservoir; particularly, if the reservoir is relatively homogeneous and has high permeability, it is well suited for intermediate storage of CO_2. Consequently, reservoir heterogeneity may have a positive effect, slowing down the rise of CO_2 to the top of the reservoir and forcing it to spread laterally, giving more complete invasion of the formation and greater storage potential (Flett et al., 2005). With respect to the Umbum Creek terminal splay complex, the proximal splay formations facilitate fast amalgamation of CO_2 because of high porosity and permeability within the rocks. However, the widespread interlayered clay and silt laminations in the distal splay deposits reduce the migration of CO_2. Thus, the dryland depositional setting and the heterogenous reservoir nature of Umbum Creek terminal splay suggest that it is suitable for intermediate and long term storage purposes.

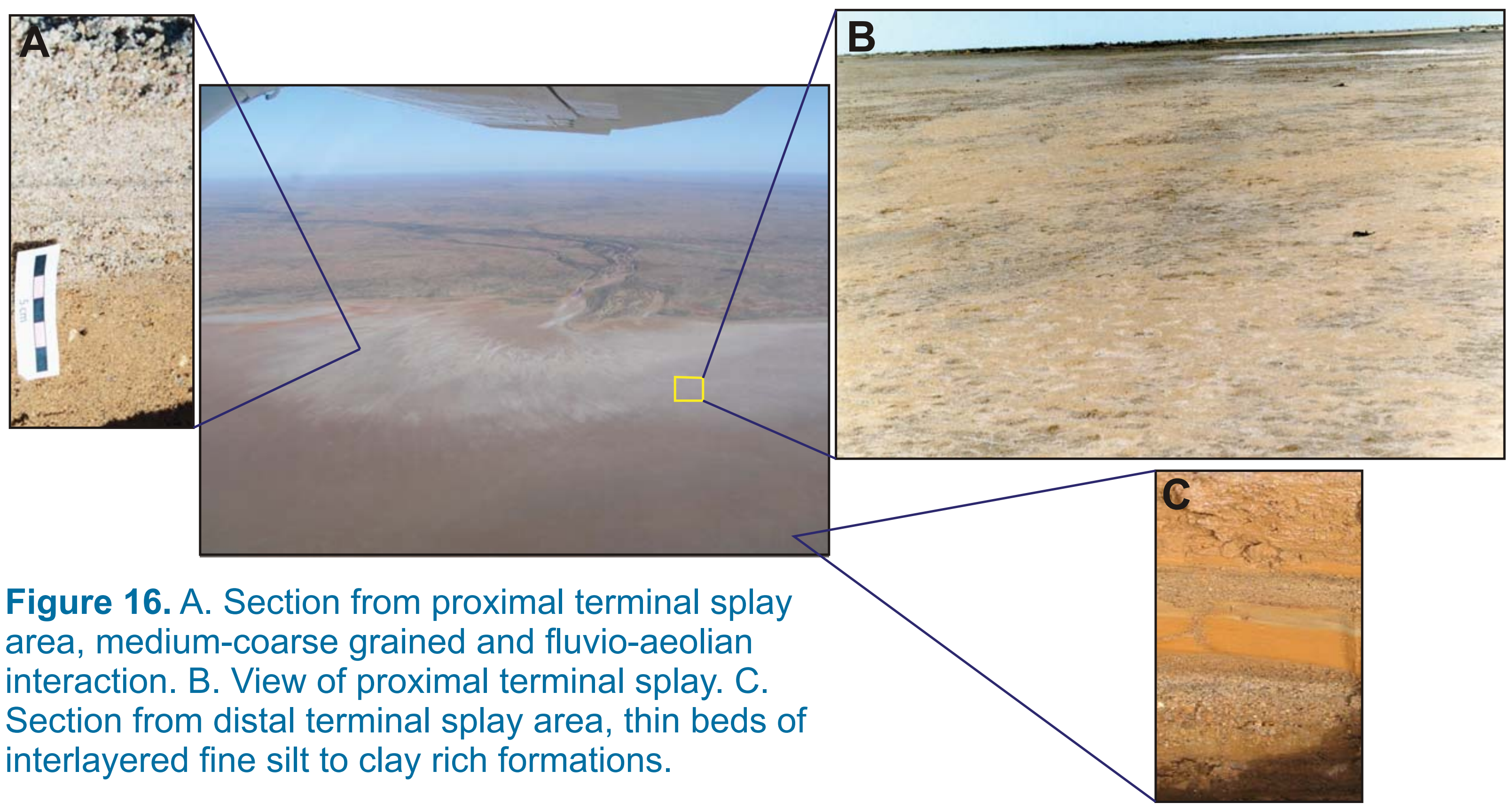


Figure 16. A. Section from proximal terminal splay area, medium-coarse grained and fluvio-aeolian interaction. B. View of proximal terminal splay. C. Section from distal terminal splay area, thin beds of interlayered fine silt to clay rich formations.

Saline Aquifers: When CO_2 is injected into a deep saline formation in a (liquid-like) supercritical phase, it is immiscible in water. Because supercritical CO_2 is much less viscous (flows more easily) than water and oil (by an order of magnitude or more), migration is controlled by the contrast in mobility of CO_2 and the *in situ* formation fluids (Celia et al., 2005). Thus due to the comparatively high mobility of CO_2, some of the oil or water is displaced, leading to an average saturation of CO_2 in the range of 30–60%.

In saline formations, the comparatively large density difference (30–50%) between CO_2 and formation water creates strong buoyancy forces that drive CO_2 upwards. The upward migration of the buoyant plume of injected CO_2, however, may not be evenly distributed. This is because the presence of a lower permeability layer will act as a barrier/baffle and cause the CO_2 to migrate laterally, thus filling any stratigraphic or structural trap it encounters. This creates conditions where part of the injected CO_2 is able to dissolve in the formation water. Due to changing formation water *p*H, solubility trapping occurs. Solubility trapping eliminates the buoyant forces that drive CO_2 upward migration through the reservoir.

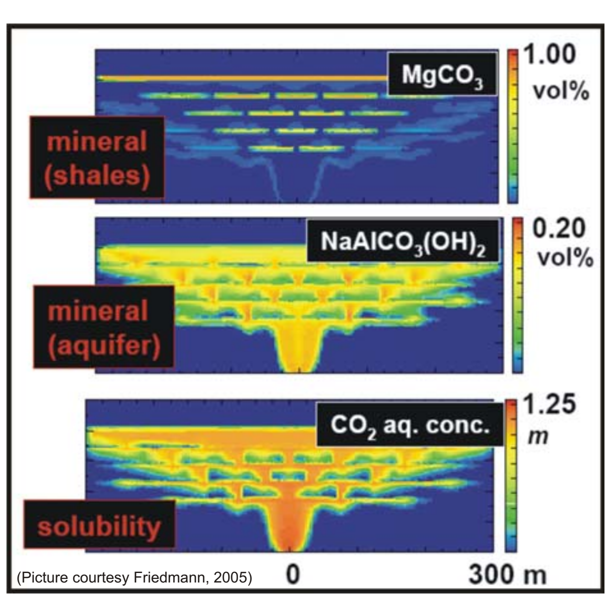
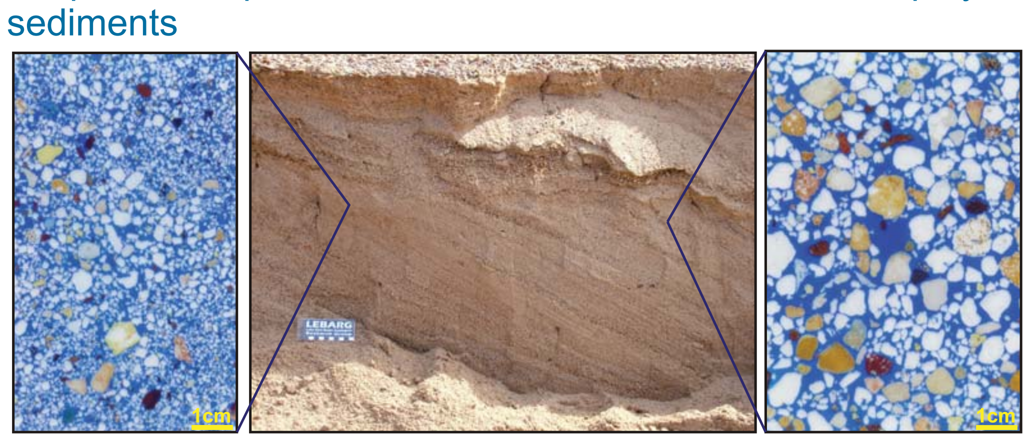


Figure 17. Illustrates mineral trapping mechanisms in shale and aquifer section of the formation and solubility trapping in deep saline aquifer formations. Thin section from the splay sediments



The residual trapping of CO_2 may immobilize significant amounts of CO_2. Studies show that when the degree of trapping is high and CO_2 is injected at the bottom of a highly porous and permeable heterogenous formation, all of the CO_2 may be trapped by this mechanism, even before it reaches the caprock at the top of the formation. While this effect is formation-specific (depositional setting), Holtz (2002) has demonstrated that residual CO_2 saturations may be as high as 15–25% for storage formations.

The combined effects of dissolution, solubility trapping and residual trapping thus favour the use of deep saline aquifers for long term CO_2 storage. However, proper injection planning such as gas-phase injection may reduce the dissolution of CO_2 in the formation water and thus facilitate intermediate storage in saline aquifers. The Umbum Creek terminal splay complex sediment composition consists of higher quartz content, with lesser feldspar and lithics contents and cements of clay, halite and evaporites. This mineralogy suggests a high potential for geochemical reactions with CO_2 and formation water. Thus, Umbum Creek fluvial-aeolian terminal splay sediments may allow for permanent CO_2 storage in the formations, if buried.

The interaction of CO_2 in high permeability proximal splay formation could have low reactive potential, due to the dominance of quartz and limited labile minerals, such as feldspar, carbonates and clays. However, CO_2-induced diagenesis increases the partial to total dissolution reaction from feldspar to kaolinite, and minor siderite and calcite precipitation (Watson and Gibson-Poole, 2005).

The study, based on the depositional settings and the petrological aspects suggests that CO_2 flow and transport processes are directly linked to the geochemical trapping mechanisms. The migration pathways of CO_2 are highly controlled by the reservoir heterogeneities in the terminal splay complex. Other site characterization criteria such as formation pressures, *in situ* stresses, tectonic stability, faulting intensity and geothermal gradient are not discussed in this study.

15 CONCLUSIONS

The storage of CO_2 in a reservoir depends very much on criteria such as the depth of injection and density, CO_2 flow and transport processes, storage mechanisms, reservoir heterogeneity, type of the reservoir and duration of storage (intermediate or long term).

1. The heterogeneous nature of Umbum Creek terminal splay complex deposition facilitates the intermediate and long term CO_2 storage.
2. Mineralogy enables high potential for porosity and permeability, which increase the geochemical reaction with CO_2 and formation water, thus accelerating mineralization, solubility trapping and residual trapping for a long term permanent CO_2 storage.
3. Solubility trapping increases with the interaction of diagenetic minerals and cements with CO_2 plume.
4. Migration pathways are controlled by the proximal and distal splay depositional settings and mineral composition.
5. Understanding the variation in terminal splay architecture, depositional setting and mineral composition has very significant implications for the modeling of analogues for potential characterization of sites for CO_2 sequestration.

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ACKNOWLEDGEMENTS

1. Contribution of colleagues on field trips to Lake Eyre Basin, particularly Mark Reilly, Carmen Krapf and Victor Waclawik.
2. Thanks to Ric Daniel and Sally Edwards.
3. The authors want to acknowledge the traditional landowners of the Lake Eyre region.

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