PS Hydrogeological Analysis in Support of Identifying Suitable CO_2 Storage Sites and ECBM in the Sydney Basin, Australia*

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Abstract

The Sydney Basin contains the largest concentration of industrial stationary CO_2 emission sources in Australia. However, no actual sites for CO_2 geological storage have been identified to date. The Sydney Basin comprises an up to 6,000 m thick succession of mainly Permo-Triassic clastic sediments with large coal resources and an emerging coalbed methane industry. Coal seams are an attractive target for CO_2 sequestration in the Sydney Basin due to their proximity to power plants and their potential for enhanced coalbed methane production (ECBM). However, the impact on existing coal resources and containment of the injected CO_2 at relatively shallow depth might prove to be a liability. Geological storage in deep saline aquifers may provide a lower-risk alternative.

The main challenge of finding a suitable CO_2 storage site in saline aquifers in the Sydney Basin is the generally low permeability, particularly at depths below 800 m. Although a large part of the sedimentary succession consists of sandstones potentially forming aquifers, the majority of the original porosity is plugged with diagenetic cements. Testing of deep potential reservoirs produced some gas; however rates were generally uneconomic with little water production. Preliminary analysis of the fluid pressures and compositions suggests that the deeper parts of the Sydney Basin are gas-saturated and underpressured.

Exploration for suitable reservoirs or CO_2 storage sites should therefore focus on identifying “sweet spots” in the otherwise low-permeability environment by combining detailed litho-stratigraphic mapping with the analysis of the hydrogeology and the stress regime. A comprehensive analysis of flow patterns in the Sydney Basin would also help the CBM industry to identify areas of increased CBM producibility, and to assess the quality and quantity of produced water.

Hydrogeological Analysis in Support of Identifying Suitable CO_2 Storage Sites and ECBM in the Sydney Basin, Australia

Cooperative Research Centre for Greenhouse Gas Technologies

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INTRODUCTION

The Sydney Basin contains the largest concentration of stationary CO_2 emission sources in Australia. However, no specific sites for CO_2 geological storage have been identified to date. The basin comprises an up to 6000 m thick succession of Permo-Triassic clastic sediments (Figure 1) with large coal resources and an emerging coalbed methane industry. Previous studies have suggested the Sydney Basin having CO_2 storage potential predominantly in coal seams and, to a lesser extent, in saline aquifers. Coal seams are an attractive target for CO_2 sequestration due to their proximity to power plants and their potential for enhanced coalbed methane production (ECBM). However, the impact on existing coal resources and containment of the injected CO_2 at shallow depth might prove to be a liability and geological storage in deep saline aquifers may provide a lower-risk alternative.

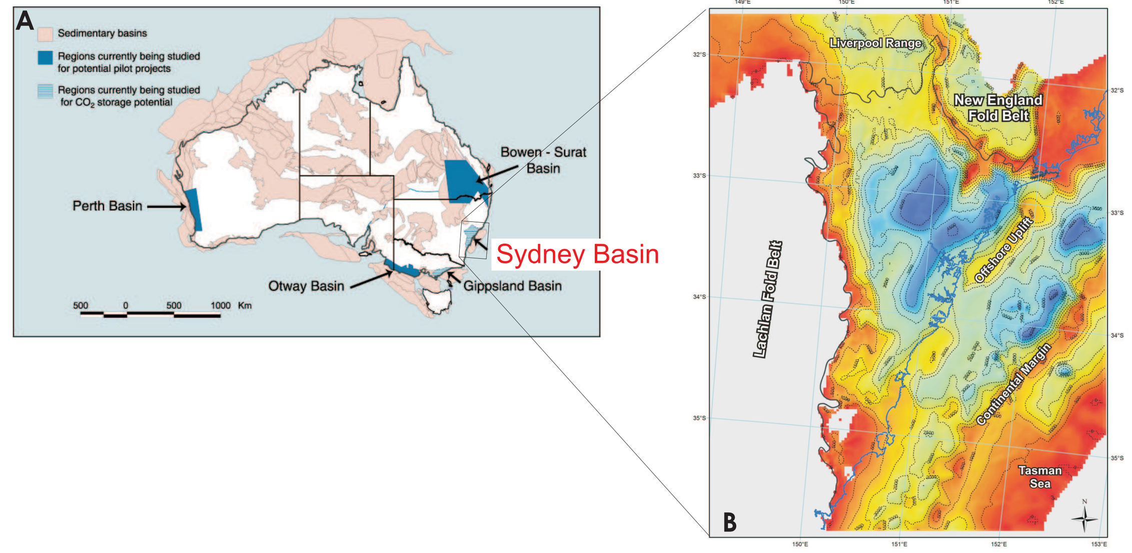

Figure 1. Location of the Sydney Basin in Australia (A) and sediment thickness distribution (B).

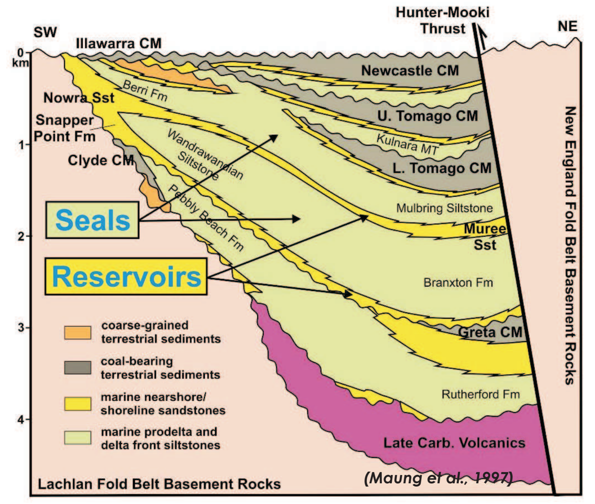

Figure 2. Schematic stratigraphic cross-section showing potential reservoir-seals pairs in the Permian succession of the Sydney Basin.

Although the Sydney Basin contains various source rocks and reservoir-seal pairs (Figure 2), no known conventional petroleum reserves exist. Gas flows have been recorded from fluvio-deltaic and marginal marine sandstones in the Narrabeen Group, Illawarra Coal Measures, Budgong Sandstone, Berry Siltstone and Nowra Sandstone (Figure 3).

HYDROSTRATIGRAPHY

Sandstone aquifers (potential reservoir sandstones) occur mainly at shallow depths in the Sydney Basin with porosities up to 20%. Terrestrial sediments in the basin commonly contain a high percentage of lithic volcanic detritus which has altered to clays during diagenesis. These clays generally cause low permeabilities in the lithic quartz and lithic sandstones even though the rocks have moderate to good porosities.

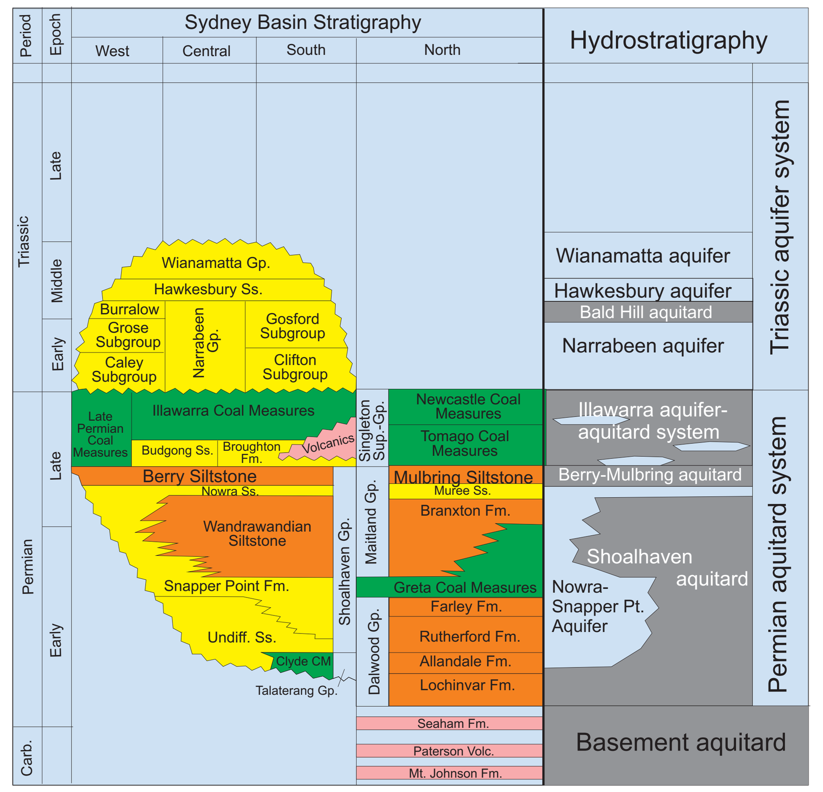

Figure 3. Sydney Basin (hydro-) stratigraphy.

The Maitland/Shoalhaven Group, which generally forms a thick aquitard at the base of the sedimentary succession, contains several isolated sandstone aquifers (Nowra, Cessnock, Snapper Point)(Figure 3). The overlying silt-, clay- and mudstones of the Illawarra/Singleton coal measures sequence act as local aquitards to interbedded fluviodeltaic sandstone aquifers. Interbedded claystones within the Narrabeen Group form locally aquitards to individual fluvial sandstone bodies. The Bald Hill Claystone at the top of the Narrabeen Group acts as an effective regional aquitard and the shallow Hawkesbury and Wianamatta aquifers are generally semi- or unconfined.

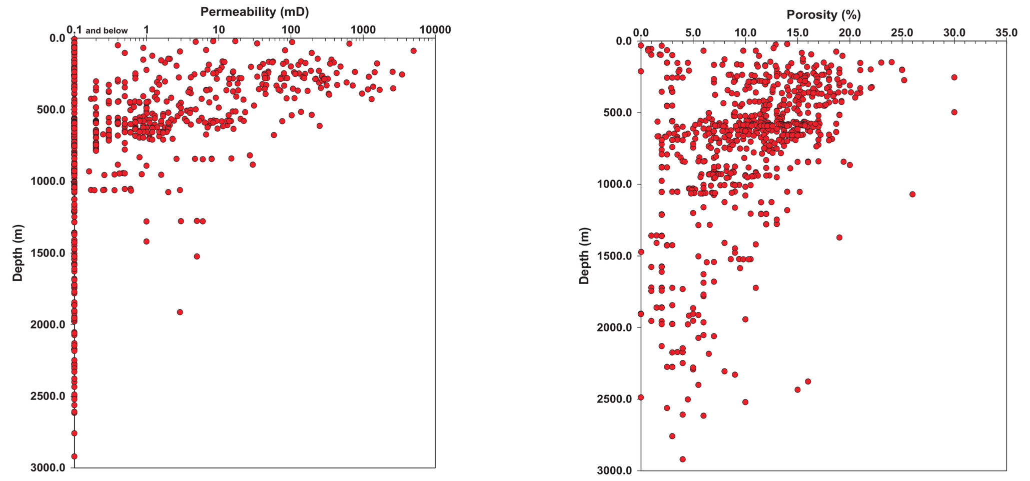

Figure 4. Permeability and porosity versus depth measured from cores in the Sydney Basin.

BASIN-SCALE HYDROGEOLOGY

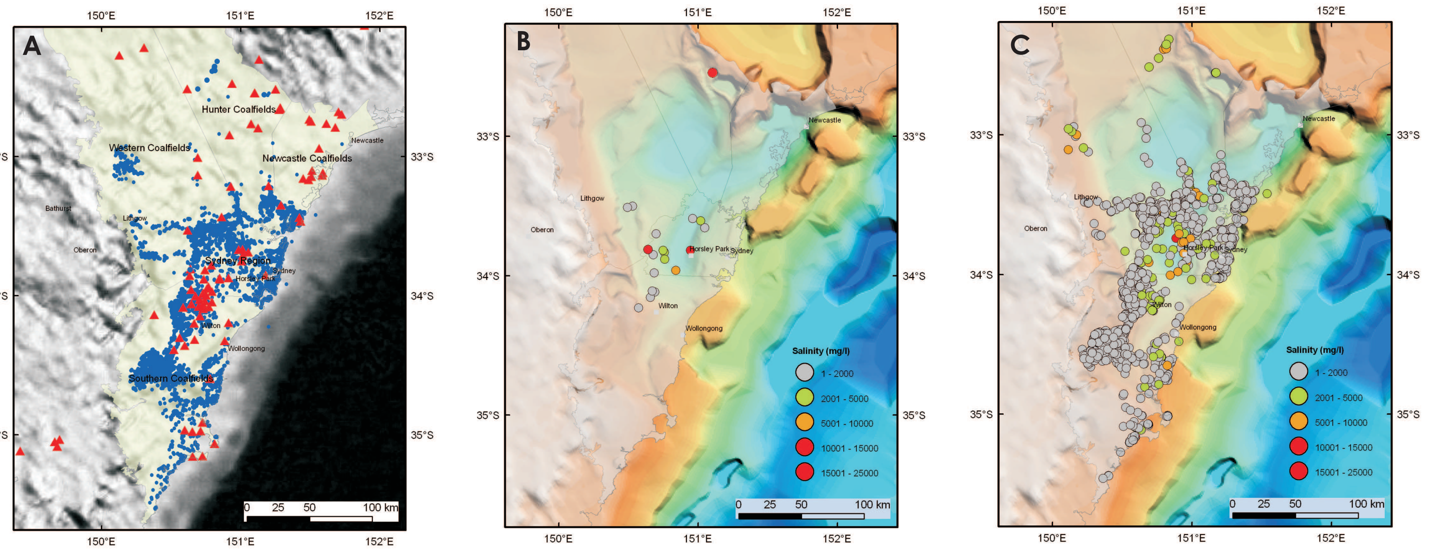

Figure 5. Hydrogeological data in the Sydney Basin: A) Location of water wells (blue) and petroleum exploration wells (red); B) Salinity distribution in shallow groundwater wells (< 250 m); C) Salinity distribution in deeper wells (> 250 m).

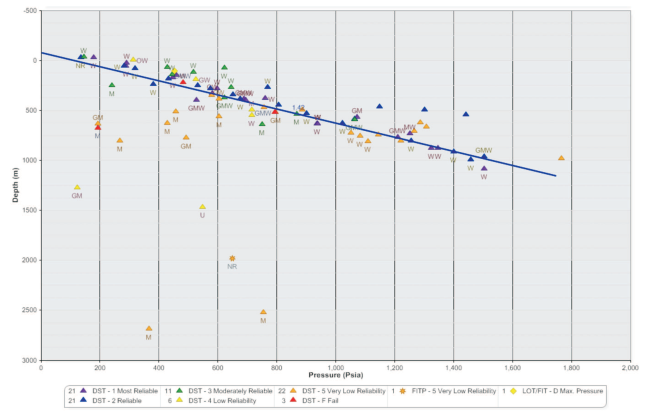

Figure 6. Subsurface formation pressures. The blue line represents a hydrostatic pressure gradient. Indices indicate type of fluid recovery: M = mud, W = water, GM = gas & mud, OW = oil and water, U = unknown.

The conceptual hydrogeological model of the central part of the Sydney Basin inferred from limited data indicates that:

1. Groundwater flow in the Hawkesbury Sandstone and other shallow aquifers is driven by local-scale topography; salinity generally less than 2000 mg/l.
2. Flow in the Narrabeen aquifer system and aquifers within the Illawarra aquitard-aquifer system is driven by regional-scale topography with recharge occurring in the Blue Mountains (and other topographic highs) and discharge possibly taking place in the offshore area of the Sydney Basin. Formation water is fresh in the recharge area and salinity increases towards 15,000 mg/l in the basin centre.
3. The lower Permian succession forms the Shoalhaven aquitard system with only isolated sandstone aquifers (e.g., Nowra and Snapper Point).In the west and in the shallower parts of the basin the aquifers are thick , contiguous and in hydraulic communication with the overlying aquifers. The Nowra and Snapper Point aquifers thin out and exhibit a decrease in permeability towards the deep basin centre. Isolated salinity measurements at intermediate depths (~ 1500-2000 m) in the range of 20,000 mg/l indicate that these parts of the aquifers are not significantly replenished by meteoric recharge.
4. Limited data from the deep parts of the Sydney Basin (> 2000 m) indicate very low permeability, no formation water recovery, but gas shows. The deepest section of the basin is isolated from the shallow groundwater system and appears to be underpressured and gas-saturated, similar to the "Deep Basin" in Alberta, Canada.

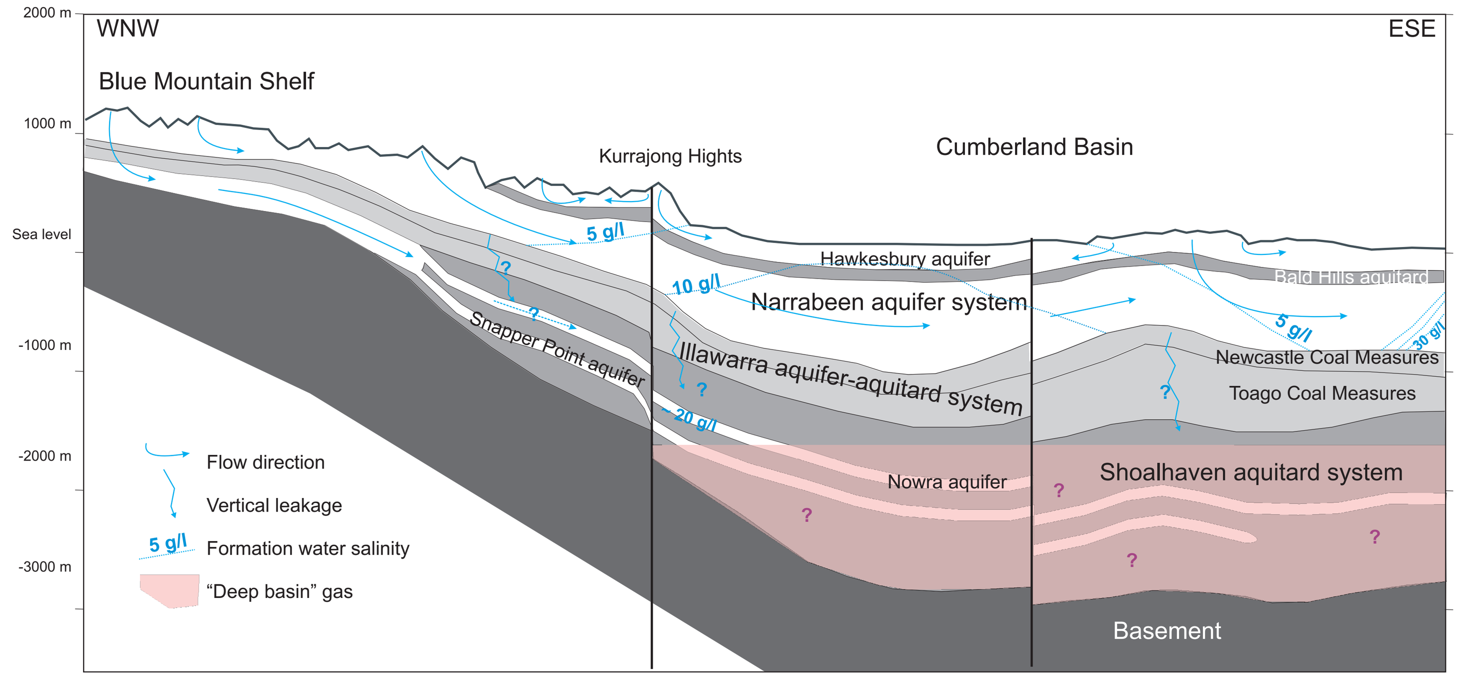

Figure 7. Conceptualized basin-scale hydrogeology along a WNW-ESE cross section in the Sydney Basin.

CONCLUSIONS

Based on the currently available data and state of technology, storage of supercritical CO_2 in saline formations within the Sydney Basin cannot be considered an economically viable option to significantly decrease CO_2 emissions in NSW. Previous studies have been based mainly on a few data sets from depth below 2000 m. The occurrence of gas shows and almost no water production in all deep exploration wells, indicates that the deep part of the Sydney Basin might be gas-saturated. Future exploration targeted towards stratigraphic traps might prove more successful, possibly changing the currently pessimistic interpretation of storage suitability if more data become available.

Experience and technology from "tight gas" development should be investigated for CO_2 geological storage in low-permeability rocks. For example, reservoir stimulation (fracturing) or horizontal/multilateral drilling could provide viable solutions to create sufficient injectivity.

The most practical (and economical) opportunities for storing anthropogenic CO_2 in coal seams are in areas where coal seam methane reserves have been identified and in particular in those producing fields where evidence for sufficient storage capacity, permeability and reservoir integrity exist. Currently, such reserves are confined to the Camden Syncline in the southern Sydney Basin. However, the shallow depths and relatively low formation water salinity presents potential conflicts with coal mining and drinking water development.

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