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Geological storage of gas: evaluation of seal properties for containment of Carbon Dioxide, Methane and Hydrogen

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Abstract

The injection and storage in geological formations of gasses such as Methane (CH_4) and Carbon Dioxide (CO_2) has been successfully implemented for several decades. More recently, Hydrogen (H_2) has gained attention for its characteristics as a clean, safe, and versatile energy carrier and industrial feedstock. Similar to the storage for CH_4, the underground storage of H_2 is a potentially cost-effective option to balance the seasonal demand and intermittent generation of the gas both for export and domestic use. Underground storage of large volumes of H_2 gas may be necessary to support an emerging hydrogen economy. However, hydrogen-rich gas has only been stored in the subsurface in very limited locations around the globe, and the feasibility for hydrogen storage in many parts of the world has yet to be established.
The geological storage of gases such as H_2, CH_4 and CO_2 in geological formations, requires a porous and permeable reservoir rock (such as a sandstone) overlain by an impermeable caprock or top seal, such as salt, shale or claystone. The caprock / top seal is one of the most important elements in the geological containment system and therefore characterising the seal is crucial to ensuring the successful, long term storage of injected gases in a storage reservoir. Fine grained claystone and shales comprise the most common seal lithologies in Australia, and possibly globally. These rocks form seals due to their nano-scale porosity and narrow pore throats resulting in low permeability and high capillary displacement pressures. The key parameter in determining the column of gas that a seal can retain is the *seal capacity*. Seal capacity refers to the gas column height that a caprock can retain before capillary forces are exceeded which then allows the

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migration of the gas into and through the caprock. Many factors influence a caprock's seal capacity. These include rock properties such as capillary threshold pressures, and the thermodynamic properties of fluids at subsurface conditions, such as density, wettability and interfacial tension. The determination of seal capacity is achieved primarily through petrophysical analyses such as Mercury Injection Capillary Pressure (MICP) tests. This project involved the analysis of MICP data from proven hydrocarbon seal rocks sampled from oil and gas wells from seven Australian basins. Subsurface gas properties and formation brine conditions were used to compare properties of carbon dioxide, methane and hydrogen, and determine the seal capacities for the retention of each the three different gases. This is the first study to attempt such comparisons. A significant conclusion of this study is that, despite its low density and small molecular size, the seal capacity for hydrogen was found to be very similar to that of methane, and slightly more effective than for containing CO_2. Therefore, the geological subsurface presents a feasible storage option not only for the storage of CH_4 (for seasonal supply /demand requirements) and CO_2 (for greenhouse gas emission reductions), but also for large volumes of H_2 that will be required to support an emerging hydrogen economy.

Keywords: Storage; Containment; Seals; Hydrogen