An Overview of the Gorgon Project: CO2 Injection

Mckenna, J.[1], R. Gurton[1], S. Leigh[1], T. Tankersley[1] (1) Chevron Australia Pty Ltd, Perth, Australia

The Gorgon Project will be the first project in Australia to significantly reduce greenhouse gas emissions by the injection of reservoir CO2 underground. The CO2 disposal target is the Dupuy Formation located around 2000m beneath Barrow Island. The volume of reservoir CO2 to be re-injected is about 100MT. The proposed injection site was selected to maximise the CO2 migration distance from major faults and limit environmental disturbance. The injection wells are planned to be directionally drilled from two surface locations to minimise the area of land required for the well sites, surface facilities, pipelines and access roads. Once the CO2 is injected into the subsurface, it will move through the host reservoir, driven by the injection pressure and buoyancy until it becomes trapped. There are four mechanisms that can trap injected CO2 within the host reservoir: 1) large-scale geometric trapping; 2) residual gas trapping; 3) solution trapping; and 4) mineralogical trapping. Monitoring is an integral component of the CO2 injection proposal. The main monitoring activities will comprise: routine observation of injection rates and surface pressures at the injection wells; pressure and saturation measurements at observation wells; and large-scale plume migration via repeated surface seismic measurements. Monitoring data will provide information required to update and history match reservoir simulation models to predict the subsurface behaviour of the injected CO2.

Problems and Practice in Calculating the CO2 Storage Capacity of the UK and its Continental Shelf

Holloway, Sam[1] (1) British Geological Survey, Nottingham, United Kingdom

Britain is surrounded by sedimentary basins, six of which - the Southern North Sea, Northern and Central North Sea, Faroes-Shetland, East Irish Sea, St George's Channel and Central Channel basins - are known to be hydrocarbon-bearing. The methodologies used to estimate their CO2 storage capacities, and the shortcomings of these methodologies, will be discussed. Whilst the storage capacity of their oil and gas fields can be estimated with reasonable precision, quantifying the storage capacity of their aquifers is far more difficult, mainly because of uncertainties about how much CO2 would be trapped by dissolution and as a residual saturation along any CO2 migration path. A further cause of uncertainty is whether, or under what pressure, the cap rocks above apparently closed structures that do not contain hydrocarbons might leak.

At present it appears that there is little CO2 storage capacity onshore in the UK. With one exception, all the oil and gas fields in the UK onshore area are too small for significant CO2 storage. Such aquifers as are present do not contain many large structural closures and their up-dip portions are either used for fresh water supply or, in the case of the Coal Measures, contain coal resources, indicating the likelihood of conflicts of use.

The CO2 storage capacity of the southern North Sea Basin is estimated to be up to 18 Gt and that for the East Irish Sea Basin up to 1.7 Gt. Storage capacity estimates for the other major offshore basins will be presented.

Assessment and Sensitivity Considerations of a Potential storage Site for Carbon Dioxide - A Queensland Case Study

Sayers, Jacques[1], Cameron Marsh[1], Adam Scott[1], Yildiray Cinar[2], John Bradshaw[3], Allison Hennig[4], Stuart Barclay[5], Ric Daniel[6] (1) Geoscience Australia/Cooperative Research Centre for Greenhouse Gas Technologies, Canberra, ACT, Australia (2) University of New South Wales/Cooperative Research Centre for Greenhouse Gas Technologies, Sydney, NSW, Australia (3) Geoscience Australia, Canberra, ACT, Australia (4) Commonwealth Scientific and Industrial Research Organisation (CSIRO) Petroleum/Cooperative Research Centre for Greenhouse Gas Te, Perth, WA, Australia (5) Commonwealth Scientific and Industrial Research Organisation (CSIRO) Petroleum/Cooperative Research Centre for Greenhouse Gas Te, Sydney, NSW, Australia (6) University of Adelaide/Cooperative Research Centre for Greenhouse Gas Technologies, Adelaide, SA, Australia

Australia's coal-fired power plants produce about 70% of the nation's total installed electricity generation capacity and emit about 190 million tonnes of CO_2/year, of which about 44 million tonnes come from central and southeast Queensland. A multi-disciplinary study has identified the onshore Bowen Basin as having potential for geological storage of CO_2. Storage potential has been documented within a 295 km^2 area on the eastern flank of the Wunger Ridge using a simplified regional 3-D model, and is based on estimating injection rates of 1.2 million tonnes CO_2/year for 25 years. Paleogeographic interpretations of the Showgrounds Sandstone reservoir in the targeted injection area indicate a dominantly meandering channel system that grades downdip into a deltaic system. Seismic interpretation indicates a relatively unfaulted seal and reservoir section. The depth to the reservoir extends to 2700 m.

CO_2 injection simulations indicate that at least one horizontal or two vertical wells would be required to inject at the proposed rate into homogeneous reservoirs with a thickness of approximately 5 m and permeability of 1 darcy. The existence of intra-reservoir shale baffles necessitates additional wells to maintain the necessary injection rate: this is also true for medium-permeability reservoirs. The long-term storage of the injected CO_2 involves either stratigraphic and residual gas trapping along a 10 to 15 km migration path, and ultimately, potentially, within updip depleted hydrocarbon fields; or trapping in medium-permeability rocks. Trapping success will be a function of optimal reservoir characteristics including specific permeability ranges and the distribution of seals and baffles. Sensitivity analysis of CO_2 injectivity indicates that dissolution effects may increase injection rates by up to 20 %.

Using Stratigraphic Heterogeneity to Maximise the Efficiency of CO_2 Geological Storage

Gibson-Poole, Catherine M.[1], Richard F. Daniel[1], Jonathan Ennis-King[2], Andy J. Rigg[3], Lotte Svendsen[1], Maxwell N. Watson[1] (1) CRC for Greenhouse Gas Technologies (CO2CRC), South Australia, Australia (2) CRC for Greenhouse Gas Technologies (CO2CRC), Victoria, Australia (3) CRC for Greenhouse Gas Technologies (CO2CRC), New South Wales,

Australia
Geological storage of carbon dioxide (CO_2) is influenced by many variables. Stratigraphic architecture and reservoir heterogeneity primarily affect the migration pathway of CO_2. An understanding of these aspects can assist with devising an injection strategy to maximise the efficiency of CO_2 geological storage. A conceptual example is presented from the Kingfish Field area in the offshore Gippsland Basin, southeastern Australia.

The potential injection targets are the interbedded sandstones, siltstones and shales of the Paleocene-Eocene upper Latrobe Group, regionally sealed by the Lakes Entrance Formation. The sequence stratigraphy suggests that there are several packages of sand separated by locally effective but regionally non-extensive intraformational seals. Seal capacity analyses indicate that the intraformational seals can retain an average CO_2 column height of around 500m. Thus, the interbedded siltstones and shales will behave as flow baffles and barriers that will hinder or slow vertical migration, encouraging the CO_2 to migrate laterally, and create localised traps throughout the stratigraphy, which reduces the reliance on the top seal.

Numerical simulations demonstrate how these baffles reduce the effective vertical permeability and create a more tortuous path, effectively increasing the length of the CO_2 migration pathway. This increases the volume of pore space moved through by the CO_2, resulting in greater residual gas trapping and dissolution along the migration pathway, and allowing more time for geochemical reactions to take place. These effects all increase the potential CO_2 storage capacity and containment security, and should be considered when devising injection scenarios to optimise the geological CO_2 storage process.

Rendering Uncertainty in Rocks and Fluids: Stochastic Integration & Inversion in CO2 Plume and Rock-Volume Prediction and Mapping

Friedmann, S. Julio[1], Abelardo Ramirez[1], Roger Aines[1], Kathy Dyer[1] (1) Lawrence Livermore National Laboratory, Livermore, CA

Reservoir simulation, flow-front monitoring, and verification of CO2 remains important subsurface tasks for geological CO2 storage. They all involve collection and integration of multiple data sets within the context of some reservoir model. We have developed a computational tool to better render subsurface liquid plumes (e.g., CO2, steam, water floods) and their reservoirs using new and prior geological, geochemical, and geophysical data. The approach formally and quantitatively integrates all available data and provides a strict measure of probability and uncertainty in the subsurface.

The tool uses statistical theory and geophysical forward models to compute images of the subsurface geology or plumes. It produces images consistent with disparate data types (well-logs, injected CO2 volume, seismic, cross-borehole electrical resistivity). Through Bayesian inference, we generate a model of the likely plume or rock volume consistent with all data. The method uses a Markov Chain Monte Carlo (MCMC) technique to sample the space of possible models and importance sampling to robustly and rapidly converge on solutions. The outputs are specific models and their probability of occurrence; as such, model uncertainty is explicit and provides insights into what data are needed to reduce uncertainty. This method is computationally expensive, and high performance parallel computation of the geophysical forward problem(s) is required to make MCMC practical. We have applied this approach to several real-world examples of subsurface plume prediction and monitoring. These include a prediction and mapping of a commercial CO2 flood, contaminant plumes, and tank leakage. They all show results superior to traditional (deterministic) inversion.

Natural CO2 Generation, Entrapment and Water-Rock Interaction of the Otway Basin CO2 Accumulations, Australia: Evidence for Optimising Site Selection for CO2 Geological Storage

Watson, Maxwell N.[1], Peter R. Tingate[1], Chris Boreham[2], Catherine M. Gibson-Poole[1] (1) CRC for Greenhouse Gas Technologies (CO2CRC), South Australia, Australia (2) CRC for Greenhouse Gas Technologies (CO2CRC), Canberra, ACT,

Natural CO_2 Generation, Entrapment and Water-Rock Interaction of the Otway Basin CO_2 Accumulations, Australia: Evidence for Optimising CO_2 Storage Site Selection.

Maxwell N. Watson[1,2], Peter R Tingate[1,2], Chris Boreham[1,3], Catherine Gibson-Poole[1,2].

[1]CRC for Greenhouse Gas Technologies (CO2CRC)
[2]Australian School of Petroleum, The University of Adelaide, SA 5005, Australia.
[3]Geoscience Australia, Canberra, ACT 2601, Australia.

Natural accumulations of CO_2 offer an excellent opportunity to examine CO_2-water-rock interactions that are likely to occur in future CO_2 geological storage sites. The Otway Basin, Australia, is the focus region for the CO2CRC's natural analogue research. The Otway Basin is a known CO_2 province, with the initial discovery of CO_2 in 1966, and is currently producing CO_2 from the Gambier Embayment, Port Campbell Embayment and Penola Trough. Through carbon ($d^{13}C_{CO2}$) and helium ($^3He/^4He$) isotopic analyses, a mantle origin has been determined as the predominant CO_2 source in these accumulations, linked to the degassing of Pleistocene to Recent magmas.

Comparative petrological studies from CO_2-rich gas fields and nearby CO_2-free gas fields display locally enhanced CO_2-water-rock interaction. Labile minerals, such as feldspars, chlorite and calcite are commonly altered to kaolinite and quartz. Precipitation of carbonate minerals also occurs, mineralogically trapping the CO_2. Mineralisation is more apparent in greensand lithologies, where higher concentrations of labile minerals allow increased CO_2-water-rock interaction. Fractured seal rock also displays CO_2 interaction, with siderite precipitation healing fractures and filling porosity, enhancing the seal capacity. 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.

Studying natural CO_2 accumulations can help validate geological storage as an option for CO_2 emission reduction. This research has also determined the optimum reservoir criteria to benefit CO_2 geological storage, including aspects of CO_2 injectivity, containment and interaction within a reservoir system.

CO2 Sequestration and Enhanced Methane Recovery with respect to Gas Reservoir Properties of Australian Coals

Saghafi, Abouna[1], Mohinudeen Faiz[2] (1) CSIRO Energy Technology, Newcastle, Australia (2) CSIRO Petroleum, North Ryde, Australia

Since 1995 coal seam methane (CSM) production in Australia has increased significantly, particularly in Queensland where currently about 40% of the state's gas consumption is supplied from coal seam methane; Queensland has CSM resources of about 150 to 500 kPJ (~250 TCF) and reserves of up to 6 kPJ (6 TCF). Carbon capture and sequestration may allow Australian dependence upon coal and gas for electricity generation to continue to rise without consequential major increases in atmospheric carbon dioxide levels. However NSW and Queensland are deficient in suitable geological structures, for CO2 sequestration, such as depleted oil and gas reservoirs, close to the main sources of CO2 production, in particular power plants. In the absence of these geological reservoirs, extensive coal formations, particularly deep, unmineable seams, potentially with CSM potential, are favourable for sequestration.

Both storage and flow properties of reservoirs are vital to the success of CO2 enhanced coalbed methane recovery (CO2-ECBM), with the ultimate aim of CO2 sequestration in coal seams. Reservoir characterization of about forty Australian coals from the Sydney and Bowen Basins were extensively measured and studied to enable the evaluation of their suitability for CO2 sequestration and ECBM. Coal rank for the samples varies from low volatile bituminous to high volatile bituminous (Ro max of 0.6 to 1.7%). The sample depths vary from less than 100 m to more than 1000 m. Using a newly developed system for measuring gas storage and flow properties at the appropriate depth/pressure conditions gives improved assessments of CO2 and CH4 flow behaviours.

Quantifying CO_2 saturation from Time-lapse Well Logging in An Onshore Saline Aquifer, Nagaoka, Japan

Xue, Ziqiu[1], Jiro Watanabe[2], Daiji Tanase[3] (1) Research Institute of Innovative technology for the Earth, Kyoto, Japan (2) Geophysical Surveying Co. Ltd, (3) Engineering Advancement Association of Japan,

Injection of carbon dioxide (CO_2) into saline aquifers has been proposed as a means to reduce greenhouse gas emissions. In geological carbon sequestration, monitoring is necessary to confirm the containment of CO_2, assess leakage paths, and gain understanding into interactions between CO_2, the rock-forming minerals and formation fluids. Monitoring is also necessary to quantify the net quantity of CO_2 that has been sequestrated within the reservoirs. The major challenge is how to correlate wave velocity or electrical conductivity with fluid (CO_2 or formation water) saturations in partially saturated porous rocks. A series of time-lapse geophysical loggings consisted of dual induction, neutron, sonic and gamma-ray has been performed frequently at the Nagaoka pilot-scale sequestration site. The pilot-scale CO_2 injection site is located at Minami-Nagaoka oil and gas fields, and one injection well (IW-1) and three observation wells (OB-2,-3,-4) were drilled at the pilot site. The goal of this paper is to interpret and analyze time-lapse sonic log data quantitatively obtained from observation wells OB-2 and OB-4, to better understand fluid saturations around the two wells. The CO_2 breakthrough was clearly confirmed from the sonic velocity reduction up to 20%. This significant velocity reduction agreed fairly well with the laboratory experiment result on drilled cores. Based on the rock-properties model and Gassmann's equation, we successfully matched the sonic velocity change due to presence of injected CO_2 at observation wells. The CO_2 saturation around the observation wells ranged from 10 to 40%. From the history matching result we also found that there is no CO_2 leakage from the reservoir, even a huge earthquake hit the Nagaoka area. Our results strongly suggested the capability for quantifying CO_2 concentration from seismic wave data with Gassmann's equation.