The Effect of Lithological Heterogeneity on Carbon Mineralization within the South West Hub CO₂ Storage Reservoir, Western Australia

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Abstract

Carbon capture and storage has been accepted as a necessary technology included in a portfolio of options to mitigate global climate change. Recent work on reservoir heterogeneity has demonstrated the potential beneficial effects it can have on CO₂ migration and trapping. Intraformational siltstone/mudstone baffles are higher in clay content and therefore in sheet silicates such as chlorite and mica compared to sandstone layers. Such minerals are enriched in calcium, magnesium and iron and are known to dissolve in CO₂-enriched, low-pH water. With more reactive sheet silicates, the intraformational baffles provide a source of potentially mobilised cations for subsequent carbonate precipitation. Therefore, these siltstone and mudstone layers are expected to act as distinct zones for carbonate mineralisation.

The South West Hub is a carbon capture and storage project led by the government of Western Australia, through the Department of Mines, Industry Regulation and Safety (DMIRS) and is currently examining CO₂ storage potential within the Lesueur Sandstone, approximately 150 km south of Perth, Western Australia. 2D and 3D seismic data as well as well-log and core data from four sites (Harvey-1, -2, -3, -4) has been acquired and used to develop static and dynamic models for the area of interest by the South West Hub Project.

The Lesueur Sandstone is a fluvial deposit of Triassic age for which nine lithofacies have been identified (Delle Piane et al., 2013). These lithofacies include channel-fill sandstones formed under variable energies, moderate energy barforms, moderate-to-low energy rippleforms, floodplain paleosols and swampy, overbank and lagoonal mudstones. The Lesueur Sandstone is divided into two members, the Upper Lesueur (Yalgorup Member) and the Lower Lesueur (Wonnerup Member). The former primarily consists of highly interbedded channel-fill deposits of varying energies, paleosols and mudstones. The Wonnerup Member comprises thick, continuous, high energy sandstone, with minor interbedding of lower energy deposits and mudstones. Floodplain paleosols and swampy, overbank and lagoonal mudstones contained within the Lesueur Sandstone represent low permeability intraformational baffles, with the other lithofacies representing moderate to high permeability reservoir rock.

The purpose of this study is to characterise sub-metre scale lithological heterogeneity within the Lesueur Sandstone and predict the extent of carbon mineralisation at the site post-injection. The project consists of three parts: 1. Define rock types and their attributes including mineral composition relevant for reactive-transport modelling. 2. Develop 2D geological model across the Lower to Upper Lesueur Sandstone boundary honouring sub-metre scale lithological heterogeneity. 2. Run reactive-
transport simulations to predict mineral dissolution and precipitation including the carbon mineralization capacity.

The mineral composition of discrete samples has been analysed by XRD and QEMSCAN and a high resolution, continuous record of the semi-quantitative mineral composition has been derived on a section of over 200m from the Harvey-1 core using HyLogger-3™. The following rock types have been defined based on the mineral composition, porosity and permeability: 1. High permeability sandstone, consisting of a quartz-dominated (>90%) mineralogy, high porosity (>20%) and high permeability (>800mD). 2. Medium permeability sandstones, consisting of a similar mineralogy (i.e. >90% quartz) but with lower porosity (18-20%) and permeability (100-200mD) values. 3. Low permeability sandstones, a quartz-dominated rock type with a porosity of 18-10% and a lower permeability of 1-50mD. 4. Feldspathic sandstone, consisting of a mineralogy that is framework mineral-dominated and with up to 50% feldspar. 5. Siltstone, which had a mineralogy that consisted of around 50% lithic components, with the remaining parts primarily framework minerals. Porosity and permeability were 10-15% and <100mD, respectively. 6. Paleosols, consisting of roughly equal parts quartz, feldspar and lithic components, with minor inclusions of other minerals such as calcite. Porosity was around 15% and permeability <20mD. 7. Sandy Paleosols, which were a quartz-dominated (>50%) paleosols with porosities of 15-18% and permeabilities typically 20-50mD. 8. Lithic Paleosols, which were clay-rich (>50% lithic components) paleosols with porosities <15% and permeabilities <1mD. 9. Mudstones, consisting of over 80% lithic components with a low porosity and permeability at <3% and <0.01mD, respectively.

Detailed facies distribution around the Harvey-1 well will be modelled using SKUA-GOCAD software and respective rock types and their properties will be integrated into a 2D geological transect derived from the existing geological model. The transect will be approximately 100m high and 2km wide and will include the lithostratigraphic boundary between the Lower and Upper Lesueur. The 2D geological transect will be imported into TOUGHREACT and reactive-transport simulations carried out.

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