[PS]Feasibility of Enhanced Permeability of Siliciclastic Reservoirs by Geochemical Stimulation*

Syed Anas Ali[1], Jay R. Black[1], and Ralf Haese[1]

[1]School of Earth Sciences, The University of Melbourne, Melbourne, VIC, Australia (alisyedanas88@gmail.com)

Abstract

One of the key challenges for the development of a CO_2 storage site is identifying and maintaining sufficient injectivity within a geologic formation. Even having a large storage volume, the reservoir's potential for storing CO_2 can be significantly reduced due to restricted flow affecting the injectivity. An example of such a case in Australia was the ZeroGen CCS project in Queensland. One of the major shortcomings due to which the project did not proceed further was low permeability of the storage units in the Northern Denison Trough causing limitations for projected industrial scale CO_2 injection. There are numerous reasons for low permeability in sandstone reservoirs. In most cases, low permeability is associated with certain types of mineral overgrowth that cements interconnecting pore space within a formation. This study focuses on the application of geochemical stimulation in undamaged clastic reservoirs to enhance their permeability. Geochemical stimulation by acids and other pH-controlled solutions can possibly promote mineral dissolution and increase permeability within a reservoir, and thus injectivity. The process of acidizing, as it is commonly known within the field of reservoir engineering, has been common practice in the oil and gas industry. The process has primarily been aimed at removing fines that result from formation damage while drilling or that accumulated over long period of production. So far, the technique has been applied in both sandstone and carbonate units using diverse methods to improve productivity in the near well bore environment. The current objective is to evaluate the efficiency of different solutions used for geochemical stimulation to bring substantial changes in the overall flow properties of a siliciclastic reservoir. The role of pH and temperature in controlling the dissolution rate of silica will be investigated with the help of batch reactors. Core flood experiments will be conducted using the most suitable chemistry to observe pore scale changes in the petro-physical properties of the rock samples at reservoir conditions. Effective deployment of a geochemical stimulation technique at field scale requires a synthesis and understanding of the underlying geochemical reactions coupled to flow properties within a reservoir. Thus, a reactive transport model will be developed to simulate enhanced injectivity at field scale under variable conditions using the ZeroGen project as a case study.

Feasibility of Enhanced Permeability of Siliciclastic Reservoirs by Geochemical Stimulation

Syed Anas Ali, Jay Black, Ralf Haese

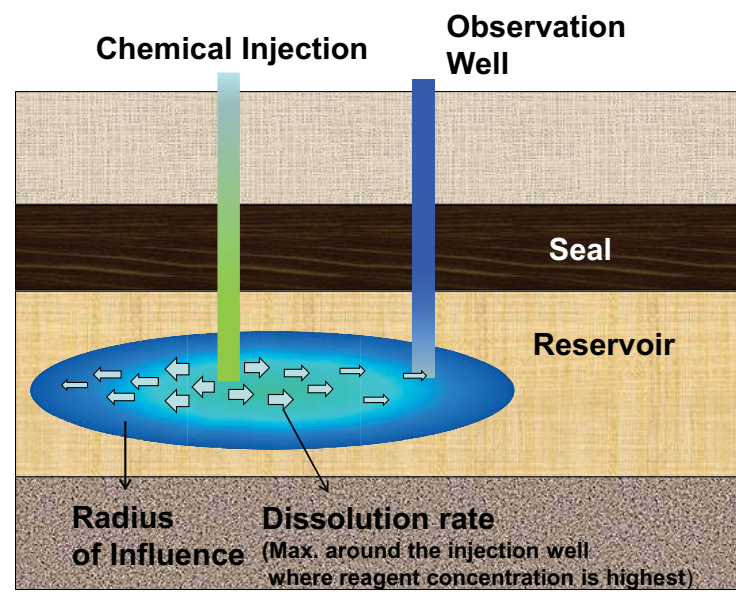### CO2CRC & Peter Cook Centre for CCS Research, University of Melbourne

1. INTRODUCTION

Large-scale CO_2 injection and storage requires a sufficiently high rate of CO_2 injection as well as a sufficiently high storage capacity and long-term containment. Sandstones with a permeability below approximately 100 mD may not be suitable for high injection rates as the pressure build-up becomes too large. For example, in case of the ZeroGen CCS project in Queensland (Australia) the low permeability of the targeted reservoir rock (Catherine Sandstone) was deemed too low and one reason to terminate further exploration. (Garnett et al., 2014).

Low permeability can be found in a range of rock types including fine grained and poorly sorted rocks as well as in rocks with mineral overgrowth. Particularly the oil and gas industry has developed procedures to remediate reduced permeability near the wellbore from mineral precipitation. This project investigates the feasibility of enhanced permeability to allow for higher CO_2 injection rates.
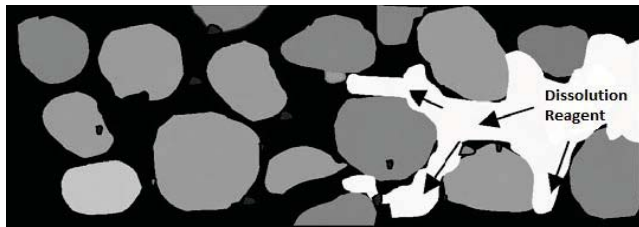
Dissolution reagent flow through sandstone matrix (Kalfayan, 2008)

Conceptual chemical reservoir stimulation

2. STUDY OBJECTIVES

- Review silicate mineral dissolution under acidic, neutral and alkaline conditions.

- Build a reactive transport model to simulate mineral dissolution and associated permeability changes at reservoir scale.

- Optimize the injection conditions in terms of choice of reagent, well configuration, injection rate and period in order to maximise permeability enhancement for reservoirs with variable mineral composition.

- Determine the feasibility and maximum degree of permeability enhancement for the Catherine Sandstone, Northern Denison Trough using a 3D geological model.

## 3. PLANNED MODELLING & EXPERIMENTAL WORK

1. Modelling
The coupled reactive transport code TOUGHREACT is used to simulate the effects of geochemical stimulation on the physical properties of the rock such as changes in porosity, permeability and mineral composition.

2. Sample Collection
The core plugs of Catherine Sandstone collected from Central Queensland, Australia for laboratory experiments.
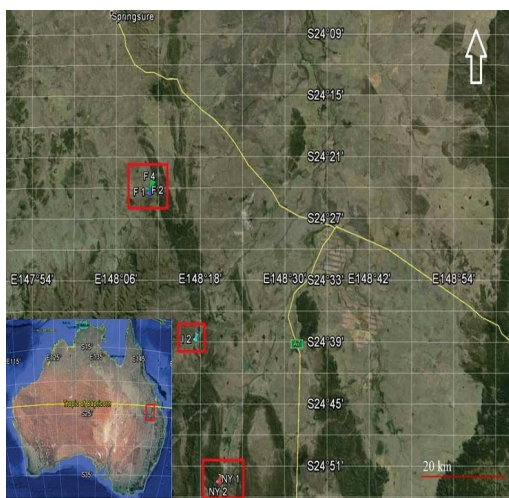
3. Laboratory Work
The core samples will be characterized using petrography techniques including thin section analysis, XRD and Scanning Electron Microscopy (SEM) together with petro-physical characterization such as porosity and permeability. The acquired data will be incorporated in the core flooding experiments to derive geochemical input parameters for the reservoir scale reactive transport model. The above experiments will also help to determine the competence of the dissolution reagent to enhance the petro-physical properties of the rock at laboratory scale.
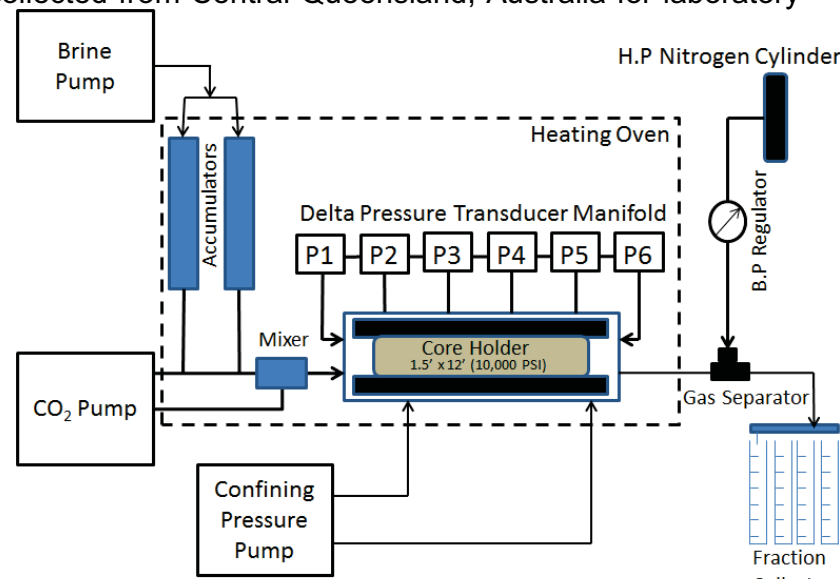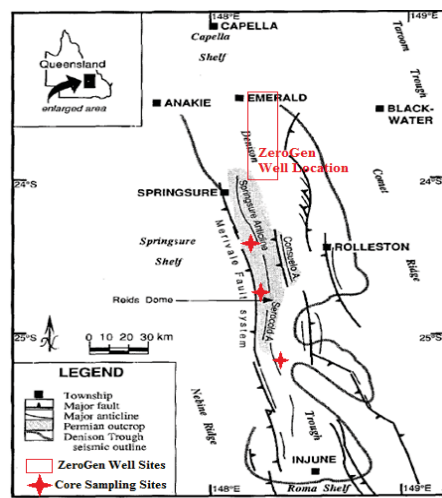
Schematic diagram of Core Flooding System facility, School of Earth Sciences, University of Melbourne

4. MODELLING RESULTS

Minerals	Neutral Mechanism			Acid Mechanism			Basic Mechanism			Mineral	Volume Fraction (%)
	A ($cm^2 s^{-1}$)	k_{25} ($mol\ m^2 s^{-1}$)	E_a ($KJ\ mol^1$)	k_{25}	E_a	$n(H^+)$	k_{25}	E_a	$n(H^+)$	Quartz	75
Quartz	98	1.14e-8	32.8	2.95e-5	18.9	1.18(F)	5.13e-17	108.0	-0.5	Low-albite	1.7
Low-albite	98	2.754e-13	69.8	6.918e-11	65	0.457	2.512e-16	71	-0.572	Anorthite	1.7
Anorthite	98	2.754e-13	69.8	6.918e-11	65	0.457	2.512e-16	71	-0.572	K-feldspar	9
K-feldspar	98	3.890e-13	38	8.710e-11	51.7	0.5	6.310e-22	94.1	-0.823	Others	12.6

Left: Simplified conceptual model of the reservoir generated in PetraSim, Right: Kinetic parameters for calculating mineral dissolution/precipitation rates (Palandri and Kharaka, 2004; Xu et al., 2009) & Initial mineralogical composition used in the model (Garnett et al., 2013)
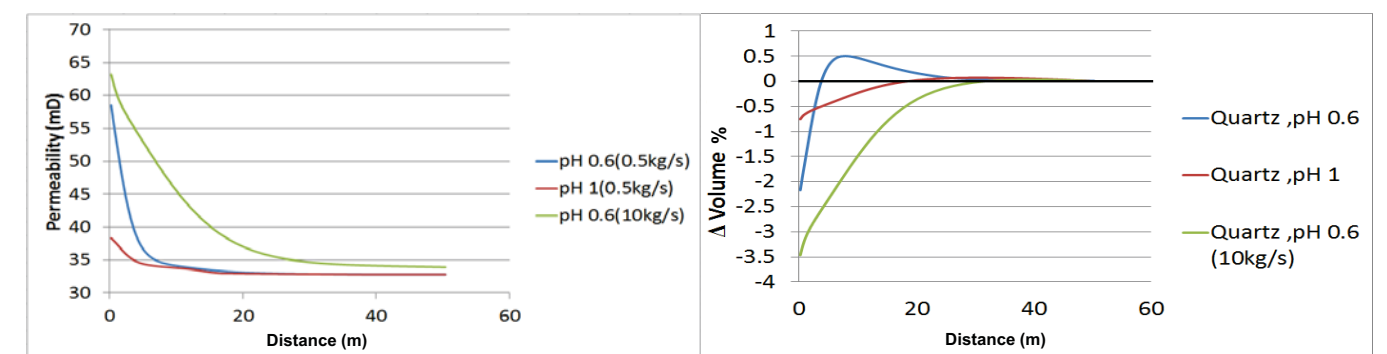
Left: Permeability changes as a function of varying injection rate (0.5 & 10 kg/s) and pH using HF as a dissolution reagent, Right: Changes in the volume fraction of Quartz at different pH and injection rate (10kg/s) using HF
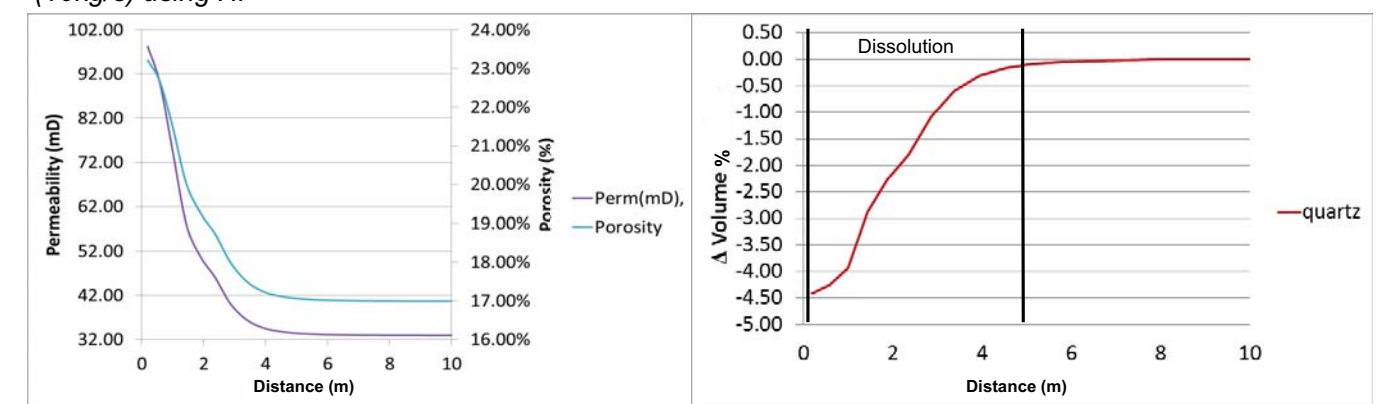
Left: Porosity and Permeability changes after 30 days of NaOH injection at pH 12, Right: Changes in the volume fraction of quartz at pH 12
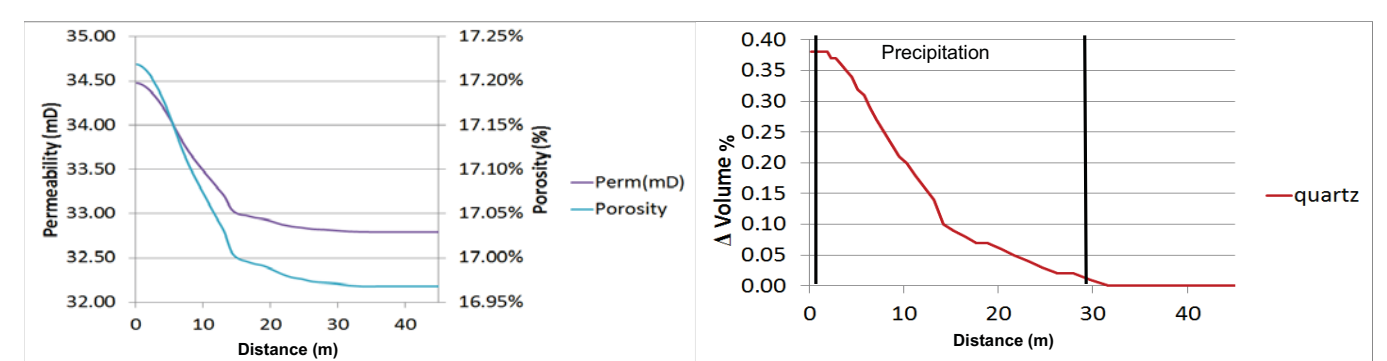
Left: Porosity and Permeability changes after 30 days of HCl injection, Right: Changes in the volume fraction of quartz after 30 days of HCl injection
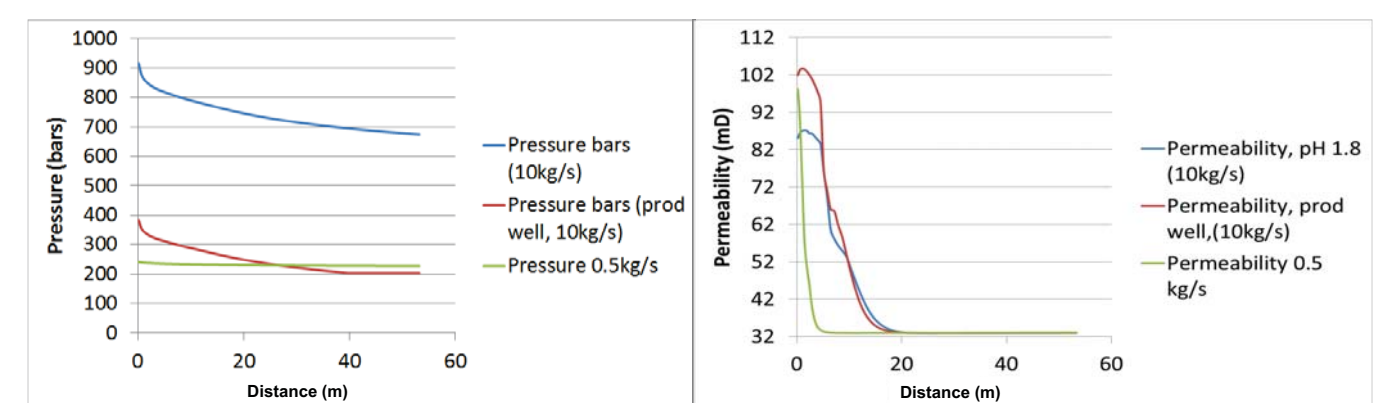
Left: Reservoir's pressure build-ups due to varying injection rate and pressure optimization by using a production well, Right: Permeability changes at different injection rate and well configuration.

5. SAMPLE COLLECTION (CENTRAL QUEENSLAND)

Rock samples from the Catherine Sandstone were collected for future analytical and experimental studies.

Satellite image of the sampling locations in the south of Springsure

Locations of ZeroGen exploration wells and core sampling sites. (After Baker & Caritat, 1992)

Drilling for core sample at Nyanda Station

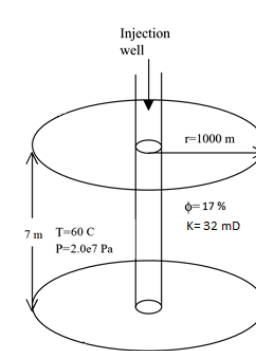*Some of the core plugs collected during the field trip*

6. FUTURE WORK

- Chemical reagents are investigated by using core flood experiments with varying fluid composition and temperature for a better estimation of its effect on the petro-physical properties of the rock.

- Preliminary model will be calibrated by the outcome of core flooding experiments.

- Three dimensional geological model of Catherine Sandstone and incorporate reservoir properties from core analysis.

- In particular, we will be looking for less hazardous dissolution reagents such as organic acids and alkaline solutions for field applications.

- Findings from the experimental and computational studies will help to evaluate the actual potential of the technology in terms of its application to CO_2 storage sites.

7. REFERENCES

- Baker, J. C., and Patrice de Caritat. (1992). "Post depositional History of the Permian Sequence in the Denison Trough, Eastern Australia" The American Association of Petroleum Geologists Bulletin V 76, No 8, P 1224-1249
- Garnett. A. J., Greig. C. R., Oettinger. M. (2013). "ZeroGen IGCC with CCS A case History". The State of Queensland (Department of Employment, Economic Development and Innovation)
- Kalfayan, L. (2008). "Production Enhancement with Acid Stimulation" 2nd Edition. PennWell Corporation, Tulsa, Oklahoma. USA.
- Palandri. J. L and Kharaka. Y. K. (2004). " A Compilation of Rate Parameters of Water-Mineral Interaction Kinetics for Application to Geochemical Modelling". U.S. Geological Survey Open File Report 2004-1068
- Xu. T., Rose. P., Fayer. S., Preuss. K. (2009). "On modelling of chemical stimulation of an enhanced geothermal system using a high pH solution with chelating agent". Geofluids 9, 167–177.