Utility of Peridotite Host Rocks for Sequestering Atmospheric CO_2

Joanna L. Speer[1], Juerg M. Matter[1], Rachael H. James[1], Damon A. H. Teagle[1], Manon T. Duret[2], Phil Newman[2], Neville Plint[2]

[1]School of Ocean and Earth Science, National Oceanography Centre Southampton , University of Southampton, Southampton, UK.

[2]Anglo American

SCAN ME TO STAY IN TOUCH

University of Southampton

AngloAmerican

V41B-0126

1 Introduction

- Global climate change demands immediate action, with anthropogenic activities pushing CO_2 concentrations beyond 410ppm, risking a **temperature increase of 3.7—4.8 °C by 2100** (IPCC, 2023).
- The **mining industry**, known for it's substantial environmental impact, annually produces **gigatonnes of waste rocks rich in reactive minerals** (Bullock et al., 2021).
- **Enhanced weathering**, leveraging waste from the mining sector, presents a scalable solution to **remove up to 2 Gt CO_2/yr**, supplementing natural weathering rates (Beerling et al., 2020).

2 The Rocks

This study investigates the reactivity of **serpentinised peridotite** samples from the Sakatti deposit in Finland, and a confidential mine location in South Africa, aiming to **identify materials with high CO_2 removal potential**.

PRD DUN CONF.A

Key XRF Oxides (Wt. %)	SiO_2	Fe_2O_3	MgO	CaO	LOI	*Total*	Enhanced Weathering Potential [Epot*] (Kg CO_2 per tonne rock)
PRD	36.15	8.71	**40.37**	1.54	9.8	*98.06*	**907.5**
DUN	37.92	9.68	**42.9**	0.66	5.5	*98.19*	**950.55**
CONF.A	34.07	9.41	**40.45**	0.05	14.9	*99.44*	**895.28**

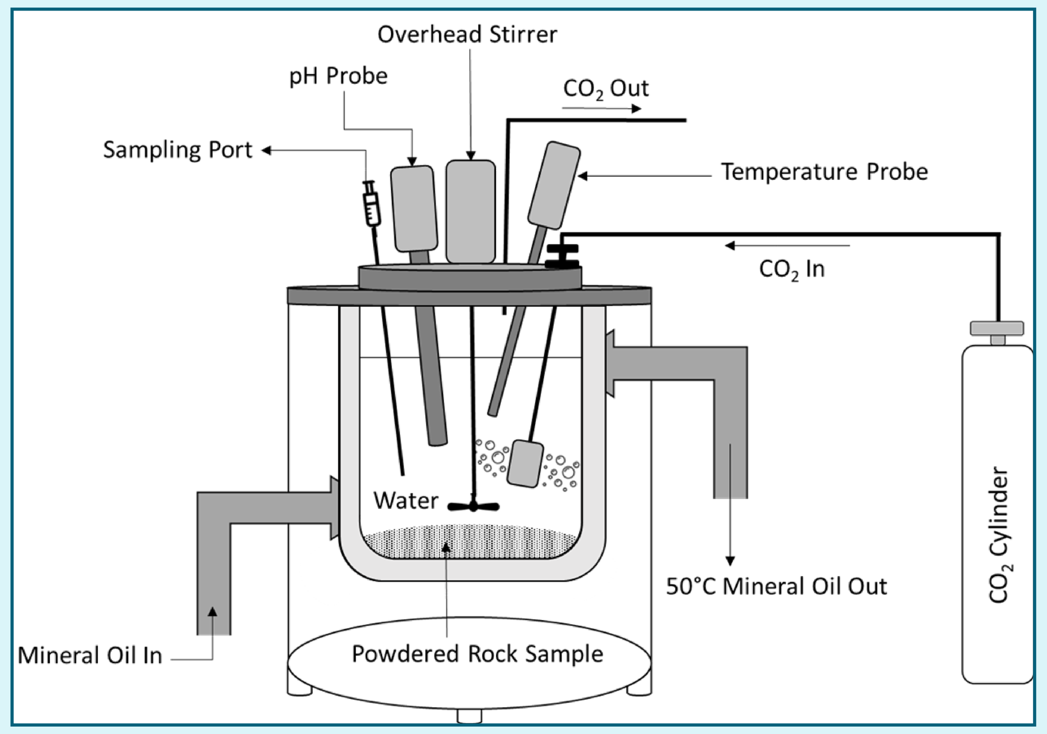
$$^{*}E_{pot} = \frac{M_{CO_2}}{100} \cdot \left(\alpha \frac{CaO}{M_{CaO}} + \beta \frac{MgO}{M_{MgO}} + \varepsilon \frac{Na_2O}{M_{Na_2O}} + \theta \frac{K_2O}{M_{K_2O}} + \rho \frac{MnO}{M_{MnO}} + \gamma \frac{SO_3}{M_{SO_3}} + \delta \frac{P_2O_5}{M_{P_2O_5}} \right) \cdot 10^3 \cdot \eta$$

(Renforth, 2019)

Key Minerals (Wt. %)	Serpentine	Forsterite	Brucite	Chlorite	Magnetite	Stichtite	Calcite	Diopside	Talc	Hornblende
PRD	**39.7**	**36.8**	-	8.1	-	-	0.6	2.7	11.8	-
DUN	**13.5**	**77.3**	-	4.9	-	-	-	-	1.6	1.4
CONF.A	**87.8**	-	**4.9**	-	4.6	2.8	-	-	-	-

3 Dissolution Method

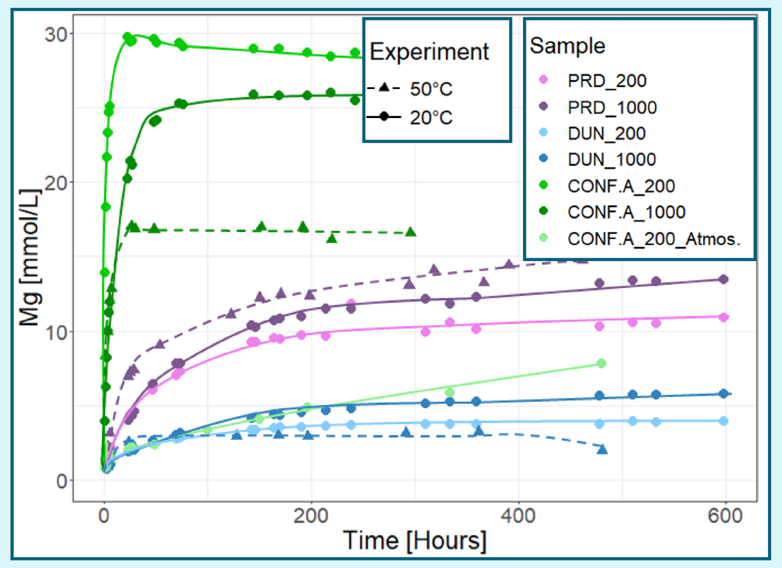
- All three lithologies (PRD, DUN, CONF.A) were characterised using thin section petrography, XRD, XRF and SEM-EDS.
- Core samples were crushed and sieved into **two size fractions** for reaction with CO_2: **180—250 μm** (PRD_200) and **750—1000 μm** (PRD_1000). Particle size distributions and surface areas (BET and Geometric) were determined for these size fractions.
- To assess CO_2 reactivity, **900ml Mili-Q water was continuously saturated with CO_2 (100% CO_2)** and **20g of powdered rock sample** was added. Fluid samples were regularly collected for ICP-OES and alkalinity analysis.
- Experiments were conducted at **room temperature (20°C) and 50°C** (PRD_1000_50).

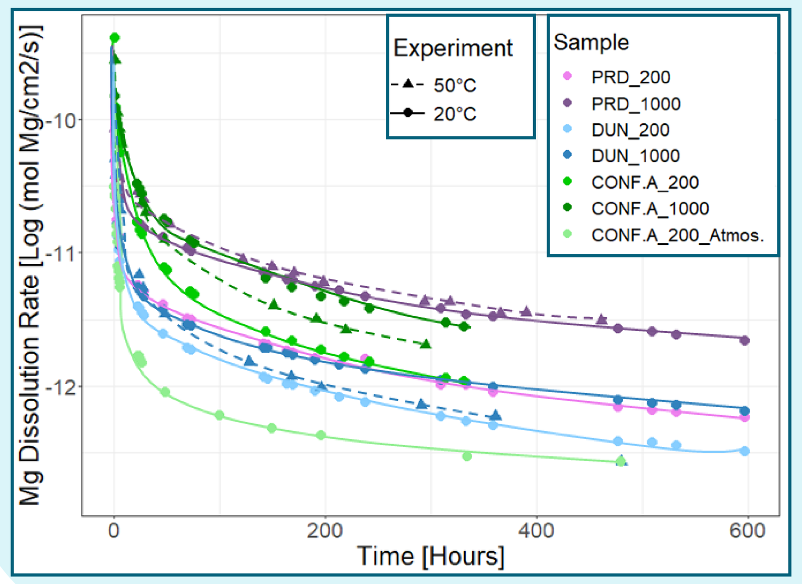


Peridotite host rocks are efficient at sequestering CO_2, especially if they contain brucite, but we need to make it faster!

4 Dissolution Results

- Samples **do not always** react faster at higher temperatures.
- Smaller grain sizes **do not always** react faster.





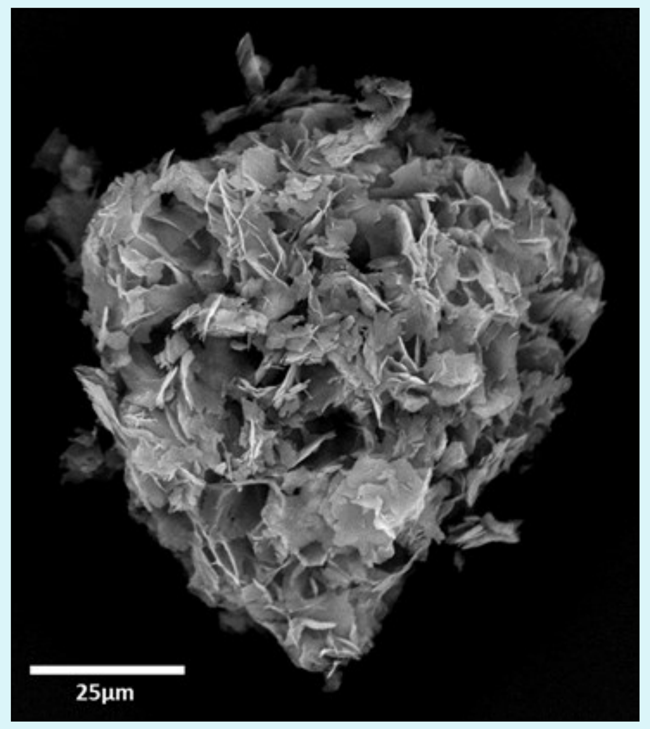
- Mg dissolution rates are normalised to Geometric Surface Area.
- **Surface area normalisation is key!**

5 Precipitation Method

- **Final fluids** from the dissolution experiments were collected and **filtered** to remove any remaining rock powder.
- The filtered fluids were **heated** to just below boiling point and **agitated** using a magnetic stirring hot plate.
- **Evaporation** of the fluid was continued **until approx. 50ml** of fluid remained.
- Any **precipitation** that formed during this process was filtered out of solution, dried, weighed and analysed by XRD to determine mineralogy.
- All fluids were sampled before and after precipitation for ICP-OES, alkalinity and DIC analyses.

$$Mg^{2+} + CO_3^{2-} + 3H_2O \leftrightarrow MgCO_3 \cdot 3H_2O$$

6 Precipitation Results

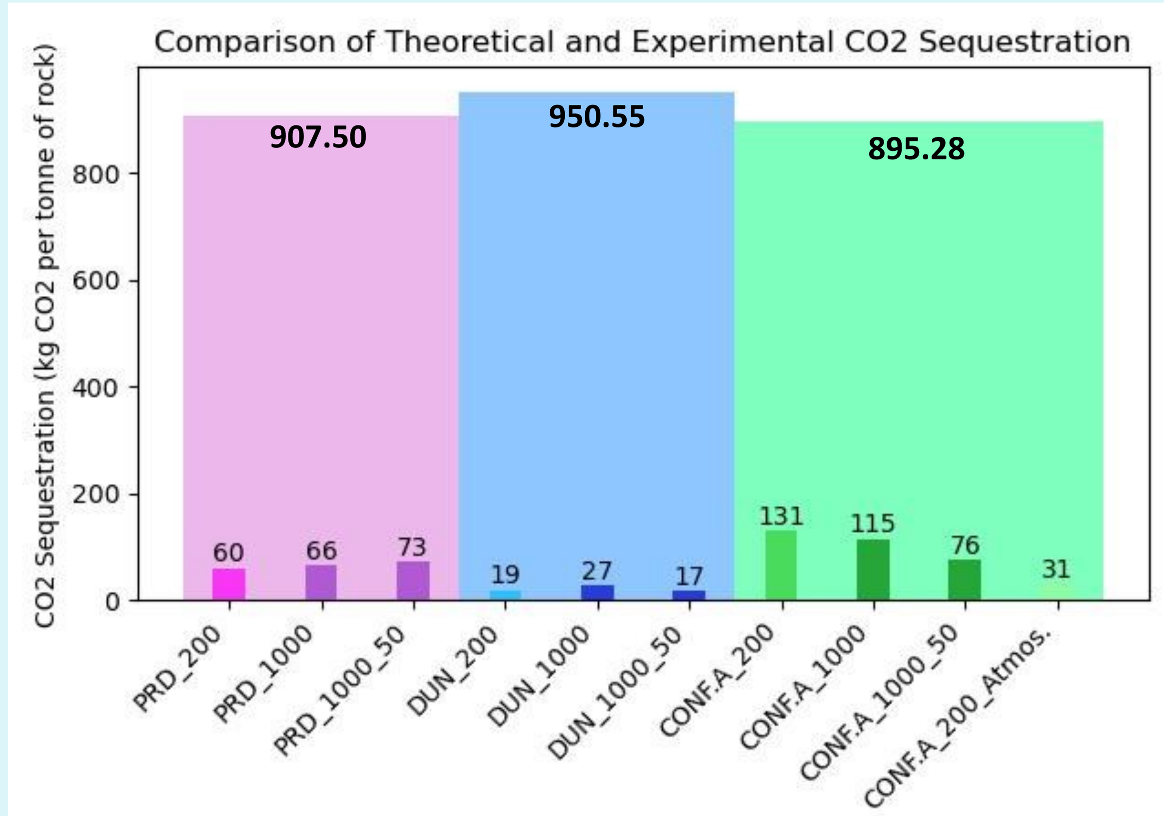


Hydromagnesite

$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$

	Pre-Precipitation		Mass of Precipitate (g)	Post-Precipitation	
	Alkalinity (mmol/L)	Mg (mmol/L)		Alkalinity (mmol/L)	Mg (mmol/L)
PRD	35.6	12.38	**0.65**	2.5	1.38
DUN	38.6	3.82	**0.21**	1.9	0.46
CONF.A	121.3	18.73	**1.04**	3.2	0.19

7 CO_2 Sequestration



$$CO_2 = 2\,(Mg_F + Ca_F) * Mm_{CO_2}$$ (Kelemen et al., 2020)

- The current experimental values are **significantly lower** than the theoretical enhanced weathering potential (Epot).
- To come close to realising this potential, **substantial improvements** in the experimental processes are **necessary to enhance efficiency**.

References:

IPCC (2023): AR6 Synthesis Report: Climate Change 2023.

Beerling, D.J., Kantzas, E.P., Lomas, M.R. et al (2020). Nature 583, 242–248.

Bullock L.A., James R.H., Matter J., Renforth P., and Teagle D.A.H. (2021). Frontiers in Climate. 3:694175.

Kelemen, P.B., McQueen, N., Wilcox, J., Renforth, P., Dipple, G., Vankeuren, A.P., (2020). Chem. Geol. 550, 119628.

Renforth, P. (2019). Nat. Commun. 10:1401.

Acknowledgements:

This project is funded by a research grant provided by Anglo American.