

Plagioclase vs Olivine: Which mineral is more reactive in driving in-situ mineralization of CO₂ in Basalt?

Muhammad Hammad Rasool^{1*}, Maqsood Ahmad¹, Numair Ahmed Siddiqui²

^{1*,1,2} Petroleum Geosciences Department, Universiti Teknologi PETRONAS, Seri Iskandar, 32610, Malaysia

INTRODUCTION & AIM

THE BACKGROUND

Basalt mineralizes CO₂ for permanent carbon storage.

- Olivine
- Plagioclase
- Pyroxene

THE AIM

Which mineral is most reactive?

Literature Splits Plagioclase or Olivine?

RESULTS & DISCUSSION

SELECTION OF FACTORS

- ✓ Low Temp
- ✓ Slow Equilibrium
- ✓ Calcite Dominant

OUTCOME

REACTIVE FRAMEWORK

- ✓ Reservoir Temp
- ✓ High Early Flux

OLIVINE

- ✓ Reservoir Temp
- ✓ High Early Flux
- Magnesite Dominant

Engineer the Reservoir: Condition-specific environment controls reactivity more than intrinsic mineralogy.

METHOD

SELECTION OF FACTORS

- ✓ Intrinsic kinetics
- ✓ Surface access
- ✓ Temp-CO₂
- ✓ Stoichiometry
- ✓ Timescale

COMPARISON OF REACTIVITY

REACTIVE FRAMEWORK

Condition-dependent controls define realized reactivity

Based on 500+ studies on Surface Condition and Reservoir Conditions

Framework Comparison

PLAGIOCLASE	OLIVINE	PYROXENE
PLAGIOCLASE	OLIVINE	PYROXENE
KINETICS	SURFACE REACTIVITY	INACTIVE
Slow Dissolution Higher Activation Energy	Fractured Texture Moderate Reactivity	Low Reactivity Limited Exposure
SURFACE	CHEMISTRY	TIMESCALE
Fractured Texture Moderate Reactivity	Initial Mg ²⁺ & Fe ²⁺ Flux Slow Ca ²⁺ Dominant Release	Limited Mg ²⁺ , Ca ²⁺ Release Mixed Carbonates Possible
CHEMISTRY (INITIAL FLUX)	CHEMISTRY (INITIAL FLUX)	TIMESCALE
Prolonged Ca ²⁺ Flux Ca Dominance (Calcite Pathway)	Slow Ca ²⁺ Dominant Release Mg Dominance (Magnesite Pathway)	Long Ca ²⁺ Timeline Minimal Reactivity

No single mineral governs; reactive outcomes are result of varying reactivity conditions.

FUTURE WORK AND REFERENCES

Construct a high-pressure reaction chamber to study real-world controls on mineral carbonation

- ✓ Test optimal P_{sat}, T, pCO₂ mix over time
- ✓ Measure reactive cation fluxes & initial passivation
- ✓ Track carbonate growth under realistic rates

CONCLUSION

PLAGIOCLASE

OLIVINE

DORMANT PYROXENE

- ✓ Plagioclase & Olivine effective for sustained CO₂ sequestration
- ✗ Limited reactivity makes Pyroxene unfit for rapid carbon storage

TARGETED MINERAL CARBONATION

PRECISION MATCH
MINERAL TO CONDITIONS

OPTIMIZE REACTION
PARAMETERS

MAXIMIZE CARBON
SEQUESTRATION

[1] A. Dey and N. A. Sommerdijk, "In situ techniques in biomimetic mineralization studies of calcium carbonate," *Chemical Society Reviews*, vol. 39, no. 2, pp. 397-409, 2010.

[2] S. Zhang and D. J. DePaolo, "Rates of CO₂ mineralization in geological carbon storage," *Accounts of chemical research*, vol. 50, no. 9, pp. 2075-2084, 2017.

[3] V. Romanov, Y. Soong, C. Carney, G. E. Rush, B. Nielsen, and W. O'Connor, "Mineralization of carbon dioxide: a literature review," *ChemBioEng Reviews*, vol. 2, no. 4, pp. 231-256, 2015.