Carbon sequestration potential of the mafic rocks from the Mindanao Eastern Pacific Cordillera, southern Philippines

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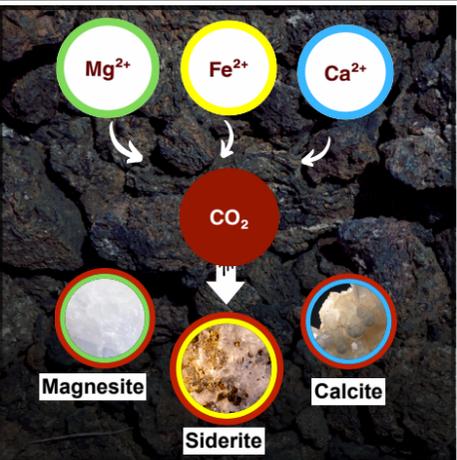
INTRODUCTION & AIM

Fig. 1 Divalent cations in unstable reactive minerals from mafic rocks can react with dissolved CO_2 to form stable carbonates.

- **Mafic Rocks** can be the most suitable for carbon sequestration via Enhanced Rock Weathering due to their composition and abundance (Lewis et al., 2021)

- **Initial carbon uptake estimations** can be done based on the rock's composition and mineralogy.

- **Three distinct exposures of mafic rock** units were identified in the **Mindanao Eastern Pacific Cordillera**, samples were taken from each rock unit and analyzed in this study to assess their theoretical carbon uptake.
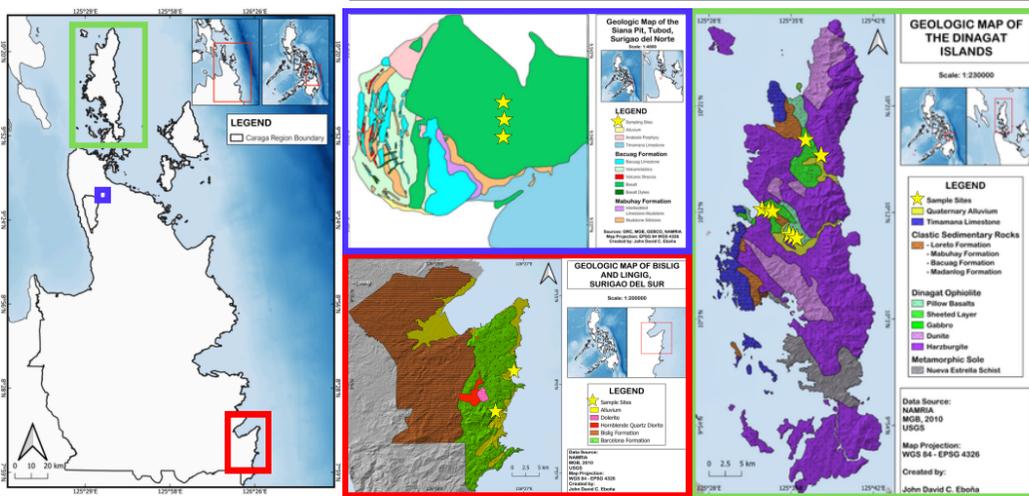

Fig. 2 Sampling sites (★) at Dinagat Islands, Tubod, Surigao del Norte, and Lingig, Surigao del Sur, Eastern Mindanao where mafic rocks are exposed.

- To conduct **petrographic analysis** of the **mafic rocks** from Eastern Mindanao, southern Philippines, specifically **Dinagat Islands**, **Surigao del Norte**, and **Surigao del Sur,** for the quantification of **CO_2-reactive silicate minerals** and the estimation of the rock's **carbon sequestration potential** based on their **modal abundance**.

METHODS

Theoretical Maximum CO_2 Uptake of Reactive Minerals (Taksavasu, 2025)

$$eq.\ 2\ U_{min} = \left(\frac{n \bullet MW_{CO_2}}{MW_{mineral}}\right)100\%$$

n = moles of CO_2 consumed per mole of mineral
MW_{CO_2} = CO_2 molecular weight (44.009 g/mol)
$MW_{mineral}$ = CO_2-reactive mineral molecular weight

- The maximum theoretical CO_2 uptake of each reactive mineral is calculated using **stoichiometric relationships between the mineral and CO_2.**

Modal Percentage

Fig 3. Point counting using a petrographic microscope

$$eq.\ 1\ V_i = \frac{C_i}{C_T}\ 100\%$$

V_i = volume percentages
C_i = individual components
C_T = points total

- **Modal percentages** of each mineral were calculated as the **ratio** of the counted **mineral points** to the total number of counted points.

Calculate Mean Theoretical Uptake per Mineral Group

Integrate Modal and Mean Uptake

$$eq.\ 3\ \ U_{total} = \sum_{i=1}^{n}\left(\overline{U_i}V_i\right)$$

$\overline{U_i}$ = mean theoretical uptake
V_i = volume/modal percentage

Table 1. Mean Theoretical CO_2 uptake potential of reactive minerals, assuming complete CO_2 mineralization (modified from Taksavasu, 2025)

Mineral Group	Mean Group Uptake (%)
Olivine	52.88
Pyroxene	38.87
Calcic Plagioclase	13.81
Serpentine	47.64

- Theoretical CO_2 uptake values of representative minerals within each group were **averaged** to obtain a mean uptake value for the reactive mineral groups (Table 1).

- Minerals such as **olivines, pyroxenes, plagioclases, and serpentines** were identified and quantified from the sample thin sections using both PPL and XPL view with a **polarized light microscope**, with the minerals' abundances and textural characteristics varying for each rock locality (Fig. 3).

- **Modal data** are combined with **mean theoretical CO_2 uptake** values (Table 1) of reactive minerals (e.g., olivine, pyroxene, plagioclase, serpentine) to estimate the **total potential CO_2 mineralization** capacity of the rock (eq. 3).

CONCLUSIONS/FUTURE WORK

Fig. 5 Amount of rock needed to sequester fixed amount of CO_2

Dinagat Islands' mafics require the least amount of rock to sequester 1 kg of CO_2 at **6.22 kg** of rock. Then followed by the **Surigao del Norte basalts** at **9.58 kg**, and lastly the **Surigao del Sur mafic rocks** with the lowest theoretical carbon uptake at **18.18 kg** of rock for 1 kg of CO_2.

- **Validate** theoretical carbon sequestration potential using representative rock samples from each locality in **laboratory experiments or monitored field applications.**
- Utilize **XRD and SEM-EDS** to precisely identify minerals and analyze physical features that impact fluid-mediated carbonation.
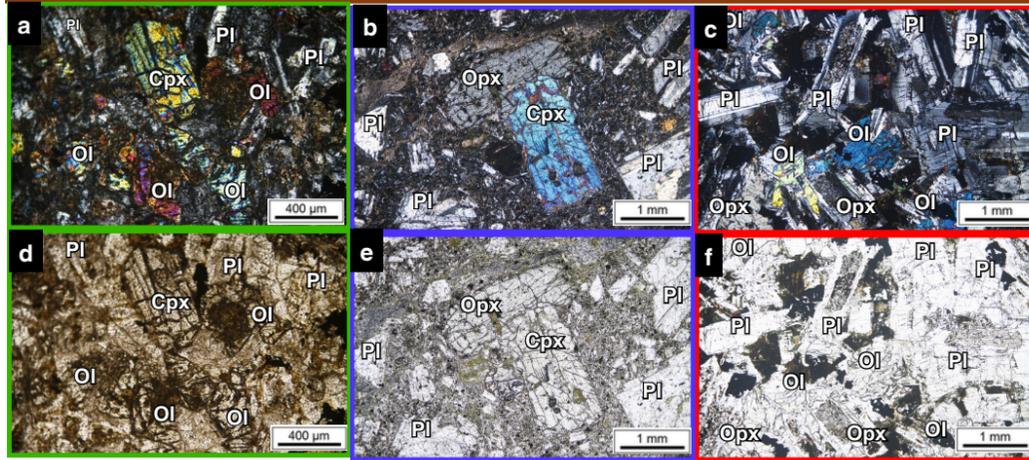
RESULTS & DISCUSSION

Fig. 4 Dinagat Islands (Dinagat Ophiolite), Surigao del Norte (Bacuag Formation), Surigao del Sur (Barcelona Formation) mafic rock photomicrographs in XPL (a,b,c) and PPL (d,e,f). (a,d) Diabase, (b,e) porphyritic basalt, (c,f) gabbro sample.

Table 2. Total theoretical CO_2 uptake (wt.% CO_2) and average mass ratio of the samples

Locality	Rock ID	Sample ID	Total CO2 Uptake	Mass ratio
Dinagat Islands	Basalt	01–01	15.77	6.34
		01–02	12.7	7.87
		03–01	13.16	7.6
		03–02	15.07	6.63
		05–01	17.5	5.71
		05–02	13.74	7.28
	Diabase	04–01	21.81	4.58
		06–01	19.64	5.09
		07–01	20.86	4.79
		07–02	21.51	4.65
	Gabbro	08–01	13.4	7.46
		09–01	13.24	7.55
		09–02	18.69	5.35
Surigao del Norte	Basalt	T1–05	16.08	6.22
		T3–07	8.65	11.56
		T4–02	9.13	10.96
Surigao Del Sur	Basalt	04–07	2.97	33.7
	Gabbro	03–09	13.29	7.53
		05–07	7.52	13.3

Table 3. Average estimated total CO_2 uptake (wt% CO_2) and average mass ratio.

Locality	Estimated total CO2 Uptake (wt%)	Average Mass Ratio
Dinagat Islands	16.7	6.22
Surigao del Norte	11.29	9.58
Surigao Del Sur	7.92	18.18

- Each **Dinagat Islands (Dinagat Ophiolite)** samples exceeded **12 wt.% total CO_2** uptake, (highest at 21.81 wt.% CO_2) (Table 2).

- Basalt sample from **Surigao del Sur (Barcelona Formation)** accounted for the **lowest CO_2 uptake** of 2.97 wt.% CO_2 (Table 2)

- **Plagioclase contributes most** to the theoretical uptakes, compensating for its low mean theoretical uptake through its major occurence among all samples.

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