Reaction-induced fracturing and rheological effects of carbonation at the slab–mantle interface: Constraints from hydrostatic and shear experiments

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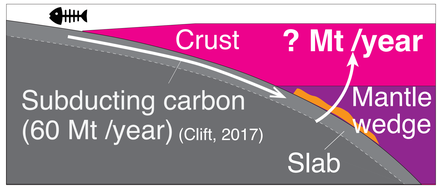
Abstract



This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

Motivation



Carboantion of ultramafic rocks accompanies **volume increase** (up to +68%)

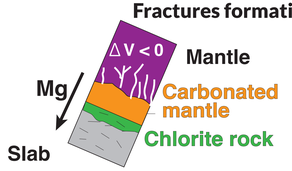
Carbonation terminates due to clogging!

- **Volume reduction by metasomatism**
- **Maintenance of pores by deformation**

may keys for the continuous carbonation

(Okamoto et al. 2021, Menzel et al. 2022)

Metasomatism Volume decrease ↓ Fractures formation?



Deformation Deformation maintains micro pores?



Aims of this study

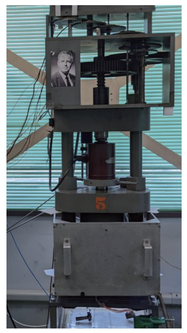
By conducting **reaction-shear experiment demonstrating crust mantle interface under mantle wedge condition**, we aim to

1. **constrain mass transfer and reaction (metasomatism) and volumetiric change leading to crack formation**
2. **reveal the rheological effect of carbonation**

Method

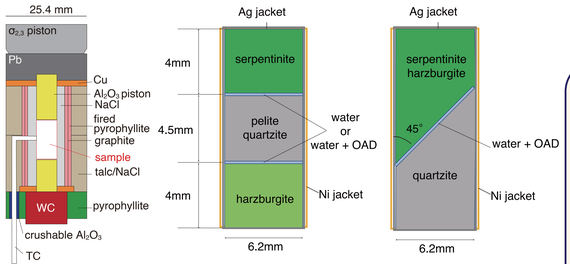
Pressure: **1.0±0.1 GPa**, Temperature: **500±30 °C**

X_{CO2} = **0.2**, F/R ratio = **0.04**



Griggs-type piston cylinder apparatus

H_2O and oxalic acid dihydrate (OAD, $C_2H_2O_4 \cdot 2H_2O$) are set at the boundary to produce H_2O+CO_2 fluid.

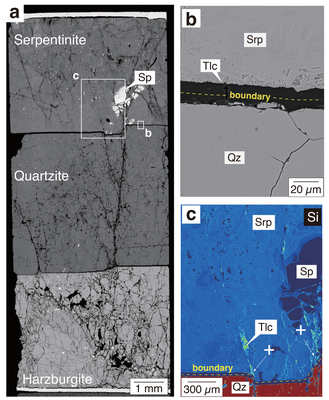


[References]

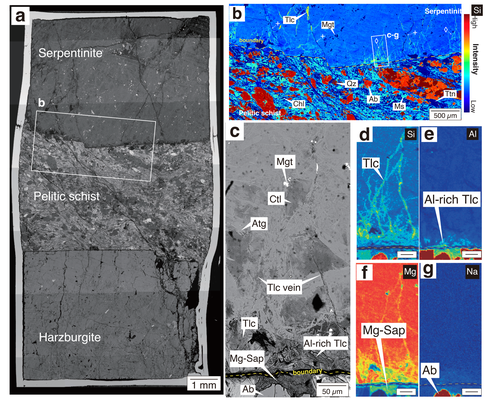
- Okamoto, A., Oyanagi, R., Yoshida, K., Uno, M., Shimizu, H., Satish-Kumar, M., 2021. Rupture of wet mantle wedge by self-promoting carbonation. Commun Earth Environ 2, 151. https://doi.org/10.1038/s43247-021-00224-5
- Menzel, M.D., Urai, J.L., Ukar, E., Hirth, G., Schwedt, A., Kovács, A., Kibkalo, L., Kelemen, P.B., 2022. Ductile deformation during carbonation of serpentinized peridotite. Nat Commun 13, 3478. https://doi.org/10.1038/s41467-022-31049-1
- Oyanagi, R., Uno, M., Okamoto, A., 2023. Metasomatism at a metapelite–ultramafic rock contact at the subduction interface: Insights into mass transfer and fluid flow at the mantle wedge corner. Contrib Mineral Petrol 178, 27. https://doi.org/10.1007/s00410-023-02011-1
- Okino, S., Okamoto, A., Oyanagi, R., Kita, Y., Sawa, S., Muto, J., 2026. Reactions, element transfer, and fracturing at ultramafic rock–sediment contacts: insights from reaction experiments at 500 °C and 1 GPa. Contributions to Mineralogy and Petrology 181, 7. https://doi.org/10.1007/s00410-025-02283-9

Hydrostatic Experiments (H2O fluid) (Okino et al. 2026)

Quartzite-Mantle (Q-H_2O-M)



Pelitic schist-Mantle (P-H_2O-M)



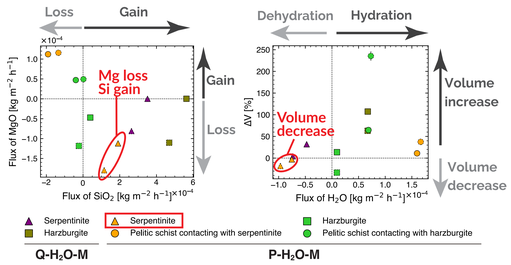
Mass balance calculation

Q-H_2O-M experiment

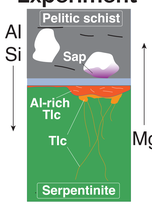
- Ultramafic rocks gained Si
- Volume increased in mantle

P-H_2O-M experiment

- Pelitic schist gained Mg, lost Si
- Ultramafic rocks lost Mg, gained Si
- Volume decreased in serpentinite

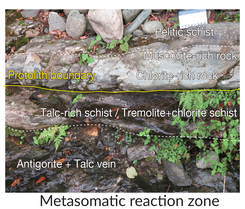


Experiment



Schematic illustration of serpentinite in P-H2O-M

Natural



Metasomatic reaction zone developed at Srp - Ps contact in Sanbagawa belt, Japan

Comparison with outcrop

Experiment

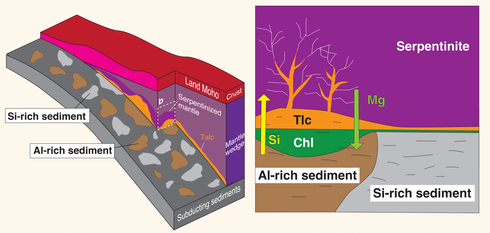
- Mg saponite formed in pelitic schist
- Talc veins precipitaed within serpentinite

Natural

- Chlorite rock formed in pelitic schist
- Talc veins precipitaed within serpentinite

Experimental results acculately reproduce the natural occurrence

(Oyanagi et al. 2023)

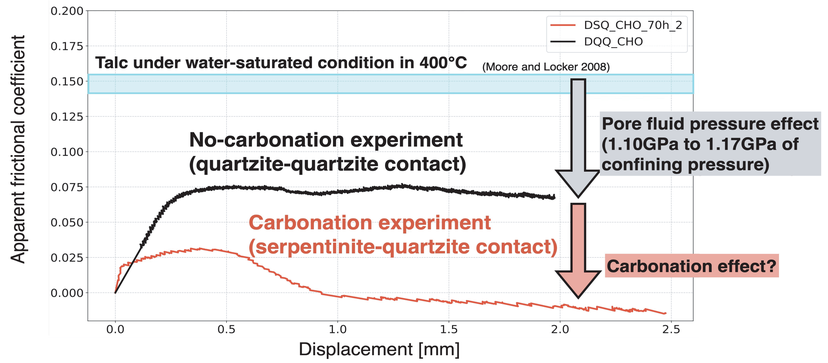


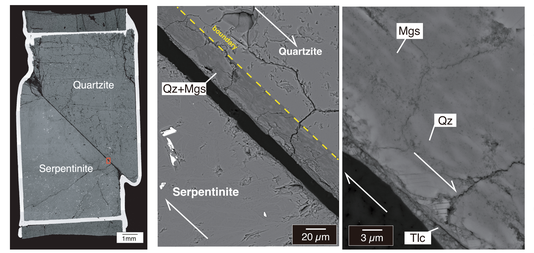
Schematic illustration of mantle wedge and subducting slab (left) and the contact (right)

Al-rich sediment acts as the reservor of Mg released from mantle, which enhance the talc formation

Mg metasomatism from mantle to crust plays important role for continuous reaction in mantle wedge condition

Shear Experiments (H2O-CO2 fluid)



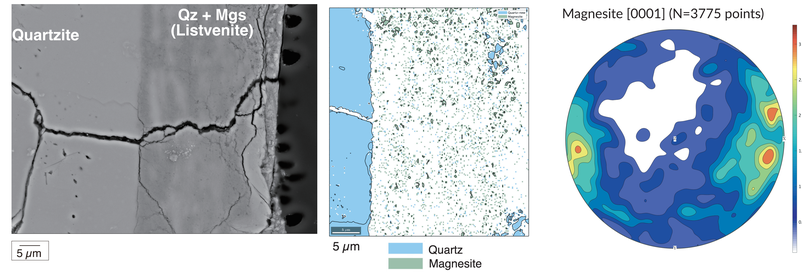


Micro texture (FE-SEM)

- Only Qz + Mgs (listvenite) which show laminar texture
- Little Tlc was observed
- Fractures within quartzite continues to listvenite.

TEM observation is planned to gain further insight

EBSD analysis

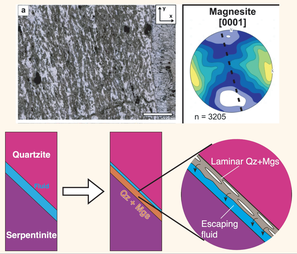


The c-axis of magnesite tends to align perpendicular to the laminar direction

Implication & Conclusion

Perspective

Coupling of mass transfer and carbonation Reveal the relationship to rheology



The aligned c-axis of magnesite is reported in natural listvenite (Menzel et al. 2022)

Our experimental results are valid including mechanical data?

Although the cause of the extreme decrease in shear strength is unclear, the dehydration of serpentinite may play a significant role.

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