【Grant-in-Aid for Scientific Research (S)】

Generation of CO2 fluid and mantle carbonation in subduction zones

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Purpose and Background of the Research

●Outline of the Research

The global carbon cycle has a significant impact on the Earth's surface environment and the state of plate boundaries. Mantle is a rock that can absorb CO_2 like a sponge. However, except near the surface, the nature of CO_2 fixation (carbonation) of mantle is not well understood. We conceived this study to elucidate the reactions between CO_2 fluids and rocks at the surface and at depth, and their chemical and mechanical effects on plate boundaries. In this study, carbonation and serpentinization of mantle bodies within the subduction zones will be clarified through geological surveys, and through laboratory experiments on mantle carbonation at conditions near the surface and beneath island arcs (Fig. 1). We will clarify the essential mechanism of CO_2 fixation in mantle rocks related to fracturing and mass transport, and propose a CO_2 cycle model linking the CO_2 fluid-rock interaction, fault behavior, and earthquakes at plate boundaries.

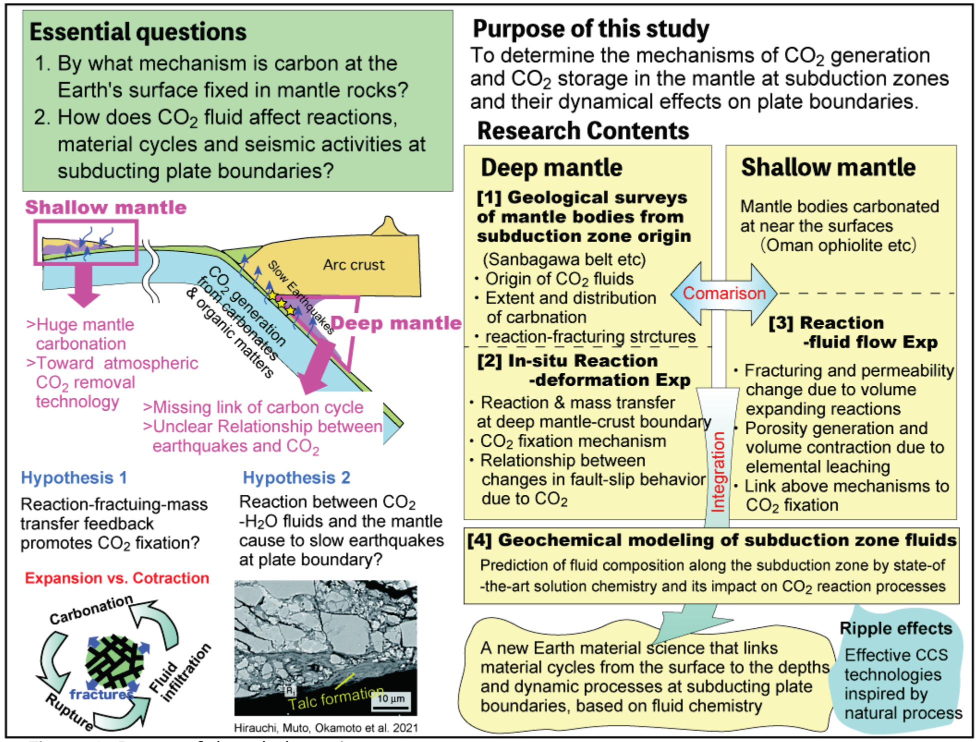

Figure 1. Image of the whole project.

● The paradox of CO_2 fixation in rocks

A continuous fluid supply is essential for the mantle carbonation. However, as CO_2 absorption causes the rock volume expansion, clogging of the flow paths and inhibits a supply of CO_2. There are two possible ways to overcome this problem in nature; first is fracturing rock by the volume expansion; second is volume contraction accompanied by removal of elements. We will elucidate this paradox through multiple approaches: natural, experimental, and modeling.

● Fluid - rock reactions and fault processes within subduction-zone plate boundaries

We focus on the characteristic chemical reactions via CO_2 fluids at the mantle-crustal boundary within subduction zones, and tests whether the reaction products slow fault slip at plate boundaries (associated with slow earthquakes).

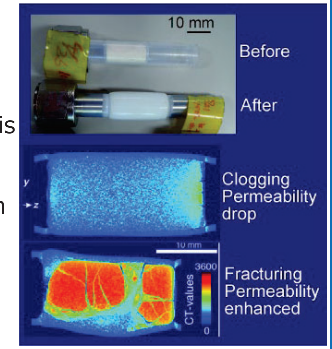

Figure 2. Clogging vs. fracturing during hydration of MgO (Uno, Okamoto et al. 2022)

Expected Research Achievements

● The state of mantle carbonation in subduction zones

State of carbonatation in mantle wedge in subduction-zones are still unknown. We investigate the Sanbagawa metamorphic Belt, where numerous mantle wedge-derived bodies occur, to assess the degree of carbonation progression and to investigate the origin of CO_2 fluids, based on mass transport and stable C-O isotopes analyses (Fig. 3).

● Mechanism of CO_2 fixation in the mantle with crack and porosity formation

We will construct a new apparatus for reaction-fluid flow hydrothermal experiments with monitoring the volume change during the reactions. We will conduct systematic runs by changing the initial fluid (pH, ions, complexes) and the rocks to investigate the control factors on CO_2 fixation associated with fracturing and porosity formation (Fig. 4).

● Influence of CO_2 fluid-rock reactions on fault slip behavior

Reaction-deformation experiments will be conducted at mantle wedge conditions. First, a crustal-mantle boundary is set up to reveal the reactions under hydrostatic conditions. Then, deformation experiments with differential stress are conducted to know how the reactions involving H_2O-CO_2 fluid affect the slip behavior of the plate boundary fault.

● Integration based on the geochemical modeling of subduction zone fluids

We will calculate the fluid compositions from surface to deep subduction zones, and build fluid-rock interaction model that integrates lab experiments and natural observations, and links material circulation and behaviors of subduction zone faults.

● Toward CO_2 fixation Technology inspired by nature

Based on the carbonation mechanism in natural mantle bodies, we will search an effective CO_2 fixation technology that is controlled by the fluid composition.

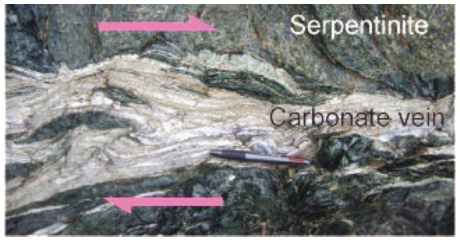

Figure 3. Sheared carbonated mantle rocks

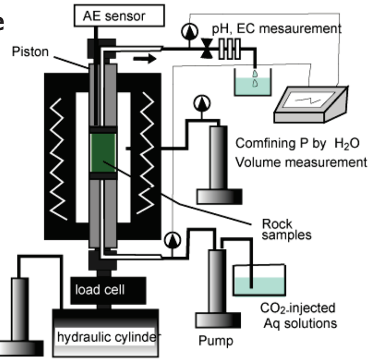

Figure 4. Apparatus of new reaction fluid flow exps.

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