Natural analogue for behavior observation of liquid CO_2 in the ocean

Background

Large amounts of CO_2 are supplied to the ocean from the seafloor as a natural phenomenon. This phenomenon was discovered in hot springs or geysers on the seafloor, in so-called seafloor hydrothermal systems. As the seafloor hydrothermal systems provide a natural analogue *1 of CO_2 droplet behavior, including its impact on ambient seawater, observation of hydrothermal CO_2 would provide an opportunity for understanding the physico-chemical behavior of CO_2, *i.e.*, the dispersion and dissolution processes of liquid CO_2 in the ocean water column. An understanding of the hydrothermal vent ecosystem in this CO_2-rich environment is the target of natural analogue research into CO_2 ocean sequestration and CO_2 storage in sub-seabed geological formations.

Objectives

In order to evaluate the effectiveness of natural analogue of liquid CO_2 behavior in the ocean, initial observations of the behavior of rising CO_2 droplets issued from seafloor hydrothermal systems and changes in the chemical environment surrounding the CO_2 droplets ascending in the water column are carried out at the Hatoma knoll, Okinawa Trough (Fig.1).

Principal Results

1. Tracking observation of the rising CO_2 droplet

Tracking observation of rising CO_2 droplet from 1480 m to 700 m using a monitoring box (Fig.2) succeeded. With decreasing pressure, CO_2 droplet size diminishes and the rise rate of the CO_2 droplet decreases due to the dissolution of the CO_2 droplet in the ambient seawater (Fig.3). CO_2 droplets disappeared at 679 m depth in the form of CO_2 hydrate (Fig.4).

2. In-situ measurement of pH and pCO_2

Although rising CO_2 droplets dissolved gradually into ambient seawater, these observations and measurements indicate that the impact of pH depression and pCO_2 increase caused by dissolution of ascending liquid CO_2 barely extends spatially to the ambient environment (Fig.5). The in-situ pH mapping also revealed that the discharged liquid CO_2 does not cause widespread pH depression in the ambient environment.

3. Measurement of initial rise rate of CO_2 droplet

The initial rise rate of a CO_2 droplet having a cross-section area of 46 mm^2 just after issuing was 18.3 cm/s and the immediate temperature of the CO_2 droplet was 4.5 °C, while the ambient temperature of seawater was 3.8 °C. In addition, the pH of ambient seawater was very close to that of the CO_2 droplet at pH 5.539.

4. Phase change of CO_2 droplet

The captured CO_2 droplets in a glass cylinder continued expanding with the ascent, and then were completely gasified at 455 m. Since the captured CO_2 droplets in the glass cylinder have some restricted contact with the ambient seawater during the ROV ascent, their dissolution rates were not so fast.

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Future Developments

By applying the observation instruments, such as in-situ pH/pCO_2 sensor and towing multi-layer monitoring system, to the seafloor hydrothermal systems as a natural analogue, it is expected that the dispersion and dissolution behavior of the liquid CO_2 in the ocean will be understood and the assessment of environmental impact for CO_2 ocean sequestration and CO_2 storage in sub-seabed geological formations will become possible.

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References

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*1：Natural analogue:Natural analog is an experimental technique for a similar natural phenomenon for the field experiment that enforcement is difficult.

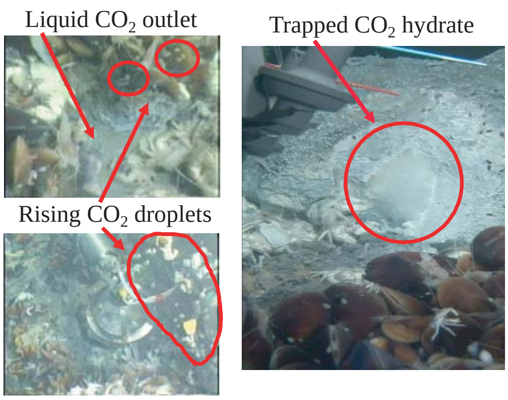

Fig.1 Photos of emitted CO_2 droplets from the seafloor (left) and trapped CO_2 hydrate under over-hanging rock and living organisms (right). The natural CO_2 droplets contain 95-98% of CO_2, 2-3% of H_2S, and other gas species.

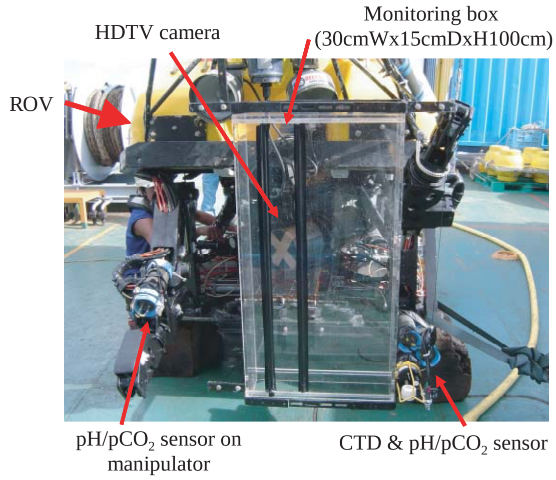

Fig.2 Views of the ROV and the survey equipment attached to front of the ROV, including the monitoring box mounted in front of the HDTV camera.

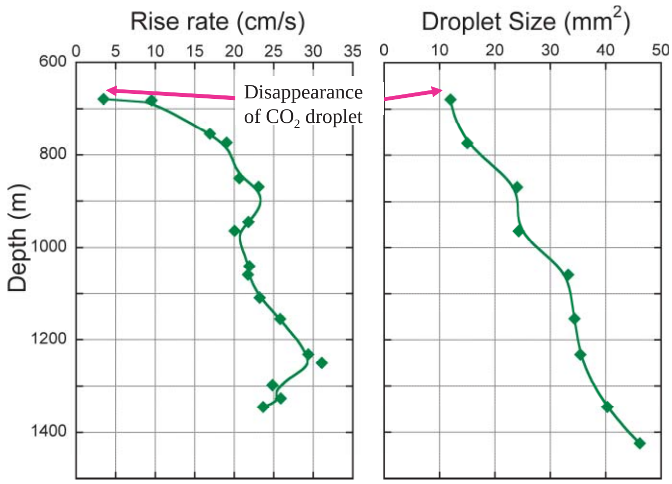

Fig.3 Vertical change in droplet size (left; area of a CO_2 droplet) and rise rate (right) of CO_2 droplets.

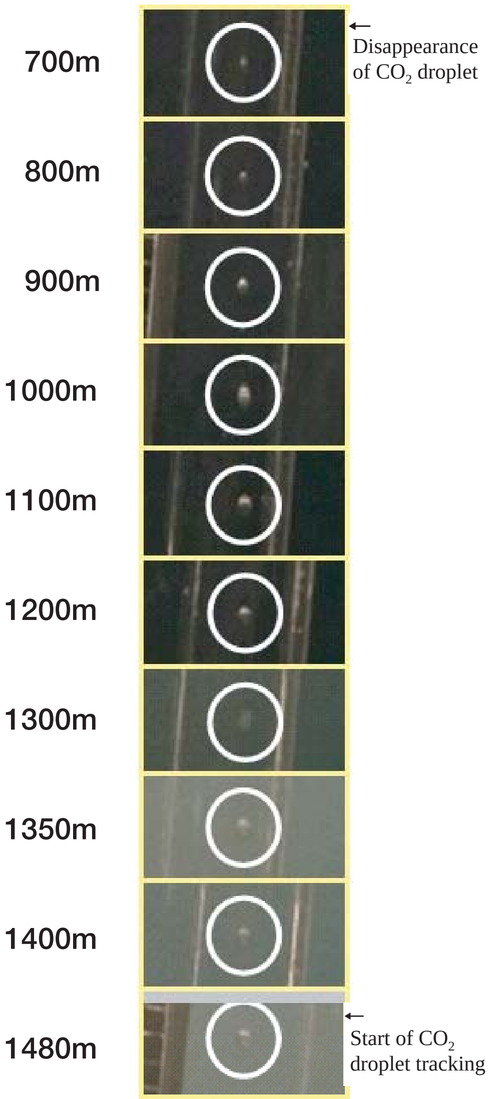

Fig.4 HDTV image of the rising CO_2 droplet at each depth.

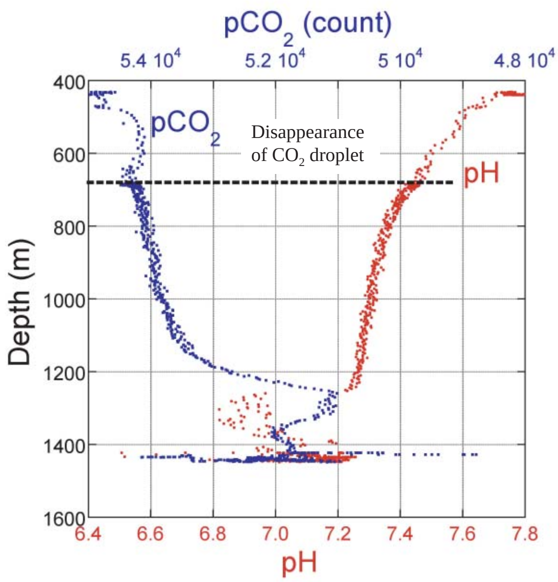

Fig.5 Vertical profiles of pH and pCO_2 during the CO_2 droplet tracking.