Principal Research Results

Natural analogue for behavior observation of liquid CO₂ in the ocean

Background
Large amounts of CO₂ 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 of CO₂ droplet behavior, including its impact on ambient seawater, observation of hydrothermal CO₂ would provide an opportunity for understanding the physico-chemical behavior of CO₂, i.e., the dispersion and dissolution processes of liquid CO₂ in the ocean water column. An understanding of the hydrothermal vent ecosystem in this CO₂-rich environment is the target of natural analogue research into CO₂ ocean sequestration and CO₂ storage in sub-seabed geological formations.

Objectives
In order to evaluate the effectiveness of natural analogue of liquid CO₂ behavior in the ocean, initial observations of the behavior of rising CO₂ droplets issued from seafloor hydrothermal systems and changes in the chemical environment surrounding the CO₂ 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 CO₂ droplet
Tracking observation of rising CO₂ droplet from 1480 m to 700 m using a monitoring box (Fig.2) succeeded. With decreasing pressure, CO₂ droplet size diminishes and the rise rate of the CO₂ droplet decreases due to the dissolution of the CO₂ droplet in the ambient seawater (Fig.3). CO₂ droplets disappeared at 679 m depth in the form of CO₂ hydrate (Fig.4).

2. In-situ measurement of pH and pCO₂
Although rising CO₂ droplets dissolved gradually into ambient seawater, these observations and measurements indicate that the impact of pH depression and pCO₂ increase caused by dissolution of ascending liquid CO₂ barely extends spatially to the ambient environment (Fig.5). The in-situ pH mapping also revealed that the discharged liquid CO₂ does not cause widespread pH depression in the ambient environment.

3. Measurement of initial rise rate of CO₂ droplet
The initial rise rate of a CO₂ droplet having a cross-section area of 46 mm² just after issuing was 18.3 cm/s and the immediate temperature of the CO₂ 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 CO₂ droplet at pH 5.539.

4. Phase change of CO₂ droplet
The captured CO₂ droplets in a glass cylinder continued expanding with the ascent, and then were completely gasified at 455 m. Since the captured CO₂ 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/pCO₂ 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 CO₂ in the ocean will be understood and the assessment of environmental impact for CO₂ ocean sequestration and CO₂ storage in sub-seabed geological formations will become possible.

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References

*1: Natural analogue:Natural analog is an experimental technique for a similar natural phenomenon for the field experiment that enforcement is difficult.
2. Environment - Environmental and innovative technology

Fig.1 Photos of emitted CO₂ droplets from the seafloor (left) and trapped CO₂ hydrate under over-hanging rock and living organisms (right). The natural CO₂ droplets contain 95-98% of CO₂, 2-3% of H₂S, 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 CO₂ droplet) and rise rate (right) of CO₂ droplets.

Fig.4 HDTV image of the rising CO₂ droplet at each depth.

Fig.5 Vertical profiles of pH and pCO₂ during the CO₂ droplet tracking.