Formation processes of CO2 hydrate chimney grown in a pressure cell

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Gas hydrates exist in permafrost and submarine sediments under high pressure and low temperature conditions. CO2 hydrate chimney was first observed in the JADE hydrothermal field, mid-Okinawa trough (Sakai et al., 1990). This study was conducted to understand the formation process of CO2 hydrate chimney by using a special pressure cell.

CO2 gas from a supply container (3 MPa) was injected into pure water (25 to 30 cm deep, and CO2 saturated before each test run) in the pressure cell (400 ml capacity, 5 MPa maximum) through an aluminum nozzle (1 mm inner diameter) at the bottom. Pressure in the cell increases and gas supply rate decreases with time during each run by the gas injection because the pressure cell is of a closed system. Temperature was initially kept constant between 0.9 and 1.5 degree C, but slightly increased up to 5.2 degree C at highest during the test runs. Formation process of hydrate near the nozzle was observed and recorded by a video-camera through a cell window.

Ten experimental runs were conducted by varying gas supply rate. Each test run took between 2 minutes and one hour. Gas hydrate started to form at the contact position between the nozzle and gas bubble around pressure values of 1.7 MPa or higher, but most bubbles climbed up to the water surface, apart from the nozzle without forming chimney structures. Chimney structures were formed when pressure values were higher than 2 MPa and the hydrate formed is strong enough to keep the bubble at the nozzle. The key factors to form a chimney structure found were (1) keeping the bubble at the nozzle long enough to form hydrate crystal by lowering gas supply rate and (2) making hydrate growth rate faster by increasing super-cooling.