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Pattern formation of methane hydrates in oceanic sediments

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Objective

The methane hydrates found globally in oceanic sediments are of significant interest as a global climate change and as a potential energy resource. Sediment cores recovered from the ocean floor have been reported to have a variety patterns and sizes of hydrates, which were classified into four categories by Malone [1]: disseminated, nodular, layered, and massive. In order to reproduce the variety patterns, clarify the pattern formation mechanism of hydrates in the sediments, tetrahydrofuran (THF) clathrate hydrates were grown using a directional growth apparatus in oceanic sediment model.

Experimental Method

The oceanic sediment model is mixed glass beads of 2 um (um denotes micrometer) and 50 um in diameter. The mixing ratio between 2um beads and 50um beads, W_2:W_{50}, was variable. A model system consists of the mixed glass beads and a stoichiometric THF water solution (THF-17H_2O).The weight ratio of the solution and the glass beads was fixed unity. A directional growth apparatus was used to grow the hydrates at a constant growth rate, V, under an applied temperature gradient. That is, a growth rate, V, and a mixing ratio, W_2:W_{50}, were variable.

Results and Discussions

Various patterns such as layered, nodular, massive and disseminated pore space type hydrates were reproduced. Our previous work showed that the hydrates formed a layered type in the 2um glass beads [2]. However, mixing small amount of 50 um beads in the present study, the layered type changed to massive type, nodular type. Finally, disseminated type formed in the 50um glass beads only. In the mixed glass beads of W_2:W_{50} = 5:5, the layered type changed to massive type, nodular type when V increased from low growth rate. Finally, disseminated type formed at high growth rate. Additionally, needle type formed in the mixed glass beads of W_2:W_{50} = 3:7, at V = 8um/s. Thus, all patterns classified by Malone are reproduced, and the hydrates patterns classified into diagram about experimental conditions. Pattern formation of various patterns of hydrates formed in soil model was qualitatively explained by our model based on mechanism as frost heave during ice growth in soil.

[1] R.D. Malone, Gas Hydrate Topical Report, DOE/METC/SP-218, U.S. Department of Energy, April 1985.

[2] Nagashima et al., J. Phys. Chem. B112 (2008), pp. 9876?9882.

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