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Pattern formation of tetrahydrofuran hydrate and an image-analysis technique to measure hydrates size scale

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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. In addition, a method to measure those variety patterns is not established. It is important establishing the method to clarify the pattern formation mechanism. This study presents a simple image analysis technique to measure hydrates size scale.

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 was unity. 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 unity. A directional growth apparatus was used to grow the hydrates at a constant growth rate, V, under an applied temperature gradient. The effect of the growth rate was studied in the range of 0.04um/s ? V ? 20um/s.

The digital pictures of hydrates convert to 256 gray-scale pictures. Processing of the 256 gray-scale pictures produced binary (black and white) images, where white pixels represent the pure hydrate and black pixels represent glass beads rich region. Those pictures were processed on a Windows computer, using public domain Image J program. Area of hydrate and grain number was measured using Analyze Particle function of Image J. And White pixels and Black pixels were counted. To calculate hydrate diameter and distance of each hydrate from those data, hydrate patterns were simplified to 2D square lattice and shapes of hydrate were simplified to disk. The detail of this method will be stated in poster session.

Results and Discussions

The large size hydrates were formed at the growth rate V = 0.04um/s ˜ 1.0um/s. These patterns were regarded as massive type hydrate because the hydrates were much larger than nodular hydrates and contain about 5 % glass beads (This is one of criterion of massive pattern by Malone). When the growth rate was increased, the sizes of hydrates were decreased. Thus, the massive patterns changed to nodular patterns at V = 1.0um/s ˜ 5.0um/s. When the growth rate was much increased, pure hydrates region was not formed at V = 10um/s ˜20um/s. Consequently, as growth rate was increased, sizes of hydrates were decreased and the massive patterns changed to nodular patterns. Finally, disseminated type formed at high growth rate.

The relationship between area of hydrate and growth rate V was measured by the method as previously explained applied to massive, nodular and disseminated patterns. When growth rate was increased, the area of hydrate was decreased. And the area of hydrate was discontinuously decreased at V = 1.0um/s. Thus, the value of area was discontinuously decreased at the point of massive pattern changed to nodular pattern. The distance of each hydrate and grain number was similarly measured.

Massive, nodular and disseminated patterns were reproduced. And those hydrate diameter was measured by hydrate patterns were simplified to 2D square lattice and shapes of hydrate were simplified to disk. This method is automatically, and enable to measure hydrate size scales in short time.

[1] R.D. Malone, Gas Hydrate Topical Report, DOE/METC/SP-218, U.S. Department of Energy, April 1985.
[2] Rasband, W.S., ImageJ, U. S. National Institutes of Health, Bethesda,
Maryland, USA, http://imagej.nih.gov/ij/, 1997-2011.

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