Gas-Hydrate Imaging Using X-Ray Computed Tomography

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RESEARCH OBJECTIVES

Gas hydrates are ice-like crystalline solids formed from a mixture of water and natural gas at high pressures and temperatures near freezing. They are abundant in deep oceans and underlie vast stretches of permafrost. There is general scientific agreement that naturally occurring hydrates contain significantly more energy than is stored in traditional fossil fuel reserves. While gas-hydrate dissociation (the process of hydrate separating to gas and water or ice) is well understood, there is very little known about hydrate behavior in oceanic sediments or porous media. Our objective was to develop a technique capable of observing gas-hydrate dissociation in oceanic sediments or porous media, so that we may eventually extract the natural gas as an economic resource.

APPROACH

We used x-ray computed tomography (CT), coupled with physical measurements of temperature, pressure, and volume, to observe hydrate dissemination and monitor dissociation of synthetic samples. We compared the results from the physical measurements to the x-ray CT scanning to examine the effectiveness of using x-ray CT scanning in quantifying hydrate dissociation.

ACCOMPLISHMENTS

We have performed several experiments to accomplish our objective. In one experiment, we used a modified medical x-ray CT scanner to observe the changes in a hydrate/silica sand sample. The sample contained two different mixtures of hydrate and sand. We measured the temperature at the bottom of the sample, as well as the volume and composition of the produced gas. The sample warmed from top to bottom, and as dissociation occurred, methane gas was produced. Simultaneously, changes in x-ray attenuation were observed in the top of the sample. The location where the hydrate was dissociating was identifiable in the x-ray images as a horizontal front, and we were able to track the front from the sample top to the bottom. As expected, gas production ceased when the front reached the sample bottom.

We conducted another experiment using the Berkeley Lab portable x-ray CT scanner. In this experiment, we measured the pressure change and temperature as the sample, consisting of clean 1 mm sand as well as chunks of hydrate and ice (Figure 1), warmed from –196°C. As in the first experiment, the x-ray CT images clearly show changes in the hydrate as dissociation occurs.

SIGNIFICANCE OF FINDINGS

We have shown that x-ray CT scanning is a valuable tool in examining samples containing hydrates, and can be used to track hydrate dissociation. The use of x-ray CT scanning at remote locations can be performed using the Berkeley Lab portable x-ray CT scanner, allowing examination of natural samples in their most representative condition. The x-ray CT results, combined with pressure and temperature measurements, provide clear indications of hydrate changes in samples.

RELATED PUBLICATION

Freifeld, B.M., T.J. Kneafsey, L. Tomutsa, L.A. Stern, and S.H. Kirby, Use of x-ray computed tomographic data for analyzing the thermodynamics of a dissociating porous sand/hydrate mixture. Proceedings of the Fourth International Conference on Gas Hydrates, pp. 750–755, Yokohama, Japan, May 19–23, 2002.

ACKNOWLEDGMENTS

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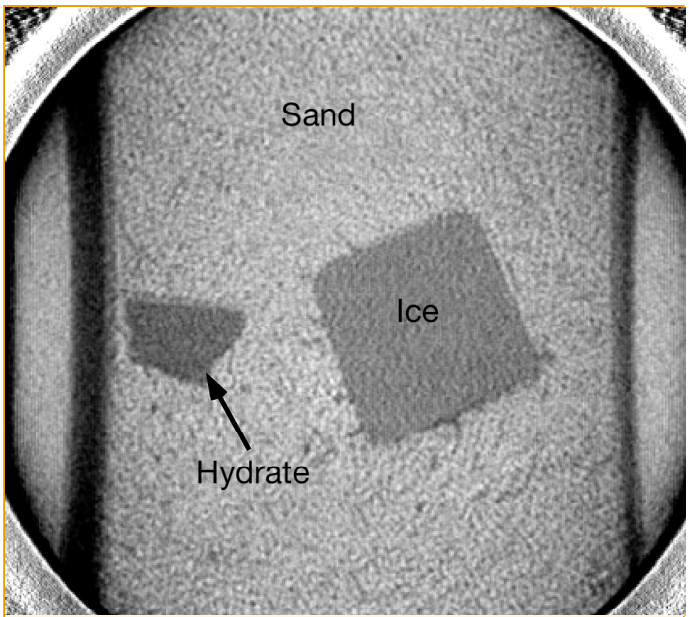

Figure 1. X-ray CT image of the sand/ice/hydrate sample