MECHANISMS LEADING TO CO-EXISTENCE OF GAS AND HYDRATE IN OCEAN SEDIMENTS

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QUARTERLY PROGRESS REPORT
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Summary

Work during this quarter focused on creating and characterizing model sediments (dense, random packings of spheres; Task 3). The task has been completed per the timeline in the proposal, and the report summarizing this task is in preparation. The model sediments are good representations of the hydrate-bearing strata in locations such as the Mackenzie Delta in Canada. On the other hand the models have smaller porosities (30% - 40%) than many ocean sediments containing hydrates (50% - 80%). The fact that a wide range of porosities are encountered in gas hydrate provinces is important, but accounting for the full range is not crucial to this project. Rather, the goal here is to develop a fundamental understanding of the competition and coupling between capillarity control and fracture mechanics control of the movement of methane gas into brine-saturated sediments. The development can be done most rapidly in densely packed model sediments. The methods we are using are not "hard wired" to those models, so the extending our findings to low density sediments will be feasible.

The development and application of Level Set Methods for locating gas/water interfaces in granular materials is a key part of this project. Preliminary results of this research were presented at the SIAM Conference on Computational Engineering and Sciences, Costa Mesa, CA, February 2007 and at SIAM Conference on Mathematical and Computational Issues in Geosciences, Santa Fe, NM, March 2007. A proposal was accepted to present the work at International Congress on Industrial and Applied Mathematics in summer 2007, and another is pending for the SPE Annual Technical Conference and Exhibition for fall 2007.

Background: Project Motivation

The mass of carbon held in sediments below the seafloor is a significant part of the Earth's carbon cycle. The amount currently in place may be very large; enough to implicate methane hydrates in global warming events in the geological past and to raise the prospect of a vast energy resource. However, estimates of this mass and the rate at which it can accumulate in or dissipate from sediments vary widely. One reason is the difficulty in ascertaining the form and spatial distribution of methane within the hydrate stability zone (HSZ). The goal of this project is to understand quantitatively the manner in which methane is transported within the HSZ. The research will seek validation of the following hypothesis: the coupling between geomechanics, the dynamics of gas/water interfaces, and phase behavior of the gas/brine/hydrate system make co-existence of free gas and hydrate inevitable in the HSZ.

If borne out, our hypothesis would provide a mechanistic basis for several observations of co-existing gas and hydrate in the HSZ. The models have implications for interpretation of seismic and borehole log data and thus for estimates of carbon held in the HSZ. It would explain observations of lateral and vertical variability in hydrate saturation, e.g. preferential occurrence in coarse grained material above and below a fine grained layer. The model would be a step toward explaining active and passive hydrate accumulations with a single set of mechanisms.

Activities in This Reporting Period

<u>Task 3.0 – Creation of Sediment Models</u>

We completed this task and a report summarizing the models is nearing completion.

<u>Task 4.0 – Fracture Initiation and Propagation</u>

We continued our work on the mechanical loading of model sediments under different confining conditions, using the computer code PFC. We have been able to reproduce the main features (stiffness, bulk modulus, stress/strain curves) of mechanical lab tests of hydrate-bearing ocean sediments under drained conditions. The next step will involve introducing pore-fluid forces in the system.

<u>Task 5.0 – Compute Grain-Scale Gas/Water Geometry</u>

While preparing the model sediments, a trial of the level set method for computing gas/water interfaces was conducted on model fractures. The results are very encouraging. A primary difficulty for other models is a mechanistic accounting for the in-plane radius of curvature of the interface when the aperture of the fracture varies. Our method requires no special adjustment to handle this situation.

As a model problem we considered a rough walled fracture constructed by placing two irregular grain packs in proximity. Such geometries are anticipated to be characteristic of the fracture formed when gas pressure exceeds confining stresses in the mechanics modeling of this project. Figure 1 shows the fluid/fluid interfaces (invasion occurs from left to right) in a two-dimensional example.

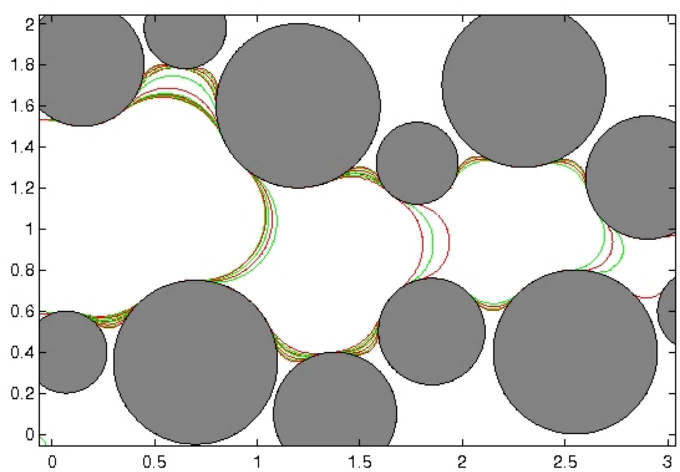

Figure 1. Selected fluid-fluid interface positions during drainage (shown in alternate red and green colors) for a 2D fracture obtained by numerically separating a dense pack of grains into an upper pack and lower pack (shown in gray).