Oil & Natural Gas Technology

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Quarterly Progress Report
(January – March 2008)

Laboratory Studies in Support of Characterization of Recoverable Resources from Methane Hydrate Deposits

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National Energy Technology Laboratory

May 27, 2008

Office of Fossil Energy

Quarterly Progress Report
FY 2008 Q2
(January 1, 2008 through March 31, 2008)

LBNL Laboratory Studies 1) in Support of Characterization of Recoverable Resources from Methane Hydrate Deposits and 2) of Basic Rock Properties in Oceanic Hydrate Bearing Sediments

ESD05-048

Lawrence Berkeley National Laboratory

Tim Kneafsey

May 27, 2008

Task 1: Continued and repeated estimation of parameters for the relative permeability-saturation and capillary pressure-saturation functions using inverse modeling.

Anticipated Completion Date 9/30/08

This section pertains to determination of capillary pressure curves of hydrate bearing sand packs. All tests are being conducted using Ksand and F110 sand, packed to achieve 40% total porosity (in the absence of hydrate). Between January and now, 7 tests have been performed (two of which were continuation of tests reported in the previous report). A summary of all the tests is provided in Table 1. For the Ksand, retention curves at 20%, 35%, and 45% hydrate saturation have been successfully determined (see Figure 1). Of these, the 20% and 45% measurements include both drainage and imbibition curves, whereas, the 35% saturation consists of only a drainage curve. For the remaining sands, only drainage curves will be determined because the time needed to complete an experiment.

In the experiments that use F110 sand, two tests were interrupted because hydrate did not form for several days after the system was brought to temperature and pressure conditions that favor hydrate formation. This problem is attributed to the relatively smooth surface of the F110 grains compared to the jagged grains of the K sand.

Table 1. Summary of experiments conducted from 01/26/08 to 05/27/08

Test #	Duration	Material	Hydrate Saturation	Status/Remark
5	01/14/08-02/04/08	K Sand	35%	Successfully completed
6	12/28/07-02/08/08	K Sand	0 %	Test interrupted because of poor pressure control. Pressure plate apparatus reconfigured
7	02/11/08-03/05/08	K Sand	45 %	Successfully completed (includes an drainage and imbibition curves)
8	03/11/08-04/13/08	F110	20%	Successfully completed. Formation of hydrate took much longer time than any of the Korean Sand tests
9	04/15/08-04/27/08	F110	35%	Test interrupted because hydrate did not form after two weeks.
10	04/29/08-05/03/08	F110	35%	Test repeated using a new bag of sand. Test interrupted because hydrate did not form
11	05/03/08-continuing	F110	35%	Ongoing, six (6) steps of drainage performed to date; four more expected.

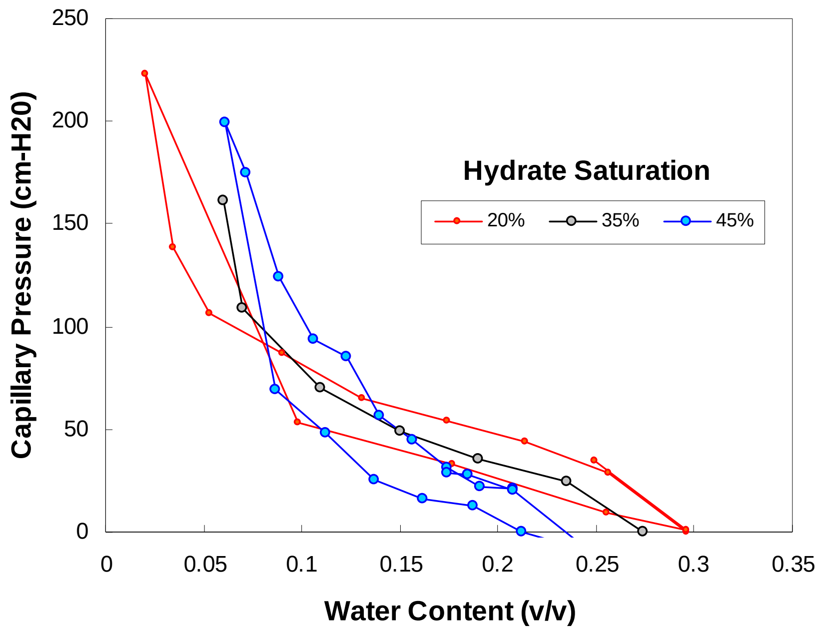

Figure 1. Capillary pressure curves for K sand at three hydrate saturations.

Task 2: Development of a combined relative permeability/capillary pressure estimation technique using laboratory measurements and inverse modeling.

Subtask 2a: Method Modification Complete method modification
Anticipated Completion Date 7/31/08

A computational model has been developed to interpret the capillary pressure results and this model has been tested. Preliminary model tests are providing reasonable match without any fitting of parameters (see Figure 2). Further refinement of the model should lead to better-constrained parameters.

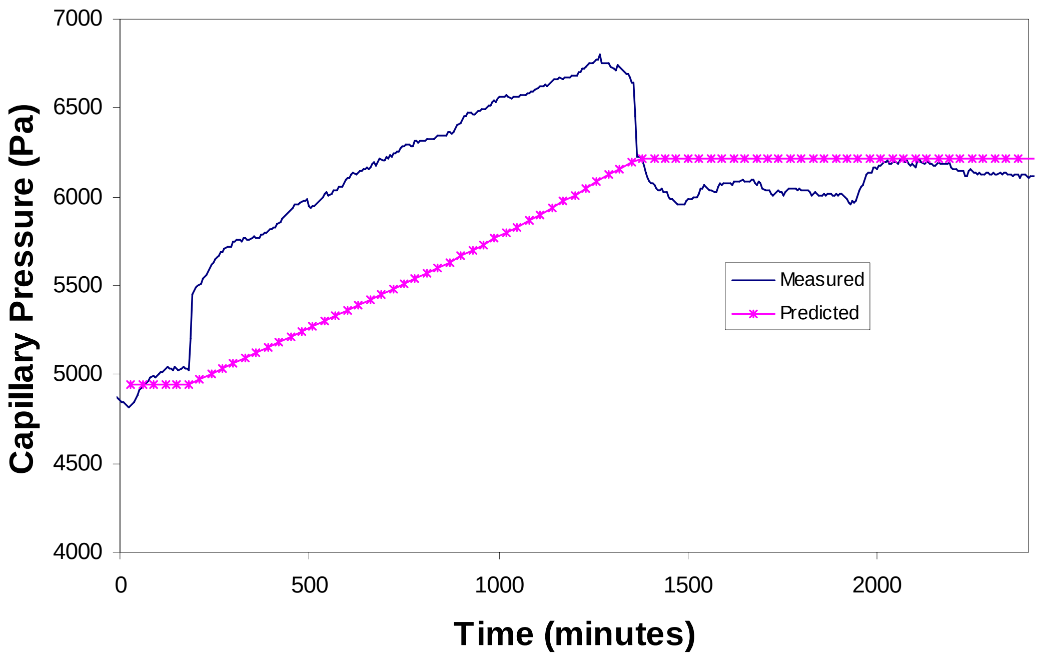

Figure 2. Comparison of measured and modeled capillary pressure curves as function of time for the sixth drainage step of Test # 08 (F110 Sand, 20% hydrate saturation).

Subtask 2b: Measurements Complete measurements of combined relative permeability/capillary pressure for sand/hydrate and hydrate-bearing artificial rock samples with controlled properties
Anticipated Completion Date 9/30/08

Several sets of measurements with sand as the porous medium have been made (See Table 1).

Subtask 2c: Data Analysis and Inversion
Anticipated Completion Date 11/30/08

Preliminary analysis of a data set has been completed. This analysis indicated a difficulty in modeling one of the experimental components – the glass frit that provides the contact between the sand and the water. Work is continuing to resolve this issue.

Subtask 2d: Result Comparison and Reporting
Anticipated Completion Date 12/30/08

Preliminary result comparison of a portion of a data set is presented in Figure 2.

Task 3: Continued Laboratory Studies of Geomechanical Behavior of Oceanic HBS and Geophysical Signature of HBS Undergoing Thermomechanical Changes

Subtask 3.1: Determination of HBS Geomechanical Properties Complete triaxial compression tests and CT scanning on synthetic hydrate-bearing cores (sand only)
Anticipated Completion Date 9/30/08

Three geomechanical/geophysical tests have been completed using tetrahydrofuran (THF) hydrate as an analog for methane hydrate. THF hydrate was used because of difficulties in obtaining an approval for the Engineering Safety Note to conduct the anticipated experiment using methane hydrate under required pore pressures. (A detailed finite element analysis of our Geomechanical /Geophysical test cell identified stress concentrations, which are being reduced by reworking portions of the vessel.) In these three tests, a 100% hydrate-saturated sample, a 50% THF hydrate - 50%THF fluid saturated sample, and a 40% THF hydrate saturated sample were used, in an attempt to compare the strength of hydrate-bearing samples with comparable hydrate saturations made in a manner (1) thought to form pore-filling hydrate (called Saturated THFH in Figure 3), and (2) thought to form grain-cementing hydrate (called Unsaturated 40%THFH in Figure 3).

From this test, which is not considered to be the final word on this subject, the strength of the Unsaturated 40% THFH sample was unexpectedly lower than the strength of the Saturated 50%THFH sample. The strength of both samples was less than the Saturated 100%THFH sample. X-ray CT imaging during the experiment revealed that: the 100%-hydrate-cemented sample failed in a brittle fashion, exhibiting a narrow shear zone (Figure 4 left); the 50% fluid-50% hydrate sample failed in a more ductile way (wider shear zone) (Figure 4 middle); and the unsaturated sample failed in a ductile fashion (uniform bulging of the sample) (Figure 4 right). The reason for the high ductility of the third sample was due to the core-scale heterogeneity in the hydrate distribution—rather than the grain-scale heterogeneity of the grain-cementing and pore-filling models.

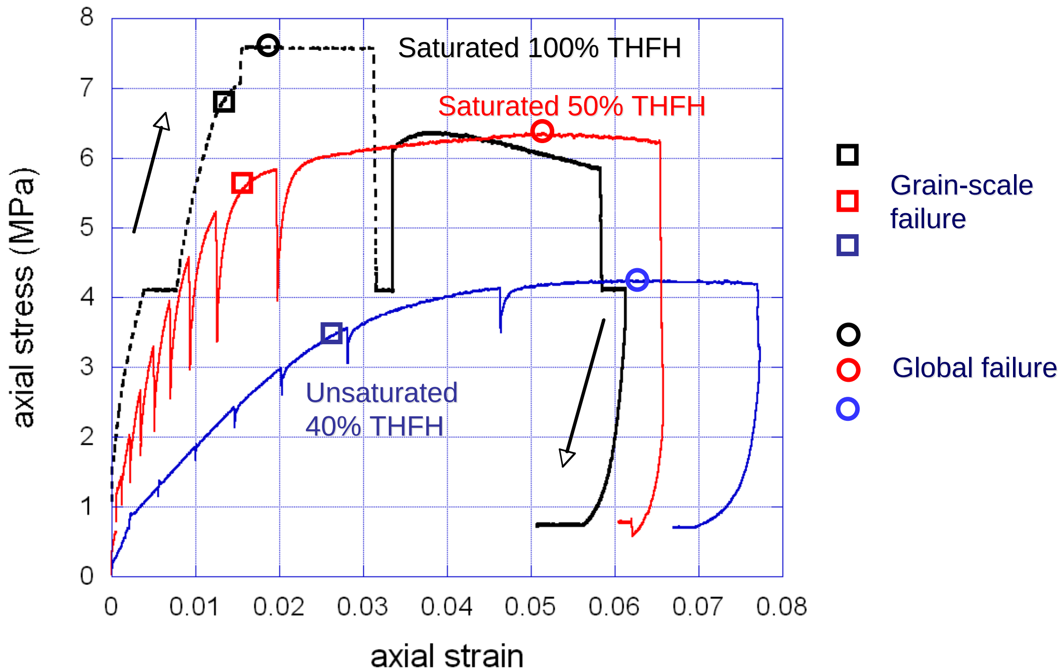

Figure 3. Results of triaxial stress tests on three samples.

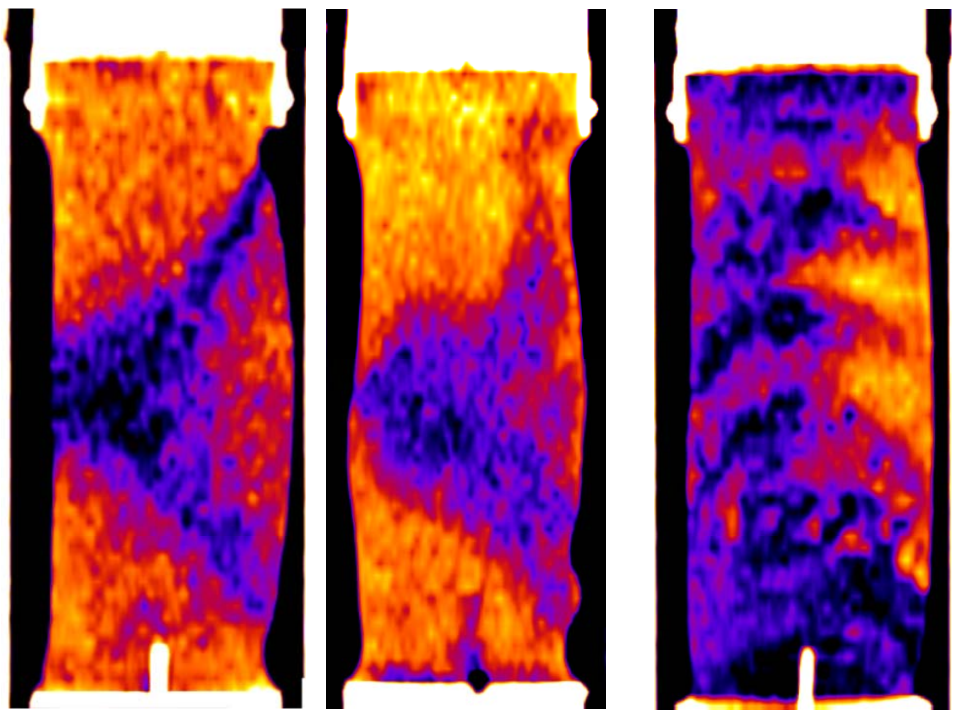

Figure 4. Cross-sections of CT-scanned samples showing different modes of failure. From the left, Saturated 100% THFH, Saturated 50%THFH, and Unsaturated 40%THFH. Dark blue/purple indicates reduced density (increased porosity) of the sample.

Complete triaxial compression tests and CT scanning on synthetic hydrate-bearing cores (sand/silt, clay)
Anticipated Completion Date 12/30/08

No progress.

Subtask 3.2: Determination of the Geophysical Signature of HBS Undergoing Thermomechanical Changes Complete acoustical property measurements on synthetic hydrate-bearing cores (sand only)
Anticipated Completion Date 9/30/08

Changes in geophysical signatures of the three samples discussed in Task 3.1 were measured during hydrate formation and during the mechanical stressing of the sample. Figure 5 shows both compressional and shear (torsion) waves measured during the experiment on the 100% THFH saturated sample (other two samples showed the same general behavior). For all the samples and the wave types, the waves exhibited significant increases in velocity and amplitude upon hydrate formation (Note the labels "before" and "after" in Figure 5). Determined wave velocities are plotted as a function of applied axial stress in Figure 6. The relative magnitudes of the velocity among the three samples followed the same trend as the strength of the samples measured in Task 3.1: The 100% THFH showed the highest velocity, while the unsaturated 50%-THFH sample unexpectedly exhibited the lowest velocity. Although expected, the good correlation between the strength and seismic velocities of the samples is encouraging for using geophysical (seismic) measurements to predict the in-situ mechanical strength of hydrate-bearing sediments. Also, it is interesting to notice that both compression and shear velocities in Figure 6 seem to show a slight reduction immediately before the failure of the samples: a possible precursor for predicting the imminent formation failure in the field.

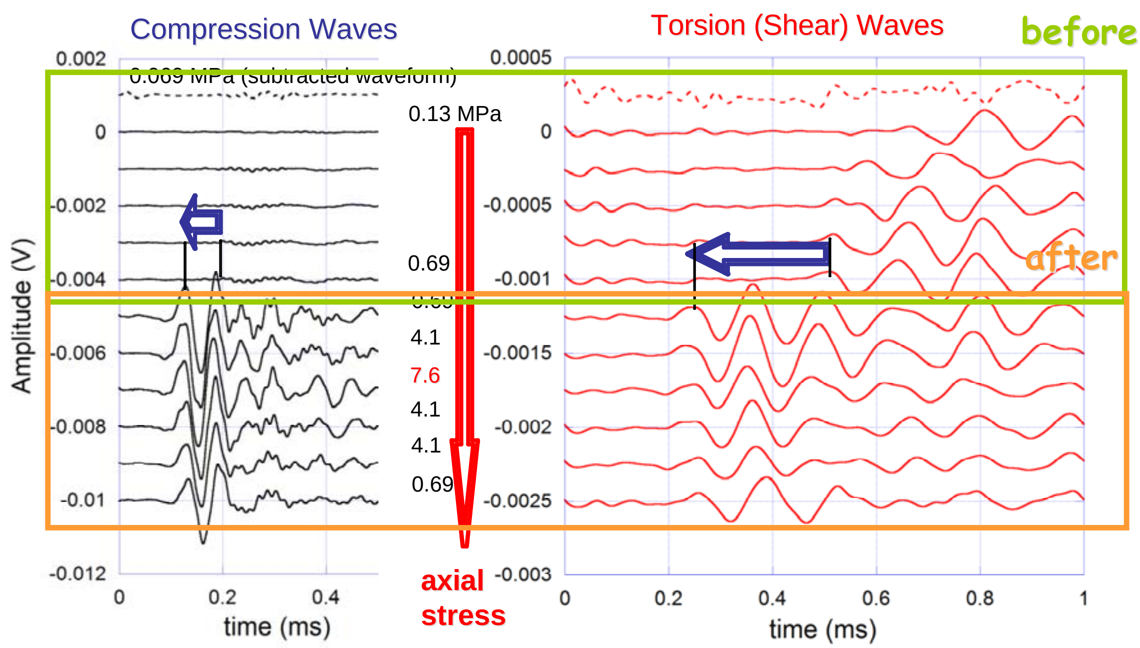

Figure 5. Compression and shear waves before and after hydrate formation.

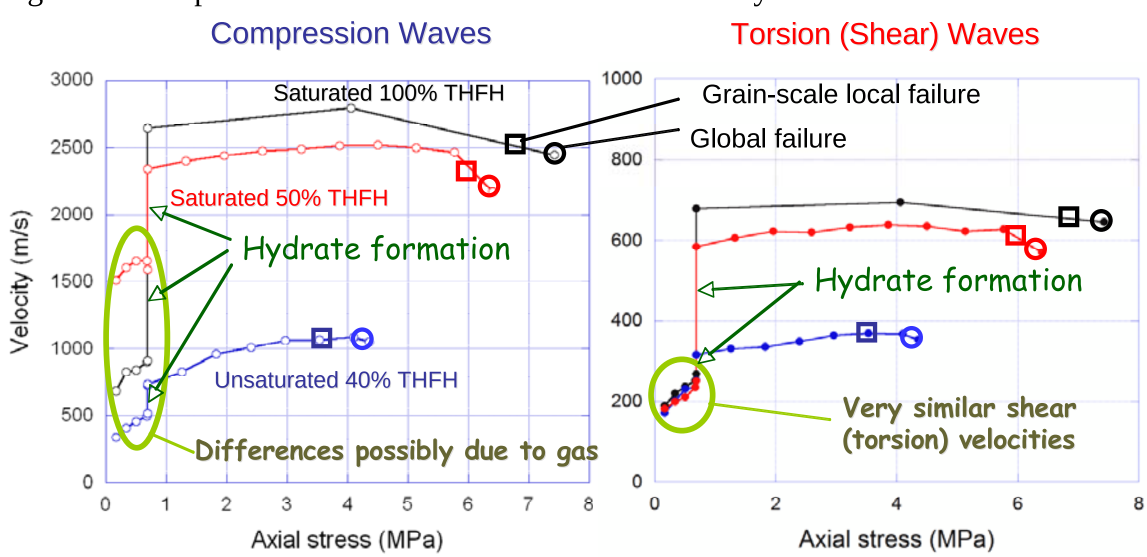

Figure 6. Effect of axial stress on compression and shear wave velocities. As in Figure 3, grain-scale and global failure are identified by squares and circles respectively.

Complete acoustical property measurements on synthetic hydrate-bearing cores (sand/silt, clay)
Anticipated Completion Date 12/30/08

No progress.

Subtask 3.3: Validation of Coupled Geomechanics/Flow Code by Using Data from a Geomechanical Lab Experiment Perform experiment for validation of coupled geomechanics/flow code
Anticipated Completion Date 9/30/08

No progress.

Papers and Presentations

Poster presentation and paper in progress resulting from:

Kneafsey, Timothy J., and L. Tomutsa, X-ray Computed Tomography Scanning of NGHP Core Samples, NGHP GAS HYDRATE CONFERENCE 2008 (Under the Aegis of Indian National Gas Hydrate Program), New Delhi, India, February 6 to 8, 2008, Organized by Directorate General of Hydrocarbons, Ministry of Petroleum & Natural Gas, Government of India

Presentation:

Kneafsey, Timothy J., and L. Tomutsa, CT Scanning, Analysis, and Production Test - Mt Elbert Core Samples, BP-DOE Mount Elbert-01 Gas Hydrate Stratigraphic Test, Data Analyses/Interpretation and Production Test Design Workshop, March 4-7, 2007, USGS Conference Room, Denver Federal Center, Denver CO

Paper in progress resulting from:

Kneafsey, Timothy J. and others, Title to be determined, Physical Properties of Hydrate-Bearing Sediments Workshop**,** Atlanta, GA, March 16 – 19, 2008

Submitted paper and presentation:

Kneafsey, T. J., A. Gupta, Y. Seol, and L. Tomutsa, Permeability of Laboratory-Formed Methane Hydrate-Bearing Sand, OTC-19536-PP, SPE Offshore Technology Conference, Houston, TX, May 7, 2008

Nakagawa, S., T.J. Kneafsey, G. J. Moridis, Mechanical strength and seismic property measurements of hydrate-bearing sediments (HBS) during hydrate formation and loading tests, OTC 19559, SPE Offshore Technology Conference, Houston, TX, May 8, 2008

Submitted paper:

Seol, Y. and T.J. Kneafsey, Fluid flow through heterogeneous methane-hydrate bearing sand: observations using x-ray CT scanning, Proceedings of the 6th International Conference on Gas Hydrates (ICGH 2008), Vancouver, British Columbia, Canada, July 6-10, 2008.

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