Oil & Natural Gas Technology

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Quarterly Progress Report
(October – December 2007)

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

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Office of Fossil Energy

Quarterly Progress Report
FY 2008 Q1
(October 1, 2007 through December 31, 2007)

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

January 25, 2008

Tasks Performed

Numerous tasks were performed in the first quarter of FY08 in the investigation of the influence of gas hydrate on the behavior of a porous medium including:

- Permeability tests with gas hydrate in sand/silt medium
- Permeability test with moist sand
- X-ray CT scanning of USGS Menlo Park India NGHP Samples
- Geomechanical studies
- Capillary pressure- saturation tests
- Test design for India NGHP cores

Permeability tests with gas hydrate in sand/silt medium (Tim Kneafsey and Yongkoo Seol)

Gas permeabilities were measured at prescribed conditions and waterflood tests were performed in three sand/silt samples containing methane hydrate at nominal hydrate saturations of 20%, 35%, and 45%. The porous medium was formed by mixing US Silica F110 quartz sand with US Silica Sil-co-sil 45 silica flour, a ratio of 90% sand and 10% flour. CT scanning was used to quantify sample homogeneity and phase saturations, including waterflood saturations. Each test required about two to three weeks to complete. The experiment apparatus is shown in Figure 1.

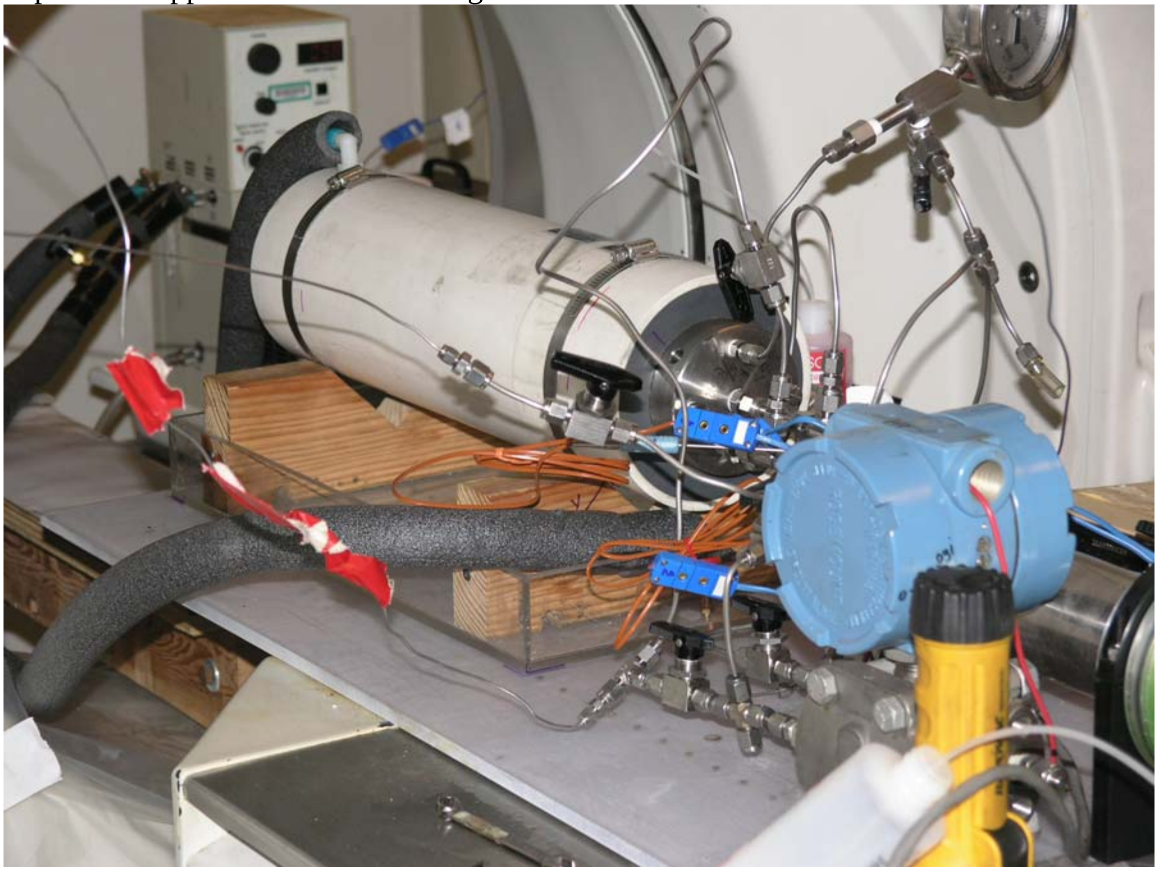

Figure 1. Experiment setup for relative permeability tests.

Permeability test with moist sand (Tim Kneafsey and Yongkoo Seol)
A single waterflood test was performed using moist sand/silt to provide a baseline for calculating relative permeability values in hydrate-bearing media by numerical inversion.

X-ray CT scanning of USGS Menlo Park NGHP Samples (Tim Kneafsey and Liviu Tomutsa)
Ten samples from the NGHP core were CT scanned at the request of Laura Stern of the USGS Menlo Park. The results of this scanning exercise altered the selection of subsamples for further analysis at the USGS, as hydrate nodes were located for USGS study (Figure 2), conserving both time and sample quality.

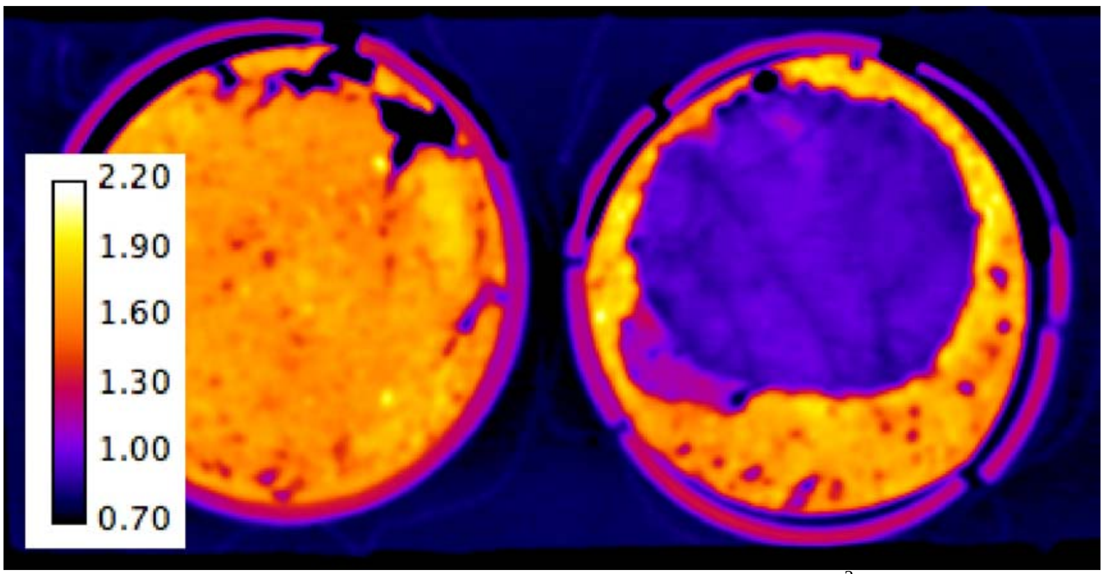

Figure 2. CT scan of two USGS NGHP cores showing density in g/cm^3. Section on right shows probable hydrate node, later identified by the USGS to be methane hydrate.

Geomechanical Studies (Seiji Nakagawa and Tim Kneafsey)
Previously, the LBNL team fabricated a geomechanical/geophysical testing cell for hydrate-bearing sediment cores. During this reporting period, we tested the cell for x-ray transparency, and conducted a preliminary geomechanical test on a sand core with concurrent seismic wave measurements. These experiments confirmed that (1) clear x-ray images of the saturation differences within a sediment/rock core can be obtained through an aluminum cell wall (Figure 3), (2) the test cell functions correctly during loading tests, and (3) both compressional and shear waves can be measured during the loading test (Figure 4). We also made several modifications to the test cell to address some of the concerns raised by the review panel during the peer review conducted in September 2007. Lastly, production of a safety document for the test cell identified some critical design specifications that needed to be changed (we do not expect these changes to affect our experimental parameters, but they are impacting our schedule). Currently, detailed finite element modeling is conducted to further verify the safety of the test cell during operation.

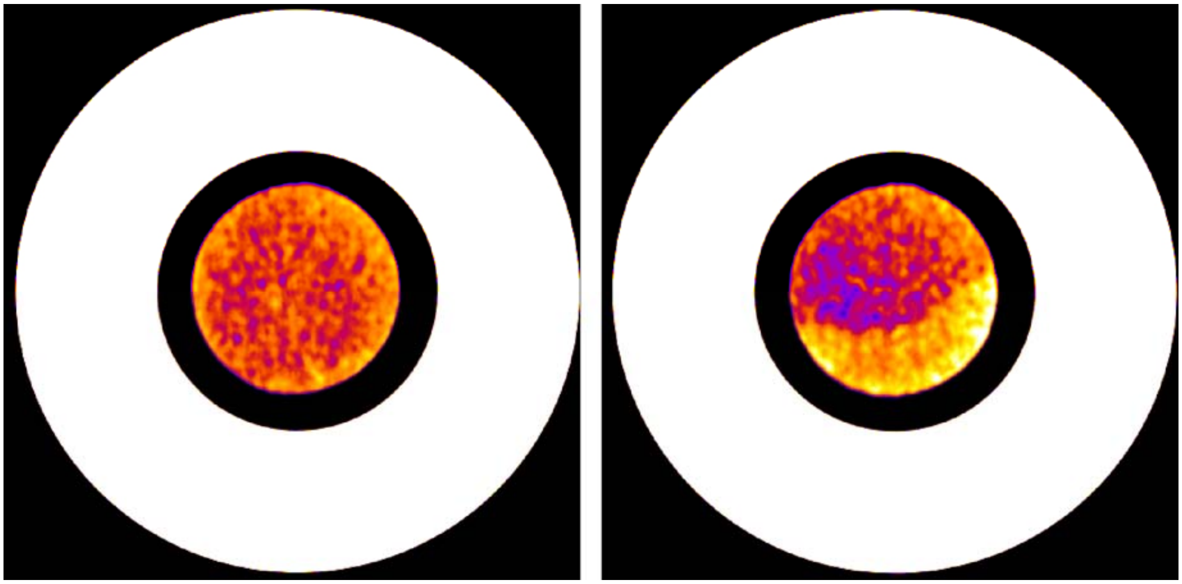

Figure 3. Left - Cross section CT scan of Berea Sandstone core (in color) in Geomechanical Cell (white); Right – with invading water at the bottom.

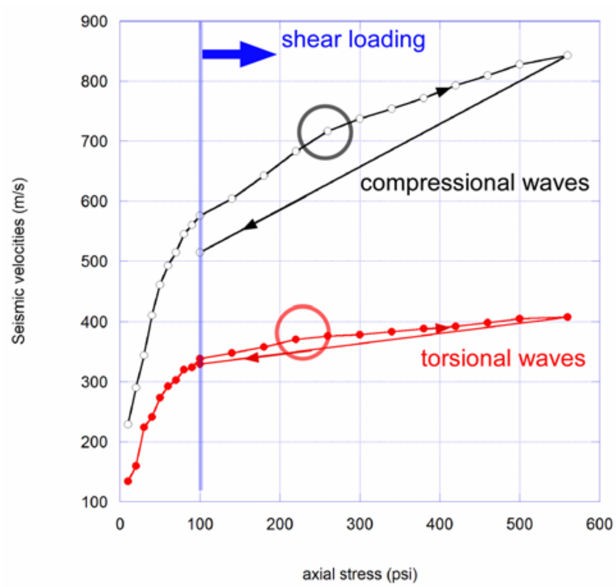

Figure 4. Seismic velocities for a sand pack during uniform and shear loading. The changes in the slopes in the axial stress vs. seismic velocity during shear loading (indicated by circles) correspond to the onset of increased plastic deformation and dilation of the sample.

Concerns raised by the panel included, unwanted supporting effect of a stiff, thick Teflon jacket, and small clearance between the sample and the test cell's internal wall. To address these concerns, we reduced the jacket thickness from the original 2 millimeters to 250 microns (1/8 of the original thickness) for the center section of a core sample corresponding to a length L=2W, where W is the diameter of the core. Although the supporting effect of the jacket may not be totally eliminated, the effect should be reduced significantly. This reduction of the jacket thickness adds an extra clearance in the cell for the sample to dilate. Further, we have modified the cell to give an extra travel length for the axial compression piston. Combined, these modifications should allow up to 20% of axial sample compaction, as well as resulting radial expansion of the sample.

Capillary Pressure- Saturation Tests (Teamrat Ghezzehei and Tim Kneafsey)
To date, tests have been conducted using coarse-grain quartz sand with ~100 micron average diameter packed to achieve 40% total porosity (in the absence of hydrate). Five tests have been conducted with hydrate and one test without hydrate (0% hydrate saturation). In addition a computational model has been developed that will be used to derive flow properties by inverse modeling.

The experiments with hydrate-bearing sand involve the following main steps.

1. Packing sand to desired bulk density at prescribed moisture content and assembling within high-pressure vessel.
2. Testing for leaks
3. Formation of hydrate by consuming all the water held in the sand
4. Bringing the pressure-temperature condition to the methane-hydrate stability condition.
5. Injection of water to completely saturate the sand
6. Extraction of water in multiple steps while continuously measuring capillary pressure.

Each of the above steps presented unique challenges with two most significant. First, in step 4, uncertainty in absolute pressure and temperature measurements that made it difficult to know whether the stability condition was achieved before injection of water is started. Second, apparent capillary pressure measurement appeared to depend significantly on temperature (because of large differences in thermal expansion of gas, liquid water, and metal tubing slight changes in temperature of the air surrounding the pressure transducer results in huge apparent capillary pressure fluctuations) It was observed that the apparent capillary pressure fluctuation depended more significantly on the rate of change of temperature and only slightly on the absolute temperature. Several attempts were made to control the temperature fluctuation by constructing enclosures using various materials, the coolant bath, foam-board, and using electronically controlled heater. The latest design, which is used in Test #4 and #5, involves surrounding most of the sensitive components of the experiment using thick foam-board and using the residual heat generated by the different transducers to maintain stable temperature.

The tests that have been conducted thus far will provide capillary pressure curves for 0%, 20%, and 35% hydrate saturation. In addition, because the data from Test #5 (20% hydrate) is of high quality, it will be used in inverse modeling to determine relative permeability independently. An example of the data collected is in Figure 5.

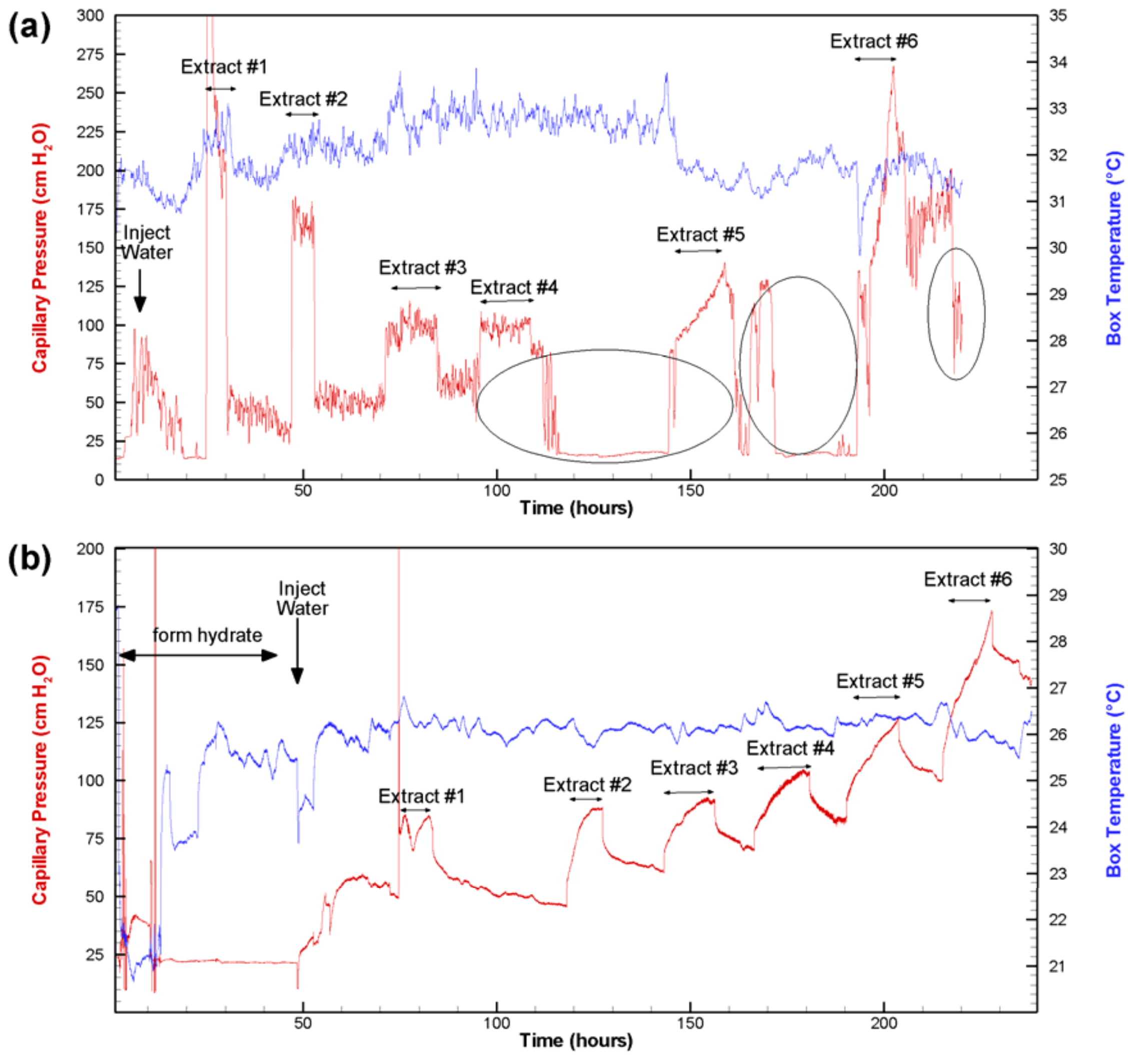

Figure 5. Capillary pressure and temperature data from (a) Test #2 and (b) Test #5.

Design Test for NGHP Cores (Tim Kneafsey)
A test methodology was designed to observe gas production from an NGHP core sample that was previously scanned by LBNL. The cores are currently stored in liquid nitrogen. Core machining, placement into a rubber sleeve, sleeve placement into a pressure vessel, application of confining pressure, thawing, and dissociation were considered in the design.

Planned Tasks for January through March 2008

Relative Permeability
Analyze data collected and complete paper suitable for journal submission. Submit paper to the SPE Offshore Technology Conference 2008 (due February 2008).

Geomechanical Studies
Complete an acceptable engineering note for the test vessel, pressure test the vessel, add a thermal jacket, and begin tests with hydrate-bearing sands.

Capillary Pressure Tests
Continue with tests.

NGHP
Perform gas production test with an Indian NGHP sample. Attend NGHP Meeting in Delhi, India and present results of CT scanning NGHP cores and of first NGHP core test.

Hydrates Physical Properties Meeting
Attend Physical Properties Meeting in Atlanta in March and contribute to ideas and review paper.

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