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Quarterly Research Performance Progress Report
(Period Ending 09/30/2017)

Hydrate-Bearing Clayey Sediments:
Morphology, Physical Properties, Production and Engineering/Geological Implications
Project Period (10/1/2012 to 9/30/2017)

Submitted by:
Sheng Dai

Signature

Georgia Institute of Technology
DUNS #: 097394084
505 10th Street
Atlanta, GA 30332
Email: sheng.dai@ce.gatech.edu
Phone number: (404) 385 - 4757

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ACCOMPLISHMENTS

Context – Goals. Fine grained sediments host more than 90% of the global gas hydrate accumulations. Yet, hydrate formation in clayey sediments is least understood and characterized. This research focuses on hydrate bearing clayey sediments. The goals of this research are (1) to gain a fundamental understanding of hydrate formation and ensuing morphology, (2) to develop laboratory techniques to emulate “natural” formations, (3) to assess and develop analytical tools to predict physical properties, (4) to evaluate engineering and geological implications, and (5) to advance gas production alternatives to recover methane from these sediments.

Accomplished

The main accomplishments for this period include:

- THF hydrate in clayey sediments
  - Super-cooling temperature and morphology
  - Elastic properties
  - Dynamic properties, i.e., damping

Plan - Next report will be the final report of this project
RESEARCH IN PROGRESS

THF hydrate in clayey sediments

Supercooling temperature and hydrate morphology. THF is used as a proxy of hydrate formed in clayey sediments (i.e., kaolinite). Specimens are prepared by mixing THF, water, and kaolinite with the same mass ratios but different super-cooling temperatures. Resultedhydrates in kaolinite show different morphology and saturation (Figure 1).

Figure 1: (Left) Temperature signatures and X-ray images of two specimens with identical initial mass ratio of 100% stoichiometric solution and clay, i.e., 60:100 in this case.

Figure 2 shows the 3D CT images of hydrate in kaolinite sediments. Hydrate morphology and saturation vary with (THF, water, kaolinite) mass fractions and super-cooling temperature.

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<td>$T_s=4.85 \degree C$ $S_h=0.47$</td>
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**Figure 2:** 3D X-ray CT images of six hydrate-bearing specimens with different initial mass ratios and supercooling temperature ($T_{sc}$).

**Elastic properties.** Measured p- and s-wave velocities as a function of hydrate saturation are presented in Figure 3. With simultaneous measurement of $V_p$ and $V_s$, all elastic moduli (i.e., Young’s, shear, constraint, and bulk) of the hydrate-bearing sediments can be computed, as well as the Poisson’s ratio. Although data are scattered, the self-consistent model can still capture the hydrate saturation dependent elastic properties for hydrate-bearing clayey sediments.

**Figure 3:** Elastic properties of THF hydrate-bearing sediments. (a) P-wave velocity versus hydrate saturation. (b) S-wave velocity versus hydrate saturation. (c) Poisson’s ratio versus hydrate saturation. These elastic properties are not monotonically depending on hydrate...
saturation mainly due to random distribution and morphology of segregated hydrate lenses.

**Dynamic properties.** The presence of hydrate in the sediments makes the sediments stiffer, yet attenuates the wave more efficiently. Measured quality factor $Q^{-1}$ values range between hydrate-bearing sediments and pure THF hydrate (reported in the literature).

![Figure 4](image_url)

**Figure 4:** Measured quality factor $Q^{-1}$ (i.e., damping) from both p- and s-waves in THF hydrate-bearing clayey sediments.
MILESTONE LOG

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Planned completion date</th>
<th>Actual completion date</th>
<th>Verification method</th>
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<td>Report (with preliminary validation data)</td>
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<td>9/2016</td>
<td>Comprehensive Report</td>
<td>Final report due 30/12/17</td>
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PRODUCTS

- **Publications & Presentations:**


**Website:** Publications and key presentations are included in [http://pmrl.ce.gatech.edu/](http://pmrl.ce.gatech.edu/) (for academic purposes only)

**Technologies or techniques:** X-ray tomographer and X-ray transparent pressure vessel

**Inventions, patent applications, and/or licenses:** None at this point.

**Other products:**

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Research Team: The current team involves:

- Carlos Santamaria (Professor)
- Sheng Dai (Assistant Professor)
- Zhonghao Sun (PhD student)
- Jongchan Kim (PhD student)

IMPACT

Understanding of fine grained hydrate-bearing sediments.

CHANGES/PROBLEMS:

None.

SPECIAL REPORTING REQUIREMENTS:

None.

BUDGETARY INFORMATION:

All budget has been zeroed out. Details will be presented in the final report.
National Energy Technology Laboratory

626 Cochran's Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

13131 Dairy Ashford Road, Suite 225
Sugar Land, TX 77478

1450 Queen Avenue SW
Albany, OR 97321-2198

Arctic Energy Office
420 L Street, Suite 305
Anchorage, AK 99501

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