# METHANE HYDRATE
## ONSITE RESEARCH ACTIVITIES

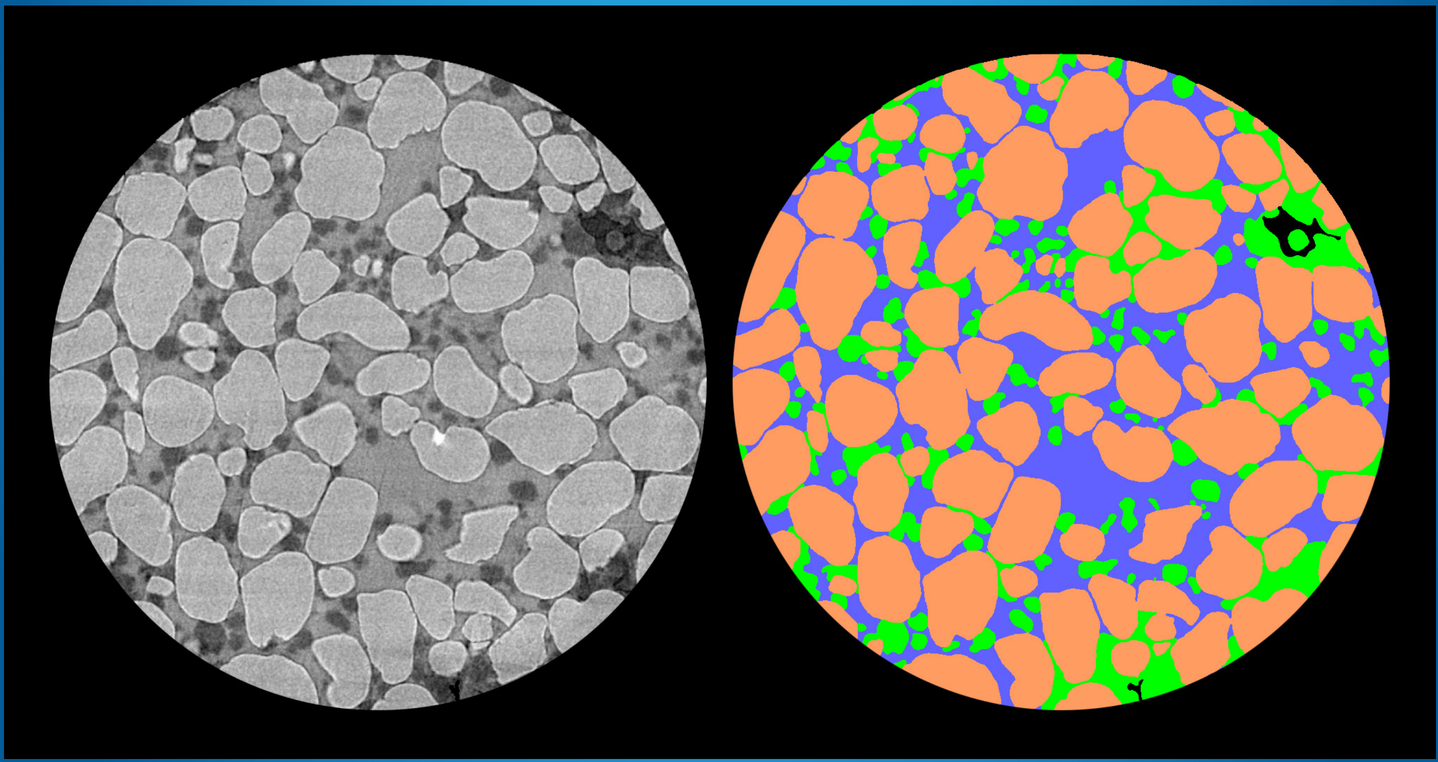

Figure 1. Pore-scale images of hydrate-bearing sand specimens. Original image (left) is compared to image showing separated fluid phases (right). Orange areas are sand grains; green is hydrate; and blue is water. Sand grains are approximately 200 micrometers in diameter.

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## BACKGROUND

Methane hydrate represents a potentially vast natural gas resource for the United States (U.S.) and the world. Once thought to be rare in nature, methane hydrate deposits are now known to occur in great abundance in association with arctic permafrost and in sedimentary deposits found along continental shelves. Recent estimates suggest that the gas hydrate abundance contains more organic carbon than the world's coal, oil, and gas combined. One objective of the Department of Energy's (DOE) National Energy Technology Laboratory (NETL) is to develop the knowledge base and facilities to support development of gas hydrate resources.

In support of this objective, the NETL Methane Hydrate research team is working to obtain high-quality data and information for use in optimizing models of gas hydrate reservoir behavior in a variety of natural settings and under a range of realistic production conditions.

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## INTRODUCTION

The NETL Methane Hydrate research team combines modeling, code development, and laboratory experimentation to enhance the understanding of methane hydrate properties and behaviors in natural settings and in realistic production scenarios supports the development of the nation's methane hydrate resource potential through focused research activities. These activities include: (1) numerical simulation for predicting methane hydrate reservoir behavior, (2) code development for fully coupled Thermal-Hydrological-Chemical-Mechanical (THCM) models of methane hydrate response and behavior during gas production, (3) laboratory experimentation for fundamental characterization of methane hydrates, and (4) tool development for analysis and characterization of natural methane hydrate samples. Results of these activities will ultimately lead to a better understanding of the role of methane hydrate as an energy resource and as a source and sink for methane in the Earth's global carbon cycle.

## PROJECT GOAL

The goal of the Methane Hydrate project is to complete experimental and modeling research on the nature and behavior of natural gas hydrates. This research will improve models for predicting formation, dissociation, and other processes associated with gas hydrates in their natural environment and in realistic production scenarios.

## PROJECT OBJECTIVES

Project objectives include: 1) completion of 2D and 3D reservoir modeling runs; 2) code development for the open-source THCM simulator; 3) laboratory experimentation on pressurized samples; and 4) tool development for advanced pressure core testing.

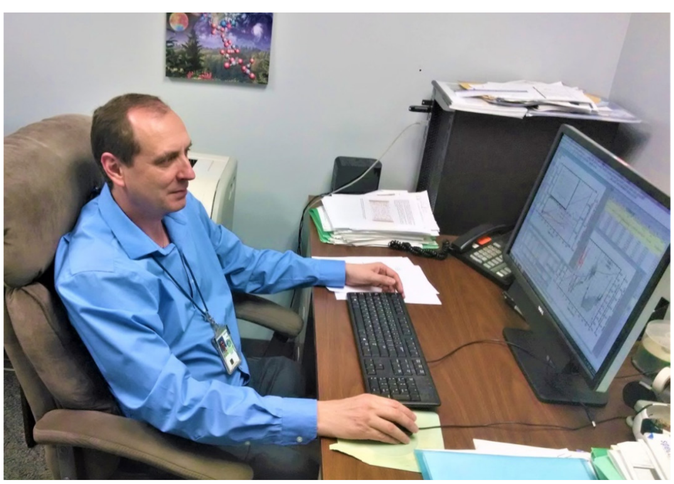

Figure 2. NETL researcher conducting reservoir modeling to improve the understanding of hydrate reservoir behavior.

## NETL CAPABILITIES

### *NUMERICAL SIMULATION AND CODE DEVELOPMENT*

NETL's onsite researchers are leading numerical simulation and code development activities aimed at improving predictive estimates of hydrate reservoir performance. These activities include: (1) numerical estimations of gas production potential and reservoir performance; (2) basin and petroleum system modeling to develop high resolution 1D, 2D, and 3D basin models of gas hydrate petroleum systems; (3) geomechanical simulation to study mechanisms of reservoir deformation; and (4) code development for a new, open-source THCM simulator that couples gas production and geomechanical modeling and therefore allows for enhanced prediction of hydrate reservoir behavior during production. NETL scientists completed 2D and 3D reservoir modeling efforts for gas production from onshore hydrate reservoirs associated with permafrost on the North Slope of Alaska and from marine hydrate reservoirs of offshore India. In addition, work continues for basin modeling and code development for the THCM simulator.

### *LABORATORY STUDIES*

NETL Methane Hydrate laboratory studies are focused on obtaining accurate measurements of hydrological and geomechanical properties of hydrate-bearing sediments. This research will lead to an enhanced understanding of hydrate formation and dissociation processes and the potential development of new techniques for monitoring hydrate behavior during gas production. Laboratory work has focused on completing geomechanical property measurements with single/multi-stage triaxial testing and developing a relative permeability testing apparatus.

### *TOOL DEVELOPMENT*

Methane hydrate tool development activities are aimed at developing a suite of pressure core characterization and testing tools for measuring and observing physical properties of hydrate-bearing specimens at core scale and pore scale. These tools include the Pressure Core Characterization Tools (PCCT), for conducting laboratory tests on pressurized cores at in situ pressure and temperature conditions. These highly specialized tools will support more realistic and relevant property measurements for use as input into hydrate reservoir simulators.

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*COLLABORATIVE RESEARCH*

Collaborative laboratory and numerical code comparison studies are underway through work with domestic and international research groups. The NETL Methane Hydrate research team is working to combine NETL's expertise with the broad capabilities of nationally and internationally recognized methane hydrate researchers from universities, industry, and government institutes to realize global energy potential of methane hydrate.

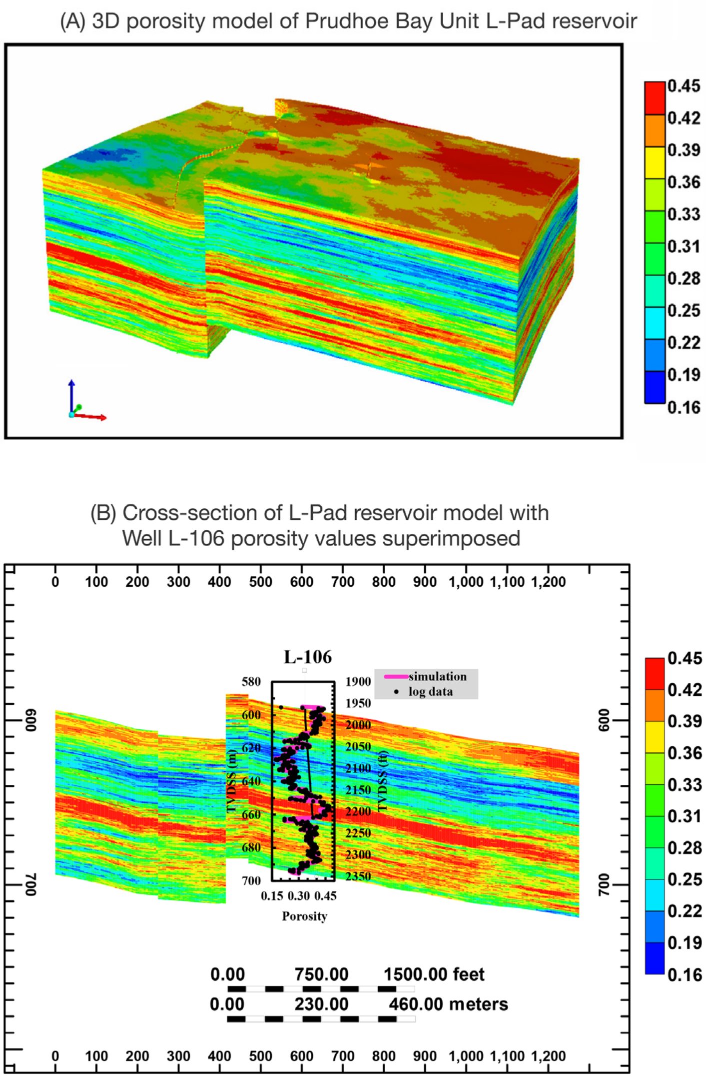


Figure 3. Modeling results for the Prudhoe Bay Unit, L-Pad reservoir, North Slope Alaska. (A) 3D model of the L-Pad reservoir geology showing sedimentary layering, faulting, and porosity. (B) Cross-section of the L-Pad reservoir model with Well L-106 porosity curves superimposed– including simulated log curve (in red) and measured log data (black dots).

## PROJECT BENEFITS

Research conducted by the Methane Hydrate research team will lead to a better understanding of hydrate formation and dissociation processes; more effective predictive modeling of hydrate reservoir behavior during a range of different production scenarios; and the establishment of more realistic input parameters for methane hydrate reservoir simulators. Ultimately, these advances will lead to more effective approaches for developing methane hydrate as an energy resource, as well as better strategies for minimizing environmental impacts associated with gas hydrates.

## ACCOMPLISHMENTS/ SUCCESSES

The Methane Hydrate research team has accomplished the following:

- 3D heterogeneous reservoir model of methane hydrate formations in the Prudhoe Bay Unit, Kuparuk Site.
- 2D THM simulations for gas production potential from marine hydrate deposits offshore of India.
- Development of new production technology with numerical modeling utilizing $CO_2$ injection strategy.
- Comprehensive triaxial compression tests performed on gas hydrate bearing sediments with varied hydrate saturations and confining stresses.
- THCM code development with new geomechanical constitutional relation and solid migration formula.
- High resolution 3D visualization of methane hydrate in pore space with micro-CT scanning.

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## Research Partners

U.S. Geological Survey
Georgia Institute of Technology
University of Pittsburgh
Rensselaer Polytechnic Institute
West Virginia University

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