Characterization of Natural Hydrate Bearing Core Samples

B. Pete McGrail (PI)
H. Todd Schaef
Philip E. Long
Mark D. White

Annual Project Review
August 26-27, 2008
Pittsburgh, PA

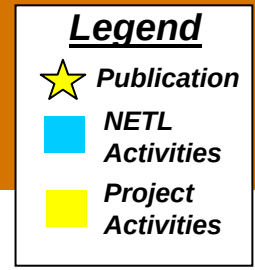
Pacific Northwest
NATIONAL LABORATORY

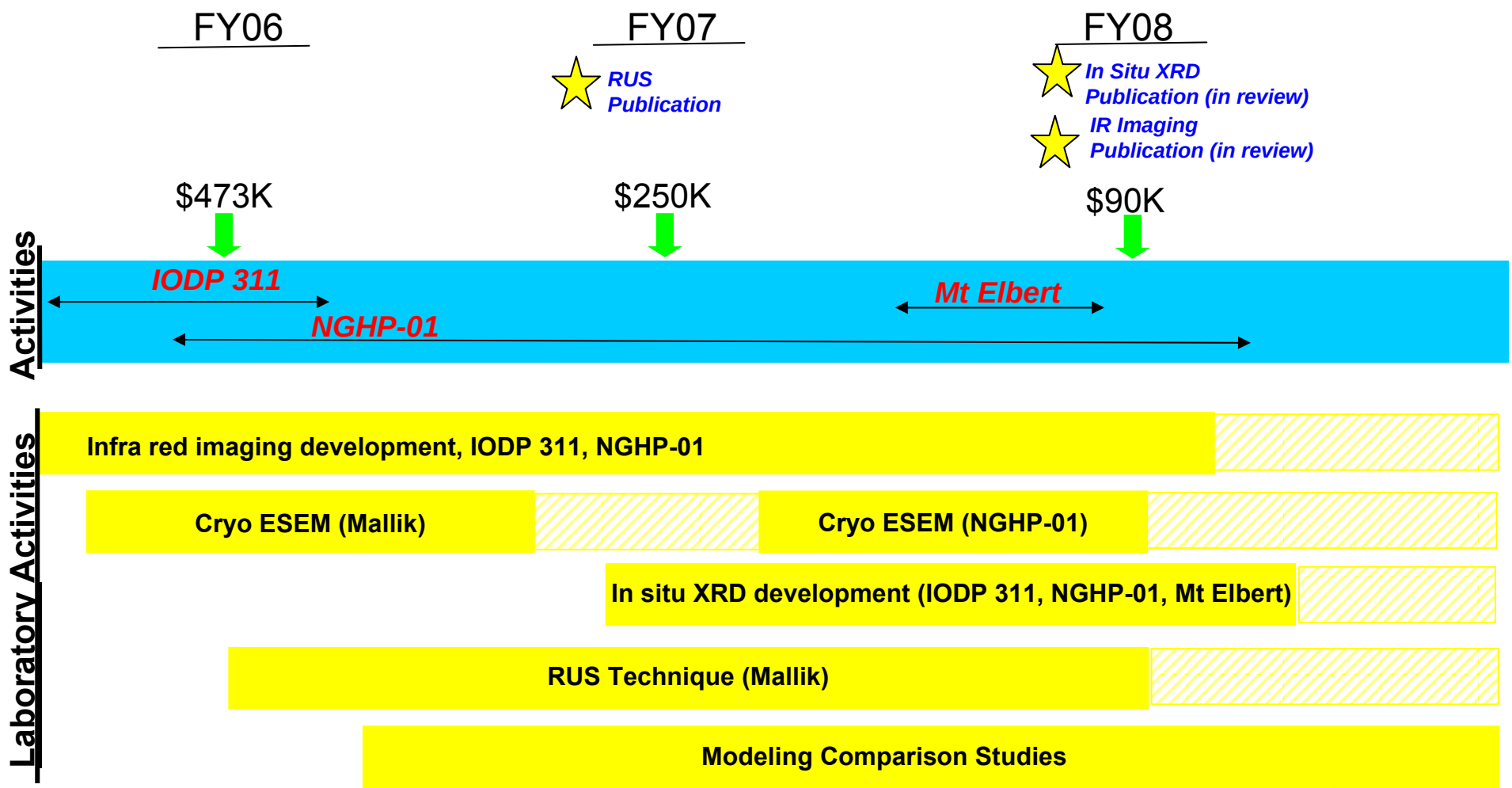
Project Strategy and Objectives

- Provide a consistent set of measurements on a broad range of natural gas hydrate samples representing both marine and terrestrial sources
  - Link core scale IR with pore scale laboratory measurements
    - Correlate IR data with gas hydrate abundance
      - Porewater chemistry
    - Reprocess IR data from ODP leg 204, IODP 311, & NGHP-01
  - Laboratory core studies characterizing hydrate equilibrium and dissociation properties
    - Environmental scanning electron microscopy
      - Imaging gas hydrate texture and dissociation behavior at pore scale
    - Resonant ultrasound spectroscopy
      - Hydrate abundance
    - In situ XRD
      - Reservoir conditions
- Modeling efforts
  - STOMP-HYD
  - Simulator code intercomparison study

Pacific Northwest
NATIONAL LABORATORY

Project Timeline

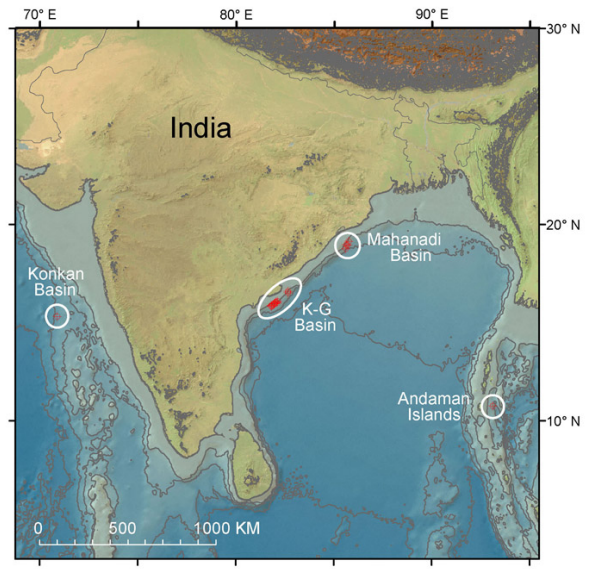




Pacific Northwest
NATIONAL LABORATORY

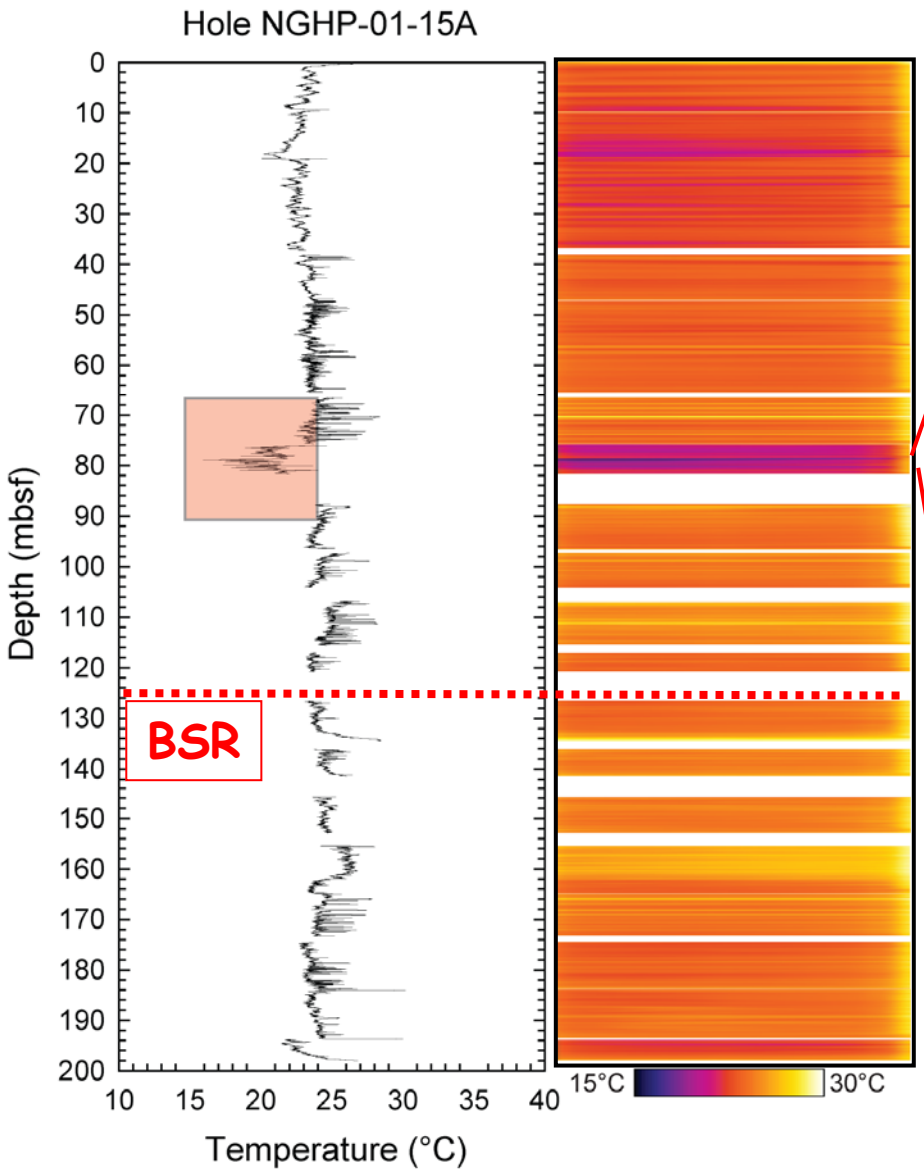
Infrared Imaging Field Application

- India's Natural Gas Hydrate Program (NGHP)
  - PNNL participated in Expedition 01 (NGHP-01)
    - Infrared core imaging
      - 2 staff shipboard
  - Supported by Department of Energy (DOE)
- Shore Based Studies
  - IR imaging data
    - Reprocessing
  - HXRD
  - Attended NGHP-01 conference
    - Held in Delhi, India February 2008
    - Two staff presented results



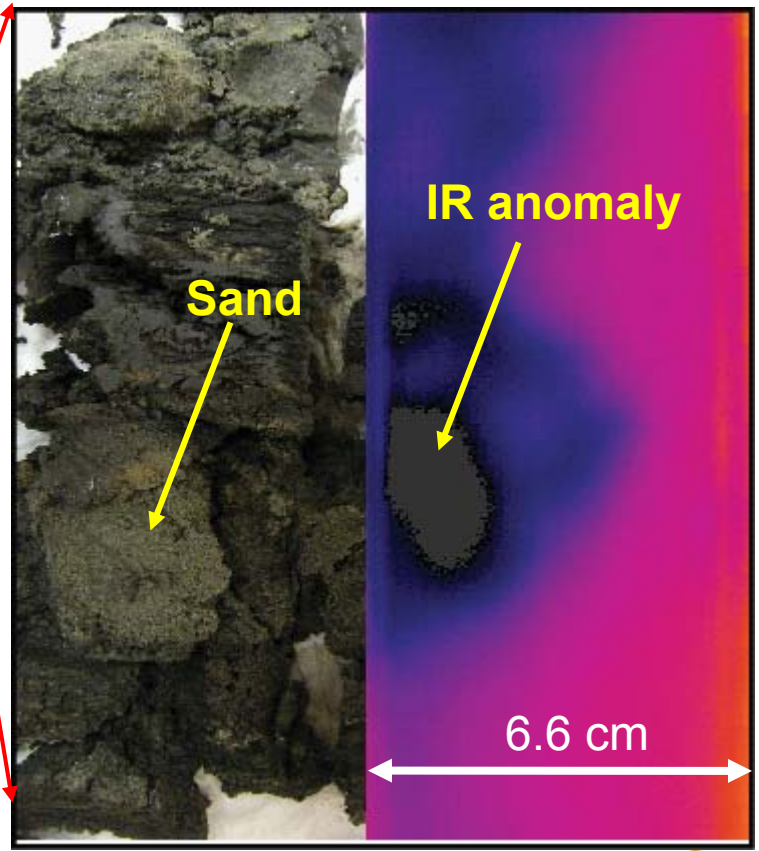
Pacific Northwest
NATIONAL LABORATORY

Infrared Imaging Field Application



Krishna-Godawari Basin

Core NGHP-01-15A-09X-2

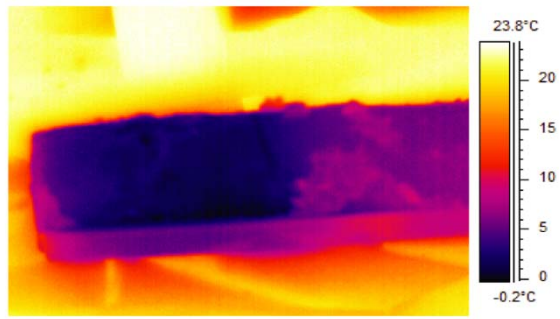


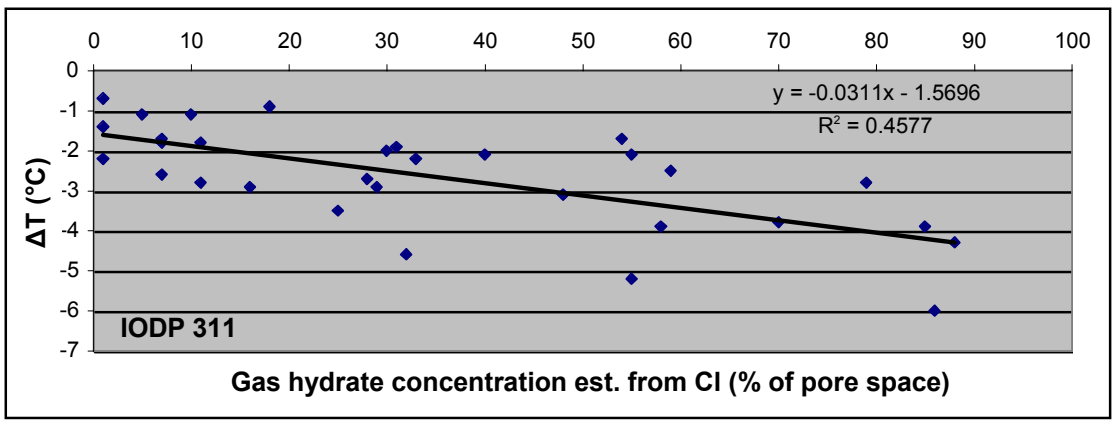
Pacific Northwest
NATIONAL LABORATORY

Infrared Imaging Based Technologies

- Shore based IR data processing
  - Proxy for hydrate abundance on cores lacking geochemistry?
    - Chlorinity classical method for estimating hydrate abundance
  - IODP 311 Expedition IR data set
    - Correlation between ΔT and pore water chlorinity
    - Publication "Torres, ME; Trehu, AM; Cespedes, N; Kastner, M; Wortmann, UG; Kim, JH; Long, P; Malinverno, A; Pohlman JW; Riedel, M; Collett, T. 2008. Methane hydrate formation in turbidite sediments of northern Cascadia, IODP Expedition 311. Earth and Planetary Science Letters 271 (1-4) p.170-180"
- Refinement of NGHP-01 IR data set
  - Core history
  - Modeling application

NGHP-01 Core 17

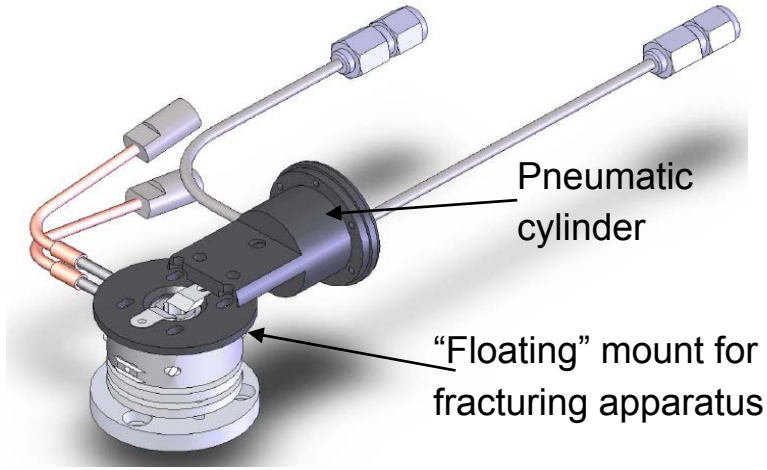


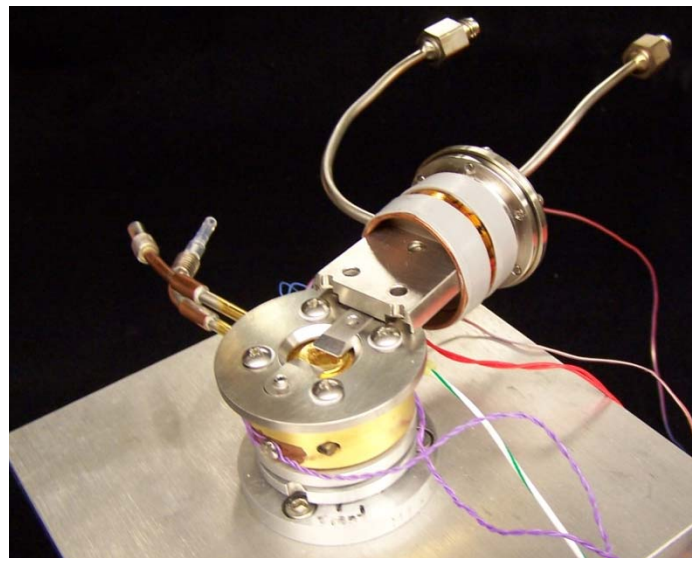


Pacific Northwest
NATIONAL LABORATORY

ESEM Gas Hydrate Research

- Detailed survey of hydrate-bearing samples without high vacuum
  - Image in N_2, CO_2, CH_4, and C_3H_8 atmospheres (~2 mbar)
  - Cold stage (-170°C) stabilizes gas hydrate
- In situ sample fracturing
  - Micromanipulator used to expose fresh surface
- Video imaging system to capture gas hydrate dissociation processes
- Gas Chemistry
  - Integrated mass spectrometer system
  - In situ gas monitoring during hydrate dissociation

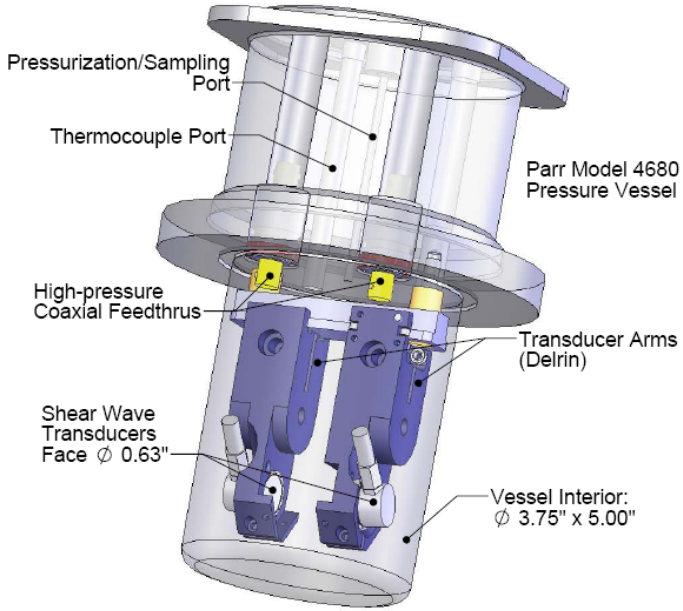


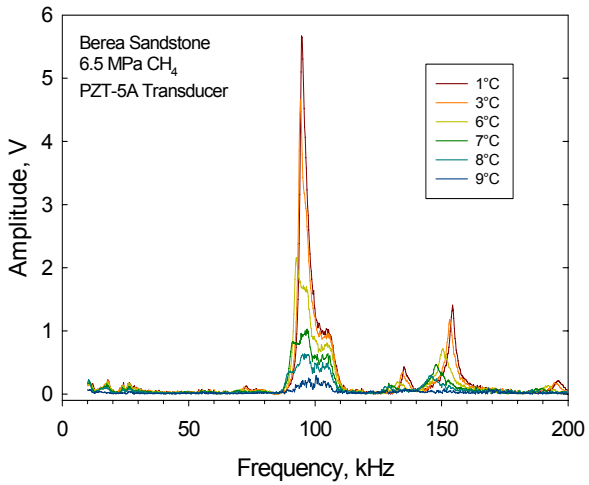


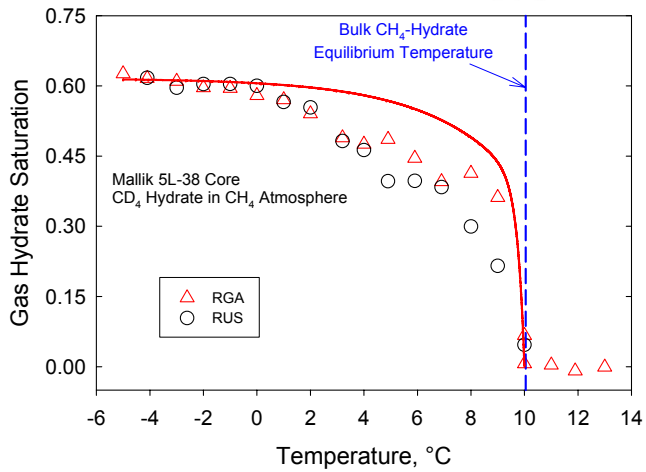
Pacific Northwest
NATIONAL LABORATORY

Resonant Ultrasound Spectroscopy

- RUS development
  - Resonant peak amplitude correlated with gas hydrate saturation
    - Reservoir conditions
      - Pressure
      - Temperature
  - Coupled with residual gas analysis
    - Isotopic gas (CD_4)
    - Track hydrate dissociation
- Gas hydrate estimates
  - Pore water freezing model
  - Pore water chemistry controlling factor





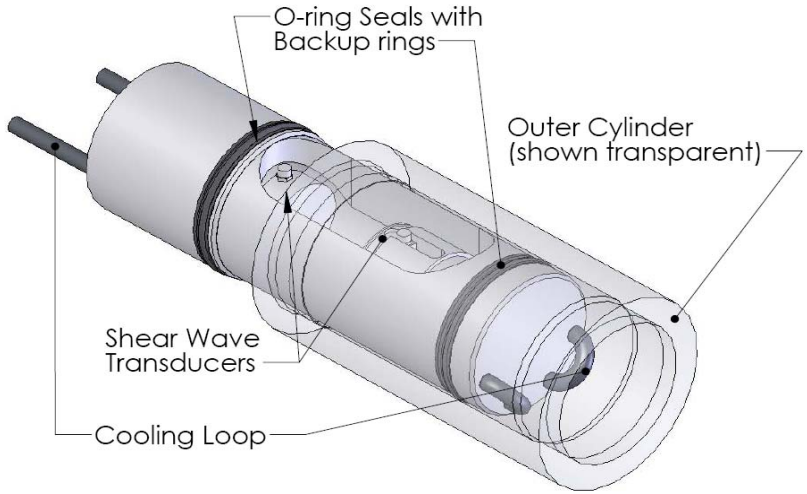


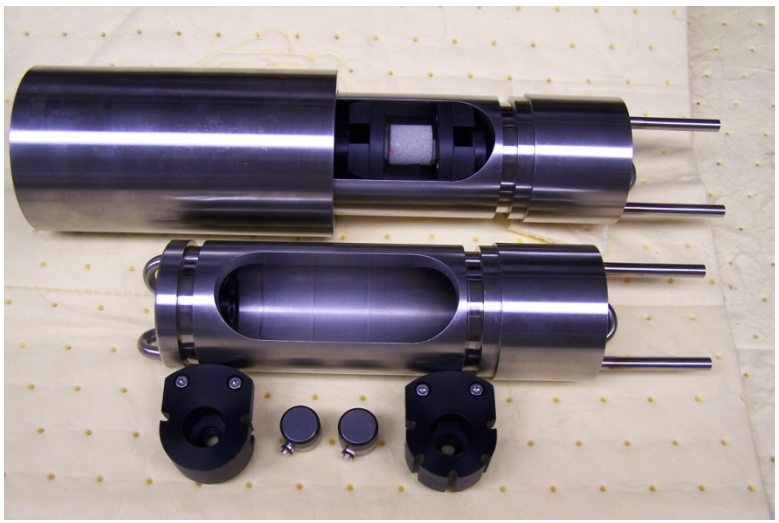
McGrail et. al., 2007, “Gas hydrate property measurements in porous sediments with resonant ultrasound spectroscopy” Journal of Geophysical Research, Vol 112, B05202.

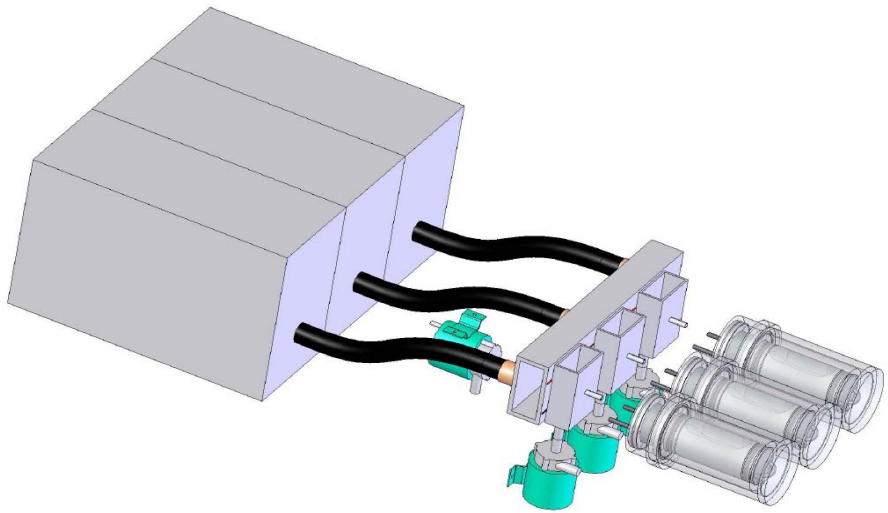
Pacific Northwest NATIONAL LABORATORY

Resonant Ultrasound Spectroscopy

- Field Application
  - Portable system 75% complete
    - Smaller pressure vessels
    - Shipboard or field laboratory
  - Multiple sample analysis
    - 5 core samples
- Couple with Residual Gas Analysis
  - Track gas chemistry



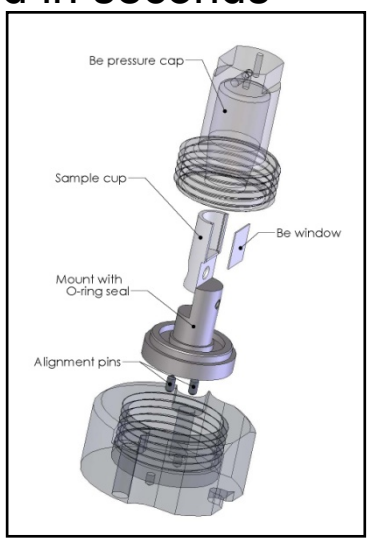




Pacific Northwest
NATIONAL LABORATORY

In Situ High Pressure X-Ray Diffraction

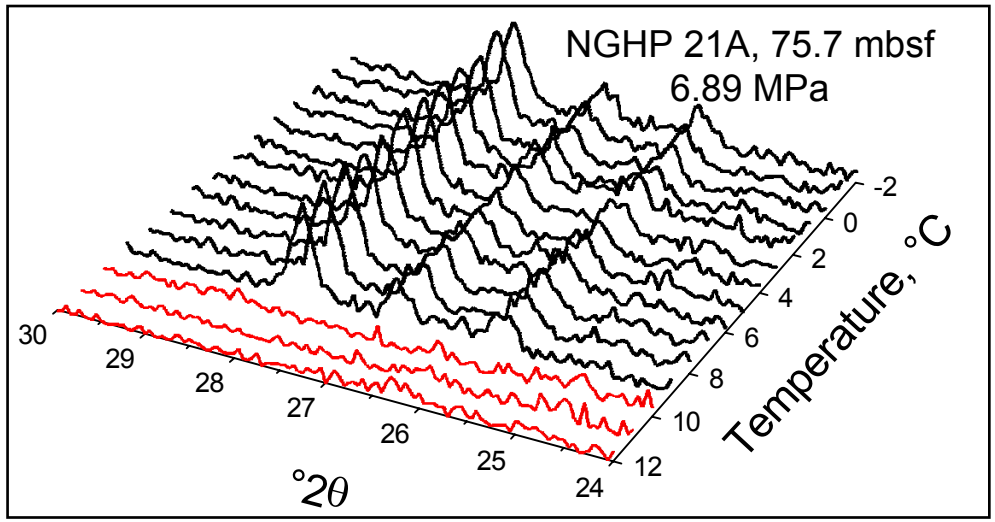
- X-Ray Photon Source
  - Rotating Anode
    - 18 kW
    - Transmission
  - Variable spot size
- High Precision Goniometer
  - Vertical & lateral movement
  - GADDS Detector
    - True photon counter
    - 100 micron spatial resolution
    - 70° of data collected in seconds
- Sample Stage
  - -100 to +227°C
  - Computer mapping
- Be Pressure Cell
  - X-ray transparent
  - 20 MPa
  - 1cm^3

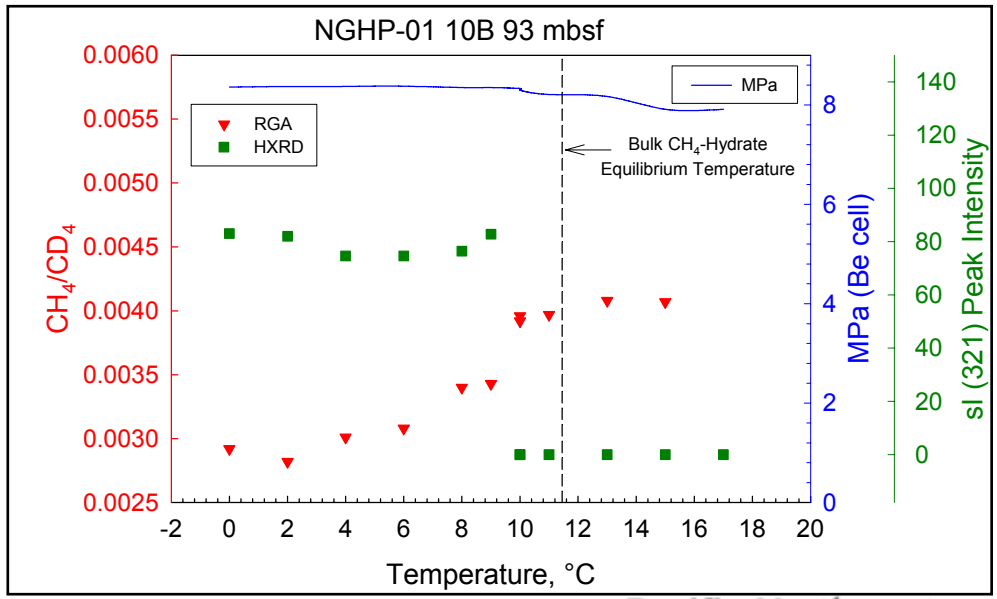


Pacific Northwest
NATIONAL LABORATORY

In Situ High Pressure X-Ray Diffraction

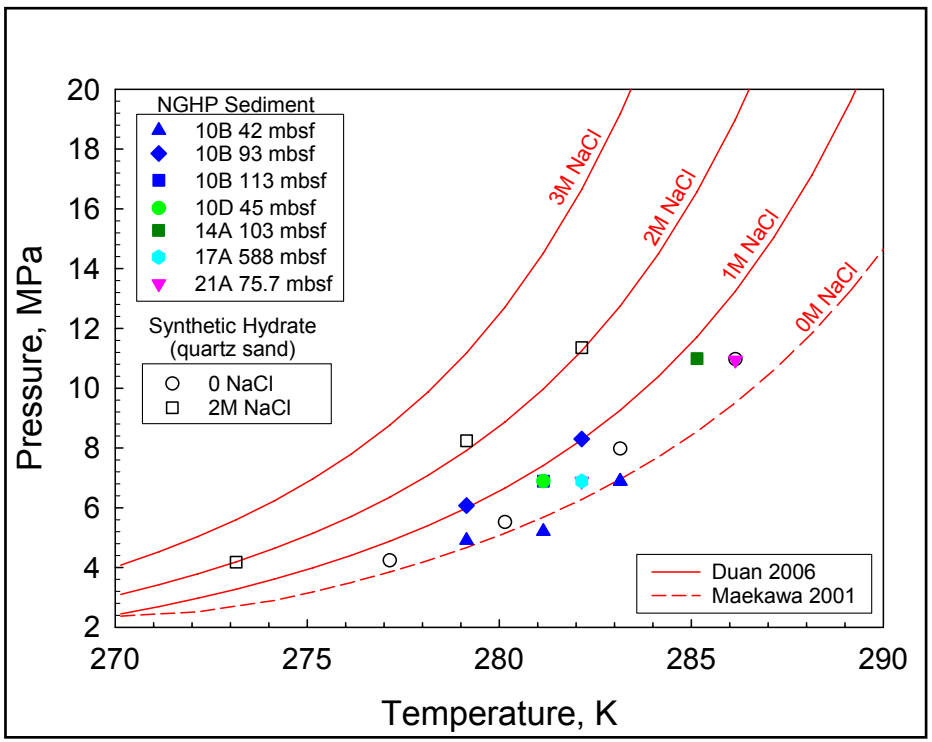
- In Situ XRD
  - Technique developed for gas hydrate samples
    - Reservoir conditions
  - Identify and confirm presence of gas hydrate
    - sI, sII, H, or water ice (1h)
- Gas Hydrate Rich Sediments
  - Dissociation parameters
    - Observe dissociation of gas hydrate in sediment
  - Gas Chemistry
    - Coupled with RGA
      - Direct gas sampling
    - Continuous gas hydrate dissociation





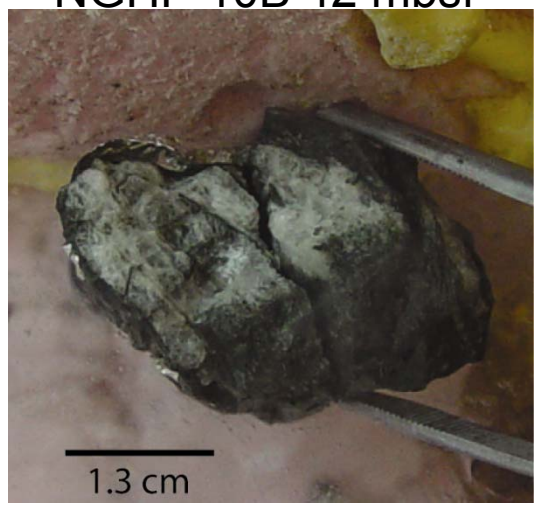
In Situ High Pressure X-Ray Diffraction

- Core Sediment Characterization
  - Mt. Elbert cores (2)
    - sI hydrate detected by in situ XRD
  - NGHP-01 core (11)
    - Variation in gas hydrate stability
      - Natural vs synthetic
    - Gas chemistry



Mt Elbert Core

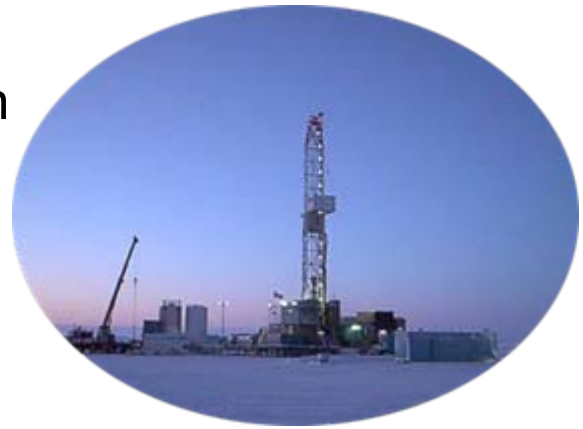
NGHP 10B 42 mbsf

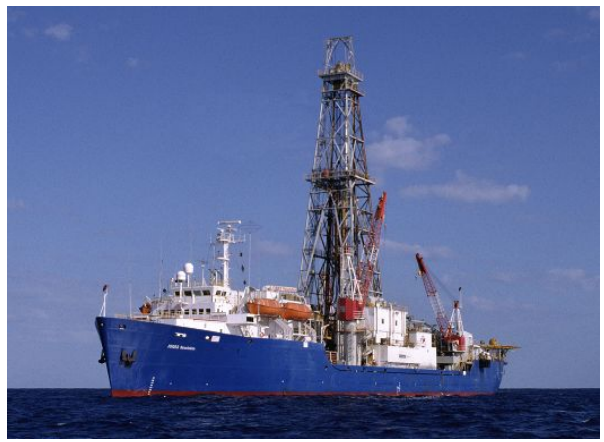


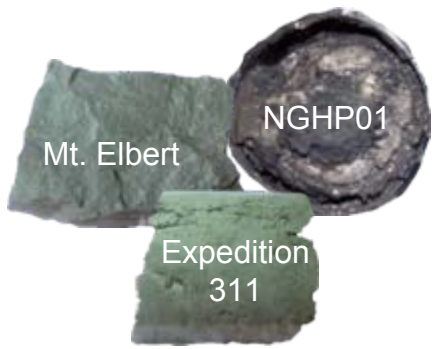
Pacific Northwest
NATIONAL LABORATORY

Summary

- Supporting the National Gas Hydrate Research Program by better understanding gas hydrate properties in natural sediments
  - IR imaging extended beyond core collection
    - Correlate to core properties
      - Porewater chemistry
      - Microbial populations
    - Develop IR imaging applications
      - Use existing IR data for correlation factors
  - Marine and terrestrial core characterization
    - Controlling factors
      - Physical
      - Chemical
    - Portable techniques
- Modeling efforts
  - STOMP-HYD
  - Code comparison







Pacific Northwest
NATIONAL LABORATORY

Publications

B. P. McGrail, S. Ahmed, H. T. Schaef, A. T. Owen, P. F. Martin, and T. Zhu. 2007 “Gas Hydrate Property Measurements in Porous Sediments With Resonant Ultrasound Spectroscopy” Journal of Geophysical Research, VOL. 112, B0520.

M. E. Torres, A. M. Tréhu, N. Cespedes, M. Kastner, U.G. Wortmann, J. H. Kim, P. E. Long, A. Malinverno, J. W. Pohlman, M. Riedel, T. Collett. 2008. “Methane hydrate formation in turbidite sediments of northern Cascadia, IODP Expedition 311”, Earth and Planetary Science Letters 271 (1-4) p.170-180.

P. E. Long, M. Holland, P. Schultheiss, M. Riedel, J. Weinberger, A.M. Trehu, and H.T. Schaef. “Infrared (IR) Imaging of Gas Hydrate-Bearing Cores: State-of-the-Art and Future Prospects” Soc. Expl. Geophy., (in review).

H. T. Schaef, B. P. McGrail, A. T. Owen, and P. E. Long. “Characterization of NGHP-01 Hydrate Samples by *In Situ* High-Pressure X-Ray Diffraction Coupled with Residual Gas Analysis”, Marine Geology, (in review).

Pacific Northwest
NATIONAL LABORATORY