Geologic Controls on the Occurrence of Gas Hydrates in the Indian Continental Margin: Results of the Indian National Gas Hydrate Program (NGHP) Expedition 01*

By

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Abstract

The Indian National Gas Hydrate Program (NGHP) Expedition 01 was designed to study the gas hydrate occurrences both spatially and temporally off the Indian Peninsula and along the Andaman convergent margin with special emphasis on understanding the geologic and geochemical controls on the occurrence of gas hydrate in these two diverse settings. During NGHP Expedition 01, dedicated gas hydrate coring, drilling, and logging operations were conducted from the 28th April, 2006, to the 19th August, 2006. During its 113.5-day voyage, the JOIDES Resolution cored or drilled 39 holes at 21 sites (1 site in Kerala-Konkan, 15 sites in Krishna-Godavari, 4 sites in Mahanadi and one site in Andaman deep offshore areas), penetrated more than 9250 meters of section and recovered nearly 2850 meters of core with ~78% recovery. Twelve holes were logged with logging-while-drilling tools and an additional 13 holes were wireline logged. NGHP Expedition 01 established the presence of gas hydrates in Krishna-Godavari, Mahanadi, and Andaman basins. The expedition discovered and closely examined one of the richest gas hydrate accumulations yet documented (Site 10 in the Krishna-Godavari basin), documented the thickest and deepest gas hydrate stability zone yet known (Site 17 in Andaman Sea), and established the existence of a fully-developed gas hydrate system in the Mahanadi basin (Site 19). In addition to the work accomplished on board, the science team also collected an unprecedented number of samples and data for analysis by an international team of experts in microbiology, sedimentology, geochemistry, and numerous other disciplines. A final synthesis of the project’s technical findings is expected to be published in 2008.
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Presentation Outline

• Project Goals, Objectives, and Results
• The Gas Hydrate Petroleum System
  Examples from NGHP Expedition 01
  - Sand dominated reservoirs
  - Fracture dominated reservoirs
• Conclusions & NEXT STEPS
NGHP Expedition 01
Project Goal

The primary goal of NGHP Expedition 01 was to conduct scientific ocean drilling/coring, logging, and analytical activities to assess the geologic occurrence, regional context, and characteristics of gas hydrate deposits along the continental margins of India in order to meet the long term goal of exploiting gas hydrates as a potential energy resource in a cost effective and safe manner.
NGHP Expedition 01
Research Organizations

Directorate General of Hydrocarbons
Oil and Natural Gas Corporation Ltd.
OIL India Ltd.
GAIL India Ltd.
Reliance Industries Ltd.
National Institute of Oceanography
National Institute of Ocean Technology
Binghamton University
Colorado School of Mines
Fugro-McClelland, Inc.
Geological Survey of Canada
Geotek Ltd.
Idaho National Laboratory
Integrated Ocean Drilling Program
Joint Oceanographic Institutions, Inc.
Lamont-Doherty Earth Observatory
McGill University
National Energy Technology Laboratory
Ocean Drilling Limited
Oregon State University
Pacific Northwest National Laboratory
Schlumberger
Technical University of Berlin
Texas A&M University
University of California, San Diego
University of Cardiff
University of New Hampshire
Universität Bremen
University of Rhode Island
U.S. Department of Energy
U.S. Geological Survey
U.S. National Science Foundation
Woods Hole Oceanographic Institution
NGHP Expedition 01 - Initial Reports

Expedition 01 of the Indian National Gas Hydrate Program from Mumbai, India to Chennai, India Sites NGHP-01-01 through NGHP-01-21 April 2006 – August 2006

Volume Authorship

Published by
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Prepared by
The United States Geological Survey

Cover: Waves crash over the bow of the drilling vessel JOIDES Resolution. Inside: Rough seas in the Bay of Bengal. Above: Top Left: Infrared image from Core NGHP-01-10B-12X. Top Right: Derrick of the drilling vessel JOIDES Resolution. Middle: Researchers at work in the Physical Properties lab. Bottom: Gas hydrate. Photographs by members of the NGHP Expedition 01 Scientific Party.
NGHP Expedition 01
Downhole Log Data

Expedition 01 of the
Indian National Gas Hydrate Program
from Mumbai, India to Chennai, India
Sites NGHP-01-01 through NGHP-01-21
April 2006–August 2006

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Cover: Waves crash over the bow of the drilling vessel JOIDES Resolution.
Inside: Rough seas in the Bay of Bengal.
Above: Top Left: Infrared image from Core NGHP-01-10B-12X.
Top Right: Derrick of the drilling vessel JOIDES Resolution.
Middle: Researchers at work in the Physical Properties Lab.
Bottom: Gas hydrate.
Photographs by members of the NGHP Expedition 01 Scientific Party.

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Prepared by
The United States Geological Survey
Scientific Coring-Logging

Kerala-Konkan:
One Site

Krishna-Godavari:
Fifteen Sites

Mahanadi:
Four Sites

Andaman Islands:
One Site

-Total 123 Days
-Total 21 Sites
Summary NGHP Expedition 01

• Expedition began in Mumbai, India (April 28, 2006) and ended in Chennai, India (August 19, 2006).

• A total of 113.5 operational days. 19.0 days (16.8%) in port; 24.2 days (21.3%) was spent in transit; 70.4 days (62%) spent on site.

• 13.04 days (18.5%) were spent on LWD/MWD drilling operations; 38.46 days (54.7%) was spent drilling and coring; 0.65 days (0.9%) lost time.

• 21 “Sites” were established during NGHP Expedition 1, Total of 39 holes, 12 LWD-MWD holes were drilled; 27 core holes; 13 wireline logged holes and six VSP surveys.

• Examined 9,250 m sedimentary section; 2,850 m of recovered core (78% overall recovery).

• Water depths of sites ranged from 906.6 m to 2,674.2 m. Penetration depths varied from 9.5 mbsf to 718.0 mbsf.
Controls on the Occurrence Gas Hydrate

-Gas Hydrate Petroleum System-

-Formation temperature
-Formation pressure
-Pore water salinity
-Gas chemistry
-Availability of gas and water
-Gas and water migration
-Presence of reservoir rocks and seals
Gas Hydrate Stability

**PERMAFROST**

**MARINE**

- **DEPTH IN METRES**
  - 0
  - 200
  - 400
  - 600
  - 800
  - 1000
  - 1200
  - 1400
  - 1600

- **TEMPERATURE C**
  - -20
  - -10
  - 0
  - 10
  - 20
  - 30

- **Sediment**
  - Geothermal Gradient in Permafrost
  - Depth of Permafrost
  - Methane Hydrate
  - Phase Boundary

- **WATER**
  - Hydrothermal Gradient
  - Phase Boundary
  - Methane Hydrate
  - Zone of Gas Hydrate

- **Zone of Gas Hydrate**

- **Base of Gas Hydrate**

- **Geothermal Gradient**

- **Drill Rig**
NGHP Expedition 01
Gas Geochemistry Summary

NGHP EXP 01 Gas Hydrate Composition
- Microbial origin of methane
- 99.9 - 100% methane, Structure-I hydrate
- Up to 0.1 % CO$_2$
- Up to 0.02% ethane

• Sediment Gas Composition
  - Microbial origin, mainly methane, traces of thermogenic gas (C$_3^+$) in Mahanadi and Andaman.
The Gas Hydrate Resource Pyramid

- Arctic sandstones under existing infrastructure (~10’s of Tcf in place)
- Arctic sandstones away from infrastructure (100s of Tcf in place)
- Deep-water sandstones (~1000s of Tcf in place)
- Non-sandstone marine reservoirs with permeability (unknown)
- Massive surficial and shallow nodular hydrate (unknown)
- Marine reservoirs with limited permeability (100,000s Tcf in place)

- increasing in-place
- decreasing reservoir quality
- decreasing confidence in resource estimates
- increasing technical challenges and likely decreasing % recoverable
Sand dominated gas hydrate reservoirs - NGHP EXP 01 Examples
NGHP Expedition 01

Scientific Coring-Logging

- Kerala-Konkan Basin
- Krishna-Godavari Basin
- Mahanadi Basin
- Andaman Islands
Krishna-Godavari Basin
Site 15

BSR

Cl⁻ (mM)

- Ṣextrator
- Back ground

- Titrator
- IC
Site 15 - Sand Reservoir - Gas Hydrate Distribution -

Time slice (196 ms below seafloor) of instantaneous amplitude showing a channel cutting through the study area of Site NGHP-15.

Seismic X-line 3023, showing the channel with edges enhanced in reflection amplitude at the BSR level.

Michael Riedel, 2008
Time slice (196 ms below seafloor) of instantaneous amplitude showing a channel cutting through the study area of Site NGHP-15.

Site 15 – Sand Reservoir -Gas Hydrate Distribution-

Seismic X-line 3023, showing the channel with edges enhanced in reflection amplitude at the BSR level.

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Fractured gas hydrate reservoirs - NGHP EXP 01 Example
NGHP Expedition 01

Scientific Coring-Logging

- Kerala-Konkan Basin
- Krishna-Godavari Basin
- Mahanadi Basin
- Andaman Islands
Hole 10A - Gas Hydrate Saturation
Site 10 - Fractured Reservoir - Gas Hydrate Distribution -

Time slice at 1.41 seconds (top of gas hydrates) of reflection amplitude (positive amplitude in red, negative amplitude in black).

Time slice at 1.41 seconds (top of gas hydrates) of seismic coherency attribute through the 3-D seismic data block (black = incoherent, white = coherent) highlighting faults and fractures in the vicinity of Site NGHP-10.

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Next Steps

Government and industry focusing on integrated research, development and testing of gas hydrates as a necessary precursor to commercial production

Actions Already Underway

- Link industry, academic, and government efforts into overall effective research team – COOPERATION!

- Assess the amount of technically recoverable natural gas hydrates in the Outer Continental Shelf of “India”.

Next Steps

**Actions Needed**

1. Conduct exploratory drilling and production testing by first identifying viable test sites through an improved seismic and geologic understanding of gas hydrates.

2. Work with industry, government, and the international research community to develop the production technology for safe and economic gas hydrate development.
Next Steps (cont’d)

**Actions Needed**

3. Development and calibrate gas hydrate production models through field testing projects – **PILOT TEST**

Long term production rate calculations are critical to evaluating field economics
Reference

THANK YOU