

ALASKA GAS HYDRATE PLANNING WORKSHOP
August 17-18, 2005, Anchorage, Alaska

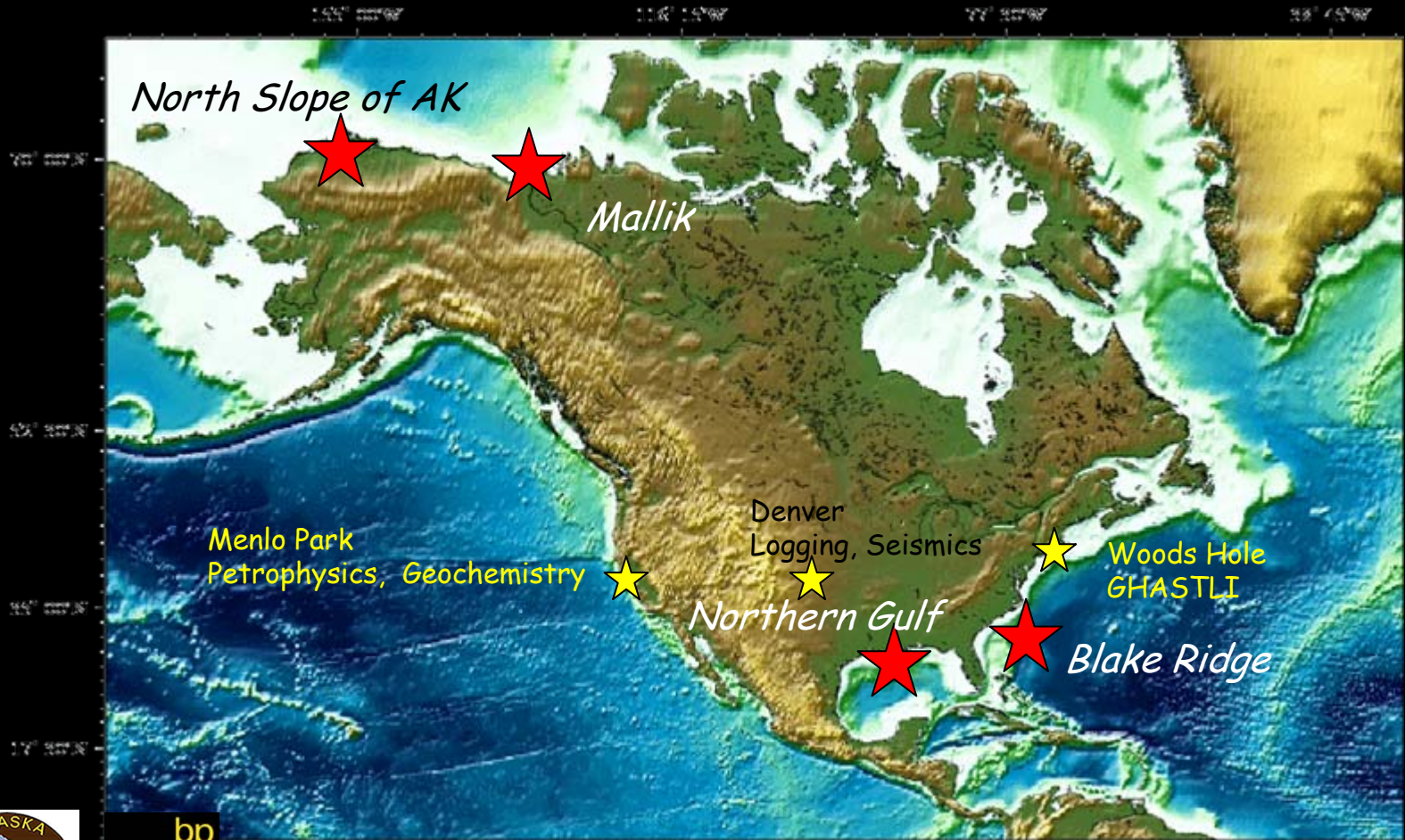
Energy Resource Potential of Gas Hydrates on the North Slope of Alaska

Historical Review Through Current Programs
-Assessment and Prospecting-

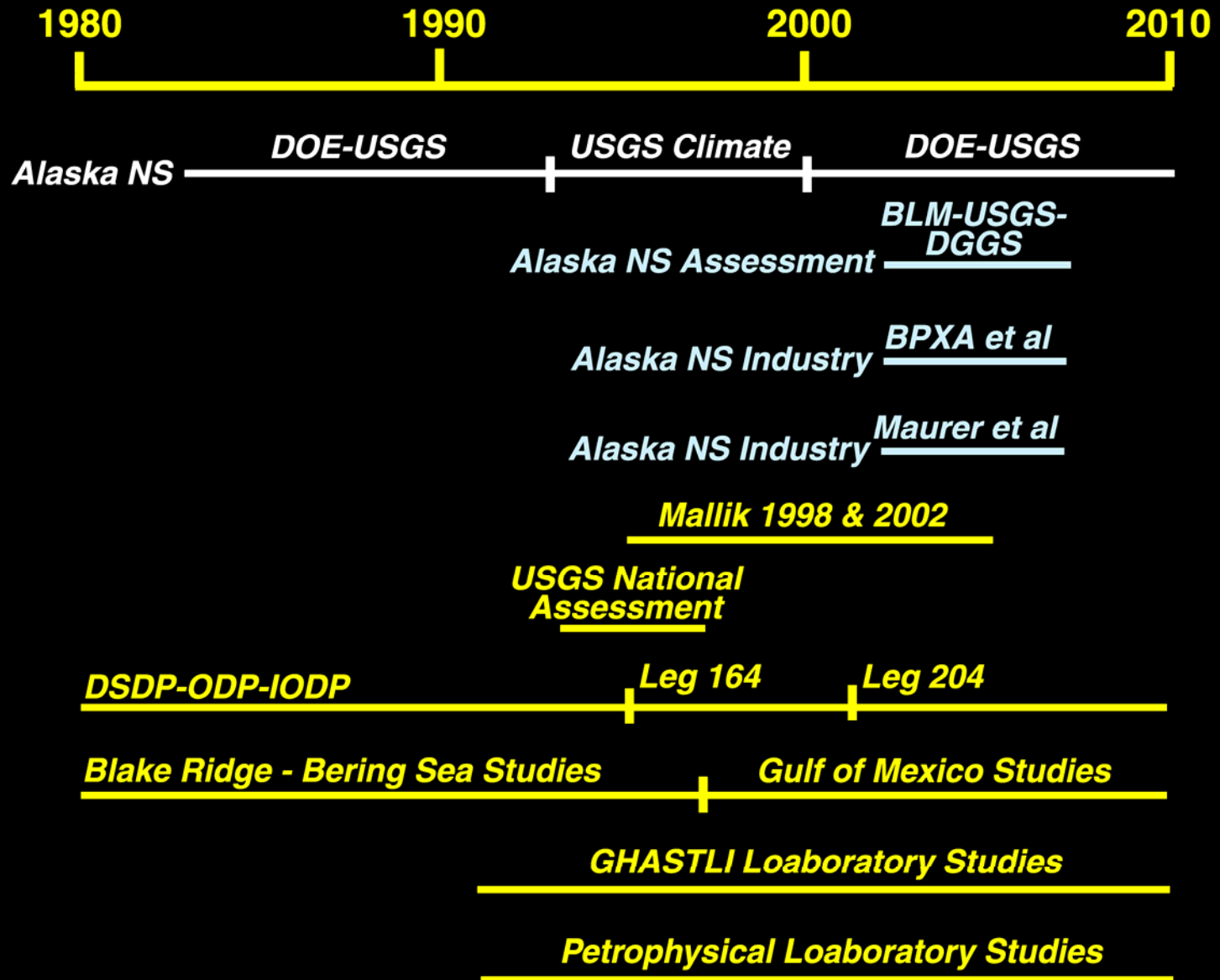
-USGS Project Team-

*T. Collett, M. Lee, D. Taylor, T. Lorenson,
W. Agena, J. Miller*

USGS Gas Hydrate Studies



1980-2010 USGS Gas Hydrate Research



Briefing Outline

1. Why Alaska?
2. Hydrate Resources Flow Chart - ALASKA
 - WHERE-HOW-WHY Hydrates Occur in Nature?
 - HOW MUCH Hydrates and Gas?
 - Production Methods
 - Motivations - Economics and Political
 - Gas Hydrate Resources
3. Ongoing Research Activities
 - USDOE-Industry-et al Projects
 - BLM-USGS-DGGS Gas Hydrate Assessment
 - MMS National Marine Gas Hydrate Assessment

Briefing Outline

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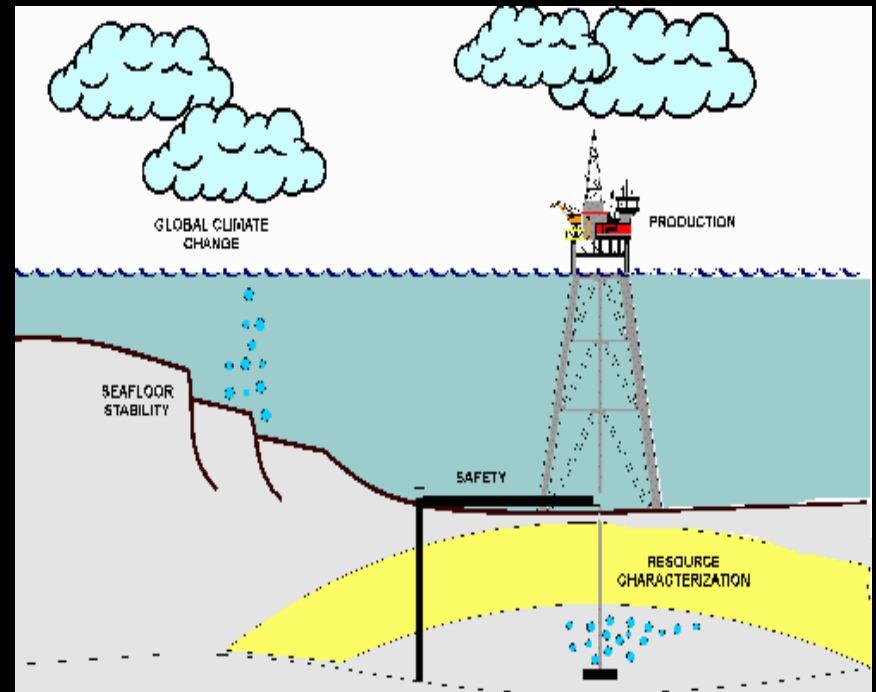
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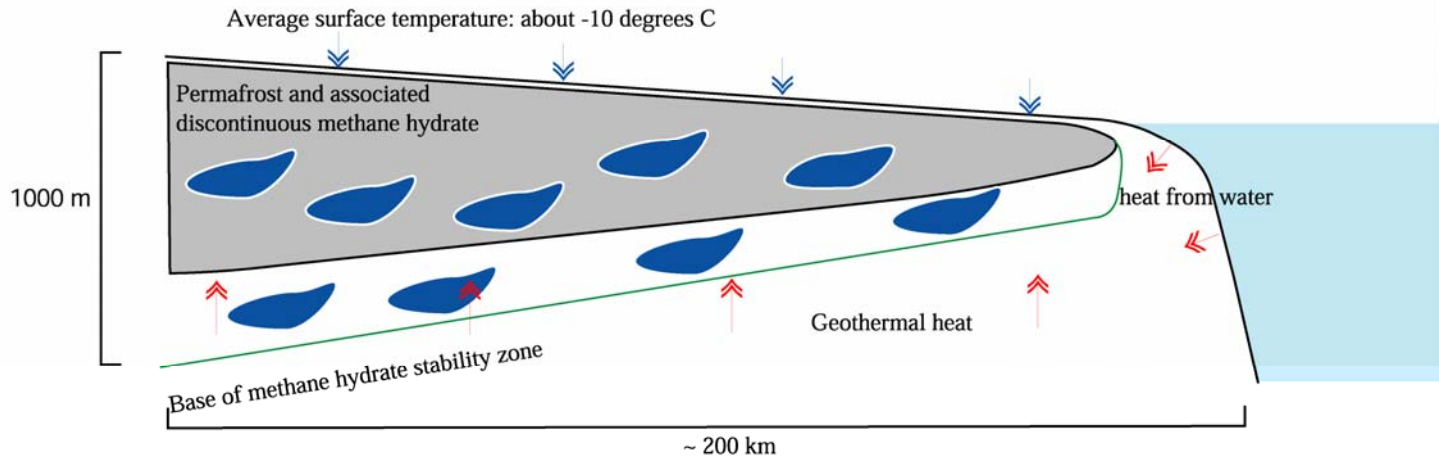
Interest in Gas Hydrates

- Energy Resource
- Operational Hazard
 - Slope stability and platforms
 - Drilling
- Global Warming
 - Methane 20 times more effective greenhouse gas than CO₂

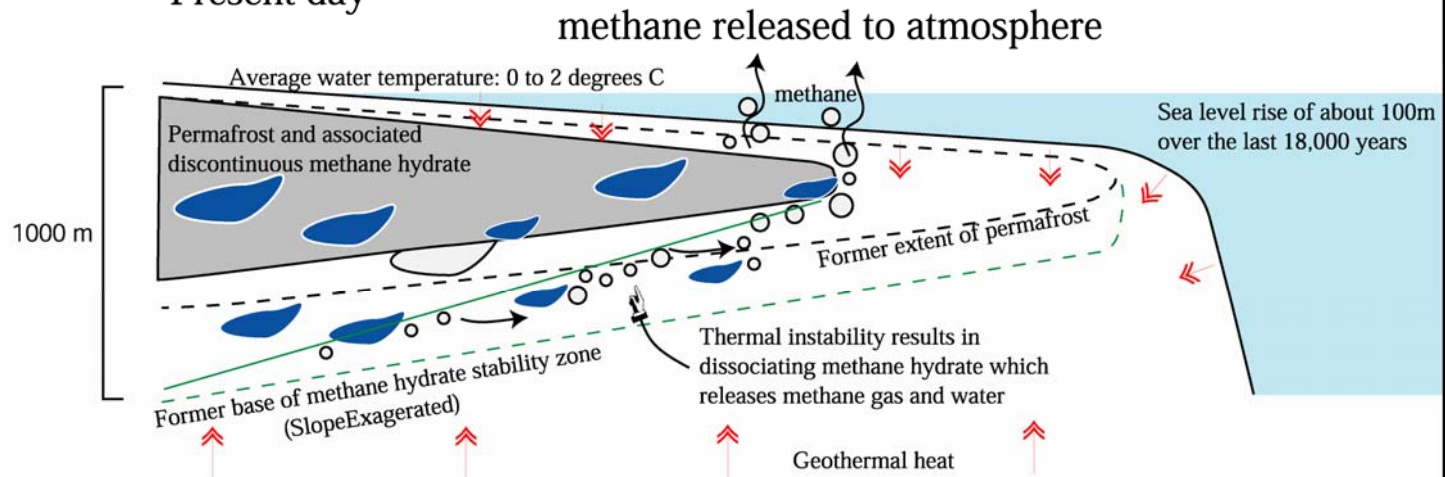


Climate Change Studies

Late Pleistocene

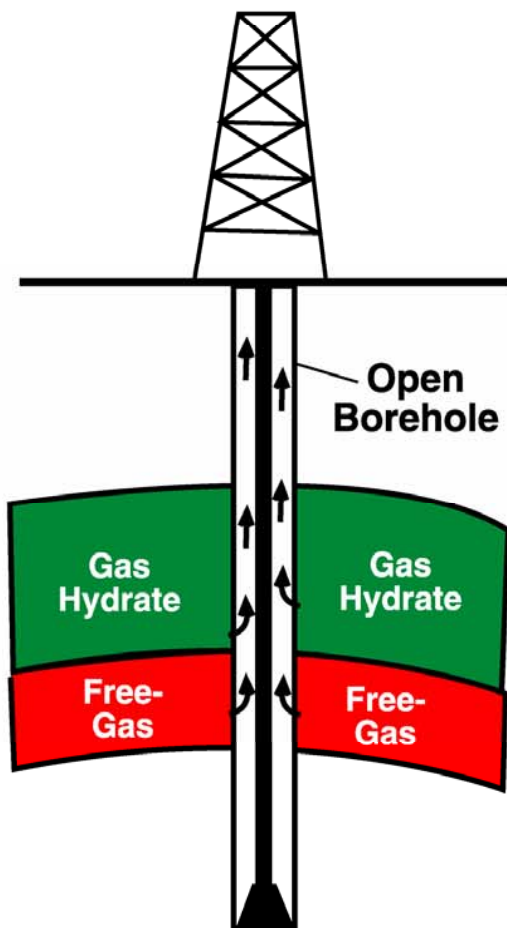


Present day

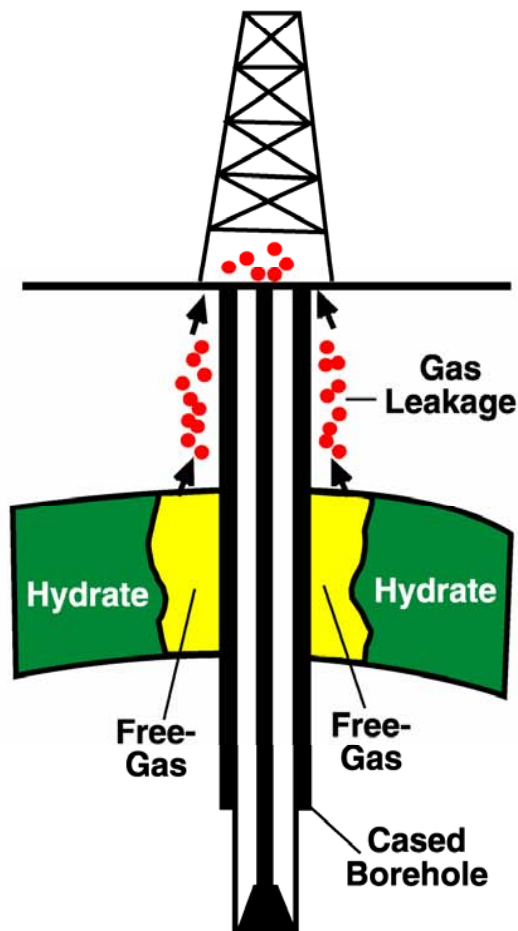


Gas Hydrate Drilling and Production Problems

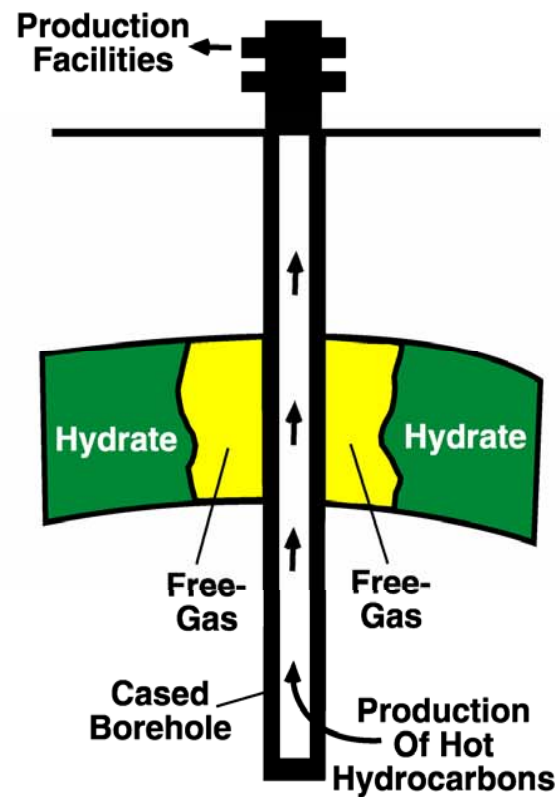
Gas Release



Gas Leakage

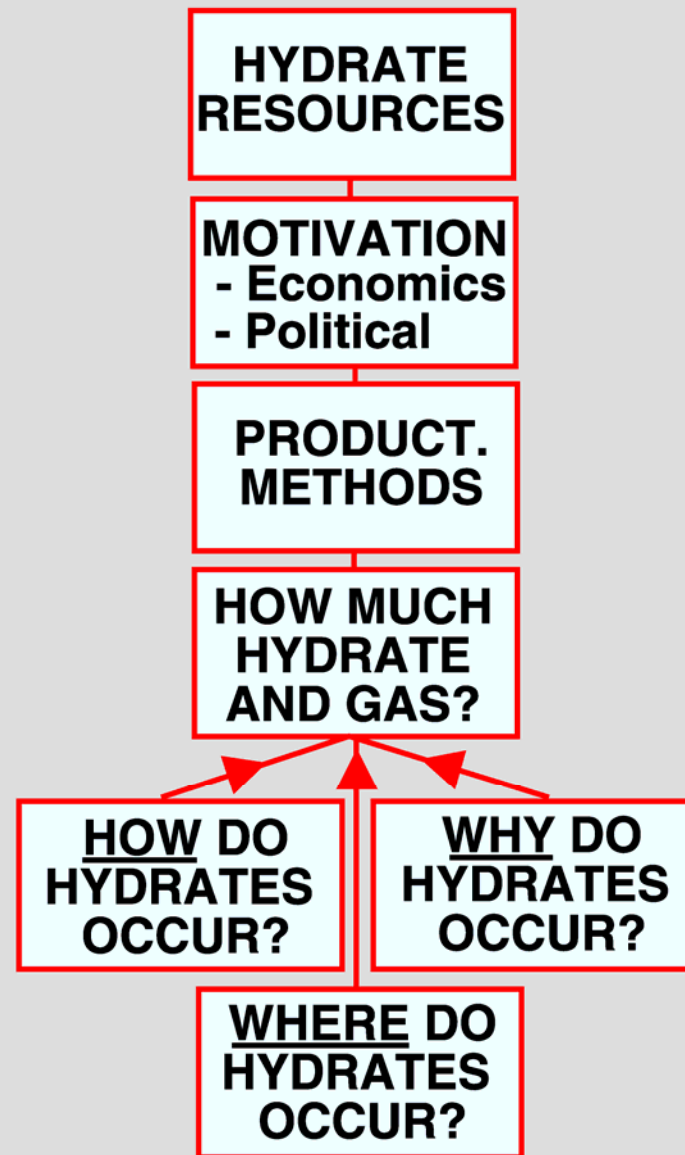


Collapsed Casing



Gas hydrate energy resource flow chart

- Evolution from a nonproducing unconventional gas resource to a producible energy resource



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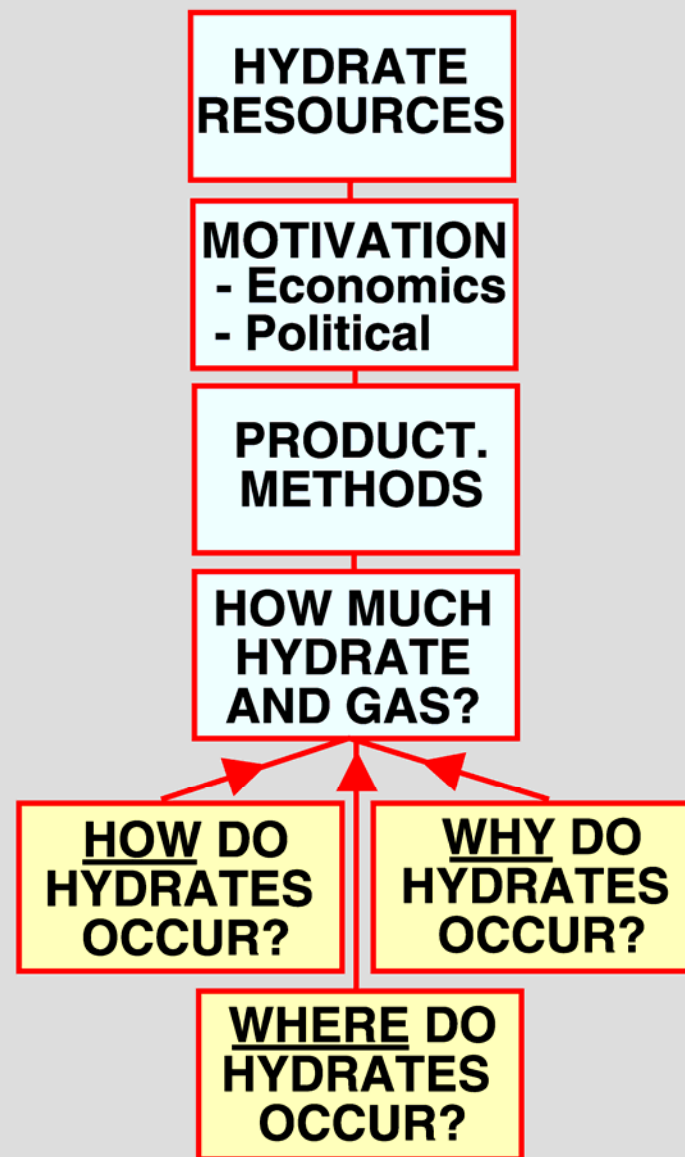
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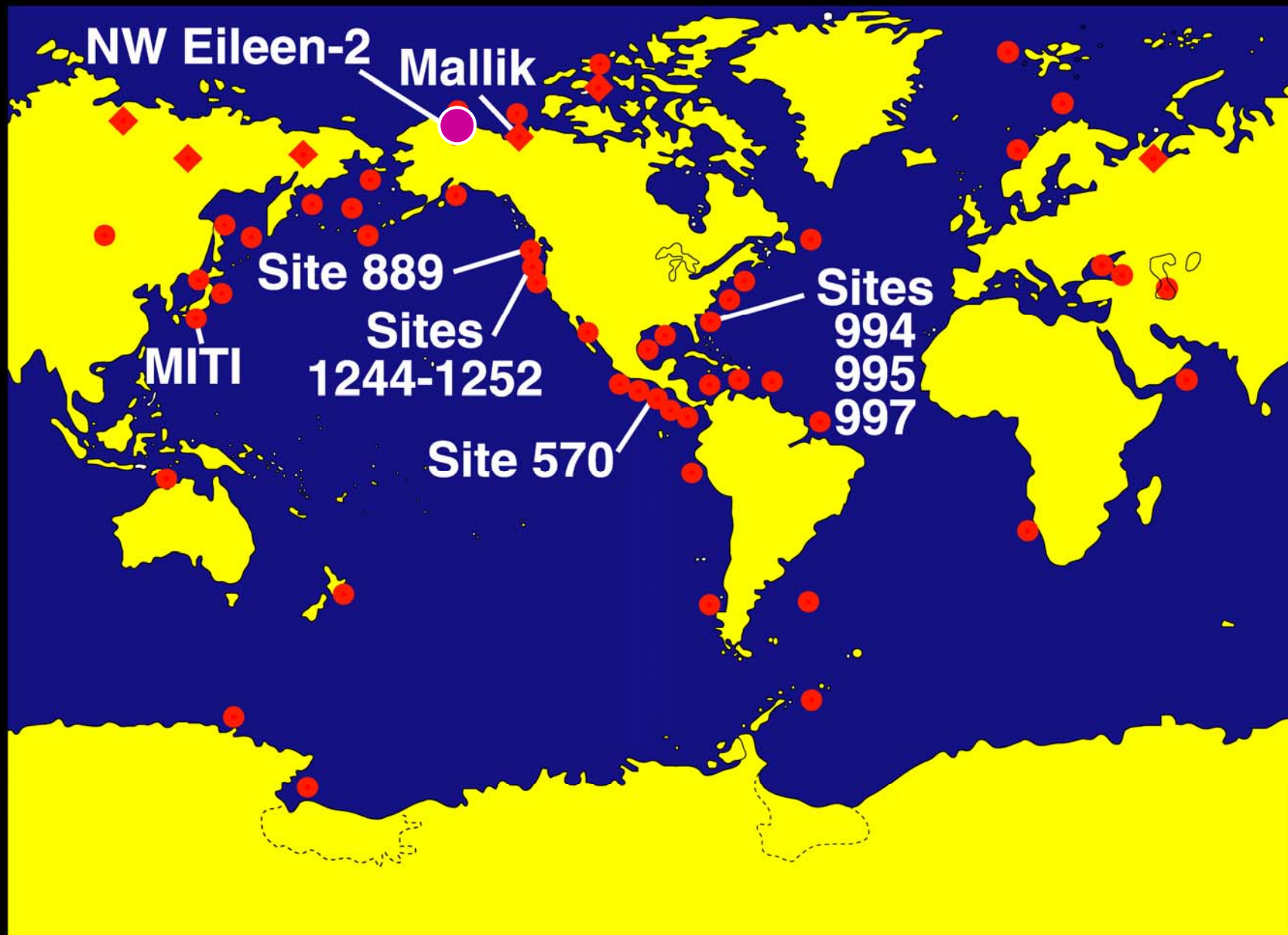
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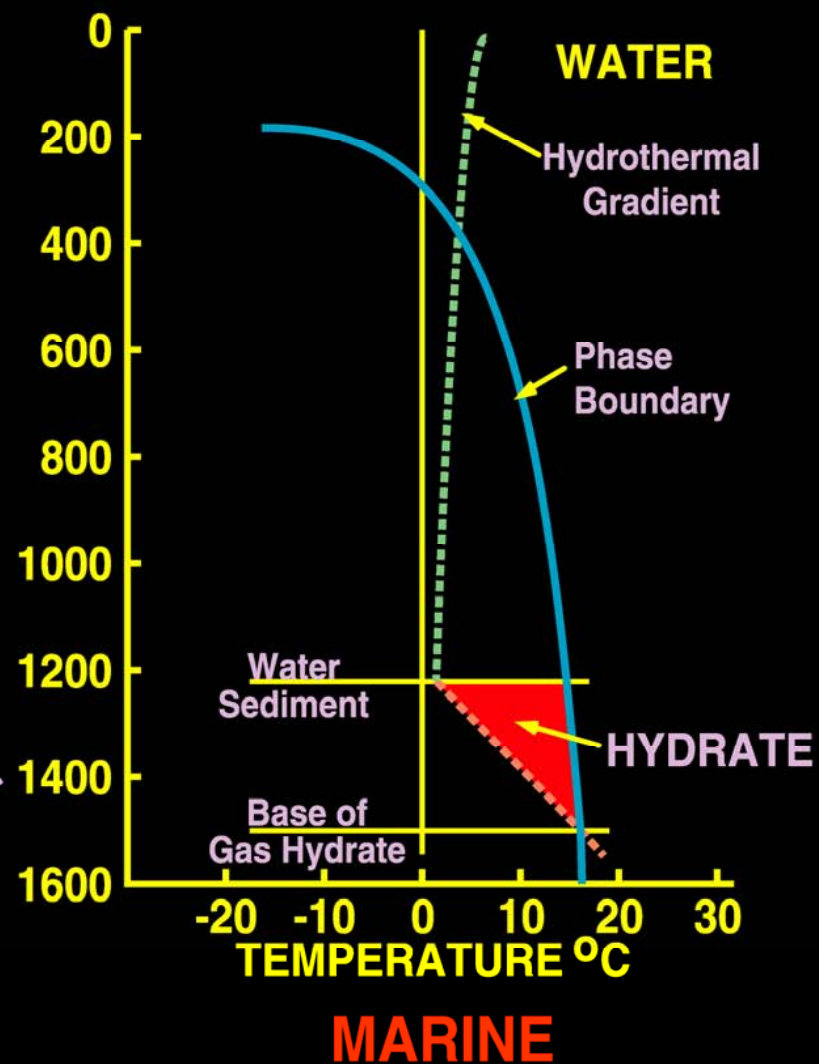
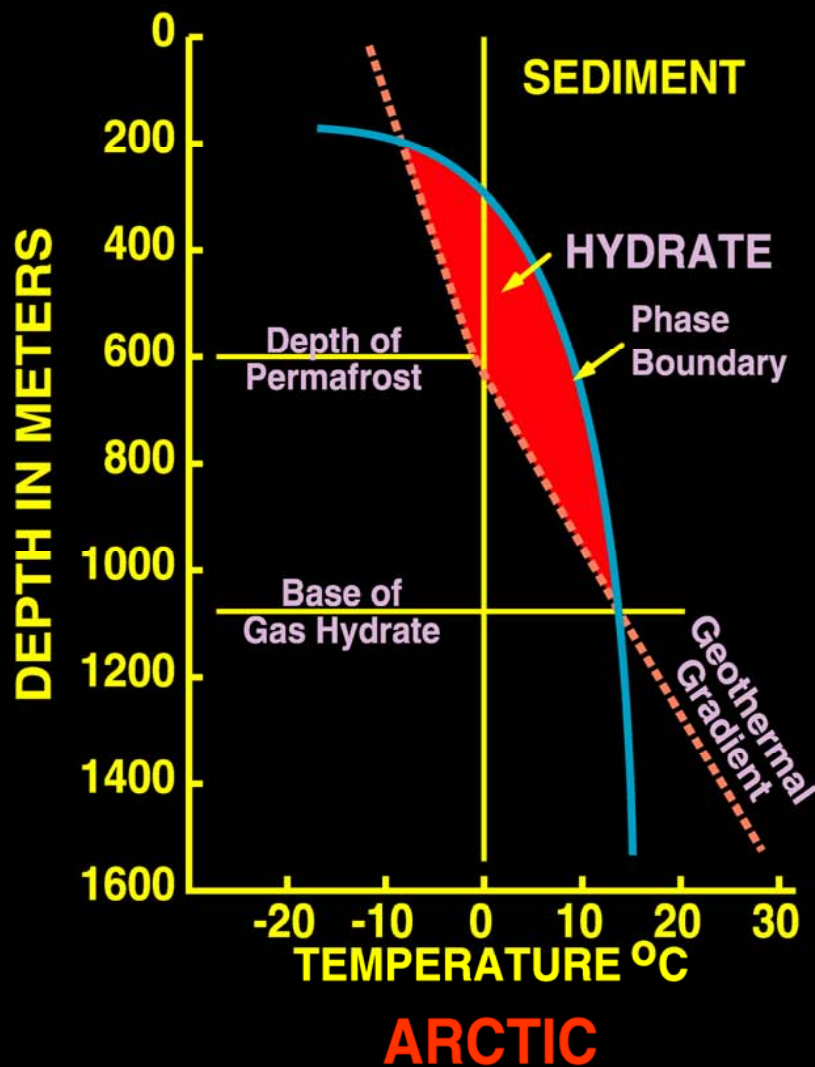
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Gas hydrate energy resource flow chart

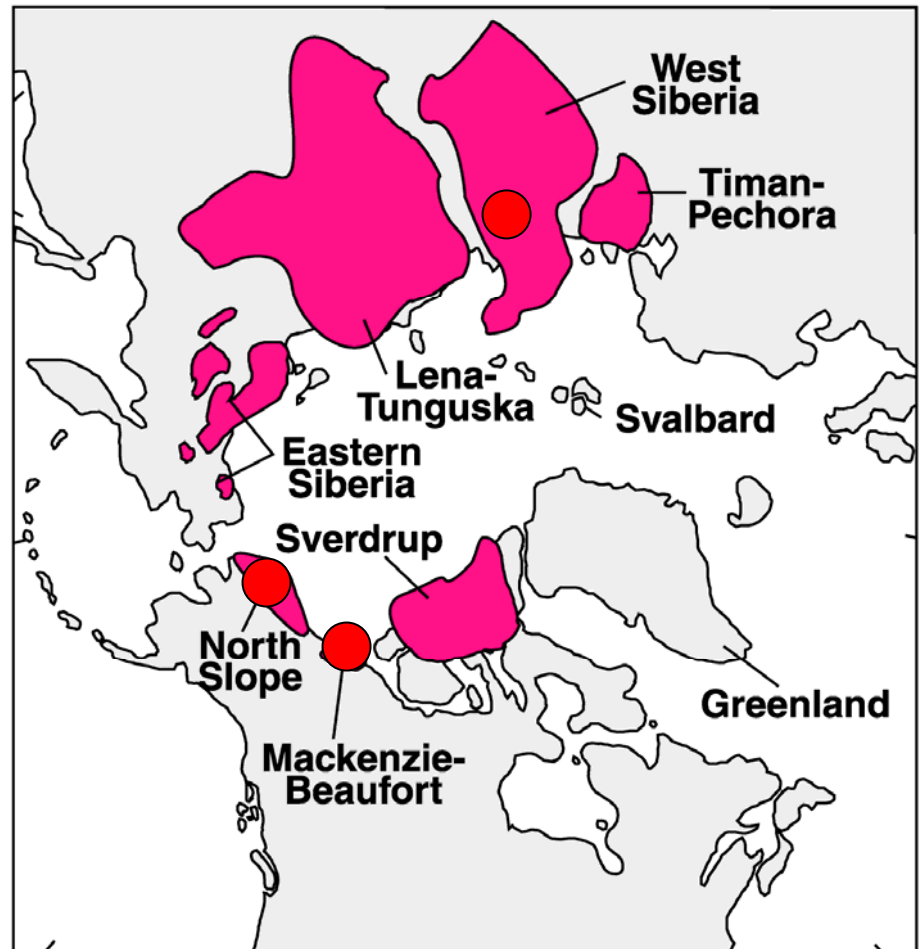
- Evolution from a nonproducing unconventional gas resource to a producible energy resource



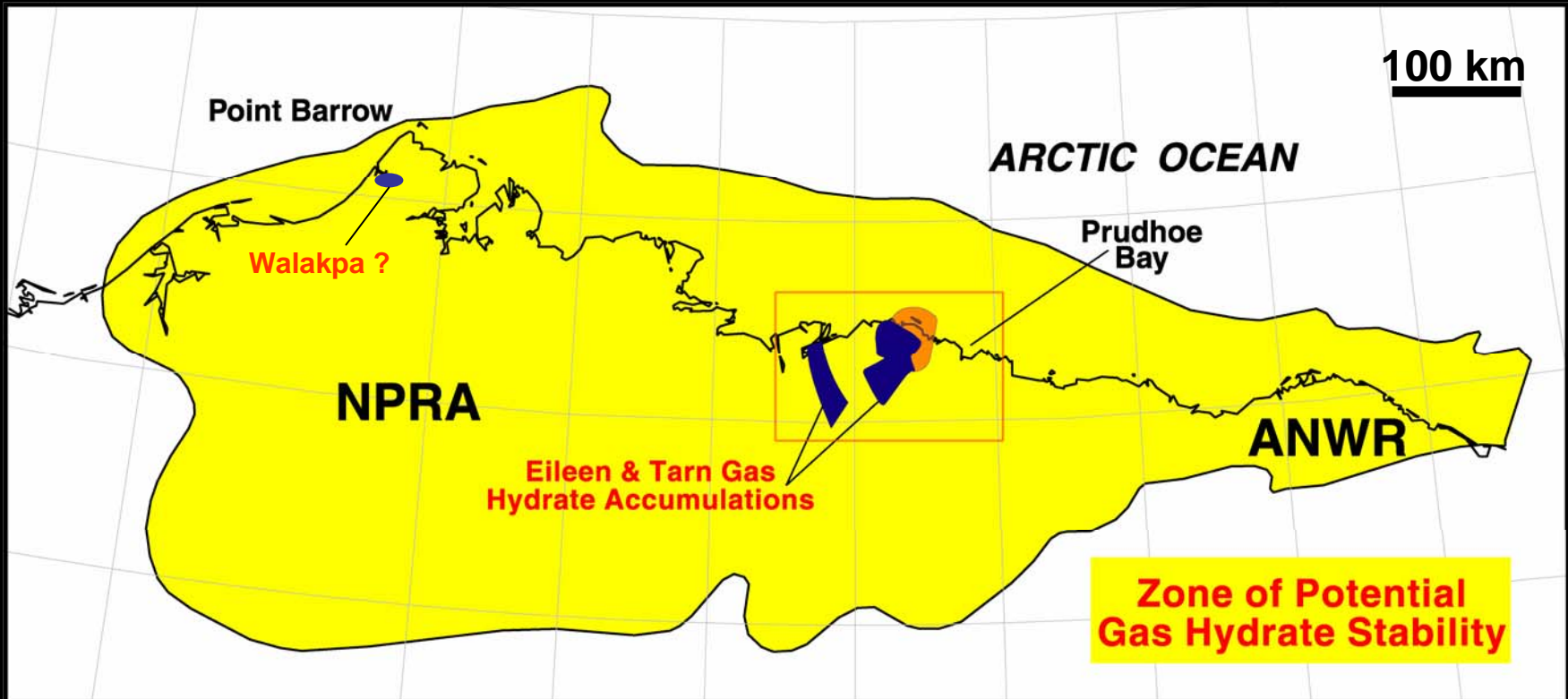




Arctic Basins - Area of known or inferred gas hydrates



Alaska NS Gas Hydrates

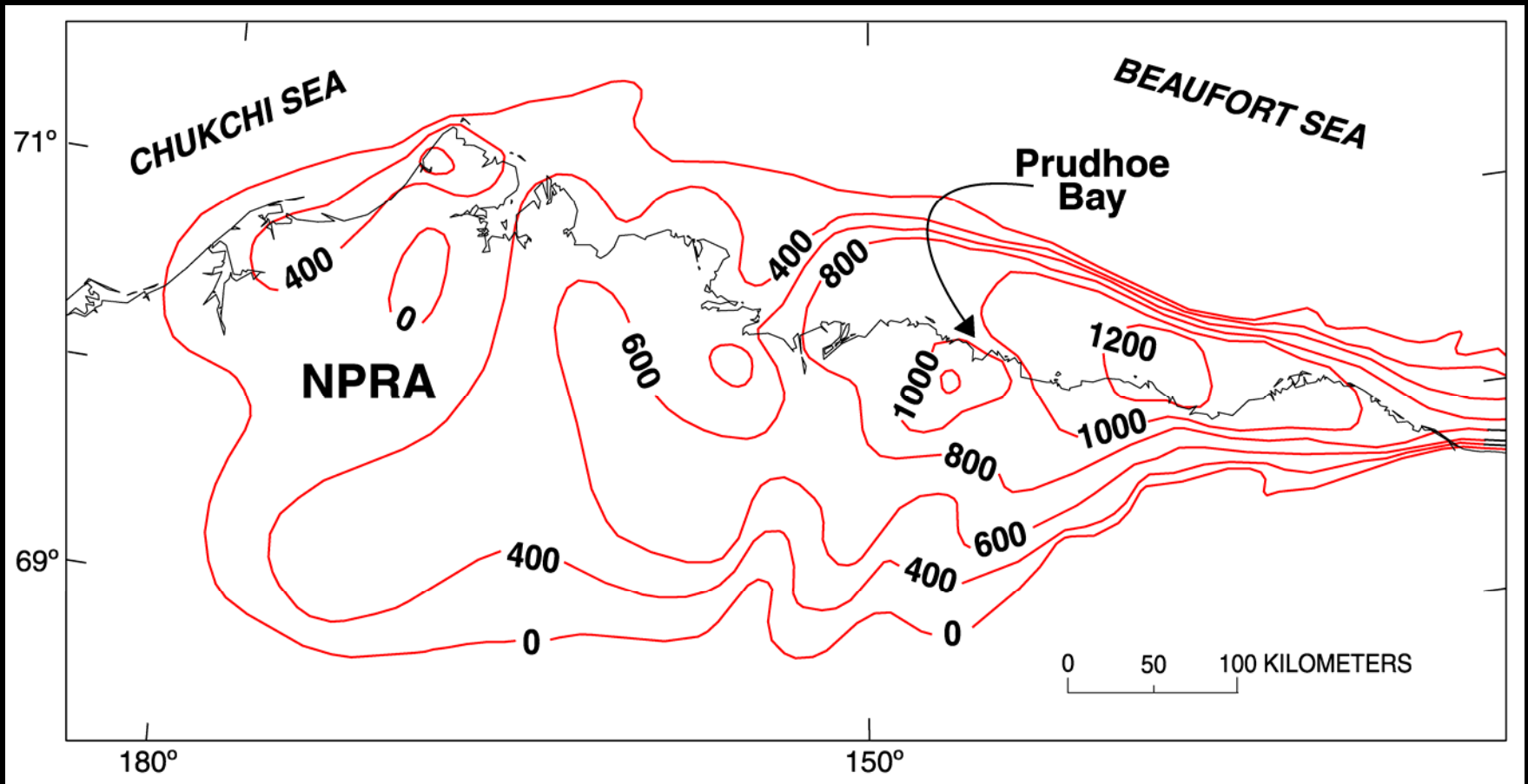


Controls on the Occurrence Gas Hydrate

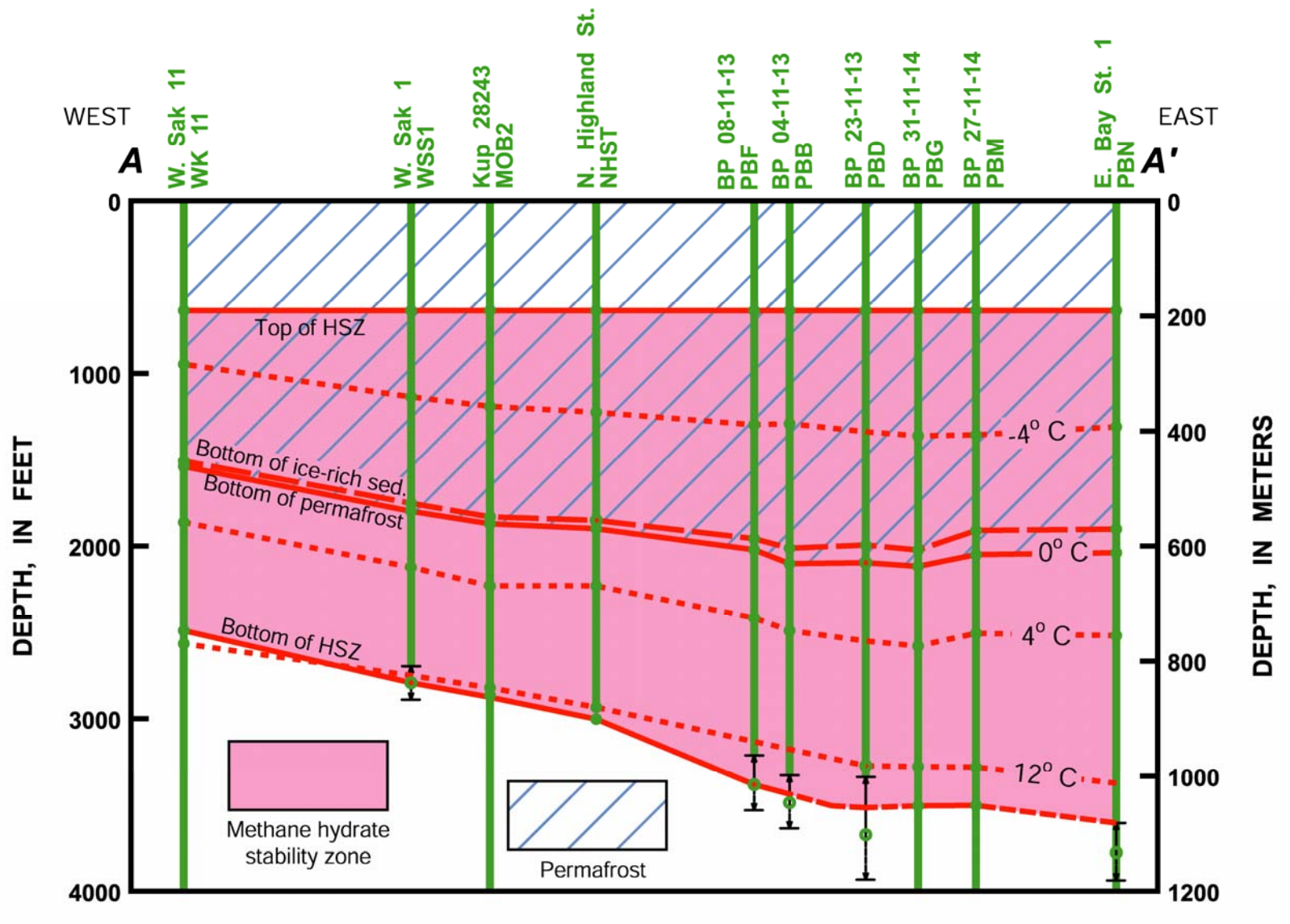
-Gas Hydrate Petroleum System-

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

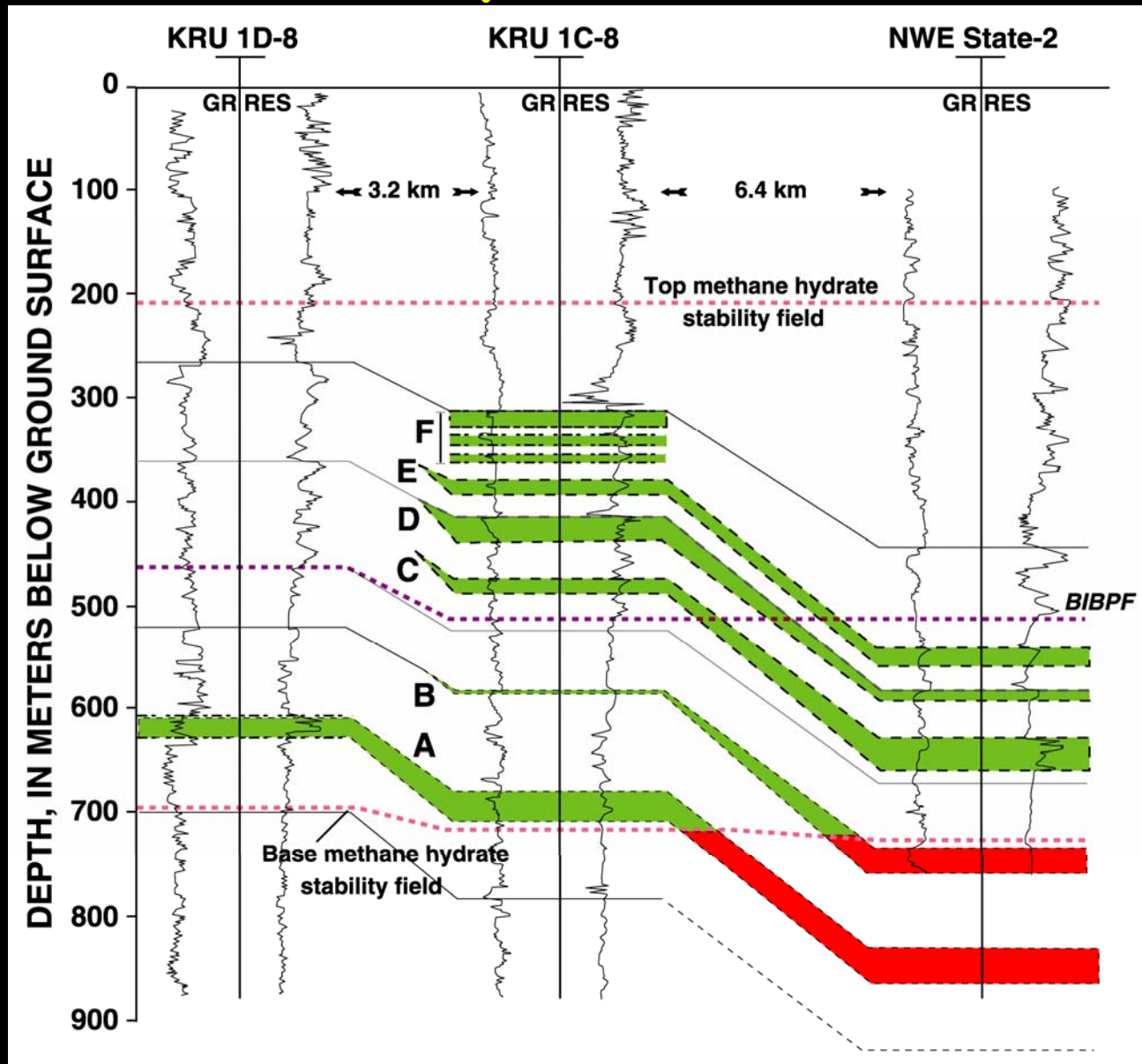
Alaska NS Hydrate Stability Map



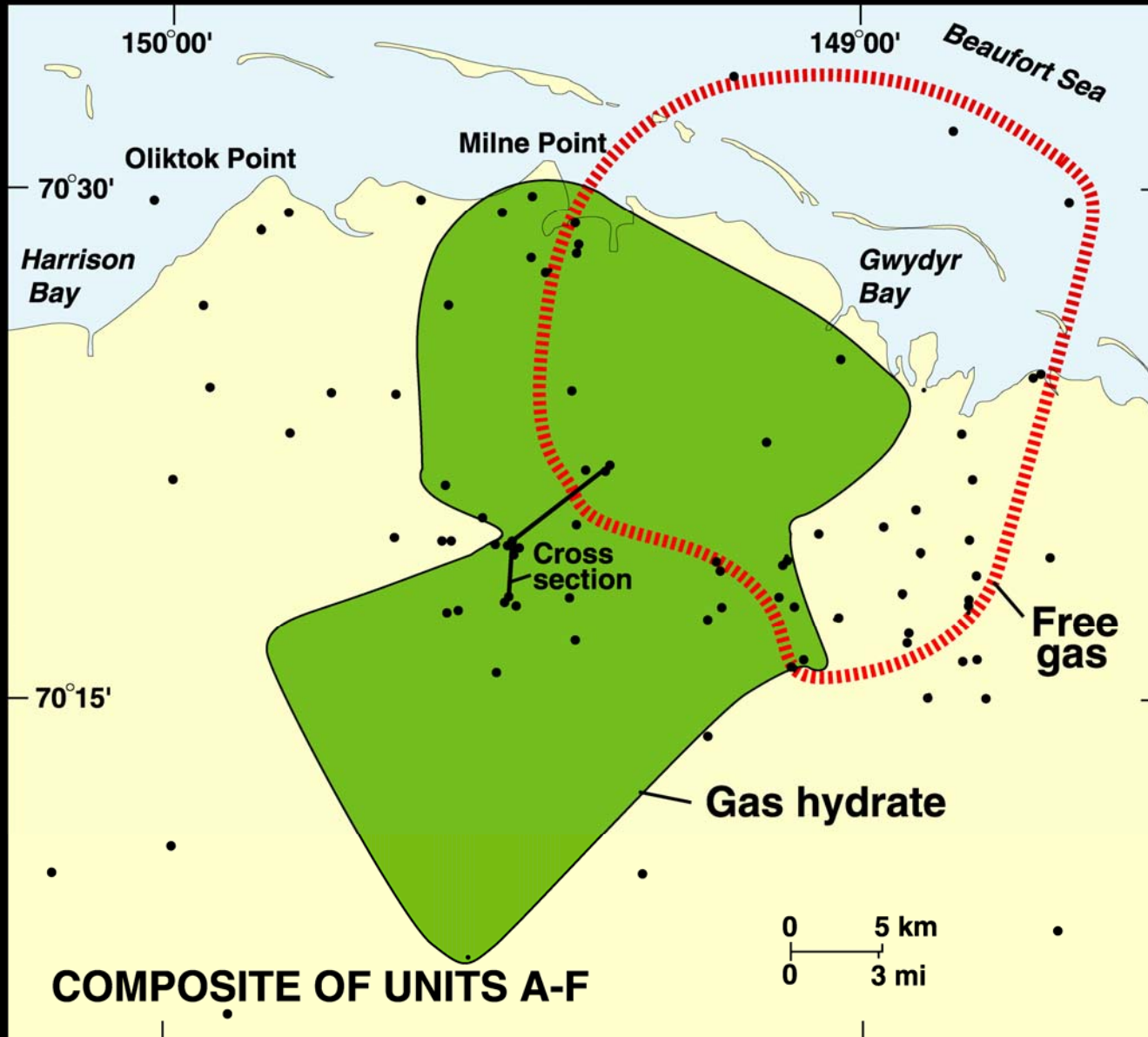
Prudhoe-Kuparuk Methane Hydrate Stability



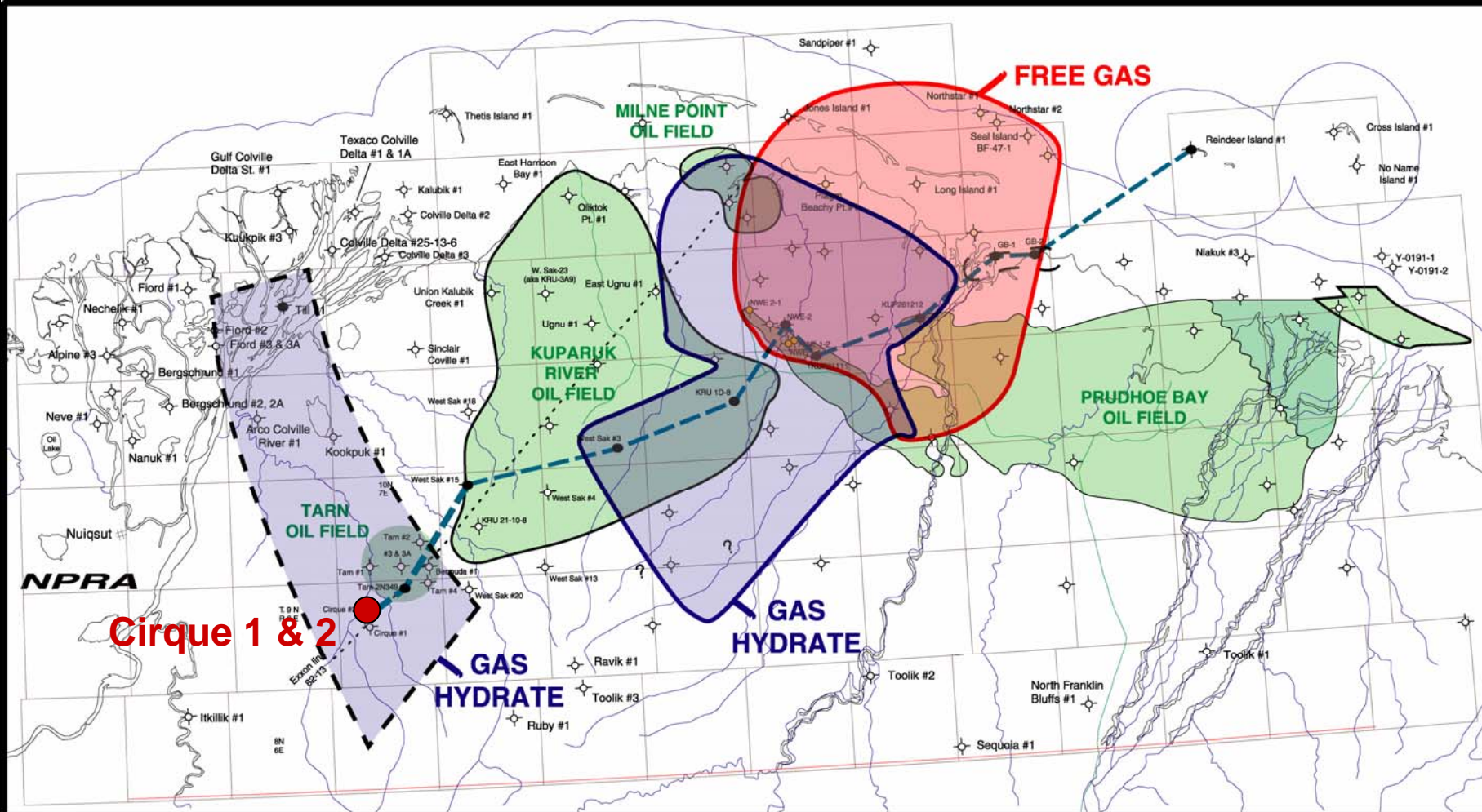
Eileen Gas Hydrate Accumulation



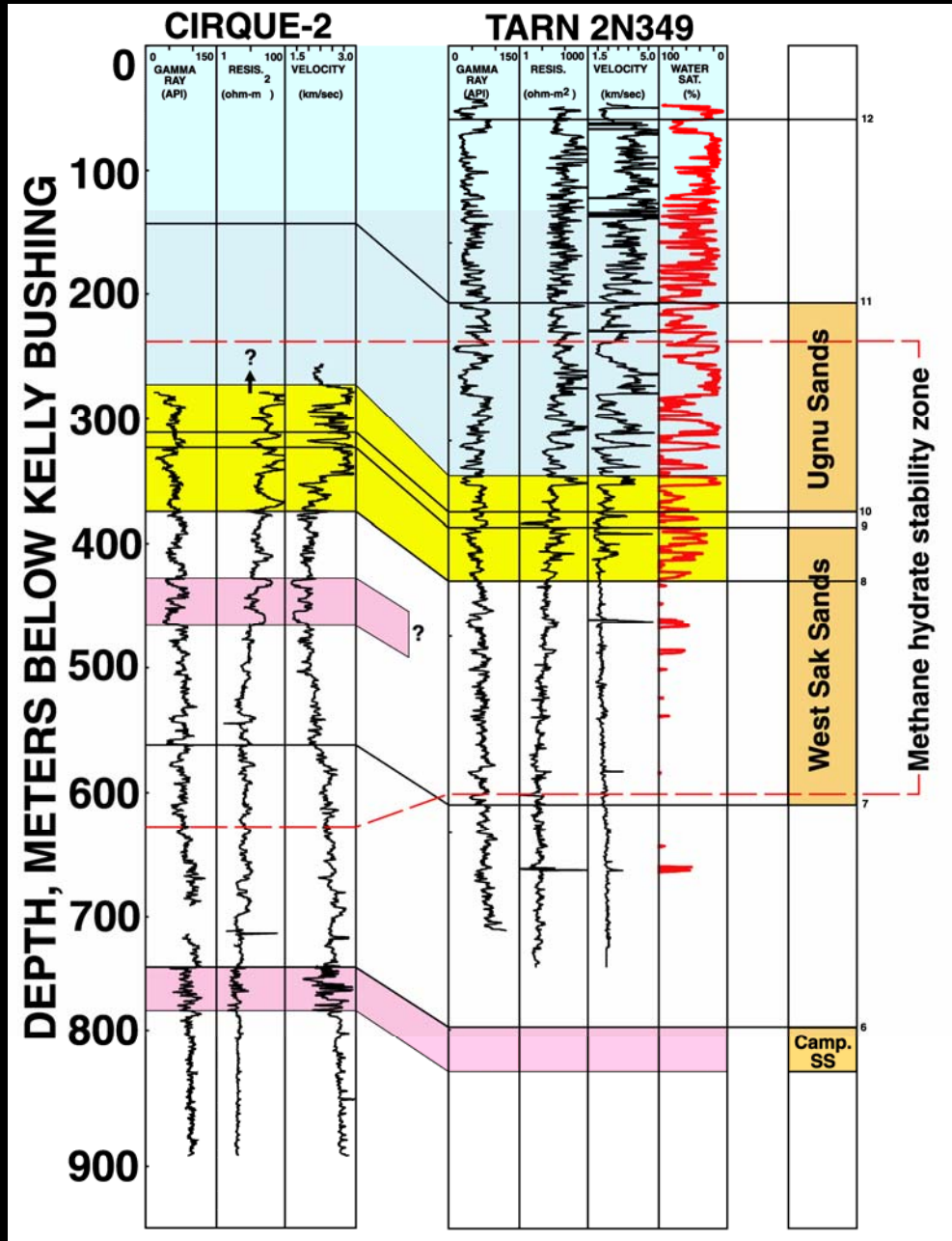
Eileen Gas Hydrate Accumulation



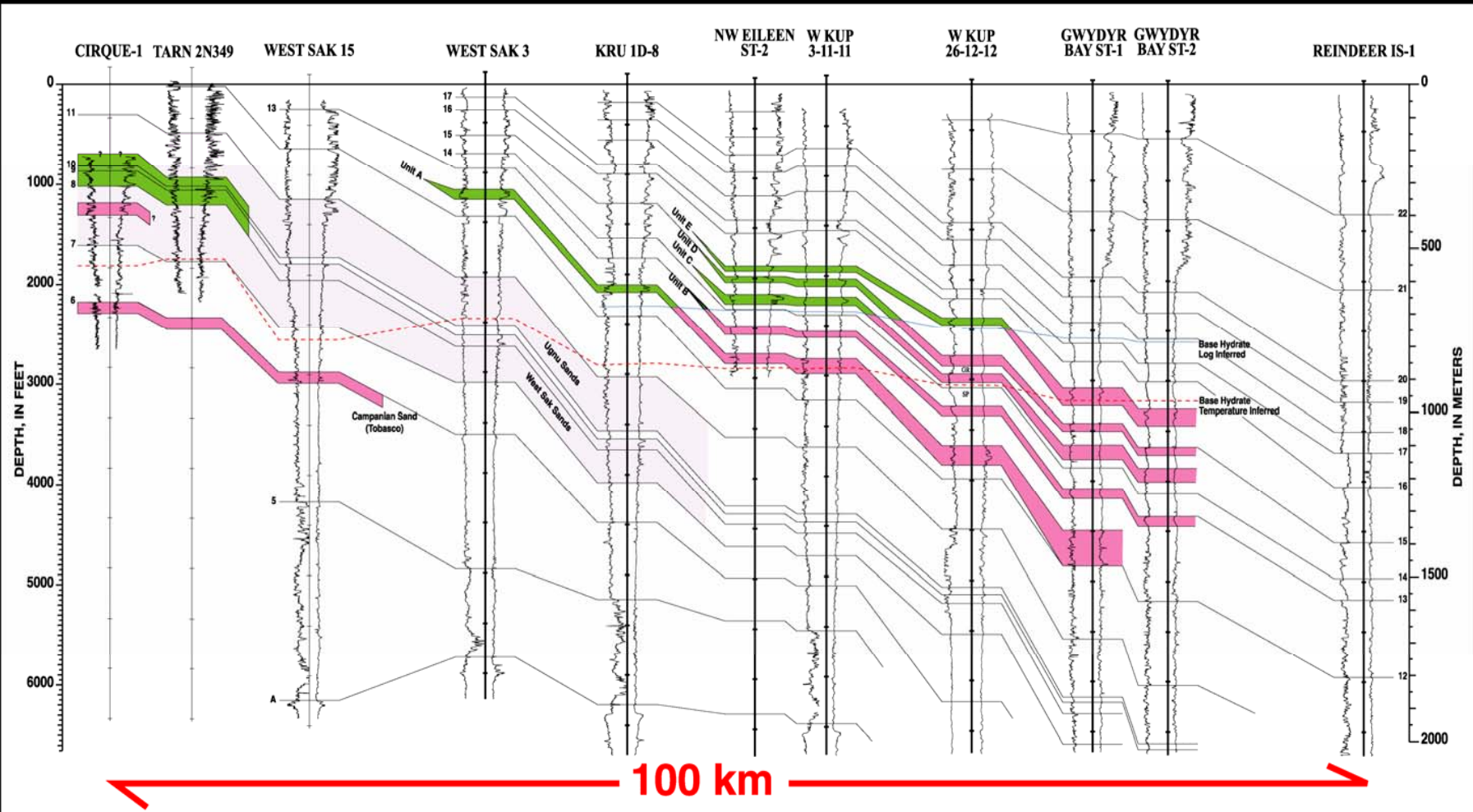
Tarn Gas Hydrate Accumulation



Cirque-Tarn Well Display

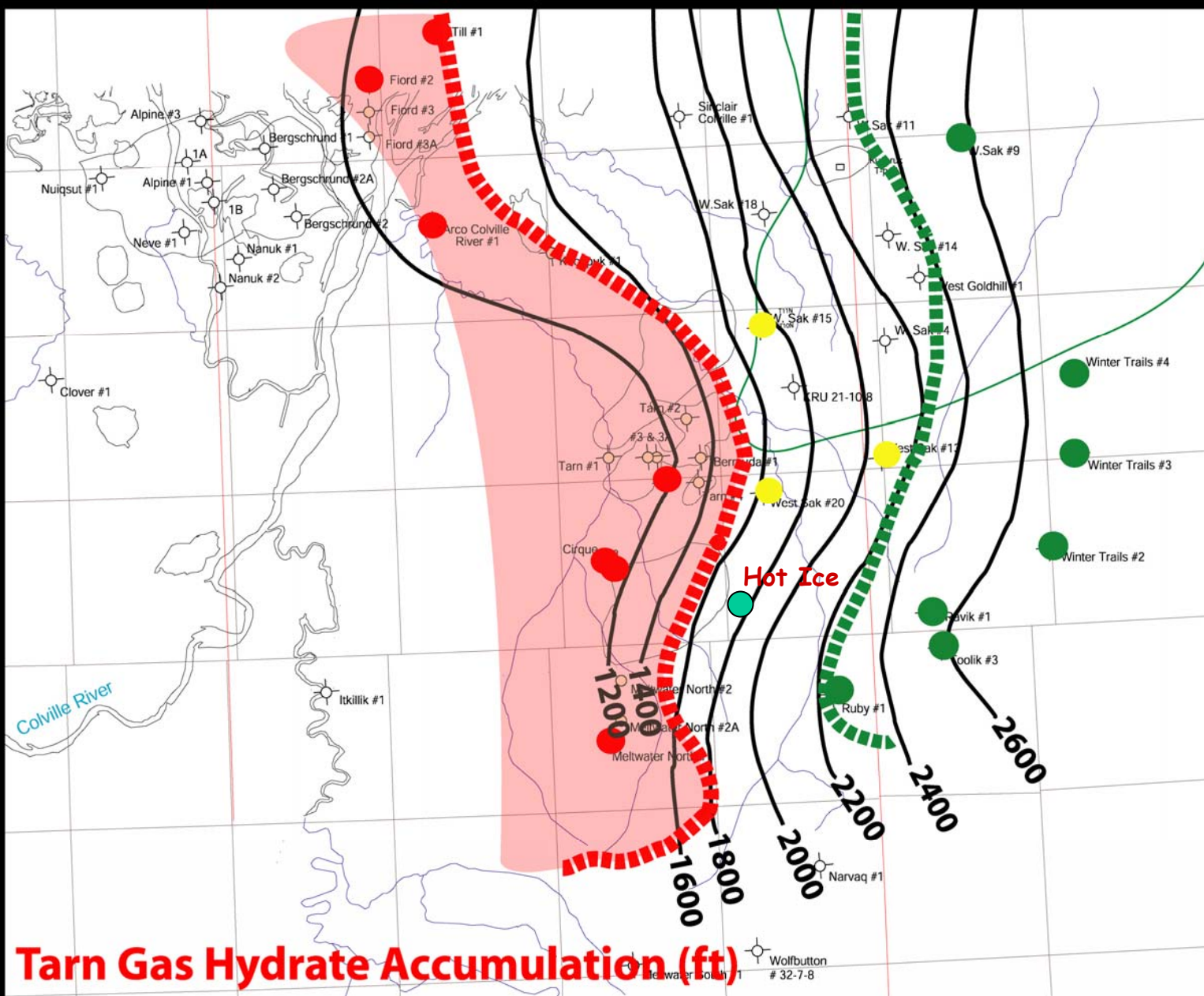


Eileen and Tarn Gas Hydrate Accumulations



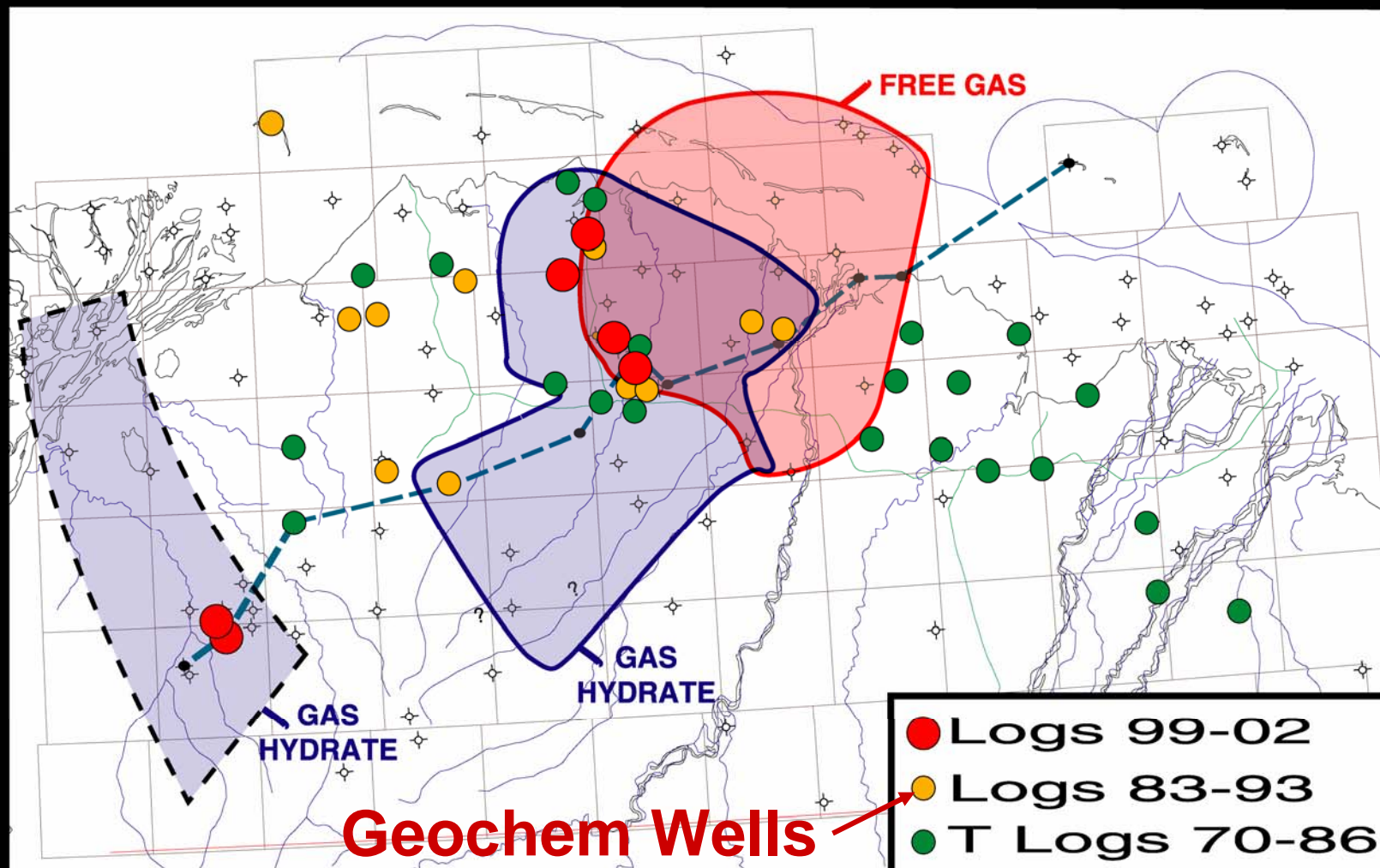
The map displays the North Slope of Alaska with several key features:

- Oil Fields:**
 - MILNE POINT OIL FIELD:** Located in the north-central region, outlined in green.
 - KUPARUK RIVER OIL FIELD:** Located in the central region, outlined in green.
 - PRUDHOE BAY OIL FIELD:** Located in the east-central region, outlined in green.
 - TARN OIL FIELD:** Located in the southwest, outlined in green.
- Gas Hydrate Regions:**
 - GAS HYDRATE:** Indicated by blue dashed lines and labels in the central and southwest areas.
- Other Regions:**
 - FREE GAS:** A red shaded area in the northeast, labeled "FREE GAS" in red.
- Wells and Landmarks:**
 - Wells: Numerous wells are marked with star symbols and labels, including Gulf Colville Delta #1, Texaco Colville Delta #1 & 1A, Kuukpik #3, Fiord #1, Fiord #2, Fiord #3 & 3A, Nechelek #1, Alpine #3, Neve #1, Nanuk #1, Nuiqsut, West Sak #15, West Sak #16, West Sak #13, West Sak #4, West Sak #20, Ravik #1, Toolik #3, Ruby #1, Toolik #2, North Franklin Bluffs #1, Sequoia #1, Toolik #1, Niakuk #3, Y-0191-1, Y-0191-2, Reindeer Island #1, Cross Island #1, No Name Island #1, Seal Island BF-47-1, Long Island #1, Northstar #1, Northstar #2, Sandpiper #1, Thetis Island #1, Kalubik #1, Colville Delta #2, Colville Delta #25-13-6, Colville Delta #3, Union Kalubik Creek #1, Sinclair Coville #1, Ugnu #1, East Ugnu #1, W. Sak-23 (aka KRU-3A9), KRU 10-6, KRU 21-10-6, Tarn #1, Tarn #2, Tarn #3 & 3A, Tarn #4, Tarn #2049, Cirque #1, Cirque #2, Exon life 6C-10, T. 9 N R. 6 E, 8N 6E, and Itkillik #1.
 - Landmarks: Oil Lake, Nuiqsut, and various islands.
- Administrative Boundaries:**
 - NPRA:** National Petroleum Reserve for Alaska, indicated by a dashed line in the southwest.

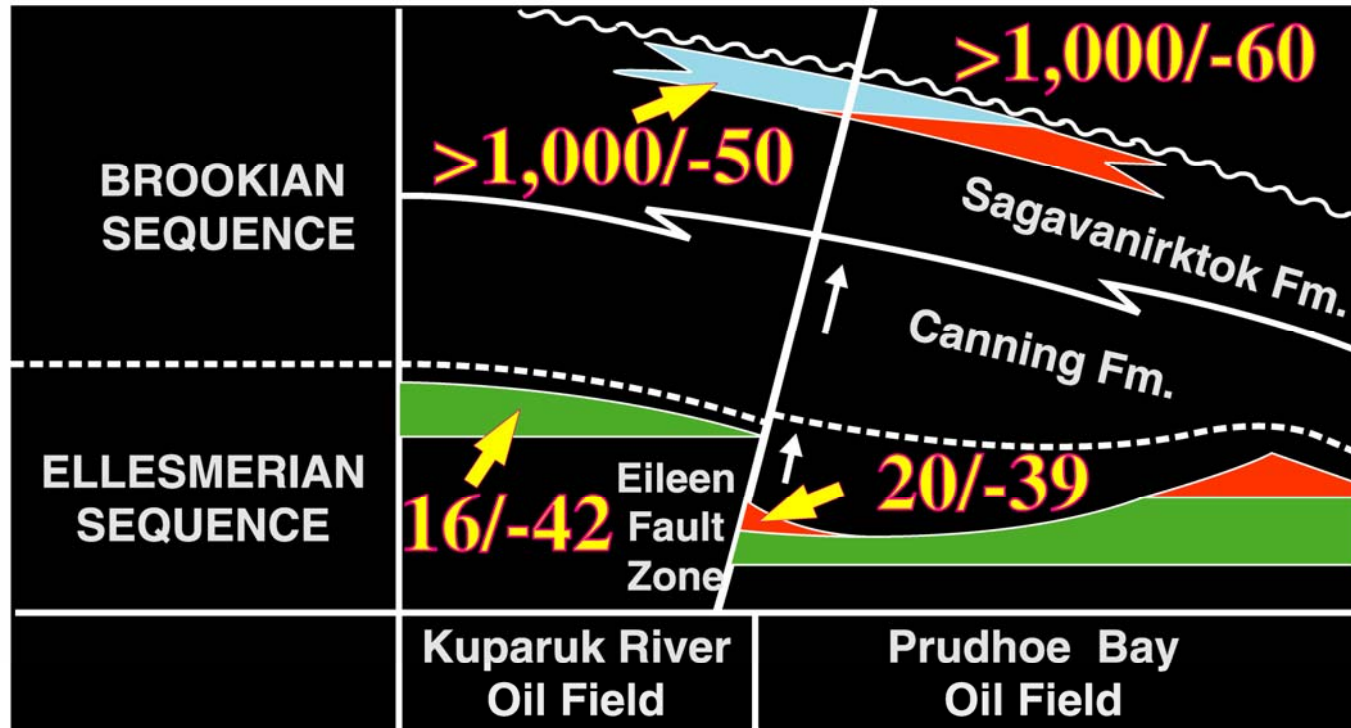


Tarn Gas Hydrate Accumulation (ft)

Wells of Opportunity - Geochemical Sampling



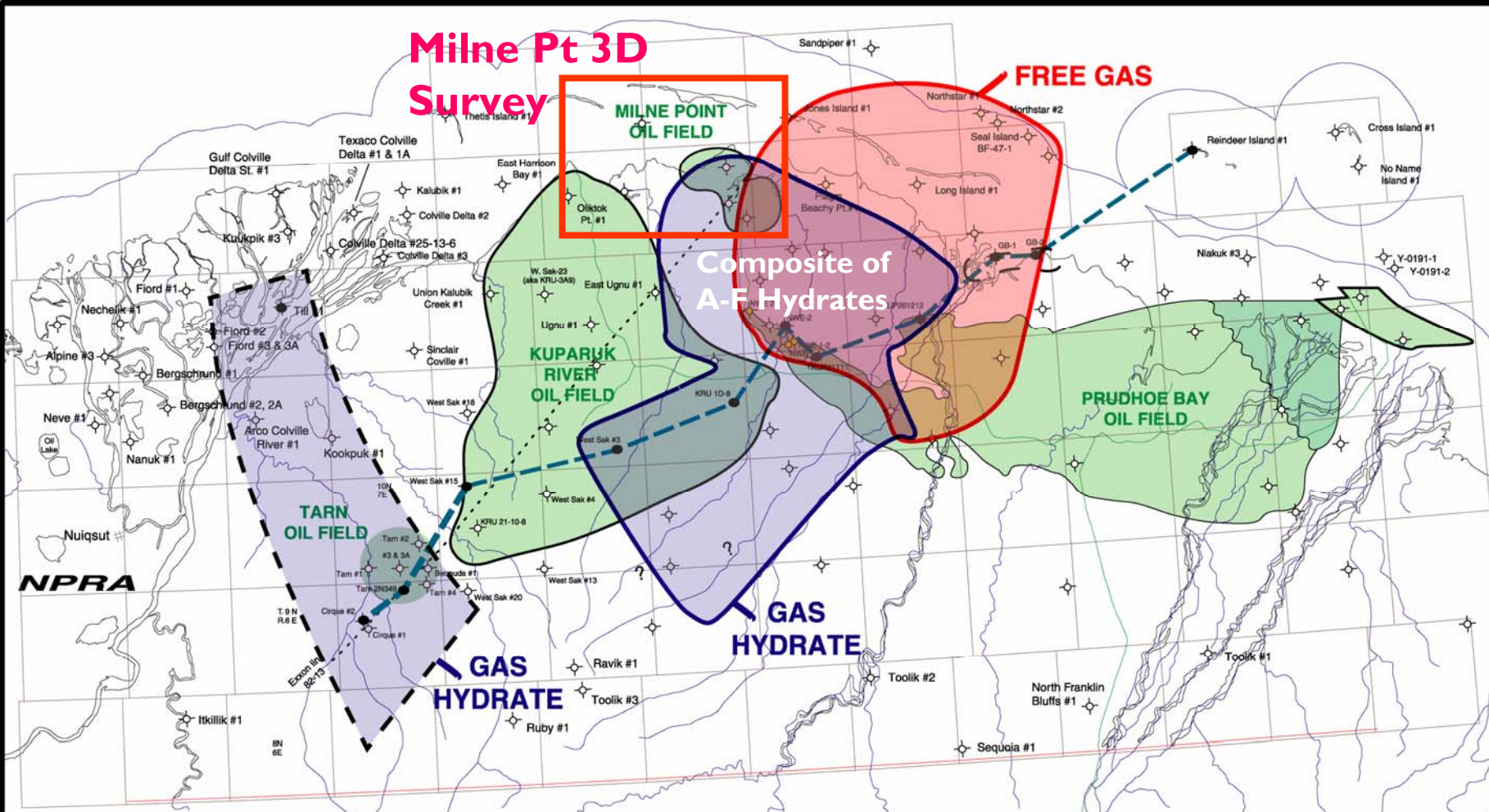
Eileen and Tarn Gas Hydrate Petroleum System



 GAS HYDRATE  OIL

 FREE GAS  MIGRATION PATH

Milne Pt 3D Survey



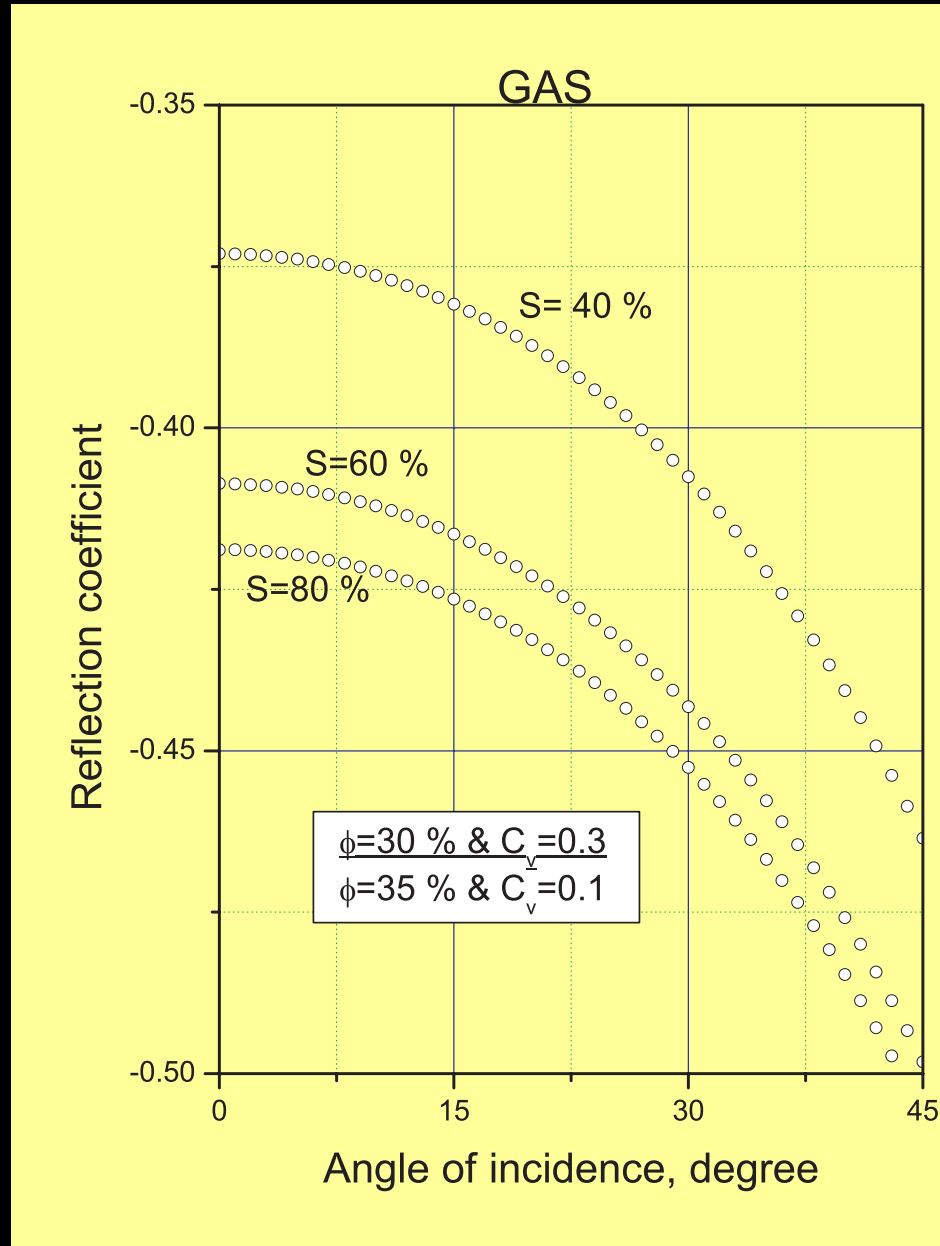
MPU Seismic Evaluation Project Workflow

- **Wavelet Processing**
- **Project Preparation**
 - Synthetic ties
 - Stratigraphic ties
 - Historical Tops
- **Petrophysical Analysis and Attribute Development**
- **Structural Interpretation**
- **Calculation of Base Hydrate Stability Zone (BHSZ)**
- **Intra-Gas Hydrate prospecting**
- **Sub-Hydrate Gas prospecting**
- **Volumetrics**

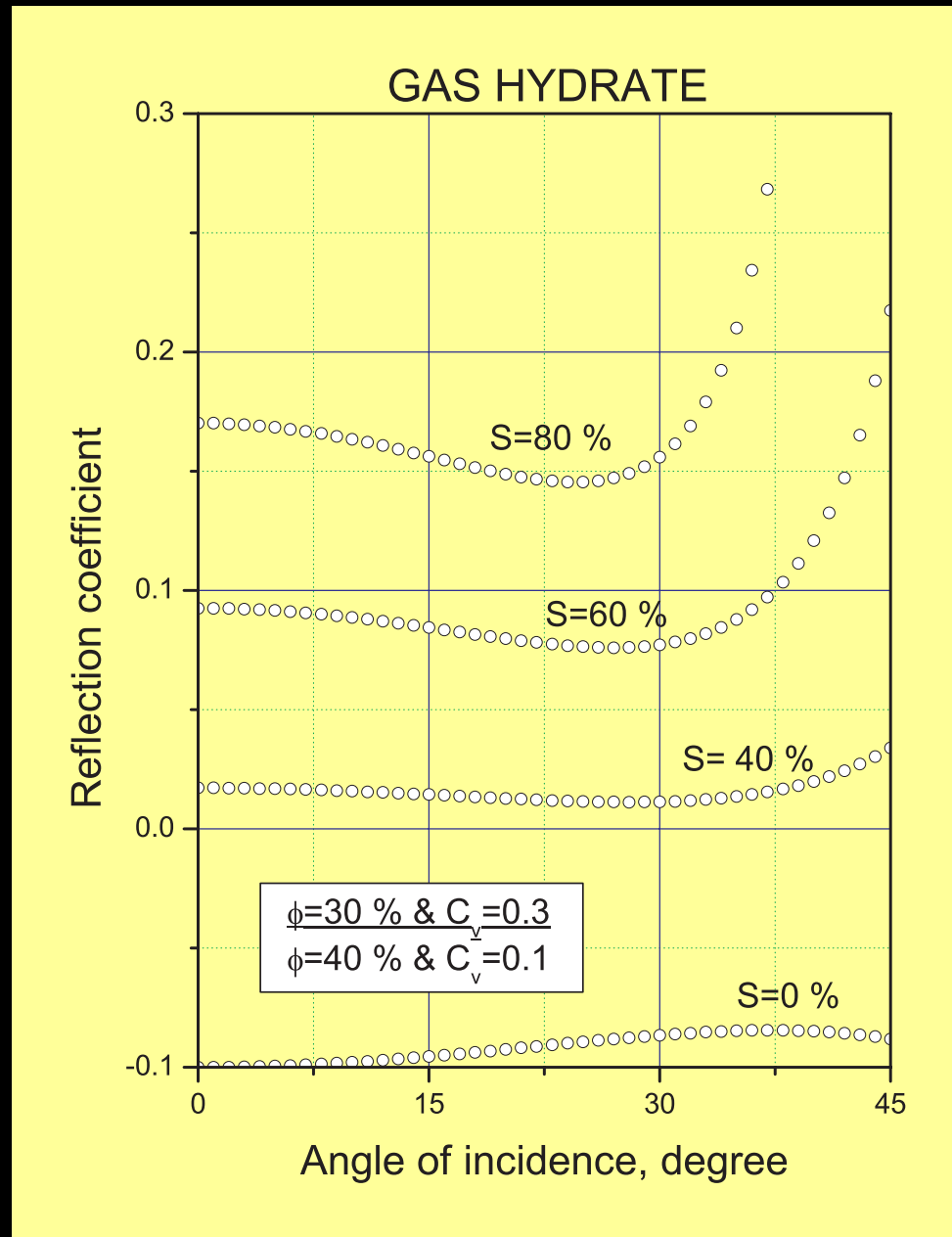
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Shale over Gas-Filled Reservoir Sands

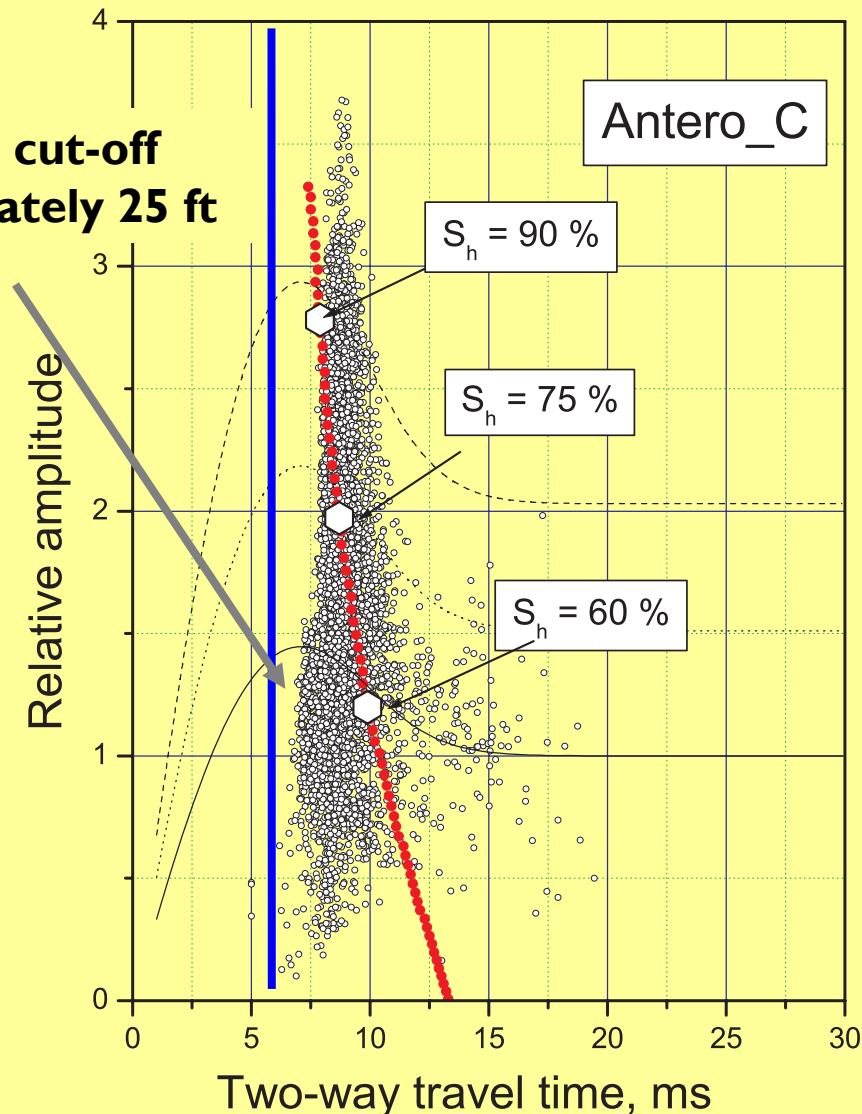


Shale over Hydrate-Filled Reservoir Sands



Seismic Response to Saturation Changes in Gas Hydrate-bearing Reservoir Sands

**Thickness cut-off
approximately 25 ft**

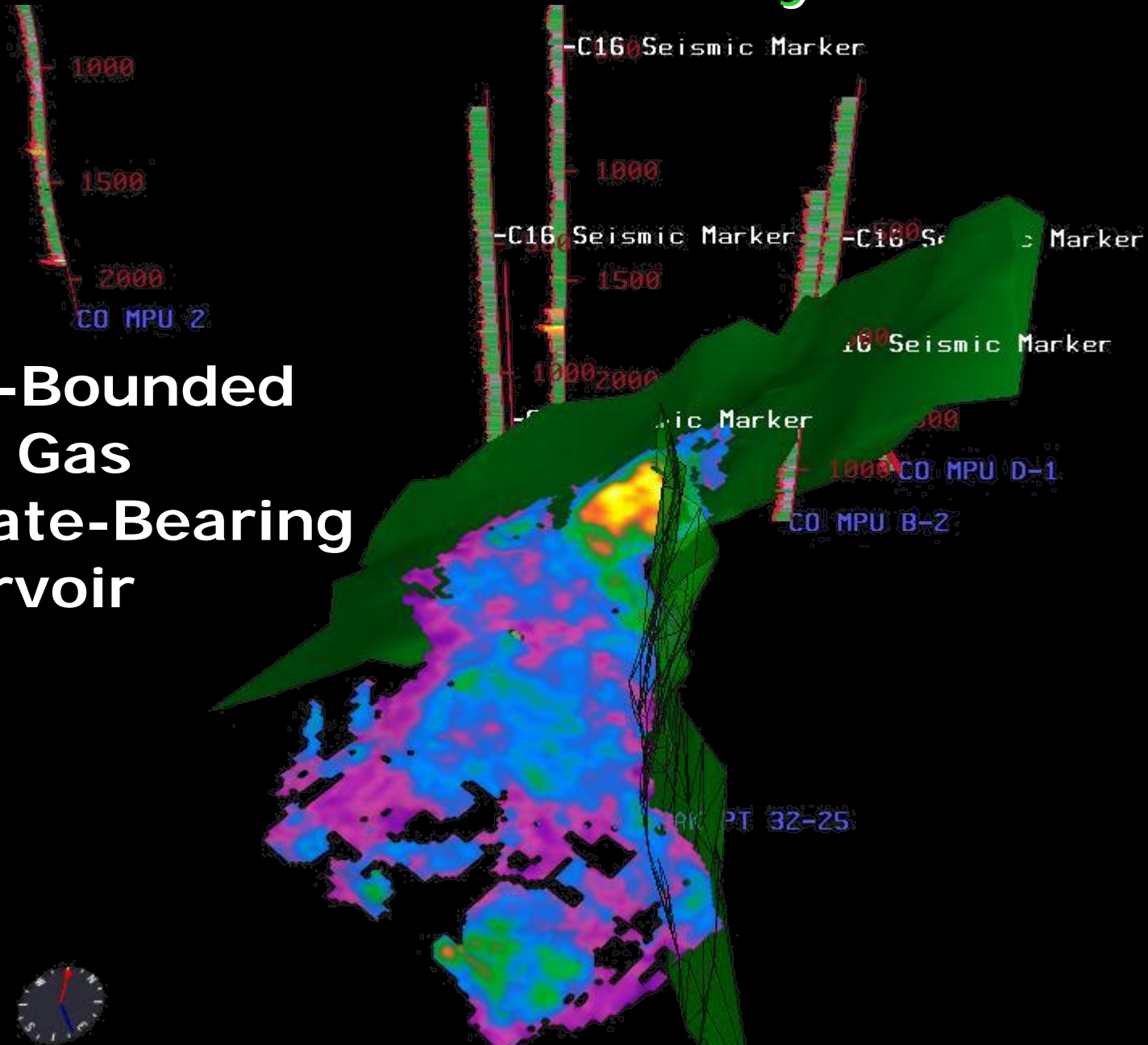


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MT. ELBERT "C" and "D" Hydrate Anomaly

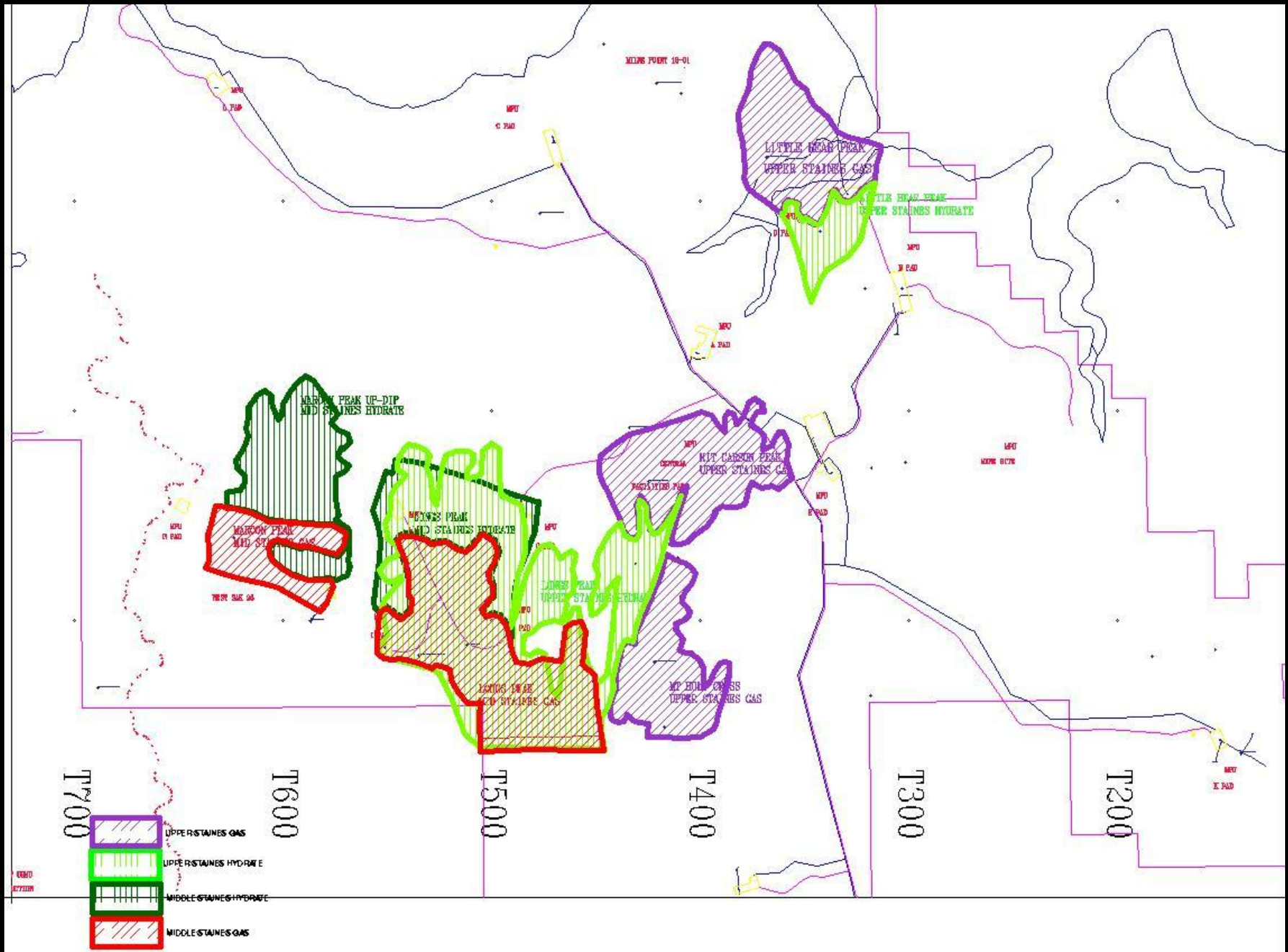
**Fault-Bounded
Trap, Gas
Hydrate-Bearing
Reservoir**



MPU Seismic Evaluation Project Workflow

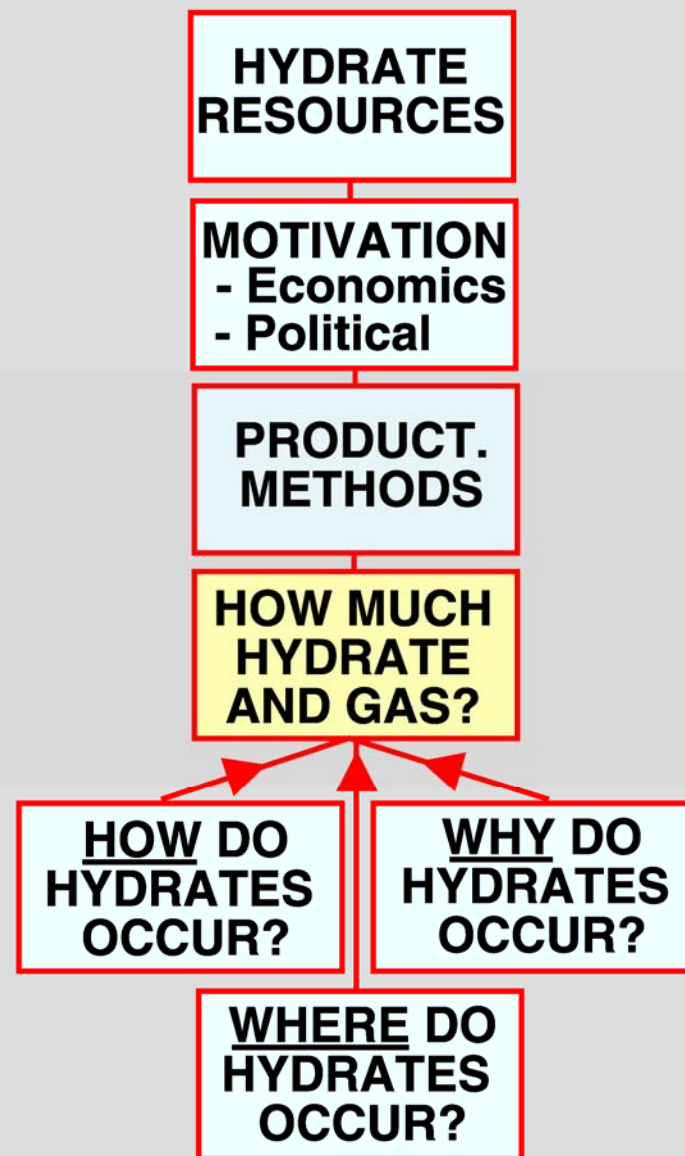
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MPU Gas Hydrate/Free Gas Prospects



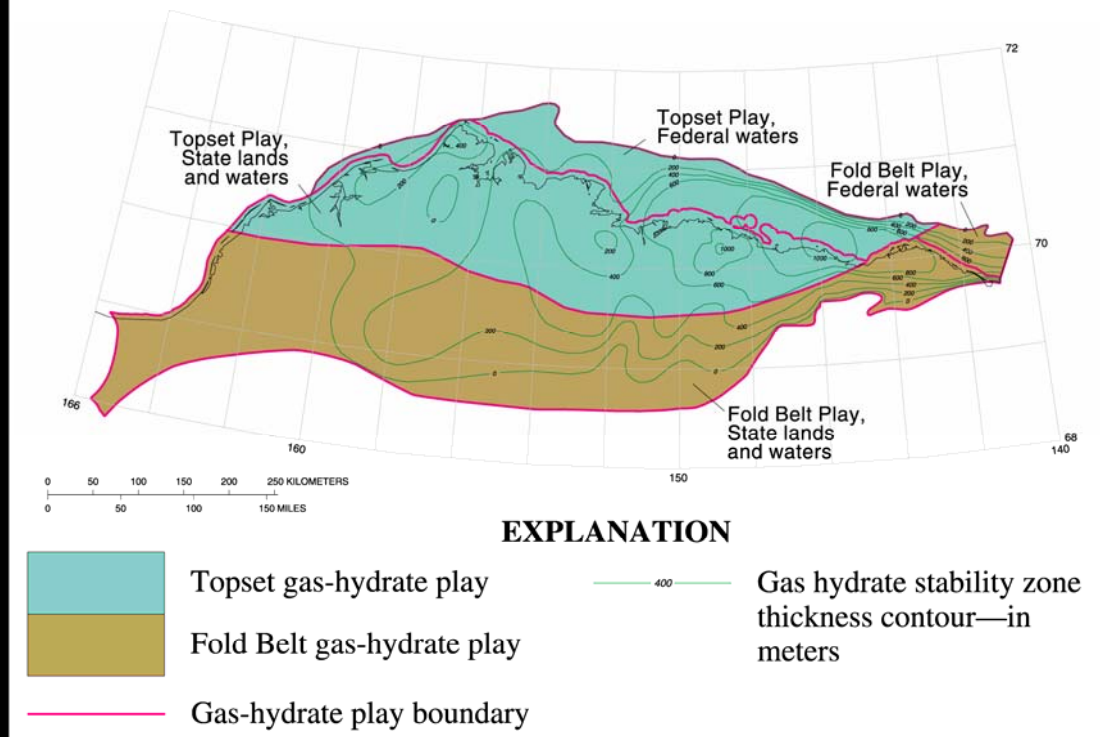
Gas hydrate energy resource flow chart

- Evolution from a nonproducing unconventional gas resource to a producible energy resource

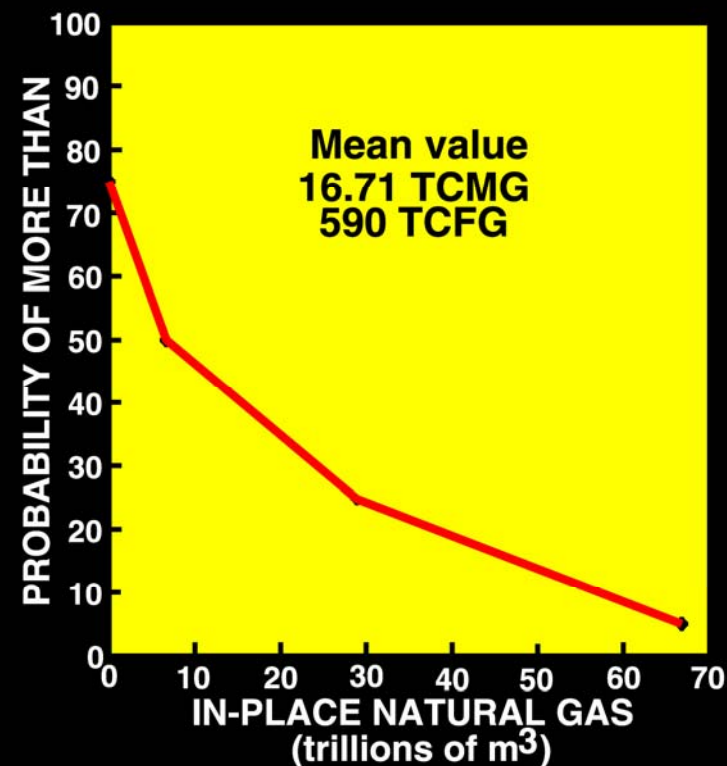


1995 USGS Hydrate Resource Assessment

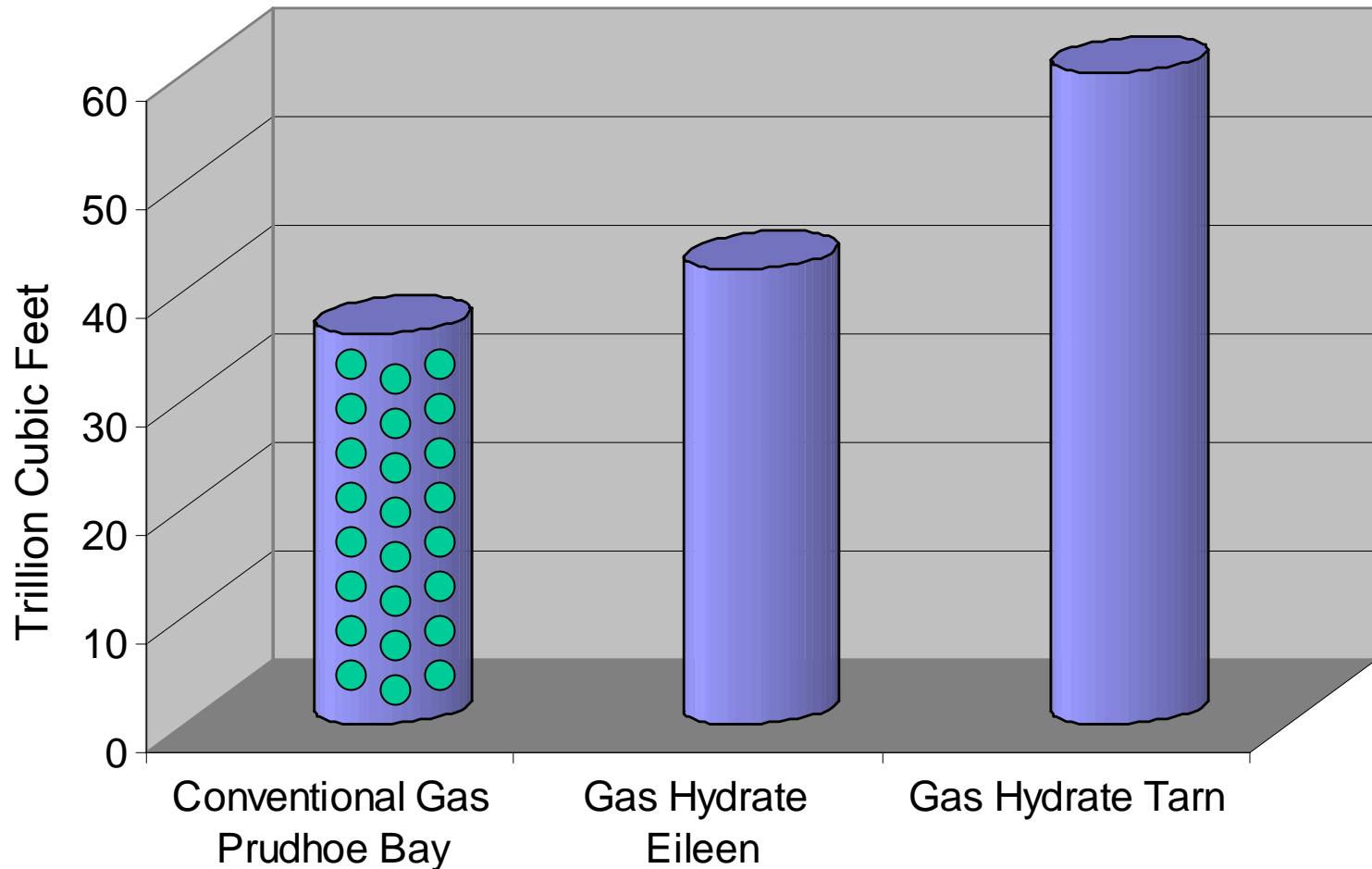
MAP OF THE ALASKA GAS HYDRATE PLAYS



Alaska Gas Hydrate Play Based Assessment

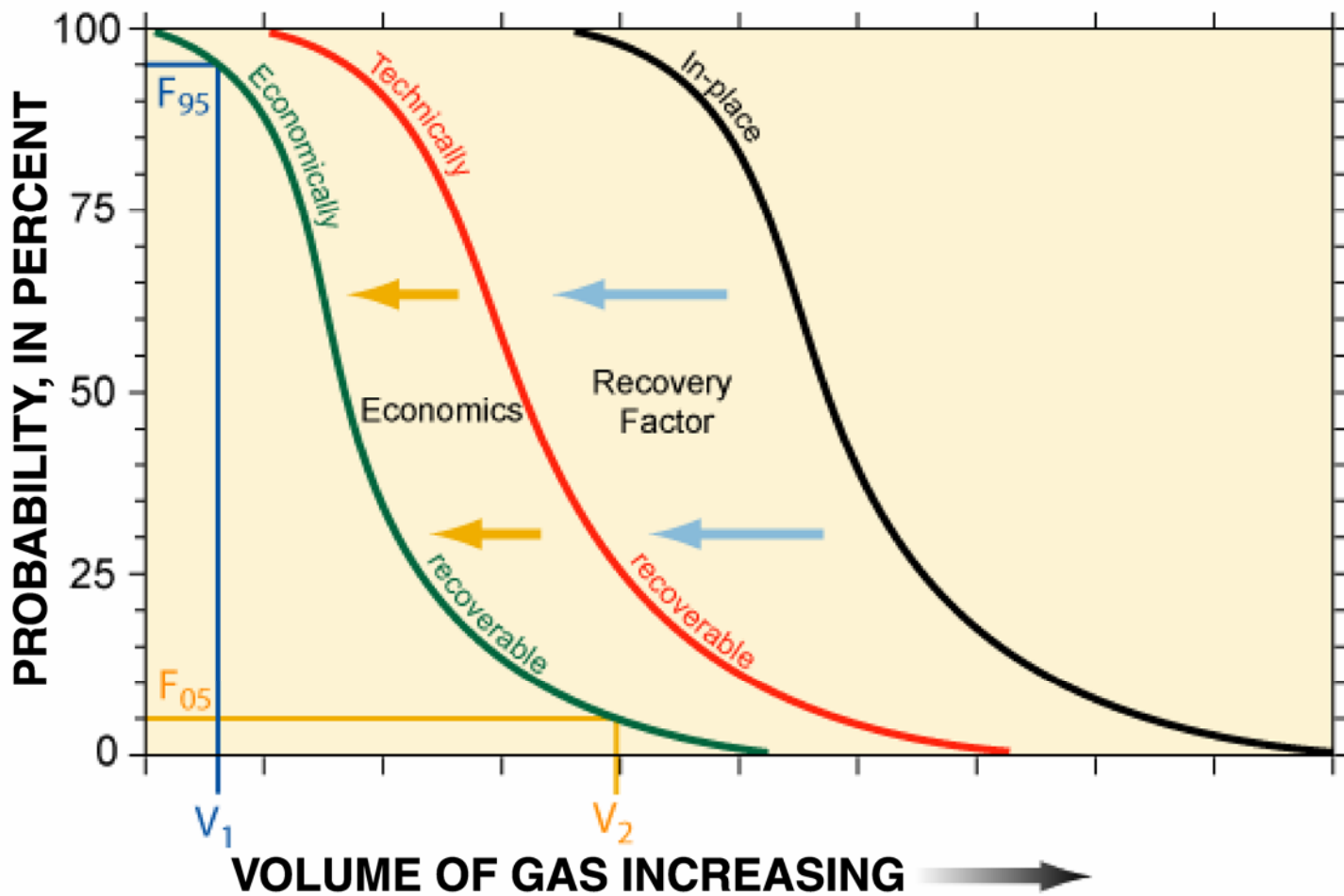


Alaska Gas Hydrate "Resource" Assessments



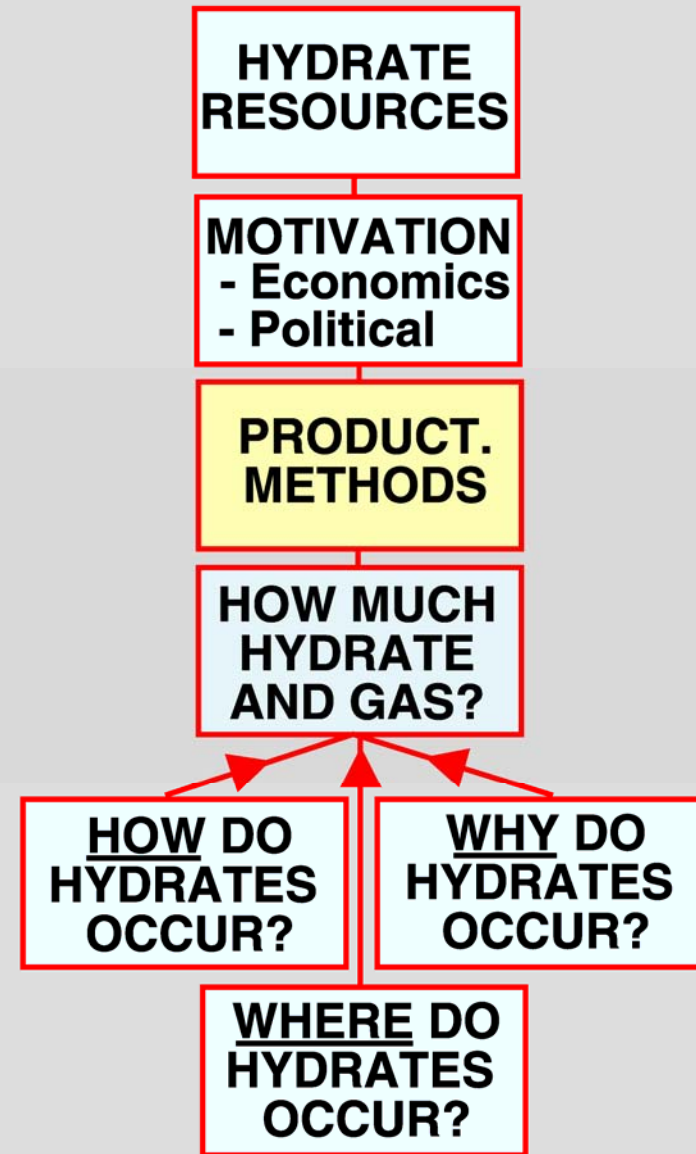
Hydrate Resource Assessment

"Economically Recoverable Assessment"



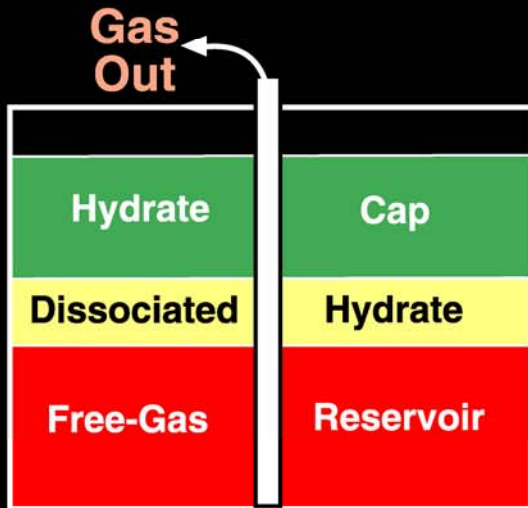
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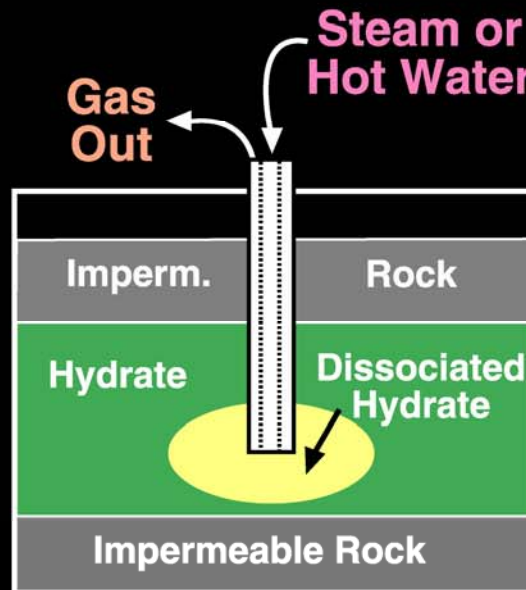


Gas Hydrate Production Methods

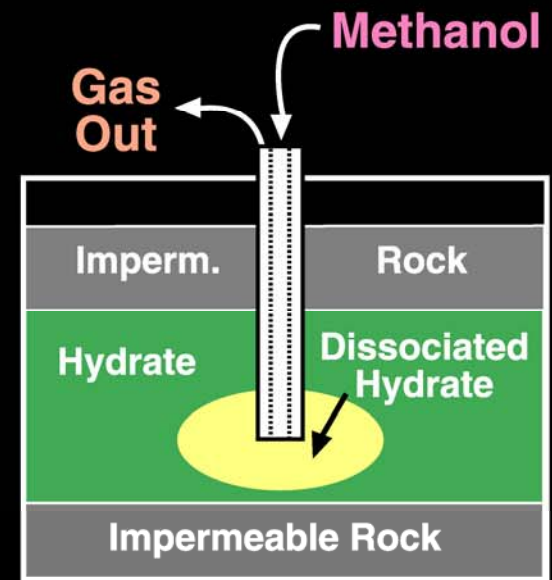
Depressurization



Thermal Injection



Inhibitor Injection

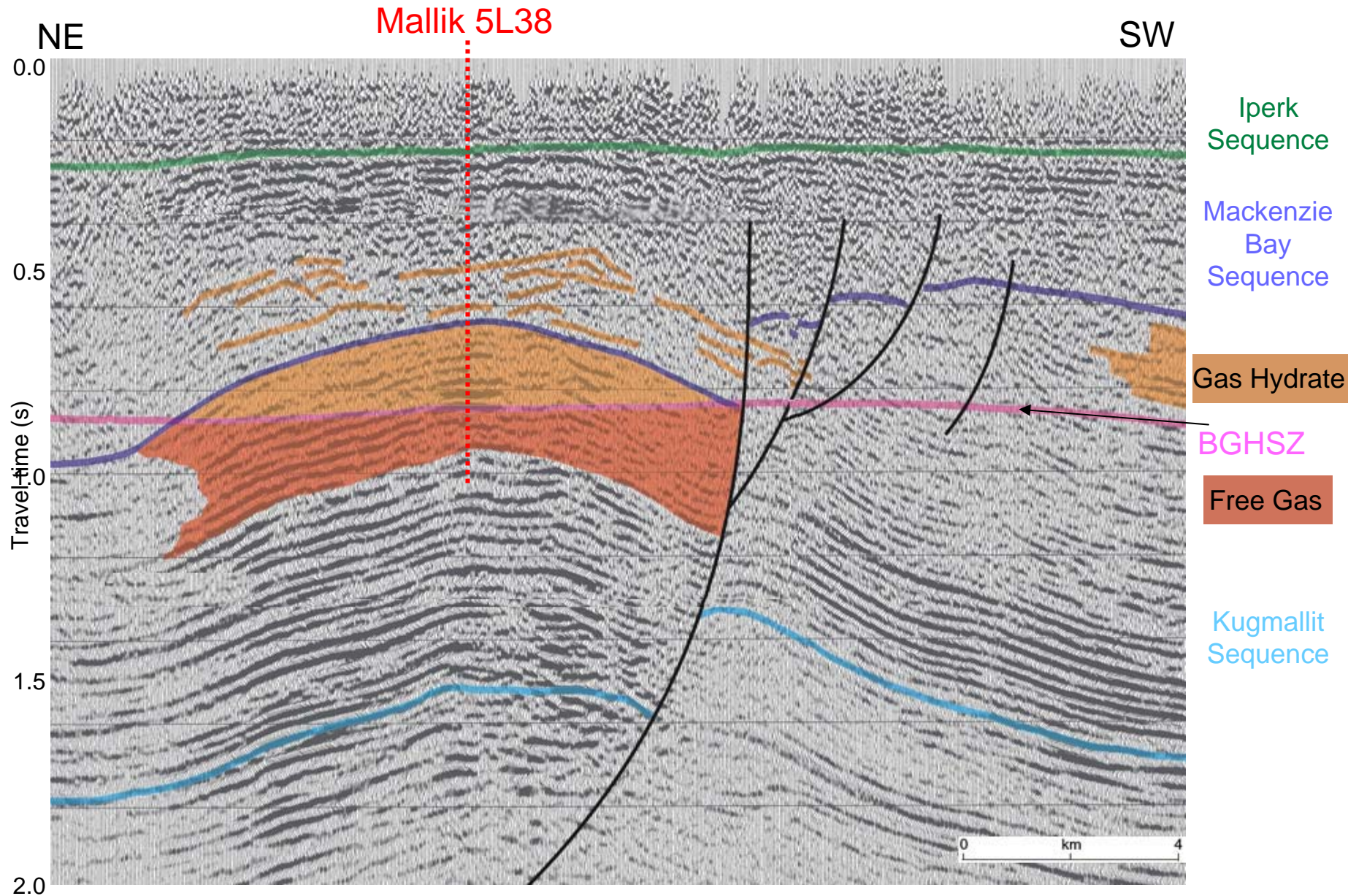


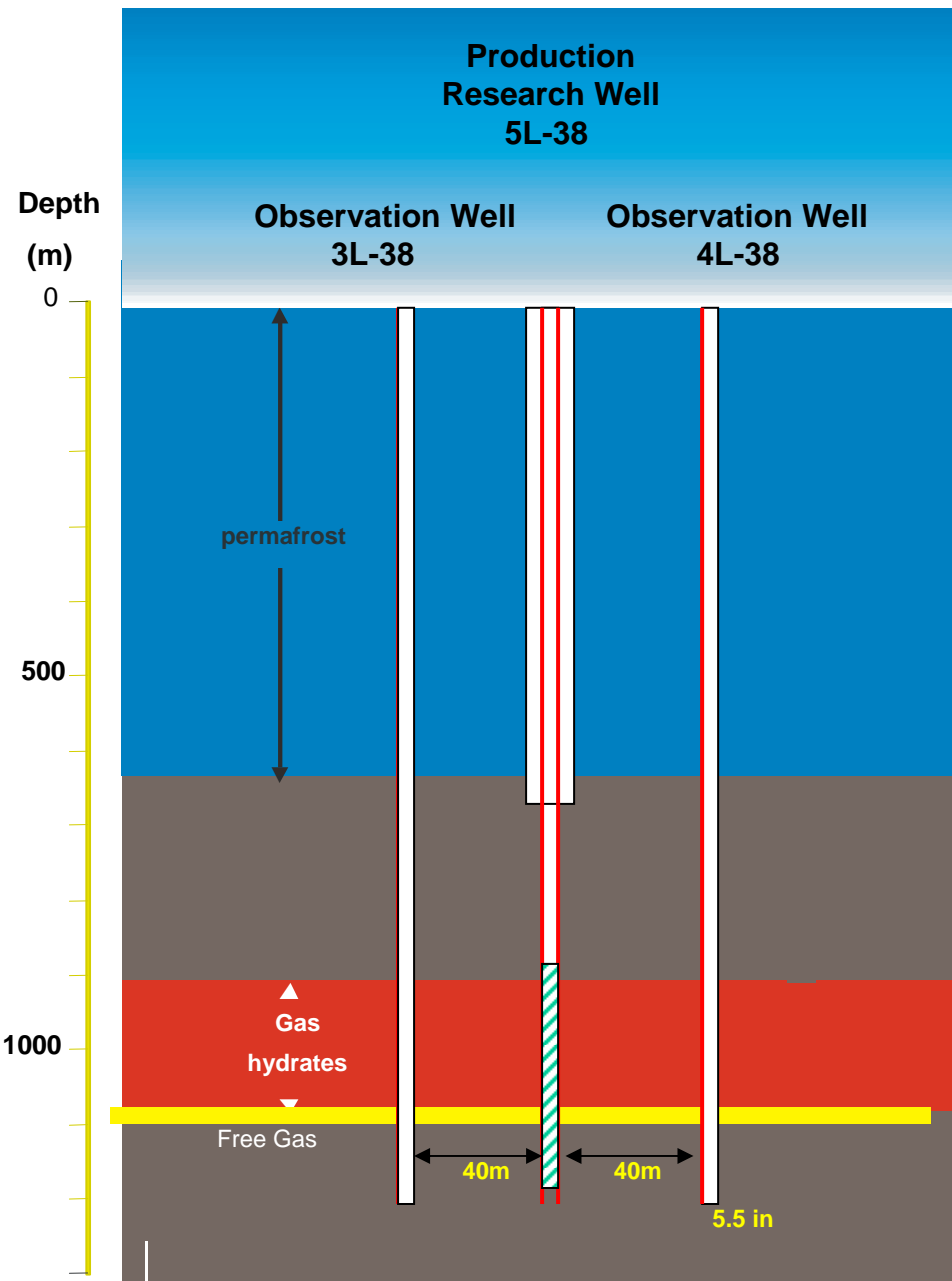
Mallik 2002 Gas Hydrate Production Test Well

- Japan
 - JNOC/JOGMEC (METI)
 - JNOC collaborators
- Canada
 - GSC
 - BP/Chevron/Burlington
 - (Japex Canada, Imperial Oil)
- USA
 - USGS
 - USDOE
- Germany
 - GeoForschungsZentrum Potsdam
- India
 - National Gas Hydrate Program (NGHP), with DGH, MOP&NG, ONGC, and GAIL
- International Continental Scientific Drilling Program
 - Universities and research institutes in Japan, Canada, USA, Germany and China



Mallik 5L-38 Geological Setting





Three well concept enabled a diverse and flexible program

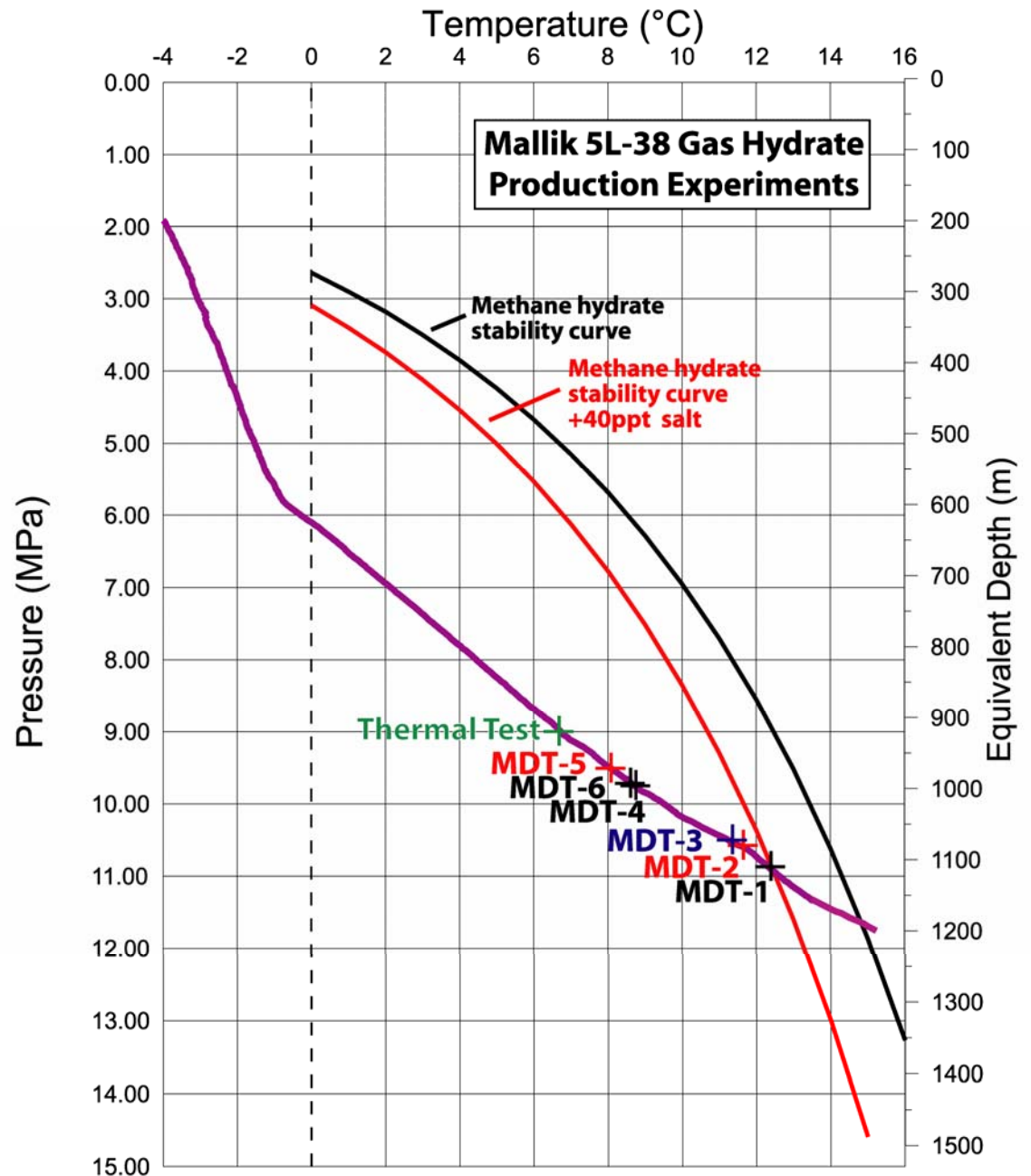
- Controlled production experiments, with real time formation monitoring
- Access for experimental logging and cross hole geophysics
- Integrated permafrost and gas hydrate research program

Mallik-2002 Production Testing and Modeling

PROJECT ACCOMPLISHMENTS:

- Tested the response of a in-situ natural gas hydrate occurrence to changes in pressure and temperature conditions.
- Produced gas from gas hydrate by thermal stimulation and reservoir depressurization.
- Production test results, combined with other project data, have provided the scientific and engineering data set needed to develop and calibrate gas hydrate production simulators.
- Calibrated Mallik specific gas hydrate production simulations.
- Used calibrated simulators to project the results of the Mallik 5L-38 gas hydrate thermal production test beyond the duration and conditions of the actual test.

Mallik 5L-38 gas hydrate thermal stimulation & reservoir depressurization production experiments

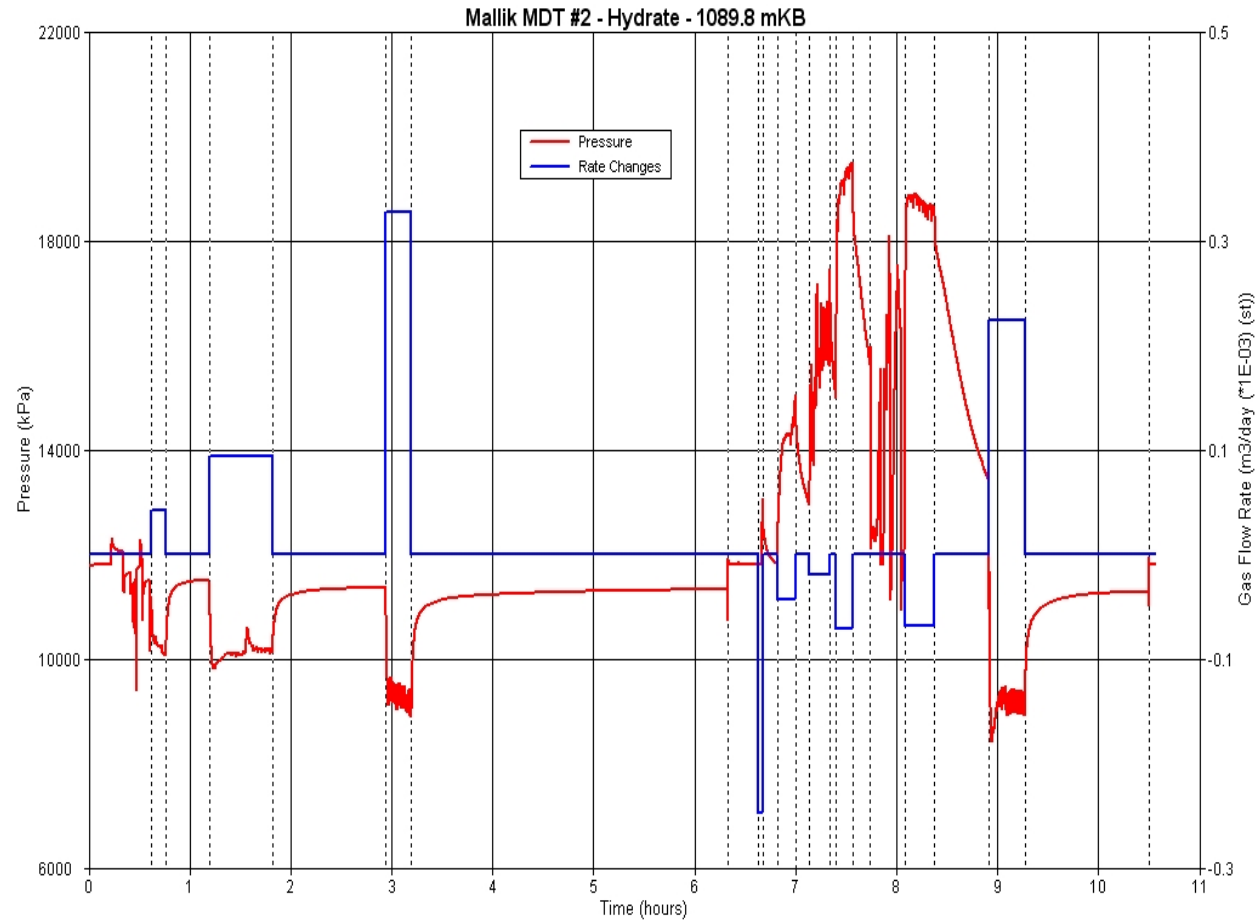


Mallik 5L-38 MDT

Pressure Transient Analyses

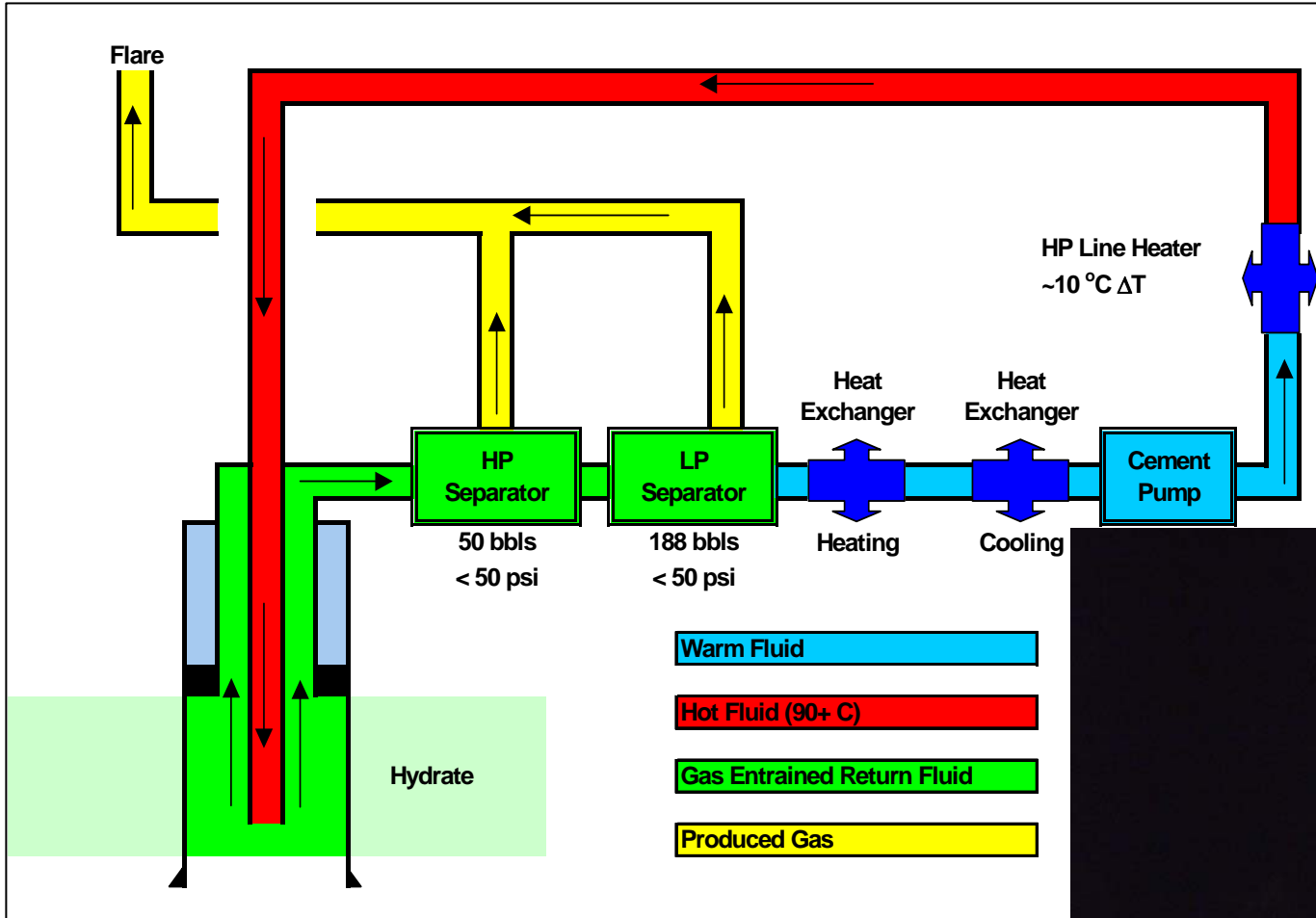
MDT #2

- 3 flow & shut-in sequences
 - 8/25 min.
 - 37/69 min.
 - 16/190 min.
- 3 fracture sequences
- 1 final flow and shut in sequence
 - 21/76 min.

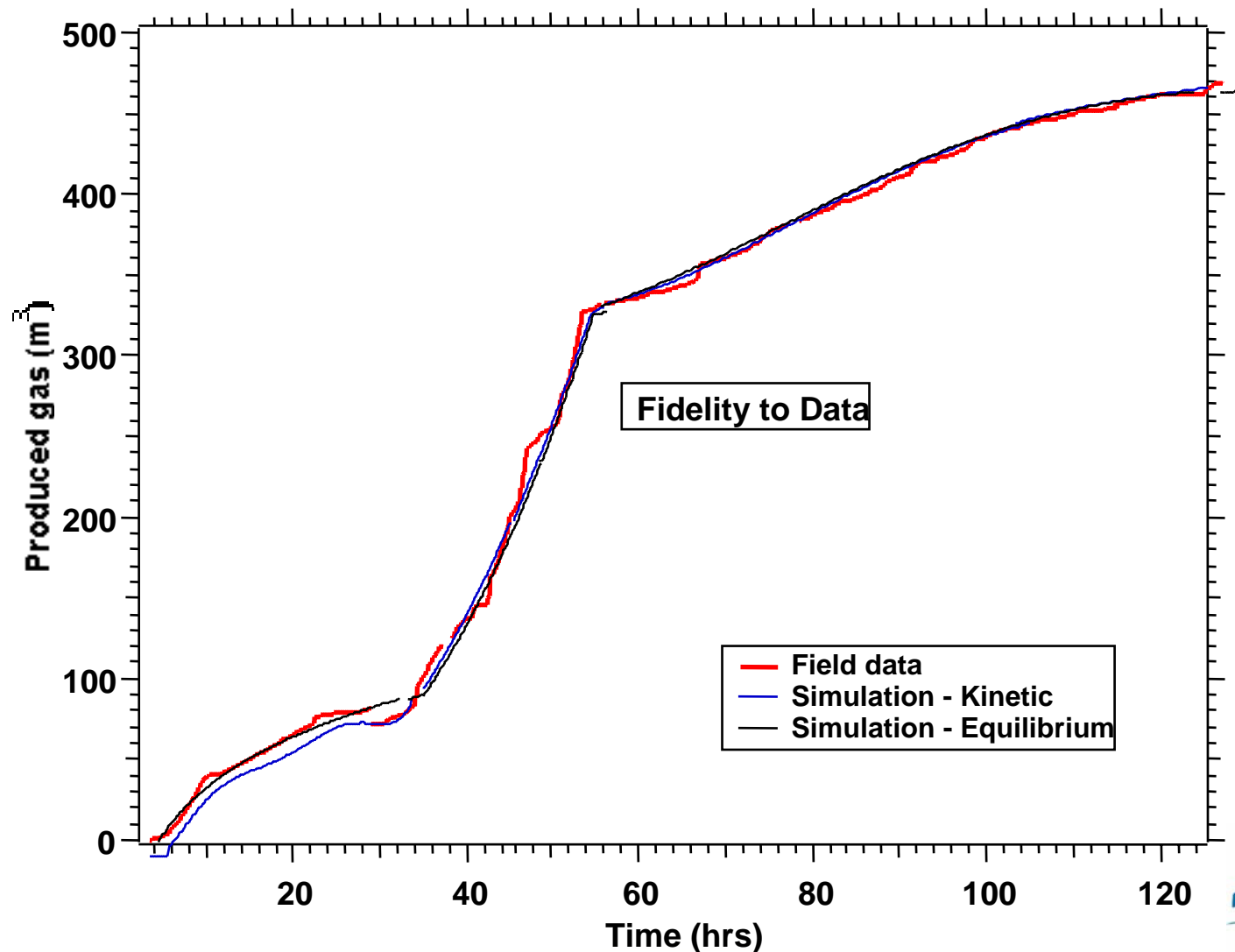


Production Testing

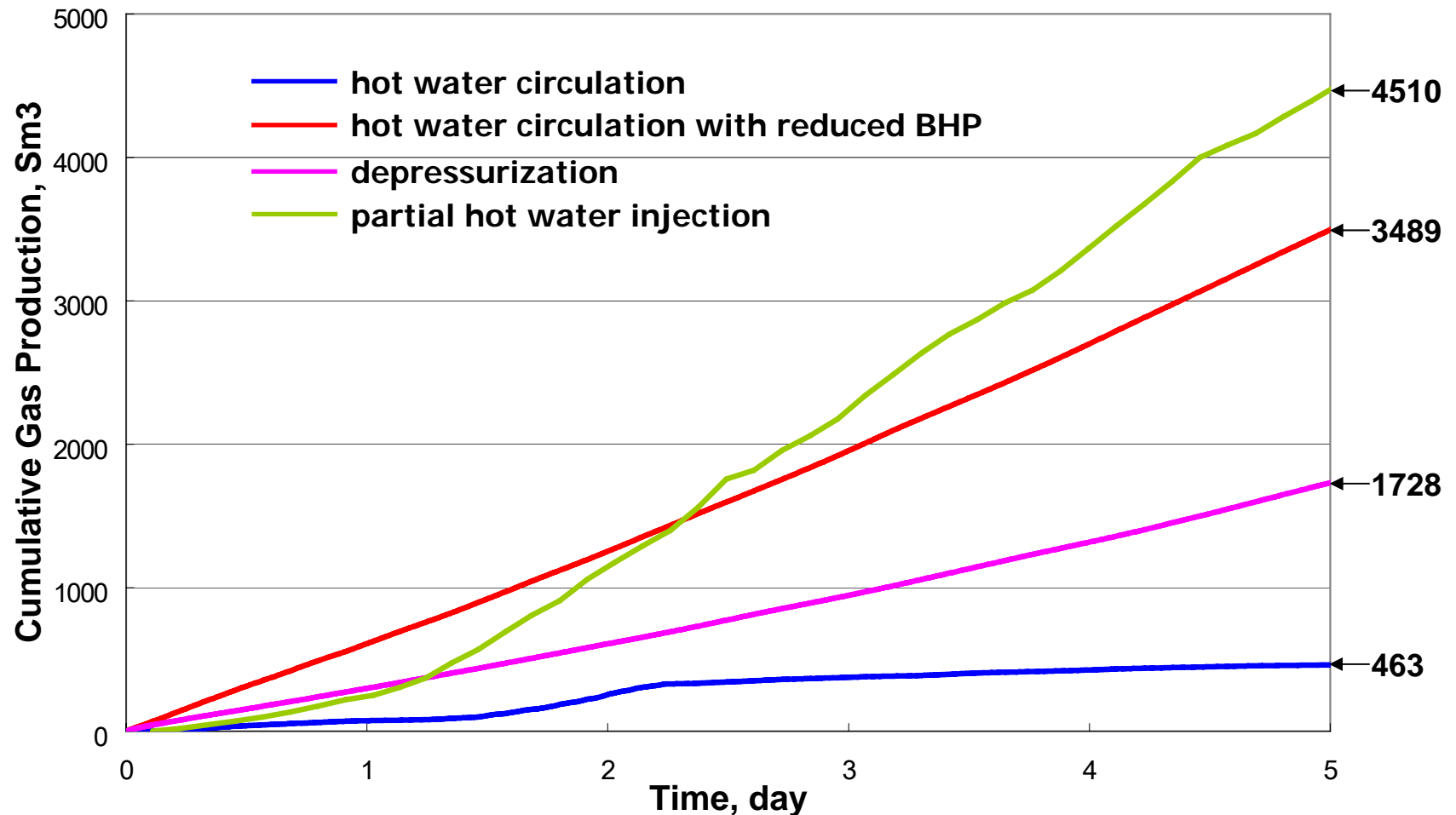
Thermal Stimulation Production Testing



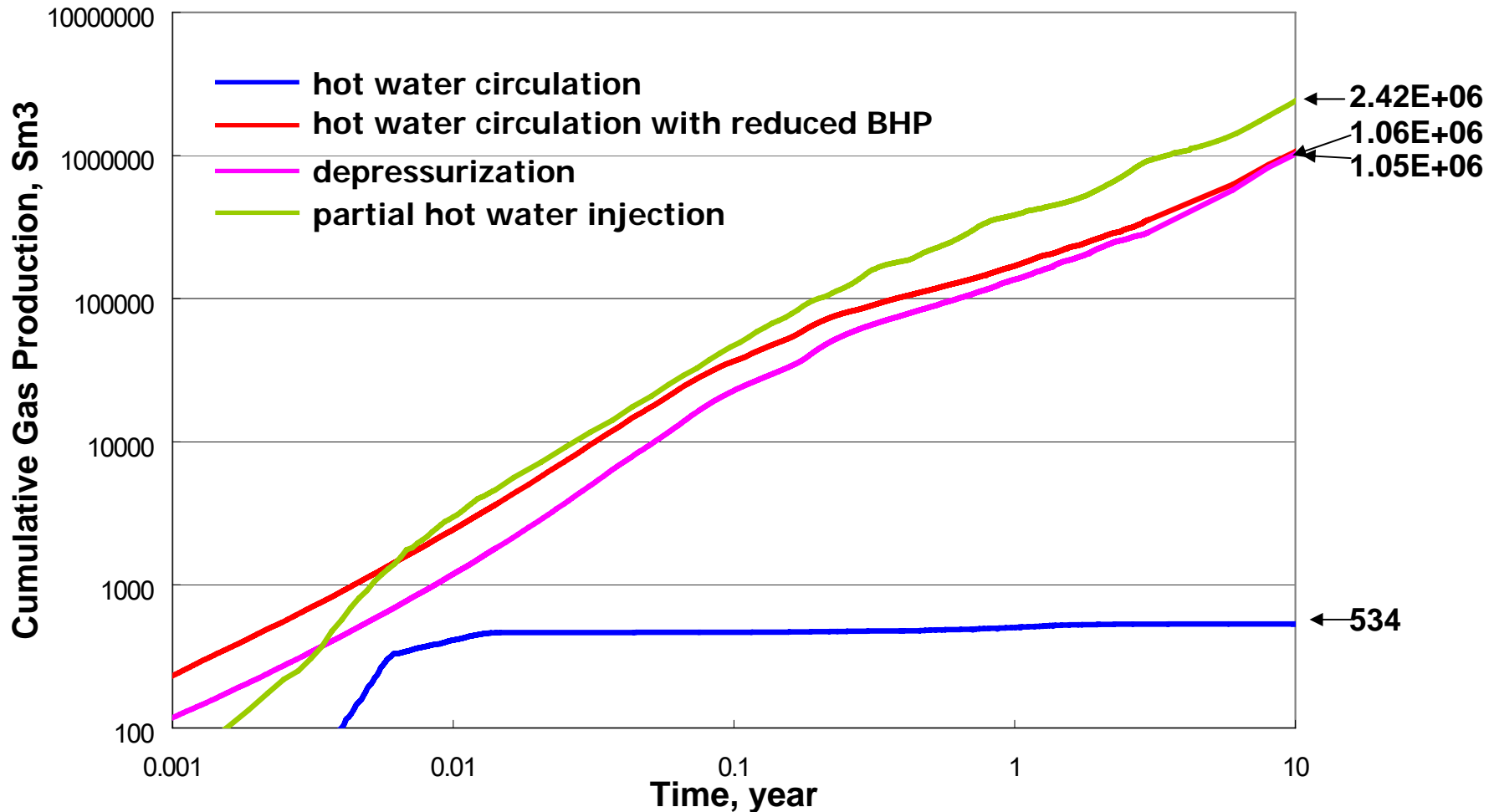
Thermal Test Cumulative Gas Production



Cumulative Gas Production - 5 days

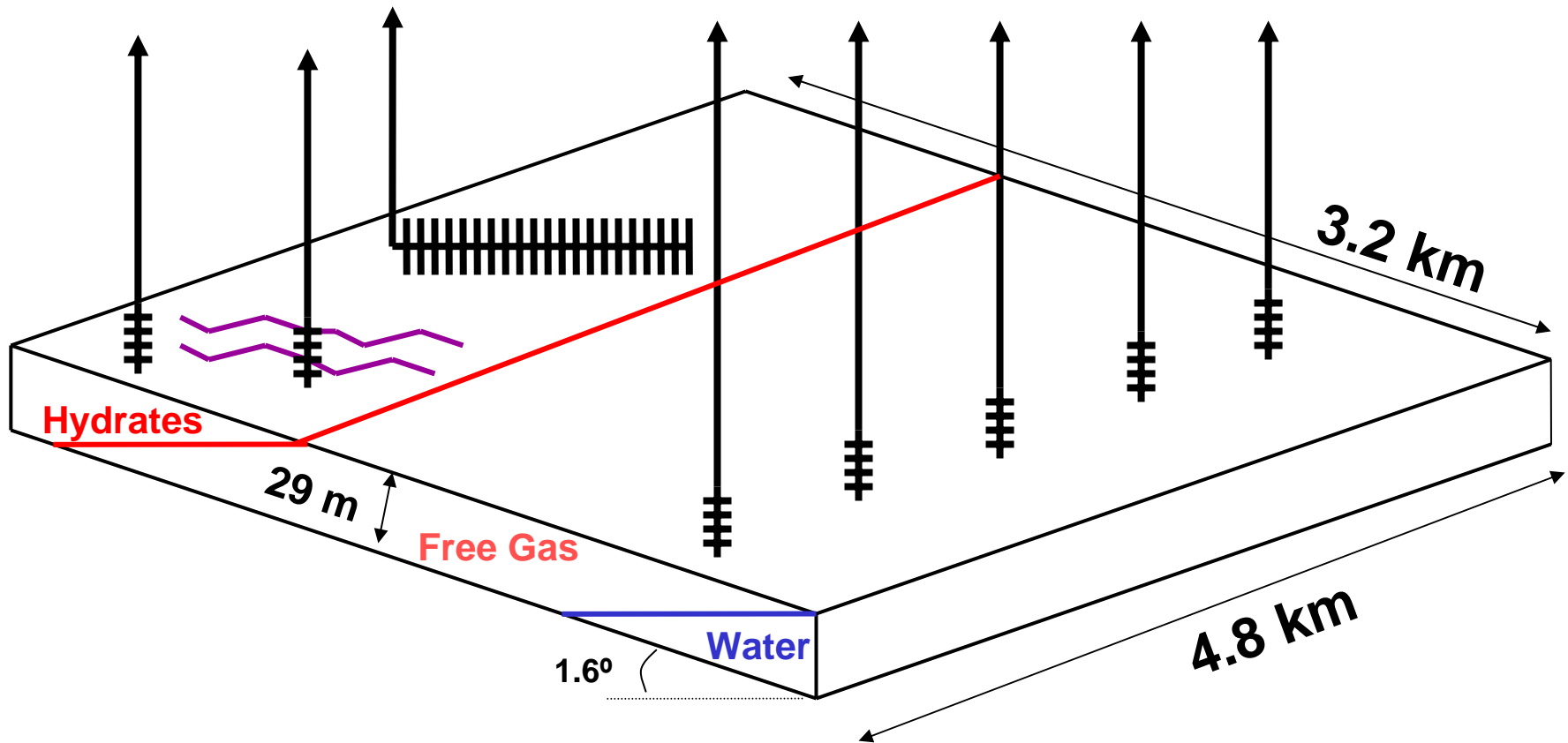


Cumulative Gas Production - 10 Years



Japan Oil Engineering Co., Ltd.

Hydrate Production - "Surface Area"



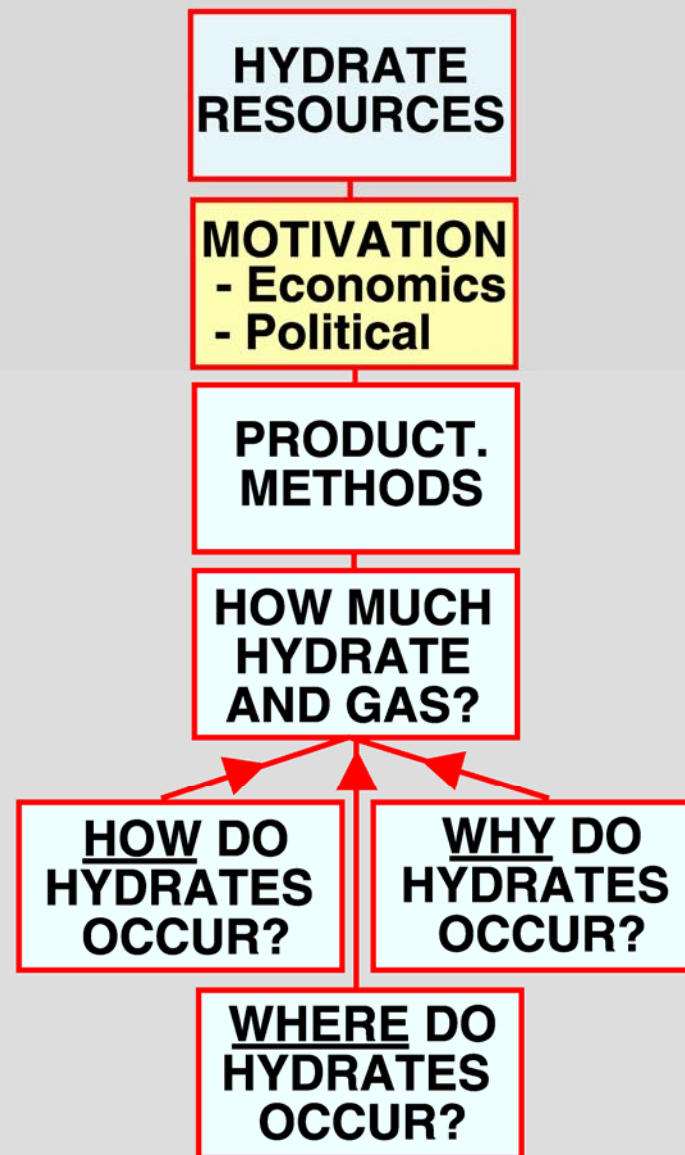
Vertical well penetration (29m) - 10 m^2

Horizontal well penetration (300m) - 105 m^2

Stratigraphic contact (3.2x4.8km) - $5,000,000 \text{ m}^2$

Gas hydrate energy resource flow chart

- Evolution from a nonproducing unconventional gas resource to a producible energy resource



ECONOMIC STUDY OF HYDRATE PRODUCTION*

	Thermal injection	Depres- surization	Conventional gas
Investment (M US\$)	5,084	3,320	3,150
Annual cost (M US\$)	3,200	2,510	2,000
Total production (MMcf/year)**	900	1,100	1,100
Production cost (US\$/Mcf)	3.60	2.28	1.82
Break-even wellhead price (US\$/Mcf)	4.50	2.85	2.25

* Assumed reservoir properties: $h=25\text{ft}$, $\phi=40\%$, $k=600\text{md}$

** Assumed process: injection of 30,000 b/d of water at 300 F

UNIQUE MOTIVATIONS LEADING TO GAS HYDRATE PRODUCTION

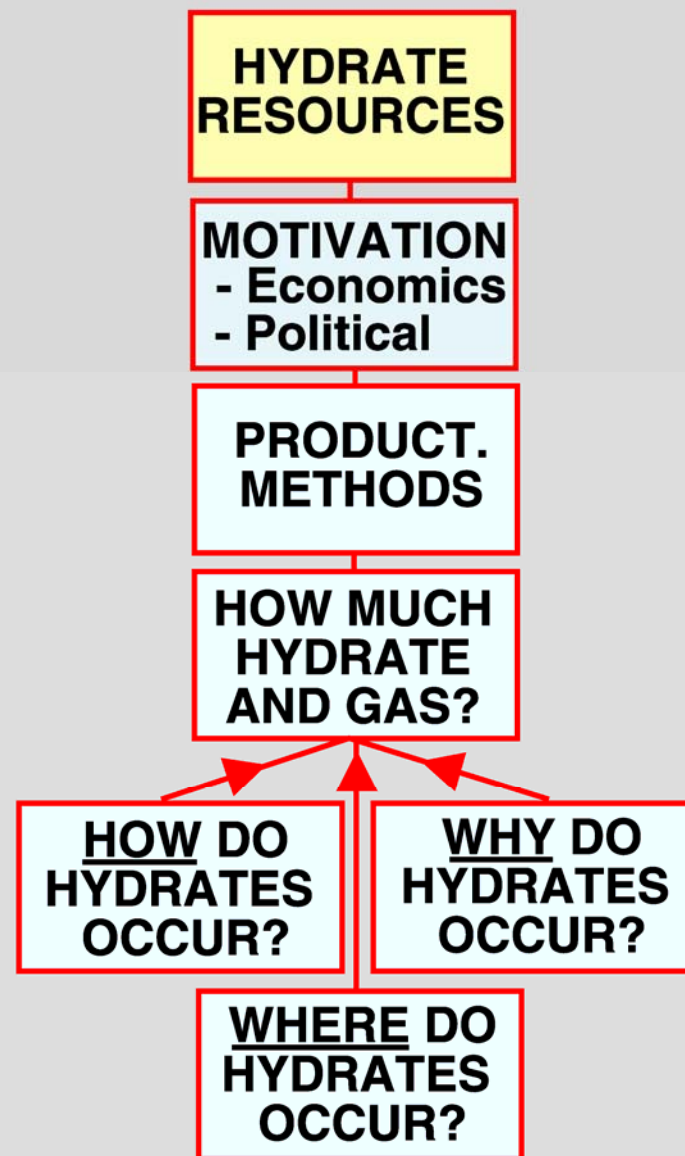
- Industry uses of natural gas in northern Alaska:
 - Generate electricity for field operations
 - Miscible gas floods
 - Gas lift in producing oil wells
 - Reinjection to maintain reservoir pressures
 - Steam generation for EOR projects
 - ?

ALASKA GAS EXPORT



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GAS HYDRATE PROJECTS IN NORTHERN ALASKA

- **USDOE/BPXA/U-ARZ/UAF/USGS:** Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations Prudhoe Bay - Kuparuk River Area, North Slope of Alaska
- **USDOE/Maurer/Anadarko/et al:** Methane Hydrate Production from Alaskan Permafrost
- **BLM/USGS/DOG-DGGS:** Alaska North Slope Gas Hydrate Assessment
- **MMS:** EEZ National Marine Gas Hydrate Assessment

Resource Characterization and Quantification of Natural Gas-Hydrate and Associated Free-Gas Accumulations Prudhoe Bay - Kuparuk River Area, North Slope of Alaska

US Department of Energy, BP Exploration (Alaska) Inc.,
University of Arizona, University of Alaska, US Geological Survey

-Project Mission-

Characterize, quantify, & determine commerciality of gas hydrate & associated free gas resources in arctic regions through integrated academic, industry, & government collaborative research to promote safe, low cost, & environmentally responsible production of abundant, strategic, & secure energy resources.



➔ FREE GAS

Eileen Accumulation

GAS HYDRATE

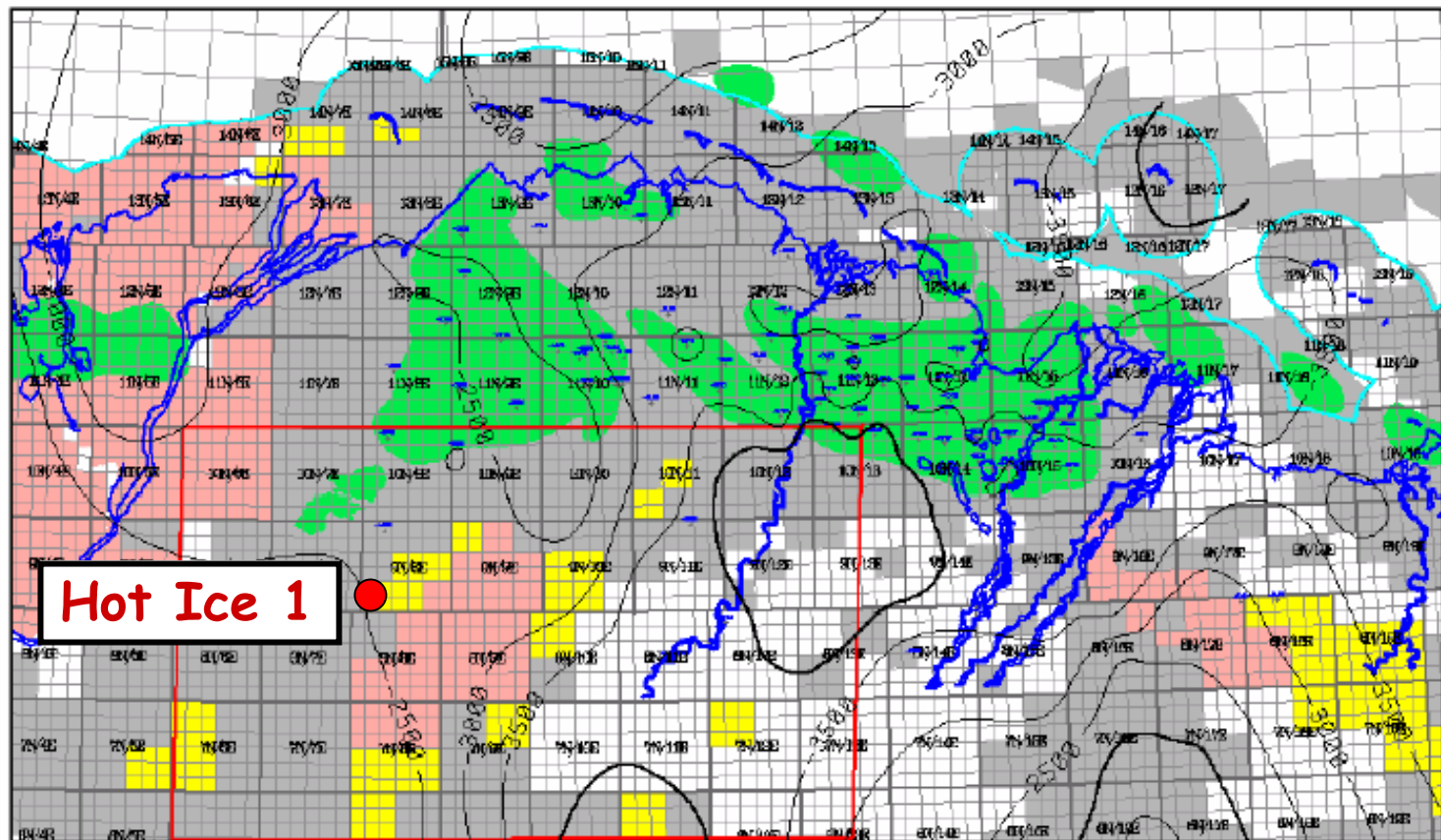
Methane Hydrate Production from Alaskan Permafrost

US Department of Energy, Maurer Technology Incorporated,
Anadarko Petroleum Corporation, Noble Engineering and
Development, University of Alaska, University of Oklahoma

-Project Objective-

The objective of this project is to analyze existing geological and geophysical data and obtain new field data required to predict hydrate occurrences; to test the best methods and tools for drilling and recovering hydrates; and to plan, design, and implement a program to safely and economically drill and produce gas from hydrates.

Base of Hydrate Stability Zone



Hot Ice 1



ANADARKO PETROLEUM CORP
NORTH NORTH DAKOTA

BASE OF HYDRATE STABILITY ZONE
C. J. = 500 FT

CONTOURS ARE SUBSEA DEPTHS

— 808 —

Evaluation of Alaska North Slope Gas Hydrates

US Bureau of Land Management, US Geological Survey, State of
Alaska Division of Geological and Geophysical Surveys

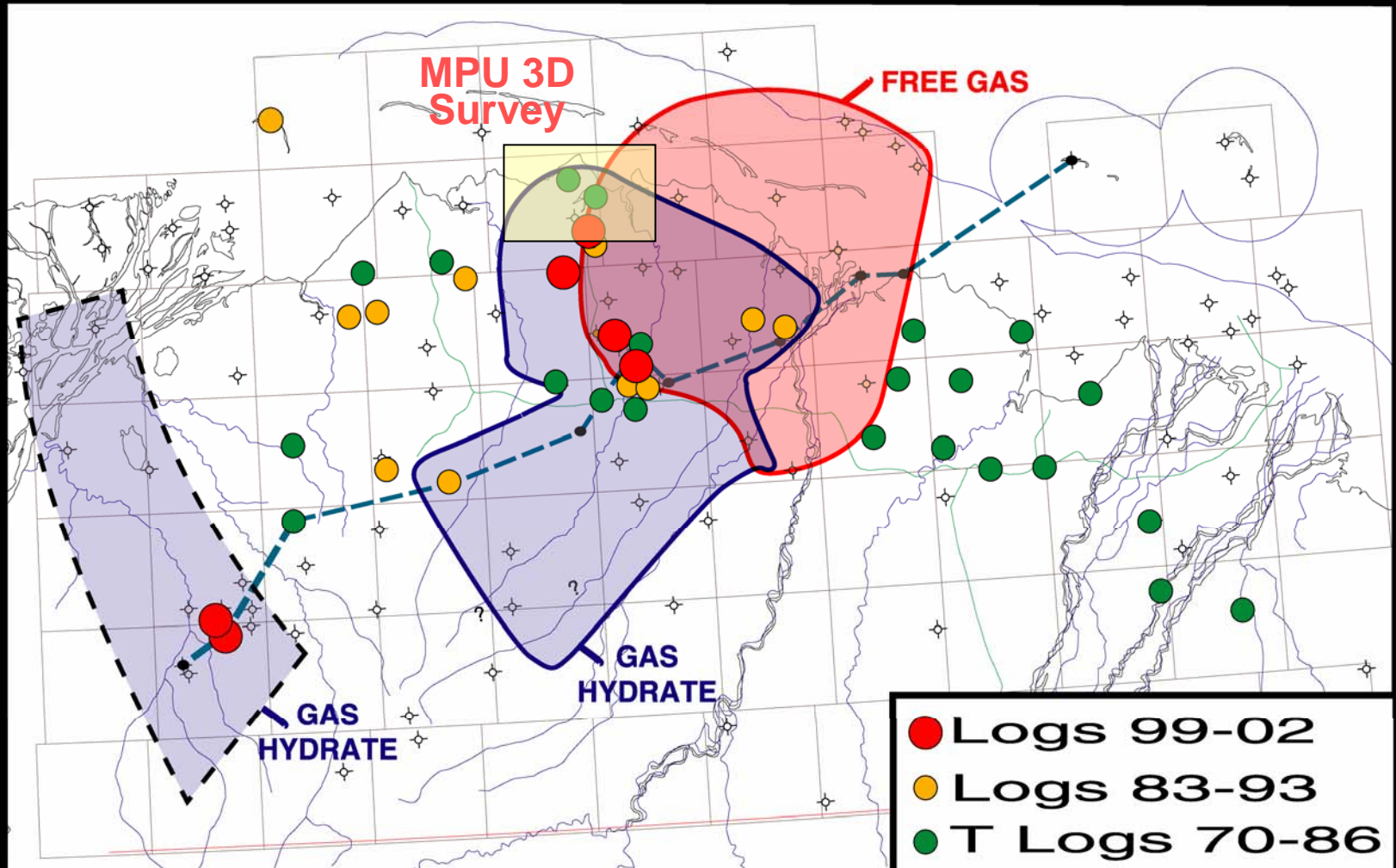
-Project Work Plan-

Phase-I. Assess existing geologic, geophysical, and engineering data to characterize the resource potential of the Eileen and Tarn gas-hydrate/free-gas accumulations (FY 03-04).

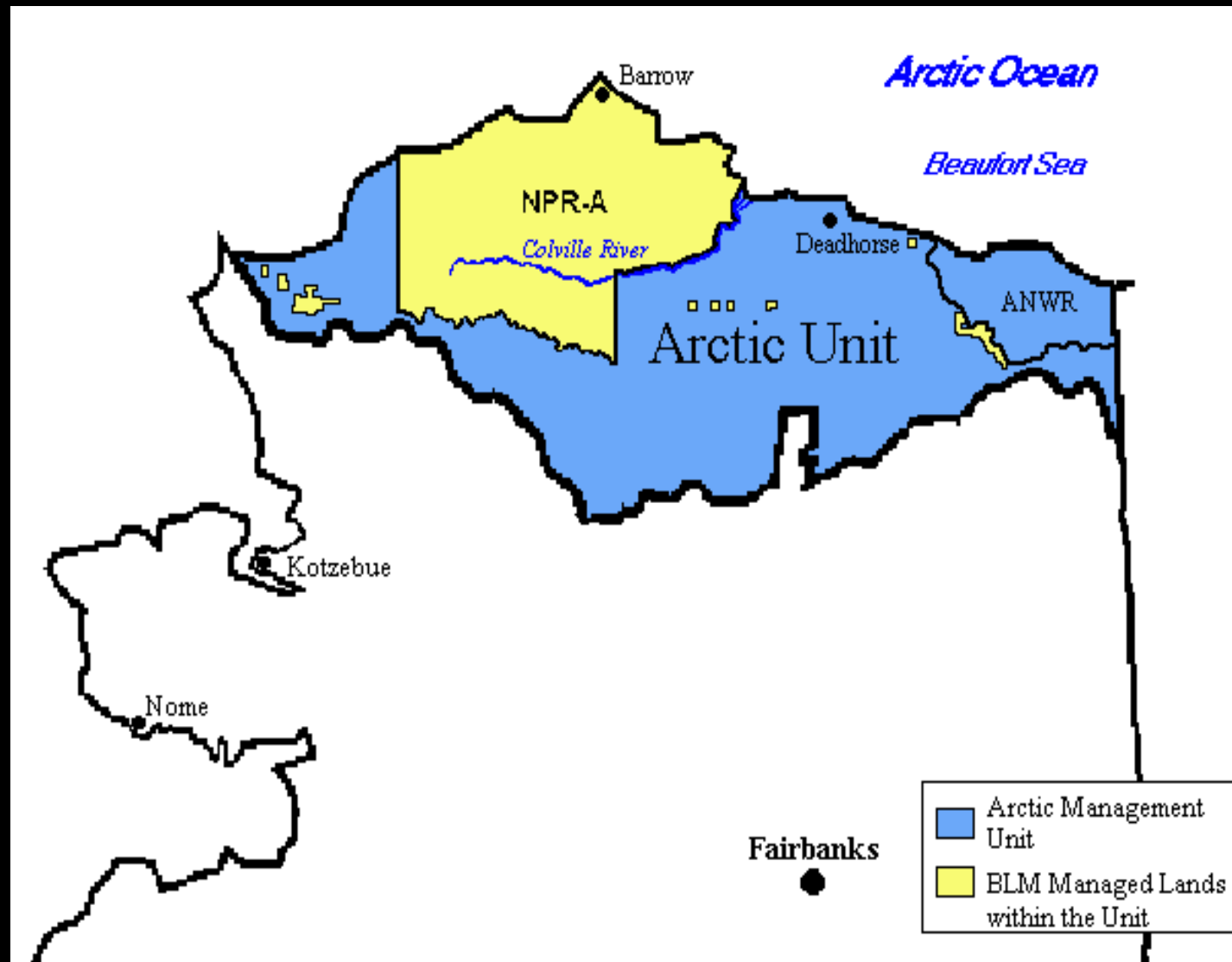
Phase-II. Assess existing geologic, geophysical, and engineering data to characterize the resource potential of the undiscovered gas hydrate accumulations in NPRA, ANWR, and the State lands between the Canning and Colville Rivers (FY 05-06).

Phase-III. Conduct an assessment of the economically recoverable resource potential of gas hydrates and associated free-gas accumulations in northern Alaska (FY 07).

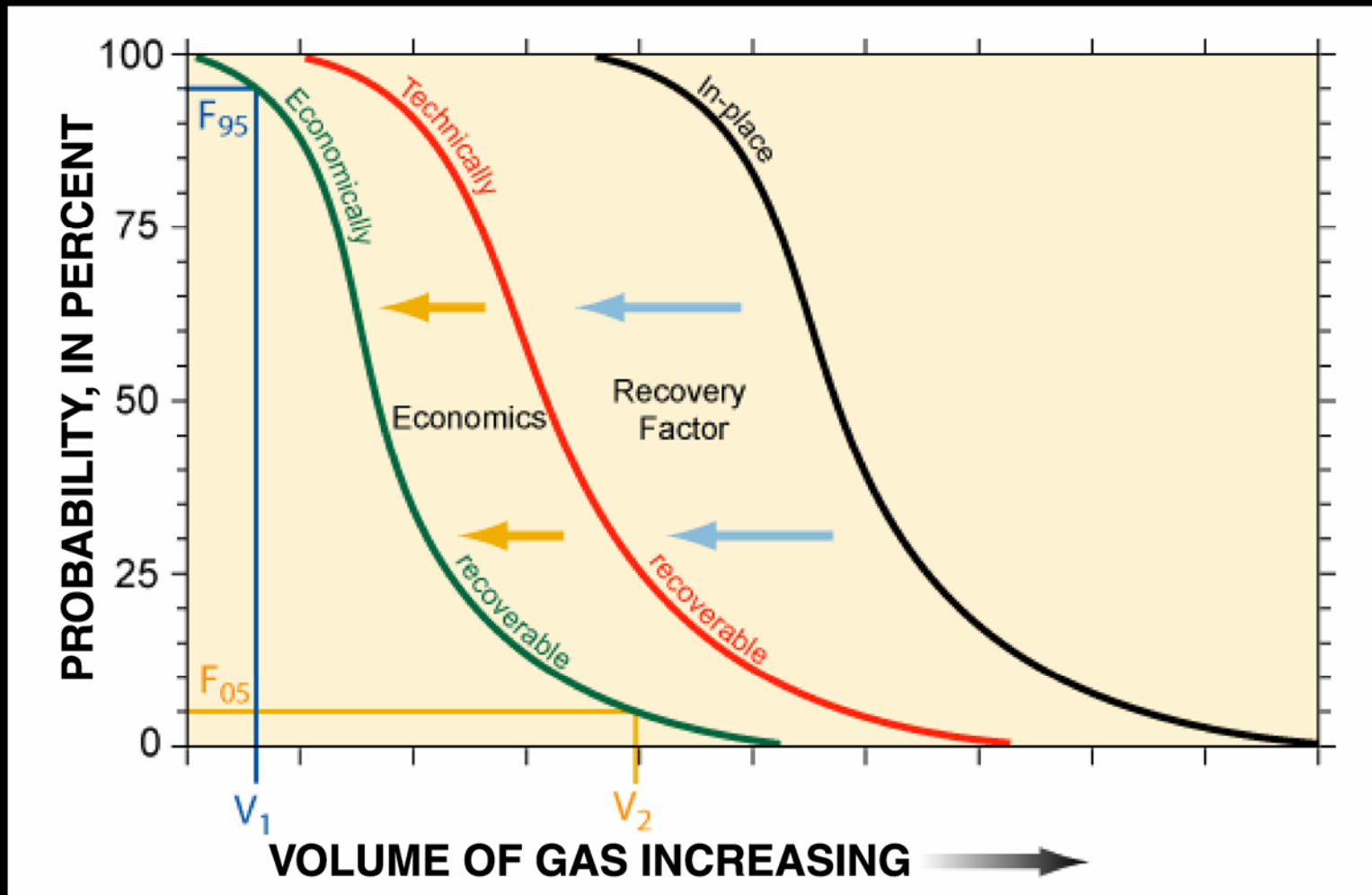
Phase-I. Eileen and Tarn Hydrate Accumulations



Phase-II. Hydrates in NPRA, ANWR, and State Lands



Phase-III. Hydrate Resource Assessment *"Economically Recoverable Assessment"*



EEZ National Marine Gas Hydrate Assessment

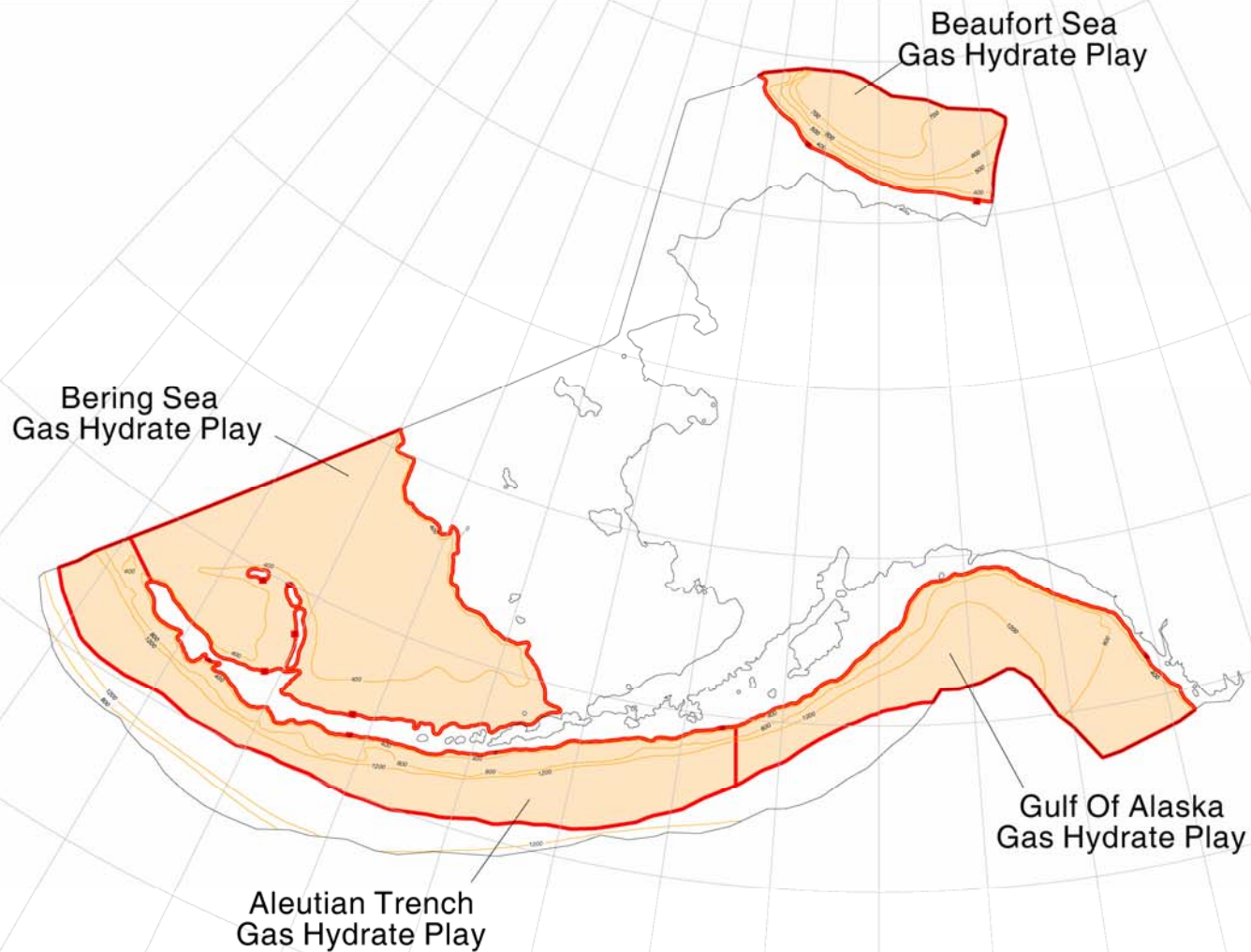
Minerals Management Service

-Project Work Plan-

Phase-I. In-place natural gas hydrate volumes include all hydrate bounded methane molecules within an area, defined here as the offshore US Economic Exclusion Zone (EEZ).

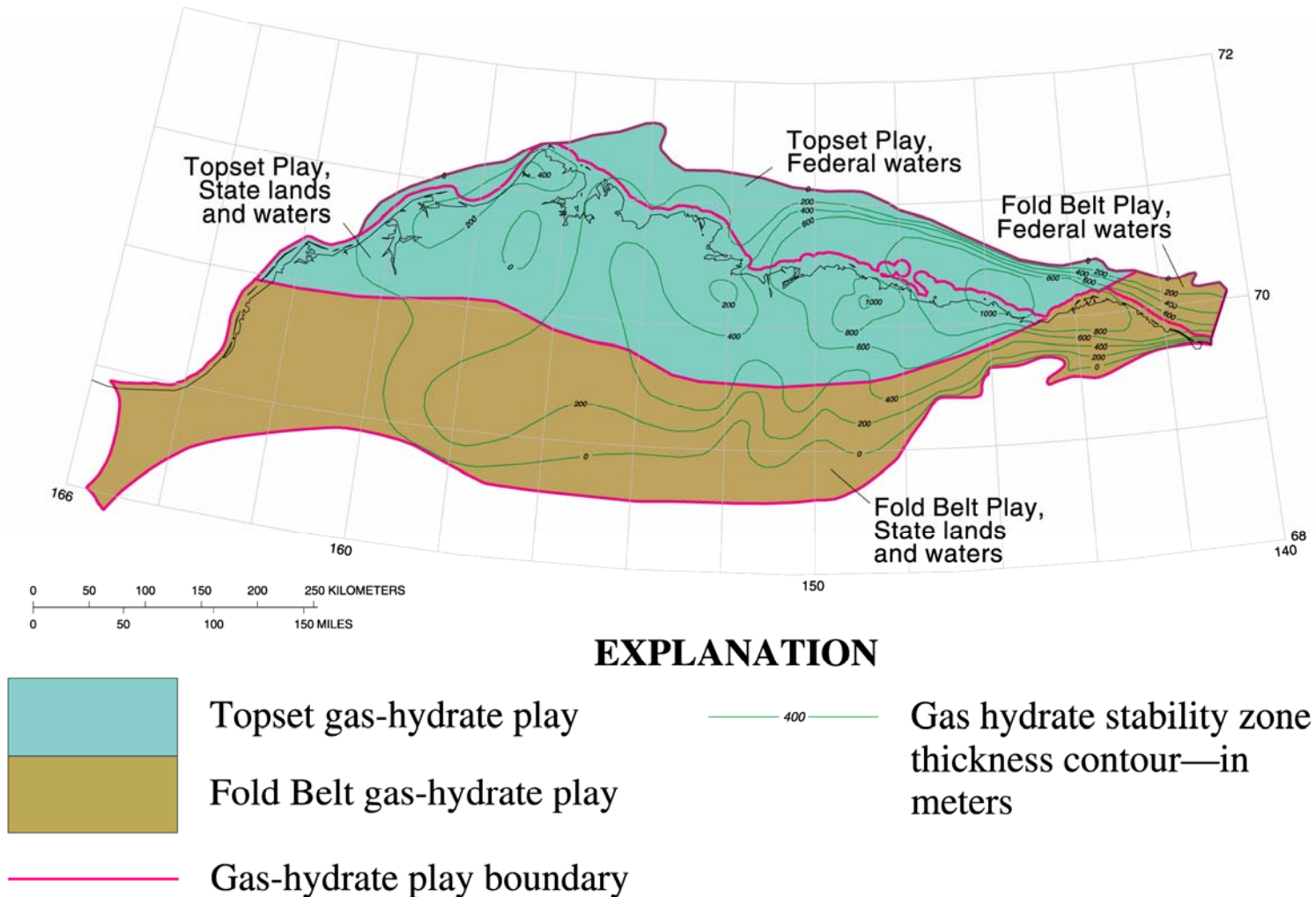
Phase-II. Technically recoverable natural gas hydrate resources form a subset of in-place volumes.

MAP OF THE BEAUFORT SEA, BERING SEA, ALEUTIAN TRENCH, AND GULF OF ALASKA GAS HYDRATE PLAYS



1995 USGS Hydrate Resource Assessment

MAP OF THE ALASKA GAS HYDRATE PLAYS



Summary

- The occurrence of the Eileen and Tarn gas hydrate accumulations have confirmed that gas hydrates may represent an important energy resource for the future.
- The occurrence of gas hydrates in a definable petroleum system provides us with a gas hydrate exploration model.
- Significant technical issues need to be resolved before gas hydrates can be considered a viable energy resource option.