# USGS Energy Resources Program

## Alaska North Slope Gas Hydrate Research and Resource Assessments

*Results of 2018 Assessment of Undiscovered Gas Hydrate Resources in the North Slope of Alaska*

**U.S. Geological Survey**
**Central Energy Resources Science Center**
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# USGS Gas Hydrates Project

## *Alaska North Slope Research and Assessment Efforts*

**Task 1.** Develop and test the production technology required to safely produce gas hydrates.

**Task 2.** Examine existing geologic, geophysical, and engineering data to characterize the resource potential of known and undiscovered gas hydrate accumulations in NPRA, ANWR, and the State lands between the Canning and Colville Rivers.

**Task 3.** Assess the technical recoverable resource potential of gas hydrate accumulations in northern Alaska:

- *2008 Geologic Assessment of Undiscovered Gas Hydrate Resources in the Alaska North Slope*
- *2018 Geologic Assessment of Undiscovered Gas Hydrate Resources in the Alaska North Slope*

# USGS Energy Resources Program

- The USGS assesses potential for undiscovered oil and gas resources in priority geologic provinces in the United States and the World
- Based on geology and geologic models
- Undiscovered, technically recoverable resource
  - Not economically recoverable resource estimates
  - Not in-place resource estimates
  - Not reserves

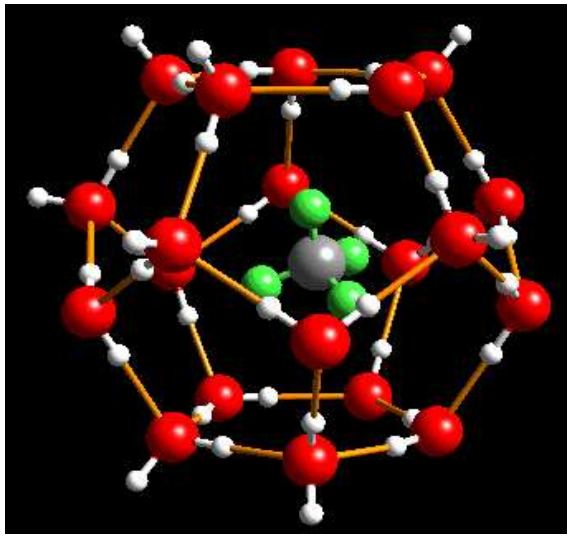
# 2018 USGS ANS Gas Hydrate Assessment

## *Briefing Outline*

1. What are Gas Hydrates ?
2. Assessment Methodology
3. Gas Hydrate Occurrences
4. Gas Hydrate Production
5. Gas Hydrate Assessment Units
6. Size of Undiscovered Accumulations
7. Number of Undiscovered Accumulations
8. Assessment Results

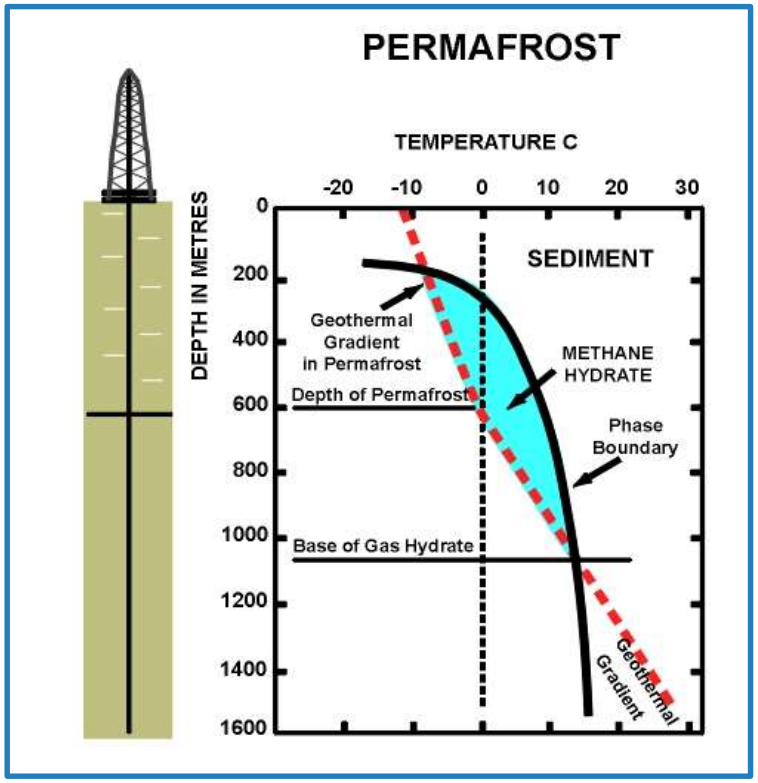
# What are Gas Hydrates ?

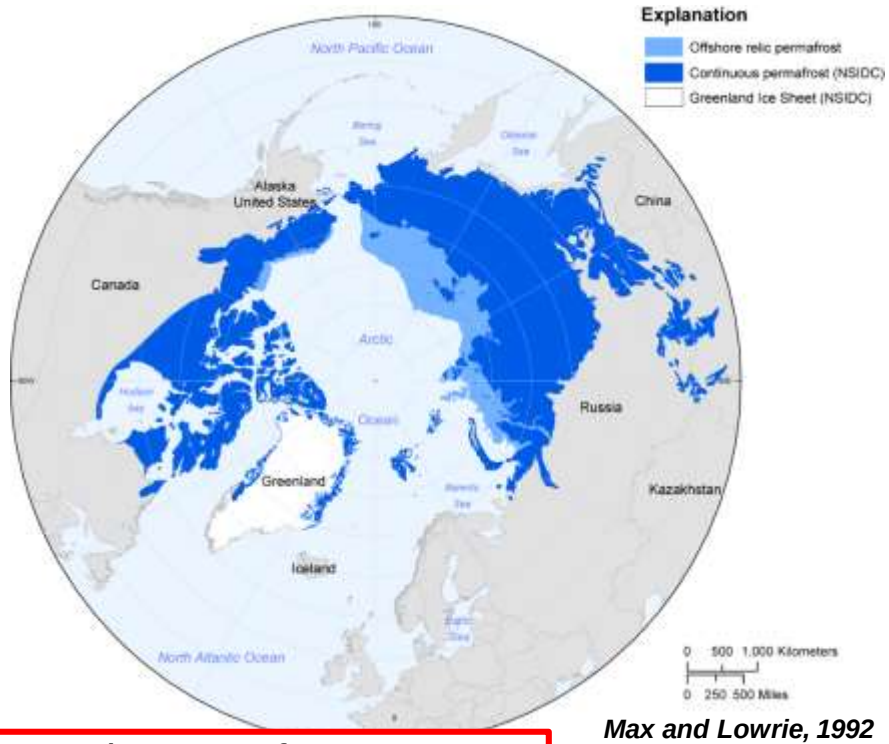
- **Crystalline solid consisting of gas molecules, usually methane, each surrounded by a cage of water molecules**
  - **One volume hydrate typically equivalent to 160-180 volumes methane gas**
- **Occur abundantly in nature, under a limited range of pressure and temperature conditions**
  - **Arctic regions:** Alaska North Slope, northern Canada, West Siberia, etc. (subsurface depths 300-4000 ft)
  - **Marine environments:** Gulf of Mexico, Atlantic and Pacific margins of the United States, Gulf of Alaska, Beaufort Sea, Bering Sea, etc. (all of the world oceans at water depths greater than 1,500 ft)




Arctic Gas Hydrate Stability Conditions (blue shading)

# Gas Hydrate Stability Conditions

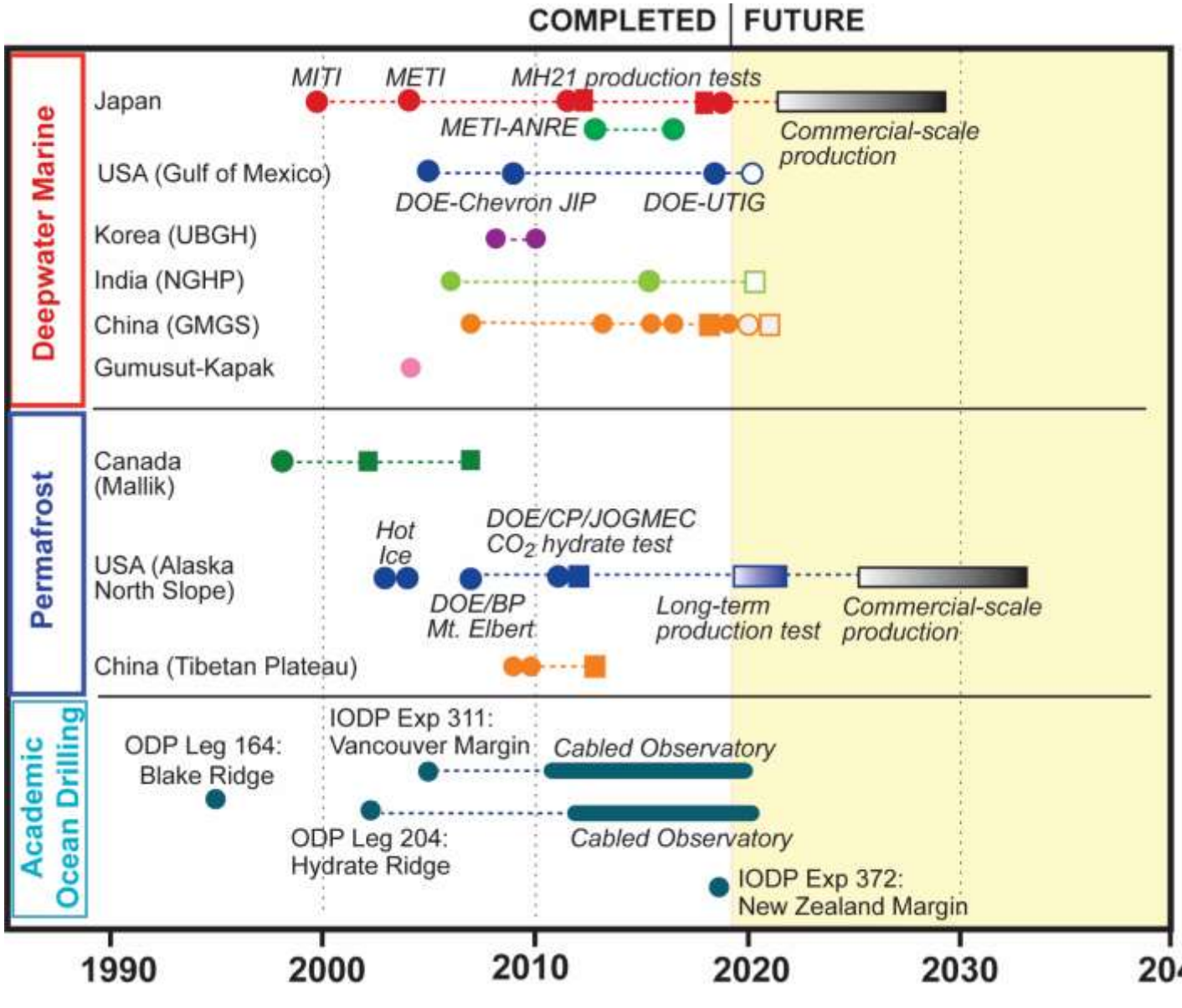



Arctic Permafrost Gas Hydrate Stability Conditions

*Max and Lowrie, 1992*
*Collett et al., 2009*

# Gas Hydrate Scientific and Industry Drilling

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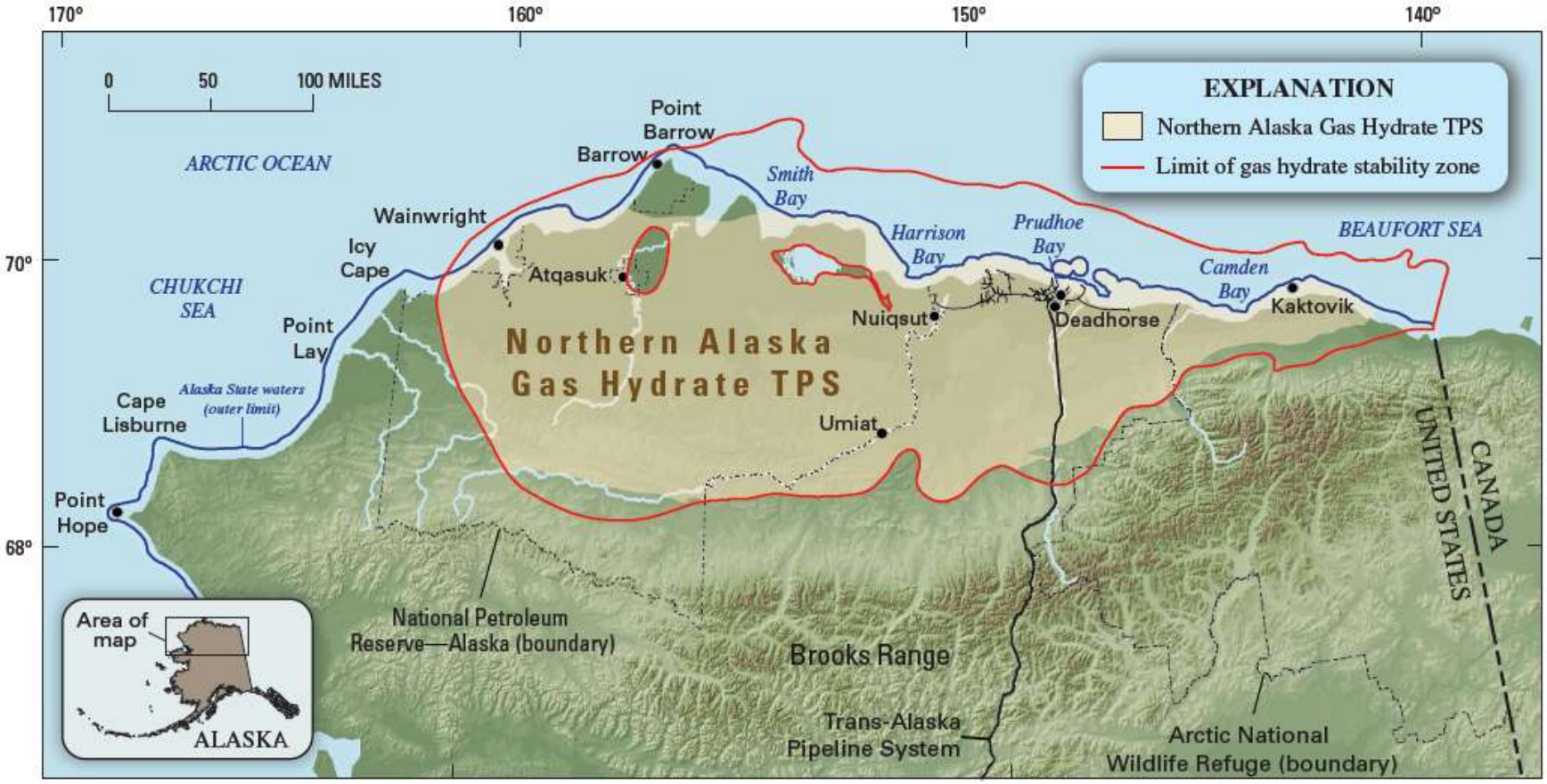
# Alaska North Slope

## *Gas Hydrate Geologic & Production Testing*




**1983-2019: USGS Alaska North Slope Gas Hydrate Project**

**2007: BPXA Mount Elbert Gas Hydrate Stratigraphic Test**

**2011-2012: ConocoPhillips $CO_2$ Displacement Test**

**2018-2023: Alaska North Slope Extended GH Production Test**

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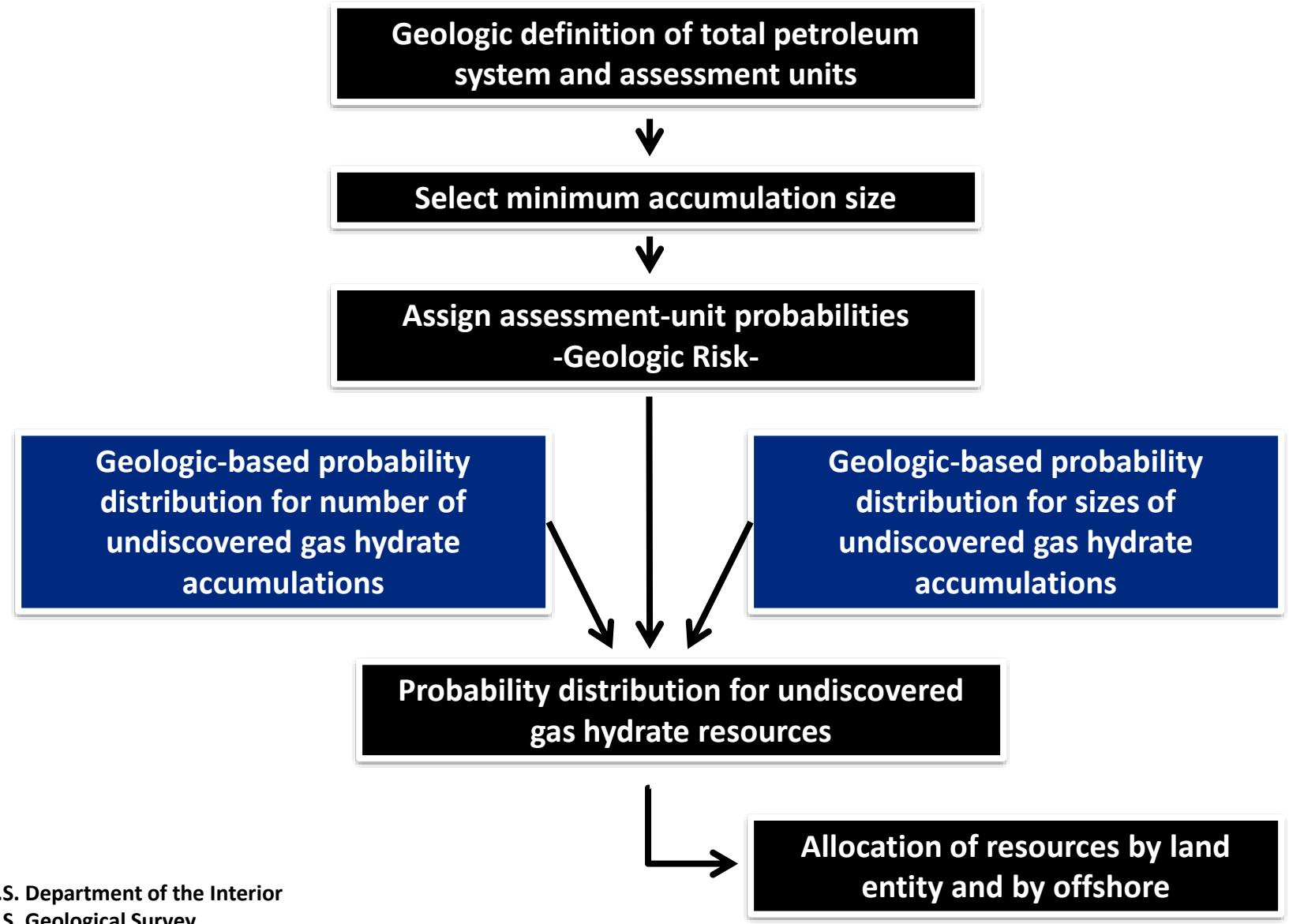
## *Assessment Methodology*



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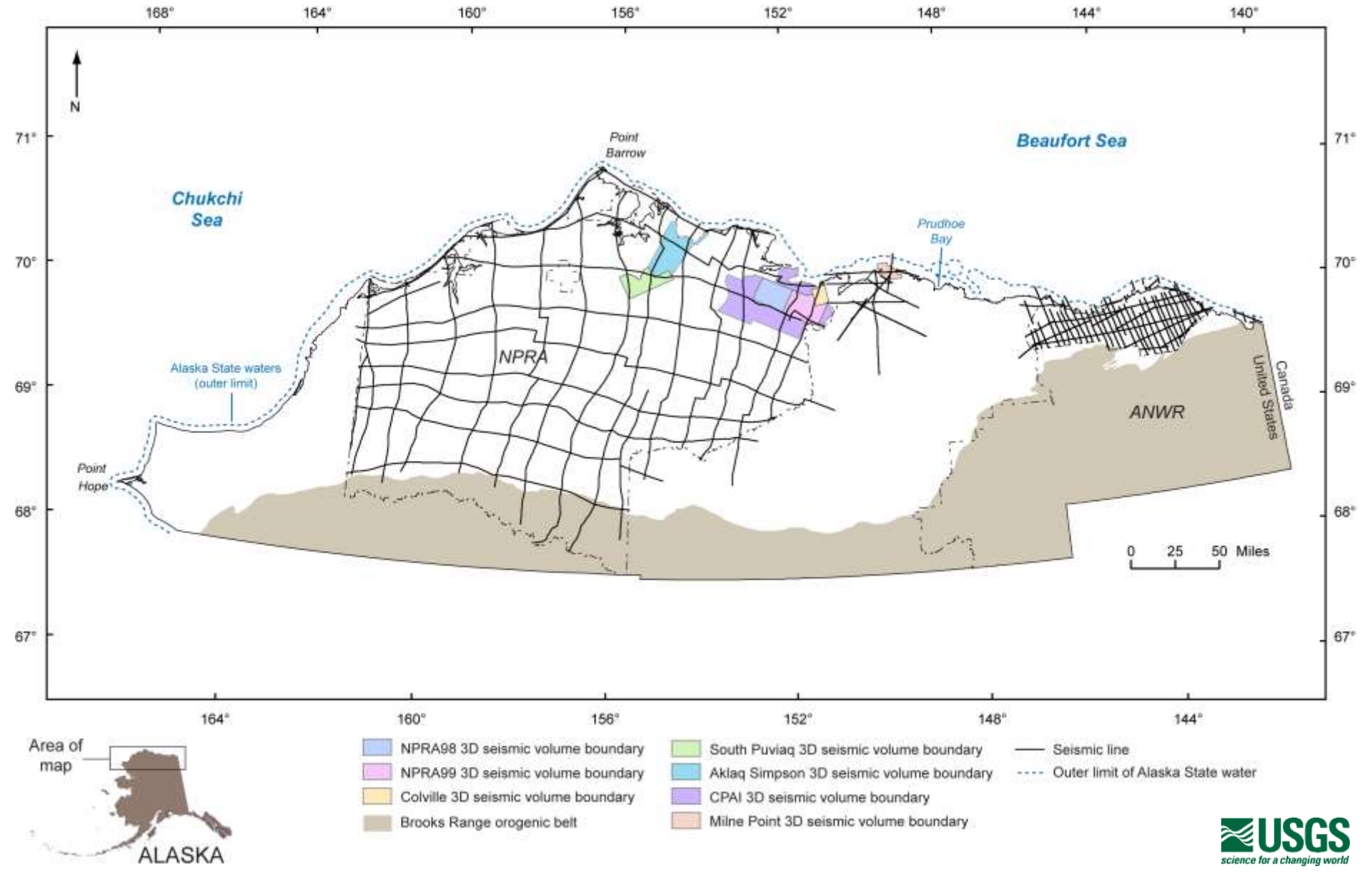
# Alaska North Slope Gas Hydrate Occurrence

## *Gas Hydrate Prospecting*

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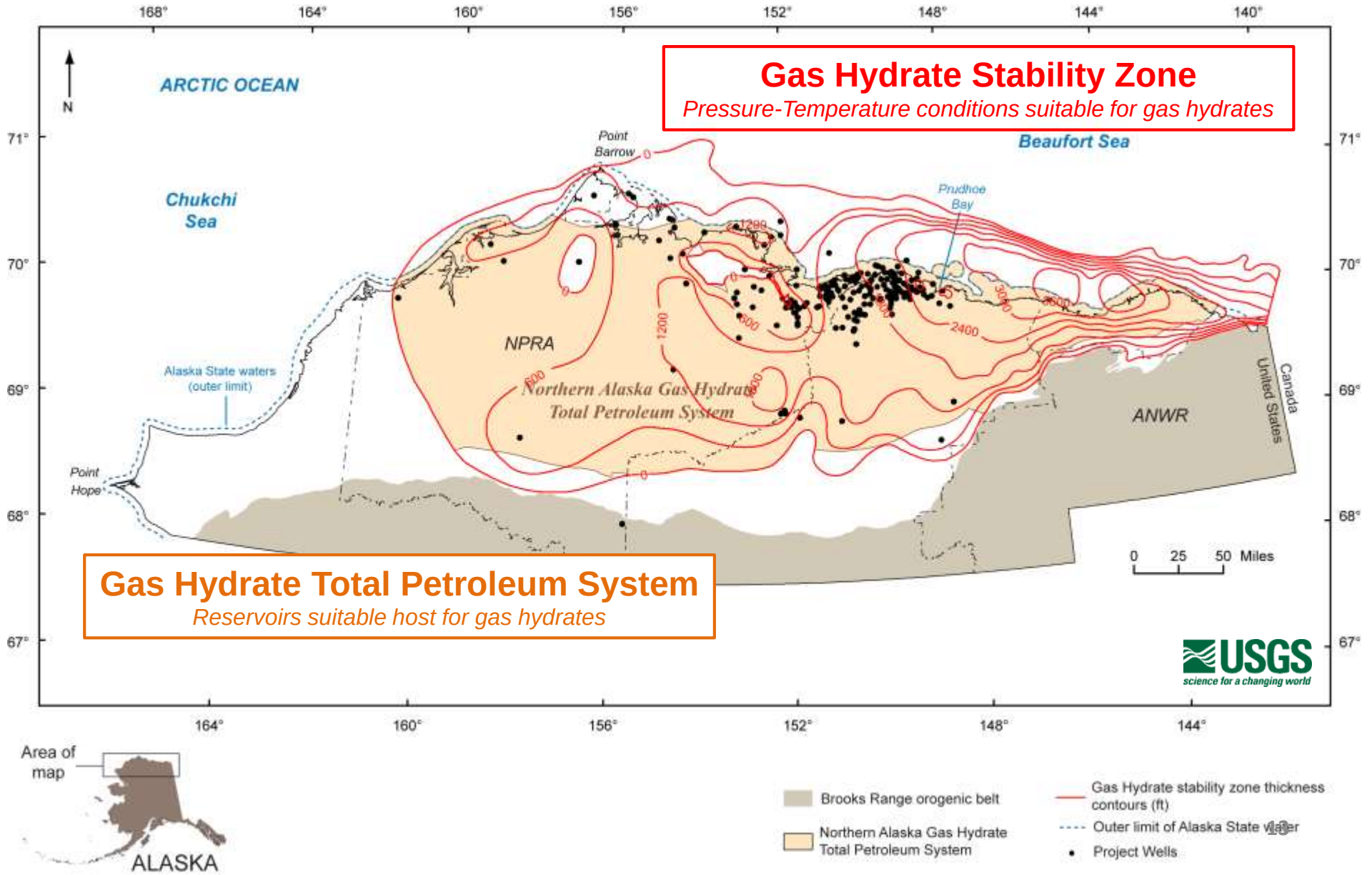
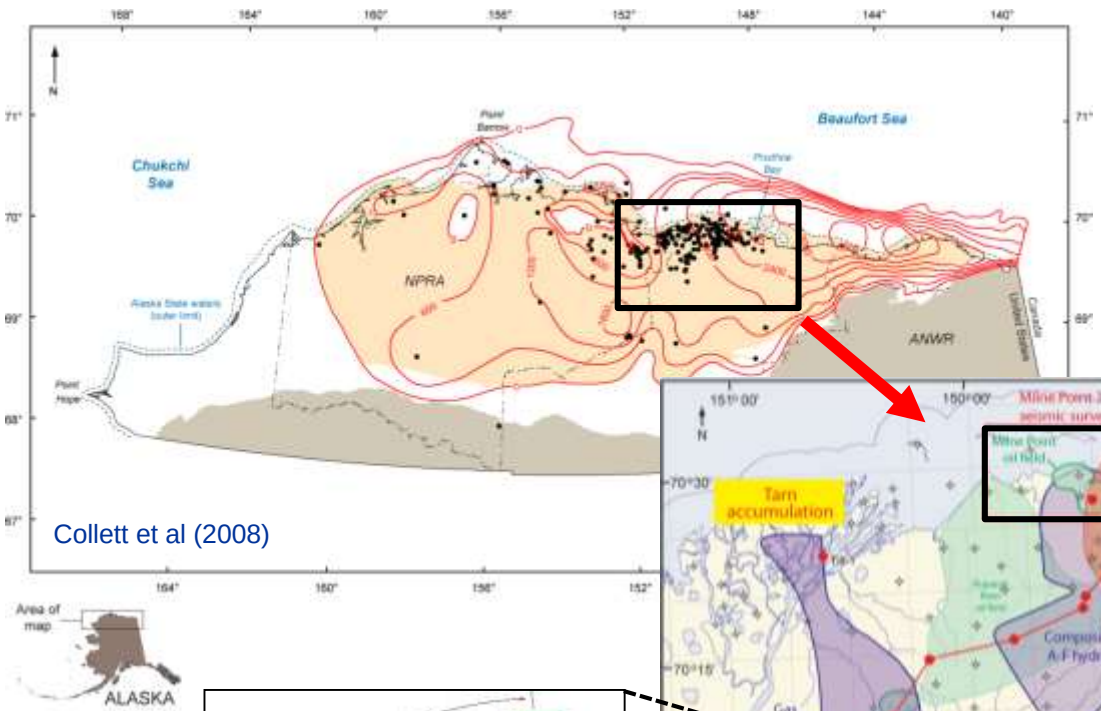
# Northern Alaska Gas Hydrate Total Petroleum System

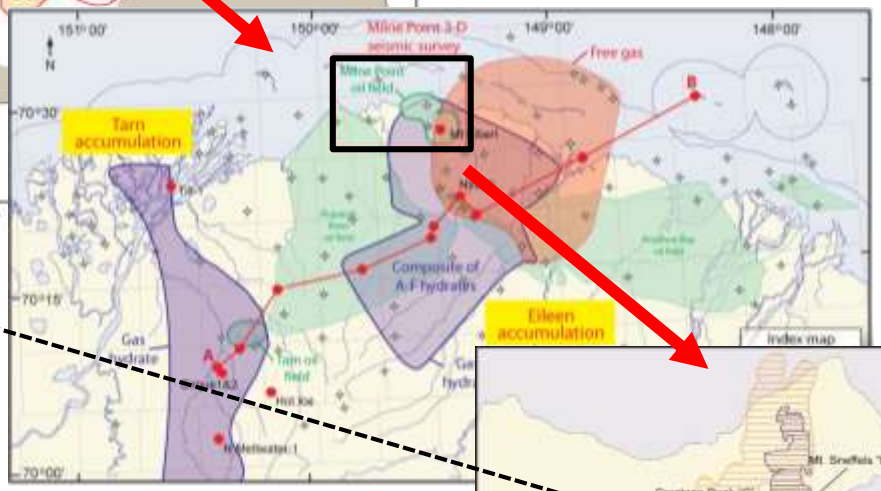


# Controls on the Occurrence Gas Hydrate

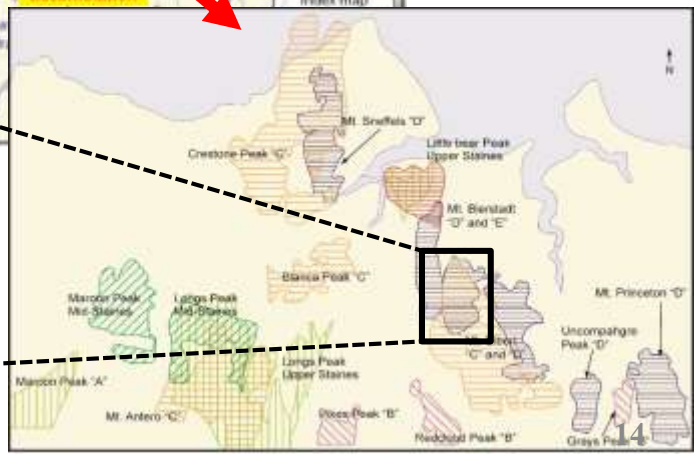
## *Gas Hydrate TPS to Gas Hydrate Accumulations*

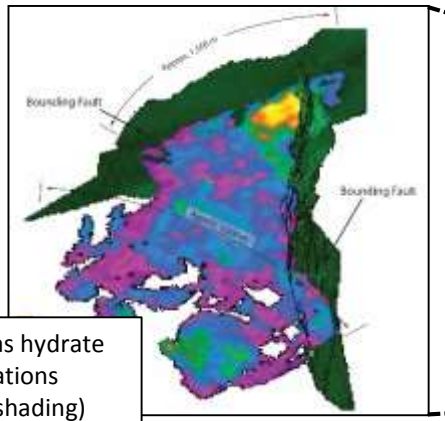



Collett (2002)




After Inks et al (2009)




Highest gas hydrate saturations (yellow shading)

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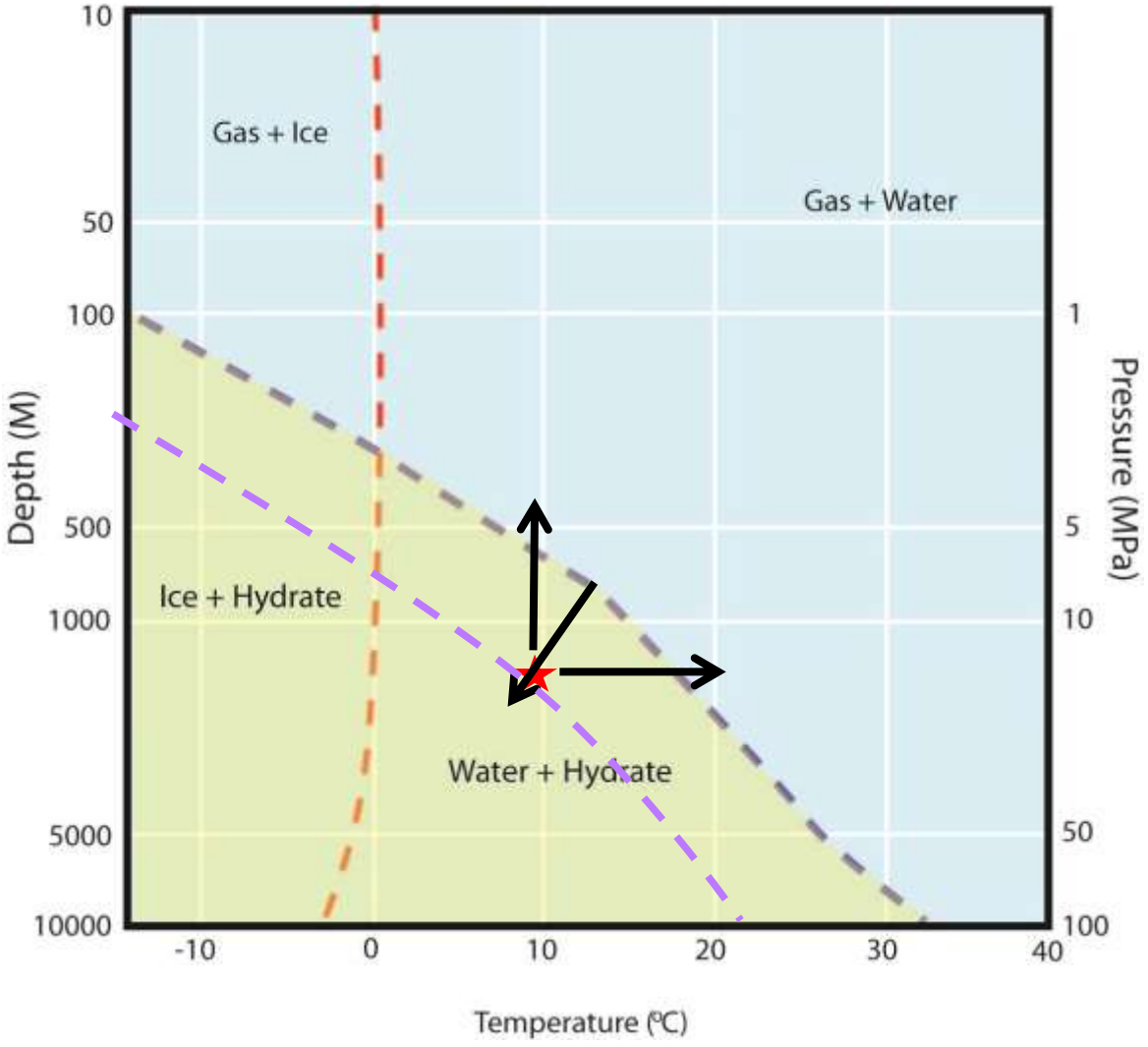
# Gas Hydrate Production Concepts

- **Depressurization**
- **Heating**
- **Inhibitor Injection**
- **Chemical Exchange**
  - $CO_2$ sequestration



# Alaska North Slope – Iġnik Sikumi Field Trial (2012)

**GOAL:**

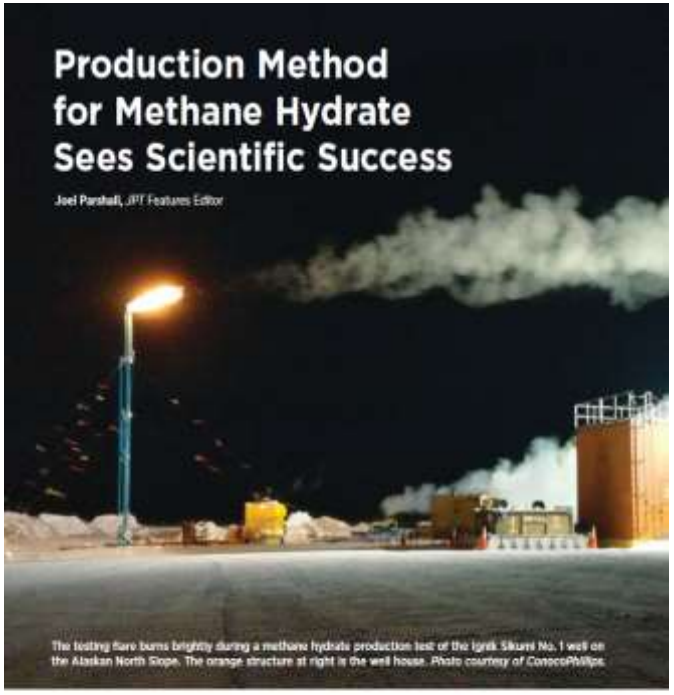
**Investigate potential role of $CO_2$ injection in future hydrate production approaches.**

- improved carbon balance? improved geomechanical stability?

**FINDINGS:**

- Confirmed, delineated gas hydrate rich deposits in westend PBU
- Demonstrated ability to inject mixed gas and to exchange $CO_2$ for $CH_4$
- Observed favorable geomechanical response
- Injection leads to complex reactions *and will sacrifice production rate*
- Depressurization remains most promising process for production
- Exchange may have a role in select settings

**DOE-NETL international modeling consortium convened to further investigate downhole processes**



Production Method for Methane Hydrate Sees Scientific Success

Joel Parshall, JPT Features Editor

The testing flare burns brightly during a methane hydrate production test of the Iġnik Sikumi No. 1 well on the Alaskan North Slope. The orange structure at right is the well house. *Photo courtesy of ConocoPhillips.*

A production method that could unlock large reserves of methane hydrate in sand-dominated reservoirs was tested successfully from a scientific and operational standpoint in a recent research experiment on the Alaskan North Slope (ANS). The experiment was conducted by the National Energy Technology Laboratory (NETL) of the United States Department of Energy (DOE) in partnership with ConocoPhillips and Japan Oil, Gas, and Metals National Corporation.

A proof-of-concept test was conducted between 15 February and 10 April at the Iġnik Sikumi No. 1 well in the Prudhoe Bay field operated by ConocoPhillips. The production technique featured the injection of carbon dioxide ($CO_2$) to exchange and release methane ($CH_4$) from the hydrate, a method developed through laboratory collaboration between the University of Bergen in Norway and ConocoPhillips. The released gas was then produced by means of reservoir depressurization.

"The test objective was to perform injection and flowback from a single well to validate that the $CO_2/CH_4$ exchange mechanism demonstrated in laboratory tests will occur in a reservoir of natural methane hydrates," said Ray Boswell, technology manager for gas hydrates at the NETL. It was the first field-level trial of a production method involving the exchange of $CO_2$ with the methane molecules contained in a methane hydrate structure. "The focus of the test, including the design of the well, was on the technical feasibility of this new technology, rather than an attempt to produce gas at commercial rates," Boswell said.

### $CO_2$ Mixture Injected in Reservoir

The Iġnik Sikumi well test was equipped with downhole fiber-optic distributed temperature and acoustic sensing, three downhole pressure gauges, and full surface instrumentation,

ConocoPhillips JOGMEC NETL USGS science for a changing world

*Potential for $CO_2$ sequestration through $CO_2$-$CH_4$ Exchange Technology*

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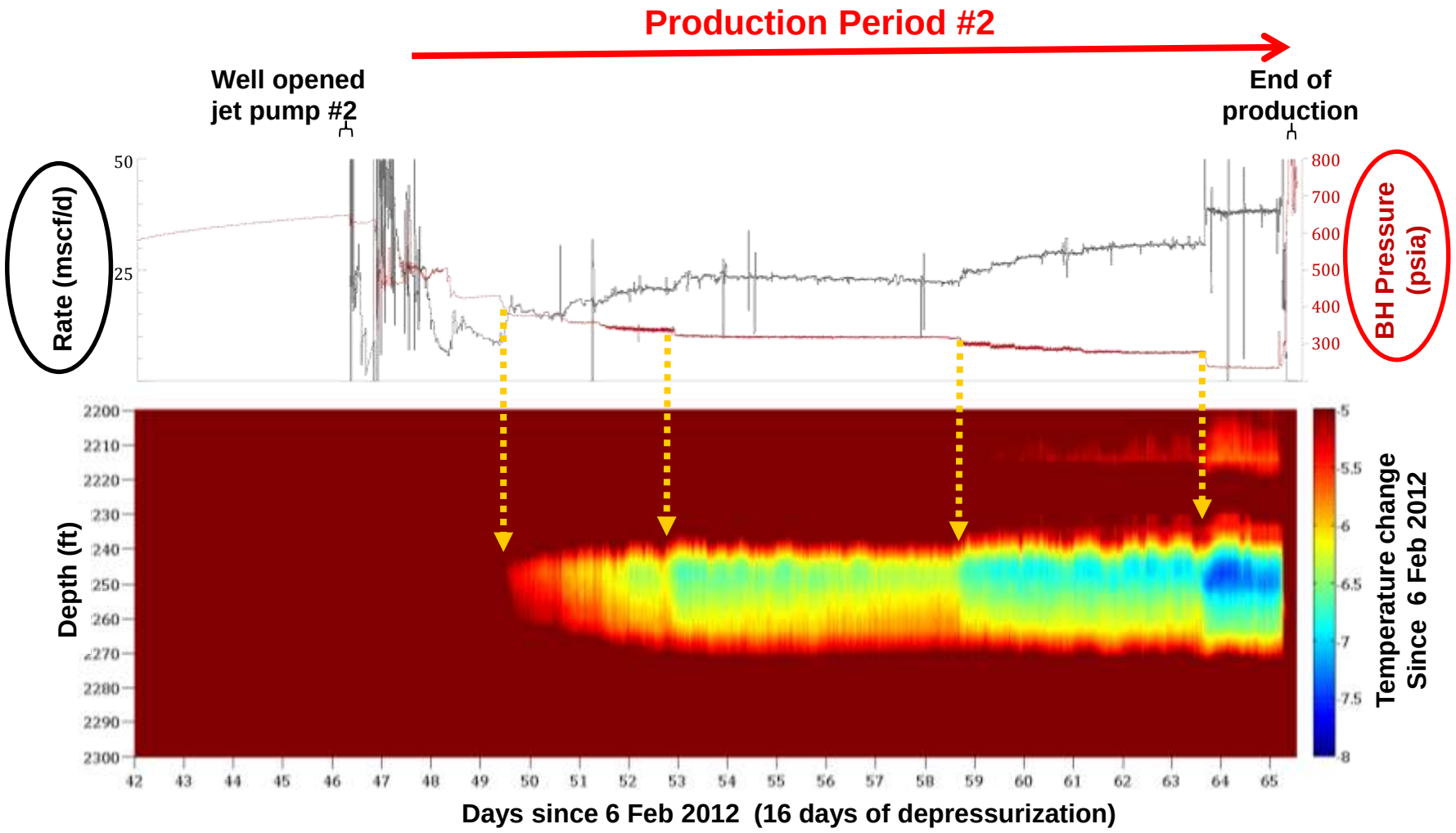
# Iġnik Sikumi – Depressurization Test Phase

## *Production Period #2 – 25 Days*




***Pressure – Production Rate - Temperature***

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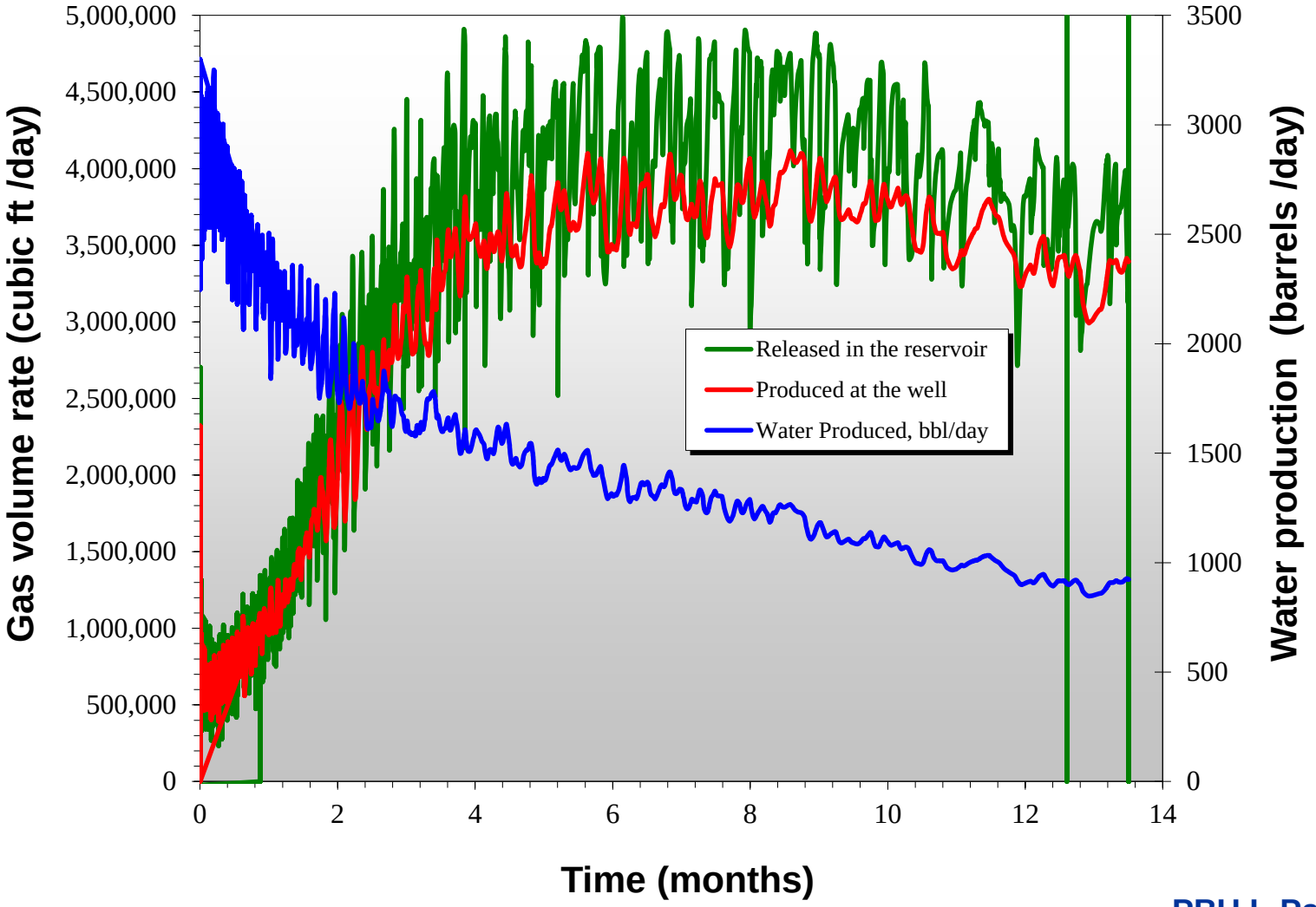
# Gas Hydrate Production Model

## *Shale Bounded Sand-Rich Unit (Unit C) – 180 days*




**PBU L-Pad Unit C**

***Predicted Gas and Water Production***

# Alaska North Slope
## *Extended Gas Hydrate Production Testing*

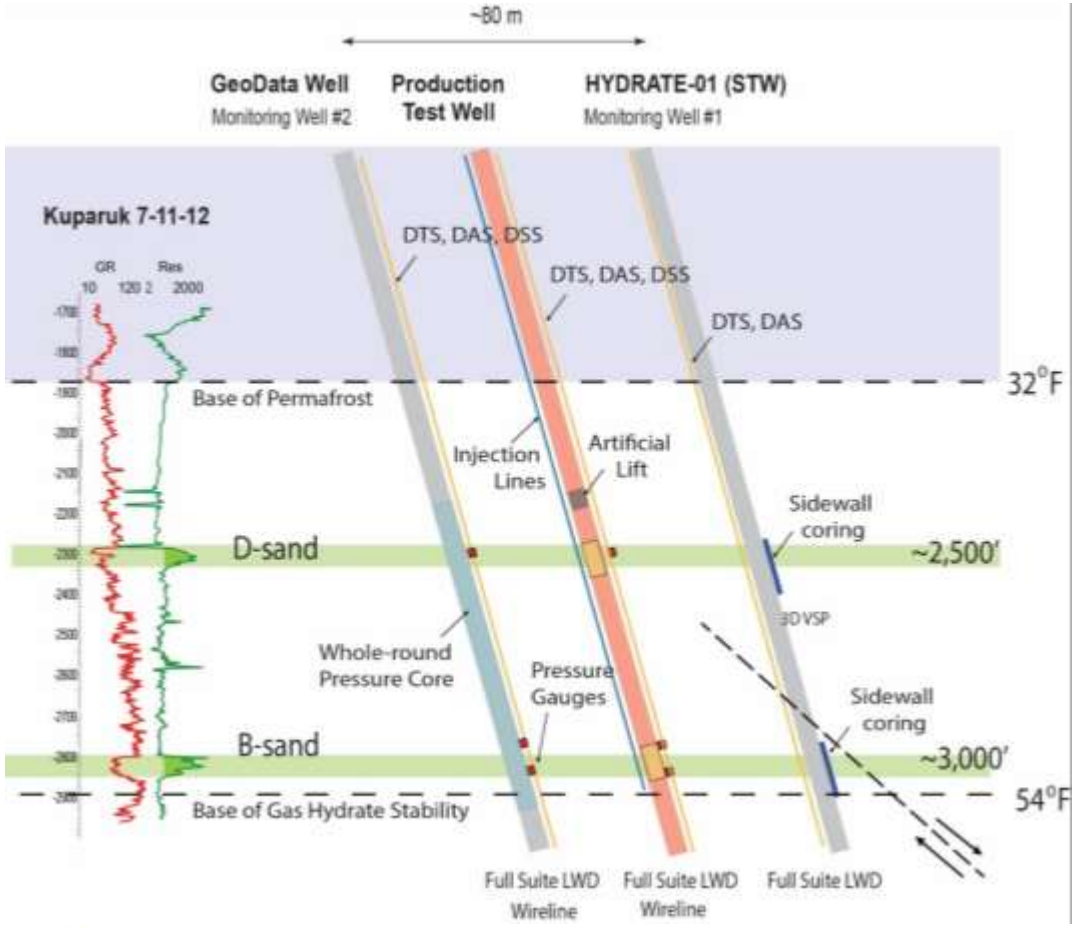
## Alaska Gas Hydrate R&D

### Milne Point Unit Fuel Gas Options

- Evaluated gas hydrate and conventional shallow gas options.

### Initiative with the State of Alaska

- State of Alaska withheld acreage and signed an MoU with DOE to facilitate continued research.
- Cooperative effort to evaluate project logistics, gather necessary G&G, and conduct monitored depressurization test.
- DOE, JOGMEC, and USGS identified and evaluated potential test sites.
- Completed Hydrate-01 Stratigraphic Test Well in December 2018.




JOGMEC

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AIST
NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

NETL

PRA

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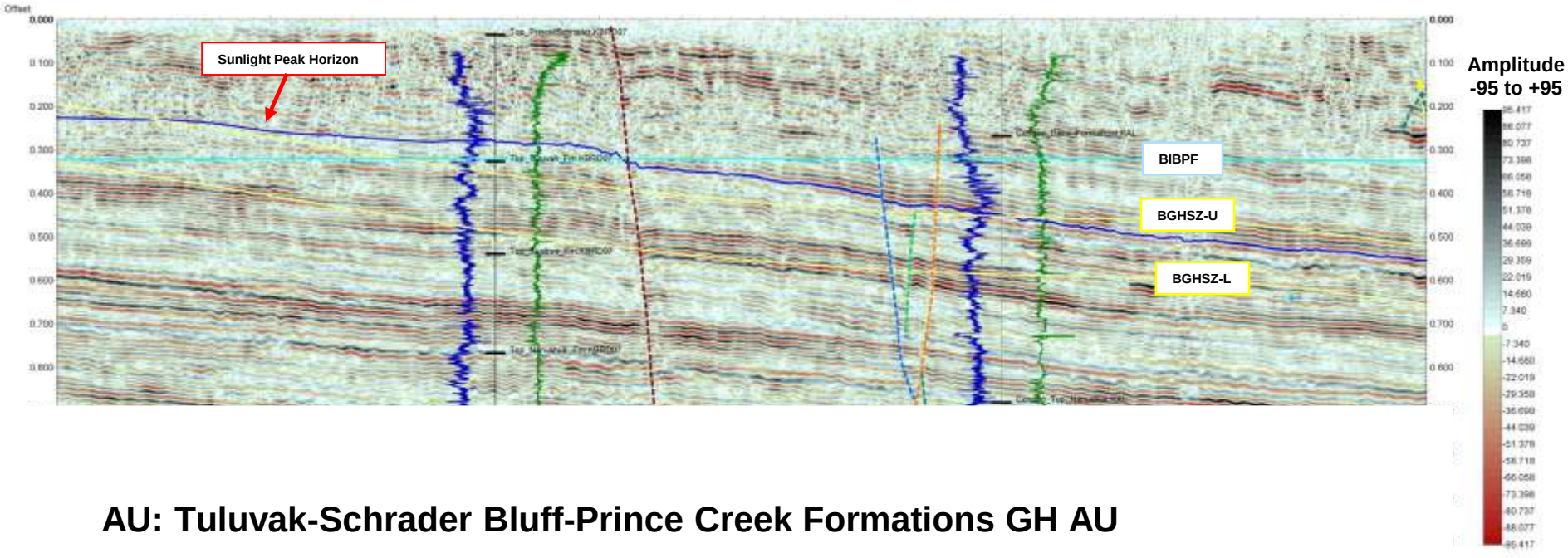
# NPRA Seismic Prospecting
# Sunlight Peak Horizon (Accumulations 1-10)




**AU: Tuluvak-Schrader Bluff-Prince Creek Formations GH AU**

**Formation Tops: Torok, Nanushuk, Tuluvak (well log and seismic analysis)**

**Base of Ice-bearing permafrost: BIBPF**

**Base of gas hydrate stability zone (upper): BGHSZ-**

**-------Window of 600ft (174 milliseconds TWT)**

**Base of gas hydrate stability zone (lower): BGHSZ-L**

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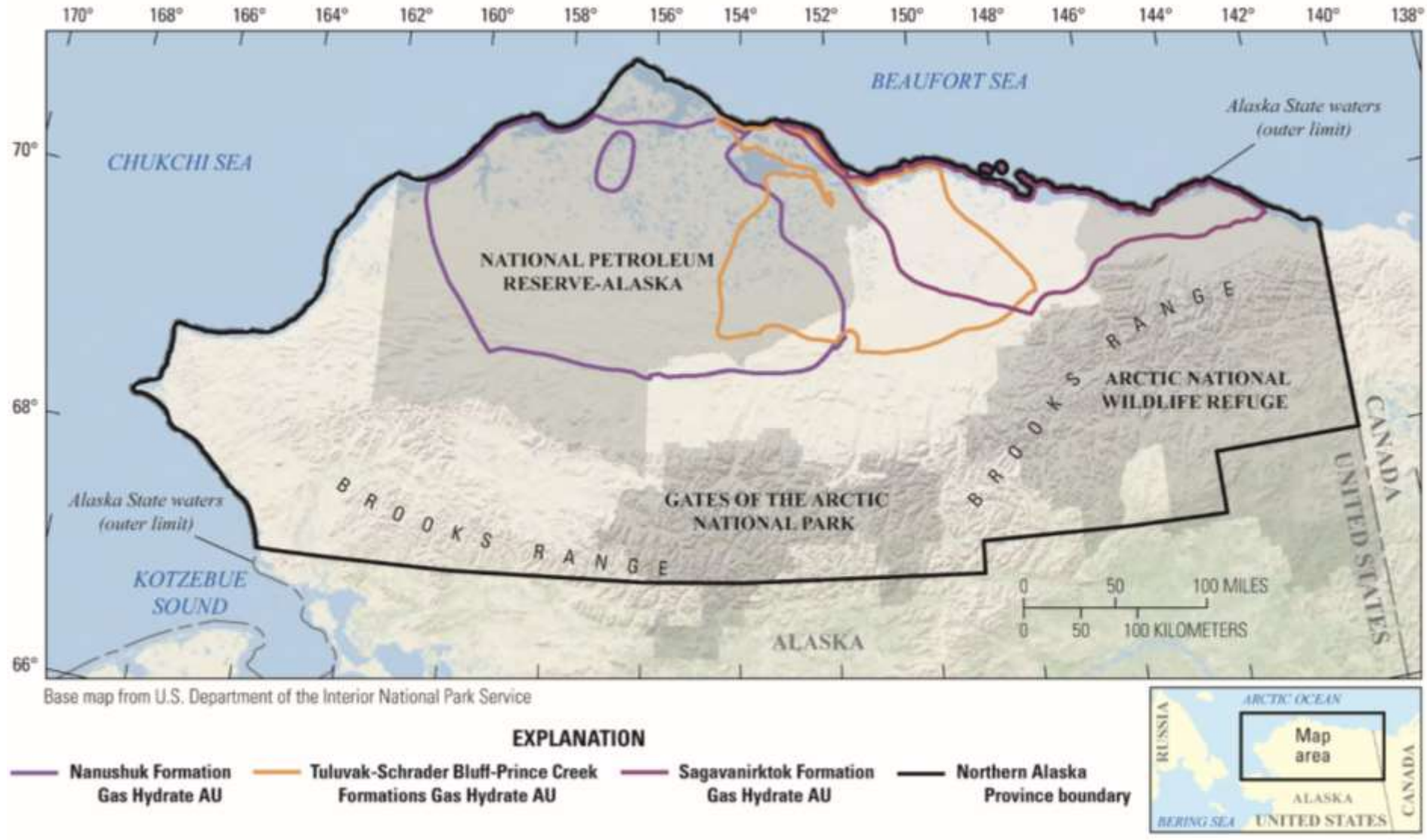
# Nanushuk Formation Gas Hydrate Assessment Unit
# Tuluvak-Schrader Bluff-Prince Creek Formations Gas Hydrate Assessment Unit
# Sagavanirktok Formation Gas Hydrate Assessment Unit




Base map from U.S. Department of the Interior National Park Service

**EXPLANATION**

- Nanushuk Formation Gas Hydrate AU
- Tuluvak-Schrader Bluff-Prince Creek Formations Gas Hydrate AU
- Sagavanirktok Formation Gas Hydrate AU
- Northern Alaska Province boundary

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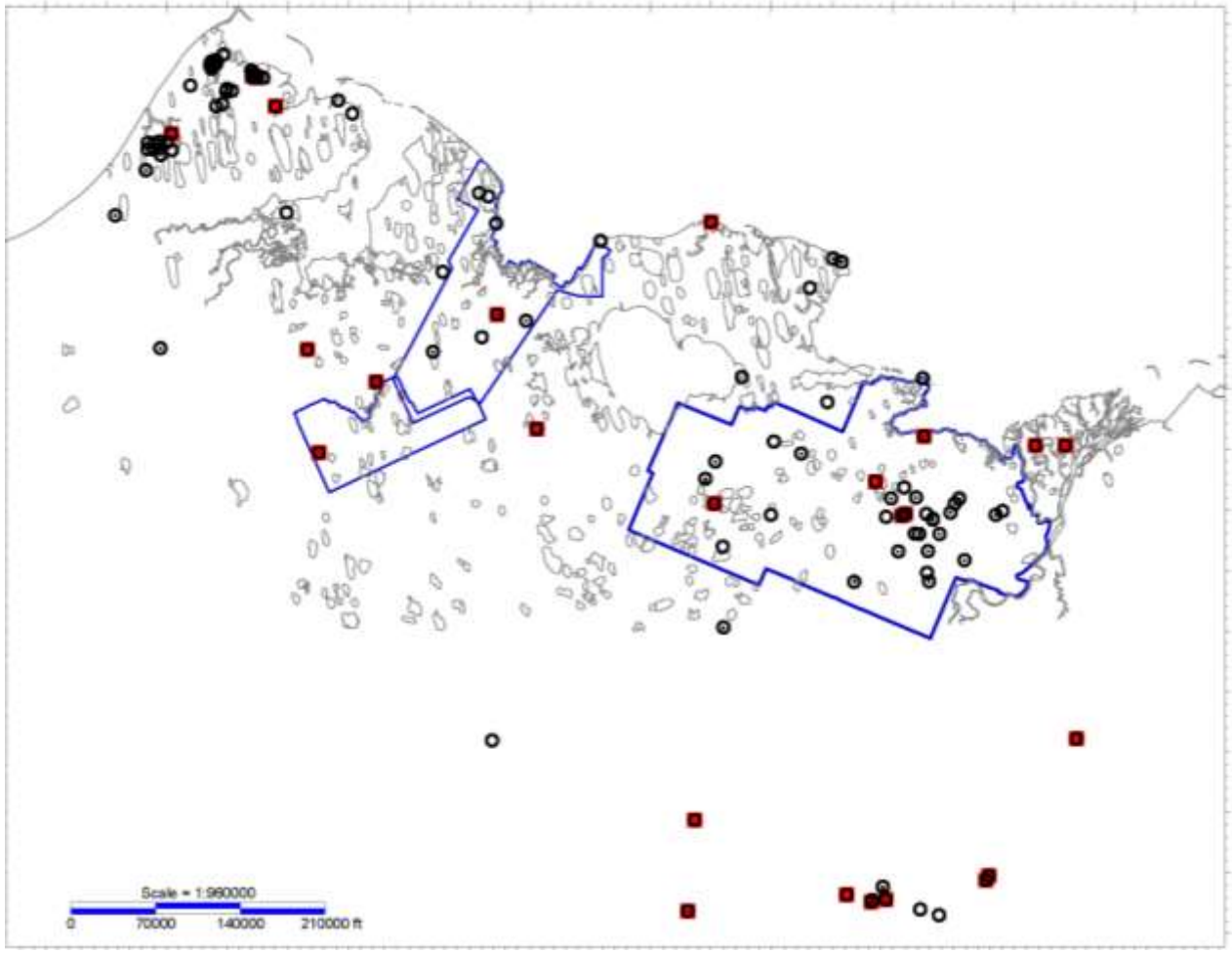
# Alaska North Slope Gas Hydrate Occurrence

## *National Petroleum Reserve Alaska (NPRA)*

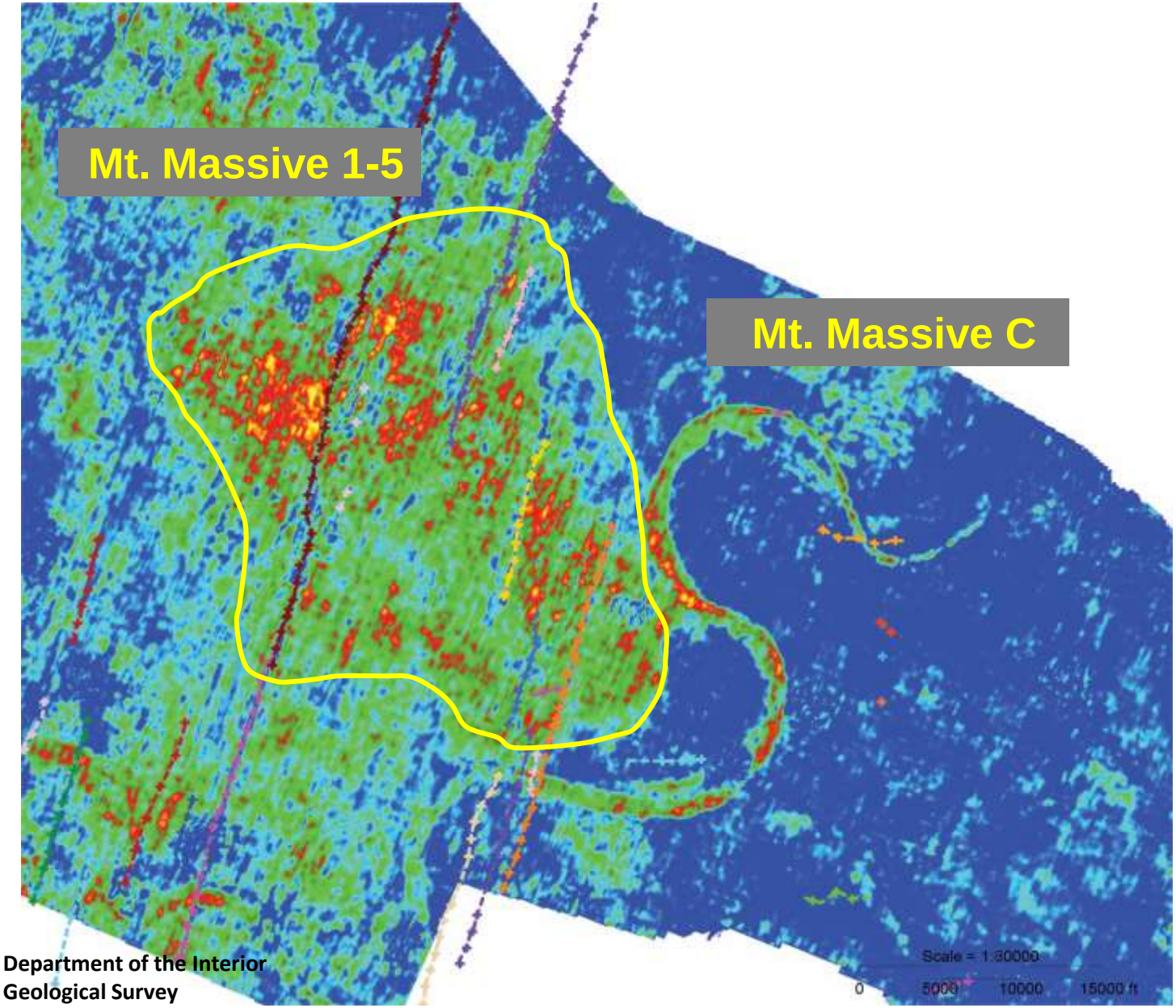
- 189 NPRA wells reviewed
- Inventory data
- Confirmed Fm tops
- Permafrost (BIBPF)
- Hydrate stability (GHSZ)
- GH well log responses
- Mud/cuttings gas log/data

**Possible Gas Hydrate Occurrence: 25 wells (shown with red dots)**



# NPRA Seismic Prospecting

## Mt. Massive: RMS Amplitude plus/minus 10 milliseconds
## Gas Hydrate Accumulations




RMS Amplitude 0.8-4.0

4.000
3.920
3.840
3.760
3.680
3.600
3.520
3.440
3.360
3.280
3.200
3.120
3.040
2.960
2.880
2.800
2.720
2.640
2.560
2.480
2.400
2.320
2.240
2.160
2.080
2.000
1.920
1.840
1.760
1.680
1.600
1.520
1.440
1.360
1.280
1.200
1.120
1.040
0.960
0.880
0.800

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# 2018 USGS ANS Gas Hydrate Assessment

## *Size of Undiscovered Accumulations*

1. Use the project provided 3D seismic volumes to identify and delineate (area) gas hydrate accumulations.

   *Sagavanirktok Form. GH AU: 16 Accumulations*
   *Tuluvak-Schrader Bluff-Prince Creek Form. GH AU: 35 Accumulations*
   *Nanushuk Form. GH AU: 54 Accumulations*

2. Use available project derived well log and core data to assign and risk gas hydrate reservoir properties of each seismic delineated gas hydrate accumulation.

   *Size (gas volume distribution) of Undiscovered GH Accumulations =*
   *Accum. Area x Reservoir Thick. x Net-to-Gross x Por. x GH Sat. x GH-Gas Conversion*
   *With each reservoir variable risked (triangular distribution around the mean)*

3. Derive size (volume of gas) of each seismic delineated gas hydrate accumulation and apply appropriate recovery ratio (85% in all cases).

4. Remove all gas hydrate accumulations below a minimum accumulation size of 30 bcf.

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# 2018 USGS ANS Gas Hydrate Assessment

## *Size and Number of Undiscovered Accumulations*

| Assessment input data—Conventional AUs | Nanushuk Formation Gas Hydrate AU | | | |
|---|---|---|---|---|
| | Minimum | Median | Maximum | Calculated mean |
| Number of gas fields | 1 | 100 | 400 | 110.3 |
| Size of gas fields (BCFG) | 30 | 70 | 11,000 | 217.4 |
| AU probability | 0.9 | | | |

| Assessment input data—Conventional AUs | Tuluvak-Schrader Bluff-Prince Creek Formations Gas Hydrate AU | | | |
|---|---|---|---|---|
| | Minimum | Median | Maximum | Calculated mean |
| Number of gas fields | 1 | 90 | 360 | 99.2 |
| Size of gas fields (BCFG) | 30 | 65 | 10,000 | 197.3 |
| AU probability | 0.9 | | | |

| Assessment input data—Conventional AU | Sagavanirktok Formation Gas Hydrate AU | | | |
|---|---|---|---|---|
| | Minimum | Median | Maximum | Calculated mean |
| Number of gas fields | 1 | 150 | 600 | 165.4 |
| Size of gas fields (BCFG) | 30 | 50 | 3,000 | 98.9 |
| AU probability | 0.9 | | | |

[AU, assessment unit; BCFG, billion cubic feet of gas. Shading indicates not applicable]

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## *Number of Undiscovered Accumulations*

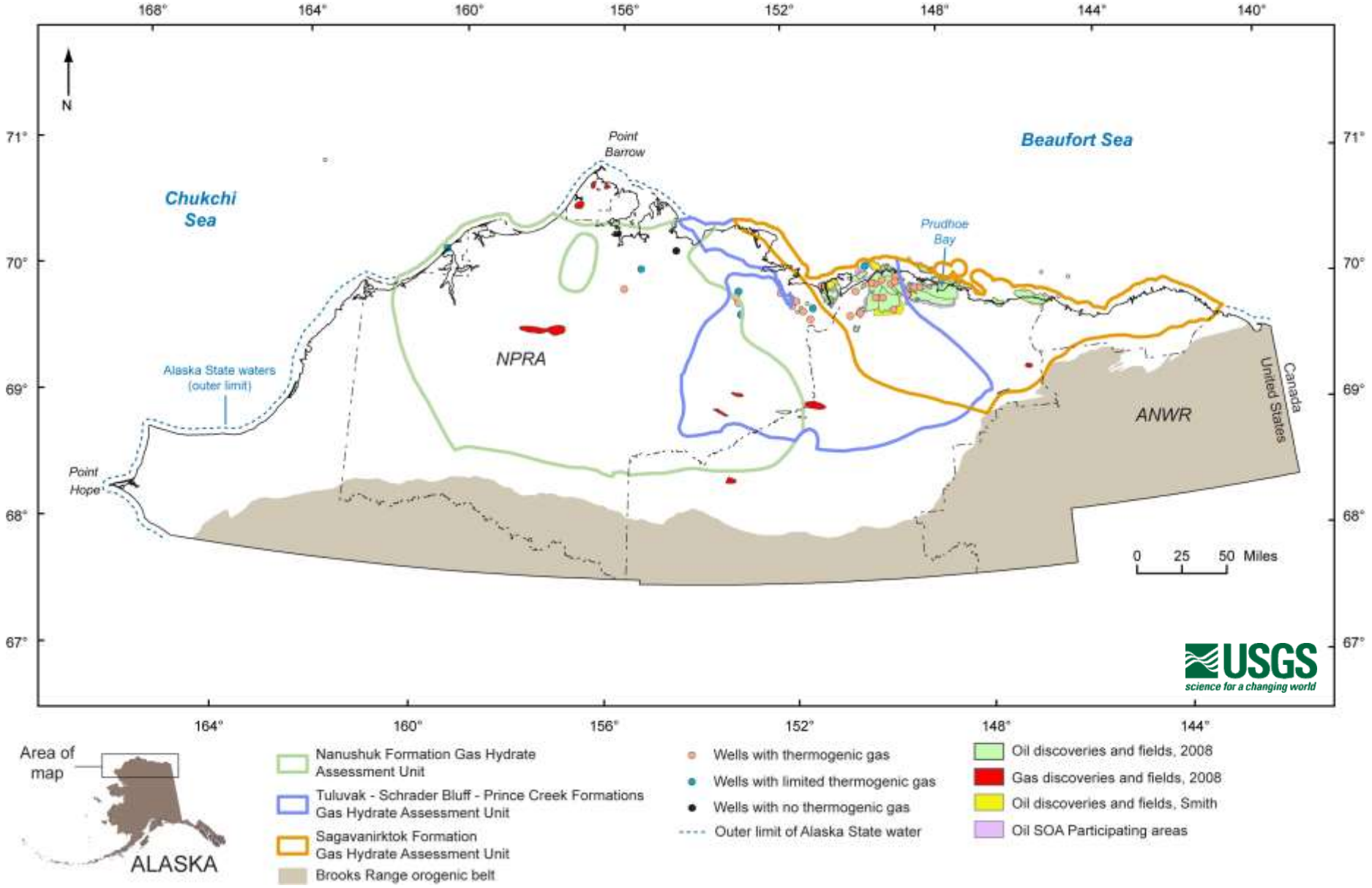
1. Use the seismic identified gas hydrate accumulations to derive a “Discovery Ratio”, which is the number of gas hydrate accumulations per unit area within each seismic volume.

2. The “Discovery Ratio” is “risked” with a probability distribution that is used to estimate the number of undiscovered gas hydrate accumulations in the portions of the AU without seismic coverage.

3. The gas hydrate petroleum system concept (i.e., source of thermogenic gas) is used to assign the risked “Discovery Ratio” probability distributions to various unique mapped areas within the AU with similar geologic conditions.

# Alaska North Slope GH Petroleum Systems

## *Potential Thermogenic Gas Sources to the GHSZ*



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## *Size and Number of Undiscovered Accumulations*

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| Assessment input data—Conventional AUs | Tuluvak-Schrader Bluff-Prince Creek Formations Gas Hydrate AU | | | |
|---|---|---|---|---|
| | Minimum | Median | Maximum | Calculated mean |
| Number of gas fields | 1 | 90 | 360 | 99.2 |
| Size of gas fields (BCFG) | 30 | 65 | 10,000 | 197.3 |
| AU probability | 0.9 | | | |

| Assessment input data—Conventional AU | Sagavanirktok Formation Gas Hydrate AU | | | |
|---|---|---|---|---|
| | Minimum | Median | Maximum | Calculated mean |
| Number of gas fields | 1 | 150 | 600 | 165.4 |
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[AU, assessment unit; BCFG, billion cubic feet of gas. Shading indicates not applicable]

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# 2018 USGS ANS Gas Hydrate Assessment

## *Assessment Results*

| Total petroleum system and assessment units (AUs) | AU probability | Accumulation type | Total undiscovered resources | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Gas (BCFG) | | | | NGL (MMBNGL) | | | |
| | | | F95 | F50 | F5 | Mean | F95 | F50 | F5 | Mean |
| Northern Alaska Gas Hydrate Total Petroleum System | | | | | | | | | | |
| Nanushuk Formation Gas Hydrate AU | 0.9 | Gas | 0 | 19,978 | 46,706 | 21,511 | 0 | 0 | 0 | 0 |
| Tuluvak-Schrader Bluff-Prince Creek Formations Gas Hydrate AU | 0.9 | Gas | 0 | 16,231 | 38,449 | 17,608 | 0 | 0 | 0 | 0 |
| Sagavanirktok Formation Gas Hydrate AU | 0.9 | Gas | 0 | 13,840 | 30,475 | 14,677 | 0 | 0 | 0 | 0 |
| **Total undiscovered conventional resources** | | | **0** | **50,049** | **115,630** | **53,796** | **0** | **0** | **0** | **0** |

[BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included in the NGL category. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. Shading indicates not applicable]

***Of the estimated 53.8 TCF of gas within hydrates on the North Slope, 48 percent occurs on federally managed lands, 45 percent on lands and offshore waters managed by the State of Alaska, and 7 percent on Native lands.***

# 2018 USGS ANS Gas Hydrate Assessment

## *Comparison of 2008 and 2018 Assessment Results*

**2018, Alaska North Slope Gas Hydrate Assessment**
**Mean Gas: 53.8 TCF (F95 = 00.0; F50 = 50.1; F05 = 115.6)**

**2008, Alaska North Slope Gas Hydrate Assessment**
**Mean Gas: 85.4 TCF (F95 = 25.2; F50 = 81.0; F05 = 157.8)**

### Reasons for the lower 2018 gas volumetric estimates

1. Access to new 3D seismic and well log datasets led to improved mapping of AUs and the reduction in the size of the Nanushuk GH AU and the Tuluvak-Schrader Bluff-Prince Creek GH AU (reduction in the number of accumulations).
2. Increase of the minimum field-size cutoff from 20 BCFG in 2008 to 30 BCFG of gas in 2018 for all three AUs.
3. The inclusion of a new "AU probability" risk factor of 0.90 in 2018.

# 2018 USGS ANS Gas Hydrate Assessment

## *Comparison Alaska Gas Hydrate with Other Gas Resources*

- **Arctic Alaska**
  - Undiscovered gas offshore estimated at ~105 TCF (BOEM)
  - Undiscovered gas onshore estimated at ~100 TCF (USGS)
  - Undiscovered gas hydrate onshore estimated at ~54 TCF (USGS)
  - Undiscovered shale-gas onshore estimated at ~40 TCF (USGS)
  - Undiscovered coalbed gas onshore estimated at ~18 TCF (USGS)
- **Selected comparison to significant Lower 48 gas assessments**
  - Marcellus Shale, Appalachian Basin estimated at ~84 TCF (USGS)
  - Mancos Shale, Piceance Basin (CO/UT) estimated at ~66 TCF (USGS)

# Assessment of Undiscovered Gas Hydrate Resources in the North Slope of Alaska, 2018


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**USGS Fact Sheet 2019-3037**
https://doi.org/10.3133/fs20193037

**USGS News Release**
https://www.usgs.gov/news/usgs-estimates-538-trillion-cubic-feet-natural-gas-hydrate-resources-alaska-north-slope

**USGS Data Release**
https://doi.org/10.5066P9HSWE98