

## **Methane Hydrate Resource Potential Associated with the Barrow Gas Fields\***

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### **Abstract**

The North Slope of Alaska has significant methane hydrate resource potential, and previous studies suggest that gas hydrates exist in the Barrow area. Currently, gas from three producing fields provides heating and electricity for Barrow, the economic, transportation, and administrative center of the North Slope Borough. As energy demands grow, it is important to characterize, quantify, and evaluate the potential impact of the postulated gas hydrate accumulation to guide future development. The Barrow Gas Fields (BGF) provide an excellent opportunity to study the interaction between a producing free gas reservoir and an overlying hydrate accumulation. A phased research program is underway, funded jointly by the U.S. Department of Energy, NETL and the North Slope Borough to prove the existence of hydrate accumulations associated with the free gas fields, quantify the size of postulated accumulations, and drill and production test a dedicated hydrate test well.

Modeling work completed in Phase 1A of the study supports the existence of methane hydrates in association with the East Barrow and Walakpa Gas Fields. Phase 1A included sampling and analysis of produced gas, determination of temperature and pressure gradient, and modeling of hydrate stability. In Phase 1B, a detailed reservoir characterization was completed.

Phase 2 of the study commenced December 1, 2008, with the goal of drilling a hydrate test well in late 2010 in the East Barrow Gas Field. This well is intended to collect core from the Barrow Sandstone within the hydrate stability zone, gather LWD and wireline logs over the hydrate and free gas zones, and produce free gas while monitoring the interface between free gas and hydrate.

Core and logs will be analyzed in the field, and a comprehensive decision matrix will be utilized in the decision to complete a monitoring well, and drill a horizontal production test well, or to move to a secondary location in the Walakpa Gas Field. A detailed coring operation, preservation and analysis plan has been designed to allow for the real-time decision process in the field.

In the success case, a gas production test well will be completed with slotted production liner straddling the base methane hydrate stability zone (BHSZ). A nearby monitoring well will monitor changes in the BHSZ. The production test well will be produced at a relatively high rate from the free gas leg just below the BHSZ, thereby reducing reservoir pressure, and inducing depressurization dissociation.

### References

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Website

<http://doddys.files.wordpress.com/2006/10/petroleum-system.jpg>

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P.K. Singh, M.D. Dunn

AAPG Annual Convention and Exhibition  
April 14, 2010

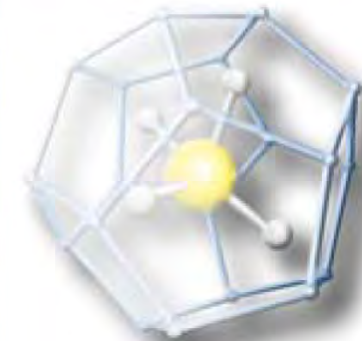
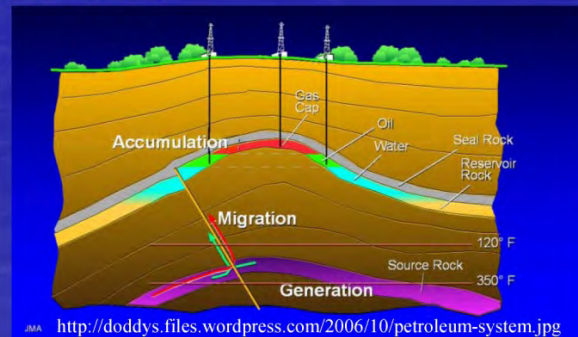
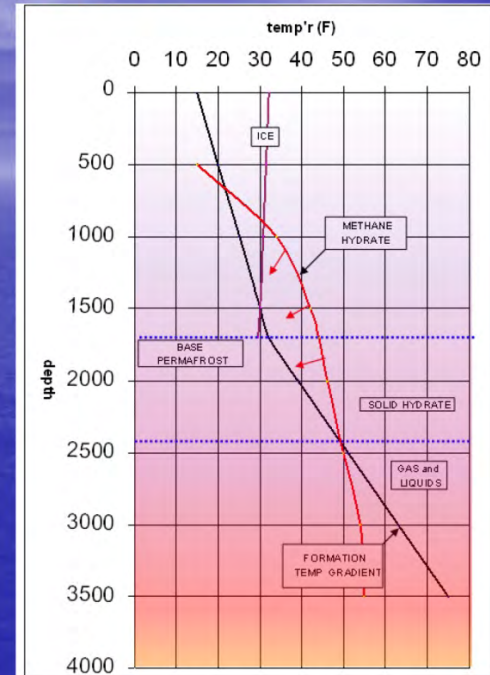


# Outline

- Introduction
- Regional Overview
- Barrow Gas Fields
- Project Objectives
- Modeling
- Drilling, Completion, Surveillance Plan
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# What Is Required for Methane Hydrate Formation?

- Petroleum System: Reservoir, Gas Source, Migration Path, Trap
- Suitable Temperature and Pressure Regime
- Formation Water
- Critical Timing of All Components

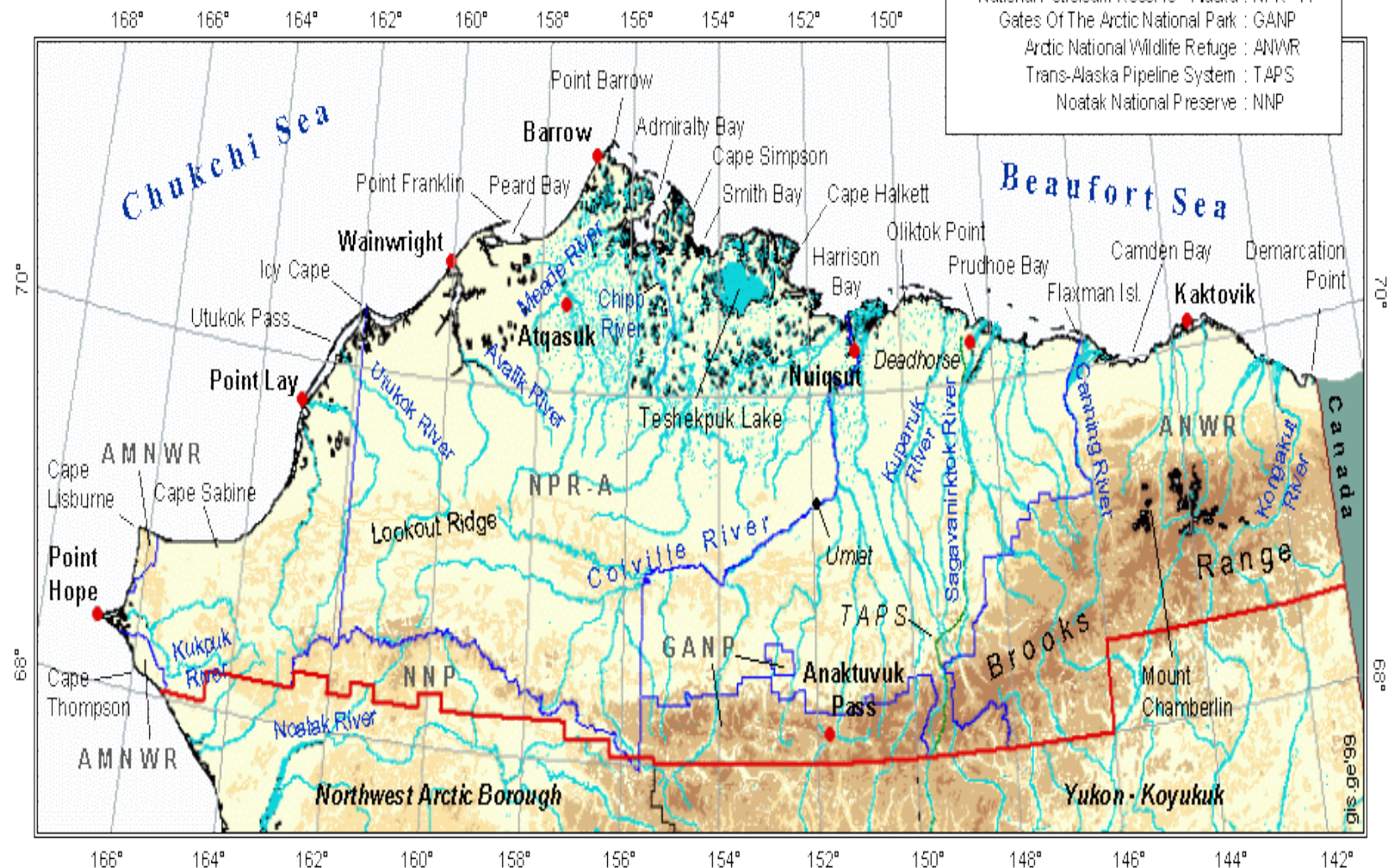


Notes by Presenter: We have **proven** world-class petroleum system, low salinity formation water. Need to prove P/T regime and timing support hydrate formation



# Geographic Setting

## NORTH SLOPE BOROUGH



Notes by Presenter (for previous slide):

NSB is >90,000 sq. miles.

North Slope oil and gas basin

ANWR to Chukchi, Brooks Range to Beaufort

Borough government is in Barrow, population 4300+

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# Regional Tectonic Setting

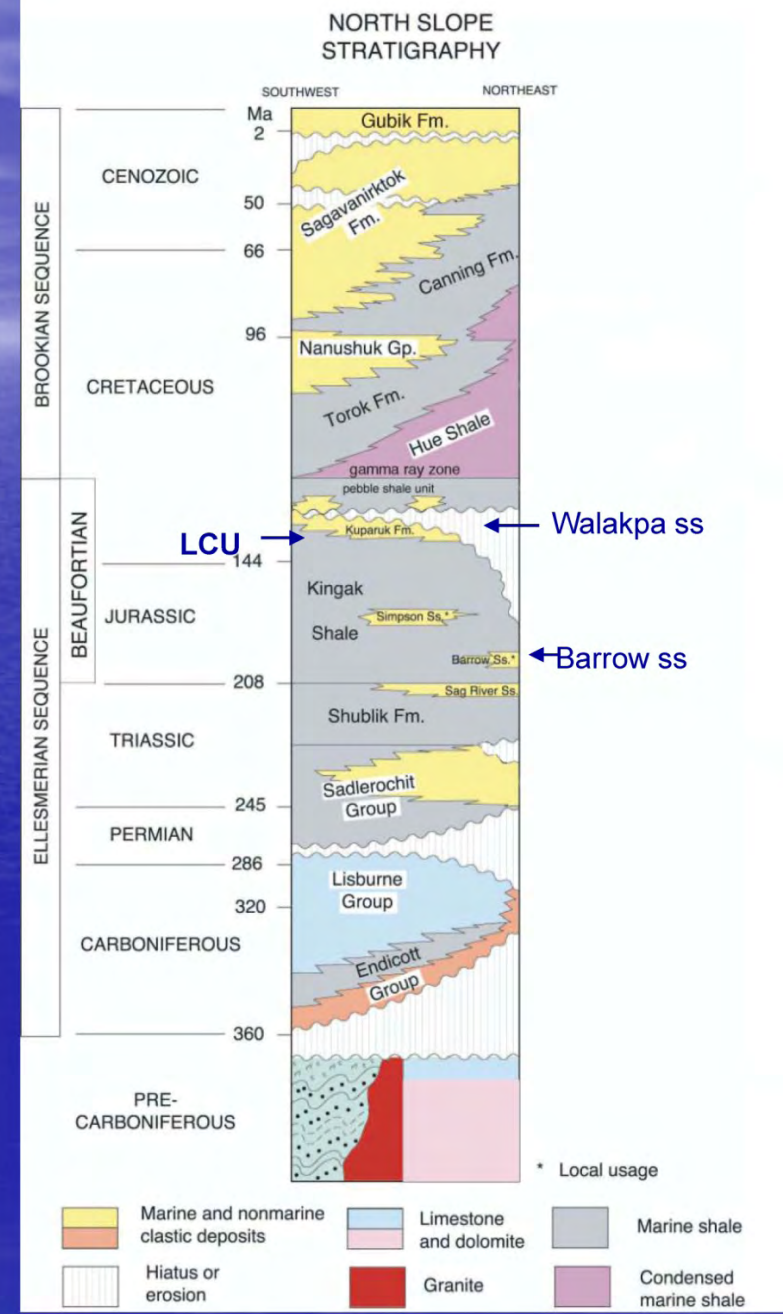


U.S. Geological Survey Open-File Report 03-040, D.W. Houseknecht

Notes by Presenter: Barrow Gas Fields lie along the Barrow Arch, south of successful rifted Arctic Ocean, north of Brooks Range and foredeep.



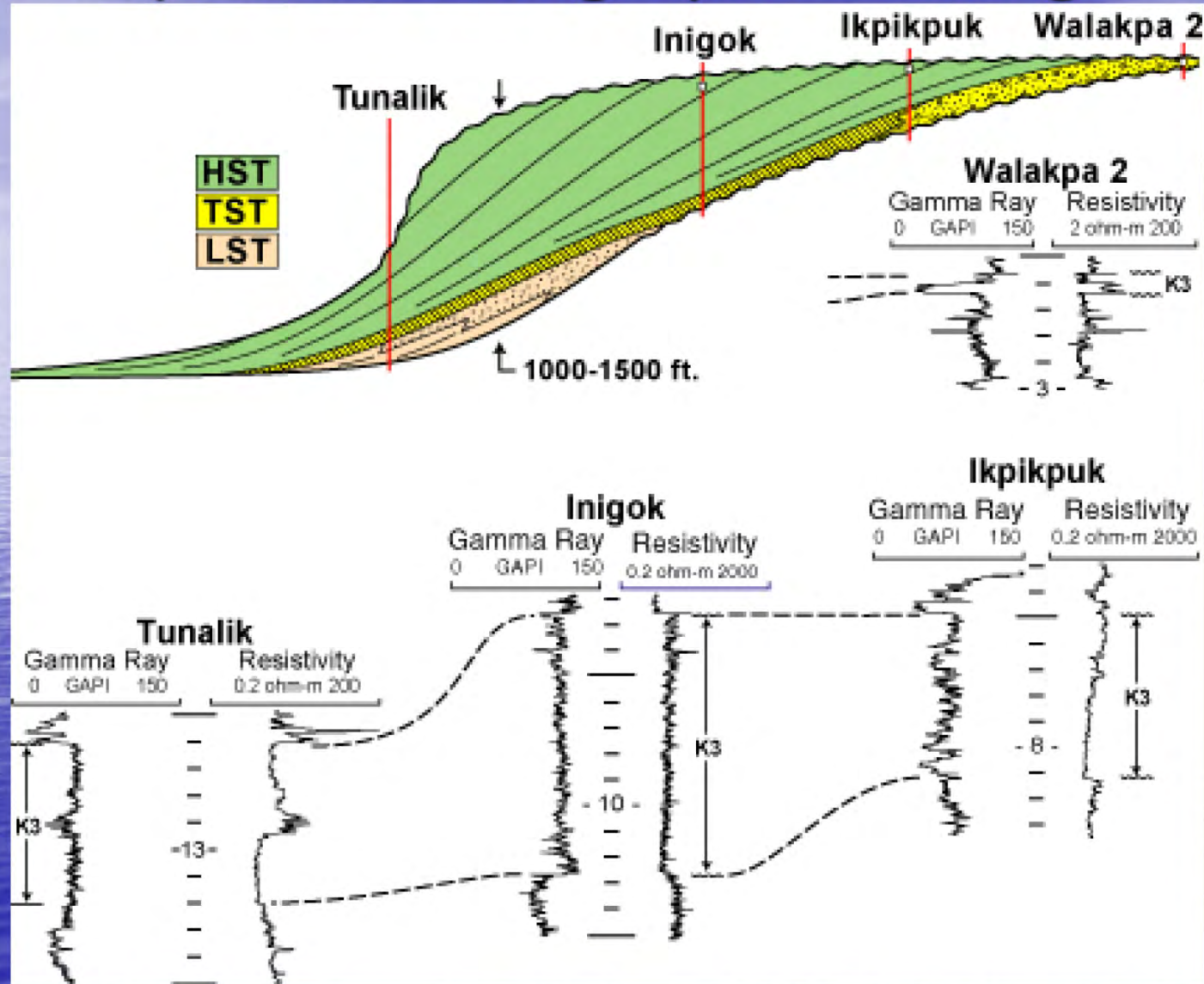
# Barrow Gas Field Stratigraphy



Modified from K.J. Bird, 2001

Notes by Presenter: Walakpa time genetically related to Kupaak, Burger, Niakuk, etc. Barrow SS related to Alpine, Nuiqsut.

# Sequence Stratigraphic Setting



U.S. Geological Survey Open-File Report 03-040, D.W. Houseknecht

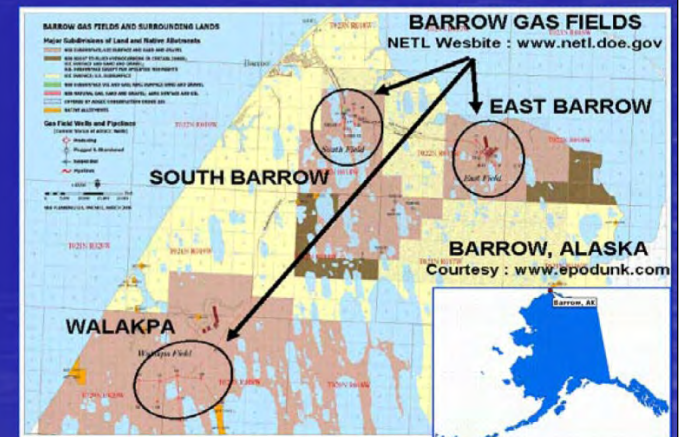
Notes by Presenter: Sequence stratigraphic facies for Walakpa Sandstone TST, extensive shallow marine sands, Chukchi to ANWR.



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# Barrow Gas Fields

- South Barrow Gas Field
  - Discovered in 1949 by U.S. Navy
- East Barrow Gas Field
  - Discovered in 1974
- Walakpa Gas Field
  - Discovered 1980 by Husky for U.S. DOI
- 80+ % of fuel for Barrow from Walakpa Gas Field



Notes by Presenter: South Barrow OGIP >25B, East Barrow >6B, Walakpa >250B



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# Project Objectives

- Characterize and Quantify Methane Hydrate Resource Associated With Barrow Gas Fields
- Contribute to Global Research Effort Through Practical Research
- Advance North Slope Borough's Understanding of It's Energy Supply
- Prove Hydrate Productivity
- Add Gas Reserves and Production

Notes by Presenter: Long-term production test using existing infrastructure. Gas is commercial in Barrow



# Scope

- Integrated Study (Seismic, Well Log, Production History, Geochem)
- Focus on Barrow Gas Fields—South Field, East Field, Walakpa
- Phased Approach
- Integrate Prior Research Efforts/Current Knowledge
- DOE-NETL/NSB 80-20% Funded Research

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Notes by Presenter: Gas is good. In the Arctic, sometimes gas is frozen.

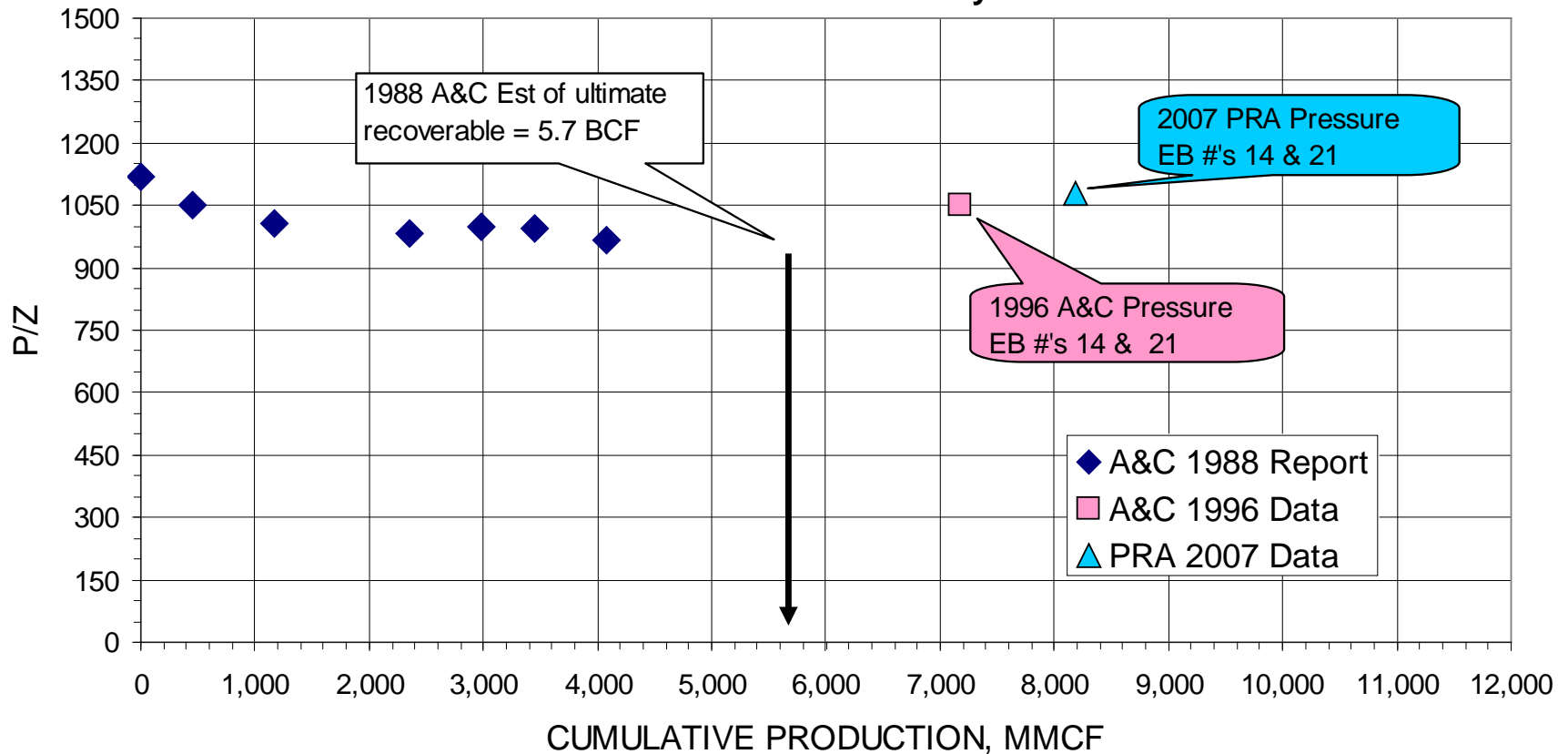


# Interpretation and Modeling

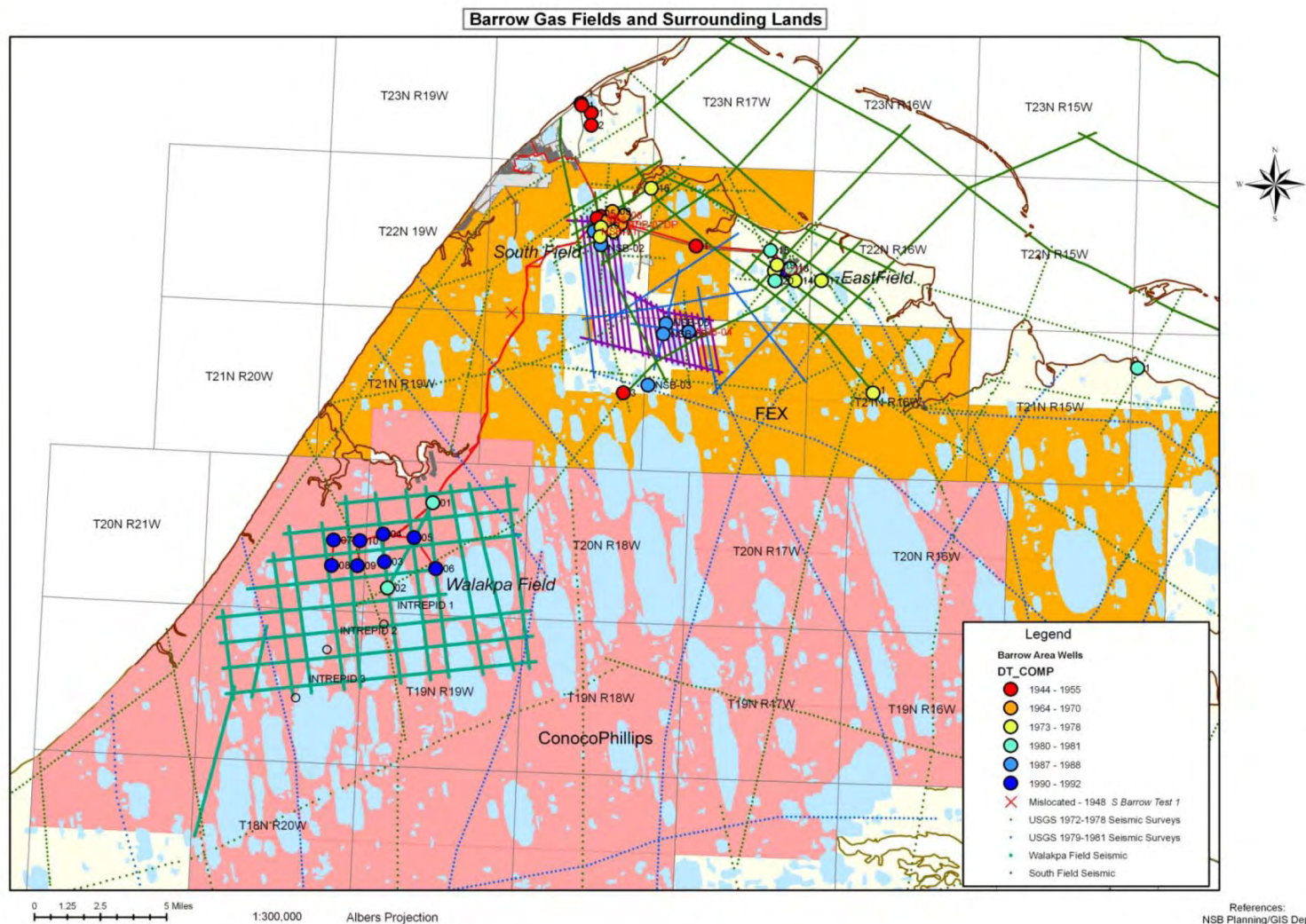
- Peculiar Material Balance Modeling Results and Anecdotal Evidence
- Seismic Interpretation and Mapping (the "Container")
- Hydrate Stability Modeling (Probability of In-Situ Hydrates)
- Material Balance Modeling (Depletion Mechanisms)
- Full Field History Matched Modeling (Characterization and Quantification)

# P/Z vs. Cumulative Production

## East Barrow Field P/Z vs. CUMULATIVE PRODUCTION PRA 2007 Reserves Study



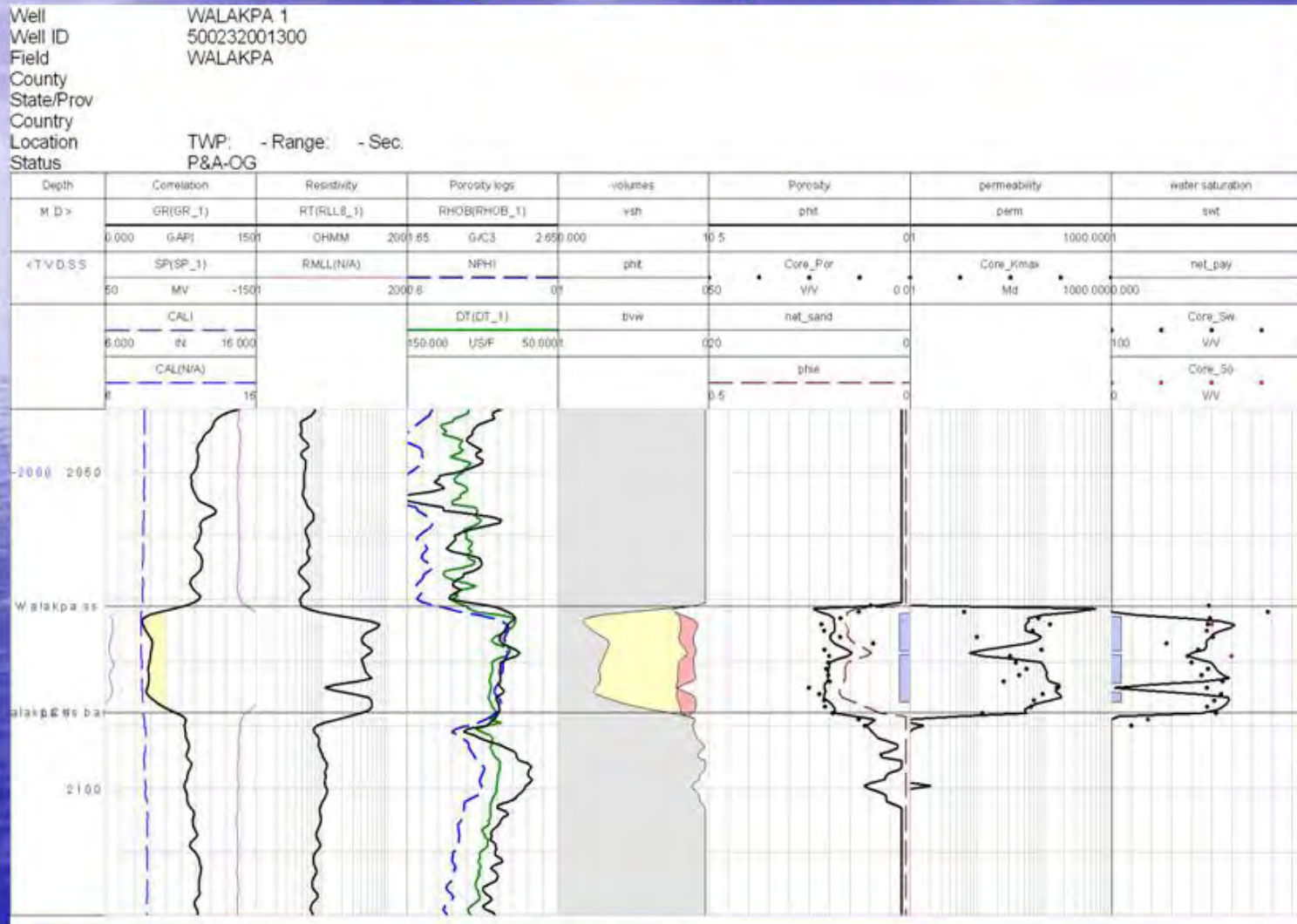
# Well and Seismic Data



Notes by Presenter: Thirty-five wells of variable vintage and data quality. 2D seismic grid of variable spacing and quality.

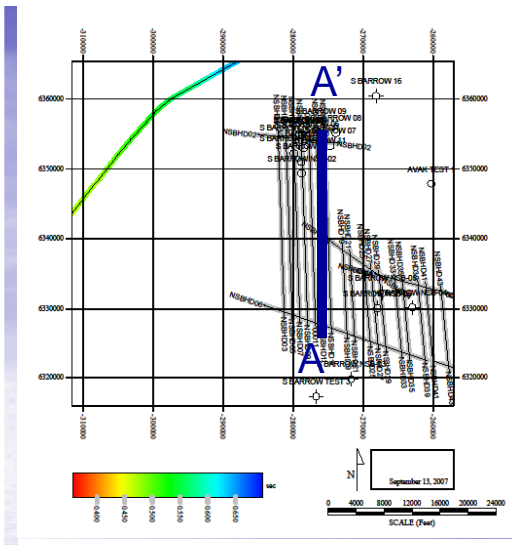


# Well Log Interpretation

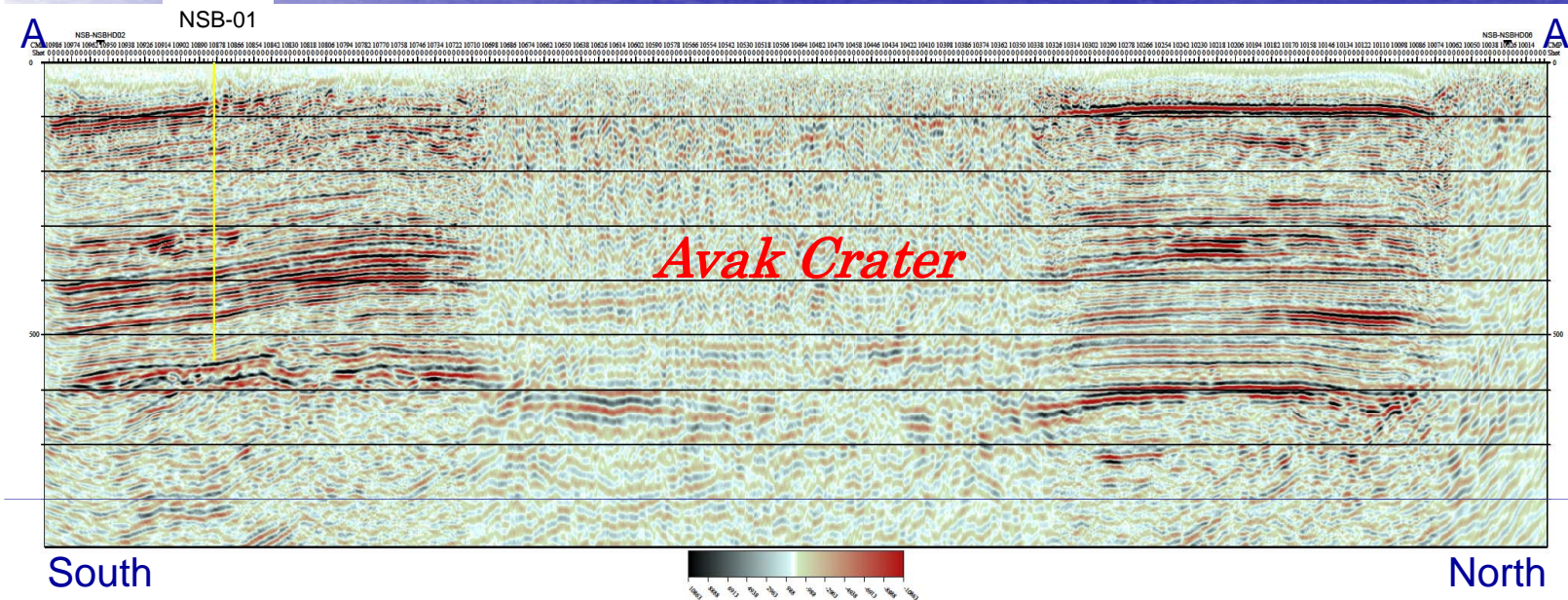


Notes by Presenter: While well show some indication of hydrates, they are by no means conclusive. Elevated resistivity, sonic log spikes, and lack of neutron-density crossover, along with DST results.





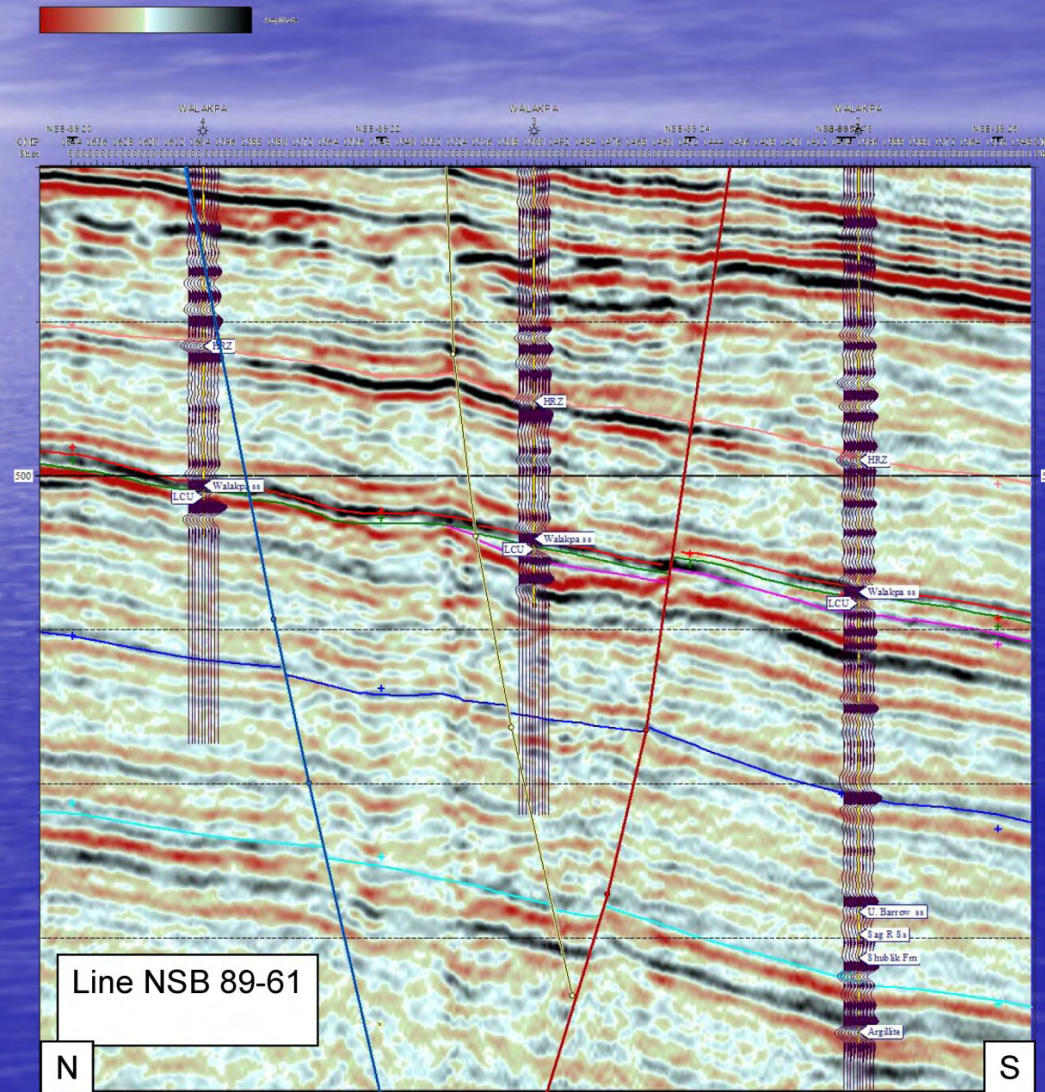
# South Barrow Seismic Line (N-S) Through Edge of Avak Crater to South Barrow #1 Well



Notes by Presenter: South and East Barrow Gas Fields are adjacent to astrobleme rim.



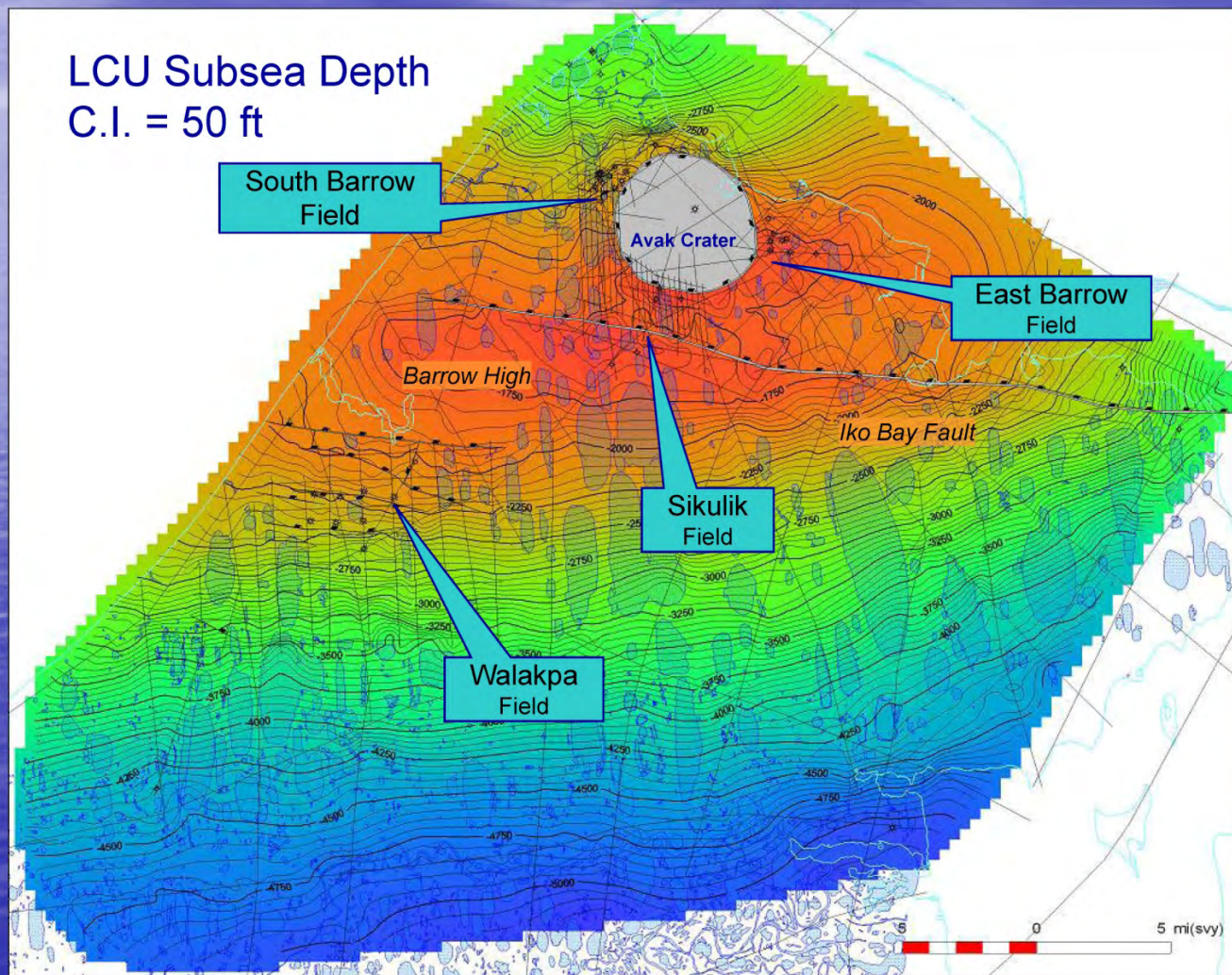
# Seismic Interpretation



Notes by Presenter: Confident seismic to well tie. Decent seismic grid. Able to map LCU and top Barrow SS



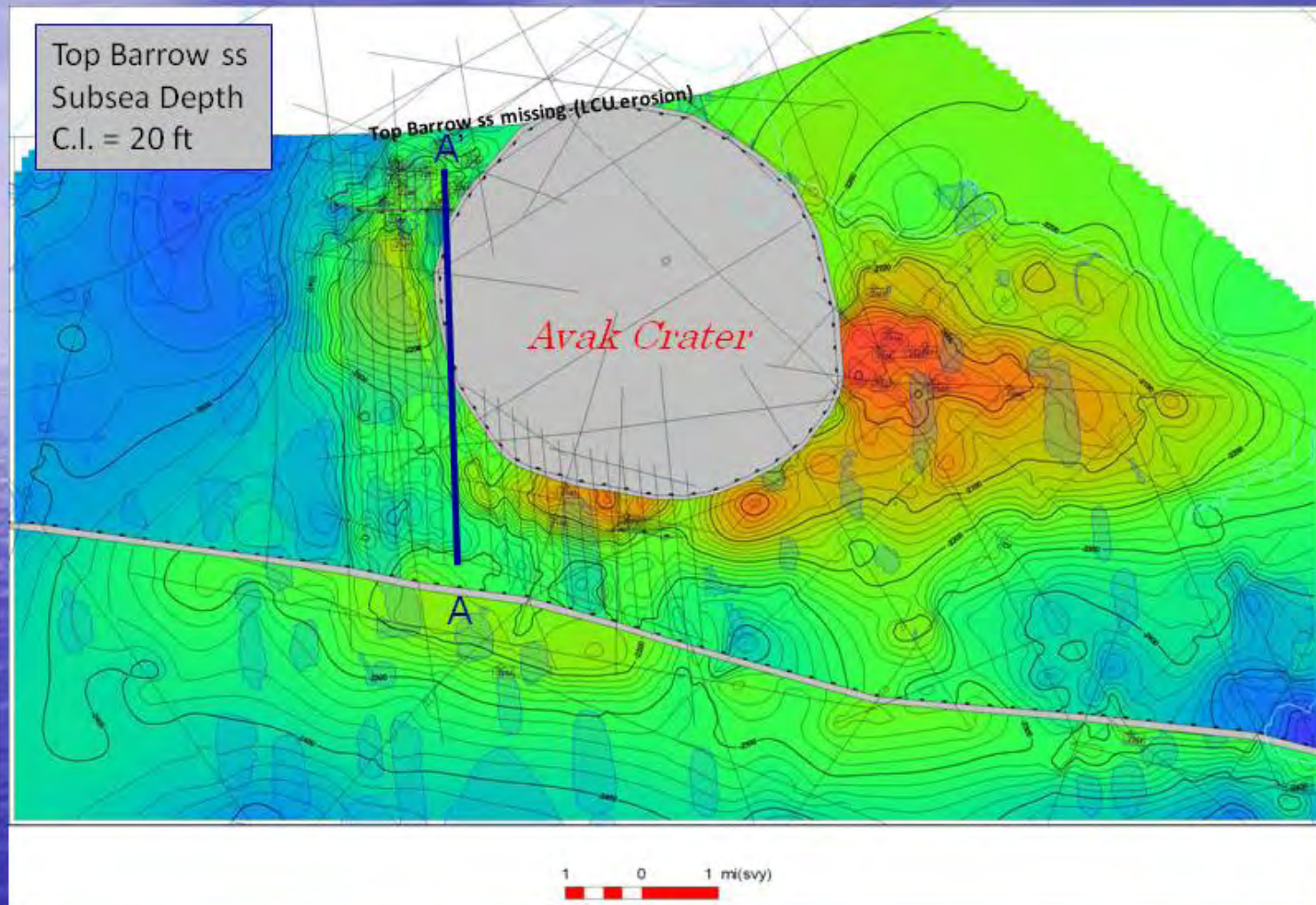
# Regional Structure Map – Walakpa Sand



Notes by Presenter: Barrow Arch, minor faulting, Avak Crater

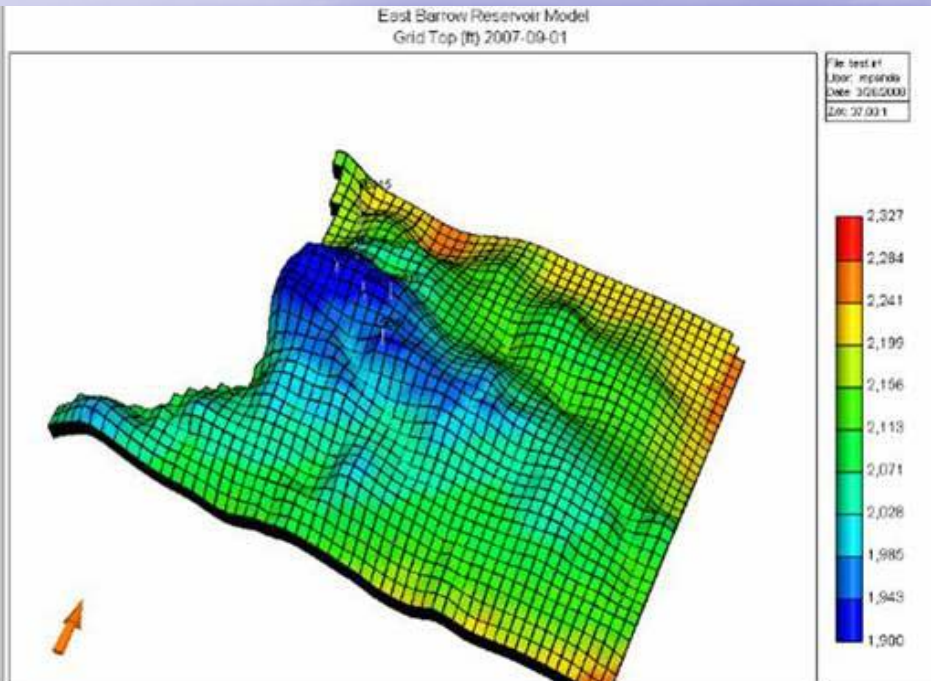


# Structure Map Top Barrow Sand

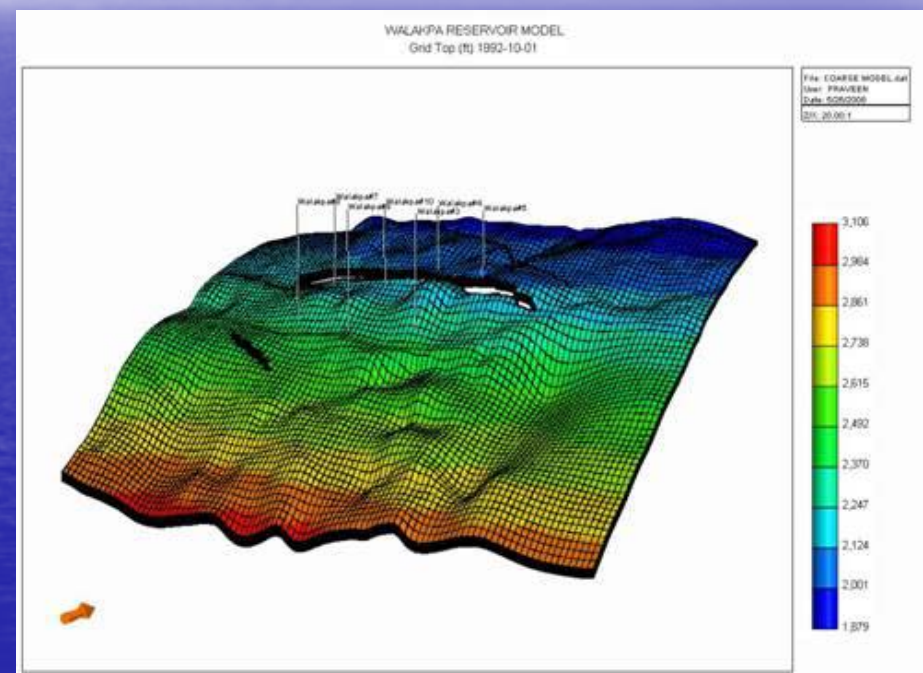


Notes by Presenter: Structure map from seismic of South Barrow and East Barrow gas fields

# Depth Mapping



Depth grid on Top Upper Barrow Sandstone,  
E Barrow Field



Depth Grid on Top Walakpa Sandstone,  
Walakpa Gas Field

Notes by Presenter (for previous slide):

Defining the container

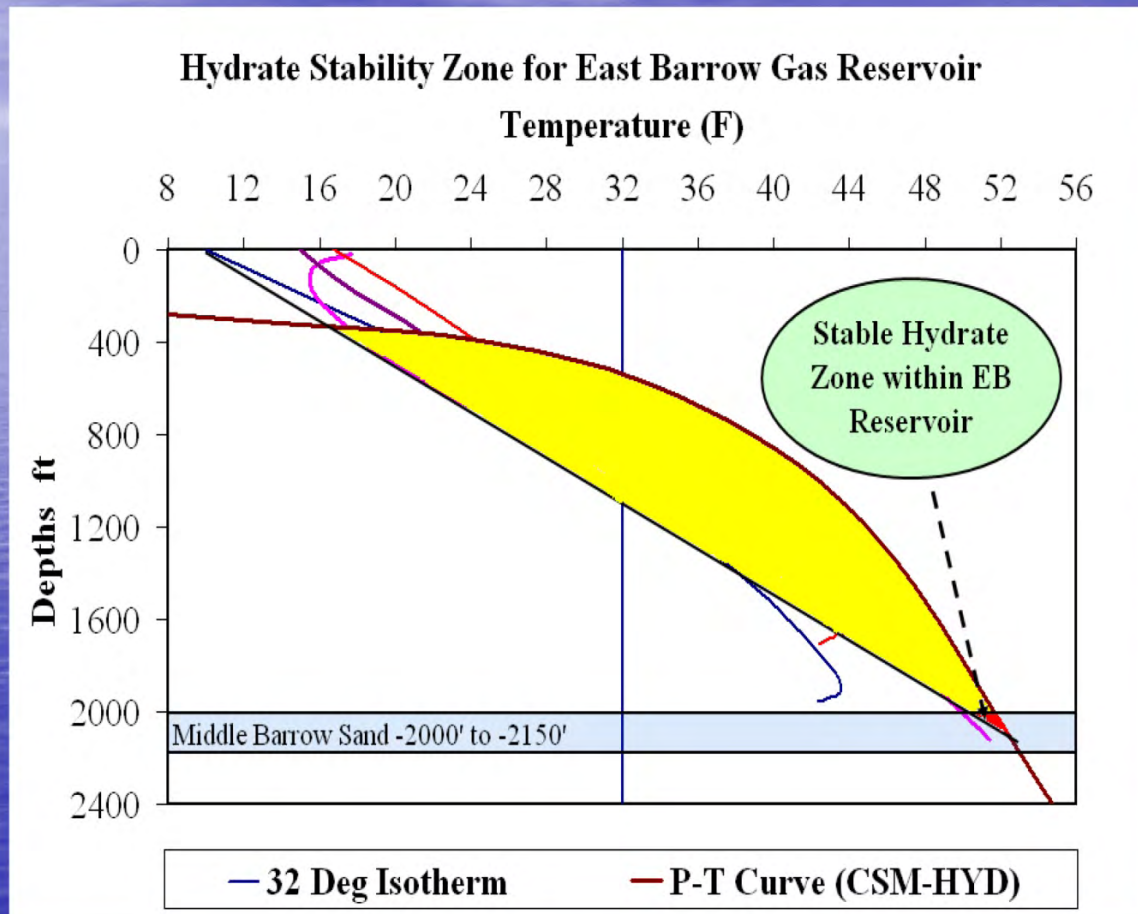
EB three way dip closure against crater

Walakpa monoclinial with stratigraphic or hydrate seal

Detailed RMS reservoir models



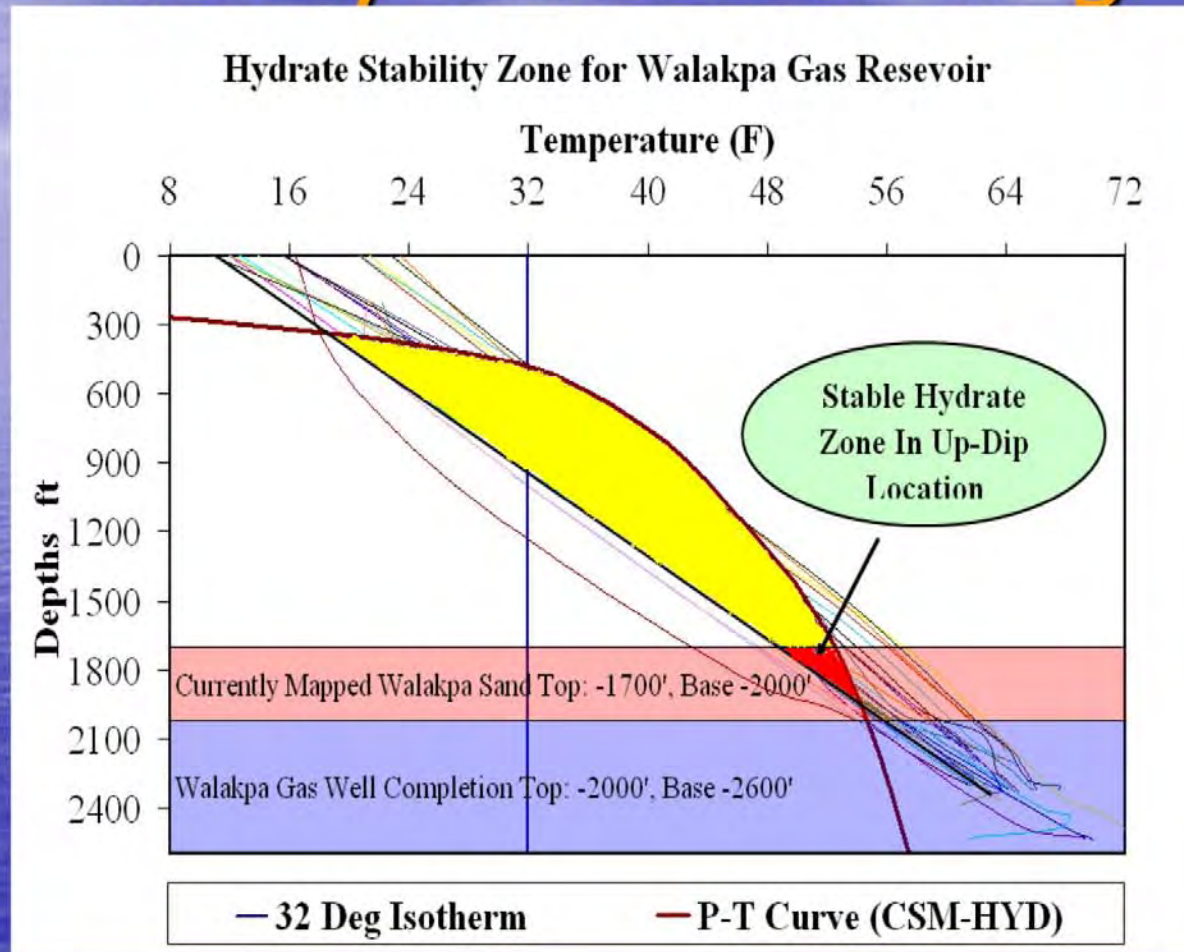
# Stability Zone Modeling



## Methane Hydrate Stability Zone Modeling for East Barrow Gas Field

Notes by Presenter: HSZ modeling conducted at UAF parallel to seismic interpretation. BHSZ intersects top of reservoir.

# Stability Zone Modeling

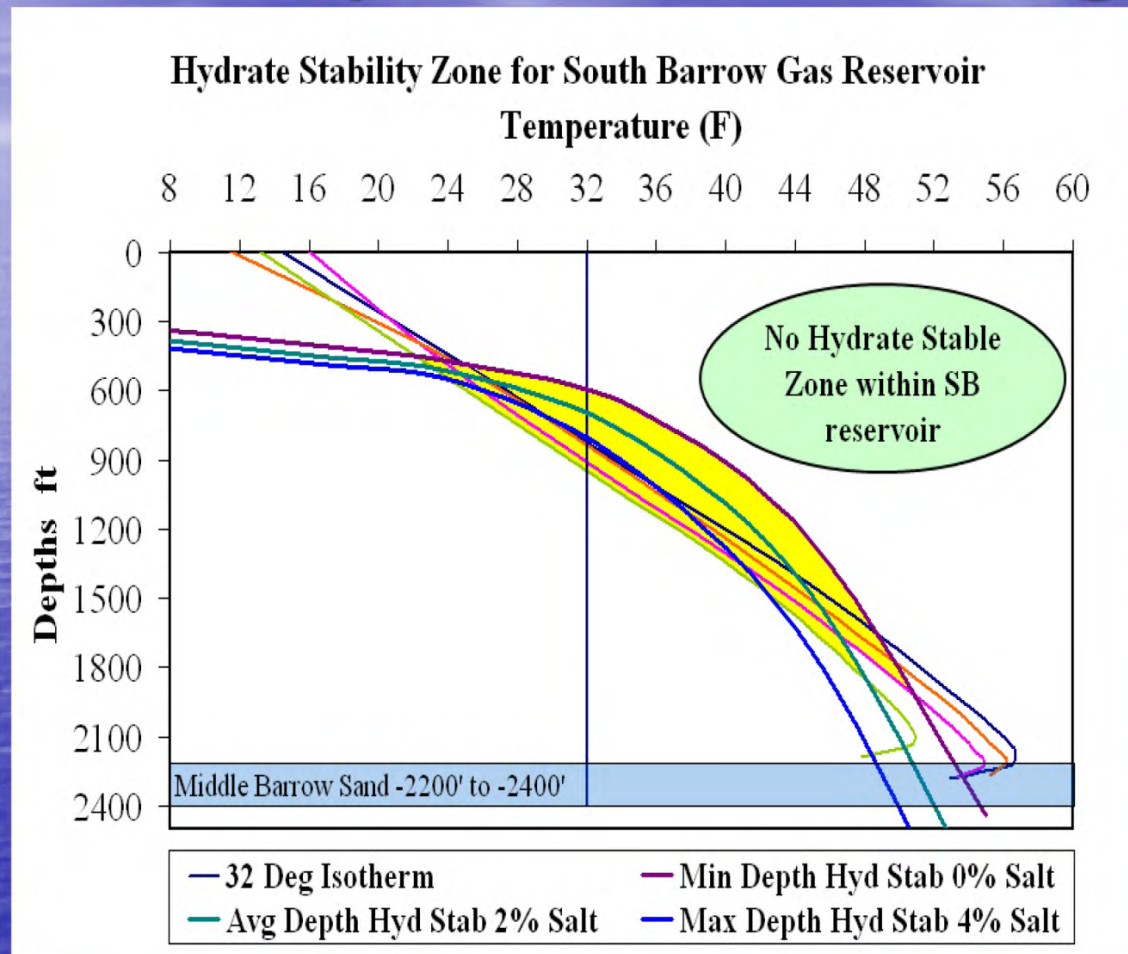


## Methane Hydrate Stability Zone Modeling for Walakpa Gas Field

Notes by Presenter: BHSZ penetrates reservoir shallower than updip-most well (Walakpa #1).



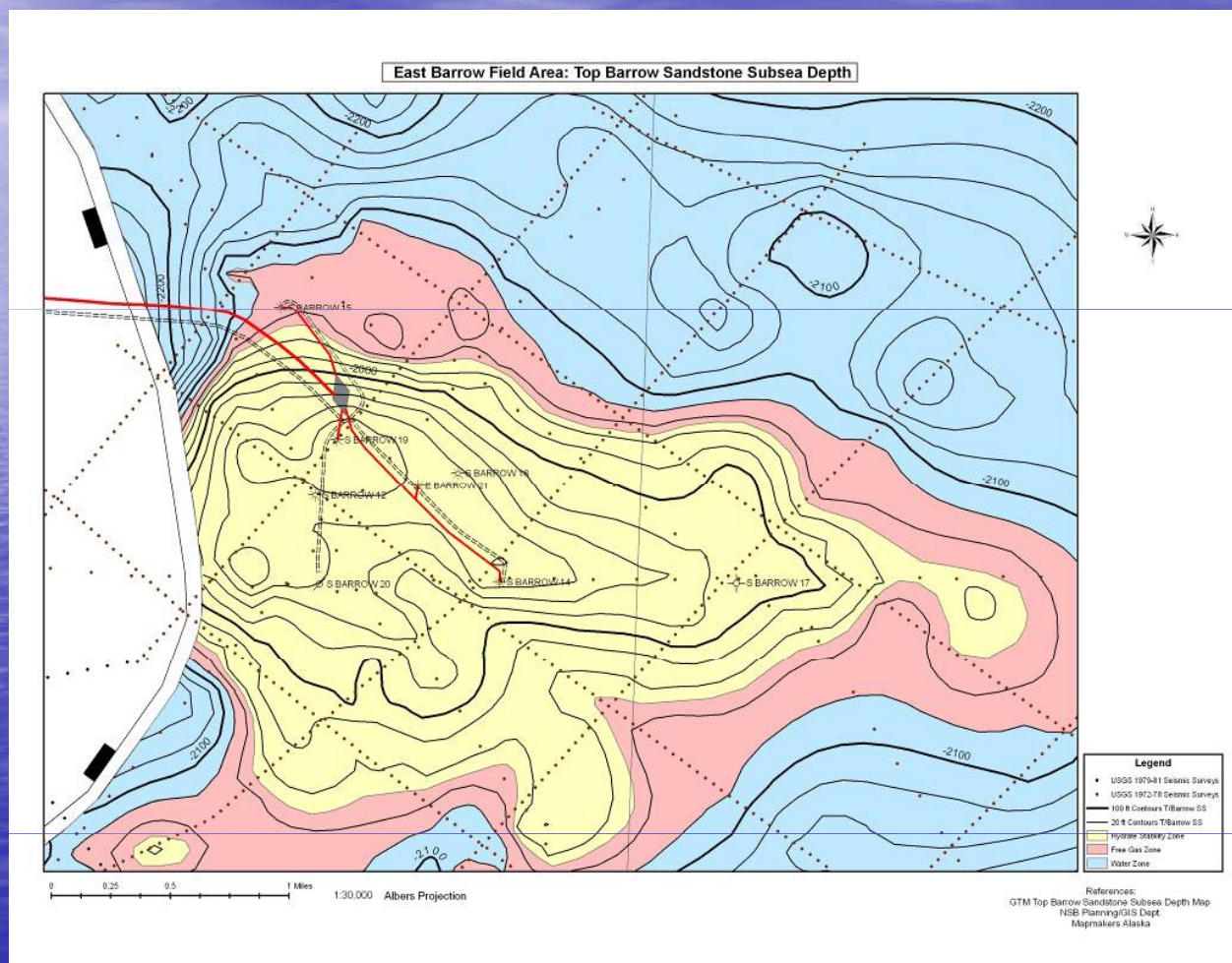
# Stability Zone Modeling



## Methane Hydrate Stability Zone Modeling for South Barrow Gas Field

Notes by Presenter: No intersection of BHSZ and reservoir, and no material balance support for hydrate.

# Modeled most likely hydrate stability zone depth in East Barrow Field

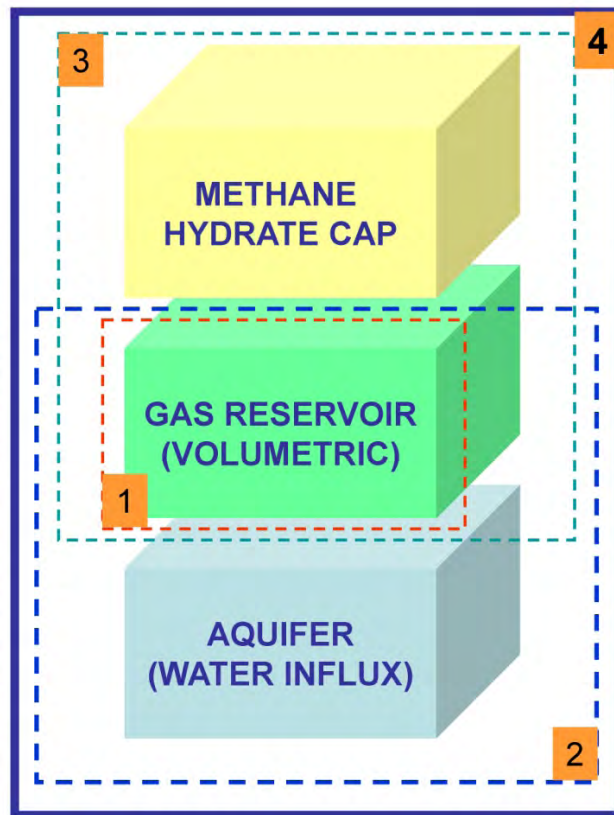


Notes by Presenter: Structure map from seismic and well control showing the hydrate cap, free gas leg, and water leg on the top of the Barrow SS. BHSZ at 2050', GWC at 2080' TVDSS.



# Material Balance

## MATERIAL BALANCE STUDIES



### STEP 4.

#### CMG-STARS Model

*(Steam, Thermal & Advanced Reservoir Simulator)*

*[Computer Modeling Group 2005v.10]*

### STEP 3.

#### Hydrate Model

*[Gerami & Darvish, 2006]*

### STEP 1.

#### Volumetric (EMB) Model

*[West & Cochrane, 1994]*

### STEP 2.

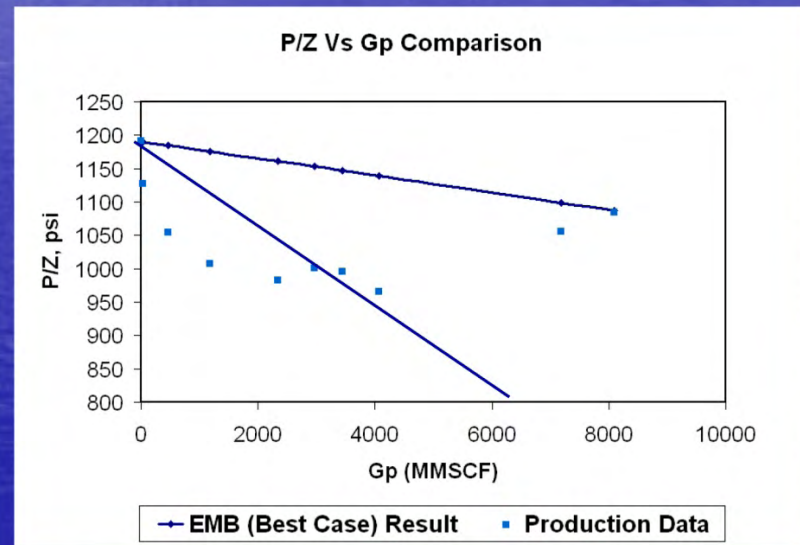
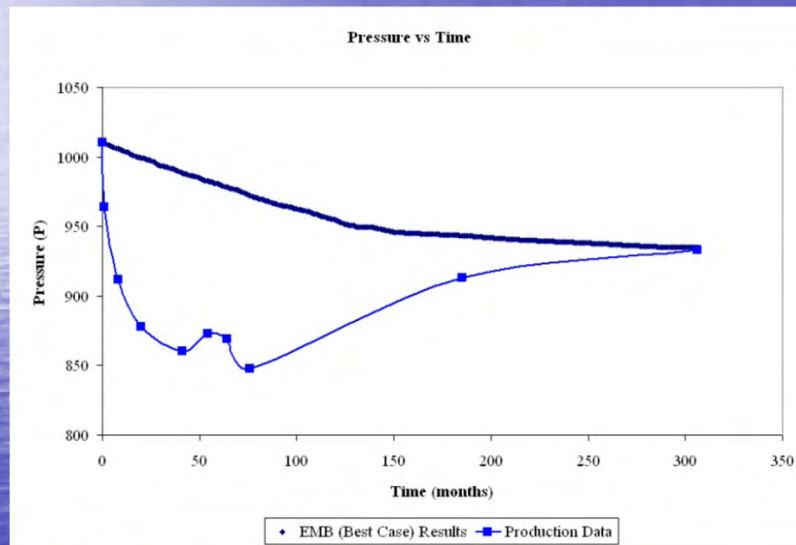
#### Water Influx Model

*[Pletcher 2001, Ahmed & McKinney 2005]*

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**Tank Modeling (Material Balance): Three elements of pressure support**

# Material Balance

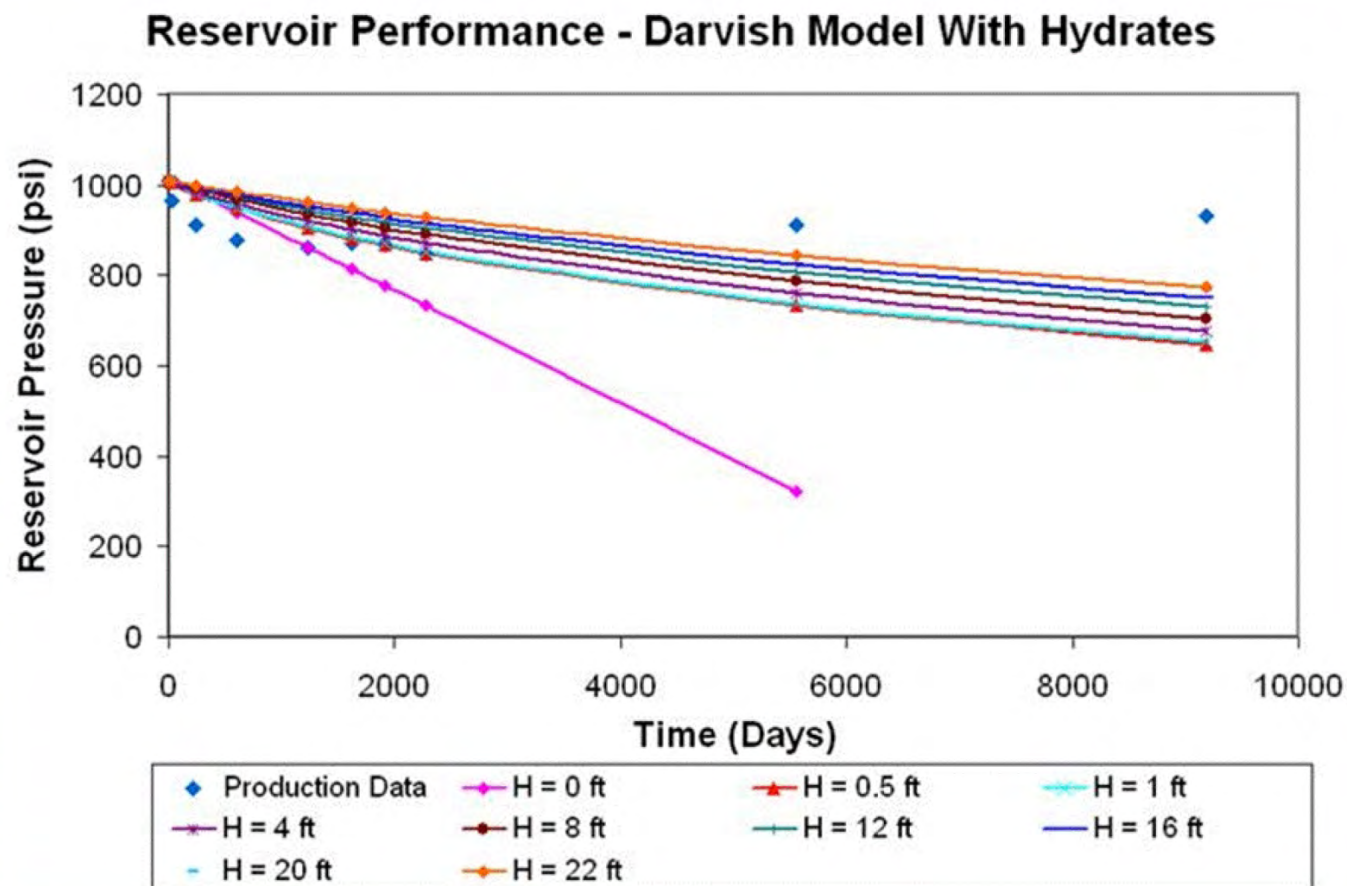


**EMB Model – Pressure (P) vs. Time plot and P/Z vs. Gp plot for East Barrow gas reservoir**

Notes by Presenter: Volumetric cannot explain response. 6.5 BSCF original reserves estimate. OGIP cannot be estimated from material balance.



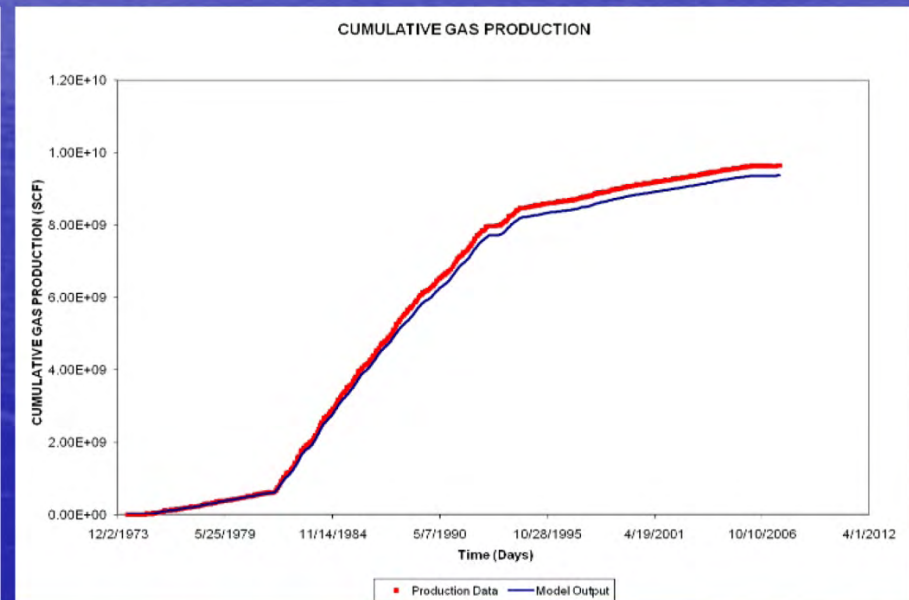
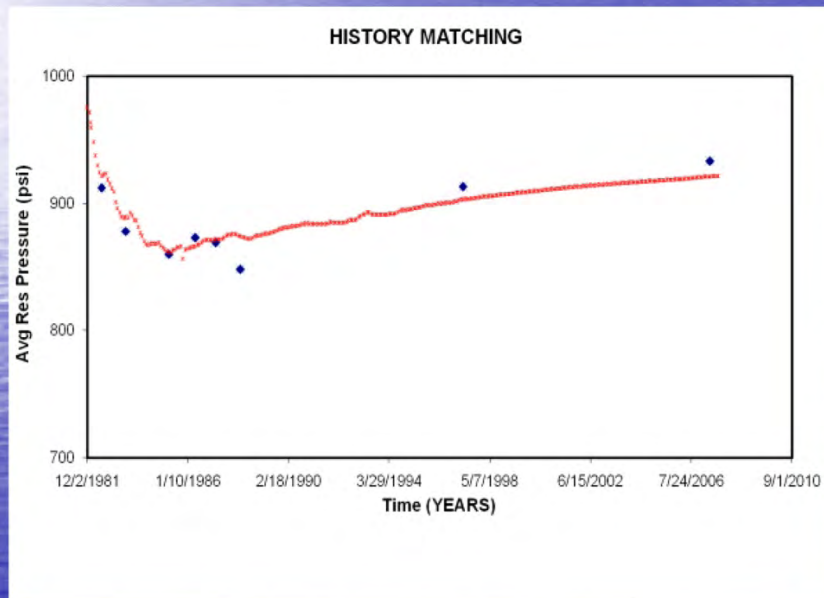
# Material Balance



**EMB Model – Pressure (P) vs. Time plot for various depletion mechanisms**

Notes by Presenter: Introduction of hydrate layer at top of reservoir helps match reservoir pressure response.

# Full Field History Match

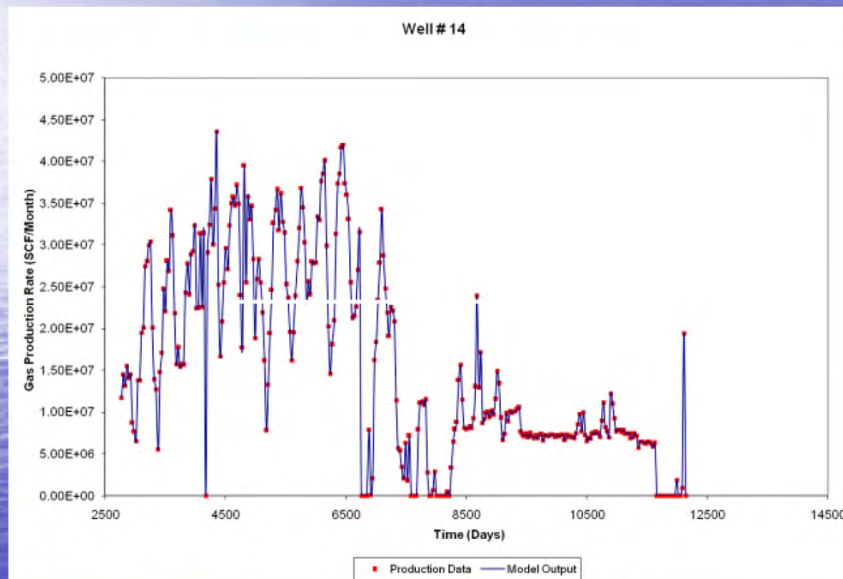


**Barrow Field Average Reservoir Pressure and Cumulative Production History Match**

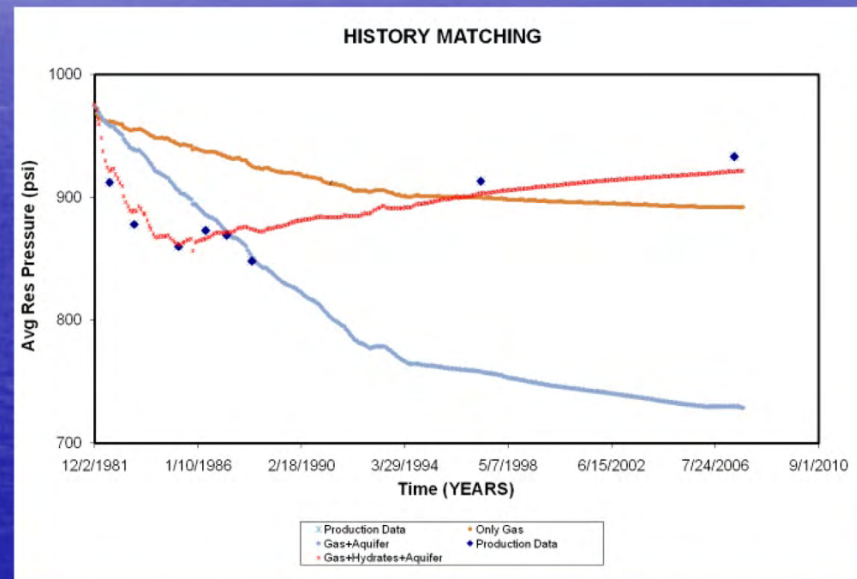
Notes by Presenter: History matched pressure, water and gas response field wide and well by well



# E. Barrow #14 History Match



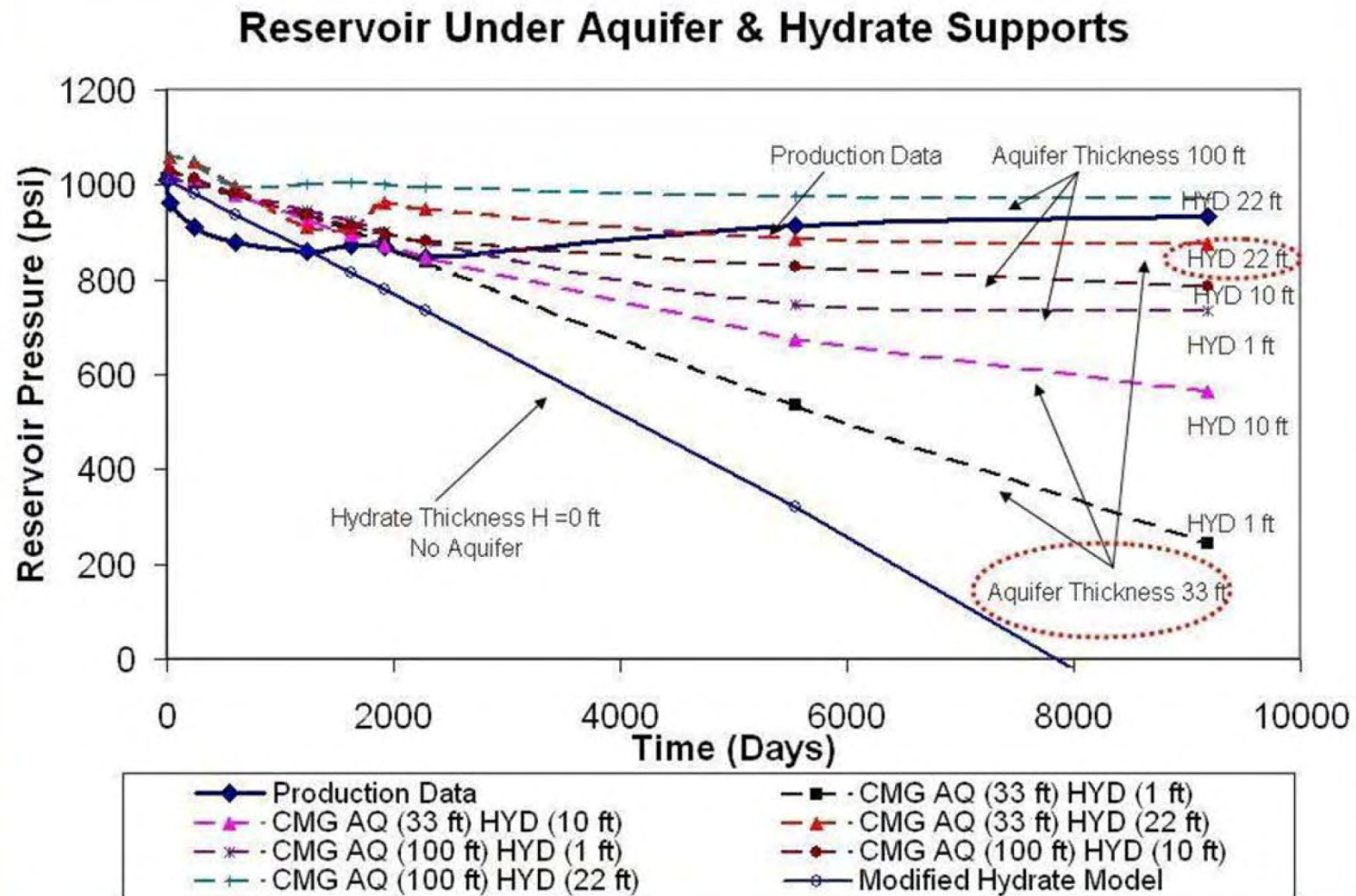
History match EB# 14 well



Fieldwide Average Pressure History Match

Notes by Presenter: Well level response of EB-14 and field-level pressure response

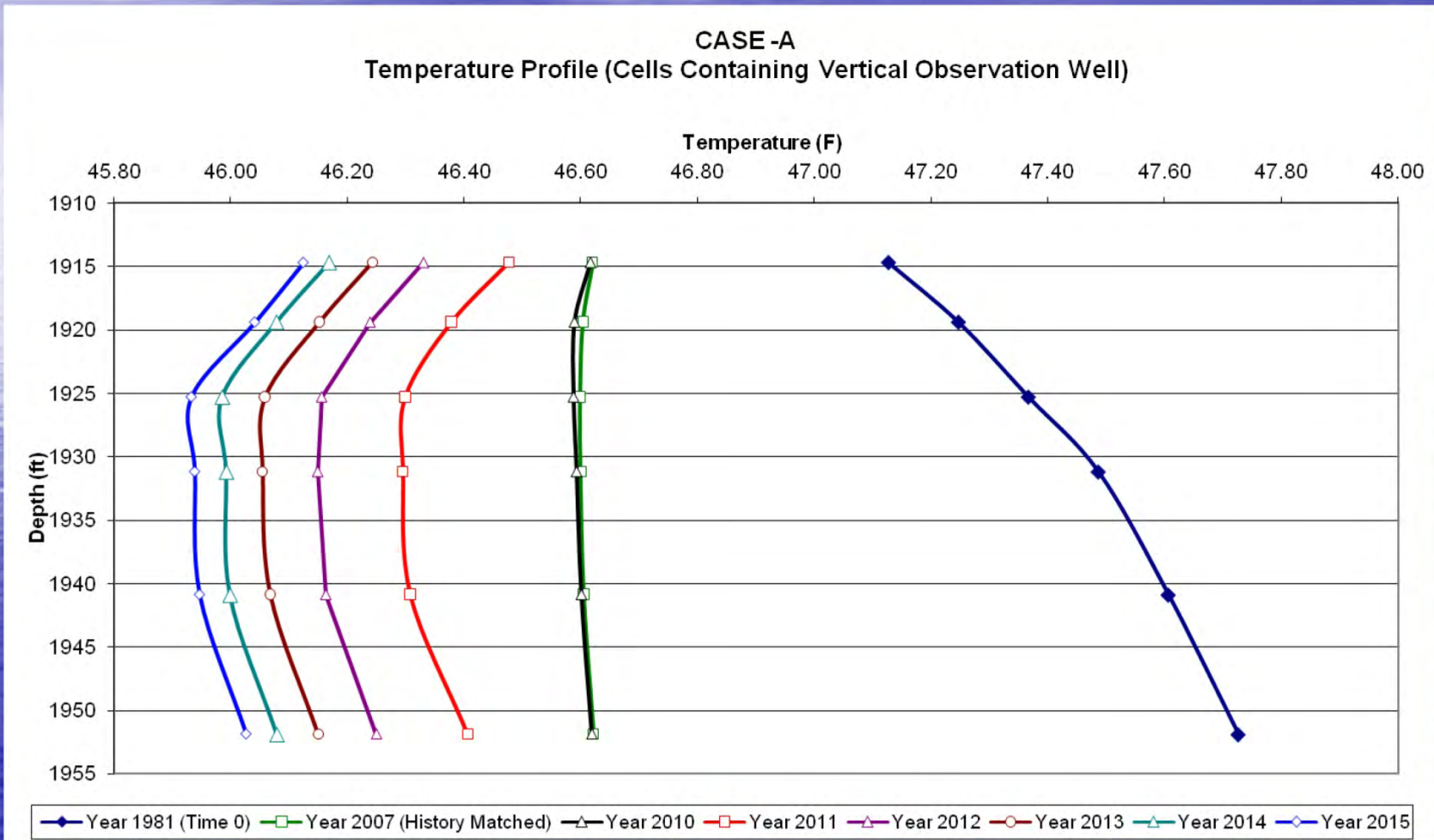
# History Matched Model



Notes by Presenter: Full Field history match, hydrate thickness of 22 ft., and aquifer of 33 ft. best fit



# Temperature Response in Observation Well



Notes by Presenter: Fine-grid simulation modeling shows that the observation well should see cooling as hydrate layer disassociates. Thermal modeling indicates that we should be able to detect hydrate dissociation (endothermic response).

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# Drill, Complete and Test

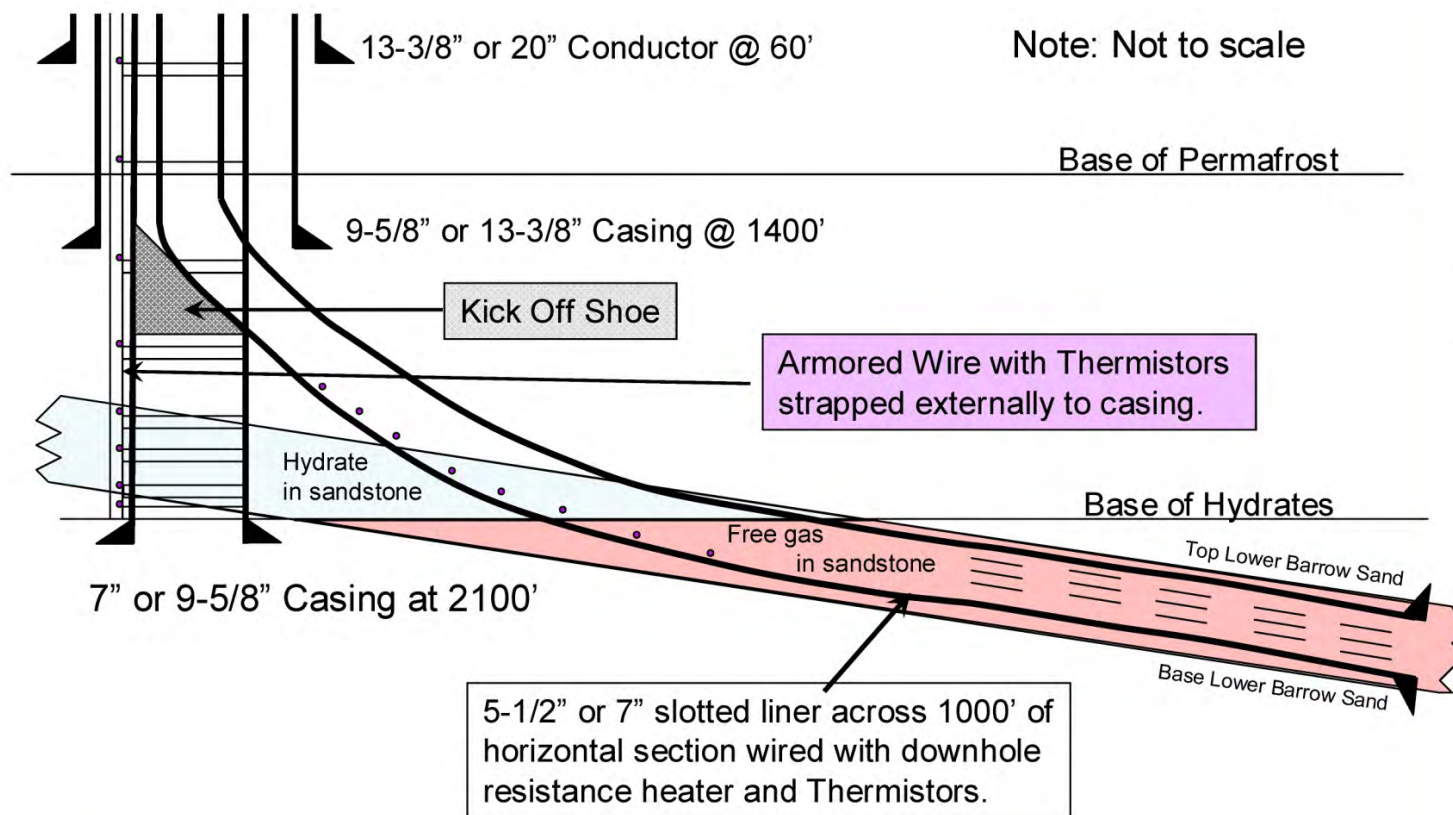
- Prove existence of in situ methane hydrates (core, log, geochem)
- Prove hydrate dissociation and production (Distributed Temp Survey, gas and water comp)
- Design and drill methane hydrate production test well
- Surveillance program to monitor reservoir pressure and temp, water and gas composition and isotopes

# Well Design Objectives

- Producer can produce at sufficient rates to change the hydrate layer at the observation well.
- The response at the observation well should not be affected by near wellbore production affects.
- Conclusion – Dedicated single wells, producer drilled as a high angle or horizontal well.

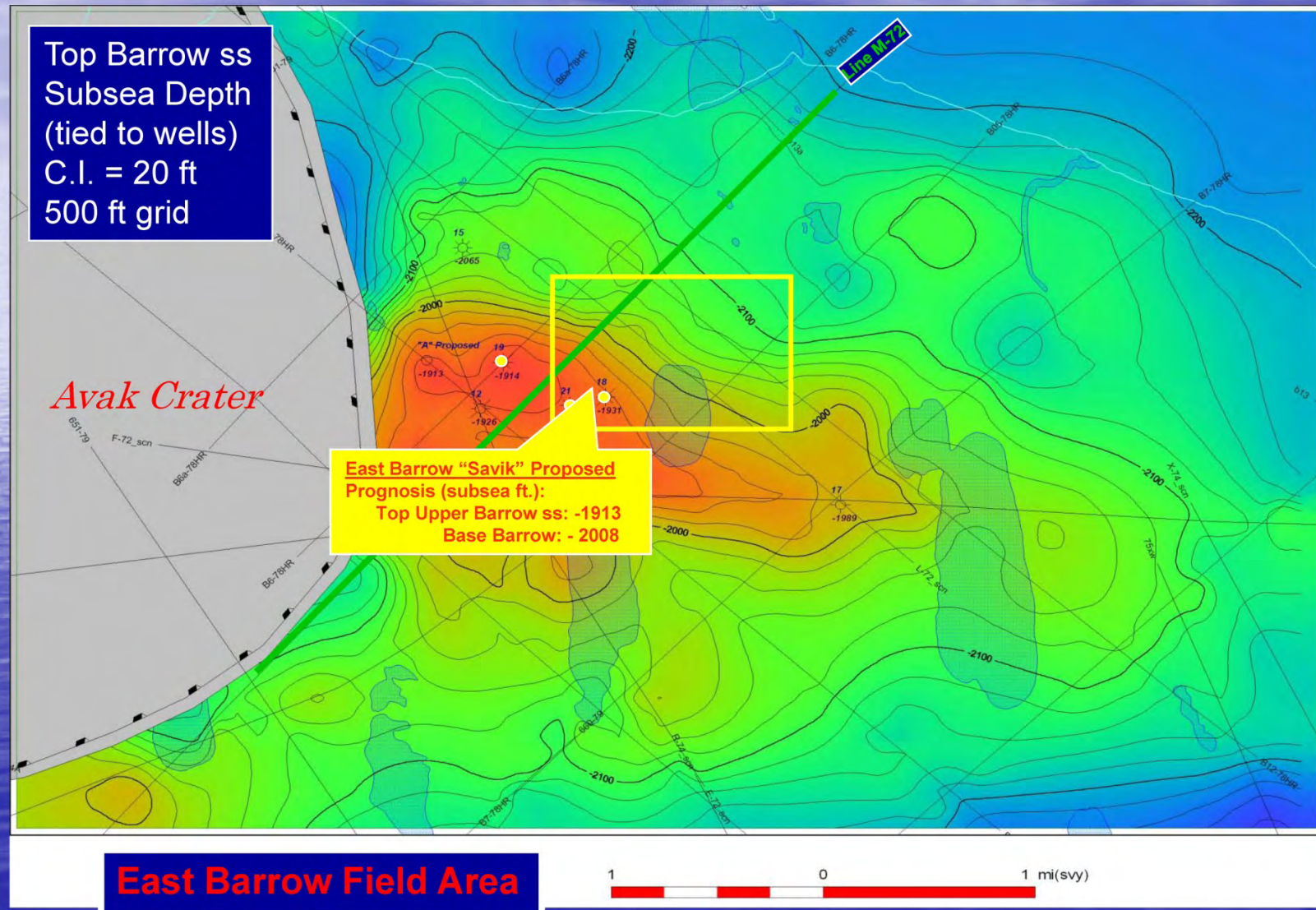


# E Barrow Hydrate Test Well Conceptual Design



Notes by Presenter: Original plan to drill one well. Does not comply with near-wellbore production effects constraint.

# Barrow SS Depth Structure, E. Barrow

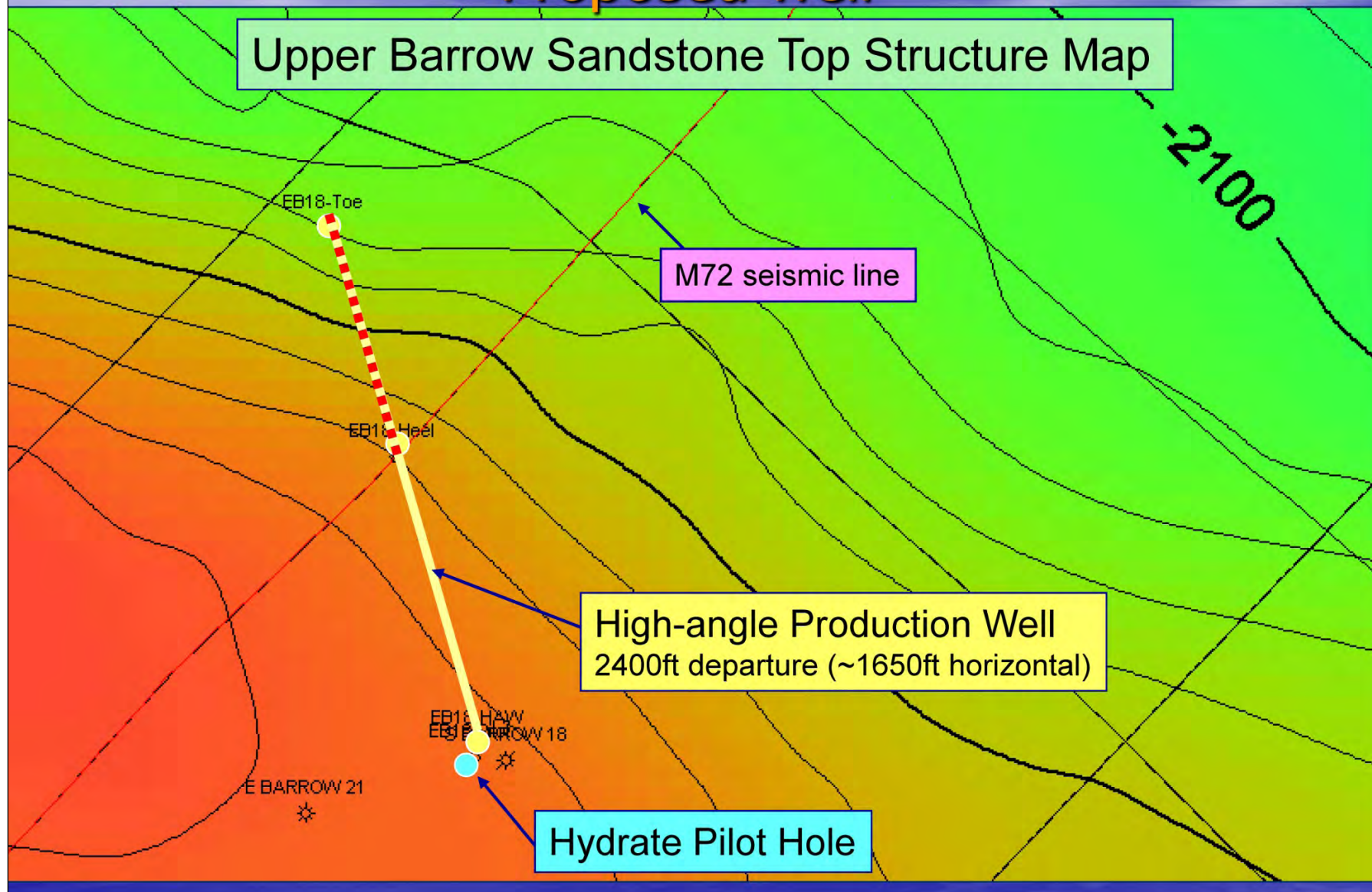


Notes by Presenter: Crestal location. Well and seismic control. Steep dip



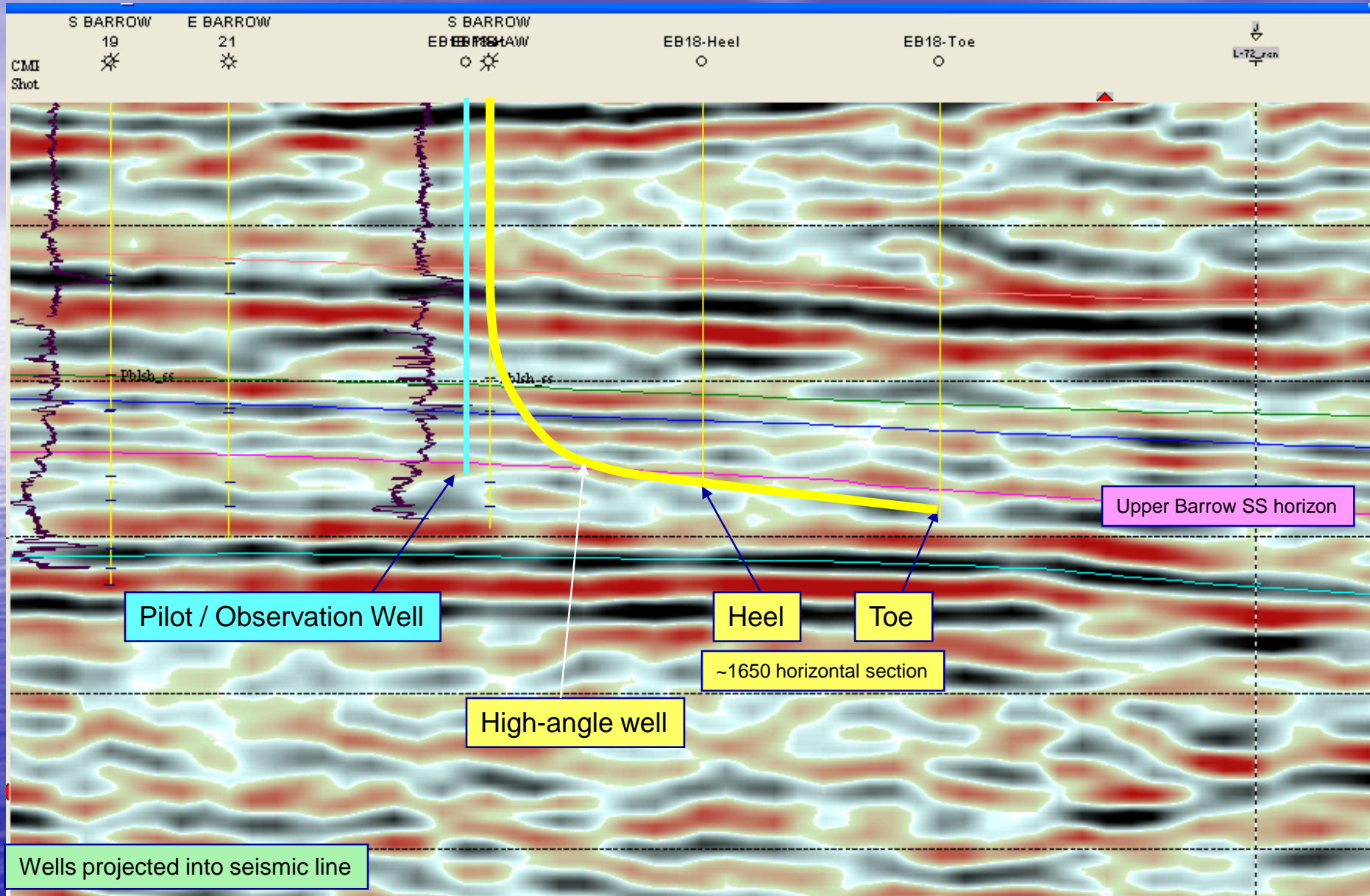
# Barrow SS, E. Barrow Field Proposed well

## Upper Barrow Sandstone Top Structure Map



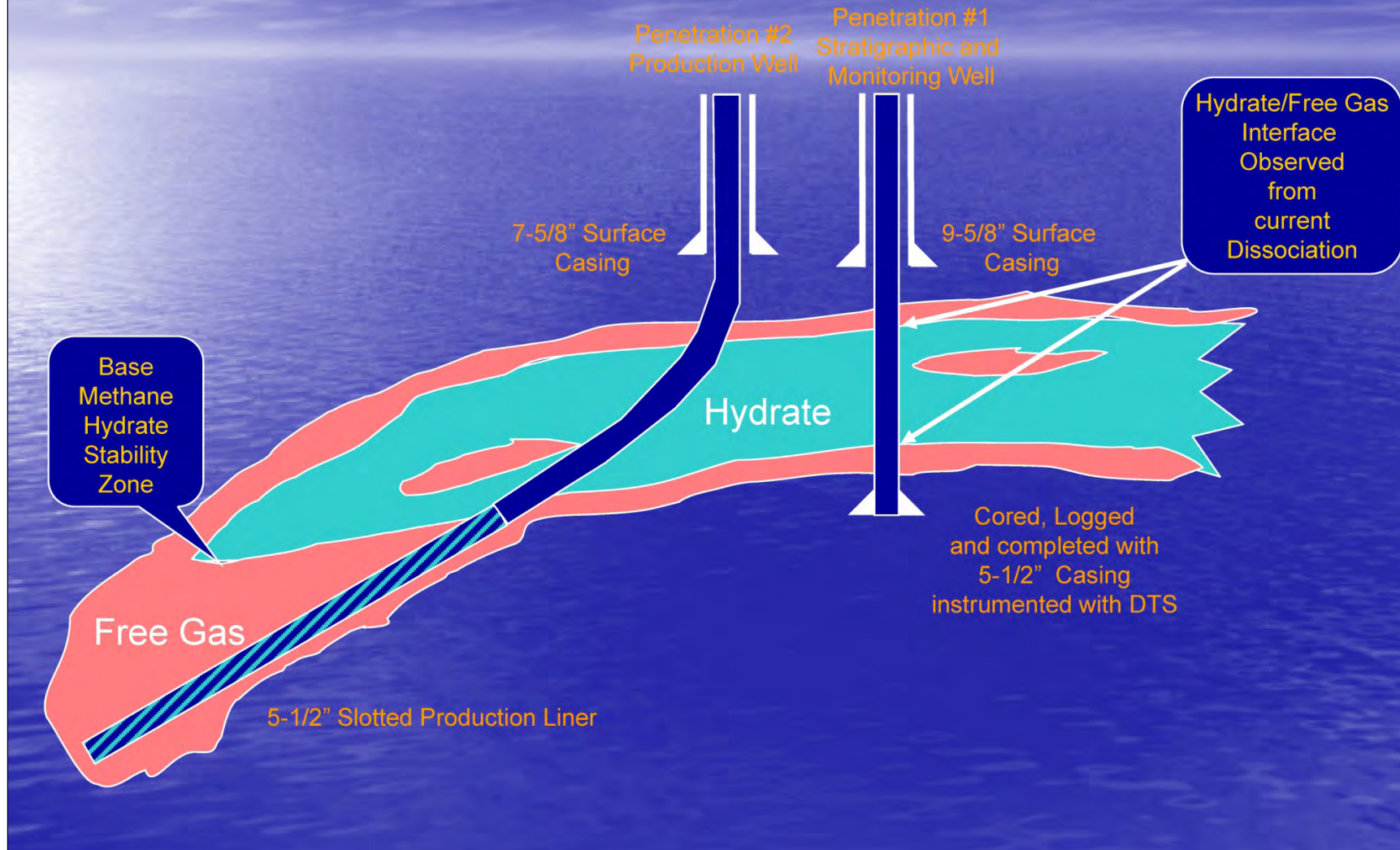
Notes by Presenter: 1650' horizontal section from HSZ to free gas

# M72 Seismic Line





# E Barrow Methane Hydrate Well Drilling/Completion Sequence



Notes by Presenter: Pilot hole, "horizontal" producer, expect discontinuous hydrates

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# Project Status

- Project start Nov. 14, 2006
- Phase 1 Completed March 2008. All modeling results support move to Phase 2
- Phase 2 initiated December 1, 2008. Design dedicated hydrate production test and observation well
- Planning, Procurement, Cost Estimate
- DOE Decision Not to Fund Execution in Dec. 09

# Conclusions

- Borough Continuing with Development Drilling Plan, Spud in October 2011
- Research Effort Suspended Due to DOE Decision
- Possibility of alternative research funding