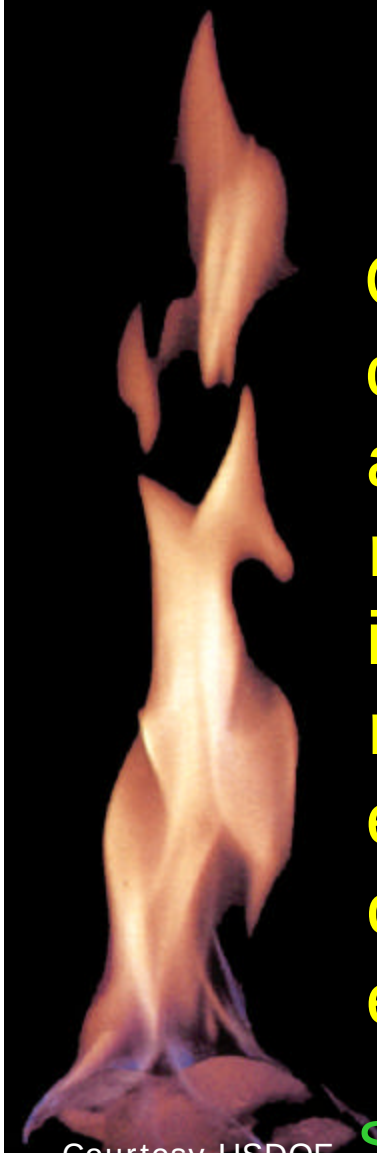
BP Exploration (Alaska), Inc. Methane Hydrate Project

Robert Hunter

Project Manager, Independent Consultant

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



Courtesy USDOE

September 29, 2003 – DOE Hydrate Conference

Methane Hydrate Project Presentation Outline

- Research Alignment and Teams
- Gas Hydrate Resource Potential
- Alaska North Slope Review
- BP Gas Hydrate Research Program
  - Resource Characterization
  - Resource Development Modeling and Technology

Methane Hydrate Research Alignment and Interaction

U.S. Department of Energy

GOVERNMENT

Unconventional Resource Determination

3D Seismic & Well Data, Infrastructure

INDUSTRY

Resource Evaluation

Research/ Expertise

UNIVERSITY

Research Innovation

USGS science for a changing world

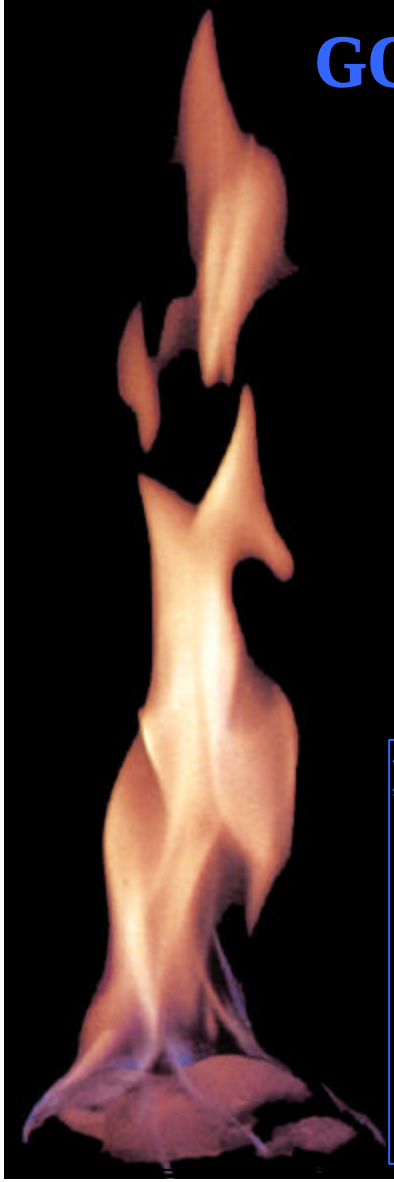
THE UNIVERSITY OF ARIZONA

UAF UNIVERSITY OF ALASKA FAIRBANKS

Collaborative Research

- Industry-Focused Project Funding
  - Encourages Industry Collaboration
    - Enables Methane Hydrate Project Research
  - Ensures Research Fit-for-Purpose
    - Enables Long-Term Value
  - Supports Industry & Government Goals
    - Enables Resource Decisions and Planning
- Industry – Academic Research Alignment
  - Research Topic Important to Both
  - Industry Not Inclined to Self-Perform
  - Industry-Directed Research Programs
  - Industry Expectations Clear
  - Industry-focused Research Results

Methane Hydrate Program Collaborative Research Team



GOVERNMENT

USGS science for a changing world

USGS Lead
Gas Hydrates
Timothy Collett

USGS
Geophysics
David Taylor

USGS
Geophysics
Myung Lee

INDUSTRY

bp

Alaska Gas
Ken Konrad

Technical Advisor
Scott Digert

Gas Hydrate
Project Manager
Robert Hunter

UNIVERSITIES

UAF University of Alaska Fairbanks

UAF PI
Engineering
Shirish Patil

Co-PI
Abhijit Dandekar

Participating
Scientist
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Participating
Scientist
Godwin Chukwu

Participating
Scientist
David Ogbe

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UA PI
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Mary Poulton

Co-PI
Geoscience
Charles Glass

Consultant to UA
Geoscience
Ken Mallon

National Laboratory Collaborative Projects

Lawrence-Berkeley

LBNL Lead
Reservoir Model
George Moridis

Pacific Northwest

Pete McGrail (PNNL)
Tao Zhu (UAF)
CO_2 Injection

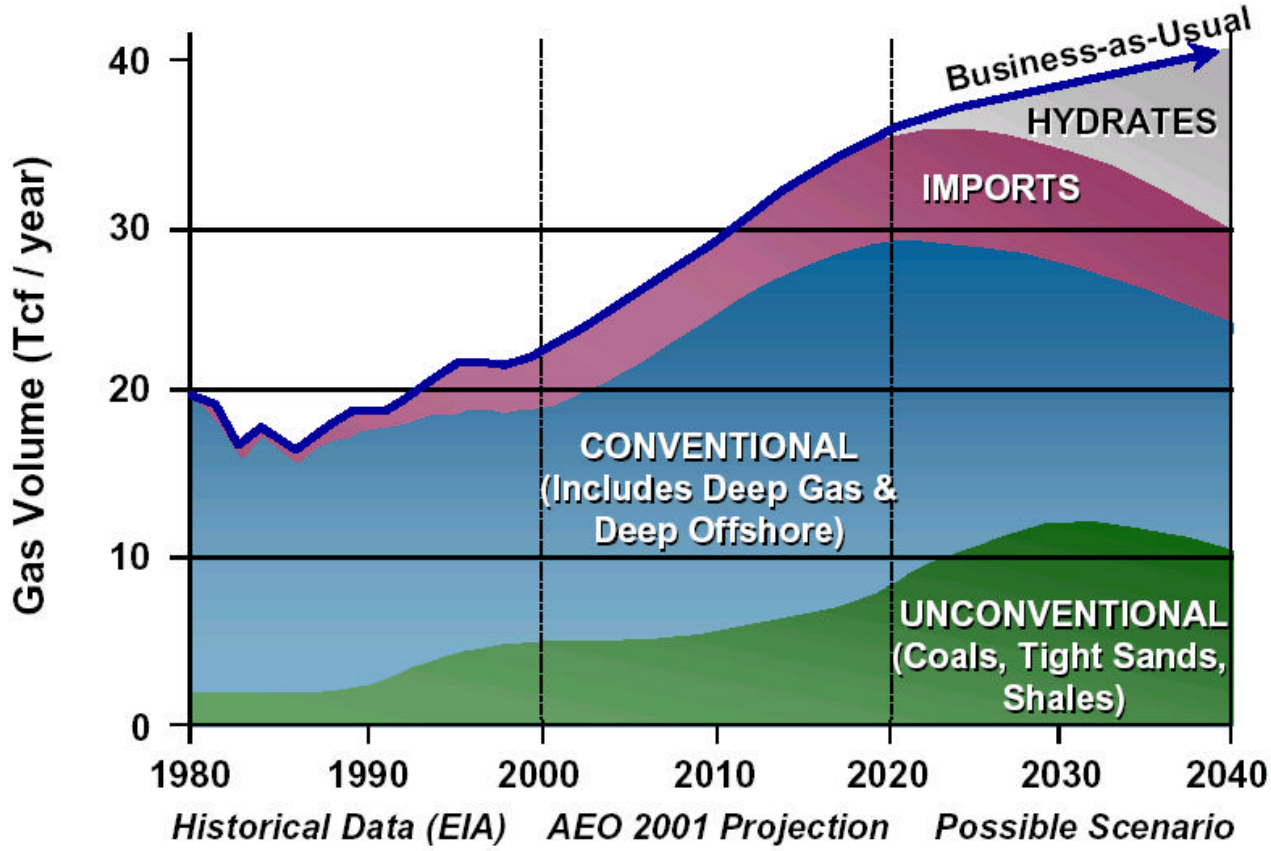
Arctic Energy UAF-DOE

Argonne

Arun Wagh (ANL)
Ceramicrete Cement

Methane Hydrate Resource - Potential to Fill Projected Gap?

Enough Affordable Gas to Meet Demand?

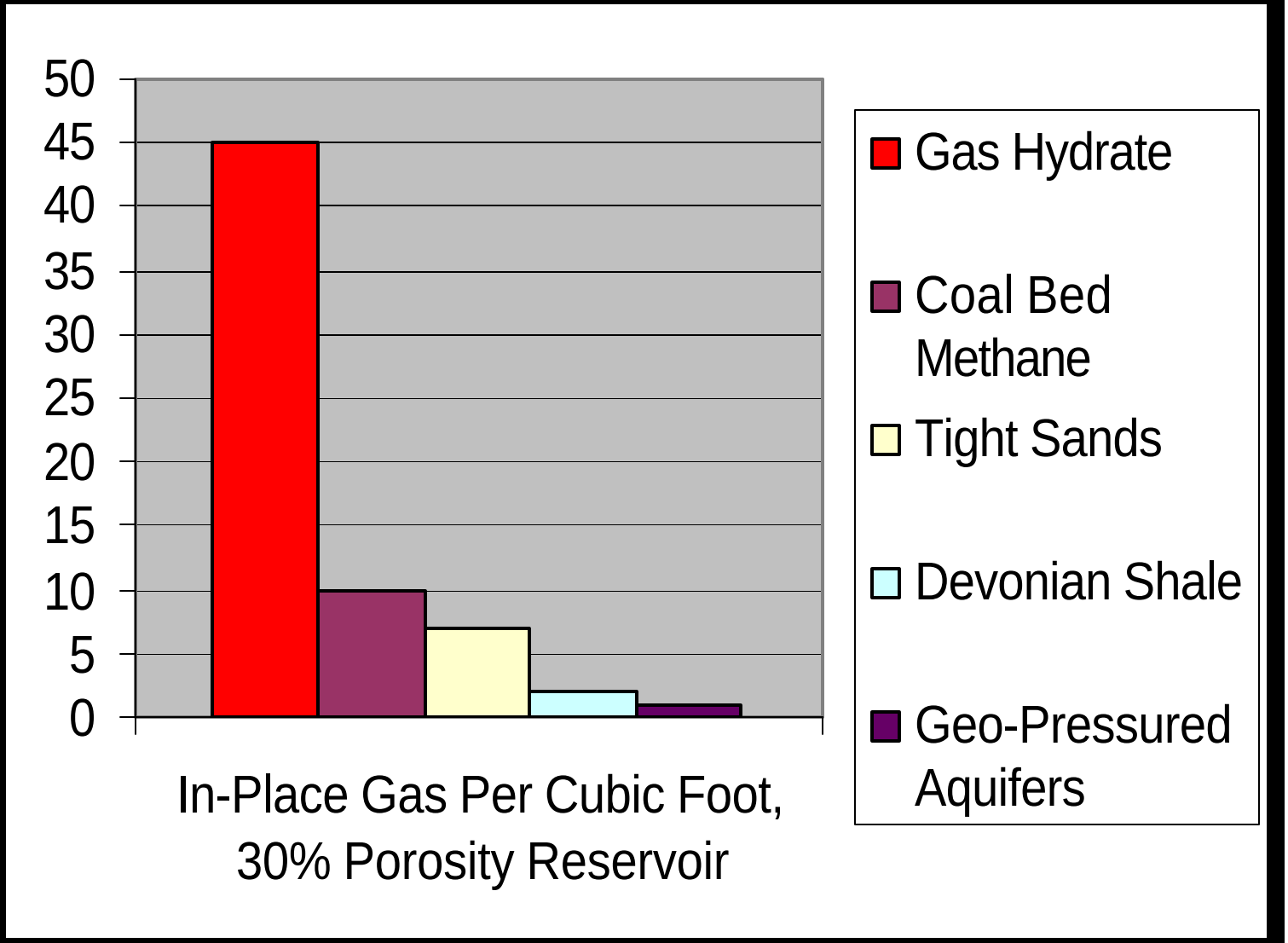


Options to Increase Gas Supply

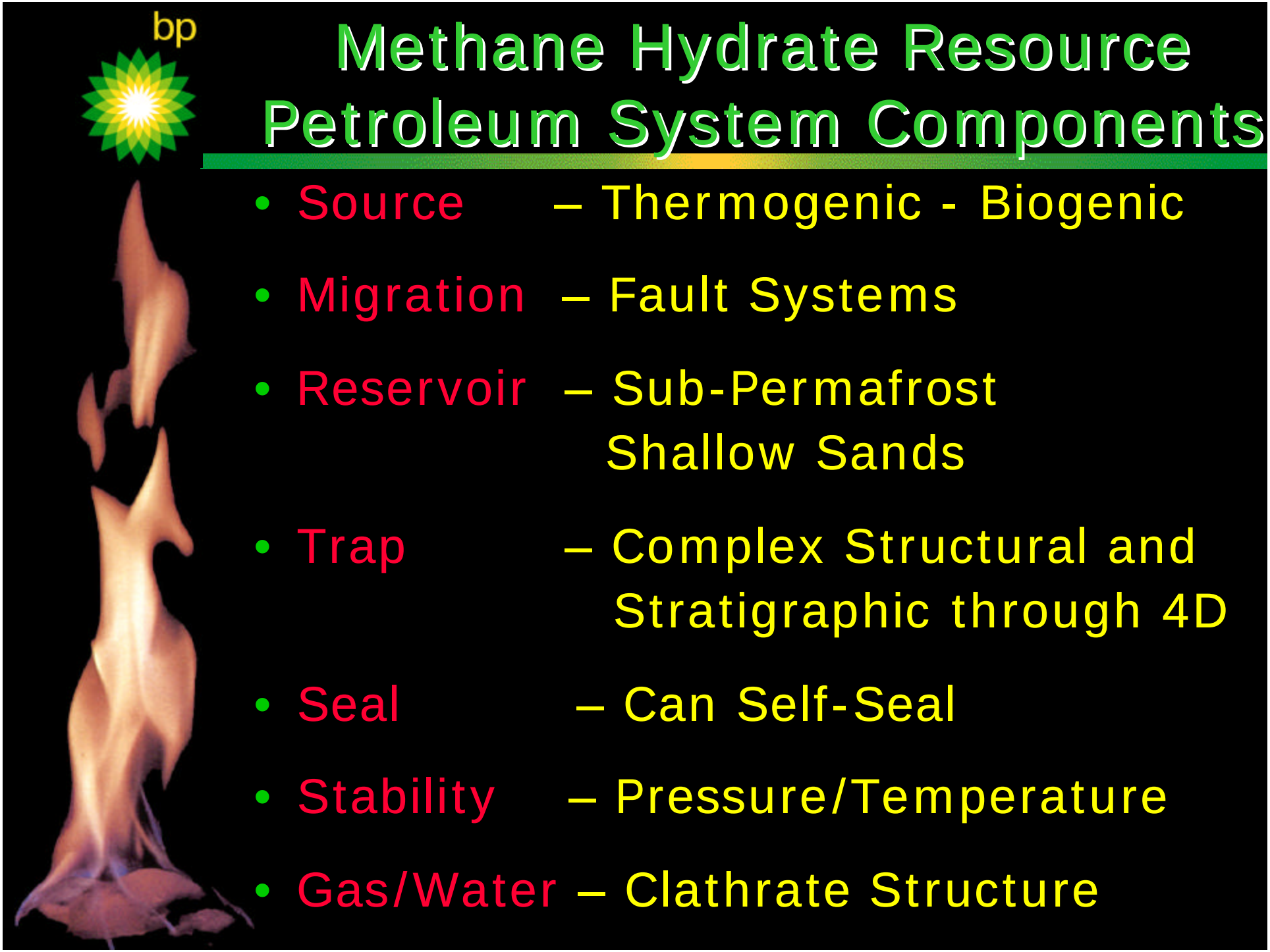
- Open Exploration/Production Areas
- Increase LNG Imports
- Develop Unconventional Resources
  - Coalbed Methane
  - Deep Gas
  - Shale Gas
  - Gas Hydrate
    - Best Gas Storage Capacity
    - Technically and Economically Challenging

HEI

Unconventional Gas Resources
Gas Storage Capacity Contrast



After National Petroleum Council, 1992

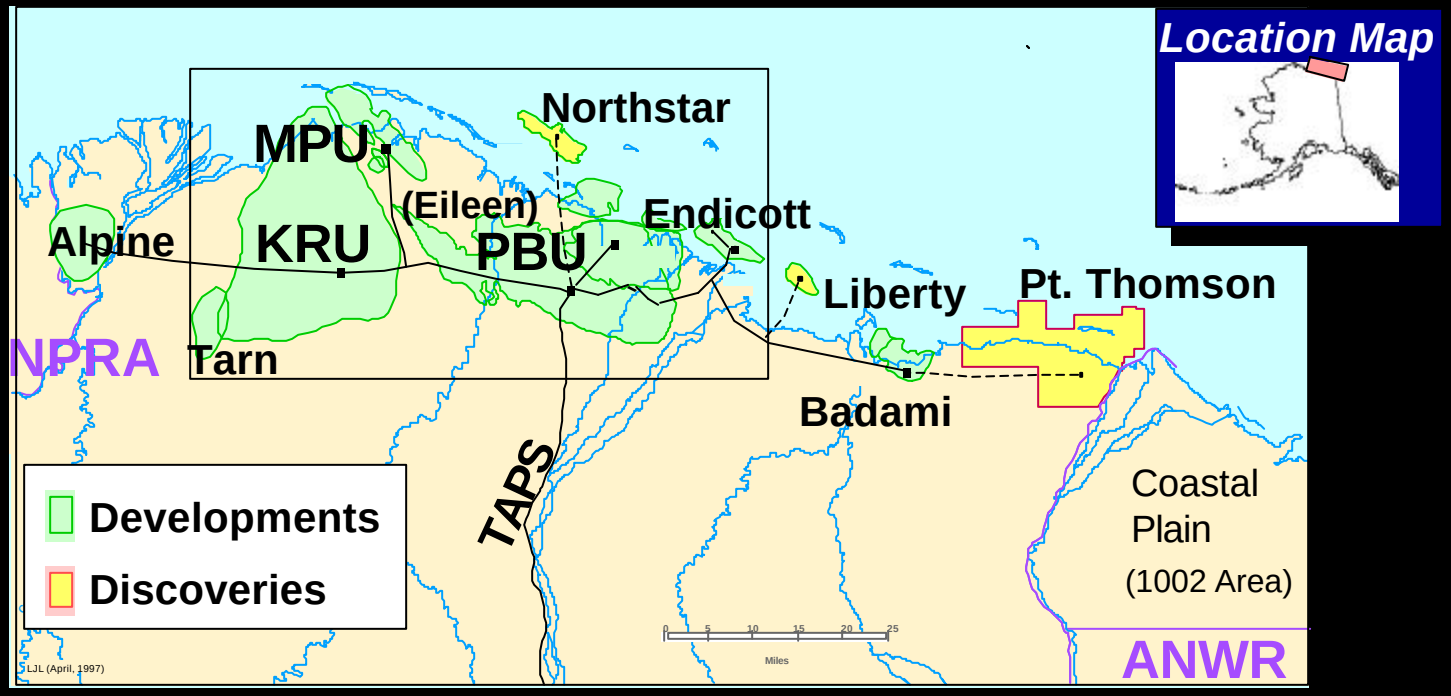

bp
Methane Hydrate Resource
Petroleum System Components
• Source – Thermogenic - Biogenic
• Migration – Fault Systems
• Reservoir – Sub-Permafrost
Shallow Sands
• Trap – Complex Structural and
Stratigraphic through 4D
• Seal – Can Self-Seal
• Stability – Pressure/Temperature
• Gas/Water – Clathrate Structure

Gas Hydrate Resource and Prospect Requirements

- Petroleum System Components
- Industry Infrastructure
- Industry Acreage Access
- Production Technology (Familiar)
- Economics and Risk Assessment
  - Ultimate Recovery Potential?
  - Daily Production Rate?
  - Operating Cost?
  - Profitability?
- Research Support in Aligned Areas: Gulf of Mexico and Alaska

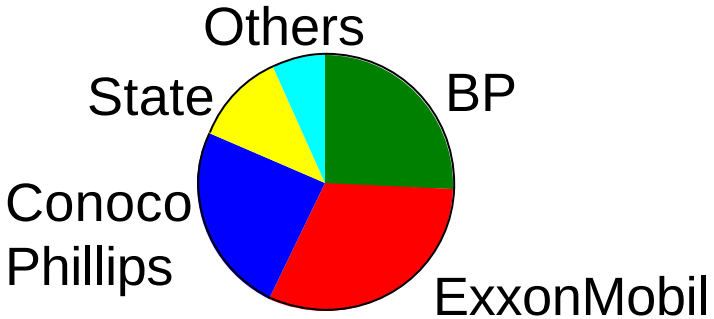
HEI

Alaska North Slope (ANS) Development Infrastructure

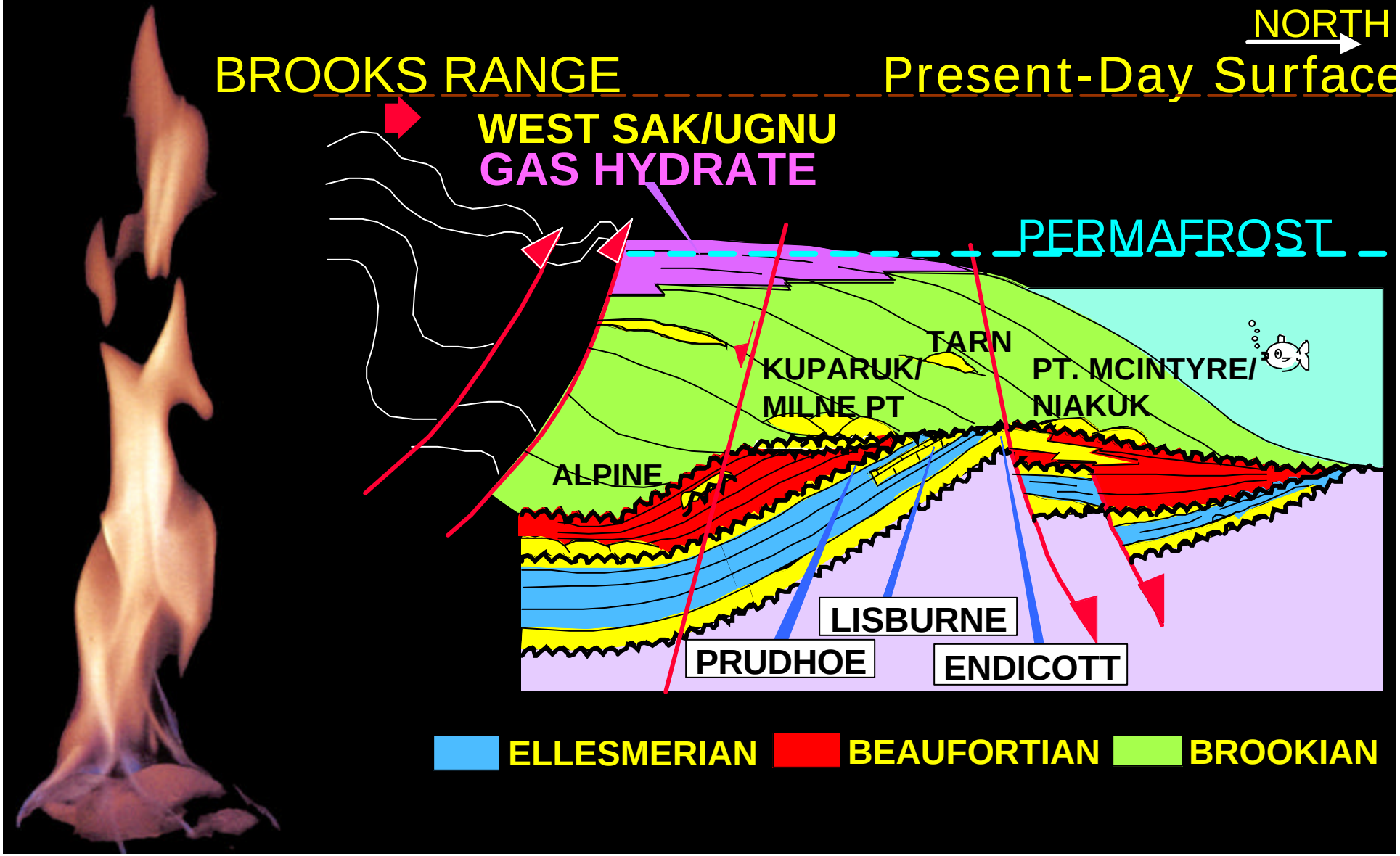


- North Slope Proven Gas = 35 TCF
- Prudhoe Bay 8 BCF/Day Production
- Reinjected Gas → Reservoir Energy

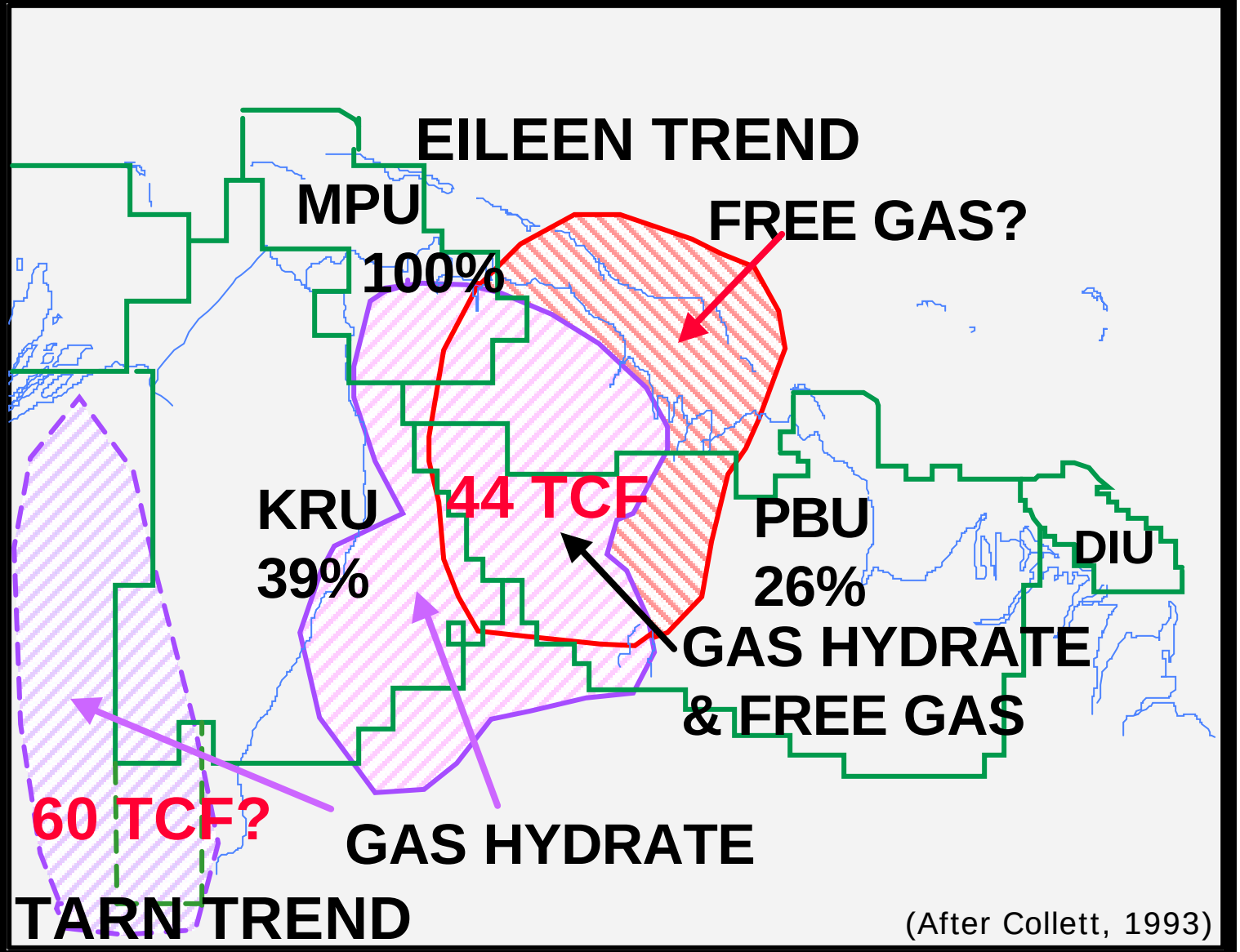
Alaska Gas Owners



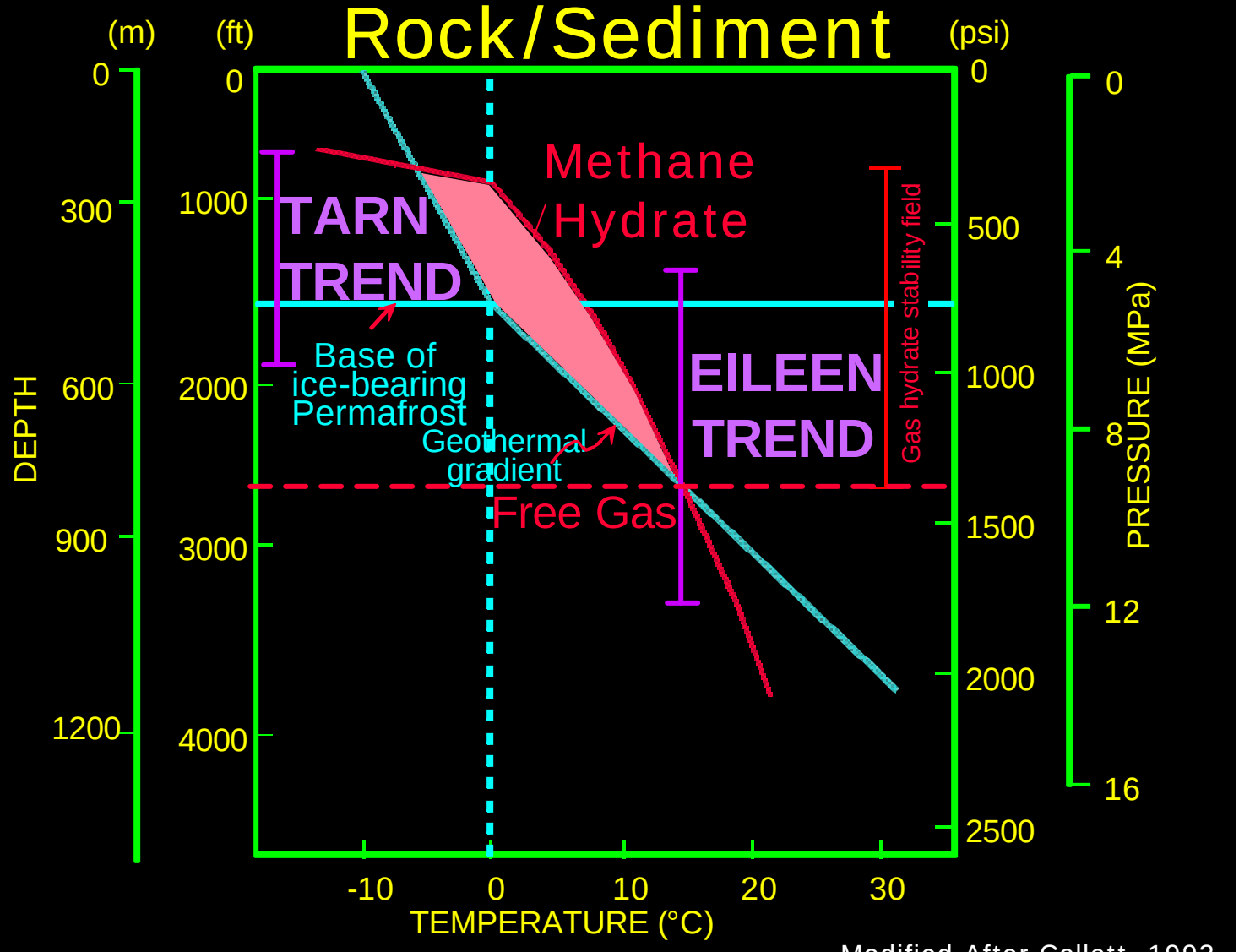
ANS Schematic Cross-Section



ANS Methane Hydrate Estimated In-Place Resource



Alaska Gas Hydrate Resource
Methane Hydrate Stability Field



Modified After Collett, 1993

Alaska Gas Hydrate Resource
Historical ANS Perspective

Year

1960 — Initial ANS Exploration

Prudhoe Bay Field Discovery

1970

NW Eileen #2 Gas Hydrate Test Well

Oil-Focus Research Gap

1980

USGS Research Projects

USDOE Gas Hydrate Projects

BP EWE Seismic Study

1990

USGS Resource Assessment – 590 TCF

ARCO Gas/Hydrate Study

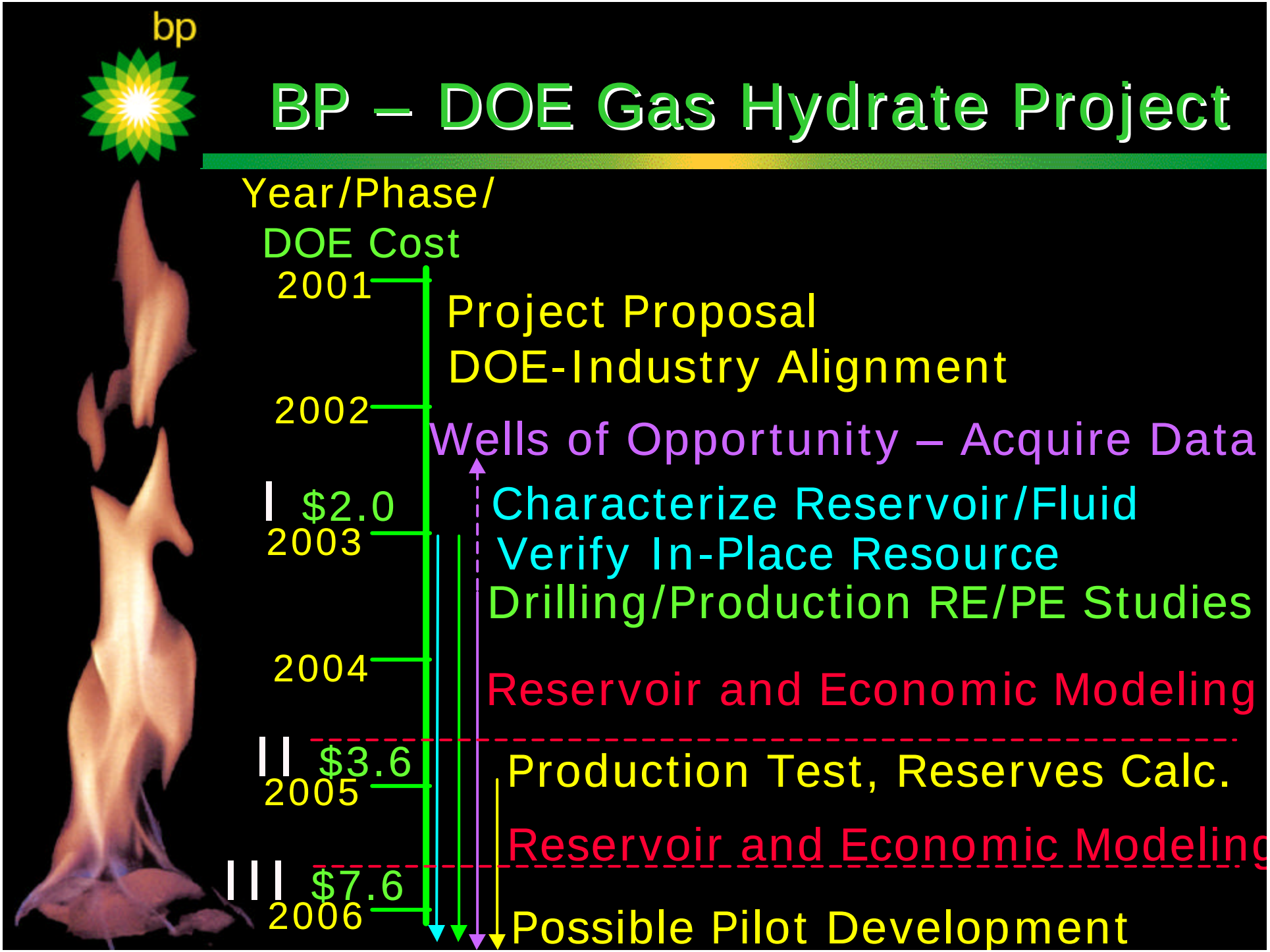
2000

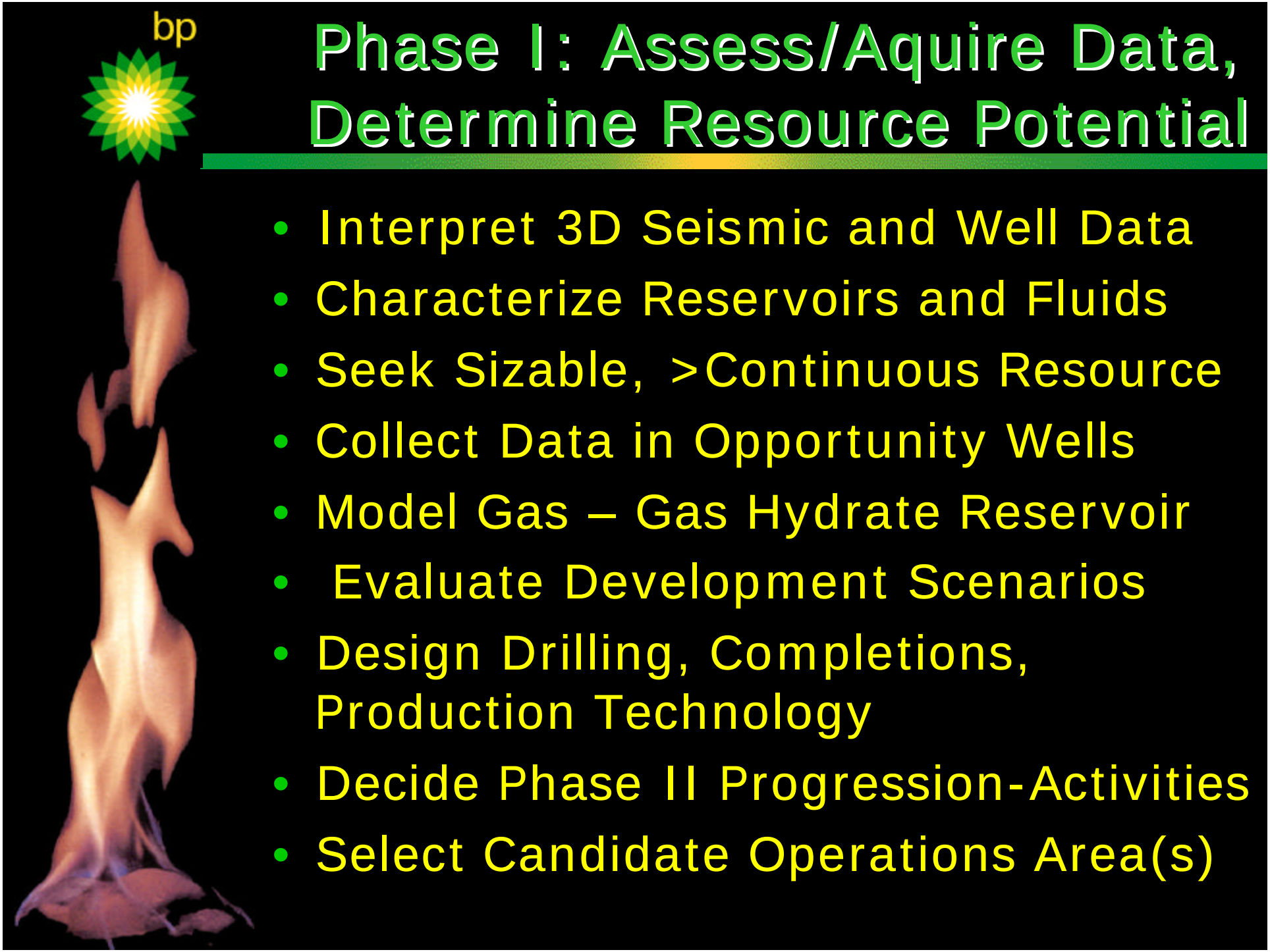
USDOE-BP Gas Hydrate Project

Possible Pilot Development

2010

BP – DOE Gas Hydrate Project





Phase I: Assess/Aquire Data, Determine Resource Potential

- Interpret 3D Seismic and Well Data
- Characterize Reservoirs and Fluids
- Seek Sizable, >Continuous Resource
- Collect Data in Opportunity Wells
- Model Gas – Gas Hydrate Reservoir
- Evaluate Development Scenarios
- Design Drilling, Completions, Production Technology
- Decide Phase II Progression-Activities
- Select Candidate Operations Area(s)

BPXA – DOE Gas Hydrate Project Components and Collaborations

- **Gas Hydrate Productivity Studies: UAF, LBNL, PNNL, ANL**
  - Control Gas Hydrate Stability
  - Assess Drilling/Completion/Production Ops
  - Model Thermodynamics – Productivity
  - Develop Production Scenarios/Technology
- **Resource Characterization Studies: UA, USGS, BPXA**
  - Assess Shallow Conventional 3D Seismic
  - Evaluate Fluid Acoustic Properties
  - Incorporate and Acquire Well Data

Reservoir-Fluid Characterization
Gas/Hydrate In-Place Calculation

3D Seismic / Well Data Interpretations

- Stacked Fluvial-Deltaic / Marine Sands
- Disrupted Reservoir Continuity/Quality
  - Facies, Fluid, & Reservoir Heterogeneity
  - Intraformational Unconformities
  - Fault Compartmentalization

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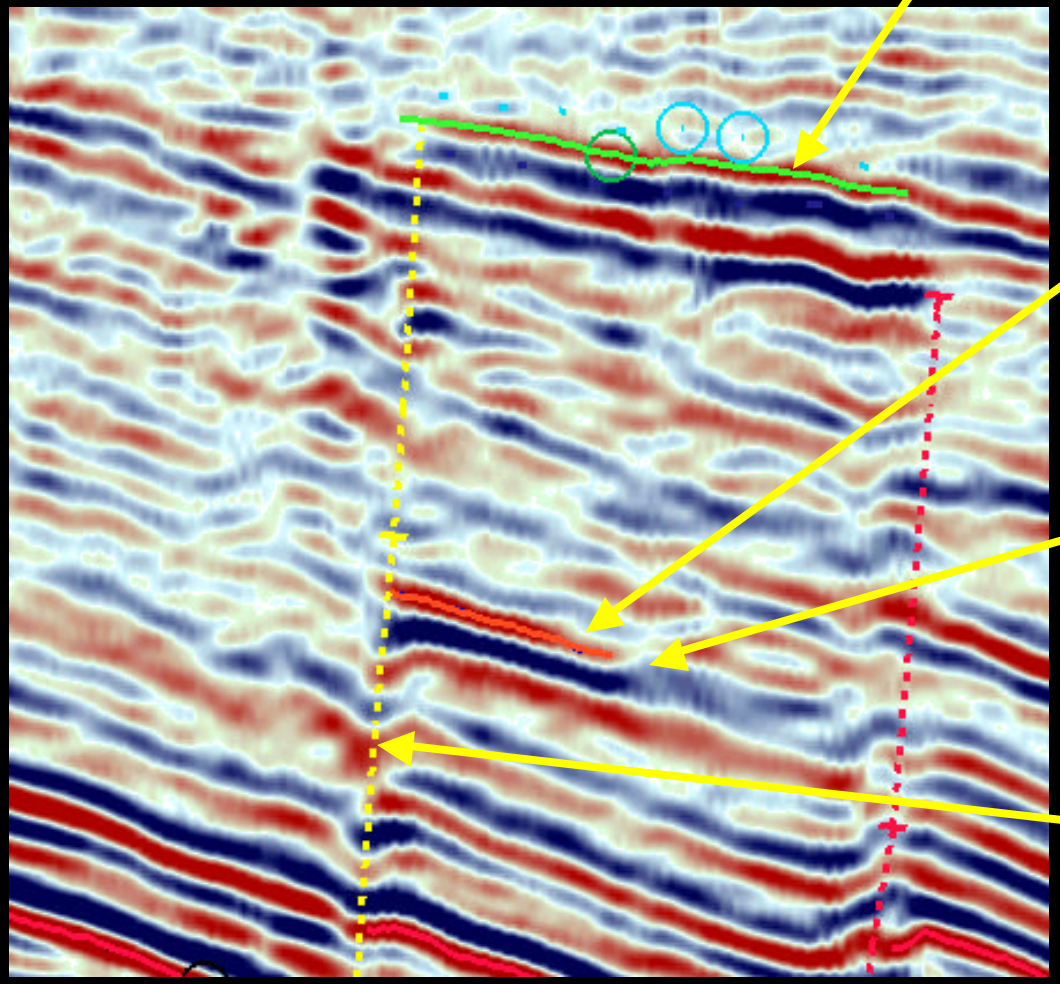
Geophysical Characterization Reservoirs and Fluids



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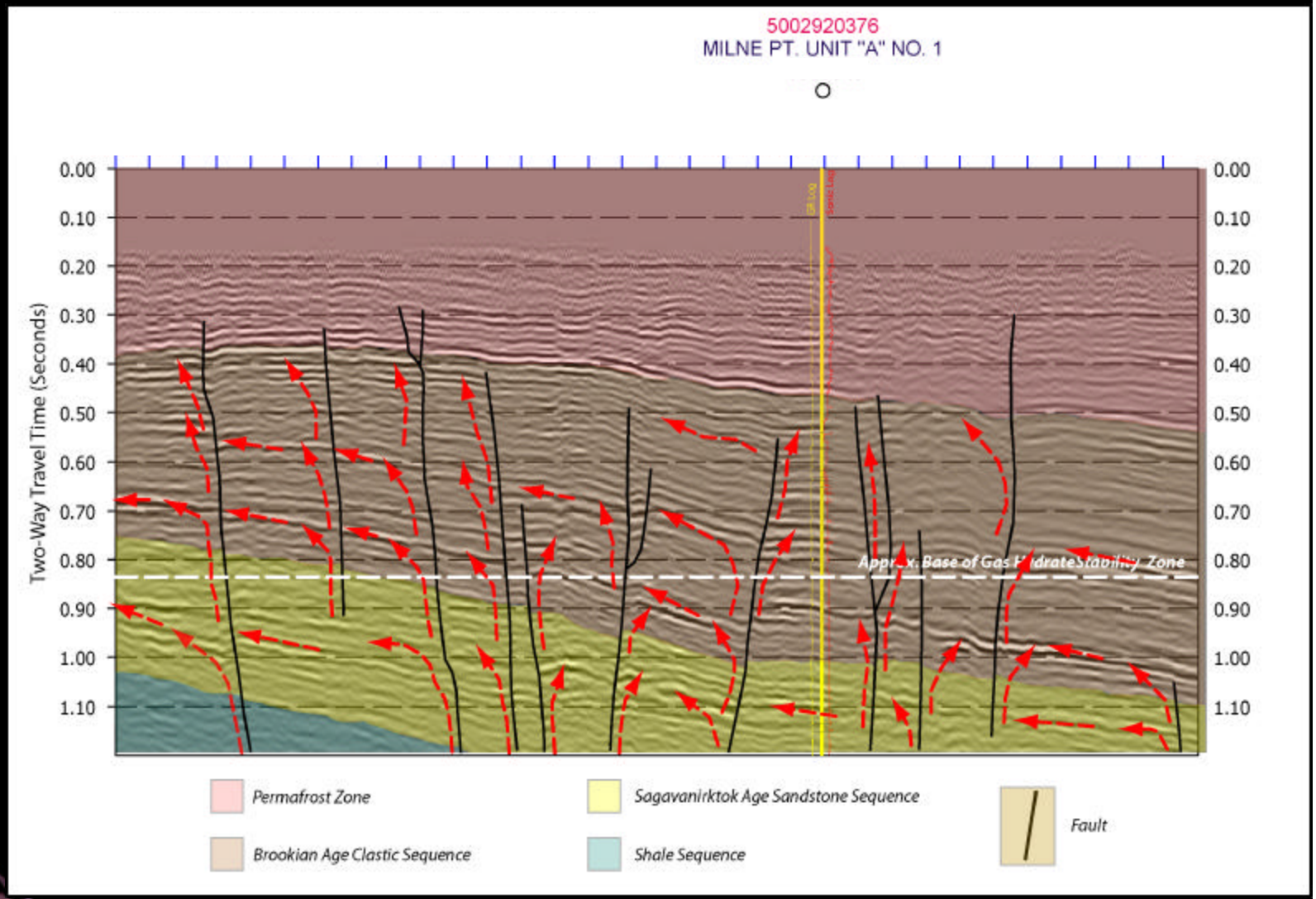
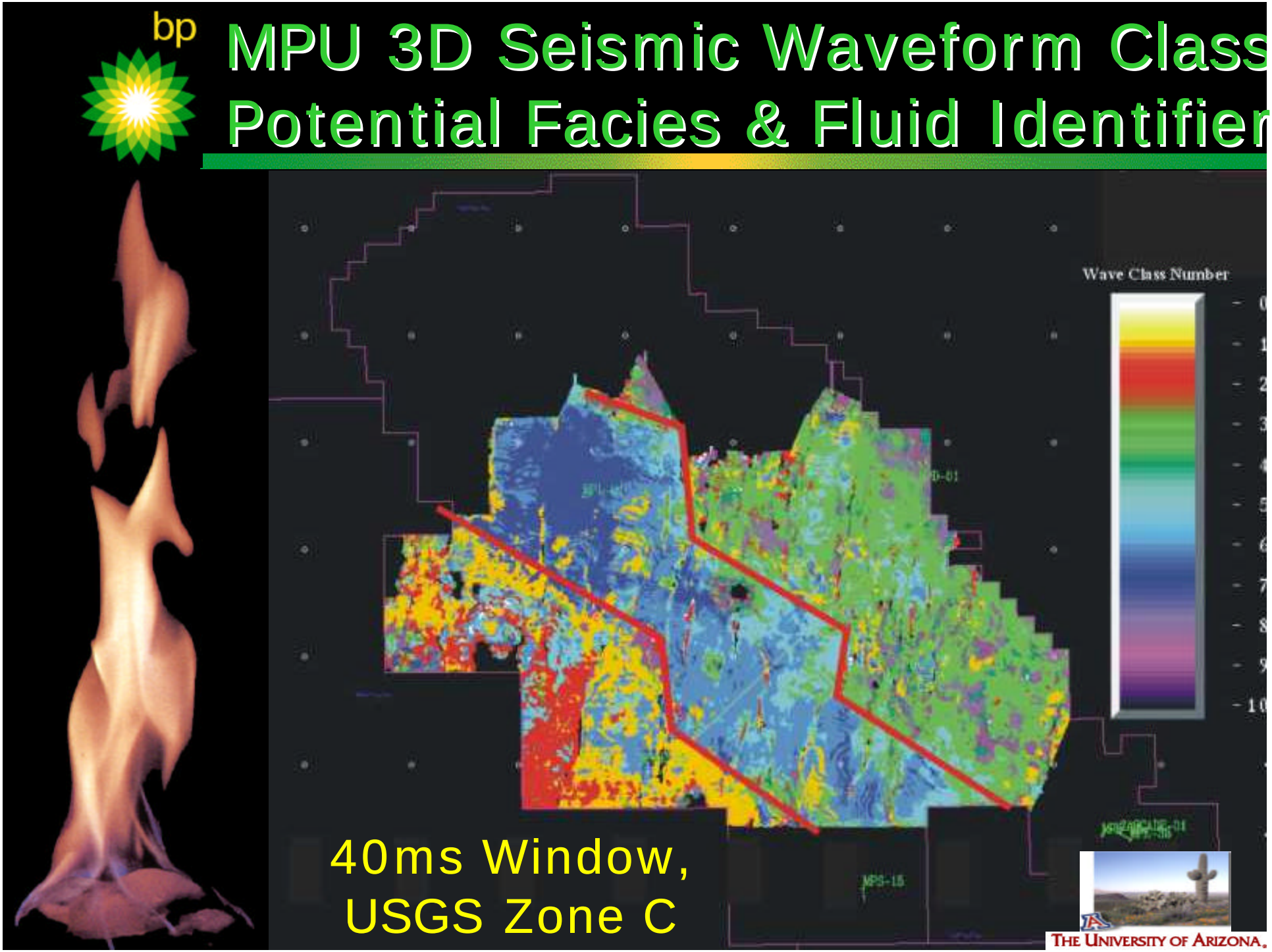
Milne Point 3D Seismic Line
Gas Migration: Fault Conduits



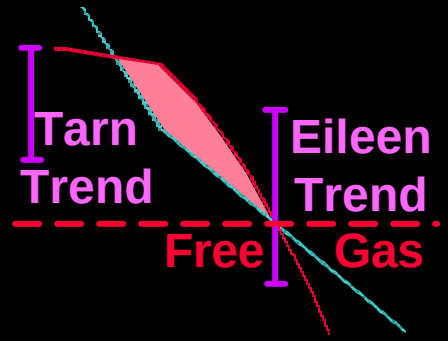
Courtesy USGS

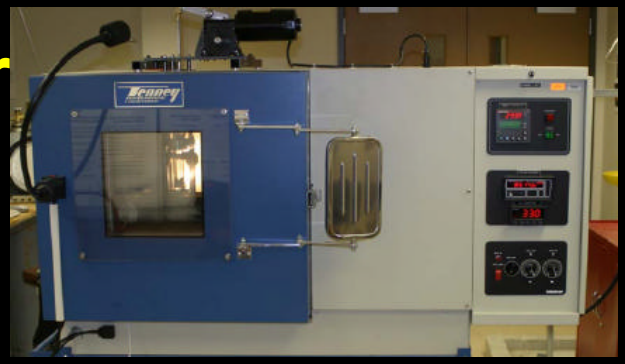
MPU 3D Seismic Waveform Class Potential Facies & Fluid Identifier



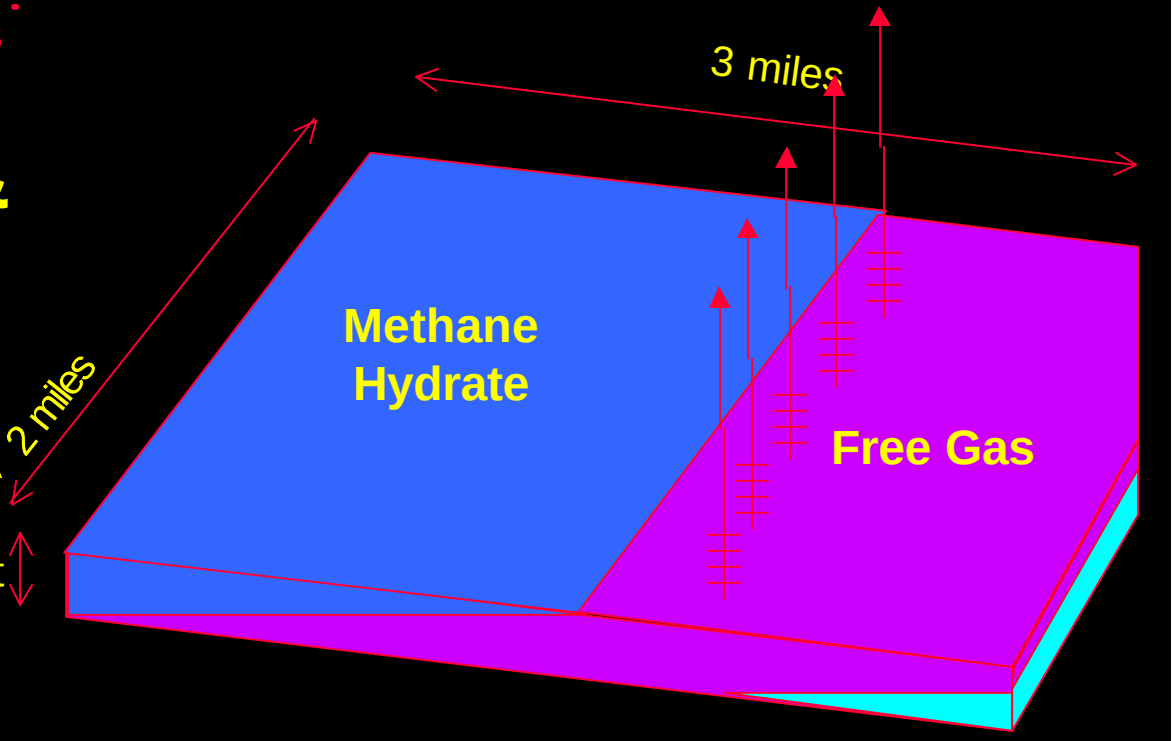
Petroleum and Reservoir Engineering Research

Phase Behavior





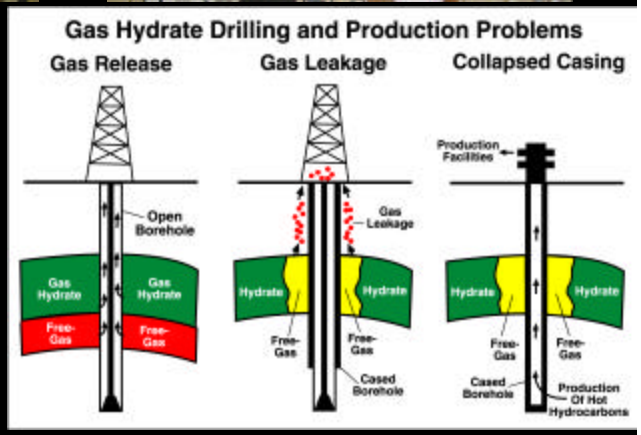
Reservoir & Economic Modeling (UAF-BPXA LBNL-RS)



Petroleum and Reservoir Engineering Research

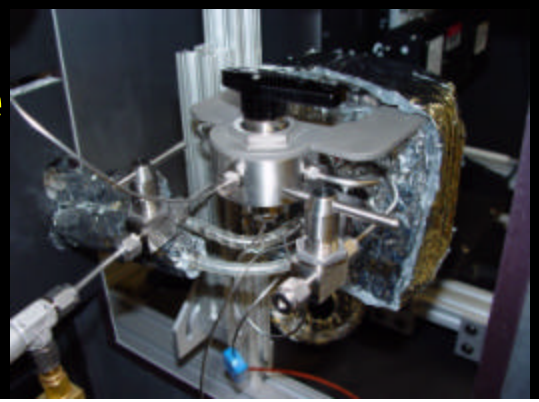
Relative Permeability (UAF, LBNL)

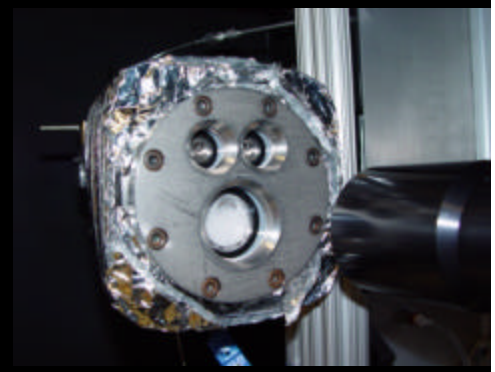
Drilling, Completion and Production Studies (UAF, ANL, others)



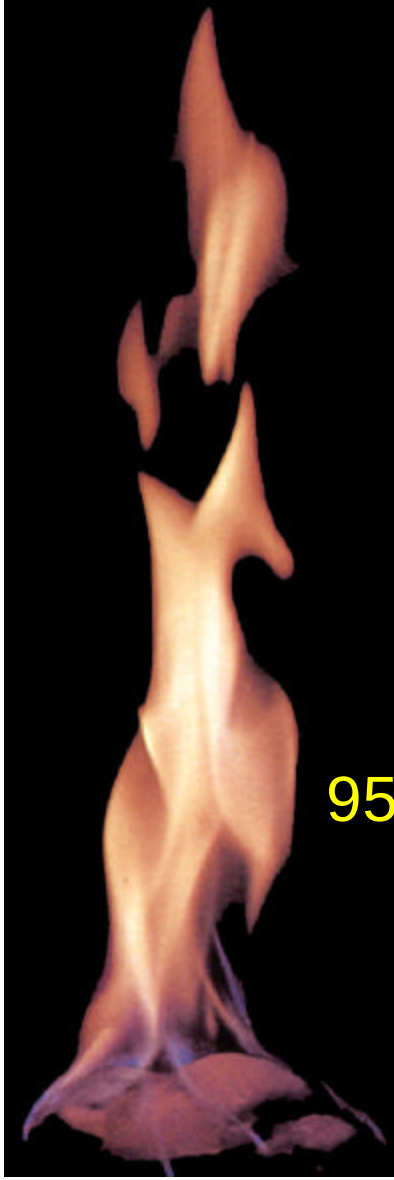
CO_2 to Enhance CH_4 Recovery (UAF-PNNL)

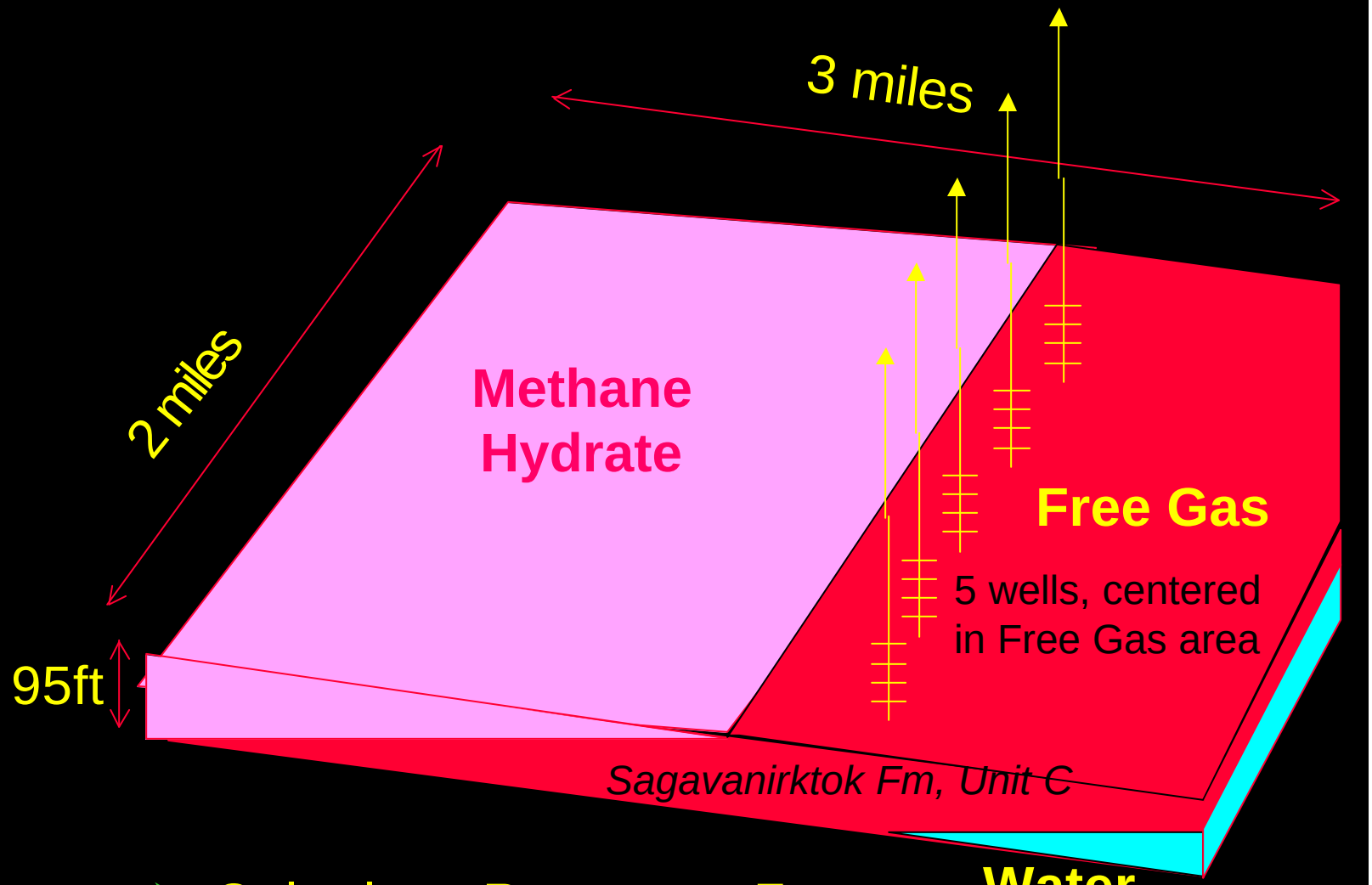
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy





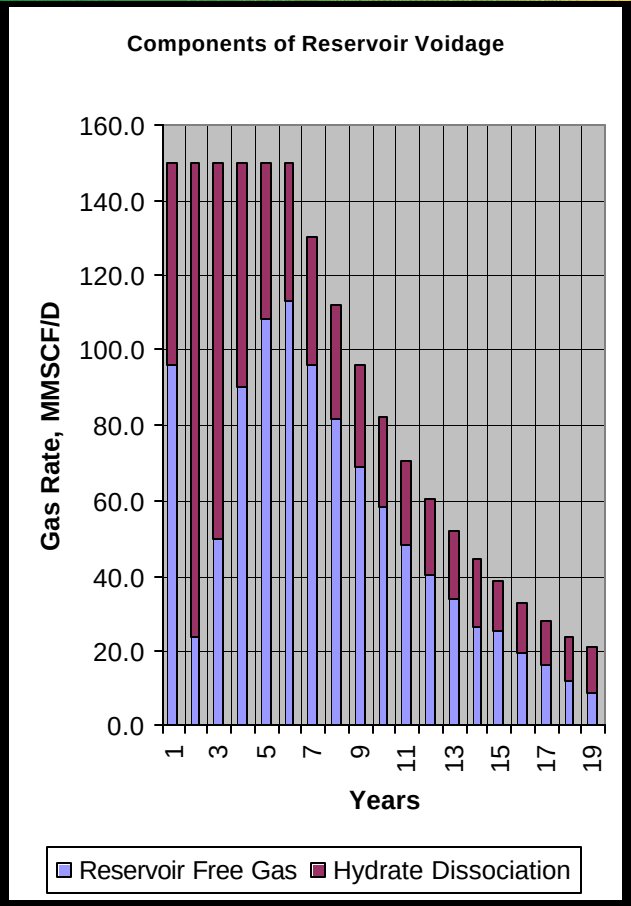
Preliminary Reservoir Model (LBNL-BPXA-USGS-UAF-RS)

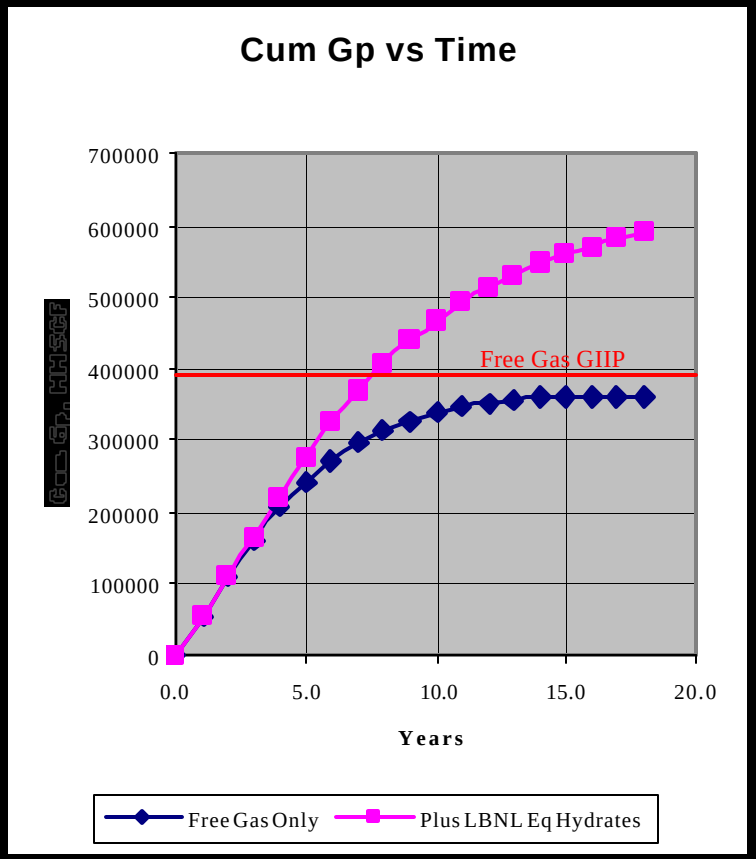




- Calculate Recovery Factors
- Develop Production Scenarios

Preliminary Reservoir Model
Gas Hydrate Dissociation

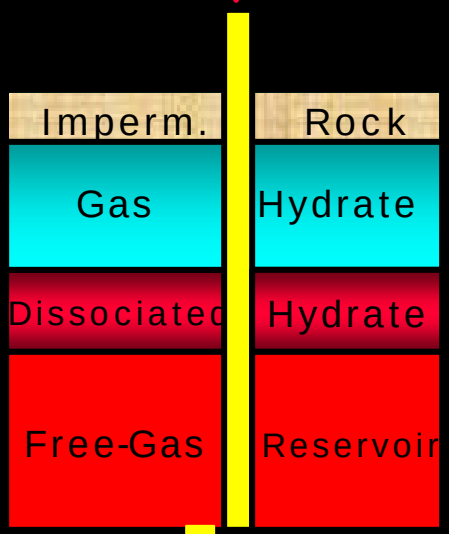




- Significant Production Increase due to Free Gas Dissociation from Gas Hydrate
- Significant Uncertainties: Use with Caution

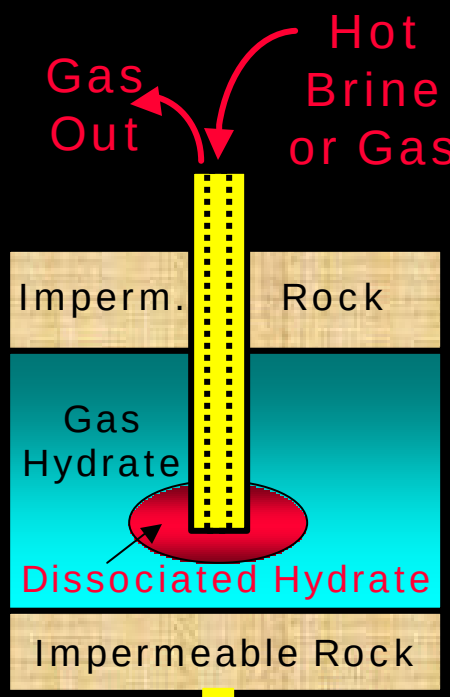
Productivity Challenges
Gas Hydrate Production Methods

Depressurization



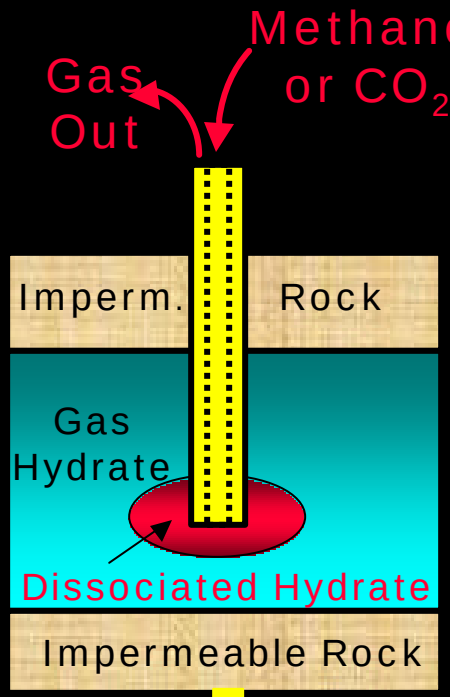
- Endothermic heat of dissociation
- Temperature recovery lag time
- Hydrate self-preservation

Thermal Injection



- Large energy in
- Heats Host Rock
- Possible in-situ Electromagnetic

Inhibitor or CO_2 Injection



After Collett, 2000

- High cost
- PNNL Lab Testing
- Unk. Effectiveness

Proof-of-Principle
$CH_4 \rightarrow CO_2$

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

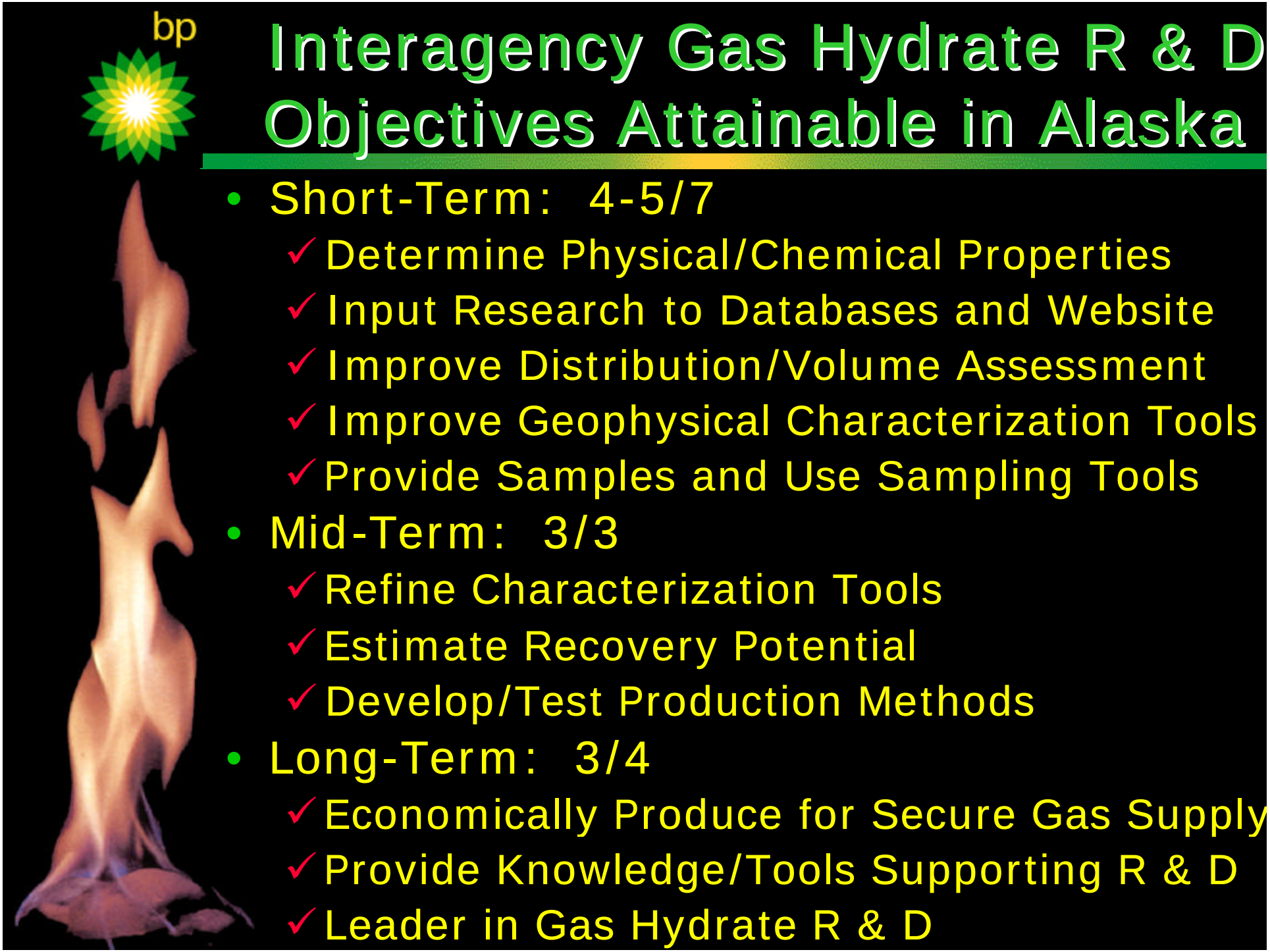
UAF University of Alaska Fairbanks

Theory: Inject CO_2 to Recover CH_4 from Gas Hydrate

- Thermodynamically Favorable
- Offsetting Dissociation Enthalpy: Heat of formation for CO_2 hydrate ~20% larger than CH_4 hydrate heat of dissociation
- Reforming CO_2 Hydrate Mechanically Stabilizes Hydrate-Bearing Sediments

Results: CH4 from Gas Hydrate by Injecting CO2

- Temperature Reading Immediately Spiked from -2.5°C to 8°C
- Collected Gas Samples Displayed Strong Methane Peaks with Small to No CO_2 Peaks on GC Analysis



Interagency Gas Hydrate R & D Objectives Attainable in Alaska

- Short-Term: 4-5/7
  - ✓ Determine Physical/Chemical Properties
  - ✓ Input Research to Databases and Website
  - ✓ Improve Distribution/Volume Assessment
  - ✓ Improve Geophysical Characterization Tools
  - ✓ Provide Samples and Use Sampling Tools
- Mid-Term: 3/3
  - ✓ Refine Characterization Tools
  - ✓ Estimate Recovery Potential
  - ✓ Develop/Test Production Methods
- Long-Term: 3/4
  - ✓ Economically Produce for Secure Gas Supply
  - ✓ Provide Knowledge/Tools Supporting R & D
  - ✓ Leader in Gas Hydrate R & D

BP Alaska Gas Hydrate Project Summary

- Alaska North Slope: Premier Area/Time
  - Resource – Infrastructure – Alignment
- Characterize and Quantify Resource
- Determine Production and Economic Resource Potential
- Develop Drilling, Completion, Production Technology
- Benefit Industry and Government
  - Assess Technical/Economic Hurdles
  - Convert Potential Resource into Reserves
  - Develop Huge/Unconventional Resource
  - Use Gas for Reservoir Energy &/or Sales