Petroleum Potential of the Arctic Offshore of Alaska

Geophysical Society of Alaska
Anchorage, AK

Kirk Sherwood
Geologist, MMS

April 6, 2006
Colleagues Sharing Blame

Beaufort Sea Assessment: Peter Johnson & Jim Scherr

Economic Assessment: Jim Craig, Larry Cooke, & Cameron Reitmeier

HQ Computer Model Guys: Barry Dickerson & John Buffington
Outline

• Petroleum-rich Arctic Alaska offshore province
• MMS Assessment method
• Economic assessment results for Arctic offshore
Arctic Offshore = Chukchi & Beaufort Sea Planning Areas

Arctic AK Petroleum Province = North Slope & Offshore Shelves

- Exploration/COST Well
- Gas Discovery

Image from July 1998
Beaufort & Chukchi Seas

2006 Undiscovered Oil and Gas
Risked, Technically Recoverable

<table>
<thead>
<tr>
<th>Commodity</th>
<th>&gt;95% chance</th>
<th>MEAN</th>
<th>&gt; 5% chance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas (Trillion Cubic Feet)</td>
<td>11.0</td>
<td>104.4</td>
<td>281.7</td>
</tr>
<tr>
<td>Oil (billion barrels)</td>
<td>2.7</td>
<td>23.6</td>
<td>63.3</td>
</tr>
</tbody>
</table>

Yr 2000: 92.2 Tcfg + 22.4 Bbo
The Arctic Offshore Accounts For:

- 79% of Alaska Offshore Gas &
  89% of Alaska Offshore Oil
  (2006-Undiscovered)

- Offshore has 39% of Total
  Arctic AK Endowment (117 Bboe)*

*Northern Alaska “Endowment”, 46.6 Bbo + 139 Tcfg** = 71.3 Bboe
Arctic Offshore “Endowment”, 24.7 Bbo + 118 Tcfg = 45.7 Bboe

** Undiscovered + Discovered EUR, D.W. Houseknecht, 2006, pers. comm., State AK DOG, 2004
Why is Arctic Offshore So Rich?

Reason #1: Geological continuity with highly successful northern Alaska petroleum province
### CHUKCHI SEA, BEAUFORT SEA, ARCTIC ALASKA

#### STRATIGRAPHIC COLUMN

<table>
<thead>
<tr>
<th>AGE</th>
<th>MY BP</th>
<th>STRATIGRAPHY (SOUTH)</th>
<th>LITH.</th>
<th>PLAY SEQUENCE</th>
<th>MAJOR SEQUENCE</th>
<th>MAJOR ARCTIC PETROLEUM DISCOVERIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVONIAN</td>
<td>400</td>
<td>ACoustic Basement (ARGILLITE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PENN.</td>
<td>300</td>
<td>LISBURNIE GP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MISS.</td>
<td>200</td>
<td>SAG RIVER FM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JURASSIC</td>
<td>100</td>
<td>NANUSHUK GP</td>
<td></td>
<td>BROOKIAN SEQUENCE</td>
<td></td>
<td>KUVLUM (325 MMBOR)</td>
</tr>
<tr>
<td>TERTIARY</td>
<td>2</td>
<td>GUBIK FM</td>
<td></td>
<td>EXTREMELY THIN IN NAP-A</td>
<td></td>
<td>KAVIK SHALE (13 BCFG)</td>
</tr>
<tr>
<td>QUAT.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BEAUFORTIAN SEQUENCE</td>
<td>PRUDHOE BAY (13.7 BBOIP)</td>
</tr>
</tbody>
</table>

#### Stratigraphic Continuity Across Arctic Alaska & OCS

- **Brookian Sequence**
- **Beaufortian = Rift Sequence**
- **Ellesmerian Sequence**
- **Franklinian Sequence**

### Canadian Beaufort
- 17 gas, 22 oil & oil and gas fields; rec. reserves = 1.1 BBOIP and 12.7 TCFGR
- Schrader Bluff (400 MMBOR)
- West Sak (300-500 MMBOR)
- Umiat (70 MMBOR, 0.05 TCFGR)
- Pt. Thomson (300 MMBOR, 5 TCFGR)
- Prudhoe Bay (13.7 BBOIP, 26 TCFGR)
- Lisburne Pool-Prudhoe Bay (164 MMBOR, 276 BCFGR)
- Endicott (582 MMBOR, 0.9 TCFGR)
- Badami (11 MMBOR), Flaxman Island (RU)
- Walakpa (32 BCFG)
- S. Barrow + E. Barrow (39 BCFGR)
- SIKULIK (12 BCFGR)
- Prudhoe Bay (4 BBOIP)
- Sand Piper (RU)
- Pt McIntyre (549 MMBOR)
- Hammerhead (RU)
- Niauk (65 MMBOR, 0.03 TCFGR)
- Pt. Thomson (300 MMBOR, 5 TCFGR)
- Prudhoe Bay (13.7 BBOIP)
- Liberty-Tern (138 MMBOR)
- Pt. MCINTYRE (549 MMBOR)
- Hammerhead (RU)
- Niauk (65 MMBOR, 0.03 TCFGR)
- Pt. Thomson (300 MMBOR, 5 TCFGR)
- Prudhoe Bay (13.7 BBOIP)
ELLESMERIAN SEQUENCE BASINS

ELLESMERIAN ROCKS IN SUBSURFACE
STABLE SHELF SETTINGS

ELLESMERIAN ROCKS IN
SUBSURFACE RIFT BASINS

ELLESMERIAN-EQUIVALENT
ROCKS AT SURFACE

"BARROVIA" - ELLESMERIAN SEDIMENT SOURCE TERRANE
(Now Rifted Away)

BARROVIA - ELLESMERIAN SEDIMENT SOURCE TERRANE

CHUKCHI PLATFORM SED. SOURCE

CHUKCHI PLATFORM - ELLESMERIAN ROCKS IN SUBSURFACE
STABLE SHELF SETTINGS

ELLESMERIAN SEQUENCE ABSENT

ELLESMERIAN SEQUENCE BASINS

ELLESMERIAN SEQUENCE BASINS

ARCTIC PLATFORM

ARCTIC ALASKA BASIN

ANWR

EXPLORATORY WELL, P&A

OIL FIELD

GAS FIELD

SEISMIC PROFILE

OIL PIPELINE

50 0 150 MILES

50 0 150 KILOMETERS

Sherwood...Figure Chuk-06-Map-Ellesmerian Basins.cdr
 Rift Sequence Tectonic Features

Chukchi Sea

Active Rift Zone

Area Underlain by Stable Shelf and Basin Sequences Equivalent to Rift Sequence

Rift Grabens

shelf edge onshore from Bird (1988, fig. 16.15) and Moore et al. (1994, fig. 13)

Hypothetical Rift System

Barrow Arch

Exploratory Well, P&A

Oil Field

Gas Field

Seismic Profile

50 0 150 MILES

50 0 150 KILOMETERS

Sherwood.../Figure Chuk-07-Rift Basins.cdr
Why So Rich?

**Reason #2:** Presence of many complex structures which created numerous potential traps
**Pe(k?)**: Permian, shales equivalent to Kavik Formation (Sadlerochit Gp.)

Jk(e-m): Jurassic (E.-M.) Kingak Shale
Pel: Permian Lisburne Gp. carbonates
**Approximate Depths (Feet, Meters)**

- 2,000 (610 m)
- 4,000 (1,220 m)
- 6,000 (1,830 m)
- 8,000 (2,440 m)
- 10,000 (3,050 m)
- 12,000 (3,660 m)
- 14,000 (4,270 m)
- 16,000 (4,880 m)
- 18,000 (5,490 m)
- 20,000 (6,100 m)
- 25,000 (7,625 m)
- 30,000 (9,150 m)
- 35,000 (10,670 m)
- 40,000 (12,200 m)
- 45,000 (13,720 m)

**Well Locations**

- **Belcher (U.S.)**
- **Natsek E-56 (Canada)**
- **Edlock N-56 (Canada)**

**Ages of Rocks**

- Eocene
- Eocene (Taglu Sequence)
- Eocene (Both Wells)
- Paleocene
- Eo Pal

**Interpretation**

Interpretation of unmigrated line published by Craig et al. (MMS 85-0111, 1985, pl. 7)

**Seismic Profile**

- Northwest
- Southeast

**Index Map**

- Chukchi Sea
- Beaufort Sea-Canadian Waters
- Salek Sea-Russian Waters

**Approximate Depths**

- 0
- 5 km
- 10 MILES
- 10 KILOMETERS

**Location Map**

- Brooks Range
- NPR-A
- ANWR Basin
- Herchel Arch
- Edlock N-56 (Canada)
- Natsek E-56 (Canada)

**Well Locations**

- South
- Northwest

**Structural Features**

- Brookian Sequence
- En Echelon Folds
- Antiformal Duplex Stack?
Why so Rich?

**Reason #3:** Numerous large prospects
ARCTIC OFFSHORE PROSPECTS

Prospect Areas Compared to Pool Areas for Selected North Slope Fields

Statistics for Untested Prospects:
12 Prospects > 150,000 Acres
24 Prospects > 100,000 Acres
95 Prospects > 40,000 Acres

Rank by Prospect Areas (n=1,129 [Chukchi, 856; Beaufort, 273])
The MMS Assessment Method
Play Identification

(“Play” = genetically-related group of pools, sharing hydrocarbon charge, reservoir, and trap styles)

MMS Arctic Plays

1. Grouped by Stratigraphic Sequence
2. Structural Setting
3. Reservoir Thermal Maturity (All Gas?)
### Stratigraphic Column

**Chukchi Shelf, Beaufort Shelf, and Arctic Alaska**

<table>
<thead>
<tr>
<th>AGE</th>
<th>MY BP</th>
<th>STRATIGRAPHY</th>
<th>LITH.</th>
<th>RESERVOIR/SOURCE</th>
<th>PLAY SEQUENCE</th>
<th>MAJOR ARCTIC PETROLEUM DISCOVERIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENOZOIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EOCENE</td>
<td>2</td>
<td>DAQAVANNIKTOX FM</td>
<td></td>
<td></td>
<td>BROOKIAN SEQUENCE</td>
<td>KUVLUM (325 MMBOR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COLVILLE GP</td>
<td></td>
<td></td>
<td></td>
<td>BADAM (710 MMBOR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAANUSHUK GP</td>
<td></td>
<td></td>
<td></td>
<td>SHUHUNGP (425 MMBOR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOYUK FM</td>
<td></td>
<td></td>
<td></td>
<td>坻版 (295 MMBOR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RUBIK FM</td>
<td></td>
<td></td>
<td></td>
<td>ALAPAH FM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WACHSMUTH FM</td>
<td></td>
<td></td>
<td></td>
<td>WAHOO FM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>統</td>
<td></td>
<td></td>
<td></td>
<td>ECHOOKA FM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IVISHAK FM</td>
<td></td>
<td></td>
<td></td>
<td>WAHKAN FM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ECHOOKA FM</td>
<td></td>
<td></td>
<td></td>
<td>LIPPIE FM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ALAPI FM</td>
<td></td>
<td></td>
<td></td>
<td>ALAPI FM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WACHSMUTH FM</td>
<td></td>
<td></td>
<td></td>
<td>WAHOO FM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IVISHAK FM</td>
<td></td>
<td></td>
<td></td>
<td>BROOKIAN SEQUENCE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ELLESMERIAN SEQUENCE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENDICOTT GP</td>
<td></td>
<td></td>
<td></td>
<td>FRANKLINIAN SEQUENCE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KAWARNIKTOX FM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>KAWARNIKTOX FM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Explanation**

- BU: BROOKIAN UNCONFORMITY
- LCU: LOWER CRETACEOUS UNCONFORMITY
- JU: JURASSIC UNCONFORMITY
- PU: PERMIAN UNCONFORMITY
- TAB: TOP OF ACOUSTIC BASEMENT

<table>
<thead>
<tr>
<th>RESERVOIR/SOURCE</th>
<th>PLAY SEQUENCE</th>
<th>MAJOR ARCTIC PETROLEUM DISCOVERIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>OIL FIELD (RESERVE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GAS FIELD (RESERVE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OIL, AND GAS FIELD (RESERVE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMBO: MILLIONS OF BARRELS OF OIL, RECOVERABLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MBBO: MILLIONS OF BARRELS OF OIL, IN PLACE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCFTGR: BILLION CUBIC FEET OF GAS, RECOVERABLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCFGR: TRILLION CUBIC FEET OF GAS, RECOVERABLE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RESERVES FROM AKDOAG (2000) AND OTHER SOURCES AS OF MAY 2001**

**Beaufortian Sequence**

**Brookian Sequence**

**Ellesmerian Sequence**

**Franklinian Sequence**
HERALD THRUST, FOLD AND THRUST BELT, AND TRANSTENSIONAL FAULT ZONE

Transtensional Fault Zone

ARCTIC PLATFORM (Unfaulted)

Explanation
- Exploration Well, Plugged and Abandoned, With Gas Shows in Lower Brookian Rocks
- Axis of Anticline, with Arrows Denoting Plunge
- Thrust Fault, Teeth on Uplifted Block
- Normal Fault, Hachures on Downton Block
STRUCTURE AND THERMAL MATURITY OF TRIASSIC OIL SOURCE ROCKS IN HANNA TROUGH

Estimated Potential Triassic Charge to Chukchi Shelf = 2.97 Trillion Barrels
(Sherwood et al., 1998, p. 144)

**HYPOTHETICAL OIL MIGRATION PATHS**

**OIL GENERATIVE**
(0.6-1.35 Ro%)

**GAS GENERATIVE**
(1.35-2.0 Ro%)

**ONLY GAS PRESERVED**
(>2.0 Ro%)

**DATUM CHANGE AT SHORELINE:**
OFFSHORE, TOP SHUBLIK; ONSHORE, TOP SADLEROCHIT

**LCU:** LOWER CRETACEOUS UNCONFORMITY (BASE PEbble SHALE).
**JU:** JURASSIC UNCONFORMITY (LATE JURASSIC TO EARLY CRETACEOUS).

**POSTED VITRINITE REFLECTANCES ARE FOR TOP OF SHUBLIK FORMATION. ONSHORE DATA CALCULATED FROM JOHNSSON AND OTHERS (1993, AAPG, 77/11, 1874).**

**SURFACE THERMAL MATURITIES IN BROOKS RANGE FROM JOHNSSON AND HOWELL, 1996, USGS MI, MAP I-2142.**

**SURPRISE CREEK LOCALITY DATA FROM MULL (1997, AK. GEOL. SOC., APRIL NEWSLETTER AND PERS. COMM., 1998).**
ARCTIC OFFSHORE PLAYS

2 Franklinian Sequence Plays (1 Chukchi, 1 Beaufort)
9 Ellesmerian Sequence Plays (6 Chukchi, 3 Beaufort)
4 Rift/Beaufortian Sequence Plays (3 Chukchi, 1 Beaufort)
24 Brookian Sequence Plays (16 Chukchi, 9 Beaufort)

39 Plays Total
Basics of Assessment Method

• Determine Sizes and Numbers of Pools
• Summation of Pools
• Acknowledge Uncertainty (Reflected by Ranged Estimates or Probability Distributions)
POOL VOLUMES
(Acre-Feet)

- Prospect Areas from Seismic Mapping.
- Fill Fraction Estimates (Analogs; Seal)
- Pay Thickness from Regional Data
Log-Normal Fit (@RISK-Bestfit) to Prospect Areas
(Chukchi Shelf Play 11-Foreland Foldbelt)

**Log-Normal Fit**

- **Mean** = 21,925 acres
- **Median** = 13,223 acres
- **Std. Dev.** = 28,998 acres

---

**Prospect Areas**

- **BROOKIAN FOLDBELT-CHUKCHI SHELF**
- **CHUKCHI SHELF PLAY 11 (UACS1100)**

**Prospect Area (acres x 1,000)**

Probability for Exceedance, in Percent

- N=57

---

**Figure 10.1:** Log probability plot for maximum areas within closure, in acres, for 57 prospects identified as play 11 in Chukchi shelf assessment province. Mapped prospects range from 588 to 135,278 acres in size. The log-normal fit predicts larger prospects at very low probabilities. The linear arrangement of the plotted points is characteristic of a log-normal probability distribution.
PROSPECT NUMBERS

(Probability Distribution)

1. Numbers of Prospects from Seismic Mapping ("Identifieds").
2. Numbers of Prospects Not Mapped Owing to Deficiencies in Mapping ("Unidentifieds").
3. Create log-normal probability distribution between minimum and maximum.
CALCULATE NUMBERS OF POOLS

- Construct Risk Model for Play to Estimate Exploration Chance
- Set Exploration Chance Against Prospect Numbers to Calculate Probability Distribution for Number of Pools
DEFINITIONS

1. Pool: hydrocarbons in sufficient concentration in a pore system to flow into a conventional wellbore (may establish minimum size if feasible)

2. Successful Play: any play known or believed to contain at least one pool (play chance = 1). All others <1.0.
MORE DEFINITIONS

3. Prospect Chance: Assuming a successful play, fraction of prospects that contain pooled petroleum

4. Play Exploration chance: [play level chance] \( \times \) [prospect chance]
# Play Risk Model

## Risk Analysis Form - 2005 National Assessment

<table>
<thead>
<tr>
<th>Assessment Province:</th>
<th>Chukchi Sea OCS Planning Area</th>
<th>Play Number, Name:</th>
<th>7. Rift Sequence-Active Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessor(s):</td>
<td>K.W. Sherwood</td>
<td>Play UAI:</td>
<td>AAAAA DAH</td>
</tr>
<tr>
<td>Date:</td>
<td>1-Jan-05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each component, a quantitative probability of success (i.e., between zero and one, where zero indicates no confidence and one indicates absolute certainty) based on consideration of the qualitative assessment of ALL elements within the component was assigned. This is the assessment of the probability that the minimum geologic parameter assumptions have been met or exceeded.

### 1. Hydrocarbon Fill component (1a \* 1b \* 1c)

<table>
<thead>
<tr>
<th>Factor Description</th>
<th>Play Chance Factors</th>
<th>Average Conditional Prospect Chance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of a Quality, Effective, Mature Source Rock</td>
<td>1</td>
<td>1.0000</td>
</tr>
<tr>
<td>Effective Expulsion and Migration</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Preservation</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### 2. Reservoir component (2a \* 2b)

<table>
<thead>
<tr>
<th>Factor Description</th>
<th>Play Chance Factors</th>
<th>Average Conditional Prospect Chance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of reservoir facies</td>
<td>2</td>
<td>1.0000</td>
</tr>
<tr>
<td>Reservoir quality</td>
<td>0.4800</td>
<td>0.80</td>
</tr>
</tbody>
</table>

### 3. Trap component (3a \* 3b)

<table>
<thead>
<tr>
<th>Factor Description</th>
<th>Play Chance Factors</th>
<th>Average Conditional Prospect Chance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of trap</td>
<td>3</td>
<td>1.0000</td>
</tr>
<tr>
<td>Effective seal mechanism</td>
<td>0.8000</td>
<td>0.80</td>
</tr>
</tbody>
</table>

### Overall Play Chance (Marginal Probability of hydrocarbons, MPhc)

Product of all subjective play chance factors:

- **1.0000**

### Average Conditional Prospect Chance

Product of all subjective conditional prospect chance factors:

- **0.3840**

### Exploration Chance

(Product of overall play chance and average conditional prospect chance):

- **0.3840**

**Comments:** See guidance document for explanation of the Risk Analysis Form.

- **2b:** Chance That Porosity >10%, Based on Regional Model for Porosity vs Reservoir Thermal Maturity
- Gas tested (RFT) from Rift sequence sandstones at Burger 1 and Popcorn 1 wells.
RESERVOIR YIELD

1. Recoverable Stock-Tank Barrels of Oil Per Acre-Foot.
2. Recoverable Gas at STP in Millions of Cubic Feet Per Acre-Foot.
3. Use Reservoir Equations in Monte Carlo Aggregation in @RISK
### @RISK Data Model for Oil & Gas Recovery Factors

#### Table 8: DATA SHEET FOR @RISK MODELS FOR OIL AND GAS RECOVERY FACTORS FOR PLAY 1

<table>
<thead>
<tr>
<th>Assessment Area: North Aleutian Basin</th>
<th>Date: December 2003</th>
</tr>
</thead>
</table>

**Oil Recovery Factor (barrels recoverable per acre-foot)**

- Input Constant and @RISK Equation: 
  \( \text{=775} \times 3.0 \times a^2 \times b^2 \times c^2 \times d^2 \)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>f(x) Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Porosity</td>
<td>0.314705</td>
<td>0.065704</td>
<td>0.010</td>
<td>0.414</td>
<td>Normal</td>
</tr>
<tr>
<td>b Water Saturation</td>
<td>0.343750</td>
<td>0.059615</td>
<td>0.030</td>
<td>0.700</td>
<td>Normal</td>
</tr>
<tr>
<td>c Oil Recovery Efficiency</td>
<td>0.348810</td>
<td>0.067227</td>
<td>0.050</td>
<td>0.650</td>
<td>Normal</td>
</tr>
<tr>
<td>d Oil Volume Factor [1/FVF]</td>
<td>0.793075</td>
<td>0.094363</td>
<td>0.500</td>
<td>1.000</td>
<td>Normal</td>
</tr>
</tbody>
</table>

**Dependency or Correlation Matrix for Oil Yield Calculation**

<table>
<thead>
<tr>
<th>Porosity</th>
<th>Water Saturation</th>
<th>Oil Recovery Efficiency</th>
<th>Oil Volume Factor [1/FVF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>1</td>
<td>-0.9</td>
<td>0</td>
</tr>
<tr>
<td>b Water Saturation</td>
<td>0.9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>c Oil Recovery</td>
<td>0.9</td>
<td>-0.8</td>
<td>1</td>
</tr>
<tr>
<td>d Oil Volume Factor</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Gas Recovery Factor (mcfh recoverable per acre-foot)**

- Input Constant and @RISK Equation: 
  \( \text{=1537} \times 8 \times a^2 \times b^2 \times c^2 \times d^2 \times e^2 \times (1-f)/g^2 \)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>f(x) Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Porosity</td>
<td>0.314705</td>
<td>0.065704</td>
<td>0.100</td>
<td>0.414</td>
<td>Normal</td>
</tr>
<tr>
<td>b Water Saturation</td>
<td>0.343750</td>
<td>0.059615</td>
<td>0.030</td>
<td>0.700</td>
<td>Normal</td>
</tr>
<tr>
<td>c Pressure (psi)</td>
<td>2609.400000</td>
<td>439.190000</td>
<td>978.000</td>
<td>4390.000</td>
<td>Normal</td>
</tr>
<tr>
<td>d Gas VFV (1/2)</td>
<td>1.079112</td>
<td>0.028545</td>
<td>0.960</td>
<td>1.200</td>
<td>Normal</td>
</tr>
<tr>
<td>e Gas Recovery Efficiency</td>
<td>0.797408</td>
<td>0.038382</td>
<td>0.950</td>
<td>0.950</td>
<td>Normal</td>
</tr>
<tr>
<td>f Gas Shrinkage Factor*</td>
<td>0.126230</td>
<td>0.161910</td>
<td>0.000</td>
<td>1.000</td>
<td>Normal</td>
</tr>
<tr>
<td>g Temperature (°Rankine)</td>
<td>594.101000</td>
<td>10.089000</td>
<td>525.000</td>
<td>664.000</td>
<td>Normal</td>
</tr>
</tbody>
</table>

**Dependency or Correlation Matrix for Gas Yield Calculation**

<table>
<thead>
<tr>
<th>Porosity</th>
<th>Water Saturation</th>
<th>Pressure (psi)</th>
<th>Gas VFV (1/2)</th>
<th>Gas Recovery Efficiency</th>
<th>Gas Shrinkage Factor*</th>
<th>Temperature (°Rankine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Porosity</td>
<td>1</td>
<td>-0.9</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>b Water Saturation</td>
<td>-0.9</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>-0.6</td>
<td>0</td>
</tr>
<tr>
<td>c Pressure (psi)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.95</td>
</tr>
<tr>
<td>d Gas VFV (1/2)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>e Gas Recovery Efficiency</td>
<td>0.8</td>
<td>-0.6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>f Gas Shrinkage Factor*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>g Temperature (°Rankine)</td>
<td>0</td>
<td>0</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

* Includes gas volume lost to condensate drop-out and content of inert gases (Nitrogen, Oxygen, Argon, Hydrogen Sulfide, Carbon Dioxide, and Helium)
10,000 Trials Calculate Conditional Oil & Gas Resources for 10’s-100’s of Thousands of “Simulation Pools”

Simulation Pools Are:
1. Used to Construct Actual Pools
   Forecast for Play
2. Aggregated and Risked to Estimate “Geologic” Endowments of Plays
3. Individually Sampled and Tested for Economic Success
>100 model parameters (engineering, costs, scheduling, and financial) are entered as ranged distributions.
ECONOMIC ASSESSMENT

• Hypothetical “simulation pools” as modeled by geological model

• Engineering simulation based on sizes and locations of hypothetical “simulation pools”

• Cost schedule and production & revenue stream based on engineering simulation

• Economic outcome based on discounted-cash-flow (DCF) model
2006 Beaufort Price/Supply Curve (Mean Resource Case)

Trillions of Cubic Feet of Gas

Billions of Barrels of Oil & Condensate

- **OIL & CONDENSATE**
  - ANS Crude $55-$65/bbl
  - Sept ’05-Mar ’06

- **FREE GAS AND SOLUTION GAS**

Economic Thresholds
- Oil $22 ($2005)/barrel
- Gas $3.33 ($2005)/Mcf

Data & Image Provided by C. Reitmeier, Dec ’05

Oil Price $2005/bbl at U.S. West Coast

Gas Price $2005/Mcf at U.S. Midwest

Data & Image Provided by C. Reitmeier, Dec ’05
2006 Chukchi Price/Supply Curve (Mean Resource Case)

Trillions of Cubic Feet of Gas

Billions of Barrels of Oil & Condensate

Oil Price $2005/bbl at U.S. West Coast

Gas Price $2005/Mcf at U.S. Midwest

Free Gas and Solution Gas

Economic Thresholds
- Oil $30 ($2005)/barrel
- Gas $4.54 ($2005)/Mcf

ANS Crude
- $55-$65/bbl
- Sept '05-Mar '06

Data & Image Provided by C. Reitmeier, Dec '05
# 6 Lease Sales for Arctic Offshore

<table>
<thead>
<tr>
<th>Sale No.</th>
<th>Area</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>202</td>
<td>Beaufort Sea</td>
<td>Mar 2007</td>
</tr>
<tr>
<td>193</td>
<td>Chukchi Sea</td>
<td>2007?</td>
</tr>
<tr>
<td>209</td>
<td>Beaufort Sea</td>
<td>2009</td>
</tr>
<tr>
<td>211</td>
<td>Cook Inlet</td>
<td>2009</td>
</tr>
<tr>
<td>212</td>
<td>Chukchi Sea</td>
<td>2010</td>
</tr>
<tr>
<td>217</td>
<td>Beaufort Sea</td>
<td>2011</td>
</tr>
<tr>
<td>219</td>
<td>Cook Inlet</td>
<td>2011</td>
</tr>
<tr>
<td>221</td>
<td>Chukchi Sea</td>
<td>2012</td>
</tr>
</tbody>
</table>