Source-Reservoired Oil Resources
Alaskan North Slope

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Unconventional resources

Distinguished from conventional resources by

- **lower geologic risk**... hydrocarbons are almost certainly present everywhere within the play fairway

**BUT**

- **higher engineering risk**... not sure the resource will be recoverable everywhere (massive stimulations must succeed)
Unconventional terminology
Some terms are more specific than others

- Resource plays
- Continuous accumulations
- Basin-centered accumulations
- Technology reservoirs
- Tight oil / gas
- Shale gas / shale oil (≠ oil shale)
- Source-reservoired oil / gas

✓ Source = Reservoir = Trap
North Slope Region

Great Bear Petroleum approximate land position

Seismic transect
North Slope Petroleum Systems

3 prolific source rock intervals

- Kuvluum, Hammerhead
- Ugnu, Badami, Sourdough
- W. Sak, Schrader Bluff, Nikolaichuk, Orion, Polaris, Tabasco

- Tarn, Meltwater
- Umiat, Fish Creek, Simpson
- Gubik, E Umiat, Skar Lake, Wolf Creek, Qumalik, Meade

- Nanuq
- Pt Thomas, Kuparuk, Pt McIntyre, Miile Pt, Fiord (Kuparuk), Niakuk
- Burger, Walkapa, Alpine, Lookout, Spark, Rendezvous
- Fiord (Nechelik)

- South Barrow, East Barrow
- Kernik
- Prudhoe Bay, Northstar, Raven
- Sandpiper, Kavik

- Lisburne
- Endicott, Liberty

- Lisburne (Kuna) (oil source)
- Endicott (Kekiktuk) (gas source)

- Hue (GRZ) - Pebble Shale - Torok (oil source)
- Kingak - Blankenship (oil source)
- Shublik - Otuk (oil source)

- Mostly Stratigraphic
- Mostly Structural

Beaufortian Brookian

Modified by Alaska Division of Oil and Gas staff from Ken Bird and David Houseknecht (U.S. Geological Survey), personal communication, 2002
Central North Slope Seismic Transect
Public Seismic Line ARCO 80-07 & 80-06

West

- Total length ~120 miles

• GRZ-Hue Sh at ~8,000 – 13,000 ft depth
• Shublik + Lower Kingak at ~10,000 ft depth

East

(Decker, unpublished data, 2010-11)
Key Geologic Factors -- Shale Resource Plays

- **Organic Geochemistry**
  - Total Organic Carbon content (richness)
  - Hydrogen Index (oil-prone, gas-prone, or inert kerogen types)
  - Oil properties (gravity, in-situ viscosity, wax & asphaltene content, etc.)

- **Thermal and Tectonic History**
  - Thermal maturity (immature → oil window → gas window → supermature)
  - Stress-strain history (# of phases of natural fracturing, etc.)
  - Current stress regime (determines orientation of artificial fractures and whether natural fractures are propped open)

- **Petrophysics**
  - Porosity (void space between grains, within grains, and in fractures)
  - Permeability (how connected are pore spaces?)
  - Relative Permeability (oil, gas, water – which flows more readily?)

- **Geomechanics** -- Is the rock brittle enough to create and sustain fractures?
  - Cement content and types (carbonate, silica, sulfides, etc.)
  - Grain content and types (silt, sand, fossil debris, etc.)
  - Layering (thickness and mechanical contrast)
Close Well Spacing, Many Pads

70 acres total surface impact (14 pads, 5 acres each) → 17,920 acres of subsurface development (2 mile-long laterals on each side of road times 7 miles length times 640 acres/mi²)

(Canadian Business Resources)

(courtesy Lynn Helms NDIC, DMR, 2011)
Close Well Spacing, Many Pads
Infrastructure-intensive development

- Bakken Shale 640 acres/well (Sanish & Parshall Fields)
- Eagle Ford Shale 125-140 acres/well (EOG plans)
- North Slope 120-160 acres/well (Great Bear estimates)

(Paneitz/Whiting Petroleum, 2010)
Frac FAQs

❖ How do they work?

Fluid (water + sand + additives for gelling and gel-breaking, etc.) is pumped into an isolated part of the borehole under increasing pressure. When the fluid pressure exceeds the rock strength, the formation fractures and the sand-rich fluid shoots out into the growing cracks. The sand props the fractures open after the frac fluid flows back into the wellbore.

❖ How much water do they use?

Frac jobs for horizontal producers in L48 shale plays consume 1 to 5.5 million gallons of water (and millions of pounds of sand) per well, depending on rock properties, number of stages pumped, etc.

❖ What are the environmental risks?

Contamination of fresh water aquifers with hydrocarbons and/or frac fluids can occur where the hydrocarbon target and aquifer are not sufficiently separated. THIS SHOULD BE AVOIDABLE!
Frac Jobs
Where are the fractures and how far do they extend?

In this example, frac wings appear to extend ~450-550 ft to either side of the wellbore with some asymmetry.

Microseismic map of 9-stage hydraulically fractured horizontal well (Bello, 2009)
Successful shale wells produce at a relatively high initial rate.

Rates decline sharply early on, then decline more slowly.

Individual wells may produce for decades (depending on costs, etc.).
Texas Analogue (?)
Upper Cretaceous Eagle Ford Shale

- Brittle: up to 70% calcite
- 50-250 ft thick; potentially all net pay
- 2-7% TOC
- Extensive area of thermal maturity
- Porosity 7-15%
- Narrow overpressure zone

(Energy Information Administration, 2010)
North Dakota Analogue (?)
Devonian-Mississippian Bakken Fm – First 60-90 day oil rates

(Nordeng, 2010; Nordeng and others, 2010)
**Bakken Well Economics and Production**

North Dakota Industrial Commission, Department of Mineral Resources

- **Well Cost, Horizontal Producer**: $6.1 million (47 jobs)
- **Operating Cost, Monthly**: < $7,000 (1 job)
- **Royalty Rate**: 16.7%
- **Average Initial Production Rate**: 955 BOPD
- **Breakeven IP Oil Rate**: 235 BOPD
- **Breakeven Reserves per well**: 183,000 bbl
- **Breakeven Reserves Success**: 83%

(courtesy Lynn Helms NDIC, DMR, 2011)
Shublik Formation
Variability in outcrop and well logs

Interbedded shale & limestone, silty-muddy, phosphatic, pyritic (up to 600 ft thick)
Shublik Formation
Well logs and zonal correlations

(Decker, unpublished data, 2011)
Lower Kingak Formation

\[ \Delta \text{Log R source rock screening} \]

Inigok 1
- Lower Kingak Fm source
- ~175-550 ft thick

Itkillik River 1

Bush Fed 1

Sag River

Shublik
Hue Shale/GRZ

Correlations and log-based Total Organic Content estimates

Itkillik R 1  Atlas 1  Narvaq 1  W Sak 26  Toolik 2  Hemi Spr 3

\[ \Delta \text{Log R calculated TOC estimates} \]

\begin{align*}
\text{Hue Sh} & : 4.9\% & 2.6\% & 3.1\% & 4.8\% (\text{?}) \\
\text{GRZ} & : 2.6\% & 2.4\% & 1.6\% & 5.0\% & 3.1\% & 10.3\% (\text{?}) \\
\end{align*}

(Decker, unpublished data, 2009)
Shublik and Lower Kingakak Formations
Thermal Maturity Zone

(mature area after Peters and others, 2006)
Hue Shale/GRZ
Thermal Maturity Zone

(mature area after Peters and others, 2006)
## Comparison

### Source rock characteristics

<table>
<thead>
<tr>
<th>Source Rock</th>
<th>Bakken</th>
<th>Eagle Ford</th>
<th>Shublik</th>
<th>L. Kingak</th>
<th>Hue/GRZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Organic Carbon</td>
<td>10% avg</td>
<td>2-7%</td>
<td>2.4% avg</td>
<td>5% avg</td>
<td>3% avg</td>
</tr>
<tr>
<td>Main Kerogen Types</td>
<td>I/II (oil)</td>
<td>I/II (oil)</td>
<td>I/II-S (oil)</td>
<td>II/III (oil-gas)</td>
<td>II/III (oil-gas)</td>
</tr>
<tr>
<td>Oil Gravity, °API</td>
<td>42°</td>
<td>30-50°</td>
<td>24°</td>
<td>40°</td>
<td>38°</td>
</tr>
<tr>
<td>Thickness</td>
<td>up to 100 ft</td>
<td>50-250 ft</td>
<td>0-600 ft</td>
<td>175-550 ft</td>
<td>100-800 ft</td>
</tr>
<tr>
<td>Thermal Maturity</td>
<td>Imm-Oil-Gas</td>
<td>Imm-Oil-Gas</td>
<td>Imm-Oil-Gas</td>
<td>Imm-Oil-Gas</td>
<td>Imm-Oil-Gas</td>
</tr>
<tr>
<td>Lithology &amp; Variability</td>
<td>Sh-Slts-Sh</td>
<td>Sh-Slts-Ls</td>
<td>Sh-Slts-Ls</td>
<td>Shale</td>
<td>Sh-Tuff</td>
</tr>
<tr>
<td>Brittleness</td>
<td>Yes - Quartz</td>
<td>Yes - Calcite</td>
<td>Yes - Calcite</td>
<td>No ?</td>
<td>No ?</td>
</tr>
<tr>
<td>Natural Fractures</td>
<td>Yes</td>
<td>Locally</td>
<td>some zones</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Overpressure</td>
<td>Yes</td>
<td>Locally</td>
<td>?</td>
<td>Probably</td>
<td>Locally</td>
</tr>
</tbody>
</table>

(Compiled from various sources, Decker, 2011)
Summary

- Many variables impact productivity of source-reservired oil and gas
  - Organic geochemistry
  - Thermal and tectonic history
  - Petrophysics
  - Geomechanics
  - Drilling and completion practices

- Development of North Slope shale oil will likely depend on
  - Successful exploration drilling, data gathering to establish geological favorability
  - Successful production pilot project(s)
  - Lowering drilling and operating costs
  - All-season roads for year-round surface access to new areas
  - More hydraulic frac crews
  - Sufficient water supplies for frac make-up fluid
  - Factual understanding and operator transparency regarding frac practices