U.S. Geological Survey 2011 Assessment of Undiscovered Oil and Gas Resources of the Cook Inlet Region, South-Central Alaska

Richard G. Stanley, Brenda S. Pierce, and David W. Houseknecht

Outline of this presentation:

• Summary of results
• What we did
• Where the resources might be found
USGS estimates of technically recoverable undiscovered resources, onshore & State waters parts of Cook Inlet

Mean, $F_{95}$, and $F_{05}$:
- Oil: mean 599 MMBO, range 108 to 1,359 MMBO
- Gas: mean 19,037 BCFG, range 4,976 to 39,737 BCFG
- NGL: mean 46 MMBNGL, range 6 to 121 MMBNGL

Explanation of abbreviations and terms:
MMBO, million barrels of oil.
BCFG, billion cubic feet of gas.
MMBNGL, million barrels of natural gas liquids (NGL).
$F_{95}$ represents a 95 percent chance of at least the amount shown.
$F_{05}$ represents a 5 percent chance of at least the amount shown.
Technically recoverable resources are those resources that can be discovered and produced using current technology.
Comparison 1:
Mean amount of undiscovered gas in Cook Inlet: ~19,000 BCFG

Compare to:
• 7,800 BCFG: Cumulative gas production in Cook Inlet to 2010
• 24,140 BCFG: Gas consumption in U.S. in 2010, according to U.S. Energy Information Administration (EIA) web site
• 35,400 BCFG: Remaining recoverable reserves of discovered gas on the North Slope of Alaska (Alaska Division of Oil and Gas, Annual Report 2009)
Comparison 2:
Mean amount of undiscovered oil in Cook Inlet: ~600 MMBO

Compare to:
- 1,300 MMBO: Cumulative oil production in Cook Inlet to 2010
- 7,000 MMBO: Oil consumption in U.S. in 2010, according to U.S. Energy Information Administration (EIA) web site
- 5,950 MMBO: Remaining recoverable reserves of discovered oil on the North Slope of Alaska (Alaska Division of Oil and Gas, Annual Report 2009)
Context 1: Public concern about possible near-term gas shortage in Anchorage and nearby communities

• Assumed future demand for natural gas ~90 BCF per year

From Hartz and others (2009), Alaska Department of Natural Resources (DNR)
Context 2: USGS estimates are *Technically Recoverable*

- Not all of the undiscovered oil and gas resources assessed by the USGS are accessible or economically viable.

- *For example, on this map from Hartz and others (2009), green shading shows areas with exploration access restrictions.*
New science by USGS and Alaska DNR (DGGS & DOG) since the previous USGS assessment of Cook Inlet (U.S. Geological Survey, 1995):

• Digital geologic map of Cook Inlet region
• New seismic reprocessing and interpretation
• Gravity and magnetics modeling
• Comprehensive review of organic geochemistry of oils and potential source rocks
• Modeling of the timing of oil generation
• New surface and subsurface geologic mapping and geochronology
• Field-based studies of Tertiary and Mesozoic depositional systems
• New studies of sedimentary petrology and reservoir quality
We gratefully acknowledge the State of Alaska, Department of Natural Resources (DNR), Division of Geological and Geophysical Surveys (DGGS) and Division of Oil and Gas (DOG), for collaboration in developing the geologic model used in this assessment.

Dave LePain (DGGS) and Ken Helmold (DOG) near Capps Glacier, Alaska
Geologic setting: Cook Inlet is a forearc basin
Cook Inlet region geography
Cook Inlet oil and gas

33 discovered fields with oil & gas production:
• 8 mostly oil
• 25 mostly gas

Cumulative production to the end of 2010, according to Alaska Oil and Gas Conservation Commission (AOGCC):
• Oil, ~1.3 BBO
• Gas, >7.8 TCFG
Cook Inlet regional geology

Geologic map by Wilson & others, 2009
Heavy black line shows location of cross section (next slide)
Cross section: Cook Inlet basin is deep

- Tertiary and Quaternary (66 to 0 m.y.) nonmarine strata (brown, orange, tan) about 25,000 ft (8 km) thick
- Jurassic and Cretaceous (200 to 66 m.y.) marine sedimentary rocks (shades of green) about 30,000 ft (9 km) thick, underlain by about 10,000 to 20,000 ft (3 to 6 km) of volcanic rocks
- Folds and related faults are mainly of late Miocene age and younger

Cross section by Plafker and others (1982)
### Cook Inlet rock units

<table>
<thead>
<tr>
<th>Age</th>
<th>Ma</th>
<th>Stratigraphic unit</th>
<th>Ma</th>
<th>Petroleum production</th>
<th>Petroleum source rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tertiary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pliocene</td>
<td>5</td>
<td>Quaternary deposits &amp; Sterling Fm., undivided</td>
<td>8</td>
<td>Microbial and thermogenic gas</td>
<td>Microbial gas</td>
</tr>
<tr>
<td>Miocene</td>
<td>23</td>
<td>Beluga and Tyonek Formations and Hemlock Conglomerate, undivided</td>
<td>33.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligocene</td>
<td>33.9</td>
<td>West Foreland and Chickaloon Fms., undivided</td>
<td>56</td>
<td>Oil</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>65.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eocene</td>
<td>55.8</td>
<td>Matanuska and Kaguyak Formations and Saddle Mountain unit, undivided</td>
<td>91-112</td>
<td></td>
<td>Oil</td>
</tr>
<tr>
<td>Paleocene</td>
<td>65.5</td>
<td></td>
<td>125</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cretaceous</strong></td>
<td></td>
<td></td>
<td>136-141</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>99.6</td>
<td>Herendeen &amp; Nelchina Formations, undivided</td>
<td>145.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>145.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>145.5</td>
<td>Naknek Formation</td>
<td>161</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>161</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Jurassic</strong></td>
<td></td>
<td></td>
<td>170</td>
<td>Oil</td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>161</td>
<td>Chinitna Fm. &amp; upper part of Tuxedni Gr, undiv.</td>
<td>176</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>176</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>176</td>
<td>Tuxedni Group, source rock interval</td>
<td>201.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>201.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>201.6</td>
<td>Talkeetna Formation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Triassic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>251</td>
<td>Kamishak Formation</td>
<td>216</td>
<td>(Oil &amp; thermogenic gas?)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>251</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Permian</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>251</td>
<td>Unnamed Permian volcaniclastic rocks</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Geologic time from Walker and Geissman (2009)*
Cook Inlet assessment units (AU)

- Assessment unit: a mappable volume of rock with common geologic traits

- Cook Inlet Coalbed Gas AU
- Tertiary Sandstone Oil and Gas AU
- Tuxedni-Naknek Continuous Gas AU
- Mesozoic Sandstone Oil and Gas AU
- Excluded from Coalbed Gas AU
Conventional versus continuous accumulations

Source: Schenk and Pollastro, 2002
Tertiary Sandstone Oil and Gas AU

• Conventional accumulations
• About 1200 well penetrations; about 30 known accumulations; cumulative production ~1.3 BBO and >7.8 TCFG to the end of 2010
• Source of oil and thermogenic gas is marine shale in Middle Jurassic Tuxedni Group
• Gas is mostly microbial, sourced from Tertiary nonmarine coals
• Reservoirs are mainly Tertiary fluvial sandstone and conglomerate
• All discovered traps are structural (anticlines and faulted anticlines)
• Undiscovered traps probably structural and stratigraphic
Tertiary Sandstone Oil and Gas AU

- Conventional accumulations
- About 1200 well penetrations; about 30 known accumulations; cumulative production ~1.3 BBO and >7.8 TCFG to the end of 2010
- Source of oil and thermogenic gas is marine shale in Middle Jurassic Tuxedni Group
- Gas is mostly microbial, sourced from Tertiary nonmarine coals
- Reservoirs are mainly Tertiary fluvial sandstone and conglomerate
- All discovered traps are structural (anticlines and faulted anticlinal)
- Undiscovered traps probably structural and stratigraphic
- Underexplored
<table>
<thead>
<tr>
<th>Tuxedni Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Jurassic</td>
<td></td>
</tr>
<tr>
<td>Middle and Upper Jurassic</td>
<td></td>
</tr>
<tr>
<td>Callowian</td>
<td></td>
</tr>
<tr>
<td>L. Bathonian - Callovian</td>
<td></td>
</tr>
<tr>
<td>Early Bajocian</td>
<td></td>
</tr>
<tr>
<td>Lower middle Bajocian</td>
<td></td>
</tr>
<tr>
<td>Middle Bajocian</td>
<td></td>
</tr>
<tr>
<td>Upper middle Bajocian</td>
<td></td>
</tr>
<tr>
<td>Early Jurassic</td>
<td></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinitna Fm</td>
<td>Local unconformity</td>
</tr>
<tr>
<td>Bowser Fm. (~550 m)</td>
<td></td>
</tr>
<tr>
<td>Twist Creek Silstone (~100 m)</td>
<td>Major unconformity</td>
</tr>
<tr>
<td>Cynthia Falls Sst. (~200 m)</td>
<td></td>
</tr>
<tr>
<td>Fitz Creek Siltstone (~330 m)</td>
<td></td>
</tr>
<tr>
<td>Gaikema Sst. (~180 m)</td>
<td>Local unconformity</td>
</tr>
<tr>
<td>Red Glacier Fm. (~1,400 m)</td>
<td></td>
</tr>
</tbody>
</table>

Approximate position of outcrop

Middle Jurassic shale (176 to 161 m.y. old), near Red Glacier

(Column drafted by Dave LePain, DGGS)
Reservoir rocks, Tertiary Sandstone Oil and Gas AU

Sterling Formation, Clam Gulch

Beluga Formation, west of Homer

Beluga Formation, west of Homer

Tyonek Formation, near Capps Glacier
All discovered fields are on anticlinal structures

Illustration by Paul Lillis, USGS, Sept. 2010
Cross section by Alaska Geological Society, 1970
Undiscovered fields probably include stratigraphic and combination traps

Cook Inlet Geology
Discontinuous Sands

Source: Biddle and Wielchowsky, 1994, AAPG Memoir 60
Seismic data suggest untested oil and gas potential in the Tertiary Sandstone Oil and Gas AU

Seismic interpretation by Krissy Lewis, USGS

Potential for stratigraphic traps on homocline

Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of the USGS.
Tertiary Sandstone Oil and Gas AU

Mean undiscovered oil: 372 MMBO
Mean undiscovered gas: 12,178 BCFG

Area ~21,800 km²
Federal, 21%
Private/municipal, 13%
Native, 8%
State onshore, 27%
State offshore, 31%
Mesozoic Sandstone Oil and Gas AU

- Conventional accumulations
- More than 100 well penetrations, but few drilled deep into Mesozoic
- 1 oil accumulation with cumulative production ≤ 332,951 barrels of oil from M-28 well, McArthur River field, 1990-1999
- Oil seeps onshore on SW side of basin; oil shows in wells on Kenai Peninsula and in Federal offshore
- Source of oil and thermogenic gas is Middle Jurassic Tuxedni Group
- Reservoirs may be Mesozoic sandstone and volcanic rocks, fractured
- Undiscovered traps probably structural and stratigraphic
- Mostly unexplored
Potential reservoir rocks, Mesozoic Sandstone Oil and Gas AU

Naknek(?) Formation, Chinitna Bay

Naknek Formation, Chisik Island

Cynthia Falls Formation, Tuxedni Bay

Red Glacier Formation, Tuxedni Bay
Mesozoic Sandstone Oil and Gas AU

Mean undiscovered oil: 227 MMBO
Mean undiscovered gas: 1,548 BCFG

Area ~20,100 km²
Federal, 21%
Private/municipal, 11%
Native, 10%
State onshore, 26%
State offshore, 31%
Tuxedni-Naknek Continuous Gas AU

- Proposed by Phil Nelson and Chris Schenk, USGS, Denver
- Continuous accumulations
- Speculative
- No discovered accumulations
- Inferred resource is thermogenic gas derived from source rocks in Middle Jurassic Tuxedni Group
- Reservoirs hypothesized to be low-permeability Mesozoic sandstone at depths of 20,000 ft (6,000 m) or more
- Overpressured, possibly related to hydrocarbon generation
- Entirely unexplored (no known well penetrations)
Tuxedni-Naknek Continuous Gas AU

Mean undiscovered gas: 637 BCFG

Area ~900 km²
Federal, 1%
Private/municipal, 20%
Native, 5%
State onshore, 2%
State offshore, 72%

BLM
USFS
Military
NPS
FWS
Native
Private/Municipal
State
State & Native

USGS
Cook Inlet Coalbed Gas AU

• Proposed by Bill Rouse and Dave Houseknecht, USGS, Reston

• Continuous accumulations

• No discovered commercial accumulations

• About 20-25 wells drilled specifically in search of coalbed gas, 1994-2005, all unsuccessful

• Microbial gas sourced from, and trapped in, thick coal beds; mostly in Beluga and Tyonek Formations

• Excluded is an area where the principal coal-bearing units are buried deeper than 6000 feet

• Mostly unexplored
Cook Inlet Coalbed Gas AU

Mean undiscovered gas: 4,674 BCFG

Area ~34,300 km²
Federal, 14%
Private/municipal, 8%
Native, 8%
State onshore, 56%
State offshore, 14%
SUMMARY

• The USGS has completed an assessment of the volumes of undiscovered, technically recoverable oil and gas resources in conventional and continuous accumulations in Cook Inlet.

• The assessment used a geology-based methodology and results from new scientific research by the USGS and the State of Alaska DGGS and DOG.

• In the Cook Inlet region, the USGS estimates mean undiscovered volumes of nearly 600 million barrels of oil, about 19 trillion cubic feet of gas, and about 46 million barrels of natural gas liquids.
For Additional Information:

Cook Inlet assessment fact sheet available at
http://pubs.usgs.gov/fs/2011/3068/

Other USGS petroleum fact sheets available at
http://energy.usgs.gov/

Other inquiries may be directed to
Rick Stanley, rstanley@usgs.gov
(650) 329-4918
Brenda Pierce, bpierce@usgs.gov
(703) 648-6421
Dave Houseknecht, dhouse@usgs.gov
(703) 648-6466
References Cited


Energy Information Administration (EIA), http://www.eia.gov/


