Major Oil Finds and Exploration Potential in the Brookian Sequence, Alaska North Slope

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Presented by: Paul Decker and Joe Chmielowski, Resource Evaluation Section, Division of Oil and Gas, Alaska Department of Natural Resources

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Several exciting Nanushuk and Torok Formation discoveries are at different stages of maturity. Significant delineation drilling this winter in the Pikka-Horseshoe and Willow trends.
# Major Recent Brookian Discoveries

<table>
<thead>
<tr>
<th></th>
<th>Smith Bay</th>
<th>Willow</th>
<th>Pikka/Horseshoe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operator</strong></td>
<td>Caelus</td>
<td>ConocoPhillips</td>
<td>Armstrong</td>
</tr>
<tr>
<td><strong>Reservoir Formation</strong></td>
<td>Torok Fm</td>
<td>Nanushuk Fm</td>
<td>Nanushuk Fm</td>
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<tr>
<td><strong>Location</strong></td>
<td>State Waters Offshore of NPRA</td>
<td>Federal Onshore Northeast NPRA</td>
<td>Onshore Colville Delta</td>
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<tr>
<td><strong>Road/Pipeline Tie-in</strong></td>
<td>~ 125 miles</td>
<td>~ 28 miles</td>
<td>~ 20 miles</td>
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<tr>
<td><strong>Trap type</strong></td>
<td>Turbidite Stratigraphic</td>
<td>Topset Stratigraphic</td>
<td>Topset Stratigraphic</td>
</tr>
<tr>
<td><strong>Net Pay</strong></td>
<td>183-223 ft (unconfirmed)</td>
<td>42-72 ft</td>
<td>&lt; 225 ft</td>
</tr>
<tr>
<td><strong>Oil Gravity</strong></td>
<td>40-45 deg API (est)</td>
<td>44 deg API</td>
<td>30 deg API</td>
</tr>
<tr>
<td><strong>Test Rate</strong></td>
<td>No Flow Tests</td>
<td>&lt; 3,200 bopd vertical</td>
<td>~ 2,100 bopd vertical; 4,600 bopd horizontal</td>
</tr>
<tr>
<td><strong>Contingent Recoverable Resource</strong></td>
<td>1.8-2.4 BBO (est)</td>
<td>300 MMBO</td>
<td>1.2 BBO</td>
</tr>
<tr>
<td><strong>Expected Production (Operator Releases)</strong></td>
<td>&lt; 200,000 bopd</td>
<td>40,000-100,000 bopd</td>
<td>&lt; 120,000 bopd</td>
</tr>
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</table>
The Brookian sequence represents a wide range of clastic rocks shed from the Chukotka and ancestral Brooks Range orogens into the Colville foreland basin during Cretaceous and Tertiary time.

Multiple formations make up the clinoformal succession, which filled the basin from west to east.

Readily apparent in seismic, Brookian clinoforms consist of:
- **Topsets**: sand-prone coastal plain and shallow marine shelf
- **Foresets**: muddy slope and sandy turbidite channels and slope apron fans
- **Bottomsets**: sandy basin-floor turbidites, organic-rich condensed shales

In the central to western North Slope, the topsets are the Nanushuk Formation, whereas the time-equivalent foresets and bottomsets represent the Torok Formation.

Nanushuk tends to have superior reservoir quality due to matrix winnowing and less compaction (shallower burial)
Cretaceous Brookian Sequence

- Line A -

Nanushuk Fm Topsets
Torok Fm Slope foresets & Basin-floor bottomsets

Note distortion of Tuluvak growth-faulted interval caused by flattening on shallower horizon

Image from David Houseknecht, USGS; courtesy GeoExpro and Western-Geco Multiclient
• Overall progradation of Nanushuk-Torok clinothem across foreland basin illustrated schematically as series of advancing shelf margins.
• Numerous higher-order sea-level fluctuations repeatedly set up potential for enhanced reservoir and stratigraphic traps.
• Play extends across central and western North Slope.
Basal Nanushuk Seismic Anomalies - 1981 2D Data, NPRA -

Inigok 1  North Inigok 1  North Kalikpik 1

SW

Torok Fm

Tuluvak & Seabee Fms

Nanushuk Fm

HRZ – Hue Shale (oil source rock)

Fish Creek slumps

Public seismic line USGS 81-27
Nanushuk Shelf-Margin Anomalies
- Northern NPRA -

Far offset stack reconnaissance

20-40° angle stack

AVO Class volume characterization

Source: Niglio and others, 2011 (BLM, BOEMRE) with permission of data owners WesternGeco, LLC and Geokinetics
Amplitudes corresponding to lowstand sands perched on incised outer shelf/upper slope

Source: Niglio and others, 2011 (BLM, BOEMRE) with permission of data owners WesternGeco, LLC and Geokinetics
Pikka Discovery - Nanushuk Fm

Repsol Qugruk 3,
P&A 4/1/2013

Nanushuk Fm
(seismic topset facies)

Top Torok Fm
(sandy lowstand wedge,
seismic upper slope facies)

Known pay, 30 deg API on MDT

Potential pay

upper facies tested 4,600 bopd
in horizontal Q8 offset well

Qugruk 3 announced as multi-horizon discovery April 2013; Play type is characterized by stratigraphically-trapped shelf margin/lowstand wedge sandstones in lower Nanushuk and underlying sandy slope Torok Formation.
Pikka-Horseshoe Trend
2018 Stony Hill Targets, Nanuq South 3D

Nan3 Two-Way Time Horizon
- Picked on 5X5 Grid
- TWT range: 0.95 to 1.45 sec
**Pikka-Horseshoe Nanuq South 3D**

**Time Slice vs. Far Stack Amplitudes**

**Full Stack Time Slice (1156ms)**

**Far Stack RMS Amplitude Extraction**

*(20ms offset, 60ms window)*

- **Putu 2 & 2A**
- **Horseshoe 1 & 1A**
- **Nan 0**
- **Nan 2**
- **Nan 3**
- **Itkillik River Unit #1**
- **2018 Stony Hill 1 & 1A**

- **Putu 2 & 2A**
- **Horseshoe 1 & 1A**
- **Itkillik River Unit #1**
- **2018 Stony Hill 1 & 1A**
- **Nan 0**
- **Nan 2**
- **Nan 3**
Willow discovery announced January, 2017 was a follow-up of this 2002 discovery. Play type is characterized by stratigraphically-trapped lowstand shoreface shelf margin sandstones in lower Nanushuk Formation.


Lower part of Nanushuk Fm (basal topset facies)

Willow interval: secondary objective with light oil/gas shows; Tinmiaq 2 and 6 wells confirmed discovery with up to 3,200 bopd test.

Top Torok Fm (uppermost slope facies)
Nanushuk poroperm data cluster in geographically defined trends, which in turn relate to maximum burial and uplift.
USGS and BOEM are actively reassessing the Arctic Alaska region’s mean undiscovered, technically recoverable conventional resources.

- As of December 2017, interim revisions raise the mean estimate for all of Arctic Alaska by ~9 billion barrels to nearly 50 billion barrels of oil + NGL.
  - Mean onshore and offshore resource estimates each total to more than 24 billion barrels of oil + NGL.

- The Nanushuk topset play of the central and western North Slope is far more prospective than recognized in previous resource assessments.
  - For example, at 300 million barrels recoverable, the Willow discovery alone far exceeds even the 2010 USGS upside estimate (F5 case) for the entire Stratigraphic Brookian Topset play in NPRA.
  - By itself, the Nanushuk Fm play (NPRA, state lands, and nearby OCS) is now assessed with a mean of 7.3 billion barrels of oil + NGL.
Data are updated frequently and available for discounted purchase at [http://dggs.alaska.gov/gmc/seismic-well-data.php](http://dggs.alaska.gov/gmc/seismic-well-data.php)