Crustal and Petroleum Framework of the U.S. Chukchi Shelf as Interpreted from 9-km Long-Offset ArcticSPAN™ 2-D Seismic Data*

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Abstract

The U.S. Chukchi Shelf is a highly prospective petroleum province with estimated mean technically recoverable resources of more than 29 billion barrels of oil equivalent (MMS, 2006). Because of the remoteness of the area in the northwest Alaskan offshore and the cost of operations, the area has seen only one round of leasing and drilling which was almost 20 years ago. With high oil prices and new technology, industry has shown a renewed interest in the area.

In response to this interest, ION Geophysical (GX Technology) acquired 3,132 km of 2-D long-offset seismic data in the area in late 2006. The program was designed to image down to the base of the crust with a 9 km-long cable, 18 second recording, and final depth processing (Pre-stack Depth Migration) to 40 km. The interpretation of these data has allowed us to regionally map the MOHO discontinuity and the top of the crystalline basement as well as to identify the major stratigraphic sequences which extend from the highly petroliferous North Slope of Alaska. We have also attempted to interpret the pre-Mississippian (prior to the opening of the Canada Basin) rifting and compressional history of the area based on these data.

Interpretation highlights of the data set include: 1) The Chukchi Shelf is underlain by “normal” continental crust (30-40 km thick) with some suggestion of an attenuated crust in the northern and north-western part of the area; 2) The North Chukchi Basin contains up to 12 km (40,000 ft) of apparent Cretaceous- and Tertiary-age sediments and should be considered quite prospective; 3) Part of the shelf is underlain by mildly deformed pre-Mississippian sediments and may be prospective for hydrocarbons; and 4) The interpretation of the data supports the anticlockwise rotational hypothesis of the Alaska-Chukotka plate away from the Canadian Arctic islands.
AAPG International Conference, Cape Town
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James Granath, Naresh Kumar, and Pete Emmet
Consultants on the ArcticSPAN Team

With contributions from Dale Bird, consultant to ION
Canada Basin Conjugate Margin Focus

Russia SPANs

SverdrupSPAN

BeaufortSPAN East I

Chukchi Span

BeaufortSPAN West I

Modified from Klemperer and Miller (2004)

Completed

Proposed
SPAN Programs Along the Southern Canada Basin Margin

Topographic Setting of ChukchiSPAN and BeaufortSPAN

ChukchiSPAN

BeaufortSPAN East
Phases 1, 2, & 3
Chukchi Shelf Highlights

• Area approximately same area as the State of Mississippi but with only 5 wells!

• One undeveloped discovery plus shows in other wells

• First lease sale in almost 17 years took place on Feb. 6, 2008 – industry spent almost 2.7 billion dollars.

• Contiguous geology with North Slope of Alaska (>15 billion barrels produced).

• Mean undiscovered resource of Chukchi Shelf (MMS, 2006):
  
  15.4 billion barrels of oil and natural gas liquids
  76.8 trillion cubic feet of gas
Technical Specifications: ArcticSPAN™ s

Acquisition Parameters:
50 meter SP interval
25 meter record interval
**9,000 meter cable length**
Record Length: 18.0 sec
Sampling Interval 2 ms
Tape O/P – 3590 - SEGD

Processing Parameters:
CMP spacing 12.5 meters
90 Full fold
Sampling Interval 4 ms
Multi-frequency noise attenuation
Numerous multiple attenuation techniques (TAU-P, RADON, SRME)

Standard Products:
Raw Navigation Merged Shot Gathers
*Post-Processed Final Kirchoff PSDM stack to 40 km*
Final PSDM Depth-Interval Velocity Model
Structural and Stratigraphic Interpretation
Gravity and Magnetic data and interpretation
Final Report
Chukchi Shelf Geologic Setting

3,534 km of data

KNOWN PETROLEUM VOLUMES
~ 15 BBO PRODUCED
~ 7 BBO RESERVES
~ 35 TCF GAS RESERVES

(USGS, 2008)
Tectonic Setting of Sale 193 Lease Blocks

I. Foreland Compressional Structures
II. Chukchi Platform
III. Arctic Platform
IV. Hanna Trough
V. North Chukchi Basin
## Seismic Horizons Identified on the ChukchiSPAN data

### Target Reservoir Intervals

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Unconformity/Estimated Age (m.y.)</th>
<th>Approx. Sequence/Formation Boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brookian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Tertiary</td>
<td>65 (mBU)</td>
<td>Upper Brookian Seq.</td>
</tr>
<tr>
<td>Torok</td>
<td>97 (BU)</td>
<td>Sagavanirktok Fm.</td>
</tr>
<tr>
<td>Pebble Shale</td>
<td>125 (LCU)</td>
<td>Nanushuk Group/Colville Gp.?</td>
</tr>
<tr>
<td>Lower Cretaceous Unconformity</td>
<td>136 (JU)</td>
<td>Lower Brookian Sequence</td>
</tr>
<tr>
<td>Kingak</td>
<td>270 (PU?)</td>
<td>Torok Fm</td>
</tr>
<tr>
<td>Lisburne</td>
<td>340 (AB)</td>
<td>Pebble Shale/HRZ</td>
</tr>
<tr>
<td>Endicott</td>
<td>377? (AB)</td>
<td>LCU/Upper Kingak?</td>
</tr>
<tr>
<td>Franklinian</td>
<td></td>
<td>Lr. Kingak Fm./Sadlerochit Gp.</td>
</tr>
<tr>
<td>Intra-Franklinian A</td>
<td></td>
<td>Lisburne Group</td>
</tr>
<tr>
<td>Intra-Franklinian B</td>
<td></td>
<td>Endicott Group</td>
</tr>
<tr>
<td>Intra-Franklinian C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-Franklinian D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-Franklinian E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-Franklinian F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-Franklinian G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-Franklinian H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crystalline Basement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Franklinian (Top Acoustic Basement)**

*Note: In thrusting terrains, when horizons repeat vertically, they have been named G1, G2 etc. on seismic lines. That just indicates a repeat section.*
Composite Line Connecting All Five Wells

Modified from Houseknecht and Bird, 2006
Isopachs of the Upper Ellesmerian Sequence

ChukchiSPAN Isopach Kingak to Lisburne

Target Reservoirs

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Upper Ellesmerian Seq</th>
<th>Lr. Kingak Fm./Sadlerochit Gp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingak</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>Lisburne</td>
<td>340</td>
<td>Lisburne Group</td>
</tr>
</tbody>
</table>
N-S Regional Line Across The Shelf

- Klondike
- Crackerjack
- Popcorn

- LCU
- Lisburne
- Franklinian

- MOHO

- Brookian (Post-Rift)
- Beaufortian (Rift)
- Ellesmerian (Pre-Rift)

350 km
N-S Regional Line Across The Shelf

Cryst. Bsmt.

MOHO
Isopachs of the Rift Sequence

ChukchiSPAN Isopach LCU to Kingak

Target Reservoirs

136 (LCU)
148 (JU)

Rift Sequence

LCU/Upper Kingak?
Structural Interpretation of Franklinian Sequences

V.E. = ~x3

Klondike  Burger  Diamond

300 km

LCU  Lisburne  Franklinian

Alpine Field
Seismic Tie Line Connecting Existing Wells

Well Tie Composite Line 7300 – 6100: Shallow (10 km) Structural Interpretation

Well Tie Composite Line 7300 – 6100: Deep (40 km) Structural Interpretation

Well Tie Composite Line 7300 – 6100: Velocity Structure to 40 km
Chukchi Shelf Rotated to Pre-drift Location

Arctic Reconstruction
150 my ago
Canada Basin Closed

700 km

1. Mackenzie Delta
2. Arctic Alaska
3. Chukotka
4. Lomonosov Ridge
5. Sverdrup Basin

C- ChukchiSPAN

Modified from Lawver, Gahagan, and Grantz, 2004
Notes by Presenter: Various tectonic features and the locations of SPAN lines shown on gravity anomaly map of Canada basin. Note the linear feature which extends towards the Mackenzie Delta area. A change in the pole of rotation is implied from the shape of this feature which we interpret as an extinct spreading center. Large gravity anomaly at the continental margin in Canada and Alaska is interpreted as the COB. This boundary is shown as a dashed boundary because the nature of the anomaly is subdued in the area, perhaps because of 14 km of delta sediments. The thin dashed lines are lineaments seen in the gravity data, perhaps, they suggest the location of fracture zones created during the sea-floor spreading in the basin.
Structure Map on Top of Mantle (MOHO)
Summary and Conclusions

• Stratigraphic sequences ranging from Pre-Cambrian to Tertiary can be identified.

• North Chukchi Basin contains sediments of Beaufortian and Brookian age (Upper Jurassic through Tertiary) almost 12 km thick.

• At least part of the Franklinian (Pre-Mississippian) sequence is represented by mildly-deformed Paleozoic and older (?) rocks.

• SPAN data provides a regional stratigraphic and tectonic framework at crustal level down to the MOHO.

• Regional deep crustal seismic profiles using advanced imaging technology yield advancement in the knowledge of basin evolution and thus, in petroleum-system assessment.
Acknowledgements

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THANK YOU
References

