

Nanushuk Formation Discoveries: World-class exploration potential in a newly proven stratigraphic play, Alaska North Slope

2018 AAPG ACE Discovery Thinking Forum

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- Alaska Division of Oil and Gas



Nanushuk and Torok Formations, Slope Mountain

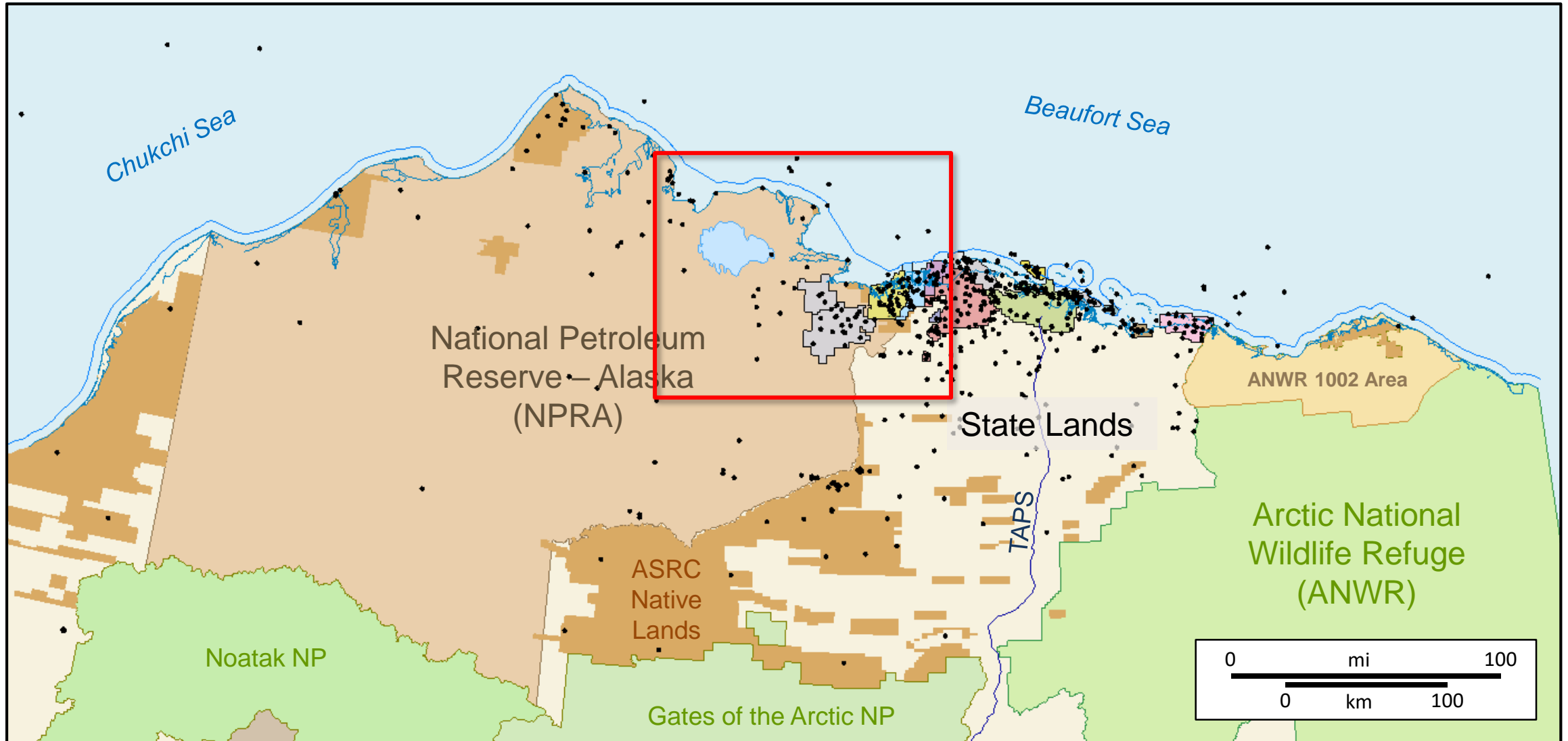
TOPICS & THEMES

- North Slope introduction and recent activity
- Regional geology – Nanushuk & Torok Fm plays
- Compare & contrast recent major discoveries
- Basal Nanushuk topset play – seismic expression
- Cracking the nut – significance of the new play
- Implications for undiscovered oil

Nanushuk Formation, Killik Bend, Colville River

NORTHERN ALASKA

- UNDEREXPLORED PETROLEUM PROVINCE -



WINTER-ONLY REMOTE EXPLORATION

- ICE ROADS, ICE PADS -



*Photo: US Army Corps of Engineers
Nanushuk Project EIS, 2017*



Photo: Oil Search Investor Presentation, December 2017



Photo: ConocoPhillips Alaska, Meet Alaska 2018

RECENT BROOKIAN DISCOVERIES

- NANUSHUK AND TOROK FORMATIONS -

Several exciting Nanushuk and Torok Formation discoveries are at different stages of maturity.

The 2018 winter exploration season saw 7 Nanushuk penetrations, 5 flow tests, and a 250-square-mile 3D survey in the Pikka-Horseshoe and Willow trends.

Smith Bay
(Torok Fm turbidites)

Interior Department reviewing
2013 restrictions on future
leasing in northern NPRA.

USGS recently dramatically
increased estimates of NPRA's
undiscovered oil resource.

Unavailable to Leasing

National Petroleum
Reserve - Alaska
(NPRA)

Cassin
(Torok Fm turbidites)

Unavailable to Leasing and no new
non-subsistence infrastructure

Willow
(Nanushuk Fm topsets)

25 mi

Nuna/Moraine
(Torok Fm turbidites)

NN-01

Pikka/Horseshoe
(Nanushuk Fm topsets)

Putu 2, 2A

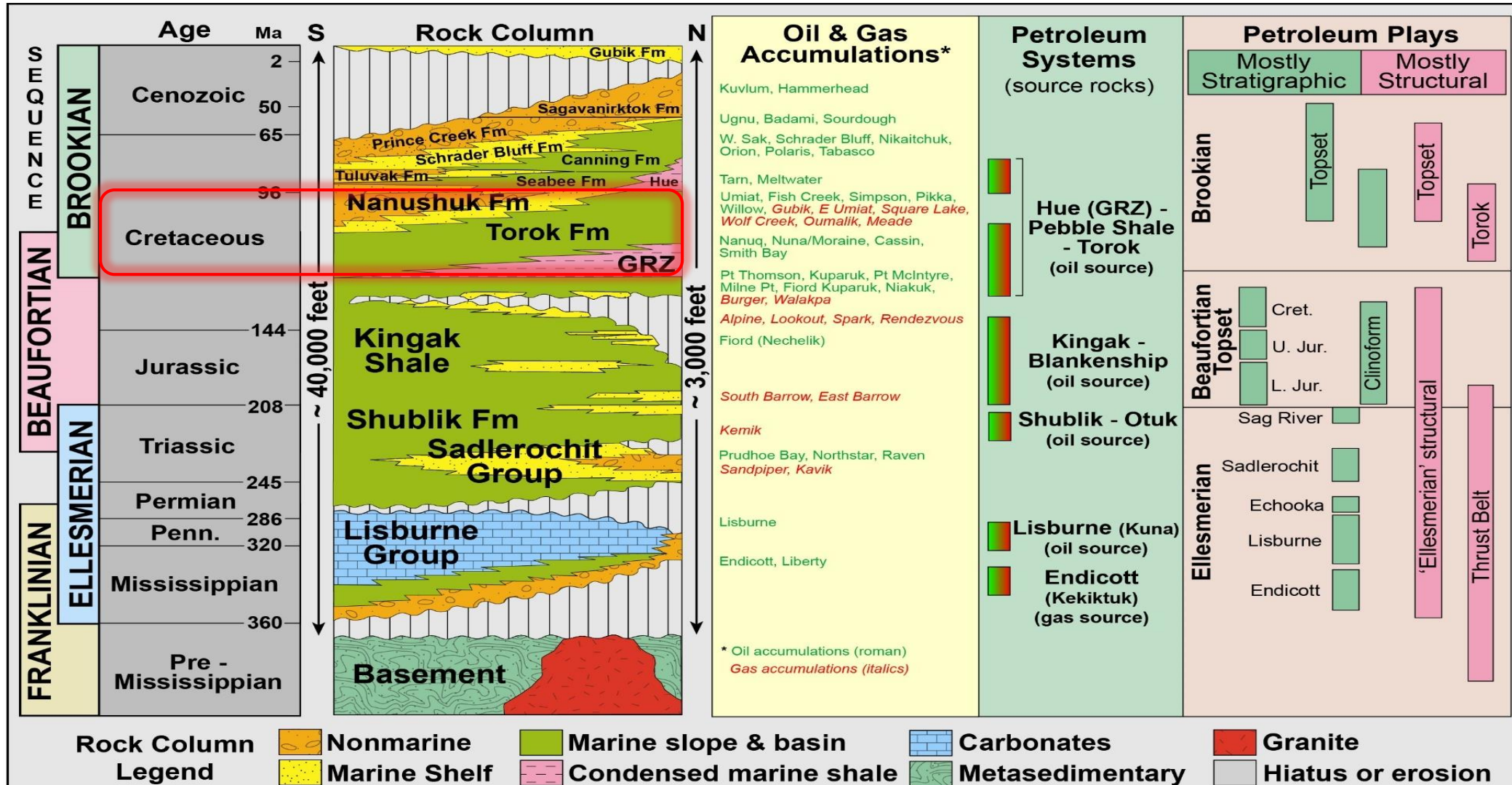
SH 1

Horseshoe 1, 1A
(2017)

2018 Bear 3D

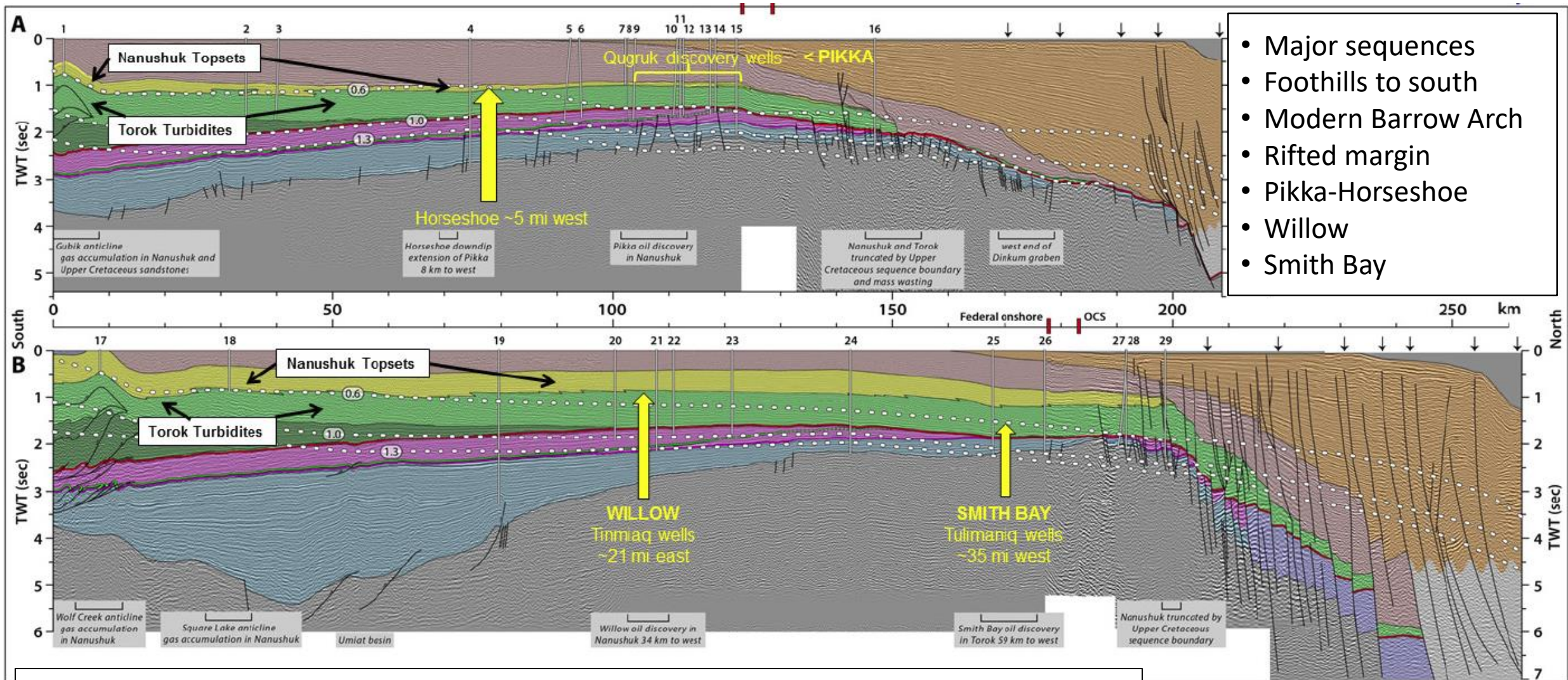
NORTH SLOPE PETROLEUM SYSTEMS

- FOCUS ON LOWER BROOKIAN SEQUENCE -



NORTH SLOPE TECTONIC SETTING

- NANUSHUK AND TOROK DISCOVERIES -



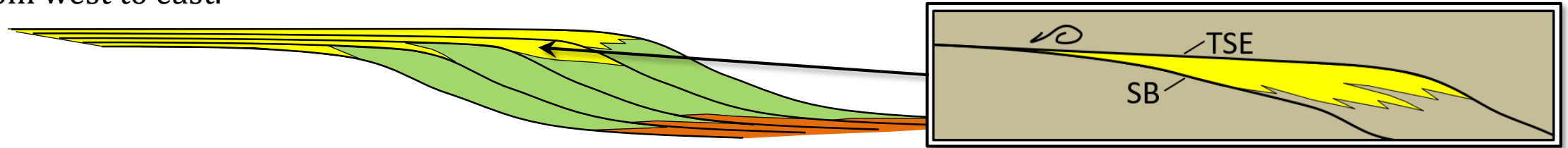
Interpreted seismic profiles courtesy of David Houseknecht, USGS (in BOEM Fact Sheet 2017-12b)

MAJOR RECENT BROOKIAN DISCOVERIES

	Smith Bay	Willow	Pikka/Horseshoe
Operator(s)	Caelus	ConocoPhillips	Oil Search/ConocoPhillips
Reservoir Formation	Torok Fm	Nanushuk Fm	Nanushuk Fm
Penetrations to date	2	7	12
Location	State Waters Offshore of NPRA	Federal Onshore Northeast NPRA	Onshore Colville Delta
Road/Pipeline Tie-in	~ 125 miles	~ 28 miles	~ 20 miles
Trap type	Turbidite Stratigraphic	Topset Stratigraphic	Topset Stratigraphic
Net Pay	183-223 ft	42-72 ft	< 225 ft
Oil Gravity	40-45 degree API (calc)	44 degree API	30 degree API
Test Rate	No Flow Tests	< 3,200 bopd vertical	~ 2,100 bopd vertical; 4,600 bopd horizontal
Contingent Recoverable Resource	1.8-2.4 BBO (est)	300 MMBO	1.2 BBO
Expected Production (Operator Releases)	< 200,000 bopd	40,000-100,000 bopd	< 120,000 bopd

OVERVIEW OF BROOKIAN SEQUENCE AND PLAYS

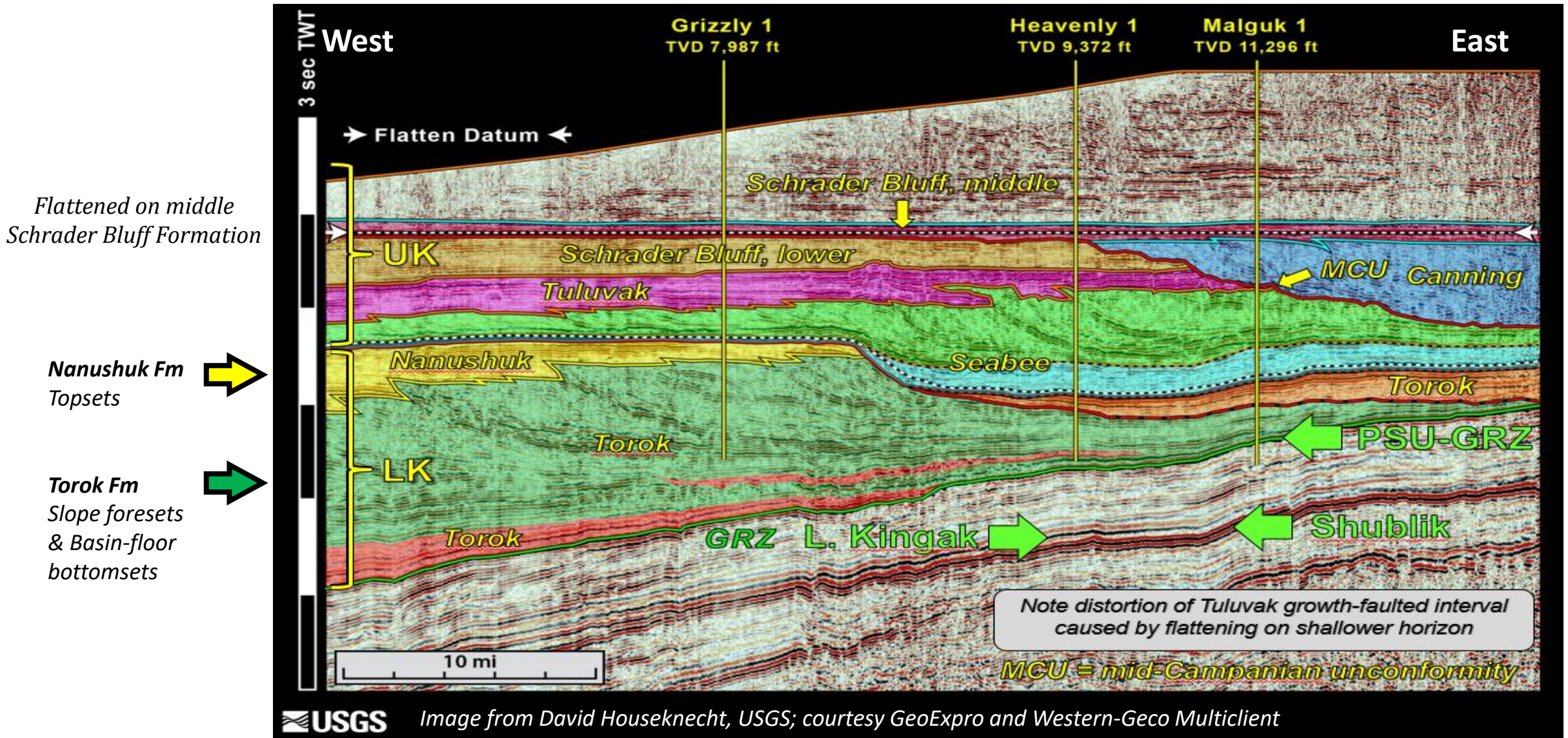
- The Brookian sequence represents a wide range of clastic rocks shed from the Chukotka and ancestral Brooks Range orogens into the Colville foreland basin during Cretaceous and Tertiary time.
- Multiple formations and clinoformal successions make up the Brookian sequence, which filled the basin from 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.
- The newly proven play is stratigraphically trapped sandstones deposited on muddy strata near the shelf edge during falling stage or lowstand stage, and sealed by overlying mudstone deposited with next transgression.

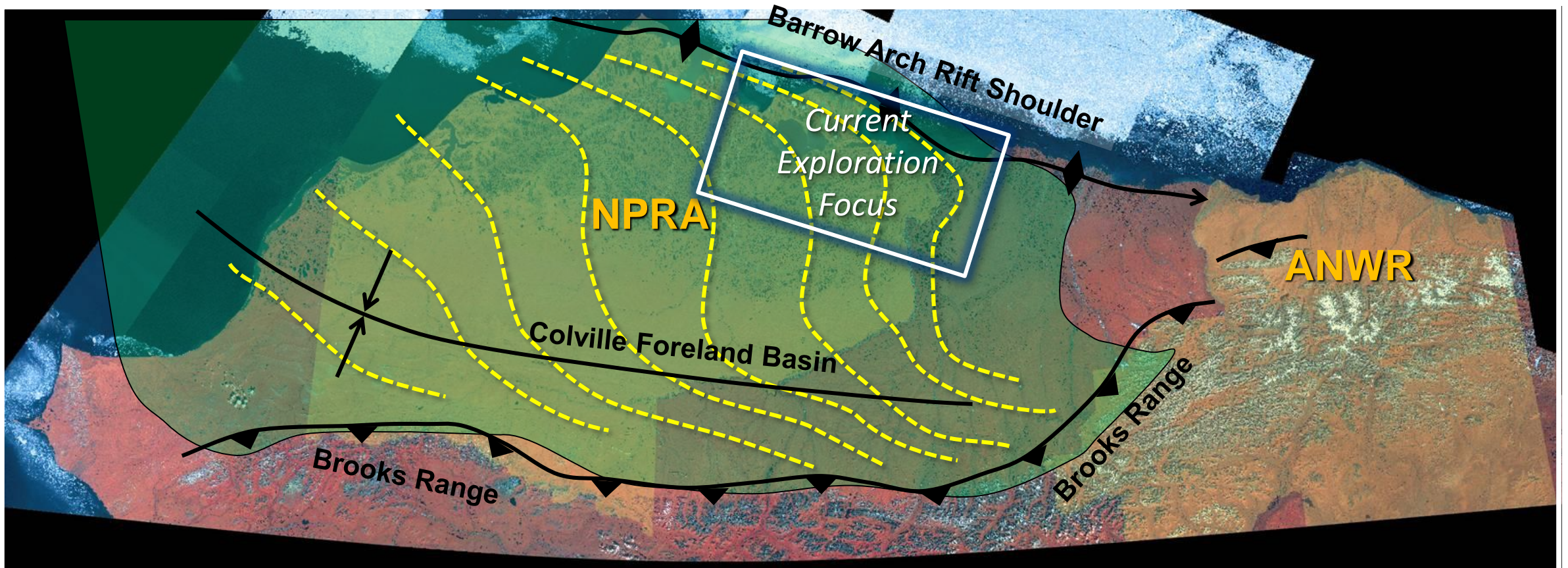
BROOKIAN SEQUENCE CLINOFORMS

- CENTRAL NORTH SLOPE STATE LANDS -



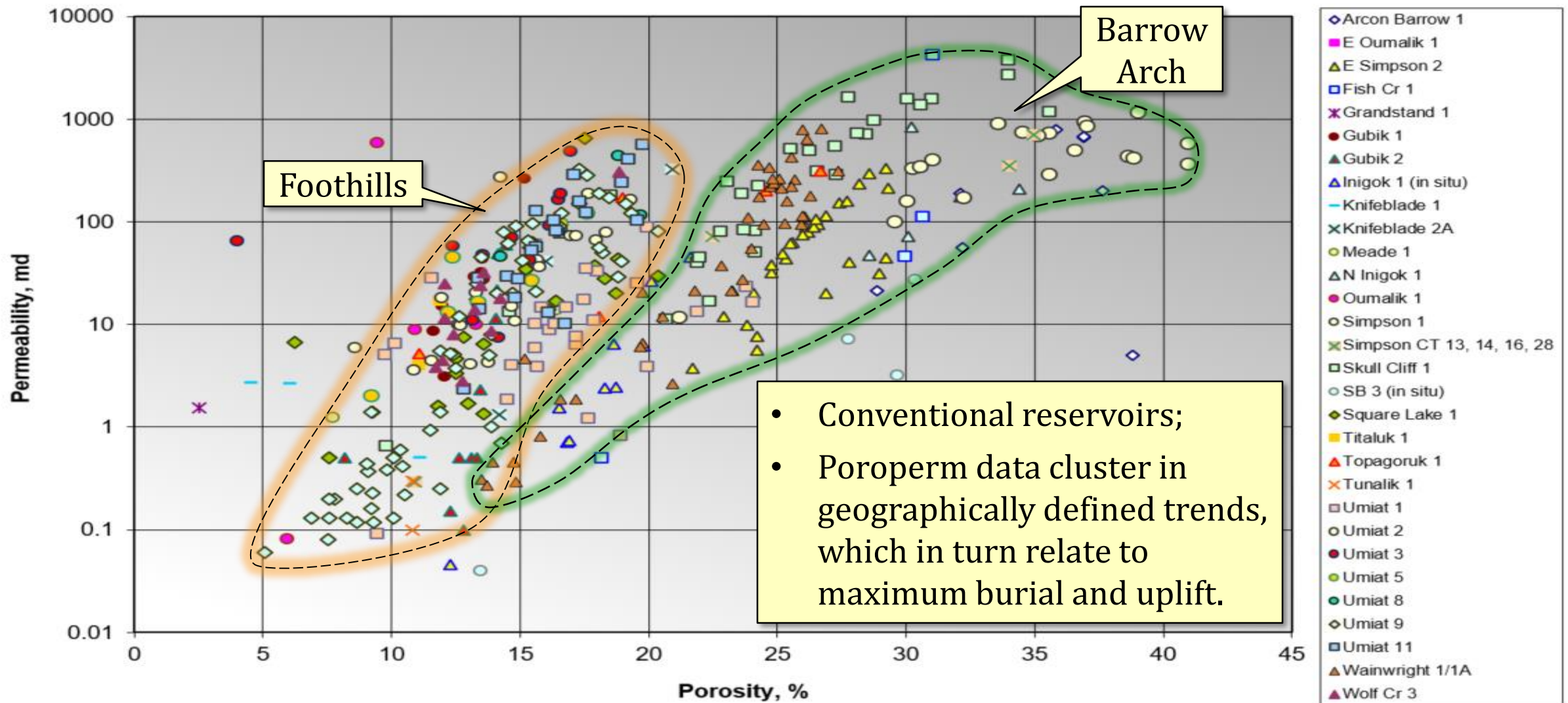
NANUSHUK-TOROK DEPOSITIONAL SYSTEM

- REGIONAL PLAY EXTENTS -



- Overall progradation of Nanushuk-Torok clinothem across foreland basin illustrated schematically as series of advancing shelf margins (dashed yellow lines).
- Numerous higher-order sea-level fluctuations repeatedly set up potential for enhanced reservoir and strat traps.
- Nanushuk and Torok Formation plays exist over large areas of the central and western North Slope.

NANUSHUK FM RESERVOIR QUALITY



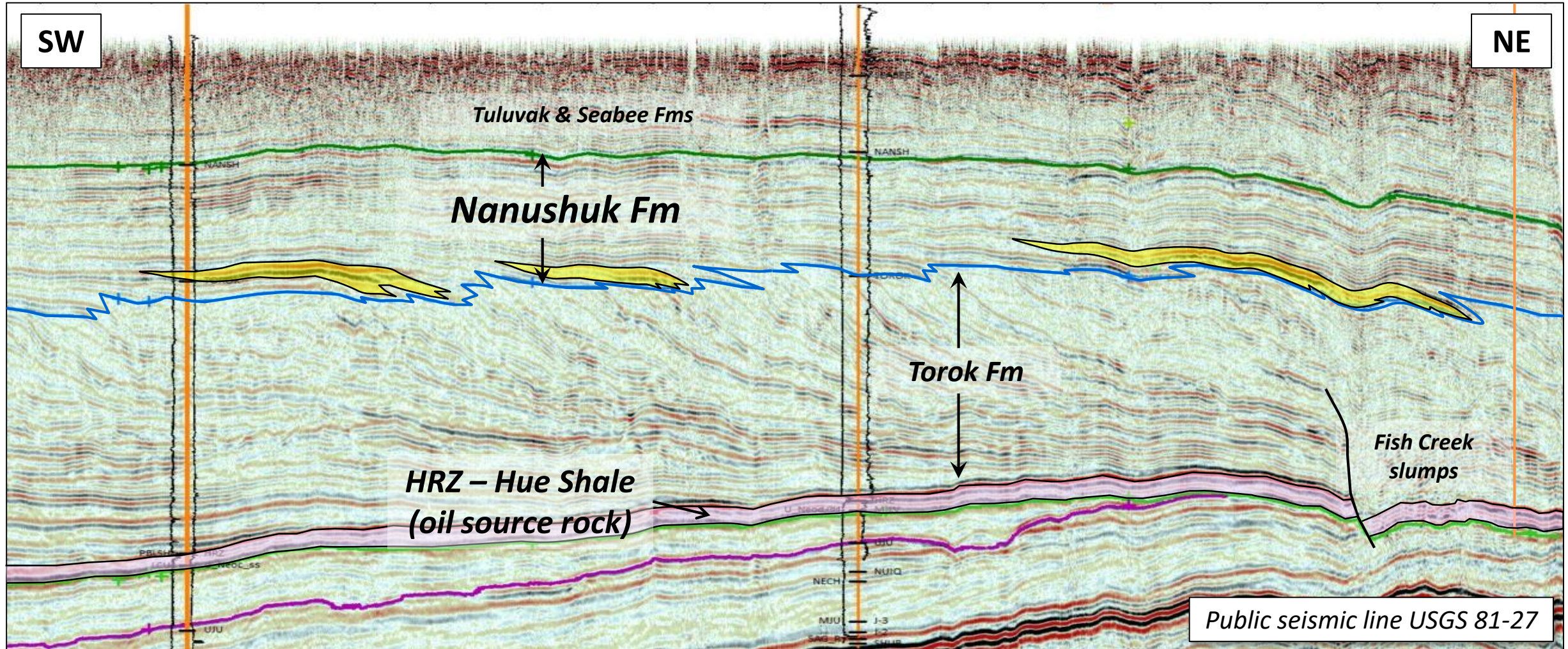
BASAL NANUSHUK SEISMIC ANOMALIES

- 1981 2D DATA, NORTHEAST NPRA -

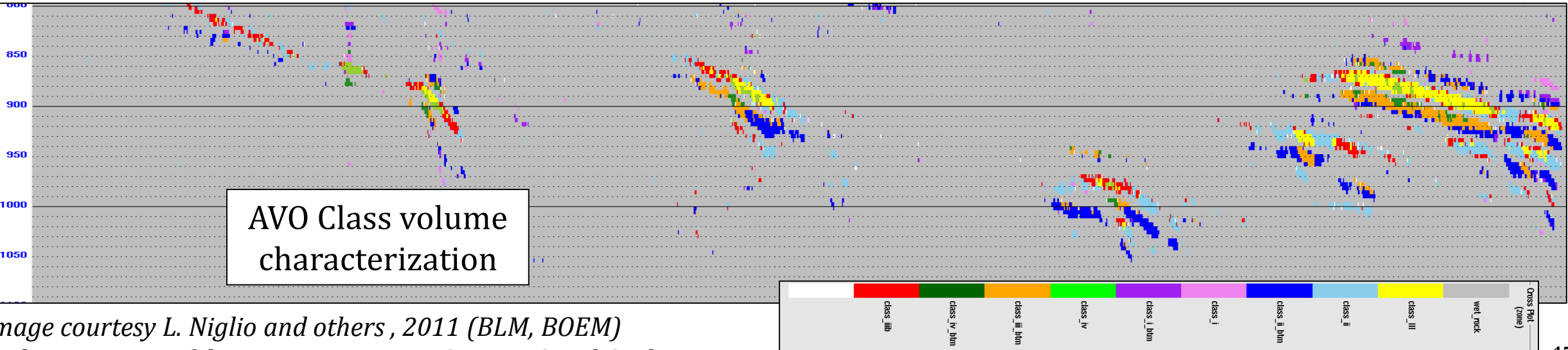
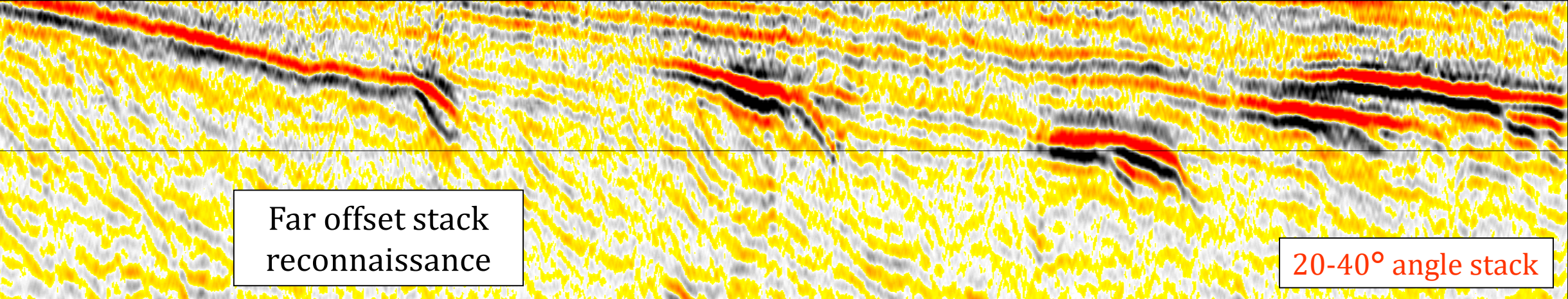
Inigok 1

North Inigok 1

North Kalikpik 1



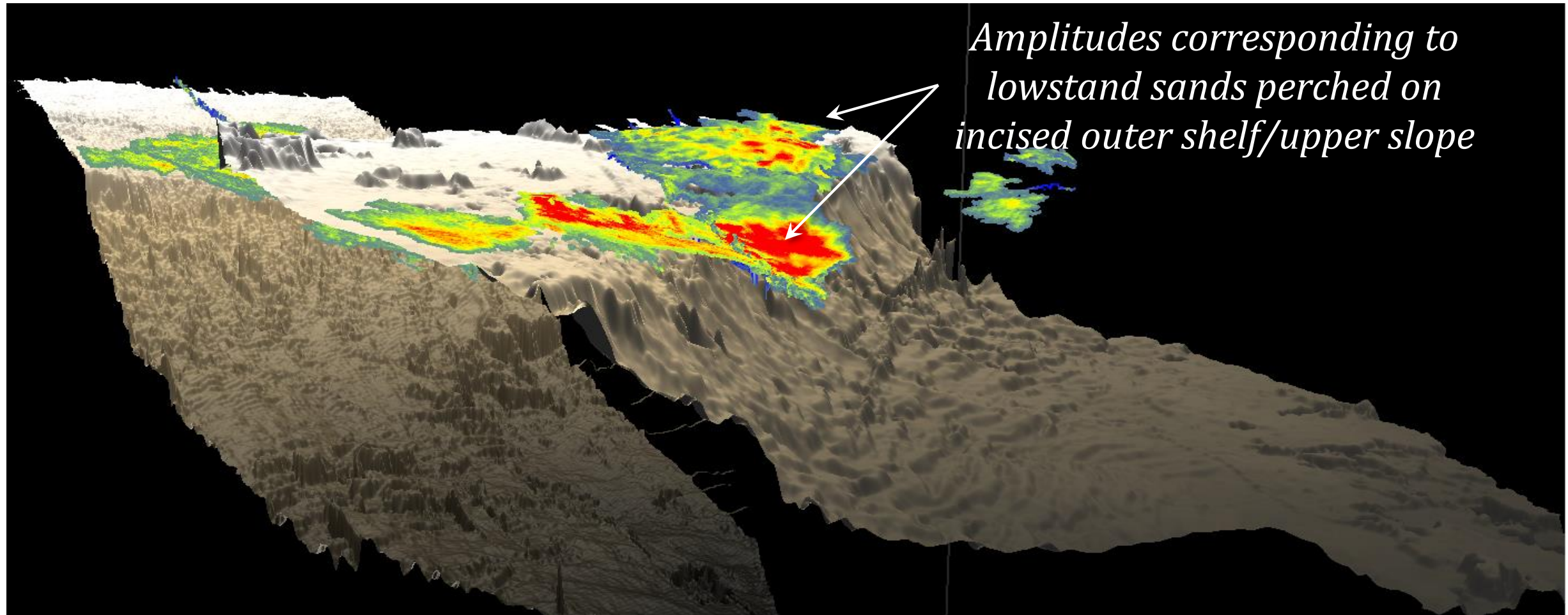
BASAL NANUSHUK SHELF-MARGIN ANOMALIES - 3D SEISMIC, NORTHERN NPRA -



*Image courtesy L. Niglio and others , 2011 (BLM, BOEM)
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NANUSHUK SHELF-MARGIN ANOMALIES

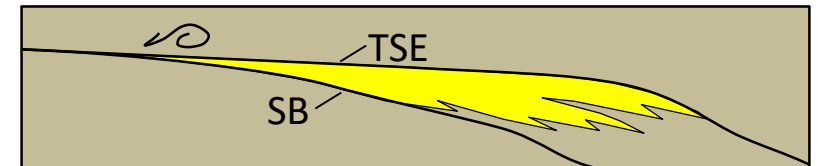
- NORTHERN NPRA -



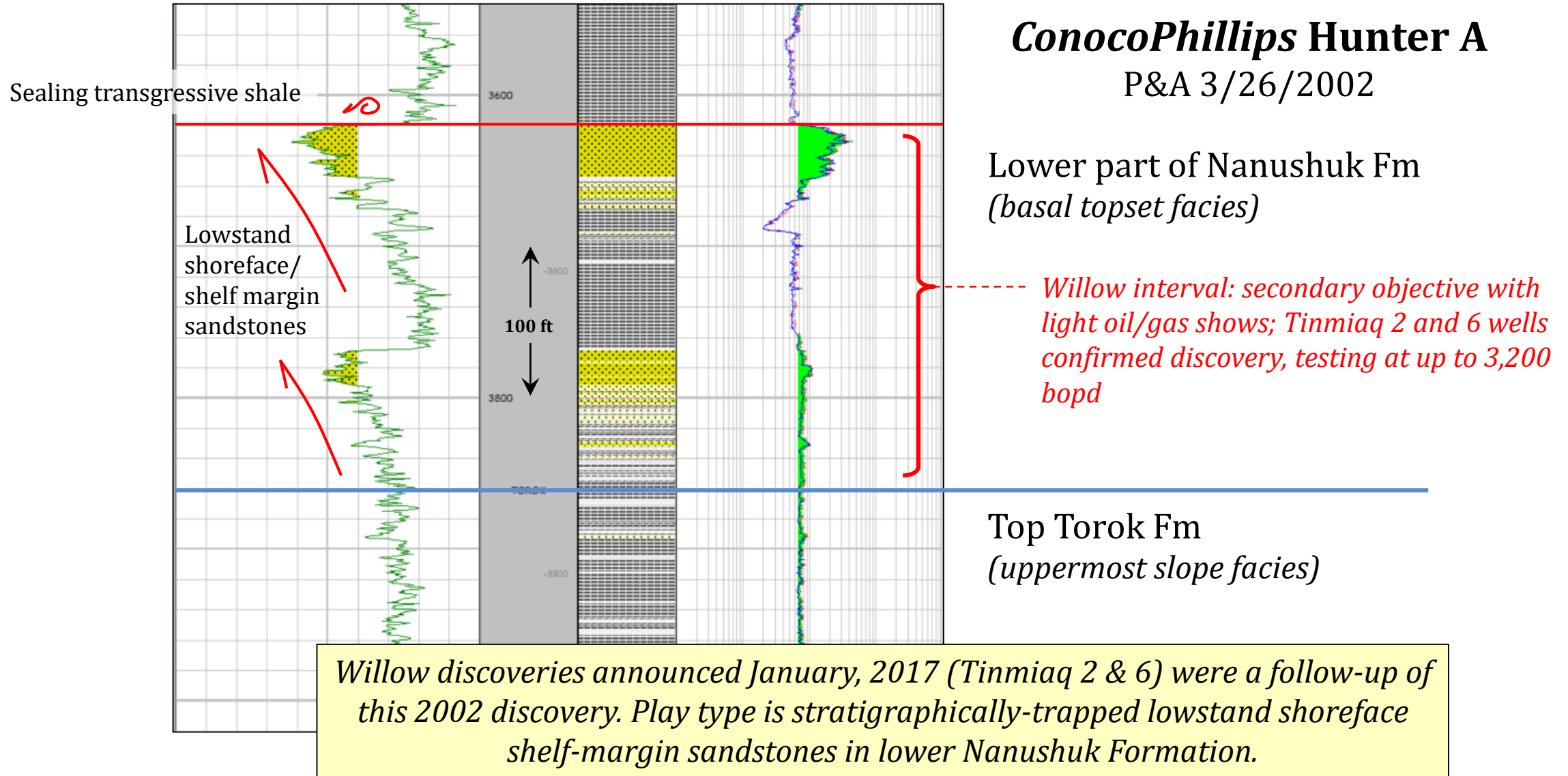
*Image courtesy L. Niglio and others , 2011 (BLM, BOEM)
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WHY DIDN'T WE TARGET THEM SOONER?

- Busy targeting, drilling, and developing deeper discoveries;
- Brookian Sequence is variable and confusing – geologists need regional stratigraphic context for correlating serendipitous sands, shows, etc.;
- Nanushuk-Torok plays absent at the highly developed legacy fields to the east;
- Expectation of biodegraded, viscous or heavy oil in shallow topsets, as above Prudhoe Bay, Kuparuk, & other fields, even locally in nearby NPRA;
- Adjacent fields and prospects drilled from central pads, using deviated or horizontal trajectories, leaving upper stratigraphic units underexplored;
- Many doubted existence of large topset strat traps, specifically ones that rely on updip pinch out in the proximal direction.



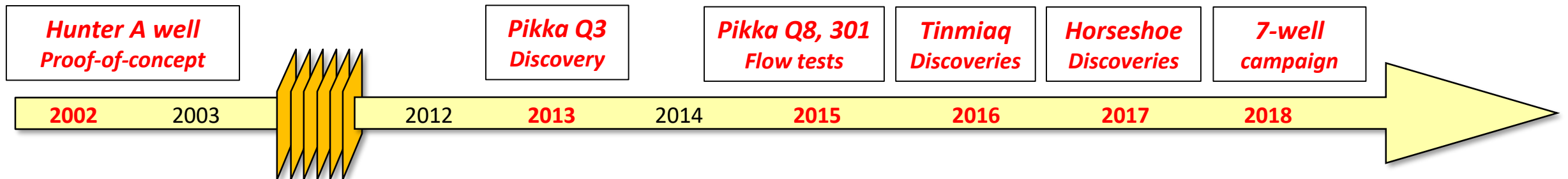
INITIAL WILLOW DISCOVERY - NANUSHUK FM



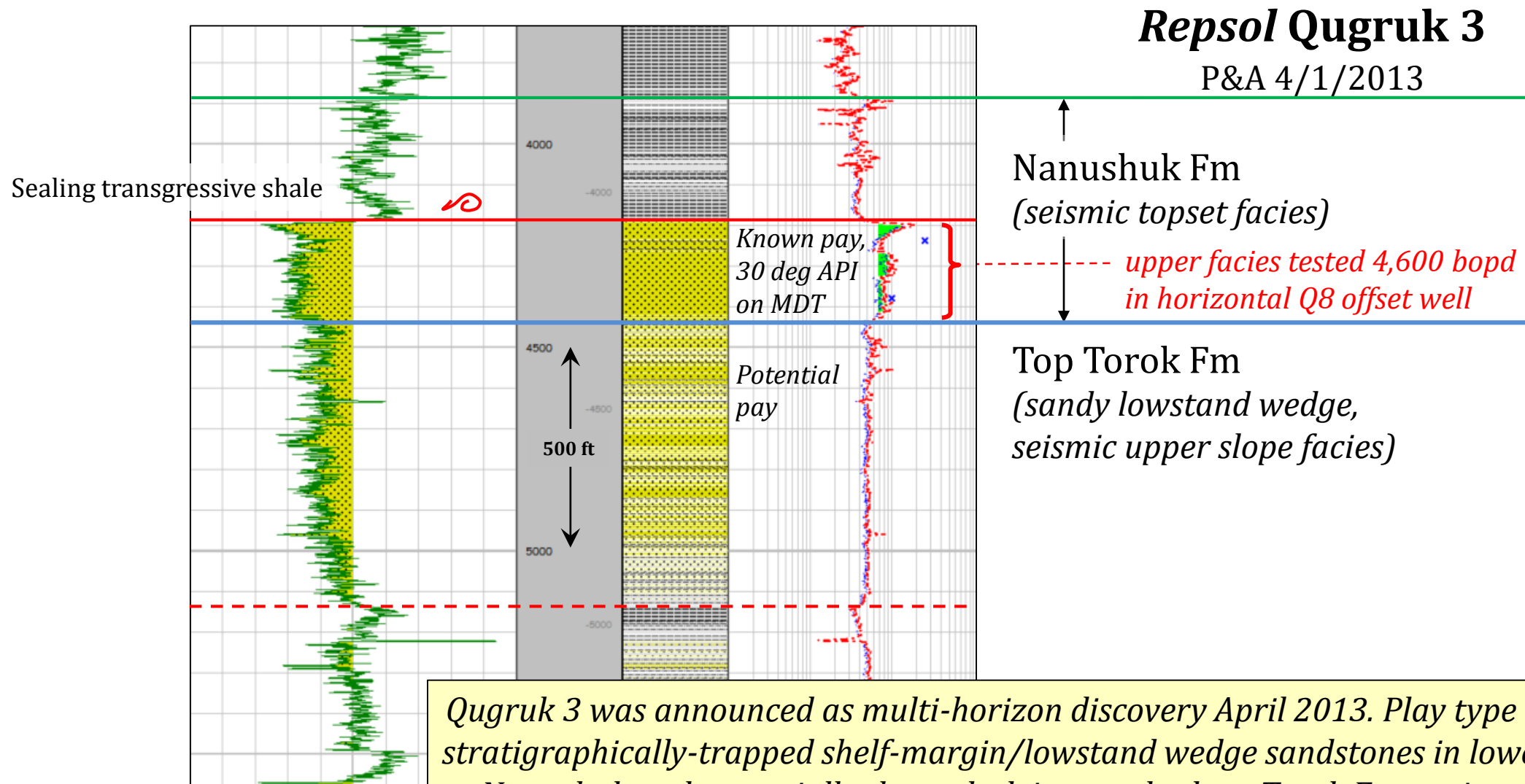
THE EVENTS UNFOLD

- DISCOVERY TIMELINE -

- Hunter A well drilled in NPRA in 2002 penetrated but didn't fully evaluate an amplitude anomaly (Willow) noted at the bottom of the Nanushuk topsets. Not the primary or secondary objective, but provided key encouragement:
 ✓ ***Shoreface sands + Oil Shows + Seismic Amplitude = Viable Strat Trap Play!***
- ConocoPhillips bid and won leases in 2002 NPRA lease sale on Nanushuk topset prospects supported by Hunter A results;
- Repsol/Armstrong drilled the Pikka discovery well Qugruk 3 in 2013 to a deeper Jurassic objective, discovered ~200' pay in Nanushuk lowstand shelf margin sands as well as in Jurassic;
- Qugruk 8 and Qugruk 301 wells drilled in 2015 found and tested oil in same Nanushuk shelf-edge reservoir; announced discovery with very good flow rates;
- ConocoPhillips drilled Tinmiaq 2 and Tinmiaq 6 wells in 2016, targeting northern continuation of Willow trend discovered at Hunter A; announced Willow as major discovery in 2017.
- Armstrong/Repsol drilled Horseshoe 1, 1A discoveries in 2017, extending the Pikka trend some 20 miles to the south;
- ConocoPhillips conduct 7-well exploration/appraisal campaign in both Pikka-Horseshoe and Willow trends this winter.



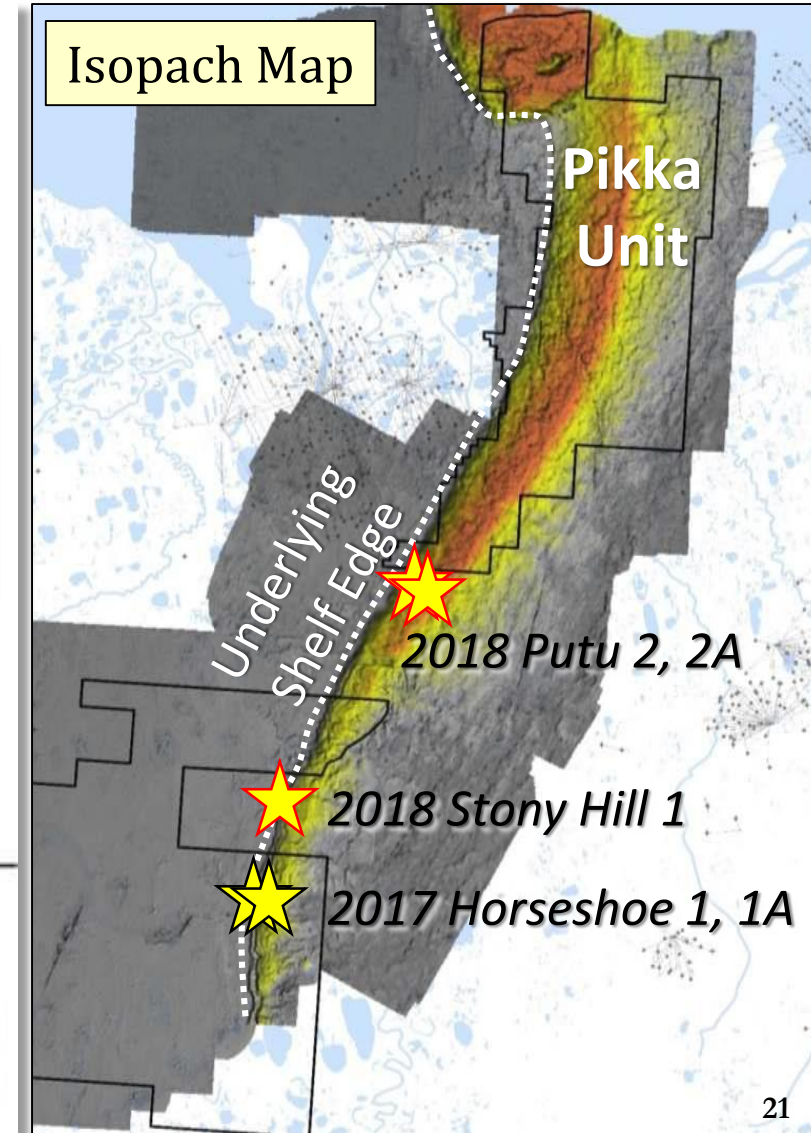
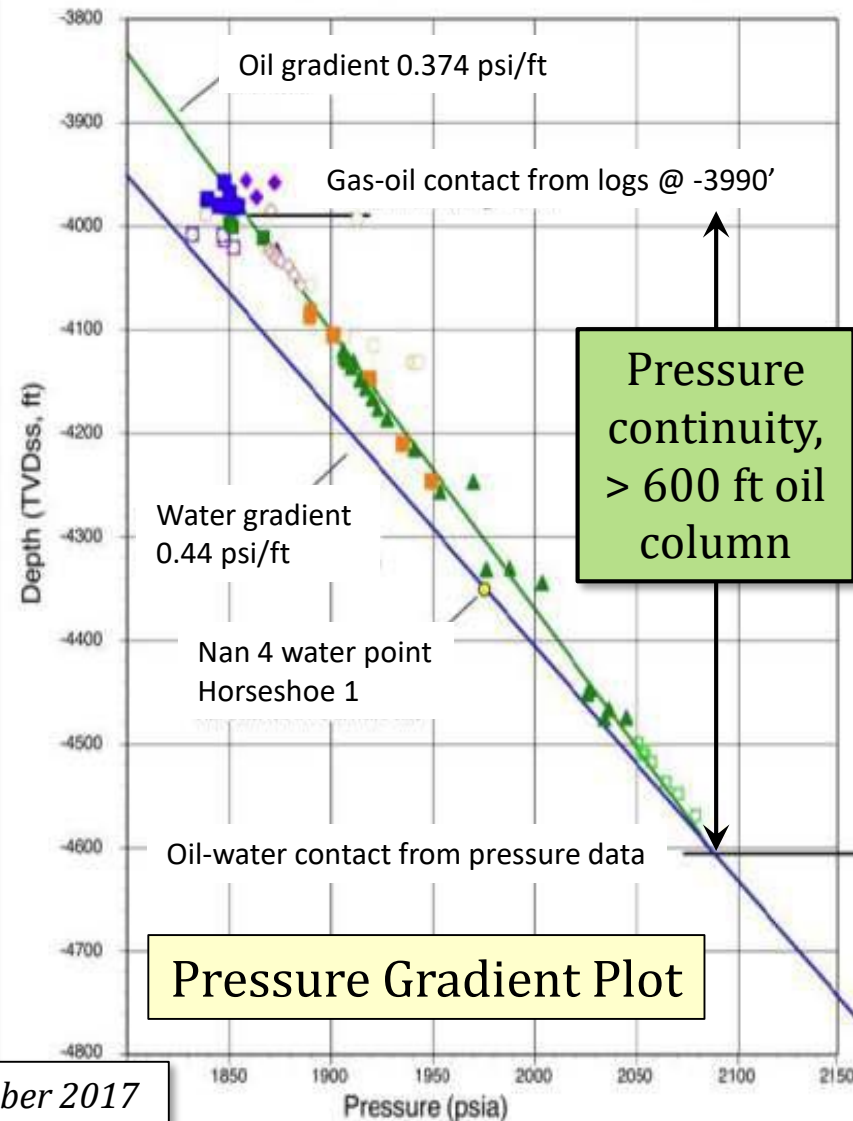
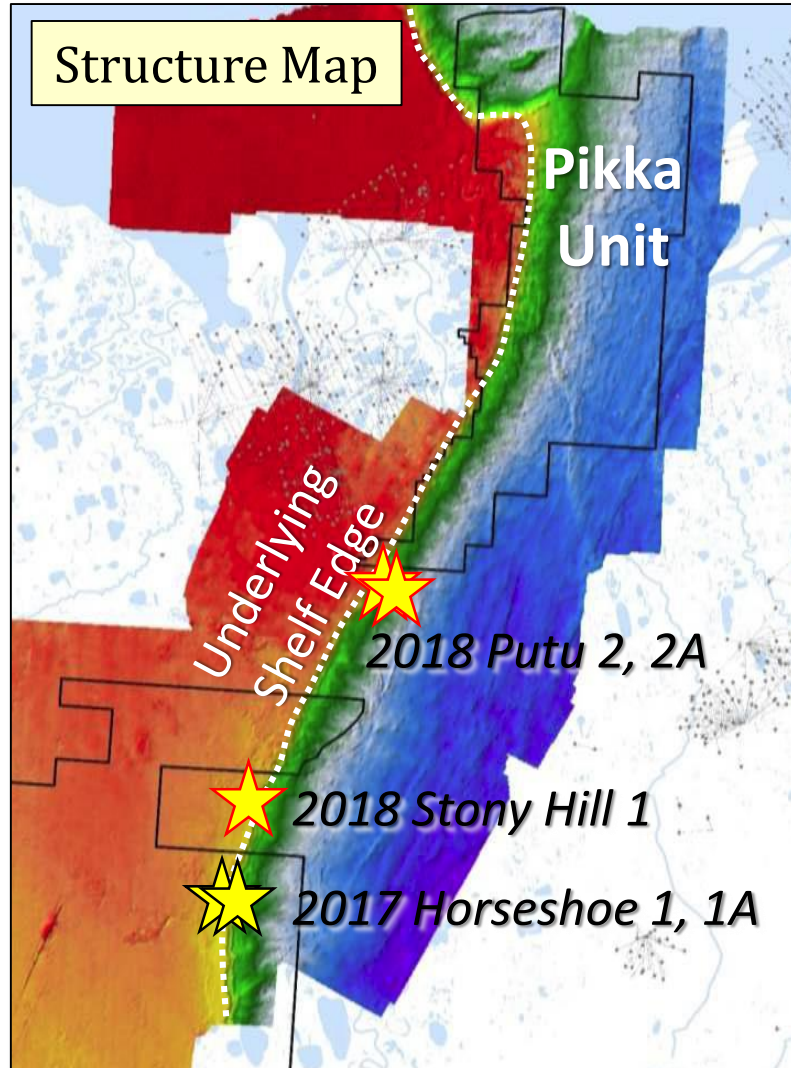
PIKKA DISCOVERY TYPELOG - NANUSHUK FM



Qugruk 3 was announced as multi-horizon discovery April 2013. Play type is stratigraphically-trapped shelf-margin/lowstand wedge sandstones in lower Nanushuk and potentially the underlying sandy slope Torok Formation.

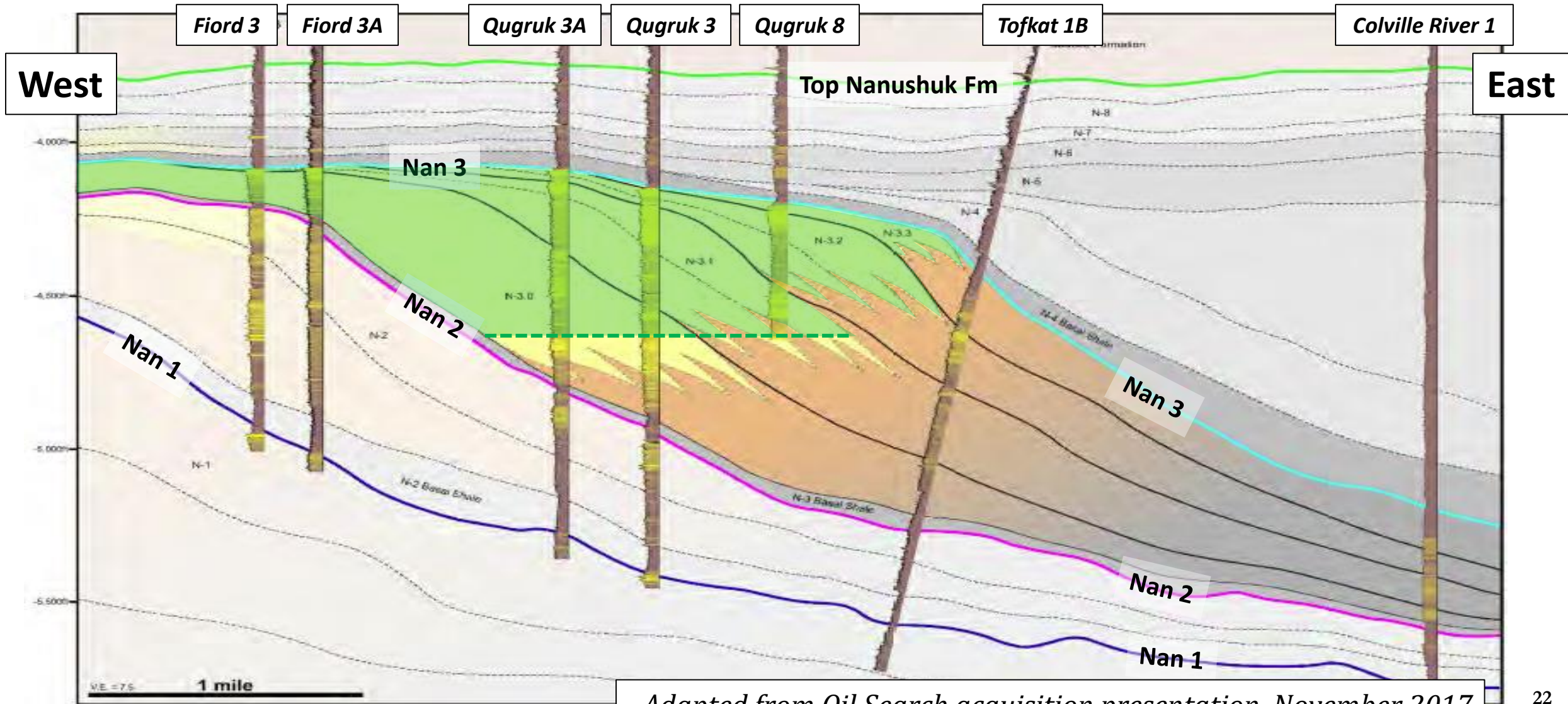
PIKKA-HORSESHOE NANUSHUK RESERVOIR

- LATERALLY CONTINUOUS SANDS, THICK OIL COLUMN -



PIKKA NAN 3 RESERVOIR

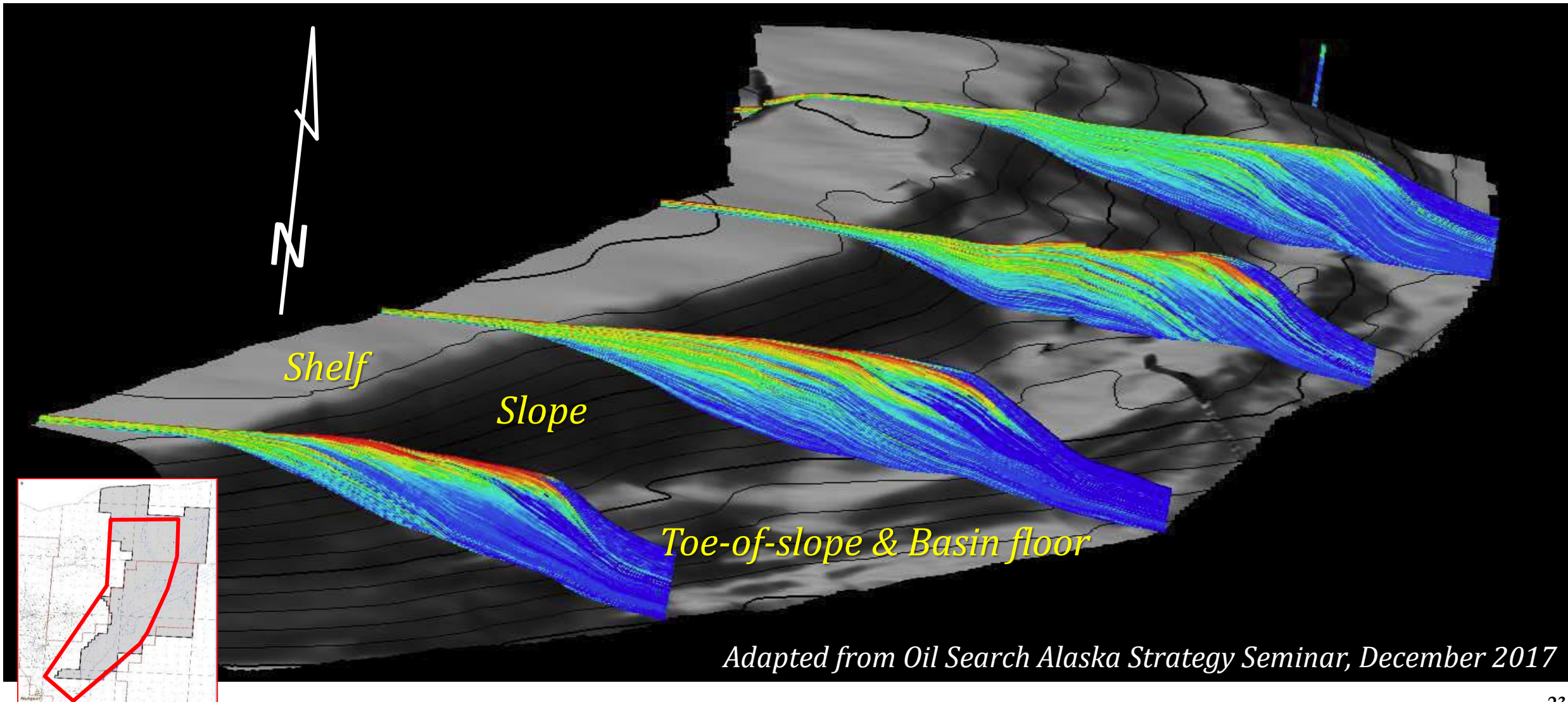
- DIP-ORIENTED NANUSHUK & TOROK CROSS SECTION -



Adapted from Oil Search acquisition presentation, November 2017

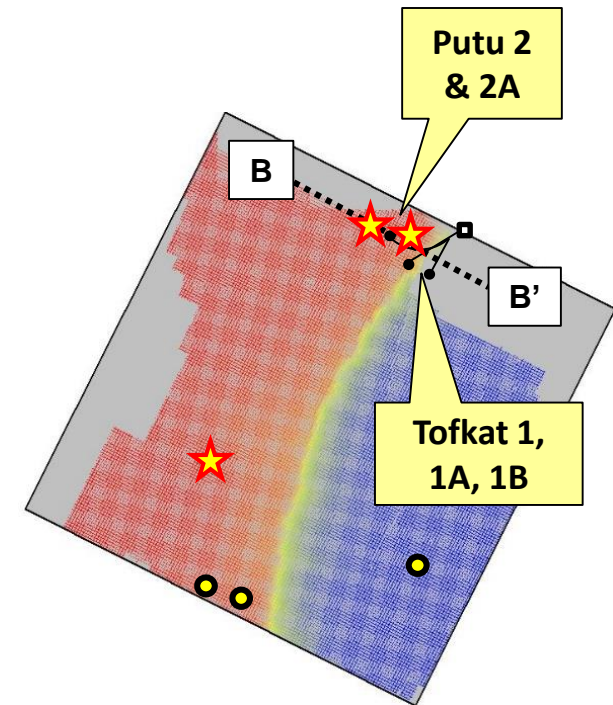
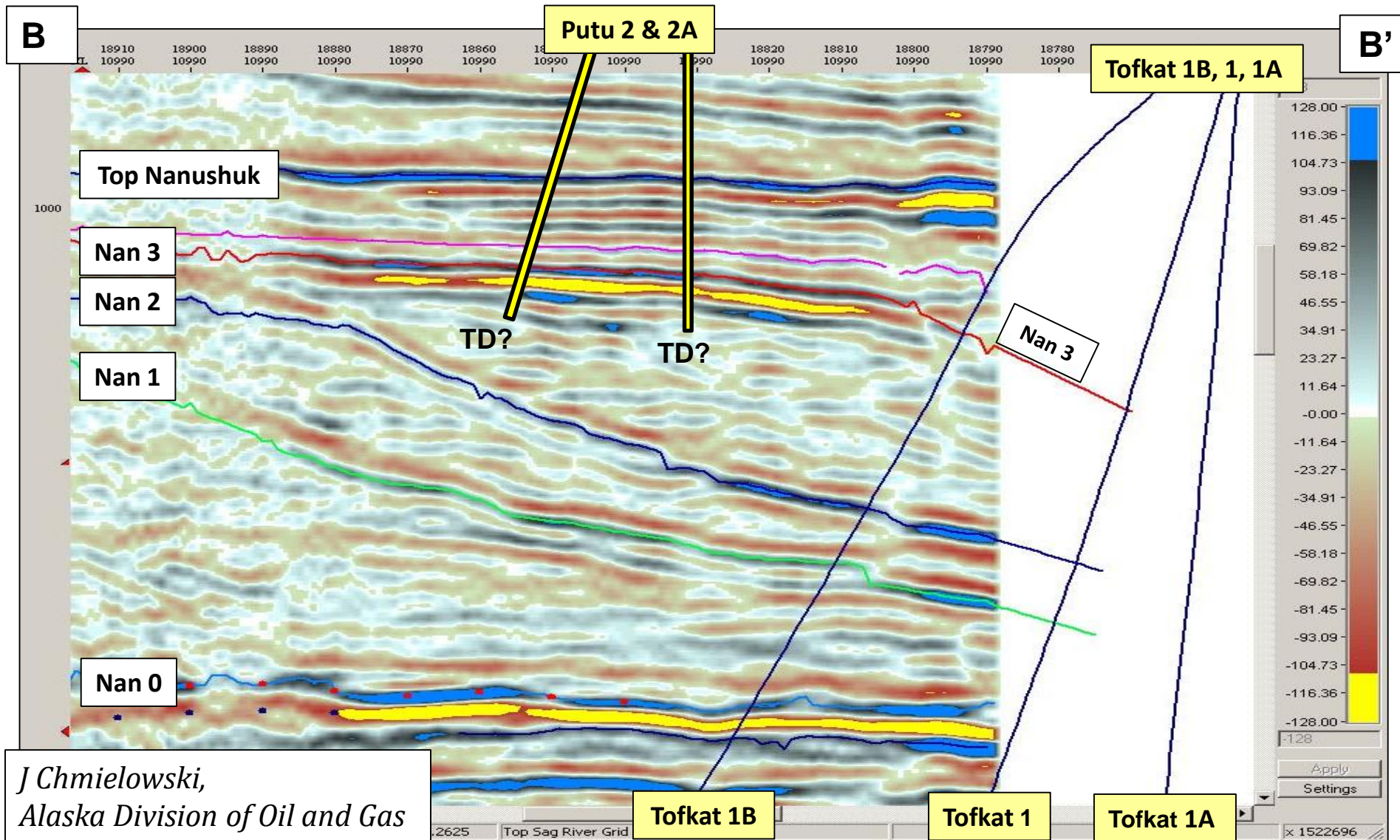
PIKKA NANUSHUK GEO-MODEL

- NANUSHUK 3 INTERVAL -

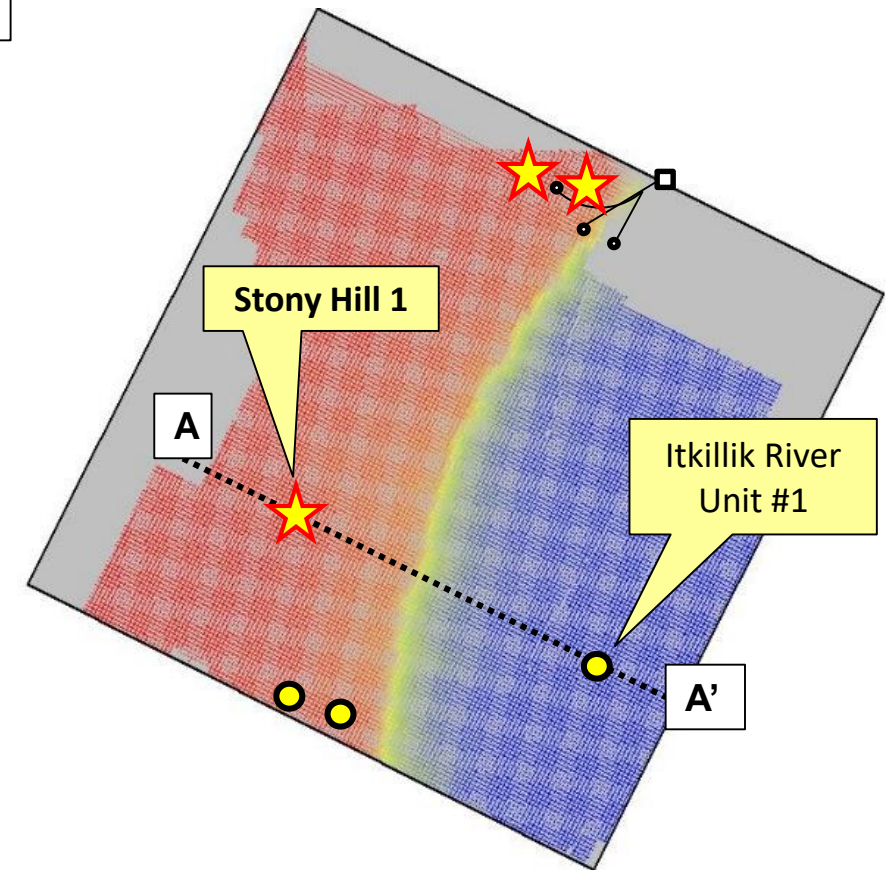
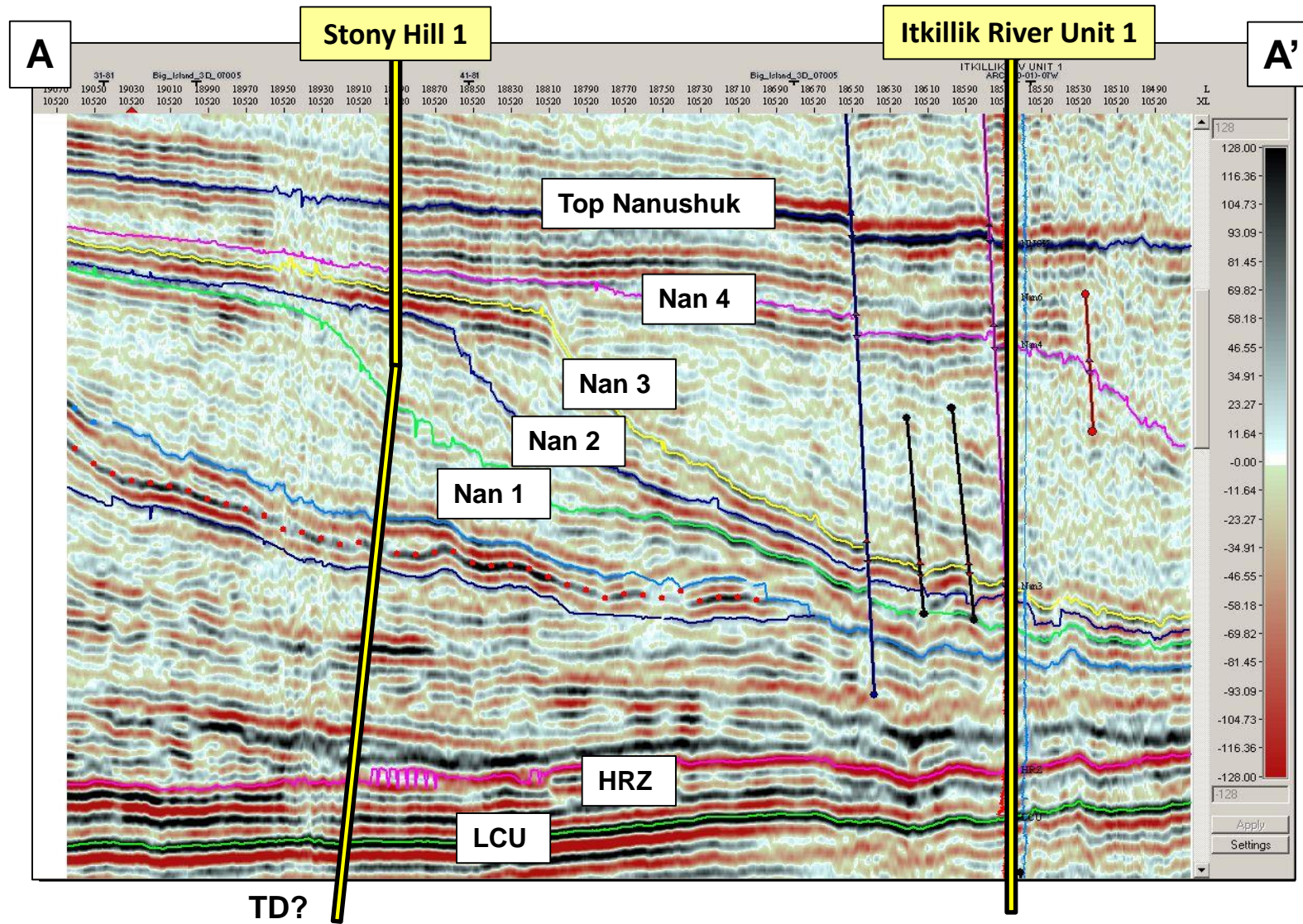


2018 PUTU 2 & 2A WELLS

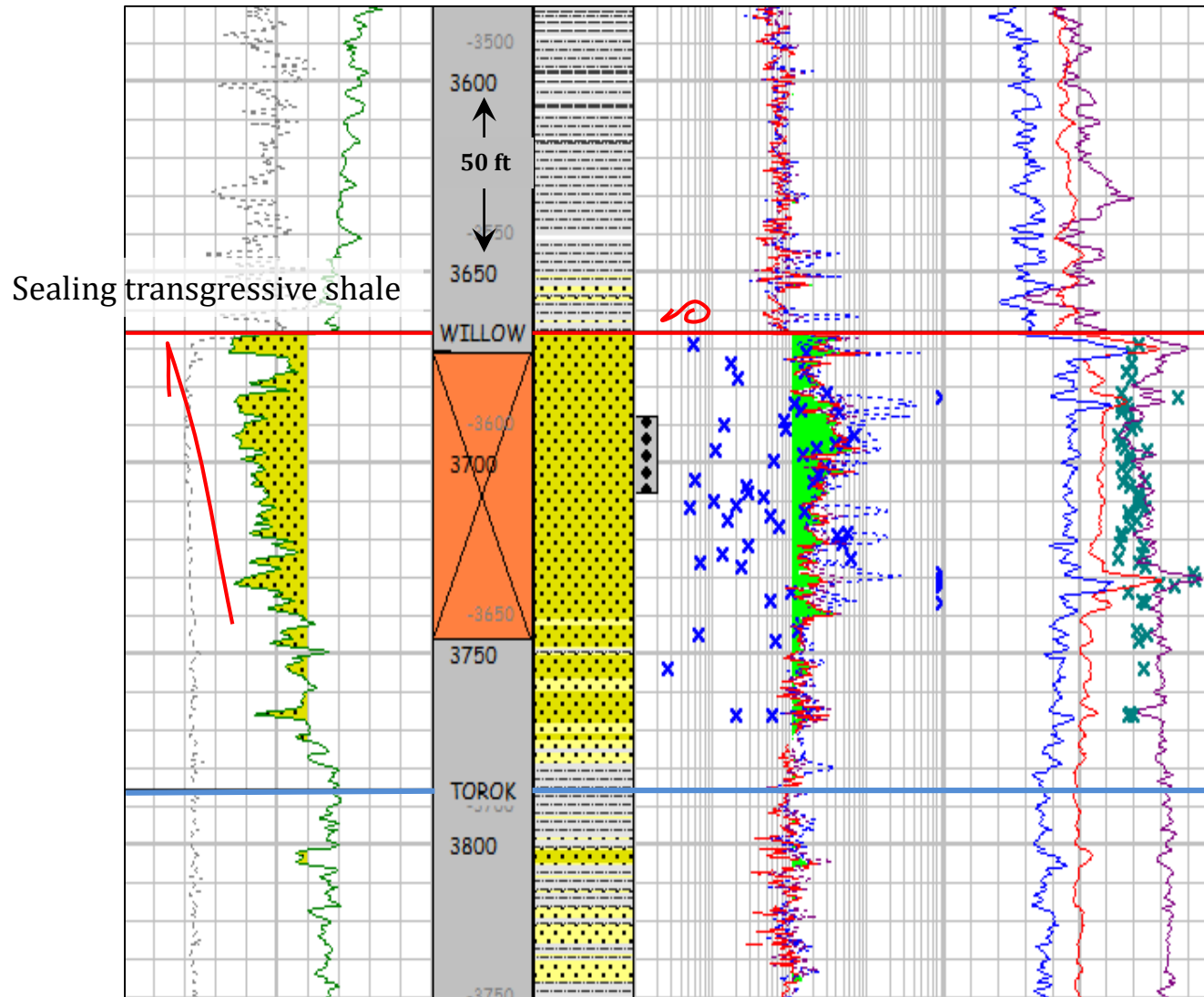
- DELINEATING THE PIKKA-HORSESHOE TREND, NANUQ SOUTH 3D -



2018 STONY HILL 1 WELL - REDESIGNED FOR NANUSHUK AND DEEPER TARGETS -



WILLOW TREND - NANUSHUK FM



ConocoPhillips Tinmiaq 2

Suspended 03/02/2016

Lower part of Nanushuk Fm
(basal topset facies)

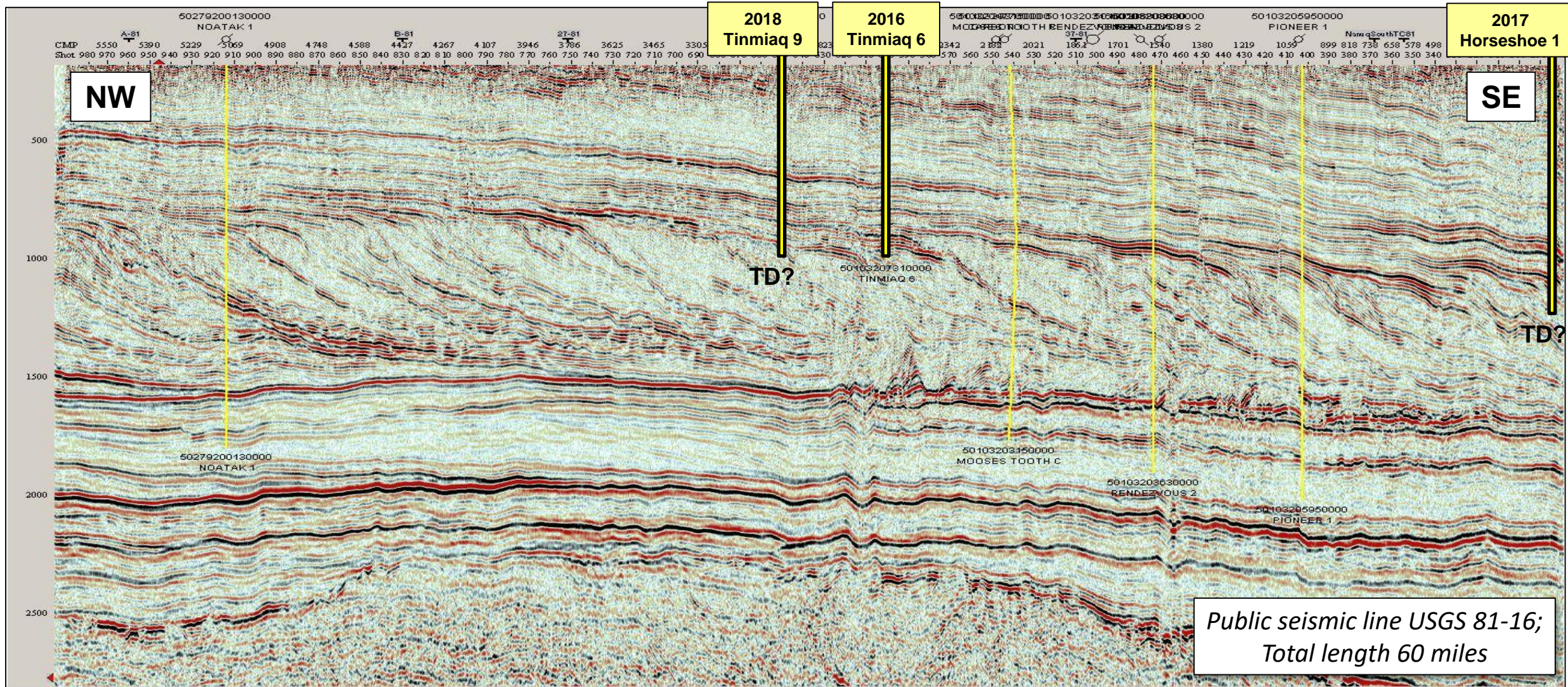
Willow Interval Core & Test

- Upper very fine sand to silt, average is coarse silt.
- Porosity avg = 17%
- Permeability avg = 11 md
- Flowed 3,220 bopd (41-45 API), 1.26 mmscf/d

Top Torok Fm
(uppermost slope facies)

HAVE WE SEEN JUST THE TIP OF THE ICEBERG?

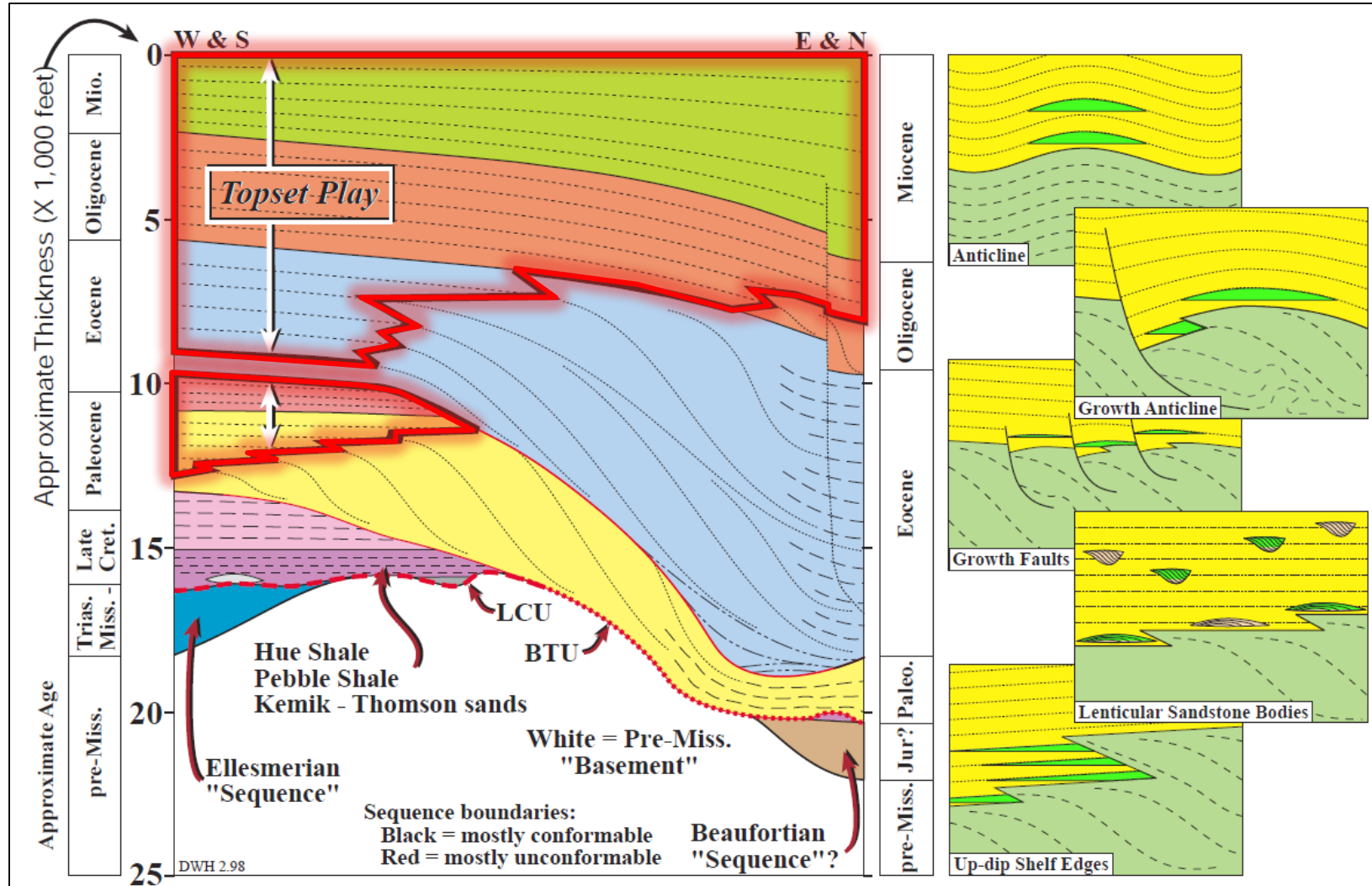
- WILLOW, HORSESHOE TRENDS AMONG MANY MORE -



UNDISCOVERED RESOURCES

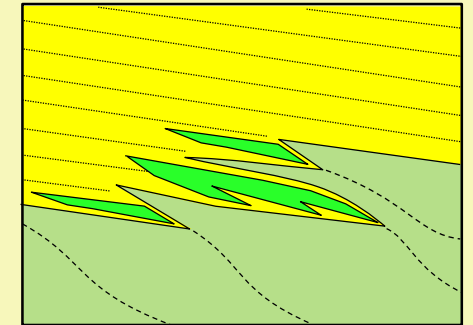
- USGS and BOEM are actively reassessing Arctic Alaska's undiscovered, technically recoverable conventional resources:
 - As of December 2017, interim revisions raise the mean estimate for all of Arctic Alaska by ~9 billion barrels to nearly 50 billion barrels of oil + natural gas liquids (NGL), ~evenly split between onshore and offshore.
- The Nanushuk topset play in the central and western North Slope is far more prospective than previous resource assessments recognized:
 - 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 undiscovered oil + NGL.

YOUNGER BROOKIAN TOPSET PLAY - ANWR



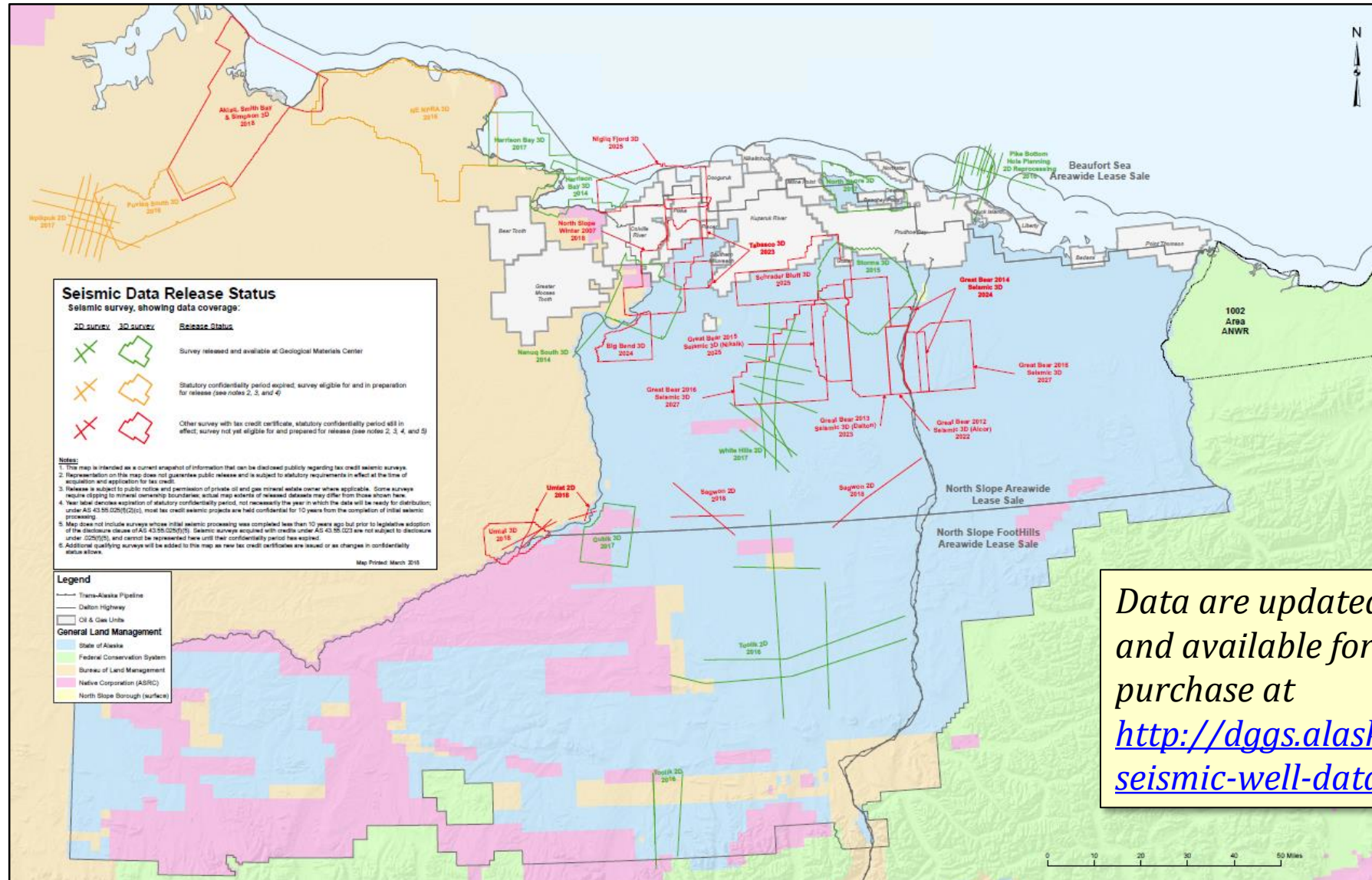
**Critical new
variant of
topset play**

Shelf-margin Sand Wedge,
Up-dip Proximal Pinchout



STATE OF ALASKA TAX CREDIT SEISMIC SURVEYS

- PUBLIC RELEASE IN PROGRESS -



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)

RECAP – KEY POINTS

- Of the recent discoveries, greatest promise is from proving up the basal Nanushuk topset play;
- No substitute for serendipity, but we need robust regional framework to understand & incorporate clues;
- North Slope underexplored, conventionals still surprising us;
- Nanushuk play – Larger prospects, more assessed oil resource, lots of undrilled leads and running room
- Tax Credit program 2D/3D seismic data release ongoing.