

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

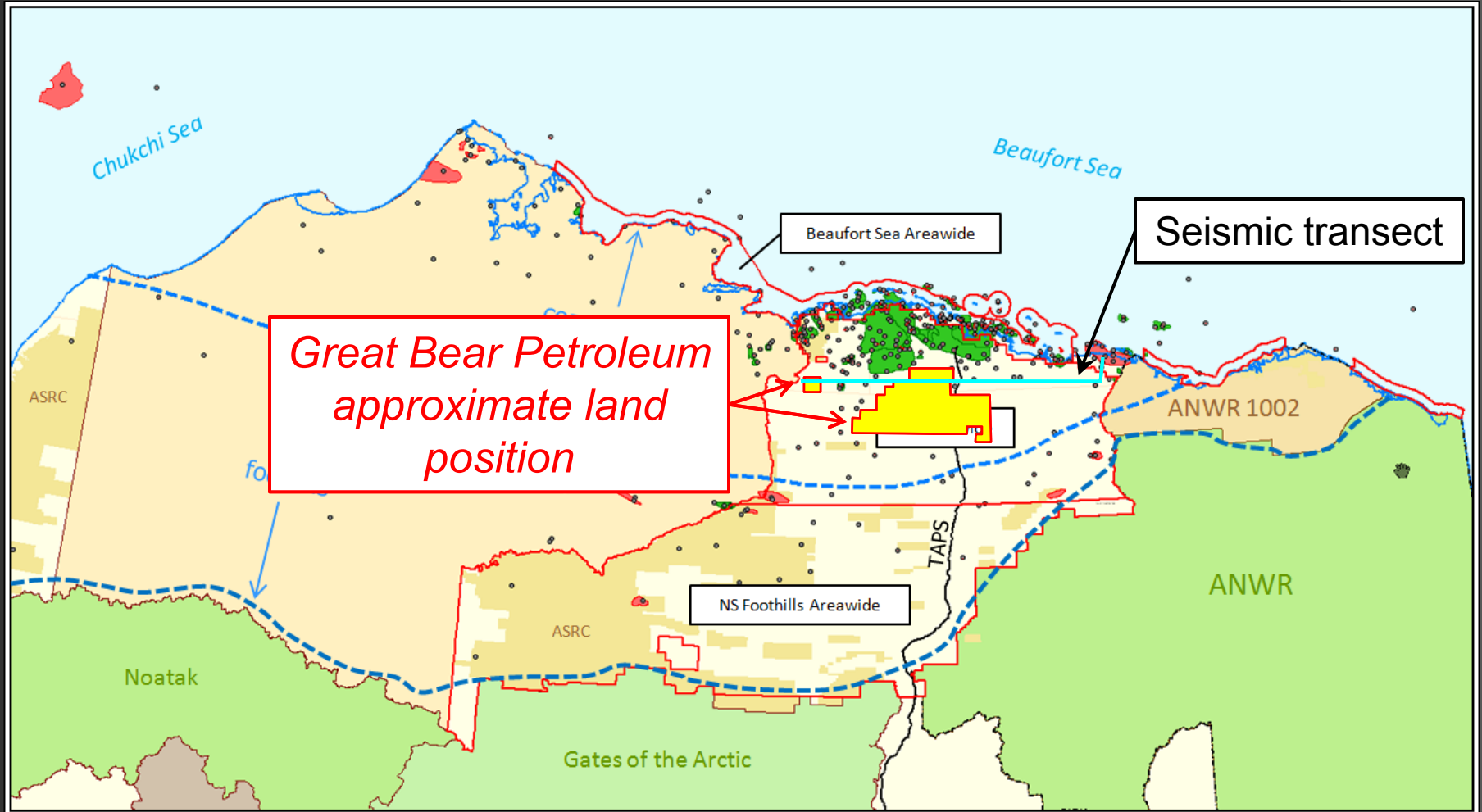
- **higher engineering risk...** not sure the resource will be recoverable everywhere (massive stimulations must succeed)

Unconventional terminology

Some terms are more specific than others

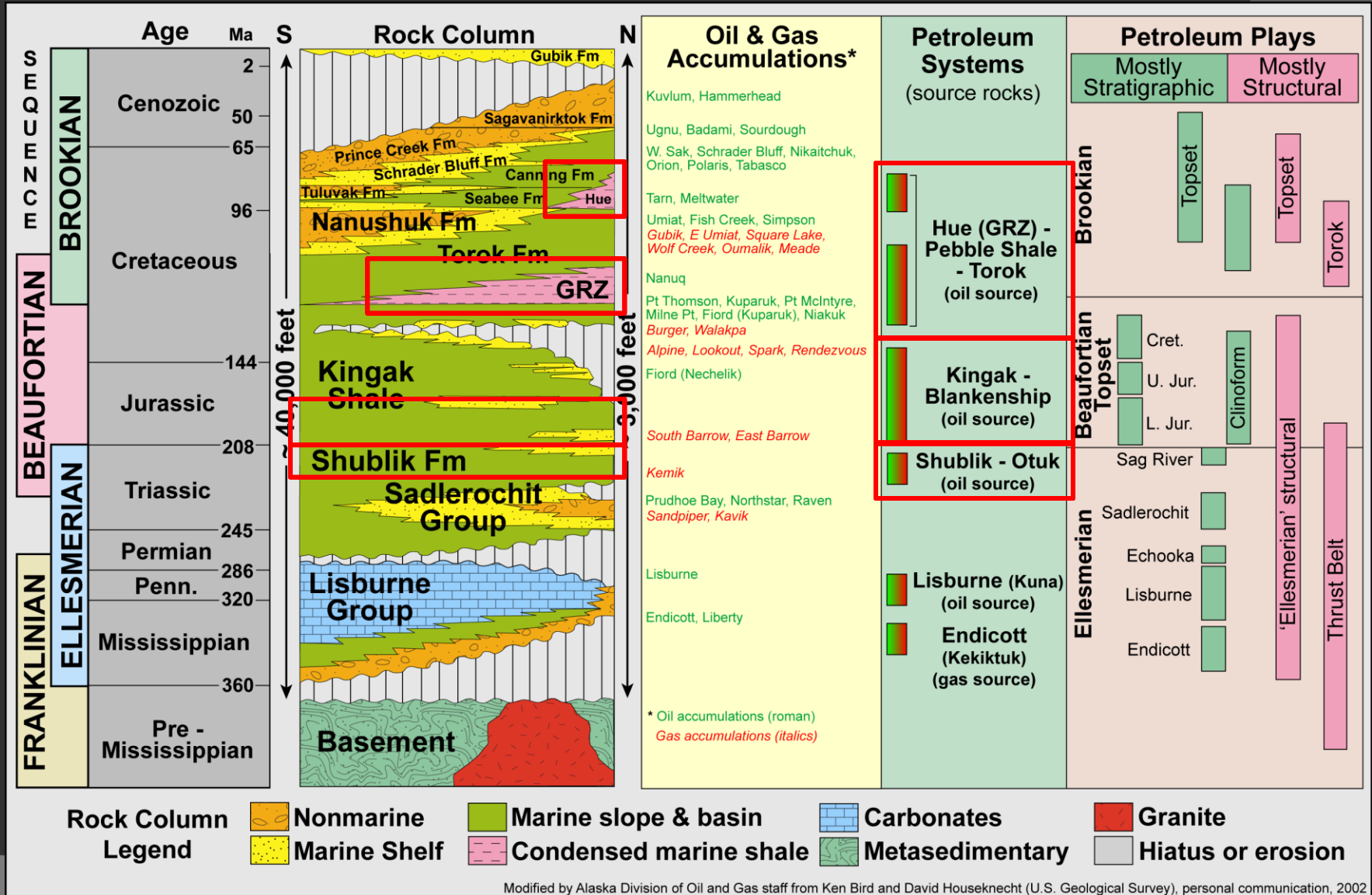
- Resource plays
- Continuous accumulations
- Basin-centered accumulations
- Technology reservoirs
- Tight oil / gas
- Shale gas / shale oil (**≠ oil shale**)
- Source-reservoired oil / gas
 - ✓ *Source = Reservoir = Trap*

North Slope Region



North Slope Petroleum Systems

3 prolific source rock intervals



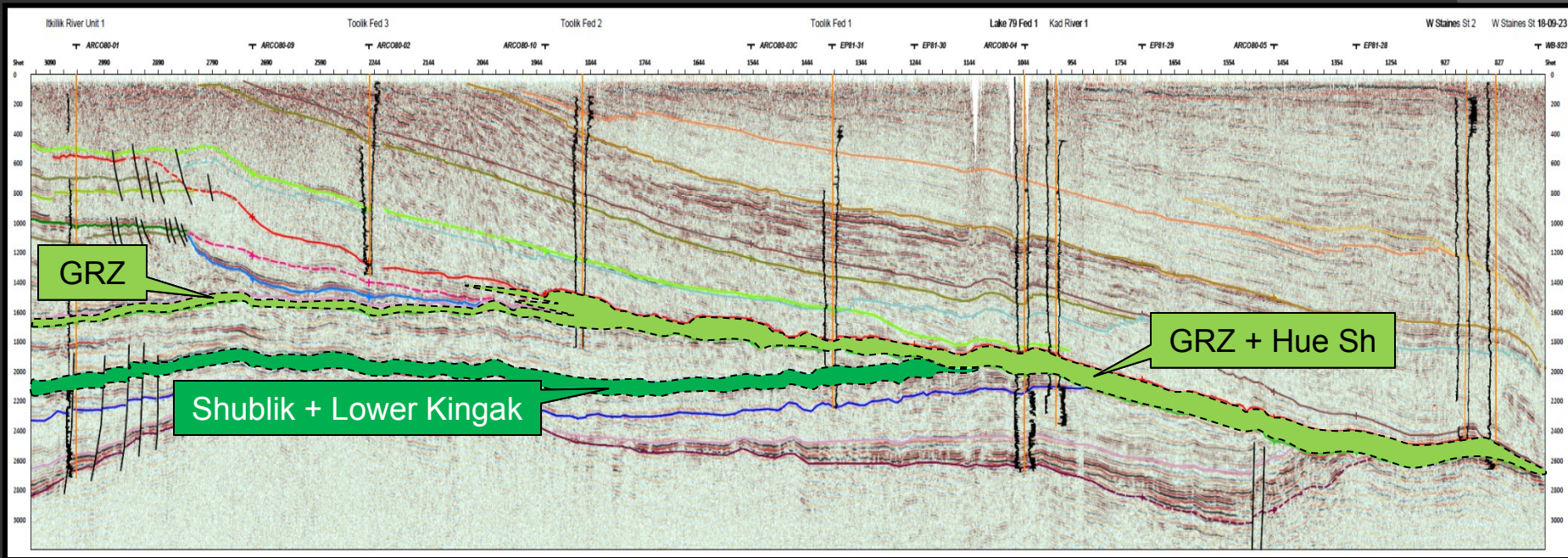
Central North Slope Seismic Transect

Public Seismic Line ARCO 80-07 & 80-06

West

Total length ~120 miles

East



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

(Decker, unpublished data, 2010-11)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)

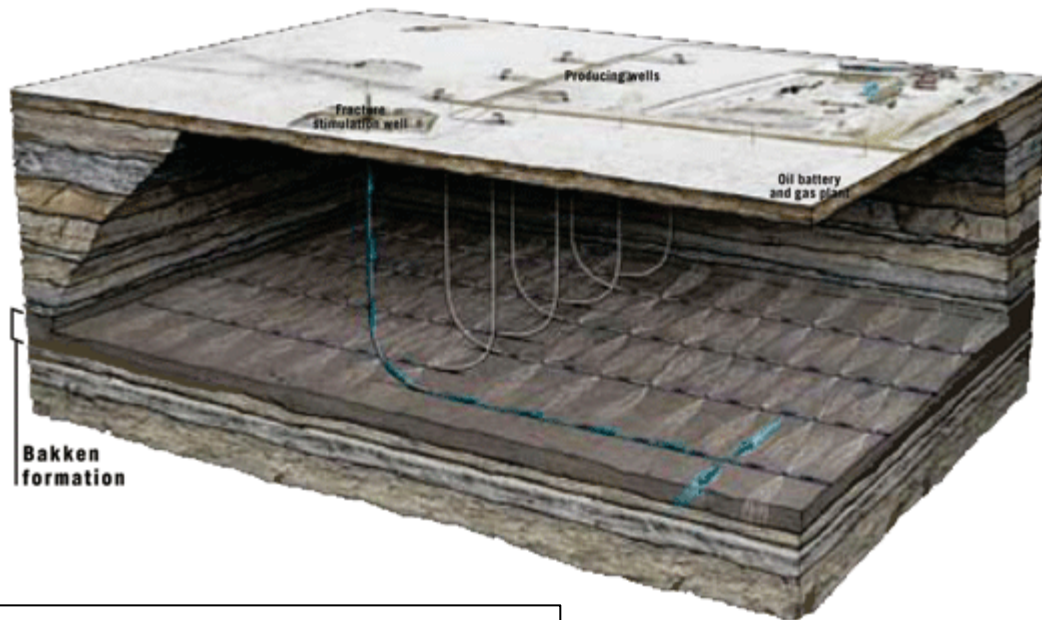
○ Petrophysics

- 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



(Canadian Business Resources)

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)

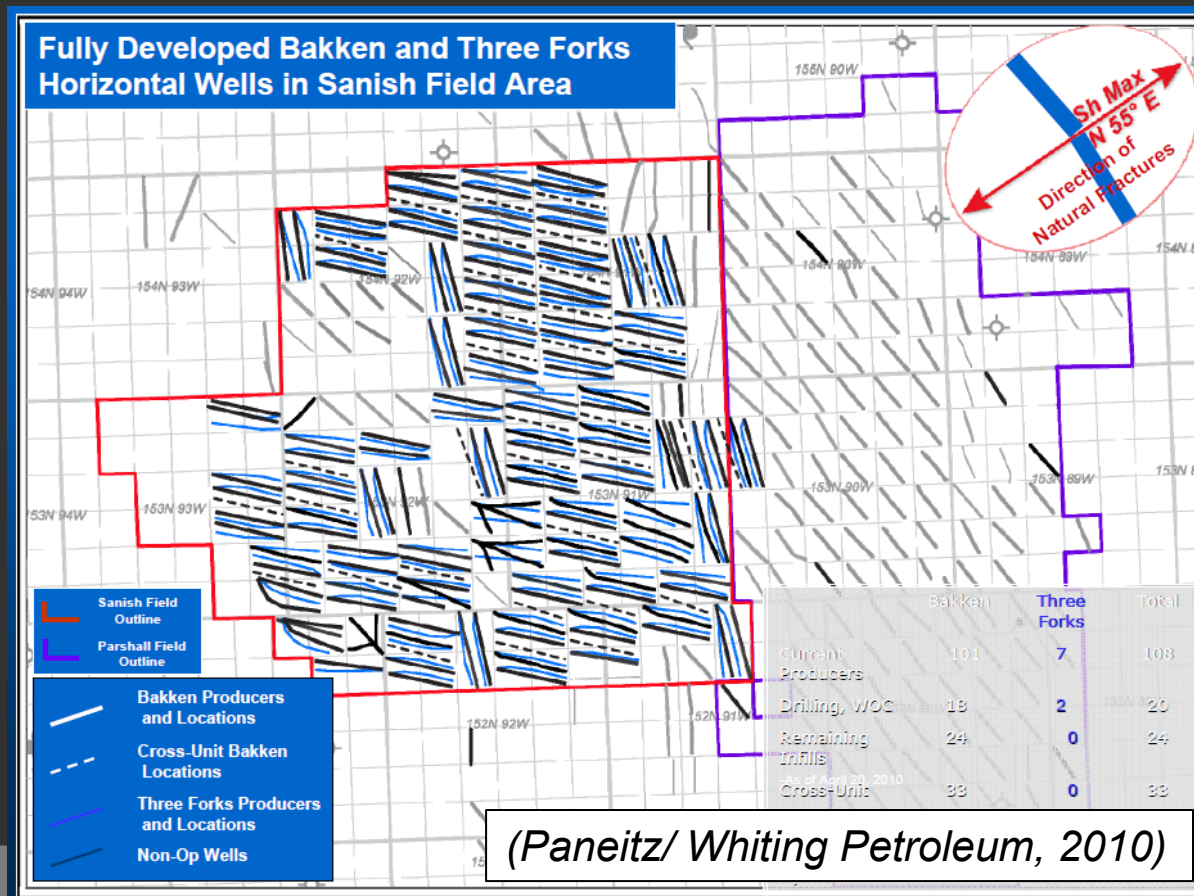


(courtesy Lynn Helms NDIC, DMR, 2011)

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 ? 120-060 acres/well (Great Bear estimates)



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?

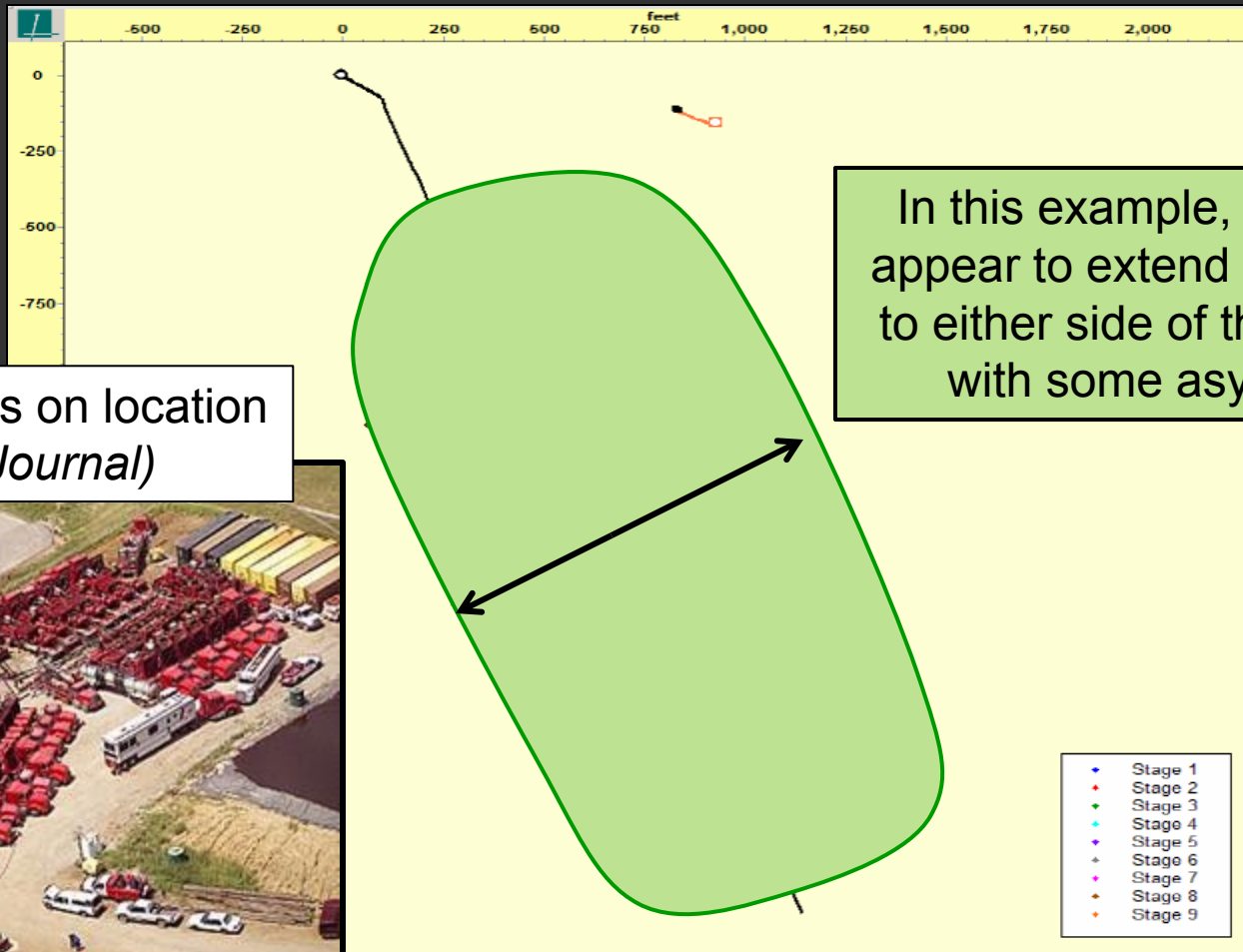
Frac jobs for horizontal producers in L48 shale plays consume 1 to 5.5 million gallons of water (and millions of pounds of sand) per well, depending on rock properties, number of stages pumped, etc.

❖ 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

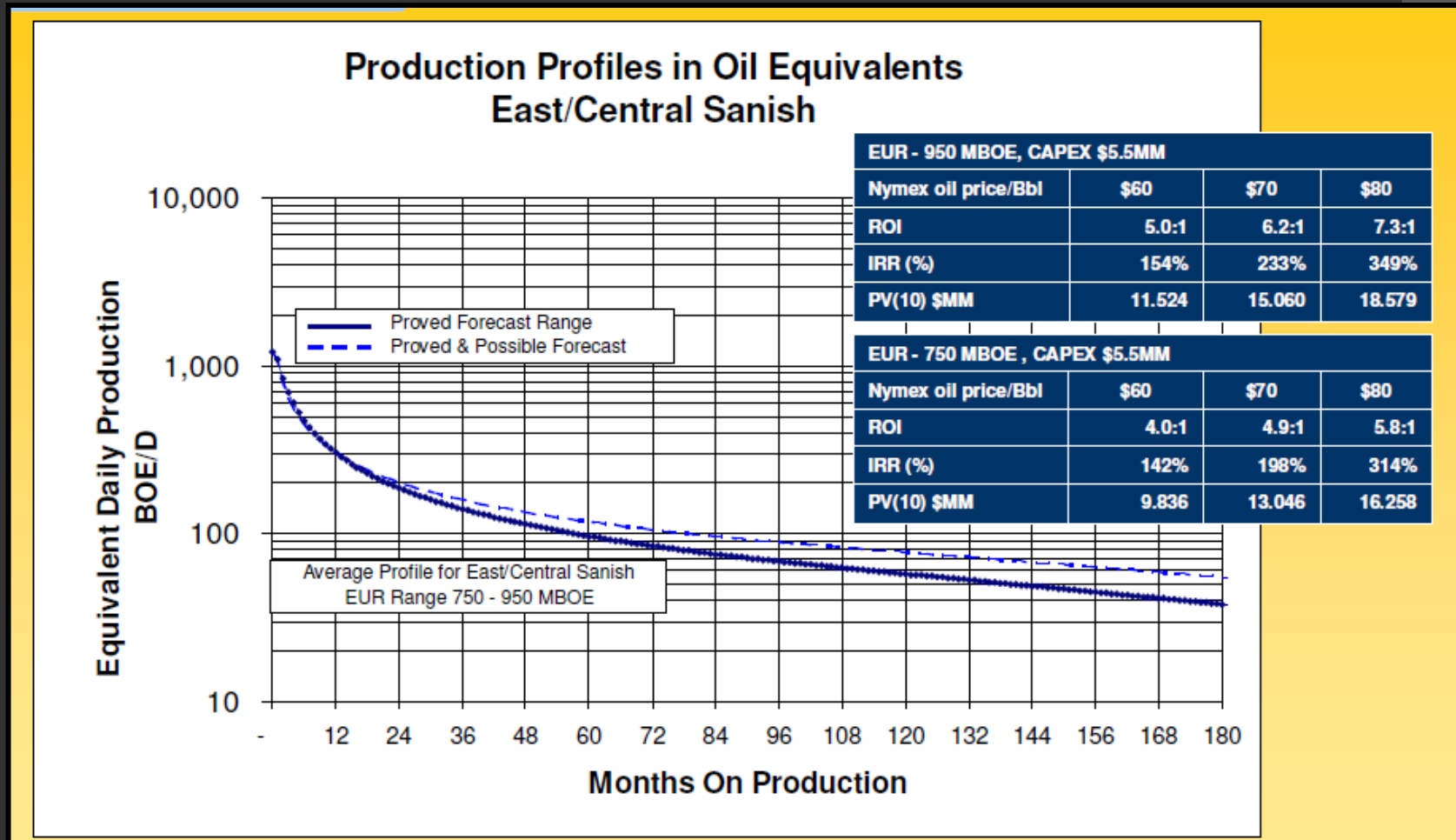
Where are the fractures and how far do they extend?



Microseismic map of 9-stage hydraulically fractured horizontal well (Bello, 2009)

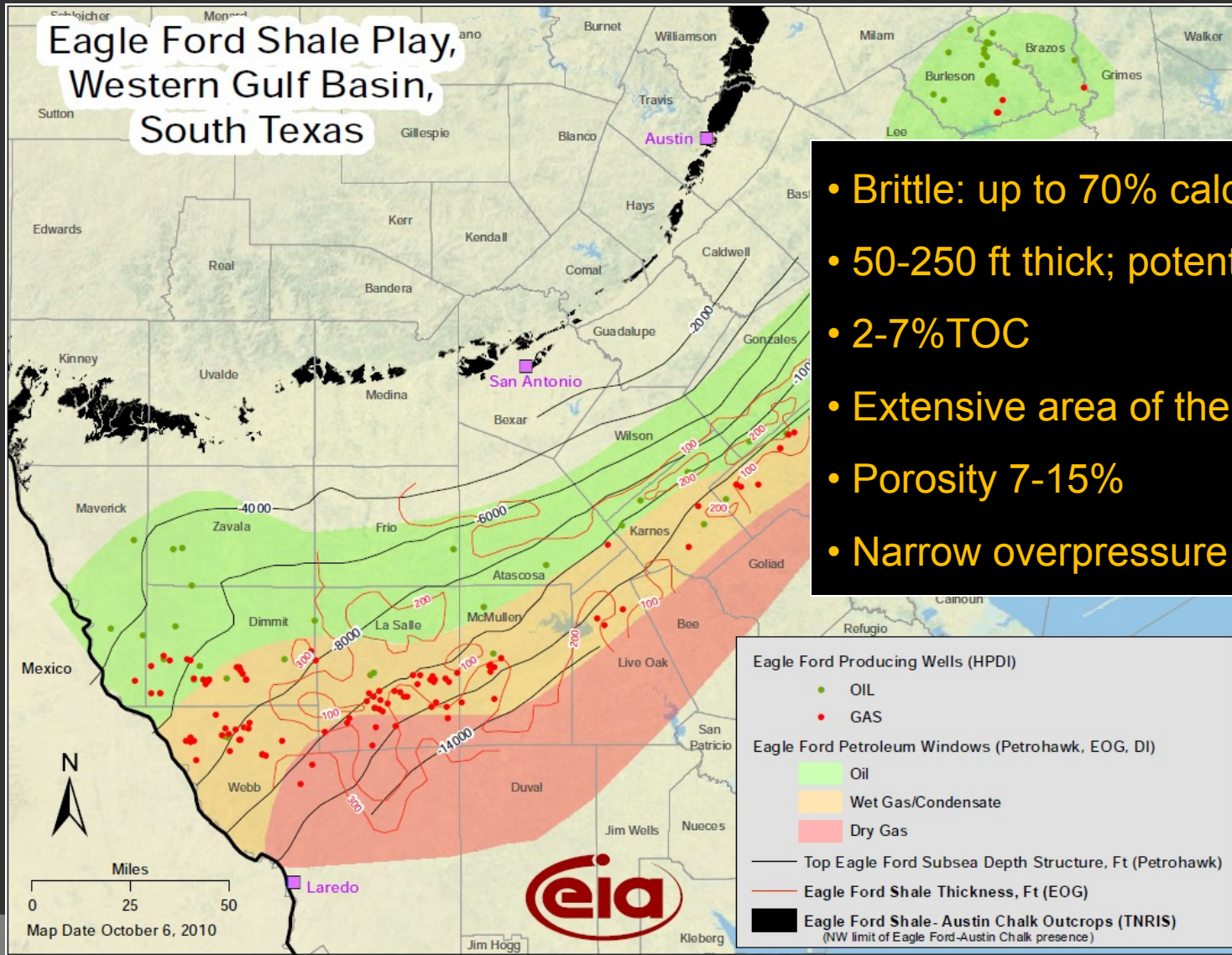
Single well flow rate over time

One producer's average production profile for Bakken Formation production wells – North Dakota



Texas Analogue (?)

Upper Cretaceous Eagle Ford Shale

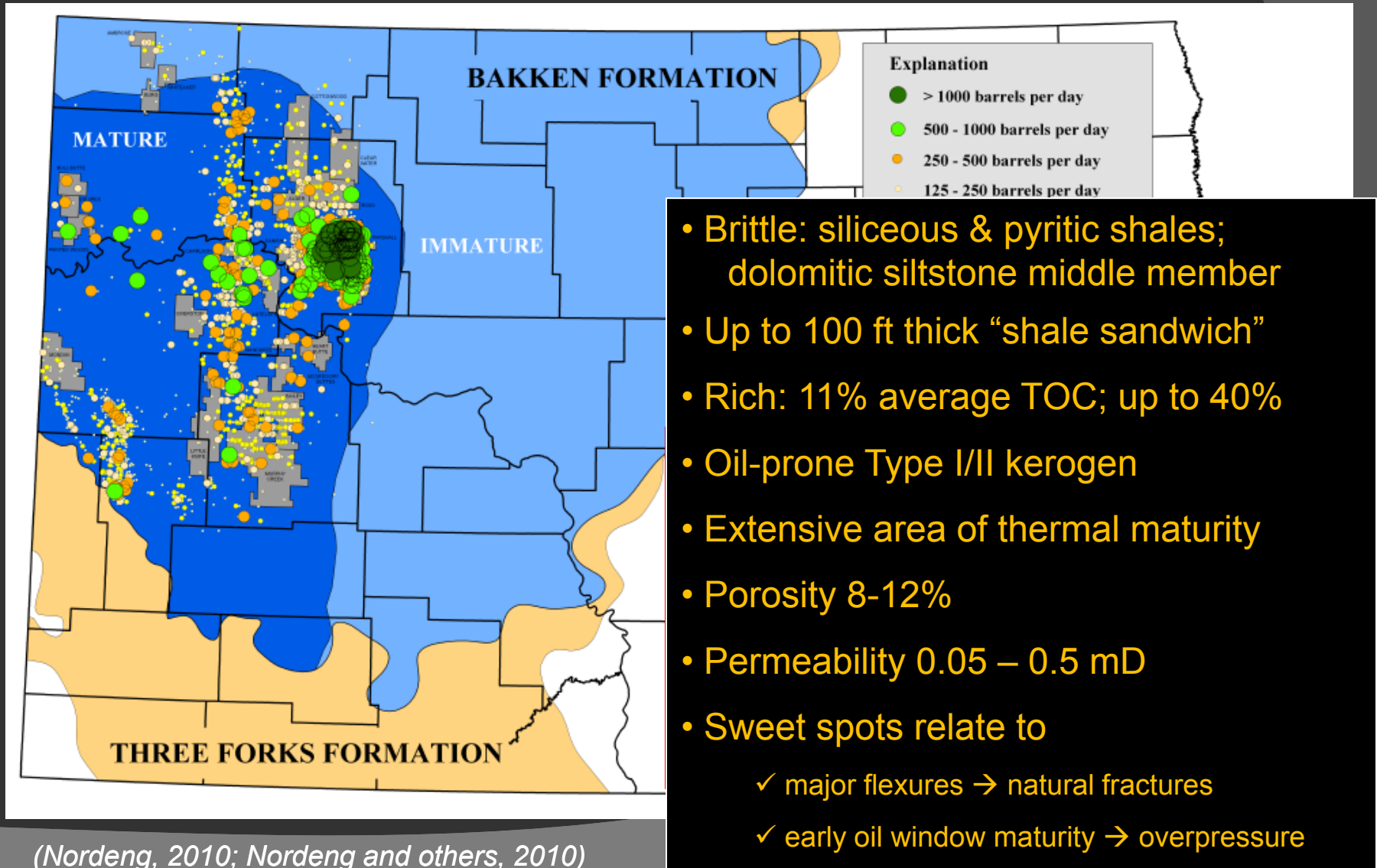


- Brittle: up to 70% calcite
- 50-250 ft thick; potentially all net pay
- 2-7% TOC
- Extensive area of thermal maturity
- Porosity 7-15%
- Narrow overpressure zone

(Energy
Information
Administration,
2010)

North Dakota Analogue (?)

Devonian-Mississippian Bakken Fm – First 60-90 day oil rates

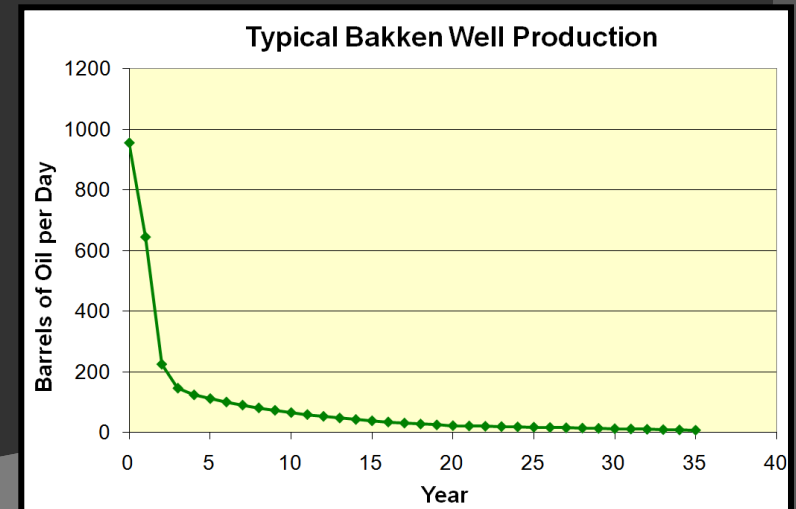
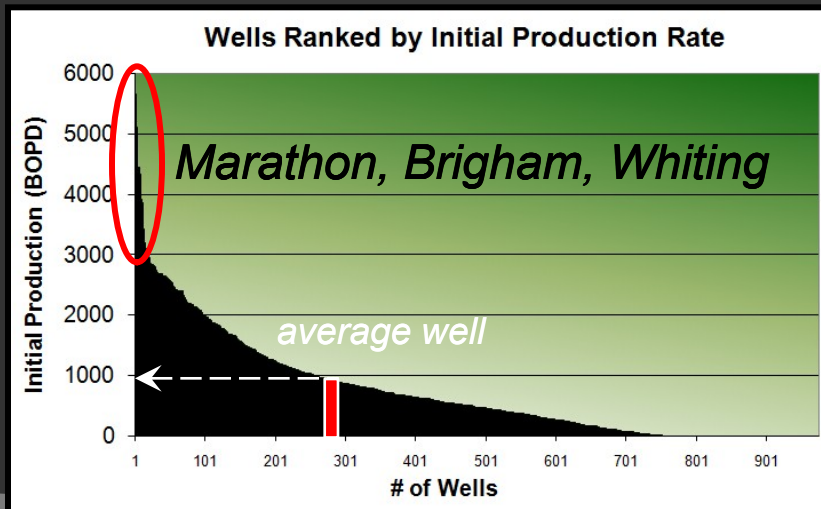


(Nordeng, 2010; Nordeng and others, 2010)

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

Rock Flour 1



Interbedded shale & limestone, silty-muddy, phosphatic, pyritic (up to 600 ft thick)

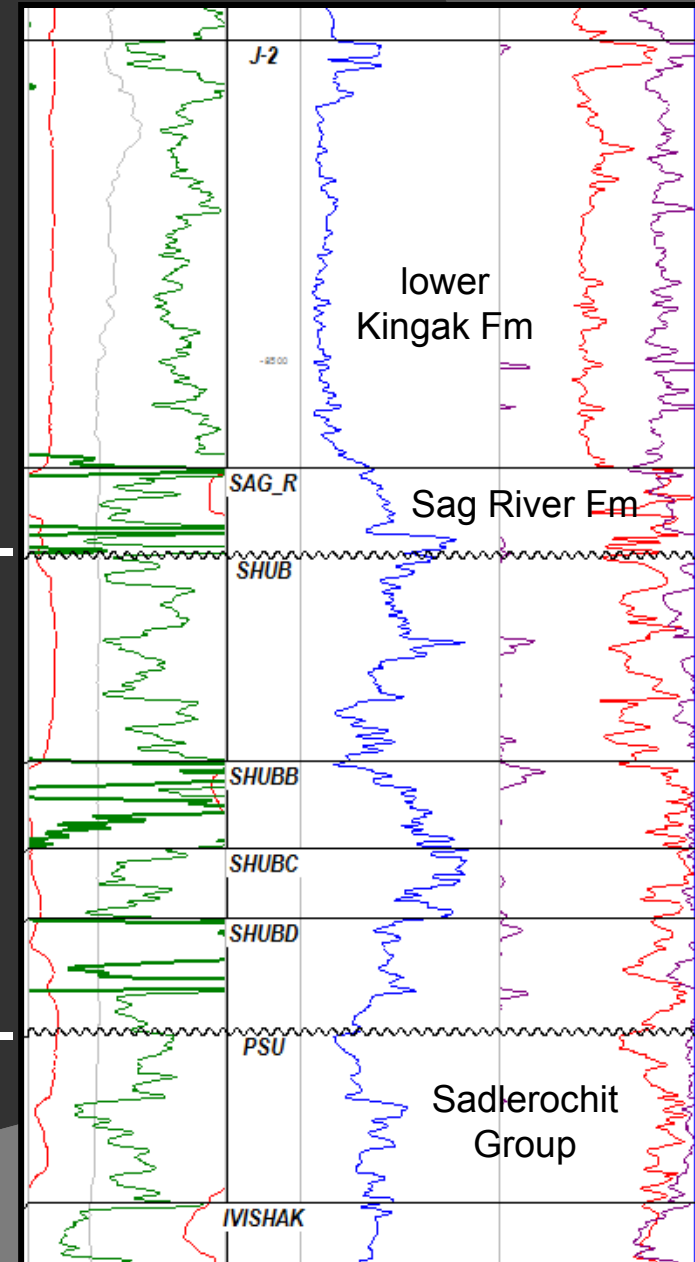
Shublik Fm

Zone A

Zone B

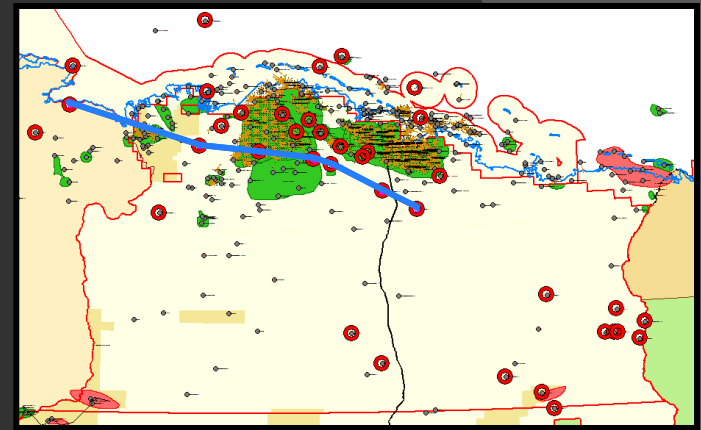
Zone C

Zone D



Shublik Formation

Well logs and zonal correlations



S Harr Bay 1

Kookpuk 1

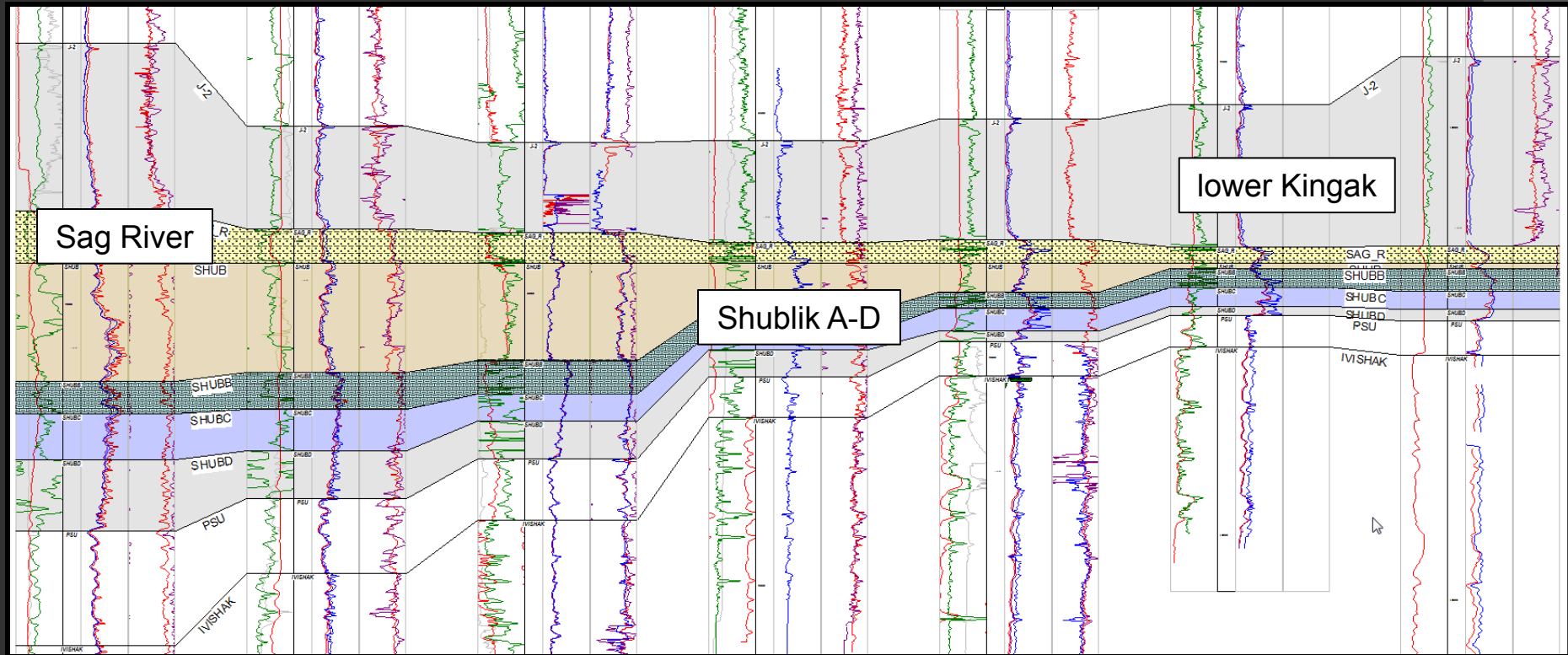
KRU 2F-20

Rock Flour 1

Hemi Spr 1

Hemi Spr 3

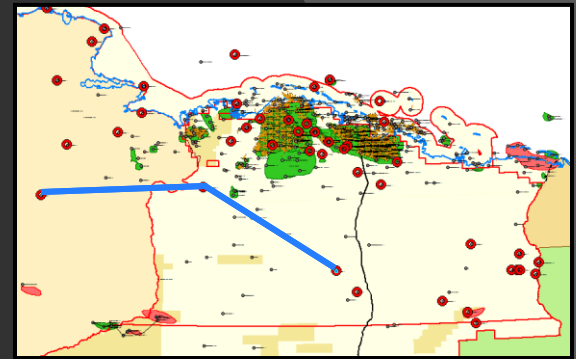
Toolik 1



(Decker, unpublished data, 2011)

Lower Kingak Formation

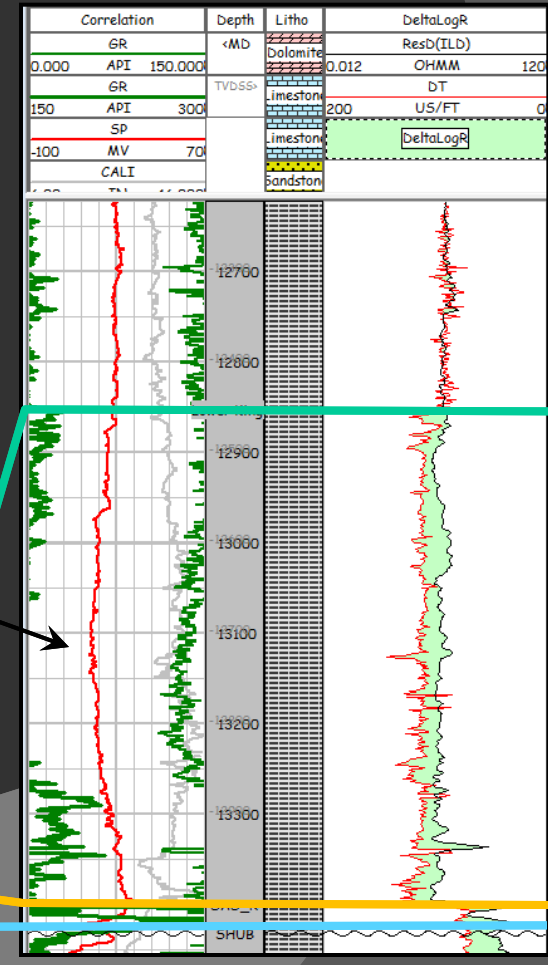
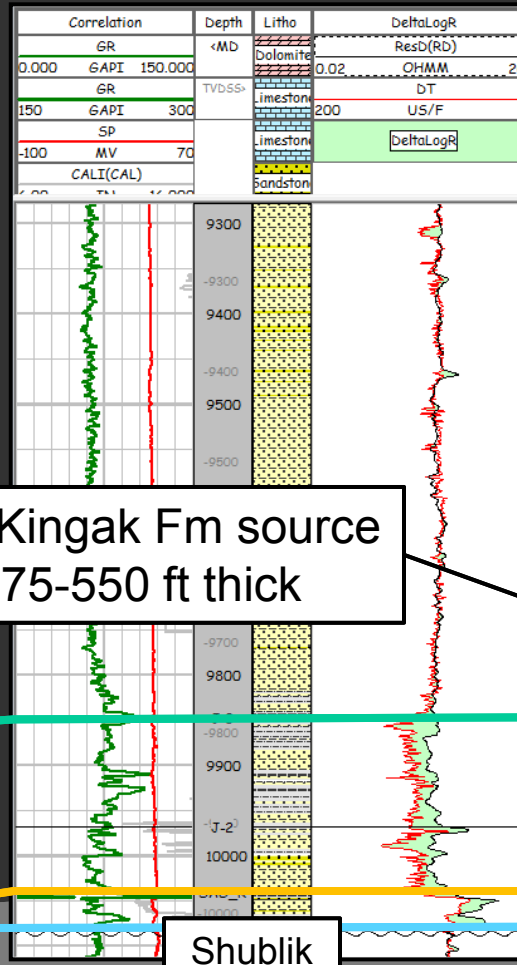
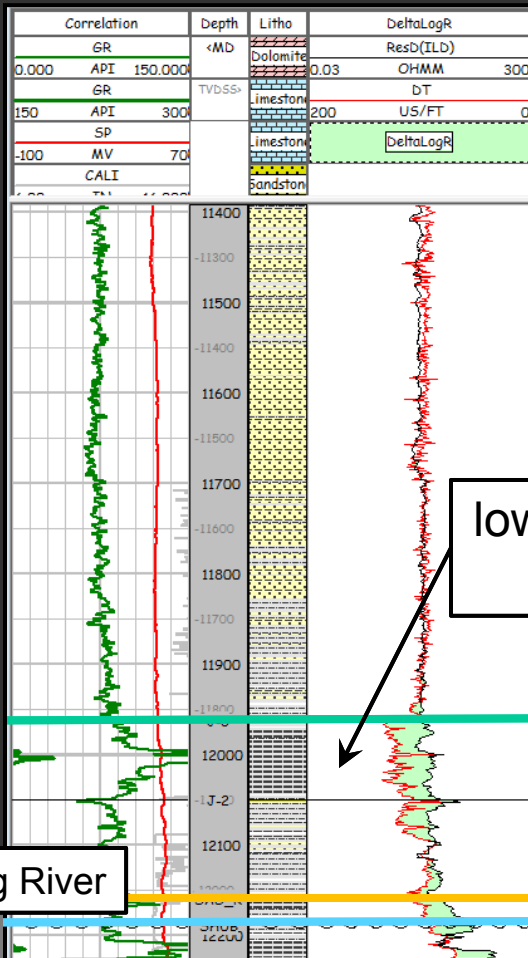
log R source rock screening



Inigok 1

Itkillik River 1

Bush Fed 1



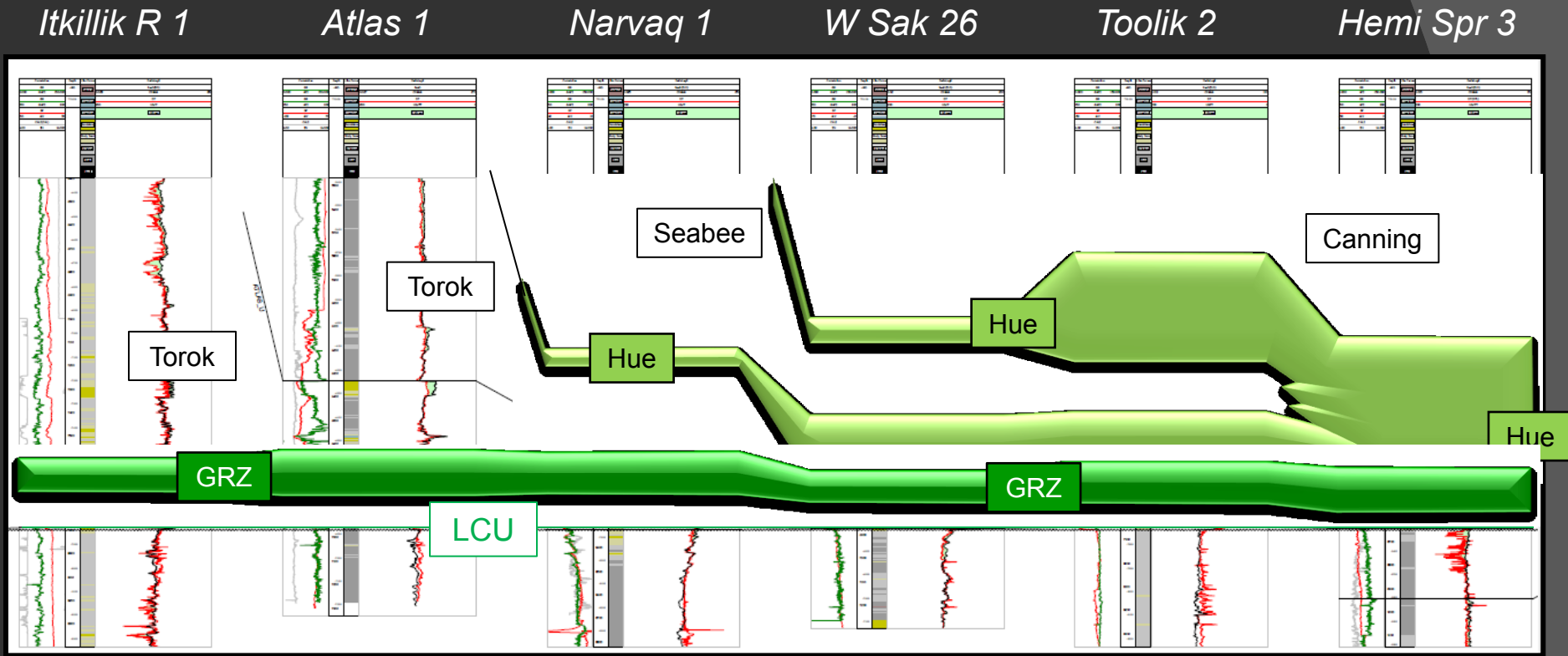
lower Kingak Fm source
~175-550 ft thick

Sag River

Shublik

Hue Shale/GRZ

Correlations and log-based Total Organic Content estimates



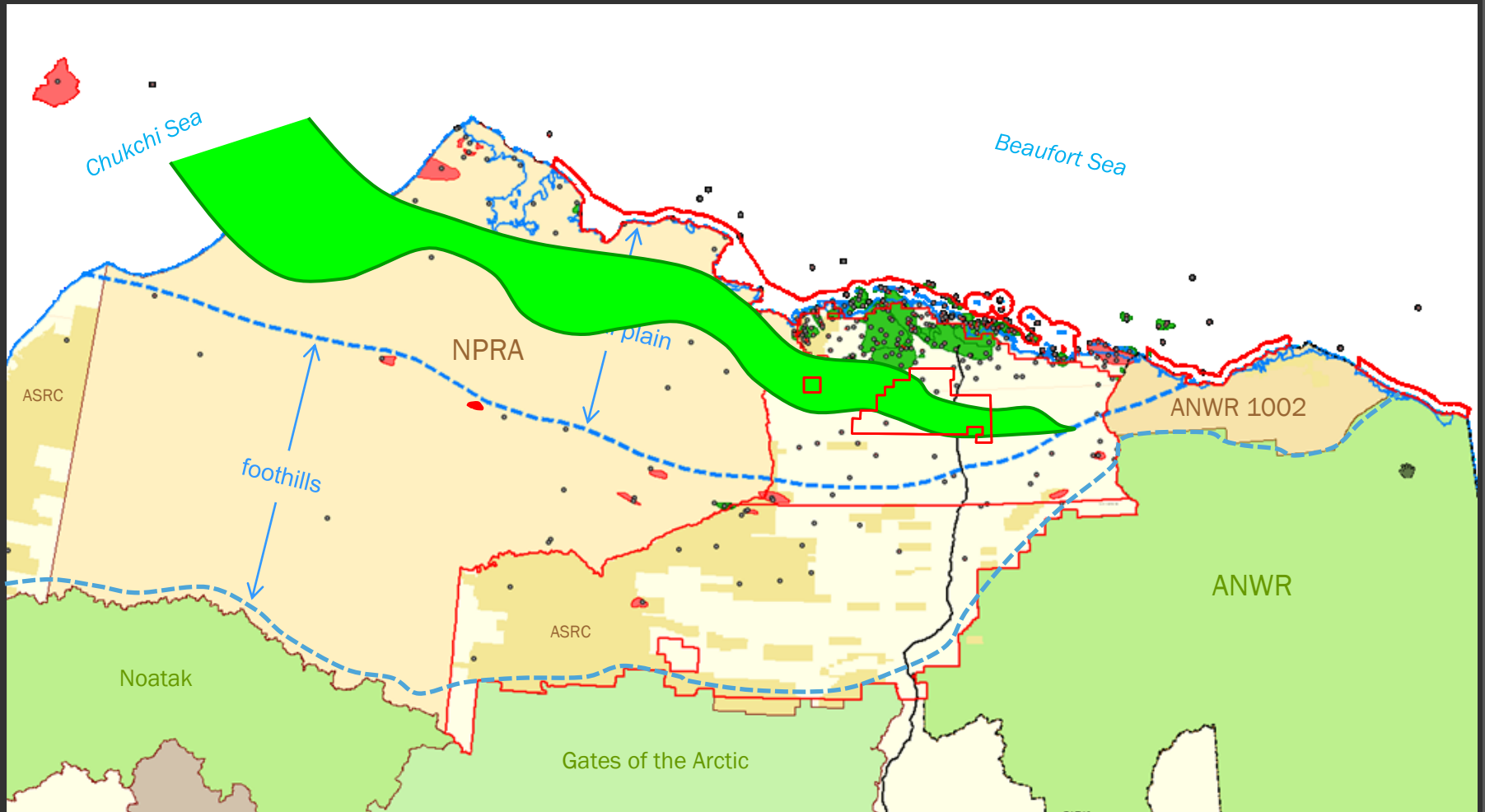
Log R calculated TOC estimates

Hue Sh	4.9%	2.6%	3.1%	4.8% (?)		
GRZ	2.6%	2.4%	1.6%	5.0%	3.1%	10.3% (?)

(Decker, unpublished data, 2009)

Shublik and Lower Kingak Formations

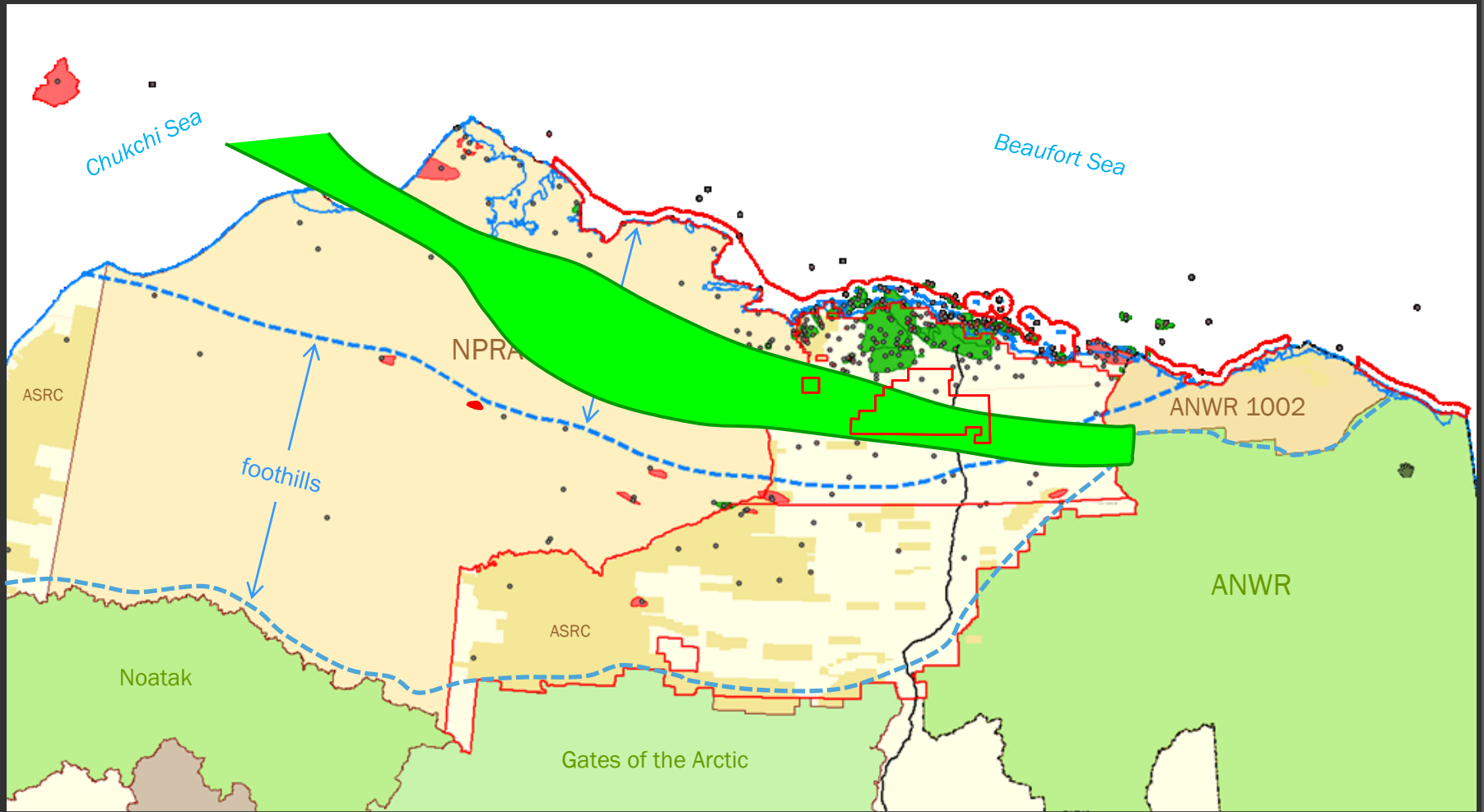
Thermal Maturity Zone



(mature area after Peters and others, 2006)

Hue Shale/GRZ

Thermal Maturity Zone



(mature area after Peters and others, 2006)

Comparison

Source rock characteristics

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

(compiled from various sources, Decker, 2011)

Summary

- Many variables impact productivity of source-reservoired 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