Petroleum Systems and Exploration Potential of Northern Alaska

an introduction to the November 2012 State of Alaska Areawide Lease Sales

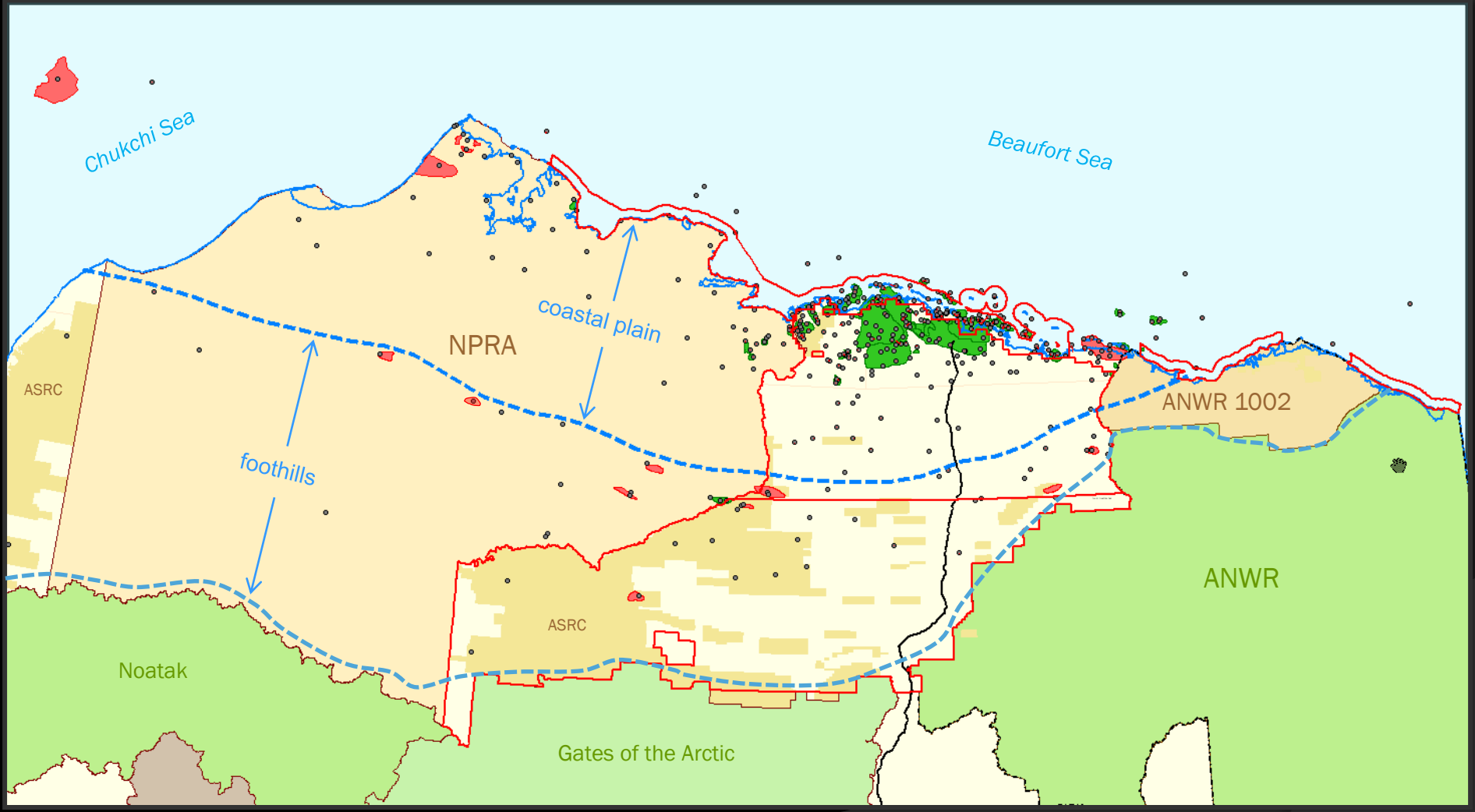
Paul L. Decker
Alaska Division of Oil and Gas

July, 2012

Presentation Outline

- Regional Geologic & Tectonic Framework
- Petroleum Systems Overview
- Exploration Potential and Play Types
- Foothills Geology and Hydrocarbon Potential
- Shale Resource Potential
- Northern Alaska Lease Sales

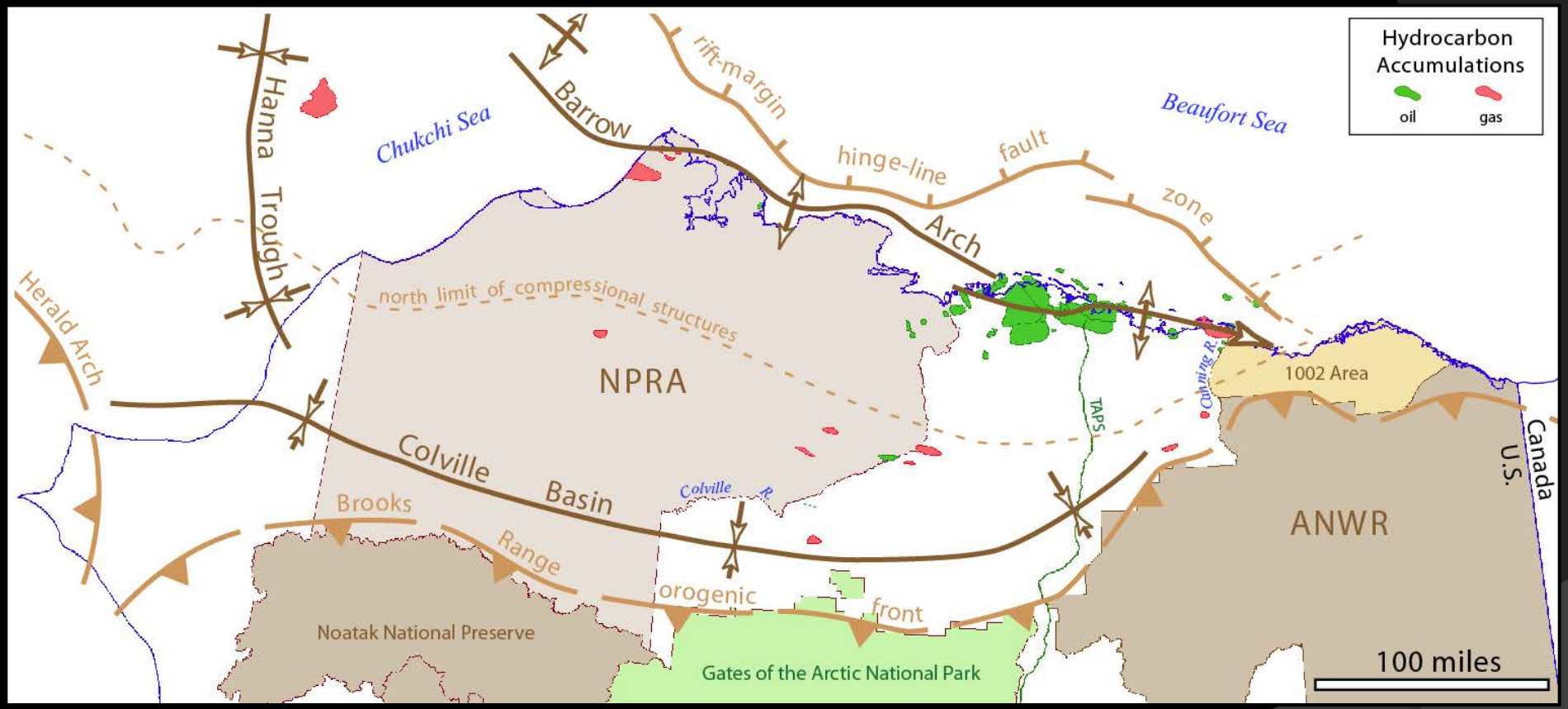
Northern Alaska Location Map



Northern Alaska Areawide Lease Sales

Scheduled each year in Fall -- All available unleased State tracts

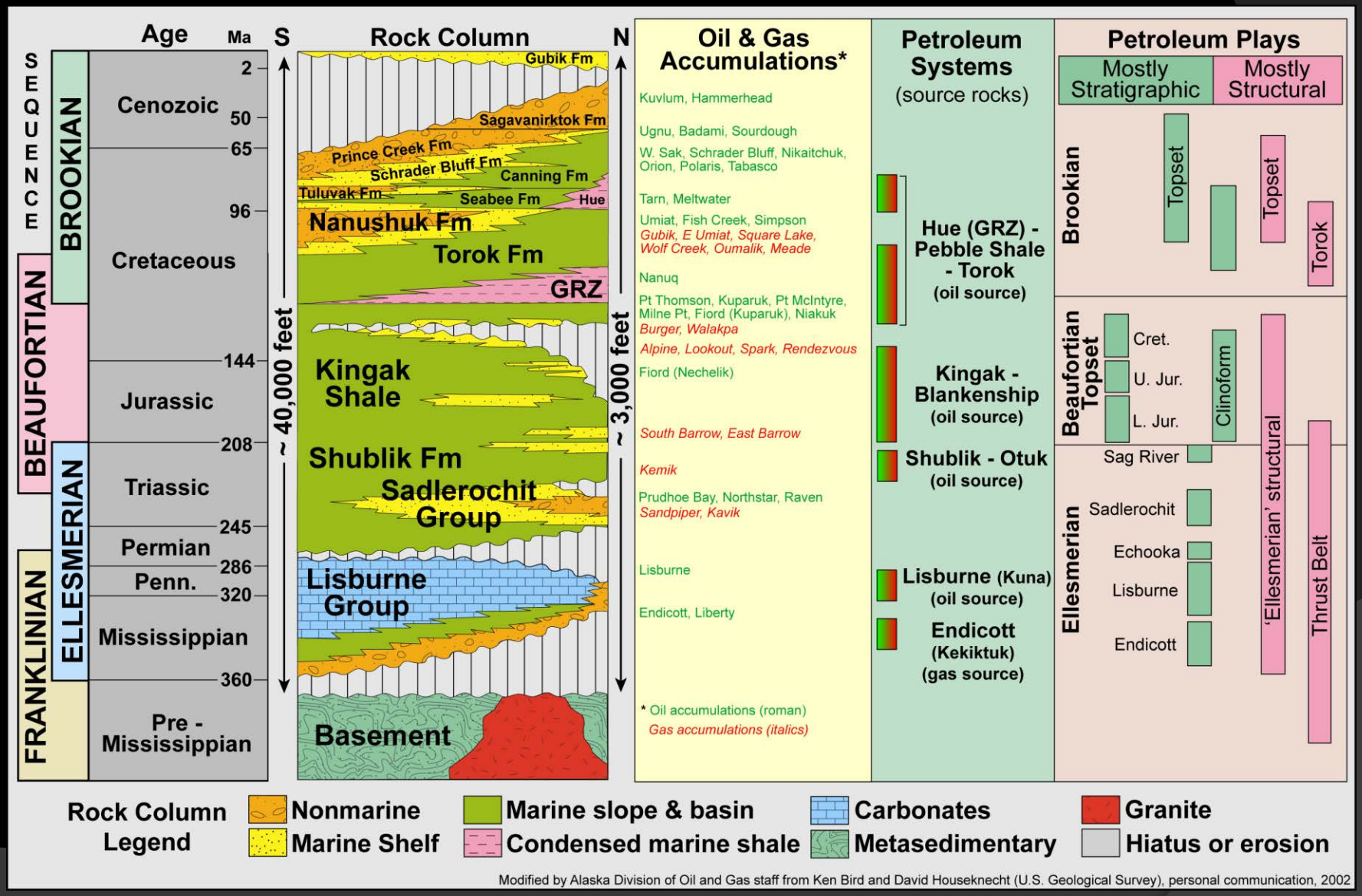
Regional Tectonic Elements



Decker, 2007

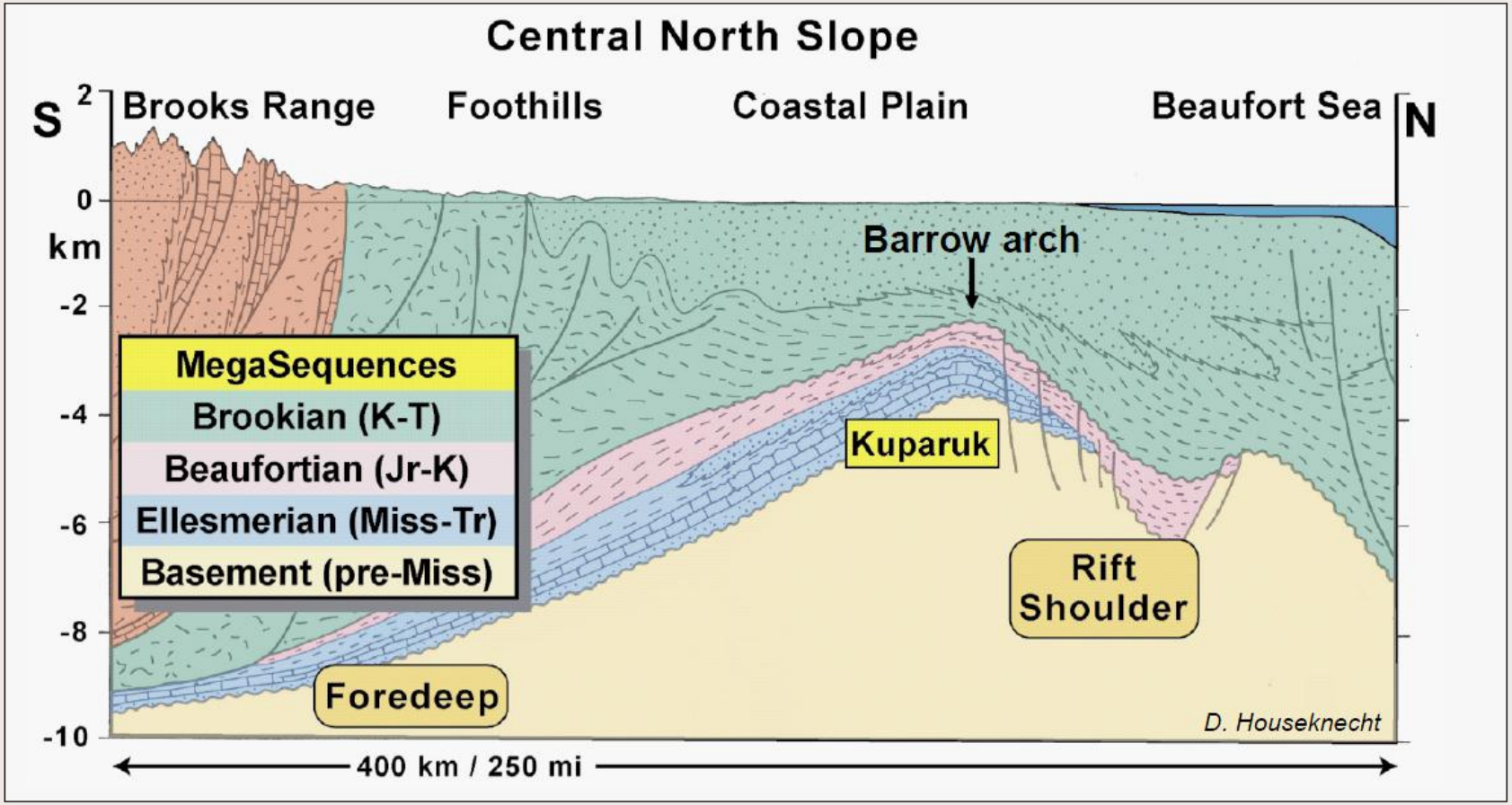
North Slope Petroleum Systems

4 mega-sequences – Prolific source rocks – Numerous play types



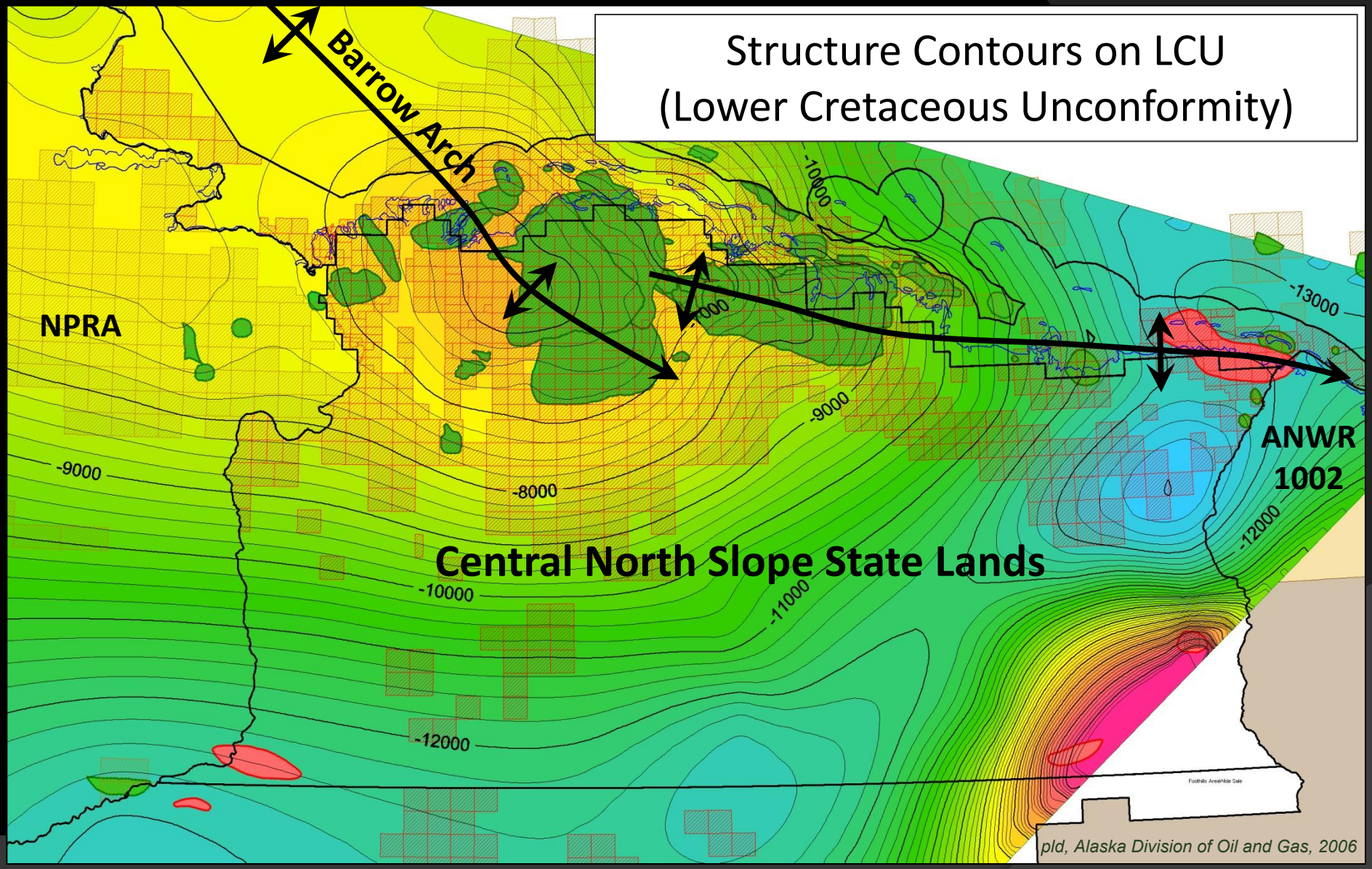
Modified by Alaska Division of Oil and Gas staff from Ken Bird and David Houseknecht (U.S. Geological Survey), personal communication, 2002

South-North Schematic Cross Section



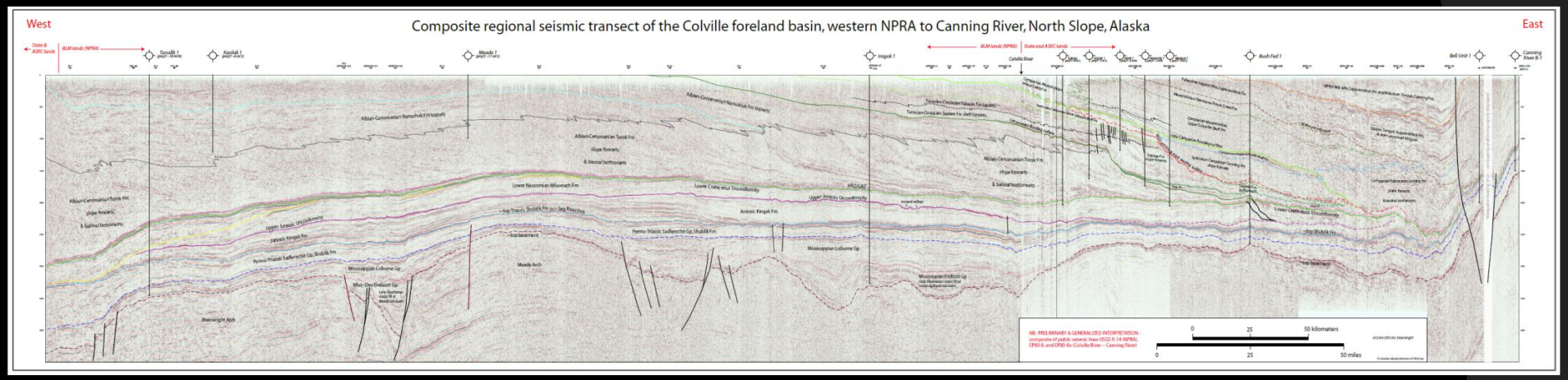
- **Ellesmerian**: Late Devonian-Triassic south-facing passive continental margin
- **Beaufortian**: Jurassic-Hauterivian north-facing rift margin superimposed on older margin
- **Brookian**: Jurassic-Barremian arc-continent collision produced Brooks Range and Colville Trough foreland basin and fill (latter two tectonic settings overlap)

North Slope Fields and Barrow Arch



West-East Seismic Transect

Western NPRA-Colville River-Canning River/ANWR



pld, Alaska Division of Oil and Gas

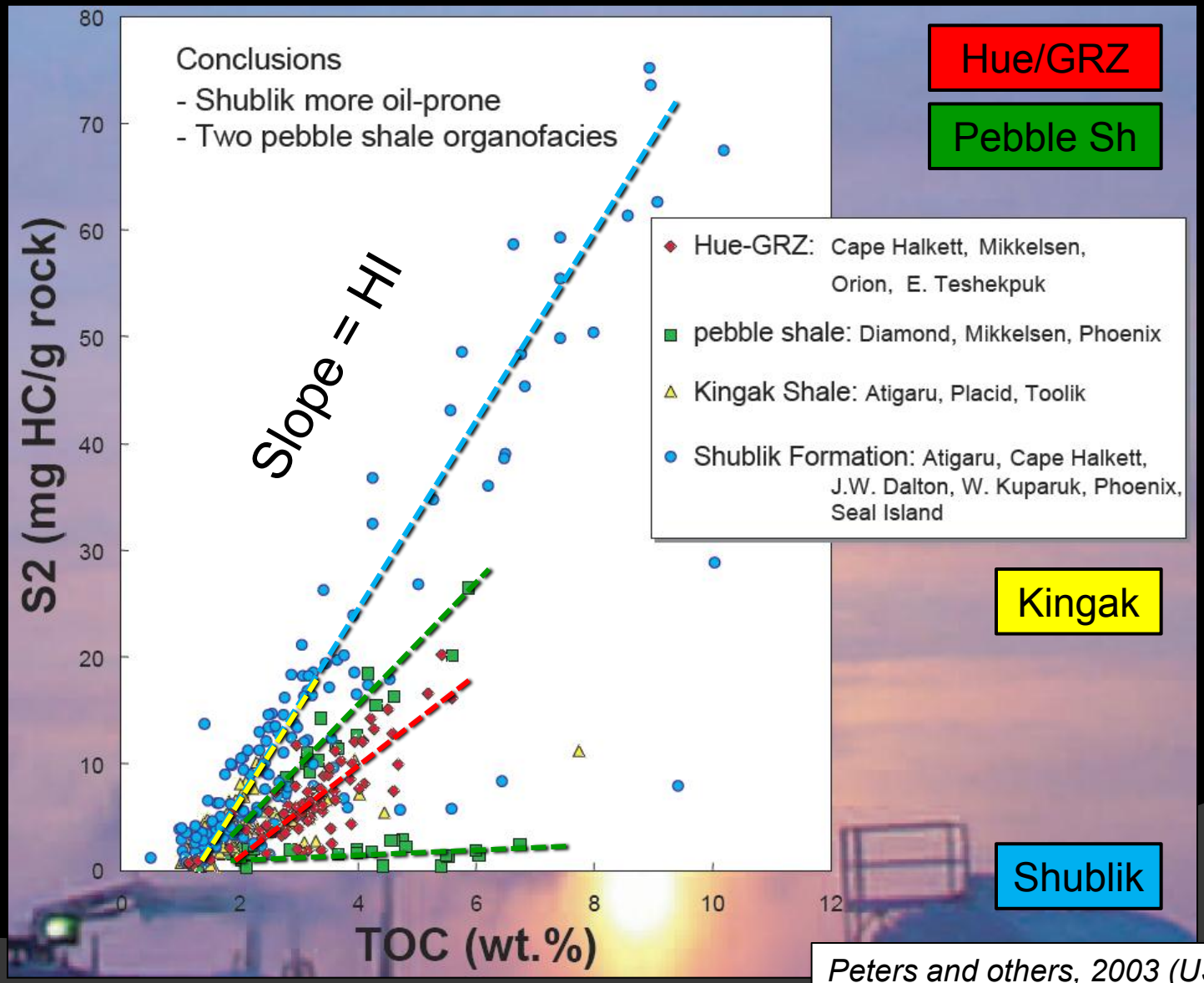
North Slope Petroleum Systems

Rift Margin and northern Arctic Platform Provinces

- Source Rocks:
  - Cretaceous GRZ/Hue Shale,
  - Jurassic Kingak Shale
  - Triassic Shublik Fm & TR-Jurassic Otuk Fm
  - Mississippian Lisburne Gp (locally)
- HC Charge:
  - Prolific oil and gas charge; wide range of GOR, API, viscosity, etc.
- Trap Styles:
  - Rift-related fault buttress, unconformity combination, & purely stratigraphic traps;
  - Source-rock oil & gas plays (under evaluation);
  - Permafrost-associated gas hydrate; heavy oil
- Reservoirs:
  - Brookian Sequence – topset & turbidite sands
  - Beaufortian Sequence – shallow marine sands
  - Ellesmerian Sequence – sands & carbonates

North Slope Source Rocks

Hydrocarbon Generation Potential vs Total Organic Carbon

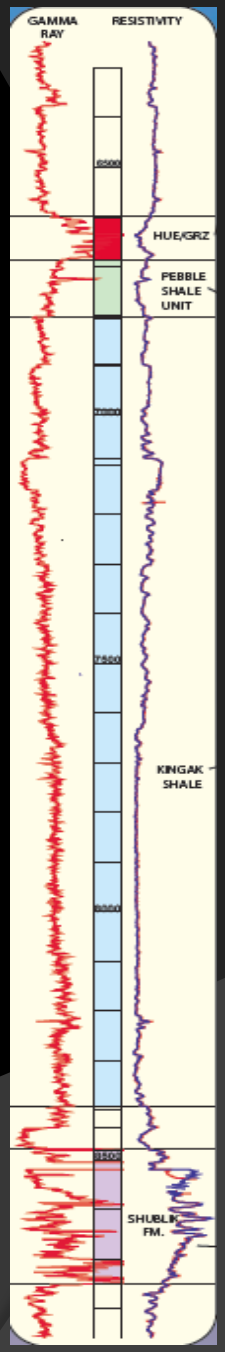


Hue/GRZ

Pebble Sh

Kingak

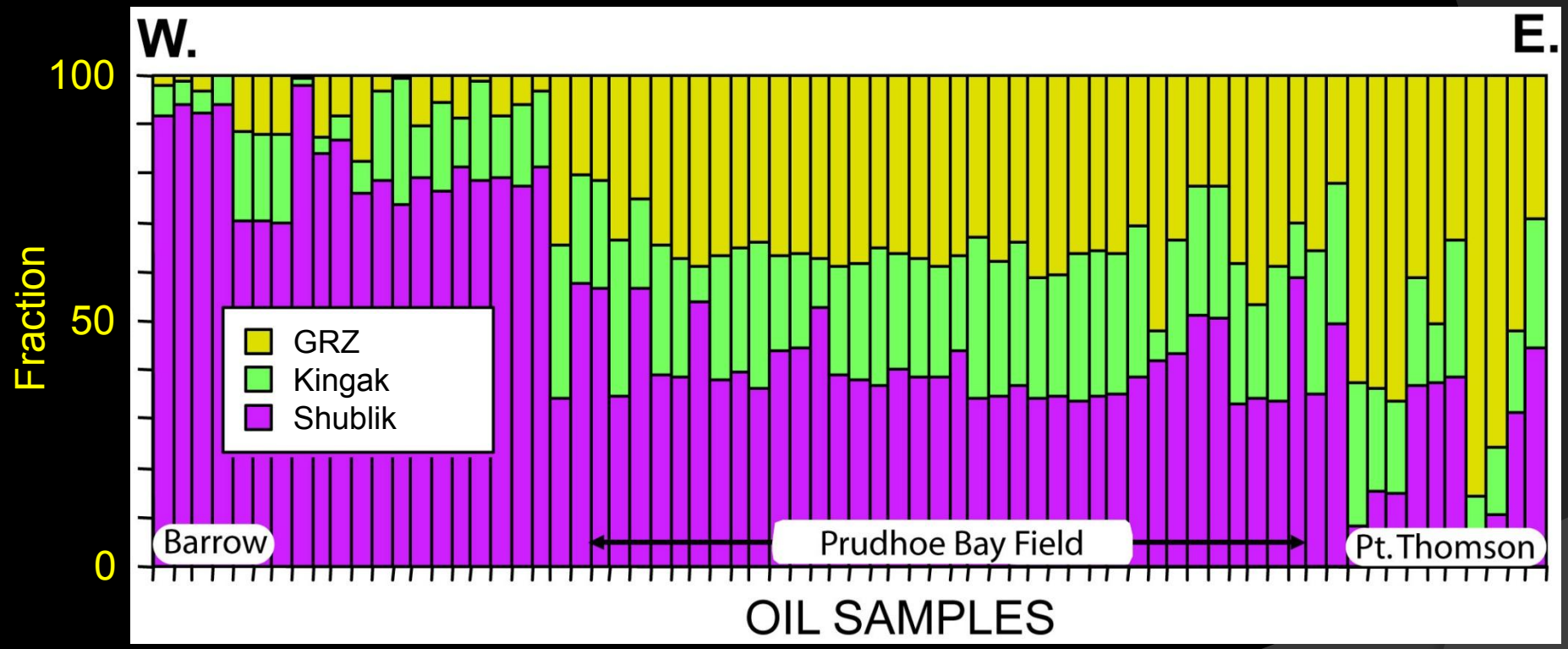
Shublik



Peters and others, 2003 (USGS)

Composite Petroleum System

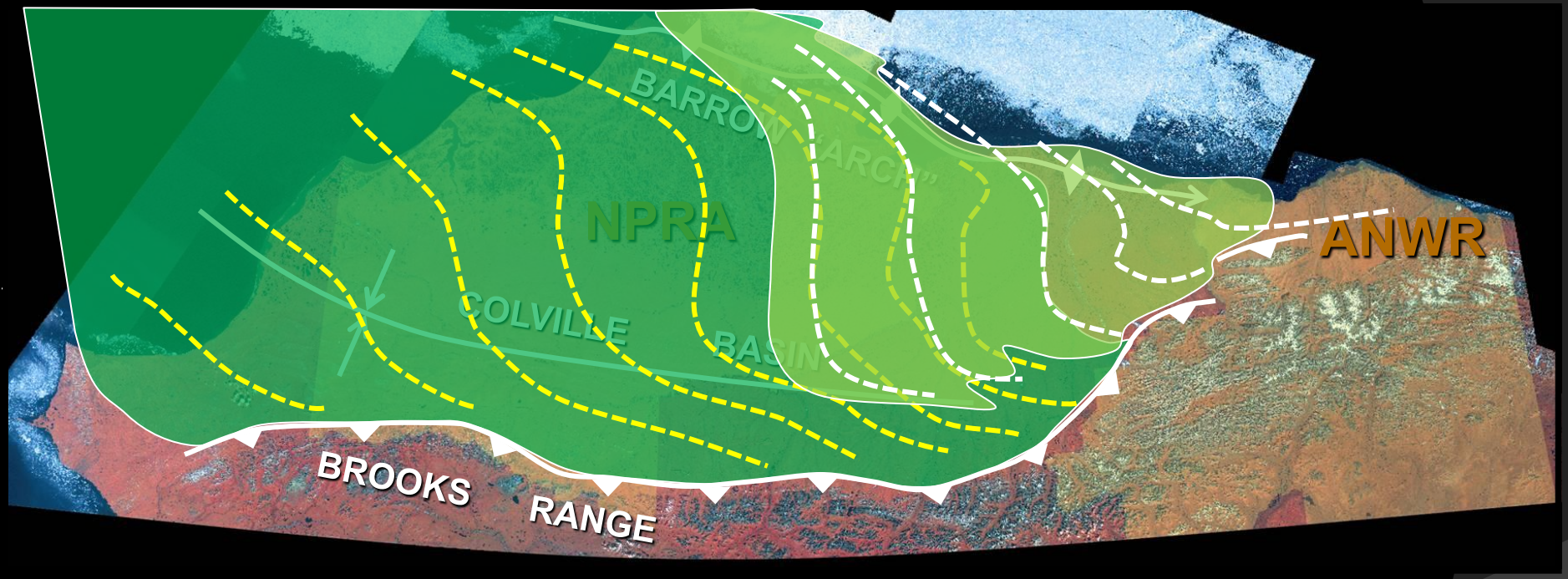
Evidence of Oil Mixing based on Chemometric Analysis



Peters et al., 2008

Colville Foreland Basin Filling

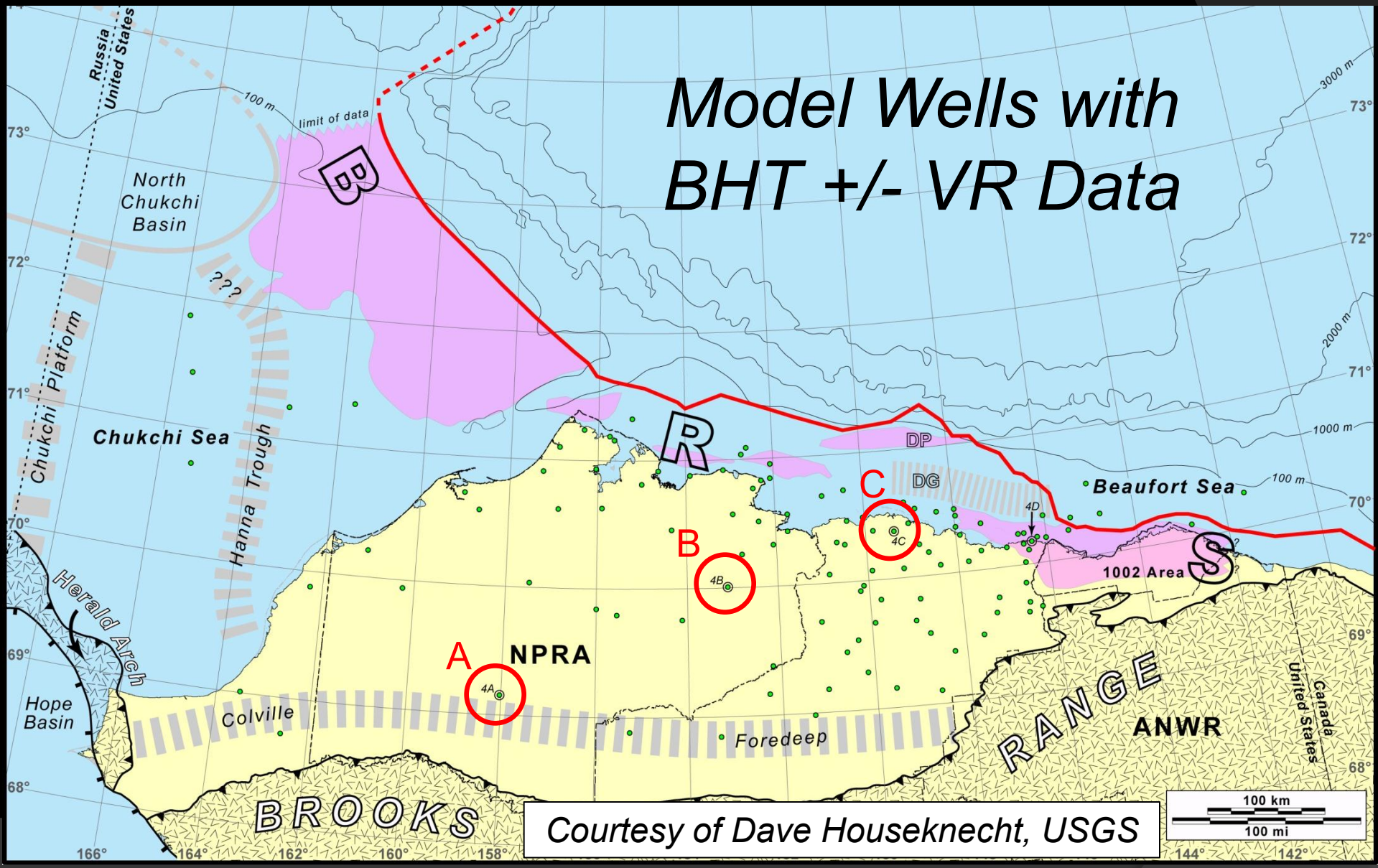
Eastward migrating clinoforms drive source rock burial & maturation



Lower Brookian basin fill: Early to middle Cretaceous
(Okpikruak-Fortress Mtn-Nanushuk-Torok)

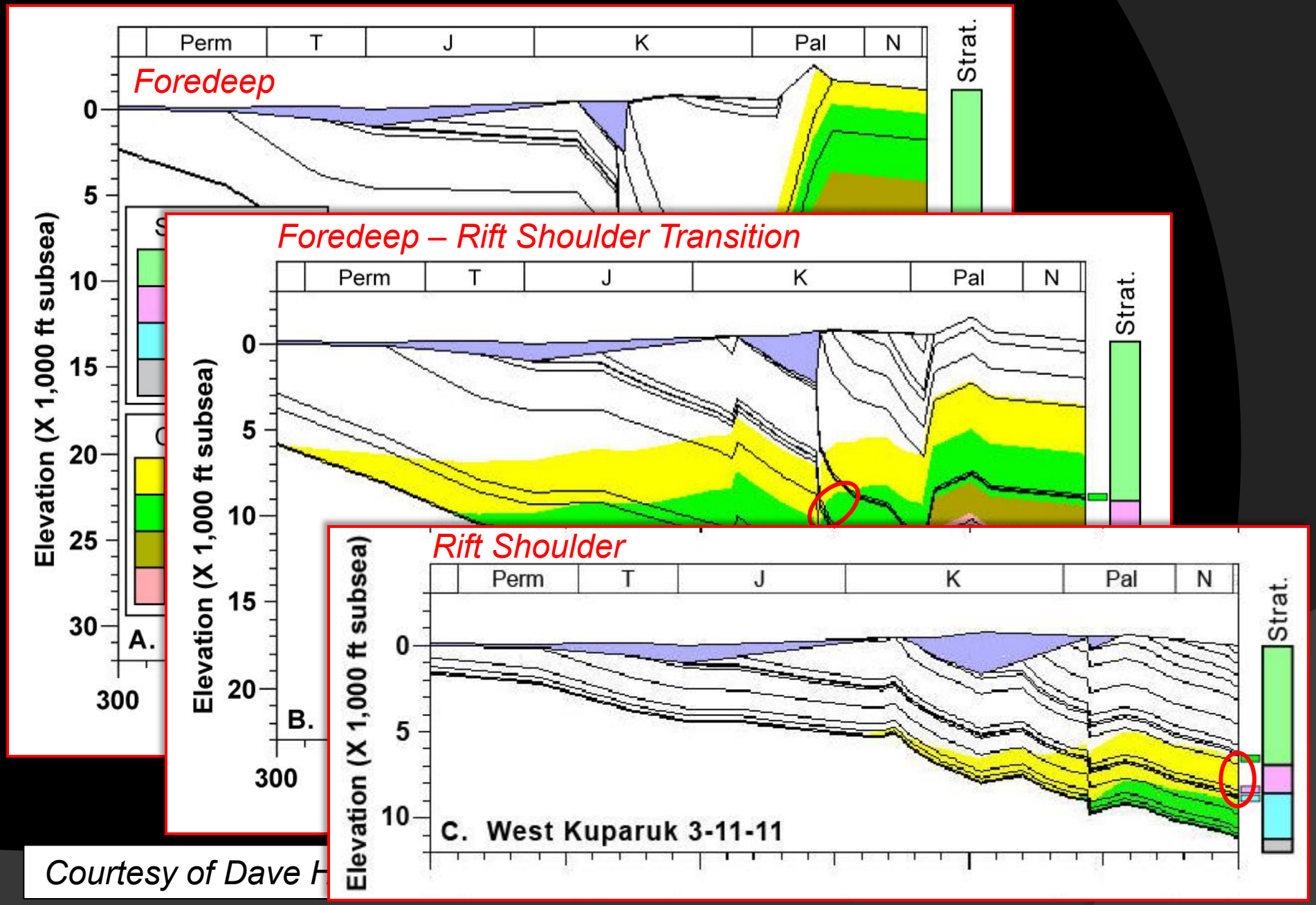
Middle & Upper Brookian basin fill: middle Cretaceous to Tertiary
(Tuluvak-Seabee → Prince Creek-Schrader Bluff-Canning → Sagavanirktok-Canning)

Thermal Maturation Modeling



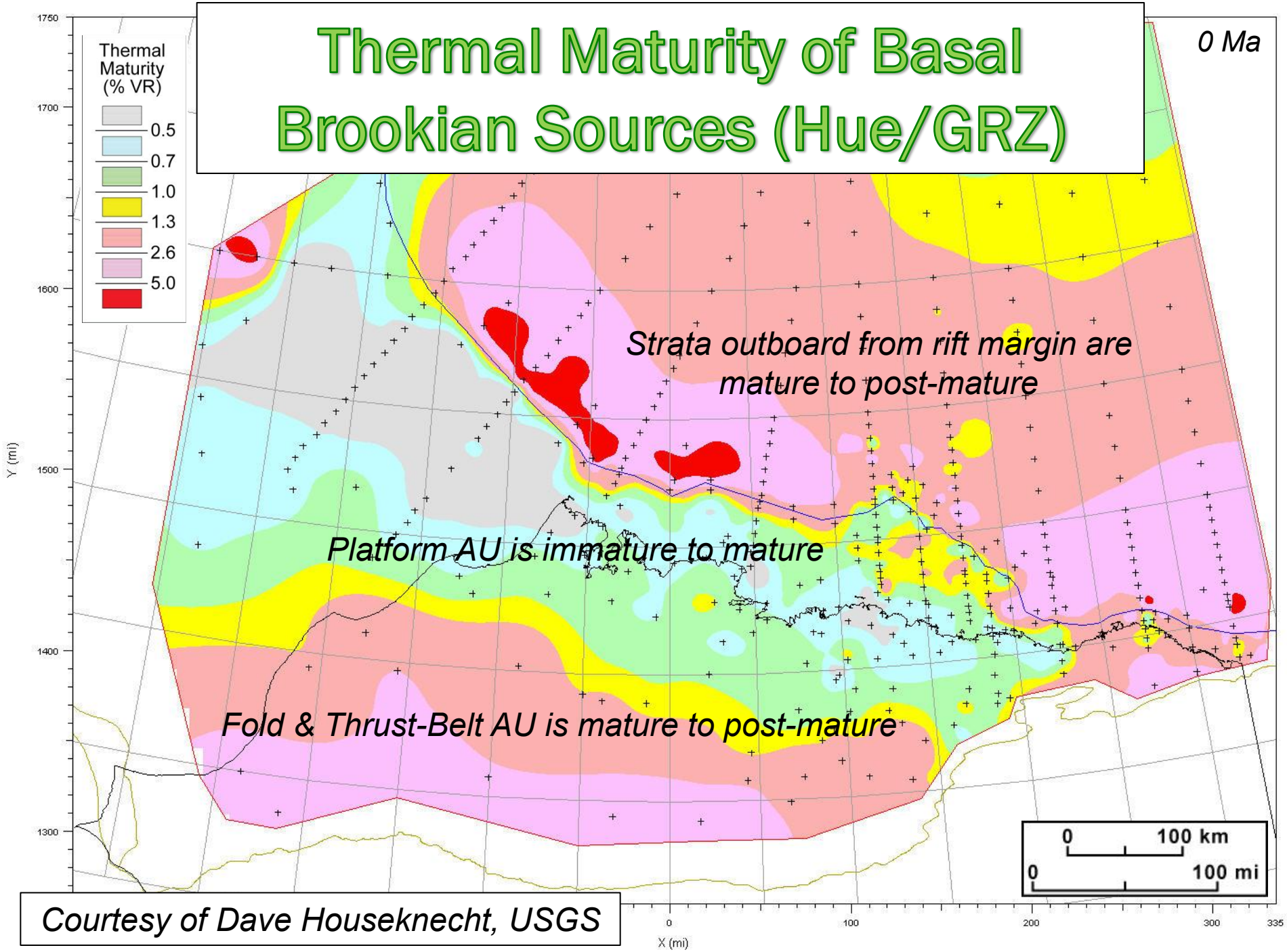
Courtesy of Dave Houseknecht, USGS

Burial History & Petroleum-Generation Models



Courtesy of Dave H

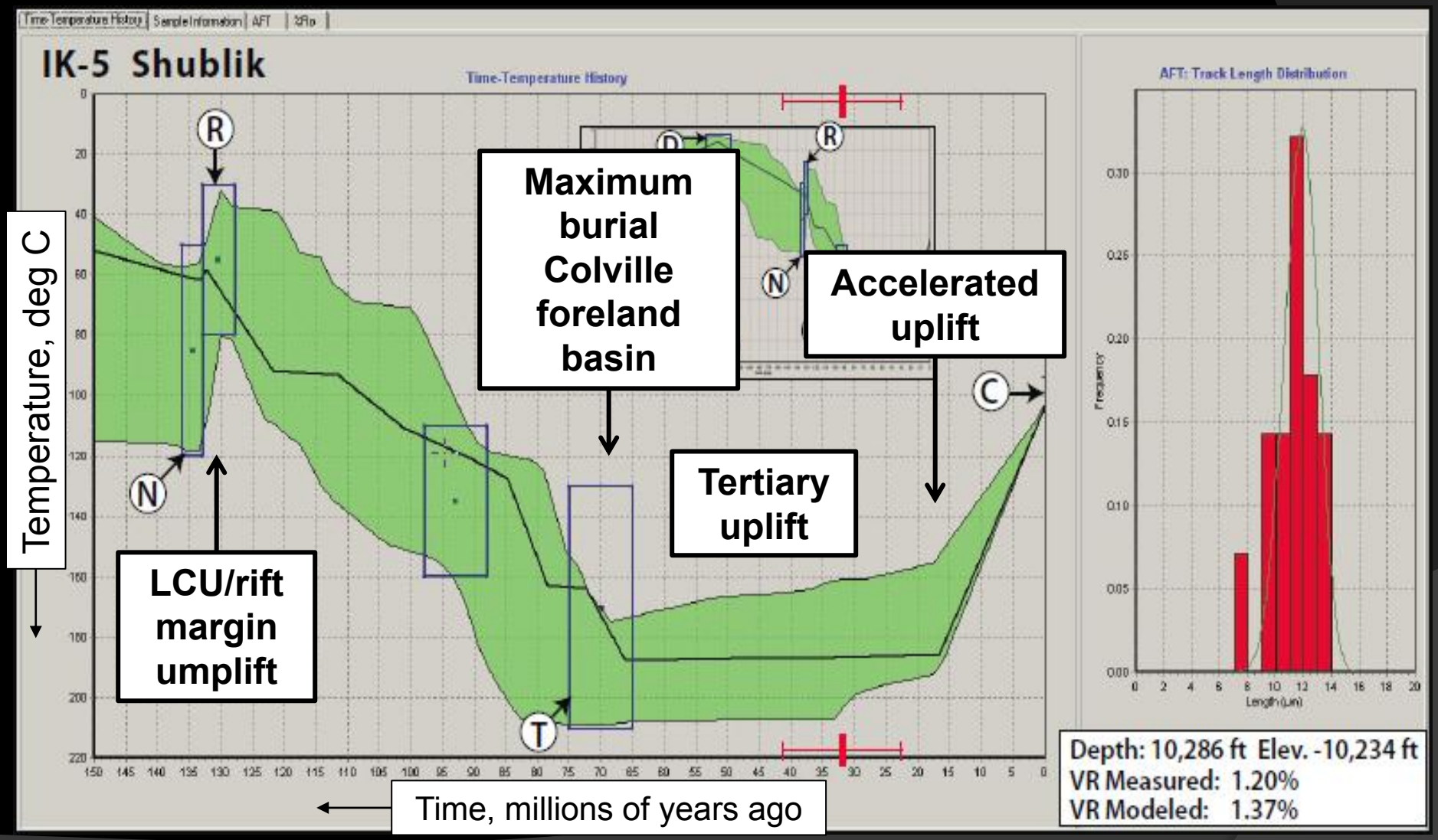
Thermal Maturity of Basal Brookian Sources (Hue/GRZ)



Courtesy of Dave Houseknecht, USGS

Thermal History

Apatite Fission Track example, south flank Barrow Arch, NPRA



Houseknecht and others, 2011 (USGS)

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Arctic Alaska Resource Estimates

USGS and BOEM Assessments

Technically Recoverable Undiscovered Conventional Oil and Gas Resources

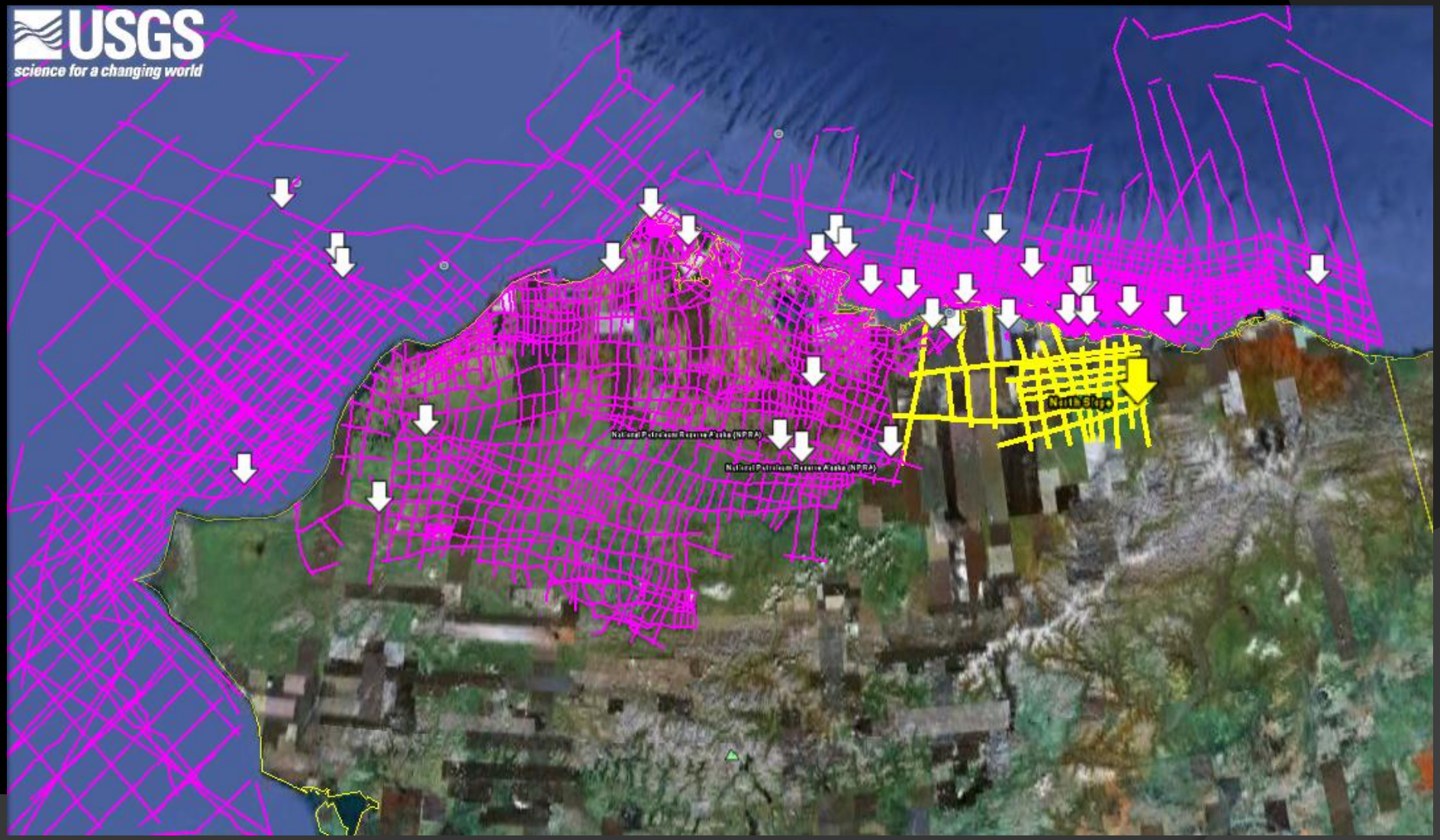
Region and Assessment Segment		Oil, MMSTB (million stock tank barrels)			Gas, BCF (billion cubic feet)		
		Probabilty Distribution			Probabilty Distribution		
North Slope Onshore & State Waters[2]		**F95**	**Mean**	**F05**	**F95**	**Mean**	**F05**
Central North Slope	*Oil & Associated gas*	2,565	3,984	5,854	2,681	4,198	6,092
	NGL & Non-associated gas	--[3]	478	--[3]	23,939	33,318	44,873
Nat'l Petrol Reserve Alaska	*Oil & Associated gas*	--	896	--	--	--	--
	NGL & Non-associated gas	--[3]	--	--[3]	--	52,839	--
ANWR coastal plain[2]	*Oil & Associated gas*	5,724	10,360	15,955	--	4,764	--
	NGL & Non-associated gas	--[3]	190	--[3]	0	3,841	10,852
total - North Slope Onshore		--[3]	15,908	--[3]	--[3]	98,960	--[3]
Arctic Alaska Outer Continental Shelf (OCS)							
Chukchi Shelf	*Oil & all gas*	2,320	15,380	40,080	10,320	76,770	209,530
Beaufort Shelf	*Oil & all gas*	410	8,220	23,240	650	27,640	72,180
Hope Basin	*Oil & all gas*	0	150	600	0	3,770	14,980
total - Arctic OCS (offshore)		--[3]	23,750	--[3]	--[3]	108,180	--[3]
TOTAL - Arctic Alaska		--[3]	***39,658***	--[3]	--[3]	***207,140***	--[3]

pld, Alaska Division of Oil and Gas

Publicly Available Seismic Data

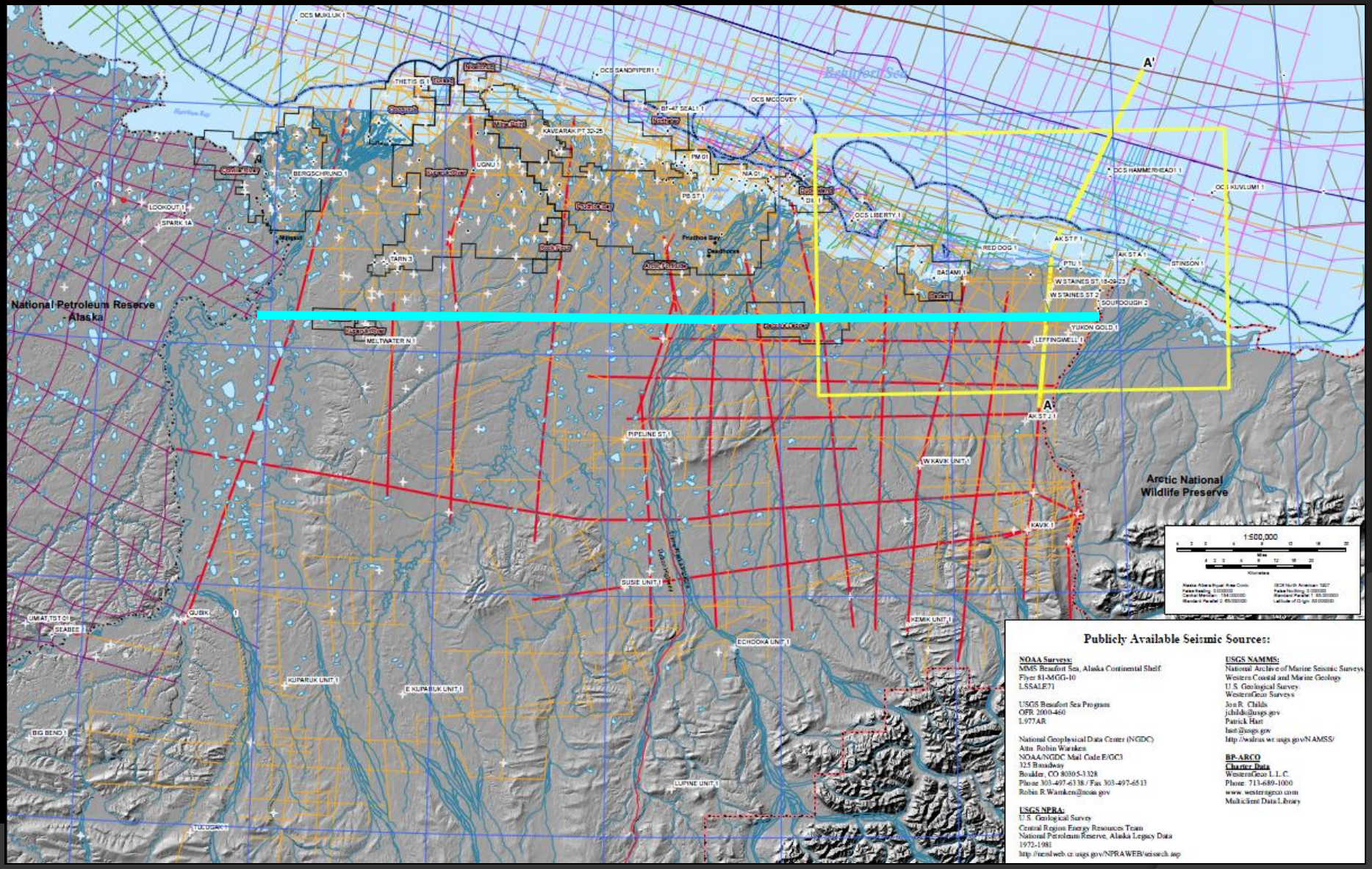
USGS National Archive of Marine Seismic Surveys

http://walrus.wr.usgs.gov/NAMSS/search_and_download_data.html



Publicly Available Seismic Data

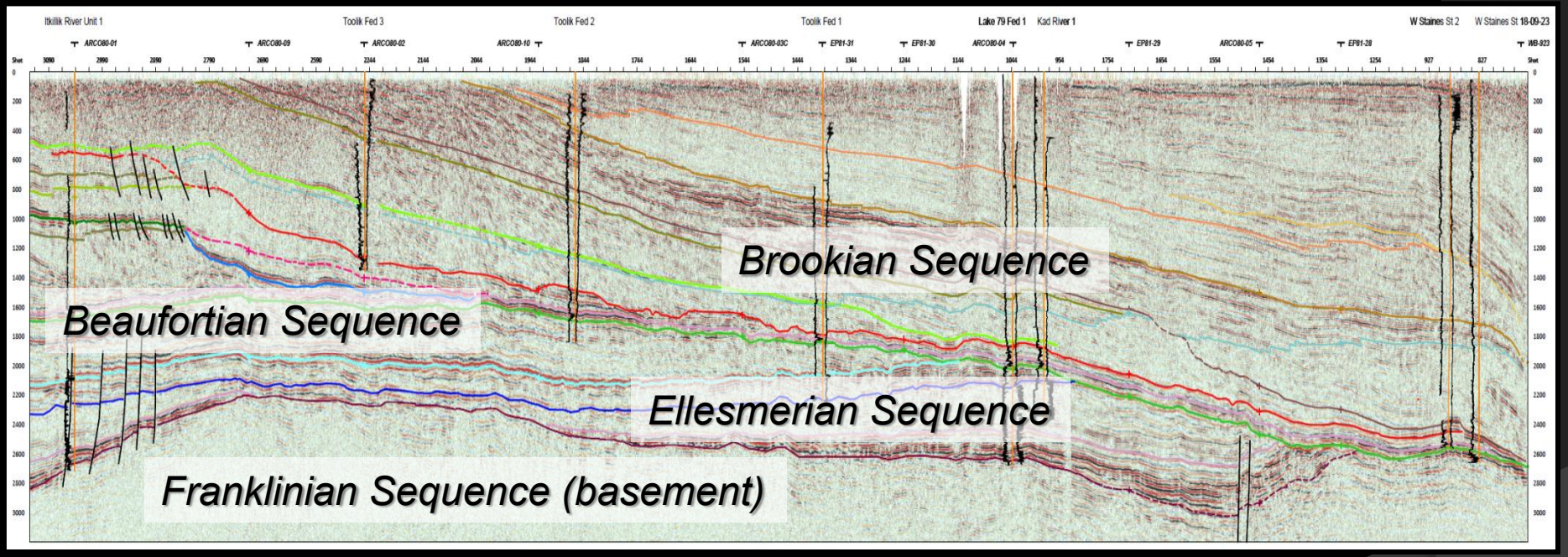
USGS National Archive of Marine Seismic Surveys & BP-ARCO Charter Data



Central North Slope Seismic Transect

Example of public domain seismic, state lands

West *Total length ~120 miles* East



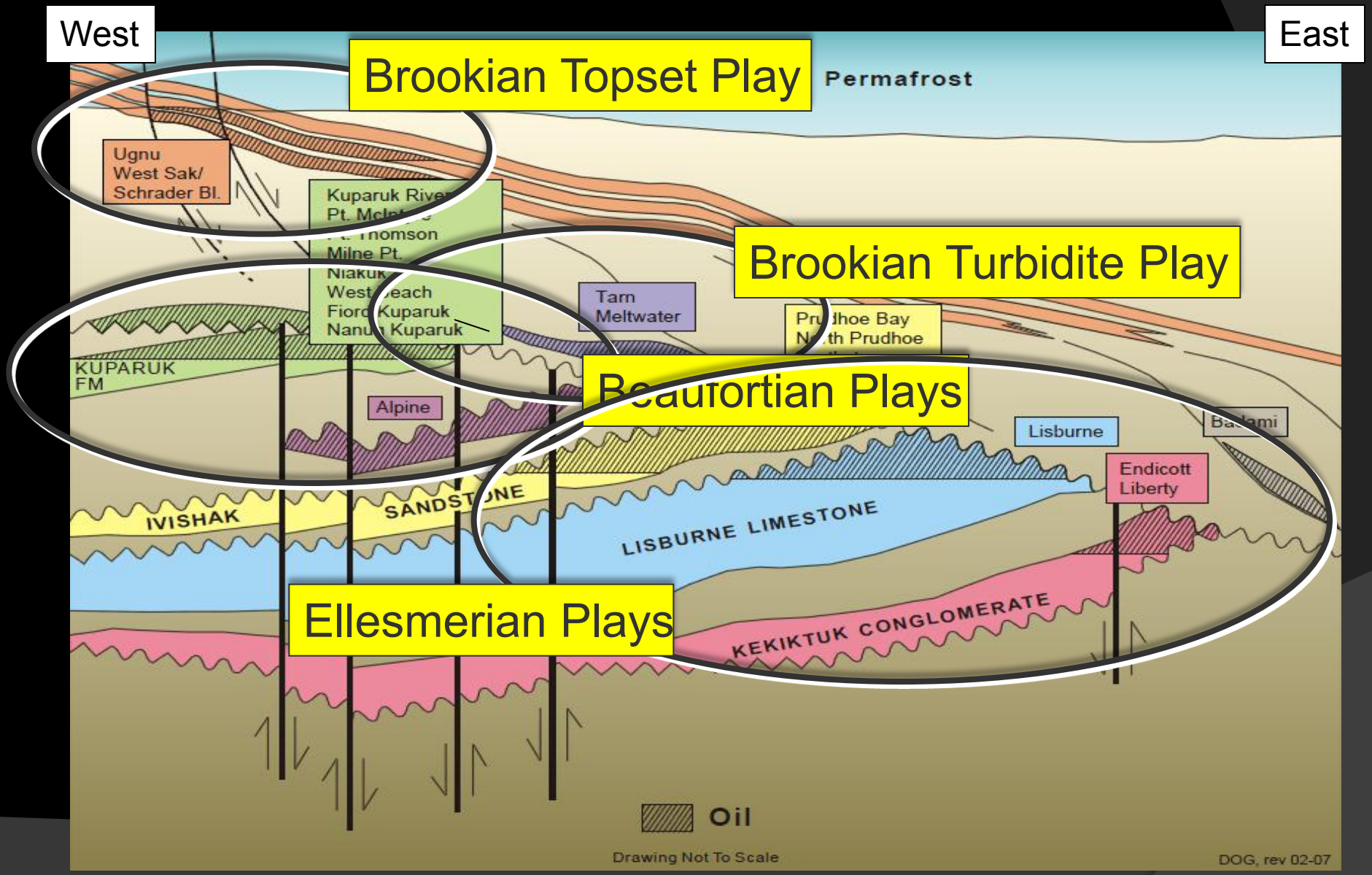
(Decker, unpublished data, 2010-11)

Generalized North Alaska Play Types

- Cretaceous – Tertiary Brookian Topset Play
  - Structural and potential strat traps, various shallow marine & non-marine sands
  - *Fields: West Sak, Schrader Bluff, Orion, Polaris, Ugnu, Umiat, Gubik, Kuvlum, Hammerhead, …*
- Cretaceous – Tertiary Brookian Turbidite Play
  - Strat traps (north), structural traps (foothills), local deepwater sands
  - *Fields: Tarn, Meltwater, Nanuq, Badami, Sourdough, …*
- Early Cretaceous Rift-related Shallow Marine Play
  - Structural traps, Upper and Lower Kuparuk and loosely equivalent sands
  - *Fields: Kuparuk, Milne Pt , Pt McIntyre, Niakuk, West Beach, Aurora, Borealis, Walakpa, Pt Thomson, …*
- Jurassic Shoreface Play
  - Strat traps, Kingak Fm shallow marine sands (Alpine, Nuiqusut, Nechelik, Simpson, Barrow sands)
  - *Fields: Alpine, Lookout, Spark, Rendezvous, Fiord, Barrow Gas Field…*
- Ellesmerian Sequence Plays
  - Structural and unconformity combination traps in Triassic and older sands, carbonates
  - *Fields: Prudhoe Bay, Northstar, Sandpiper (Triassic Ivishak sand), Lisburne (Carboniferous Lisburne carbonates), Endicott, Liberty (Mississippian Kekiktuk sand), …*

Schematic Geologic Cross Section

Central North Slope – Barrow Arch Province



Play Distribution of North Alaska Fields

Alaska Department of NATURAL RESOURCES DIVISION OF OIL & GAS

		Burger	Walakpa Pool	South Barrow Pool	East Barrow Pool	Sikulik	Meade	Oumalik	Wolf Creek	Square Lake	Umiat	East Umiat	Gubik	Fish Creek	Rendezvous	Spark-Carbon	Lookout	East Kurupa	West Alpine	Alpine Pool	Nanuq Pool	Fiord Pool	Kuparuk Pool	West Sak Pool	Tobasco Pool	Tarn Pool	Meltwater Pool	Milne Kuparuk Pool	Schrader Bluff Pool	Milne Sag River Pool	Nikaitchuk Pool	Thetis Island	Sandpiper	Northstar	Prudhoe Bay Pool	Lisburne Pool	Raven Pool	Put River Pool	Aurora Pool	Borealis Pool	Orion Pool	Polaris Pool	Pt McIntyre Pool	Niakuk - W Niakuk Pools	West Beach Pool	Midnight Sun Pool	Endicott Pool	Endicott Ivishak Pool	Endicott Elder Pool	Liberty	Kemik	Kavik	Mikkelsen	Badami Pool	Pt Thomson	Flaxman Is	Sourdough	Hammerhead	Kuulum
West			National Petroleum Reserve -- Alaska															Colville River Unit				Kuparuk River Unit					Milne Pt Unt							Prudhoe Bay Unit												Duck Is Unit												East
Cretaceous – Tertiary Brookian Topset Reservoirs																																																											
Sagavanirktok Fm, including Ugnu Ss	Paleocene-Eocene																							Oil Field, Developed/Producing					Oil Field, Developed/Producing																													Oil Accumulation, Undeveloped	Oil Accumulation, Undeveloped
Upper Schrader Bluff Fm & West Sak S	Maastrichtian																							Oil Field, Developed/Producing					Oil Field, Developed/Producing		Oil Field, Development Underway										Oil Field, Developed/Producing	Oil Field, Developed/Producing																	
Middle Schrader Bluff Fm Tobasco Ss	Campanian																								Oil Field, Developed/Producing																																		
Tuluvak Fm	Turonian-Santonian												Gas Accumulation, Undeveloped																																												
Nanushuk Fm	Albian-Cenomanian						Gas Accumulation, Undeveloped	Gas Accumulation, Undeveloped	Gas Accumulation, Undeveloped	Gas Accumulation, Undeveloped	Oil Accumulation, Undeveloped	Gas Accumulation, Undeveloped	Gas Accumulation, Undeveloped	Oil Accumulation, Undeveloped																																															
Cretaceous – Tertiary Brookian Turbidite Reservoirs																																																											
Canning Fm Flaxman Ss and equivalen	Paleocene-Eocene																																																				Oil Accumulation, Undeveloped	Oil Field, Developed/Producing	Oil Accumulation, Undeveloped	Oil Accumulation, Undeveloped	Oil Accumulation, Undeveloped		
Seabee Fm Bermuda Ss	Cenomanian-Turonian																									Oil Field, Developed/Producing	Oil Field, Developed/Producing																																
Torok Fm	Albian-Cenomanian																	Gas Accumulation, Undeveloped			Oil Field, Developed/Producing																																						
Fortress Mtn Fm	Aptian-Albian																	Gas Accumulation, Undeveloped																																									
Lower Cretaceous Rift-related Shallow Marine Reservoirs																																																											
Thomson Ss	Barremian-Aptian																																																						Gas Accumulation, Undeveloped				
Upper Kuparuk Fm, Put River, Walakpa	Hauterivian-Barremian	Gas Accumulation, Undeveloped	Gas Field, Developed/Producing	Gas Field, Developed/Producing																	Oil Field, Developed/Producing	Oil Field, Developed/Producing	Oil Field, Developed/Producing					Oil Field, Developed/Producing										Oil Field, Developed/Producing	Oil Field, Developed/Producing	Oil Field, Developed/Producing			Oil Field, Developed/Producing	Oil Field, Developed/Producing	Oil Field, Developed/Producing	Oil Field, Developed/Producing													
Lower Kuparuk Fm & equivalents	Berriasian-Valanginian	Gas Accumulation, Undeveloped																					Oil Field, Developed/Producing					Oil Field, Developed/Producing																															
Jurassic Shoreface Reservoirs (all Kingak Fm)																																																											
Upper Alpine Ss	Kimmeridgian														Gas Accumulation, Undeveloped	Gas Accumulation, Undeveloped	Oil Field, Development Underway			Oil Field, Developed/Producing																																									
Lower Alpine Ss	Kimmeridgian																		Oil Field, Developed/Producing																																								
Nuiqsut Ss	Oxfordian-Callovian																															Oil Accumulation, Undeveloped																											
Nechelik Ss	Oxfordian-Callovian?																					Oil Field, Developed/Producing																																					
Simpson Ss	Bajocian-Bathonian																																																										
Barrow Ss	Hettangian-Pleinsbachian?			Gas Field, Developed/Producing	Gas Field, Developed/Producing	Gas Accumulation, Undeveloped																																																					
Ellesmerian Reservoirs																																																											
Sag River Fm	Upper Triassic																													Oil Field, Developed/Producing	Oil Field, Developed/Producing				Oil Field, Developed/Producing																								
Shublik Fm	Upper Triassic				Oil Accumulation, Undeveloped																														Oil Field, Developed/Producing																Gas Accumulation, Undeveloped								
Sadlerochit Gp Ivishak Fm	Lower-Middle Triassic																																Gas Accumulation, Undeveloped	Oil Field, Developed/Producing	Oil Field, Developed/Producing		Oil Field, Developed/Producing											Oil Field, Developed/Producing	Oil Field, Developed/Producing			Gas Accumulation, Undeveloped							
Sadlerochit Gp Echooka Fm	Upper Permian																																																										
Lisburne Gp Wahoo Fm	Pennsylvanian																																			Oil Field, Developed/Producing																							
Lisburne Gp Alapah Fm	Mississippian																																			Oil Field, Developed/Producing																							
Kekiktuk Fm, Endicott Gp	Mississippian																																														Oil Field, Developed/Producing			Oil Field, Development Underway				Oil Accumulation, Undeveloped					

Gas Field, Developed/Producing
Gas Accumulation, Undeveloped
Oil Field, Developed/Producing
Oil Field, Development Underway
Oil Accumulation, Undeveloped

Undeveloped Discoveries

1. Burger—gas and con
2. East Kurupa—gas (N
3. East Umiat—gas (Nat
4. Fish Creek—oil (NPR
5. Gubik—gas (Native la
6. Gwydyr Bay—oil (Sta
7. Hammerhead—oil (Fe
8. Hemi Springs—oil (Sta
9. Kalubik—oil (State offs
10. Kavik—gas (State onsh
11. Kemik—gas (State onsh
12. Kuvlum—oil (Federal of
13. Liberty—oil (Federal off
14. Meade—gas (NPRA)
15. Mikkleson—oil (State on
16. Mooses Tooth—oil (NPR
17. Rendezvous—oil (NPRA)
18. Sandpiper—gas and conde
19. Sikulik—gas (Native lands
20. Simpson—oil (NPRA)
21. Square Lake—gas (NPRA)
22. Stinson—oil (State offshore
23. Umiat—oil (NPRA)
24. Wolf Creek—gas (NPRA)

Table 2.8. North Slope, Alaska–Undeveloped oil and gas accumulations as of January 1, 2005 (after Bird, 1991 and Thomas, and others, 1991 and 1993)

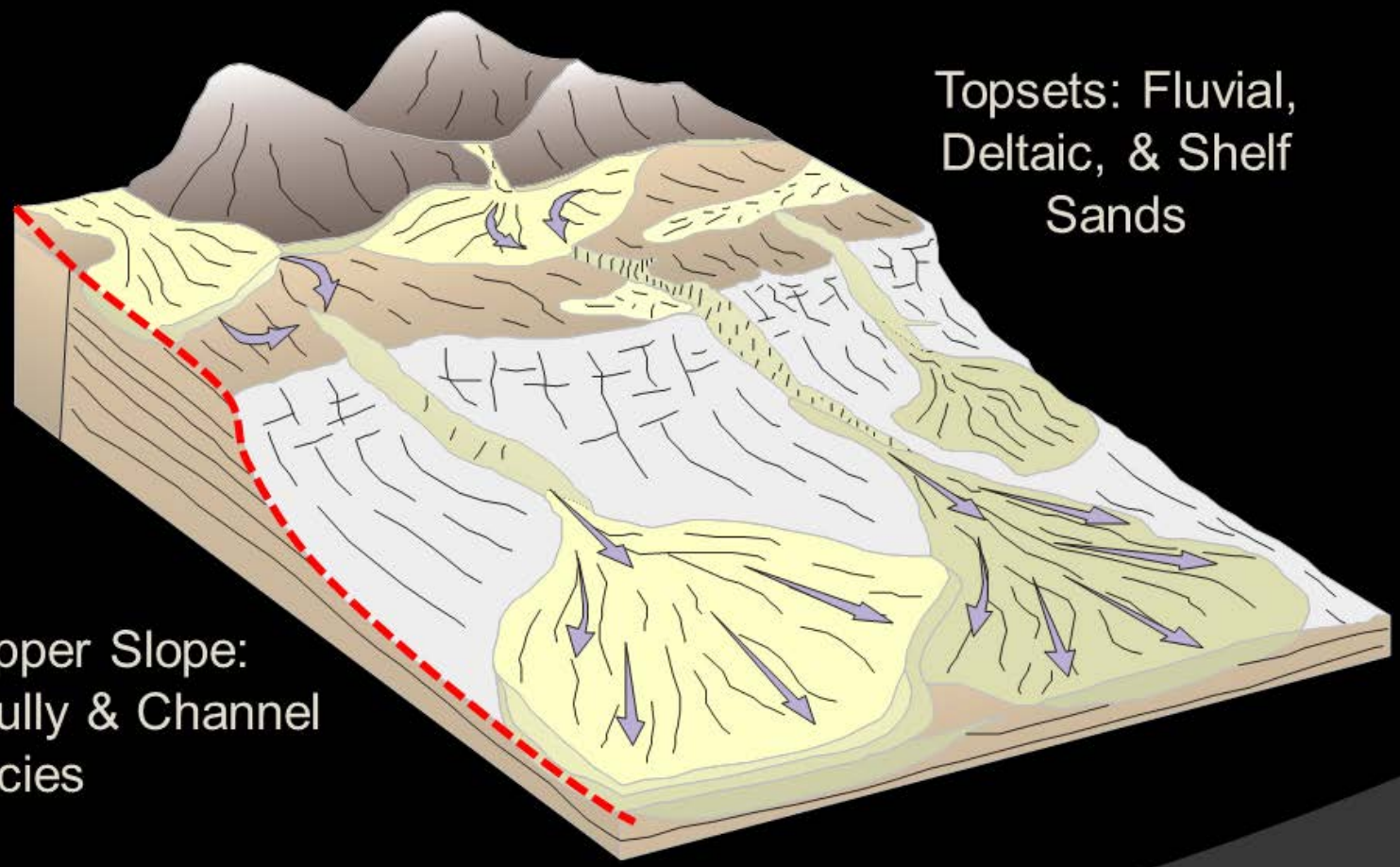
Accumulation or Field/ Reservoir Formation(s)	Year of Discovery	Estimated Technically Recoverable Resources
Umiat[11]/Nanushuk Fm.	1946	70 MMBO, 50 BCF
Fish Creek[11]/Nanushuk Fm.	1949	OIL (? MMBO)
Simpson[11]/Nanushuk Fm.	1950	12 MMBO
Meade[11]/Nanushuk Fm.	1950	20 BCF
Wolf Creek[11]/Nanushuk Fm.	1951	GAS (? BCF)
Gubik[11]/TuluvakAnd Nanushuk Formations	1951	600 BCF
Square Lake[11]/Nanushuk Fm.	1952	58 BCF
E. Umiat/Nanushuk Fm.	1964	4 BCF
Kavik/Ivishak Fm.	1969	115 BCF
Gwydyr Bay[12]/Ivishak Fm.	1969	30-60 MMBO
Kemik/Shublik Fm.	1972	100 + BCF
Flaxman Island/Canning Fm.	1975	OIL (? MMBO)
East Kurupa/Torok-Fortress Mtn. Formations	1976	GAS (? BCF)
Pt. Thomson/Thomson Sandstone and Canning Fm.	1977	300 MMBO, 5000 BCF
Mikkelson/Canning Fm.	1978	OIL (? MMBO)
Tern Is. (Liberty)/Kekiktuk Conglomerate	1982	150 MMBO
Hemi Springs/Kuparuk Fm.	1984	OIL (?MMBO)
Hammerhead/Sagavanirktok Fm.	1985	~200 MMBO
Sandpiper/Ivishak Fm.	1986	150 MMBO/GAS (? BCF)
Sikulik/Barrow Sandstone	1988	16 BCF
Stinson[13]/????	1990	OIL (? MMBO)
Burger/Kuparuk Equivalent	1990	14,000 BCF, 724 MMBO
Kuvlum[13]/????	1993	400 MMBO
Thetis Island[13]/Nuiqsuit	1993	OIL (? MMBO)
Sourdough[13]/?????	1994	~100 MMBO
Pete's Wicked[13,14]/Sagavanirktok and Ivishak Fms.	1997	OIL (? MMBO)
Sambucca[13]/Ivishak Fm.	1997	19 MMBO(?)
Oooguruk[13]/Nuiqsut Sandstone(?)	2003	70 MMBO(?)
Nikaitchuq[13]/Nuiqsut and Sag River Sandstones(?)	2004	70 MMBO(?)
Tuvaaq/Schrader Bluff Fm.	2005	OIL (?MMB0)
Total		**2,300 + MMBO/ 20,000 + BCF**

Thomas and others, 2007

Houseknecht and Bird, 2005

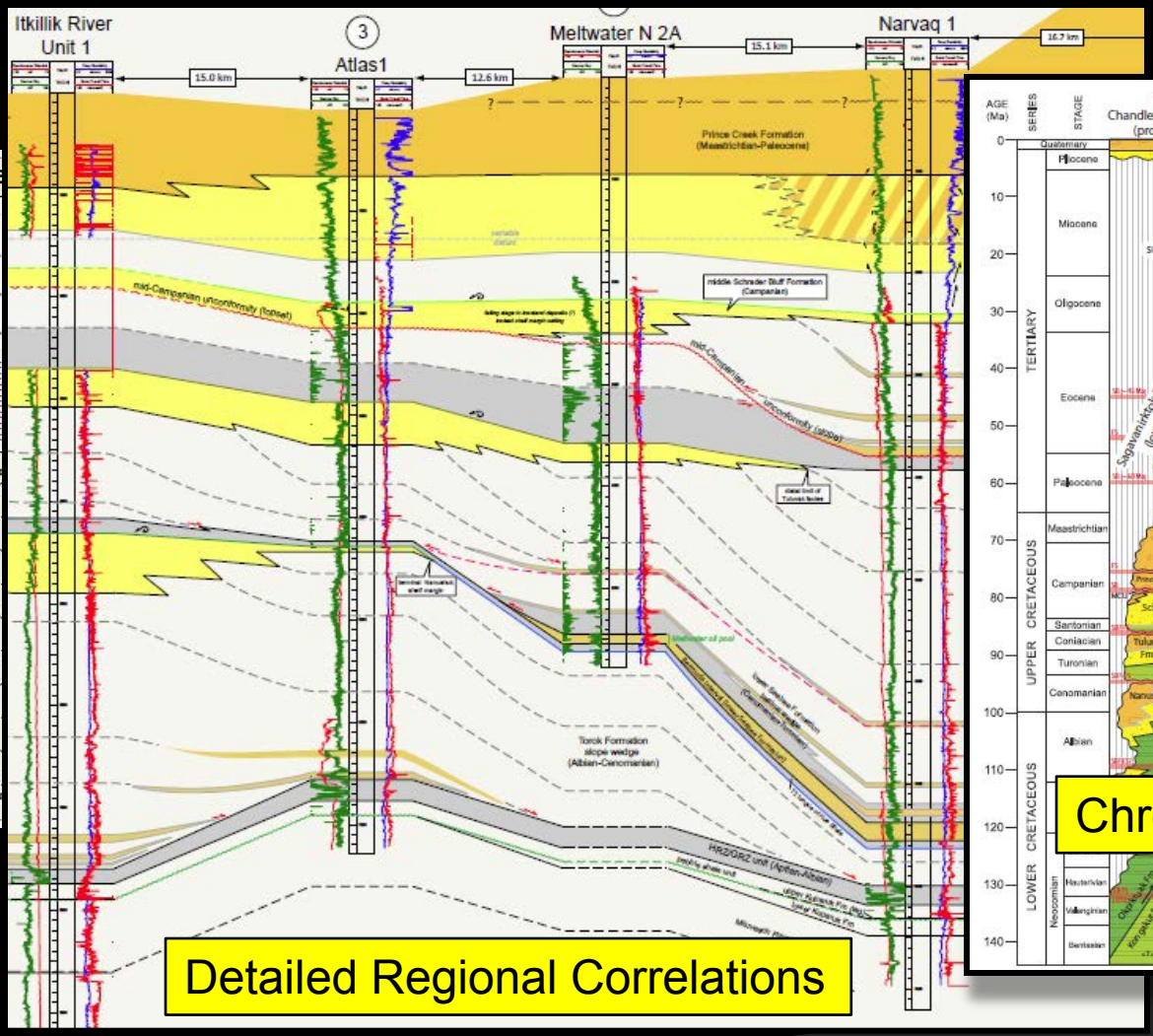
Brookian Sequence Depositional Model

Foreland basin filled by eastward prograding clinoform units

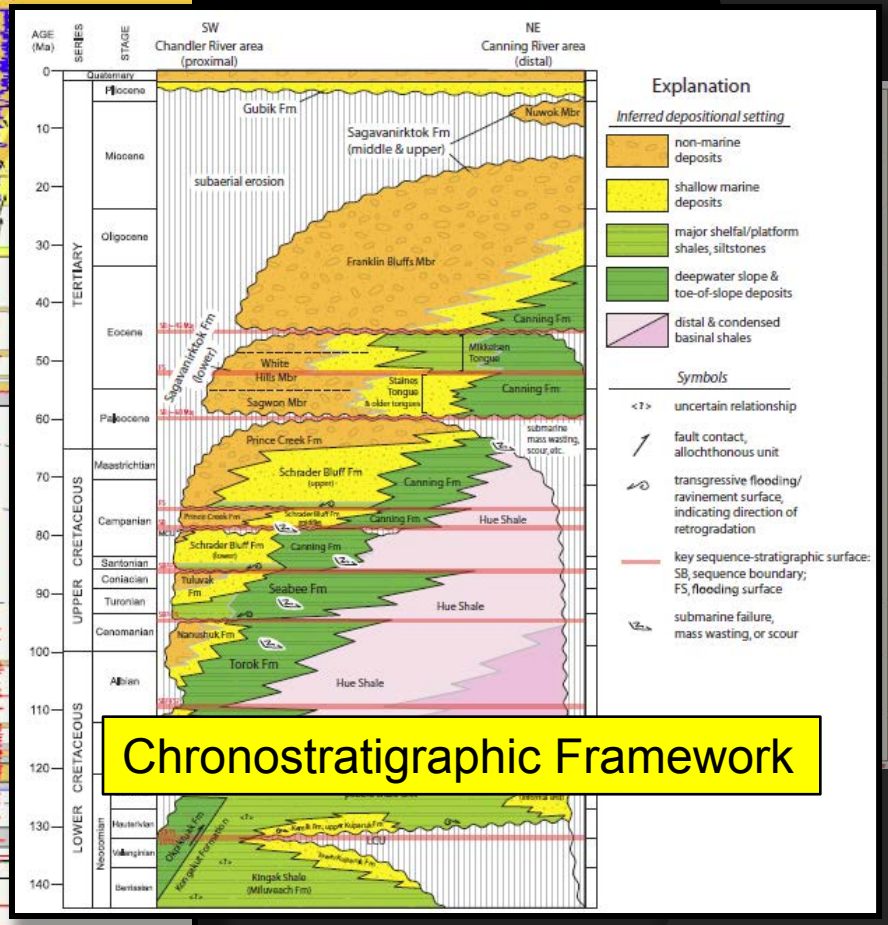


Brookian Sequence Stratigraphic framework

Interpretive technical products developed by DOG & DGGS



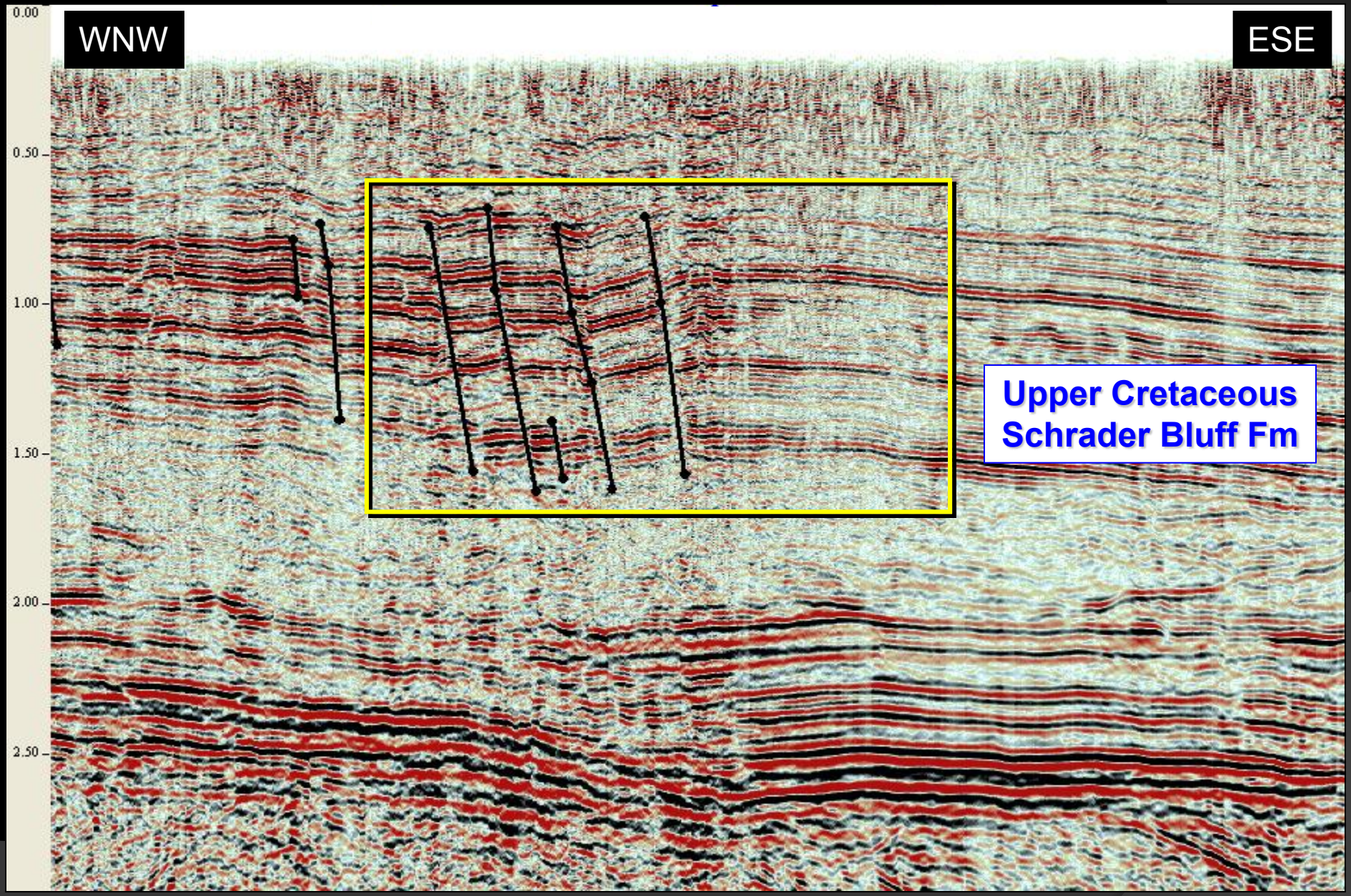
Detailed Regional Correlations



Chronostratigraphic Framework

Brookian Topset Play

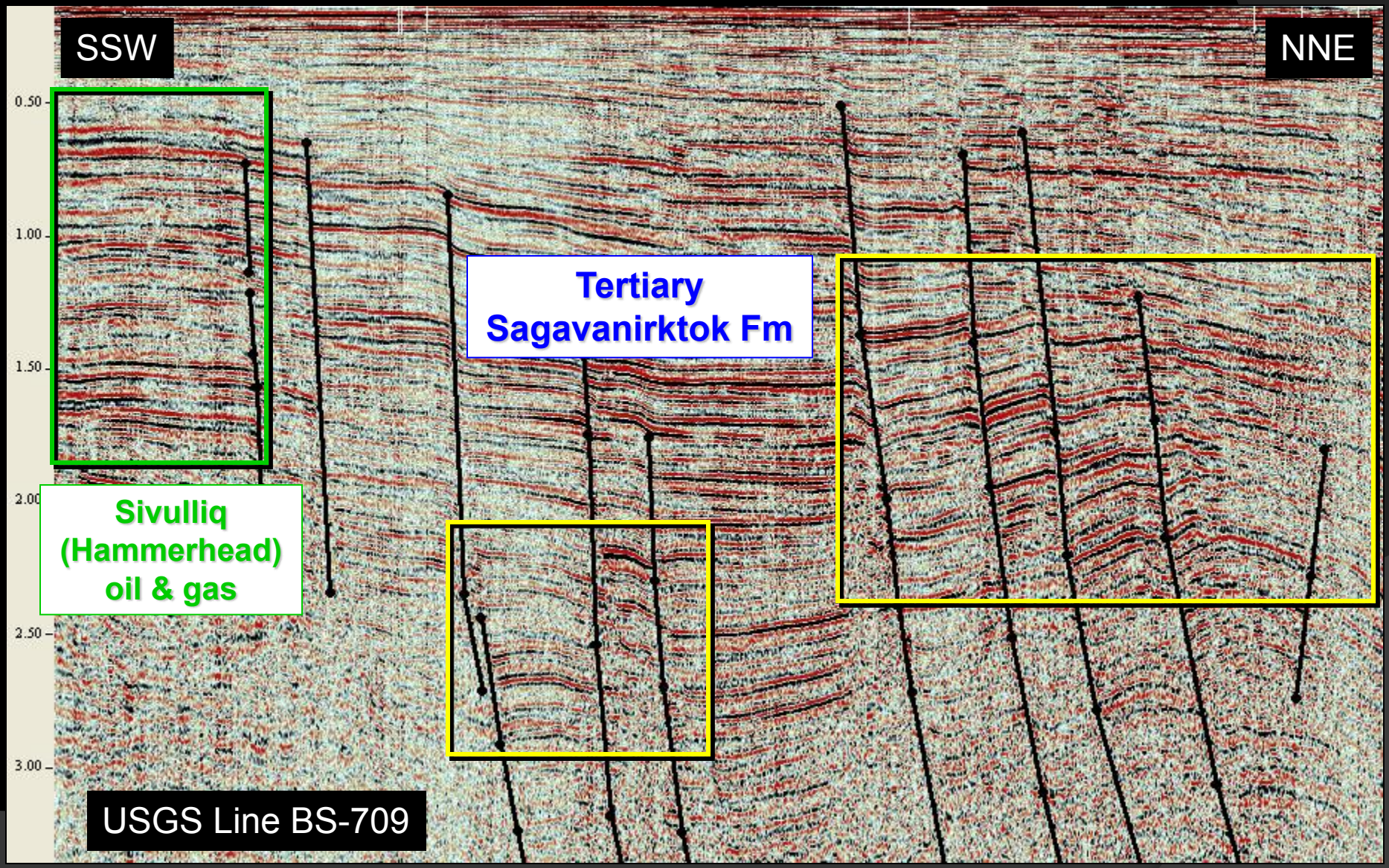
offshore state waters near Milne Point



Brookian Topset Play

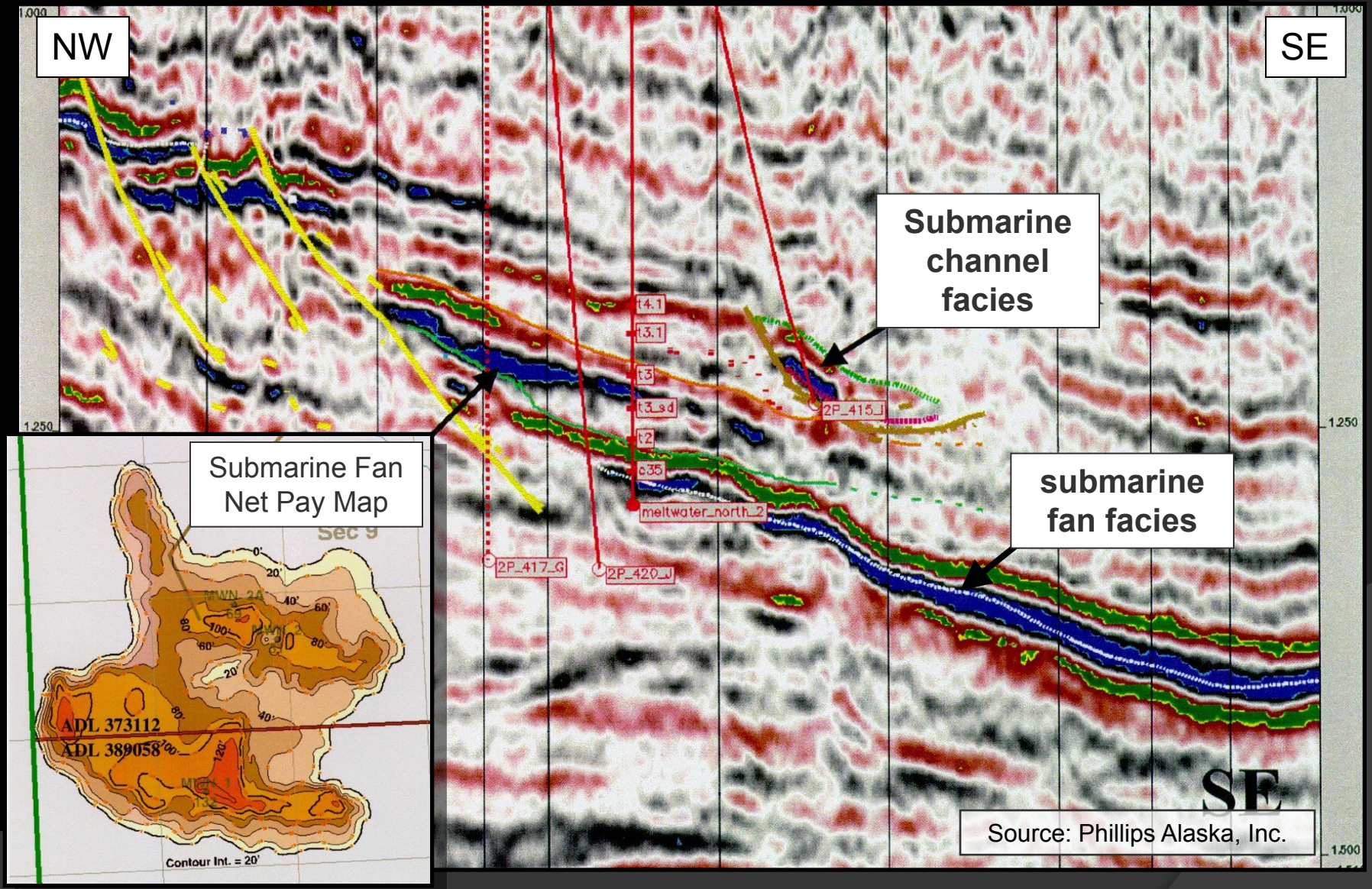
Tertiary Growth Fault trend

Eastern Beaufort OCS



Brookian Turbidite Stratigraphic Play

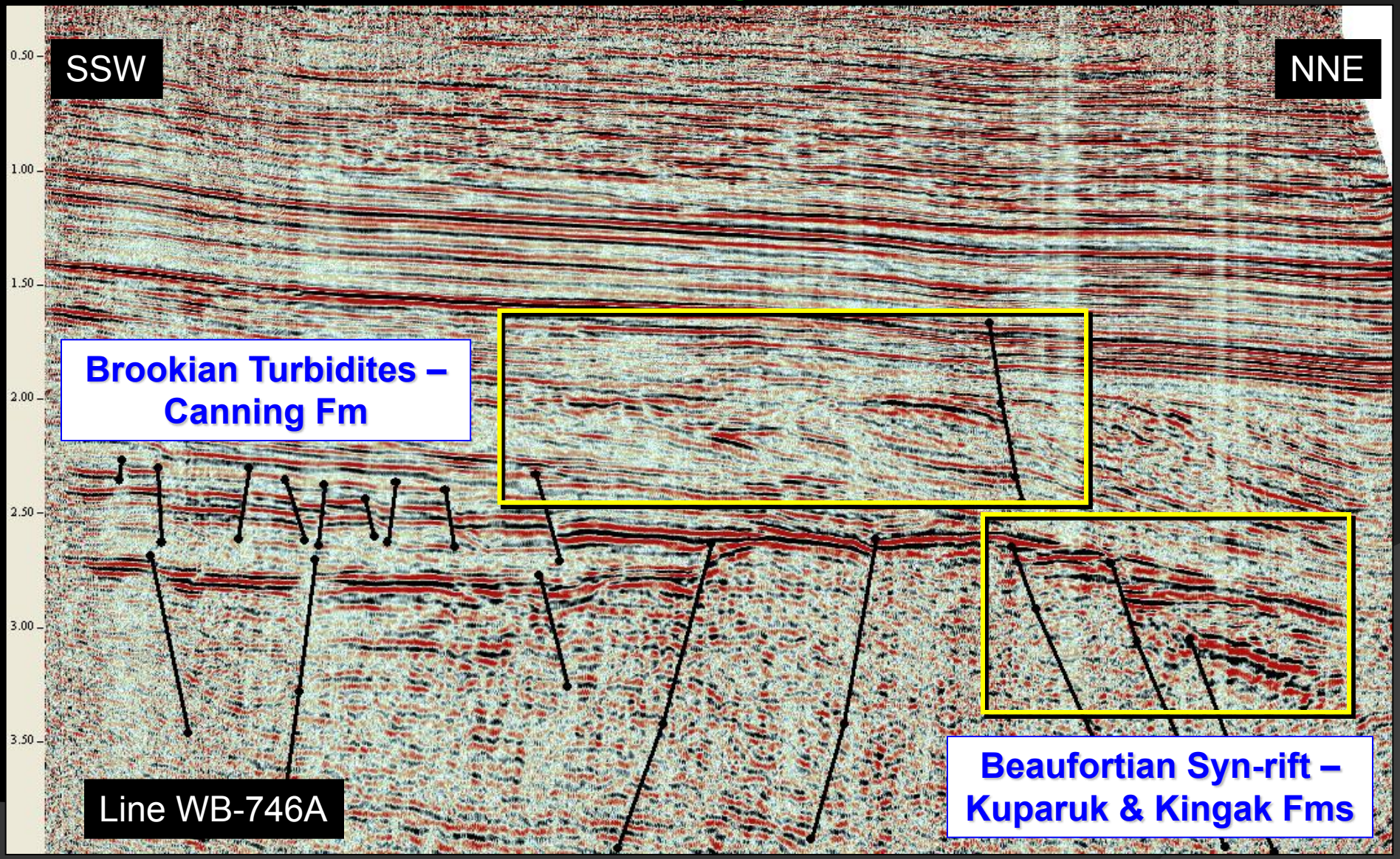
Upper Cretaceous Seabee Fm, Bermuda interval Kuparuk River Unit



Source: Phillips Alaska, Inc.

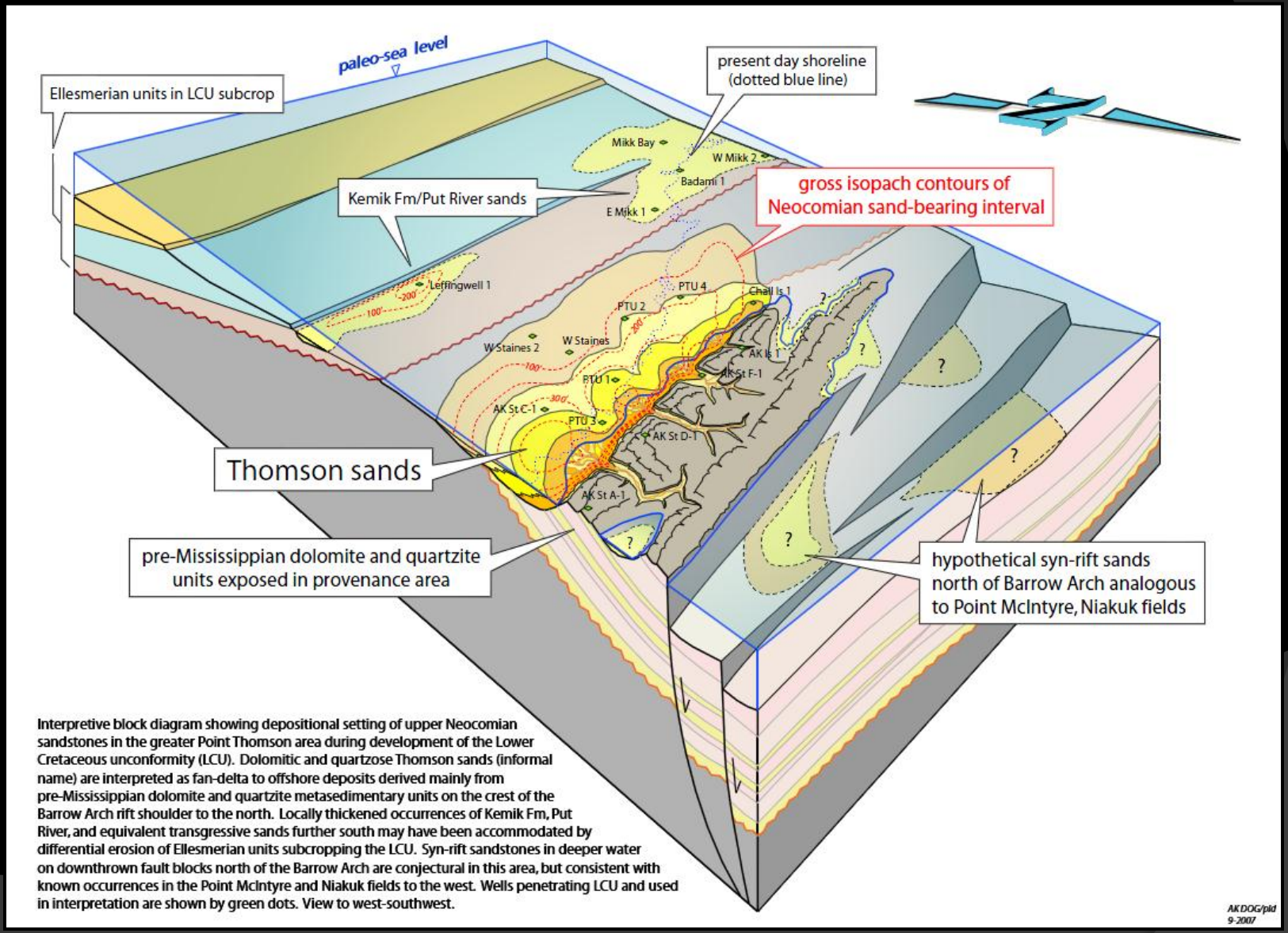
Beaufortian Syn-rift & Brookian Turbidite Plays

Cross Island area



Barrow Arch syn-rift depositional model

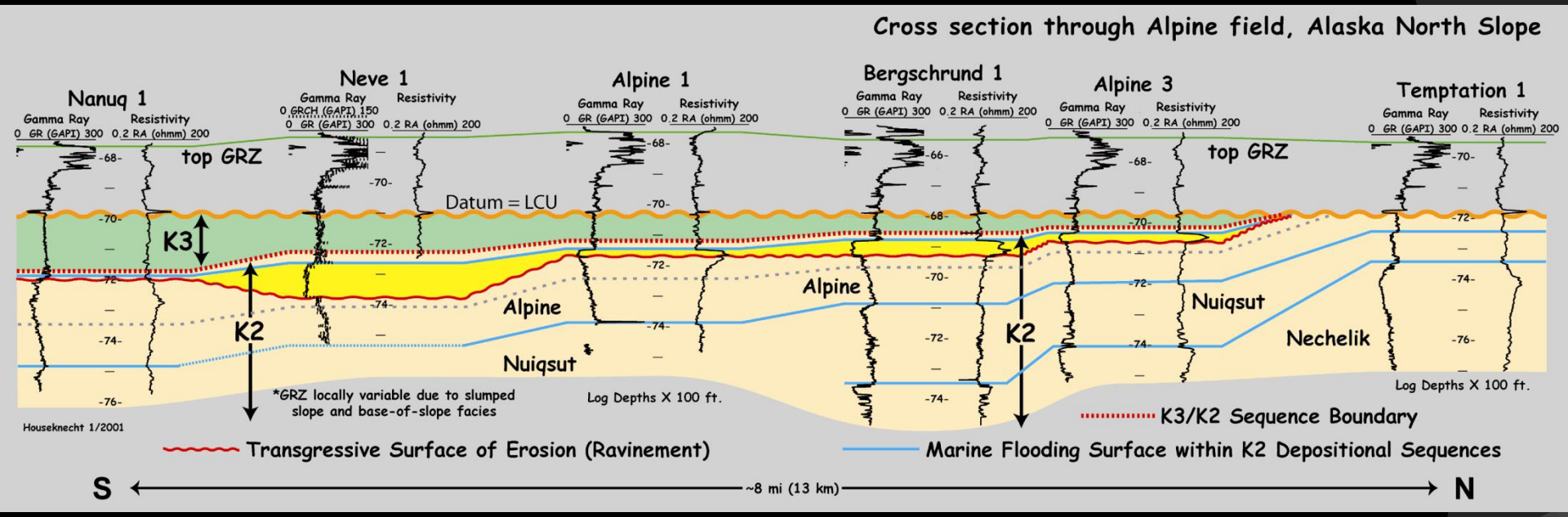
Point Thomson area, early Cretaceous time



Interpretive block diagram showing depositional setting of upper Neocomian sandstones in the greater Point Thomson area during development of the Lower Cretaceous unconformity (LCU). Dolomitic and quartzose Thomson sands (informal name) are interpreted as fan-delta to offshore deposits derived mainly from pre-Mississippian dolomite and quartzite metasedimentary units on the crest of the Barrow Arch rift shoulder to the north. Locally thickened occurrences of Kemik Fm, Put River, and equivalent transgressive sands further south may have been accommodated by differential erosion of Ellesmerian units subcropping the LCU. Syn-rift sandstones in deeper water on downthrown fault blocks north of the Barrow Arch are conjectural in this area, but consistent with known occurrences in the Point McIntyre and Niakuk fields to the west. Wells penetrating LCU and used in interpretation are shown by green dots. View to west-southwest.

Beaufortian Stratigraphic Traps

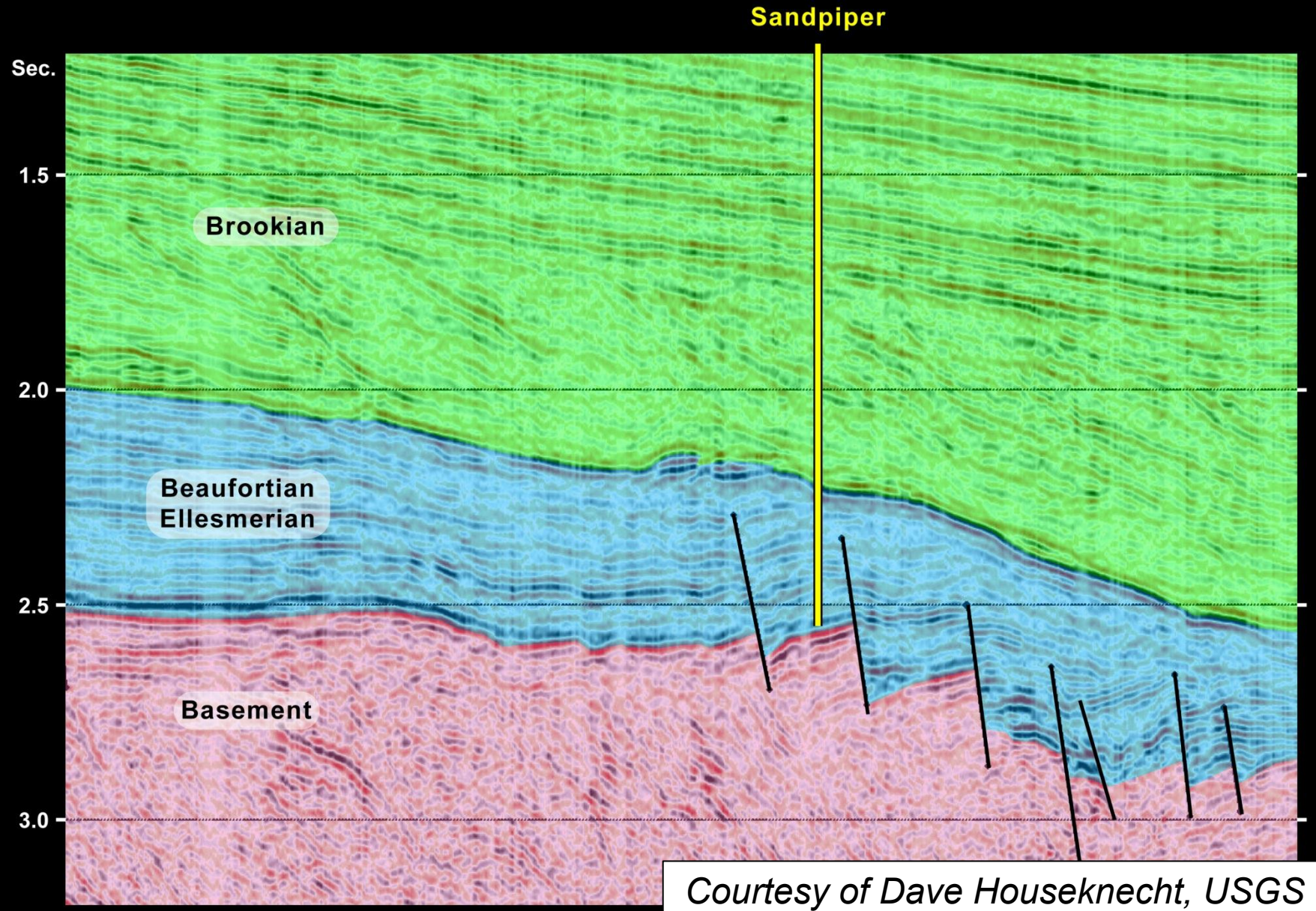
Alpine Field – incised accommodation transgressive shoreface



Courtesy of Dave Houseknecht, USGS

Fault-Block Traps -- Beaufort Rift Shoulder

Sandpiper Gas & Condensate Accumulation (~150 MMBOE?)



Courtesy of Dave Houseknecht, USGS

Presentation Outline

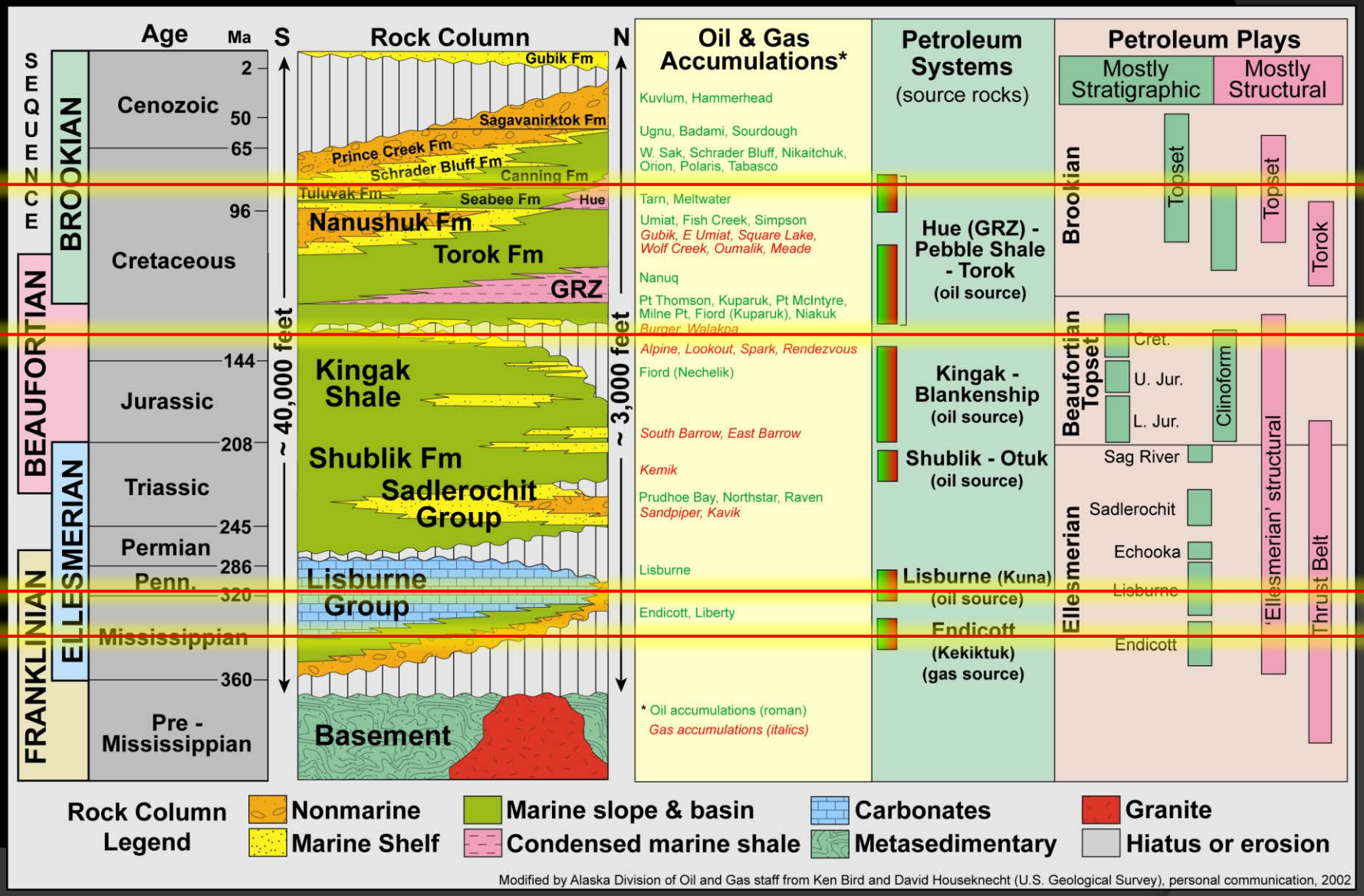
- Regional Geologic & Tectonic Framework
- Petroleum Systems Overview
- Exploration Potential and Play Types
- Foothills Geology and Hydrocarbon Potential
- Shale Resource Potential
- Northern Alaska Lease Sales

Foothills Petroleum Systems

Colville Foreland Basin and southern Arctic Platform Province

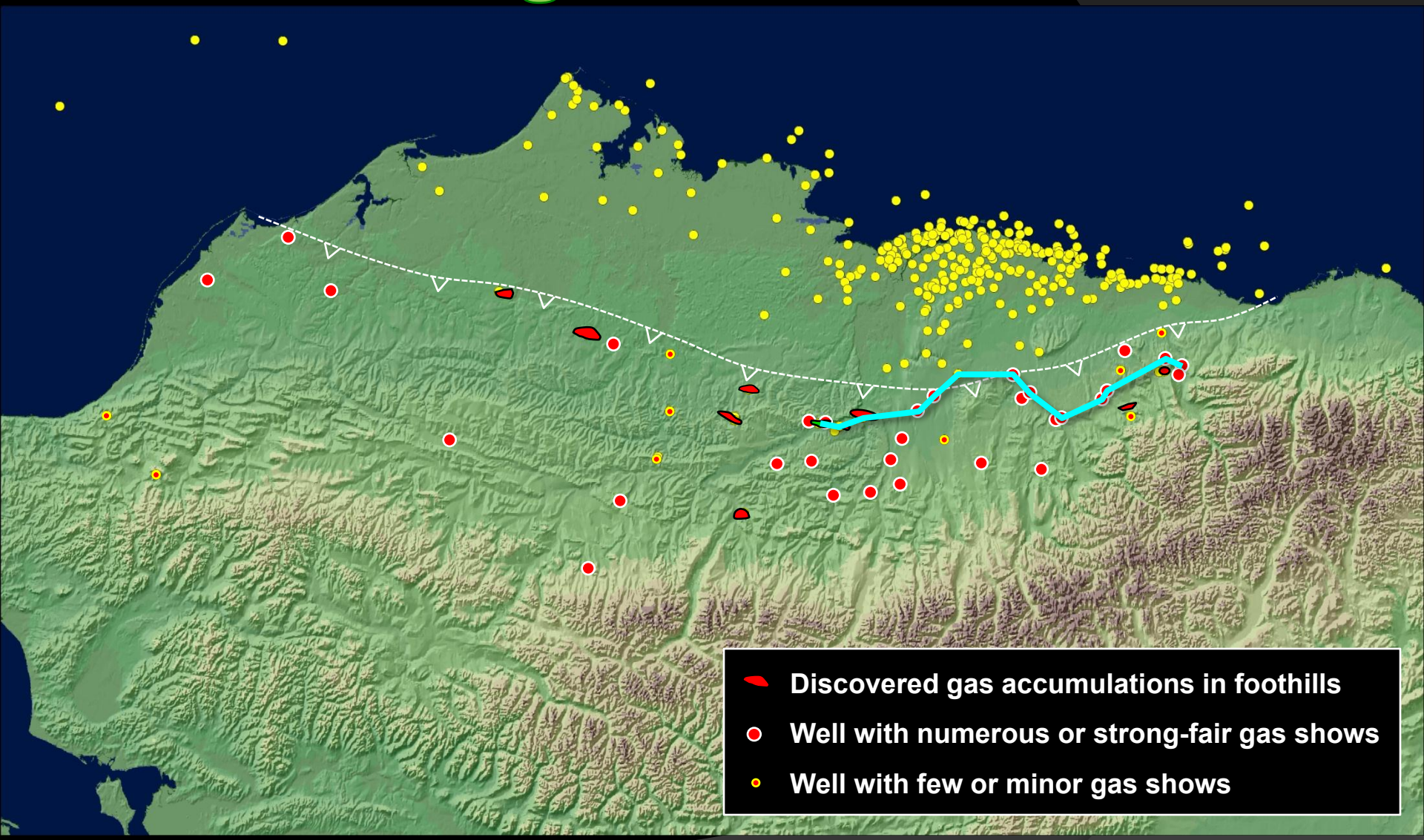
- Trap Styles: - *Conventional:* compressional anticlines, duplexes, subthrust, & stratigraphic traps;
  - *Unconventional:* tight gas sands, source-rock plays
- Source Rocks: - Cretaceous GRZ/Hue Shale,
  - Jurassic Kingak Shale
  - Triassic Shublik Fm & TR-Jurassic Otuk Fm
  - Mississippian Lisburne Gp (locally)
- HC Charge: - Mostly gas (condensate?), common overpressure;
  - possible local oil charge in low maturity zone
- Reservoirs: - Brookian Sequence – Nanushuk Fm topsets & Lower Torok/Fortress Mtn Fm deepwater sands
  - Ellesmerian carbonates - Lisburne Gp

Foothills Reservoir Potential



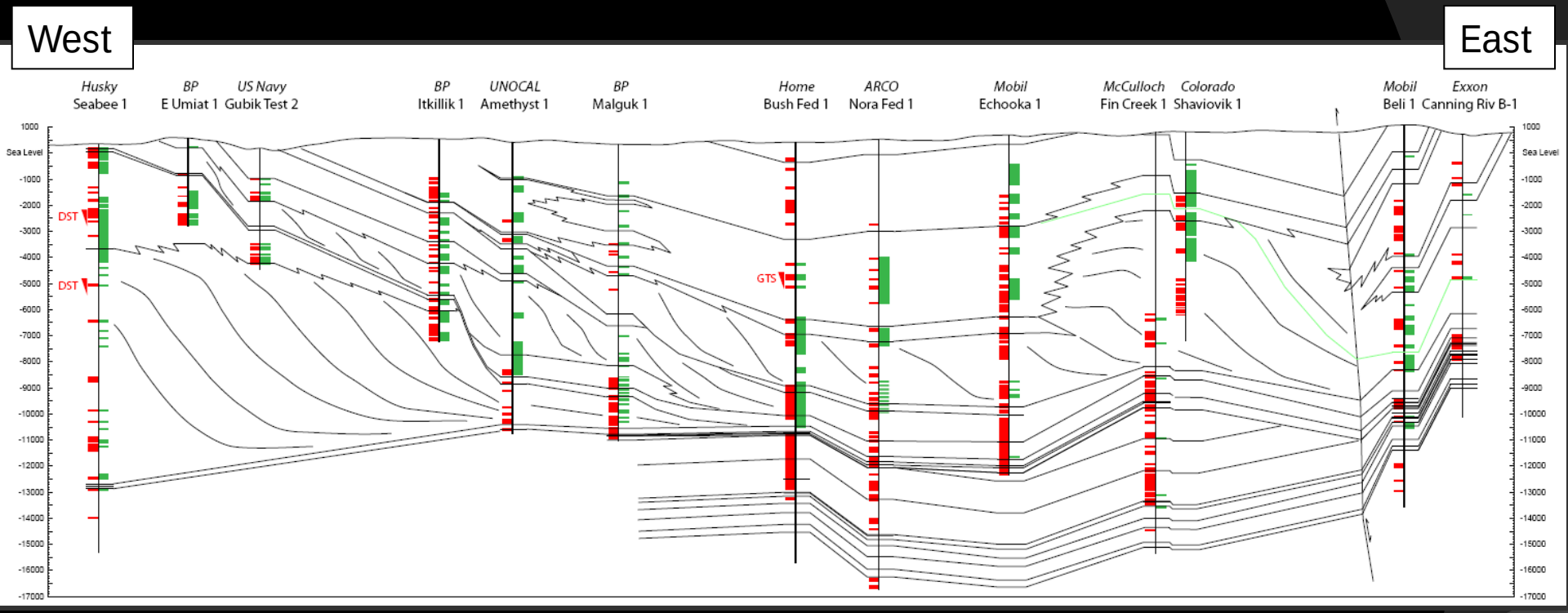
Modified by Alaska Division of Oil and Gas staff from Ken Bird and David Houseknecht (U.S. Geological Survey), personal communication, 2002

Foothills Drilling and Gas Occurrences



Foothills Cross Section

West-East Stratigraphic Changes, Oil & Gas Shows

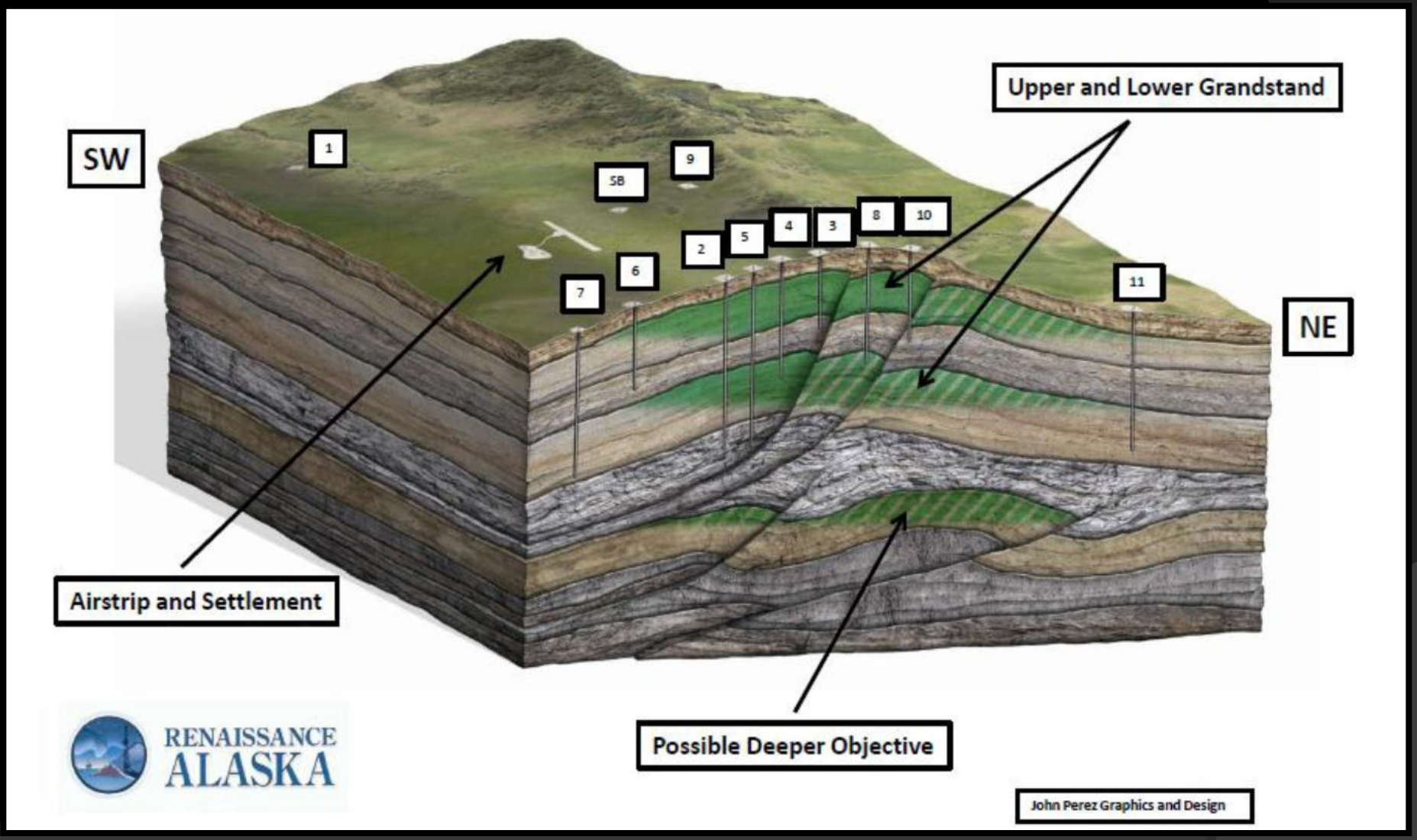


Discovered, undeveloped oil and gas -- Foothills

Accumulation	Reservoir	Discovery Year	Estimated Technically Recoverable Resources
Umiat	Nanushuk Formation	1946	70-300 MMBO, 5 BCF
Oumalik	Nanushuk Formation	1949	Gas (? BCF)
Meade	Nanushuk Formation	1950	20 BCF
Wolf Creek	Nanushuk Formation	1951	Gas (? BCF)
Gubik	Nanushuk and Tuluvak Formations	1951	600 BCF
Square Lake	Nanushuk Formation	1952	58 BCF
East Umiat	Nanushuk Formation	1964	4 BCF
Kavik	Ivishak Formation (Sadlerochit Group)	1969	115 BCF
Kemik	Shublik Formation	1972	>100 BCF
East Kurupa	Lower Torok or Fortress Mountain Formation	1976	Gas (? BCF)
Total Discovered Recoverable Resource			***70-300 million barrels, >902 billion cubic feet***

Undeveloped Umiat Oil Field

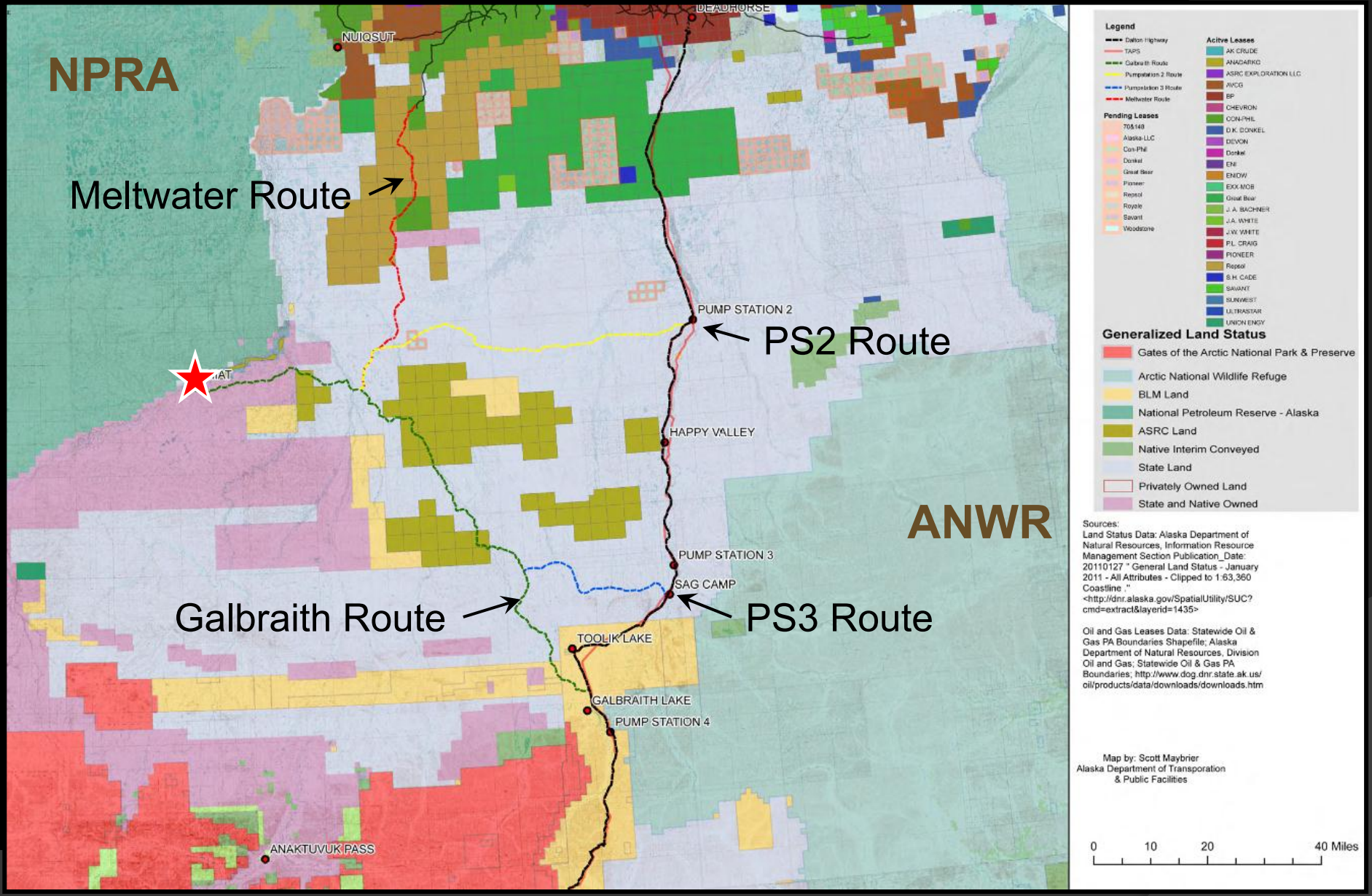
Estimated 70-300 MMBO Recoverable Resource



Watt et al., 2009 Oil & Gas Journal

Umiat Road Project

Current Alternatives



Foothills Resource Estimates

Technically Recoverable Undiscovered Conventional Gas Resource

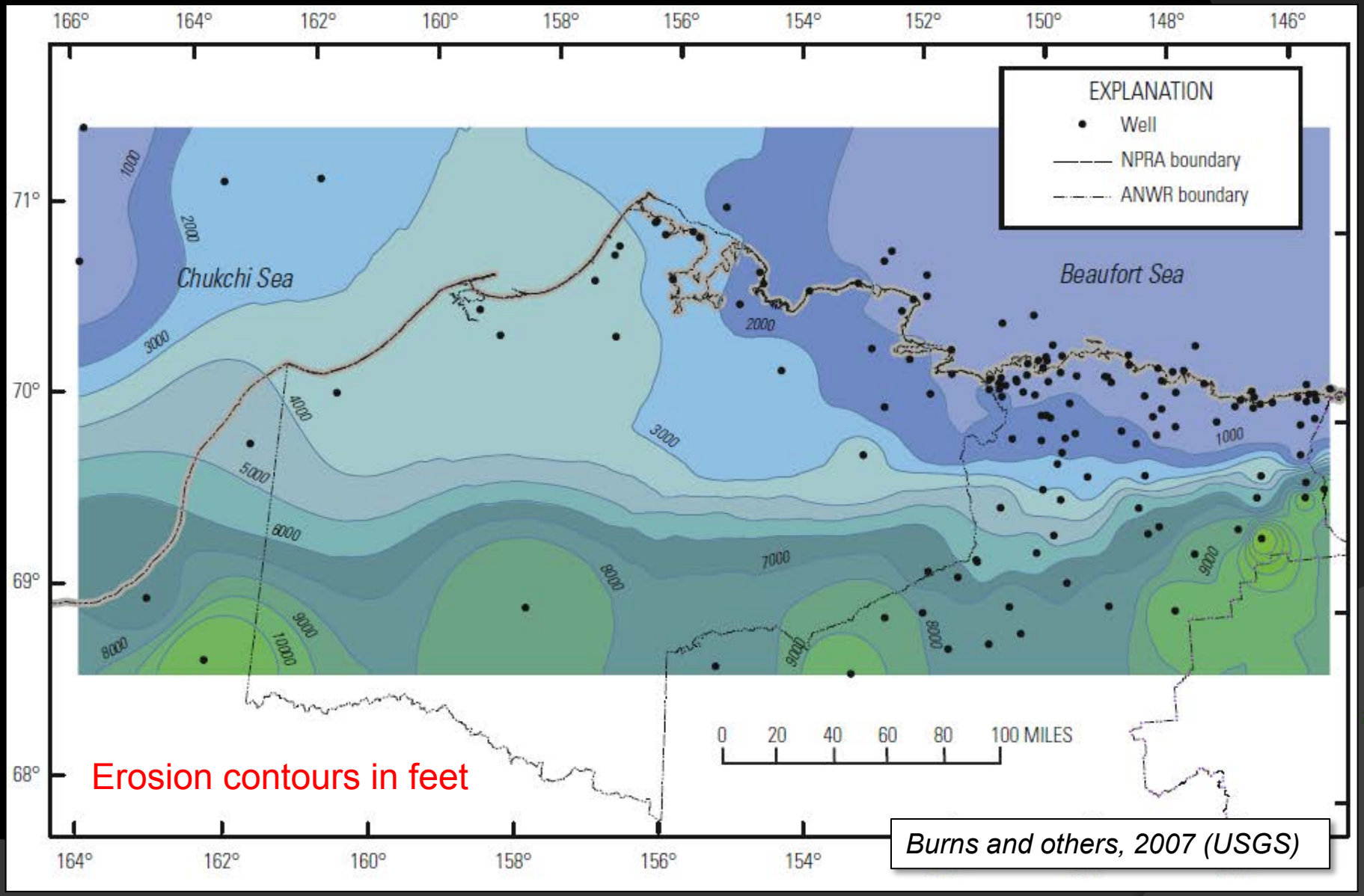
Table 2. Mean estimates of technically recoverable, undiscovered, non-associated, conventional gas resource in North Slope foothills plays assessed by USGS (see text for discussion).

Assessment Area	mean gas resource, trillion cubic feet (TCF)	Reference
NPRA foothills (13 plays)	~ 57	Bird and Houseknecht, 2002
Central North Slope foothills (17 plays)	~ 31	Garrity and others, 2005
ANWR 1002 deformed area (4 plays)	~ 3	Schuenemeyer, 1999
Total	~ 91 TCF	

Beaufortian Upper Jurassic Topset West	288
Thrust Belt Triangle Zone	3,843
Brookian Topset Structural North	288
Thrust Belt Lisburne	3,589
Brookian Clinoform Structural North	248
Kemik-Thomson	2,308
Beaufortian Upper Jurassic Topset East	141
Basement Involved Structural	3,016
total, all listed plays	**31,390**

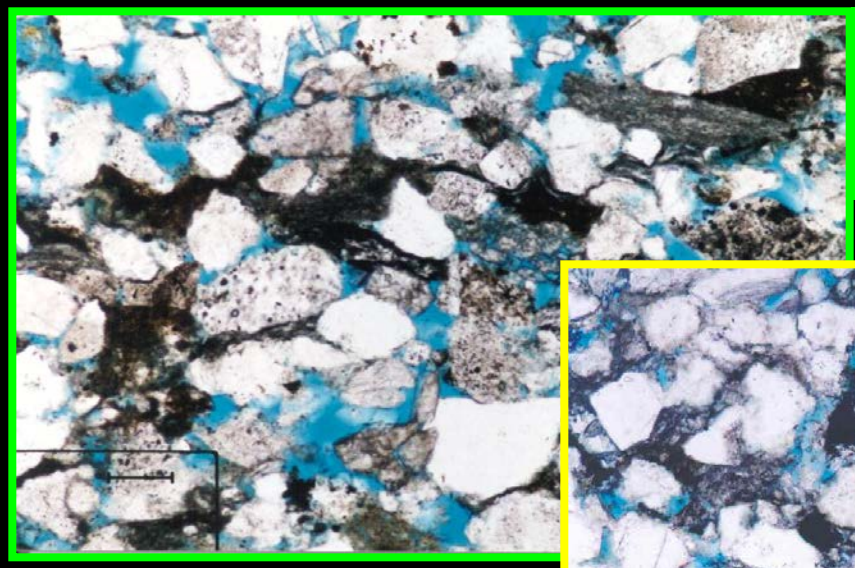
Tertiary Uplift and Erosion

Estimated from sonic compaction trends



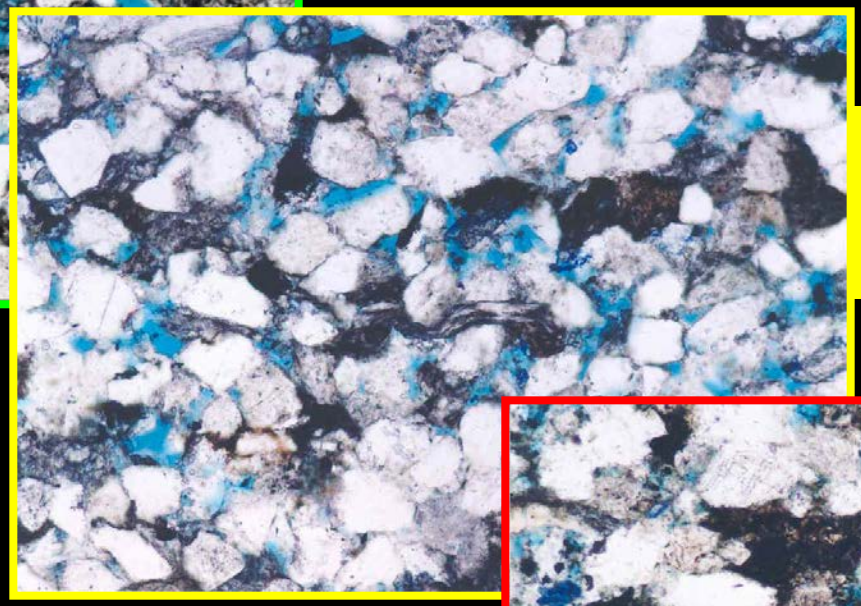
Burns and others, 2007 (USGS)

Compaction of Brookian Reservoirs



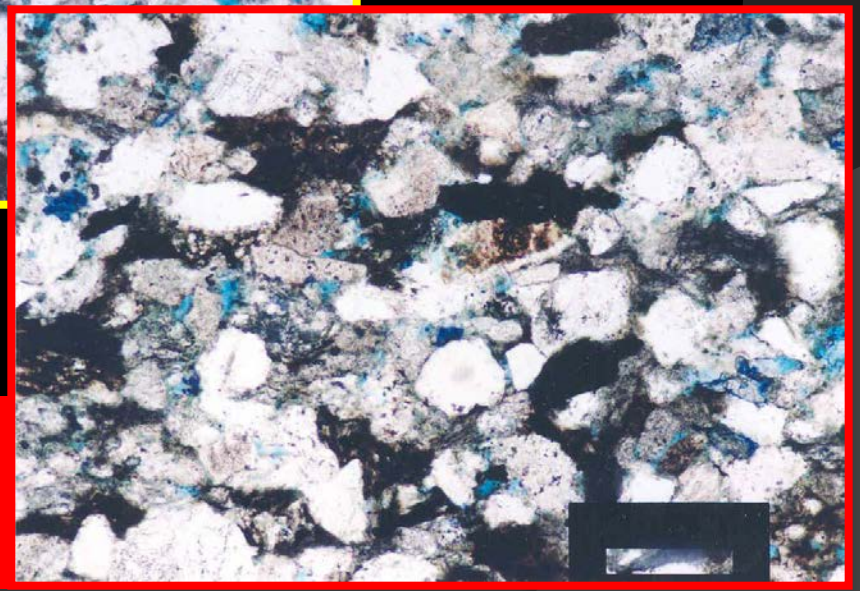
< 7000' Dmax
ø = 18 %
k = 12 md

100 µm



7000-9000' Dmax
ø = 15 %
k = 3 md

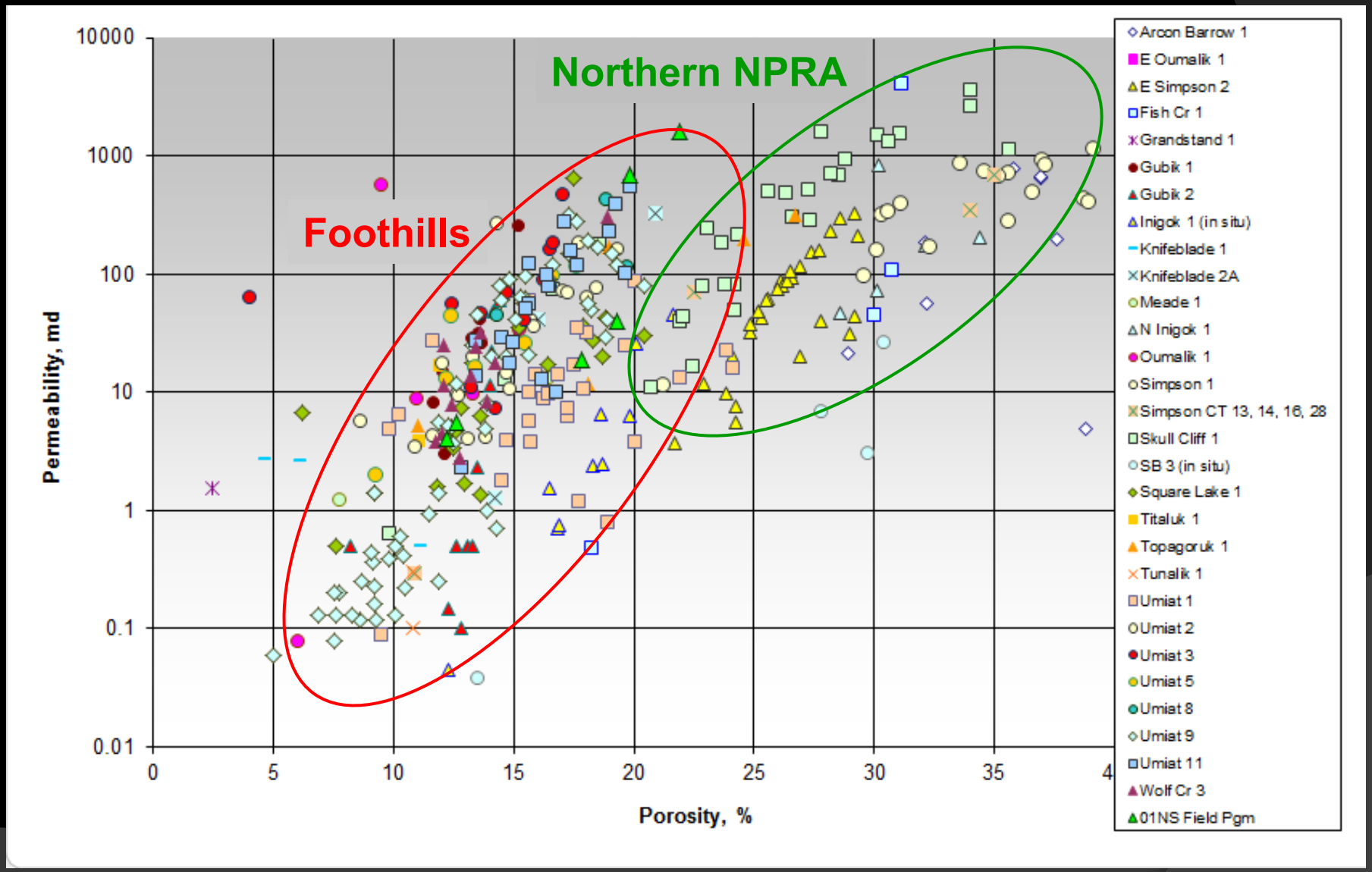
Loss of Porosity and Permeability



> 9000' Dmax
ø = 11 %
k = 0.1 md

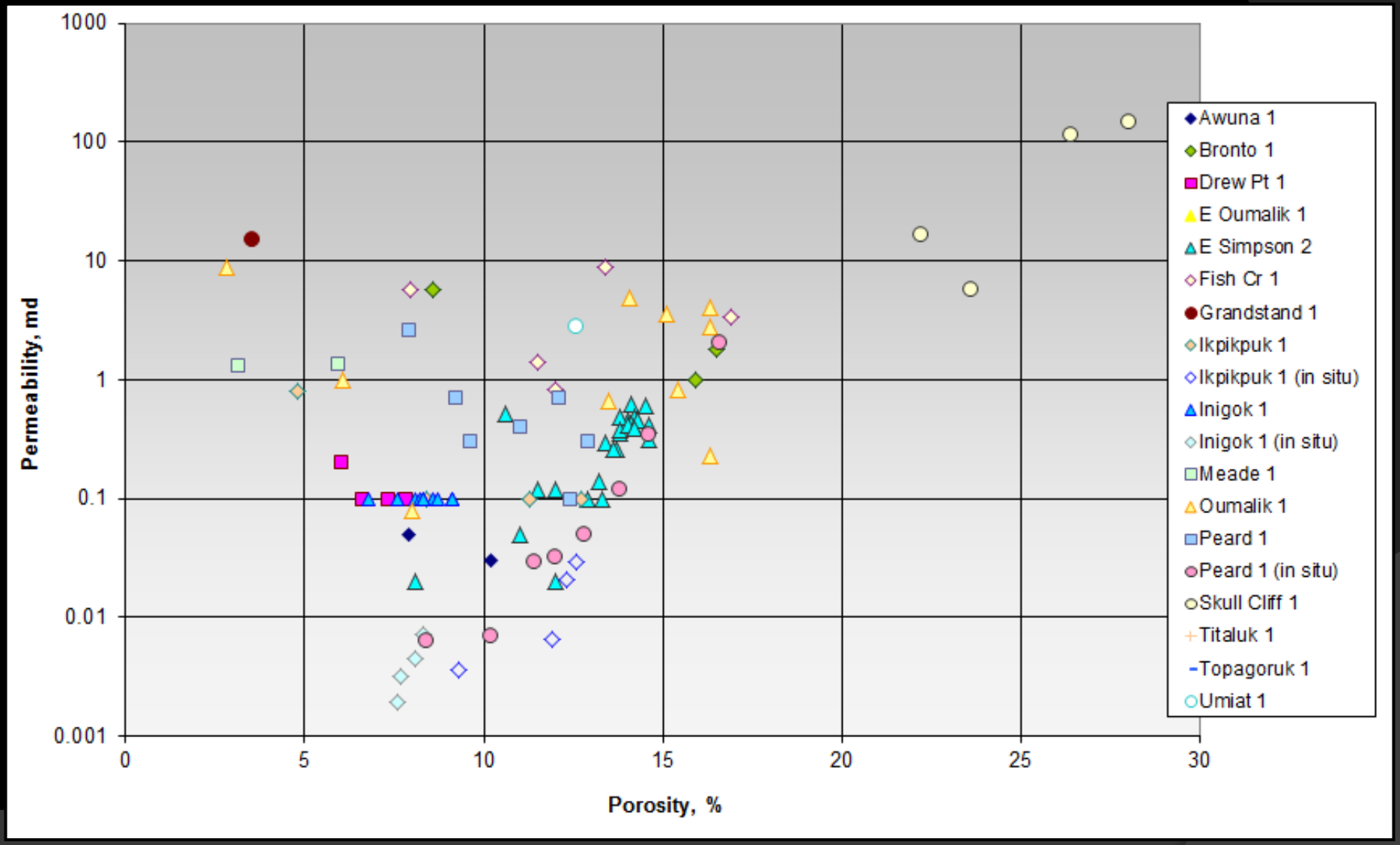
Nanushuk Topsets Poroperm

North Slope wells



Torok Bottomsets Poroperm

North Slope wells

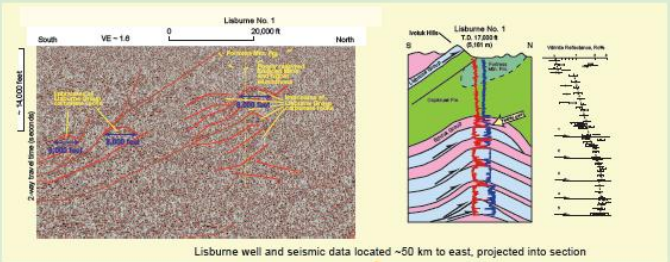


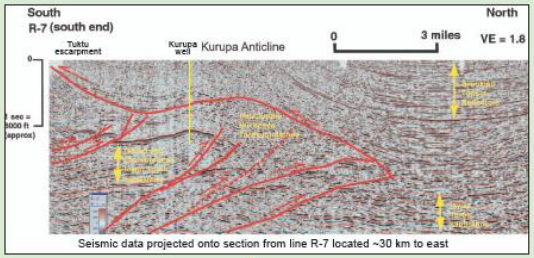
Foothills Structural Plays

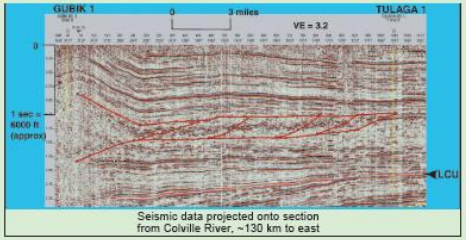
Lisburne anticlinal stack

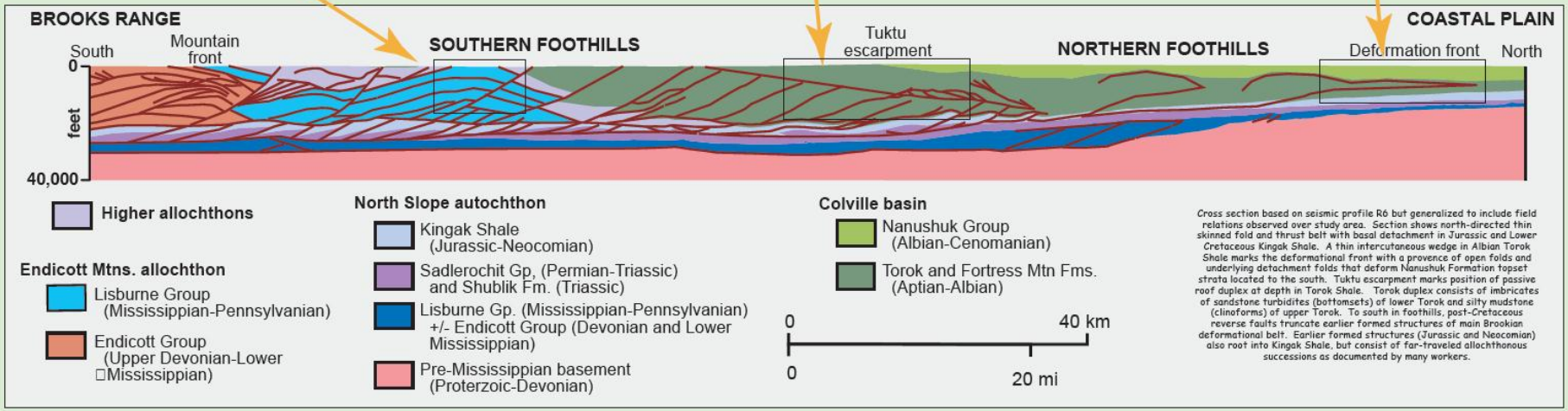
Torok/Ft Mtn duplex

Nanushuk anticline





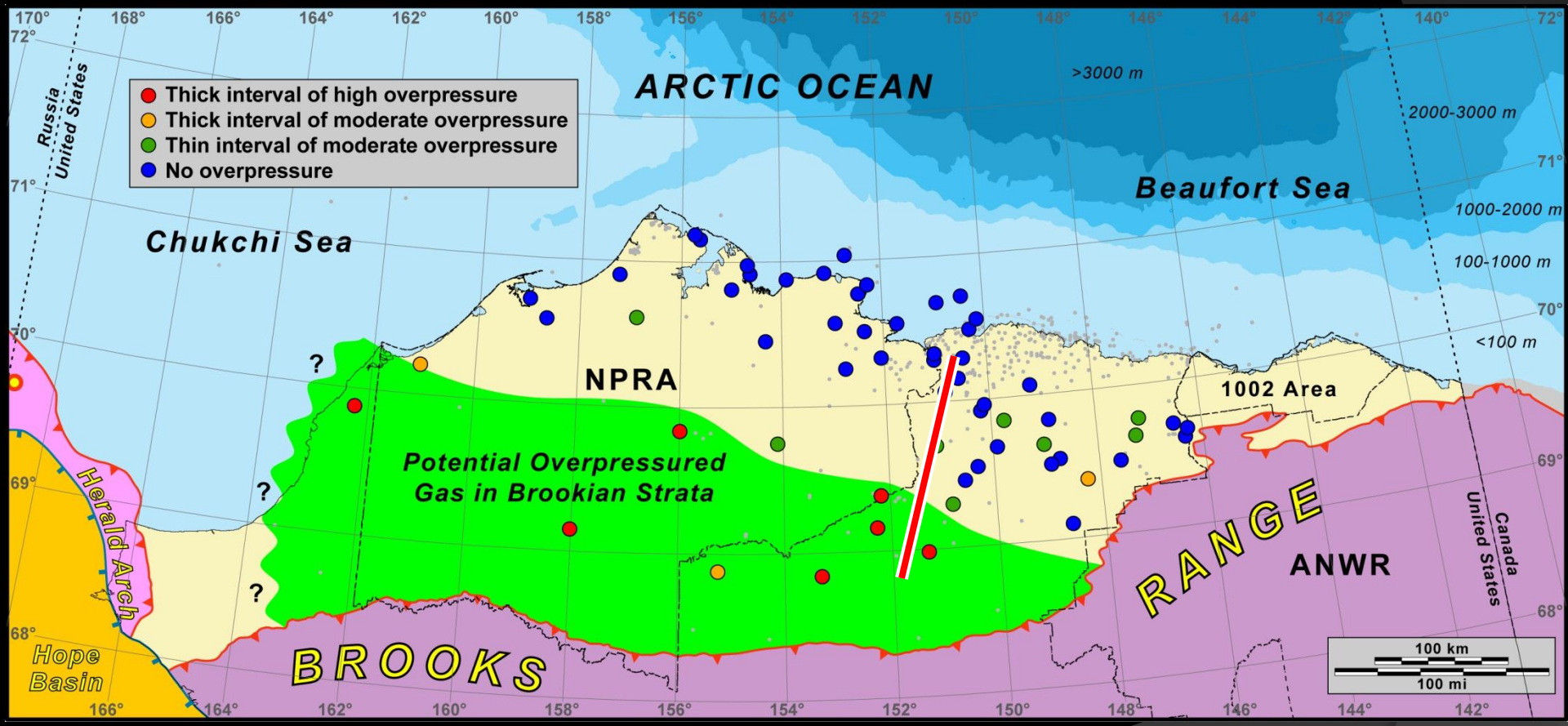




Moore and others, 2003 (USGS)

Overpressured Natural Gas -- Colville Basin

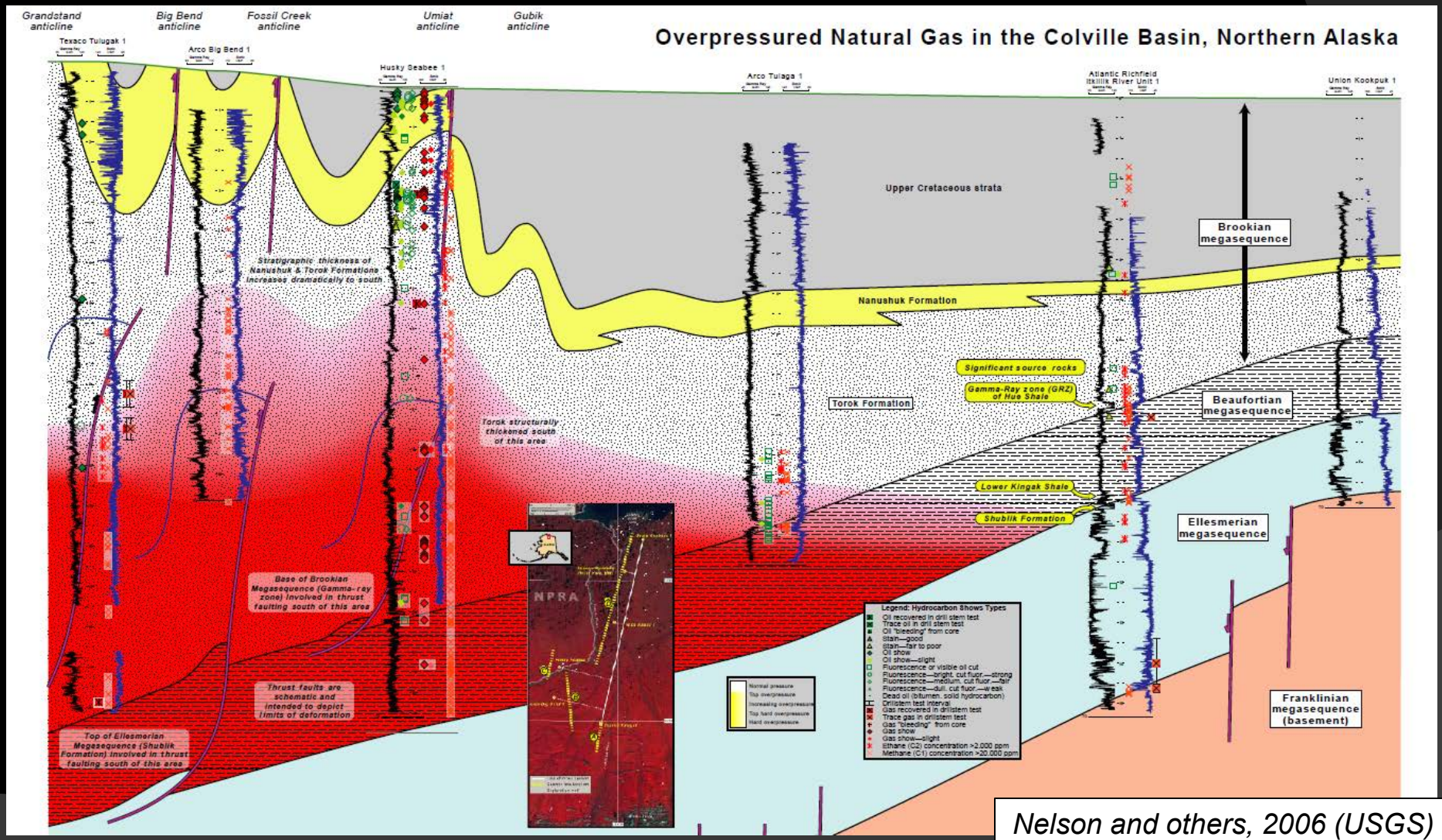
Brookian strata (Torok & Fortress Mountain Formations)



Courtesy of Dave Houseknecht, USGS

Overpressured Foothills Gas Charge

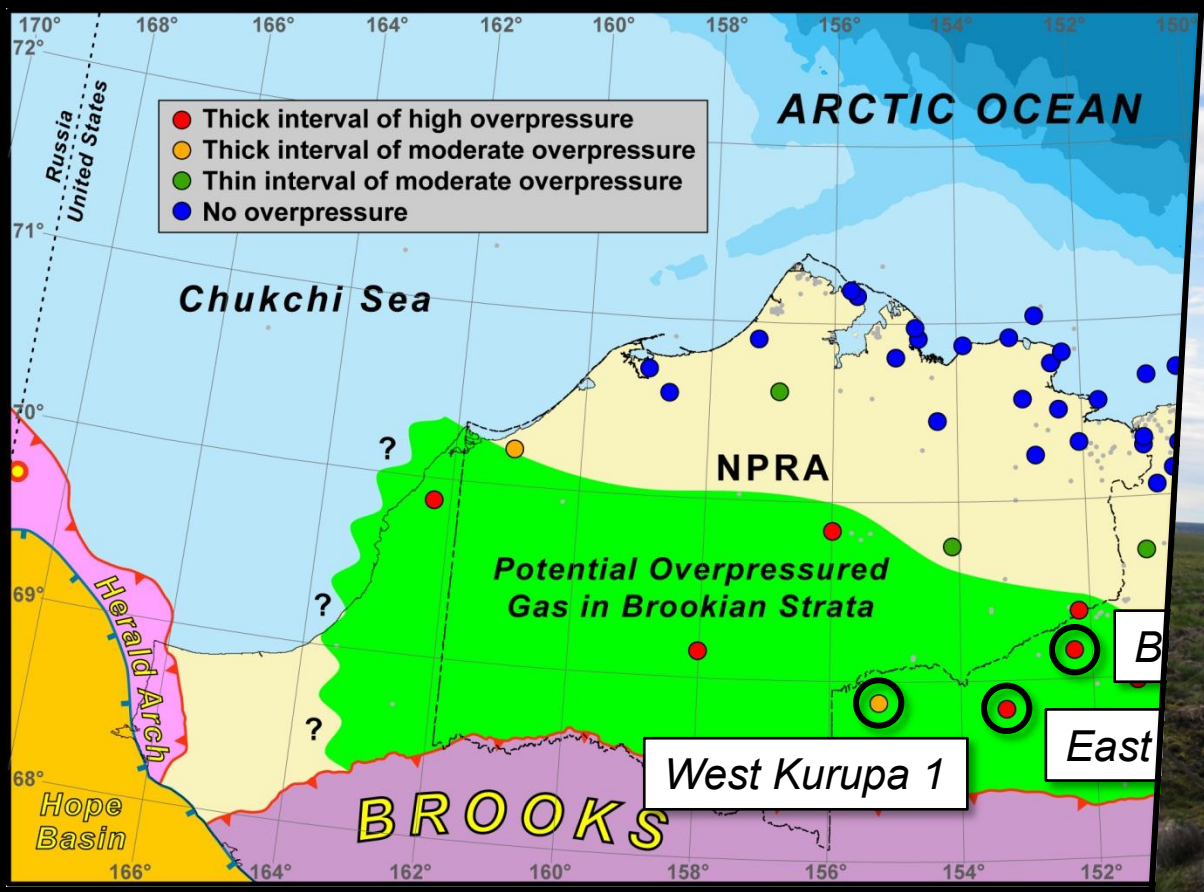
Lower Brookian and Beaufortion sequences



Nelson and others, 2006 (USGS)

Overpressured Natural Gas -- Colville Basin

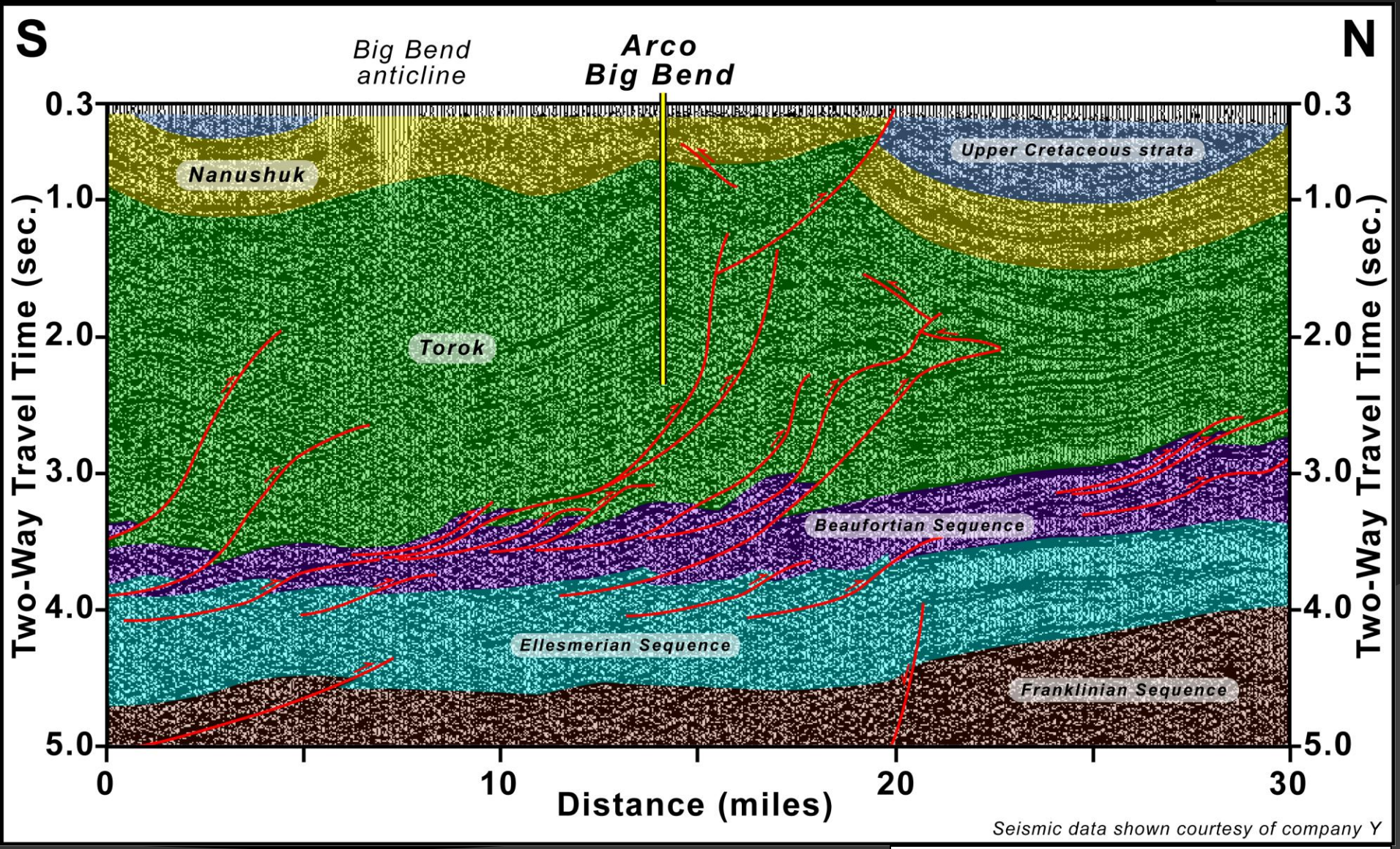
Brookian strata (Torok & Fortress Mountain Formations)



Courtesy of Dave Houseknecht, USGS

Central Foothills Structural Traps

Brookian and Beaufortian Strata

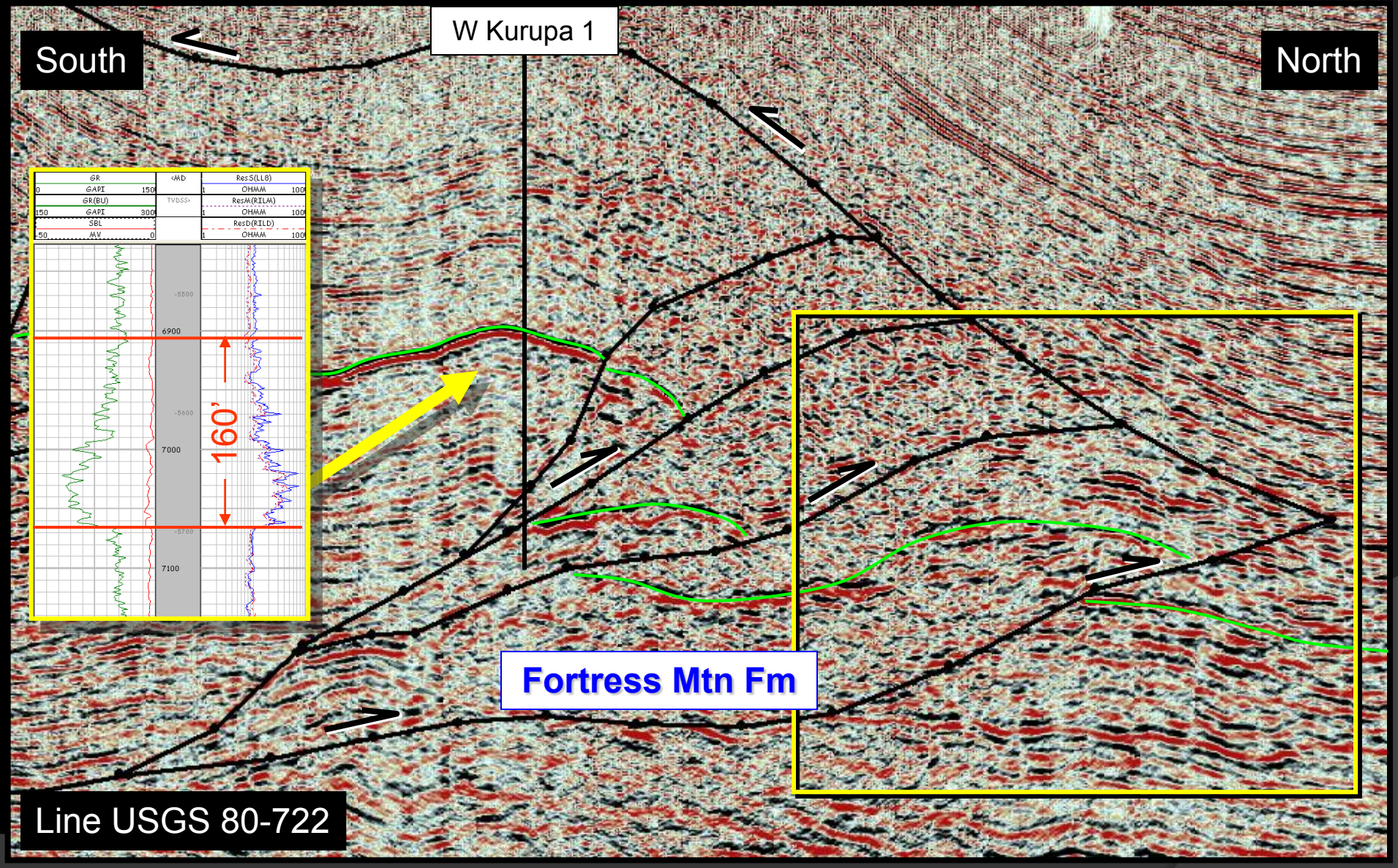


Courtesy of Dave Houseknecht, USGS

Brookian Turbidite Structural Play

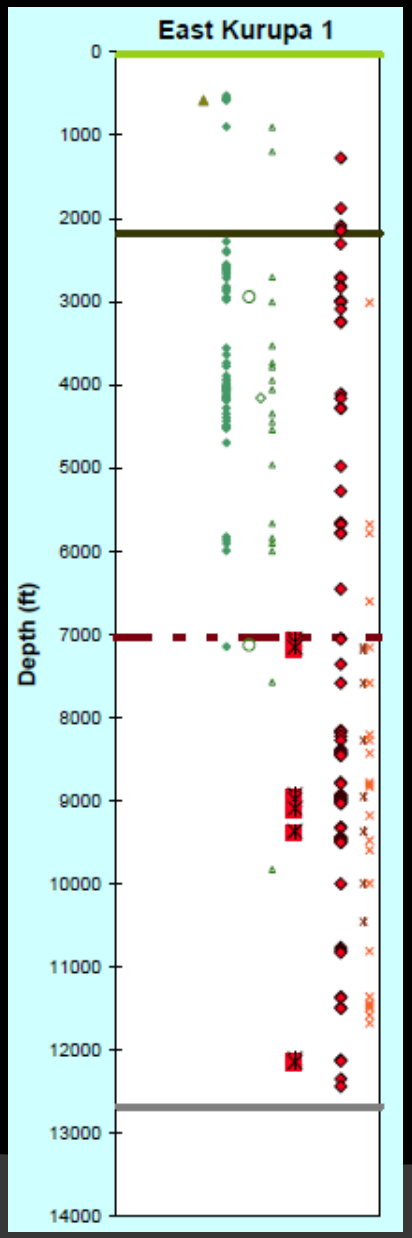
Thrust Belt-Triangle Zone

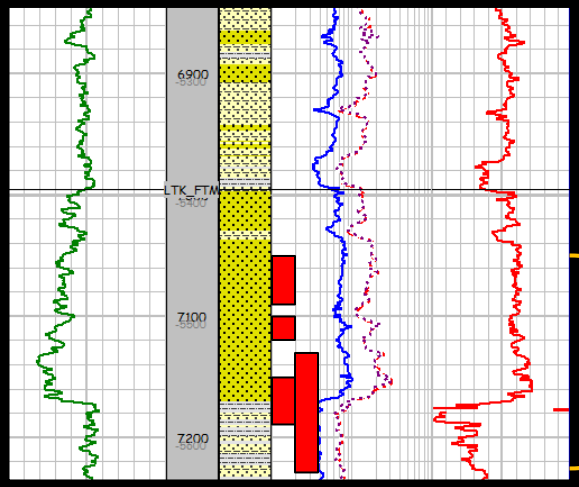
North Slope Foothills

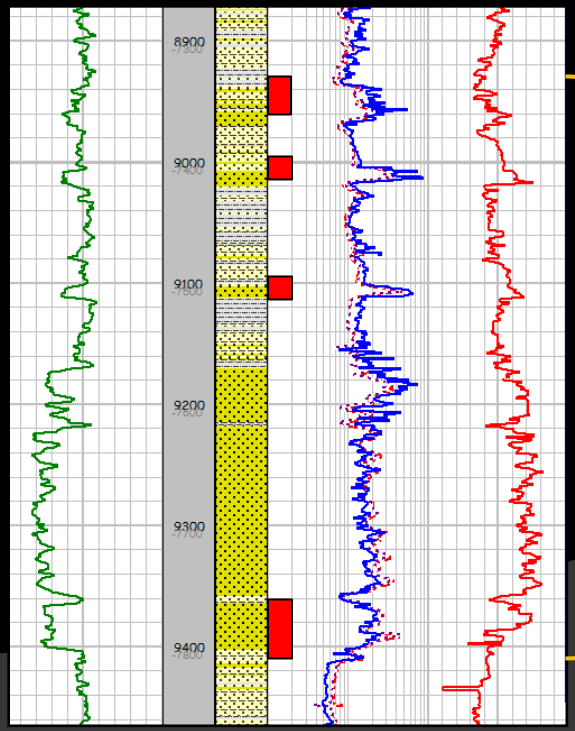


Brookian Turbidite Structural Play

East Kurupa 1 -- Lower Brookian Gas Discovery







Unstimulated Tests

DSTs #5 & #6: 7050-7230': 1000-3800 MCF/D average flow rates over 7 flow periods, various chokes.

Ss: vf-f, lt-md gry, feldsp, p sorted, silty, mod consol, 10-20% dk minerals, calc NOSCF

DST #4: 8930-9410': 1300 MCF/D average flow rate.

Ss: vf-f, lt gry, predom qtz, well sorted, silty, micac, calc, locally fair porosity, NOSCF

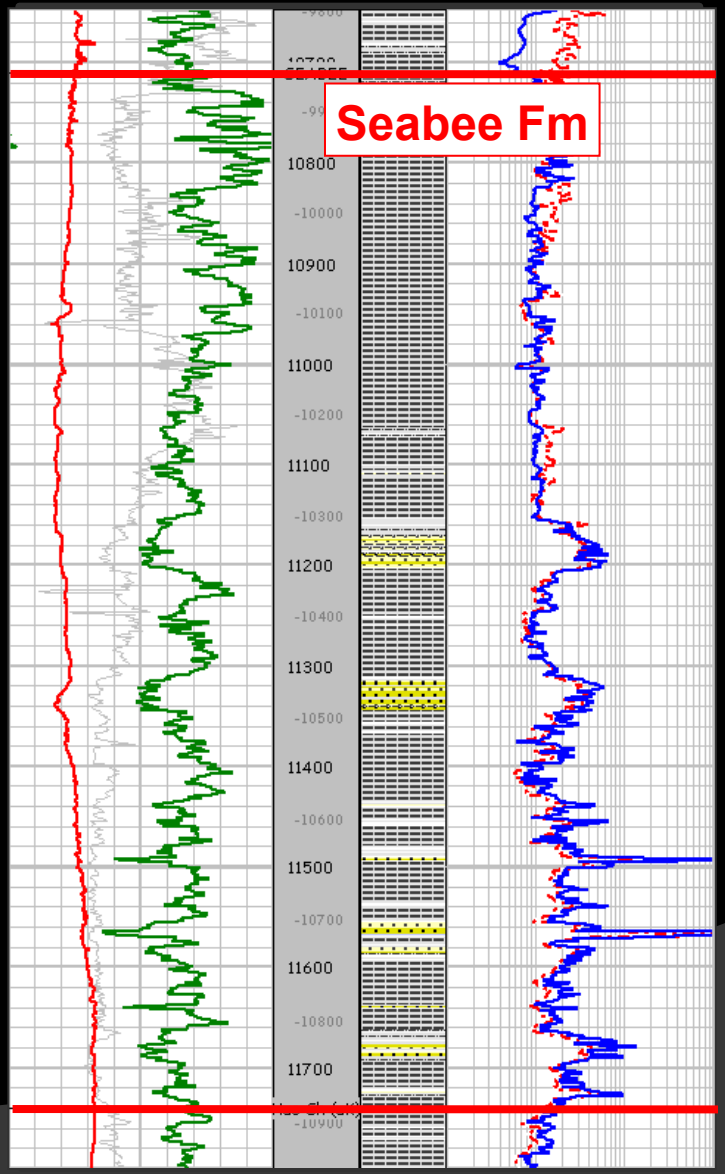
Seabee Fm Basin Floor (?) Turbidites

Sagavanirktok-Ivishak rivers area

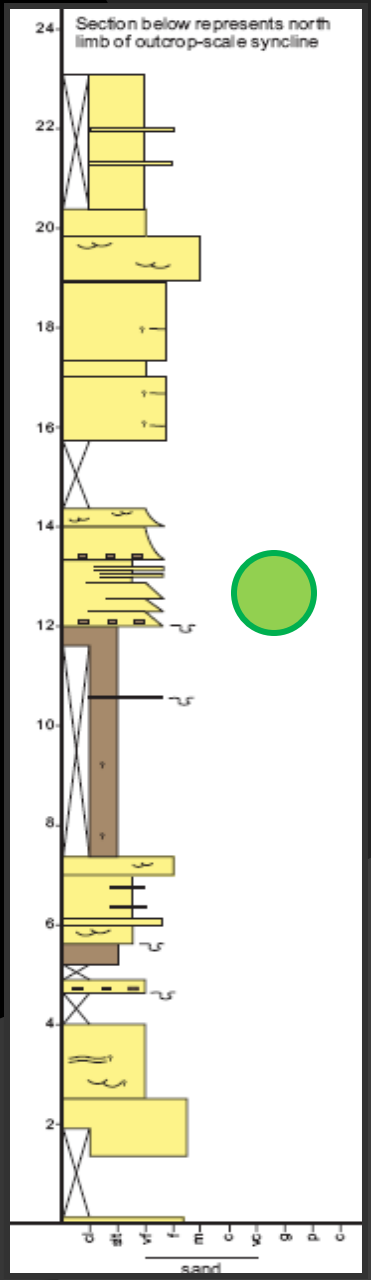
A.

C.

Echooka 1 well log

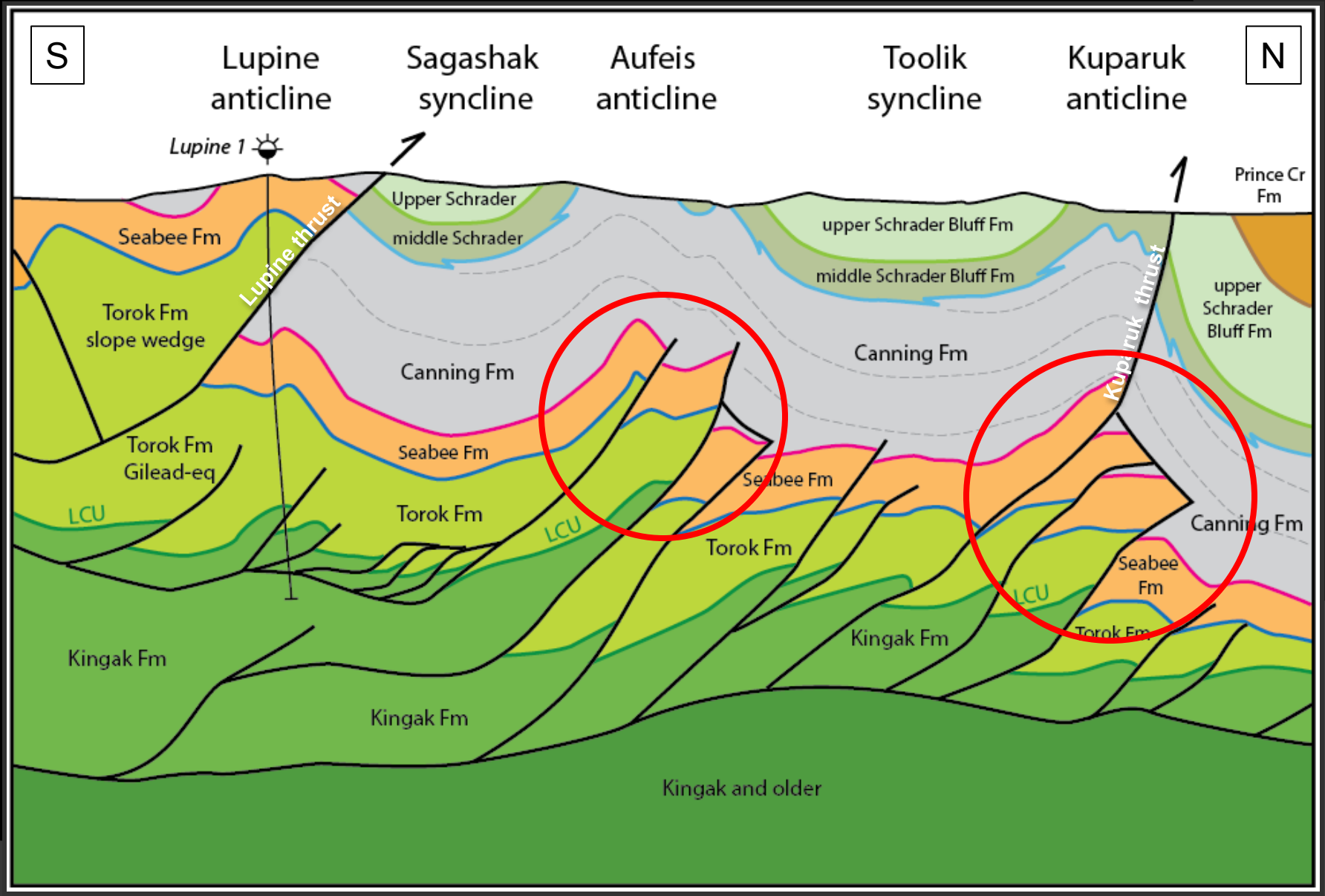


B.



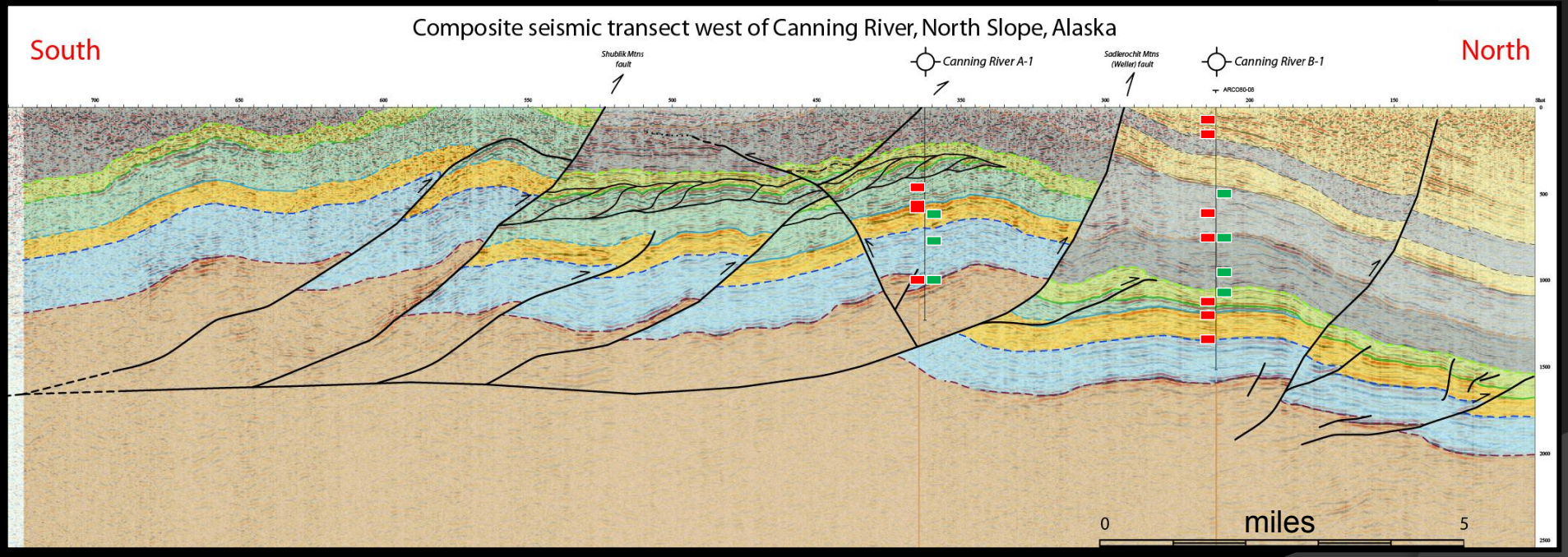
East-central Foothills near Dalton Highway/TAPS

DNR Seismic-assisted geologic mapping



Eastern Foothills Fold and Thrust Belt

Structural Traps in Ellesmerian and Beaufortian Strata



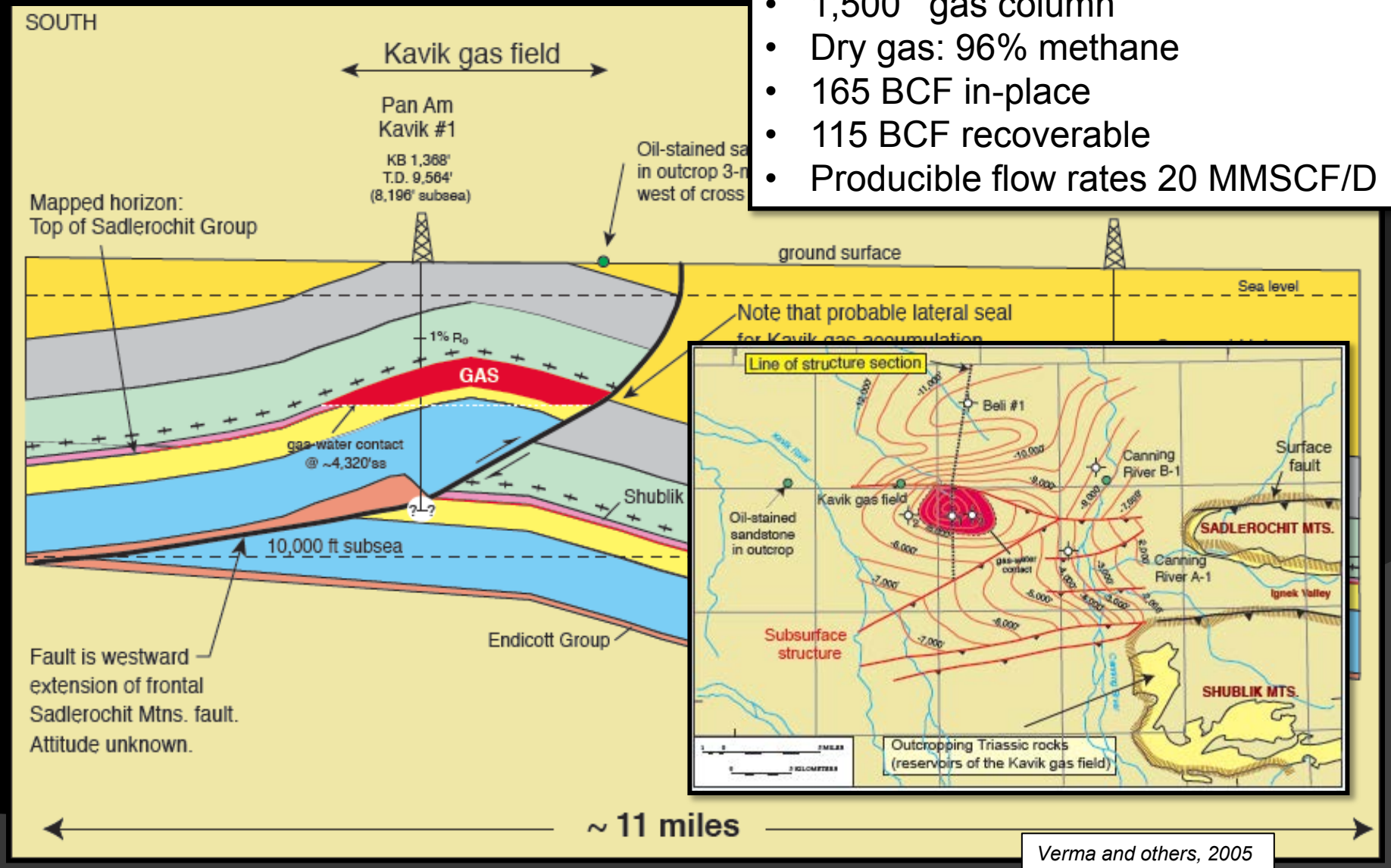
Public seismic lines EP81-27S, -27C, & -27N

pld, Alaska Division of Oil & Gas

Eastern Foothills Fold and Thrust Belt

Kavik Gas Field – Ivishak Fm fractured reservoir

- 1,500 ‘ gas column
- Dry gas: 96% methane
- 165 BCF in-place
- 115 BCF recoverable
- Producible flow rates 20 MMSCF/D

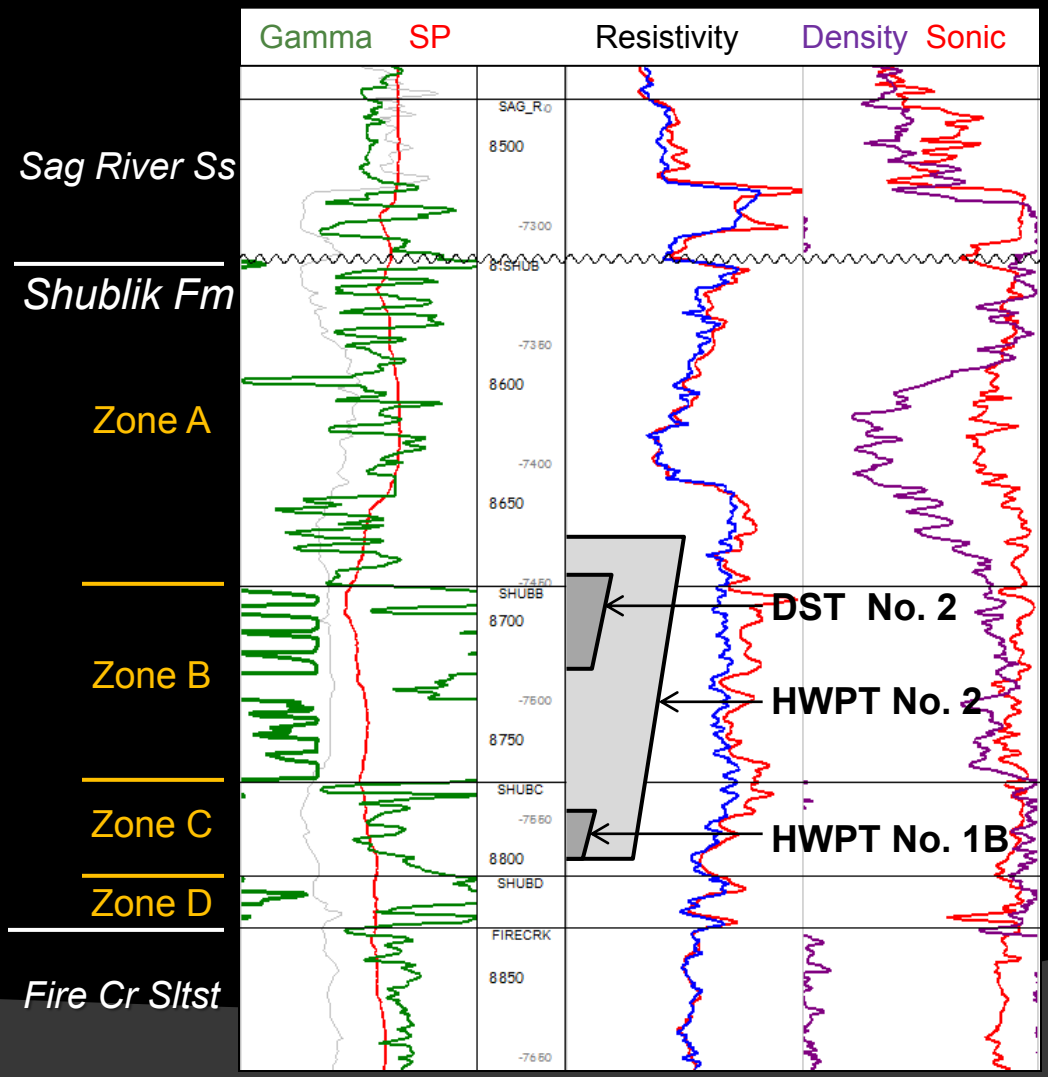


Verma and others, 2005

Shublik Fm Flow Tests

Kemik gas field: Naturally fractured reservoir (?)

Kemik Unit 1



Gas Flow Rates

Shublik A-B: ***12 MMCFD (AOF?)***

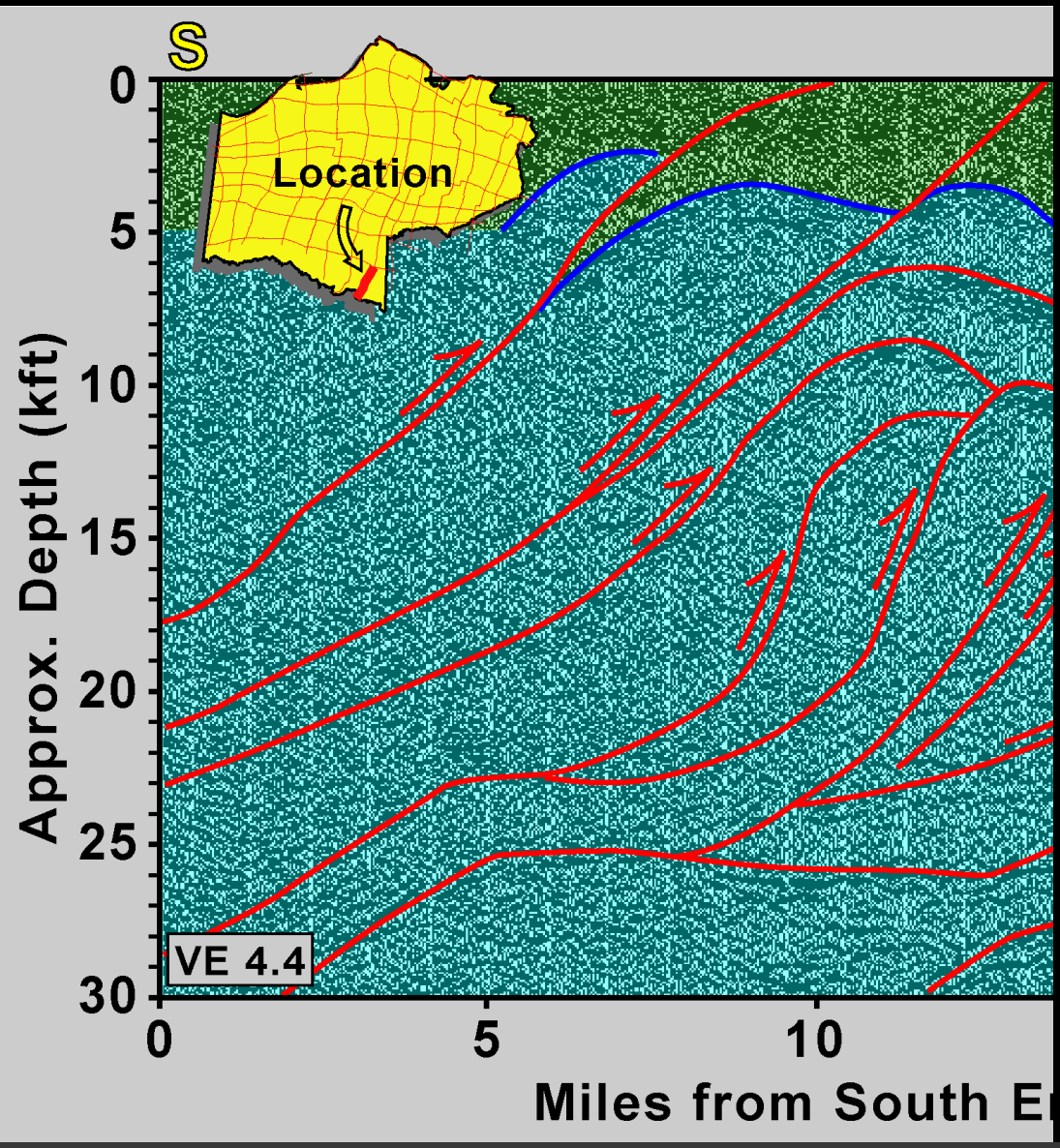
Shublik A-C: ***~10 MMCFD***

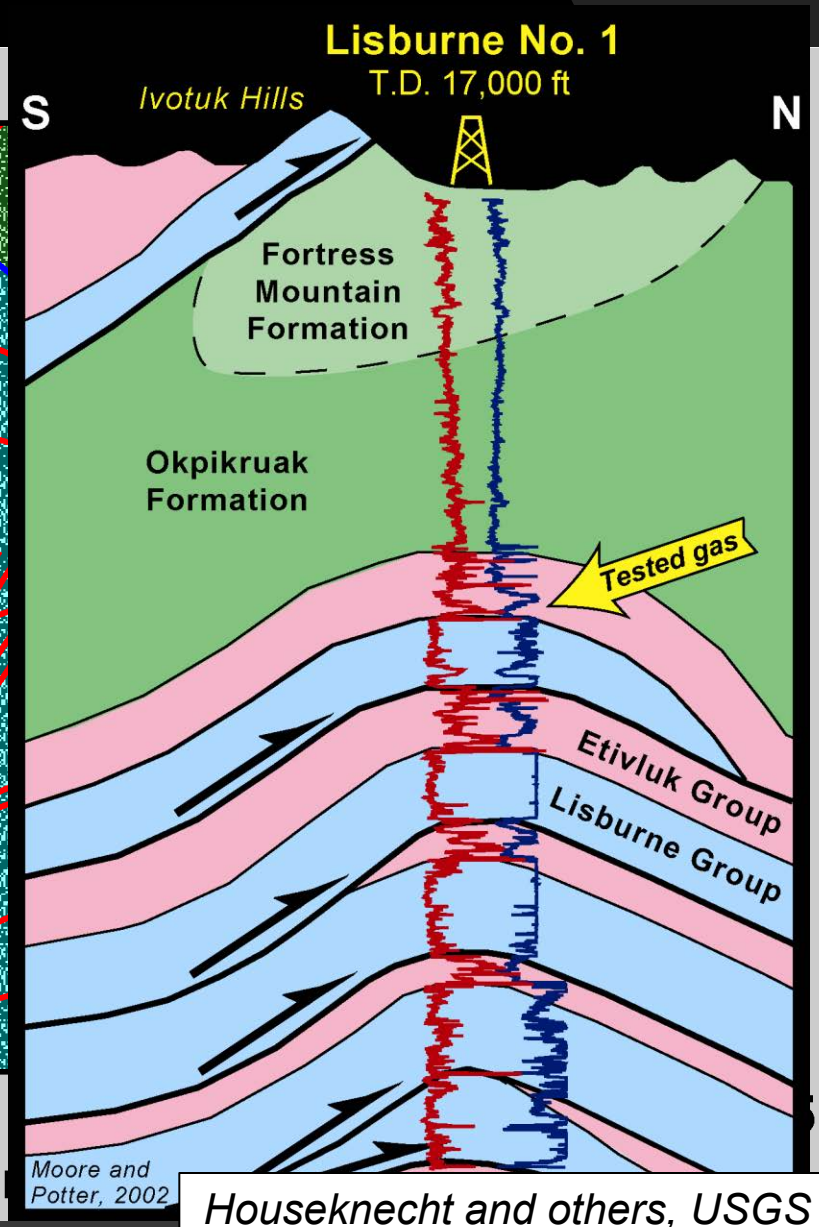
Shublik C: ***~2 MMCFD***

Thrust ramp in Lisburne Gp carbonates,
Akmagolik Creek, Brooks Range mountain front
Photo courtesy of Dave Houseknecht, USGS

Structural Traps in Ellesmerian Carbonates

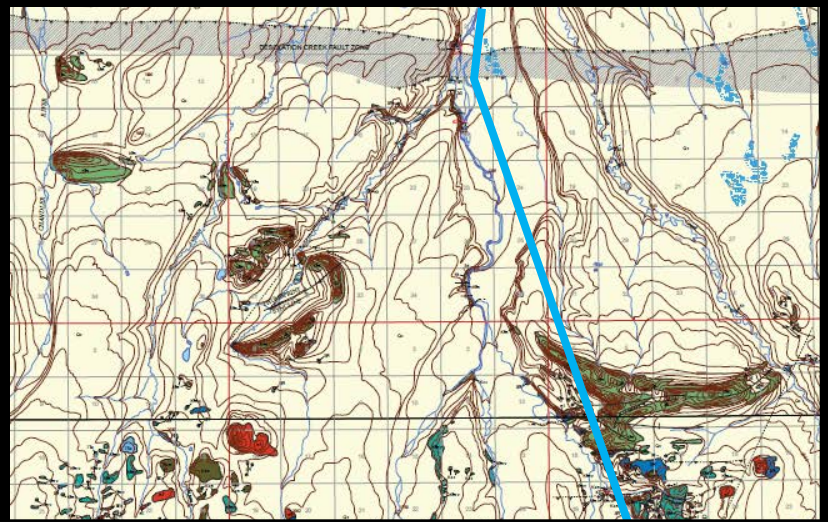
Southern Foothills near mountain front





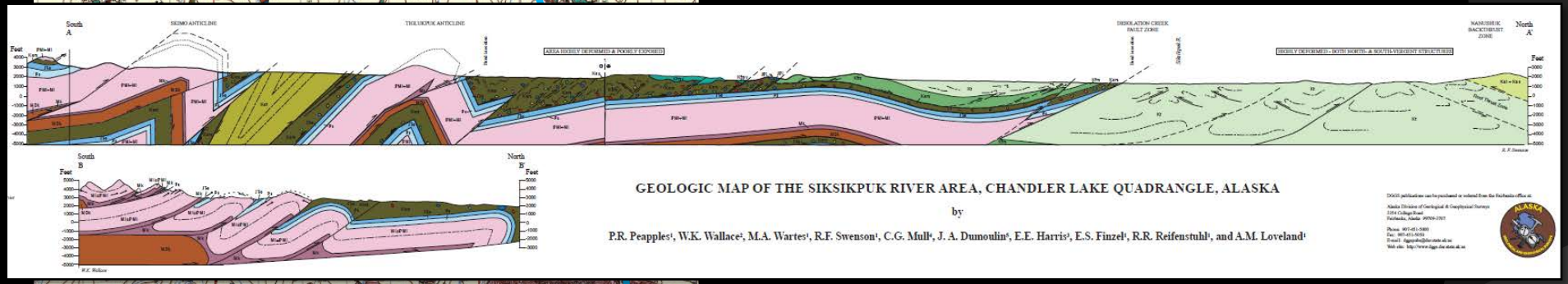
Houseknecht and others, USGS

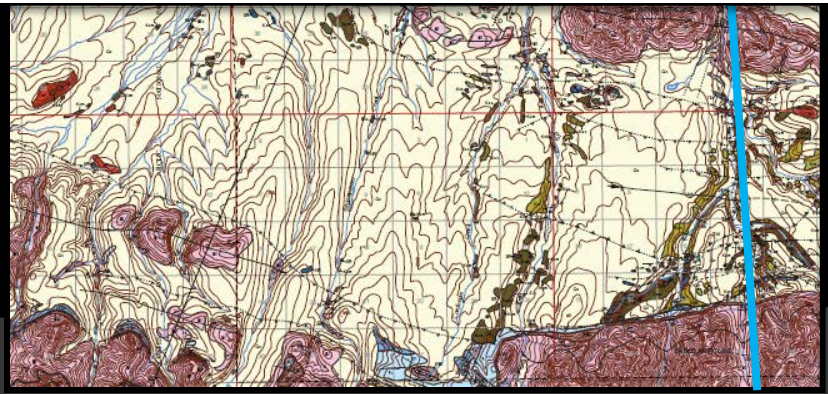
DGGS Energy Program Foothills Mapping



Siksikpuk River area STATEMAP, southern foothills

Example of recent DGGS-led geologic mapping, structural, and stratigraphic studies





Significant tundra cover typical of foothills field projects

Peapples and others, 2007

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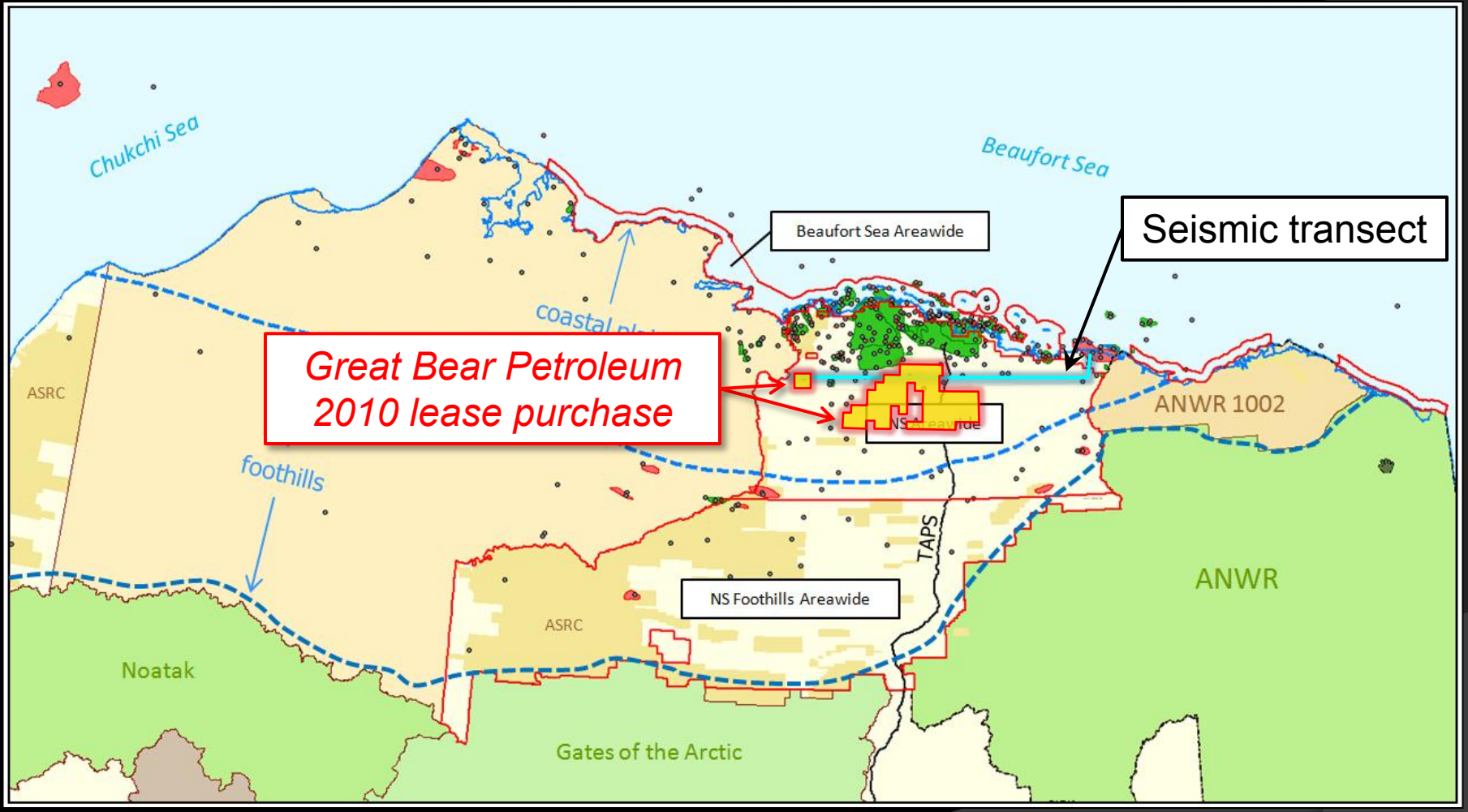
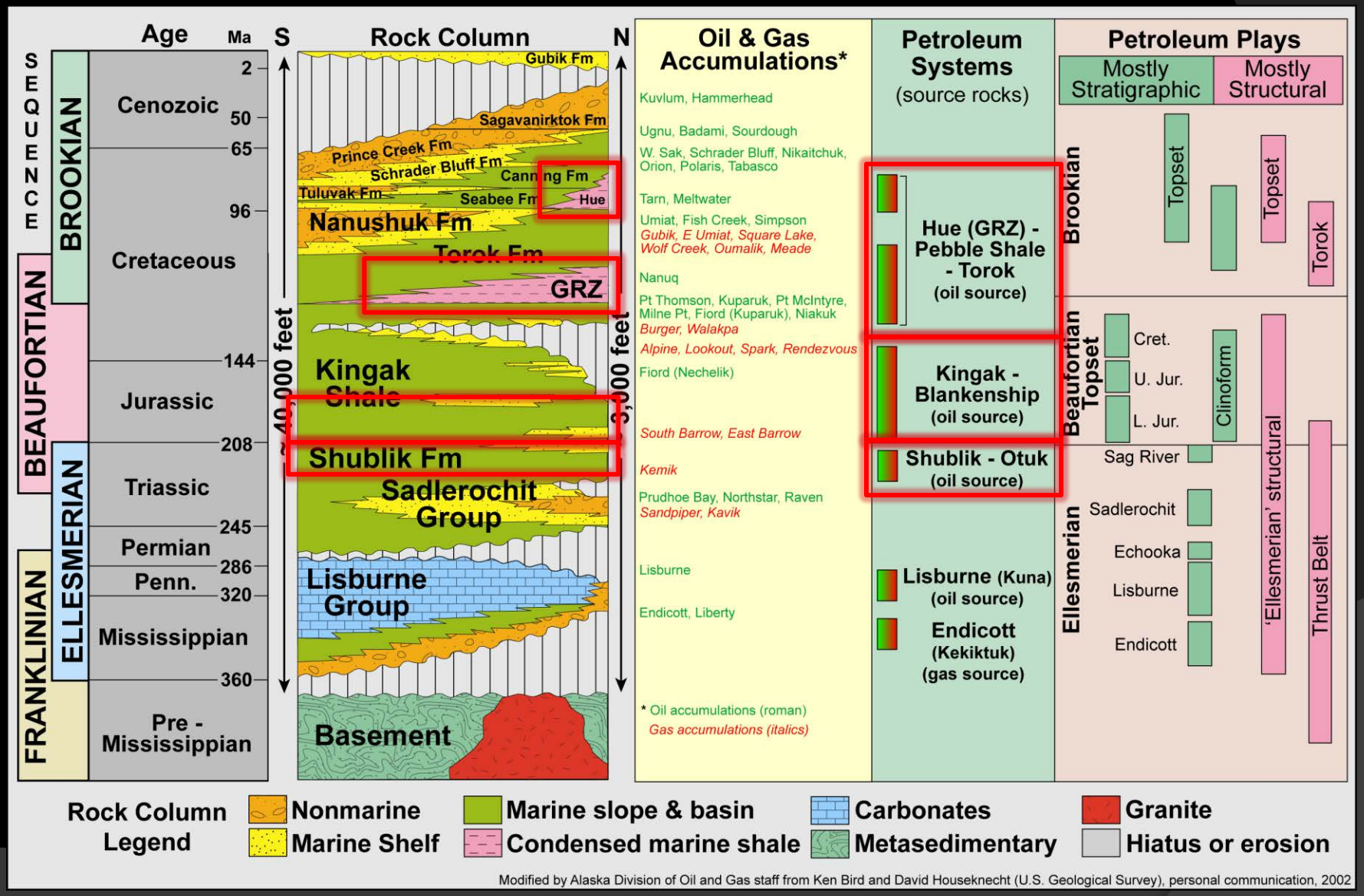
North Slope Region



North Slope Petroleum Systems

3 prolific source rock intervals

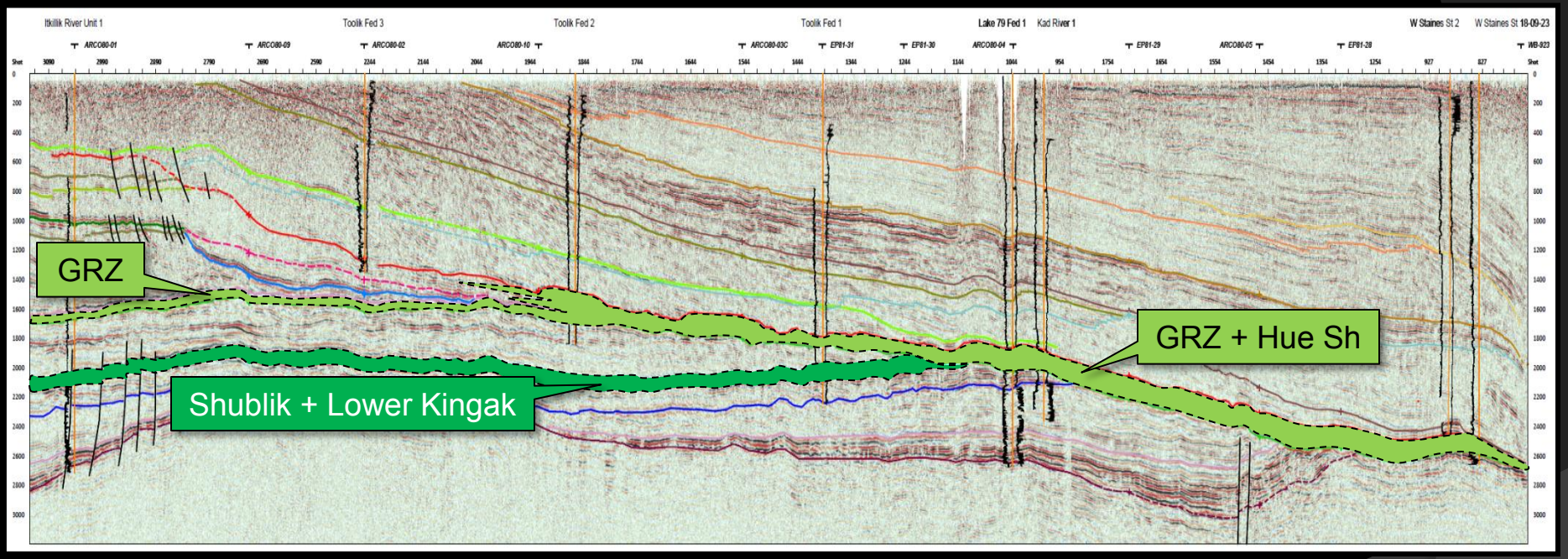


Modified by Alaska Division of Oil and Gas staff from Ken Bird and David Houseknecht (U.S. Geological Survey), personal communication, 2002

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

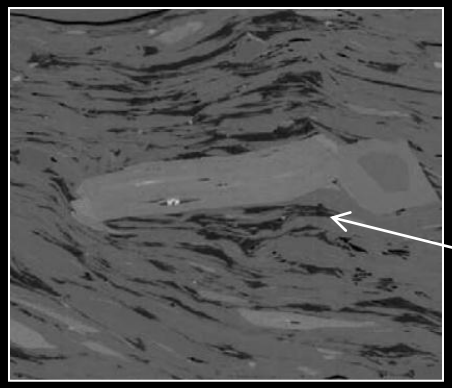
(Decker, unpublished data, 2010-11)

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)

Shale Resource Evaluation Tools

- Core and Outcrop analyses
  - RockEval – TOC (→ richness, kerogen type, general thermal maturity)
  - Vitrinite Reflectance (→ thermal maturity)
  - Porosity and Permeability
  - Inorganic chemical content (XRD)
  - Rock Mechanics testing
  - Hydrocarbon desorption
  - Optical and Scanning Electron Microscopy →
  - Fracture measurements and statistics



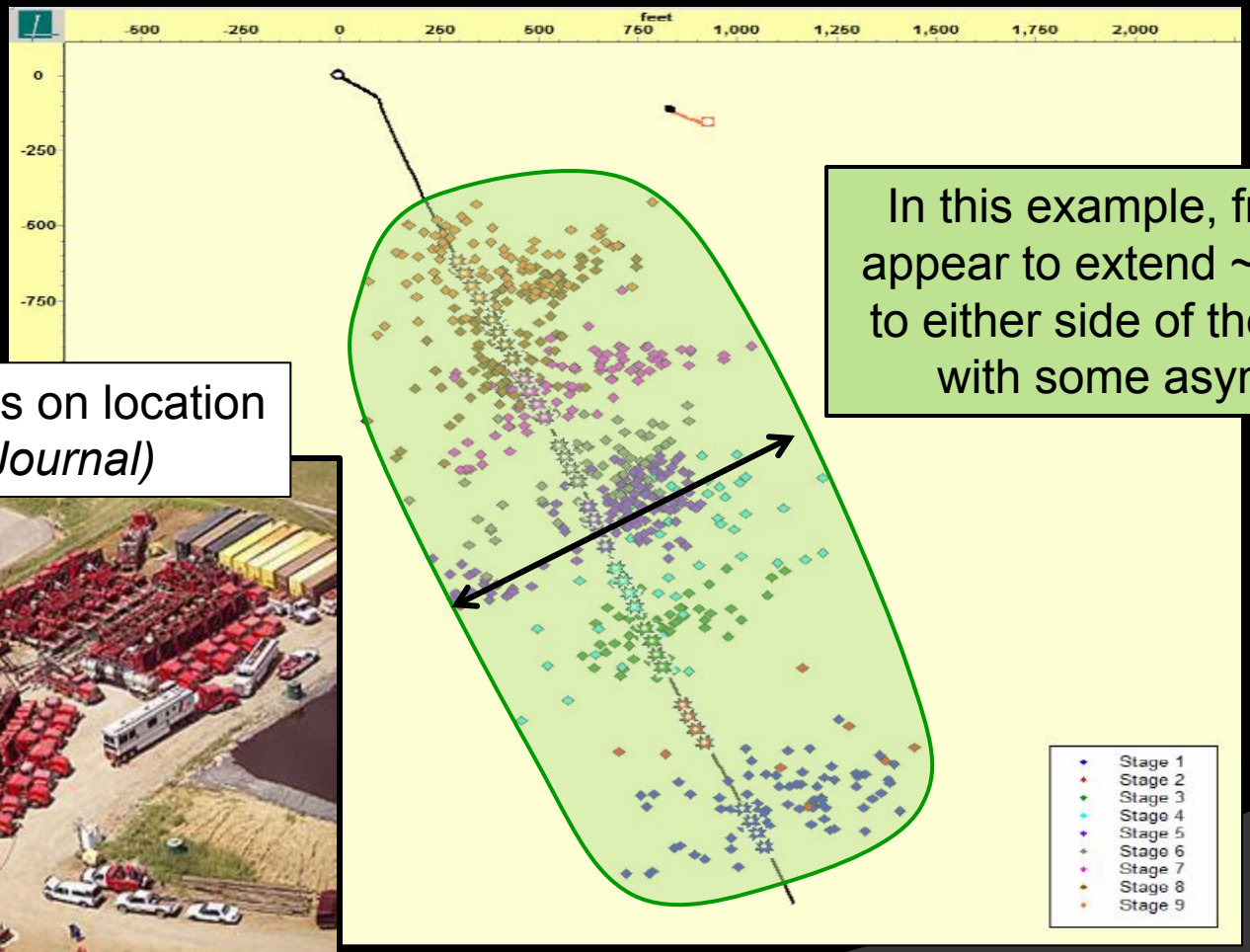
Pore throats are less than 1 millionth of a meter across

15 microns (0.015 mm)

- Wellbore and Well Log analyses
  - Conventional logging suites
  - Fracture imaging logs
  - Magnetic Resonance, Photoelectric Effect, …
  - Delta Log-R log overlays
  - Production testing → flow rates, pressure
  - Microseismic monitoring of hydrofracture stimulations
- Advanced seismic analyses
  - AVO → Geomechanical brittleness (Incompressibility and Rigidity) for artificial fracs
  - AVAZ → Anisotropy due to fractures or stress (zones prone to natural fractures)

Frac Jobs – Microseismic Monitoring

Where are the fractures and how far do they extend?



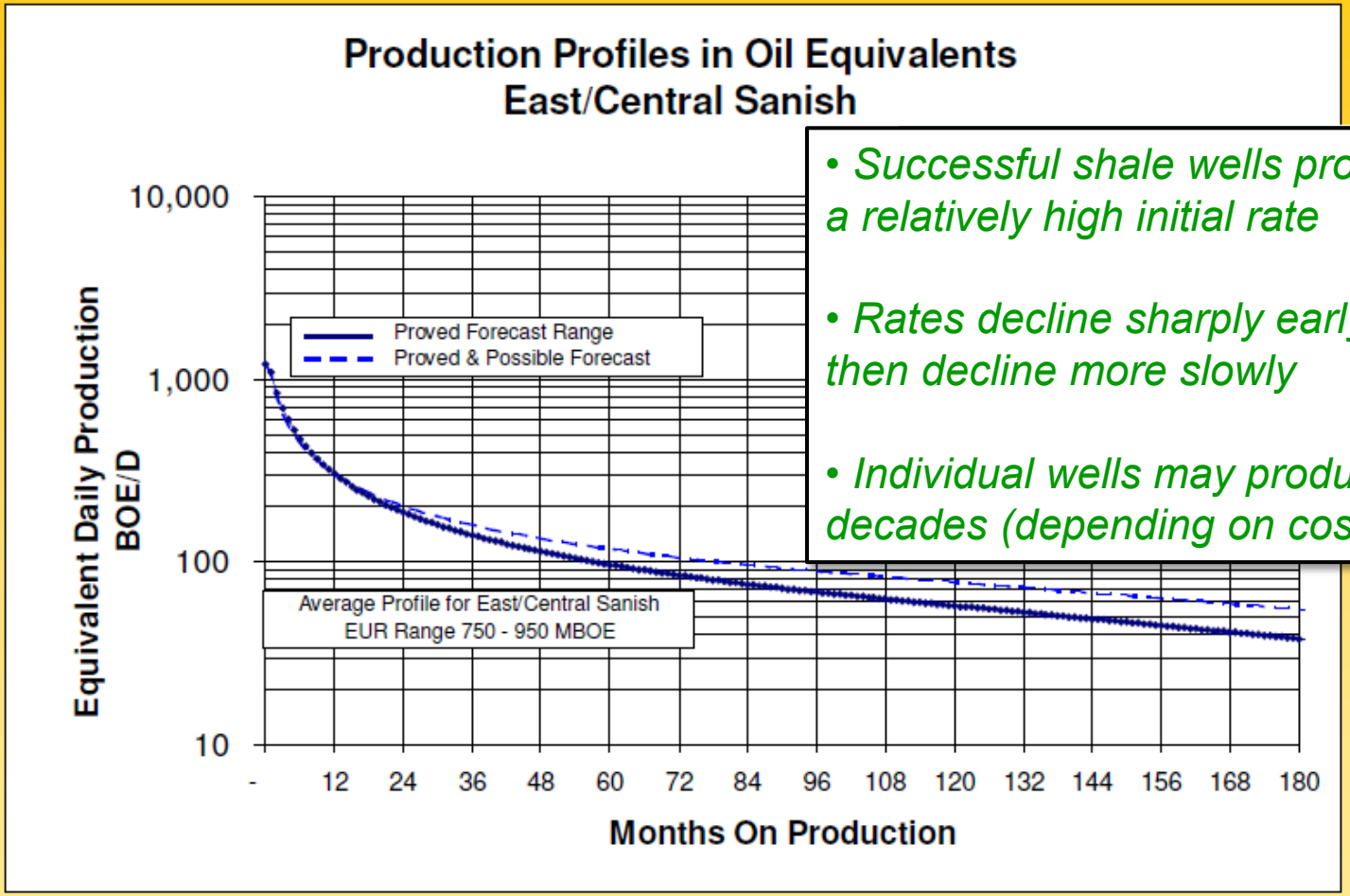
In this example, frac wings appear to extend ~450-550 ft to either side of the wellbore with some asymmetry

34 frac trucks on location
(Oil & Gas Journal)

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



- *Successful shale wells produce at a relatively high initial rate*
- *Rates decline sharply early on, then decline more slowly*
- *Individual wells may produce for decades (depending on costs, etc.)*

(Whiting Petroleum, 2011)

Shublik Formation

Variability in outcrop and well logs

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

Shublik Fm

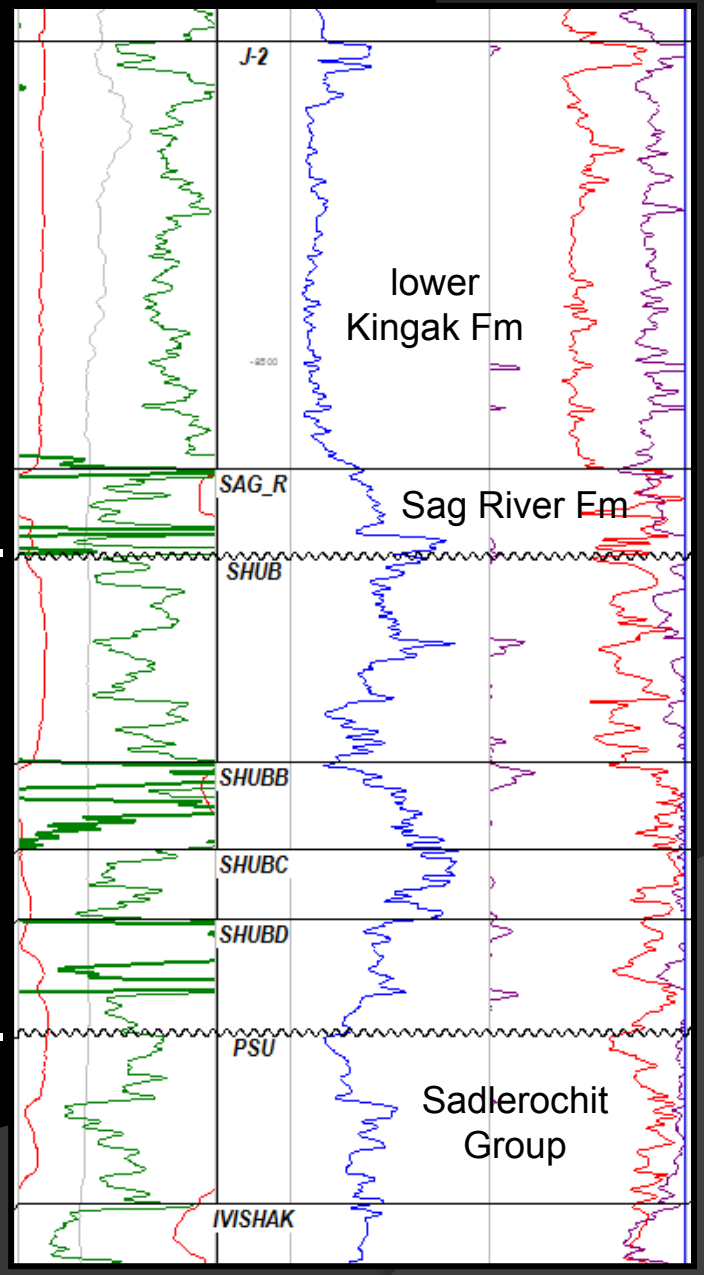
Zone A

Zone B

Zone C

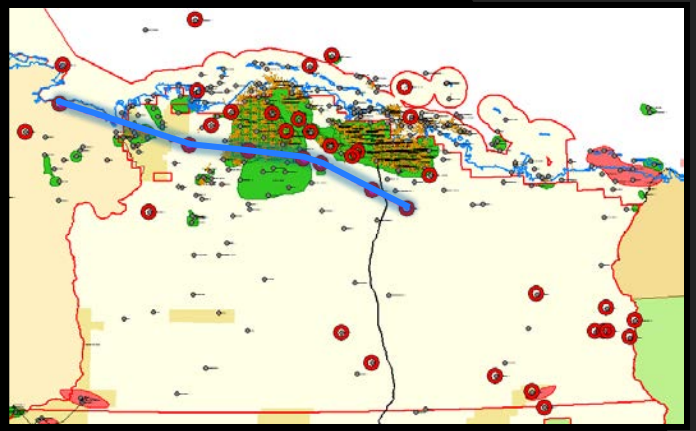
Zone D

Rock Flour 1



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

Sag River

lower Kingak

Shublik A-D

J-2

SAG_R

SHUB

SHUBB

SHUBC

SHUBD

PSU

IVISHAK

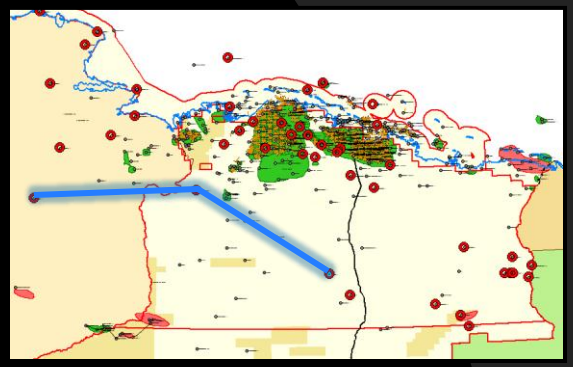
(Decker, unpublished data, 2011)

Shublik-equivalent Otuk Fm

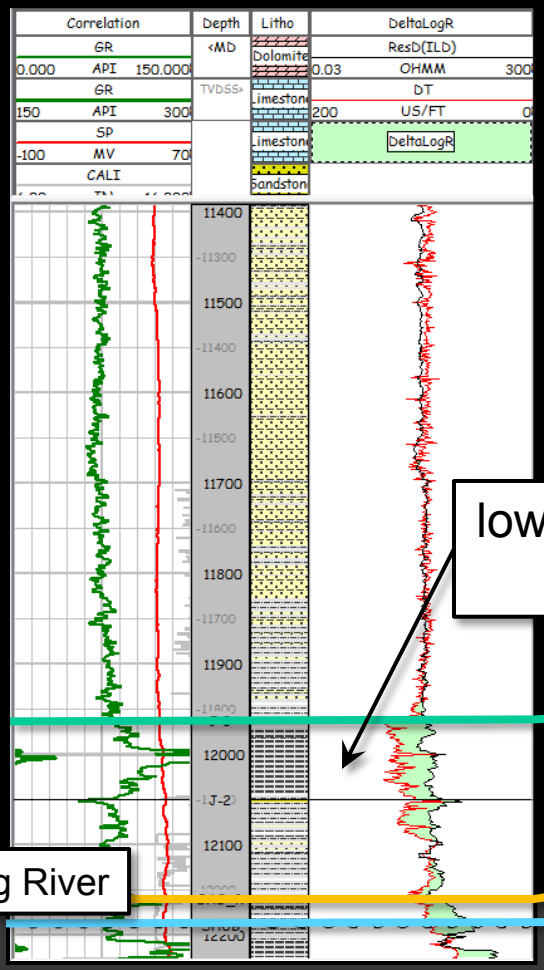
Oil- & pyrobitumen-saturated lime mudstone fault breccia, Kukpowruk River

Lower Kingak Formation

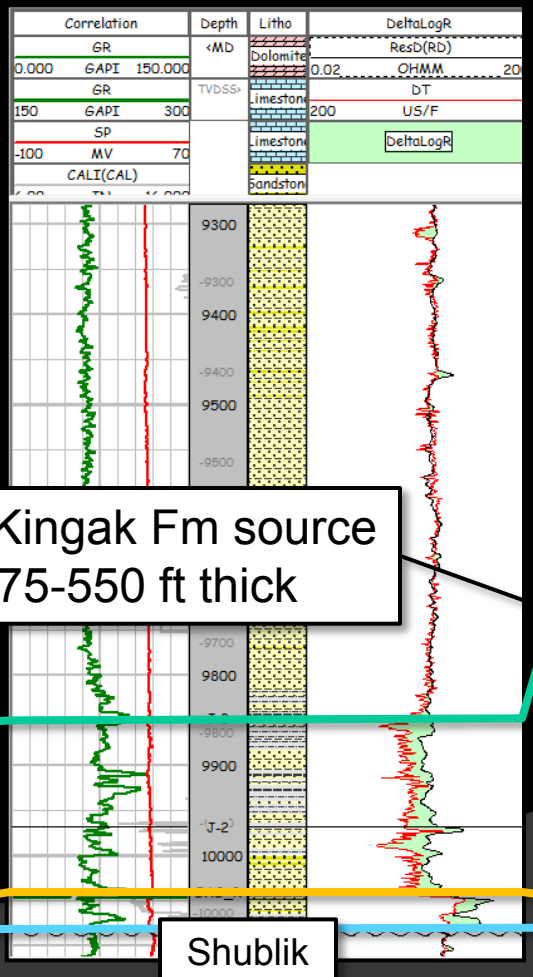
Δ Log R source rock screening



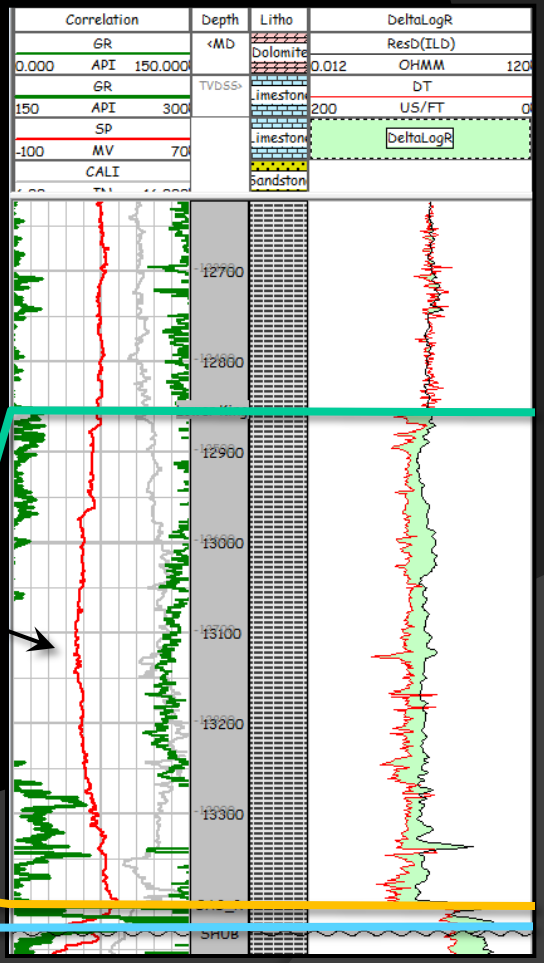
Inigok 1



Itkillik River 1



Bush Fed 1



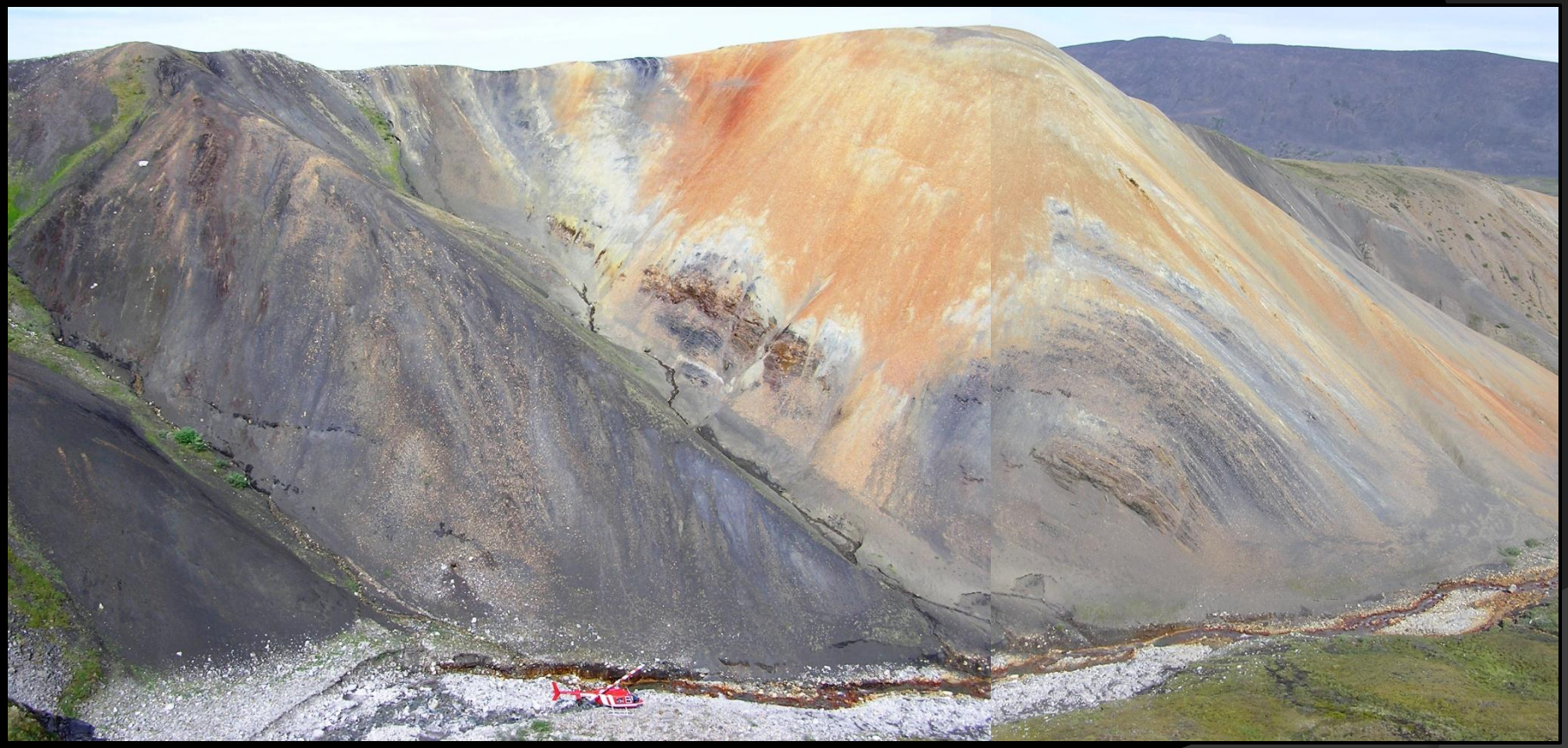
lower Kingak Fm source
~175-550 ft thick

Sag River

Shublik

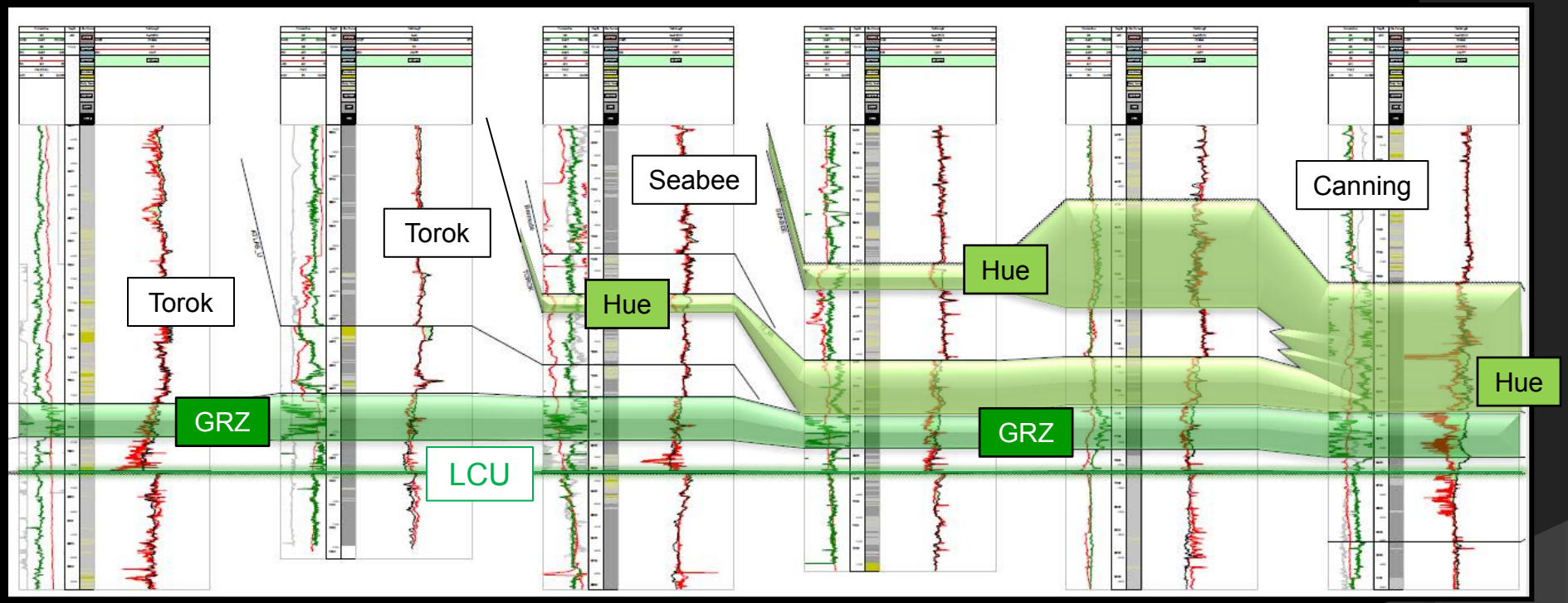
Hue Shale/GRZ

Type section outcrops at Hue Creek, ANWR



Hue Shale/GRZ

Correlations and log-based Total Organic Content estimates

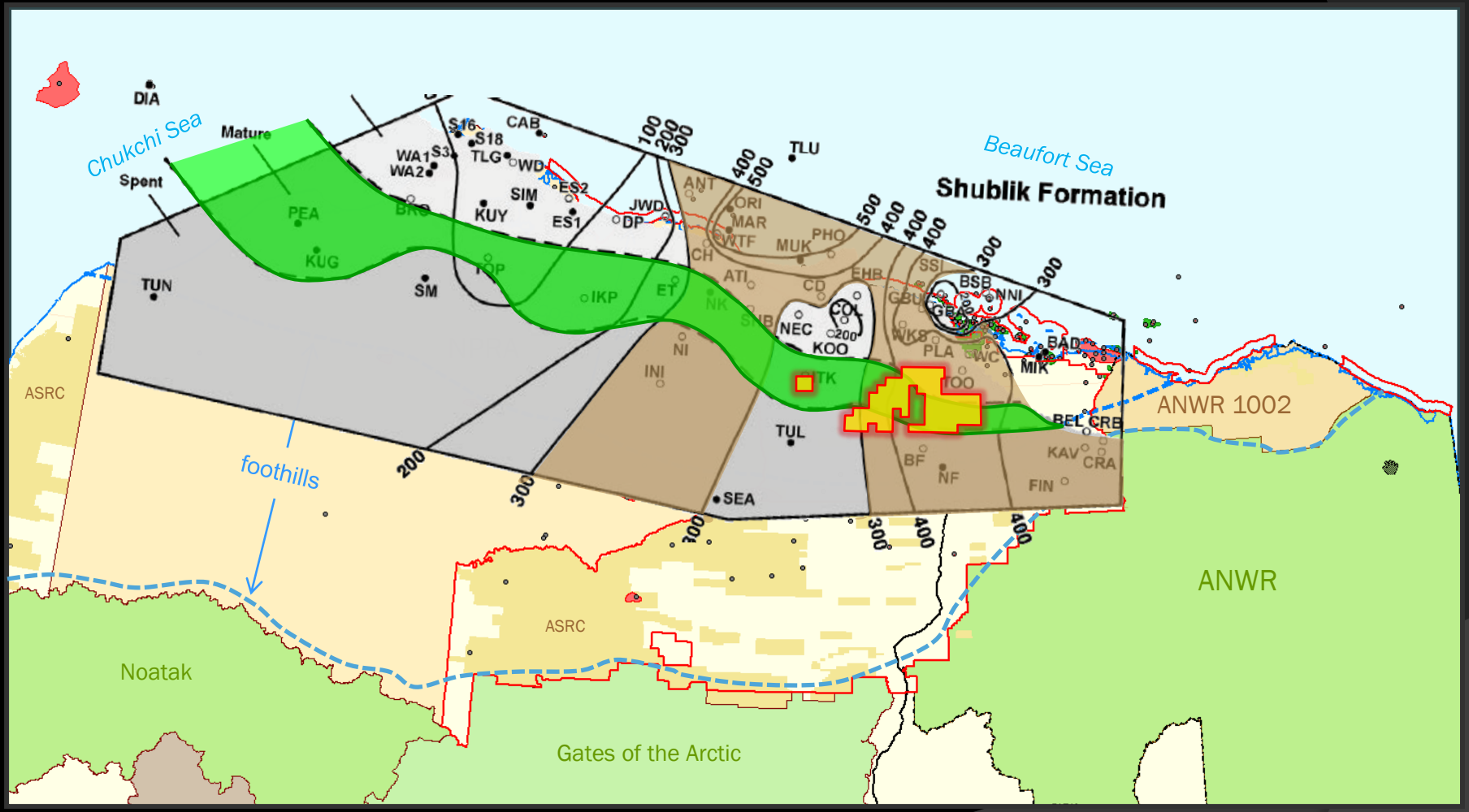


Δ Log R calculated TOC estimates	Itkillik R 1	Atlas 1	Narvaq 1	W Sak 26	Toolik 2	Hemi Spr 3
Hue Sh			4.9%	2.6%	3.1%	4.8% (?)
GRZ	2.6%	2.4%	1.6%	5.0%	3.1%	10.3% (?)

(Decker, unpublished data, 2009)

Shublik Formation

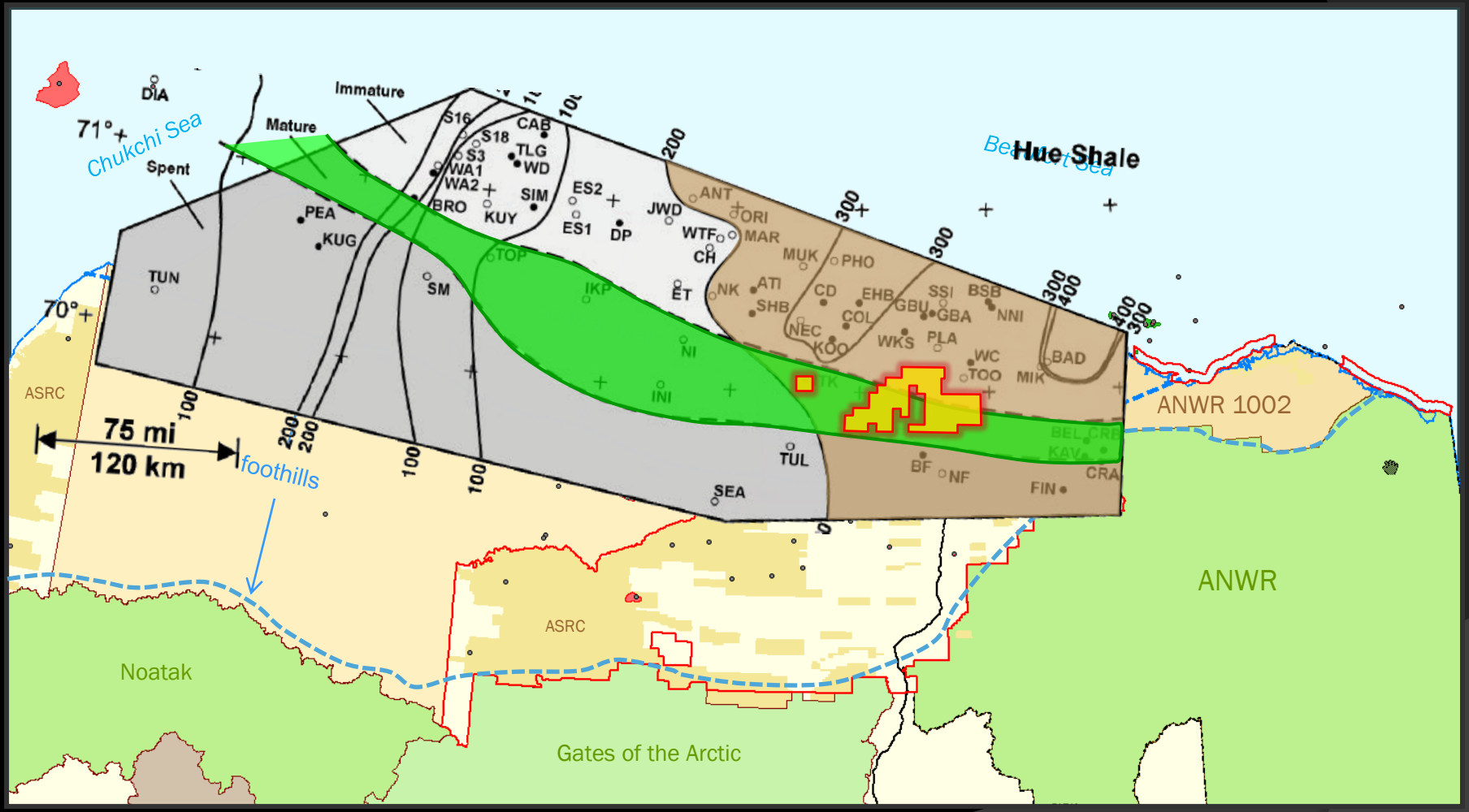
Hydrogen Index and Thermal Maturity



(overlay figure from Peters and others, 2006)

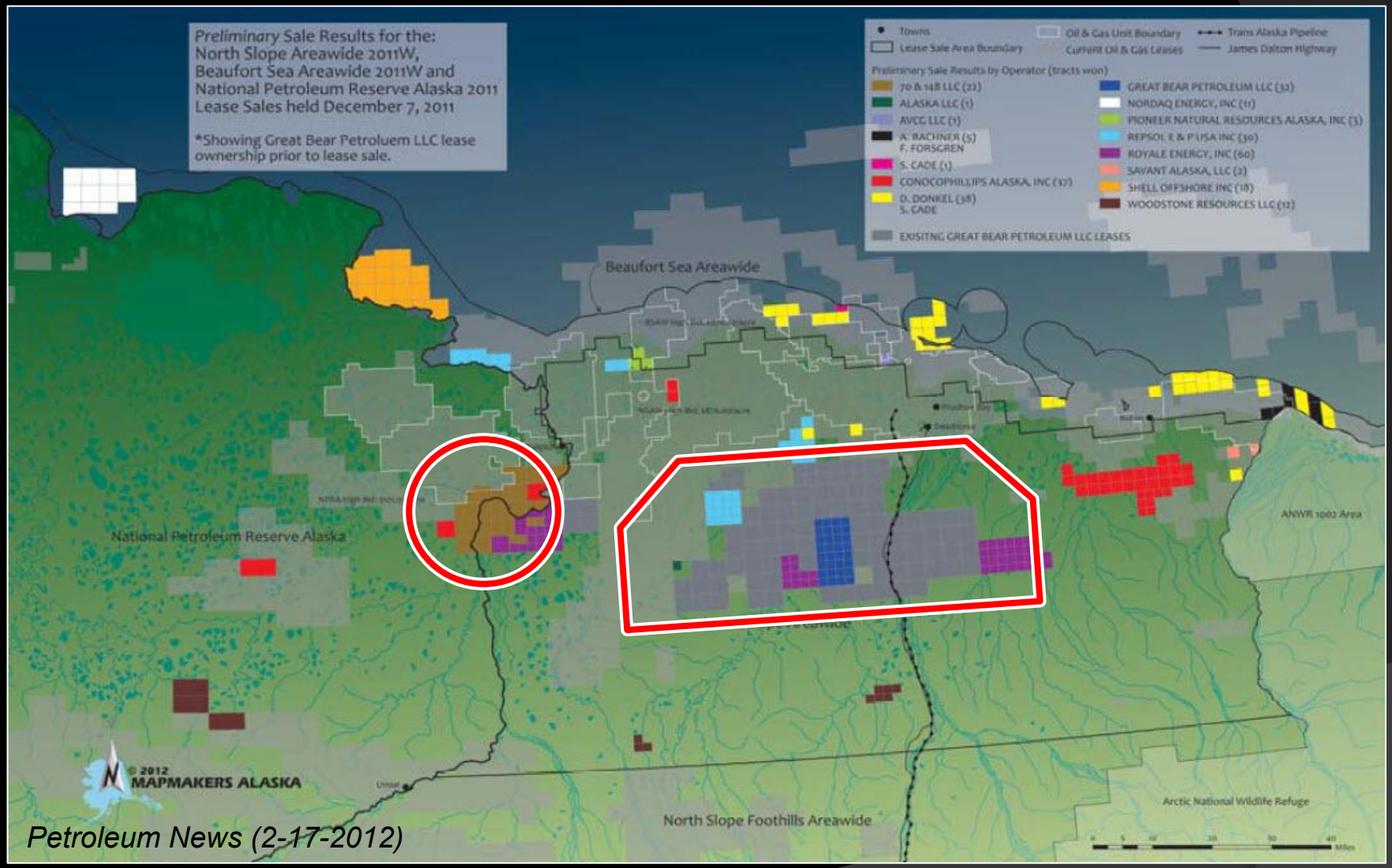
Hue Shale/GRZ

Average Hydrogen Index and Thermal Maturity



(overlay figure from Peters and others, 2006)

2011 Lease Sale Results – Shale oil trend



Petroleum News (2-17-2012)

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 (oil)	I/II (oil)	I/II-S (oil)	II/III (oil-gas)	II/III (oil-gas)
Oil Gravity, °API	42°	30-50°	24-50°	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)

USGS Shale Resource Assessment

Potential for undiscovered, technically recoverable oil and gas

- Brookian shale (Cretaceous)
- Kingak Shale (Jurassic)
- Shublik Formation (Triassic)

All generated oil and gas that migrated into conventional accumulations; all likely retained oil and gas that did not migrate.

Total resources

- Shale Oil: 0 – 2 BBO (mean 940 MMBO)
- Shale NGL: 0 – 571 MMBO (mean 262 MMBO)
- Shale Gas: 0 – 80 trillion cubic feet (mean 42 TCF)

Houseknecht and others, 2012

USGS Shale Resource Assessment

North Slope Results Compared to Other Basins

- **Shale Oil** – *USGS mean estimates of undiscovered oil*
  - Bakken: 3,645 MMBO
  - North Slope: 940 MMBO
  - Eagle Ford: 853 MMBO
  - Woodford (Anadarko): 393 MMBO
  - Niobrara (Powder River B.): 227 MMBO

- **Shale Gas** – *USGS mean estimates of undiscovered gas*
  - Marcellus: 81,374 BCFG
  - Haynesville: 60,734 BCFG
  - Eagle Ford: 50,219 BCFG
  - North Slope: 42,006 BCFG
  - Woodford (Delaware B.): 15,105 BCFG

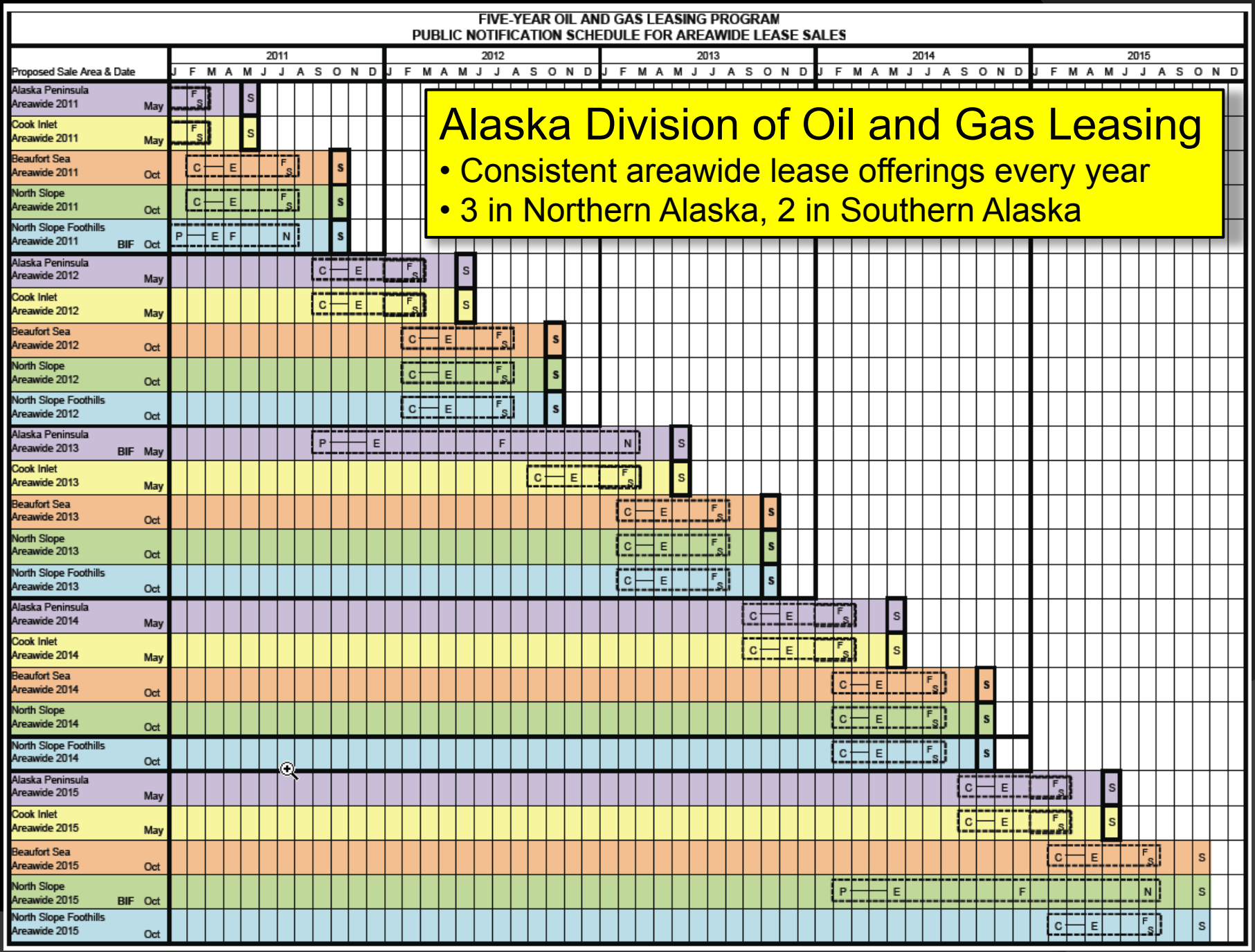
Houseknecht and others, 2012 *Top 5 shale-oil and shale-gas assessment units in rank order*

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

North Alaska Areawide Lease Sales

Scheduled each year in Fall-- All available unleased State tracts

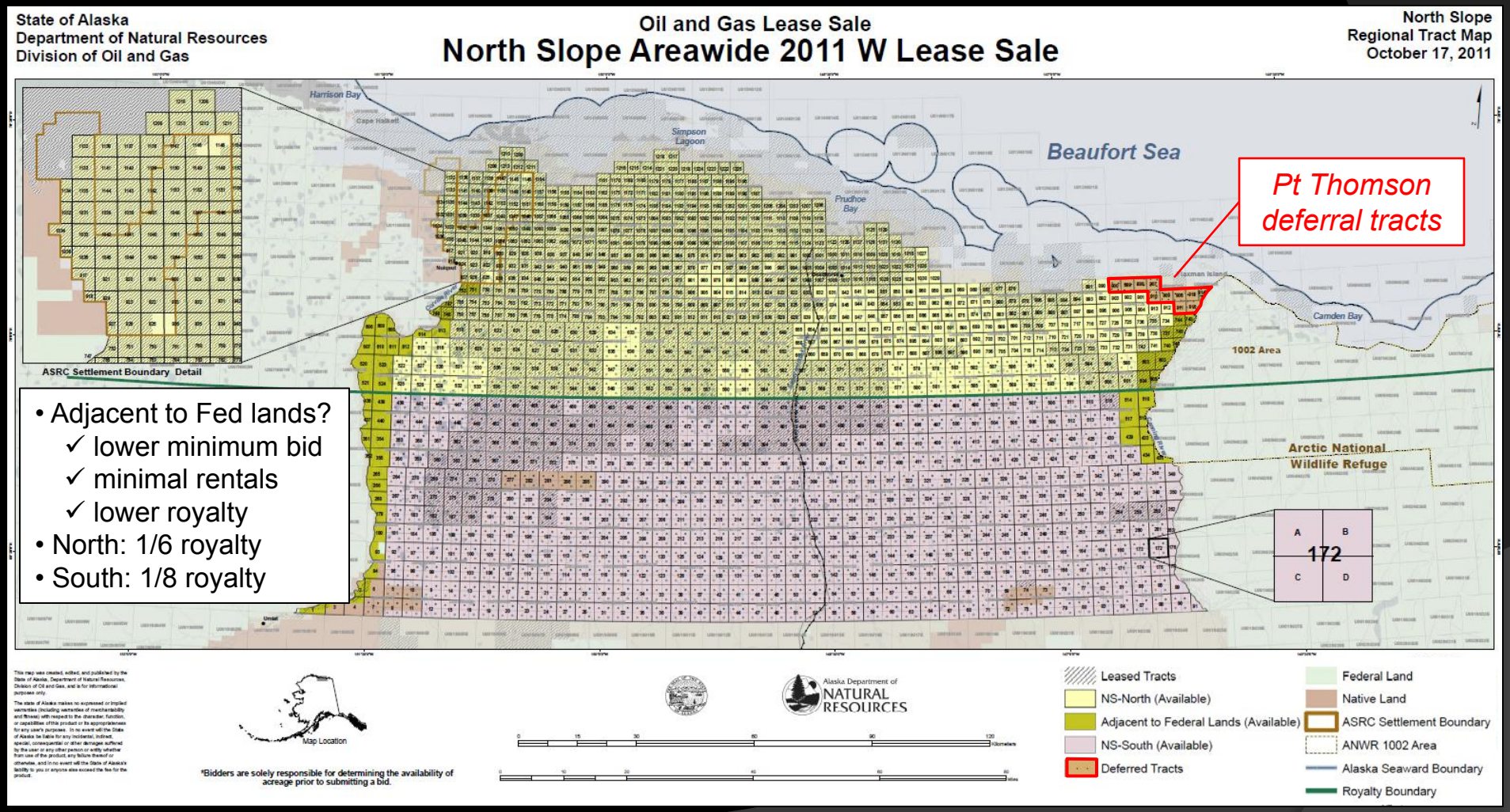


Alaska Division of Oil and Gas Leasing

- Consistent areawide lease offerings every year
- 3 in Northern Alaska, 2 in Southern Alaska

North Slope Areawide Lease Sale

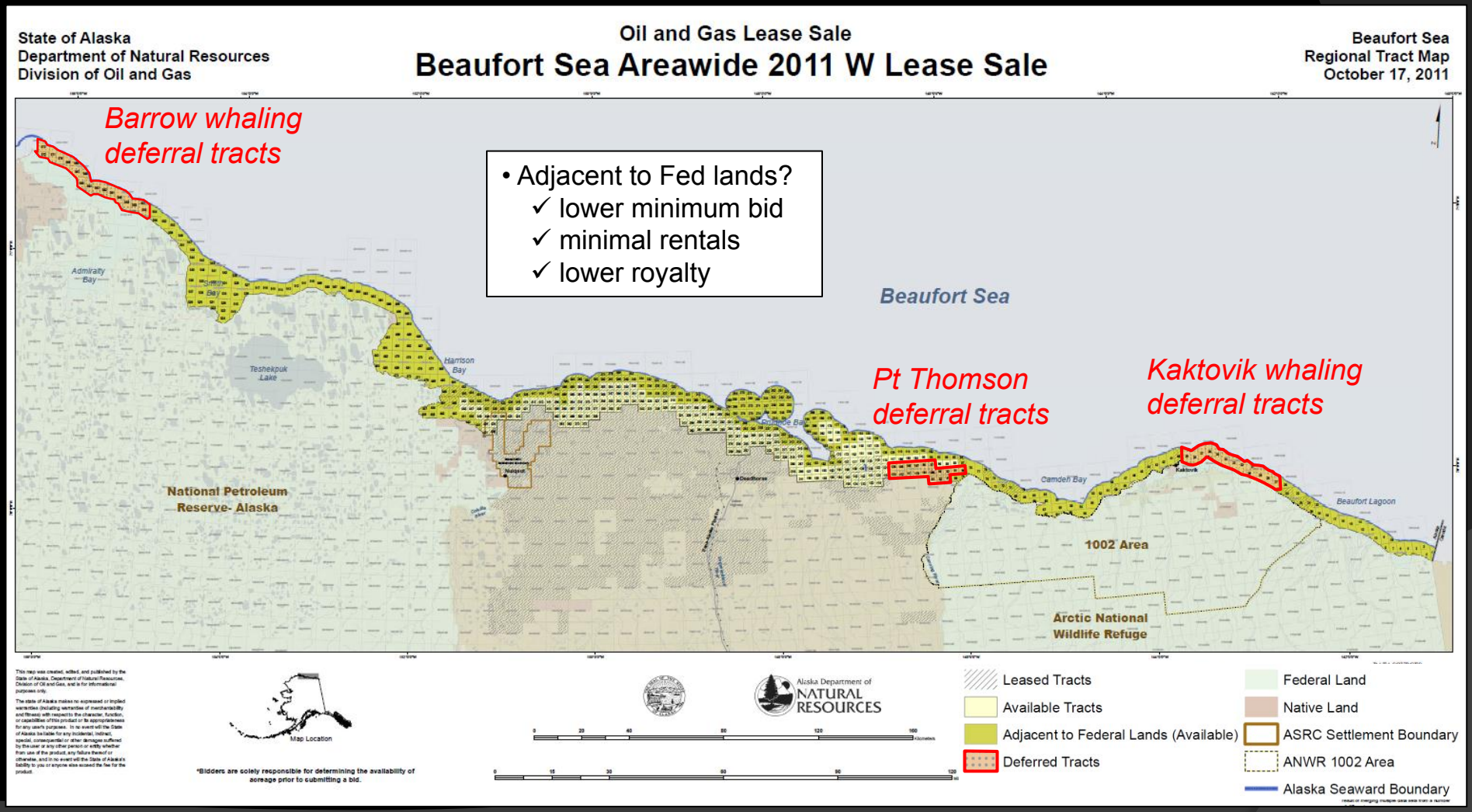
Fall 2011 status – next sale November 2012



- Adjacent to Fed lands?
  - ✓ lower minimum bid
  - ✓ minimal rentals
  - ✓ lower royalty
- North: 1/6 royalty
- South: 1/8 royalty

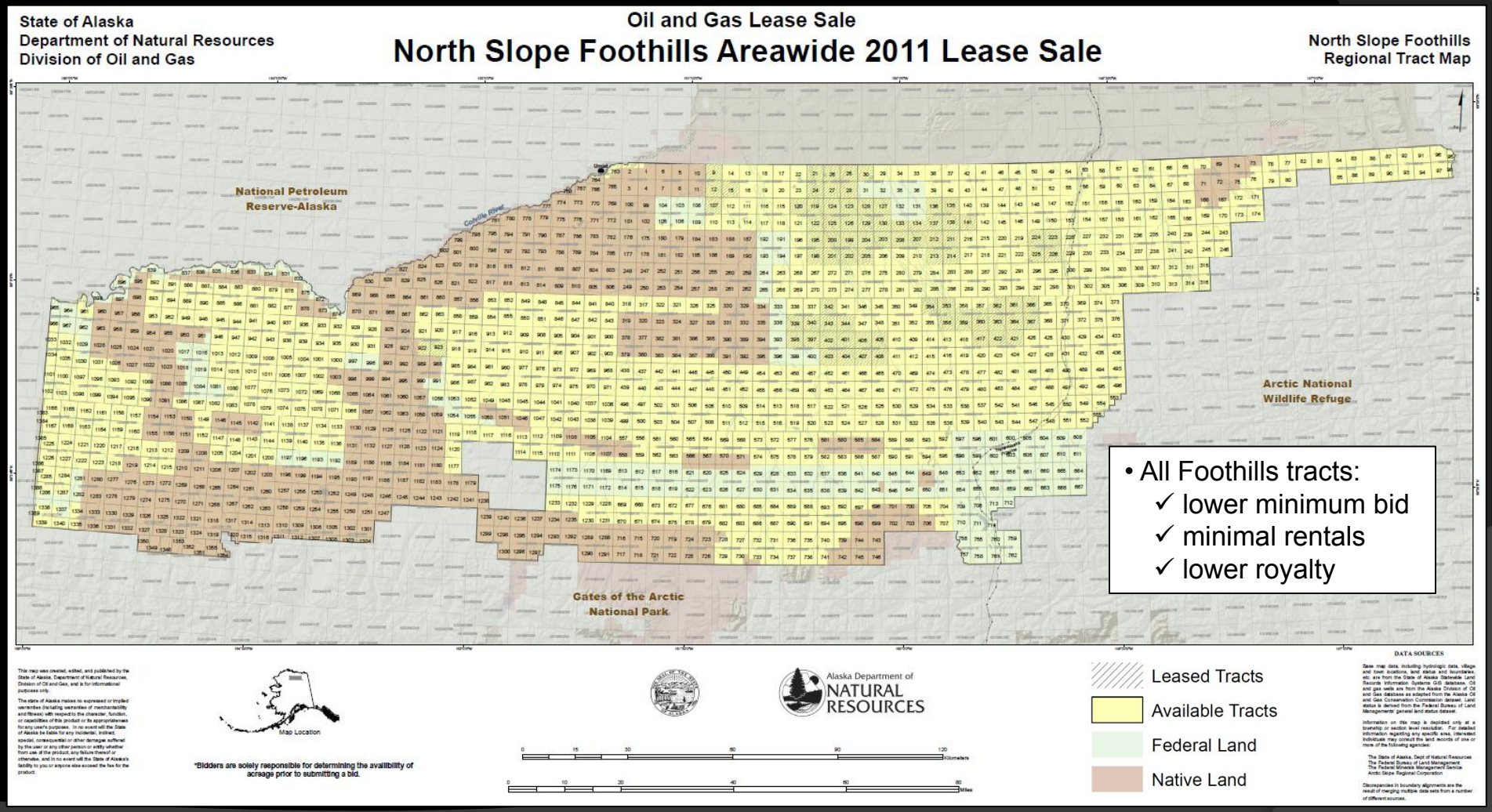
Beaufort Sea Areawide Lease Sale

State-owned waters 0-3 miles from shoreline – next sale November 2012



NS Foothills Areawide Lease Sale

Sale planned for November 2012 (no bids in 2011 sale)



Further Information

- Meet with us in person:
  - Summer NAPE, August 22-24, 2012
    - NAPE Expo booth and Boardroom 334 at the Hilton of the Americas.
    - Contact kathlene.rowell@alaska.gov to arrange a private briefing.
  - Visit our offices

    Alaska Department of Natural Resources
    Division of Oil and Gas
    550 West 7th Avenue, Suite 1100
    Anchorage, Alaska 99501
- Follow-up questions by email: paul.decker@alaska.gov
- Resources Online:
  - DOG website: http://dog.dnr.alaska.gov
  - DGGS website publications page: http://www.dggs.dnr.state.ak.us/publications/index.php
  - AOGCC website: http://doa.alaska.gov/ogc/