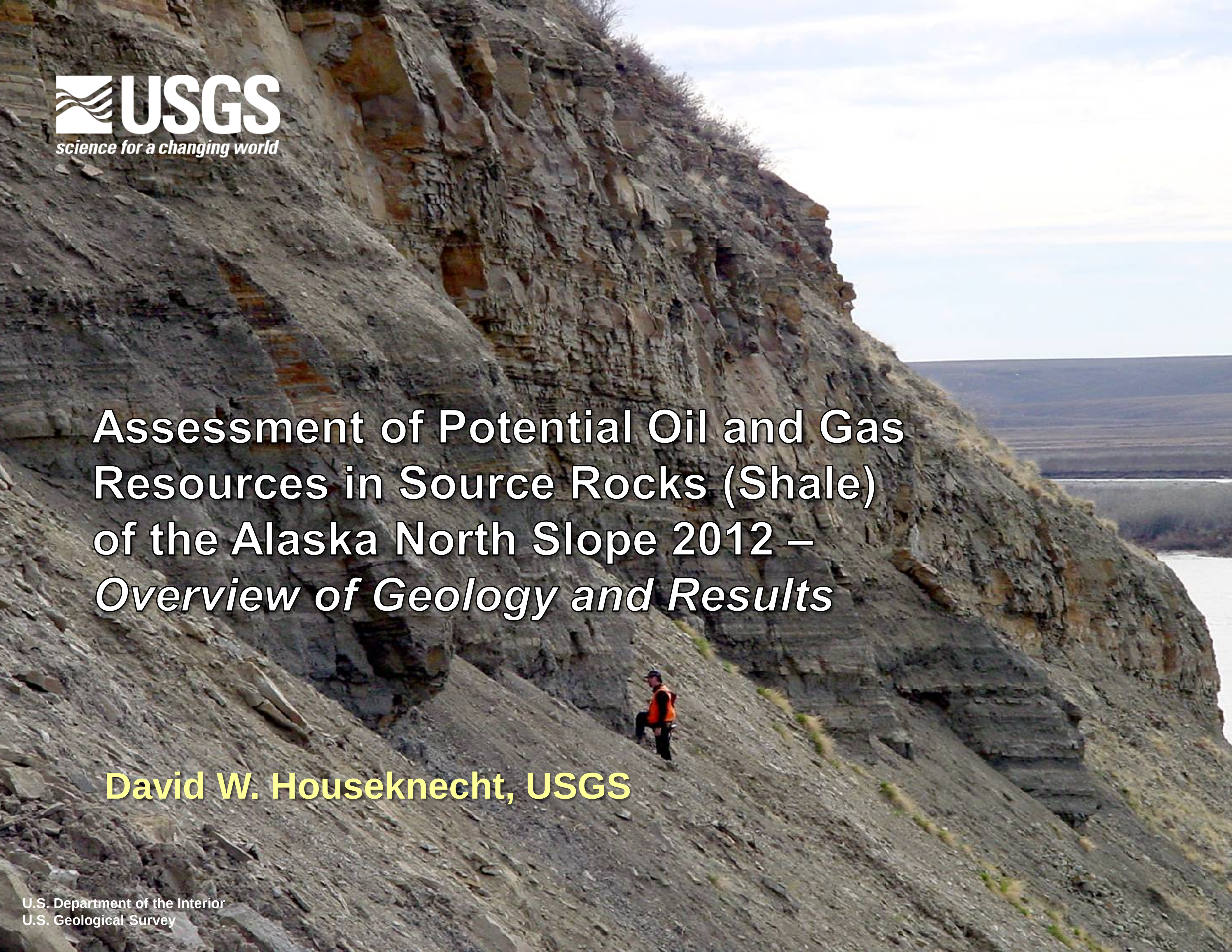

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Assessment of Potential Oil and Gas Resources in Source Rocks (Shale) of the Alaska North Slope 2012 – *Overview of Geology and Results*

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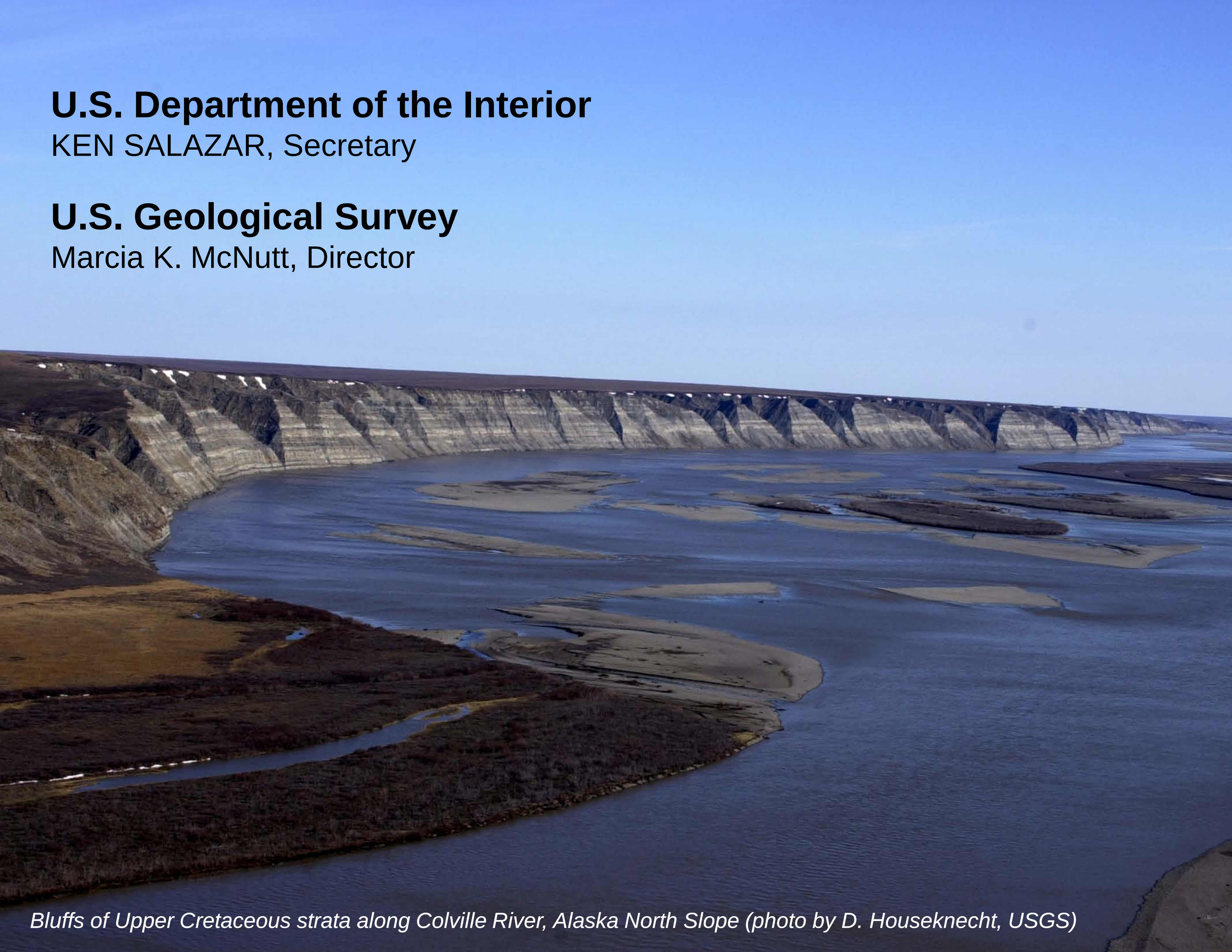

Bluffs of Upper Cretaceous strata along Colville River, Alaska North Slope (photo by D. Houseknecht, USGS)

Summary

USGS assessed potential for undiscovered, technically recoverable oil and gas resources in three North Slope source rocks

- 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: range and mean values*

- **Shale Oil:** **0 – 2 BBO (mean 940 MMBO)**
- **Shale NGL:** **0 – 571 MMBNGL (mean 262 MMBNGL)**
- **Shale Gas:** **0 – 80 TCFG (mean 42 TCFG)**

* Zero values explained on following page; abbreviations defined as follows: BBO, billion barrels of oil; NGL, natural gas liquids; MMBNGL, million barrels of natural gas liquids; TCFG, trillion cubic feet of gas

USGS *Sources of information include Houseknecht et al. (2012a), Magoon et al. (2003), and Peters et al. (2006, 2008).*

Assessment Unit Probability (Risk)

- What is the probability that essential petroleum system elements occur in at least part of the assessment unit (AU)?
- Petroleum system elements considered include source-rock quality and thickness, thermal maturity, presence of brittle rock types, depth, structural deformation, and overpressure.
- In plays that already have oil or gas production from shale, AU probability is 100% .
- In frontier areas with no production from shale, AU probability must be estimated based on evaluation of as many essential petroleum system elements as possible. An AU probability less than 100% typically is estimated for such areas because production is not assured.
- AU probability less than 100% yields results that include zero resources at the high probability end of resource volume distribution.

- <u>Alaska North Slope AU Probabilities</u>:
  - Shublik Oil and Gas AU's: 95% (best set of essential elements)
  - Brookian Oil and Gas AU's: 90% (risk – do source & reservoir rocks occur together?)
  - Kingak Oil AU: 40% (risk - lack of brittle reservoir facies)

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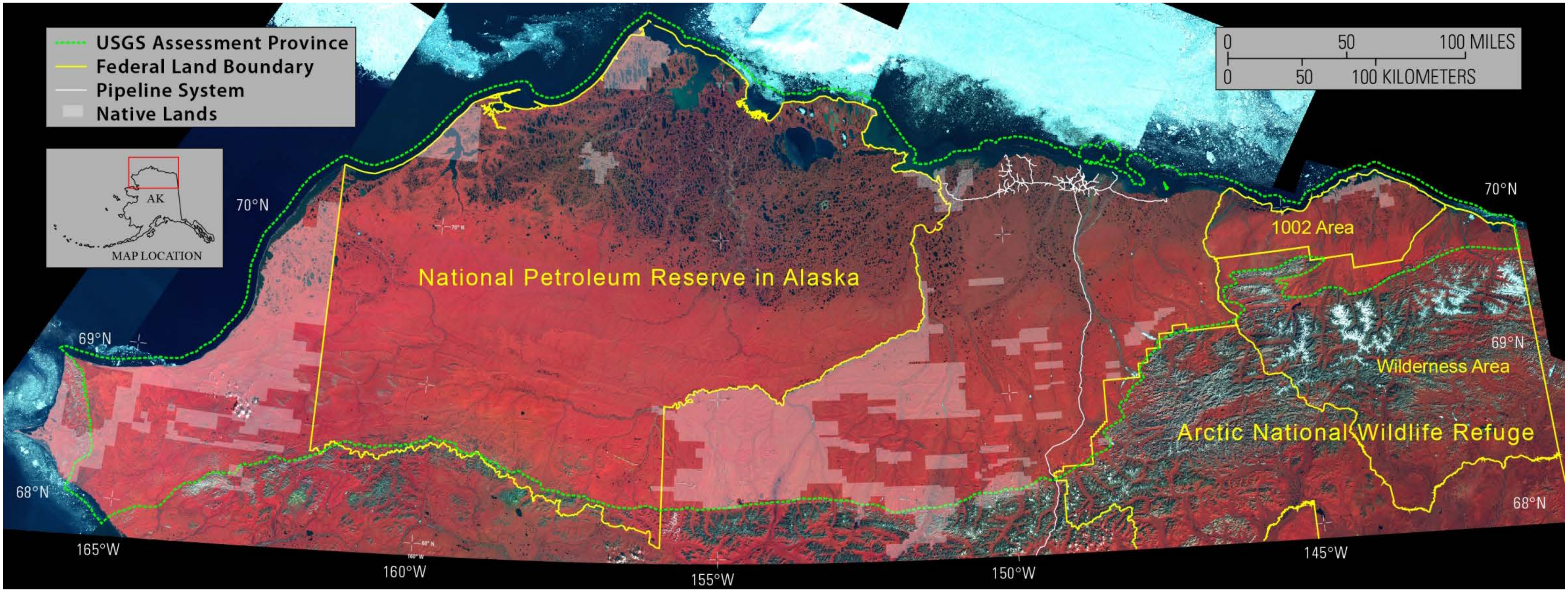
Source of information: Houseknecht et al. (2012)

USGS Northern Alaska Assessment Responsibility



Satellite image of northern Alaska showing outline of USGS Northern Alaska assessment responsibility, which includes all onshore areas north of the Brooks Range and adjacent State waters. This entire area, outlined by the green dashed line, was considered during the assessment of North Slope shale resources.

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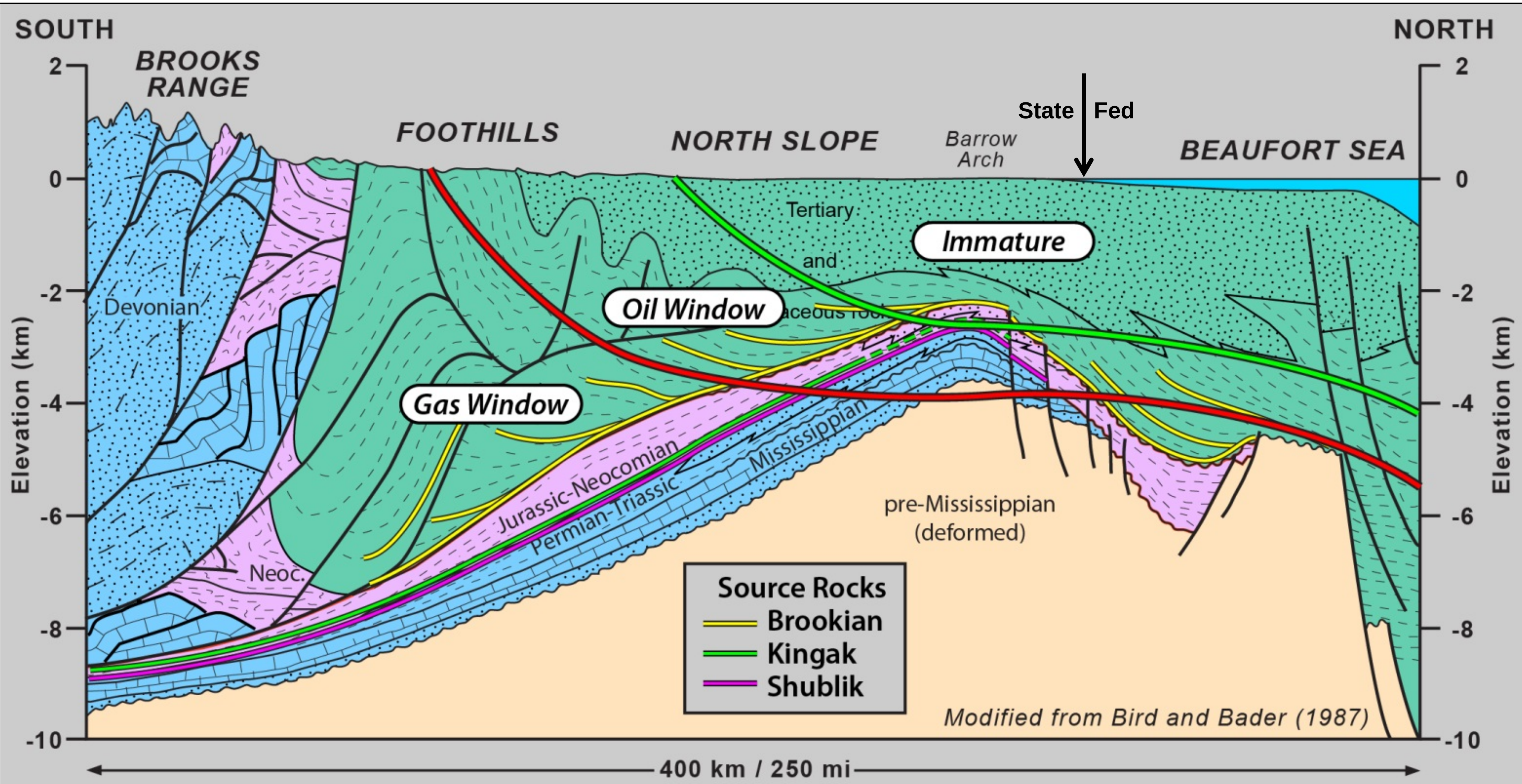
North Slope Petroleum Systems



Geologic cross section from the Brooks Range to the Beaufort shelf showing schematically the distribution of Shublik, Kingak, and Brookian source-rock systems and areas where source rocks are thermally immature, in the oil window, and in the gas window. Areas where each source rock is inferred to fall within the oil and gas windows were used to delineate the oil and gas assessment units, which are shown on the following maps.

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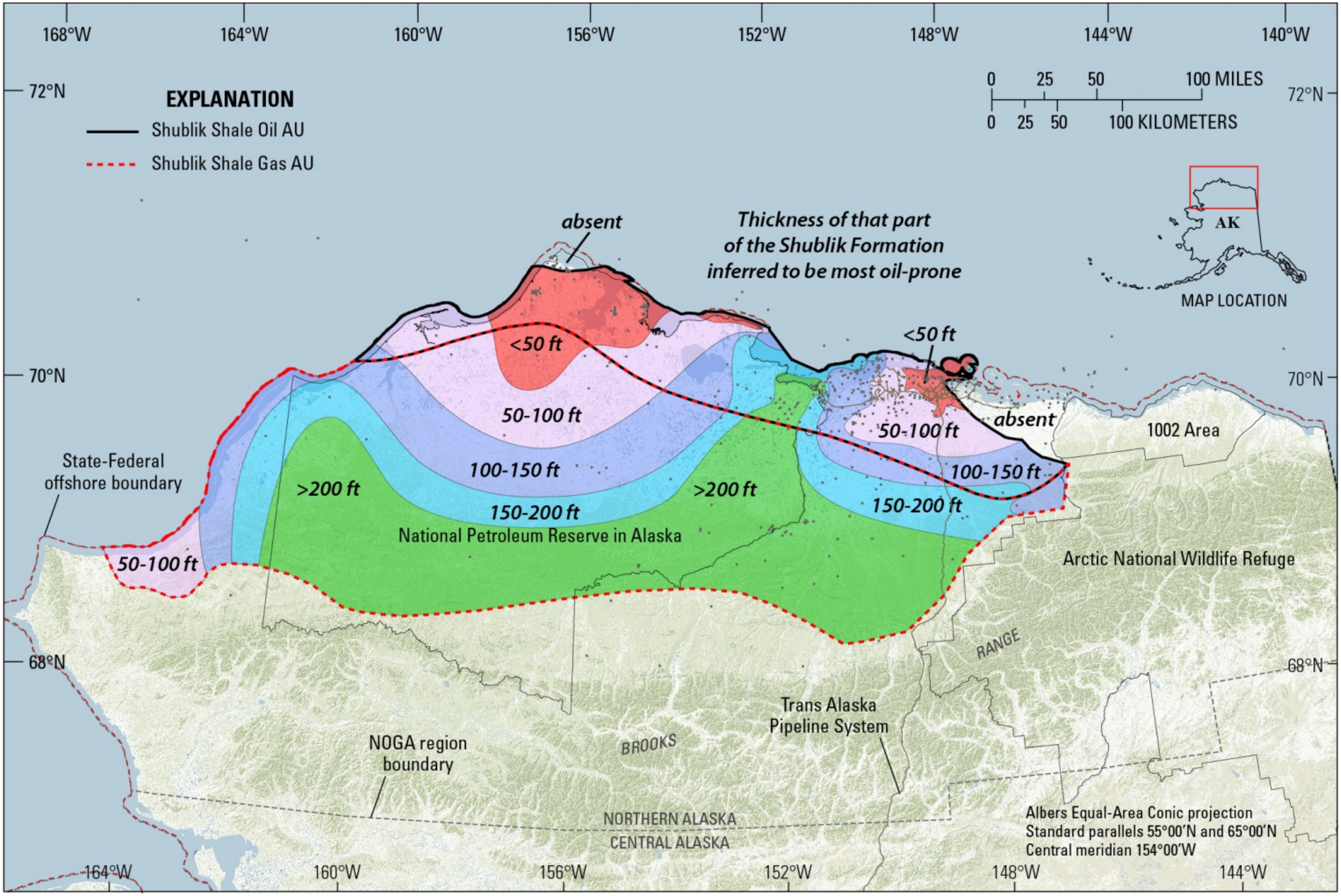
Sources of information include Bird and Bader (1987) and Houseknecht et al. (2012b).

Shublik Formation – Petroleum System Elements



Map of northern Alaska showing boundaries of the Shublik shale-oil and shale-gas assessment units and generalized thickness of those parts of the Shublik Formation inferred to be most oil-prone. Inferred oil-prone character is based on correlation of lithology and stratigraphy (Hulm, 1999; Kelly et al., 2007) with source-rock data (Robison and Dawson, 2001; Peters et al., 2006), and original mapping.

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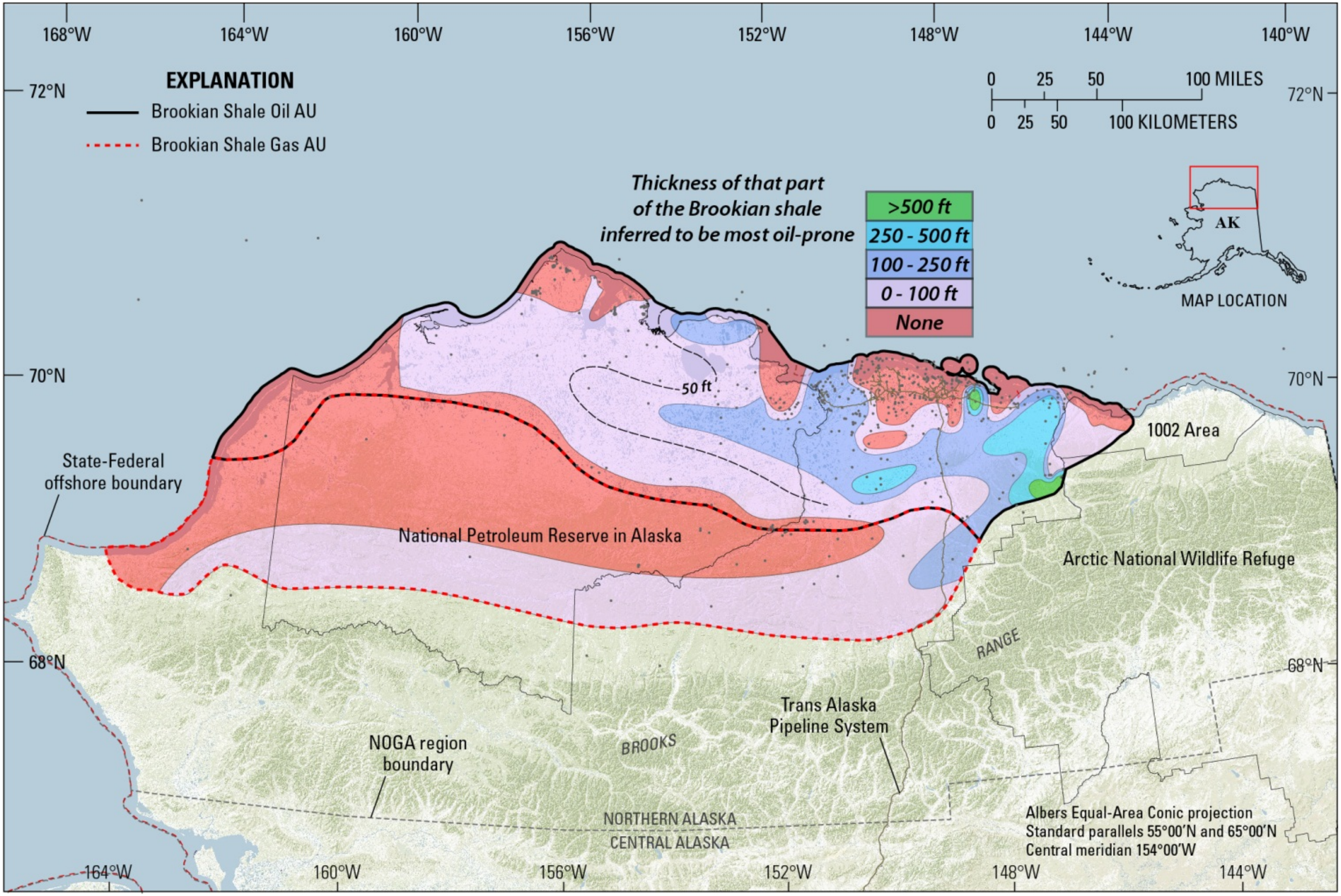
Brookian Shale – Petroleum System Elements



Map of northern Alaska showing boundaries of the Brookian shale-oil and shale-gas assessment units and generalized thickness of those parts of the Brookian shale inferred to be most oil-prone. Inferred oil-prone character is based on mapping of high gamma-ray response (a measure of low-level, natural radioactivity) in exploration well logs, a parameter known to be correlated with organic content in many petroleum source rocks (e.g., Schmoker, 1981).

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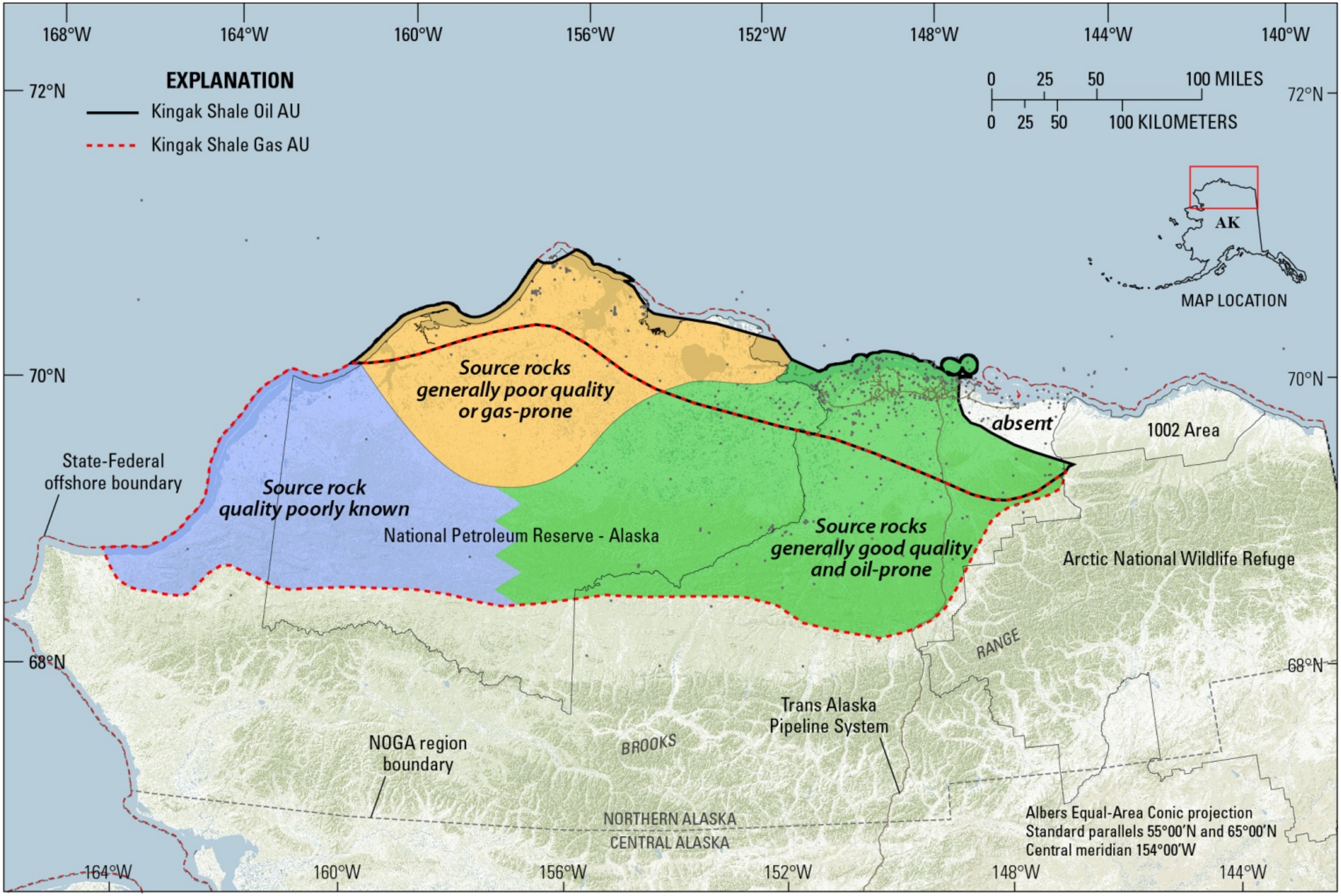
Kingak Shale – Petroleum System Elements



Map of northern Alaska showing boundaries of the Kingak shale-oil and shale-gas assessment units and generalized distribution of parts of the Kingak considered most and least oil-prone. Oil-prone character is based on correlation between previously mapped stratigraphy (Houseknecht and Bird, 2004) and source-rock data (Peters et al., 2006).

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Results by Source Rock – Oil Assessment Units

Shublik Shale Oil Assessment Unit

Oil:	0 – 928 MMBO	(mean 463 MMBO)
Associated Gas:	0 – 981 BCFG	(mean 462 BCFG)
Nat. Gas Liquids:	0 – 26 MMBNGL	(mean 12 MMBNGL)

Brookian Shale Oil Assessment Unit

Oil:	0 – 955 MMBO	(mean 449 MMBO)
Associated Gas:	0 – 1,996 BCFG	(mean 898 BCFG)
Nat. Gas Liquids:	0 – 51 MMBNGL	(mean 22 MMBNGL)

Kingak Shale Oil Assessment Unit

Oil:	0 – 117 MMBO	(mean 28 MMBO)
Associated Gas:	0 – 238 BCFG	(mean 57 BCFG)
Nat. Gas Liquids:	0 – 6 MMBNGL	(mean 1 MMBNGL)

Abbreviations defined as follows: MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids

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Source of information: Houseknecht et al. (2012a).

Results by Source Rock – Gas Assessment Units

Shublik Shale Gas Assessment Unit

Nonassociated Gas:	**0 – 72,195 BCFG**	**(mean 38,405 BCFG)**
Nat. Gas Liquids:	**0 – 442 MMBNGL**	**(mean 205 MMBNGL)**

Brookian Shale Gas Assessment Unit

Nonassociated Gas:	**0 – 4,375 BCFG**	**(mean 2,184 BCFG)**
Nat. Gas Liquids:	**0 – 46 MMBNGL**	**(mean 22 MMBNGL)**

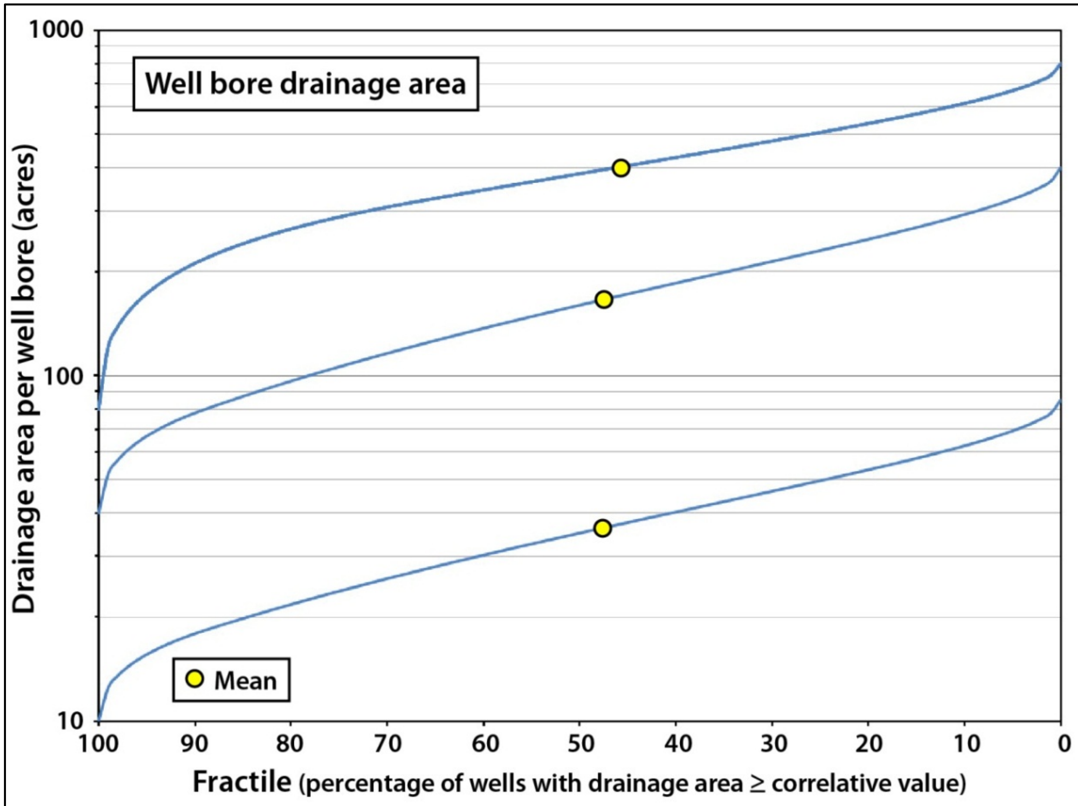
Kingak Shale Gas Assessment Unit

No quantitative assessment conducted

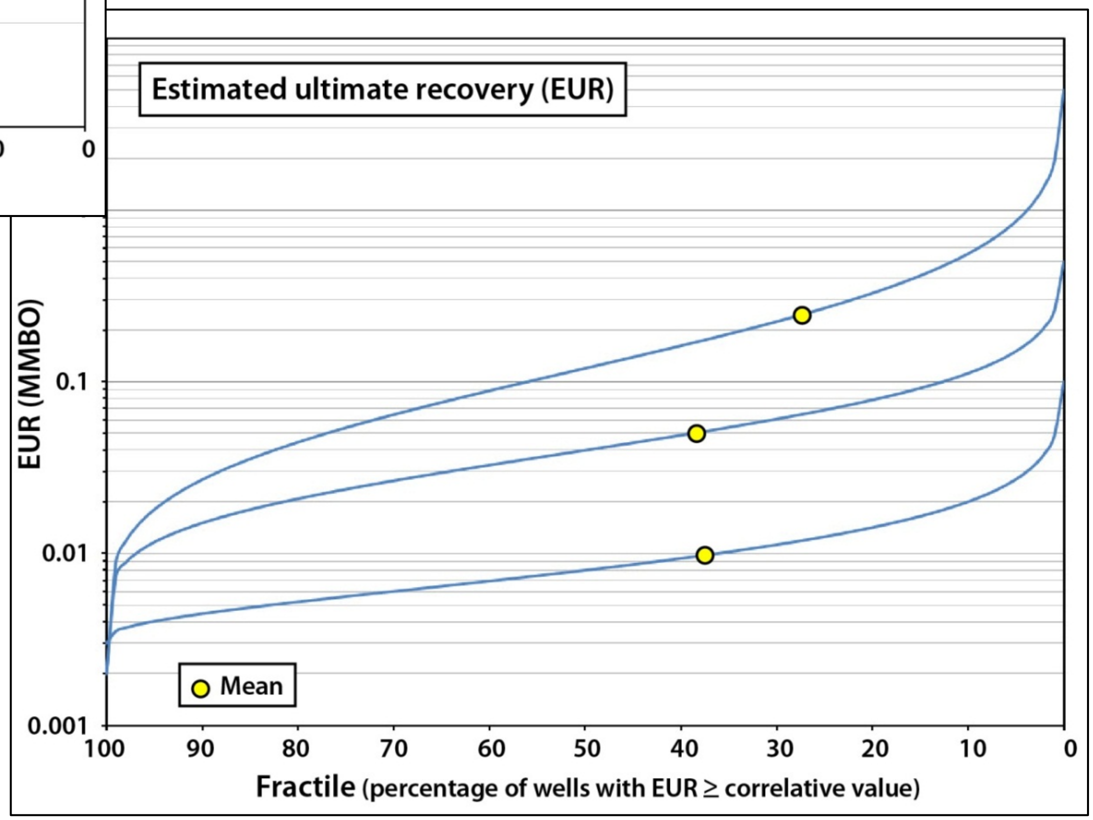
Abbreviations defined as follows: BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids

Source of information: Houseknecht et al. (2012a).

Drainage Area and EUR



These plots illustrate conceptual distributions of well bore drainage area and estimated ultimate recovery (EUR) – they are based on shale-oil analogs in the lower-48 states. Assessment inputs include the means for three distributions estimated to represent minimum, mode, and maximum cases for each AU. Distributions such as these are used to capture the uncertainty inherent in the assessment of untested shale plays.



These plots represent probability distributions of well drainage area and productivity. For example, if wells in a shale-oil play perform like the middle EUR distribution at right: the worst well might produce ~2,000 barrels of oil (0.002 MMBO), the best well might produce ~500,000 barrels of oil (0.5 MMBO), and the average well might produce ~50,000 barrels of oil (0.05 MMBO).

Additional background on generation and use of plots such as these is available in Charpentier and Cook (2011).

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Shublik Shale-Oil Assessment Inputs

Implications – Success and Well Productivity

Assessment input data	Shublik Shale Oil AU			
	Min.	Mode	Max.	Mean
Potential production area (million acres)	5.0	7.3	7.5	6.6
Average drainage area of wells (acres)	100	160	400	220
Percentage of AU in sweet spots (%)	0.5	15.0	40.0	18.5
Input for inside sweet spots				
Average EUR (MMBO, oil; BCFG, gas)	0.020	0.050 *	0.250 *	0.061
Success ratio (%)	70 *	85 *	95 *	83
Input for outside sweet spots				
Average EUR (MMBO, oil; BCFG, gas)	0.010	0.025	0.125	0.031
Success ratio (%)	0	10	70	27

* Success ratio inside sweet spots may range from 70 to 95 percent.

* Inside sweet spots – <u>mean</u> of EUR distributions:
in middle of performance spectrum: 50,000 BO
at top of performance spectrum: 250,000 BO

This page illustrates how the assessment input data provided in Table 1 of Houseknecht et al. (2012a) can be used to build scenarios of shale-oil play performance. Note that uncertainty is included in all input data. Some of the greatest uncertainty is associated with (1) the percentage of the AU that may be "sweet spots" (areas of greater well productivity – see Schmoker, 2005 for more on sweet spots), (2) well success in sweet spots (highlighted by the blue asterisks), and (3) EUR. The red asterisks emphasize that the average well might produce 50,000 barrels of oil (BO) if the Shublik inside sweet spots performs according to a probability distribution in the middle of the performance spectrum (mode input) and might produce 250,000 BO if the Shublik inside sweet spots performs according to a probability distribution at the top of the performance spectrum.

Shublik Shale-Oil Assessment Inputs

Implications – Footprint

Assessment input data	Shublik Shale Oil AU			
	Min.	Mode	Max.	Mean
Potential production area (million acres)	5.0	7.3 *	7.5	6.6
Average drainage area of wells (acres)	100	160 *	400	220
Percentage of AU in sweet spots (%)	0.5	15.0 *	40.0	18.5
Input for inside sweet spots				
Average EUR (MMBO, oil; BCFG, gas)	0.020	0.050	0.250	0.061
Success ratio (%)	70	85	95	83
Input for outside sweet spots				
Average EUR (MMBO, oil; BCFG, gas)	0.010	0.025	0.125	0.031
Success ratio (%)	0	10	70	27

* Area of sweet spots: 7.3 million acres x 15% = 1.1 million acres

* Number of well bores to develop sweet spots:
  1.1 million acres / 160 acres per well bore = 6,844 well bores

  Potentially 3 to 8 well bores per surface location (pad) = 855 to 2,280
  pads x 1 to 2 acres per pad = 855 to 4,560 acres

This page illustrates how the assessment input data provided in Table 1 of Houseknecht et al. (2012a) can be used to build scenarios for potential surface impact of shale-oil development.

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**

Comparisons are based on USGS mean estimates of undiscovered shale oil and shale gas: http://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment/AssessmentUpdates.aspx

Lists include 5 shale-oil and shale-gas assessments by estimated mean resource and presented in rank order. MMBO, million barrels of oil; BCFG, billion cubic feet of gas.

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