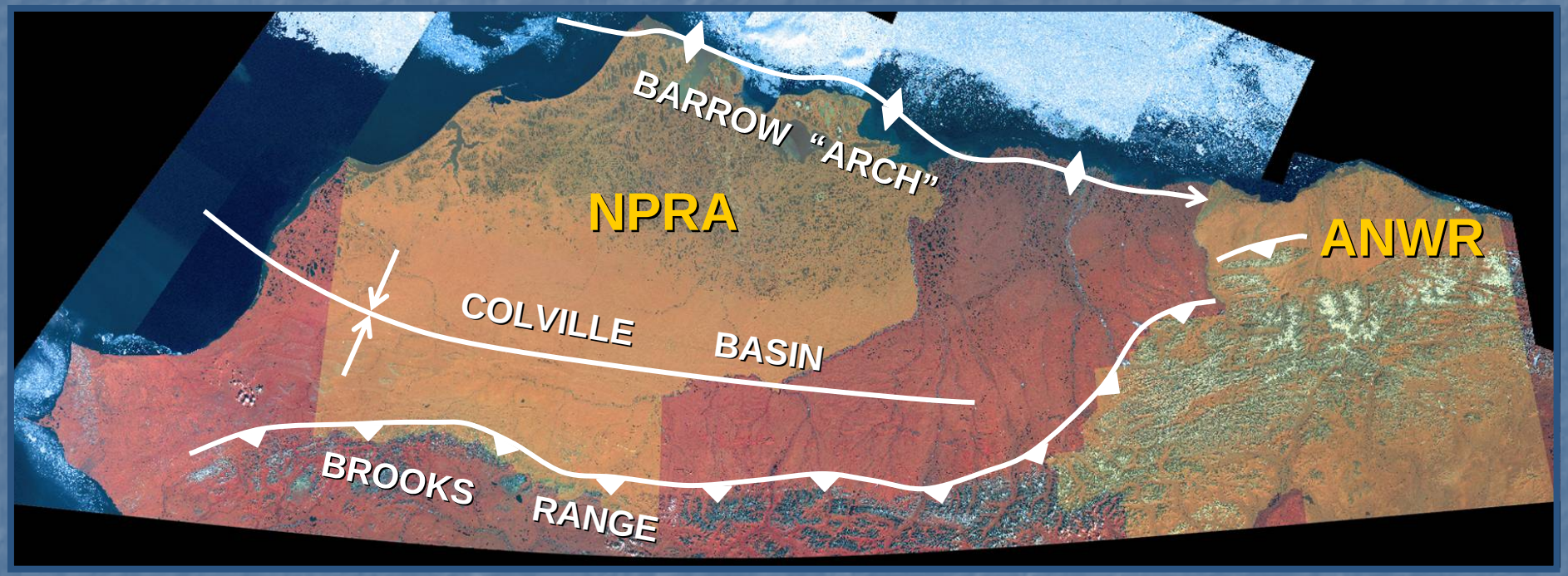
# Summary of Recent North Slope Studies—Lower Cretaceous Southern Colville Basin



# Introductory Comments:

**This material was presented at a Department of Natural Resources Technical Review Meeting held in Anchorage on March 26th, 2008. This public gathering was aimed at creating a venue to formalize the rapid communication data and results from ongoing work by the Division of Geological & Geophysical Surveys (DGGS) and Division of Oil & Gas (DOG). Additionally, this meeting sought to stimulate discussion on the petroleum geology of northern Alaska.**

**The following presentation was created and delivered by Marwan Wartes (DGGS). The version included here is only slightly modified from the original; in the absence of a speaker, some slides have been annotated to improve improve clarity and any animations have been removed.**

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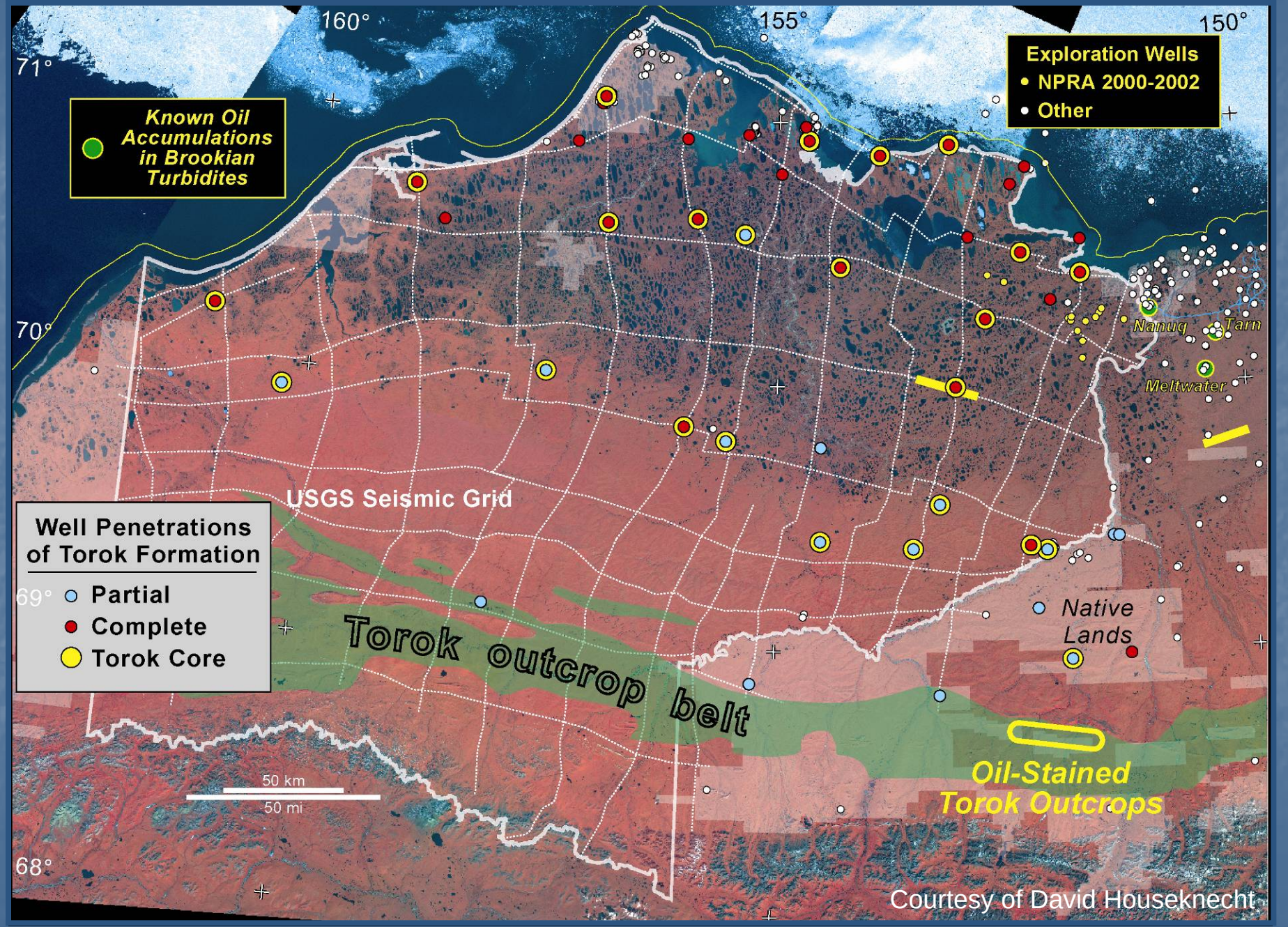
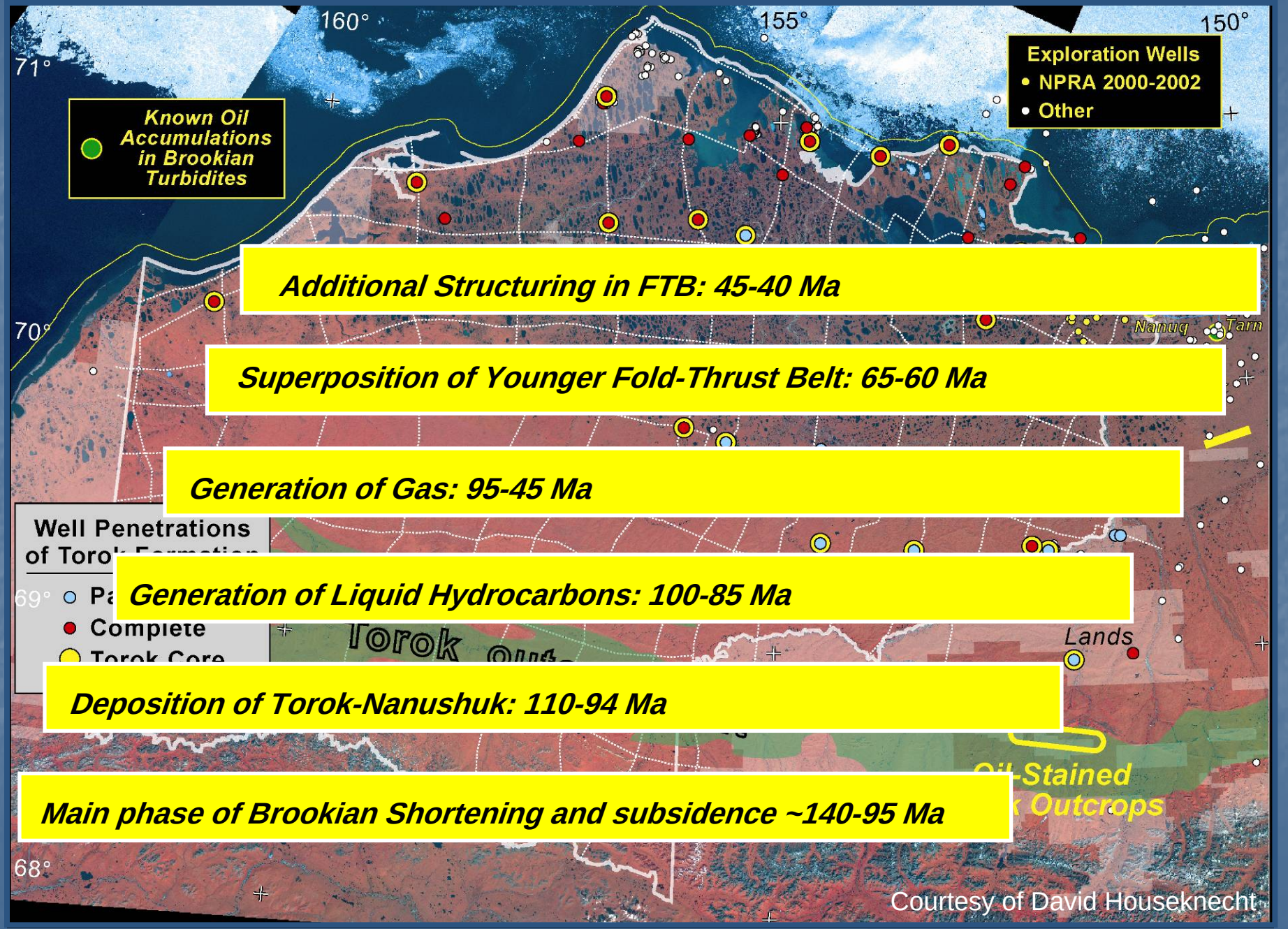
# Timing of Key Events

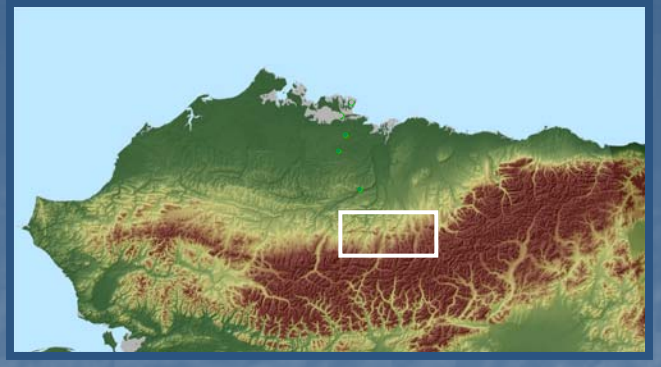


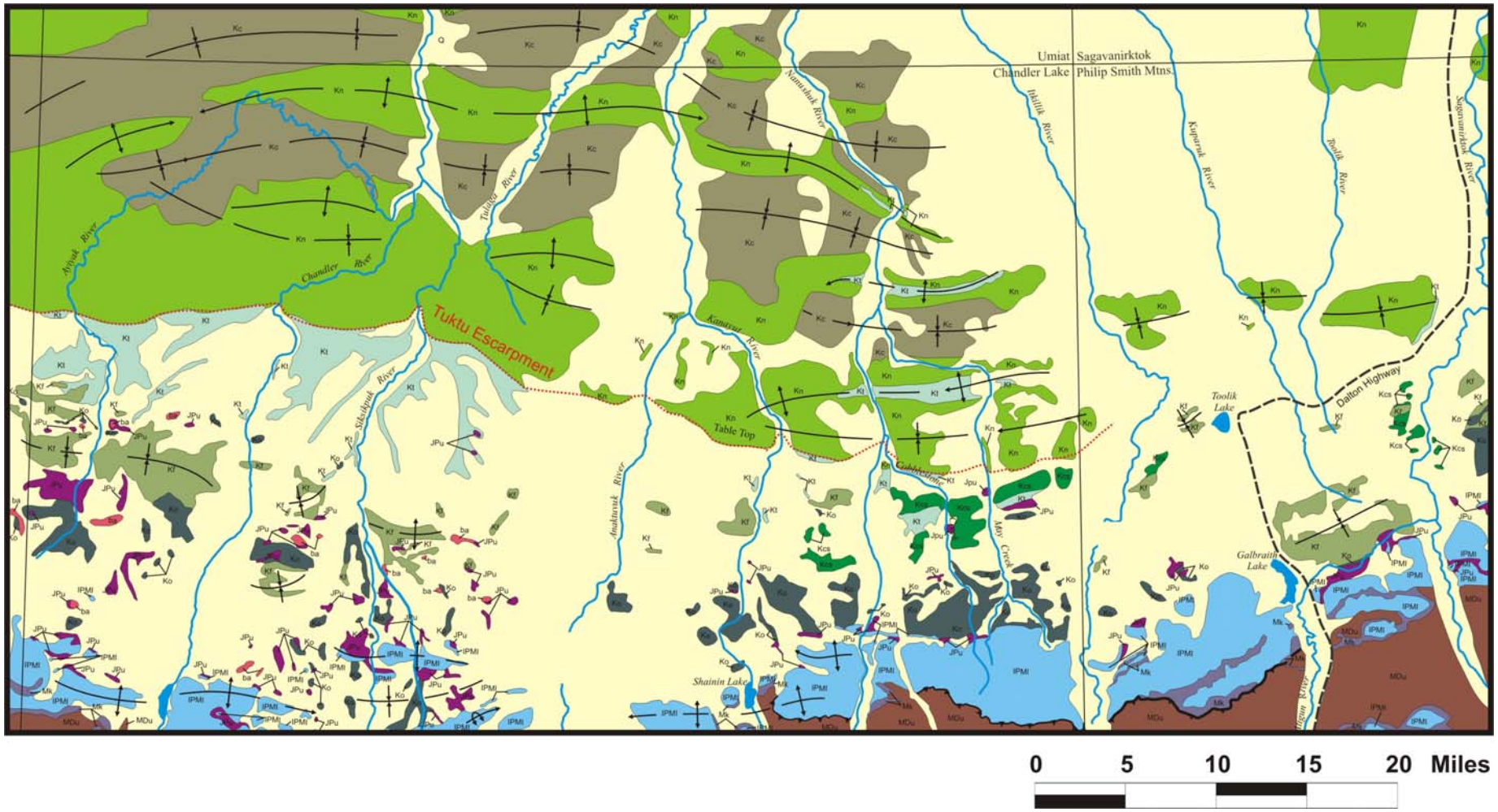
# Timing of Key Events



# 2007 Program Focus

- Proximal Foreland Basin

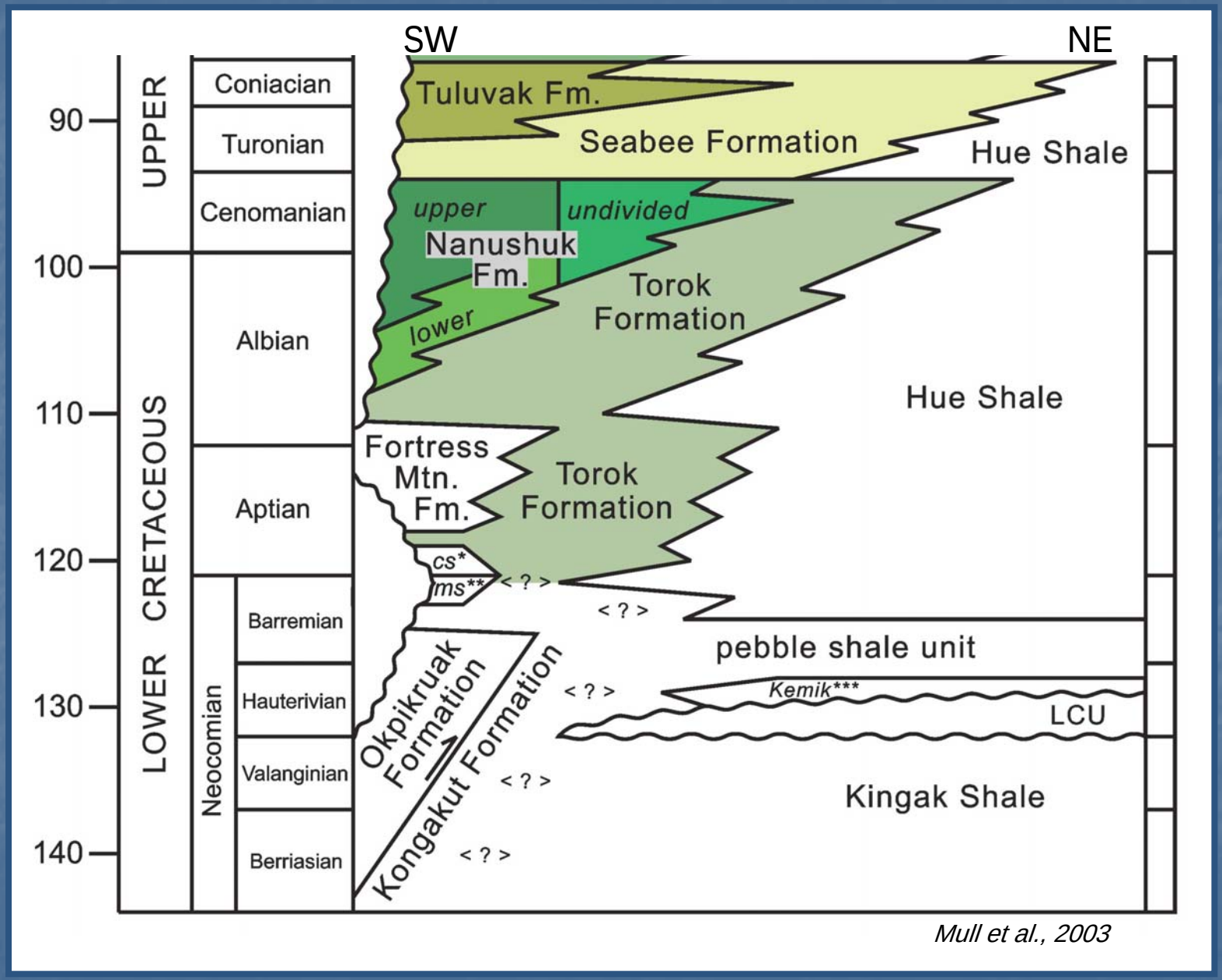




# 2007 Program Focus

- **NORTHERN (East-central North Slope)**
  - ***Sedimentology and Sequence Stratigraphy of Upper Cretaceous and Tertiary Exposures in the Sagavanirktok River Area***
  - ***Stratigraphy, Structural Geology, and Depositional Setting of Albian-Turonian Rocks in the Gilead Area***
- **SOUTHERN (Proximal Foreland Basin)**
  - ***Reconstruction of the Lower Cretaceous Depositional System, Southern Colville Basin***
  - ***Structural Evolution of the Brooks Range Foothills—Constraining Burial History and Timing in the Foothills Province***
- **GENERAL**
  - ***Controls on Brookian Sandstone Reservoir Quality***
  - ***Source Rock Quality and Hydrocarbon Occurrence***
  - ***Geologic Mapping***

# Stratigraphy



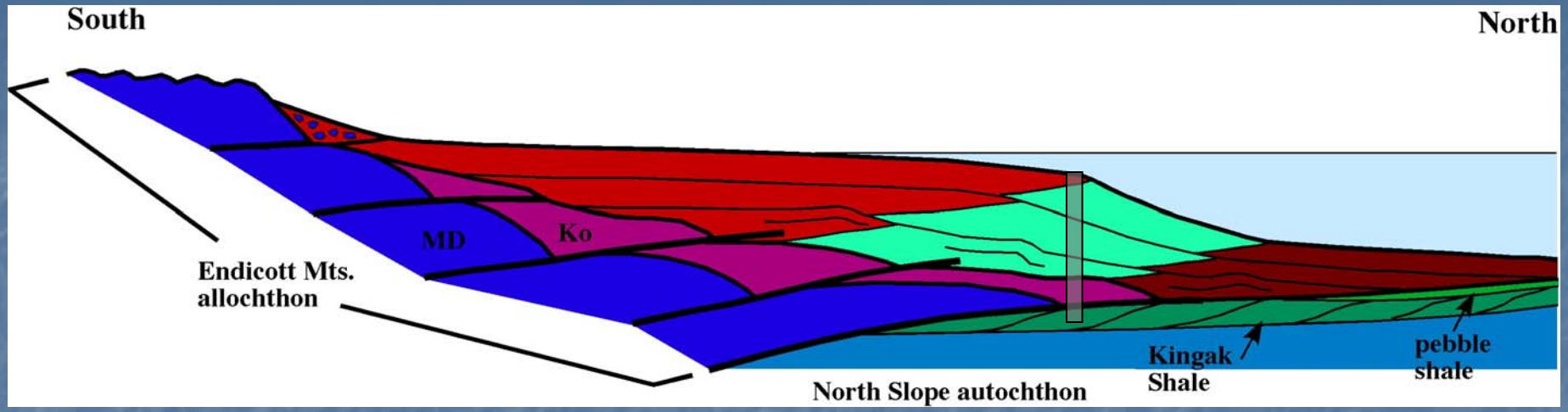

*Mull et al., 2003*

# Okpikruak Formation (Berriasian-Valanginian)

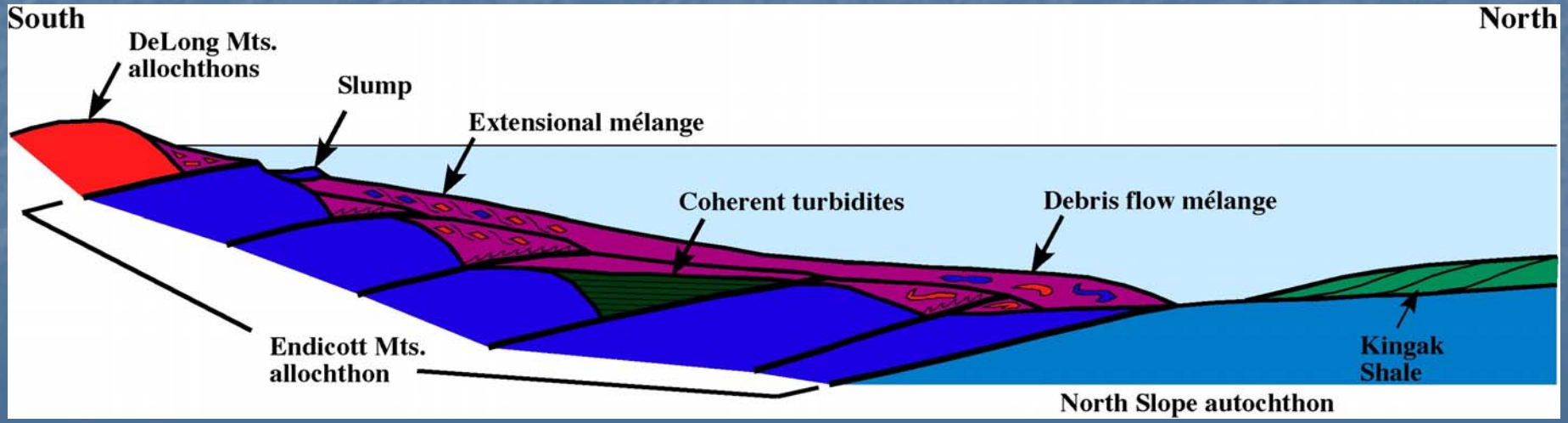
- Earliest record of Brookian orogenesis
- Probable upward transition into Fortress Mountain Formation
- Locally overlies Kingak Shale in Section Creek area
- Identified several new coquinoid limestone localities (key marker bed)

*View of ~75 m (Section Creek)*

# Fortress Mountain time




# Okpikruak time




*Courtesy of W. Wallace*

# Phosphatic-Manganiferous Shale (informal unit)

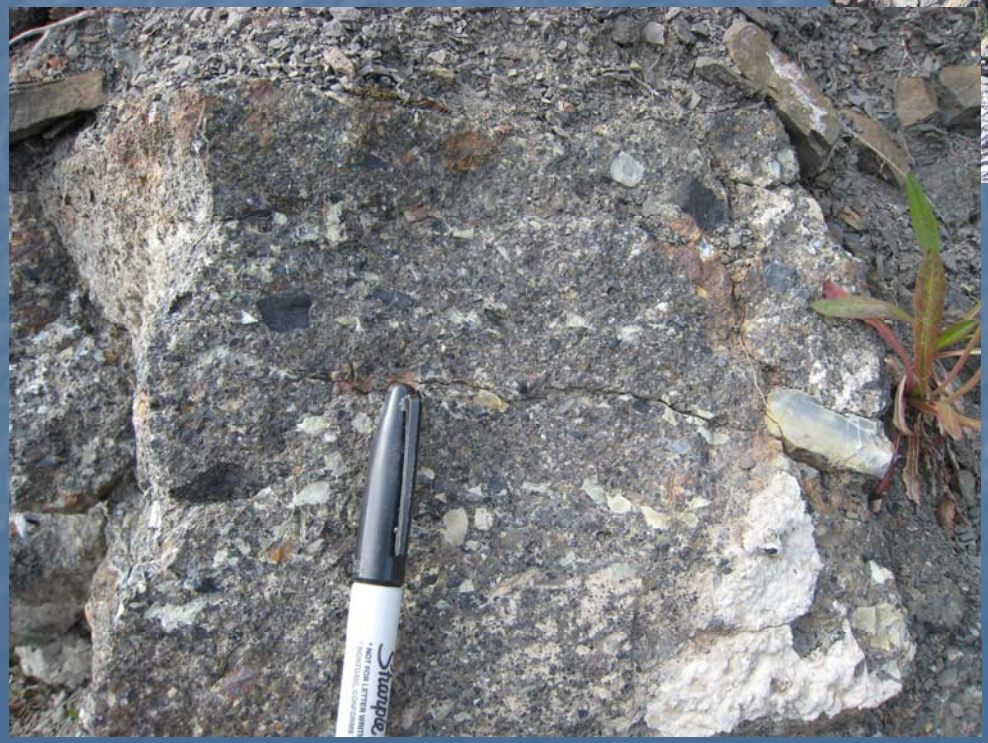
- Enigmatic early Brookian mudstone
- Probable record of change in basin polarity (sediment dispersal direction)
- Correlative to Beaufortian Pebble Shale unit (Barremian-Aptian(?))

*Cobblestone Creek*

# Cobblestone Ss
## (Barremian(?) – Aptian(?))

- Basal Fortress Mountain
- Amalgamated sediment gravity flows
- Unique petrology
- Probable correlative with “Kfmv” unit

*Cobblestone Creek*

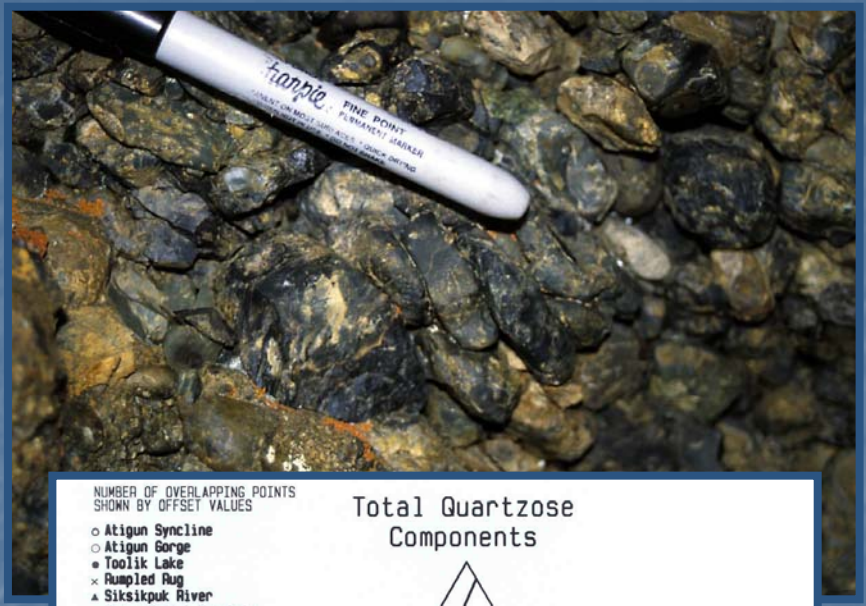


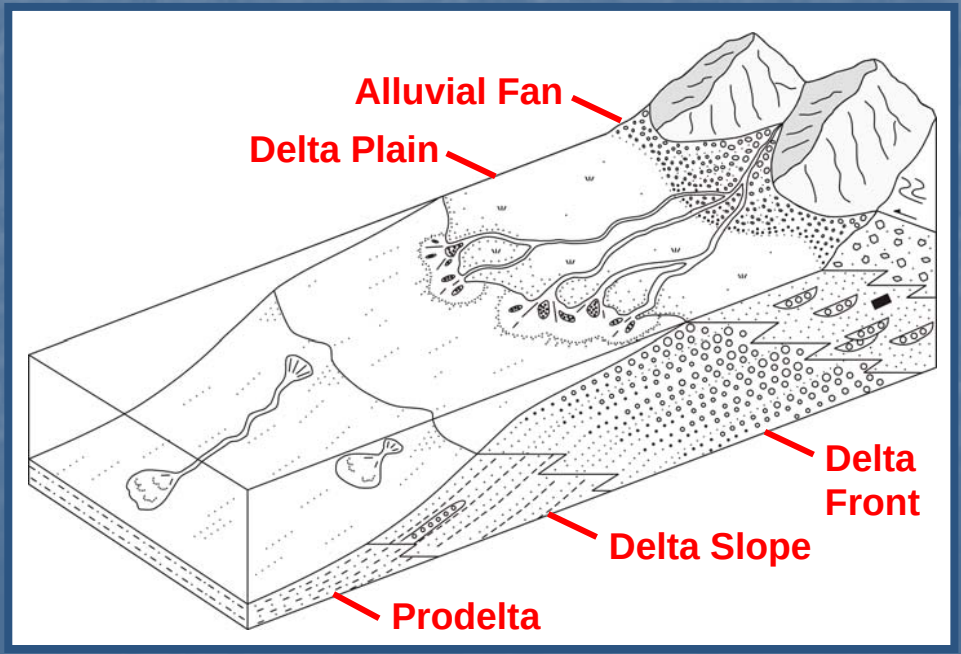
*Nanushuk River*

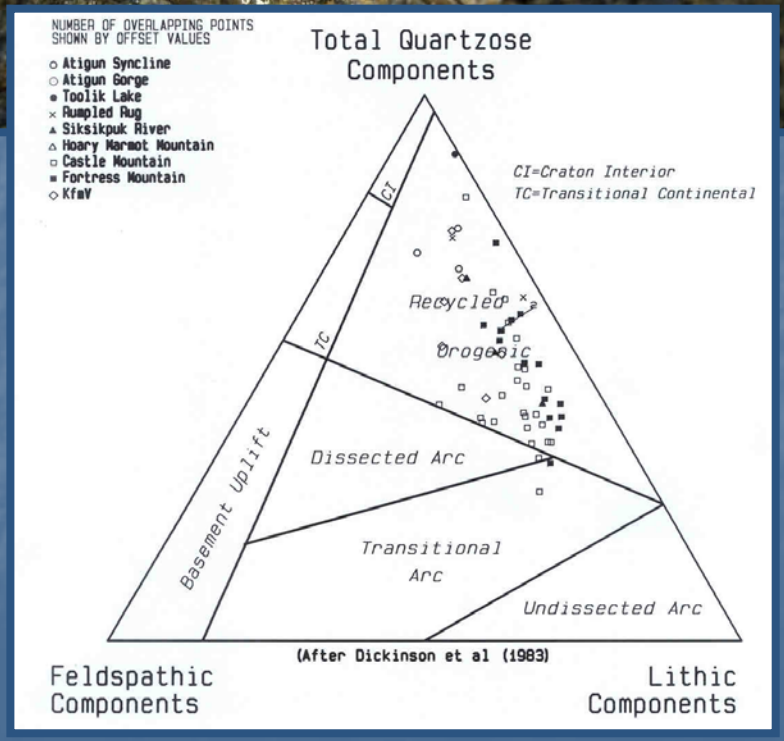

*Kfmv unit (Tiglukpuk Creek)*

# Fortress Mtn. Formation (Barremian(?)- early Albian)

- Facies Analysis
- Depositional Model
- Reservoir Quality

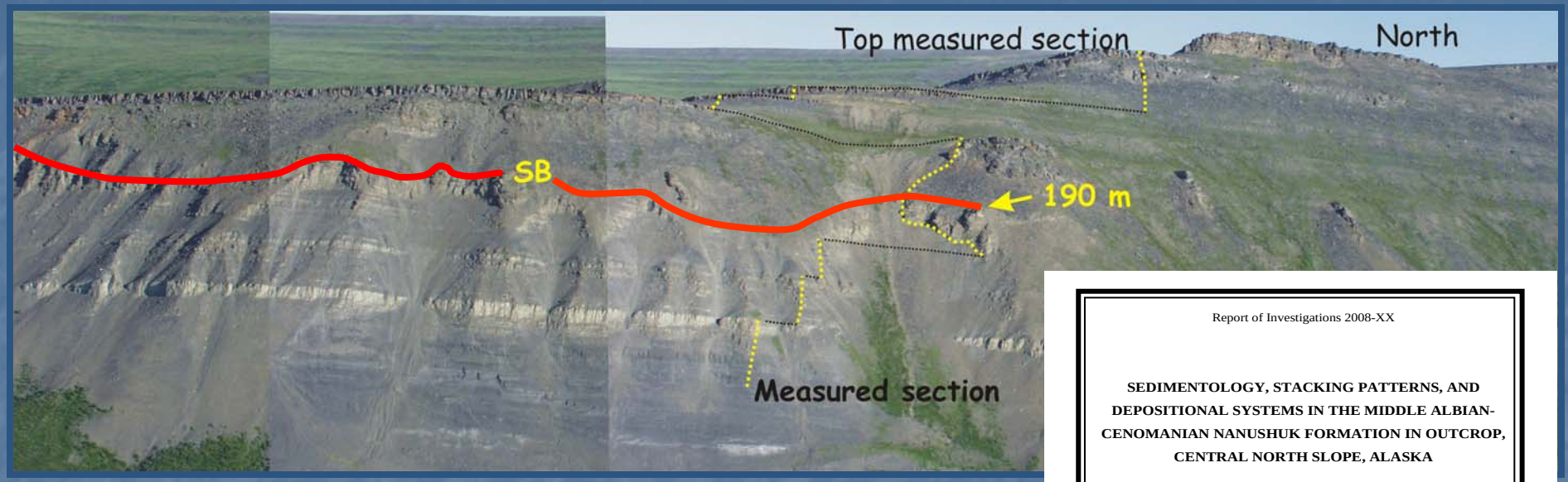


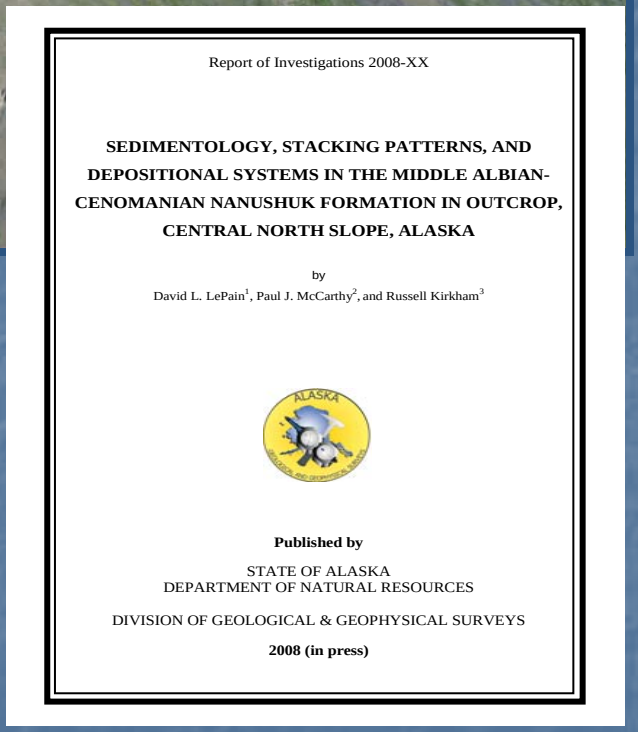

*Wartes, 2008*

# Nanushuk Formation (middle Albian – Cenomanian)




## Multi-year Study:

- Sedimentology
- Facies analysis
- Biostratigraphy
- Ichnology
- Sequence stratigraphy



Report of Investigations 2008-XX

**SEDIMENTOLOGY, STACKING PATTERNS, AND DEPOSITIONAL SYSTEMS IN THE MIDDLE ALBIAN-CENOMANIAN NANUSHUK FORMATION IN OUTCROP, CENTRAL NORTH SLOPE, ALASKA**

by

David L. LePain[1], Paul J. McCarthy[2], and Russell Kirkham[3]

**Published by**

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DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

**2008 (in press)**

LePain et al., in press

Division of Geological & Geophysical Surveys

**PRELIMINARY INTERPRETIVE REPORT 2008-1**

# PRELIMINARY RESULTS OF RECENT GEOLOGIC FIELD INVESTIGATIONS IN THE BROOKS RANGE FOOTHILLS AND NORTH SLOPE, ALASKA

by
Marwan A. Wartes and Paul Decker, *editors*

March 2008



Released by
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Fairbanks, Alaska 99709-3707

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**D** Measured sections and preliminary interpretations of the Nanushuk Formation exposed along the Colville River near the confluences with the Awuna and Killik rivers

**E** Geochemistry of the Aupuk gas seep along the Colville River—Evidence for a thermogenic origin

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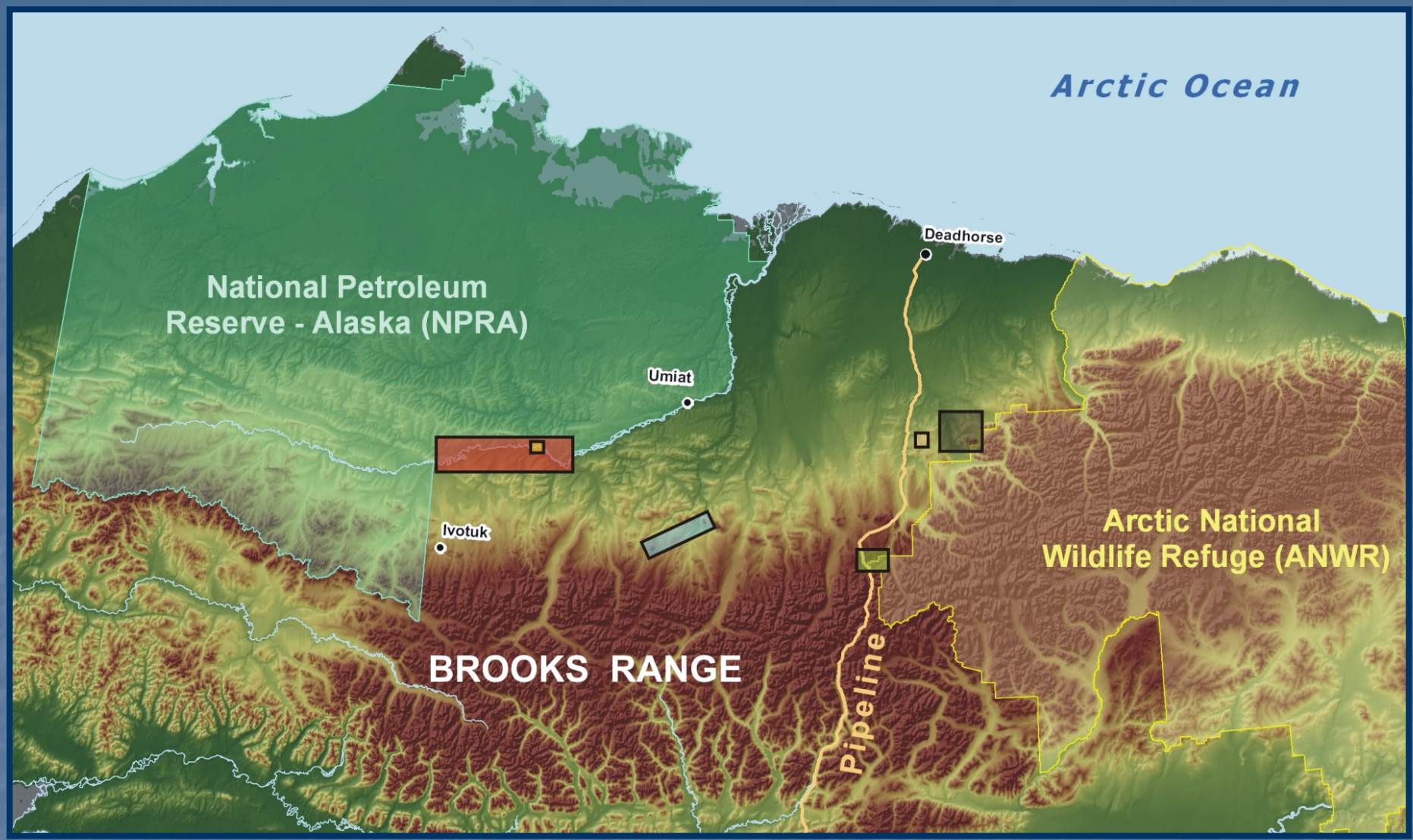
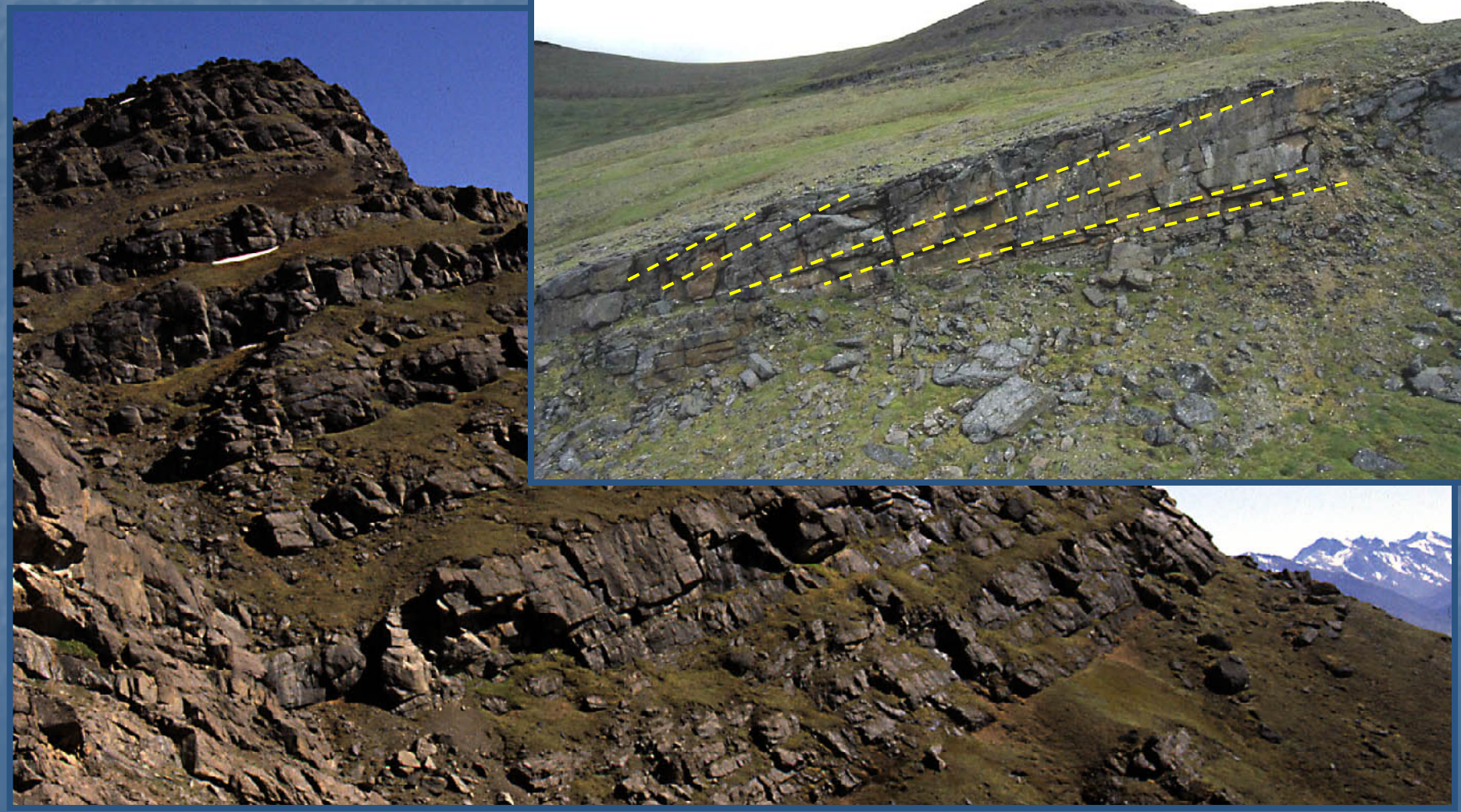


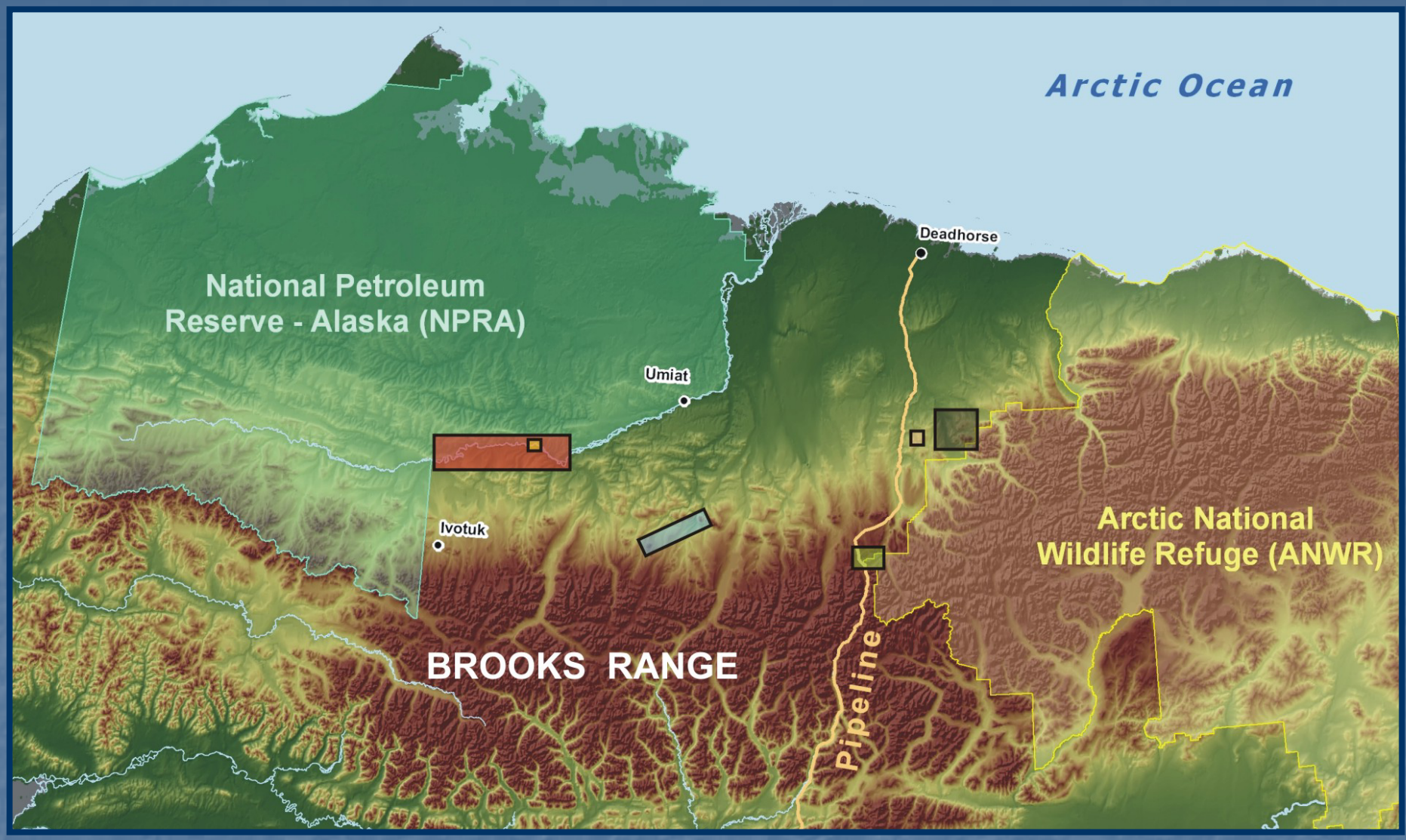

Wartes – Atigun syncline
Facies analysis of Fortress Mountain Fm.

# Fortress Mtn Formation – Atigun Syncline

Aptian(?)-Albian proximal topset facies (fan delta front)

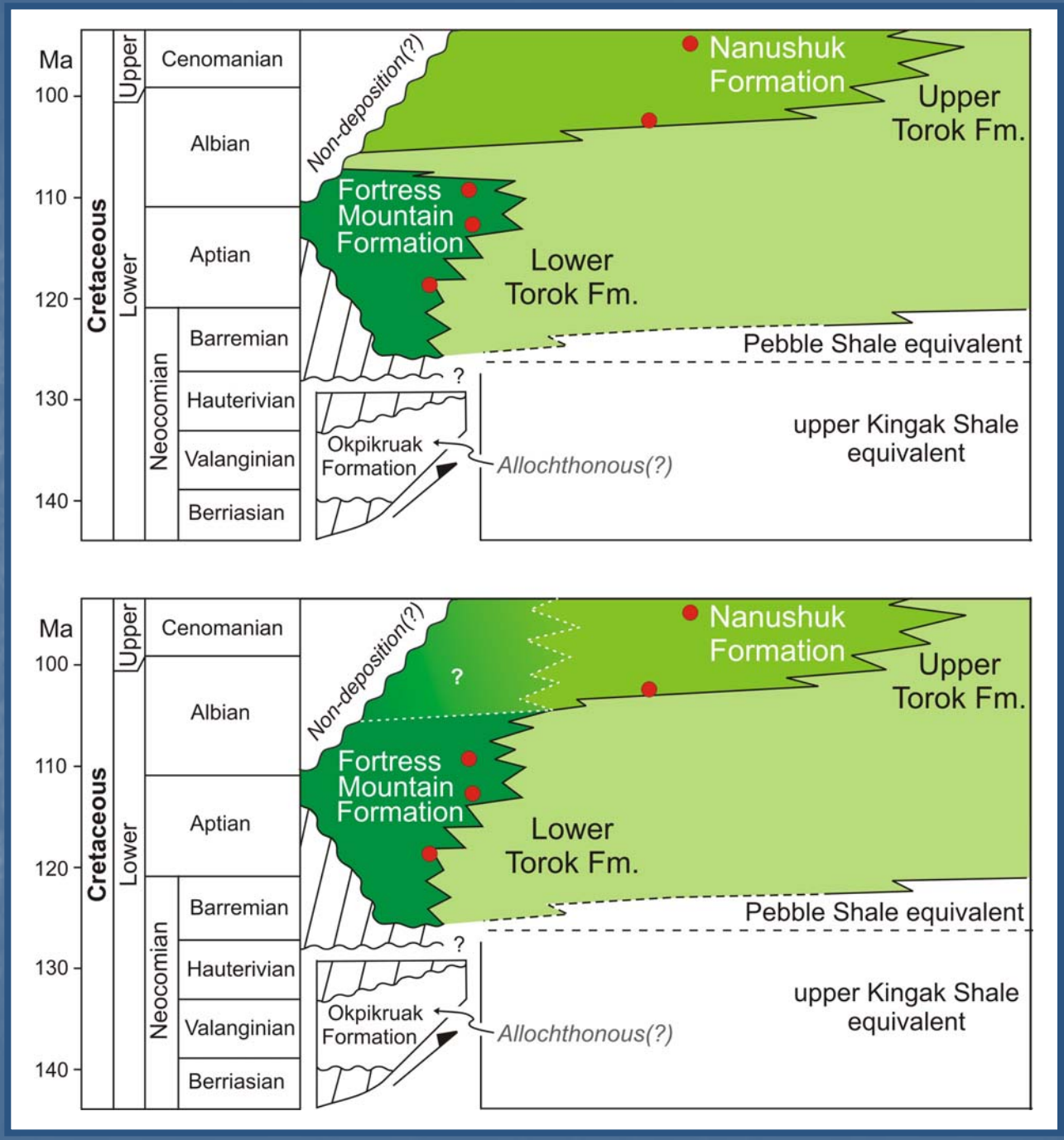
Basinward dipping foresets

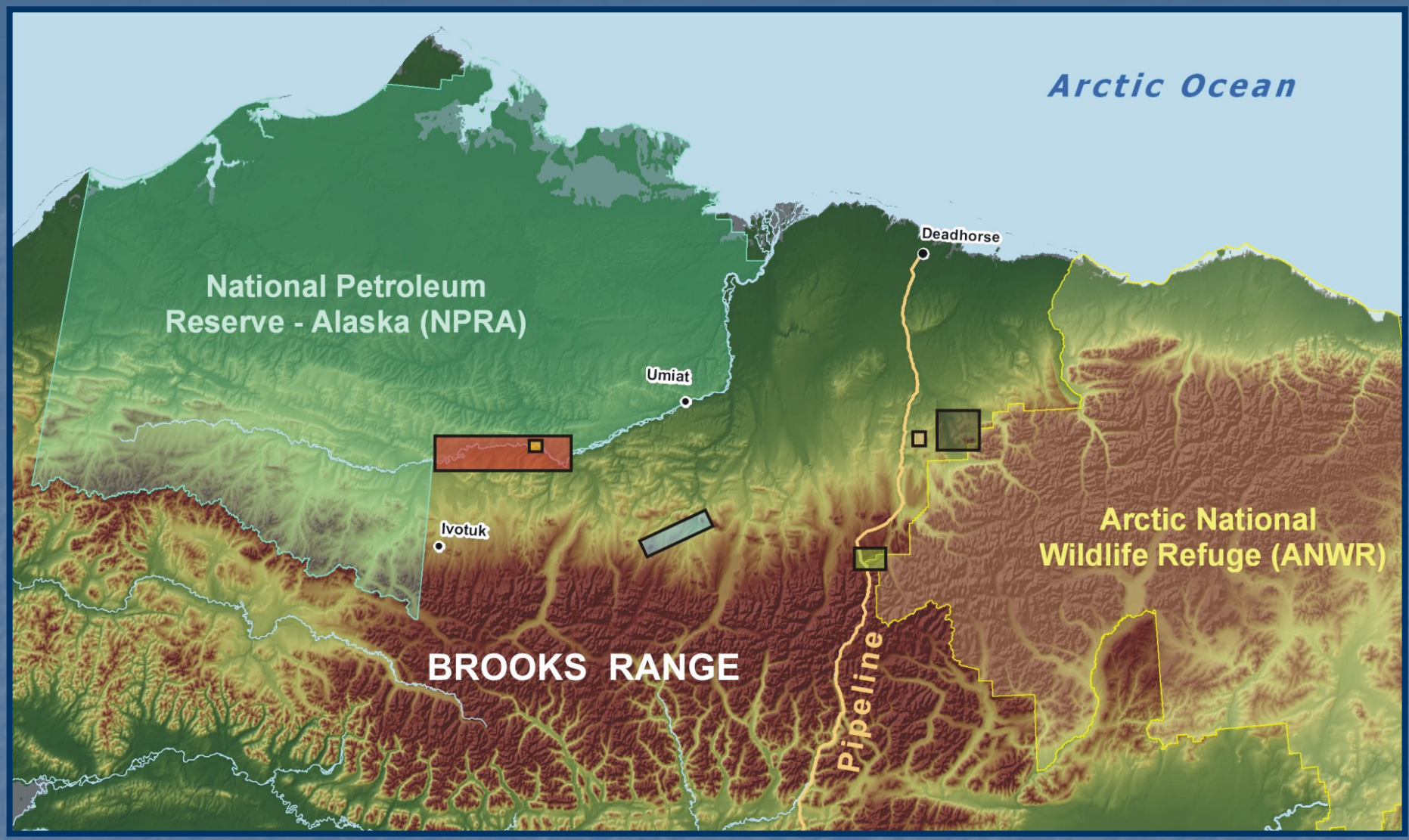





Wartes – Castle Mtn. and Gunsight Mtn.
Provenance of Fortress Mountain and Nanushuk Fms.

# Relationship between the Fortress Mtn. and Nanushuk Formations

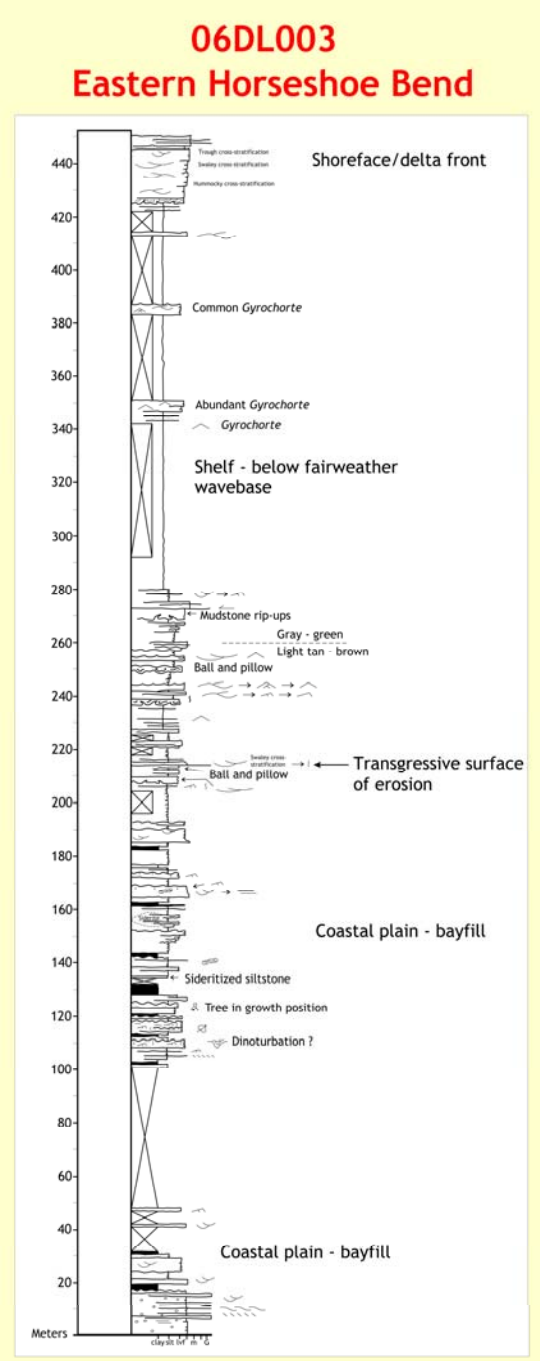




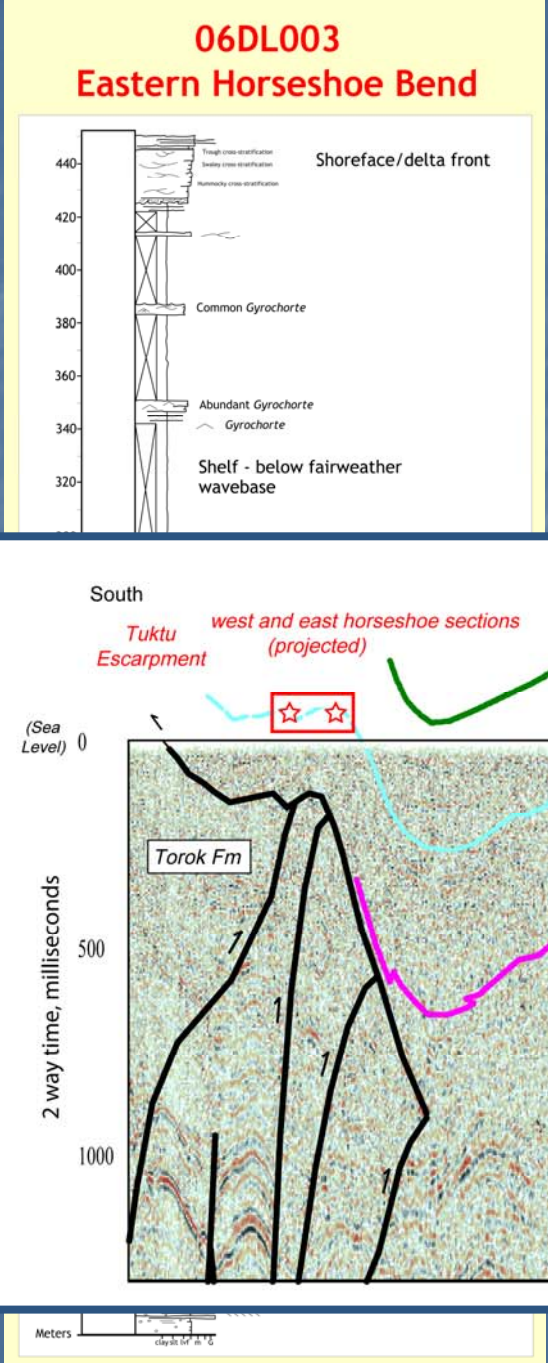

LePain et al. – Colville River
Nanushuk Fm. sedimentology and stratigraphy

*Colville River, near confluence with Awuna River*

*HCS -SCS*



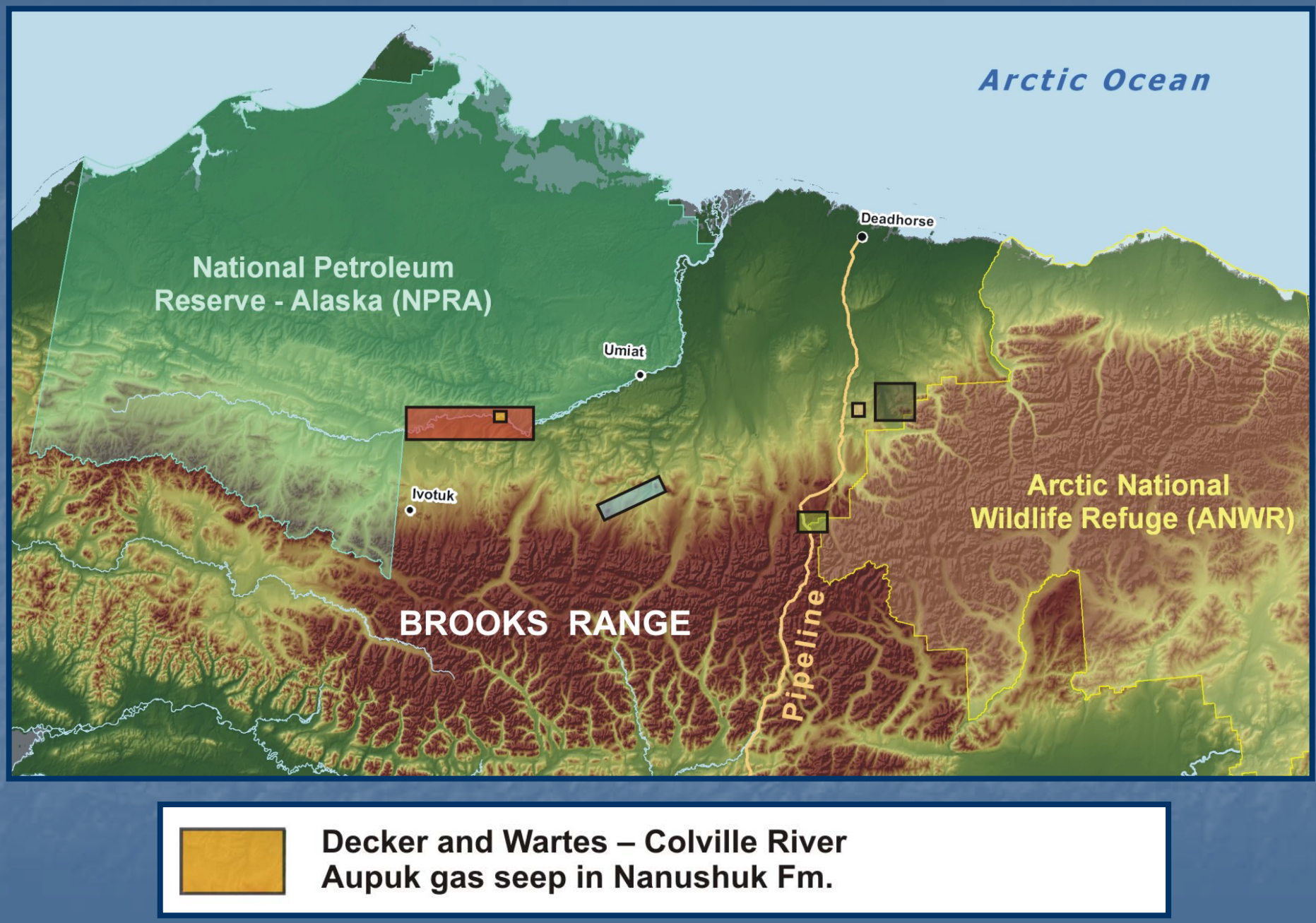

# Correlation into subsurface. . .




# Correlation into subsurface. . .




*LePain et al., 2008*

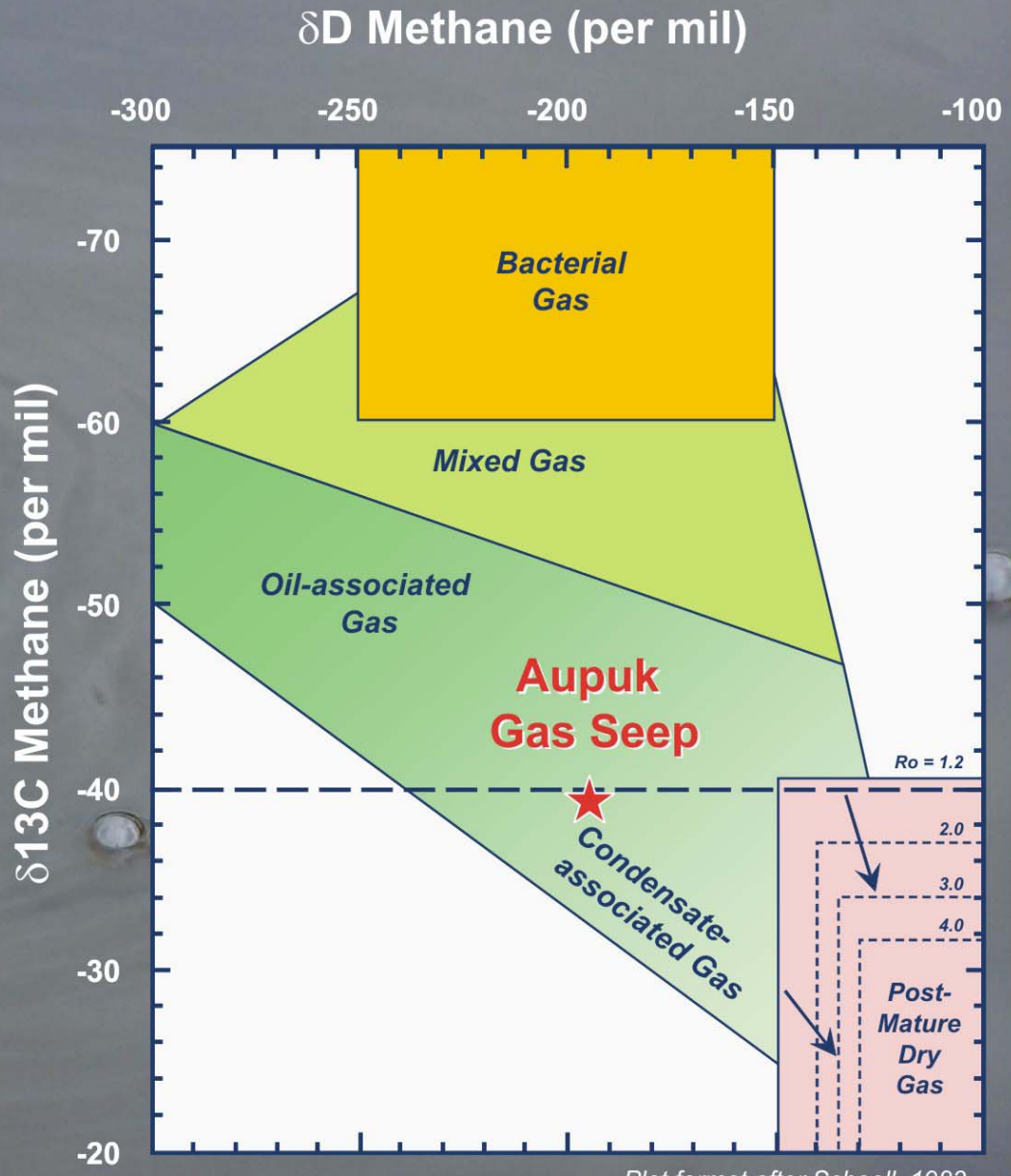


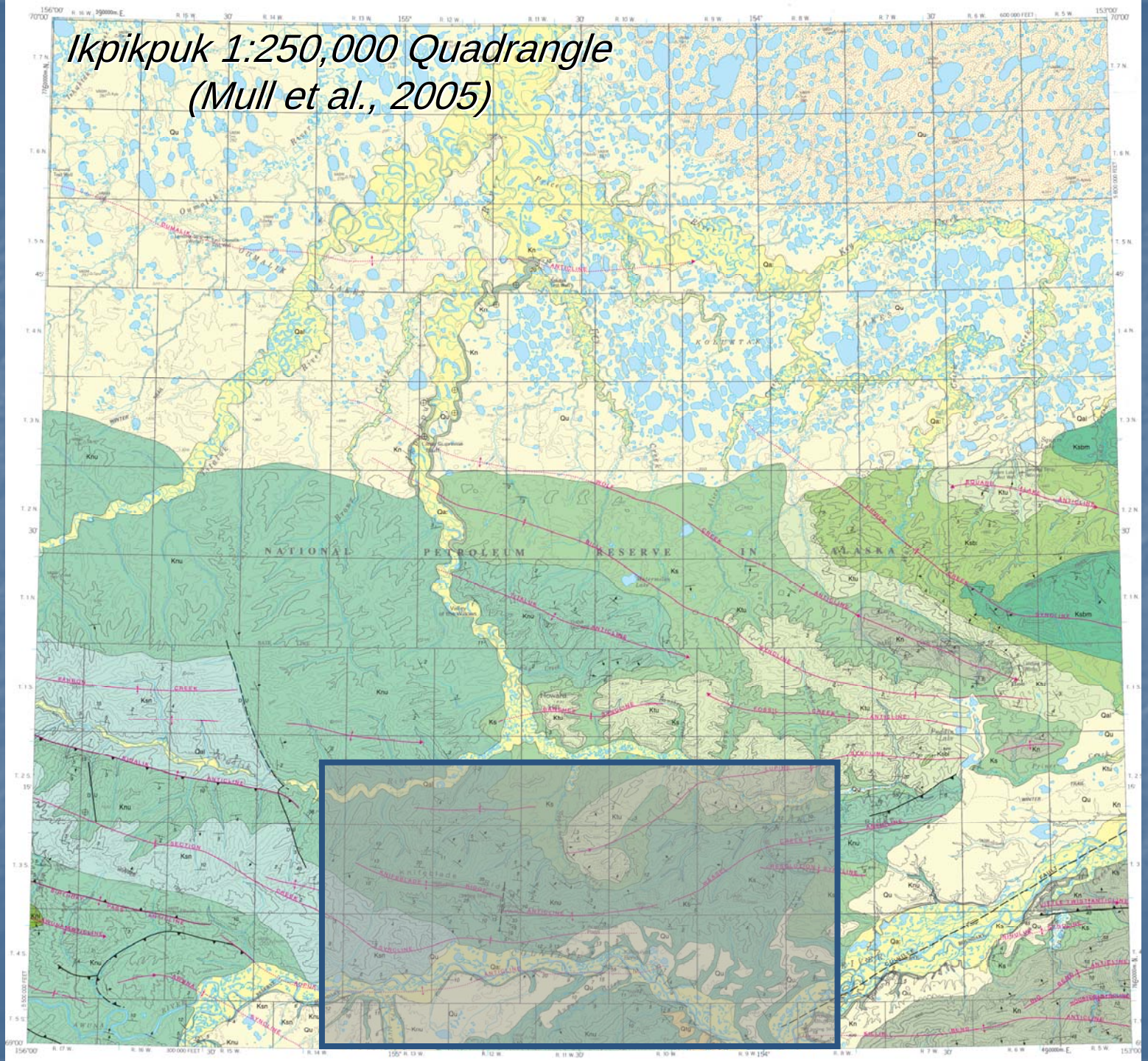

Decker and Wartes – Colville River
Aupuk gas seep in Nanushuk Fm.

# Aupuk Gas Seep -- Colville River

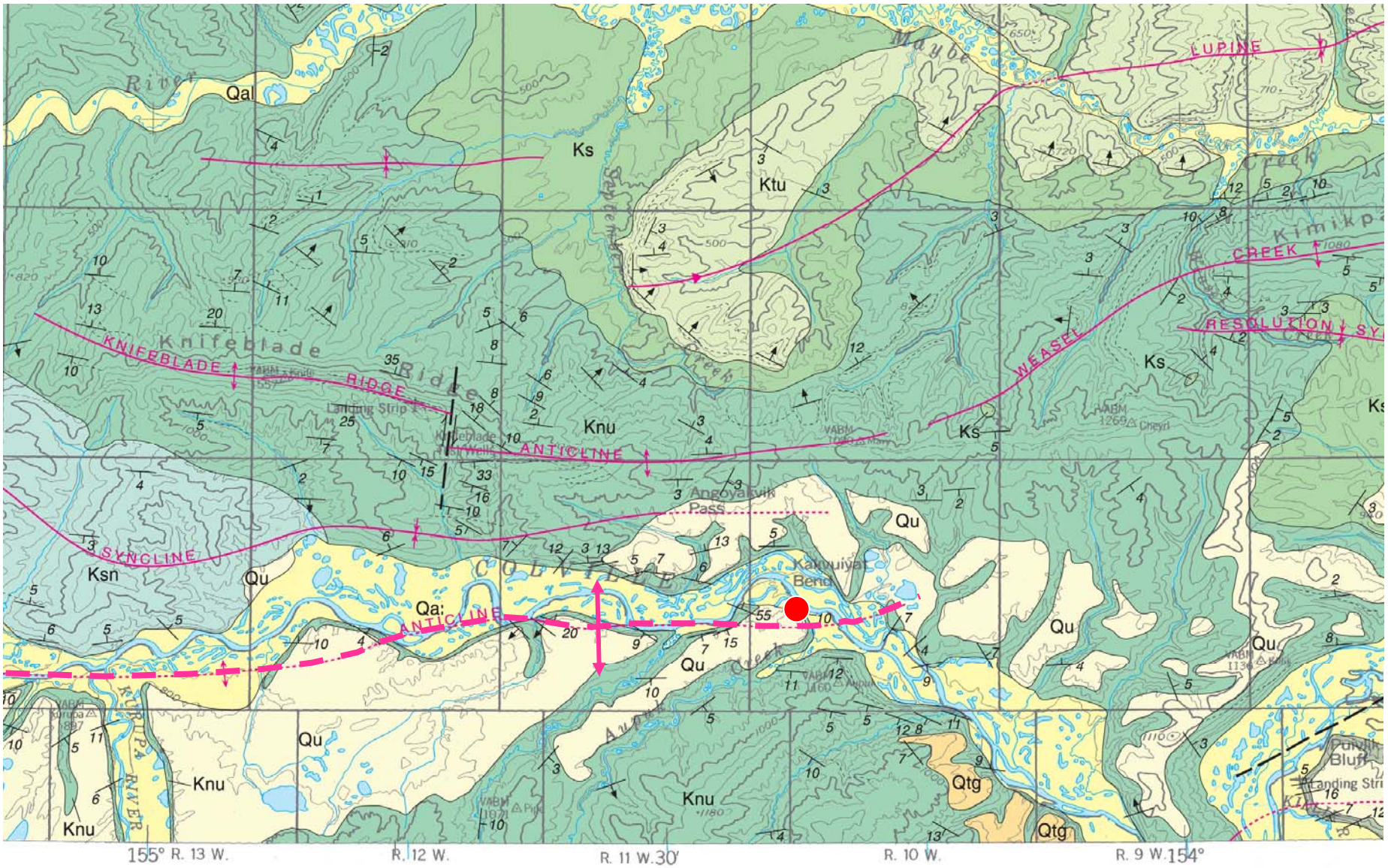
- **Composition:**
  - 86.98% Methane
  - 1.20% Carbon dioxide
  - 11.77% Nitrogen
  - 0.05% Oxygen
- **Thermogenic gas, condensate- or oil-associated origin**
- **Probable generation at oil window maturity**
- **Carbon and Deuterium methane isotopes**:

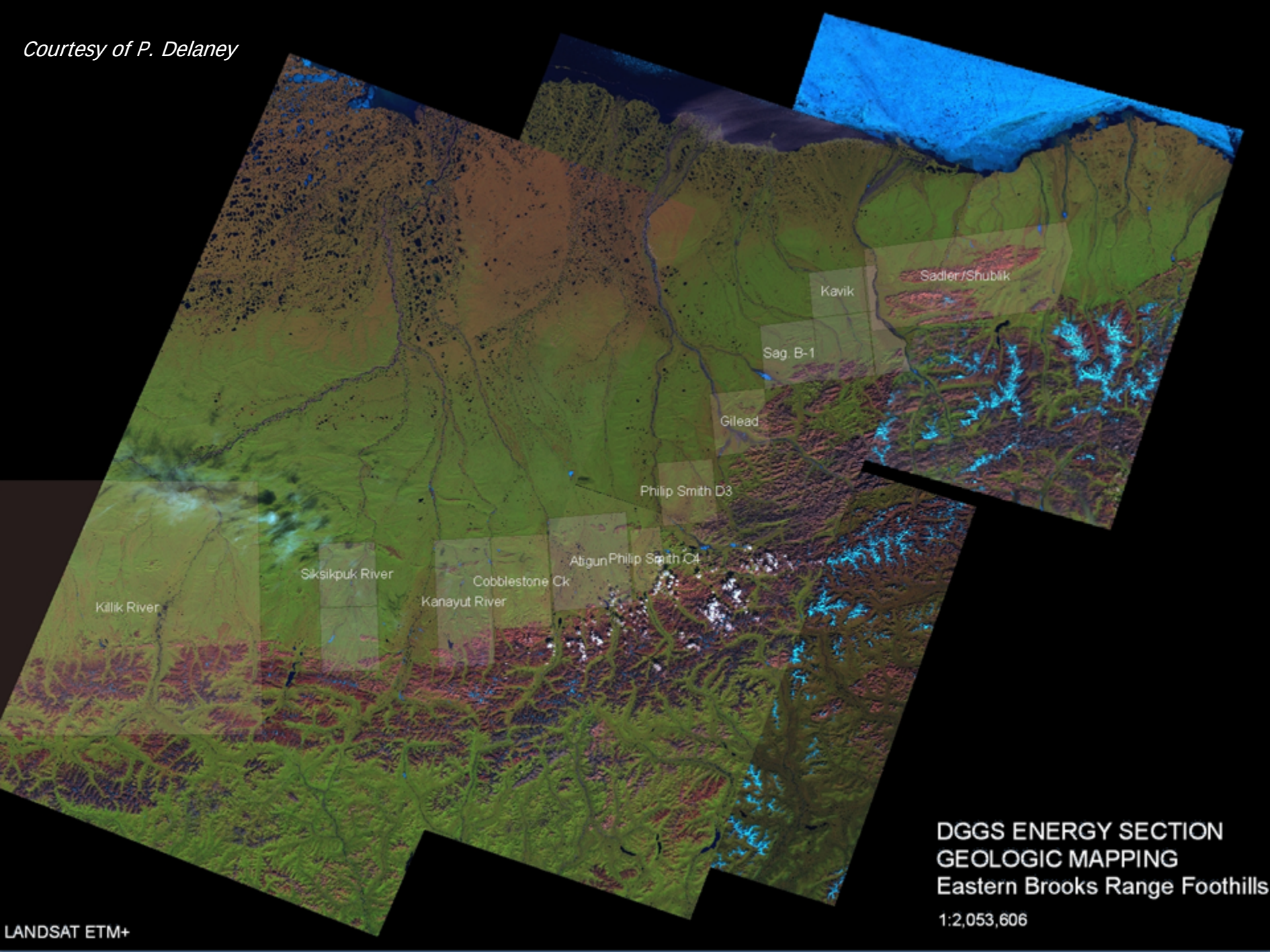
| δD | δ13C |
|---|---|
| -195 | -39.3 |



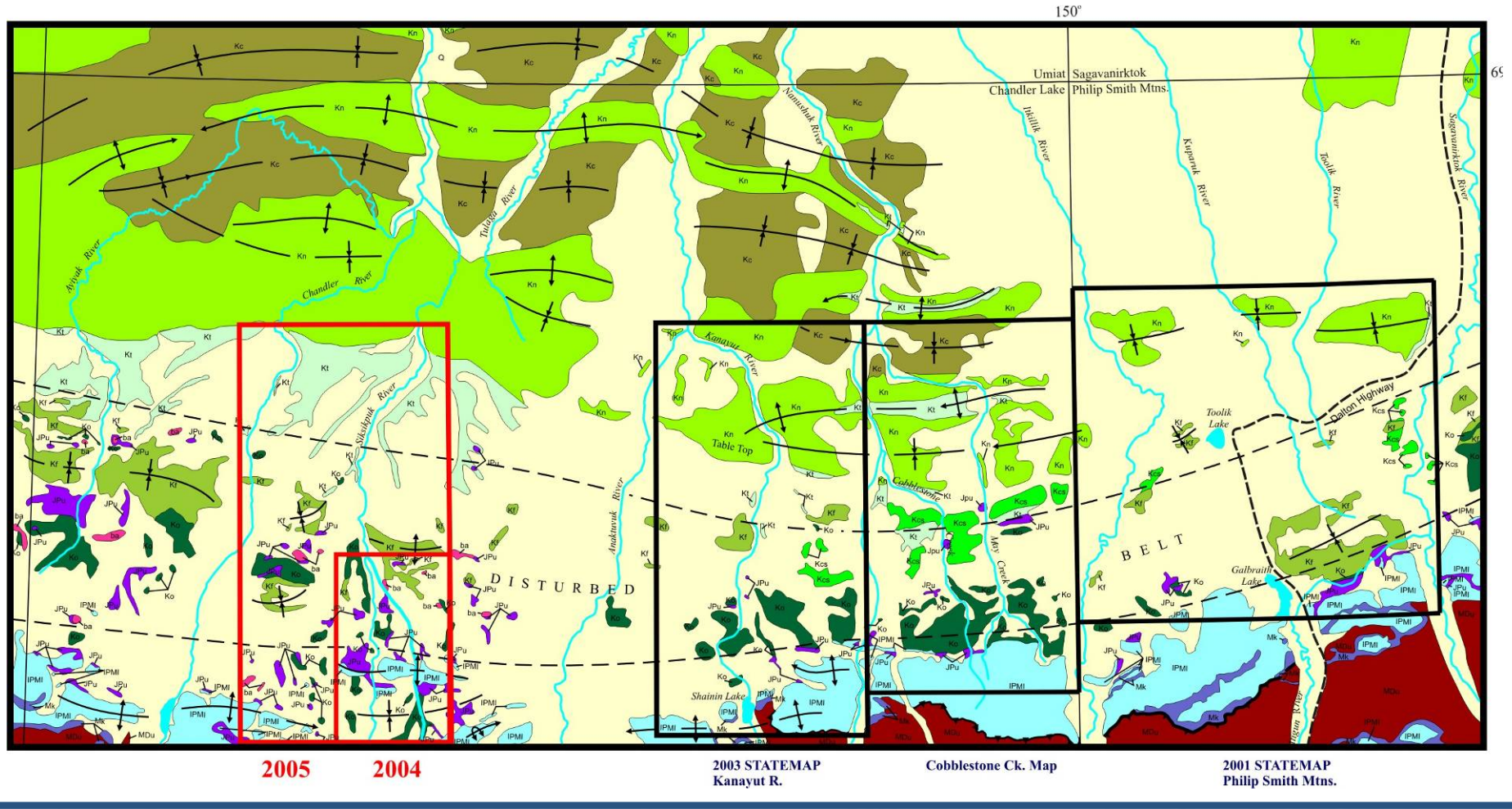

Ikpikpuk 1:250,000 Quadrangle
(Mull et al., 2005)
NATIONAL PETROLEUM RESERVE IN ALASKA

# *Ikpikpuk 1:250,000 Quadrangle (Mull et al., 2005)*

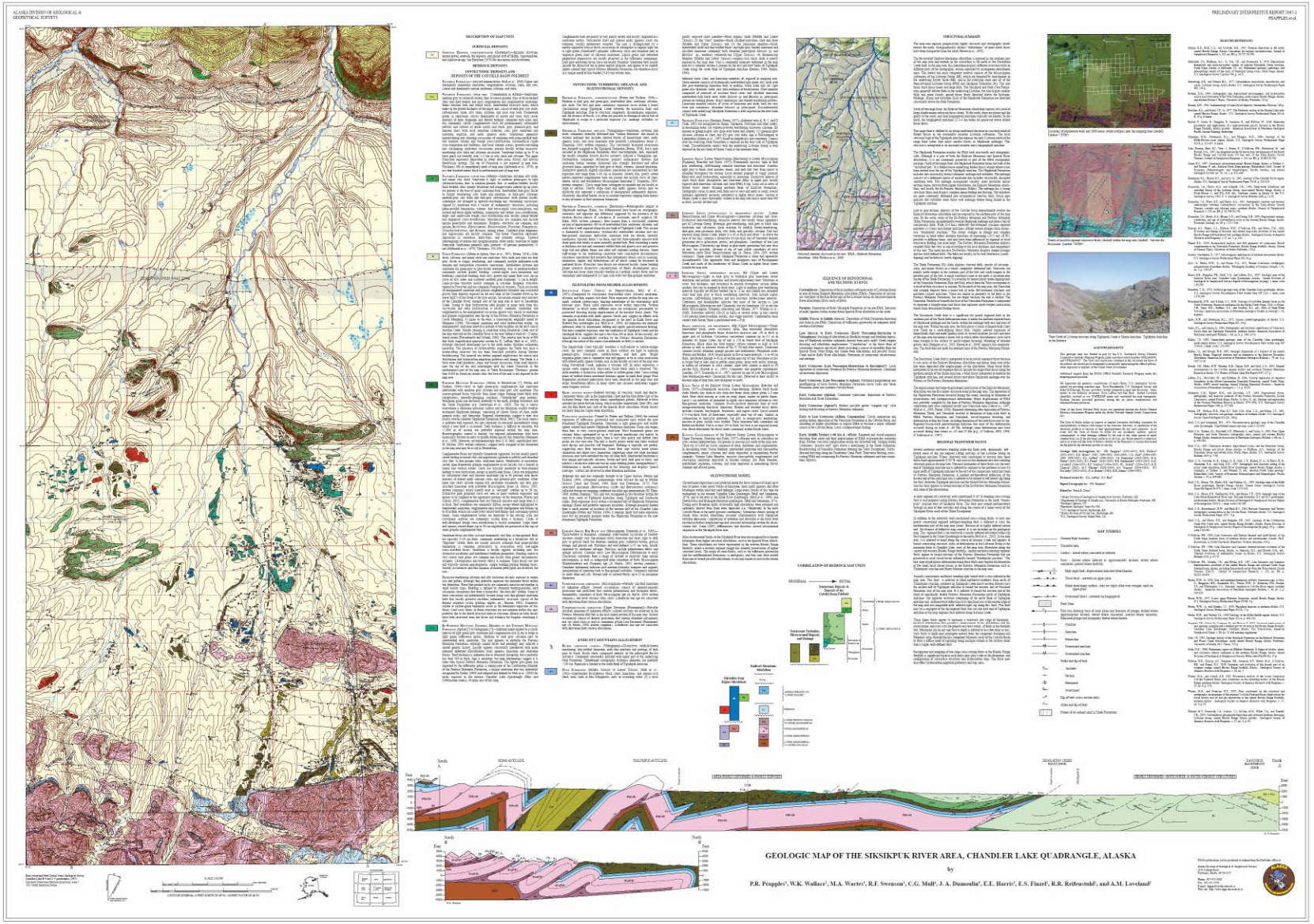



Courtesy of P. Delaney
Sadler/Shublik
Kavik
Sag. B-1
Gilead
Philip Smith D3
Atigun
Philip Smith C4
Siksikpuk River
Cobblestone Ck
Kanayut River
Killik River
DGGS ENERGY SECTION
GEOLOGIC MAPPING
Eastern Brooks Range Foothills
1:2,053,606
LANDSAT ETM+

# Detailed Geologic Mapping (1:63,360 Scale)



# Siksikpuk River Geologic Map (Peapples et al, 2007)



Studies by the U.S. Geological Survey in Alaska, 2006
U.S. Geological Survey Professional Paper 1739–D

# Sedimentology and Sequence Stratigraphy of the Lower Cretaceous Fortress Mountain and Torok Formations Exposed Along the Siksikpuk River, North-Central Alaska

By David W. Houseknecht, Christopher J. Schenk, and Marwan A. Wartes[1]

## Abstract

An exposure of the Lower Cretaceous Fortress Mountain and Torok Formations along the Siksikpuk River in north-central Alaska provides a rare opportunity to observe the stratigraphic contact between these two formations and to interpret the depositional facies and sequence stratigraphy of the exposed strata. The Fortress Mountain Formation at the base of the measured section includes braided-fluvial and coastal-plain facies deposited in a lowstand-systems tract, and an overlying succession of mostly shallow marine facies deposited in the basal part of a transgressive-systems tract. The overlying Torok Formation includes a thick, upward-deepening succession of marine-shelf to marine-slope facies deposited in the upper part of the transgressive-systems tract. The upper part of the section includes marine-slope and incised-slope-channel turbidite deposits of the Torok Formation, interpreted as a highstand-systems tract.

Consideration of the balance between accommodation and sediment flux inferred from the sequence-stratigraphic analysis suggests that both tectonics and eustasy may have influenced deposition of the lowstand-systems and transgressive-systems tracts. In contrast, the highstand-systems tract may have been primarily influenced by progradation of a regional sediment-dispersal system and by subsidence induced by sediment loading.

## Introduction

The Brookian tectonostratigraphic sequence of northern Alaska (fig. 1) includes Cretaceous and Tertiary strata that reflect the evolution of the Colville foreland basin (Lerand, 1973; Hubbard and others, 1987; Bird and Molenaar, 1992). The Albian through Miocene part of the Brookian sequence (fig. 2) is well known from numerous studies that have documented stratal geometries and depositional facies in outcrops and the subsurface (Molenaar, 1983, 1985; Huffman, 1985; Houseknecht and Schenk, 2001). In contrast, the pre-Albian part of the Brookian sequence (fig. 2) is less well known because those strata are more structurally deformed and dissected by erosion in the Brooks Range foothills and because few subsurface datasets include information on these rocks.

The Fortress Mountain Formation and related parts of the Torok Formation (strata of Barremian?, Aptian, and early Albian? age) are the focus of this chapter. Despite studies that have advanced knowledge of the depositional facies and regional stratigraphy of these rocks (for example, Hunter and Fox, 1976; Crowder, 1987, 1989; Molenaar and others, 1988; Wartes and Carroll, 2002), interpretations of the sedimentology of the Fortress Mountain Formation include wide-ranging depictions of depositional environments, and demonstrable stratigraphic relations between the Fortress Mountain Formation (mostly sandstone and conglomerate) and the Torok Formation (mostly mudstone) remain poorly understood.

An outcrop of the upper part of the Fortress Mountain Formation and the overlying Torok Formation along the Siksikpuk River (fig. 1) provides a rare opportunity to directly observe a contact between these two formations. The objectives of this chapter are to describe and interpret the succession of facies exposed there, to interpret the sequence-stratigraphic framework of those facies, and to infer the significance of these interpretations to the regional paleogeography of the Colville foreland basin.

## Geologic Setting

The study area (fig. 1) is in the southern foothills of the Brooks Range, an area of mostly Lower Cretaceous foreland-basin deposits deformed by northward-vergent thrust faults and folds (Moore and others, 1994). A chronostratigraphic column of the Fortress Mountain and Torok Formations in the context of the Brookian sequence is shown in figure 2. The rocks exposed along the Siksikpuk River provide insights

[1]Alaska Division of Geological and Geophysical Surveys.
Manuscript approved for publication, October 4, 2007.

Studies by the U.S. Geological Survey in Alaska, 2006
U.S. Geological Survey Professional Paper 1739–B

# Lithofacies, Age, and Sequence Stratigraphy of the Carboniferous Lisburne Group in the Skimo Creek Area, Central Brooks Range

By Julie A. Dumoulin, Michael T. Whalen, and Anita G. Harris

## Abstract

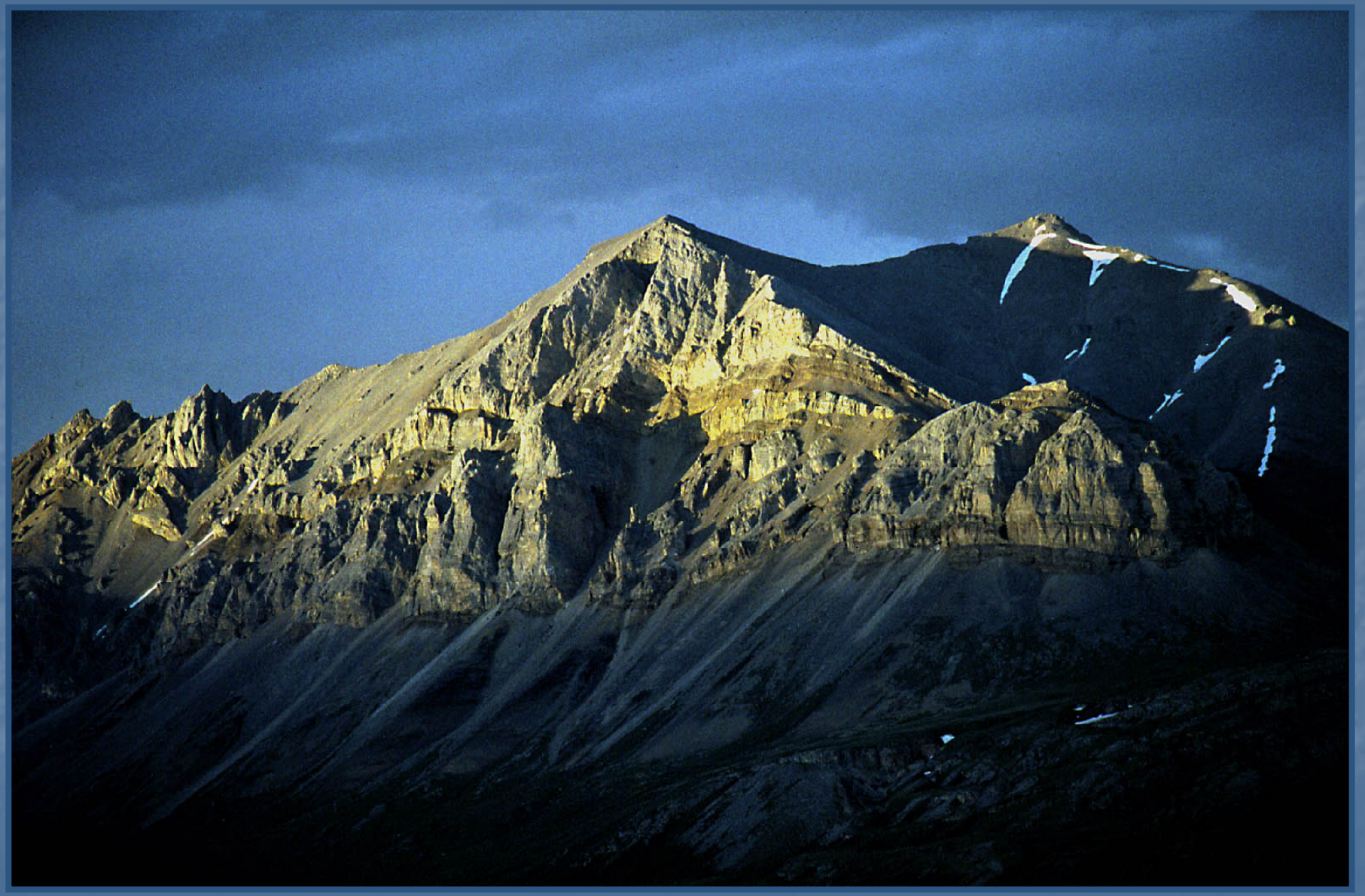
The Lisburne Group, a mainly Carboniferous carbonate succession that is widely distributed across northern Alaska, contains notable amounts of oil and gas at Prudhoe Bay. Detailed studies of the Lisburne in the Skimo Creek area, central Brooks Range, delineate its lithofacies, age, conodont biofacies, depositional environments, and sequence stratigraphy and provide new data on its hydrocarbon source-rock and reservoir potential, as well as its thermal history, in this area.

We have studied the Lisburne Group in two thrust sheets of the Endicott Mountains allochthon, herein called the Skimo and Tiglukpuk thrust sheets. The southern, Skimo Creek section, which is >900 m thick, is composed largely of even-bedded to nodular lime mudstone and wackestone intercalated with intervals of thin- to thick-bedded bioclastic packstone and grainstone. Some parts of the section are partially to completely dolomitized and (or) replaced by chert. A distinctive, 30-m-thick zone of black, organic-rich shale, lime mudstone, and phosphorite is exposed 170 m below the top of the Lisburne. The uppermost 40 m of section is also distinctive and made up of dark shale, lime mudstone, spiculite, and glauconitic grainstone. The northern, Tiglukpuk Creek section, which is similar to the Skimo Creek section but only ~760 m thick, includes more packstone and grainstone and less organic-rich shale. Analyses of conodonts and foraminifers indicate that both sections range in age from late Early Mississippian (Osagean) through Early Pennsylvanian (early Morrowan) and document a hiatus of at least 15 m.y. at the contact between the Lisburne and the overlying Siksikpuk Formation. No evidence of subaerial exposure was observed along this contact, which may represent a submarine erosional surface.

Lithofacies and biofacies imply that the Lisburne Group in the study area was deposited mainly in midramp to outer-ramp settings. Deepest water strata are mud rich and formed below storm or fair-weather wave base on the outer ramp to outer midramp; shallowest facies are storm, sand-wave, and shoal deposits of the inner midramp to inner ramp. A relatively diverse, open-marine fauna occurs throughout much of the Lisburne in the study area, but some beds also contain clasts typical of more restricted, shallow-water environments that were likely transported seaward by storms and currents. Radiolarians are abundant in the shale and phosphorite unit at Skimo Creek and also occur in equivalent strata at Tiglukpuk Creek; high gamma-ray response and elevated total organic-carbon contents (max 5–8 weight percent) also characterize this unit at Skimo Creek. Lithologic, faunal, and geochemical data all suggest that these rocks formed mainly in an outer-ramp to basinal setting with low sedimentation rates, high productivity, and poorly oxygenated bottom water. Shale and mudstone at the top of the Lisburne Group accumulated in a similarly sediment starved, mainly outer ramp environment but lack comparable evidence for high nutrient and low oxygen levels during deposition.

Vertical shifts in rock types and faunas delineate numerous parasequences and six probable third-order sequences in the study area; the same sequences are also recognized in the Lisburne Group to the east. Transgressive-system tracts in these sequences generally fine upward, whereas highstand-system tracts coarsen upward. Sequences in the Tiglukpuk Creek section are mostly thinner, contain thinner and more numerous parasequences, and accumulated in somewhat shallower settings than those in the Skimo Creek section. These differences reflect the more seaward position and, thus, increased accommodation space of the Skimo Creek section relative to the Tiglukpuk Creek section during deposition.

Organic-rich calcareous shale in the shale and phosphorite unit has a cumulative thickness of at least 15 m and a lateral extent of >50 km; this lithology is the best potential hydrocarbon source rock in the Lisburne Group at Skimo Creek. The best potential reservoir facies of the Lisburne in the study area is dolomitized crinoidal grainstone that contains intercrystalline, moldic, and vuggy porosity and locally abundant dead oil. Maximum porosities of ~10 percent occur in intervals that are 1 to 2 m thick, of uncertain lateral extent, and best developed near the tops of sequences 1 through 4. Color-alteration indices of conodonts from both the Skimo Creek and Tiglukpuk Creek sections chiefly range from 1.5 to 2, indicating thermal maturities within the oil window.



*Midnight sun on overturned Lisburne Group – view from Galbraith Lake*