Northern Colville Foreland Basin,
Central North Slope, Alaska

BROOKIAN SEQUENCE STRATIGRAPHIC FRAMEWORK

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This interpretive work is based on integration of subsurface and outcrop data. Related outcrop studies were conducted in collaboration with geologists of the Alaska Division of Geological & Geophysical Surveys, notably Marwan Wartes, David Lepain, Robert Gillis, and Trystan Herriott; and the U.S. Geological Survey, including David Houseknecht and Chris Schenk. Recent field studies have been funded in part by industry contributions from Anadarko Petroleum Corp., BG Alaska, Chevron, ConocoPhillips Alaska, Inc., ENI, Petro-Canada, Pioneer Natural Resources, Shell International Exploration and Production Co., and Talisman Energy, Inc/FEX Gp. Inc. The author thanks M. Wartes and D. Houseknecht for countless invaluable discussions of Brookian sequence depositional systems, correlations, and sequence stratigraphic development.

Purpose

- Advance our evolving interpretation of Brookian sequence architecture – in this case, near producing fields and infrastructure on northern flank of the Colville foreland basin, formerly known as...

  ~~*the "shale pit"*~~

- Brookian sequence historically of secondary interest to industry. Important petroleum systems, but stratigraphy is still challenging to work in detail – need comprehensive framework

- Extend stratigraphic hypotheses advanced from previous field and subsurface work
  - *Decker, 2007 (DGGS Preliminary Interpretive Report 2007-2)*
  - *Decker and others, 2008 (AAPG poster & DGGS, in press)*
  - Farther north & northeast, into the eastern Beaufort Sea
  - Consider Paleocene and younger strata in more detail

Approach

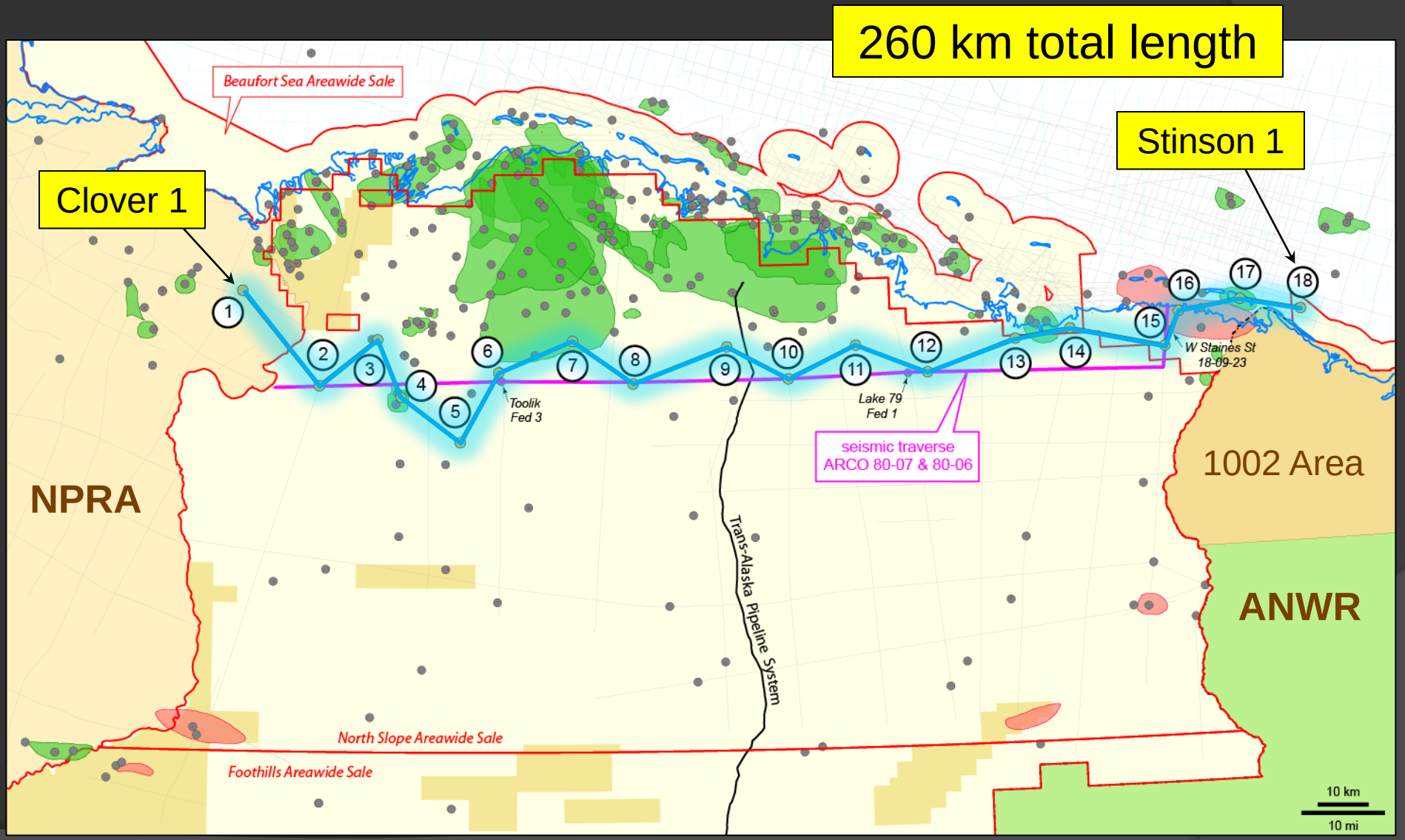
- Dip-oriented regional cross section ~260 km long
  - 18 wells (wireline logs, mudlogs, AOGCC well history files, literature details, etc.)
  - public-domain seismic (coarse grid)
  - outcrop findings
  - formal (new) USGS lithostratigraphy
  - sequence-stratigraphic thinking
- Floating datum, flattened on topsets
- Colored by generalized depositional environment and/or lithology
- Accompanying structural datum version and sub-parallel seismic transect

Key Findings

- 7 semi-regional surfaces of fundamental sequence-stratigraphic significance (A-G)
  - lowstand sequence boundaries
  - transgressive flooding surfaces
  - surfaces of composite origin

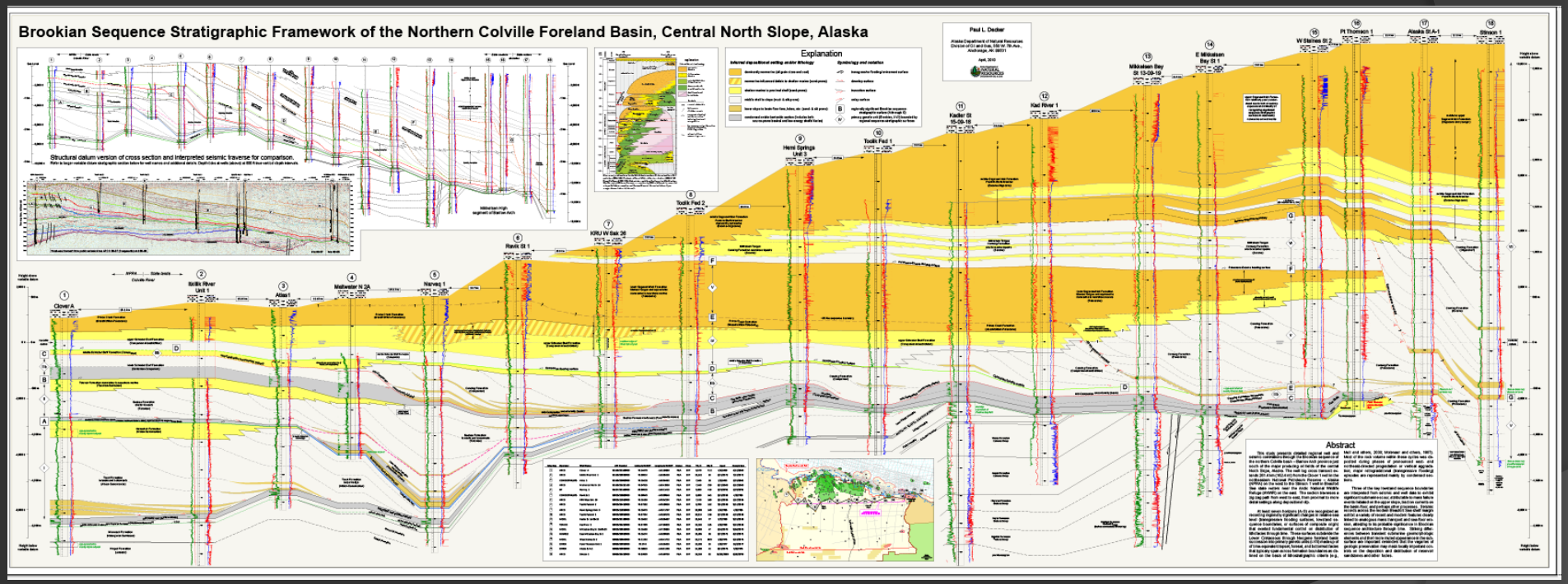
- Primary genetic units (I-VII) made up of time-equivalent topset, foreset, and bottomset facies
  - Some genetic units encompass multiple entire formations defined by lithostratigraphic criteria
    - e.g., Nanushuk – Torok – HRZ system (Aptian to Cenomanian)
  - Other genetic units include only portions of one or more formations
    - e.g., upper Prince Creek – upper Schrader Bluff – lower Canning system (Campanian to lower Paleocene)
    - e.g., Mikkelsen Tongue of Canning Formation (Eocene)

Location Map – this study

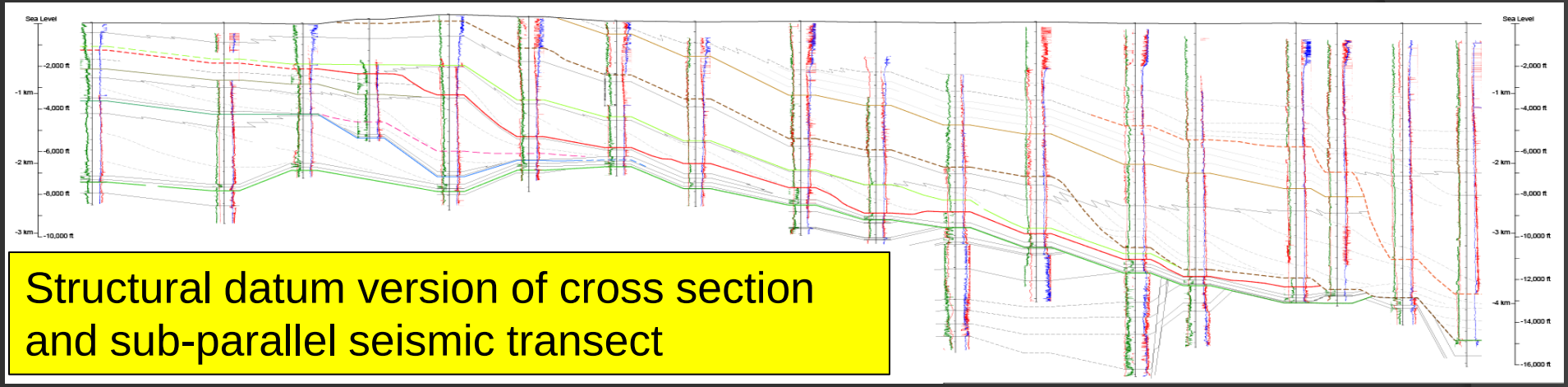


Poster Overview

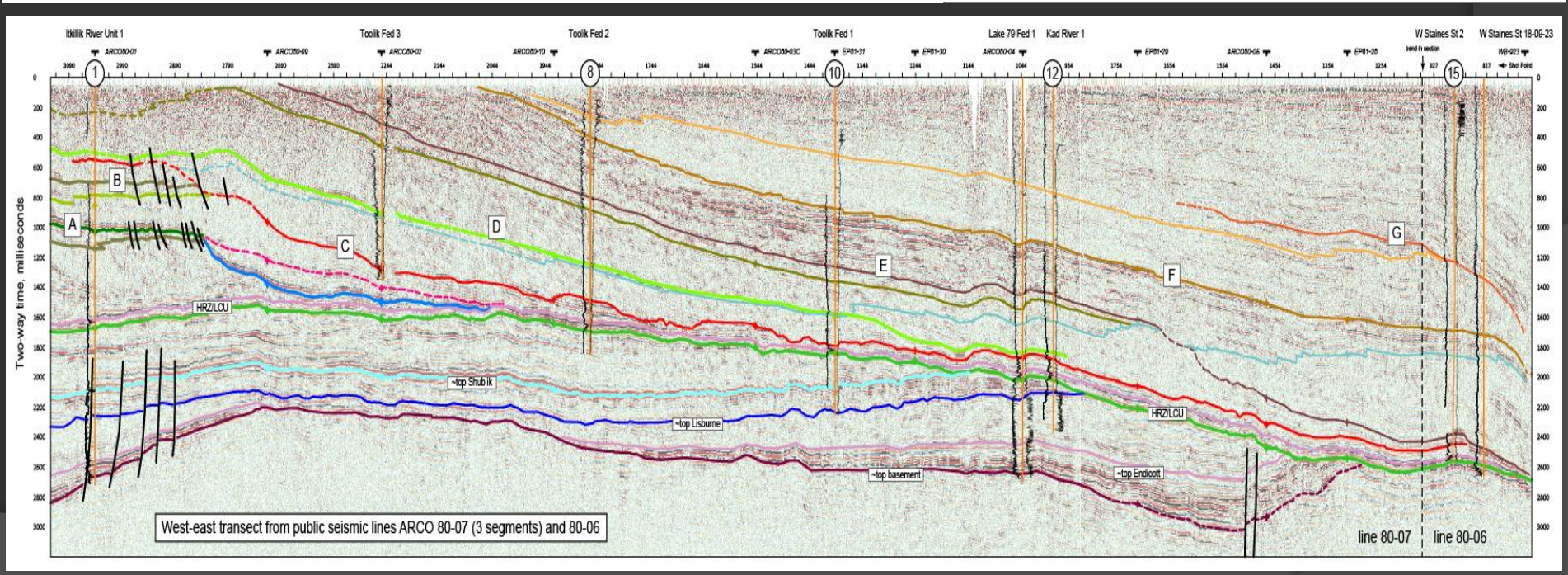
Main Section -- Floating Datum



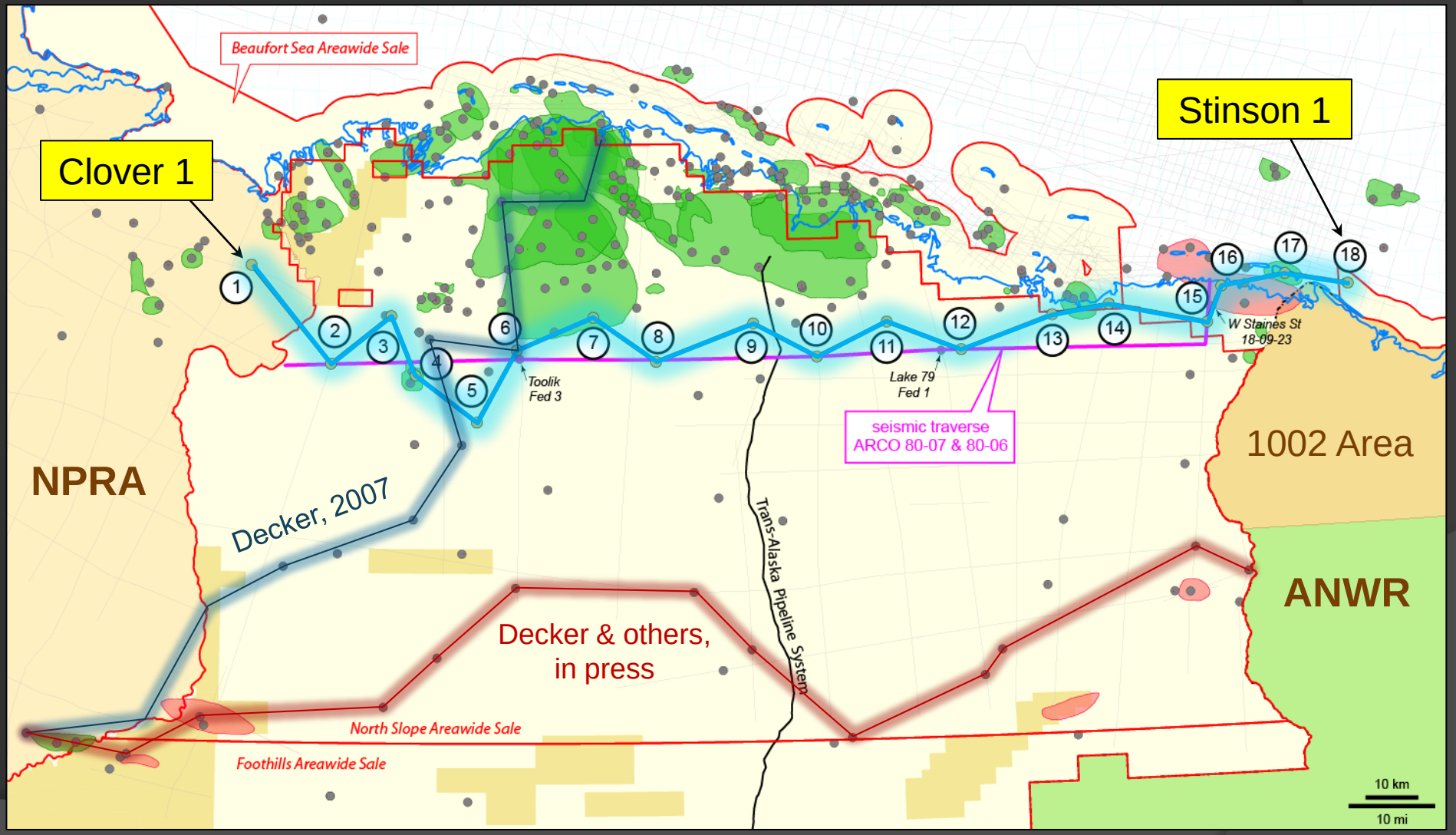
Structural Datum



Structural datum version of cross section and sub-parallel seismic transect



Previously Published Regional Brookian Correlations -- DNR



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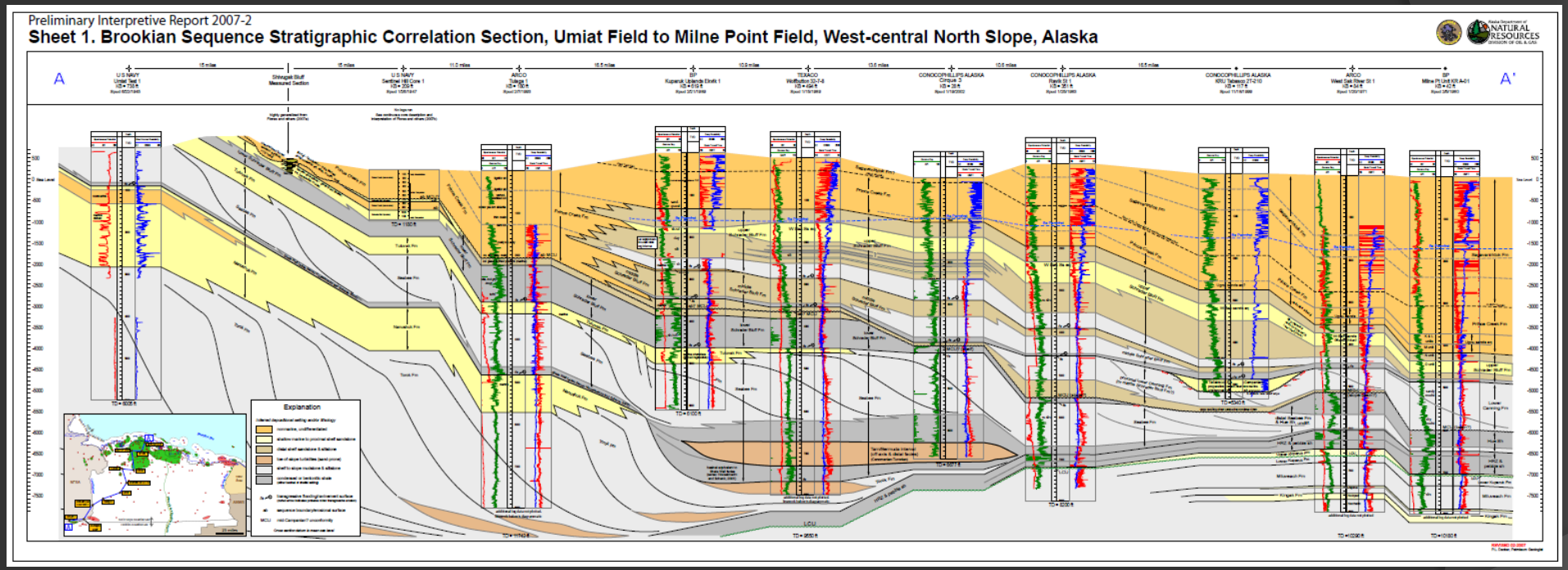
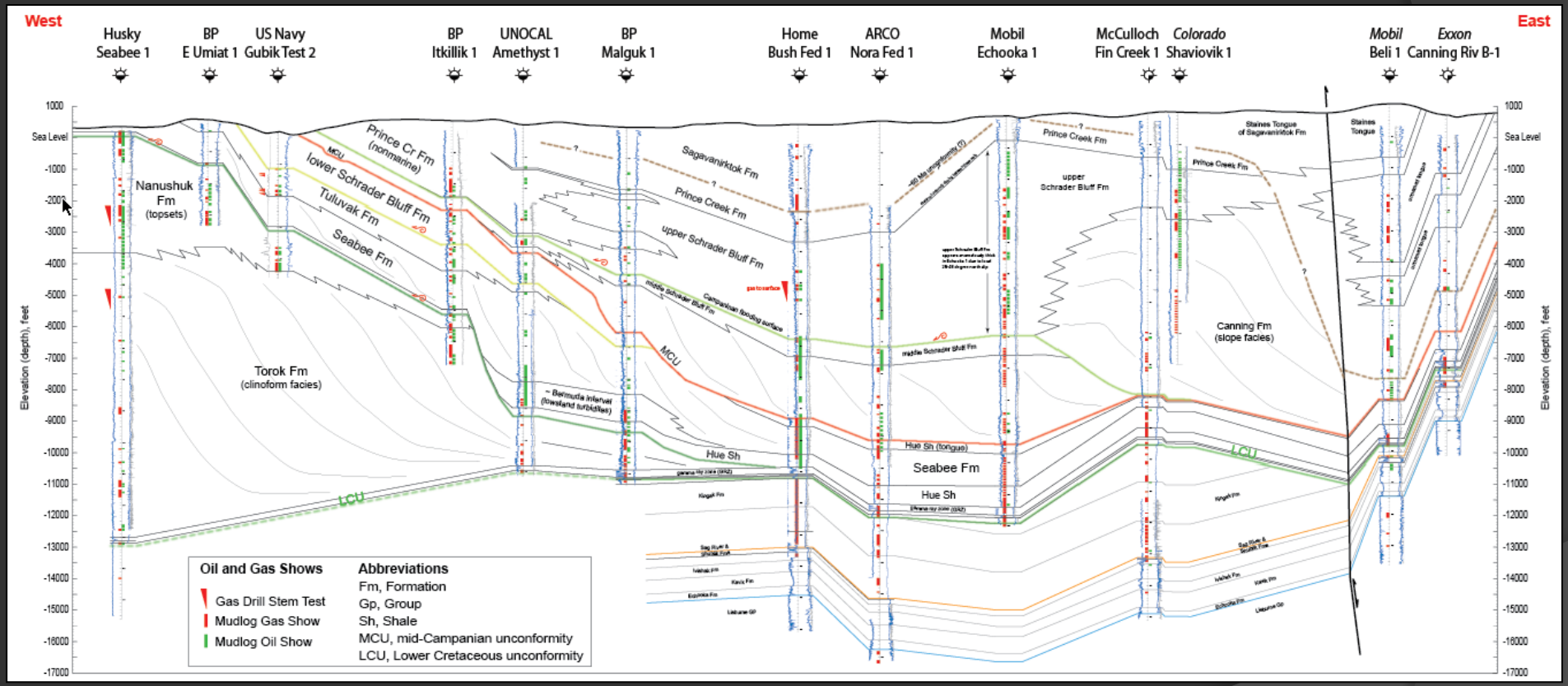


Decker 2007, PIR 2007-2

Previously Published Regional Brookian Correlations -- DNR



Decker and others, PIR 2009-1C (in press)

Brookian Chronostratigraphy

Mull and others, 2003

Major revisions to Brookian nomenclature

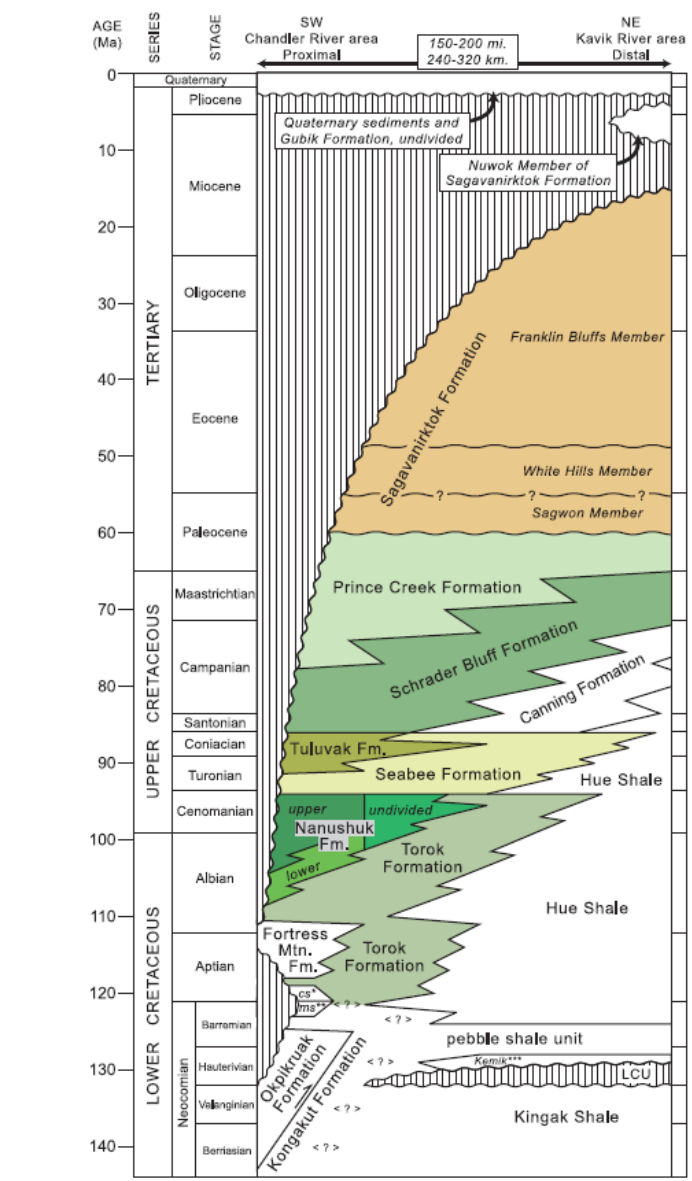


Figure 3. Chronostratigraphic column for the Colville basin, northern Alaska, showing revised stratigraphic nomenclature and ages of units discussed in this paper (in color); laterally correlative and overlying and underlying units not discussed in this paper are uncolored in diagram. Abbreviations or symbols are as follows: <?>, uncertain relationship; cs*, cobblestone sandstone of Fortress Mountain Formation (informal unit of Mull and others, 2003); ms**, manganiferous shale unit (informal term); Kemik***, Kemik Sandstone (formation) as revised by Molenaar and others (1987); Fm., Formation; Mtn., Mountain; LCU, Lower Cretaceous unconformity. Geologic time scale from Gradstein and Ogg (1996).

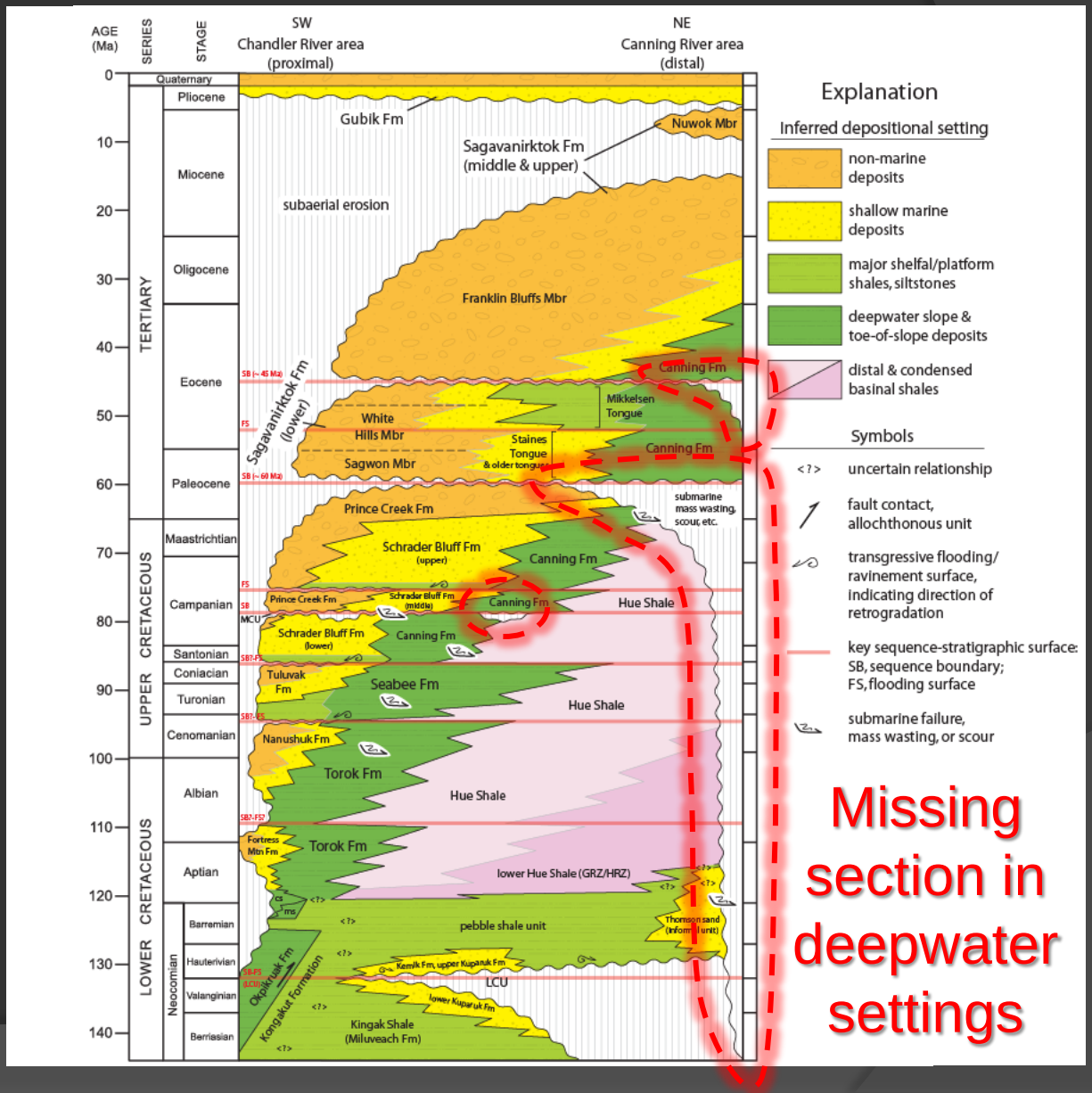
Brookian Chronostratigraphy

Mull and others, 2003

Decker and others, in press

Low-order sequence-stratigraphic bounding surfaces

Primary genetic units averaging ~ 5-10 million years duration



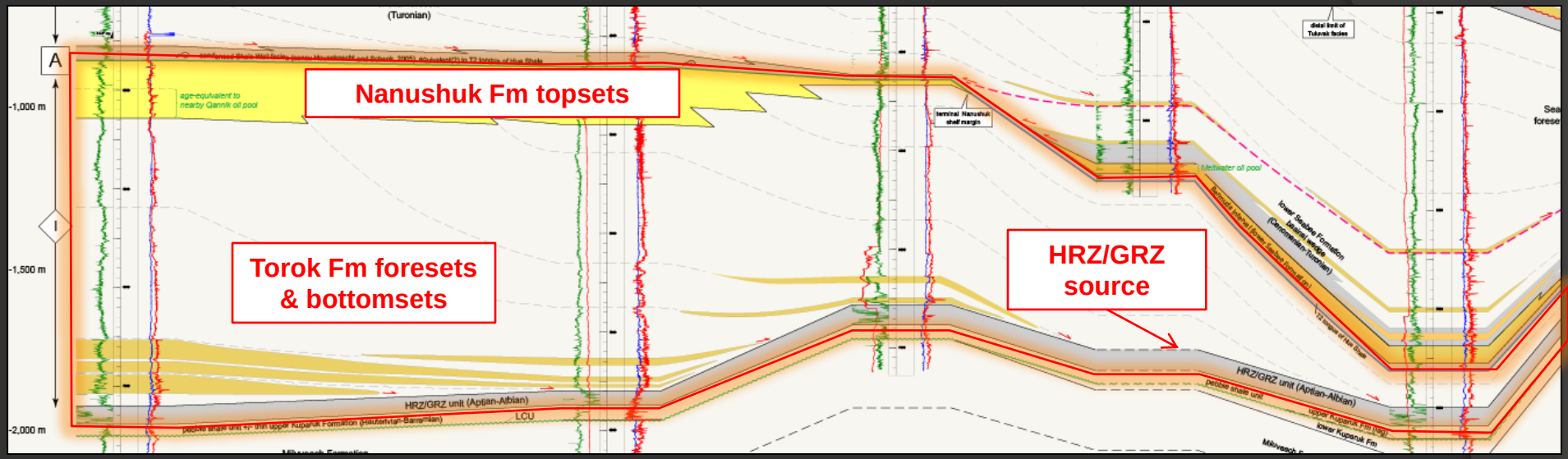
Key Brookian Surfaces

- base HRZ downlap surface (top pebble shale)
- A top Nanushuk-Torok flooding surface
- B top Tuluvak-Seabee flooding surface
- C mid-Campanian sequence boundary (MCU)
- D Campanian flooding surface (K-10)
- E ~60 Ma sequence boundary
- F Paleocene-Eocene flooding sfc / base Mikkelsen Tongue
- G mid-Eocene sequence boundary

Primary Genetic Units

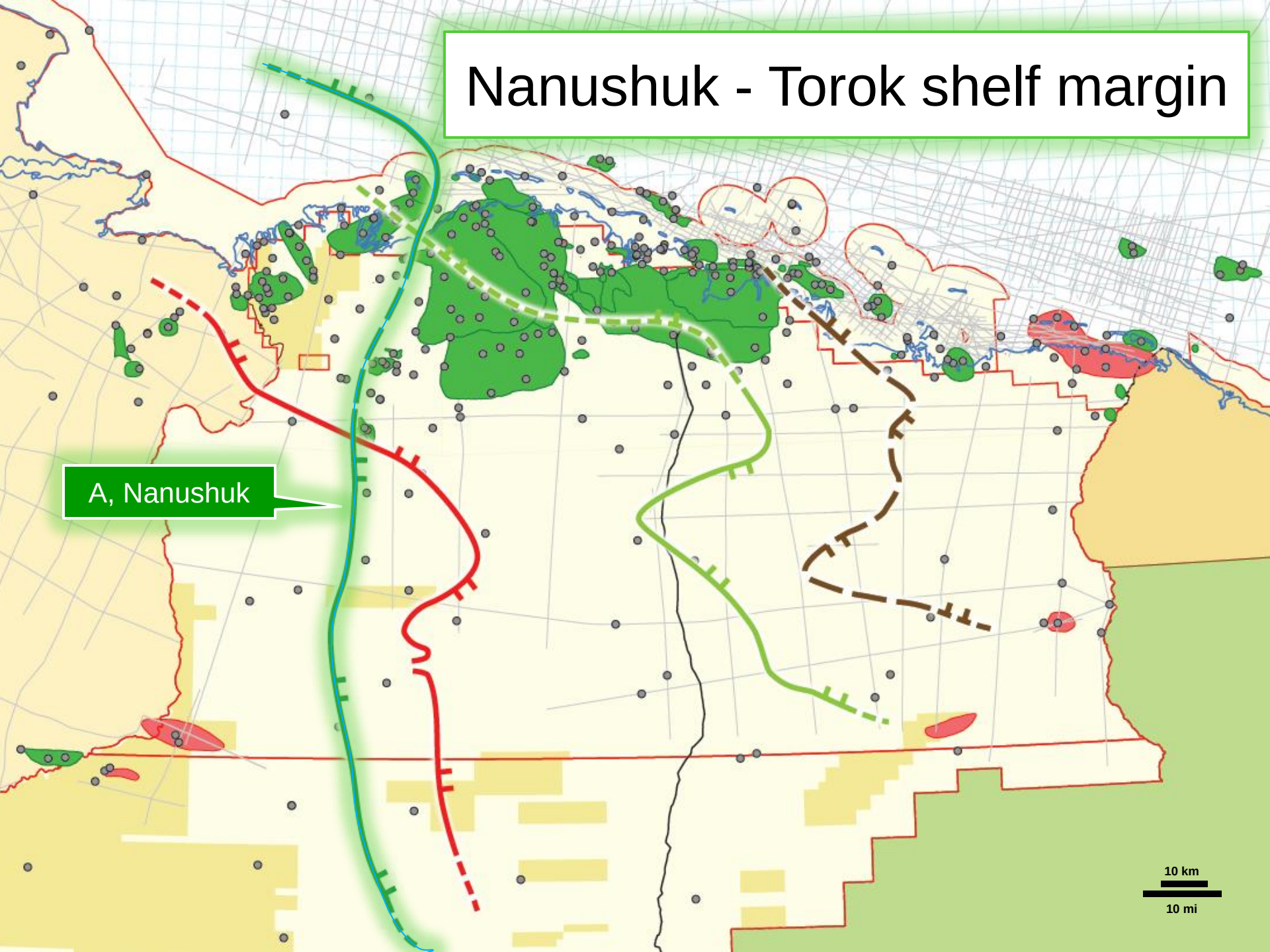
- I
  - Nanushuk – Torok – HRZ/GRZ unit
- II
  - Tuluvak – Seabee – lower tongue Hue Shale
- IIIa
  - lower Schrader Bluff – upper tongue Hue Shale
- IIIb
  - lower Prince Cr – middle Schrader Bluff – lowest Canning
- IV
  - upper Prince Cr – upper Schrader Bluff – lower Canning
- V
  - lower Sagavanirktok Staines Tongue – lower Canning
- VI
  - Mikkelsen Tongue = topset middle Canning
- VII
  - upper Sagavanirktok – upper Canning

Nanushuk – Torok – HRZ/GRZ unit

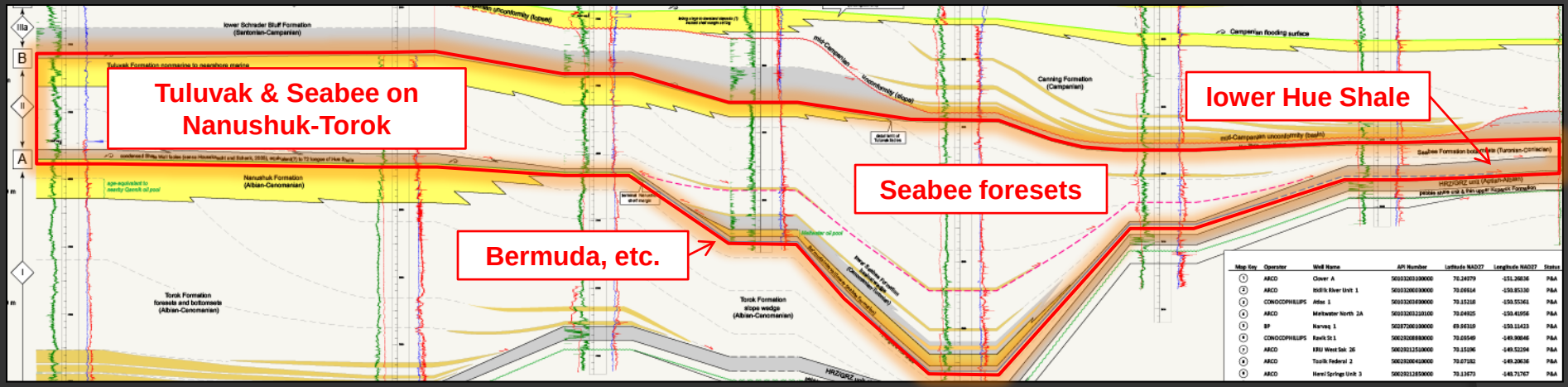


- Aptian-Albian-Cenomanian clinoform system
- Nanushuk Fm topsets >20,000’ thick in proximal settings, western NPRA
- Torok Fm foresets and bottomsets up to 18,500’ thick in foothills outcrop belt
- Overall all genetic unit ranges up to ~3,500’ thick on southern flank of Barrow Arch *(west end of cross section, this study)*
- Reservoir potential in topsets (e.g., Qannik) and deepwater settings (e.g., Nanuq)
- HRZ/GRZ source rock quality increases northeastward across basin

Nanushuk - Torok shelf margin

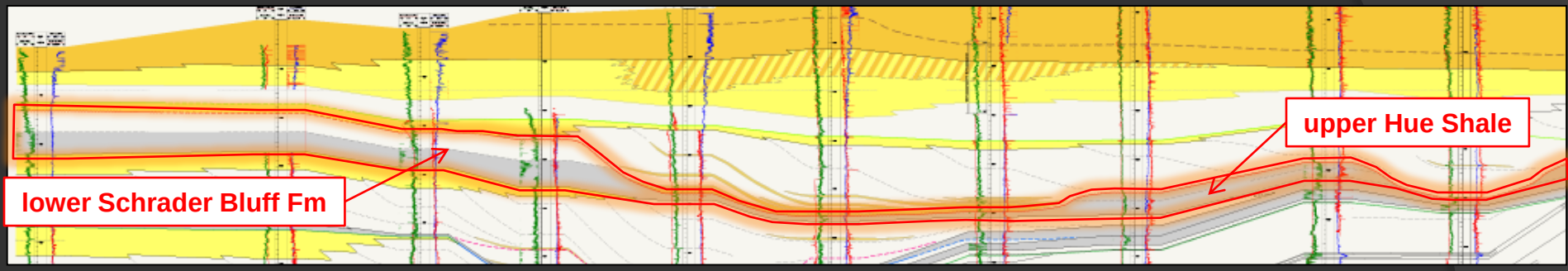


Tuluvak – Seabee – lower Hue Shale

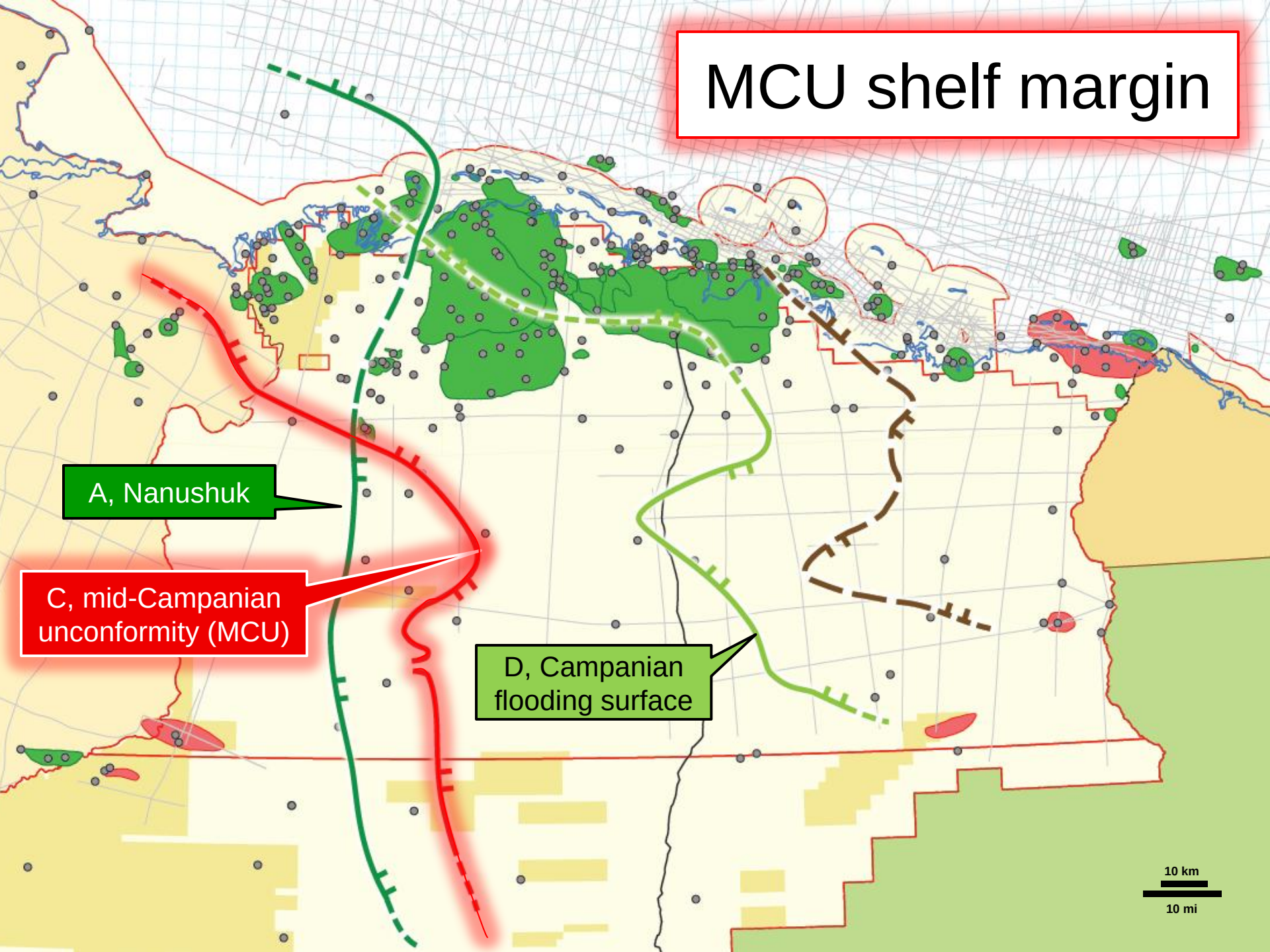


- Cenomanian-Turonian-Coniacian prograding clinoform system
- Tuluvak Fm topsets include exceptional reservoir quality to southwest
- Seabee Fm thickness and clinoform height varies relative to inherited Nanushuk-Torok shelf margin
- Lowstand wedge that encompasses Bermuda sands (Tarn and Meltwater fields) onlaps the older Torok slope … *timing of lowstand relative to western Seabee Fm (?)*
- Reservoir potential in both topsets and deepwater settings
- Upper Cretaceous Hue Shale source rock

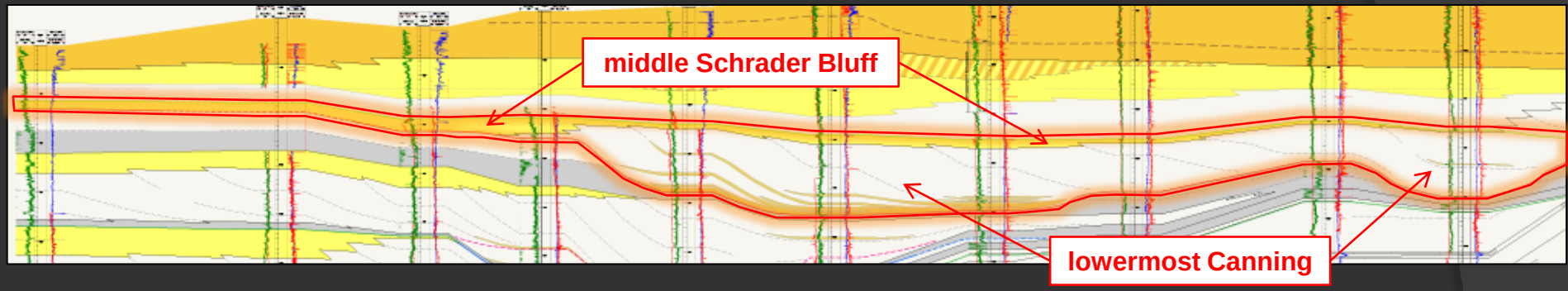
IIIa lower Schrader Bluff – upper Hue Shale



- Santonian-Campanian shelf to basin deposits overlying major flooding surface
- Very tuffaceous/bentonitic basin-wide
- Shelfal lower Schrader Bluff Fm fine-grained with laterally-persistent correlations → quiescent, relatively deep conditions very different than previous Tuluvak-Seabee cycle (highstand systems tract)
- Relatively low bathymetric relief between shelf and basin
- Rich upper Hue Shale source rocks preserved in basinal setting
- Upper surface is mid-Campanian sequence boundary (MCU)
  - *Incised valleys, shelf-margin incisions, and upper slope truncations*
  - *Basinal scours and erosional remnants*

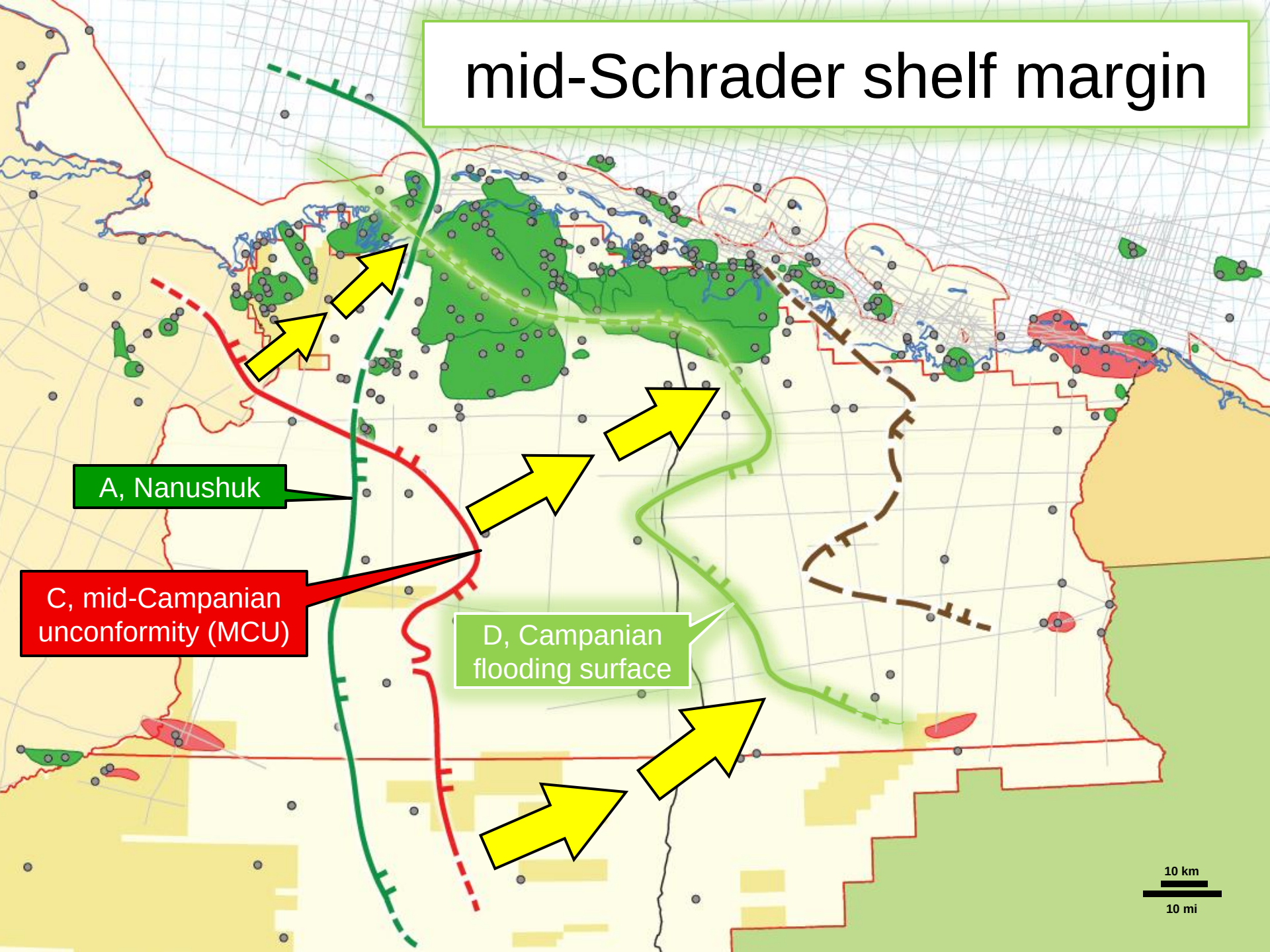

MCU shelf margin
A, Nanushuk
C, mid-Campanian unconformity (MCU)
D, Campanian flooding surface
10 km
10 mi

IIIb middle Schrader Bluff – lowermost Canning

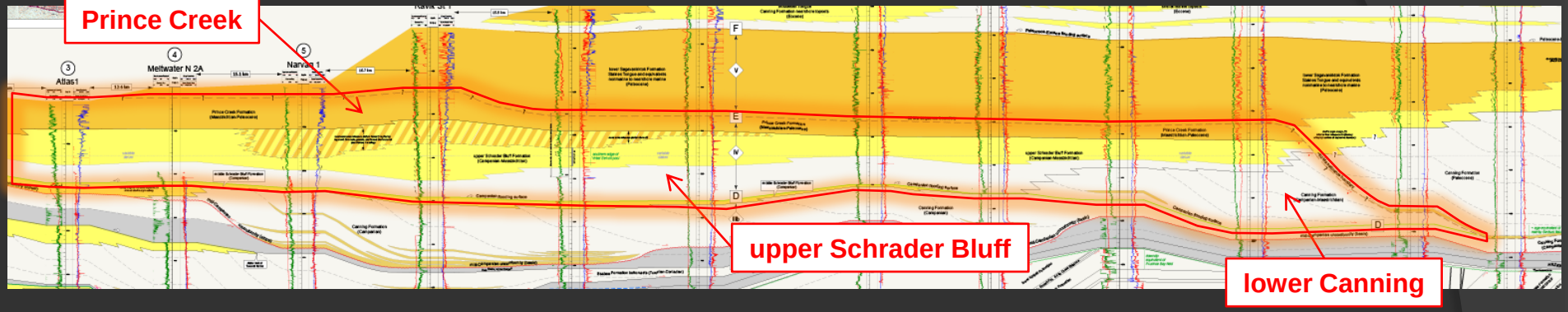


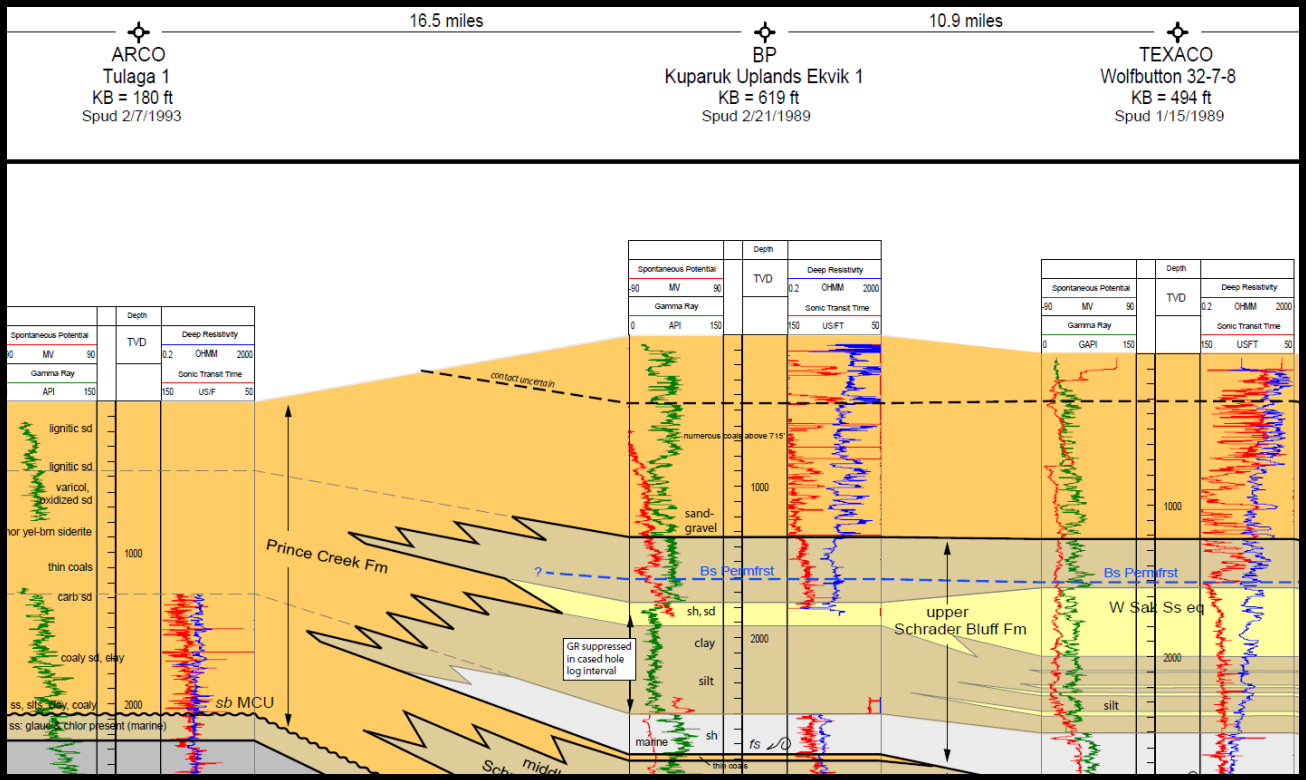
- Strongly progradational Campanian topsets, foresets, and bottomsets
- Infills relief created by MCU sequence boundary
  - *Incised valley fills, shelf-margin deltas in middle Schrader Bluff (outcrops, Tabasco field)*
  - *Toe-of-slope lowstand wedge, ponded sediment-gravity flows, etc. in Canning Fm*
- Equivalent nonmarine lower Prince Creek facies recognized in outcrop and logs to south and west *(Flores and others, 2007, 2007b; Decker, 2007; Gillis and others, in press)*
- Shelf margin advanced 30-60 km basinward (!) from MCU shelf edge position
- Deposition ends with major Campanian transgressive flooding event

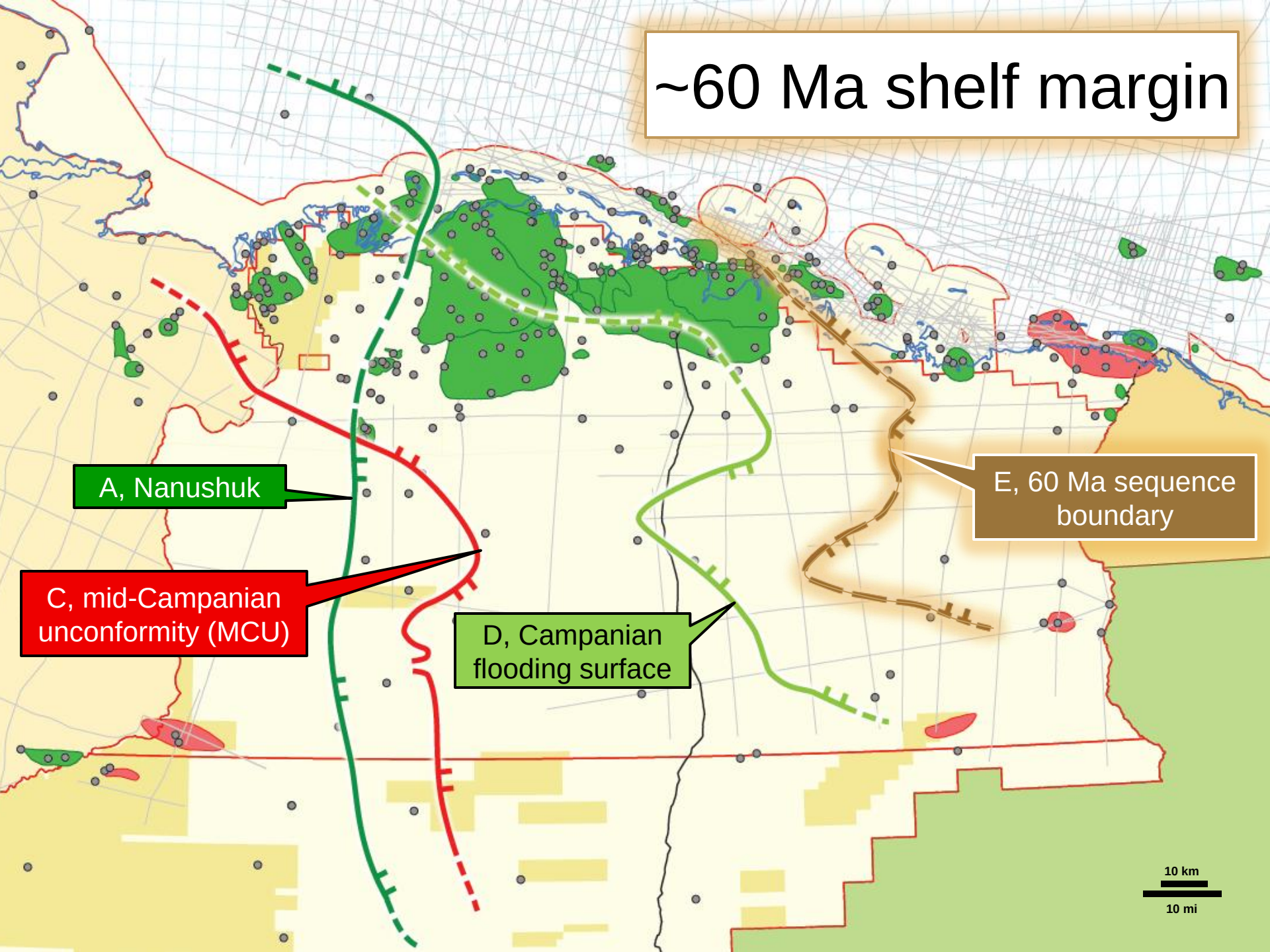
mid-Schrader shelf margin



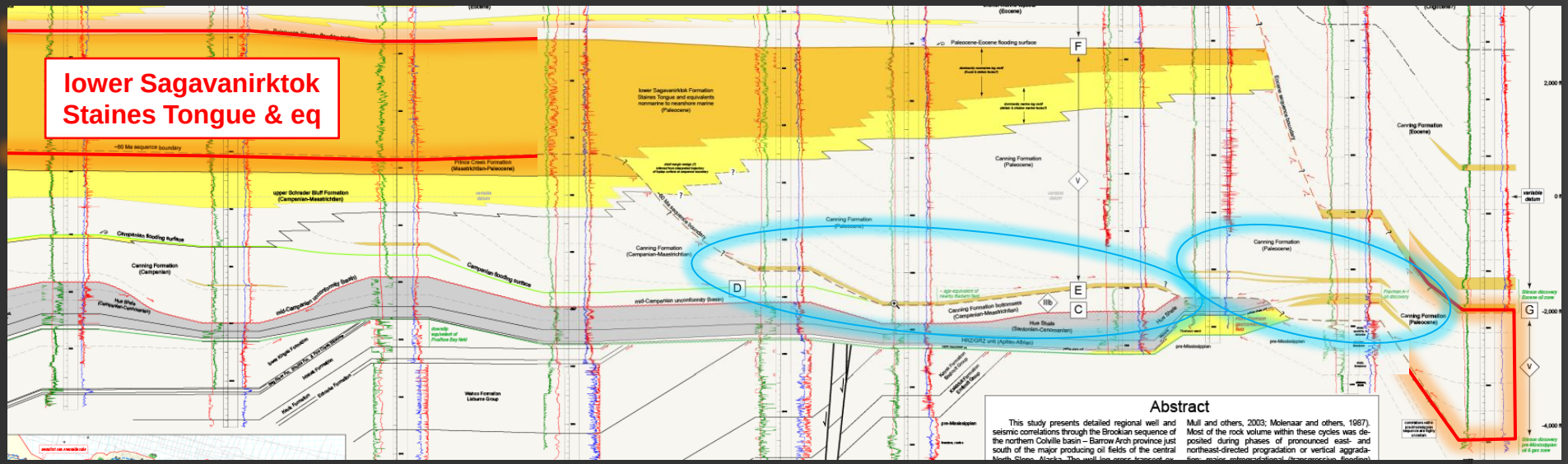
IV Prince Creek – upper Schrader Bluff – lower Canning





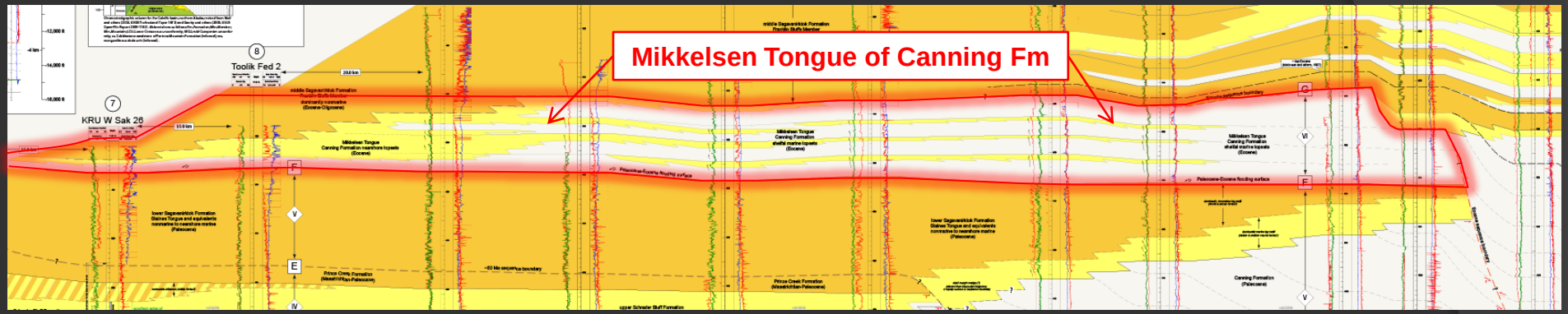

~60 Ma shelf margin
A, Nanushuk
C, mid-Campanian unconformity (MCU)
D, Campanian flooding surface
E, 60 Ma sequence boundary
10 km
10 mi

lower Sagavanirktok (Staines Tongue) – Canning



- Progradational, dominantly nonmarine Paleocene topsets and deepwater eq.
- Massive increase in coarse clastic sediment supply and significant provenance change across ~60 Ma unconformity relative to underlying Prince Creek Fm
- In deepwater, ~60 Ma surface rests on Maastrichtian -- pre-Mississippian units
- Deepwater sandstone reservoirs deposited on and near scoured ~60 Ma sequence boundary, perhaps during shelfal bypass: *Badami, Flaxman A-1 pools*
- Cycle ended with major transgression near Paleocene-Eocene boundary (onset of eustatic event due to PETM greenhouse earth)
  → deposition of Mikkelsen Tongue of Canning Formation

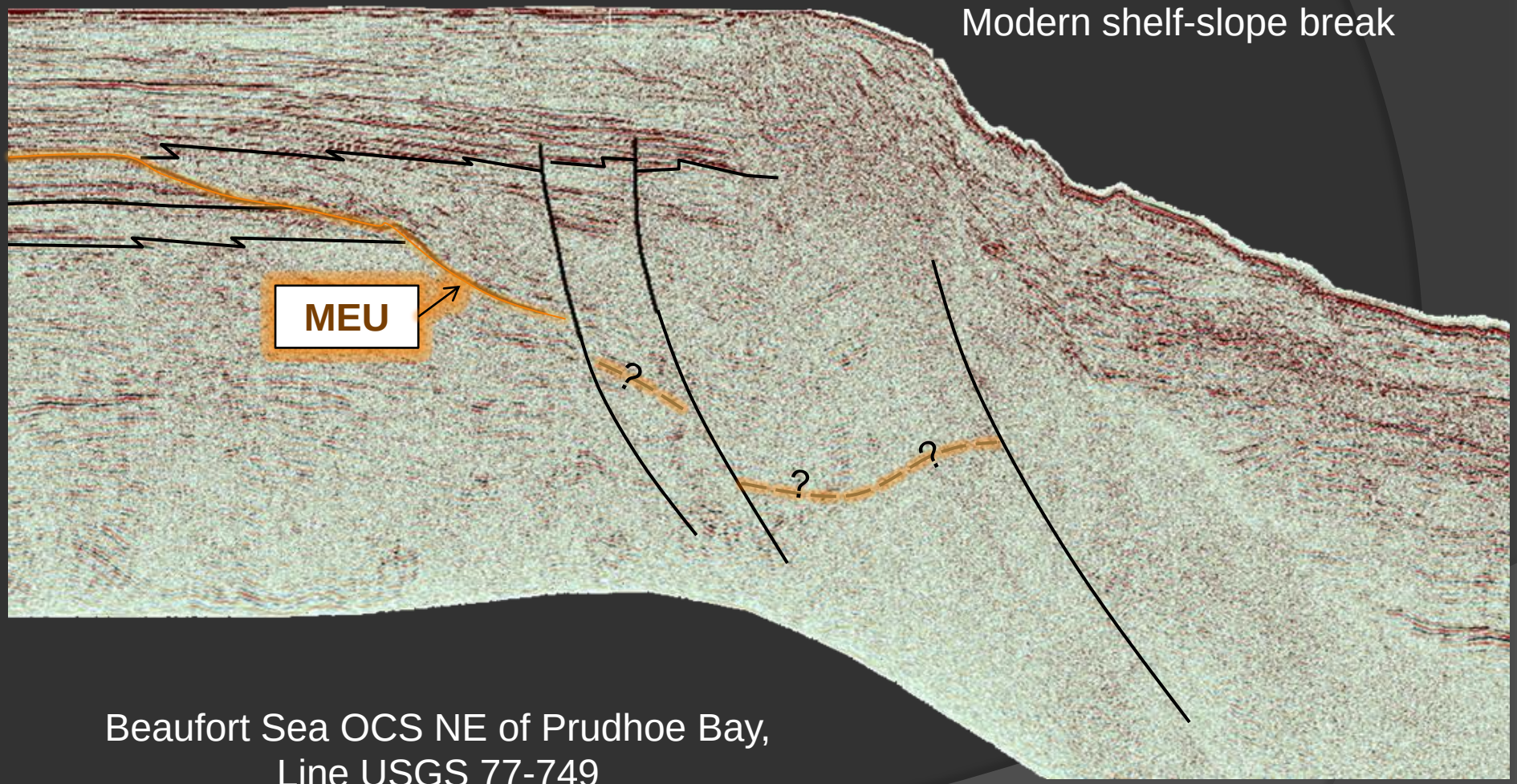
VI Mikkelsen Tongue of Canning Fm & equivalents



- Aggradational-progradational Eocene marine topset unit – the only part of Canning Fm deposited in topset environment
- Cycle began with major transgression near Paleocene-Eocene boundary (PETM onset?) (low-order highstand system)
- Shoreline shifted southwest an estimated 40-50 km
- Laterally persistent, widely correlatable upward-coarsening parasequence stacks
- Little foreset or bottomset equivalent
- Deposition ended with rapid facies shift (tectonically forced regression?)

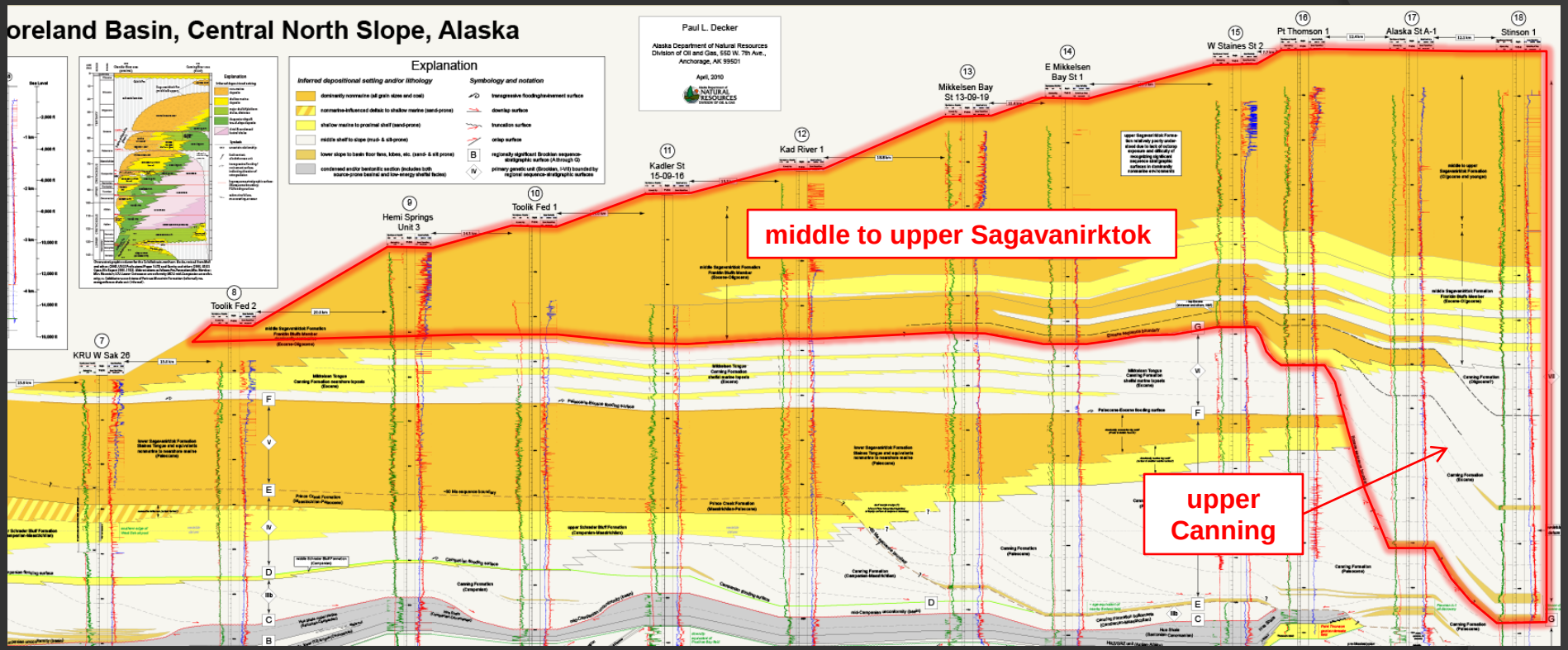
  → Eocene sequence boundary (MEU) with incised & collapsed shelf margin

G ~45 Ma Eocene Sequence Boundary



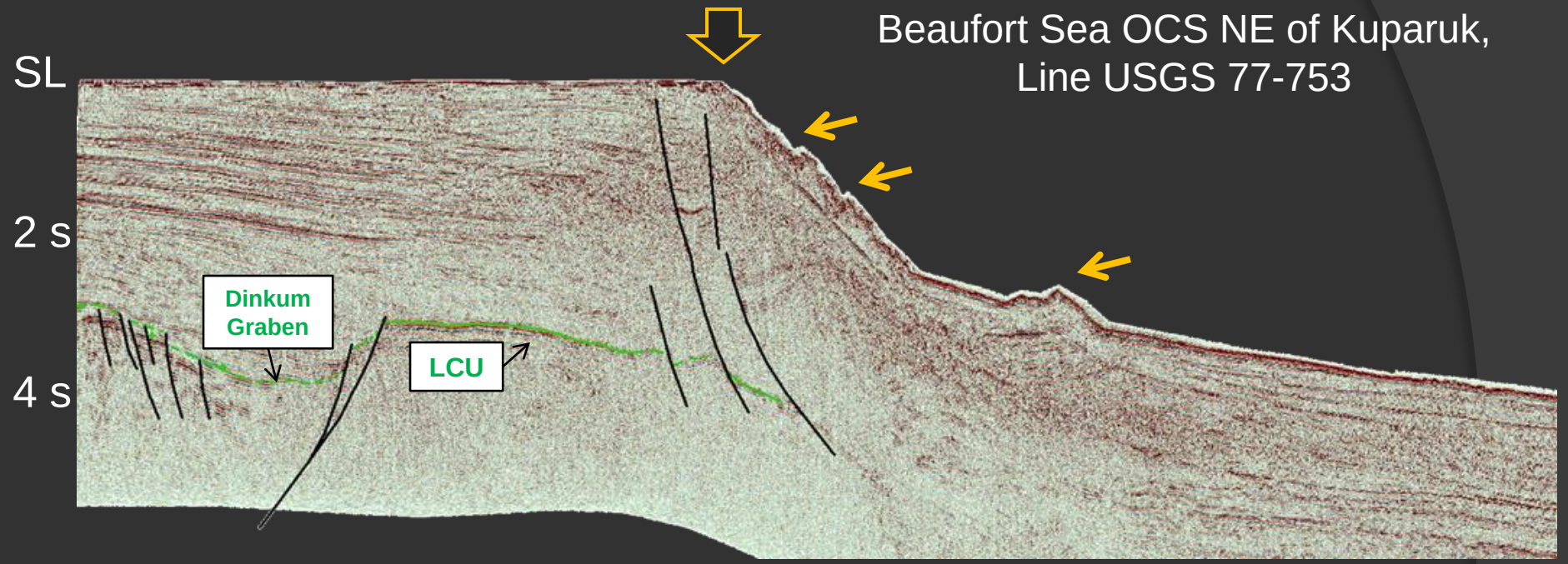
Beaufort Sea OCS NE of Prudhoe Bay,
Line USGS 77-749

VII middle & upper Sagavanirktok – upper Canning



- Aggradational-progradational late Eocene and younger topsets, foresets, and bottomsets
- Sagavanirktok Fm, Franklin Bluffs Member, perhaps Nuwok Member (offshore)
- Abundant coarse clastics shed from rejuvenation of Brooks Range
  - pulses of uplift at 45 Ma, ~40-30 Ma, ~23 Ma, etc. (O'Sullivan, 1993)
- Probable significant T-R episodes, but correlatability challenged in shallow parts

Modern Beaufort Shelf Margin



- Numerous shelf margin and slope failure features → sea floor relief
- These features likely formed during modern highstand conditions… how would lowstand features differ?
- Brookian slope-wasting & basinal scour processes (MCU, ~60 Ma, ~45 Ma)
- Modern examples show bathymetric relief that is muted or not preserved in subsurface → controls on deposition of reservoir-prone deepwater sand bodies

SUMMARY

- Aptian through Neogene Brookian sequence strata of the northern Colville foreland basin can be subdivided into primary genetic units (I-VII) bounded by isochronous surfaces (time lines) of regional sequence stratigraphic significance (A-G)
  - *public-domain, alpha-numeric framework for naming additional Brookian surfaces and intervals (seismic interp., paleogeographic mapping, etc.)*
- Regional validation of previous interpretations and hypotheses based on surface and subsurface data central and southern parts of foreland basin
- Low-order systems tract interpretations useful for predicting reservoir facies distribution within genetic units (topset vs bottomsets, etc.)
- Genetic insights critical for deciding what formation names to use in surface geologic mapping (e.g., no Prince Creek or Schrader Bluff Formations east of ~60 Ma shelf margin)