FORELAND BASIN RESPONSE TO PALEOCENE REJUVENATION IN THE BROOKS RANGE, NORTHERN ALASKA

Marwan A. Wartes ***Alaska Division of Geological & Geophysical Surveys***

Decker, P.L. (DOG)
Houseknecht, D.W. (USGS)
Gillis, R.J. (DGGS)
LePain, D.L. (DGGS)

ABSTRACT

The Brooks Range and its coupled foreland basin record a major episode of Late Jurassic to mid-Cretaceous collisional orogenesis. However, geologic mapping of cross cutting structural relations and folded Late Cretaceous - Paleogene strata indicate younger deformation affected the region. Stratigraphy and thermochronologic data suggest most of this rejuvenation occurred in the Paleocene when much of northern Alaska underwent widespread uplift and denudation. Despite the significance of this exhumational event, little is known about its attendant stratigraphic record in the foreland basin.

Recent surface and subsurface stratigraphic studies on the eastern North Slope provide new insight on Paleocene depositional systems and sequence stratigraphy. At Sagwon Bluffs, near the Dalton Highway, a significant unconformity separates the Maastrichtian to Paleocene Prince Creek Formation from the Paleocene Sagwon member of the Sagavanirktok Formation. Abrupt changes across this intra-Paleocene surface include 1) increase in grain size, 2) sandstone and clast composition, and 3) reduced sinuosity of fluvial systems. These observations are interpreted as the record of uplift in the Brooks Range and increased gradient and sediment supply across the foreland.

Recent surface mapping farther east indicates this subaerial unconformity can be correlated basinward. Seismic and well data suggest the correlative Paleocene shelf margin was incised and deeply eroded during a major base level fall, resulting in a regional downward stepping trajectory of toplap surfaces. This surface can be traced into deep-water strata, where significant submarine scouring is evident. Wells drilled beyond this shelf margin typically exhibit a sharp dislocation in log motif, indicating an abrupt influx of sandstone in slope and basinal facies of the Canning Formation. Several oil-charged slope-channel and slope-apron turbidite systems have been discovered in association with this lowstand systems tract.

The greatest thickness of Paleocene strata is observed on the easternmost North Slope, reflecting the greater inherited accommodation in the remaining underfilled sector of the basin. However, this portion of the basin does not appear to record passive filling; instead, consideration of northward prograding and southward thickening tongues of Paleocene strata in the Canning River area are most consistent with synchronous tectonic subsidence in a flexural foredeep lying directly north and west of the growing orogenic wedge. This pattern of subsidence contrasts markedly with coeval uplift of much of the North Slope to the west. By the end of the Paleocene, most of the basin was filled, setting the stage for subsequent Tertiary sedimentation to overtop the Barrow Arch and begin significant growth of the Beaufort shelf.

Authors note: These slides accompanied an oral presentation delivered at the AAPG 3P Arctic Meeting (The Polar Petroleum Potential Conference & Exhibition) in Halifax, Nova Scotia, Canada, August 30 – September 2, 2011. The slides included here have been slightly modified for clarity.

Brooks Range Orogen and Colville Foreland Basin Reflect Jurassic to mid-Cretaceous Arc-Continent Collision

Arctic Ocean
100 Miles
Barrow
Beaufort Sea
Prudhoe Bay
National Petroleum Reserve - Alaska (NPRA)
Pipeline
North Slope
COLVILLE BASIN
Arctic National Wildlife Refuge (ANWR)
CANADA
Brooks Range

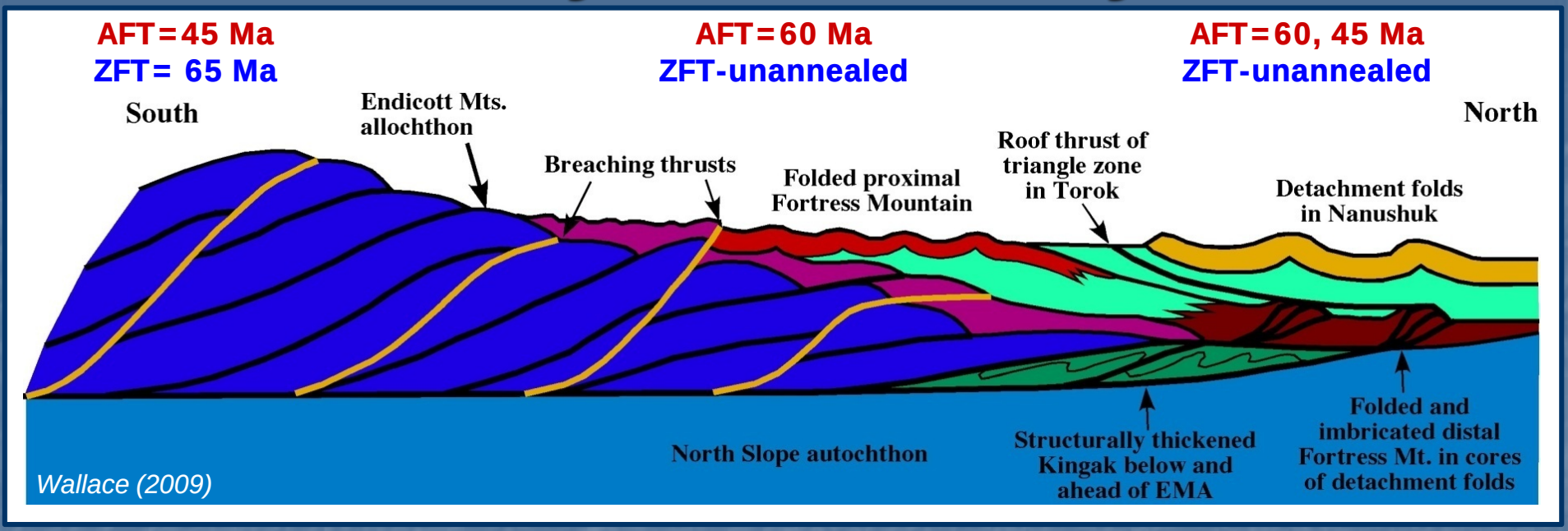
However. . .

- Deformed Upper Cretaceous Rocks
- Cross-cutting Structures
- Early Paleogene Cooling Ages (~60 Ma)

. . . Indiacte A Superposed Tertiary Orogen

Photo by C. G. Mull

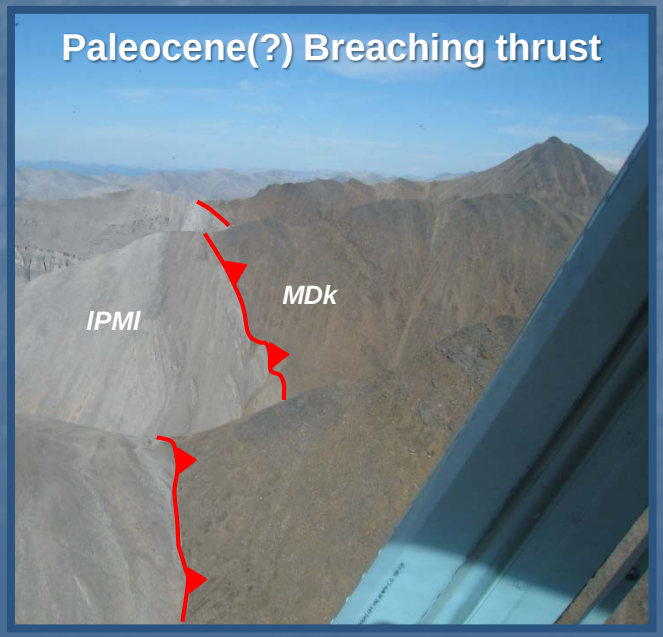
Tertiary Structural Style



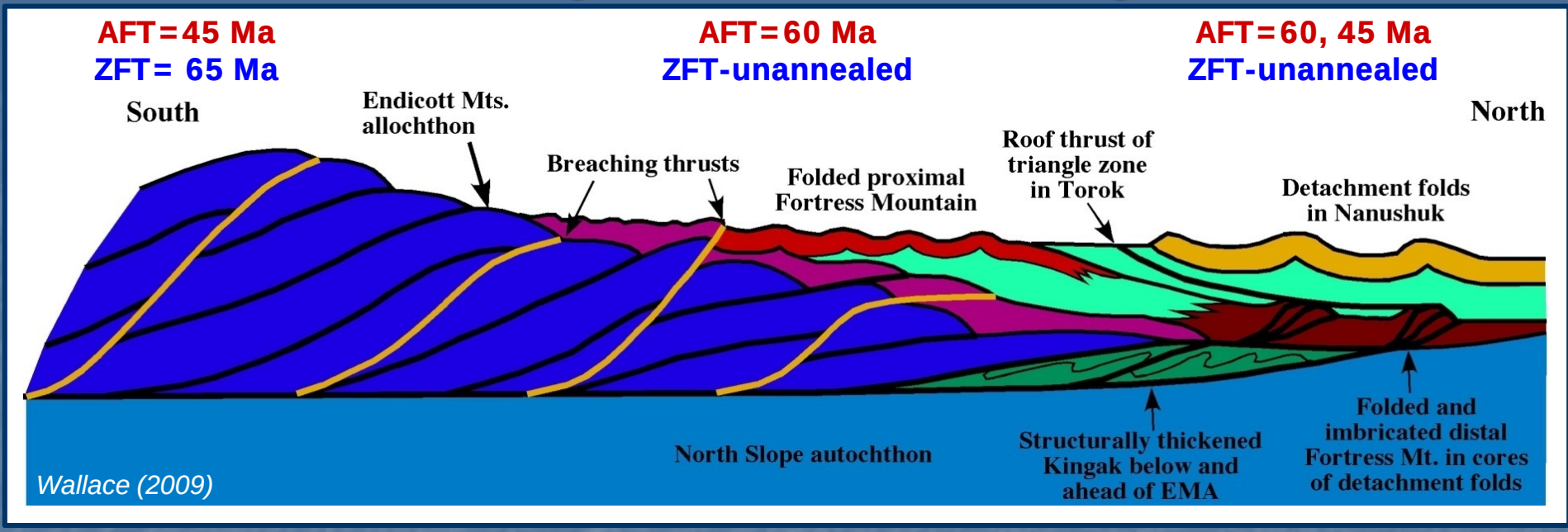
- Small-displacement reactivation and thickening of orogenic wedge
- Out-of-sequence(?) *Breaching thrusts* cut older structures and post-allochthon units
- Detachment folds and triangle zone involving Nanushuk Formation

Result:

Significant structural relief and exhumation



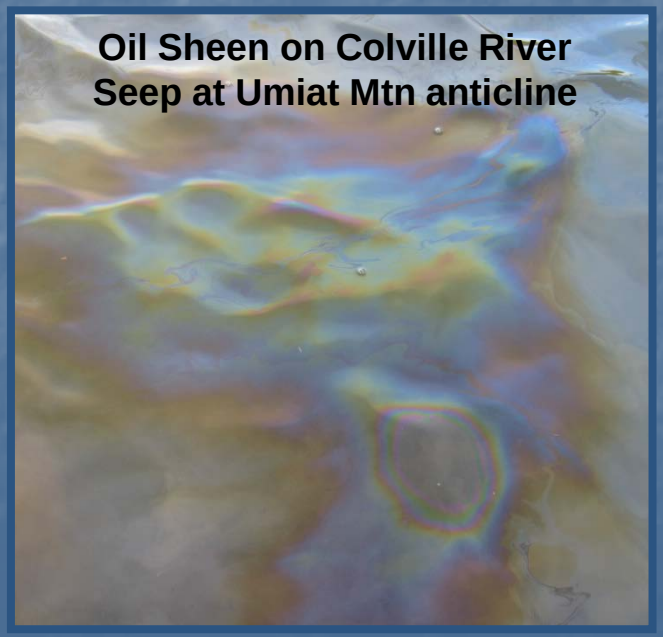
Tertiary Structural Style



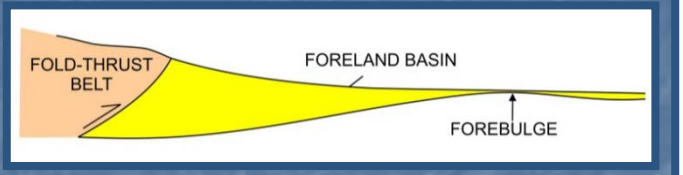
- Small-displacement reactivation and thickening of orogenic wedge
- Out-of-sequence(?) *Breaching thrusts* cut older structures and post-allochthon units
- Detachment folds and triangle zone involving Nanushuk Formation

Relevancy:

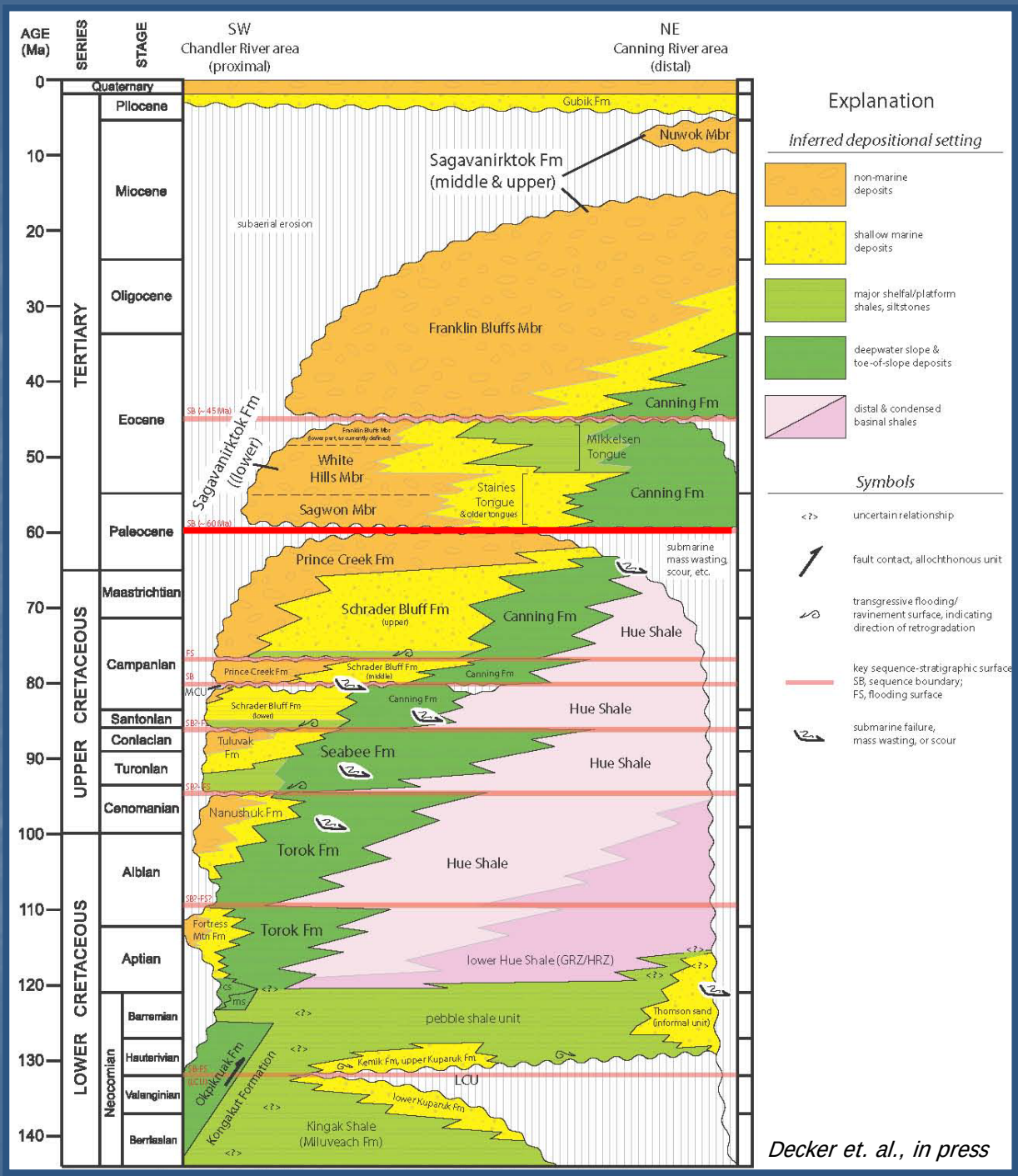
Trap timing and hydrocarbon generation



Paired fold-thrust belts and foreland basins are genetically coupled



Is the Paleocene event recorded in the stratigraphy of the Colville Basin?

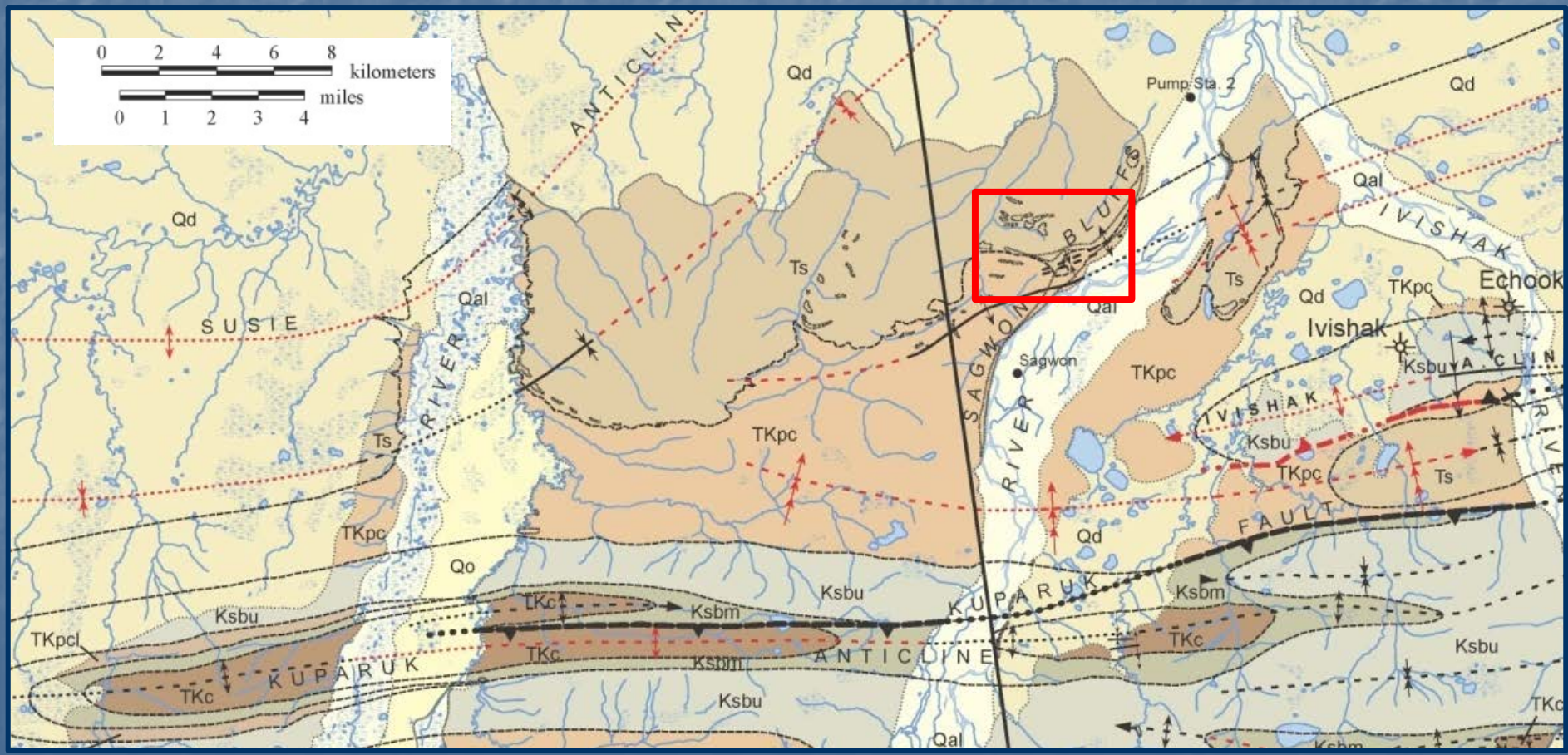


Decker et. al., in press

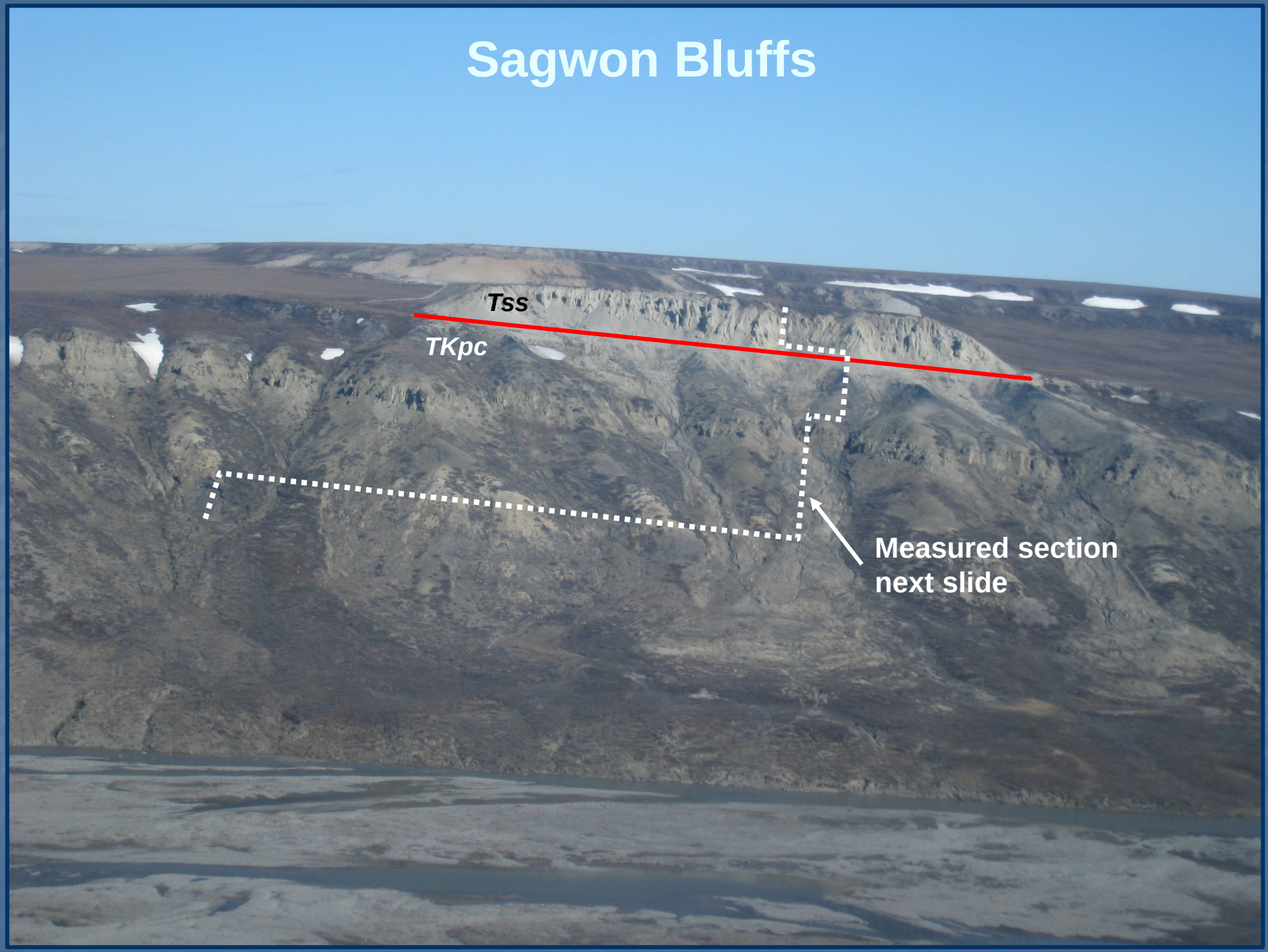
Sagavanirktok River geologic map

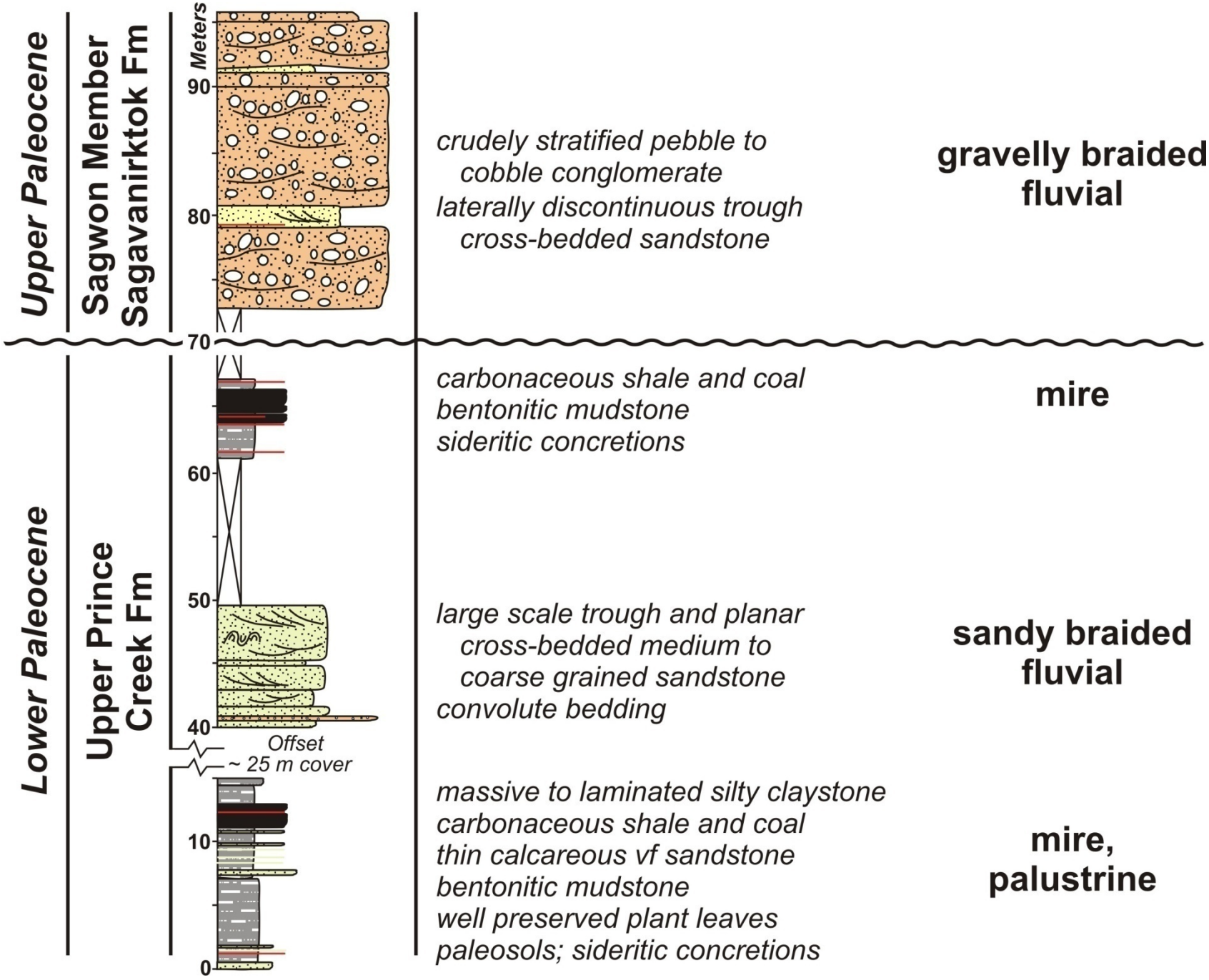
-- Sagwon Bluffs --

Simplified from Gillis et al. (2014)

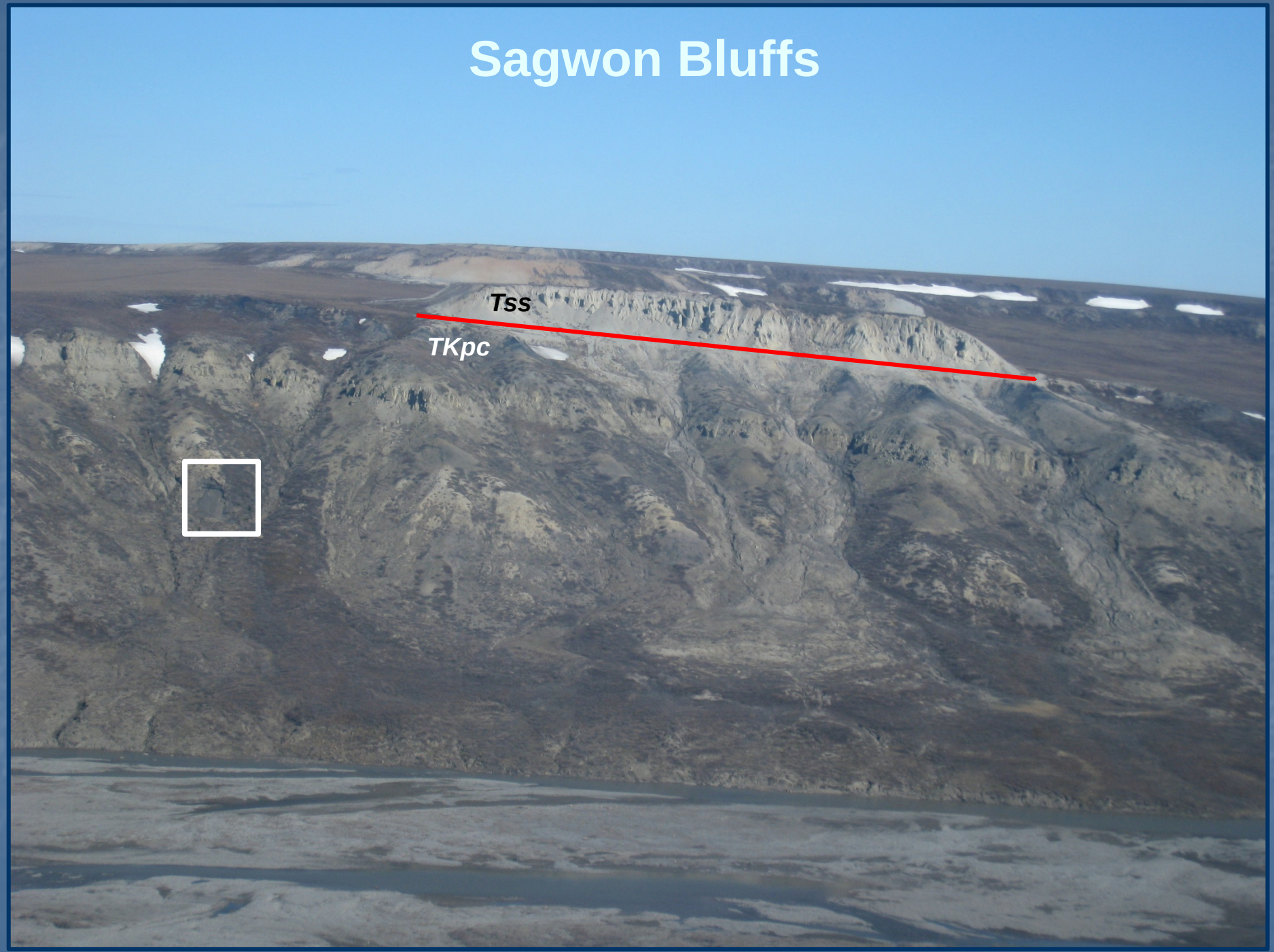


Sagwon Bluffs

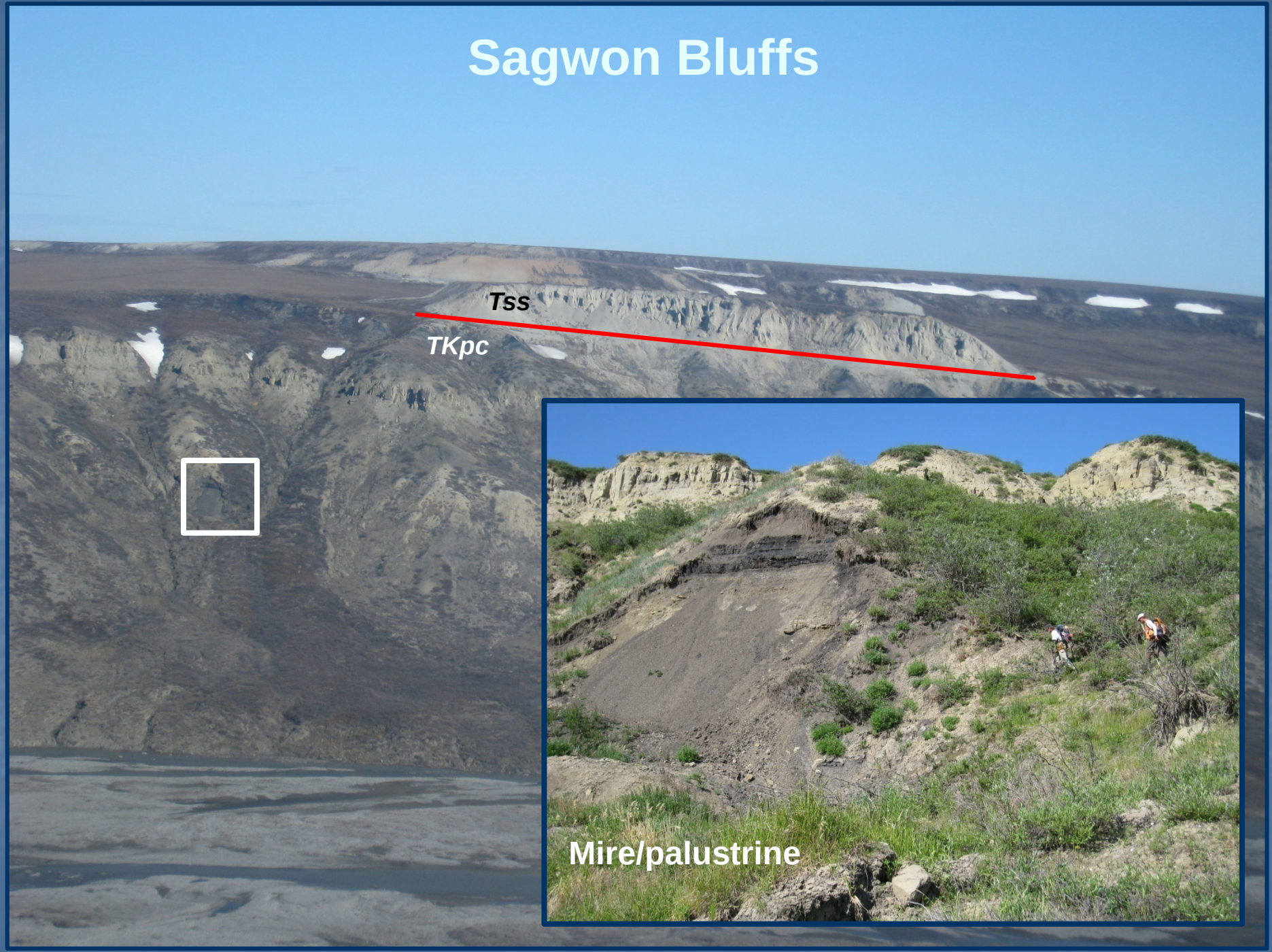



Upper Paleocene
Sagwon Member
Sagavanirktok Fm
Meters
90
80
70
Lower Paleocene
Upper Prince Creek Fm
60
50
40
Offset
~ 25 m cover
10
0
crudely stratified pebble to cobble conglomerate
laterally discontinuous trough cross-bedded sandstone
gravelly braided fluvial
carbonaceous shale and coal
bentonitic mudstone
sideritic concretions
mire
large scale trough and planar cross-bedded medium to coarse grained sandstone
convolute bedding
sandy braided fluvial
massive to laminated silty claystone
carbonaceous shale and coal
thin calcareous vf sandstone
bentonitic mudstone
well preserved plant leaves
paleosols; sideritic concretions
mire, palustrine

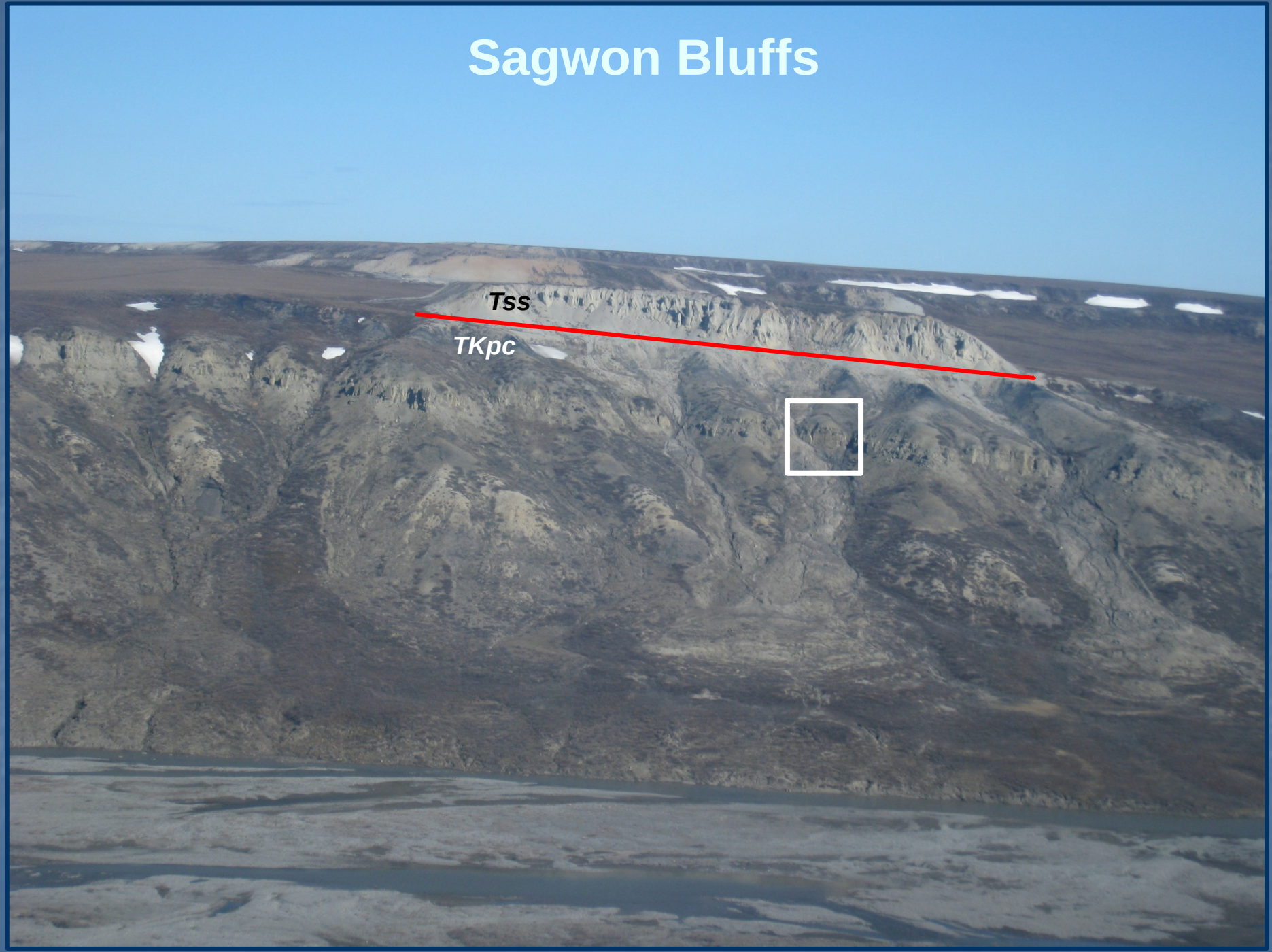
Sagwon Bluffs



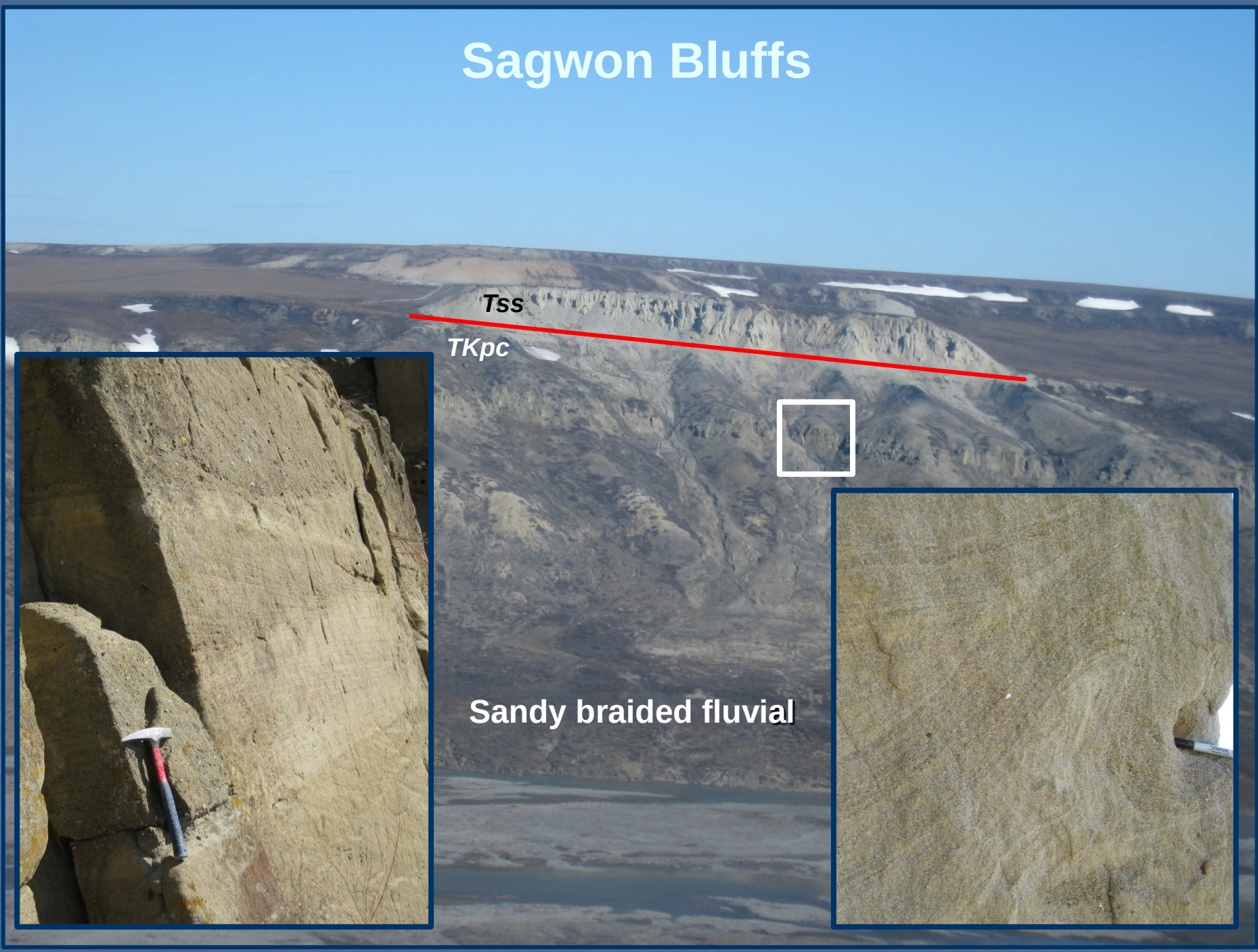
Sagwon Bluffs



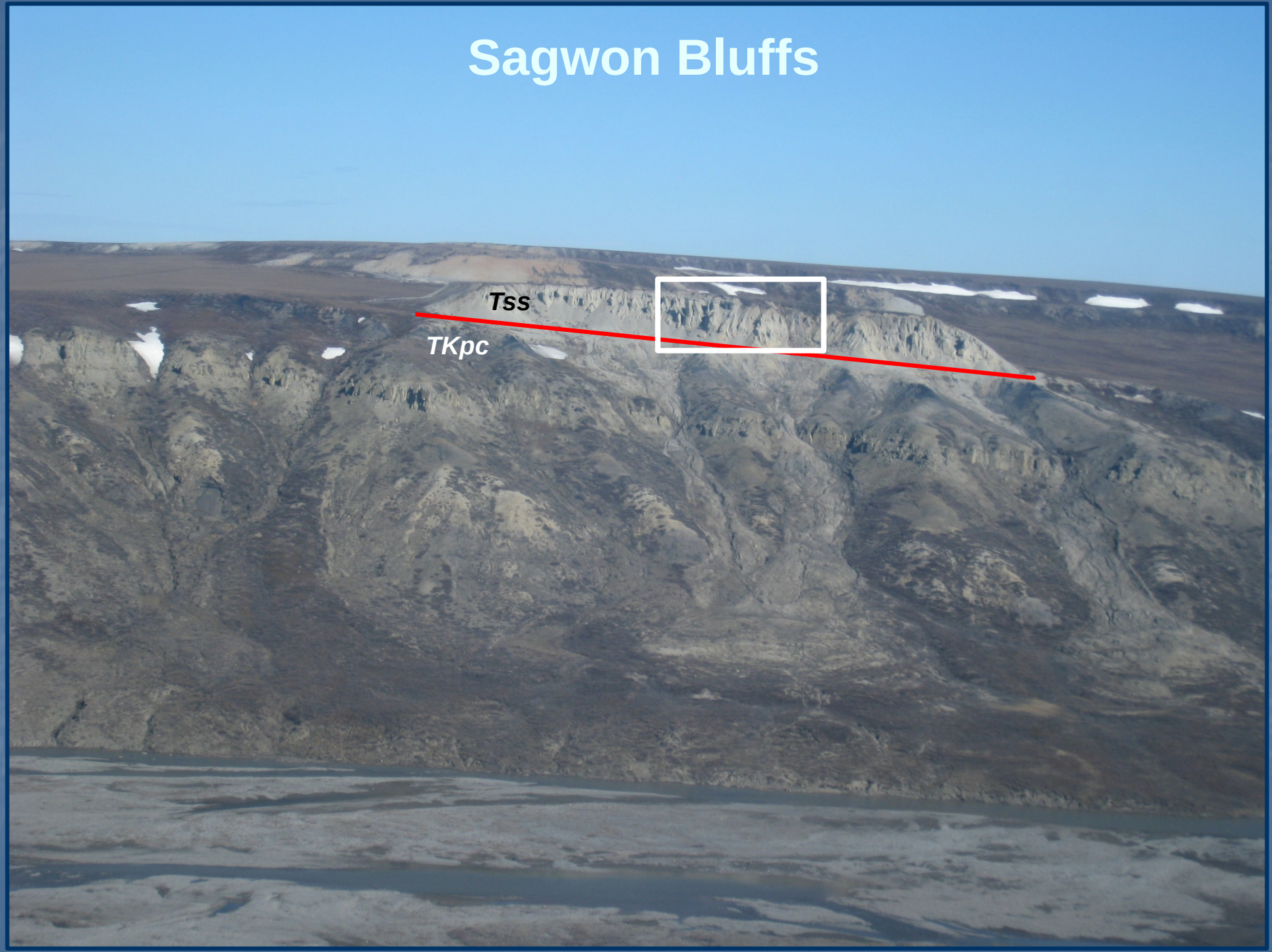
Sagwon Bluffs



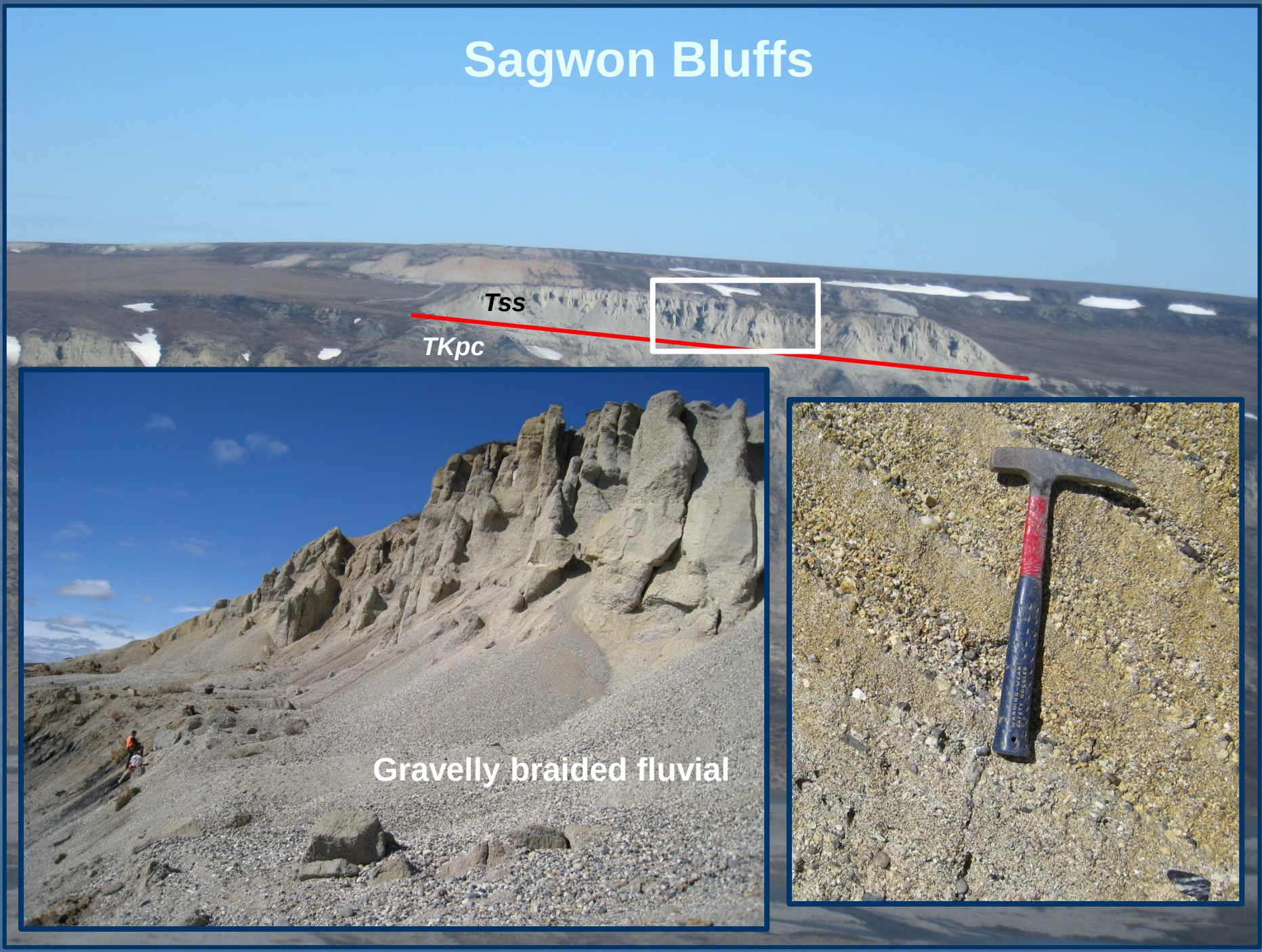
Sagwon Bluffs



Sagwon Bluffs



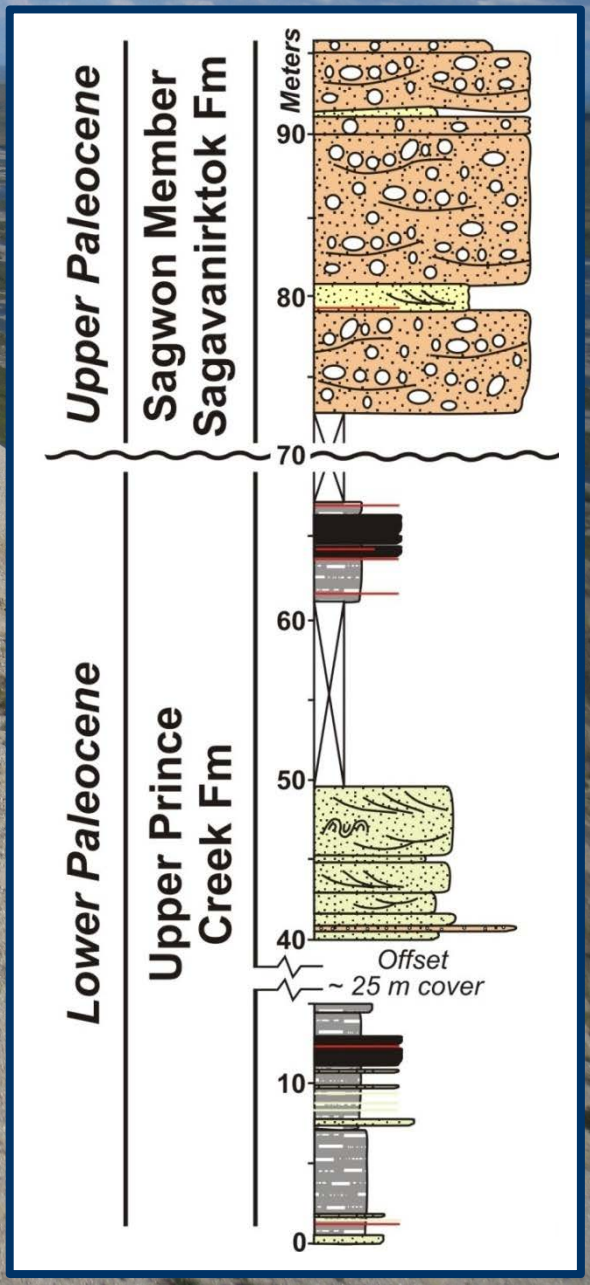
Sagwon Bluffs



Paleocene sequence boundary in outcrop (Sagwon Bluffs)

Summary -- changes across the unconformity

- Abrupt increase in grain size
- Fluvial style
- Sandstone composition
- Clast composition



Subsurface Expression

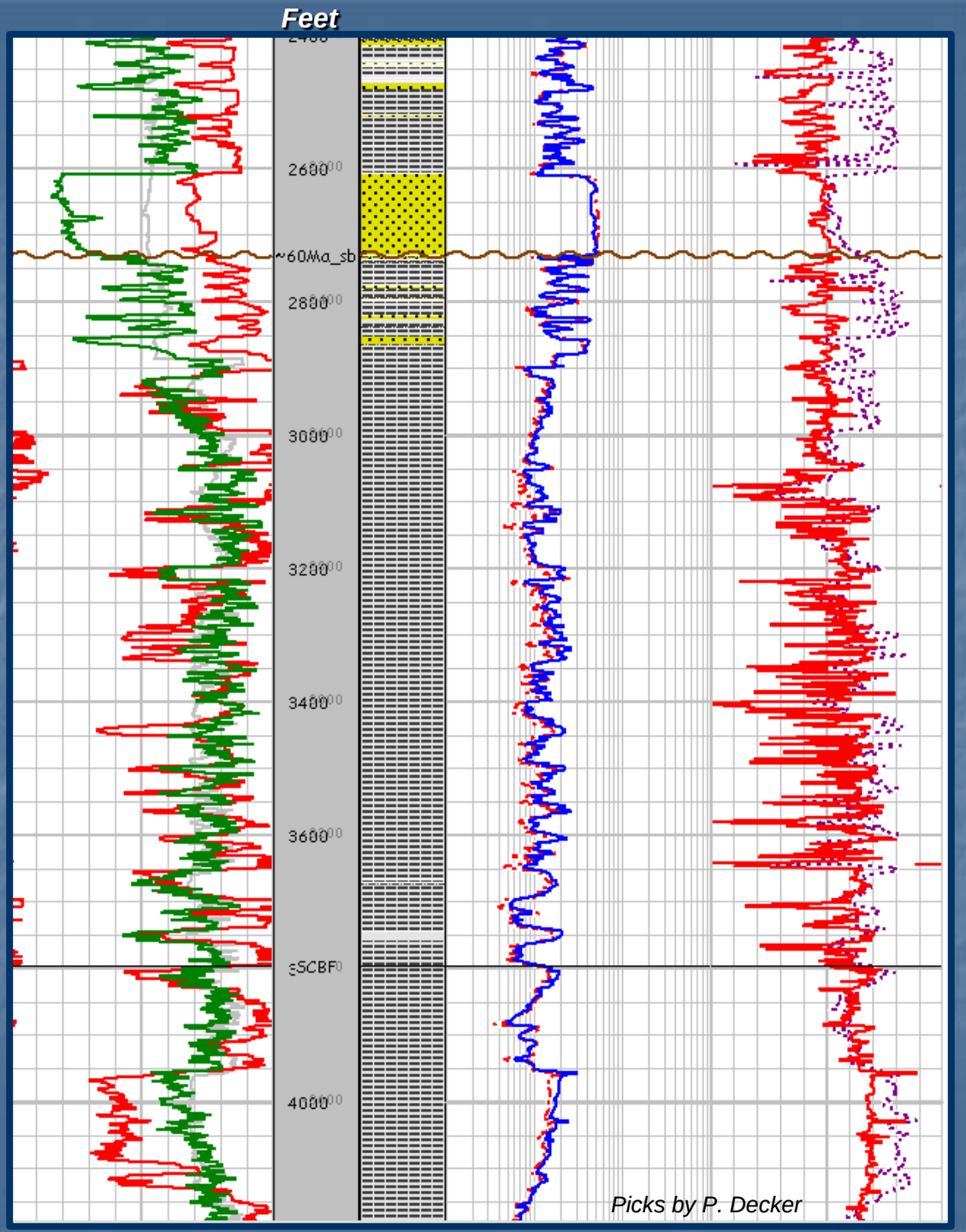
Bush Federal No. 1

(~31 km northwest of Sagwon Bluffs)

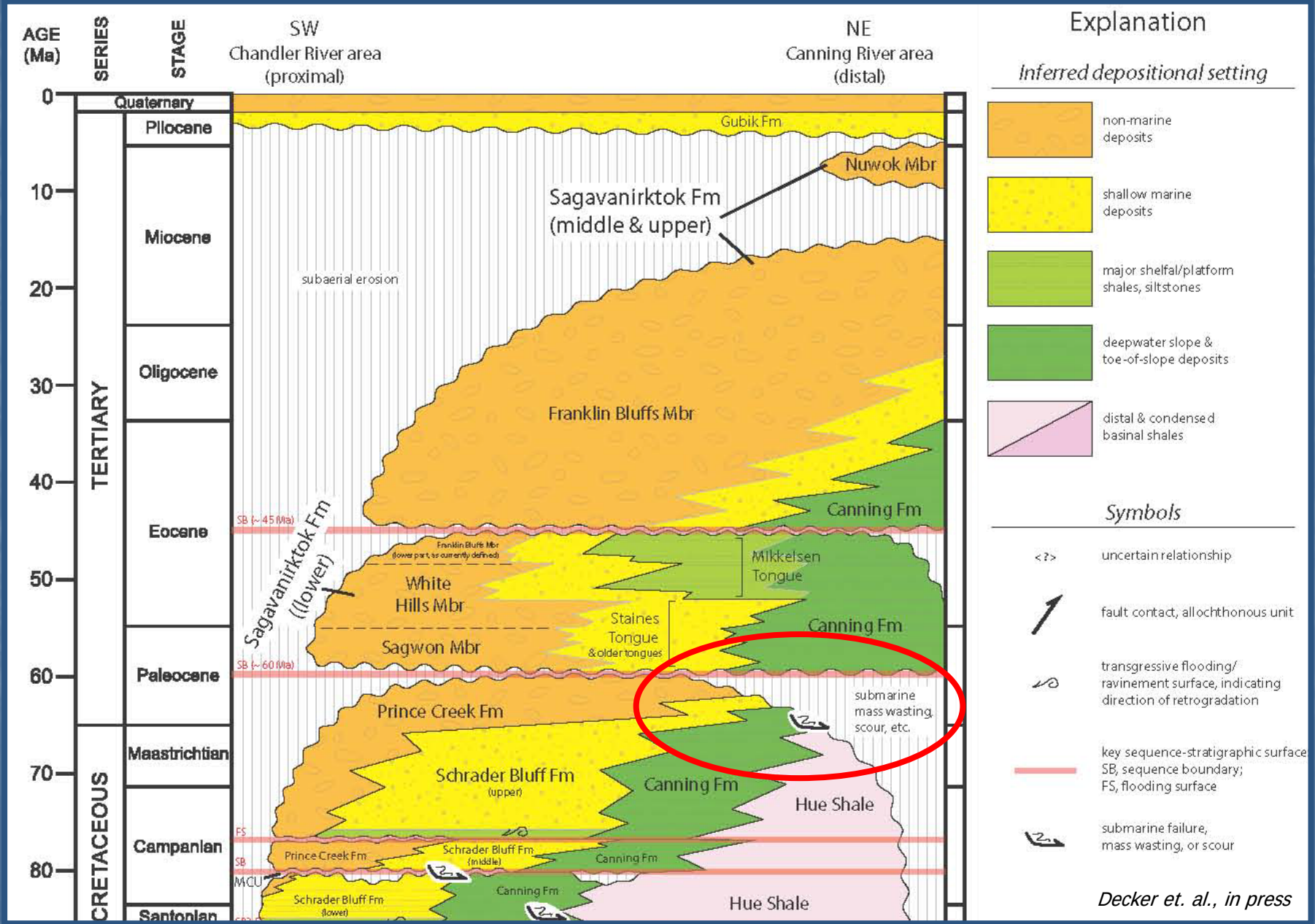
-- Sandy upper Prince Creek Fm

-- Unconformity picked at abrupt log kick

Shaviovik 1

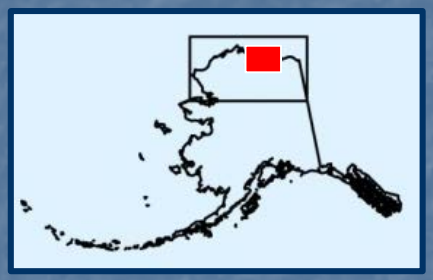


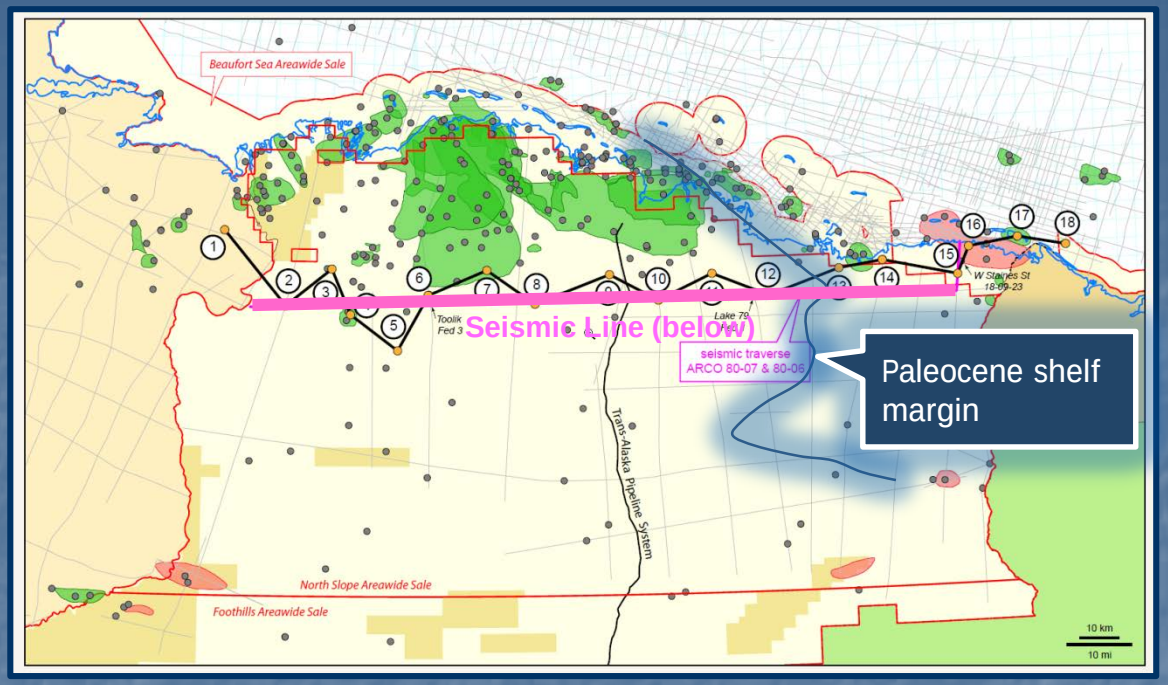
Basinward Record of Paleocene Sequence Boundary

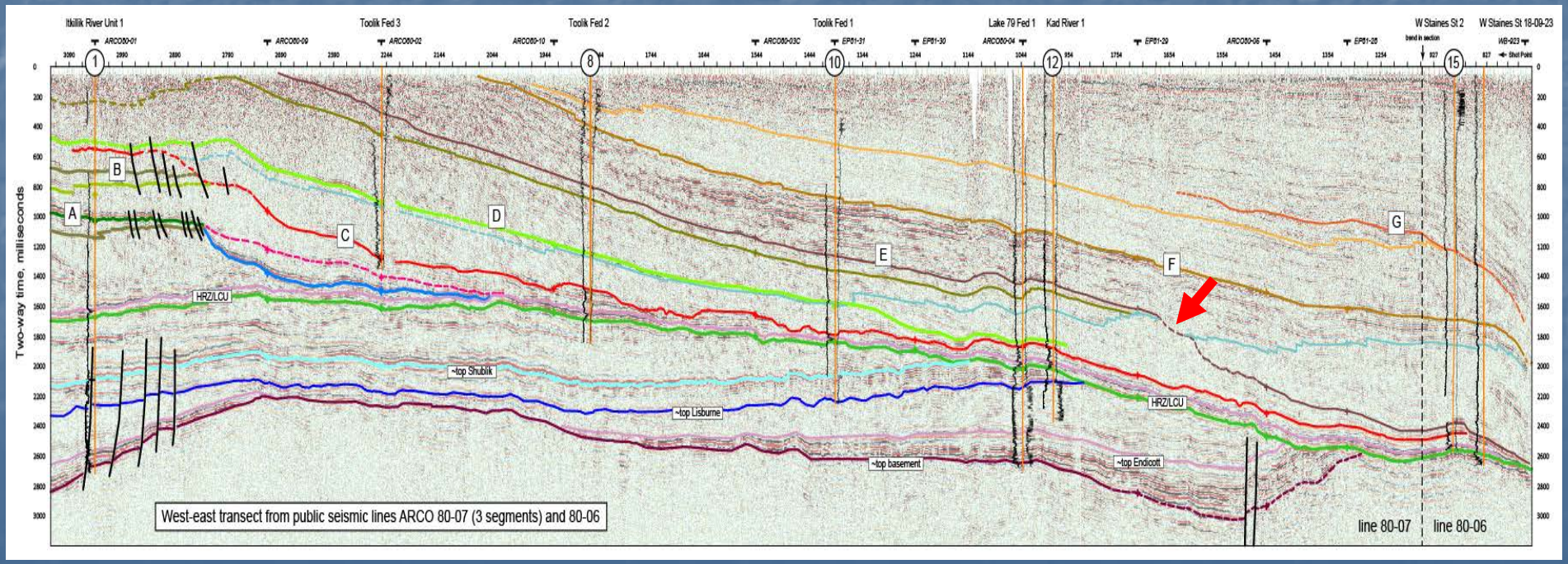


Decker et. al., in press

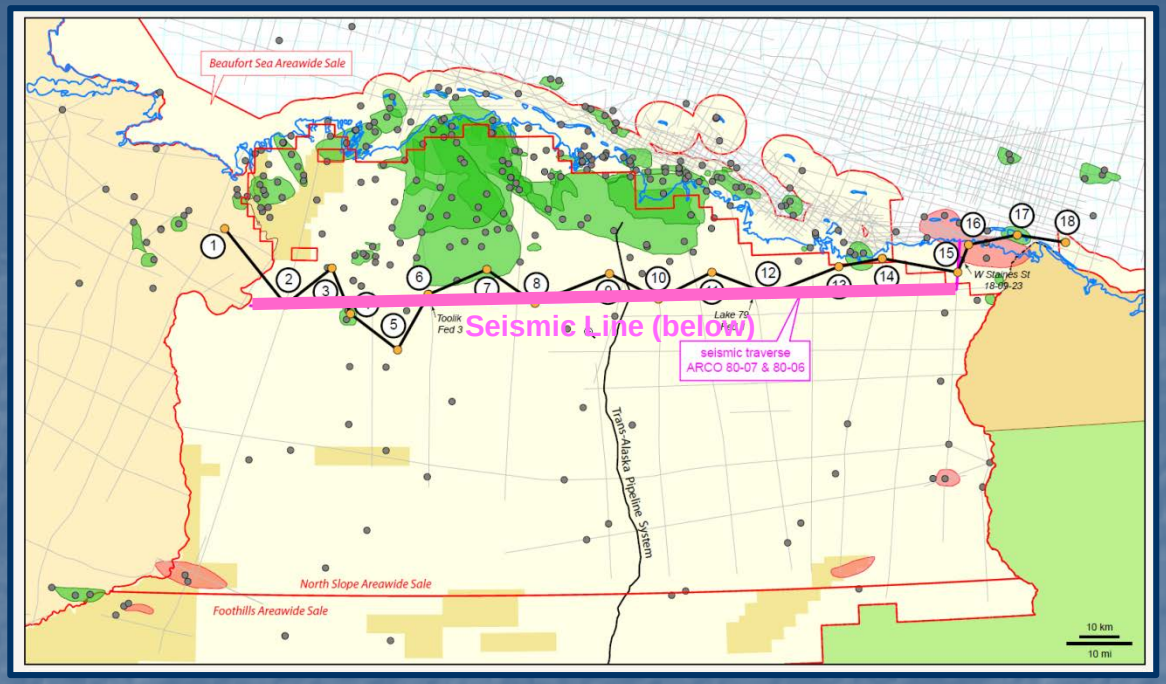
- Shelf margin incision
- Downward stepping trajectory of toplap surfaces

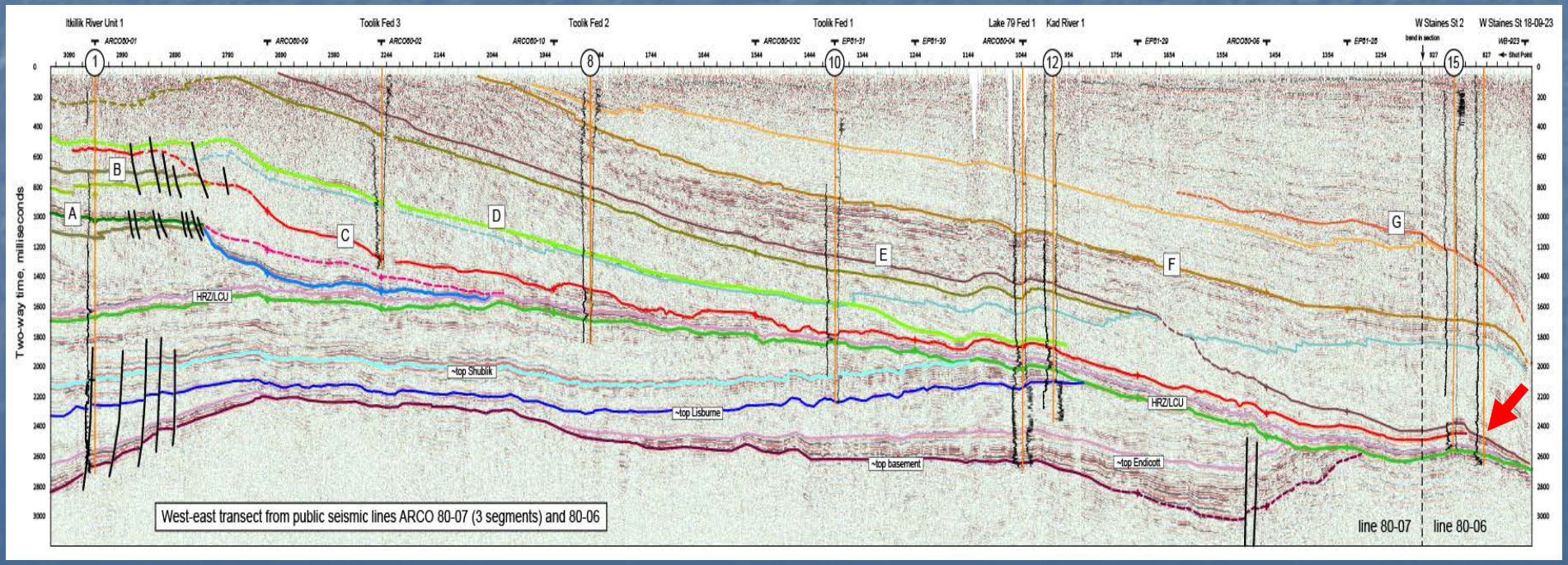




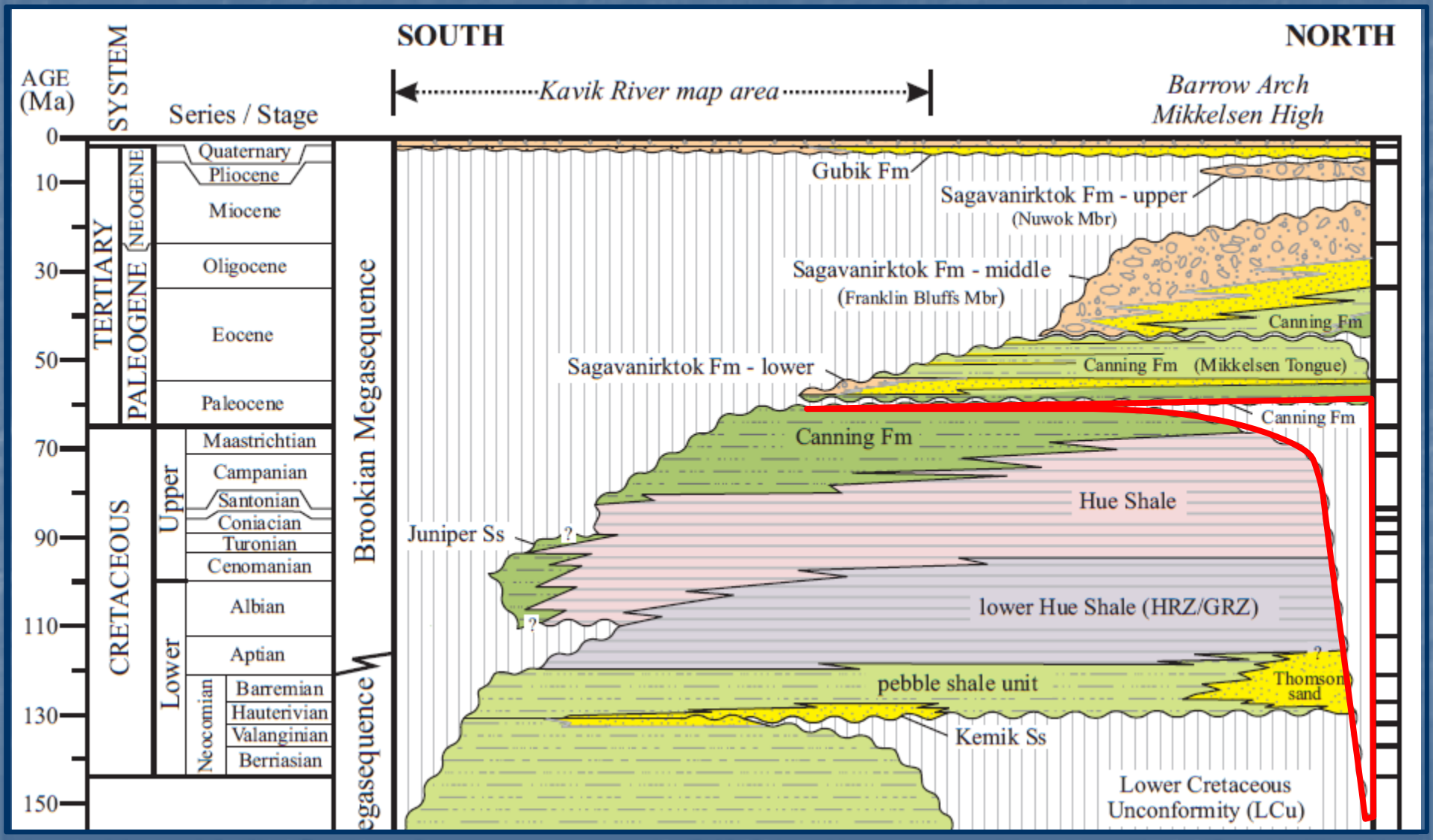


- Shelf margin incision
- Downward stepping trajectory of toplap surfaces
- Submarine scouring and slumping
- Significant relief on unconformity





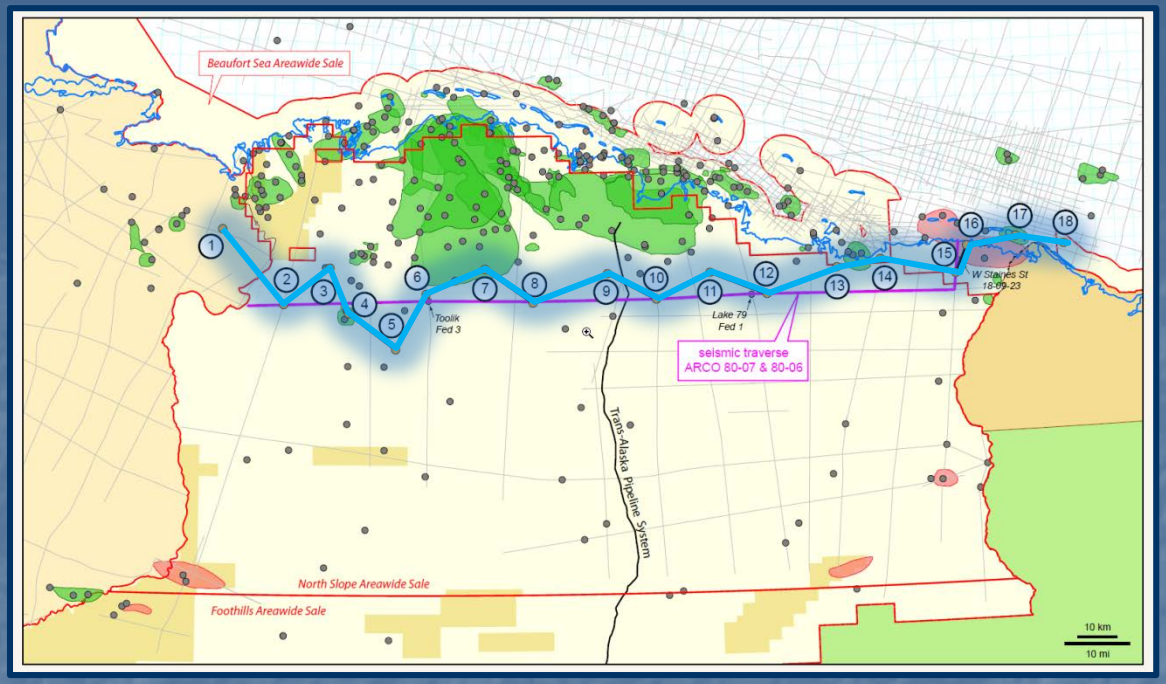
Paleocene unconformity underlain by Maastrichtian – pre-Mississippian units

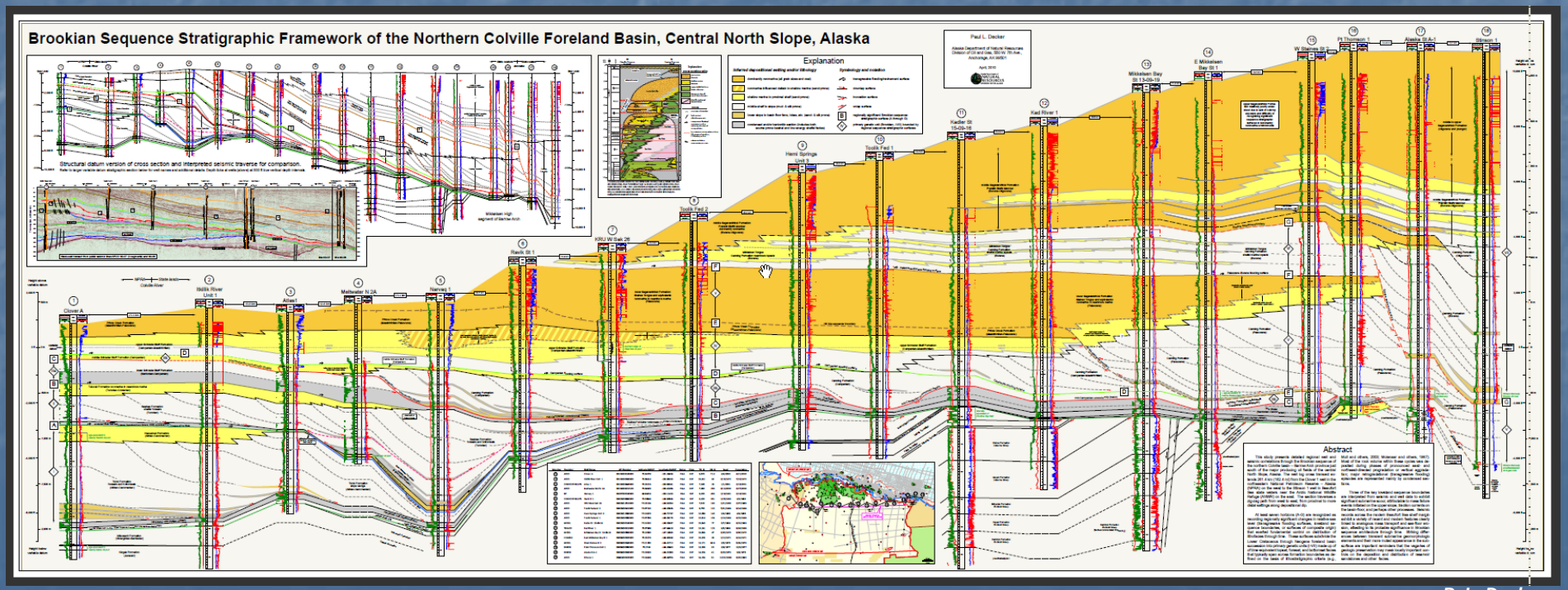


Wartes et al., 2011

~260 Km Well Log X-Section (floating datum)

- Sequence boundary marked by sharp dislocation in log motif
- Abrupt influx of sandstone in slope and basinal position





P. L. Decker

~260 Km Well Log X-Section (floating datum)

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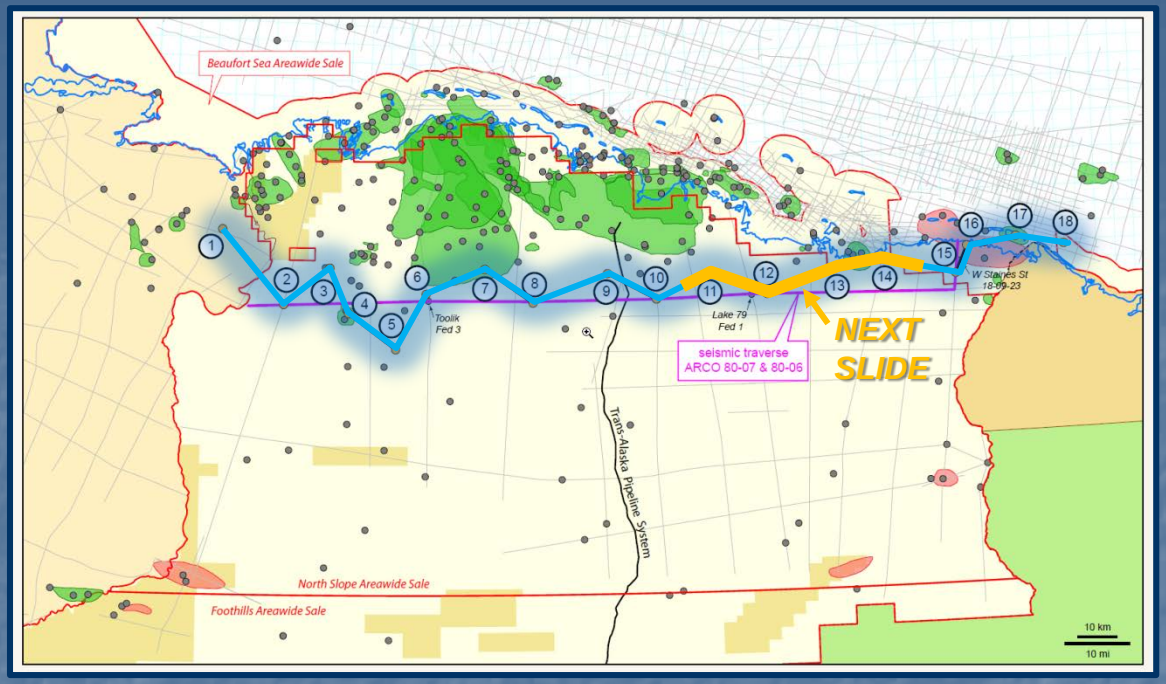
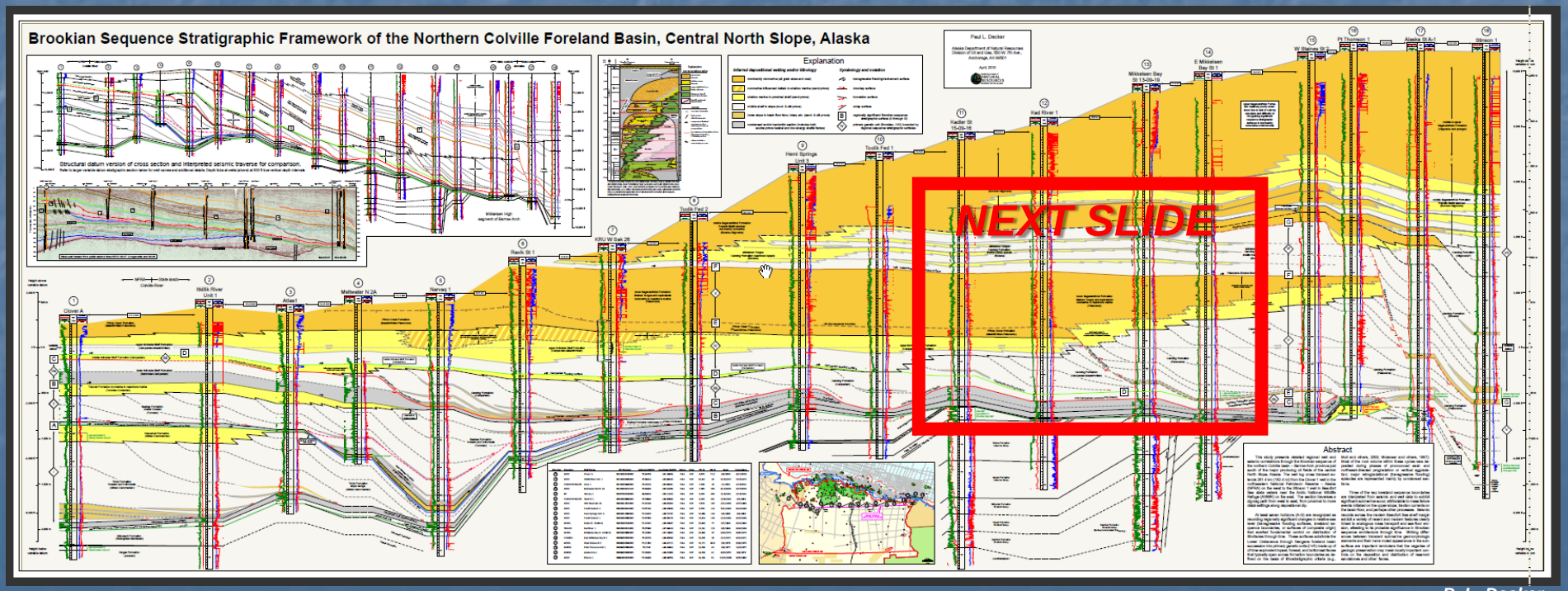
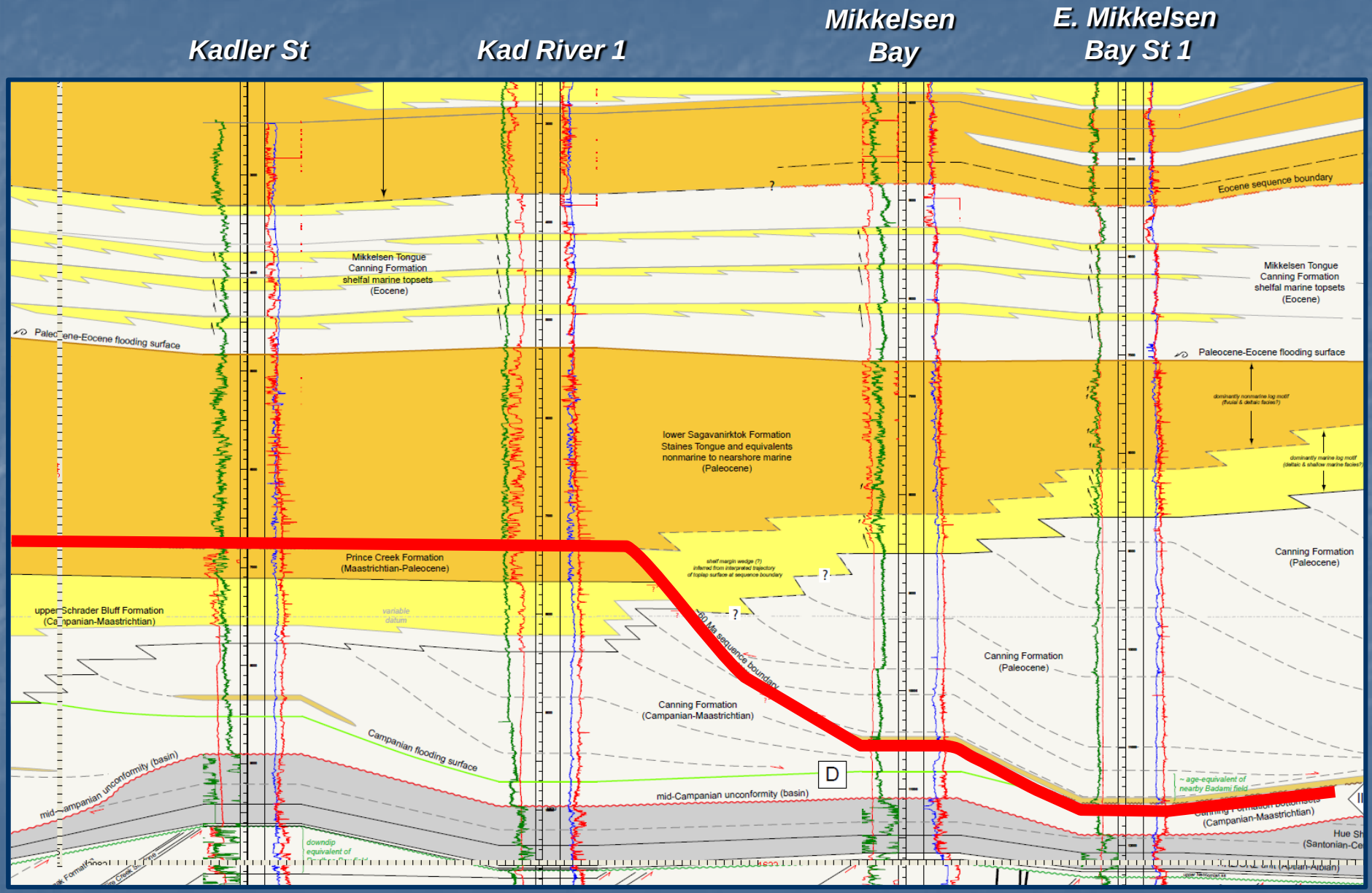




P. L. Decker

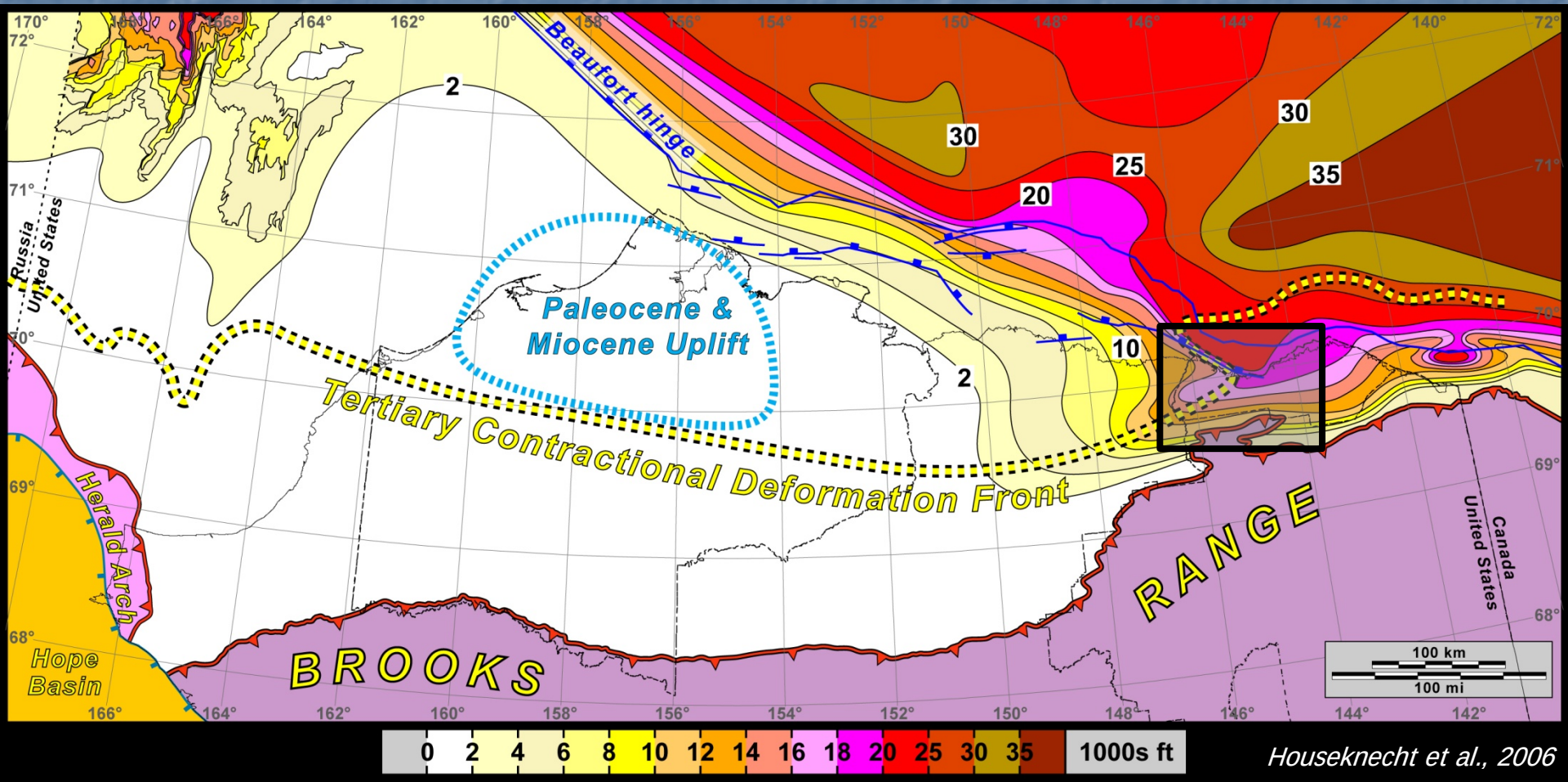
Deepwater sandstone reservoirs deposited on and near scoured Paleocene sequence boundary, perhaps during shelfal bypass: *Badami, Flaxman A-1 pools*



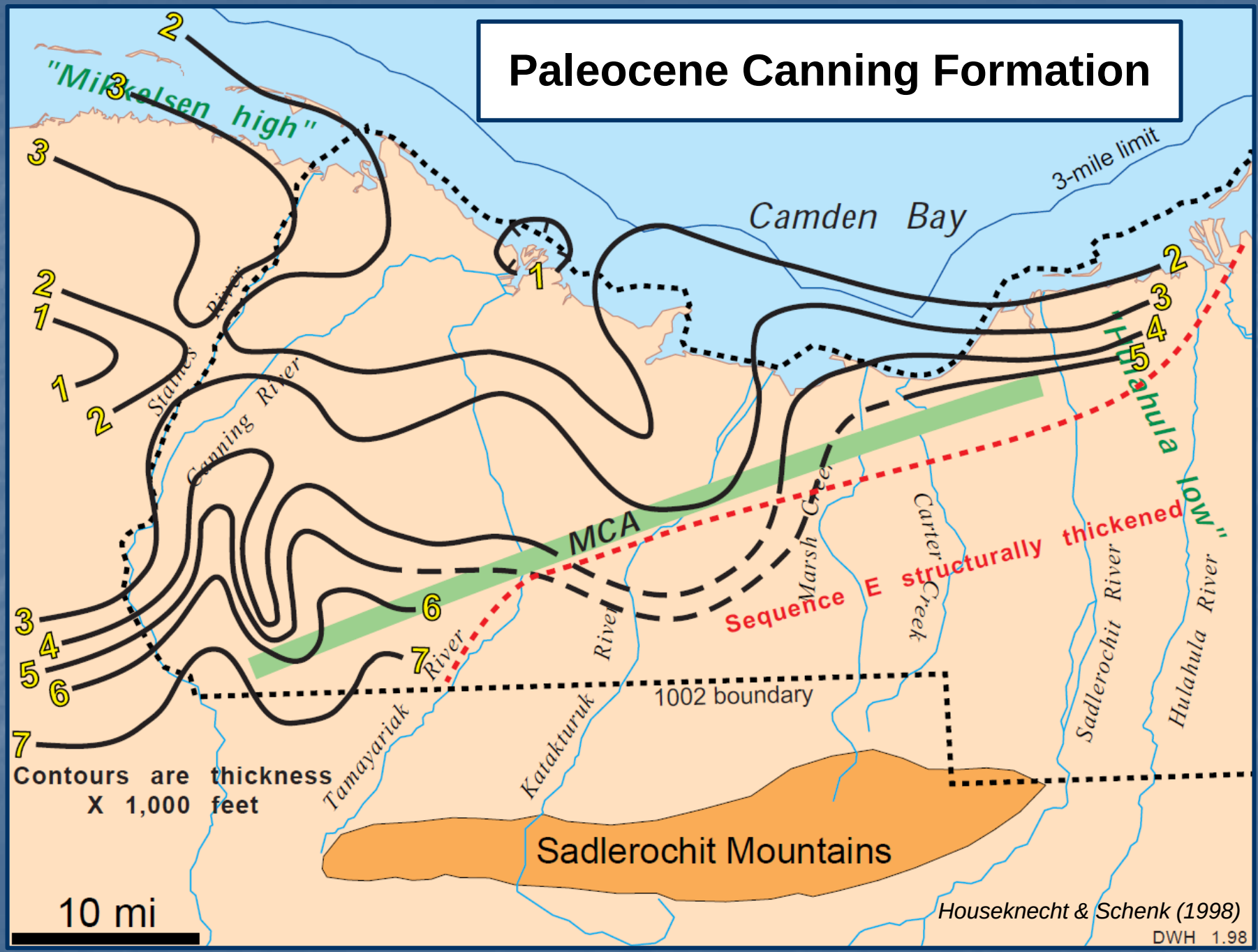
P. Decker

Inferred Original Tertiary Thickness

Question: Is it just passively filling the remnant accommodation?



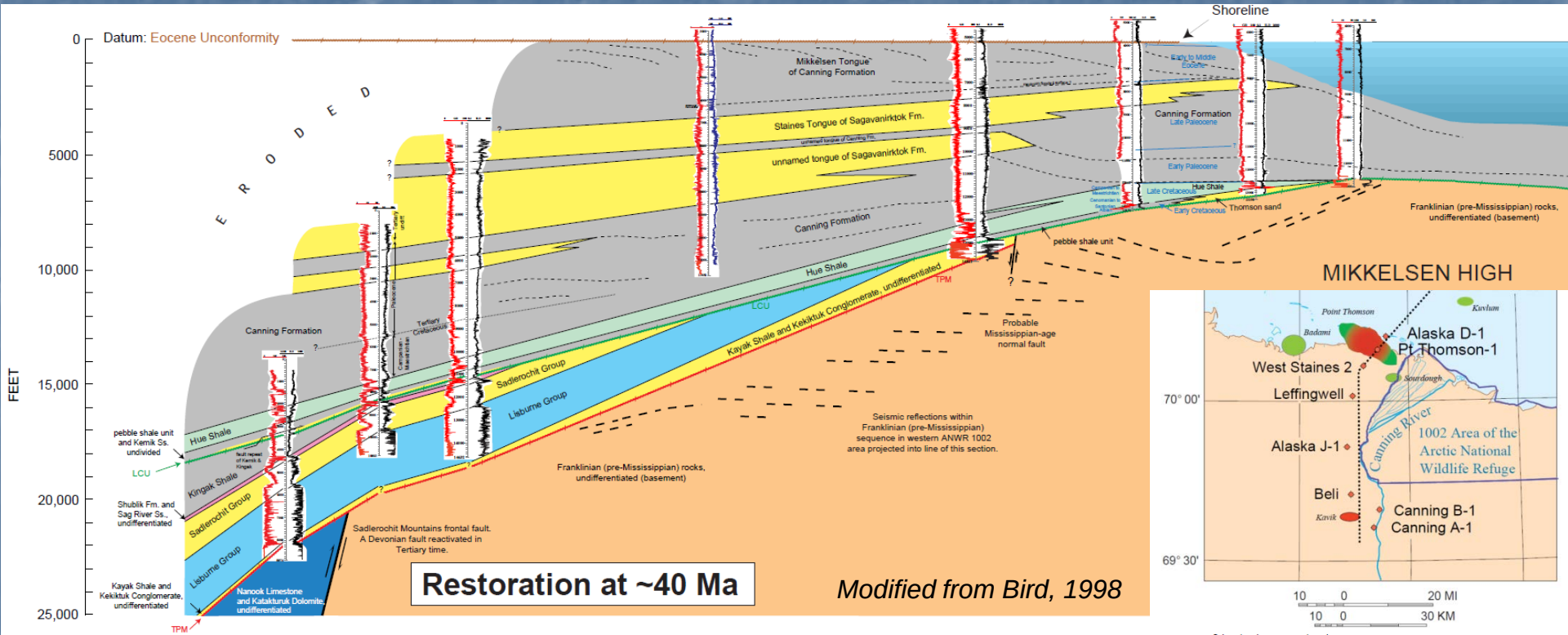
Houseknecht et al., 2006


Paleocene Canning Formation
"Mikkelsen high"
3-mile limit
Camden Bay
Staines River
Canning River
MCA
Marsh Creek
Carter Creek
Sadlerochit River
Hulahula River
"Hulahula low"
Sequence E structurally thickened
1002 boundary
Tamayariak River
Katakturuk River
Sadlerochit Mountains
Contours are thickness
X 1,000 feet
10 mi
Houseknecht & Schenk (1998)
DWH 1.98

- Three northward prograding deltaic tongues
- Southward thickening packages, despite deeper water to north

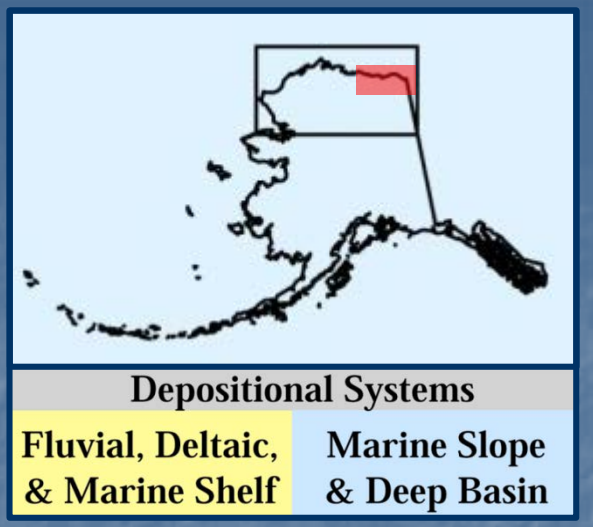
. . .Consistent with synchronous tectonic subsidence in a flexural foredeep

Lower tongue of Sagavanirktok Fm (topset)
Kavik anticline forelimb (oil-stained)



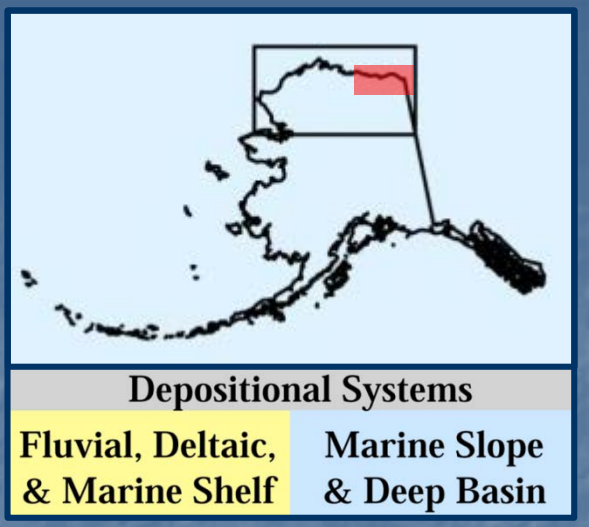
Late Paleocene Paleogeography

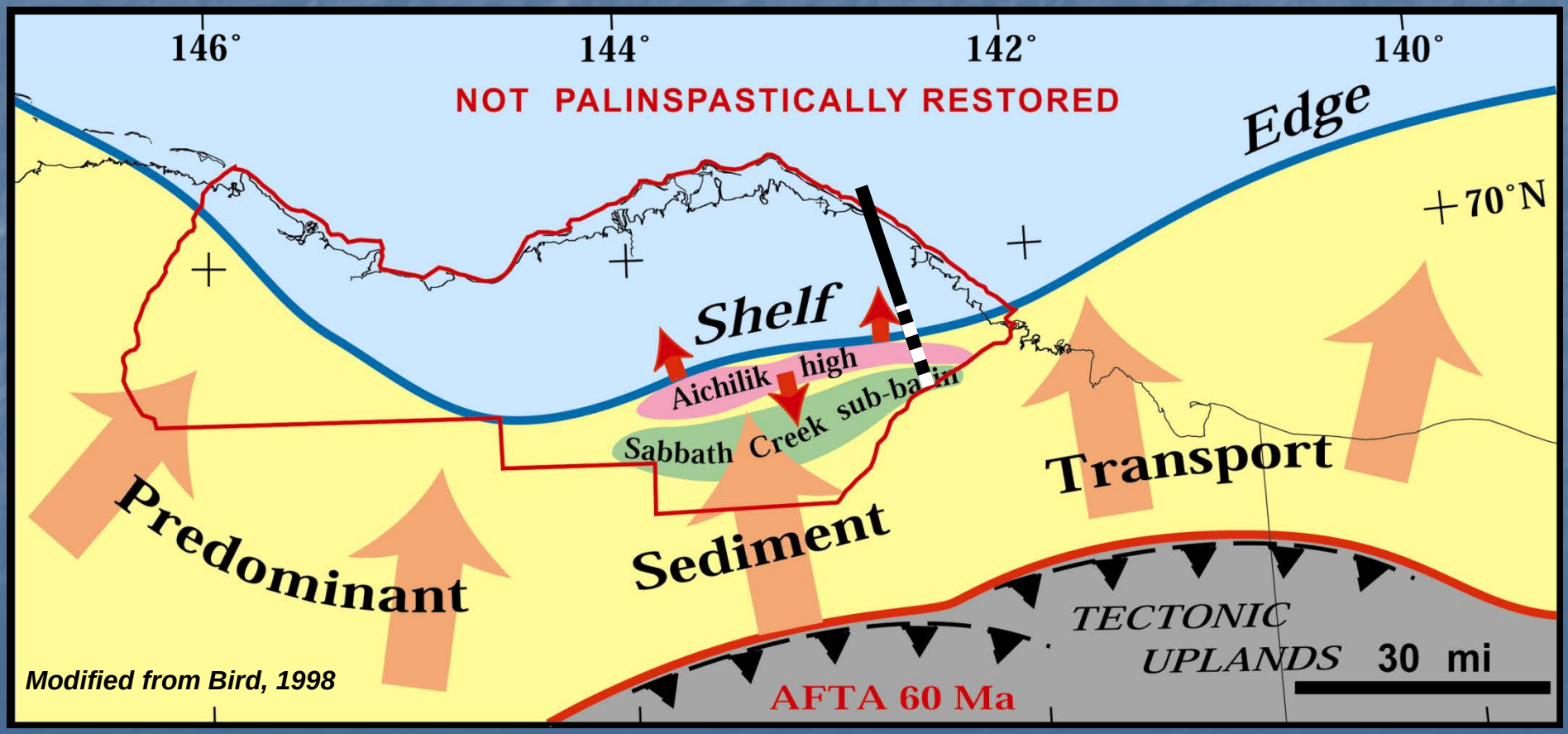
- High sediment supply
- Coarse grained
- Syntectonic sub-basins
- Growth strata



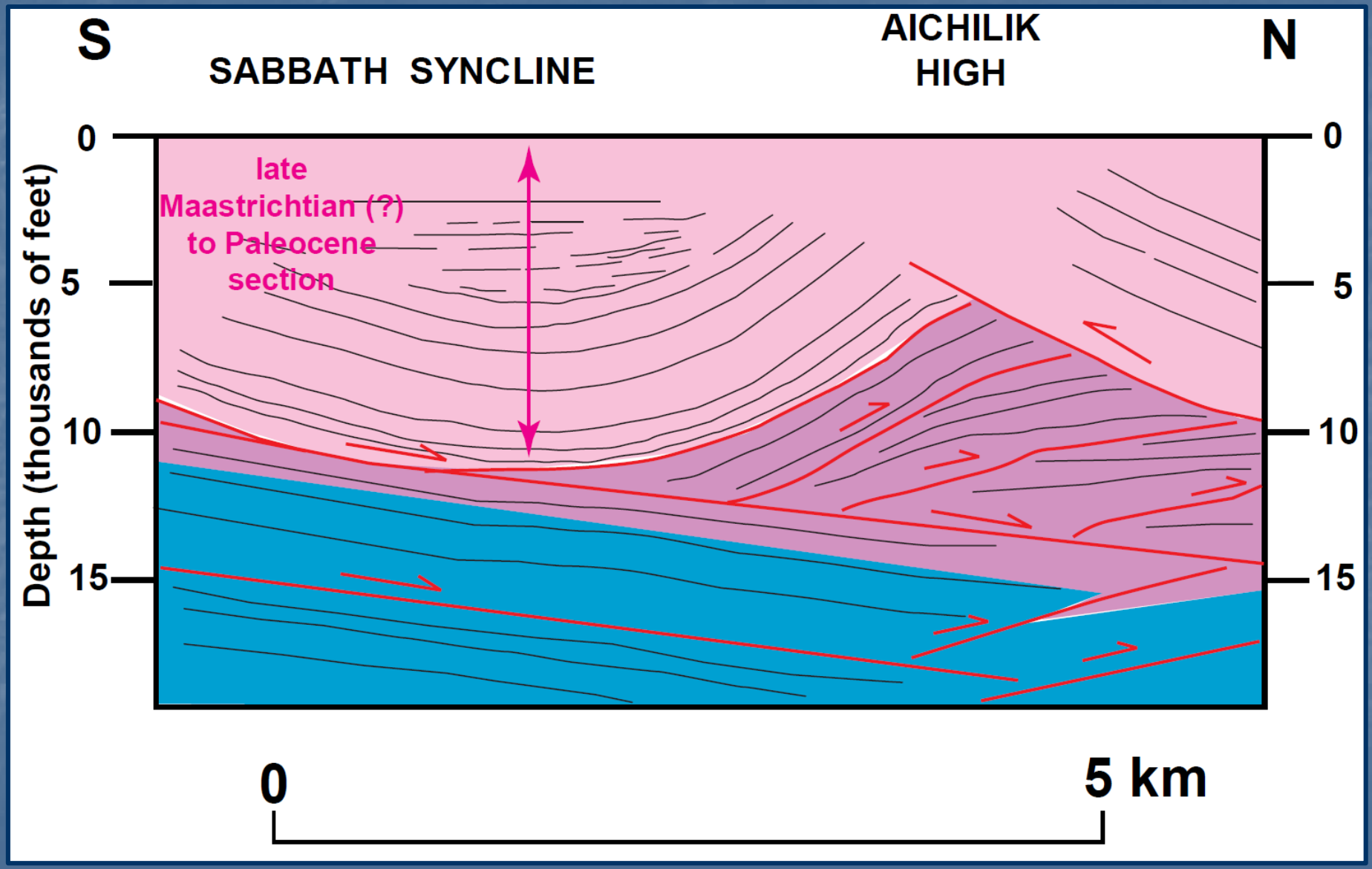
Late Paleocene Paleogeography

- Sabbath syncline seismic line





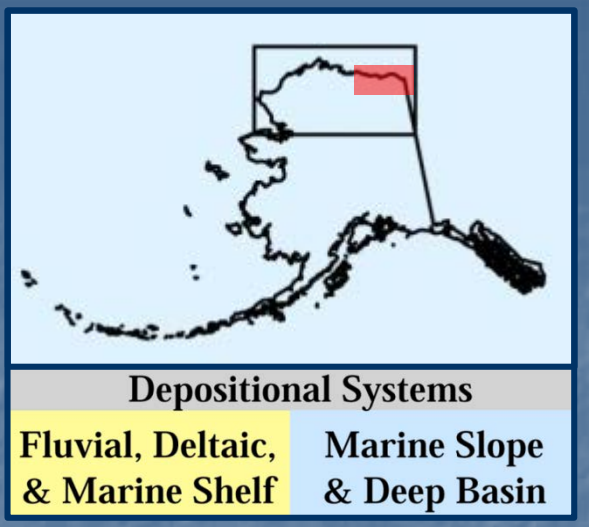
Paleocene Growth Strata

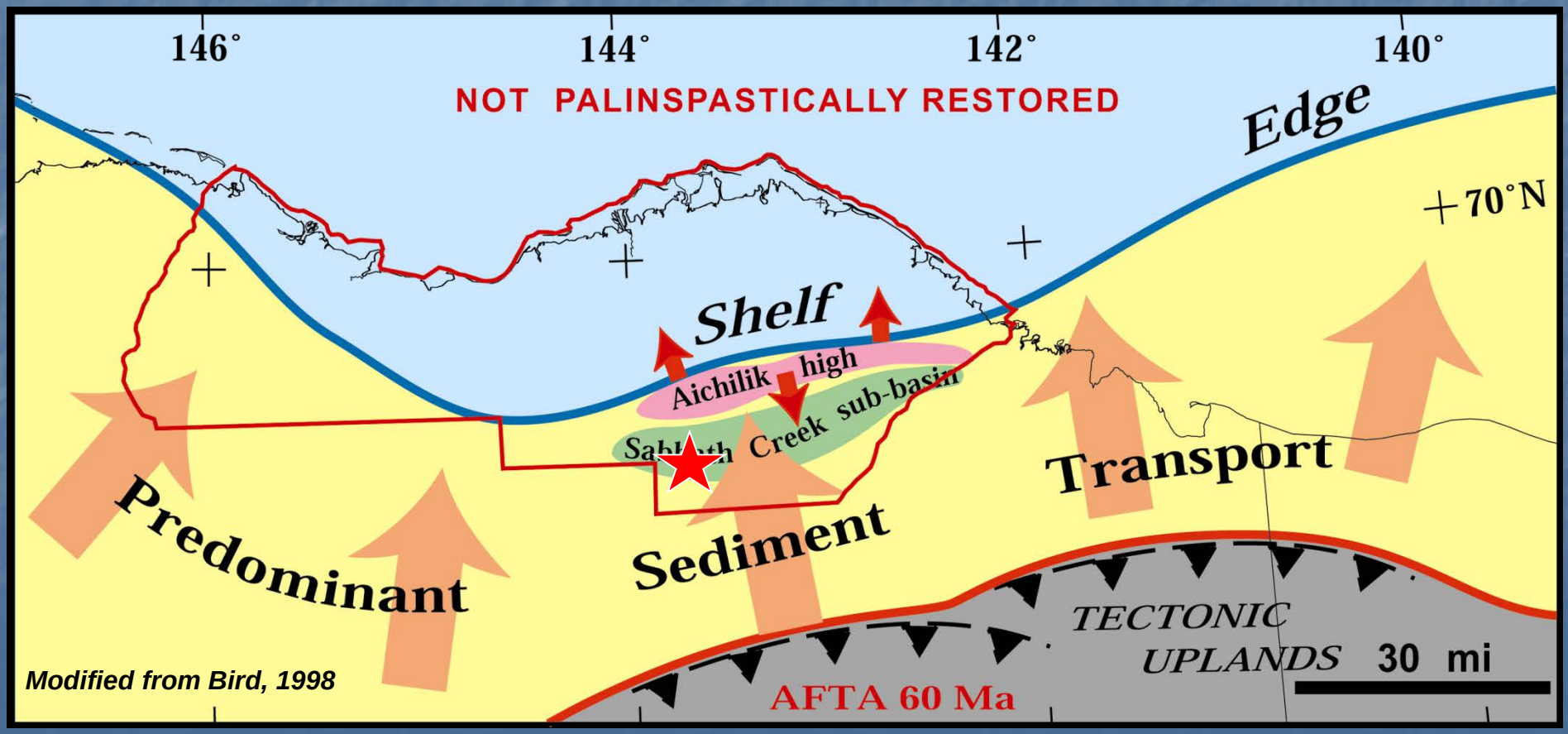


Line drawing of seismic reflection data (line 84-30) from Potter et al. (1998)

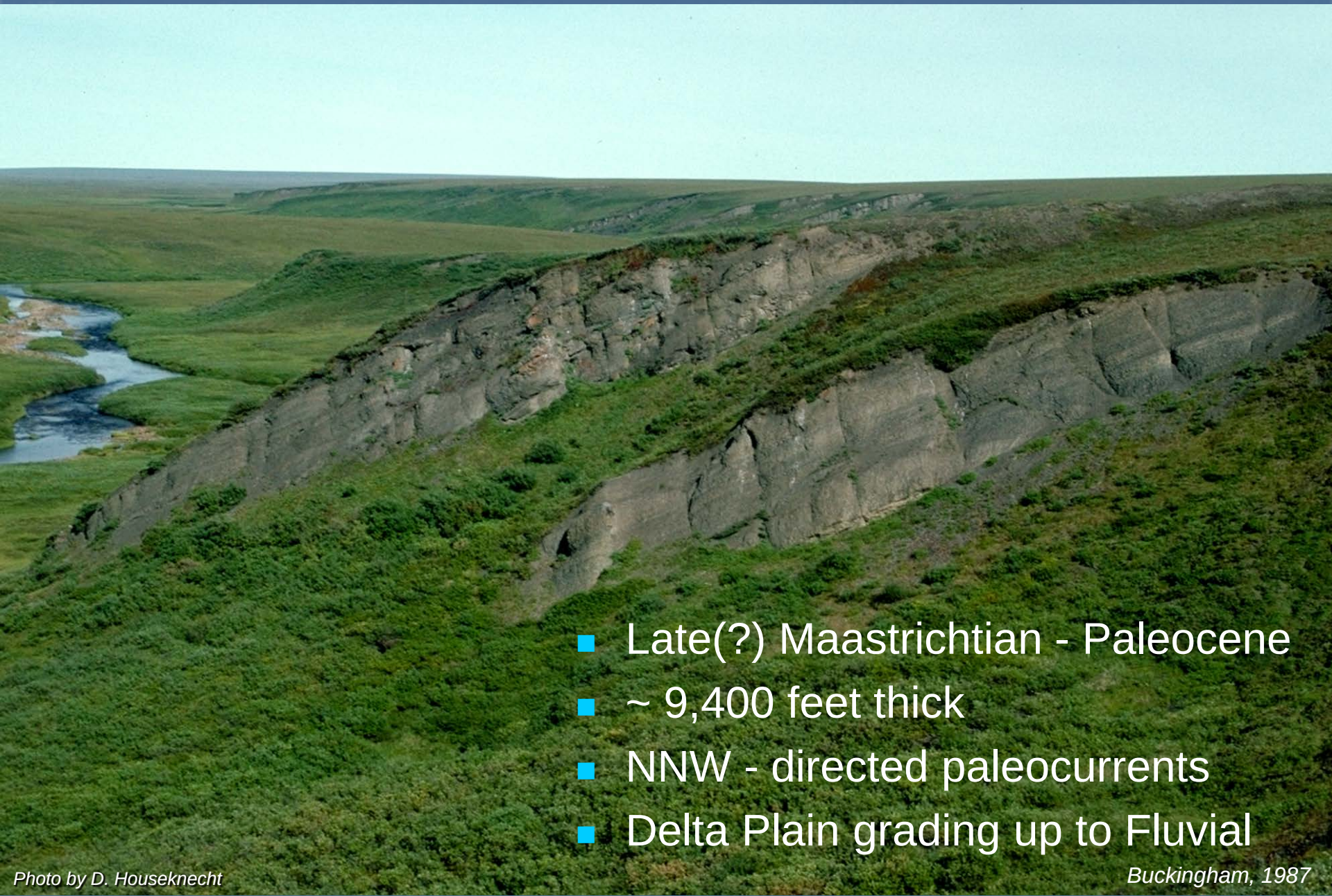
Late Paleocene Paleogeography

- Jago River outcrop (red star)





Sub-Basin in Outcrop – Jago River/Sabbath Crk.



- Late(?) Maastrichtian - Paleocene
- ~ 9,400 feet thick
- NNW - directed paleocurrents
- Delta Plain grading up to Fluvial

Photo by D. Houseknecht

Buckingham, 1987

Summary

- Paleocene orogenesis in Brooks Range is recorded by a major reorganization of the foreland basin
- Candidate sequence boundary recognized in topset, shelf margin, and basinal settings
- Resultant bypass of unroofed material accumulated in the eastern sector of the basin, including sand-prone reservoir facies
- Thick Paleocene strata in the eastern North Slope likely reflect both remnant underfilled accommodation *and* new flexural subsidence
- The northeastern salient of the Brooks Range may have developed first in the Paleocene—earlier than previously suggested
- Paleocene deposition completed basin filling, allowing for subsequent Tertiary growth of the Beaufort shelf

Acknowledgments

- **Financial support**
  - *AK Div. of Geological & Geophysical Surveys*
  - *AK Div. of Oil & Gas*
  - *USGS*
  - *DNR Industry Sponsors Group*

Anadarko	*FEX*
BG Alaska	*Chevron*
Petro-Canada	*Pioneer*
ENI	*Shell*
ConocoPhillips	*BP*

Photo by R. Gillis

Questions. . .

Photo by R. Relfenstuhl