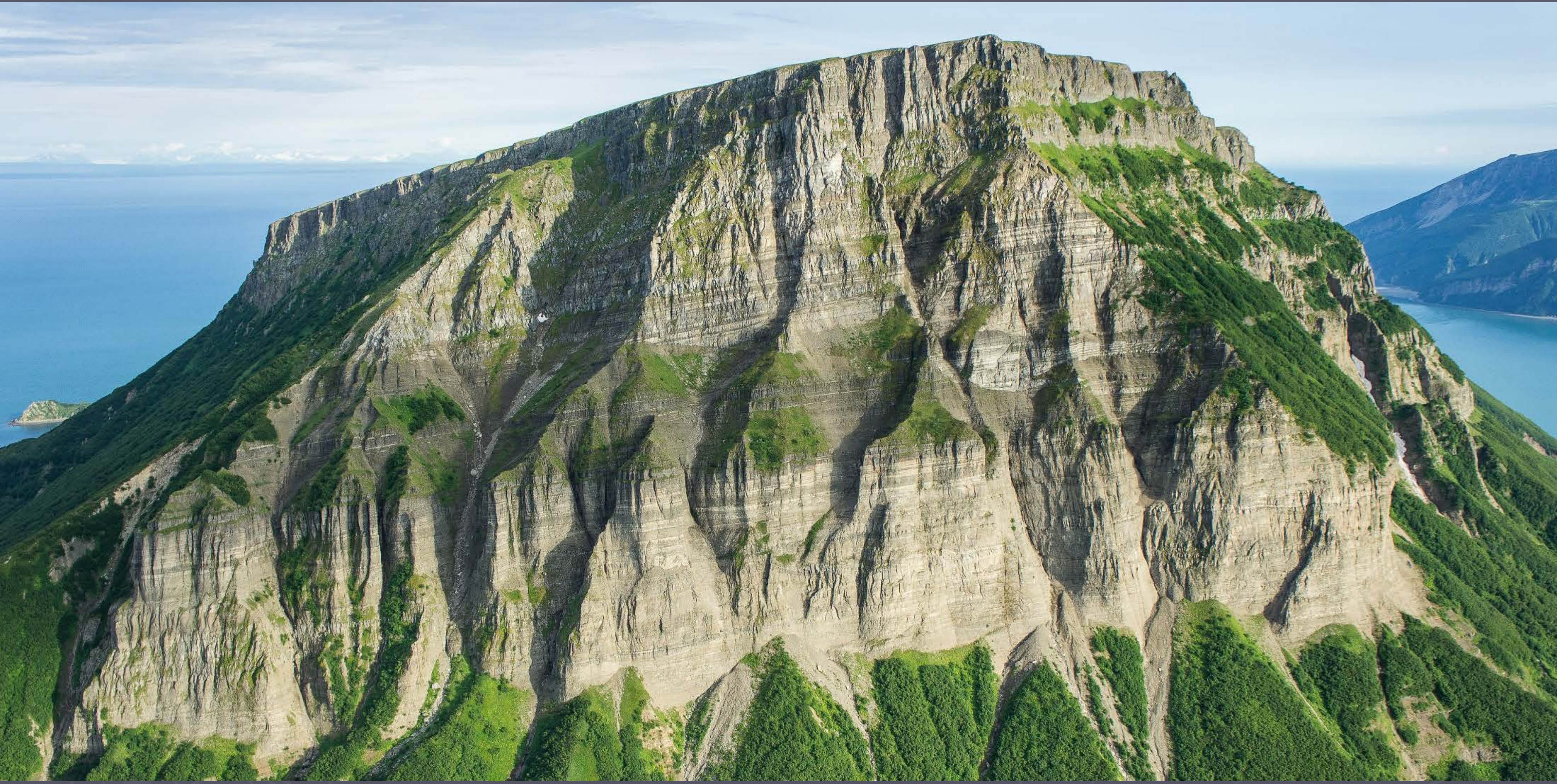
Sequence Stratigraphic Framework of the Upper Jurassic Naknek Formation, Cook Inlet Forearc Basin, South-Central Alaska



Trystan M. Herriott[1], Marwan A. Wartes[1], Paul L. Decker[2]

[1]Alaska Division of Geological & Geophysical Surveys
[2]Alaska Division of Oil and Gas

Abstract

The Naknek Formation records Late Jurassic forearc basin sedimentation and crops out discontinuously along an ~1000 km trend in southern Alaska. Recent sedimentologic and stratigraphic studies of the Iniskin–Tuxedni bays outcrop belt have yielded the first depositional environment interpretations for the Naknek members of lower Cook Inlet (in ascending order): Chisik Conglomerate (fan delta), lower sandstone (shelf), Snug Harbor Siltstone (outer shelf and slope), and Pomeroy Arkose (base of slope and basin floor). Furthermore, geologic mapping of the Iniskin–Tuxedni area led to the discovery of three deep-water paleo-canyons in the upper Snug Harbor–lower Pomeroy interval. These erosive-based, seismic-scale features were incised into chiefly fine-grained and tabular-bedded slope strata of Snug Harbor and filled with channelized, tabular, and lobate packages of dominantly Pomeroy sandstone. Canyon margins likely transitioned from being chiefly erosional to chiefly aggradational as the depositional system matured, as indicated by anomalously thick canyon-margin successions of Snug Harbor that suggest large-scale constructional confinement via master levees.

Recognition of these deep-water canyons and an expanded analysis of our depositional systems work permit the first sequence stratigraphic interpretation for the Naknek Formation. The basal members—Chisik Conglomerate and lower sandstone—overlie the Middle Jurassic Chinitna Formation along a sequence bounding unconformity (basal surface of forced regression (BSFR)/SB–1) and constitute a lowstand systems tract (LST–1). A transgressive surface (TS) caps LST–1 at the base of Snug Harbor (outer shelf) and marks onset of a transgressive systems tract (TST). A somewhat thicker-bedded and coarser-grained depositional motif commences in the mid-Snug Harbor (slope), defining the base of a highstand systems tract (HST) above a maximum flooding surface (MFS) at the top of TST. Erosional establishment of the deep-water canyons terminated HST at a sequence boundary (BSFR/SB–2), which in inter-canyon areas is recognized as a correlative conformity. The lower Pomeroy constitutes the deep-water aspect of a lowstand systems tract (LST–2). Thus, a complete, probable third-order (i.e., 10^6 years duration) stratigraphic sequence occurs in the lower three members of the Naknek, with the noted exception that Snug Harbor strata locally crop out as basal canyon fill and levee deposits above BSFR/SB–2 that marks onset of a renewed accommodation succession cycle.

Key aspects of this sequence stratigraphic interpretation include: 1) Dominant sediment supply signals are recorded by LST–1 and LST–2. These lowstand systems tracts suggest episodic tectonic activity along the Bruin Bay fault system, exhuming Talkeetna arc plutons and providing a prolific source of arkosic sediment. 2) TST and HST reflect periods of alternating balance

Abstract (continued)

between accommodation (favored during TST) and sediment supply (favored during HST). The relative contributions of tectonism and eustasy during this inter-lowstand systems tracts time is not known, but sediment supply may have diminished during a tectonically quiescent period in the arc–forearc region. 3) A shelf–slope–basin floor depositional profile was established in the study area by progradation of clinoforms during HST, with incipient erosional development of canyons along a relatively high gradient slope. Accumulation of bypassed, coarse-grained detritus of LST–2 occurred along deep-water reaches of diminishing gradient at and beyond the base of slope, forming a clastic wedge of Pomeroy strata that may fine and thin abruptly basinward of the outcrop belt. Field observations strongly suggest that depositional elements of the lower Pomeroy (LST–2) backstepped and onlapped the relict Snug Harbor slope (HST), an example of a stratigraphic relationship that is common to seismic data sets but rarely directly observed in outcrop.

This sequence stratigraphic framework also sheds predictive light on facies distribution in the underexplored Cook Inlet basin. LST–1 may contain prospective hydrocarbon reservoir facies basinward of the study area and consists nearly exclusively of sandstone and conglomerate in outcrop. Four marine settings of LST–2 were prone to accumulating coarse-grained sediment and could host reservoir facies: shelf (inferred), deep-water canyon fill, canyon-associated master levee, and base of slope to basin floor. However, Naknek sandstones contain a high proportion of labile grains, resulting in diagenetic destruction of porosity and permeability. Nevertheless, we propose that compositional variability in the batholith in conjunction with sediment routing pathways to depocenters prone to coarse-grained sedimentation influenced whether and where conventional reservoir quality might occur in the basin. This study is relevant to exploration in Cook Inlet regardless of conventional reservoir quality parameters, as ubiquitous fracture networks in the Naknek may in the subsurface yield unconventional, fractured reservoir prospectivity.

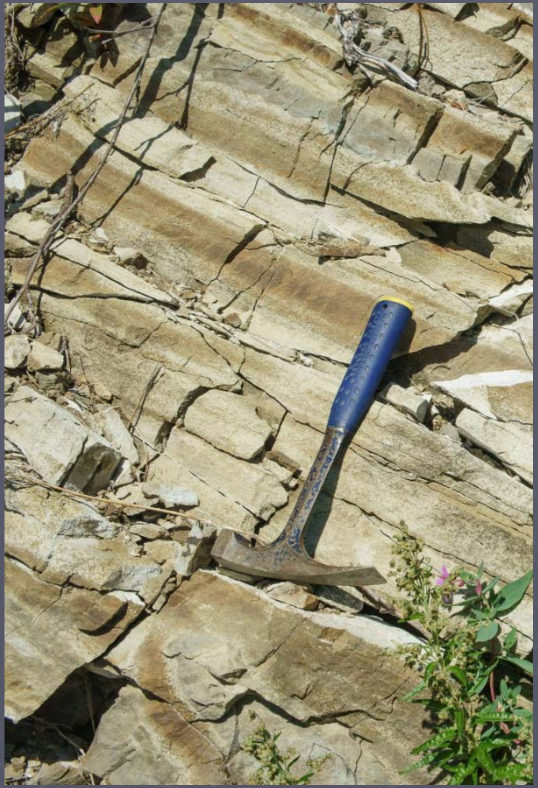
The Naknek Formation exhibits remarkable tectono-stratigraphic similarities across its regional extent, likely reflecting convergent margin-scale factors that influenced the structural and depositional evolution of the arc–forearc region in southern Alaska during the Late Jurassic.

*Authors' note: these slides were presented at the Alaska Geological Society monthly luncheon on 17 November 2015 and the University of Alaska Fairbanks Department of Geosciences Friday seminar on 20 November 2015.

Abstract also available at: http://www.alaskageology.org/newsletters.html (see November 2015)

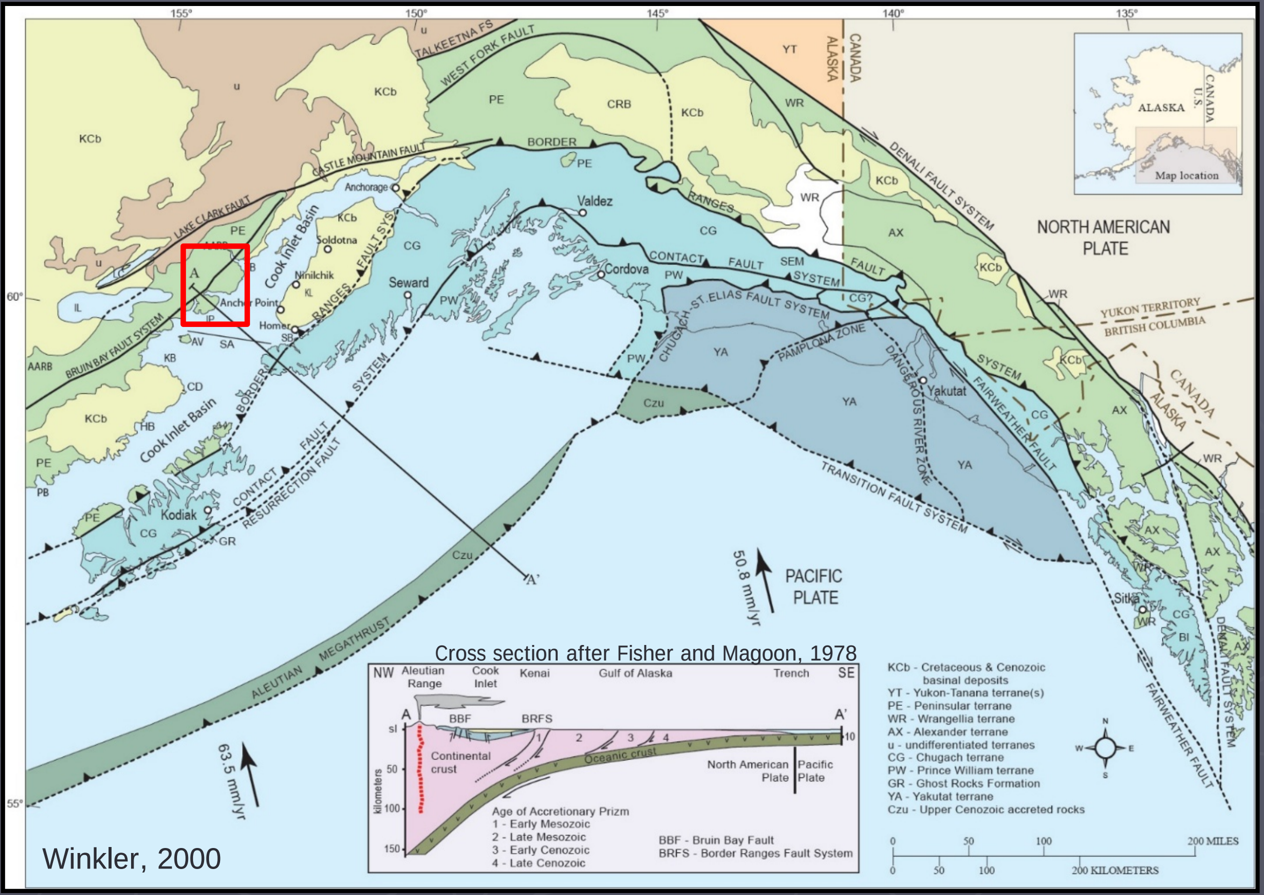
Presentation Outline

- Geologic setting—Cook Inlet forearc basin
- Naknek Formation: Members and depositional environments
  - Pomeroy Arkose
  - Snug Harbor Siltstone
  - lower sandstone (informal)
  - Chisik Conglomerate
- Stacking relations of the Snug Harbor and Pomeroy
  - Typical and atypical: Deep-water depositional elements
- Sequence stratigraphy of the Naknek Formation
  - Surfaces, systems tracts, and stratigraphic sequences
  - Chisik and lower sandstone stacking in further detail
- Implications: Hydrocarbon reservoirs
- Summary and conclusions

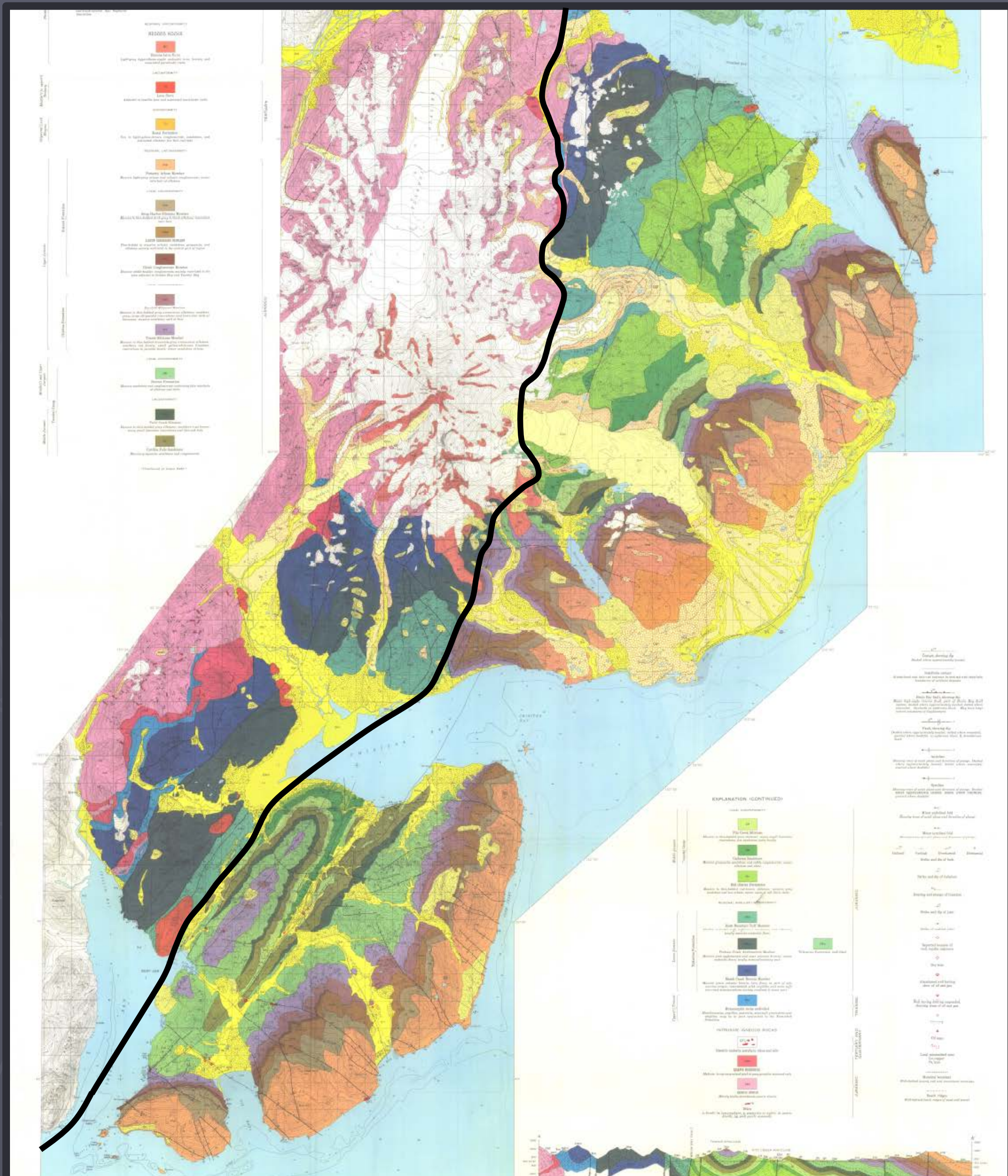


Geologic Setting—Cook Inlet Forearc Basin

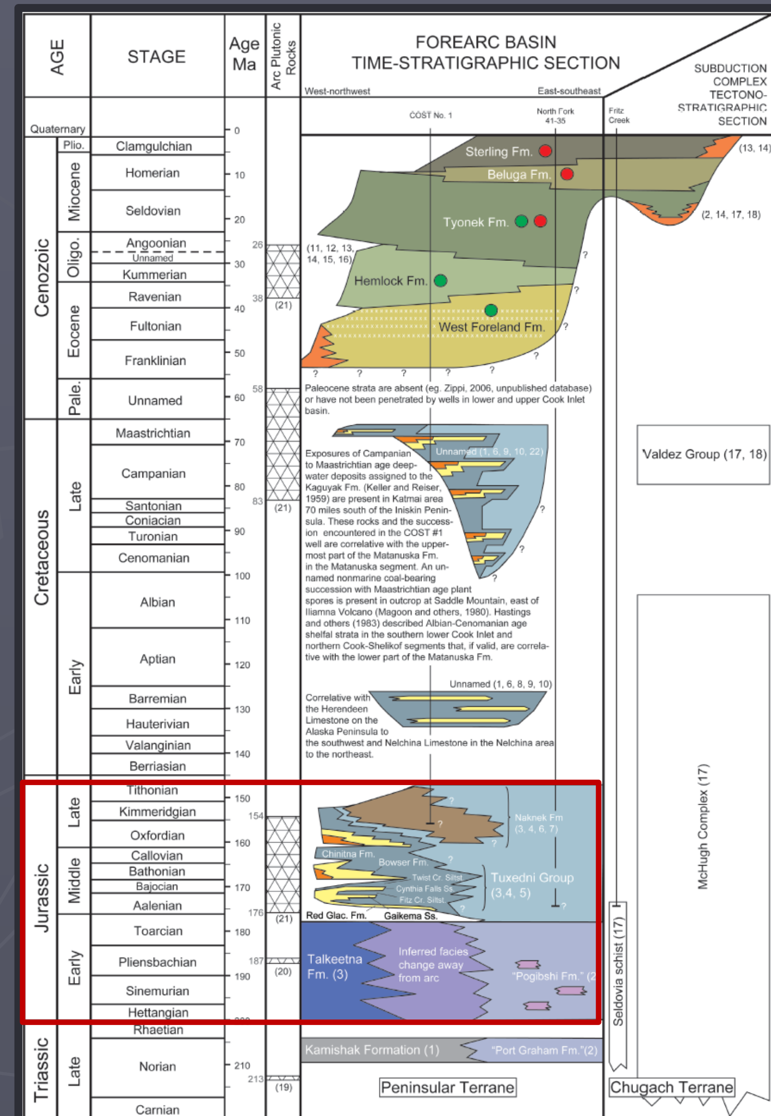
- Arc–forearc–accretionary wedge
- Cook Inlet forearc basin between BBFS and BRFS
  - ~200 m.y. record
- Jurassic stratigraphy exposed in the Iniskin–Tuxedni bays region
  - Naknek Formation
  - Chinitna Formation
  - Tuxedni Group
  - Talkeetna Formation



Iniskin–Tuxedni Bays Region: Study Area

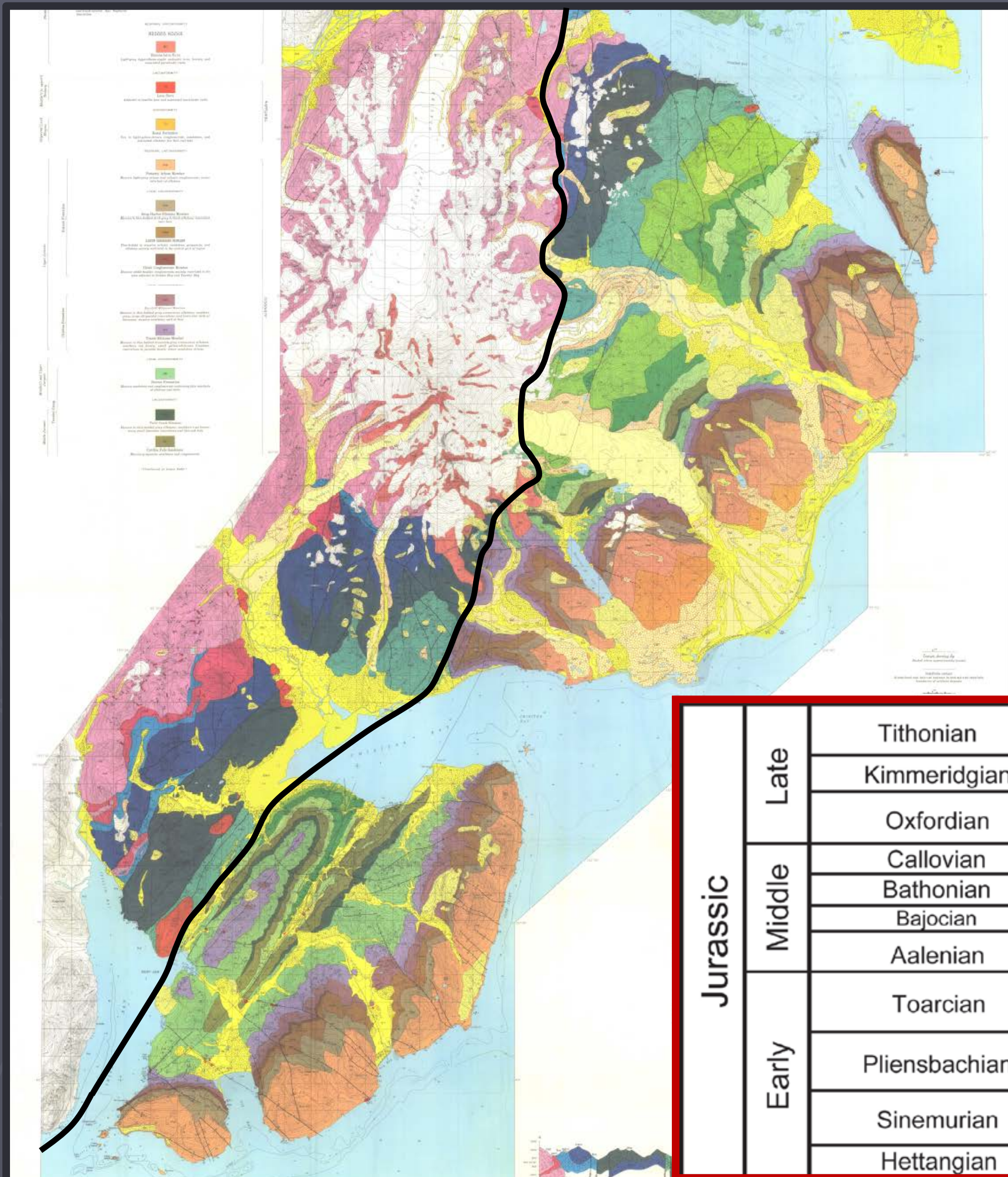


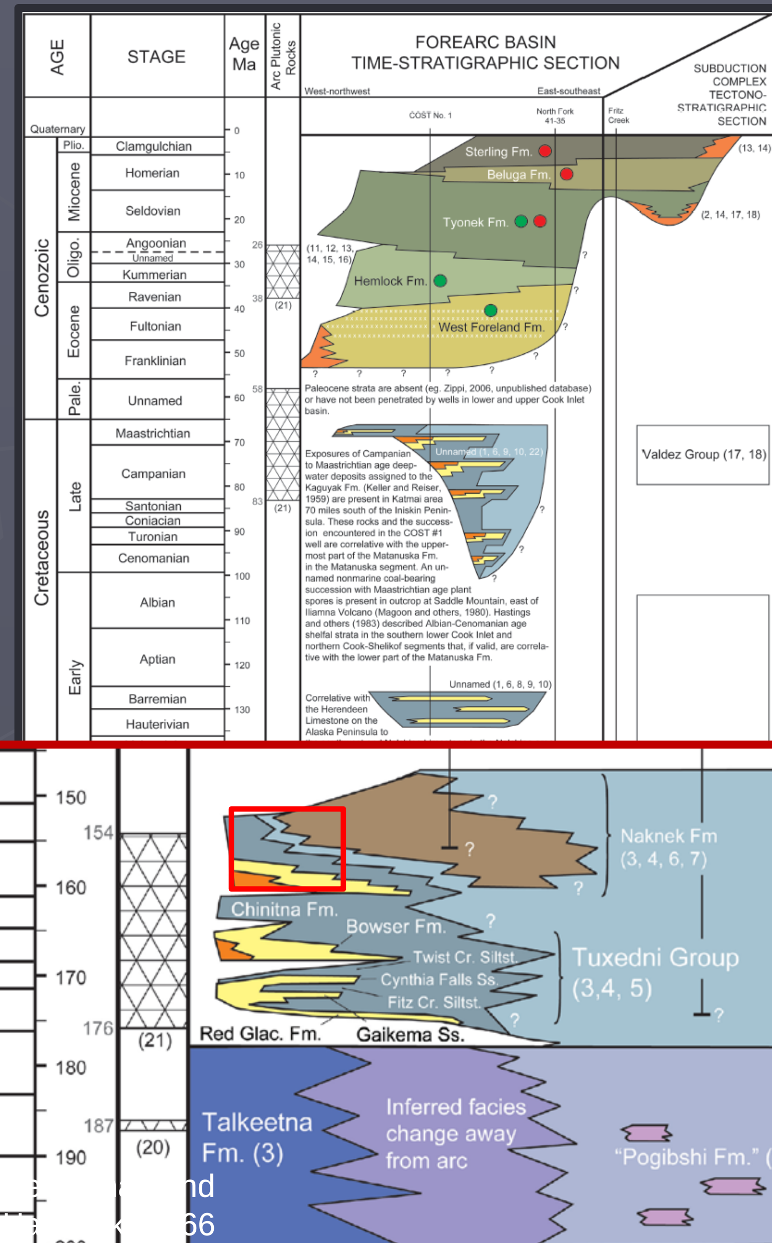
Detterman and Hartsock, 1966



LePain et al., 2013

Iniskin–Tuxedni Bays Region: Study Area





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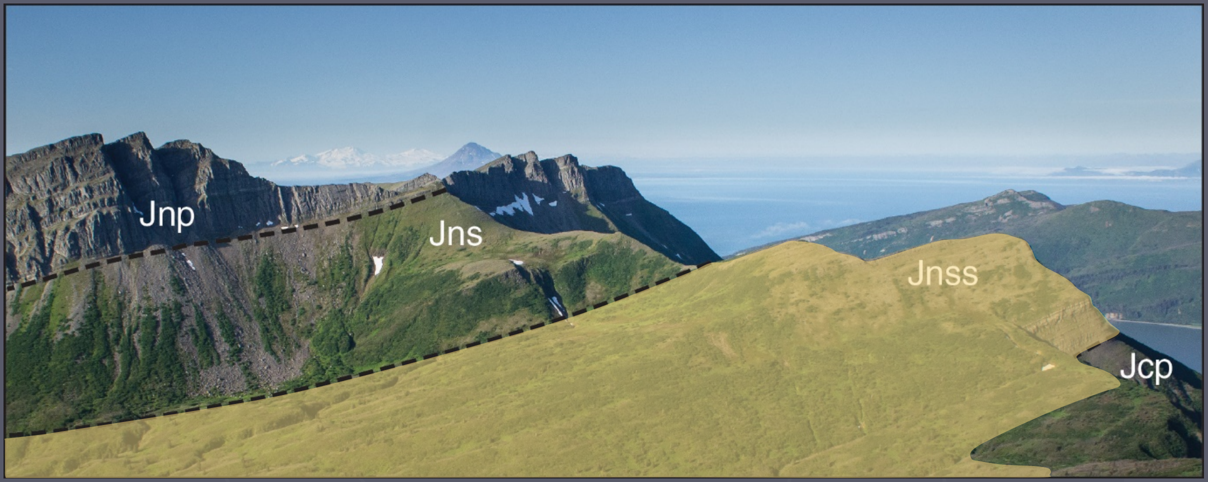
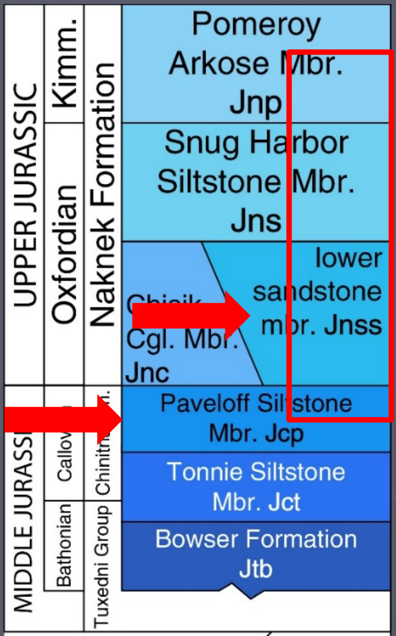
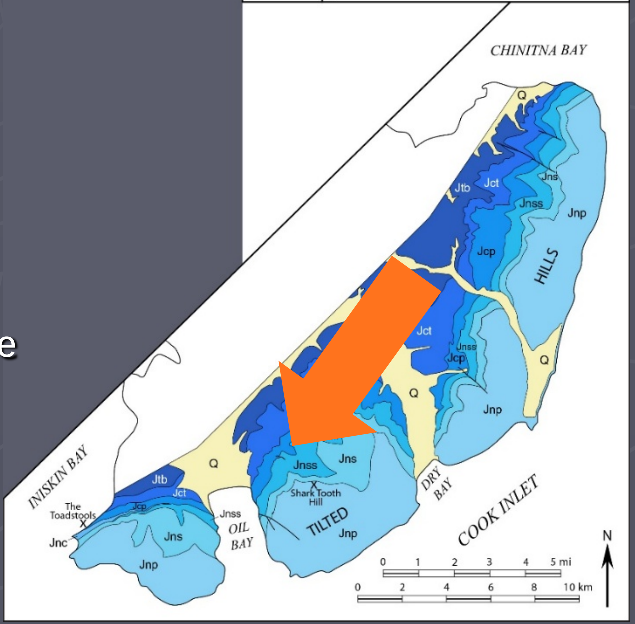
Naknek Members: Facies and Environments of Deposition







- lower sandstone (~240 m):
  - Thick-bedded, very fine- to fine-grained sandstone
  - Local HCS and SCS, diverse and abundant trace fossil assemblage

~~UNCONFORMITY~~

- Chinitna Formation

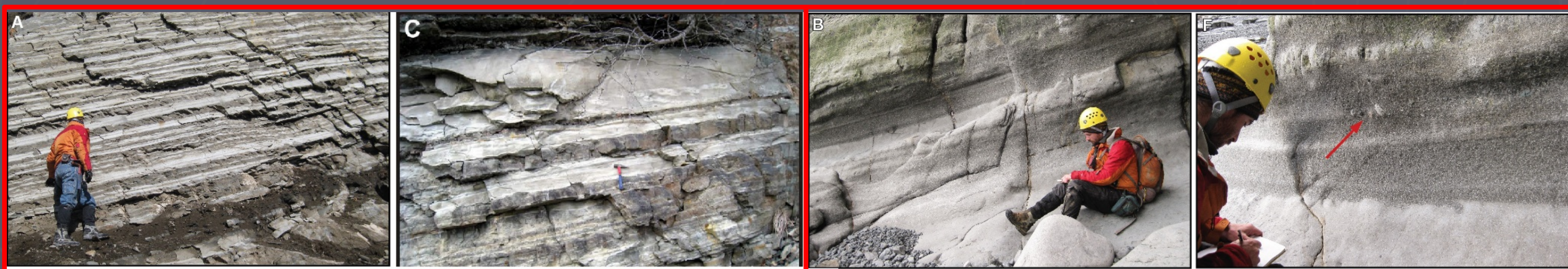
Naknek studies: Wartes et al., 2013, 2015; LePain et al., 2013; Herriott and Wartes, 2014; Herriott et al., 2015, in review, in preparation

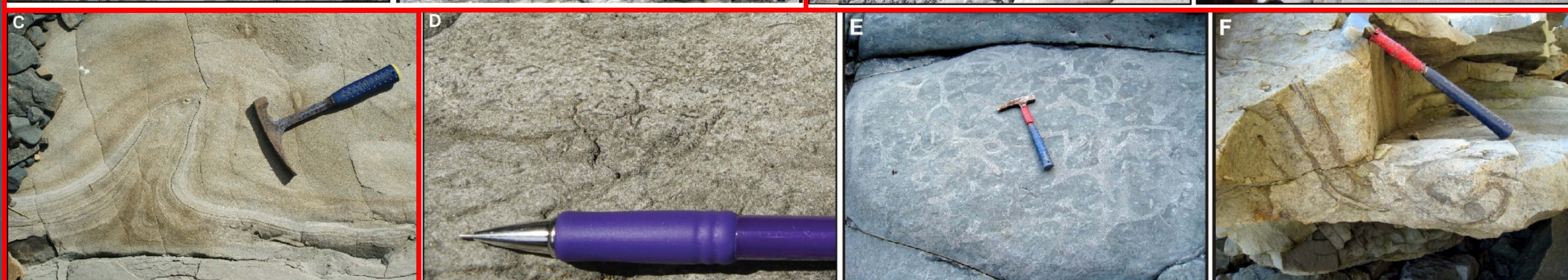
Naknek Members: Facies and Environments of Deposition

lower sandstone

Cyclic stacking of rippled and bioturbated sandstone and siltstone

Coarse-grained sandstone: structureless to faint stratification



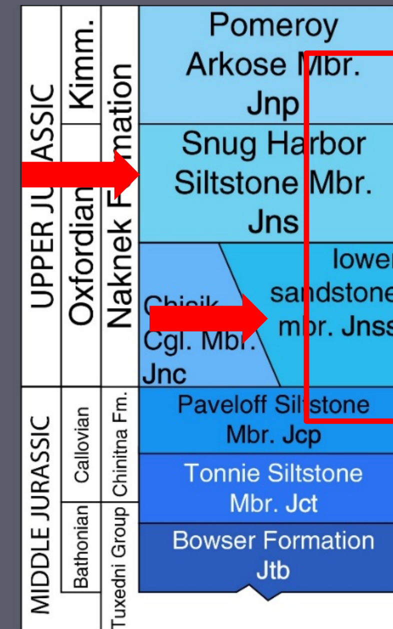


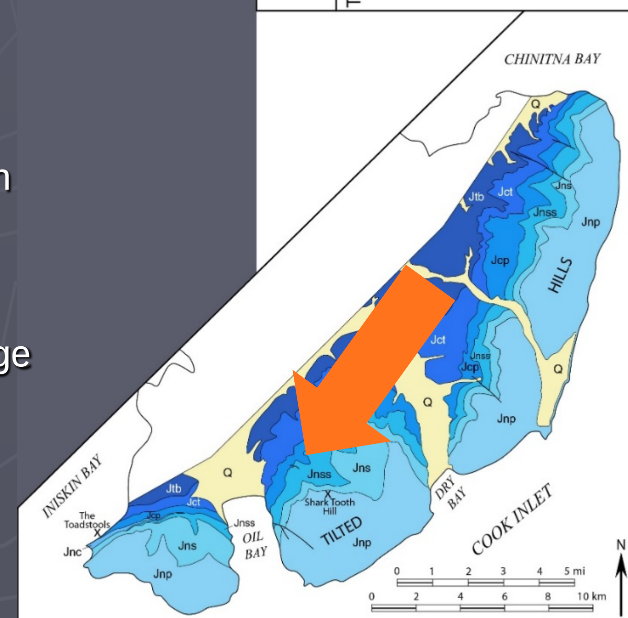
Convolute stratification

Examples of discrete trace fossils

from Wartes et al. (2013) and Herriott and Wartes (2014)

Naknek Members: Facies and Environments of Deposition





- Snug Harbor Siltstone (~260 m):
  - Thin- to thick-bedded siltstone and very fine-grained sandstone
  - SGFD, DFD, locally channelized, moderate to sparse bioturbation
- lower sandstone (~240 m): **INNER SHELF**
  - Thick-bedded, very fine- to fine-grained sandstone
  - Local HCS and SCS, diverse and abundant trace fossil assemblage

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- Chinitna Formation

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Naknek Members: Facies and Environments of Deposition

Snug Harbor Siltstone

Typical outcrop character

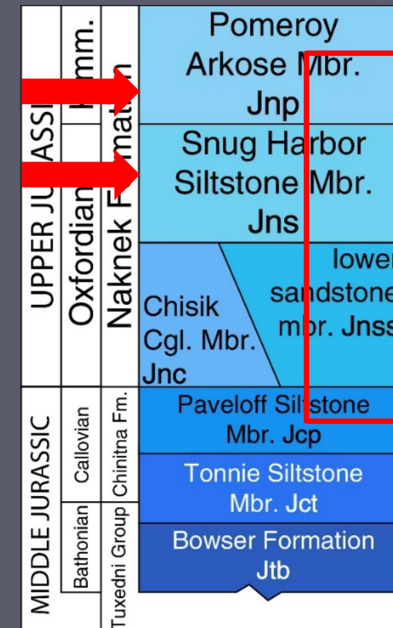
Sediment gravity flow deposit

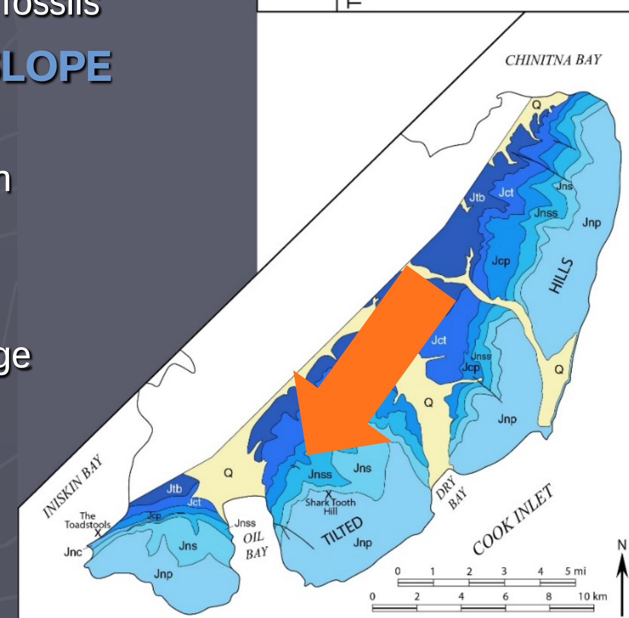
Debris flow deposit

Conglomeratic channel-form strata

from Herriott and Wartes (2014) and Herriott et al. (2015)

Naknek Members: Facies and Environments of Deposition





- Pomeroy Arkose (>900 m) :
  - Amalgamated sandstone and conglomerate, and siltstone
  - SGFD, DFD, MTD, locally channelized, dearth of trace and body fossils
- Snug Harbor Siltstone (~260 m): **OUTER SHELF and SLOPE**
  - Thin- to thick-bedded siltstone and very fine-grained sandstone
  - SGFD, DFD, locally channelized, moderate to sparse bioturbation
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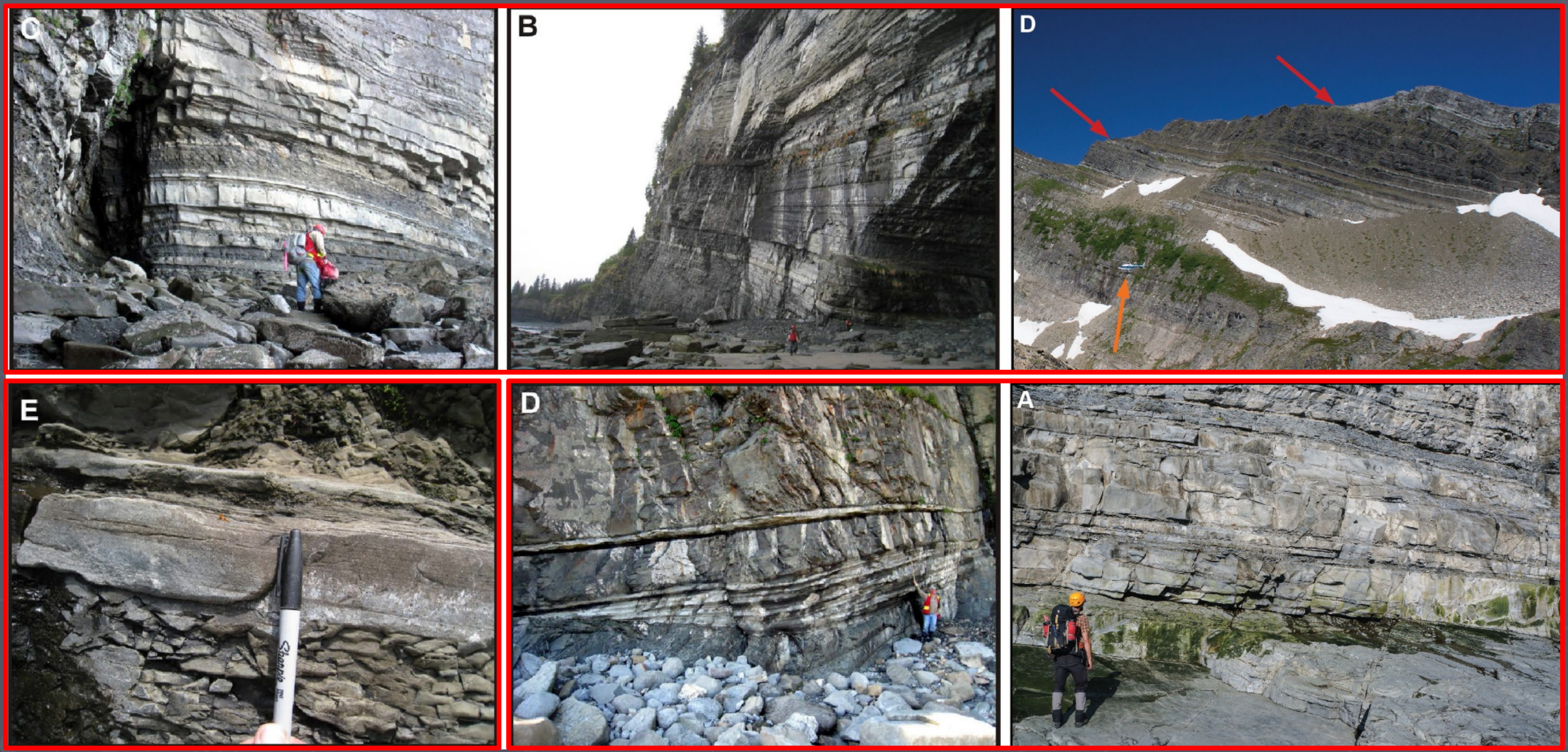
Naknek Members: Facies and Environments of Deposition

Pomeroy Arkose

Typical outcrop character



Sediment gravity flow deposit

Channel-form strata

from Wartes et al. (2013) and
Herriott and Wartes (2014)

Naknek Members: Facies and Environments of Deposition

- Pomeroy Arkose (>900 m) : **BASE OF SLOPE and BASIN FLOOR**
  - Amalgamated sandstone and conglomerate, and siltstone
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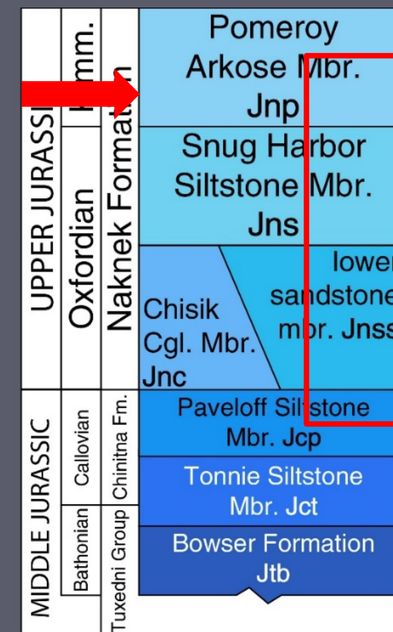

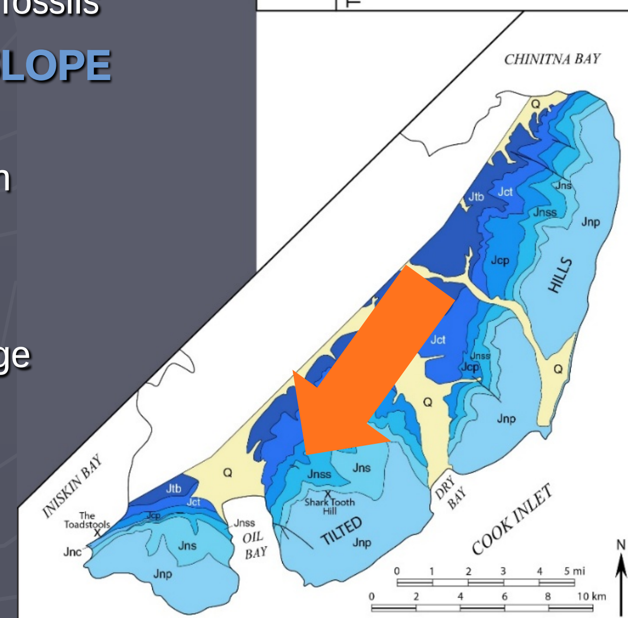

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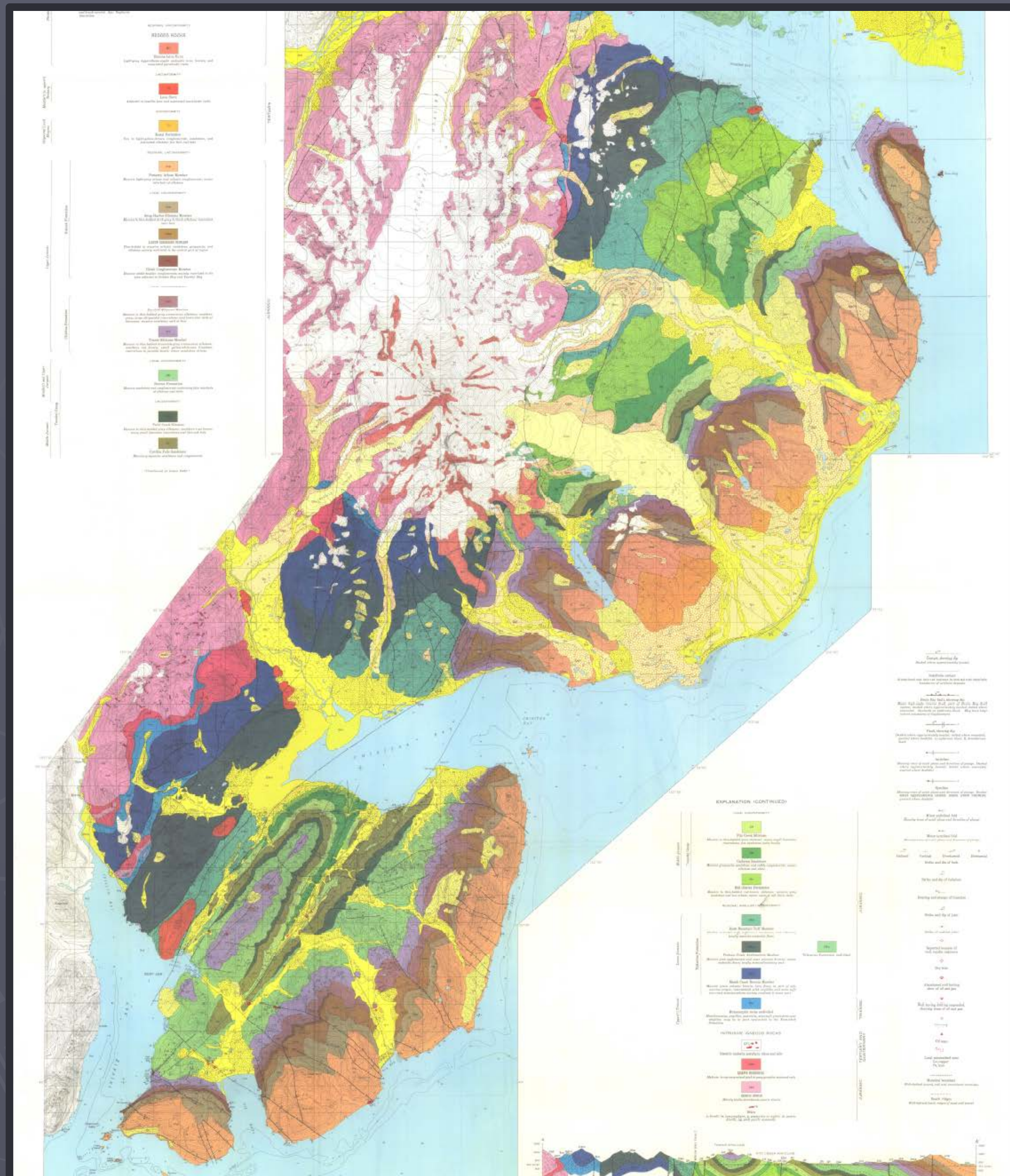
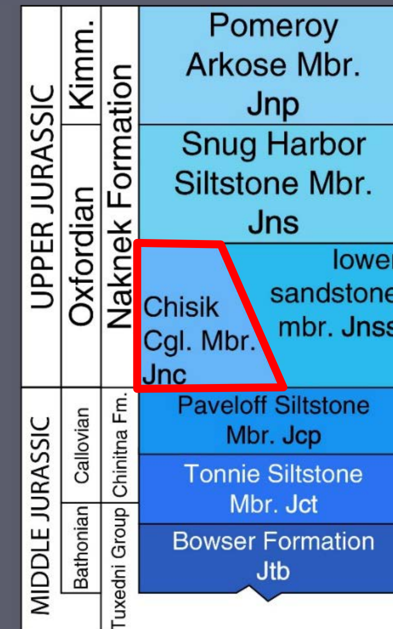
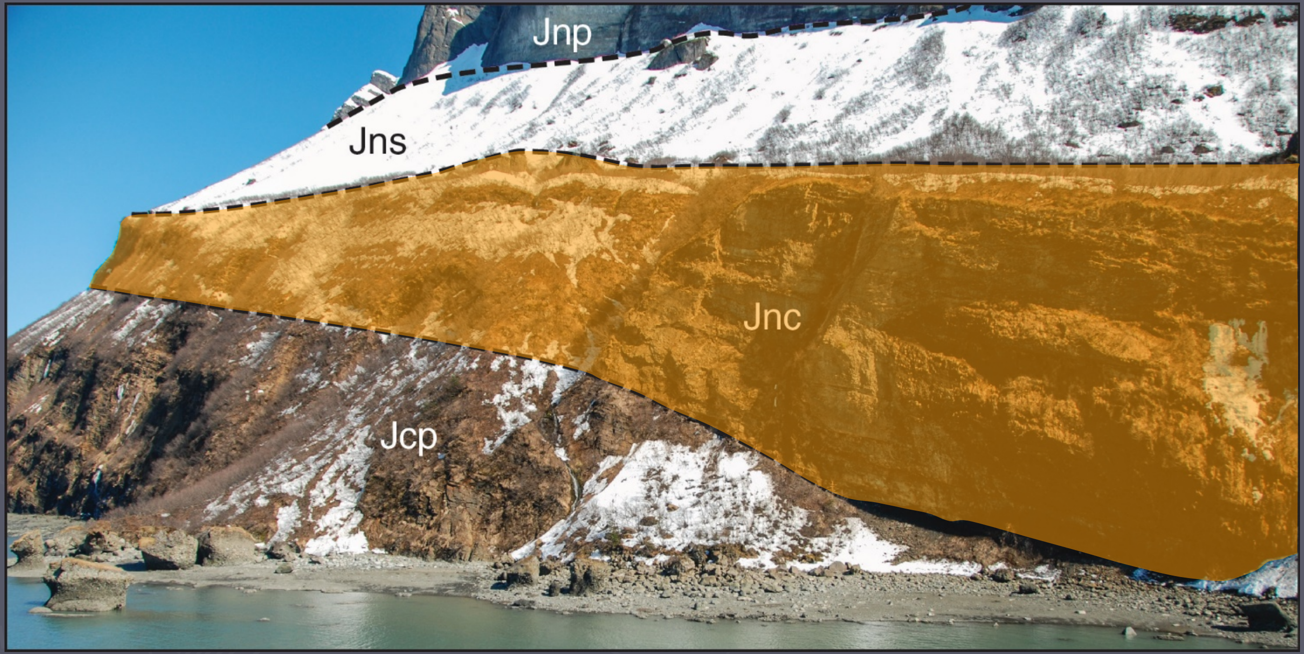
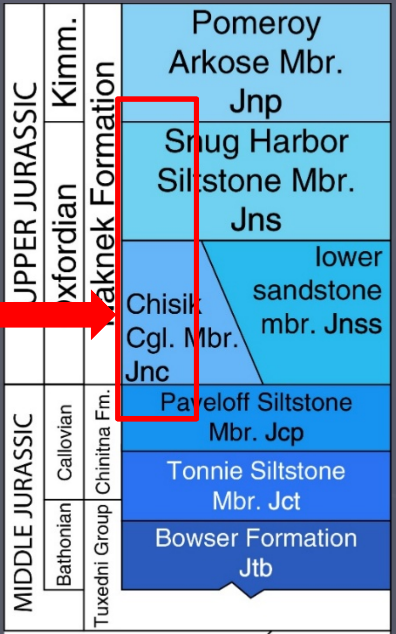


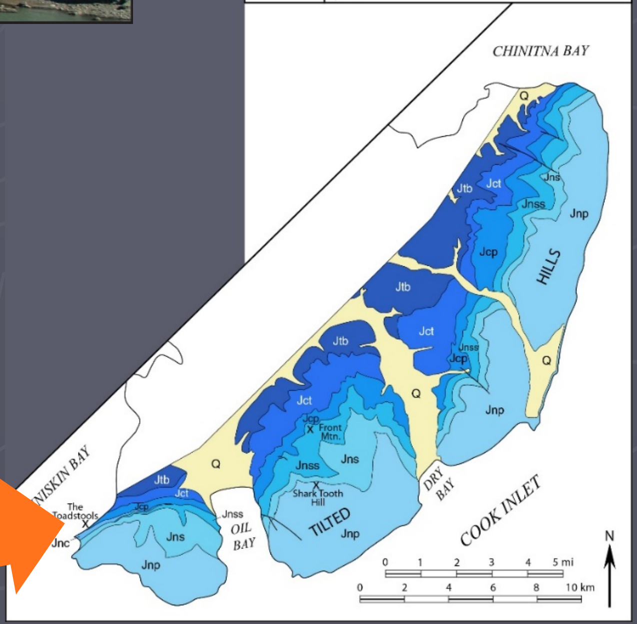


Detterman and Hartsock, 1966

Naknek Members: Facies and Environments of Deposition







- Chisik (~100 m):
  - Very thick-bedded conglomerate and sandstone
  - Locally cross-stratified, poorly sorted, belemnite-bearing

~~UNCONFORMITY~~

- Chinitna Formation

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Naknek Members: Facies and Environments of Deposition

Chisik Conglomerate

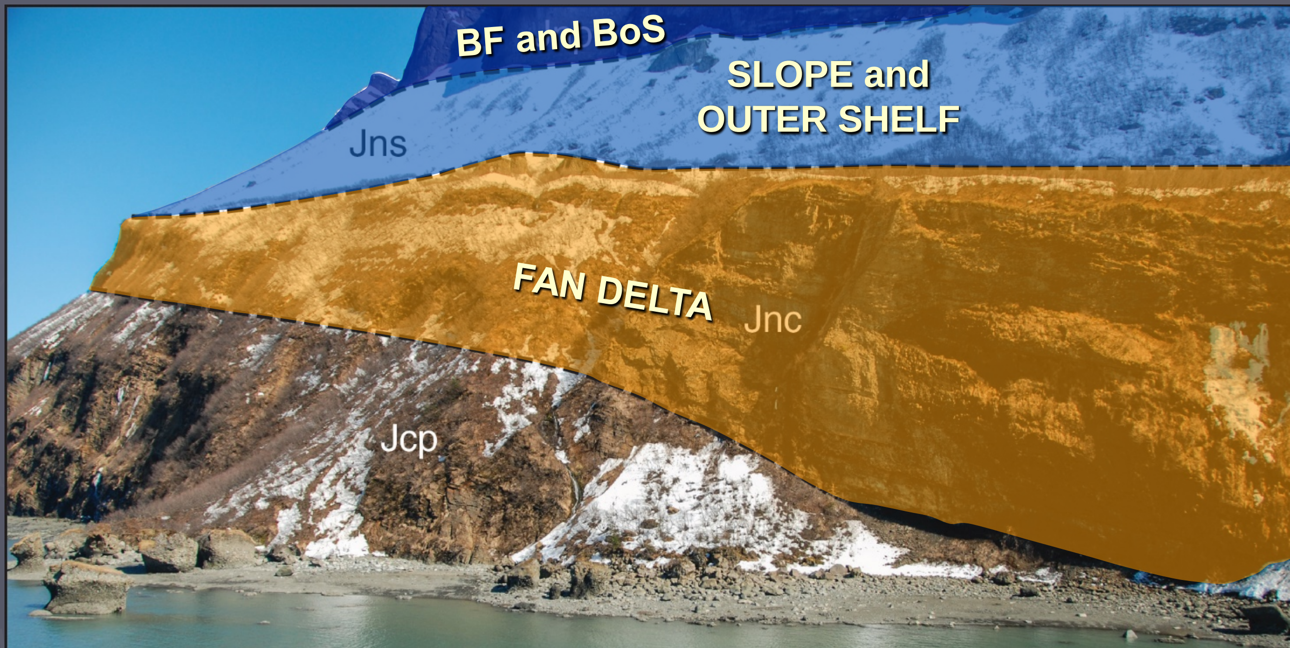
Typical outcrop character

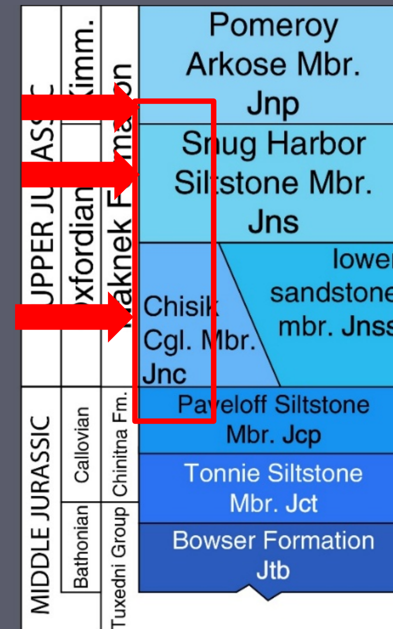
Poorly organized texture

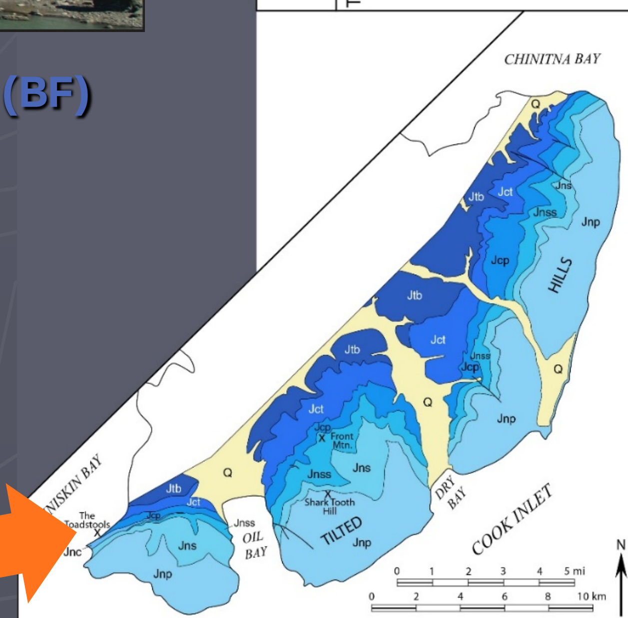
Meter-scale outsized clasts

from Wartes and others (2013) and
Herriott and Wartes (2014)

Naknek Members: Facies and Environments of Deposition







- Pomeroy: **BASE OF SLOPE (BoS)** and **BASIN FLOOR (BF)**
- Snug Harbor: **OUTER SHELF** and **SLOPE**
- Chisik (~100 m): **FAN DELTA**
  - Very thick-bedded conglomerate and sandstone
  - Locally cross-stratified, poorly sorted, belemnite-bearing

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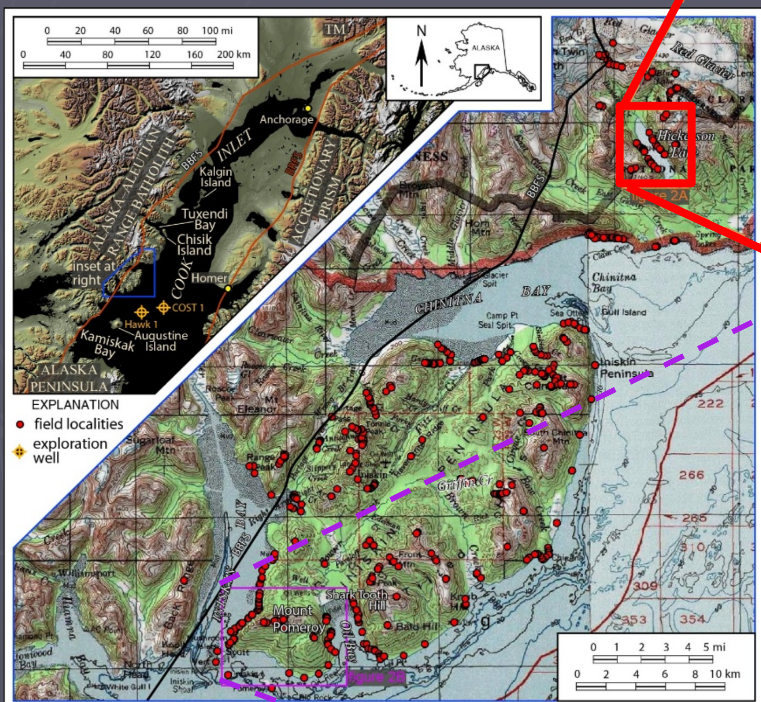
Snug Harbor Siltstone–Pomeroy Arkose Stacking: Typical

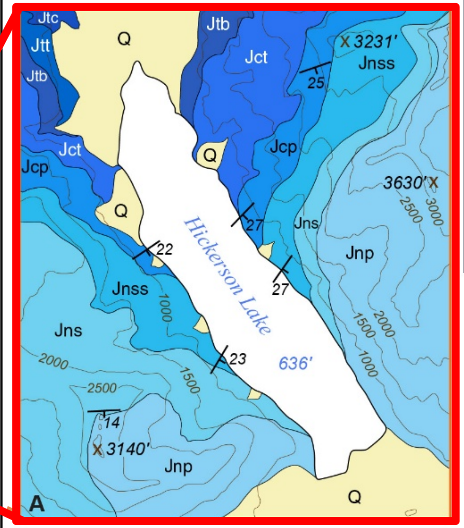
- Uppermost Snug Harbor is lithologically gradational to Pomeroy
  - Very thick arkoses are Pomeroy facies, but subordinate to Snug Harbor facies
- Contact is abrupt and conformable
  - Mapped at onset of amalgamated arkosic sandstone
  - Stratal onlap not observed

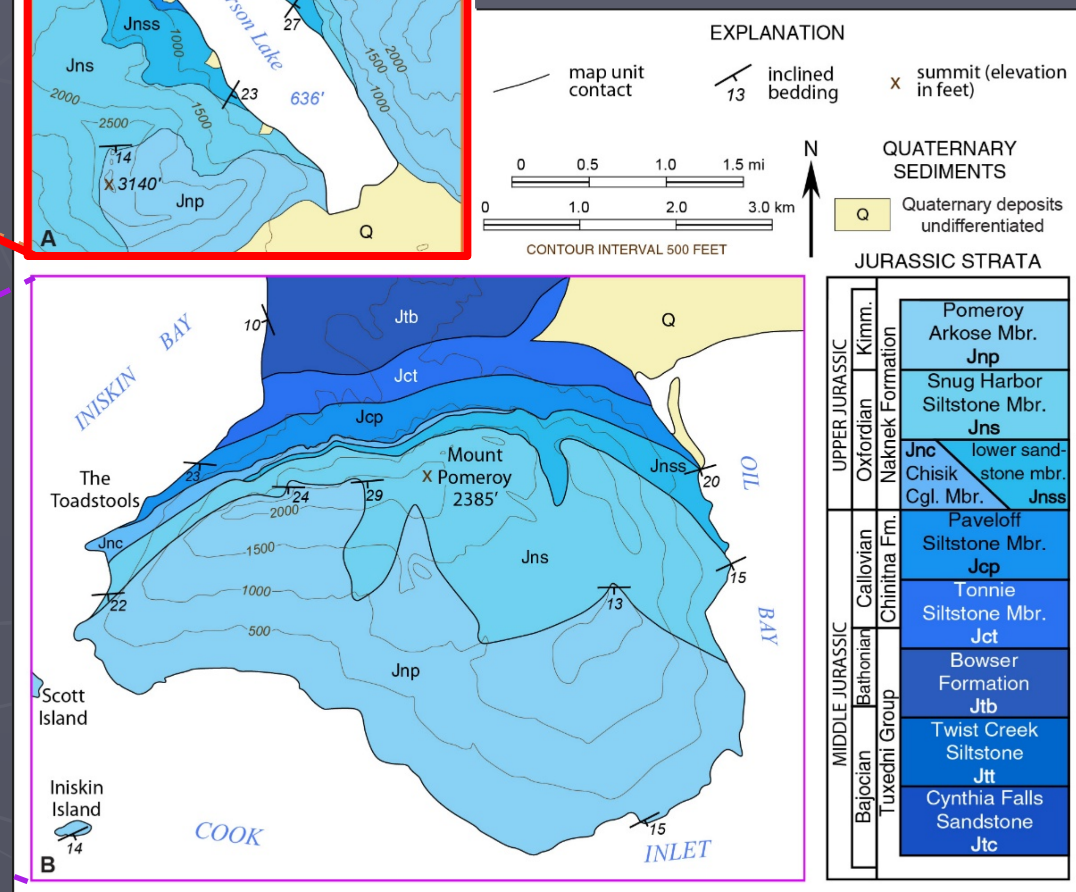
Snug Harbor Siltstone–Pomeroy Arkose Stacking: Atypical

Lithostratigraphic “containers” at Hickerson Lake & Mount Pomeroy

Hickerson Lake

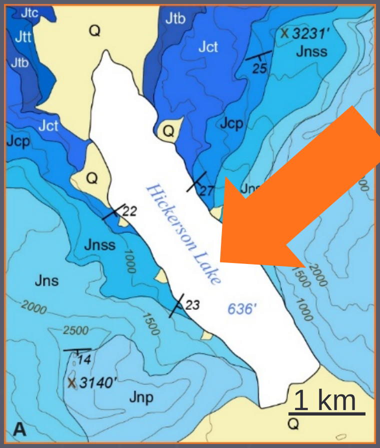




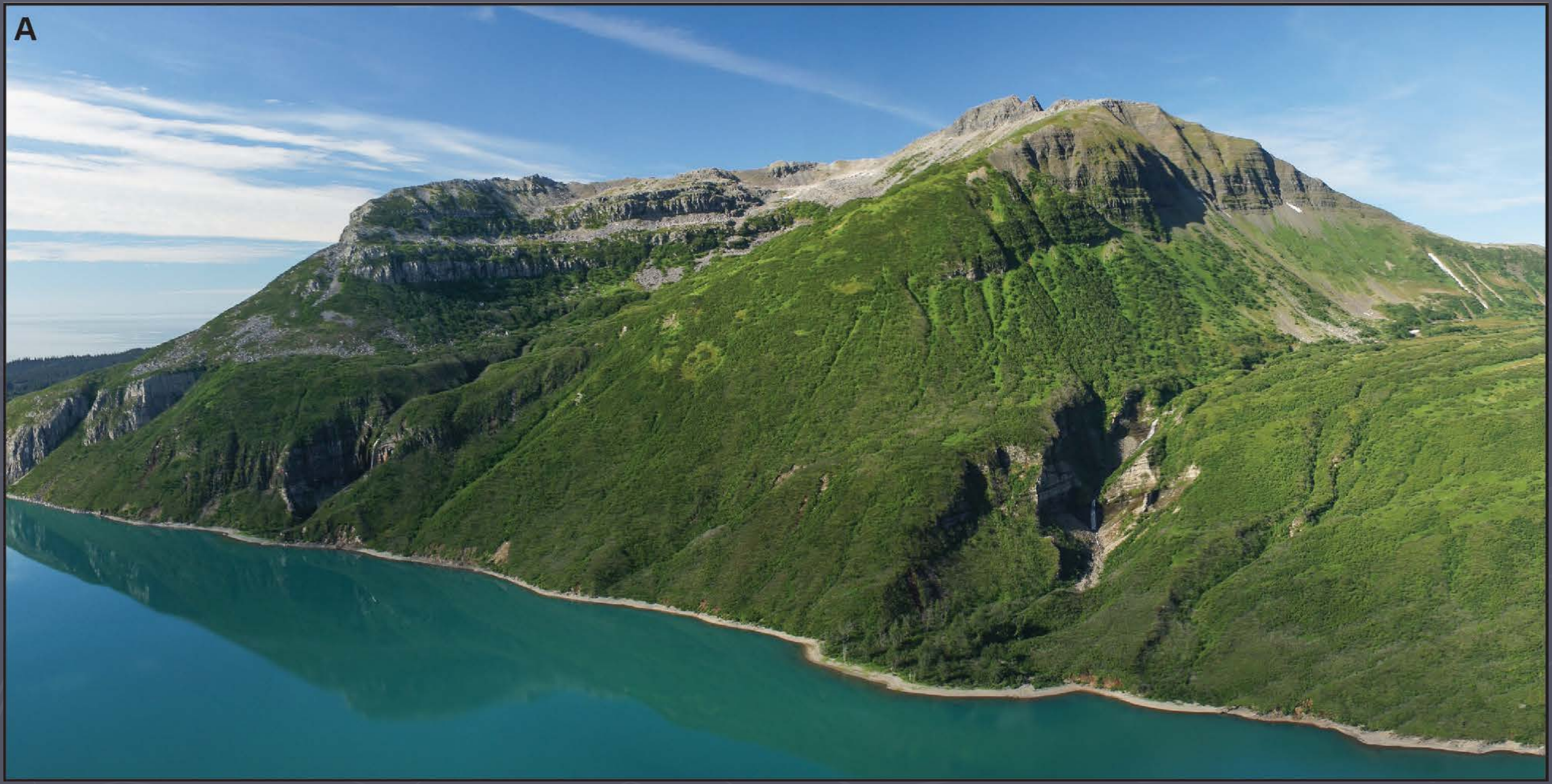


Herriott et al., in preparation

Hickerson Lake Area

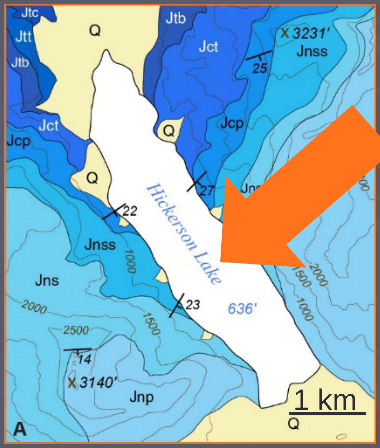


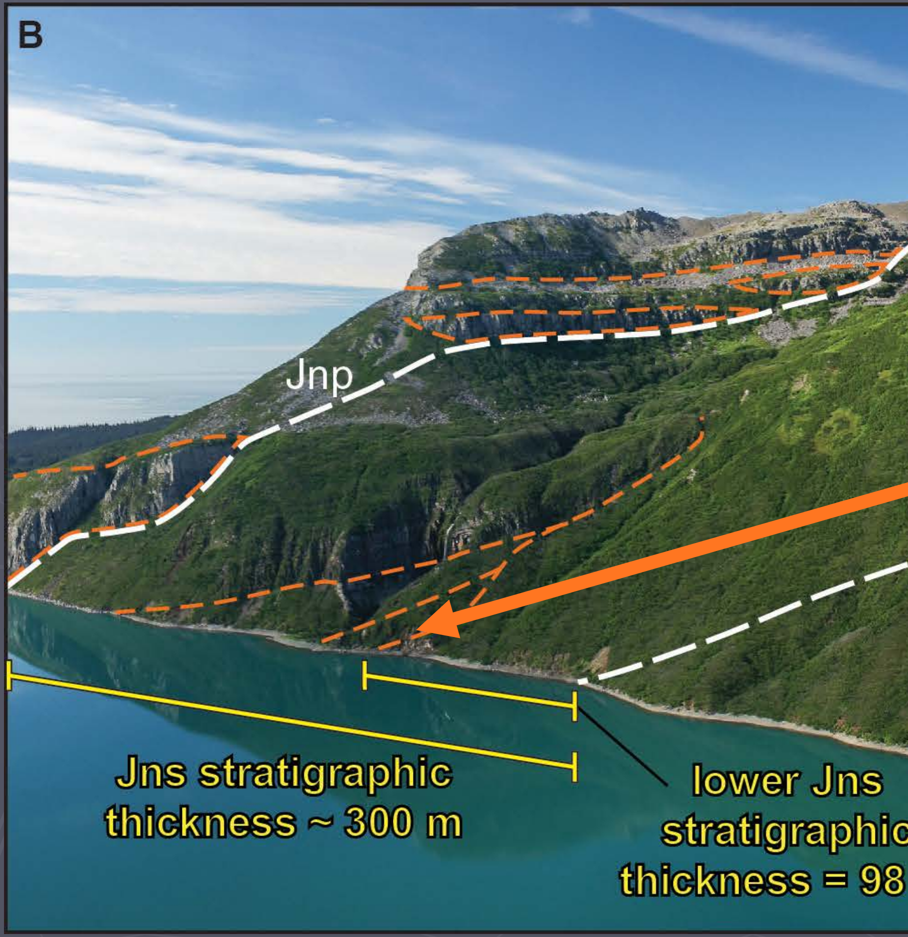
- Approximately strike-parallel view
- Snug Harbor “transitions” into Pomeroy



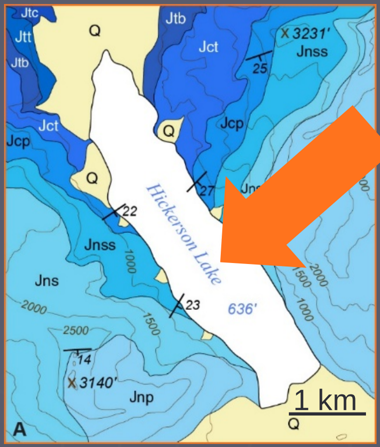
Hickerson Lake Area

- Upper ~200 m of Jns along lakeshore:
  - Coarser grained and thicker bedded than typical Jns
  - Channelform strata
    - Conglomerate at base
- Jns ~500 m thick 1.5 km west of the lakeshore

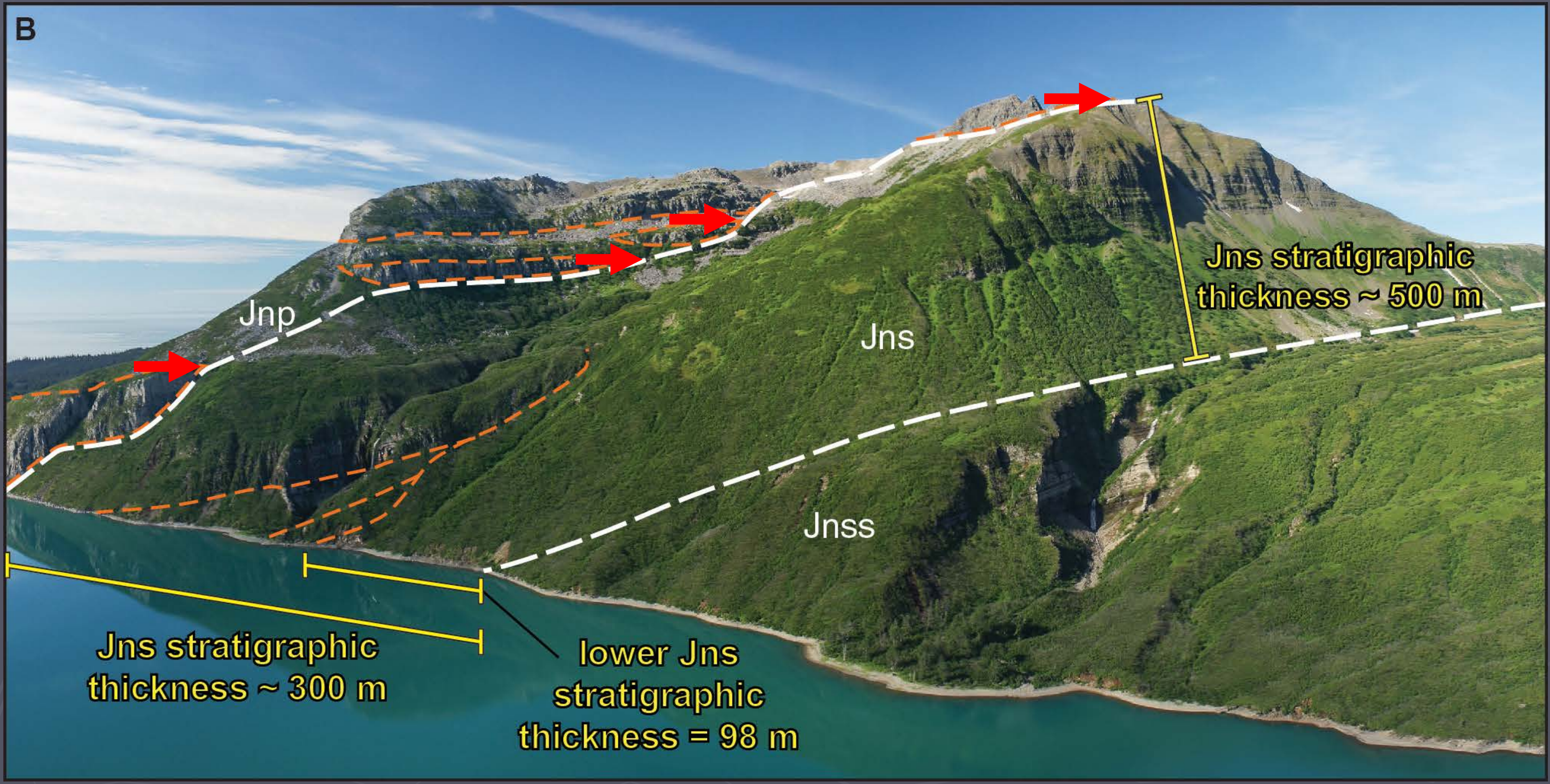




Hickerson Lake Area

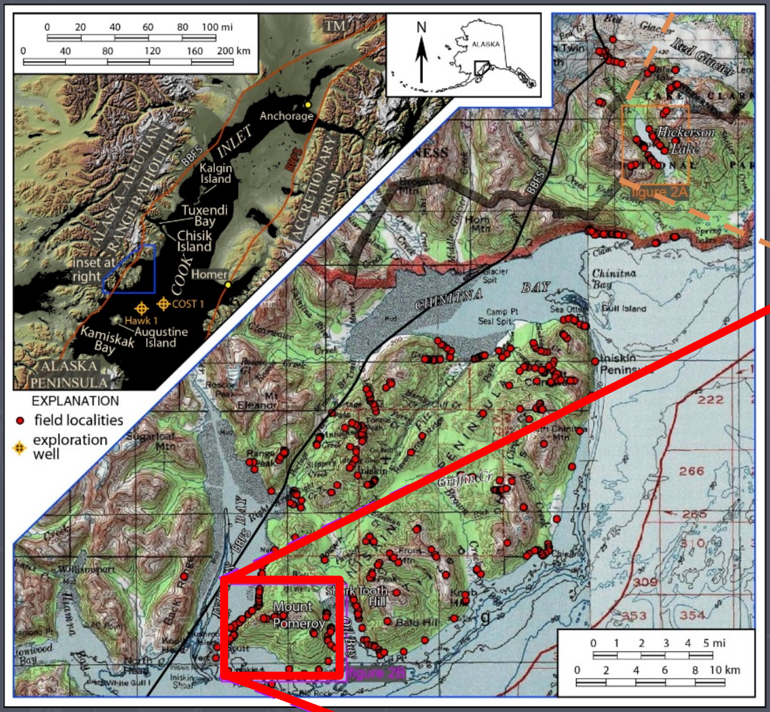


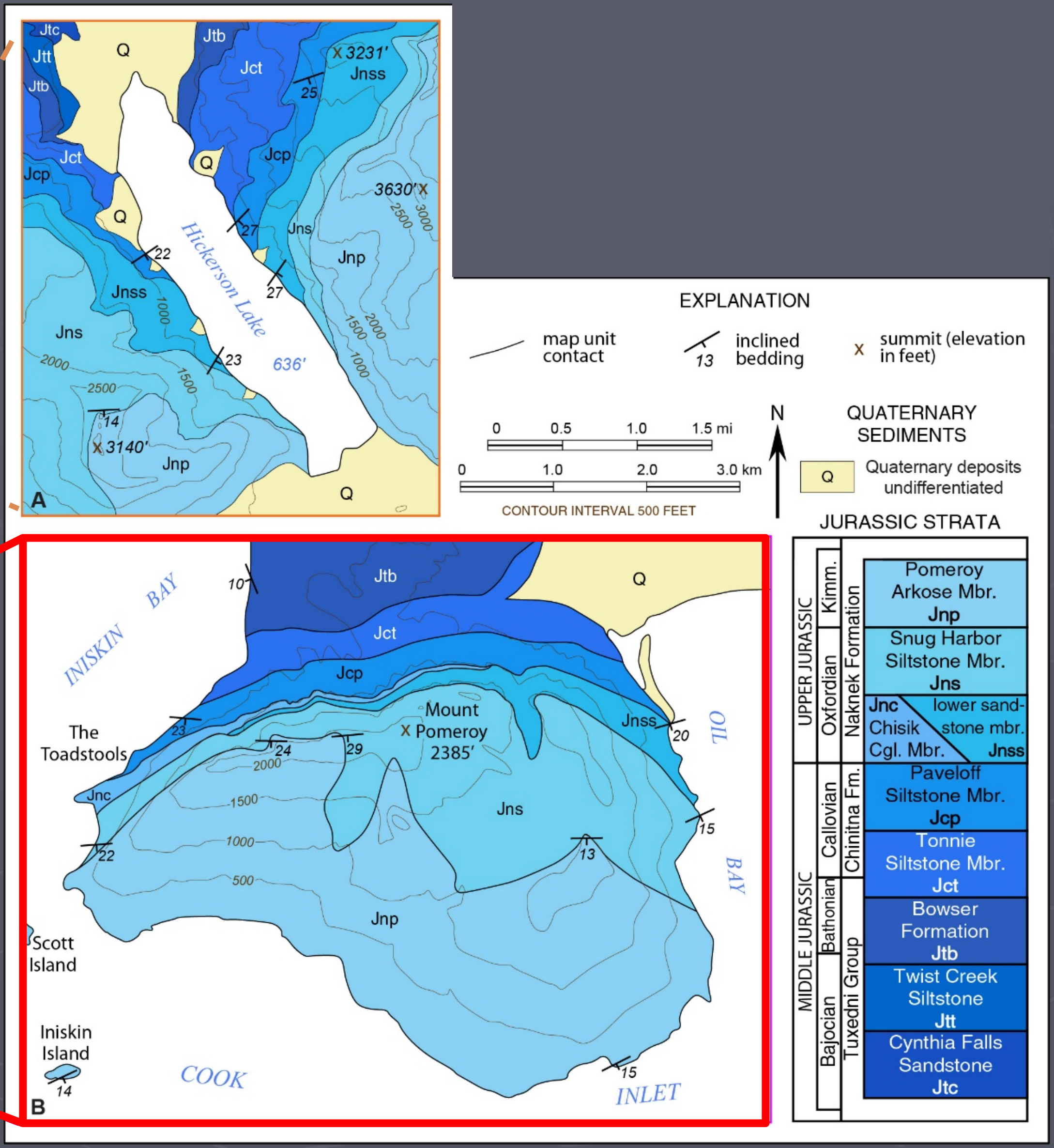
- ~200 m of lithostratigraphic relief at Jns–Jnp contact
  - Onlap of Jnp channelform strata onto Jns



Snug Harbor Siltstone–Pomeroy Arkose Stacking: Atypical

Lithostratigraphic "containers" at Hickerson Lake & Mount Pomeroy



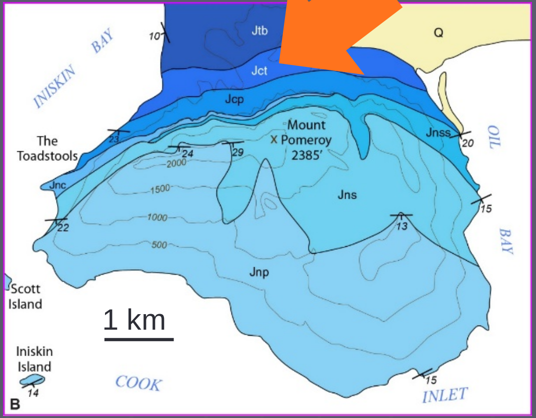


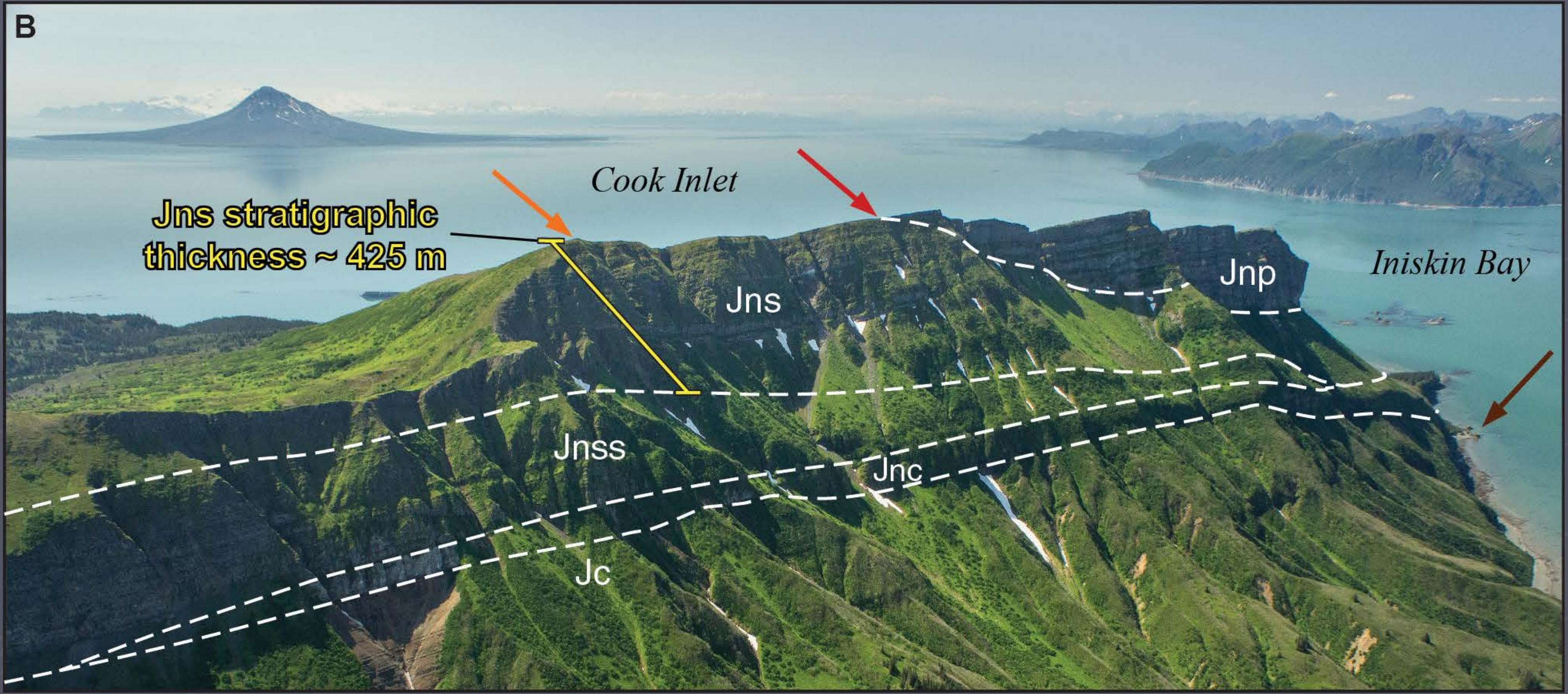
Mount Pomeroy

Herriott et al., in preparation

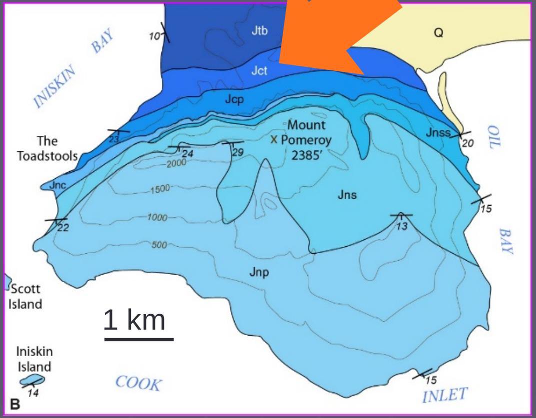
Mount Pomeroy Area

- ~425 m of Jns at Mount Pomeroy
- Jns "transitions" along strike into Jnp
- Marked lithostratigraphic relief along Jns–Jnp contact

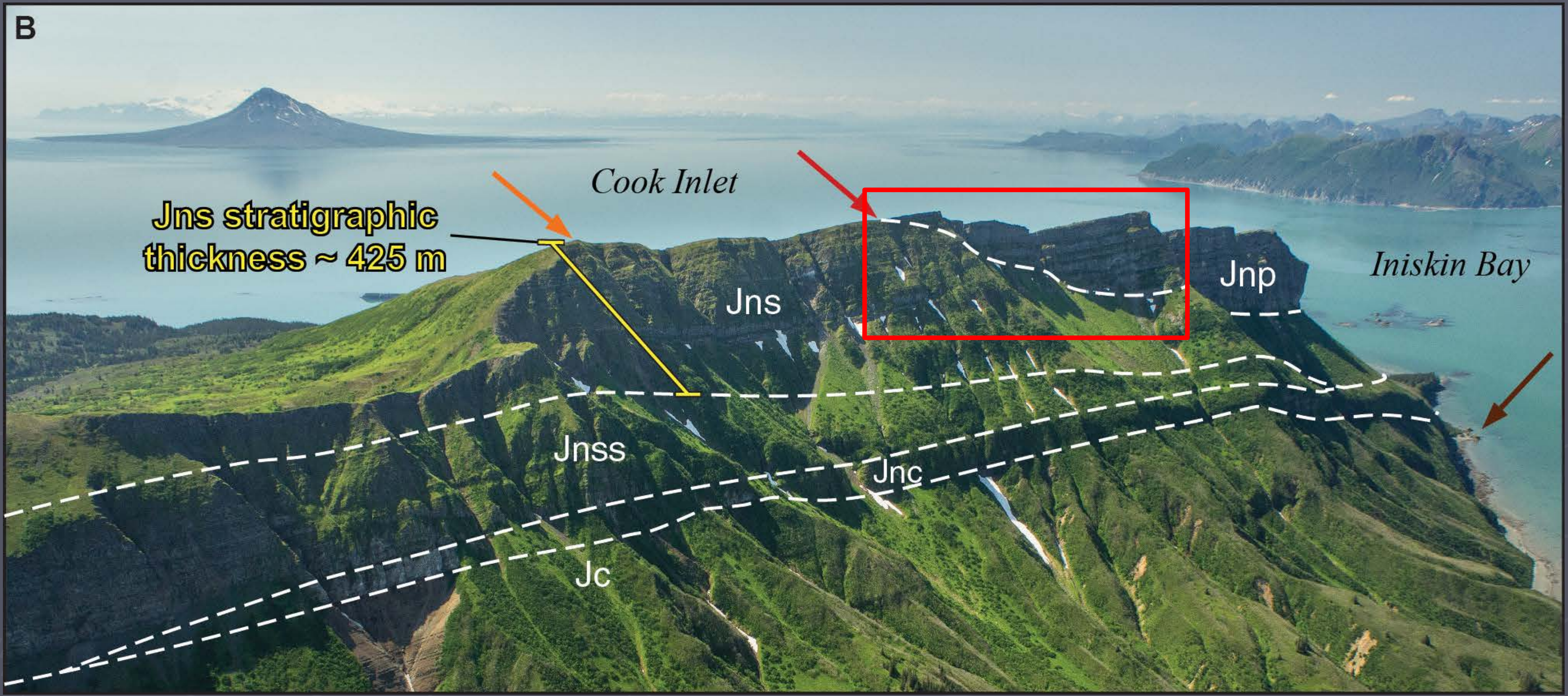




Mount Pomeroy Area

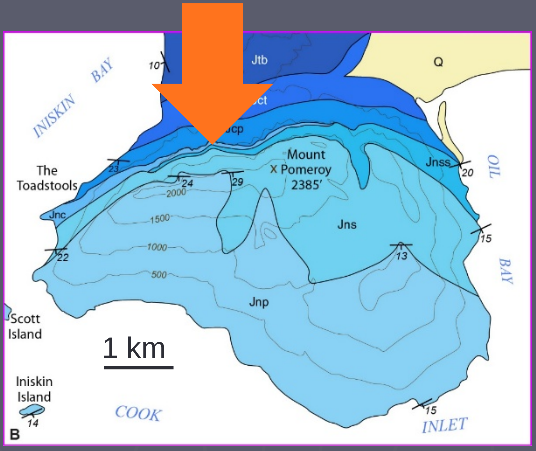


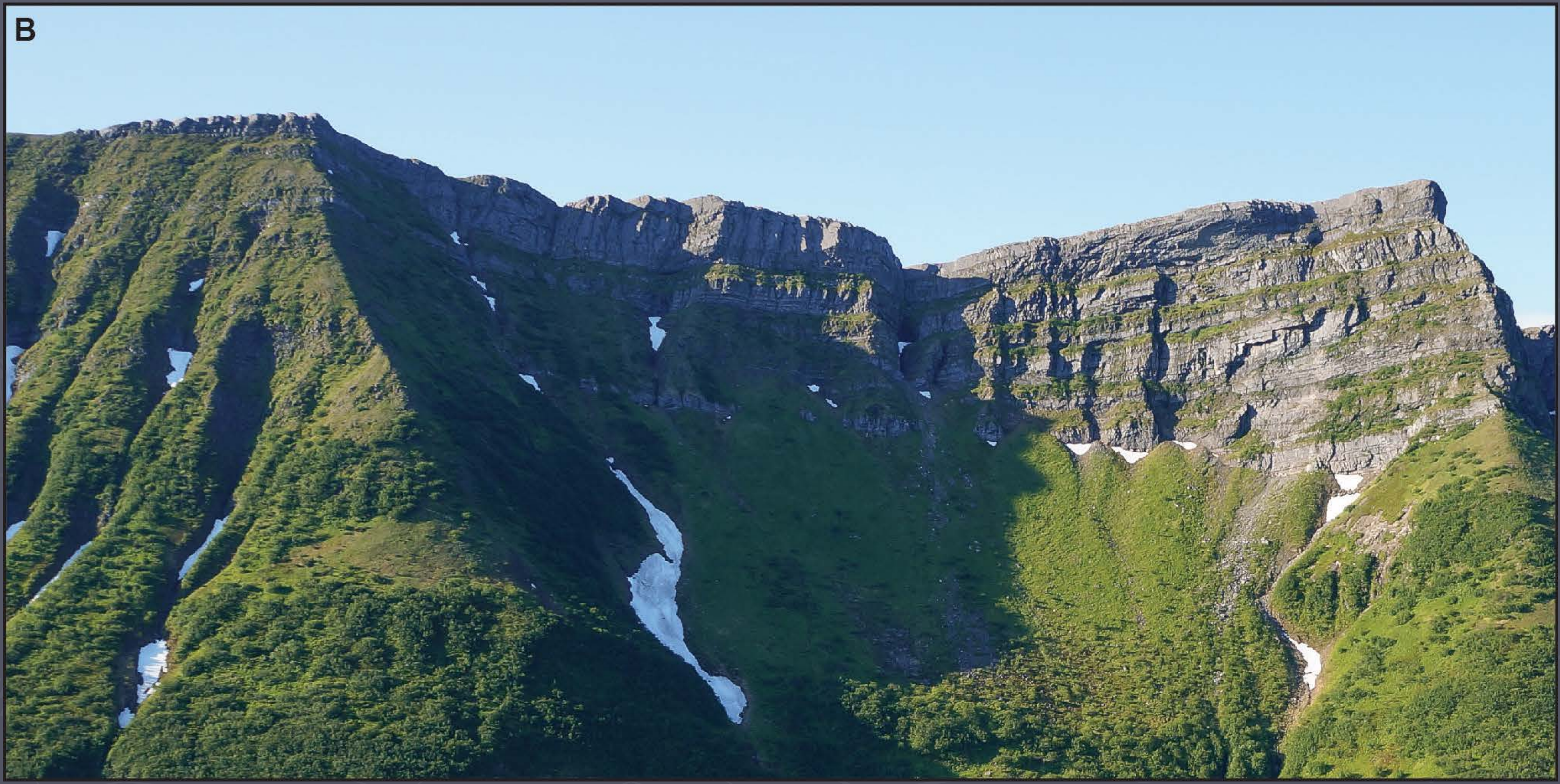
- ~425 m of Jns at Mount Pomeroy
- Jns “transitions” along strike into Jnp
- Marked lithostratigraphic relief along Jns–Jnp contact



Mount Pomeroy Area

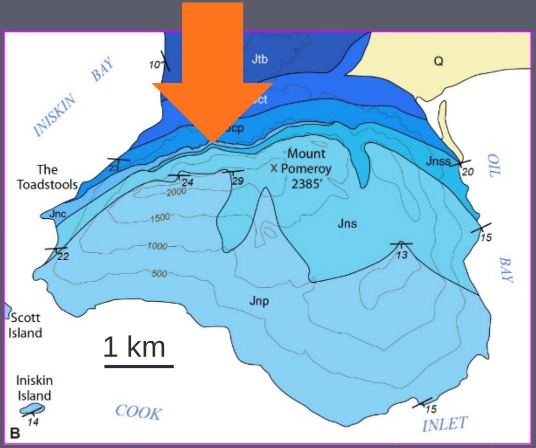
- Approximately dip-direction-parallel view of Jns “transitioning” along strike into Jnp

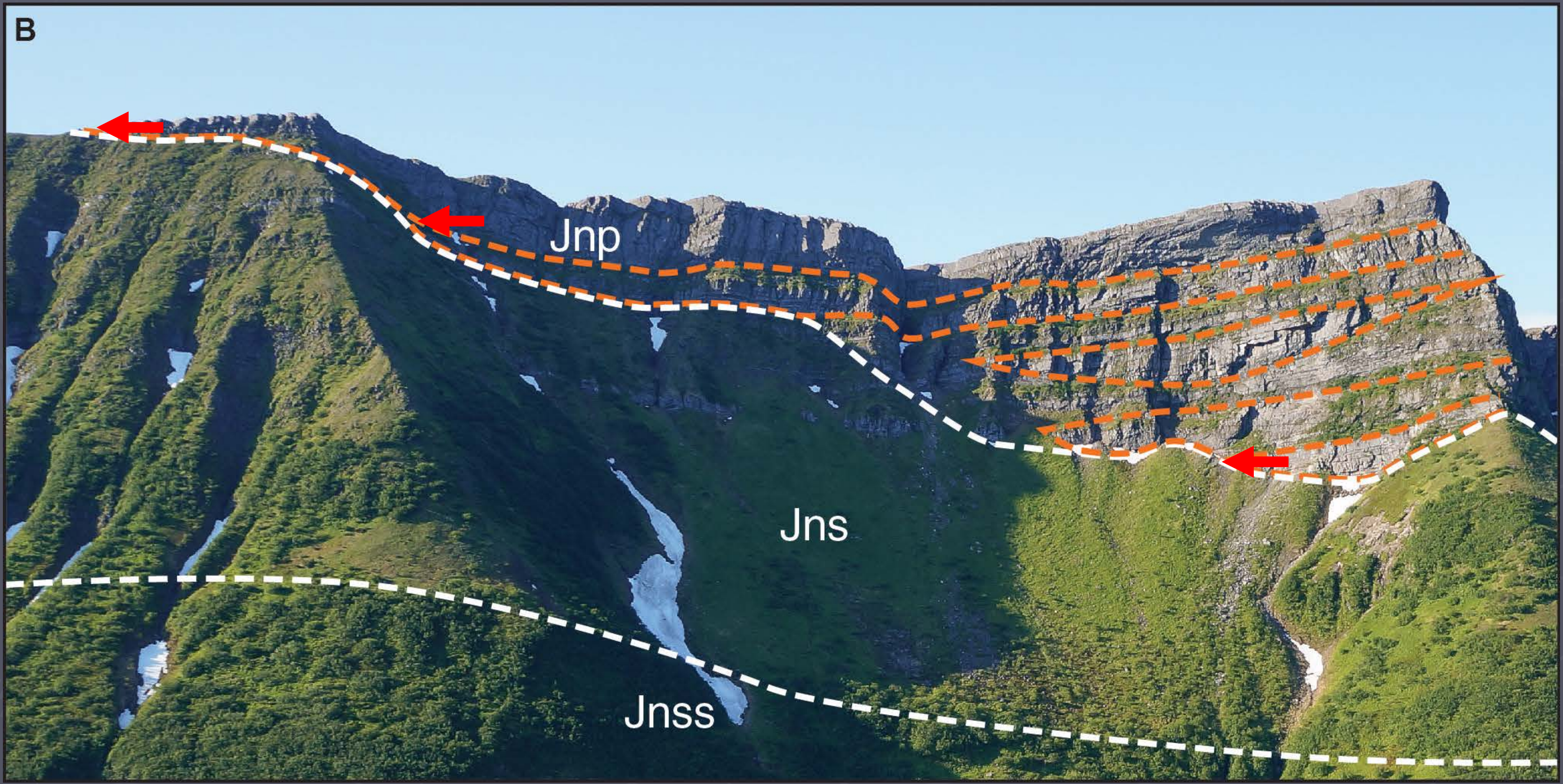




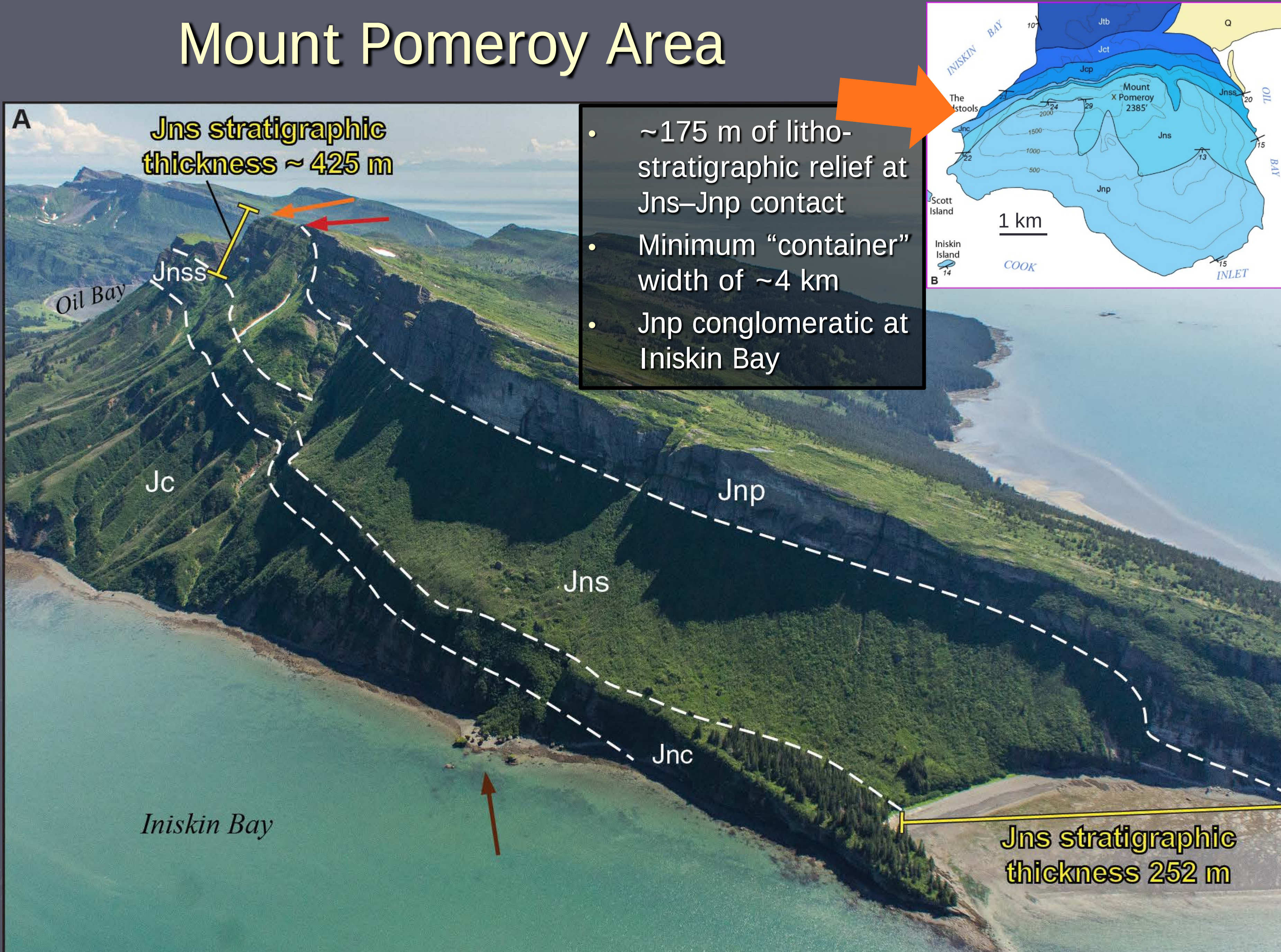
Mount Pomeroy Area

- ~100 m of local lithostratigraphic relief at Jns–Jnp contact
  - Onlapped by channelform strata of Jnp



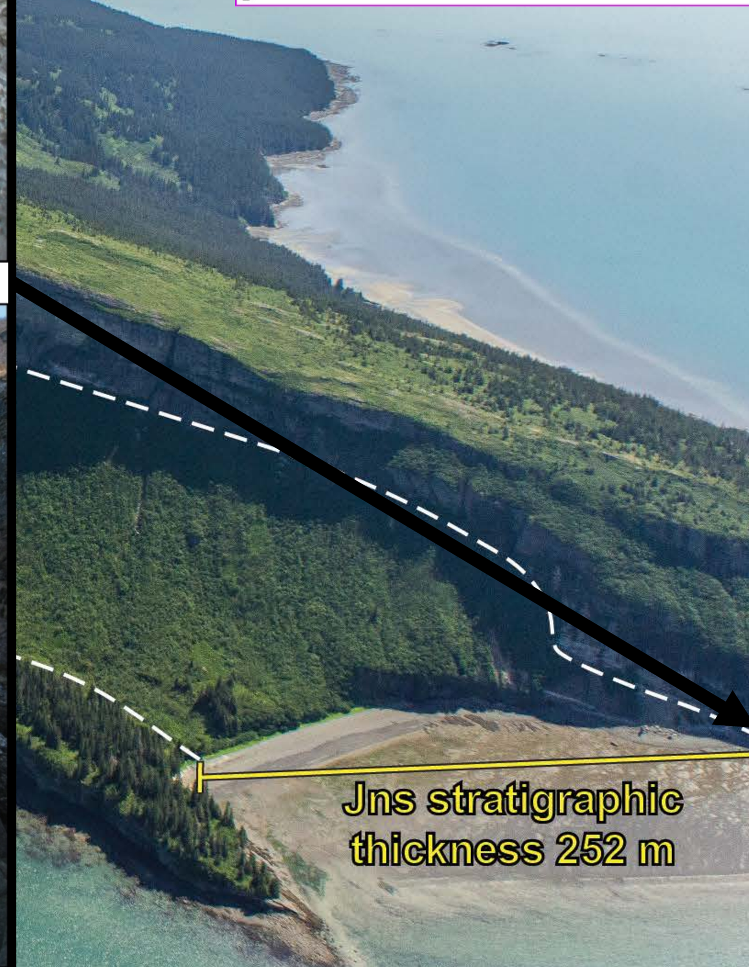


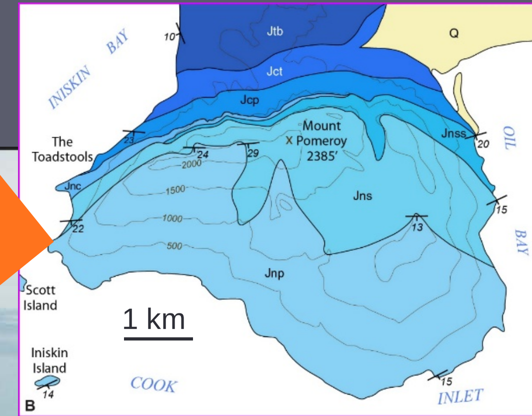
Mount Pomeroy Area



- ~175 m of litho-stratigraphic relief at Jns–Jnp contact
- Minimum “container” width of ~4 km
- Jnp conglomeratic at Iniskin Bay

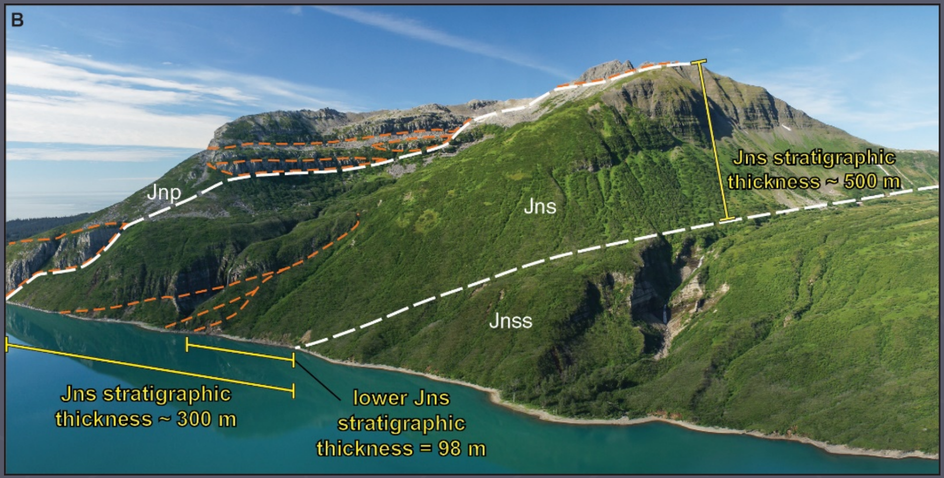
Mount Pomeroy Area

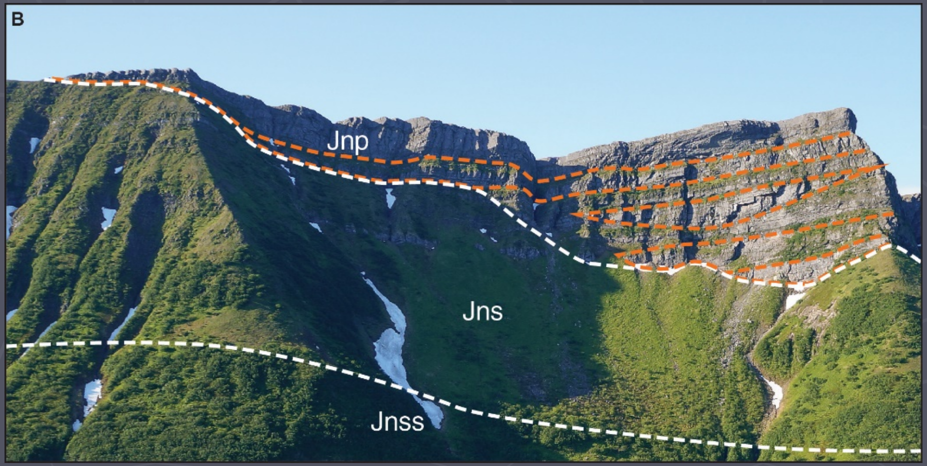




Hickerson Lake & Mount Pomeroy "Containers":

- Seismic-scale features exhibit 100s of m of relief and extend laterally for many km
  - Host: tabular-bedded Jns strata
    - Anomalously thick approaching "container" rims
  - Fill: channelized, tabular, and lobate strata of dominantly Jnp (locally Jns)
    - Onlaps host strata
    - Locally conglomeratic
  - Erosional signature at margins/floors



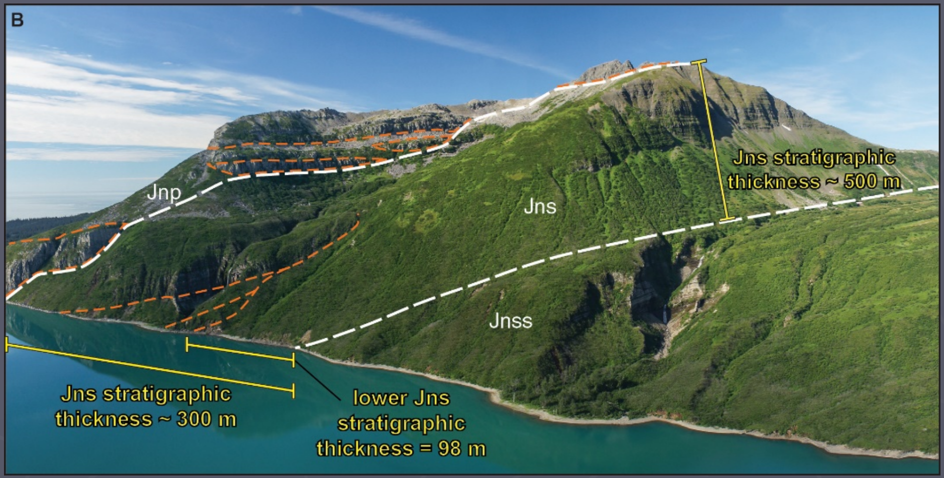


Hickerson Lake & Mount Pomeroy "Containers": Deep-Water Canyons

- Definition: wide (km-scale), deep (100s of m), erosive-based, slope-associated, long-lived (~m.y.-scale) conduits for transport of mud, sand, and gravel in deep-marine environments

  e.g., Reading and Richards, 1994; Galloway and Hobday, 1996; Richards et al., 1998; Posamentier and Allen, 1999; Prather, 2003; Sprague et al., 2005; Weimer and Slatt, 2006; Di Celma, 2011; Jobe et al., 2011; Williams and Graham, 2013; Hubbard et al., 2014

- Transport pathways for bypass of coarse-grained arkosic sediment that fed Jnp



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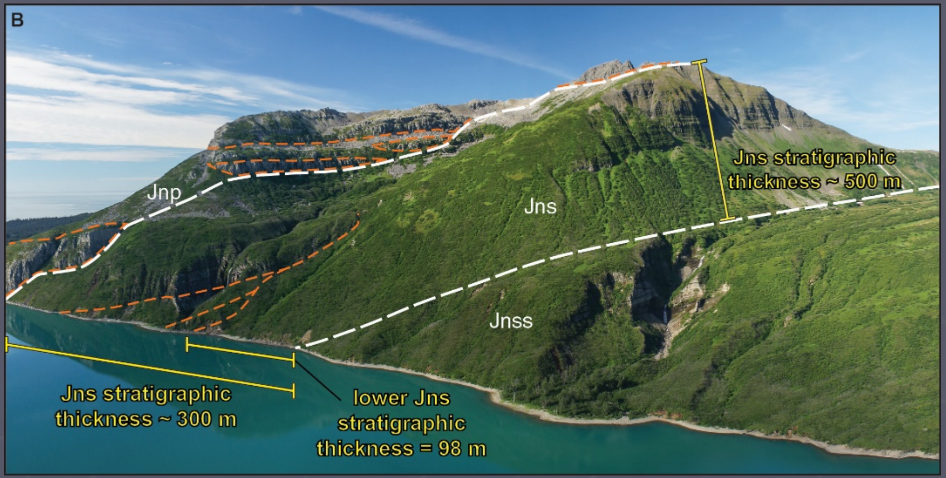
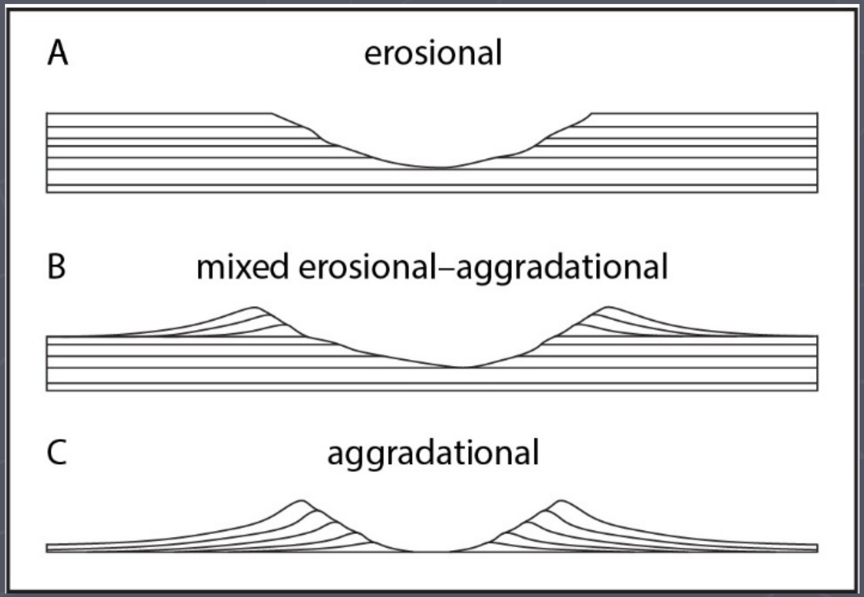
- Transport pathways for bypass of coarse-grained arkosic sediment that fed Jnp
- Canyon confinement: Erosional (inception) to aggradational (later-in-life)
  - Deep-water channel systems (e.g., Fildani et al., 2013)
  - Jns thicknesses at canyon rims: Levees





modified from Clark and Pickering, 1996

Hickerson Lake & Mount Pomeroy “Containers”: Deep-Water Canyons

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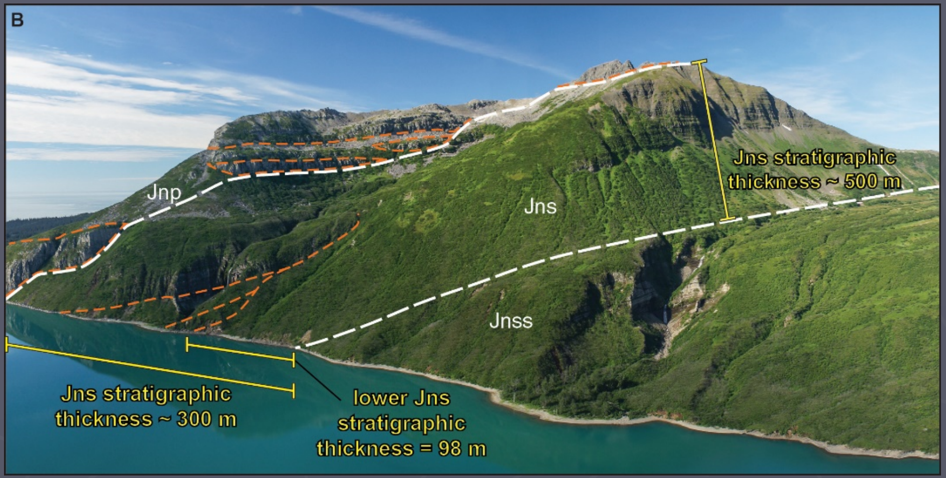

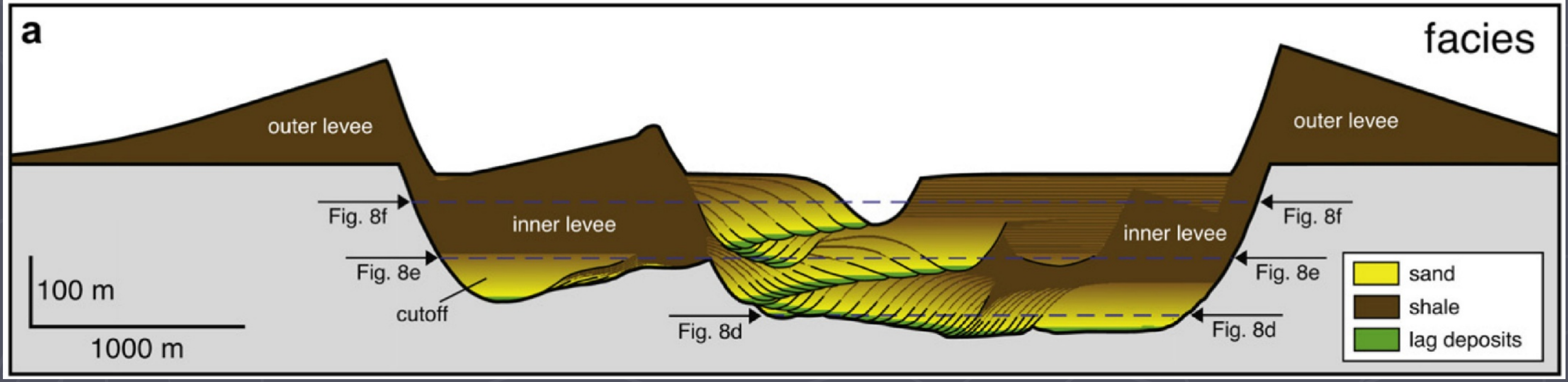

Sylvester et al., 2011

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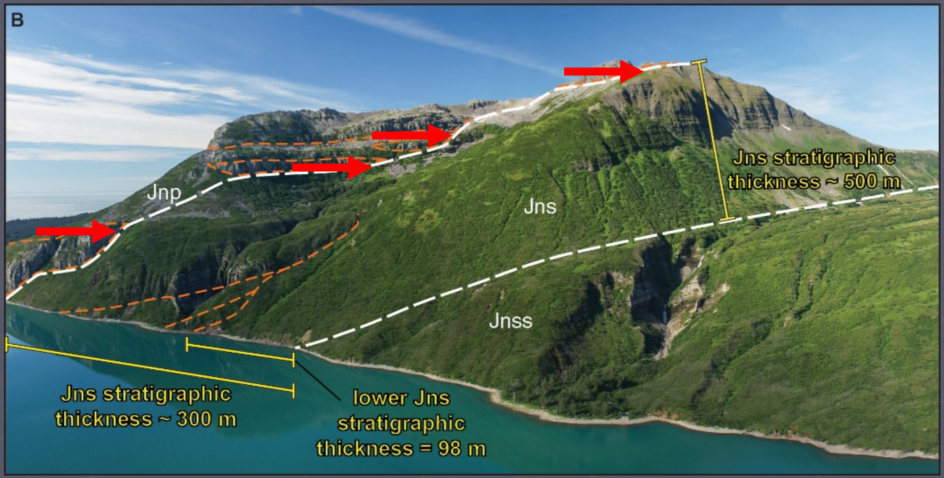
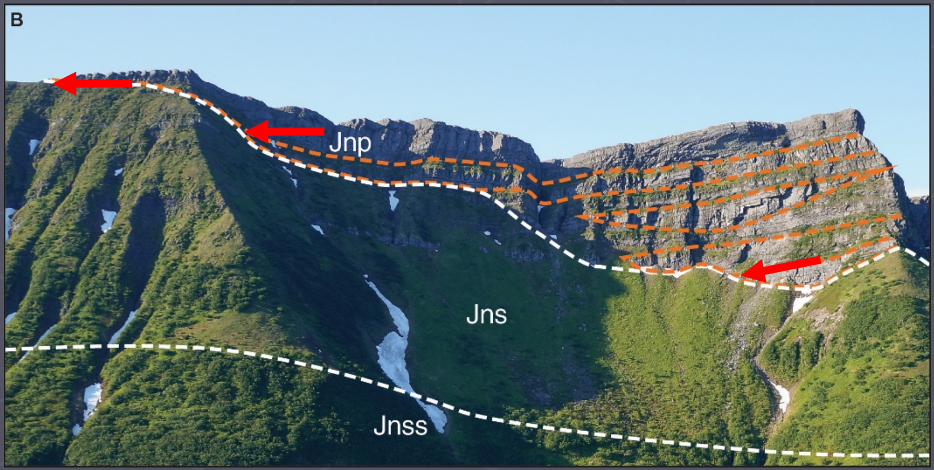
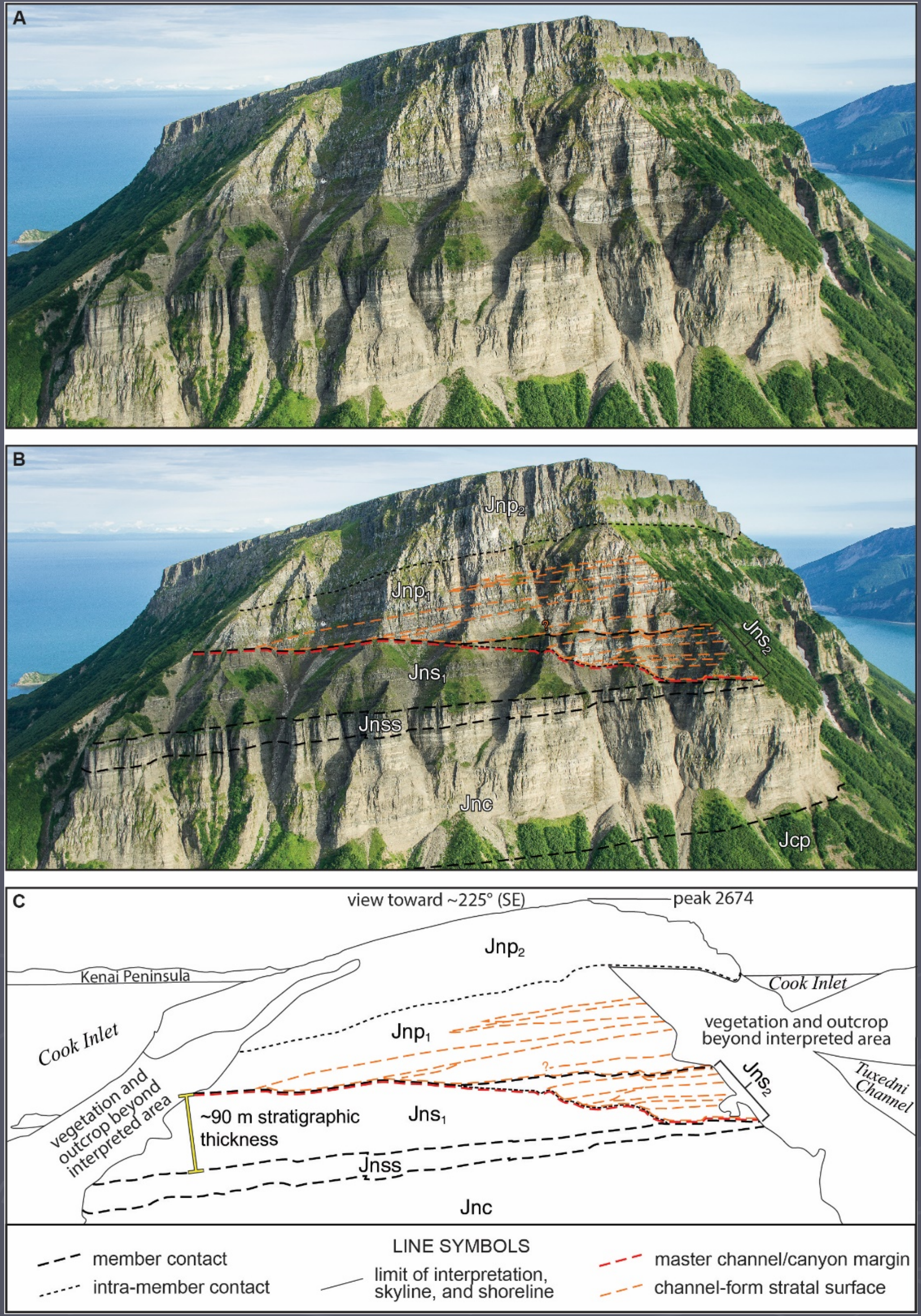
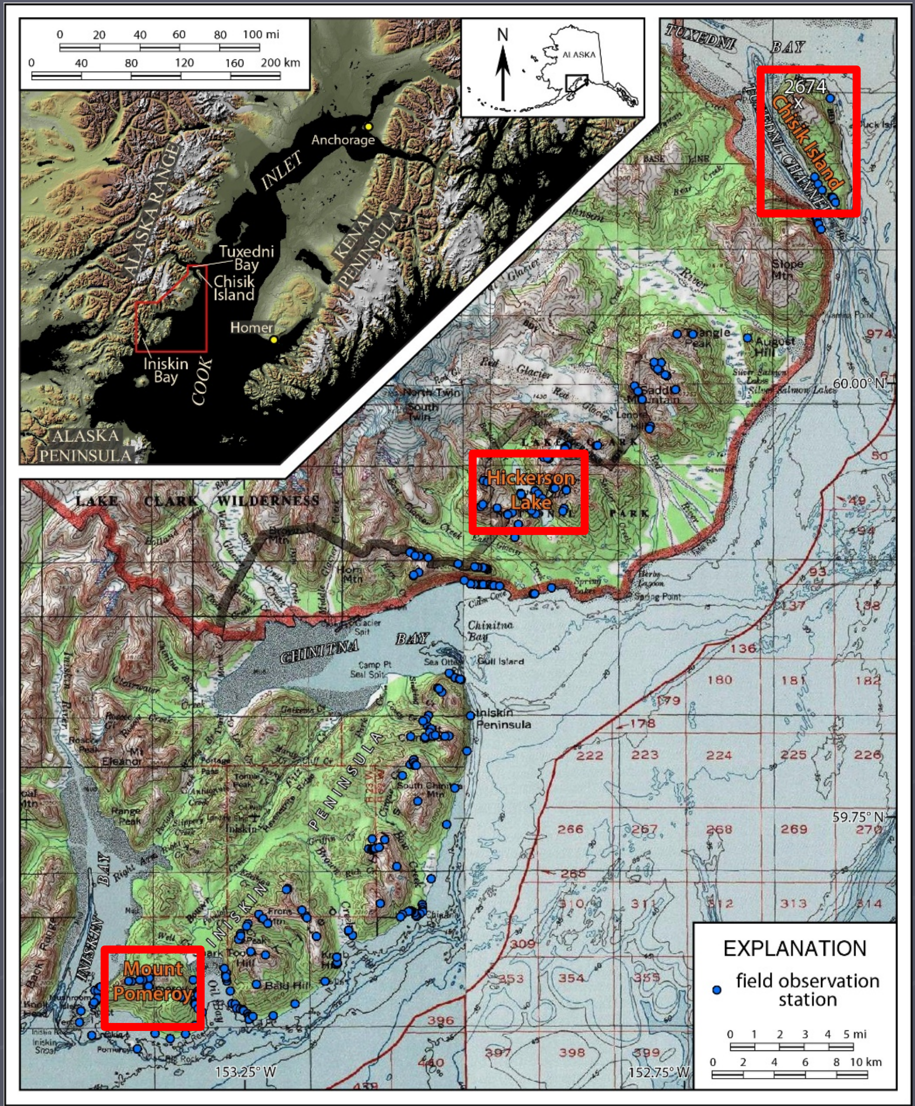


- Transport pathways for bypass of coarse-grained arkosic sediment that fed Jnp
- Canyon confinement: Erosional (inception) to aggradational (later-in-life)
  - Deep-water channel systems (e.g., Fildani et al., 2013)
  - Jns thicknesses at canyon rims: Levees
- Canyons were ultimately backfilled by depositional elements of lower Pomeroy that backstepped and onlapped the inherited Snug Harbor slope depositional profile



Chisik Island: A Third Deep-Water Canyon

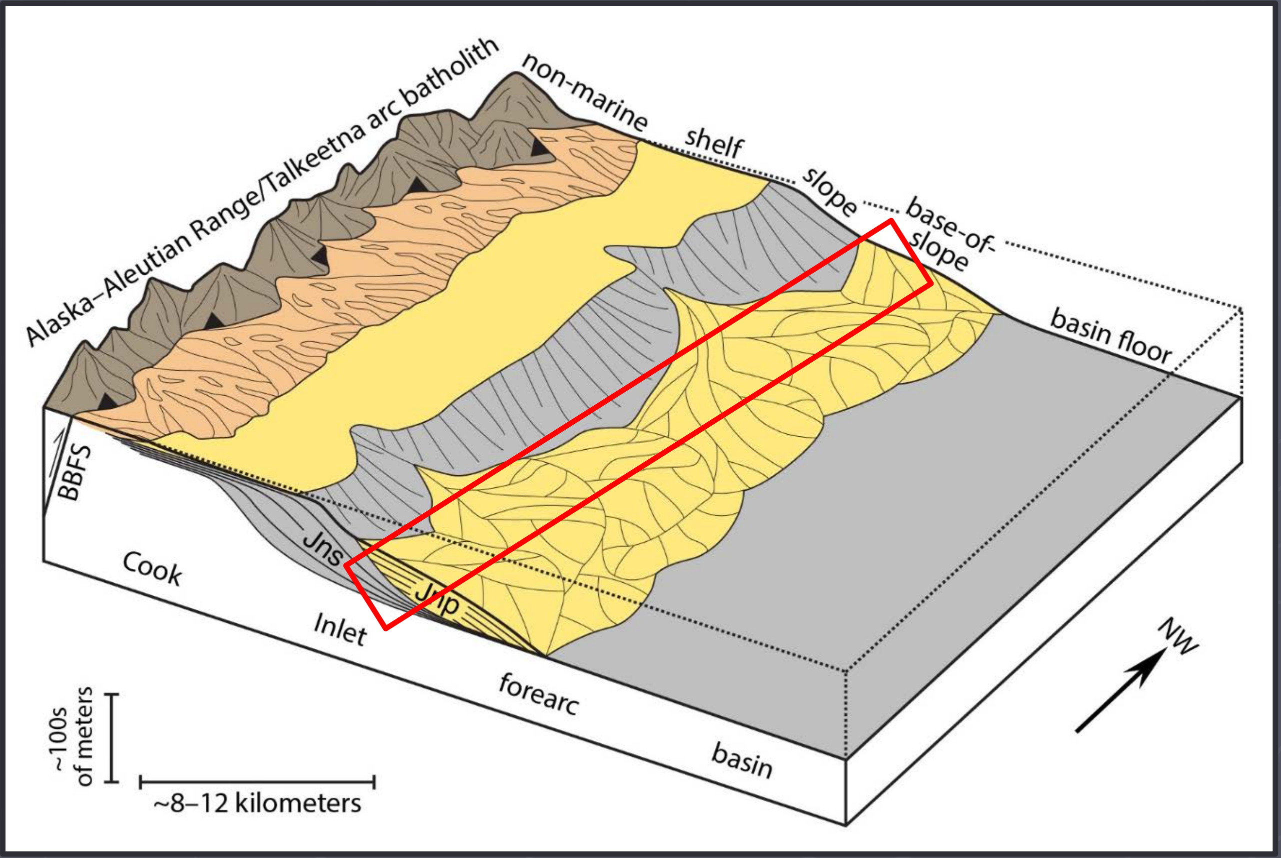




Herriott et al., in review

Snug Harbor–Pomeroy: A Depositional Model

- Base of slope (Jnp) on slope (Jns) stacking predicts bypass: deep-water canyons (e.g., Miall, 1990; Hubbard et al., 2012)
- Deep-water erosion is a gravity driven process that varies as a function of seafloor gradient
- Depositional environment trends and canyon erosion strongly suggest shelf–slope–basin floor depositional profile during Jns sedimentation

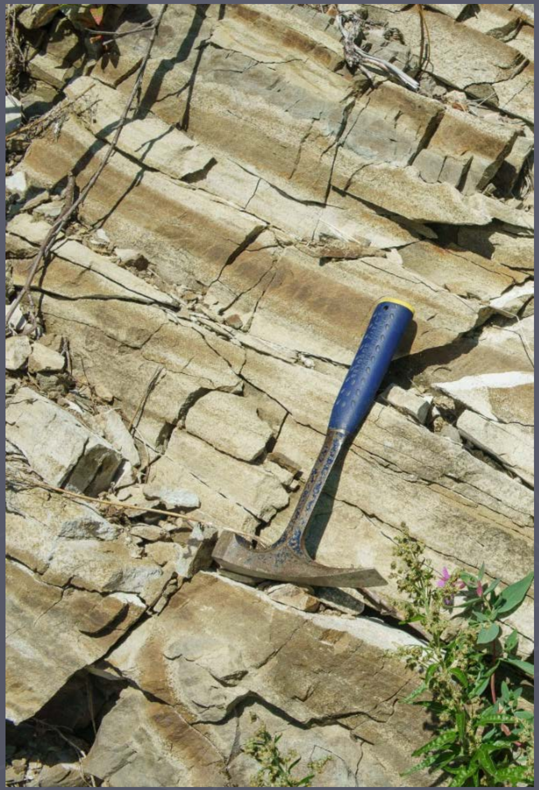


modified after Reading and Richards, 1994

- Gradient transitions along deep-water depositional profiles delineate regions prone to erosion and bypass vs. sedimentation
  - Erosion and bypass: slope
  - Sediment accumulation: base-of-slope and beyond
- Changes through time and space: equilibrium grade
  - Erosion vs. aggradation

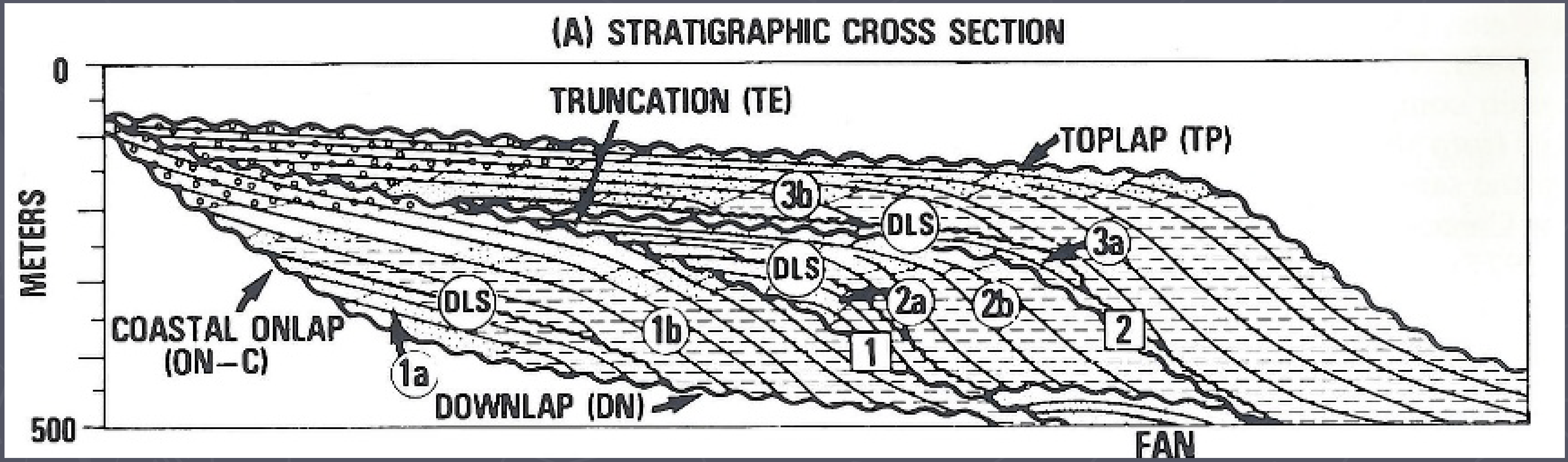
Presentation Outline

- Geologic setting—Cook Inlet forearc basin
- Naknek Formation: Members and depositional environments
  - Pomeroy Arkose
  - Snug Harbor Siltstone
  - lower sandstone (informal)
  - Chisik Conglomerate
- Stacking relations of the Snug Harbor and Pomeroy
  - Typical and atypical: Deep-water depositional elements
- Sequence stratigraphy of the Naknek Formation
  - Surfaces, systems tracts, and stratigraphic sequences
  - Chisik and lower sandstone stacking in further detail
- Implications: Hydrocarbon reservoirs
- Summary and conclusions



Sequence Stratigraphy

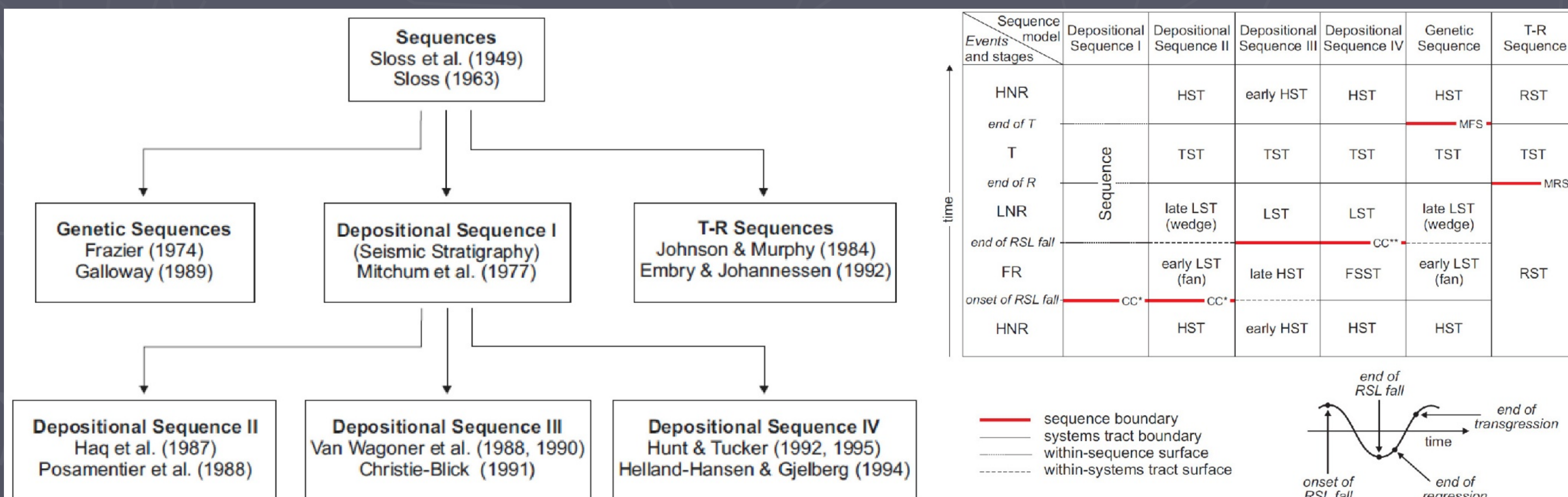
- What is sequence stratigraphy? The study of stratal stacking patterns in a multi-dimensional framework, with emphases on depositional systems trends, stratigraphic cyclicity, and the interplay between accommodation and sediment supply



Kendall and Lerche, 1988

Sequence Stratigraphy

- Heavily dependent on a method-specific nomenclature
  - Sometimes conflicting terminology:
    - Late highstand (Van Wagoner et al., 1988) = early lowstand (Posamentier et al., 1988) = falling stage (Plint and Nummedal, 2000)
      - The <u>same</u> geologic interpretation can be made using <u>different</u> terms
    - Correlative conformity *sensu* Hunt and Tucker (1992) DOES NOT equal correlative conformity *sensu* Posamentier and Allen (1999)
      - A <u>different</u> geologic interpretation can be made by using the <u>same</u> terms
  - Case studies have to be translated to be understood, depending on what “school” a sequence stratigrapher may come from (or what basin they are working in)



Catuneanu and others, 2011

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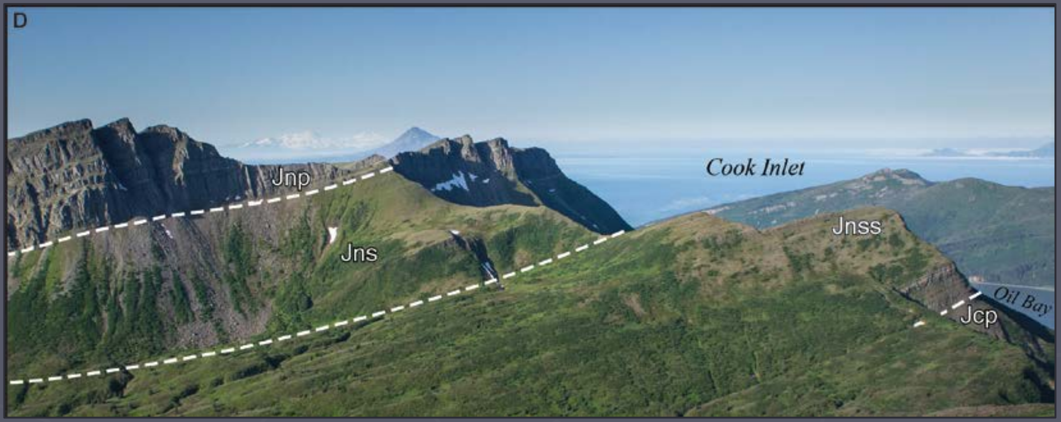
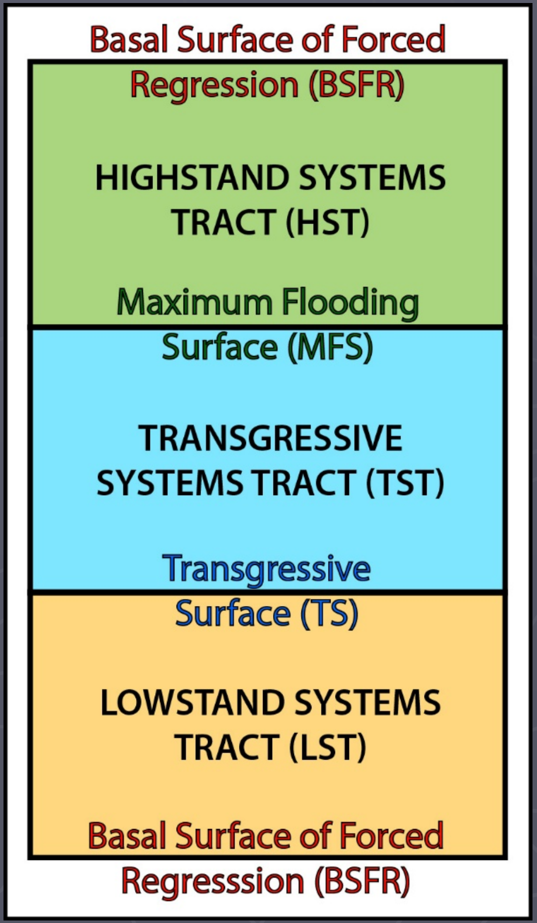
- Sequence stratigraphy is a method that provides a framework to organize observations, generate reasonable (and ideally testable) hypotheses, and leverage observations and interpretations (from one’s own “window into the world”) to depositional reaches beyond the study area
  - See review papers by Catuneanu et al. (2009, 2011); also Catuneanu (2002)

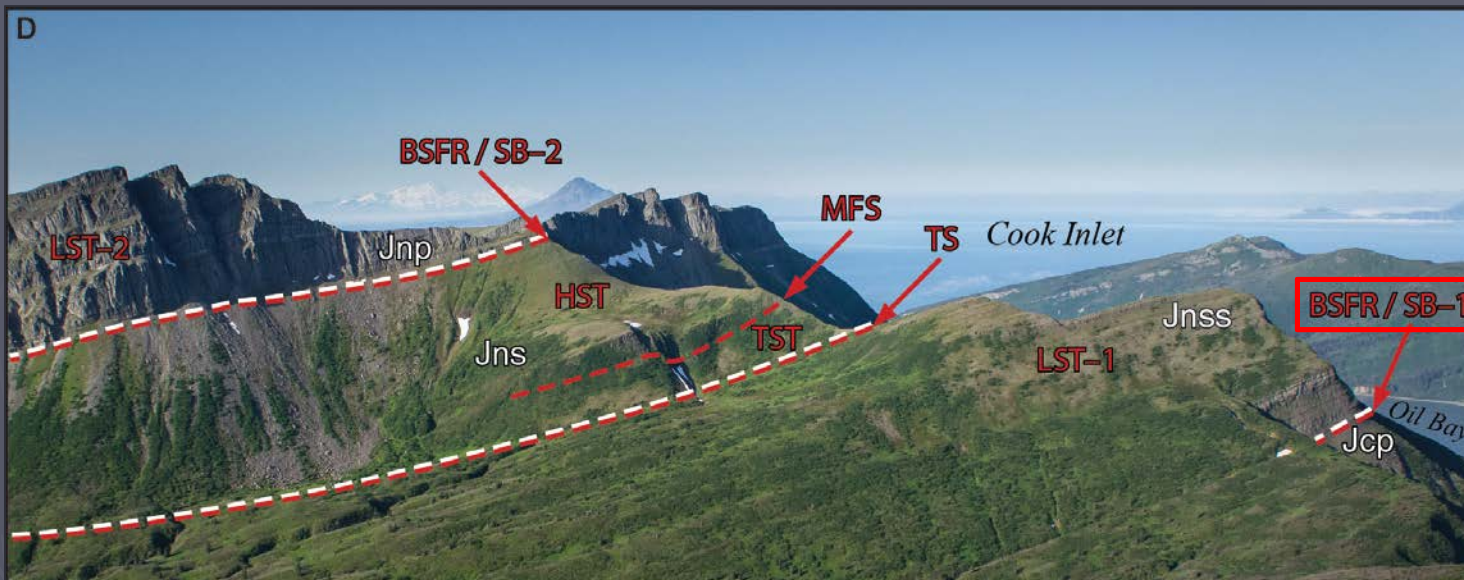
Sequence Stratigraphic Framework of the Naknek Formation

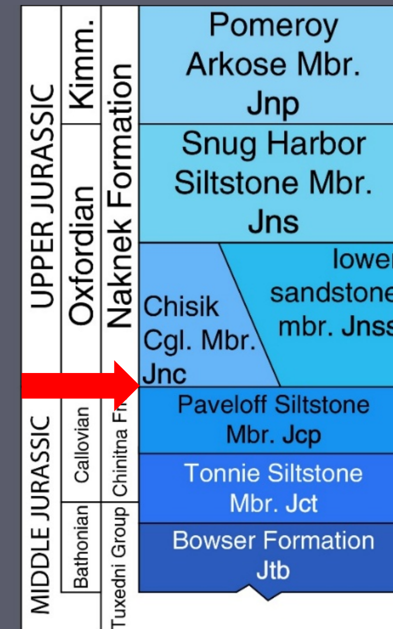


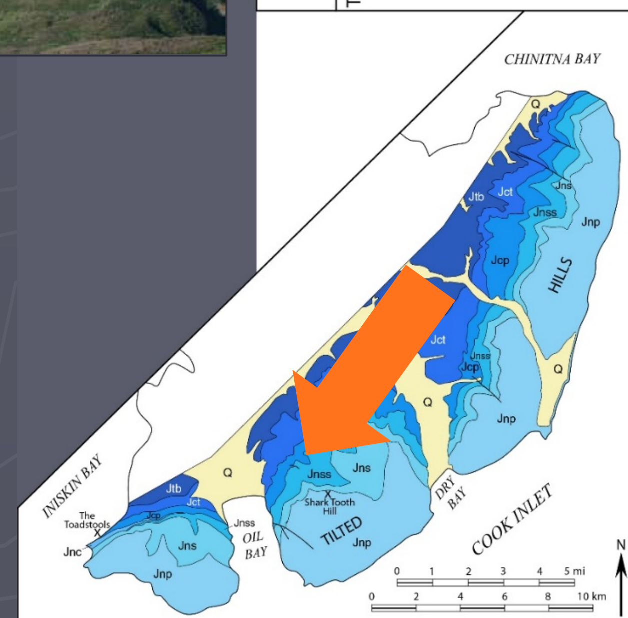
- Outcrop based study of depositional environment trends, stratigraphic architecture, and stratal terminations:
  - Sequence stratigraphic surfaces
  - Systems tracts
  - Stratigraphic sequences
- Methods (this study):
  - Three surfaces: BSFR, TS, MFS
    - BSFR (Hunt and Tucker, 1992) as sequence boundary (Posamentier and Allen, 1999)
  - Three systems tracts (Posamentier and Allen, 1999)
    - LST (FR+LNR), TST, and HST (HNR)



Sequence Stratigraphic Framework of the Naknek Formation



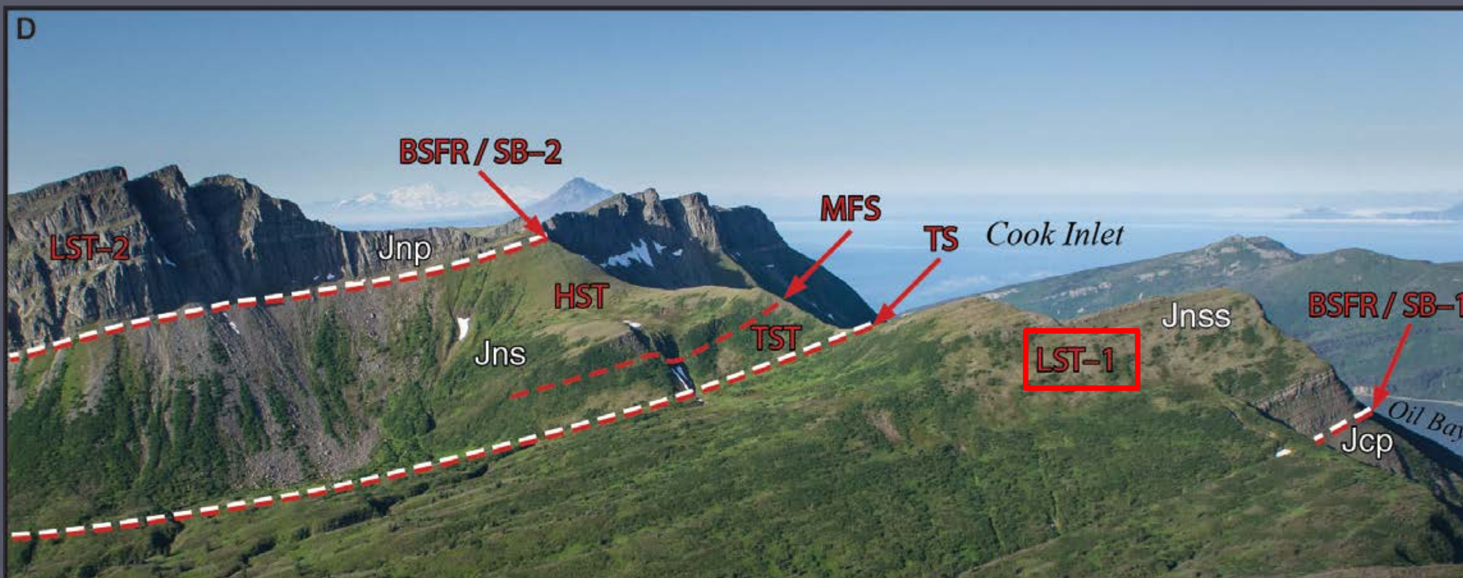


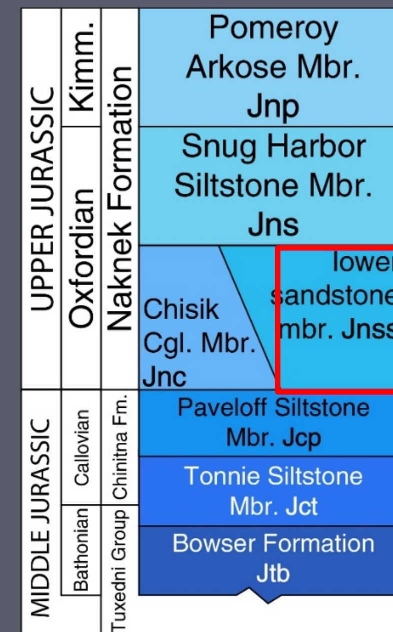


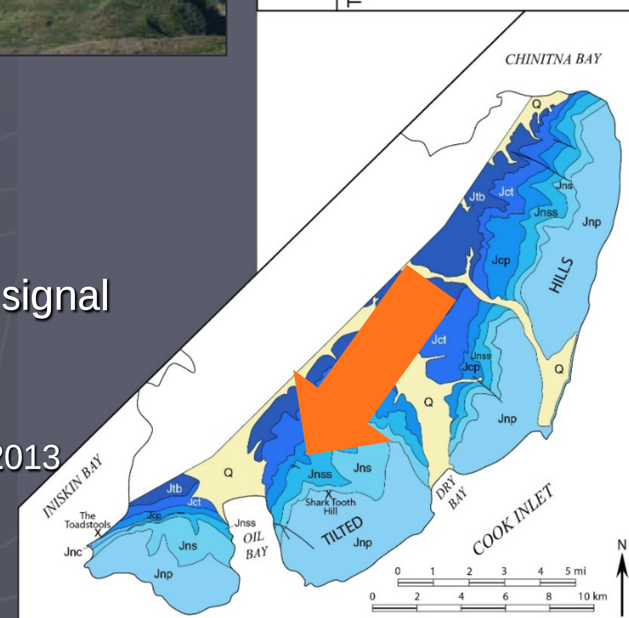
SURFACES AND SYSTEMS TRACTS

- BSFR/SB–1: Sequence Boundary–1
  - Shallow marine on unconformity stacking
    - Locally erosional
    - <1 m.y. hiatus at end of Callovian (Detterman and Hartsock, 1966; Imlay, 1975)
  - Shoreline trajectory: seaward

Sequence Stratigraphic Framework of the Naknek Formation



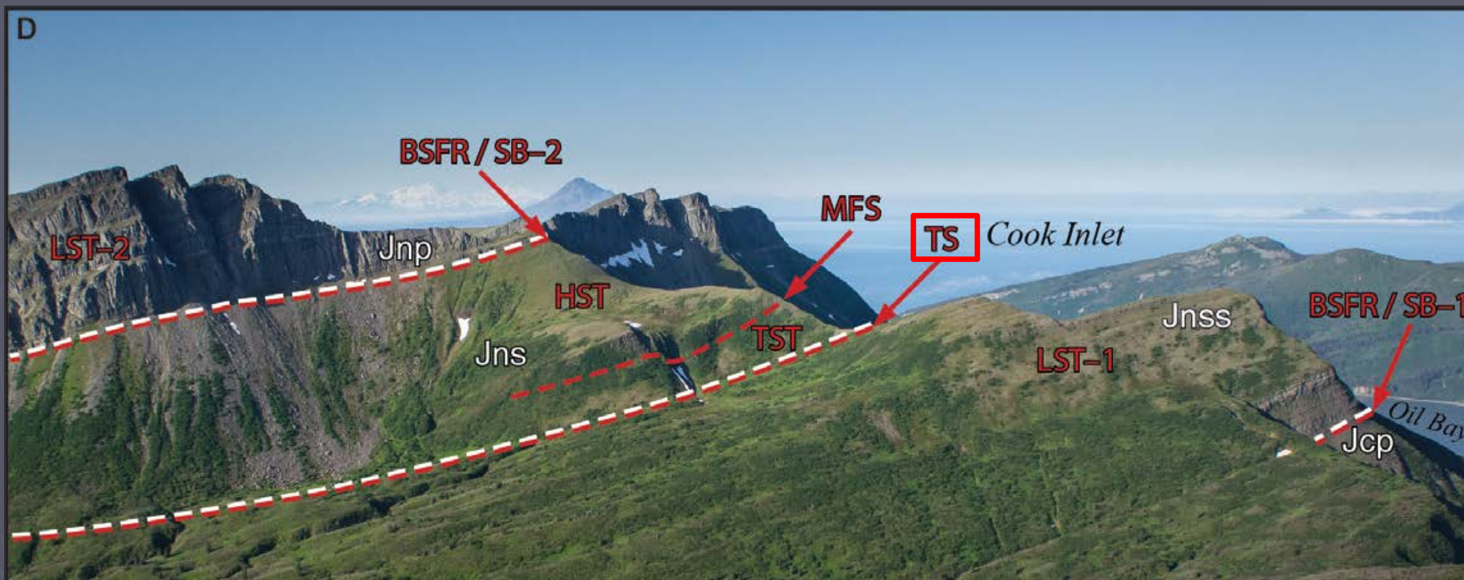


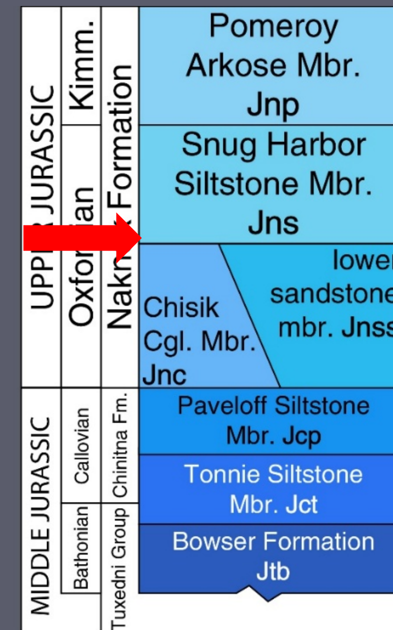


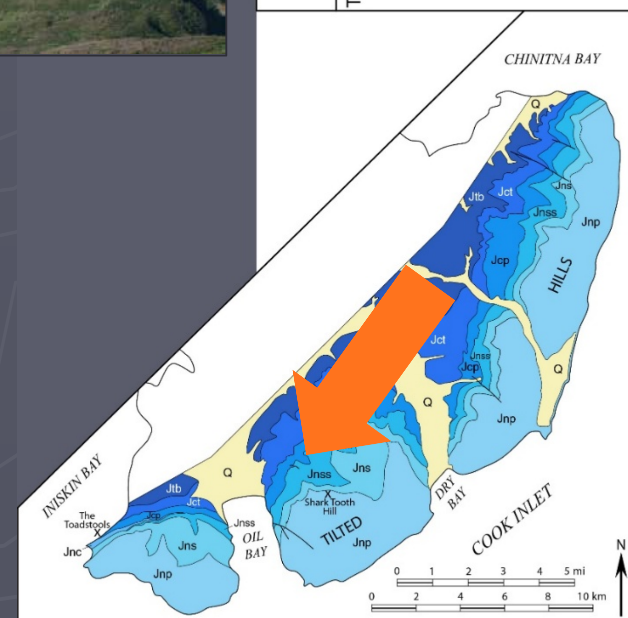
SURFACES AND SYSTEMS TRACTS

- LST–1: Lowstand Systems Tract–1
  - Lower sandstone and Chisik Conglomerate
  - Strong, convergent margin-scale arkosic sediment supply signal
    - Onset of pluton exhumation; uplift along BBFS(?)
      - Alaska Peninsula: e.g., Detterman et al., 1996
      - Cook Inlet: Detterman and Hartsock, 1966; Wartes et al., 2013
      - Talkeetna Mountains: Trop et al., 2005
  - Increase of accommodation

Sequence Stratigraphic Framework of the Naknek Formation



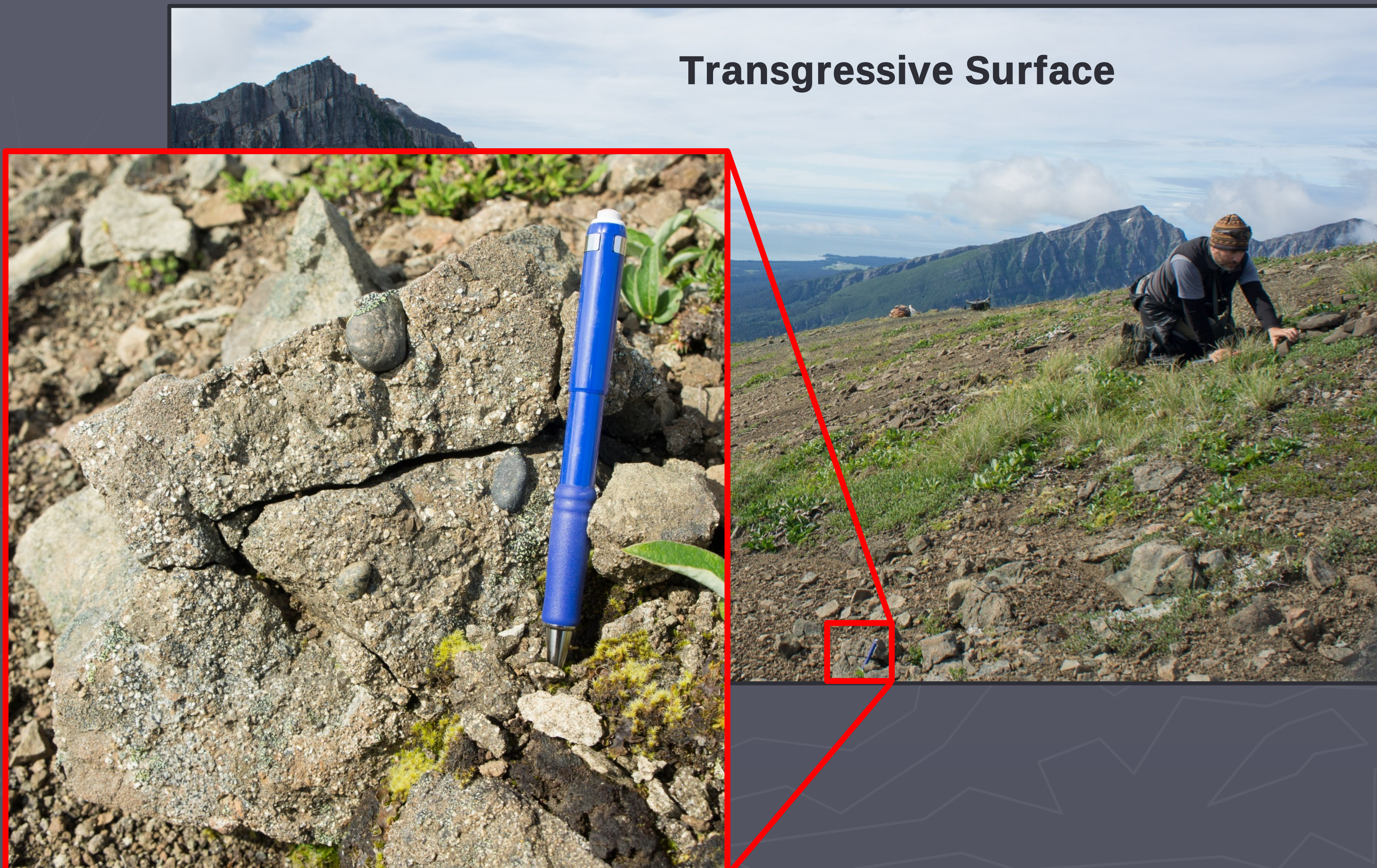




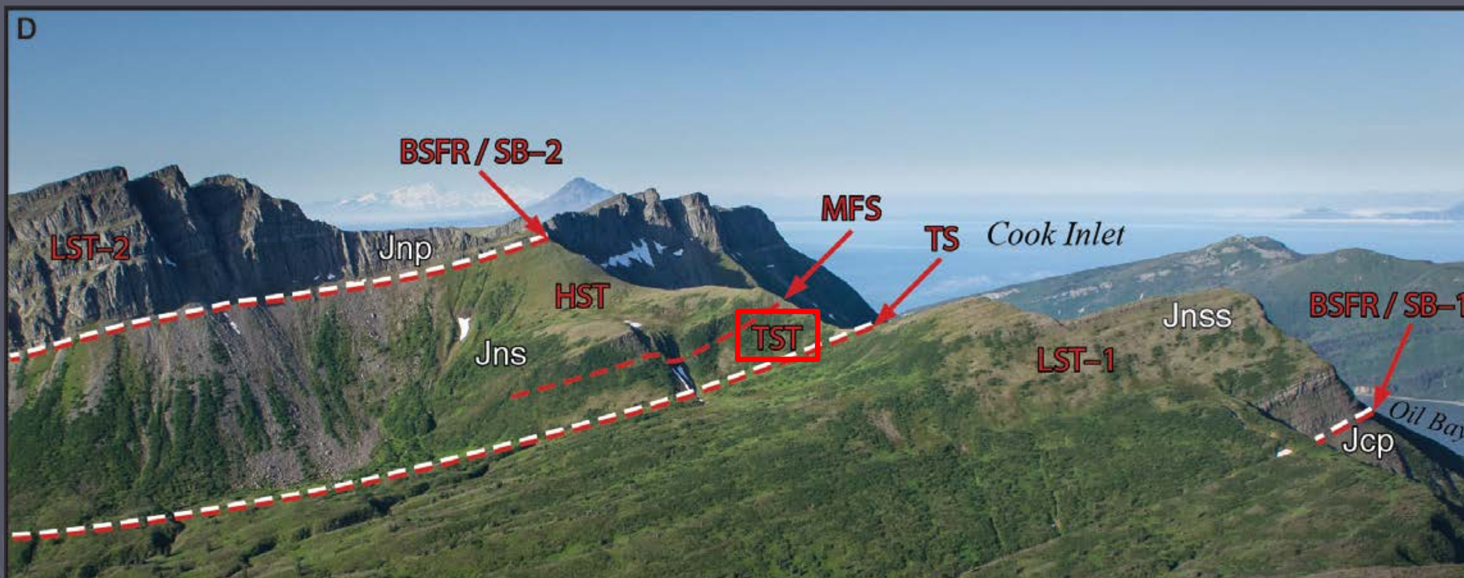
SURFACES AND SYSTEMS TRACTS

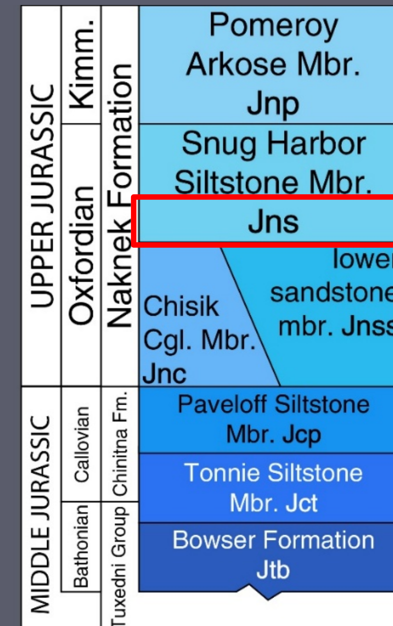
- TS: Transgressive Surface
  - Outer shelf on inner shelf stacking
  - Recessive weathering profile
  - New shoreline trajectory: landward

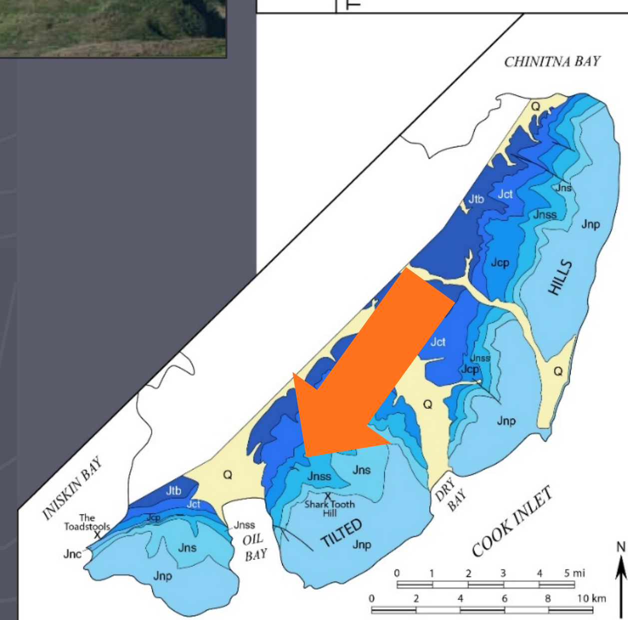
Sequence Stratigraphic Framework of the Naknek Formation



Sequence Stratigraphic Framework of the Naknek Formation



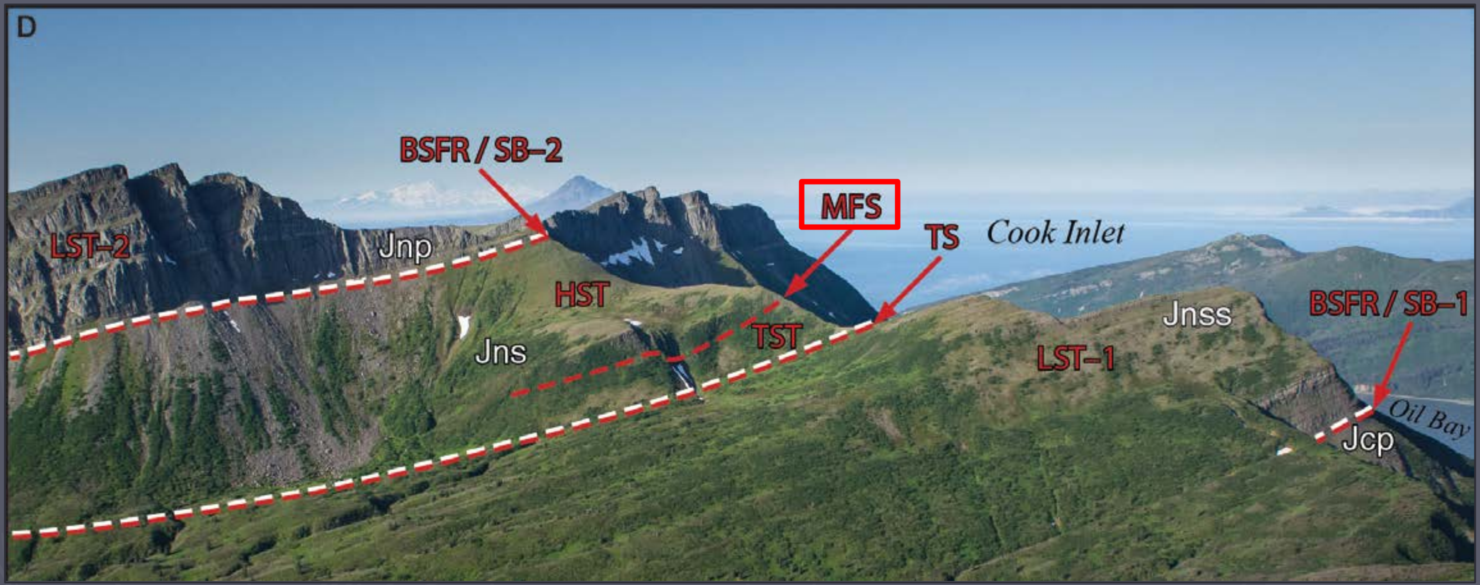


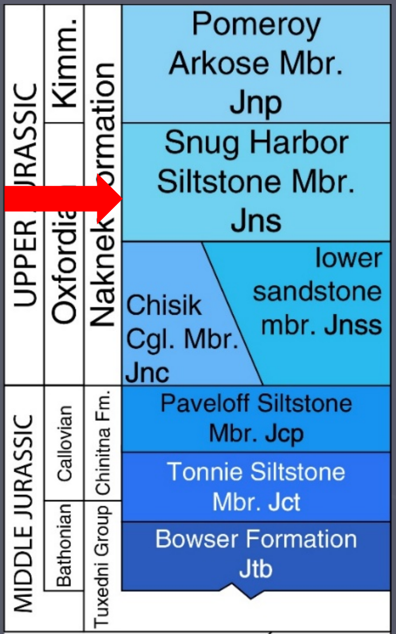


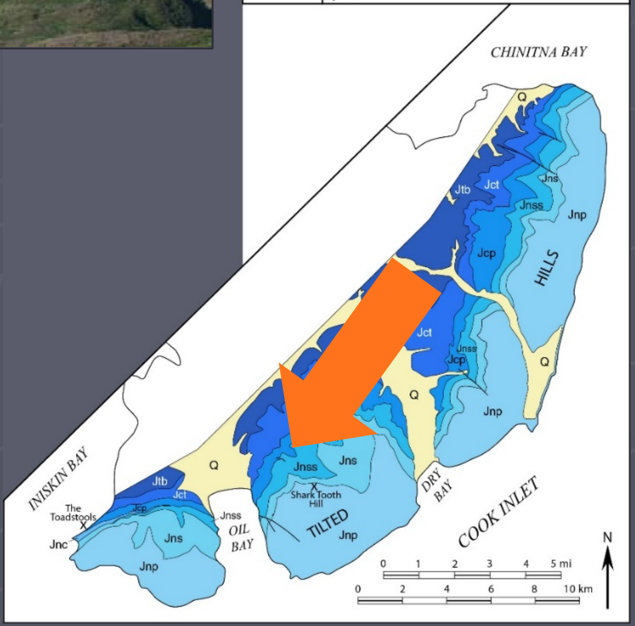
SURFACES AND SYSTEMS TRACTS

- TST: Transgressive Systems Tract
  - Lower part of Snug Harbor Siltstone
  - Accommodation > sediment supply
  - Tectonically quiescent period?

Sequence Stratigraphic Framework of the Naknek Formation



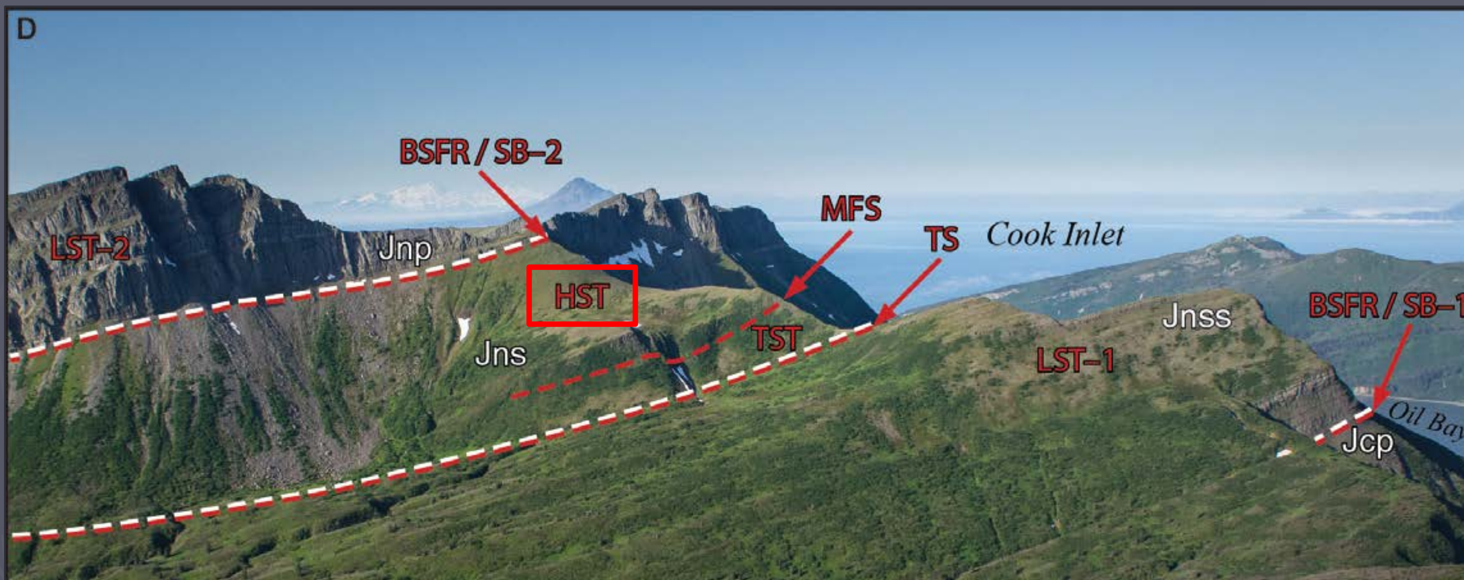


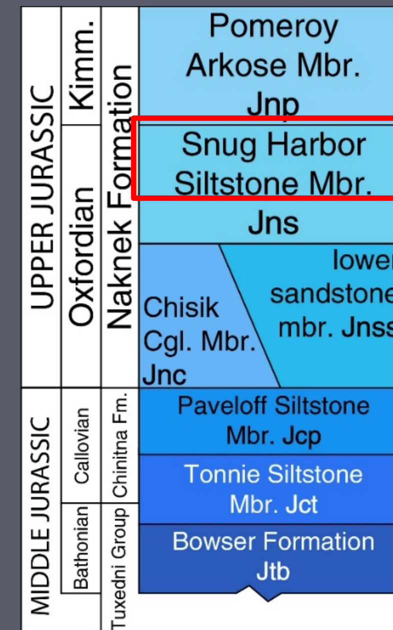


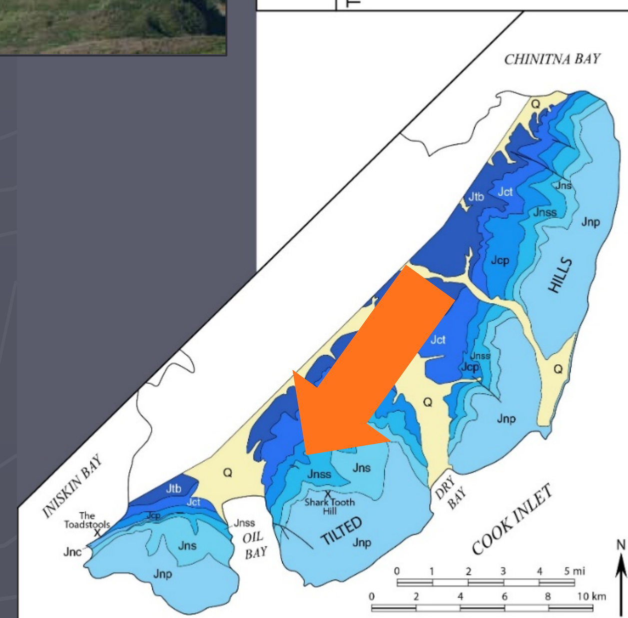
SURFACES AND SYSTEMS TRACTS

- MFS: Maximum Flooding Surface
  - Slope on outer shelf stacking
  - Weathering profile changes
  - Stacking motif changes
  - New shoreline trajectory: seaward

Sequence Stratigraphic Framework of the Naknek Formation



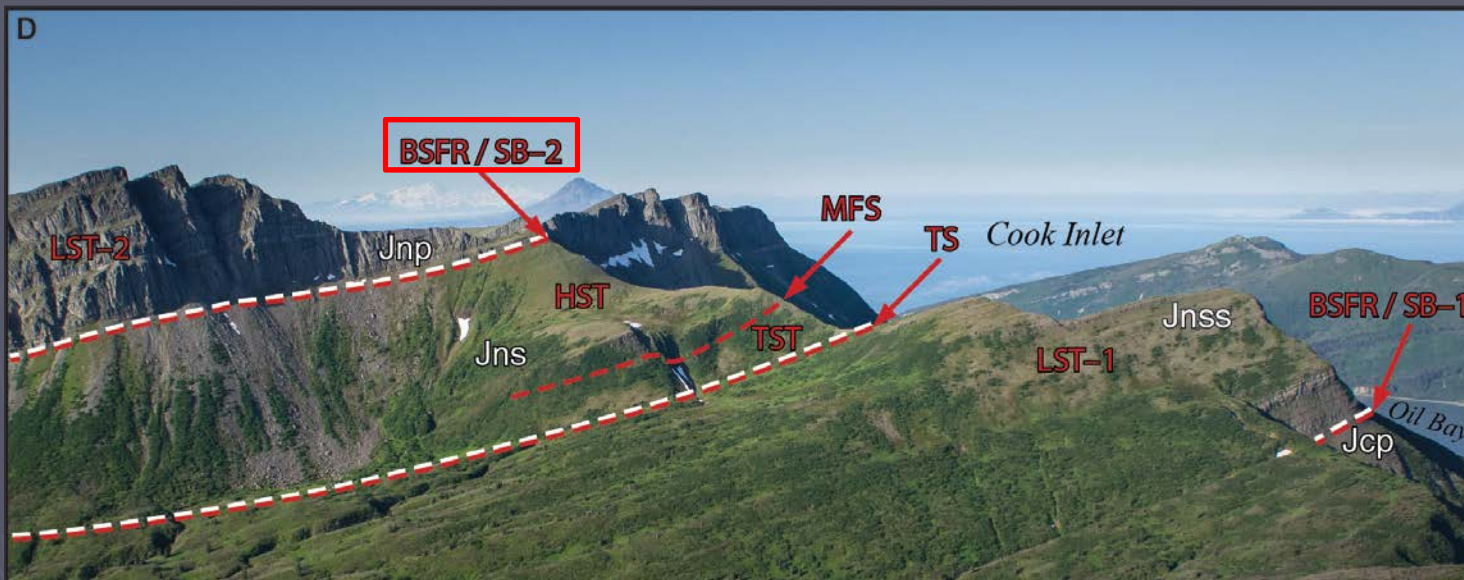


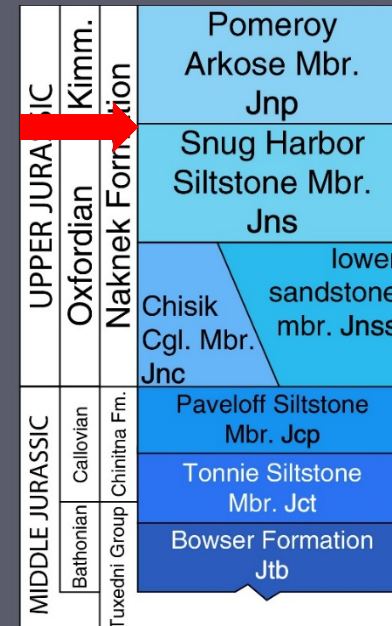


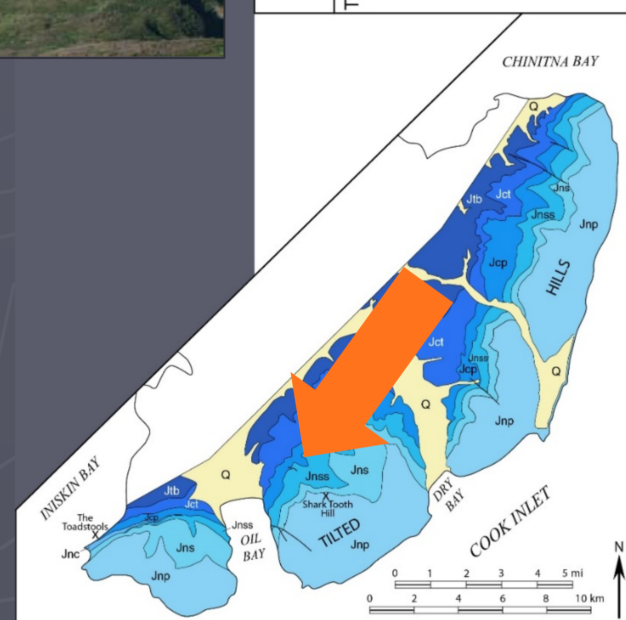
SURFACES AND SYSTEMS TRACTS

- HST: Highstand Systems Tract
  - Upper part of Snug Harbor Siltstone
  - Sediment supply > accommodation
  - Progradation of clinoforms
    - Depositional profile setting the stage for:
      - Erosion of canyons
      - Accumulation and onlap of lower Pomeroy onto inherited Jns slope

Sequence Stratigraphic Framework of the Naknek Formation



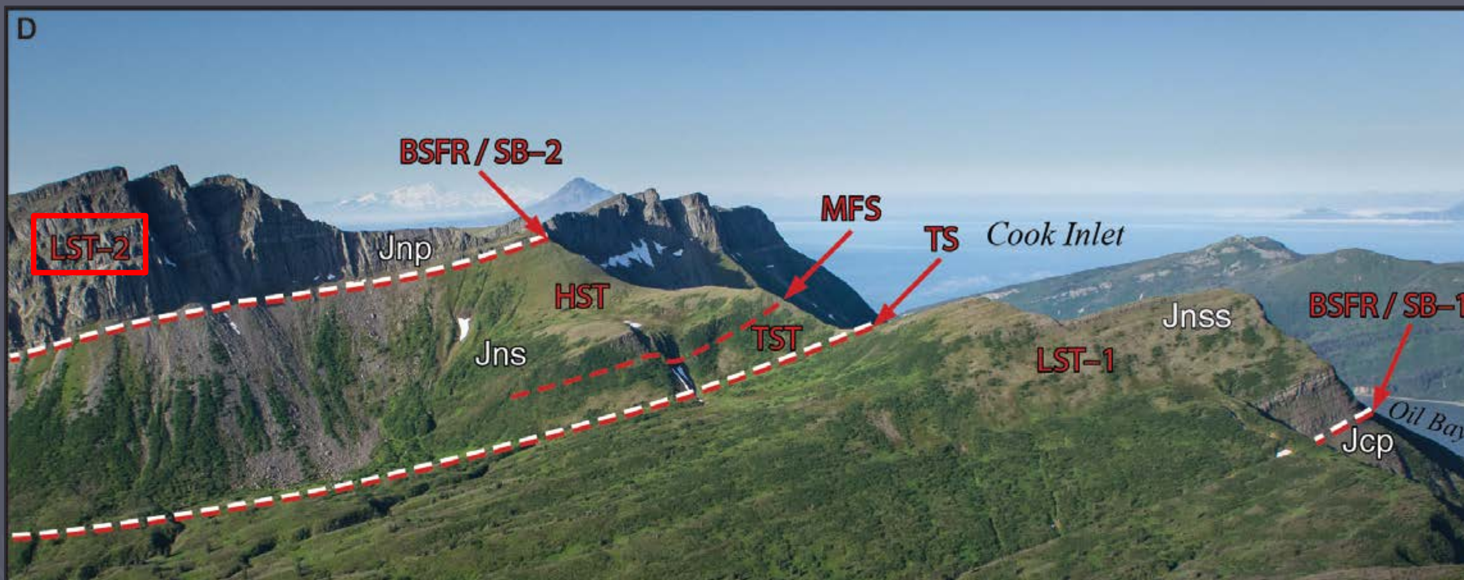


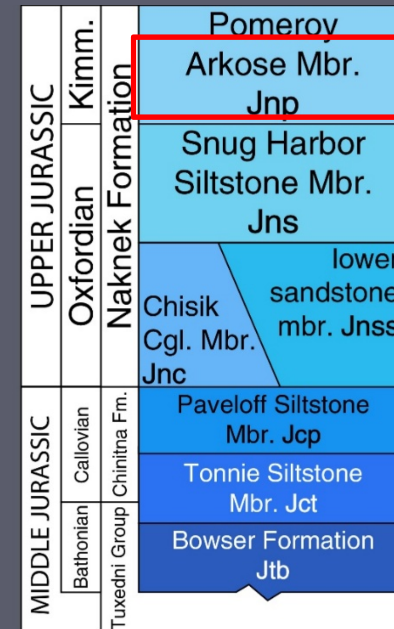


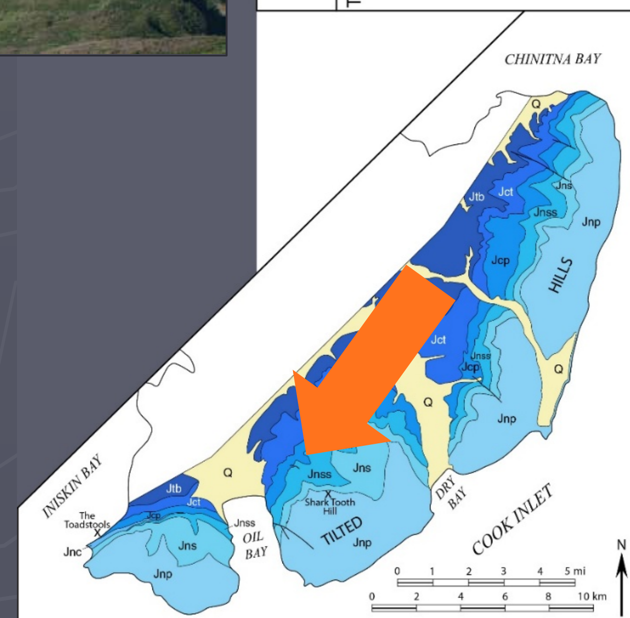
SURFACES AND SYSTEMS TRACTS

- BSFR/SB–2: Sequence Boundary–2
  - Deep-water canyons-associated SB
  - Base of slope on slope stacking
  - Shoreline trajectory: seaward

Sequence Stratigraphic Framework of the Naknek Formation





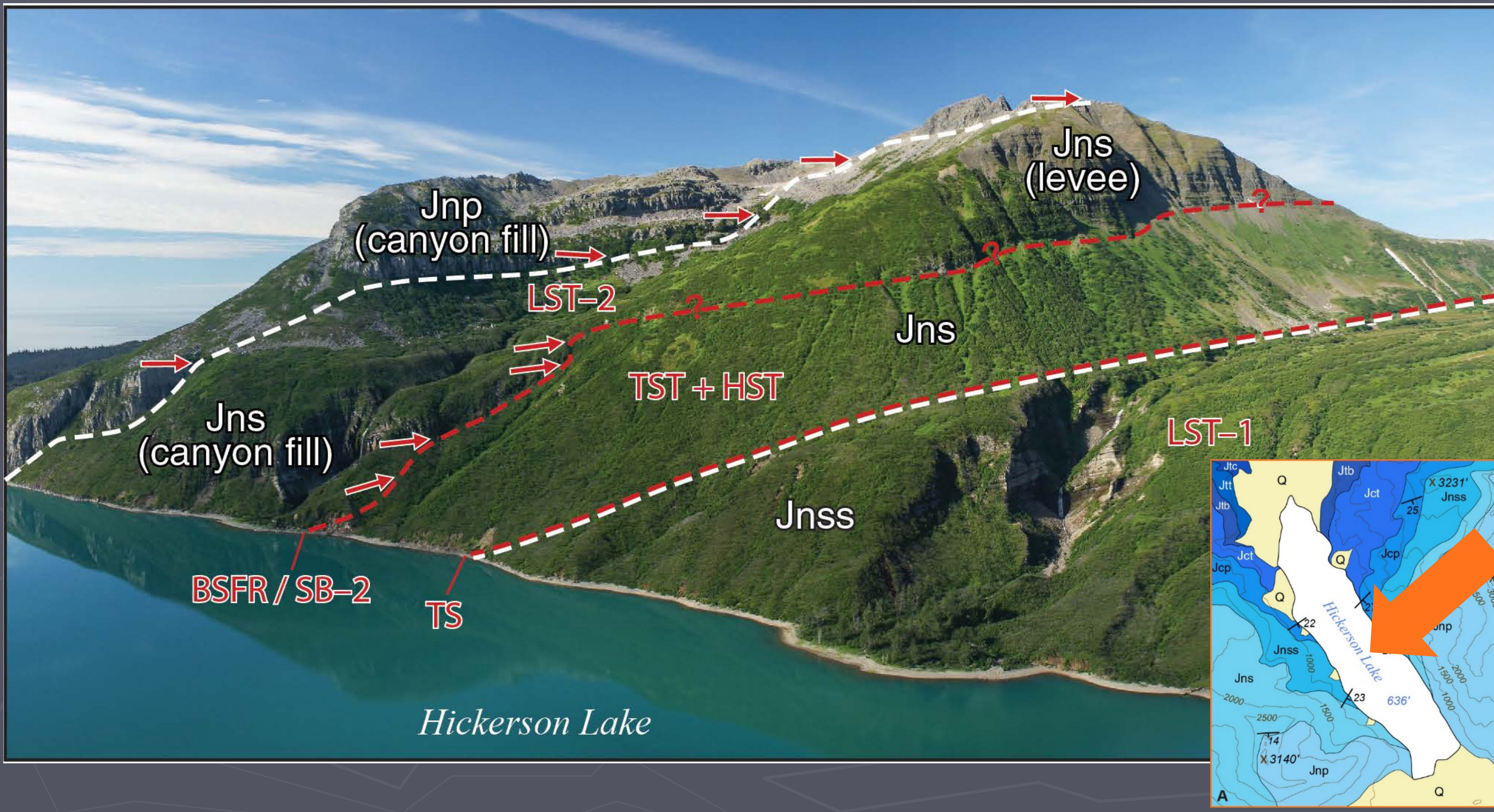


SURFACES AND SYSTEMS TRACTS

- LST–2: Lowstand Systems Tract–2
  - Lower part of Pomeroy Arkose
    - Locally canyon fill (including Jns)
  - Strong sediment supply signal: Episodic exhumation along BBFS?
    - Deep-water accommodation not a limiting factor

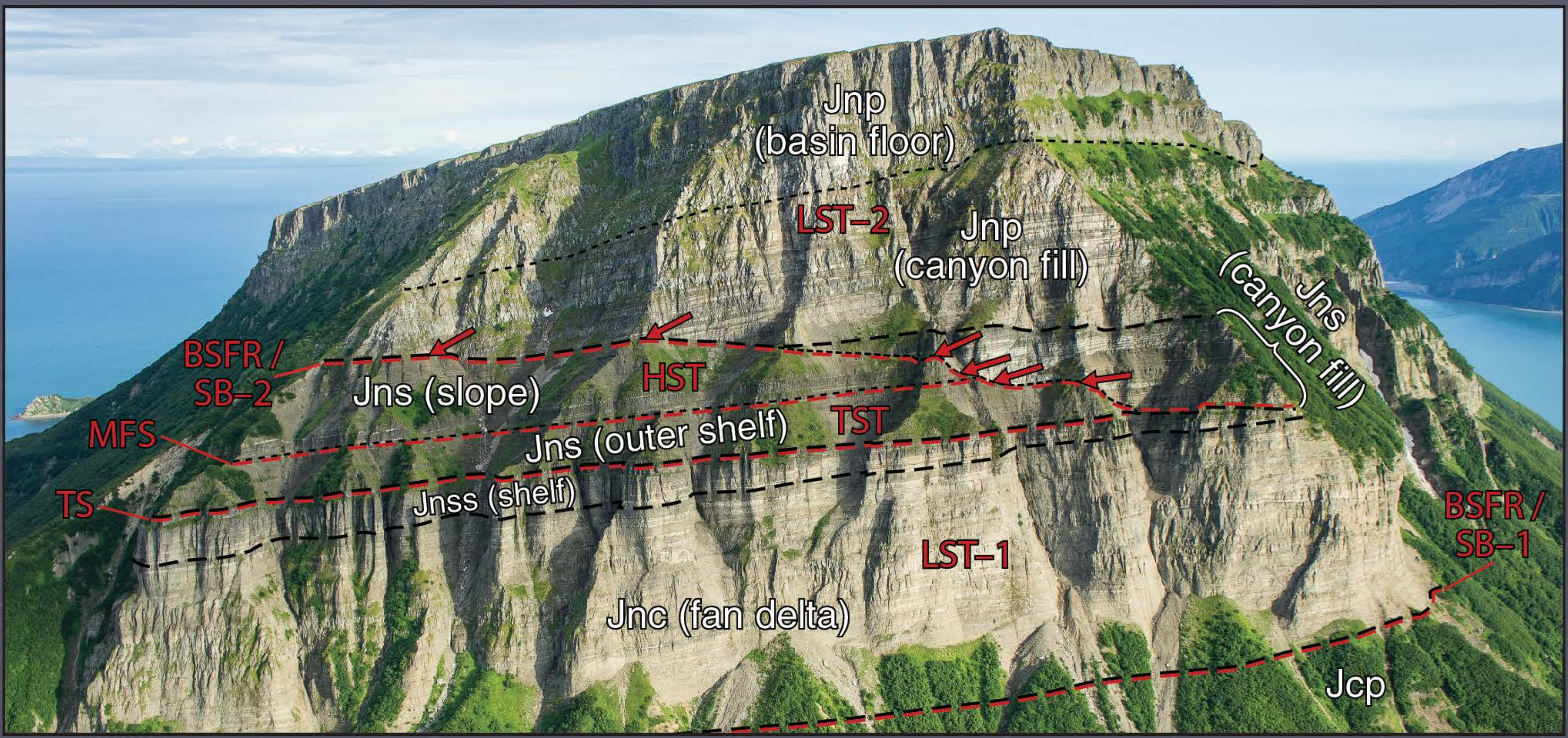
Sequence Stratigraphic Framework of the Naknek Formation—Canyon Localities

Hickerson Lake Canyon



Sequence Stratigraphic Framework of the Naknek Formation—Canyon Localities

Chisik Island Canyon



LST–1: Chisik and Lower Sandstone Stacking in Further Detail: Iniskin Bay to Oil Bay Trend

A new working hypothesis:

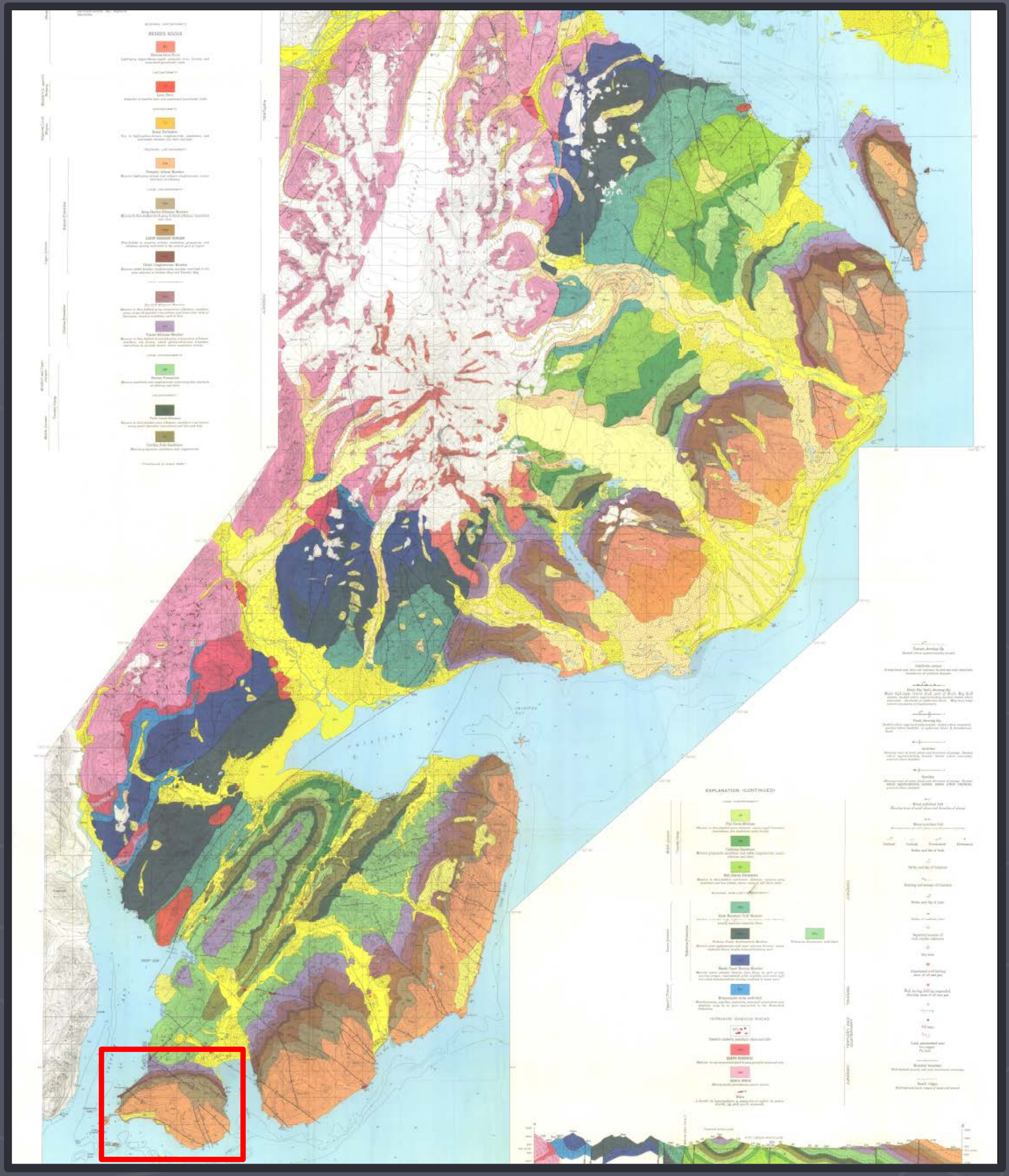
Consistent with our observations and the sequence stratigraphic interpretation

Accounts for some perplexing relations between the Chisik—lower sandstone

Answers more questions than it creates

Some questions remain unanswered

Further testing to come



Detterman and Hartsock, 1966

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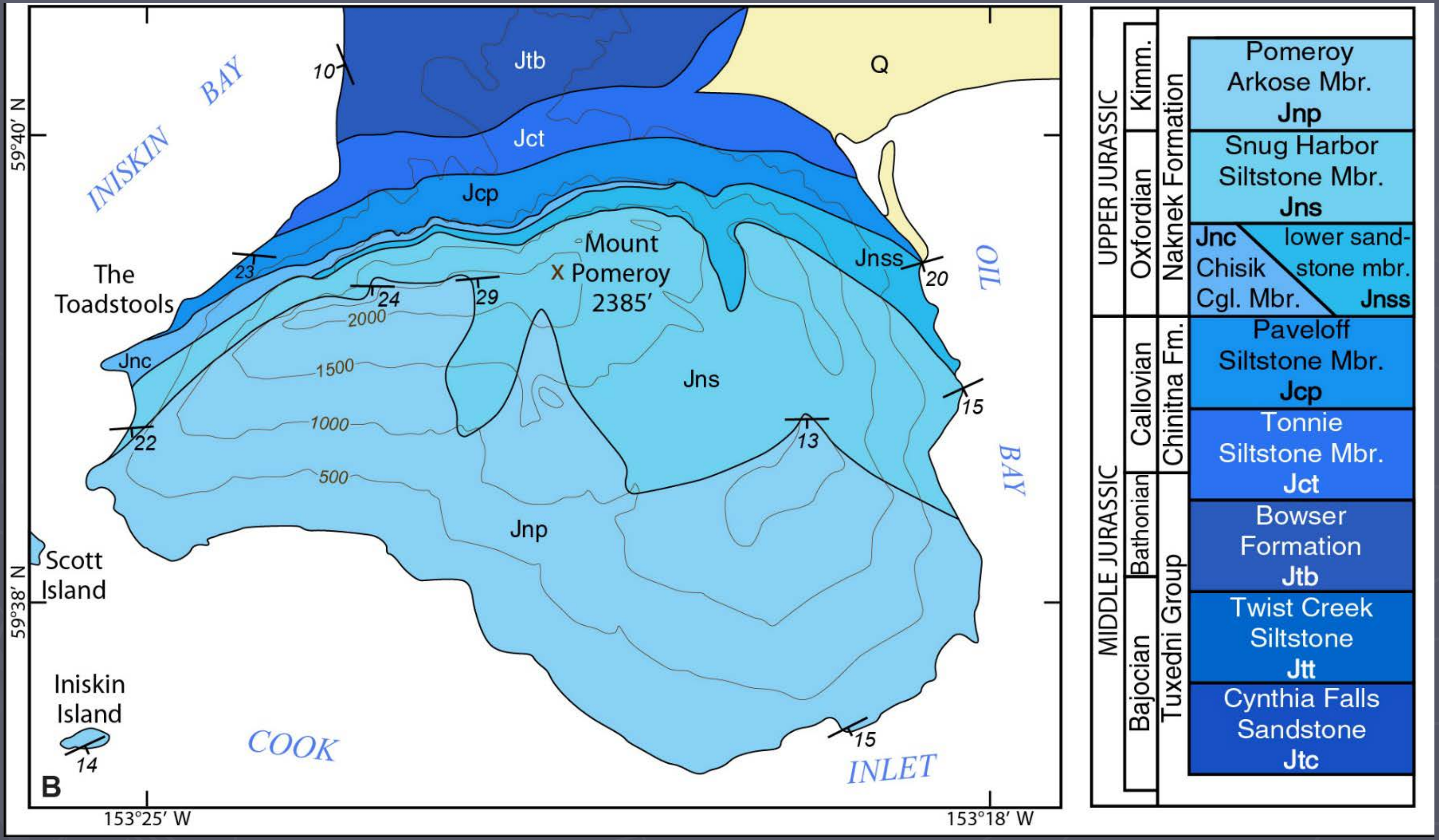

Herriott et al., in preparation

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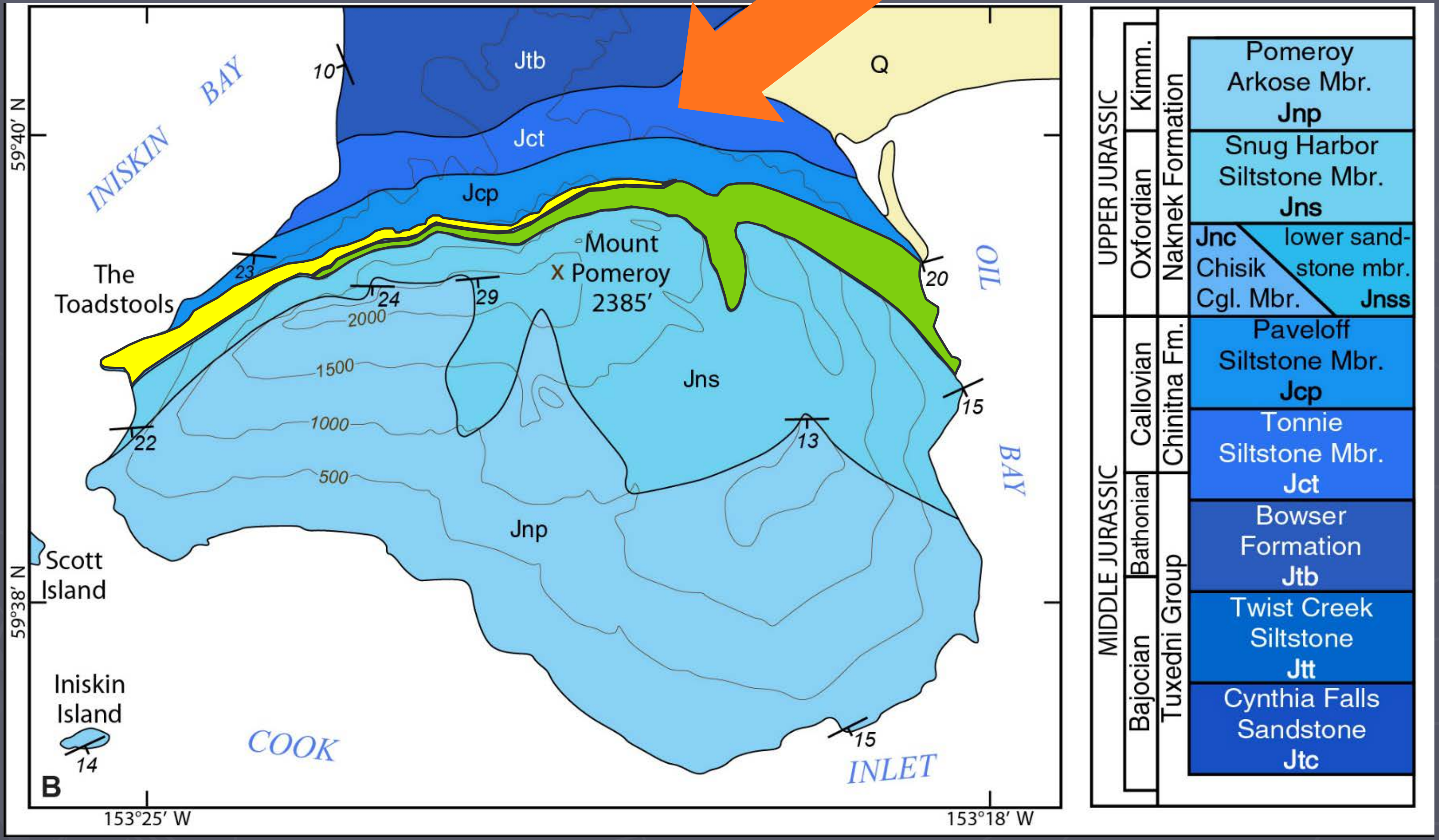

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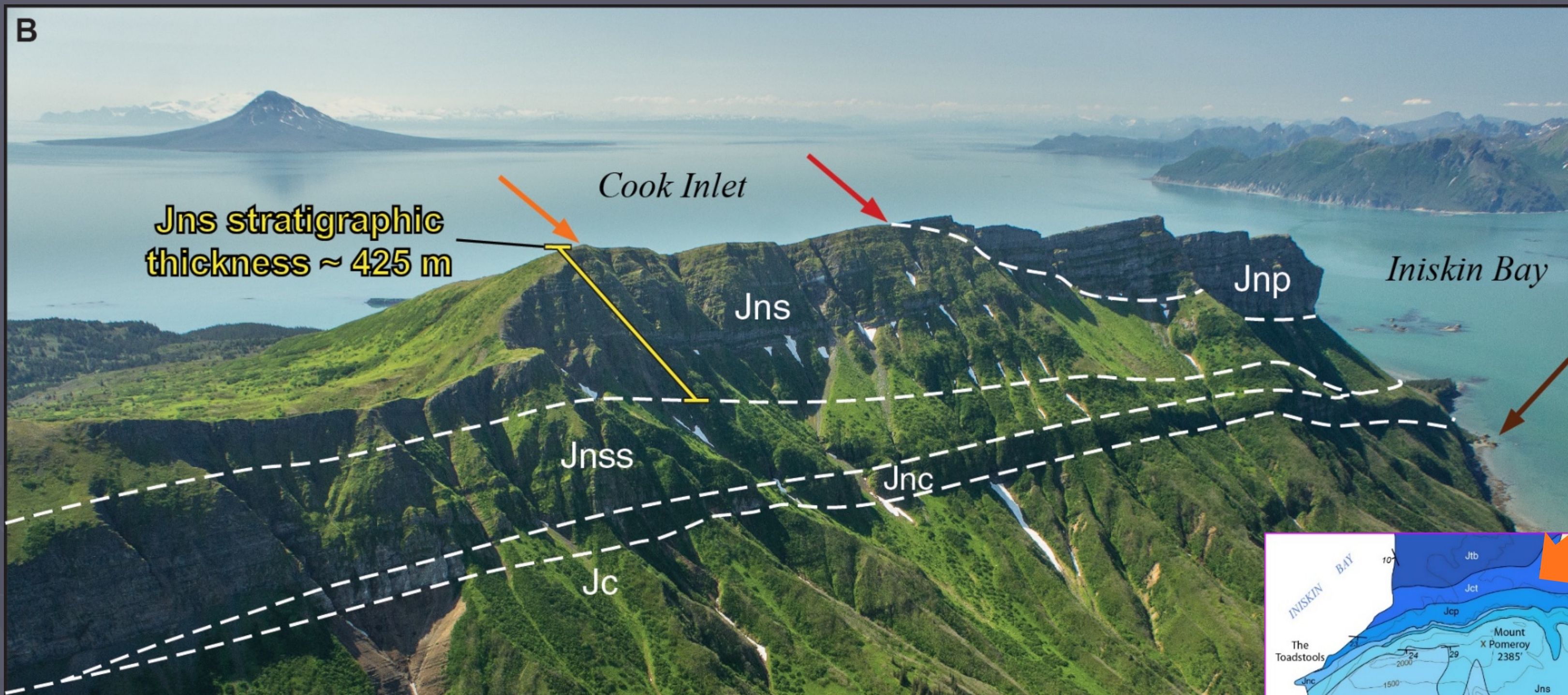
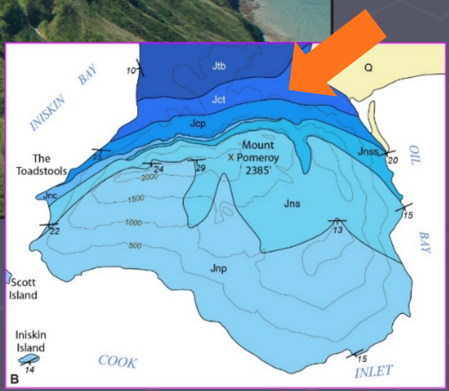
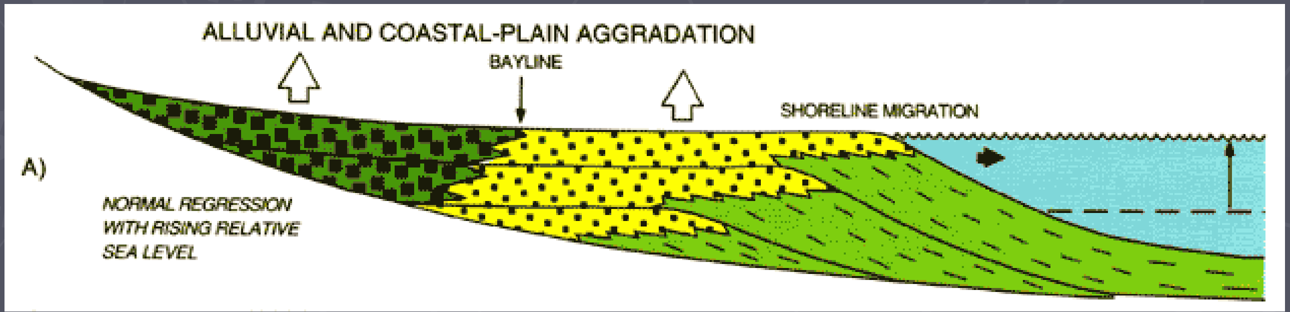
Jnss overlies Jnc.







Posamentier and Allen, 1999

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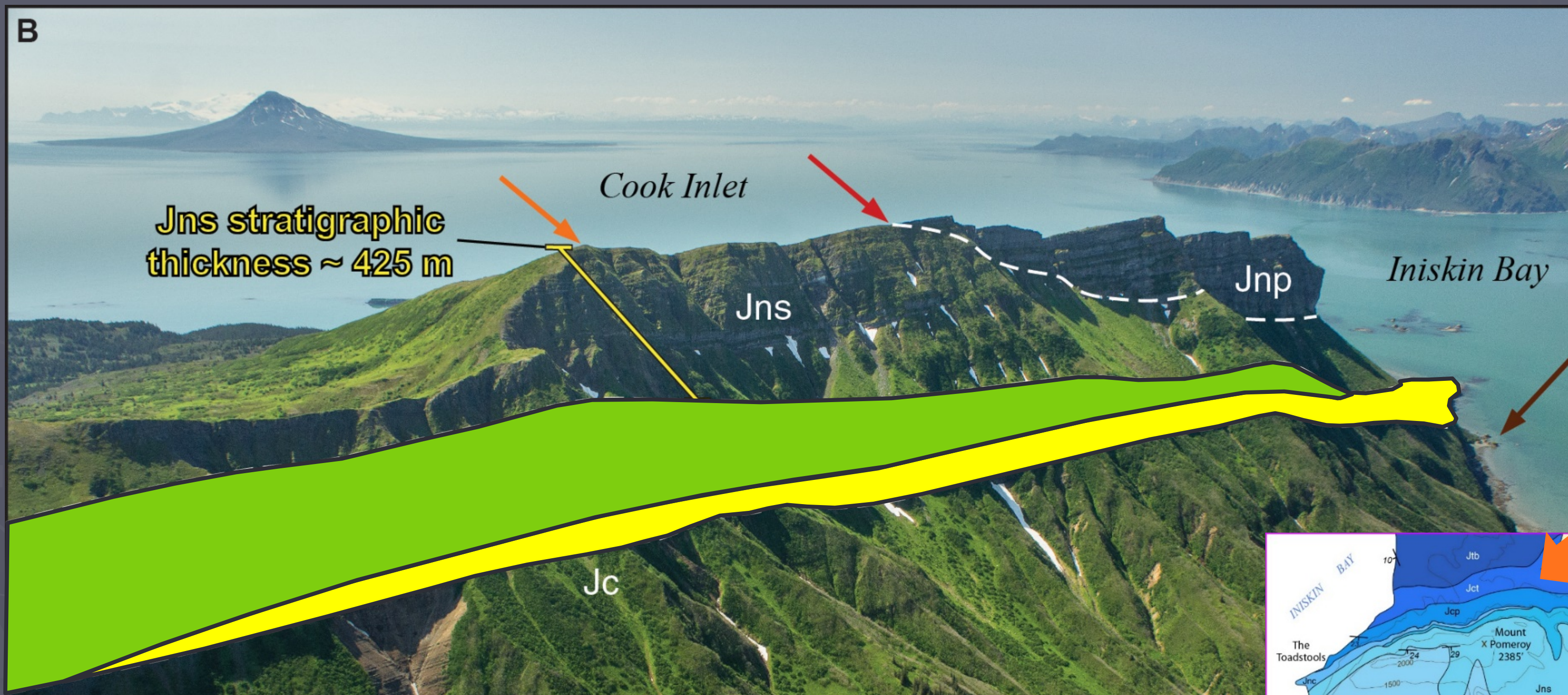
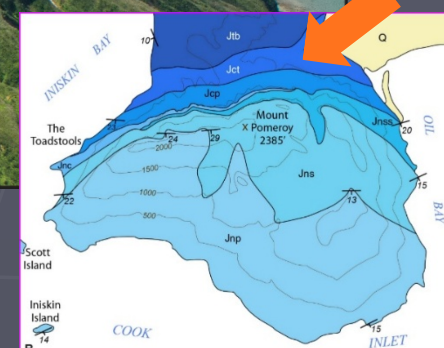
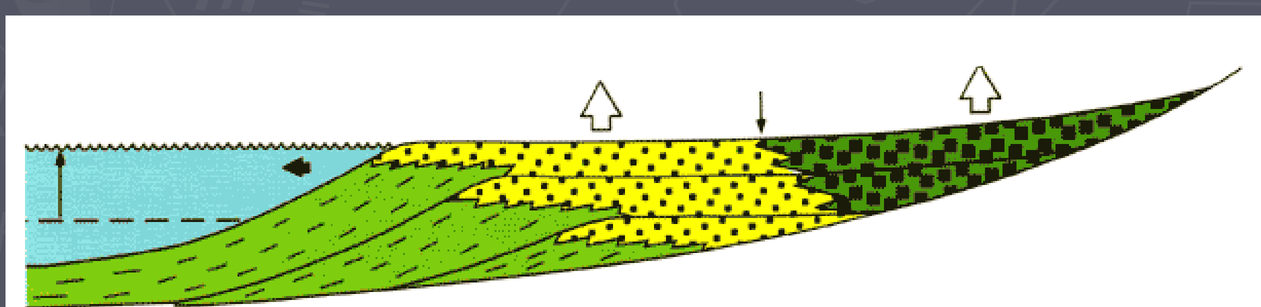


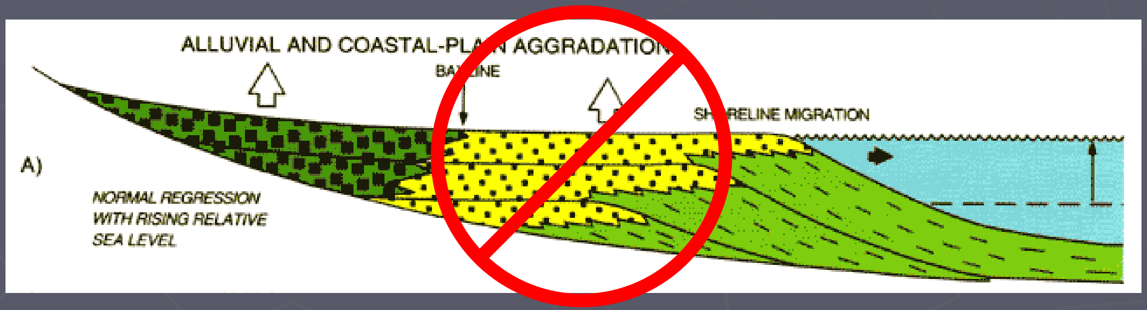




Posamentier and Allen, 1999

LST–1: Chisik and Lower Sandstone Stacking in Further Detail: Iniskin Bay to Oil Bay Trend—FR vs. LNR

1) Chisik and lower sandstone are between an unconformity and a well-constrained TS: Not likely a transgressive assemblage, and not a time-transgressive progradational couplet



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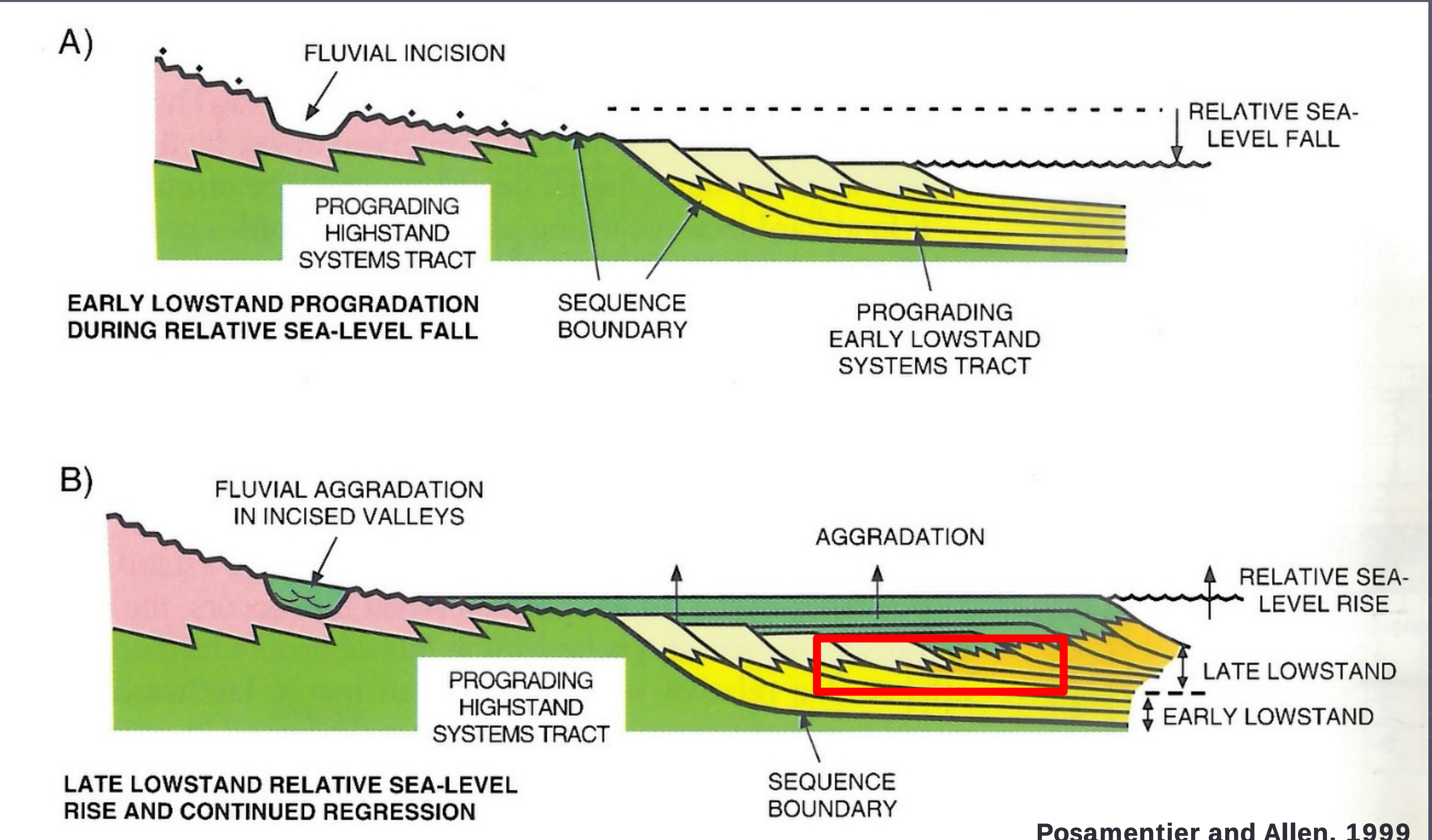

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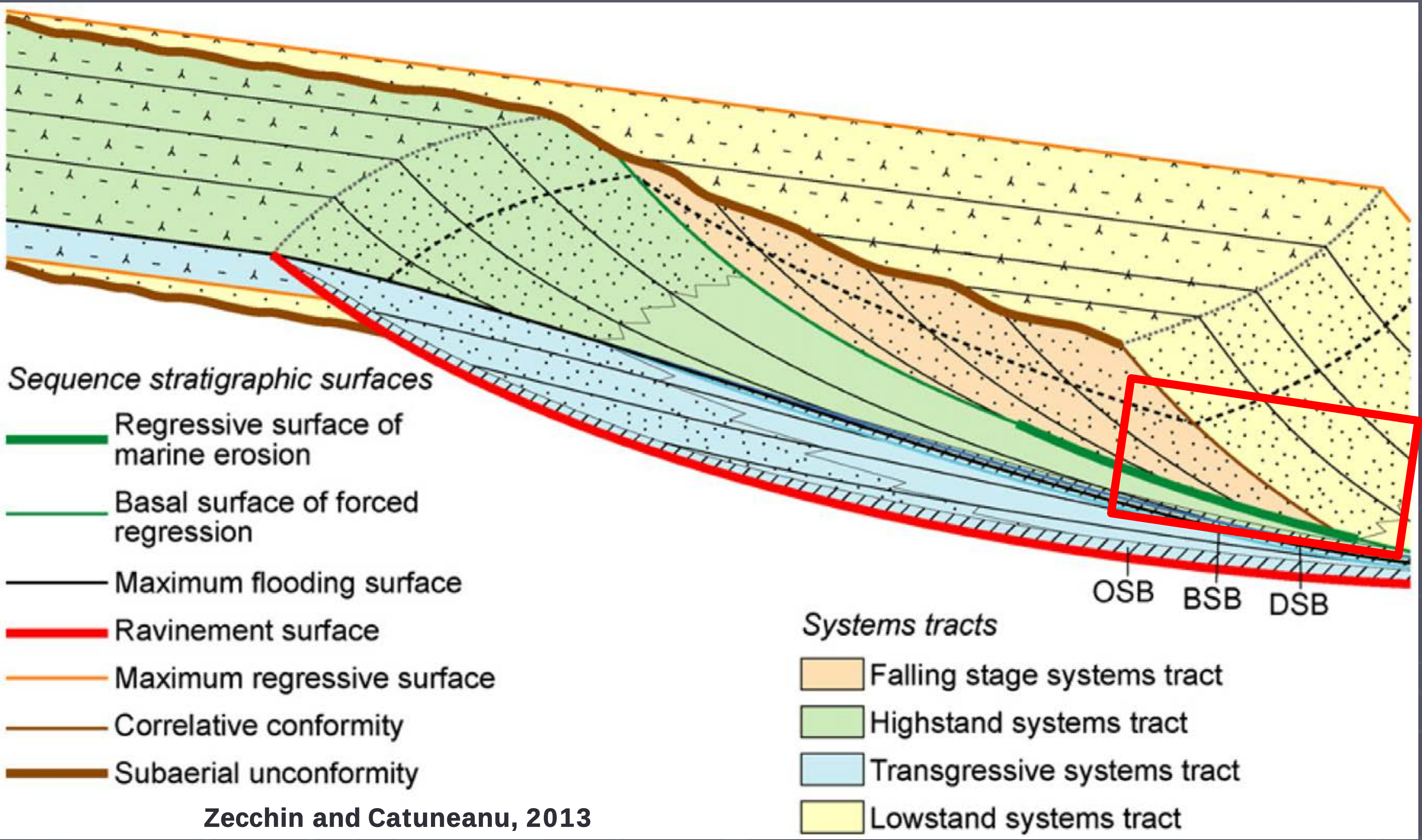

Zecchin and Catuneanu, 2013

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1) Chisik and lower sandstone are between an unconformity and a well-constrained TS: Not likely a transgressive assemblage, and not a time-transgressive progradational couplet

2) Chisik is gravel-rich, lower sandstone is sand-rich and gravel poor

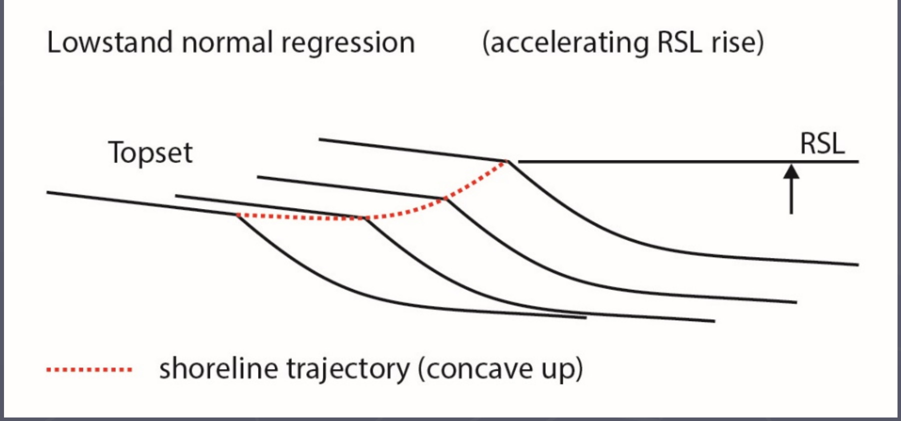
- Forced regression: Minimal to no fluvial accommodation
- Lowstand normal regression: Fluvial accommodation is positive
  - FR coarser-grained than LNR (Posamentier and Morris, 2000; Catuneanu, 2006)

3) Chisik is sharp-based, near-shore deposit on Chinitna (outer?) shelf:

- Marked facies juxtaposition with missing transitional facies (compare with Plint, 1988)
  - Long distance shoreline regression across a shelf
    - Forced regression (Posamentier and Morris, 2000)

LST–1: Chisik and Lower Sandstone Stacking in Further Detail: Iniskin Bay to Oil Bay Trend—FR vs. LNR

4) Lower sandstone is strongly aggradational, consistent with LNR



Catuneanu et al., 2011

Caveats and complexities:

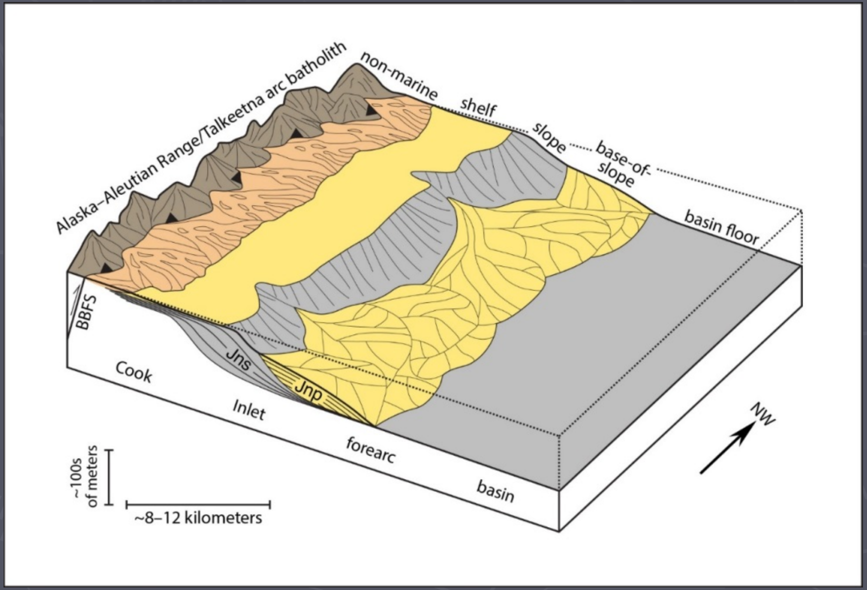
- Along-strike variability in sediment supply during FR strongly affects stratigraphic record, as do regressive and (younger) transgressive surfaces of marine erosion (Jnss at Iniskin Bay?)
- FR vs. LNR record likely deviates from Chisik vs. lower sandstone
  - FR may comprise a somewhat coarser-grained Jnss (i.e., the lithostratigraphic units could diverge from the sequence stratigraphic units)
  - The CC (*sensu* Hunt and Tucker, 1992) between FR and LNR deposits can be exceedingly difficult to identify (Plint and Nummedal, 2000)
    - Candidate case at Chinitna Bay: TBC

Presentation Outline

- Geologic setting—Cook Inlet forearc basin
- Naknek Formation: Members and depositional environments
  - Pomeroy Arkose
  - Snug Harbor Siltstone
  - lower sandstone (informal)
  - Chisik Conglomerate
- Stacking relations of the Snug Harbor and Pomeroy
  - Typical and atypical: Deep-water depositional elements
- Sequence stratigraphy of the Naknek Formation
  - Surfaces, systems tracts, and stratigraphic sequences
  - Chisik and lower sandstone stacking in further detail
- Implications: Hydrocarbon reservoirs
- Summary and conclusions

Hydrocarbon Reservoir Implications: LSTs

- LST–1 sand-prone settings:
  - Shelfal in outcrop
  - Distal extents not well defined
    - Deep-water sands(?)
- LST–2 sand-prone settings:
  - Shelf (inferred)
  - Canyon axis
  - Master levee
  - Base of slope and basin floor



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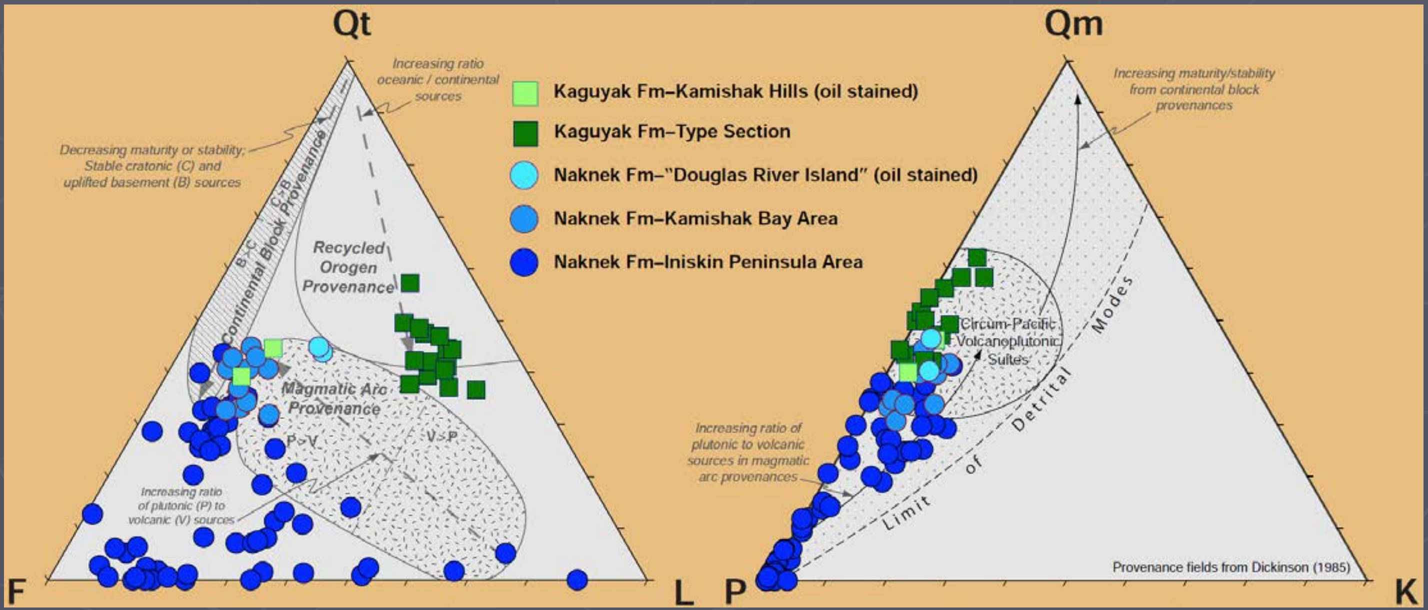
- What about reservoir quality?
  - Helmold et al., 2013: Poor RQ parameters for Naknek sandstones in Iniskin–Tuxedni region
  - Better plutonic provenance elsewhere? Maybe.



Herriott et al., 2013

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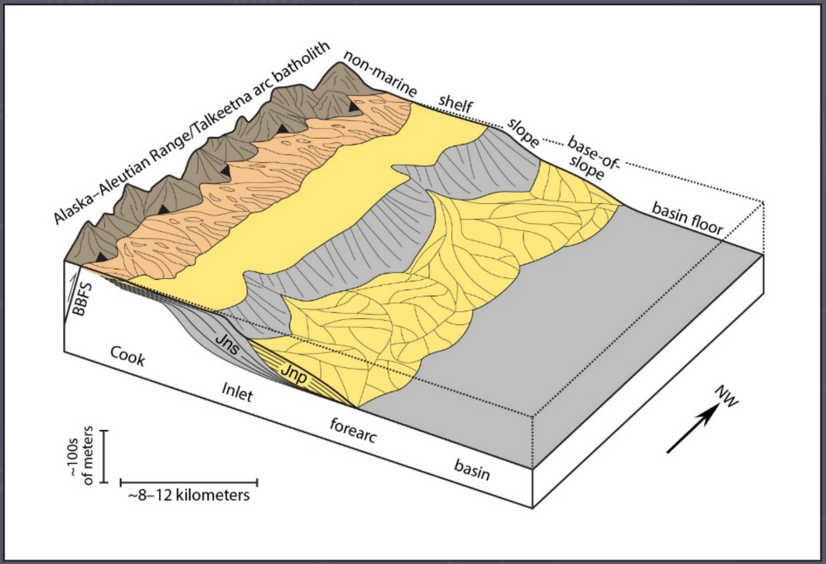


- What about reservoir quality?
  - Helmold et al., 2013: Poor RQ parameters for Naknek sandstones in Iniskin–Tuxedni region
  - Better plutonic provenance elsewhere? Maybe.
  - If so, sediment routing is key
- Unconventional, fractured reservoirs

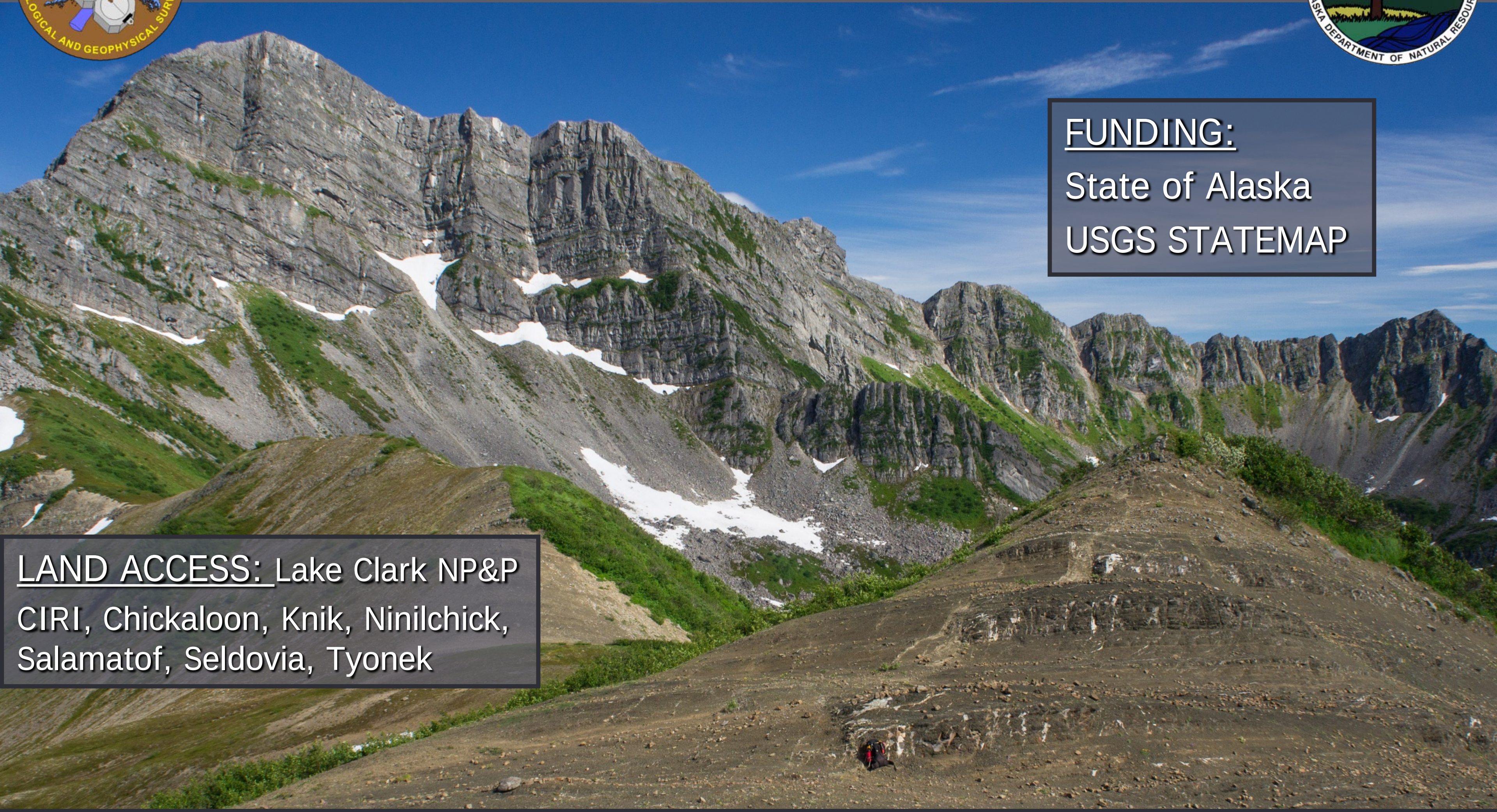
from Gillis et al., 2013

Summary and Conclusions

- Recent studies proposed depositional environments for the Naknek Formation of Cook Inlet
- Three newly recognized seismic-scale stratigraphic “containers” are deep-water canyons
  - Shelf–slope–basin floor depositional profile established during Snug Harbor time
  - Pomeroy backstepped and onlapped the inherited Snug Harbor slope profile
  - Globally, similar features are observed in seismic data, but are rare in outcrop
- Geologic mapping, depositional systems, stratigraphic architecture, and stratal terminations permit the first sequence stratigraphic interpretation of the Naknek Formation of Cook Inlet
  - Two strong sediment supply signals marked by LST–1 and LST–2, suggestive of episodic tectonic activity along the BBFS exhumed plutons of the Talkeetna arc
  - Tectonically quiescent periods recorded by TST and HST?
  - Is Chisik the record of forced regression? Probably, at least in part
- Framework for predicting coarse-grained Naknek sedimentation in time and space
  - Implications for hydrocarbon reservoirs
    - Sediment routing may be key to understanding whether and where conventional reservoir quality may occur
      - This study provides constraints on permissible sediment transport pathways and distribution of lithostratigraphic packages
    - Relevant to conventional and unconventional reservoirs
- Increased resolution of how the Late Jurassic Cook Inlet forearc basin filled with sediment

http://dggs.alaska.gov/publications/ **Title:** “Naknek”, **Range of Years:** 2013–2015

Acknowledgments



FUNDING:

State of Alaska

USGS STATEMAP

LAND ACCESS: Lake Clark NP&P

CIRI, Chickaloon, Knik, Ninilchick, Salamatof, Seldovia, Tyonek

DNR/USGS COLLEAGUES:

Dave LePain, Bob Gillis, Bob Swenson, Bekah Tsigonis, Kate Bull

Rick Stanley, Ken Helmold, Paul Betka, Jacob Rosenthal, Nina Harun

Acknowledgments by TMH

- Paul Betka, Jacob Rosenthal, Bekah Tsigonis, Ken Helmold, Merlin “Spanky” Handley
- Doctors and nurses at South Peninsula Hospital, Regions Hospital, and Alaska Spine Institute; Denise Jerome, PT
- DGGS: Dave LePain, Bob Swenson, and Steve Masterman
- Mareca Guthrie, Guthrie and Herriott/Lundell families, friends and co-workers

Thank You.