FACIES ARCHITECTURE OF A SLOPE INCISION, CANNING FORMATION, IVISHAK RIVER, ALASKA: IMPLICATIONS FOR SEDIMENT BYPASS AND DEEPWATER RESERVOIR POTENTIAL

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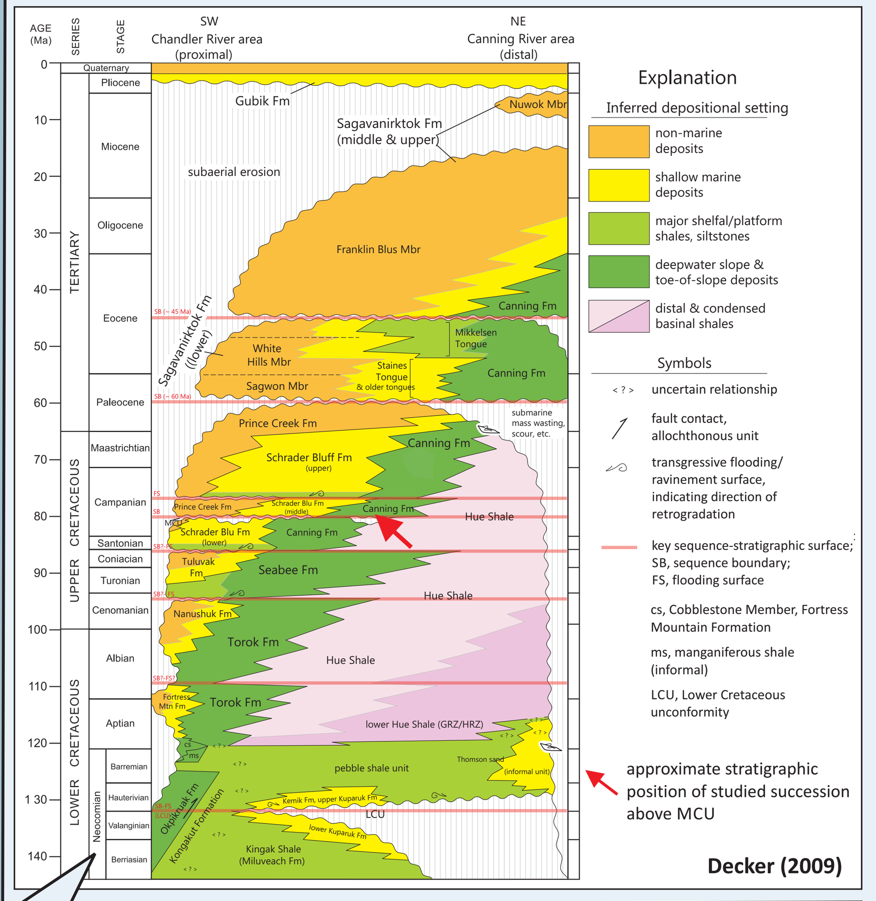
ABSTRACT

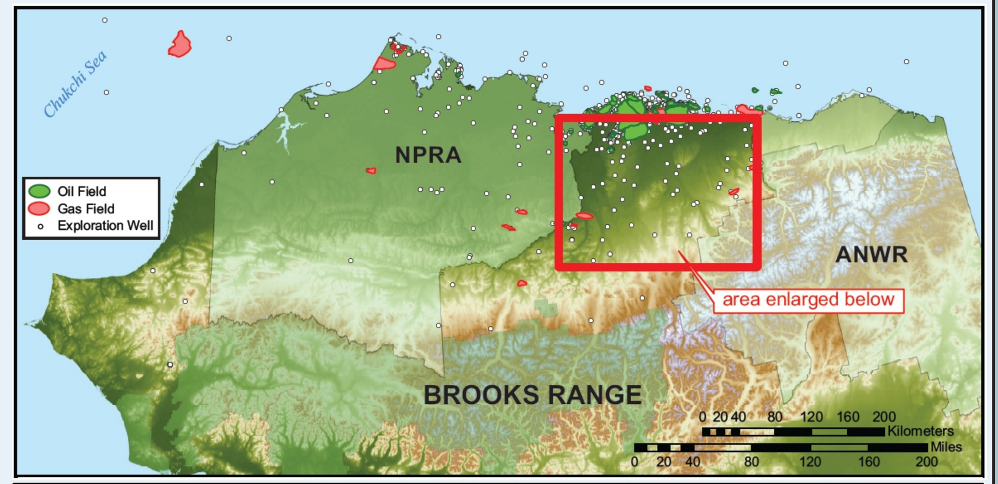
An outcrop along the west side of the Ivishak River, North Slope, Alaska, provides a rare view of a sandstone-rich succession overlying an incision surface in the Canning Formation. The outcrop is characterized by a series of complex folds cut by several faults. Nearby seismic, well, and outcrop control suggest the succession is Campanian. The incision surface is exposed on a flat-lying to gently north-dipping anticlinal limb, where it truncates bedding in underlying mudstones at a relatively low angle. Two facies associations are recognized: 1.) a slope-basin-floor (SBF) association consisting of mudstone and minor thinly interbedded coarse siltstone and very fine sandstone, and 2.) an incision-fill (IF) association consisting of abundant beds a few centimeters to 40 cm thick of upper very fine to lower fine sandstone, separated by thin interbeds of mudstone and siltstone. The IF association is subdivided into two sub-associations—a lower IF and an upper IF—the difference between these subdivisions is a slightly higher net-to-gross in the upper division. The lower IF association is truncated by an intra-incision(?) surface that is overlain by mudstones resembling the SBF association. Bioturbation appears absent in both associations. Due to the limited outcrop extent, the upper IF subdivision is not known with certainty to be part of the incision-fill. Both associations (SBF and IF) are interpreted to record deposition in a lower slope to proximal basin-floor setting. The SBF association records deposition from turbid suspensions and very dilute, low-volume turbidity currents in an unconfined setting. The IF association records deposition from decelerating, confined turbidity currents and some concentrated density flows (terminology of Mulder and Alexander, 2001). The basal incision is interpreted to record a mass-wasting event triggered during relative sea level fall. The basal incision and intra-incision(?) truncation surfaces represent potential bypass surfaces across which significant volumes of sand could have been transported seaward to accumulate in a slope apron or basin-floor fan system. It seems probable that similar incisions are common in slope deposits of the Canning Formation, with similar implications. Sandstone composition and reservoir quality are addressed in a companion report by Helmold.

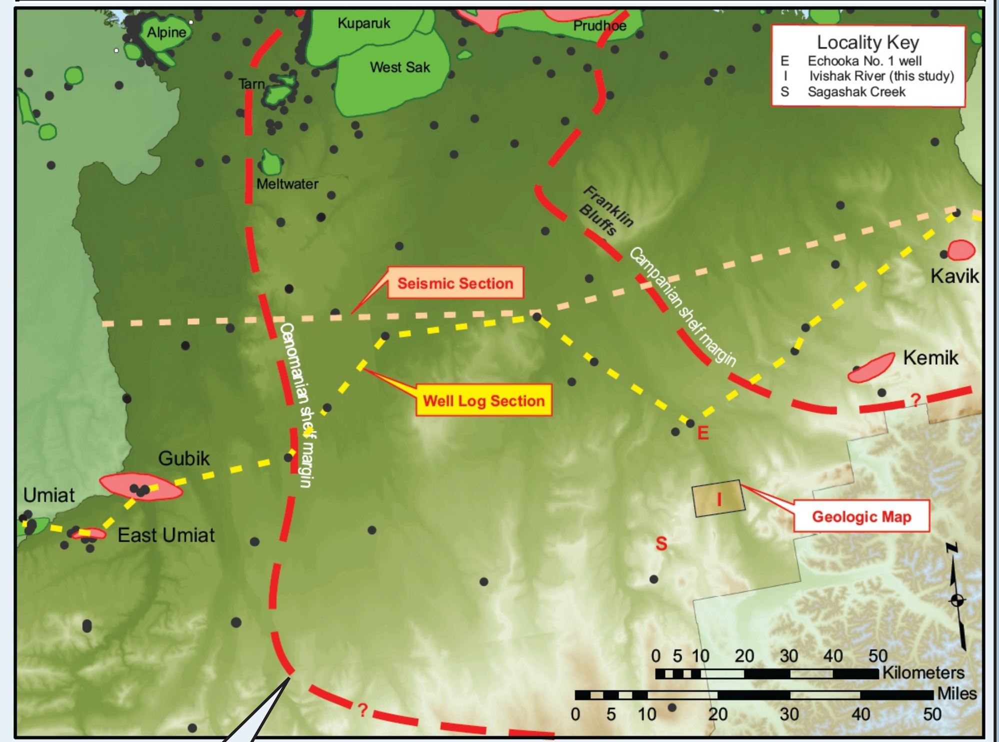
REGIONAL SETTING



The Mesozoic-Cenozoic fill of the Colville foreland basin consists of eight economically significant regressive-transgressive depositional cycles

Depositional cycles become progressively younger toward the east, recording the fill history of the foreland basin



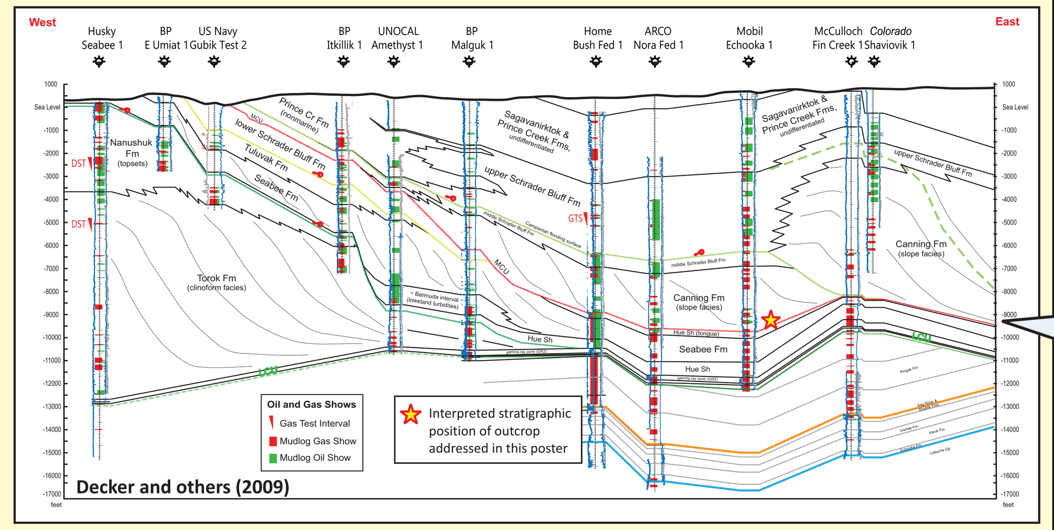


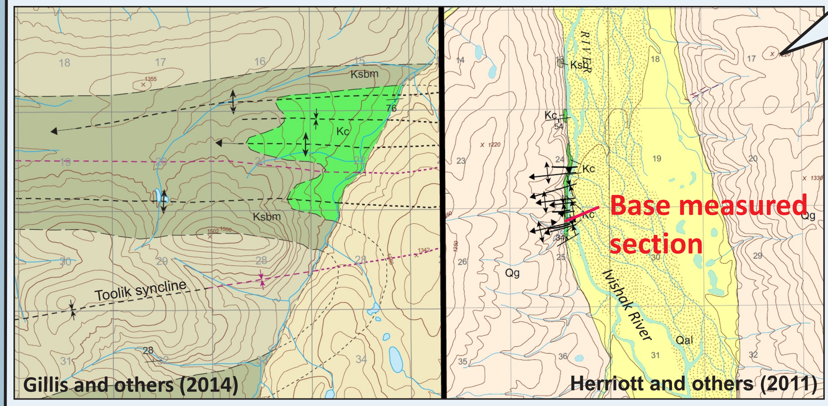
The Torok-Nanushuk cycle records extremely high sediment supply, filling the western two-thirds of basin; Upper Cretaceous strata fill the eastern third of basin, beyond the terminal Nanushuk shelf margin (Cenomanian shelf margin)

The Canning Formation represents slope and basinal deposits of the Schrader Bluff-Canning and Sagavanirktok-Canning cycles

The Echooka 1 well and exposures along "Sagashak Creek" provide important stratigraphic context for outcrops of the Canning Formation on the Ivishak River

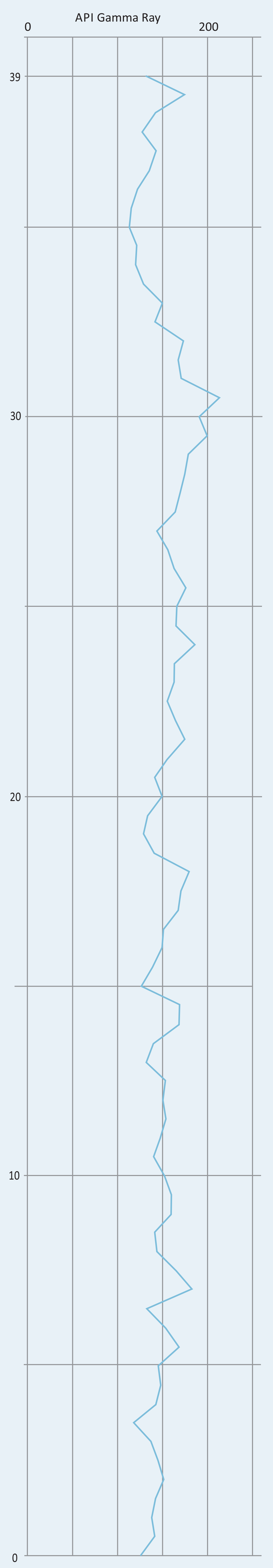
BROOKIAN SEQUENCE REGIONAL SUBSURFACE CORRELATIONS





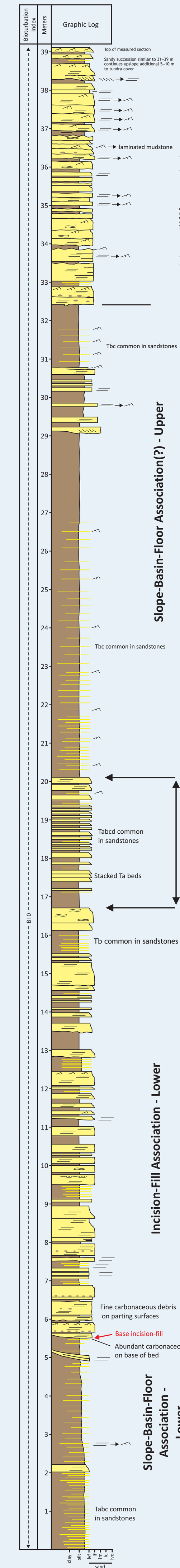
1:63,360-scale bedrock geologic mapping in the foothills belt has defined a series of east-west-trending folds.

Studied outcrop is located in an area of complex folding and faulting.



Spectral gamma data were acquired on the outcrop using a Radiation Solutions RS-230 gamma ray spectrometer. The count time for each measurement was 90 seconds. API gamma ray was calculated using the following formula (Doveton, 1994): API GR = 4(Th)+8(U)+16(K).

Measured Section



Base of section 19DL050: N69.24525 W148.15204 Datum: WGS 84

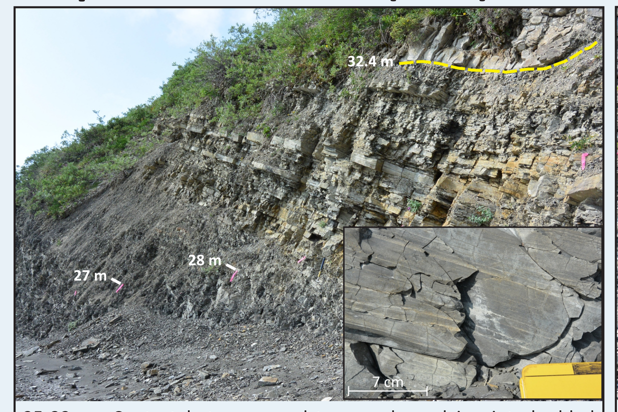
Key to Symbols in Measured Section

- Shale, siltstone, mudstone
- Sandstone
- Rip-up clasts (shale, siltstone, mudstone)
- Horizontal lamination
- Wavy lamination
- Cross-bedding
- Current-ripple cross-lamination
- Succession of sedimentary structures in single bed (flow unit)

Photomosaic made from low-altitude oblique air photos. Note the stratigraphic architecture of the Canning Formation and its position on a flat-lying to gently dipping fold limb between two steeply dipping limbs. View toward the west.

FACIES ASSOCIATIONS

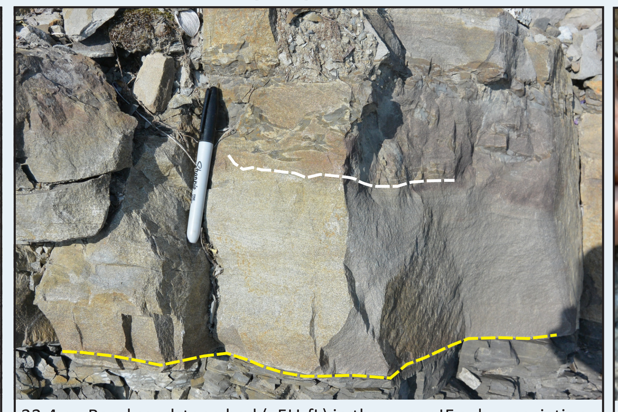
Slope-Basin-Floor (SBF) Association(?) - Upper



25-32 m: Contact between mudstone and overlying interbedded mudstone and sandstone at 29.2 m presages the arrival of the upper IF sub-association at 32.4 m. Inset of mudstone at 27.5 m.

30-34 m: Contact between mudstone and upper IF sub-association (at geologist's left hand). This contact is erosional and includes up to 15 cm of local relief.

Incision-fill (IF) Association - Upper



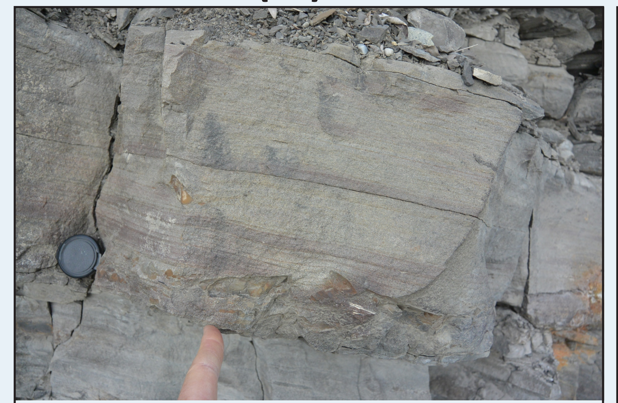
32.4 m: Basal sandstone bed (vfU-fL) in the upper IF sub-association. Lower two-thirds of bed includes faint horizontal laminations. Yellow line marks contact with mudstone at 32.4 m. Mudclast-bearing interval above dashed white line is interpreted as a different flow unit.

32.4 m: Flute cast on underside of vfU-fL sandstone bed shown in photo to left. Flute shows transport toward the east (toward right).

~36-37 m: Beds of fL sandstone grading upward to mudstone. Lens cap diameter is approximately 4.5 cm.

~37.5-38 m: Beds of fL sandstone grading upward to vfL sandstone and mudstone.

Incision-Fill (IF) Association - Lower

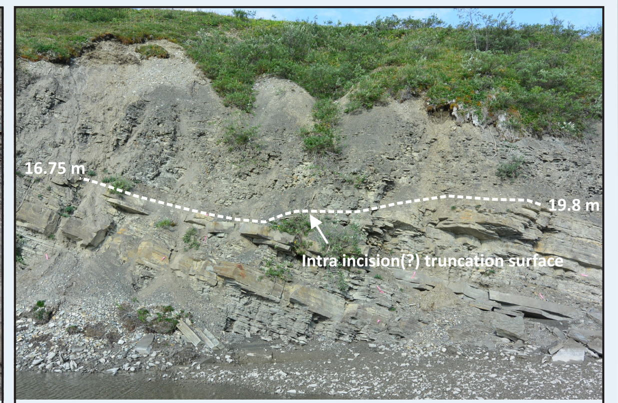


5.7 m: Close-up showing features in bed near base of lower IF association. Note the lag of sideritized mudstone rip-up clasts (above finger tip) and horizontal laminae in fL sand in the upper 80% of bed.

7-8.5 m: vfL to fL sandstone beds and thinly interbedded mudstone typical of the lower IF association.

7.7 m: fL sandstone bed (base at 7.7 m) showing prominent horizontal laminations. This is the dominant facies in the lower and upper IF sub-associations.

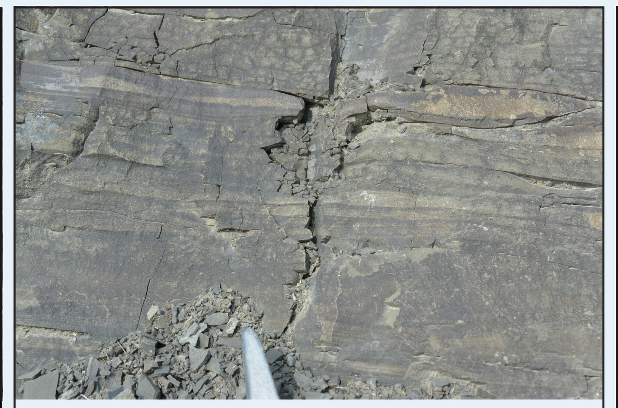
Intra-Incision(?) Truncation



14-22 m: Intra incision(?) truncation surface cuts down-section 3.25 m into the lower IF sub-association. It is unclear, given the outcrop extent, if this surface marks the top of the incision fill.

Slope-Basin-Floor (SBF) Association - Lower

1.5-2 m: Close-up showing typical appearance of SBF association with abundant centimeter-thick laminae of coarse siltstone-vfL sandstone. Partial Bouma sequences common (Ta, Tab, Tb, Tbc, starved Tc).



3.5 m: Close-up showing typical appearance of SBF association with few millimeter- to centimeter-thick laminae of coarse siltstone-vfL sandstone. Partial Bouma sequences common, as near base section.

3.5-4.5 m: Close-up showing typical appearance of SBF association. Note lighter colored coarse siltstone and vfL sandstone laminae in mudstone to left of the hammer head.

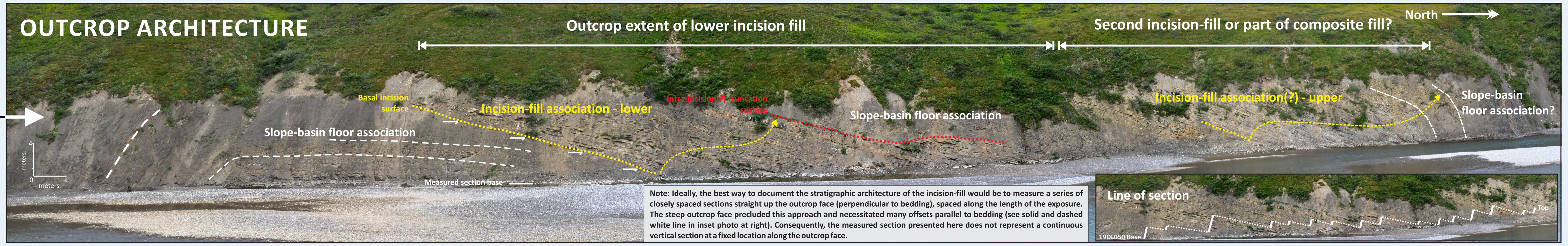
3.5-7.0 m: Contact between SBF mudstones and sandstone-rich IF association at approximately 5.6 m in measured section. Hammer is 42 cm long and handle is resting on the basal bed in the incision fill.

Two facies associations are recognized:

1) Slope-basin-floor (SBF) association: consists of mudstone and common to sparse very thinly interbedded siltstone and vfL sandstone; siltstone and sandstone include partial Bouma sequences (Ta, Tab, Tb, Tc and Tbc). The succession between the intra-incision(?) truncation surface and 32.4 m appears macroscopically similar to the lower 5.5 m of the measured section and is included in the SBF association. Bioturbation is absent. Mudstone records deposition in an unconfined lower slope to proximal basin-floor setting from turbid plumes emanating from fluvial-deltaic systems located up dip to the west; the setting was interrupted by short duration, dilute, low-volume turbidity currents.

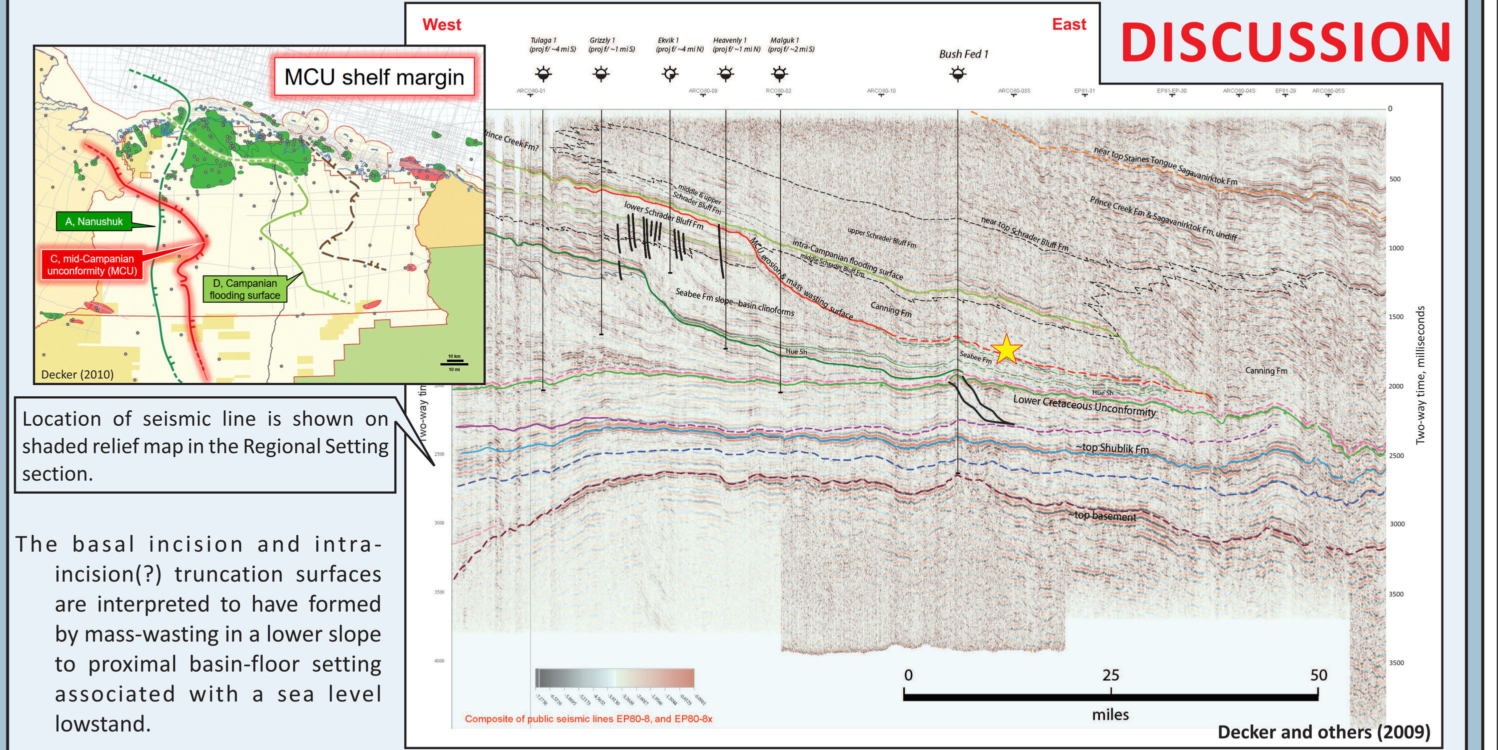
2) Incision-fill (IF) association: consists of interbedded mudstone, siltstone and vfL to fL sandstone. Two subdivisions are recognized - the lower subdivision consists of sandstone beds ranging in thickness from a few centimeters to 20 cm, sandstones include partial Bouma sequences (Ta, Tab, Tabc, Tb, Tbc, Tc) and rare mudstone rip-ups; the upper subdivision is similar to the lower, but sandstone beds are thicker, on average, and mudstone rip-ups are locally abundant. Sandstones record deposition in a lower slope to proximal basin-floor setting from dilute, confined turbidity currents and possibly, concentrated density flows (upper subdivision); mudstones record deposition from the waning tails of turbidity currents and turbid plumes blanketing slope.

OUTCROP ARCHITECTURE



Note: Ideally, the best way to document the stratigraphic architecture of the incision-fill would be to measure a series of closely spaced sections straight up the outcrop face (perpendicular to bedding), spaced along the length of the exposure. The steep outcrop face precluded this approach and necessitated many offsets parallel to bedding (see solid and dashed white line in inset photo at right). Consequently, the measured section presented here does not represent a continuous vertical section at a fixed location along the outcrop face.

DISCUSSION



Location of seismic line is shown on shaded relief map in the Regional Setting section.

The basal incision and intra-incision(?) truncation surfaces are interpreted to have formed by mass-wasting in a lower slope to proximal basin-floor setting associated with a sea level lowstand.

The mass-wasting scars served as conduits that focused density flows, directing sediment to the lower slope and proximal basin floor, where they decelerated and deposited their sediment load in a slope apron or basin-floor fan.

The scale of the basal incision is unknown due to outcrop limitations and structural complications.

The basal incision cut into unbioturbated mudstones and thinly interbedded siltstones and very fine-grained sandstones of the SBF association, interpreted as unconfined lower slope to proximal basin-floor deposits.

The lower sand-rich package consists of dilute turbidites and is clearly part of the incision fill (IF association). The upper part of this package has been removed by the event that created the intra-incision(?) truncation surface. The extent of this surface is unknown (limited to incision fill or extends into slope-basin-floor deposits beyond?)

The intra-incision(?) surface is overlain by mudstones resembling the SBF association below the basal incision surface. It is unknown if these deposits are limited to the incision or if they extend beyond its boundaries.

The upper sand-rich package caps the measured section and, at least qualitatively, appears to include more sandstone in slightly thicker beds. This package consists of dilute turbidites and concentrated density flow deposits (Lowe sequences?). It is unknown if this package fills the same incision as the lower IF sub-association or if it is part of the fill of a different incision. The stratigraphy above this package appears to be mudstone-rich and similar to the SBF association, but is poorly known due to structural complications and limited outcrop access.

The studied exposure is correlated with the sand-rich package comprising a lowstand sequence set in the lower part of the Canning Formation in the Echooka 1 well and a succession of tuffaceous sandstones, stacked levee deposits, and an anomalous pebble-cobble conglomerate in the lower part of the Canning Formation exposed along Sagashak Creek (see Decker and others, 2009). More precise correlation is not possible given available age control.

The basal incision and intra-incision(?) truncation surfaces represent potential bypass surfaces across which significant volumes of sand could have been transported seaward to accumulate in a slope apron or basin-floor fan system. It seems probable that similar incisions are common in the slope deposits of the Canning Formation, with similar implications for the basinward transport of sand.

ACKNOWLEDGMENTS

The authors are indebted to Gil Mull (DGGS/DOG, retired) for first showing the outcrop addressed in this report to LePain during the 1999 field season, albeit at 90 miles per hour and 50 feet above the river in a Bell Jet Ranger helicopter. During that season, the thalweg of an active channel of the Ivishak River had migrated, or avulsed, to the western edge of the valley and the outcrop was inaccessible. At that time we thought the sandy succession above the basal incision represented shallow water deposits of the Schrader Bluff Formation. Subsequent detailed bedrock geological mapping by DGGS (Gillis and others, 2014; Herriott and others, 2011) and detailed stratigraphic studies by DGGS and DOG (LePain and others, 2008; Decker and others, 2009, 2010; Wartes and others, 2013) greatly improved our understanding of Brookian stratigraphy in the east-central North Slope, including this outcrop, and the authors gratefully acknowledge their efforts. We thank Bill Rouse (U.S. Geological Survey) for help in using DGGS' gamma ray spectrometer. We thank Christina De Vera (U.S. Geological Survey) for calibrating our spectrometer on the U.S. Geological Survey's calibration pad in Reston, VA. Finally, we thank our helicopter pilot, Sarah Rafaelli (Maritime Helicopters), for safely ferrying us to and from the outcrop. Marwan Wartes (DGGS) reviewed a draft of this report and made many insightful suggestions for its improvement. Funding was provided by Chevron North America Exploration and Production Company, ConocoPhillips Alaska, Oil Search Alaska, U.S. Geological Survey, and the State of Alaska.

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