MEASURED STRATIGRAPHIC SECTION, NANUSHUK FORMATION (ALBIAN–CENOMANIAN), NANUSHUK RIVER (ROOFTOP RIDGE), ALASKA

David L. LePain, Russell A. Kirkham, and Simone Montayne

Preliminary Interpretive Report 2021-5

This publication is PRELIMINARY in nature and meant to allow rapid release of field observations or initial interpretations of geology or analytical data. It has undergone limited peer review, but does not necessarily conform to DGGS editorial standards. Interpretations or conclusions contained in this publication are subject to change.

2021
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

STATE OF ALASKA
Mike Dunleavy, Governor

DEPARTMENT OF NATURAL RESOURCES
Corri A. Feige, Commissioner

DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
Steve Masterman, State Geologist & Director

Publications produced by the Division of Geological & Geophysical Surveys are available to download from the DGGS website (dggs.alaska.gov). Publications on hard-copy or digital media can be examined or purchased in the Fairbanks office:

Alaska Division of Geological & Geophysical Surveys (DGGS)
3354 College Road | Fairbanks, Alaska 99709-3707
Phone: 907.451.5010 | Fax 907.451.5050
dggspubs@alaska.gov | dggs.alaska.gov

DGGS publications are also available at:

Alaska State Library, Historical
Collections & Talking Book Center
395 Whittier Street
Juneau, Alaska 99801

Alaska Resource Library and
Information Services (ARLIS)
3150 C Street, Suite 100
Anchorage, Alaska 99503

Suggested citation:
LePain, D.L., Kirkham, R.A., and Montayne, Simone, 2021, Measured stratigraphic section, Nanushuk Formation (Albian-Cenomanian), Nanusuk River (Rooftop Ridge), Alaska: Alaska Division of Geological & Geophysical Surveys Preliminary Interpretive Report 2021-5, 8 p.
https://doi.org/10.14509/30744

Cover, Back. View toward the northwest showing the thick, poorly exposed mudstone interval that divides the Nanushuk at this location into two halves. A candidate sequence boundary is identified in the amalgamated sandstone package near the right edge of the image. Note the two, thin parasequences exposed to the right of the thick tongue of vegetation extending down slope to the gravel bar. These parasequences form the base of a transgressive systems tract. A maximum flooding surface is located in the mudstone succession, inferred to be located straight up from the two geologists standing next to the helicopter. **Front.** View toward the southwest showing a transgressive lag of pebbly granule conglomerate. Most of the black, dark gray and gray pebbles and granules are chert; the light-colored clasts are mostly quartz. This lag rests on a composite surface located a few inches below the geologist's index finger. This surface is interpreted as a candidate sequence boundary that was subsequently modified during transgression, forming a transgressive surface of erosion.

MEASURED STRATIGRAPHIC SECTION, NANUSHUK FORMATION (ALBIAN–CENOMANIAN), NANUSHUK RIVER (ROOFTOP RIDGE), ALASKA

David L. LePain[1], Russell A. Kirkham, and Simone Montayne

INTRODUCTION

LePain and others (2009) presented a detailed analysis of Nanushuk depositional systems in the eastern part of its outcrop belt. They presented detailed segments of larger measured stratigraphic sections in the body of the report to illustrate facies associations and included more complete, although simplified, versions of measured sections from key locations in an appendix. The purpose of this brief report is to present a detailed version of a measured section through the Nanushuk Formation at an exposure along the west bank of the Nanushuk River, at the eastern end of Rooftop Ridge anticline (figs 1–2). Detailed measured sections from other important Nanushuk outcrops will be released in forthcoming reports. The reader is referred to Decker (2018) and Houseknecht (2019) for discussions of the Nanushuk's petroleum potential.

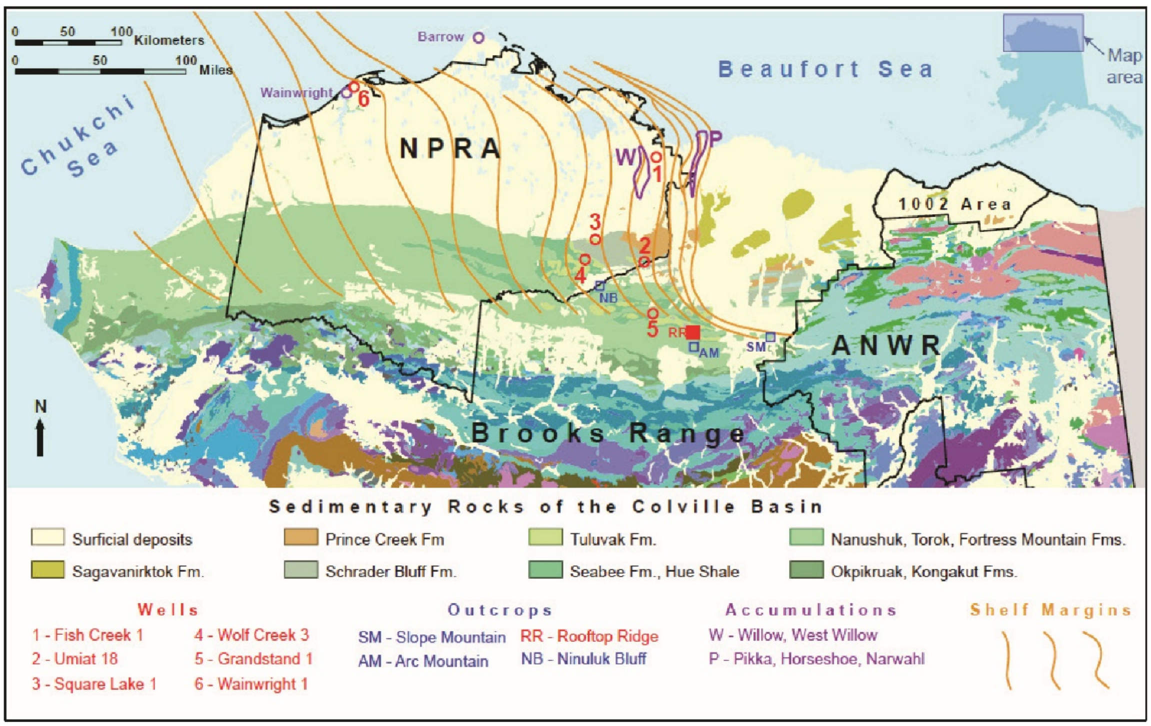

Figure 1. Simplified geologic map of northern Alaska showing the location of the Rooftop Ridge measured stratigraphic section (solid red square labeled RR). Other significant Nanushuk outcrops are also shown, as are selected wells with important cores from the Nanushuk Formation. Numbered dots correspond to wells: 1, Fish Creek 1; 2, Umiat 18; 3, Square Lake 1; 4, Wolf Creek 3; 5, Grandstand 1. Red ovals show the approximate locations of Willow (W) and Pikka (P). Yellow lines show the approximate locations of Nanushuk lowstand shelf margins. Shelf margins from Houseknecht (2019). Geology from Wilson and others (2015).

[1] Alaska Division of Geological & Geophysical Surveys, 3354 College Road, Fairbanks, AK 99709; david.lepain@alaska.gov
[2] Alaska Division of Mining, Land and Water, 550 W. 7th Ave, Suite 1360, Anchorage, AK 99501

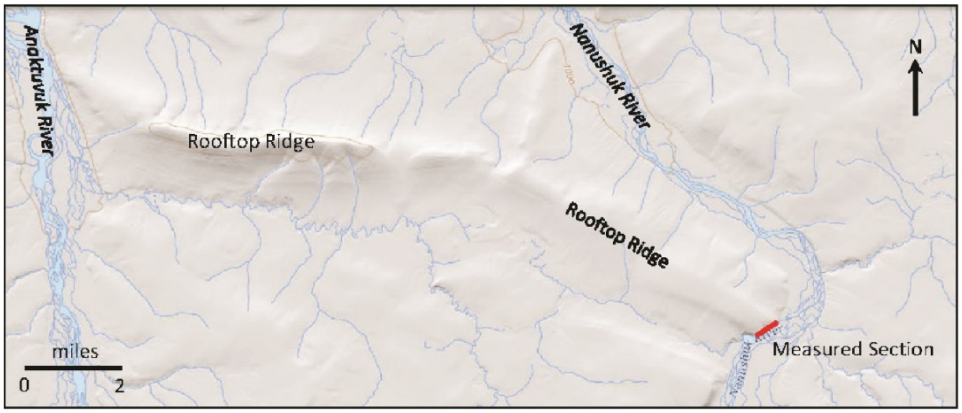

Figure 2. Shaded relief map showing Rooftop Ridge and the location of the measured section addressed in this report. Map taken from U.S. Geological Survey National Map.

SUMMARY OF STRATIGRAPHIC ORGANIZATION

Nearly the entire depositional thickness of the Nanushuk Formation is exposed at the east end of the Rooftop Ridge anticline (figs. 1–2). Here the formation is 519.8 m thick (sheet 1), in fault contact with the underlying Torok Formation, and overlain disconformably by Turonian-age bentonitic clay shales of the Seabee Formation (fig. 3). Beds dip toward the south-southwest from 42 to 50 degrees. The thrust fault separating the Nanushuk and Torok at the northeast end of the exposure is north-vergent and interpreted as a minor structure with limited displacement (Gil Mull, oral communication, July, 1999). Therefore, the 519.8 m thickness is interpreted as close to the depositional thickness of the Nanushuk at this location.

The Nanushuk at Rooftop Ridge is divided into two prominent successions, each interpreted as a third-order seismic-scale sequence dominated by shallow marine facies (figs. 4–5; sheet 1; LePain and others, 2009). No unequivocal nonmarine deposits have been recognized at this location. The lower succession is 242.2 m thick (or 245.5 m thick, depending on position of sequence boundary) and consists of at least 10 smaller-scale, sandier-upward parasequences ranging in thickness from 15 m to 50 m. Parasequences in the lower 157.7 m stack to form an aggradational succession in which each successively higher parasequence consists of roughly the same suite of facies in roughly similar proportions. These parasequences record deposition in offshore shelf, offshore transition, and lower to middle shoreface settings, and comprise an early highstand systems tract (fig. 4; sheet 1). The upper 84.5 m forms a progradational stack of parasequences that include progressively more proximal facies toward a candidate sequence boundary at 242.2 m and comprise a late highstand systems tract. The bed contact at 242.2 m is overlain by cross-bedded, medium-grained sandstone interpreted as the fill of a small channel (fig. 6; sheet 1). The actual contact is poorly exposed, but the grain size increase suggests the presence of a possible sequence boundary (candidate sequence boundary) and the presence of a thin lowstand succession between 242.2 m and 245.5 m. Alternatively, and probably more likely, this surface might be nothing more than the scour surface at the base of a channel-fill. If the latter is true, the sequence boundary is placed at the top of the cross-bedded sandy channel-fill at 245.5 m; if correct, the sequence boundary was modified during the ensuing transgression and is a composite surface (sequence boundary and transgressive surface). Most parasequences in the lower half include abundant hummocky and swaley cross-stratification, indicating deposition in storm-wave modified settings.

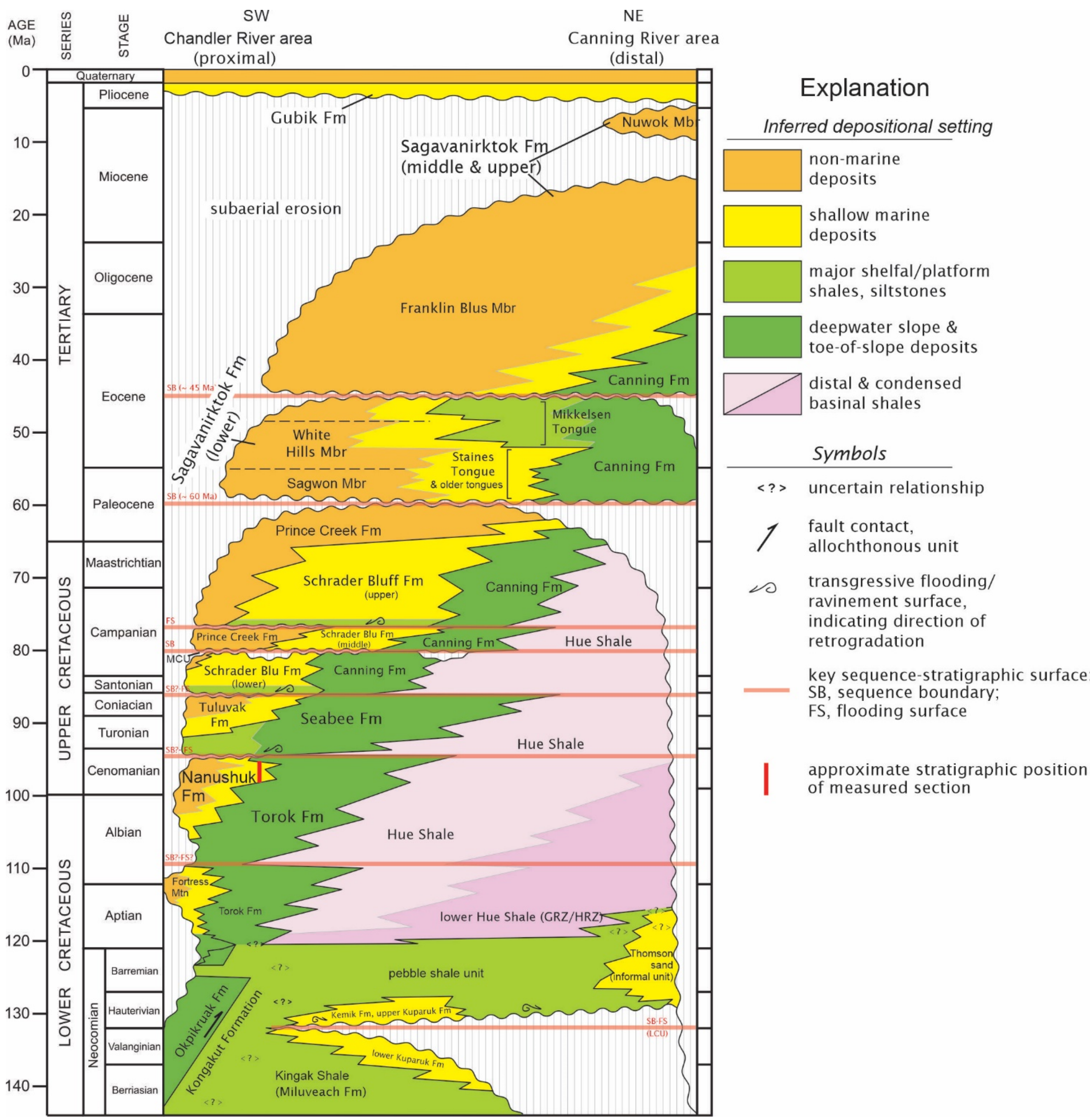

Figure 3. Simplified sequence stratigraphy of the Brookian Sequence. Modified from Decker and others, 2009.

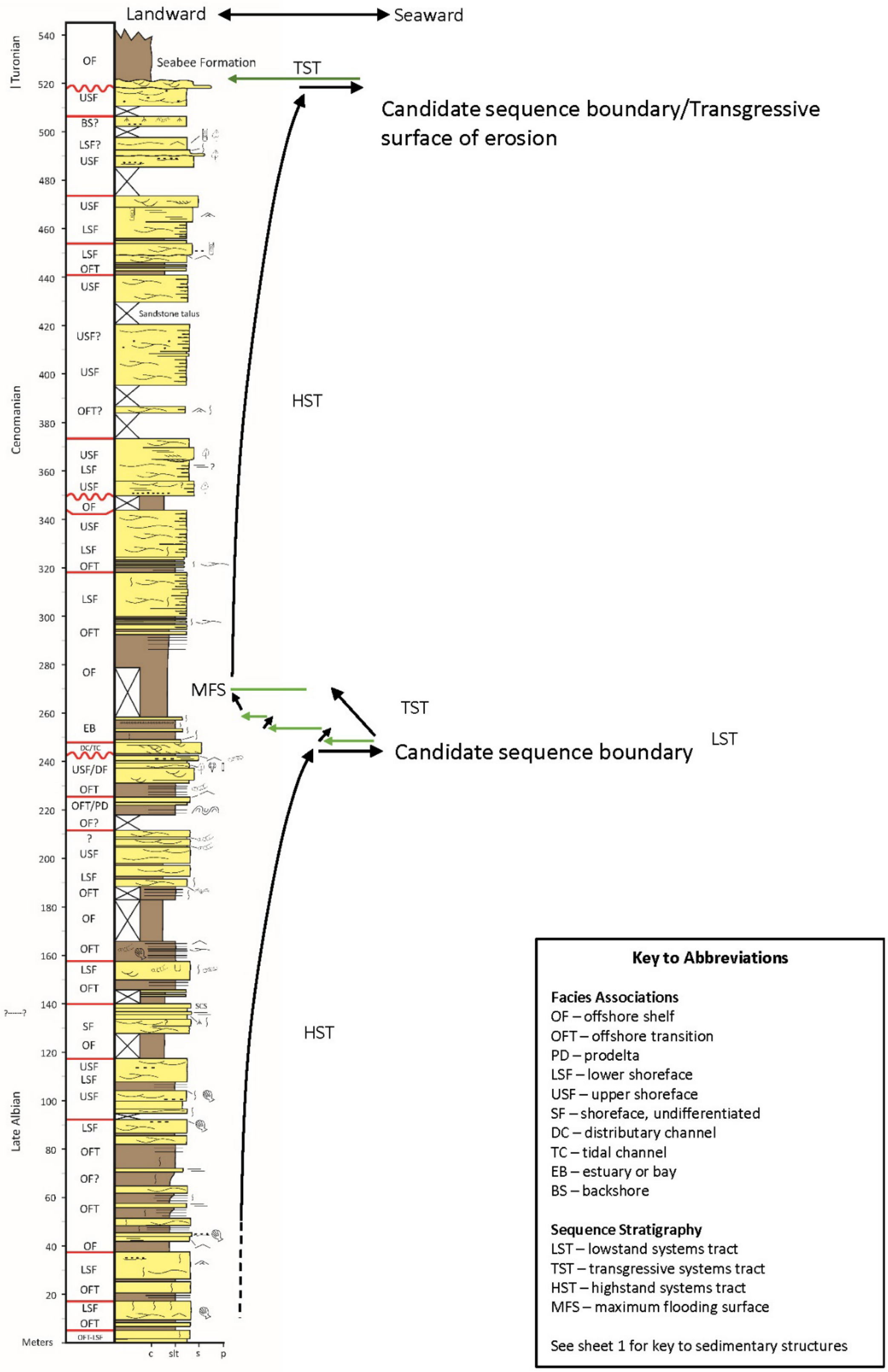

Figure 4. Simplified version of the Rooftop Ridge measured section showing 3rd-order sequence stratigraphy. Modified from LePain and others (2009).

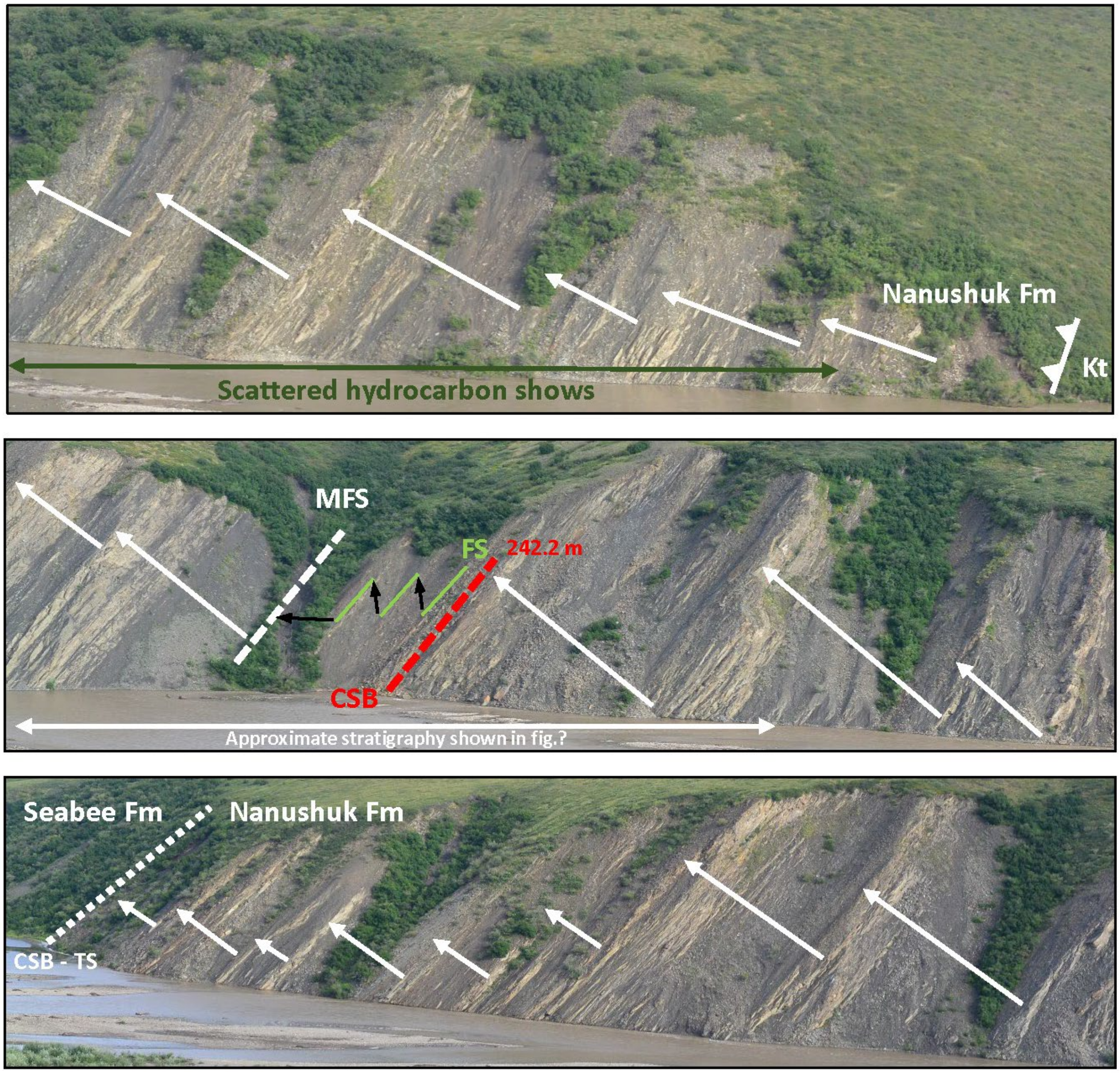

Figure 5. Oblique low elevation air photos showing the Rooftop Ridge outcrop. The base of the section is visible in the lower right corner of the upper image; the top of the section corresponds to the Nanushuk-Seabee contact visible near the left edge of the lower image. The middle image shows the transition between the lower and upper halves of the Nanushuk Formation (at 242.2 m). Note the right and left edges of the middle image do not tie directly to the upper and lower images – minor stratigraphic gaps exist between the three photomosaics. The white arrows show coarsening-upward shoreface parasequences. At least 10 parasequences have been identified in outcrop in the lower half (only nine are shown in these photographs) and ten in the upper half of the Nanushuk at this location. Kt – Torok Formation; TS – transgressive surface; FS – flooding surface; CSB – candidate sequence boundary; MFS – maximum flooding surface.

The upper succession is approximately 277.6 m thick and extends from the candidate sequence boundary at 242.2 m to the Nanushuk–Seabee contact at 519.8 m (figs. 4–6). Alternatively, the succession is 274.3 m thick if the sequence boundary is placed at 245.5 m, as discussed in the previous paragraph. The upper succession consists of at least 10 parasequences ranging in thickness from 5 m to 65 m and component facies define a progradational parasequence stacking pattern (sheet 1).

The upper succession displays an organization similar in gross appearance to the lower one but is different in detail (fig. 4). The basal 3.3 m consists of cross-bedded, medium-grained sandstone in sets 10 cm to 50 cm thick and is largely unbioturbated (fig.6; sheet 1). This interval is interpreted as a channel-fill, possibly in an estuarine setting, and if the sequence boundary is correctly placed at the base, it represents a thin lowstand systems tract. The interval from 245.8 m to 258 m consists of two thin parasequences defining a retrogradational stacking pattern, interpreted to record muddy estuary mouth barriers (LePain and others, 2009), and represents the basal part of a transgressive systems tract. The youngest of these includes a thin tephra that was sampled for U-Pb geochronology (LA-ICPMS and TIMMS) in 2018 (results will be released in a forthcoming report). A covered interval from 258 m to 290 m is underlain by fine-grained facies, likely clay shale and silty clay shale, and conceals a maximum flooding surface (figs. 4 and 6; sheet 1). A thick stack of parasequences like those comprising the lower succession extends from the maximum flooding surface to the Nanushuk-Seabee contact at 519.8 m and defines a highstand systems tract. Parasequences gradually record deposition in more proximal settings—parasequences in the lower part record deposition in offshore transition to lower and middle shoreface settings, whereas in the upper part they record deposition in offshore transition (inferred for covered intervals) to middle and upper shoreface, and possibly foreshore, settings. The sand body at 469.9 m consists of medium-grained, trough cross-bedded sandstone interpreted as the fill of a small channel, possibly a rip channel or a small tidal inlet, which could also represent a thin lowstand systems tract (candidate sequence boundary at 469.9 m). The coarsest material at this location (very coarse sandstone to granule conglomerate as discontinuous lags) occurs immediately above the contact with the Seabee Formation. The Nanushuk–Seabee contact at 519.8 m is interpreted as a composite surface—a sequence boundary that was subsequently modified during transgression to a form a transgressive surface of erosion (ravinement surface). This coarse material represents a transgressive lag deposit. Most parasequences in the upper half include abundant hummocky and swaley cross-stratification, indicating deposition in storm-wave modified settings.

Bioturbation is common to abundant throughout most of the Rooftop Ridge succession and appears to record a diverse, open marine assemblage, including common *Arenicolites*, *Diplocraterion*, *Gyrochorte*, *Helminthopsis/Phycosiphon*, *Palaeophycos*, *Rhizocorallium*, *Schaubcylindrichnus*, *Skolithos*, and *Thalassinoides,* defining a mixed *Cruziana-Skolithos* ichnofacies (sheet 1). Bioturbation is sparse to absent in the upper part of some of the most proximal parasequences, recording deposition in high-energy settings where preservation potential is lowest. Macerated plant material is common throughout the Rooftop Ridge outcrop, but the largest plant fragments tend to be most abundant near the top of the lower and upper successions, as would be expected in progradational successions. Collectively, the suite of trace fossils and physical sedimentary structures indicate deposition as a thick stack of storm-wave-modified shoreface parasequences, with possible channelized facies capping the lower and upper halves.

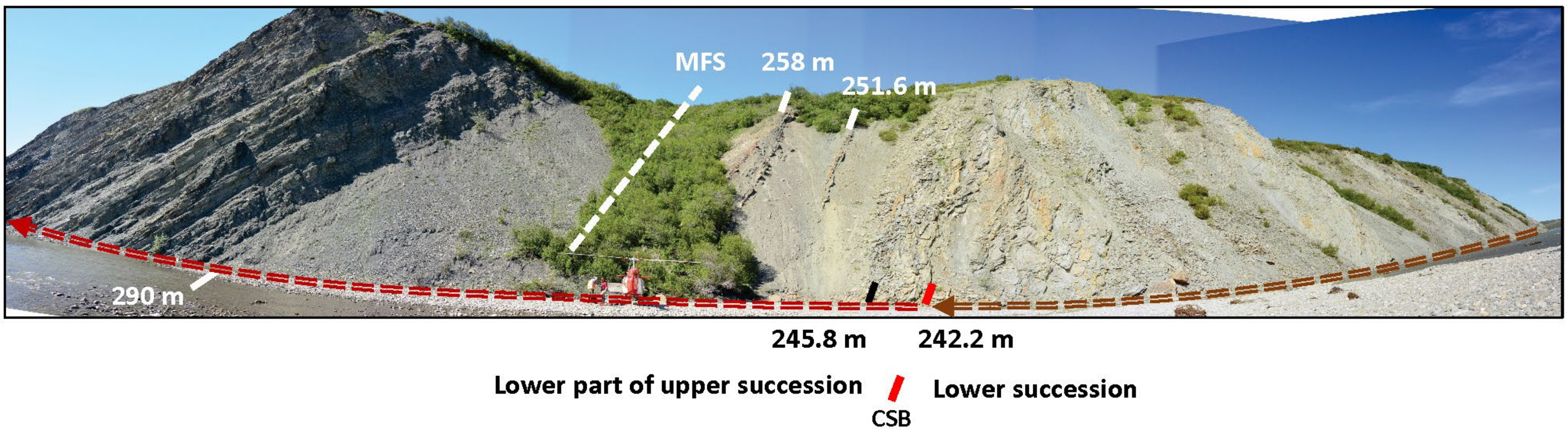

Figure 6. Photomosaic showing the upper and lower parts of the lower and upper halves of the Nanushuk Formation, respectively, at Rooftop Ridge. MFS – maximum flooding surface. The surface at 242.2 m is interpreted as a candidate sequence boundary (CSB). See text for additional details.

OIL SHOWS

Five hydrocarbon shows have been recognized in the Nanushuk Formation at Rooftop Ridge (sheet 1). Four shows are in the lower third of the lower half of the Nanushuk and one in the upper half. All shows occur in friable sandstones. Shows in the lower half are characterized by moderate to strong hydrocarbon odors and most beds show visible evidence of oil staining. The show at approximately 60 m includes several thin sandstone beds that emit strong hydrocarbon odors and are cut by a dike filled with solid bitumen. Shows at approximately 83 m and 88.5 m are in sandstone beds that are medium to dark brown (visible heavy staining) and emit a strong, heavy (weathered/biodegraded?) hydrocarbon odor. The single show recognized in the upper half, at approximately 369 m, occurs in light to medium gray weathering, friable sandstone that emits a faint, light hydrocarbon odor. Interestingly, the greater number of recognized shows occur in the lower half, closer to inferred carrier beds in slope deposits of the Torok Formation and a minor fault that could also have served as a hydrocarbon migration pathway.

ACKNOWLEDGEMENTS

We thank Gil Mull for making us aware of the Rooftop Ridge exposure at the start of the 1999 field season and Nina Harun for reviewing the manuscript. Our work on the Nanushuk was funded by an industry consortium that most recently includes ConocoPhillips, Chevron, and Oil Search. Many companies that contributed financial support in the past no longer exist (Anadarko, ARCO, etc.). Additional support was provided by the U.S. Geological Survey and the State of Alaska.

REFERENCES

Decker, P.L, 2018, Nanushuk Formation discoveries: World-class exploration potential in a newly proven stratigraphic play, Alaska North Slope: Discovery Thinking Forum, AAPG ACE, Salt Lake City, Utah.

Decker, P.L., LePain, D.L., Wartes, M.A., Gillis, R.J., Mongrain, J.R., Kirkham, R.A., and Shellenbaum, D.P., 2009, Sedimentology, stratigraphy, and subsurface expression of upper Cretaceous strata in the Sagavanirktok River area, east-central North Slope, Alaska: Alaska Division of Geological & Geophysical Surveys, 3 sheets. https://doi.org/10.14509/30156

Houseknecht, D.W., 2019, Petroleum systems framework of significant new oil discoveries in a giant Cretaceous (Aptian-Cenomanian) clinothem in Arctic Alaska: AAPG Bulletin, v. 103, p. 619–652.

LePain, D.L., McCarthy, P.J., and Kirkham, R.A., 2009, Sedimentology and sequence stratigraphy of the middle Albian-Cenomanian Nanushuk Formation in outcrop, central North Slope, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2009-1 v. 2, 76 p., 1 sheet. https://doi.org/10.14509/19761

Wilson, F.H., Hults, C.P., Mull, C.G., and Karl, S.M., 2015, Geologic map of Alaska: U.S. Geological Survey Scientific Investigations Map 3340, 196 p., 2 sheets, scale 1:1,584,000. https://alaska.usgs.gov/science/geology/state_map/interactive_map/AKgeologic_map.html