ABSTRACT

The integration of recent fieldwork with available subsurface data has rendered a new geologic map (1:63,360) of the hydrocarbon-bearing Umiat–Gubik region of the central North Slope. The map spans $\sim 2100 \text{ km}^2$ and lies at the northern extent of the Brooks Range foothills fold-and-thrust belt in the Colville foreland basin.

Cenomanian–Maastrichtian strata of the Nanushuk, Seabee, Tuluvak, Schrader Bluff, and Prince Creek Formations locally constitute an ~2-km-thick succession that crops out sparsely in the dominantly low-relief, tundra-mantled region; however, exceptional cutbank exposures occur locally. The stratigraphy comprises chiefly marine (Nanushuk, Tuluvak, Schrader Bluff) and nonmarine (Prince Creek) topsets and slope clinoforms (Seabee). This work benefits from and further elucidates recent sequence stratigraphic advances in understanding how this part of the Colville basin was filled during Late Cretaceous time. As an example, the geologic map of this study is the first of the Umiat–Gubik area to distinguish that the three local Schrader Bluff Formation members underlie a regionally significant mid-Campanian unconformity and are entirely older than Schrader Bluff strata that crop out east of the formation's Anaktuvuk River type section.

The map reveals a series of west- to northwest-trending gentle folds with km-scale wavelengths. Anticlines are locally thrusted and interpreted to be folded above structurally thickened and/or duplexed fine-grained successions of Torok Formation. Three culminations host known yet undeveloped petroleum accumulations at Umiat (mainly oil), East Umiat (gas), and Gubik (gas). These currently stranded discoveries occur along doubly plunging anticlinal traps and the main Umiat culmination is modified by what we interpret as south-dipping reverse faults.

The geologic map was prepared through assimilation of our field data, aerial and satellite imagery, seismic data, and well logs. Near surface formation picks are available or derived for most of the area's 24 exploration wells and cross sections are constructed along lines of section approximately coincident with publicly available 2D seismic data. This integrative approach yields an improved understanding of the Umiat–Gubik area geology that is constrained by numerous and corroborating datasets

HIGHLIGHTS AND KEY OBSERVATIONS

• The map area hosts dominantly topset strata that record continued filling of the Colville foreland basin during the Late Cretaceous (see Regional Context)

 This new geologic map of the Umiat–Gubik area is based on the integration of geologic and geophysical datasets, photogeologic mapping, and previsously published data (see Geologic Mapping: An Integrated Approach)

• Three known, undeveloped petroleum accumulations occur in the map area along doubly plunging anticlinal traps at Umiat, East Umiat, and Gubik <u>Gubik gas field</u> (see A–A')

- Umiat trend oil and gas fields:
- The East Umiat gas field occurs in the hangingwall of a north dipping
- thrust (see A–A') • The <u>Umiat oil field</u> lies farther west-northwest along the same trend,
- but is in the hangingwall of a south dipping thrust(s) (cf. Mull et al., 2004) (see B–B')
- A transfer fault is locally interpreted in seismic data and mapped along the Colville River corridor between these two fields

 The regional lower part of Schrader Bluff Formation (Ksbl) thins northward across the study area (see A–A'), potentially reflecting reduced accomodation to the north during Santonian–mid-Campanian time

 The regionally recognized mid-Campanian unconformity (MCU sensu Decker, 2007) crops out locally



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GEOLOGIC MAPPING: AN INTEGRATED APPROACH

INPUTS

• Seismic Data (e.g., see A–A' and B–B') Geologic Mapping Stratigraphic Studies • Time and Depth Structure Maps Photogeologic Mapping

Previously Published Studies and Datasets

• Well Picks (Collins, 1958; Robinson, 1958; Geologic Geologic Maps (Detterman et al., 1963; Brosgé Materials Center (Top Picks spreadsheet); AOGCC) and Whittington, 1966; Mull et al., 2004)

• Recent Sequence Stratigraphic Advances (e.g., Houseknecht and Schenk, 2005; Decker, 2007; Flores et al., 2007a, b; LePain et al., 2009; Gillis et al., 2014; see also Regional Context)

• Stratigraphic Thicknesses (e.g., Collins, 1958; Robinson, 1958; • Time and Depth Structure Maps (e.g., Detterman et al., 1963; Brosgé and Whittington, 1966) Kumar et al., 2002; Molenaar, 1982)

EXAMPLES OF INPUTS

ktuvuk River (this study)	Field Name	Well Name	Uppermost Formation Pick	Depth Interval (feet)	Pick Source	Comment (this study)	Interpretation (this stud
		Umiat Test No. 1	Seabee	9-915	K. Bird (GMC Top Picks)		Seabee at surface
		Umiat Test No. 2 Umiat Test No. 3	Nanusnuk Nanushuk	60–total depth	K. Bird (GMC Top Picks) K. Bird (GMC Top Picks)	not sampled: 9–60' (Collins, 1958)	Nanushuk near surrace Nanushuk near surface
		Umiat Test No. 4	Nanushuk	90–total depth	K. Bird (GMC Top Picks)	not sampled: 1—90' (Collins; 1958); total	Nanushuk near surface
		Umiat Test No. 5	Nanushuk	65–1060	Collins, 1958	not sampled: 0–65' (Collins, 1958); probably soudded in Kn (Collins, 1958)	Nanushuk near surface
	Umiat Oil	Umiat Test No. 6	Seabee	30–220	K. Bird (GMC Top Picks)	not sampled: 3–100' (Collins, 1958); top of Ks at 31' (Collins, 1958)	Seabee near surface
	Field	Umiat Test No. 7	Seabee	50-380	K. Bird (GMC Top Picks)	Quaternary: 4–50' (Collins, 1958)	Seabee near surface
		Umiat Test No. 8	Seabee	20–60	K. Bird (GMC Top Picks)	Quaternary: 5–20' (Collins, 1958)	Seabee near surface
		Umiat Test No. 9	Nanushuk	6–1090	K. Bird (GMC Top Picks) Collins (1958)		Nanushuk at surface
		Umiat Test No. 10	Nanushuk	5-250	K. Bird (GMC Top Picks)	Nanushuk thrusted over Seabee at 250'	Nanushuk near surfac
		Umiat Test No. 11	Tuluvak	22–775	K. Bird (GMC Top Picks)		Tuluvak near surface
		Seabee Test No. 1	Seabee	100-280	K. Bird (GMC Top Picks)		Seabee near surfac
		Umiat No. 18	data held confidentially	<u> </u>			
		Umiat No. 23H	data held confidentially	<u> </u>			
The start and the start and the start and		Gubik Test No. 1	Schrader Bluff (Barrow Trail member)	67–295	Robinson, 1958	Pliocene to Recent: 12-67' (Robinson, 1958)	Ksbl ₂ near surface
Children to the second second		Gubik Test No. 2	Schrader Bluff (Barrow Trail member)	160–555	Robinson, 1958	no core or cuttings from 12–160' (Robinson, 1958)	Ksbl ₂ near surface
the state of the second	GUDIK Gas	Gubik Unit No. 1	Schrader Bluff	110-1136	K. Bird (GMC Top Picks)	Schrader Bluff members not picked	Ksbl ₂ near surface
	Field	Gubik No. 3	Tuluvak	1079–?	Well Completion or Recompletion Report and Log (AOGCC)	Schrader Bluff not designated; top Seabee not picked	Ksbl ₂ near surface
		Gubik No. 4	Tuluvak	1461–2315	Well Completion or Recompletion Report and Log (AOGCC)	Schrader Bluff not designated; top Seabee not picked	Ksbl₃ near surface
		East Umiat Unit No. 1	Tuluvak	17–510	K. Bird (GMC Top Picks)		Ktu near surface
	Franklinist	East Umiat Unit No. 2	Tuluvak	12-?	K. Bird (GMC Top Picks)	top Seabee not picked	Ktu near surface
			Prince Creek/Schrader Bluff	23–?	K. Bird (GMC Top Picks)	top Tuluvak not picked	
	East Umlat	Colville Unit No. 1	Seabee	1640-2950	K. Bird (GMC Top Picks)		Ksbl ₁ near surface
	Gas Field	Colville Unit No. 2	Tuluvak	23?	K. Bird (GMC Top Picks)	top Seabee not picked	Ktu near surface
				,,			

Depth Structure Map—Top Nanushuk (generated from publicly available 2D seismic data (this study))



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GEOLOGIC MAP OF THE UMIAT-GUBIK AREA, CENTRAL NORTH SLOPE, ALASKA-INTEGRATION OF FIELDWORK AND SUBSURFACE DATA IN A REGION OF KNOWN OIL AND GAS ACCUMULATIONS

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SURFICIAL DEPOSITS

ALLUVIAL DEPOSITS (Quaternary)—Undifferentiated alluvium, including deposits of active and abandoned fluvial channels, as well as floodplains and alluvial terraces up to 8 m above modern streams. Chiefly comprises stratified deposits of fine- to coarse-grained sand, silty to gravelly sand, and gravel. Adopted after Qal (alluvium) of Carter and Galloway (1986). BROOKIAN MEGASEQUENCE

The Brookian megasequence (Lerand, 1973; Molenaar, 1983; Hubbard et al., 1987) records Early Cretaceous through Cenozoic northeasterly progradational infilling of the Colville foreland basin (Bird and Molenaar, 1992) with clastic sediments sourced from the Brooks Range orogenic belt along the basin's southern margin (see summary by Moore et al. (1994) and references therein). Portions of three major, chiefly progradational and aggradational packages of sediment (megacycles sensu Moore et al., 1994) are observed in the Umiat map area: 1) Nanushuk–Torok (e.g., Molenaar, 1985 and 1988; Houseknecht and Schenk, 2001); 2) Tuluvak–Seabee (e.g., Mull et al., 2003; Decker, 2007); 3) Prince Creek–Schrader Bluff–Canning (e.g., Mull et al., 2003; Decker, 2007). Brookian units that crop out in the mapped area are limited to Upper Cretaceous strata-dominantly recording nonmarine, shallow marine, and shelfal sedimentation-of the Nanushuk, Seabee, Tuluvak, Schrader Bluff, and Prince Creek formations (see Correlation of Map Units herein; Detterman et al., 1963; Brosgé and Whittington, 1966; Mull et al., 2003 and 2004). Notably, with the exception of Seabee clinoform and bottomset seismic facies (Houseknecht and Schenk, 2005, fig. 22 therein), no Brookian slope or toe-of-slope strata (i.e., Torok and Canning), or distal, condensed deposits (i.e., Hue Shale), were observed during this study. However, regional stratigraphic work (e.g., Huffman, ed., 1985; see also summary by Mull et al., 2003) and subsurface data (e.g., Molenaar, 1988; Decker, 2007) in northern Alaska indicate that the topset facies units of the Umiat area grade basinward (east and northeast) into correlative seismic clinoform and bottomset facies. Additionally, recent detailed geologic mapping in the Sagavanırktok River (Gillis et al., 2014) and Gilead Creek (Herriott et al., in preparation) areas of the Sagavanirktok Quadrangle further demonstrate the proximal-distal stratigraphic relationships that developed and evolved through time and space during mid-Cretaceous to early Cenozoic infilling in the central to east-central part of the Colville foreland basin. Bedrock exposures in the Umiat area are generally limited to cutbanks along the major creeks and rivers, and largely consist of the Schrader Bluff Formation. However, superb exposures of Prince Creek strata occur along the Colville River at Shivugak and Uluksrak bluffs (see also Flores et al., 2007a). Nanushuk, Seabee, and Tuluvak formations are mostly poorly exposed in the mapped area, with outcrops generally occurring within a several kilometers wide swath northwest of the Colville River near Umiat between Seabee Creek and Umiat Mountain; however, generally excellent exposures of these three units comprise the south face of Umiat Mountain (see also Houseknecht and Schenk, 2005). Furthermore, a notably outstanding outcrop of Nanushuk Formation lies along the northwest bank of the Colville River near the southern map boundary (see Colville incision locality of LePain et al. (2009)); relatively resistant Nanushuk beds also crop out discontinuously on tundra-covered slopes west of Umiat Mountain. Pre-Schrad-

JMIAT OIL FIELD AT 150% MAP SCALE

er Bluff units do not crop out south or east of the Colville River in the mapped area.



PRINCE CREEK FORMATION (locally lower(?) Campanian Maastrichtian(?))-Light- to dark-brown- to gray-brownreathering, dominantly light-gray, thick- to very thick-beded, moderately indurated, commonly cross-stratified (for et amplitudes to greater than 1 m), quartzose pebbly sand stone, fine- to coarse-grained sandstone, and conglomeration lag deposits, with subordinate gray to dark-gray, chiefly thinto medium-bedded, carbonaceous to bentonitic very fine-grained sandstone and mudstone, as well as medium- to very-thick bedded, dull to bright-and-dull-banded lignitic to subbituminous coal. The cross-stratified sandstone and pebbly sandstone lithofacies have scoured, sharp basal contacts and centimeter-scale, coalified woody debris is commonly observed; pebbles (commonly 1.5 cm long-axis dimension) are subangular to subrounded and generally comprise vein quartz and cherty argillite; both the pebble and sand fractions exhibit "salt- and-pepper" compositional coloring. Very fine-grained sandstone and mudstone facies are commonly rusty-orange- to tannish-yellow-weathering,

Schrader Bluff Formation, regional lower part, undifferentiated (locally Santonian(?) to Campanian)—Typically gray to tan to brown, thin- to thick-bedded, chiefly moderately to poorly indurated, tuffaceous to bentonitic to siliceous, bioturbated, dominantly marine mudstone, siltstone, and sandstone. In a regional context, Schrader Bluff Formation strata that crop out in the mapped area are limited to the lower part of the unit (i.e., below the significant mid-Campanian unconformity (MCU) of Decker (2007)). In the Umiat area we recognize three generally distinctly mappable units within the Schrader Bluff Formation: these units are described below and were mapped in detail where we could do so with moderate confidence. Our informal subdivisions of the Schrader Bluff Formation generally follow the members apped by Detterman et al. (1963) and Brosgé and Whittington (1966), although these Schrader Bluff members were formally abandoned by Mull et al. (2003).

and root traces are also observed.

- Schrader Bluff Formation, regional lower part, local ³ UPPER MAPPABLE UNIT (informal subdivision)—Locally distinctly brown-purple-weathering, light- to dark-gray, chiefly thin-bedded, moderately to poorly indurated, tuffaceous to locally siliceous, faintly ripple cross-laminated to wispy, disrupted, or convolute laminated siltstone and very fine-grained sandstone, with subordinate light-gray- to brown-purple-weathering, plane-laminated to ripple cross-laminated to locally trough cross-stratified, very fine-grained sandstone in amalgamated bedsets to 10 m thick. Commonly recessive, "popcorn"-weathering intervals are light- to dark-gray, bentonitic claystone and yellow-green to pistachio-lime-colored bentonite. Amalgamated sandstone lithofacies contains thin lag deposits of intra-formational siltstone rip-up clast conglomerates, with laminae defined by carbonaceous debris and rhizoliths are locally observed. Trace fossil assemblage commonly includes *Schaubcylin*drichnus, Paleophycos, and locally densely packed Phycosi phon. Shell fragments from large Sphenoceramus are locally
- Schrader Bluff Formation, regional lower part, local MIDDLE MAPPABLE UNIT (informal subdivision)—Light-gray to tan to brown, thin- to medium-bedded, typically well-indurated, locally friable, low angle wavy, trough, hummocky, and swaley cross-stratified, locally argillaceous, locally carbonceous and woody debris-bearing, tuffaceous(?) very fine- to fine-grained sandstone, with subordinate gray, medium- to thick-bedded, carbonaceous mudstone, dark-gray to black, thin-bedded, siliceous tuff, and chocolate-brown to olive-green, medium-bedded, "popcorn"-weathering bentonitic tuff. Finer grained sandstones are locally ripple cross-laminated. Sandstone beds locally exhibit sharp, scoured bases with up to 80 cm of erosional relief. Siderite nodule, sandstone rip-up clast, and extra-basinal clast conglomerates occur as thin lag deposits. Sand-

observed.

one and siltstone beds are locally bioturbated, and discre trace fossils include Macaronichnus, Asterosoma, a Schaubcylindrichnus; a medium- to dark-gray, hackly wear ring, well-indurated very fine-sandstone and siltstone lith cies distinctly occurs within this unit and is commonl intensely bioturbated by *Phycosiphon*. *Inoceramus* prisms are locally abundant, as are partially preserved *Sphenocerc mus* specimens.

Schrader Bluff Formation, regional lower part, local LOWER MAPPABLE UNIT (informal subdivision)—Light- t dark-gray to olive-brown, thin- to medium-bedded, typically poorly indurated, tuffaceous to bentonitic, ripple cross-laminated to structureless siltstone and mudstone, with subordinate light-gray- to light-tan-weathering, locally thick-bedded, tuffaceous, ripple cross-laminated, locally well-developed hummocky and swaley cross-stratified, coarsening and thickening upward packages of very fine- to fine-grained sandstone. Distinctive light-yellow- to white-weathering, very well-indurated, siliceous tuff beds locally observed, as are rare, buff-weathering, very well-indurated, limestone beds with a probable siliciclastic constituent. Common recessive intervals are inferred to contain abundant bentonite based on "popcorn"-weathering of colluvium. Skolithos traces and Sphenoceramus body fossils are observed within the sandstone facies.

TULUVAK FORMATION (locally Turonian to Conia cian(?))—Tan- to brown- to orange-brown-weathering, medium-gray to medium-brown, chiefly thin- to medium-bedded, commonly normally graded, well-indurated, moderately-sorted, lithic- and locally quartz-rich, locally carbonaceous, very fine- to medium-grained sandstone, with subordinate thin-bedded, plane-parallel laminated mudstone. Sandstone grains are subrounded to subangular. Mudstone rip-up clasts and siderite nodules as clasts are locally observed in sandstone beds, as are symmetrical ripples and low angle cross-stratification.

SEABEE FORMATION (locally Cenomanian(?) to Turonian)—Tan-gray- to medium-gray-weathering, medium- to dark-gray, thin-bedded, dominantly poorly indurated, tuffaceous to bentonitic, locally fissile, plane-parallel laminated to rippled siltstone, mudstone, and claystone, with subordinate tan-gray-weathering, medium-gray, thin- to very thick-bedded, locally well-indurated, commonly normally graded, low angle cross-stratified (e.g., hummocky, swaley, and irregularly) very fine-grained sandstone. Discrete, very thin-bedded bentonite horizons are common, and mudrock-dominated zones within the Seabee are typically covered in bentonite-rich, clayey slope wash that exhibits a characteristic "popcorn"-weathering style. *Inoceramus* prisms are locally

NANUSHUK FORMATION (locally Cenomanian)—Tangray-brown- to rusty-brown-weathering, medium-gray to light-brown to gray-brown, thick- to very thick-bedded, dominantly well-indurated, commonly normally graded, lithic to quartzose, locally structureless but commonly trough, hummocky, swaley, or tabular (planar and tangential) cross-stratified chiefly fine- to medium-grained sandstone. The fine- to medium-grained sandstone lithofacies is commonly overlain by subordinate dark-gray- to gray-brown- to light-rusty-brown-weathering, medium-gray to tan-gray to tan, very thin- to thin-bedded, moderately well-indurated, ripple to low-angle cross-laminated to plane-parallel laminated very fine-grained sandstone and siltstone. Centimeter-scale, coalified wood fragments and very thin pebbly lags are locally observed. Porous, oil-stained sandstone in the uppermost Nanushuk Formation was reported b Houseknecht and Schenk (2005) at Umiat Mountain, and we observed an oil seep along the Colville River near their measured section locality.

EXPLANATION AND DESCRIPTION OF MAP UNITS