Revised Cretaceous and Tertiary Stratigraphic Nomenclature in the Colville Basin, Northern Alaska

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Prepared in cooperation with the
Alaska Department of Natural Resources,
Division of Geological and Geophysical Surveys and
Division of Oil and Gas

U.S. Department of the Interior
U.S. Geological Survey

Cover. Poorly consolidated, crossbedded fluvial sandstones in Franklin Bluffs Member of Sagavanirktok Formation at Franklin Bluffs. Photograph by C.G. Mull.

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FIGURES

TABLE

CONVERSION FACTORS

[Measurements in the report are given in U.S. customary units. Conversions to the International System of Units (SI) are shown below]

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

Revised Cretaceous and Tertiary Stratigraphic Nomenclature in the Colville Basin, Northern Alaska

By C.G. Mull,[1] D.W. Houseknecht,[2] and K.J. Bird[3]

Abstract

A revised stratigraphic nomenclature is proposed for Cretaceous and Tertiary geologic units of the central and western North Slope of Alaska. This revised nomenclature is a simplified and broadly applicable scheme suitable for a suite of digital geologic quadrangle maps being prepared jointly by the U.S. Geological Survey and the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys and Division of Oil and Gas. This revised nomenclature scheme is a simplification of a complex stratigraphic terminology that developed piecemeal during five decades of geologic investigations of the North Slope. It is based on helicopter-supported geologic field investigations incorporating information from high-resolution aerial photography, satellite imagery, paleontology, reflection seismic records, and sequence stratigraphic concepts.

This revised nomenclature proposes the abandonment of the Colville Group; demotion of the Nanushuk Group to formation status; abandonment of six formations (Kukpowruk, Tuktu, Grandstand, Corwin, Chandler, and Ninuluk); revision of four formations (Sagavanirktok, Prince Creek, Schrader Bluff, and Seabee); elevation of the Tuluvak Tongue of the Prince Creek Formation to formation status; revision of two members (Franklin Bluffs Member and Sagwon Member of the Sagavanirktok Formation); abandonment of eight members or tongues (Kogosukruk, Rogers Creek, Barrow Trail, Sentinel Hill, Ayiyak, Shale Wall, Niakogon, and Killik); and definition of one new member (White Hills Member of the Sagavanirktok Formation).

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Introduction

Recent geologic investigations by the U.S. Geological Survey (USGS) and the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys (ADGGS) and Division of Oil and Gas (ADOG), in the outcrop belt north of the Brooks Range in northern Alaska have focused on Cretaceous and Tertiary rocks of the central and western parts of the Colville basin (fig. 1). Publicly available geologic maps of the Arctic North Slope and the northern flank of the Brooks Range have been published largely by the USGS and in recent years by the ADGGS and represent the work of numerous geologists over a period of more than 50 years. The maps have been published at a variety of scales, have varied cartographic styles, and utilize stratigraphic nomenclature that has evolved markedly over the years.

We are endeavoring to synthesize the stratigraphy of the area into a simplified and broadly applicable scheme suitable for a suite of geologic quadrangle maps that is being prepared jointly by the USGS, the ADGGS, and the ADOG at the scale of 1:250,000 (fig. 1). The new suite of maps will incorporate a consistent stratigraphic nomenclature and a uniform cartographic presentation and will be released in digital format.

In our recent studies on the central and western North Slope of Alaska, we have been aided by the availability of modern high-resolution false-color infrared aerial photographs and by Landsat satellite imagery. These relatively new types of photographs and images replace the low-resolution vertical and oblique twinplex black-and-white aerial photographs used by the pioneering geologists on the North Slope as they first delineated the stratigraphy and structure of the area. We also have been aided by the availability of modern helicopters with long-ranging capabilities that have made it possible to easily revisit the type localities of many of the stratigraphic units and to more easily trace units laterally on the ground and on aerial photographs. In addition, a large amount of new micropaleontologic data and additional collections of macrofossils have improved the biostratigraphic resolution. Reflection seismic data in some areas and modern sequence stratigraphic concepts also have facilitated understanding of stratigraphic relations in the Colville basin.

New regional stratigraphic insights, gained as a result of recent mapping and detailed stratigraphic and sedimentologic studies, particularly in the Umiat, Sagavanirktok, Chandler Lake, and Philip Smith Mountains quadrangles (fig. 2), suggest that simplification of stratigraphic nomenclature is warranted for both clarity of understanding and ease of use. We have found that some of the named stratigraphic units are not readily distinguishable from adjacent units in the field, have only limited distribution, and cannot be readily traced laterally into adjacent areas. As such, some of these units do not appear to represent consistently useful mappable rock units as defined by the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). In other cases, we have found that combining members of two formations represents a more readily mappable unit of genetically related rocks that can be traced laterally for many miles both in the field and through study of aerial photographs. The revised stratigraphic nomenclature and correlation with previous nomenclature are illustrated in figures 3 and 4. Revisions are summarized in table 1.

In the broader sense, we recognize that exposures of Tertiary and Cretaceous rocks in northern Alaska are the surface expression of a great thickness of clastic sediments derived from the ancestral Brooks Range and deposited in a foreland basin. Outcrop studies combined with subsurface well control and seismic data show that the foreland basin was filled in a northeasterly direction, that deposits in southern parts of the basin record more proximal facies, and that all depositional units grade northward and eastward into more marine and generally finer grained facies (Ahlbrandt, 1979; Huffman, 1985; Molenaar, 1985; Mull, 1985). Uplift and erosion in the foothills of the Brooks Range provide discontinuous exposures of these facies in a folded and faulted setting. The rock units discussed here are dominantly nonmarine to near-shore shallow-marine shelf sediments deposited in fluvial, delta-plain, delta-front, prodelta, and shallow-shelf environments. Slope and basinal sediments deposited as turbidites and other sediment gravity flows correlative with the units discussed here typically are found in the subsurface and are not included in the revised nomenclature. As a result of this regional perspective, we are proposing a simplified stratigraphic nomenclature in the belief that it will lead to a better understanding of the depositional and tectonic history of the basin.

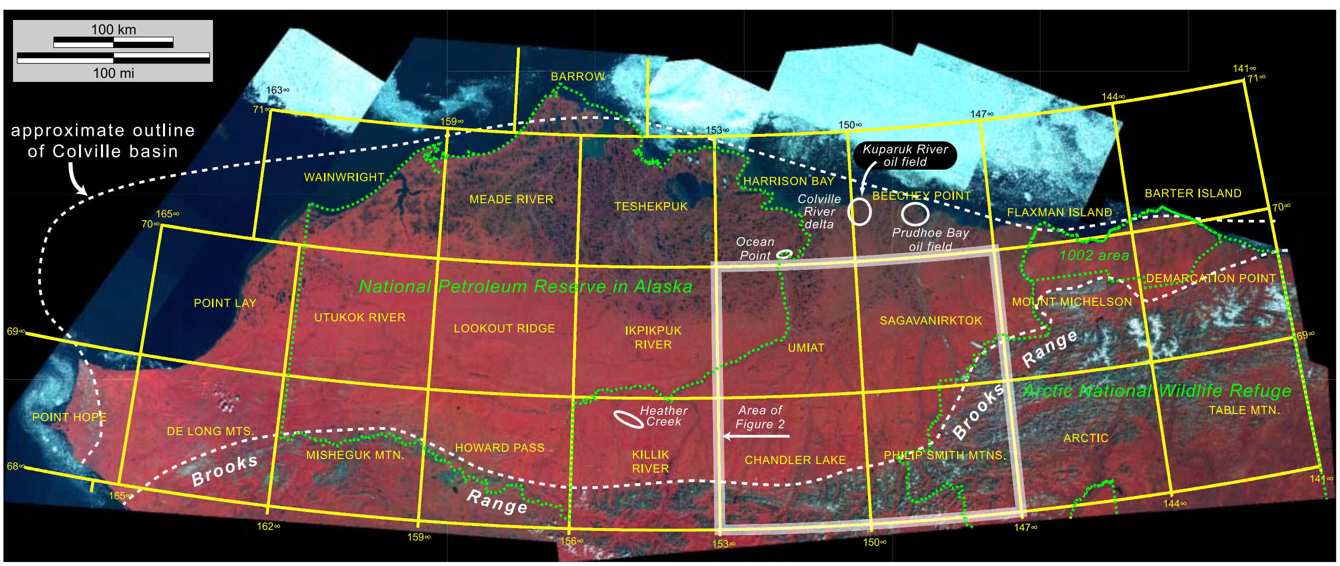

Figure 1. False-color composite Landsat image of northern Alaska showing quadrangles discussed in text and approximate outline of the Colville basin (dashed white line). New geologic maps are being prepared jointly by the U.S. Geological Survey and the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys and Division of Oil and Gas for many of the quadrangles. Boundaries for the National Petroleum Reserve in Alaska (NPRA), the Arctic National Wildlife Refuge (ANWR), and the ANWR 1002 area are shown in green, dotted lines. See Bird and Houseknecht (2001, 2002) for additional information regarding ANWR and NPRA, including explanation of ANWR 1002 area. Area outlined in white is shown in greater detail in figure 2. Image compiled by U.S. Geological Survey, Earth Resources Observation Systems (EROS) Data Center, Sioux Falls, S. Dak.

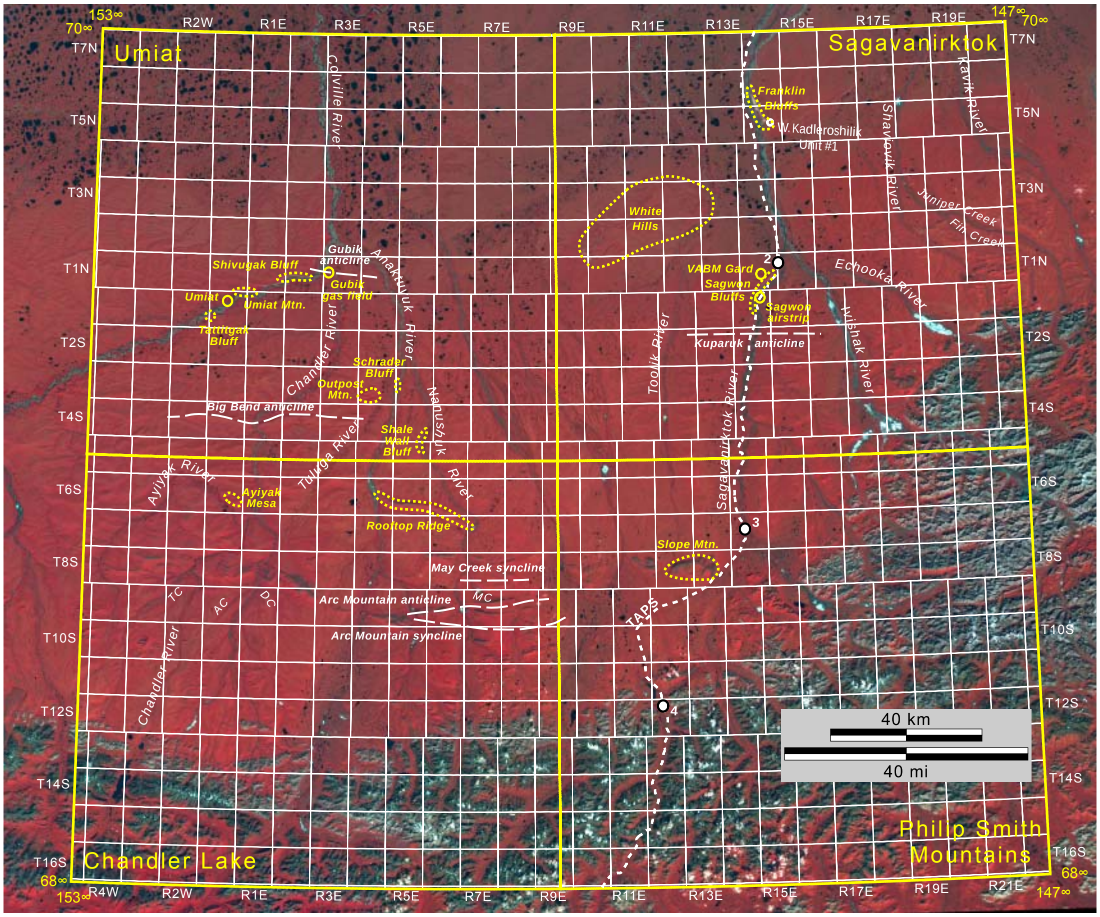

Figure 2. False-color composite Landsat image of the Umiat, Sagavanirktok, Chandler Lake, and Philip Smith Mountains quadrangles, northern Alaska, showing township-range grid, streams, and other features mentioned in text and figure captions. Recent geologic investigations in these quadrangles provided the basis for revisions of Cretaceous and Tertiary stratigraphic nomenclature presented in this paper. TAPS, Trans-Alaska Pipeline System; numbered white dots, TAPS pump stations with pump station number; AC, Autumn Creek; DC, Desolation Creek; MC, May Creek; TC, Torok Creek. Image compiled by U.S. Geological Survey, Earth Resources Observation Systems (EROS) Data Center, Sioux Falls, S. Dak.

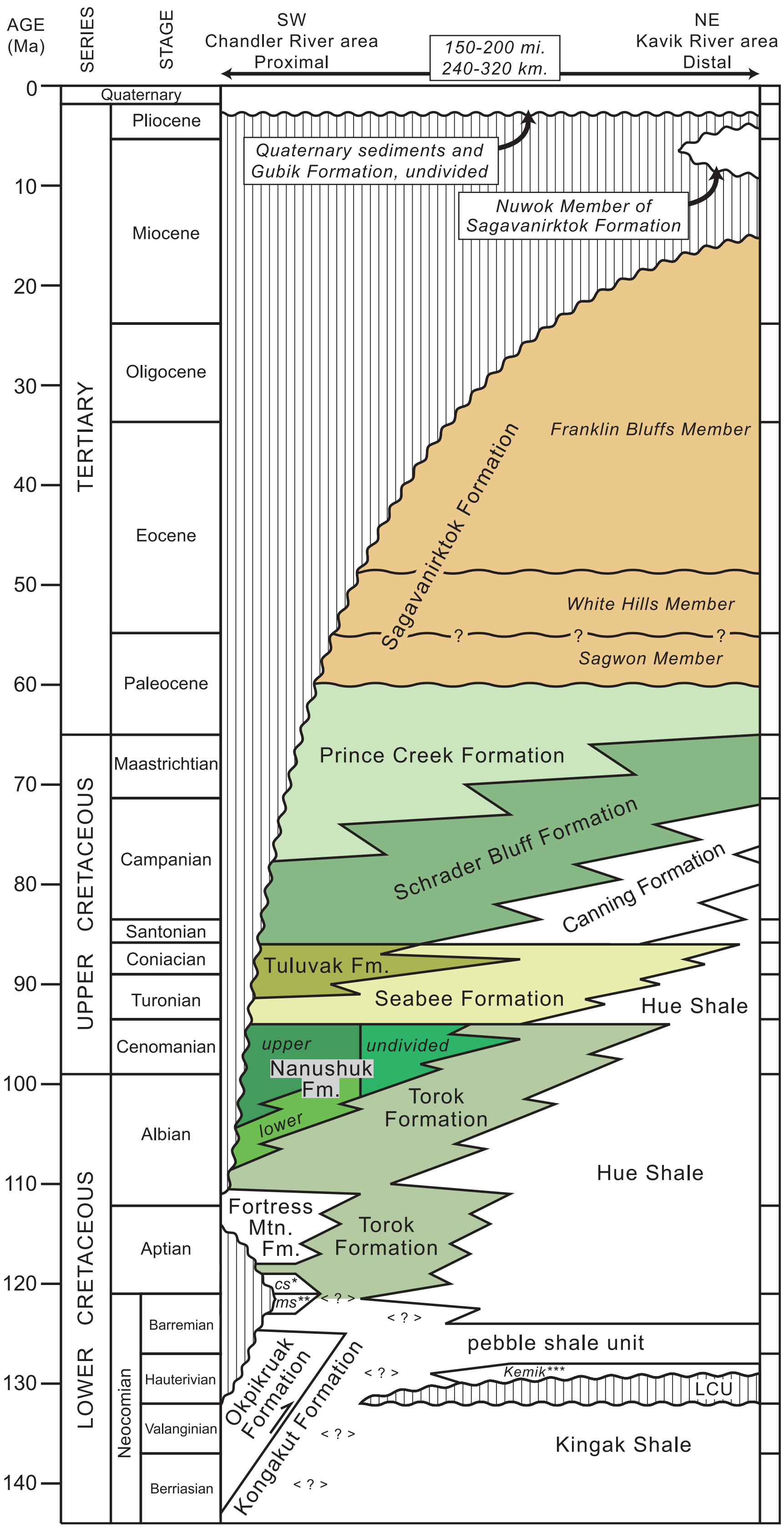

Figure 3. Chronostratigraphic column for the Colville basin, northern Alaska, showing revised stratigraphic nomenclature and ages of units discussed in this paper (in color); laterally correlative and overlying and underlying units not discussed in this paper are uncolored in diagram. Abbreviations or symbols are as follows: <?>, uncertain relationship; cs*, cobblestone sandstone of Fortress Mountain Formation (informal unit of Mull and others, 2003); ms**, manganiferous shale unit (informal term); Kemik***, Kemik Sandstone (formation) as revised by Molenaar and others (1987); Fm., Formation; Mtn., Mountain; LCU, Lower Cretaceous unconformity. Geologic time scale from Gradstein and Ogg (1996).

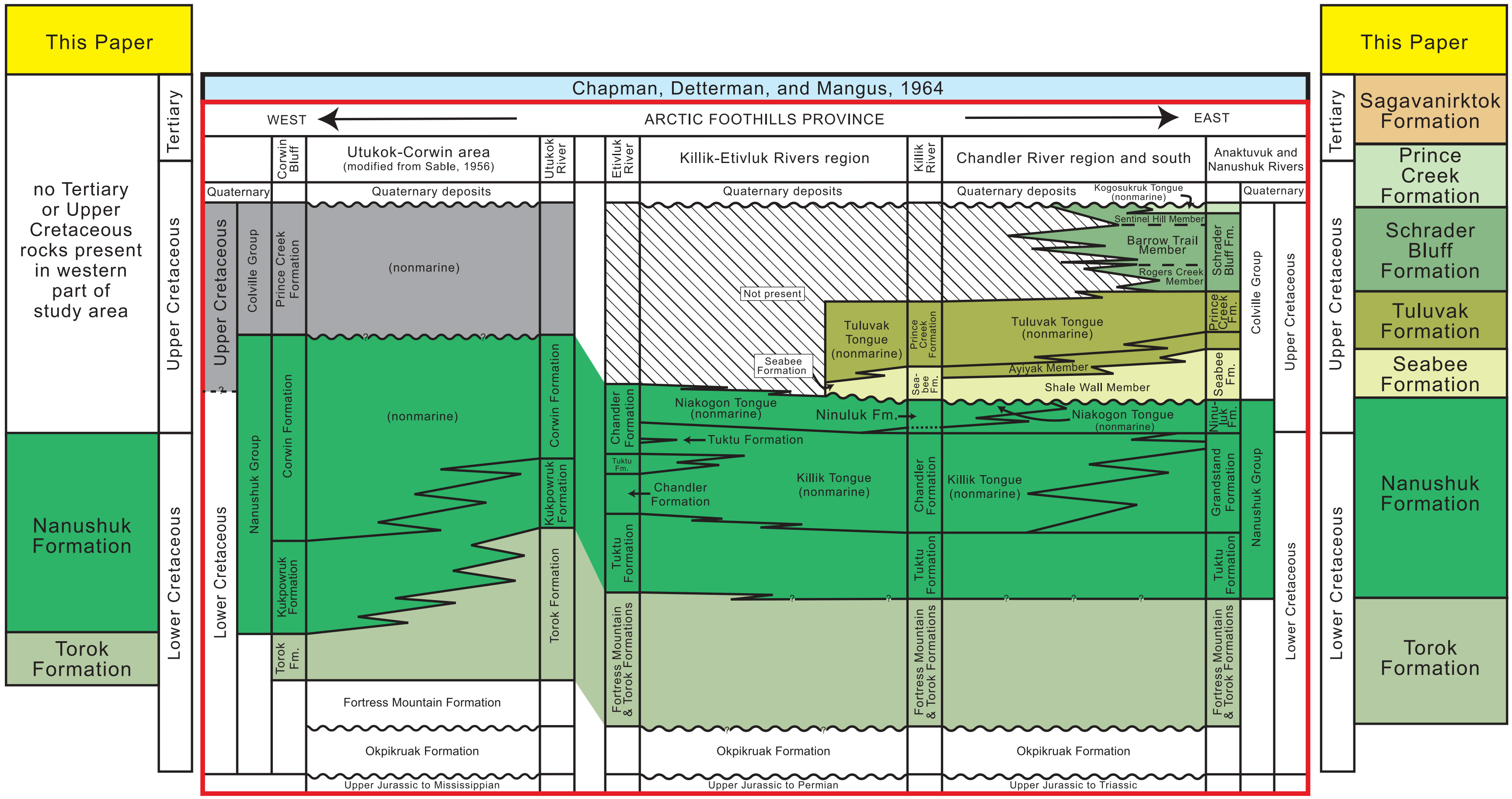

Figure 4. Chart illustrating relationship between former stratigraphic nomenclature and revised stratigraphic nomenclature as proposed in this paper for the Colville basin, northern Alaska. Stratigraphic columns in red box summarize lateral variation in previous stratigraphic nomenclature for Cretaceous strata from west to east across the western and central foothills of the Brooks Range, as presented by Chapman and others (1964). Colored columns on both sides of chart show revised stratigraphic nomenclature proposed in this paper. Colors extending across chart show correlation of newly revised nomenclature with previous nomenclature. Note that age and stratigraphic nomenclature indicated by gray have been revised; these rocks are now considered Early Cretaceous in age and assigned to the Nanushuk Formation. Quaternary units are not considered in this paper.

Table 1. New and revised Cretaceous and Tertiary stratigraphic nomenclature, Colville basin, northern Alaska.

This paper		Previous work		Comments
Unit	Age	Unit	Age	
Units of Tertiary age				
Sagavanirktok Formation (revised).	Paleocene to Pliocene(?).	Sagavanirktok Formation	Paleocene to Pliocene(?).	------
Nuwok Member (unchanged).	Miocene(?) to Pliocene(?).	Nuwok Member	Miocene(?) to Pliocene(?).	The Nuwok Member is exposed in the eastern Colville basin and was not considered in this study. The member was defined by Detterman and others (1975).
Franklin Bluffs Member (revised).	early Eocene to Miocene.	Franklin Bluffs Member	Oligocene(?) to Miocene(?).	The lower boundary of the Franklin Bluffs Member is revised.
White Hills Member (new).	late Paleocene(?) to early Eocene.	------	------	The White Hills Member includes some rocks formerly in the Franklin Bluffs and Sagwon Members.
Sagwon Member (revised).	late Paleocene	Sagwon Member	Paleocene to Eocene(?).	The upper and lower boundaries of the Sagwon Member are revised.
Units of Cretaceous to Tertiary age				
Colville Group (abandoned).	------	Colville Group	Late Cretaceous	Names are retained for units formerly in the Colville Group: Prince Creek Formation, Schrader Bluff Formation, Tuluvak Formation, and Seabee Formation.
Prince Creek Formation (revised).	Campanian to Paleocene.	Prince Creek Formation	Late Cretaceous	The revised Prince Creek Formation consists only of the rocks formerly mapped as the Kogosukruk Tongue. The Tuluvak Tongue is raised to formation rank.
Kogosukruk Tongue (abandoned).	------	Kogosukruk Tongue of the Prince Creek Formation.	Late Cretaceous	The Kogosukruk Tongue is abandoned. Its rocks are assigned to the Prince Creek Formation.

Table 1. New and revised Cretaceous and Tertiary stratigraphic nomenclature, Colville basin, northern Alaska—Continued.

This paper		Previous work		Comments
Unit	**Age**	**Unit**	**Age**	
Units of Cretaceous age				
Schrader Bluff Formation (revised).	Santonian to Maastrichtian.	Schrader Bluff Formation, consisting of, in descending order, Sentinel Hill Member, Barrow Trail Member, and Rogers Creek Member.	Late Cretaceous	The three named members of the Schrader Bluff Formation are abandoned; where appropriate, the informal terms upper, middle, and lower parts of the Schrader Bluff Formation are recommended.
Sentinel Hill Member (abandoned).	------	Sentinel Hill Member	Late Cretaceous	The Sentinel Hill Member is abandoned.
Barrow Trail Member (abandoned).	------	Barrow Trail Member	Late Cretaceous	The Barrow Trail Member is abandoned.
Rogers Creek Member (abandoned).	------	Rogers Creek Member	Late Cretaceous	The Rogers Creek Member is abandoned.
Tuluvak Formation (revised).	Turonian to Coniacian.	Tuluvak Tongue of the Prince Creek Formation and Ayiyak Member of the Seabee Formation.	Late Cretaceous	The Tuluvak Tongue is raised in rank to the Tuluvak Formation. The revised Tuluvak Formation includes rocks formerly mapped as the Tuluvak Tongue of the Prince Creek Formation and the Ayiyak Member of the Seabee Formation. The Ayiyak Member is abandoned.
Seabee Formation (revised).	Cenomanian to Coniacian, mostly Turonian.	Shale Wall Member of the Seabee Formation.	Late Cretaceous	The revised Seabee Formation includes only rocks formerly mapped as the Shale Wall Member of the Seabee Formation. The Shale Wall Member is abandoned.
Ayiyak Member (abandoned).	-------	Ayiyak Member of the Seabee Formation.	Late Cretaceous	The Ayiyak Member is abandoned. Its rocks are assigned to the Tuluvak Formation.
Shale Wall Member (abandoned).	-------	Shale Wall Member of the Seabee Formation.	Late Cretaceous	The Shale Wall Member is abandoned. Its rocks are assigned to the Seabee Formation.

Table 1. New and revised Cretaceous and Tertiary stratigraphic nomenclature, Colville basin, northern Alaska—Continued.

This paper		Previous work		Comments
Unit	Age	Unit	Age	
Units of Cretaceous age—Continued				
Nanushuk Formation (revised).	Albian to Cenomanian.	Nanushuk Group. On the east-central Arctic Slope, the former Nanushuk Group consisted of, in descending order, Ninuluk Formation (marine), Niakogon and Killik Tongues of Chandler Formation (nonmarine), Grandstand Formation (transitional marine and nonmarine), and Tuktu Formation (marine). On the western Arctic Slope, the former Nanushuk Group consisted of, in descending order, the Corwin Formation (nonmarine) and the Kukpowruk Formation (marine).	Early and Late Cretaceous.	The Nanushuk Group is reduced in rank to the Nanushuk Formation. The unit names (middle column) in the Nanushuk Group are abandoned. In areas in which the formation can be divided into dominantly nonmarine and dominantly marine units, the informal terms upper and lower parts of the Nanushuk Formation, respectively, are recommended.
Ninuluk Formation (abandoned).	-------	Ninuluk Formation	Early and Late Cretaceous.	The Ninuluk Formation is abandoned.
Chandler Formation (abandoned).	-------	Chandler Formation	Early and Late Cretaceous.	The Chandler Formation is abandoned.
Niakogon Tongue (abandoned).	-------	Niakogon Tongue	Early and Late Cretaceous.	The Niakogon Tongue is abandoned.
Killik Tongue (abandoned).	-------	Killik Tongue	Early and Late Cretaceous.	The Killik Tongue is abandoned.
Corwin Formation (abandoned).	-------	Corwin Formation	Early and Late Cretaceous.	The Corwin Formation is abandoned.
Grandstand Formation (abandoned).	-------	Grandstand Formation	Early Cretaceous	The Grandstand Formation is abandoned.
Tuktu Formation (abandoned).	-------	Tuktu Formation	Early Cretaceous	The Tuktu Formation is abandoned.
Kukpowruk Formation (abandoned).	-------	Kukpowruk Formation	Early Cretaceous	The Kukpowruk Formation is abandoned.
Torok Formation (unchanged).	Aptian to Cenomanian.	Torok Formation	Early Cretaceous	The formation definition is unchanged.

Stratigraphy

Torok Formation (Unchanged)

The Torok Formation was originally named by Gryc and others (1951) and revised by Patton (1956) for a thick sequence of dominantly nonresistant, fine-grained sedimentary rocks that underlie the herein revised Nanushuk Formation. The Torok forms the base of the folded sedimentary sequence that constitutes most of the northern foothills belt. The unit is typically poorly exposed, underlies lowland areas, and is generally exposed only in discontinuous stream cutbanks. The Torok Formation as revised by Patton (1956) is used here with no revision. We include this summary of the Torok for the sake of completeness because the formation is an important mappable unit across the region where we are preparing new digital geologic maps.

Patton (1956) designated the type section of the Torok Formation as a discontinuous series of exposures through approximately 6,000 ft of stratigraphic section along Torok Creek and the Chandler River in northwestern Chandler Lake quadrangle (fig. 2). The lower part of the type section is located along Torok Creek (sec. 9, 4, 3, and 2, T. 9 S., R. 2 W.), and the exposures continue up stratigraphic section along the Chandler River (sec. 2 and 1, T. 9 S., R. 2 W. and sec. 36, 25, and 23, T. 8 S., R. 2 W.).

Lithology

The Torok consists dominantly of dark-gray to black silty shale, mudstone, and clay shale with interbedded thin-bedded siltstone and lesser amounts of greenish-gray, thin-bedded siltstone and fine-grained sandstone (fig. 5). Fine- to medium-grained sandstone also is common in the lower part of the formation. Channelized, thin-bedded fine-grained sandstone and debris-flow deposits (fig. 6) are locally present in the lower part of the formation in the southern part of the fold belt and may represent a depositional style present but unexposed elsewhere in the belt. The unit can be broadly considered to represent the clinoform portion of the Nanushuk-Torok clastic wedge, with mudstone facies deposited in marine slope and basin-floor settings and sandstone facies deposited as turbidites in lower slope and basin-floor settings. Owing to its thickness and relative incompetence, the unit acts as a detachment surface for décollement folding of the overlying Nanushuk Formation and thus is commonly intensely deformed by chevron folding and faulting (fig. 7).

Oil-stained sandstone turbidite beds, primarily in the lower part of the formation, occur locally throughout the Torok outcrop belt. At a few locations, including a prominent bluff that is part of the type section along Torok Creek (sec. 3 and 2, T. 9 S., R. 2 W.), amalgamated sandstone beds that total as much as 300 ft in thickness are pervasively oil stained. The topographic expression of the oil-stained sandstones can be traced from the Torok Creek exposure eastward along strike for 12 mi, and similar exposures of oil-stained sandstones occur along this trend at Autumn Creek (sec. 6 and 7, T. 9 S., R. 1 E.) and at Desolation Creek (sec. 12, T. 9 S., R. 1 E.). This zone of oil-stained sandstones is a significant indication that similar turbidite deposits may be oil prospective to the north in the subsurface of the Colville basin.

Thickness

The Torok Formation ranges in thickness from more than 18,500 ft in the area of the outcrop belt on the south to less than 3,100 ft beneath the northern part of the Arctic Coastal Plain (Molenaar, 1985; Bird, 1988). The Torok Formation in surface exposures is commonly complexly folded, and subsurface seismic data suggest substantial amounts of tectonic thickening.

Age

The Torok Formation is Aptian to Cenomanian based on fossil evidence and subsurface relationships. Torok outcrops have yielded a limited ammonite and pelecypod fauna that has been dated as early and middle Albian (Detterman and others, 1963; Elder and others, 1989; Cole and others, 1997). The upper part of the formation has yielded both Foraminifera and palynomorphs of Albian age (Detterman and others, 1963; Micropaleo Consultants, 1999, 2000a,b). However, most surface samples from the lower part of the formation are either barren of microfauna or yield a relatively restricted nondiagnostic, long-ranging microfauna of Aptian to Albian age. Although it is commonly difficult or impossible to determine the exact stratigraphic level of most surface samples, those from what is thought to be the lower part of the formation have yielded a radiolarian fauna, whereas Foraminifera seem to be more common in the upper part of the formation. This apparent faunal distribution suggests that the lower part of the formation was deposited as bottomsets below the carbonate compensation depth (CCD), whereas at least the upper part of the foresets may have been above the CCD.

Subsurface evidence indicates the Torok Formation generally becomes younger to the east, from mostly Aptian in the western National Petroleum Reserve in Alaska (NPRA) to mostly Albian in the eastern NPRA (Bird and Molenaar, 1992). Seismic data in the region of the Colville River indicate that the uppermost part of the Torok Formation is equivalent to the uppermost part of the Nanushuk Formation (revised herein) (Houseknecht and Schenk, 2001), which has been dated as Cenomanian (see subsequent section).

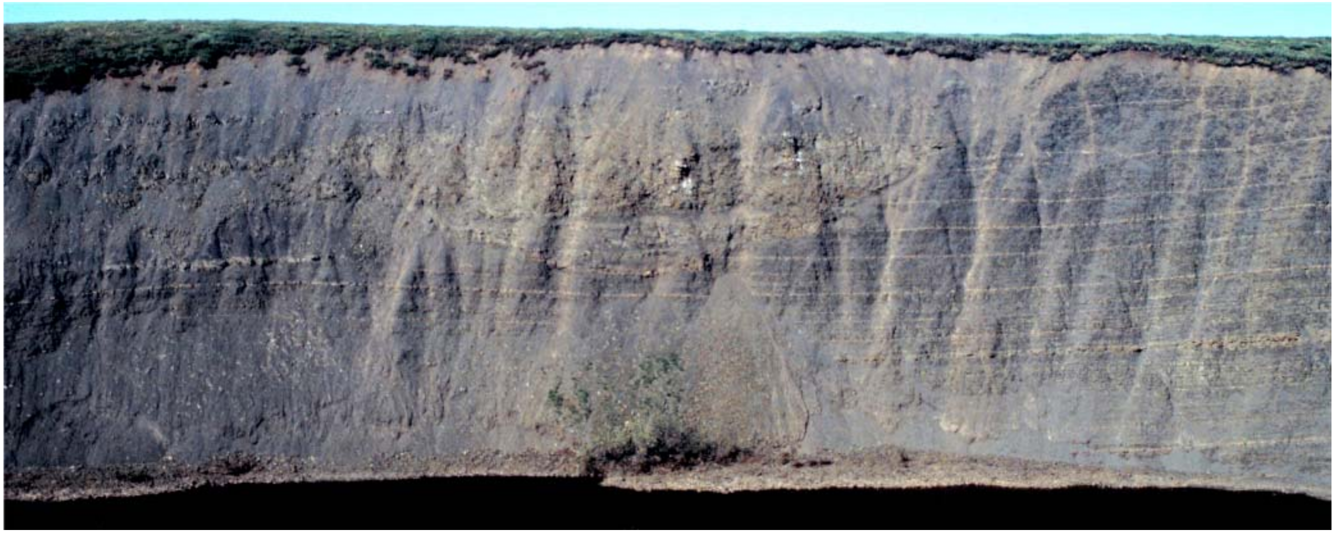

Figure 5. Sandstone in turbidite channel incised into interbedded mudstone and thin turbidite sandstones of Torok Formation on Heather Creek, Killik River quadrangle. Height of bluff is approximately 100 ft. View to north. Photograph by D.W. Houseknecht.

Figure 6. Poorly sorted pebble-cobble conglomerate in debris-flow deposit within Torok Formation, Autumn Creek, Chandler Lake quadrangle. Photograph by C.G. Mull.

Figure 7. Relatively incompetent folded and faulted mudstone in Torok Formation, Autumn Creek, Chandler Lake quadrangle. Exposure is about 25 ft high. View to east. Photograph by C.G. Mull.

Nanushuk Formation (Revised)

Schrader (1902) originally named the Nanushuk series after the Nanushuk River on the Arctic Slope of Alaska. Gryc and others (1951) applied the name "Nanushuk Group" to a thick series of resistant sandstone and conglomerate beds interbedded with shales, siltstones, and coals and exposed along the Nanushuk River in the east-central Colville basin. The group contained the Chandler and Umiat Formations; the Umiat Formation later was abandoned by Gryc (1956). Detterman (1956a) revised the group to include several intertonguing dominantly marine and nonmarine formations and tongues, in ascending order: the Tuktu Formation (dominantly marine), the Grandstand Formation (transitional marine and nonmarine), the Chandler Formation, and the Ninuluk Formation. The lower part of the Chandler Formation, which was considered to be dominantly nonmarine, was termed the Killik Tongue. The Killik Tongue, as defined by Detterman (1956a), was overlain by interfingering marine beds of the Ninuluk Formation and nonmarine beds of the Niakogon Tongue of the Chandler Formation, which together formed the top of the Nanushuk Group (figs. 3 and 4).

In the western part of the Colville basin, Sable (1956) revised the Nanushuk Group to consist of two formations: dominantly marine sandstones of the Kukpowruk Formation at the base interfinger upward with dominantly nonmarine sandstone, conglomerate, and interbedded coal of the Corwin Formation. Genetically and lithologically, the Kukpowruk Formation resembles the Tuktu Formation of the central Colville basin, and the Corwin Formation resembles the Chandler Formation. Molenaar (1985) discussed the Nanushuk Group and its regional setting in detail and illustrated the depositional setting and correlation of these genetically similar units from west to east across the Colville basin.

Subsequent reconnaissance mapping throughout the region has shown that in the central Colville basin, a number of the lithostratigraphic subdivisions of the Nanushuk Group (1) are not lithologically distinctive, (2) are commonly difficult to distinguish in the field on the basis of lithology, depositional facies, or stratigraphic position, (3) cannot readily be traced laterally, and (4) do not readily conform to the guidelines of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983) for recognition and mappability of lithostratigraphic units at the scale of mapping in common usage in northern Alaska (1:63,360 and 1:250,000). In the course of mapping in both the southwestern and southeastern parts of the Colville basin, Mull and others (2000, 2003) found that within the Nanushuk, only two regional mappable units can be distinguished readily and mapped at a scale of 1:63,360. These mappable units consist of the upper, dominantly nonmarine unit of sandstone, conglomerate, siltstone, shale, and coal and the lower, dominantly marine sandstone, siltstone, and shale unit that previous workers have recognized (figs. 8 and 9). The two units constitute deposits of a prograding delta plain and marine shelf and are characterized by a complicated pattern of lateral facies changes and both vertical and lateral interfingering of marine, marginal marine, and nonmarine beds. Thus, in some areas, marine intertongues are recognized within and at the top of the dominantly nonmarine upper part of the formation. Moreover, in the area of the northern parts of the Chandler and Nanushuk Rivers, the Nanushuk consists of only one mappable unit composed dominantly of marine and marginal marine sandstones.

In regional studies of the Nanushuk, Huffman and others (1985), Molenaar (1985), and Mull (1985) recognized the major marine and nonmarine units and showed that the Nanushuk and underlying Torok Formation represent coeval upper (topset) and lower (clinoform) parts, respectively, of a major eastward and northeastward prograding clastic wedge. The Nanushuk includes marine shelf, delta, and nonmarine deposits, whereas the Torok includes marine slope and basin-floor deposits. This Nanushuk-Torok clastic wedge progressively filled the Colville basin from west to east to an ultimate shelf margin located in the eastern Umiat and Chandler Lake quadrangles in the east-central Colville basin. As a result of this progradation, the Nanushuk thins eastward to a depositional pinchout at that shelf margin. Coeval strata in the eastern Colville basin consist of eastward thinning marine slope and basin-floor deposits that grade eastward into a condensed section, which is part of the Hue Shale (Bird and Molenaar, 1992).

In order to simplify the nomenclature and facilitate regional understanding of these rocks, the Nanushuk Group is here reduced in rank and revised as the Nanushuk Formation, consisting, where appropriate, of unnamed informal lower and upper units that are dominantly marine and nonmarine, respectively (figs. 8 and 9). The Kukpowruk, Tuktu, Grandstand, Corwin, Chandler, and Ninuluk Formations are here abandoned. The Killik and Niakogon Tongues of the Chandler Formation also are abandoned.

The Nanushuk Formation, as here revised, overlies and interfingers with shale and mudstone of the underlying Torok Formation; its top is marked by a sharp flooding surface that is disconformably overlain by marine shale of the Seabee Formation. A well-exposed reference section (fig. 9) of the transition from the upper part of the Torok Formation into overlying marine facies in the lower part of the Nanushuk Formation is located along the eastern bank of the Nanushuk River on the south flank of the Arc Mountain anticline (NW1/4 sec. 19, T. 9 S., R. 7 E.; fig. 2). This overall coarsening-upward succession, more than 500 ft thick, grades from silty shale in the upper part of the Torok to fine-grained sandstones, which form the prominent ridge shown in figure 9, in the lower part of the

Nanushuk. These sandstone beds display hummocky and swaley crossbedding and wave-ripple bedforms, evidence of the shallow-marine, shoreface setting in which they were deposited (LePain and Kirkham, 2001).

A reference section for the marine to marginal-marine part of the revised Nanushuk Formation is here designated as the well-exposed section on the west bank of the Nanushuk River at the east end of Rooftop Ridge (SW1/4 sec. 7, T. 7 S., R. 7 E.; fig. 2). More than 1,100 ft of silty shale, siltstone, and very fine to medium-grained sandstone are arranged in coarsening-upward successions that each range from 30 to more than 100 ft in thickness (LePain and Kirkham, 2001). Sandstone beds display plane-parallel lamination, hummocky and swaley crossbedding, and a variety of trace fossils; collectively these inorganic and organic sedimentary structures indicate deposition in a wave-dominated shoreface or delta-front setting (LePain and Kirkham, 2001). Some beds in this reference section are lightly oil stained and emit a hydrocarbon odor from freshly broken surfaces.

A reference section for the nonmarine part of the revised Nanushuk Formation is here designated as the easily accessible series of exposures in the axis of the Arc Mountain syncline east of the Nanushuk River (sec. 19 and 30, T. 9 S., R. 7 E.; fig. 2). The most prominent lithology in this part of the Nanushuk consists of crossbedded, medium-grained sandstone to pebble conglomerate (fig. 10) in lenticular beds that range from 20 to 80 ft in maximum thickness. These beds are laterally discontinuous and typically pinch out over a distance of 1 to 5 mi along strike (fig. 9). The lateral geometry and crossbedded nature of the beds suggest these are channel-shaped fluvial deposits. The sandstone and conglomerate beds are separated by recessive, tundra-covered slopes that probably conceal mudstones into which the lenticular sandstone beds are incised (fig. 9).

Throughout its outcrop area, the Nanushuk is relatively resistant and forms long, linear, cuestalike ridges and elevated mesas or plateaus that rise above adjacent lowlands underlain by less resistant shales of the underlying Torok Formation and overlying Seabee Formation. The beds of the Nanushuk define the surface exposure of most of the anticlines and synclines in the Colville basin fold belt.

Lithology

The upper part of the Nanushuk Formation consists of numerous thick horizons of typically fine- to medium-grained, and in places coarse-grained, gray to light-gray lithic arenites and quartz- and chert-pebble conglomerate that commonly form resistant ledges and cuestas (fig. 10), interbedded with poorly exposed dark-gray carbonaceous shale and coal. The sand grains are dominantly quartz and chert, with lesser calcite, feldspar, and lithic grains. The conglomerate consists predominantly of subrounded pebbles and cobbles of white quartz and black, gray, greenish-gray, and maroon chert, local ironstone, coal, gray sandstone, quartzite, argillite, and mafic igneous clasts. Clasts generally range up to 2 in. in diameter, but in the extreme western Colville basin, near the western source of detritus, boulder conglomerates contain numerous clasts more than 6 in. in diameter. The sandstones are generally nonporous, except for beds in the uppermost part of the formation, which were deposited under greater marine influence and commonly exhibit better porosity and permeability (Ahlbrandt and others, 1979). The wide variety of depositional settings in which these sediments were deposited was illustrated by Molenaar (1985).

The lower, dominantly marine part of the Nanushuk typically consists of greenish-gray, very fine to fine-grained, locally fossiliferous sandstone (fig. 11), with minor conglomerate in some localities. It interfingers upward with marginal marine to nonmarine beds at the top of the unit; its base interfingers with the upper part of the Torok Formation. The lower Nanushuk forms the generally resistant high linear ridge of the Tuktu Escarpment and defines the flanks of many anticlines in the foothills belt (fig. 9).

Thickness

In the outcrop belt of the central Colville basin, the Nanushuk Formation thins from about 4,600 ft in the western Chandler Lake quadrangle, where it consists of both nonmarine and marine units, to about 775 ft to the northeast, where the formation consists dominantly of marine and marginal marine sandstone. Subsurface data reveal that the formation pinches out along an ultimate shelf margin, which trends southward from the area of the Colville River delta to the southeast part of the Umiat quadrangle and then eastward across the Sagavanirktok quadrangle.

In areas where both the dominantly marine and nonmarine parts of the formation can be distinguished, the proportion of the formation that is nonmarine decreases gradationally from south to north and from west to east. This regional trend reflects the predominant proximal to distal sediment dispersal pattern during deposition of the Nanushuk Formation as documented by previous workers (Huffman and others, 1985; Molenaar, 1985; Mull, 1985; Bird and Molenaar, 1992). In the western Colville basin, closer to the western source of detritus, the thickness of the combined marine and nonmarine parts of the Nanushuk increases markedly to over 20,000 ft (Chapman and Sable, 1960). Molenaar (1985) tabulated the thickness of the Nanushuk in surface localities and wells throughout the Colville basin, and Bird (1988) presented an isopach map of the Nanushuk in the NPRA.

Age

Throughout the geographic extent of the Nanushuk Formation, the marine beds contain a locally abundant and varied megafauna consisting dominantly of pelecypods and lesser numbers of gastropods and ammonites; plant fossils are common in the nonmarine beds, and a microfauna has been recovered from shales. Detailed studies of both megafauna and microfauna were reported by Detterman and others (1963) and Brosgé and Whittington (1966) and show that the Nanushuk Formation as here revised ranges from middle Albian to Cenomanian. These data indicate that most of the formation is Albian and that only the top of the upper part of the formation extends into the Cenomanian. Studies of plant microfossils and megafossils (May, 1979; May and Stein, 1979; Scott and Smiley, 1979; May and Shane, 1985; Spicer and Herman, 2001) also indicate an Albian to Cenomanian age for the Nanushuk Formation. Samples collected in our current studies have yielded an Albian microfauna from the Nanushuk in the Chandler Lake quadrangle (Micropaleo Consultants, 2001).

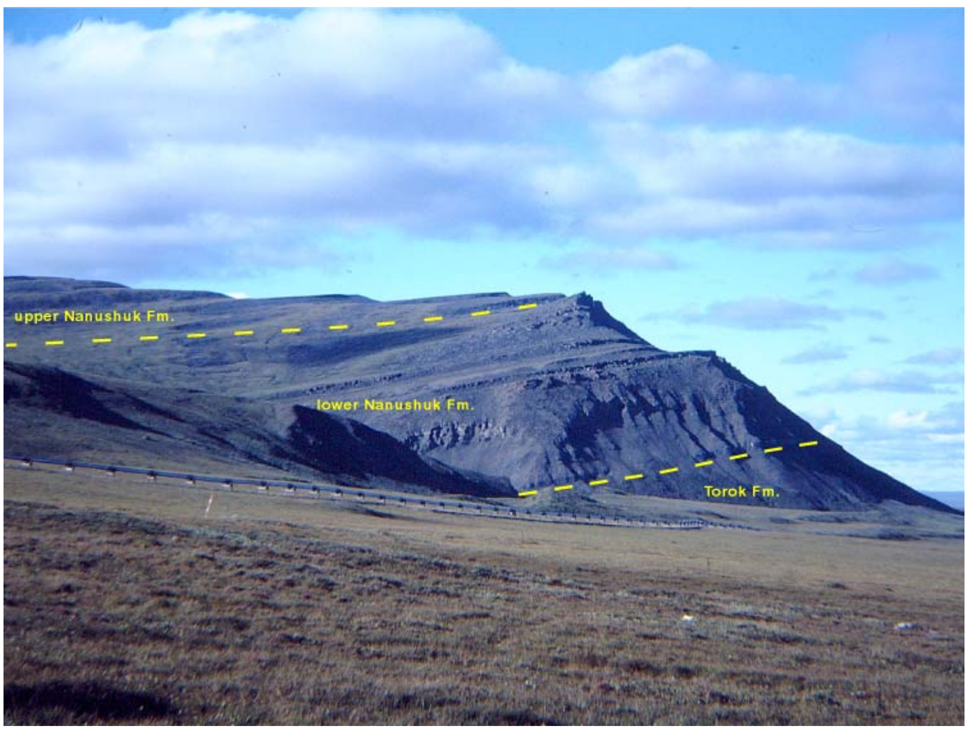

Figure 8. Slope Mountain, a prominent landmark in northwestern Philip Smith Mountains quadrangle near Mile 305 of the Dalton Highway. Upper part of mountain consists of dominantly nonmarine sandstone, conglomerate, and coal of upper Nanushuk Formation overlying dominantly marine sandstone of lower Nanushuk, which prograded over outer shelf silty mudstones of Torok Formation exposed in lowermost slope. Note Trans-Alaska Pipeline at base of mountain. View to northwest. Photograph by C.G. Mull.

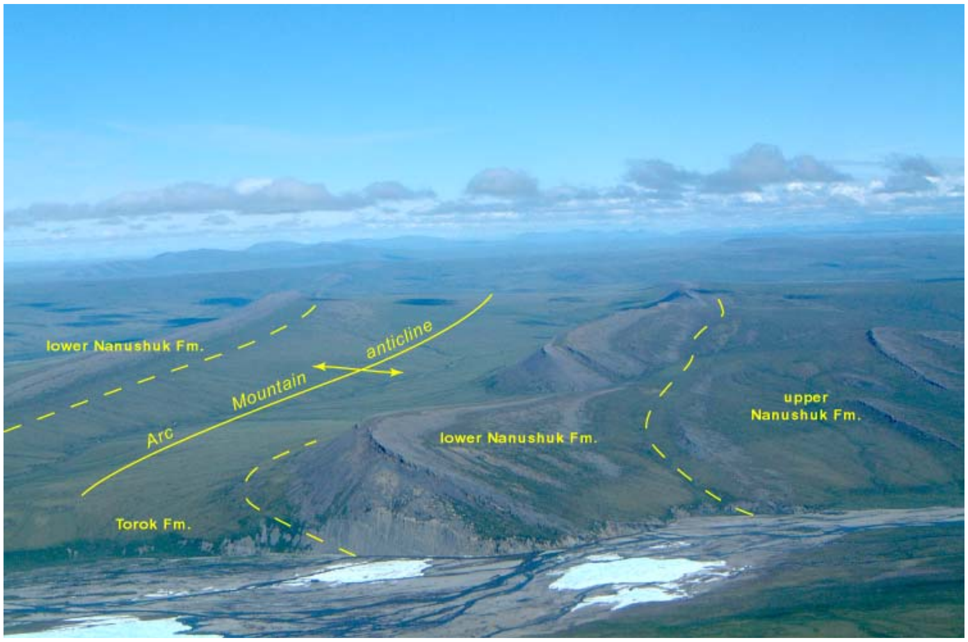

Figure 9. Nanushuk Formation on south flank of Arc Mountain anticline at Nanushuk River, eastern Chandler Lake quadrangle. Lowland, tundra-covered core of anticline is underlain by mudstone of Torok Formation as shown in left-center of photograph. Marine sandstones of lower Nanushuk form resistant ridge on south flank of anticline; discontinuous ledges of dominantly nonmarine sandstone and conglomerate of upper Nanushuk are exposed to the right in axis of Arc Mountain syncline. View to east. Photograph by C.G. Mull.

Figure 10. Resistant, crossbedded sandstone and conglomerate in characteristic exposure of upper part of Nanushuk Formation west of the Anaktuvuk River, Chandler Lake quadrangle. Exposure is about 25 ft thick. View to west. Photograph by C.G. Mull.

Figure 11. Crossbedded sandstone in upper part of lower Nanushuk Formation on Slope Mountain, Philip Smith Mountains quadrangle. Predominance of planar crossbedding and local occurrence of herringbone crossbedding (above arrowhead) suggest deposition in a shoreface system influenced by tidal currents (perhaps a tidal inlet on a barred coast). View to north. Photograph by D.W. Houseknecht.

Colville Group (Abandoned)

The Colville Group was formally defined by Gryc and others (1951) to include Upper Cretaceous strata lying above the Nanushuk Group (Albian to Cenomanian) and below the Sagavanirktok Formation (Tertiary). It consists of a wide variety of relatively resistant to nonresistant, intertonguing nonmarine, marginal-marine, and marine deposits of the Seabee, Tuluvak, Schrader Bluff, and Prince Creek Formations. Owing to the diversity of lithologies within the Colville Group, it underlies a wide variety of topographic landforms and has no characteristic map character or pattern that can be readily recognized on aerial photographs. As a result, in recent years, the term “Colville Group” has fallen into disuse. We herein abandon the Colville Group. The more readily mappable Seabee, Tuluvak, Schrader Bluff, and Prince Creek Formations should be used individually in the future.

Seabee Formation (Revised)

Gryc and others (1951) defined the Seabee Member as the lowest of three members of the Schrader Bluff Formation and named the member for Seabee Creek, a tributary of the Colville River near Umiat (fig. 2). Exposures along Seabee Creek were designated as the type locality of the Seabee Member (Gryc and others, 1951; Whittington, 1956). The unit was elevated to formation status by Whittington (1956), who redesignated Umiat test well No. 11 as the type locality for the Seabee Formation.

Detterman (1956b) defined the Ayiyak Member of the Seabee Formation, naming the unit for the Ayiyak River (fig. 2) along which it is exposed. Exposures along the east fork of the Tuluga River in the north-central part of the Chandler Lake quadrangle were designated as the type locality (Detterman, 1956b). According to Detterman (1956b), the unit consists of tuffaceous siltstone, silty shale, and sandstone that overlies “the dark, marine clay shale typical of the Seabee Formation” and underlies the nonmarine clastic beds of the Tuluvak Formation as revised in this report. Whittington (1956) provided additional descriptions of the Ayiyak Member and further explained its stratigraphic relations.

Detterman and others (1963) defined the Shale Wall Member of the Seabee Formation, naming the unit for Shale Wall Bluff along the western bank of the Nanushuk River in southeastern Umiat quadrangle (fig. 2). The exposure at Shale Wall Bluff was designated as the type section of the Shale Wall Member (Detterman and others, 1963). The Shale Wall Member consists dominantly of shale and abundant bentonite.

The coarser clastic rocks of the Ayiyak Member are lithologically more similar to, and genetically more closely related to, the sandstone and conglomerate of the overlying Tuluvak Formation as herein revised. For this reason, the Ayiyak Member is here abandoned and rocks previously assigned to the Ayiyak Member are included in the lower part of the Tuluvak Formation as revised in this paper.

The Seabee Formation is here revised to consist only of the rocks previously assigned to the Shale Wall Member, which is here abandoned. The lower contact of the Seabee Formation with the underlying Nanushuk Formation is not well exposed but appears to be both abrupt and conformable. This contact is thought to represent a major transgressive marine flooding surface at the top of the Nanushuk Formation. At the top, the Seabee Formation interfingers with thin-bedded sandstone and siltstone of the lower part of the Tuluvak Formation as revised in this report.

Because of the abundance of bentonite in the Seabee Formation, it is relatively incompetent, is rarely well exposed, and is commonly intensely folded. It commonly underlies broad tundra-covered valleys with scattered white-weathering bare shale patches downslope from resistant ridges of Tuluvak Formation as revised herein.

The most continuous exposure of the Seabee Formation is at Shale Wall Bluff on the Nanushuk River (sec. 2, T. 5 S., R. 5 E., to sec. 35, T. 4 S., R. 5 E.; fig. 2), about 35 mi southeast of Umiat. This exposure, designated by Detterman and others (1963) as the type section of the Shale Wall Member (herein abandoned), is a reference section for the revised Seabee Formation. The exposed section at Shale Wall Bluff, more than 1,300 ft thick, includes fissile, organic-matter-rich paper shale with bentonite interbeds; large concretions (4 ft in diameter); and the gradation into sandstones of the overlying Tuluvak Formation as revised in the following section.

The upper part of the formation is well exposed in a Colville River bluff (fig. 12) at the base of Umiat Mountain (NW1/4 sec. 6, T. 1 S., R. 1 E.; fig. 2) 3 mi downstream from Umiat. It also is exposed in scattered stream cuts along the Chandler and Nanushuk Rivers and locally along tributaries of the upper Ikpikpuk River west of Umiat.

Lithology

The Seabee Formation as here revised consists of mudstone, silty mudstone, and distinctive medium- to dark-gray to black, fissile, organic-matter-rich paper shale, with interbedded bentonite and some thin, silicified tuff beds (fig. 13). Thin siltstone and fine-grained sandstone beds are locally present in the upper part of the Seabee near its upward transition into the overlying Tuluvak Formation. Very large concretions approximately 4 ft in diameter are common in some localities (fig. 14).

Thickness

The Seabee Formation seems to thicken markedly eastward. Detterman and others (1963) reported thicknesses of less than 400 ft west of the Chandler River and nearly 1,200 ft along the Nanushuk River in the eastern part of the Chandler Lake quadrangle. More than 1,300 ft of section is exposed at Shale Wall Bluff.

Seismic data in the Umiat quadrangle indicate that the Seabee Formation thickens abruptly eastward across the ultimate shelf margin formed by the underlying Nanushuk Formation. The Seabee Formation is less than 500 ft thick west of that ultimate Nanushuk shelf margin, and the Seabee is 2,000 to 3,000 ft thick east of that ultimate Nanushuk shelf margin.

Age

The Seabee Formation as here revised ranges in age from Cenomanian to Coniacian. Detterman and others (1963) and Jones and Gryc (1960) reported that an ammonite and pelecypod megafauna and a microfauna, which are more abundant in the lower part of the formation, are indicative of a Turonian age for the Seabee Formation. A review of these paleontologic data by Lanphere and Tailleur (1983) and comparison with then-current biostratigraphy reached the same conclusion—that the Seabee Formation is no older than Turonian. However, isotopic ages reported for bentonites in the Seabee range from 93.6 to 91.5 Ma (Lanphere and Tailleur, 1983; D.W. Houseknecht, USGS, and D.L. LePain, ADGGS, unpublished data, 2002) and suggest that the basal part of the Seabee might be as old as latest Cenomanian. The Cenomanian-Turonian boundary is 93.5±0.2 Ma according to Gradstein and others (1994). Foraminifera and palynomorphs suggest that the upper part of the formation may range to as young as Coniacian (Micropaleo Consultants, 2002).

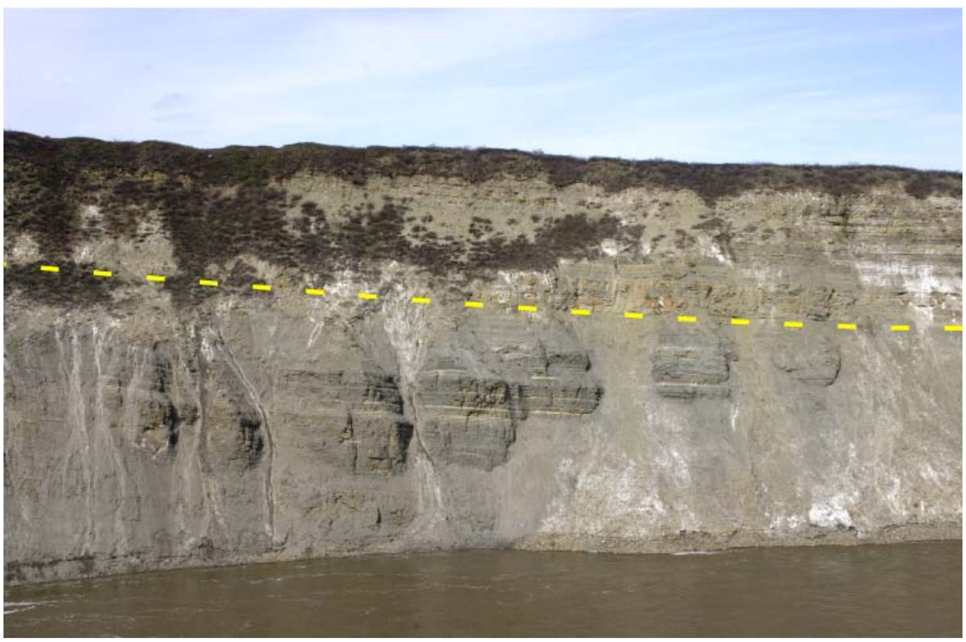

Figure 12. Exposure of Seabee Formation overlain by Tuluvak Formation along Colville River at base of Umiat Mountain, central Umiat quadrangle. The Seabee Formation extends from river level more than halfway up to prominent sandstone at base of Tuluvak Formation; contact is shown by yellow dashed line. Note yellow tuff beds within Seabee. Bluff has approximately 400 ft of relief. View to north. Photograph by D.W. Houseknecht.

Figure 13. Seabee Formation at base of Umiat Mountain showing predominant mudstone lithology with yellow tuff interbeds. Hammer for scale. Photograph by D.W. Houseknecht.

Figure 14. Bentonitic shale with large concretions in upper part of Seabee Formation, east fork of Tuluga River. View to west. Largest concretions are approximately 4 ft in diameter. Photograph by C.G. Mull.

Tuluvak Formation (Revised)

As originally defined by Gryc and others (1951) and further described by Whittington (1956), a conspicuous unit of sandstone and conglomerate underlying the Schrader Bluff Formation was named the Tuluvak Tongue of the Prince Creek Formation. In the southern Umiat and northern Chandler Lake quadrangles, the unit is widespread, and its middle part forms conspicuous resistant mesas and elevated uplands (figs. 15 and 16) in the axes of regional synclines, where it can be easily traced relatively long distances on aerial photographs. Parts of the Tuluvak are well exposed in scattered resistant bluffs where cut by stream drainages. Because it is an easily mappable unit on a regional basis, the Tuluvak Tongue is here elevated to formation status.

An underlying thickening- and coarsening-upward unit of fine-grained sandstones, siltstones, and interbedded shales formerly defined as the Ayiyak Member of the underlying Seabee Formation (Detterman, 1956b) is here reassigned to the Tuluvak Formation and the Ayiyak Member is herein abandoned.

Although the top of the Tuluvak Formation is not well exposed, it is probably gradational and interfingers upward with the overlying Schrader Bluff Formation. The contact with the Schrader Bluff Formation is drawn at the top of the uppermost prominent sandstone or conglomerate above which the overlying section is predominantly shale.

Inasmuch as the Tuluvak Formation is not well exposed in its type area along the Chandler River, exposures of the formation near the Ayiyak River (sec. 31, T. 6 S., R. 3 W.), on Ayiyak Mesa west of the Chandler River (sec. 25, T. 6 S., R. 1 W.), and between the Nanushuk and Anaktuvuk Rivers (N1/2 sec. 12, T. 7 S., R. 5 E.) are suggested as partial reference sections. At Ayiyak Mesa, a section more than 60 ft thick contains crossbedded conglomerate and pebbly sandstone. The conglomerate includes chert, quartz, and quartzitic sandstone clasts that range up to 18 in. in diameter. At the location between the Nanushuk and Anaktuvuk Rivers, crossbedded pebble conglomerate and pebbly sandstone are exposed along a subtle ledge about 20 ft thick. At this site and nearby locations, the conglomerate is very well sorted and consists dominantly of well-rounded, pebble-sized clasts of white quartz and black chert.

Lithology

Exposures of the middle part of the Tuluvak Formation, which is its coarsest and best-exposed part, demonstrate a marked vertical and also eastward and northeastward gradational progression from coarser to finer grained and from nonmarine braided-stream deposits to marine sandstones in its eastern exposures. Tuluvak exposures in the western part of the Chandler Lake quadrangle near the Ayiyak River (sec. 31, T. 6 S., R. 3 W.; fig. 2) and Chandler River (sec. 25, T. 6 S., R. 1 W.) contain abundant cobble to boulder conglomerate, and the clast size and thickness of conglomerate decrease markedly to the east. North of the Colville River, pebble and minor cobble conglomerate is reported in the eastern Ikpikpuk River quadrangle (Brosgé and Whittington, 1966). Interbedded coals and carbonaceous shales also are abundant north of the Colville River. At several localities near the Nanushuk River in the eastern Chandler Lake quadrangle and near the Anaktuvuk River in the southern Umiat quadrangle, the upper part of the Tuluvak contains beds up to 25 ft thick of conspicuous, distinctive pebble conglomerate (fig. 17), which is composed of well-rounded and well-sorted quartz and black chert pebbles ranging in size from pea gravel to small pebbles 0.5 in. in diameter (fig. 18), and well-sorted fine- to medium-grained quartz sandstone (sec. 34, T. 8 S., R. 7 E.). Sandstone and conglomerate with clasts having diameters as large as 1.5 in. are particularly well exposed at an isolated stream cut between the Nanushuk and Anaktuvuk Rivers at N1/2 sec. 12, T. 7 S., R. 5 E. At Schrader Bluff on the Anaktuvuk River (sec. 30, T. 3 S., R. 5 E.; fig. 2) and on the Nanushuk River downstream from Shale Wall Bluff (sec. 13, T. 4 S., R. 5 E.; fig. 2), the formation contains dominantly fine- to medium-grained sandstone (fig. 19).

The eastward thinning and fining of the conglomerate in the Tuluvak suggest that the unit prograded eastward across the area of the Chandler Lake and Umiat quadrangles to a shelf margin that at the time of Tuluvak deposition may have been located in the western Sagavanirktok quadrangle. The Tuluvak is not recognized as a mappable unit in the Sagavanirktok quadrangle. However, an unnamed tributary of the Sagavanirktok River in the central Sagavanirktok quadrangle (E1/2 sec. 17, T. 3 S., R. 15 E.) may contain distal deposits that are correlative with the Tuluvak.

The marine sandstones in the upper part of the Tuluvak in the Chandler Lake quadrangle are composed dominantly of greater than 95 percent clean, well-sorted, well-rounded, fine- to medium-grained quartz sandstone. The beds are characterized by conspicuous low-angle crossbedding, marine pelecypods, and trace fossils that are indicative of marine or marginal marine deposition. Many outcrops reveal sandstones that are friable and contain visible porosity and would be excellent hydrocarbon reservoir units if present in the subsurface. However, in the Ikpikpuk River quadrangle north of the Colville River, in the area where interbedded coals are common, Brosgé and Whittington (1966) reported that many sandstones in the Tuluvak Formation are ferruginous and calcareous lithic sandstones containing <30 percent quartz.

The Tuluvak Formation is the dominant reservoir horizon for the Gubik gas field (fig. 2), which is 17 mi northeast of Umiat (Robinson, 1958). The Tuluvak is locally oil stained on the north flank of Big Bend anticline (fig. 20) (W1/2 sec. 5, T. 4 S., R. 4 E.; fig. 2).

Thickness

The Tuluvak Formation as here revised is probably as much as 1,200 ft thick. The upper part of the unit, formerly called the Tuluvak Tongue of the Prince Creek Formation, has been measured in a number of localities (Detterman and others, 1963; Brosgé and Whittington, 1966; Detterman and others, 1975) and is reported to be as thick as 830 ft. Rocks formerly considered part of the Ayiyak Member of the Seabee Formation are reported to be as thick as 370 ft. However, our regional reconnaissance studies suggest that the Tuluvak Formation as here revised is probably <460 ft thick in the vicinity of the Nanushuk River in the eastern Chandler Lake quadrangle.

Age

The Tuluvak Formation as here revised is Turonian to Coniacian. On the basis of a pelecypod fauna, Jones and Gryc (1960) inferred a late Turonian age for the Ayiyak Member of the Seabee Formation, which is here abandoned and its rocks reassigned to the lower part of the Tuluvak Formation. Brosgé and Whittington (1966) suggested that the rocks here considered to be the upper part of the Tuluvak Formation are probably equivalent to the Coniacian because of the age of the overlying lower part of the Schrader Bluff Formation. Shales from the lower part of the Tuluvak Formation along the Nanushuk River are dated as Turonian to Coniacian (Micropaleo Consultants, 2001), whereas the lower part of the overlying Schrader Bluff Formation is dated as Santonian (discussed below).

Figure 15. Marine or marginal marine sandstone and pea-gravel conglomerate in Tuluvak Formation in May Creek syncline, north of May Creek, eastern Chandler Lake quadrangle. Ledge-forming conglomerate is about 20 ft thick. View to north. Photograph by C.G. Mull.

Figure 16. Discontinuous, resistant ledge of Tuluvak Formation on north flank of Big Bend anticline, south side of Outpost Mountain, southern Umiat quadrangle. View to north. Photograph by C.G. Mull.

Figure 17. Fluvial conglomerate of Tuluvak Formation near the Anaktuvuk River in the southern Umiat quadrangle. Conglomerate ledge is about 25 ft thick. View to east. Photograph by C.G. Mull.

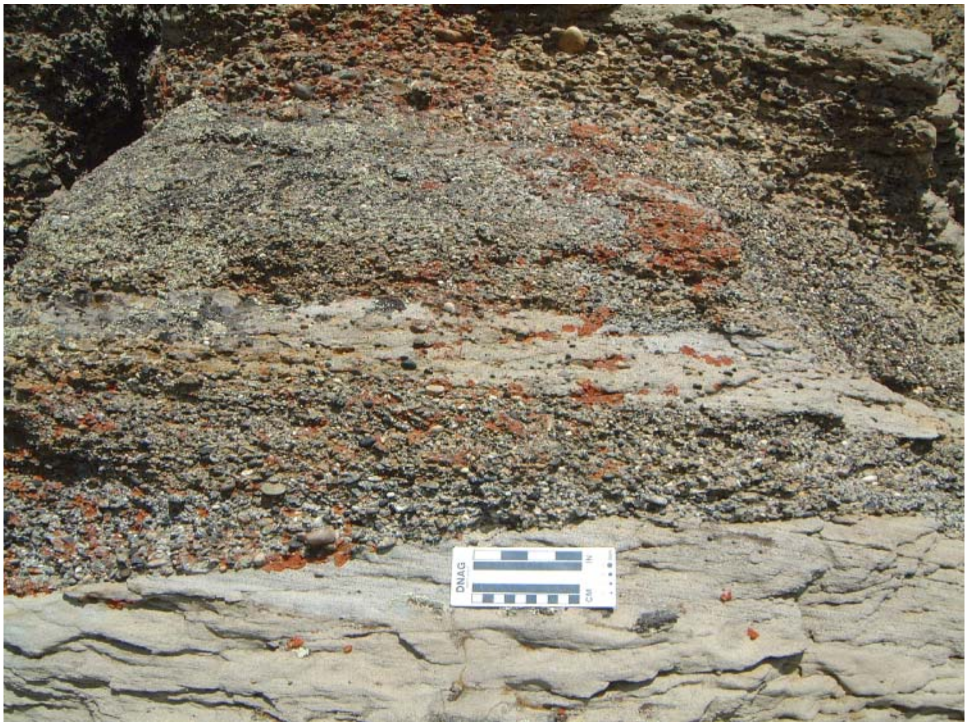

Figure 18. Crossbedded quartz- and chert-pebble conglomerate and sandstone in Tuluvak Formation at same outcrop shown in figure 17. A sandstone sample from this locality has measured 18 percent porosity and 812 millidarcies (mD) permeability (data from C.G. Mull). Photograph by C.G. Mull.

Figure 19. Bioturbated marine sandstone in Tuluvak Formation along west side of Nanushuk River on south side of Rooftop Ridge, Chandler Lake quadrangle. Photograph by D.W. Houseknecht.

Figure 20. Oil-stained sandstone in Tuluvak Formation, north flank of Big Bend anticline near Outpost Mountain. Photograph by C.G. Mull.

Schrader Bluff Formation (Revised)

The Schrader Bluff Formation was named by Gryc and others (1951) for Schrader Bluff, a prominent feature on the Anaktuvuk River just south of the junction with the Tuluga River (fig. 2). The unit consists dominantly of marine sandstones and shale, which are locally and variably tuffaceous (Gryc and others, 1951; Whittington, 1956). The Schrader Bluff Formation is divided into three members, in ascending order: the Rogers Creek, Barrow Trail, and Sentinel Hill Members. The Rogers Creek and Sentinel Hill Members were defined from subsurface information because surface exposures are poor. The type section for the Rogers Creek Member was designated in the U.S. Navy Gubik No. 1 (sec. 19, T. 1 N., R. 3 E.) and U.S. Navy Gubik No. 2 (sec. 20, T. 1 N., R. 3 E.) test wells by Whittington (1956). The type section for the Sentinel Hill Member was designated in the U.S. Navy Sentinel Hill Core Test No. 1 (sec. 20, T. 3 N., R. 3 E.) by Gryc and others (1951). The Barrow Trail Member is well exposed in the foothills of the central Colville basin and the type locality was designated as “the bluffs along the north side of the Colville River 3 to 5 mi northeast of Umiat Mountain” (Whittington, 1956).

The Schrader Bluff Formation overlies the Tuluvak Formation (revised) and is succeeded by the overlying, regressive, dominantly nonmarine Prince Creek Formation (revised). Subsurface data indicate that the Schrader Bluff Formation intertongues basinward (northeastward) with deeper marine strata of the Canning Formation (Molenaar and others, 1987), but that relationship is not expressed in the outcrop belt of the Brooks Range foothills.

Regional relationships suggest a general northeasterly progradation of the Schrader Bluff and overlying Prince Creek Formations, which collectively appear to be a genetically related, large-scale prograding couplet of shallow-marine to marginal-marine facies and coastal-plain facies. The members of the Schrader Bluff Formation seem to represent various parts of a relatively continuous transgressive-regressive-transgressive cycle within the overall regressive succession of the Schrader Bluff and Prince Creek Formations. A section measured on the Ivishak River consists of several retrogradational and progradational successions, each 800–1,200 ft thick and each consisting of numerous smaller scale coarsening-upward successions that are 15–75 ft thick (D.L. LePain, ADGGS, written communication, 2002).

Our regional studies indicate no distinctive lithologic characteristics of the Rogers Creek and Sentinel Hill Members, which are distinguished from the Barrow Trail Member only by the presence of thicker and more resistant, marine, tuffaceous sandstones in the Barrow Trail. In areas of poor exposure, the Rogers Creek and Sentinel Hill Members can be identified only by their position relative to the more resistant beds of the Barrow Trail Member, if present. The formal member names–Rogers Creek, Barrow Trail, and Sentinel Hill Members–are hereby abandoned; the informal designations of lower, middle, and upper parts of the Schrader Bluff Formation should be used where appropriate.

Reference sections for the middle part of the Schrader Bluff Formation may be seen at two localities in the Umiat quadrangle (fig. 2): (1) The unit is relatively well exposed at the type locality of the Schrader Bluff Formation at Schrader Bluff (sec. 30, T. 3 S., R. 5 E.), where the exposure consists of nearly vertical beds that include 800 ft of the Tuluvak Formation (revised) and 1,900 ft of the overlying Schrader Bluff Formation. At this locality, the Schrader Bluff Formation includes 25- to 65-ft-thick beds of sandstone that display hummocky and swaley crossbedding as well as a distinctive trace fossil assemblage that is indicative of shoreface deposition (for example, *Macaronichnus*). The sandstone beds are separated by intervals of siltstone, tuffaceous siltstone, tuff, and shale that form recessive parts of the bluff. (2) The upper part of the unit is well exposed at Shivugak Bluff (fig. 2) on the north side of the Colville River, 10 mi downstream from Umiat (sec. 19, T. 1 N., R. 2 E.), where gently dipping beds are exposed for several miles along the river. At this locality, most sandstone beds display hummocky and swaley crossbedding as well as trace fossils indicative of shoreface deposition. Finer grained lithologies interbedded with the sandstones are not well exposed but generally appear to be similar to those described at Schrader Bluff (above). Locally, thin intervals of claystone, carbonaceous mudstone, and laterally discontinuous coal represent nonmarine interbeds that indicate occasional nonmarine conditions in an otherwise shallow-marine depositional setting.

Typical exposures of sandstones in the middle part of the Schrader Bluff Formation also occur on Outpost Mountain (T. 3 S., R. 4 E.) and at Tattitgak Bluff (sec. 25, T. 1 S., R. 2 W.) on the Colville River 3 mi southwest of Umiat (fig. 2). At both locations, the sandstones and interbedded fine-grained lithologies appear to be similar to those at Schrader Bluff and Shivugak Bluff, described above.

No reference sections are defined for the lower and upper parts of the Schrader Bluff Formation as those bentonite-rich intervals are poorly exposed throughout the region. Descriptions of these strata in the Gubik and Sentinel Hill test wells are available in Robinson (1958) and Robinson and Collins (1959), respectively. Locations and measured sections for outcrops of these strata are available in Detterman and others (1963).

Lithology

The lower and upper parts of the Schrader Bluff Formation characteristically contain varying amounts of bentonite interbedded with bentonitic shale, tuffaceous mudstone, and bentonitic fine-grained, fossiliferous sandstone, as well as beds of relatively pure bentonite (figs. 21, 22, and 23); the upper and lower parts are relatively incompetent and are exposed only locally in stream cuts. The upper part of the formation is gradational upward into the sandstones, mudstones, and coal of the overlying Prince Creek Formation (fig. 24). The upper part of the Schrader Bluff Formation consists mostly of shallow-marine sandstones, as indicated by abundant marine fossils and hummocky cross stratification. Locally, sandstones inferred to represent nonmarine channel deposits are incised into the shallow-marine sandstones (fig. 25). The contact between the Schrader Bluff Formation and the overlying Prince Creek Formation is characterized by an increase of nonmarine sandstone and conglomerate, as well as nonmarine carbonaceous mudstone and coal.

A notable characteristic of the middle part of the Schrader Bluff Formation is a resistant interval of tuffaceous sandstone and tuff, some of which contains flakes of biotite. The tuffaceous sandstones are more resistant than the upper and lower parts of the formation. In the Umiat quadrangle, they crop out locally and underlie tundra-covered upland ridges. The middle part of the Schrader Bluff Formation also may be marked by a fossiliferous marine sandstone that locally forms prominent dip slopes in the central Sagavanirktok quadrangle, but how this sandstone horizon correlates with the middle part of the formation in the Umiat area to the west is unknown.

Thickness

The thickness of the Schrader Bluff Formation is as much as about 2,500 ft in the Chandler River region and apparently decreases northward to about 1,800 ft in the Umiat area. Details of the lithologies and thicknesses of the upper, middle, and lower Schrader Bluff Formation at numerous locations in the Umiat-Chandler River area were discussed by Detterman and others (1963) and Brosgé and Whittington (1966).

Age

The age of the Schrader Bluff Formation is Santonian to Maastrichtian. In the Umiat area, the unit is Santonian to Campanian, as indicated by bivalves and microfauna (Detterman and others, 1963; Brosgé and Whittington, 1966). In the Sagavanirktok quadrangle, palynomorphs from the Schrader Bluff Formation are dated as mostly Santonian to Maastrichtian (Micropaleo Consultants, 1994). In the same quadrangle, Frederiksen and others (1996) dated marine rocks here included as part of the Schrader Bluff Formation as Campanian to Maastrichtian. Bivalves from the fossiliferous tuffaceous sandstones in the middle part of the Schrader Bluff Formation in the Sagavanirktok River area have been dated as Campanian by W.P. Elder (private consultant, written communications, 1995 and 1999).

Figure 21. Exposure of upper part of Schrader Bluff Formation at Shivugak Bluff, along Colville River east of Umiat. Strata consist of resistant sandstones, mostly of shallow-marine origin, interbedded with mudstone, tuffaceous sandstone, tuff, and bentonite. Bluff has approximately 300 ft of relief. View to north. Photograph by D.W. Houseknecht.

Figure 22. Tuff beds intercalated with tuffaceous mudstone and bentonite in upper part of Schrader Bluff Formation at Shivugak Bluff. View to northeast. Photograph by D.W. Houseknecht.

Figure 23. Shallow-marine sandstone in upper part of Schrader Bluff Formation at Shivugak Bluff showing lag of marine shells in a hummocky cross-stratified facies. White ovals just beneath pen are likely *Schaubcylindrichnus* trace fossils. Photograph by D.W. Houseknecht.

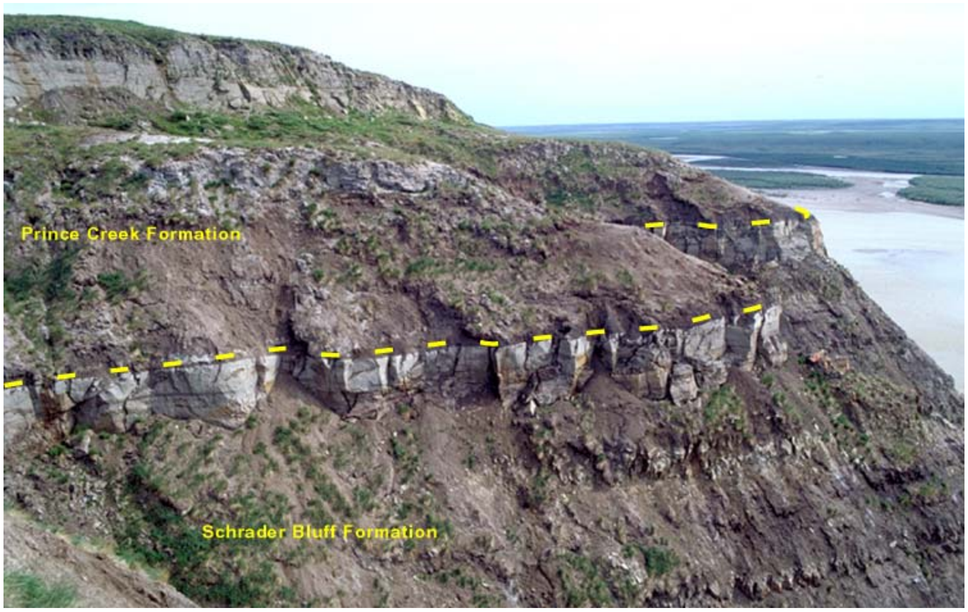

Figure 24. Upper part of Shivugak Bluff showing section that includes the contact between the Schrader Bluff Formation and the overlying Prince Creek Formation (yellow dashed line). The prominent sandstone shown in middle of photograph and underlying rocks are predominantly marine, whereas all overlying rocks are predominantly nonmarine; thus, the top of that sandstone represents the formation contact at this locality. The prominent marine sandstone shown in middle of photograph is approximately 25 ft thick, and the fluvial sandstone at top of bluff is approximately 40 ft thick. View to east with the Colville River in background. Photograph by D.W. Houseknecht.

Figure 25. Nonmarine channel sandstone incised into shallow-marine sandstones in Schrader Bluff Formation at Shivugak Bluff. Yellow dashed line marks approximate base of incised channel. Exposure is about 30 ft high. View to north. Photograph by D.W. Houseknecht.

Prince Creek Formation (Revised)

The Prince Creek Formation was named by Gryc and others (1951) for Prince Creek, a tributary of the Colville River. The Prince Creek Formation consisted of two predominantly nonmarine clastic tongues—the Tuluvak Tongue at the base and the Kogosukruk Tongue at the top (Gryc and others, 1951). These two tongues of the Prince Creek Formation were separated by a thick section of dominantly marine sandstone and shale of the Schrader Bluff Formation (Brosgé and Whittington, 1966). The term “Kogosukruk Tongue” is here abandoned, and the Prince Creek Formation is here revised to consist of (1) beds originally assigned to the Kogosukruk Tongue, and (2) the brown-weathering, coal-bearing rocks previously assigned to the lower part of the Sagwon Member of the Sagavanirktok Formation (see following discussion). The Tuluvak Tongue is here revised and raised in rank to formation status (discussed above).

The Prince Creek Formation as here revised is characterized dominantly by nonmarine sandstone, conglomerate, and interbedded coal-bearing mudstone. The lower part of the Prince Creek Formation forms the upper part of the prominent Shivugak Bluff along the north and west side of the Colville River downstream from Umiat (sec. 17, 18, and 19, T. 1 N., R. 2 E.); forms bluffs along the west side of the Colville River downstream from the mouth of the Anaktuvuk River (sec. 6 and 7, T. 2 N., R. 3 E.) (fig. 26), which are designated here as typical exposures for the lower part of the formation; and crops out at scattered sites along the Chandler and Anaktuvuk Rivers in the Umiat quadrangle (fig. 2). In the Sagavanirktok quadrangle, the Prince Creek Formation is exposed as prominent resistant ledges along the Sagavanirktok, Ivishak, and Kavik Rivers, as well as at sites along Fin Creek, Juniper Creek, and the Shaviovik River and in scattered upland locations. Elsewhere in upland areas, it underlies broad, linear, tundra-covered ridges and has almost no exposures.

The top of the Prince Creek Formation is exposed only in the vicinity of the Sagavanirktok River, where its sharp upper contact with the Sagavanirktok Formation is probably a sequence-bounding unconformity. Its base is gradational and interfingers with the underlying bentonitic shales of the marine Schrader Bluff Formation. Regionally, the Prince Creek represents an eastward and northeastward prograding wedge of dominantly nonmarine clastic detritus (Molenaar, 1983; Molenaar and others, 1984).

Lithology

The Prince Creek Formation is characterized by light-colored, nonmarine sandstones interbedded with carbonaceous mudstone, coal, and bentonite (fig. 27). Throughout much of the formation, the sandstones are very fine to fine grained and variably tuffaceous. Sands grains are dominantly quartz and black to gray chert. The fine-grained sandstone beds commonly display low-angle internal bedding inferred to represent accretionary beds deposited in meandering fluvial systems (fig. 27). The formation contains thick sections of interbedded bentonite, bentonitic mudstone, carbonaceous shale, and coal (fig. 28). It commonly weathers gray to brownish gray, and some parts weather reddish brown. Deposits characteristic of fluvial, meandering-stream environments are interbedded with deposits from marginal-marine and intermittent shallow-marine intervals.

Phillips (1988, 1990) described a 550-ft-thick section of these rocks that includes dinosaur-bone-bearing beds at Ocean Point on the Colville River 60 mi downstream from Umiat (fig. 1). He described carbonaceous mudstones and very fine grained to fine-grained fluvial sandstones showing a progressive marine influence up section; the top of the exposed interval is capped by a fully marine, abundantly fossiliferous sandstone about 45 ft thick. Stratigraphically above the marine beds at Ocean Point are 600 ft of uppermost Maastrichtian nonmarine strata, and above these are lower Paleocene nonmarine strata (Carter and Galloway, 1985; Frederiksen and others, 1988; Frederiksen, 1991).

Distinctive beds of medium- to coarse-grained sandstone locally containing lenses of pebble to cobble conglomerate are present (fig. 29), especially in the lower part of the formation. The coarser grained sandstone beds appear to be stratigraphically distinct from the more common fine-grained sandstone beds discussed above and do not appear to represent coarser and finer grained facies of a single depositional system; thus, the two facies likely have sequence stratigraphic significance. Clasts are dominantly quartz, black chert, and lesser amounts of gray and greenish-gray chert. Ironstone clasts are locally common (fig. 29) and may be intraformational in origin. Conspicuous clasts of dull light-gray to pale-green tuff are present in some localities in the Sagavanirktok quadrangle and may be derived from tuff beds in the Hue Shale. Large clasts of gray quartzite have been observed at a few localities. These coarser grained sandstone beds display a predominance of trough crossbedding (fig. 30) and likely represent the deposits of braided fluvial systems. The sandstone and conglomerate beds are commonly 20–40 ft thick and form resistant ledges and bluffs.

Thickness

No complete sections of the Prince Creek Formation are present in outcrop, and its thickness is unknown. In the Colville River bluffs downstream from Umiat in T. 1 N., R. 2 E. (fig. 26), the sandstone and conglomerate in the lower part of the formation are about 1,200 ft thick. Total thickness along the Colville River from the Gubik anticline (fig. 2) to Ocean Point is 1,800 ft, including 300 ft of interbedded Schrader Bluff Formation according to Brosgé and Whittington (1966, pl. 54).

Age

As defined by Gryc and others (1951), the Prince Creek Formation was considered to be entirely Late Cretaceous in age (see also Gryc and others, 1956). Detterman and others (1963, p. 300) and Brosgé and Whittington (1966, p. 570) considered beds of the Prince Creek Formation, as revised in this paper, to be Campanian and younger. Detterman and others (1975, p. 35) felt that the Prince Creek Formation could range to as young as Maastrichtian. As a result of the revision of the Sagavanirktok Formation (discussed below), we here extend the age of the Prince Creek Formation into the Tertiary, making the unit Campanian to Paleocene. Foraminifera and palynomorphs recovered from the Prince Creek Formation as here revised range in age from Campanian to early Paleocene (Micropaleo Consultants, 1994; Frederiksen and others, 1996; Frederiksen and McIntyre, 2000). As revised, the Prince Creek Formation is a temporal equivalent of the West Sak and lower Ugnu sands (Werner, 1987) in the subsurface of the Kuparuk River oil field area (fig. 1).

Figure 26. Exposures of nearly horizontal Prince Creek Formation forming bluff on west side of the Colville River near confluence with the Anaktuvuk River, Umiat quadrangle. Light-colored strata are mostly nonmarine sandstones, and dark-colored strata are carbonaceous mudstones and coal. Bluff has approximately 300 ft of relief. View to north. These strata are typical exposures for the lower part of the Prince Creek Formation. Photograph by D.W. Houseknecht.

Figure 27. Exposure of Prince Creek Formation along west side of the Colville River, just north of confluence with the Anaktuvuk River. Light-colored, nonmarine sandstones are interbedded with dark-colored coal and carbonaceous mudstone. Note low-angle bedding (gentle dip to right) in sandstone just beneath thickest coal; this is accretionary bedding in a meandering fluvial (point-bar) deposit. Bluff has approximately 300 ft of relief. View to west. Photograph by D.W. Houseknecht.

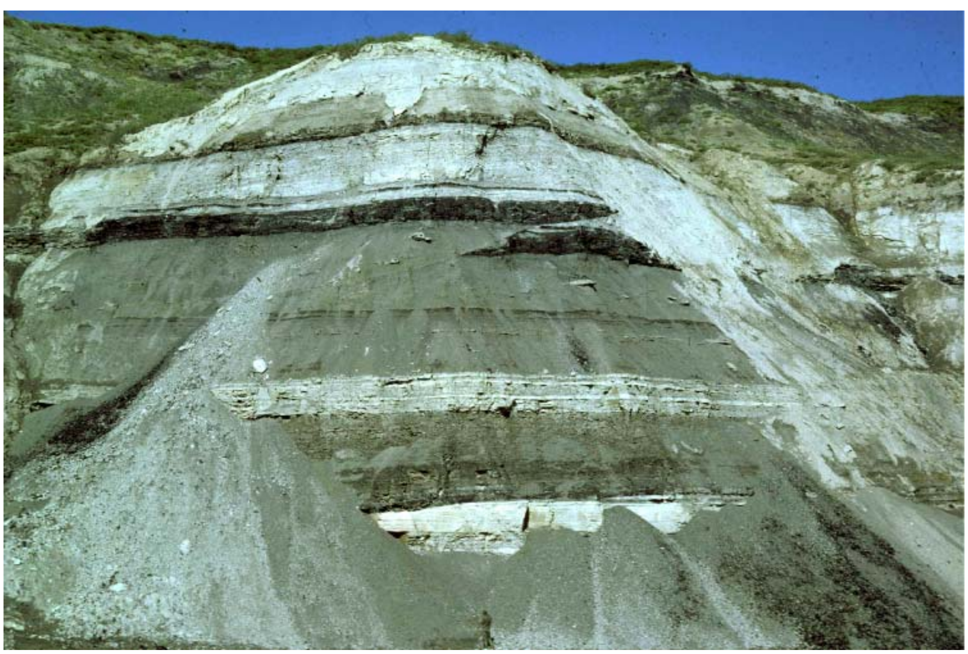

Figure 28. Silty mudstone, coal, and sandstone in upper part of the Prince Creek Formation at Sagwon Bluffs, central Sagavanirktok quadrangle. Note thrust fault offsetting prominent coal bed. View to west. Photograph by Tim Collett, U.S. Geological Survey.

Figure 29. Conglomerate in Prince Creek Formation along Colville River in northern Umiat quadrangle. Ironstone clasts are common and appear reddish brown. Photograph by D.W. Houseknecht.

Figure 30. Medium- to coarse-grained, pebbly, crossbedded sandstone in Prince Creek Formation at Shivugak Bluff. This facies is inferred to be of braided fluvial origin. Photograph by D.W. Houseknecht.

Sagavanirktok Formation (Revised)

The Sagavanirktok Formation was named by Gryc and others (1951) for the Sagavanirktok River in the Colville basin. The type locality is exposures east of the Sagavanirktok River at Franklin Bluffs in the northern Sagavanirktok quadrangle of the eastern Colville basin (fig. 2). The unit consists of poorly consolidated siltstone, sandstone, conglomerate, and lignite of Tertiary age. Detterman and others (1975) revised the definition and named the Sagwon, Franklin Bluffs, and Nuwok Members in ascending order. The Miocene(?) and Pliocene(?) Nuwok Member is exposed more than 60 mi northeast of Franklin Bluffs, outside the area discussed here, and is not considered further. The lower two members are present in outcrop in the Sagavanirktok quadrangle. The Sagwon Member, at the base of the Sagavanirktok Formation, crops out in bluffs on both the east and west sides of the Sagavanirktok River near Pump Station 2 on the Trans-Alaska Pipeline (fig. 2) and was considered by Detterman and others (1975) to be Paleocene and Eocene(?). Lithologically similar rocks of Cretaceous age were assigned by Detterman and others (1975) to the Prince Creek Formation. The Franklin Bluffs Member as defined by Detterman and others (1975) crops out conspicuously at Franklin Bluffs and was considered to be Oligocene(?) and Miocene(?) in age.

New regional geologic mapping in the Sagavanirktok quadrangle (C.G. Mull, ADOG, and R.R. Reifenstuhl, ADGGS, unpublished data, 2002) and evaluation of the stratigraphy in a sequence stratigraphic context suggest that the Sagavanirktok Formation in the eastern Colville basin consists of three mappable, northeasterly prograding sequences, each of which is characterized by a basal unit of coarse clastic fluvial sediments that grade upward into finer grained sediments that are commonly bentonitic and contain coal or lignite beds. The base of each sequence is marked by the occurrence of poorly consolidated sandstones and conglomerates that interfinger basinward (to the east and north) and upward into poorly consolidated, carbonaceous siltstone, bentonitic mudstone, and coal or lignite.

On the basis of these studies, the Sagavanirktok Formation of Detterman and others (1975) is here revised with the addition of a new member—the White Hills Member—and a revision of the bases of both the Franklin Bluffs and Sagwon Members. The Nuwok Member, the youngest member of the Saganvirktok Formation, is exposed in the north-central Mount Michelson quadrangle (fig. 1) and was not considered in this study.

Sagwon Member (Revised)

The Sagwon Member of the Sagavanirktok Formation as defined by Detterman and others (1975) consisted of relatively well lithified to poorly consolidated fluvial sandstone, conglomerate, and coal-bearing siltstone and mudstone that formed high bluffs, cliffs, and white conglomerate caps on ridgetops on the west side of the Sagavanirktok River near the abandoned Sagwon airstrip and south of Pump Station 2 of the Trans-Alaska Pipeline (Dalton Highway, Mile 359) (figs. 2 and 31). Their type section is described as starting at VABM Gard (1,210 ft above sea level in sec. 27, T. 1 N., R. 14 E.), a high point about 1.2 mi northwest of the Sagavanirktok River (fig. 2), and extending 1 mi south along the river bank.

Recent mapping (C.G. Mull, ADOG, and R.R. Reifenstuhl, ADGGS, unpublished data, 2002) shows that VABM Gard is situated on a ridgetop formed by a conspicuous white-weathering sandstone and conglomerate unit (fig. 32) that abruptly overlies and contrasts markedly with the underlying section of brownish-gray, silty and sandy mudstone and claystone containing scattered coal and conglomeratic sandstone beds that form most of the Sagwon Bluffs (fig. 2). The white-weathering ridge-capping conglomerate unit can be traced laterally both to the east side of the Sagavanirktok River, where it forms a vertical river bluff (fig. 33) (NE1/4 sec. 18, T. 1 N., R. 15 E.), and westward 12 mi to the Toolik River.

The underlying brown-weathering coal-bearing unit that constitutes the lower part of the Sagwon Member of Detterman and others (1975) at the Sagwon Bluffs also can be traced southwestward to an area of better exposures along a unnamed tributary of the Toolik River on the north flank of the Kuparuk anticline (T. 1 S., R. 12 E.). There the lower part of the unit contains fluvial sandstone beds that interfinger with marine sandstone, siltstone, and bentonitic mudstone of the Schrader Bluff Formation. Similar fluvial sandstone beds crop out in a series of resistant ledges exposed along the Dalton Highway between Miles 352 and 354, 1–1.5 mi west of VABM Gard (fig. 2).

The relationship of the coal-bearing mudstones and fluvial sandstone beds interfingering with the underlying Upper Cretaceous Schrader Bluff Formation suggests that the lower part of the type section of the Sagwon Member of Detterman and others (1975) is more properly considered part of the Prince Creek Formation. Although the contact at the base of the white conglomerate unit with the underlying brown-weathering coal-bearing unit is not exposed, it appears to be sharp and to represent a sequence-bounding unconformity (figs. 31, 32). Consequently, the Sagwon Member of the Sagavanirktok Formation is here revised to exclude the underlying coal-bearing rocks that form much of the Sagwon Bluffs along the Sagavanirktok River. The type section specified by Detterman and others (1975) is here modified to also exclude the coal-bearing rocks.

The base of the Sagwon Member as here revised is formed by the white-weathering unit that caps ridges in the northernmost Brooks Range foothills adjacent to the Sagavanirktok River in the vicinity of the Sagwon Bluffs (fig. 2). The white-weathering sandstone and conglomerate of the basal Sagwon Member contrast markedly with the brownish-gray-weathering beds of bentonitic claystone, coal, and sandstone that we assign to the underlying revised Prince Creek Formation. Although the basal contact is in a covered interval, we think that it probably represents a sequence-bounding unconformity.

Both the basal Sagwon Member and the upper part of the Prince Creek Formation as here revised are exposed in the Sagwon Bluffs on both sides of the Sagavanirktok River downstream from the abandoned Sagwon airstrip. The Sagwon Member is locally exposed in uplands between the Ivishak and Toolik Rivers and is well exposed about 6 mi downstream from the Sagwon airstrip in a vertical bluff (fig. 33) on the east side of the Sagavanirktok River (NE1/4 sec. 18, T. 1 N., R. 15 E.; fig. 2); the bluff is designated here as a reference section of the Sagwon Member. The Sagwon Member also is exposed fairly well in a stream meander bluff of the Toolik River in N1/2 sec. 13, T. 1 S., R. 12 E., which is designated here as a reference section. At both localities, bluffs more than 50 ft high consist of crossbedded sandstone, pebbly sandstone, and pebble- to cobble-conglomerate apparently deposited in low-sinuosity river systems.

At both the Toolik River and Sagavanirktok River localities, the basal sandstones and conglomerates of the Sagwon Member dip regionally northward into the subsurface beneath the coastal plain north of the foothills belt. Similar conglomerates exposed along the lower Echooka River (sec. 24, T. 1 N., R. 16 E.) and on Fin Creek (SW1/4 sec. 30, T. 2 N., R. 20 E.) are probably also part of this member.

Scattered exposures of poorly consolidated claystones, siltstones, sandstones, and coals of the upper part of the Sagwon Member are present in stream meanders downstream from the Toolik River locality mentioned above for several miles toward the White Hills. The upper part of the Sagwon Member is exposed elsewhere only on the southeast side of the White Hills just below the basal conglomerates of the White Hills Member. A reference section for the upper part of the Sagwon Member is exposed along the west side of the Toolik River (E1/2 sec. 1, T. 2 N., R. 12 E. to NW1/4 sec. 6, T. 2 N., R. 13 E.) where it consists of a conspicuous red clinker zone that is poorly exposed but appears to be about 10 ft thick overlain by a well-exposed, 20-ft-thick section consisting of fissile, carbonaceous shale with coal interbeds.

Lithology

The lower part of the Sagwon Member consists dominantly of poorly consolidated quartz-rich sandstone and conglomerate; locally, sandstone and conglomerate form resistant cliffs (figs. 33 and 34). The clasts in the basal sandstones and conglomerates consist dominantly of white quartz, black chert, and light-gray quartzitic sandstone (fig. 35); lesser amounts of pale-green chert and light-gray tuff are present. Most clasts are less than 2 in. in diameter, but some are as much as 4 in. in diameter. Although the unit generally weathers white, on the Toolik River, it weathers to a conspicuous orange where it overlies coaly beds of the upper part of the Prince Creek Formation.

The upper part of the Sagwon Member has only scattered exposures along the Toolik River and consists dominantly of gray bentonitic claystone and interbedded coals. A well-exposed fining-upward point-bar sequence is exposed in a Toolik River meander in NE1/4 sec. 34, T. 1 N., R. 12 E.; this section fines upward from poorly consolidated pea-gravel conglomerate to coarse- to fine-grained sandstone, which is overlain by claystone. Coal is generally poorly exposed, but near the top of the unit in the eastern White Hills, a coaly interval that may be up to 30 ft thick is locally marked by conspicuous zones of red-weathering clinkers (fig. 36), from which large chunks of petrified wood have been recovered.

Thickness

The basal white-weathering conglomerate and sandstone unit of the Sagwon Member is estimated to be about 75–100 ft thick. The thickness of the upper part of the Sagwon Member is unknown but is probably as much as 3,000 ft.

Age

Detterman and others (1975) assigned a Paleocene to Eocene(?) age to the Sagwon Member of the Sagavanirktok Formation. The age of the Sagwon Member as here revised is late Paleocene on the basis of palynomorphs from the upper coal-bearing part of the member in the eastern White Hills (Frederiksen and others, 1996). An early Paleocene age reported by Frederiksen and others (1996) from the underlying coal-bearing rocks in the southern part of the Sagwon Bluffs is from beds that are now considered to be part of the upper Prince Creek Formation. The Sagwon Member is apparently a lithologic and temporal correlative of part of the subsurface Staines Tongue of the Sagavanirktok Formation and other, older unnamed parts of the Sagavanirktok Formation of Molenaar and others (1987).

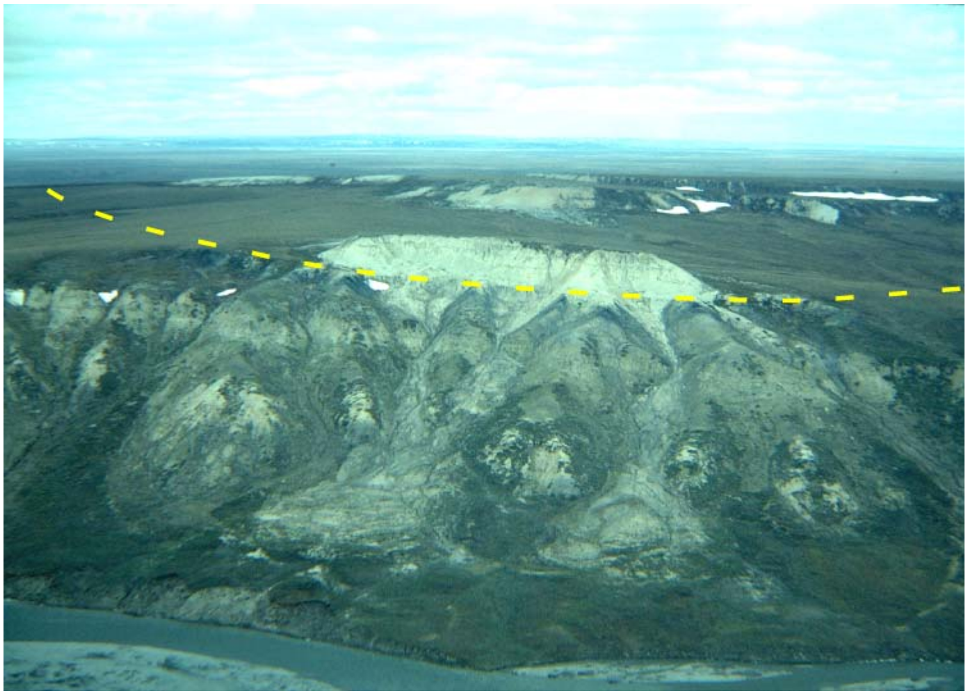

Figure 31. Sandstones and conglomerates of Sagwon Member of Sagavanirktok Formation at VABM Gard on northwest side of Sagwon Bluffs, central Sagavanirktok quadrangle, overlying the Prince Creek Formation in lower slopes. Approximate contact is shown by yellow dashed line. The White Hills are visible on horizon. View to west. Photograph by C.G. Mull.

Figure 32. Poorly consolidated conglomerates at base of Sagwon Member of Sagavanirktok Formation at VABM Gard on west side of Sagavanirktok River. Contact with underlying Prince Creek Formation is concealed beneath gravel talus (approximate location shown by yellow dashed line). View to north. Photograph by C.G. Mull.

Figure 33. Lower part of Sagwon Member of Sagavanirktok Formation, at north end of Sagwon Bluffs on east side of the Sagavanirktok River, dipping regionally northward beneath the Arctic Coastal Plain. View to north. This is a reference section for the lower part of the Sagwon Member. Photograph by C.G. Mull.

Figure 34. Cliff-forming sandstone and conglomerate in lower part of Sagwon Member of Sagavanirktok Formation on east side of the Sagavanirktok River; exposed section is about 100 ft thick. View to northeast. Photograph by C.G. Mull.

Figure 35. Closeup view of quartz-rich sandstone, with quartz- and chert-pebble lag, overlying coal in Sagwon Member of Sagavanirktok Formation. This is the same location shown in figure 33. Photograph by C.G. Mull.

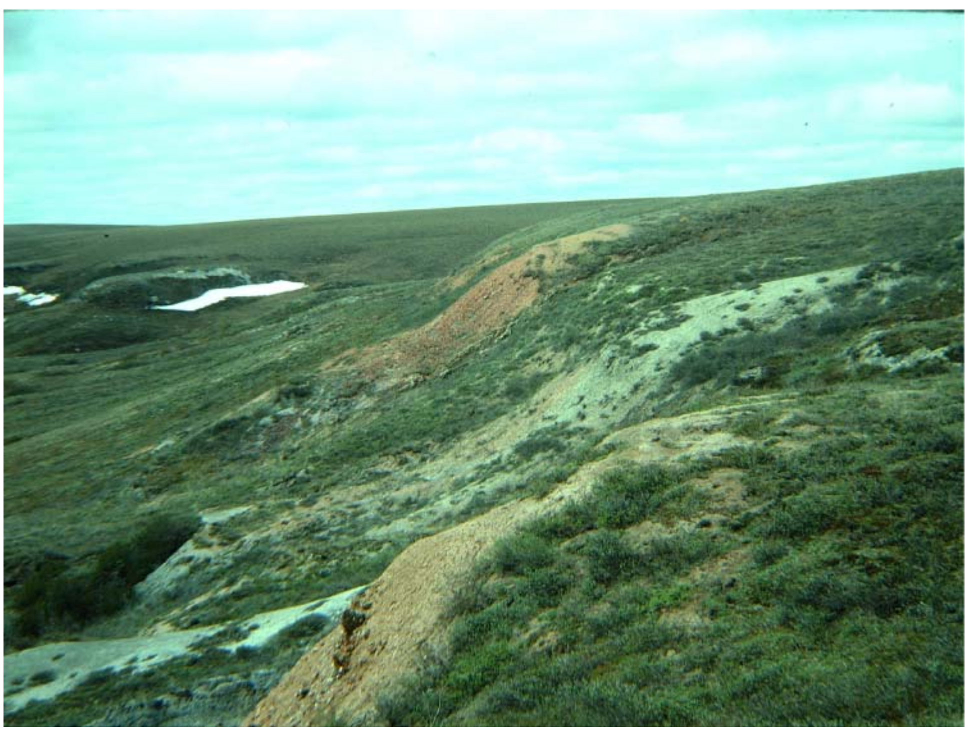

Figure 36. Oxidized clinker zone in coal-bearing upper part of Sagwon Member of Sagavanirktok Formation in southeast part of the White Hills. View to south. Photograph by C.G. Mull.

White Hills Member (New)

The White Hills Member of the Sagavanirktok Formation is here named for the White Hills, a prominent rolling upland area (fig. 37) on part of the Arctic Coastal Plain 12–35 mi west of the Sagavanirktok River and 45 mi southwest of Prudhoe Bay. The White Hills Member is a conspicuous unit of poorly consolidated, white-weathering conglomerate and sandstone that has scattered exposures in the White Hills (fig. 2). The basal part of the White Hills Member forms prominent unvegetated ridges and uplands in the highest part of the southwestern White Hills and locally in lower parts of the central and eastern White Hills.

The unit is well exposed in a stream cut in the northwestern White Hills (E1/2 sec. 5, T. 2 N., R. 10 E.) (fig. 38) and on the southeast side of the White Hills in a meander of the Toolik River (NW1/4 sec. 28 and NE1/4 sec. 29, T. 2 N., R. 12 E.) (fig. 39). These localities are here designated the type and reference sections, respectively, for the basal part of the White Hills Member. The type section consists of 300 ft of sandstone, pebbly sandstone, and pebble- to cobble-conglomerate, all of which is characterized by cut-and-fill bedding and pervasive crossbedding indicative of deposition in a low-sinuosity fluvial system. A few thin, laterally discontinuous interbeds of carbonaceous shale are scattered through the section. The reference section on the Toolik River is 60 ft thick and consists of crossbedded sandstone, pebbly sandstone, and pebble- to cobble-conglomerate similar to that exposed at the type section.

The base of the White Hills Member is not exposed but appears to be a sharp sequence-bounding unconformity that overlies poorly exposed bentonitic mudstone, lignite, and red-weathering clinkers at the top of the underlying Sagwon Member. Locally, the basal part of the White Hills Member weathers reddish-brown to orange where it directly overlies lignite or coal. The contrast in lithology and weathering character of the white conglomerate with the underlying darker colored, fine-grained carbonaceous deposits makes it an easily distinguishable map unit. The white conglomerate and sandstone that form the basal part of the White Hills Member appear to regionally dip gently northeastward; they are probably gradationally overlain by poorly consolidated, bentonitic, carbonaceous mudstone and coal.

The upper part of the member is not exposed in the White Hills but is locally exposed beneath the overlying Franklin Bluffs Member a short distance south of Franklin Bluffs (fig. 40), where the upper contact with the Franklin Bluffs Member appears to be sharp and probably represents an unconformity. The exposure a short distance south of Franklin Bluffs in W1/2 sec. 27, T. 5 N., R. 14 E. is designated here as the reference section for the upper part of the White Hills Member. At this locality, 80 ft of brown-weathering, silty mudstone with thin, discontinuous lignite interbeds is exposed.

Lithology

The white-weathering conglomerates of the basal White Hills Member (fig. 41) consist dominantly of well-rounded, cobble-sized clasts of gray quartzitic sandstone, white quartz, black chert, leached light-gray siliceous tuff, and lesser amounts of gray to pale-green and maroon to red chert up to about 1.5–2 in. in diameter. A few clasts of silicified leached crinoidal limestone, quartzitic conglomerate, and chloritic and graphitic schist also have been observed. The largest clasts in the conglomerates consist entirely of brownish-gray quartzitic sandstone boulders that range up to 12 in. in maximum dimension but constitute only a small percentage of the total clasts. These clasts are probably derived from the Kanayut Conglomerate (Upper Devonian to Lower Mississippian), which is widespread in the central Brooks Range to the south. Lenticular sandstone bodies within the conglomerates (fig. 41) consist dominantly of rounded to subrounded, fine to coarse quartz grains. Where well exposed in stream cuts on the Toolik River on the southeastern side of the White Hills and in the northwestern White Hills, the conglomerates are characterized by spectacular cut-and-fill crossbedding typical of braided-stream deposition (fig. 42). In the western White Hills, three distinct northeast-dipping, apparently shingled and slightly offset successions of the conglomerates are indicative of deposition in a northeastward prograding fluvial depositional system. The upper part of the White Hills Member is known mostly from subsurface well control and is exposed only along the Sagavanirktok River a short distance south of Franklin Bluffs, where it consists dominantly of brown-weathering silty mudstone and lignite.

Thickness

The basal conglomerates of the White Hills Member appear to be about 160 ft thick where relatively well exposed in the northwestern White Hills and along the Toolik River. The thickness of the virtually unexposed upper part of the member is unknown but may be as much as 2,500 ft.

Age

The White Hills Member of the Sagavanirktok Formation is here assigned a late Paleocene(?) to early Eocene age. The age is inferred from the late Paleocene age of the top of the underlying Sagwon Member in the eastern White Hills reported by Frederiksen and others (1996) and the probable early Eocene age of palynomorphs from coaly beds at the top of the member south of Franklin Bluffs. The White Hills Member is apparently a temporal correlative of the lower part of the subsurface Mikkelsen Tongue of the Canning Formation and part of the Staines Tongue of the Sagavanirktok Formation of Molenaar and others (1987).

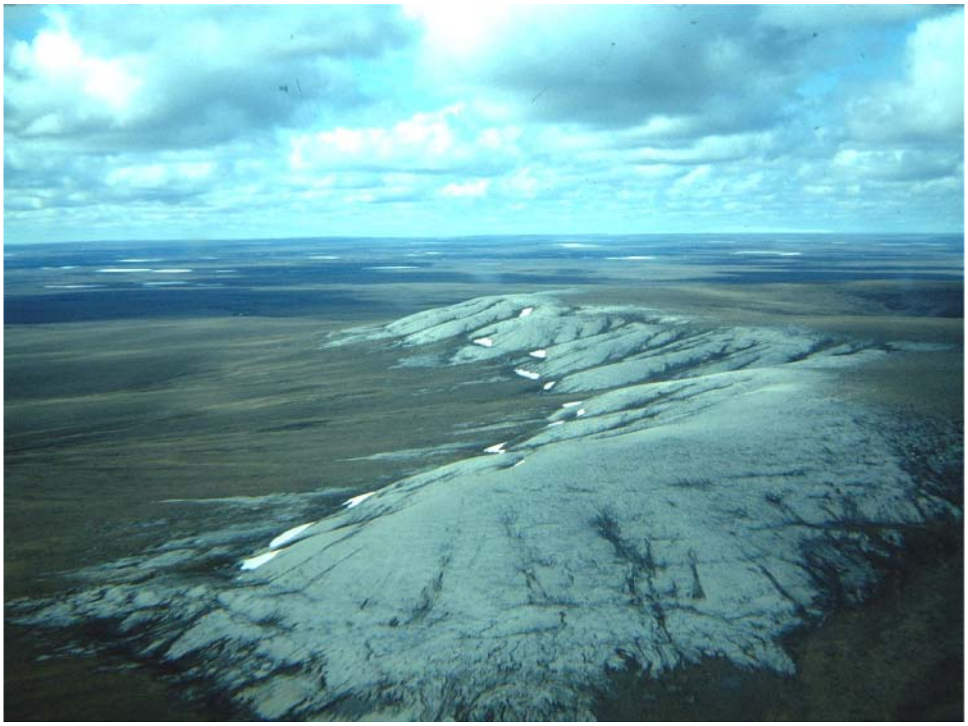

Figure 37. White conglomerate cap of basal White Hills Member of Sagavanirktok Formation, at southwest end of the White Hills, western Sagavanirktok quadrangle. View to north. Photograph by C.G. Mull.

Figure 38. Poorly consolidated sandstone and conglomerate yield the typical rounded hillsides pattern of the White Hills Member of Sagavanirktok Formation. This photograph shows one of the few good outcrops in the area in an unnamed stream drainage on northwest side of the White Hills. This locality is the type section for the basal part of the White Hills Member. Relief from streambed to hilltop is about 300 ft. View to east. Photograph by D.W. Houseknecht.

Figure 39. Crossbedded fluvial sandstones and conglomerates in basal part of White Hills Member of Sagavanirktok Formation along the Toolik River. View to north. This locality is a reference section for the basal part of the White Hills Member. Photograph by C.G. Mull.

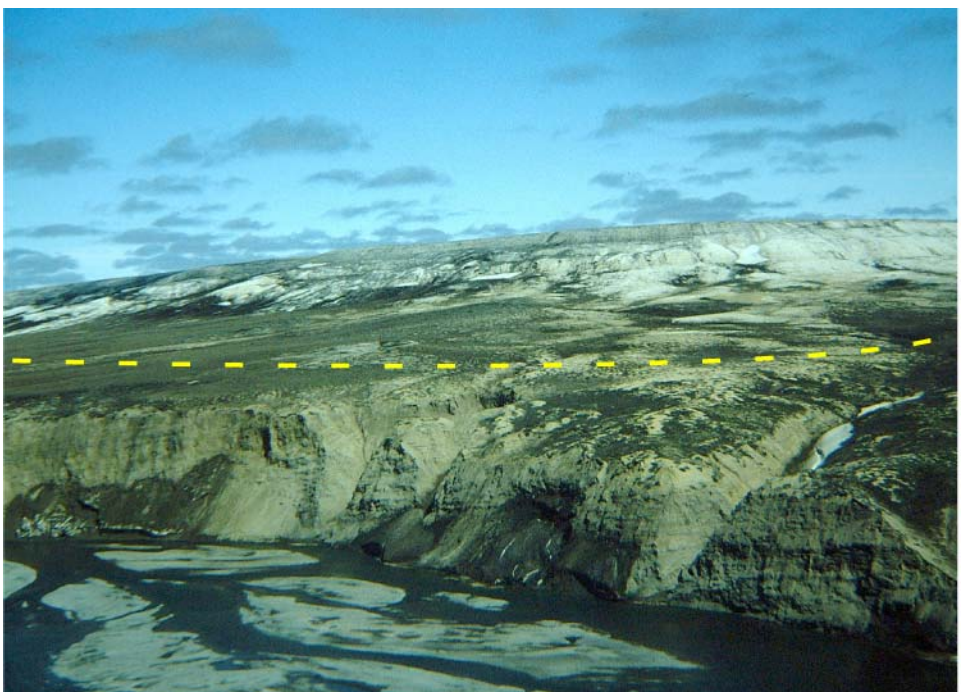

Figure 40. Bluff along east bank of Sagavanirktok River (foreground) and southern end of Franklin Bluffs (background), showing contrast between Franklin Bluffs Member of Sagavanirktok Formation (background) and brown-weathering, lignite-bearing silty mudstone of upper part of White Hills Member (foreground). The contact between the two members is concealed beneath the gentle slope in the middle of the photograph as shown by yellow dashed line. View to northeast. Photograph by C.G. Mull.

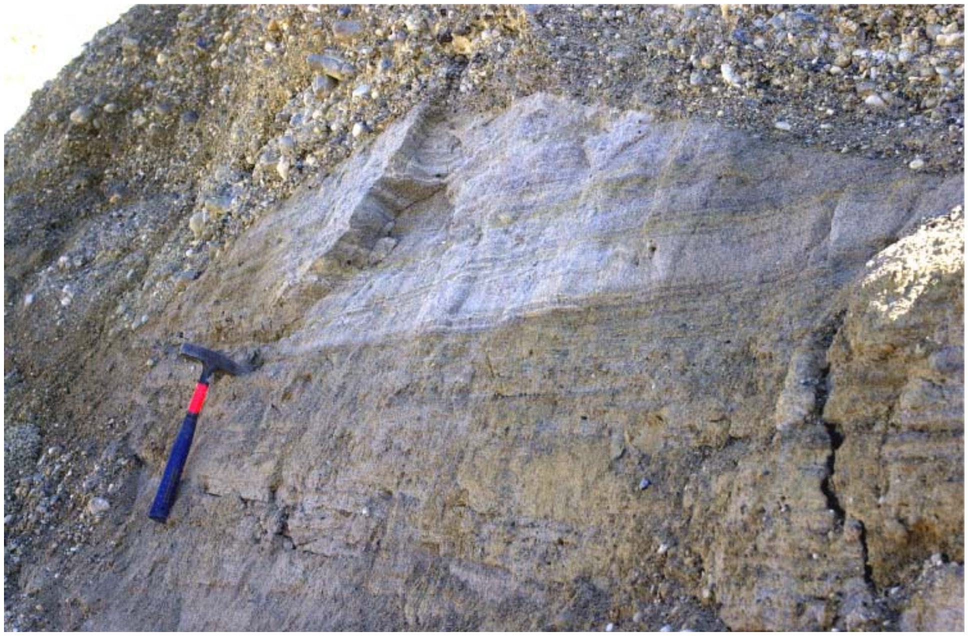

Figure 41. Crossbedded sandstone and conglomerate in basal part of White Hills Member of Sagavanirktok Formation in an unnamed stream drainage on northwest side of the White Hills. This photograph was taken at the outcrop shown in figure 38. Photograph by D.W. Houseknecht.

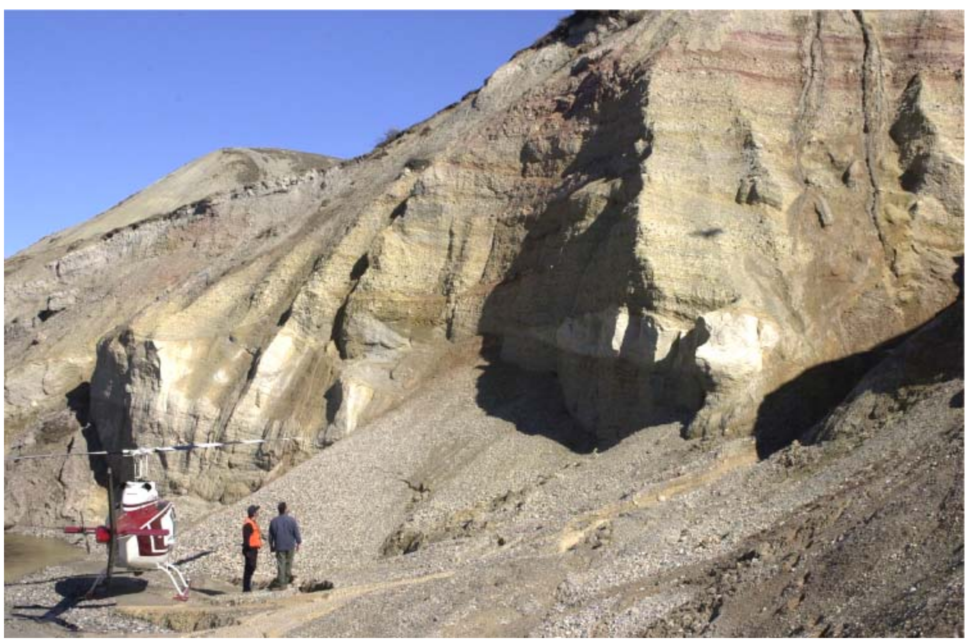

Figure 42. Poorly consolidated, crossbedded sandstone and conglomerate of the White Hills Member of Sagavanirktok Formation in unnamed stream drainage on northwest side of the White Hills. This photograph was taken at the outcrop shown in figures 38 and 41. View to northeast. Photograph by D.W. Houseknecht.

Franklin Bluffs Member (Revised)

The Franklin Bluffs Member of the Sagavanirktok Formation was named by Detterman and others (1975) and consists of a unit of poorly consolidated siltstone, sandstone, and conglomerate that forms Franklin Bluffs (fig. 2) and is apparently overlain by finer grained sediments. The type section of the Franklin Bluffs Member is along a small side tributary to the Sagavanirktok River (NW1/4 sec. 4 and NE1/4 sec. 5, T. 5 N., R. 14 E.). As here revised, the lower part of the member is a conspicuous light-gray- to pink-weathering unit overlain by a white-weathering conglomerate cap (fig. 43). The contact of the unit with the underlying rocks is not exposed but is inferred to be sharp and to represent an abrupt influx of well-sorted, clean, clastic sediments. The contact is inferred to be sharp a short distance south of Franklin Bluffs, where the contact is obscured beneath a gentle slope developed above a unit of brown-weathering silty mudstone exposed along the eastern bank of the Sagavanirktok River (fig. 40). The brown-weathering silty mudstone shown in the foreground of figure 40 was included by Detterman and others (1975) in the Franklin Bluffs Member and was included by Frederiksen and others (1994, 2002) in the top of the Sagwon Member.

We here revise the definition of the Franklin Bluffs Member and consider its base to consist of the conspicuous, dominantly white- to pink-weathering siltstone, sandstone, and conglomerate unit that forms the main body of Franklin Bluffs (fig. 44). The locality along the Sagavanirktok River at the southern end of Franklin Bluffs (SE1/4 sec. 16, T. 5 N., R. 14 E.), approximately 2 mi south of the type section, is designated here as a reference section for the lower part of the Franklin Bluffs Member. At this locality, a section more than 300 ft thick consists of an interval of sandy siltstone overlain by poorly consolidated sandstones, pebbly sandstones, and conglomerates characterized by colorful weathering patterns in shades of yellow, pink, and white.

This lower part of the Franklin Bluffs Member constitutes a distinctive mappable unit that contrasts with and probably unconformably overlies the underlying brown-weathering, lignite-bearing silty mudstone that is here considered to represent the top of the underlying White Hills Member (defined above). At Franklin Bluffs, the Franklin Bluffs Member dips about 4° northeastward into the subsurface so that the upper part of the member is not exposed and is known only from subsurface well control. The nature of the contact with the overlying Nuwok Member is unknown.

An exploratory well, the Mobil West Kadleroshilik Unit #1, located on the highest part of Franklin Bluffs near its southern end, was drilled to a total depth of 4,566 ft. Well logs, rock samples, and microfossils from this well provide additional information on the Franklin Bluffs Member and underlying strata and enable tentative correlation of the surface nomenclature with subsurface nomenclature to the northeast (fig. 45). However, the boundary between the Franklin Bluffs Member and the underlying White Hills Member cannot be correlated with a distinctive well log response, and, therefore, only an approximate contact can be identified (fig. 45).

Lithology

The lower part of the Franklin Bluffs Member at Franklin Bluffs consists of siltstone (fig. 46), sandstone (fig. 47), and conglomerate composed predominantly of clasts of black chert and lesser amounts (20–30 percent) of gray and white quartz. Scattered thin pebble and gravel lags occur within the silty and sandy lower part of the unit and become more abundant upward (fig. 48). Clasts are dominantly less than 0.5 in. in diameter, although scattered larger clasts having diameters as big as 5 in. have been observed. Silty and sandy strata in the lower part of the Franklin Bluffs Member contain dinoflagellate cysts that indicate a nearshore marine or estuarine environment of deposition (Frederiksen and others, 2002).

The lower part of the Franklin Bluffs Member is capped by a conglomerate containing clasts up to 4 in. in diameter of quartz and light-gray to black chert and containing lesser amounts of red and green to aquamarine chert. Some of the light-gray chert may be silicified tuff; other chert clasts contain possible radiolarians. Well data indicate that the upper part of the Franklin Bluffs Member consists dominantly of poorly consolidated and generally thinly bedded mudstone and siltstone.

Thickness

The basal light-gray- to pink-weathering silty and sandy part of the Franklin Bluffs Member is approximately 250–400 ft thick; the white conglomerate cap is estimated to range from 120 to 210 ft in thickness. The thickness of the upper part of the Franklin Bluffs Member is unknown but probably exceeds 3,000 ft.

Age

The basal part of the Franklin Bluffs Member as exposed at Franklin Bluffs is probably early Eocene. Frederiksen and others (1994, 1996, 2002) reported early and perhaps middle Eocene palynomorphs from the Franklin Bluffs Member and probable early Eocene palynomorphs from underlying coaly beds a short distance south of Franklin Bluffs that are here considered to be the top of the underlying White Hills Member. The age of the upper part of the Franklin Bluffs Member ranges to as young as Miocene in the eastern Colville basin. The probable early to middle Eocene age makes the Franklin Bluffs strata coeval with at least part of the subsurface Mikkelsen Tongue of the Canning Formation (Molenaar and others, 1987). If the conglomerate cap marks the beginning of a new sequence, that part of Franklin Bluffs Member may represent the lowermost part of the post-Mikkelsen Tongue part of the Sagavanirktok Formation of Molenaar and others (1987), and the base of the conglomerate cap may mark the regional intra-Eocene unconformity. The Franklin Bluffs Member is here assigned an early Eocene to Miocene age.

Figure 43. South end of Franklin Bluffs, Sagavanirktok quadrangle, showing white conglomerate cap and underlying sandstones of Franklin Bluffs Member of Sagavanirktok Formation. Contact between Franklin Bluffs Member and underlying White Hills Member lies just below river level. View to southeast. Photograph by C.G. Mull.

Figure 44. White conglomerate cap and underlying pink-weathering sandstones of Franklin Bluffs Member of Sagavanirktok Formation at Franklin Bluffs. View to north. Photograph by C.G. Mull.

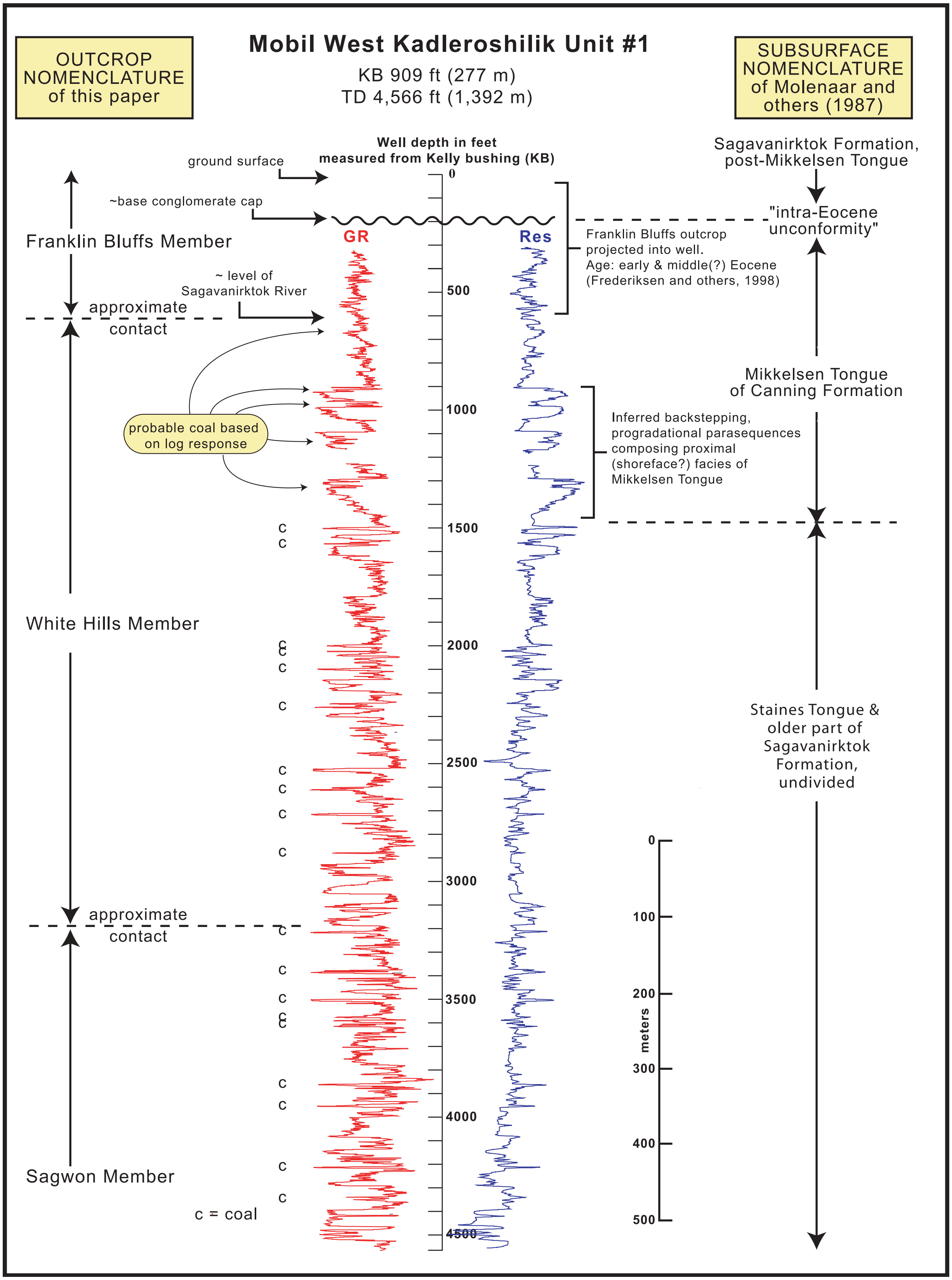

Figure 45. Wireline log of Mobil West Kadleroshilik Unit #1 well showing correlation of lower Tertiary stratigraphic nomenclature in Franklin Bluffs area with subsurface nomenclature to the northeast. GR, gamma ray log; Res, resistivity log.

Figure 46. Brown-weathering, sandy siltstones in lower part of Franklin Bluffs Member of Sagavanirktok Formation at Franklin Bluffs. Dinoflagellate cysts from this facies indicate a nearshore marine or estuarine environment of deposition (Frederiksen and others, 2002). Photograph by C.G. Mull.

Figure 47. Poorly consolidated, crossbedded fluvial sandstones in Franklin Bluffs Member of Sagavanirktok Formation at Franklin Bluffs. Photograph by C.G. Mull.

Figure 48. Pebble lag in crossbedded sandstone in Franklin Bluffs Member of Sagavanirktok Formation at Franklin Buffs. Photograph by C.G. Mull.

Summary

In this paper, we revise names of Cretaceous and Tertiary rock units in the Colville basin and abandon the use of other names. This new, simplified stratigraphic scheme is based on regional insights developed in the course of recent mapping and detailed stratigraphic and sedimentologic studies. We believe that these revisions will result in improved understanding of the Cretaceous and Tertiary stratigraphy of the outcrop belt of the North Slope of Alaska. The revisions modify a complex stratigraphic nomenclature developed in a local, piecemeal fashion over the last 50 years into a set of regional, more consistently mappable rock units that will be used in a suite of revised geologic quadrangle maps in preparation. Most of the units discussed are best exposed in the Chandler Lake, Umiat, Ikpikpuk River, and Sagavanirktok 1:250,000 quadrangles (fig. 1), and some of the Lower Cretaceous units extend westward into the western Colville basin. The revised stratigraphic nomenclature we propose is illustrated in figure 3 and is compared with the previous nomenclature in figure 4 and in table 1.

This revised nomenclature proposes the abandonment of the Colville Group; demotion of the Nanushuk Group to formation status; abandonment of six formations (Grandstand, Corwin, Kukpowruk, Tuktu, Chandler, and Ninuluk); revision of four formations (Sagavanirktok, Prince Creek, Schrader Bluff, and Seabee); elevation of the Tuluvak Tongue of the Prince Creek Formation to formation status; revision of two members (Franklin Bluffs Member and Sagwon Member of the Sagavanirktok Formation); abandonment of eight members or tongues (Kogosukruk, Rogers Creek, Barrow Trail, Sentinel Hill, Ayiyak, Shale Wall, Niakogon, and Killik); and definition of one new member (White Hills Member of the Sagavanirktok Formation).

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