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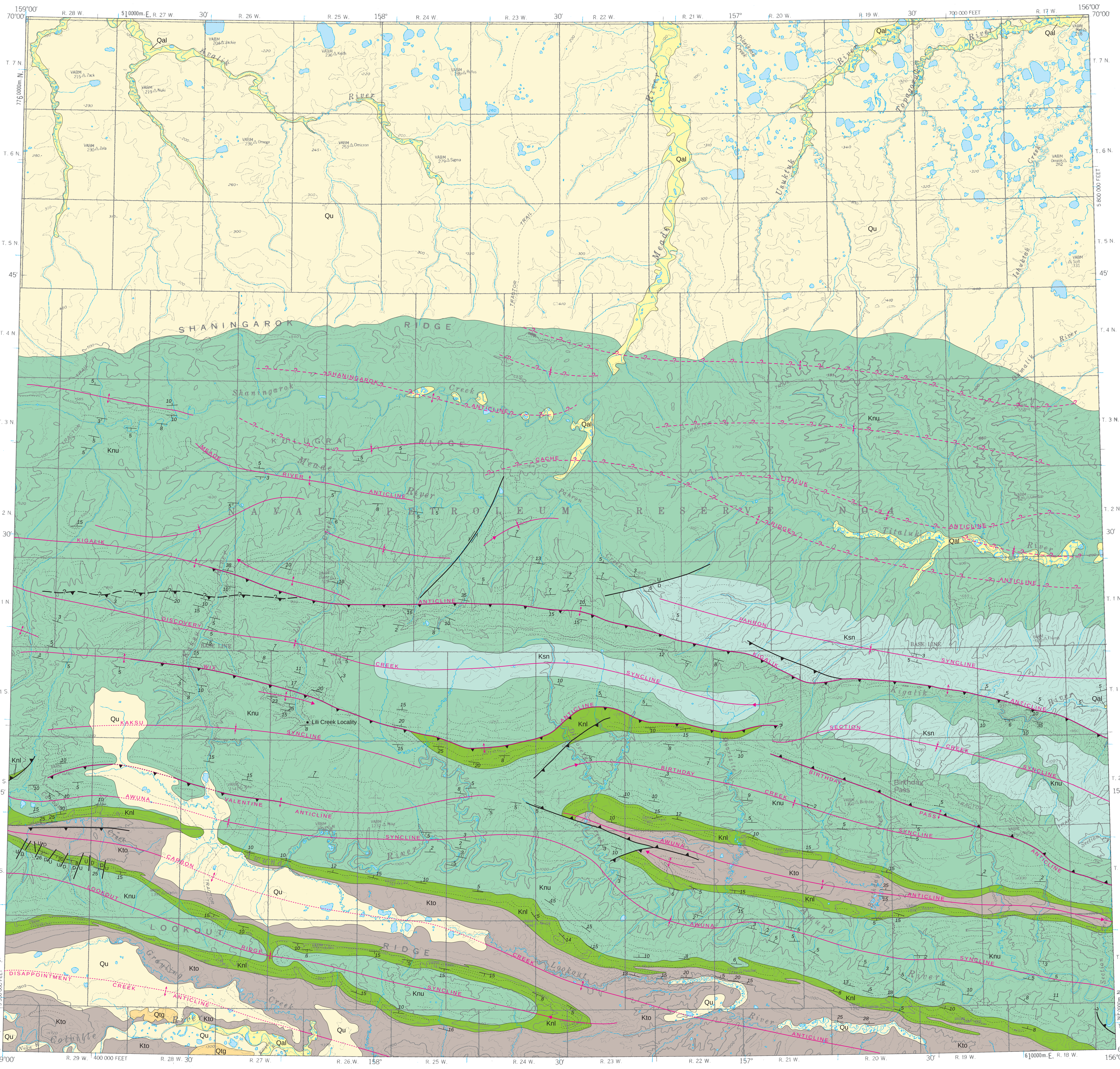
ALASKA DEPARTMENT OF NATURAL RESOURCES,
DIVISION OF OIL AND GAS



Base from U.S. Geological Survey, 1956
Universal Transverse Mercator projection
1927 North American Datum
100,000-foot grid ticks based on Alaska coordinate system, zone 4

APPROXIMATE MEAN DECLINATION, 2005

SCALE 1:250 000

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Geology by G.H. Pessel and C.G. Mull, 1964; aerial photographic revisions by C.G. Mull, 2002
Digital cartography and compilation by Christopher P. Garrity
Edited by Elizabeth D. Koozmin

GEOLOGIC MAP OF THE LOOKOUT RIDGE QUADRANGLE

By
Charles G. Mull, David W. Houseknecht, G.H. Pessel, and Christopher P. Garrity

INTRODUCTION

The Lookout Ridge quadrangle (1:250,000) is located in the east-central Arctic North Slope of Alaska. This geologic map of the quadrangle is a compilation of unpublished geologic mapping by Pessel and Mull (1964) for Richfield Oil Corporation combined with data on location of structural axes from regional maps by Payne and others (1951), Lathram (1965), Mayfield and others (1988) and unpublished mapping by Martin and others (1968) for British Petroleum Company. The report incorporates recent revisions in stratigraphic nomenclature by Mull and others (2003). Stratigraphic and structural interpretations were revised with the aid of modern high-resolution color infrared aerial photographs, which were invaluable for the delineation of previously unrecognized areas of probable outcrop of the Seabee Formation.

HISTORY OF EXPLORATION

The area of the Lookout Ridge quadrangle is in the most remote part of the foothills belt of northern Alaska and has been mapped by most workers only at a regional scale in reconnaissance fashion. The Lookout Ridge quadrangle is located in the central part of the National Petroleum Reserve in Alaska (NPRA), which was established in 1923 as Naval Petroleum Reserve #4 (NPR-4). The first geological traverse of the area was in 1924 by a U.S. Geological Survey (USGS) field party headed by P.S. Smith. This party crossed the Brooks Range to the headwaters of the Killik River in the winter of 1924 and, after the ice breakup in the spring, descended the Killik River in canoes to the junction with the Colville River (Smith and others, 1926; Smith and Mertie, 1930). The canoes then were towed by hand up the Colville River to the mouth of the Awuna River. The Awuna River was found to be relatively sluggish and was ascended by paddling and poling to a small stream flowing in from the north that the field party named Birthday Creek. From there, the boat and supplies were portaged northward over a divide to and part of the way down a north-flowing drainage that was assumed to flow into the Meade River. Instead, this drainage was found to be a tributary of the Kigalik River, which flowed eastward into the Ikpikpuk River. In spite of this disappointment, the party traversed a significant part of the foothills fold belt and was the first to document the long, linear, west-east-oriented anticlines and synclines, which decrease in amplitude toward the north.

A summary report by Smith and others (1926) and a generalized cross section from the Brooks Range mountain front to the Ikpikpuk River, east of the Lookout Ridge quadrangle, provided the first description and illustration of the belt of regional anticlines and synclines of decreasing amplitude to the north that deform the Cretaceous rocks of the foothills fold belt. This report also discussed the logistical constraints to oil exploration and development, and pointed out that (1) a railroad or 1,000-mile-long pipeline (with the attendant defense issues), and (2) enormous capital expenditures would be needed to develop oil resources on the North Slope. The report also recommended further study and the drilling of shallow stratigraphic test holes on the North Slope.

Additional field studies in the region did not occur again until the late 1940s as part of an intensive program of exploration in NPR-4 by the U.S. Navy. This time, extensive field geological mapping and geophysical surveys were conducted to the east of the Ikpikpuk River and Umiat quadrangles following the initial exploration and the discovery in 1946 of oil at Umiat and gas at Gubik (see discussion by Mull and others, 2004). Several exploratory wells were drilled by the Navy in 1951 and 1952 on anticlines in the Ikpikpuk River quadrangle, resulting in the discovery of subcommercial gas accumulations at Square Lake and Wolf Creek. The results of this period of exploration in NPR-4 are summarized by Reed (1958). Subsequently, a regional map compilation of the geology of the North Slope and Brooks Range by Lathram (1965) incorporated the results of the NPRA exploration and named a number of the regional anticlines in the foothills fold belt.

The oil discovery at Umiat and the gas discovery at Gubik served as the impetus for active oil industry exploration on the North Slope that began in 1958. Geophysical surveys and drilling of several wildcat wells east of NPR-4 led to the 1968 discovery of the supergiant Prudhoe Bay oil field (217 miles (mi) northeast of the Lookout Ridge quadrangle) by Atlantic Richfield Company and Humble Oil Company (now ExxonMobil). Following the success of industry exploration, the U.S. Navy and U.S. Department of the Interior carried out renewed exploration of the renamed National Petroleum Reserve in Alaska from 1974 to 1982, including additional geophysical surveys in the northeastern part of NPRA. The results of this second phase of government exploration in NPRA were published in Gryc (1988). A regional map of NPRA by Mayfield and others (1988) in Gryc (1988) also included names for some of the regional anticlines in the foothills fold belt.

Four Federal lease sales were held in NPRA in the 1980s, but only two exploration wells were drilled by industry and neither discovered any oil or gas. Following a 10-year hiatus in exploration activity, NPRA again became a focus of interest with the 1996 announcement of the discovery of the Alpine oil field, located northeast of the Lookout Ridge quadrangle just outside NPRA. Federal lease sales were held in 1999, 2002, and 2004 in northern NPRA that included land in the northern part of the Lookout Ridge quadrangle. Several exploration wells were drilled by industry during subsequent winter drilling seasons, but none of them were located within the Lookout Ridge quadrangle; several of those wells were announced as oil and gas discoveries.

REGIONAL SETTING

The geology of the Lookout Ridge 1:250,000 quadrangle spans part of the transition from the deformed rocks of the foothills of the northern Brooks Range into the undeformed rocks of the Arctic coastal plain. Rocks exposed in the quadrangle (fig. 1) are part of the gently south dipping northern flank of the Colville basin, which is a deep, asymmetrical foreland basin of Cretaceous and Tertiary age that lies north of the Brooks Range orogenic belt. The Colville basin is underlain by a Devonian and older, deformed and weakly metamorphosed basement complex (Dumoulin, 2001) assigned to the Franklinian sequence (Lerand, 1973; Hubbard and others, 1987a,b; Bird and Molenaar, 1992). A relatively thin section of Carboniferous to lowest Cretaceous (lower Neocomian) strata representing platform deposits of the Ellesmerian and Beaufortian sequences (Bird and Molenaar, 1992) overlies the basement.

The rocks of the Colville basin are assigned to the Brookian sequence, a thick section of Lower Cretaceous to Miocene foreland basin deposits (see regional map in Mull and others, 1987, or Moore and others, 1994). Brookian sediments were eroded and transported northward from orogenic belts in the Brooks Range and eastward from the Chukchi platform, an ancestral highland that now lies beneath the Chukchi Sea west of northern Alaska (Mull, 1979). The basin fill comprises a thick (more than 12,000 feet (ft)), eastward-prograding clastic wedge consisting of deep marine basin and slope deposits (Torok Formation) and overlying shallow-marine shelf, deltaic, and nonmarine deposits (Nanushuk Formation) (Molenaar, 1985). The Nanushuk Formation forms most of the surface exposures in the foothills fold belt and underlies most of the coastal plain of northern Alaska. Following the eastward progradation of the Torok-Nanushuk clastic wedge to an ultimate shelf margin east of the Colville River in the eastern Umiat quadrangle, the top of the Nanushuk was flooded by a regional marine transgression, which led to deposition of the Upper Cretaceous (Cenomanian to Coniacian) Seabee Formation (fig. 1). Renewed progradation of clastic depositional systems subsequently resulted in deposition of shallow-marine through nonmarine strata of the Upper Cretaceous (Turonian through Maastrichtian) Tuluvak, Schrader Bluff and Prince Creek Formations, and the early Tertiary Sagavanirktok Formation east of the Lookout Ridge quadrangle. Deposition of these shallow-marine to nonmarine sediments to the east completed the filling of the Colville basin. Exposures of the Brookian sequence in the Lookout Ridge quadrangle consist of (in ascending order) the Torok, Nanushuk, and Seabee Formations. No Brookian strata younger than the Seabee Formation are known to be present in the Lookout Ridge quadrangle.

The northern part of the Lookout Ridge quadrangle is part of the Arctic coastal plain and consists almost entirely of tundra cover, shallow tundra lakes (thaw lakes), and a few meandering streams that have no bedrock exposures within. The southern half of the quadrangle consists of upland areas that are dominantly underlain by relatively resistant rocks of the Nanushuk Formation and locally less resistant rocks that are probably part of the lower part of the Seabee Formation, which is probably present in the axes of some of the regional synclines. This upland area is partly incised by the headwaters of the Awuna, Kigalik, and Titaluk Rivers, Shaningarok Creek, and other tributaries of the Meade River. Rubble exposures, which are an expression of surface weathering of the Nanushuk Formation, are widespread in parts of this area and greatly facilitated the 2002 interpretation of modern color infrared aerial photographs that is incorporated in this map. These rubble exposures allow mapping of outcrop patterns of the Nanushuk Formation in areas of poor bedrock exposure.

Of particular interest in the Lookout Ridge quadrangle is an area where there are several petrified trees, some more than 2 ft in diameter and 14 ft high, preserved in growth position in the upper part of the Nanushuk Formation (figs. 2 and 3). This locality is near the head of Lili Creek, a tributary of the Meade River at 69°19.310' N., 158°11.258' W., sec. 28, T. 1 S., R. 26 W. (Decker and others, 1997).

REGIONAL STRUCTURE

The succession of relatively resistant Cretaceous (Albian to Turonian) clastic rocks in the Lookout Ridge and adjacent quadrangles is regionally deformed into a series of linear, open synclines and generally tighter anticlines that are commonly faulted in the southern part of the quadrangle. The fold amplitudes generally decrease to the north so that the northernmost structures are markedly more subdued than those to the south. These structures developed above a décollement in relatively incompetent shales and mudstones of the underlying Torok Formation (probably Aptian to Albian in the subsurface across this area) and Kingak Shale (Jurassic to Lower Cretaceous). The Torok Formation is exposed in the cores of the anticlines in the southern part of the quadrangle, but the Kingak Shale is not exposed in the Lookout Ridge quadrangle. The magnitude of shortening within the Nanushuk Formation in the fold belt appears to increase toward the Colville River to the east but cannot be quantified.

The anticlinal axes, which are better exposed in the southern part of the quadrangle, are characterized by both north- and south-vergent thrust faults that occur in the Nanushuk Formation. The Kigalik anticline, which is particularly prominent, can be traced westward for nearly 100 mi from the Kigalik River drainage in the western part of the adjacent Ikpikpuk River quadrangle to the western part of the Lookout Ridge quadrangle. Along its entire length, the crest of this anticline is marked by a significant north-vergent thrust fault. This fault is particularly evident along the eastern end of the anticline, where the Nanushuk Formation on the south is thrust northward over the north-dipping uppermost part of the Nanushuk and probable Seabee Formation in the Pahron Creek syncline (new name), a regional syncline in the headwater tributaries of the Titaluk River. South of the Kigalik anticline, a regional synclinal trend composed of two separate synclines (here named the Discovery Creek and Section Creek synclines) can be traced from the Colville River in the adjacent Ikpikpuk River quadrangle westward across the entire Lookout Ridge quadrangle.

In the southeast part of the quadrangle, south of the Discovery Creek and Section Creek synclinal trend, the structural style becomes more complex and is marked by several shorter, low-amplitude anticlinal and synclinal axes and a regional anticlinal trend within the Nanushuk Formation. The crestal part of this anticlinal trend is marked by both north- and south-vergent thrust faults. In the western part of the quadrangle, the Wix anticline is marked by a north-vergent thrust fault, but in the eastern end of the quadrangle, the Birthday Pass anticline (new name) is marked by an apparent south-vergent thrust fault that extends eastward into the Ikpikpuk River quadrangle (Mull and others, 2005). This south-vergent thrust fault overrides rocks of the upper part of the Nanushuk Formation on the flanks of both the Birthday Pass syncline (new name) and Awuna anticline, which plunges eastward into the Ikpikpuk River quadrangle (Mull and others, 2005). In the southwestern part of the quadrangle south of the Awuna syncline, the Carbon Creek anticline and Lookout Ridge syncline are relatively simple, long, regional, symmetrical folds that are well expressed in the Torok and Nanushuk Formations.

Regional structural and stratigraphic analysis and apatite fission-track data suggest that the deformation of the western and central parts of the Brooks Range foothills fold belt probably occurred during early Tertiary time in response to a late stage of uplift of the Brooks Range orogenic belt to the south (Mull and others, 1997; O'Sullivan and others, 1997).

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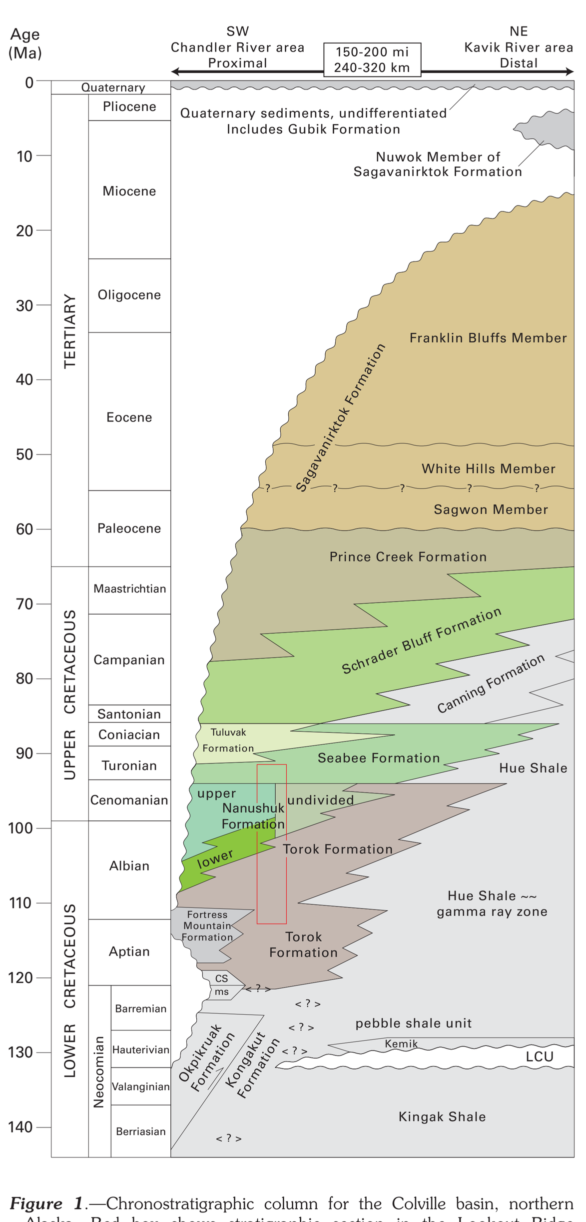


Figure 1.—Chronostratigraphic column for the Colville basin, northern Alaska. Red box shows stratigraphic section in the Lookout Ridge quadrangle. Abbreviations or symbols are as follows: <?>, uncertain relationship; CS, cobblestone sandstone of Fortress Mountain Formation (informal unit of Mull and others, in press); ms, manganiferous shale unit (informal term); Kemik, Kemik Sandstone (formation) as revised by Molenaar and others (1987); LCU, Lower Cretaceous unconformity. Geologic time scale from Gradstein and Ogg (1996).

DESCRIPTION OF MAP UNITS

Qu — **Surficial deposits, undifferentiated (Holocene and Pleistocene)**—Tundra-covered, fine-grained, organic-rich silt, loess, and local colluvium and fine-grained alluvial sand and silt in areas adjacent to upland slopes. In northern part of quadrangle, includes unstratified marine sand, silt, and local gravel of Gubik Formation (Black, 1964), which coincides with area of abundant shallow lakes in Arctic coastal plain (Brosgé and Whittington, 1966) and the topographically lower reaches of stream valleys in the northern part of the foothills fold belt

Qal — **Alluvial deposits, undivided (Holocene and Pleistocene)**—Alluvial sand, gravel, and silt in active braided and meandering stream flood plains, and in adjacent low, lightly vegetated abandoned flood plains and low terraces

Qtg — **Terrace gravels (Holocene and Pleistocene)**—Gravel and sandy gravel, forms locally conspicuous terraces adjacent to Colville River in southwest part of quadrangle

Ksn — **Seabee Formation (Gryc and others, 1956; Whittington, 1956; revised by Mull and others, 2003) and Nanushuk Formation, undivided (Upper Cretaceous, Turonian, to Lower Cretaceous, Albian)**—Mapped in axes of Pahron, Section Creek, and Discovery Creek synclines that flank Kigalik anticline, where presence of scattered areas of white-weathering frost boils and scattered resistant bedrock traces visible on aerial photographs suggests that Seabee Formation probably locally overlies Nanushuk Formation. Where better exposed in adjacent Ikpikpuk River quadrangle, Seabee Formation is mostly deeply weathered bentonitic mudstone; silty mudstone; and some medium- to dark-gray to black, fissile, organic-rich shale with interbedded bentonite and some thin, silicified tuff beds. Sandstone in lower part of unit is mostly tundra-covered, but is probably dominantly fine- to medium-grained. Contact of map unit with underlying Nanushuk Formation poorly constrained

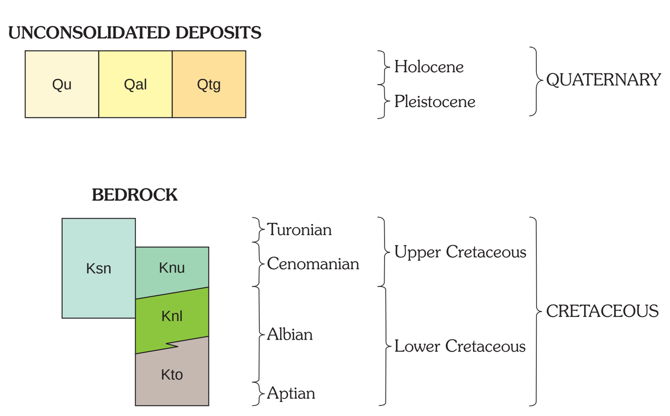
Nanushuk Formation, undivided (Gryc and others, 1951; Detterman, 1956; revised by Mull and others, 2003) (Upper Cretaceous, Cenomanian, to Lower Cretaceous, Albian)

Knu — Upper part (Upper Cretaceous, Cenomanian, to Lower Cretaceous, Albian)—Dominantly nonmarine to marginal-marine, gray to light-gray sandstone, and quartz- and chert-pebble conglomerate interbedded with poorly exposed siltstone; dark-gray, silty, carbonaceous shale; and coal; interbedded with marine rocks in upper and lower part of unit. Includes rocks formerly mapped regionally as Ninuluk, Niakogon, Chandler, and Grandstand Formations by Detterman (1956) and Detterman and others (1963). In upland areas, forms rolling tundra-covered hills with occasional resistant sandstone or conglomerate ledges with scattered rubble traces. Contact with overlying Seabee Formation is not exposed and is poorly constrained on aerial photographs; in southern part of quadrangle, top of unit mapped may contain beds of Seabee Formation. Contact with lower part of Nanushuk is approximate, and was determined using aerial photography; traces of resistant sandstone beds with less lateral continuity are assigned to the upper part of the Nanushuk; resistant beds with greater lateral continuity are assigned to the lower part of the Nanushuk. Sandstone beds are generally tight with relatively low porosity and permeability, but regionally transgressive, quartz-rich, marine sandstones in upper part of this unit have better porosity and permeability

Knl — Lower part (Lower Cretaceous, Albian)—Dominantly gray to greenish-gray, very fine to fine-grained marine sandstone and minor conglomerate. Contains resistant beds that form rubble traces which display long, lateral continuity on aerial photographs. In southern part of quadrangle, basal part of unit intertongues conspicuously with upper part of underlying Torok Formation where some resistant horizons prograde eastward into nonresistant horizons. Includes rocks formerly named Tuktu Formation by Detterman (1956) and Detterman and others (1963)

Kto — **Torok Formation (Gryc and others, 1951; Patton, 1956) (Lower Cretaceous, Albian to Aptian)**—Dark-gray mudstone and silty mudstone with lesser amounts of greenish-gray, thin-bedded siltstone. Generally poorly exposed, present only in axes of Carbon Creek and Awuna anticlines in southern part of quadrangle

CORRELATION OF MAP UNITS



EXPLANATION OF MAP SYMBOLS

Contact—Approximately located

Faults—Dashed where approximately located; dotted where concealed; queried where uncertain

U
D
Normal fault—U, upthrown side; D, downthrown side

Thrust fault—Teeth on upper plate

Wrench fault—Arrows indicate relative movement

Folds—Approximately located; dotted where concealed; queried where uncertain

Anticline—Showing direction of plunge

Syncline—Showing direction of plunge

Traceable beds

40
Strike and dip of beds

Figure 2.—Photograph of a petrified tree trunk in the Nanushuk Formation at the Lili Creek locality (sec. 28, T. 1 S., R. 26 W.). Photograph by Paul Decker (ConocoPhillips, Inc.).

GEOLOGIC MAPS OF NORTHERN ALASKA

Edited by
David W. Houseknecht

Arctic Alaska hosts a spectrum of geology and a wealth of natural resources matched by few areas on Earth. Prior to the 1940s, geologic investigations in the region mostly were limited to coastal surveys and inland reconnaissance studies. Nevertheless, the potential for petroleum accumulations beneath Alaska's North Slope and for mineral deposits in the Brooks Range was recognized through the observations of the early expeditions. World War II demonstrated an urgent need for domestic energy and mineral resources and stimulated the initial systematic geologic mapping in northern Alaska as a basis for energy and mineral exploration. The geologic maps generated by those initial efforts also served as the foundation for additional petroleum exploration in the wake of the oil embargo of the 1970s. A few years into the 21st century, the natural resources of northern Alaska again are a focus of national attention. The need for detailed geologic maps is greater than ever, not only as a basis for petroleum and mineral exploration, but also for land-use planning and mitigating the environmental impacts of developing those resources.

The U.S. Geological Survey (USGS) performed the initial systematic mapping of the geology of Alaska's North Slope, including the northern front and foothills of the Brooks Range, between 1944 and 1953. Maps resulting from that work were published between 1960 and 1966 as USGS Professional Paper 303. Since that time, numerous geologic maps of individual quadrangles, or parts of quadrangles, have been published by the USGS and by the Alaska Division of Geological and Geophysical Surveys (ADGGS). Until now, no attempt was made to produce an integrated set of geologic maps using a uniform scale and cartographic standards, and consistently applied stratigraphic nomenclature. SIM–2817 is a set of digital geologic maps comprising individual 1:250,000 quadrangles, each assigned a unique letter (for example, this map of the Lookout Ridge quadrangle is SIM–2817–C). The objective of these reports is to provide a new unified set of geologic maps of the northern flank and foothills of the Brooks Range using a uniform scale and cartographic style, as well as consistent stratigraphic nomenclature.

Although this collection of geologic maps incorporates significant contributions by many geologists who have mapped in northern Alaska during the past six decades, it would not be possible except for one geologist. This compilation is a testament to the career contributions of Charles G. (Gil) Mull, who has spent nearly forty years mapping the geology of the region for the petroleum industry, the USGS, the ADGGS, and the Alaska Division of Oil and Gas.

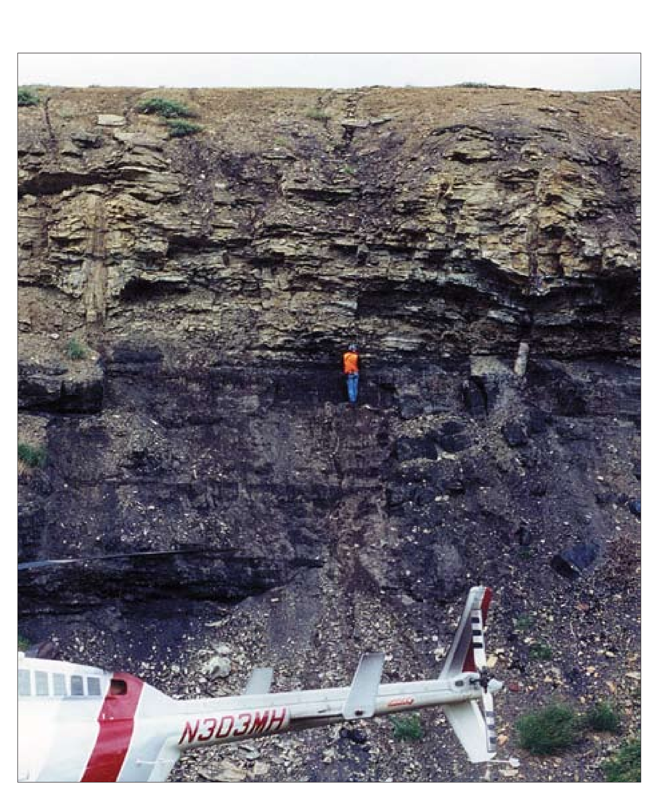


Figure 3.—Photograph of sandstone and coal in the Nanushuk Formation at the Lili Creek locality (sec. 28, T. 1 S., R. 26 W.). Geologist at center is approximately 6 ft tall. The observed composite thickness of the coal seam is approximately 27 ft. Petrified trees in growth position occur in the portion of overlying fluvial sandstone shown in this view, a large one at the left and a smaller one at right center. Photograph by Paul Decker (ConocoPhillips, Inc.).

GEOLOGIC MAP OF THE LOOKOUT RIDGE QUADRANGLE, ALASKA

By
Charles G. Mull,[1] David W. Houseknecht,[2] G.H. Pessel,[3] and Christopher P. Garrity[2]
2006
[1]Alaska Division of Oil and Gas, Anchorage, AK 99501, [2]U.S. Geological Survey, Reston, VA 20192, [3]Alaska Division of Geological and Geophysical Surveys, Fairbanks, AK 99709

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