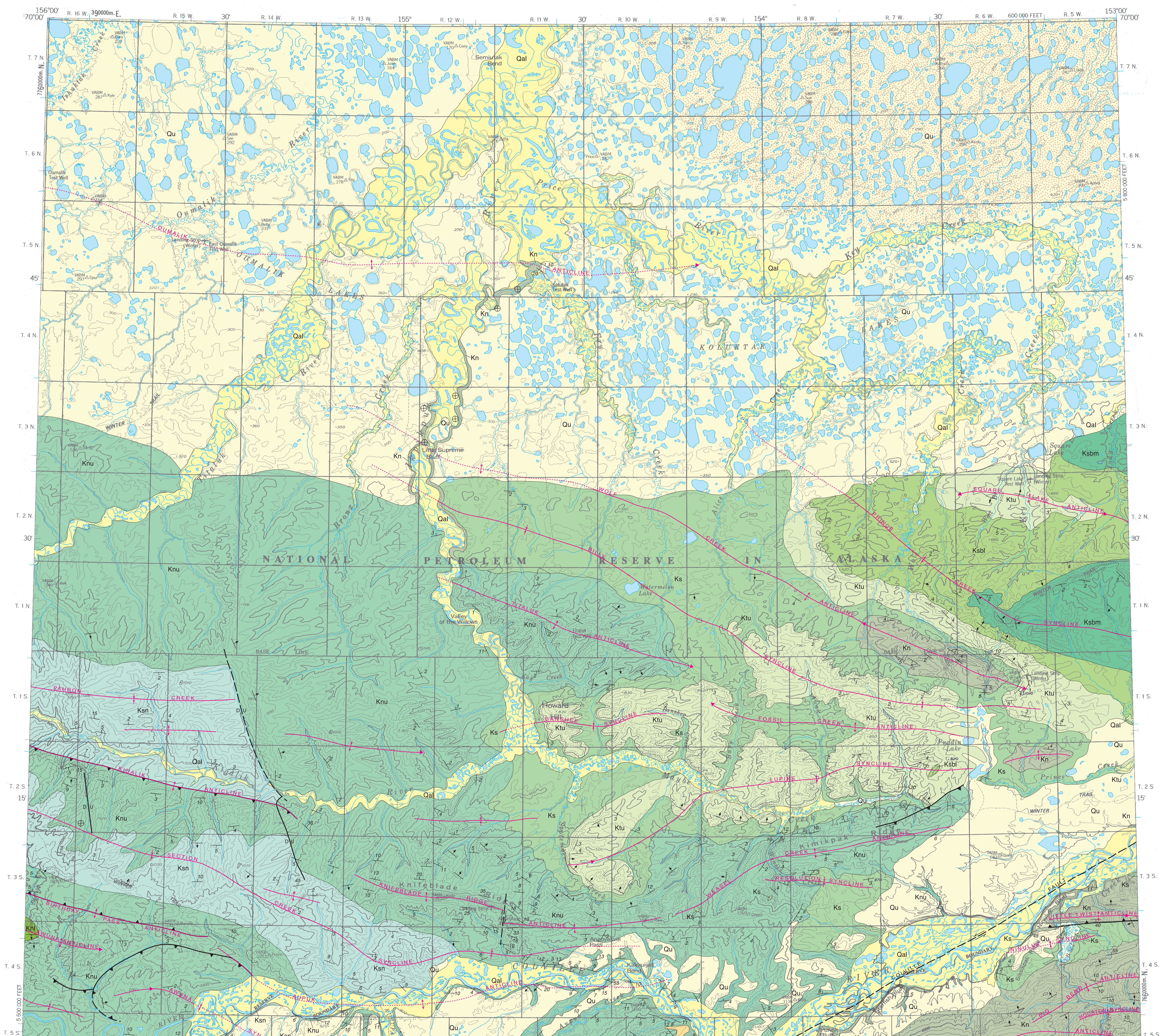
Prepared in cooperation with
ALASKA DEPARTMENT OF NATURAL
RESOURCES, DIVISION OF OIL AND GAS



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 5

APPROXIMATE MEAN DECLINATION, 2005

SCALE 1:250 000

5 0 5 10 15 20 MILES

5 0 5 10 15 20 25 KILOMETERS

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Geology mapped by W.P. Brosgé, C.L. Whittington, 1966; R.L. Detterman, R.S. Bickel, George Gryc, 1963; A.J. Martin and others, 1968; G.H. Pessel, C.G. Mull, 1964
Digital cartography by Christopher P. Garrity and Joseph A. East
Edited by Elizabeth D. Koozmin

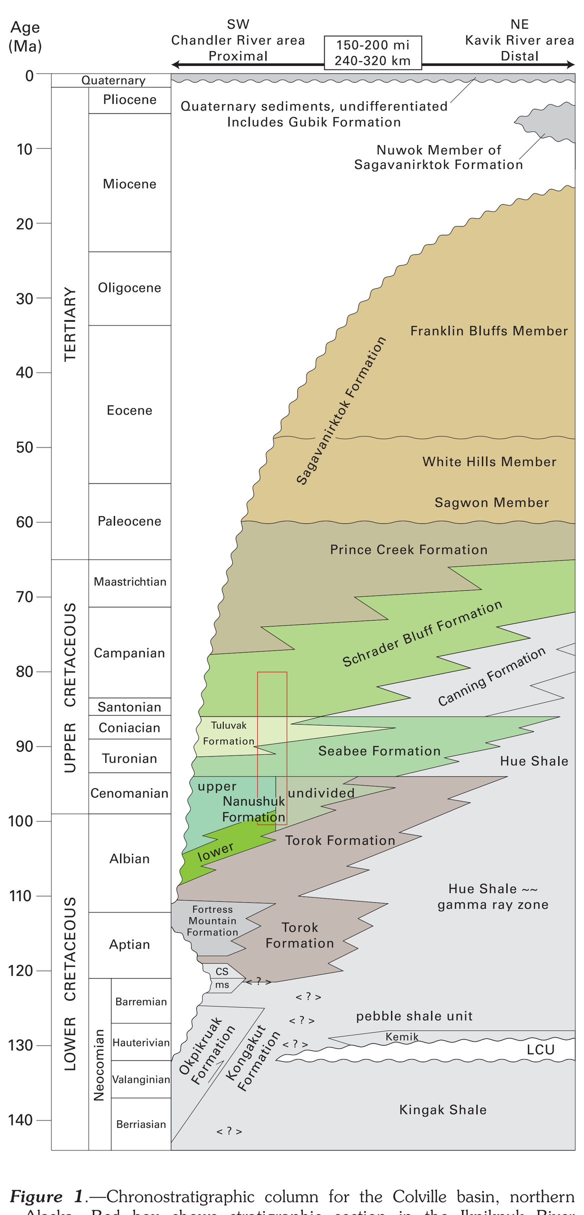


Figure 1.—Chronostratigraphic column for the Colville basin, northern Alaska. Red box shows stratigraphic section in the Ikpikpuk River quadrangle. Abbreviations or symbols are as follows: <?>, uncertain relationship; CS, cobblestone sandstone of Fortress Mountain Formation (informal unit of Mull and 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. Overlies several levels of terrace deposits up to about 150 ft above stream level adjacent to the Colville River. Also includes unstratified marine sand, silt, and local gravel derived from the Gubik Formation, which underlies much of area of abundant shallow lakes in the northern part of the Ikpikpuk River quadrangle and adjacent areas in Arctic coastal plain (Brosgé and Whittington, 1966), but is not differentiated on map. Includes vegetated eolian sand dunes in northern part of quadrangle

Qal — **Alluvial deposits (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)**—Tundra-covered, high-level alluvial gravels from glacial outwash, mapped only on south side of Colville River about 250 ft above present stream level

Schrader Bluff Formation (Mull and others, 2003) (Upper Cretaceous, Campanian to Santonian)—Only lower and middle parts are exposed in this quadrangle

Ksbm — Middle part (Campanian)—Resistant tuffaceous sandstone, bentonite, and tuff. Sandstone contains characteristic biotite flakes and relatively abundant marine bivalves. Crops out and underlies tundra-covered upland ridges in eastern part of quadrangle

Ksbl — Lower part (Campanian to Santonian)—Dominantly bentonitic mudstone, thin-bedded bentonitic sandstone, and bentonite. Mostly covered by tundra

Ktu — **Tuluvak Formation (Gryc and others, 1951; Whittington, 1956; revised by Mull and others, 2003) (Upper Cretaceous, Coniacian to Turonian)**—Fine- to coarse-grained to granular sandstone and quartz- and chert-pebble conglomerate in several relatively resistant intervals, some of which consist of conspicuously well-rounded and well-sorted pea gravel with no interstitial matrix. Forms mesa-like uplands with locally resistant ledges and rounded tundra-covered benches on hillsides east of September Creek and north of Maybe Creek in central part of quadrangle. Resistant intervals are separated by less resistant bentonitic shale and mudstone exposed only in scattered stream cutbanks. Lower part interfingers with Seabee Formation and includes sandstone, siltstone and interbedded shale formerly mapped as upper part of the Ayiyak Member of the Seabee Formation (Detterman and others, 1963); upper part apparently intertongues with lower part of Schrader Bluff Formation. Appears to be thicker and contain more resistant sandstone and conglomerate intervals than in Umiat and Chandler River quadrangles to east and southeast. Some intervals have excellent porosity and permeability

Ks — **Seabee Formation (Gryc and others, 1951; Whittington, 1956; revised by Mull and others, 2003) (Upper Cretaceous, Coniacian to Cenomanian)**—Bentonitic mudstone, silty mudstone; and medium- to dark-gray to black, fissile, organic-rich shale, with interbedded bentonite and some thin, silicified tuff beds; some localities characterized by large, yellowish-brown-weathering ovoid concretions greater than 3 ft diameter. Generally poorly exposed, forms broad tundra-covered valleys marked by scattered, bare, white-weathering shale frost boils. Basal part of mapped unit in western part of quadrangle probably contains rocks of underlying Nanushuk Formation. Unit consists only of rocks formerly mapped as Shale Wall Member by Detterman and others (1963)

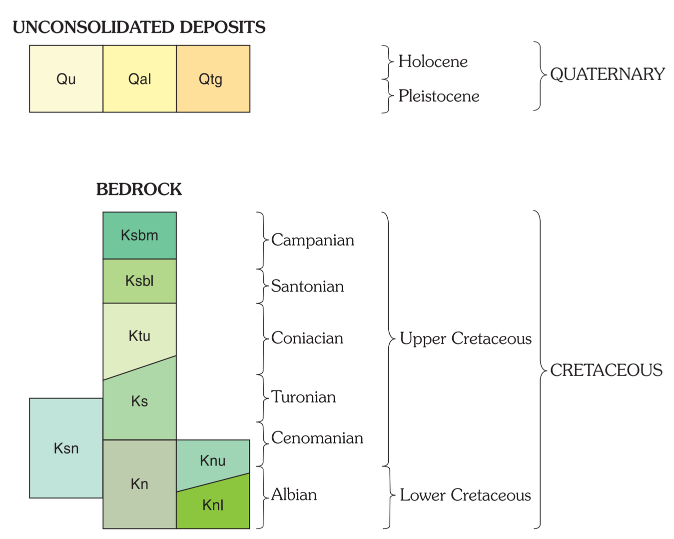
Ksn — **Seabee Formation and Nanushuk Formation, undivided (Upper Cretaceous, Turonian, to Lower Cretaceous, Albian)**—Mapped in areas of few exposures adjacent to coastal plain in northwestern part of outcrop belt and adjacent to Colville River in southwestern part of quadrangle. These are areas in which the regional structural pattern suggests that Seabee Formation is probably present overlying Nanushuk Formation; however, because of the scarcity of outcrops, Seabee cannot be confirmed or mapped separately from the Nanushuk. See unit descriptions above and below

Kn — **Nanushuk Formation, undivided (Gryc and others, 1951; Detterman, 1956; revised by Mull and others, 2003) (Upper Cretaceous, Cenomanian, to Lower Cretaceous, Albian)**—Fine- to medium-grained, locally conglomeratic sandstone, consisting dominantly of quartz and black chert, with interbedded siltstone and silty carbonaceous mudstone. Sandstones are generally well-cemented and have relatively low porosity and permeability; probable transgressive, quartz-rich, marine sandstones in upper part of formation have higher porosity and permeability. Forms relatively resistant linear ridges with scattered rubble traces in upland areas. Well exposed at Ninuluk Bluff on south side of Colville River in southeastern part of quadrangle. In most of the quadrangle and adjacent areas to the south and west, Nanushuk is characterized by two regionally mappable generalized units: (1) upper unit of marine to marginal-marine to nonmarine sandstone, contglomerate, and coal formerly mapped as Ninuluk, Chandler, and Grandstand Formations by Detterman (1956) and Detterman and others (1963), gradationally underlain by (2) a lower interval of dominantly marine sandstone formerly mapped as Tuktu Formation by Detterman (1956) and Detterman and others (1963). In the eastern part of Ikpikpuk River quadrangle and in Umiat quadrangle to the east, the Nanushuk Formation grades eastward to dominantly marine to marginal-marine beds, and distinction between upper and lower Nanushuk cannot be readily made. Facies relations at top of unit have been studied in detail at Ninuluk Bluff (LePain and Kirkham, 2001)

Knu — Upper part (Cenomanian to 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. Forms relatively resistant linear ridges with scattered rubble traces in upland areas, particularly on Knifeblade Ridge and Kimikpak Ridge in southern and western part of quadrangle. Contact with overlying Seabee Formation is not exposed; mapped unit in western part of quadrangle probably contains beds of Seabee Formation

Knl — Lower part (Albian)—Dominantly gray to greenish-gray, very fine- to fine-grained marine sandstone and minor conglomerate. Unit mapped in only one small area along the southwestern edge of quadrangle. Base of unit and underlying Torok Formation are not exposed in quadrangle

CORRELATION OF MAP UNITS



EXPLANATION OF MAP SYMBOLS

Contact—Approximately located

Faults—Dashed where approximately located

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

Thrust fault—Teeth on upper plate

Wrench fault—Approximately located. Arrows indicate relative movement

Folds—Dotted where concealed

Anticline—Showing direction of plunge

Syncline—Showing direction of plunge

Traceable beds

Strike and dip of beds

40 — Inclined

Horizontal

Estimated

Vegetated dunes

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 Ikpikpuk River quadrangle is SIM–2817–B). 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.

GEOLOGIC MAP OF THE IKPIKPUK RIVER QUADRANGLE

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

INTRODUCTION

The Ikpikpuk River quadrangle (1:250,000) is located in the east-central Arctic North Slope of Alaska. This geologic map is a compilation of previously published USGS geologic mapping by Detterman and others (1963), Chapman and others (1964), and Brosgé and Whittington (1966), combined with data from unpublished geologic mapping by Pessel and Mull (1964) for Richfield Oil Corporation and Martin (1968) for British Petroleum Company. Geologic mapping from these primary sources was modified to incorporate recent revisions in stratigraphic nomenclature by Mull and others (2003), to which the reader is referred for more detailed discussions of the age, thickness, regional distribution, and depositional environments of the stratigraphic units. Stratigraphic and structural interpretations in the Ikpikpuk River quadrangle were revised with the aid of modern high-resolution color-infrared aerial photographs. Selected localities were field checked in the summers of 2002 and 2003.

HISTORY OF EXPLORATION

The Ikpikpuk River quadrangle and the adjacent Umiat quadrangle played an important role in the early stages of oil exploration in Naval Petroleum Reserve #4 (NPR-4, now known as the National Petroleum Reserve in Alaska, or NPRA). The area was first traversed by a USGS field party in 1924 (Smith and others, 1926; Smith and Mertie, 1930), not long after the establishment of NPR-4 in 1923. Their 1926 summary report and a generalized cross section from the Brooks Range mountain front to the Ikpikpuk River provided the first description and illustration of the belt of regional anticlines and synclines of northwardly decreasing amplitude that deform the Cretaceous rocks of the foothills belt. That report also discussed the logistical constraints on oil exploration and development and pointed out that a railroad or 1,000-mi-long pipeline (with the attendant defense issues) and enormous capital expenditures would be needed to develop oil resources on the North Slope. The report went on to recommend further study and drilling of shallow stratigraphic test holes, but additional field studies did not occur until the late 1940s as part of an intensive program of exploration in NPR-4 by the U.S. Navy. Extensive field geological mapping and geophysical surveys were carried out in the area of the Ikpikpuk River quadrangle following the initial exploration and 1946 discovery of oil to the east at Umiat (see discussion by Mull and others, 2004). Several exploratory wells were drilled by the Navy in 1951 and 1952 on anticlines at Square Lake, Wolf Creek, Titaluk, and Knifeblade Ridge, with the discovery of subcommercial gas accumulations at Square Lake and Wolf Creek. The results of this period of geologic mapping and drilling in the Ikpikpuk River quadrangle were summarized by Reed (1958), Collins (1959), Robinson (1959), and Brosgé and Whittington (1966).

The oil discovery at Umiat and a gas discovery at Gubik, a short distance east of Umiat, 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 160 mi northeast of the Ikpikpuk River quadrangle by Atlantic Richfield Company and Humble Oil Company (now ExxonMobil). Following the success of the industry exploration, renewed exploration of NPR-4 (renamed the National Petroleum Reserve in Alaska in 1978) was carried out by the U.S. Navy and the U.S. Department of Interior from 1974 to 1982, and included additional geophysical surveys in NPRA. The results of this second phase of government exploration in NPRA are summarized in Gryc (1988).

Four Federal lease sales were held in NPRA in the 1980s, but only two exploration wells were drilled by industry and neither resulted in development of petroleum resources. 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 Ikpikpuk River quadrangle, just outside NPRA. Federal lease sales were held in 1999, 2002, and 2004 in northern NPRA and included lands in the northern part of the Ikpikpuk River quadrangle as well as outside the quadrangle area. Several exploration wells were drilled by industry during subsequent winter drilling seasons, but none of the wells was drilled within the Ikpikpuk River quadrangle; several of those wells were announced as oil and gas discoveries.

REGIONAL SETTING

The geology of the Ikpikpuk River 1:250,000-scale quadrangle spans 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 through 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 is a thick (>12,000 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). 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. Renewed progradation of clastic depositional systems subsequently resulted in deposition of Upper Cretaceous to Miocene shallow-marine through nonmarine strata of the Tuluvak, Schrader Bluff, Prince Creek, and Sagavanirktok Formations.

Exposures of the Brookian sequence in the Ikpikpuk River quadrangle consist of, in ascending order, the Nanushuk, Seabee, Tuluvak, and Schrader Bluff Formations. Although the Torok Formation is present in the subsurface throughout the area, no exposures of the Torok are known in the Ikpikpuk River quadrangle. No Brookian strata younger than the Schrader Bluff Formation are inferred to be present in the Ikpikpuk River quadrangle.

North of the Colville River, the Ikpikpuk River quadrangle is characterized by extensive areas of tundra cover and relatively few good bedrock exposures; thus, the mapping relies heavily on the interpretation of aerial photographs. The contact between the Nanushuk and Seabee Formations is particularly difficult to map because of the nonresistant nature of the Seabee Formation. Consequently, the upper part of the Nanushuk Formation and the overlying Seabee Formation are mapped as an undivided unit in part of the western part of the quadrangle. The type localities of many of the rock units present in the quadrangle are in the adjacent Umiat and Chandler Lake quadrangles to the east and southeast, where they are better exposed. However, Ninuluk Bluff, on the southeast bank of the Colville River at the eastern edge of the quadrangle, contains a significant exposure of the upper part of the Nanushuk Formation, which is the main oil-bearing horizon of the Umiat oil field and is one of the major potential reservoir horizons elsewhere in the east-central Colville basin.

REGIONAL STRUCTURE

The succession of relatively resistant Cretaceous (Albian to Campanian) clastic rocks in the Ikpikpuk River 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 are developed above a décollement in relatively incompetent shales and mudstones of the underlying Torok Formation (Aptian to Cenomanian) and Kingak Formation (Jurassic to Lower Cretaceous), which form the cores of the anticlines but are not exposed in the Ikpikpuk River quadrangle. Many of the anticlines mapped in the foothills of the Brooks Range are characterized by north-vergent thrust faults. However, south-vergent back thrusts also are evident in some areas, particularly where the anticlines are defined at the surface by resistant beds of the Nanushuk Formation. A south-vergent back thrust is associated with the Little Twist anticline in the southeast part of the Ikpikpuk River quadrangle; the southward vergence of this back thrust also is evident to the east in the Umiat quadrangle (Mull and others, 2004). South-vergent back thrusts also are inferred to be present in the southwest corner of the quadrangle, most notably along the axis of the Aupuk anticline.

The Square Lake anticline, located in the east-central part of the quadrangle, was the site of exploration drilling in the 1940s. This structure is a continuation of the Umiat anticline to the east. Different names were applied to this anticline during early exploration activities, when the continuity of the structure was not known.

Regional structural and stratigraphic relationships and apatite fission-track data suggest that the deformation of this part of the foothills fold belt probably occurred during the early Tertiary 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; Mull and others, in press).

A northeast-southwest-trending regional fault zone not mapped by earlier workers is inferred to underlie the linear N. 65° E.-trending reach of the Colville River valley in the southeastern part of the Ikpikpuk River quadrangle and adjacent Umiat quadrangle. This fault, termed the Colville fault, is inferred on the basis of (1) the anomalous linear character of the Colville River valley, and (2) the presence of apparent structural anomalies adjacent to the river. In the Ikpikpuk River quadrangle, the axis of the Killik Bend anticline on the south side of the Colville River is particularly anomalous; its regional east-west trend changes abruptly to a northeast-southwest trend adjacent to the Colville fault zone. Elsewhere on the south side of the Colville River, the Ninuluk Creek syncline and Little Twist anticline are well defined by the resistant beds of the Nanushuk Formation, but seem to have no comparable structural expression on the north side of the river. In the adjacent Umiat quadrangle, the Umiat anticline is also anomalous near the Colville River; its regional northwest-southeast trend north of the river changes to a structurally more complicated east-west trend adjacent to the inferred fault zone (Mull and others, 2004).

The anomalous bends in the trends of the Killik Bend and Umiat anticlinal axes are compatible with left-lateral strike-slip movement along a high-angle fault. The Colville fault is thus interpreted as a deep-seated, left-lateral wrench fault above which the alternating relatively competent and incompetent Lower and Upper Cretaceous strata are deformed differentially above the underlying, more competent basal Mesozoic and Paleozoic rocks. Slip along the fault probably does not exceed a few miles. The fault is oblique to and apparently post-dates the early Tertiary deformation that formed the foothills foldbelt. The pattern of deflected axial traces in some areas and the apparent termination of fold axes in other areas adjacent to the Colville River is compatible with deformation associated with small- to intermediate-displacement wrench faults (Harding and Lowell, 1979).

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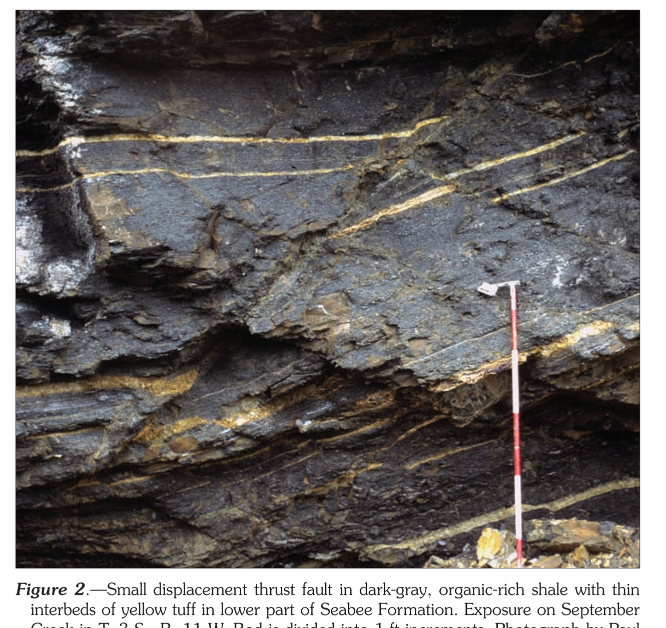

Figure 2.—Small displacement thrust fault in dark-gray, organic-rich shale with thin interbeds of yellow tuff in lower part of Seabee Formation. Exposure on September Creek in T. 3 S., R. 11 W. Rod is divided into 1-ft increments. Photograph by Paul Decker (Alaska Department of Natural Resources, Division of Oil and Gas).

GEOLOGIC MAP OF THE IKPIKPUK RIVER QUADRANGLE, ALASKA

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2005

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