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Surficial Geologic Map of parts of the Misheguk Mountain and Baird Mountains Quadrangles, Noatak National Preserve, Alaska

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INTRODUCTION

PHYSICAL SETTING

The map area, which comprises part of the Noatak National Preserve, includes approximately the southern two-thirds of the Misheguk Mountain quadrangle and the northern one-third of the Baird Mountains quadrangle. It is centered on a belt of west-trending lowlands along the Noatak River which separates the De Long Mountains to the north from the Baird Mountains to the south (Burch, 1990, p. 196-201). The map area extends between the drainage divides which bound the Noatak drainage system to the north and south, separating that network from streams that flow north into the Arctic Ocean and south into the Kobuk River. An additional small segment in the southwest corner of the map area covers the upper drainage basin of Eli River, which flows west and then south to intersect the Noatak River about 50 km upvalley from Kotzebue Sound.

In addition to broad lowlands and isolated blocks of low mountains along the Noatak River and lower courses of its principal northern tributaries, the map area includes rugged highlands that rise to 4000-4500 ft (1225-1375 m) in the De Long Mountains[1]. Highlands within the Baird Mountains are more subdued. They generally rise to only 3000-3500 ft (900-1050 m), although Mt. Angayukaqsraq, in the southeast corner of the map area, rises to 4760 ft (1452 m).

Most of the map area is tundra-covered, but riparian stands of cottonwood (*Populus balsamifera*) are discontinuously present along the Noatak River and lower courses of its principal tributaries. Riparian spruce (*Picea glauca*) stands occur along the Noatak River in the extreme western part of the map area, where they extend upvalley to just above Noatak Canyon. All of the map area is underlain by continuous permafrost (Ferrians, 1965; Brown and others, 1997), which commonly is ice rich and occurs at shallow depths.

HISTORY OF INVESTIGATIONS

Initial geologic study of the Noatak River valley was undertaken in 1911 by a U.S. Geological Survey field party led by Philip S. Smith that portaged into the upper Noatak drainage and then traversed the river to its mouth (Smith, 1913). More detailed helicopter-supported bedrock geologic mapping was carried out later by the U.S. Geological Survey (e.g., Tailleur and others, 1977). This work culminated in bedrock geologic maps that spanned the southern part of the Misheguk Mountain quadrangle (Curtis and others, 1984; Ellersieck and others, 1984; Mayfield and others, 1984) and the entire Baird Mountains quadrangle (Karl and others, 1989). A derivative map of construction materials within the Baird Mountains quadrangle has been compiled by Combellick and others (1993).

Regional syntheses of western Brooks Range geology include Mayfield and others (1988), Till and others (1988), and Moore and others (1994). Other geologic studies have dealt with the igneous and intrusive rocks of the map area (Boak and others, 1987; Karl and others, 1989; Till, 1989; Saltus and others, 2001). Mineral-resource data for the Misheguk Mountain and Baird Mountains quadrangles have been compiled by Dover (1997) and Williams (2000), respectively.

Surficial geology of the western Brooks Range was compiled from aerial photographs in 1960 by A.T. Fernald, H.W. Coulter, and E.G. Sable. Their data were incorporated into statewide maps of surficial geology (Karlstrom and others, 1964) and glacial limits (Coulter and others, 1965). Later field mapping of the Noatak River valley immediately east of the map area (Hamilton, 1984a, 1984b) led to recognition of a series of large ancient lakes created by glaciers that originated in the De Long Mountains and flowed southward to dam the Noatak River (Hamilton and Van Etten, 1984). Subsequent detailed study of river bluffs through this sector of the Noatak valley resulted in recognition and dating of interstadial deposits of middle Wisconsin age (Hamilton and others, 1987), identification of the Old Crow tephra, a widespread interglacial marker bed (Hamilton and Brigham-Grette, 1992), and paleoecologic analysis of a locally rich interglacial insect and vegetation record (Elias and others, 1999). An overview of the depositional record exposed in these bluffs reveals a complex history of interrelated glacial advances, stages of lake formation, and episodes of river downcutting (Hamilton, 2001).

BEDROCK SURFACE FORMS

The five bedrock divisions designated on the map refer to surface morphology, and only indirectly reflect bedrock composition.

Alpine bedrock (unit $B_{\mathbf{a}}$) generally is underlain by resistant rock types, such as conglomerates, massive carbonates, and intrusive igneous rocks, that support relatively high, rugged uplands. Within the De Long Mountains and locally within the Baird Mountains, late Pleistocene glacial erosion has further steepened valley walls, sharpened ridge crests, and indented valley heads with cirque basins. Such bedrock areas are subject to rockfalls, landslides, snow avalanches, and other hazards characteristic of steep slopes.

Bedrock exposed by erosion (unit B_e) is present both as narrow strips that highlight former meltwater channels and also as more extensive tracts along the Aklumayuak Creek and parts of the Noatak River that underwent late Pleistocene downcutting. The mapped distribution of this

[1] Elevations are presented in feet when taken directly from topographic maps. They are followed in parentheses by their calculated metric equivalents.

unit provides a useful guide to Pleistocene drainage changes, and would be helpful in locating bedrock exposures in areas generally covered by surficial deposits.

Glaciated bedrock (unit B_g) has been overridden and scoured by glacier ice. Areas thus designated serve as useful indicators of the extent and distribution of former glaciers. Because the glaciated surfaces commonly are streamlined and channeled in the directions of glacier flow and meltwater drainage (see map symbols), they also serve as flow-direction indicators. Glaciated bedrock generally yields excellent rock exposures in areas where other rock surfaces are weathered, frost-shattered, or silt-covered.

In areas of silt-covered bedrock (unit B_s), upland surfaces are largely obscured by fine-grained sediments or weathering products. On adjoining hillsides and valley walls, solifluction has transported and mixed these deposits, forming extensive aprons of rubbly or organic silt that thicken downslope. Areas of silt-covered bedrock generally were not glaciated during late Pleistocene time. They are common downwind from glacier-dammed lakes, which served as sources of windblown silt (loess) when the lakes were freshly drained and their floors not yet revegetated. Lake beds exposed repeatedly by outburst floods would have been especially effective loess sources. Within the Baird Mountains, some low-lying areas of silt-covered bedrock more distant from Pleistocene lake beds are underlain by rock types such as phyllite that weather readily to yield abundant fine-grained detritus.

Areas designated *B* (undifferentiated bedrock) generally have characteristics intermediate between those of the other bedrock surface forms. They commonly contain isolated areas with other surface forms that are too small to map individually.

THE PLEISTOCENE RECORD

GLACIAL, LACUSTRINE, EOLIAN, AND FLUVIAL INTERACTIONS

Surficial geologic units and their relationships within the map area are compatible with the glacial-lacustrine-fluvial model described by Hamilton (2001) for the Noatak basin. During each of several successive Pleistocene glaciations, glaciers developed at valley heads within the De Long Mountains; they expanded down south- to southeast-trending valleys and spread into lobes within lowlands along the Noatak River. Dammed by the lobes, large lakes formed and inundated the Noatak basin for as much as 50 km upvalley (Hamilton, 2001). Although some of the older and larger larger lakes had outlets to the north and south from the Noatak basin, most probably filled and emptied repeatedly as their ice dams eroded or became buoyant (Walder and Costa, 1996; Hamilton, 2001). The resulting glacial outburst floods would have flowed westward down the Noatak River. Outburst-flood drainage of the glacier-dammed lakes must have occurred with greater frequency as ice thinned or retreated toward the close of a glaciation, with the lake refilling each time to a lower surface level. Each time a lake drained, its newly exposed surface was swept by winds that entrained fine-grained sediments and deposited them downwind as loess. The Noatak River re-established its course across the lake floor early in each interglacial, then cut down progressively to a level near that of the present day. The river bluffs created by this downcutting exhibit early-interglacial fluvial deposits at levels several tens of meters above present river level, whereas full-interglacial deposits appear at or slightly below the modern river (Elias and others, 1999; Hamilton, 2001). These interglacial deposits were buried and preserved beneath till-like sediments that formed during subsequent glacial and glacio-lacustrine episodes.

Smaller glaciers developed on local highlands within the Baird Mountains, but these were mostly restricted to valley heads. They locally crossed divides into upper valleys of the Kobuk drainage system, but generally did not extend northward far enough to intersect the lowlands along the Noatak River.

GLACIAL NOMENCLATURE

A consistent set of terms has been employed for glacial-geologic mapping through the central Brooks Range (Hamilton, 1977, 1978, 1986, 1994; Hamilton and Porter, 1975), and these terms have been extended into the present map area. The *Sagavanirktok River glaciation* is broadly equated with multiple glacial advances of middle Pleistocene age; the *Itkillik glaciation* with multiple advances during the late Pleistocene (table 1). However, glaciers in the De Long Mountains were nourished largely from moisture sources in the Bering Sea, and probably responded somewhat differently from central Brooks Range glaciers during each glacial cycle. Throughout the map area I have employed the unit designations used in the central Brooks Range to facilitate comparison with mapped areas farther east in the Noatak basin (Hamilton 1984a, 1984b). These map units also permit the use of generalized designations (for example, unit *id*) in cases where more age-specific designations (such as id_1, id_2, and id_3) are not feasible. However, many glacial deposits within the map area are directly traceable into end moraines that are named for tributary drainages that join the Noatak River close to where the moraines cross the valley center (Hamilton, 2001). I consequently employ a double set of names in the map-unit descriptions: the local moraine name followed in parentheses by its probable central Brooks Range equivalent (see table 1).

Table 1. *Glacial advances recognized in Misheguk Mountain and Baird Mountains quadrangles and their central Brooks Range equivalents.* **MIS**, marine isotope stage

Local Glacial Advance	Map Unit	Central Brooks Range Equivalent	Age	
Neoglacial	nd	Neoglaciation	Late Holocene	
Unnamed	id_3	Late Itkillik II readvance	Late Wisconsin (MIS 2)	Late Pleistocene
Avan	id_2	Itkillik II		
Unnamed	id_{1C}	None recognized		
Anisak	id_{1B}	Itkillik IB	Early Wisconsin (MIS 4)	
Makpik	id_{1A}	Itkillik IA	Late interglacial (MIS 5d-5a)	
Okak	sd?	Sagavanirktok River (late phase)	Middle Pleistocene	
Cutler	sd	Sagavanirktok River	Middle Pleistocene	
Unnamed older drift	od	Sagavanirktok River or older	Middle Pleistocene or older	

GLACIER DAMMED LAKES

The lakes that formed during the Itkillik glaciation filled and drained dynamically rather than remaining at static levels. Their shoreline features therefore are weakly developed and difficult to trace. The deposits of the former lakes are recognizable as poorly drained, ice-rich, fine-grained sediments that blanket valley floors and thin upward on lower valley sides, generally wedging out at consistent altitudes. Fan-delta deposits are common at the mouths of tributary valleys; they splay into unusually broad, low-gradient, uniformly fine-grained deposits below the levels of the former lakes. Wave-cut notches are present along the inner flanks of moraines, especially north and south of the Noatak River above Nimiuktuk River confluence, where unusually great fetch (span of open water) would have allowed wave action to be especially effective. Rare linear gravel outcrops aligned with the notches are interpreted as probable beach ridges. End moraines in some valleys become diffuse at a level that probably represents a contemporaneous lake stand; other end moraines are eroded to distinctive levels that represent lake stands during or after abandonment of the moraines by glaciers.

Three principal lake stages are recognized in the map area, and a series of younger and lower lake stands occur on the Noatak valley floor near the west margin of the map area (table 2). The lake stages, which can be dated approximately by their interrelationships with moraines, form an important part of regional drainage history, controlling the locations of overflow channels and the timing of glacial outburst floods. The fine-grained lake deposits cause valley floors and lower valley sides to be poorly drained, resulting in shallow ice-rich permafrost, active solifluction, and other frost-related processes. The presence or absence or lake deposits of a given age can indicate the extent of contemporaneous glaciation, and former glaciated areas also are indicated by postglacial isostatic uplift of initially horizontal lake planes.

MIDDLE PLEISTOCENE AND OLDER(?) GLACIATIONS

Most bedrock types within the map area weather rapidly, and erratic stones consequently are rare on surfaces older than late Pleistocene. Thick deposits of windblown silt, derived from the beds of newly drained lakes, also cover many of these older surfaces. For these reasons, limits of glaciations older than late Pleistocene are difficult to determine, and boulder weathering and other physical characteristics cannot be used to distinguish glacial deposits or glaciated bedrock surfaces of differing middle Pleistocene and older ages.

Broad U-shaped troughs that cross drainage divides along its north and south margins may be among the oldest glacial features recognized in the map area. Remnant patches of drift (unit *(sd)*) are evident on the floor of only one pass, but bedrock abraded by glacier ice (unit B_g) is more widely present in and around the passes, especially those carved from readily sculpted marble within the Baird Mountains. These ice-abraded surfaces exhibit smoothed

Table 2. *Observed upper limits of lake deposits within Misheguk Mountain and Baird Mountains quadrangles*

Drainage Area	Upper Lake Limit		Map Unit
	Feet	Meters	
Upper Anisak	1630–1650	500	sgl
	1400	430	igl_1
Lower Anisak	1580–1600	480	sgl
	1300	400	igl_1
Noatak above Nimiuktuk R.	1540	470	sgl
	1250	380	igl_1
	1000	300	igl_2
Nimiuktuk basin	1300–1350	400–410	igl_1
	1100	340	igl_2
Noatak between Nimiuktuk R. and Kaluktavik R.	1500	460	sgl?
	1250–1300	380–400	igl_1
	1000	300	igl_2
Upper Kaluktavik	1300–1350	400–410	igl_1
	1150	350	igl_2
Lower Kaluktavik	1250–1300	380–400	igl_1
	1100	340	igl_2
Noatak between Kaluktavik R. and Kelly R.	1300	400	igl_1
	500	150	igl_2 (late phase)
Upper Kugururok	1100–1150	340–350	igl_2
Lower Kugururok	1150	350	igl_2
	1050	320	igl_2 (late phase)
	700–750	210–230	
	550	170	
Lower Avan	1050–1060	320	igl_2 (late phase)
	700	210	
	550	170	
Upper Kelly	1300–1350	400–410	igl_1
	1150	350	igl_2
Lower Kelly	1000	300	igl_2 (late phase)
	700	210	
	500–550	150–170	

and streamlined ridges, faceted valley walls, and adjoining beveled uplands. The troughs along the north margin of the map area probably were eroded by outlet glaciers from an ice cap that covered much of the De Long Mountains. The troughs along the map area's south margin may have been outlets from smaller individual glacier complexes around prominent highlands such as Mt. Angayukaqsraq, Kanaktok Mountain, and other peaks near the heads of Eli River and the North Fork of Squirrel River. Drift patches and isolated erratic stones must originally have been present on the ice-sculpted surfaces, but they must have been eradicated during a long span of postglacial weathering.

An extensive blanket of featureless drift (unit *od*) that lies beyond Cutler-age deposits in the southeastern part of the map area is inferred to represent a glaciation of early or middle Pleistocene age that preceded the Cutler advance.

It is contiguous with drift remnants that were mapped beyond the Cutler moraine in southern parts of the adjoining Noatak basin (Hamilton, 1984b).

The Cutler advance represents a distinctive event of middle Pleistocene age. Its end moraine, which intersects the Noatak River near the mouth of Cutler River 30 km east of the map area, was originally assigned to the late Pleistocene Itkillik glaciation (Hamilton, 1984b), but subsequent stratigraphic studies of bluff exposures along the Noatak River have shown that deposition of this moraine preceded the last interglaciation and therefore is assignable to the middle Pleistocene (Hamilton, 2001). It may be correlative with the middle Pleistocene glacial advance described by Huston and others (1990) that created the massive Baldwin Peninsula moraine complex in Kotzebue Sound.

South of the Noatak River, the Cutler moraine is traceable westward from its terminus into the map area near Lake Kangilipak, where its outer flank is continuous with the outer limit of drift unit *sd*. Farther west, in the south-central part of the map area, featureless drift that lies south of the Noatak River beyond Itkillik glacier limits may also be of Cutler age. These deposits outline an ice margin that extended southward from the De Long Mountains across the Noatak River valley into uplands and valleys of the northern Baird Mountains, overriding most of the valley through a stretch of perhaps 150 km. A glacial advance of this magnitude must have been generated by an ice cap over much of the De Long Mountains rather than by individual valley glaciers.

In the northeast part of the map area, drift of probable Cutler age east of the upper Nimiuktuk River (unit *sd*) outlines a large glacier that flowed southeastward, perhaps draining the eastern margin of a De Long Mountains ice cap. Glacier-scoured bedrock in the western part of the Iggiruk Mountains probably was overridden at the same time because the orientations of grooved and streamlined features are consistent with a southeasterly ice-flow direction. The drift, ice-scoured features, and associated meltwater channels are assumed to correlate with the Cutler moraine, but some of the lower-lying deposits just beyond Itkillik ice limits near New Cottonwood Creek may have formed later as part of the Okak end moraine, which intersects the Noatak River at Okak Bend, about 20 km east of the map area (Hamilton, 2001). Because thick glaciolacustrine deposits cover most of the intervening basin floor north of the Noatak River, surface exposures of glacial deposits are rare and correlations with the Cutler and Okak end moraines are uncertain.

Although lake deposits of inferred middle Pleistocene age are widespread in the Ambler River and Howard Pass quadrangles (Hamilton, 1984a, 1984b), comparable deposits in the map area have been largely obliterated by younger glacial advances. Lake deposits of this age (unit *sgl*) are widely exposed only in the upper Anisak River valley near the northeast corner of the map area. They rise here to a maximum altitude of about 1650 ft (500 m), and truncate or overlap end moraines of inferred Cutler age along Setting Sun and Stone Ring Creeks. The water plane declines southward to about 1600 ft (490 m) asl east of the lower Anisak River (just beyond the east margin of the map area), and it may have stood at about 1540 ft (470 m) asl near the southeast corner of the map area; its upwarping to the north probably reflects isostatic recovery from crustal depression beneath glaciers in the De Long Mountains. The lake's outlet may have been through Howard Pass, whose floor was at about 520 m asl, because isostaticaly warped water planes rise eastward across the Noatak basin (Hamilton, 2001). A local meltwater drainage channel near present-day Lake Kangilipak issues from the outer flank of a Cutler-age moraine at an altitude of about 1500 ft (460 m), and trends south into the valley of Aklumayuak Creek. Aklumayuak Creek must have been established as a major meltwater outlet channel during Cutler time. Because evidence for lake stands at comparable heights is absent from all parts of the map area farther to the west, extensive glaciers must have covered most of this part of the De Long Mountains and the Noatak River valley at this time.

LATE PLEISTOCENE GLACIATIONS

Five successively less extensive glacial advances of late Pleistocene age developed within the De Long Mountains (see table 1). Several can be traced into named end moraines that cross the Noatak valley center, but relationships are not always clear because of the extensive glacial-lake deposits that fill low-lying areas along the Noatak and lower parts of its principal northern tributaries. The moraine succession postdates deposition of the last-interglacial Old Crow tephra, and therefore is assignable to the Itkillik glaciation (Hamilton, 2001). The two oldest advances of the succession created the Makpik and Anisak moraines, which cross the Noatak valley floor 14 km east of the map area and at the map area's eastern boundary, respectively. Much less extensive younger glacial advances issued from source areas within the De Long Mountains. By analogy with the central Brooks Range glacial sequence, the principal drift units assigned to these advances have been termed Itkillik IA, Itkillik IB, and Itkillik II (table 2), and are labeled id_{1A}, id_{1B}, and id_2 on the map. A very localized readvance or stillstand toward the end of Itikillik I time is labeled id_{1C} (a term new to this map); a limited readvance of late Itkillik II age (recognized widely the Brooks Range) is labeled id_3.

Late Pleistocene glaciation within the Baird Mountains was restricted to a few isolated highlands, and consequently is discussed separately at the end of this section.

Glaciations and related events of Itkillik I age

The Makpik and Anisak advances are most clearly differentiated in the east-central part of the map area, where large compound lateral moraines outline successive ice lobes that flowed southeastward out of Nimiuktuk River valley. The outer lobe (unit id_{1A}) extended beyond the map area and is traceable into the Makpik moraine; the inner lobe (unit id_{1B}) extended into a probable floating ice tongue near the mouth of Anisak River and also created the basin now occupied by Lake Kangilipak. A younger moraine, formed during a subsequent stillstand or readvance, intersects the Noatak River 11 km farther west. The Nimiuktuk glacier was fed by a small ice cap near the valley head (note highland areas labeled B_g) and by major western tributaries that flowed down the valleys of Seagull and Tumit creeks from sources in the north-central part of the map area.

A smaller western lobe of the Nimiuktuk glacier diverged near the mouth of Nimiuktuk valley and flowed southward through a narrow bedrock-bounded passageway. The limit of the older (id_{1A}) advance of the western lobe is obscured by glaciolacustrine deposits, but the glacier may have extended down the Noatak to the vicinity of Kaluktavik River to become confluent with ice flowing south down that drainage system. The younger (id_{1B}) advance of the western lobe terminated about 6 km above the mouth of Aklumayuak Creek, where it formed an end moraine across the valley floor.

Glaciers of Itkillik I age farther west formed major south-flowing systems that filled the Kugururok and Kaluktavik drainages. Patches of drift and expanses of ice-scoured bedrock (bedrock unit B_g) are exposed locally above the limits of widespread glacial-lake deposits. End moraines generally are buried beneath the blanket of lacustrine sediments, but commonly are evident as subdued arcuate ridges (see map symbol).

Glacial-lake deposits of Makpik and Anisak age cannot be differentiated from each other, so are shown together as unit igl_1. These deposits extend widely through the map area beyond the limits of younger glaciolacustrine sediments (unit igl_2). In the upper Anisak drainage the limit of Itkillik-age lake deposits is at about 1400 ft (430 m) altitude, and a series of fan-delta deposits occurs along the former north shore of the lake. Within the Nimiuktuk lobe the lake limit is at about 1200-1300 ft (370-400 m) both north and south of the Noatak River, and is associated with wave-eroded notches and sparse beach deposits (unit *b*) along the inner flanks of id_{1A} moraines. The 1200-1300 ft (370-400 m) lake limit remains unchanged westward down the Noatak River and through the lower Kaluktavik valley, but farther north up Nimiuktuk valley it rises to 1300-1350 m (400-410 m). Elevated lake limits in northern and northeastern parts of the map area probably reflect ice load in the De Long Mountains and farther east in the central Brooks Range. Lake deposits at comparable levels are generally absent from the De Long Mountains between the Kelly River to the west and Imikneyak Creek to the east. This sector of the mountains may have still been ice-covered when the lake existed.

Through the eastern part of the map area, the lake level must have been controlled by an overflow channel at about 1300 ft (400 m) asl that extended southward into Aklumayuak Creek from the id_{1A} moraine south of Lake Kangilipak. Drainage from Aklumayuak Creek then flowed westward down the Noatak River valley, skirting southern ice margins. During much of Itkillik I time, glaciated highlands through the central part of the map area may have divided glacier-dammed lakes into eastern and western compartments that were controlled by separate outlets. In west-central parts of the map area, deposits of inferred igl_1 age along lower valley walls are heavily modified by solifluction and dissected by erosion. The water body that formed those deposits may have drained through a pass at about 1150 ft (350 m) asl at the head of Ahliknak Creek near the southwest corner of the map area.

A limited stillstand or readvance of glaciers took place near the close of Itkillik I time. Glaciers generated on and around Black Mountain radiated southward for short distances into upper Nimiuktuk valley and probably also into Seagull Creek and headward parts of Trail Creek. In Nimiuktuk River valley, till and outwash assigned to this event (units id_{1C} and io_{1C}) were eroded by a glacial lake and overlapped by its deposits to an altitude of about 1350 ft (410 m), the characteristic upper limit for lakes of Itkillik I age in this part of the map area. The drift therefore cannot be younger than the lake phases of Itkillik I glaciation.

Glaciation and related events of Itkillik II age

The Itkillik II ice advance is broadly equated with late Wisconsin glaciation and dated between about 24,000, and 11,000 ^{14}C years B.P. (Hamilton, 1986). During Itkillik II time, the moisture necessary to nourish glaciers was extremely limited in highlands around the Bering Straits owing to glacio-eustatic sealevel depression and consequent subaerial exposure of the broad Bering Platform (Burch, 1990, p. 45-47). Brigham-Grette and others (2003) have documented restricted glaciation in easternmost Russia at this time, and only limited glacial advances occurred within the De Long and Baird Mountains as well. In central to north-central parts of the map area, short glaciers radiated from Misheguk Mountain, Mount Bastille, and other unnamed highlands that rise to 3500-4500 ft (1075-1375 m) altitude. These glaciers terminated within the mountain valleys of Tumit, Okotak, and Trail creeks and at the heads of Kaluktavik and Kugururok rivers. Farther west, in lower source areas (3000-4000 ft; 925-1225 m) flanking Avan River valley, numerous cirques generated an unusually large valley glacier that flowed south, crossed the Noatak valley floor near the west margin of the map area, and built the Avan moraine. The Avan valley area must have been subjected to much heavier snowfall at this time relative to highlands just a few tens of kilometers to the east.

During this interval, extensive lowlands remained ice-free but were inundated by lakes. A glacier-dammed lake (unit *igl*$_2$) occupied the broad valley floor around the Nimiuktuk-Noatak valley confluence. Around its shores, wave-eroded notches formed at altitudes of about 1000 ft (300 m) along the lower flanks of moraines of the Itkillik IB (unit *id*$_{IB}$) drift complex. Deposits of this glacial lake are traceable up Nimiuktuk valley and its tributaries, terminating in each drainage where the valley floor rises above 1100 ft (340 m) altitude. Extensive lake deposits that cover lower-lying valley floors farther west onlap adjoining lowlands and valley sides to about 1000-1050 ft (300-320 m) asl. Their upper limits are marked by abrupt contacts between little modified lake sediments below and more strongly soliflucted and dissected older deposits above. Near Avan River and farther north up the Kugururok, Kagvik, and Kalaktavik valleys the younger lake limit rises to 1100 ft (340 m) and locally to 1150 ft (350 m) asl, probably because of postglacial isostatic recovery in these more intensely glaciated parts of the map area. An eastern arm of the glacier-dammed lake may have extended into the Lake Kangilipak basin, where an abandoned channel that heads at 1000 ft (300 m) altitude and trends south into the Aklumayuak drainage may have served as its outlet. Near the west margin of the map area, a pass at about 925 ft (280 m) altitude would have allowed drainage from the lake to flow south and then west around the Avan moraine.

Evidence for lower lake stages occurs in the southwest corner of the map area, where the Avan moraine has been incised to heights locally as great as 1050 ft. The lake then stood at successively lower levels between about 750 and 500 ft (230 and 170 m) during thinning and wastage of its ice dam.

Parts of the map area that were unglaciated during Itkillik II time were subjected to intense periglacial activity. Some of these surfaces were consistently above lake level, but others must have been exposed subaerially as the lake repeatedly burst out through its ice dam and then refilled. These nonglaciated areas exhibit extensive solifluction slopes that are inactive or weakly active today. Where surface or near-surface bedrock is present, stabilized frost-shattered rubble represents formerly active felsenmeer (Washburn, 1980, p. 219-223) on upland surfaces, and stabilized sheets or aprons of talus rubble are widely present on slopes. The weathered and lichen-covered surfaces of some bedrock blocks that were partly detached from their outcrops demonstrate that displacement by frost wedging has ceased.

Glaciation in the Baird Mountains

Only a few small glaciers of late Pleistocene age were generated within the Baird Mountains. Their advances were marked by moraines and outwash near valley heads and by adjoining freshly ice-scoured surfaces. The most extensive advance, about 8 km in length, issued from a cirque in rugged but unnamed highlands at the head of Akikukchiak Creek (14 km south of Tututalak Mountain). Outwash that spilled eastward from this advance formed a local terrace in an adjoining valley, which also has a small morainal deposit at its head. Two short glaciers about 3-4 km in length developed from cirques on the north face of Mt. Angayukaqsraq near the east margin of the map.

Other valley-head glacial deposits (unit *d*) lack morainal ridges and surface erratics but form arcuate bodies bordered by former ice-marginal channels. These features could be of either late or middle Pleistocene age. They outline a north-flowing glacier that extended about 4 km from a cirque on Tutatalak Mountain to the valley of Akikukchiak Creek. Similar subdued glacial deposits associated with abraded and channeled bedrock occur a few kilometers beyond the limits of Itkillik-age drift in the two other localities described above.

THE PLEISTOCENE-HOLOCENE TRANSITION AND LATER HOLOCENE EVENTS

A final readvance of alpine glaciers in the De Long Mountains generated end moraines (unit *id*$_3$) near the mouth of a cirque-headed tributary valley at the north flank of Misheguk Mountain and in several mounain valleys between headward parts of Trail and Tumit creeks and near the head of Avan River. Patches of drift (units *d* and *d?*) on the floors of these valleys and neighboring steep mountain valleys may also date from this interval. By analogy with the central Brooks Range glacial record (Hamilton, 1986), this readvance may have taken place between about 12,800 and 11,500 ^{14}C yr B.P.

Because of the high seasonal discharge of the Noatak River (Childers and Kernodle, 1981) incision through lake deposits of Itkillik II age probably was rapid. However, as the river continued downcutting, it would have been superimposed on bedrock along parts of its course, and would have been held for some time at that level until it could incise the bedrock barrier. Because of the map's small scale, it cannot show every individual river terrace that was formed during downcutting. Therefore I have combined those terrace remnants into 2-3 general terrace levels within each of four reaches of the Noatak River (table 3).

The highest terrace level (designated *tg*$_1$) occurs along the entire length of the Noatak River across the map area. It most commonly stands about 50 m above modern river level, but ranges between about 40 and 60 m along some sectors of the river (table 3). It must have formed when stagnant glacier ice was still present on the valley floor, because at several localities (for example, at the mouth of Nimiuktuk River) its surface bears kettle lakes and kettle depressions. The Noatak River may have reoccupied this level several times as breaching of the ice dam near Noatak Canyon caused outburst floods that drained the lake.

Table 3. *Terraces along Noatak River and its principal tributaries within Misheguk Mountain and Baird Mountains quadrangles*

Drainage	Terrace Level (m)	Map Unit	Comments
Above Nimiuktuk R.	50	tg_1	Widespread
	40	----	Local
	25	----	Local
	15	tg_3	Widespread
	8 – 10	tg_4	Extensive around New Cottonwood Cr.
Nimiuktuk R. to Aklumayuak Cr.	52 – 44	tg_1	Widespread
	19 – 25	tg_2	Common near Aklumayuak Cr. mouth
	10	----	Local
Aklumayuak Cr. to Noatak Canyon	40 – 60	tg_1	Widespread
	30 – 35	tg_2	Extensive around mouth of Sisiak Cr.
	15	tg_3	Common
	10	al_1	Recent floodplain
Noatak Canyon to Kelly R.	45 – 50	tg_1	Widespread
	25	----	Local
	15	tg_3	Common

Terraces at about 25-35 m height (designated tg_2) are most extensive along the Noatak River near the mouths of Aklumayuak and Sisiak Creeks. Terrace remnants at comparable levels occur sparsely elsewhere, but generally are too small to map. Two radiocarbon ages of about 13,310 and 13,370 ^{14}C yr B.P. were obtained from a 25-meter terrace near the mouth of Aklumayuak Creek (table 4), and a 35-m bluff a short distance downvalley yielded a similar age of about 13,140 yr B.P. The Noatak River must have been downcutting through an interval about 35-25 m above its modern level at about 13,500-13,000 ^{14}C yr B.P. Radiocarbon ages representing this time span are relatively common within the central Brooks Range, and evidently mark a time of widespread recolonization by shrubs and peat-forming plants under conditions of increasing temperature and moisture (Bigelow and Powers, 2001). Perhaps vegetation was able to stabilize the river's floodplain sufficiently at this time to permit better preservation of alluvial terrace remnants.

Widespread terraces at about 15 m height (designated tg_3) are present along stretches of the Noatak River above Nimiuktuk River and below Aklumayuak Creek (table 3). Bluff deposits standing 20 m high near the west margin of the map represent a probably comparable or slightly older terrace. Thaw-lake deposits and basal peats in thaw depressions near the bluff crest yielded radiocarbon ages of about 9,220 and 9,360 ^{14}C yr B.P. (table 4). The thaw features, which formed under higher summer temperatures of the early Holocene warm interval (Bigelow and Powers, 2001), do not date river levels directly but provide a minimum limiting age on river downcutting.

An extensive lower terrace (tg_4) stands at about 8-10 m height around the mouth of Little Cottonwood Creek and along Kugururok River opposite Lake Kaiyak. Although alluvial surfaces at this level are present elsewhere, they are too small to map separately or are indistinguishable from higher floodplain deposits (unit al_1).

Glacial deposits of late Holocene (Neoglacial) age are common in cirques through the central Brooks Range (Ellis and Calkin, 1984), but generally they only occur within short distances of the termini of present-day glaciers. Modern glaciers are not present in the map area, and consequently drift of Neoglacial age is rare. Several very small deposits that may be of this age (unit *nd*) occur at the bases of steep north-facing cirque headwalls in highlands between headward parts of Trail and Tumit creeks; and one other deposit that may be of comparable age is present in highlands that form the east flank of Avan River valley.

Following deglaciation of cirques and upper valley heads, talus rubble began forming on lower parts of cirque and valley walls that were oversteepened by glacial erosion. Within upper valleys glaciated during Itkillik II time, active talus accumulations are so numerous and closely spaced that they must be shown as symbols rather than named depositional units. Older talus accumulations that have become stabilized, weathered, and lichen-covered (unit tr_i) are more characteristic of cirques and valley heads that were not glaciated during Itkillik II time, and therefore they may serve as useful relative-age indicators.

Table 4. *Radiocarbon ages from alluvial terrace deposits along Noatak River within Misheguk Mountain and Baird Mountains quadrangles*

Age and Lab. Number	Material and Setting	Location
9,220 ±40 (Beta-156899)	Wood and small plant fragments from basal peat in thaw depression	20-m bluff. North side Noatak R. 2 km above Kelly Ranger Station
9,360 ±40 (Beta-156902)	Wood in probable thaw-lake deposit	Slip-off slope at downstream end of 20-m bluff at above location
13,140 ±40 (Beta-156900)	Wood fragments from woody peat 1.1 m below surface	35-m bluff, south side Noatak R. 4.5 km downvalley from Sapun Creek
13,310 ±40 (Beta-156904)	Wood from pod of organic detritus near base of floodplain sand that caps alluvial gravel	25-m bluff 1.5 km above Aklumayuak Cr.
13,370 ±50 (Beta-156903)	Rodent feces from same pod of detritus as described above	As above

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