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Surficial Geologic Map of the Hughes Quadrangle, Alaska

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INTRODUCTION

PHYSICAL SETTING

The Hughes quadrangle is at the interface between the Brooks Range to the north and the less rugged uplands and valleys of interior Alaska to the south. Southern foothills of the Brooks Range—principally the Angayucham Mountains, Helpmejack Hills, and Alatna Hills—extend across the northern part of the map area from west to east, and the east-west-trending Lockwood and Norutak Hills farther south form the south flank of the Kobuk River valley. The west-central part of the map area is dominated by the Pah River Flats and by broad muskeg-covered lowlands along the Hogatza River; these contiguous lowlands form an elliptical basin about 80 km long and up to 35 km wide. Farther to the east and south occur a diverse assemblage of hills and ridges, isolated low mountains, muskeg-covered flats, and river and stream valleys. The west-flowing Kobuk River and the southeast-flowing Alatna River drain the northern part of the quadrangle, whereas drainages farther south are dominated by the southwest-flowing Koyukuk River and its tributaries.

The Hughes quadrangle is located near the south margin of continuous permafrost (Ferrians, 1965; Brown and others, 1997). Although permafrost is generally present, it may be absent beneath reaches of the Koyukuk River that remain unfrozen in winter and perhaps beneath steep south-facing slopes in uplands near the south margin of the map area (Swanson, 1996). Depth to permafrost generally is 25-40 cm in peat-covered lowlands, and it may be as much as 100-150 cm in well-drained upland sites (Rieger and others, 1979, p. 94-95, 139-140). During 1941-1970, the only years of record, the community of Hughes had a mean annual temperature of -4.6^{o}C (Alaska Climate Center, 1989, p. 184; Swanson, 1996).

HISTORY OF GEOLOGIC MAPPING

Geology of the Hughes quadrangle was mapped by Patton and Miller (1966). They distinguished four general categories of Quaternary deposits and delineated some of the end moraines in the northern part of the map area. Patton and Miller also designated several “areas of conspicuous drift”, and mapped the east-west-trending fault that cuts Quaternary deposits along the upper Kobuk valley and across the Kobuk-Alatna divide. Pallister and Carlson (1988) subsequently mapped the bedrock geology of the Angayucham Mountains in more detail, and Patton and others (1994) have compiled a regional overview of bedrock geology and structure that includes the Hughes quadrangle. Volcanic rocks of Tertiary age at Indian Mountain (Miller and Lanphere, 1981) are of widespread interest because of associated obsidian, which was dispersed widely by prehistoric humans and occurs in archeological sites throughout northwestern Alaska (Patton and Miller, 1970; Clark, 1972; Clark and Clark, 1993).

My Quaternary geologic investigations in the Hughes quadrangle were initiated in the Alatna River valley during 1962-66 (Hamilton, 1969), and completed during 1983-87 (Hamilton, 1989). In addition to mapping glacial deposits and related features, we mapped in detail the conspicuous east-west trending fault of Patton and Miller (1966) that crosses the northern part of the map area. This structure, which cuts or offsets deposits as young as late Quaternary in age (Hamilton, 1984), forms part of the Kobuk fault zone (Avé Lallemant and others, 1998). The right-lateral offsets that we mapped at stream crossings are consistent with the dextral offsets indicated by recent seismicity along the fault (Gedney and Marshall, 1981; Estabrook and others, 1988).

THE GLACIAL SEQUENCE

The late Cenozoic geologic record of the Hughes quadrangle reflects the complex interplay between glaciers that flowed south through broad mountain valleys of the Brooks Range (see Hamilton, 1981) and the barriers created by its generally east-west-trending southern foothills. Glaciers from the Alatna valley system were able to flow farther south between the Helpmejack Hills and Alatna Hills but then were deflected sharply eastward by a broad tract of uplands north of the Koyukuk River. A comparable series of glacial advances extended south through the upper Kobuk drainage system, but only the older and larger glaciers were able to flow southward through and around the Lockwood and Norutak Hills and into the southern part of the map area (Hamilton, 1989). Younger and less extensive glaciers were deflected by those hills into a westward course down the Kobuk valley. During each of the major glacial advances, small alpine glaciers were generated in the Angayucham Mountains and the northern Zane Hills and were also present locally on Indian Mountain.

The glacial sequence in the Hughes quadrangle consists of seven advances: these are grouped into four major glaciations that are named (from oldest to youngest) the Gunsight Mountain, Anaktuvuk River, Sagavanirktok River, and Itkillik glaciations from type localities along the north flank of the Brooks Range. Although correlations with the well-established northern Brooks Range glacial sequence (Detterman and others, 1958; Porter, 1964; Hamilton and Porter, 1975; Hamilton, 1986, 1994) are tenuous for events older than the Itkillik glaciation, the names used on this map have value for distinguishing each major glacial advance and associated glacial-lake stage and for placing these events in a relative-age sequence. However, range-wide correlations and age assignments should be considered tentative.

The Gunsight Mountain advance is the oldest glacial event recorded in the Hughes quadrangle. Farther east, it filled the Koyukuk basin (Hamilton, 1969; 2002), but it is recognized only in extreme eastern parts of the Hughes

quadrangle. The drift has been highly eroded, and in many places is obscured by as much as 30-40 m of eolian and lacustrine silt. It is best exposed on high hilltops and ridge crests, where scattered and highly weathered granitic boulders and boulder fragments can be found. Drift remnants generally stand high above modern drainages, and also above the highest recognizable river terraces of Pleistocene age. However, a set of erosion surfaces along the Koyukuk River in the southeastern part of the map area may be of Gunsight Mountain age. These planar features are incised into bedrock 60-75 m above modern river level. The Gunsight Mountain advance may also correlate with the oldest recognized glaciation of Indian Mountain, which Reger (1979) termed the Sleepy Bear Glaciation.

The subsequent Anaktuvuk River advance is marked by more continuous arcuate end moraines with broad crests that generally bear thick covers of eolian and lacustrine silt and highly organic muskeg deposits. Three major glacier tongues of Anaktuvuk River age flowed southward across the Hughes quadrangle to terminate in large glacial lakes near its south margin. Arcuate end moraines enclose the Pah River Flats to the south and east, and probably contemporaneous deposits of proglacial and moraine-enclosed lakes underlie high-level muskegs (unit **m_1** around Pah River Flats). More fragmentary or more deeply buried end moraines outline a second large glacier that extended southward down the valleys now occupied by Hogatza River and Klikhtentotzna Creek, probably overriding the hills between those drainages. The moraine probably dammed an extensive lake that is marked today by the broad, high-level, muskeg-filled flats along Hogatza River. Fragmentary moraine remnants farther east define smaller glacial lobes derived from the Alatna valley glacier that overflowed low divides southwest of the Alatna River valley and extended into drainages around the headwaters of Hughes Creek. The largest of these lobes flowed southward near the east margin of the map area; it crossed the Koyukuk River and dammed a proglacial lake that filled the headwaters of the Mentanontli River system east of Indian Mountain. Smaller local glaciers of Anaktuvuk River age developed in the southern part of the map area; they formed small piedmont lobes that extended beyond the north and east flanks of the Zane Hills and beyond the east flank of Indian Mountain. The Indian Mountain lobe was mapped by Reger (1979) and assigned to the Indian Mountain Glaciation. Outwash from end moraines of Anaktuvuk River age can be traced into an extensive terrace system that stands about 30 m high along the Koyukuk River and its principal tributaries (unit **tg_1** on map).

During the subsequent maximum advance of the Sagavanirktok River glaciation, valley glaciers from the Brooks Range extended south into the northern part of the Hughes quadrangle along the Kobuk and Alatna valley systems. Ice tongues of the Kobuk valley glacier extended south into the Lockwood Hills and crossed the Norutak Hills through low divides. Another ice tongue flowed southeast through the broad trough that separates these two uplands, forming a delta-like body of drift that lacks end moraines and probably was deposited at the north margin of a proglacial lake. Farther east, the Kobuk and Alatna valley glaciers coalesced in the lowlands east of the Norutak Hills. Near the east margin of the Hughes quadrangle, drift of Sagavanirktok River age extends along both flanks of the Alatna River valley, outlining a glacial lobe that terminated just beyond the map margin. Local glaciers of Sagavanirktik River age were generated within the Angayucham Mountains and the Zane Hills: some extended to the margins of these highlands, but others terminated within mountain valleys. Glaciation of Sagavanirktok River age is not recognized on Indian Mountain, but inactive rock glaciers and other periglacial features indicate intervals of climate more intensely cold than at present that may correspond to the Sagavanirktok River and younger glaciations.

Drift of Sagavanirktok River age generally cannot be differentiated into older and younger components on the Hughes quadrangle, but a separate younger advance is recognized locally by drift and outwash (units **sd_2** and **so_2**) near the northwest corner of the map area and in the Helpmejack Hills. Drift of this age elsewhere in the map area may have been overridden and obliterated during the subsequent Itkillik glaciation.

The Itkillik glaciation had multiple phases and subphases within the south-central Brooks Range (Hamilton and Porter, 1975; Hamilton, 1986), but only the older advances of the Itkillik sequence extended south into the Hughes quadrangle. Glaciers of the Kobuk valley complex flowed south through several broad valleys that cross the Angayucham Mountains and terminated at or near the south flank of those mountains. Between the Angayucham Mountains and the Helpmejack Hills, south-flowing ice streams formed a pair of piedmont lobes along the north flank of the Norutak Hills. The western lobe terminated at the head of a prominent outwash valley train, which is traceable as outwash and terrace deposits (units **io_1** and **td_1**) beyond the west margin of the map area. The eastern lobe formed an arcuate end moraine that encloses Norutak Lake to the east and south and that dammed a proglacial lake farther to the southeast. The largest single glacial lobe of the Itkillik maximum advance was that of the Alatna valley glacier, which extended down the Alatna River valley nearly to the east margin of the map. Local glaciers formed within the Angayucham Mountains and Zane Hills at this time. Most were cirque glaciers, but a few ice tongues extended several kilometers down upper mountain valleys from their source areas.

The outermost (Phase I) drift of Itkillik age in both the Kobuk and Alatna valley sytems is divisible into older and younger components (termed Phase IA and Phase IB, respectively). Drift of Phase IB age generally is steeper sided, sharper crested, and less weathered than drift of Phase IA and, within the Alatna valley, it is associated with a separate younger set of glaciolacustrine and deltaic

deposits. These relations indicate that Phases IA and IB were separate glacial advances and that they probably occurred at least several thousand years apart.

Glaciers of the succeeding Itkillik Phase II advance did not extend south from the Brooks Range into the Hughes quadrangle. However, outwash of that age is inset as terraces within higher standing glacial, fluvial, and lacustrine deposits of Itkillik Phase I. Separate higher and lower outwash terraces of Itkillik Phase II age are present along the Kobuk River near the north margin of the map area. These can be traced northward into the double moraine belt that encloses Walker Lake (Hamilton, 1981). Itkillik Phase II glaciation is of late Wisconsinan age (Hamilton, 1986, 1994), but all of the preceding glacial advances are older than the age range of radiocarbon dating.

CONCLUDING REMARKS

This map and a companion map of the Bettles quadrangle (Hamilton, 2002) complete a series of ten surficial geologic maps of the central Brooks Range and its foothills. The Hughes quadrangle extends much farther south of the Brooks Range than the areas mapped previously in this series (for example, Hamilton, 1979, 1981); consequently its surficial geology is much more complex and more obscure. Diverse individual upland areas and depositional basins are present south of the Brooks Range; each has its own distinctive Quaternary geologic history, and several have their own separate glacial records. Very old unconsolidated deposits cover a large part of the map area. These have been extensively eroded in some places and typically are obscured beneath thick cover of silt or muskeg. Most of the map area also is heavily forested, obscuring surficial geologic deposits and causing access to be poor. In addition, sediments accumulating in depositional basins tend to form "stacked" or composite units (for example, glaciolacustrine deposits draped over a buried end moraine). Stacked units have been designated where significant subsurface deposits are evident in bluff exposures or can be inferred from physiography, erratic boulders, or other indirect evidence. They are designated by slashes (for example, **agl/ad**), which indicate that deposits of the first unit overlie known or inferred deposits of the second unit.

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DESCRIPTION OF MAP UNITS

[Map units shown in parentheses, such as **(st)**, indicate thin and generally discontinuous deposits over near-surface bedrock. These units are described below only where additional explanation is necessary. Map units shown with slashes, such as **si/al**, indicate deposits of the first unit over known or inferred deposits of the second unit. These units are described below only where additional explanation is necessary.]

FAN DEPOSITS

af_i **Inactive deposits of steep alpine fans (late Pleistocene)**—Coarse, very poorly sorted, subangular to subrounded, silty, sandy gravel at mouths of avalanche chutes and steep canyons. Upper segments may be channeled, containing levees of angular to subangular, coarse debris. Surface gradients generally 12^o to 25^o, intermediate between those of alluvial fans and talus cones. Formerly subject to snow avalanches, slushflows, and debris flows, but now inactive and vegetated. Occur locally in Angayucham Mountains, Zane Hills, and Indian Mountain

f **Fan deposits (Holocene to late Pleistocene)**—Range from poorly sorted, weakly stratified, subangular, silty, sandy coarse gravel at mouths of mountain valleys to gravelly sand and silt within lowlands

f_i **Inactive fan deposits (late Pleistocene)**—As described in unit **f**. Generally completely vegetated

fd **Fan-delta deposits (Holocene to late Pleistocene)**—Alluvial-fan deposits (as described in unit **f**) that grade downslope into deltaic and lacustrine facies (well sorted and generally well stratified silt and sand, commonly with some fine gravel)

fd_i **Inactive fan-delta deposits (Holocene? to Pleistocene)**—As described in unit **fd**. Vegetated and generally forest-covered

ALLUVIUM

al **Alluvium, undivided (Holocene)**—Varies from moderately sorted, stratified, coarse gravel in northern part of map area to well sorted, sandy, fine gravel and gravelly sand along Koyukuk River and its lower tributaries. Commonly contains beds and lenses of sand and silt. Along smaller streams, unit includes fan, flood-plain, and low terrace deposits that are too small to be designated separately

al_s **Fine-grained silty alluvium**—Generally well sorted silt, sandy silt, and organic silt. Mapped only along slow-moving sections of creeks that traverse thick, silt-rich, glacial-lake deposits

al_{sa} **Fine-grained sandy alluvium**—Moderately sorted to well sorted, fine to medium sand, commonly with thin interbeds of sandy peat or organic silty fine sand. Mapped along slow-moving reaches of Beaver Creek and Baathbakizuni Creek (northwestern and south-central parts of map area, respectively) and on low-level terrace on west side of Koyukuk River

al_2 **Modern alluvium (late Holocene)—**Gravel and sandy gravel, as described in unit **al**, generally unvegetated and subject to annual flooding. Differentiated only along principal streams

al_1 **Low alluvial-terrace deposits (Holocene)**—Gravel and sandy gravel, as described in unit **al,** mantled with 0.3-1 m of silt, sand, turf, and peat, and generally vegetated. Forms terraces generally within 3-4 m of modern stream levels. Differentiated only along principal streams

gr **Gravel deposits, other (Pleistocene)**—Isolated, gravelly erosion remnants of uncertain composition and origin. Most common along valleys south of Norutak Hills, where they may be poorly exposed occurrences of unit **gr_{fn}**

gr_{fn} **Fine gravel**—Rounded pebbles and small cobbles in matrix of slightly oxidized sand that commonly has high quartz content. Forms terrace-like erosion remnants and broader alluvial surfaces about 18-23 m above modern drainage levels in lowlands south of Norutak Hills. Queried where gravel present but grain size uncertain

pg **Piedmont gravel (Pleistocene)**—Moderately well sorted, rounded to subrounded pebbles of schist and quartz in abundant matrix of medium to coarse sand containing schist chips; commonly interbedded with medium to coarse sand. Generally oxidized yellowish brown to dark yellowish brown. Grades laterally into fan deposits consisting of platy pebbles, small cobbles, and some large cobbles of schist and quartz in coarse sand-granule matrix. Commonly overlain by erratic cobbles and boulders of Itkillik Phase I. Recognized only near north margin of map area

TERRACE DEPOSITS

td_2 **Terrace deposit, low-level (late Pleistocene)**—Deposits with terracelike upper surface standing 8 m above Reed River near its mouth. Outwash gravel and silty flood-plain deposits of Itkillik Phase II advance; underlain by laminated clay and silt (lacustrine) and sandy fine gravel (deltaic) of Itkillik Phase I age

td_1 **Terrace deposit, high-level (middle Pleistocene)**—Alluvial surface 53-60 m above modern level of Kobuk River. Underlain by coarse and fine gravel, strongly oxidized gravel, some sand, silt, and clay; and generally thick (up to 24 m) till deposits of Sagavanirktok River age. Capped by silt up to 7 m thick

tg_3 **Terrace gravel, low-level (late Pleistocene)**—Alluvial gravel and sandy gravel, with 2-3 m silt cover. Forms widespread surfaces 8-10 m above modern levels of Koyukuk, Indian, and lower Hogatza Rivers

tg_2 **Terrace gravel, intermediate-level (middle Pleistocene)**—Alluvial gravel, as described in unit **al**, with silt cover probably intermediate in thickness between that of low-level and high-level terraces. Forms isolated surfaces 20-25 m above Koyukuk River at mouth of Hughes Creek and 25-30 km north of Hughes

tg_1 **Terrace gravel, high-level (early Pleistocene)**—Alluvial gravel, as described in unit **al**, generally with thick (commonly 5-10 m) silt and muskeg cap. Forms widespread surfaces 30-35 m above modern levels of Koyukuk, Indian, and lower Hogatza Rivers. Appears contemporaneous with outwash of Anaktuvuk River age along east flank of Zane Hills

tg_H **Terrace deposit, highest-level (early Pleistocene?)**—River-formed surface 75 m above Koyukuk River; present only at extreme east margin of map area. Loess cap about 15 m thick covers sand and gravel deposits that overlie bedrock

tg **Terrace gravel, other (Pleistocene)**—Gravel terrace inset within drift of Itkillik Phase I along unnamed western tributary to Alatna River south of Helpmejack Hills. Probable nonglacial alluvium graded to outwash terrace of Itkillik Phase II. Also present along Indian River at south margin of map area

COLLUVIAL DEPOSITS

av **Avalanche tracks and deposits (Holocene)**—Angular, unsorted, nonstratified loose rock debris; forms tongues and fans along lower walls of mountain valleys. Associated with tracks or chutes that generally lack soil and vegetation and commonly are bordered by battered trees and shrubs from which bark and branches have been partly stripped. Mapped only in Angayucham Mountains

c **Colluvium, undivided (Holocene and Pleistocene)**—Mixed solifluction deposits and talus rubble, as described individually (see units **st** and **tr**), in sheets and aprons more than about 1-2 m thick. Common on upper slopes below surface or near-surface bedrock. Thinner but generally continuous colluvial sheets and aprons, shown as **(c)**, are most common across uplands southeast of Kanuti River, where loess cover is thin

fl **Flow deposits (Holocene and late Pleistocene)**—Very poorly sorted, angular rock rubble in abundant silty matrix. Forms lobes subject to slow and probably discontinuous downslope movement. Mapped only along north side Alatna River at mouth of Sinyalak Creek

ls **Landslide deposits (Holocene and late Pleistocene)**—Unsorted, unstratified, coarse to fine, angular rubble, commonly with matrix of finer debris, forming lobes below detachment scars and slide tracks on steep rock walls. Subject to rapid downslope movement and long periods of relative stability. Mapped only in Angayucham Mountains and Zane Hills

pr **Protalus rampart deposits (late Holocene)**—Unsorted, nonstratified, coarse angular rock debris forming arcuate low ridges. Associated with persistent snowbanks in shaded sites, commonly at bases of cirque headwalls. Subject to rockfalls during spring thaw. Recognized only in Angayucham Mountains and Zane Hills and on Indian Mountain

rg_a **Rock glacier deposits, active (late Holocene)**—Very poorly sorted, nonstratified, coarse angular rock debris with matrix of silt and fine rubble; contains abundant interstitial ice. Upper surfaces generally unvegetated, unweathered to moderately weathered, and with sparse lichen cover. Frontal slopes barren, steep, and highly unstable, meeting upper surfaces at abrupt angle. Form lobate deposits at base of talus cones along valley walls. Recognized only in Angayucham Mountains

rg_i **Rock glacier deposits, inactive (Holocene and late Pleistocene)**—Coarse, angular rock debris, as described in unit **rg_a**, but lacking interstitial ice. Upper surfaces and frontal slopes weathered, covered by lichens, and commonly partly covered by sod and vegetation. Frontal slopes grade into upper surfaces without abrupt angles. Present in Angayucham Mountains and Zane Hills and on Indian Mountain

tr_a **Talus rubble, active (late Holocene)**—Angular, unsorted, nonstratified rock debris forming cones and aprons generally sloping 30^o-33^o along lower walls of mountain valleys. Also forms thinner and generally discontinuous sheets over many uplands mapped as "bedrock". Generally unvegetated, unweathered to slightly weathered, and with sparse to absent lichen cover. Subject to rockfalls, especially during spring thaw

tr_i **Talus rubble, inactive (Holocene and late Pleistocene)**—Angular rock debris, as described in unit **tr_a**, generally weathered and lichen covered, and with partial sod cover

SAND, SILT, AND ORGANIC (MUSKEG) DEPOSITS

ds **Dune sand (Holocene and late Pleistocene)**—Moderately well sorted, fine to medium sand, commonly in alternating beds. Generally inactive and vegetated, but subdued parabolic ridges with relict slip faces commonly are preserved

sa **Sand-sheet deposits (Pleistocene)**—Commonly stratified, silty fine sand to coarse sand that may contain alluvial granules and sparse small pebbles along valley centers. Generally wind-deposited, but lack dunal morphology. Most abundant west of Koyukuk River near south margin of map area. Thin sand sheets draped over uplands are designated **(sa)**

sap **Sand aprons (Pleistocene)**—Very fine to fine sand. Forms smoothly sloping, vegetated, wedge-like deposits that extend to heights of 100-200 m against flanks of uplands near south-central margin of map area. Winnowed, transported, and deposited by wind from areas of formerly exposed sand (dunes, sand sheets, and flood-plains)

st **Silt deposits (Holocene and Pleistocene)**—Thick (up to 15 m) deposits of nonstratified to weakly stratified silt and organic silt, with local lenses of stony to sandy silt. Includes primary eolian deposits (loess) and silty deposits that were eroded from loess by debris flows, solifluction, gulley-incision, and other slope processes, and then redeposited on lower slopes and valley floors. Most deposits presently are stable and vegetated, but some in northern part of map area are subject to present-day solifluction activity. Symbol **(st)** designates thin sheets of silt and stony silt, largely of solifluction origin, that overlie bedrock or rock rubble. Unit **st/al** designates

thick silt deposits that overlie alluvium and are common along many valley centers south of Lockwood and Norutak Hills. Unit **st/gr** designates thick silt deposits that overlie broad, fanlike gravel deposits (outwash?) at north end of Zane Hills

si **Ice-rich silt deposits (Holocene and Pleistocene)**—Silt deposits, commonly with ice-wedge polygons, more than 1-2 m thick in swales and other depressions. Also common along valley centers, where silt may overlie alluvium. Unit **si/al** designates thick deposits of ice-rich silt that overlie alluvium of uncertain composition on floors of river valleys. Unit **si/gr** designates thick (commonly about 5 m) silt, clayey silt, and organic silt, commonly ice-rich, over fluvial gravel to sandy gravel. Unit **si/ao?** designates very thick (commonly 15 m or more) deposits of ice-rich silt above probable outwash gravel of Anaktuvuk River age

us **Upland silt deposits (Holocene and Pleistocene)**—Poorly to moderately sorted, generally unstratified, silt, organic silt, and slightly stony silt draped over uplands of low to moderate relief. Represents loess mixed by frost action with local organic matter and weathering products. Commonly grades downslope into thick, massive, organic-rich silt or into solifluction deposits

m **Muskeg (Holocene and Pleistocene)**—Peat, organic silt, and organic detritus forming deposits more than 1-2 m thick in areas of restricted drainage with water table at or close to surface. Most extensive across floors of former lake basins. Unit **m/al** is thick deposits of peat and organic-rich silt above alluvium inset within drift of inferred Anaktuvuk River age along Klikhtentotzna Creek.

m_3 **Muskeg that forms floor of Pah River Flats (Holocene and latest Pleistocene)**—Partly drained by highly meandering small streams that flow in shallow peat- or mud-rimmed channels, but most of surface lacks integrated stream drainage. Contains abundant lakes and ponds with irregular outlines and vegetated margins. Forms near-level surface at 105-120 m altitude (350-390 ft on topographic base)

m_2 **Isolated muskeg remnants at intermediate levels (Holocene and late Pleistocene)**—Occurs between lower (**m_3**) and higher (**m_1**) surfaces, which are separated by subdued bluffs

m_1 **High-level muskeg deposits (Holocene and Pleistocene)**—Underlie nearly level surfaces at altitudes of about 120-140 m (400-450 ft on topographic base) around Pah River Flats. Dissected by integrated system of small streams, which has drained most lakes and ponds, leaving small, shallow ponds or marshy depressions. Separated from lower-level muskeg and from modern floors of larger valleys by heavily vegetated bluffs as much as 30 m high. Probably overlies glacial-lake deposits of Anaktuvuk River and (or) Sagavanirktok River age

LACUSTRINE AND GLACIOLACUSTRINE DEPOSITS

b **Beach deposits (Holocene and Pleistocene)**—Moderately well sorted, coarse to medium sand, commonly mixed or interbedded with platy fine gravel, around shores of modern lakes. Locally forms ridges of poorly sorted, gravelly sand to sandy coarse gravel where mixed by ice shove. Mapped only around margins of Lake Selby, Lake Tokhakklanten, and Norutak Lake

dt **Deltaic deposits (Holocene and late Pleistocene)**—Generally well stratified sand and sandy fine gravel deposited by streams at lake margins. Commonly build outward into lake, and overlie fine-grained lacustrine deposits

dt_a **Active deltaic deposits (late Holocene)**—Mapped at north ends of Narvak Lake and Lake Minakokosa near north margin of map area

dt_i **Inactive deltaic deposits (age uncertain)**—Mapped at north shores of lakes that formerly filled Pah River Flats and upper basin of Klikhtentotzna Creek. Associated with deposits of Sagavanirktok River age, but may be composite features related to multiple lake episodes

idt **Deltaic deposits of Itkillik age (late Pleistocene)**—Sandy fine gravel, as described in unit **dt**. Overlie till, ice-contact, and lacustrine deposits of Itkillik Phase I age. Widespread in Alatna Valley and present locally in upper Kobuk Valley

sdt **Deltaic deposits of Sagavanirktok River age (middle Pleistocene)**—Sandy fine gravel, as described in unit **dt**. Associated with outwash of Sagavanirktok River age at south flanks of Lockwood and Norutak Hills

l **Lacustrine deposits (Pleistocene)**—Well stratified clayey silt, silt, and sand, grading into sand and gravelly sand near former shorelines and sandy fine gravel near former river mouths. Shown only by stippled pattern where buried beneath younger deposits. Include beach deposits too small to be designated separately

l_{sa} **Sandy lacustrine deposits**—Sand dominant. Mapped only where Baathbakdizuni Creek traverses thick eolian sand-sheet and sand-apron deposits

l_3 **Lacustrine deposits, eroded (late Pleistocene)**—Stratified silt and related deposits, as described in unit **l**. Forms muskeg-covered lacustrine flats, heavily eroded by streams

l_2 **Lacustrine deposits, low-level (middle Pleistocene)**—Stratified silt and related deposits, as described in unit **l**, separated from unit **l_1** by bluffs up to about 30 m high. Overlain by muskeg with abundant lakes

l_1 **Lacustrine deposits, high-level (early Pleistocene)**—Stratified silt and related deposits, as described in unit **l**, that underlie near-horizontal, poorly drained surfaces along floor of upper Mentanontli River and its headward tributaries (southeast corner of map area) at altitudes up to about 210 m (680-690 ft on topographic base). Lakes and marshes abundant. Stream and lake banks stand up to 6 m high and expose peat, silt, and locally sand. Segments close to valley sides commonly are overlain by thick aprons of solifluction debris. Probably distal equivalent of glacio-lacustrine unit **agl**

igl **Glacial-lake deposits of Itkillik age (Late Pleistocene)**—Stratified silt, clayey silt, and silty fine sand, commonly with dispersed dropstones. Grades into gravelly sand to sandy fine gravel near former stream mouths. Units **igl_{1A}** and **igl_{1B}** designate glacial-lake deposits that formed behind moraine dams of Itkillik Phases IA and IB, respectively, in Alatna Valley

sgl **Glacial-lake deposits of Sagavanirktok River age (middle Pleistocene)**—Poorly exposed probable lacustrine sediments. Deeply inset within drift of Anaktuvuk River age along lower course of Mentanontli River and appear related to a separate, younger glacial event

agl **Glacial-lake deposits of Anaktuvuk River age (early Pleistocene)—**Stratified deposits of stony silt, as described in unit **l**. Form extensive muskeg-covered plains with numerous thaw lakes at altitudes to about 150 m (500 ft on topographic base) behind end moraines of inferred Anaktuvuk River age in Pah River Flats and comparable silt- and muskeg-covered plains at altitudes of 120-135 m (400-450 ft) farther east along Hogatza River. Also present to about 210 m (680 ft) altitude in southeast part of map area along Mentanontli River, where it probably is contemporaneous with unit **l_1** farther south. Unit **agl/ad** is lacustrine deposit that overlaps end moraine of Anaktuvuk River age north of Koyukuk River at east margin of map area

OTHER GLACIAL DEPOSITS

d **Drift, undivided**—Glacial deposits, as described in unit **id**, of uncertain age. Locally present on Indian Mountain and at north flank of Zane Hills

Itkillik glaciation (late Pleistocene)

id **Drift of Itkillik age, undivided**—Unsorted to poorly sorted, generally nonstratified, compact till ranging in composition from muddy sandy gravel to gravelly muddy sand, with local stratified ice-contact deposits consisting of moderately sorted sand and sandy gravel. Contains faceted and striated stones up to large boulder size

id_2 **Drift of Itkillik Phase II**—Glacial deposits, as described in unit **id**. Mapped only in Angayucham Mountains and in some valleys near north margin of map area

id_1 **Drift of Itkillik Phase I**—Glacial deposits, as described in unit **id**. Mapped mainly in highlands near north margin of map area

id_{1B} **Drift of Itkillik Phase IB**—Separate end moraines and associated drift upvalley from outermost moraines of Itkillik age. Probably represents younger readvance of Itkillik Phase I glaciers in Alatna and Kobuk valleys and locally in Angayucham Mountains

id_{1A} **Drift of Itkillik Phase IA**—Outermost moraine of Itkillik complex and associated drift along Alatna and Kobuk Rivers and at Nutuvukti Lake. Also recognized locally in Angayucham Mountains

ik **Kame and kame-terrace deposits of Itkillik Phase IB**—Thick and extensive water-washed sand and gravel deposited in contact with stagnating glacier of Itkillik Phase IB age. Mapped principally around Helpmejack Lakes in Alatna Valley. Smaller deposits occur locally in upper Kobuk Valley

io **Outwash of Itkillik age, undivided**—Moderately well sorted and well stratified sandy gravel forming aprons and valley trains in front of moraines of Itkillik age and terrace remnants farther downvalley. Largest stones decrease in size from subrounded cobbles and very small boulders near moraine fronts to rounded to subrounded pebbles and granules farther downvalley

io_2 **Outwash of Itkillik Phase II**—Sandy gravel, as described in unit **io**, associated with end moraines of Itkillik Phase II age in Angayucham Mountains. Subdivided into **io_{2B}** and **io_{2A}** along Kobuk River near north margin of map area, where outwash terraces occur at two distinct levels. These are traceable northward into multiple end moraines of Itkillik Phase II age around Walker Lake (in Survey Pass quadrangle)

io_1 **Outwash of Itkillik Phase I**—Sandy gravel, as described in unit **io**, associated with end moraines or drift of Itkillik Phase I age

io_{1B} **Outwash of Itkillik Phase IB**—Sandy gravel in outwash terrace remnants associated with end moraine of Itkillik Phase II age in upper Kobuk Valley

io_{1A} **Outwash of Itkillik Phase IA**—Sandy gravel in outwash terrace remnants that originate at outermost moraine of Itkillik Phase I age in Alatna Valley

ii_1 **Inwash of Itkillik Phase I**—Well sorted to moderately well sorted and well stratified gravelly sand and sandy fine gravel, grading upvalley into fan deposits and downvalley into lacustrine beds. Deposited near mouth of tributary valley blocked by glacier of Itkillik Phase I age in main valley; forms benches and terraces that abut outer flank of moraines formed by that glacier. Mapped only in Angayucham Mountains

Sagavanirktok River glaciation (middle Pleistocene)

sd **Drift of Sagavanirktok River age**—Poorly sorted nonstratified till, probably ranging in composition from silty, sandy, bouldery gravel to clayey, stony silt, with local deposits of moderately well sorted and well stratified gravel. Generally covered by thick (>3 m) blanket of silt, stony silt, and organic silt (loess, solifluction, and muskeg deposits), but crests of some ridges and knolls expose weathered gravel and erratic boulders of resistant lithologies

sd_2 **Drift of Sagavanirktok River late phase**—Till and stratified ice-contact deposits, as described in unit **sd**. Mapped within or near mouths of valleys that traverse Angayucham Mountains and Helpmejack Hills

sd_1 **Drift of Sagavanirktok River main phase**—Till and stratified ice-contact deposits, as described in unit **sd**. Differentiated in valleys of Kobuk, Hogatza, and Alatna rivers

so **Outwash of Sagavanirktok River age**—Moderately well sorted and well stratified gravel to sandy gravel, forming aprons and valley trains in front of moraines of Sagavanirktok River age and terrace remnants farther downvalley. Commonly oxidized to several meters depth. Subdivided into **so_1** and **so_2** where associated with end moraines or drift sheets of Sagavanirktok River main and late phases, respectively

Anaktuvuk River glaciation (early Pleistocene)

ad **Drift of Anaktuvuk River age—**Poorly sorted nonstratified till, probably ranging in composition from silty, sandy, bouldery gravel to clayey, stony silt. Contains local deposits of moderately well sorted coarse gravel. Overprint designates areas that have been dissected by fluvial erosion close to Koyukuk and Hogatza rivers and at east tip of Lockwood Hills. Where thin and commonly discontinuous above bedrock (designated **(ad)**), drift commonly has been mixed with silt, rock rubble, and organic detritus by frost action

ao **Outwash of Anaktuvuk River age—**Gravel and sandy gravel, forming aprons and valley trains in front of moraines of Anaktuvuk River age. Capped by thick deposits of eolian silt. Mapped on east flanks of Indian Mountain and Zane Hills, and north of Koyukuk River near east margin of map area

Gunsight Mountain glaciation (Tertiary?)

Tgmd **Drift of possible Gunsight Mountain age—**Till and stratified ice-contact deposits, as described in unit **ad**, north and east of Koyukuk River near east margin of map area. Deposits stand 50 m or more above drift of inferred Anaktuvuk River age, and are much more heavily dissected by postglacial erosion. Not exposed in river bluffs, and generally visible only where recent forest fires have exposed gravelly soils with erratic cobbles and boulders on hilltops and ridge crests. Generally bears thick (up to 15-20 m) silt cover. Also may be locally present near east flanks of Zane Hills and Indian Mountain