Surficial Geology of the Central Kobuk River Valley Northwestern Alaska

By ARTHUR T. FERNALD

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1181-K

A reconnaissance study of the glacial, eolian, and alluvial history of parts of the Shungnak and Ambler River quadrangles

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library has catalogued this publication as follows:

Fernald, Arthur Thomas, 1917–

Surficial geology of the central Kobuk River valley, northwestern Alaska. Washington, U.S. Govt. Print. Off., 1964.

iii, 31 p. illus., fold. col. map (in pocket) diagr. 24 cm. (U.S. Geological Survey. Bulletin 1181–K)

Contributions to general geology.

Bibliography: p. 30–31.

1. Geology—Alaska—Kobuk River valley. I. Title. (Series)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

CONTRIBUTIONS TO GENERAL GEOLOGY

SURFICIAL GEOLOGY OF THE CENTRAL KOBUK RIVER VALLEY, NORTHWESTERN ALASKA

By Arthur T. Fernald

ABSTRACT

The central part of the Kobuk River valley comprises, from south to north, the broad westward-trending lowland of the Kobuk River, the narrow Ambler Lowland that parallels it, and the tributary valleys within the Baird and Schwatka Mountains, part of the Brooks Range. The Kobuk River valley is covered with surficial deposits that are principally of glacial, eolian, and fluvial origin. These deposits include drift of five glaciations, ranging in age from pre-Wisconsin to Recent, and dune sand in both stable and active fields. Two active fields, the Great Kobuk Sand Dunes and the Little Kobuk Sand Dunes, cover an area of about 30 square miles.

The oldest drift in the area, representing the Kobuk Glaciation, occurs principally in terraces that abut the north side of the Kobuk River. It has no recognizable morainal topography and is of pre-Wisconsin age. Glaciers of the next younger, or Ambler, glaciation deposited lobate moraines in the Ambler Lowland and reached the Kobuk River along the Mauneluk River. These moraines, which are all subdued, are of Wisconsin(?) age. Conspicuous fresh moraines of the next younger, or Walker Lake, glaciation were deposited in the tributary valleys within the mountains, except along the Mauneluk River where the moraine occurs in the Ambler Lowland. These moraines represent the last major glaciation in the area and are of Wisconsin age. A series of very fresh moraines, confined to the higher parts of the Schwatka Mountains, represent the Ulaneak Creek Glaciation of Recent age. Modern glacial deposits occur at the foot of north-facing cirques within the Schwatka Mountains where snow patches remain throughout the year; one small glacier is also present here.

Fine-grained fluvial and eolian deposits of sand and silt, with admixtures of organic material, occur in five areas of the central valley They were deposited principally during an interglacial period that followed the Kobuk Glaciation and preceded the Ambler Glaciation. This period, of pre-Wisconsin age, is the major time break recognized in the glacial sequence.

Active and stabilized dune fields cover more than 300 square miles of the central valley, principally on the south side of the Kobuk River. The glacial periods provided conditions most favorable to formation of dunes. The present dune-building winds are easterly, as were those in the past.

Terraces and fans, developed jointly by the Kobuk River and its tributaries, are diverse in extent and location throughout the valley, but they are uniformly separated from modern flood-plain and fan deposits by low to moderate escarpments. These terraces and fans span a considerable time from the Wisconsin to an indefinite time within the recent past. The flood plain developed by the

meandering Kobuk River ranges in width from 1 to 8 miles, and modern alluvial and colluvial deposits are present in many places at the base of valley walls. Hundreds of thaw lakes and innumerable ice-wedge polygons occur over large parts of the valley.

INTRODUCTION

GEOGRAPHY

The central part of the Kobuk River valley in northwestern Alaska, as defined for this report, is located between long 156° and 159° W. and lat 66°45′ and 67°30′ N. It covers an area of about 3,700 square miles within the Shungnak and Ambler River quadrangles of the Alaska Topographic Series. Its position in Alaska is shown on figure 1.

The central Kobuk River valley comprises, from south to north, the broad westward-trending lowland of the Kobuk River, the narrow Ambler Lowland that parallels it, and the tributary valleys within the Baird and Schwatka Mountains. A series of U-shaped valleys and high mountains, Ingricherk Mountain on the west and unnamed mountains on the east, separate the Ambler Lowland from the lowland along the Kobuk River. The northern border of the mapped area closely parallels the crest of the rugged Baird and Schwatka Mountains; the southern border follows fairly closely the northern edge of an uplands area. These uplands are, from west to east, the Waring Mountains, the Sheklukshuk Range, and the Lockwood Hills. A low 12-mile-wide divide between the Waring Mountains and the Sheklukshuk Range separates the Kobuk River valley from the Selawik lowland to the southwest.

The lowland along the Kobuk River is fairly flat, but local relief in dunes, moraines, and terraces is as much as 200 feet. The altitude of the Kobuk River rises from about 50 feet above sea level at the western edge of the mapped area to about 150 feet at the eastern edge. At its lowest point the divide area between the Kobuk River valley and the Selawik lowland has an altitude of slightly more than 200 feet above sea level. The topography of the Ambler Lowland is highly irregular; the mountains between the two lowlands range from 1,500 feet to more than 4,000 feet above sea level. The rugged Baird and Schwatka Mountains rise to maximum heights of more than 3,500 and 5,500 feet above sea level, respectively, within the mapped area. The uplands south of the Kobuk River valley generally range from 1,000 to 2,000 feet above sea level; Angutikada Peak in the Lockwood Hills, however, rises to more than 4,000 feet.

The principal tributaries on the north side of the Kobuk River are, from west to east, Akiak Creek, Hunt River, Akillik River, Nuna Creek, Miluet Creek, Redstone River, Kalurivik Creek, Ambler River,

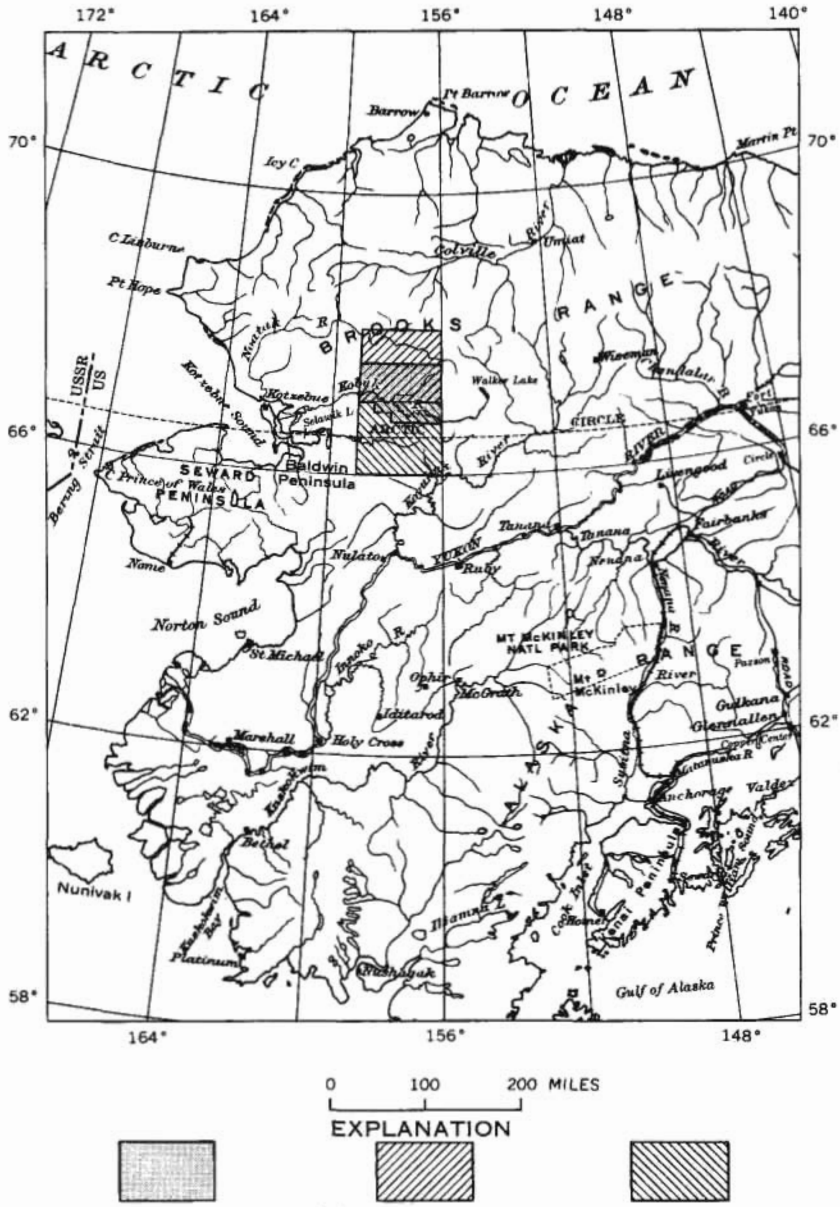

Figure 1.—Index map of Alaska showing location of central Kobuk River valley.

Shungnak River, Kogoluktuk River, and Mauneluk River. The last four tributaries, upon entering the Ambler Lowland, turn to the west and then south to join the Kobuk River; in crossing the mountains between the two lowlands they have been offset by one or two valleys. Thus, the Ambler River valley north of the Ambler Lowland is lined up with the lower valley of the Shungnak River, and the Kogoluktuk River is lined up with a valley that now contains Kollioksak Lake. South of the Kobuk River, the Pick and the Pah Rivers are the two main tributaries that rise within the uplands area. The Kugarak River, a tributary of the Selawik River, drains the southwest side of the Kobuk-Selawik divide. Drainage of a small area on the north side of the Baird Mountains that is included within the mapped area is accomplished by tributaries of the Noatak River.

Weather observations made at Shungnak during 1915–16 and 1941–50 show a climate characterized by very cold dry winters and cool moist summers (U.S. Weather Bur., 1958; U.S. Weather Bur. Climatological Office, Anchorage, written communication, 1952). The mean annual temperature is 22°F, with a January mean of −2°F and a July mean of 59°F. The recorded extremes are −61°F and 90°F. The mean annual precipitation is 16 inches, much of which falls during the months of July, August, and September. The mean snowfall is 72 inches. Winds are predominantly easterly from September through May and westerly for the summer months.

The vegetation of the central Kobuk River valley consists of boreal forest (white spruce, black spruce, white birch, and aspen), wet tundra (sedges and dwarf shrubs), and dry tundra (low matlike plants and scattered clumps of shrubs). Dense white spruce forests grow on actively forming parts of the Kobuk River flood plain, along its tributaries, and on lower slopes of mountains, but they become scattered at higher elevations. Sparse forests of spruce, birch, and aspen grow on the drier parts of dune fields and moraines. Wet tundra, locally with scattered black spruce, is characteristic of older parts of the Kobuk River flood plain, alluvial terraces and fans, and parts of dune fields and moraines. Dry tundra is characteristic of the lower slopes of mountains above the spruce forest. Bare rock characterizes all of the high mountains, and sand is exposed in actively forming dunes and river bars.

Permafrost, which is present throughout, generally lies at depths of 1 to 5 feet; but in areas covered with wet tundra it is at depths of 1 to 2 feet. Ice-wedge polygons and thaw lakes are widespread on the older alluvial and eolian surfaces; the polygons are particularly prominent and sharply defined on older parts of the Kobuk River flood plain. A few small pingos are present on the south side of the Kobuk River in the vicinity of Shungnak.

Shungnak, the largest of two settlements in the mapped area, has a population of 135 (1960); the settlement at Kobuk has a population of 54 (1960). Small airplane landing fields are situated along the Kobuk River 3 miles east of the village of Shungnak, along Dahl Creek 2 miles north of the village of Kobuk, and along Ruby Creek 10 to 12 miles north of Kobuk. Scheduled air service by float plane is available from Kotzebue. There are no roads.

FIELD INVESTIGATIONS

The first exploration of the central Kobuk River valley was made in 1884 by a party under Lt. J. C. Cantwell, of the U.S. Revenue Marine Service, which ascended the Kobuk River nearly to the Pah River (Cantwell, 1889; McLenegan, 1889). The same summer another party under Lt. G. M. Stoney, of the U.S. Navy, also explored the valley by ascending the Kobuk River to about 10 miles upstream from the Pah River (Stoney, 1900). The following summer the same two men continued their explorations, with Stoney's party establishing a winter base camp at the mouth of Cosmos Creek (Cantwell, 1887; Stoney, 1900). In 1901, W. C. Mendenhall, leader of a U.S. Geological Survey party that descended the Kobuk River by canoe, mapped the geology at a scale of approximately 1:1,250,000 (Mendenhall, 1902). Five years later, O. H. Hershey ascended the river to the vicinity of the Shungnak River and made observations on the surficial deposits (Hershey, 1909). P. S. Smith, of the U.S. Geological Survey, mapped the geology at a scale of 1:500,000 in his traverse of the valley by pack train in 1910 (Smith, 1913; Smith and Eakin, 1911). The mineral resources of the area were investigated during World War II (Anderson, 1945); currently, copper lodes are being mined in the Ruby Creek area (R. H. W. Chadwick, oral comm., 1960).

The present investigation, a reconnaissance field study of the Kobuk River valley, was made in the summer of 1952. A float plane was used for transportation from a base camp established at the CAA landing area located along the Kobuk River 3 miles east of the village of Shungnak. Canoe traverses were made down the Ambler River from Lake Anirak, the Mauneluk River from Avaraart Lake (in the upper Kobuk River valley), and the Kobuk River from Lake Minakokosa (in the upper Kobuk River valley) to the village of Shungnak. Local observations were made along the Kobuk River downstream from Shungnak and at six lakes, all unnamed except for Tekeaksakrak Lake. The Great Kobuk Sand Dunes were examined from a subbase camp established at the mouth of Kavet Creek. Areas not covered by ground surveys were mapped on the basis of information obtained from aerial observations and photographs.

727-987 O—64——2

The fieldwork for this report was done in connection with the study of Alaskan terrain and permafrost and was financed in part by the Engineer Intelligence Division, Office of the Chief of Engineers, U.S. Army. R. S. and M. D. Sigafoos, botanists, D. R. Nichols, geologist, and Sam White, Alaskan bush pilot, were efficient and pleasant field companions throughout the summer. Thanks are due the local inhabitants of the area for innumerable kindnesses to the party and for much valuable information on the country. The radiocarbon age determinations were done in the laboratory of the U.S. Geological Survey, except for sample L-237E, which was done in the Lamont Radiocarbon Laboratory. Size analyses of the sediments were run by Paul D. Blackmon, of the U.S. Geological Survey; the mineralogic composition of the dune sand was determined by Dorothy Carroll, also of the U.S. Geological Survey.

PLEISTOCENE GEOLOGY AND HISTORY

EARLIEST GLACIATION

The central Kobuk River valley was covered by ice, perhaps of ice-cap proportions, during an early glaciation that was centered over the Brooks Range and extended as far west as the Baldwin Peninsula on Kotzebue Sound and as far south as the Koyukuk River valley. The ice deposited a conspicuous moraine—first recognized by Hershey (1909, p. 83–88) and recently studied in detail (Hopkins, D. M. and others, 1962)—that underlies Baldwin Peninsula and extends along the southern shore of Selawik Lake. Ice-scoured uplands south of the central Kobuk River valley comprise erosional evidence for this glaciation. Many boulders in gravel deposits south of the Lockwood Hills in the Pah River Flats (Smith, 1913, p. 98) may be of glacial origin and related to this glaciation.

KOBUK GLACIATION

Distribution.—The earliest episode of glaciation represented by mappable deposits in the central Kobuk River valley is here named the Kobuk Glaciation after extensive exposures along the Kobuk River (pl. 1). The drift lies beyond less extensive subdued lobate moraines of a younger glaciation, has no recognizable morainal topography, and has been greatly dissected. It was deposited by glaciers that originated in the Baird and Schwatka Mountains to the north and northeast and coalesced in the Ambler Lowland and the Kobuk River lowland.

The drift occurs in terraces that abut the north side of the Kobuk River with steep 100- to 150-foot escarpments and extend discontinuously from the eastern border of the area westward to the Hunt River. The terraces are bordered by the mountain front to the north and can be traced into the Ambler Lowland along the Ambler River and up the valley between Ingricherk and Bismark Mountains. Terrace remnants in this lowland occur several hundred feet above subdued moraines of a younger glaciation. In places, as near Shungnak and west of the mouth of the Ambler River, the drift has been covered with younger alluvial and eolian deposits. Stony till has been noted about midway between the Hunt and Ambler Rivers (Hershey, 1909, p. 90). Drift is present south of the Kobuk River at the eastern edge of the mapped area where the Pah River joins the Kobuk River.

Maximum extent of ice of the Kobuk Glaciation is not known. The terrace deposits north of the Kobuk River have clearly been eroded laterally by the river. No drift was found south of the river, except in the Pah River area, but any such deposits would be hard to detect because of burial by extensive dune fields or removal by stream action. In the upper Kobuk River valley, east of the mapped area, ice related to this glaciation extended to at least the south side of the valley. In the lower Kobuk River valley, west of the area, certain deposits and features may also be related to this glaciation. There, gravel and large boulders of probable glacial origin occur along the Kobuk River at least as far west as the mouth of the Tutuksuk River and also along the lower course of the Squirrel River near Kiana where till has been reported (Hershey, 1909, p. 90). The Baird Mountains to the north have been extensively glaciated.

Nature of the deposits.—Deposits of the Kobuk Glaciation, as exposed in the bluffs along the rivers, compose a complex of till and outwash gravel and sand. Only one episode of glaciation is represented in the sections, as evidenced by the lack of a soil profile or sharp contact between the several units. The drift is characterized by a high sand content.

An exposure near the mouth of the Ambler River, first described by Mendenhall (1902, p. 48), can be considered the type locality; a measured section is given below (Bluff 5, pl. 1). The bluff (fig. 2) decreases in height downstream, and at a point several hundred feet from the measured section only two units are exposed: 30 feet of dark bluish-gray till overlain by 50 feet of yellowish-gray outwash sand. Between the two sections the lower sand unit has lensed out and the upper gravel unit has been eroded.

A 100-foot bluff (Bluff 3, pl. 1) along the Kobuk River 4 miles upstream from the Hunt River contains outwash deposits but no till. Seventy feet of brown and gray medium gravel and sand is overlain by 30 feet of yellowish-gray sand with lenses of fine gravel. In an-

FIGURE 2.—Exposure of till and outwash of the Kobuk Glaciation along the east bank of the Ambler River. Stratified yellowish-gray gravel, sand, and silt (a) in the upper part of the bluff overlies bluish-gray till (b) in the lower part. The 100-foot section (Bluff 5) was measured near the left side of the picture. The bluff is 2 miles upstream from the junction of the Ambler and Kobuk Rivers.

the fluvial deposits in Bluff 4 (p. K23), collected 8 feet above its base, has an age of greater than 33,000 years; peaty material (sample W-420) from the same bluff 15 feet above its base is dated at greater than 38,000 years. The antiquity of the eolian sand is evident from its lack of dunal expression.

The deposits were probably laid down principally during the interglacial period, of pre-Wisconsin age, that followed the Kobuk Glaciation and preceded the next younger, or Ambler Glaciation, described below. This interglacial period is the major time break recognized in the glacial sequence within the central Kobuk River valley, and the extent, thickness, and location of the fine-grained sediments indicate a major period of fluvial and eolian deposition. The fineness and organic content of the fluvial deposits point to an interglacial period, and the currently active dunes show that eolian activity commonly continues into such a period. Stratigraphically, the overlying loess was deposited during the later glacial episodes, and some is being added even today. The coarse material that underlies the deposits north of the Kobuk River in several places, and possibly entirely, has been related to the Kobuk Glaciation. Deposits south of the Kobuk River, although not known to overlie drift related to the Kobuk Glaciation, are clearly later than that glaciation, for its vigorous glacial streams would have removed them. Streams generated by the next younger glaciation, confined to the Ambler Lowland except along the Mauneluk River, were much less effective in this part of the valley.

AMBLER GLACIATION

Distribution.—Lobate moraines, present along the larger rivers that rise in the Baird and Schwatka Mountains, were deposited by valley glaciers that, from west to east, extended progressively farther south. The glaciers were contained within the mountains between Akiak and Miluet Creeks, spread out in the Ambler Lowland between the Redstone and Shungnak Rivers, nearly reached the Kobuk River along the Kogoluktuk River, and reached it along the Mauneluk River. The moraines are all subdued, and the glacial episode during which they were deposited is here named the Ambler Glaciation after the deposits that nearly filled the Ambler Lowland.

Beyond the mapped area, similar lobate moraines are located in the upper Kobuk River valley. There, glaciers that originated and coalesced in the headwaters of the river within the Schwatka Mountains extended down the river to the southwest as far as Sulakpoatokvik Creek and to the southeast around Norutak Lake. Other valley glaciers left moraines along the Killak River and around Lake Selby, first described by Smith (1913, p. 95). North of the area, glaciers other 100-foot bluff (Bluff 12), 1 mile downstream from the Pah River, 50 feet of yellowish-gray outwash gravel is overlain by 30 feet of brownish-gray till that consists of pebbles, cobbles, and boulders in a silty matrix. The till is overlain by 20 feet of yellowish-gray outwash sand and silt. Bluffs at and near the village of Shungnak are poorly exposed, and no sections could be measured. Small zones of sand and gravel are present within the bluffs, and the slump material consists of boulders, gravel, sand, and silt. One large boulder occurs in slumped material 90 feet above the river (Bluff 8), and many others of various types are present at the base of the bluff. The largest boulder, found in the Kobuk River below the village, measures 6 feet in longest dimension.

Measured section of bluff along Ambler River, 2 miles upstream from the Kobuk River (Bluff 5, pl. 1)

	Thickness (feet)
Outwash gravel, yellowish-gray; pebble and cobble sizes	10
Outwash sand and silt, yellowish-gray	50
Till, bluish-gray; pebbles, cobbles, and boulders in a silty clay matrix; large boulders predominantly limestone and greenstone	10
Outwash sand and silt, yellowish-gray. Similar to unit above	15
Till, bluish-gray. Similar to unit above	15
Base at edge of river.	

Age.—Maximum extent of ice of the Kobuk Glaciation is not known; neither is its relationship to the earliest glaciation that overrode the valley and reached many miles to the west and south. The Kobuk appears to be a separate and later glacial episode, although detailed mapping may indicate it to be a late phase of the earliest glaciation; for purposes of this report, it defines a glacial advance known to have occurred in the central part of the valley.

No radiocarbon dates that pertain directly to the Kobuk Glaciation are available; however, fine-grained deposits that have been related to the interglacial period following this glaciation and those that have been dated at greater than 33,000 and 38,000 years are described under "Eolian and alluvial deposits." The antiquity of the drift is evident from its great dissection and from the absence of morainal expression. The glaciers extended a minimum of 12 to 15 miles beyond subdued lobate moraines of a younger glaciation. Elsewhere in Alaska, glacial deposits that have a similar occurrence are considered to be Illinoian in age (Péwé, T. L., and others, 1953; Karlstrom, T. N. V., 1957; Coulter, H. W., and others, 1964). The Kobuk Glaciation is, in all probability, of pre-Wisconsin age and it is so mapped; a more specific assignment is not attempted.

age (Péwé, T. L., and others, 1953; Karlstrom, T. N. V., 1957; Coulter, H. W., and others, 1964). As reasoned for the Selatna Glaciation in the upper Kuskokwim region (Fernald, 1960, p. 232), because the deposits of the Ambler Glaciation have morainal topography, this glaciation is probably post-Illinoian in age and is therefore designated as Wisconsin(?).

WALKER LAKE GLACIATION

Distribution.—A series of prominent lobate moraines were deposited by glaciers that originated in the Schwatka Mountains and flowed down the valleys of the Ambler, Shungnak, and Kogoluktuk Rivers, within the mapped area, and the valleys of the Mauneluk River, Beaver Creek, and the Reed River, east of the area. A particularly conspicuous moraine, first described by Mendenhall (1902, p. 47) encloses the southern end of Walker Lake, near the headwaters of the Kobuk River (location is shown on fig. 1); the glacial episode during which these conspicuous moraines were deposited is here named the Walker Lake Glaciation.

The Mauneluk River glacier spread out in the Ambler Lowland where a westward-flowing arm reached the border of the area. The glaciers that flowed down the valleys of the Kogoluktuk and Shungnak Rivers reached almost to the edge of the lowland. The maximum extent of the Ambler River glacier, which did not reach the Ambler Lowland, is about 10 miles from the mountain front. In the Baird Mountains, glaciers were confined to the highest parts, where their development was favored on north-facing slopes, as well shown in the Jade Mountains. Many were confined to cirques, but some extended as much as 3 miles from their source.

Nature of the moraines.—The lobate moraines of the Walker Lake Glaciation in the large valleys are sharply defined and well preserved. In the type locality, a 1- to 2-mile-wide arcuate moraine rises 100 to 200 feet above Walker Lake and extends completely around the southern end of the lake, from mountain wall to mountain wall, except for a narrow valley cut by a small outlet stream (fig. 3). The moraine is divisible into an outer and an inner loop, each made up of a series of closely spaced arcuate ridges and intervening swales. The drift consists of coarse rubble and sand, as exposed in shallow excavations, and many large boulders are scattered over its surface. The equivalent moraine along the Mauneluk River has a triple division, each loop about ½ miles wide and 1 mile apart. It has been dissected to a greater degree than the Walker Lake moraine, in common with moraines on valley floors where there are large throughgoing streams. Its drift contains much sand and many large boulders. The moraines along the Shungnak, Kogoluktuk, and Reed Rivers are double, but

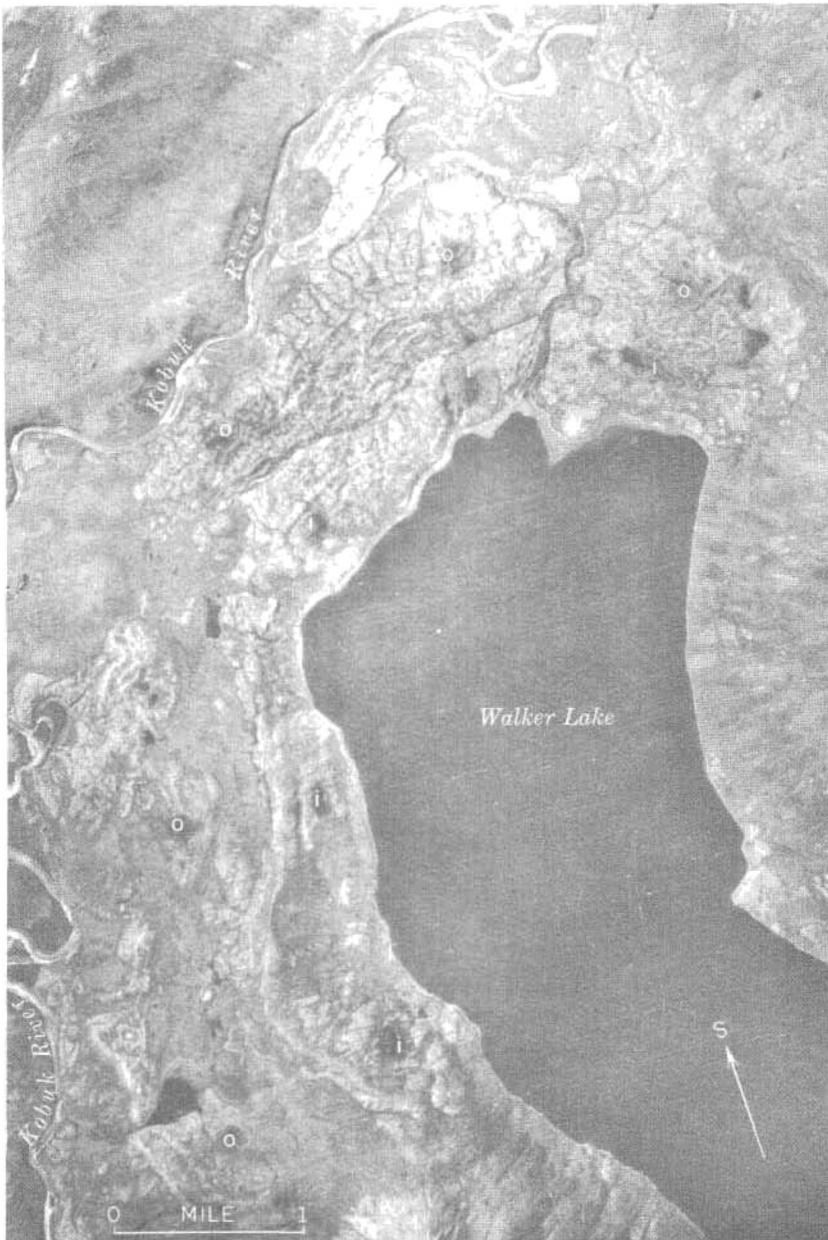

FIGURE 3.—Oblique aerial view of the fresh moraine of the Walker Lake Glaciation at Walker Lake. The prominent moraine, divisible into an outer (o) and an inner (i) loop, extends completely around the southern end of the lake except for a narrow valley cut by its outlet stream. The lake is near the headwaters of the Kobuk River, which, in somewhat within the picture, a low oblique high altitude view. Photograph by U.S. Geological Survey, 1955.

only a single moraine is present along Beaver Creek. Along the Ambler River where the valley is narrow and the river wide and swift, the moraine consists of remnants at the foot of valley walls. Close similarity in topographic expression exists between the outer and inner loops of the double and triple moraines, and the loops are therefore considered to be due to pulsations of a single glaciation.

The topographic expression of the equivalent small moraines in the cirques and narrow valleys of the Baird Mountains, in contrast to the large valley moraines, is subdued. Knobs and ridges are low and rounded; the intervening hollows, some of which contain ponds and small lakes, are smooth and shallow. The appearance of the moraines results from their high elevation above timberline where vigorous frost action rapidly smooths surface irregularities.

Age.—No radiocarbon dates are available to delimit the Walker Lake Glaciation; possible ages range from Wisconsin to Recent. The fresh prominent moraines contrast sharply with the more extensive subdued moraines of the Ambler Glaciation of Wisconsin(?) age; they also contrast sharply with much less extensive moraines of a younger glaciation restricted to the higher parts of the Schwatka Mountains. The Walker Lake Glaciation is, in all probability, the last major glaciation in the valley and is therefore considered to be of Wisconsin age. Comparable moraines elsewhere in Alaska are assigned a Wisconsin or a late Wisconsin age (Péwé, T. L., and others, 1953; Karlstrom, T. N. V., 1957; Coulter, H. W., and others, 1964). Moraines of the Walker Lake Glaciation are mapped as of Wisconsin age rather than late Wisconsin, because of the questionable Wisconsin age of the Ambler Glaciation.

PLEISTOCENE AND RECENT GEOLOGY

DUNE FIELDS

Distribution.—Active and stabilized dune fields cover more than 300 square miles of the central Kobuk River valley. By far the largest dune field, on the south side of the Kobuk River, extends nearly continuously from the vicinity of Black River to the vicinity of Tunutuk Creek on the north side of the Waring Mountains and to beyond the area on the south side of the mountains, in the Kugarak River region. An active dune area, termed the "Little Kobuk Sand Dunes," is included within this field. The second largest field, also south of the Kobuk River and including the Great Kobuk Sand Dunes, is north of the Waring Mountains, between Niaktuvik Creek on the east and Kavet Creek on the west where it extends a short distance beyond the mapped area. Smaller fields, all stabilized except for one near the mouth of the Hunt River, are present on the flood plain and low terraces of the Kobuk River. Other small fields occur on the high terraces north of the Kobuk River, the two largest of which are west of the Ambler River and in the vicinity of Shungnak. Many fields are too small to map at the given scale.

On its eastern border the large dune field in places is separated from the Kobuk River flood plain by a low escarpment, and in other places it overlaps the low terraces of the river. It rises from about 100 feet above sea level on the eastern border to more than 500 feet toward the western border where it is banked up against the Waring Mountains. Much of its southern border abuts the higher and older eolian and alluvial deposits. A steep escarpment separates its northern border from the Kobuk River flood plain. Several bedrock hills project above the surrounding sea of sand. Meandering tributaries of the Kugarak and Kobuk Rivers flow in highly irregular courses through the dune fields.

The second large dune field on the east rises from the flood plains and low terraces of Ahnewetut and Niaktuvik Creeks, and on the west, southwest and south it is banked up along Kavet Creek, the Waring Mountains, and the upper course of Niaktuvik Creek. A 100-foot escarpment outlines its northern border with the Kobuk River flood plain. The Great Kobuk Sand Dunes, in the southwest corner, cover about a third of the entire field. Ahnewetut Creek has been able to maintain its course through the dune field; but Kavet Creek has clearly been pushed to the west by the advancing sand, and Niaktuvik Creek in its upper course has been confined to the foothills of the Waring Mountains.

Character of dunes.—Stabilized dunes, the oldest and largest of three mappable eolian units, cover much of the eastern half of the two large dune fields and nearly all the other dune fields. Their topography is highly irregular—a maze of rounded hillocks and hollows—with no distinct dune types recognizable. The dunes have been intensely eroded, and an intricate pinnate drainage pattern has been established. Many of the hollows have swamps and ponds. There are no bare spots, except for scattered blowouts, and the vegetation cover consists of both tundra and boreal forest. Higher, better drained parts support sparse forests of spruce, birch, and aspen; low, wet ground has tundra and scattered black spruce, with permafrost at shallow depths (1–2 ft).

Dunes that are in part stabilized and in part active, the second mappable unit, cover large areas of the western half of the two large dune fields. They consist of vegetated areas of sparse forest and wet tundra interspersed with innumerable bare patches of sand. In places, they have been dissected by streams, and elsewhere some of the interdune hollows have ponds and swamps. Dune types within this unit are all of the phytogenic class in which vegetation plays an active role. They range from small single dunes to large complex patterns, all basically parabolic or U-shaped. Cliff-head dunes are present on low terraces where streams have dissected the sand. Small blowouts that consist of a saucer-shaped depression and a pile of sand on the leeward side are scattered throughout the area. Some of the blowouts are large and complex and consist of canoe-shaped troughs bordered laterally by long arcuate ridges made up of a series of many U-shaped dunes; these ridges are alined east-west, virtually parallel to the dune-building wind (fig. 4).

The third and youngest unit is the active dunes of the Little Kobuk Sand Dunes and the Great Kobuk Sand Dunes. They are almost free of vegetation except for clumps of grass (*Bromus pumpelliamus* and *Elymus innovatus*). The active fields are bordered on the east by dune fields that are in part active and in part stable. A complete transition from stable to active dune fields is shown as the amount of sand increases and the vegetation cover decreases (fig. 5). The dune type also shows a complete transition from the phytogenic class, characterized by parabolic dunes with ends to the windward, to the vegetation-free class, characterized by barchans with ends to the leeward. In this transition a series of U-shaped dunes form, first, large parabolic ridges with long broadly curved sides (in effect, two longitudinal ridges) and then long undulating transverse ridges with ends at the edge of the active field curved back to the windward. In the western part of the larger field, a series of barchans that rise to 100 feet have been developed from the transverse ridges (fig. 6).

Dune-building winds.—The position of the dune fields and the morphology and bedding of individual dunes indicate general easterly winds as the effective present and past dune-building winds (Fernald and Nichols, 1953). The large field rises from the valley floor on the east and, driven by easterly winds, is now banked up against and around the Waring Mountains on the west. The two active fields form a wedge of sand that rises gently on the east and is terminated by a steep escarpment on the west. The slopes of the U-shaped dunes, the transverse ridges, and the barchans are consistently steeper on the west, or leeward, side than on the east side.

FIGURE 4.—Vertical aerial view of stable dune field, with locally active dunes, near the Little Kobuk Sand Dunes. Small active dunes (a, smooth white areas) and many swamps and ponds (b) are scattered over the area. The active dune (c) near the center of the picture is part of a large and complex blowout, characterized by canoe-shaped troughs (d) and broadly arcuate longitudinal ridges (e). The dune-building winds are southeast to east. The dune field is about 5 miles south of the Kobuk River, midway between Nakochelik and Mishuk Creeks. Photograph by U.S. Coast and Geodetic Survey, 1951.

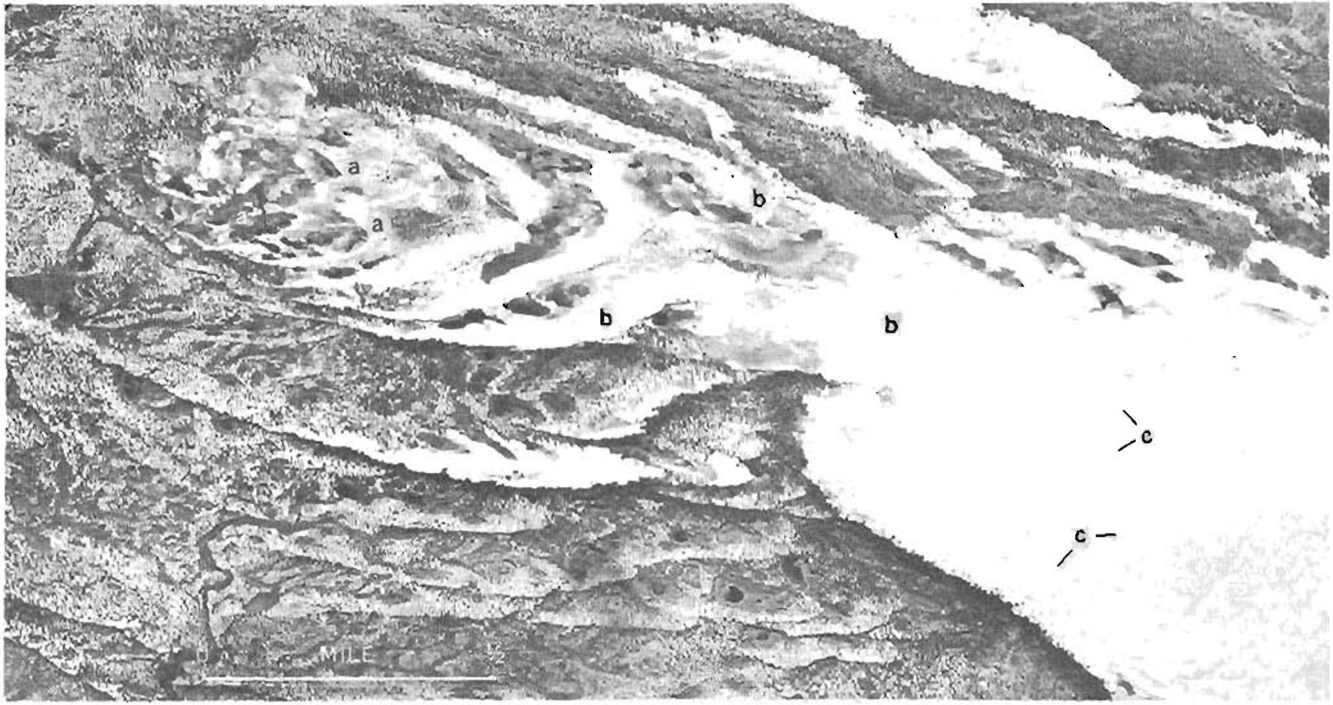

FIGURE 5.—Vertical aerial view of the eastern half of the Little Kobuk Sand Dunes. The dune field at the left of the picture, in part stabilized and in part active, becomes increasingly active toward the right where it merges into the Little Kobuk Sand Dunes. On the left a series of U-shaped dunes (a) form large parabolic ridges (b) with long gently curved sides; in the active field they form undulating transverse ridges (c) with ends at the edge of the field curved back to the windward. The dune-building winds are southeasterly. Photograph by U.S. Coast and Geodetic Survey, 1951.

FIGURE 6.—Oblique aerial view of the Great Kobuk Sand Dunes. The eastern part of the field has many undulating transverse ridges, made up of a series of U-shaped dunes; the ends of the ridges at the edge of the field are curved back to the windward. In the western part of the field, where the amount of sand has increased and the vegetation cover has decreased, the ridges consist of a series of barchans. The dune-building winds are easterly. Scale and orientation vary somewhat within the picture, a low oblique high altitude view. Photograph by U.S. Geological Survey, 1955.

Today's winds are predominantly easterly, because the valley is within the zone of polar easterlies, and this flow is accentuated by the westward trend of the valley. Frequent migrating storms, however, cause the winds to swing around to the west, and the prevailing winds in the summer months as recorded at Shungnak are actually westerly. (See table below.) The sand was observed to move with moderate easterly winds, but little or no movement occurred during the stormy westerly winds. Stronger and more frequent easterly winds probably occurred during the glacial periods because of intensified atmospheric circulation and steep pressure gradients between ice-covered and ice-free areas. The land bridge that existed during those times between Alaska and Siberia (Hopkins, 1959) probably favored the intensification of the polar easterlies.

Wind, precipitation, and temperature data for Shungnak

[Data from U.S. Weather Bureau, 1958; U.S. Weather Bureau Climatological office, Anchorage, written comm., 1952]

Month	Prevailing wind direction (Period 1944-48)	Mean total precipitation (inches) (Period 1941-50)	Mean temperature (degrees F) (Period 1941-50)
January	East	0.43	−1.8
February	East	.46	−3.8
March	East-northeast	.42	.4
April	East	1.02	16.2
May	East-southeast	1.09	36.0
June	West-southwest	1.66	53.2
July	West-southwest	2.35	58.5
August	West-southwest	4.40	50.2
September	East	2.52	40.1
October	East	.84	23.3
November	East	.48	2.0
December	East	.55	−6.4
Average for year	East	16.22	22.3

Nature of the deposits.—The dune sand is characteristically well rounded, frosted, and nonuniform in size, ranging from very fine (0.05–0.1 mm) to very coarse (1–2 mm). Nearly 50 percent of the grains from a coarse sample collected from the Great Kobuk Sand Dunes ranges in diameter from 0.5 to 1 mm; 63 percent of the grains from a fine sample from the same area ranges in diameter from 0.1 to 0.25 mm (fig. 7). The mineral composition of the coarse sample shows an abundance of quartz, feldspar, and opaque minerals; the fine sample from the same area has an abundance of quartz, chlorite, and chloritoid. (See following table.)

Mineralogic composition of dune sand from central Kobuk River valley, Alaska

[Analyst, Dorothy Carroll. Symbols: A, 20-40 percent; B, 10-15 percent; C, 1-5 percent]

Mineral	Sample	
	81 [1]	82 [2]
Chlorite	B	A
Chloritoid	C	A
Epidote and zoisite	--------	B
Feldspar (altered)[3]	B	B
Garnet	C	B
Glaucophane	C	C
Hypersthene	B	--------
Magnetite	C	C
Muscovite	C	--------
Opaque minerals (undifferentiated)	A	C
Plagioclase ($n>1.52$)	B	C
Pyroxene	C	--------
Quartz	A	A
Rutile	--------	C
Tourmaline	--------	C

[1] Coarse sample from northern end of Great Kobuk Sand Dunes, near Kavet Creek.
[2] Fine sample from northern end of Great Kobuk Sand Dunes, near Kavet Creek.
[3] Includes other altered minerals, such as chlorite.

A thick section of dune sand from a stabilized area is exposed in a bluff along the south side of the Kobuk River west of Omaluruk Creek. A measured section at the eastern end of the bluff is given below (Bluff 4). The underlying alluvial deposits are discussed on page K11.

Measured section of east end of bluff on south side of Kobuk River, 1.5 miles downstream from Omaluruk Creek (Bluff 4)

	Thickness (feet)
Sand and organic material, mixed. Cliff-head dune	1.5
Soil zone: Organic material (3 in.) over gray silt (3 in.) over reddish-brown silty sand (6 in.)	1
Dune sand, tan, crossbedded	8.5
Dune sand, gray, crossbedded	65
Alluvial sand and silt, with organic material; mottled yellow and gray; top irregular, with no soil profile or weathering zone; peaty material concentrated in two bands, one from 5 to 8 ft above the base and the other from 10 to 20 ft above the base. Interglacial deposits(?)	35
Base at edge of river.	

Age.—The glacial periods provided conditions most favorable to formation of dunes. An abundant source of sand free of vegetation was available from the glacial streams, the glacial winds were strong, and the rigorous climate restricted growth of vegetation. Perhaps the most intense dune activity occurred during and following the Kobuk Glaciation when part, and possibly all, of the central Kobuk valley was filled with drift that contained much sand. This period is represented by the eolian deposits included with pre-Wisconsin inter-

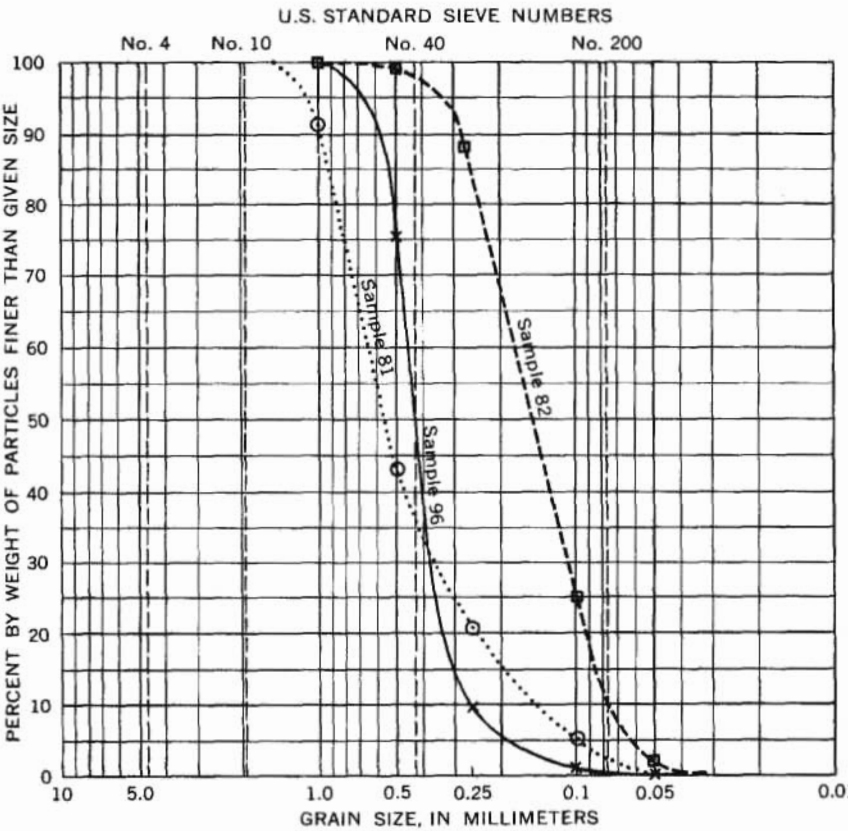

FIGURE 7.—Cumulative frequency curves showing the size of sand from active dunes, central Kobuk River valley, Alaska. Sample 81 is a coarse sample from the northern end of the Great Kobuk Sand Dunes near Kavet Creek; sample 82 is a fine sample from the same area; sample 96 is from a small dune field supplied directly from river bars of the Kobuk River near its junction with the Hunt River. Analyses by P. D. Blackmon, U.S. Geological Survey.

glacial deposits. The mapped dune fields very probably date back to the Walker Lake Glaciation of Wisconsin age, and they may date back to the Ambler Glaciation of Wisconsin (?) age. No radiocarbon dates are available, except that the ages of peaty material within the fluvial deposits that underlie the dune sand in Bluff 4 are greater than 33,000 and 38,000 years (p. K11).

With the retreat of the glaciers of the Walker Lake Glaciation, conditions favorable to formation of dunes diminished. The supply of sand decreased, the glacial winds disappeared, and the growth of vegetation was favored; dune activity, however, has continued to the present, maintained for the most part by the previously deposited dune sand. In addition, dissection of the glacial and interglacial deposits by the Kobuk River and its tributaries has continued to supply additional sand. The small active dunes along the Kobuk River south of the Hunt River are today supplied directly from bare sand bars.

TERRACE AND FAN ALLUVIUM

Distribution.—Dissected alluvial terraces and fans are present along parts of the Kobuk River and some of its tributaries. Most of the terraces and fans have been developed jointly by the master stream and one or more tributaries. These deposits are therefore mapped together as "terrace and fan alluvium." The more recent parts of the alluvium that are separated from modern flood-plain and fan deposits by low escarpments (generally 5–25 ft high) are differentiated on the geologic map.

The largest area is a broad surface developed principally by the Kobuk River and three of its tributaries, the Black, Pick, and Kuicherk Rivers. The surface is gently sloping and nearly continuous between the Kobuk River on the north and the uplands on the south, extending from west of the Black River to beyond the Kuicherk River on the east. It is generally separated from the flood plain of the Kobuk River by a low escapment that ranges in height from 5 to 15 feet. Dozens of small dune fields, a few large enough to map, rise from 5 to 50 feet above the surface; and many thaw lakes, several of which are larger than a square mile in area, cut the surface with steep, 5- to 20-foot embankments. The second largest area, located north of the Waring Mountains, is triangular shaped, with the Kobuk River on the north, Niaktuvik Creek on the southeast, and Ahnewetut Creek on the southwest. Many thaw lakes cut its gently sloping surface, and several dune fields rise above it. Smaller terraces and fans are present along other parts of the Kobuk River and also along some of its tributaries. Most noteworthy are those formed jointly by the Kobuk River and its south-flowing tributaries, including Hunt River, Rabbitt Creek, Shungnak River, Wesley Creek, and Cosmos Creek.

Nature of the deposits.—The terrace and fan alluvium is a complex of deposits consisting of gravel, sand, silt, and organic material. The alluvium is generally finer grained south of the Kobuk River where it consists predominantly of fine gravel, sand, and silt with admixtures of organic debris; coarse gravel is present locally. The surface material in places has been redeposited by migrating thaw lakes; in other places a cover of dune sand is present. North of the Kobuk River the alluvium is predominantly gravel and sand, locally with admixtures of silt and organic debris.

The alluvium in a 10-foot bluff (Bluff 10) along the Kobuk River 4 miles downstream from the Kogoluktuk River consists of 7 feet of crossbedded sand with lenses of fine gravel, overlain by 3 feet of layered peat. A 20- to 30-foot bluff along an unnamed lake near Niaktuvik Creek (Bluff 2) exposes well-bedded fluvial sand overlain by involuted sand, silt, and peat, and capped by windblown sand with admixtures of peat. South of the Kobuk River, a promontory that rises more than 75 feet above Tekeaksakrak Lake exposes a 15-foot section of thinly bedded sand and silt with organic material (Bluff 7). Low terraces along the Mauneluk River and the lower Ambler River expose gravel with a high content of sand. The fan developed by Wesley Creek has several remnants that form 15- to 25-foot bluffs on the south side of the Kobuk River. A typical one (Bluff 9) exposes 15 feet of crossbedded gray gravel and sand with logs, overlain by 10 feet of sand and silt, also with logs. The Dahl Creek fan at the base of high mountains consists of well-rounded gravel.

Age.—The deposition of the terrace and fan alluvium, diverse in areal extent and in location but uniformly separated from modern flood-plain and fan deposits by low to moderate escarpments, spans a considerable time. Older higher parts of the alluvium, such as southern parts of the largest area, probably date back to the general alluviation associated with the last major glaciation of Wisconsin age. At that time, in common with episodes of glacial advance in general, the Kobuk River and its tributaries alluviated their valleys, and the Kobuk River itself was pushed to the south. Younger parts of the alluvium, such as the northern part of the largest area, were deposited by the meandering Kobuk River and its tributaries in the recent past. A log within the gravel deposits of the Wesley Creek fan, collected 15 feet down from the top (Bluff 9), has been dated at 2,500±300 years (sample L–237E). Here, as in other parts of the valley, the Kobuk River is currently migrating northward, accounting for part of the dissection of the fans north of the river. In general, the terrace and fan alluvium as a unit dates from the Wisconsin to an indefinite time within the recent past.

ULANEAK CREEK GLACIATION

A series of very fresh moraines, much less extensive than those of the Walker Lake Glaciation, are confined to the higher parts of the Schwatka Mountains. Several glaciers that originated in the Blind Pass Mountains, where the Schwatka Mountains rise rather abruptly from altitudes of 4,000–4,500 feet to 5,500–6.000 feet above sea level, reached the edge of the Ulaneak Creek valley, and the Ulaneak Creek Glaciation is herein named for this valley. The type moraine was laid down by a glacier that extended 8 miles from the headwall of the cirque where the ice accumulated; the cirque is floored with modern drift that extends about a mile from the headwall. The maximum extent of the glaciers as recorded within the area is about 8 miles, but most of the glaciers were confined to cirques. Within the Baird Mountains, small moraines were deposited on the north side of the Jade Mountains.

The drift of the Ulaneak Creek Glaciation occurs in distinct lobate moraines in cirques and across valleys and in morainal patches on valley bottoms and walls. The lobate moraines have a very fresh appearance and in part are bare of vegetation. Their topography is highly irregular and generally sharp, but locally, where frost action is vigorous, it is smooth. In the type locality, three distinct morainal loops are recognizable, but this division is not recognized elsewhere. The drift consist of very coarse rubble with many large bounders.

The very fresh moraines of the Ulaneak Creek Glaciation represent a glacial episode that is clearly younger than the considerably more extensive and prominent moraines of the Walker Lake Glaciation, considered to be of Wisconsin age. They are older than the modern moraines at and near the snouts of modern glaciers and snowfields within the very highest parts of the Schwatka Mountains. Such moraines may be very latest Wisconsin or Recent, and comparable moraines elsewhere in Alaska have been so assigned (Péwé, T. L., and others, 1953; Karlstrom, T. N. V., 1957; Coulter, H. W., and others, 1964). The limited extent and patchy distribution of the moraines of the Ulaneak Creek Glaciation point to their closer relation to the modern moraines and indicate that the more significant time break is between this glaciation and the Walker Lake Glaciation. A Recent age is favored.

MODERN GLACIATION

Several dozen north-facing cirques in the Schwatka Mountains within the area are floored with morainal debris that extends as much as 2 miles from the headwalls. Most of the cirques contain patches of snow that persist throughout the year, and one contains a stagnant glacier about a quarter of a mile long. Dozens of small glaciers, all of which are retreating at present, occur east of the area where the Schwatka Mountains rise to maximum heights of more than 8,000 feet above sea level. Ablation moraines are characteristically present on the glaciers; end moraines occur at and near glacier snouts. The longest glacier extends about 2 miles.

The end moraines are almost bare of vegetation, have extremely rough topography, and consist principally of very coarse rubble. Some are being deposited today; others were deposited in the very recent past; all are of Recent age.

MODERN ALLUVIUM AND COLLUVIUM

Distribution.—The Kobuk River, in its meandering course through its central valley, has formed a meander plain that ranges in width from about 1 mile to 8 miles. The plain is characterized by gentle slip-off slopes, steep cut banks, many oxbow lakes in various stages of formation, and innumerable ice-wedge polygons. The tributaries of the Kobuk River, where their flood plains are large enough to map, commonly have meander plains. The Ambler River, however, upstream from the moraine of the Ambler Glaciation is a braided stream.

Alluvial fans have been formed by small tributaries where they emerge from uplands or mountains onto valley floors. The fans are scattered within the U-shaped valleys of the Baird and Schwatka Mountains; they are also present along the northern rim of the uplands south of the Kobuk River valley. With their discrete fan shape and drainage pattern, they are easily differentiated from flood plains and are therefore mapped separately. In places, however, the alluvial-fan deposits merge into colluvial deposits that have also accumulated in many places at the base of valley walls. In the transition zone, alluviation by stream action progressively diminishes, and mass movement principally by frost action progressively increases. The alluvial-fan deposits and the colluvial deposits are therefore mapped together as "fan alluvium and colluvium."

Nature of the deposits.—The flood plains are composed of a complex of deposits—boulders, gravel, sand, silt, and organic material. The Kobuk River deposits consist principally of sand and lesser amounts of silt and gravel and some organic debris; glacial erratics are present locally. Much of the gravel occurs upstream from the Kollioksok River and at other places where the Kobuk River is impinging, or has recently impinged, against the glacial deposits. Large sand bars, completely bare of vegetation, line much of the river's edge throughout its course. Away from the sand bars, the vegetation shows a sequential distribution, with willow and alder on actively forming parts of the meander scrolls followed by a dense forest of spruce. Higher and older parts of the meander plains have tundra vegetation, a cover of peaty material intermixed with silt, and innumerable ice-wedge polygons.

The flood-plain deposits of the tributaries south of the Kobuk River consist principally of sand and silt, and locally, considerable organic material and gravel. The deposits of the tributaries north of the Kobuk River generally include much coarse gravel, a high content of sand, large glacial erratics, and little silt and organic material.

The fan alluvium and colluvium consist of rubble, gravel, sand, silt, and organic debris. The deposits north of the Kobuk River, in the Baird and Schwatka Mountains, are principally gravel and rubble, whereas those south of the river commonly contain both coarse and fine material.

Age.—The age of the flood-plain alluvium is Recent and ranges from the present to an indefinite time in the recent past, in the older parts of the meander plains. The fan alluvium and the colluvium, which are currently being laid down or were laid down in the recent past, are also Recent in age.

THAW LAKES

Thaw lakes, very common in the central Kobuk River valley, are most abundant on the flood plain of the Kobuk River, the alluvial terraces and fans, the areas underlain by the older alluvial and eolian deposits, and parts of the stabilized dune fields. Thaw lakes on the flood plain and the dune fields are characteristically small and irregular in outline, as are many of those on the other surfaces; some larger ones, however, are circular or oval or, where several lakes have coalesced, have a complex scalloped outline. The largest such lake, an unnamed lake located between Shaleruckik Mountain and the Black River, measures more than a mile in diameter. Actively caving banks are generally 5 to 20 feet high and commonly serrated where thawing proceeds more rapidly along ice-wedge polygons.

Thaw lakes occupy depressions that result from subsidence following the thawing of permafrost or that have been enlarged by thawing and caving at their margins (Hopkins, 1949, p. 119). Most of the lakes in the central Kobuk River valley, particularly those on the flood plain of the Kobuk River and the dune fields, formed in inital depressions, but some originated through subsidence. The lakes in general show various stages of development. Some are being enlarged completely around their margins, but others are being filled where thawing and caving is no longer active. Some of the lakes have been partly emptied where an outlet to a lower level has been established. Many of the lakes are migrating through enlarging on one shore and filling on opposite shores. In general, the thaw lakes are a potent agent of erosion in the reduction of the land surface.

Several lake basins, bordered by well-defined escarpments marking former shores, are large enough to map. The four largest ones, including that containing Tekeaksakrak Lake, have diameters of about 2 miles; they are south of the Kobuk River, one just west of Shaleruckik Mountain and the others between this mountain and the Pick River. The smaller ones are also on the south side of the Kobuk River east of Shaleruckik Mountain. The basins, all of which contain smaller thaw lakes and innumerable ice-wedge polygons, are floored with fine-grained deposits consisting of sand, silt, clay, and organic material. The age of these lake deposits, which accumulated before the lakes were drained, is uncertain, but obviously it is younger than that of the surfaces on which the lakes were formed. One of the lakes is within the area underlain by interglacial deposits of pre-Wisconsin age; the others are on alluvial terraces and fans that span a considerable time between the late Wisconsin and the recent past. Because all the mapped basins appear to have been occupied by lakes up to fairly recent times, as evidenced by the well-defined escarpments that have undergone relatively little modification, the deposits are considered to be of Recent age.

REFERENCES CITED

Anderson, Eskil, 1945, Asbestos and jade occurrences in the Kobuk River region, Alaska: Alaska Dept. Mines Pamph. 3-R, 26 p.

Cantwell, J. C., 1887, Exploration of the Kowak River, Alaska, *in* Healy, M. A., Report of the cruise of the Revenue Marine Steamer *Corwin* in the Arctic Ocean in the year 1885: Washington, U.S. Treasury Dept., p. 21–52.

——— 1889, Exploration of the Kowak River, Alaska, *in* Healy, M. A., Report of the cruise of the Revenue Marine Steamer *Corwin* in the Arctic Ocean in the year 1884: Washington, U.S. Treasury Dept., p. 47–98.

Coulter, H. W., and others, 1964, Map showing the extent of glaciations in Alaska: U.S. Geol. Survey Misc. Geol. Inv., Map I–415 (in press).

Dall, W. H., and Harris, G. D., 1892, Correlation papers: Neocene: U.S. Geol. Survey Bull. 84, 349 p.

Fernald, A. T., 1960, Geomorphology of the upper Kuskokwim region, Alaska: U.S. Geol. Survey Bull. 1071–G, p. 191–279.

Fernald, A. T., and Nichols, D. R., 1953, Active sand dunes in the Kobuk River valley, northwestern Alaska [abs.]: Geol. Soc. America Bull., v. 64, p. 1421–1422.

Hershey, O. H., 1909, The ancient Kobuk glacier of Alaska: Jour. Geology, v. 17, p. 83–91.

Hopkins, D. M., 1949, Thaw lakes and thaw sinks in the Imuruk Lake area, Seward Peninsula, Alaska: Jour. Geology, v. 57, p. 119–131.

——— 1959, Cenozoic history of the Bering land bridge: Science, v. 129, p. 1519–1528.

Hopkins, D. M., McCulloch, D. S., and Janda, R. J., 1962, Pleistocene stratigraphy and structure of Baldwin Peninsula, Kotzebue Sound, Alaska [abs.]: Geol. Soc. America Spec. Paper 68, p. 116.

Karlstrom, T. N. V., 1957, Tentative correlation of Alaskan glacial sequences, 1956: Science, v. 125, p. 73–74.

McLenegan, S. B., 1889, Exploration of the Kowak River, Alaska—Notes on the natural history and resources, *in* Healy, M. A., Report of the cruise of the Revenue Marine Steamer *Corwin* in the Arctic Ocean in the year 1884: Washington, U.S. Treasury Dept., p. 99–108.

Mendenhall, W. C., 1902, Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska by way of Dall, Kanuti, Allen, and Kowak Rivers: U.S. Geol. Survey Prof. Paper 10, 68 p.

Péwé, T. L., and others, 1953, Multiple glaciation in Alaska, a progress report: U.S. Geol. Survey Circ. 289, 13 p.

Russell, I. C., 1890, Ice cliffs on Kowak River, Alaska, observed by Lieut. Cantwell: Am. Geologist, v. 6, p. 49–52.

Smith, P. S., 1913, The Noatak-Kobuk region, Alaska: U.S. Geol. Survey Bull. 536, 160 p.

Smith, P. S., and Eakin, H. M., 1911, The Shungnak region, Kobuk Valley: U.S. Geol. Survey Bull. 480, p. 271–305.

Stoney, G. M., 1900, Naval explorations in Alaska: Annapolis, Md., U.S. Naval Inst., 105 p.

U.S. Weather Bureau, 1958, Climatic summary of Alaska—Supplement for 1922 through 1952, serial no. 11–43, 40 p.

U.S. GOVERNMENT PRINTING OFFICE: 1964 O—727-987