Geomorphology of the Upper Kuskokwim Region, Alaska

By ARTHUR T. FERNALD

CONTRIBUTIONS TO GENERAL GEOLOGY

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A reconnaissance study covering various aspects of the geomorphology, including the physiographic features, glacial history, and surficial deposits

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[Plates are in pocket]

CONTRIBUTIONS TO GENERAL GEOLOGY

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By Arthur T. Fernald

ABSTRACT

The upper Kuskokwim region as described in this report covers an area of about 6,000 square miles in southwest-central Alaska, and includes a small section of the Alaska Range, its bordering piedmont and lowland, and an adjacent upland area. It is drained by the upper part of the Kuskokwim River, which originates from the convergence of its several major tributaries in the lowland area. The region is underlain by sedimentary rocks of Paleozoic and of Cretaceous age and igneous rocks of Tertiary age. Most of the region, including large parts of the uplands and mountains, is covered with surficial deposits of several types—colluvial, glacial, eolian, alluvial, and organic material.

An extensive erosion surface formed over part of the region during the late Tertiary. This surface was differentially uplifted, probably in the late Pliocene or early Quaternary, and now covers upland summits at an altitude ranging from 1,000 to 2,000 feet above sea level. Rejuvenated streams following the uplift carved out innumerable valleys within the uplands, and the ancestral Kuskokwim River, which probably flowed on the erosion surface in about its present position, cut a broad canyon through the uplands. The Alaska Range was probably uplifted at the same time, and has undergone continued uplift during the Quaternary. Differential movement is still going on along two large faults, the Farewell fault at the north edge of the Alaska Range, and the Nixon Fork fault within the uplands.

Much of the lowland area, where debris derived principally from the rising Alaska Range has accumulated to an unknown thickness, has subsided, probably during the Quaternary. This wedge of sediments has pushed the Kuskokwim River to its present position along the north edge of the lowland.

Climatic fluctuations during the Pleistocene gave rise to repeated glaciations in the Alaska Range, where glaciers scoured large U-shaped valleys and also spread out onto the bordering piedmont. These fluctuations influenced the erosion and deposition in the nonglaciated areas. In the lowland, the accumulation of fluvial and eolian deposits was accelerated during the glacial advances. In the uplands, which were for the most part unglaciated, the zone of intense frost action, now at about 2,000 feet and above, was lowered during the glacial advances. Coarse rubbly colluvium is characteristic of this zone, and the rubble at the base of some of the creek valleys was probably deposited during the glacial climates; in other valleys the material was reworked by streams

into well-rounded gravel. Present streams in the valleys, which are partially filled with organic material and silt over the rubble and gravel, are sluggish and clogged with vegetation.

Two major glaciations of late Quaternary age are recorded by two sets of moraines in each of three areas on the piedmont; the moraines were deposited by glaciers that originated within the Alaska Range and extended down the valleys of the Big River and the Windy Fork and the South Fork of the Kuskokwim River. The older, or Selatna, glaciation is of Wisconsin(?) age, and is represented by greatly subdued moraines at maximum distances of 18, 12, and 25 miles, respectively, from the base of the mountains. It is also represented by an outwash slope in the Big River area. The younger, or Farewell, glaciation is represented by generally fresh to slightly subdued moraines at maximum distances of 0, 8, and 20 miles, respectively, from the mountains, and by widespread outwash slopes in the Windy Fork and South Fork areas. This glaciation is of Wisconsin age, and is divisible into an early phase (Farewell 1) and a late phase (Farewell 2).

The Farewell glaciation was accompanied by a period of maximum eolian activity in which loess was deposited over much of the region and dune sand was deposited over a large part of the lowland. Long arcuate ridges of sand that are oriented northeastward, with the concave side to the southeast and the steeper slope to the northwest, are the most conspicuous dune type. They belong to the phytogenic class of dunes, and were formed principally by southeast winds but modified by southerly and, probably, southwest winds. Some of the dunes became stabilized only in fairly recent time, and comparatively small amounts of loess are still being deposited. Remnants of old dune fields in the western part of the region are probably related to the Selatna glaciation.

The present surface deposits of the piedmont and lowland areas, other than the glacial and eolian sand deposits and a widespread veneer of organic and loessal material, are those of several alluvial features. The modern rivers, braided on the piedmont and meandering in the lowland, have formed narrow flood plains and large fans on the piedmont and broad meander plains in the lowland; tributary rivers in the lowland have formed small fans after emerging from the uplands. Rivers have also formed two older plains in the lowland, widespread fan aprons at the base of the uplands, and cones at the base of the Alaska Range. The deposits encompass several age spans within the late Quaternary.

A widespread cover of organic material, largely peat, is accumulating today over much of the lowland, parts of the piedmont, and locally within the uplands; similar material probably accumulated widely in the interval between the Selatna and Farewell glaciations. The modern peat is found below living muskeg vegetation, where permafrost is generally present at depths of 1½ to 3 feet. Peat also is found in bogs, which are interspersed within the areas of muskeg vegetation and are so numerous in poorly drained parts of the flatlands that they cover a fourth or more of the surface. A cyclic formation of permafrost below muskeg vegetation and its melting in bogs apparently goes on continuously. Completely undrained parts of the flatlands contain many large lakes.

INTRODUCTION

LOCATION

The upper Kuskokwim region, so named because it is drained by the upper part of the Kuskokwim River, is in the southwest-central

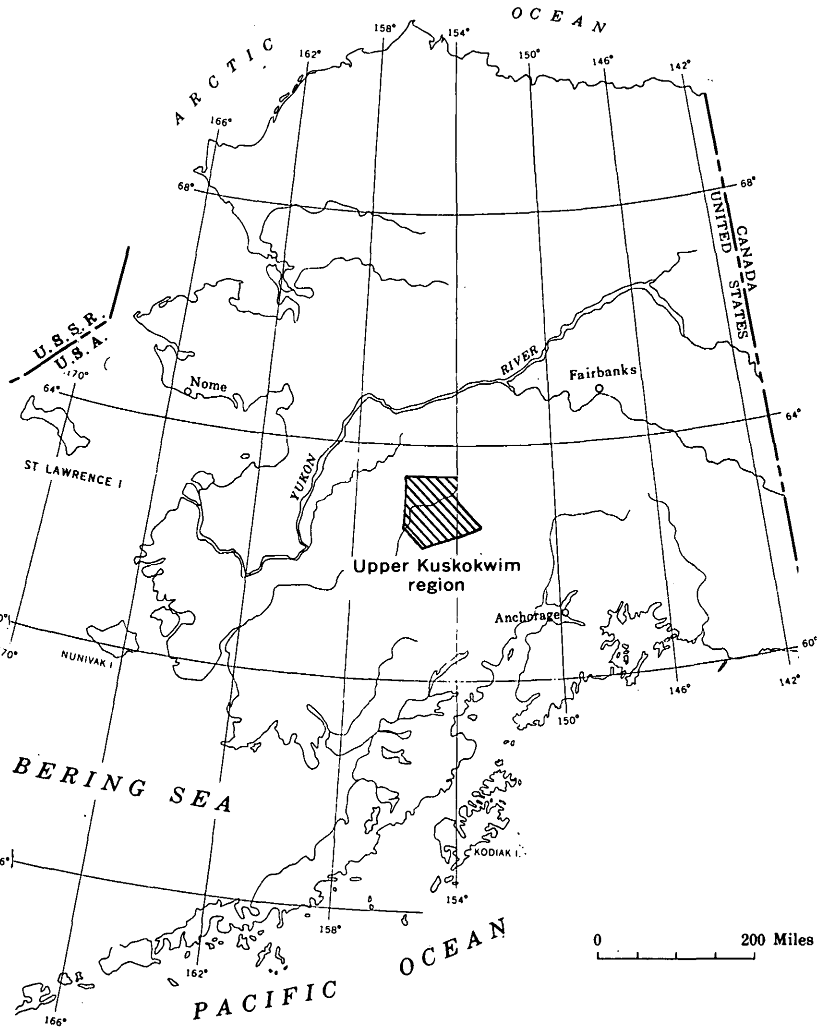

FIGURE 18.—Index map of Alaska showing location of upper Kuskokwim region.

part of Alaska. As defined for this report, it is an irregularly shaped area of about 6,000 square miles between lat 62° and 64° N. and long 153° and 156° W. It includes parts of the McGrath and Tonzona districts of the Kuskokwim region, as outlined by P. S. Smith (1939, pl. 3), and also includes part of the northwest flank of the Alaska Range. Its position in Alaska is shown in figure 18.

PREVIOUS INVESTIGATIONS

The first geologic information on the upper Kuskokwim region resulted from J. S. Spurr's historic trip across the Alaska Range, in the summer of 1898, for the U.S. Geological Survey (Spurr, 1900). He descended the South Fork and the Kuskokwim River (fig. 19) by canoe and traversed a considerable part of the region described in this report. With the assistance of W. S. Post, topographer, he made a sketch map (scale 1: 625,000) of the topography and geology along the route.

The next summer, the War Department sent a party by pack train, led by Lt. J. S. Herron, across the Alaska Range and down the South Fork. His route closely paralleled that of Spurr as far as the village of Nikolai on the South Fork, where Herron turned to the northeast. He lost his way in the broad, swampy lowlands of this area, was rescued by natives, and finally reached his destination in late fall. He made a rough sketch map of his estimated route (Herron, 1901).

In the summer of 1902, A. H. Brooks, in charge of a U.S. Geological Survey party, took a pack train across the Alaska Range, followed the South Fork to where it emerges from the mountains, and then swung to the northeast along the northern foothills of the range. His topographic and geologic maps (scale 1:625,000) covered the southeast corner of the upper Kuskokwim region and were more detailed than Spurr's sketch map (Brooks, 1911, pl. 9).

After the discovery of gold in the Kuskokwim region in the summer of 1906 (Mertie, 1936, p. 118), the U.S. Geological Survey sent several parties to investigate and map selected areas. During the summer of 1915, R. H. Sargent, topographic engineer, and J. B. Mertie, geologist, surveyed the Iditarod and Innoko area, which includes the northwest corner of the upper Kuskokwim region. Their topographic and geologic maps were published on a scale of 1:250,000 (Mertie and Harrington, 1924). G. C. Martin visited the Nixon Fork district in the summer of 1920 and made a preliminary geologic report (Martin, 1921). R. H. Sargent and J. S. Brown, geologist, resurveyed the Nixon Fork district in 1924 and made a topographic and a geologic map on a scale of 1:250,000 (Brown, 1926). In 1933, J. B. Mertie made a rapid survey of gold mining operations in the upper Kuskokwim region (Mertie, 1936).

PRESENT INVESTIGATION

SCOPE OF REPORT

This report is based on a reconnaissance study covering all aspects of the geomorphology of the upper Kuskokwim region. A large part of the region is covered with surficial deposits, and 16 mappable units of these deposits are differentiated. Their distribution is shown on a map at a scale of 1:250,000 (pl. 22). The physiography of the uplands and the glacial geology of the Alaska Range are discussed. Various geomorphic features, including sand dunes, bogs, and lakes, are also discussed. The report includes a brief section on the bedrock and the structural geology of the region and a map of the bedrock geology at a scale of 1:250,000 (pl. 21).

FIELDWORK

The fieldwork for this study was done in 1949 and 1950. The time involved totaled seven months and included the summers of both years. Mapping was done on aerial photographs, and the McGrath and Medfra reconnaissance sheets (scale 1:250,000) were used as base maps.

Traverses were made over the following areas: (a) the Kuskokwim River upstream to Medfra, (b) the lower half of the Nixon Fork, (c) the entire length of the Big River, (d) the road from Sterling Landing on the Kuskokwim River to Ophir (outside the Kuskokwim region), (e) the road from Medfra to the Nixon Fork mining district, (f) the area along the South Fork at the base of the Alaska Range, and (g) the area along Sheep Creek at the base of the Alaska Range.

Transportation over the roads was by motor vehicle. A river boat equipped with two outboard motors was used for investigations along the Kuskokwim River, and frequent stops were made for foot traverses away from the river. The Nixon Fork and the Big River were descended by canoe after transportation by float plane to an adjacent lake, from which portage to the rivers was made on foot. Ground surveys along Sheep Creek and the South Fork were carried out on foot.

Areas not covered by ground surveys were mapped on the basis of information obtained from aerial observations and photographs. Observations were made from planes flying at low altitudes, and interpretations of aerial photographs were based on photographic criteria established from the ground studies.

In both years the field party consisted of a botanist, a geological field assistant, and the writer as geologist and party chief.

ACKNOWLEDGMENTS

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. The aerial photographs of the region, which were invaluable for mapping purposes, were made by the U.S. Army Air Force and the U.S. Air Force.

The writer is greatly indebted to the late Kirk Bryan of Harvard University for his advice on many aspects of the fieldwork and some of the preliminary results, and to M. P. Billings, K. F. Mather, and J. P. Miller of Harvard University for their continued help. W. H. Drury, Jr. served as botanist during both field seasons. The section on vegetation is a condensation of one of his unpublished studies, and in other references to vegetation the author has made use of Drury's publication (1956) and information obtained in discussions with him. His invaluable assistance is greatly appreciated. Leon Hammar and George Corchary, members of the field parties during the summers of 1949 and 1950, respectively, were of great help.

To the inhabitants of the villages and mining camps of the Kuskokwim region, the author is indebted for innumerable kindnesses and services to the party, as well as for bringing to his attention features of the country that might otherwise have been overlooked.

GEOGRAPHY

The upper Kuskokwim region embraces rugged mountainous terrain, hilly uplands, gently sloping piedmont areas, and generally flat lowland areas. Altitudes range from about 300 feet above sea level in the lowlands to about 6,000 feet in the rugged mountains of the Alaska Range. The region is drained by the Kuskokwim River and its many tributaries.

The climate is cold and dry in winter, but the relatively short summers are warm and moist. The mean annual temperature at McGrath is 25.5°F and the mean annual precipitation is 19.13 inches. The vegetation includes tundra and boreal forest; timberline varies considerably in altitude but averages about 2,000 feet above sea level. The region is within the zone of discontinuous permafrost (Hopkins, Karlstrom, and others, 1955, fig. 11).

The total population is about 300 people, most of whom live either at McGrath on the Kuskokwim River or at Nikolai on the South Fork.

RELIEF AND DRAINAGE

The upper Kuskokwim region is divisible into three physiographic units: the Alaska Range, the Kuskokwim uplands, and the Tanana-Kuskokwim lowland (fig. 19). For purposes of discussion in this report, the Tanana-Kuskokwim lowland is subdivided into two geographic areas: the upper Kuskokwim River lowland and the Big River–South Fork piedmont. The boundary between them is arbitrarily drawn where the gently sloping piedmont merges into the nearly flat lowland. Several local areas are also designated: (1) Medfra flats, the broad swampy flatland south and southeast of Medfra where numerous tributaries of the Kuskokwim River converge; (2) Nixon Fork district, the mining district north of Medfra

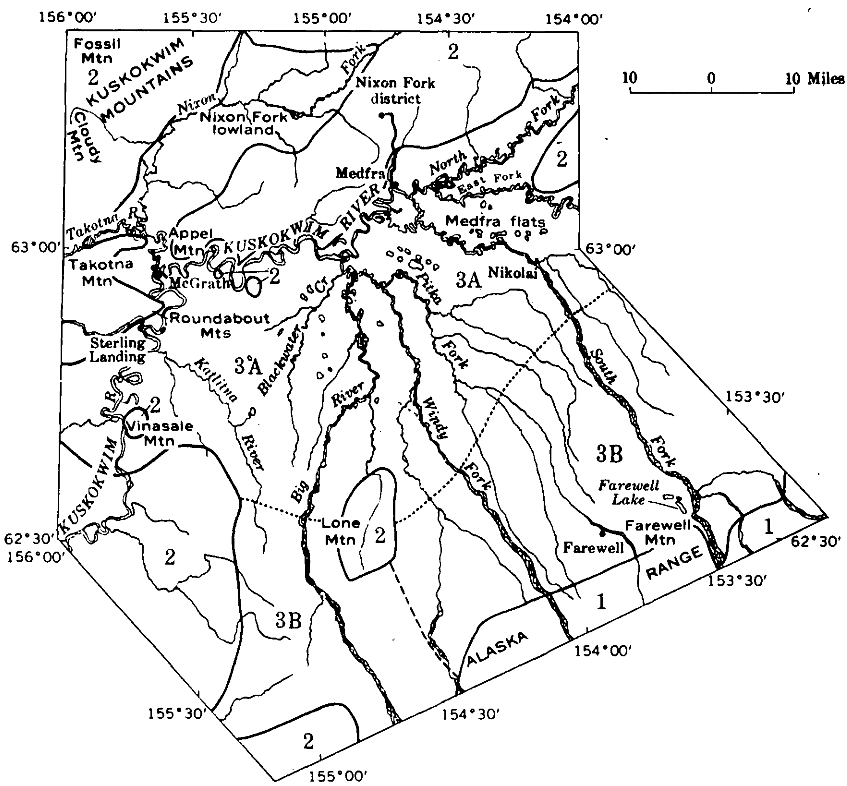

FIGURE 19.—Map of the physiographic units of the upper Kuskokwim region, Alaska. The physiographic units are: 1, Alaska Range; 2, Kuskokwim uplands; 3, Tanana-Kuskokwim lowland. For purposes of discussion, the Tanana-Kuskokwim lowland is subdivided into two geographic areas: *3A*, upper Kuskokwim River lowland; *3B*, Big River–South Fork piedmont (boundary shown by dotted line). The piedmont is further divisible into an eastern and a western part (boundary shown by dashed line).

between the Nixon Fork and the Kuskokwim River; (3) Nixon Fork lowland, the broad valley along the lower course of that river.

The Kuskokwim River proper originates from the convergence of its several major tributaries in the broad, flat area south of Medfra. Three of these tributaries—the Big River and the Windy Fork and the South Fork of the Kuskokwim River—flow in a general northerly direction from the Alaska Range. The East Fork and the North Fork of the Kuskokwim River flow from the east and the northeast, respectively, to the area of convergence. The Nixon Fork is a tributary of the Takotna River, which joins the Kuskokwim near McGrath. The Kuskokwim flows across the lowland and then cuts through the uplands in the southwest part of the region. In addition to these major rivers, many minor rivers and streams originate from the Alaska Range, the piedmont area, and the uplands. Large areas of the lowland are poorly drained or have no drainage, and swamps, bogs, and lakes abound in those areas.

The rivers freeze over around the first of November and remain frozen until late spring. Locally, in the braided sections of the rivers, freezing may penetrate to the bottom of the river and overflows may occur. The breakup of ice on the rivers in spring is generally of major concern to the inhabitants of settlements on the flood plains. The rivers are swollen by the influx of snowmelt water and the surface cover of ice is lifted and broken into ice blocks of various sizes. The floating ice blocks add to the danger of damage by floods, as some of them weigh many tons. Ice jams cause additional rises of water levels in local areas. The breakup generally takes place first in the upper reaches of the tributaries of the Kuskokwim River and progresses rapidly downstream. At McGrath the breakup usually takes place during the first or middle part of May as shown in the table below.

Dates of ice breakup on the Kuskokwim River at McGrath, Alaska, 1944–54

[Data from U.S. Weather Bureau, 1943–1955]

Year	Day of ice breakup	Year	Day of ice breakup
	May		*May*
1954	3		
1953	1	1948	13
1952	24	1947	10
1951	3	1946	13
1950	11	1945	18
1949	19	1944	7

During the summer, river levels are highly variable, as they respond rapidly to local precipitation. The glacial streams from the Alaska Range also respond to the amount of glacial melting and have a diurnal fluctuation.

Alaska Range.—The Alaska Range extends along the southeast border of the region to the vicinity of the Middle Fork of the Kuskokwim River, and then turns sharply to the south, outside the region. The range rises abruptly above the piedmont and is characterized by sharp peaks, steep slopes, and deeply dissected valleys. Altitudes range from about 2,000 feet to about 6,000 feet within the region and approach 10,000 feet south of it. The northwestward-facing front of the range is cut by numerous deep, U-shaped valleys, the largest of which are those of the Windy and South Forks.

Kuskokwim uplands.—The uplands lie in the northern, western, and southwestern parts of the region. Most of the upland areas are part of the Kuskokwim Mountains, which extend for many miles northeast and southwest of the region. The uplands also include Lone Mountain and the unnamed mountains that are along the southwest border of the region, between the Kuskokwim Mountains and the Alaska Range (between the Tatlawiksuk River and the Big River). Hills and mountains are generally rounded, their crests ranging between 1,000 and 2,000 feet above sea level. However, several rugged mountain masses project well above the general level of the rounded mountains. The Kuskokwim River flows through the uplands in a broad canyon, and numerous creeks flow in open valleys within the uplands.

Big River–South Fork piedmont.—The piedmont is bordered on the southeast by the Alaska Range and and the unnamed upland area southwest of the range. Between the range and this upland, the piedmont projects southward and merges into the Big River trench that extends over 40 miles outside the region to the Swift River. Other uplands border the piedmont on the west. To the northwest the piedmont merges into the lowland, and to the northeast it extends for many miles outside the region. Altitudes range from a minimum of about 600 feet along the northwest border of the piedmont to about 2,000 feet at the base of the range. Three large braided rivers—the Big River, the Windy Fork, and the South Fork—cross the piedmont.

Most of the piedmont is covered with moraines, outwash slopes, flood plains, and alluvial fans. It is divisible into an eastern and a western part on the basis of differences in topography. The eastern part, which borders the steep front of the Alaska Range, has a fairly smooth surface except for extensive moraines along the South and Windy Forks. Streams, originating within the range and on the piedmont, flow in a northerly direction. The western part has irregular topography. The Big River flows northward across a large morainal loop that covers much of this part of the piedmont. Other rivers originate within this morainal loop and flow in divergent directions—the Tatlawiksuk River to the southwest and tributaries of the Selatna River to the northwest.

Upper Kuskokwim River lowland.—The lowland of the upper Kuskokwim River is an irregularly shaped area bordered by uplands on the west and north. On the south it adjoins the piedmont, and to the northeast it extends beyond the region for many miles. In addition to widespread alluvial deposits of several types, dune sand covers parts of the lowland.

CLIMATE

Climatological data for the upper Kuskokwim region comes principally from the U.S. Weather Bureau station at McGrath, which has kept continuous records since 1940. A subsidiary weather station has been maintained at Farewell since 1947. The data for McGrath, which is 334 feet above sea level, can be considered as fairly representative of the lowland area, and that for Farewell, 1,499 feet above sea level, is fairly representative of the piedmont area.

McGrath.—The climate of the McGrath area, like that of the region in general, is characterized by an extreme range between summer and winter temperatures (fig. 20). The summers are warm and moist, the winters cold and relatively dry, and the transition periods between them short. With a mean annual temperature of 25.5°F and a mean annual precipitation of 19.13 inches, the climate can be classified as very moist (Hauritz and Austin, 1944, p. 114).

The temperature extremes are 89°F and −64°F. During the winter months the minimum temperatures normally fall to at least 50° below zero. Periods of extremely low temperatures may last from 5 to 10 days or more. Occasional influxes of warm maritime air result in maximum daily temperatures of 45°F or more for 1 or 2 days. The summer months are warm, with the average daily maximum temperatures in the high sixties. Maximum temperatures rise to the eighties on about 15 days.

The mean annual precipitation is 19.13 inches, of which over half falls during the 4 months from June through September. Most of the precipitation is due to cyclonic storms that generally move from the southwest to the northeast. The monthly variability in the precipitation is great, ranging from an extreme low of 0.01 inch in April to a high of 6.26 inches in August (see table below). No data are available on the annual evaporation, but it is probably low because of the generally low temperatures.

Maximum and minimum monthly precipitation at McGrath, for period 1940–55

[Data from U.S. Weather Bureau, 1955]

Month	Precipitation, in inches		Month	Precipitation, in inches	
	Maximum	Minimum		Maximum	Minimum
January	2. 92	0. 26	August	6. 26	1. 29
February	3. 05	. 07	September	4. 00	. 98
March	2. 12	. 03	October	4. 59	. 33
April	1. 39	. 01	November	2. 02	. 21
May	1. 98	. 34	December	2. 42	. 05
June	4. 36	. 41			
July	4. 75	. 58	Year	6. 26	. 01

From September to April the prevailing wind directions are north and northwest; in summer the prevailing winds are southerly

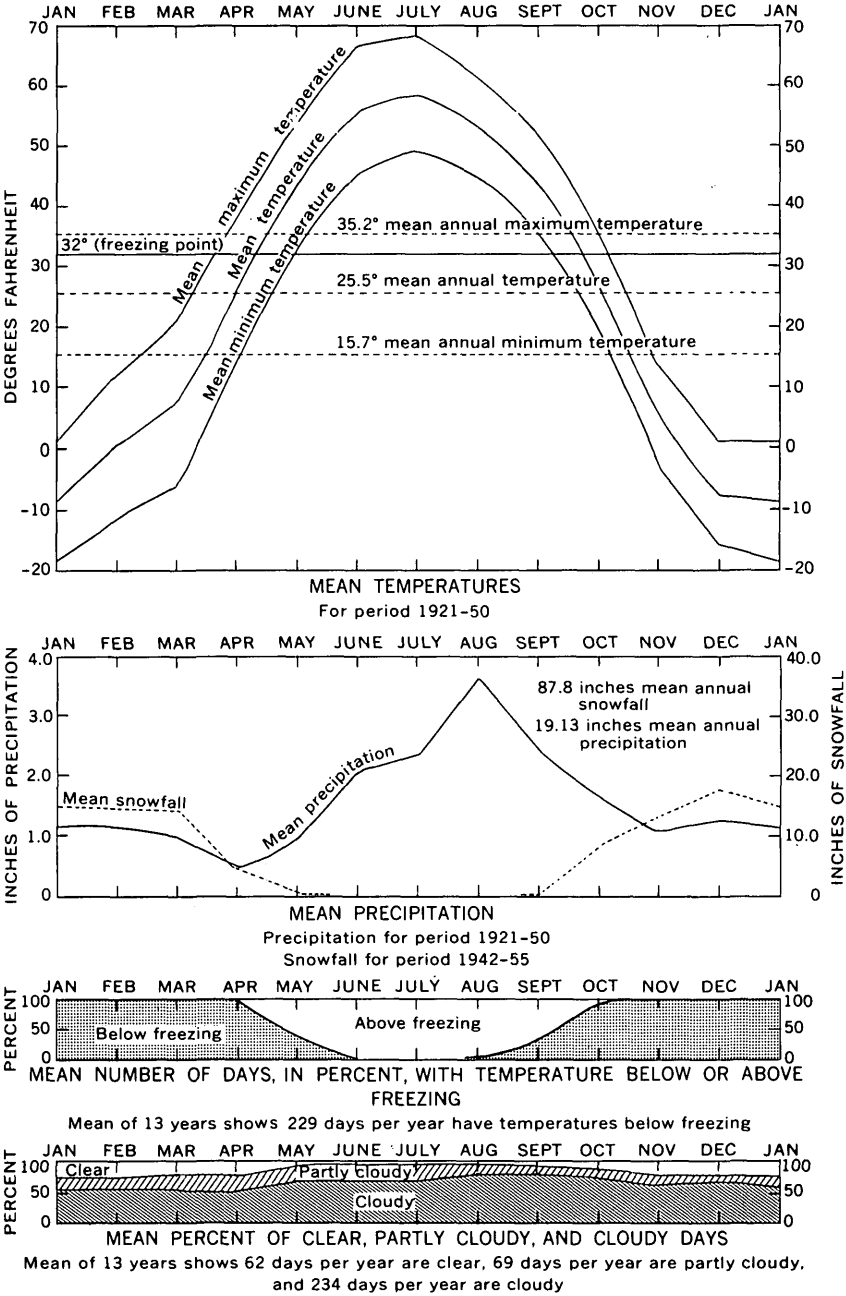

FIGURE 20.—Climatic chart for McGrath, Alaska.

(see table below). The strongest winds are associated with the cyclonic storms and are usually southerly in all months. However, winds from all quadrants can be expected in all seasons. Since the McGrath station is located within a pocket of the uplands, the details of its wind record are only approximately representative for the lowland.

Wind data for McGrath for period 1950–55

[Data from U.S. Weather Bureau, 1955]

Month	Prevailing direction	Maximum wind—		Mean velocity (mph)
		Direction	Velocity (mph)	
January	Northwest	South	37	2.6
February	do	do	75	3.5
March	do	do	44	4.0
April	North	South-southwest.	38	4.9
May	South	South	35	5.3
June	do	East	30	6.0
July	do	South	33	5.3
August	do	do	43	5.2
September	North	South-southeast	50	4.7
October	do	South	43	3.7
November	do	do	30	2.6
December	Northwest	do	48	2.6
Year	Northwest	South	75	4.2

Farewell.—The mean annual temperature at Farewell is 25.7°F; the January mean temperature is 2.0°F and the July mean temperature is 54.9°F. The mean annual precipitation is 16.26 inches.

The climatological data for Farewell reflect its proximity to the Alaska Range in several respects. In the winter warm foehn winds, sometimes of hurricane velocity, roar down the valley of the South Fork and sweep out onto the piedmont area. Consequently, the mean January temperature is about 10° warmer than that of McGrath, even though Farewell is over 1,000 feet higher. In summer, thunderstorms frequently occur within the range and occasionally move over the adjacent areas. A partial rain-shadow effect reduces the mean annual precipitation several inches below that of McGrath.

VEGETATION

The vegetation of the upper Kuskokwim region includes tundra and boreal forest. The tundra is divisible into alpine, or dry, type and brush, or wet, type. The alpine tundra is composed of low, matlike plants and scattered clumps of shrubs and bushes. The wet tundra is composed of sedges, dwarf heaths, and dwarf birches, with a dense carpet of mosses and local areas of lichens. The boreal forest consists of white spruce–deciduous forest, black spruce forest, and mixtures of the two types. The white spruce–deciduous forest consists of white spruce (*Picea glauca*), white birch (*Betula papyrifera*), aspen (*Populus tremuloides*), and poplar (*Populus balsamifera*). The black spruce (*Picea mariana*) forest, which commonly contains some white birch and larch (*Larix laricina*), is characteristically associated with muskeg vegetation. For this report, muskeg is defined as a wet, spongy area with a thick carpet of peat mosses, predominantly *Sphagnum*, and sedge tussocks. Quaking, or floating, bogs are interspersed throughout large areas of the black spruce–muskeg vegetation. A quaking bog is defined as a watery area with a high content of floating vegetation, predominantly peat mosses, sedges, and shrubs, that is usually concentrated into a mat at the surface.

The distribution of the vegetation differs in each of the physiographic units, and it is therefore discussed on the basis of its regional distribution.

The vegetation of the Alaska Range is largely tundra. Brush tundra generally grows at altitudes below 3,000 feet, and alpine tundra grows at altitudes above 3,000 feet. Large areas of the range, especially the higher altitudes and steeper slopes, are bare of vegetation. Forests are limited to the flood plains and to lower slopes of larger valleys. White spruce and poplar are dominant in the forested areas.

In the uplands, vegetation consists of both alpine tundra and boreal forest. Timberline varies considerably in altitude but averages about 2,000 feet; on northward-facing slopes it is usually several hundred feet lower than on southward-facing slopes, and on large mountain masses, such as Takotna Mountain, it may be as much as 1,000 feet lower. Many of the crests of hills and mountains have alpine tundra vegetation, even though some are considerably below 2,000 feet in altitude. White spruce, white birch, and aspen generally grow on the steeper, drier slopes and at the higher altitudes. Black spruce forest is characteristic of the poorly drained areas, such as the more gentle slopes and the creek valley bottoms. Northward-facing slopes, more moist than the sunnier southward-facing slopes, favor the black spruce forest.

Most of the flat or gently sloping surfaces in the lowland support either black spruce forest, black spruce–muskeg vegetation, or bog vegetation. The flood plains of meandering rivers have a sequential distribution of vegetation: white spruce, white birch, and poplar on young deposits, black spruce–muskeg vegetation on older parts of the flood plain, and a combination of black spruce–muskeg and bog vegetation on the oldest parts. The dune fields have a mixed forest. In general, the dune crests have black and white spruce, white birch, and aspen; also a carpet of lichens. The slopes favor black spruce or mixtures of black and white spruce, and many inter-dune areas have black spruce–muskeg vegetation.

The piedmont area, intermediate in altitude between the lowland and the Alaska Range, has vegetative elements of both areas. The higher morainal areas of the Big River area and the Windy Fork area generally have tundra vegetation. Those at lower altitudes are forested, with white spruce–deciduous forest dominant in the South Fork area, and black spruce forest dominant in the Big River area. The outwash slope of the eastern piedmont has wet tundra, which is mixed with black and white spruce on lower parts of the slope. The western outwash area has a forest cover that is dominantly black spruce and black spruce interspersed with muskeg vegetation. White spruce–deciduous forest is dominant on the braided flood plains.

PERMAFROST

Permanently frozen ground, or permafrost (Muller, 1945), is defined here as surficial material or bedrock that has a temperature of 32°F or lower and is not subject to seasonal thawing. It is known to be present in parts of the lowland and the piedmont of the upper Kuskokwim region. Where ice was observed, it was disseminated through the frozen ground and generally was not segregated into wedges or large lenses.

In areas within the lowland where black spruce and Sphagnum moss grow in peat that is a foot or more thick, permafrost lies 1½ to 3 feet beneath the surface (Fernald, 1955, p. 131). Areas so covered are found over large parts of the alluvial surfaces and some parts of the dune fields. Permafrost lies at greater depths or may be entirely lacking in areas where the peat is less than a foot thick. Wells at McGrath on the flood plain of the meandering Kuskokwim River provide subsurface data on frozen ground in the lowland. On the older parts of the meander scrolls 5 wells passed through the bottom of permafrost at depths ranging between 15 and 40 feet, and 6 wells at depths of 40 to 50 feet. Wells on the newer parts of the meander scrolls, including the 262-foot CAA well, are ice free.

Tundra areas on the interfluves of the piedmont are underlain by permafrost at depths of 1 to 3 feet. The 360-foot CAA well in the tundra area at Farewell passed through the zone of permafrost to unfrozen ground below; unfortunately, conflicting data give the bottom of permafrost at both 12 and 125 feet (Fernald, 1955, p. 131).

SETTLEMENTS AND TRANSPORTATION

The largest settlement is McGrath, located on the Kuskokwim River in the western part of the region; it has a population of about 150 (1950). The second largest settlement is the native village of Nikolai, located on the South Fork about 20 miles east-southeast of Medfra; it was reported in 1950 to have a population of about 100. About a dozen people live in Farewell, which is on Sheep Creek near the base of the Alaska Range; a few people live in Sterling Landing and in Medfra, two small settlements on the Kuskokwim River.

McGrath has an airfield operated by the Civil Aeronautics Administration, and regularly scheduled air service is available from Anchorage, Nome, Fairbanks, and Bethel. An airfield at Farewell, also operated by the Civil Aeronautics Administration, is an auxiliary field for flights between Anchorage and McGrath. A small landing field on Candle Hill serves the Candle mine. Medfra also has a small landing field.

There are two roads in the area, both maintained by the Alaska Road Commission. The longer road connects Ophir, which is west of the upper Kuskokwim region, with Sterling Landing, 8 miles south of McGrath. The other road connects Medfra with the Nixon Fork mining district.

Shallow-draft steamboats and diesel-powered boats operate between Bethel, on the lower Kuskokwim River, and McGrath in the summer season and make occasional trips to Medfra. Small inboard and outboard motor boats are used on many of the rivers.

SUMMARY OF BEDROCK AND STRUCTURAL GEOLOGY

Information on the bedrock and structural geology of the region is summarized from the recorded works of previous authors, and includes some additional observations of the writer. The map of bedrock geology (pl. 21) includes data collected in five previous surveys of different parts of the region, the approximate areas of which are outlined in an inset. All of these investigations were of a reconnaissance nature except for the detailed mapping of a small part of the Nixon Fork mining district north of Medfra (Brown, 1926). Some of the interpretations of the age of the rocks have been modified by two compilations of the bedrock of Alaska (Smith, P. S., 1939; Dutro and Payne, 1957). The map of major structural units (fig. 21) comes from the recent compilation of the Mesozoic and Cenozoic history and tectonic elements of Alaska (Payne, 1955).

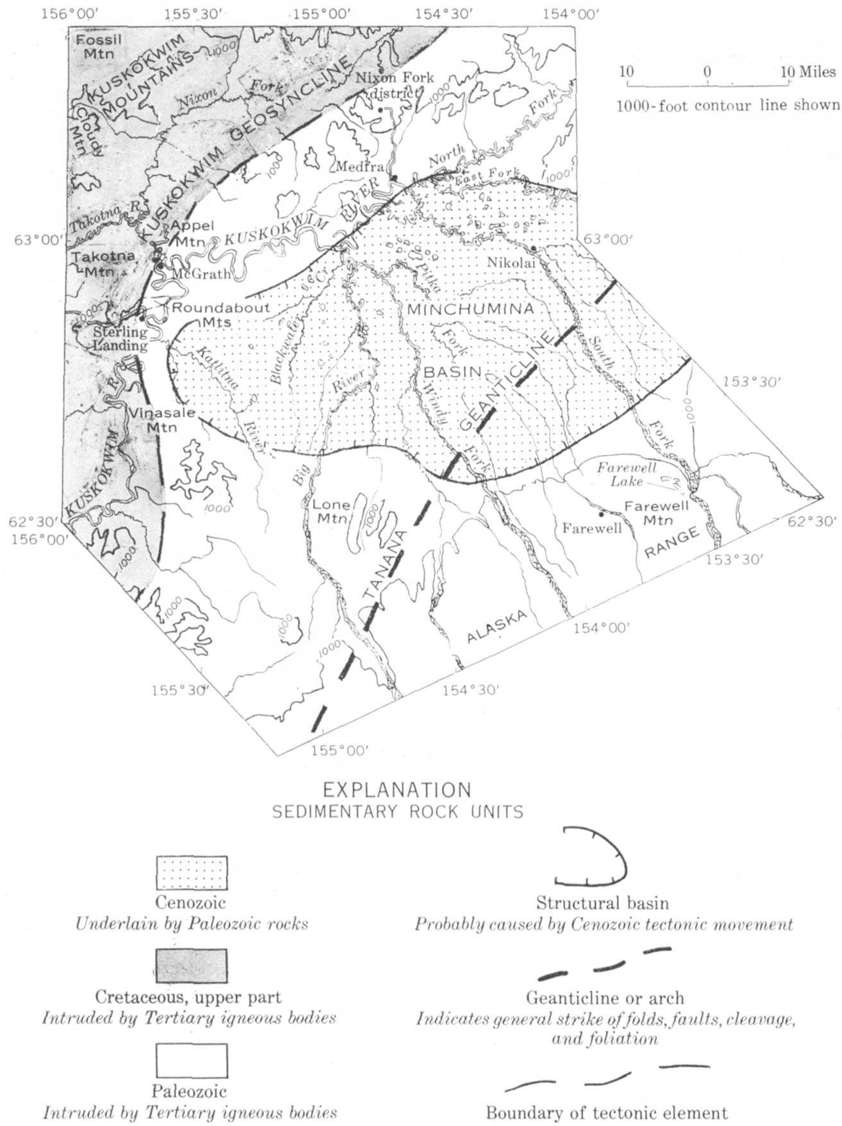

FIGURE 21.—Map of the major structural units of the upper Kuskokwim region, Alaska (after Payne, 1955).

LITHOLOGY

SEDIMENTARY ROCKS

Ordovician rocks.—Predominantly calcareous rocks, named the "Tatina group" (Brooks, 1911, p. 69–73), crop out on the east side of the South Fork valley within the Alaska Range and along the north flank of the range. They have been highly folded, cut by numerous faults, and intruded by diabase and granitic dikes and by granitic stocks. Small collections of fossils made by Brooks date the rocks along the north flank of the range as Ordovician, but because of uncertain correlations the rocks along the South Fork valley are mapped as undifferentiated Paleozoic (Dutro and Payne, 1957).

Ordovician and Silurian rocks.—Limestone is widespread in the Nixon Fork district north of Medfra, an area investigated by Martin (1921) and by Brown (1926). The structure of the limestone rocks is complex, and commonly the beds are sharply folded (Brown, 1926, p. 102–105). A major fault forms the northwest border of these rocks, dividing them from sedimentary rocks of Cretaceous age. Numerous fossils collected by Brown show that the limestone in this area includes beds of both Ordovician and Silurian, and possibly of Devonian, age.

Silurian or Devonian rocks.—To the east of Brooks' "Tatina group," along the South Fork, are rocks which he describes (1911, p. 73–76) as blue-black phyllite interbedded with graywacke and some chert; he gave the name "Tonzona group" to these rocks. They are strongly folded, faulted, and intruded by diabase and granitic bodies. No fossils were found within this series, but because Brooks believed that they overlie the Tatina group of Ordovician age and underlie limestone of Middle Devonian age, he assigned them to the Silurian or the Early Devonian.

Devonian rocks.—Spurr (1900, p. 157–159) mapped the rocks along the Kuskokwim River from near Medfra to the mouth of the Selatna River as the "Tachatna series" (now spelled "Takotna") and defines them as "a series of gray limestones (generally thin bedded and fissile), limy, carbonaceous, and chloritic slates, and occasional generally fine-grained arkoses." The writer, in covering the same area, found that the noncalcareous rocks, which are mostly dark fissile shale and thin beds of dark sandstone, are more widespread than limestone. The rocks are moderately to intensely folded and are intruded by granitic dikes and stocks. Corals collected by Spurr from limestone beds, about 10 miles east of McGrath, indicate a probable Middle Devonian age. Rocks in the area south from Vinasale Mountain, mapped as part of the Tachatna series by Spurr, are included with the Cretaceous rocks, following Dutro and Payne (1957).

Paleozoic rocks undifferentiated.—On the west side of the South Fork, within the Alaska Range, Spurr (1900, p. 156–157) noted a series of limestone, slate, and arkose beds that are highly folded and contain numerous intrusive bodies. He named them the "Terra Cotta series," but Brooks (1911, p. 72) believed this series to include rocks of both his Tatina and Tonzona groups. P. S. Smith (1939, pl. I) mapped these rocks as undifferentiated Paleozoic.

The writer examined the rocks on the west side of Sheep Creek, within the foothills of the Alaska Range. Near Farewell, north of a major fault (described below), several outcrops of blue-gray limestone were observed. South of the fault were outcrops of phyllite and chert. The limestone may be equivalent to Brooks' Tatina group, which he considered to be of Ordovician age, and the phyllite and chert equivalent to his Tonzona group, which he considered to be of Silurian or Devonian age. However, these rocks are included with the Paleozoic rocks, undifferentiated because dating criteria were not found during this reconnaissance survey.

Cretaceous rocks.—Interbedded graywacke and dark shale underlie the uplands along much of the north and west borders of the upper Kuskokwim region (Spurr, 1900, p. 159–161; Mertie and Harrington, 1924, p. 24–41; Brown, 1926, p. 107–110), and, as mentioned previously, part of Spurr's Tachatna series is also included. These rocks, which are part of an extensive belt within the Kuskokwim Mountains and extend for many miles to the southwest of the region, have recently been studied in more detail in the central Kuskokwim region (Cady, and others, 1955, p. 35–47).

The rocks are moderately folded into a series of anticlines and synclines that trend northeastward. Minor faults occur locally, and a major fault separates these rocks from the lower Paleozoic sedimentary rocks in the Nixon Fork mining district. Fossils collected from several localities, both within and without the region, dated these rocks as of Late Cretaceous and Eocene age (Mertie and Harrington, 1924, p. 39–41; Brown, 1926, p. 109–110). However, a reexamination of some of these fossils made Tertiary affinities seem doubtful, and they are now believed to be of Late Cretaceous age only (Cady, and others, 1955, p. 44–47).

Tertiary rocks of nearby areas.—Bedded rocks of Tertiary age have not been found within the region, although a more extensive and detailed bedrock survey might disclose their presence. Tertiary rocks do occur just outside the region, along the north flank of the Alaska Range (Brooks, 1911, p. 96); they also occur farther eastward in the Toklat-Tonzona region (Capps, 1927, p. 95–100) and the Nenana River region (Capps, 1940, p. 118–128). A brief description of the Tertiary rocks, which are divisible into two formations, is included here, since the reconstruction of the Tertiary history of central Alaska is based, to a great degree, on these rocks (Capps, 1940, p. 120–121, 123–128; Wahrhaftig, 1950; 1958).

The older formation consists of poorly to moderately consolidated sand, silt, clay, and some gravel, and scattered seams of coal. On the north flank of the Alaska Range, these coal-bearing sediments extend westward almost to the Kuskokwim region (Brooks, 1911, pl. IX). In general the rocks are tilted, folded, and locally faulted; they have recently been dated as of Eocene age (Wahrhaftig, 1958). The original sediments were deposited by streams in local basins when the area now occupied by the Alaska Range was a region of lower relief (Capps, 1940, p. 120).

The younger Nenana gravel consists of poorly consolidated, coarse, well-rounded gravel and some beds and lenses of sand. On the north flank of the Alaska Range this gravel has been mapped as far west as Clearwater Creek in the Toklat-Tonzona region, and it probably extends farther southwest (Capps, 1927, p. 99). The Nenana gravel, which generally lies unconformably on the coal-bearing sediments (Wahrhaftig, 1951, p. 182–183), is tilted, folded, and locally faulted. This coarse stream-deposited gravel, which reflects a pronounced uplift of the Alaska Range (Capps, 1940, p. 123–124), is tentatively assigned an Oligocene or Miocene age (Wahrhaftig, 1958).

INTRUSIVE IGNEOUS ROCKS

Stocks of both mafic and felsic composition are present in the Kuskokwim Mountains, where they generally underlie the higher mountains (Mertie and Harrington, 1924, p. 66–71; Brown, 1926, p. 115–118). The mafic stocks are composed of pyroxene diorite, gabbro, diabase, and pyroxenite; they are found on Candle Hill, Takotna Mountain, Cloudy Mountain, and the mountains east of Fossil Mountain. The felsic stocks are composed of quartz monzonite; they are found in the Nixon Fork mining district and on Candle Hill and Takotna Mountain. On Candle Hill the quartz monzonite is partly bordered by mafic rocks, and on Takotna Mountain it is completely surrounded by mafic rocks. The association of the two types of rocks suggests a close genetic relation, and the quartz monzonite is considered the younger in age (Mertie and Harrington, 1924, p. 69). All five igneous intusive bodies cut Upper Cretaceous sedimentary rocks. Because these sedimentary rocks were thought to be, in part, of Eocene age, the igneous rocks were dated as Eocene or post-Eocene (Mertie and Harrington, 1924, p. 69, 71; Brown, 1926, p. 120). Recent detailed studies of apparently similar stocks in the central Kuskokwim region suggest an Oligocene or Miocene age (Cady, and others, 1955, p. 83).

MAJOR STRUCTURAL UNITS

Parts of three major structural units recognized in Alaska (Payne, 1955) are included in the upper Kuskokwim region: the Kuskokwim geosyncline, the Tanana geanticline, and the Minchumina basin (fig. 21). All three structures trend northeastward in this part of Alaska, as does the Alaska Range geosyncline, which is just to the southeast of the upper Kuskokwim region. A brief description of each unit is given in the following paragraphs, all derived from Payne (1955) with the exception of the data on the McGrath well.

The Kuskokwim geosyncline, which follows the general trend of the Kuskokwim Mountains, crosses the northwestern and western parts of the region and exposes Cretaceous rocks. This geosyncline, like the Alaska Range geosyncline, existed from the Late Triassic through the Cretaceous and received both marine and nonmarine sediments in addition to some lava and tuff. These rocks were uplifted and folded, probably in early Eocene time, and eroded to a surface of low relief during the Eocene.

The Tanana geanticline underlies most of the upper Kuskokwim region and exposes rocks of Paleozoic age in the Kuskokwim Mountains and the Alaska Range. It was probably formed during the Jurassic period and, from that time through the Cretaceous, was repeatedly uplifted and eroded. The geanticline was a source of sediment for the Kuskokwim geosyncline to the northwest and the Alaska Range geosyncline to the southeast. It was probably eroded to a surface of low relief during the Eocene and remained topographically low during much of the Tertiary.

Much of the upper Kuskokwim River lowland is a structural basin that formed by subsidence of part of the Tanana geanticline. This basin, termed the Minchumina basin, extends northeast outside the region to the vicinity of Lake Minchumina. It probably subsided during the Quaternary, as did the middle Tanana basin to the northeast where Quaternary deposits below sea level have been reported in wells.

No data are available on the depth of fill within the Minchumina basin; the nearest deep well is at McGrath, located within a pocket of the uplands between the basin and the Nixon Fork lowland. At that point the unconsolidated deposits, presumably Quaternary in age, are 230 feet thick and consist of sand, silt, organic material, and some gravel. McGrath has an altitude of 334 feet above sea level, and the base of the fill is therefore about 100 feet above sea level. In all probability the thickness of the fill within the Minchumina basin is considerable and its base is below sea level.

FAULTS

There are two major faults within the region: one along the north flank of the Alaska Range and the other within the Kuskokwim Mountains along the Nixon Fork (pl. 21). Where shown on the map of surficial geology (pl. 22), these faults form prominent scarps that are readily recognizable from the air and on aerial photographs (fig. 22). In many places they cut recent surficial deposits—an indication that they have been active in very recent time and probably are still active. Both faults are probably continuous with major faults recognized in the central Kuskokwim region: the first has been named the Farewell fault and the second, the Nixon Fork fault (Cady, and others, 1955, pl. 2).

Farewell fault.—Within the upper Kuskokwim region the Farewell fault forms a prominent scarp that extends from near the South Fork for about 40 miles to near the Big River (pl. 22). The trace of the fault, which crosses rugged mountain slopes and several deep valleys, is remarkably straight, and the dip of the fault plane is probably almost vertical. The fault cuts bedrock and colluvial material, old and young glacial moraines, and recent alluvial cones; only the active braided flood plains show no trace of it (fig. 22). Where observed by the writer near Farewell, the fault forms a steep 8-foot scarp across recent alluvial cone material that fronts the Alaska Range. As mentioned in the lithology section, limestone crops out north of the fault, and phyllite and chert crop out south of the fault. Sufficient data are not available to determine the stratigraphic displacement along the fault.

The fault is probably continuous with the Boss Creek fault of the central Kuskokwim region (Cady, and others, 1955, p. 92), but its location across the uplands west of the Big River is problematic. It may curve toward the southwest, outside the upper Kuskokwim region, and connect with a recognizable fault within the uplands (Cady, and others, 1955, pl. 2), but it is believed more likely that it continues in a nearly straight line and connects with a probable fault along the north flank of the uplands (pl. 21).

Toward the northeast, the Farewell fault is probably continuous with a fault noted by Brooks (1911, p. 70), between the South Fork and Jones River, that separates his Tatina group on the north from his Tonzona group on the south. Farther eastward, it probably extends to the Dillinger River and connects with a major fault that follows the north flank of the Alaska Range for many miles (Dutro and Payne, 1957).

Nixon Fork fault.—The Nixon Fork fault forms a prominent scarp that extends for a distance of about 10 miles from the edge of the Nixon Fork lowland northeastward to the north border of the region (pl. 22), and is recognizable for an additional 8 miles outside the north border. The fault plane is a steep northwestward-facing escarpment; the southeast block is many hundreds of feet higher than the northwest block. Upper Cretaceous rocks occur on the northwest, or lower, block and lower Paleozoic rocks on the


ALASKA RANGE
ALASKA RANGE
Windy Fork
Qab
Qab
Qab
Qof
Qaf
Qac
Qac
Qac
Qdf_2
Qdf_2
Qdf_2
Qdf_2
Qdf_2
a
b
0
1 Mile
SSE

FIGURE 22.—Oblique aerial view of the north edge of the Alaska Range and the bordering piedmont in the Windy Fork area.

The Farewell fault, indicated by a number of short arrows (*a*), extends across the front of the Alaska Range. The flood plain (*Qab*) of the Windy Fork and a small alluvial fan (*Qaf*) of a tributary stream are cut into drift (Qdf_2) of the late phase of the Farewell glaciation (Farewell 2). On the right side of the picture is another flood plain (*Qab*), of an unnamed stream, cut into outwash (*Qof*) of the Farewell glaciation. A number of large cones (*Qac*) blanket the base of the range and extend onto the piedmont. Two isolated bedrock hills (*b*) project above the surficial deposits of the piedmont. Photograph by U.S. Army Air Force, 1942.

southeast block. The trace of the fault is fairly straight although somewhat sinuous in places, as observed by Brown (1926, p. 123) and as seen on aerial photographs. A steeply dipping fault, with the upthrown side on the southeast, is strongly suggested.

Toward the southwest the Nixon Fork fault probably crosses the alluvial fill of the Nixon Fork lowland, follows the nearly straight course of the lower Takotna River, and continues for many miles to the southwest. The remarkable alinement of the Nixon Fork valley, the lower Takotna River valley, and several other valleys in the Kuskokwim Mountains led Mertie and Harrington (1924, p. 76–77) to suggest this fault zone. It has also been recognized in the central Kuskokwim region, where it is termed the "Iditarod fault"; this extensive fault zone is believed to be a great scissors fault (Cady, and others, 1955, p. 90–91).

PHYSIOGRAPHY OF THE UPLANDS

The uplands include all highlands outside the Alaska Range (fig. 19), and for the most part consist of rounded mountains and open creek valleys. The crests of the mountains generally range between 1,000 and 2,000 feet in altitude and form a widespread upland surface (fig. 23). A number of isolated mountains project well above the general level of the upland surface. A broad canyon has been cut through the uplands by the Kuskokwim River.

The uplands were not extensively glaciated, as was the Alaska Range. They have been molded principally by stream action and intense frost action. These processes have varied in their effectiveness during the climatic changes of the Quaternary. A variety of surficial deposits covers most of the uplands.

SURFICIAL DEPOSITS

Except for scattered bedrock outcrops, the surface of the uplands is everywhere mantled with unconsolidated deposits. On the isolated mountain peaks and the higher ridges of the rounded mountains this mantle is composed almost entirely of rubble and is here termed "rubbly colluvium." Lower ridges and valley slopes are mantled with a variety of colluvial material, termed "mixed colluvium," and locally with loess. Deposits of various types have accumulated in the creek valleys and are mapped collectively as "creek valley fill." Such accumulations are common in many of the creek valleys in Alaska (Taber, 1943, p. 1467–1473).

Rubbly colluvium.—Rubbly colluvium mantles an estimated 90 percent of the surface of the high mountain peaks and the rounded summits above an altitude of 2,000 feet; a similar percentage of the surface in the Alaska Range is also mantled with rubble. All these areas are above timberline. The bedrock exposures, which occur very irregularly, generally on precipitous slopes and at crests of peaks and ridges, are not mappable at the given scale and are therefore included with the surficial unit (pl. 22). The lower boundary of the rubbly colluvium within the uplands corresponds rather closely with the 2,000-foot contour line. Here, the colluvium merges into the mixed colluvial material that is characteristic of the lower altitudes.

The rubble is angular and ranges in size from small pebbles to large blocks many feet in diameter. It generally occurs as talus or as a relatively thin mantle over the bedrock. Some of the mountain peaks are almost completely covered with talus. The rubble mantle over the bedrock is characterized by innumerable frost-produced features: some steep slopes are completely covered with stone streams and sorted stone stripes; other, more gentle slopes are covered with a series of lobate terraces.

The rubble is produced by intense frost riving, or "congelifraction" (Bryan, 1946, p. 640), of the bedrock. On the steeper slopes the rubble is moved rapidly downslope by falling, sliding, and avalanching over snow surfaces. On the more gentle slopes, it is moved principally by "congeliturbation" (Bryan, 1946, p. 640), in response to alternate freezing and thawing of the ground.

Mixed colluvium and loess.—The summits and valley slopes below an altitude of about 2,000 feet are almost completely mantled with unconsolidated deposits. This mantle generally consists of a variety of colluvial material, with admixtures of loess at lower altitudes. However, large areas of the uplands that border the Kuskokwim River are completely blanketed with loess. The colluvium and the loess are mapped together (pl. 22) because they cannot be differentiated without detailed subsurface investigations. The contact with the rubbly colluvium of the higher altitudes is gradational, but generally there is a distinct break in slope where the colluvial and loessal deposits merge into the fill of the creek valleys and the alluvium of the broad valleys. The mixed colluvium and loess are fronted by terrace escarpments at a number of places where meandering rivers have swung against the uplands.

The colluvium is composed of a mixture of rubble, sand, silt, and organic material, the proportions of which vary locally and regionally. Much of the organic content is peat, which is characteristic of the areas of black spruce–muskeg vegetation. Exposures that contain a high proportion of organic debris and loess occur in 4 bluffs on the north side of the Kuskokwim River, where meanders abut the uplands. These bluffs are located 7 miles south of McGrath (near Sterling Landing), 3 miles east-northeast of McGrath, 5 miles southwest of Medfra, and 3 miles southwest of Medfra. The tops


SSW
Qam
River
Takotna
Takotna Mt
Qam
0
1 Mile

FIGURE 23.—Oblique aerial view of the Takotna River valley and the bordering uplands.

The flood plain of the meandering Takotna River (*Qam*) floors the broad canyon cut through the uplands along the Nixon Fork fault. On the left side of the river, Takotna Mountain rises about 3,500 feet above sea level. It has a core of mafic and felsic igneous rocks of Tertiary age and is mantled with rubble. To the right of the river are rounded mountains and creek valleys underlain by folded sedimentary rocks—graywacke and shale—of Cretaceous age. The summits form a prominent upland surface that has been intensely dissected by streams. Photograph by U.S. Army Air Force, 1942.

of the bluffs are irregular and locally notched by recent stream cuts. All contain a jumble of rubble, sand, silt, and organic debris. These deposits have been built up by the downslope movement of mixed colluvial material, which includes much organic debris and loess, by vegetation growing in place, and by direct deposition of loess and eolian sand.

The inorganic content of the colluvium has been derived by the comminution and weathering of bedrock. The loess has been derived from outside the uplands (discussed under "Eolian activity and deposits"). The mixed colluvium and loess are, in many places, undergoing downslope movement. In the reentrant valleys on the lower slopes, streams are the important agent. In the interfluves, movement is by slope wash and congeliturbation. On upper slopes and crests, movement is solely by congeliturbation, as evidenced by involutions within the deposits, by tilted trees, and by lobate terraces. This process is extremely variable in its effectiveness: in moist areas and in areas of alpine tundra, it is highly effective; in areas of open forest it is less effective, and heavily forested slopes, generally found at lower altitudes, seem to be stable.

Creek valley fill.—Unconsolidated deposits have accumulated in the larger creek valleys of the uplands. The boundary between the fill at the valley bottom and the mixed colluvium and loess of the valley walls is mapped at the generally distinct break in slope. Toward the head of the creek valleys the boundary is arbitrarily mapped at the point where the valley begins to narrow and the gradient increases rather sharply.

The creek valley fill is made up of several types of material—boulders, gravel, rubble, sand, silt, and organic material. The amount and proportion of the several types vary from valley to valley. Along Candle Creek, northeast of Candle Hill in the McGrath area, the fill ranges from 9 to 35 feet in thickness and consists of stream gravel with some large boulders as much as 4 feet in diameter (Mertie, 1936, p. 197–198). The overburden along Hidden Creek, in the Nixon Fork mining district, ranges from 12 to 200 feet in thickness, and in one cut consists of 45 feet of angular gravel overlain by "a great thickness of sticky mud" (Mertie, 1936, p. 194). At Birch Gulch, a tributary of Hidden Creek, the fill consists of "3 feet of angular wash overlain by 8 feet of muck" (Mertie, 1936, p. 195).

The stratigraphic sequence of the fill in all the creek valleys is generally similar. On the bedrock surface is gravel or rubble that contains some large boulders and may contain placer gold. This coarse material is generally overlain by a mixture of silty, sandy, and organic material that locally contains some rubble and is generally referred to as "muck." The muck is topped by a peaty layer in many of the creek valleys of the region.

The materials of the creek valley fill, except for the loess, were generally derived from local sources. The coarse materials at the base of the fill are the result of active erosion of the local bedrock, and the rounded gravel in some of the valleys indicates much reworking by streams. Most of the overlying fine-grained fill was supplied from the mixed colluvium and loess of the valley walls by streams and, in the interfluves, by congeliturbation and slope wash. Part of the organic material, however, was derived from vegetation growing on the valley bottoms, and some of the loess was deposited directly.

PHYSIOGRAPHIC FEATURES

Mountain peaks.—The high mountains that project well above the general level of the rounded mountains are scattered throughout the uplands. In their altitude above sea level, the high mountains range between 2,800 feet (Fossil Mountain, in the extreme northwest corner of the region) and 4,400 feet (Cloudy Mountain, along the west border of the region). Some of the mountains have originated through faulting. The mountains northeast of the Nixon Fork mining district are on the upthrown side of the Nixon Fork fault (pl. 21). Similarly, the group of mountains west of the Big River, in the southwestern part of the region, are on the upthrown side of the Farewell fault. Other mountains are underlain by intrusive rocks that, together with related metamorphic zones in adjacent sedimentary rocks, are more resistant to erosion. These include Takotna Mountain, Cloudy Mountain, and an unnamed mountain 10 miles east of Fossil Mountain.

Two of the mountains have been glaciated and contain cirques and U-shaped valleys; they are Cloudy Mountain (Mertie and Harrington, 1924, p. 42–44 and pl. VI) and the mountain group west of the Big River. Glaciers also carved U-shaped valleys within the rounded mountains between the Selatna and Tatlawiksuk Rivers. All other mountains show no glacial features and were apparently unglaciated. In general, north of the Kuskokwim River only mountains that are 4,000 feet or higher were glaciated (Brown, 1926, p. 111); near the Alaska Range the limiting height is about 2,000 feet.

The unglaciated mountains have been molded principally by intense frost action. In the rigorous climate of these high altitudes, exposed bedrock is quickly shattered into a mass of rubble. Late-melting snowfields are centers of particularly intense frost action (nivation). Locally, streams are an important agent of erosion and have cut deep reentrant valleys into the mountain slopes. During the more rigorous glacial climates of the Quaternary, frost action was undoubtedly even more intense and the formation of rubble accelerated. Snowfields were probably more extensive, and melt-water streams more effective in valley cutting during these periods.

Upland surface.—The summits of the rounded mountains, generally ranging between 1,000 and 2,000 feet in altitude, form a prominent upland surface. This upland surface is best and most uniformly formed in areas underlain by sedimentary rocks of Cretaceous age that extend along the northwest border of the region (pl. 21); it is rather poorly formed and discontinuous in the areas of Paleozoic rocks that extend from McGrath northeast to beyond the Nixon Fork mining district. The youngest rocks cut by this surface are intrusive rocks, believed to be of Oligocene or Miocene age, on Candle Hill and in the Nixon Fork mining district.

This surface extends for many miles outside the region, both to the northeast and to the southwest. In the central Kuskokwim region it has been termed the "Sleetmute upland surface" by Cady and others (1955, p. 96–97). Their studies indicate that the surface represents a widespread erosion surface that probably formed in the Pliocene. Much of the surface was then uplifted, probably during the late Pliocene–early Quaternary orogeny, and dissected. Some undissected parts of the surface still exist there.

In the upper Kuskokwim region the surface has been intensely dissected and only rounded summits remain. These summits have been molded principally by frost action. The higher, rubbly summits, generally above an altitude of about 2,000 feet, are now in the zone of intense frost action. Lower, forested summits are subject to less rigorous frost action. During the glacial climates of the Quaternary, the zone of intense frost action undoubtedly extended into areas that are now forested and therefore subject to less frost action. It was during these periods that the summit levels may have been reduced in altitude.

Creek valleys.—Creek valleys occur everywhere within the uplands of the upper Kuskokwim region and indicate an intense erosion of the upland surface. The local relief between mountain crests and valley bottoms is highly variable, generally ranging between 100 and 1,000 feet. The slopes are, for the most part, gentle to moderate, with convex mountain summits and concave valley walls. Comparable valleys, termed "Boss valleys," occur in the central Kuskokwim region (Cady, and others, 1955, p. 97–100).

The creek valleys have been formed principally by stream erosion, as evidenced by their dendritic pattern and by their cross profiles (fig. 23). Solution has also been a factor in erosion of valleys in the limestone areas of the Nixon Fork district (Mertie, 1936, p. 194). Only the U-shaped valleys in the uplands between the Selatna and Tatlawiksuk Rivers show evidence of glacial erosion. Here, glaciers probably scoured valleys previously cut by streams.

The valleys were initially dissected by rejuvenated streams after uplift, probably during the late Pliocene or early Quaternary. Subsequently, the formation of the valleys was affected by the climatic changes of the Quaternary. During the glacial climates in general, the zone of intense frost action was lowered and large areas of the uplands encompassed. Much of the coarse rubble and gravel of the valley fill was very probably deposited during these periods. Locally, as in the uplands between the Selatna and Tatlawiksuk Rivers, the valleys were scoured by glaciers.

Headward sections of the valleys are still undergoing erosion, but erosion of valley bottoms in their middle and lower sections ceased as bedrock became covered with creek valley fill. The fine-grained muck that overlies the coarse basal material indicates a marked change in nature and size of material supplied. Present streams in the creek valleys are generally sluggish and clogged with vegetation, whereas past streams, in those valleys where the basal material contains well-worn gravel, were vigorous. The cause and effect relations of this filling cannot be evaluated with any degree of certainty, as each region, and probably each creek, has its own history. The fundamental causes involve both climatic and tectonic factors, and also relate to the general alluviation that has taken place throughout the upper Kuskokwim River lowland.

Kuskokwim River canyon.—The upland surface has also been dissected by the Kuskokwim River, which flows through the uplands in a broad canyon that averages 2 miles in width at the base. This river, after skirting the north and west edges of the lowland, enters the uplands in the southwestern part of the region. From the point of entrance it flows in a nearly straight course to the southwest, then, a short distance outside the region, turns and flows in a nearly straight course in a more southerly direction to the Stony River lowland. Where it enters the uplands the altitude of the river is less than 350 feet above sea level; the summits of the bordering uplands generally range between 1,000 and 1,500 feet. Bedrock cliffs, kept steep by frequent swinging of the meanders against them, form the walls of the canyon.

Field data bearing on the origin of the canyon are scarce, and the structure of the rocks in the bordering uplands has not been directly observed. However, in nearby areas the remarkable straightness of a number of rivers and their northeastward alinement with the structural trend have been noted; among these rivers are the Nixon Fork, the Takotna River, and the Tatalina River (Mertie and Harrington, 1924, p. 7, 76). It can be inferred with a fair degree of certainty that the course of the Kuskokwim River also follows the structural trend. Based on this inference, it is believed that the river once flowed on the upland surface in approximately its present position and has maintained its course following uplift, probably during the late Pliocene or early Quaternary. Thus the Kuskokwim River, in this section of its course, as in the central Kuskokwim region (Cady and others, 1955, p. 98–100), is interpreted as an antecedent stream.

An alternate interpretation of the canyon as due to superposition of the Kuskokwim River from a Tertiary or Quaternary cover seems improbable if the inference that the river is alined with the structure is accepted. The canyon may also be postulated as an overflow channel from a lake that was ponded in the upper Kuskokwim River lowland before the canyon was cut. A minimum lake level of about 1,000 feet above sea level would be required before overflow could occur at this point. Because lower outlets are present, one northeast to the Tanana lowland and the other southwest to the Stony River lowland along the Tatlawiksuk River, the ponding could not be due to defeat of an ancestral drainage system by uplift. Ponding might be due to blocking by glaciers simultaneously in the two outlet areas, but this seems unlikely. Finally, the absence of widespread lacustrine deposits within the upper Kuskokwim River lowland makes this postulate tenuous.

GLACIATION OF THE ALASKA RANGE

Two major glaciations of the Alaska Range are recognized in the upper Kuskokwim region: the younger one is the Farewell glaciation, and the older, more extensive one is the Selatna glaciation (Fernald, 1953, p. 6–7). The glaciers scoured large U-shaped valleys within the Alaska Range and extended onto the bordering piedmont. The rest of the region, with the exception of local areas within the uplands, shows no evidence of glaciation.

Ground observations were made in glaciated areas along the Big River and along the South Fork at the base of the Alaska Range. Other areas were interpreted from aerial photographs and from observations made during plane flights at low altitudes. The glaciated terrain along the South Fork was first noted by Spurr (1900, p. 252–253) and later by Brooks (1911, p. 108, 126). The occurrence of earlier, still more extensive glaciations in other parts of the Alaska Range strongly suggests the probability of pre-Selatna glaciations in this region.

NATURE AND SOURCE OF THE GLACIERS

Glaciers originated within the Alaska Range and scoured large U-shaped valleys, which formed complex tributary pattern of valley glaciers. The three principal valleys down which the ice advanced are those of the Big River, the Windy Fork, and the South Fork.

In the Big River area glaciers emerged from the westward-facing edge of the Alaska Range and formed a coalescing glacier in the broad trench of the river, south of the upper Kuskokwim region. During the older glaciation a glacial prong extended northward and formed a large lobe in the piedmont area. The younger glacier reached just to the edge of the mountainous area. Its morainal deposits are bordered by those of the older glacier and are at a much lower altitude. Along the South and Windy Forks, both the old and the young glaciers spread out onto the bordering piedmont.

The principal source area for the glaciers of the Big River and the Windy Fork was the higher part of the Alaska Range, south of the upper Kuskokwim region, where altitudes approach 10,000 feet above sea level; this area was also a partial source for the ice of the South Fork valley. Thus, the ice in the three valleys had, in part, a common source area. This higher part of the Alaska Range still contains many small glaciers.

DEPOSITS OF THE SELATNA GLACIATION

Big River area.—The older, or Selatna, glaciation is represented by a large morainal lobe on the piedmont in the Big River area. This lobe is completely bordered by an end moraine that is continuous with two lateral moraines within the mountainous area. The name of the glaciation is derived from the Selatna River, a tributary of which heads in this end moraine.

The large morainal lobe extends about 18 miles beyond the mountains. The bordering end moraine is from 2 to 3 miles wide and is characterized by greatly subdued knob-and-kettle topography. The inner area of the lobe has a fairly smooth surface, locally dissected by streams that rise in the end moraine. The Big River flows through this morainal lobe in a steep-walled valley that is 75 to 150 feet deep. Thick deposits of gray till and some limonite-stained yellow gravel are exposed in cuts within the lobe. Gray till interbedded with yellow gravel is exposed in the end moraine (fig. 24). A measured section through this end moraine is given below.

Measured section of bluff through end moraine of the Selatna glaciation along the Big River, 6 miles southwest of Lone Mountain

	Feet
Peat, with admixtures of loess	2
Loess, yellowish-gray	10
Peat, compact, with admixtures of loess	15
Till and outwash, interbedded. Till is gray and consists of many pebbles and cobbles and a few boulders in silty matrix; outwash is coarse yellow gravel	70
Base at river's edge.	

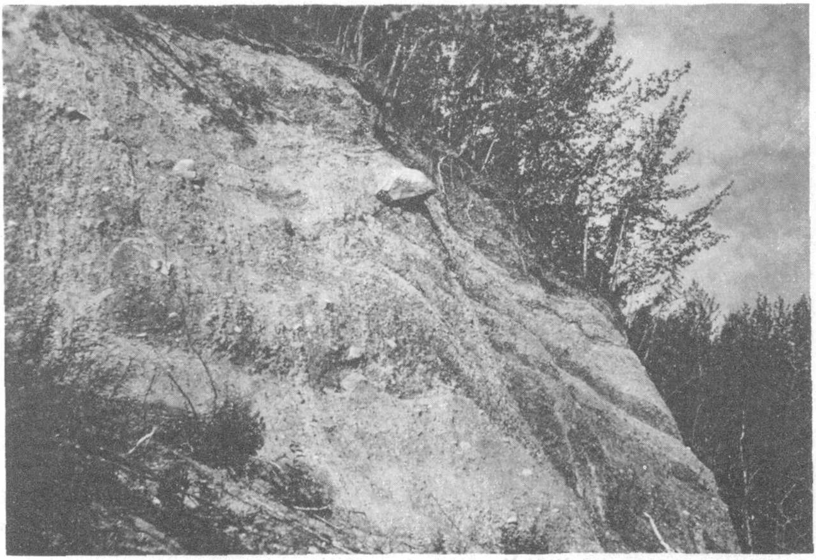

FIGURE 24.—Exposure through the end moraine of the Selatna glaciation along the Big River. Till (light-gray bands) is interbedded with outwash gravel (dark-gray bands), reflecting minor advances and retreats of the ice margin. Large boulder shown in picture has diameter of about 4 feet. This exposure is 6 miles southwest of Lone Mountain.

The lateral moraine on the east side of the Big River can be traced 5 miles south of the region, and that on the west side for at least 20 miles. These moraines are 2 to 3 miles wide and are made up of a series of long smooth ridges (fig. 25). In places the ridge crests are over 1,000 feet above the flood plain of the Big River. Large erratic boulders are scattered over the surface of these moraines.

A gently rolling outwash surface leads away from the end moraine of the Selatna glaciation and extends to the uplands bordering the piedmont. Along a part of its north border the outwash surface merges into a dune-covered surface. Several low, smooth hills, believed to be underlain by bedrock, project above the outwash surface. The Big River flows across it in a valley that is narrow and steep-walled near the end moraine but broadens a short distance beyond. Cuts in the steep-walled part of the valley expose gravel and sand.

South Fork and Windy Fork areas.—Along the South Fork the Selatna glaciation is represented by scattered remnants of a long, arcuate moraine that extend from the Alaska Range for a maximum distance of 25 miles. The morainal topography is greatly subdued (fig. 26).

Along the Windy Fork there is an area of greatly subdued morainal topography on the piedmont 10 to 12 miles north of the

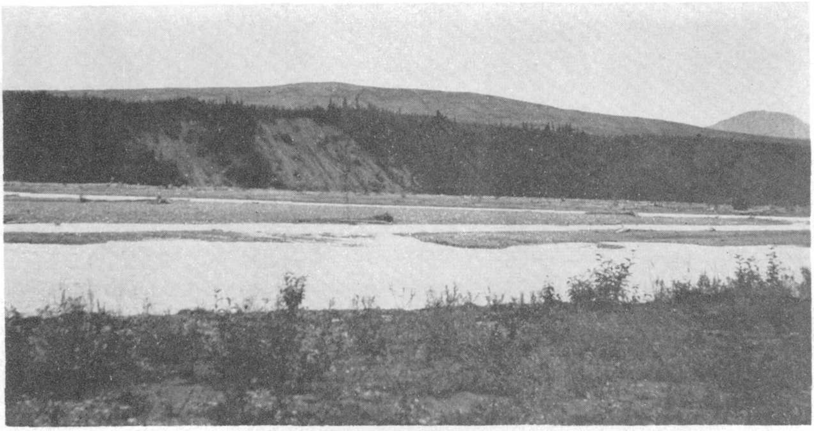

FIGURE 25.—Moraines of the Selatna and Farewell glaciations along the Big River. The end moraine of the Farewell glaciation forms the high escarpment on the far side of the Big River flood plain. The escarpment averages about 100 feet in height. The long smooth ridge beyond, and rising above, the end moraine is one of the lateral moraines of the Selatna glaciation. These moraines are 4 miles north of the south border of the upper Kuskokwim region.

Alaska Range. This area covers about 4 square miles and cannot be traced to the mountain front.

DEPOSITS OF THE FAREWELL GLACIATION

South Fork and Windy Fork areas.—In the South Fork and Windy Fork areas, the younger, or Farewell, glaciation is represented by large morainal lobes on the piedmont. In both areas these lobes are divisible into an inner and an outer part; also, the rivers have dissected the morainal lobes and flow through them in steep-walled valleys. The glaciation is named after the settlement of Farewell, located on Sheep Creek just outside the moraines of the South Fork.

In the South Fork area the outer part of the morainal lobe extends a maximum distance of 20 miles from the Alaska Range. It forms a partial loop around the inner part, curving back to the mountain front on its west side and to the inner lobate area on its east side. This loop is made up of a number of sectors, generally ranging between ½ and 2 miles in width, and has a slightly subdued knob-and-kettle topography (figs. 26 and 27).

The inner part of the morainal lobe extends a maximum distance of 15 miles from the Alaska Range. It forms a large oval with an extension on the east side where ice from the valleys of the Dillinger and Jones Rivers joined ice from the South Fork valley. This oval-shaped area is characterized by fresh morainal topography (fig. 27). Its east side has a number of discontinuous mo-

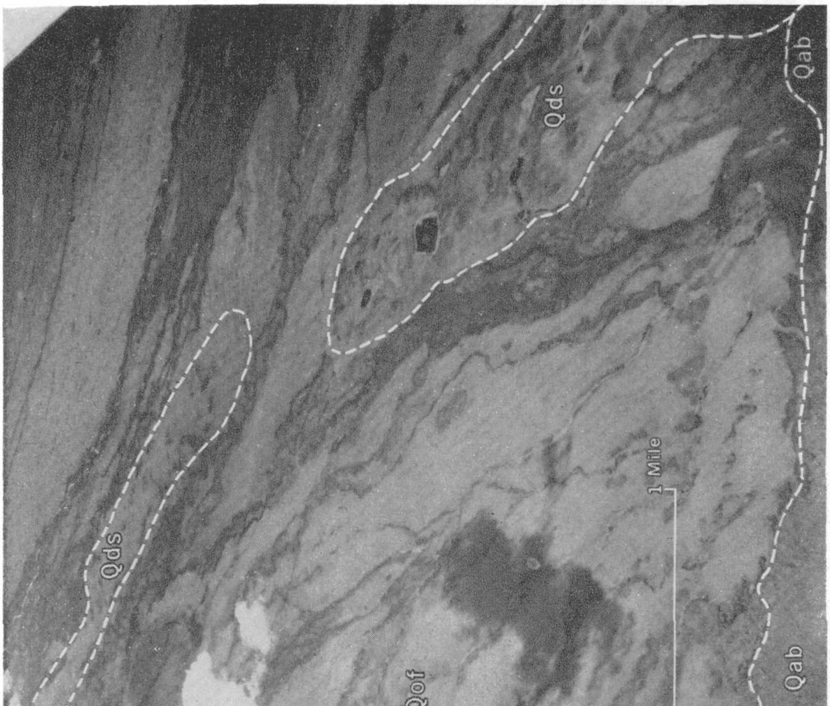
Qds
Qds
Qab
Qab
Qof
Qdf1
SSW
0
1 Mile

FIGURE 26.—Oblique aerial view of the moraines of the Farewell and Selatna glaciations along the South Fork.

The topographic expression of the slightly subdued outer moraine (Qdf_1) of the early phase of the Farewell glaciation (Farewell 1), on the left side of the picture, contrasts sharply with that of the greatly subdued moraine (*Qds*) of the Selatna glaciation, on the right side of the picture. Between the two morainal systems and also enveloping the older moraine is the widespread outwash slope (*Qof*) of the Farewell glaciation. It is smooth and fairly steep at the immediate front of the younger moraine and appears on the photograph as a light-gray strip. Small streams flow on the outwash slope. The braided flood plain (*Qab*) of the South Fork, which is cut into the moraines and the outwash slope, is along the lower edge of the picture. Photograph by U.S. Army Air Force, 1941.

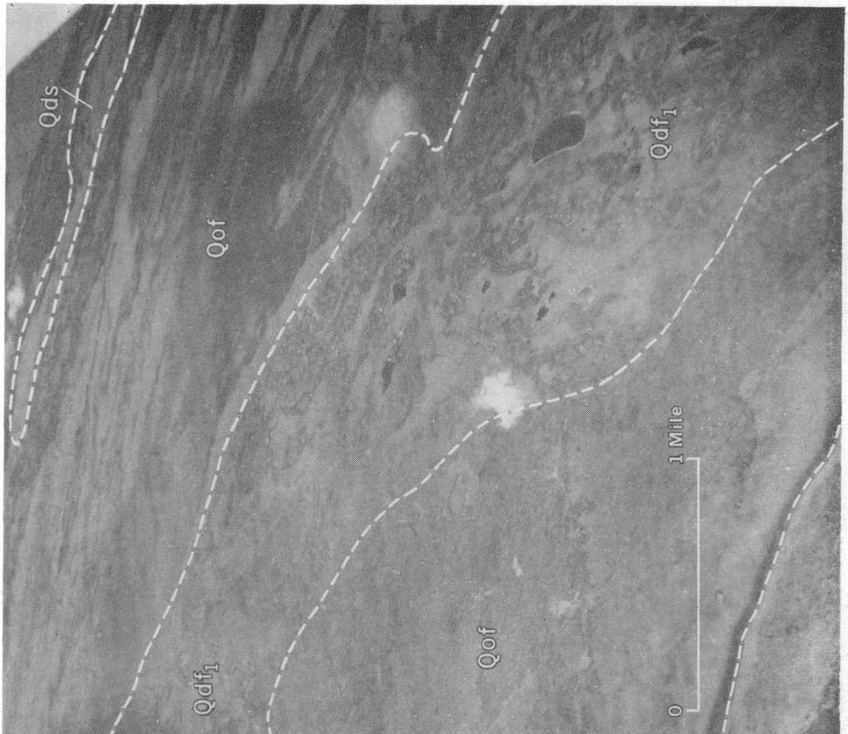
Qds
Qof
Qdf$_1$
Qdf$_1$
Qof
1 Mile
0
Qof
Qdf$_1$
Qdf$_2$
SSW
Qab
Qab
South Fork

FIGURE 27.—Oblique aerial view of the outer and inner moraines of the Farewell glaciation along the South Fork.

The fresh inner moraine (Qdf_2) of the Farewell glaciation (Farewell 2) is at the left of the picture, and the slightly subdued outer moraine (Qdf_1) of the same glaciation (Farewell 1) in the middle and right foreground. Outwash (*Qof*) of this glaciation leads away from these moraines and forms a smooth, fairly steep slope at their immediate front and a gentle slope away from them. A segment of the greatly subdued moraine (*Qds*) of the Selatna glaciation can be seen in the right background. This segment, and a part of the outer moraine of the Farewell glaciation, are pictured on the right and left sides, respectively, of figure 26. The braided flood plain (*Qab*) of the South Fork, bordering by steep terrace escarpments, is in the foreground. Photograph by U.S. Army Air Force, 1941.

rainal ridges and is bordered by a high morainal ridge. The west side has knob-and-kettle topography. The south-central part has a pitted outwash surface and a number of lakes. Thick deposits of till and gravel are exposed in the terrace escarpments bordering the South Fork.

In the Windy Fork area the morainal deposits form two continuous lobes, one extending a maximum of 4 miles out from the Alaska Range and the other an additional 4 miles, or a maximum of 8 miles, from the range. The lobe next to the range is on a fairly steep piedmont slope and has moderately subdued knob-and-kettle topography (fig. 22). The farther lobe is on a more gentle piedmont slope. It has numerous lakes and its knob-and-kettle topography is slightly more subdued than that of the inner lobe.

A broad outwash slope flanks the moraines of the Farewell glaciation in the South and Windy Forks areas. It has a gently rolling surface and merges into alluvial deposits northward. The surface has been cut into segments of various sizes by the South Fork, the Windy Fork, and other streams emerging from the range. A number of small streams also flow on this slope. The outwash deposits that were observed in the Sheep Creek area are predominantly gravel.

Big River area.—The Farewell glaciation is represented in the Big River area by a long, narrow moraine, V-shaped in plan, which lies between the lateral moraines of the Selatna glaciation and at a lower altitude (fig. 25). The V-shaped moraine extends northward approximately to the edge of the mountainous area; southward it can be traced at least 20 miles outside the region. On the valley bottom this moraine is characterized by fresh knob-and-kettle topography. It widens southward and forms a series of ridges on the inner flanks of the lateral moraines. Deposits of till and till interbedded with some gravel are exposed in the terminal portion of the V-shaped moraine. No significant outwash apron formed in front of the moraine.

CORRELATIONS AND AGE DETERMINATIONS

Valley to valley correlations.—The correlations of the moraines in the Big River, South Fork, and Windy Fork areas is based principally on similarity of sequence and of gross topographic expression. As the glaciers in the three areas had, in part, a common source area, similarities in glacial advances and retreats may logically be expected. That these similarities did exist is shown by the moraines in the three areas—the outer moraines all greatly subdued and the inner ones generally fresh to slightly subdued. No other moraines, except for small ones near the snouts of present glaciers, were observed in the three areas.

Differences exist, however, in the detailed topographic expression of the moraines; this varies with their altitudes in relation to timberline. Moraines above timberline are in the zone of active frost action, where smoothing and rounding of surface irregularities are accomplished in a relatively short time. Slopes on forested moraines are modified much more slowly and are stabilized at steeper angles. Thus the tundra-covered moraines of the Windy Fork are more subdued in their topographic expression than the equivalent moraines in the South Fork area, which are generally forested.

The contrasting physiographic settings of the moraines have caused differences in the degree of their preservation. For example, in the eastern part of the piedmont the older moraines were in part buried by younger glacial deposits and in part eroded by streams from the younger glaciers; only morainal remnants exist today. By contrast, the equivalent moraine in the western part of the piedmont was little affected by streams from the younger glacier, which was confined within the mountainous area, and is well preserved.

The contrasting physiographic settings have also caused differences in the drainage of the moraines and consequent differences in their topographic features. In the Windy Fork area, for example, the inner lobe of the Farewell glaciation is on a fairly steep slope of the piedmont at the base of the Alaska Range. Drainage on the slope is well integrated and the morainal lobe has no lakes. However, the outer lobe is on a gentle slope of the piedmont, drainage is poor, and the lobe has numerous lakes.

Differentiation of the glaciations.—The differentiation of two major glaciations is based on the great contrast between the gross topography of the outer and the inner moraines in the three areas discussed (fig. 26). A major time break is clearly indicated.

The deposits of the younger glaciation in the South Fork and Windy Fork areas are divisible into an inner and an outer part. The degree of modification of the outer part is only slightly greater than that of the inner one (fig. 27). Because only a minor time break is indicated, the moraines have accordingly been designated as representing an early and a late phase of the Farewell glaciation; the younger as Farewell 2 and the older as Farewell 1.

In the Big River area the writer could not detect any clear-cut division of the younger V-shaped moraine, and therefore believes it represents both phases of the Farewell glaciation. A division here would not be easily recognized, because the moraine is within the mountainous area and is confined between the high lateral ridges of the Selatna glaciation (fig. 25).

Regional correlations and age determinations.—Glacial deposits have been examined in three other areas on the north flank of the Alaska Range, all of which are northeast of the upper Kuskokwim region. The Mount McKinley area was examined by J. C. Reed, Jr., the Nenana River valley by Wahrhaftig (1953, 1958), and the Delta River area by Péwé (1953). In these three areas, as in the upper Kuskokwim region, young moraines of a major glaciation have been recognized and have been correlated chiefly on the basis of position and freshness of glacial topography (Péwé and others, 1953, p. 12–13; J. C. Reed, Jr., oral communication, 1956). Older, modified moraines of a more extensive glaciation have also been correlated. These correlations are outlined below.

Correlation of the Farewell and Selatna glaciations of the upper Kuskokwim region with those of three other areas of the Alaska Range

Age	Upper Kuskokwim region Fernald (1953)	Mount McKinley area Reed (oral communication, 1956)	Nenana River valley Wahrhaftig (1953)	Big Delta area Péwé (1953)
Wisconsin	Farewell	Wonder Lake	Riley Creek	Donnelly
Wisconsin(?)	Selatna	Slow Fork	Healy	Delta

Correlations with young moraines and older moraines in other parts of Alaska have also been made (Péwé and others, 1953, p. 12–13). These moraines were tentatively assigned to a late Wisconsin and an early Wisconsin age on the basis of the general nature of the moraines and several radiocarbon age determinations. Due to additional radiocarbon determinations, the young moraines were reassigned to a Wisconsin age and the older moraines to a pre-Wisconsin age (Alaskan Glacial Map Committee, U.S. Geological Survey, oral communication, 1956; Karlstrom, 1957). Hence, the age of the Farewell glaciation is very probably Wisconsin, but the age of the Selatna glaciation is problematic. Because the deposits of the Selatna glaciation have morainal topography, this glaciation is probably post-Illinoian in age and is therefore desgnated in the correlation chart (see table above) and in the legend of the surficial geology map (pl. 22) as Wisconsin(?).

Pre-Selatna glaciations.—The studies in the three areas of the Alaska Range northeast of the upper Kuksokwim region have also revealed deposits of older, more extensive glaciations outside the limits of the subdued moraines correlated with the Selatna glaciation. These deposits consist of remnants of old till with little or no morainal expression, and large glacial erratics (J. C. Reed, Jr., oral communication, 1956; Wahrhaftig, 1953, p. 7; Péwé, 1953, p. 9). Their occurrence in these three areas strongly suggests the probability of pre-Selatna glaciations within the upper Kuskokwim region. Glaciers may have extended far beyond the moraines of the Selatna glaciation. Because no glacial deposits were found along the Big River beyond the subdued moraines of the Selatna glaciation, however, it is assumed that all such deposits were completely buried or eroded.

A pre-Selatna glaciation may be represented by glacial erratics near the top of Farewell Mountain in the South Fork area. These erratics occur on a rubble-covered limestone ridge, over 1,200 feet above Farewell Lake. Most of the erratics are granitic in composition, although a few cobbles of conglomerate and basalt are included among them. One boulder of quartz monzonite measured 10 × 10 × 8 feet. The moraines of the Farewell glaciation can be traced around the north and northeast flanks of the mountain, and are at an altitude well below that of the erratics. The erratics therefore represent a pre-Farewell glaciation, either the Selatna glaciation or a still earlier one. Since no clue could be found as to the maximum altitude of ice during the Selatna glaciation, definitive proof of a pre-Selatna glaciation here is lacking.

EOLIAN ACTIVITY AND DEPOSITS

Two major periods of dune formation are recognized in the upper Kuskokwim region. The older period is represented by greatly modified dunes that were probably active during and after the Selatna glaciation. The younger period was initiated during the Farewell glaciation and is represented by prominent dunes, some of which were active up to fairly recent time.

The origin of widespread silt deposits over the uplands in Alaska has been debated for many years. Péwé (1955) has summarized the numerous theories of origin and presented effective arguments for the eolian origin of the upland silt in the Fairbanks area. In the upper Kuskokwim region much of the upland silt at the lower altitudes is also eolian in origin and therefore correctly termed "loess." Loess also occurs as a relatively thin mantle over the glacial, alluvial, and eolian sand deposits of the lowland and piedmont. Most of the loess was deposited during and after the glaciations, although some loess is still derived from the flood plains of the rivers.

A few thin beds of volcanic ash have been observed in several localities.

EOLIAN SAND

OLD DUNE FIELDS

Distribution.—Areas covered with greatly modified sand dunes form two broad surfaces in the lowland, termed the "old dune fields." For the most part, the two dune fields are outlined by uplands and by the flood plains of the Kuskokwim and Katlitna Rivers, from which the dune fields are separated by steep terrace escarpments. Minor streams, which originate in the uplands, have locally dissected the dune fields.

The larger of the dune fields, on the east side of the Kuskokwim River, covers an area of about 135 square miles and extends southeastward to the alluvial fan of the Big River. The northeast border of the dune field is formed by the flood plain of the Katlitna River for about four-fifths of the length of the border and by two younger dune fields for the other fifth. The terrace escarpment that separates the dune field from the flood plain decreases from about 200 feet near the mouth of the river to about 75 feet upstream. A moderately steep slope separates the older, and higher, dune field from the two younger dune fields. Bedrock uplands rise above the old dune field along most of its south border. To the southeast, between the uplands and the alluvial fan of the Big River, this field merges into the outwash surface of the Selatna glaciation.

The smaller dune field, on the west side of the Kuskokwim River, covers about 45 square miles within the region and about 20 square miles just outside its west border. The entire field is a triangular-shaped area outlined by the Kuskokwim River on one side and by uplands on the other two sides. The height of the terrace escarpment that separates the dune field from the flood plain ranges between 100 and 200 feet.

Character of dunes.—The dune fields are characterized by hundreds of sand ridges and irregularly shaped sand hillocks (fig. 28). Their crests are rounded and their slopes smooth and fairly gentle. Local relief ranges from about 10 feet to an estimated 50 feet. Particularly high hillocks occur for part of the distance along the flood plain of the Katlitna River.

No clearly recognizable types of dunes can be discerned. The sand ridges, some of which are oriented northeastward, may be similar to the arcuate dunes of the younger fields, described later. The high hillocks that border the flood plain of the Katlitna River are believed to be old cliff head dunes.

The dune fields are completely forested. On dune crests and slopes, white spruce and black spruce are dominant. Interdune areas have black spruce and muskeg vegetation growing on a cover of peat.

Nature of the deposits.—The only observed exposure of the old dune field is a high bluff at the junction of the Kuskokwim and Katlitna Rivers. It has a maximum height of 102 feet, and its top is irregular and eroded. As recorded in the measured section below, the entire bluff above 10 feet, except for a thin band of loess and peat that blankets the top, is composed of eolian sand. Over 90 percent of the sand grains are between 0.05 and 0.25 mm in diameter (fig. 29, sample 240).

Measured section of bluff at junction of the Kuskokwim and Katlitna Rivers

	Feet
Peat, fresh	0.5
Loess, tan	3
Eolian sand, tan, with irregularly shaped limonitic streaks; cross bedded; grains frosted and of uniform size	85
Sand, with lenses of fine gravel containing pebbles as much as 1 inch in diameter; yellowish gray; well stratified. No soil profile or weathering zone. Alluvial deposits	10
Base concealed by modern flood-plain deposits.	

Old eolian sand, exposed at the base of a 100-foot bluff along the Kuskokwim River 6 miles west of its junction with the Big River, was probably deposited during the same eolian period that produced the old dune field. The bluff is in an area of young dunes, and an irregular zone of peaty silt and sand, ranging from 10 to 25 feet in thickness, separates the two dune layers. The older sand extends from the river's edge to a height of 45 to 70 feet. About 90 percent of the sand grains range between 0.05 and 0.5 mm in diameter (fig. 29, sample 342). This bluff, which is mentioned in subsequent discussions, may conveniently be termed the "Kuskokwim–Big River bluff." A measured section taken from near the east end of the bluff, which extends several thousands of feet along the river, is given here.

Measured section near east end of Kuskokwim–Big River bluff, located 6 miles west of the junction of the Kuskokwim and Big Rivers

	Feet
Peat, with admixtures of loess	4
Eolian sand, upper part light tan grading downward into light gray; cross bedded; grains frosted and of uniform size (young eolian sand)	15
Peat, silt, and sand; dark, compact, fetid	15
Sharp contact; rises irregularly from east end of bluff to west end.	
Eolian sand, tan with local zones of yellow and gray; cross bedded; grains frosted and of uniform size (old eolian sand)	60
Base concealed by modern flood-plain deposits.	

YOUNG DUNE FIELDS

Distribution.—Areas covered with fresh dunes, termed "young dune fields," occur in numerous places between the rivers of the

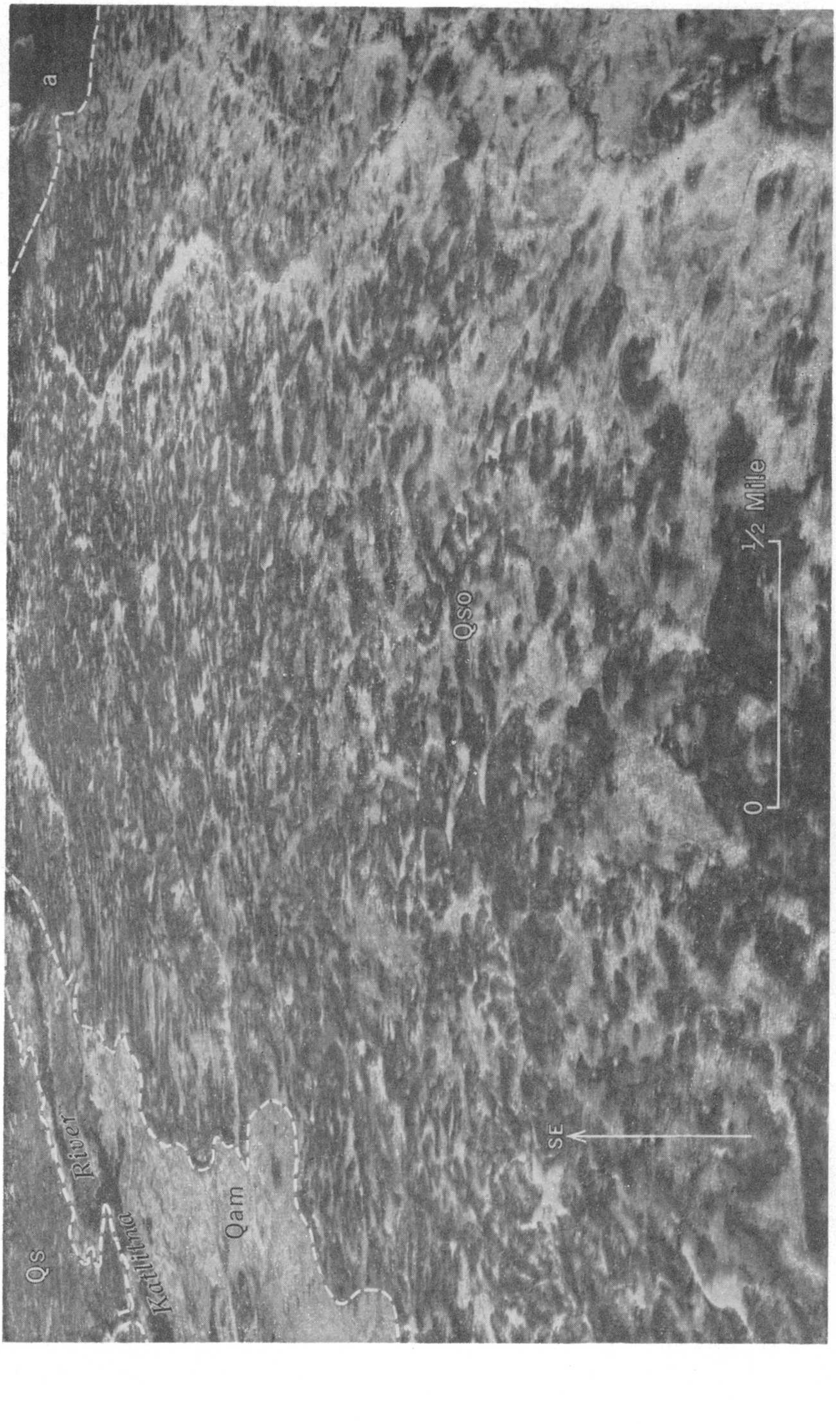
a
Qs
River
Katlitna
Qam
Qso
SE
0
½ Mile

FIGURE 28.—Oblique aerial view of a large part of the older dune field between the Kuskokwim and Big Rivers.

The field (*Qso*) is characterized by sand ridges and irregularly shaped sand hillocks, on which white spruce and black spruce are dominant (dark-gray areas). Interdune areas have scattered black spruce and a heavy cover of muskeg vegetation (light-gray areas). The dune field is bordered on the northeast (upper left corner of the picture) by the flood plain (*Qam*) of the meandering Katlitna River, from which it is separated by an irregular escarpment estimated to range between 100 and 150 feet in height. On the opposite side of the river is a small part of the younger McGrath dune field (*Qs*), separated from the flood plain by a steep escarpment estimated to average about 50 feet in height. The uplands (*a*) are visible in the extreme upper right corner of the picture. Photograph by U.S. Air Force, 1949.

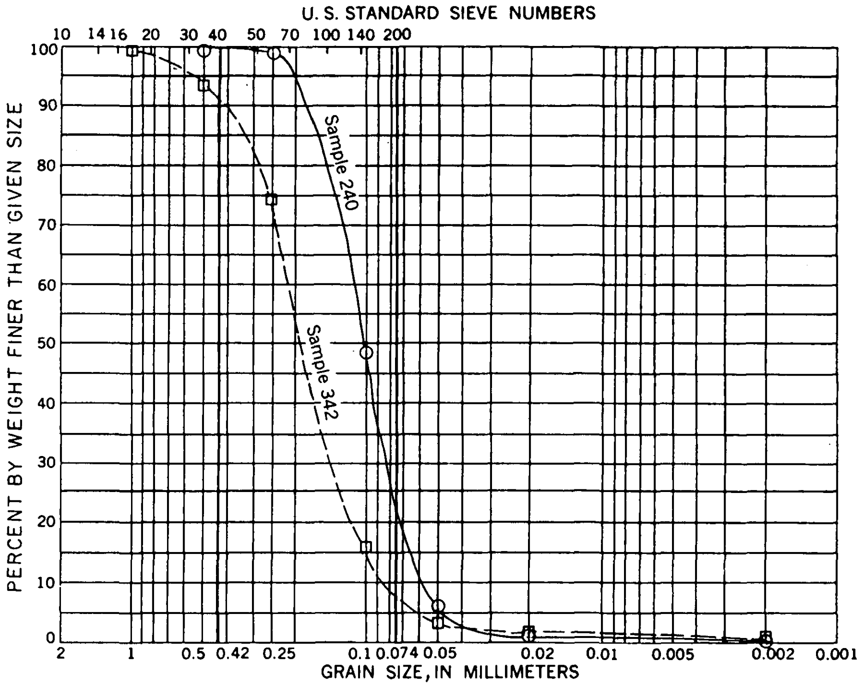

FIGURE 29.—Cumulative frequency curves showing the size of eolian sand from river bluffs, upper Kuskokwim region, Alaska. Sample 240, from bluff at junction of the Kuskokwim and Katlitna Rivers, 25 feet above flood-plain level; sample 342, from bluff along the Kuskokwim River, 6 miles west of junction of the Kuskokwim and Big Rivers, 20 feet above flood-plain level. Analyses by Soils Division, U.S. Department of Agriculture.

upper Kuskokwim River lowland. These areas, which total about 300 square miles, range in size from large dune fields to small isolated ones along the rivers.

The largest area, a dune field covering about 190 square miles, is southeast of McGrath and for easy reference is termed the "McGrath dune field." It is completely surrounded by flood plains and low terraces of meandering rivers, and generally separated from them by terrace escarpments. These rivers are Blackwater Creek on the southeast and east, the Kuskokwim River on the north and west, and the Katlitna River on the southwest. The terrace escarpments average 100 feet in height along the Kuskokwim River and progressively decrease in height upstream along the Katlitna River. The escarpment along the flood plain of Blackwater Creek ranges between 10 and 35 feet, except toward the mouth of the creek where it rises rapidly to 100 feet.

Between the McGrath dune field and the Big River are three smaller dune fields. One field is an elongate area of about 40 square miles between Blackwater Creek and the Big River; this field ranges from about 10 to 35 feet above the flood plain of Blackwater Creek on the west and the same height above the Big River on the east. The other two fields are on the south side of the swampy plain between the Katlitna River and Blackwater Creek. A southward extension of this swampy area, probably the flood plain of a former tributary of Blackwater Creek, lies between the two dune fields. The more westerly of the two fields covers about 12 square miles; the eastern one, about 10 square miles. Both fields average about 25 feet above the bordering flood plains. On the south they abut the older and higher dune field, with a gentle to moderately steep slope between.

Thirteen mappable areas of prominent dunes lie between the Big River and the South Fork. They rise above the swamp-covered alluvial deposits of the several tributaries of the Kuskokwim River with a relief ranging from about 10 to 35 feet. The largest area covers about 15 square miles and the smallest, less than one-half square mile.

Eight small dune areas of mappable size occur elsewhere in the lowland. One area is just west of McGrath, four are in a cluster north of the North Fork, and three lie between the East and South forks. All are irregularly shaped, and range from about 10 to 25 feet above the bordering flood plains.

Character of dunes.—The dune fields are characterized by prominent dunes rising sharply above generally flat interdune areas. Some sections, such as the west half of the McGrath dune field, are covered with hundreds of dunes; other sections are largely sandy plains, and dunes are widely scattered. They are divisible into gently curved, or arcuate, ridges, V-shaped hillocks, and irregularly shaped sandy areas. The arcuate ridges are the most conspicuous type of dune and are discussed in the following paragraphs.

The arcuate ridges occur singly, compositely, and in closely spaced groups. The single ridges average about three-fourths of a mile in length and about 25 feet in height. A maximum height of 50 feet has been observed. Some of the composite ridges are more than a mile long. The groups of ridges, made up of both large and small ridges, form irregularly shaped areas as large as 1 square mile. The dunes are well illustrated in aerial views; a large number of dunes are shown and outlined on figure 30, a vertical aerial photograph of the north edge of the McGrath dune field.

All the arcuate ridges throughout the dune fields trend approximately northeast, with the concave side to the southeast. Slopes on the northwest sides of the single ridges are between 8° and 20°; on the southeast sides, between about 5° and 12°. In general, the slope on the northwest side of the dunes ranges from 5° to 15° steeper

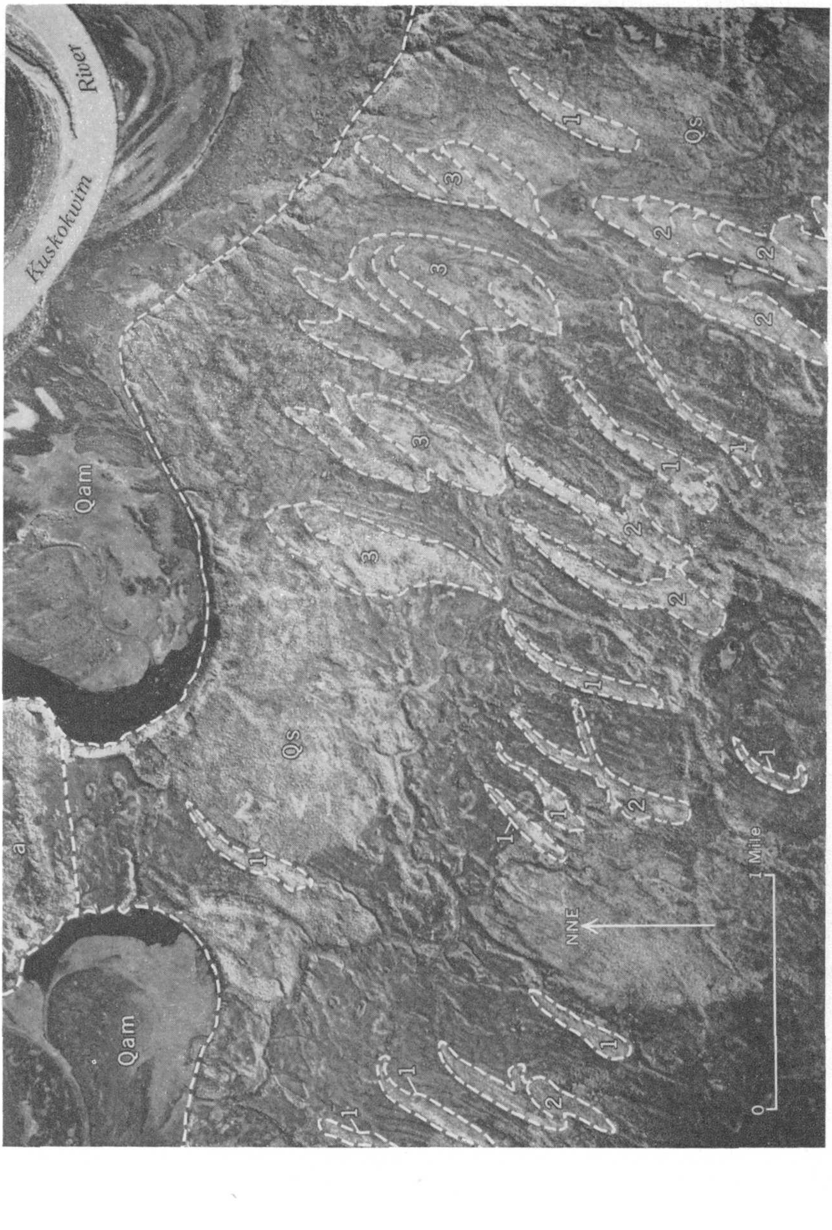
Kuskokwim River
Qam
Qs
a
NNE
0
1 Mile

FIGURE 30.—Vertical aerial view of part of the younger dune field bordering the Kuskokwim River.

Prominent dune ridges in the field (*Qs*) are outlined and numbered as follows: (1) single ridges, (2) composite ridges, and (3) groups of ridges. The dune field is bordered on the northeast by the flood plain (*Qam*) of the meandering Kuskokwim River, from which it is separated by a steep escarpment that averages 100 feet in height. Along this border there is also a low bedrock hill (*a*). Center of the picture is located about 8 miles east-southeast of McGrath. Photograph by U.S. Army Air Force, 1942.

than the slope on the southeast, or concave, side. The steeper northwest sides, made up of a series of gentle curves, are rather sharply defined. The southeast sides, by contrast, are poorly defined and irregular in shape.

The curvature of the central section of all the ridges is uniformly gentle, but the curvature of the ends of the ridges are diverse. The southwest ends are generally poorly defined, and many grade into irregularly shaped sandy areas with numerous hollows and hillocks. However, some of the ends are gently curved, and a few are abrupt. The northeast ends, by contrast, are well defined. They range from gently curved in most of the single ridges to sharply curved, either U-shaped or V-shaped in plan, in many of the composite ridges and the groups of ridges. In the composite ridges the V-shaped ends may form a series of barbs on the southeast sides of the dunes. The U-shaped ends may curve back and grade into low ridges that are concave to the northwest; these minor ridges appear in an aerial view (fig. 30) as faint lineations between the main ridges.

Dunes of nearly similar shape, some active and some inactive, have been observed by the writer in the Kobuk River valley of northwestern Alaska (Fernald and Nichols, 1953). The dunes in both regions belong to the general class described as "parabolic, U-shaped, V-shaped, bow-shaped, horseshoe-shaped, etc." (Smith, H. T. U., 1949, p. 1487), and termed "parabolic dunes," "blowout dunes," or "windrift dunes" (Hack, 1941, p. 242–243; Melton, 1940, p. 126–130). Because the presence of vegetation is the common denominator of this class of dunes, the genetic term "phytogenic" (Smith, H. T. U., 1940, p. 161) seems appropriate.

The dune areas in the upper Kuskokwim region are now completely covered with vegetation. Aspen, white spruce, white birch, and black spruce grow on the crests and slopes of the dunes. Interdune areas of the western part of the McGrath dune field are generally dry and have the same vegetation as the dune slopes and crests. By contrast, the interdune areas of all other sections, including the eastern part of the McGrath dune field, are generally wet and swampy. These areas, which are generally not far above the bordering swampy flood plains, are characterized by black spruce and a thick moss cover. Numerous lakes, some as large as a square mile, are scattered over these swampy interdune areas.

Nature of the deposits.—The terrace escarpment of the McGrath dune field along the Kuskokwim River has no clean exposures with the exception of the Kuskokwim–Big River bluff. The bluff, which exposes old eolian sand at its base and an overlying zone of peaty silt and sand, is topped with 10 to 35 feet of young eolian sand and a veneer of peat and loess. A measured section from the east end of this bluff was given on page 235.

Two cut banks along the Big River located about 10 miles north of Lone Mountain and at the junction of the Middle Fork and the Big River, expose dune sand down to flood-plain level and river level, respectively. The minimum thickness of the two exposures is 30 feet and 35 feet, respectively.

The dunes characteristically have an incipient soil profile, below which the sand is light tan or light gray, locally mottled. Where overlain by organic deposits, the sand is a uniform gray. Over 90 percent of the grains from three dune crests range between 0.05 and 0.5 mm in diameter (fig. 31), and many are frosted. The mineral composition of two samples shows an abundance of altered feldspar and opaque minerals and a moderate amount of quartz, plagioclase, and hypersthene (see table below).

Mineralogic composition of dune sand from the upper Kuskokwim region, Alaska

[Analyst: Dorothy Carroll. Symbols: A, 20–40 percent; B, 10–15 percent; C, 1–5 percent; D, 1 or 2 grains]

Mineral	Sample	
	269 [1]	329 [2]
Amphibole	B	--------
Apatite	C	--------
Chlorite	B	--------
Chloritoid	C	B
Epidote and zoisite	C	B
Feldspar (altered) [3]	A	A
Garnet	C	C
Glass	--------	C
Glaucophane	D	--------
Hypersthene	B	B
Magnetite	D	D
Opaque minerals (undifferentiated)	A	B
Plagioclase ($n>1.52$)	B	B
Pyroxene	--------	C
Quartz	B	B
Tourmaline	--------	C

[1] From McGrath dune field, 4 miles southeast of McGrath, 1 foot below crest of dune.
[2] From McGrath dune field, 9½ miles east-southeast of McGrath, 2 feet below crest of dune.
[3] Includes other altered minerals, such as chlorite.

EOLIAN HISTORY

DIFFERENTIATION OF TWO EOLIAN PERIODS

The differentiation of two eolian periods is based on the sharp contrast between the greatly modified dunes of the old dune fields and the fresh-appearing dunes of the younger dune fields. Evidence for two periods is also indicated by the two distinct layers of eolian sand separated by an organic zone, in the Kuskokwim–Big River bluff.

Favorable conditions for dune formation undoubtedly existed during both the Selatna and Farewell glaciations. During those

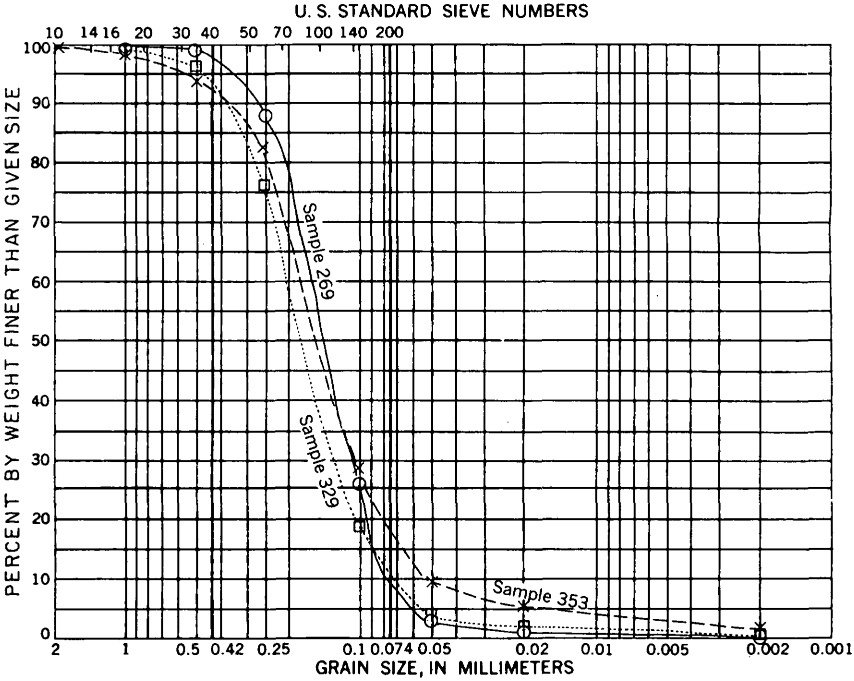

FIGURE 31.—Cumulative frequency curves showing the size of sand from dune crests, upper Kuskokwim region, Alaska. Sample 269, from McGrath dune field, 4 miles southeast of McGrath, 1 foot below crest of dune; sample 329, from McGrath dune field, 9½ miles east-southeast of McGrath, 2 feet below crest of dune; sample 353, from dune area 2 miles south of junction of the Big River and Middle Fork, 2½ feet below crest of dune. Analyses by Soils Division, U.S. Department of Agriculture.

times broad outwash slopes with many braided streams formed in front of the moraines. Large areas of sand free of vegetation, exposed as a result of fluctuating water levels in the glacial streams, provided an abundant source of sand, in some cases already sorted, for the formation of dunes. Strong glacial winds, produced by the steep pressure gradient between ice-covered areas and ice-free areas and by the intensified atmospheric circulation, existed. Numerous places on the piedmont and in the lowland, between the streams, were available for the deposition of sand.

Both eolian periods may be related to the Farewell glaciation, but it is believed more likely that the older period is related to the Selatna glaciation and the younger period to the Farewell glaciation. The sharp contrast in the degree of dune modification indicates a considerable time interval between the two periods. The position of the older dunes suggests a genetic relation to the Selatna outwash of the western piedmont, whereas that of the younger dunes suggests a similar relation to the Farewell outwash of the eastern piedmont.

OLD EOLIAN PERIOD

The old dune fields, which were probably initiated during the Selatna glaciation, are believed to be remnants of more widespread dune fields, as indicated by the buried eolian sand at the base of the Kuskokwim–Big River bluff. They were probably carried north and west of their principal source areas on the outwash slopes by southerly and easterly winds. As exposed in the bluff at the junction of the Kuskokwim and Katlitna Rivers, the advancing dune field moved across alluvium that had apparently been deposited a short time before, as no soil or weathering zone is present. The base of the dune field was about 10 feet above the present level of the Kuskokwim River flood plain. Presumably, the Kuskokwim River flowed in about its present position, or had been pushed to it by the migrating dune field, and at a slightly higher level. On the other, or west, side of the river, dune sand derived from the flood-plain deposits was banked up against the uplands. The sand bluffs that border the flood plain have been kept steep by the occasional swinging of meanders against them.

This period may have continued long after the retreat of the Selatna ice, and the dunes were probably stabilized by vegetation some time during the interval between the Selatna and Farewell glaciations. Parts of the original dune fields were subsequently eroded. The difference in height between the older dune field and the younger field, the McGrath dune field, along the Katlitna River gives an indication of the minimum amount of this erosion. Here the older field averages 50 to 100 feet higher than the younger field. Where the two younger fields abut the older field, between the Katlitna and Big Rivers, the difference in height is about 50 feet. Other parts of the dune fields, as exposed in the Kuskokwim–Big River bluff, were covered by dune sand associated with the younger eolian period.

YOUNG EOLIAN PERIOD

The young dune fields were very probably initiated during the Farewell glaciation and were supplied from the glacial stream deposits and, in some areas, from the old dune fields. Dune activity probably continued long after the retreat of the glaciers, as parts of the dune fields were apparently stabilized in the recent past. This is evidenced by the particularly fresh appearance of some of the dunes, such as those in the western part of the McGrath dune field.

Dune-building winds.—The arcuate dune ridges—all of which trend approximately northeast, are concave to the southeast, and have the steeper slope to the northwest—indicate that southeasterly winds have played a major role in the formation of the dunes.

Winds from the opposite, or northwest, quadrant played no part in the formation of the dunes, because the steeper slope would then be on the windward side. Winds from the northeast quadrant, blowing more or less parallel to the axis of the ridges, also played little or no part in their formation, because all ridges are concave to the southeast, their cross profiles are asymmetric, and many of their northeast ends are sharply curved. However, the poorly defined southwest ends of the ridges, which suggest later modification, and the sharp curvature of the northeast ends of many dunes indicate that southerly and, probably, southwest winds have also influenced the formation of the dunes.

Two generations of dunes may therefore be indicated: first, the formation of arcuate ridges by southeast winds, then the modification of these ridges by more southerly winds. More probably, however, the dunes reflect the repeated shifting of strong winds from southeast to south and southwest with the passage of cyclones or low pressure storms. The strong winds in the summer season are associated, at the present time, with moving cyclones; and it is probable that the dune-building winds of the past, before the stabilization of the dunes, were also cyclonically controlled. Today's strongest winds are southerly (see p. 202) and usually shift from the southeast to south and southwest with the approach of storms. Generally similar winds probably existed in the past and were the effective dune-building winds.

Formation and stabilization of the dunes.—Presumably, the larger dune fields, such as the McGrath dune field, were extended to the northwest principally by southeasterly winds. The sand formed an embankment along the Kuskokwim River, and, as exposed in the Kuskokwim–Big River bluff, covered old eolian sand and an overlying organic zone. The writer has observed a similar embankment along Kavet Creek in the Kobuk River valley of northwest Alaska, on the leeward side of an actively migrating dune field.

During the formation of phytogenic dunes in general, there is a continual battle between the blowing sand, which engulfs the vegetation, and the vegetation, which covers and stabilizes the dune sand (Moss, 1951, p. 45). Strong winds, a replenishable source of sand, and periods of drought favor the building of dunes. Accidental factors, such as fires, also favor their formation. On the other hand, light winds, curtailment of the sand source, and wet ground favor the growth of vegetation and the stabilization of dunes.

With the retreat of the glaciers of the Farewell glaciation, conditions favorable to formation of the dunes diminished. The supply of sand slowly decreased and the strong glacial winds disappeared.

The less rigorous climate favored the growth of vegetation. However, dune activity continued, maintained for the most part by the previously deposited dune sand, much as it is continuing in the Kobuk River valley of northwestern Alaska, where dunes are currently active (Fernald and Nichols, 1953). Some additional sand was still derived from river deposits and from erosion of the older eolian deposits related to the Selatna glaciation. Cyclonic winds were still fairly strong at times, probably much like those of today. Periods favoring stabilization of the dunes alternated with periods of rejuvenated dune activity. Fires and periods of drought probably occurred to favor rejuvenation.

Vegetation won the final battle. All the dunes were stabilized and covered with vegetation, and an incipient soil profile has developed. The final stabilization probably did not happen suddenly, but took place over a period of time. A combination of factors caused the overall trend toward stability: decreased wind velocities, reduced supply of replenishable sand, and a moderating climate. Innumerable swamps, bogs, and lakes now cover large parts of the interdune areas. Peat deposits are also accumulating in these areas and on the lower slopes of the dunes. The dune fields are being slowly reduced in size by the swinging of the meandering rivers against their borders.

LOESS

Distribution.—As described under "Physiography of the uplands," silty material of eolian origin blankets parts of the uplands, where it is generally mixed with colluvial material.

In the lowland and piedmont, loess is characteristically a relatively thin mantle over the glacial, alluvial, and eolian sand deposits. In many places the loess is mixed with organic material, which is also widespread over these areas. Loess deposits attain their greatest thickness in the terraces bordering the rivers.

Character.—Exposures of loess and colluvial material in bluffs where meander curves of the Kuskokwim River abut the uplands were described previously.

Other terraces observed along the rivers are topped with relatively pure loess. In an exposure at Medfra, the loess is 14 feet thick and overlies an organic layer. Several feet of loess veneer the two eolian sand bluffs along the Kuskokwim River (the Kuskokwim–Big River bluff and the bluff at the mouth of the Katlitna River). A few miles southwest of the region, a bluff along the Kuskokwim River exposes 60 feet of loess. Along the Big River a 10-foot band of loess tops a bluff cut into the end moraine of the Selatna glaciation. This bluff is 6 miles southwest of Lone Mountain and is shown in figure 24; a measured section of this bluff was given on page 223. Other exposures along the Big River, and several along the South Fork near the base of the Alaska Range, are also topped with loess or loess mixed with organic material.

The loess is generally tan, but other colors also occur. Where the loess underlies, or is mixed with, organic material, it is gray. In some places it is a mottled tan and gray, and locally there are irregular yellow zones due to limonite staining.

Size analyses of 3 samples from the upland areas bordering the Kuskokwim River show from 89 to 96 percent of the material ranging between 0.002 and 0.1 mm in diameter (fig. 32). Three samples from near tops of bluffs along the Kuskokwim River show from 86 to 95 percent of the material in the same size class (fig. 33). A single sample (262) from the piedmont area, collected within the mantle over an alluvial fan, has about 70 percent of its material in this size class and about 25 percent with a diameter of less than 0.002 mm (fig 33). All samples contain low percentages of organic carbon and coarser fragments. These coarser fragments have probably been derived from material upslope or from the underlying material through frost churning.

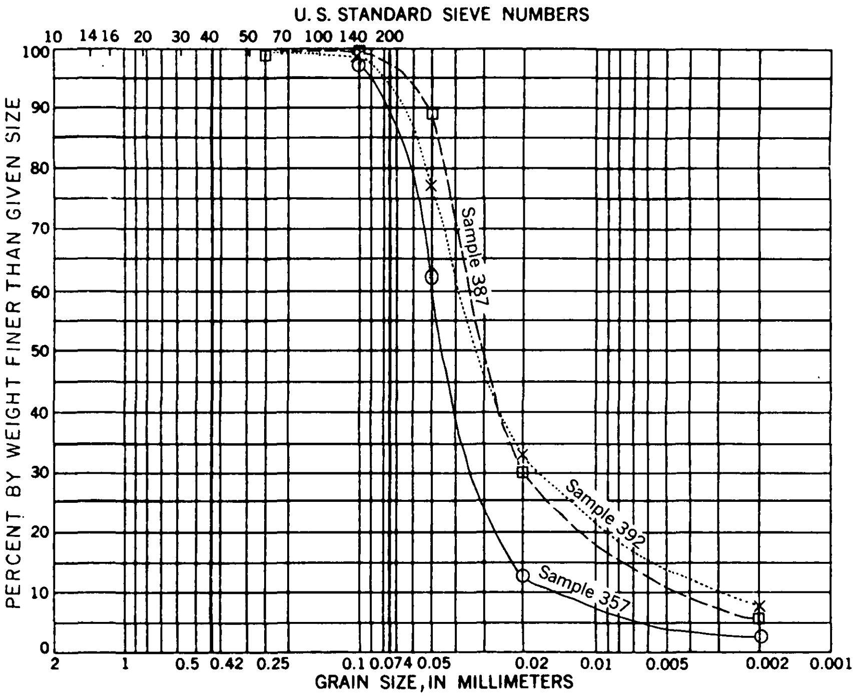

FIGURE 32.—Cumulative frequency curves showing the size of silty material from upland areas, upper Kuskokwim region, Alaska. Sample 357, from west side of Appel Mountain, 500 feet above the Takotna River; sample 387, from top of east end of Porcupine Ridge, 200 feet above the Takotna River; sample 392, from northeast side of Roundabout Mountains, 300 feet above the Kuskokwim River. Analyses by Soils Division, U.S. Department of Agriculture.

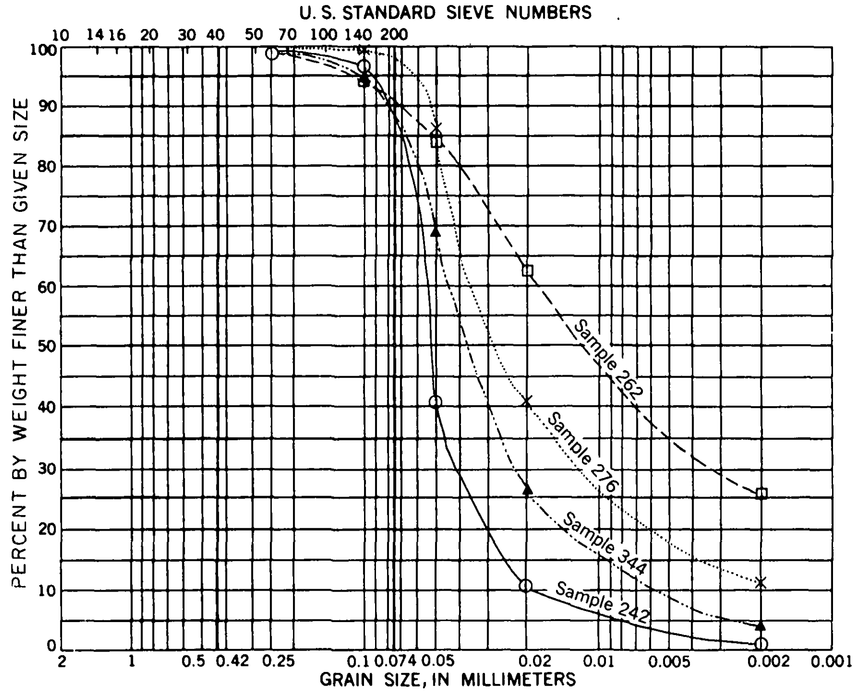

FIGURE 33.—Cumulative frequency curves showing the size of silty material from river areas, upper Kuskokwim region, Alaska. Sample 242, from bluff at junction of the Kuskokwim and Katlitna Rivers, 3 feet down from top of bluff; sample 262, from surficial mantle on the alluvial fan of Sheep Creek, near Farewell; sample 276, from bluff at Medfra, 14 feet down from top of bluff; sample 344, from bluff along Kuskokwim River, 6 miles west of junction of the Kuskokwim and Big Rivers, 3 feet down from top of bluff. Analyses by Soils Division, U.S. Department of Agriculture.

The mineral content of these 7 samples is fairly uniform (see table below). All contain 10 to 40 percent altered feldspar, chloritoid, plagioclase, and undifferentiated opaque minerals. The quartz content ranges from 1 to 40 percent. Mica was reported from only 1 sample.

Origin and age.—The evidence for an eolian origin of the silty material described herein is clear. The silt forms a widespread mantle of fairly uniform grain size and mineral content over different types of bedrock and unconsolidated deposits. Stratification is lacking. The hundreds of square miles of stabilized dunes is proof of great eolian activity in the past, and an abundant source of silt was available from the numerous glacial streams. Finally, loess is still being deposited.

Most of the loess at or near the surface was deposited during and following the Farewell glaciation, its deposition favored by the same general conditions that were also favorable to the formation of dunes. After the retreat of the glaciers, conditions became less favorable to eolian activity and the deposition of loess diminished. The less rigorous climate permitted vegetation to spread and grow, and the comparatively small amounts of loess that were still being deposited were largely incorporated into the organic deposits. Some dust is still being picked up by the wind from alluvial deposits along the braided parts of the rivers. Dust has also been observed rising from bars in the meander parts of the Kuskokwim River when they are exposed at low water stage.

Mineralogic composition of silty material from the upper Kuskokwim region, Alaska

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

Mineral	Sample						
	242 [1]	262 [2]	276 [3]	344 [4]	357 [5]	387 [6]	392 [7]
Amphibole [8]	------	------	B	B	B	C	------
Apatite	C	C	------	------	------	------	------
Chlorite	------	------	B	B	------	------	------
Chloritoid	B	B	B	A	B	A	A
Epidote	------	------	------	------	------	B	B
Feldspar (altered) [9]	B	A	B	A	B	B	A
Garnet	B	------	------	C	------	C	------
Glass	------	------	C	------	------	------	------
Glaucophane	C	------	B	C	C	------	C
Hypersthene	------	C	------	------	C	B	B
Magnetite	B	C	C	C	C	C	C
Mica	------	------	------	------	B	------	------
Opaque minerals (undifferentiated)	B	A	B	B	B	B	B
Plagioclase ($n>1.52$)	A	A	A	B	A	A	A
Pyroxene	------	C	------	------	------	------	------
Quartz	B	B	B	A	C	C	C
Rutile	------	------	C	C	C	------	C
Sphene	------	------	C	C	C	C	------
Tourmaline	C	------	C	C	------	------	C
Zircon	------	------	------	C	------	C	------
Zoisite	B	------	B	B	B	------	------

[1] From bluff at junction of the Kuskokwim and Katlitna Rivers, 3 feet down from top of bluff.
[2] From surficial mantle on the alluvial fan of Sheep Creek, near Farewell.
[3] From bluff at Medfra, 14 feet down from top of bluff.
[4] From bluff along the Kuskokwim River, 6 miles west of junction of the Kuskokwim and Big Rivers 3 feet down from top of bluff.
[5] From west side of Appel Mountain, 500 feet above the Takotna River.
[6] From top of east end of Porcupine Ridge, 200 feet above the Takotna River.
[7] From northeast side of Roundabout Mountains, 300 feet above the Kuskokwim River.
[8] Brown, green, and colorless varieties.
[9] Includes other altered minerals, such as chlorite.

The combination of conditions that is prerequisite to the abundant deposition of loess also existed during and after the Selatna glaciation. Although such deposits are probably widespread at depth, none of the loess examined in cuts could be identified as of this period. In the Kuskokwim–Big River bluff, it is believed that the silty material in the zone between the two dune layers was deposited in the interval between the two glaciations.

VOLCANIC ASH

Thin deposits of volcanic ash have been observed in several of the cut banks of the Kuskokwim flood plain near McGrath. The ash is composed of light-gray frothy shards; it occurs in thin, discontinuous zones within, or just below, the peat and silty peat deposits that cap the cut banks and overlie the flood-plain deposits. Possible sources of this ash are the Aleutian Islands, the Pribilof Islands, the Yukon delta, and the Seward Peninsula, all in the western or southwestern part of Alaska; the nearest and most probable source is Mount Spurr, an active volcano located south-southeast of the upper Kuskokwim region within the southern Alaska Range. In his study of this part of the Alaska Range, Capps (1935, p. 87–88) describes an extensive layer of ash, probably from Mount Spurr, that occurs below the surface layer of plant roots and soil.

In two places the loess mantle overlying young sand dunes contains a thin bed of volcanic ash. Near the junction of the Big River and the Middle Fork, a bed of ash is contained within a 3-foot cover of loess over dune sand. This ash is at a depth of 2½ feet, is 1 inch thick, and has sharp contacts. On the McGrath dune field several dunes, located 10 miles east-southeast of McGrath, are also overlain by a thin bed of ash near the base of the loess mantle. Other dunes, both nearby and in other parts of the dune field, have no ash overlying them. This probably indicates that the ash fall took place before the final stabilization of the dunes.

Volcanic ash has also been observed within the Kuskokwim–Big River bluff. It occurs as a thin, discontinuous band within the zone of peaty silt and sand that lies between the older and the younger eolian sand.

RIVERS AND ALLUVIAL DEPOSITS

The streams of the upper Kuskokwim region are arbitrarily divisible into the smaller creeks of the bedrock uplands and the larger rivers of the lowland and piedmont area. The creeks and the deposits of the creek valleys were described under "Physiography of the uplands"; the rivers, with the Big River as an example, and the alluvial deposits are described below.

Over half of the lowland and piedmont is covered with alluvial deposits, such as flood plains, alluvial plains, fans, fan aprons, and cones. These deposits have several age spans between the Farewell glaciation and the present, except for those of one apron believed to be related to the Selatna glaciation. Large areas of the alluvium are covered with swamps, bogs, and lakes.

NATURE OF THE RIVERS

The principal rivers of the upper Kuskokwim region are either braided or meandering. Those of the lowland areas are generally meandering. All the rivers that originate within the Alaska Range are braided in their upper reaches. In traversing the piedmont toward the lowland, the rivers from the Alaska Range change from the braided to the meandering type.

The Big River, typical of the larger rivers of this region which rise in the Alaska Range and flow northward across the piedmont, is described in some detail in the following paragraphs. Observations on the river were made during a canoe descent from near its source to its confluence with the Kuskokwim River.

The Big River, originating from a valley glacier about 30 miles south of the upper Kuskokwim region, emerges from the westward-facing flank of the Alaska Range into the Big River trench. There, the river turns and flows to the north through the trench and across the bordering piedmont. It has cut a valley ½ to 3 miles wide through the deposits of the Selatna and Farewell glaciations; this valley is bordered by steep terrace escarpments that range from 50 to 150 feet in height. About 3 miles beyond the end moraine of the Selatna glaciation, the river has formed an alluvial fan bounded by outwash and eolian deposits. The bordering terrace escarpments spread out and, gradually decreasing in altitude from about 100 feet near the apex of the fan, disappear near its base. The fan extends about 15 miles along the river and merges into the aluuvial plain of the lowland. The river flows in a flood plain 1 to 1½ miles wide down the middle of the fan. Several streams on the lower part of the fan probably originate from ground water fed by the Big River.

From the base of the fan to the Kuskokwim River, on the north side of the lowland, the meandering Big River flows in a valley 4 to 6 miles wide formed by its own flood plain and related low terraces. For much of its length the valley is bordered on both sides by a 10- to 35-foot terrace escarpment, in which eolian sand deposits are exposed. Blackwater Creek, originating on the alluvial fan of the Big River, flows through eolian deposits and joins the Big River near its mouth.

The Big River is braided at its glacial source and continues to be so through the glaciated terrain and to about halfway down its alluvial fan. Through the length of the braided section, where the flood plain ranges in width from ½ to 3 miles, the river alternates continually between concentrated flow in a few channels and dispersed flow in numerous channels. The change from concentrated to dispersed flow is effected by the repeated branching, or "peeling," of the main channels at points where the bordering low natural levees have been breached. Shallow gravel bars underlie these breaches, and log jams are frequent at such points. An irregular convergence of the numerous channels effects the change back to concentrated flow in a few channels. During low water stages fewer channels are utilized than when the water is high. Throughout its braided section the main flow of the river swings irregularly from one side of the valley to the other.

The transition from a braided to a meandering type of river takes place on the lower half of the alluvial fan over a distance of about 9 miles. Although the transition is completely gradational, the following four steps were observed: (1) The alternation in course of the river from one side of the flood plain to the other becomes more pronounced and more regular; (2) the zones of concentrated flow develop a fairly regular swinging, or meandering, and the number of channels in the areas of dispersed flow decreases; (3) a typical meander pattern is fully established, with a number of channels on the gentle slip-off slopes; (4) the number of channels on the slip-off slopes decreases until the river is confined to a single channel.

Below the transition, the Big River remains a meandering stream all the way to its junction with the Kuskokwim River. The upper part of the meander section has a fairly regular pattern. The meanders of the lower part make long complex loops, frequently doubling back on themselves for over a mile, and form a very sinuous pattern; there are numerous oxbow lakes on this lower half. Throughout the meander section the river generally flows in a single channel.

ALLUVIAL DEPOSITS

For mapping purposes, the alluvial deposits are subdivided into flood plains, fans, alluvial plains, fan aprons, and cones. For convenience of presentation they are discussed in this order.

The flood plains and fans have been formed by the modern braided and meandering rivers and are readily recognizable from their surface features. Flood plains of braided rivers are narrow and generally occur in the piedmont area; fans of braided rivers are large and occur where the rivers fan out at variable distances from the Alaska Range. Flood plains of meandering rivers generally occur in the lowland where they form broad surfaces, termed "meander plains" (Melton, 1936, p. 594), that are characterized by meander scrolls and meander scars; fans of meandering rivers are small and occur where tributaries fan out after emerging from the uplands.

Two extensive alluvial plains, one located in the Medfra flats and the other in the Nixon Fork lowland, are differentiated from the flood plains of meandering rivers by lack of recognizable meander features. These two plains are contiguous with, and slightly higher than, the meander plains, and were presumably formed by meandering rivers in the past.

The fan aprons are made up of series of coalescing fans that form gently sloping surfaces along the flanks of the uplands. They lack the discrete fan shape and drainage pattern of the more modern fans, from which they are differentiated. The cones, which have considerably steeper slopes than either the fans or the fan aprons, occur at the base of the Alaska Range.

FLOOD PLAINS AND FANS

BRAIDED RIVERS

Distribution.—The flood plains of the braided rivers range in width from less than 1 mile in the smaller rivers to as much as 3 miles in the larger rivers (South Fork, Big River). On the piedmont the flood plains are bordered by steep terrace escarpments for varying distances from the Alaska Range. Downstream the flood plains occur on the alluvial fans formed by the rivers, and because no perceptible break separates the flood plains from the fans, they are mapped together (pl. 22). On the lower half of the fans, the rivers change over to meandering types; this transition zone is included with the braided part for mapping purposes.

The apexes of all the fans are outlined by terrace escarpments, which become progressively lower in height downstream and generally disappear a short distance from the apexes; however, those of the Big River and the South Fork extend for a number of miles before disappearing on the lower half of the fans. The bases of the larger fans, including the series of coalescing fans formed by the Windy Fork and the Middle Fork drainage complex, merge into the meander plains of the lowland area. The base of Sheep Creek fan merges into the outwash slope of the Farewell glaciation, and the Jones River fan joins the flood plain of the South Fork, from which it is partially separated by a low terrace.

Character.—The flood plains are characterized by low relief, but there are many irregular details. These include hundreds of channels and low terraces that probably do not exceed 5 feet in maximum relief. The vegetation of the flood plains shows a sequential distribution. The actively forming sections near the rivers are bare of vegetation, and willow and alder grow away from the rivers; inactive parts of the flood plains have white spruce and white birch.

The fans are also characterized by low relief, and their surfaces are cut by numerous channels that probably do not exceed 5 feet in maximum relief. A few distributaries that probably originate from ground water fed by the master stream flow on each fan. The vegetation on the fans is characteristically white spruce and white birch, but the lower parts of the larger fans have black spruce and muskeg vegetation.

Nature and age of the deposits.—Within the Alaska Range and in the glaciated part of the piedmont, the flood-plain deposits are composed of well-rounded boulder, cobble, and pebble gravel that contains much sand and scattered glacial erratics. Beyond the glaciated terrain, as observed along the Big River, the boulder content decreases sharply, and the cobble content decreases progressively downstream as the content of pebble gravel and sand increases. A veneer of peat and silty peat covers inactive parts of the flood plains. Since the flood-plain deposits are currently being laid down, or have been laid down in the recent past, their age is Recent.

The deposits of the fans are generally composed of well-rounded cobble and pebble gravel and much sand. Like the flood-plain deposits, the cobble content decreases progressively downstream as the content of pebble gravel and sand increases. The deposits of the Jones River fan include much boulder gravel and scattered glacial erratics. Large parts of the fans have a veneer of peat and silty peat.

Formation of fans in the eastern piedmont very probably began soon after the retreat of the glaciers of the Farewell glaciation, whereas that in the Big River area probably began during this glaciation. Formation has continued to the present time. The deposits themselves span a considerable, though variable, time within the Recent.

MEANDERING RIVERS

Distribution.—The flood plains of the meandering rivers, in their alternating erosion of cut banks and deposition on slip-off slopes, form broad surfaces, or meander plains, which cover close to 15 percent of the region. The largest area of this unit is in the Medfra flats where numerous tributaries converge to form the Kuskokwim River. The flood plain of the Kuskokwim River itself, in the lowland, is between 3 and 5 miles in width and is bordered by bedrock uplands and by eolian sand deposits with a high terrace escarpment; it becomes 2 miles in width where the river flows through the bedrock uplands. The flood plain of the Takotna River has a very sinuous meander pattern, is 1 to 1½ miles in width, and is bordered by bedrock uplands. The flood plain of the Nixon Fork, which skirts the northwest edge of the Nixon Fork lowland, is ½ to 1 mile in width. There are numerous small flood plains, of which those of the Selatna, Katlitna, Tatlawiksuk, and Tatalina Rivers, and Blackwater Creek are of mappable size.

Most of the boundaries of the meander plains are clearcut. However, where the meander plains merge into the alluvial fans of the braided rivers and adjoin the outwash slopes of the piedmont area, boundaries are poorly defined.

Alluvial fans have been formed by a number of meandering tributaries of the Nixon Fork and the North Fork after emerging from the uplands. Several of the fans are compound. The sides of the fans are partially outlined by low terraces cut into aprons that generally flank the uplands. Low terraces also separate the bases of the fans from the meander plains of the Nixon and North Forks.

Character.—At the rivers edge the meander plains have gentle slip-off slopes and steep cut banks. It is estimated that the cut banks at Medfra and McGrath are 5 and 8 feet, respectively, above the mean summer flow of the Kuskokwim River. Heights increase progressively along the Kuskokwim River downstream from McGrath.

The gross topography of the meander plains is flat, but the detailed topography is irregular due to meander scrolls and meander scars, many of which contain oxbow lakes in various stages of filling. Local relief generally does not exceed 10 feet, except in the flood plain of the Nixon Fork, where some 15-foot terraces were observed.

The vegetation shows a sequential distribution. Willow and alder grow on the actively forming parts of the meander scrolls near the rivers, and white spruce, white birch and poplar grow away from the rivers. Black spruce–muskeg vegetation and bog vegetation grow on the higher, and older, parts of the meander plains.

The fans have low gradients, and the large areas of their surfaces are covered with bogs.

Nature and age of the deposits.—The flood plains are composed of a complex of deposits—sand, silt, organic material, and some gravel locally. In some places this complex includes compact, sticky silt representing the fill of old oxbow lakes. In others it includes deposits of small alluvial fans from bordering uplands and high terraces. The organic material, ranging in size from small pieces of debris to large logs, is dispersed throughout the deposits. Older parts of the meander plains are covered with peat and bog deposits intermixed with some loess.

The amount of gravel included in the deposits varies locally. In the Kuskokwim River and Nixon Fork flood plains, lenses of pebble and cobble gravel are small and occur only where the rivers are impinging or have impinged against the uplands. The flood-plain deposits of the Takotna River include much gravel, which, as exposed in cut banks, is generally overlain by finer grained material.

Along the large tributaries in the flatland south of Medfra, the amount of gravel increases gradually toward the piedmont.

The age of the deposits is Recent, ranging from the present to an indefinite time in the past, in the older parts of the flood plains.

Where observed along the Nixon Fork, the fans are composed of sand, silt, organic material, and some gravel locally. The age of these deposits, which are currently being laid down or were laid down in the recent past, is Recent.

ALLUVIAL PLAINS

MEDFRA FLATS

In the Medfra flats, a lake-dotted plain of about 30 square miles occurs between the meander plains of the Pitka and South Forks. Two similar plains, a small one of about 4 square miles and a large one of about 50 square miles, are located to the east, between meander plains of the South and East Forks. These areas average an estimated 10 feet above the general level of the bordering meander plains. The boundaries are generally gradational and are mapped at the innermost limit of recognizable meander features. Locally, a low terrace escarpment separates these areas from the meander plains.

The gross topography of the three areas is nearly flat but the detail is irregular, with low depressions and gentle rises. Small accumulations of dune sand occur locally, and several areas of low dune hillocks along the north edge are large enough to map (pl. 22). Vegetation is dominantly black spruce, larch, and muskeg. The only observed exposure, located near the junction of the Big and Kuskokwim Rivers, showed bedded sand, silt, and organic material.

These three areas are considered to be segments of an alluvial plain that was formed in the past by tributaries, very probably meandering, of the Kuskokwim River. This is evident from the location of the plain between, and its general gradation into, the modern meander plains, the flatness and low altitudes of the surfaces, and the nature of the deposits.

The age of the deposits is not known with any degree of certainty. They were laid down previous to a slight dissection that accounts for the difference in height between the alluvial plain and the flood plains of the modern rivers. This deposition may have taken place at an indefinite time within the Recent or during the general alluviation associated with the Farewell glaciation of Wisconsin age, or it may have been initiated during the Farewell glaciation and continued into the Recent. This latter age span seems the most likely, and the deposits are so mapped (pl. 22).

NIXON FORK LOWLAND

A broad alluvial plain of about 160 square miles, extending from near the north border of the upper Kuskokwim region southwest to the Takotna River, covers much of the Nixon Fork lowland. The Nixon Fork flows across this plain, generally on the northwest side, in a flood plain ½ to 1 mile wide. Meandering streams from the bordering uplands also flow across the plain and join the Nixon Fork. These streams divide the plain into a number of segments. Boundaries between the alluvial plain and the meander plains are mapped at the outermost recognizable meander features. In many places these boundaries are marked by low terrace escarpments; in others, they seem to be gradational. Along its border with the Nixon Fork, the alluvial plain averages about 15 feet above the general level of the meander plain.

On its southeast border and part of its north border, the alluvial plain merges into gently sloping fan aprons leading down from the uplands. Contacts have been mapped where a break in slope, however slight, is detectable. Generally this is at the outer limit of extremely boggy areas, which characterize the surface of the plain (fig. 34). However, the narrow northeastern part of the plain is partially outlined by a few low terraces.

The alluvial plain has an extremely flat surface, much of which is covered with peat and bog deposits, discussed later under "Organic deposits, bogs, and lakes." Below this organic layer, exposures in the plain where the Nixon Fork and the Takotna River are actively cutting against it showed stratified sand, silt, and organic material. A measured section from an exposure located 5 miles north of McGrath is given below. The content of organic material is considerably less than that in the deposits of the modern flood plains.

Measured section in bluff cut into alluvial plain of Nixon Fork lowland, located on north side of the Takotna River 5 miles north of McGrath

	Feet
Peat, layered	5
Sand and silt. At top, gray silt and fine sand grading downward into gray silt and yellow fine to coarse sand; in nearly horizontal beds, ranging from less than 1 inch to about 12 inches in thickness; contains some thin, irregular zones of organic matter	10
Slump, interval covered	8
Sand and silt, like lower part of unit above slump but is very compact and some layers are moderately contorted	12

Base covered by modern flood-plain deposits.

This plain was formed by an aggrading Nixon Fork and tributaries, very probably during the general alluviation associated with the Farewell glaciation of Wisconsin age. At that time, vegetation had apparently not attained its present heavy growth and the supply of sand and silt was abundant. Deposition has ended for the most part, and the Nixon Fork has incised its course into the alluvial plain.

FAN APRONS

Distribution.—Gently sloping fan aprons, made up of innumerable coalescing alluvial fans, lead away from the uplands that border broad valleys and lowlands. They characteristically form broad surfaces that cover about 300 square miles of the region. The largest area borders the uplands that surround the Nixon Fork lowland. A second area occurs between the Kuskokwim and Big Rivers, in the southwestern part of the region, where the uplands are in part surrounded by aprons, and other aprons occur in the broad valleys within the uplands. A third area of fan aprons leads away from the uplands that border the North Fork. Two smaller aprons occur just west of McGrath along the Tatalina River. Small, isolated aprons occur at several other places in the region.

The fan aprons are differentiated from the alluvial fans of meandering rivers by lack of discrete fan shape and drainage pattern. Upslope, the fan aprons merge into the creek valleys and are separated from the hills and mountains by a distinct break in slope. Downslope, the aprons for the most part either merge into the valleys and lowlands or, where bordered by flood plains and alluvial fans of meandering rivers, are terminated by terracelike escarpments. One apron, however, is conspicuously higher and clearly older than the other aprons. It forms a high bench north of Medfra within a reentrant of the upland, covers an area of about 10 square miles, and is bordered on the southwest and southeast by younger aprons. A 100-foot terrace escarpment, which has a small meandering stream at its base, separates the two units on the southeast. This apron is the only mappable area of "older alluvial deposits" within the region (pl. 22).

Character.—The surfaces of the younger aprons are fairly smooth and have gently concave slopes. Their characteristic vegetation is black spruce and muskeg. Boggy areas are numerous, particularly on the lower parts of the aprons.

The surface of the older apron has been dissected by several streams. The vegetation is black spruce and muskeg, and there are some boggy areas.

Nature of the deposits.—The deposits of the younger aprons, as observed in the Nixon Fork lowland and along the Kuskokwim River near McGrath, consist of stratified sand and silt and scattered zones of organic material; a few lenses of gravel and rubble occur locally near bedrock uplands. These exposures are located

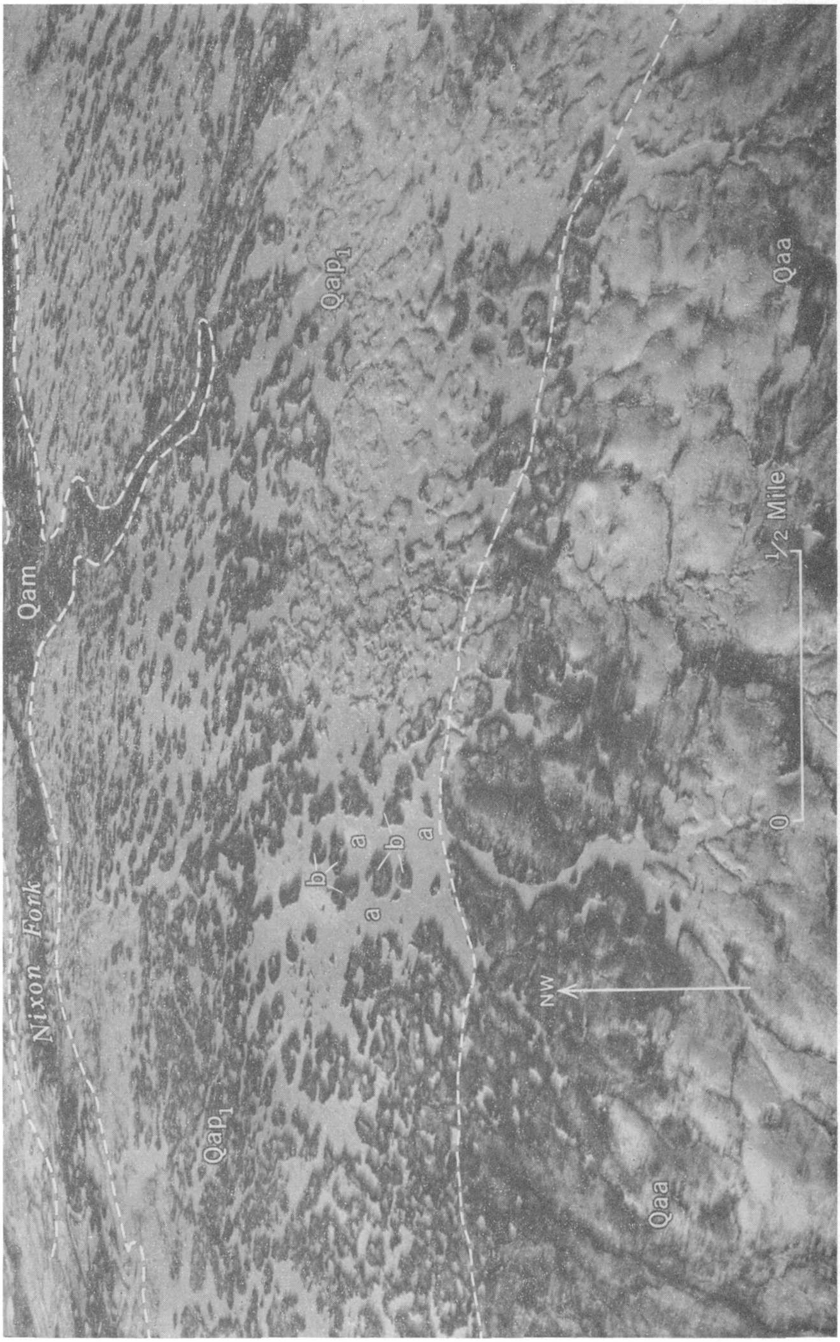
Qam
Nixon Fork
Qap1
Qap1
Qaa
Qaa
a
b
NW
0
1/2 Mile

FIGURE 34.—Oblique aerial view of the bog-covered alluvial plain of the Nixon Fork lowland and the bordering fan apron.

The bog-covered alluvial plain (*Qap*$_1$) covers much of the upper half of the picture. The bogs (*a*, smooth light-gray areas) and islands (*b*) together give a ragged, mottled appearance to the picture. On the lower half is a fan apron (*Qaa*) that leads down from bordering uplands and merged into the alluvial plain. The flood plains (*Qam*) of the Nixon Fork and one of its tributaries are along the upper edge of the picture. Photograph by U.S. Air Force, 1949.

along the Kuskokwim River 3 miles southwest and 7 miles northeast of McGrath, along the Nixon Fork 16 miles north-northeast of its junction with the Takotna River, and along the Takotna River on the west side of Appel Mountain, 3 miles north of McGrath. A measured section from the exposure along the Takotna River is given below; its deposits are similar to, and apparently interfinger with, the nearby alluvial-plain deposits. A cover of peat below the black spruce–muskeg vegetation occurs over large parts of the apron surfaces.

Measured section in fan apron, located on east side of the Takotna River 3 miles north of McGrath

	Feet
Peat, layered	5
Silt and sand, gray; irregularly bedded; contains thin, discontinuous zones of organic matter	3
Peat, compact; pinches out southward	1.5
Silt and sand, like unit above between the peat units	2.5
Peat, compact; pinches out southward	1
Silt and sand, gray at top grading downward into gray streaked with dark yellow; increasingly compact downward; in gently sloping beds, some with minor contortions; contains thin, discontinuous zones of organic matter	15
Base covered by modern flood-plain deposits.	

Most of the material that make up the younger fan aprons is derived from the mixed colluvium, loess, and creek valley fill of the uplands. Streams in the creek and reentrant valleys, and slope wash and congeliturbation in the interfluves, have brought the material to the base of the uplands. There, streams have reworked it to form the fan aprons. A relatively small proportion of the material—some of the sand in aprons facing the Kuskokwim River and some of the silt—has been deposited directly by the wind.

Two exposures within the older apron, located along the Medfra–Nixon Fork road near the uplands, showed well-rounded gravel and sand below a thin cover of loess. Elsewhere along the road the loess cover is at least 1½ feet thick.

Age of the deposits.—In the origin of their deposits, the younger aprons are closely related to the alluvial fans of meandering rivers. However, the aprons have been differentiated from the fans by lack of discrete fan shape and drainage pattern; present streams on the aprons, large parts of which are covered with peat, are sluggish and clogged with vegetation. Low terrace escarpments partially separate the two units, and in the composition of their deposits, the aprons contain considerably less organic matter than the modern fans.

It is believed that the stream activity responsible for these younger aprons took place for the most part during the general alluviation associated with the Farewell glaciation. Conditions at that time were favorable for widespread fan formation at the borders of the uplands. Within the uplands, where the zone of intense frost action was lowered, there was an abundance of frost-produced debris and loess which was moved downslope at an accelerated rate to the base of the uplands. Here, stream activity was less hindered by vegetation, which had apparently not attained its present heavy growth; a general reduction in the vegetation cover over all the lowland is inferred from the reduction over parts of the lowland, as indicated by the widespread dune fields.

Fan formation decrease in the postglacial period, when conditions became less favorable, and in many places ceased completely. Only the larger streams continued to build fans, which are mapped separately, to the present time.

The deposits of the older apron, which is differentiated from the adjacent aprons by its height above them, are quite clearly related to an earlier period of fan formation. This period presumably was during the Selatna glaciation, and the preservation of the apron since that time is probably due to its location within a reentrant of the uplands.

CONES

Coalescing alluvial cones occur along the steep northern front of the Alaska Range and form broadly undulating surfaces. There are also innumerable small individual cones, most of them too small to map. The slope of the cones is strongly concave, the upper part steep and the lower part moderate to gentle. Most of the cones head from reentrants within the mountains; many originate just below the escarpment of the Farewell fault. Downslope most of them merge into the glacial and alluvial deposits of the piedmont. Numerous streams from the reentrants radiate in fanlike fashion over the cones.

The alluvial cones are composed of rubble that varies greatly in size and contains some admixtures of loess. The rubble is derived from the frost-riven bedrock debris of the mountain slopes, and distributed at the base of the mountains by streams.

The cones have a wide age span. Some were initially formed during the Farewell glaciation and others date from the end of the glaciation. All have continued to be active to the present time.

ALLUVIAL HISTORY

In a general way the alluvial history of the region is one of accumulation of sediments on the piedmont and in the lowland, large parts of which have subsided probably during the Quaternary. The wedge of sediments derived from the Alaska Range has pushed the Kuskokwim River to its present location on the north side of the lowland. Sediments have also accumulated in the lower and middle sections of the creek valleys within the uplands, as discussed under "Physiography of the uplands."

Specific information on this alluvial history previous to the Selatna glaciation of Wisconsin(?) age is lacking. During this glaciation, glacial rivers in the piedmont area built broad outwash aprons that undoubtedly extended far into the lowland. Other streams from the uplands built extensive alluvial fans along the borders of the lowland. Parts of these deposits, as well as morainal and eolian deposits, were eroded in the interval between the Selatna and Farewell glaciations.

Another period of alluviation occurred during the Farewell glaciation of Wisconsin age. In the eastern piedmont, braided rivers from the glaciers formed an extensive outwash slope that reached well into the lowland. Upland streams also supplied much material to the lowland in the form of coalescing fans. In the western piedmont, no significant outwash apron formed in front of the moraine, and the ancestral Big River probably flowed across the deposits of the Selatna glaciation in about its present course. The river at that time may have been quite small, with much of the drainage from this part of the Alaska Range flowing southward through the Big River trench to the Swift River.

With the retreat of the glaciers, the drainage in the eastern piedmont area was concentrated into fewer, and larger, braided rivers that immediately incised their channels into the glacial deposits. Segments of the morainal and outwash deposits between the rivers have remained virtually unchanged except for minor stream action. At variable distances from the Alaska Range, where the rivers approached the general level of the outwash slope, they began to fan out. These fans probably extended farther northward than they do today, and the transition zone from braided to meandering river types probably was farther north. Much of the stream load was deposited on the lower part of the fans and in the Medfra flats where the streams converged. Here, the rivers probably migrated freely and, gradually becoming larger in size, formed broad meander plains. The modern meander plains are slightly lower than segments of an older alluvial plain in the Medfra flats due to recent stream dissection.

ORGANIC DEPOSITS, BOGS, AND LAKES

Organic deposits are very widespread in the upper Kuskokwim region. They cover extensive areas of surficial deposits of other types, and they also occur below the surface, either derived from vegetation growing in place and later buried or transported as debris and incorporated as an integral part of alluvial and colluvial deposits (described previously). It is, therefore, not practicable to map the organic deposits as a separate unit.

The surface deposits are largely peat, which occurs below living muskeg vegetation and in bogs. Bogs are so numerous over parts of the wet, poorly drained flatlands that they cover a fourth or more of the surface. These bog-covered areas, described in detail by Drury (1956) and only briefly here, have been termed "bog flats." Other parts of the flatlands contain many large lakes. Bog flats and lake-dotted surfaces cover more than 1,000 square miles of the region.

ORGANIC DEPOSITS

Distribution.—Peat forms in layers below living muskeg vegetation and its distribution is thus closely related to that of the muskeg vegetation. Hence, layered peat covers parts of the uplands, the piedmont, and the lowland. Within the uplands, it mantles parts of the mixed colluvium, the loess, and the creek valley fill. On the piedmont, it covers large areas of the glacial deposits along the Big River. In the lowland, where muskeg vegetation is very widespread, layered peat covers large parts of the alluvial deposits. It also covers parts of the dune-covered areas.

Peat also accumulates within the bogs, which are interspersed through the muskeg vegetation. The occurrence of the bogs ranges from widely scattered to closely spaced. Regionally, they occur in great abundance over large areas of the lowland, in scattered areas of the western piedmont, and in a few areas in upland creek valleys. Large areas of alluvial deposits and some areas of eolian and glacial deposits are covered with these bogs.

Character and age.—Layered peat, which is derived from muskeg vegetation, is composed principally of peat mosses and sedges, and contains varying amounts of loess. Permafrost is generally present at shallow depths. The peat generally ranges in thickness from less than 1 foot to about 6 feet. Cut banks in the older sections of the Kuskokwim River flood plain commonly expose 2 to 3 feet of layered peat. Exposures in the alluvial plain of the Nixon Fork lowland are topped by 4 to 6 feet of peat.

Bog peat consists of a tangled mass of organic material—mosses, sedges, and shrubs—with admixtures of inorganic material. The inorganic content is in part loess and in part material incorporated from the edges of the bogs. The general thickness of these deposits is highly variable. A thickness of 40 feet was observed in one such deposit, along the South Fork, overlying drift of the Farewell glaciation. In this exposure, a considerable amount of loess had been incorporated into the organic material.

Both types of peat have accumulated because each year's heavy vegetal growth is only partially decomposed. Decomposition is hindered by the cold, wet environment characteristic of these areas. The age of the peat, for the most part, is Recent.

BOG FLATS

Bogs are particularly numerous on the alluvial plain of the Nixon Fork lowland and on the older parts of the meander plains. They cover several hundred square miles of the Medfra flats, where numerous tributaries with broad meander plains converge. Such areas, termed "bog flats" by Drury (1956), are defined here as flat to gently sloping areas with quaking bogs so numerous that they cover a fourth or more of the surface.

In the flats the bogs are irregularly shaped, commonly interconnected, and surround irregularly shaped areas of firmer ground. These islands have a cover of peat below black spruce–muskeg vegetation, permafrost at depths of 1½ to 3 feet, and, in some parts of the Nixon Fork lowland, are bordered by steep banks as high as 10 feet above the bog surface. Permafrost is lacking within 6 feet of the surface in the bogs, but may be present at greater depth. On aerial photographs the bogs and islands, together, have a ragged, mottled appearance that can be readily recognized (fig. 34).

The process leading to bog flats is observable on the flood plains of meandering rivers (Drury, 1956, p. 30–35). Poplar, white spruce, and white birch on recently formed parts of the slip-off slope give way to black spruce–muskeg vegetation on older parts, and black spruce–muskeg vegetation interspersed with bog vegetation on the oldest parts, the bog flats. Permafrost, not present in the recently formed areas, is present in the older areas. A progressive waterlogging of the terrain has taken place, first drowning out the white spruce and white birch and then, in turn, some of the black spruce.

The waterlogged environment of the bog flats results from several climatic and terrain factors that prevent the ground from drying out after the late spring thaw. Summer precipitation is high, and evaporation and transpiration from the ground and the vegetation is limited. Surface drainage is poor because the terrain is flat or has a very low gradient. The generally fine-grained nature of the materials, together with permafrost, severely restricts or inhibits infiltration of the water into the ground. The hydrophytic vegetation itself is self-perpetuating because it further impedes surface and subsurface drainage.

The bog flats of the Nixon Fork lowland have formed over a longer period of time than those of the meander plains. They occur on alluvium deposited during and following the Farewell glaciation of Wisconsin age, and are notable for their high percentage of bogs (fig. 34). In some parts of the flats, bogs are actively invading areas of black spruce–muskeg vegetation (Drury, 1956, p. 20–21). Where steep banks separate the islands from the surrounding bogs, thawing of permafrost underlying the islands is taking place as evidenced by active caving of the banks. In other parts of the flats, black spruce–muskeg vegetation is encroaching on boggy areas (Drury, 1956, p. 23–25). A cyclic process, of alternate formation of permafrost below muskeg vegetation and its melting in bogs, has apparently been going on throughout the history of the bog flats.

LAKES

Lakes are numerous on two types of lowland surfaces within the areas of muskeg vegetation—the alluvial plain of the Medfra flats (fig. 35), and the younger dune fields, except the western part of the McGrath dune field. These lake-dotted surfaces are not far above the bordering meander plains. Locally, bogs are interspersed between the lakes.

FIGURE 35.—Low aerial view of several lakes on alluvial plain in Medfra flats. The lakes are between the East and South Forks, about 18 miles east-southeast of Medfra. A floating mat of vegetation outlines the near end of the lake in the foreground. Forested areas between the lakes have a heavy carpet of muskeg vegetation.

The lakes range widely in size. The largest, formed by the coalescence of two lakes, is about 2 miles long and has an average width of 1 mile. Although the lakes are generally irregular in shape, particularly on the dune surfaces, most can be classified as circular, triangular, or rectangular. The rectangular lakes are generally restricted to the alluvial plains and have their longest axis oriented west-northwest. Some of the lake shores are steep cut banks; others are gently sloping. Commonly, floating mats of vegetation extend out from the lake shores for varying distances.

The lake-dotted surfaces are waterlogged because of the same climatic and terrain factors that result in bog flats in other areas of the lowland. The lake-dotted surfaces, in contrast to the bog flats, have no streams and are completely undrained. This is due to their flatness, their general location away from bordering uplands, and their slight altitude above the meander plains. As a result, water has collected in depressions and has restricted the encroachment of vegetation. These lakes, like those in the valleys of Nabesna, Chisana, and Tanana Rivers of east central Alaska (Wallace, 1948), have been enlarged through thawing of permafrost along the lake shores.

The orientation of the rectangular lakes in a general westerly direction is probably due to the prevailing strong southerly winds of the summer season (see p. 202). Lakes on the Arctic coastal plain are generally oriented at right angles to the strongest summer winds. Their extension transverse to this wind direction has recently been attributed to longshore currents set up by the winds (Livingstone, 1954). A similar explanation is probably applicable to the orientation of lakes in this region.

CHRONOLOGY OF THE SURFICIAL DEPOSITS

The ages of the several types of surficial deposits were previously discussed. It remains to integrate this information and summarize the regional and chronological relations of the deposits.

Two cross sections illustrate the relations between deposits of the piedmont and lowland areas. One of the sections is along the general course of the Big River (pl. 22, section *A–A′*) and the other, along that of the South Fork (pl. 22, section *B–B′*). Because the topography is inadequately mapped, projected profiles of the rivers have been used as bases for the sections. These profiles were drawn from interpolations between the 1,000-foot contour, which in both instances is near the base of the Alaska Range, and the 450-foot altitude of Medfra, near the north point of both sections. The height of the surficial deposits above the projected profile is generalized from measurements made in the field and from estimates made from aerial photographs.

The surficial deposits of the region are, for the most part, of late Quaternary age. Their chronology has been related to the Selatna glaciation of Wisconsin(?) age, the interglacial, the Farewell glaciation of Wisconsin age, and the Recent (fig. 36). However, the colluvial deposits and the creek valley fill of the uplands have

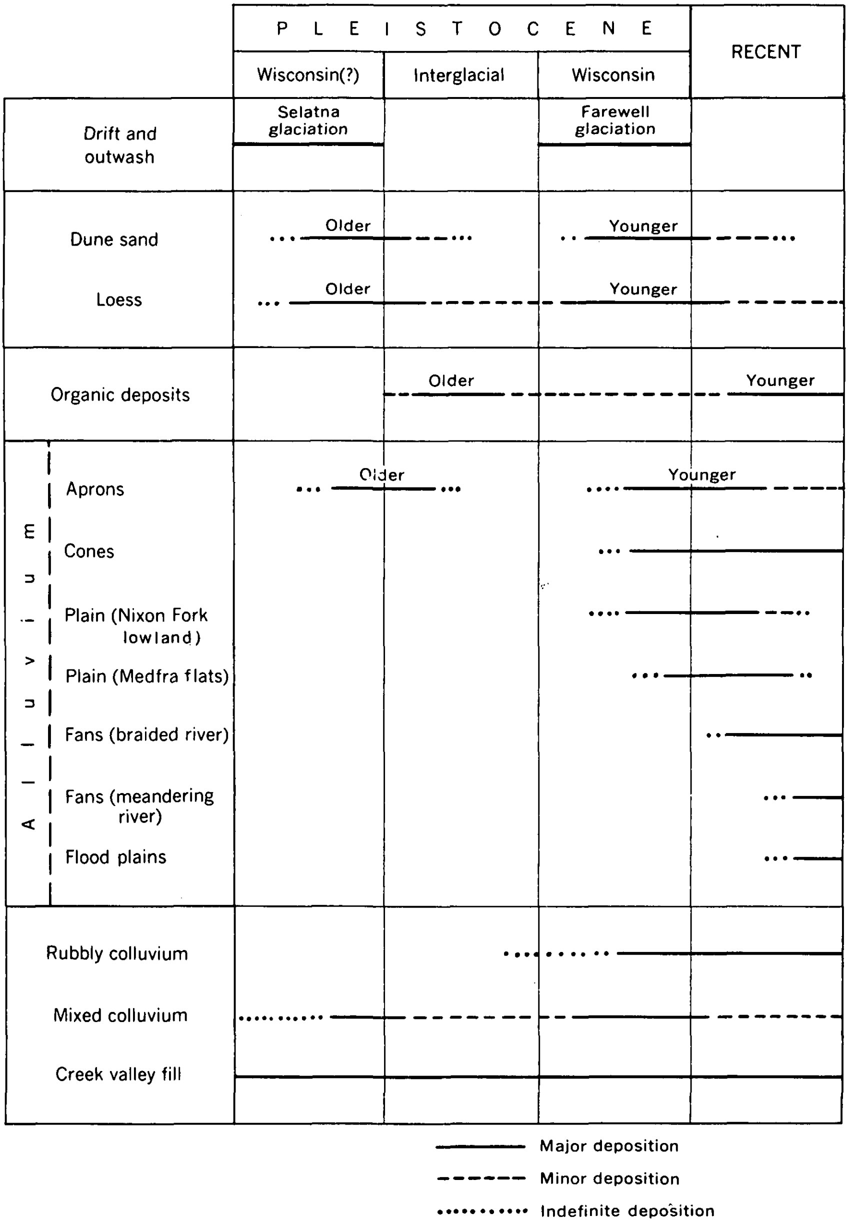

FIGURE 36.—Chart showing the chronology of the surficial deposits, upper Kuskokwim region, Alaska.

wide age spans of indefinite limits. Much of the rubbly colluvium is of Recent age, although some very probably date back to the Farewell glaciation of Wisconsin age. The mixed colluvium was formed and deposited, for the most part, during the Farewell glaciation, but locally deposition has continued to the present. Some of the mixed colluvium at depth was probably deposited during the Selatna glaciation, or even earlier. The creek valleys have served as loci for the accumulation of material over a long period of time. The gravel and rubble, which are at the bottom of these valleys and which date the beginning of deposition, are certainly of pre-Wisconsin age; some are probably of pre-Quaternary age.

Much organic material is accumulating today over the glacial, eolian, colluvial, and alluvial deposits of the region, and it is believed that organic deposits were also widespread during the interglacial period between the Selatna and Farewell glaciation. A zone of compacted organic material exposed in each of two bluffs along the Big River, measured sections of which were given previously, are assigned to this interglacial period (fig. 37). Because both zones are overlain by eolian deposits, the basis for this assignment

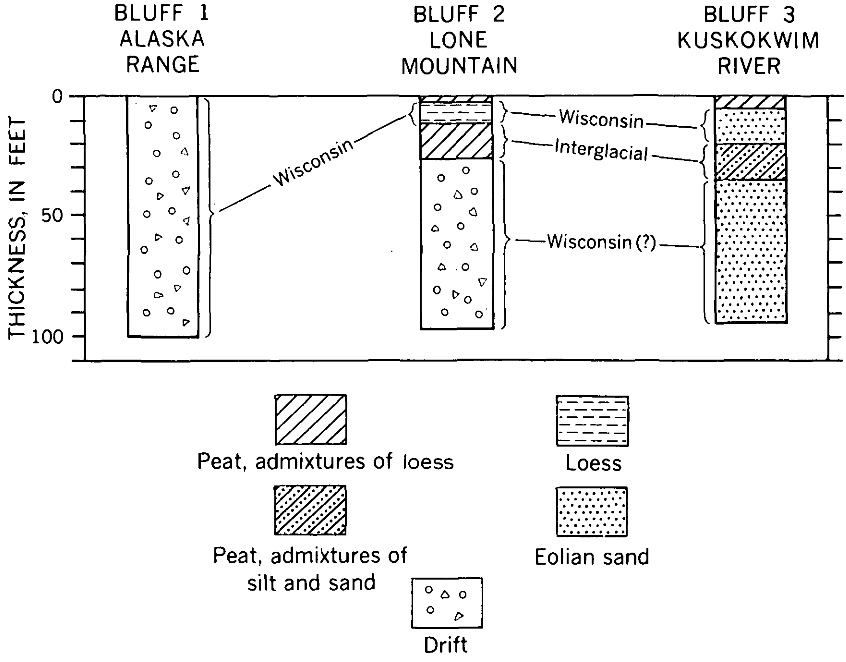

FIGURE 37.—Correlation of deposits in three bluffs along the Big River. Bluff 1, cut in end moraine of Farewell glaciation on west side of the Big River about 5 miles north of south border of region; bluff 2, cut in end moraine of Selatna glaciation on east side of the Big River, 6 miles southwest of Lone Mountain; bluff 3, the Kuskokwim–Big River bluff, located on south side of the Kuskokwim River 6 miles west of junction of the Big and Kuskokwim Rivers.

is the association of maximum eolian deposition with the glacial periods. The thickness and extent of the deposits in the two bluffs and the order of their deposition in relation to that of the glacial deposits (fig. 37) indicate general, rather than local, chronological significance. However, the time limits of the "eolian period" and the "organic period" are very indefinite, as periods of eolian and organic deposition overlap.

SUMMARY OF GEOLOGIC HISTORY

Marine inundation characterizes the known Paleozoic history of the region, beginning in the Ordovician period with the deposition of calcareous sediments in the South Fork area and in the Nixon Fork district. Similar deposits also accumulated in this district during the Silurian, whereas in the South Fork area, either during this period or in the early part of the Devonian, argillaceous and cherty material were deposited. In the Middle Devonian calcareous and silty sediments accumulated in the McGrath area.

Two structural elements, the Tanana geanticline and the Kuskokwim geosyncline, dominate the Mesozoic history of the region. The geanticline probably originated in the Jurassic and was repeatedly uplifted and eroded during the Cretaceous. It was a source area for many thousands of feet of sediment that accumulated in the geosyncline during the Cretaceous. These sediments were laid down in marine waters and formed interbedded graywacke and shale.

In the early part of the Teritary, probably at the beginning of the Eocene, the rocks of the Kuskokwim geosyncline were uplifted and folded, and during the Eocene were eroded to an area of low relief. The region as a whole probably remained topographically low during much of the Tertiary. The only rocks of known Tertiary age within the region are felsic and mafic intrusive rocks of probable Oligocene or Miocene age. Just outside the region to the east, coal-bearing sediments were laid down during the Eocene and were followed in the Miocene by coarse gravel, reflecting an uplift of the ancestral Alaska Range.

Probably by late Pliocene time an erosion surface, above which rose a few mountains cored with intrusive rocks, had formed over part of the region. The surface was differentially uplifted, probably in the late Pliocene or early Quaternary, and is now on upland summits. Rejuvenated streams have cut innumerable valleys within the uplands, and the Kuskokwim River has cut a broad canyon through the uplands. The Alaska Range was probably uplifted at the same time, and has undergone continued uplift during the Quaternary. Another part of the region subsided, probably during the Quaternary, to form the present lowland, which has been a collecting basin for debris derived principally from the rising Alaska Range.

Erosion and deposition over all parts of the region were affected by the climatic fluctuations of the Quaternary, which gave rise to repeated glacial advances within the Alaska Range and onto the bordering piedmont area. During these periods, frost action was even more intense over the slopes of the Alaska Range. In the piedmont and lowland areas, accelerated deposition is associated with the glacial advances. In the uplands, which were unglaciated for the most part, the zone of intense frost action was lowered, erosion was accelerated, and much rubbly colluvium produced.

Detailed information on the Quaternary history of the region begins with the Selatna glaciation of Wisconsin(?) age, when glaciers along the valleys of the Big River, the Windy Fork, and the South Fork built moraines on the piedmont at maximum distances of 18, 12, and 25 miles, respectively, from the base of the mountains. Outwash slopes in front of the moraines extended well into the lowland. Strong winds probably carried much sand, derived principally from bars of flood plains free of vegetation, to the north and west, and banked it against the uplands. Winds also picked up much dust and deposited it over large parts of the region. Within the uplands, a few local glaciers may have formed, and some rubbly colluvium and gravel may have been deposited in the creek valley bottoms. Streams at the base of the uplands probably formed widespread fans, one of which today is a high bench north of Medfra.

In the period that followed the Selatna glaciation, with the related climatic amelioration, the vegetal growth became increasingly heavy over much of the region and a widespread cover of organic material was probably deposited. Dune activity ended, frost action in the uplands became less effective, and fan formation at the base of the uplands decreased.

During the Farewell glaciation of Wisconsin age, glaciers again advanced down the valleys of the Big River, the Windy Fork, and the South Fork, forming moraines at maximum distances of 0, 8, and 20 miles, respectively, from the base of the mountains. In a later phase of the same glaciation, moraines were deposited in the Windy Fork and the South Fork areas at maximum distances of 4 and 15 miles from the mountain front. In the eastern part of the piedmont, glacial streams built extensive outwash slopes that buried part of the deposits of the Selatna glaciation. In the western part of the piedmont, where ice was confined within the mountainous area, no significant outwash apron formed in front of the moraine. Strong winds and a plentiful supply of bare sand in the flood plains of the glacial streams gave rise to widespread dune fields, the largest of which is the McGrath dune field. In one locality, an advancing dune field buried an organic layer overlying eolian sand, probably related to the Selatna glaciation. Much dust was also picked up by the winds and deposited over the region. In both the Medfra flats and the Nixon Fork lowland, streams formed a large alluvial plain. Other streams formed numerous coalescing fans at the base of the uplands, and steep cones at the base of the Alaska Range. Within the uplands, where the zone of intense frost action was lowered, rubbly colluvium was produced over wider areas.

With the retreat of the Farewell glaciers, the rivers incised their channels into the glacial deposits of the piedmont area and began to fan out at variable distances from the Alaska Range. In the lowland south of Medfra, where the rivers converged and gradually increased in size, they formed broad meander plains. A slight dissection has taken place here recently.

Dune activity continued into the postglacial period but gradually diminished. The final stabilization of the dune fields by vegetation took place over a period of time, with some of the dunes active up to fairly recent time. Deposition of loess also diminished, and only small amounts are still being deposited.

In the uplands, the zone of intense frost action was raised, decreasing the area of rubbly colluvium and increasing that of mixed colluvium. At the base of the uplands, formation of fans ceased in many places and only the larger tributaries continued to form fans to the present time. Cones have continued to be active at the base of the Alaska Range.

Muskeg vegetation is growing today over large parts of the lowland, parts of the piedmont, and locally within the uplands. In the flatlands, the terrain has become progressively waterlogged, with innumerable bogs in poorly drained parts and many large lakes in completely undrained parts. Peat is accumulating below the muskeg vegetation, where permafrost forms at shallow depths, and in the bogs, which expand by thawing of permafrost.

Differential movement is still going on along two large faults, the Farewell Fault at the north edge of the Alaska Range, and the Nixon Fork fault within the uplands.

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