Geologic Reconnaissance Along the Alaska Highway Delta River to Tok Junction, Alaska

By G. WILLIAM HOLMES

CONTRIBUTIONS TO GENERAL GEOLOGY

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Bedrock and surficial geology of the middle section of the Tanana lowland and adjacent parts of the Alaska Range and the Yukon-Tanana upland

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CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGIC RECONNAISSANCE ALONG THE ALASKA HIGHWAY, DELTA RIVER TO TOK JUNCTION, ALASKA

By G. William Holmes

ABSTRACT

The area along the final 100 miles of the Alaska Highway lies in the middle section of the Tanana lowland and includes parts of the Yukon-Tanana upland on the northeast and the Alaska Range on the southwest. The major bedrock units, mostly exposed in the mountains and hills, are the Birch Creek Schist, regarded as Precambrian; granitic rocks of Cretaceous age; and volcanic rocks of Tertiary age. Very small exposures of lower Tertiary shale, sandstone, and conglomerate crop out along the Tanana River near Tok Junction; a small bed of Nenana Gravel of middle Miocene age or younger lies on the north end of Independent Ridge; and thick but limited carbonaceous silt and clay beds of upper Tertiary age lie along a tributary of the Johnson River.

Most of the Tanana lowland and of the piedmont of the Alaska Range is covered by glacial and alluvial deposits. The most conspicuous glacial deposits are the large, well-preserved moraines at the mouths of the major tributaries of the Tanana River. Spreading northward from these moraines are outwash plains that coalesce laterally with alluvium from nonglacial streams to form extensive fan aprons. Most fan aprons are composed of rocks from the Alaska Range, but the fan in the Tok Junction area contains large percentages of volcanic rocks which are not abundant locally. Smaller moraines occur in tributary valleys and in cirques. Two major Pleistocene glaciations are indicated by moraine sequences, which are correlated with the Delta and Donnelly advances of the Delta River area. Other surficial deposits of considerable areal extent are the terrace sediments of the Tanana River and its major tributaries and the eolian loess, which covers nearly all other deposits and rocks. Alluvial silt, eolian sand, colluvium, organic silt, and flood-plain alluvium are also widespread but are mainly confined to valleys. Rubble and talus are of limited extent, occurring at high altitudes in the mountains.

INTRODUCTION

SCOPE

This report and map are the result of a geologic reconnaissance along the Alaska Highway between the Delta River and Tok Junction in the Tanana lowland and adjacent parts of the Alaska Range and the Yukon-Tanana upland. Emphasis in this report is placed on the mapping of surficial deposits and on their engineering aspects.

GENERAL GEOGRAPHY

The area is adjacent to that section of the Alaska Highway from the junction with the Glenn Highway at Tok Junction to a point near the junction with the Richardson Highway on the Delta River (fig. 1). The area is 108 miles long in a northwest-southeast direction and is as much as 22 miles wide at right angles to the highway. By road, the northwestern end of the area is 95 miles from Fairbanks, and the southeastern end is 93 miles from the Canadian border. Settlements include Tok Junction, part of which lies east of the mapped area; Tanacross, to the northwest; and Dot Lake, in the central part of the area. Delta Junction lies just northwest of the map boundary. Fort Greely, an Army installation for cold-weather testing and training, and the Federal Aviation Agency community at the Big Delta Airport lie immediately south of Delta Junction. An Army Chemical Corps test site is south of the west bank of the Gerstle River.

The axial part of the area is occupied by the middle section of the narrow, irregularly shaped Tanana lowland. On the southwest is the Alaska Range and its foothills; to the northeast, across the Tanana River, lie the rolling hills of the Yukon-Tanana upland. Within the mapped area, peaks of the Alaska Range rise to more than 6,500 feet above sea level, or about 5,000 feet above the Tanana River. Hills of the Yukon-Tanana upland immediately north of the Tanana River rise to more than 3,300 feet above sea level; the maximum relief is about 1,800 feet. The rugged, glaciated landscape of most of the Alaska Range contrasts sharply with the maturely dissected Yukon-Tanana upland, which here exhibits no evidence of Pleistocene glaciation.

The Tanana River flows in a northwesterly direction and is joined by the following major tributaries which flow northeastward from the Alaska Range: The Robertson, Johnson, Gerstle, and Delta Rivers. Smaller streams include Yerrick and Jarvis Creeks, which flow from the south, and Fish, Billy, Sand, and George Creeks, which enter the Tanana lowland from the north.

The climate generally is typical of the continental subarctic climate of interior Alaska: long cold winters, moderately warm summers, and light precipitation, mostly in the form of summer rain (table 1). Strong winds are frequent in the Big Delta area, blowing either from the south through the pass or from the southeast down the

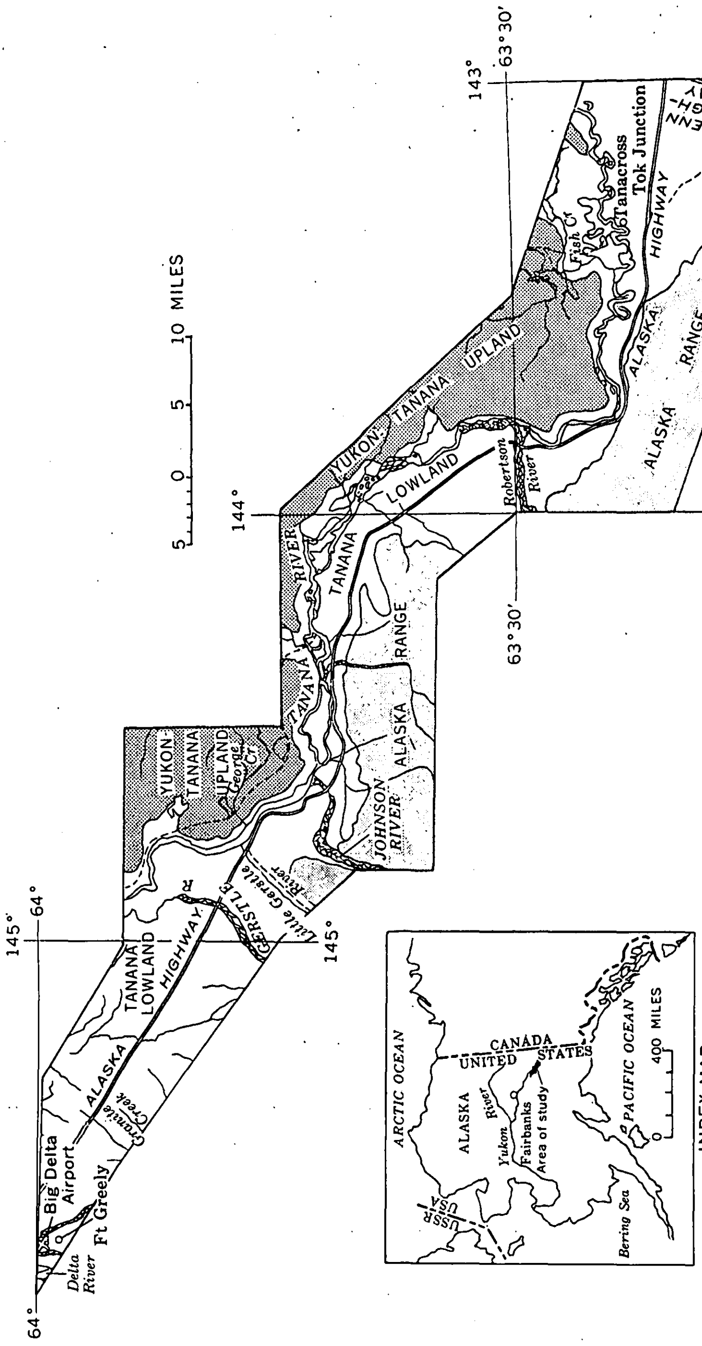

FIGURE 1.—Physiographic subdivisions and drainage of the Delta River-Tok Junction area, Alaska.

Tanana River valley. Less persistent local winds also blow down the flood plains of the Gerstle, Johnson, and Robertson Rivers and deposit loess on the valley sides. Possibly as a result of the strong winds, generally accompanied by higher temperatures, climatic averages indicate warmer winters in the Delta River area, than at Northway and possibly at Tok Junction.

TABLE 1.—*Climatic summary for stations in and adjacent to mapped area*

[Summary for years 1942–52 at Big Delta Airport (Fort Greely) and at Northway Airport. Northway is about 40 miles southeast of Tok Junction]

Month	Mean temperature (°F)		Mean precipitation (inches)			
			Total		Snowfall	
	Big Delta	Northway	Big Delta	Northway	Big Delta	Northway
January	−5.6	−17.1	0.38	0.61	7.1	8.7
February	2.5	−9.5	.16	.34	2.6	4.1
March	12.0	6.8	.34	.22	5.8	3.1
April	28.4	25.8	.28	.35	2.9	2.9
May	46.4	44.8	.64	.72	.3	.4
June	56.4	55.6	2.31	1.99	Trace	Trace
July	59.4	59.2	2.99	2.93	0	Trace
August	54.1	53.6	1.98	1.81	Trace	.3
September	44.1	42.5	1.34	1.18	.6	1.5
October	27.0	24.3	.50	.49	6.7	5.3
November	7.4	−2.2	.29	.36	5.0	5.4
December	−3.3	−14.8	.33	.37	4.2	5.5
Annual	27.4	22.4	11.54	11.37	35.2	37.2

PREVIOUS INVESTIGATIONS

The earliest major geologic reconnaissance of the area was made by W. J. Peters and A. H. Brooks (Brooks, 1900), who explored the Tanana valley in 1898. Thereafter, many investigations, which are summarized in two principal publications, were made in the Alaska Range and the Yukon-Tanana upland. Mertie (1937) published the results of his own studies and those of several others in a comprehensive presentation of the geology of the Yukon-Tanana upland. Moffit's work of more than 30 years in the Alaska Range and adjacent areas was reported in short publications as well as in a regional treatise (Moffit, 1954). In more recent years, the work of Péwé (1952, 1953) established a chronology for glaciation in the Big Delta area. Detailed mapping of the surficial deposits was continued in the Delta and Gerstle River areas by Holmes, Benninghoff, and Péwé (Holmes and Benninghoff, 1957; Péwé and Holmes, written communications, 1962), and in the Delta River area by Lindholm, Thomas, and Davidson (Lindholm and others, 1957).

PRESENT INVESTIGATION

This report is based on fieldwork done from mid-May to mid-September 1957 and from late May to early August 1960. The writer was associated with Lloyd A. Spetzman, botanist, and Harry B. Groom, geologist, in 1957, and with Helen L. Foster, geologist, in 1960. Lt. Col. Joseph K. Paull, U.S. Army, and Lt. Col. James R. Evans, U.S. Air Force, at times accompanied the writer in the field. Traverses were made by automobile, river boat, helicopter, and foot, and light aircraft were used for preliminary reconnaissance. A few small areas were mapped from aerial reconnaissance and by photogeology. Major support was furnished by the Army Cold Weather and Mountain School, the Army Test Board, and the Army Chemical Corps Arctic Test Activity at Fort Greely; this support is gratefully acknowledged. The investigation was financed in part by the Office of the Chief, U.S. Army Corps of Engineers.

BEDROCK GEOLOGY

Bedrock units, shown on plate 1, and the following descriptions are based on the publications of Mertie (1937) and Moffit (1954), modified by the work of H. B. Groom, H. L. Foster, and the writer. Although bedrock information is incomplete, especially in the southeastern half of the area, available information is presented as a background for the discussion of the superficial deposits.

METAMORPHIC AND SEDIMENTARY ROCKS

BIRCH CREEK SCHIST

The largest areas of Birch Creek Schist are south of the Tanana River in the mountains between the Tok and Robertson Rivers and on Independent Ridge. North of the Tanana River, the largest area of Birch Creek Schist is north of Lake George.

The Birch Creek Schist is a thick, areally extensive group of metamorphic rocks that has resulted from one or more periods of high-grade regional metamorphism. The chief rock types in the mapped area are schist, gneiss, quartzite, and amphibolite.

The schist is mostly gray quartz-mica schist, but some is chloritic; graphitic schist has also been reported. The quartz-mica schist ranges from types that are composed almost entirely of quartz and have rather poor schistosity to those that contain large amounts of mica and have excellent schistosity. In places, garnet is present as porphyroblasts. The schist commonly grades into gneiss.

Gneissic phases include gray or light-brown biotite gneiss, gray hornblende gneiss, and hornblende-biotite gneiss. The gneiss ranges from finely to coarsely banded; in some rocks the bands are very indistinct and are indicated megascopically only by somewhat irregularly alined patches of dark minerals.

The quartzite is mostly white to light brown, but some is gray or greenish gray. It occurs as small lenticular masses in the schist and gneiss, as masses or lenticular bodies large enough to be mapped, and as thin layers parallel to planes of schistosity. Irregular masses of quartzite are especially common near contacts with granitic intrusives. Original sedimentary structures such as bedding and laminations were not observed in the quartzite.

Black amphibolite, which is not abundant, occurs as bands a few inches to several feet thick in the gneiss and schist. The schistosity is parallel to that of the associated rocks.

The planes of schistosity of the Birch Creek Schist generally are considerably contorted, but locally they are horizontal. In places, as on Independent Ridge, there are large-scale folds whose axes are hundreds of feet apart. Commonly, smaller folds having axes a few feet apart are superimposed upon the limbs of the larger folds. Drag folds having axes one to several inches apart are also common. The formation is much broken by closely spaced joints, and generally more than one set of joints is present. Faults are common, but little is known concerning their kind and size.

Dikes of fine-grained igneous rocks, mostly mafic in composition, cut the Birch Creek Schist. They display both aphanitic and porphyritic textures. Some of the dike rocks are metamorphosed, and others are not; thus, two or more periods of emplacement are indicated.

The Birch Creek Schist is regarded as Precambrian, possibly early Precambrian (Capps, 1940, p. 97).

LOWER TERTIARY(?) SEDIMENTARY ROCKS

Poorly exposed light-brown to brown clastic rocks that occur only on the north side of the Tanana River in the extreme eastern part of the area are apparently the sedimentary rocks which Brooks (*in* Mertie, 1937, p. 175–176) described as fine yellow sandy shale overlain by coarse sandstone and conglomerate. The sandy shale contains obscure molds of plant parts. Another exposure of these sediments is in the river bank at the base of a conical cratered hill immediately east of the boundary of the mapped area. Mertie (1937, p. 177–180) considered these rocks as probably early Tertiary.

NENANA GRAVEL

A small patch of poorly consolidated, deeply weathered brown gravel occurs on the north end of Independent Ridge. It is apparently flat lying and at least 8 feet thick, and it rests on a surface approximately 1,600 feet above the Tanana River. It is composed of well-rounded pebbles, cobbles, and boulders as much as 0.9 foot in diameter; rock types include quartz, schist, quartzite, diorite, and granite, in the proportions shown in table 2. Moffit (1954, p. 146–147) described similar deeply weathered, partly consolidated gravel on the west side of the Gerstle River and near MacCumber and Morningstar Creeks in the mountains south of Delta Junction, outside the mapped area. Poorly to partly consolidated, deeply weathered, apparently pre-Pleistocene gravel on the north flank of the Alaska Range is generally correlated with the Nenana Gravel. In the Nenana River region, this gravel in places unconformably overlies the Tertiary coal-bearing formation. On the basis of one fossil, *Trapa* sp. (Wahrhaftig, 1958, p. 11–12), the Nenana Gravel has been assigned an age of middle Miocene or younger (MacNeil and others, 1961, p. 1806).

TABLE 2.—*Composition of Nenana Gravel from Independent Ridge*

Sample 15	*Percent, based on count of 109 pebbles*
Granitic rocks	5
Diorite	3
Quartz and quartzite	53
Gneiss and schist	39

UPPER TERTIARY SEDIMENTARY ROCKS

Silt and clay containing thin carbonaceous layers occur on a tributary of the Johnson River between Horn Mountain and Macomb Plateau. The beds are gently inclined to the north and are at least 150 feet thick. A typical section is as follows:

	Thickness (feet)
Till, slumped	1–2
Silt, medium-gray; has yellow mottling	5.0
Clay and silt, gray; has yellow mottling and lenses of gray silt	50.0±
Shale, carbonaceous (bone coal), black, plastic; contains plant parts	.3
Silt, dark-gray	.7
Coal, black; contains plant parts	.2
Silt, gray, arkosic; slumped in places	5.0

Benninghoff (Benninghoff and Holmes, 1961) described a spore and pollen flora from the carbonaceous layers which includes the conifers *Picea*, *Pinus*, *Tsuga* (two species); broad-leaved tree genera *Betula*, *Alnus*, *Carya*, *Juglans?*, *Quercus?*, and *Tilia; Ilex;* ferns *Dryopteris*, *Osmunda cinnamomea*, and *Adiantum;* and club moss *Lycopodium*. This flora, because of its mixture of conifers and temperate-zone broad-leaved trees, is markedly different from both the temperate-zone mid-Tertiary floras and the boreal flora of the Pleistocene. These beds are apparently younger than the coal-bearing formation of the Nenana River region, which is now regarded as Eocene (Wahrhaftig, 1958, p. 10), and they are probably younger than the Jarvis Creek deposits, correlated with the coal-bearing formation (Wahrhaftig and Hickcox, 1955, p. 359).

IGNEOUS ROCKS

GRANITIC ROCKS

Granitic bodies of batholithic size occur in the lower Gerstle River area, on Horn Mountain and Knob Ridge, and along the north side of the Tanana River from Lake George to the vicinity of Tanacross. The rocks range in composition from diorite to granite. They are fine to coarse grained, and some are porphyritic, having phenocrysts of feldspar more than 1 inch long. The most common dark mineral is biotite, but hornblende is also present in many rocks. The rocks are generally gray, but some are pink because of pink feldspar or weathering. Rectangular jointing is common, and the joints range from widely to closely spaced. In places, dikes and lenticular granitic bodies extend into the country rock and are probably apophyses and offshoots from the main pluton or plutons. Dikes also cut the granitic rocks in places, as in the vicinity of Dot Lake and on the south side of the Tanana River 11 miles east-northeast of Tanacross. Most of the dikes are dacitic orrhyolitic in composition, but some may be more mafic.

The lead-alpha ages of three widely spaced granitic samples indicate that most of the granitic rocks of the mapped area are probably Cretaceous in age (table 3).

TABLE 3.—*Age of granitic rocks*

[From lead-alpha ages of included zircon. T. W. Stern, written commun., June 23, 1960]

Sample	*Location*	*Age (million years)*
16	Gerstle River quarry	105±10
17	Horn Mountain	90±10
18	Near Dot Lake	110±10

VOLCANIC ROCKS

A small hill of basalt rises above a Pleistocene gravel plain north of the highway, about halfway between Tanacross and Tok Junction. Excavation for a pipeline pumping station and a fuel storage facility has resulted in excellent exposures on this isolated hill. The rock is dark gray to black; locally, it is porphyritic, having plagioclase phenocrysts. Zones of intense crushing and fracturing are common; along them, deep weathering and secondary lime deposition have occurred. The form, composition, and fractured condition of this basaltic body suggest that it is a remnant of a volcanic neck.

Other volcanic rocks, probably mostly basaltic, crop out in a hill on the north side of the Tanana River about 7 miles north-northeast of the basaltic mass just described. These rocks may be the remains of a shield volcano.

The mafic volcanic rocks are tentatively considered Tertiary in age because they are younger than the Cretaceous granitic rocks but do not appear fresh enough to be Quaternary in age. Mertie (1937, p. 226–228) considered other similar volcanic rocks in the Yukon-Tanana area to be of Tertiary age.

SURFICIAL GEOLOGY

DELTA GLACIATION

The oldest recognized Pleistocene sediments were deposited during the Delta Glaciation. This advance was named by Péwé (1952, p. 1289) for a pair of prominent end moraines in the Fort Greely and Delta Junction area. Parts of the type moraines appear in the extreme northwest corner of the map.

Péwé (1952) also described high-level glacial deposits in the middle Delta River valley, which are attributed to the earlier Darling Creek Glaciation. Although no evidence for this early advance has been found in the mapped area, it is possible that some of the nonglacial deposits, such as rubble or alluvium, may be as old or older than the Darling Creek Glaciation.

MORAINE DEPOSITS

In addition to the two large moraines in the type area, large end moraines of the Delta Glaciation were deposited in the valleys of the Gerstle, Little Gerstle, and Robertson Rivers and in the valleys of Dry, Berry, and Yerrick Creeks. Dozens of small moraines, tentatively correlated with the Delta Glaciation, lie in valleys of streams tributary to these streams or to the Tanana River. The moraines in the small valleys typically rest on steep piedmont slopes or lie within the cirques. Ground moraine of this glaciation occurs on Horn Mountain and Macomb Plateau. This till was apparently deposited by a small ice cap fed, in part, by cirque glaciers south of the mapped area. Outlet glaciers flowed down Dry Creek and formed a distinct end moraine; they also flowed down Berry Creek and down the unnamed stream between Berry and Dry Creeks.

The large Delta end moraines retain some of their original forms, such as knobs, ponds, ridges, and drainage channels; but they also show distinct signs of modification by mass movement, by eolian deposition, and by both glacial and nonglacial stream action. Delta moraines that have suffered the greatest change are those which were nearly overridden by younger glaciers whose melt-water streams scoured the frontal slopes of the older end moraines. This situation is well illustrated on the moraine north of the Robertson River, where channeling by melt water and nonglacial streams was severe. In minor valleys where the Delta moraines were deposited on steep slopes, very little of the knob-and-kettle topography remains because of the vulnerable position of these deposits in the path of torrential streams. Delta moraines in the major valleys are as much as 200 feet thick, and frontal slopes range from 1 to 20 percent.

Surface boulders are widely scattered, well weathered, and usually small. Other common microrelief forms are sedge tussocks and earth hummocks, especially in bogs and swales. Ground moraine on Horn Mountain and Macomb Plateau displays a wider variety of minor features, including active segregated stone circles, nets, and stripes; unsegregated mounds, terracettes, and soil stripes ("horsetail" drainage patterns); and frost scars or pits. Delta till is poorly stratified, unconsolidated, poorly sorted, and gray to light yellowish brown. Coarse particles are angular to well rounded. The till consists of variable mixtures of granitic rocks, gneiss, schist, quartzite, quartz, and a minor amount of basalt and diorite. Oxidation and disintegration of particles have occurred throughout the entire thickness of most natural exposures; the deepest oxidation observed was on Horn Mountain, where iron staining has occurred to a depth of at least 10 feet. The moraines are covered by loess, which is very thin on knobs and ridges but is more than 2 feet thick in swales or on level areas near wide bare flood plains.

OUTWASH GRAVEL

Delta outwash is widespread, but it is not shown on the map because it has coalesced with other gravel or has been partly buried or reworked. It is included in the fan-apron unit discussed below. Immediately in front of Delta moraines, Delta outwash is unmodified and consists of light-yellowish-brown gravel ranging in size from sand to boulders. Particles are well rounded and include granitic rocks, gneiss, quartzite, schist, and minor amounts of mafic rocks. The gravel is stained by iron in the upper 3.5 feet, and disintegrated fragments occur to a depth of at least 12 feet. A layer of silt, normally 1 to 2 feet thick, mantles this gravel.

DONNELLY GLACIATION

The youngest major glaciation is named for a large, nearly unmodified moraine near Donnelly Dome south of Delta Junction (Péwé, 1952, p. 1289). The physiography of this moraine in the Delta River valley, south of the mapped area, suggests that this advance was compound. Moraines of this glaciation also rest in the valleys of Granite and Jarvis Creeks and on the piedmont of Granite Mountain (T. L. Péwé and G. W. Holmes, unpub. data).

MORAINE DEPOSITS

End moraines correlated with the Donnelly advance occur on the Gerstle, Little Gerstle, Johnson, and Robertson Rivers; on Dry, Berry, and Yerrick Creeks; and on many smaller streams in the Alaska Range. Donnelly moraines consist of steep-sided hillocks and ridges interspersed with small kettle depressions and ponds. Slopes of the moraine fronts, knobs, and ridges exceed 30 percent in places. The Donnelly moraines are covered by large slightly weathered closely spaced boulders, except for those moraines buried by loess, such as the Johnson River moraine. Patterned ground is poorly defined, except on the silt that has collected in swales.

Donnelly till is unstratified, unconsolidated, and poorly sorted. It is gray, olive brown, or yellow brown. Large fragments are angular to subrounded and include schist, gneiss, quartzite, quartz, and granitic and fine-grained mafic rocks. The upper 1–1.5 feet is a weathered zone containing stained and disintegrated schist, gneiss, or granitic rocks. It is mantled by loess or alluvial silt ranging in thickness from less than 0.1 foot to 3 feet.

In a few of the higher cirques, upvalley from Donnelly terminal moraines, lie distinct end moraines tentatively correlated with a late Donnelly advance. Most of these moraines lie less than a mile from headwalls of cirques in the mountains between the Robertson River and Tanacross. They are typically crescent shaped and have very steep frontal slopes, knob-and-kettle topography, and a cover of closely spaced, slightly weathered boulders and tundra vegetation. The till is composed of angular boulders and smaller fragments of rock lithologically similar to the bedrock upvalley; it has been weathered to depths of as much as 1 foot. The weathering and the tundra cover of these moraines contrasts with the fresh bare bouldery moraines (such as occurs south of the mapped area) near or resting against the modern glaciers of the eastern Alaska Range. This contrast suggests that they represent a late Pleistocene advance rather than a Recent advance.

OUTWASH GRAVEL

Discrete outwash aprons or valley train remnants of the Donnelly Glaciation are not common, for they have merged laterally with, or have spread over, older gravel sheets in many places. The best examples of Donnelly outwash deposits are along the Gerstle and Little Gerstle Rivers, east of the Johnson River, on Yerrick Creek, and on the steep mountain front southwest of Tanacross. The maximum observed thickness is about 77 feet (on the south bank of the Tanana River between the Little Gerstle and Johnson Rivers); but, elsewhere, vertical exposures indicate that the outwash gravel may be only 4 feet thick, such as along the lower Gerstle River. The outwash occurs as nearly flat aprons and terraces or, where it rests on steep piedmont slopes, as channeled fans. The outwash is composed of poorly stratified poorly sorted, well-rounded gravel and boulders as much as 2.5 feet across and includes interstratified sand lenses. Granitic rocks, gneisses, quartzite, and quartz are the commonest rock types; some schist and mafic rocks also are present. The upper 2–3 feet is oxidized and contains some disintegrated schist fragments; a mantle of eolian or alluvial silt or sand as much as 3.5 feet thick rests on most of these deposits.

FAN-APRON DEPOSITS

Extensive sheets of gravel spread from the mountains in the form of fan aprons, which are composed of coalescent alluvial fans from glacial and nonglacial sources. For discussion, these deposits are divided into two types: (1) fan aprons composed mostly of locally derived rocks from the Alaska Range, and (2) a fan apron composed mostly of volcanic rocks from outside the mapped area.

FAN APRONS COMPOSED OF ALASKA RANGE ROCKS

The most extensive of these deposits lie on the piedmont of the Alaska Range, northwest of the Gerstle River, on both sides of Bear Creek, and southeast of the Robertson River. Maximum thickness observed in terrace scarps is 38 feet. The broad plain northwest of the Gerstle River is mantled in places by silt and peat deposits and low (unmapped) sand sheets, and it is pocked by several pond and dune depressions. The plain in the Bear Creek area is nearly flat and featureless, but the steep coalescent fans southeast of the Robertson River are marked by ridges and channels created by torrential mountain streams. These fans are composed of poorly stratified light-yellowish-brown pebble-to-boulder gravel. As suggested in table 4, major components were derived from Birch Creek Schist, granitic rocks, and possibly the Nenana Gravel.

Basalt and andesite occur as minor components in some samples; this is consistent with the known distribution of these rock types in the Alaska Range (Moffit, 1954, p. 163–165). Gravel in the fan aprons is stained by iron to depths of as much as 22 feet; disintegrated stones occur throughout the entire section in nearly all exposures. Silt or, less commonly, younger unweathered gravel or sand mantles the gravel deposits; the thickness of the mantle ranges from 1 to 10 feet. In many places along the major tributaries of the Tanana River, the silt mantle contains peat lenses and a thin ash layer. These fan aprons are adjacent to Delta end moraines in places but cannot be mapped as discrete Delta glaciofluvial deposits because their lateral boundaries merge with nonglacial gravel or with glaciofluvial deposits of a younger advance. The reasons for this relation are:

1. Post-Delta trenching of the Delta outwash has been negligible except along the major rivers of the Alaska Range; this has probably been due to a sudden loss of discharge as the streams have emerged from the mountains and infiltrated the gravel piedmont, as occurs at the present time.
2. Alluviation between ice advances or during a later glaciation resulted in the deposition of an indistinct sheet of gravel on the older glaciofluvial material or in the reworking of the older gravel rather than in the formation of distinct terraces deposited in a trench cut in the older gravel.
3. Streams from adjacent unglaciated valleys deposited alluvium which coalesced laterally with the glaciofluvial gravel.

Although many of the fan aprons are composed mainly of Delta outwash, they have been modified or reworked, or their boundaries have been obscured by later alluviation; thus, as a unit, they cannot be assigned a definite age.

TABLE 4.—*Composition of fan-apron deposits*

[Figures, in percent, based on a minimum of 100 pebbles per sample]

Component	Northwest of Gerstle River							Bear Creek area	Piedmont southeast of Robertson River	Tanacross-Tok Junction area				
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Granitic rocks	2	27	11	4	32	4	18	4	3	4	7	13	18	21
Basalt, dense	10	4	2	2	4	2	3	9	0	53	59	60	51	48
Basalt, vesicular	0	0	0	0	0	0	0	0	0	8	4	6	20	16
Quartz and quartzite	22	19	25	41	18	7	5	20	3	14	3	6	6	9
Gneiss and schist	58	47	62	53	46	87	71	26	88	3	5	7	2	0
Andesite	0	0	0	0	0	0	0	16	0	5	9	5	0	0
Miscellaneous	8	3	0	0	0	0	3	25	6	13	13	3	3	6

FAN APRON COMPOSED OF VOLCANIC ROCKS

This apron, which occurs in the Tanacross-Tok Junction area, forms a wide, nearly flat, featureless gravel plain. It is composed of moderately well stratified unconsolidated, fairly well sorted brown to reddish-brown well-rounded pebble gravel. The composition (table 4) contrasts with that of other fan aprons in respect to the high percentage of basalt, the presence of vesicular basalt, and the low percentages of granitic or Birch Creek Schist rock types. Rocks in the miscellaneous group include tuff, gabbro, rhyolite, amygdaloidal basalt, diorite, limestone, mudstone, felsite, and shale. The gravel in this fan apron is stained by iron to the base of the deepest exposures (6 ft) and is mantled by loess 1–1.5 feet thick. The origin of this fan apron is unknown. Its composition, however, suggests volcanic sources, possibly in the Copper River basin to the south, in the Nabesna River valley to the southeast (the Nabesna River heads in the Wrangell Mountains and is a major tributary of the upper Tanana River), or along the Tanana River immediately east of the mapped area. Although the deep weathering suggests that the fan apron is as old as the Delta Glaciation, present evidence does not demonstrate whether it is glacial, nonglacial, or both.

ALLUVIAL SILT

Fine-grained alluvium lies in nearly all valleys which head in the unglaciated parts of the Yukon-Tanana upland and in the hills beyond the glacial limit southwest of the Tanana River. The maximum observed thickness, in a terrace scarp on Fish Creek northwest of Tanacross, is 9 feet. These valley-fill deposits are commonly covered by peat, earth hummocks, and sedge tussocks, and they are dotted with small bogs and ponds or are slightly incised by small streams. The alluvium is composed of well-stratified brown, black, or gray silt, sandy silt containing interbedded wood fragments, and both convoluted and undisturbed peat layers.

This alluvium is not easily correlatable with glacial deposits and, therefore, cannot be assigned a definite chronological position. Inasmuch as most of these deposits are incised, however, they are probably not forming at present.

RUBBLE

Debris derived by frost action from local sources rests on flat or nearly flat upland surfaces of some of the foothills, such as Horn Mountain and Knob Ridge. On Horn Mountain the rubble is derived from bedrock and from drift of a small ice cap, and it consists of particles of schist, gneiss, quartzite, and granitic rocks. Here rubble occurs as block fields that merge with talus from the bedrock knobs; as segregated rings, nets, loops, and stripes; or as unsegregated steps, lobes, spot medallions, and hummocks. Rubble on Knob Ridge is granitic and occurs as large segregated boulder rings and nets or as boulder fields. Debris on Knob Ridge was not affected by glaciation; hence, some of it may be older than the Delta advance. Rubble on Horn Mountain probably has developed since the Delta Glaciation. The freshly upturned and riven boulders and the rings and mounds having bare centers demonstrate that this material is being disturbed by frost action and that rubble formation occurs under present climatic conditions.

TALUS

Sheets or cones of angular, locally derived rock fragments occur on steep valley and cirque walls in the mountains. Only the larger talus sheets are shown on the map; thin sheets and narrow stripes of talus mantle nearly all steep slopes at higher altitudes. Talus commonly merges downslope with coarse angular alluvium, colluvium, or glacial drift on the lower slopes and valley floors. Most of the larger accumulations are weathered; however, fresh talus occurs as narrow stripes in gullies in the highest cirques. Talus, like rubble, has been forming since the earliest recorded glaciation.

COLLUVIUM

Undifferentiated mixtures of loess, talus, alluvium, drift, and bedrock fragments that have been transported downslope by gravity, aided by frost action and sheet wash, are widespread in the area. Colluvium covers nearly all middle and lower slopes and rests on some valley floors. The largest colluvium-covered area shown is on the rolling unglaciated surface of Independent Ridge, which is mantled by a mixture of loess and bedrock fragments and which is marked by well-formed solifluction lobes, steps, and stone stripes. This material has been forming continuously since the Delta Glaciation or before. Colluvial mixtures of drift, alluvium, and talus rest on the lower slopes of most alpine valleys. This material has been forming since the last major glaciation.

ORGANIC SILT

Alluvial, eolian, and lacustrine silt, mixed with peat and finely divided organic material, occurs throughout the area in several environments: in swales on summits of the foothills, in kettle and channel depressions on the moraines, in channels cut in coarse alluvium along the foot of the mountain, in channel and late depressions on the low terraces along the Tanana River, and in the valleys of the unglaciated hills north of the river. The surface of these deposits is commonly marked by earth hummocks or sedge tussocks, and bog or marsh vegetation is characteristic.

The silt is well stratified, well sorted, poorly consolidated, and light brown to black. Depending on drainage, weathering may produce a mottled gray and brown Half-bog soil or a black Bog soil.

Some silt has been accumulating continuously since the Delta Glaciation or before. Younger silt rests in swales on Donnelly moraines and outwash or on post-Donnelly terrace deposits and alluvium.

STREAM-TERRACE DEPOSITS

Low terraces lie along the Tanana River and along nearly all the major tributaries from the Alaska Range. They rise 2–15 feet above the present streams or active flood plains and, in places, lie as much as 7 feet below the surface of the alluvial silt deposits. Terraces along the Tanana River are almost flat and are marked by meander and channel scars, shallow bog- or pond-filled depressions, tributary channels, and silt-covered sand dunes. Only the largest areas of organic deposits are shown on the map, but many smaller areas of silt and peat occur on the Tanana terrace. Terraces on the tributaries have steeper slopes, are better drained, and are marked chiefly by channel scars parallel to the stream.

These low terraces are composed of stratified sand and rounded gravel and boulders overlain by 1–5 feet of stratified silt or sandy silt and interbedded peat. The terraces are younger than the Donnelly Glaciation, as they lie below and against terrace scarps on Donnelly outwash aprons; however, they predate the stabilized silt-covered sand dunes that rest on them.

EOLIAN DEPOSITS

The largest sand dunes occur near the lower Gerstle River; these are as much as 15 feet high and 3 miles long and are oriented northwest-southeast. They are composed of yellow to light-gray well-sorted crossbedded sand, and most are covered by 1–3 feet of loess. These dunes rest on the low terrace deposits, which are post-Donnelly in age. The loess and vegetation cover suggests that the dunes are not being formed at present.

Formless tree-covered sand sheets lie along the Alaska Highway west of the Gerstle River. These deposits are typically less than 10 feet thick and are interspersed by shallow dry depressions and ponds. The sand is medium yellow, well sorted, and crossbedded. These deposits cannot be outlined on aerial photographs and do not appear on the map; however, a hint of their general distribution is the occurrence of the small dry or pond-filled depressions.

Small sand sheets are moved by the wind across the flood plains of the Gerstle, Johnson, and Robertson Rivers. These deposits, which are not mapped, are as much as 5 feet high and may be 30–50 feet across. They are composed of fresh gray sand derived from the flood plain.

Loess is widely distributed, especially on the moraines of the Johnson and Robertson Rivers and on the bedrock hills north and south of the Tanana River. It is not mapped, although reworked loess occurs in organic silt, alluvial silt, stream-terrace deposits, and colluvium, which are shown on the map. The loess is typically 1–3 feet thick, the greatest thicknesses being along the banks of the major rivers. The loess is light-brown, faintly stratified well-sorted sandy silt; in well-drained localities a reddish-brown Subarctic Brown Forest soil has formed, and in poorly drained areas a mottled gray and brown Half-bog soil has formed. Loess has been deposited from the Delta Glaciation to the present.

FLOOD-PLAIN ALLUVIUM

Alluvium is exposed on the surface of active flood plains of most of the mountain streams and of the Tanana River. On the Gerstle, Johnson, and Robertson Rivers, on Yerrick Creek, and on some parts of the Tanana River, alluvium occurs as islands surrounded by braided channels, which shift laterally during the warm season. Hence, the distribution of alluvium shown on the map is merely suggestive of their pattern and represents only the occurrence at the time the base-map data were compiled. On the larger streams, the flood-plain gravel is incised by dry channels and is mantled by migrating sand sheets. The alluvium consists of fresh glacial silt, sand, and well-rounded gravel and boulders; it is poorly sorted and irregularly stratified. Parts of the flood plain are covered by overflow ice in winter; in summer, silt is carried from the flood plains and deposited as loess on the terraces and nearby moraines.

GEOLOGIC HISTORY

This résumé is drawn from published literature and from the present study. In the Precambrian, a very thick sequence of sedimentary rocks was deposited and was later metamorphosed, faulted, and folded. The intensity of metamorphism and deformation was sufficient to obscure all apparent vestiges of original structure and stratification. These rocks, identified as the Birch Creek Schist, probably were elevated and eroded before the next younger rocks were deposited. Although Paleozoic and Mesozoic rocks are not preserved in the mapped area, their occurrence elsewhere in the Alaska Range attests a long sequence of sedimentation (Capps, 1940, p. 130–131).

Deformation and batholithic intrusion of the Alaska Range occurred at intervals during the Cretaceous (Payne, 1955). At least some of the granitic rocks in the mapped area were emplaced at this time. Then the mountains were eroded to low relief; and, in Eocene time, clay, silt, gravel, and coal were deposited in nearby local basins (Wahrhaftig, 1958, p. 10), such as near Jarvis Creek immediately west of the mapped area. The nonmarine sedimentary rocks in the Tok

Junction area may also have been deposited in early Tertiary time. In late Tertiary, the coal-bearing formation was deformed, and the associated uplift of the Alaska Range resulted in the deposition of the Nenana Gravel (Moffit, 1954, p. 183). Carbonaceous silt and clay were also deposited in local basins, such as the basins that formed near the Johnson River. The Nenana Gravel is regarded as Oligocene or Miocene, probably Miocene (Wahrhaftig, 1958, p. 12), and the carbonaceous silt and clay are considered to be Pliocene (Benninghoff and Holmes, 1961).

Volcanic activity occurred during Tertiary time, as shown by bodies of lava in the Tok Junction area.

Final elevation and the creation of the major drainage systems of the Alaska Range occurred before the Delta Glaciation. Glaciers of the Delta Glaciation flowed from the present cirques and formed ice caps on several of the flat-topped foothills such as Horn Mountain and Macomb Plateau. Most of the large valley glaciers of this advance became piedmont ice tongues and deposited broad moraines on the floor of the Tanana lowland. The glacier in the Robertson River valley was the largest and may have slightly deflected the course of the Tanana River, but no evidence was found to show that the Tanana River was dammed during this advance. There is no evidence, however, that a glacier reached the mouth of the Johnson River during the Delta Glaciation. During this glaciation, several discrete outwash plains were formed, and some of them coalesced with gravel from nonglacial mountain streams. This outwash probably was graded to nonglacial silty alluvium from the Yukon-Tanana upland.

The Donnelly Glaciation was almost as vigorous as the Delta advance in the major valleys, but it was appreciably less extensive in small valleys. In the Johnson River valley, Donnelly ice moved at least to the banks of the Tanana River and may have crossed the present channel and deflected the river toward Lake George. If drift of the Delta Glaciation lies in the Johnson River valley, Donnelly deposits have mantled or incorporated them. Donnelly outwash deposits are restricted to small aprons and terraces near the major end moraines; other gravel of Donnelly origin lies in formless deposits either on older glacial outwash or coalescent with the older outwash and nonglacial gravel. A late advance, probably a readvance of Donnelly glaciers, is recorded in a few high well-sheltered cirques.

Deposition of organic silt, eolian sand, loess, alluvial fans and fan aprons, and flood-plain deposits, as well as formation of talus, rubble, colluvium, and low terraces, while not always reflecting events as distinct as glaciations, continued to play major roles in the modification of the landscape throughout the late Pleistocene and into the Recent.

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