Quaternary Geology of the Mount Chamberlin Area Brooks Range, Alaska

GEOLOGICAL SURVEY BULLETIN 1201-B

Prepared on behalf of the U.S. Air Force Cambridge Research Laboratories

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By G. WILLIAM HOLMES *and* CHARLES R. LEWIS

CONTRIBUTIONS TO GENERAL GEOLOGY

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A study of glacial and other surficial deposits in the mountains and foothills of Arctic Alaska

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QUATERNARY GEOLOGY OF THE MOUNT CHAMBERLIN AREA, BROOKS RANGE, ALASKA

By G. William Holmes and Charles R. Lewis

ABSTRACT

Glaciers originating in the Franklin Mountains of the northeastern Brooks Range advanced in four major Pleistocene glaciations and in two minor Recent fluctuations. The oldest advance, the Weller Glaciation, covered the foothills and reached the south flank of the Sadlerochit Mountains. This advance is recorded by scattered quartzite and granitic erratics on bedrock ridges and by smooth sheets of till on the middle and lower slopes. These oldest till deposits have been profoundly modified by frost action and by processes caused by gravity. Next, the Chamberlin Glaciation deposited till sheets and outwash aprons which still retain some of their original form. The end moraine of this glaciation is clearly mappable, and the moraine-outwash relationship is generally preserved, but minor topographic features have disappeared. The less extensive Schrader Glaciation is represented by ridged lobate end moraines, some of which enclose Lake Schrader. These moraines are marked by a few shallow ponds and low hillocks and by a widely distributed, well-formed assortment of frost features. The last major advance, the Peters Glaciation, did not extend beyond the mountain front. The moraines are fresh, bouldery, and steep sided, and frost features are rare or absent. Modern glaciers have formed two groups of moraines: a slightly weathered single or double moraine several hundred yards from the ice front, and a very fresh moraine in contact with the ice.

The development of colluvium, alluvial-fan deposits, terrace deposits, alluvial silt, and stream gravel, although it does not clearly record all climatic changes within the Quaternary, was an important aspect of the present landscape.

INTRODUCTION

The Mount Chamberlin area, which includes Lakes Peters and Schrader, is in the eastern Brooks Range, northeastern Alaska (fig. 1). The area mapped includes the Mount Michelson B–2 quadrangle and the southern part of the Mount Michelson C–2 quadrangle. Neither of these maps has been published, but manuscript copies, which were used in compiling the 1956 edition of the U.S. Geological Survey Alaska Topographic Series Mount Michelson sheet (scale 1:250,000), were available as a base for the geologic map (pl. 1). Mount Cham-

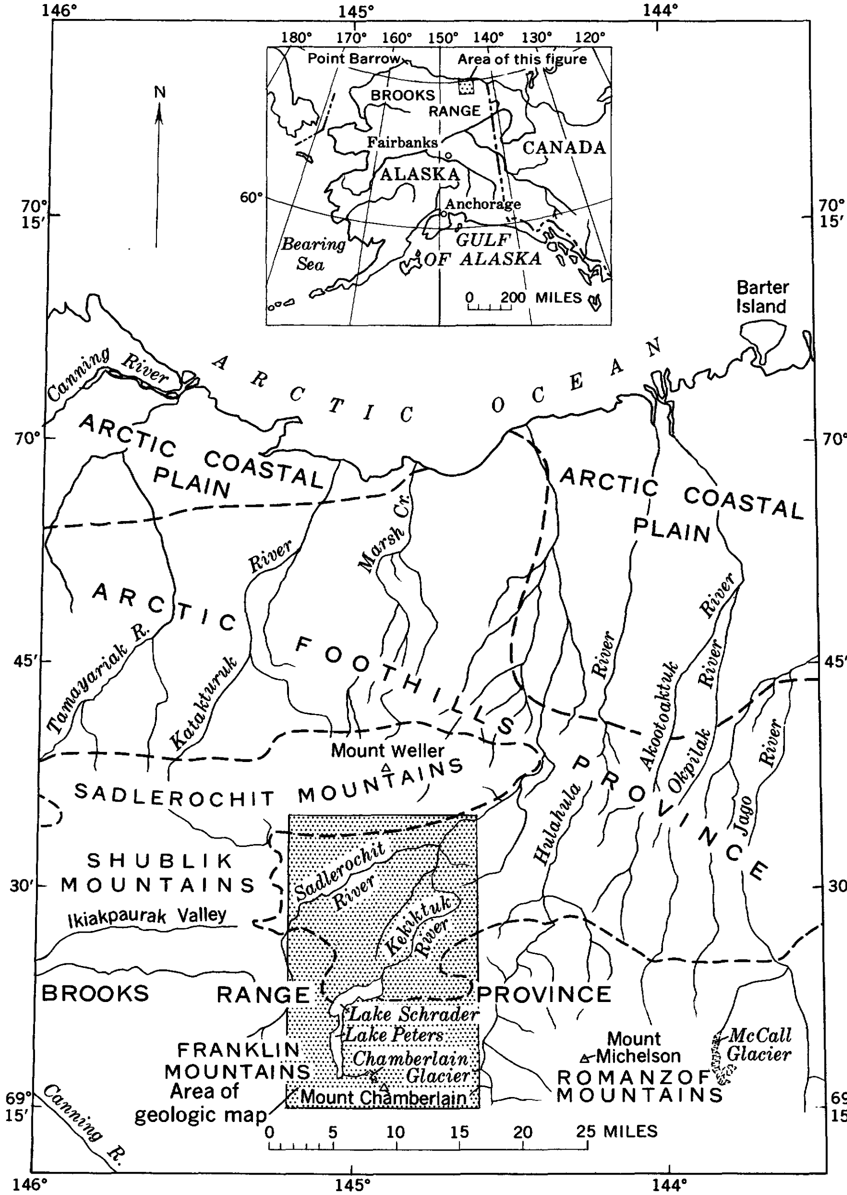

FIGURE 1.—Map showing physiographic provinces of northeastern Alaska.

berlin is about 60 miles south of the Arctic Ocean, 100 miles west of the Canadian border, and 30 miles north of the crest of the Brooks Range. The area is drained by the Sadlerochit River and its tributaries. The large Hulahula River valley lies immediately to the east, and the Canning River drains the region to the west. The mapped area lies within the recently created Arctic National Wildlife Range.

Investigations were conducted by Holmes from June 21 to August 29, 1958, and in April and May 1959, and by Lewis in June 1959. Traverses were made throughout the northern half of the area, down the Sadlerochit River, and up the major valleys and tributaries in the mountains. The area immediately east of Mount Chamberlin was mapped by photogeologic methods, supplemented by reconnaissance from a single engine plane.

The project was conducted by the U.S. Geological Survey on behalf of the Terrestrial Sciences Laboratory, Geophysical Research Directorate, U.S. Air Force Cambridge Research Laboratories. Fernand de Percin, meteorologist, U.S. Army Quartermaster Research and Engineering Center, and John E. Hobbie, limnologist, University of California, took time from their own studies and assisted Holmes on several traverses. Livingston Chase, geologist, and Lloyd Spetzman, botanist, both of the U.S. Geological Survey, accompanied Lewis on the Sadlerochit River traverses. The base camp at Lake Peters and other logistic functions were under the management of Maj. Frank Riddell, Royal Canadian Army (Ret.).

The Mount Chamberlin area has received considerably more scientific attention than other parts of the eastern Brooks Range. Leffingwell (1919) spent three seasons in the region, including a two-month study of the area around Lakes Peters and Schrader. He described, mapped, and named many of the major bedrock units, devoted some attention to the glacial deposits and the frost features, and noted especially the glacial deposits around Lake Schrader (1919, p. 136–138). Whittington and Sable (1948) and Brosgé and others (1952) reexamined the bedrock in the central and northern parts of the area. Their interest was in extending the stratigraphic and structural investigations of Naval Petroleum Reserve No. 4, which lies along the north slope of the range to the west. These investigations also resulted in two recent papers on glaciation of the north-central Brooks Range (Detterman, 1953; Detterman, Bowsher, and Dutro, 1958), which are especially germane to the present study. During the International Geophysical Year, glaciological and geological studies were conducted in the area east of the Hulahula River (Mason, 1959; Sater, 1959; Keeler, 1959; Sable, 1961). More recently, Stephen Porter (1963) modified the chronology of Detterman and others.

GEOGRAPHIC SETTING

TOPOGRAPHY

The mountains of this region, specifically the Franklin and the Romanzof Mountains (fig. 1), are as rugged as any part of the Brooks Range, and include the highest peaks in the North American Arctic area. Mount Chamberlin (fig. 2) and, to the east, Mounts Michelson and Hubley rise in the drainage of the Okpilak and Jago Rivers and are approximately 9,000 feet above sea level. The general level of the peaks is 6,000 feet and local relief is typically 3,000 to 4,000 feet. The mountains are sharp crested and steep and are deeply dissected by closely spaced streams.

North of the Franklin Mountains is a double pair of ridges and valleys, beyond which are the outlying Shublik and Sadlerochit Mountains. The Arctic Foothills province borders the Sadlerochit Mountains on the north and extends to the basin of Lake Schrader. North of the foothills is the Arctic Coastal Plain, which is narrow in this region.

Descriptions of the physiographic subdivisions of Arctic Alaska appear in Payne and others (1951), Black (1955, p. 118), and Reed (1958, p. 5–10). Physiographic boundaries on figure 1 are based on recent work by Lewis.

The Sadlerochit River drains most of the area by means of its main branch on the west and the Kekiktuk River ("lake branch" of Leffingwell, 1919, p. 56). Streams in the area rise from small glaciers, from melting snow and seasonally frozen ground, and from rainfall. Although total precipitation is light, the streams respond quickly to rainstorms because the shallow permafrost restricts infiltration. Most of the streams in the Brooks Range have flood plains of boulders and gravel, whereas those originating on the rolling tundra of the Arctic Foothills flow over silt- and peat-mantled valley floors. Some of the streams of the foothills have developed beaded drainage features consisting of small circular thaw ponds along the paths of the streams.

VEGETATION

The following summary of the vegetation is based on the work of Spetzman (1959). The Arctic Coastal Plain, the Arctic Foothills, and the north slope of the Brooks Range are mostly covered by tundra vegetation, except for the barren areas on the mountains and some of the larger valleys, where willow and poplar grow in narrow groves. The tundra consists of a mosaic of several plant communities, such as moist cottongrass meadows, dry meadows, sedge marsh, and willow brush. The largest and greatest variety of species occur in the foot-

FIGURE 2.—Mount Chamberlin (right), Lake Peters, and part of Lake Schrader, looking north, showing large alluvial fans in Lake Peters and delta between the lakes.

hills; the number and size of plants decrease toward both the coastal plain and the mountains. The tundra in this part of Alaska consists of 439 known species of higher plants.

In the Mount Chamberlin area, dry-meadow tundra, composed of about 150 species of flowering plants (including grass, low willow, and heath shrub), covers the valley floors, low hills, and alluvial fans to an elevation of about 4,000 feet. Feltleaf willow (*Salix alaxensis*) as much as 6 feet high grows in patches along the streams. Dryad (*Dryas octopetala*) is dominant on moraine ridges, and mountain heather (*Cassiope tetragona*) form patches in snow-accumulation depressions. The vegetation from 4,000 to 5,000 feet consists of about 80 species, including *Saxifraga* and other alpine plants that grow only in favorable habitats such as moist areas below snowfields. Most of the area above 5,000 feet is barren, except for lichens and fewer than 10 species of flowering plants; above 6,000 feet lichens are the only vegetation.

CLIMATE

Weather records from Lake Peters have been made only during parts of the summer of 1958 (de Percin, 1959; Larsson, 1959) and during the period May 1959 to May 1960 (Rock, 1959; John E. Hobbie, written commun. 1961). Hence, little is known about climatic averages of the area; however, the record from Anaktuvuk Pass (table 1), 200 miles to the southwest and in a setting similar to that of Lake Peters, suggests in a general way the climatic conditions in the mapped area.

On the basis of analogy with Anaktuvuk Pass and on the brief record from Lake Peters, the summer climate of the mapped area may be summarized as follows: Average daily temperatures are generally above freezing, although minimum temperatures occasionally fall below 32°F; maximum temperatures during summer probably range from 65° to 75°F; abrupt temperatures changes are probably rare, in part reflecting the influence of the two large lakes; skies are commonly overcast and fog is common, especially at lower elevations in the major valleys; precipitation generally occurs as drizzle or light rain, but there are occasional light snowfalls, and thunderstorms have been observed; winds are generally light and are oriented parallel to the major valleys.

TABLE 1.—*Climatological data, Anaktuvuk Pass, Alaska*

[Data from U.S. Weather Bureau, 1954–59]

Month	Average temperature (°F)	Average precipitation (inches)	Month	Average temperature (°F)	Average precipitation (inches)
January	−11.7	0.52	July	50.7	1.38
February	−15.7	.51	August	43.1	1.43
March	−6.7	.75	September	29.9	1.12
April	4.5	.72	October	5.9	.93
May	32.1	.57	November	−7.6	.61
June	47.8	1.46	December	−16.2	.66
			Annual average	13.0	10.66

The observations of Hobbie (written commun., 1961) and the record at Anaktuvuk Pass suggest that temperatures usually fall below freezing in September or early October and remain below freezing until the following April or May. Average daily winter temperatures probably range from about 10° to −20°F; several colder periods may have lows of −30° to −50°F. In winter skies are generally clearer than in summer. Winds tend to parallel the major valleys; chinooks from the south may occur, accompanied by temperatures above freezing. Snow accumulation probably does not exceed 3 to 4 feet (Leffingwell, 1919, p. 62) except in drifted areas.

The brief record at Lake Peters shows that wide variations occur from year to year in the mapped area. In the summer of 1958, temperatures did not fall below freezing until September, no snow fell at the lake, and ice on the lake melted in late June. During the summer of 1959, temperatures fell below freezing several times, snow fell at the lake station, and the lake ice did not melt until late July.

The mean annual temperature in the mapped area is probably about 10°F, and the 32°F isotherm is estimated to be reached or crossed 60 to 80 times per year, mainly in midspring and early fall.

SUMMARY OF BEDROCK GEOLOGY AND GEOMORPHOLOGY

LITHOLOGY

The following summary and accompanying sketch map (fig. 3) are based on the work of Leffingwell (1919), Whittington and Sable (1948), and Brosgé and others (1952).

The rugged mountains of the southern part of the area are composed of the Neruokpuk Formation (Late (?) Devonian or older), a sequence of quartzites, phyllites, schists, and argillites. Younger rocks lie to the north in east-west trending belts and appear as hogbacks or anticlinal hills and low mountains. In stratigraphic succession, these rocks are: an unnamed conglomerate (Mississippian (?), not shown on fig. 3); Kayak Shale (Mississippian); Lisburne Group (Mississippian), limestone and dolomite; Sadlerochit Formation (Permian and Lower Triassic), sandstone, siltstone, and shale; Shublik Formation (Lower (?), Middle, and Upper Triassic), dark shale, siltstone, sandstone, and limestone; Kingak Shale (Jurassic), black shale, and dark siltstone; and the Ignek Formation (Cretaceous), gray shale, siltstone, and sandstone.

STRUCTURAL GEOLOGY RELATED TO GEOMORPHOLOGY

The Franklin Mountains are part of the Romanzof uplift, a major structural element of the Brooks Range (Payne, 1955). The last major tectonic phase apparently occurred during the Pliocene and Pleistocene epochs. Major valley systems in this area were probably eroded during this time. The present elevation of the Franklin Mountains is attributable in part to the resistance of the Neruokpuk metasediments. This relationship may have been accentuated by uplift along major thrust faults along the north flank of the range.

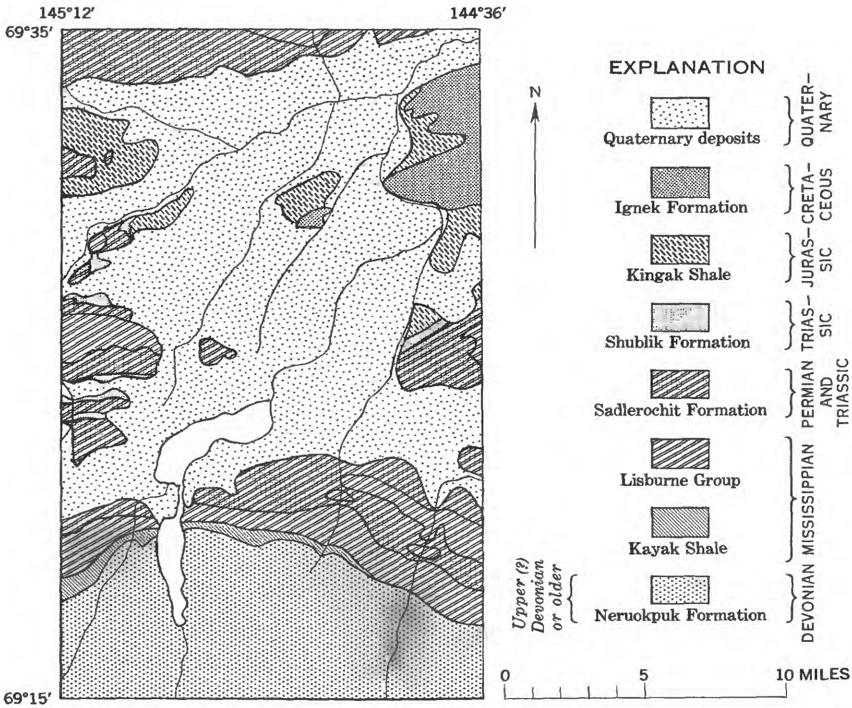

FIGURE 3.—Geologic sketch map of the Mount Chamberlin area, Brooks Range, Alaska (modified from Whittington and Sable, 1948, and Brosgé and others, 1952).

North of the Franklin Mountains the anticlines and synclines, both simple and overturned, produce an outcrop pattern of alternating ridges of resistant limestone of the Lisburne Group and sandstone of the Sadlerochit Formation that alternate with lowlands underlain by shale of the Sadlerochit, Shublik, and Kingak Formations (Whittington and Sable, 1948). The valleys and ridges influenced paths of north-flowing glaciers which coalesced as piedmont sheets in east-west troughs. The Sadlerochit Mountains were a barrier to the earliest glacier from the Franklin Mountains, causing the ice to be deflected down the Sadlerochit River valley.

GLACIAL DEPOSITS

The shallow permafrost table limits chemical weathering and makes examination of deposits at depth impractical; moreover, churning and flow of the thin active layer destroy or limit the formation of easily identifiable soil profiles. In this absence of sedimentary, pedologic, and other conventional criteria, the correlation of glaciations and the evaluation of the age of these events must be based primarily on geomorphology, and hence are difficult and uncertain, especially when comparisons are made with areas outside the Arctic.

WELLER GLACIATION

The oldest glaciation recognized in the region is here named for Mount Weller, a prominent peak in the Sadlerochit Mountains, which was named by Leffingwell (1919, p. 100) for Professor Stuart Weller.[1]

The existence of this glaciation was suggested by Leffingwell (1919, p. 137), who speculated that glacial ice reached the lower southern slopes of the Sadlerochit Mountains; he described erratics of possible glacial origin along Camp 263 Creek.

Deposits of the Weller Glaciation include several short low till ridges, a few gravel benches, and scattered erratics. These deposits lie at altitudes of 1,750 to 2,150 feet along the southern slopes of the Sadlerochit Mountains (pl. 1). The subdued, rounded ridges slope downvalley and resemble remnants of lateral moraines. Above these ridges are several small gravel benches, one of which is shown on the map 1 mile east of Camp 263 Creek; these benches, which are about 300 feet above the present river bed, may be kame-terrace remnants of the Weller Glaciation. Weller drift also appears as scattered erratics and till patches on bare shale ridges north of the nearly east-west stretch of Kekiktuk River. A scattering of erratic boulders in colluvium along the east side of Kekiktuk River in the northeast part of the mapped area may be reworked Weller till. Similar erratics along the Sadlerochit River in the extreme northeast part of the mapped area suggest that the colluvium there too is reworked Weller till. Also in the northeast, along the south side of the Sadlerochit Valley, east-striking ridges of soft shale show evidence of rounding by ice of the Weller Glaciation. These ridges are 300 to 400 feet above the river. Deposits of the Weller Glaciation are not recognized south of the till border of the next younger glaciation.

Weller deposits are rarely exposed. Surface boulders of this glaciation are 2 to 6 feet in diameter; most are quartzite, sandstone, or limestone; a few are schist or gneiss. The morainal ridges have a firm, dry surface of gravel and silt; there is little vegetation and only a few boulders on the surface. Among the few exposures are those along Camp 263 Creek; even here, however, the till is badly slumped and is mixed with old alluvium of the stream. The drift consists of poorly sorted, angular gravel and small boulders in a

[1] Leffingwell also honored other geology professors at the University of Chicago, which he attended, by naming peaks for them; for example: Mount [A. A.] Michelson, Mount [R. D.] Salisbury, and Mount [T. C.] Chamberlin.

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light-brown sandy matrix. Although Leffingwell (1919, p. 137) reported granitic erratics along this week, only sandstone, limestone, and minor fragments of schist and gneiss were noted by Lewis.

The discontinuity, fragmentary preservation, and subdued nature of the Weller deposits indicate that they have been extensively eroded. The low relief and smooth surface character of Weller deposits may also be a result of the composition of the till. The Weller glacier traversed a broader expanse of shale than subsequent glaciers, and probably contributed a large quantity of weak rock to the till. An initially subdued aspect of the Weller till as well as the presence of material that was susceptible to weathering and erosion may also be due to the shale which the glaciers crossed. Loess (see p. B14) may have blanketed and obscured some Weller moraine deposits.

CHAMBERLIN GLACIATION

The oldest glaciation represented by distinct end moraines is here named the Chamberlin Glaciation, from Mount Chamberlin, the dominant peak in the area. Leffingwell (1919, p. 137) described the terrain of the Chamberlin drift sheet, noting the large scattered boulders on the smoothly rolling tundra north of Lake Schrader.

The maximum extent of the Chamberlin Glaciation is indicated in places by a well-defined drift border and elsewhere by lateral drainage channels and scattered erratics. Ice from the Hulahula River valley moved westward through the lowland south of Kikiktat Mountain and joined the glacier that flowed northward from Lake Peters valley. The drift border on the south side of Kikiktat Mountain is generally well defined, although in places colluvium and alluvium have covered the till. Lateral channels that cut across both the bedrock structure and modern gullies on the west side of Kikiktat Mountain (fig. 4) probably formed during the maximum of the Chamberlin Glaciation. The ice surface apparently sloped steeply northward in this sector, toward the lobate terminus south of the main branch of the Sadlerochit River. North of Kikiktat Mountain the former position of the ice border is indicated by scattered erratics on bedrock bluffs east of Kekiktuk River. Where the Kekiktuk River makes its sharp swing to the west, the Chamberlin drift border is distinct, and a well-preserved outwash apron extends from the moraine front (fig. 5). The northern-most limit of Chamberlin Glaciation is also marked by a subdued end moraine, which merges with a more extensive outwash apron that flanks the Sadlerochit River in the northeast.

Stream cuts and other natural exposures of undisturbed Chamberlin till are rare. Most of the till has been disturbed by frost action and by mass movement. Turf-covered colluvium, derived from till and,

FIGURE 4.—West side of Kikiktat Mountain, viewed from Chamberlin ground moraine east of Lake Schrader outlet. Sloping channels on side of this mountain were probably formed during the Chamberlin Glaciation.

FIGURE 5.—Chamberlin end moraine and hills of Ignek Shale (center) and Kingak Shale (right), at the big bend in Kekiktuk River. Smooth profile of the outer edge of the Chamberlin end moraine in middle distance, left, merges with outwash apron that extends to the bank of the creek. Erratics of the Weller Glaciation lie on the shale hills in the background.

in places, from bedrock, normally extends to the banks of the streams. The few exposures, such as along the north-flowing creek immediately east of Kekiktuk River, may give some indication of the lithology of Chamberlin drift, but they cannot be regarded as sections of undisturbed till. Shallow permafrost limits the examination of the Chamberlin till (as well as younger till) on the slopes and summits of the moraines.

Chamberlin morainal deposits rest on the rolling terrain of the piedmont, apparently deriving their gross form from a preexisting mature topography. A few low mounds of till lie along the flat crests of the divides (fig. 6), but elsewhere the surface is smooth or gently rounded. Streams from the Franklin Mountains and the foothills cross the Chamberlin moraine in valleys 600 to 800 feet below the ridge tops. Tributaries are widely spaced marshy rills, which flow through peat- and silt-covered swales. Surface boulders are rare, although a few boulder patches occur on the ridges, and frost action commonly brings isolated stones to the surface. Patterned ground is conspicuous on Chamberlin drift.

Chamberlin till consists of fragments of all local bedrock types, notably quartzite, schist, sandstone, limestone, and conglomerate, and a dark-gray matrix derived in part from shale. Along its eastern border, this till contains a small amount of granitic rocks, presumably from the Mount Michelson area.

Figure 6.—Smooth surface of Chamberlin ground moraine on flat interfluve north of Lake Schrader. Schrader moraines (not shown) occupy valleys on each side of this ridge. Sadlerochit Mountains are on the skyline.

A few particle-size analyses were made of samples that are not necessarily representative, but which seem to be consistent with field observations (table 2). Chamberlin till appears to be a typical alpine drift derived from crystalline source rocks; it has a small fraction of silt and clay sizes, a moderately large fraction of sand size, and an abundance of particles of larger sizes. The till is very poorly sorted.

The drift has almost no weathering profile, probably because of the slow rate of chemical alteration and the churning of the surface layer by frost (Tedrow and Cantlon, 1958, p. 168–170). The only indications of weathering are the paucity of surface boulders and the presence in the drift of stained fragments of quartzite and schist; some schist fragments are partially disintegrated.

TABLE 2.—*Particle-size analyses of tills*

[Analyses by U.S. Geol. Survey, Washington, D.C. Samples are of particles less than 76.2 mm (3 in.) in diameter. Size limits are those used by U.S. Army Corps of Engineers: gravel, 76.2–5.76 mm (No. 4 U.S. Standard sieve); sand, 5.76–0.74 mm (No. 200 U.S. Standard sieve); and silt and clay sizes (fines), <0.74 mm]

Glaciation	Sample locality (pl. 1)	Composition (percent)			Median size (mm)	Sorting coefficient	Remarks
		Gravel	Sand	Silt and clay			
Peters	1	60	31	9	8.0	4.7	Lateral moraine; from Neruokpuk Formation only.
Do	2	33	40	27	.9	8.2	End moraine from several bedrock sources and lake silt.
Schrader	5	38	29	33	.7	21.8	Probably enriched by lake silt.
Do	6	36	44	20	1.2	9.5	
Chamberlin	3	61	28	11	12.0	7.2	Till buried by younger alluvium.
Do	7	44	38	18	3.2	9.0	

Outwash aprons associated with the Chamberlin moraine occur along the Kekiktuk and Sadlerochit Rivers in the northeast part of the mapped area. The small boulder-strewn aprons by the Kekiktuk River have been modified by enroaching colluvium and by streams, but are easily recognized as outwash-plain remnants (fig. 5). A more extensive, deeply trenched outwash apron extends northward from the moraine front near the junction of the Kekiktuk and Sadlerochit Rivers. This apron, about 150 feet above the streams, is composed of poorly stratified gravel and boulders in a matrix of angular shale particles; it may have been continuous with a high bouldery terrace at about the same elevation along the north side of the Sadlerochit River. Because this terrace may be a valley-train remnant, it has been mapped as a glaciofluvial deposit.

SCHRADER GLACIATION

The Schrader advance, younger and less extensive than the Chamberlin Glaciation, is here named for the large lake in the center of the study area. The lake was named by Leffingwell for F. C. Schrader of the U.S. Geological Survey, an early explorer and investigator of the Brooks Range.

This glaciation left well-defined lobate moraines, notably north and northeast of Lake Schrader. An end moraine on Katak Creek on the eastern edge of the area, is attributed to the Schrader Glaciation. The largest ice mass of this glaciation flowed down the valley now occupied by Lake Peters, pushed through the basin of Lake Schrader, and split into three lobes. The edges of this glacier were, in places, at least 1,000 feet above the present Lake Schrader, or about 1,200 feet above the bottom of the lake at its deepest part.

The marginal zone of the Schrader moraines, unlike that of the older drift sheets, consists of recognizable morainal features. The moraine front is fairly distinct and moderately steep; in places small streams flow in narrow valleys immediately in front of the moraine. The marginal zone, a belt as much as 1 mile wide, consists of two or more rounded, moderately steep ridges that have a relief of 30 to 100 feet (pl. 1, fig. 7). Many of these ridges are separated by narrow stream valleys floored with peat and silt. Other morainal features, such as kettles and knobs, are not common, and most of the ponds on the moraines have outlets. Behind (south of) the marginal zone, the ground moraine is drained by a widely spaced dendritic stream system.

Patterned ground and other frost features are well formed on Schrader moraines, and active earthflows (fig. 8) are common. Boulders mantle the flat ridge crests but many slopes and swales are completely covered by colluvium, peat, or turf. A loess mantle was not observed on this or other drift throughout most of this area, probably because of remoteness from broad, bare flood plains. However, Schrader till near the mouth of Katak Creek has a more silty texture in the surface layer; the silt may be derived from loess blown from the Hulahula River flood plain.

Schrader till is composed of particles of quartzite, schist, conglomerate, sandstone, limestone, and shale, in a dark-gray matrix. In sections where the permafrost table is deeper, such as along Katak Creek, a faint weathering profile, approximately 3 feet thick, is exposed. In sections in the fresh earthflows along Lake Schrader, where the till has been churned, stained rock fragments occur in the upper 2 feet, but no distinct soil profiles were observed.

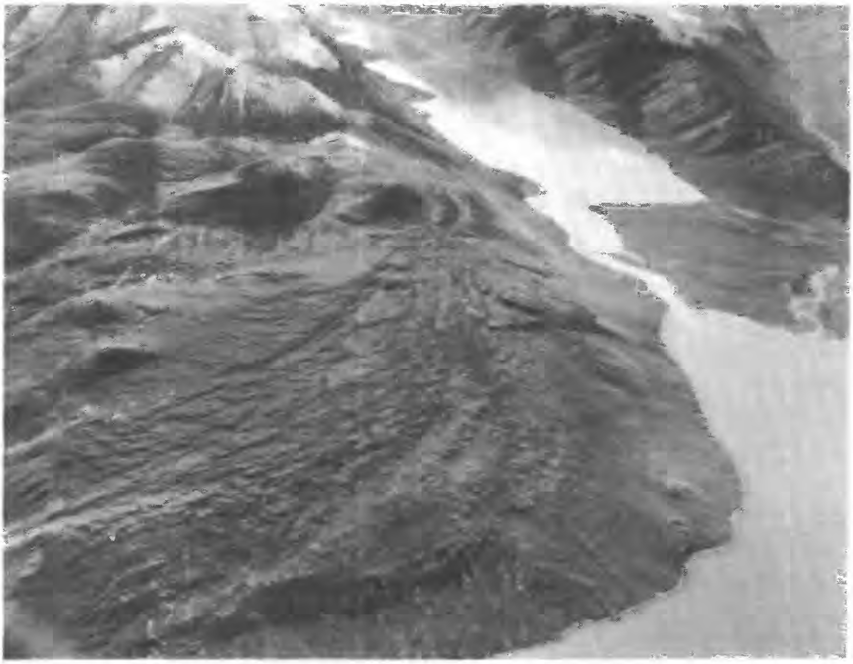

FIGURE 7.—Lateral moraine of Schrader Glaciation on Lake Schrader, composed of several steep-sided boulder-strewn ridges. Bedrock knobs rise above this moraine.

Schrader till samples (table 2) contain a higher percentage of silt- and clay-size particles than the Chamberlin samples. The two samples analyzed are poorly sorted; one is an extreme example of poorly sorted material.

Outwash aprons fronting Schrader moraines are narrow and low. The most complete apron, whose surface is about 20 feet above the stream, merges with the terminus of the large Schrader moraine due north of Schrader Lake. This outwash deposit is a recognizable terrace near the moraine, but a short distance downstream its outlines are obscured by colluvium from the valley sides. A similar apron extends eastward from the moraine on Katak Creek. Terraces on the Sadlerochit River below the Chamberlin outwash are probably, at least in part, valley-train remnants of the Schrader Glaciation (See p. B18).

PETERS GLACIATION

The youngest of the major glaciations is here named for Lake Peters, which was named by Leffingwell for W. J. Peters, a U.S. Geological Survey topographer and an early explorer of the Brooks Range.

FIGURE 8.—Earthflow on northwest shore of Lake Schrader in Schrader till; this flow occurred within a 3-day period in August 1958.

Moraines of the Peters Glaciation in this area are confined to valleys in the Franklin Mountains. The type moraine is on Coke Creek, east of Lake Peters. This end moraine consists of a group of very steep, boulder-strewn hillocks and ridges on the west side of the creek valley, about 2 miles from its mouth. The outwash from this glacier was deposited as a large delta in Lake Schrader.

Lateral moraines (pl. 1, fig. 9) of the Peters Glaciation rise about 200 feet above the surface of Lake Peters and extend upstream beyond the edge of the study area. These steep-sided ridges are boulder-strewn and hummocky, and they are breached by streams which have built alluvial fans that partly bury the ridges. The lateral moraine on the west side of the lake merges with a remnant of the end moraine on the northern shore of Lake Peters, beyond which is a small outwash apron. The terminal moraine on the northeast side of the lake is not preserved. A small gravel terrace a short distance from the north end of the lateral moraine may be a remnant of Peters outwash.

The Peters moraine along Katak Creek (in the Hulahula River drainage) is a narrow elongated loop. The terminal section is marked by small unmodified knobs and closed depressions. No outwash of this glacier was found or mapped; perhaps it was flushed down the gorge by melt water.

FIGURE 9.—Southwest shore of Lake Peters, showing bouldery lateral moraine of Peters Glaciation (center, on the lakeshore), a steep alluvial fan (right), and fresh talus on the valley wall.

The Peters moraines are strewn with closely spaced, slightly weathered boulders and, except for the encroachment by alluvial fans, are not mantled by surficial deposits. Frost features are absent or only poorly formed.

The till is largely composed of quartzite, schist, and phyllite of the Neruokpuk Formation and has a light gray-brown sandy matrix. Only the terminal moraines contain appreciable quantities of limestone or dolomite of the Lisburne Group. Peters till near the surface is not perceptibly weathered, although surface boulders are stained and lichen encrusted.

Two samples of Peters till illustrate contrasting size characteristics of a single till deposit and reflect the influence of local sources. A sample (loc. 1, pl. 1) from the east lateral moraine on Lake Peters is the typical sandy gravelly alpine till which may be expected from crystalline source materials such as the Neruokpuk Formation. Till from the end moraine on Lake Peters contrasts sharply with the lateral moraine till and resembles the poorly sorted silty Schrader till samples. The fine texture of this sample of Peters till may be a result of incorporation of fine alluvial or lake sediments by the advancing Peters glacier.

TERRACE DEPOSITS

Terrace deposits lie along the main branch of the Sadlerochit River and along the lower stretch of Kekiktuk River. Two prominent terraces flank the Sadlerochit River, one at about 25 feet and another at about 75 feet above the river. Both terraces consist largely of poorly sorted, little stratified, rounded to subrounded gravel, cobbles, and boulders. The lower terrace deposits are benched at several levels above the river and, in exposure, show about 10 feet of coarse alluvium overlain by 1½ to 5 feet of peaty silt. The higher terrace deposits consist of 50 to 60 feet of coarse alluvium overlain by about 2 feet of silt and sand. Both terraces are tundra covered; high-center polygons occur on the better drained higher terrace, low-center polygons on the more poorly drained lower terrace.

These terrace deposits cannot be traced directly to moraines. However, as the higher terrace lies approximately 50 feet below the top of the Chamberlin outwash apron, it is younger than this glaciation and is possibly a remnant of the Schrader valley train. The lower terrace may be a late Schrader or possibly a Peters terrace.

KATAK GLACIATION

Distinct moraines lie in front of nearly all the present glaciers; most flow from the flanks of Mount Chamberlin (fig. 10). The moraines in front of present glaciers are very small compared to the Peters moraines; they record only minor Recent readvances of the alpine ice. The advances are here named the Katak Glaciation for a creek between the Hulahula River and Mount Chamberlin.

A series of moraines near the glacier on the northwest flank of Mount Chamberlin suggests that glaciation since the Peters advance has been compound. In contact with the ice is a steep-sided moraine covered by large angular unweathered boulders. Downstream from this ridge is a flat, boulder-strewn outwash apron, crossed by a braided stream. Beyond the outwash is a pair of steep moraines covered by very slightly stained boulders. A few alpine plants have become rooted in the sandy matrix, and the boulders are somewhat more firmly emplaced than those in the moraine in contact with the ice. A narrow valley train leads from the outer moraine into the rocky V-shaped canyon below. On the valley sidewall beyond the outer loop is a lateral moraine remnant which may represent an earlier readvance or possibly a recessional moraine of the Peters Glaciation.

These small moraines are composed entirely of Neruokpuk metasediments and have a light-gray, sandy matrix. Except for the stained boulders on the outer ridges, there is no evidence of weathering.

FIGURE 10.—Moraines of the Katak Glaciation on the west slope of Mount Chamberlin. These moraines are steep sided and are 100 to 300 feet in height. A fresh moraine lies against the glacier, and two slightly weathered moraines rest a few hundred yards downstream.

Table 3 briefly gives the distinguishing characteristics of the moraine deposits of the five glacial advances (Weller, Chamberlin, Schrader, Peters, and Katak).

NONGLACIAL DEPOSITS

PIEDMONT ALLUVIUM

Gravel deposits that spread northward from Kikiktat Mountain on a piedmont surface are composed of well-rounded cobbles of locally derived sandstone of the Sadlerochit Formation and Lisburne limestone or dolomite. Inasmuch as no other rock types were observed in the gravel or on bedrock knobs that rise about it, the gravel presumably is not glacial drift.

Although the piedmont gravel deposits are mapped as one unit, they were probably deposited in several episodes. Low knobs of Kingak Shale, 20 to 40 feet above the general level of the piedmont, are capped by scattered boulders of Sadlerochit sandstone. This suggests that alluvium was transported from Kikiktat Mountain on a surface slightly higher than the main piedmont surface. The second episode in the formation of the piedmont created the surface now present. Distinct terracettes and solifluction lobes containing large

TABLE 3.—*Summary of characteristicis of moraine deposits*

Characteristic	Glacial advance				
	Weller	Chamberlin	Schrader	Peters	Katak
Gross form	Low, small discontinuous ridges or patches of till, and scattered erratics; till patches typically less than 1 mile long and ¼ mile across.	Extensive compound lobate moraines that have a continuous outer border and smooth surface profile. Lobate moraines about 11 miles wide.	Broad compound lobate moraines that show distinct recessional ridges, scattered depressions, and ponds. Individual lobes as much as 2½ miles across.	Small steep-sided hummocks and ridges, mostly less than ¼ mile wide.	Very small, very steep, unstable ridges, less than 1/10 mile wide.
Maximum distance from cirque (approximate, in miles).	40	30	25	17	2½.
Wastage and modification.	Profoundly eroded; covered in places by colluvium and possibly loess.	Profiles smoothed by mass movement and stream erosion; few undrained areas.	Perceptibly eroded, but many original forms persist; active earthflows.	Slightly eroded, primarily by tributaries from valley sides.	Breached by glacial streams.
Lithology	All local rock types and a matrix rich in shale particles.	All local bedrock types in a matrix rich in shale particles.	All local rock types; matrix rich in shale particles.	Mostly quartzite, schist, and phyllite.	Quartzite, schist, and phyllite.
Outwash relationships.	No outwash attached to moraine remnants.	Extensive colluvium-covered outwash aprons attached to terminal sections.	Very small outwash aprons attached to some lobes.	Outwash deposits restricted in size and rarely attached.	Small but distinct outwash aprons.
Surface features	Scattered boulders.	Widely scattered boulders; patterned ground; dendritic drainage.	Abundant surface boulders; high density of varied frost features.	Closely spaced, slightly weathered boulders.	Closely spaced almost unweathered boulders.

quantities of angular Sadlerochit sandstone have moved across the upper parts of the piedmont gravel surface. Modern streams have cut boulder-strewn flood plains, typically 50 feet wide and 20 to 25 feet deep, into the main piedmont surface.

COLLUVIUM

Colluvial deposits are widespread. They are composed of various mixtures of drift, frost-riven bedrock, and alluvium, and are the product of sheet erosion, movement caused by gravity, and frost processes. Thick deposits that cover bedrock or drift are shown on plate 1, but a thin covering rests on nearly all surfaces except the steepest slopes or on the younger moraines and alluvial deposits.

Silty colluvium that covers much of the lower slopes of the Sadlerochit River valley in the northeast part of the area may also include loessial silt. Outwash deposits related to both the Weller and Chamberlin Glaciations must have contained large quantities of silt derived from the broad belt of soft Kingak and Ignek Shales that these glaciers traversed. Winds blowing down the valley then would have distributed this silt over much of the Weller till. Any eolian deposits that may have been deposited on the valley floor, however, have been largely removed by post-Chamberlin downcutting by the Sadlerochit River. Any loess that may mantle Weller till on the southern side of the valley was not distinguished from colluvium derived from the soft shale that crops out in the vicinity. Colluvium on the north side of the valley, in the area of possible Weller till, has only Sadlerochit sandstone as an immediate source; therefore, the silt in this colluvium may include loess.

Features on colluvial sheets include lobes and terracettes, soil stripes, stone stripes, stone garlands, polygons, tussocks, and frost mounds. Colluvium derived from till is marked by widely scattered erratic boulders. A pattern of closely spaced rills and ridges ("horsetail drainage," fig. 11) is common on colluvium derived from till. Movement of fine colluvium downslope produces large, irregular fractures, typically 8 feet deep and 10 feet wide (fig. 12). Colluvium has been forming in this area continuously, but probably at different rates, since Tertiary time.

TALUS

Accumulations of frost-riven bedrock, chiefly Neruokpuk quartzite and schist, Lisburne limestone and dolomite, and Sadlerochit sandstone, cover many of the slopes of the foothills and mountains (fig. 13). The boundaries of these deposits are in places difficult to draw; many small deposits are omitted. Much of the alpine terrain in the southern part of the area is mantled by scattered rubble or talus sheets that are not mappable.

Most talus deposits are weathered and lichen encrusted, and probably represent one or more episodes during the Pleistocene. Conditions most favorable for talus accumulation may not, however, be contemporaneous with glacial advances. A higher frequency of freeze-thaw cycles, deeper permafrost table, and greater precipitation than at present may encourage intensified frost riving and talus formation. Such conditions might be aspects of a warmer, maritime climate that may have prevailed when the Arctic Ocean was ice free, possibly during an interstadial or interglacial interval. Similarly, growth of frost features (see B24) may have been greatest during warmer, moister phases of the Pleistocene.

Small stripes and fans of unweathered talus forming in high cirques and valleys commonly encroached on older talus sheets. This younger talus probably formed in the cirques during or since the Recent glaciation.

ALLUVIAL FAN DEPOSITS

Coarse, poorly sorted and poorly stratified gravel occurs on valley walls in the mountains as single or coalescing alluvial fans. Some of the best examples are on the shores of Lake Peters (pl. 1, fig. 9). Similar fans line the valley walls of Whistler Creek, Katak Creek, and smaller streams. The fans are usually covered by sand or silt, and in places by peat and colluvium. They are being dissected by intermittent streams which flow during snowmelt and after heavy rains. Inasmuch as the fans are well supplied with water, ground ice is abundant in the gravel below 2 to 3 feet.

The large fans on Lake Peters are modified in late spring or early summer by the movement of lake ice after it breaks into large floes and migrates up and down the lake. Thick sheets of ice impinging on the ends of the fans shove gravel into parallel ridges, which are as much as 10 feet high.

Most fans lie in canyons that were partly filled by ice of the Peters Glaciation and therefore are younger than that advance.

FIGURE 11.—Parallel swales, or "horsetail drainage" patterns, on Schrader ground moraine, immediately north of Lake Schrader. The swales are mostly less than 1 foot deep, are 5 to 10 feet wide, and are spaced 25 to 50 feet apart.

FIGURE 12.—Fractured colluvium on slope about 1 mile west of Katak Creek, on the northern flank of the Franklin Mountains. Fractures and solifluction lobes on this slope indicate active movement of the colluvium, which is here composed mostly of Chamberlin ground moraine.

FIGURE 13.—Typical talus sheet, on the west side of Kikiktat Mountain. The talus, derived from sandstone of the Sadlerochit Formation, is weathered; it probably formed in late Pleistocene.

ALLUVIAL SILT

Most of the minor valleys are floored by silt that is mixed with or covered by peat. Silt also occurs in morainal swales, or mantles terraces, alluvial fans, and outwash deposits. The silt is typically dark brown or black, is mixed or interbedded with peat, and is frozen at shallow depths. Silt carried by mountain streams is from the present glaciers; elsewhere it is derived from old till and colluvium. Silt near the Hulahula River and on the terraces of the Sadlerochit River may be in part eolian in origin.

STREAM GRAVEL

Coarse stream deposits are restricted to the narrow flood plains of streams originating in the mountains, especially the Sadlerochit River system, Whistler Creek, and the stream 3 miles east of Lake Schrader. These streams have bare, bouldery flood plains and in places are braided. On the upper reaches of many mountain tributaries and on Katak Creek, alluvium is discontinuous or confined to the stream bed. These deposits are composed of resistant rocks, especially Neruokpuk quartzite and schist, Lisburne limestone and dolomite, and Sadlerochit sandstone.

PERMAFROST

Perennially frozen ground is presumably continuous in the Brooks Range, Arctic Foothills, and Arctic Coastal Plain (Black, 1955, p. 118), with the possible exception of areas beneath large lakes or rivers. Frost features indicating permafrost, ground ice, and frozen soil are common. For example, during August 1958, large ice lenses, 2 to 3 feet thick, were exposed in a fresh earthflow on the south side of a pond near Katak Creek (fig. 14). Ground ice occurs not only in frost-susceptible till and silt, but also in gravel deposits, especially where surface water is abundant. The permafrost table in surficial materials is 2 to 4 feet below the surface. On steep, south-facing slopes, where vegetation cover is absent, or near large bodies of water, the permafrost table is probably somewhat more than 4 feet below the surface.

PATTERNED GROUND

Frost features are exceptionally conspicuous in the area, as was shown in the classic study of permafrost and ground ice by Leffingwell (1919). The report area is favorable for quantitative studies of frost features, because the features have formed on several different types and ages of surficial materials and occur under a variety of topographic and vegetational conditions. The terminology used here follows generally the classification of Washburn (1956).

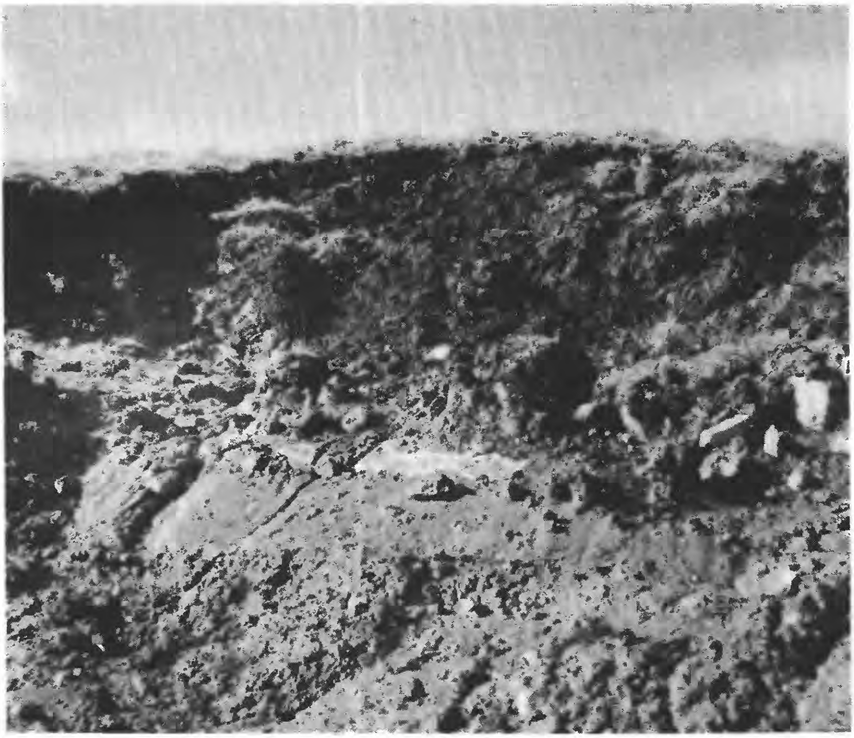

FIGURE 14.—Ice lens in Schrader till, exposed by a 1958 earthflow on the south shore of a small pond northwest of Katak Creek. Lens is at least 3 feet thick; only the upper surface is exposed.

SORTED FORMS

Patterned ground characterized by segregations of particles that contrast in size with other constituents (for example, stone circles) are not as common as nonsorted forms. The principal types are stone circles and polygons on the flat upland surfaces of Schrader moraines. These forms are typically 10 to 30 feet in diameter and are bordered by large, weathered, apparently stablized boulders.

Spot medallions, another type of circle, that have bare flat centers composed of the finer constituents of till and are bordered by vegetation-covered till, are scattered on moraine summits.

A few sorted steps occur on the Schrader moraines, Kikikat Mountain, and other foothills. Steps on the foothills are conspicuous stone-banked terraces composed of colluvial mixtures of Sadlerochit sandstone or Lisburne carbonate rocks. Sorted boulder stripes are widely scattered on moraine slopes and on foothills.

NONSORTED FORMS

Forms which occur on all but the youngest till deposits are the predominant frost features. They are generally homogenous or, rarely, show very weak segregations. High-centered circles, nets, and polygons are very common on the wide flat upper surfaces of Schrader moraines. The unit mesh is typically 1 to 2 feet high, 3 to 10 feet in diameter, and is bordered by a shallow trench, 0.5 to 1.0 foot deep. The centers are normally bare—an indication that they are active. The fact that the centers are also somewhat more stony than the till in streambank exposures indicates that fine material has been removed by rainwash or deflation. The till below the surface is very moist in summer, and the permafrost table is typically less than 4 feet deep.

High-centered nonsorted circles and polygons grade into steps on moraine slopes. These are best formed on Schrader moraines and on the middle slopes of Kikiktat Mountain.

Nonsorted circles and nets occur as turf-covered earth hummocks which are best formed on the silt and peat deposits in swales, on colluvium, and on the older moraines. These circles and nets are normally 1 to 2 feet high and 2 to 4 feet in diameter. They grade into steplike forms on hillsides.

Sedge tussocks, which may be regarded as nonsorted circles or nets, are among the most widely distributed forms. They form on nearly all the surficial deposits where moisture is abundant and where peat and silt have accumulated. They may be on flat summits or gentle slopes of moraines or colluvial sheets, on silt-covered outwash deposits, on alluvial fans, or in silt- and peat-filled swales. The tussocks are generally about 1 foot in diameter, approximately 1 to 1.5 feet high, and are spaced on 3- to 4-foot centers.

Peat ridges or peat circles, composed of vegetation, peat, and silt, occur in very moist or inundated swales. The ridges are 1 to 3 feet high, and 2 to 3 feet wide, and may occur as large, irregular circles or as curving individual ridges.

Large nonsorted polygons have formed in the gravel of the Peters outwash delta in Lake Schrader and on the alluvium between the two large lakes. These polygons are 50 to 100 feet in diameter and are bordered by trenches 1 to 2 feet wide and 1 foot deep. The gravel is covered by silt and sand 1 to 2 feet thick. Marsh vegetation and sedge tussocks cover the surface.

Nonsorted stripes occur on Chamberlin and Schrader moraines in the patterns informally called "horsetail drainage" (fig. 11). The stripes consist of shallow, parallel swales in till, marked by lines of more lush tundra vegetation which function as drainageways. The swales are less than 1 foot deep and may be 5 to 10 feet across. Two types of patterns are easily recognized on aerial photographs: straight, parallel swales on moderate slopes of Chamberlin ground moraine that meet the main streams more or less at right angles; and series of curving, parallel, branching, or converging swales that form on the flat and gently sloping surfaces of Schrader and Chamberlin till and on colluvium derived from these tills. The swales on steeper slopes may be in part derived from earthflows (see below), but those on nearly flat surfaces are probably drainage or frost phenomena.

MASS MOVEMENT

Wastage by gravity movement, here accelerated by frost riving and frost churning, is one of the most important erosional processes. Two mappable products of mass movement, talus and colluvium, have been described, but it should be noted again that nearly all slopes are covered by various thicknesses of material transported downslope by gravity. Much of this material is in the form of uneven or smooth sheets in addition to talus cones, fans, or stripes.

Much of the colluvium is readily identified by step features such as turf-banked and stone-banked terraces, or by solifluction lobes. These terraces or lobes are normally covered with a moss-lichen-sedge turf and have smooth profiles. Their length ranges from a few feet to several hundred feet, and the riser may have a relief of 10 or more feet.

The most obvious type of mass movement is the earthflow, a sudden movement of saturated till or colluvium that leaves a scar typically 5 to 10 feet deep, 50 to 100 feet wide, and several hundred feet long (fig. 8). The lower end of the earthflow is a rough lobe consisting of blocks of soil, turf, and peat in a matrix of till or colluvium.

Earthflows are common on colluvium and till that rests on black shales, and on morainal slopes facing Lake Schrader. Twelve large flows occurred on the lakeshores between August 1950 and the autumn of 1957, and one more formed suddenly on or about August 16, 1958. The flow of 1958 followed 2 days of unusually warm weather during a season that was probably milder than normal. The flow occurred on a 10° to 15° slope, leaving a scar 6 to 8 feet deep and a berm of turf 2 to 3 feet above the original surface. Conspicuous movement of turf blocks, boulders, and saturated till continued for 3 days, and the upper end of the scar enlarged during the following week. Another smaller earthflow apparently occurred the same summer on the shore of a small pond near Katak Creek (fig. 14). Several similar flows may be seen on north-facing slopes of Chamberlin till at the bend in Kekiktuk River.

A majority of the flows extend to a lake or stream, where the material is transported by waves or running water. Commonly a rill flows down the scar, deepens the depression, and removes additional material from the thawing permafrost. After the scar is healed by vegetation, small streams continue to flow, and eventually a layer of silt and peat accumulates. Some, but not all, of the parallel peat-covered swales on the steep slopes were probably formed in this manner.

Although evidence from aerial photographs suggests that earthflow activity has increased in the past decade, the common occurrence of old turf-covered earthflow scars and lobes indicates that this catastrophic mass-wastage process has taken place, at least intermittently, since the oldest glaciation. The present activity, which is presumed to be related to the warming trend in the Arctic, suggests that earthflow of high intensity is related to the warmer phases of the Quaternary.

QUATERNARY HISTORY

Major uplift of this part of the Brooks Range in the late Pliocene or early Pleistocene (Payne, 1955) set the stage for repeated alpine glaciations. The distribution of the oldest drift indicates that the topography has remained virtually unchanged and that little local tectonic activity has occurred since the earliest recorded glaciation. This situation contrasts with that in the Rocky Mountains (Flint, 1957, p. 328–330) and in the Alaska Range (Wahrhaftig, 1958) where uplift occurred after the earliest glaciation.

During the Weller Glaciation, the oldest and most extensive glacial advance in the area, ice from valleys in the Franklin Mountains coalesced into extensive piedmont glaciers that covered most, if not all, of the foothills south of the Sadlerochit Mountains. The piedmont ice was deflected eastward by the Sadlerochit Mountains and terminated in the lower course of the Sadlerochit River. Lateral drainage during the glaciation may have escaped through Sunset Pass to the north, as suggested by Leffingwell (1919, p. 137), although no erratics have been found in this broad valley. Colluvium and talus probably formed on slopes beyond the ice border during and following this glaciation.

A considerable interval elapsed between the Weller and Chamberlin Glaciations, as indicated by the contrast between the severely eroded oldest drift and the modified but recognizable moraines of the Chamberlin Glaciation.

The Chamberlin Glaciation was likewise a major event. Ice from the largest valleys coalesced and formed very broad, thick piedmont glaciers that moved northward and overrode the low foothills north of the Franklin Mountains. Drainage from these glaciers deposited what are now well-preserved, extensive outwash plains. On unglaciated piedmont slopes, broad sheets of alluvium were deposited.

Lakes probably formed in the Peters and Schrader basins after the Chamberlin advance.

The Schrader advance was also a major glaciation, although less extensive than earlier advances. It is recorded by erosionally modified end moraines which retain some constructional features such as ponds, parallel ridges, or knobs. One of the moraines encloses a large lake.

The last Pleistocene advance, the Peters Glaciation, extended only to the mouths of the canyons of the Franklin Mountains and deposited moraines much smaller than those of earlier glaciations. The moraines are bouldery, steep sided, and little weathered.

Moraines in the cirques of the Katak Glaciation are at least one order of magnitude smaller than the Peters moraines. This fact suggests that they represent Recent advances and there is abundant evidence in many alpine regions to support this assumption. Deposition of silt, alluvial fans, and stream gravel continued into the Recent.

The tentative correlation of the glaciations described here with those in the Brooks Range, the Alaska Range, or elsewhere, as shown in table 4, are little better than guesses. No radiocarbon data are available, and weathering characteristics and soil profiles are of limited value. Moreover, the reduction of Pleistocene landforms in the Arctic may not be primarily a function of absolute age but may rather depend upon the number, length, and intensity of periods of warm climate that the landforms have undergone. During warm periods the permafrost table would be deeper, and mass movement, frost churning, and stream action would be more effective than they are at present or were during the glacial advances. Greater precipitation, which may have accompanied higher temperatures and more maritime

TABLE 4.—*Tentative Quaternary chronologies in the Brooks and Alaska Ranges*

Epoch	Alaska Range	Brooks Range		
	Péwé (1952); Holmes (1959)	Holmes and Lewis (present report)	Detterman, Bowsher, and Dutro (1958)	Porter (1963)
Recent	Black Rapids II Stade Black Rapids I Stade	Katak Glaciation	Fan Mountain Stade	Fan Mountain II Stade Fan Mountain I Stade Alapah Mountain Glaciation
Pleistocene	(Post-Donnelly advance) Donnelly Glaciation	Peters Glaciation	Alapah Mountain Glaciation Echooka River Glaciation	Itkillik Glaciation (subdivided into four advances)
	Delta Glaciation	Schrader Glaciation	Itkillik Glaciation	
	Darling Creek Glaciation	Chamberlin Glaciation Weller Glaciation	Sagavanirtok River Glaciation Anaktuvuk River Glaciation	

conditions (possibly a result of open water in the Arctic Ocean), would also encourage stream action. Conversely, during cooler phases of the Pleistocene, frost churning and mass movement would be minimal.

Tentative correlation with glaciations in the north-central Brooks Range is based in part on information in Detterman, Bowsher, and Dutro (1958), on personal conferences with Dutro and Porter, and on comments by Detterman (table 3). According to Detterman (written commun., 1963), Weller moraines appear very similar to Anaktuvuk River drift, Chamberlin moraines are similar to the type Sagavanirtok River moraines, and the Schrader moraines, with their vestiges of constructional topography resemble the Itkillik moraines. Uncertainty arises when attempting to correlate the Peters advance, which in this area resulted in the last major Pleistocene moraines. Detterman believes the Peters Glaciation is equivalent to the Echooka River advance; if it is, the Alapah Mountain advance was either not represented or was not recognized here. As stated by Porter (1963), the Alapah Mountain drift may be Recent in age; hence in the Mount Chamberlin area the Alapah Mountain Glaciation might be included in the Katak advances.

Keeler (1959, p. 93–94) correlates a series of five glaciations in the McCall Glacier area (fig. 1) with the sequence described by Detterman, Bowsher, and Dutro (1958). He also notes that the oldest moraine deposits in the McCall River valley are probably equivalent to the Anaktuvuk or the Sagavanirtok advances.

Porter (1963) has recently extended the meaning of the term Itkillik to include the original Itkillik and Echooka advances plus two others heretofore not recognized in the Anaktuvuk Pass area. Porter provisionally correlated the four advances of the Itkillik Glaciation with the classical four-fold Wisconsin Glaciation of central North America, and, as stated, believes that the Alapah Mountain advance is Recent.

Sable (1961, p. 186) correlates the recessional and end moraines which lie 1,000 to 3,000 feet from the terminus of the Okpilak Glacier (about 9 miles south-southeast of Mount Michelson, beyond the boundaries of location map, fig. 1) with the Fan Mountain advance of the north-central Brooks Range. The Katak moraines in the Mount Chamberlin area are probably equivalent to the Okpilak moraines described by Sable, which he regards as historically recent in age.

A more tenuous correlation is attempted between the Brooks Range and the Alaska Range, with which the senior author is familiar. This suggested correlation is based primarily on geomorphic similarities.

Correlation with the glacial chronology of central North America is even more tenuous. The Weller deposits, which have no morainal form, are probably considerably older than the Chamberlin moraines, and, as a corollary, it is suggested that succeeding Chamberlin, Schrader, and Peters deposits, which have morainal form, were deposited at closer intervals than that which occurred between the Weller and Chamberlin Glaciations. This relationship may indicate that the Weller Glaciation was pre-Wisconsin and that the Chamberlin, Schrader, and Peters Glaciations were Wisconsin in age.

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