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LATE PLEISTOCENE GLACIAL CHRONOLOGY OF NORTH-CENTRAL BROOKS RANGE, ALASKA*

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ABSTRACT. End moraines and exposed stratigraphic sections of glacial sediments along the Anaktuvuk and Chandler Rivers represent four substages of the late Pleistocene Itkillik glaciation in the north-central Brooks Range, Alaska. Ice of the maximum advance, the Banded Mountain, flowed north along the Anaktuvuk Valley from an ice divide south of the present stream-drainage divide and formed a broad piedmont lobe extending 23 miles north of the mountain front. Two subsequent readvances, the Anayaknaurak and Antler Valley, left morainal borders 4 and 7 miles, respectively, behind the moraine of the maximum advance. Ice of the still later Anivik Lake readvance built a moraine 6 miles north of the drainage divide at Anaktuvuk Pass.

Radiocarbon dates indicate that the Anayaknaurak readvance occurred soon after 13,270 ± 160 years B.P. and that deglaciation following the Anivik Lake readvance began by 7241 ± 95 years B.P. The Itkillik glaciation is correlated broadly with the classical Wisconsin glaciation of central North America; its four substages are provisionally correlated with four substages (Tazewell, Port Huron, Valders, and Cochrane) of the classical Wisconsin.

Moraines in tributary valleys record three post-Itkillik advances that were restricted to the highest parts of the range. The Alapah Mountain advance, radiocarbon-dated at 2830 ± 120 years B.P., and the Fan Mountain I and II advances were post-Hypsithermal events that appear comparable to correlative advances noted elsewhere in the North American Cordillera.

INTRODUCTION

Like other high mountain systems of Alaska, the Brooks Range supported a complex network of valley glaciers during the later part of the Pleistocene epoch. At times of maximum glaciation, ice tongues flowed out beyond the range along preexisting stream valleys, overrode low interstream divides, and coalesced to form broad piedmont lobes. Although glaciation on the south side of the range probably was even more extensive than on the Arctic Slope, the glacial history of that region is as yet little known. Multiple glaciation of the north flank of the range, however, has been reported in several papers dealing with the extent, characteristics, and correlation of glacial deposits of this region (Detterman, 1953; Péwé and others, 1953; Karlstrom, 1957; Detterman, Bowsher, and Dutro, 1958; Keeler, 1959; Keller, Morris, and Detterman, 1961; and Holmes and Lewis, 1961). In the absence of more reliable dating criteria, correlations have been based primarily on the position, topographic expression, and preservation of drift sheets. Correlations between drifts in adjacent valley systems within and north of the range appear reasonably certain, but long-range correlations with classical sequences elsewhere in North America necessarily have been tentative and in some instances highly speculative.

Recent field work in the north-central Brooks Range along the Anaktuvuk and Chandler River drainages (fig. 1) has clarified the relationships between successive drift sheets and also has resulted in the discovery of a number of organic samples that permit close dating by the radiocarbon method of certain late Pleistocene events. This work shows the need for modification of the

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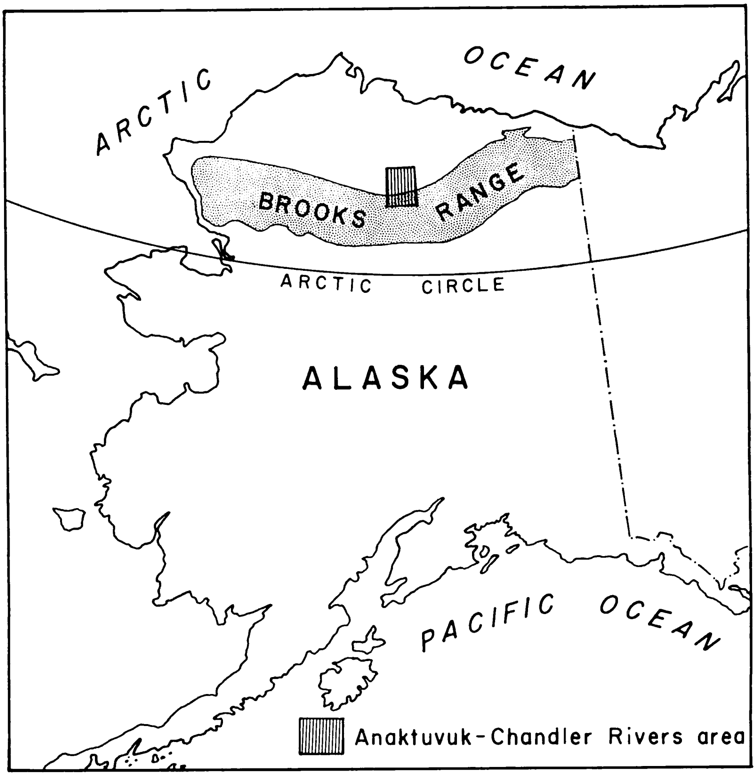

Fig. 1. Index map of Alaska showing location of Anaktuvuk-Chandler Rivers area.

existing Brooks Range glacial sequence, as well as for a revision of correlations with chronologies from other regions.

PREVIOUS CORRELATIONS

A five-fold glacial sequence on the north slope of the Brooks Range was first reported by Detterman (1953) and tentatively correlated with the standard North American sequence (Péwé and others, 1953). Two early ice advances, the Anaktuvuk and Sagavanirktok, regarded as pre-Wisconsin in age, were followed by two Wisconsin glaciations, the Itkillik and Echooka (fig. 2). An unnamed advance limited mainly to cirques was believed to be of Recent age.

This sequence subsequently was modified by Karlstrom (1957), who added a second unnamed post-Wisconsin advance and revised the correlations of the earlier glaciations, broadly equating the Anaktuvuk with Nebraskan, Sagavanirktok with Kansan, Itkillik with Illinoian, and Echooka with Wisconsin.

A further revision of the Brooks Range sequence was made by Detterman, Bowsher, and Dutro (1958), who restricted the Itkillik and Echooka glaciations to the early Wisconsin, cited evidence for a post-Echooka glaciation (Alapah

PÉWÉ and others (1953)

RECENT	Unnamed
LATE WISCONSIN	Echooka
EARLY WISCONSIN	Itkillik
PRE-WISCONSIN	Sagavanirktok
	Anaktuvuk

KARLSTROM (1957)

"LITTLE ICE AGE"	Unnamed
	Unnamed
ALTITHERMAL	
WISCONSIN	Echooka
SANGAMON	
ILLINOIAN	Itkillik
YARMOUTH	
KANSAN	Sagavanirktok
NEBRASKAN	Anaktuvuk

DETTERMAN, BOWSHER, and DUTRO (1958)

RECENT	Fan Mountain
LATE WISCONSIN	Alapah Mountain
EARLY WISCONSIN	Echooka
	Itkillik
PRE-WISCONSIN	Sagavanirktok
	Anaktuvuk

Fig. 2. Previous correlations of Brooks Range glacial sequence.

Mountain) which was assigned a late Wisconsin age, and introduced the name Fan Mountain for the most recent cirque glaciation. Recently, Holmes and Lewis (1961) tentatively correlated this sequence with the glacial succession delineated by them in the northeastern Brooks Range.

PRESENT WORK AND ACKNOWLEDGMENTS

New evidence bearing on the revised correlations presented in this paper was collected during 1959 and 1960 at Anaktuvuk Pass and during 1961 along the Anaktuvuk and Chandler Rivers. Field work at Anaktuvuk Pass was supported by grants from the Arctic Institute of North America in cooperation with the Office of Naval Research and was summarized in a doctoral dissertation submitted to Yale University (Porter, ms). Field data from adjacent areas were collected largely during a George Washington University archeological expedition in 1961 which was supported by a grant from the National Science Foundation and led by Dr. John M. Campbell. Radiocarbon samples collected during the field studies were dated by the Yale Geochronometric Laboratory under the supervision of Dr. Minze Stuiver. The use of facilities of the Department of Geology of Yale University, where the bulk of this study was completed, is gratefully acknowledged. The author is indebted to H. A. Coombs, H. W. Coulter, R. P. Goldthwait, and D. L. Livingstone for reviewing a preliminary draft of this paper, to R. F. Flint and A. L. Washburn for many helpful discussions during its preparation, and to Anne H. Porter for able assistance in the field during part of the investigation.

MORAINAL SEQUENCE ALONG ANAKTUVUK AND CHANDLER RIVERS

Morainal topography and exposed stratigraphy of drift sheets along the Anaktuvuk River provide evidence of four significant late Pleistocene glacial advances. The outer limit of the most extensive is marked by a terminal moraine which was first noted by Detterman, Bowsher, and Dutro (1958, fig. 3), who correlated it with the type Itkillik moraine along the Itkillik River. Drift of an earlier glaciation, the Anaktuvuk, is found north of this moraine, but it was not included in the present study.

The Banded Mountain moraine, which reaches the latitude of Banded Mountain, is the northernmost well-defined moraine along the Anaktuvuk River (fig. 3). The ice lobe delimited by the moraine terminated 23 miles north of the mountain front and was as much as 10 miles wide. Near the front of the range it overflowed low interstream divides and coalesced east of the Anaktuvuk River with other north-flowing ice tongues to form a broad piedmont lobe. West of the river the glacier terminated just north of Natvakruak Lake, where it built a prominent morainal ridge, the Natvakruak Lake moraine, from 10 to 40 feet high. Gravel outwash fans, now greatly dissected, extend north from both the Banded Mountain and Natvakruak Lake moraines. Behind the terminal moraine lies a series of five recessional ridges that mark successive stands of the glacier during its recession from the Banded Mountain maximum. Throughout the region in which drift of this advance constitutes the present land surface, glacial landforms have been appreciably modified by postglacial mass-wasting, resulting in a more subdued topography than that found on younger drifts further up the valley.

Seven miles south of the Banded Mountain moraine lies a second, even larger end moraine, here designated the Antler Valley moraine after Antler Valley Creek which borders the northeastern margin of this drift sheet (fig. 3). The moraine constitutes a broad zone of irregular hummocky topography averaging about a mile in width and characterized by numerous lakes and ponds which occupy small basins. Gravel of ice-contact origin comprises a large part of the drift within this morainal belt. Along much of its extent the outer edge of the moraine rises steeply above more subdued landforms beyond, resulting in an abrupt terminal rampart. A broad apron of outwash gravel, dissected and terraced by the Anaktuvuk River, can be traced north from the moraine as far as Banded Mountain. Four major recessional ridges lie south of the terminal ridge; behind them ground moraine and isolated patches of ice-contact gravels mantle the valley floor to a point well back in the range.

A large cutbank on the west side of the Anaktuvuk River 2.5 miles north of the apex of the Antler Valley moraine and a quarter of a mile north of the mouth of Anayaknaurak Creek displays a sequence of 5 stratigraphic units that provides evidence of an ice advance intermediate between those that produced the Banded Mountain and Antler Valley moraines. The section exposes, from bottom to top, 15 feet of very stony, compact till; 7 feet of coarse gravel with a sandy matrix; 7 feet of well-sorted sand and silt, even-layered near the base but deformed near the top, which locally contains much organic matter and which, in the upper part, contains large erratic stones that were forceably emplaced in the enclosing layered sediments; 4 to 5 feet of compact stony till; and 3 feet of cobble-pebble gravel (fig. 4). At the top of the cutbank is an erosional terrace that extends for several hundred feet both upstream and downstream; the gravel in which it is carved can be traced south into the outwash apron built out from the Antler Valley moraine. The upper till of the cutbank, therefore, clearly antedates the Antler Valley ice advance. The thinness of this till and apparent lack of appreciable erosion of the underlying sand and silt strongly suggest that the till was deposited by a minor and probably short-lived readvance of the glacier. The sand-and-silt unit is interpreted as a local

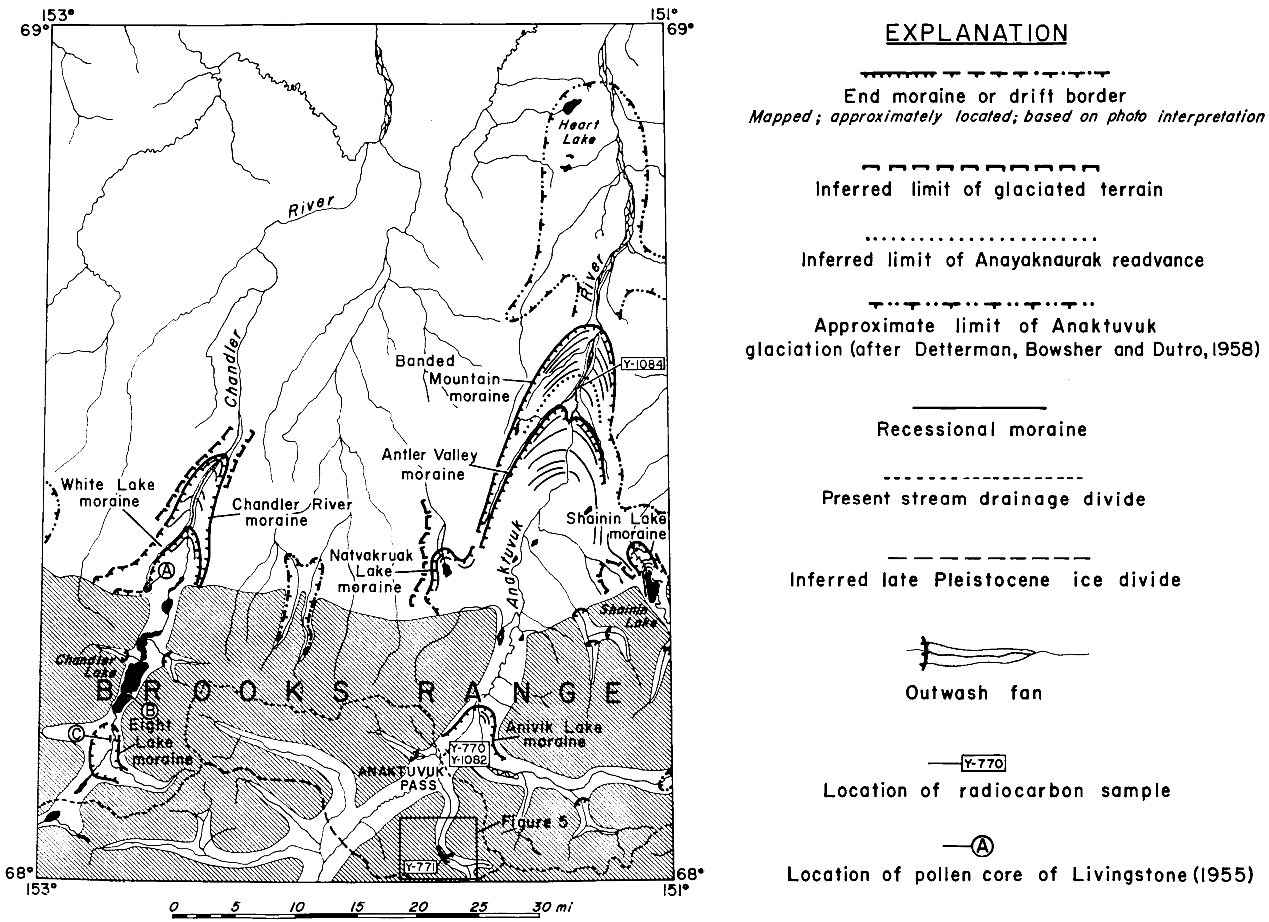

Fig. 3. Late Pleistocene morainal features of the Anaktuvuk-Chandler Rivers area.

body of lacustrine sediments that were overridden by the advancing glacier following a period, probably short, during which erratic stones were dropped by floating ice that calved into the proglacial lake in which the stratified sediments were accumulating. The thick lower till is believed to have been deposited by the glacier that built the Banded Mountain moraine; however, it could not be traced continuously to that moraine and therefore might conceivably be older. The overlying coarse gravel is interpreted as outwash deposited during the recessional phase of the Banded Mountain advance and prior to the local readvance, here designated the Anayaknaurak readvance, represented by the upper till.

The maximum extent of the Anayaknaurak readvance is not known precisely, but a belt of subdued, hummocky topography with a number of lake-filled depressions which extends about 3 miles north of the Antler Valley moraine (0.5 mile north of the cutbank shown in fig. 4) contrasts sharply with the zone of linear recessional ridges to the north and with the fresh hummocky surface of the Antler Valley moraine to the south. The northern margin of this belt is marked by a morainal ridge on the east side of the Anaktuvuk River.

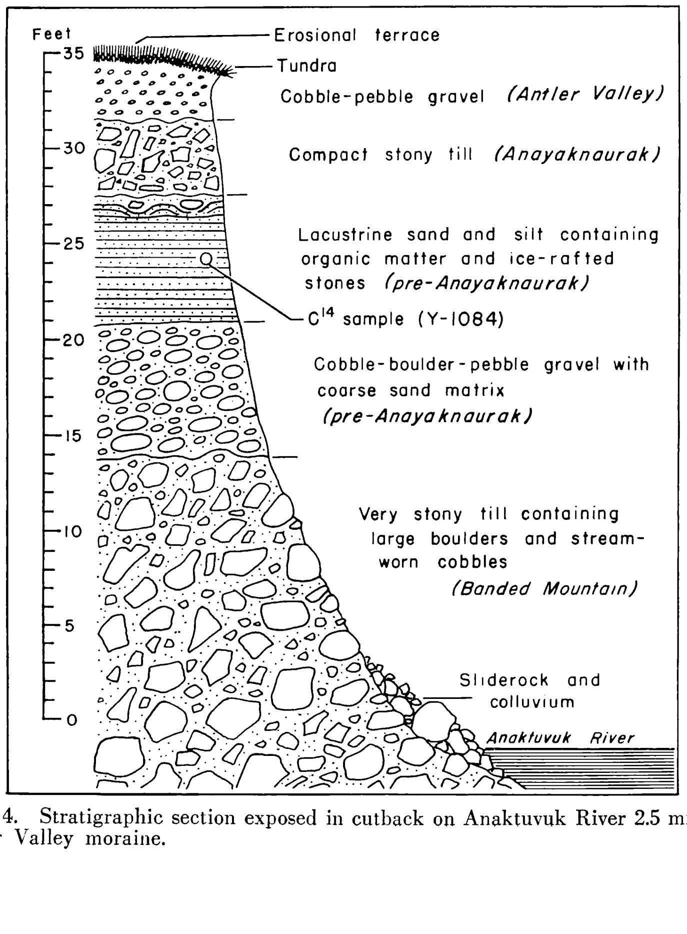

Fig. 4. Stratigraphic section exposed in cutback on Anaktuvuk River 2.5 miles north of Antler Valley moraine.

Landforms of stagnant-ice origin within this belt strongly suggest that the regimen of the glacier that built them differed markedly from that of the ice that left the series of recessional ridges to the north. Therefore, the northern limit of these features is provisionally regarded as the border of the Anayaknaurak drift sheet.

The Anivik Lake moraine, an arcuate morainal complex consisting of broad linear ridges of till and irregular bodies of stratified drift, crosses the Anaktuvuk Valley at the latitude of Anivik Lake, 6 miles north of the drainage divide at Anaktuvuk Pass (fig. 3). The glacier that built this moraine, which now is greatly dissected where crossed by the Anaktuvuk River, was between 2 and 3 miles wide and nearly covered the floor of the valley. Extensive stratified drift and ice-contact topography of the moraine indicate that during its construction the terminal part of the glacier was either stagnant or very thin and slow-flowing. Several lines of evidence, including close similarity in morphology and physical character of the Anivik Lake and Antler Valley drifts, the apparent transition of one into the other, and the continuity of ice-margin drainage channels formed during these two successive substages, strongly suggest that the moraine was built during a late readvance of the same glacier that earlier built the Antler Valley moraine (Porter, ms). Two low linear ridges of till between the moraine and the Anaktuvuk River may mark still younger recessional stands of the glacier. Unlike the Banded Mountain and Antler Valley moraines, the Anivik Lake moraine has no associated outwash apron.

A belt of arcuate morainal ridges that extends 3 miles north of Shainin Lake may be correlative in whole or in part with the Anivik Lake moraine. The lake fills a deep basin behind the innermost morainal ridge (fig. 3). Although the Shainin Lake drift was referred by Detterman, Bowsher, and Dutro (1958, fig. 3) to the same ice advance that built the Anivik Lake moraine, the true relation of this drift complex to the Anivik Lake and Antler Valley moraines is not clear.

Moraines along the Chandler River form a sequence comparable to that along the Anaktuvuk River 28 miles to the east but they are less extensive, for the drainage basin is correspondingly smaller (fig. 3). The outermost moraine, here designated the Chandler River moraine, terminates 12 miles north of the mountain front. The degree of dissection and mass-wasting on this drift is similar to that on the Banded Mountain drift. A thick dissected outwash train which extends downstream from the front of the moraine forms a steep scarp 100 feet high east of the river. Behind the terminal moraine lies a series of arcuate recessional ridges that cross the valley.

A second moraine, the White Lake moraine, which appears comparable both in position and character to the Antler Valley moraine, begins near White Lake at the front of the range and crosses the Chandler River 7 miles south of the Chandler River moraine. It too has an extensive terraced outwash apron which can be traced downstream for at least 6 miles.

South of Chandler Lake is a belt of morainal topography (designated the Eight Lake drift by D. G. MacVicar, Jr. on unpublished field maps, using a name originally proposed by Livingstone, 1955, p. 588) characterized by an abundance of ice-contact features composed of stratified drift. The discontinuous moraine that borders it, the Eight Lake moraine, is largely missing along the northern side of the drift sheet. Both in position with respect to the range front and in the physical character of the deposits, this drift appears equivalent to the Anivik Lake drift at Anaktuvuk Pass.

In summary, two corresponding sets of three major end moraines occur along both the Anaktuvuk and Chandler Rivers. Equivalence is based on position of moraines with respect to the range front and to the ice divide (taking into consideration the size of the respective glacial drainage basins), degree of mass-wasting and erosion, presence or absence of associated outwash fans, presence or absence of ice-contact stratified drift in morainal systems, and the number and nature of recessional moraines behind the major end moraines. A fourth advance, for which the stratigraphic evidence is found along the Anaktuvuk River, was not recognized along the Chandler River and probably represents a relatively minor glacial fluctuation in comparison with the other three.

MORAINAL SEQUENCE IN TRIBUTARY VALLEYS

Evidence of younger, more-restricted glacial advances is present throughout the higher parts of the north-central Brooks Range and occurs mainly in tributary valleys that head in cirques. A three-fold morainal sequence near Anaktuvuk Pass along the valley of Inukpasugruk Creek and its tributaries (fig. 5) is correlated with moraines of the Alapah Mountain and Fan Mountain glaciations of Detterman, Bowsher, and Dutro (1958).

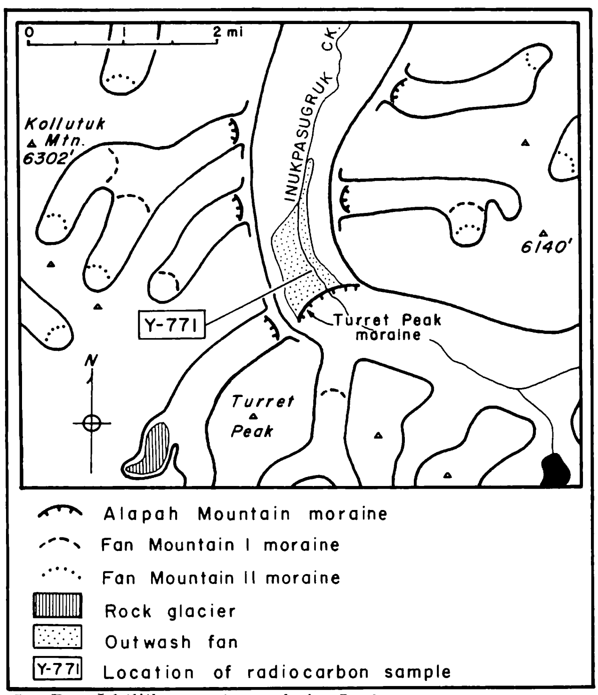

Fig. 5. Post-Itkillik moraines of the Inukpasugruk Creek drainage.

A prominent moraine that crosses Inukpasugruk Creek 7.5 miles above its mouth was named the Turret Peak moraine by Porter (ms). A terraced sand-and-gravel outwash fan extends north of the moraine for over a mile. The freshness of the moraine and its position relative to the cirques that supplied the ice to build it strongly suggest that it is correlative with the type Alapah Mountain moraines on the south side of Alapah Mountain, approximately 21 miles to the northeast.

Most streams tributary to Inukpasugruk Creek enter its valley through deep postglacial gorges cut in thick sections of morainal debris that lie at the mouths of hanging tributary valleys. In degree of freshness and modification these moraines are similar to the Turret Peak moraine. Their position relative to cirques at the heads of their valleys is also comparable when the size of the snow-catchment basin is taken into consideration. Tributaries upvalley from the Turret Peak moraine lack moraines at similar positions near their mouths, suggesting that ice from these valleys coalesced in Inukpasugruk Valley to form a large trunk glacier, while simultaneously smaller glaciers occupied hanging valleys downstream.

Fresh moraines composed of unstable rubble are found in almost all cirques in this region. A few are in contact with residual glacier ice, and some may be ice-cored. In terms both of position and morphology they resemble typical Fan Mountain moraines described by Detterman, Bowsher, and Dutro (1958). In most valleys, however, a third and previously undescribed moraine lies between the moraine of the Alapah Mountain advance and the fresh cirque moraine. These are more stable than the cirque moraines but less modified than Alapah Mountain moraines beyond. Clearly they represent a post-Alapah Mountain ice advance, but whether glaciers had retreated into cirques prior to this advance or were merely undergoing fluctuating retreat following the maximum expansion of the Alapah Mountain ice is not yet known. For the present, these moraines will be tentatively regarded as the product of the most recent glacier fluctuations and accordingly will be referred to as Fan Mountain I. The still younger and fresher cirque moraines will be designated Fan Mountain II.

In a tributary valley 2 miles southwest of the Turret Peak moraine the sequence of Fan Mountain moraines is missing. In their place is a large active rock glacier that extends a mile below the headwall of the cirque in which it originates (fig. 5). Very likely this feature dates at least from the time of the Fan Mountain II advance. The absence of identifiable Fan Mountain I drift in this valley suggests either that the rock glacier was present during Fan Mountain I time as well or that it has recently overridden Fan Mountain I drift during its advance down the valley.

RADIOCARBON SAMPLES

Prior to the present study, glacial deposits of the Brooks Range had not been dated directly by radiocarbon, so correlations were necessarily based on physical criteria. Organic samples, primarily peat and willow twigs, obtained from stratified deposits during this investigation provided dates that are the basis for revised correlations presented in this paper.

A radiocarbon sample (Y-1084) collected from the cutbank north of Anayaknaurak Creek that exposes till of the Anayaknaurak readvance establishes an approximate age for this readvance. The sample, consisting of fibrous organic matter, was taken from the upper several feet of lacustrine sediment that immediately underlies the Anayaknaurak till (fig. 4). The organic matter is believed to have been deposited shortly before the locality was overridden by the readvancing ice. Therefore the age of the sample antedates the maximum of this readvance, but probably by a relatively brief span of time.

Two samples bearing on the age of Anivik Lake readvance were obtained from perennially frozen lacustrine silt in an Eskimo meat cellar at Anaktuvuk Pass, 5 miles south of the Anivik Lake moraine. One sample (Y-770) was collected 9 feet below the present ground surface; the second (Y-1082) near the bottom of the cellar at a depth of 14 feet. The silt is interpreted as the deposit of an ice-margin lake that formed during wastage of the Anivik Lake glacier. The samples, therefore, should date this period of sedimentation and should provide a minimum age for the Anivik Lake readvance.

A fourth sample (Y-771) was collected 17.5 feet below the top of a body of stratified outwash sand and gravel approximately a quarter of a mile downstream from the Turret Peak moraine. The outwash coarsens upvalley and grades into the leading edge of the moraine. Because this moraine is correlated on physical grounds with type moraines of the Alapah Mountain glaciation, the sample should date approximately the maximum stand of this ice advance.

Ages of the radiocarbon samples, which were dated by the Yale Geochronometric Laboratory, are shown in table 1 (Stuiver and Deevey, 1961; Minze Stuiver, written communication, November 1961).

TABLE 1

Sample	Age (years B.P.)
Y-1084	13,270 ± 160
Y-1082	7241 ± 95
Y-770	6260 ± 160
Y-771	2830 ± 120

REVISED CHRONOLOGY AND CORRELATIONS

The two dates (Y-770, Y-1082) associated with drift of the Anivik Lake readvance provide only a minimum age for this glacial event, for both come from sediments deposited during a late phase of deglaciation. It seems unlikely, however, that stagnant residual ice of that glacier could have persisted for much more than one or two thousand years following the maximum extent of the readvance, for widespread ice-contact gravels on the valley floor, with which the dated lacustrine sediments are associated, point to extensive and probably rapid ice wastage following the construction of the Anivik Lake moraine. Independent evidence from the Chandler Lake area supports this contention and suggests that deglaciation of the presumably contemporaneous Eight Lake glacier began not long before 7500 years ago.

Pollen evidence bearing on the late-glacial and postglacial climatic history of the Chandler Lake area has been summarized by Livingstone (1955, 1957), who analyzed three lake-sediment cores for pollen content. A core from Chandler Lake (fig. 3, pollen core B) was subdivided into three zones. Zone I, characterized by herbaceous pollen, shows a marked increase in sedge toward the bottom and comes from a sequence of laminated sediments that appear graded. Zone II shows a dominance of birch, whereas in zone III the most abundant pollen is alder.

Only zones II and III appear in a core from Eight Lake, a small body of water within the margin of the Eight Lake drift sheet (fig. 3, pollen core C). Livingstone (1955, p. 561) felt that "the glaciation that produced Eight Lake is the same one that laid down the laminae in Chandler Lake". Because the core seems to have reached the rocky floor of the kettle in which the lake lies, probably it represents the total time since the lake formed. The pollen profile from Eight Lake differs little from the Chandler Lake profile half a meter above the laminated section. If the laminae in the Chandler Lake core were deposited during the maximum stand of the Eight Lake glacier, as Livingstone believes, the area now occupied by Eight Lake probably was deglaciated shortly after the deposition of laminated sediments in Chandler Lake ceased (i.e., shortly after the transition from zone I to zone II). The Eight Lake pollen diagram therefore must represent most of postglacial time for this area.

Although zones II and III were identified in a third lake-sediment core (fig. 3, pollen core A) from a kettle on White Lake drift, apparently the core did not penetrate all the sediments, for zone I, which should be present, is missing.

Pollen from zone I of the Chandler Lake core was interpreted as marking climatic conditions during the Eight Lake (Echooka) advance. A decrease in sedge near the top of this zone and an increase in species indicative of sparsely vegetated ground may reflect conditions at Eight Lake maximum. The appearance of birch at the bottom of zone II was interpreted as marking a change to warmer, postglacial conditions. The presence of alder in zone III was interpreted as a weakly developed postglacial thermal maximum when the summer climate may have been milder than that of today. A slight decline in alder near the top of zone III may reflect a shift to cooler conditions following the alder maximum.

A pollen core from Umiat, 90 miles north of Chandler Lake, revealed the same three-fold vertical sequence: ". . . tundra with many indicators of open ground; next, tundra in which dwarf birch shrubs were more important; finally, tundra with enough alder bushes to influence the pollen rain" (Livingstone, 1957, p. 258 and 259).

Three radiocarbon samples from the Umiat section provided dates for the pollen zones (Broecker, Kulp, and Tucek, 1956). The oldest (L-277B) lies in zone I and has an age of 8300 ± 270 years. A second (L-277C), collected immediately above the zone I–zone II transition, was dated at 7530 ± 150 years. The third sample (L-277D), taken near the transition from zone II to zone III, is 5890 ± 170 years old.

If contemporaneity of pollen zones at Umiat and at Chandler Lake is assumed, then glacial events in the Brooks Range can be dated approximately using the Umiat dates. On this assumption the Eight Lake advance, represented by zone I of the Chandler core, would have been in progress 8300 years ago. Probably it reached its maximum extent not more than several hundred years earlier than this date. The dated pollen-zone boundaries from Umiat, if correlated with pollen-zone boundaries from Chandler Lake that mark the transitions from glacial to late-glacial and postglacial conditions, are compatible with the two radiocarbon dates from Anaktuvuk Pass that indicate deglaciation from the Anivik Lake readvance between 7241 and 6300 years ago (fig. 6).

The date of 13,270 years on organic matter from stratified sediments underlying the Anayaknaurak till provides a maximum date for the Anayaknaurak readvance. Rafted stones in the upper part of the sand-and-silt unit suggest that glacier ice was nearby during deposition of the lake sediments and may have been actively advancing northward at that time. The radiocarbon date, therefore, probably does not antedate the overriding of this locality by the glacier by more than several hundred years.

The precise age of the Antler Valley readvance is not known, but this event is bracketed by dates on the Anayaknaurak and Anivik Lake readvances. Consequently it is younger than 13,270 years, the maximum age for the Anayaknaurak readvance, and older than 8300 years, a date associated with the Anivik Lake readvance. Probably the maximum northward extent of the glacier during this advance occurred between 10,000 and 11,000 years ago.

The Banded Mountain advance is regarded as the earliest recognized advance of the Itkillik glaciation, the terminal moraine of which marks the maximum extent of Itkillik ice along the Anaktuvuk River. Although its age is not yet known, this advance clearly is older than the 13,270-year date related to the Anayaknaurak readvance. Assuming that degree of mass-wasting and stream integration on drift sheets is a function of age, a qualitative comparison of these parameters on the Banded Mountain, Anayaknaurak, and Antler Valley drifts suggests that the difference in age between the Banded Mountain drift and the Anayaknaurak drift is about twice that between the Anayaknaurak and Antler Valley drifts. It follows that if the Antler Valley advance took place

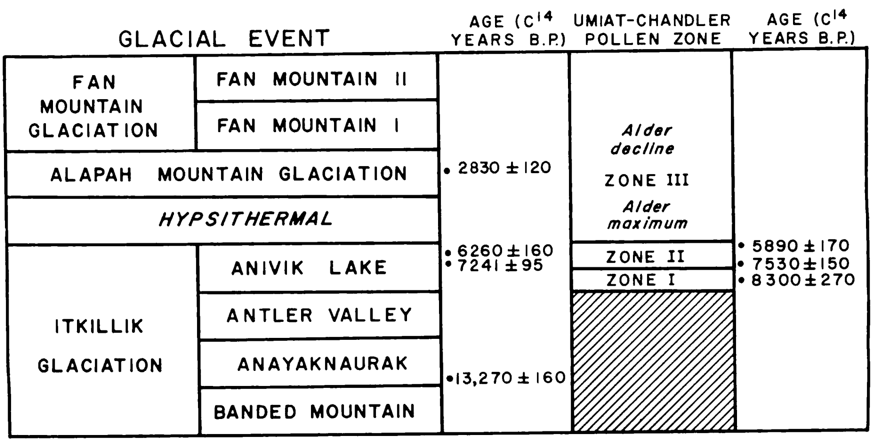

Fig. 6. Late Pleistocene glacial chronology of north-central Brooks Range.

between 10,000 and 11,000 years ago, as suggested above, then the age of the Banded Mountain advance may well fall between 18,000 and 20,000 years B.P.

The Itkillik glaciation originally was regarded as an early Wisconsin event which was followed by a later Wisconsin glaciation, the Echooka (fig. 2). The drift stratigraphy along the Anaktuvuk and Chandler Rivers and the associated radiocarbon dates indicate, however, that the Itkillik stage includes four substages which, for the Anaktuvuk River drainage, are designated the Banded Mountain, Anayaknaurak, Antler Valley, and Anivik Lake.[1] Detterman, Bowsher, and Dutro (1958, p. 60) recognized that the Echooka drift might not represent a separate major glaciation, for they stated that "the possibility that the Echooka represents a major readvance or a period of stand-still within the Itkillik glaciation cannot be ruled out definitely at the present time". In view of the probable equivalence of Anivik Lake drift with the type Echooka drift (Detterman, Bowsher, and Dutro, 1958, fig. 3; Porter, ms), it seems preferable to remove the "Echooka glaciation" from the Brooks Range sequence. The name "Echooka" might then be used informally for drift of the latest substage of the Itkillik glaciation along the Echooka River.

If the Turret Peak moraine on Inukpasugruk Creek is correlative with the type moraines of the Alapah Mountain advance, as advocated in this paper, the date of 2830 ± 120 years on outwash associated with this moraine indicates that the Alapah Mountain was a post-Hypsithermal event and should be regarded as post-Wisconsin, rather than late Wisconsin, in age (fig. 6). This age seems consistent with the very late Wisconsin age of the Anivik Lake readvance and with the much more restricted extent of the Alapah Mountain ice as compared with ice of the Anivik Lake readvance.

The freshness of Fan Mountain II moraines and their close association in some cirques to wasting residual glacier ice suggest that they were built within the last several centuries. Very likely they date from the last significant period of glacier advance, which appears to have attained its maximum in the first half of the 18th century throughout much of North America (Ahlmann, 1953).

Fan Mountain I moraines are clearly older than those of the Fan Mountain II advance for they lie beyond them, are more stable, and have been more greatly modified by erosion and mass-wasting. In degree of modification they appear to be intermediate between Alapah Mountain moraines and Fan Mountain II moraines. Their absolute age may also be intermediate and fall within the range of 1000 to 1500 years B.P.

The Itkillik glaciation is provisionally and broadly correlated with the classical Wisconsin glaciation of central North America. Radiocarbon dates suggest reasonably close correlation of the four subdivisions of the Itkillik recognized in this report with four substages of the classical Wisconsin, as shown in figure 7. The Itkillik also is equated broadly with the Naptowne glaciation of the Cook Inlet region of southern Alaska. The Tanya substage of

[1] Although Anivik Lake drift at Anaktuvuk Pass and Eight Lake drift at Chandler Lake previously have been referred to as "Echooka" (Detterman, Bowsher, and Dutro, 1958; Livingstone, 1955, 1957; Porter, ms), because it has not yet been possible to prove conclusively the equivalence of these drifts with the type Echooka drift, a local geographic name has been given here to drift of the youngest substage of the Itkillik glaciation along the Anaktuvuk River.

CENTRAL BROOKS RANGE			CENTRAL NORTH AMERICA		
ITKILLIK	Anivik Lake	>7241 (8300)	CLASSICAL[1] WISCONSIN	Cochrane[2]	>6730 <9000
	Antler Valley	>(8300) <13,270		Valders[3]	10,700
	Anayaknaurak	13,270		Port Huron[4]	>12,200 <13,600
	Banded Mtn.	>13,270		Tazewell[5]	18,000-19,000

Fig. 7. Provisional correlation of Itkillik glacial stage. (Radiocarbon ages are in years B.P.).

[1] Flint (1957, p. 341).
[2] Flint (1956); Karlstrom (1956).
[3] Flint (1956).
[4] Flint (1956); Flint and Rubin (1955).
[5] Flint (1956); Flint and Rubin (1955).

the Naptowne, which Karlstrom (1960) brackets between the dates of 3500 and 7000 B.C. (approximately 5500 and 9000 B.P.), would appear to be correlative with the Anivik Lake readvance. Similarly, the Antler Valley and Anayaknaurak advances appear to be correlatives of Karlstrom's Skilak I and Skilak II which he correlates with Port Huron and Valders, respectively (Karlstrom, 1960). The Banded Mountain, in turn, may prove equivalent to the Moosehorn and/or Killey of the Cook Inlet sequence. If the Anivik Lake and Cochrane drifts are correlative, as suggested in figure 7, the age of the climatic change related to these glacial events appears to be more closely delineated by radiocarbon dates from the Brooks Range than those from either southern Alaska or central North America.

The age of the Alapah Mountain advance in the Brooks Range falls within the limiting dates of 1500 B.C. (3450 B.P.) and 500 B.C. (2450 B.P.) for the Tustumena II advance of the Cook Inlet region which Karlstrom (1957) has assigned to post-Altithermal (Hypsithermal) time. The Fan Mountain I and II advances may in turn be correlative with Karlstrom's (1957) Tunnel I and II of the Cook Inlet chronology and with two late ice advances of the eastern Brooks Range, named "Cirque Moraine I" and "Cirque Moraine II", which were described by Holmes and Lewis (1961).

The date (2830 ± 120 years B.P.) associated with the Alapah Mountain advance is nearly identical to the age (2800 ± 200 years B.P.) assigned the lower member of the Gold Basin formation of the La Sal Mountains, Utah, which Richmond (1962) correlated with the Temple Lake glaciation of the Wind River Mountains, Wyoming (Moss, 1951; Holmes and Moss, 1955), and suggests widespread synchrony of glacial events in the North American Cordillera during the early part of what F. E. Matthes (1939, 1940) has called "the little ice age".

Drift bodies assigned to the Sagavanirktok and Anaktuvuk glaciations were not included in the present investigation, so any attempt to correlate them with glacial sediments from other regions would constitute mere guesswork. However, because the deposits left by these advances were described by Detterman, Bowsher, and Dutro (1958) as being considerably more modified by erosion and mass-wasting than deposits of the Itkillik glaciation, and therefore probably are of much greater age. it appears safe to assign them to pre-classical Wisconsin time. Possibly one or both are early Wisconsin in age, although a pre-Wisconsin age cannot be ruled out. As pointed out by Detterman. Bowsher. and Dutro (1958), the exact relationship of these older drifts is not known and conceivably they are deposits of the same glaciation. The apparent absence of still older glacial deposits on the Arctic Slope of Alaska suggests that, were this true and were these drifts both late Pleistocene in age, the Brooks Range may not have experienced intensive glaciation during middle and early Pleistocene time, possibly because it had not yet been uplifted to altitudes necessary for the generation of large valley glaciers.

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