(200)
R290
no.80-790

USGS LIBRARY-RESTON
3 1818 00073917 5

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

QUATERNARY STRATIGRAPHIC SECTIONS WITH RADIOCARBON DATES CHANDLER LAKE QUADRANGLE, ALASKA

by

Thomas D. Hamilton
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025

U.S. GEOLOGICAL SURVEY
RESTON, VA.
OCT 01 1980
LIBRARY

OPEN FILE REPORT
80-790

314138

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

CONTENTS

TABLES

PLATE

ILLUSTRATIONS

SUMMARY

Twenty-eight organic samples from 17 localities in the Anaktuvuk, Tulunga, and Itkillik Valleys and at Shainin Lake range in age from more than 40,000 to about 1000 ^{14}C yr B.P. These dates, combined with fossil identifications and measured stratigraphic sections, provide significant insights into the history of glaciation, climatic change, and related events of late Quaternary time in the north-central Brooks Range.

Two dates from Tulunga Valley show that peat-forming intervals during the middle Wisconsin and during an earlier period were terminated by episodes of loess accretion that probably correspond to glaciations in the Brooks Range.

The Anayaknaurak Bluff exposure in Anaktuvuk Valley contains a weathered till of the Banded Mountain (Itkillik I) glaciation overlain by unweathered outwash gravel of Antler Valley (Itkillik II) age. Radiocarbon dates from finer alluvium above the outwash indicate that a subsequent glacial readvance north of the range front occurred shortly after 13,000 yr B.P. This event was synchronous with a major glacial readvance that culminated between about 12,900 and 12,700 yr B.P. farther east in the Atigun and Sagavanirktok Valleys.

Additional dates from Anaktuvuk Valley show that glacier ice had retreated from the Antler Valley end-moraine complex by 10,600 yr B.P. The elongate basin that formed behind the moraine dam was being filled by alluvium at this time, and filling continued as late as 6200 yr B.P. near the range front. A possible climatic reversal during this interval is suggested by dates from Anaktuvuk Valley and from Toolik Valley farther east, which show peat formation between about 9500 and 8200 yr B.P. followed by solifluction and fan-building.

Soil test pits and other excavations near Anaktuvuk Pass show that the pass was deglaciated some time prior to 7250 yr B.P., and was suitable for human habitation by at least 6500 yr B.P. Dated buried peat suggests a change to more severe frost climate sometime after about 4750 yr B.P.

Other dates from the Chandler Lake quadrangle bear mainly on formation of low (generally 2.5 to 6 m) river terraces during intervals of renewed glaciation at valley heads during the late Holocene. Neoglaciation in the north-central Brooks Range evidently began about 3500 yr B.P., or at least was perceptible by this time as increased loess influx to sites north of the range front. Stream alluviation was in progress 2800-2700 yr B.P. at sites near Anaktuvuk Pass, and continued until sometime after 2000 yr B.P. Final phases of alluviation began about 1200 and 450 yr B.P. Independent dating of cirque-glacier advances by lichenometry supports the alluvial chronology and suggests that alluviation was controlled largely by increased sediment yield to streams during times of cirque-glacier expansion and increased rock-glacier activity.

INTRODUCTION

The Chandler Lake quadrangle plays a key role in the history of Quaternary research in northern Alaska. Anaktuvuk Pass, in the south-central part of the map area, has been a focal point for archeological investigations since 1950; its soils and surficial deposits have also received intensive study. Anaktuvuk Valley is the type locality for the Anaktuvuk River glaciation of Detterman and others (1958), and for the four substages of Itkillik glaciation proposed by Porter (1964). Peaks and valley heads a short distance northeast of Anaktuvuk Pass comprise the type localities for the Alapah Mountain and Fan Mountain glaciations, episodes of glacier fluctuation that were restricted to higher altitudes during Holocene and perhaps latest Pleistocene time (Detterman and others, 1958; Porter, 1964; Hamilton, 1979a, b).

Interest in the Quaternary geology around Anaktuvuk Pass was spurred by discovery in 1950 of archeologic sites that contained multiple cultural components and that were inferred to represent several thousand years of human occupation (Irving, 1951, 1953; Solecki, 1951). Extensive archeologic excavations in the area around Anaktuvuk Pass were carried out during 1956 and several subsequent field seasons by John M. Campbell (1962). Investigations of soils at Anaktuvuk Pass were made independently during this time by field parties from Rutgers University (e.g., Ugolini and Tedrow, 1963), and geologic mapping with particular emphasis on glacial deposits was carried out concurrently by Stephen C. Porter (1964, 1966). Among the results of these studies, six radiocarbon dates from Anaktuvuk Pass and ten dates from additional localities within or near Anaktuvuk Valley were published in Radiocarbon and in other technical journals (table 1 and plate 1)[1/]. Based on dates, stratigraphy, and geologic mapping carried out between 1959 and 1961, Porter (1964) suggested that major revisions were necessary for the late Quaternary glacial succession of the central Brooks Range proposed by Detterman and others (1958).

[1/] Two of the archeological dates from Anaktuvuk Pass are from shallow soil horizons and are reported as "modern" (Stuiver and others, 1960, p. 56-57). They are not shown in the table, and will not be discussed further in this report.

Table 1. Radiocarbon dates from the Chandler Lake quadrangle.

	Exposure No.	Site Location	Date & Lab No.*	Collector & Date	Material Dated	Comments
Tulunga Valley	TU-1	69°00'N 151°22.5'W	>40,000 (I-11,240)	T. D. Hamilton 6/30/78	Peat	Very sparse pollen; predominantly Cyperaceae and Gramineae, with traces of Picea, Betula, Alnus, Compositae, Lycopodium, and Sphagnum (1)
Tulunga Valley	TU-2	68°51.5'N 151°39.5'W	33,220 ± 1760 (I-11,012)	T. D. Hamilton 6/30/78	Wood	Sparse pollen including traces of Gramineae, Cyperaceae, Salix, Ericaceae, Caryophyllaceae, Saxifragaceae, and Cruciferae (1). Bryophytes suggest in situ fen deposit (3)
Anaktuvuk Valley	AN-1	68°34.5'N 151°17.5'W	13,000 ± 140 USGS-695	T. D. Hamilton 7/7/78	Wood	
			13,170 ± 70 USGS-694	T. D. Hamilton 6/29/78	Peat and misc. plant fragments	
			13,270 ± 160 (Y-1084)	S. C. Porter 1961	Wood (Salix)	See Porter (1964)
	AN-2	68°27.5'N 151°20'W	9720 ± 140 (I-10,783)	T. D. Hamilton 6/29/78	Peat	
			10,580 ± 150 (I-11,010)	T. D. Hamilton 6/29/78	Wood and misc. plant fragments	Mixed bryophyte assemblage consisting of dry and moist calcareous elements (3)
	AN-3	68°25'N 151°29.5'W	7940 ± 75 (USGS-696)	T. D. Hamilton 7/23/78	Wood	Salix (2)
			9620 ± 60 (USGS-697)	T. D. Hamilton 7/23/78	Wood and peat	Very sparse pollen, with traces of Cyperaceae (1)
	AN-4	68°18'N 151°30'W	6200 ± 120 (I-10,925)	T. D. Hamilton 7/18/78	Wood	Salix (2). Mixed bryophyte assemblage consisting of dry and wet calcareous elements (3)
			6220 ± 140 (I-10,784)	T. D. Hamilton 7/18/78	Wood and misc. plant fragments	Mixed bryophyte assemblage consisting of moist fen elements with some drier elements (3)
	AN-5	68°09'N 151°43'W	4750 ± 110 (I-206)	Jerry Brown 1959	Peat	Forms layer of fibrous plant remains 5-10 cm thick beneath 0.3 m of mineral soil (Trautman, 1963, p. 64-65)
		68°09'N 151°43'W	6260 ± 160 (Y-770)	S. C. Porter 1959-60	Wood	From lacustrine silt 2.5 m below surface (Porter, 1964)
		68°12'N 151°36'W	6510 ± 610 (SI-114)	J. M. Campbell 1959	Charred bone	From hearth at 10-20 cm depth in gravel of kame terrace (Long, 1965, p. 250)
		68°09'N 151°43'W	7240 ± 100 (Y-1082)	S. C. Porter 1961	Unknown	From lacustrine silt 4.2 m below surface (Porter, 1964)
	AN-6	68°34'N 151°17'W	5180 ± 70 (Y-1085)	S. C. Porter 1961	Unknown	Near top of 4.5 m cutbank (Stuiver and others, 1963, p. 325)
	AN-7	68°02'N 151°43.5'W	2830 ± 120 (Y-771)	S. C. Porter 1959	Wood	From base of 5.5 m section of stratified gravel (Porter, 1964)
	AN-8	68°14.5'N 151°32'W	2760 ± 150 (Y-871)	S. C. Porter 1959-60	Wood	Near base of 2.5 m cutbank (Stuiver and Deevey, 1961, p. 129)
	AN-9	68°18'N 151°29.5'W	1935 ± 80 (I-11,011)	T. D. Hamilton 6/29/78	Bryophytic peat	Numerous leaves and short stems of the moss Scorpidium scorpioides in marl matrix; indicates extremely rich fen (3)
	AN-10	68°18'N 151°29'W	1045 ± 200 (Y-873)	S. C. Porter 1960	Wood	Near base of 6 m cutbank (Stuiver and Deevey, 1961, p. 129)
	AN-11	68°16'N 151°30.5'W	1120 ± 90 (Y-872)	S. C. Porter 1960	Wood	Near base of 4.4 m cutbank (Stuiver and Deevey, 1961, p. 129)
	AN-12	68°37'N 151°15'W	1280 ± 80 (Y-1083)	S. C. Porter 1961	Peat and Salix twigs	Near middle of 3.3 m cutbank (Stuiver and others, 1963, p. 324)
	AN-13	68°12'N 151°32'W	1170 ± 120 (Y-772)	S. C. Porter 1959	Unknown	Organic layer buried beneath 0.4 m loess (Stuiver and Deevey, 1961, p. 129)

Shainin Lake	SH-1	68°20'N 151°02'W	1530 ± 70 (Y-1086)	S. C. Porter 1961	Wood (Salix)	1.5 m above base of cutbank near mouth of Alapah Cr. (Stuiver and others, 1963, p. 324)
			2195 ± 115 (I-10,927)	T. D. Hamilton 7/22/78	Peat and plant fragments	
			2330 ± 90 (I-10,926)	T. D. Hamilton 7/22/78	Peat and plant fragments	
			2750 ± 70 (Y-1087)	S. C. Porter 1961	Wood (Salix)	3 m above base of cutbank near mouth of Alapah Cr. (Stuiver and others, 1963, p. 325)
Itkillik Valley	I-4	68°59.5'N 150°10.5'W	3890 ± 90 (I-10,258)	T. D. Hamilton 7/17/76	Wood and peat	

* I = Isotopes, Inc.
SI = Smithsonian Institution
USGS = U.S. Geological Survey, Menlo Park Lab.
Y = Yale

(1) Identified by T. A. Ager, U.S. Geological Survey
(2) Identified by Forest Products Laboratory, Madison, Wisconsin
(3) Identified and interpreted by J. A. Janssens, University of Alberta, Edmonton, Alberta

A later phase of regional surficial geologic mapping was initiated in 1975 by the Arctic Environmental Studies Program of the U.S. Geological Survey (Hamilton, 1977). Portions of the Chandler Lake quadrangle were mapped in 1976 and 1977; the remainder of the quadrangle was completed in 1978, and a surficial geologic map was published the following year (Hamilton, 1979a)[2/]. This project also resulted in further revisions of the central Brooks Range glacial succession (table 2). One radiocarbon sample was collected from the Itkillik Valley in 1976; 13 additional samples were taken from the remainder of the quadrangle during 1978 (table 1 and plate 1).

ACKNOWLEDGMENTS

Of the 14 radiocarbon samples collected during 1976-1978, four were dated by Stephen W. Robinson at the U.S. Geological Survey Radiocarbon Laboratory in Menlo Park, California, and the remaining 10 by Isotopes, Inc. under the supervision of James Buckley. Wood collected for dating was identified by the Forest Products Laboratory at Madison, Wisconsin, and peats were examined for pollen by Thomas A. Ager of the U.S. Geological Survey. Bryophytes (mosses) from peat samples were identified by Jan A. Janssens at the University of Alberta. Stephen C. Porter generously provided field notes and other unpublished information concerning his field studies and radiocarbon samples.

STRATIGRAPHIC SECTIONS

Tulunga Valley

The two oldest radiocarbon samples from the Chandler Lake quadrangle came from cutbank exposures along Tulunga River in unglaciated terrain beyond the limits of the most extensive of the Brooks Range ice advances (Hamilton, 1979a). Although Tulunga Valley itself was not glaciated, it received outwash from the western flank of the glacier that filled Anaktuvuk Valley during Anaktuvuk River time. It received only windblown silt during subsequent less extensive glacier advances.

[2/] The surficial geologic map of the Chandler Lake quadrangle should be consulted for definitions, locations, and geologic interrelationships of the surficial geologic units discussed on the following pages.

Table 2. Late Quaternary glacial succession, Anaktuvuk Valley (from Hamilton, 1979b).

	Porter (1964)	This paper	
Neoglaciation	Fan Mountain Glaciation	Fan Mountain Glaciation	Neoglaciation
	Alapah Mountain Glaciation	- - - - - - - -	Itkillik Glaciation
Itkillik Glaciation	Anivik Lake Stade	- - - - - - - -	
	- - - - -	Late Itkillik readvance	
	Antler Valley Stade	Itkillik II phase	
	Anayaknaurak Stade	- - - - - - - -	
	Banded Mountain Stade	Itkillik I phase	
	- - - - - -	Early Itkillik (?)	

Exposure TU-1 (fig. 1), a 7-m cutbank on the east side of Tulunga River, exposes silt above fluvial sand and gravel. Although Tulunga River originates in foothills north of the Brooks Range, many stones within the gravel (Unit 1) were derived from areas near the Continental Divide deep within the mountains. These stones probably were contributed to the Tulunga drainage system by meltwater streams that issued from the western flank of the Anaktuvuk River glacier. The overlying fluvial sand (Unit 2) probably is an overbank deposit that formed shortly after deposition of the gravel. It contains peat older than 40,000 ^{14}C yr B.P. and sparse pollen that suggests herbaceous tundra with some shrubs present. The sand extends to only 2.5 m above modern river level, forming a low terrace that lies within an older and higher outwash terrace along Tulunga River. The low terrace and little-weathered sand and gravel possibly are as young as Itkillik I in age (Hamilton, 1979a), and contain stones derived from older outwash and redeposited by a nonglacial stream. The overlying silt (Unit 3) probably is loess that was draped over the terrace during a later ice advance, but the infinite radiocarbon date from Unit 2 provides no firm age limit for this event.

Exposure TU-2 (fig. 2), a similar cutbank along the east side of Tulunga River, lies 20 km south of TU-1. At its downstream end, the exposure stands only 2 m high and consists of compact black peat over stream gravel; it extends farther inland as an amphitheater that is forming by thaw and flowage of ice-rich silt. At the upstream end of the cutbank, silt extends to the river edge and no gravel is evident. The gravel (Unit 1) appears to be a bar deposit with 1.5 m or more of relief, comparable to the point bars that rise to heights of 1 m or more above the modern low-water stage of Tulunga River. The peat (Unit 2), which dates 33,220 $\pm$ 1760 yr B.P., probably formed on a low terrace created when Tulunga River incised into Unit 1. It contains sparse pollen of tundra plants and a moss assemblage that is characteristic of marshy valley floors. The overlying stone-free silt (Unit 3) mantles the hillslope that rises from the valley floor. It evidently formed as loess during late Wisconsin time, but may in part have been modified by solifluction.

Anaktuvuk Valley

All of the dated exposures from Anaktuvuk Valley lie within the limits of the drift sheet of Itkillik II age and its outwash train (Hamilton and Porter, 1975; Hamilton, 1979a). Three exposures (AN-1, AN-2, and AN-3) lie close to the massive Antler Valley end-moraine complex of Porter (1964); dates from these sites place limits on the last major advance and final fluctuation of Pleistocene glaciers beyond the north flank of the Brooks Range in the Anaktuvuk Valley region. Other measured sections along Anaktuvuk River and its tributaries represent alluvial episodes of the Holocene, some of which are related to expansions of cirque glaciers during the last 3500-4000 years. Four other samples, from pits excavated near Anaktuvuk Pass, place limits on final deglaciation of the main valley and define a subsequent Holocene period of soil stability.

Exposure AN-1 (fig. 3) extends for more than 0.5 km along the west side of Anaktuvuk River about 1.5 km downstream from the Antler Valley moraine front. Its face is concave eastward in plan, being most deeply indented through its central part and extending outward toward the valley center at both ends. A pronounced outwash terrace about 15 m high, which extends down-valley past the site, lies just inland from the edge of the bluff and is separated from it by an erosional surface littered with small lag boulders. Strongly jointed and moderately weathered till (Unit 1) at the base of the exposure is identical in postglacial modification to jointed and weathered till of Itkillik I age in the Koyukuk Valley (Hamilton, 1980). This deposit probably was subjected to weathering for an appreciable time prior to renewed deposition at the site. Unit 2 is unweathered outwash that originated from the Antler Valley end moraine, which is of Itkillik II age (Hamilton and Porter, 1975; Hamilton, 1979a). The river continued to aggrade after deposition of outwash ceased, and finer overbank deposits (Unit 3) were laid down to a height of 10 m above modern river level. Organic fragments taken from a shallow trough on a bedding-plane surface 0.9 m below the top of Unit 3 date 13,170 ± 160 yr B.P., and *in situ* roots at a comparable level farther along the bluff date 13,000 ± 140 yr B.P. These dates are nearly identical to the date of 13,270 ± 160 yr B.P. obtained in 1961 from this locality by S. C. Porter (1964). The sand is discolored by oxides through its upper 0.7-0.9 m, suggesting that it was exposed to the surface for some time before being covered by the overlying sediments. Unit 4, a diamicton, was considered a true till by Porter (1964), but now is believed to be a colluvial deposit for reasons discussed in a subsequent section. Unit 5, an outwash gravel, was subsequently deposited to 15.5 m in height then was cut down to about 12.5 m across a slip-off slope that connects the terrace face with the bluff edge. Carbonate crusts, vertically oriented stones, and admixed silt indicate that the 12.5-m surface has been exposed to weathering and frost mixing for an appreicable period.

Exposure AN-2 (fig. 4) is a 7-m cutbank along Anaktuvuk River near the upvalley end of the Antler Valley moraine complex. The bank exposes horizontally bedded fluvial sand that contains peaty interbeds and fragments of detrital wood. Organic debris 2.5 m above the base of the exposure dates 9720 ± 140 yr B.P. Near the upvalley end of the exposure, beds of detrital peat that dip south at 12 degrees fill an erosional channel cut in the sand. Wood fragments from the channel floor date 10,580 ± 150 yr B.P. The two dates show an apparent age reversal, which may be due to redeposition of older organic debris eroded at the time of channel incision, but which might also have been caused by (a) an additional cut-and-fill structure not noted in the field, (b) accidental switching of the two samples in the field or in the laboratory, or (c) laboratory counting errors somewhat larger than those reported. Despite the age reversal, these two dates provide a minimum limiting age for final glacier retreat from the Antler Valley moraine complex and, together with the dates from AN-1, bracket the last major readvance of late Itkillik age between about 13,000 and 10,600 yr B.P. In addition, the two dates show that filling of the basin created by ice recession was in progress between about 10,500 and 9700 yr B.P.

Exposure AN-3 (fig. 5) was measured along the west wall of a gravel pit excavated into till and fan gravel within the drift limit of late Itkillik age 8 km upvalley from the Antler Valley moraine complex. Diamicton (Unit 1) occurs throughout the gravel pit; it appears to be basal till that grades upward into water-washed ice-contact stratified drift. Weathering near the upper contact of Unit 1 suggests that an appreciable interval separated deposition of till and accretion of fan gravel at the site. Peat (Unit 2) between these two deposits dates 9620 ± 60 yr B.P. The overlying sandy gravel is present only locally; its fabric and distribution suggest fan deposition by the small tributary stream that flows eastward toward the center of Anaktuvuk Valley. Willow fragments near the base of the gravel date 7940 ± 75 yr B.P.

The two concordant dates from AN-2 provide a minimum age limit for deglaciation of this segment of Anaktuvuk Valley, and suggest that revegetation and stabilization of the drift sheet had occurred by about 9700 yr B.P. The cause of fan accumulation about 1800 yr later is uncertain. It could relate to climatic deterioration, leading to increased sediment yield to the tributary stream; alternatively, it could reflect destruction of sod cover by some agency unrelated to climate or merely the normal outward expansion of a growing alluvial fan.

Exposure AN-4 (fig. 6) is the actively caving bank of a thaw lake on a broad, nearly level segment of the valley floor at the north margin of the Brooks Range. Through this stretch of Anaktuvuk Valley, the postglacial fill consists of a complex of fluvial and lacustrine deposits that formed behind the Antler Valley moraine belt. Most of the measured section at AN-4 consists of well stratified fine sand and silty fine sand (Unit 1) that dips eastward at about 8 degrees and contains detrital peat along many bedding planes (table 1). These sediments probably represent distal fan-delta deposits derived from Akmagolik Creek, a western tributary to the Anaktuvuk that crosses the valley floor about 2 km north of AN-4. Wood and peat 2.1 m above the base of Unit 1 date 6220 ± 140 yr B.P.; wood and peat 1 m below its upper contact date 6200 ± 120 yr B.P. The bedded sand evidently was deposited rapidly in middle Holocene time, possibly while this segment of the valley still supported a moraine-dammed lake. The fan-delta deposits are overlain by silt and sandy silt (Unit 2) that may have formed subaerially after drainage of the lake or alluviation of the fan-delta above its surface. Sandy peat and modern surface sod (Unit 3) cap the section.

Soil Pits Near Anaktuvuk Pass

Four middle Holocene dates were obtained by S. C. Porter, J. M. Campbell, and Jerry Brown from excavations at Anaktuvuk Pass (Locality AN-5). Ages of 7240 ± 100 and 6260 ± 160 yr B.P. were reported by Porter (1964) from organic material at 4.2 and 2.5 m depth in lacustrine silt on the floor of the pass. These two dates place minimum limits on deglaciation of Anaktuvuk Pass, and also represent a time at which kettle lakes were more extensive than at present prior to downcutting of their outlets. A comparable date of 6510 ± 610 yr B.P. on charred bone fragments near the surface of a kame terrace was reported by Campbell. This date provides a minimum limit not only on deglaciation but also on revegetation sufficient to permit influx of game animals and their human predators into the Anaktuvuk Pass area. A date of 4750 ± 110 yr B.P., obtained by Brown on buried peat beneath silty tundra soil, represents a period of soil stability that later was terminated by increased frost action or by increased deposition of windblown silt.

Additional Dates From Anaktuvuk Valley

Eight other radiocarbon dates of middle to late Holocene age have been obtained from low terraces along Anaktuvuk River and some of its tributaries. The oldest sample, from Exposure AN-6 near Anayaknaurak Creek (table 3), is peat from overbank deposits that overlie coarse gravel at a height of about 3 m above river level. The peat is covered by about 0.4 m of finer gravel and by mixed debris that possibly was frost-churned above the permafrost table. The date of 5180 ± 70 yr B.P. may represent a pause during alluviation, but the differing character of the gravel above and below the peat indicate that the river could have eroded down to the 3-m level, then alluviated slightly before final downcutting.

A date of 2830 ± 120 yr B.P. from Exposure AN-7 in Inukpasugruk Valley near Anaktuvuk Pass (table 3) appears to represent alluviation of an outwash terrace that both Porter (1964, 1966) and Hamilton (1979a) assigned to an end moraine that lies a short distance upvalley. However, this conclusion is inconsistent with lichenometric measurements carried out in 1978 by Parker E. Calkin and James M. Ellis on moraines of cirque glaciers near Anaktuvuk Pass. Calkin and Ellis found that local glaciers have not extended beyond cirque thresholds since at least middle Holocene time (J. M. Ellis, written communication, 10/12/78). Drainage patterns evident on aerial photographs suggest the alternative possibility that the outwash train was locally eroded at the sample locality by a steep tributary stream that enters Inukpasugruk Valley from the southwest, and that the stream later alluviated in response to renewed glacier activity in cirques at its head. A similar date of 2760 ± 150 yr B.P. (table 3) was obtained near the base of a low cutbank at Exposure AN-8 in Anaktuvuk Valley about 25 km farther north, suggesting that alluviation in response to renewed cirque-glacier activity may have been widespread at this time.

Exposure AN-9 (fig. 7), an 8.8-m cutbank along Anaktuvuk River, intersects an alluvial terrace that extends down the center of the valley and is

Table 3. Stratigraphic sections measured in Anaktuvuk Valley by S. C. Porter.

1. Exposure AN-6. Cutbank, west side Anaktuvuk River about 200 m above mouth of Anayaknaurak Creek. Measured 8/2/61.

UNIT	THICKNESS (m)	DESCRIPTION
4	0.46	Till or till-like sediment.
3	0.38	Pebble gravel.
2	0.41	Dusky-yellow sand with dark brown peaty layer near base dating 5180 ± 70 yr B.P. (Y-1085). Sand thickens northward; thins southward abruptly.
1	3.05	Cobble-boulder gravel.

2. Exposure AN-7. Cutbank, west side Inukpasugruk Creek 11 km above its mouth. Measured 1959.

UNIT	THICKNESS (m)	DESCRIPTION
2	5.3	Gravelly alluvium.
1	0.2	Silt and clay containing wood dating 2830 ± 120 yr B.P. (Y-771).

3. Exposure AN-8. West bank Anaktuvuk River 0.5 km below mouth of Akvalutak Creek. Measured 1960.

UNIT	THICKNESS (m)	DESCRIPTION
3	0.8	Fine to very fine sand containing rooted tundra vegetation.
2	0.9	Fine to medium sand, with beds of silt and organic silty fine sand. Thin (0.15 m) bed of silt and clay at base.
1	0.4	Silt and fine to medium sand containing organic matter that includes willow twigs to 2.5 cm diameter and 20 cm length. Wood dates 2760 ± 150 yr B.P. (Y-871).
--	0.3	Covered.

4. Exposure AN-10. East side Anaktuvuk River 2 km above mouth of Itikmalaiyak Creek. Measured 1960.

UNIT	THICKNESS (m)	DESCRIPTION
2	0.6	Organic mat containing rooted tundra vegetation.
1	5.6	Interstratified sand and silt, with fine sand dominant. Wood fragments 0.76 m from base of exposure date 1045 ± 200 yr B.P. (Y-873).

5. Exposure AN-11. Cutbank along Anaktuvuk River 6 km above mouth of Itikmalaiyak Creek. Measured 8/7/60.

UNIT	THICKNESS (m)	DESCRIPTION
3	0.5	Organic mat containing rooted tundra vegetation.
2	1.8	Fine to medium sand.
1	1.5	Bedded fine to medium sand, silt, and clay. Willow twigs present at base and near top. Twigs near base date 1120 ± 90 yr B.P. (Y-872).
--	0.6	Covered.

6. Exposure AN-12. Cutbank, west side Anaktuvuk River 5 km below mouth of Anakaknaurak Creek. Measured 8/4/61.

UNIT	THICKNESS (m)	DESCRIPTION
3	0.9	Sand and gravel. Bedded fine sand, sandy pebbly gravel, and cobble-pebble gravel.
2	0.15	Fine dark brown sand containing peat and willow twigs dating 1280 ± 80 yr B.P. (Y-1083).
1	0.5	Medium sand containing plant fragments.
--	0.8	Covered.

7. Site AN-13. Soil pit near north shore of Anivik Lake. Excavated and measured 8/22/59.

UNIT	THICKNESS (m)	DESCRIPTION
5	0.30	Tundra vegetation rooted in silt.
4	0.27	Nonstratified fine silt.
3	0.03	Dark brown organic layer. Dates 1170 ± 120 yr B.P. (Y-772).
2	0.18	Stratified fine sand.
1	0.15+	Pebble gravel. Extends below base of pit.

inset within basin deposits of early to middle Holocene age. Fluvial sand containing shale chips and peaty interbeds is exposed through most of the section, with increasing amounts of eolian sand probably incorporated in the upper 2 m. An especially prominent peat horizon 3.3 m above river level dates 1935 ± 80 yr B.P. and marks a pause in alluviation. The deposit subsequently accreted to a height of 8.8 m, with at least some of the accretion resulting from influx of windblown sand.

Three additional dates from low alluvial terraces along Anaktuvuk River (Exposures AN-10, AN-11, and AN-12; table 3) fall within the time range of about 1300-1000 yr B.P. These dates suggest that a final episode of alluviation may have been widespread through the valley beginning about this time. A comparable date of 1170 ± 120 yr B.P., obtained by Porter from a buried organic soil beneath loess near Anivik Lake (Exposure AN-13; table 3), appears to record an interval of soil stability followed by frost activity or loess influx.

Itkillik Valley

Five radiocarbon dates from a section of Itkillik Valley that lies just beyond the east margin of the Chandler Lake quadrangle near the north margin of the Brooks Range have been discussed in a previous report (Hamilton, 1979c). One additional date (from Exposure I-4, fig. 8) was obtained from a low cutbank along Itkillik River about 65 km north of the range front within the Chandler Lake quadrangle. A widespread alluvial terrace about 4 m high may represent outwash of Itkillik age in this stretch of Itkillik Valley (Hamilton, 1979a). Exposure I-4 consists of coarse gravel that is overlain by floodplain deposits and by peat buried beneath about half a meter of silt and sod. The peat dates 3890 ± 90 yr B.P., and probably represents an episode of nondeposition and soil stability that was followed by renewed influx of loess.

Shainin Lake Area

Shainin Lake occupies the north end of an elongate moraine-dammed basin that was partly filled from the south by prograding deltaic sediments from Alapah Creek. Exposure SH-1, a 6.7-m cutbank near the mouth of Alapah Creek, exposes northward-dipping deltaic deposits of fine to medium sand with interbedded mats of detrital plant fragments (fig. 9). Samples were taken near the north and south ends of the exposure in an attempt to determine the rate of northward progradation of the delta. The dates show a small apparent age reversal, but counting errors are sufficiently high that the two samples may be considered essentially contemporaneous. If this inference is valid, the dates indicate very rapid northward growth of the delta about 2200-2300 yr B.P. at a time when Shainin Lake stood approximately 7 m higher than present.

This locality was examined independently in 1961 by S. C. Porter, who obtained radiocarbon dates of 1530 $\pm$ 70 and 2750 $\pm$ 70 yr B.P. from beds about 1.5 and 3 m above river level in a cutbank along Alapah Creek that probably lies a short distance upstream from SH-1. Porter's field notes show a younger 2-m alluvial terrace set within the older deltaic deposits along Alapah Creek. His younger date might represent construction of this terrace about 1500 yr B.P.; his older date may document a phase of deltaic progradation a few hundred years older than that recorded closer to the modern lake shore at SH-1.

DISCUSSION

The oldest radiocarbon dates in the Chandler Lake quadrangle were obtained from two exposures in Tulunga Valley, where organic deposits on low alluvial terraces are buried beneath silt and muck. The finite date of 33,220 $\pm$ 1760 yr B.P. from a buried peat at TU-2, if valid despite its large counting error, suggests that during middle Wisconsin time much of the valley floor may have been a stable and loess-free floodplain marsh where peat accumulated. Renewed influx of loess took place probably during a subsequent glaciation that corresponds in time with the Itkillik II phase as defined and dated by Hamilton and Porter (1975) and by Hamilton and others (1980).

Within Anaktuvuk Valley, the section at Anayaknaurak Bluff (AN-1) demonstrates that a major unconformity separates glacial phases of Itkillik I and Itkillik II age, and shows that the Itkillik II interval was marked by at least two glacial advances into the end-moraine complex near Antler Valley. Three concordant radiocarbon dates from AN-1 demonstrate that the youngest readvance occurred shortly after about 13,100 yr B.P., a date that correlates very well with a beginning date of 12,840 $\pm$ 160 yr B.P. or slightly earlier for the advance of an ice lobe through Atigun Canyon into Sagavanirktok Valley (Hamilton, 1979c, p. 5-7). As dated in the Sagavanirktok Valley, the glacier during this advance remained at its maximum between about 12,900 and 12,700 yr B.P., and ice had receded or substantially diminished by 11,890 $\pm$ 200 yr

B.P. The Sagavanirktok Valley chronology is further supported by the older of two radiocarbon dates from AN-2, at the upvalley end of the Antler Valley moraine complex, which shows that final recession of ice from this part of Anaktuvuk Valley occurred prior to 10,580 ± 150 yr B.P.

Anayaknaurak Bluff is the type locality for the Anayaknaurak readvance of Porter (1964), which is based on his identification of till above the 13,000-year-old alluvium. This deposit (Unit 4 in fig. 3) was restudied in 1978, and the following evidence suggests that it is not a true till:

1. Absence of clasts larger than those carried by glacial meltwater streams. Most stones are 5-10 cm diameter, and rarely exceed 15 cm.
2. Lack of basal deformation. Some stones are pressed down slightly into the underlying sand, which must have been unfrozen during emplacement of the "till", but no mixing or interpenetration of the 2 units is evident.
3. Lack of compaction. Unlike till, which generally supports near-vertical faces in river bluffs, the diamicton shows little consolidation and flows readily in all exposures.
4. Localized occurrence. The diamicton forms a lens 1.5-2.0 m thick through the central part of the bluff where till is exposed near the river edge. It thins and disappears toward both ends of the bluff, where the basal unit is outwash gravel, and is represented only by a stone line in outwash.

The till-like sediment (diamicton) evidently occurs only where the deeply indented central section of the bluff intersects till near the base of the valley side. Erosion of the till by lateral cutting of the meltwater stream may have formed an oversteepened face down which the highly mobile clayey sediment flowed readily (fig. 10). The stone line within the outwash indicates that emplacement of the diamicton and redeposition of small erratic boulders were contemporaneous with outwash deposition.

Ice retreat from the Antler Valley moraine complex was followed by progressive filling of the depositional basin that formed behind the moraine dam. Filling was in progress close to the moraine belt by 10,600 yr B.P., and continued as late as 6200 ± 120 yr B.P. near the range front. The 9700-year-old buried peat at AN-3 does suggest an episode of at least local stability followed by renewed sedimentation about 8000 yr B.P. Comparable dates of 9500-8200 yr B.P. for peat formation that was followed by solifluction near Toolik River (Hamilton, 1979c, p. 12-13) suggest that the peat-forming interval might have regional significance.

Dates of about 6300 to 7300 yr B.P., obtained from Anaktuvuk Pass by Porter and Campbell (table 1), place minimum limits on final glacier recession from portions of Anaktuvuk Valley deep within the Brooks Range. The actual interval when ice disappeared from the pass is uncertain. By analogy with the Sagavanirktok Valley record, it falls somewhere within the broad time range of about 11,800 to 7300 yr B.P.

Subsequent geologic history in the Chandler Lake quadrangle is marked mainly by renewed glacier expansion and stream alluviation during the last 4000-3500 yr following a middle Holocene episode of downcutting and soil formation under probably milder climate. Dates from Anaktuvuk River and Anaktuvuk Pass show peat formation about 5200-4700 yr B.P. that was followed by renewed alluviation and loess deposition. A date of 3890 ± 90 yr B.P. on buried peat along the Itkillik River places a maximum limit on the onset of Holocene loess accretion north of the range front. Neoglacial alluviation began at an unknown time, but was in progress 2800-2700 yr B.P. at sites AN-8 and AN-9, and rapid delta building continued until at least 2200 yr B.P. at Shainin Lake. A thick buried peat at AN-9 may record a pause in alluviation about 1900 yr B.P. A possible younger episode of alluviation to heights generally 2.5 to 3.5 m above modern stream levels is indicated by three similar dates of 1300-1000 yr B.P. in lower portions of low alluvial terraces along Anaktuvuk River; peat buried beneath loess near Anivik Lake (Site AN-13) has a corresponding date of 1170 ± 120 yr B.P.

Radiocarbon dates on possible episodes of late Holocene alluviation correspond closely to dates reported by Hamilton (1979c) from northern Brooks Range valleys within the Philip Smith Mountains quadrangle (fig. 11). Dates of 3890 ± 90 yr B.P. from Itkillik Valley (this report) and 3570 ± 90 yr B.P. from the Sagavanirktok Valley (Hamilton, 1979c, p. 10) bracket the beginning of a widespread episode of loess deposition and stream aggradation that correlates with Neoglacial ice advances in cirques at valley heads (Hamilton, in press). Vigorous alluviation appears to have continued until perhaps 2600 yr B.P., for widespread thick peats of that age in stream deposits indicate a a general pause or reversal in alluviation. This corresponds to the beginning of an interval of reduced cirque glaciation which, according to lichenometry, lasted between about 2600 and 1100 yr B.P. in the central Brooks Range (Calkin and Ellis, in press). According to the Shainin Lake record, downcutting to a stream level close to present may have taken place sometime between about 2000 and 1500 yr B.P., and dates from Itkillik Valley show comparable downcutting must have occurred there at about the same interval. Renewed alluviation began about 1300 yr B.P. in both Itkillik and Anaktuvuk Valleys, and a separate later phase of alluviation that began about 450 yr B.P. or earlier in Itkillik Valley (Hamilton, 1979c, p. 13) may be widespread through at least headward portions of mountain valleys.

REFERENCES CITED

Calkin, P. E., and Ellis, J. M., 1980, A lichenometric dating curve and its application to Holocene glacier fluctuations in the central Brooks Range, Alaska: Arctic and Alpine Research, v. 12, no. 3 (in press).

Campbell, J. M., 1962, Cultural succession at Anaktuvuk Pass, arctic Alaska, p. 39-54, in Campbell, J. M., ed., Prehistoric cultural relations between the arctic and temperate zones of North America: Arctic Institute of North America Technical Paper No. 11, 181 p.

Detterman, R. L., Bowsher, A. L., and Dutro, J. T., Jr., 1958, Glaciation on the Arctic Slope of the Brooks Range, northern Alaska: Arctic, v. 11, p. 43-61.

Hamilton, T. D., 1977, Surficial geology of the east-central Brooks Range, p. B15-B16, in Blean, K. M., ed., The United States Geological Survey in Alaska - Accomplishments during 1976: U.S. Geological Survey Circular 751-B, 112 p.

_____1979a, Surficial geologic map of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1121, scale 1:250,000, 1 sheet.

_____1979b, Late Cenozoic glaciations and erosion intervals, north-central Brooks Range, p. B27-B29, in Johnson, K. M., and Williams, J. R., eds., The United States Geological Survey in Alaska - Accomplishments during 1978: U.S. Geological Survey Circular 804-B, 163 p.

_____1979c, Radiocarbon dates and Quaternary stratigraphic sections, Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 79-866, 44 p.

_____1980, Quaternary stratigraphic sections with radiocarbon dates, Wiseman quadrangle, Alaska: U.S. Geological Survey Open-File Report 80-791.

Hamilton, T. D., 198_, Episodic Holocene alluviation in the central Brooks Range - Chronology, correlations, and climatic implications, in Albert, N. R. D., and Hudson, Travis, eds., The United States Geological Survey in Alaska - Accomplishments during 1979: U.S. Geological Survey Circular 823-B (in press).

Hamilton, T. D., and Porter, S. C., 1975, Itkillik glaciation in the Brooks Range, northern Alaska: Quaternary Research, v. 5, p. 471-497.

Hamilton, T. D., Stuckenrath, Robert, and Stuiver, Minze, 1980, Itkillik glaciation in the central Brooks Range - Radiocarbon dates and stratigraphic record [abs.]: Geological Society of America Abstracts with Programs, v. 12, p. 109.

Irving, W. N., 1951, Archaeology in the Brooks Range of Alaska: American Antiquity, v. 17, p. 52.

_____1953, Evidence of early tundra cultures in northern Alaska: Anthropological Papers, University of Alaska, v. 1, no. 2, p. 55-85.

Long, Austin, 1965, Smithsonian Institution radiocarbon measurements II: Radiocarbon, v. 7, p. 245-256.

Porter, S. C., 1964, Late Pleistocene glacial chronology of north-central Brooks Range, Alaska: American Journal of Science, v. 262, p. 446-460.

_____1966, Pleistocene geology of Anaktuvuk Pass, central Brooks Range, Alaska: Arctic Institute of North America Technical Paper No. 18, 100 p.

Solecki, R. S., 1951, Notes on two archaeological discoveries in Alaska, 1950: American Antiquity, v. 17, p. 55-57.

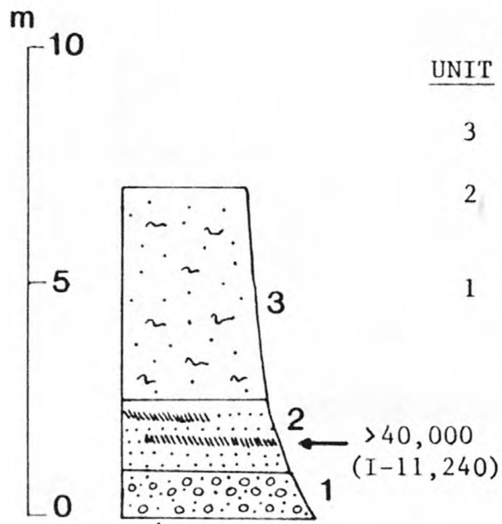
Stuiver, Minze, and Deevey, E. S., 1961, Yale natural radiocarbon measurements VI: Radiocarbon, v. 3, p. 126-140.

Stuiver, Minze, Deevey, E. S., and Gralenski, L. J., 1960, Yale natural radiocarbon measurements V: Radiocarbon, v. 2, p. 49-61.

Stuiver, Minze, Deevey, E. S., and Rouse, Irving, 1963, Yale natural radiocarbon measurements VIII: Radiocarbon, v. 5, p. 312-341.

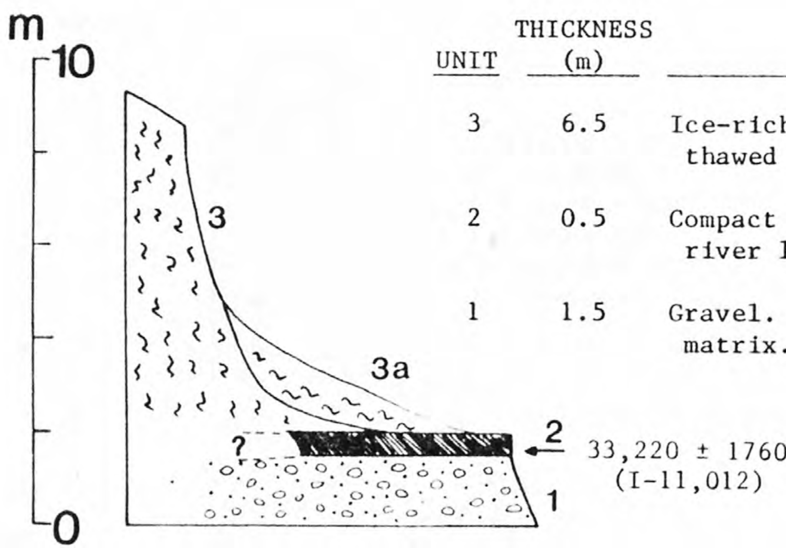
Trautman, M. A., 1963, Isotopes, Inc. radiocarbon measurements III: Radiocarbon, v. 5, p. 62-79.

Ugolini, F. C., and Tedrow, J. C. F., 1963, Soils of the Brooks Range, Alaska - 3. Rendzina of the arctic: Soil Science, v. 96, p. 121-127.



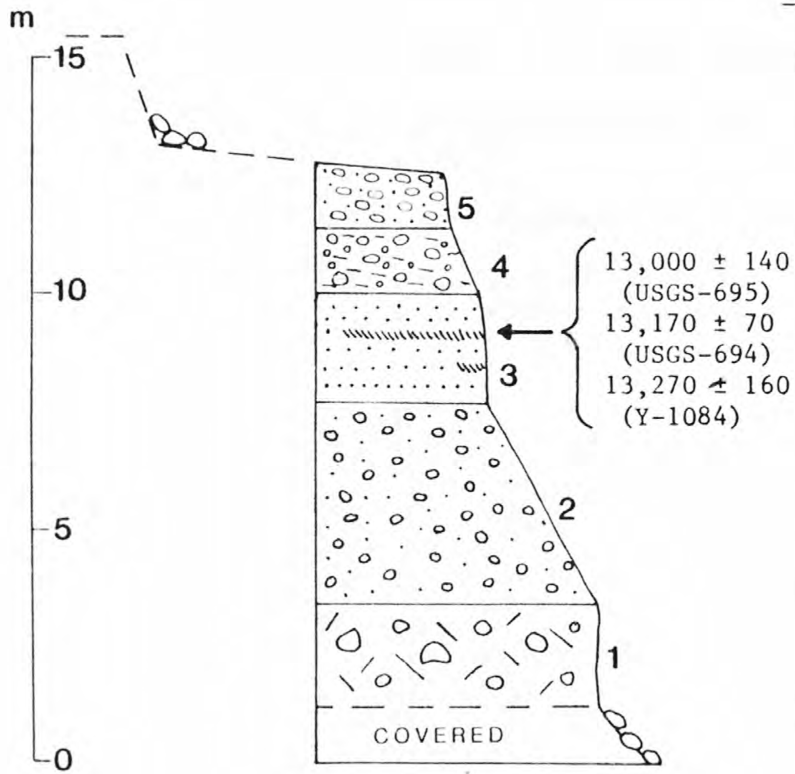
UNIT	THICKNESS (m)	DESCRIPTION
3	4.5	Grey to very dark grey silt and organic silt.
2	1.5	Bedded fluvial sand, containing detrital wood and peat lenses along bedding planes.
1	1.0	Pebble-cobble gravel containing clasts of Devonian Kanayut Conglomerate.

Figure 1. Exposure TU-1. East bank Tulunga River at north margin of Chandler Lake quadrangle. Stands 7 m high.



UNIT	THICKNESS (m)	DESCRIPTION
3	6.5	Ice-rich frozen grey silt. Subject to flowage when thawed (subunit 3a).
2	0.5	Compact black peat. Forms resistant ledge 2 m above river level.
1	1.5	Gravel. Rounded pebbles and small cobbles in sandy matrix.

Figure 2. Exposure TU-2. East bank Tulunga River 8 km above confluence with East Fork. Stands 2 m high, rising inland to 8.5 m.



UNIT	THICKNESS (m)	DESCRIPTION
5	1.2	OUTWASH GRAVEL. Pebbles, cobbles and scattered small boulders in poorly sorted brown sandy matrix. Carbonate crusts on undersides of stones. Forms prominent 15-m terrace along both sides of valley.
4	1.5	DIAMICTON. Pebbles, cobbles, and very sparse small boulders in silty matrix. Upper 0.5 m oxidized (7.5 YR 5/4); lower 1.0 m very dark grey (10 YR 3/1). Present only in central part of bluff. Flows readily on all exposed faces.
3	2.2	SAND; brown (7.5 YR 5/4), fine to medium, horizontally bedded with some local crossbeds. Contains some interbeds of organic silty fine sand.
2	4.3	OUTWASH GRAVEL. Subrounded to rounded pebbles and cobbles, with some small boulders, in cleanly washed medium sand to granule matrix.
1	3.5	TILL. Striated stones up to 1 m diameter in very compact dark grey (10 YR 4/1) muddy matrix. Strongly jointed, with some oxide penetration and some stone weathering along joint planes.

Figure 3. Exposure AN-1. West bank Anaktuvuk River 0.5 km below mouth of Anayaknaurak Creek. Stands 12.7 m high, rising inland to 15.5 m terrace.

UNIT	THICKNESS (m)	DESCRIPTION
4	2.5	Medium sand, horizontally bedded; contains peaty interbeds and detrital wood.
3	1.5	Organic fine sand with peaty interbeds. Dips upvalley at 12°, filling channel in Unit 1
2	0.01	Wood fragments in matrix of sedge-bryophyte peat.
1	3.0	Medium sand, as in Unit 4, with layers and lenses of coarse and fine sand. Continuous with Unit 4 to N; interupted by erosional channel to S.

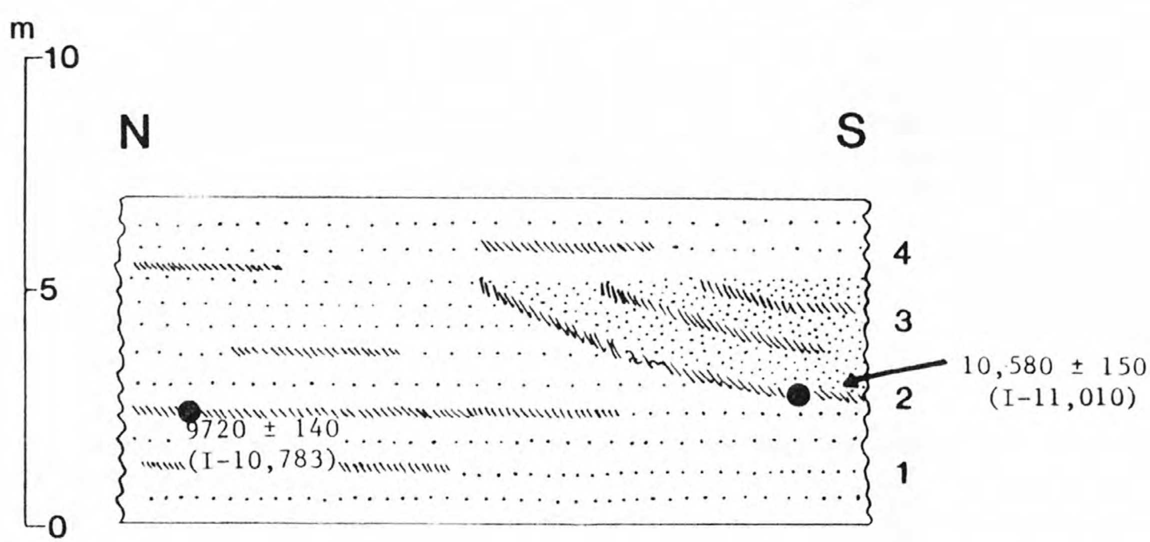
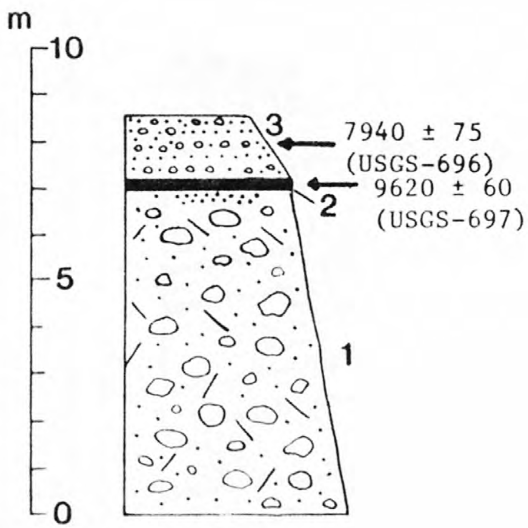
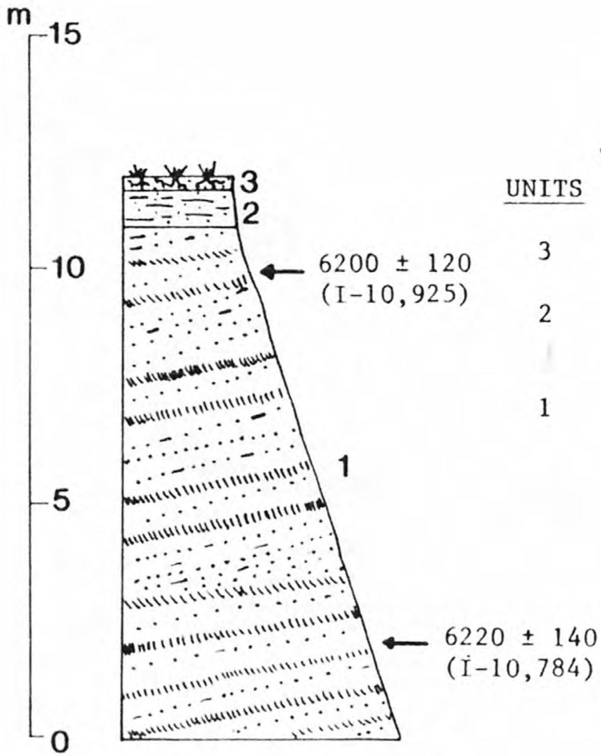


Figure 4. Exposure AN-2. East bank Anaktuvuk River 0.8 km above mouth of Irgkivik Creek. Stands 7 m high. Section measured at south end of exposure.



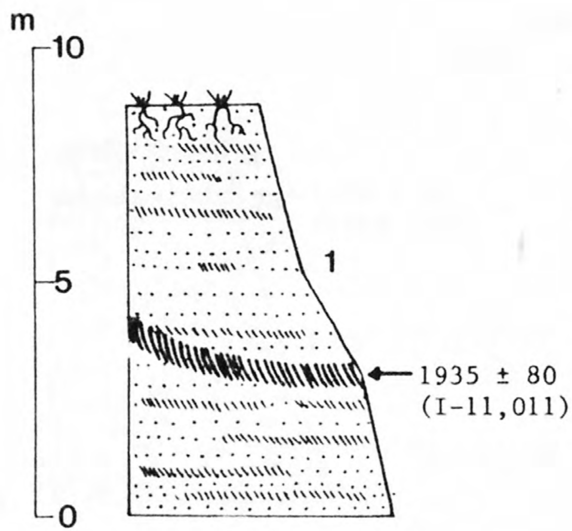
UNIT	THICKNESS (m)	DESCRIPTION
3	0.7-1.5	Sandy gravel, dominantly pebbles and small cobbles, interbedded with layers and lenses of organic fine sand 5-15 cm thick.
2	0.4	Compact black peat; strong fetid odor.
1	7.0	Diamicton. Stones up to 1 m exposed diameter, nonsorted and nonstratified, in generally sandy matrix. Upper 0.2-1.0 m commonly is water-washed sand and gravel. Upper 0.6 m oxidized, with stones weathered and carbonate-encrusted; some stones oriented vertically.

Figure 5. Exposure AN-3. Gravel pit near Tiglukpuk airstrip, 1.5 km west of Anaktuvuk River opposite mouth of Iknivik Creek. Stands up to 8.9 m high.



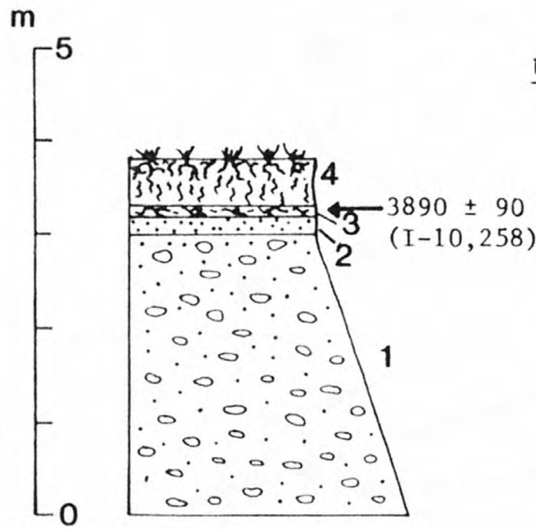
UNITS	THICKNESS (m)	DESCRIPTION
3	0.2	Sandy peat.
2	0.8	Silt and sandy silt; dark greyish brown (10 YR 4/2) with yellowish brown (10 YR 5/6) layers and lenses.
1	11.0	Very dark greyish brown (10 YR 3/2) silty fine sand, with layers and lenses of dark yellowish brown (10 YR 4/4) fine sand. Well stratified, with parallel beds 0.2-1.5 cm thick. Thin (0.2-1.0 cm) peat mats along many bedding planes. General eastward dip into bluff face.

Figure 6. Exposure AN-4. East bank of thaw lake 1 km west of Anaktuvuk River at north flank of Brooks Range about 2 km upvalley from mouth of Akmagolik Creek. Stands 12 m high, with upper surface forming part of extensive lacustrine plain.



UNIT	THICKNESS (m)	DESCRIPTION
1	8.8	Angular medium to fine sand containing shale chips of large sand to granule size. Beds of peaty sand common in lower 4.5 m and upper 2 m. Especially prominent peat bed at 3.3 m above river level.

Figure 7. Exposure AN-9. West bank Anaktuvuk River 2 km above mouth of Itikmalaiyak Creek at north flank of Brooks Range. Stands 8.8 m high.



UNIT	THICKNESS (m)	DESCRIPTION
4	0.55	Surface sod above mottled dark grey (5 Y 4/1) to light olive brown (2.5 Y 5/4) clayey silt.
3	0.10-0.15	Very dark brown (10 YR 2/2) peat alternating with very dark greyish brown (2.5 Y 3/2) slightly clayey silt in layers and lenses 2-4 cm thick. Detrital wood and lenses of grass peat present near base.
2	0.05-0.25	Very dark greyish brown (10 YR 3/2) to very dark grey (10 YR 3/1) well sorted nonbedded fine sand.
1	3	Gravel. Rounded cobbles and pebbles in coarse sandy matrix. Usual maximum diameter 15 cm.

Figure 8. Exposure I-4. East bank Itkillik River at north margin of Chandler Lake quadrangle. Stands 3.8 m high.

UNIT	THICKNESS (m)	DESCRIPTION
1	6.7	SAND, fine to medium, in beds 6-10 cm thick; alternate with detrital organic mats in beds of same thickness. Beds steepen upward from 8-12° at base of bank to 15-20° near top.

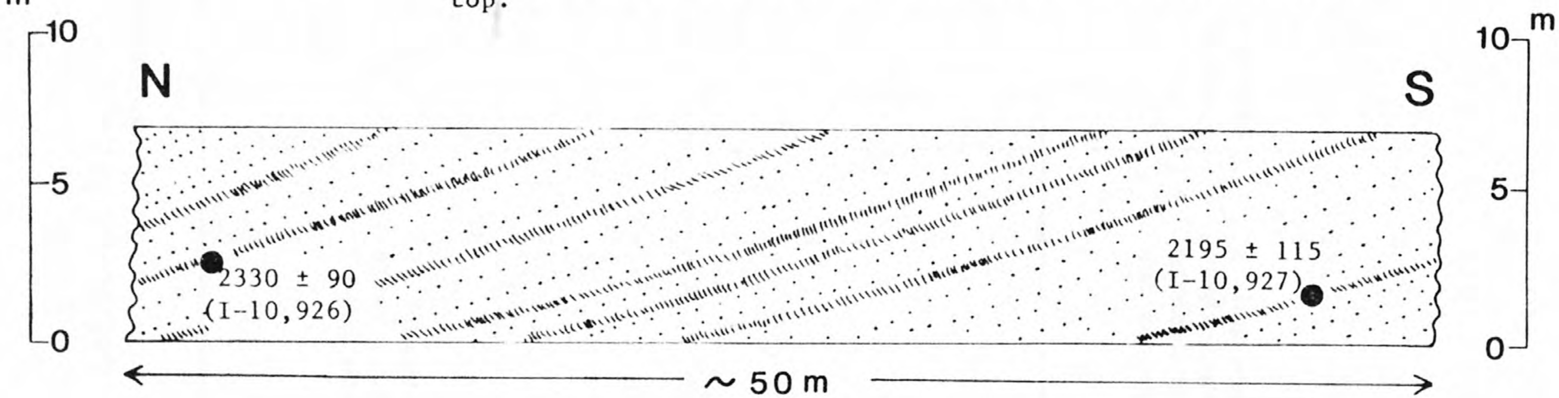
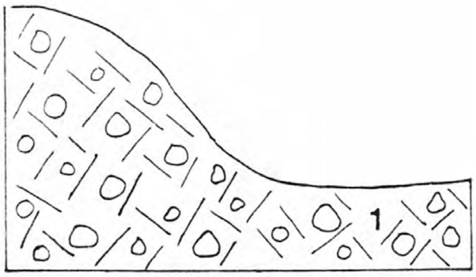
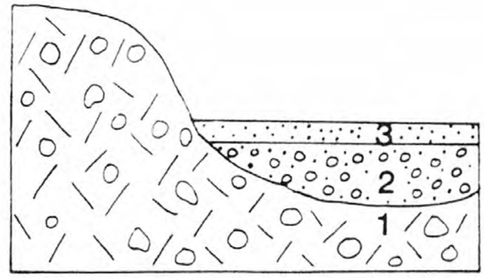


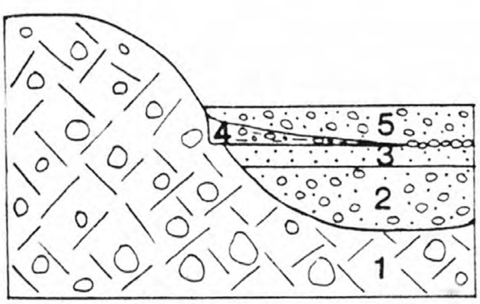
Figure 9. Exposure SH-1. East bank of Alapah Creek on delta at south shore of Shainin Lake.



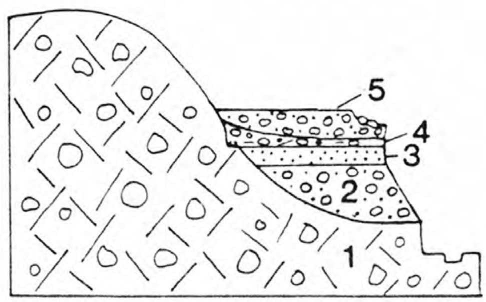
1. Deposition of till (Unit 1) across floor and flank of Anaktuvuk Valley during Itkillik I time.



2. Deposition of outwash and interstadial alluvium (Units 2 and 3) during maximum ice advance of Itkillik II time and subsequent glacier recession.



3. Deposition of outwash (Unit 5) during readvance of late Itkillik time. Erosion of till bluff generates diamicton (Unit 4) and stone line.



4. Subsequent incision of Anaktuvuk River forms terraces at 15.5 and 12.5 m (shown above) as well as at lower levels.

Figure 10. View north down Anaktuvuk Valley, showing valley floor and its west flank in area of Exposure AN-1. Inferred depositional sequence and subsequent terrace formation.

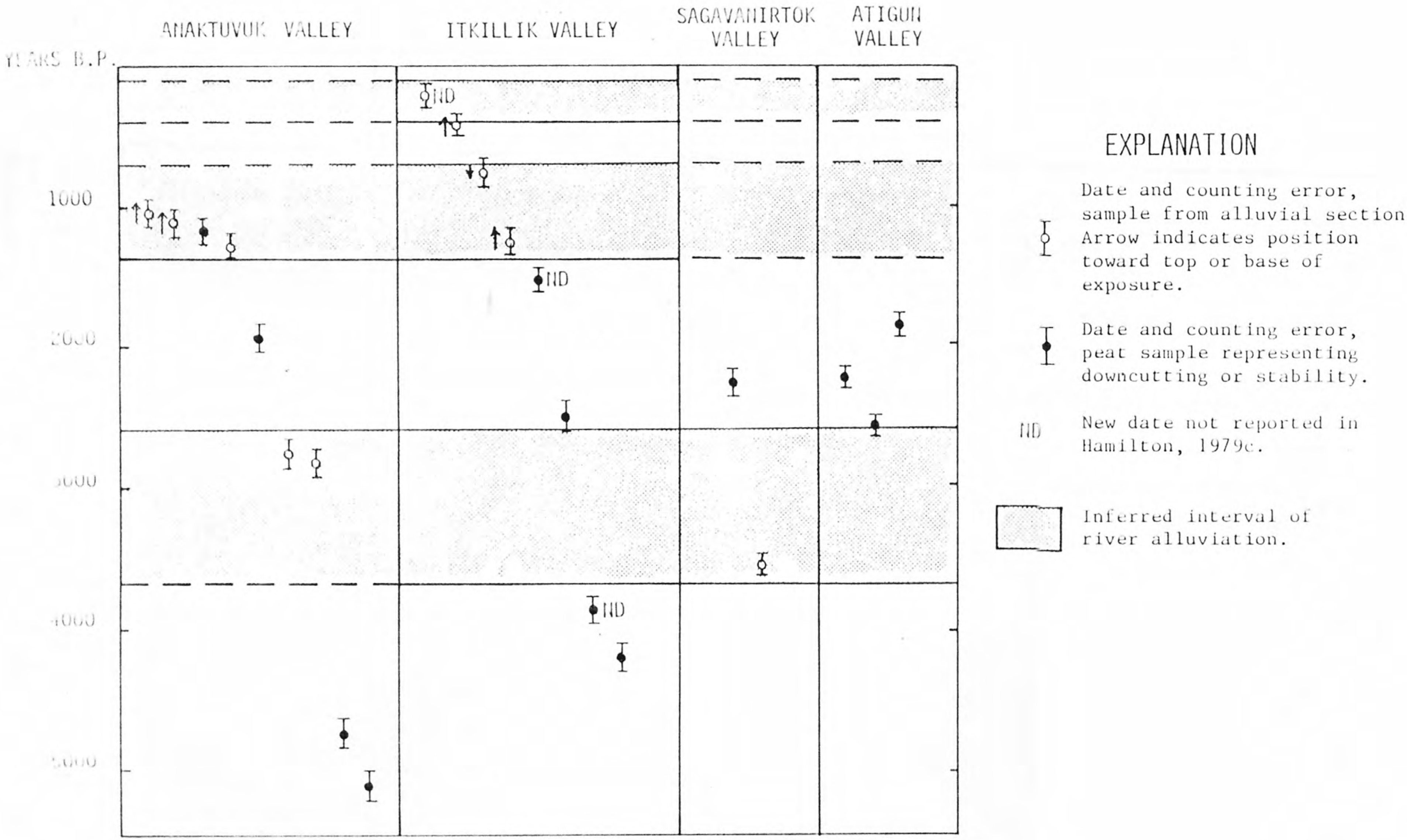


Figure 11. Middle to Late Holocene radiocarbon dates and inferred alluvial episodes, North Central Brooks Range.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHANDLER LAKE

ALASKA
TOPOGRAPHIC SERIES

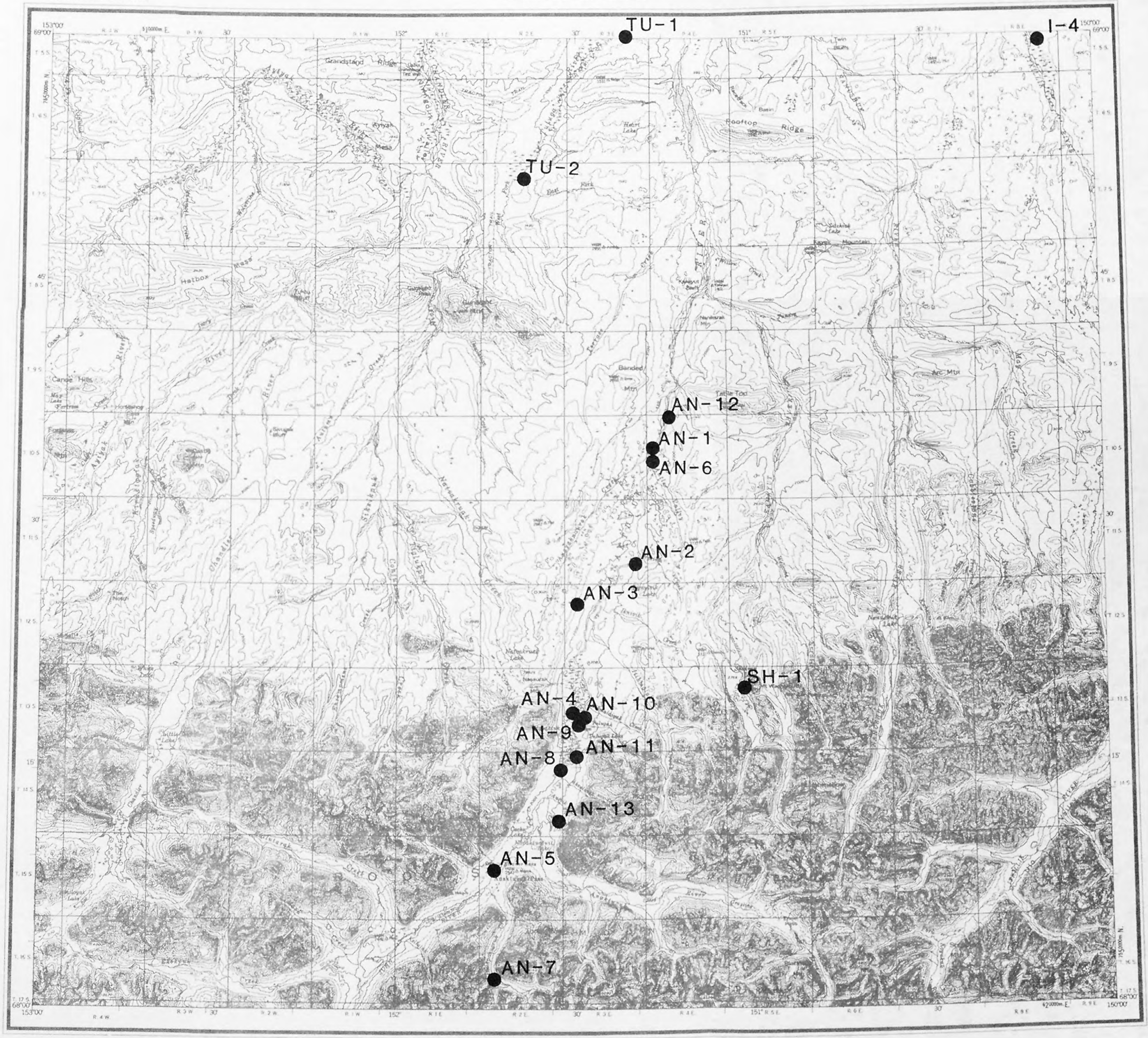


Plate 1. Location of bluff exposures, test pits, and other localities dated by radiocarbon; Chandler Lake quadrangle, Alaska.

SCALE 1:250 000

CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

FOR SALE BY U.S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA DENVER 2, COLORADO WASHINGTON 25, D.C.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

USGS LIBRARY-RESTON
3 1818 00073917 5