DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

RADIOCARBON DATES AND QUATERNARY STRATIGRAPHIC SECTIONS PHILIP SMITH MOUNTAINS QUADRANGLE, ALASKA

by

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OPEN FILE REPORT
79-866

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

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SUMMARY

Thirty-two radiocarbon dates from 19 measured sections in the Sagavanirktok, Atigun, Toolik, and Itkillik Valleys range between about 13,000 and 200 yr B.P. Stratigraphic relations indicate that a major glacier readvance of late Itkillik age culminated about 13,000-12,500 yr B.P. and that glacier tongues retreated from the Galbraith Lake-Atigun Gorge area during the following 500-1000 yr. Retreat of the Atigun Valley glacier and the probably contemporaneous retreat of ice from the Itkillik Valley created extensive depositional basins that filled with organic-rich lacustrine, fluvial, marsh, and eolian sediments during subsequent millennia.

Initial filling of moraine-dammed lakes in the Atigun and Itkillik basins presumably took place between about 10,000 and 6000 yr B.P., but deltaic and lacustrine sediments of this age generally are not exposed owing to burial beneath younger deposits and to erosion along valley centers. The five available dates for the interval 10,000-6000 yr B.P. suggest relatively mild conditions, with formation of peat on a stabilized till slope, growth of poplar in arctic valleys, and occupation by human hunting bands. The initial episode of alluviation within the Sagavanirktok, Itkillik, and perhaps Atigun basins may have culminated about 5000-4500 yr B.P., but neither contemporaneity nor control by regional geologic or climatic events can be proven. However, a new episode of alluviation, caused by intensified glacial and periglacial sedimentation, began about 4000-3500 yr B.P. in the Ribdon Valley and perhaps also at this time in other glacier-fed valleys of the region. Three subsequent cycles of alluviation and downcutting in the Itkillik Valley began sometime after about 2500, 1300, and 430 yr B.P. The youngest cycle correlates with fan-building and glacier expansion dated within the past 450 yr by radiocarbon and lichenometry; the next older cycle, which culminated about 800 yr ago, could correlate with an earlier dated episode of fan-building, glacier expansion, and rock-glacier activity.

Seven additional radiocarbon dates, from three measured sections south of the Continental Divide in the Wind River Valley, range from >38,000 to about 4000 yr B.P. The infinite date furnishes a minimum limit on Itkillik I glaciation and on at least part of the Itkillik I/II interglacial or interstade; these clearly are older than the range of conventional radiocarbon dating. Alluviation following the late Itkillik readvance may have ceased about 10,500 yr B.P.; it was followed by an interval of weathering and general nondeposition that terminated about 9000 yr ago when a lake filled this part of Wind River Valley. Onset of Neoglaciation is recorded by a peat dated about 4000 yr B.P. that was overridden by solifluction.

Fifty other radiocarbon dates from 11 archeologic sites demonstrate that postglacial environments suitable for game animals and their human predators were widely available in the Sagavanirktok Valley by 11,500-10,500 yr B.P. Subsequent occupation of the Sagavanirktok-Atigun area appears to have been markedly episodic, with relatively high human populations within the interval 2700-1600 yr B.P. as well as during the last few hundred years. Controls over these apparent population fluctuations are uncertain, but they may in part be related to Neoglacial climatic changes.

INTRODUCTION

During the past decade, the Philip Smith Mountains quadrangle has been the focus of intensive research by geologists, archeologists, biologists, and workers in related fields. The initial impetus for these studies was the requirement for engineering-geologic data preparatory to construction of the trans-Alaska pipeline (Ferrians, 1971; Kreig and Reger, 1976) and for salvage of archeologic information and materials that otherwise would be destroyed by construction activities (Cook, 1971, 1977). Subsequent studies were motivated by continued need for environmental monitoring along the pipeline and for assessment of natural resources in formerly remote areas now readily accessible via the haul road that parallels the pipeline (Brown and others, 1977; Hamilton, 1978b; Ellis, 1978; Brosgé and others, 1979). As one result of these studies, 89 radiocarbon dates became available for the Philip Smith Mountains quadrangle during the brief interval 1970-1979.

Measurement and sampling of stratigraphic sections within the Sagavanirktok Valley was carried out initially in 1972 with field support provided by the Alyeske Pipeline Service Company and by E. James Dixon (Anthropology Department, University of Alaska). Four organic samples collected at that time were dated by William Reeburgh and Margie Young at the Radiocarbon Dating Laboratory of the University of Alaska's Marine Institute; two additional samples were dated by Robert Stuckenrath at the Smithsonian Institution Radiocarbon Laboratory (table 1 and plate 1). The entire Philip Smith Mountains quadrangle subsequently was mapped during 1975 and 1976 as part of the Arctic Environmental Studies Program of the U.S. Geological Survey (Hamilton, 1978b). Ten samples collected at that time were dated by Stephen Robinson at the U.S. Geological Survey Radiocarbon Laboratory in Menlo Park, CA, and 16 samples were dated by Isotopes, Inc. under the supervision of James Buckley. Fifty additional radiocarbon dates (table 2 and plate 1) were obtained from excavations carried out during 1970-1975 as part of the trans-Alaska pipeline archeological salvage program (Cook, 1971, 1977; Alexander, 1974; Dixon, 1975). Michael Kunz and Robert Gal (Bureau of Land Management, Fairbanks, AK) helped me in locating some of these sites, and furnished additional information on their stratigraphy and geomorphic settings. Six unpublished radiocarbon dates with stratigraphic information

Table 1. Radiocarbon dates from bluff exposures, Philip Smith Mountains quadrangle, Alaska. Collected by T. D. Hamilton unless noted otherwise.

	Exposure No.	Site Location	Date and Laboratory No. (1)	Material Dated	Comments
UPPER SAGAVANIRKTOK VALLEY	S-1	68°30'N 149°01'W	8930 ± 140 (I-10,469)	Peat	
			11,890 ± 200 (AU-70)	Wood	Includes willow and possibly dwarf birch
			12,770 ± 180 (I-10,468)	Roots	Willow (2)
			12,540 ± 160 (USGS-47)	Roots & wood fragments	
	S-2	68°24.5'N 148°58'W	1180 ± 45 (SI-1428)	Wood (willow)	
			2275 ± 110 (SI-1427)	Grass	
			11,760 ± 200 (AU-69)	Wood (willow)	
	S-3	68°42'N 148°58'W	5310 ± 100 (I-10,504)	Wood fragments	Associated peat includes at least 2 beetle species (3)
			5270 ± 105 (I-10,470)	Wood fragments	
LOWER SAGAVANIRKTOK VALLEY	S-4	68°46.5'N 148°44'W	12,780 ± 440 (Au-72)	Wood (willow?)	
	S-5	68°42'N 148°58'W	12,170 ± 270 (AU-71)	Wood	Detrital fragments
	S-6	68°37'N 148°50.5'W	12,690 ± 180 (I-10,567)	Peat	
	S-7	68°39'N 148°27'W	3570+90 (I-10,503)	Wood	Detrital twigs
ATIGUN VALLEY	A-1	68°23.5'N 149°21'W	4630 ± 100 (I-10,505)	Peat & twigs	
			4800 ± 100 (USGS-42)	Peat	
	A-2	68°25'N 149°23'W	2000 ± 80 (USGS-43)	Peat	
	A-3	68°27'N 149°22'W	740 ± 100 (BGS-513)	Wood (willow?)	Collected by P. E. Calkin and J. M. Ellis, SUNY, Buffalo, NY
			2245 ± 120 (I-10,506)	Peat	
			2510 ± 110 (BGS-512)	Peat	Collected by P. E. Calkin and J. M. Ellis, SUNY, Buffalo, NY
	Near A-3	68°27'N 149°23'W	3080 ± 65 DIC-442	Wood (willow?)	In situ twigs. Collected by P. J. Webber, INSTAAR, Boulder, CO
	A-4	68°29.5'N 149°35'W	1850 ± 85 (USGS-44)	Peat	
TOOLIK VALLEY	T-1	68°49'N 149°17.5'W	8230 ± 130 (I-10,373)	Sedge peat	
			9460 ± 150 (I-10,715)	Sedge peat	
ITKILLIK VALLEY	I-1	68°26.5'N 149°58.5'W	4220 ± 95 (I-10,510)	Wood	
	I-2	68°26'N 149°59.5'W	2505 ± 190 (I-10,520)	Peat, bryophytic	
	I-3	68°27'N 149°59.5'W	430 ± 50 (USGS-165)	Wood (willow?)	Roots in growth position
			770 ± 130 (USGS-166)	Wood (willow?)	Roots in growth position
			1275 ± 80 (I-10,519)	Peat, bryophytic	
WIND RIVER VALLEY	W-1	68°13.5'N 147°14'W	3995 ± 95 (I-10,256)	Organic silt	
			>38,000 (USGS-162)	Wood	Detrital fragments
	W-2	68°08'N 147°11'W	9380 ± 150 (I-10,508)	Wood	
			9600 ± 85 (USGS-163)	Wood	
	W-3	68°05'N 147°09'W	9080 ± 150 (I-10,509)	Wood & peat	Insect fauna includes at least 3 species of ground beetles (Carabidae) and 1 species of weevil (3)
			9730 ± 230 (USGS-164)	Wood & peat	
			10,500 ± 80 (USGS-229)	Peat	

(1) AU = University of Alaska; BGS = Brock University; DIC = Dicar Corporation; I = Isotopes, Inc.; SI - Smithsonian Institution; USGS = U.S. Geological Survey Menlo Park Lab.

(2) Identified by Forest Products Laboratory, Madison, WI

(3) Preliminary identifications by A. V. and M. A. Morgan, University of Waterloo, Waterloo, Ont.

Table 2. Radiocarbon dates on archeologic sites, Philip Smith Mountains quadrangle.

LOCALITY NO. (1)	SITE NAME	DATE(S)	LABORATORY NUMBER(S)(2)	MATERIAL DATED (3)	REFERENCE
?	Putu	6090±430	Gak-4940	O	Alexander, 1974;
		8450±150	WSU-1318	C	Bryan, 1978, p. 308
		11,470±500	SI-2382	O	
PSM-049	Mosquito Lake	<200	GX-4076	C	Kunz, 1977, p. 756-930
		305±130	GX-4077	B	
		1030±140	GX-4081	C	
		1975±140	GX-4248	C	
		2135±160	GX-4080	C	
		2425±160	GX-4079	C	
		2665±155	GX-4104	C	
		2705±160	GX-4075	C	
		3515±160	GX-4250	C	
		4830±155	GX-4078	O	Kunz, 1977, p. 751
PSM-050	Gallagher Flint Station	970±160 to 2665±180(4)	GX-4252-4265	C	Cook, 1977, p. 65
		2620±175	SI-975	C	Dixon, 1975
		2920±155	SI-972A	C	
		3280±155	SI-973A	C	
		10,540±150	SI-974	C	
PSM-055	Tea Lake Knoll	1570±150	GX-4094	C	Cook, 1977, p. 62-64
		1995±165	GX-4093	C	
PSM-056	Anaqpak	2305±135	GX-4070	C	Cook, 1977, p. 62-64
		2360±175	GX-4249	C	
PSM-057	Ipnaq	<200	GX-4092	C	Cook, 1977, p. 62-64
		270±140	GX-4091	C	
PSM-058	No Name Knob	3440±160	GX-4071	C	Cook, 1977, p. 62-64
		3855±155	GX-4072	C	
PSM-060	Ribdon	1780±150	GX-4085	B	Cook, 1977, p. 62-64
PSM-072	1629	<200	GX-4073	C	Cook, 1977, p. 62-64
		<200	GX-4074	C	
PSM-073	Blip (5)	<200	GX-4082	C	Cook, 1977, p. 62-64
		Modern	GX-4083	C	
		210±110	GX-4086	C	
		3480±180	GX-4084	C	
PSM-074	Atigun	<200	GX-4089	C	Cook, 1977, p. 62-64
		115±140	GX-4087	C	
		310±140	GX-4088	C	
		360±100	GX-4090	C	

(1) PSM prefix is not used on location map (plate 1) owing to lack of space.

(2) Gak = Gakushuin University; GX = Geochron, Inc.; SI = Smithsonian Institution; WSU = Washington State University.

(3) C = charcoal; B = bone; O = unidentified organic matter.

(4) 14 dates total. See reference for individual listing.

(5) Located within 15 m of PSM-072.

were contributed by Parker Calkin and Stephen Ellis (State University of New York at Buffalo); an additional unpublished date was furnished by Patrick Webber (Institute of Arctic and Alpine Research, Boulder, CO). Three of these dates are assignable to stratigraphic sections listed in table 1; the remaining four are presented separately in table 3.

In the following sections, I describe the geologic setting and stratigraphic placement of the dated organic samples, and discuss the geologic and paleoecologic history indicated by this remarkably large assemblage of radiocarbon dates. The surficial geologic map of the Philip Smith Mountains quadrangle (Hamilton, 1978b) should be consulted for definitions, locations, and geologic interrelationships of the surficial geologic units discussed below.

STRATIGRAPHIC SECTIONS

Sagavanirktok Valley Above Atigun Gorge

Three bluffs along the upper course of the Sagavanirktok River contain dated sediments that formed during the last 13,000 years within a depositional basin created by advance of an ice tongue of late Itkillik age down the Atigun Valley (Hamilton, 1978b). The glacier extended to a terminal position a few km north of the present Galbraith Lake and 50 km north of source areas along the Continental Divide. A distributary ice stream flowed eastward through Atigun Gorge, then spread out to form a spatulate tongue that blocked the Sagavanirktok Valley. Glacier ice originating near the head of the Sagavanirktok Valley was surprisingly restricted at this time; it formed end moraines about 30 km south of Atigun Gorge and only 15-25 km north of the cirques from which it originated.

Exposure S-1 (fig. 1) is located at the southern flank of the late Itkillik moraine that blocked the Sagavanirktok Valley, and most of the sediment sequence at this locality appears to reflect alluviation behind that barrier. Fluvial features include cross-bedding, layers and lenses of rounded and well sorted pebbles, detrital wood along bedding planes, and lateral facies changes from relatively coarse bar deposits to relatively fine-grained channel fillings. Units 1, 2, and lower unit 3 indicate rapid alluviation by channel deposits; sparse organic matter, absence of weathering, and general scarcity of fine-grained overbank deposits indicate that alluviation probably proceeded without major pauses or reversals.

Table 3. Radiocarbon dates, Atigun Pass area. Based on data of J. M. Ellis and P. E. Calkin, State University of New York at Buffalo (written communication, 4/9/79).

Sample designation	Site location	Stratigraphy (showing date in yr B.P. and laboratory no.)	Material dated
CE-1	68°17'N 149°23'W	5 cm Surface organic mat 58 cm Silt and sand, with intermixed organic material 5 cm Organic horizon • 210 ± 90 (BGS-547) 27+ cm Coarse gravel	Peaty silt?
CE-2	68°08'N 149°26'W	~5 cm Surface organic mat 90 cm Sandy cobble gravel ? Buried organic layer • 800 ± 90 (BGS-548)	Clayey peat
CE-3	68°08'N 149°48'W	Till • 320 ± 100 (BGS-522) Bedrock (sandstone)	Dried vegetation from joints in bedrock
CE-4	68°20'N 149°30'W	Younger rock-glacier deposit • 480 ± 140 (BGS-549) Older rock-glacier deposit	Dead roots incorporated in younger rock glacier at its terminus

The radiocarbon dates appear to confirm that rapid alluviation took place between about 13,000 and 12,500 yr B.P., and continued until at least 12,000 yr B.P. if the date on sample AU-70 is valid. Rapid alluviation probably was the result of (1) blockage by actively flowing glacier ice, which prevented permanent incision by the Sagavanirktok River, and (2) relatively high rate of sediment yield from headward portions of the Sagavanirktok Valley owing to activity of the late Itkillik glacier in that area. Decreasing rates of sedimentation or increased intervals between pulses of alluviation are indicated by the increasing presence of in situ organic matter in unit 4 and upper unit 3. This probably reflects weakening activity of the Atigun Gorge ice tongue and its ultimate stagnation. By about 9000 yr B.P., the Sagavanirktok River no longer was alluviating, and sediments above the 20-m level in the bluff consist almost entirely of eolian sand and silt with in situ organic matter. The date of 11,890 ± 200 yr B.P. at about 18 m height in the bluff is puzzling. No physical evidence was noted for a significant hiatus between this level and the 20-m level, which dates about 3000 yr younger. In addition, the character of sediments and organic matter suggests that the most rapid decrease in rates of alluviation occurred farther down in the section, at and just above the level of floodplain willows dated 12,770 ± 180 yr B.P. On the other hand, repeated wind scour and deposition on a partly vegetated surface no longer subjected to alluviation could account for slow rate of net accretion between the 18- and 20-m levels and for the absence of significant soil and weathering profiles.

Exposure S-2 (fig. 2) contains fluvial sand at its base (unit 1) that probably correlates with the basin-filling sand of upper unit 3 or lower unit 4 at Exposure 1. The radiocarbon date of 11,760 ± 200 is virtually identical to the 11,890-year date from unit 4 of Exposure 1, suggesting that continued slow alluviation of the upper Sagavanirktok River behind the moraine dam may indeed have continued up to about this time. Absence of gravel suggests that outwash deposition from the upper Sagavanirktok Valley glacier either had ceased or was unable to extend this far north in the sand-filled basin. A conspicuous unconformity at the top of unit 2 probably marks downcutting of the Sagavanirktok River after breaching of the moraine dam near the mouth of Atigun Gorge. The date of this event is uncertain. Later accretion of eolian sand at Exposure 2 began sometime before 2275 $\pm$ 110 yr B.P., and continues to the present. An archeologic site in the upper part of the exposure was studied in collaboration with E. James Dixon. The site was occupied sometime within the past 1200 yr, but charcoal on the occupation horizon was too sparse for dating.

Exposure S-3 (fig. 3) is situated between Exposures 1 and 2, but differs from them in its gravelly character. Two radiocarbon dates of approximately 5300 yr B.P. indicate active alluviation at that time, but probably ceasing soon afterward. Some of the coarse sediment probably was derived from alluvial fans that built outward from the western valley wall (Hamilton, 1978b), but its diverse lithology suggests that some of the deposit originated from source areas farther up the Sagavanirktok Valley. Interbedded laminated fine sediments probably were deposited along the floodplain of the Sagavanirktok River, which remained partly dammed at a level about 11 m above present. The river may have eroded rapidly through drift abandoned by the retreating late Itkillik glacier, but it undoubtedly remained longer at a level determined by the surface of the underlying bedrock upon which it was superimposed. This rock surface presently rises 15 m above the river level in the canyon which the Sagavanirktok River has eroded through the moraine.

Sagavanirktok Valley Below Atigun Gorge

Radiocarbon dates were obtained from natural bluff exposures in four localities along the Sagavanirktok River and its tributaries north of Atigun Gorge (plate 1). Three localities (Exposures S-4, S-5, and S-6) are especially significant because each yielded radiocarbon dates that lie within the interval when late Itkillik glacier ice blocked the upper Sagavanirktok Valley. The fourth locality (Exposure S-7) yielded a date and inferred history assignable to late Holocene (Neoglacial) resurgence of glaciers near valley heads. Two localities (Exposures S-4 and S-5) are situated within the Itkillik II drift sheet (Hamilton, 1978b), and therefore also provide minimum ages for that glacial event.

Exposure S-4 (fig. 4) yielded little detailed stratigraphic information owing to the active mudflows that obscured its lower units and the hazardous nature of its overhanging and collapsing face. Unit 1 probably is lacustrine sediment that formed within the basin created behind the

Itkillik II moraine by the retreating Ribdon Valley glacier. The coarse alluvium of unit 2 probably is outwash generated by the readvance of a glacier of late Itkillik age that terminated a short distance upvalley in the area round Elusive Lake (see Hamilton, 1978b). The radiocarbon date of 12,780 ± 440 yr B.P. provides a limiting minimum age for the maximum extent of the late Itkillik readvance in this valley.

Exposure S-5 (fig. 5), within an outwash terrace of late Itkillik age, is situated 6 km downvalley from the mapped limit of the spatulate drift sheet from which the outwash originated (Hamilton, 1978b). The lowest exposed sediments are basin-fill deposits, dated 12,170 ± 270 yr B.P., that accumulated after the Sagavanirktok Valley glacier retreated from the Itkillik II moraine. The overlying outwash (unit 2) and frost-churned loess (unit 3) are assigned respectively to the maximum stand and subsequent recession of the late Itkillik glacier. The radiocarbon date is incompatible with dates from Exposure 1, which seem to demonstrate that the late Itkillik ice tongue was at its maximum extent from about 13,000 to 12,500 or 12,000 yr ago; it probably is too young.

Exposure S-6 (fig. 6) lies at higher altitude within a basin of Section Creek that was dammed by glacier ice of Itkillik I or II age, but probably was not directly affected by glacial fluctuations during late Itkillik time. Exposed sediments are dominantly lacustrine silt and clayey silt that alternate with gravelly beach deposits. Peat near the base of the section dates 12,690 ± 180 yr B.P., defining an interval of subaerial exposure preceded and followed by lacustrine sedimentation. The continued effectiveness of the moraine barrier at that time suggests that it probably is Itkillik II in age rather than Itkillik I as inferred previously (Hamilton, 1978b). The peat layer could represent slightly milder conditions followed by harsher climate and renewed deposition along Section Creek due to some combination of (1) increased sediment yield in its upper basin, (2) permafrost aggradation within the moraine dam, decreasing its permeability, and (3) increased solifluction or other mass movements partly sealing the stream incision through the moraine dam. The alternative hypothesis of damming by Itkillik II glacier ice at this time is rejected because there is no evidence of glacier ice as young or younger than about 12,700 yr B.P. overriding adjacent valley centers in the areas around Exposures S-4 and S-5.

Exposure S-7 (fig. 7) is located within the lacustrine plain of Elusive Lake, a surface that aggraded to a level of about +5 m in response to alluviation along Ribdon River. The entire section exposes laminated lacustrine sediments, and dates 3570 ± 90 yr B.P. near its base. This date would be appropriate for alluviation by Neoglacial outwash derived from the cirque glaciers at the heads of both forks of Ribdon Valley. Neoglacial outwash is particularly conspicuous along the south fork of Ribdon Valley, and evidently extended farther downvalley than was mapped previously (Hamilton, 1978b).

Atigun Valley Near Galbraith Lake

Readvance of the late Itkillik glacier in Atigun Valley formed a broad moraine composed largely of redeposited lacustrine sediments that presently encloses Galbraith Lake to the north (Hamilton, 1978b). Subsequent glacial retreat created an extensive proglacial lake that probably extended up Atigun Valley at least 16 km beyond the present south shore of Galbraith Lake. The lake filled rapidly with deltaic deposits derived from tributary valleys and from the two glacier-fed forks at the valley head. Filling extended progressively northward, and was especially rapid where deposition of tributary fans and deltas narrowed and partly filled the valley floor.

Exposure A-1 (fig. 8) occupies the concave bank of a tight meander loop along Atigun River 6 km south of Galbraith Lake. The river bluff exposes 15 m of basin-fill deposits that formed behind the Galbraith Lake moraine of late Itkillik age (Hamilton, 1978b). Clayey, silty, shallow-water to wet-marsh deposits through the middle portion of the exposure grade upward into sandier deposits of probable fluvial and eolian origin near its crest. Two radiocarbon dates indicate that filling of this portion of the moraine-dammed basin was completed by middle Holocene time, and that aggradation by fluvial and eolian processes continued after earlier open-water and marsh phases in the basin.

Exposure A-2 (fig. 9), 3.5 km farther north, also occupies the cutbank of an active meander bend of Atigun River. Although this exposure stands 22.1 m high, fluvial and marsh sediments similar to those of Exposure 1 rise only 17.3 m above the river; their upper contact defines a surface that could be correlative with the terrace of Exposure A-1. The overlying sediments probably represent eolian-deposited sand sheets and dunes that formed during or following downcutting of Atigun River. A single radiocarbon date from the middle portion of the exposure suggests that aggradation of the basin with fluvial and marsh sediments continued as recently as 2000 ± 80 yr B.P. Aggradation took place either as progressive northward expansion of a deltaic plain or as a separate late Holocene event that followed earlier alluviation and downcutting.

Exposure A-3 (fig. 10) is located along the north bank of Atigun River 0.5 km below the mouth of the outlet stream from Galbraith Lake. This river bluff exhibits three principal sediment units that probably correlate with those of exposures farther upvalley. Basal sediments represent filling of the moraine-dammed Atigun basin by streams entering an area of standing to sluggishly flowing water. The overlying peat represents an interval during which Atigun River and the lacustrine plain around the south end of Galbraith Lake may have aggraded at a slower rate. This interval dates between about 2245 ± 120 and at least 2500 yr B.P.; it probably extends back beyond 3000 yr according to a radiocarbon date obtained by P. J. Webber from a road cut west of Exposure A-3 (table 1). The peat accumulation corresponds in time to a period of continued active alluviation farther up Atigun River. The topmost unit, dune sand, evidently began accumulating more than 740 ± 100 yr ago, and continues to be actively scoured and redeposited by strong downvalley winds.

Exposure A-4 (fig. 11), the headwall of an active earthflow, is situated on the inner flank of the late Itkillik moraine 4.5 km northwest of Galbraith Lake. Silty diamicton - either till, glacio-lacustrine sediment, or glacial deposits redeposited as colluvium - is overlain by peat dated 1850 ± 85 yr B.P. Solifluction deposits overlie the peat. This record reflects the extreme instability of the silt-rich Galbraith Lake moraine, upon which earthflows, solifluction, and other slope processes are reworking older sediments. The peat represents a period of stability that was followed by renewed solifluction; it could correspond to milder climate and generally more stable slope conditions, or it may merely be of local significance.

Upper Atigun Valley

Four radiocarbon dates obtained by P. E. Calkin and J. M. Ellis (table 3) bear on the history of late Holocene fan building near the head of Atigun Valley and on glacier and rock-glacier expansion within two cirques close to the Continental Divide.

Sample CE-1 (table 3) was obtained from a buried organic horizon within an alluvial fan along the east side of Atigun Valley 17 km south of Galbraith Lake. This possible paleosol was buried by renewed fan alluviation sometime after 210 ± 90 yr B.P. The tributary stream that built the fan originates in a set of cirques, two of which contain glaciers. Renewed fan deposition at the sampling locality may have been caused merely by lateral displacement of the tributary stream across its fan, or it could have been the result of glacier expansion and increased sediment yield within the drainage basin.

Sample CE-2, dated 800 ± 90 yr B.P., is from a similar buried organic layer within an alluvial fan close to Atigun Pass (table 3). The organic horizon was buried by 90 cm of fan sediment following an interval of stability. As this fan also was generated by a cirque-headed tributary stream fed by a glacier (J. M. Ellis, written communication, 4/9/79), the episode of alluviation could possibly be related to intensification of glacier activity.

Sample CE-3 was taken at the terminus of the informally named "Buffalo Glacier" at the head of the western fork of Atigun Valley. Calkin and Ellis report a date of 320 ± 100 yr B.P. on vegetation overridden by the advancing ice tongue.

A slightly older date of 480 ± 140 yr B.P. was obtained on Sample CE-4 from a cirque 11 km southwest of Galbraith Lake. Roots from the surface of an older rock glacier were incorporated into the advancing terminus of a younger rock glacier. The younger rock glacier apparently formed from Neoglacial drift generated by the glacier that nearly fills the cirque (Hamilton, 1978b).

Toolik Valley

A single dated exposure from the Toolik Valley occupies a site similar to that of Exposure A-4 and likewise reveals a history of slope processes independent of valley alluviation.

Exposure T-1 (fig. 12) is located at the north end of an enlarging thaw lake that formed on morainal deposits assigned to the Sagavanirktok River Glaciation (Hamilton, 1978b). Diamicton at the base of the exposure (unit 1) consists of either primary till or till redeposited by earthflows or other slope processes. The overlying peat (unit 2) formed during an interval of stability about 9500-8000 yr B.P.; solifluction subsequently covered the site with a colluvial blanket 0.5 m thick (unit 3). As in the case of Exposure A-4, peat formation may correspond either to an interval of generally more stable slope conditions or to local site factors unrelated to climate.

Itkillik Valley

Three dated exposures near Itkillik Lake lie within the depositional basin that formed behind an end moraine of late Itkillik age (Hamilton, 1978b). The exposures, like those within Atigun Valley, show a complex history of basin infilling, punctuated by several episodes of incision, and continuing until very recent time.

Exposure I-1 (fig. 13), at the north end of a probable thaw lake on the valley floor, consists of sandy basin-fill deposits that accumulated to a height of 11 m above lake level and perhaps 12-13 m above the present level of the Itkillik River. Alluviation to a surface about 8 m above lake level was completed by about 4200 yr B.P., according to a dated peat horizon (unit 2). Subsequent accretion was dominantly by eolian processes.

Exposure I-2 (fig. 14) shows a later episode of incision and terrace-building along the present course of the Itkillik River. The river lay at a level at or below present during an episode of peat accumulation about 2500 yr B.P., then alluviated to a level nearly 8 m above present. During alluviation the river was vigorously eroding a kamelike complex of gravelly ice-stagnation deposits that protrudes above the valley floor in this area. Gravel derived from the eroded flank of this deposit was intermixed with sandy alluvium derived from sources farther up the Itkillik Valley.

Exposure I-3 (fig. 15) shows a generally younger history than Exposures I-1 and I-2, and provides dates for building of the two lowest terrace levels in the Itkillik Valley. About 1300 yr ago the river again was at a level close to the present; it then alluviated during the following 500 yr to build a terrace at a height of about 6.5 m. A subsequent episode of down-cutting culminated shortly before 430 ± 50 yr B.P., then was followed by alluviation to form an inner terrace about 4 m above modern river level.

Wind River Valley

Seven radiocarbon dates were obtained from exposures along the east bank of the Wind River, which flows southeast from the Continental Divide into the subarctic environment of the southern Brooks Range. All the exposures are situated beyond an end moraine assigned to the late Itkillik readvance (Hamilton, 1978b), and within drift of older Itkillik age. Unfortunately, the Wind River trends eastward from the corner of the Philip Smith Mountains quadrangle into a region where no surficial geologic mapping has been done, and the distribution and limits of Itkillik I and II deposits are unknown. Most of the Itkillik drift of unassigned age in Hamilton (1978b) is assumed to be Itkillik II in the following discussion. All three dated exposures therefore lie within a stretch of glacio-lacustrine and other basin-filling deposits that postdate the Itkillik II maximum advance.

Exposure W-1 (fig. 16) contains a thin sheet of probable till (unit 2) underlain by gravel of nonglacial rather than outwash character (unit 1). The infinite date on the gravel, if valid, suggests preservation of interstadial or interglacial deposits that predated the Itkillik II glacial advance. These sediments probably were frozen prior to glacier expansion, and apparently survived overriding by an ice tongue that must have advanced sluggishly down the gentle gradient of the Wind River Valley. The date of about 4000 yr B.P. on unit 3 probably represents a minimum age on a paleosol that formed on the till and subsequently was buried by solifluction deposits derived from the base of the eastern valley wall. Solifluction activity apparently followed an interval of slope stability that extended through the middle Holocene.

Exposure W-2 (fig. 17), 11 km farther downvalley, occupies a wider and flatter segment of the valley floor that today contains scattered pingos and numerous thaw lakes. Fine fluvial gravel (unit 1) at the base of the deposit is overlain by peat dated about 9400 and 9600 yr B.P. (unit 2), which ranges in height along the bluff from 0.5 to 4 m above river level. Lacustrine sediments more than 11 m thick (unit 3) cap the section. Thickness and high clay content of the lake sediments suggest a widespread and possibly deep lake basin existed at this time, and that the smaller thaw lakes of today postdate drainage of the ancestral lake. Two species of ostracodes, *Candona rectangulata* and *Cyclocypris ampula*, from clay near the base of unit 3 indicate cold, alkaline, fresh water and suggest a shallow, nearshore, plant rich habitat during an early stage of lake formation (R. M. Forester, personal communication, 6/15/79).

Exposure W-3 (fig. 18), 6 km downvalley from Exposure 2, exhibits a virtually identical history. Alluviation of fine-grained fluvial sediments (unit 1) began prior to 9700 yr B.P. and was followed by an interval of stability and peat deposition that may have ended about 9100 yr ago (unit 2). A subsequent lacustrine stage is indicated by the 6 m or more of clayey sediments (unit 3) that cap the section. Although bedding and other structures within unit 3 are largely obscured by flowage, the character of its sediments as well as similarities in limiting ages, lithology, and inferred histories between Exposures 2 and 3 strongly indicate that a widespread single lake filled this portion of Wind River Valley (see Hamilton, 1978b). The modern thaw lakes therefore comprise a separate and younger lacustrine stage. Origin of the ancient lake is uncertain. It presumably was dammed by a landslide or other barrier in the unmapped portion of Wind River Valley that lies east of the Philip Smith Mountains quadrangle.

ARCHEOLOGIC DATES

Fifty radiocarbon dates from archeologic sites in the Philip Smith Mountains quadrangle have been summarized in table 2. Most dates are on charcoal recovered from shallow levels in sediments highly disturbed by human activities at localities where detailed stratigraphic information is not available. These dates, especially where younger than a few thousand years, will not be discussed individually. Other dates, from older levels in deeper and more carefully recorded excavations, are more informative. These sites include Gallagher Flint Station, Putu, and Mosquito Lake.

The oldest well documented archeologic site is Gallagher Flint Station (PSM-050), situated on a prominent kame on the floor of the Sagavanirktok Valley. The site was dug initially by E. J. Dixon, Jr., in 1970 and 1971 (Dixon, 1971, 1975); further excavations were carried out during later stages of the trans-Alaska pipeline salvage program (Cook, 1977, p. 65). Dixon (1975) described three stratigraphic levels at the Gallagher site: a surface organic horizon up to 9 cm thick, a 20-30 cm loess blanket, and underlying ice-contact deposits. Three charcoal dates between about 2600 and 3300 yr B.P. were obtained at or near the base of the surface organic horizon; a much older charcoal date of 10,540 ± 150 yr B.P. came from within the loess at a depth of 20-25 cm below the surface (Dixon, 1975;

Stuckenrath and Mielke, 1973, p. 405-406). The Itkillik II drift sheet near the Gallagher site clearly was deglaciated, stabilized, and sufficiently revegetated to support game animals and their human predators by 10,500 yr B.P.

The Putu site, 16 km upvalley from the Gallagher locality, occupies a kamelike knob on the crest of a late Itkillik lateral moraine that extends along the east wall of the Sagavanirktok Valley. The site initially was dated 8450 ± 130 yr B.P. (Alexander, 1974; stated as 8450 ± 150 yr B.P. in Sheppard and Chatters, 1976, p. 144). Later, it reportedly was dated 11,470 ± 500 yr B.P. (Bryan, 1978, p. 308). No stratigraphic description has been published for the Putu site so the older date, if valid, can be used merely to confirm that this portion of the late Itkillik moraine was deglaciated and revegetated by about 11,500 yr ago.

Excavations around the informally-named "Mosquito Lake" (PSM-049) were carried out during 1971-1975 as part of the trans-Alaska pipeline archeological salvage program (Cook, 1977; Kunz, 1971, 1977). A test pit excavated just north of the lake on a surface about 4 m above modern river level exposed 95 cm of eolian sand above organic-bearing lake or marsh deposits which date 4830 ± 155 yr B.P. at the contact (table 2). The dated material may have been obtained from sediments truncated during river downcutting, hence it could be significantly older than the close of fluvial or lacustrine sedimentation and the beginning of eolian deposition at this locality. Younger dates from the Mosquito Lake site tend to cluster within the interval of about 2000-2700 yr B.P., which corresponds in general to the second human occupation at Gallagher Flint Station and to a small cluster of archeologic dates from the Atigun and Sagavanirktok Valleys (fig. 19). A later phase of relatively intensive human occupation within the last 350 yr is suggested by dates from Mosquito Lake and other sites, but not from Gallagher Flint Station.

DISCUSSION

Nine radiocarbon dates from seven localities in the Sagavanirktok Valley fall within the time interval of 13,000 to 10,000 yr B.P. (fig. 20). This suite of dates as a whole indicates that large segments of the valley were deglaciated and revegetated by about 12,000 yr B.P.; the dates from the

Gallagher and Putu archeologic sites show that habitats became suitable for game animals and human hunting bands by at least 11,500-10,500 yr B.P. In detail, the dates show some distressing inconsistencies. Two concordant dates from S-1 and the limiting date on outwash at S-4 appear to demonstrate that the Atigun Gorge and Ribdon Valley ice tongues remained at their maximum late Itkillik positions from some time shortly before 13,000 yr B.P. until about 12,500 yr ago; they then began to stagnate or retreat. Radiocarbon dates of about 11,800 yr B.P. from fluvial deposits in S-1 and S-2 seem a little too young for this inferred history, but could be explained by possible late fluctuations of the Atigun Gorge ice tongue or by some other factor that delayed downcutting by the Sagavanirktok River following culmination of the late Itkillik advance. Some support for a relatively complex model of glacial and climatic history at this time is provided by S-6, where peat dated 12,690 ± 180 yr B.P. represents an interval of stability preceded and followed by lake stages that possibly were caused by intensified periglacial activity. The date of 12,170 ± 270 yr B.P. from S-5, on the other hand, must be rejected as too young. This site should be resampled and redated because of its potential for furnishing a maximum age limit on the late Itkillik advance.

The radiocarbon record from the Wind River Valley includes one infinite date and five dates within the interval of about 10,500 to 9000 yr B.P. The infinite date confirms the radiocarbon record from the Chandalar quadrangle (Hamilton, 1978a), which indicates that (1) deep scouring of glacial valleys by Itkillik I glaciers occurred at some time beyond the range limit of conventional radiocarbon dating, and that (2) the subsequent Itkillik II advance in many valleys did not erode deeply enough to remove all of the sediments deposited during the Itkillik I/II interglacial or interstade (Hamilton, 1979). Three dates of about 9600-9000 yr B.P. from W-2 and W-3 demonstrate a widespread interval of subaerial exposure, general stability, and peat formation within a stretch of the valley that later was inundated. The duration of the lake stage is unknown. Two other dates from W-3 comprise the only major stratigraphic inconsistency evident in radiocarbon dates from any of the bluff exposures (see fig. 18). Either of the dates from unit 1 could be correct, but one clearly must be in error. If the lower date (9730 ± 230 yr B.P.) were incorrect, the age span of 10,500 yr B.P. and older for unit 1 would imply that alluviation corresponded in time to late Itkillik glaciation in the upper valley.

Two dates from the Toolik Valley and two from the Sagavanirktok fall within a time range (9500-8000 yr B.P.) generally similar to that of the early Holocene Wind River dates. The two dates from T-1 define a peat-forming interval lasting from about 9500-8200 yr B.P.; the date from S-1 shows continued sediment accumulation at that time followed by a later episode of relative stability and soil formation. The Putu site apparently was occupied about 8500 yr B.P., but descriptions of sediments and stratigraphy at the site are vague. An additional date of 8400 ± 300 yr B.P. was reported by R. L. Detterman (1970) from a poplar log buried within terrace gravel near the Sagavanirktok River north of the Philip Smith Mountains quadrangle at 69°31'N, 148°52'W. No regional geologic or climatic pattern is evident in the small assemblage of early Holocene dates from these northern valleys.

Six radiocarbon dates from four northern valleys range between about 6000 and 4000 yr B.P. (fig. 20). Two dates from S-3 suggest that alluviation of the Sagavanirktok River to a level controlled by the rock barrier near Atigun Gorge may have culminated about 5000 yr ago. Two dates from A-1 suggest that alluviation of this part of Atigun Valley to a level about 15 m above present must have culminated shortly after 4600 yr B.P., either as a basin-wide event or as part of a northward-extending deltaic plain. Both pairs of dates exhibit minor age reversals, but in each case these are well within the bounds of counting errors. An additional date from the test pit near "Mosquito Lake" suggests that downcutting near Atigun Gorge to a level within 3-4 m of the present could have taken place sometime after 4800 yr B.P. Alluviation of the Itkillik River near I-1 culminated at a level 7.5 m or less above the modern river[1/], then was followed by an episode of stability and peat formation dating 4220 ± 95 yr B.P. Alluviation could have ceased a few hundred years earlier, in phase with possible filling of the Atigun and Sagavanirktok basins, but the contemporaneity of such events cannot be proven with the dates presently available.

1/ Reference level for the measured section (fig. 13) was the unnamed lake rather than the Itkillik River. The lake could be at the same altitude as the river, or it could be as much as 2-3 m higher.

Two important dates from Wind River Valley and Elusive Lake appear to document onset of Neoglacial conditions about 4000-3500 yr ago. Neoglaciation, as defined by Porter and Denton (1967), refers to colder climates and renewed glacier activity that followed a middle Holocene interval of milder conditions. Although Neoglaciation began close to 4600 yr ago according to Porter and Denton, it evidently intensified appreciably in northern and central Alaska about 500-1000 yr later (Hamilton and Robinson, 1977). The 3600-yr-old sample from S-7 appears to date an early phase of alluviation in Ribdon Valley that was controlled by renewed activity of cirque glaciers at the valley head. The date of 3995 ± 95 yr B.P. for W-1 provides a maximum limiting age on a possibly contemporaneous solifluction blanket that covered parts of the valley floor of Wind River following a long weathering interval.

Among radiocarbon dates younger than about 3000 yr, eight dates from four river bluffs yield significant information on alluvial history within the Itkillik and Atigun basins. The most detailed chronology was obtained from I-2 and I-3, which contain peat lenses and in situ roots that formed when the Itkillik River was close to its modern level about 2500, 1300, and 430 yr ago. The river may have alluviated to a height of about 8 m between 2500 and 1300 yr B.P.; it built a 6.5-m terrace during the 500-yr interval following 1300 yr B.P., then probably incised to a level close to the present sometime between about 770 and 430 yr ago. A final cycle of alluviation to 4 m height and downcutting to the modern level occurred within the past 400-450 yr. The alluvial cycles may have been controlled by increased sediment yields resulting from periods of intensified glacial and periglacial activities. The alluvial record in Atigun Valley is less clear. An interval of general stability and peat formation occurred between about 3000 and 2250 yr B.P. in the area round A-3, but rapid alluviation only 3.5 km farther upvalley was in progress about 2000 yr ago and must have started at least several hundred yr earlier. Alluvial history in this valley could be generally similar to that in Itkillik Valley, but alluviation may have taken place partly as a northward-building deltaic system and sites close to the rock-floored Atigun Gorge probably are controlled largely by this local base level.

Farther up Atigun Valley, glacier-fed alluvial fans at localities CE-1 and CE-2 were subject to renewed deposition following intervals of stability and soil information dated 210 ± 90 and 800 ± 90 yr B.P. (J. M. Ellis, written communication, 4/9/79). The alluvial episodes may represent only the lateral migrations of streams across the fan surfaces, or they could reflect regional climatic controls. The younger episode possibly corresponds to a period of glacier expansion dated 320 ± 100 yr B.P. at CE-3, to moraines dated AD 1500 and younger by lichenometry (Calkin and Ellis, 1978; Ellis, 1978), and to the final alluvial cycle of the Itkillik River. The older episode of fan alluviation could correlate with the glacier readvance that initiated a renewed phase of rock-glacier activity sometime prior to 480 ± 140 yr B.P. at CE-4, with the episode of terrace-building along the Itkillik River that culminated about 770 ± 130 yr B.P., and with widespread readvances of cirque glaciers in the Atigun Pass region that are dated about AD 700-850 by lichenometry (Ellis, 1978).

Three additional dates from bluff exposures in northern valleys fall within the last 2000 yr. Buried peat at A-4 north of Galbraith Lake represents an interval of stability about 1850 yr B.P. that was followed by renewed soil flowage. No lichen-dated glacier expansions occurred in the Atigun Pass area at this time, and existing radiocarbon dates are inadequate to prove concurrent alluviation or downcutting along the Atigun, Sagavanirktok, or Itkillik Rivers. The colluvial episode could be a local phenomenon - perhaps caused by destruction of turf by fire, animals, or man and resulting thaw of ice-rich permafrost; it need not have regional climatic significance. Dates of 1180 ± 45 and 740 ± 100 yr B.P. were obtained on eolian sediments that cap bluffs at S-2 and A-3. Accretion of sand sheets and dunes probably continued during most of late Holocene time in the Sagavanirktok, Atigun, and Itkillik basins; the two dates consequently appear to have no special environmental relevance.

If the age distribution (fig. 19) of 50 radiocarbon dates on 11 archeologic sites is a valid measure, human occupation of parts of the Sagavanirktok and Atigun Valleys shows striking fluctuations during the past 4000 yr:

Relative intensity of occupation	Time range (yr B.P.)	Number of dates	Duration (yr)
Heavy	350-0	13	350
Light	1600-350	4	1250
Heavy	2700-1600	21	1100
Light	>4000-2700	6	>1300

It is tempting to equate the early phase of light occupation with harsher environmental conditions of early Neoglacial time and the subsequent intensive phase with a later milder interval about 2700-1600 yr B.P. The rationale for the subsequent 1200-yr span of sparse occupation is less clear, however. Relatively sparse occupation apparently continued through most of the last major episode of cirque-glacier expansion dated by lichenometry at about AD 1500-1750, and the succeeding relatively heavy use of the area of hunting bands could coincide with milder conditions and generally retreating glaciers of the past 200-250 yr. Many other factors could regulate the seemingly episodic human occupation, however, and the case for environmental control remains unproven.

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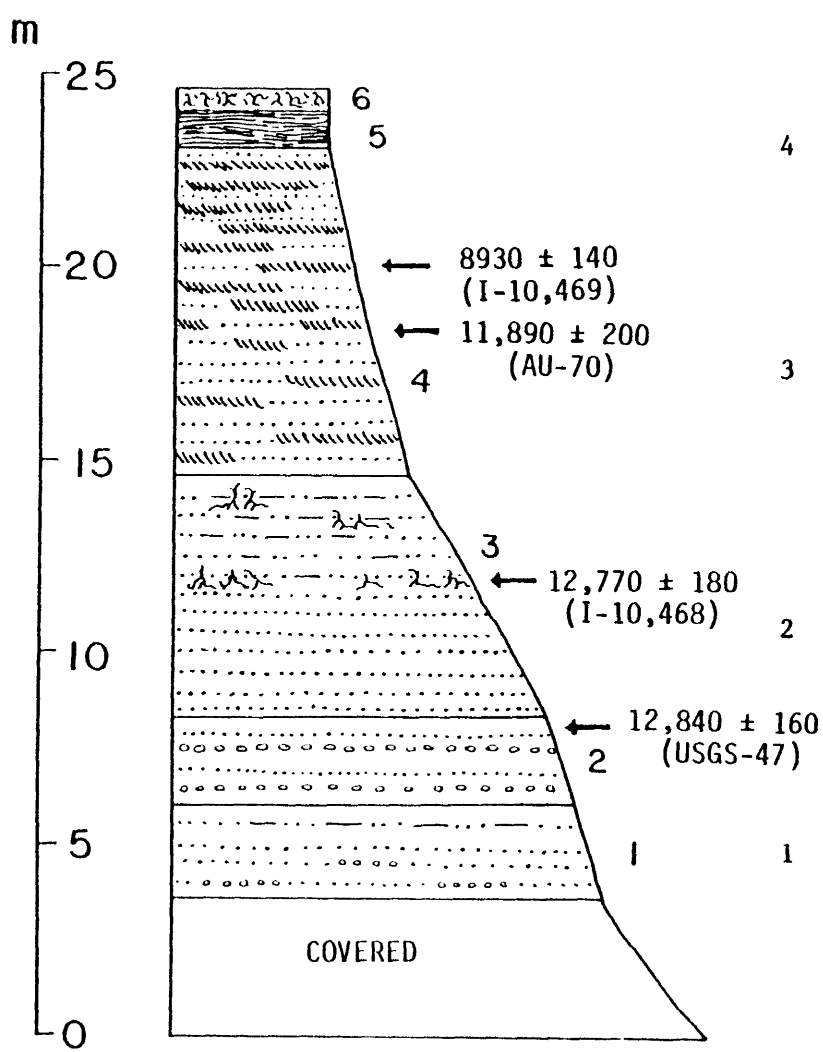
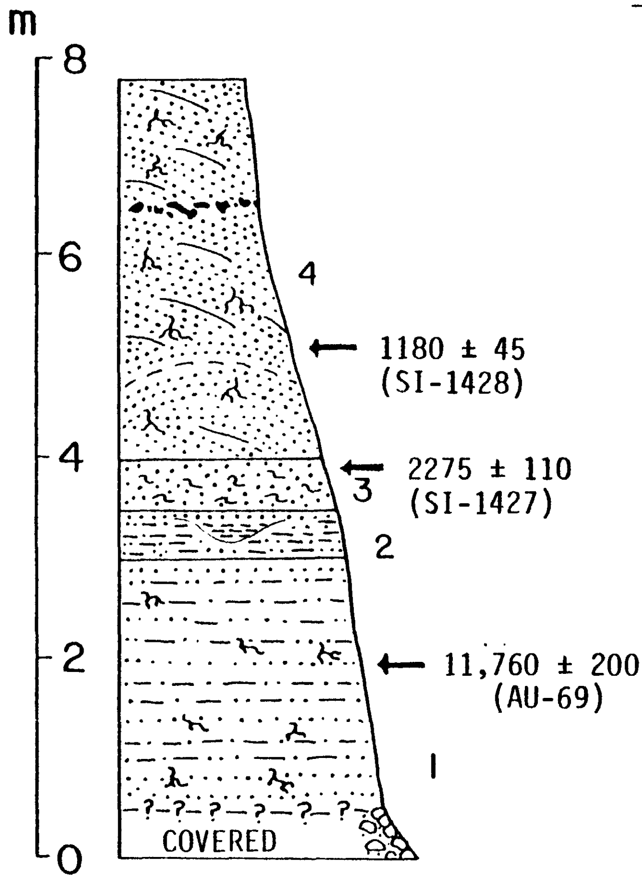


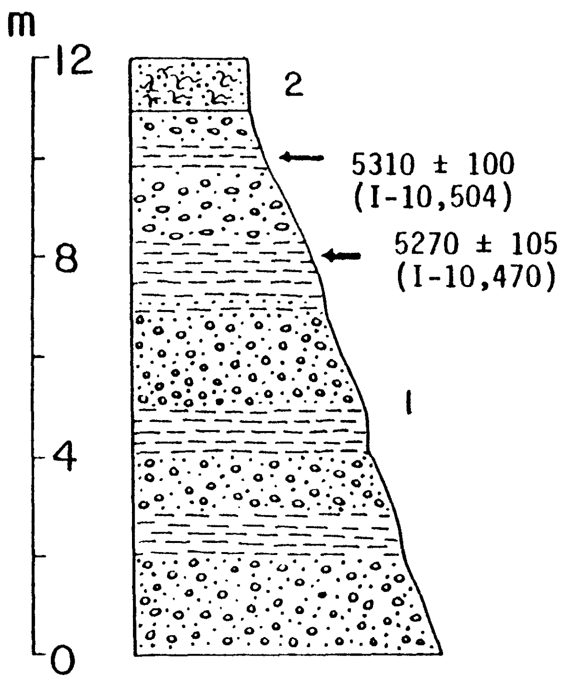
UNIT	THICKNESS (m)	DESCRIPTION
6	0.5	Surface sod and underlying organic mat.
5	1.0	Organic silt; light grey (2.5 Y 6/0) where weathered; dark greyish brown (10 YR 4/2) where freshly exposed. Some intermixed organic matter; some iron oxide staining. Prismatic structure near upper contact. Probably buried tundra soil.
4	8.7	Sandy peat and peaty sand, horizontally bedded. Peat mainly matted plant roots with twigs; sand ranges from very coarse with granule-sized shale chips to silty fine sand. Sand and sandy peat layers 3 cm thick alternate near base; sandy peat with thin sand interbeds in mid part of unit; massive peat in uppermost 3 m.
3	6.0	Bedded sand, fining upward; near-horizontal beds 3-5 cm thick; plant remains along bedding planes. Dark grey (10 YR 4/1), with some reddish brown (5 YR 5/4) oxide mottling. Medium and coarse sand alternate through lower 3 m; concentration of willow roots in middle of unit; medium and silty fine sand alternate through upper 3 m. Rooted plant remains increase in abundance upward.
2	2.4	Grey (10 YR 4/1) sand and fine gravel, interbedded in near-horizontal beds 6-12 cm thick. Gravel in well sorted fine granule layers and less sorted granule-small pebble layers. Sand medium to coarse, with some fine sand layers and thin (0.5 cm) interbeds of very coarse sand and shale granules. Cross-bedding locally present.
1	2.4	Grey (10 YR 5/1) fine to coarse sand, fining upward. Faint near-horizontal bedding; slightly undulose and rarely cross-bedded. Lower 1.2 m contains interbedded granule and rare small pebble lenses and layers 1-2 cm thick; upper 1.2 m contains very thin (<0.5 cm) clayey interbeds. Rounded pebbles to 5 cm diameter form thin (5 cm) bed near upper contact.
0	3.6	Covered. Debris apron at slope base.

Figure 1. Exposure S-1. North bank Sagavanirktok River 3 km above mouth of Atigun River. Total height above river level 24.6 m.



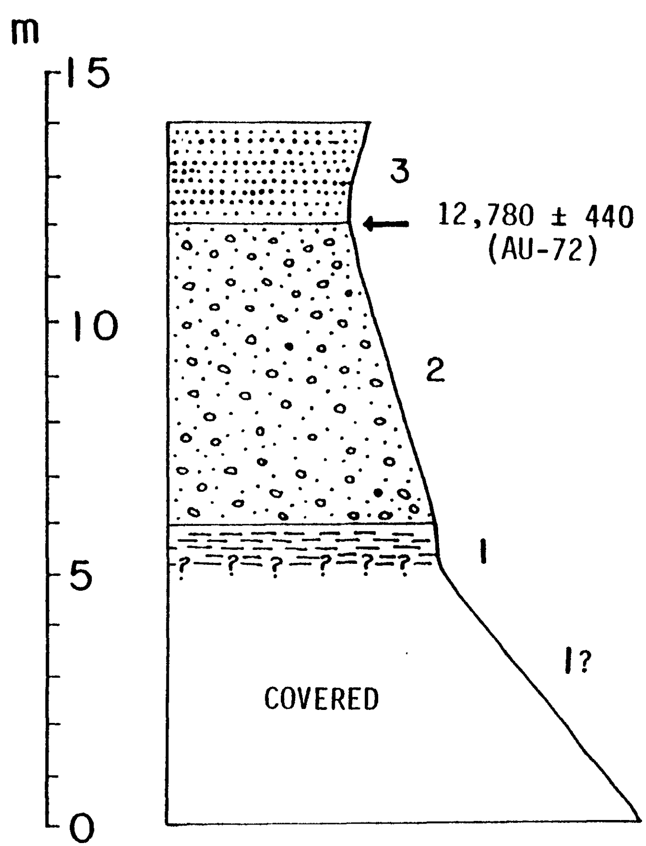
UNIT	THICKNESS (m)	DESCRIPTION
4	3.8	Weakly bedded medium to silty fine sand, containing abundant roots and other plant fragments; some beds stained reddish brown by iron oxides. Upper surface rises inland 5 m to dune crest. Cultural horizon at 1.3 m depth consists of compacted surface littered with fire-cracked rocks, river cobbles, broken caribou bones, charcoal fragments, and sparse chert chips. Probably eolian sand accreting on vegetated surface. Gradual transition to unit 3.
3	0.5	Mottled fine sand with abundant grass remains. Probably eolian; possibly on active river floodplain. Sharp transition to unit 2.
2	0.5	Clayey, silty fine sand, with layers of nearly pure clay in middle of unit. Cut-and-fill structures present, with fillings generally clay-rich. Probably marsh or shallow pond on floodplain. Gradual transition to unit 1.
1	2.5	Grey sand; horizontally bedded, with weakly defined strata 1-5 cm thick, containing roots and other plant fragments. Beds range from organic-stained silty fine sand to grey shaly medium to coarse sand. Probably overbank deposits of aggrading floodplain.
0	0.5	Boulder-cobble lag concentrate. Possibly primary; more likely secondary inset formed by modern river.

Figure 2. Exposure S-2. West side Sagavanirktok River 13 km above mouth of Atigun River. Height of exposed face 7.8 m above river level.



UNIT	THICKNESS (m)	DESCRIPTION
2	0.5-1.0	Sand, peat, and sandy peat. Sand dominantly eolian.
1	11	Interbedded silt and gravel. Rounded to subrounded, fairly well sorted pebbles and small cobbles of diverse lithologies in matrix of shale chips in medium sand to granule range. Interbedded with finely laminated clayey silt to silty fine sand in beds 0.3-0.5 mm thick containing detrital twigs and matted plant remains along bedding planes. Probably channel gravel and overbank deposits.

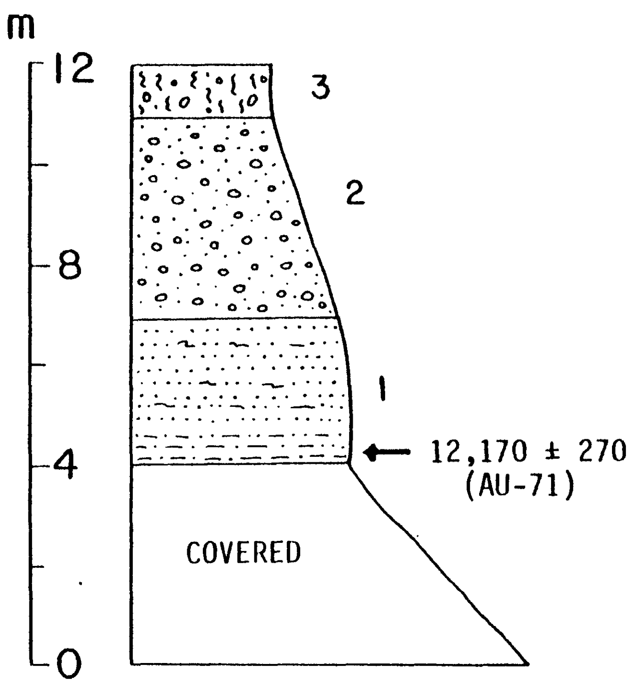
Figure 3. Exposure S-3. West side Sagavanirktok River 6 km above mouth of Atigun River. Total height 12 m above river level.



UNIT	THICKNESS (m)	DESCRIPTION*
3	2	Bedded sand
2	6	Gravel
1	6	Ice-rich silty clay? Covered with active flow apron.

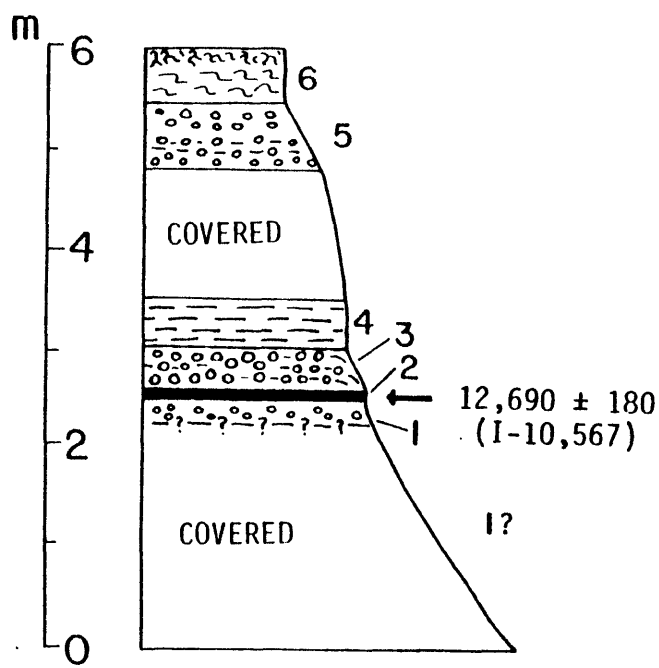
*Detailed measurement and description of units was not possible owing to hazardous condition of actively caving bluff face.

Figure 4. Exposure S-4. South bank Ribdon River 4 km above its mouth. Total height above river level 14 m.



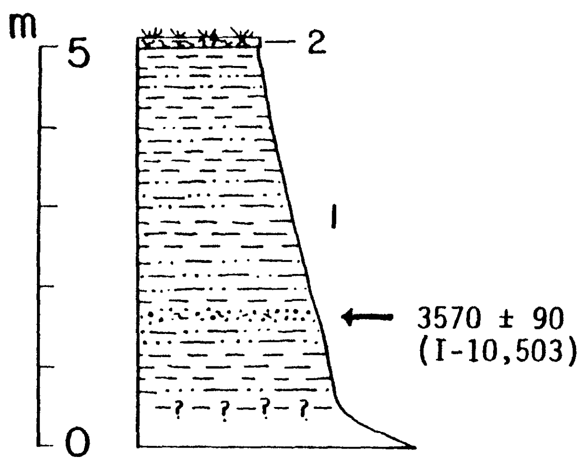
UNIT	THICKNESS (m)	DESCRIPTION
3	1	Frost-churned stony silt. Gravel from unit 2 mixed with probable loess cap.
2	4	Gravel. Subrounded cobbles and pebbles in sandy matrix. Probably outwash.
1	3	Bedded sand with detrital organic fragments along bedding planes; becoming clayey near base. Probably fluvial, grading upward into lacustrine sediment.
0	4	Basal apron of flow debris.

Figure 5. Exposure S-5. West bank Sagavanirktok River 0.5 km above mouth of Accomplishment Creek. Total height above river level 12 m.



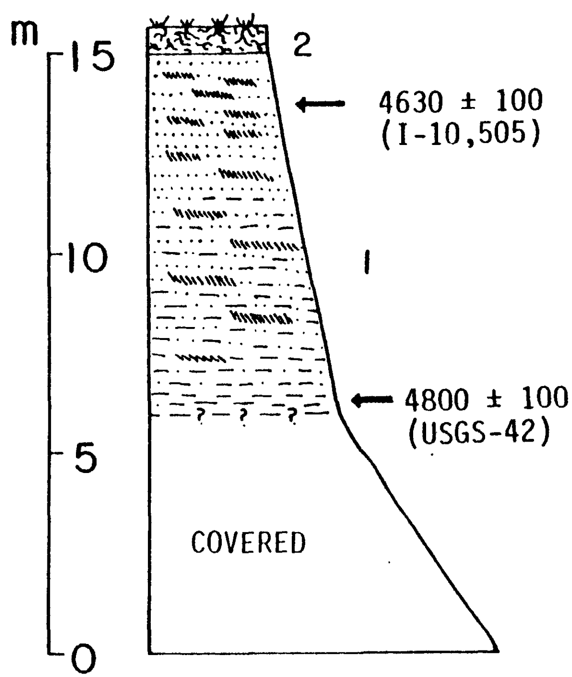
UNIT	THICKNESS (m)	DESCRIPTION
6	0.5	Surface organic mat above dark brown (10 YR 3/3) silt and very dark grey (10 YR 3/1) clayey silt. Highly deformed by frost action.
5	0.7	Open-textured, very dark grey (10 YR 3/1), platy, pebble-granule gravel. Thin gravel beds with silty matrix alternate with thick (20 cm) gravel beds that lack matrix. Probable beach deposit.
		------------------ covered by slumped sediments ------------------------
4	0.4	Brown to grey silt and clayey silt, as in unit 6. Deformed by slumping.
3	0.4	Grey platy gravel, as in unit 5. Weakly bedded, with thin interbeds of silty gravel and stiff clayey silt.
2	0.05	Black (10 YR 2/1) peat.
1	0.1+	Grey platy gravel, as in unit 5. Mostly covered.

Figure 6. Exposure S-6. East bank Section Creek 9 km above its mouth. Total height above creek level 6 m.



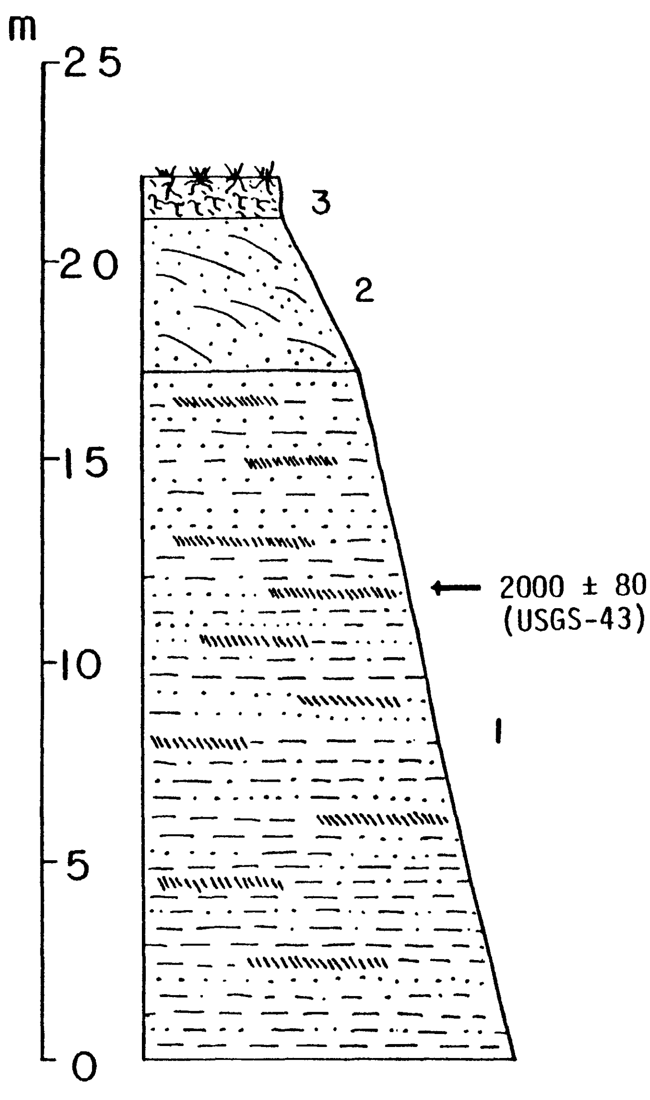
UNIT	THICKNESS (m)	DESCRIPTION
2	0.1	Surface sod and root mat.
1	4.5	Very dark greyish brown (2.5 Y 3/2) silty clay to silty fine sand, horizontally laminated in beds 1-5 cm thick. Contains detrital wood in medium sand 1.6 m above lake level and mats of detrital plant fragments higher in section.
0	0.5	Covered. Debris apron at base of bank.

Figure 7. Exposure S-7. Wave-cut bluff, east end Elusive Lake. Total height above lake level 5.1 m.



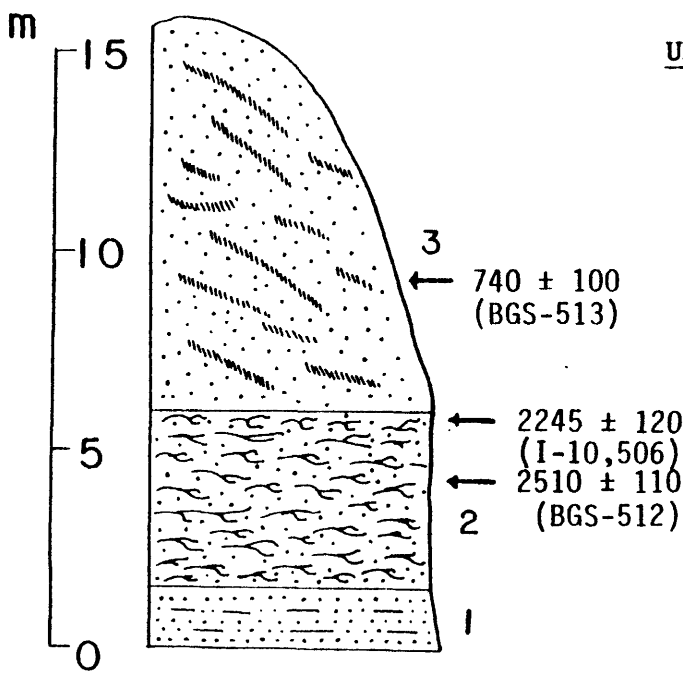
UNIT	THICKNESS (m)	DESCRIPTION
2	0.6	Sod cap.
1	9.0	Horizontally bedded sand, silt, and clayey silt. Beds 0.5-1.5 cm thick near base, with interbedded bryophytic peat layers. Overlying beds thicker (1-5 cm) and sandier, with interbedded grass and twigs.
0	6.0	Debris apron at base of bluff. No stones present.

Figure 8. Exposure A-1. East side Atigun River 6 km south of Galbraith Lake. Total height above river level 15.6 m.



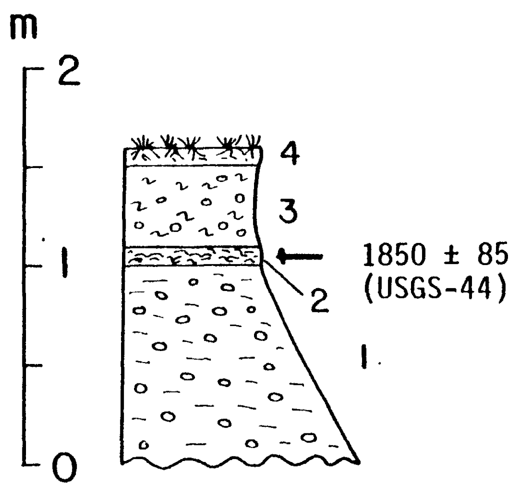
UNIT	THICKNESS (m)	DESCRIPTION
3	1.0	Sandy peat above nonbedded peaty sand.
2	3.8	Grey medium to coarse sand containing abundant shale chips; weakly bedded. Probably eolian.
1	17.3	Silt, silty fine sand, and some silty clay; horizontal beds 1-8 cm thick, with interstratified layers of bryophytic and grassy peat.

Figure 9. Exposure A-2. East side Atigun River 2.5 km south of Galbraith Lake. Total height above river level 22.1 m.



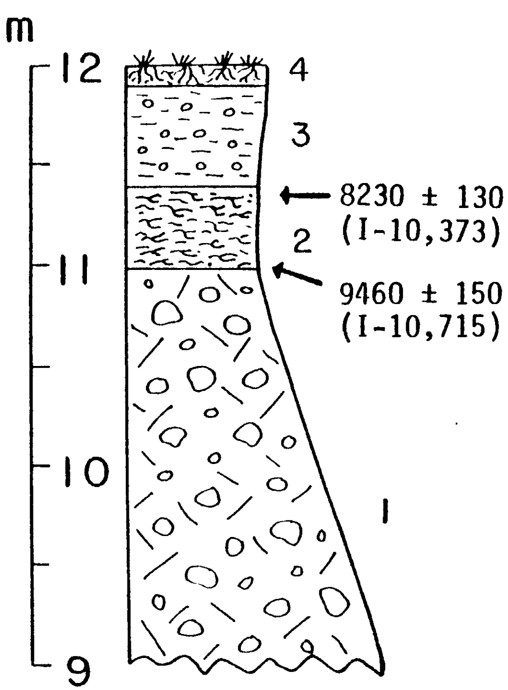
UNIT	THICKNESS (m)	DESCRIPTION
3	5-10	Dune sand. Dominantly medium sand to granules, with shale chips abundant in coarse sand to granule range. Upper 2 m mainly peaty fine to medium sand. Irregular upper surface with dunal morphology.
2	4.5	Sandy bryophytic peat with scattered twigs; loose texture; oxide-stained. Sharp near-horizontal upper contact; gradational lower contact.
1	1.5	Sand and silty fine sand with some lenses of granule-sized shale chips. Horizontal beds, generally 1-2 cm thick; maximum thickness 4 cm.

Figure 10. Exposure A-3. North bank Atigun River 0.5 km east of Galbraith Lake outlet stream. Height above river level ranges from 11 to 16 m.



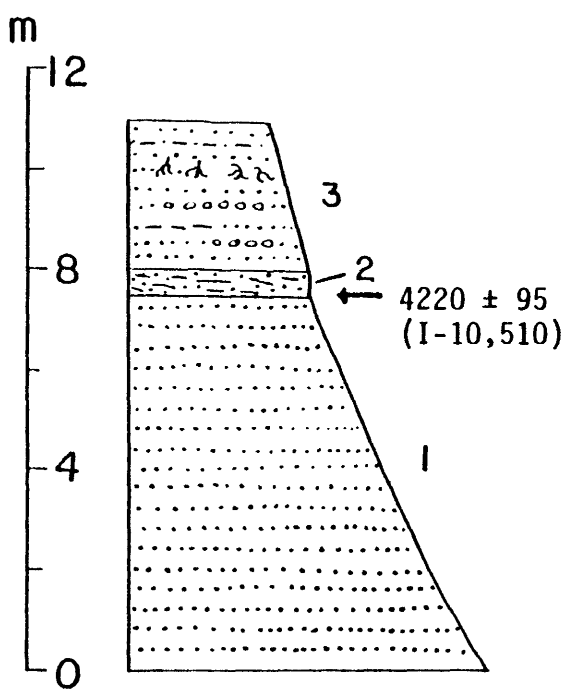
UNIT	THICKNESS (m)	DESCRIPTION
4	0.1	Organic mat.
3	0.4	Stony clayey silt, mottled brown (7.5 YR 4/4) to dark grey (5 Y 4/1). Probable solifluction deposit.
2	0.1	Dark brown (7.5 YR 3/2) peat, grading laterally into organic silt with thin (1 cm) peat cap.
1	1+	Dark grey stony silt, containing striated stones up to 1.5 m diameter. Contains excess ice in lenses and layers up to 0.5 cm thick. Underlain by massive ground ice more than 1 m thick.

Figure 11. Exposure A-4. Headwall of earthflow on late Itkillik moraine 4.5 km northwest of Galbraith Lake.



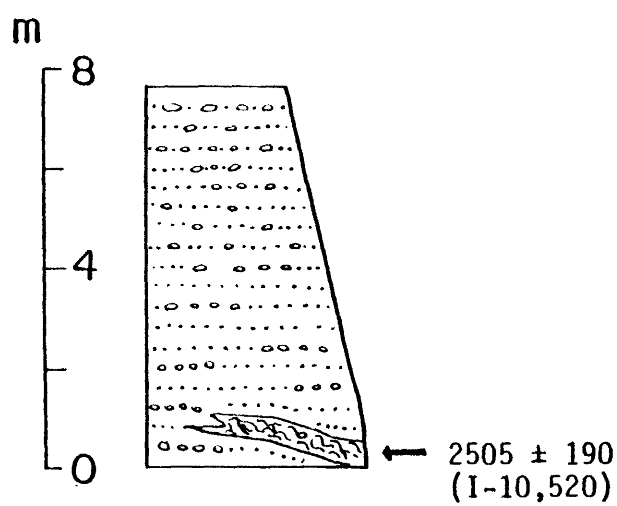
UNIT	THICKNESS (m)	DESCRIPTION
4	0.1	Surface sod mat.
3	0.5	Stony grey silt with platy structure. Probable solifluction deposit.
2	0.4	Very dark brown sedge peat.
1	11?	Diamicton. Subrounded to subangular stones up to 90 cm diameter in poorly sorted silty matrix. Lower portion obscured by flowage.

Figure 12. Exposure T-1. North bank of unnamed lake west of Toolik River 6.5 km northeast of Imnavait Mountain. Total height above lake level about 12 m.



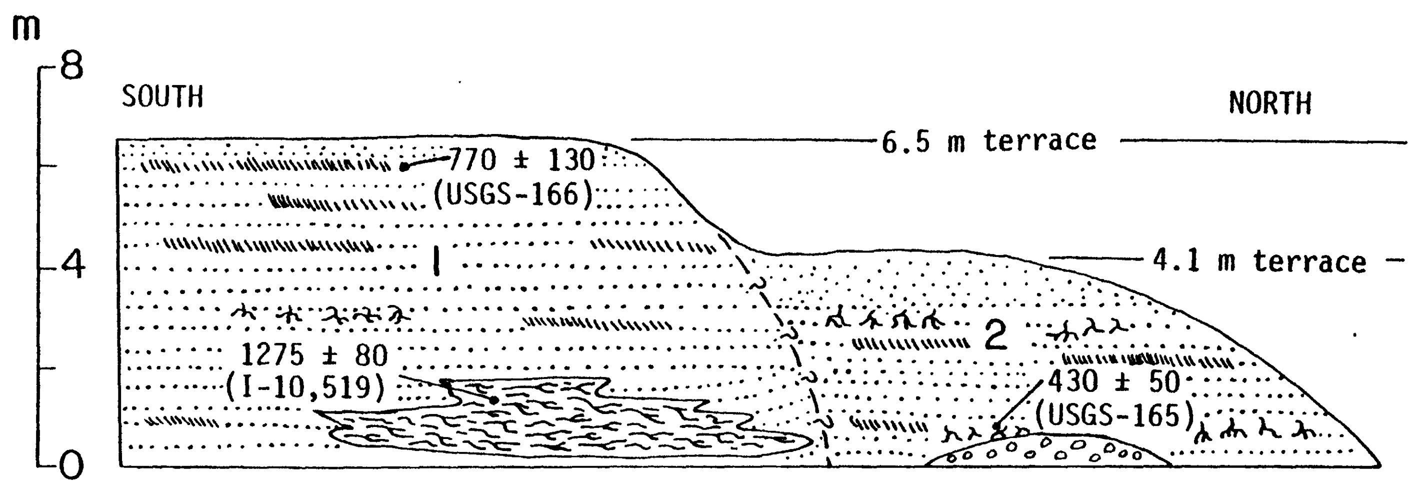
UNIT	THICKNESS (m)	DESCRIPTION
3	3	Dark greyish brown (10 YR 4/2) medium sand, containing shale chips of coarse sand to granule size. Weak horizontal bedding, accentuated by roots at series of growth levels and by thin lenses and beds of shaly granules. Probable cliff-head sand sheet.
2	0.5	Interbedded dark grey (10 YR 4/1) to very dark greyish brown (10 YR 3/2) humic-stained to gleyed sand, silty sand, and sandy silt; containing wood fragments. Grades laterally into dark grey to yellowish brown (10 YR 5/6) peaty sand to sandy peat.
1	7.5	Dark grey (5 Y 4/1) medium and coarse sand, interbedded with dark greyish brown (10 YR 4/2) fine sand. Weakly defined near-horizontal bedding.

Figure 13. Exposure I-1. North end of unnamed lake 3 km northwest of Itkillik Lake. Total height above lake level 11 m.



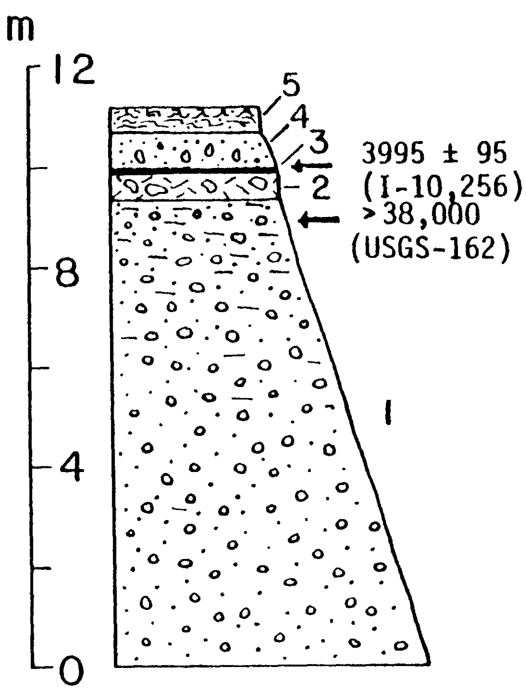
THICKNESS (m)	DESCRIPTION
7.8	Bedded fluvial sand, as at Exposures I-1 and I-3, with intermixed pebbles and cobbles derived from eroding glacial deposits. Bryophytic peat forms local swale-filling deposit that dips below river level.

Figure 14. Exposure I-2. East side Itkillik River 3 km west of Itkillik Lake. Total height above river level 7.8 m.



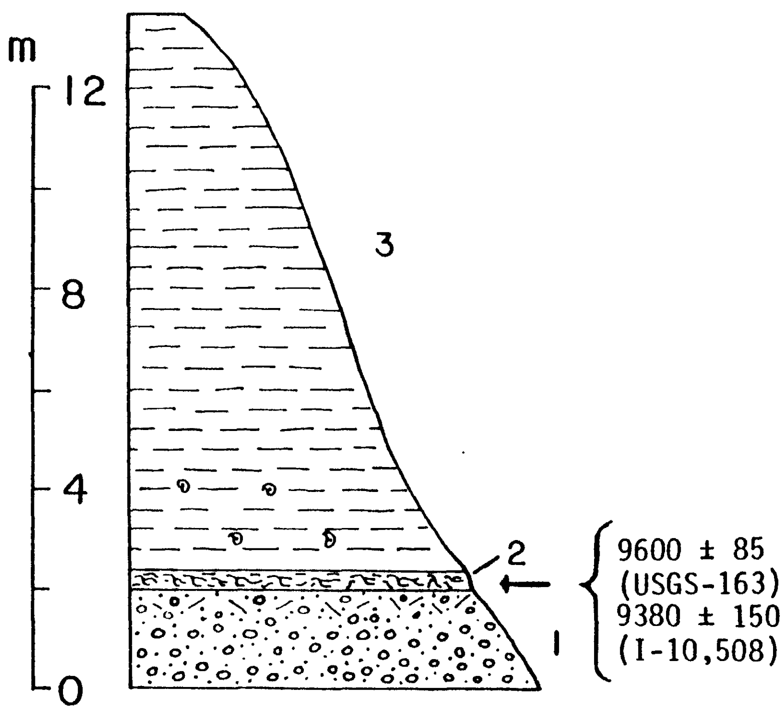
UNIT	THICKNESS (m)	DESCRIPTION
2	4.1	Dark greyish brown (10 YR 4/2) fine sand interbedded with dark grey (5 Y 4/1) shaly coarse sand in horizontal beds 1-8 cm thick. Contains abundant in situ roots and less common peaty sand layers and fragments of detrital wood. Upper 0.5 m structureless, probably owing to reworking by wind. Lens of fine gravel locally present at base consists of subrounded pebbles in sandy matrix.
1	6.5	Fine sand interbedded with coarse sand containing shale chips, as described above. Upper 3 m contains abundant mats of grasses and sedges along bedding planes. Basal 2 m contains lens of byrophytic peat that fills swale in sand.

Figure 15. Exposure I-3. West side Itkillik River 5 km northwest of Itkillik Lake. Heights measured above river level.



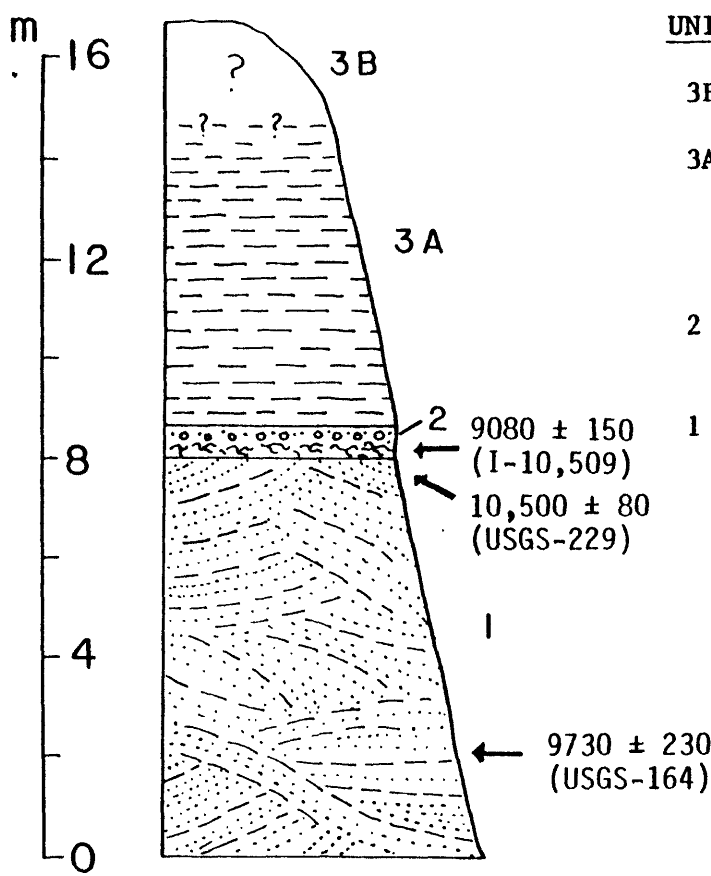
UNIT	THICKNESS (m)	DESCRIPTION
5	0.4	Organic mat above dark greyish brown (10 YR 4/2) silty peat and peaty silt.
4	0.6	Greyish brown (2.5 Y 5/2) silt containing subrounded to subangular pebbles and small cobbles, many oriented vertically.
3	0.1	Very dark brown (10 YR 2/2) organic silt with abundant plant rootlets. Possibly A horizon of buried tundra soil.
2	0.6	Till. Subrounded to subangular striated and faceted stones up to 1 m diameter in compact olive grey (5 Y 5/2) clayey sandy silt matrix. Base incorporates tongue of unit 1.
1	9.5	Gravel. Rounded to subrounded pebbles and cobbles in light grey (5 Y 5/1) silty sand matrix. Platy stones imbricated, dipping upvalley. Matrix sandy near base, becoming more silty and more variable upward. Detrital wood near upper contact.

Figure 16. Exposure W-1. East bank Wind River 39 km south of Continental Divide. Total height above river level 11.2 m.



UNIT	THICKNESS (m)	DESCRIPTION
3	11.2	Dark grey (5 Y 4/1) calcareous clayey silt, silty clay, and clay; horizontally bedded, with beds 1-3 cm thick. Contains fragmented gastropods and pelecypods, which are associated with Chara in zone that extends at least 3.4 m above base. Basal 10 cm is olive brown (2.5 Y 4/4) Chara-rich clay. Highly disturbed by flowage.
2	0.15	Very dark greyish brown (10 YR 3/2) peat above clayey peat. Contains flattened wood fragments.
1	2.0	Dark olive grey (5 Y 3/2) sand and gravel. Rounded to subrounded granules and small pebbles dispersed in sand-granule matrix. Upper 18 cm intermixed with mud, probably by frost churning.

Figure 17. Exposure W-2. East bank Wind River 50 km south of Continental Divide. Total height above river level 13.4 m.



UNIT	THICKNESS (m)	DESCRIPTION
3B	2	Covered. Probably same as unit 3A.
3A	6.1	Dark greyish brown (2.5 Y 4/2) silt, dark grey (5 Y 4/1) silty clay, and dark grey clay; calcareous; probably horizontally bedded. Blocky to platy structure.
2	0.5	Granules and small pebbles in sandy matrix above very dark brown (10 YR 2/2) woody peat.
1	8.2	Very dark grey (5 Y 3/1) sand interbedded with dark grey (5 Y 4/1) silt in beds 3-10 cm thick; cross-bedded. Sand beds range from well sorted medium sand to coarse sand with granules and dispersed small pebbles. Silt beds contain lenses of peat and detrital wood, dispersed gastropod shells, and some clayey laminae.

Figure 18. Exposure W-3. East bank Wind River 56 km south of Continental Divide. Total height above river level about 17 m.

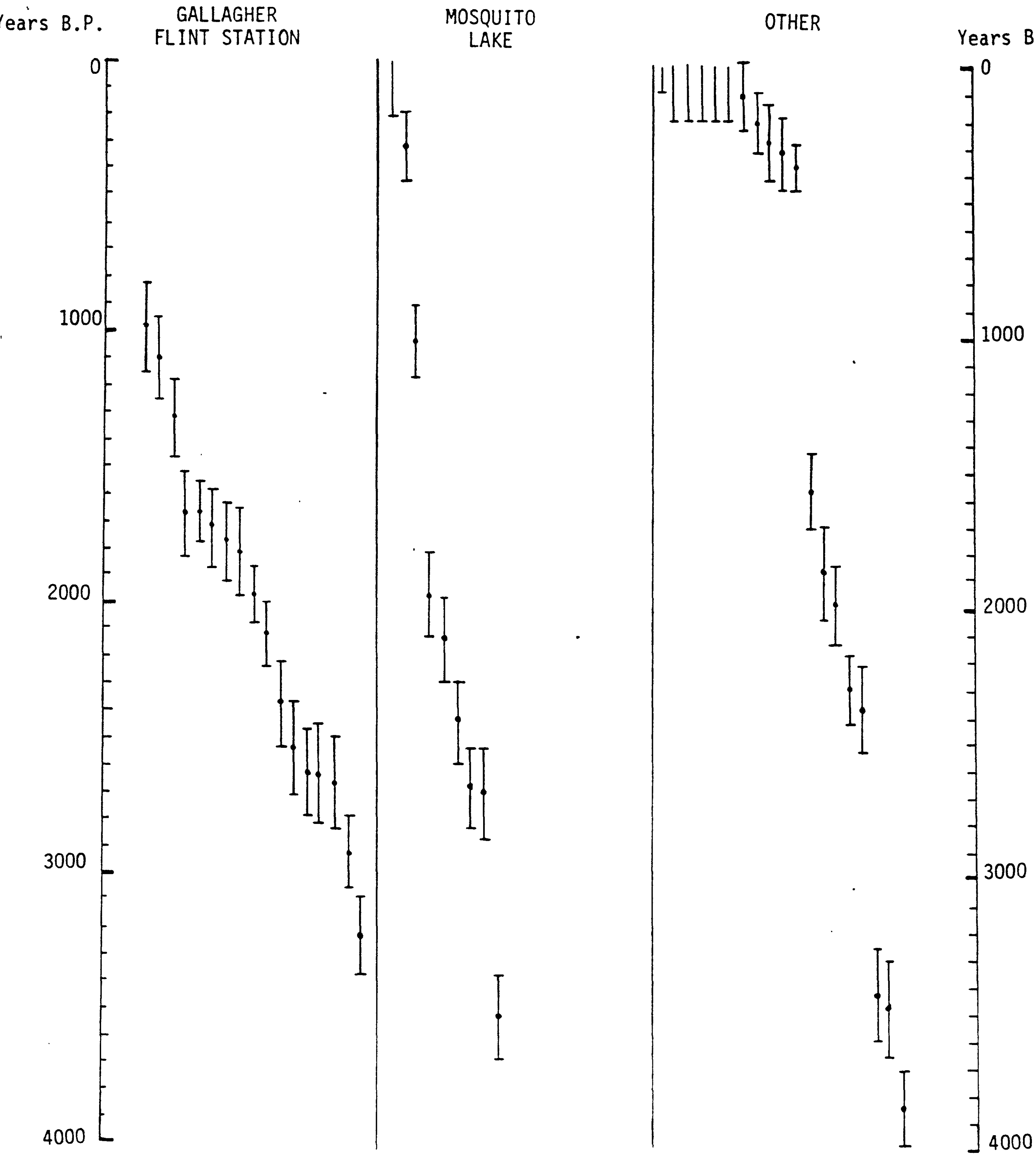


Figure 19. Age distribution of late Holocene archeologic sites, Philip Smith Mountains quadrangle.

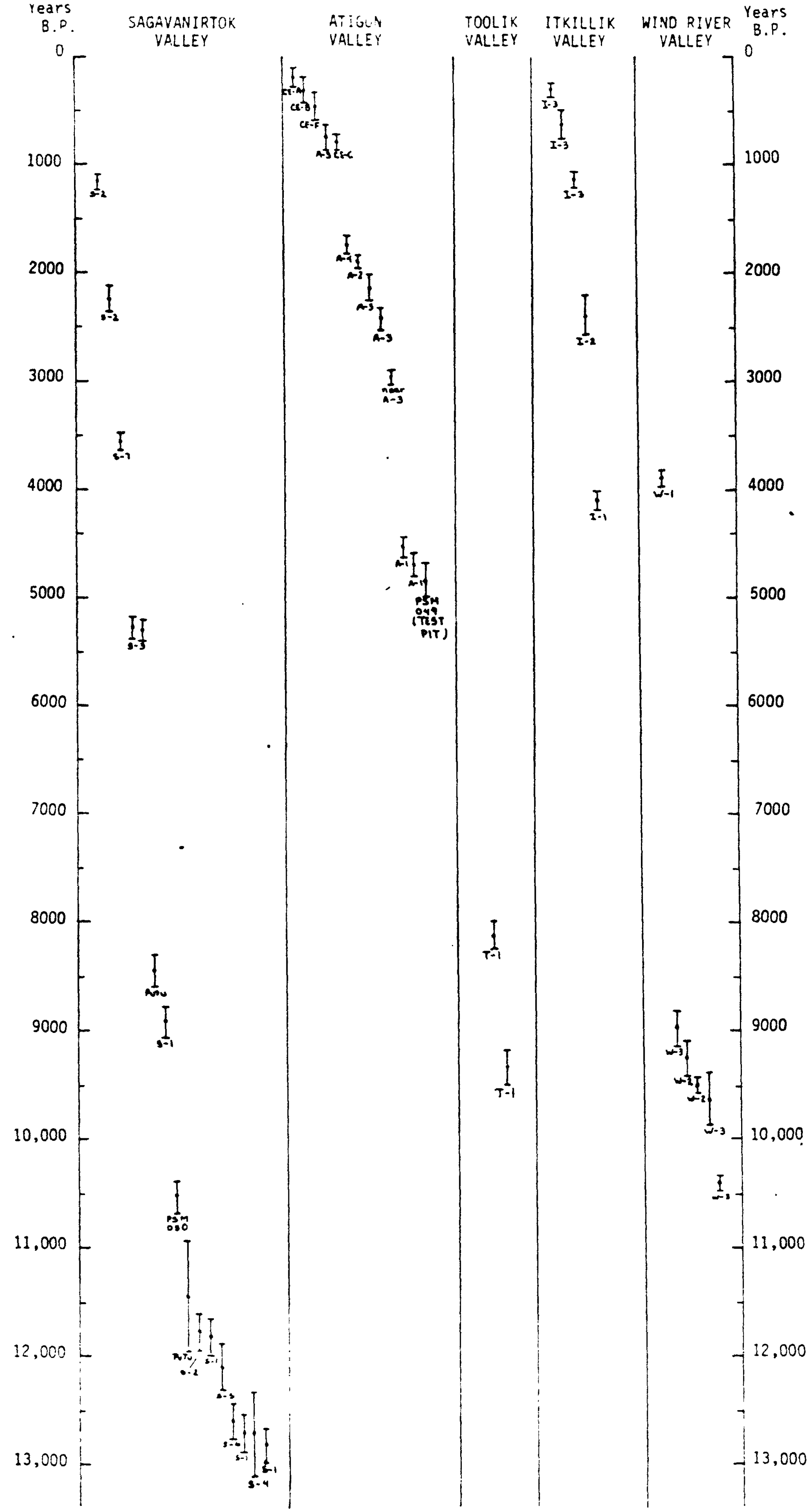
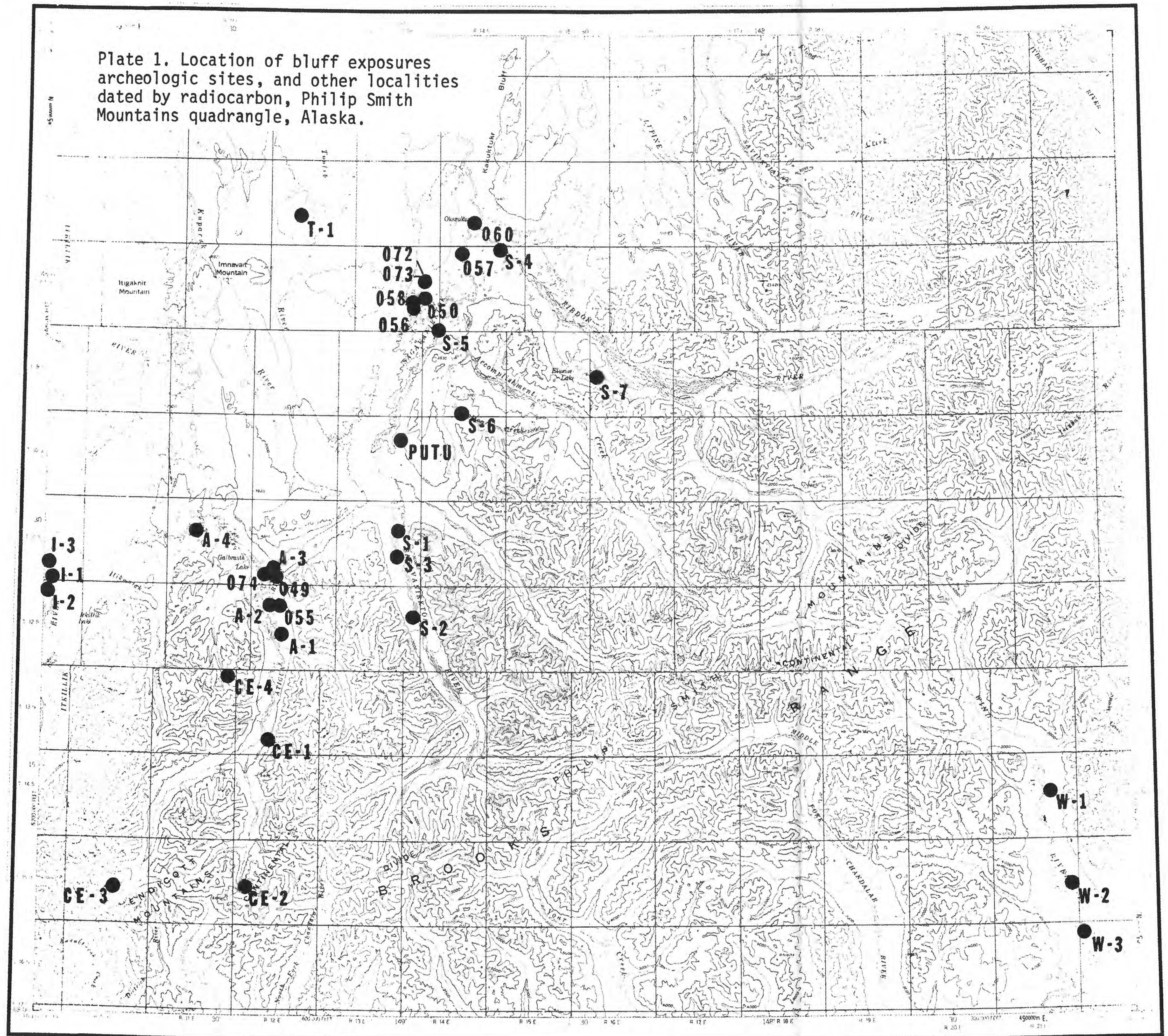
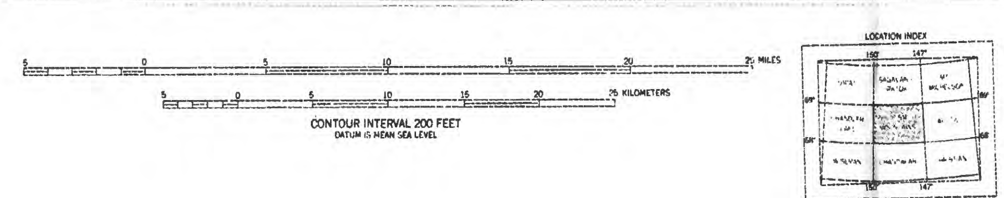


Figure 20. Age distribution of radiocarbon dates from bluff exposures and other stratified localities, Philip Smith Mountains quadrangle. Dates shown in figure 19 are not included.

Plate 1. Location of bluff exposures archeologic sites, and other localities dated by radiocarbon, Philip Smith Mountains quadrangle, Alaska.





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