DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

QUATERNARY STRATIGRAPHIC SECTIONS WITH RADIOCARBON DATES

WISEMAN QUADRANGLE, ALASKA

by

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

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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-four radiocarbon dates were obtained from 20 river bluff and terrace exposures and three roadcuts in the Wiseman quadrangle, and from an additional river bluff a few km farther south near Bettles. The dates and the stratigraphy of unconsolidated deposits at these localities provide a framework for the late Pleistocene Itkillik I and II glacial phases in the Koyukuk drainage. Younger dates, obtained primarily from alluvial terraces, provide information on episodes of soil formation, fan-building, and river aggradation during the Holocene.

The multiple glacier expansions of the Itkillik I phase were preceded and followed by growth of boreal forests through the Koyukuk and Chandalar lowlands near the south flank of the Brooks Range. Wood fragments with apparently finite radiocarbon ages underlie till in two separate bluffs, but weathering relationships and two other infinite dates indicate that the entire history of the Itkillik I phase may lie beyond the range of conventional radiocarbon dating.

Glaciation of Itkillik II age began sometime around 30,000 to 28,000 years ago, and probably attained two or more maxima during the interval of about 24,000 to 14,000 yr B.P. Advancing glaciers within the Brooks Range blocked nonglaciated tributary valleys, causing streams within them to aggrade rapidly; they also caused widespread alluviation through the Koyukuk lowland. Pollen data indicate marshy treeless floodplains, dominated by sedges and with willow shrubs common. Spruce did not recolonize the Koyukuk region until perhaps 8000 years ago. In addition to river alluviation, periglacial processes included solifluction, loess deposition, frost-churning, growth of ice wedges, and construction of alluvial fans on surfaces that now are forested and inactive. Buried soils within periglacial deposits and at least one hiatus recorded in an alluvial succession suggest that an interstadial episode possibly occurred sometime between about 23,000 and 20,000 yr B.P.

Two nearly coincident dates averaging about 11,600 yr B.P. place minimum age limits on final retreat of glaciers from end moraines close to the south margin of the range. Major downcutting by the John River near the range front occurred sometime between about 11,600 and 10,000 years ago, possibly representing the time of final deglaciation of the upper valley near Anaktuvuk Pass.

Holocene history was dominated by three episodes of possibly widespread soil formation on uplands and along valley floors. Most streams may have been close to their modern levels at these times, and either were downcutting or remaining at a relatively constant level. Each of the soil-forming episodes was terminated by solifluction on slopes, frost churning and loess accretion on more level surfaces, and stream or fan alluviation on the floors of some valleys. Lichenometric data suggest that at least the two youngest of these events coincided with major episodes of cirque-glacier activity in higher parts of the range (Calkin and Ellis, 1980). The earliest soil-forming interval dates about 9200-8400 yr B.P. in the Wiseman quadrangle, and is supported by comparable dates on peat at four other localities in the central Brooks Range. The second interval, documented by buried soils at four localities, terminated shortly after 4000 years ago. The youngest interval dates 1700-1600 yr B.P. at two localities.

Late Holocene alluviation of many fans and valley floors was controlled by local environmental factors rather than by regional climatic changes. Alluviation within the John Valley may be related to fault activity near the valley mouth and to episodic movements of the Eagle Creek landslide farther north. Fan-building intervals in the metamorphic terrane may be due to episodic movements of the numerous flow-slides in tributary basins and along valley walls. Alluviation of many cirque-headed valleys, in contrast, probably reflects increased sediment yield that followed regional climatic reversals about 3500 and 500 years ago.

INTRODUCTION

The Wiseman quadrangle contains a rich stratigraphic record of alluvial, glacial, and periglacial events of the late Quaternary in the south-central Brooks Range. The numerous bluffs along the Koyukuk River and its tributaries expose drift sheets of the late Pleistocene Itkillik I glacial phase (table 1), and outwash and other proglacial deposits of the succeeding Itkillik II phase. During Itkillik I time, glaciers flowed south through virtually all of the valleys of the south-central Brooks Range to terminate in piedmont lobes within the Koyukuk lowland (Hamilton, 1978, 1979a). Outwash covered the Koyukuk Valley floor beyond the ice limits. Glaciers of Itkillik II age were more restricted; the largest reached positions near the south margin of the range, but many mountain valleys of the Wiseman quadrangle remained unglaciated. Lower alluvial terraces of Holocene age record alternating episodes of aggradation and soil development. Some of these events were controlled locally by mass movements and perhaps by faulting, but others may be related to regional climatic reversals and to fluctuations of cirque glaciers at valley heads.

Field studies of Quaternary geology in the Wiseman quadrangle began in 1973 with a traverse by boat down the Koyukuk River and the lower course of the John River. Eight radiocarbon samples were collected at that time from three of the bluff exposures discussed in this report (table 2 and plate 1). Additional stratigraphic studies were carried out in 1975 during a reconnaissance along the Alyeska pipeline haul road (Hamilton, 1979b). Three radiocarbon samples were collected at that time from three of the many roadcuts that were examined (table 2 and plate 1). The entire Wiseman quadrangle subsequently was mapped during 1977 as part of the Arctic Environmental Studies

Table 1. Stratigraphic succession in the Koyukuk drainage system. From Hamilton, 1978.

Holocene	Postglacial downcutting, thaw-lake formation, and peat accumulation in major valleys. Accumulation of basin-fill deposits up-valley from Itkillik II end moraines.
Late Pleistocene	ITKILLIK II GLACIATION. Deposition of till, ice-stagnation deposits, outwash, loess, and proglacial lake sediments. Interglacial or interstadial unconformity with local peat and forest beds. ITKILLIK I GLACIATION. Deposition of till, outwash, and loess.
Middle(?) Pleistocene	Deposition of interglacial gravel, now heavily oxidized. SAGAVANIRKTOK RIVER GLACIATION. Deposition of younger pre-Itkillik drift(s).
Early(?) Pleistocene	Deposition of thick interglacial alluvium. ANAKTUVUK RIVER GLACIATION. Deposition of older pre-Itkillik drift(s).
Pliocene(?)	Deposition of preglacial gravel.

Table 1. Radiocarbon dates from the Wiseman quadrangle, Alaska.

Exposure No.	Site Location	Collector and Date	^{14}C Date & Lab No. (1)	Material Dated	Comments
KY-1	67°07'N 150°23.5'W	T. D. Hamilton 6/19/77	50,000 +3200 -2600 (USGS-410)	Wood	Picea (2)
KY-2	67°03'N 151°06.5'W	T. D. Hamilton & C. E. Schweger 7/26/73	13,160 ± 170 (SI-1877)	Wood	Pollen dominated by Cyperaceae, with abundant Gramineae, Artemisia, Cruciferae, and minor herbaceous elements. Salix is dominant shrub, with minor Betula and Alnus (3)
			15,455 ± 130 (SI-1876)	Willow (3) Wood	
			23,500 ± 380 (SI-1875)	Sedge and grass	
			35,400 ± 2000 (SI-1878)	Plant roots & stems	
KY-3	67°01.5'N 151°07.5'W	T. D. Hamilton & C. E. Schweger 7/27/73	>40,000 (SI-1879)	Peat and wood	Sphagnum and Betula twigs. Pollen dominated by Cyperaceae and Salix; Gramineae, Artemisia, Tubuliflorae, and Cruciferae common (3)
KY-4	66°57'N 151°44.5'W	T. D. Hamilton & C. E. Schweger 7/29/73	17,420 ± 180 (SI-1882)	Wood	Pollen dominated by Cyperaceae, with Salix common; Gramineae rare to abundant; minor Artemisia, Tubuliflorae, and Cruciferae; rich assemblage of herbaceous taxa (3)
			19,700 ± 360 (SI-1881)	Willow (3) Wood	
			29,000 ± 700 (SI-1880)	Willow (3) Wood	
KY-5	67°04'N 150°12'W	T. D. Hamilton 6/21/77	20,600 ± 400 (I-10,573)	Peaty silt	Paleosol
JO-1	67°28'N 151°49'W	T. D. Hamilton 7/25/77	>48,000 (USGS-414)	Wood	Salix; Populus(?) (2)
JO-2	67°20.5'N 152°18'W	T. D. Hamilton 7/11/77	1670 ± 80 (I-10,597)	Peat	
			27,700 ± 950 (USGS-413)	Wood	
JO-3	67°49.5'N 152°20'W	T. D. Hamilton 7/31/77	6630 ± 110 (I-10,277)	Peat	
JO-4	67°13'N 151°28'W	T. D. Hamilton 6/25/77	11,560 ± 170 (I-10,471)	Wood	In situ Salix (2)
JO-5	67°07.5'N 151°53'W	T. D. Hamilton 6/14/77	2630 ± 85 (I-10,570)	Peat	
			6820 ± 110 (I-10,571)	Wood	Betula; twig or small branch (2). Pollen dominated by Picea and Betula, with lesser Alnus and Sphagnum (5)
			9890 ± 80 (USGS-412)	Wood fragments	Salix (2). Matrix contains Carex remains but no bryophytes (4)
JO-6	67°25'N 152°04.5'W	T. D. Hamilton 7/29/77	6260 ± 110 (I-10,602)	Wood	Picea (2)
JO-7	67°24'N 152°27'W	T. D. Hamilton 7/27/77	2060 ± 75 (I-10,601)	Wood and peat	
JO-8	67°31'N 152°10'W	T. D. Hamilton	695 ± 75 (I-10,830)	Wood	In situ Picea roots (2)
JO-9	67°39.5'N 152°32.5'W	T. D. Hamilton	450 ± 75 (I-10,999)	Wood	In situ Salix roots (2)
WI-1	67°13'N 151°26.5'W	T. D. Hamilton 7/21/77	22,740 ± 560 (I-11,238)	Wood	Salix fragments (2)
MI-1	67°12'N 150°16'W	T. D. Hamilton 6/24/75	28,450 ± 950 (I-10,816)	Wood	Small twigs
MI-2	67°32.5'N 150°07'W	T. D. Hamilton 8/11/77	9180 ± 280 (I-10,603)	Wood	
MI-3	67"25'N	T. D. Hamilton 6/25/75	8430 ± 70 (USGS-45)	Peaty muck	No identifiable organics

MI-4	67°09'N 150°21'W	T. D. Hamilton 6/24/75	7990 ± 130 (I-10,501)	Wood	Salix and Picea or Larix (2)
NO-1	67°15.5'N 150°13'W	T. D. Hamilton 7/19/77	Undated	Peat	
			11,660 ± 170 (I-10,714)	Wood	
NO-2	67°34'N 151°12'W	T. D. Hamilton 7/21/77	10,700 ± 190 (I-10,600)	Wood	
NO-3	67°22.5'N 150°15.5'W	T. D. Hamilton 7/18/77	2355 ± 80 (I-10,598)	Wood	Picea and Salix (2)
			3230 ± 90 (I-10,599)	Wood	Salix roots (2)
NO-4	67°35'N 150°23'W	T. D. Hamilton 8/10/77	1380 ± 120 (I-11,239)	Wood	Small fragments picked from peat. Pollen and spores sparse; include Picea, Betula, Alnus, Salix (5)
			1185 ± 80 (I-11,008)	Wood	Small fragments picked from peat
NO-5	67°31.5'N 150°24.5'W	T. D. Hamilton 8/10/77	1035 ± 140 (I-11,009)	Wood	Small fragments picked from peat. Trace amounts Picea pollen and Sphagnum spores (5)

(1) I = Isotopes, Inc.; SI = Smithsonian Institution; USGS = U.S. Geological Survey Menlo Park Lab.

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

(3) Identified by C. E. Schweger, University of Alberta

(4) Identified and interpreted by J. A. Janssons, University of Alberta

(5) Identified by T. A. Ager, U.S.G.S., Reston, VA

Program of the U.S. Geological Survey (Hamilton, 1979a)[1/]. Twenty-three radiocarbon dates were obtained from 18 of the stratigraphic sections that were measured at that time (table 2 and plate 1).

Archeological studies in the Wiseman quadrangle were intiated by J. M. Campbell in the late 1950s (Campbell, 1962). Further archeological research was carried out during 1970-1975 as part of the trans-Alaska Pipeline archeological salvage program (Cook, 1971, 1977; Holmes, 1971). According to available information, most of the known archeologic sites lie at the surface or at very shallow depth, and only a single "modern" radiocarbon date (<200 yr B.P.; GX-4095) has been obtained from the archeologic excavations.

ACKNOWLEDGMENTS

The eight organic samples collected in 1973 were dated by Robert Stuckenrath at the Smithsonian Institution Radiocarbon Laboratory. Five additional dates were furnished by Stephen W. Robinson at the U.S. Geological Survey Radiocarbon Laboratory in Menlo Park, CA. The remaining 21 dates were provided by Isotopes, Inc. under the supervision of James Buckley. Wood collected for dating was identified by the Forest Products Laboratory at Madison, Wisconsin, and peat samples were examined for identifiable bryophytes (mosses) by Jan A. Janssens at the University of Alberta. Samples for pollen analysis were collected in 1973 by Charles E. Schweger from bluffs along the Koyukuk and lower John Rivers; the analyses subsequently were carried out by Schweger at the University of Alberta. Peat samples collected within the Brooks Range in 1977 were examined for pollen by Thomas A. Ager of the U.S. Geological Survey. John M. Campbell and Robert Gal provided unpublished information on their archeologic studies in the Wiseman quadrangle. Assistance in the field was provided by C. E. Schweger in 1973, Robert M. Thorson in 1975, and James P. McCalpin in 1977. Funding for field studies in the Koyukuk lowland in 1973 was provided by the University of Alaska and by a Penrose Bequest Grant from the Geological Society of America.

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

STRATIGRAPHIC SECTIONS

Koyukuk Lowlands

Ten radiocarbon dates (table 2) were obtained from five sections measured on bluff exposures along portions of the Koyukuk River, its North and South Forks, and the John River that lie 5-20 km south of the Brooks Range. These exposures, from which deposits ranging in age from more than 40,000 to about 13,000 ^{14}C years old have been dated, document glacial advances and climatic changes during the Itkillik I and Itkillik II glacial phases (Hamilton and Porter, 1975; Hamilton, 1978, 1979a). Seven radiocarbon dates that range between about 13,000 and 30,000 yr B.P. show good internal consistency; these seem to provide reliable dates on the Itkillik II glacial phase. Three older dates, from samples that underlie Itkillik I till and outwash, are mutually inconsistent and leave the true age of this glacial event in question.

Exposure KY-1 (fig. 1), along the Koyukuk's North Fork, exposes drift of Itkillik I age above preglacial gravel. The gravel (Unit 1), which is strongly oxidized, consists of rounded pebbles and small cobbles with abundant sand; it contrasts strongly with the bouldery outwash gravel exposed elsewhere through the Koyukuk lowlands. The gravel is more strongly oxidized near its upper contact, implying that surface weathering rather than groundwater circulation controlled oxide penetration into the deposit. Lenses of compact grey silt, probably overbank deposits, become more abundant near the top of the oxidized gravel. Direct overriding by glacier ice is demonstrated by deformation at the contact between the gravel and the overlying till. The till (Unit 2) is continuous with glacial deposits of Itkillik I age mapped through this section of the valley (Hamilton and Porter, 1975; Hamilton, 1979a). Jointing[2/] and oxidation in Unit 2 contrast strongly with the unweathered appearance of till that was deposited during the subsequent Itkillik II phase, suggesting that a considerable interval of time separated the two glacial episodes. Fragments of detrital spruce wood that were collected along a bedding plane at the top of a sand layer 5 m above river level date 50,100 + 3200/-2600 yr B.P. This date may be finite, but it also could be merely a limiting minimum age (i.e., true age is greater than 50,100 yr B.P.) because

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[2/] The most prominent joint set is subparallel to the face of the bluff, indicating that jointing was caused by expansion outward toward this exposed surface.

of its large counting error. As an additional problem, datable material was found only at the west end of the bluff, where till does not directly overlie the gravel from which the wood was obtained. The wood probably predates the till, which has been stripped by erosion, because (a) its sand and gravel matrix is similar to that directly under till farther east along the bank, and (b) individual sand layers are traceable eastward beneath the debris apron that covers the base of the main section of the bluff. However, there is a slight possibility that the wood could be contained within alluvium that postdates the till and is incised within it.

Exposure KY-2 (fig. 2), about 17.5 km downvalley from KY-1, ranges in height between 23 and 28 m and extends 0.8 km along the north bank of the Koyukuk River. Oxidized gravel at the base of the section (Unit 1) resembles the basal gravel at KY-1 in size, shape, and oxidized character; the gravel probably was widespread through the Koyukuk Valley prior to the time of Itkillik glaciation. The overlying till (Unit 2) resembles that at KY-1, and this unit extends across the Koyukuk Valley floor as part of a widespread deposit. Unit 3, above the till, is more variable along the bluff; it ranges in character from rhythmically bedded grey clay beneath fine gravel to fissile grey clay interbedded with buff silt and oxidized silty sand. These sediments probably formed in a lake enclosed by the end moraine of Itkillik I age; they include alluvium deposited after drainage of the lake but prior to downcutting. Jointing and oxidation within Unit 3 suggest a close affinity in age to the underlying till and a considerable hiatus before deposition of the overlying unweathered sand. The sand (Unit 4) appears entirely fluvial near its base, where it is cross-bedded and contains detrital mats of organic debris. The sand becomes finer and more silty higher in the section and, toward the west end of the bluff, it contains interbeds of organic silt about 5 cm thick. This part of Unit 4 appears to be a floodplain deposit that contains increasing amounts of loess. Pollen spectra from Unit 4 suggest floodplain communities comparable to those that presently occur north of the Brooks Range (Charles E. Schweger, written communication, 6/79). Sedge pollen is dominant, with abundant willow and with grasses and herbs also present. Massive loess (Unit 5) overlies the sand, and the section is capped by an organic mat and a zone of frost-churned loess (Unit 6).

Four radiocarbon dates were obtained from KY-2 (table 1): 35,400 ± 2,000 yr B.P. from plant roots in a thin sand layer within Unit 1; 23,500 ± 380 and 15,455 ± 130 yr B.P. from detrital organic mats near the base of Unit 4, and 13,160 ± 170 yr B.P. from wood fragments in the loess of Unit 5. The date from the basal gravel, if correct, would permit only a very short interval for deposition of the till and lacustrine beds and for their deep weathering prior to fluvial sedimentation about 23,500 yr B.P. Because of its large counting error, this 35,400-yr date should be considered an upper age limit rather than a true age (R. Stuckenrath, personal communication, 6/24/80). Sand deposition began about 23,500 yr ago at the site when the alluviating Koyukuk River overtopped the lacustrine plain into which it earlier had incised. A limiting minimum age on the alluvial episode is provided by the date of 13,160 ± 170 yr B.P. from the overlying loess. These dates suggest that sand deposition was contemporaneous with the advance of glaciers of Itkillik II age down the North and Middle Forks of the Koyukuk to terminal positions just within the south flank of the Brooks Range (Hamilton, 1979a; Hamilton and others, 1980). Pollen data, which suggest treeless tundra vegetation with sparse shrubs, confirm that deposition took place under glacial conditions significantly harsher than at present (C. E. Schweger, written communication, 6/79). The sand evidently is distal outwash, as described by Boothroyd and Ashley (1975).

Exposure KY-3 (fig. 3) extends along the south bank of the Koyukuk River 3.5 km below KY-2 at the downvalley limit of the drift sheet of Itkillik I age (Hamilton, 1979a). The bluff face stands 50 m high, exposing two gravel deposits separated by organic-bearing silt and sand and overlain by thick loess. The lower gravel (Unit 1) is generally fine-grained; it resembles the preglacial alluvium at KY-1 and KY-2, but stands about 15 m higher above the modern river. Silt and sand (Unit 2) subsequently were deposited on a floodplain during a pause in alluviation. Peat and wood from this deposit are more than 40,000 yr old; pollen spectra are dominated by sedge and willow, and resemble floodplain spectra from units 3 and 4 of KY-2. The upper gravel (Unit 3) is relatively coarse, and formed during a time that the Koyukuk River alluviated by about 10 m; it is traceable directly into the end moraine of Itkillik I age, and clearly is outwash derived from it. A thick loess deposit (Unit 4) overlies the weathered surface of the gravel, which indicates that loess and gravel deposition were separated by a substantial time interval. Units 1, 2, and 3 probably represent a long-lasting alluviation of the Koyukuk Valley that apparently was not interrupted by a major interglacial episode and that may have taken place during a 2-phase glaciation of

Itkillik I age. That event was followed by downcutting and by a long weathering interval, which in turn was terminated by loess deposition during the succeeding Itkillik II time.

Exposure KY-4 (fig. 4) lies inside the arcuate end moraine of Itkillik I age that crosses the mouth of John Valley near Bettles (see Hamilton and Porter, 1975, fig. 2). Although this bluff lies 5 km south of the Wiseman quadrangle, it is included in this report because of (1) its nearness to and close stratigraphic association with other Itkillik-age deposits of the Koyukuk lowland and (2) its importance in the chronology of Itkillik-age glaciation. Unit 1, at the base of the exposure, consists of stream-deposited fine gravel that formed after glacier retreat from the Bettles moraine. A lake subsequently filled the moraine-dammed basin for an interval sufficiently long for deposition of a 4-m section of lacustrine clay (Unit 2). Alluviation began about 29,000 yr B.P. and continued until sometime after 17,500 yr ago (Units 3-6). The alluvial sediments consist of sand with considerable silt that may have been redeposited from loess. A massive silt bed (Unit 4) underlain by flow deposits that perhaps were generated by thaw of ice-rich silt, suggests a possible pause or reversal in alluviation sometime between about 29,000 and 20,000 yr B.P. Subsequent alluviation was relatively rapid and marked by predominance of sand. Pollen spectra from the alluvial sequence show sedges dominant, willow abundant, grasses rare to abundant, and a rich assemblage of herbaceous taxa (C. E. Schweger, written communication, 6/79); willow also is dominant among wood fragments collected for ^{14}C dating. This plant assemblage, like that from KY-2 and KY-3, is characteristic of treeless tundra in which willow locally is important on floodplains. Alluviation ceased sometime after about 17,500 yr B.P., downcutting may have started, and a thick loess cap (Unit 7) formed at the site. Alluvial history at KY-4 shows close correspondence in age and in environment to that recorded at KY-2. Both events probably are synchronous, and were contemporaneous with the Itkillik II glacial phase.

Exposure KY-5 (fig. 5) is located in the extreme southeastern corner of the Wiseman quadrangle where the Koyukuk's South Fork intersects the drift sheet of Itkillik I age (Hamilton, 1979a). The exposed face stands about 34 m high, rising inland another 6.5 m to the crest of the end moraine that marks the outer limit of the Itkillik I ice advance. Partly obscured river gravel near the base of the bluff (Unit 1) continues upward into similar gravel containing multiple stone lines of closely packed cobbles and small boulders (Unit 2). The stone lines probably are lag deposits derived from erosion of coarse outwash that issued from the moraine front and spread into the aggrading floodplain of the South Fork. Overlying finer gravel (Unit 3) is interpreted as alluvium that was deposited by the South Fork during or after glacial retreat. A thick deposit of silty colluvium (Unit 4) caps the section; it is connected to the moraine crest by a smoothly graded slope that resembles a stabilized solifluction apron. A sharp contact separates colluvium from underlying gravel, indicating that the South Fork probably had abandoned its high-level floodplain prior to the flowage of debris down the moraine front. A paleosol within the colluvium consists of peaty silt, dated 20,600 $\pm$ 400 yr B.P., that has been segmented and deformed into a series of overturned folds by downslope movement subsequent to its formation. Some of the flat stones beneath the paleosol stand on end; their vertical flanks bear carbonate crusts that must have formed initially beneath the stones. Following an initial episode of solifluction, the stones evidently remained in place long enough for carbonate crusts to form on their undersides and for the peaty paleosol to develop. Stones and soil later were subjected to renewed flow and deformation. The date and stratigraphy from KY-5 indicate that the Itkillik II glacial phase was associated with intensified periglacial activity near the south flank of the Brooks Range. This episode was punctuated by an interval of relative slope stability about 20,600 yr ago that could coincide with possible pauses in alluviation along the Koyukuk and John Rivers.

John Valley

Twelve radiocarbon dates were obtained from nine sections measured on river bluffs 16 to 70 m high and on lower alluvial terraces within John Valley and along its principal tributaries. The bluff deposits range in age from more than 49,000 yr B.P. to middle Holocene; they provide information on the Itkillik I and II glacial advances and on alluviation and related events during late-glacial and early postglacial time. The terraces, which range in height up to about 8 m, provide data on alluvial episodes of the John River system between about 6,250 and 450 yr B.P. All of the radiocarbon dates show good consistency within and between exposures, and are considered reliable.

Exposure JO-1 (fig. 6) lies along Allen River, an eastern tributary to the John River, at a point where an unusually sharp bend of the river intersects the base of the southeastern valley wall. During Itkillik I time, the valley of Allen River formed a conduit for glacier ice that was generated near the heads of Tinayguk and Publituk Valleys and that flowed southward across low divides to join the John Valley ice stream. During the subsequent Itkillik II phase, ice from John Valley intruded about 8 km into the lower course of Allen Valley, but the remainder of Allen Valley remained unglaciated (Hamilton, 1979a). The exposure lies near the upvalley end of a thick sandy valley fill that appears to have formed against the outer face of the moraine that blocked the valley mouth. The measured section consists of 22.5 m of fluvial sand and gravel (Units 1-5) that bears a poorly exposed cap of sand containing at least one 2-3 cm bed of clayey silt (Unit 6). A lens of detrital wood from a bedding plane 1.5 m below the top of Unit 3 includes willow and is more than 48,800 yr old. Many of the wood fragments are strongly impregnated with iron oxides. The alluvium of Units 1, 2, and 3 generally lacks clasts larger than small cobbles, and probably formed in the interglacial or interstadial interval that separated the Itkillik I and II glacial phases. Unit 4, in contrast, contains some flatiron-shaped large cobbles that may have been introduced as outwash into Allen River. The clayey silt within Unit 6 possibly was emplaced when Allen Valley was blocked by the John Valley glacier during Itkillik II time.

Exposure JO-2 (fig. 7) fills a reentrant near the mouth of Sixtymile Creek, a western tributary that also was blocked by the John Valley glacier during Itkillik II time (Hamilton, 1979a). The valley fill in this area has a total height of 102 m from the crest of the bluff to the lowest exposures along the floor of a small tributary gulley that trends north into Sixtymile Creek. Plastic sediments squeezed upward along the gulley floor consist of dark grey (5 Y 4/1) laminated silty clay with striated dropstones, and flows of clayey sediments are common along the lower valley sides. The deepest continuous exposure has been cut to a depth of 69 m below the bluff crest (fig. 7). The oldest deposit exposed in this section (Unit 1) is crossbedded sand with some gravel that dates 27,700 ± 950 yr B.P. Dips near the top of Unit 1 suggest deposition by water flowing southeast parallel to the present course of Sixtymile Creek. Interbeds of clayey silt and silty clayey fine sand indicate that drainage periodically was blocked, probably by a barrier near the mouth of Sixtymile Creek. The sand coarsens upward, passing without any sharp break into sandy gravel (Unit 2) that continues to coarsen toward the top of the bluff. The fine component of the gravel is well sorted, rounded to subrounded, small to medium pebbles that consist dominantly of quartz and quartzite; it includes cobble interbeds of the same lithology, which is characteristic of headwaters of Sixtymile Creek. The boulders at the top of Unit 2 are glacially faceted, and consist mainly of marble that was derived from the Skagit Limestone, which crops out widely in John Valley (Brosgé and Reiser, 1971). The section is capped by silt, peat, and sand about 85 cm thick that are associated with a sloping colluvial surface that rises toward the valley side at an angle of 11 degrees. The peat (Unit 4), which forms part of a paleosol that dates 1,670 ± 80 yr B.P., is buried beneath a solifluction deposit. The older radiocarbon date from JO-2 appears to place a firm age of about 28,000 yr B.P. on the growth of the John Valley glacier during Itkillik II time to its terminal position at the south margin of the Brooks Range. It corresponds to dates of about 29,000 to 24,000 yr B.P. for early phases of alluviation farther south in the Koyukuk lowland. The significance of the poorly exposed clays at the base of the section is uncertain. These lacustrine sediments could have formed either during glacier recession at the close of the Itkillik I phase or during initial glacier advances of Itkillik II age.

Exposure JO-3 (fig. 8), along the east side of John River near its head, lies within a section of the valley that is floored by till and ice-contact stratified drift of late Itkillik age (Hamilton, 1979a). The bluff face stands 55 m high, its upper surface rising inland to a terracelike level 60 m above the river that is underlain by sand or very sandy gravel. Irregular kamelike mounds littered with erratic boulders protrude above this surface. At its south end, the bluff has been eroded to form a lower terrace 18 m high. The measured section, a composite of main bluff and 18-m terrace, consists of a succession of till and alluvial deposits that reflect the interaction of glacier ice and running water along the narrow floor of the mountain valley. Most of the tills contain abundant rounded to subrounded pebbles and cobbles in very sandy matrix material; these components represent alluvium redeposited by the glacier. Two of the tills terminate upward in boulder concentrations that were formed by subsequent stream erosion of their exposed surfaces. The thick basal till (Unit 1) has been eroded in this manner, forming a concentration of oxide-stained boulders that represents a significant weathering interval prior to deposition of a thinner younger till (Unit 2). No erosional features separate the succeeding gravel (Unit 3) from the tills above and below it, a relationship that suggests nearly continuous aggradation by till and alluvium with little or no intervening interval of weathering and erosion. The thick till of Unit 4 is eroded at the top and overlain by gravel that appears continuous with the extensive kame and kame-terrace deposits mapped in this segment of John Valley (Hamilton, 1979a). The three tills exposed in the bluff range in age from late Itkillik to possibly Itkillik I. The oxidized boulders on top of Unit 1 suggest a major weathering interval that may have been comparable to the one that separates the Itkillik I and II glacial phases elsewhere in the Koyukuk drainage system; the thick upper till of Unit 4 lies close to the terminus of the drift sheet formed by a late Itkillik readvance. The intervening till, which is not separated from Unit 4 by any evident interval of weathering or downcutting, may date from the maximum advance of the John Valley glacier during Itkillik II time. Following deglaciation, major downcutting of the valley floor resulted in formation of an 18-m terrace that consists of eroded till overlain by gravel (Unit 6) and capped by partly decomposed brown peat that dates 6,630 ± 110 yr B.P. near its base. The peat probably formed after abandonment of the 18-m terrace and further incision of John River to a position closer to its present level.

Exposure JO-4 (fig. 9) lies along the west side of John River just within the end-moraine belt of Itkillik II age that crosses the valley at the south flank of the Brooks Range (Hamilton, 1979a). The bluff stands 42 m high, exposing sand and sandy fine gravel that filled a basin created by glacier retreat from the moraine complex. The oldest organic component in the section, large fragments of *in situ* willow, occurs at 30 m height. These date 11,560 ± 170 yr B.P., providing a minimum limiting age for ice retreat from the John Valley moraine belt and for subsequent revegetation of this segment of the aggrading valley floor. The rate of alluviation may have decreased markedly at about this time to permit growth of large willows on the floodplain. Sand above the 30-m level may in part be eolian, and it is uncertain whether John River aggraded to the full height of the bluff.

Exposure JO-5 (fig. 10) which extends along the east bank of John River 11.5 km downvalley from JO-4, consists of four terrace levels that range in height from more than 30 m to about 7.7 m. Several possible fault lines cross John Valley in this area (Hamilton, 1979a). These are marked by straight linear patterns of relatively dense vegetation that transect natural drainage systems on both sides of the river. The linear elements continue into unusually straight, narrow, and deep swales and gullies that extend down to the river from bluffs on either side. John River in this area has an exceptionally narrow, parallel-sided bend that curves back upvalley for about 1 km; it also exhibits a sequence of terrace levels that may be unique to this locality. Each of the four measured terrace sections shown in figure 10 differs sufficiently from its neighbors to suggest that it is wholly or largely a separate depositional sequence rather than a single fluvial deposit that has been beveled to successively lower levels. They are interpreted as a series of constructional terraces for this reason, although the basal few meters may be relict (i.e., fill-strath) in nature. Sequence A, exposed in the highest and oldest terrace, stands 30 m high and consists entirely of sand. The deposit rises farther inland to a general terrace level a few meters higher, but lacks exposures through this interval. In its height and lack of organic deposits, Sequence A resembles the basal inorganic portion of JO-4, and the two deposits may be of equivalent age. Sequence B, measured about 75 m farther downstream, consists of 16 m of silt and fine sand with thin peaty interbeds. The sediments are very well sorted, with bedding indistinct except on weathered faces where horizontal strata stand out in sharp relief. Willow fragments from an especially prominent 10-cm layer of woody peat 6.6 m above river level date 9,890 ± 80 yr B.P. Sequence C, 50 m farther downstream, is 11.5 m high and consists of beds of fine sand separated by a 6-m deposit of sandy gravel (Unit 2). The youngest terrace, 7.7 m high where measured 25 m downstream from sequence C, consists of sand and silty fine sand containing some black peaty beds. Twigs 4 m above river level date 6,820 ± 110 yr B.P. and associated pollen, dominated by spruce and birch with lesser alder and Sphagnum spores, suggests that an open spruce forest occupied the valley floor at that time (T.A. Ager, written communication, 6/5/78). Peat 3 m higher in the section dates 2,630 ± 85 yr B.P. The radiocarbon dates from JO-5 place a minimum limiting age of about 10,000 yr B.P. on downcutting through thick sand deposits that formed shortly after glacier recession from the end-moraine complex near the mouth of John Valley. The dates from JO-5 and the probably correlative JO-4 suggest that multiple episodes of downcutting and alluviation may have taken place locally between about 11,500 and 7,000 yr B.P. Stream fluctuations of this age and magnitude are unusual in the central Brooks Range; they could be related to local fault activity.

Exposure JO-6 (fig. 11) was cut by John River into the northern flank of the large alluvial fan built by McKinley Creek. The cutbank declines in height eastward toward the center of John Valley and the distal end of the alluvial fan. It stands 11.2 m high at its west end, exposing 2.3 m of sand and muck above 9 m of gravel. Farther east, as shown in figure 11, it stands 10.7 m high and consists of peat and muck above about 8 m of gravel. This part of the fan contains an ancient floodplain forest floor that includes rooted spruce stumps dating 6,260 ± 110 yr B.P. The buried forest may merely indicate a change in locus of deposition on the fan, or it could reflect a general mid-Holocene interval of stability that was terminated abruptly by renewed deposition of fan gravel.

Exposure JO-7 (fig. 12) is located on a broad, level, and marshy segment of the valley floor of Sixtymile Creek just above the alluvial fan of Organ Creek, one of its largest tributaries. This segment of the valley floor presently forms a low terrace, covered by dense muskeg vegetation and numerous thaw ponds, and underlain by ice-rich, fine-grained sediments. A 3.3-m cutbank along the west side of Sixtymile Creek exposes highly organic sand and silt, probable slackwater deposits that accumulated when the creek was partly blocked by growth of Organ Creek's alluvial fan. Wood and peat sampled 1 m above stream level date 2,060 ± 75 B.P., suggesting that alluviation of the fan was taking place at about that time.

Exposure JO-8 (fig. 13), a cutbank along the east side of John River, is located 5 km southeast of a very large landslide that covers the entire northern valley wall of Eagle Creek near its mouth (Hamilton, 1979a). The bank intersects a terrace about 5.7 m high, and exposes ice-rich sandy to silty floodplain deposits that contain a succession of buried peats with *in situ* spruce roots. A prominent peat horizon 4.8 m above river level dates 695 ± 75 yr B.P. Terrace-building to heights of 5-6 m rarely occurred in other valleys of the central Brooks Range during the last 1,000 yr, hence alluvial history at JO-8 may have been affected by episodic movements of the Eagle Creek landslide. If so, further study and dating of this exposure could provide valuable insights into the past history, present stability, and potential future movements of the enormous slide block on Eagle Creek.

Exposure JO-9 (fig. 14), a cutbank on Shukokluk Creek 6 km above its confluence with Wolverine Creek, exposes fluvial sand that alluviated to form a low (3.5 m) but unusually broad and smooth-surfaced deposit. *In situ* willow roots 1.4 m above stream level, which date 450 ± 75 yr B.P., apparently were buried during a time of rapid alluviation. The fine-grained character of the deposits suggests slackwater conditions and possibly partial blockage of Shukokluk Creek by aggradation farther south along Wolverine Creek.

Wild River Valley

The valley of Wild River, which contains only a few small and low-lying cirques, apparently served mainly as a conduit for glacier ice that was generated farther north in the headwaters of Tinayguk River. The Tinayguk glacier overflowed southward through passes north of Wild Lake (Hamilton, 1979a), and some additional ice reached the valley from the Allen River drainage system farther to the west.

The main valley of Wild River was filled with glacier ice during Itkillik I time, but remained virtually ice-free during all of the Itkillik II glacial phase.

Exposure WI-1 (fig. 15), a low bluff along the west side of Wild River 6 km north of the range front, intersects an extensive depositional slope that consists of fan deposits interstratified with colluvium. The exposure is made up entirely of fan gravel at its downvalley end, but farther north the fan sediments interfinger with fine-grained, organic-rich bog and marsh deposits that were confined along the upvalley flank of the fan. These deposits include micaceous fine sand and dark brown to dusky red organic silt with wood fragments in addition to the prominent buried organic soil illustrated in figure 15. All wood fragments are heavily impregnated with iron oxides. Where measured near its upvalley end, the exposure stands 14 m high and consists of a buried soil profile between two thick deposits of platy fan gravel. Willow fragments from the paleosol date 22,740 $\pm$ 560 yr B.P. This date demonstrates that at least the lower segment of Wild Valley remained unglaciated during Itkillik II time, and supports the hypothesis that Itkillik II glaciation was marked by fan-building in valleys of the southern Brooks Range that remained unglaciated at that time (see description of Unit f_i in Hamilton, 1979a). The date further suggests that fan development was punctuated by an interval of stability that might correspond to the other interruptions in solifluction activity and river alluviation noted at exposures KY-2, KY-4, and KY-5.

Middle Fork Koyukuk River

The valley of the Middle Fork, like Wild River Valley, contains few cirques that generated glaciers in Itkillik time; it served largely as a conduit for glacier ice that originated elsewhere. During Itkillik I time, the Middle Fork supported a relatively small glacier that joined more extensive ice from the Koyukuk's North Fork to form a piedmont lobe just south of the Brooks Range. During Itkillik II time, glacier ice in the Middle Fork was much more restricted, terminating about 18 km inside the range. Four radiocarbon dates are available from four exposures within the drainage system of the Middle Fork. Three of the four were obtained from road cuts during a rapid reconnaissance of the Alyeska haul road in 1975 (Hamilton, 1979b). These exposures were measured and described in haste, and are presented here with little detail. The fourth date, from a western tributary to the Middle Fork, was collected in 1977 from a natural exposure that was studied more closely.

Exposure MI-1 (fig. 16), a roadcut about 5 m deep, intersects the alluvial fan of Rosie Creek near the south flank of the range about 12 km beyond the limit of ice advances of Itkillik II time. Exposed sediments consist of sand and silty fine sand (Unit 1) overlain by fan gravel (Unit 2) that contains ice-wedge casts and other features indicative of severe frost activity. Although covered by a basal debris apron, the sand or similar fine-grained deposits must extend to at least the level of the roadway, which was wet and subsiding in 1975 owing to thaw of ice-rich permafrost. Small twigs near the upper contact of Unit 1 date 28,450 ± 950 yr B.P., providing a maximum age limit on alluviation of the fan deposits. Alluviation evidently took place under a severe frost climate, and seems to have coincided in time with the Itkillik II glacial phase as dated elsewhere in the John and Koyukuk Valleys.

Exposure MI-2 (fig. 17) was measured near the mouth of Canyon Creek, a western tributary to Hammond River, which in turn enters the Middle Fork near Wiseman. During Itkillik II time, Hammond River was blocked by a lobe of glacier ice from the Middle Fork; till and outwash from the ice lobe blocked the mouth of Canyon Creek and created a lake in its lower valley (Hamilton, 1979a). The 47-m exposure in Canyon Creek consists mainly of laminated clayey silt (Unit 1) that probably extends beneath mudflow deposits to a level near the modern valley floor. The lacustrine beds should be contemporaneous with the maximum advance of glacier ice in Itkillik II time; the overlying alluvium (Unit 2) probably was formed by Canyon Creek during a brief interval before it cut down through the plug of glacial deposits in the valley of Hammond River. Overlying solifluction deposits (Units 3 and 5) are unmixed with alluvium and probably postdate downcutting. A paleosol within the solifluction sequence is 9,180 ± 280 yr old; it provides a minimum limiting age on downcutting and dates a subsequent interval of stability during accretion of the solifluction apron.

Exposure MI-3 (fig. 18) is a cut 4-5 m deep that extends 100 m along the west side of the Alyeska haul road close to the mouth of Minnie Creek opposite the town of Wiseman. The haul road in this area crosses a prominent end moraine of late Itkillik age (Hamilton, 1979a, b). The exposure consists of two diamictons (Units 1 and 5) that are separated by a sequence of sand, diamicton, and organic soil (Units 2-4) that fills a kettle-like depression in the lower diamicton. Sand and gravel (Unit 6) overlap the upper diamicton and cover its eroded north and south flanks. The buried soil, a peaty muck in the area of the depression, grades laterally into lenses of organic silt that separate Units 1 and 5. The section shown in figure 18 was measured near the south end of the roadcut where the filled depression is deepest and the buried soil best developed. Peaty muck (Unit 4) in this location has a surprisingly young age of 8,430 ± 70 yr B.P. It had been expected that the upper diamicton and gravel (Units 5 and 6) would represent a glacial readvance of late Itkillik age that dates about 13,000 to 12,000 yr B.P. in other valleys of the central Brooks Range (Hamilton, 1979c, 1980a). The radiocarbon date from MI-3 may be too young owing to contamination or to sampling or laboratory error. If the date is correct, however, the upper diamicton probably was emplaced as a post-glacial debris flow from the Wiseman moraine. Postglacial landslide deposits from over-steepened valley walls have been confused with glacial deposits in other mountain valleys (Porter and Orombelli, 1980), but the pebbly, sandy, boulder-free nature of the diamicton at MI-3 makes this alternative origin unlikely.

Exposure MI-4 (fig. 19) is a cut along the Alyeska haul road where it crosses the edge of the highest alluvial terrace of the Middle Fork at the south flank of the Brooks Range. This terrace probably correlates with other terrace remnants at about the same height that were mapped as outwash of Itkillik II age through this part of Middle Fork Valley (Hamilton, 1979a). The cut extends about 50 m along the road, exposing up to 10 m of sand and gravel beneath a peaty surface cap. The peat thickens to 2 m depth near the north end of the cut, where it fills a depression in the surface of the gravel. In this locality, willow wood and fragments of either spruce or larch date 7,990 ± 130 yr B.P. (fig. 19). This date places a minimum limiting age on the outwash terrace and on early Holocene reforestation of the area.

North Fork Koyukuk

Six radiocarbon dates are available from five measured sections along the North Fork and its two largest tributaries, Tinayguk and Glacier Rivers. The dates, which range between about 12,000 and 1,000 yr B.P., represent episodes of fan-building and alluviation associated with waning phases of Itkillik glaciation and with fluctuating environmental conditions of middle and late Holocene time.

Exposure NO-1 (fig. 20) lies along the west side of North Fork about 5 km downvalley from the end moraine of Itkillik II age (Hamilton, 1979a). The bluff stands about 13 m high, with its upper surface rising inland as a smooth and gentle slope of about 3 degrees. Unit 1, at the base of the section, is outwash derived from the end moraine immediately upvalley. It contains abundant clasts derived from resistant rock types that crop out along the Continental Divide near the valley head. The gravel is heavily impregnated with iron and manganese oxides, and cemented blocks as much as 1.5 m diameter have fallen intact from the bluff into the river. Fine-grained sediments that cap the outwash date 11,660 ± 170 yr

B.P.; these in turn are overlain by about 6 m of fan gravel consisting largely of angular platy fragments of local schist and vein quartz. A layer of fine-grained sediment within the gravel (Unit 4) contains peaty horizons 5-10 cm above its base. Peat from this unit was sampled but has not yet been dated. The date of about 11,650 yr B.P. between fan and outwash deposits places a minimum limit on retreat of the North Fork glacier from its moraine belt of Itkillik II age and on stabilization of its outwash train. This date coincides very closely with the limiting age of 11,560 ± 170 yr B.P. on ice retreat from the John Valley moraine belt. Ice retreat may have occurred shortly before this interval, or the coincident dates may represent a time at which climatic amelioration allowed recolonization of the south flank of the central Brooks Range by willow and perhaps other shrubs.

Exposure NO-2 (fig. 21), within a small unnamed tributary to Tinayguk River, stands 21.5 m high; its upper surface forms an inactive alluvial fan that has been deeply incised by the modern stream. Coarse fan gravel at the base of the exposure (Unit 1) grades upward into finer and more sandy beds that dip parallel to the gradient of the modern stream. The beds contain accumulations of iron and manganese oxides similar to those in modern fans. Wood fragments collected at the center of Unit 2, 8 m below its surface, date 10,700 ± 190 yr B.P. The significance of this date is uncertain. It was believed originally that the sandy fan gravel (Unit 2) of NO-2 must have formed when Tinayguk Valley was blocked by glacier ice; this impeded streamflow from the unglaciated tributary and caused it to aggrade. If this were the case, however, the radiocarbon date should be significantly older than 10,700 yr B.P. If the date is correct, on the other hand, Unit 1 must represent fan accretion under glacial conditions and Unit 2 marks a transitional phase between late Pleistocene fan-building and modern conditions under which fan construction is rare in this part of the North Fork drainage system. As a third possibility, the valley may have been blocked by a landslide, not recognized during field study, that caused alluviation of the sandy fan gravel.

Exposure NO-3 (fig. 22) is a 5-m incision into a broad, flat, marshy segment of valley floor along the North Fork just above the large alluvial fan of Ruby Creek (Hamilton, 1979a). Unit 1, the deposit of a sluggish stream, consists of cross-bedded sand and fine gravel containing abundant detrital wood. The overlying peaty to clayey silt, which fills the irregular surface that was eroded into Unit 1, forms the widespread marshy flats on this segment of the valley floor. In situ roots of spruce and willow immediately below the contact between Units 1 and 2 date 3,230 ± 90 yr B.P.; spruce and willow fragments 30 cm below the top of Unit 2 date 2,355 ± 80 yr B.P. The sandy fine gravel and the overlying marsh deposits probably were deposited when the North Fork was partly blocked by the alluvial fan of Ruby Creek. An initial episode of fan-building associated with deposition of Unit 1 took place sometime during the early or middle Holocene. Later decrease in intensity of fan construction allowed incision of Unit 1 and development of a spruce forest with willow shrubs across its eroded surface. Shortly before 3,200 yr ago, renewed fan aggradation may have blocked the North Fork sufficiently to cause alluviation to begin once more. The partly blocked river created a broad marshy floodplain that built up to a height of about 3 m above modern river level by 3,230 yr B.P. and to about 4 m by 2,350 yr B.P. If sedimentation rates remained fairly constant, downcutting by the North Fork may have begun 150-200 yr later.

Exposure NO-4 (fig. 23), a 12-m bluff along the east side of Glacier River, exposes stratified fan gravel with peat interbeds that contain in situ roots. Peat taken 3.4 m above river level dates 1,185 ± 80 yr B.P.; peat taken 2.7 m higher in the section dates 1,380 ± 120 yr B.P. and contains sparse pollen in which spruce is most abundant. The two dates are in reversed stratigraphic order, but the discrepancy is less than the counting errors at a 95 percent (2 sigma) confidence level and they are best interpreted as indicating rapid fan alluviation centered about 1,200-1,300 yr B.P. and lasting at least several hundred years. The cause of this fan accretion is unknown.

Exposure NO-5 (fig. 24) was measured along Glacier River about 7 km downvalley from NO-4. It stands 8.2 m high, with its upper surface extending inland as part of the inactive alluvial fan into which Little Swede Creek has incised. Thick fan gravel (Unit 1) is capped by peaty sand and sandy peat that dates 1,035 ± 140 yr B.P. near its base and contains trace amounts of spruce pollen and *Sphagnum* spores. The date places a limiting age on alluviation of the fan and on the beginning of its dissection by Little Swede Creek.

DISCUSSION

Exposures along the faces of river bluffs and terraces in the Koyukuk drainage system provide important information on the history of glaciation during Itkillik time in the south-central Brooks Range, and on climatic changes and other environmental fluctuations during the Holocene. Supporting data are provided by exposures and radiocarbon dates reported previously for the Chandalar and Wind River drainage systems farther east (Hamilton, 1979c, d).

Detrital spruce wood beneath till of Itkillik I age at exposure KY-1 and spruce stumps above outwash of the same age in the Chandalar Valley (Hamilton, 1979d) indicate that boreal forest covered all or much of the Koyukuk and Chandalar lowlands preceding and following the Itkillik I glacial phase. In the Koyukuk lowland, three radiocarbon dates of 51,100 + 3,200/-2600, 35,400 ± 2,000, and >40,000 yr B.P. from exposures KY-1, KY-2, and KY-3 appear to demonstrate that a piedmont glacier of Itkillik I age attained its maximum development some time after about 51,000 years ago. However, this age assignment is considered questionable because the dates are close to the limits for conventional radiocarbon dating at the U.S. Geological Survey and Smithsonian laboratories and because large counting errors commonly have proved to be indicative of dates that actually are infinite. In addition, the stratigraphic record from KY-2 indicates that the Itkillik I glacial phase terminated sufficiently long ago that deep weathering of till and overlying lacustrine deposits took place prior to renewed alluviation about 23,500 yr B.P. A forest bed above outwash of Itkillik I age in the Chandalar Valley dates >42,000 yr B.P. (Hamilton, 1979d), and a slightly older limit of >48,000 yr B.P. is provided by alluvium at exposure JO-1 in the valley of Allen River. These radiocarbon analyses tend to support the stratigraphic record from KY-2, and suggest that the entire history of the Itkillik I glacial phase could lie beyond the range of conventional radiocarbon dating. An earlier assumption that the Itkillik I phase was broadly contemporaneous with the late Wisconsin maximum advance of the Laurentide ice sheet (Hamilton and Porter, 1975) is no longer considered valid. That assumption was based on the relatively few radiocarbon dates available in the early 1970's, and on uncritical acceptance of several seemingly finite radiocarbon dates with large counting errors that subsequently have been contradicted by additional dates and field data.

Surficial geologic mapping in the Wiseman quadrangle suggested that at least two major glacier advances may have taken place during Itkillik I time (Hamilton, 1979a). This inference is supported stratigraphically by the two gravel units separated by organic-rich sediments of interstadial character in the aggrading outwash sequence at exposure KY-3.

Dates for the onset of Itkillik II glaciation are provided by deposits in the glacier-blocked valley of Sixtymile Creek (exposure JO-2), where rapid alluviation was taking place 27,700 years ago, and at exposure MI-1, on the Koyukuk's Middle Fork, where periglacial fan-building began shortly after 28,500 yr B.P. A slightly older date of 33,220 ± 1,760 yr B.P., reported previously from the

Chandler Lake quadrangle (Hamilton, 1980a), was obtained on peat that was buried by loess correlated with glacier expansions of Itkillik II time.

Renewed glacier expansion during the Itkillik II phase was associated with widespread alluviation in valleys south of the Brooks Range. Aggradation of the Koyukuk River at KY-2 began sometime prior to 23,500 ± 380 yr B.P., and net accretion of sandy alluvium was especially rapid after about 15,500 yr B.P. The lower course of John River, a tributary to the Koyukuk, shows a comparable history of alluviation by finer-grained slackwater deposits, probably in response to aggradation along the Koyukuk. Radiocarbon dates from KY-4 show that the John River began alluviating as long ago as 29,000 ± 700 yr B.P., and that net alluviation was especially rapid between about 19,700 and 17,400 years ago following a possible hiatus. These dates correspond to alluvial history at Epiguruk bluff on the Kobuk River where, as described by Schweger (1971, 1976), alluviation began shortly before 24,000 yr B.P. and terminated sometime after 17,700 yr ago. All three alluvial sequences show similar patterns of initially slow net alluviation followed by very rapid accumulation of sediments (fig. 25). The slower initial net accumulation may have been caused by a pause or reversal in alluviation rather than consistently lower sedimentation rates. An initial episode of glaciation and alluviation might have been followed by an interstadial interval, then by renewed glacial and alluvial activity. Some support for this inference is furnished by the possible hiatus at KY-4 and by episodes of stability during accumulation of periglacial deposits at two other sites. A paleosol and associated weathering horizon dating 20,600 yr B.P. represent an interval of stability during the accretion of a solifluction apron at exposure KY-5, and periglacial fan building near the mouth of Wild Valley shows a comparable interval of stability dating about 22,750 yr B.P.

Two nearly coincident dates of 11,560 ± 170 and 11,660 ± 170 yr B.P. from John Valley and the North Fork (exposures JO-4 and NO-1) place minimum limits on the retreat of glaciers from their moraine complexes close to the south flank of the Brooks Range. These dates support a time range of about 12,850-11,900 yr B.P. proposed earlier for the final major readvance of Itkillik-age glaciers to positions near the mouths of their mountain valleys (Hamilton, 1979c, 1980a).

A seemingly complete stratigraphic record of Itkillik-age tills occurs at exposure JO-3 near the head of John Valley. Two basal tills (Units 1 and 2) at this locality are separated by weathered lag boulders that appear to represent the interglacial or interstadial episode between phases I and II of Itkillik-age glaciation. If the basal till is indeed Itkillik I in age, its preservation at JO-3 demonstrates that, even within confined mountain valleys, glaciers of the subsequent Itkillik II phase were not always able to erode all preexisting unconsolidated deposits. The Itkillik II phase at JO-3 was marked by nearly continuous sedimentation during which two tills and an intervening outwash train were deposited (Units 2-4). The two tills probably correspond to the maximum advance of Itkillik II age and to the final readvance about 12,900 years ago; they indicate that the interstadial interval between these events was marked by ice recession to positions close to the heads of mountain valleys.

Early Holocene history in the south-central Brooks Range was marked by widespread downcutting through glacial deposits followed by an apparent general interval of stability and nondeposition on slopes and on valley floors. Downcutting through the deep sand fill near the mouth of John Valley had occurred by 9,890 ± 80 yr B.P. at JO-5, and the John River near its head had attained a position close to its modern level by 6,630 ± 110 yr B.P. Episodes of stability and soil formation dated 9,180 ± 280 yr B.P. on the solifluction slope at Canyon Creek (MI-2) and 8,430 ± 70 yr B.P. at MI-3 on the Wiseman moraine may be only of local significance, but they coincide in time with buried peats at several localities in the central Brooks Range. A peat-forming interval, terminated by solifluction, lasted between about 9,460 ± 150 and 8,230 ± 130 yr B.P. in Toolik Valley (Hamilton, 1979d); it may correlate with peat formation in Anaktuvuk Valley that was taking place 9,620 ± 60 yr B.P. and that was terminated by fan-building sometime before 7,940 ± 75 yr B.P. (Hamilton, 1980). A widespread buried peat overlain by lacustrine deposits of unknown origin in the valley of Wind River dates about 9,600 to 9,100 years ago (Hamilton, 1979c).

A few radiocarbon dates of middle Holocene age from the Wiseman quadrangle suggest a later and possibly separate episode of general stability and peat formation, with spruce forest present in most valleys by this time. Spruce wood near the base of peat beds on the Middle Fork near MI-4 is 7,990 ± 130 yr old; this is the oldest date presently available for the expansion of spruce forest to the margin of the Brooks Range in the Koyukuk region. Spruce pollen at JO-5 indicates that a floodplain forest was present in John Valley near the south flank of the range by 6,820 ± 110 yr B.P., and spruce was growing 30 km farther north on the alluvial fan of McKinley Creek by 6,260 ± 110 yr B.P. Thick brown peat dating 6,630 ± 110 yr B.P. at JO-3 near the head of John Valley is similar to peat forming beneath spruce forest today. This suggests that spruce may have reached positions very close to its modern limits by early middle Holocene time. Pollen records from areas farther west suggest that recolonization by spruce occurred as recently as 7,000-5,000 years ago along the south flank of the Brooks Range in the Kobuk Valley (Schweger, 1976, p. 130) and about 5,000 yr B.P. inside the range within the Alatna Valley (L. B. Brubaker, written communication, 1980). On the other hand, much older spruce wood dating 9,730 ± 230 yr B.P. was recovered from Wind River Valley east of the Wiseman quadrangle (Hamilton, 1979d). Holocene spruce forests may have expanded westward as well as northward into the southern valleys of the central Brooks Range.

The late Holocene record of the south-central Brooks Range is more variable than that reported from northern valleys (Hamilton, 1979c, 1980). Soil-forming intervals appear compatible with a regional chronology of Neoglacial climatic changes and cirque-glacier expansions (Hamilton and Robinson, 1977; Calkin and Ellis, 1980; Hamilton, in press), but episodes of alluviation show less consistency and clearly were influenced by local environmental factors as well as by regional climatic controls (fig. 26). Paleosols dated 4,175 ± 45 and 3,995 ± 95 yr B.P. underlie frost-churned stony silt along Chandler River and Wind River (Hamilton, 1979c, d); a similar soil dating 4,750 ± 110 yr B.P. underlies stony silt at Anaktuvuk Pass (Hamilton, 1980). A comparable date of 4,880 ± 95 yr B.P. (I-11, 235) was obtained recently from a thick peat bed within an alluvial fan along Smoke Creek, close to the Continental Divide just east of the Chandalar quadrangle. A possible younger episode of soil formation is represented by peat dated 1,670 ± 80 yr B.P. that underlies solifluction deposits at exposure JO-2, and by peat of a similar age (1,590 ± 50 yr B.P.) beneath frost-churned stony loess in the Chandalar quadrangle (Hamilton, 1979d).

Alluviation in the Koyukuk lowlands and in most valleys of the south-central Brooks Range appears related to local environmental factors rather than any regional controls (fig. 26). John River at JO-5 shows evidence for three episodes of terrace building during the Holocene. Radiocarbon dates suggest that the oldest Holocene terrace was forming when downcutting and soil formation prevailed in other valleys; the youngest terrace was forming at least in part during a comparable middle Holocene interval of downcutting and general stability along valley floors. The unique record at JO-5 possibly is due to fault activity. The stretch of Sixtymile Creek above Organ Creek's alluvial fan was aggrading about 2,060 ± 75 yr ago. Aggradation probably was in response to active fan-building by Organ Creek, but the cause of this episodic fan construction is unclear. Active fan-building by tributaries to Glacier River was taking place about 1,300-1,200 yr B.P. at bluff NO-4, and had terminated shortly before 1,035 ± 140 yr B.P. at NO-5. Fan construction appears to be in phase between the two sites, but is out of phase with alluviation elsewhere in the central Brooks Range. Many alluvial fans within the metamorphic terrane near the south flank of the range may respond to pulses of sedimentation originating from episodic movement of the numerous flow-slides that characterize this lithologic belt (Hamilton, 1979a). John Valley near the Eagle Creek landslide underwent episodic alluviation for an interval of at least several hundred years prior to 695 ± 75 yr B.P. Alluviation at this site may in part be controlled by landslide activity. Two other localities have alluvial histories that seem in phase with alluviation elsewhere in the Brooks Range. The Koyukuk's North Fork above Ruby Creek fan began alluviating after middle Holocene time and buried a mature floodplain forest about 3,230 ± 90 yr ago; it abandoned its 5-m terrace shortly after 2,355 ± 80 yr B.P. Alluviation probably was in response to fan-building by Ruby Creek, a cirque-headed tributary. Farther to the northwest, Shukokluk Creek began building a widespread 3.5-m terrace about 450 ± 75 yr ago in response to alluviation by Wolverine Creek, which also originates in a suite of cirques. Alluviation of these two cirque-headed tributary streams may reflect increased sediment yield that followed regional climatic reversals (Hamilton, in press).

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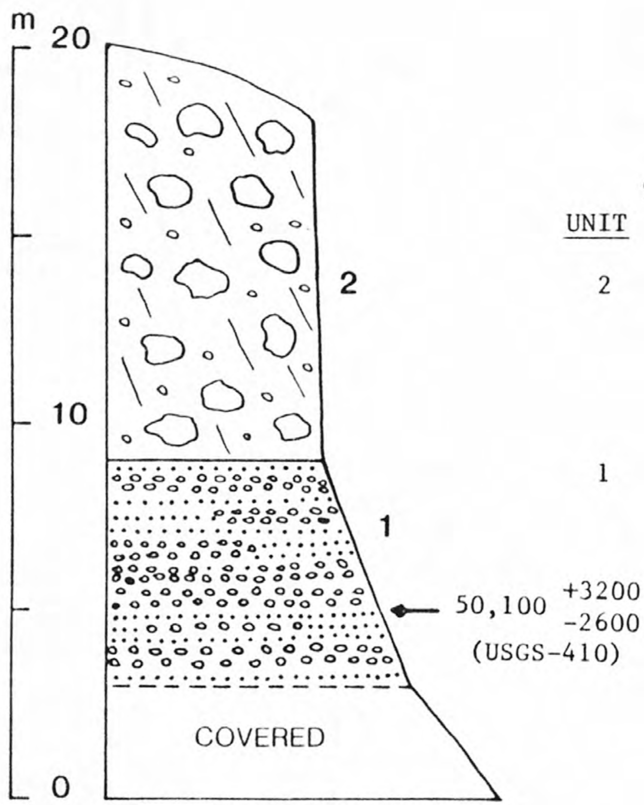
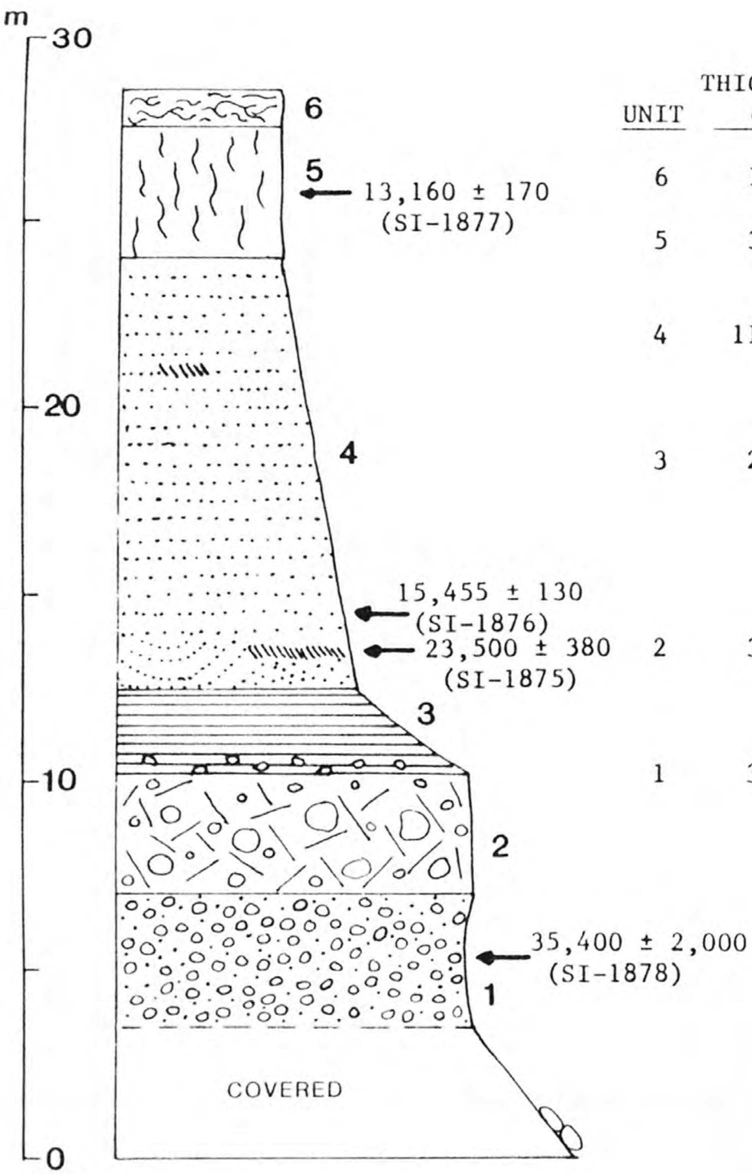


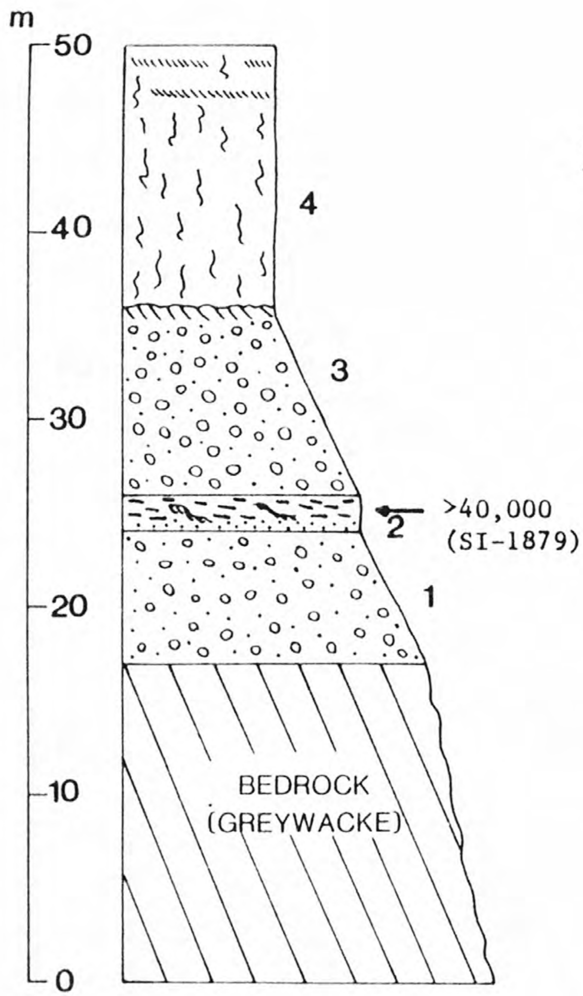
UNIT	THICKNESS (m)	DESCRIPTION
2	9	TILL. Subrounded to subangular stones to boulder size in compact grey muddy matrix; many stones striated and faceted. Jointed, with fractures dipping toward river. Oxidized along some joint planes.
1	9?	OXIDIZED GRAVEL. Pebbles and small cobbles in oxidized sandy matrix; interstratified with cross-bedded, well sorted, yellowish brown (10 YR 5/7) medium sand in beds 10-30 cm thick and with lenses of compact grey silt. More strongly oxidized (10 YR 5/8) near upper contact, and locally deformed by ice shove.

Figure 1. Exposure KY-1. South bank of North Fork Koyukuk River 16 km above its mouth. Stands 18 m high, with basal 3 m covered by debris apron.



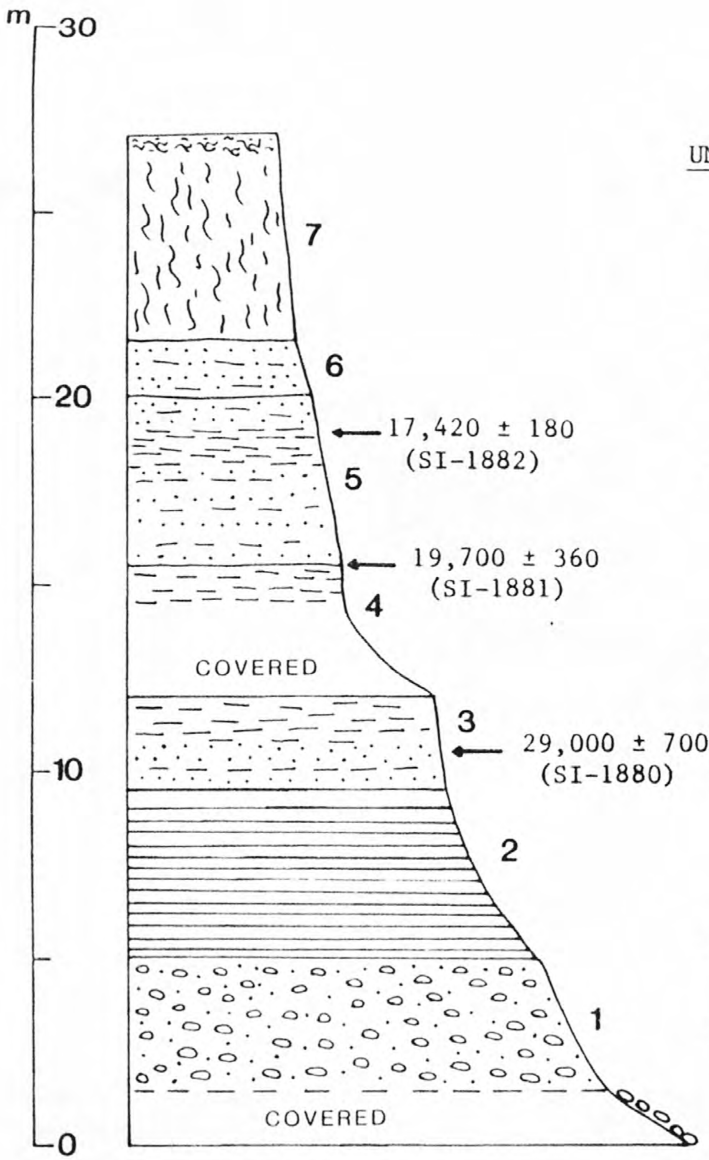
UNIT	THICKNESS (m)	DESCRIPTION
6	1.0	SURFACE CAP. Organic mat above frost-deformed loess.
5	3.5	LOESS. Massive blue-grey to tan silt; slightly micaceous. Contains abundant organic material.
4	11.5	SAND. Bedded grey to tan sand, grading upward into faintly bedded buff silty fine sand. Fluvial cross-bedding and detrital organic mat near base.
3	2.3	CLAY. Dark grey clay and light grey silty clay, interbedded in rhythmic couplets 0.6-1.0 cm thick; indurated and heavily jointed. Overlies 0.5 m compact and strongly jointed grey silt and 0.3 m dark grey clay with scattered dropstones.
2	3.2	TILL. Stones to small boulder size in grey clayey matrix. Some stones faceted and striated; others rounded as if inherited from preglacial alluvium.
1	3.5	OXIDIZED GRAVEL. Rounded to subrounded stones to small cobble size in sandy matrix; some thin sand layers present; cross-bedded. Platy stones imbricated, with upvalley dips. Heavy oxide stain along some beds.

Figure 2. Exposure KY-2. North bank Koyukuk River 1.5 km below North Fork confluence. Stands 23-28 m high. Section measured near center of exposure. Basal 3.5 m covered by debris apron and bouldery lag deposit.



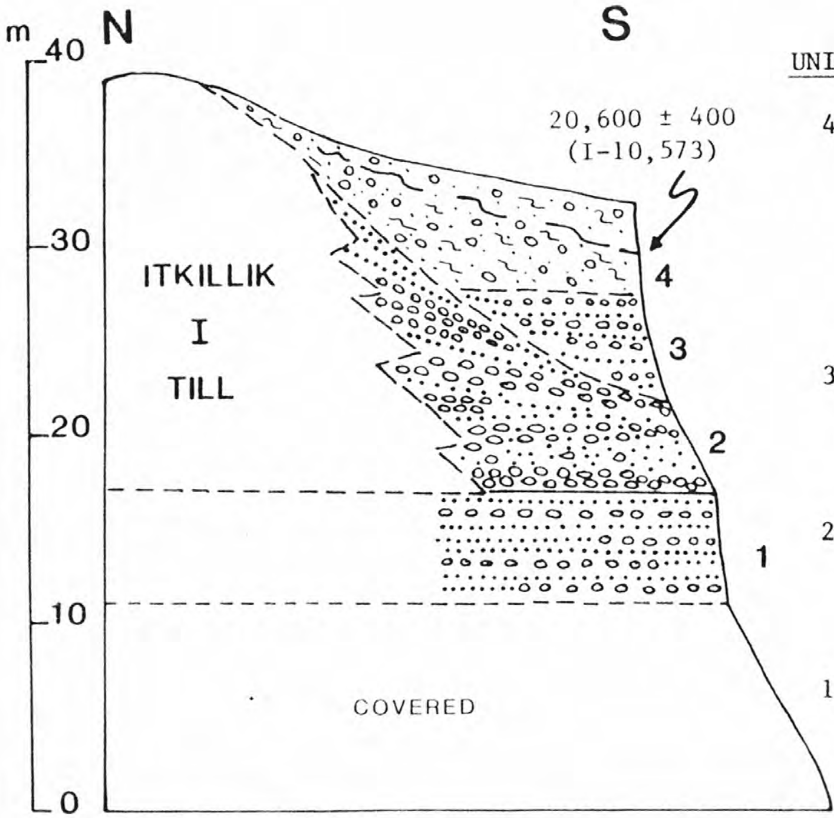
UNIT	THICKNESS (m)	DESCRIPTION
4	14	LOESS. Brown to tan silt; very porous; lacks visible bedding. Vertical rootlets increasing upward; woody peat layers present near top.
		------------------ DISCONFORMITY --------------------
3	10	GRAVEL. Subrounded pebbles, cobbles, and sparse small boulders in sand-granule matrix; boulders lacking in upper 3 m. Stones frost-shattered at upper contact, oxidized to 10-15 cm depth, and bear clay-silt coatings to 30-40 cm depth.
2	2	SILT AND SAND. Dark grey to brown organic silt above tan to grey very well sorted nonbedded fine sand. Silt contains distorted lenses of bryophytic peat with dwarf birch fragments.
1	7	GRAVEL. Subrounded stones to small cobble size in sandy matrix. Structures obscured by slope movements.

Figure 3. Exposure KY-3. South bank Koyukuk River 3.5 km below Exposure KY-2.



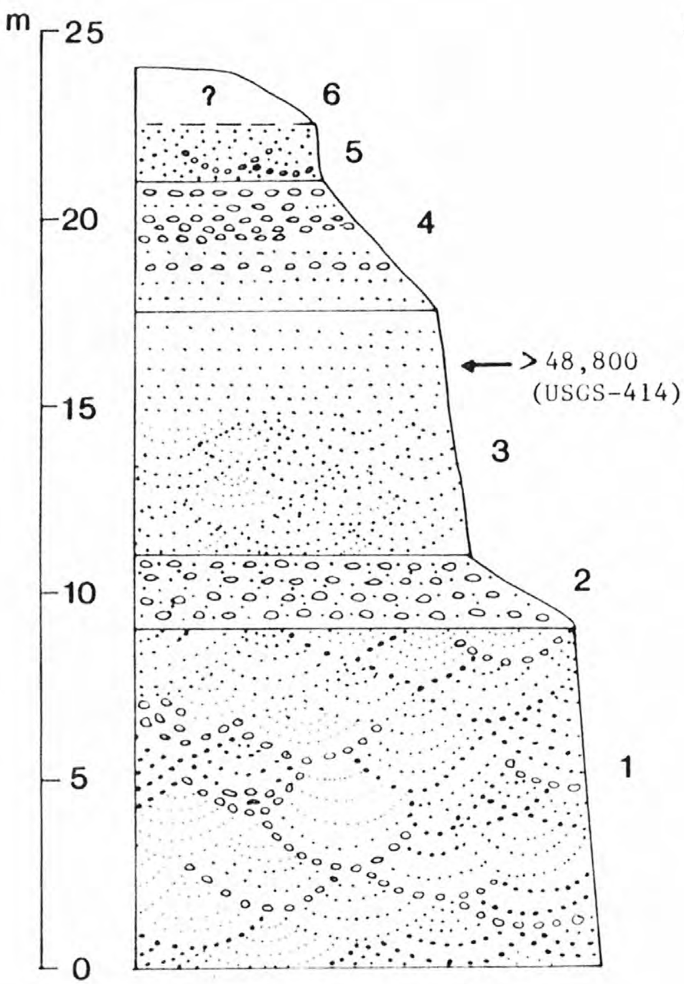
UNIT	THICKNESS (m)	DESCRIPTION
7	5.5	LOESS. Light yellowish brown (10 YR 6/4) silt, grading downward into grey (7.5 YR 6/0) silt. Upper 2 m contains reddish yellow (7.5 YR 7/6) oxidized layers. Capped by 0.5 m silty peat.
6	1.5	SAND. Brown medium sand interbedded with grey silty fine sand in beds 2-10 cm thick.
5	4.5	SILT AND FINE SAND. Grey silty fine sand in sub-horizontal beds 2-4 cm thick; detrital willow fragments along bedding planes. Dark greyish brown (10 YR 4/2) massive silt at 1-2 m depth; interbeds of white eolian fine sand near top.
4	1+	SILT. Dark greenish grey (5 BG 4/1) silt containing scattered wood fragments and small detrital wood mat. Base covered by flow deposits.
3	2.5	SILT AND SAND. Very dark grey (5 YR 3/1) silt to silty fine sand, interbedded with fine sand mottled rust-red (5 YR 3/4). Overlies tan, current-rippled, medium to fine sand with grey to brown silt interbeds.
2	4.0	CLAY. Highly plastic grey (7.5 YR 6/0) clay. Severely deformed by slump and flowage.
1	3.5	GRAVEL. Subrounded pebbles and sparse cobbles in sandy matrix.

Figure 4. Exposure KY-4. West bank John River 6.2 km northwest of its mouth. In Bettles quadrangle, 5.2 km beyond south margin of Wiseman quadrangle. Stands 27 m high, with basal 1.5 m covered by lag gravel.



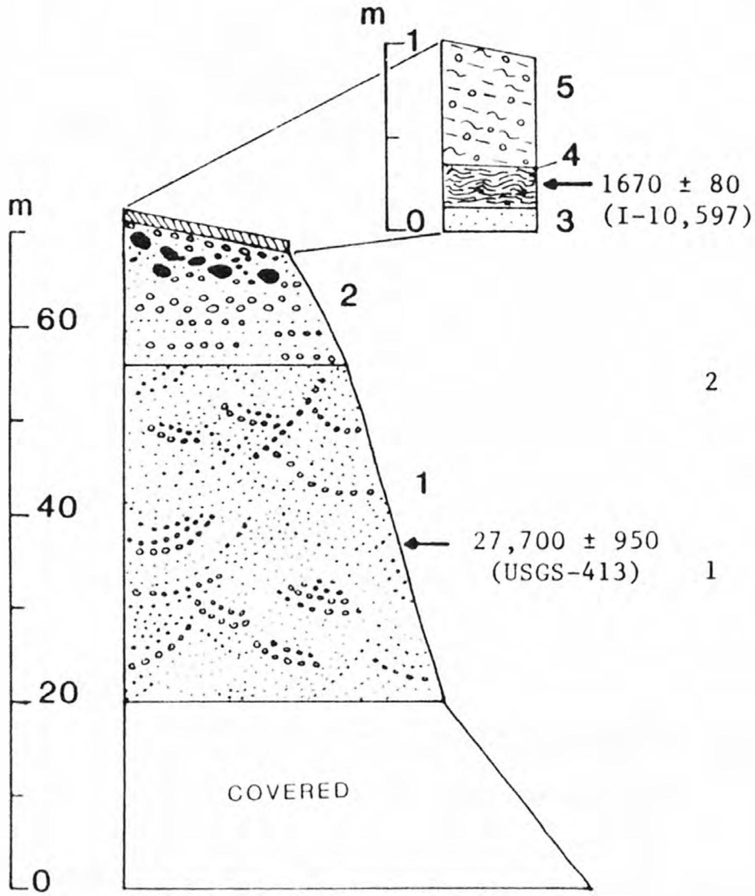
UNIT	THICKNESS (m)	DESCRIPTION
4	6.3	COLLUVIUM. Subangular to subrounded pebbles, small cobbles, and sparse large cobbles in pale olive (5 Y 6/3) silty sand matrix. Crudely bedded, with most stones subhorizontal. Contains deformed (segmented and overturned) fossil soil consisting of peaty silt above light grey (5 YR 6/1) stony fine sand.
3	5.0	FINE GRAVEL. Alternating beds about 10 cm thick consisting of (a) pebbles and sparse cobbles in coarse sand to granule matrix, (b) greyish medium sand, and (c) greyish-brown silt.
2	4.4	COBBLE GRAVEL. Pebble to small cobble gravel, as in Unit 3, with 5 separate stone lines consisting of closely packed cobbles and small boulders up to 35 cm diameter.
1	6.0	SAND AND FINE GRAVEL. Probably as in Unit 2, but largely obscured by slumps and flows. Gravel to small cobble size dominant; sand minor; silt very sparse.

Figure 5. Exposure KY-5. South Fork Koyukuk River 1.3 km below mouth of Wilson Creek. Internal relationships hypothetical. Stands 32.7 m high, with basal 11 m covered by debris apron of sand and fine gravel.



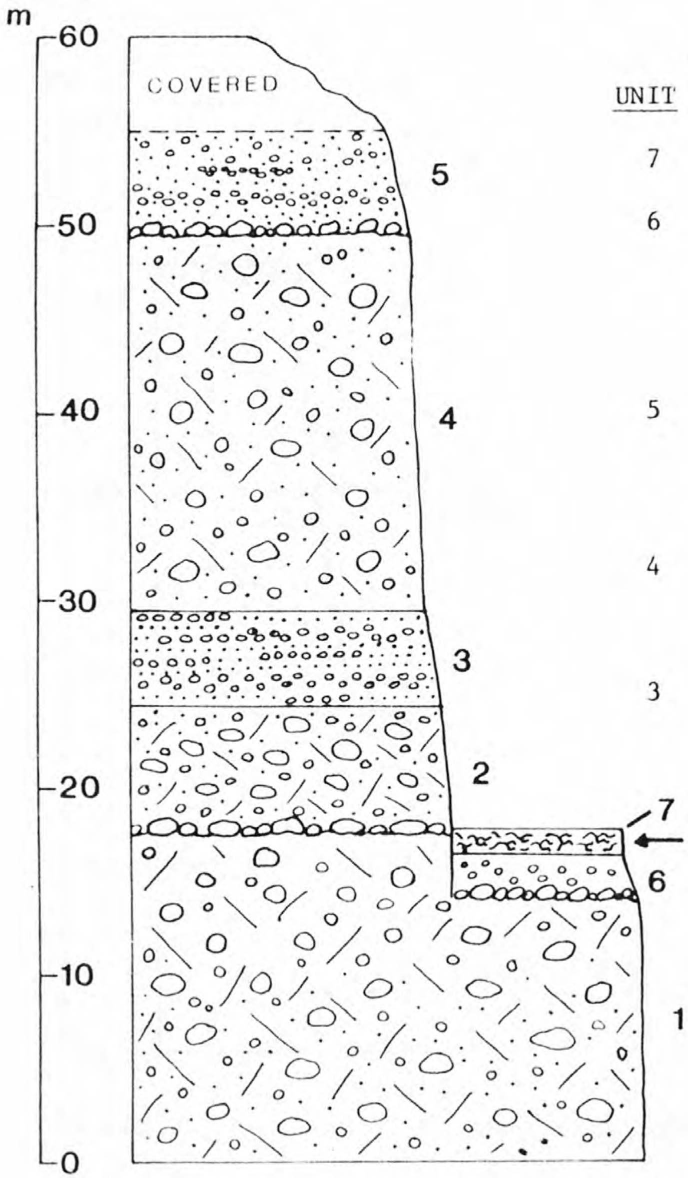
UNIT	THICKNESS (m)	DESCRIPTION
6	1.5	COVERED. Highly unstable bluff crest; subject to slump and flowage. Brown clayey silt exposed in places.
5	1.5	SAND. Well sorted, cross-bedded medium sand, coarse sand, and very sandy fine gravel. Grades upward into subhorizontally bedded strong brown (7.5 YR 5/6) fine and medium sand.
4	3.5	GRAVEL. Subrounded pebbles and cobbles in coarse sand-granule matrix. Quartz very abundant in pebble-small cobble range; quartzites and flatiron shapes common among the large cobbles. Some thin (5-10 cm) interbeds of medium sand, coarse sand, and granules. Basal 1 m fines downward from granules to medium sand.
3	6.5	SAND. Grey, well sorted medium sand with weak subhorizontal bedding; grades downward into cross-bedded coarse to medium sand. Near base, silty fine sand fills channels in coarser sand with granules.
2	2.0	GRAVEL. Subrounded pebbles and small cobbles in coarse sand-granule matrix. Well stratified, with thin (about 2 cm) coarse sand interbeds. Beds near base contain some large cobbles.
1	9.0	SAND WITH GRAVEL. Cross-bedded grey silty fine sand and "salt and pepper" medium to coarse sand, with thin (about 10 cm) beds of pebbles and granules. Thick (1-2 m) lenses of pebble-small cobble gravel in lower 6 m of unit.

Figure 6. Exposure JO-1. East side Allen River 14.5 km above its mouth.



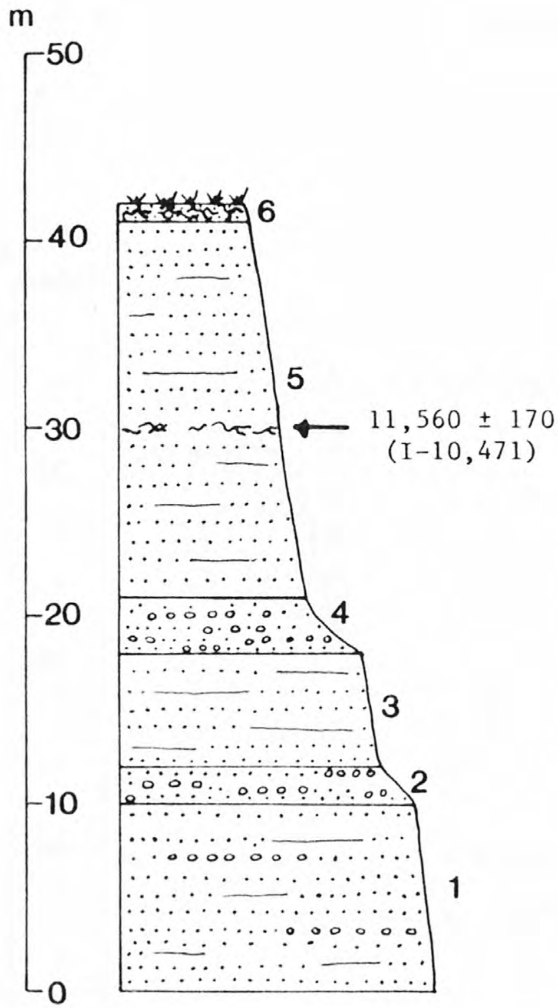
UNIT	THICKNESS (m)	DESCRIPTION
5	0.6	SOLIFLUCTION DEPOSIT. Grey (10 YR 5/1) silt with peat lenses and scattered stones.
4	0.15	PEAT. Dark reddish brown (2.5 YR 3/4), compact, massive peat with several charcoal zones and thin interbeds of grey silt.
3	0.1	SAND. Grey fine sand with strong brown (7.5 YR 5/8) oxidized lenses and scattered pebbles.
2	12	GRAVEL WITH SAND. Very well sorted pebble gravel with stones rounded to subrounded and about 50% quartz. Contains interbeds of cobble gravel about 40 cm thick that increase upward in frequency. Capped by gravel containing erratic boulders up to 110 cm length.
1	36	SAND WITH GRAVEL. Cross-bedded; coarsens upward. Beds of fine sand about 1 cm thick alternating with 5-cm beds of medium sand and thicker (up to 60 cm) beds of pebbly coarse sand. Beds at top of unit strike N15°E, dip 15° SE. Beds in lower midpart of unit consist dominantly of 2-m layers of medium sand with silty clayey fine sand partings. Lower beds consist dominantly of 5-cm layers of fine sand with clayey silt interbeds.
	20	DEBRIS APRON. Covers beds that appear to consist of sand and fine gravel, as in Unit 1.

Figure 7. Exposure JO-2. South side Sixtymile Creek 11.5 km above its mouth. Exposed deposits overlie glaciolacustrine sediments.



UNIT	THICKNESS (m)	DESCRIPTION
7	1.4	PEAT; brown; with interbeds of grey silt and brown humic silt.
6	2.4	GRAVEL. Subrounded cobbles and pebbles in matrix of sand and phyllite chips. Upper 0.3 m frost-stirred, with admixed light yellowish brown (10 YR 6/4) silty fine sand; basal 0.5 m contains lag concentrate of boulders and large cobbles from erosion of Unit 1.
5	5.5	SAND AND GRAVEL. Grey well sorted medium sand and coarse sand with phyllite chips; interbedded with sandy pebble-cobble gravel. Obscured at top, but probably rises to 60-m terrace level. Boulder line at base.
4	19.5	TILL. Stones to 1 m diameter in matrix of compact, dark grey (10 YR 4/1) medium sand with some silt. Subrounded pebbles and cobbles very abundant.
3	5.0	SAND AND GRAVEL. Subrounded pebbles and cobbles in sandy matrix, interbedded with layers and lenses 0.2-0.5 m thick of finely stratified, cross-bedded sand and granules. Very compact and strongly deformed close to upper contact.
2	7.0	TILL. Gravelly, as in Unit 4. Stone line at base consists of oxide-stained boulders 0.6-1.1 m diameter.
1	17.5	TILL. Cobbles and boulders in compact silty matrix. Grades downward into gravelly till, as in Unit 2.

Figure 8. Exposure JO-3. East side John River 6.5 km above mouth of Hunt Fork.



UNIT	THICKNESS (m)	DESCRIPTION
6	0.7	PEAT AND SILT. 0.4 m dark brown silty peat above 0.3 m yellowish brown sandy silt.
5	20	SAND. Dark grey (10 YR 4/1), faintly bedded, coarse to medium sand. Prostrate willow fragments with bark intact lie along bedding plane 11 m below upper contact.
4	3	SANDY FINE GRAVEL. Rounded to subrounded pebbles and sparse very small cobbles in abundant matrix of coarse sand.
3	6	SAND; dark greyish brown, medium to coarse; faintly to moderately well bedded.
2	2	SANDY FINE GRAVEL. As in Unit 4, but with sand more abundant and cobbles absent.
1	10	SAND; very well sorted, brown (2.5 Y 5/2), fine grained. Faintly bedded, with sparse thin gravel lenses along bedding planes.

Figure 9. Exposure JO-4. West side John River opposite Threetime Mountain near south flank of Brooks Range.

SEQUENCE	THICKNESS (m)	DESCRIPTION
D	7.7	SAND. Yellowish brown (10 YR 5/6), fine to medium; interbedded with dark grey (10 YR 4/1) silty fine sand in weakly defined subhorizontal layers. Some black peaty beds 2-10 cm thick.
C	11.5	3. (2.5 m) FINE SAND. Some beds organic and silty; weakly defined horizontal bedding. 2. (6.0 m) SANDY GRAVEL. Poorly sorted, weakly bedded, rounded to subrounded pebbles and small cobbles. 1. (3.0 m) FINE SAND. Pale brown, well sorted, in beds 5-15 cm thick. Interbedded with greyish silt layers about 5 cm thick.
B	16	SILT AND FINE SAND. Very well sorted, in horizontal beds ½-1 cm thick; with interbedded layers of peat and woody peat. Bedding indistinct except on weathered faces.
A	30+	FINE SAND. Grey, with some thin beds of medium sand. Probably horizontally bedded, but slumping has destroyed all primary structures along bluff face.

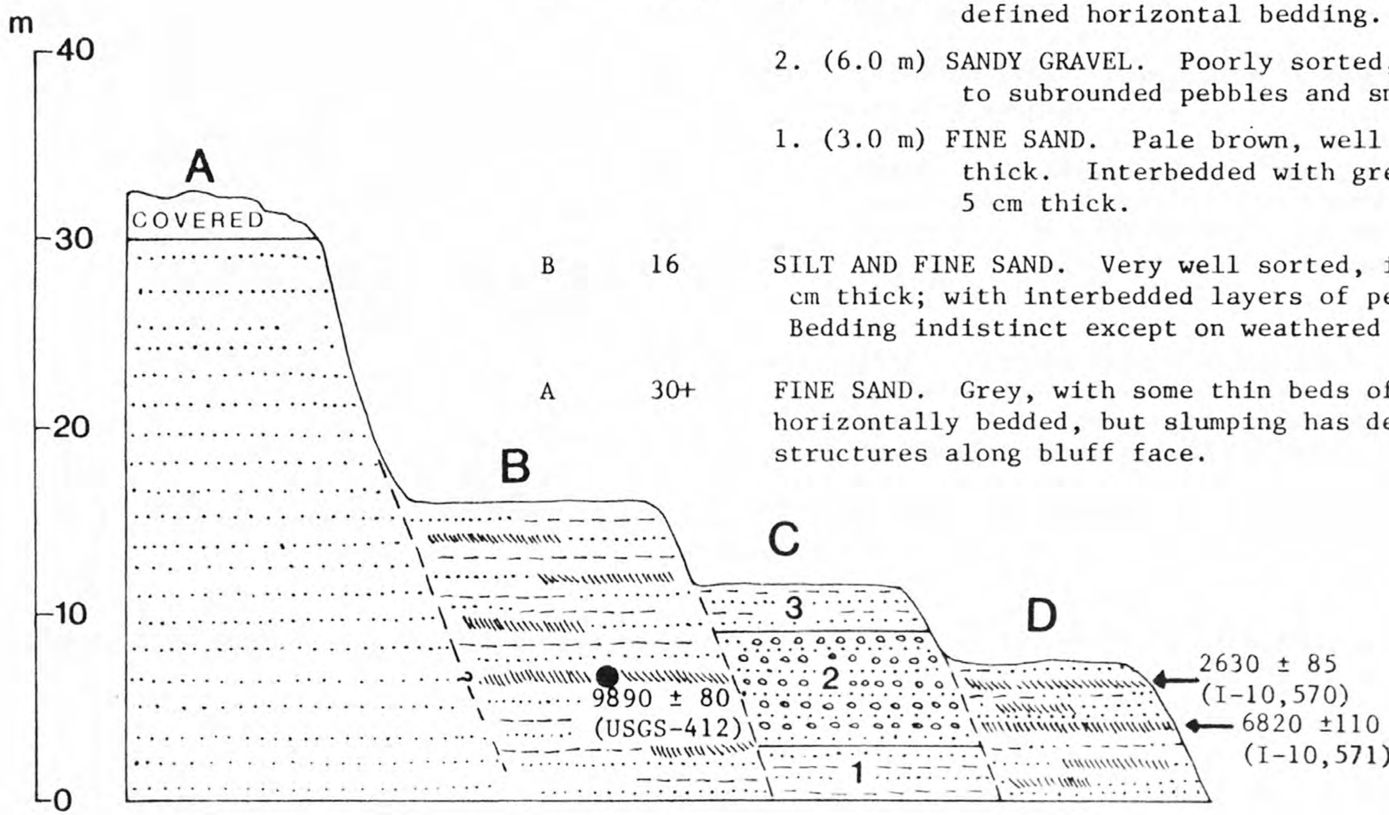
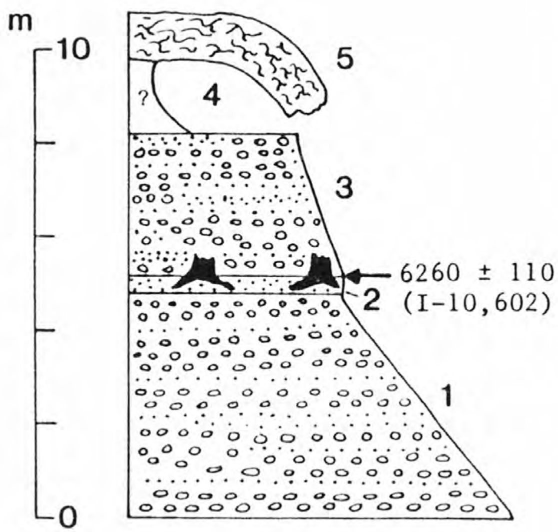
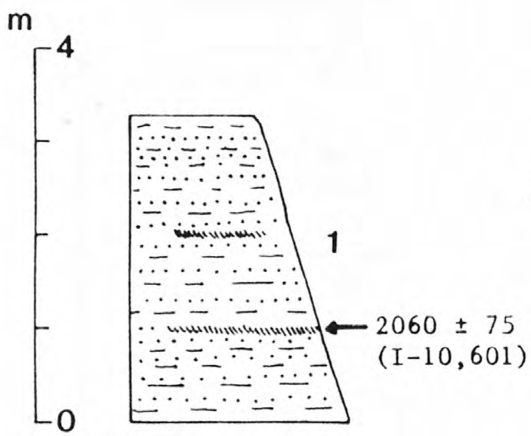


Figure 10. Exposure JO-5. East side John River 6.5 km above mouth of Timber Creek.



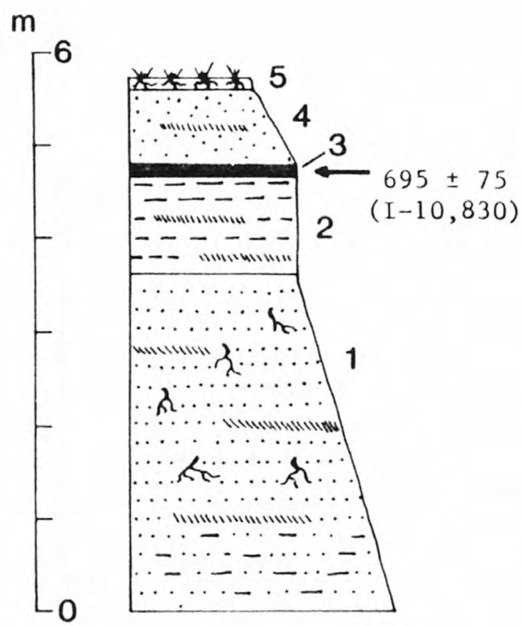
UNIT	THICKNESS (m)	DESCRIPTION
5	1.0	PEAT AND MUCK.
4	1.6	ICE-RICH SILT? Depression formed by melt of ice lenses or ice wedges.
3	3.0	GRAVEL. Rounded to subrounded pebbles and cobbles in matrix of well sorted coarse sand and granules. Forms beds 0.5-2.0 m thick which are interbedded with 15-25 cm beds of sand, granules, and small pebbles. Capped in places by 30-40 cm of sand. Upper 25 cm oxidized.
2	0.4	SAND. Greyish brown medium sand interbedded with grey to dark grey silty fine sand and organic silty fine sand. Contains rooted spruce stumps and abundant wood fragments along bedding planes.
1	4.7	GRAVEL. As in Unit 3.

Figure 11. Exposure JO-6. Southwest side of John River along north flank of McKinley Creek alluvial fan.



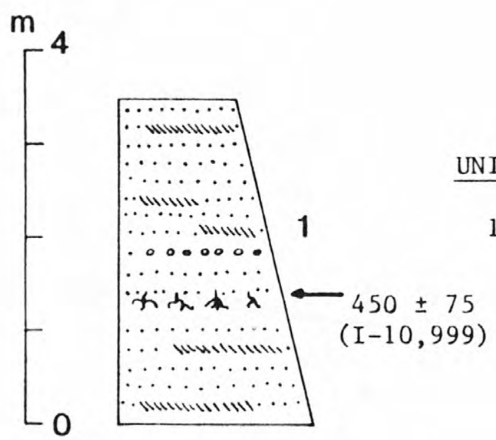
UNIT	THICKNESS (m)	DESCRIPTION
1	3.3	SAND AND SILT. Weakly bedded grey silty fine sand, brown medium sand, oxidized (strong brown: 7.5 YR 5/6) fine to medium sand, and organic-rich dark brown clayey silt. Contains gastropod shells, wood fragments, and peaty layers.

Figure 12. Exposure JO-7. West side Sixtymile Creek 1.5 km above mouth of Organ Creek.



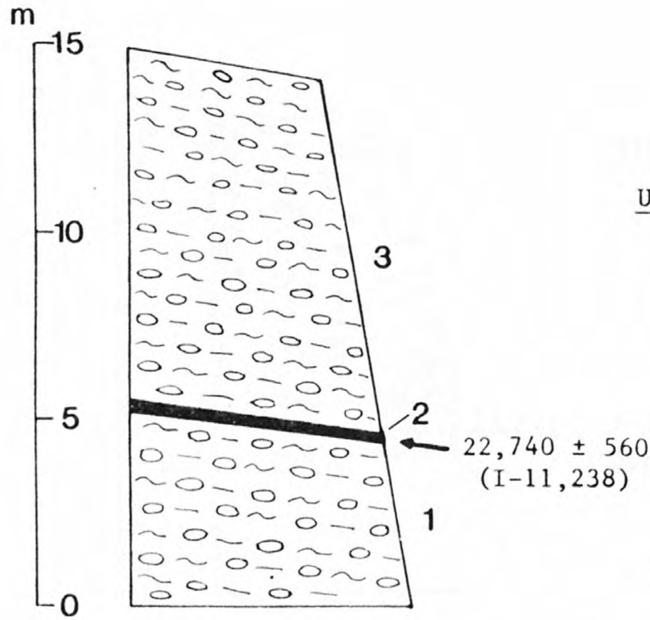
UNIT	THICKNESS (m)	DESCRIPTION
5	0.15	SOD AND SILTY PEAT.
4	0.8	SAND. Mottled silty fine sand with thin (½-1 cm) peat interbeds.
3	0.1	PEAT. Contains small *in situ* spruce roots.
2	1.1	SILT. Brown to grey silt and organic silt, with layers and lenses of peat. Contains ice grains and lenses.
1	3.6	SAND. Micaceous fine sand; grading downward into brownish grey, micaceous, medium sand to silty fine sand. Contains *in situ* roots and lenses of buried peat.

Figure 13. Exposure JO-8. East side John River 3.5 km below mouth of Eagle Creek.



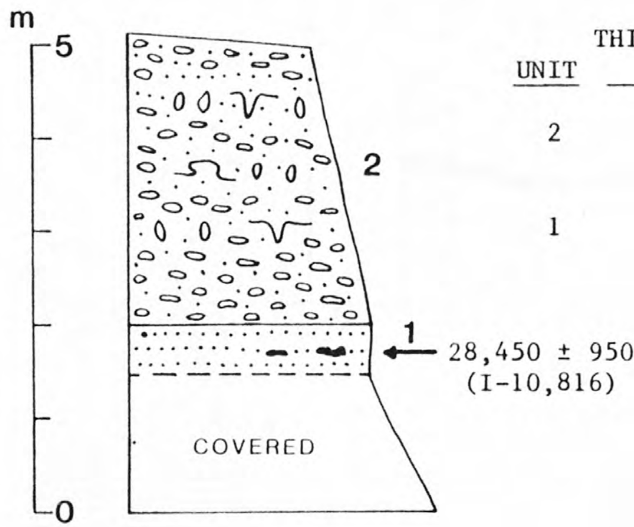
UNIT	THICKNESS (m)	DESCRIPTION
1	3.5	SAND. Faintly bedded grey sand, with 1-10 cm beds consisting of (a) coarse sand with phyllite chips, (b) well sorted medium sand, (c) fine sand with reddish-brown mottles, and (d) dark grey humic fine sand. Organic matter abundant as (a) layers of matted sedge and grass, (b) layers of matted roots, and (c) *in situ* willow roots.

Figure 14. Exposure JO-9. South side Shukokluk Creek 6.5 km above mouth of Wolverine Creek.



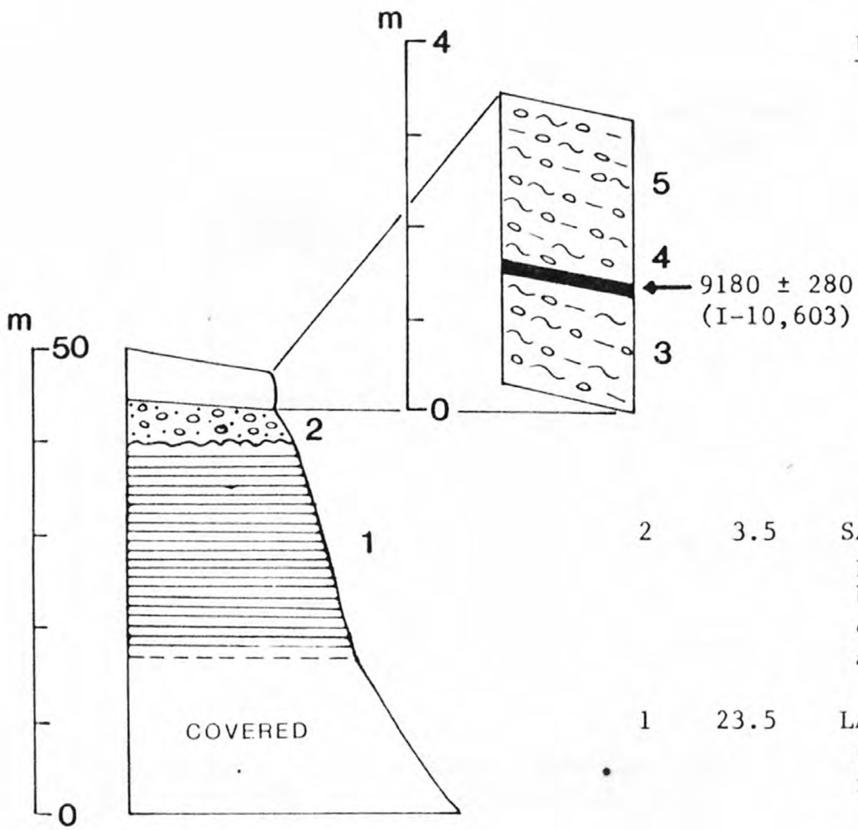
UNIT	THICKNESS (m)	DESCRIPTION
3	9.6	FAN DEPOSIT. Fragments of micaceous schist, pebble to cobble size, in poorly sorted platy micaceous sand-granule matrix. Contains sparse interbeds of micaceous medium to coarse sand.
2	0.05	PALEOSOL. Very dusky red (2.5 YR 2/2) peat and decomposed humic material with abundant wood fragments above 2 cm intensely oxidized yellowish red (5 YR 4/8) silt or fine sand.
1	4.4	FAN DEPOSIT. As in Unit 3.

Figure 15. Exposure WI-1. West side Wild River at base of Gilroy Mountain.



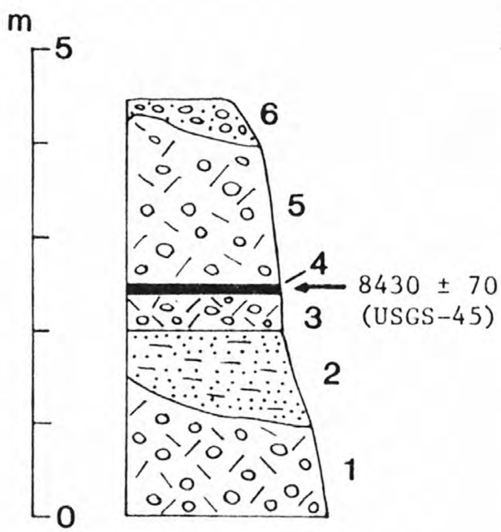
UNIT	THICKNESS (m)	DESCRIPTION
2	3	GRAVEL. Contains frost structures that include involutions, wedge casts, and vertical stone fabric.
1	0.5	SAND. Bedded sand and silty fine sand. Contains twigs in 1 locality

Figure 16. Exposure MI-1. East side Middle Fork Koyukuk River 0.5 km above Rosie Creek. Road cut intersecting alluvial fan of Rosie Creek. Stands 5 m high, with basal 1.5 m covered. See Hamilton, 1979c, p. 30 (Site 76).



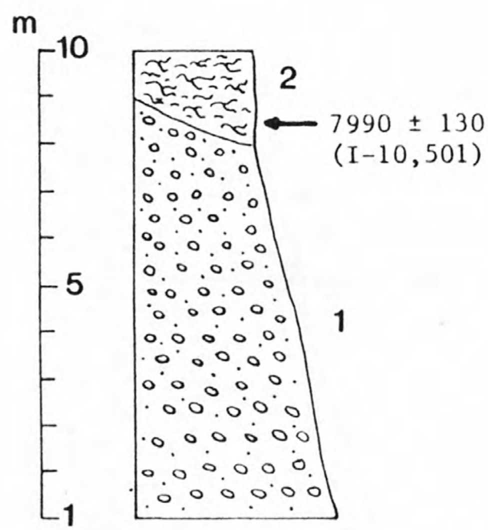
UNIT	THICKNESS (m)	DESCRIPTION
5	2	SOLIFLUCTION DEPOSIT. Schist rubble dispersed in mottled grey to reddish brown silt matrix. Weakly stratified, with strata inclined toward valley center parallel to surface slope.
4	0.1	PALEOSOL. Silty peat with humus. Contains shell and wood fragments. Inclined toward valley center at 1-2^{o}.
3	1	SOLIFLUCTION DEPOSIT. Silty rubble with organic layers, as in Unit 5.
2	3.5	SAND AND GRAVEL. Subangular to subrounded platy schist pebbles in matrix of schist and phyllite chips; interbedded with olive (5 Y 5/3) silty fine sand and with cross-bedded fine to medium sand. Erosional contact at base.
1	23.5	LACUSTRINE BEDS. Olive grey (5 Y 4/2) thinly laminated (about 2 mm) clayey silt. Contains thin (1-3 mm) sand interbeds.

Figure 17. Exposure MI-2. East bank Canyon Creek 2 km above its mouth. Stands 46.6 m high, with upper surface sloping inland. Basal 16.5 m covered by mudflow apron.



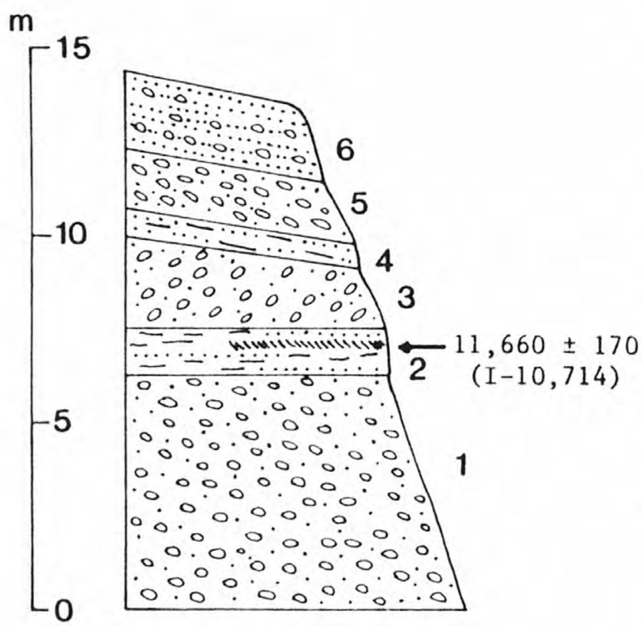
UNIT	THICKNESS (m)	DESCRIPTION
6	0-0.5	SANDY GRAVEL. Caps erosional surface.
5	1.5-2.0	DIAMICTON. Unsorted, nonstratified pebbles and cobbles in matrix of silty sand.
4	0.1	PALEOSOL. Black to dark reddish brown (5 YR 2/2) peaty muck. Overlain by 0.5 cm white calcareous marl(?).
3	0.4	DIAMICTON. Unsorted, nonstratified pebbles in brown sandy matrix.
2	0.5-1.0	SAND. Gleyed and locally organic silty fine sand. Fills depression on surface of Unit 1.
1	1.0-1.5	DIAMICTON. As in Unit 5.

Figure 18. Exposure MI-3. Roadcut, east side Middle Fork Koyukuk 1 km south of Minnie Creek. See Hamilton, 1979c, p. 33 (Site 82).



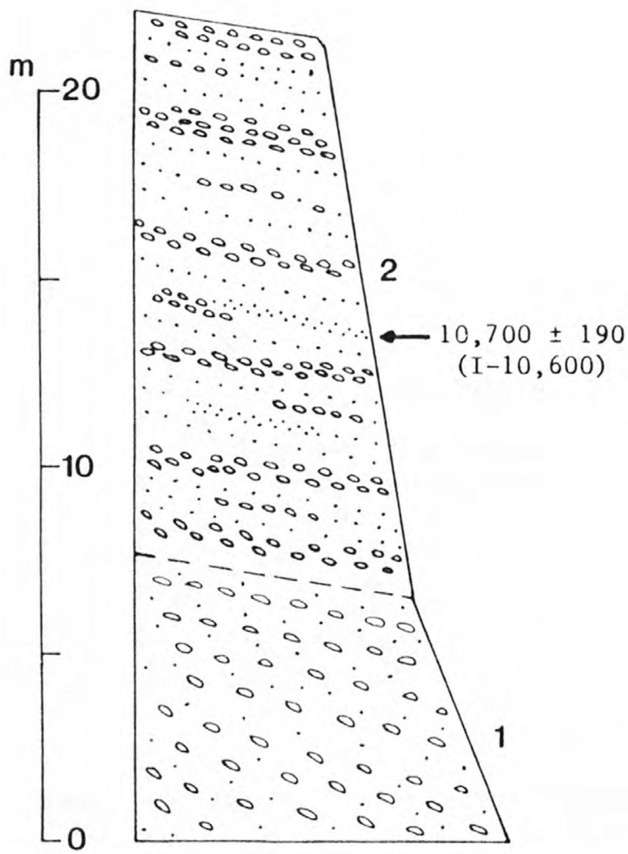
UNIT	THICKNESS (m)	DESCRIPTION
2	0.5-2	PEAT. Fills depression in gravel surface.
1	10+	GRAVEL. Size, shape, and lithology uncertain.

Figure 19. Exposure MI-4. Roadcut at edge of highest alluvial terrace, east side Middle Fork Koyukuk River 6 km below mouth of Rosie Creek. See Hamilton, 1979c, p. 23-24 (Site 68).



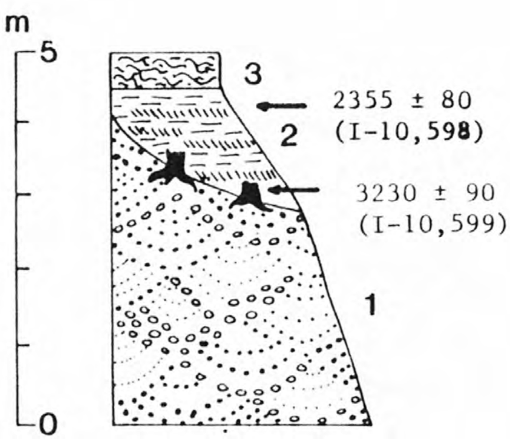
UNIT	THICKNESS (m)	DESCRIPTION
6	1.9	SAND WITH GRAVEL. Bedded fine to medium sand, highly micaceous; interbedded with layers and lenses of angular schist and quartz fragments in matrix of micaceous sand and platy schist granules.
5	1.6	FAN GRAVEL. Subrounded to subangular schist fragments up to large cobble size in matrix of micaceous sand and schist granules.
4	0.6	SAND AND SILT. Grey silty fine sand, bright orange fine sand, and grey clayey silt; contains thin peaty horizons near base.
3	1.6	FAN GRAVEL. As in Unit 5. Stones imbricated, dipping into bluff.
2	1.3	SILT, SAND, AND CLAY. Grey clayey silt, grey silty fine sand, greyish brown micaceous medium sand, and very greasy (micaceous?) silty clay. Thin woody peat layer at 50 cm depth.
1	6.3	OUTWASH GRAVEL. Subrounded pebbles, cobbles, and some very small boulders in sandy matrix. Conglomerate very abundant among larger clasts; quartz very abundant among pebbles.

Figure 20. Exposure NO-1. West side North Fork Koyukuk River 2.5 km below Rock Creek.



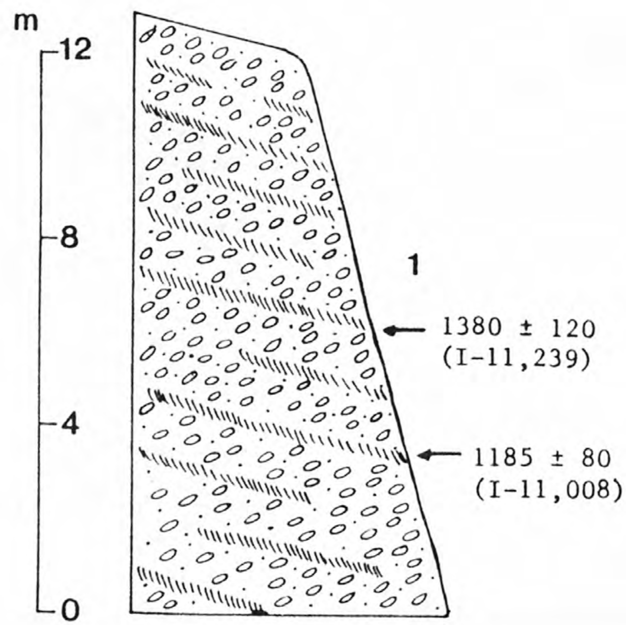
UNIT	THICKNESS (m)	DESCRIPTION
2	15	SAND AND FINE GRAVEL. Beds of sand and granule-sized phyllite plates alternating with sandy fine gravel (schist and phyllite pebbles) and with beds of silty organic fine sand. Beds dip toward valley center parallel to gradient of modern stream.
		Transitional contact
1	6.5	FAN GRAVEL. Subangular fragments of schist, phyllite, and quartz in unsorted matrix of sand-to-granule sized phyllite plates.

Figure 21. Exposure NO-2. Unnamed western tributary to Tinayguk Valley 6 km west of confluence of Tinayguk River with North Fork Koyukuk.



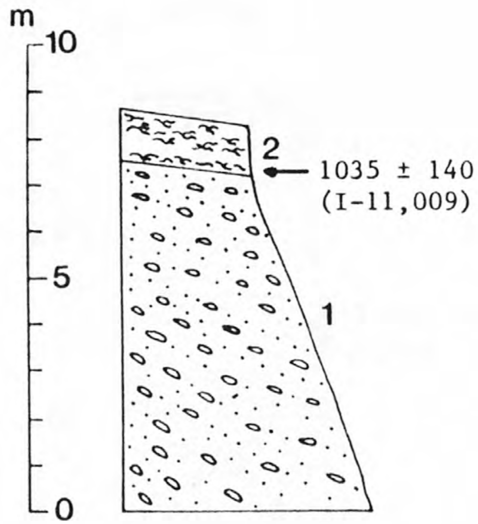
UNIT	THICKNESS (m)	DESCRIPTION
3	0.5	SOD AND PEAT. Surface sod above brown sedge-grass peat.
2	0.4-1.7	SILT, dark gray (N4), clayey; interstratified with thin (1-5 cm) peat beds. Fills and levels out irregular upper contact of Unit 1.
1	2.8-4.1	SAND, cross-bedded, with lenses of pebble-small cobble gravel and with detrital wood along bedding planes. Abundant spruce stumps with <u>in situ</u> roots along upper contact.

Figure 22. Exposure NO-3. West side North Fork Koyukuk River 3 km above mouth of Ruby Creek.



UNIT	THICKNESS (m)	DESCRIPTION
1	12	FAN GRAVEL. Subangular to subrounded platy pebbles and cobbles of schist and phyllite in sand-granule matrix of same material. Stones imbricate, dipping into bank. Peaty interbeds at 0.5-1 m intervals.

Figure 23. Exposure NO-4. East side Glacier River 3.5 km below mouth of Sleepy Creek.



UNIT	THICKNESS (m)	DESCRIPTION
2	0.85	PEATY SAND AND SANDY PEAT. Buried soil horizons with _in situ_ roots alternate with sand layers containing _in situ_ sedge and sparse wood fragments. Well developed 5-cm peat layer at base.
1	7.3	FAN GRAVEL. Pebble-cobble gravel consisting dominantly of platy schist fragments, with 1-2 percent angular quartz fragments, in matrix of platy sand and granules.

Figure 24. Exposure NO-5. West side Glacier River just below mouth of Little Swede Creek. Intersects alluvial fan of Little Swede Creek.

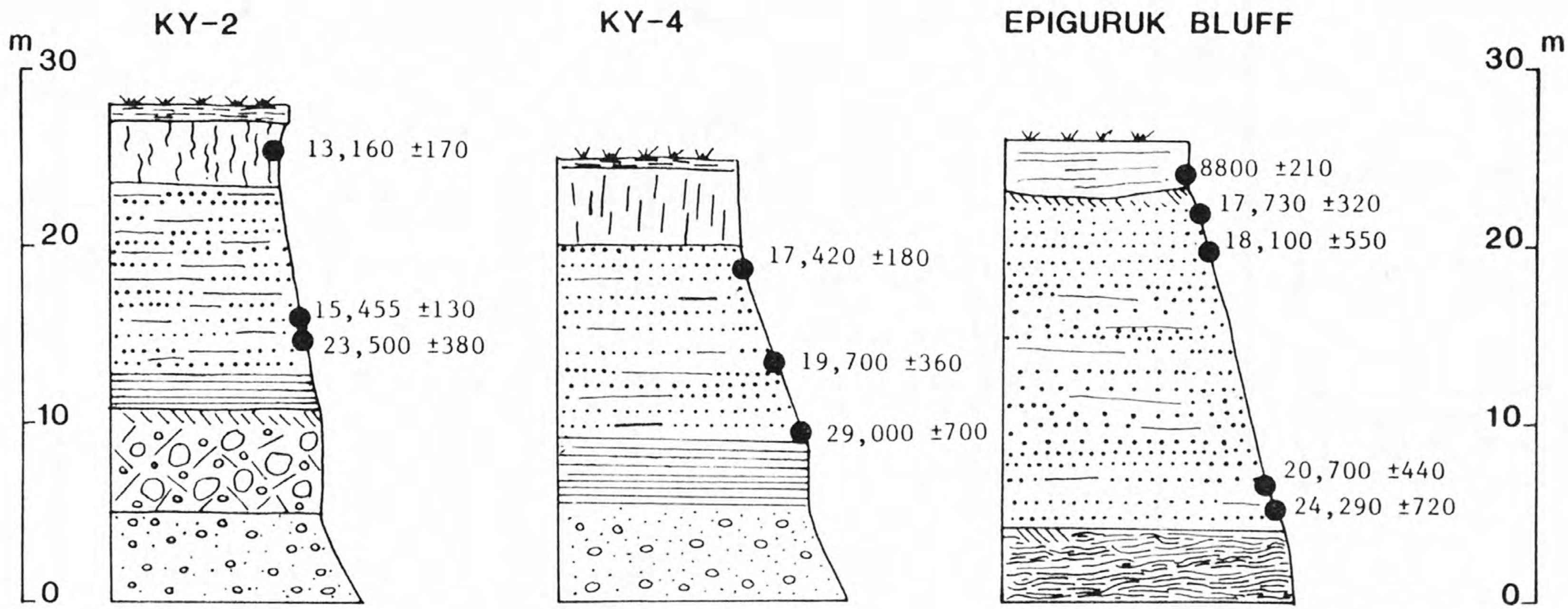


Figure 25. Alluviation correlated with glacier advances of Itkillik II age in Koyukuk, John, and Kobuk Valleys.

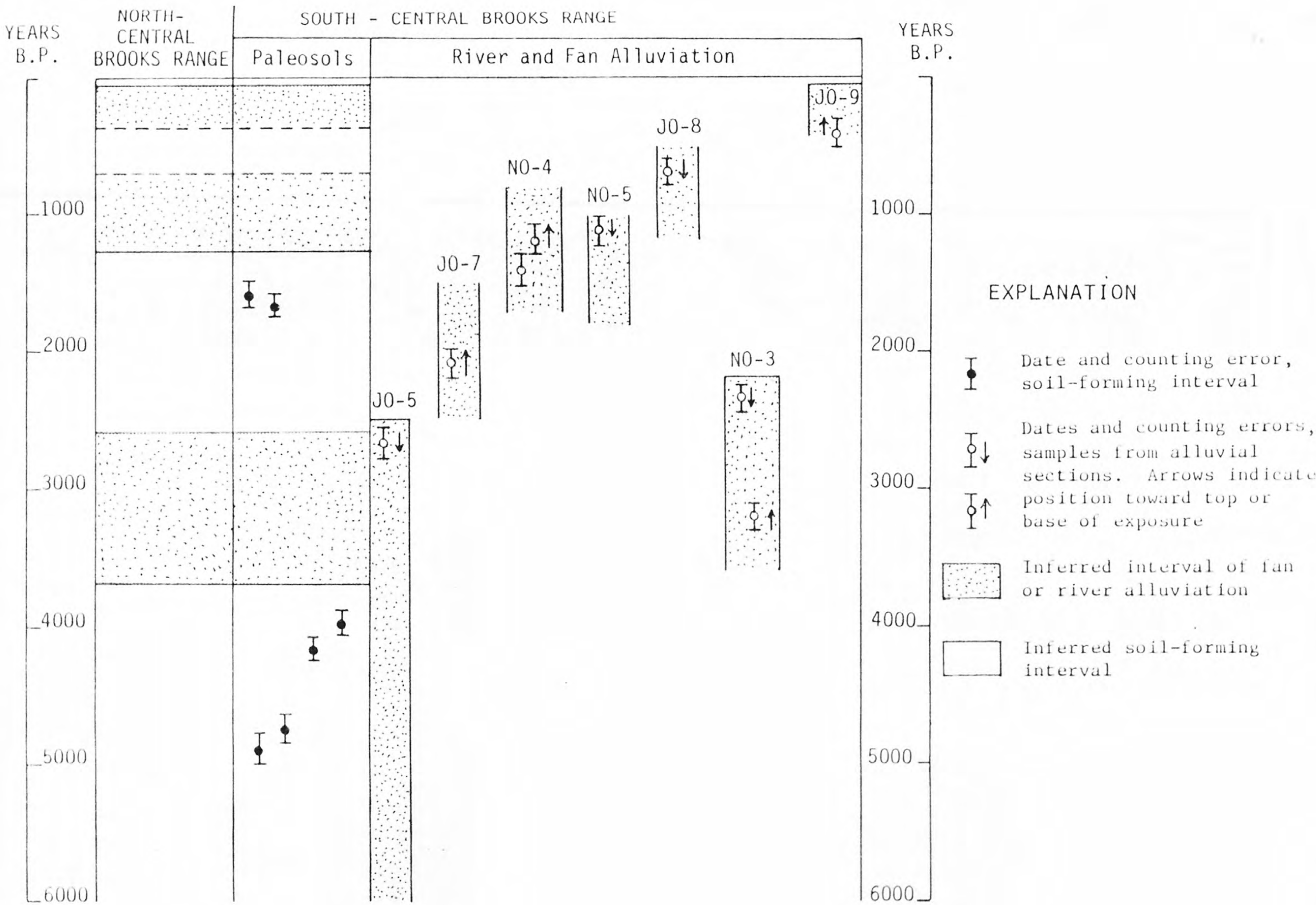


Figure 26. Middle to late Holocene radiocarbon dates, south-central Brooks Range. North-central Brooks Range data summarized from Hamilton (1980).

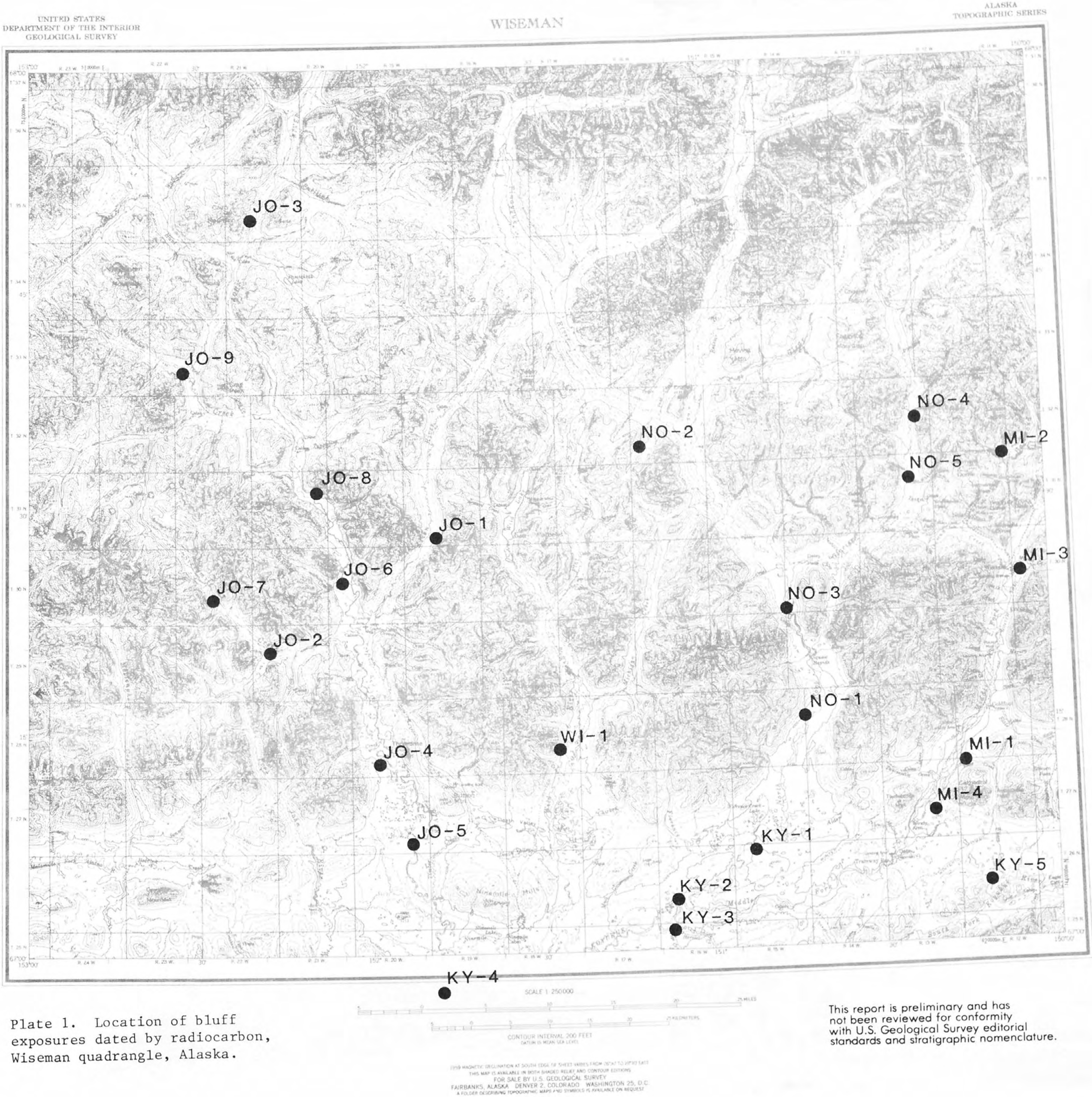


Plate 1. Location of bluff exposures dated by radiocarbon, Wiseman quadrangle, Alaska.

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