DEPARTMENT OF THE INTERIOR
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QUATERNARY STRATIGRAPHIC SECTIONS WITH RADIOCARBON DATES, SURVEY PASS QUADRANGLE, ALASKA

by

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SUMMARY

1. Radiocarbon dates and measured stratigraphic sections from 18 localities in the Survey Pass quadrangle provide significant insights into regional glacier fluctuations, postglacial vegetation history, and local fan-building, alluviation, and peat accumulation. The data base consists of 25 radiocarbon dates from 13 natural exposures and 27 additional dates from 5 lake-sediment cores.

2. Fifteenmile bluff, near the head of the Alatna River, records two glacial advances since the last recognizable interglacial stage. Both advances began prior to 45,000 yr B.P. and probably exceed 60,000 years in age. The older advance took place under warmer conditions and may have terminated within the upper valley. The younger advance was by a "cold" glacier that may have covered headward parts of the Alatna Valley continuously until about 12,000 years ago.

3. Bluff exposures and pollen cores near the outer flank of the range suggest that a significant interstadial interval began more than 31,000 years ago, and terminated about 24,000 yr B.P. when glaciers readvanced to positions near the south flank of the range. Glaciers fluctuated near their marginal positions for at least several thousand years, then abandoned cirques and end-moraine belts near the range front by about 13,500 yr B.P. and retreated back into the range. Deglaciation proceeded rapidly, and upper valleys were at least partly revegetated by about 11,800 years ago.

4. Full-glacial pollen assemblages dominated by grass (Gramineae), sedge (Cyperaceae), and sage (*Artemisia*) were replaced by dwarf birch (*Betula nana*, *B. glandulosa*) assemblages beginning about 12,500-13,000 yr B.P. at the south flank of the range and about 11,800 yr B.P. in upper mountain valleys. Adler (*Alnus*) pollen became dominant at most sites approximately 7500 years ago. Modern boreal forest communities consisting of white spruce (*Picea glauca*), black spruce (*P. mariana*), and paper birch (*B. papyrifera*) became established along the south flank of the range about 5000 years ago, and peat accumulation on the Walker Lake outwash terrace began at the same time.

5. Dates on meander cutbanks in depositional basins behind moraine dams indicate that filling by slackwater deposits to levels at or above modern river floodplains was generally complete by middle Holocene time. Banks that are defended by tributary fans consistently yield older radiocarbon dates than those that are fully exposed to lateral cutting by meandering streams. The Alatna River was still alluviating behind its moraine dam 6800-6900 years ago; Reed River and Walker Lake had attained essentially their modern levels by 5800 and 4600 years ago.

6. Alluvial fans may have grown more rapidly during the late Holocene Neoglacial interval than they did about 1400-1000 yr B.P. Our records are not adequate to demonstrate this conclusively, however.

7. Discordant radiocarbon dates in two of our lacustrine cores may be due in part to a landslide into Ranger Lake sometime before 7260 yr B.P. and short-lived disturbances of unknown character at Ruppert Lake about 7500-8000 years ago. Because of the known seismicity of the Kobuk trench, we speculate that the lake basins could have been affected by seismic events.

INTRODUCTION

The Survey Pass 1:250,000 quadrangle extends from the forested southern slopes of the Brooks Range across the Continental Divide into headwaters of streams that flow north toward the Arctic Ocean and west into Kotzebue Sound. The area is a transition zone between the drier continental climate of the central Brooks Range to the east and the wetter environment of the Kobuk and Noatak valley systems to the west (Ellis and others, 1981). An equivalent transition zone existed during Pleistocene glaciations, when valley-glacier systems of the central Brooks Range graded westward into highland ice caps that developed at lower altitudes and supported large outlet glaciers (Hamilton, 1981).

Almost all of the Survey Pass map area lies within the Brooks Range, hence its glacial record is confined mainly to ice advances of late Pleistocene age that buried or obliterated older glacial deposits. Although its time span was short, this glacial record is surprisingly complex (table 1). In this report we follow the stratigraphic system used during recent surficial geologic mapping of the Survey Pass quadrangle (Hamilton, 1981). However, we have modified the nomenclature to reflect a growing body of radiocarbon dates which indicate that the younger of the two glacial phases termed Itkillik locally followed a significant interstadial interval, occurred during a single major episode of glacier advance and recession, and began and ended in phase with the late Wisconsin fluctuations of the Laurentide ice sheet (Hamilton, 1982). Our data from the upper Alatna Valley, on the other hand, indicate that ice could have remained continuously within upper valleys of the Brooks Range for 50,000 years or more during middle and late Wisconsin time and that the Walker Lake event might not always be separable from older events of Itkillik age. We therefore retain the term Itkillik Glaciation as employed previously (Hamilton and Porter, 1975), but consider it to consist of a younger (Walker Lake) substage and one or more older substages (table 1).

Initial observations on Quaternary geology of the Survey Pass quadrangle were carried out by W.C. Mendenhall in 1901 and P.S. Smith in 1910 and 1911 during geologic traverses of the region (Mendenhall, 1902; Smith, 1912, 1913); the map area received little scientific attention of any kind during the following 50 years, however. One of us has investigated the region intermittently since 1961 (Hamilton, 1966, 1969, 1981), concentrating primarily on the Pleistocene glacial record. The second author initiated palynologic studies in the region during 1978 (Brubaker and others, 1982). Our present data base includes 25 radiocarbon dates from natural exposures (deepened in places by trenching) and 27 dates from 5 lake-bottom cores that were taken for pollen analysis (tables 2 and 3; plate 1). These dates and associated stratigraphic sections provide useful information on the last Pleistocene glaciation of the

Table 1. Nomenclature and correlation of younger Pleistocene glacial sequences in southern valleys of the Brooks Range. Modified from Hamilton (1982).

KOBUK VALLEY (Fernald, 1964)	ALATNA VALLEY (Hamilton, 1969)	SURVEY PASS QUAD (Hamilton, 1981)	SOUTHWESTERN BROOKS RANGE (This paper)	
	Itkillik Glaciation	Itkillik Glaciation	Itkillik Glaciation	Late Pleistocene
Walker Lake Glaciation	"Range-front" moraines	Late Itkillik phase Itkillik II Phase	Walker Lake substage	
Ambler Glaciation	Helpmejack moraine Chebanika moraine --- Siruk Creek moraine	Itkillik I Phase	Chebanika substage --- Siruk Creek substage	
Kobuk Glaciation	Kobuk Glaciation	Kobuk Glaciation	Kobuk Glaciation	Middle Pleistocene

Table 2--Radiocarbon dates from natural exposures, Survey Pass quadrangle, Alaska.

Exposure No.	Coordinates	Date & Lab. No.(1)	Material Dated	Comments
AL-1	67°44'N 154°58'W	>45,000 (AU-470)	Peat	
		>45,600 (USGS-467)	Wood fragments	
		>45,800 (USGS-470)	Wood and plant fragments	Very sparse Salix and Cyperaceae (sedge) pollen (2)
		>60,000 (QL-1487)	Wood	Salix (3)
		----------(4)		
		>28,000 (AU-46)	Wood	
		>31,000 (AU-47)	Wood	
		>42,900 (USGS-468)	Peat	Very sparse Picea, Alnus, and Cyperaceae (sedge) pollen (2)
		>52,500 (USGS-469)	Wood	Picea (3)
		>55,300 (USGS-465)	Wood	Alnus? (3)

		>47,300 (USGS-466)	Peat	Pollen includes Alnus, Betula, Cyperaceae, and Picea. Sphagnum and fern spores also present (2)
AL-2	67°05'N 153°11'W	31,000 ± 900 (W-1427)	Wood fragments	
AL-3	67°06'N 153°26'W	6760 ± 90 (UW-84)	Detrital wood	
		8690 ± 115 (I-11,241)	Detrital wood and misc. plant fragments	
AL-4	67°14'N 153°43'W	4600 ± 95 (I-10,928)	Silty peat	
AL-5	67°11'N 153°20'W	2045 ± 80 (I-10,929)	Detrital wood	Picea (3)

Table 2--Radiocarbon dates from natural exposures, Survey Pass quadrangle, Alaska (Continued)

AL-6	67°42'N 154°44'W	1260 ± 80 (I-10,596)	Wood	*In situ Picea* roots (5)
KO-1	66°58'N 154°25'W	5140 ± 50 (USGS-1045)	Peat	Abundant *Picea* and *Sphagnum* pollen; Ericaceae pollen common (5)
		22,650 ± 220 (USGS-1044)	Peat	
		24,300 ± 250	Twigs and small plant fragments	*Salix* (5)
KO-2	67°14'N 154°34.5'W	5630 ± 115 (I-11,468)	Woody peat	
KO-3	67°13.5'N 154°34'W	4160 ± 100 (I-11,571)	Peat	Abundant *Alnus* and *Betula* pollen; *Picea*, *Salix*, and Cyperaceae also present (5)
RE-1	67°07.5'N 154°46'W	5810 ± 115 (I-11,673)	Wood	*Salix* (5)
RE-2	67°04.5'N 154°48'W	3220 ± 85 (I-11,400)	Wood fragments	
NK-1	67°40'N 155°22'W	1015 ± 80 (I-11,450)	Peat and wood	
NK-2	67°29.5'N 155°25'W	880 ± 75 (I-11,508)	Wood	*Salix* (5)

(1) AU = University of Alaska Institute of Marine Science; I = Isotopes, Inc.; QL = Quaternary Research Center, University of Washington; USGS = U.S. Geological Survey at Menlo Park, Calif.; W = U.S. Geological Survey at Reston, Va.
(2) Identified by Thomas A. Ager, U.S. Geological Survey, Reston, Va.
(3) Identified by Forest Products Laboratory, Madison, Wis.
(4) Dashed lines separate stratigraphic units of exposure AL-1
(5) Identified by authors.

Table 3. Radiocarbon dates from lake cores, Survey Pass quadrangle, Alaska.

Lake Name and Coordinates	Depth Interval (cm)	Date	Lab. No.
Ruppert	25.5-30.5	1840 ± 110	BA-3436
67°04'N	80- 86	3710 ± 120	BA-3433
154°14.5W	99-106	5110 ± 50	QL-1348
	139-146	7690 ± 60	QL-1379
	162-168	7280 ± 150	BA-3434
	182-188	7950 ± 120	BA-3692
	276-282	10,370 ± 110	BA-3435
	365-370	12,500 ± 80	QL-1380
	450-455	13,230 ± 90	QL-1381
Headwaters	66-78	3520 ± 100	QL-1382
67°56'N	166-178	6860 ± 110	QL-1384
155°03'W	255-264	11,750 ± 150	QL-1383
Angal	96-105	6540 ± 290	BA-1695
67°08.5'N	123-132	8080 ± 230	BA-1696
153°53'W	186-200	13,735 ± 245	BA-1697
Redondo	21-30	1540 ± 40	QL-1528
67°41'N	89-96	4080 ± 100	BA-3437
154°32.5W			
Ranger	65-80	2200 ± 80	QL-1519
67°08.5'N	130-145	3970 ± 70	QL-1520
153°38'W	205-215	5690 ± 120	QL-1521
	265-275	7260 ± 140	QL-1522
	315-325	10,600 ± 150	QL-1523
	350-370	20,680 ± 400*	QL-1524
	460-480	20,700 ± 900*	QL-1526
	502-520	20,900 ± 1,200*	QL-1527
	567-589	16,400 ± 250	QL-1480
	589-601	6250 ± 50	QL-1432

*Dates considered unreliable because of low organic content of samples.

Survey Pass quadrangle, on regional vegetation changes during and after final ice retreat, and on hydrologic changes within individual valleys during Holocene time.

The Survey Pass map area is of additional interest because of its location close to the Kobuk trench, which may conceal a major strike-slip fault (Grantz, 1966, p. 38). An east-west trending fault mapped by Patton and Miller (1966) 18 km beyond the south margin of the map cuts Quaternary deposits that include drift of Itkillik age. One of us (T.D.H.) has followed this fault trace farther east across the Alatna River and observed offsets within outwash of probable Walker Lake age. A series of earthquakes in October 1980 with magnitudes up to 5.0 had an epicentral location (66.9°N, 155.2°W) about 45 km west-southwest of Walker Lake and evidently was generated by right-lateral fault movement within or close to the Kobuk trench (University of Alaska, 1981, p. 13).

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THE ALATNA VALLEY

The complex glacial flow system in the Alatna Valley has been studied intermittently for more than 20 years (Hamilton, 1969, 1981), but still is incompletely understood. The Arrigetch Peaks, only 40 km from the south flank of the range, were a major source area for glacier ice through southern parts of the Alatna Valley. Cirques are less well developed around the head of the Alatna River, but ice caps probably covered this part of the valley system during one or more late Pleistocene glaciations. Vegetation of the Alatna Valley has been described recently by Murray (1975).

In the following sections, we discuss the geologic and paleoecologic records of 5 natural exposures, 1 test trench, and 3 pollen cores from the Alatna drainage system, and evaluate the 31 radiocarbon dates that have been obtained from these sites. Several exposures that were discussed in earlier publications (Hamilton, 1969; Hamilton and Porter, 1975; Hamilton, 1982) are reviewed here in order to present complete documentation of the Survey Pass quadrangle radiocarbon record.

Fifteenmile Bluff (Exposure AL-1)

Exposure AL-1 (figs. 1 and 2) provides an unusually long, old, and complex record of glacial and alluvial sedimentation in an upper mountain valley. Beds are well exposed for nearly 1 km along the face of a conspicuous terrace that averages about 35 m height and extends along the northeast side of the Alatna River 20 km downvalley from its head. This segment of the valley contains undifferentiated drift of Itkillik age (Hamilton, 1981) that may have been deposited in a complex transition zone between ice cap and outlet glaciers. The terrace is a few kilometers north of the limit of continuous spruce forest, but isolated spruce trees extend farther up the valley floor to positions near the south end of the bluff. The terrace consists primarily of fluvial sediments that are older than the age range of conventional radiocarbon dating (fig. 2); these lie above and below diamicton in the northern part of the exposure. Erratic boulders of metasandstone, gray phyllite, and vein quartz up to 62 cm diameter are scattered across the terrace surface.

Oxidized sandy gravel at the base of the bluff (unit 1) is interpreted as gravel-bar deposits interspersed with finer-grained channel fillings. Lithologies, textures, and structures are comparable to those of the modern Alatna River: imbricate stones dip upvalley parallel to the fabric of the modern river gravels, and cut-and-fill structures within the oxidized gravel resemble sediments that fill recently-abandoned channels on the modern flood plain. Peat from the base of a sand bed 3.2 m below the upper contact of the unit is older than 47,300 radiocarbon years.

Unit 2, consisting of silt with some peat, clay and fine sand, is variable in thickness, ranging upward to more than 3 m in places. This deposit fills channels in unit 1; it also interfingers laterally with the gravel and overlies it conformably. It resembles modern flood plain deposits of the Alatna River in both structure and composition, and clearly is interrelated with unit 1 in a manner identical to that of modern floodplain-channel sedimentary sequences. Two infinite radiocarbon determinations were obtained on organic sediments from unit 2 near the south end of the bluff (section C in figs. 1 and 2). Compact peat near the top of the unit is older than 42,900 yr B.P., and peat with wood fragments near the basal contact is older than 52,500 years. Less closely limiting dates of >28,000 and >31,000 yr B.P. (not shown in fig. 2) were determined earlier on samples near the top and bottom of unit 2, respectively (Reeburgh and Young, 1976). An additional age of >55,300 yr B.P. was obtained near the base of unit 2 close to the north end of the bluff (section A in fig. 2)

Unit 3 is an indurated diamicton that stands in vertical scarps and pinnacles. Near the north end of the bluff, subunit 3A is nonbedded and consists of subrounded stones in a mixed matrix; its irregular surface has relief as great as 5 m. Boulders are sparse and generally small (0.6 m or less), but rare individual stones have diameters as great as 1.5 m. Sparse lenses of clay, peaty clay, and sand occur near the base of the unit. The diamicton differs from most tills in that (1) its stones generally are subrounded, (2) stones coarser than cobbles are rare, (3) the deposit is not strongly compacted, and (4) particles in the clay-to-silt range are rare. It resembles alluvium, but lacks bedding and size-sorted matrix. This enigmatic deposit may be a basal till derived primarily from stream gravel that perhaps was modified also by subglacial meltwater. The unit changes facies southward into a better sorted, indurated, faintly cross-bedded, pebble-small cobble gravel in a sandy matrix (unit 3B) that has a regular upper surface and probably formed as outwash. Although clasts rarely exceed 10 cm diameter, unit 3B is capped by a discontinuous stone line consisting of small (up to 0.5 m) boulders. No organic remains were found within unit 3.

Unit 4, a fine-grained and generally laminated deposit, occurs only above the irregular surface of unit 3A and generally is restricted to fillings of topographic depressions on the diamicton. Beds range from silty and clayey to sand with silt partings. In places, beds coarsen upward from clayey to sandy; elsewhere they consist of thin parallel silt laminae that not only fill depressions but also are draped over convex surfaces. No organic remains are evident within the laminated sediments.

Unit 5, which caps the section, is a uniform sandy gravel. It consists of stones up to cobble size with widely scattered small boulders up to 0.6 m diameter in a matrix of platy grains ranging from coarse sand to small pebbles. Small boulders at one locality form stone lines 1.6 to 2.5 m below the upper contact of the gravel.

Composition is similar to modern alluvium of the Alatna River, and imbrication of platy stones parallels that of modern gravel. Lenses of silt, peaty silt, and humic sand are restricted to the basal 2-4 m of the unit and are older than the time range of conventional radiocarbon dating. A humic lens near the base of the gravel in section A was dated >40,000 yr B.P. (Reeburgh and Young, 1976), and later was redated to a higher limiting age (>45,000 yr B.P.) A subsequent attempt at more precise dating of wood fragments from section A yielded an age of >60,000 yr B.P. Plant fragments at the same or slighly higher stratigraphic position in sections B and C have also yielded infinite dates (>45,600 and >45,800 yr B.P.) as well as pollen of sedges and willows. The gravel generally grades directly upward into thin surface sod, or is separated from it by a few centimeters of stony sand. Well defined soil or weathering profiles are absent.

Exposure AL-1 may record a series of interglacial, stadial, and interstadial events that preceded development of an ice cap over the upper Alatna region during middle to late Wisconsin time. The organic-bearing, oxidized gravel and flood plain deposits at the base of the section may be of interglacial age. They resemble deposits of the modern Alatna River and contain spruce wood. The overlying diamicton and gravel of units 3A and 3B may represent till and outwash of a subsequent ice advance. Although diamicton could also be formed by mass movement or other slope processes, the rounded gravels of unit 3 make this alternative unlikely, and the inorganic nature of units 3 and 4 seem to indicate an unvegetated state for the upper Alatna Valley at that time. Unit 5, in contrast, contains organic sediments near its base. These contain pollen of willow and sedge, and may represent interstadial shrub tundra. Draping of laminated silt over convex irregularities could indicate meltout of buried ice after deposition of the silt. The gravel cap is virtually inorganic through its upper 8-10 m, and bouldery stone lines are locally present in its upper part. Scattered boulders also are present on the terrace surface. Unit 5 may represent interstadial stream deposits that coarsen upward as glacial ice began to accumulate locally around the head of the Alatna Valley. The site subsequently may have been overwhelmed by a growing ice cap (Hamilton, 1981), which evidently did not erode deeply into unit 5 because of the bouldery, inorganic, and presumably proglacial character of its upper beds. Soil and weathering profiles at the top of the exposure are no more developed than in other valleys of the central Brooks Range that were deglaciated about 10,000 to 12,000 years ago, suggesting that the present terrace surface may have been glacier-covered until some time close to the beginning of the Holocene.

Other Exposures

Exposure AL-2 (fig. 3) is a trench that was excavated in 1963 along the east side of the Iniakuk Lake outlet stream (a tributary to the Alatna River) at the inner flank of the end moraine of Walker Lake age that borders the lake to the south (Hamilton, 1969, p. 208-210). The trench was dug down to permafrost in an attempt to determine the stratigraphic position of a wood-bearing layer of deformed clay that had been found in a slump block along the stream. The presence of permafrost in the trench did not allow deep excavation into the clay layer, however. Gray clay (unit 1) at the base of the trench forms an irregular layer 1-10 cm thick above a lens-like body of fine to medium sand. The upper surface of the clay was horizontal within the limits of the trench, but elsewhere was irregular and in places severely deformed. Very well sorted medium sand (unit 2) above the clay bears an eroded upper contact associated with a thin oxidized zone. The sediments above unit 2 consist of cross-bedded alluvial sand and fine gravel (unit 3) that bears a thin surface mat of peat (unit 4) above a podzolic soil profile. Elsewhere along the stream bank, unit 3 contains ice-wedge casts which cut slump structures caused by the melting out of former blocks of glacier ice. The section initially was interpreted as consisting entirely of lacustrine and fluvial sediments that formed during and following glacier retreat from the Iniakuk Lake basin, and a 31,000-year-old radiocarbon date on small wood fragments from the clay layer was rejected as too old owing to probable redeposition (Hamilton, 1969, p. 217-218). Alternatively, the wood-bearing clay layer could have been overridden and deformed by advance of the ice tongue into its terminal zone at the south shore of Iniakuk Lake.

Locality AL-2 was trenched again in 1979 in attempt to locate and resample the wood-bearing clay, but no unconformity, clay layer, or organic detritus was found within the trench. The 31,000-year date probably provides a maximum limit on the beginning of the last glaciation of the Iniakuk Lake basin (Hamilton, 1982), but it remains uncertain whether the wood was redeposited after the glacier had retreated from the basin or whether the wood-bearing sediments preceded the glacial advance and were preserved beneath overriding glacier ice.

<u>Exposure AL-3</u> (fig. 4) is a long (0.5 km) north-facing bank of the Alatna River close to the inner flank of the end moraine of Walker Lake age that encloses the valley at its mouth (Hamilton, 1969, p. 209-212). The Alatna River through this stretch meanders sluggishly through a broad, level, sandy flood plain that fills the valley from wall to wall (Hamilton, 1981). The sand was deposited in a topographic basin that developed as the ice tongue receded from its end moraine. The bank stands 14.2 m high where the section was measured, but declines to about 12 m some 50-100 m upstream. Its upper surface forms part of a flat, nearly featureless, marshy terrace that extends south to the inner flank of the moraine. Sand and silt throughout the cutbank are predominantly fluvial in origin, resembling flood plain and overbank deposits along the modern slackwater stretch of the Alatna River confined behind the moraine belt. Coarser units are cross-bedded and current-rippled; they commonly contain detrital wood. Finer units are faintly oxidized, contain

plant remains, and overlie the cross-bedded sands in relationships similar to those of modern floodplain-channel sequences. Peat and wood collected from bedding planes 0.3 m above the base of unit 3 date 6890 ± 115 yr B.P., and wood fragments from a slightly higher level farther west along the bank has an age of 6790 ± 90 yr B.P. (Hamilton, 1969, p. 219, section C). These concordant dates indicate that basin-filling to a level above that of the modern flood plain took place during middle Holocene time.

Exposure AL-4 (fig. 5) is situated 42 km north of AL-3 toward the upvalley end of the depositional basin that was confined by end moraines of the Walker Lake substage at the south flank of the range (Hamilton, 1981). The Alatna River occupies a narrower valley here, and is partly blocked by a series of large fans at the mouths of tributary streams. Exposure AL-4 is a southwest-facing cutbank 7 m high that was formed by the Alatna River in a slackwater stretch confined between the fans of Pingaluk and Nahtuk Rivers. The site resembles the area around AL-3 in that a broad, flat, marshy plain fills the valley from wall to wall. It differs from the AL-3 area, however, in that it lies within the active meander belt of the Alatna River and does not intersect an older terrace. The deposits consist of sand and silt that coarsen upward and, farther west along the bank, are interrupted by gravelly channel fillings. Frost-deformed micaceous organic silt beds near the base of the section date 4600 ± 95 yr B.P. The section may represent progressive infilling of the moraine-dammed depositional basin, but its low height and position within a modern meander belt indicate the alternative possibility that alluviation could have resulted simply from lateral migration by the river channel and that the site may be a part of the modern active flood plain.

Exposure AL-5 (fig. 6) is a 3.4-m bank located along the west side of Tobuk Creek 3 km above its mouth near the head of a delta built into Iniakuk Lake. Cross-bedded fluvial sand fines upward and becomes horizontally laminated through the upper 1.4 m of the exposure; this sequence resembles the modern channel-overbank depositional sequence along the Tobuk Creek meander belt. A lens of detrital wood that lies along a bedding plane 2.4 m below the top of the bank has been dated as 2045 ± 80 yr B.P. Alluviation appears to be related mainly to progressive delta-building and to lateral migration of the meander belt.

Exposure AL-6 (fig. 7) is a 9-m-high cutbank along the east side of the Alatna River 30 km downvalley from its head. The bank is situated at the southeast edge of an alluvial fan built by a short, steep, unnamed tributary stream. Segments of the 35-m terrace described previously at locality AL-1 are traceable downriver past this stretch, but the alluvial fan is a lower and younger feature inset within the terrace. The exposure consists predominantly of subangular fragments of local rock types (schist, phyllite, and quartz) in a loose, open-textured, poorly sorted matrix of platy sand and granules. Platy stones are imbricated and dip into the bank. Composition and fabric are identical to those of modern alluvial fans along this sector of the valley. The gravel contains two forest beds at 1.5 to 3.0 m depth that consist of peat with clayey partings and abundant spruce roots. Stumps up to 2 m high and 24 cm diameter project from each forest floor into the overlying gravel. An in situ root from the lower forest bed (unit 2) has been dated as 1260 ± 80 yr B.P.

Pollen Cores

The informally named Ranger Lake lies at 800 m altitude within a north-facing cirque 8.5 km west of the Alatna River near the mouth of its bedrock valley. Sharp-crested lateral moraines are traceable northeastward from the cirque, which evidently supported glacier ice during at least part of the Walker Lake substage (Hamilton, 1981). Neither this cirque nor its neighbors bears any evidence for glacier or rock-glacier activity during late Holocene (Neoglacial) time. Ranger Lake is confined behind a bedrock sill to the north; its south shore abuts a rock knob with a ragged, near-vertical face about 100 m high. The 6.1 m core from this lake penetrated sediments with very low organic content (3-5 percent loss on ignition at 600°C). An anomalous pollen assemblage rich in alder and a young radiocarbon date at the base of this core suggest that basal sediments were contaminated from above during coring (fig. 8). The remainder of the pollen record does not show evidence of disturbance or contamination during coring of the overlying sediments. That part of the pollen record suggests that sediments with a full-glacial pollen assemblage dominated by grass, sedge, and sage were succeeded by pollen zones dominated by shrub birch and later by alder. Radiocarbon dates down to 275 cm depth increase linearly with age implying a nearly constant sedimentation rate of about 0.4 mm per year (fig. 9A), but dates throughout the lowest, herb-dominated pollen zone form an erratic pattern when plotted against depth. The very young date at the base is probably due to contamination by near-surface sediments, as discussed above. Several particularly old dates have large counting errors and were obtained on samples with very low organic carbon content. Perhaps these samples were contaminated with small amounts of graphite which is present in the local quartzite (Nelson and Grybeck, 1980). Landsliding may also have disturbed the sediments in the lower part of the cove. Rubble at the base of the rock knob that overlooks the lake includes very large (8-10 m) blocks that are rare in normal talus rubble but common in landslide debris. The lake basin also is rimmed by a shallow shelf of muddy sediment that is absent where the hypothesized landslide took place. It is possible that a large slide or fall of rock from the face of the knob mobilized sediments near the south shore and redistributed them across the lake bed.

Headwaters Lake[1/] is a kettle within drift at 850 m altitude on the broad, low divide that separates the drainage systems of the Alatna, Nigu, and Killik Rivers. It lies within an ice-stagnation zone that developed during final wastage of Itkillik-age glaciers in the upper Alatna Valley region (Hamilton, 1981). The 2.6-m core from this lake penetrated fine-grained organic-rich sediments (loss on ignition 15-35 percent) and was stopped by impenetrable deposits of unknown character. The core extends through sediments dominated by pollen of alder and birch but ends in levels showing higher percentages of grass, sedge, and sage pollen (fig. 10). Three concordant radiocarbon dates imply a fairly constant sedimentation rate of about 0.23 mm/yr (fig. 9B). A basal radiocarbon date of 11,750 ± 150 yr B.P. provides a minimum limiting age for deglaciation near the head of the Alatna Valley and for recolonization by plants.

Redondo Lake[1/] is located south of the Alatna River opposite the mouth of Ram Creek. It lies 40 km downvalley from the Alatna-Nigu divide and only 17 km downvalley from the modern limit of spruce. The lake is a small rock basin scoured in Hunt Fork Shale (Nelson and Grybeck, 1980) by glacier ice or meltwater during Walker Lake time (Hamilton, 1981). The shallow (1.4 m) core consists of alternating bands of light- and dark-colored sediment with loss-on-ignition values varying between 20 and 60 percent. The pollen record consists of a single zone dominated by alder (fig. 11), and a date of 4080 ± 100 yr B.P. near the base is consistent with a middle to late Holocene age for the entire pond deposit. Two concordant radiocarbon dates indicate a rate of 0.24 mm per year for sedimentation in the lake (fig. 9C), a value that is almost exactly equal to that at Headwaters Lake. Spruce pollen is present throughout the core, but becomes more abundant after about 1540 yr B.P. This increase in relative abundance may reflect expansion of spruce into the upper valley. The 1260-year-old date on a buried spruce stand at AL-6 (fig. 7) provides supporting evidence for forested conditions in the area around Ram Creek shortly after the spruce increase in the Redondo Lake cove.

1/ Informal name

UPPER KOBUK RIVER AND WALKER LAKE

The Walker Lake area, type locality for the last major glacial advance in the southern Brooks Range (Fernald, 1964; Hamilton, 1982), provides an excellent geomorphic and stratigraphic record of late Pleistocene glaciation. Soils around Walker Lake have been described by Ugolini and others (1981), and the vegetation by Goldstein (1981). Three natural exposures furnish dates on glacier fluctuations in the Walker Lake area and on postglacial basin filling and peat accumulation. Two local lake cores provide important limiting dates on deglaciation, and record consistent patterns of changes in vegetation during the last 13,000-14,000 years.

Exposure KO-1 (fig. 12) is located along the north bank of the Kobuk River 14 km south of Walker Lake and 4 km beyond the south edge of the Survey Pass quadrangle. Although located within the Hughes 1:250,000 map area, the importance of this exposure to the Walker Lake glacial record warrants its inclusion in this report. The river bluff at KO-1 intersects the higher of two outwash terraces that emanate from the double moraine that encloses the south end of Walker Lake (Hamilton, 1981). The outwash consists of sandy coarse gravel close to Walker Lake, but fines downvalley and consists primarily of sand with some granules and small pebbles in the area around KO-1. The exposure stands 12.4 m high and consists of sandy outwash with a thin (0.5 m) peat cap. Detrital wood and very sparse peat laminae 3.3 m above river level have been dated as 24,300 ± 250 yr B.P.; and peat within a clayey, lenticular, channel filling higher in the outwash dates 22,650 ± 220 yr B.P. Peat that subsequently developed above the outwash has a basal date of 5140 ± 50 yr B.P. The two older dates indicate rapid alluviation of the Kobuk River between about 24,500 and 22,500 years ago when glacier ice was in an advanced position at or near the outer Walker Lake moraine. The younger peat, in which pollen of spruce and spores of *Sphagnum* are abundant, probably represents a black spruce bog that developed on the terrace surface in mid-Holocene time.

Exposure KO-2 (fig. 13) is an east-facing cutbank of Kaluluktok Creek 2 km above Walker lake. Through its lower course, the creek meanders across a level, marshy flood plain that fills its valley from wall to wall. This stretch of the valley formerly was flooded by Walker Lake, which is bordered by flights of conspicuous shorelines that rise 13 m above its modern level. At KO-2, the creek is partly confined behind an alluvial fan formed by a small tributary stream that enters the valley from the west. The exposure ranges in height between 10 and 12 m and consists mainly of sand with interbeds of silt and fine gravel. Beds dip upvalley at about 2 degrees through much of the exposure, indicating that at least part of the sediment was deposited as part of the radiating fan of the tributary stream. A lens of woody, sandy peat 1.8 m above river level was dated as 5630 ± 115 yr B.P. Because this deposit probably formed subaerially, the date provides a minimum age limit on the decline of Walker Lake to a level within a few meters of the present. It probably applies to local fan aggradation rather than an episode of valley-wide alluviation.

Exposure KO-3 (fig. 14) is a 4-m bank on the margin of a thaw pond within muskeg terrain near the southeast corner of Walker Lake. The pond lies within a remnant of older drift that is confined between the Walker Lake end moraine to the north and west and the Kobuk River to the east and south (Hamilton, 1981). The bank is severely slumped, with basal portions covered by frozen debris. Upper parts of the bank that are exposed naturally or in shallow trenches consist of peat (unit 2) above silty peat (unit 1) that becomes more silty with depth. A peat sample just above the contact between the two units has been dated as 4160 ± 100 yr B.P. The sample contains abundant pollen of alder and birch, with lesser spruce, willow, and sedges.

Angal Lake is dammed by glacial deposits within a north-facing cirque at the head of an unnamed eastern tributary to the Kobuk River. The cirque is situated close to the south flank of the Brooks Range between Walker Lake, 18 km to the west, and Ranger Lake, 11 km to the east. It has the same topographic setting as the basin that contains Ranger Lake, and probably had an identical history of glacier activity that terminated during Walker Lake time. A 2-m sediment core, ending on bedrock, extends through fine-grained sediment with highly variable organic content (loss on ignition 3-47 percent). It displays three pollen zones dominated (from base to top) by herb, shrub birch, and alder pollen (fig. 15). Pollen of white spruce, black spruce, and paper birch reach modern frequencies in lower portions of the alder zone. The basal sediments have been dated as 13,735 ± 245 yr B.P., and two dated samples higher in the core have concordant ages. The three radiocarbon dates indicate that accumulation of sediment in the lake basin took place at a fairly uniform rate of about 0.15 mm/yr (fig. 9D).

Ruppert Lake lies at the contact between the outer and inner moraines of Walker Lake age near the southeast corner of Walker Lake. It may be a kettle formed by a melting body of stagnant glacier ice, but its position at the contact between the two moraines suggests that its origin could possibly be more complex. A 4.5-m sediment core from Ruppert Lake exhibits a pollen profile almost identical to that of Angal Lake, and this correlation is further supported by a similar basal date of 13,230 ± 90 yr B.P. (fig. 16). Loss on ignition is 10-20 percent down to about 3.75 m depth, where it decreases abruptly to less than 3 percent. Low organic values are characteristic of the herb pollen zone, which extends nearly to the base of the core. Loss on ignition increases at the bottom of the core (4.35 - 4.50 m), where pollen is absent but hyphae of a terrestrial fungus (probably of the genus Altenaria, R. J. Campana, personal commun., 1978) are numerous. This basal organic zone probably represents a surface litter horizon which was submerged as an underlying stagnant ice block melted. Nine radiocarbon dates from

Ruppert Lake show a generally concordant pattern that indicates fairly uniform sedimentation at about 0.48 mm/yr up to about 7500-8000 years ago and about 0.18 mm per year thereafter (fig. 9E). The change in sedimentation rate occurred at about the time of a minor discordance in radiocarbon ages (fig. 16). This relation may be coincidental, or it may indicate that the dating anomaly and the rate change are interrelated. The pollen record, with its pronounced but short-lived peaks of Cyperaceae, *Sphagnum*, *Lycopodium*, and monolete and trilete fern spores suggests that one or more episodes of disturbance to soils or vegetation may have taken place around the lake basin at that time.

OTHER EXPOSURES

Four radiocarbon dates of middle to late Holocene age were obtained from natural exposures west and northwest of Walker Lake. Two of the dated sections are low (4-6 m) banks along the Reed River within a slackwater stretch confined behind end moraines of Walker Lake age (Hamilton, 1981). The two other dates, from the Noatak Valley, bear on the history of pingo development on the main valley floor and on expansion of an alluvial fan near the head of a tributary stream. The pingo and its radiocarbon date were discussed previously by Hamilton and Obi (1982); the other three dates are presented here for the first time.

Exposure RE-1 (fig. 17) is a west-facing meander cutbank 8 km north of the Reed River near the distal end of a large alluvial fan built by an unnamed tributary stream. The cutbank stands 4.6 m high and exposes a fining-upward sequence of sand and silt with sparse granules near its base. The sand is stony and cross-bedded near river level (unit 1), but passes upward into laminated sand and silty sand (unit 2) and then into silty peat (unit 3). This succession is identical to that of modern bars, overbank deposits, and flood plain forest-floor along the sluggish reach of the Reed River that is confined behind the moraine barrier. Wood fragments from a gray silty layer 1.5 m above river level have been dated as 5810 ± 115 yr B.P.

Exposure RE-2 (fig. 18) is an east-facing cutbank 5.3 m in height near the south end of the basin dammed by Reed River moraine. The top of the bank is about the same level as the entire valley floor in this stretch, and meander-scroll patterns indicate that the Reed River has shifted laterally across the site at least several times during the Holocene. The cutbank exposes a fining-upward sequence of sand that contains granules near its base but becomes silty near the top. Wood fragments 1.4 m above the base of the exposure date 3220 ± 85 yr B.P.

Exposure NK-1 (fig. 19) is the upturned flank of a pingo that rises to 27 m height on the floor of the Noatak Valley 45 km below its head. The pingo is one of a pair, one conical and one collapsed, that occupy an alluvial fan north of the river within a broad, marshy, slackwater stretch confined behind end moraines of Walker Lake age. The exposure consists of about 10 m of silt and gravel. The silt (unit 1) is clayey, laminated, and contains some thin peaty layers. It may have formed in a shallowing thaw lake on the valley floor, in a marshy oxbow, or in some other shallow body of standing water on the flood plain. The overlying gravel is identical to platy fan deposits through this stretch of the Noatak Valley, and evidently represents later expansion of an alluvial fan over the former marsh or pond. Fan expansion and pingo growth both postdate 1015 ± 80 yr B.P.

Exposure NK-2 (fig. 20) lies along Iyahuna Creek, a southern tributary to the Noatak. Thirteen km above its mouth the creek has incised the front of a steep fan built by a northern tributary. The 8.4-m exposure consists dominantly of imbricated platy stones that dip into the bank, but finer-grained sediments with rooted willow stumps also are present in places. A large *in situ* willow 3.2 m above the river has been dated as 880 ± 75 yr B.P.

DISCUSSION

Radiocarbon-dated stratigraphic sections and sediment cores from the Survey Pass quadrangle provide a regional record of late Pleistocene glaciation and subsequent revegetation history. Other dated exposures provide more local records of peat accumulation, alluviation, and fan-building.

Fifteenmile bluff, near the head of the Alatna Valley, exhibits a long and complex history of glacial advances following a probable interglacial episode during which spruce expanded to positions near its modern limit. According to our radiocarbon dating, the older glacial advance probably is older than 60,000 years. A younger episode of glacial expansion evidently was long-lasting. It may have begun about 60,000 years ago or even earlier if the uppermost sediment in the bluff alluviated rapidly as advance outwash. Absence of deep weathering at the top of the bluff suggests that the valley floor was not subaerially exposed until the time of general regional deglaciation near the beginning of the Holocene. The record at Fifteenmile bluff therefore suggests a six-fold sequence of late Quaternary events in the upper Alatna Valley: (1) interglacial interval with spruce as extensive as today, (2) limited glacial advance, (3) interstadial episode, (4) accretion of advance outwash, (5) long-lasting glacial expansion, and (6) Holocene weathering interval. A similar chronology has been suggested for core areas of the Laurentide ice sheet during the Wisconsin glaciation (e.g. Dreimanis and others, 1981), so persistence of glacier ice through middle Wisconsin time is not unprecedented in higher latitude areas of North America. The water-washed gravels of the initial glacial expansion suggest presence of a "temperate" glacier whose basal temperature is at the pressure-melting point for ice (Paterson, 1981, p. 185-216). Such glaciers commonly have abundant meltwater at their bases. Lack of erosion or deformation of the upper gravel would be more compatible with an overriding "cold" glacier whose basal temperature was below the pressure-melting point for ice. Such glaciers commonly freeze to their beds and move primarily along shear planes within the ice itself.

The 31,000-year-old wood fragments from exposure AL-2, at the south shore of Iniakuk Lake, provide evidence that the long-lasting younger glacial expansion in the upper Alatna Valley may have been represented by a series of stadial and interstadial events near the southern range front. Ice that built the end moraine of Walker Lake age may have advanced over wood-bearing lacustrine clays. If the wood fragments alternatively were redeposited in postglacial sediment, they still imply deglacial conditions and local plant growth some 31,000 years ago. Other dated bluff exposures elsewhere in the Koyukuk drainage system indicate that interstadial conditions prevailed at and beyond the south flank of the Brooks Range from before 31,000 to about 24,000 yr B.P. (Hamilton, 1982), but we do not know how far glaciers had retreated back into their mountain valleys at that time. The glacial sequence from the lower Alatna Valley consists of at least two advances that preceded the Walker Lake substage but postdate the last major interglacial (Hamilton, 1969, and unpublished field mapping). These events, together with the Walker Lake advance, may have taken place while ice continuously covered the upper Alatna Valley (fig. 21).

The last major glacial advance to the south flank of the Brooks Range is bracketed by radiocarbon dates near its type locality at Walker Lake. The higher outwash terrace along the Kobuk River south of the lake was aggrading by 24,300 yr B.P., and became incised sometime after about 22,650 years ago. The glacier evidently readvanced into its terminal zone sometime after that date, and the moraine finally was abandoned and available for plant colonization by at least 13,230 yr B.P. Angal Lake, within a nearby cirque, began to accumulate organic sediment by 13,735 years ago, demonstrating that deglaciation must have been widespread along the south flank of the range at about that time. A basal date of 11,250 yr B.P. from Headwaters Lake indicates that deglaciation proceeded fairly rapidly through upper valleys and was largely completed prior to Holocene time.

Revegetation shows a generally similar history through much of the Survey Pass region. Full-glacial pollen assemblages dominated by grasses, sedges, and sage were replaced by birch shrub assemblages beginning about 12,500-13,000 yr B.P. Alder subsequently arrived about 7500 yr B.P. Spruce pollen first appeared prior to the time of increased alder influx, but did not attain consistently high values until about 5000 years ago. This sequential dominance by birch, alder, and spruce pollen can serve as a rough guide to dating organic-bearing deposits of the central Brooks Range, and can provide an independent check on radiocarbon-dated stratigraphic records.

The remaining dates from natural exposures in the Survey Pass quadrangle are all middle to late Holocene in age. Many of them pertain to the filling of depositional basins behind morainal barriers along the south flank of the Brooks Range. Exposure AL-3, behind the Alatna Valley end moraine, demonstrates that filling of the Alatna basin by slackwater deposits was not completed until sometime after 6800-6900 yr B.P. The Alatna River subsequently incised a bedrock sill to attain its present flood plain level. Exposure AL-4, farther north in the same depositional basin, documents later sedimentation about 4600 years ago that resulted primarily from lateral migration of the meandering river channel. The upper basin had alluviated to about its modern level by that time. Radiocarbon dates from cutbanks along the moraine-dammed depositional basin of the Reed River indicate that filling to near its present level was virtually complete by 5800 years ago at exposure RE-1, which is defended by alluvial-fan deposits from erosion by the meandering river channel. Exposure RE-2, which has been eroded periodically by the Reed River, has a much younger depositional record. Exposure

KO-2 occupies a sediment-filled basin that formerly was covered by Walker Lake at a higher stage. Sediments near the modern river level date about 5600 yr B.P. and either formed subaerially or in very shallow water; these relations indicate that incision of its outlet had lowered the lake to essentially its modern level by middle Holocene time. Exposure AL-5, in a similar position near the mouth of the major inlet to Iniakuk Lake, is only about 2000 years old. This site is not defended by fan deposits, and evidently has been eroded periodically by the meandering channel of Tobuk Creek. The history of basin-filling near the south margin of the Brooks Range shows no obvious control by Holocene climatic changes. The southern valleys differ in this respect from drainage systems of the north-central Brooks Range, which alluviated in response to fluctuations of cirque glaciers during the late Holocene Neoglacial interval (Hamilton and others, 1982).

Three additional exposures provide dates on fan-building by tributary streams within the Alatna and Noatak drainage systems. Fan construction at AL-6 was punctuated by two episodes of forest growth about 1260 years ago and probably a few hundred years later. The date of 1015 yr B.P. from NK-1 provides a maximum limit on fan encroachment over that site, and a date of 880 yr B.P. at NK-2, 22 km farther south across the Noatak Valley, represents a period of active fan aggradation. These three dates could reflect increased rates of fan-building beginning perhaps 1000 years ago, but the local history at each site could merely reflect lateral shifts by the fan-building streams.

Two radiocarbon dates on peat growth in the Walker Lake area may have some wider climatic relevance. A peat cap over the outwash terrace at KO-1 began forming 5140 years ago. Peat accretion could have been in response to some local site factor, but its beginning date is about that of increased spruce cover in the Walker Lake area. Development of a peat cap on the relatively well drained gravel terrace might have been possible only after development of a coniferous forest cover. Peat at KO-2 was accumulating prior to 4160 yr B.P., but became conspicuously less silty at that time. This change might reflect some regional climatic control, but some local site factor such as progressive expansion of a peat mat within the muskeg, seems more likely.

v

Our only two dating anomalies are at Ranger and Ruppert Lakes, two of the three lakes that were cored near the range front. The minor dating anomaly at Ruppert Lake coincides with changes in sedimentation rate and sharp peaks in the influx of spores that suggest some form of site disturbance about 7500-8000 years ago. Discordant dates at Ranger Lake may in part be due to contamination by graphite and in part to redistribution of sediment by a rockfall or landslide into the lake; the anomalously young basal date likely resulted from contamination during coring. Because of the known seismicity of the region, there is some slight possibility that the sediment anomalies might be related to seismic events along the Kobuk trench.

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Unit	Thickness (m)	General Description
5	11-15	STREAM GRAVEL. Subrounded pebbles, cobbles, and very sparse small boulders in matrix of gray (N5), phyllitic coarse sand and granules; faintly bedded; imbricated.
4	0-8	LAMINATED SAND, SILT, AND CLAY. Dark gray (10YR 4/1) silty fine sand, fine sand, and some clay; generally coarsens upward.
3B	0-11	COMPACT GRAVEL. Subangular to rounded pebbles and cobbles in matrix of gray, platy, phyllitic coarse sand with some medium sand and granules; faintly cross-bedded in places.
3A	0-10	DIAMICTON. Subrounded stones up to small boulder size in matrix of mixed clay to granules; non-sorted and nonbedded.
2	1-3	OXIDIZED SILT. Gray to light gray (N5 to N6) clayey and peaty silty fine sand; upper 0.5m oxidized yellowish red (5YR 5/6) with some red (2.5YR 5/6) mottles. Faint subhorizontal, 2-4 cm beds; with thin (0.2 - 1cm) peaty lenses along some bedding planes.
1	8-9	STREAM GRAVEL. Imbricated pebbles and cobbles in sandy matrix; forms beds up to 2m thick. Contains thinner (<0.3m) cross-bedded medium to silty fine sand with 1-2 cm peat layers, sand beds oxidized, with colors as strong as yellow (10YR 7/6).

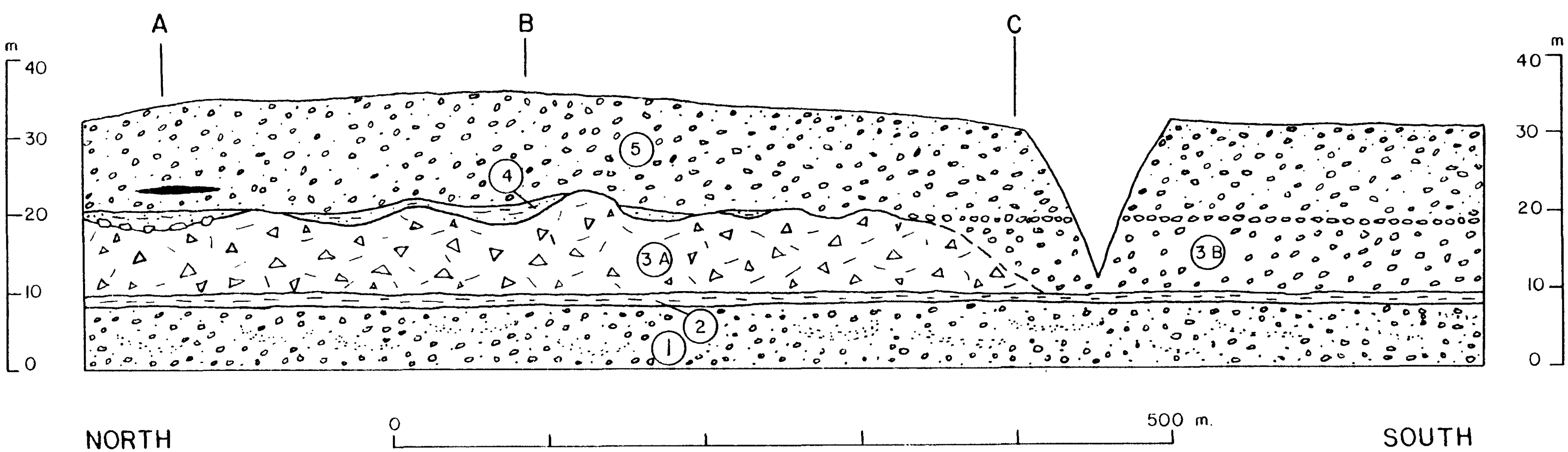
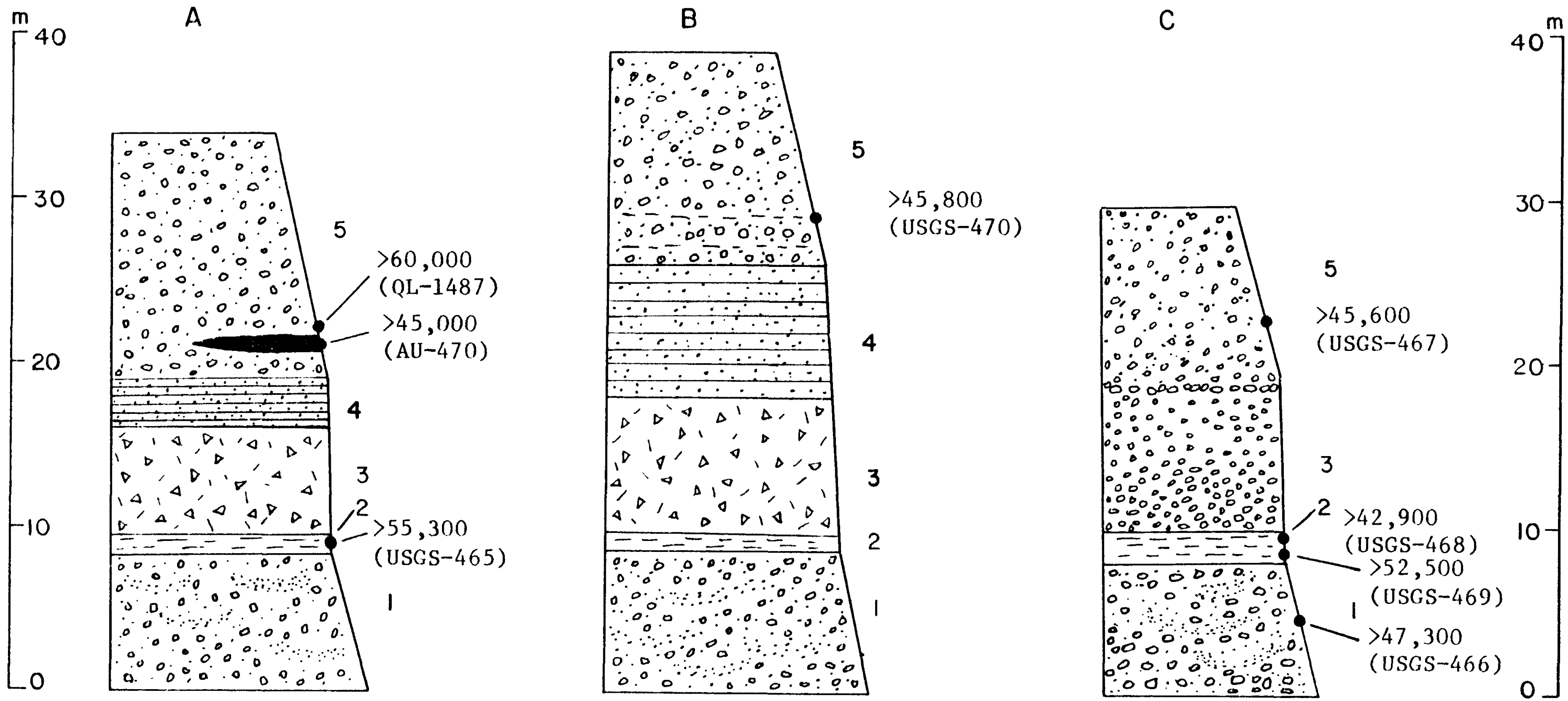


Figure 1. Fifteenmile bluff (exposure AL-1). East side Alatna River 20 km below its head. General stratigraphic relations and unit descriptions.

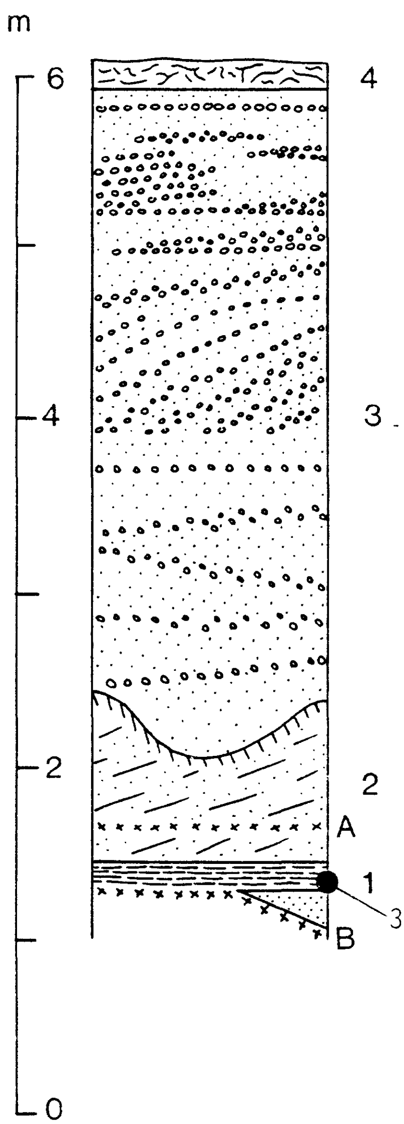


Unit	Thickness (m)	Description
5	15	Stream gravel
4	3	Laminated sand
3A	7.5	Diamicton
2	1	Oxidized silt
1	8.5	Stream gravel

Unit	Thickness (m)	Description
5	13	Stream gravel
4	8	Laminated sand
3A	8.4	Diamicton
2	0.9	Oxidized silt
1	8.7	Stream gravel

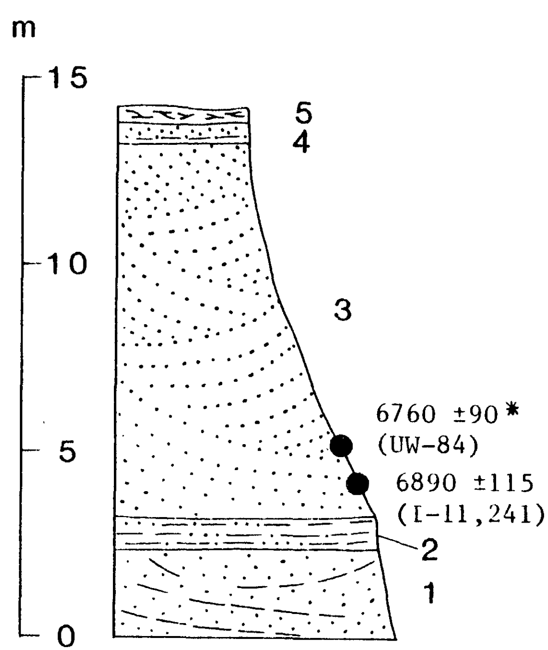
Unit	Thickness (m)	Description
5	11	Stream gravel
-	--	--
3B	9	Compact gravel
2	1.9	Oxidized silt
1	8	Stream gravel

Figure 2. Fifteenmile bluff (continued). Measured sections and radiocarbon dates. Reference datum is modern floodplain of Alatna River.



Unit	Thickness (m)	Description
4	0.07	SOD AND PEAT. Light to dark brown organic mat containing many large roots.
3	3.96	SAND AND FINE GRAVEL. Cross-bedded to horizontally bedded medium to coarse sand with granules and small pebbles; general eastward dips (2-7°) predominate at some levels. Contains 1-cm layer of gray clay (not shown) near top. Bears soil profile consisting of 5 cm light gray A_2 horizon above 13 cm medium brown B horizon and 20 cm sand and fine gravel with local Fe and Mn staining.
2	0.56	SAND. Well sorted medium sand; weak bedding, with apparent dip of 7°E. Upper surface channeled, with oxidized zone below contact.
1	0.10	CLAY. Permanently frozen gray clay, forming irregular layer 1-10 cm thick. Overlies lens of fine to medium sand.

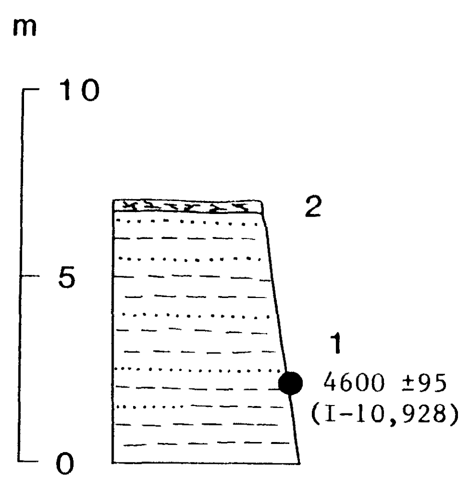
Figure 3. Exposure AL-2. Test trench along Iniakuk Lake outlet stream 0.5 km south of lake shore. Datum is river level. From Hamilton (1982).



Unit	Thickness (m)	Description
5	0.4	SOD AND SANDY PEAT.
4	0.6	SILT AND SAND. Weakly oxidized silt and silty fine sand. Lower 40 cm faintly bedded; upper 20 cm has platy structure and lacks bedding.
3	10.0	SAND. Dark grayish brown (10YR 4/2) fine and medium sand, with cross-beds and ripple marks. Contains pods and lenses of detrital wood, and some thin peat mats along bedding planes.
2	0.8	SILT AND SAND. Dark gray (5Y 4/1) silt, clayey silt, and silty fine sand. Has regular horizontal laminae 1-5 mm thick.
1	2.4	SAND AND SILT. Cross-bedded fine sand, silty fine sand, and silt, with some thin (ca. 1 cm) zones of sparse plant rootlets. Silt is dark gray (as in unit 2); sand is buff colored.

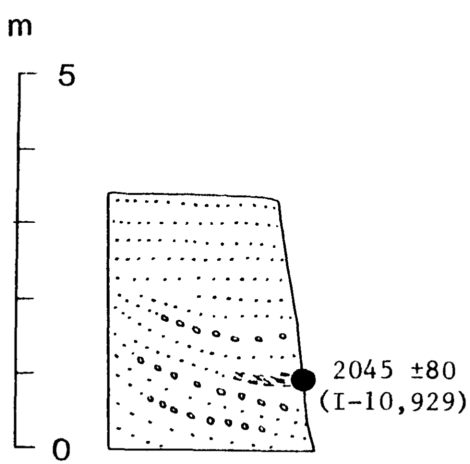
*Position projected from section measured elsewhere along cutbank.

Figure 4. Exposure AL-3. North-facing cutbank of Alatna River at south flank of Brooks Range. Section measured from river level.



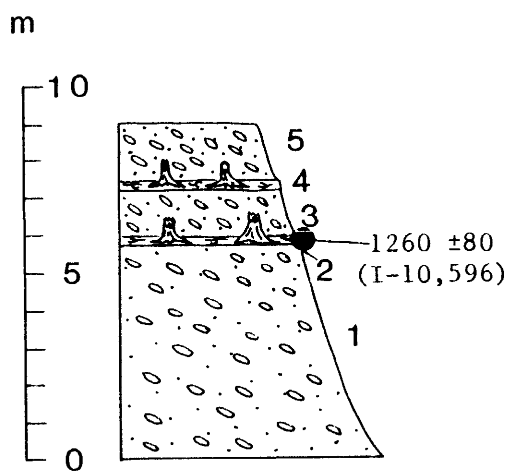
Unit	Thickness (m)	Description
2	0.2	PEAT AND SOD.
1	6.8	SILT AND SAND. Finely laminated silt in beds 3-6 cm thick alternating with 1-2 cm beds of sand. Mottled; gray (10YR 5/1) to dark yellowish brown (10YR 4/4). Grades downward into thicker (10-15 cm) mottled, frost-deformed micaceous silt with thin (1-2 cm) interbeds of fine sand. Silt becomes thicker, more micaceous, darker gray (N3), more organic, and possibly slightly clayey near base.

Figure 5. Exposure AL-4. Southwest-facing cutbank of Alatna River 3.5 km above mouth of Nahtuk River. Section measured from river level.



SAND (3.4 m). Interbedded, finely laminated fine and very fine sand; grades downward at 1.4 m depth into cross-bedded medium and coarse sand with granules.

Figure 6. Exposure AL-5. East-facing bank of Tobuk Creek 3 km above Iniakuk Lake. Section measured from river level



Unit	Thickness (m)	Description
5	1.5	FAN GRAVEL. Subangular pebbles and cobbles of blocky quartz and platy schist and phyllite in poorly sorted matrix of black platy phyllitic sand and granules.
4	0.1	FOREST BED. Peat containing rooted spruce stumps that project upward into unit 5.
3	1.4	FAN GRAVEL. As in unit 5.
2	0.1	FOREST BED. Thin (ca. 1 cm) peat beds with clayey partings, containing abundant spruce roots and stumps. Associated with slightly cross-bedded clayey to sandy overbank deposits.
1	6.0	FAN GRAVEL. As in unit 5.

Figure 7. Exposure AL-6. Northeast side Alatna River 8.5 km above Ram Creek. Datum is river level.

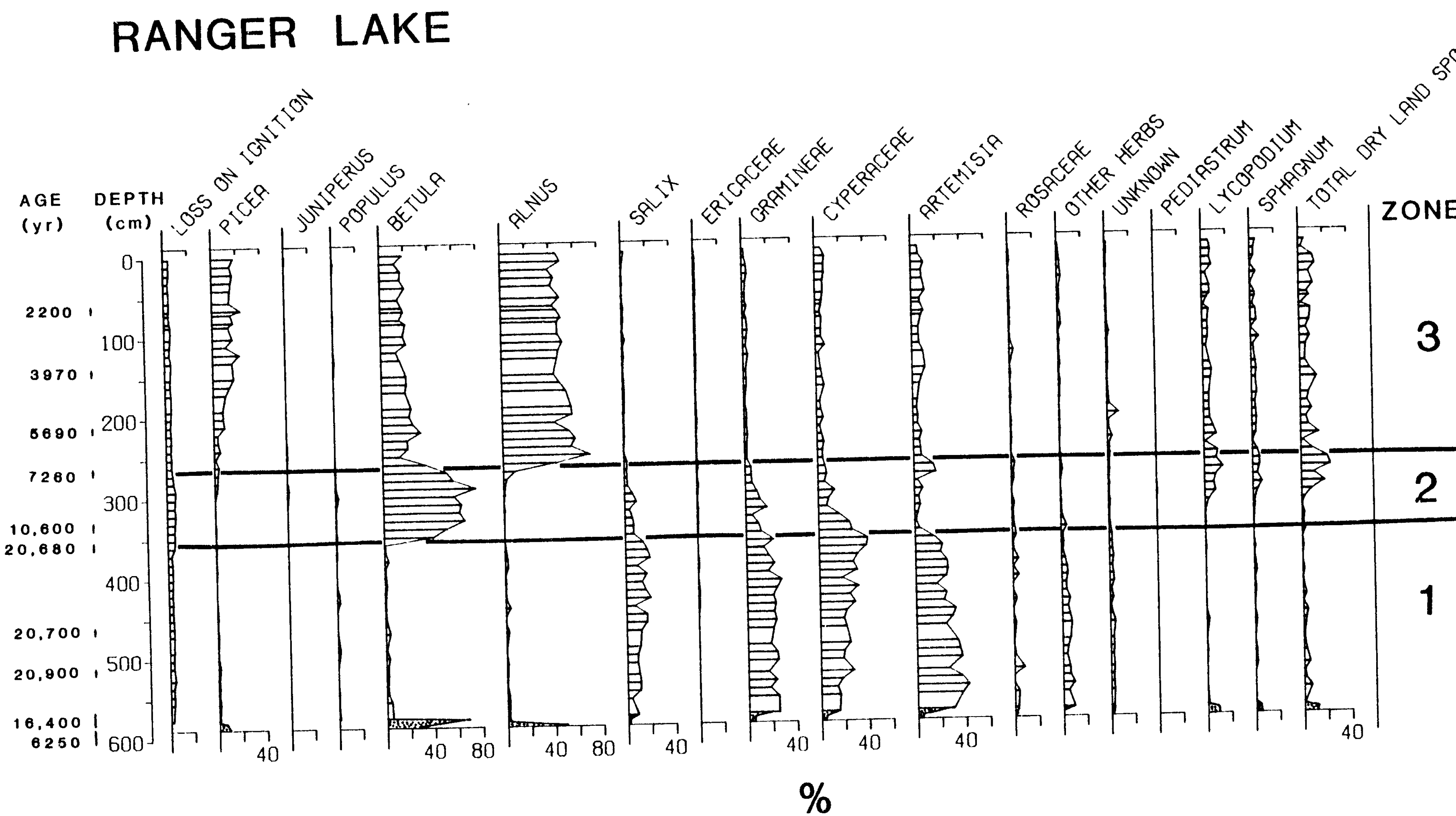


Figure 8. Ranger Lake pollen diagram.

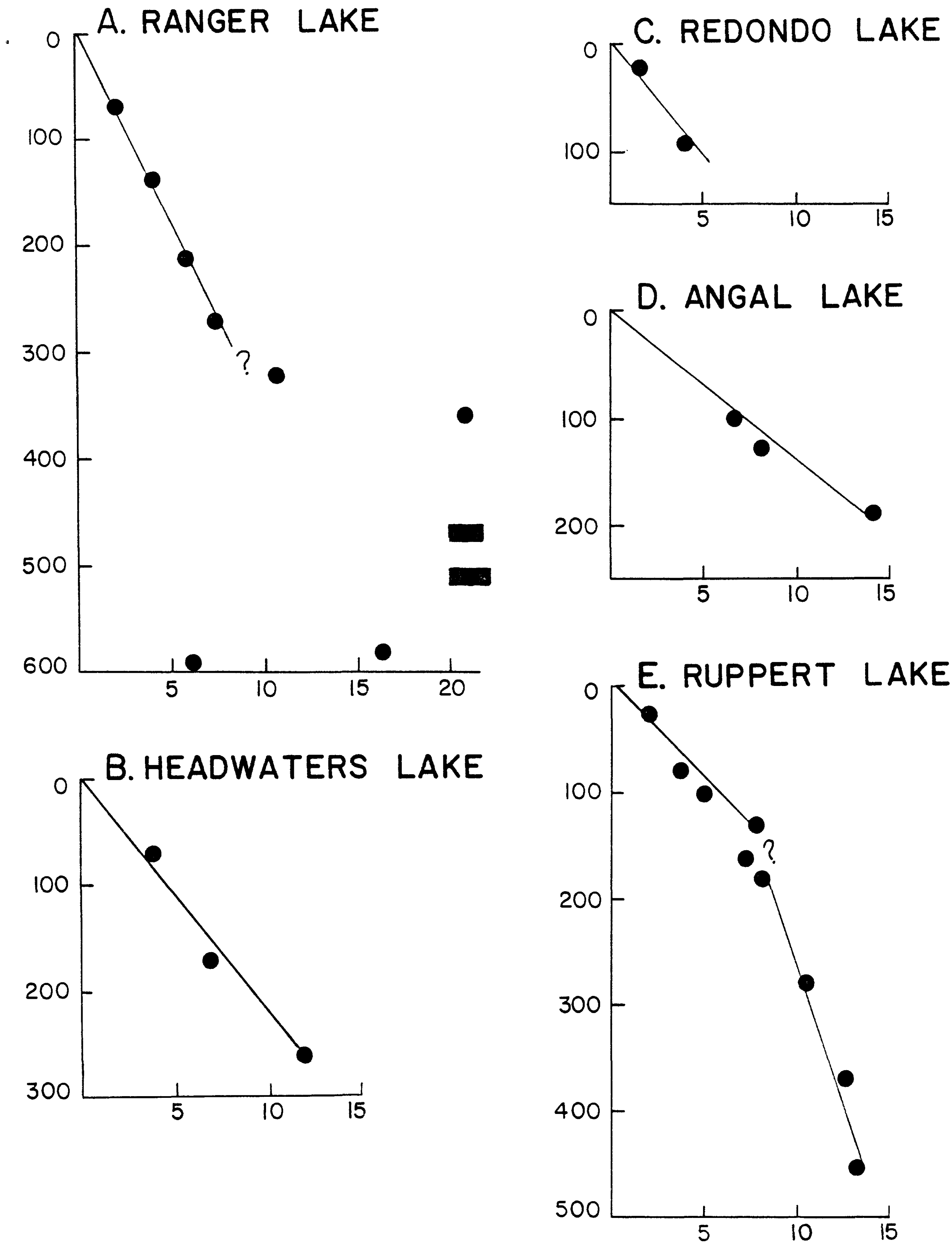


Figure 9. Sedimentation rates in lake-bottom cores from the Survey Pass quadrangle. Vertical scale is depth in centimeters; horizontal scale is thousands of radiocarbon years B.P. Size of dots approximates depth range of dated sample and analytic uncertainty in dating.

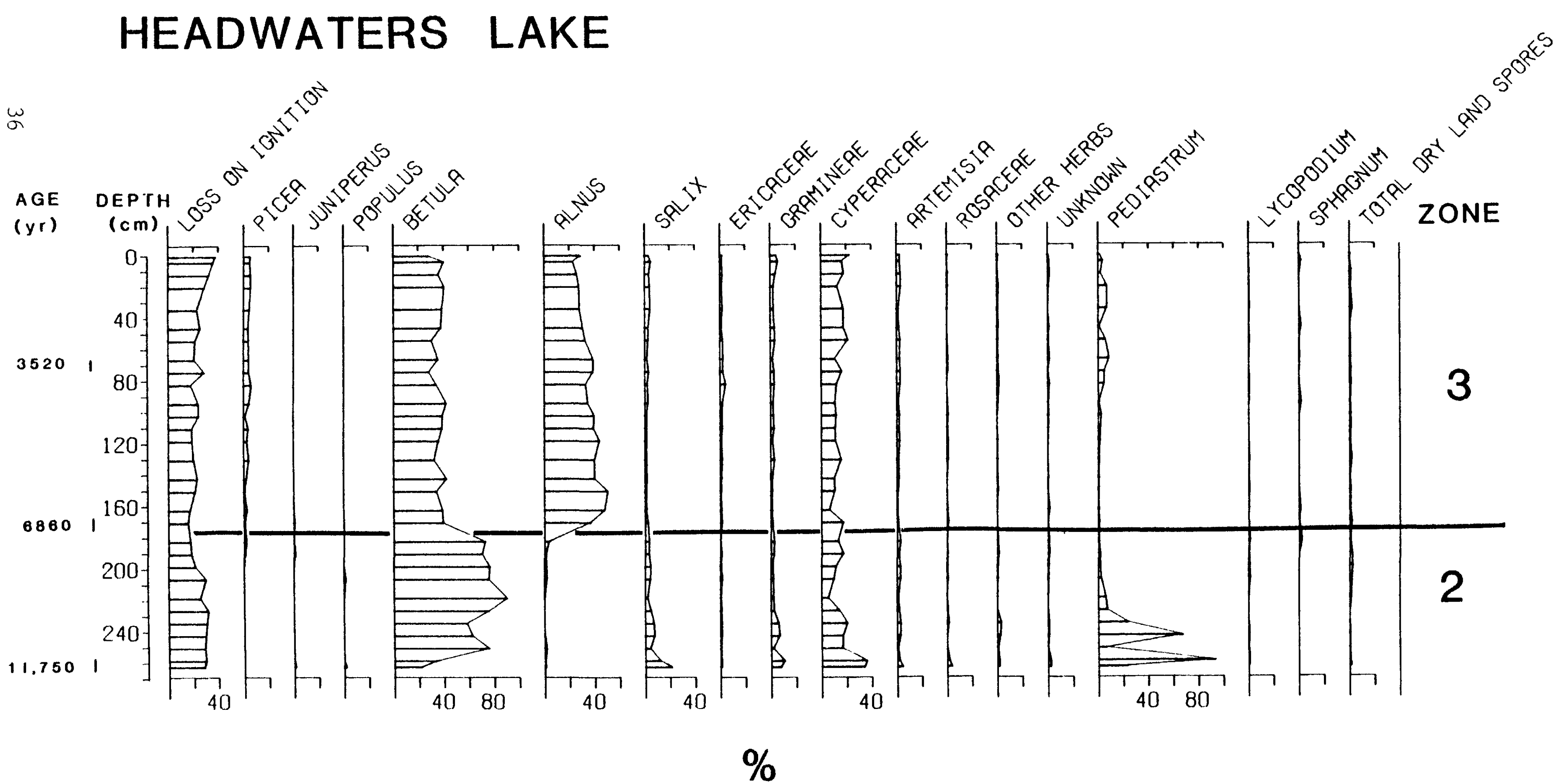


Figure 10. Headwaters Lake pollen diagram.

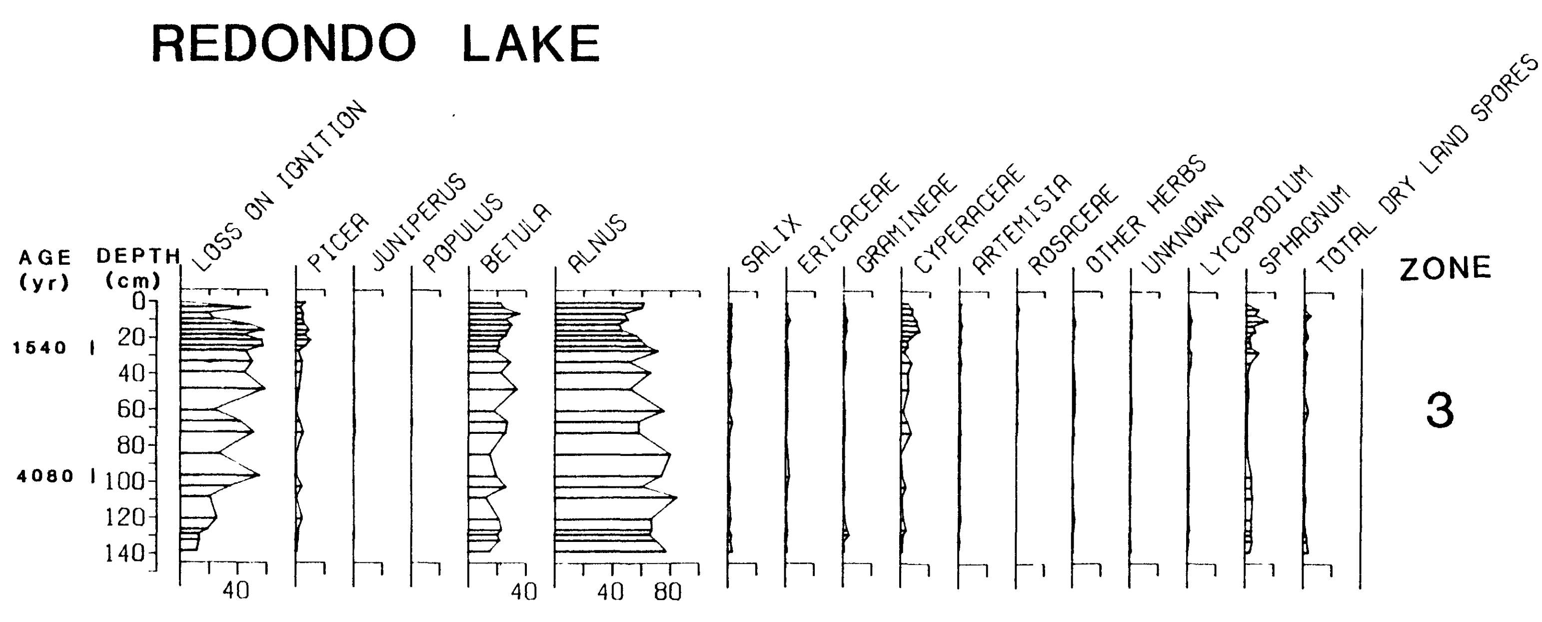
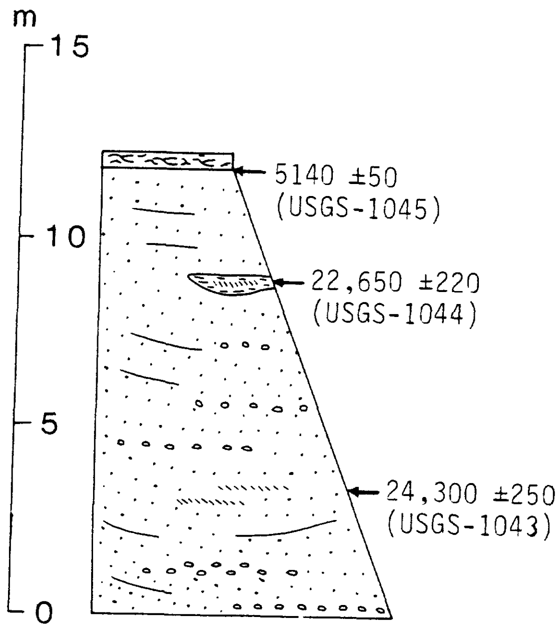


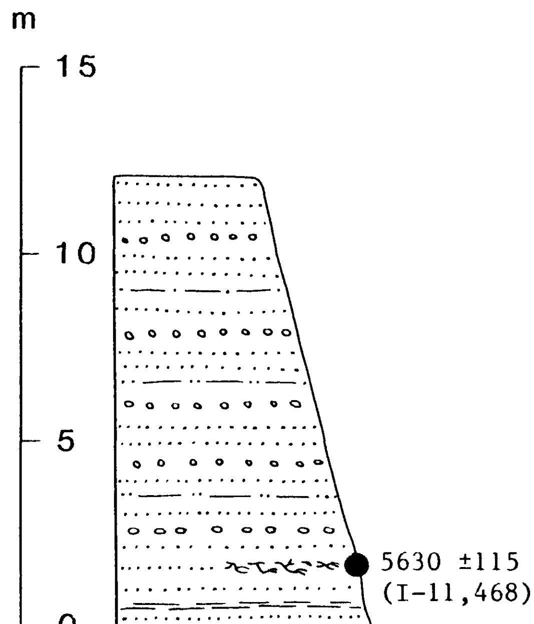
Figure 11. Redondo Lake pollen diagram.



PEAT CAP (0.5 m). Laminated fibrous brown peat.

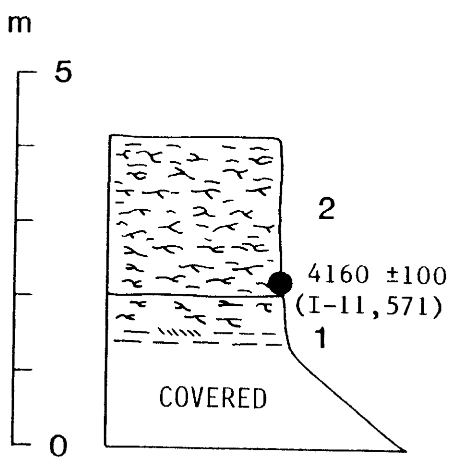
SAND (11.9 m). Horizontally bedded to slightly cross-bedded grey medium to silty fine sand; fining upward. Contains layers and lenses of sandy fine gravel (granules and small pebbles in coarse sand matrix) and scattered small pebbles. Upper 2.9 m oxidized dark brown (10 YR 4/3). Clay lens 3.0 m below upper contact.

Figure 12. Exposure KO-1. North side Kobuk River 14 km south of Walker Lake. Section measured from river level. From Hamilton (1982).



SAND AND FINE GRAVEL (12 m). Medium to coarse sand with micaceous silt along bedding-plane surfaces; interbedded with subrounded pebbles in matrix of coarse sand to platy granules. Contains lens of woody peat within gray micaceous fine sand near base.

Figure 13. Exposure KO-2. East-facing cutbank of Kaluluktok Creek 2 km above its mouth. Section measured from river level.



Unit	Thickness (m)	Description
2	2.05	PEAT. Sedge-grass-moss peat with very sparse small (1-5 mm diameter) twigs.
1	0.70	SILT AND PEAT. Very dark gray (10YR 3/1) silty peat, grading downward into slightly organic silt.

Figure 14. Exposure KO-3. South bank of thaw pond 2.5 km southeast from southeast corner of Walker Lake. Datum is pond surface.

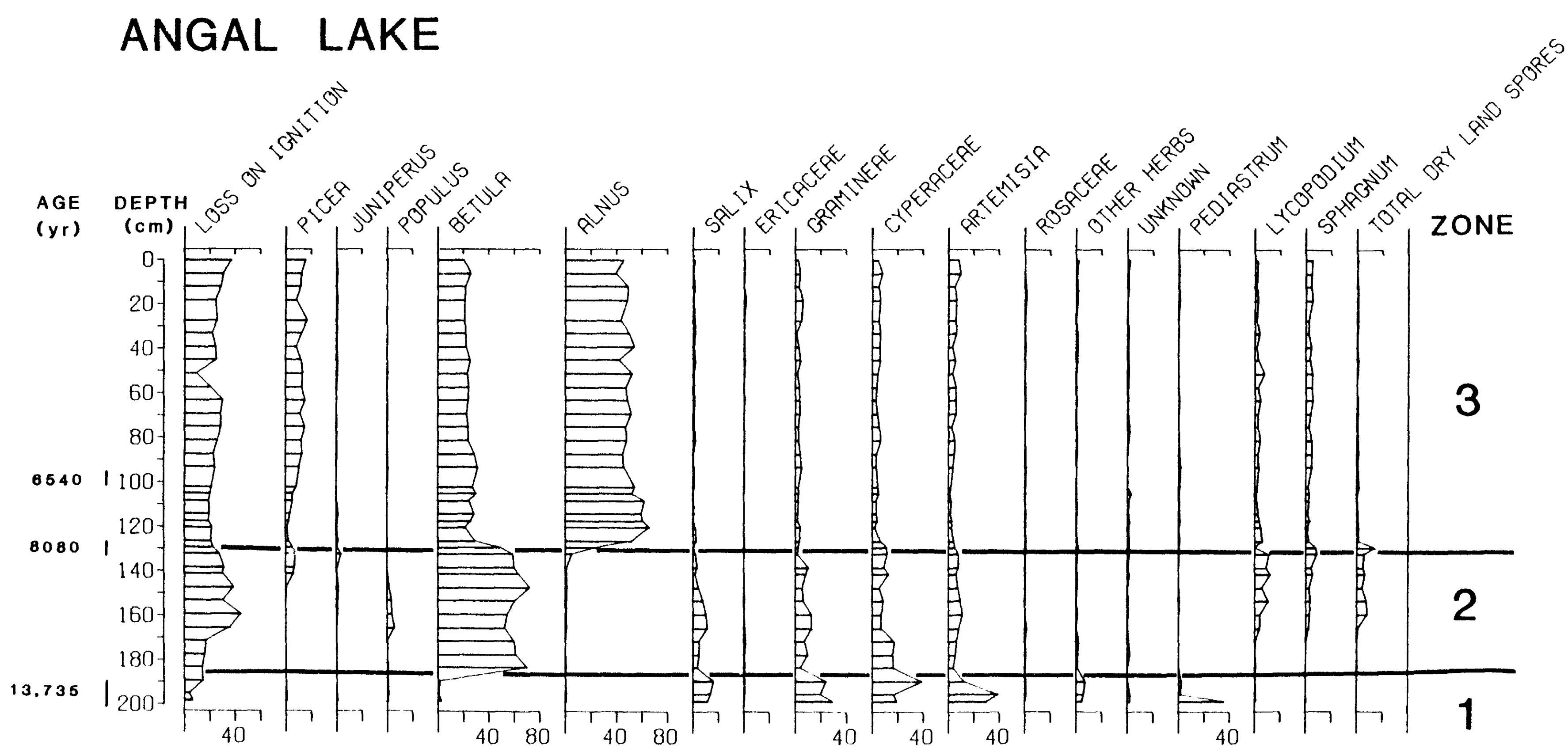


Figure 15. Pollen diagram, Angal Lake.

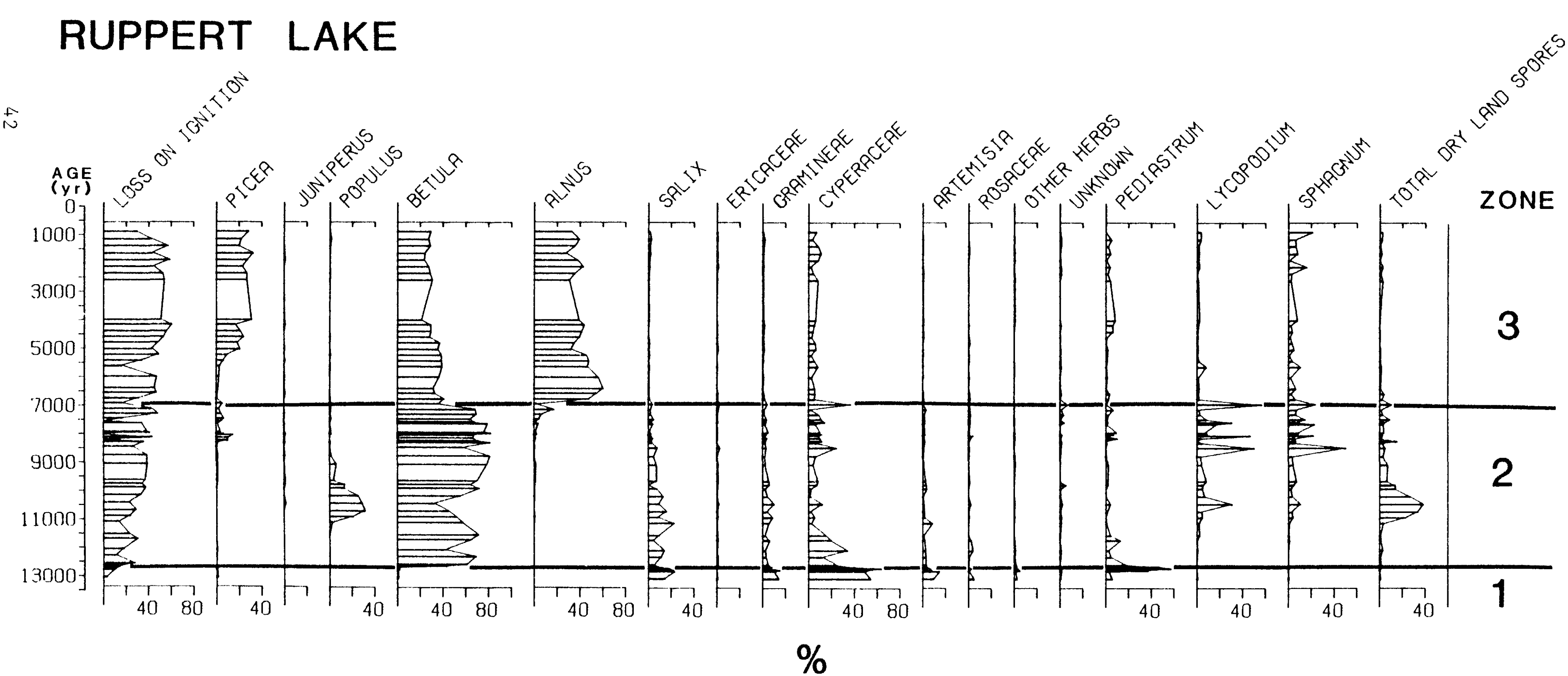
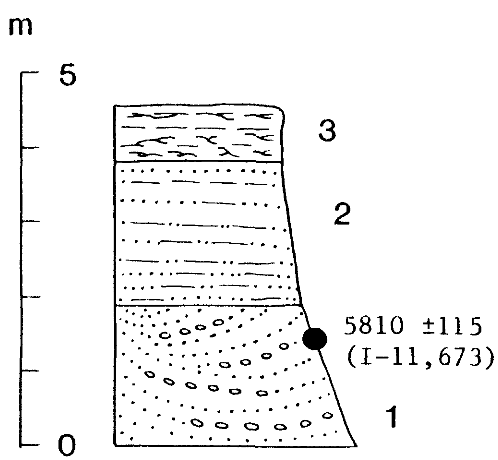
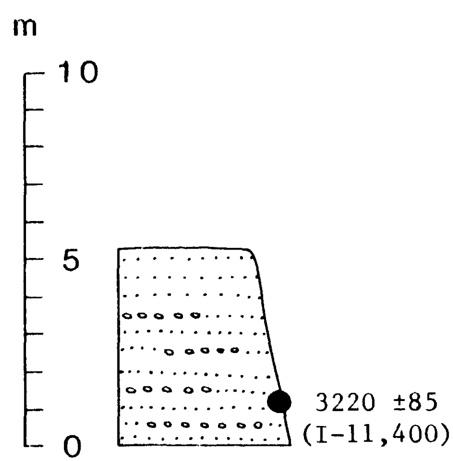


Figure 16. Pollen diagram, Ruppert Lake.



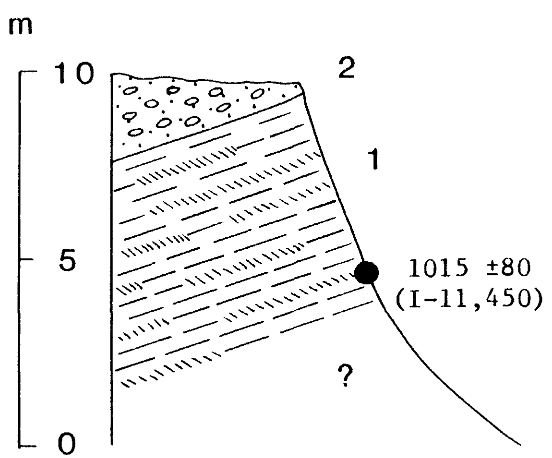
Unit	Thickness (m)	Description
3	0.75	PEAT WITH SILT. Brown laminated peat containing horizontal beds of gray micaceous silt.
2	1.85	SAND WITH SILT. Gray laminated silty fine sand with some thin (1-2 cm) layers of white medium to coarse sand.
1	1.95	SAND WITH GRANULES. White cross-bedded medium to coarse sand, with sparse granule layers, and with sparse subhorizontal 2-3 cm layers of gray, highly organic silty fine sand.

Figure 17. Exposure RE-1. West-facing cutbank of Reed River 12 km above Nutuvukti Lake. Section measured from river level.



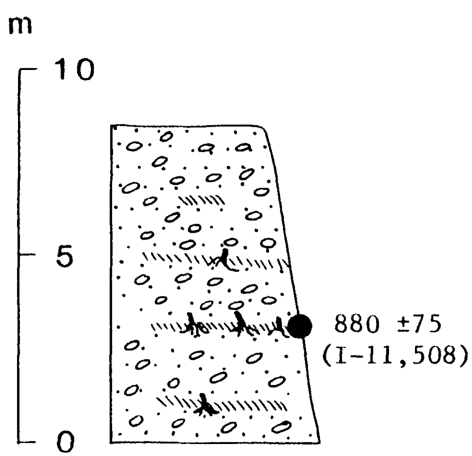
SAND (5.3 m). Horizontally bedded coarse sand with granules; grading upward into interbedded medium sand and gray silty fine sand. Upper 30 cm (active layer) is silty peaty sand.

Figure 18. Exposure RE-2. East-facing cutbank of Reed River 7 km north of Nutuvukti Lake. Section measured from river level.



Unit	Thickness (m)	Description
2	1+	GRAVEL. Platy alluvial-fan deposit.
1	6+	SILT. Gray (5Y 5/1) laminated clayey silt; laminae generally 1-2mm thick, parallel, and undeformed. Contains thin peaty layers. Base obscured by mudflows.

Figure 19. Exposure NK-1. South side of pingo on alluvial fan north of Noatak River 4 km above mouth of Anorat Creek. Measurements refer to exposed thickness only.



FAN GRAVEL (8.5 m). Subangular platy stones in matrix of black sand and phyllite chips; many stones imbricated, dipping into bank. Contains layers and lenses of finer grained sediment that contain rooted willow stumps.

Figure 20. West side Iyahuna Creek 13 km above its mouth. Section measured from creek level.

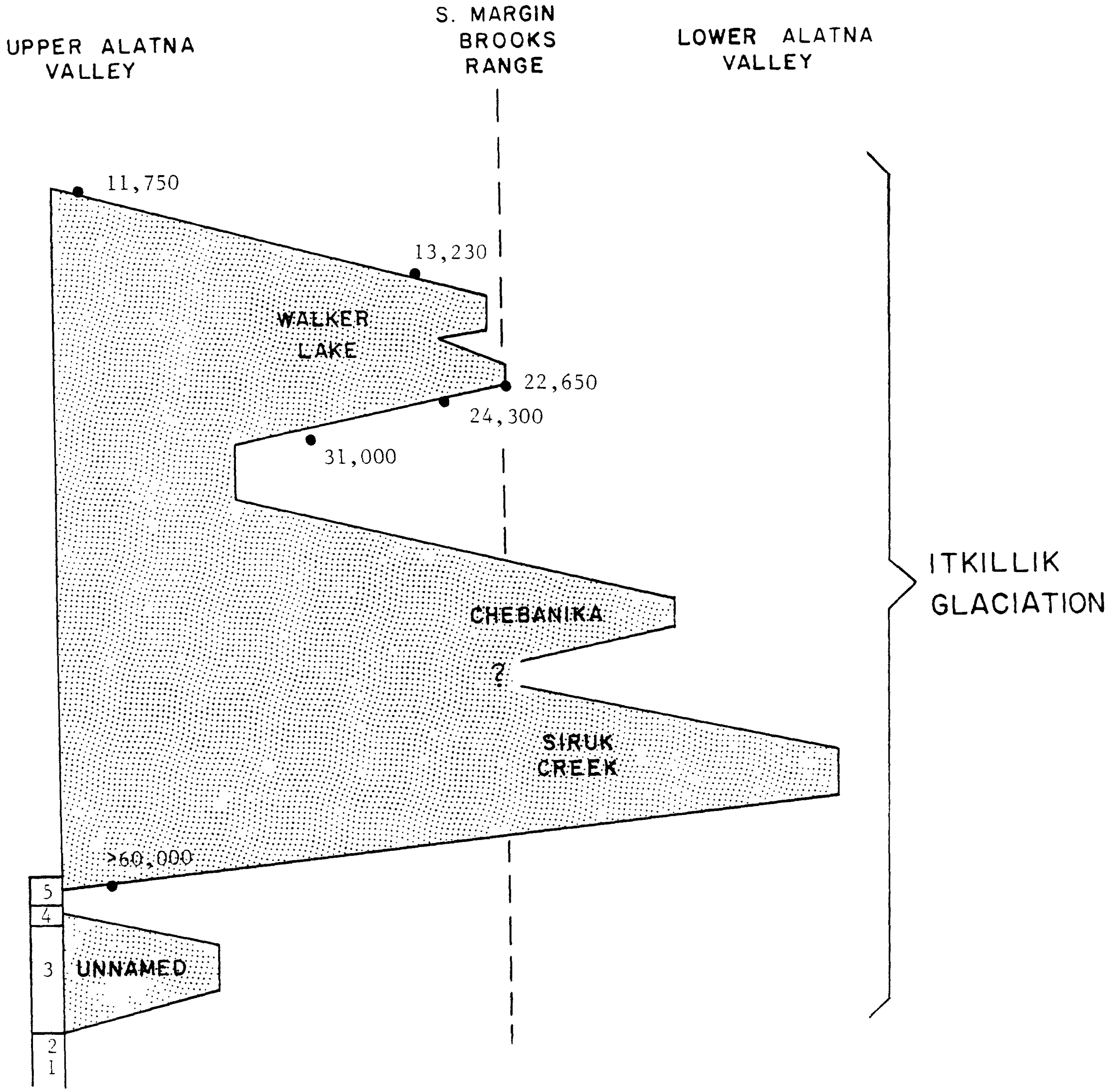


Figure 21. Sketch showing possible relations between glacial advances at head of Alatna Valley and at south margin of Brooks Range. Based on data from Fifteenmile bluff and Headwaters Lake (upper Alatna) and from Iniakuk and Walker lakes (range margin). Lower Alatna Valley from Hamilton (1969). Dates in radiocarbon years B.P. Numbers in column are depositional units at Fifteenmile bluff.