PALEOSEISMICITY OF THE COOK INLET REGION, ALASKA: EVIDENCE FROM PEAT STRATIGRAPHY IN TURNAGAIN AND KNIK ARMS

By R.A. Combellick

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Cover: *Portage area, Seward Highway, and upper Turnagain Arm in 1984, looking northwest. The great Alaska earthquake of 1964 caused this area to subside about 7.9 ft (2.4 m). Extensive tidal flooding resulted.*

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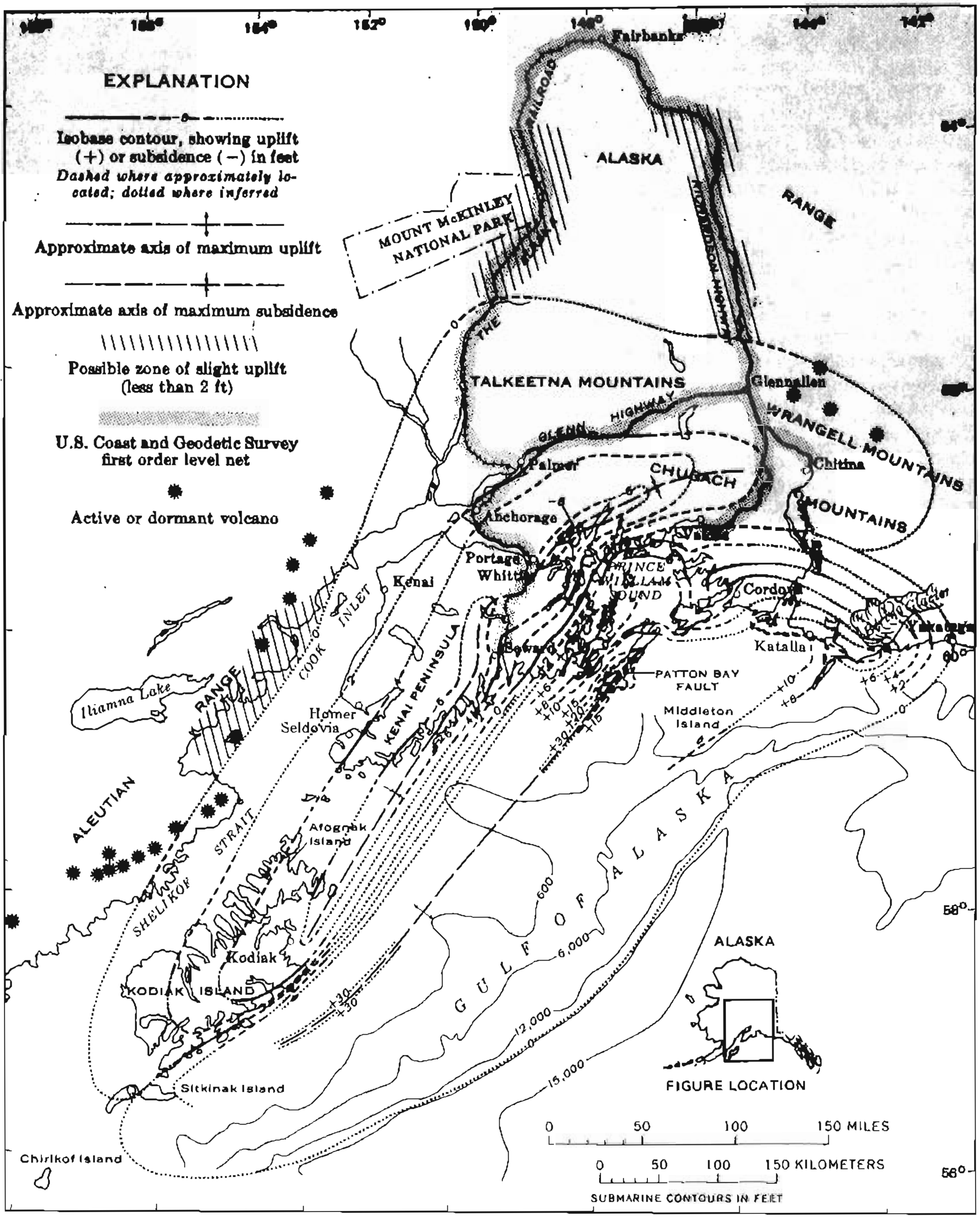

Figure 1. *Tectonic deformation associated with the great Alaska earthquake of March 27, 1964 (modified from Plafker, 1969).*

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ABSTRACT

A record of prehistoric subsidence events, possibly associated with 1964-style major earthquakes, is preserved in estuarine sediments of upper Cook Inlet. Borehole drilling and continuous sampling at nine locations in Turnagain and Knik Arms confirm that multiple peat layers were submerged below present high-tide level and buried by intertidal silt and clay during repeated subsidence events. The resulting peat-silt couplets provide a record of repeated supratidal vegetation growth, subsidence, and rapid burial. Radiocarbon dating of these peat layers provides maximum ages of the subsidence events that caused burial of the peats and allows calculation of long-term submergence rates. Although none of the borehole samples exhibit conclusive evidence that major ground shaking accompanied peat submergence and burial, repeated sudden tectonic lowering was the most likely mechanism for producing the observed peat-silt stratigraphy.

Because of uncertainties in some of the radiocarbon-age data and incomplete correlations with data from other studies in the region, it is not yet possible to construct a reliable regional chronology of events. However, the number of buried peats suggests a minimum of six to eight subsidence events during the past 4,200 radiocarbon yr. This translates to a maximum average recurrence interval of about 525 to 700 yr (590 to 780 yr for about the past 4,700 calendar yr, if calculated on the basis of tree-ring calibrated ages). In upper Turnagain Arm, three buried peat layers that date to within 100 yr of each other suggest that recurrence intervals may have been as short as several decades. At five locations in both Turnagain and Knik Arms, radiocarbon ages of shallow peat layers suggest that the most recent major subsidence event prior to the 1964 earthquake was at or before about 500 y.a. The data indicate net submergence rates of 0.23 to 0.30 cm/yr in upper Turnagain Arm for the past 4,200 radiocarbon yr and 0.13 to 0.17 cm/yr in upper Knik Arm for the past 2,100 radiocarbon yr.

INTRODUCTION

Following the catastrophic great Alaska earthquake of March 27, 1964, geoscientists began to address the question of how soon another damaging earthquake is likely to strike this area of southcentral Alaska, home to nearly 60 percent of the state's 500,000 residents. Seismic monitoring of smaller events has allowed detailed mapping of the Benioff zone and megathrust-interplate boundary and has improved estimates of earthquake-recurrence intervals based on analyses of slip rates and strain release. However, recurrence estimates of great earthquakes based on these historic data must be regarded as tentative because the instrumental record extends back only to about the turn of the century, and the 1964 event is the only known great earthquake in this segment of the Aleutian megathrust during historic time. A reliable geologic record of major prehistoric subduction-zone earthquakes in this region for the past several thousand years would complement the historic record and would greatly improve the credibility of recurrence estimates. A chronology of these events would also provide a measure of variability from the average recurrence interval.

The 1964 earthquake caused vertical ground displacements over a 100,000-mi^2 (260,000-km^2) area[1] (fig. 1). This vertical deformation consisted of an asymmetric uplift zone parallel to the arc and an adjacent landward zone of subsidence (Plafker, 1969). Geologic evidence indicates that similar deformation occurred during the late Holocene, or past 5,000 yr. A total of 131 ft (40 m) of uplift occurred at Middleton Island (fig. 1) during at least five distinct uplift pulses during the last 4,470 yr, based on radiocarbon ages of driftwood and peat on marine uplifted terraces (Plafker and Rubin, 1967). This record represents a linear uplift rate of about 1 cm/yr. A terrace is now forming on Middleton Island due to 10.8 ft (3.3 m) of 1964 uplift. Based on the known ages of uplifted terraces, the recurrence interval for megathrust earthquakes like the 1964 earthquake is 500 to 1,350 yr (Plafker and Rubin, 1967).

Knik and Turnagain Arms, located at the northeastern limit of Cook Inlet in the subsidence zone of the 1964 earthquake (fig. 1), are likely basins in which to find sedimentary evidence of subsidence events associated with major earthquakes. Based on post-1964 survey data,

[1]In this report, most measurements are reported in English units followed by metric conversions in parentheses. English units were used because measurement of sample depths in feet was more convenient with the drilling and sampling equipment available for this project. However, the results of certain calculations like sedimentation rates are reported in metric units for ease of comparison with similar results reported in the literature.

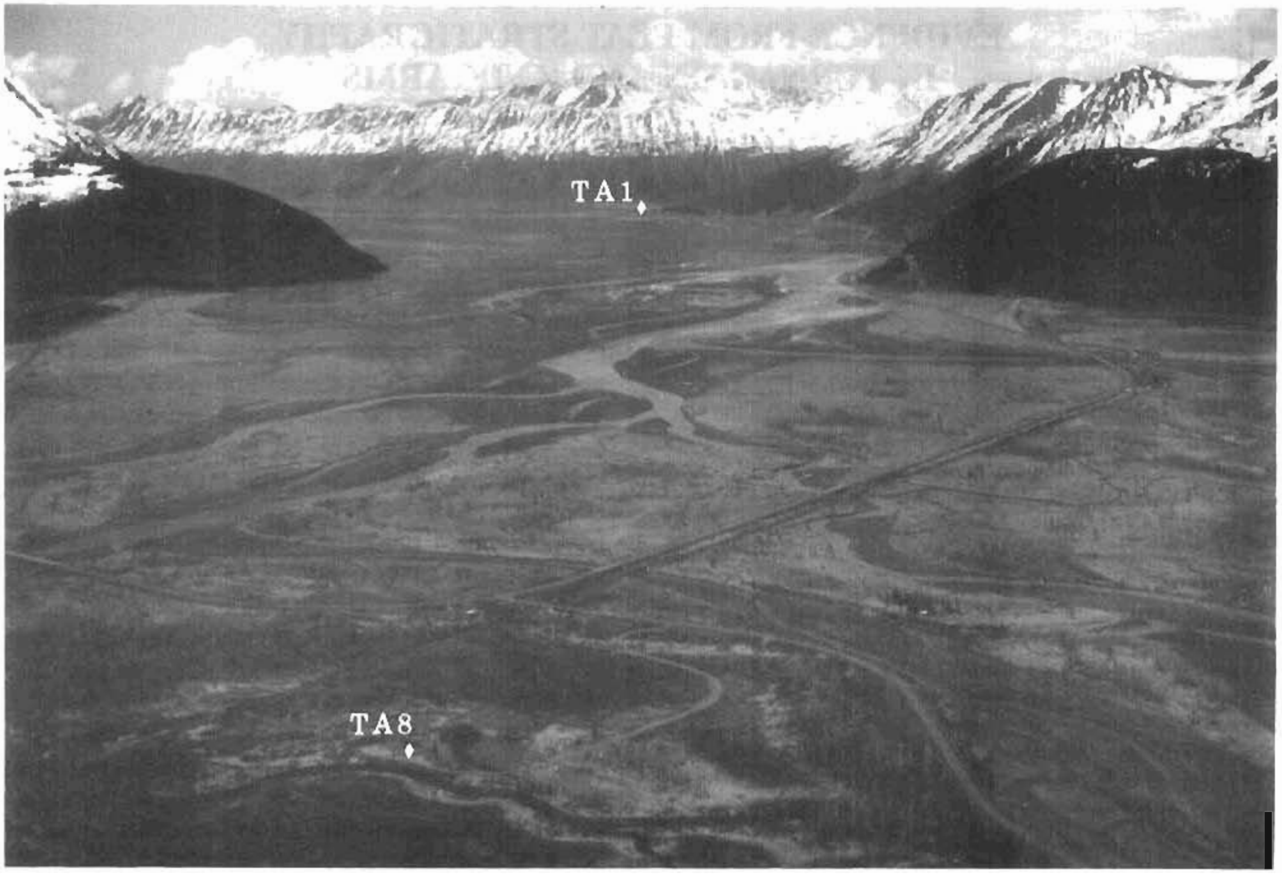

Figure 2. *Portage area, Seward Highway, and upper Turnagain Arm in 1984, looking northwest. The great Alaska earthquake of 1964 caused this area to subside about 7.9 ft (2.4 m). Extensive tidal flooding resulted. The influx of salt water killed most trees shown in the central part of the photograph and caused rapid deposition of silt on the submerged flat. Silt deposition and about 1.8 ft (0.55 m) of postseismic rebound have restored this part of the flat to predominantly supratidal conditions. Locations of boreholes at Girdwood (TA1) and Portage (TA8) are identified in the photo.*

the Knik Arm tidal flats subsided at least 2 ft (0.6 m) during the 1964 Alaska earthquake (Foster and Karlstrom, 1967; Plafker, 1969). Subsidence was due to tectonic lowering of the crust and to compaction of unconsolidated materials underneath the tidal flats. Extensive tidal flooding resulted, depositing intertidal silts over the 1964 soil horizon in at least the southwestern half of the flats.

A similar post-1964 cycle (subsidence, saltwater incursion, vegetation kill, intertidal deposition, and revegetation) has been documented for the upper part of Turnagain Arm southeast of Anchorage (Ovenshine and others, 1976; fig. 2). This cycle for upper Turnagain Arm has restored the sediment surface to its pre-earthquake level (Kachadoorian and Ovenshine, 1984; Bartsch-Winkler and Garrow, 1982). In 1964, this region subsided about 7.9 ft (2.4 m), although as much as 1.8 ft (0.55 m) of rebound occurred following the earthquake (Brown and others, 1977). About 5.2 ft (1.6 m) of intertidal silt has accumulated on the 1964 soil horizon (fig. 3), which is about the expected amount of deposition for the net subsidence of the region.

In 1985, borehole drilling at two Turnagain Arm sites, one at Girdwood and one at Portage, confirmed the presence of multiple organic layers interbedded with tidal deposits below the 1964 soil horizon. Organic layers (peat or organic silt) are each overlain by 2 to 10 ft (0.6 to 3 m) of fine silty sand, sandy silt, and clayey silt. Many peat layers have sharp upper contacts and are overlain by organic-poor intertidal sediments. This stratigraphy is interpreted to represent episodic prehistoric subsidence in Turnagain Arm similar to that resulting from the 1964 great earthquake (Combellick, 1986). Atwater (1987) interpreted similar stratigraphy of estuarine deposits in

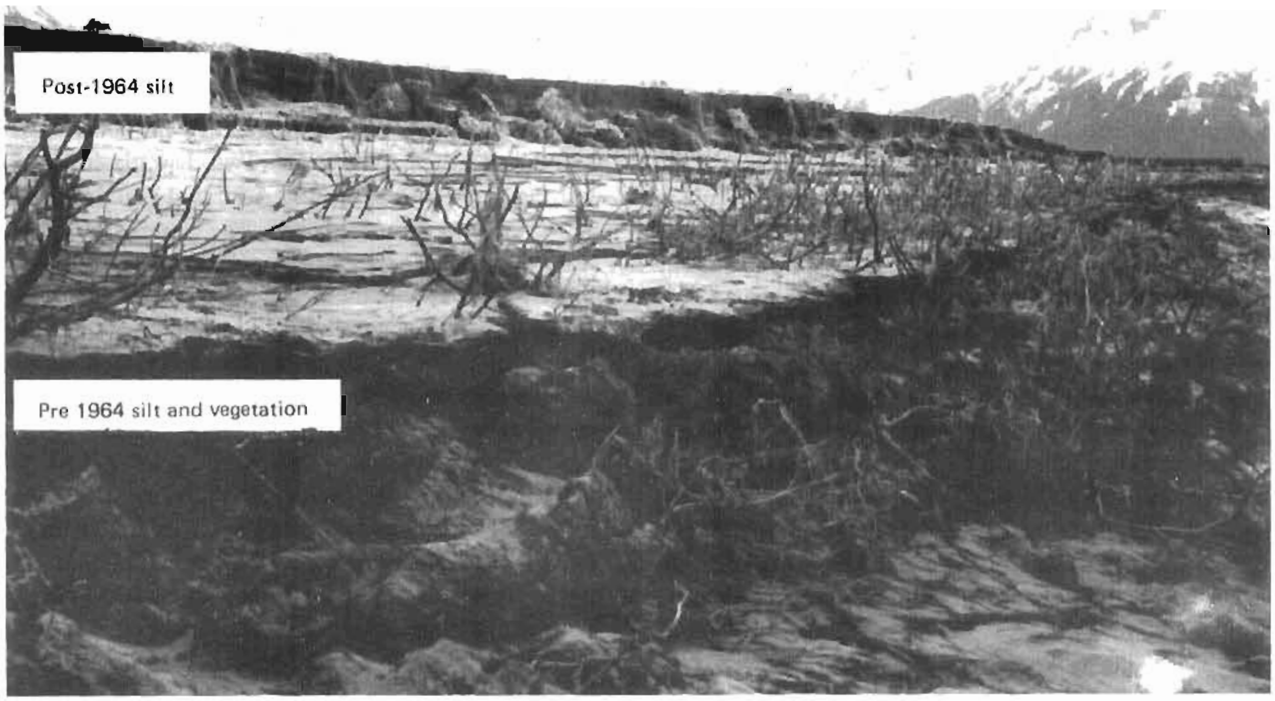

Figure 3. *Vegetation and peat layer submerged during the great Alaska earthquake of 1964 and buried beneath approximately 5.2 ft (1.6 m) of post-1964 intertidal silt. Part of the overlying silt layer has been removed by erosion. Exposure is in a tidal channel near Girdwood in upper Turnagain Arm (1984 photograph).*

Table 1. *Radiocarbon ages of samples from two boreholes drilled near Girdwood (TA-B1) and Portage (TA-B8) in upper Turnagain Arm in 1985*

Borehole	Sample depth	Laboratory number	Material dated	Radiocarbon age (yr B.P.)	Calibrated 1σ age range (yr B.P.)[a]
TA-B1	10.0 ft (3.05 m)	GX-11346	Sedge peat	1,935±150	1,710-2,059
TA-B1	20.0 ft (6.10 m)	GX-11347	Wood-sedge peat	2,735±145	2,749-2,989
TA-B1	22.0 ft (6.71 m)	GX-11348	Wood-sedge peat	2,660±100	2,739-2,859
TA-B1	25.5 ft (7.77 m)	GX-11349	Wood-sedge peat	3,365±155	3,459-3,829
TA-B8	16.0 ft (4.88 m)	GX-12199	Sedge peat	1,320±340	930-1,550
TA-B8	21.2 ft (6.46 m)	GX-11351	Sedge peat	1,915±130	1,710-2,039
TA-B8	25.0 ft (7.62 m)	GX-11352	Organic silt	3,205±195	3,219-3,683
TA-B8	30.2 ft (9.21 m)	GX-11353	Woody peat	2,635±145	2,549-2,869
TA-B8	do.	GX-11740	do. (Same sample)	2,850±150	2,789-3,209
Weighted average of above two analyses				2,739±104	2,759-2,949
TA-B8	35.2 ft (10.73 m)	GX-11354	Organic silty clay	3,790±175	3,925-4,429
TA-B8	41.5 ft (12.65 m)	GX-11355	Plant fragments	4,240±195	4,529-5,041

[a]Calibration to calendar years B.P. is based on data sets for tree rings of known ages (Linick and others, 1985, 1986; Kromer and others, 1986; Pearson and Stuiver, 1986; Pearson and others, 1986; and Stuiver and Pearson, 1986).

southwestern Washington as evidence of repeated coseismic subsidence in the Cascadia Subduction Zone.

Table 1 reports the radiocarbon ages of organic layers sampled in 1985. Sampling revealed four peat layers below the 1964 peat to a depth of 26 ft (8 m) at the Girdwood site. Radiocarbon ages of these peats indicate four pre-1964 subsidence events during the past 3.5 ka. At the Portage site, organic layers to depths up to 41 ft (12.5 m) represent five pre-1964 subsidence events during the past 4.5 ka. Because sampling at these sites was not continuous, there may be undiscovered peat layers representing additional subsidence events during the past 4.5 ka. Bartsch-Winkler and Schmoll (1987) document buried peat layers with different radiocarbon ages at numerous other locations in the intertidal zone of upper Cook Inlet.

The goal of the current project was to document as completely as possible late-Holocene sedimentation and coseismic subsidence events in two separate basins. The method used to accomplish this goal was to drill boreholes with continuous sampling at the same sites drilled at Girdwood and Portage in 1985 and at new sites along Knik Arm. In most areas of the tidal flat and coastal marsh, drilling is necessary to sample sediments and peats deeper than about 6 ft (2 m) because bluff exposures are limited.

This study has confirmed that at least a partial record of prehistoric subsidence events is preserved at the drilled locations in both estuaries. Although a complete record of all observed peats has not yet appeared at any single borehole location, radiocarbon ages of several peats correlate reasonably well between two or more borehole locations and with terrace ages on Middleton Island in the 1964 uplift zone.

FIELD PROGRAM

EQUIPMENT AND LOGISTICS

Boreholes were drilled at nine locations on vegetated supratidal flats, including sites at Girdwood and Portage along Turnagain Arm in September 1988 and at Goose Bay and Palmer Hay Flats along Knik Arm in January and February 1989 (fig. 4). All boreholes were drilled with a truck- or track-mounted CME-75 drill rig operated by the Alaska Department of Transportation and Public Facilities (fig. 5). The 40,000-lb reaction load of this drill rig allowed the sampler to be pushed into the sediment without the use of a hammer, reducing artificial sample compaction and disturbance.

SAMPLE COLLECTION

Samples were collected using a continuous-sample-tube system in conjunction with the hollow-stem auger (fig. 6). The sampler consisted of a 5-ft-long (1.5-m), 3.25-in. (8.3-cm) inside diameter split steel barrel, which was connected to the drill rig with non-rotating rods through the hollow auger. Two clear plastic liners, each 2.5 ft (76 cm) long and 2.5 in. (6.4 cm) diam were placed end-to-end in the barrel. The cutting head of the sampler extended a short distance ahead of the lead auger, which rotated around the sampler. Drilling and sampling occurred simultaneously in 5-ft (1.5-m) intervals. Samples were retrieved by lifting the sampler to the surface through the hollow-stem auger, disassembling the split barrel, and removing the filled sample liners.

As the full sample liners were retrieved from the sampler, the ends were immediately covered with plastic caps, sealed with tape, and labeled with sample number, depth, and up direction. Sample material caught in the cutting head was retained in sealed plastic bags. A generalized sample log was prepared in the field in conjunction with the drilling log (Combellick, 1990, appendix A). Detailed sample logging was postponed until the samples could be opened in the laboratory.

Successful sample recovery ranged from 78 to 94 percent. Two circumstances resulted in occasional incomplete sample recovery. First, when very firm material—such as dense peat, frozen soil, or a large pebble—had formed over less-firm material, it sometimes plugged the cutting head and forced the softer material under it to the outside of the sample barrel as the sampler penetrated farther. Second, while retrieving loose, wet sand or silt with no clay for cohesion, part of the sample occasionally flowed out of the sampler.

Samples were placed upright in crates for transportation and stored in the crates until they were opened in the laboratory.

Elevation of the ground surface relative to mean higher high water (MHHW) at each borehole location was calculated from the surveyed ground elevation above mean sea level (MSL) and published sea-level statistics from the nearest tide-gage stations (U.S. Department of Commerce, 1988). The level of borehole samples relative to MHHW must be known to show that the subsurface peat layers are now below the minimum elevation at which they could have formed and to document the minimum amount of subsidence and sedimentation that has occurred since their submergence and burial.

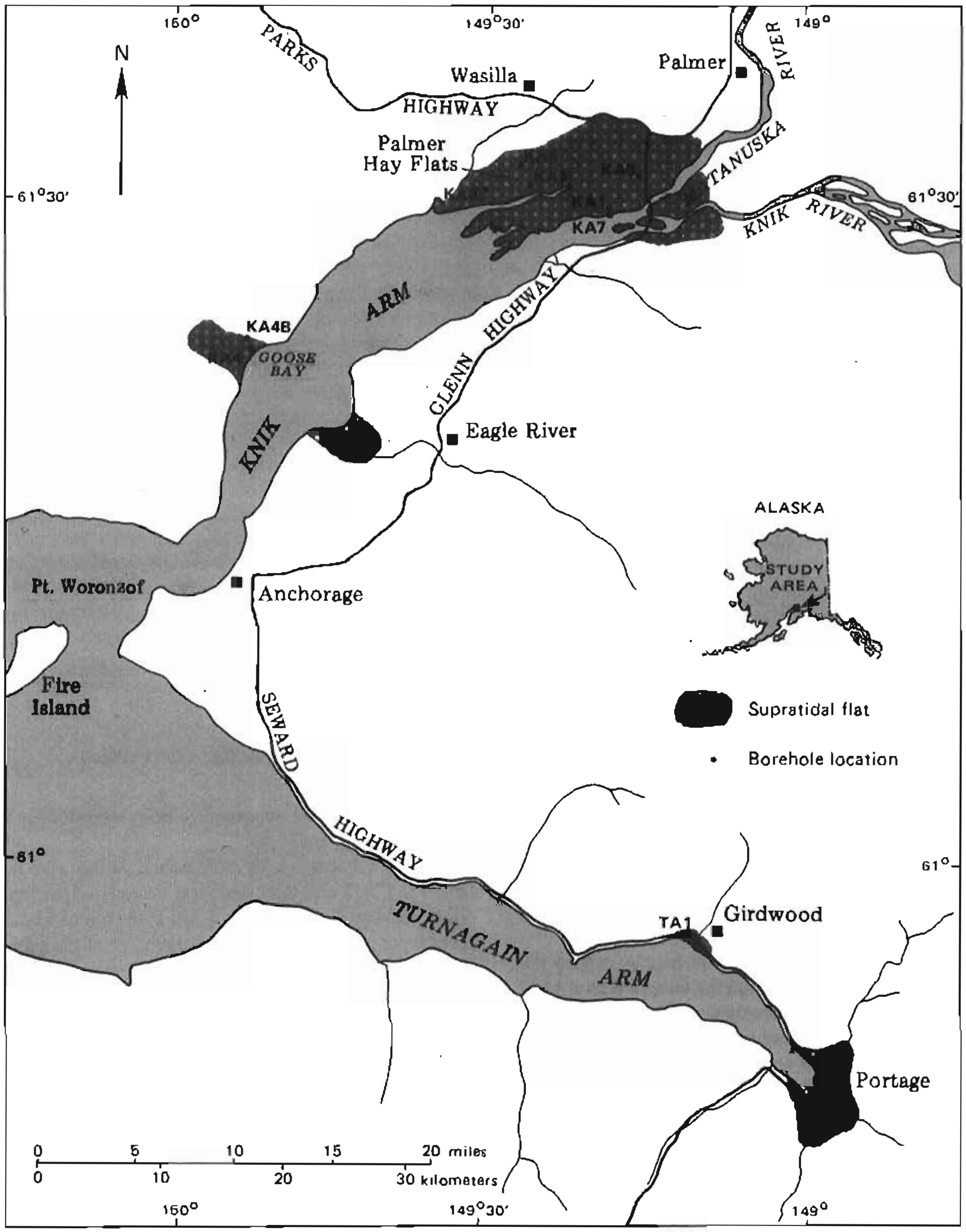

Figure 4. *Location map of region near Anchorage, Alaska, showing locations of boreholes drilled on supratidal flats in 1988 and 1989.*

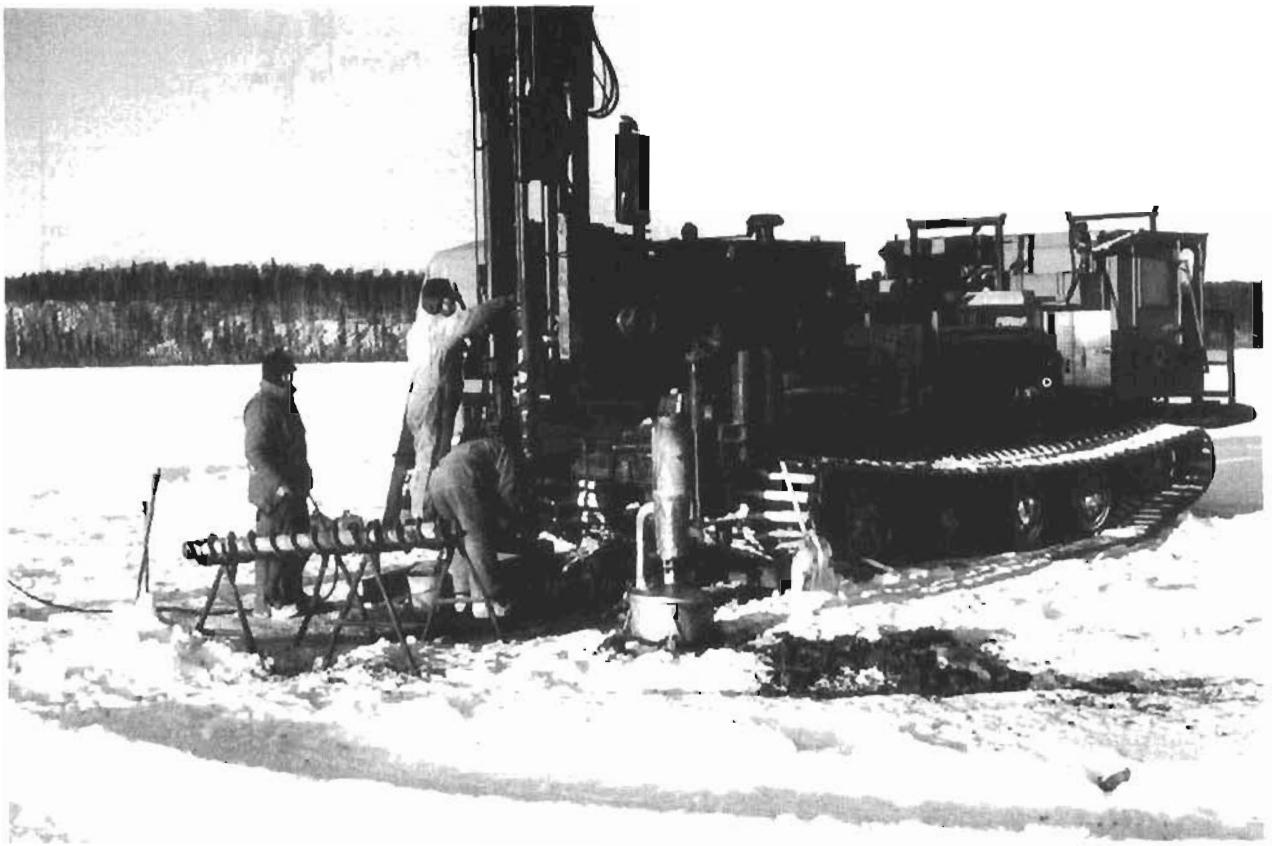

Figure 5. *Borehole drilling at site KA4 near Goose Bay in January 1989 (see fig. 4 for location).*

LABORATORY ANALYSES

CORE LOGGING AND SUBSAMPLING

Each core sample was split in half by cutting the plastic liner and slicing through the sample with a sharp knife or thin wire. Each sample was kept in its semicircular liner halves, which served as trays for handling and storage. After cleaning and smoothing the surface, the sample was described in detail (appendix A) and photographed with high-resolution black-and-white film. A tape measure was placed by each sample and registered to the top of the sample so that photographs could be keyed directly to sample logs.

Subsamples for radiocarbon dating and granulometric analyses were collected from one side of the split samples. Intact (archive) halves and the remainder of the subsampled halves were covered by plastic wrap and stored in core boxes for possible future use. Exact depths of all subsamples were recorded in the sample log (appendix A).

Peat subsamples for radiocarbon dating were normally 0.1 ft (3 cm) thick and were taken from the top of each peat layer. A radiocarbon age at the top of a buried peat layer provides a close maximum age of the ground surface at time of burial. If the peat layer was less than 0.1 ft thick, the entire layer was removed from the sample half to ensure sufficient quantity for dating. A total of 43 subsamples was collected from the nine boreholes for possible radiocarbon dating.

Some subsamples collected for radiocarbon dating were composed of organic silt or disseminated fine organic matter that may represent relict peat layers or may contain reworked or transported organics. These samples were collected primarily to obtain ages for calculation of sedimentation rates in portions of cores that were devoid of peats. Radiocarbon ages obtained from these samples are regarded with some suspicion because they may be contaminated by older detrital organic material.

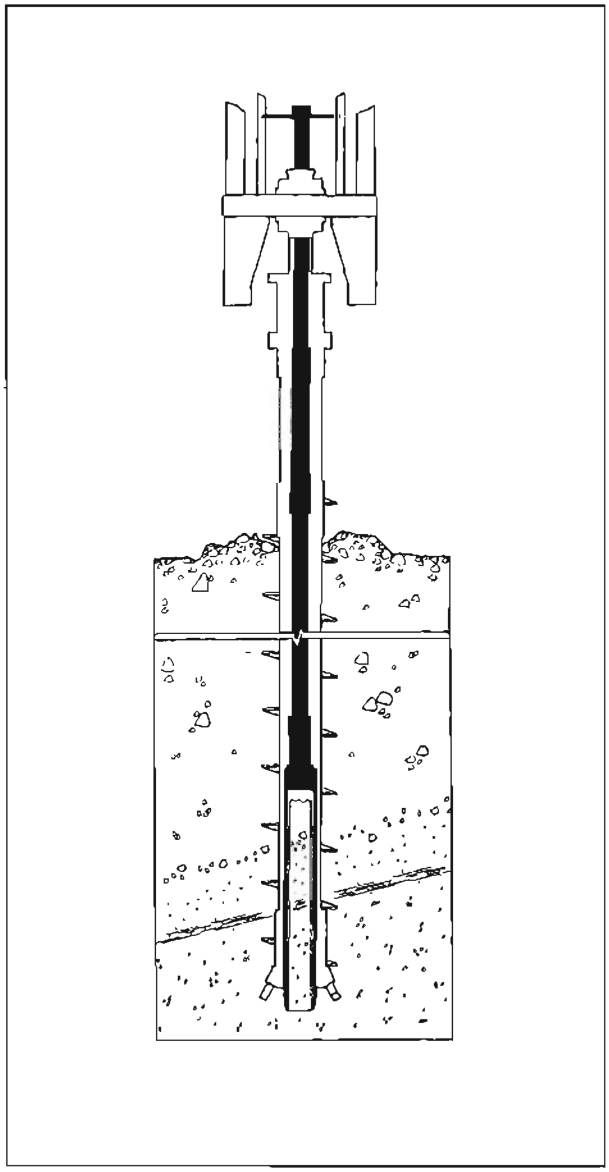

Figure 6. *Cross section of hollow-stem auger with continuous-sampling system (solid black). Drilling and sampling occur simultaneously in 5-ft (1.5-m) increments as the non-rotating sample barrel pushes ahead of the auger. Diagram provided by Central Mining Equipment.*

A total of 55 subsamples was collected for grain-size analyses of distinct stratigraphic units as an aid to interpreting depositional processes. These subsamples were also normally 0.1 ft (3 cm) thick.

Following completion of logging, photography, and subsampling, each core-sample half was wrapped in clear plastic and stored in a core box for possible future use.

RADIOCARBON DATING

Subsamples collected for radiocarbon dating were oven dried, weighed, and examined macroscopically for contaminants, such as roots of younger plants or transported older organics, which were removed. Dry subsample weights ranged from 3.6 g for low-ash peat to 149 g for silt with disseminated organic matter.

Of 43 organic subsamples collected from the cores, 38 were submitted to Geochron Laboratories Division, Krueger Enterprises, Inc., for radiocarbon dating. Three of the samples required acceleration mass spectrometry because they contained too little carbon for conventional gas-proportional age determination. Two additional samples, KA7-3.0 and KA7-3.5, collected along the Matanuska River bank at location KA7 (fig. 4) were also submitted. Sample KA7-3.0 consisted of flattened fragments of wood branches lying parallel to bedding at a depth of 3.0 ft (0.9 m). Sample KA7-3.5 was collected from a thin (<0.1 ft or 3 cm) buried peat at 3.5 ft (1.1 m) below the ground surface.

Reported radiocarbon ages (table 2) are based on the Libby half life for ^{14}C (5,570 yr) and referenced to AD 1950. A correction for $^{13}C/^{12}C$ was applied to adjust for natural isotopic fractionation. Conventional ages were calibrated to tree-ring ages (tables 1 and 2) using a procedure described by Stuiver and Reimer (1986).

PLANT IDENTIFICATION

Twenty two of the organic samples were submitted to the University of Alaska Museum for identification of plant remains contained in the submerged peat layers. Plant identifications are presented in table 3.

GRAIN-SIZE ANALYSES

Subsamples for grain-size analyses were oven dried and weighed. Subsample weights ranged from 50 g to 290 g. Six coarse-grained subsamples were analyzed with conventional 8-in.-diam (20.3-cm) sieves. The remaining 49 fine-grained subsamples were analyzed with a Micromeritics Sedigraph 5000ET rapid sediment analyzer.

Results of the analyses of two sample splits from each fine-grained sample were recorded automatically by the Sedigraph on chart paper. The graph was then scaled in full or half phi (ϕ) units to compute size distributions in weight percent. A third split was analyzed for any sample when results for the first two splits had an error greater than 5 percent in the size distribution. Mean grain

Table 2. *Radiocarbon ages of samples from boreholes drilled in vicinity of Turnagain and Knik Arms in 1988 and 1989.*

Bore-hole	Depth	Laboratory number	Material dated	Radiocarbon age (yr B.P.)	Calibrated 1σ age range (yr B.P.)[a]
TA1	6.4 ft (1.95 m)	GX-15208	Sphagnum-sedge peat	negative (post-1950)	
TA1	8.8 ft (2.68 m)	GX-15209	Woody moss-sedge peat	510±130	480-660
TA1	12.8 ft (3.90 m)	GX-15210	Sedge peat	815±115	670-907
TA1	19.7 ft (6.01 m)	GX-15212	Sphagnum-sedge peat	2,100±75	1,988-2,285
TA1	21.2 ft (6.46 m)	GX-15211	Sedge-wood peat	1,875±125	1,635-1,950
TA1	22.6 ft (6.89 m)	GX-15213	Woody moss-sedge peat	2,755±80	2,774-2,950
TA1	25.5 ft (7.77 m)	GX-15214	Sphagnum-sedge peat	3,455±145	3,559-3,909
TA1	55.3 ft (16.86 m)	GX-15215	Organic silt	10,375±310	(too old to calibrate)
TA8	4.9 ft (1.49 m)	GX-15216	Sedge blades & roots	330±150	<0[b]-520
TA8	7.0 ft (2.13 m)	GX-15217-AMS	Scattered organics	1,030±130	790-1,060
TA8	12.7 ft (3.87 m)	GX-15218	Sphagnum-sedge peat	885±120	690-930
TA8	13.4 ft (4.09 m)	GX-15404	Sedge peat	1,495±165	1,280-1,550
TA8	20.3 ft (6.19 m)	GX-15219	Moss-sedge peat	1,695±80	1,527-1,709
TA8	21.5 ft (6.55 m)	GX-15405	Sedge peat	2,630±80	2,740-2,792
TA8	24.8 ft (7.56 m)	GX-15220	Woody moss-sedge peat	2,675±80	2,749-2,857
TA8	30.3 ft (9.24 m)	GX-15221	Moss-sedge peat	2,705±85	2,754-2,876
TA8	36.2 ft (11.04 m)	GX-15222	Thin peat	3,015±140	2,989-3,379
TA8	41.5 ft (12.65 m)	GX-15223	Thin peat	4,150±130	4,455-4,859
TA8	50.8 ft (15.49 m)	GX-15224	Organic silt	10,730±525	(too old to calibrate)
KA1	1.7 ft (0.52 m)	GX-15406	Wood-sedge-moss peat	negative (post-1950)	
KA1B	2.7 ft (0.82 m)	GX-15225	Wood-sedge-moss peat	470±70	489-544
KA1	5.85 ft (1.78 m)	GX-15226	Sedge peat	955±75	784-943
KA1	11.75 ft (3.58 m)	GX-15227	Sedge peat	2,080±130	1,890-2,307
KA1	18.2 ft (5.55 m)	GX-15228	Scattered organics	7,240±295	7,729-8,369
KA1	28.2 ft (8.60 m)	GX-15229-AMS	Organic silt	8,850±120	(too old to calibrate)
KA4	0.7 ft (0.21 m)	GX-15230	Wood-sedge peat	negative (post-1950)	
KA4	3.3 ft (1.01 m)	GX-15231	Wood-sedge peat	515±75	507-628
KA4	24.2 ft (7.38 m)	GX-15232-AMS	Organic silt	4,533±84	4,996-5,317
KA4B	3.1 ft (0.95 m)	GX-15407	Wood-sedge peat	145±75	<0-290
KA4B	5.8 ft (1.77 m)	GX-15233	Wood-sedge-moss peat	510±70	507-623
KA4B	12.7 ft (3.87 m)	GX-15234	Organic silt	9,255±420	(too old to calibrate)
KA5	5.0 ft (1.52 m)	GX-15235	Wood-moss-sedge peat	1,080±85	930-1,066
KA6	2.3 ft (0.70 m)	GX-15236	Silty wood-sedge peat	185±130	<0-424
KA6	3.0 ft (0.91 m)	GX-15237	Sedge peat	560±70	523-650
KA6	4.35 ft (1.33 m)	GX-15238	Sedge peat	930±115	720-960
KA6	7.55 ft (2.30 m)	GX-15239	Organic silt	2,810±200	2,749-3219
KA6	7.85 ft (2.39 m)	GX-15240	Woody peat	1,800±125	1,560-1,880
KA6	25.3 ft (7.71 m)	GX-15241	Organic silt	11,400±720	(too old to calibrate)
KA7	3.0 ft (0.91 m)	GX-15466	Wood fragments	520±70	510-628
KA7	3.5 ft (1.07 m)	GX-15465	Wood-sedge peat	495±120	472-641

[a]Calibration to calendar years B.P. is based on data sets for tree rings of known ages (Linick and others, 1985, 1986; Kromer and others, 1986; Pearson and Stuiver, 1986; Pearson and others, 1986; Stuiver and Pearson, 1986; and Stuiver and others, 1986).
[b]<0 = negative calibrated age B.P. (post-1950).

Table 3. *Identification of plant fragments in buried peats and organic-rich layers*[a]

Sample	Depth	Composition
TA1-6.4	6.4 ft (1.95 m)	Moss-sedge peat (Calliergon and Sphagnum).
TA1-8.8	8.8 ft (2.68 m)	Sedge-moss (Sphagnum?) peat (mostly sedge). Some wood up to 3 mm diam.
TA1-12.8	12.8 ft (3.90 m)	Sedge peat with some moss and wood.
TA1-19.7	19.7 ft (6.01 m)	Moss (Sphagnum?)-sedge peat with twigs up to 5 mm diam.
TA1-21.2	21.2 ft (6.46 m)	Well-preserved sedge peat with lots of wood (maximum diameter 3 mm).
TA1-22.6	22.6 ft (6.89 m)	Moss (Sphagnum?)-sedge peat with some wood up to 4 mm diam.
TA1-25.5	25.5 ft (7.77 m)	Sphagnum peat with a few sedges.
TA8-12.7	12.7 ft (3.87 m)	Sphagnum(?) peat with a few sedges and fine (1-2 mm) woody roots or twigs.
TA8-20.3	20.3 ft (6.19 m)	Silty moss-sedge peat, mostly moss (non-Sphagnum?). No twigs apparent.
TA8-24.8	24.8 ft (7.56 m)	Decomposed moss (non-Sphagnum?)-sedge peat with some woody twigs up to 2 mm diam.
TA8-30.3	30.3 ft (9.24 m)	Moss-sedge peat (mostly moss, Drepanocladus and Calliergon), with a few woody twigs up to 2 mm diam.
TA8B-7.0	7.0 ft (2.13 m)	Sand with sedge & wood fragments.
KA1-5.85	5.85 ft (1.78 m)	Well-decomposed sedge peat.
KA1-11.75	11.75 ft (3.58 m)	Silt with some sedge-like organic fragments. Possibly some wood fragments.
KA1B-2.7	2.7 ft (0.82 m)	Well-preserved sedge peat with abundant wood with bark; twigs maximum diameter 4-5 mm.
KA4-3.3	3.3 ft (1.01 m)	Sedge peat with abundant well-preserved wood with bark (maximum diameter about 1 cm).
KA4B-5.8	5.8 ft (1.77 m)	Moss-sedge peat (Sphagnum?) with abundant wood (and bark?) fragments. Well-preserved twigs, maximum diameter 5.5 mm.
KA5-5.0	5.0 ft (1.52 m)	Moss-sedge peat (moss component Tomenthypnum and Sphagnum) with several twigs (maximum 3 mm diam) with bark and leaf scars. Tomenthypnum is often calcareous.
KA6-2.3	2.3 ft (0.70 m)	Silty sedge peat with wood twigs (maximum diameter 3 mm). No moss apparent.
KA6-3.0	3.0 ft (0.91 m)	Sedge peat with some moss (non-Sphagnum). No wood apparent.
KA6-4.35	4.35 ft (1.33 m)	Sedge peat, possibly with some woody roots. No mosses apparent.
KA6-7.85	7.85 ft (2.39 m)	Fine-grained mineral with wood fragments up to 9 mm diam, 2 cm long.

[a]Identifications by A.R. Batten and B.M. Murray, University of Alaska Museum, 1989.

size, standard deviation (sorting), skewness (asymmetry), and kurtosis (peakedness) were calculated from phi-size distributions using standard procedures for moment measures (Friedman and Johnson, 1982) and are reported with percent gravel, sand, silt, and clay in appendix B.

RESULTS

LITHOLOGY AND STRATIGRAPHY

Subsurface sediment at all boreholes and sections is predominantly clayey silt to fine sandy silt, similar to material on the modern intertidal flats (see fig. 7 for graphic logs, appendix A for detailed sample descriptions), although layers of coarser sand and gravel are present in the upper parts of the Girdwood and Portage boreholes. Gravel comprising the upper 6 ft (2 m) of borehole TA1 at Girdwood is road fill. Fine to medium sand in the upper 10 ft (3 m) of borehole TA8 at Portage displays more distinct layering, coarser grain sizes, and size grading than the remaining fine-grained samples and is interpreted as fluvial overbank deposits from Portage Creek.

The fine sediment making up the remainder of the borehole samples is mostly structureless to faintly laminated clayey silt and silty clay (see appendix B for graphic logs of grain-size statistics). Contorted bedding is rare and is attributed in most cases to disturbance during sampling and handling. In these cases, contorted bedding is restricted to soft sediment adjacent to the void at the top of the cores and extends downward along the core walls. Strongly contorted bedding that cannot be attributed to sample disturbance appears only in the bottom 3 ft (1 m) of borehole KA6 in upper Knik Arm at depths of 40.5 to 43.5 ft (12.3 to 13.3 m) (appendix A). No buried peat layers are clearly associated with contorted bedding at this or any other location.

Drilling revealed subsurface peat layers at all borehole locations. These peats are composed of fresh-water grasses, mosses, and some wood (table 3). In boreholes KA2, KA3, and KA5 on Palmer Hay Flats and in KA4 and KA4B at Goose Bay, the peat layers all appear within 6 ft (2 m) of the surface. These peat layers are immediately below zones that could not be sampled because of the wet, very loose condition of the soil beneath the frozen ground. Therefore, it is not possible to determine from these samples whether these near-surface peats are buried beneath intervening layers of silt or are parts of a single surface layer of peat.

Deeper subsurface peats interlayered with silt appear in boreholes TA1 and TA8 in Turnagain Arm, KA1 and KA6 on Palmer Hay Flats, and at section KA7 exposed in the bluff at the mouth of the Matanuska River near KA1. In borehole TA1 at Girdwood, four distinct peat layers 0.3 to 1.3 ft thick (0.1 to 0.4 m) are overlain by 0.3 to 6.5 ft (0.1 to 2.0 m) of nearly organic-free silt, minor sand, and some pebbles. Two additional peat layers at 8.5 and 21.1 ft (2.6 and 6.7 m) depth appear below sample breaks and may or may not be separate layers. The deepest peat layer is at 25.5 ft (7.8 m); all are below present MHHW.

In borehole TA8 at Portage, six peat layers 0.1 to 0.8 ft thick (3 to 24 cm) are overlain by 0.2 to 6.7 ft (0.06 to 2.0 m) of organic-free clayey silt and fine sandy silt. Two additional thin peat seams (less than 0.05 ft or 1.5 cm) in otherwise uniform silt appear at 36.2 and 41.5 ft depths (11.0 and 12.7 m) and may represent former supratidal surfaces. All subsurface peats in this borehole are below present MHHW.

Borehole KA1 on Palmer Hay Flats contains two thin peats overlain by silt below the surface organic layer. These peats occur at 5.8 to 6.0 ft (1.77 to 1.83 m) and 11.7 to 12.0 ft (3.57 to 3.66 m) below present MHHW. Borehole KA6 contains three well-developed peats interlayered with silt at 3.0 to 3.2 ft (0.91 to 0.98 m), 4.3 to 4.6 ft (1.31 to 1.40 m), and 7.8 to 7.9 ft (2.38 to 2.41 m). An additional 0.05-ft or 1.5-cm-thick organic-rich layer that appears to be a weakly developed peat is present at 7.5-ft (2.3-m) depth. The uppermost peat layer is about at the level of present MHHW.

A 6-ft-high (1.8-m) bluff section near the mouth of the Matanuska River at the edge of Palmer Hay Flats (location KA7 on fig. 4) consists mainly of silt, with scattered organics and roots near the surface. The section also contains a layer of compressed wood fragments at 3.0 ft (0.9 m) and a thin layer of peat at 3.5 ft (1.1 m). These organic layers are slightly above MHHW. The peat layer was initially thought to represent the pre-1964 vegetation, because its depth corresponds approximately to the amount of subsidence documented in this area for the 1964 earthquake. However, radiocarbon dating places both the wood layer and peat at an uncalibrated age of about 500 yr B.P., which corresponds to basal ages obtained for near-surface peats in several other boreholes.

Stratigraphic relations of several buried peat layers indicate that their development and subsequent burial began with gradual shoaling and sparse vegetation growth, followed by dense vegetation and peat development, and then by sudden burial. Peat layers showing this sequence appear at 13 ft (4.0 m) and 25.5 ft (7.8 m) in borehole TA1 and at 30.5 ft (9.3 m) in borehole TA8 (fig. 8). Silt deposits below these peats show a gradual increase in

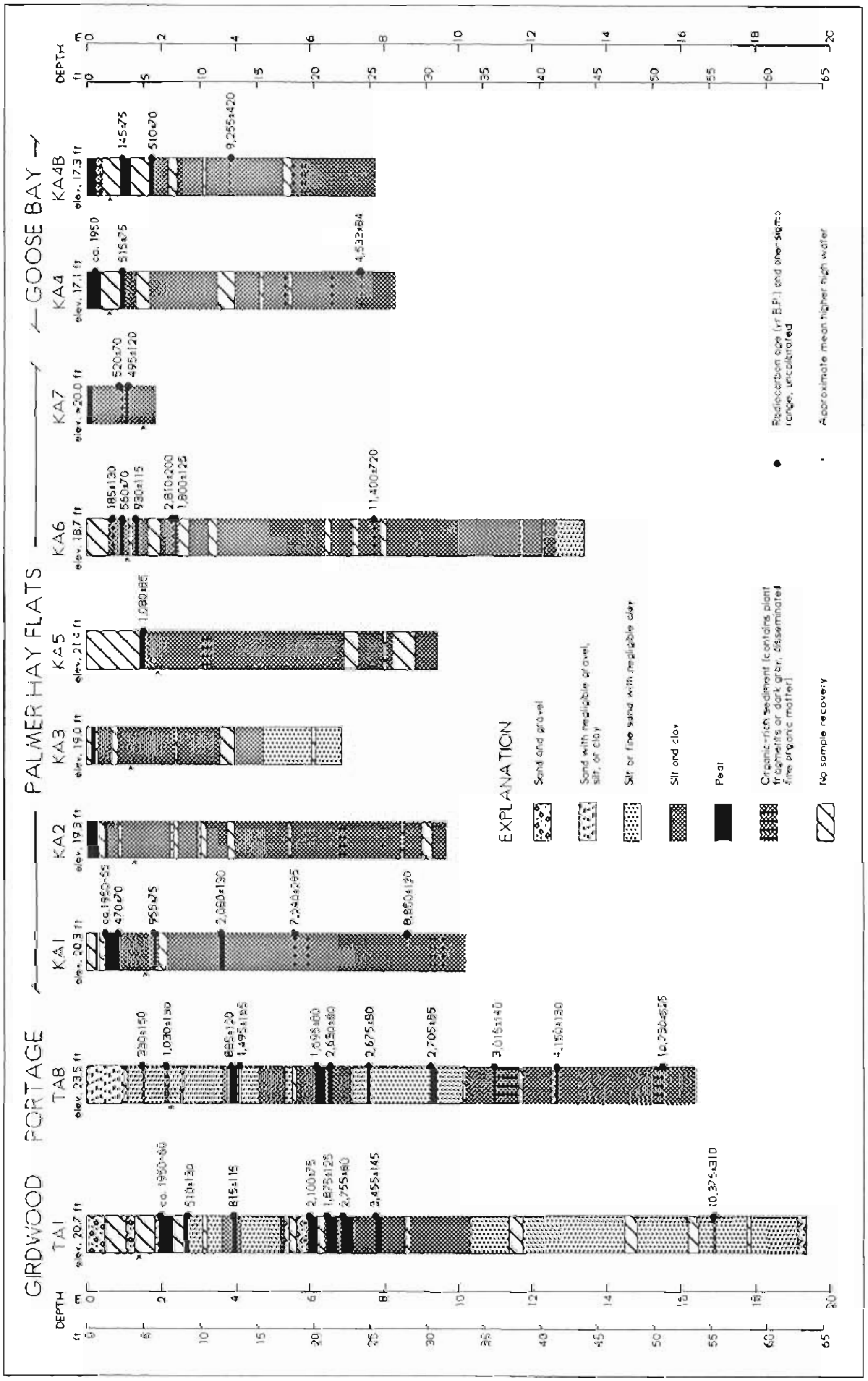

Figure 7. *Lithologic logs of boreholes and sections in vicinity of upper Turnagain and Knik Arms. See table 2 for laboratory numbers of radiocarbon ages.*

plant and root material with time (upward in the borehole). A gradational contact at the base of the peat indicates a gradual increase in density of vegetation, and a sharp upper contact between the peat and overlying silt attests to sudden burial. The overlying silt is nearly devoid of organics or has only scattered sedge blades or twigs. Scattered organics and a large twig in silt overlying the peat at 13 ft in TA1 (fig. 8, A) may be similar to the buried pre-1964 vegetation preserved in tidal channels near Girdwood. There deposits of Placer River Silt (Ovenshine and others, 1976) encase the branches of small bushes that were growing on the supratidal flat at the time of the earthquake on March 27, 1964. Silt immediately overlying the peat at 25.5 ft contains negligible organics but shows a gradual upward increase in organics within about 1 ft (0.3 m) toward the base of the next higher peat layer at 23 ft depth (7 m) (fig. 8, B).

In addition to the peats, layers of organic silt were found in the boreholes that may or may not represent buried remnants of former supratidal surfaces. These include zones of scattered plant fragments or dark gray, disseminated fine organic matter embedded in silt (fig. 7). Because of the strong possibility that this organic material was retransported, I assume that these layers are not remnants of peats and use their radiocarbon ages only for calculation of maximum ages and approximate sedimentation rates.

RADIOCARBON AGES

Radiocarbon ages of selected peats and organic-rich layers are shown in relation to borehole stratigraphy in figure 7. All ages are reported in uncalibrated radiocarbon years before present (yr B.P.), referenced to A.D. 1950. The most significant effect of tree-ring calibrations is to increase the ages of the oldest samples (> 3,000 yr) by up to several hundred years (tables 1 and 2). As these differences are probably not significant relative to other sources of error and have no major effect on the conclusions of this report, uncalibrated ages are used in figures to simplify comparisons with other reported data.

In borehole TA1 at Girdwood, the shallowest subsurface peat layer has a negative radiocarbon age (post-1950). This peat is probably the remains of surface vegetation that was buried following submergence during the 1964 great Alaska earthquake. Its depth at this location is about the same as the known pre-1964 peat in nearby tidal channels. Dated peat layers below the pre-1964 peat yield radiocarbon ages of 510±130, 815±115, 2,100±75, 1,875±125, 2,755±80, and 3,455±145 yr B.P. (table 2; fig. 7). A thin layer of organic silt at 55.3 ft (16.9 m) has a radiocarbon age of 10,375±310 yr B.P., providing a minimum age for deglaciation comparable to the 10,180±350-yr age obtained for a sample of compressed wood and peat in a gravel pit at Girdwood (Bartsch-Winkler and Schmoll, 1984a).

The 510-yr date at 8.8 ft (2.7 m) in TA1 is from a sample collected at the base of a peat layer that is immediately below a sample break. It is not possible to determine from these samples whether this peat is a separate layer or is continuous with the peat at 6.4 to 7.4 ft (2.0 to 2.3 m).

The 1,875-yr peat layer at 21 ft (6.4 m) in TA1 is also immediately below a sample break and is discordant with the ages of peats above and below. A plot of age versus depth (fig. 9, A) shows that this sample's age is inconsistent with the long-term sedimentation rate indicated by the other radiocarbon ages. The disturbed top of this core sample and the anomalously young age suggest that the sample may be contaminated by younger organic material. Because recovery was not continuous in this sample interval, it is not clear whether there are two separate peats or one continuous peat between 19.7 and 22.2 ft (6.0 to 6.8 m).

Radiocarbon ages were obtained for 11 layers in borehole TA8 at Portage: six peat layers more than 1 in. (2.5 cm) thick, two thin peat seams, and three layers of organic silt. The peats yield ages of 885±120, 1,495±165, 1,695±80, 2,630±80, 2,675±80, 2,705±85, 3,015±140, and 4,150±130 yr B.P. (table 2; fig. 7). An age discordance occurs between the organic-rich layer at 7.0 ft (2.1 m) and the peat layer at 12.6-13.3 ft (3.8-4.0 m). Although either of these ages could be wrong, I regard the 1,030-yr age of the layer at 7.0 ft with suspicion because its organic content is very low, and the fine-grained organic matter may have been retransported. Also, the 885-yr age at 12.7 ft (3.9 m) correlates closely with the 815-yr age at about the same depth in borehole TA1.

Organic silt at 50.8 ft (15.5 m) near the base of borehole TA8 at Portage yields a radiocarbon age of 10,730±525 yr B.P. This age is comparable to the lowermost age obtained at TA1 at Girdwood and provides a minimum age of deglaciation of the Portage area. Previously, the oldest radiocarbon age obtained in the Portage area was 8,230±100 yr B.P. on wood fragments at the base of a 305-ft (93-m) core about 1 mi (1.6 km) northwest of TA8 (Bartsch-Winkler and others, 1983). The discrepancy between the depths of these samples and their ages casts doubt on the validity of one of the ages: although shallower, the sample in TA8 gives the older age and results in a sedimentation rate about one-seventh that of the remainder of the section. This discrepancy may be reason to suspect that the 10,730-yr age is erroneous and may represent transported material. However, the

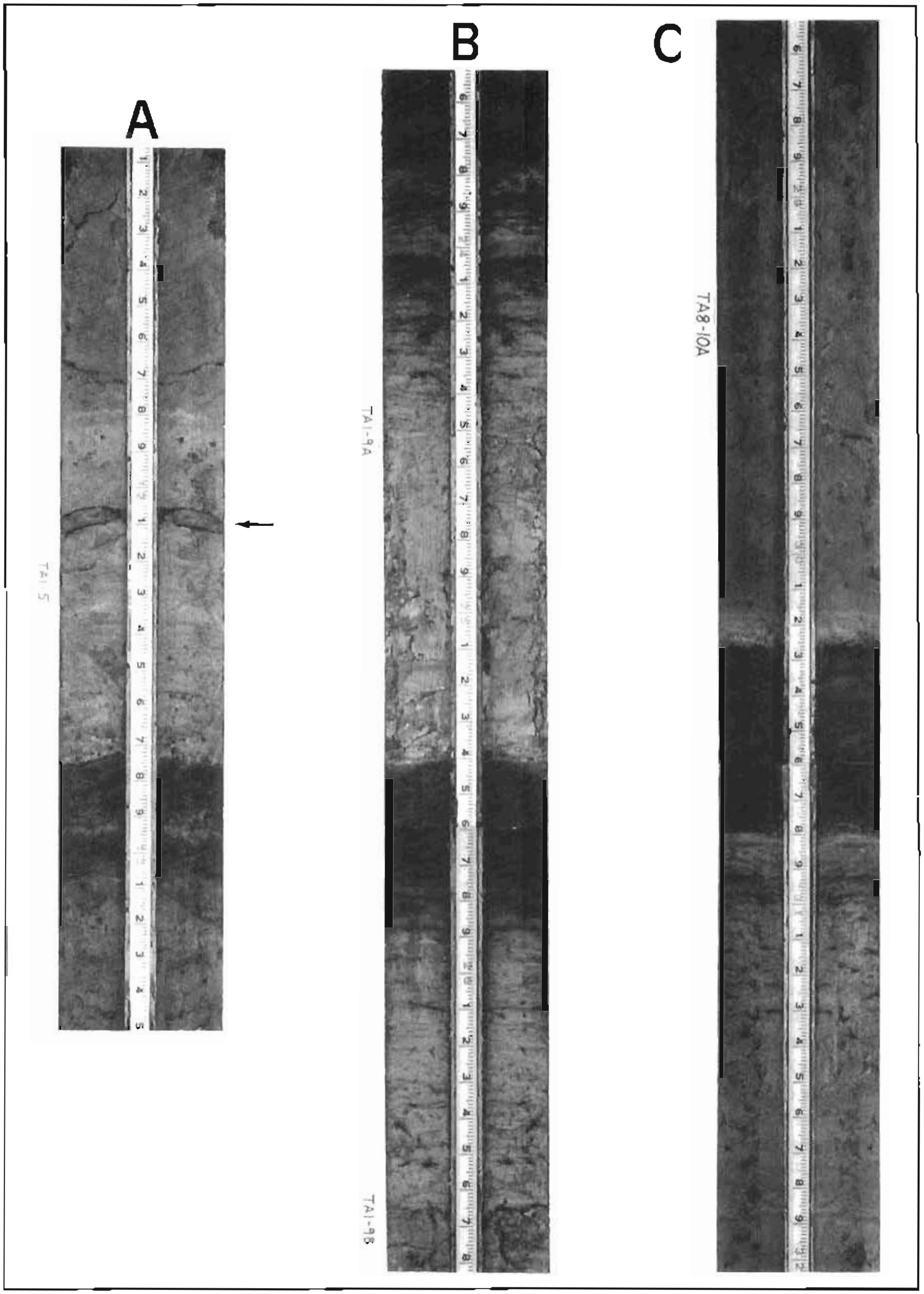

Figure 8. *Buried peat layers in boreholes TA1 and TA8, showing gradual upward increase in roots and plant fragments below the peats, sharp upper contacts, and nearly organic-free silt and clay overlying the peats. A, peat layer at 13-ft depth (4.0 m) in borehole TA1 (radiocarbon age 815 ± 115 yr). Note twig at 12.1 ft (3.72 m)(arrow). B, peat layer at 25.5-ft (7.85-m) depth in borehole TA1 (radiocarbon age 3,455 ± 145 yr). Upper part of photo shows gradational lower portion of peat layer at 23 ft (7.08 m)(radiocarbon age 2,755 ± 80 yr). C, peat layer at 30.5-ft depth (9.3 m) in borehole TA8 (radiocarbon age 2,705 ± 85 yr).*

10,730-yr age correlates closely with the 10,375-yr layer at about the same depth in borehole TA1 at Girdwood (fig. 7), so the question of which date is invalid remains unresolved. Even if the 10,730-yr organics in TA8 were retransported, the date is still a valid minimum age for deglaciation at Portage because the site had to be ice-free at the time the organics were deposited.

In borehole KA1 (Palmer Hay Flats), a thin (< 1 ft or 30 cm) layer of organic silt separates peat at the surface from a buried peat at 1.7 to 2.8 ft (0.52 to 0.85 m) (fig. 7, appendix A). A sample at the top of this buried peat layer yields a negative radiocarbon age (post-1950), and a sample at its base gives an age of 470±70 radiocarbon yr B.P. This latter age correlates closely with ages obtained on layers of wood fragments (520±70 yr B.P.) and peat (495±120 yr B.P.) in nearby tidal-channel section KA7 (table 2; fig. 4 for location). Deeper buried peat layers at 5.8 to 6.0 ft (1.77 to 1.83 m) and 11.7 to 12.0 ft (3.57 to 3.66 m) in KA1 yield radiocarbon ages of 955±75 and 2,080±130 yr B.P., respectively. Thin layers of organic silt at 18.2 and 28.2 ft (5.55 and 8.60 m) yield radiocarbon ages of 7,240±295 and 8,850±120 yr B.P., respectively, but may represent transported material.

No buried peat layers were encountered below the surface peat in boreholes KA2 and KA3 on Palmer Hay Flats (figs. 4 and 7), so no radiocarbon ages were obtained. Nearby, in borehole KA5, it was not possible to sample the upper 4.7 ft (1.43 m) of soft, wet peat below the ice. However, a basal peat sample at 5.0 ft (1.52 m) yields a radiocarbon age of 1,080±85 yr B.P. This may be the age of the base of the surface peat layer or may be the age of a buried peat that correlates with the peat at 5.8 ft (1.77 m) in KA1.

Three well-developed buried peats were sampled in borehole KA6 on Palmer Hay Flats at 3.0, 4.3, and 7.8 ft (0.91, 1.31, and 2.38 m), yielding ages of 560±70, 930±115, and 1,800±125 radiocarbon yr B.P., respectively (fig. 7). A 185±130-yr age for organic matter in silt at 2.3 ft (0.70 m) at the top of the first core probably represents surface peat mixed with silt through sample disturbance. Layered organic silt at 7.55 ft (2.30 m) yields a radiocarbon age of 2,810±200 yr B.P., which is discordant with ages above and below (fig. 9, F), but correlates closely with ages of well-developed peats in boreholes TA1 and TA8 at Girdwood and Portage. A deeper lamina of organic silt at 25.3 ft (7.71 m) dates at 11,400±720 yr B.P., which, if valid, provides a new minimum age at this location for retreat of glacial ice after the late-Wisconsin Elmendorf advance (Reger and Updike, 1983).

At borehole KA4 (Goose Bay), a negative radiocarbon age (post-1950) was obtained for peat at the base of the recovered portion of surface organics (fig. 7). A sample break at 1.2 to 3.0 ft (0.37 to 0.91 m) makes it difficult to determine whether peat at 3.0 to 3.35 ft (0.91 to 1.02 m) is the base of the surface organic layer or is buried under intervening silt. The age of a sample at the base of this layer is 515±75 radiocarbon yr B.P. A similar condition exists in the upper 6 ft (1.8 m) of nearby borehole KA4B: an age of 145±75 radiocarbon yr B.P. was obtained for a sample at 3.1 ft (0.95 m) midway in the surface(?) peat layer, and an age of 510±70 radiocarbon yr B.P. was obtained at the base of a peat at 5.8 ft (1.77 m). The peat at 5.8 ft may be the bottom of the surface organic layer or may be overlain by an unsampled silt layer.

No buried peat layers are present below surface peats in boreholes KA4 and KA4B. In borehole KA4, organic silt at 24.2 ft (7.4 m) gives an AMS radiocarbon age of 4,533±84 yr B.P. In borehole KA4B, organic silt at 12.7 ft (3.9 m) gives a conventional radiocarbon age of 9,255±420 yr B.P. Buried peat layers are present in a nearby tidal-channel section at depths of about 12 and 25 ft (3.7 and 7.6 m) and yield ages of 1,595±75 and 3,270±90 radiocarbon yr B.P., respectively (Bartsch-Winkler and Schmoll, 1984b).

The lack of complete correlation of buried peat layers among adjacent sites in the same estuary illustrates one difficulty of using borehole drilling for paleoseismicity studies: buried coastal-marsh peats are not continuous. The most likely explanations for this lack of continuity are (1) some sites were in a subtidal or lower intertidal environment where no surface peat existed at the time of subsidence, and (2) some peats may have been removed by post-seismic tidal-channel erosion and replaced by tidal muds.

COMPARISON WITH PREVIOUS DATA

A comparison of radiocarbon ages from boreholes drilled in 1988 at Girdwood and Portage with data obtained at the same locations in 1985 (Combellick, 1986) shows some close agreement and some serious disagreement between the data sets (fig. 10). Some peat layers that appear at the same depth in adjacent boreholes correlate closely in age, but others disagree by several multiples of their laboratory standard deviations. For example, reported ages of the peat layer at about 25-ft (7.6 m) depth in adjacent Girdwood boreholes differ by only 90 radiocarbon yr, well within the $\pm 1\sigma$ range of both samples. In contrast, the reported 1,935±150 yr age of peat at about 10 ft (3 m) in the 1985 borehole is clearly inconsistent with the much younger reported ages

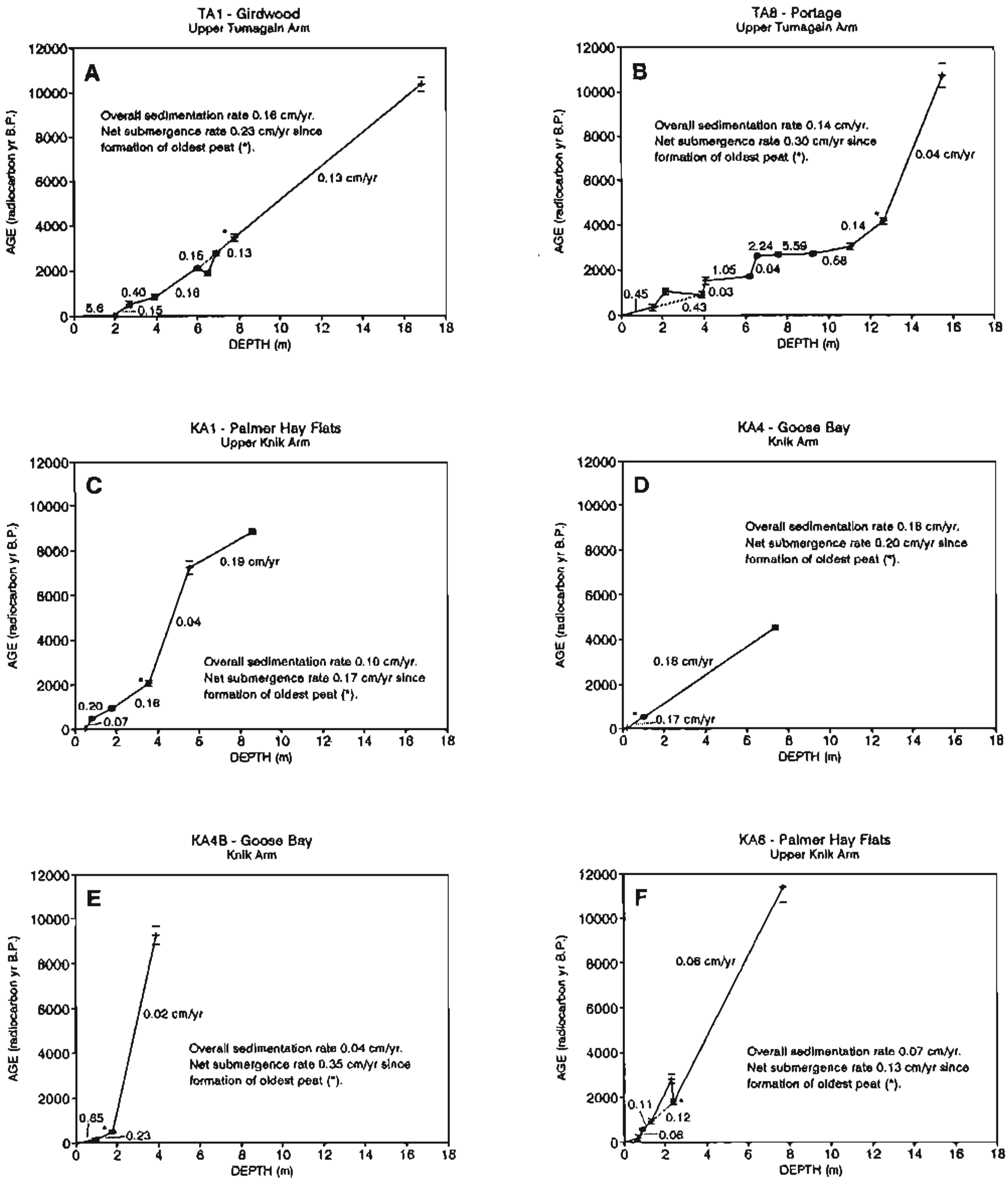

Figure 9. *Plots of radiocarbon age versus depth for six boreholes in the vicinities of upper Turnagain and Knik Arms (data from table 2). Crosses (+) indicate age and bars (-) delimit laboratory standard deviation. Sedimentation rates given in cm/radiocarbon yr. Broken lines denote sedimentation rates spanning periods of questionable radiocarbon age.*

(510 ± 130 and 815 ± 115 yr) of peats that appear slightly above and below it in the adjacent 1988 borehole. Similar discrepancies exist between adjacent boreholes at Portage, although peats at 30.3 ft and 41.5 ft (9.2 and 12.7 m) correlate closely (fig. 10).

Peat at 10-ft (3-m) depth in the 1985 and 1988 Girdwood boreholes is at about the same level (taking into account earthquake subsidence in 1964) as a peat layer dated by Karlstrom (1964) at 700 ± 250 radiocarbon yr B.P. This relation supports the validity of the 510- and 815-yr ages in the 1988 borehole and suggests that the 1,935-yr age in the 1985 borehole may be erroneous. Bartsch-Winkler and Schmoll (1987) obtained a radiocarbon age of 1,840 ± 50 yr B.P. for a peat sample collected by auger at a depth of about 22 ft (6.7 m) below the surface in the middle intertidal zone at Girdwood. This peat may correlate with one of the layers in the 20- to 23-ft (6.1 to 7.0-m) depth range in Girdwood boreholes TA-B1 and TA1, but the correlation does not clearly resolve the age discrepancies at that depth (fig. 10).

Until additional data are obtained at the Girdwood and Portage sites, the remaining age discrepancies may remain unresolved. Possible reasons for the discrepancies include (1) stratigraphic discontinuities between adjacent boreholes; (2) labeling errors; (3) contamination by external organic matter or bacterial activity; (4) handling errors in the laboratory; or (5) analytical errors arising from faulty equipment, poor technique, or calibration problems.

Tidal or fluvial channel migration disrupts stratigraphic continuity and is evident in many other boreholes in the area. However, channel deposits observed in other boreholes are much coarser than the host tidal deposits and are devoid of peat layers. Laboratory errors seem highly unlikely considering that both sets of samples were analyzed at the same reputable laboratory.

Several months elapsed before subsamples from the 1988 cores could be submitted for radiocarbon dating, so contamination by bacterial activity is a possible source of error. Bacterial uptake of recent carbon dioxide is known to be responsible for anomalously young radiocarbon ages in marine cores stored unfrozen for several years in unsealed core boxes. Geyh and others (1974) showed that the effects of bacterial contamination become more pronounced with age of the sediment, producing highly erratic results on samples of Pleistocene age (more than 10,000 yr old). In all cases, contamination results in a radiocarbon age that is younger than expected. Severely contaminated samples of Holocene age can be in error by up to 2,500 radiocarbon yr.

Unlike the results documented by Geyh and others (1974), results of this study at Girdwood and Portage show the greatest discrepancies in the youngest samples (<3,000 radiocarbon yr B.P.). And, although most of the apparent discrepancies in 1988 samples are due to radiocarbon ages that are younger than expected, some ages are older than expected. Other radiocarbon ages, particularly for older samples, show close agreement with the 1985 results.

Regardless of sources of error, until a sufficiently large regional data base exists, these discrepancies may weaken the significance of exact ages of peat layers for constructing a history of events. To avoid confusion and for the sake of consistency, the remaining discussion on sedimentation rates, subsidence, and earthquake implications is limited to data obtained from 1988 and 1989 boreholes. All radiocarbon dating of these samples was performed at the same laboratory at about the same time, which should eliminate any significant effect of differences in laboratory methods or should cause any systematic errors to be uniform.

DISCUSSION

PALEOSEISMICITY

Many of the peat layers that were observed in borehole samples in this study exhibit stratigraphic evidence of gradual shoaling, vegetation growth, and peat development, followed by rapid submergence and burial below present high-tide level. This stratigraphic evidence supports the hypothesis that each buried peat layer represents a vegetated supratidal surface that subsided during a major earthquake. Burial occurred rapidly as new sediment was deposited on the submerged flat, probably in much the same way that sedimentation in upper Turnagain Arm restored the flat to subaerial conditions within 17 yr following the 1964 earthquake (Kachadoorian and Ovenshine, 1984).

None of the borehole samples exhibit conclusive evidence of major ground shaking associated with peat submergence and burial. Liquefaction features like sand dikes crossing peat layers and sand-blow deposits directly overlying peat layers are the most conclusive forms of evidence of major ground shaking observable in cross section. Probability is low that these liquefaction features will be encountered or recognized in borehole drilling.

It may be argued that the observed stratigraphic relationships are consistent with burial of the peats by river-flood deposits, followed by submergence.

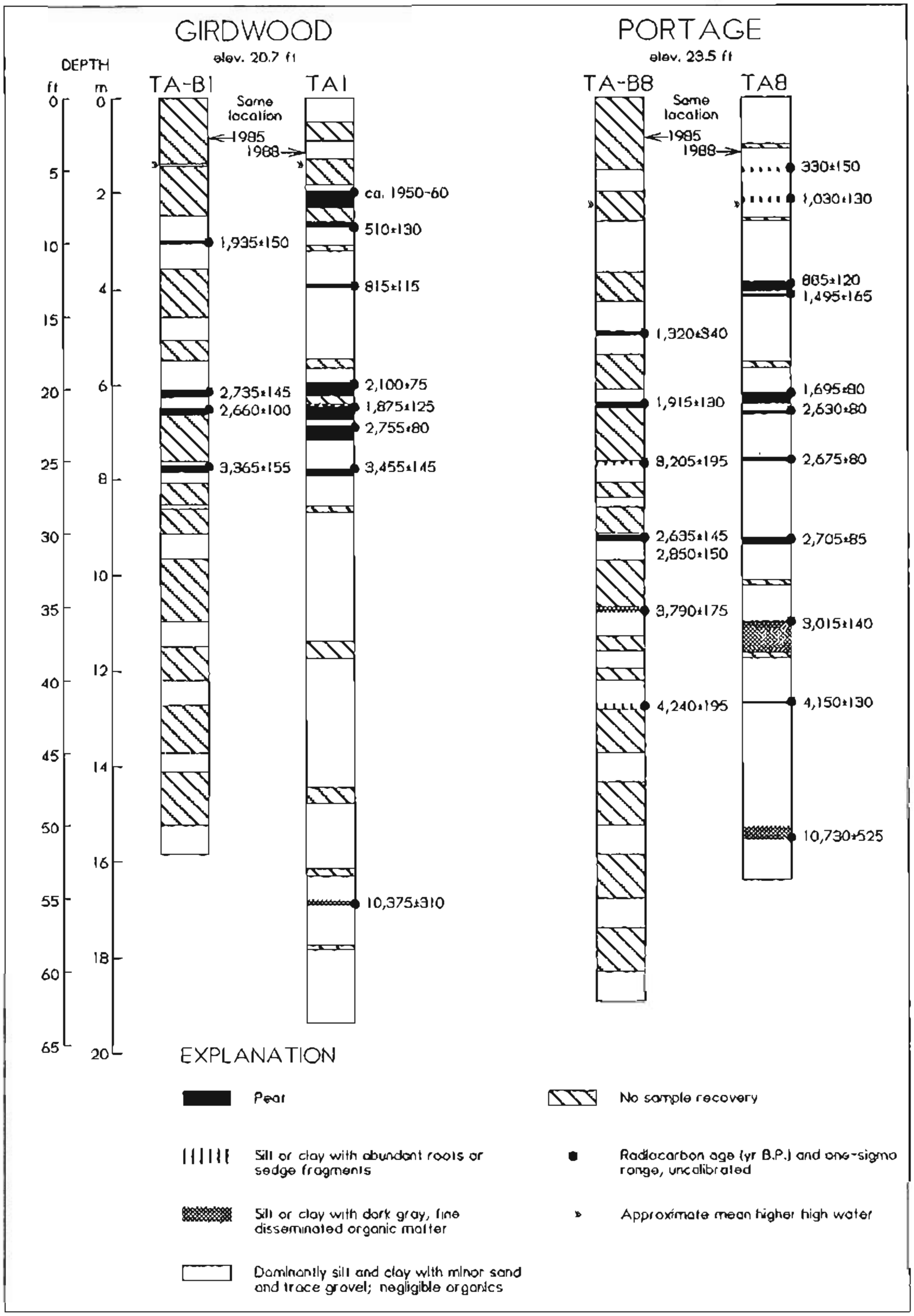

Figure 10. *Comparison between radiocarbon ages of samples from boreholes drilled at adjacent locations near Girdwood and Portage in 1985 and 1988. See tables 1 and 2 for laboratory numbers.*

However, with exception of the peat layer at 19.7 ft (6.0 m) in TA1, which is overlain by pebbly coarse sand, no significant textural differences are evident in deposits overlying buried peats to indicate a change from tidal to fluvial sedimentation.

Gradual submergence by aseismic subsidence can be ruled out as a model for formation and burial of peat layers because long stillstands would be necessary for peat to form. Also, gradual submergence would subject the surface to erosion and reworking by storm waves and tidal currents, making preservation of peats less likely. Dragging of large ice masses by tidal currents during winter in Turnagain and Knik Arms is particularly destructive.

Rise of regional sea level during the late Holocene (Clark and others, 1978) provides favorable conditions for preservation of coastal-marsh deposits. However, the observed peat-silt couplets could not result from a rise at uniform rate. Intermittent sea-level rises could produce an alternating peat-silt sequence, but these rises are not likely to be large and sudden enough to produce sharp upper peat contacts and organic-poor overlying sediment. Repeated sudden tectonic lowering followed by intertidal silt deposition seems the most likely mechanism for rapidly burying coastal-marsh peats with organic-poor silts.

Radiocarbon dating of organic material at the tops of submerged peat layers provides maximum ages for subsidence events. If fluvial-flood deposition buried the vegetation before it was submerged, an unknown period of time passed between the vegetation growth and its submergence. If burial was due to rapid marine deposition after submergence, the radiocarbon age provides a close maximum age for the event. Lack of textural changes above the peats suggests that burial was by renewed intertidal deposition following submergence rather than by fluvial flooding. In either case, assuming the hypothesis relating submerged peat layers to major earthquakes is correct, then the peats provide a minimum count of earthquakes that have occurred following deposition of the oldest peat. As previously discussed, apparent age discrepancies make attempts at assigning ages to all late-Holocene earthquakes risky at this time.

Regardless of exact timing, the number of buried peats in a borehole can be considered a minimum count of subsidence events during the period in which they were deposited because additional events may have occurred for which no peat layer was preserved. Tidal deposition may not have restored the flat at a particular site to subaerial conditions before every earthquake. As Bartsch-Winkler and Schmoll (1987) have shown, vegetated and nonvegetated zones of the tidal area migrate seaward and landward over time, so preservation of peat layers representing all subsidence events at any one location is highly unlikely.

Borehole TA8 at Portage showed the largest number of buried peat layers. Of eight layers present, six are well-developed peats > 1 in. (2.5 cm) thick and two are thin (< 0.5 in. or 1.3 cm) peat seams. The two thin peat seams do not necessarily represent former supratidal surfaces. Therefore, the Portage site shows evidence of six to eight subsidence events during about the last 4,200 radiocarbon yr (about 4,700 calendar yr)(table 2) before 1964. This rate translates to a maximum average recurrence interval of 525 to 700 yr (very roughly 590 to 780 yr if calculated on the basis of tree-ring calibrated ages from table 2).

Assuming radiocarbon ages of peats at TA8 are valid and the interpretation that they represent subsidence during major earthquakes is correct, the data suggest there were three major (great?) earthquakes within a period of less than 100 yr between 2,705 ± 85 and 2,630 ± 80 radiocarbon y.a. If calibrated ages are used, the minimum time span is only 33 yr plus laboratory standard deviations (table 2).

Occurrence of three large earthquakes within 100 yr appears inconsistent with the long-term average recurrence interval and contradictory to seismic-gap theory. This theory states that a region along an active plate boundary that has not produced a large earthquake for a long time is more likely to be the site of a future large earthquake than adjacent regions that have ruptured more recently (McCann and others, 1979). The theory implies that after a gap-filling earthquake, sufficient time must elapse before stresses can reaccumulate for release in another large earthquake. Seismologists have successfully used the seismic-gap theory to forecast large earthquakes, including the October 17, 1989, Loma Prieta, California, earthquake (Ward and Page, 1989).

Multiple large earthquakes have occurred in the same rupture zone within an unusually short period. For example, the May 7, 1986, great earthquake (Mw = 8.0) in the Andreanof Islands of the Aleutian Archipelago, Alaska, occurred in approximately the same location as a great earthquake on March 9, 1957 (Mw = 8.6). The aftershock zone of the 1986 event overlapped a significant portion of the 1957 rupture zone (Ekström and Engdahl, 1989). The time between these events was only 29 yr, even though the recurrence period had been projected at 249 yr on the basis of a time-predictable probabilistic model (Jacob, 1984). Submergence and burial of three well-developed peats with radiocarbon ages spanning less than 100 yr at Portage may be evidence of similar, unusually brief recurrence times for multiple large earthquakes in the 1964 rupture zone about 2,700 radiocarbon yr ago.

It is not possible with any degree of confidence to relate apparent amounts of subsidence between peat layers to earthquake magnitudes. Inferences could be made about relative magnitude only if reliable regional data were available to document the areal distribution of deformations associated with individual events. For example, differences in depth between peat layers at Portage (borehole TA8) cannot be used to infer differences in earthquake magnitude because the position of this borehole relative to the zero isobase of deformation is not known for each event. During the 1964 event, vertical displacements varied considerably over relatively short distances (Plafker, 1969). The position of the zero isobase and the distribution of vertical deformation undoubtedly is not the same in every large earthquake along this rupture zone. Therefore, the amount of subsidence at Portage could vary substantially during successive earthquakes of similar magnitude.

Perhaps all that can be said about magnitude of prehistoric earthquakes based on available data for this region is that a large-magnitude event is necessary to produce subsidence or uplift that is likely to be preserved in the geologic record. The relation of length of deformation zone to earthquake magnitude for historic subduction-zone events along the Pacific margin suggests a threshold of about magnitude 7, below which measurable permanent crustal deformation does not occur (West and McCrumb, 1988). A higher threshold is probably necessary for deformation to be preserved as uplifted marine terraces or submerged supratidal peat layers.

Available data from this and other studies of coseismic uplift and subsidence in the rupture zone of the 1964 great Alaskan earthquake provide strong evidence that several major events occurred during the past 5,000 yr. However, insufficient regional data are available to construct a credible, complete timetable of events. Comparison of data from this study with data from some other studies in the region shows little obvious correlation of radiocarbon ages that are presumably associated with coseismic uplift or subsidence (fig. 11). As discussed above, data from this study in upper Turnagain Arm, from both 1985 and 1988 boreholes, strongly suggest at least one and possibly three events between 2,600 and 2,900 radiocarbon yr B.P. However, radiocarbon ages of these peats do not correlate with reported ages from other areas, except for a discordant age of a poorly developed peat in borehole KA6 in upper Knik Arm (2,810±200 yr; not plotted on fig. 11). Either there are major errors in radiocarbon ages in this or other studies, or burial events were restricted to Turnagain Arm and not associated with large interplate earthquakes, or evidence of the earthquakes has not been discovered in the other areas.

Comparison of data from this study at Portage with data at Middleton Island (Plafker and Rubin, 1978) suggests possible correlation of events at about 1,300-1,500, 3,800, and 4,100-4,400 radiocarbon yr (fig. 11). There also may be regional evidence of events at about 700-1,000, 1,700-2,100, and 3,100-3,400 radiocarbon yr. Close correlation between the ages of a buried peat layer at Pt. Woronzof (Bartsch-Winkler and Schmoll, 1984b) and an uplifted terrace at Middleton Island suggest another possible event at about 2,300-2,400 radiocarbon yr B.P. Considering discrepancies in radiocarbon ages that have been discussed previously, these correlations are highly speculative.

Although radiocarbon ages were obtained for some near-surface peats where sample recovery was incomplete, their meaning with regard to recent subsidence history and earthquake occurrence is obscure because their stratigraphic context is unclear at all locations except KA6 and KA7 on Palmer Hay Flats. Shallow peat layers dating at about 500 radiocarbon yr B.P. at locations TA1, KA1, KA4, and KA4B all appear below sample breaks that could contain either continuous peat or interbeds of tidal sediments. These breaks in sample continuity occurred where the coring device did not retain soft, wet peat and sediment in the shallow subsurface beneath the frozen ground. If peat is continuous between the 500-yr layer and the surface (or between the 500-yr layer and the pre-1964 peat at TA1), 500 yr is a basal age that represents the onset of vegetation on the pre-1964 supratidal flat and is a minimum age for the most recent major pre-1964 earthquake. If the peat is buried beneath tidal silt, 500 yr (calibrated age about 530 calendar yr) (table 2) is a close maximum age for that event.

At KA6, a peat layer with a radiocarbon age of 560±70 yr is overlain by 3 ft (0.9 m) of silty clay and organic silt to the surface of the supratidal flat. At KA7, a peat layer with a radiocarbon age of 495±120 yr is overlain by 3.5 ft (1.1 m) of silt. At both locations, the 500-yr peat layer is above present MHHW, but still below the level of most high spring tides. Although burial may have resulted from regional subsidence, the possibility of burial during a major flood of either Matanuska or Knik Rivers must also be considered. Glacial-outburst flooding occurred almost annually in Knik River between 1918 and 1966 and could be a mechanism for sedimentation on Palmer Hay Flats during a major flood. However, the very fine-grained texture of the deposits overlying the peat is inconsistent with major fluvial-flood deposition except possibly in very quiet back-water conditions. The ages of these peat layers correlate closely with submerged peats at four other locations in Turnagain and Knik Arms. This correlation strongly suggests a regional subsidence event that was probably associated with the youngest pre-1964 major earthquake, at or before about 500 y.a.

SEDIMENTATION AND SUBMERGENCE RATES

From the 1988-89 data, average net sedimentation rates were computed both for intervals between radiocarbon-dated layers and for each borehole section between the oldest dated layer and the surface (fig. 9). If the model for restoration of Portage Flats after the 1964 earthquake (Kachadoorian and Ovenshine, 1984) is correct for previous subsidence events, actual sedimentation rates are not constant between events. Rates are very high immediately after an event, tapering to very low or zero for most of the remaining time before the next event. Consequently, reported sedimentation rates between dated layers represent the average rates over periods during which actual rates may have varied considerably. Additionally, the calculated rates represent net effects of sedimentation, compaction, and possible erosion.

At location TA1 (Girdwood), the data suggest an overall rate of 0.16 cm/yr for about the past 10,400 radiocarbon yr. With exception of the anomaly caused by the outlier at 21.2 ft (6.5 m) (fig. 9, A), the net rate remained relatively constant between 0.13 and 0.40 cm/yr prior to 1964.

At location TA8 (Portage), the data suggest a similar average sedimentation rate of 0.14 cm/yr for the past 10,730 radiocarbon yr. However, this rate is based on a questionable age for the oldest dated sample and is considerably slower than the rate determined by Bartsch-Winkler and others (1983) at a nearby borehole. If the rate is computed from the oldest, presumably reliably dated peat at this location (4,150 ± 130 yr B.P. at 41.5 ft or 12.7 m), the long-term sedimentation rate would be 0.30 cm/yr. This rate compares favorably with the 0.25-cm rate determined by Bartsch-Winkler and others (1983) for the past 5,740 radiocarbon yr.

Aside from the possible error in the 10,730-yr age, the remaining radiocarbon ages in borehole TA8 suggest that sedimentation rates at this site were more variable than at TA1 (fig. 9, B). In particular, the narrow age span of three peat layers between 9.2 and 6.5 m suggests sedimentation rates of 0.58 to 5.59 cm/yr, up to 40 times the long-term rate, between 3,015 ± 140 and 2,630 ± 80 radiocarbon yr B.P. Higher sedimentation rates during this period may have resulted from increased glacial activity during the Neoglacial maximum, which was under way in southern Alaska by about 3,000 y.a. and began to recede by about 2,000 y.a. (Calkin, 1988). Proximity of the Portage site to several large glaciers could explain why sedimentation rates were much higher there than at Girdwood during this period, even though both sites remained dominantly intertidal (based on lack of significant differences in texture between boreholes or above and below the peat layers in this time span). However, considering discrepancies in radiocarbon ages between the 1985 and 1988 boreholes at Portage, these variations in sedimentation rate may also be an artifact of dating errors.

Long-term sedimentation rates on Palmer Hay Flats in upper Knik Arm, represented by boreholes KA1 and KA6 (figs. 9, C and F), appear to be about half of the rate computed for Portage and Girdwood in upper Turnagain Arm. At Goose Bay, the long-term sedimentation rate indicated by radiocarbon dates at KA4 is similar to the Turnagain Arm rate (0.16 cm/yr), but the rate at borehole KA4B is significantly lower (0.04 cm/yr). Considering the proximity of the Goose Bay boreholes on the same supratidal surface (fig. 4), the sedimentation rate should be nearly the same. Most likely, either the 4,533-yr date in KA4 or the 9,255-yr date in KA4B is in error.

Assuming tidal sedimentation and postseismic rebound restore tidal flats to subaerial conditions between deposition of peat layers, the average sedimentation rate between peat layers is a measure of the net rate of submergence. Sedimentation rates calculated from dating of the oldest peat layers suggest a net rate of submergence of 0.23 to 0.30 cm/yr in upper Turnagain Arm for the past 3,400 to 4,200 radiocarbon yr, and 0.13 to 0.17 cm/yr in upper Knik Arm for the past 1,800 to 2,100 radiocarbon yr. The lower submergence rate for upper Knik Arm appears consistent with measurements following the 1964 earthquake. As a result of the earthquake, Palmer Hay Flats subsided about 2 ft (0.6 m) (Plafker, 1969), compared to about 5 ft (1.5 m) of net subsidence in upper Turnagain Arm, taking into account postseismic uplift (Brown and others, 1977).

SUMMARY AND CONCLUSIONS

A record of prehistoric subsidence events, possibly associated with 1964-style major earthquakes, is preserved in estuarine sediments of Turnagain and Knik Arms in upper Cook Inlet. Multiple peat layers, submerged below present high-tide levels and buried beneath

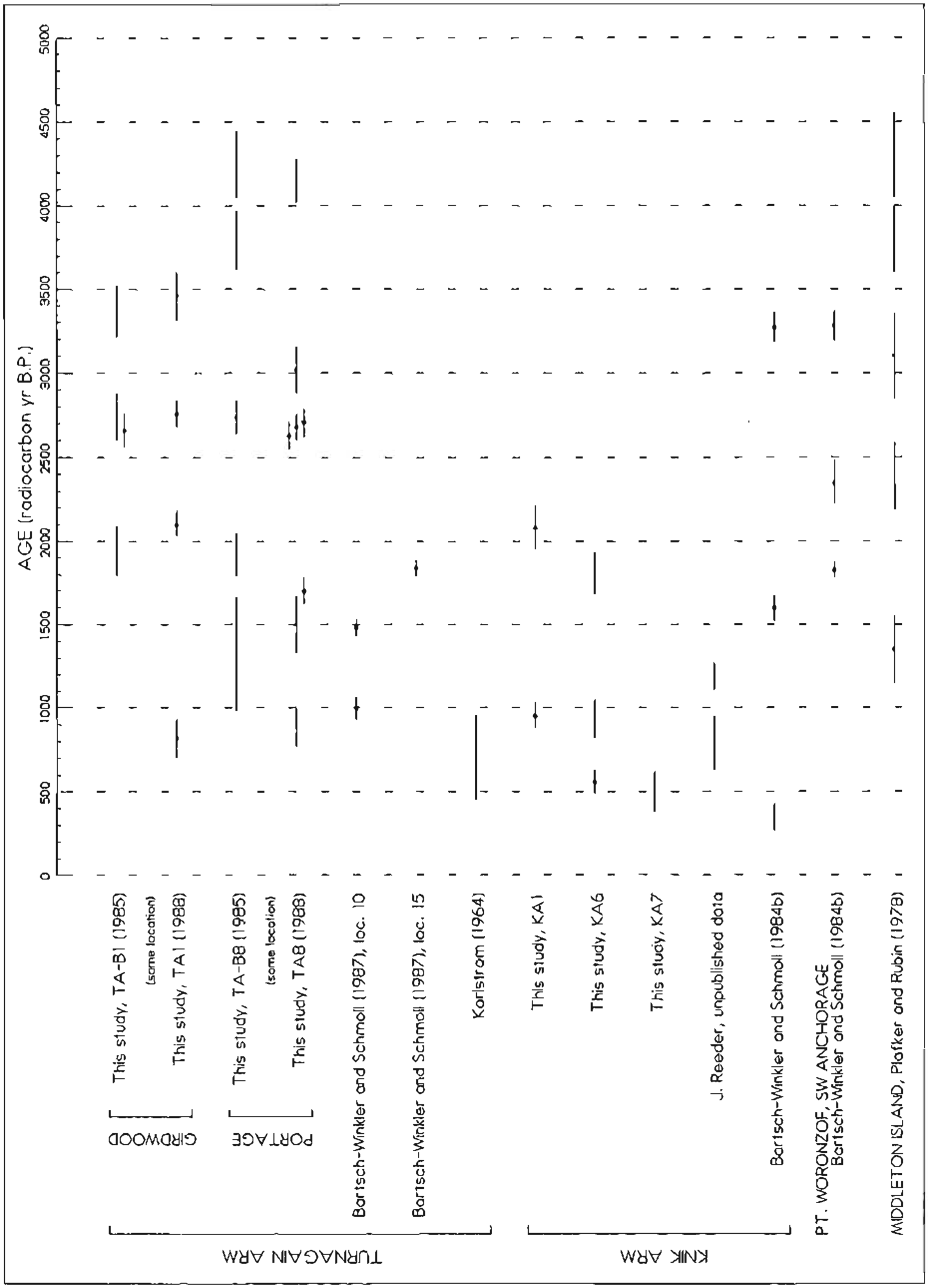

Figure 11. *Reported radiocarbon ages of submerged peats and uplifted terraces possibly associated with major prehistoric earthquakes in the rupture zone of the 1964 great Alaskan earthquake. Bars represent one laboratory standard deviation about the mean radiocarbon age. Plotted data from this study do not include ages of organic silt layers, peat layers with anomalous radiocarbon ages, or peat layers that are below sample breaks where the overlying stratigraphy was not observed.*

intertidal silt and clay, record cycles of supratidal vegetation growth, subsidence, and rapid burial during the past 5,000 yr. Radiocarbon dating of organic material at the tops of these peat layers provides maximum ages for subsidence events responsible for their burial and allows calculation of long-term submergence rates. Although uncertainties in some radiocarbon ages preclude accurate dating of all events, the buried peats provide a minimum count of subsidence events from which a maximum average recurrence interval can be calculated.

None of the borehole samples exhibit conclusive evidence, such as liquefaction features, to prove that major ground shaking was associated with peat submergence and burial. However, the sharp upper contacts of many peat layers and the organic-poor nature of overlying muds are probably the result of rapid subsidence during major earthquakes.

Borehole TA8, at Portage, revealed the largest number of buried peat layers among all boreholes drilled in this study. These buried peats are evidence of six to eight subsidence events during about the past 4,200 radiocarbon yr (4,700 calendar yr) before the 1964 great Alaska earthquake. This rate translates to a maximum average recurrence interval of 525 to 700 radiocarbon yr (about 590 to 780 calendar yr if calculated on the basis of tree-ring calibrated ages). Radiocarbon ages of shallow submerged peat layers in both Turnagain and Knik Arms indicate that the most recent major subsidence event prior to the 1964 earthquake was at or before about 500 y.a. These conclusions are reasonably consistent with data from the Copper River Delta and Prince William Sound regions (Plafker and others, 1990) that suggest an average recurrence interval of 600-950 yr and about 800 yr since the youngest major pre-1964 earthquake.

At Portage, possible evidence of three earthquakes within 100 yr, between 2,705±85 and 2,630±80 radiocarbon yr B.P. suggests that, although average recurrence times are on the order of centuries, actual recurrence times may have been as short as several decades. However, because of uncertainties in some of the radiocarbon ages, this conclusion is tentative until more regional data on events during this period are available.

Comparison with radiocarbon ages of other features interpreted to represent coseismic subsidence or uplift does not yet provide a clear chronology of pre-1964 events in the region affected by tectonic deformation during the 1964 earthquake. Although some ages roughly correlate, many do not. This poor correlation of regional data may relate to inaccuracies in radiocarbon dating, to local effects not associated with widespread tectonic changes during major earthquakes, or to a combination of these factors.

Assuming the peats developed in high-intertidal or slightly supratidal marshes, sedimentation rates computed from radiocarbon ages of the buried peats provide an estimate of the net rate of submergence. The data indicate net submergence rates of 0.23 to 0.30 cm/yr in upper Turnagain Arm for the past 4,200 radiocarbon yr and 0.13 to 0.17 cm/yr in upper Knik Arm for the past 2,100 radiocarbon yr.

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APPENDIX A

DESCRIPTIONS OF CORE SAMPLES

BOREHOLE TA1, GIRDWOOD - 60°56'39"N, 149°10'35"W; surface elevation 20.7 ft MSL

Sample	Depth (ft)	Description
TA1-1	0-1.55	Silty, gravelly sand, very poorly sorted, nonstratified (partially disturbed during splitting because of large pebbles). Brownish gray to grayish brown. Fill.
	1.55-3.5	Not recovered.
TA1-2	3.5-3.75	Brownish gray, poorly sorted silty, gravelly sand.
	3.75-3.95	Dark brown to brownish gray silty, gravelly sand with abundant organics, including disseminated charcoal, rootlets, and one wood fragment.
	3.95-4.2	Gray to brownish gray, poorly sorted silty, sandy gravel; pebbles to 1 in.
		Entire sample (TA1-2) probably fill.
	4.2-6.0	Not recovered.
TA1-3	6.0-6.25	Gray, poorly sorted, silty, gravelly sand.
	6.25-6.35	Gray silty fine sand with some organics (sedge blades).
	6.35-6.5	Brown sedge peat. Spl TA1-3-6.4 at top of peat layer, 6.35-6.45 (C14).
	6.5-7.2	Dark brown woody peat with abundant roots and twigs. Upper contact sharp along dark band.
TA1-3C	7.2-7.4	Same as 6.5-7.2 (catcher sample; bagged).
TA1B-1		(attempted resample of missed interval 7.4-8.5 ft depth, 5 ft SE of TA1)
	6.0-6.75	Gray very poorly sorted silt, sand, and gravel. Large rounded pebble at top, 0.2 in. diameter. Pebbles very angular to subrounded, mostly angular. Sharp lower contact. Possibly fill.
	6.75-7.4	Brown to dark brown fibrous peat with abundant roots and twigs. Lighter colored grassy layer in top 0.1 in. (sedge peat).
TA1B-1C	7.4-7.6	Peat as above (catcher sample; bagged).
	7.6-8.5	Not recovered.
TA1-4A	8.5-8.85	Dark brown woody peat; abundant twigs and roots. Spl TA1-4A-8.8 basal peat, 8.75-8.85 (C14).
	8.85-10.1	Interlayered gray to brownish-gray silty fine sand and sandy silt. Finely laminated between 9.2 and bottom. Laminations are horizontal and less than 1/8 in. thick. A brownish rind exists about 1/4 in. thick along sample margins, possibly from iron-rich water penetrating along edges during sampling. Laminations are visible in rind, so rind is not due to disturbance during sampling.
	10.1-10.5	Not recovered.
TA1-4B	10.5-11.0	Massive gray silt; one 1/2 in. diameter twig, probably transported.
TA1-5	11.0-11.4	Brownish-gray silt and fine sand; disturbed, probably by sampling.
	11.4-11.8	Gray silt and fine sand with contorted, thin, indistinct laminae.

	11.8-12.75	Gray to brownish gray silt, possibly clay-rich, with scattered twigs and sedge blades. Faint, thin horizontal laminae 1-4 mm thick. Twig, 1/2 in. wide, at 12.1; probably transported. Sharp lower contact.
	12.75-13.1	Dark brown to light brown sedge peat. Gradational lower contact. **Spl TA1-5-12.8** at top of peat layer, 12.75-12.85 (C14).
	13.1-13.5	Gray and stained (mottled) light brown clay and silt with scattered organics. No visible bedding.
TA1-6A	13.5-13.9	Gray to brownish gray silt/fine sand with some iron staining along edges. Trace organics.
	13.9-15.4	Gray to brownish gray silt/fine sand with distinct laminations 1-4 mm, generally horizontal and undisturbed. Scattered roots and twigs. Flat piece of wood 1 in. x 1 in. x 1/4 in. at 15.2, partially charcoal; probably transported.
TA1-6B	15.4-15.8	Disturbed zone (from sampling) of gray silt/fine sand with some iron staining around scattered organics (roots or sedge blades).
	15.8-17.1	Laminated to thin-bedded gray silt and fine sand with scattered sedge blades or roots. Iron stained around organics.
	17.1-17.45	Laminated gray silt and clayey silt. Trace organics. **Spl TA1-6B-17.1** at 17.0-17.2 (GS).
	17.45-17.75	Dark brownish gray pebbly medium to coarse sand; trace silt. No visible bedding. Pebbles subangular to well rounded.
TA1-6C	17.75-17.9	Pebbly coarse sand. Angular to subrounded pebbles to 1/2 in. diameter (catcher sample; bagged).
	17.9-18.5	Not recovered.
TA1-7	18.5-18.8	Gray medium to coarse clean sand, coarsening downward; silt lense at 18.7. A few twigs or roots at top surface; 1/4-in. twig at 18.65, probably transported.
	18.8-19.3	Gray pebbly coarse sand with angular to rounded pebbles to 3/4 in. Negligible silt, no visible bedding. **Spl TA1-7-19.0** at 18.9-19.2 (GS).
	19.3-19.6	Gray medium to coarse sand with some small pebbles and negligible silt, coarsening downward.
	19.6-19.65	Uniform gray clayey silt.
	19.65-20.2	Dark brown woody or sedge peat. Twigs up to 1/4 in. diameter. **Spl TA1-7-19.7** at 19.65-19.75 (C14).
TA1-7C	20.2-20.4	Peat as above (catcher sample; bagged).
	20.4-21.0	Not recovered.
TA1-8	21.0-21.1	Gray silt, sand, pebbles, and organics. Could be slough from drill stem.
	21.1-22.15	Dark brown layered woody or sedge peat with a few thin lenses of gray silt. **Spl TA1-8-21.2** of surface peat, 21.1-21.25 (C14).
	22.15-22.5	Gray clayey silt with some twigs and roots.
	22.5-23.5	Dark brown woody peat with minor thin silt layers near top. Lighter brown in upper 3 in. **Spl TA1-8-22.6** of surface peat, 22.5-22.7 (C14).
TA1-9A	23.5-23.6	Mixed silt, sand, and organics; probably disturbed during sampling.

	23.6-24.3	Layered dark brown sedge peat and gray silt. Possibly gradational base of lower peat in TA1-8.
	24.3-25.4	Massive gray clayey silt mottled with dark gray organic smears, but organics are negligible. **Spl TA1-9A-25.3** at 25.2-25.4 (GS).
	25.4-25.6	Dark brown sedge and woody peat. **Spl TA1-9A-25.5** at 25.4-25.6 (C14).
TA1-9B	25.6-25.9	Dark brown woody peat grading downward to brownish gray clayey silt, faintly layered (base of peat unit at bottom of TA1-9A).
	25.9-27.85	Brownish gray to gray clayey silt with scattered organics (roots and sedge blades). Very faint thin layering. Lower part mottled with dark gray organic smears. **Spl TA1-9B-26.3** at 26.2-26.4 (GS).
TA1-9C	27.85-28.1	Gray clayey silt (catcher sample; bagged).
	28.1-28.5	Not recovered.
TA1-10	28.5-30.95	Brownish gray to gray clayey silt. Very faint thin layering. Iron staining in lower portion concentrated around minor organics. Some dark gray mottling, probably organic smears.
TA1-11A	31.0-31.65	Gray clayey silt with dark gray organic smears. Trace sedge blades and minor iron staining along edges.
TA1-11B	31.65-33.8	Gray to brownish gray clayey silt with trace organics, minor iron staining, and dark gray organic smears. Grades to sandier near bottom; minor small pebbles in lower 3 in. **Spl TA1-11B-33.0** at 32.9-33.1 (GS).
TA1-12A	33.8-34.55	Brownish gray to gray silt and fine sand; no visible bedding, possibly disturbed.
TA1-12B	34.55-37.0	Brownish gray fine sandy silt and clayey silt with pebbly zones. Mottled with dark silty zones. Interlayered dark gray silt and brownish gray silty fine sand 36.3-36.8, layers 1/2 to 1 in. thick. All but 36.3-36.8 may be disturbed. No organics. Single angular pebble at 34.8. Pebbly (angular to rounded) and sandy zone 35.4-35.7. Two-inch rounded pebble at 36.8. **Spl TA1-12B-36.5** at 36.4-36.6; layered sandy silt and clayey silt (GS).
TA1-12C	37.0-37.25	Coarse silt or silty fine sand (catcher sample; bagged).
	37.25-38.5	Not recovered.
TA1-13A	38.5-40.75	Brownish gray to gray silt and fine sand with minor scattered pebbles. Most pebbles subrounded to well rounded; max. diameter about 1 in. Large (2-1/2 in.) very angular pebble at 40.5. No visible bedding. Much of this sample may be disturbed, probably during transport.
TA1-13B	40.75-41.5	Disturbed layer of brownish gray silty fine sand.
	41.5-43.25	Interlayered light brown silty fine sand and gray fine sandy silt. Some thin bedding and lamination. A few pebbles, including one subrounded pebble 1 in. diameter at 42.6. No organics. **Spl TA1-13B-41.8** at 41.7-41.9, brown sandy silt (GS).
TA1-13C	43.25-43.4	Dense silty fine sand (catcher sample; bagged).
	43.4-43.5	Not recovered.
TA1-14A	43.5-44.75	Dark gray uniform silty fine sand. No visible bedding. Trace pebbles (1/2-in. angular pebble at 44.6). No organics. Could be disturbed (according to drilling log).

TA1-14B	44.75-45.3	Gray to brownish gray silty fine sand. Slight hint of thin bedding. One rounded pebble 1-3/4 in. long at 44.8.
	45.3-45.4	Gray clayey silt, uniform.
	45.4-46.7	Grayish brown to gray silt with distinct horizontal layering in lower 0.3 ft. Two pebbles about 2 in. long at 45.9 and 46.2. Slight grading to medium sand at base. **Spl TA1-14B-45.6** at 45.5-45.7 (GS).
	46.7-47.2	Gray to brownish gray silty fine sand. No visible bedding. Dark gray zone at 46.9-47.1 may be organic-rich (disseminated).
TA1-14C	47.2-47.4	Silty fine sand or coarse silt (catcher sample; bagged).
	47.4-48.5	Not recovered.
TA1-15A	48.5-50.4	Brownish gray to gray uniform silty fine sand. Brownish (iron stained) 48.5-48.8. Minor pebbles (rounded, up to 1/2 in.) at 48.6 and 50.0. Trace shell fragments (48.65, 49.9).
TA1-15B	50.4-52.75	Gray to brownish gray uniform silty fine sand. Trace shell fragments (e.g. 50.7). Several angular to rounded pebbles to 1/2 in. at 52.6.
TA1-15C	52.75-53.0	Dense, very fine sand (catcher sample; bagged).
	53.0-53.5	Not recovered.
TA1-16	53.5-53.9	Slough from drill stem.
	53.9-55.9	Brownish gray to gray uniform silty fine sand or sandy silt. Very faint layering. One-inch angular pebble at 54.0 (probably ice-rafted). Dark gray layers at 55.2-55.4, organic-rich(?). **Spl TA1-17-55.3** at 55.2-55.4, thin laminated charcoal in silty fine sand (C14).
TA1-16C	55.9-56.0	Silty fine sand or sandy silt (catcher sample; bagged).
TA1-17	56.0-58.0	Brownish gray to gray uniform fine sandy silt. No visible bedding and no organics. Trace scattered small pebbles. Brownish color apparently from iron staining. **Spl TA1-17-57.0** at 56.9-57.1 (GS).
TA1-17C	58.0-58.25	Silty fine sand or sandy silt (catcher sample; bagged).
	58.25-58.5	Not recovered.
TA1-18A	58.5-60.6	Brownish gray to gray uniform silty fine sand with trace scattered small pebbles (probably ice-rafted). No visible bedding or organics. Brownish color from iron staining. Rounded pebble 3/4-inch at 60.4.
TA1-18B	60.6-62.3	Brownish gray to gray uniform fine sandy silt with trace scattered small pebbles (one well-rounded pebble 1/2-in. dia.) at 61.95. No visible bedding. Trace organics (dark gray smear) at 61.5. Brownish color from iron staining. **Spl TA1-18B-61.0** at 60.9-61.1 (GS).
	62.3-62.4	Thin layer of pebbly coarse sand.
	62.4-62.7	Gray uniform silty fine sand. No visible bedding or organics.
	62.7-63.05	Gray pebbly, silty fine sand; 2-in. pebble at 63.0.
TA1-18C	63.05-63.3	Gravel (catcher sample; bagged).

Maximum depth sampled 63.3 ft.

BOREHOLE TA8, PORTAGE- 60°48'54"N, 148°57'57"W; surface elevation 23.5 ft MSL.

Sample	Depth (ft)	Description
TA8-1	0-0.3	Gray fine sand mixed with surface organics (leaves, twigs, roots).
	0.3-1.8	Gray to brownish gray, layered silty very fine sand to clean fine or medium sand. Four layers 0.2 to 0.6 ft thick, reverse graded (fine at bottom to medium at top). Scattered roots and twigs throughout. Mica rich 1.0-1.6.
	1.8-2.2	Gray uniform fine to medium sand, clean. No bedding; trace organics. Probably fluvial.
TA8-1C	2.2-2.4	Fine to medium sand with trace silt (catcher sample; bagged).
TA8B-1		(From adjacent borehole to resample missed interval 2.2-3.9; 6 ft NE of TA8)
	1.4-1.6	Disturbed. Gray fine to medium sand with some organics.
	1.6-3.1	Gray to brownish gray, layered silty very fine sand to clean fine or medium sand. Three layers to 0.6-in. thick, reverse graded as in TA8-1, 0.3-1.8. Trace organics.
TA8B-1C	3.1-3.2	Clean medium sand (catcher sample; bagged).
	3.2-3.5	Not recovered.
TA8-2A	3.5-3.9	Fine sand with some silt and organic smears (bagged).
TA8-2B	3.9-4.85	Gray, uniform, fine to medium sand with minor silt. No visible layering. Trace organics. Spl TA8-2B-4.7 at 4.6-4.8 (GS).
	4.85-5.1	Interlayered brownish gray to gray silt, silty fine sand, and organics (probably sedge). Spl TA8-2B-4.9 at 4.85-5.1 (C14); sedge blades, roots, and rhizomes(?), probably in place at time of deposition.
	5.1-6.3	Gray silt and silty fine sand with faint layering and scattered minor organics.
TA8-2C	6.3-6.55	Silt or silty fine sand (catcher sample; bagged).
TA8B-2		(From adjacent borehole to sample missed interval 6.3-8.4 in TA8; 6 ft NE of TA8)
	6.0-6.4	Probably disturbed, gray, uniform, clean fine sand; probably fluvial.
	6.4-6.9	Gray silt and silty fine sand with faint layering. Minor iron staining. Trace organics.
	6.9-7.2	Brownish gray to gray layered silt, silty fine sand, and organics (sedge). Iron stained in organic zones. Fluvial(?). Spl TA8B-2-7.0 at 6.9-7.1 (C14).
	7.2-8.1	Brownish gray to gray silt, silty fine sand, and clean fine sand. Distinct layering (silt layer with sharp contacts at 7.9-8.0). Negligible organics.
TA8B-2C	8.1-8.3	Clean fine sand (catcher sample; bagged).
	8.3-8.5	Not recovered.
TA8-3	8.5-10.7	Gray silty fine sand and clean fine sand with some silt interlayers 10.0-10.7. Faint iron staining. No organics. Spl TA8-3-9.5 at 9.4-9.6 (GS).

TA8-3C	10.7-11.0	Fine sand with trace silt (catcher sample; bagged).
TA8-4	11.0-11.85	Gray silt, silty fine sand, and clean fine sand in contorted zones; probably disturbed during sampling. Some evidence of lamination at 11.4. Negligible organics. Minor iron staining.
	11.85-12.6	Gray to brownish gray clayey silt and fine sandy silt. Disseminated organics 12.1-12.3. Scattered sedge blades. **Spl TA8-4-12.5** at 12.4-12.6 (GS).
	12.6-13.25	Brown to dark brown sedge and woody peat. Increasing silt toward base. Sharp upper contact. **Spl TA8-4-12.7** at 12.6-12.75 (C14).
	13.25-13.4	Brownish gray organic-rich silt.
TA8-4C	13.4-13.5	Sedge peat (catcher sample; bagged). **Spl TA8-4C-13.4** (C14).
TA8-5A	13.5-13.6	Gray fine sand; probably not in place (sloughed or fill-in). Lower contact distorted.
	13.6-15.2	Gray silt with abundant scattered organics (sedge blades, roots).
TA8-5B	15.2-17.5	Gray to brownish gray (minor) laminated silt and clayey silt. Horizontal laminations 1-5 mm. Trace scattered organics (sedge blades). **Spl TA8-5B-16.7** at 16.6-16.8 (GS).
TA8-5C	17.5-18.1	Fine sand with some silt and clay (catcher sample; bagged).
	18.1-18.5	Not recovered.
TA8-6	18.5-19.3	Disturbed gray clayey silt and silty fine sand. Contorted laminae. No organics.
	19.3-20.2	Gray to brownish gray (at base) laminated silt and clayey silt. Minor organics near base. Lower contact gradational. **Spl TA8-6-20.0** at 19.9-20.1 (GS).
	20.2-20.9	Woody and sedge peat, mixed with silt in upper 0.1 ft. **Spl TA8-6-20.3** at 20.2-20.35 (C14).
TA8-6C	20.9-21.0	Sedge peat (catcher sample; bagged).
TA8-7	21.0-21.4	Probably fill-in (not in place). Gray silt with chunks of peat.
	21.4-21.7	Dark brown sedge(?) peat grading downward to organic-rich silt. Probably the base of peat layer that starts at 20.2. Sampled to confirm. **Spl TA8-7-21.5** at 21.4-21.5 (C14).
	21.7-23.3	Gray clayey silt and silty fine sand with minor organics near top. Faint laminations near base.
TA8-7C	23.3-23.5	Very fine sand with some silt and trace clay (catcher sample; bagged).
TA8-8	23.5-24.75	Uniform gray silt or fine sandy silt with minor clay. Very faint laminations near base. Trace organics. **Spl TA8-8-24.6** at 24.5-24.7 (GS).
	24.75-25.0	Dark brown woody/sedge peat. Sharp upper contact, fairly sharp lower contact. **Spl TA8-8-24.8** at 24.75-24.85 (C14).
	25.0-25.75	Uniform gray silt or silty fine sand. Very faint thin laminations. No organics.
TA8-8C	25.75-26.0	Very fine sand with some silt (catcher sample; bagged).

TA8-9	26.0-28.3	Gray to brownish gray silt and silty fine sand with scattered minor organics (sedge). Disturbed with some contorted laminae in upper 1.0 ft. Top 0.3 ft may be fill-in (see log). Contorted layers of sedge blades or roots at 27.7. Distinct thin lamination at 27.2-27.5 and 27.8-28.3.
TA8-9C	28.3-28.5	Very fine sand with some silt (catcher sample; bagged).
TA8-10A	28.5-30.15	Uniform gray silt or silty fine sand with negligible organics. No visible bedding.
	30.15-30.25	Gray to brownish gray thin-bedded to laminated silt and clayey silt. Sharp lower contact with peat. Spl TA8-10A-30.2 at 30.1-30.25 (GS).
	30.25-30.6	Dark brown sedge and/or sphagnum peat. Compact and horizontally layered. Spl TA8-10A-30.3 at 30.15-30.4 (C14).
TA8-10B	30.6-30.8	Dark brown sedge and/or sphagnum peat. Base of peat layer at 30.25-30.6 in TA8-10A. Sharp base.
	30.8-33.1	Gray to brownish gray (minor) silt and silty fine sand. Organic-rich 30.8-31.1. Scattered organics decrease downward. Distinct fine laminations (0.5-2 mm) at 31.7-33.1. Minor iron staining along edges and near organics.
TA8-10C	33.1-33.2	Very fine sand (catcher sample; bagged).
	33.2-33.5	Not recovered.
TA8-11A	33.5-35.65	Gray clayey silt, nearly uniform. No visible bedding except fine laminations at 33.5-33.7 (top). Rest is massive or disturbed. Minor iron staining along margins. Negligible organics. Faint dark organic smears. Spl TA8-11A-35.0 at 34.9-35.1 (GS).
TA8-11B	35.65-35.95	Gray to brownish gray silt. No bedding, possibly disturbed. Minor iron staining.
	35.95-36.2	Gray to brownish gray silt interlayered with organics. Concentrated organic layer 1/4 in. thick at 36.15. Possibly a buried peat layer. Spl TA8-11B-36.2 at 36.15-36.25 (C14).
	36.2-38.1	Gray to brownish gray silt with interlayered thin organic-rich layers, decreasing downward. Spl TA8-11B-36.8 at 36.8-36.9 (C14) for sedimentation rate.
	38.1-38.5	Not recovered.
TA8-12A	38.5-41.0	Gray silt. No visible bedding except faint laminations in lower 1.0 ft. trace organics. Trace iron staining.
TA8-12B	41.0-41.4	Gray laminated silt and silty fine sand. No visible organics.
	41.4-41.55	Gray to brownish gray silt with thin layers of organic material. Possibly a buried peat layer. Spl TA8-12B-41.5 at 41.4-41.55 (C14).
	41.55-43.5	Gray to brownish gray silt with scattered organics and very faint laminations in lower 1.0 ft. No distinct upper contact. Distorted organic zone (sedge?) at 42.3.
TA8-13A	43.5-46.0	Gray clayey silt with trace organics and minor iron staining. Faint lamination at 44.8 to 46.0. Spl TA8-13A-45.5 at 45.4 to 45.6 (GS).
TA8-13B	46.0-48.5	Gray silt and/or clayey silt with trace organics and minor iron staining. Faint laminations throughout, most visible at 47.0 where iron staining accentuates coarser laminae.

TA8-14A	48.5-50.95	Gray to brownish gray silt and clayey silt. No visible bedding. Minor iron staining (49.9-50.1). Mottled with dark gray organic smears throughout, especially visible at 50.1 to 50.95. Probably not a buried peat layer, but could be useful for determining sedimentation rate. Spl TA8-14A-50.5 at 50.4-50.6 (GS). Spl TA8-14A-50.8 at 50.6-50.9 (C14).
TA8-14B	50.95-53.4	Gray to brownish gray silt; laminated to thin bedded, except upper 0.5 ft probably disturbed. Light gray thin partings (volcanic ash?) 1 to 3 mm thick at 52.0 and 52.7-58.5.
TA8-14C	53.4-53.7	Silty clay with some fine sand (catcher sample; bagged).

Maximum depth sampled 53.7 ft.

BOREHOLE KA1, PALMER HAY FLATS - 61°29'40"N, 149°18'40"W; surface elevation 20.3 ft MSL.

Sample	Depth (ft)	Description
	0-0.7	Not sampled; mostly ice.
KA1-1	0.7-1.0	Frozen peat and silt; bagged.
	1.0-1.5	Not recovered.
KA1-2	1.5-1.65	Wet gray silt mixed with grass, twigs, and roots, probably disturbed. Appears to be silt layer between surface organics and underlying peat.
	1.65-2.5	Grayish brown to dark brown peat (wood, sedge, sphagnum?). Larger pieces at top. Could have roots from surface. Some gray silt mixed in top 0.2 in. Spl KA1-2-1.7 at 1.65-1.8 (C14).
KA1-2C	2.5-2.8	Basal peat with small amount of underlying gray silt (catcher sample; bagged).
KA1B-1		(From adjacent borehole to sample missed interval at 2.5-4.0 in KA1; 4 ft south of KA1)
	2.1-2.3	Wet gray silt mixed with sedge, twigs, and roots. Probably equivalent to 1.5-1.65 in KA1-2.
	2.3-2.8	Brown peat (wood, sedge, sphagnum?). Could be 1964 peat. Equivalent to peat at 1.65-2.5 in KA1-2. Sampled at base to compare with age of KA1-2-1.7 and avoid possible contamination by roots. Spl KA1B-1-2.7 at 2.65-2.8 (C14).
	2.8-4.3	Wet gray clayey silt with faint thin lamination at top (2.8-3.1) and trace organics. Spl KA1B-1-3.1 at 3.0-3.2 (GS).
KA1B-1C	4.3-4.5	Gray clayey silt with minor organics (catcher sample; bagged; from adjacent borehole 4 ft south of KA1).
KA1-3	4.0-5.8	Wet gray clayey silt with very faint layering and some organics. Also some dark gray organic smears. Spl KA1-3-5.7 at 5.6-5.8 (GS).
	5.8-6.0	Dark brown sedge(?) peat grading downward to brownish gray organic-rich silt. Sharp upper contact. Probably buried peat layer. Spl KA1-3-5.85 at 5.8-5.9 (C14).
KA1-3C	6.0-6.25	Gray clayey silt with some organics (catcher sample; bagged).
	6.25-7.0	Not recovered.

KA1-4	7.0-8.5	Gray silt with no visible bedding. Minor organics at 7.7-7.9 (sedge), otherwise rare. Dark gray organic smears throughout.
KA1-4C	8.5-8.75	Gray clayey silt.
KA1-5	8.75-11.3	Uniform gray clayey silt with no visible bedding and negligible organics. <u>**Spl KA1-5-10.0**</u> at 9.9-10.1 (GS).
KA1-5C	11.3-11.5	Gray clayey silt (catcher sample; bagged)
KA1-6	11.5-11.7	Gray clayey silt with no visible bedding. Trace organics. <u>**Spl KA1-6-11.6**</u> at 11.5-11.7 (GS).
	11.7-12.0	Dark brown peat (sedge?) grading down to grayish brown organic-rich silt. Upper contact slightly disturbed but sharp. Lower contact gradational. Probably a buried peat layer. <u>**Spl KA1-6-11.75**</u> at 11.7-11.8 (C14).
	12.0-13.8	Uniform wet gray silt with minor organics near top and trace at bottom. Faint laminations visible at 13.6-13.8.
KA1-6C	13.8-14.0	Gray clayey silt (catcher sample; bagged).
KA1-7	14.0-16.1	Wet clayey silt with faint layering (15.0-16.0) and no organics.
KA1-7C	16.1-16.3	Gray silt (catcher sample; bagged).
KA1-8	16.3-18.65	Uniform wet gray clayey silt. Very faint layering 18.0-18.4. Trace organics at 16.7. Several pockets of sedge blades at 18.1-18.5. Subrounded pebble 3/8 in. diameter at 18.35, probably ice rafted. <u>**Spl KA1-8-17.9**</u> at 17.8-18.0 (GS). <u>**Spl KA1-8-18.2**</u> at 18.1-18.3 (C14) for sedimentation rate (sedge blades probably transported).
KA1-8C	18.65-19.0	Gray silt with some organics (catcher sample; bagged).
KA1-9	19.0-21.5	Uniform wet gray clayey silt. Faint layering (20.9-21.1). Pockets of organics (sedge?) at 19.25-19.5.
KA1-10	21.5-23.95	Wet gray silt with faint layering (22.5-23.5) and minor scattered organics (e.g., 22.1, 23.2)
KA1-10C	23.95-24.3	Gray silt (catcher sample; bagged).
KA1-11	24.3-26.4	Gray clayey silt with some dark gray organic smears and moderate layering (see 25.1-25.6). Very minor organic pieces scattered throughout. <u>**Spl KA1-11-25.0**</u> at 24.9-25.1 (GS).
KA1-12	26.4-28.1	Uniform gray silt with minor dark gray organic smears. Small pocket of organics (sedge) at 27.1 Very faint layering.
	28.1-28.15	Layered gray silt and fine sand. Sand layer 3 mm thick at 28.15 above organic-rich layer. Too thin to sample for grain size.
	28.15-28.3	Dark gray layered organic-rich silt. Buried peat layer? <u>**Spl KA1-12-28.2**</u> at 28.15-28.3 (C14).
	28.3-28.9	Gray silt with some dark gray organic smears. Very faint layering.
KA1-12C	28.9-29.1	Gray silt (catcher sample; bagged).
KA1-13	29.1-30.7	Gray silt with very faint layering. Banded dark gray organic smears at 30.4-30.6. Doubtful buried peat layer, but would give sedimentation rate. <u>**Spl KA1-13-30.5**</u> at 30.4-30.6 (C14).

KA1-14	30.7-33.2	Gray silt with dark banded organic smears at 30.7-31.1, 31.3-31.6, and 32.4-32.5. Otherwise very faint layering. The three dark layers may be buried peats, but doubtful.
KA1-14C	33.2-33.5	Gray silt (catcher sample; bagged).

Maximum depth sampled 33.5 ft.

BOREHOLE KA2, PALMER HAY FLATS - 61°30'50"N, 149°26'15"W; surface elevation 19.3 ft MSL.

Sample	Depth (ft)	Description
KA2-1	0-1.0	Frozen ice-rich peat (bagged).
	1.0-1.5	Not recovered.
KA2-2	1.5-1.75	Dark brown peat; base of modern surface organic layer.
	1.75-2.8	Uniform wet gray silt. No visible bedding. Trace organics (one small pocket of sedge blades at 2.65).
	2.8-3.0	Not recovered.
KA2-3	3.0-3.85	Gray silt. No visible bedding or organics. Minor iron staining. Spl KA2-3-3.5 at 3.4-3.6 (GS).
	3.85-5.35	Gray clayey silt with faint laminations, grading downward to interlayered clayey silt and silty fine sand. Trace organics, minor iron staining. Spl KA2-3-4.0 at 3.9-4.1 (GS).
	5.35-5.5	Not recovered.
KA2-4	5.5-7.3	Wet, gray silt, partially liquefied. Very faint bedding, trace organics. Spl KA2-4-7.0 at 6.9-7.1 (GS).
KA2-4C	7.3-7.6	Gray fine sand with abundant mica and little or no silt (catcher sample; bagged). May be fluvial.
	7.6-8.0	Not recovered.
KA2-5	8.0-9.7	Gray clayey silt with some laminations of silty fine sand (9.0-9.7). Trace organics, minor iron staining.
KA2-5C	9.7-10.0	Firm gray fine sand (catcher sample; bagged).
	10.0-10.5	Not recovered.
KA2-6	10.5-12.2	Gray silt with iron staining along laminations. No visible layering. Possible volcanic-ash parting at 12.1 (very light gray silt-size material).
KA2-6C	12.2-12.4	Gray silt (catcher sample; bagged).
	12.4-13.0	Not recovered.
KA2-7	13.0-15.0	Gray clayey silt with no visible bedding. Minor iron staining. Trace scattered organics. Iron staining produces mottling, apparently associated with organics.
KA2-8	15.0-17.5	Gray clayey silt. Very faint bedding. Minor iron staining (mottled) at 15.0-16.4. Trace organics.
KA2-8C	17.5-17.7	Gray clayey silt (catcher sample; bagged).
	17.7-18.0	Not recovered.

KA2-9	18.0-20.5	Gray clayey silt. Distinct lamination and thin bedding at 19.5-20.3. No visible organics. Trace iron staining. Spl KA2-9-20.0 at 19.9-20.1 (GS).
KA2-10	20.5-22.3	Gray clayey silt with faint layering. Desiccation crack longitudinally along entire sample. Several lateral cracks. No visible organics; no iron staining.
	22.3-23.0	Dark gray organic-rich clayey silt. Dark organic smears show crude bedding. Possible buried peat layer, or useful for age and sedimentation rate. Spl KA2-10-22.4 at 22.3-22.45 (C14).
KA2-11	23.0-25.3	Gray clayey silt with no visible bedding. Mottled with small darker gay organic smears, but organics are negligible.
KA2-11C	25.3-25.5	Firm gray clayey silt (catcher sample; bagged).
KA2-12	25.5-27.5	Firm gray clayey silt with numerous dark gray organic smears in mottles and layers. Organic-rich zones (buried peat layers?) at 26.0-26.1, 26.7, and distinct layer at 27.05-27.15. Light brown fine-sand interbeds, 1-3 mm thick, possibly volcanic ash (?), at 26.7-26.75, 27.0-27.1, 27.2, and 27.25. Dark organic-rich layers appear oblique to bedding (dipping about 20°) at 26.0-26.5. Spl KA2-12-27.0 at 27.0-27.1 (GS). Spl KA2-12-27.1 at 27.1-27.2 (C14).
KA2-12C	27.5-27.8	Firm gray silt (catcher sample; bagged).
	27.8-28.0	Not recovered.
KA2-13	28.0-29.3	Firm gray silt with thin horizontal seams of dark gray organic-rich silt (29.0-29.3).
KA2-13C	29.3-29.6	Firm gray silt (catcher sample; bagged).
	29.6-30.5	Not recovered.
KA2-14	30.5-31.45	Very firm gray silt or clayey silt with faint lamination; no organics, except minor dark gray mottling.
KA2-14C	31.45-31.7	Very firm gray silt (catcher sample; bagged).

Maximum depth sampled 31.7 ft.

BOREHOLE KA3, PALMER HAY FLATS - 61°30'45"N, 149°30'5"W; surface elevation 19.0 ft MSL.

Sample	Depth (ft)	Description
	0-0.3	Not recovered.
KA3-1	0.3-0.7	Frozen basal surface peat over gray silt (bagged).
	0.7-1.0	Not recovered.
KA3-2	1.0-1.25	Frozen gray silt; plugged sampler (bagged).
KA3-3	1.25-2.1	Gray to brownish-gray clayey silt. Probably disturbed at 1.25-1.7. Faint laminations at 1.7-2.1. Brownish color from minor iron staining along margins. No visible organics. Spl KA3-3-2.0 at 1.9-2.1 (GS).
	2.1-2.8	Not recovered.
KA3-4	2.8-5.25	Wet, gray, layered and laminated clayey silt. Coarser layers (slightly darker) may contain some very fine sand. Layers are 2-15 mm thick with slight dip. Trace organic smears, otherwise no identifiable organics. Minor iron staining 5.0-5.25. Much rust on outside surface.

KA3-4C	5.25-5.5	Wet gray silt (catcher sample; bagged).
KA3-5	5.5-7.8	Very wet, gray, layered and laminated clayey silt, like KA3-4. Trace dark gray organic mottles. Spl KA3-5-7.0 at 6.9-7.1 (GS)
	7.8-8.0	Not recovered.
KA3-6	8.0-8.65	Wet, gray, layered clayey silt like KA3-4 and 5. No organics.
	8.65-9.15	Massive wet gray clayey silt. No visible layering or organics.
KA3-7	9.15-9.5	Gray silt with no visible bedding or organics. Continuation of lower unit in KA3-6. Spl KA3-7-9.3 at 9.2-9.4 (GS).
	9.5-11.6	Strongly laminated gray clayey silt and fine sandy silt. Organic-rich laminae at 10.05-10.15. Otherwise no organics. Spl KA3-7-9.8 at 9.7-9.9 (GS). Spl KA3-7-10.1 at 10.05-10.15 (C14).
KA3-7C	11.6-11.8	Gray silt (catcher sample; bagged).
	11.8-13.0	Not recovered.
KA3-8	13.0-13.6	Disturbed wet gray clayey silt and silty fine sand (probably disturbed in sampling or transport).
	13.6-15.1	Layered wet gray clayey silt and silty fine sand. No visible organics.
KA3-8C	15.1-15.4	Gray silt with one small wood fragment (catcher sample; bagged).
	15.4-15.5	Not recovered.
KA3-9	15.5-17.7	Wet, gray, silty fine sand. No visible layering except faint laminations at 17.4-17.7. Core possibly disturbed. No visible organics.
KA3-9C	17.7-18.0	Gray silty fine sand with scattered small wood fragments (catcher sample; bagged).
KA3-10	18.0-19.7	Uniform gray very fine sand. Possibly disturbed from liquefaction during sampling or transport. No organics. Channel sand? Spl KA3-10-19.0 at 18.9-19.1 (GS).
	19.7-20.1	Not recovered.
KA3-11	20.1-22.2	Uniform gray fine sand and (at base) silty fine sand. No visible bedding except faint lamination 22.1-22.2. No visible organics.
KA3-11C	22.2-22.5	Gray fine sand (catcher sample; bagged).

Maximum depth sampled 22.5 ft.

BOREHOLE KA4, GOOSE BAY - 61°23'25"N, 149°52'10"W; surface elevation 17.1 ft MSL.

Sample	Depth (ft)	Description
KA4-1	0-0.7	Mixed surface organics (twigs, sedge, roots) and wet gray clayey silt.
	0.7-0.8	Dark grayish brown organics (twigs, roots, sedge) with minor silt. Relatively sharp upper contact and distinctly less silt than above. Could be older peat buried by younger sediment and organics after submergence. Spl KA4-1-0.7 at 0.7-0.8 (C14) for age of possible buried peat layer.
KA4-1C	0.8-1.2	Brown peat as above (catcher sample; bagged).
	1.2-2.9	Not recovered.

KA4-2	2.9-3.0	Slough from above - disregard.
	3.0-3.35	Brown woody peat (twigs, sedge, roots, possible sphagnum). Could be base of surface organics. Basal sample collected for date. **Spl KA4-2-3.3** at 3.25-3.35 (C14).
	3.35-4.0	Sticky gray clayey silt. No visible bedding. Minor dark gray organic mottling. **Spl KA4-2-3.4** at 3.35-3.5 (GS).
KA4-2C	4.0-4.3	Gray silt (catcher sample; bagged).
	4.3-5.5	Not recovered.
KA4-3	5.5-7.6	Firm gray silt with no visible layering and trace organics (sedge). Trace iron staining.
KA4-3C	7.6-8.0	Gray silt with trace organics (catcher sample; bagged).
KA4-4	8.0-8.75	Same as 5.5-7.6 above but no visible organics.
KA4-5	8.75-11.3	Brownish gray to gray firm clayey silt with faint lamination (9.2-9.6). Trace organics. More clay-rich at 10.1-11.3. **Spl KA4-5-10.0** at 9.9-10.1 (GS).
KA4-5C	11.3-11.5	Gray clayey silt (catcher sample; bagged).
	11.5-13.0	Not recovered.
KA4-6	13.0-14.9	Firm gray silt with minor iron staining. Numerous Desiccation cracks. No visible bedding or organics.
KA4-6C	14.9-15.2	Gray silt (catcher sample; bagged).
	15.2-15.5	Not recovered.
KA4-7	15.5-17.0	Gray to brownish gray silt with faint layering and minor iron staining. Sedge blade and twig at top, otherwise no visible organics.
	17.0-17.55	Gray to dark gray silt with organic smears and mottling. Concentrated dark gray organic zone at 17.3-17.4. Probably not a buried peat layer, but sampled for age and sedimentation rate. **Spl KA4-7-17.3** at 17.25-17.4 (C14).
KA4-7C	17.55-17.8	Gray silt (catcher sample; bagged).
	17.8-18.0	Not recovered.
KA4-8	18.0-20.15	Dry, firm gray silt with some dark gray organic-rich zones at 19.7-20.1. Breaks into hard chunks.
KA4-8C	20.15-20.4	Gray silt (catcher sample; bagged).
	20.4-20.5	Not recovered.
KA4-9	20.5-22.6	Dry, very firm, light to dark gray silt with minor organic-rich layers (charcoal?) at 21.6-21.8. Breaks into large chunks. **Spl KA4-9-21.8** at 21.7-21.85 (C14) for age and sedimentation rate (probably not a buried peat layer).
KA4-9C	22.6-22.9	Firm gray silt (catcher sample; bagged).
	22.9-23.0	Not recovered.

KA4-10	23.0-25.1	Dry, very firm, light brownish gray, gray, and some dark gray layered silt. Very brittle; breaks into chunks. Dark gray organic-rich layer at 24.15-24.25, sampled for age and sedimentation rate (not a buried peat layer). Spl KA4-10-24.2 at 24.15-24.25 (C14).
KA4-10C	25.1-25.4	Very firm silt (catcher sample; bagged).
	25.4-25.5	Not recovered.
KA4-11	25.5-27.0	Dry, very firm and hard gray silt. Very faint layering and no visible organics.
KA4-11C	27.0-27.2	Very firm, dry silt; no organics (catcher sample; bagged).

Maximum depth sampled 27.2 ft.

BOREHOLE KA4B, GOOSE BAY - 61°23'35"N, 149°52'40"W; surface elevation 17.3 ft MSL.

Sample	Depth (ft)	Description
KA4B-1	0-0.8	Bagged; mixed sedge blades, twigs, and water (frozen when cored) with some roots.
KA4B-1C	0.8-1.0	Frozen organic-rich silt; catcher sample; bagged (bagged).
KA4B-2C	1.0-1.4	Frozen organic-rich silt; catcher sample; bagged (bagged); Sampler plugged and pushed through soil without recovering core.
	1.4-3.0	Not recovered.
KA4B-3C	3.0-3.3	Sedge and woody peat (catcher sample; bagged). Spl KA4B-3C-3.1 (C14).
KA4C-1C		(From adjacent borehole to attempt missed interval at 3.3-5.5 in KA4B)
	3.0-3.8	Peat; bagged.
	3.8-5.5	Not recovered.
KA4B-4	5.5-5.85	Dark brown peat (sedge, twigs, sphagnum?). Probably base of surface organics. Sampled at base for C14 age. Spl KA4B-4-5.8 at 5.75-5.85 (C14).
	5.85-7.0	Wet gray clayey silt with no visible bedding and minor organics. Spl KA4B-4-6.0 at 5.9-6.05 (GS).
KA4B-4C	7.0-7.3	Gray sticky clayey silt with organics (catcher sample; bagged).
KA4C-2		(From adjacent borehole to attempt missed interval in KA4B; unsuccessful)
	5.5-5.8	Same as 5.5-5.85 in KA4B-4.
	5.8-6.35	Same as 5.85-7.0 in KA4B-4.
	7.3-8.0	Not recovered.
KA4B-5	8.0-10.3	Gray clayey silt with faint layering. Trace organics at 8.25 and 9.35.
KA4C-3		(From adjacent borehole 2 ft away; same interval as KA4B-5; unsuccessful attempt to resample 7.25-8.0)
	8.0-8.5	Soft, wet organics. Probably fill-in from higher in hole (not in place).

	8.5-10.15	Wet, gray silt with minor scattered organics and some dark gray organic mottling. Twigs (1/2 in. dia.) at 9.4 and 9.9, possibly transported (although bark still intact).
	10.3-10.5	Not recovered.
KA4B-6	10.5-12.85	Moist gray clayey silt with faint layering and laminations. Void of unknown origin (not disturbed) at 10.85. Trace scattered organics. More concentrated organics (sedge?) at 12.6-12.8. Sampled for age and sedimentation rate (not a buried peat layer). **Spl KA4B-6-12.7** at 12.6-12.75 (C14).
KA4B-6C	12.85-13.2	Gray sticky silt with minor organics (catcher sample; bagged).
	13.2-13.3	Not recovered.
KA4B-7	13.3-14.25	Uniform gray clayey wilt. No visible bedding; trace organic smears.
KA4B-7C	14.25-14.4	Stiff gray silt (catcher sample; bagged).
	14.4-15.5	Not recovered.
KA4B-8	15.5-17.1	Uniform gray clayey silt. Minor crudely layered but distorted dark gray organic-rich layers at 16.9-17.0.
KA4B-8C	17.1-17.3	Gray silt (catcher sample; bagged).
	17.3-18.0	Not recovered.
KA4B-9	18.0-20.5	Gray to dark gray clayey silt. Several areas of dark gray organic-rich mottling and layering (18.2-18.3, 18.9-19.0, 19.2-19.3, 19.4).
KA4B-10	20.5-22.9	Very firm, nearly dry, gray to light brownish gray clayey silt. Distinct but disturbed layering. Light brownish gray zones along cracks and partings, possibly from iron staining. No visible organics, but darker gray zones may be slightly organic-rich. Concoidally fractured.
KA4B-11	22.9-25.4	Same as KA4B-10. Several small (up to 1/4 in.) subrounded pebbles at 24.8. No visible organics. **Spl KA4B-11-24.8** at 24.7-24.9 (GS).

Maximum depth sampled 25.4 ft.

BOREHOLE KA5, PALMER HAY FLATS - 61°31'40"N, 149°26'55"W; surface elevation 21.4 ft MSL.

Sample	Depth (ft)	Description
	0-4.7	Not sampled; organics and water.
KA5-1	4.7-5.1	Brown to dark brown woody, sedge, and sphagnum(?) peat. Sharp base. **Spl KA5-1-5.0** at 5.0-5.1 (C14).
	5.1-6.0	Wet, gray, layered silt with trace organics. **Spl KA5-1-5.6** at 5.5-5.7 (GS).
	6.0-6.25	Wet, gray, clayey silt with faint layering and no visible organics. **Spl KA5-1-6.2** at 6.1-6.25 (GS).
KA5-1C	6.25-6.5	Gray silt with minor organics (catcher sample; bagged).
KA5-2	6.5-8.2	Wet, gray, laminated silt and clayey silt. Laminae dip 10-30° at 6.5-7.3. No visible organics.

KA5-2C	8.2-8.6	Gray silt (catcher sample; bagged).
KA5-3	8.6-8.95	Wet, gray, laminated silt and clayey silt. No visible organics.
KA5-4	9.0-9.7	Wet, gray silt and clayey silt with distorted laminae.
	9.7-11.4	Wet, gray, laminated and thin-layered silt and clayey silt. Dark gray silt layer at 10.25-10.35 may be slightly organic-rich. Dark gray organic-rich(?) mottling at 10.6-11.0. **Spl KA5-4-10.0** at 9.9-10.1 (GS).
KA5-4C	11.4-11.8	Gray silt (catcher sample; bagged).
KA5-5	11.8-13.2	Wet, gray, laminated and thin-layered silt and clayey silt. Disturbed at 11.8-12.7. No visible organics.
KA5-6	13.2-15.7	Moist, gray, laminated and thin-layered silt and clayey silt. No visible organics. Cross-bedded fine-sandy layers at 14.5-14.7. **Spl KA5-6-15.3** at 15.2-15.4 (GS), silt. **Spl KA5-6-15.6** at 15.55-15.7 (GS), clayey silt.
KA5-6C	15.7-16.0	Gray silt (catcher sample; bagged).
KA5-7	16.0-16.5	Gray silt (bagged).
KA5-8	16.5-18.7	Moist, gray, layered silt and clayey silt. Layering less distinct than in KA5-6. No visible organics.
	18.7-18.9	Uniform gray clay or clayey silt. No visible layering or organics.
KA5-8C	18.9-19.0	Gray silt (catcher sample; bagged).
KA5-9	19.0-19.95	Uniform gray clay or clayey silt. No visible layering or organics. Continuation of layer starting at 18.7.
KA5-10	19.95-22.45	Firm, uniform gray silty clay. No visible bedding, except faint dark thin (< 1/8 in.) gray organic-rich(?) layer at 21.6. **Spl KA5-10-21.0** at 20.9-21.1 (GS).
KA5-10C	22.45-22.7	Gray silt (catcher sample; bagged).
	22.7-24.0	Not recovered.
KA5-11	24.0-25.95	Same as KA5-10. Slightly organic-rich (dark gray) layer at 25.4-25.5. Small piece of twig at 25.4.
KA5-11C	25.95-26.2	Gray silty clay (catcher sample; bagged).
	26.2-26.5	Not recovered.
KA5-12	26.5-27.0	Same as KA5-10 and KA5-11.
	27.0-29.0	Not recovered. Sample slid out of tube during recovery.
KA5-13	29.0-30.85	Gray silty clay, same as KA5-10, 11, and 12. Very faint darker gray zones, possibly organic-rich (for example, 30.1-30.15). **Spl KA5-13-30.0** at 29.9-30.1 (GS).
KA5-13C	30.85-31.1	No change (catcher sample; bagged).

Maximum depth sampled 31.1 ft.

BOREHOLE KA6, PALMER HAY FLATS - 61°31'20"N, 149°15'25"W; surface elevation 18.7 ft MSL

Sample	Depth (ft)	Description
	0-0.5	Ice.
	0.5-1.9	Frozen silt and organics (not recovered).
KA6-1	1.9-2.2	Base of frozen silt (bagged).
KA6-2	2.2-2.35	Sedge and woody peat mixed with some gray silt. Could be basal surface peat, base of older peat, or fill-in from borehole wall above. **Spl KA6-2-2.3** at 2.2-2.35 (C14).
	2.35-2.95	Uniform gray silty clay with scattered organics. Slightly organic-rich layer at 2.6-2.7. Sharp base. **Spl KA6-2-2.9** at 2.8-2.95 (GS).
	2.95-3.2	Brown to dark brown sedge and sphagnum(?) peat. Sharp upper and lower contacts. **Spl KA6-2-3.0** at 2.95-3.05 (C14).
	3.2-3.4	Uniform gray clayey silt. No organics.
KA6-2C	3.4-3.7	Gray clayey silt (catcher sample; bagged).
	3.7-4.0	Not recovered.
KA6-3	4.0-4.3	Gray clayey silt with scattered organics and very faint layering.
	4.3-4.375	Very dark brown compressed sedge or sphagnum peat. Sharp top and bottom. **Spl KA6-3-4.35** at 4.3-4.375 (C14).
	4.375-4.45	Light brownish gray organic-rich silt or ash(?). **Spl KA6-3-4.4** for microscopy.
	4.45-4.55	Dark brown compressed sedge or sphagnum peat. Could be slightly older submerged layer (2 events?). Sharp base, gradational top.
	4.55-5.15	Gray clayey silt with very faint layering and scattered organics.
KA6-3C	5.15-5.4	Gray silt (catcher sample; bagged).
	5.4-6.5	Not recovered.
KA6-4	6.5-7.3	Uniform gray clayey silt with no visible bedding or organics.
	7.3-7.4	Laminated gray clayey silt and silty fine sand. Minor dark gray organic(?) smear.
	7.4-7.525	Gray clayey silt with no visible bedding. Minor gray organic(?) smear.
	7.525-7.575	Grayish brown organic-rich silt. **Spl KA6-4-7.55** at 7.525-7.575 (C14).
	7.575-7.8	Gray clayey silt with scattered organics. No visible bedding.
	7.8-7.9	Dark brown compressed peat. Sharp top and bottom. **Spl KA6-4.7.85** at 7.8-7.9 (C14).
KA6-4C	7.9-8.1	Gray silt (catcher sample; bagged).
	8.1-9.0	Not recovered.
KA6-5	9.0-9.8	Very wet, disturbed clayey silt with faint layering and minor dark gray organic smears.

KA6-6	9.8-10.7	Same as KA6-5.
	10.7-11.5	Not recovered.
KA6-7	11.5-13.85	Wet gray clayey silt with faint disturbed bedding and scattered organics. Pocket of sedge(?) at 13.1. Mottled with dark gray smears, possibly fine organics. Spl KA6-7-12.0 at 11.0-12.1 (GS).
	13.85-14.0	Not recovered.
KA6-8	11.5-?	Extra material from unknown source (structure precludes fill-in from borehole walls). Recovered at same apparent interval as KA6-7. Wet gray clayey silt with scattered organics. Some distinct layering in lower half. Upper part disturbed.
KA6-9	14.0-16.45	Wet, uniform gray clayey silt with trace scattered organics and slight iron staining at 16.2-16.45.
KA6-10	fill-in	Gray clayey silt with some organics.
KA6-11	16.5-19.0	Gray clayey silt with faint layering and some iron staining at 16.5-18.4. Distinct layering and lamination at 18.4-18.95, and no iron staining. Trace scattered organics.
KA6-12	19.0-20.95	Gray silty clay with very faint layering and no visible organics. Several thin (1/8 in.) fine-sandy partings at 20.2-20.3. Spl KA6-12-20.0 at 19.9-20.1 (GS).
	20.95-21.5	Not recovered.
KA6-13	21.5-23.15	Firm, gray clayey silt with very faint layering and no visible organics.
KA6-13C	23.15-23.4	Gray clayey silt (catcher sample; bagged).
	23.4-24.0	Not recovered.
KA6-14	24.0-25.65	Firm, gray clayey silt. Very faint layering and no visible organics at 24.0-25.2. Distinct layering accentuated by dark gray organic smears at 25.2-25.65. Darkest layer at 25.25-25.3. Spl KA6-14-25.3 at 25.25-25.35 (C14).
KA6-14C	25.65-25.9	Gray clayey silt (catcher sample; bagged).
	25.9-26.5	Not recovered.
KA6-15	26.5-28.75	Firm, gray to dark gray clayey silt with no visible bedding. Numerous dark gray organic smears.
KA6-15C	28.75-29.0	Firm gray clayey silt with 1/2 in. dark gray organic-rich layer.
KA6-16	29.0-31.5	Firm, gray clayey silt with minor dark gray organic smears. No visible bedding. Spl KA6-16-30.0 at 29.9-30.1 (GS).
KA6-17	31.5-33.75	Same as above. Thin (1/4 in.) dark gray organic-rich(?) layer at 32.75. Trace fine sandy lenses at (e.g. 31.7, 32.65).
KA6-17C	33.75-34.0	Gray clayey silt with faint dark gray organic smears near top (catcher sample; bagged).
KA6-18	34.0-36.5	Firm gray clayey silt with minor dark gray organic smears. Numerous light gray fine sandy lenses and partings at 35.9-36.5.
KA6-19	36.5-38.2	Firm, gray clayey silt with trace dark gray organic smears, distorted faint layering, and several light gray fine-sandy lenses.

	38.2-38.55	Interlayered grayish brown silty fine sand and brownish gray to gray fine-sandy silt and clayey silt. Slightly distorted layering. No visible organics. **Spl KA6-19-38.4** at 38.35-38.45 (GS).
	38.55-39.0	Uniform gray silty clay with no visible bedding or organics. Trace fine sand. **Spl KA6-19-38.8** at 38.7-38.9 (GS).
KA6-20	39.0-39.6	Gray silty clay with faint distorted layering; probably disturbed. No organics.
	39.6-40.2	Gray laminated clayey silt and silty fine sand. Laminae tilted and distorted at 39.6-39.9. No visible organics.
	40.2-40.45	Gray to grayish brown silty fine sand. No visible bedding or organics.
	40.45-41.25	Soft gray silt and clayey silt with distorted bedding. No visible organics.
KA6-21	41.25-41.9	Soft gray clayey silt with interbeds of silty fine sand. Distorted bedding at 41.25-41.6. Less disturbed at 41.6-41.9. Layering is horizontal at base. Possibly trace organics at 41.85.
	41.9-42.35	Grayish brown fine sand with distorted interbeds of gray clayey silt. No visible bedding.
	42.35-43.35	Distorted interbeds of gray clayey silt and silty fine sand. No visible organics.
	43.55-43.75	Horizontal interbeds of gray fine sand and clayey silt. No visible organics.
KA6-21C	43.75-44.0	Firm gray silty fine sand (catcher sample; bagged).

Maximum depth sampled 44.0 ft.

RIVER BLUFF SECTION KA7, PALMER HAY FLATS - loc. near KA1; surface elev. about 18 ft MSL.

Sample	Depth (ft)	Description
	0-3.0	Not sampled; grayish brown silt with plant fragments and roots near surface.
KA7-3.0	3.0	Flattened wood pieces and twigs lying horizontally in a discontinuous layer up to 1 in. (2.5 cm) thick. **Spl KA7-3.0** at 3.0 ft (C14).
KA7-3.5	3.5	Sedge and woody peat in a laterally extensive but discontinuous layer up to 1 in. (2.5 cm) thick. **Spl KA7-3.5** at 3.5 ft (C14).

APPENDIX B

Table B-1. *Grain-size analyses. (Mean diameter and standard deviation are plotted in figures B-1 through B-9.)*

Bore-hole	Sample depth	Mean diam(mm)	Mean diam(φ)*	Standard deviation*	Skewness*	Kurtosis*	Percent gravel	Percent sand	Percent silt	Percent clay
TA1	17.1 ft (5.21 m)	0.0122	6.36	1.74	1.51	4.43	0.00	0.00	83.73	16.27
TA1	19.0 ft (5.79 m)	1.5801	-0.66	1.56	0.79	3.56	61.71	36.71	1.58	0.00
TA1	25.3 ft (7.71 m)	0.0043	7.85	1.79	0.41	2.31	0.00	0.00	58.21	41.79
TA1	26.3 ft (8.02 m)	0.0047	7.74	1.87	0.28	2.43	0.00	0.90	58.50	40.60
TA1	33.0 ft (10.06 m)	0.0060	7.38	2.11	0.51	2.13	0.00	0.40	64.00	35.60
TA1	36.5 ft (11.13 m)	0.0126	6.31	2.14	1.09	3.08	0.00	5.00	74.00	21.00
TA1	41.8 ft (12.74 m)	0.0166	5.91	1.94	1.23	3.29	0.00	4.00	78.70	17.30
TA1	45.6 ft (13.90 m)	0.0209	5.58	1.68	1.66	4.89	0.00	4.70	83.70	11.60
TA1	57.0 ft (17.38 m)	0.0337	4.89	1.27	2.45	8.77	0.00	11.80	82.40	5.80
TA1	61.0 ft (18.60 m)	0.0270	5.21	1.30	2.42	9.07	0.00	4.20	89.60	6.20
TA8	4.7 ft (1.43 m)	0.1321	2.92	0.79	0.16	2.33	0.00	85.94	14.06	0.00
TA8	9.5 ft (2.90 m)	0.1058	3.24	0.57	0.38	2.47	0.00	85.43	14.57	0.00
TA8	12.5 ft (3.81 m)	0.0145	6.11	1.65	1.19	3.59	0.00	2.00	83.10	14.90
TA8	16.7 ft (5.09 m)	0.0126	6.31	1.45	1.38	4.18	0.00	0.00	85.94	14.06
TA8	20.0 ft (6.10 m)	0.0154	6.02	1.45	1.67	5.17	0.00	0.00	88.81	11.19
TA8	24.6 ft (7.50 m)	0.0212	5.56	1.18	2.04	6.92	0.00	1.10	91.80	7.10
TA8	30.2 ft (9.21 m)	0.0182	5.78	1.32	1.50	4.60	0.00	1.20	89.00	9.80
TA8	35.0 ft (10.67 m)	0.0137	6.19	1.72	1.32	3.65	0.00	0.20	83.50	16.30
TA8	45.5 ft (13.87 m)	0.0050	7.64	1.92	0.43	2.20	0.00	0.20	61.30	38.50
TA8	50.5 ft (15.40 m)	0.0047	7.73	1.62	0.43	2.59	0.00	0.00	61.53	38.47
KA1	3.1 ft (0.95 m)	0.0043	7.87	2.03	0.34	2.04	0.00	0.00	56.33	43.67
KA1	5.7 ft (1.74 m)	0.0044	7.82	2.03	0.56	2.44	0.00	0.10	59.30	40.60
KA1	10.0 ft (3.05 m)	0.0056	7.48	1.70	0.35	2.03	0.00	0.00	63.96	36.04
KA1	11.6 ft (3.54 m)	0.0052	7.59	2.07	0.64	2.47	0.00	0.00	63.60	36.40
KA1	17.9 ft (5.46 m)	0.0067	7.23	1.86	0.83	2.74	0.00	0.00	71.20	28.80
KA1	25.0 ft (7.62 m)	0.0039	7.99	2.05	0.39	2.22	0.00	0.20	54.90	44.90
KA2	3.5 ft (1.07 m)	0.0140	6.16	1.50	1.43	4.47	0.00	0.80	86.30	12.90
KA2	4.0 ft (1.22 m)	0.0042	7.91	1.97	0.24	2.10	0.00	0.90	53.70	45.40
KA2	7.0 ft (2.13 m)	0.0148	6.08	1.61	1.54	4.51	0.00	0.40	86.00	13.60
KA2	20.0 ft (6.10 m)	0.0034	8.18	1.96	0.33	2.26	0.00	0.00	50.60	49.40
KA2	27.0 ft (8.23 m)	0.0040	7.95	2.26	0.40	2.11	0.00	0.30	55.20	44.50
KA3	2.0 ft (0.61 m)	0.0091	6.78	1.83	1.19	3.37	0.00	0.00	78.00	22.00
KA3	7.0 ft (2.13 m)	0.0067	7.23	2.21	1.02	2.92	0.00	0.00	71.10	28.90
KA3	9.3 ft (2.84 m)	0.0045	7.80	1.94	0.42	2.06	0.00	0.00	58.29	41.71
KA3	9.8 ft (2.99 m)	0.0158	5.98	1.57	2.12	6.96	0.00	0.00	89.41	10.59
KA3	19.0 ft (5.79 m)	0.0652	3.94	0.88	1.62	0.69	0.00	56.40	42.90	0.70
KA4	3.4 ft (1.04 m)	0.0039	7.99	1.83	0.24	2.20	0.00	0.00	53.20	46.80
KA4	10.0 ft (3.05 m)	0.0057	7.46	1.73	0.54	2.57	0.00	0.20	66.20	33.60
KA4B	6.0 ft (1.83 m)	0.0036	8.12	2.06	0.48	2.27	0.00	0.00	54.00	46.00
KA4B	24.8 ft (7.56 m)	0.0044	7.83	2.13	0.48	2.25	0.00	0.00	58.00	42.00
KA5	5.6 ft (1.71 m)	0.0119	6.39	1.68	1.15	3.37	0.00	1.00	81.80	17.20
KA5	6.2 ft (1.89 m)	0.0056	7.49	1.70	0.45	2.53	0.00	0.00	64.70	35.30
KA5	10.0 ft (3.05 m)	0.0075	7.06	1.71	0.96	3.02	0.00	0.00	74.48	25.52
KA5	15.3 ft (4.66 m)	0.0157	5.99	1.71	1.96	6.12	0.00	0.00	88.02	11.98
KA5	15.6 ft (4.76 m)	0.0036	8.13	2.01	0.25	2.26	0.00	0.10	50.30	49.60
KA5	21.0 ft (6.40 m)	0.0029	8.45	1.79	0.21	2.52	0.00	0.10	42.70	57.20
KA5	30.0 ft (9.15 m)	0.0023	8.78	1.88	0.02	2.45	0.00	0.20	35.40	64.40
KA6	2.9 ft (0.88 m)	0.0026	8.59	1.77	-0.19	2.51	0.00	0.60	36.50	62.90
KA6	12.0 ft (3.66 m)	0.0076	7.04	1.94	0.93	2.89	0.00	0.50	74.10	25.40
KA6	20.0 ft (6.10 m)	0.0022	8.80	1.88	0.21	2.26	0.00	0.00	37.91	62.09
KA6	30.0 ft (9.15 m)	0.0045	7.79	1.87	0.31	2.23	0.00	0.00	57.80	42.20
KA6	38.4 ft (11.71 m)	0.0203	5.62	1.94	1.59	4.51	0.00	6.40	79.40	14.20
KA6	38.8 ft (11.83 m)	0.0023	8.79	2.12	-0.25	2.20	0.00	0.00	34.00	66.00

* Mean diam (φ) = $-\log_2$(mean diam_{mm}). Standard deviation, skewness, and kurtosis are in phi units.

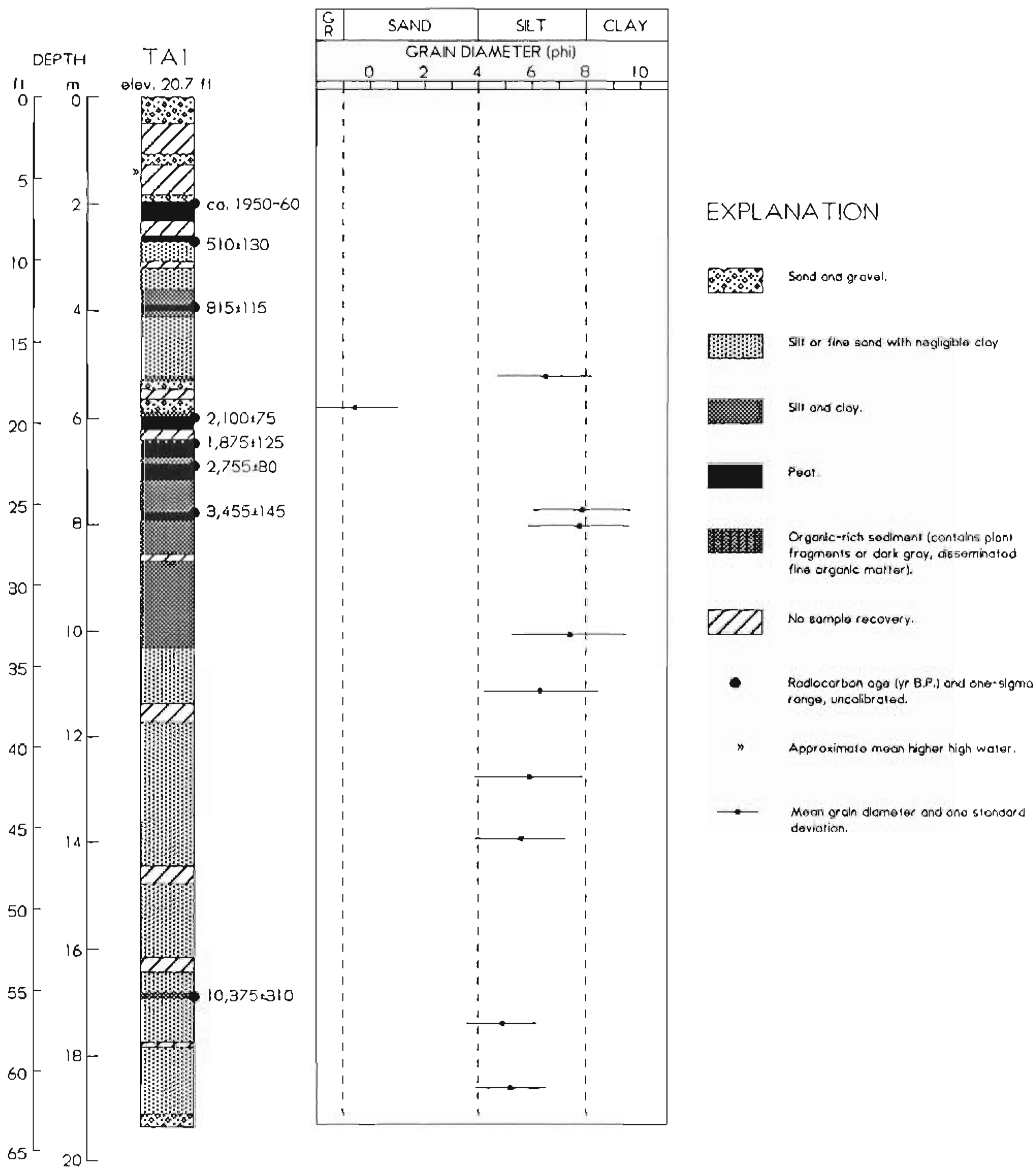

Figure B-1. *Lithologic log and plot of grain-size analyses for borehole TA1 (Girdwood).*

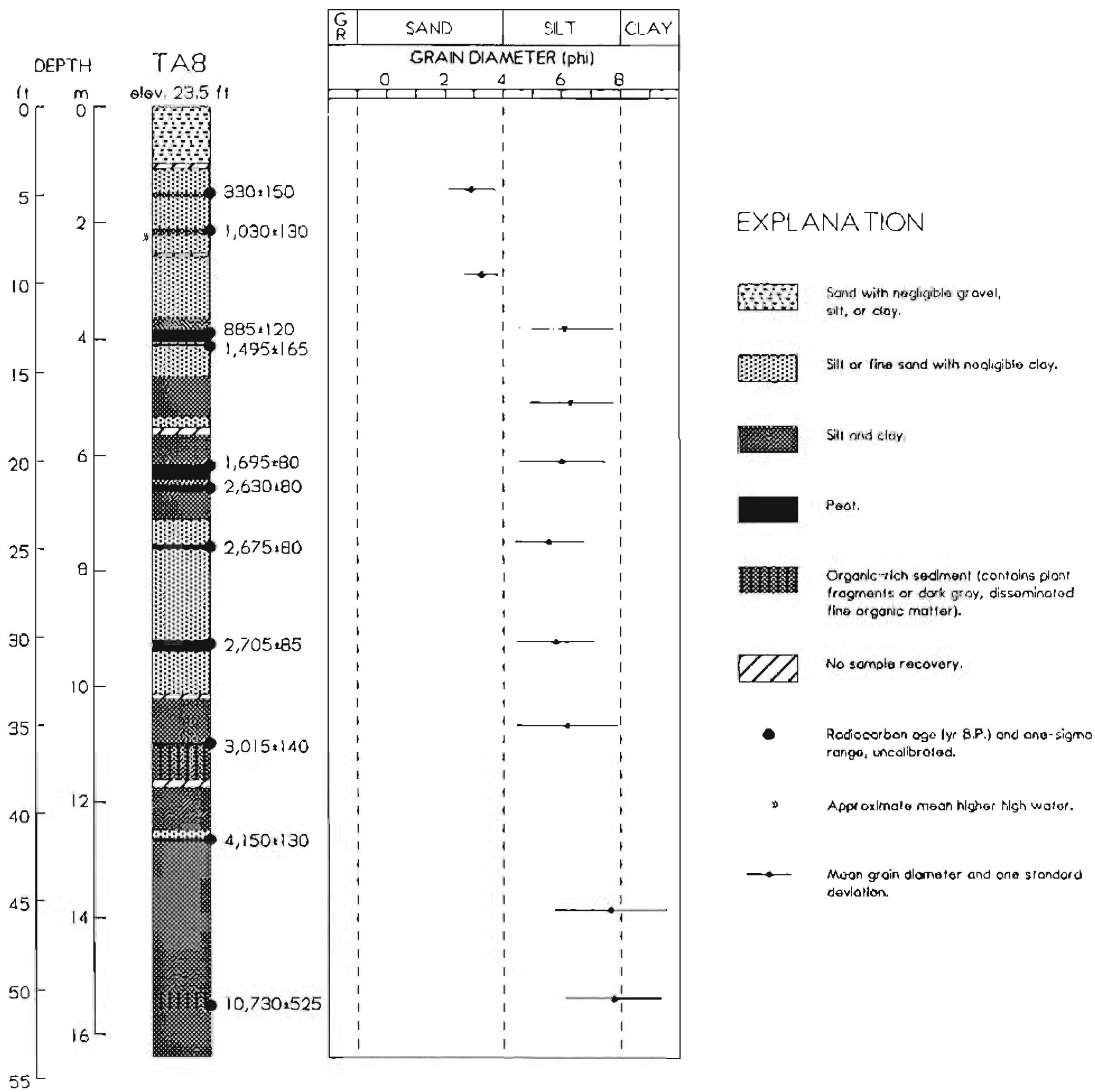

Figure B-2. *Lithologic log and plot of grain-size analyses for borehole TA8 (Portage).*

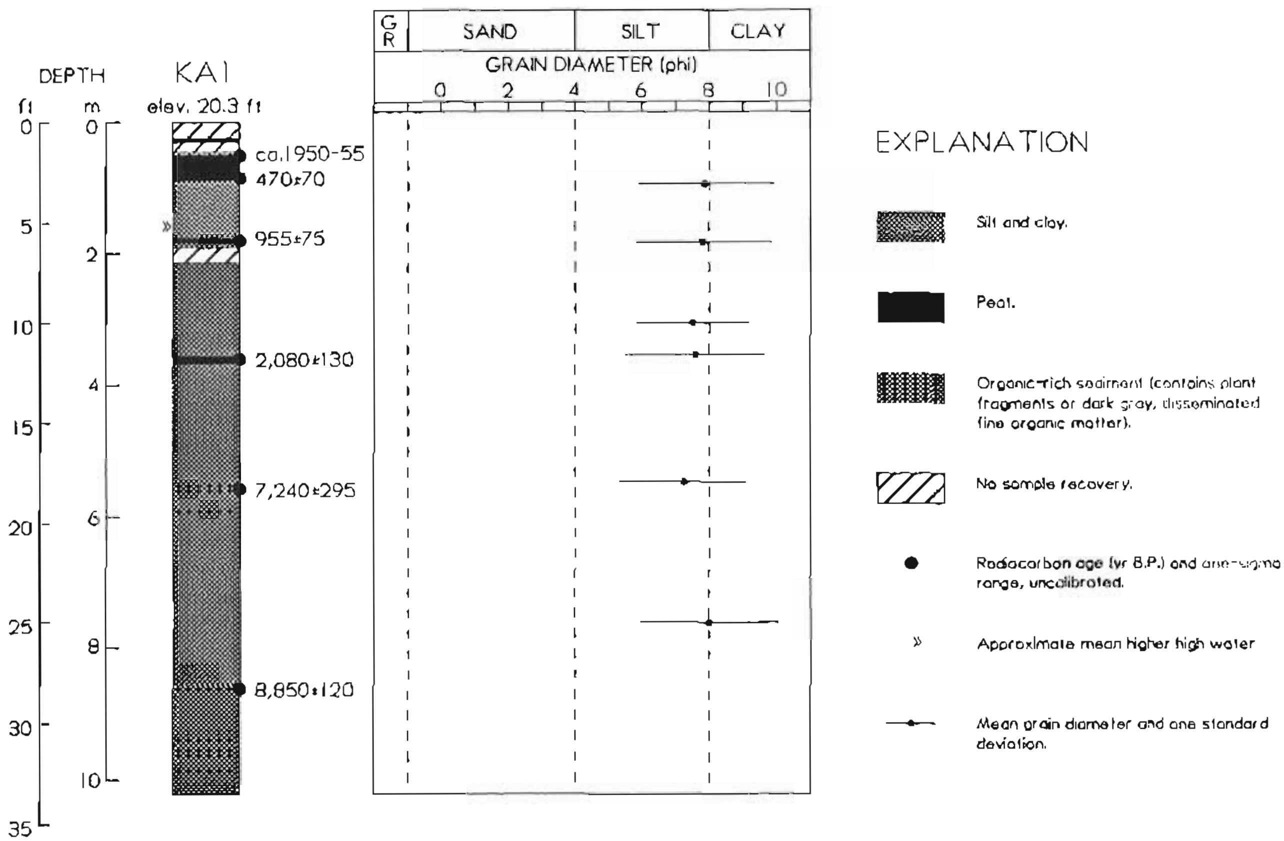

Figure B-3. *Lithologic log and plot of grain-size analyses for borehole KA1 (Palmer Hay Flats).*

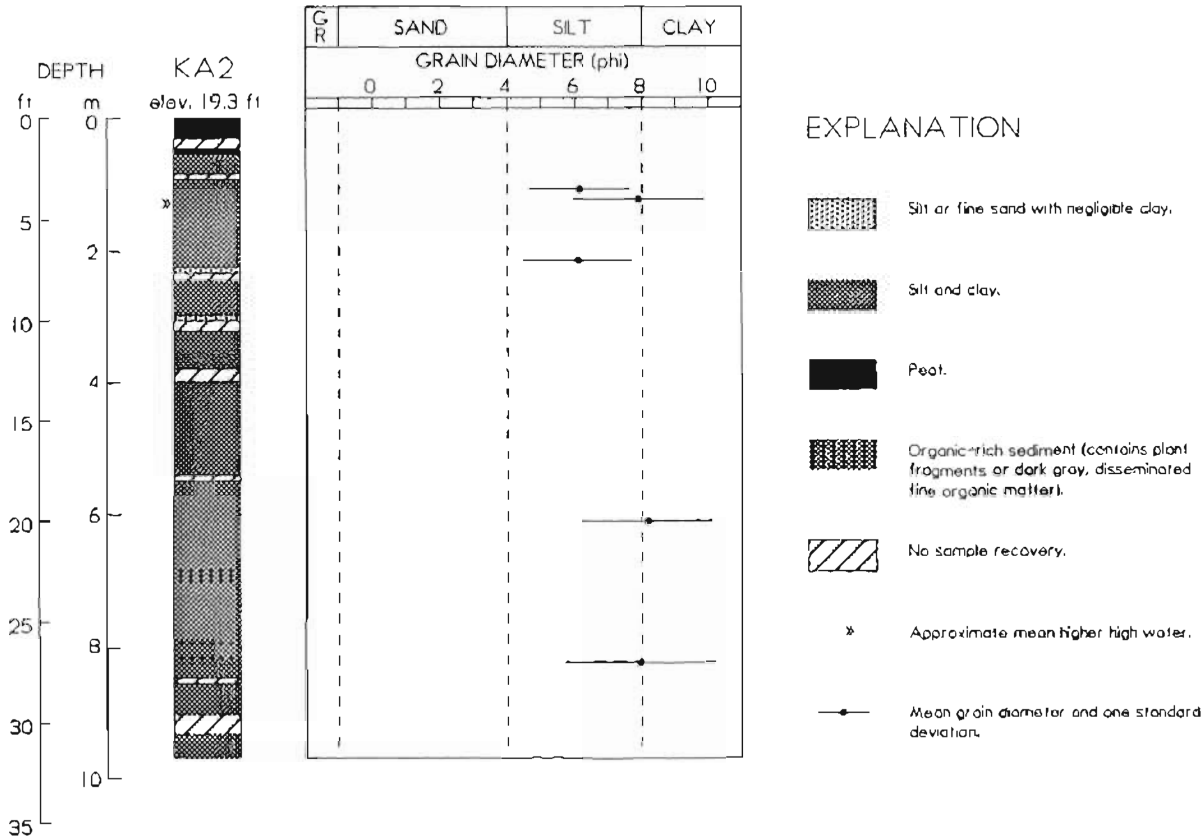

Figure B-4. *Lithologic log and plot of grain-size analyses for borehole KA2 (Palmer Hay Flats).*

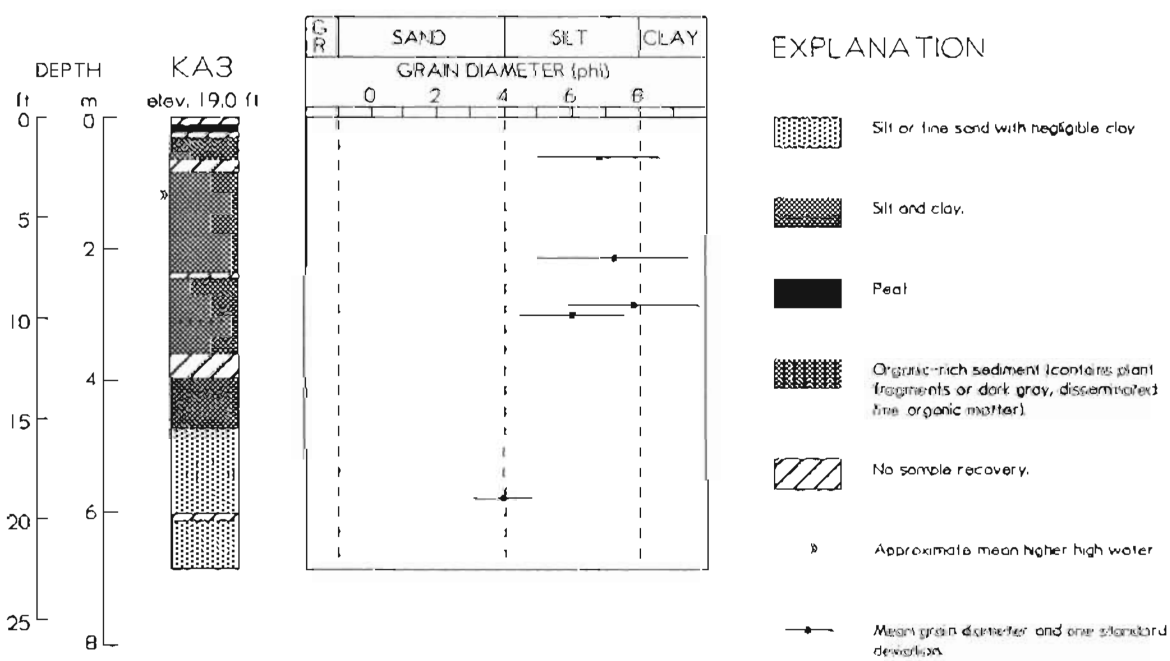

Figure B-5. *Lithologic log and plot of grain-size analyses for borehole KA3 (Palmer Hay Flats).*

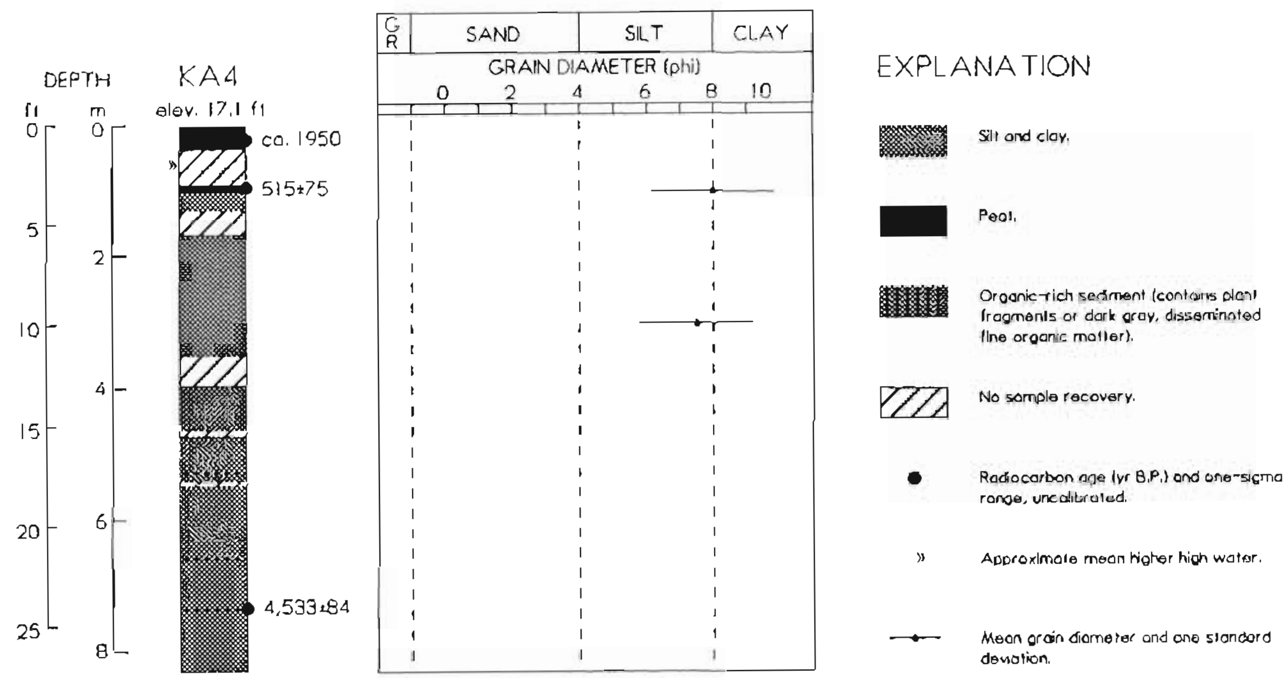

Figure B-6. Lithologic log and plot of grain-size analyses for borehole KA4 (Palmer Hay Flats).

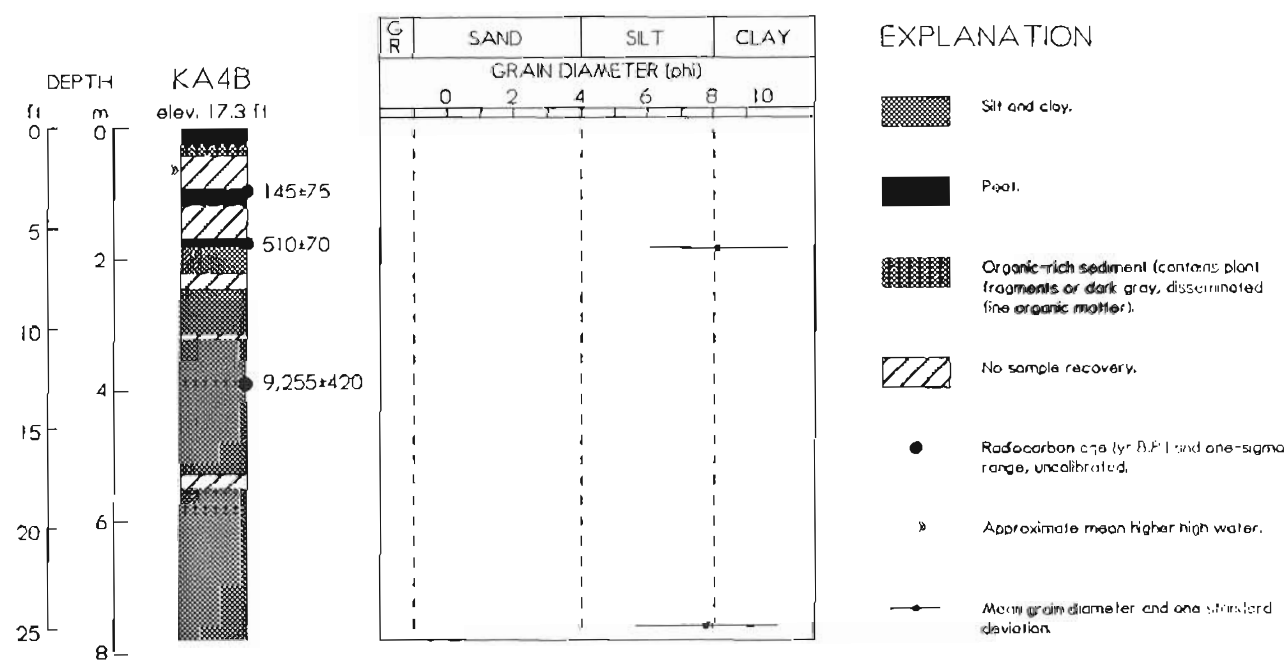

Figure B-7. Lithologic log and plot of grain-size analyses for borehole KA4B (Palmer Hay Flats).

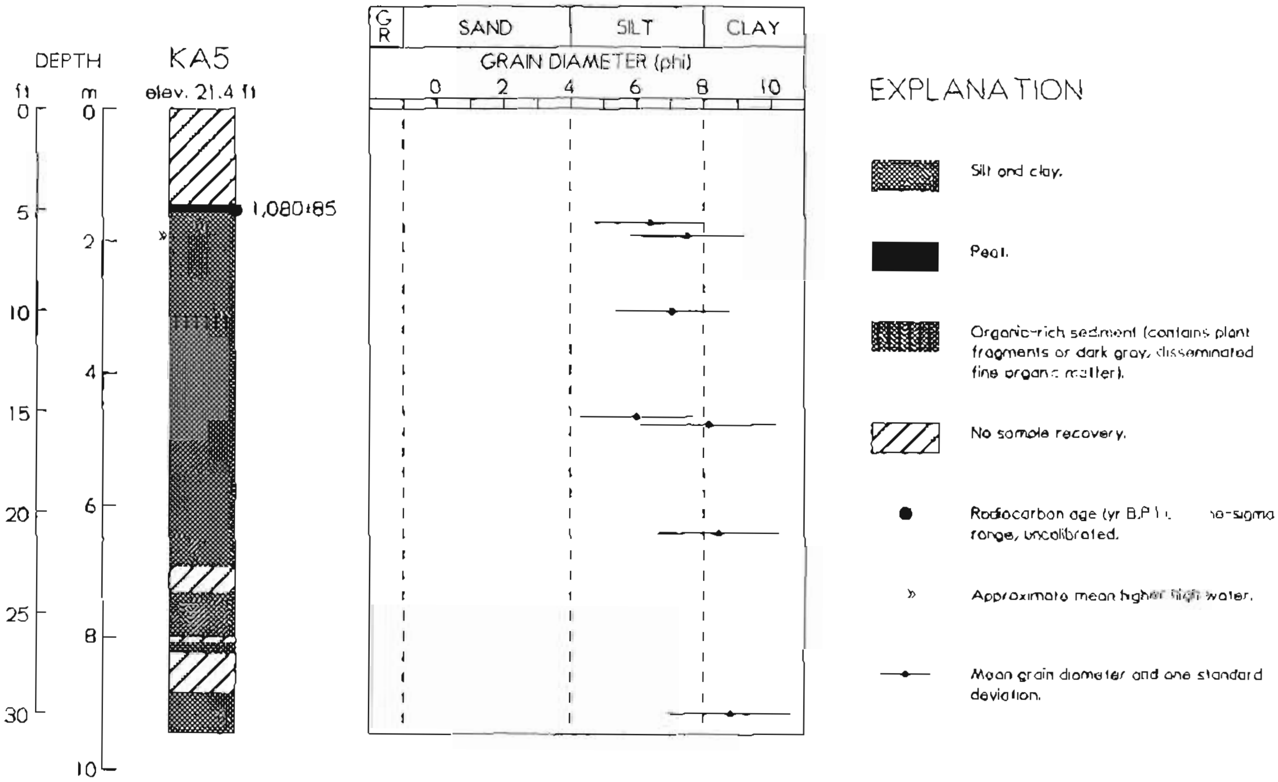

Figure B-8. Lithologic log and plot of grain-size analyses for borehole KA5 (Palmer Hay Flats).

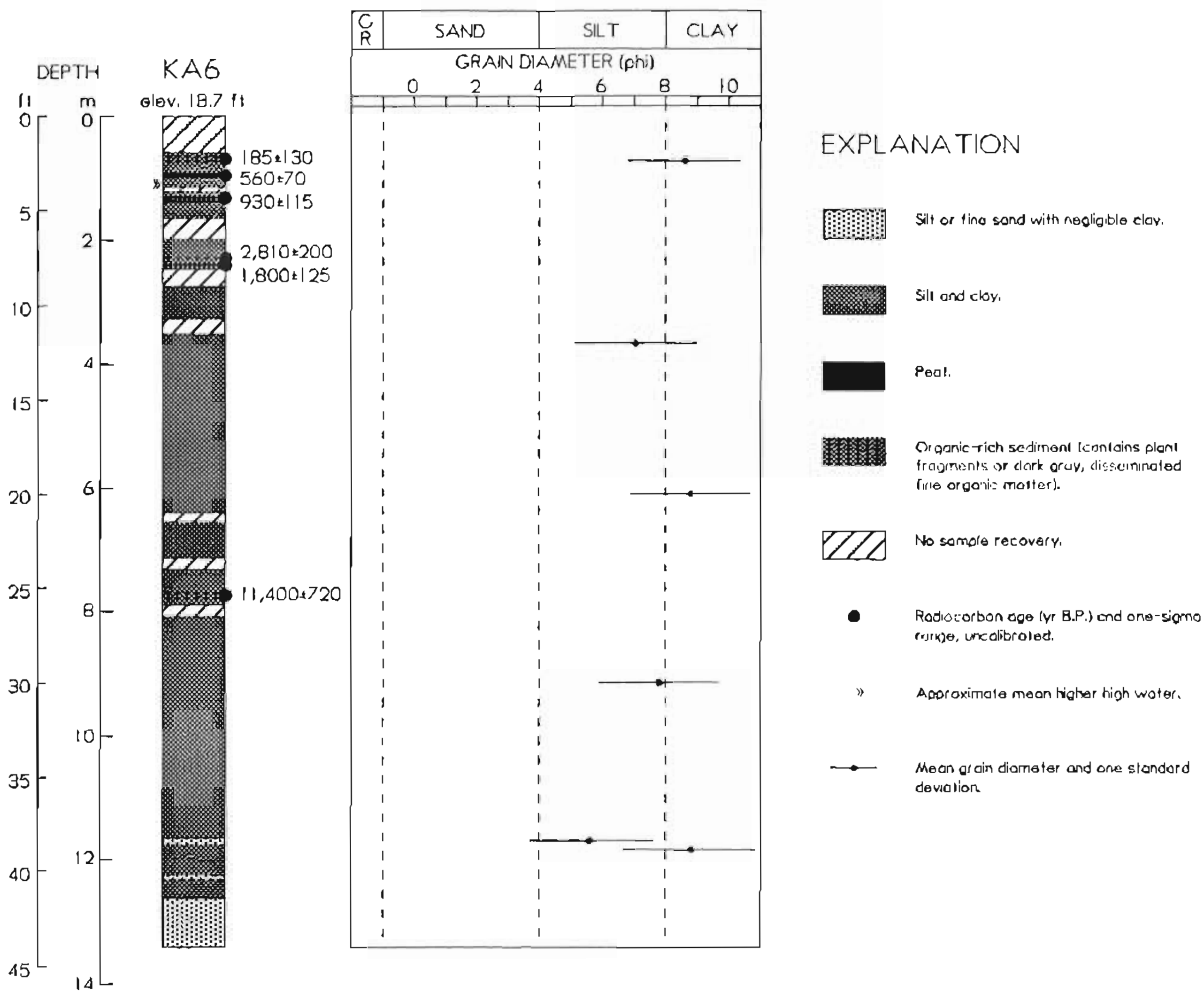

Figure B-9. Lithologic log and plot of grain-size analyses for borehole KA6 (Palmer Hay Flats).