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Holocene coastal glaciation of Alaska

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Abstract

Holocene fluctuations of the three cirque glaciers on the Seward Peninsula and five groups of tidewater- and land-terminating glaciers along the northernmost Gulf of Alaska, provide a proxy record of late Holocene climatic change. Furthermore, the movements of the coastal glaciers were relevant to late Holocene native American migration. The earliest expansion was recorded about 6850 yr BP by Hubbard Glacier at the head of Yakutat Bay in the Gulf of Alaska; however, its down-fjord advance to the bay mouth was delayed until ~2700 BP. Similarly, expansions of the Icy Bay, Bering, and McCarty glaciers occurred near their present termini by ~3600–3000 BP, compatible with marked cooling and precipitation increases suggested by the Alaskan pollen record. Decrease in glacier activity ~2000 BP was succeeded by advances of Gulf coastal glaciers between 1500 and 1300 BP, correlative with early Medieval expansions across the Northern Hemisphere. A Medieval Optimum, encompassing at least a few centuries prior to AD 1200 is recognized by general retreat of land-terminating glaciers, but not of all tidewater glaciers. Little Ice Age advances of land-based glaciers, many dated with the precision of tree-ring cross-dating, were centered on the middle 13th or early 15th centuries, the middle 17th and the last half of the 19th century A.D. Strong synchrony of these events across coastal Alaska is evident.

1. Introduction

Chronologies of Holocene glacier movements along the coast of Alaska provide an integrated proxy record of climatic and related environmental changes through this critical geologic epoch. In addition to their value as paleorecords, the glacier movements must have impacted the movements of native Americans in coastal Alaska (de Laguna, 1972; Dixon, this volume; Mandryk, this volume). Impacts include, for example, the presence or absence of physical ice barriers and changes in biological productivity of the coastal regions. Here we briefly summarize the most current and comprehensive research of Holocene glaciation available for the cirque glaciers on the Seward Peninsula and for five groups of land- and fjord-terminating glaciers located along the northernmost Gulf of Alaska between the Kenai Peninsula and Yakutat Bay (Fig. 1). These studies supplement the work across all of Alaska summarized by Calkin (1988) and build on classic observations dating back a century as reviewed by Péwé (1975) and Field (1975). New chronologies from the Gulf coastal sites incorporate the high precision of tree-ring dating.

Glaciers currently cover about 74,705 km^2 (5%) of Alaska (Post and Meier, 1980). Half of this ice occurs in the Kenai, Chugach and St. Elias Mountains rimming the northern Gulf of Alaska where it is concentrated in large ice field complexes among 2000 to 6000-m peaks (Fig. 1). The maritime climate of this area is ideal for glaciers to nucleate and persist, with cool summers, mild winters and heavy precipitation all year. The coastal town of Seward, in the Kenai Mountains, records a mean annual precipitation of about 1700 mm, while Yakutat at the foot of the higher, St. Elias Mountains records 3400 mm per year. The Gulf coastal glaciers are temperate, and characterized by heavy subglacial discharges of water. In contrast to glaciers on the Gulf, the cirque glaciers of the Seward Peninsula (Fig. 1) together occupy less than 1 km^2. These barely persist in the much lower Kigluaik Mountains with precipitation of 370 mm per year at nearby Nome.

The largest of the glaciers along the Gulf coast may have originated from the north and western extensions of the Pleistocene Cordilleran Ice Sheet (Fig. 1) (Hamilton and Thorson, 1983). Retreat of this ice from the adjacent continental shelf began as early as 16,000–14,000 BP

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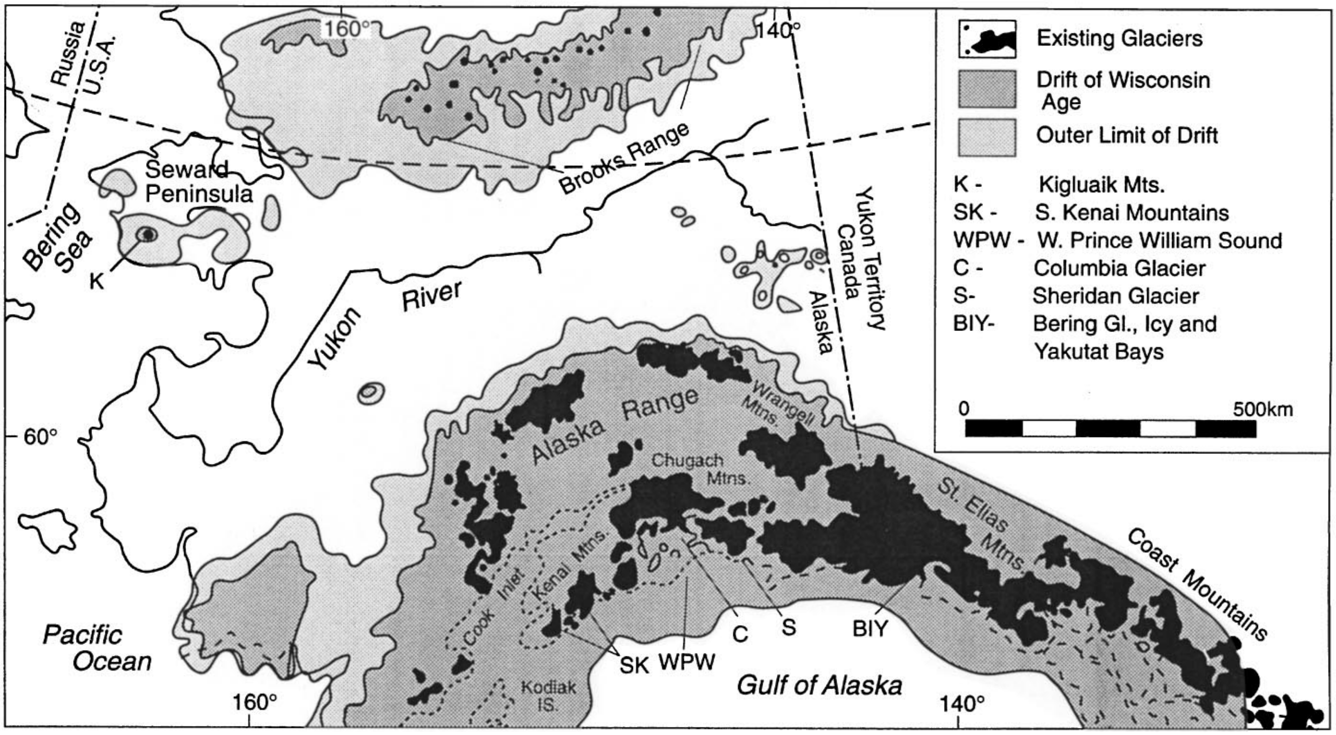

Fig. 1. Location map of Alaska showing six study areas of Holocene glaciation with existing glaciers and limits of Pleistocene glaciation.

(Mann and Hamilton, 1995). However, many smaller glaciers scattered through Alaska, including those in the Kigluaik Mountains (Fig. 1), probably have been regenerated following the warmer and drier than present (Hypsithermal) climates of the early to middle Holocene (Ager, 1983; Calkin, 1988).

Much of the late Holocene data on paleoglacial positions presented below falls in the interval referred to as the "Little Ice Age". This time of varying and cooler climates (Grove, 1988) is applied here in the sense of Porter (1986) and generally as Luckman (1986, 1995), as occurring between about AD 1200 and 1900. It was preceded by the Medieval Optimum from about AD 1000–1200 and, in turn, the early Medieval interval of glaciation from the late 6th through the middle 11th centuries. Historical records of glacier positions range from as early as 1786 in the Gulf (La Perouse, 1799), but not until 1950 in the Seward Peninsula.

2. Paleoclimatic sensitivity and dating

Fluctuations of land-terminating glaciers represent an integrated response to changes of temperature and precipitation. Changes in glacier ice volumes, and hence past climate, can be reconstructed by the dating of end moraines that record past ice-marginal positions and where available, the dating of glacially overridden forests that directly record expansion. Climatic inferences for tidewater-calving glaciers, which are shown in this text by (C) after the name, are more complicated (Post, 1975; Meier and Post, 1987). Advances of the latter are typically slow, being dependent on end moraine construction at their termini to effectively decrease water depth and maintain stability. However, retreat is usually very rapid due to disintegration of the terminus into deeper water. While movements are often asynchronous with nearby land-terminating glaciers and climate fluctuations on decadal scales, they are generally consistent over longer time scales (Mann, 1986; Porter, 1989; Wiles et al., 1995).

Several of the tidewater-calving glaciers and piedmont lobes used in this compilation are also known to surge; these include the Bering and Martin River glaciers, and the Guyot (C), Malaspina and Hubbard (C) glaciers (Fig. 1) (Post, 1969; Horvath and Field, 1969). Glacier surges involve short-lived, anomalously high movement that may not be related directly to climate change (Paterson, 1994). Workers seeking proxy climate records from advances of such glaciers have therefore avoided utilizing the typical chaotic moraines or other distinctive features of surging. However, some surging movements may be reported in this paper because other methods of identifying advances do not discriminate between surging and normal climate-induced advance.

Radiocarbon ages, unless otherwise noted, are expressed in terms of years BP (years before AD 1950). Calendar ages (AD) are reported for the Little Ice Age portion of chronologies. These are determined by calibration of radiocarbon ages following Stuvier and Reimer, (1993). Calendar ages are also determined directly by tree-ring analysis. Lichenometry yields minimum ages that are expressed in the text as lichen years (L) AD since major control is sidereal. Unofficial glacier names used in this paper are indicated with an asterisk (*).

No assumption is made that the glacial records cited in this paper are of equal value in interpreting proxy climate. The records encompass different sized areas, include variable numbers, sizes and types of glaciers, and are constrained by differing dating techniques.

3. Individual glacial chronologies

3.1. Kigluaik Mountains

The tiny Grand Union* cirque glacier and two smaller stagnating cirque glaciers called Thrush* and Phalarope*, which lie between 650 and 800 m altitude, are the only glaciers identified on the Seward Peninsula and adjacent west central Alaska (Kaufman et al., 1989; Calkin et al., 1998) (Fig. 1). Ages of moraines based on a preliminary lichen curve calibrated by historic data and tree-ring counts suggest that these glaciers advanced ~ (L) AD 1645, 1675 and by ~ (L) AD 1825, respectively, with minor moraine building by Grand Union glacier after the turn of the century (Fig. 2). Equilibrium line altitudes fell about 170 m from present levels during these Little Ice Age expansions.

3.2. Southern Kenai Mountains

Records of 16 land-terminating glacier tongues on both western (more continental) and eastern (more maritime) flanks of the Harding and the Grewingk-Yalik ice fields, as well as seven, calving fjord glaciers on the east (Figs. 3 and 4), delineate three major intervals of Holocene glaciation (Wiles and Calkin, 1994). The earliest expansion is suggested by two 3600 BP ages for detrital wood in sediment heading the 60-km-long McCarty Fiord (Fig. 3). Early Medieval ages of 1550–1400 BP date near-simultaneous expansion at the land-terminating Grewingk and Dinglestadt glaciers on the west and the McCarty (C) and Northwestern (C) glaciers on the east (Figs. 2, 3 and 5).

Tree-ring analysis allows differences in timing and climatic response to be evaluated for land-terminating tongues during three succeeding LIA glaciations between AD 1300 and 1850 (Fig. 4). While there were expansions starting about AD 1300 on both flanks, those on the more continental, west flank retreated from LIA maxima earlier and may have been affected more by summer temperatures; glaciers on the maritime east retreated more recently and were more sensitive to winter precipitation (Wiles and Calkin, 1994). Three of the four main fjord glaciers here (Wiles et al., 1995) probably were extended during the Medieval Optimum when many land-terminating glaciers were retracted (Fig. 5). Glacier reconstructions suggest LIA equilibrium line altitudes (ELAs) for land-terminating glaciers were depressed 100–150 m from present values (Padginton, 1993).

3.3. Western Prince William Sound

A three-phase, Little Ice Age chronology for outlet tongues and independent cirque glaciers near sea level between Seward and Whittier (Figs. 3 and 6), is reconstructed with particularly great precision. This history is based on radiocarbon ages and tree-ring cross-dating of 130 subfossil logs at eight glacier forefields and tree-ring ages of 28 moraines at 15 glaciers (Wiles et al., in press). Whereas an early Medieval advance overran forest at Tebenkof Glacier about 1460 BP (AD 628), the succeeding earliest Little Ice Age glacial advances of atleast three glaciers were burying forest from AD 1190 through 1300 (Fig. 6). The middle LIA expansions spanned AD 1611 to 1715 with terminal moraines stabilizing during the middle 18th century. The latest LIA advances resulted in moraine building by 10 glaciers between 1874 and 1895 followed by subsequent retreat continuing to the present.

3.4. Columbia Glacier

Dramatic retreat of the iceberg-calving Columbia Glacier (C) has occurred over the past 20 years and, in turn, revealed extensive buried forests along the margins of its fjord. Radiocarbon ages (A. Post, pers. comm., 1996; this study) suggest that Columbia Glacier (C) has advanced multiple times during the past 2000 years. Wood dated to 1855 and 1650 BP from Terentiev Bay, a recently drained, ice-dammed lake along the western fjord margin, may indicate major ice advance at this time. Two ages from overrun trees in growth position show that ice again pushed into Terentiev Bay about 850 BP (AD 1215).

The timing of a more recent expansion is based in part on wood that we sampled from a zone of almost continuous forest debris in recently deglaciated areas along the lower, eastern margin of the Columbia Glacier fjord. Tree-ring cross-dates from 21 subfossil trees at two sites here show death by glacier overriding between AD 1751 and 1777. However, preliminary tree ring measurements suggest that these kill-dates may represent a continuation of ice marginal advance begun up-glacier as early as the 15th century. Continued advance in the 18th and 19th centuries created a series of ice-marginal lakes that drowned extensive forests before ice reached its terminal moraine at Heather Island as early as AD 1850 as based on historical data (Post, 1975). The Columbia Glacier ice margin may have reoccupied this position several times

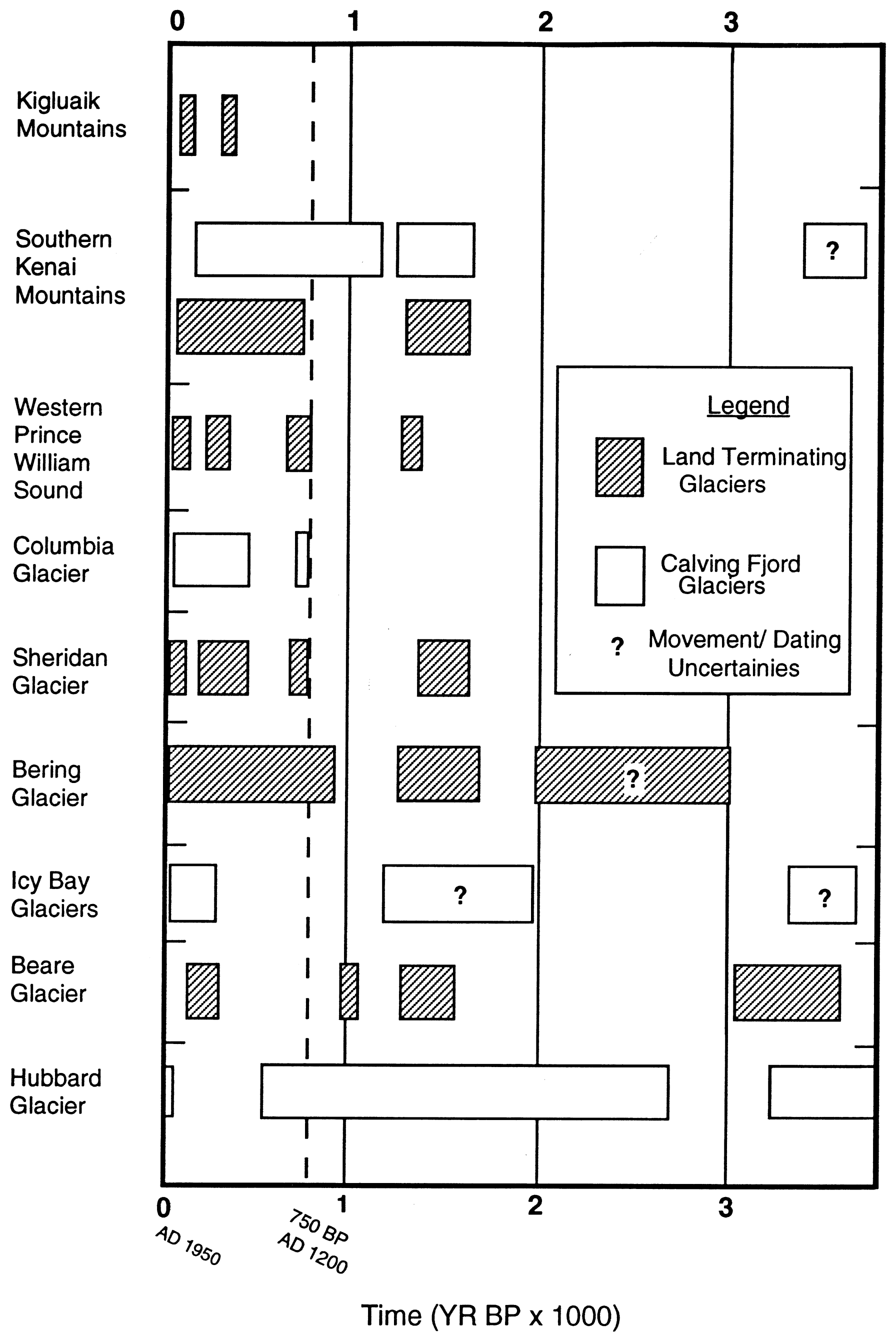

Fig. 2. Generalized intervals of Holocene glacial advance and end moraine formation compiled from references cited in text. Hubbard Glacier (C) refers to advances in Yakutat Bay and probably also the lobe in Russell Fiord. Bering Glacier graph refers to the surging Bering Lobe only; it is shown as land-terminating, but portions of it are reported to overly a fjord. Southern Kenai Mountains graph shows advances for the McCarty (C) and Northwestern (C) fjord glaciers as well as advances for the land-terminating glaciers.

during the early 20th century, prior to undergoing disintegration in its lower reaches and subsequent full-scale retreat by the early 1980s.

3.5. Sheridan Glacier

Tree-ring cross dating of 73 in situ and transported subfossil logs (Yager et al., 1998) compliments the ^{14}C history by Tuthill et al. (1968). Sheridan Glacier, one of four land-terminating glaciers that drain southward from the Chugach Mountains near Cordova (Figs. 1 and 7), could have been advancing as early as 1610 BP according to a ^{14}C age on a glacially transported log. Furthermore, two outwash aggradation events, presumably related to this early Medieval glacier expansion occurred at 1390 BP (AD 560) and 1350 BP (AD 600).

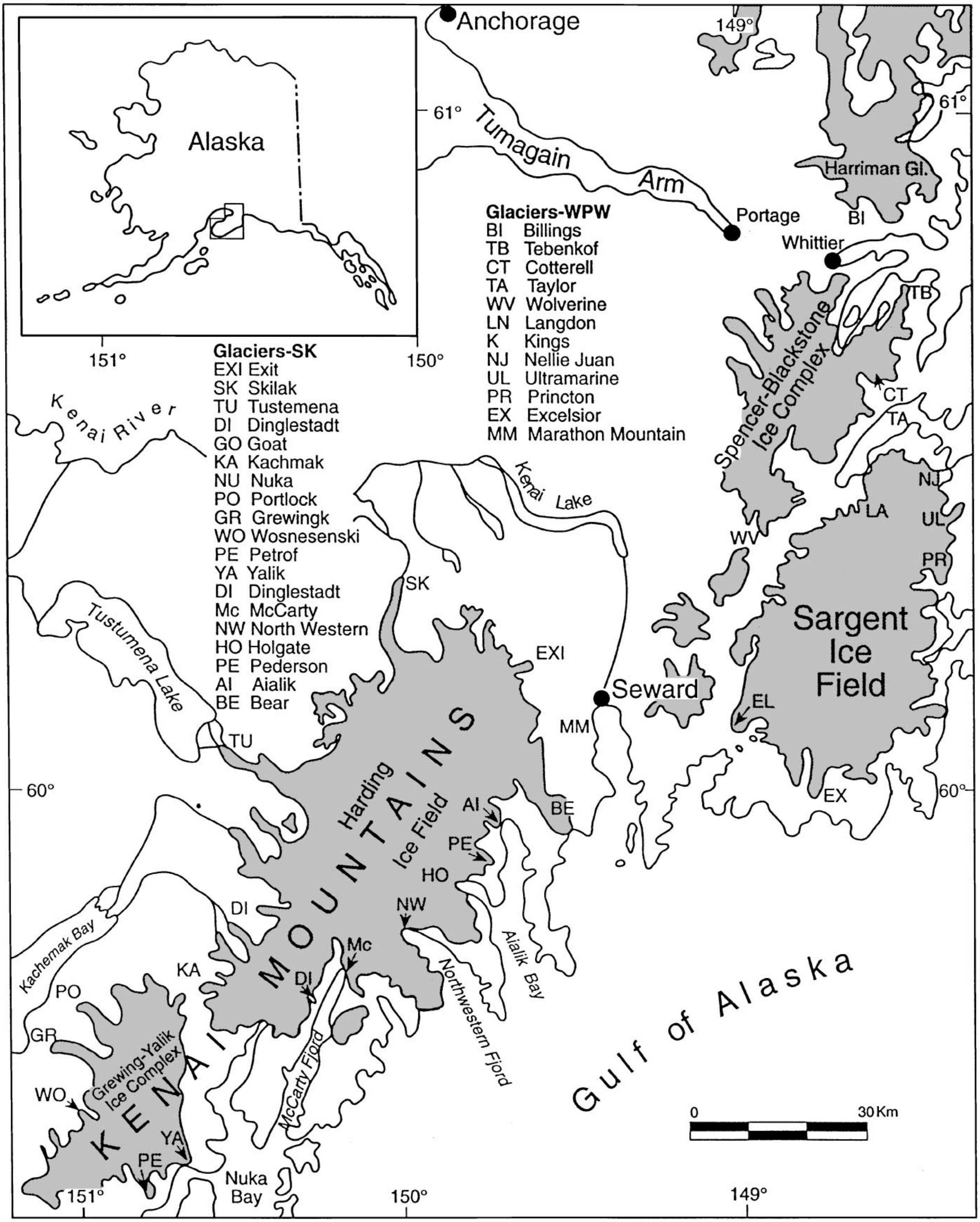

Fig. 3. Location map of study glaciers in the southern Kenai Mountains and western Prince William Sound areas.

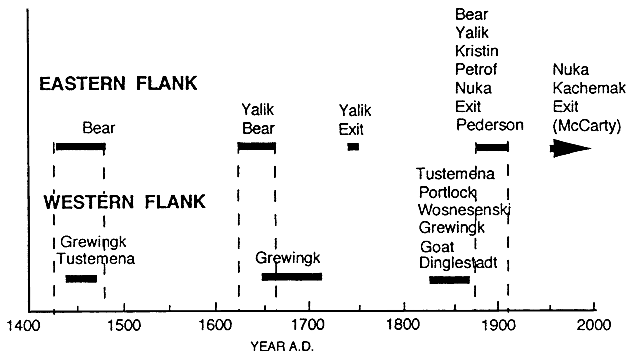

Fig. 4. Intervals of land-terminating glacier expansion (black bars) in the southern Kenai Mountains area as based on radiocarbon, tree ring, lichen, photographic and observational data. Some Little Ice Age expansions of glaciers on the cooler, less maritime mountain flank are out of phase with those on the more mild and wet east margin of the mountains (Fig. 3). From Wiles and Calkin (1994).

Tree-ring crossdates of glacially overrun trees and minimum ages of terminal moraines record culmination of Little Ice Age expansions around AD 1284, 1747 and 1897. Tree-ring dated outwash aggradation ~ 50 to 100 years before each of the glacial maxima provide some estimate of the duration of each of these advances. A cirque glacier adjacent to Sheridan Glacier began retreat from a large terminal moraine by (L) AD 1872.

3.6. Bering Glacier, Icy and Yakutat Bays

The largest glaciers of North America, including the Bering and Malaspina glaciers and the Guyot (C) and Hubbard (C) trunk glaciers, descend from névés in the towering St. Elias and Chugach Mountains (Fig. 8). While the Bering Glacier currently reaches close to the Gulf of Alaska coastline and overlies a fjord system, the retreat of Guyot and Hubbard glaciers has opened the expansive Icy and Yakutat bay systems, respectively (Fig. 9). Holocene chronologies of these three surging glacier systems and their tributaries are reconstructed using radiocarbon and tree-ring data supplemented by historic observations.

Bering Glacier: Holocene fluctuations of the Bering Glacier and its Steller Glacier sublobe (Figs. 1, 8 and 10) are reconstructed on the basis of many radiocarbon ages as well as tree-ring data from nine sites (Wiles et al., in review). The earliest recognized Holocene advance of the Bering Lobe is suggested by outwash deposition over peat dated at 2970 BP; forest returned to the area by 2000 BP according to Molnia and Post (1995). Glacial advances of the Bering Lobe associated with outwash aggradation have also interrupted intervals of forest growth between 1560 and 1370 BP (AD 390 and 580), about 870 BP (AD 1080), and again about AD 1650 (Wiles et al., in review) (Fig. 10). By AD 1260, forests near the non surging Steller Lobe were buried with an advance culminating about AD 1420. Retreat of both lobes began by the turn of the century. Surges of the Bering Lobe to 20- to 30-year intervals since 1900 are superimposed on overall retreat.

The Martin River Glacier, which is nourished by the same Bagley Ice Field as the Bering, reached its Neoglacial maximum ~ AD 1650 according to tree-ring data of Reid (1970). At least five earlier periods of moraine formation in the Holocene are interpreted to have occurred more than 800 years ago.

Icy Bay: We have chronologies from the main Icy Bay fjord glacier and from the adjacent, land-terminating Beare Glacier tongue derived from the same ice field (Fig. 8). An end moraine of Beare Glacier preserves evidence of advances at ~ 1480 BP (AD 601) and AD 1646. These ages are based on, respectively, ^{14}C-dated and tree-ring cross-dated in situ stumps buried in till; the earlier advance is supported by ages of 1540 to 1270 BP from up to 20 stumps in a down-stream outwash (Fig. 2). Cross-dated stumps buried in outwash also suggest ice marginal advance was ongoing between 1040 and 980 years BP. Ice margin retreat from the end moraine occurred by AD 1788.

The earliest recorded Holocene expansion of the Icy Bay glacier overrode wood in a forest horizon near mid-fjord about 3480 BP (Fig. 8) (Gloss, 1997). It may have reached near the fjord mouth ~ 3270–3050 BP when a series of superimposed stumps were buried in outwash near the Beare Glacier terminus (Fig. 2).

A better documented expansion of Guyot (C) and tributary fjord glaciers (Fig. 8) that make up the Icy Bay glacier, began by 1990 BP. This culminated at the bay mouth ~ 1630 BP, perhaps undergoing major fluctuations before retreat starting ~ 1200 BP (Porter, 1989). Readvance of the Icy Bay glacier margin down the fjord for the last time was underway at AD 1650 synchronous with the Beare Glacier advance. It reached the terminal moraine about AD 1880 (Gloss, 1997; Barclay et al., 1997). For the last 26 km of this expansion, the rate of advance may have averaged more than an order of magnitude above mean advance rates of Alaska tidewater glaciers. More than 40 km of catastrophic retreat has occurred from the terminal moraine since 1904.

Hubbard Glacier: Multiple advances of Hubbard Glacier and possibly other fjord glaciers of Russell Fiord are recorded between 6850 and 3290 BP by intervals of damming and sedimentation in Yakutat Bay and its Russell Fiord tributary (Figs. 8 and 9) (King, 1995; Barclay et al., 1997; Barclay, 1998). The only Holocene expansion to reach the Gulf of Alaska coastline was underway by 2700 BP, with ice advancing southward, down both Yakutat Bay and Russell Fiord.

Late Holocene readvances of the Yakutat Bay lobe of Hubbard Glacier on the west and also the Russell Fiord lobe on the east resulted in construction of terminal

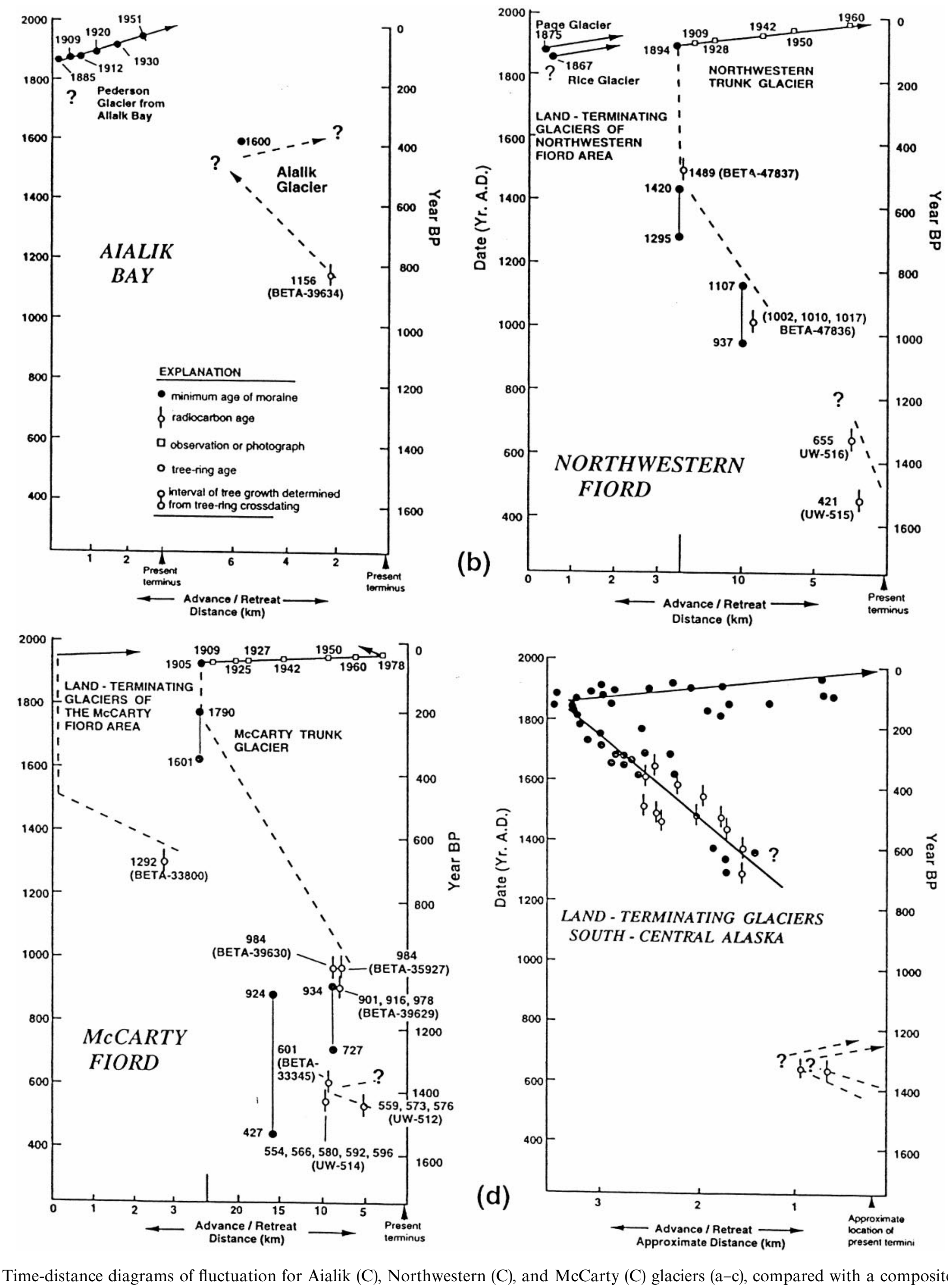

Fig. 5. Time-distance diagrams of fluctuation for Aialik (C), Northwestern (C), and McCarty (C) glaciers (a–c), compared with a composite glacial history of land-terminating glaciers from neighboring south-central Alaska (d). Dates suggest these fjord glaciers were expanded through the Medieval Optimum interval centered about AD 1000–1100 when land-terminating glaciers were contracted. From Wiles et al. (1995).

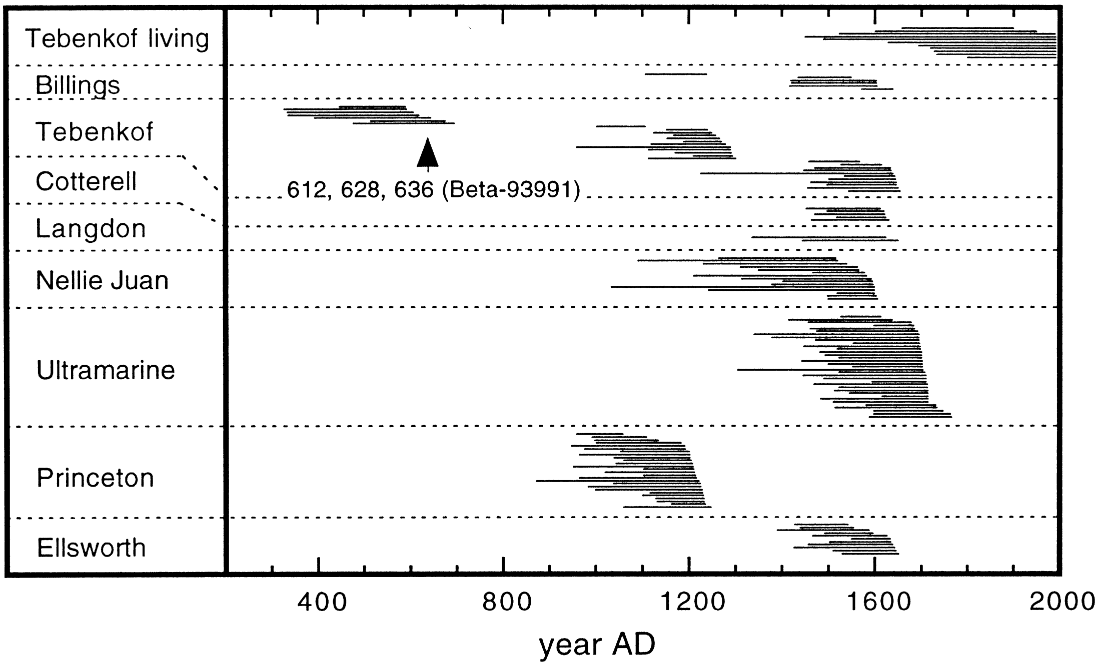

Fig. 6. Cross-dated positions of subfossil logs from nine glacier forefields in western Prince William Sound. Intervals of inundation by outwash or the glacier itself during advances are indicated by kill dates (on right) of each log. Living tree chronology to which series are tied is from Tebenkof Glacier. From Wiles et al. (in press).

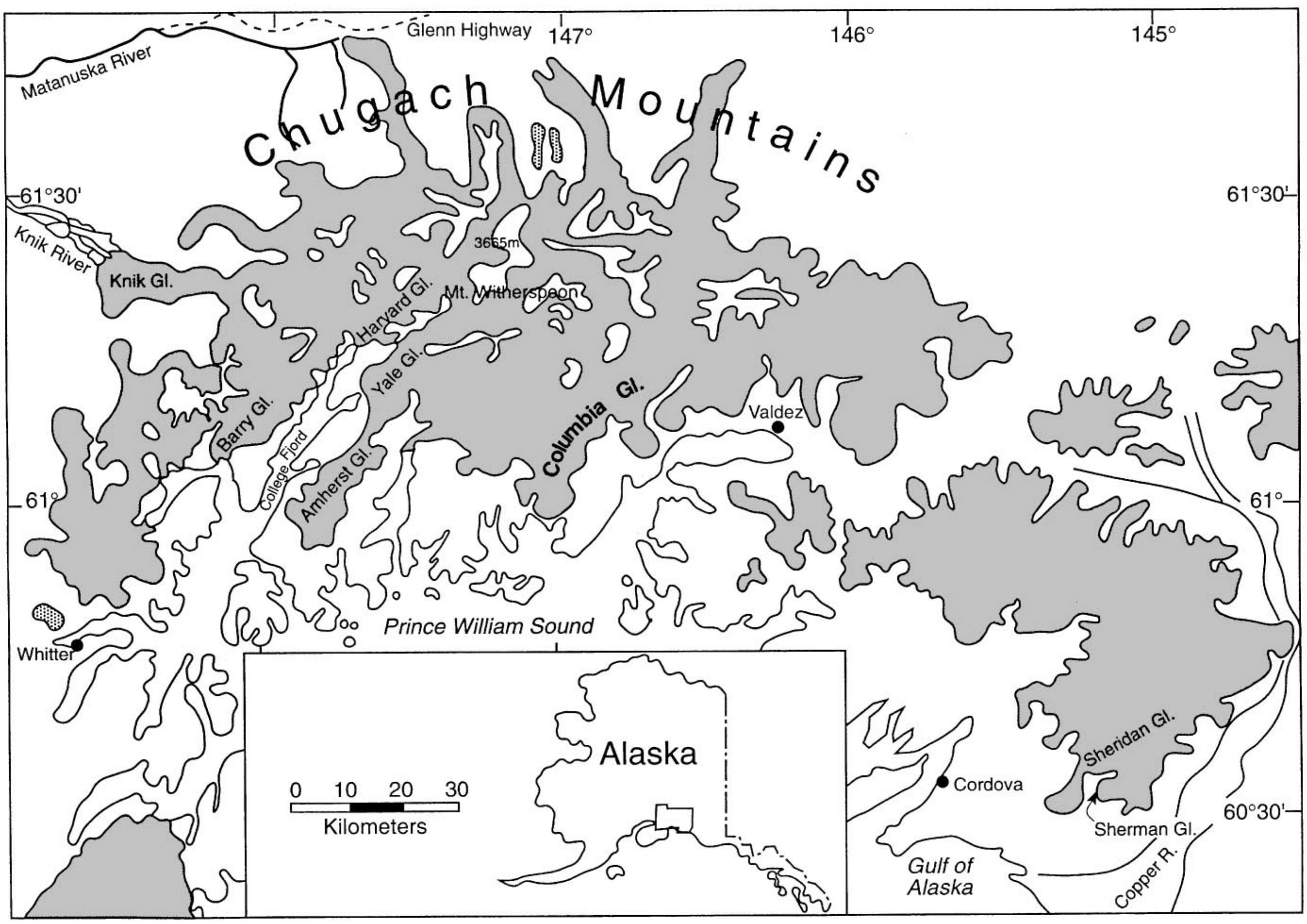

Fig. 7. Location map of northern and eastern Prince William Sound with location of Columbia Glacier (C) and Sheridan Glacier.

moraines at the south ends of their fjords around 830 BP (Plafker and Miller, 1958a, b). Tree-ring and historical data, respectively, indicate that retreat of the Yakutat Bay lobe was underway by AD 1308 and brought the margin back over 50 km to behind the present Hubbard Glacier terminal position by AD 1791. According to Sharp (1958), the Malaspina piedmont glacier (C) (Fig. 8), had expanded over forest to near its present stagnant margin at about this time. On the east, Nunatak Glacier (C), which had advanced to become confluent with the east lobe of the Hubbard, remained expanded during this period and kept Russell Fiord filled with ice until the middle of the 19th century. Hubbard Glacier (C) (Fig. 9) has readvanced from its head since 1980, temporarily damming Russell Fiord from late May through early October, 1986 (Mayo, 1987).

Yakutat Glacier, west of Russell Fiord, is a former early Holocene tidewater glacier that now calves into the deep and long Harlequin Lake (Fig. 8) (A. Post, pers. comm., 1996). Four ^{14}C ages obtained during field studies in 1996 and additional dates of Austin Post from forest and associated organic horizons buried in lake silts suggest this glacier was advancing near its present margin about 1220 BP (AD 800).

4. Discussion and conclusions

The six study areas discussed here are widely spaced and include variable numbers and types of glaciers and dating techniques. However, general patterns of climatic forcing are apparent.

The early to middle Holocene is noted for its paucity of evidence for glacial expansion in Alaska (Calkin, 1988) and particularly in the coastal Gulf of Alaska (Fig. 2). Hubbard Glacier (C) at the head of Yakutat Bay, appears to have made several expansions beginning by 6850 BP; however, it is a surging, tidewater-calving system and so these advances may not be a reflection of climatic forcing. While the small cirque glaciers of the Kigluaik Mountains may have disappeared completely during the Hypsithermal interval, the many large glaciers around the high coastal mountains that rim the Gulf of Alaska were undoubtedly still present, but retracted behind their current terminal positions.

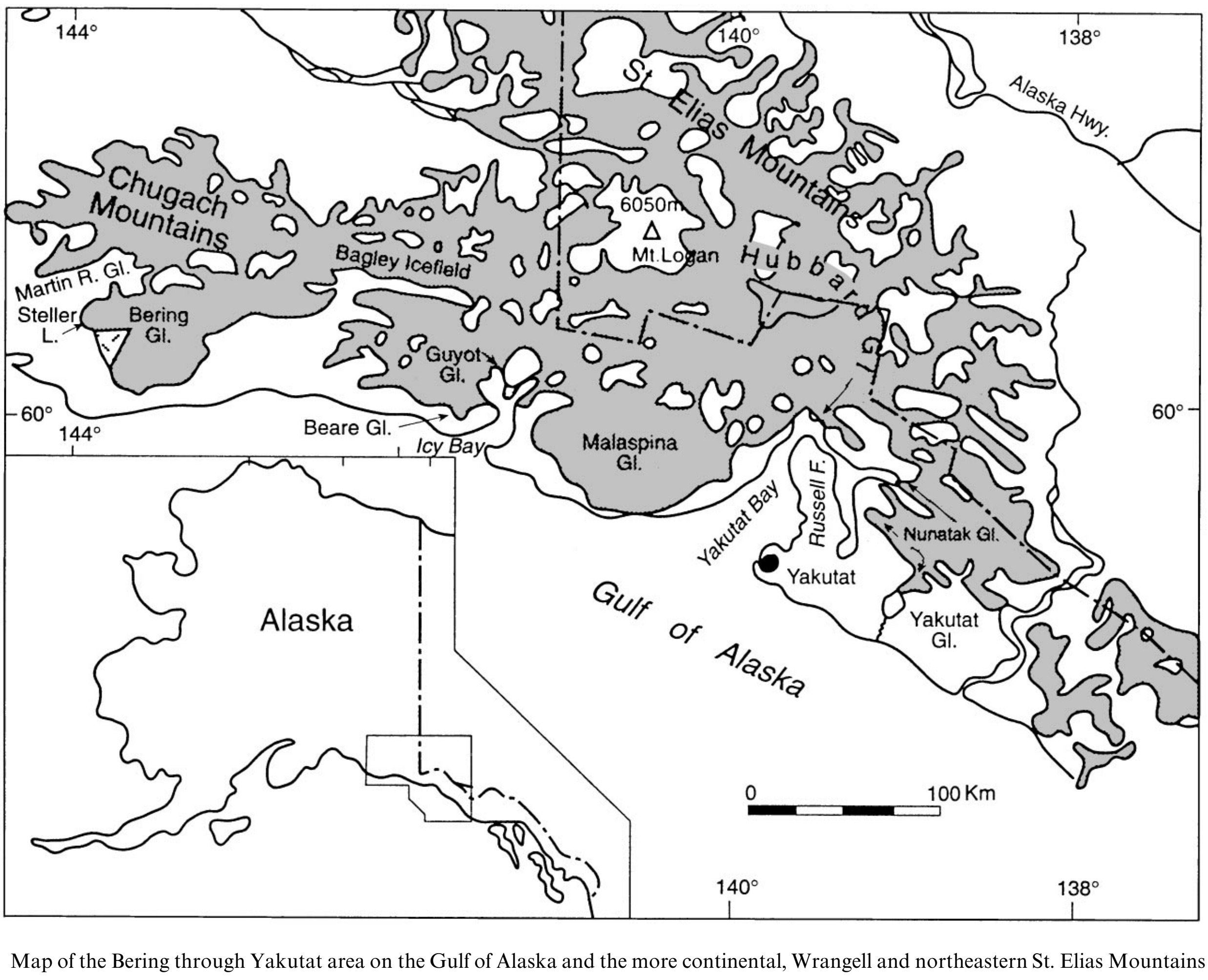

Fig. 8. Map of the Bering through Yakutat area on the Gulf of Alaska and the more continental, Wrangell and northeastern St. Elias Mountains area.

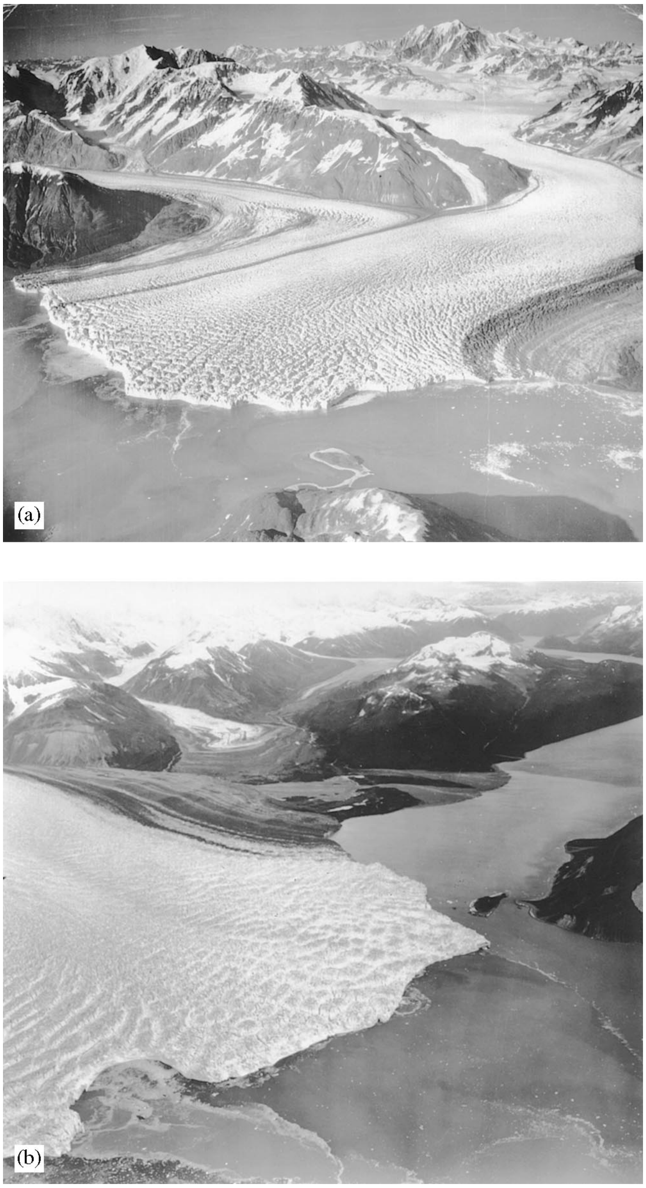

Fig. 9. Aerial photographs of the Hubbard Glacier (C) calving margin. A. 1963 view of Hubbard Glacier (right) and Valerie Glacier (C) (tributary) looking N-NW. The small island (Osier Island) between the mountain in the foreground (Gilbert Point) and terminus is presently beneath the ice margin. B. 1972 view northeast showing advance of Hubbard Glacier, across the mouth of Russell Fiord. Variegated and Orange glaciers and Nunatak Fiord are in the background. The width of the terminus is approximately 10 km. Photography by Austin Post, US Geological Survey.

A very marked change in climate occurred about 3500 BP. Pollen records (Ager, 1983; Heusser, 1995) indicate a dramatic cooling and suggest an increase in storminess in the Gulf of Alaska, and this was accompanied by a rejuvenation of glacial activity. During the fourth millennium BP, glacier expansions were underway near present termini at McCarty Glacier (C) ~ 3600 BP, the Icy Bay glacier (C) ~ 3480 BP, and possibly at Beare Glacier soon after. However, down-fjord evidence for these early movements is unclear.

A decrease in glacial activity and minor recession may have occurred about 2000 BP in the Gulf of Alaska as elsewhere in Alaska (Fig. 2) (Calkin, in press). Subsequent distinct, glacial expansion are recorded by many Gulf glaciers centered on the 1500–1300 BP interval. Tree-ring data suggest the several land-terminating glacier advances occurred about 1350 BP (AD 600). These correspond with early Medieval advances recorded elsewhere in the Northern Hemisphere (Porter, 1986, 1989). They preceded land-terminating glacier recession of the Medieval Optimum centered on the early 12th century AD. Many calving glaciers such as the McCarty and Northwestern glaciers in the southern Kenai Mountains advanced through this interval; the Hubbard Glacier (C) appears to have reached its Neoglacial maximum at about this time.

Little Ice Age glaciation, starting about 750 BP (AD 1200), and continuing through the 19th century (Porter, 1986) was ubiquitous across Alaska. During this interval, the majority of Alaskan glaciers reached their Holocene maximum extensions. ELAs were depressed 150 to 200 m below present values. The most precisely dated fluctuations of land-terminating glaciers, for example, those utilizing tree-ring dating of glacially overrun forests in the southern Kenai Mountains, Prince William Sound, or Bering and Icy Bay areas, display up to three major intervals of Little Ice Age advance (Fig. 11). These occurred around the middle 13th century or for some, the early 15th centuries, the middle 17the century, and the last-half of the 19th century.

The pattern of Little Ice Age advances (Fig. 11) is similar on decadal timescales to that of the well-constrained records of glacial fluctuations through Alaska (Calkin, 1988), and also on multi-decadal to century timescales to histories from the Canadian Cordillera derived using similar techniques (e.g., Luckman, 1986, 1995; Barclay, 1998). Furthermore, the two most recent Little Ice Age advances (Fig. 11) encompass the two coldest periods of the Northern Hemisphere over the last 500 years (Bradley and Jones, 1993; Jones and Bradley, 1995).

The Alaskan coastal record presented above dose suffer from an inherent bias towards more recent events. This is a function of the glacial geologic record. Because most glaciers reached their greatest Holocene extent in the Little Ice Age, evidence of any earlier fluctuations has often been destroyed. Recent studies such as the dating of glacially overrun forests within the Little Ice Age glacial limits in western Prince William Sound, or the non-glacial sedimentary sequences we used in Russell Fiord to infer activity of adjacent glaciers (King, 1995; Barclay et al., 1997), go some way towards addressing this problem.

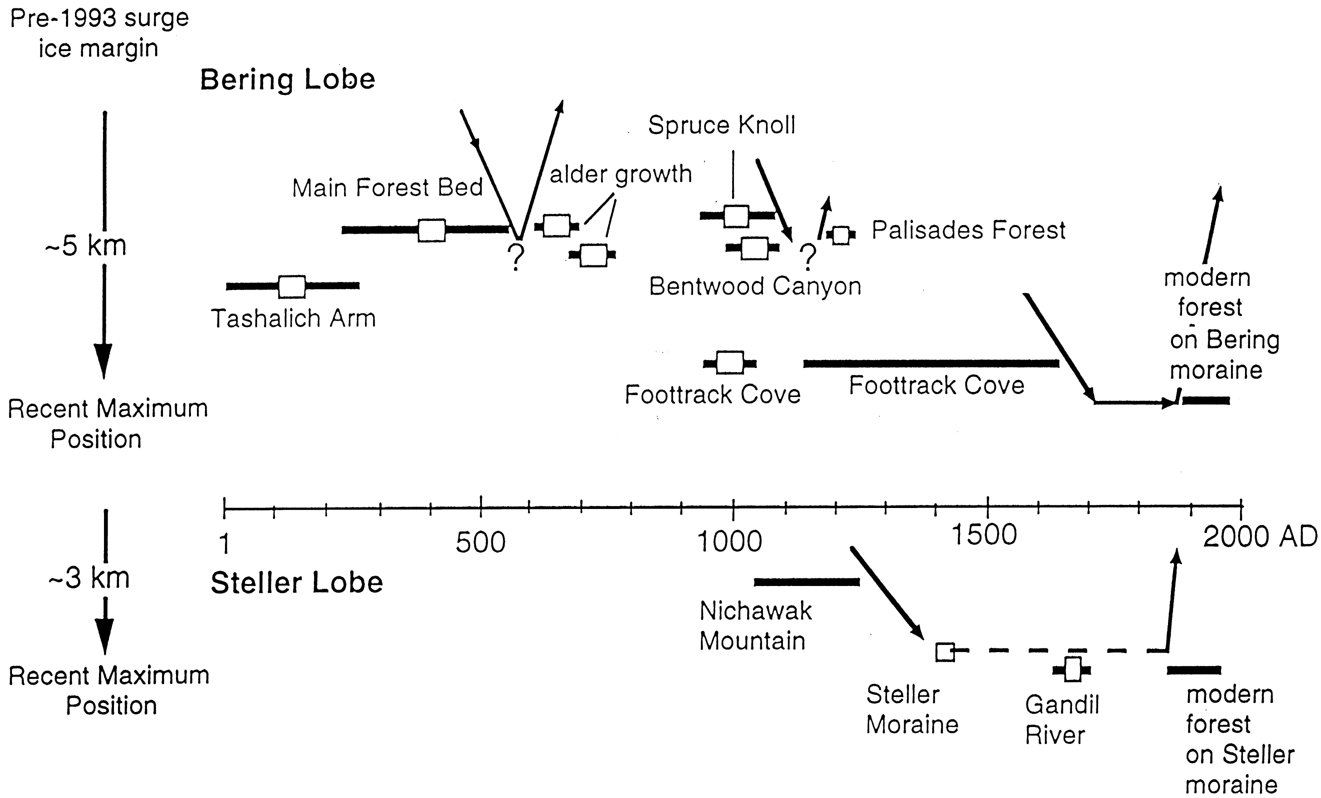

Fig. 10. A time–distance diagram showing inferred glacial advances of the Bering Glacier (arrows) interrupting intervals of forest growth (black bars = calendar-dated tree-ring series, black bars with rectangles = tree-ring series ordered in time by ^{14}C on the forefields of each glacier lobe. From Wiles et al. (in review).

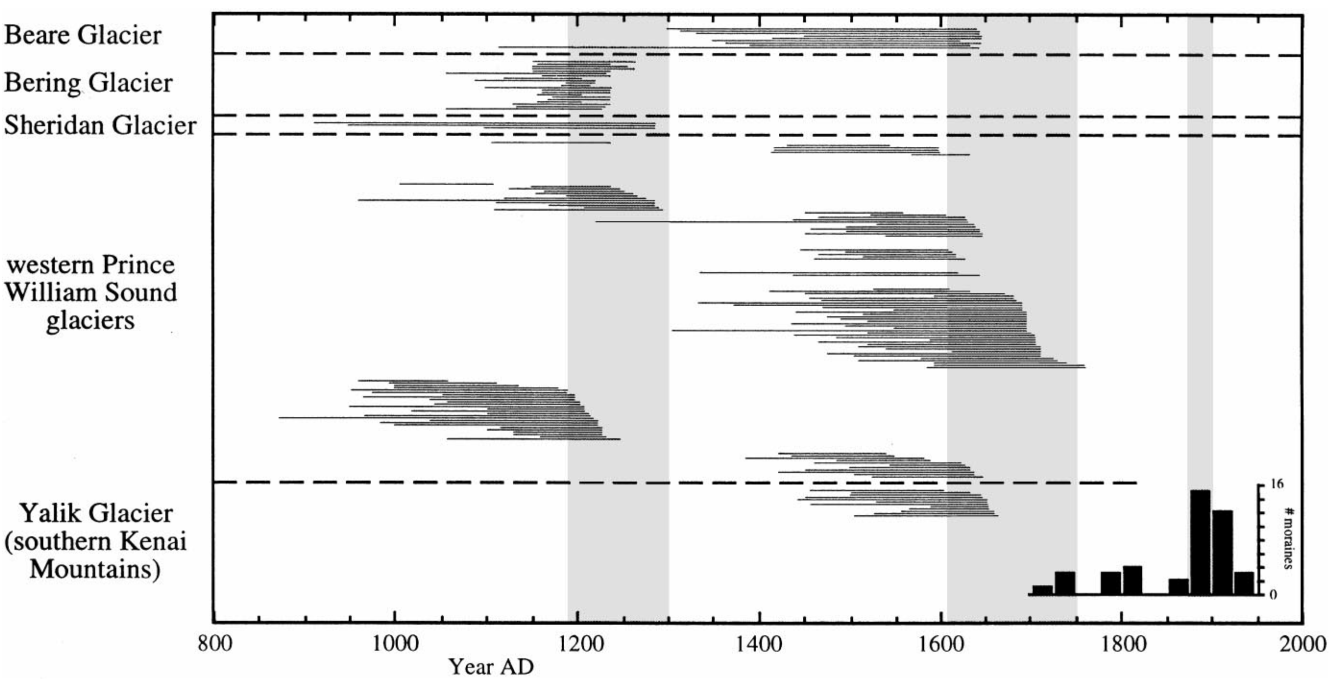

Fig. 11. Summary diagram of the Little Ice Age glacial history based on land-terminating glaciers widely spaced along the Gulf of Alaska. Horizontal bars depict lifespan of each glacially overrun tree crossdated with a living tree chronology. Note the two general times of ice expansion during decades centered around AD 1250 and again beginning about A.D. 1650. and extending into the early 1700s. The histogram, which suggests a third Little Ice Age advance culminating during the late 19th century, summarizes minimum ages assigned to end moraines of the glaciers indicated in this figure. Moraine ages were estimated using tree ring and lichen data.

The application of tree-ring dating to glacially killed trees in the Gulf of Alaska region is revealing a much greater synchrony of glacier advances as well as greater dating precision for these events of the last millennia than was previously possible with the coarse resolution of radiocarbon ages alone (e.g., Field, 1975; Calkin, 1988). Studies that focus on the development of tree-ring-width chronologies for the Gulf of Alaska also provide annually resolved proxy records of spring and summer temperatures to compliment the integrated climate record from glacial fluctuations (Wiles et al., 1997; Barclay et al., in press).

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