

# Historic retreat of Grand Pacific and Melbern Glaciers, Saint Elias Mountains, Canada: an analogue for decay of the Cordilleran ice sheet at the end of the Pleistocene?

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**ABSTRACT.** Grand Pacific and Melbern Glaciers, two of the largest valley glaciers in British Columbia, have decreased over 50% in volume in the last few hundred years (total ice loss = 250–300 km<sup>3</sup>). Melbern Glacier has thinned 300–600 m and retreated 15 km during this period; about 7 km of this retreat occurred between the mid-1970s and 1987, accompanied by the formation of one of the largest, presently existing, ice-dammed lakes on Earth. Grand Pacific Glacier, which terminates in Tarr Inlet at the British Columbia–Alaska boundary, retreated 24 km between 1879 and 1912. This rapid deglaciation has destabilized adjacent mountain slopes and produced spectacular ice-marginal land forms. The sediments and land forms produced by historic deglaciation in Melbern–Grand Pacific valley are comparable, both in style and scale, to those associated with the decay of the Cordilleran ice sheet at the end of the Pleistocene (c. 14–10 ka BP). Rates of historic and terminal Pleistocene deglaciation also may be comparable.

## INTRODUCTION

Most glaciers in mountainous regions of the world have receded substantially during the last 100 years, probably in response to climatic warming (Hansen and Lebedeff, 1987; Houghton and others, 1990). Today, surfaces of alpine glaciers lie below Little Ice Age trim lines and their termini, in many cases, are up-valley of Little Ice Age end moraines.

In the Saint Elias Mountains of southeast Alaska, northwest British Columbia and southwest Yukon Territory, recent deglaciation has been accompanied by destabilization of formerly ice-covered, steep rock slopes, mass wasting of drift and increased sediment supply to streams issuing from glaciers. In addition, significant isostatic rebound is occurring in areas where ice losses have been particularly large, for example, some inlets and bays in southeast Alaska (Hicks and Shofnos, 1965; Hudson and others, 1982). Furthermore, Meier (1984) has suggested that the melting of glaciers outside Greenland and Antarctica accounts for one-third to one-half of the observed rise in sea level in the 20th

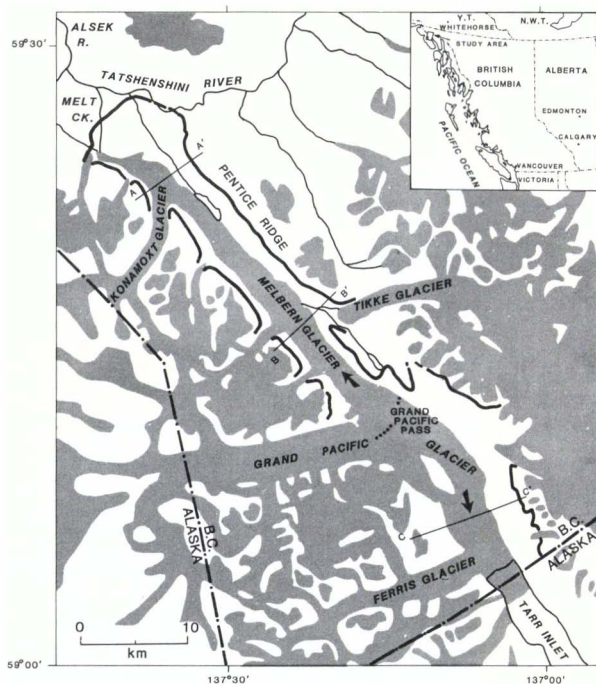


Fig. 1. Map of the study area showing the extent of glaciers in the 1970s, prior to the formation of glacial Lake Melbern (cf. Fig. 2). The Little Ice Age limit is indicated by thick solid lines. The dotted line marks the ice divide at Grand Pacific Pass and arrows indicate ice-flow directions. Topographic profiles AA', BB' and CC' are shown in Figure 5.

century and that more than one-third of this meltwater has come from glaciers in the mountains bordering the Gulf of Alaska.

This paper documents an example of historic, large-scale deglaciation in the Saint Elias Mountains of British Columbia and Alaska, specifically in Melbern Valley and Tarr Inlet (Fig. 1). The documentation is based largely on an analysis of late 19th and early 20th century survey data (International Boundary Commission, 1952), inspection of aerial photographs taken in 1979 and 1987, and field work conducted in 1991. In addition, we explore an analogy between deglaciation of this area over the last few hundred years and the disappearance of the Cordilleran ice sheet at the end of the Pleistocene.

### THE GRAND PACIFIC GLACIER—MELBERN GLACIER SYSTEM

Grand Pacific Glacier, with a length of 55 km and width of 2–5 km, is one of the largest valley glaciers in British Columbia (Fig. 1). It flows north and east from source areas at 1500–3000 m elevation in the Saint Elias Mountains near the British Columbia–Alaska boundary and bifurcates into two large ice tongues at Grand Pacific Pass. One of the tongues, Melbern Glacier, flows 20 km northwest towards Tatshenshini River and presently terminates in a glacial lake at about 250 m a.s.l. The other tongue, Grand Pacific Glacier proper, terminates at tide water in Tarr Inlet, 18 km southeast of Grand Pacific Pass.

#### Decay of Melbern Glacier

A conspicuous vegetation trim line and associated fresh lateral and end moraines delineate the margins of Melbern Glacier at the maximum of the Little Ice Age.

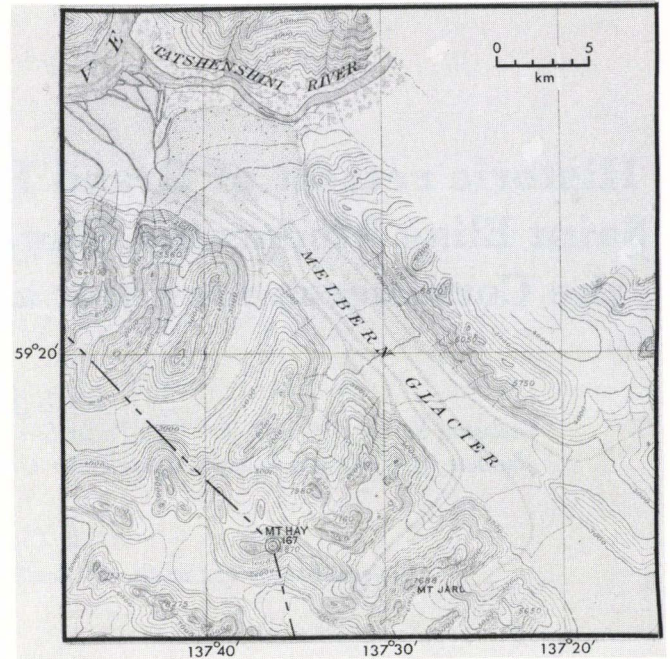


Fig. 2. Part of an international-boundary survey map (International Boundary Commission, 1928) showing the approximate extent of Melbern Glacier in 1908 (cf. Fig. 1). Comparison of this map and a 1908 photograph of the same area (Fig. 3) suggests that Melbern Glacier may not have extended quite as far north in 1908 as is shown on the map, i.e. part of the glacier terminus immediately south of Tatshenshini River, which is shown on the map as being debris-covered, may have disappeared before this date. Map reproduced by permission of International Boundary Commission (1928).

At that time, Melbern Glacier terminated about 15 km northwest of its present position, was confluent with its two largest tributaries, Konamox and Tikke Glaciers,



Fig. 3. Melbern Glacier in 1908; view to the southeast from a ridge near Alsek River. At this time, the debris-covered northern margin of the glacier was less than 2 km from the Little Ice Age end moraine. Note, however, that the surface of Melbern Glacier is well below the conspicuous Little Ice Age trim line (arrow). (Photograph by G. White-Fraser (photograph station CYR; #46); courtesy of International Boundary Commission, Ottawa, Canada.)



Fig. 4. Oblique aerial photograph, taken in 1991, of a flight of kame terraces and kame deltas along Tikki Creek east of Melbern Glacier; view east from above Melbern Glacier. These land forms record down-wasting of Melbern Glacier since the early 20th century.

and was 300–600 m thicker than today (Fig. 1). A comparison of the extent of the glacier at that time, in 1908 when Melbern Glacier was photographed during an international boundary survey (Figs 2 and 3) and in 1991, indicates that at least 50 km<sup>3</sup> of ice has been lost in Melbern Valley north of Grand Pacific Pass in the last few hundred years.

Thinning and retreat since the Little Ice Age maximum is recorded by a classical staircase-like series

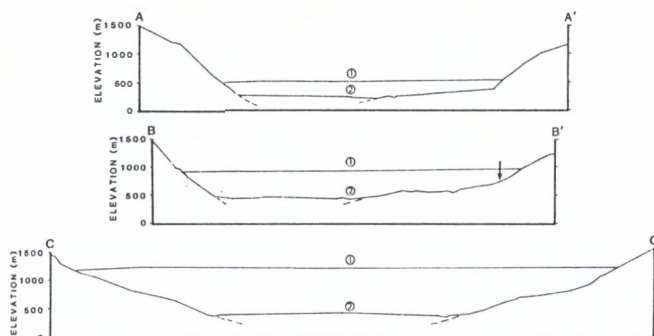


Fig. 5. Topographic profiles across Melbern-Grand Pacific Valley showing thinning that has occurred between the maximum of the Little Ice Age (surface 1) and 1979 (surface 2). The upper limit of the Tikki Creek kame terraces and kame deltas on profile BB' is indicated by an arrow. See Figure 1 for the locations of the profiles. Sources of information: 1979 ice surface — 1 : 50 000 scale topographic maps derived from 1979 air photographs; ▲ Little Ice Age maximum — trim line on 1979 air photographs.

of kame terraces and kame deltas along Tikki Creek (Figs 4 and 5) and by shore lines and thick drift which are particularly prominent on the northeast side of the valley below Pentice Ridge (Fig. 1). As deglaciation progressed, lakes were trapped between Melbern Glacier and the walls of the valley; the level of these lakes fell as the glacier thinned. Kame terraces and deltas were built below Tikki Glacier as it separated from Melbern Glacier and retreated eastward. Successively lower terraces record

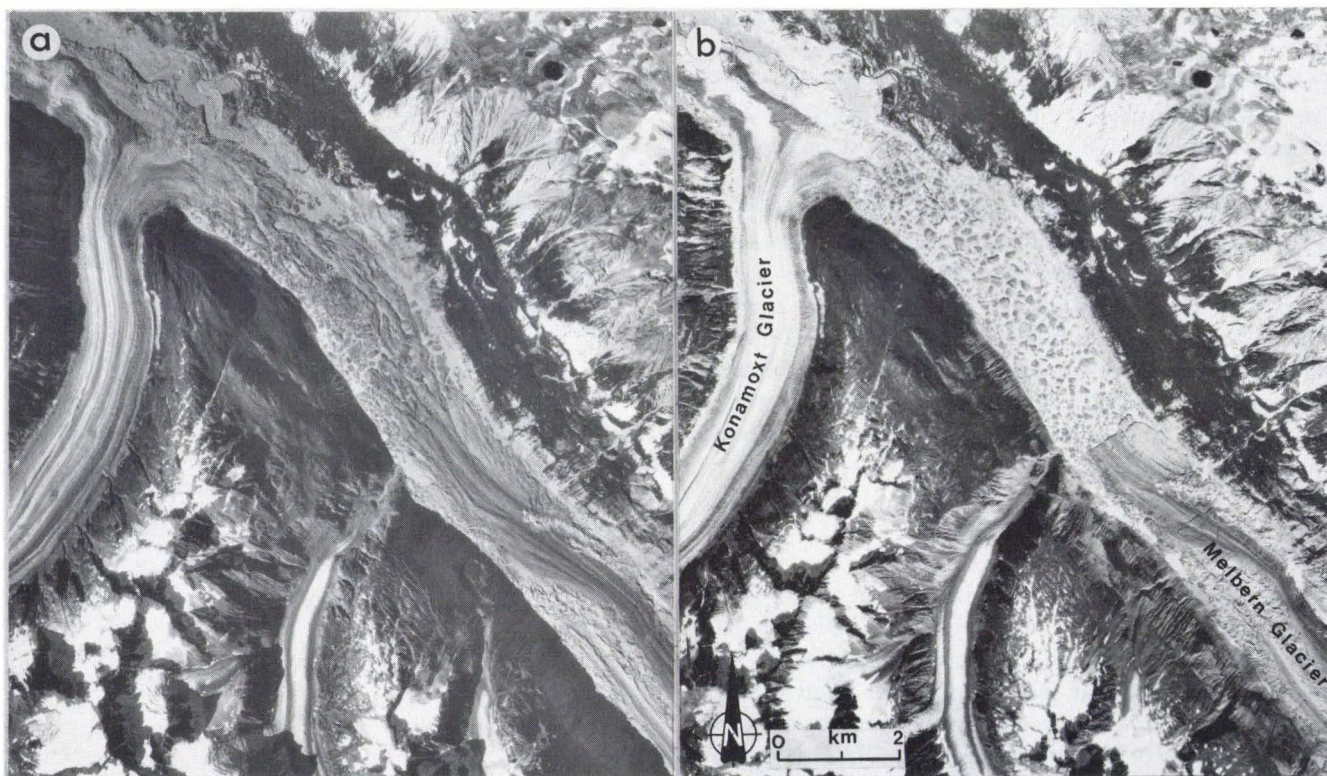


Fig. 6. Aerial photographs of Melbern and Konamoxt Glaciers in (a) 1979 (A25292-183; Energy Mines and Resources Canada) and (b) 1987 (BC87076-268; Province of British Columbia). Note that glacial Lake Melbern is just beginning to form in 1979 as dead ice between the two glaciers floats and breaks up. The lake is fully developed in 1987, although it is charged with tabular icebergs up to 200 m across.





Fig. 9. The terminus of Grand Pacific Glacier (centre of photograph) in the vicinity of Russell Island in 1894 (see Figure 8 for location). View north-northwest from a ridge east of Reid Glacier (bottom left); Johns Hopkins Glacier is at the centre left, and Russell Island abuts the toe of Grand Pacific Glacier at the right. (Photograph by A.J. Brabazon (photograph station King; #77); courtesy of International Boundary Commission, Ottawa, Canada.)

## DISCUSSION

### Causes of retreat

This paper has shown that two glaciers which share a common accumulation area, namely land-based Melbern Glacier and tide-water Grand Pacific Glacier, have had markedly different histories of retreat (Fig. 10). Glacier Bay and Tarr Inlet were deglaciated mainly in the 19th century, a time when Melbern Glacier was relatively stable and extensive. In contrast, much of the retreat of Melbern Glacier occurred during the 20th century.

Climatic warming in the last two centuries may be involved in the retreat of Melbern and Grand Pacific Glaciers but it does not explain their asynchronicity. Indeed, much of the retreat of Grand Pacific Glacier occurred prior to the warming of the late 1800s and early 1900s, and since 1912, the glacier periodically has advanced in spite of pronounced warming during the periods 1910–40 and 1975–present (Hansen and Lebedeff,

1987). Such asynchronous retreat has been noted in other studies of glaciers in the region (e.g. Mann, 1986) and has been predicted on theoretical grounds (Mercer, 1961). The retreat of Grand Pacific Glacier was driven by calving in the deep waters of Glacier Bay and Tarr Inlet (Brown and others, 1982; Powell, 1988). Calving is a complex process that is controlled by non-climatic factors (Meier and Post, 1987). Calving rates of tide-water glaciers are high in deep water, generally exceeding ice flux to the terminus. Under such conditions, a glacier will retreat to a new equilibrium position, commonly a pinning point where water is shallower or the calving front is narrower, causing ice flow to accelerate. Grand Pacific Glacier attained such a position in 1912, with a relatively narrow calving front and probably a shallower grounding line.

During retreat, the average surface gradient of Grand Pacific Glacier increased south of Grand Pacific Pass. This may have shifted the ice divide between Grand Pacific and Melbern Glaciers northward, routing more ice southward from Grand Pacific Pass towards Tarr Inlet. There is, in fact, evidence for a recent shift in this ice divide. The Little Ice Age trim line of Grand Pacific Glacier between Grand Pacific Pass and the head of Tarr Inlet is 400–800 m above the present glacier surface. It increases in elevation south of Grand Pacific Pass, indicating that the ice divide was farther south at the maximum of the Little Ice Age than at present (perhaps in the vicinity of Ferris Glacier; Fig. 1). Presumably, as the ice divide moved north, less ice flowed into Melbern Valley, causing Melbern Glacier to retreat. Recession of Melbern Glacier was therefore delayed until after Grand Pacific Glacier equilibrated to its new calving-front position.

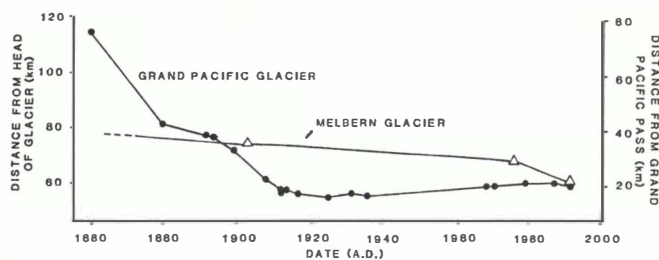


Fig. 10. Graphs summarizing the retreat of Melbern and Grand Pacific Glaciers since the mid-1800s. Data sources as in Figure 8, plus air-photograph observations and International Boundary Commission records.

### Analogy with late Pleistocene deglaciation

Recent deglaciation of Melbern Valley is analogous to deglaciation of mountain valleys throughout British Columbia at the end of the Pleistocene (c. 14–10 ka BP). Melbern Valley is rapidly becoming deglaciated by thinning, stagnation and frontal retreat. The same style of deglaciation has been inferred for the end of the Pleistocene from studies of sediments and land forms in southern and central British Columbia (Fulton, 1967, 1991). Complex valley fills deposited at the close of the last glaciation and consisting largely of thick, ice-marginal and proglacial lacustrine and fluvial sediments (Ryder and Clague, 1989; Ryder and others, 1991; and references therein) are similar to those that have accumulated in Melbern Valley during this century. Likewise, raised deltas and kame terraces identical to those in Melbern Valley are common late Pleistocene land forms throughout British Columbia. Even the scale of the recent and ancient deposits and land forms is similar: well over 100 m of 20th century, ice-marginal sediments are present on the southeast flank of Pentice Ridge and west of Tikke Glacier, and the Tikke Creek terraces extend through a vertical range of more than 350 m.

Similarly, historic deglaciation of Glacier Bay and Tarr Inlet is probably comparable, both in style and scale, to deglaciation of the coast of British Columbia at the end of the Pleistocene (e.g. Clague, 1985). In both instances, glaciers retreated rapidly by calving, probably triggered by climatic warming. About 14 000 years ago, tongues of ice rapidly retreated across the British Columbia continental shelf to pinning points in fiords where they temporarily stabilized (Clague, 1985). Similarly, most of Glacier Bay was rapidly deglaciated in the 19th century, but ice margins stabilized and even advanced in some tributary fiords such as Tarr Inlet in the 20th century.

Finally, an analogy may also be drawn between the rapidity of late Pleistocene deglaciation and the recent retreat of Melbern and Grand Pacific Glaciers. Although the chronology of the advance and retreat of the Cordilleran ice sheet is not known in detail in most areas, available evidence suggests that individual valleys became ice-free rapidly at the close of the Pleistocene, probably over a period of several decades to a few hundred years (Clague, 1986). The Grand Pacific–Melbern Glacier system has lost over 300 km<sup>3</sup> of ice, or more than 50% of its mass, in the last 200 years, most of this in the last 100 years. This may be comparable to rates of ice loss in Cordilleran valleys at the end of the Pleistocene.

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