DENDROGLACIOLOGICAL INVESTIGATIONS AT SASKATCHEWAN GLACIER, BANFF NATIONAL PARK

A PRELIMINARY REPORT BASED ON FIELD INVESTIGATIONS IN SEPTEMBER, 1999

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Abstract

This report describes the results of dendroglaciological investigations at Saskatchewan Glacier, Banff National Park, Alberta. The Saskatchewan Glacier flows *ca.* 10 km eastward from the Columbia Icefield through a steep-walled valley between Mt. Castleguard and Mt. Adromenda. Since it was first photographed in 1921, the glacier snout has receded several kms up valley. Within the last two decades detrital wood (dating between 3180 and 2540 ^{14}C years BP) has periodically appeared at the ice front. It has been assumed that these detrital branches and logs were derived from trees overridden by a Neoglacial advance of the Saskatchewan Glacier.

In late-August 1999, a severe rainstorm resulted in ice proximal incision along the northern periphery of the Saskatchewan Glacier. This resulted in the erosion of over 6 m of till and outwash deposits, and the flushing of large quantities of detrital boles, logs and stumps onto the outwash surface. At the channel base, *in situ* stumps rooted within a well-preserved paleosol were exposed. Radiocarbon dating established the stumps represented trees killed between 2910 +/60 and 2830 ± 60 ^{14}C years BP. These radiocarbon dates substantiate previous circumstantial evidence of a Neoglacial advance at Saskatchewan Glacier and are illustrative of the approximate position of the icefront at 3000 ^{14}C years BP.

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1 INTRODUCTION

The Saskatchewan Glacier is a major outlet glacier of the Columbia Icefield. It is located near the southern end of the icefield and flows *ca.*10 km through a steep-walled valley between Mt. Castleguard and Mt. Adromenda. Since it was first photographed the Saskatchewan Glacier has experienced significant downwasting and frontal retreat (Figure 1).

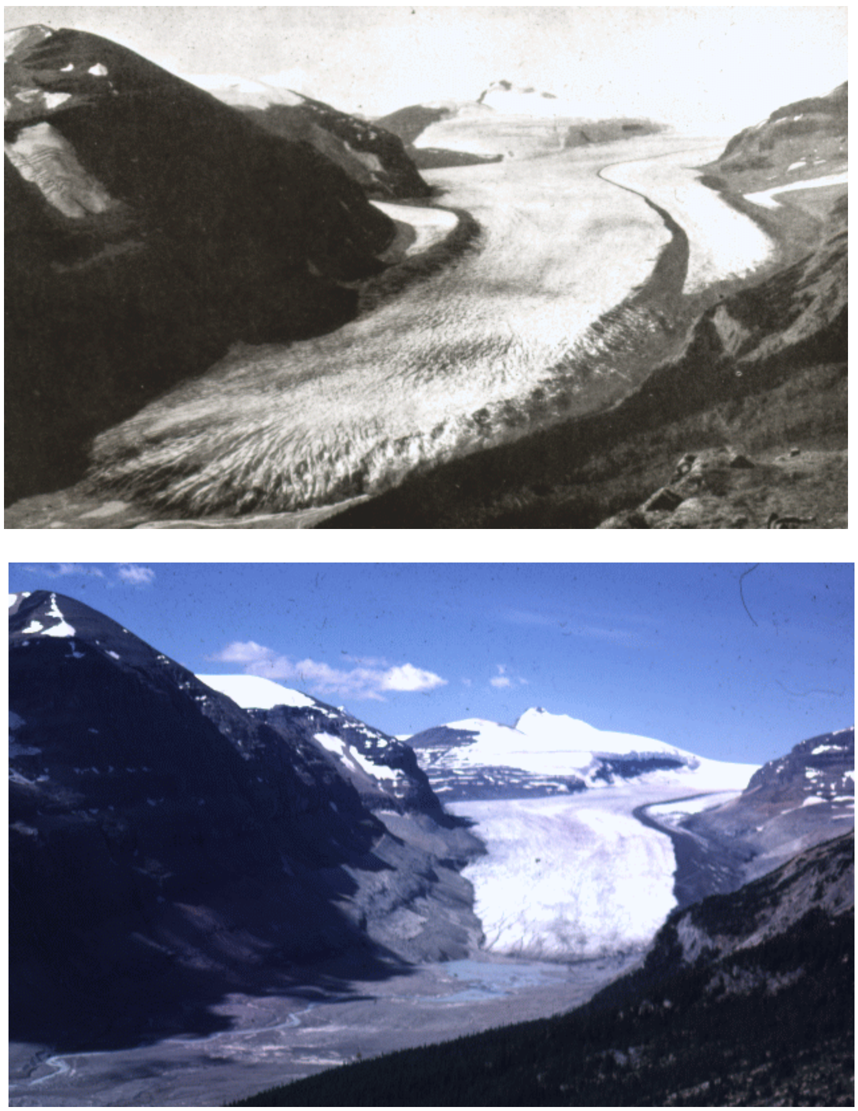

Figure 1. The Saskatchewan Glacier from Parkers Ridge, Banff National Park (upper: photograph by Byran Harmon, 1924; lower: 1985).

As a result of its accessibility, the historical (Field 1949; Henoch 1971; McPherson and Gardner 1969, Gardner 1972; Robinson 1988) and present-day glaciological behaviour of the Saskatchewan Glacier is reasonably well appreciated (Field 1949; Meier *et al.* 1954; Meier 1957, 1960). During the preceding Little Ice Age (LIA, 1200 to 1900 A.D.), glaciers throughout the Canadian Rockies experienced episodes of synchronous glacier advance (Luckman 2000). Results from studies by Heusser (1956) and Robinson (1988) at the Saskatchewan Glacier revealed that their was evidence for multiple LIA events, including a significant mid 19th century advance and a less extensive event during the early and middle parts of the 18th century. Evidence of a pre-Little Ice Age event comes detrital wood washed out of the glacier (Luckman *et al.* 1993a, 1994). The wood (dating between 3200 and 2500 ^{14}C yrs B.P.) provides strong circumstantial evidence for an advance equivalent to the *Peyto Advance* (3300-2800 yrs. B.P.) at the Saskatchewan Glacier (Luckman *et al.* 1993a ; Luckman 1996).

In late-August 1999, a severe rainstorm caused significant stream channel incision along the northern periphery of the Saskatchewan Glacier. Stream erosion removed over 6 m of till and outwash deposits, exposing 26 *in situ* stumps rooted within a well-preserved paleosol (Fig.2). Based on the circumstantial evidence noted above, it was assumed that the site most likely represented a subalpine forest buried during the *Peyto Advance* episode. Given the significance of this discovery and the likelihood of the site being buried by on-going aggradation, tree-ring samples of the stumps were removed for analysis during two days of fieldwork in early September. The intention of this report is document the nature of these collection activities in 1999 and to report on our preliminary findings.

Figure 2. *In-situ* tree stumps exposed at periphery of Saskatchewan Glacier following a rainstorm in August, 1999.

2. STUDY SITE

Saskatchewan Glacier is located at the headwaters of the North Saskatchewan River in Banff National Park Alberta. The glacier flows eastward from an altitude of *ca.* 2600 m asl in the Columbia Icefield to about 1800 m asl at the present ice margin (Figure 4). Meltwater from the terminus presently flows into a proglacial lake from supraglacial streams and subglacial outlet channels.

The subfossil forest site was exposed along the northeastern flank of the Saskatchewan Glacier (Figure 4, Lat. 117° 08' 45" N; Long. 52° 09' 30" W). Stream incision 1999, eroded through a thick sequence of till overlying glacial outwash (Figure 5). The accompanying channel bank erosion left behind a vertical (*ca.* 2-3 m in height) embankment on the south side of the channel and a steeply sloping north channel bank (*ca.* 4-5 m in height) (Figure 6). When first examined in September 1999, channel migration was causing point bar development and active erosion of a minor erosional terrace positioned 0.5 - 1 m above the stream on the north side of the channel.

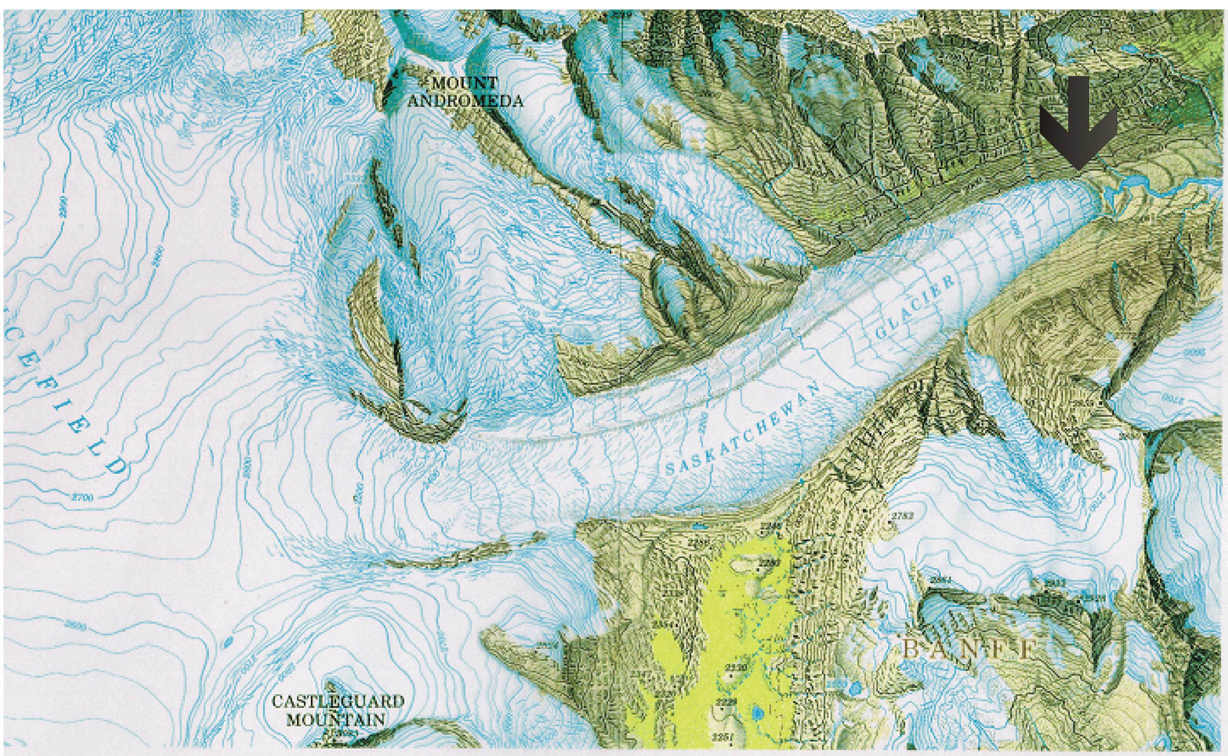

Figure 4. Topographic map of the Saskatchewan Glacier showing the location of the subfossil forest (arrow points to location).

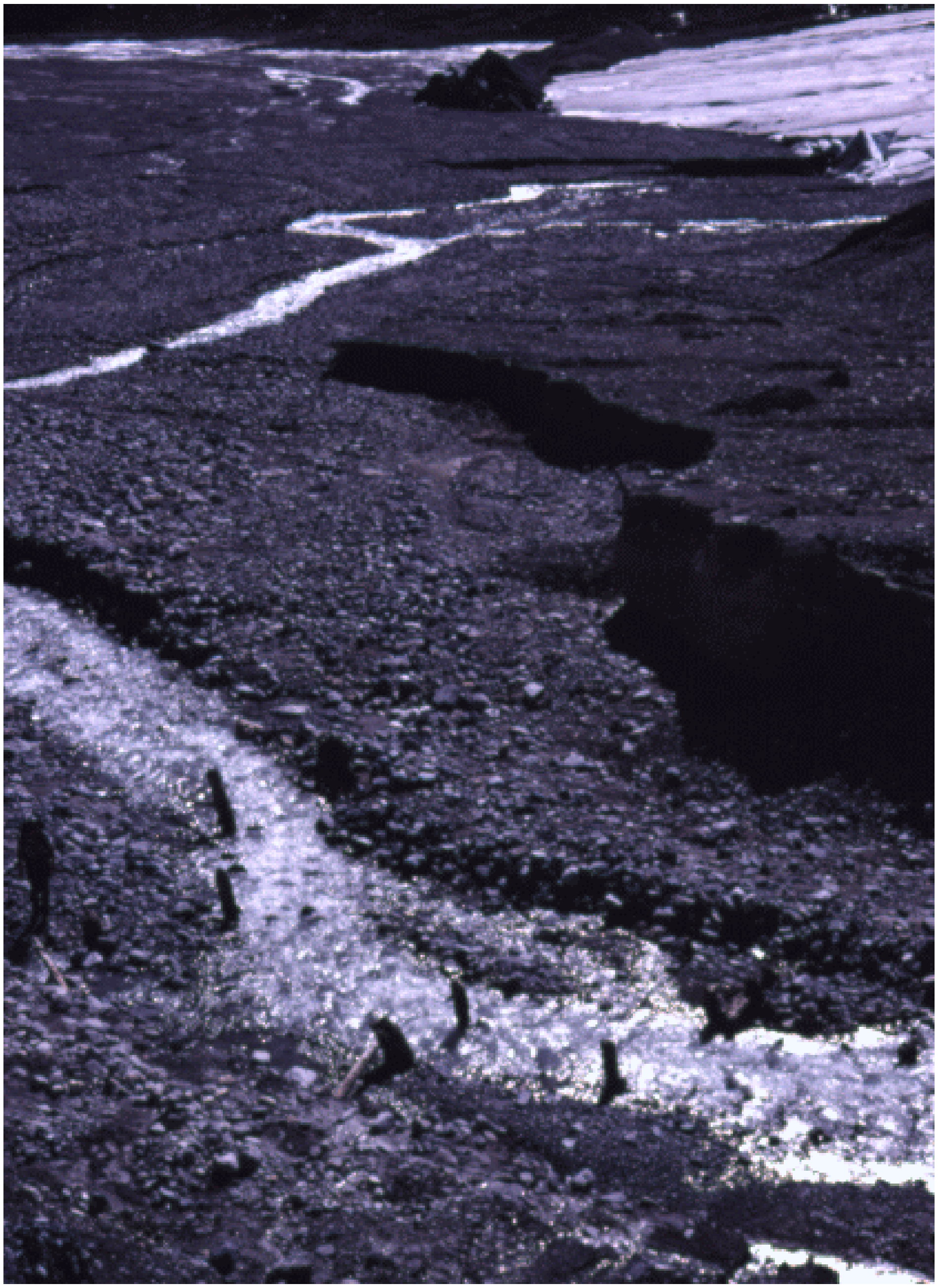

Figure 5. View to southeast showing the incised stream channel and *in-situ* tree stumps in the foreground. Note the vertical cut bank opposite the stumps and the snout of the Saskatchewan Glacier in the background (September 12, 1999).

Figure 6. View westward along the northern flank of the Saskatchewan Glacier towards Mt. Adromenda. Shown are the *in situ* stumps and the vertical cut bank to the left of the channel. Note the deeply weathered and reddish-coloured till immediately above the upstream channel meander. (September 12, 1999).

3 METHODS

Dendroglaciology is a research methodology that uses tree rings to study and date the movement of glaciers (Luckman, 1998). In recent applications, trees killed or displaced by advancing glaciers have been crossdated with reference to living tree-ring chronologies (Smith *et al.* 1995; Luckman, 1996; Smith and Laroque, 1996). For this approach to be successful, the living tree-ring chronology must have distinctive pointer years and encompass the age of the glacial advance being studied (Luckman, 1998). At sites were the subfossil trees are older than the established living tree-ring chronology, radiocarbon analysis is used to provide a relative sample age.

At Saskatchewan Glacier, tree ring samples were collected from subfossil wood samples located at three locations:

A) ***In situ* stumps** - radial discs were cut from the stumps exposed within the incised stream channel (Figure 7). As accelerating aggradation threatened to bury the site, samples were collected from all of the stumps found exposed on September 16, 1999.

Figure 7. View eastward showing down the ice proximal incised stream channel at the Saskatchewan Glacier. Note the uniform decapitation height shown by the *in situ* stumps.

B) ***Detrital wood exposed in channel bank*** - radial discs were cut from detrital found incorporated in till on north side of stream channel (Figure 8).

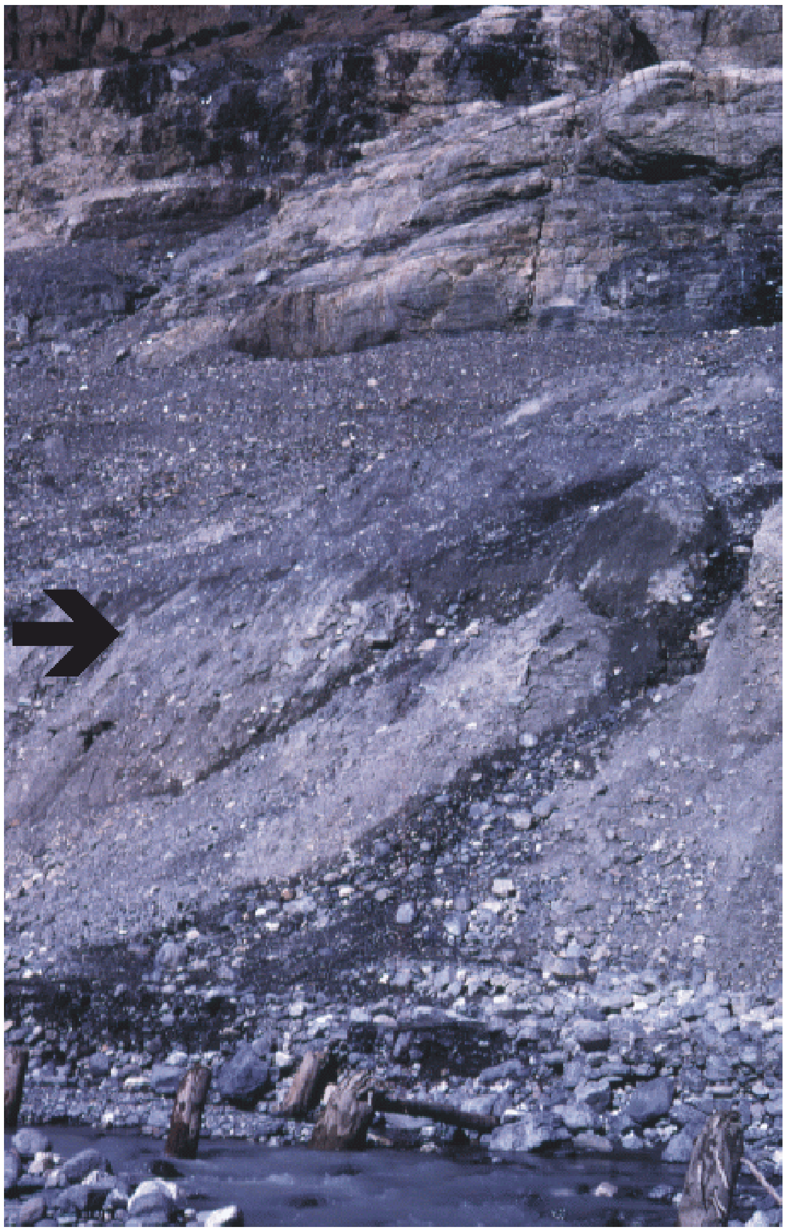

Figure 8. View to northwest showing elevation of wood incorporated in till on north side of stream above *in situ* stumps (September 12, 1999).

C) ***Detrital wood on outwash plain*** - radial discs were cut from detrital boles flushed onto the outwash plain immediately in front of the Saskatchewan (Figure 9).

Figure 9. Example of detrital wood (boles, stumps, branches) located on the outwash plain in front of the Saskatchewan Glacier (September 12, 1999).

After air drying, the discs were polished to a high finish and visually crossdated with reference to a set of common pointer years (Stokes and Smiley 1968). The annual ring-widths were measured to the nearest hundredth of a millimetre using a computerized WinDENDRO™ (Version 6.1D, 1998) image processing measurement system (Guay *et al.*, 1992). Where the ring boundaries were difficult to distinguish, a 40X microscope and Velmex-type stage measurement system were employed for ring boundary verification. The ring width data were checked for signal homogeneity using the COFECHA computer program (Holmes, 1983) and a standardized tree-ring series was constructed using a procedure within the ARSTAN computer program designed to remove any inherent age-growth trends (Holmes *et al.*, 1986).

4. OBSERVATIONS

Dendrochronological analysis

A total of 30 tree-ring samples were collected at the Saskatchewan Glacier in 1999. The samples consisted of discs cut from *in situ* stumps and boles exposed within the incised stream channel, representative samples of detrital wood found on the outwash surface and detrital wood incorporated within till. In contrast to the abraded wood found within the stream channel and on the outwash surface, the detrital wood found within the till consisted of slightly masticated branch and bole fragments. This latter set of samples was found at the boundary between two stratigraphic units, along an *ca*. 30 m reach parallel to the channel (Figure 8).

The tree-ring samples were identified as being either subalpine fir (*Abies lasiocarpa*), engelmann spruce (*Picea engelmanni*) or whitebark pine (*Pinus albicaulis*) on the basis of the anatomic characteristics of their annual rings (*cf.* Schweingruber, 1993).

- 17 subalpine fir trees were represented in our sample and 27 individual radii were measured for crossdating. Two floating subalpine fir chronologies, separated by *ca.* 100 years, were established with a preliminary means series correlation of 0.429 (Figure 10). The total number of years represented is *ca*. 376.

- 6 engelmann spruce trees were identified and 9 individual radii were used to develop a floating chronology that spans a 237 year interval (Figure 10). The preliminary mean correlation of the chronology is 0.313.

- 7 whitebark pine specimens were identified and 11 individual radii were used to develop a floating chronology spanning a 396 year interval (Figure 10). While the mean series correlation of the chronology remains somewhat low (0.118), this appears largely due to the limited sample depth in the oldest part of the chronology.

Figure 10 shows three cross-dated floating tree-ring chronologies developed from the subfossil wood found at the Saskatchewan Glacier. Shared sequences of pointer years within all three species enabled inter-species crossdating and were suggestive of common forcing mechanisms affecting radial growth. In addition, it appears that all three floating chronologies terminate at approximately the same point in time.

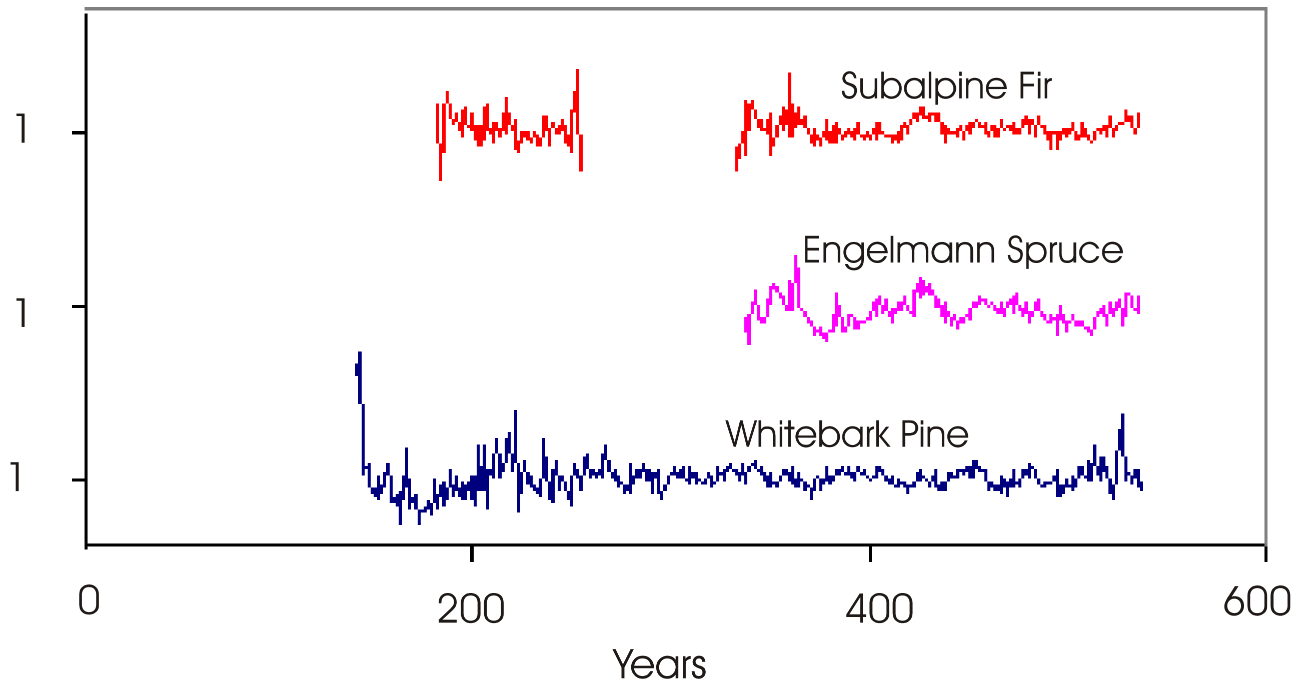

Figure 10. Preliminary species-specific floating chronologies established from subfossil stumps and detrital wood collected at the Saskatchewan Glacier in September, 1999.

Radiocarbon analysis

Three pieces of subfossil wood were submitted for radiocarbon analysis to Beta Analytic Inc. (Miami, Florida) in October, 1999. Two of these samples were from near-perimeter tree ring sequences taken from the *in situ* stumps shown in Figure 7 (UVTRL 99W07 and UVTRL 99W24). A third near-pith tree-ring sample was carved from a fragmented bole collected within the detritus band shown in Figure 8 (UVTRL 99W031). At Beta Analytic Inc, the samples were first gently crushed in deionized water and then given hot HCI acid washes to eliminate carbonates. A final alkali wash (NaOH) removed any secondary organic acids. The alkali washes were followed by a final acid rinse to neutralize the solution prior to drying. The samples were then analysed by synthesizing the sample carbon to benzene (92% C), measuring for ^{14}C content in a scintillation spectrometer, and then calculating for radiocarbon age.

The results of these radiocarbon analyses are presented in Table 1. The two *in situ* stumps have equivalent perimeter ages and indicate that the Saskatchewan Glacier killed these trees at *ca*. 2850 ^{14}C years BP. While the third radiocarbon date proved to be slightly older in radiocarbon years, it does fall within quoted errors (1 standard deviation, 68% probability) of the samples. These slight differences in radiocarbon ages may also be an true artifact of sample age, as pith dates are older than near-perimeter rings.

Table 1. Listing of radiocarbon ages of subfossil wood collected at snout of Saskatchewan Glacier.

Sample Number	**Laboratory Number**	**Radiocarbon Age (*)**
a) ***University of Victoria Tree-Ring Laboratory***		
UVTRL 99W07	Beta-135586	2830 60
UVTRL 99W24	Beta-135587	2870 60
UVTRL 99W31	Beta-135588	2910 70
b) ***Previously reported dates on detrital wood recovered near the 1988 Saskatchewan Glacier ice front*** **(#)**		
	BGS-1369	3180 80
	Beta-65384	3170 60
	Beta 29957	2940 90
	Beta 31358	2880 70
	Beta 65383	2540 60

* Dates are reported as RCYBP (radiocarbon years before present, "present" = 1950 A.D.).

\# Luckman *et* al. (1993) and Robinson (1988).

The radiocarbon-dated wood samples collected in 1999 are represented in the crossdated floating chronologies shown in Figure 10 and, as a consequence, anchor the relative duration of the chronologies in time. Further sampling and crossdating is planned in anticipation of linking these floating chronologies to the lengthy living chronology described by Luckman *et al*. (1997).

Buried soil analysis

Two pedogenic horizons were distinguished within the buried soil exposed at the study site (Figure 6). The lowermost horizon consisted of a laterally continuous (> 10 m exposure), reddish-stained (> 1 m depth) diamicton. This horizon was capped by a 5 cm thick black organic horizon with clearly visible plant macrofossils (*e.g.* needles and cones). Overlying the buried soil was a thick unit (> 4 m) of massive unsorted till that contained a single bed of woody detritus (Figure 8). Based on the radiocarbon evidence described above, the buried soil horizon was entombed at least 3000 ^{14}C years BP.

Grab samples of the buried organic horizon were collected for laboratory analysis. Representative samples were initially desegregated in a sugar water bath and subsequently with a dilute potassium hydroxide solution. Each sample was then allowed to air-dry. The sample was finally sieved though a 250 µm screen and any residue remaining saved for microscopic analysis.

A cursory microscopic analysis of the residue remaining on the sieves revealed a rich abundance of coniferous needles and deciduous plant parts (*e.g.* stems and seeds). In addition, various insect remains, notably Oribatid mites with intact sclerites, were noted.

5. INTERPRETATION

Sometime prior to 3000 ^{14}C years BP, the Saskatchewan Glacier began to flow out of the Columbia Icefield into the North Saskatchewan River Valley. This advance episode followed a lengthy period of limited glacier activity and may have been initiated as much as 800 to 1200 ^{14}C years earlier (*c.f.* Gardner and Jones 1985).

As the Saskatchewan Glacier moved down onto the valley floor, proximal outwash gravels began to bury the mixed stand of fir, pine and spruce recorded at the site. A period of rapid burial with limited erosion is indicated by forest floor preservation and the number of branches retained on the buried trees. Sometime after this event, the glacier overtopped the gravels and decapitated the partially buried trees, eventually entombing them below a thick till deposit until they were exposed in August, 1999.

The marked horizon of detrital wood located within the till unit that represents the remnants of a related forest site further up glacier. This observation suggests additional subfossil forests are likely to appear as the Saskatchewan Glacier continues to recede upvalley. The sheared character of the associated sediments also suggests the study site may be close to the maximum Neoglacial extent of the Saskatchewan Glacier. Additional sedimentological studies will be undertaken in the 2000 field season to test this hypothesis.

6. CONCLUSION

Glacial runoff generated by a late-summer rainstorm in August, 1999, resulted in the incision of ice proximal sediments at the Saskatchewan Glacier. Numerous pieces of detrital wood and a large grouping of *in situ* stumps were exposed by this event. Subsequent dendroglaciological analyses of tree ring samples collected from this subfossil wood led to the development of three floating tree-ring chronologies. Corollary radiocarbon dating shows these trees died during an advance of the Saskatchewan Glacier *ca.* 3000 ^{14}C years BP.

The preliminary findings of this study confirm that the Neoglacial advance of the Saskatchewan Glacier began sometime prior to 3000 ^{14}C years BP. This advance is contemporaneous with similar episodes at both Peyto Glacier and Robson Glacier (Luckman 1995, 1996), and serves to further confirm that the Neoglacial *Peyto Advance* was a regional event (Luckman *et al.* 1993).

7. REFERENCES

Field, W.O., Jr. 1949. Glacier observations in the Canadian Rockies. Canadian Alpine Journal 32:99-114.

Gardner, J.S. 1972. Recent glacial activity and some associated landforms in the Canadian Rockies. *In*: Mountain Geomorphology. *Edited by*: O. Slaymaker and H.J. McPherson. Tantalus Press Ltd: Vancouver. 55-62.

___________ and Jones, N.K. 1985. Evidence for a Neoglacial advance of the Boundary Glacier, Banff National Park, Alberta. *Canadian Journal of Earth Sciences* 22:1753-1755.

Henoch, W.E.S. 1971. Estimate of glaciers secular (1948-1996) volumetric change and its contribution to the discharge in the upper North Saskatchewan River basin. Journal of Hydrology 12:145-160.

Heusser, C. J. Postglacial environments in the Canadian Rocky Mountains. *Ecological Monographs* 26:263-302.

Luckman, B.H. 1995. Calender-dated, early 'Little Ice Age' glacier advance at Robson Glacier, British Columbia, Canada. *The Holocene* 5:149-159.

___________ . 1996. Dendroglaciology at Peyto Glacier, Alberta. *In* Tree Rings, Environment and Humanity. *Edited by*: J.S. Dean, D.M. Meko and T.W. Swetnam. *Radiocarbon*. 679-688

___________ . 1998. Dendroglaciologie dans les Roceuses du Canada. *Géographie physique et Quaternaire* 52:139-151.

___________ . 2000. The Little Ice Age in the Canadian Rockies. Geomorphology 32:357-384.

___________ ; Briffa, K.P.; Jones, P.D. and Schweingruber, F.H. 1997. Tree-ring based reconstruction of summer temperature at the Columbia Icefield, Alberta, Canada. *The Holocene* 7:375-389.

___________ ; Colenutt, M.E.; Kavanagh, T.A.; Seaquist, J. and McLennan, J., 1993b. *Field Investigations in the Canadian Rockies in 1992*, Report to Parks Canada, Alberta Parks and

B.C. Parks Service, May 1993, 96 pp.
___________ . Holdsworth, G. and Osborn, G.D., 1993a. Neoglacial glacier fluctuations in the Canadian Rockies, *Quaternary Research* 39, 144-153.
McPherson, H.J.; and Gardner, J.S. 1969. The development of glacial landforms in the vicinity of the Saskatchewan Glacier. *Canadian Alpine Journal* 52:90-96.
Meier, M.F. 1957. Mode of Flow of Saskatchewan Glacier, Alberta, Canada. Upublished Ph.D. dissertation. California Institute of Technology.
___________ . 1960. Mode of flow of Saskatchewan Glacier, Alberta, Canada. USGS, Professional Paper 351. Washington, D.C.
___________ ; Rigsby, G.P.; and Sharp, R.P. 1954. Preliminary data from Saskatchewan Glacier, Alberta, Canada. Arctic 7:3-26.
Robinson, B.J. 1998. Glacier history of the Columbia Icefield. Unpublished M.Sc. thesis. University of Western Ontario, London.
Schweingruber, F.H., 1993. Trees and Wood in Dendrochronology. Springer-Verlag, Berlin.
Smith, D.J. and Laroque, C.P., 1996. Dendroglaciological dating of a Little Ice Age glacial advance at Moving Glacier, Vancouver Island, British Columbia. *Géographie Physique et Quaternaire*, 50:47-55.
___________ ; McCarthy, D.P.; and Colenutt, M.E. 1995. Little Ice Age glacial activity in Peter Lougheed and Elk Lakes provincial parks, Canadian Rocky Mountains. *Canadian Journal of Earth Sciences* 32:579-589.
Stokes, M.A. and Smiley, T.L., 1968. An Introduction to Tree-Ring Dating. University of Chicago Press, Chicago, 73 p.