EXTENDING SNOW AVALANCHE CHRONOLOGIES:
THE USES AND CONSTRAINTS OF DETRITAL WOOD

by

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Abstract

Dendrochronological techniques using living trees have successfully predicted the frequency of past avalanche events. This study was undertaken to expand these dendrochronological techniques by incorporating detrital wood in avalanche chronologies. We hypothesized that detrital wood contains a record of past avalanche activity. We further hypothesized that detrital wood in the vicinity of avalanche mounds could be used to determine the frequency of high magnitude avalanche events that create plunge pool and mound complexes.

Increment cores were collected from living Engelmann spruce adjacent to an avalanche track with a well-developed plunge pool mound complex near Upper Burstall Lake, Alberta, and were used to develop a living master site chronology. Cores and disks from detrital logs on and in the immediate vicinity of the avalanche mound were cross-dated, measured, and compared with the site chronology.

Detrital wood was successfully used to extend snow avalanche chronologies beyond that recorded with living trees. Cross-dating difficulties were encountered. These arose from sample integrity, species-specific growth patterns, and age-dependent relationships with respect to how individual trees record avalanche events within the cambium. Our data provided limited insight into magnitude/frequency relationships for avalanche events. There was some suggestion of high magnitude events within the detrital wood record; however, our sample size was too small to infer the occurrence of catastrophic avalanche events.

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INTRODUCTION

Dendrochronological techniques have been used successfully to determine the frequency of avalanche events (Burrows and Burrows 1976). Living trees within or immediately adjacent to avalanche tracks contain a record of past avalanche events within their annual growth rings. In the years following an avalanche event that distorts but does not kill a tree, reaction wood forms on the downslope side of the affected tree as it regains a vertical position with respect to the slope. In conifers, this compression wood is structurally and morphologically different from normal cambial growth. Areas of compression wood on disks or cores collected from trees within avalanche zones can be dated to provide information about avalanche frequency.

Some avalanche sites develop a characteristic pit and mound topography where the avalanche collides with the valley bottom and lifts or scoops unconsolidated sediment along its trajectory path. Some of this sediment consists of logs and fragments of wood deposited by previous avalanche events. Snow-avalanche impact pits (Corner 1980, Fisheries and Omens 1984) and corresponding depositional mounds (Smith *et a.* 1994) have been described in studies from subalpine areas in several parts of the world. Where avalanche pits intercept the local water table, water-filled pools, sometimes referred to as plunge pools, form (e.g., Davis 1962, Liestol 1974, Smith *et al.* 1994).

It has been hypothesized that only high magnitude/low frequency avalanche events are capable of creating the pit/mound topography (Smith *et a.* 1994). While low magnitude/higher frequency events may add sediment and woody debris to the pit or pool, ejection of this detritus onto the mound requires a high magnitude avalanche event. Therefore, it is possible that detrital wood scattered over the avalanche mound contains a record of both low and high-frequency avalanche events.

The purpose of this study was to expand the dendrochronological techniques used to study avalanche events by incorporating detrital as well as living trees in the analyses. We hypothesized that a record of past avalanche activity exists in detrital wood, and that detrital wood obtained from the vicinity of avalanche mounds could be used to determine the frequency of high magnitude avalanche events.

STUDY AREA

Upper Burstall Lake (Peter Lougheed Provincial Park, Alberta, Canada) is the site of a well developed avalanche plunge pool/mound complex (Figures 1 and 2). The avalanche track is located below the south face of an unnamed mountain summit (2560 m a.s.l.) on the north shore of Upper Burstall Lake. The avalanche track is 580 m in length with a gradient between 27 and 36 degrees; the associated plunge pool is nearly circular, with a maximum depth close to 9 meters. The pool is flanked by a prominent, crescent-shaped mound with a steep proximal rim. The top of the mound extends 8 to 9 meters above the pool surface. Logs and fragments of wood are scattered over the top and sides of the mound and on the surface of the pool.

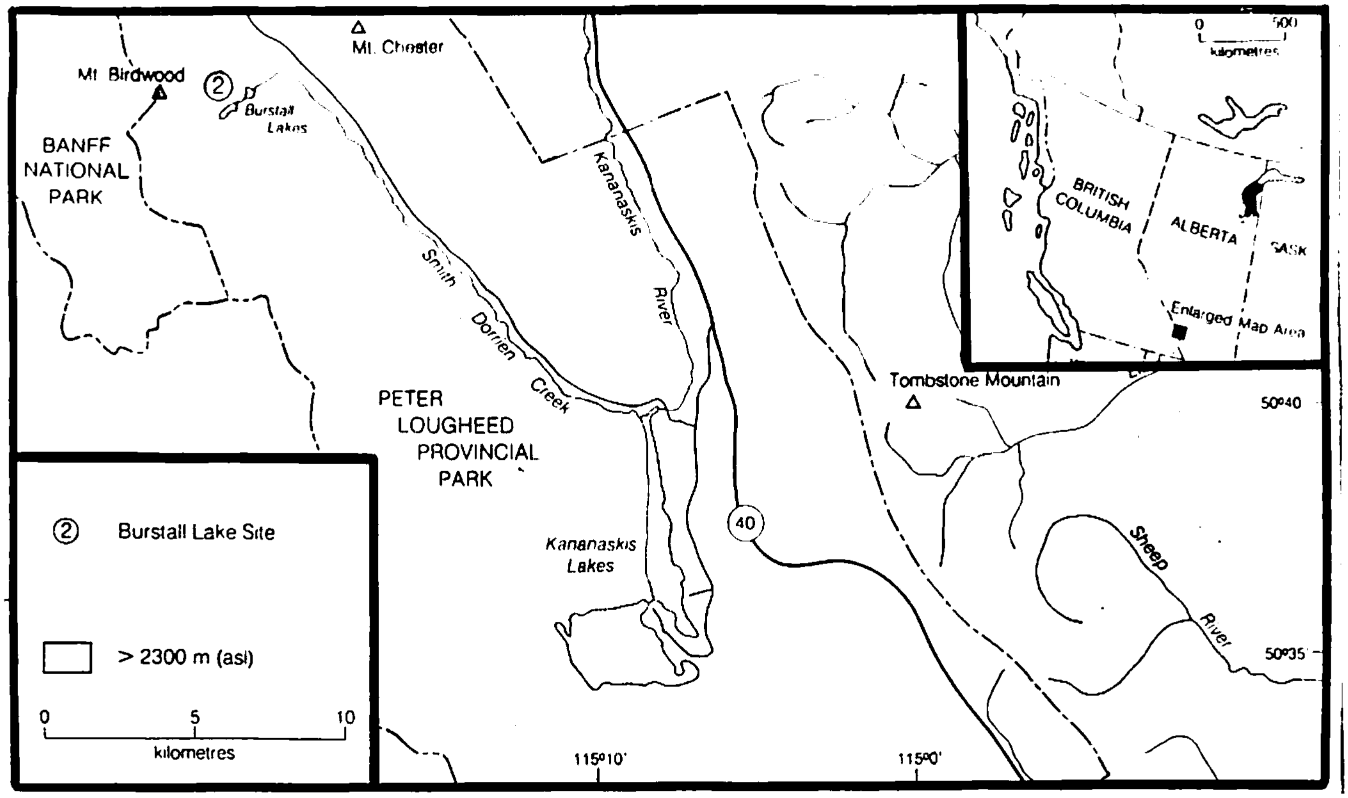

Figure 1. Location of Burstall Lake avalanche plunge pool site.

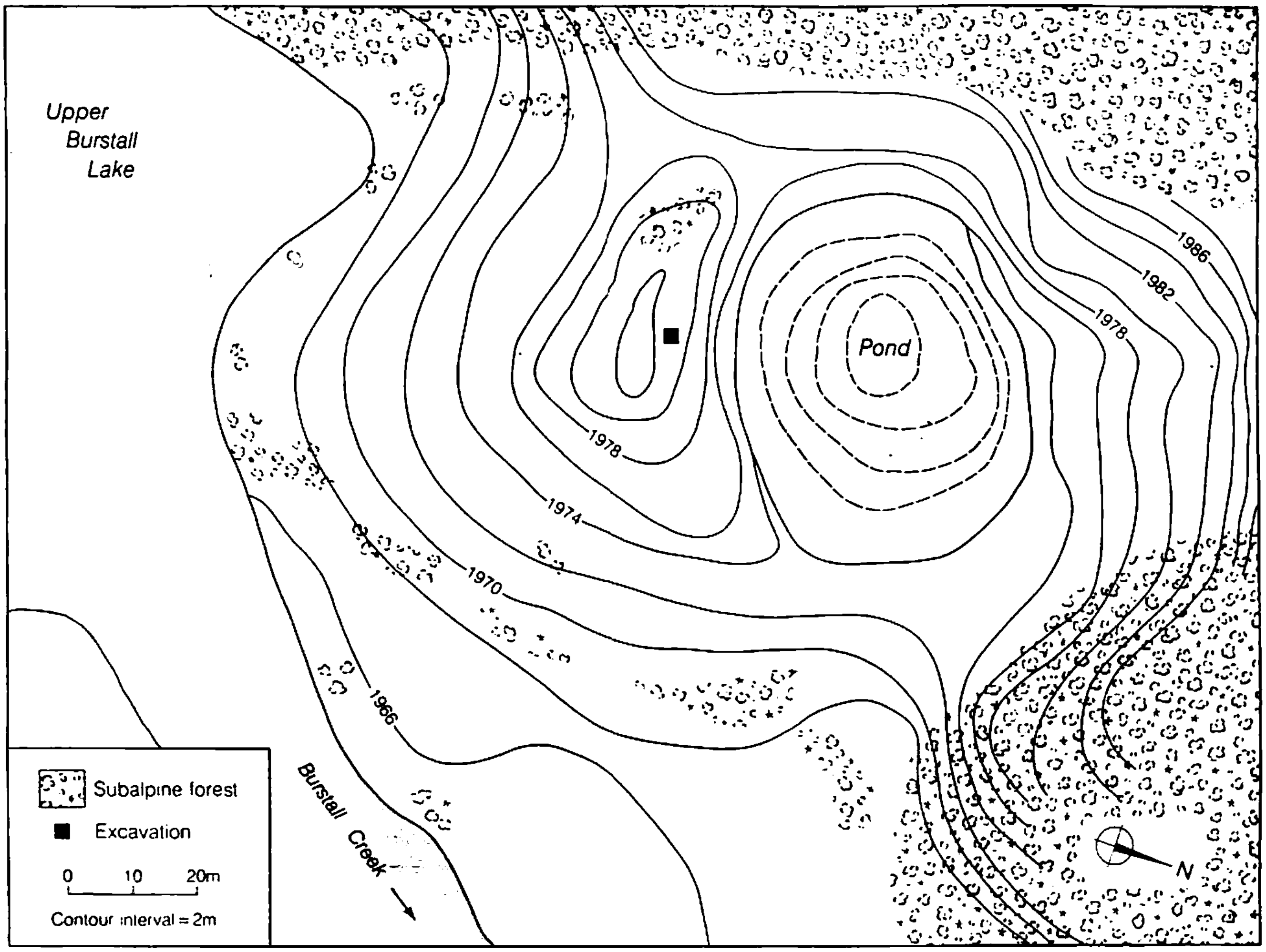

Figure 2. Topographic map of Burstall Lake site. Elevation datum is approximate.

METHODS

In July 1995, 60 increment cores were obtained from 30 living Engelmann spruce (*Picea engelmannii*) adjacent to the avalanche track. Five increment cores and 23 disks were collected from detrital logs on and in the immediate vicinity of the avalanche mound. Both the cores and disks were sanded with progressively finer sandpaper (80, 240, 320, 400, and 600 grade).

Cores from the live trees were cross-dated and their ring-widths measured using a Velmex measuring system with an accuracy of 0.001 mm. COFECHA, a quality control and dating check computer program was used to determine the correlation between each core and all other cores in the series. ARSTAN, a detrending program, was used to produce a site master chronology from the series of individual cores.

Annual rings on cores and disks from detrital wood were counted, cross-dated, and measured. COFECHA was used to compare ring patterns in detrital wood with the site master chronology to determine the time period recorded in individual pieces of detrital wood. Years containing compression wood were identified and used to derive probable dates of avalanche events.

RESULTS

The master chronology, developed for cross-dating purposes, covers the period between 1610 and 1994 (Figure 3). Eleven trees were used to derive this chronology. The series intercorrelation was 0.715 and the average mean sensitivity was 0.201 (Table 1). As Figure 3 illustrates, there appears to be 40 to 50 year cyclicity within the chronology. Intervals of lower than average growth occurred from about 1630 to

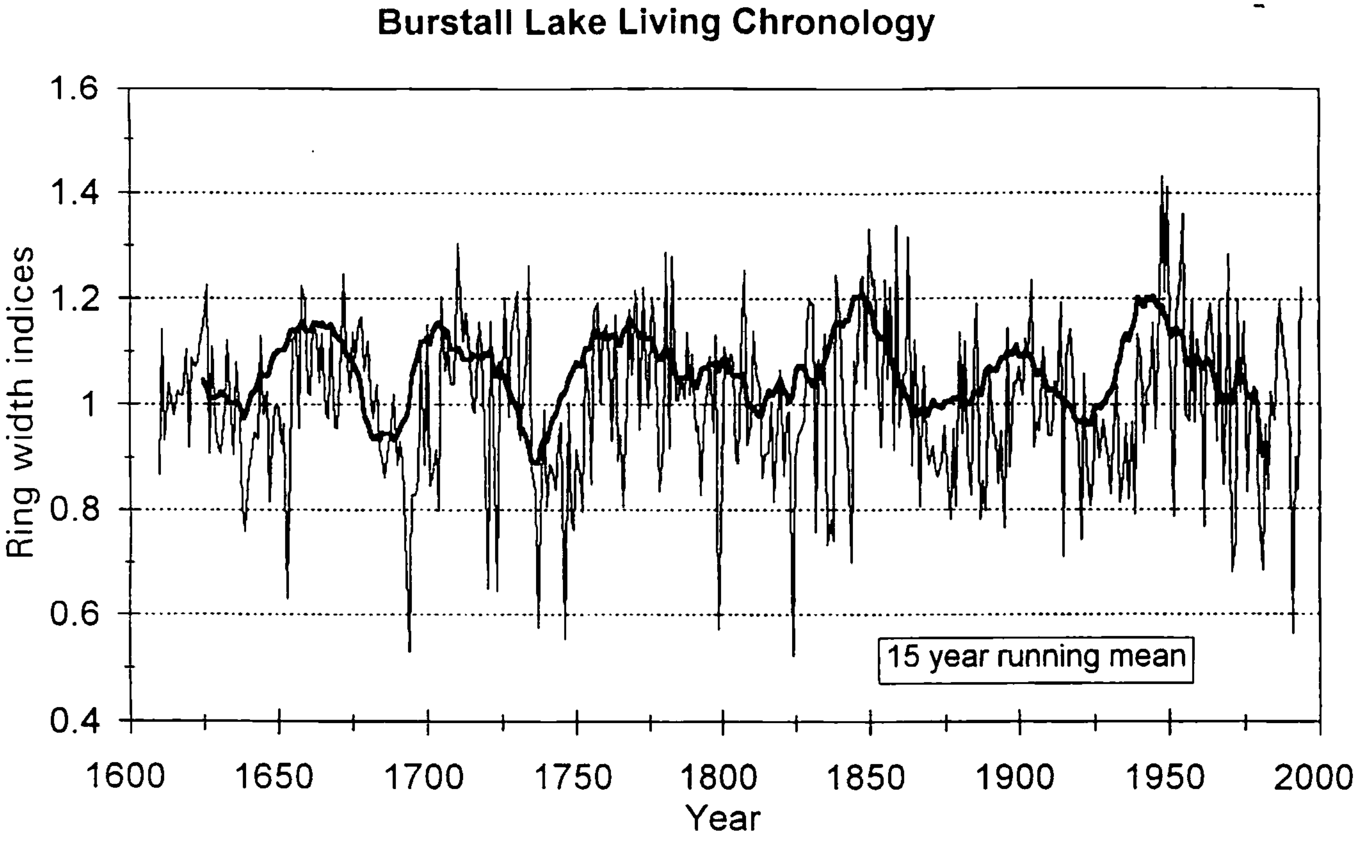

Figure 3. Standardized ARSTAN chronology constructed from living trees at the study site.

1650, 1680 to 1700, 1730 to 1750, 1810 to 1830, 1870 to 1890, 1920 to 1940, and 1980 through the present. Intervals of greater than average growth occurred from about 1710 to 1730, 1770 to 1780, 1840 to 1860, and 1950 to 1970.

Table 1. Descriptive statistics from the master chronology for *Picea engelmannii* from the Lake Burstall avalanche site.

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                                               Corr   //-------- Unfiltered --------\\ //---- Filtered -----\\
                        No.    No.    No.      with   Mean    Max     Std   Auto   Mean    Max    Std   Auto
Seq Series   Interval   Years  Segmt  Flags   Master  msmt   msmt    dev   corr   sens  value    dev   corr
--- -------- ---------  -----  -----  -----   ------ -----  -----  -----  -----  -----  -----  -----  -----
  1 12B      1759 1994    236      9      0    .527   9.80  17.18  2.719   .819   .126   2.02   .323   .005
  2 17A      1659 1994    336     13      0    .760    .48    .74   .110   .378   .208   1.82   .277  -.003
  3 12A      1707 1986    280     11      0    .626    .71   1.27   .153   .727   .133   1.91   .305   .002
  4 17B      1695 1994    300     12      0    .773    .65   1.08   .164   .595   .187   1.85   .277  -.025
  5 19A      1670 1994    325     13      1    .756    .35   1.20   .185   .825   .250   2.02   .284  -.020
  6 19B      1651 1728     78      3      0    .755    .54    .90   .158   .711   .190   1.92   .342   .040
  7 19C      1750 1994    245      9      0    .710    .46   1.07   .150   .585   .231   1.99   .294  -.019
  8 26B      1700 1994    295     11      0    .773    .44    .78   .110   .309   .245   1.84   .277  -.013
  9 24B      1706 1897    192      7      0    .755  12.25  21.79  3.892   .729   .181   1.87   .267  -.021
 10 24C      1910 1994     85      3      0    .771  10.55  15.66  2.439   .418   .191   1.87   .395   .008
 11 26A      1650 1994    345     13      0    .629    .44   1.05   .183   .822   .220   1.89   .259  -.008
 12 30A      1719 1894    176      7      0    .692    .66   1.11   .172   .691   .164   1.89   .309  -.033
 13 30A'     1921 1994     74      3      0    .629    .62   1.07   .180   .646   .205   1.83   .378  -.014
 14 30B      1708 1994    287     11      0    .636    .79   1.79   .288   .821   .170   1.86   .224  -.046
 15 13B      1610 1994    385     15      0    .721    .62   1.50   .290   .878   .199   1.85   .266  -.004
 16 BL29A    1650 1954    305     12      0    .733    .50   1.16   .168   .635   .234   1.99   .296  -.009
 17 BL15B    1650 1899    250      9      0    .776    .35    .67   .131   .850   .176   1.79   .250  -.005
 18 BL15C    1921 1994     74      3      0    .721    .43    .68   .105   .743   .140   1.94   .325  -.042
 19 4B       1620 1993    374     15      0    .704    .36   1.17   .248   .927   .230   1.97   .256   .013
 20 16A      1740 1899    160      6      0    .797    .63   1.43   .246   .838   .191   1.93   .269  -.015
 21 16C      1921 1994     74      3      0    .702    .21    .33   .046  -.010   .249   1.81   .311  -.017
 22 BL24A    1700 1994    295     11      0    .787    .75   1.63   .229   .597   .208   1.98   .284  -.021
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Total or mean:           5171    199      1    .715   1.55  21.79   .476   .692   .201   2.02   .282  -.011
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Table 2 shows pointer years having significantly narrower rings. Particularly noteworthy were the years 1653, 1694, 1799, and 1824. Additionally, the years 1899 and 1907 contained virtually no latewood.

Only 16 pieces of detrital wood were successfully cross-dated with the living master chronology. Table 3 displays, correlation with the master chronology, the time span covered by each piece of cross-dated detrital wood, avalanche dates derived from initiation dates of compression wood formation, and minimum age of tree mortality derived from the outer ring date.

Table 2. Negative pointer years used in crossdating. Asterisks indicate years with extremely narrow growth rings.

1600's	1700's	1800's	1900's
1653*	1704	1824	1915
1694	1723	1844*	1952
1737	1971	1799*	1991

Figure 4 shows avalanche frequency and tree mortality by decade. The pattern of decadal avalanche frequency is irregular over the dated period. There is a noticeable absence of events from 1840 - 1870. Both avalanche frequency and mortality were greatest between 1950 - 1970.

DISCUSSION

Detrital wood can be successfully cross-dated to determine past avalanche activity. Nevertheless, there are certain limitations in using detrital wood to extend avalanche chronologies beyond those using living trees. At this site, the oldest detrital wood sample that could be successfully cross-dated with the living chronology was killed approximately 100 years ago. In many instances, the exact dates of mortality

Table 3. Descriptions of detritus wood samples.

Sample Number	Age Range	Pith	Bark	Dated Event	Correlation With Master
SBF1	1811-1955	yes	no	1817,1821,1825,1834	0.536
SBF2	1798-1980	no	no		0.794
SBF3	1736-1893	yes	no		0.616
SBF4	1914-1963	no	no		0.350
SBF6	1810-1934	no	no		0.387
SBF9	1785-1955	yes	yes		0.485
SBF10	1822-1969	yes	no	1830,1839,1876,1880,1885, 1891,1911,1913, 1958,1961 1967	0.376
SBF11	1833-1955	no	no		0.374
SBF12	1808-1955	no	no		0.680
SBF15	1670-1879	no	no		0.706
SBF31A	1720-1912	yes	yes		0.480
SBF32A	1756-1888	yes	no		0.602
SBF33A	1858-1958	no	no		0.722
SBF34B	1610-1882	no	no		0.566
SBF35A	1665-1877	no	no		0.640
T2A	1950-1995	yes	yes	1951,1955,1958,1961,1964 1967,1970,1974,1982,1990	NA

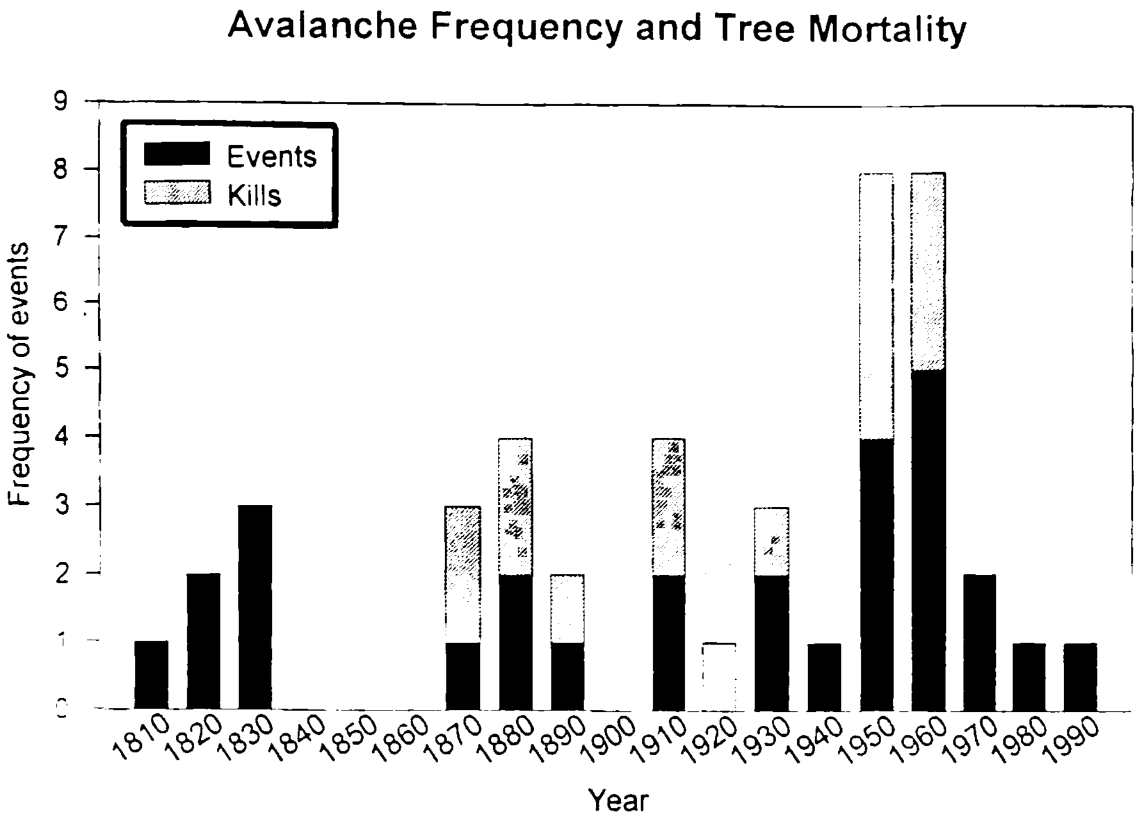

Figure 4: Decadal avalanche frequency and tree mortality.

could not be determined because outer rings had been lost to decay or abrasion. Definitive mortality dates could only be determined for samples on which bark was retained. Most detrital wood at our site lacked bark; the oldest piece of detrital wood for which a definitive mortality date could be determined died in 1912. Thus, variable surface decay rates limit the usefulness of detrital wood in extending avalanche chronologies.

Mortality of detrital material does not always correspond to avalanche events. Fire, insects, and pathogens also take their toll. Some of the woody debris from these disturbances may be incorporated into the detritus swept downslope by avalanches.

The living master chronology with which we cross-dated detrital wood was derived using Engelmann spruce. Detrital material collected at the site included both spruce and subalpine fir. Of 23 disks collected, 14 were subsequently identified as subalpine fir (60%) and could not be cross-dated with the living master chronology. Unless the species of sampled detrital wood can be accurately identified in the field, large samples may be necessary to insure an adequate number of samples that can be successfully cross-dated.

As trees age and grow, they exhibit changes in their response to and recording of avalanche events. Small trees are frequently bent or distorted and contain a structural record of past avalanche activity. Larger, mature trees are more likely to remain upright, but are very susceptible to mechanical damage from rocks and logs swept downslope. Very old trees that may have survived past avalanches, but whose wounds allowed stem pathogens to invade, may become increasingly susceptible to avalanche-induced mortality.

There is a general lack of correspondence between mortality dates and avalanche occurrence assumed from the initiation dates of compression wood formation in detrital wood. Despite this lack of correspondence, we did identify suspected historical high magnitude avalanche events. One such event likely occurred in 1955. Evidence for this occurs in 50% of our detrital samples, in the form of both compression wood formation and tree mortality.

We examined historical climatological data from Banff in an attempt to identify correspondence with derived dates of avalanche occurrence. In most instances no obvious empirical correlations were apparent, except perhaps in the case of extremely high snowfall in December, 1933. This high snowfall may correspond to an avalanche event recorded in 1934 in the growth record of a single tree.

CONCLUSIONS

Our research at this site suggests that detrital wood can be successfully used to extend snow avalanche chronologies beyond that recorded within living trees. Sample integrity, species-specific growth patterns, and age-dependent relationships with respect to the way an individual tree records avalanche events within the cambium will require careful consideration when detrital wood is used to extend avalanche chronologies.

Our data provides limited insight into magnitude/frequency relationships for snow avalanche events. While there is some suggestion of high magnitude events within the record of detrital wood, our sample size was not adequate to infer the occurrence of catastrophic avalanche events.

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