Bruce Jamieson, Pascal Haegeli and Dave Gauthier
Foreword by Justin Trudeau

Avalanche
Accidents in Canada

canadianavalancheassociation

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Avalanche Accidents in Canada

Volume 5 1996-2007

Bruce Jamieson, Pascal Haegeli and Dave Gauthier
Canadian Avalanche Association

Foreword

Justin Trudeau

Those of us who are privileged to be a part of the Canadian avalanche community are united by our love for the magnificent mountain wilderness in which we live, work and play. But so too must we be bound together by our losses: almost all of us have had friends, family or colleagues taken from us by the snows and the steeps.

The honest truth is that I was never supposed to be a part of this community. Left to my own path, I would have been more about plowing through whitewater than swimming through powder, more likely to have chosen crampons over skins, more often across a frozen lake on snowshoes than atop a windswept ridge on touring skis. My brother Michel was the backcountry Trudeau; his was to be a life in and of the mountains: skiing, guiding, exploring, discovering and sharing the immensity of the western Canadian backyard.

But on a suddenly mild mid-November afternoon in 1998, we lost him to a small slide that knocked him into Kokanee Lake. And in my search for solace, understanding, and that oh-so-elusive silver lining, Michi drew me into this world that was his. I will be forever grateful to the wonderful new friends who received me and taught me to know, respect and love the alpine ranges that were my little brother's passion.

The information in these case histories will certainly be a valuable tool for all who seek to understand the risk that is an integral element of our mountain wilderness, by compiling and sharing over a decade's worth of event reports and weather data. But even as we learn from the hard facts of the various cases, we cannot help but be mindful that almost every page represents lives altered or lost, and that these stories are at their essence an attempt to draw some small benefits from personal tragedies.

For the ultimate goal of this book, and, really, of all of us who make up the Canadian avalanche community, is to make sure that as more and more Canadians discover every year the joy and beauty of our backcountry wilderness, we are all increasingly united in our love for these mountains and not by our losses within them.

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For financial support and unwavering commitment to this book, we are very grateful to the Canadian Avalanche Association (CAA) and Canadian Avalanche Centre (CAC) as well as the Executive Directors of the CAA and CAC during this project, Clair Israelson and Ian Tomm.

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Chapter 1

Introduction

Learning from avalanche accidents

As Jill Fredston has said, "Avalanche accidents don't change, only the names change." So why write a book about avalanche accidents, especially one without the names? While there is an eerie truth about the statement, there are reasons why the Canadian Avalanche Association and the Canadian Avalanche Centre wanted this book to be published and why we wanted to write it.

First, avalanche terrain is an unforgiving learning environment, a place where gathering meaningful experience is often risky. In such learning environments, reflection is important (Hogarth, 2001, p. 217). To promote reflection and hence learning without exposure to avalanche terrain, we summarized key information about the 105 fatal avalanche accidents from the winters of 1997 through 2007 (*Figure 1.1*). Much of the important information was not available to the public. It was in coroners' judgements, investigators' reports, worn field books, yellowed profiles at the back of filing cabinets, and a mix of 35mm slides and digital photos that were becoming hard to find. If the situations, terrain and snowpack descriptions in some of the individual case histories seem familiar ("That is like the day when Ryan and I ..."), they are opportunities to learn.

Second, there are trends and patterns in these accidents that may not be obvious from reading the individual case histories. We hope the graphs, tables and analysis in Chapter 3 identify patterns from which we can all learn. For example, in 92% of the recreational accidents (with a reported trigger), the fatal avalanche were triggered by people. Also, 82% of the fatal avalanche accidents occurred when the regional avalanche danger rating was Considerable or higher.

Third, different winters have different snowpack and avalanche characteristics, which require different strategies for avoiding avalanches. For example, winters with a heavy snowfall have fewer recreational avalanche fatalities but more large natural avalanches threatening highways and sometimes mining and forestry operations. Winters with a shallow snowpack—especially the early winter snowpack—usually have a higher number of persistent weak layers and consequently a higher number of human-triggered avalanches and recreational avalanche fatalities. Achieving low recreational risk in such winters may require forgoing certain appealing avalanche terrain weekend after weekend, and sometimes month after month.

Since the interpretation of individual avalanche accidents benefits from the context of the snowpack development, in Chapters 4 to 14 we precede the case histories in southwestern Canada from each winter with an outline of the winter's weather as well as its effect on the snowpack and the formation of persistent weak layers. The accidents outside southwestern Canada are too few and too widespread to justify the snowpack-from-

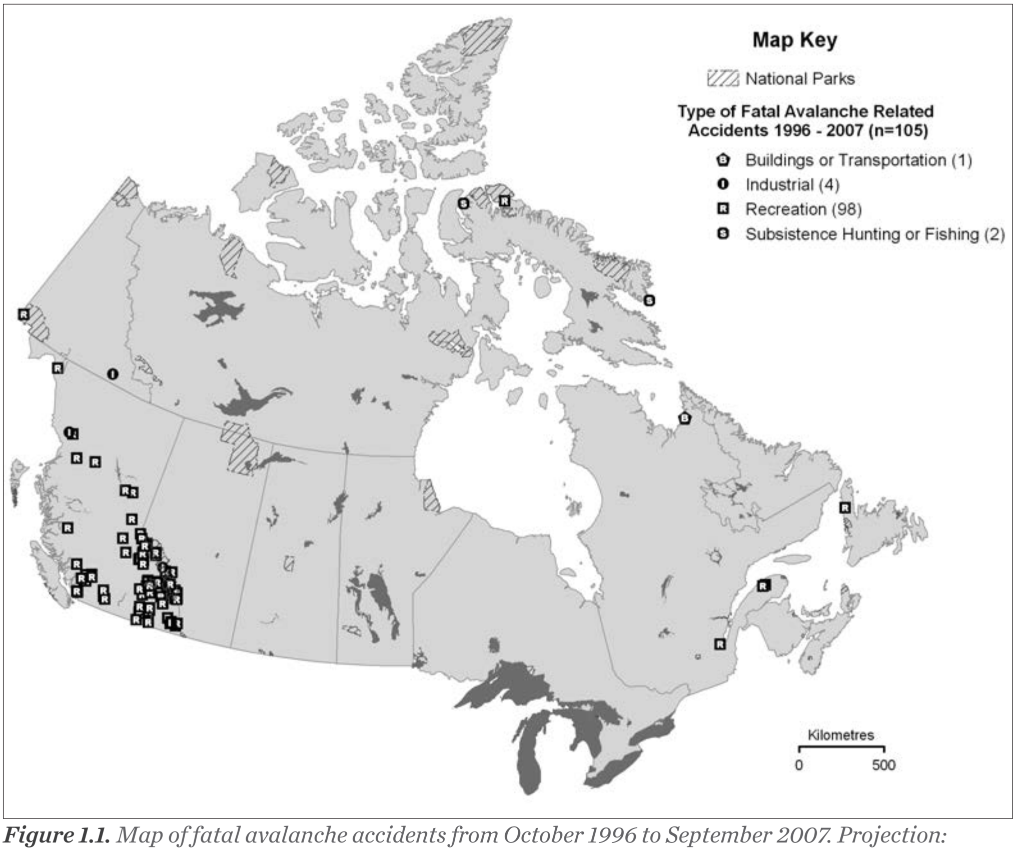

Figure 1.1. *Map of fatal avalanche accidents from October 1996 to September 2007. Projection: Canada Albers Equal Area Conic. Cartography by Smart Map Services. Smartmap@shaw.ca*

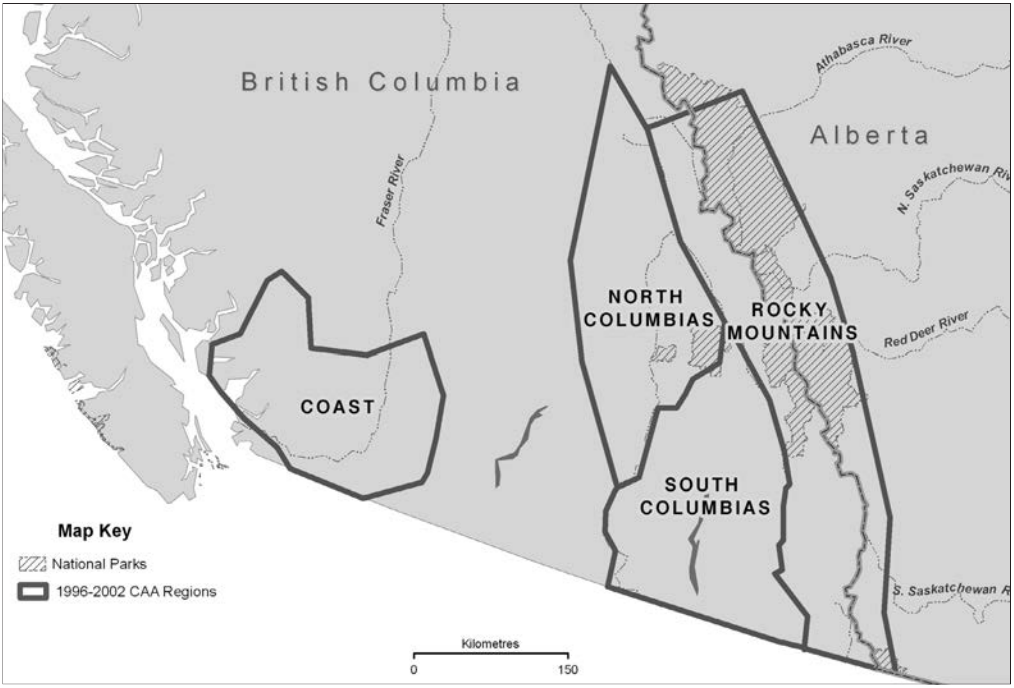

Figure 1.2. Map of the regions for the avalanche bulletins of the Canadian Avalanche Association from 1996 to 2002. Some of these regions overlapped with the national parks, which were also producing avalanche bulletins. Projection: Canada Albers Equal Area Conic. Cartography by Smart Map Services. Smartmap@shaw.ca

weather approach and are presented chronologically in Chapter 15.

Fourth, Canada is losing too many young people to avalanches. Seventy percent of the avalanche victims covered in this book were in their thirties or younger. Therefore, we wanted to write a book that would sell in the mountain shops and be read by recreationists. We hope the photos and sketches of terrain, as well as the "dashboard" at the top of each summary and the Warning Signs at the bottom, will catch the attention of modern readers and draw them into the narratives.

Fifth, we wanted to present the case histories along with modern awareness tools for recreationists such as the regional avalanche bulletin, the Avalanche Terrain Exposure Scale (ATES; Statham et al., 2006), and the Avaluator's Warning Signs (Haegeli, 2010). While ATES and the Avaluator were not developed until after the tragic winter of 2003, the ratings are presented to help readers assess their value. Further, the regional bulletins have improved greatly since the period covered by the previous volume of *Avalanche Accidents in Canada*. The forecast regions now include part of the Gaspé peninsula as well as some new and smaller regions in western Canada. Also, the bulletins are more frequent, icons are being used by more forecast centres, and the bulletins are readily available on the internet and increasingly on smart phones.

In 1996 the Canadian Avalanche Association had one forecast region for the east and west slopes of the Rocky Mountains, outside and inside the Rocky Mountain National Parks. This region extended from north of Jasper townsite, south to the US border (*Figure 1.2*). After the winter of 2002, a South Rockies region was introduced, extending south of Banff National Park and Kananaskis Country to the US border (*Figure 1.3*). This explicitly excluded the Rocky Mountain National Parks and Kananaskis Country but also excluded areas east and west of the parks where observations were too sparse for confident forecasting. Such changes have increased the accuracy of bulletins. In this book, we used the latest avalanche bulletin available to people departing on the morning of the accident, ratehr than bulletins issued later in the day.

The Avaluator and its warning signs

For each accident summary, we have used the Warning Signs from the Avaluator 2.0 (Haegeli, 2010). Although the Avaluator was not available during most of the years covered by this book, the Warning Signs provide a snap shot of the overall weather, snowpack, avalanche and terrain factors present (although often not causal) in each accident.

The Avaluator was designed to provide recreationists with a systematic approach to decision making in avalanche terrain. This information can help them to avoid the most serious conditions that have injured and killed recreationists in the past. The Avaluator is now a core component of the Avalanche Skills Training (AST1) curriculum and the graduates of these courses are the primary users of the Avaluator. Since the majority of recreationists who take AST1 courses typically only spend one to 10 days in avalanche terrain every winter (Haegeli and Haider, 2008), they have limited opportunities for making continuous observations and effectively developing decision expertise. This is in strong contrast to commercial guiding and government avalanche programs with extensive observation programs that monitor the weather, snow and avalanche conditions throughout the entire winter. As a

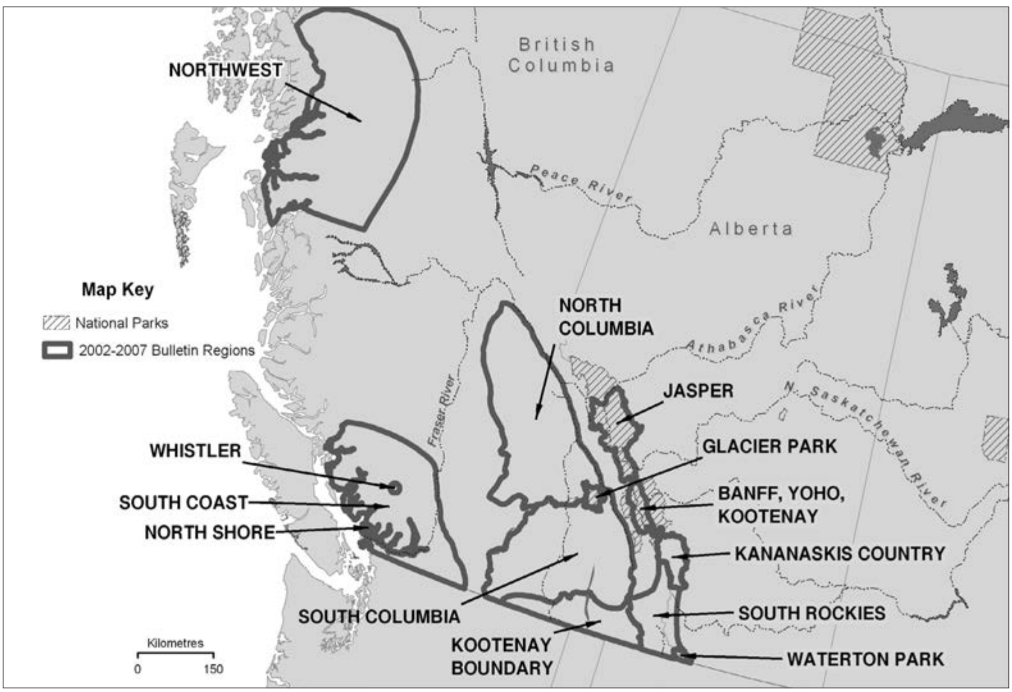

Figure 1.3. *Map of the regions for the avalanche bulletins of the Canadian Avalanche Association 2002-2004 and Canadian Avalanche Centre from 2004 to 2007. The Kootenay Boundary region was part of the South Columbia region until the summer of 2006. There was no overlap with the forecast regions for the national parks. The forecast region in the Gaspé Peninsula is not shown. Projection: Canada Albers Equal Area Conic. Cartography by Smart Map Services. Smartmap@shaw.ca*

Figure 1.4. *Avalanche investigators profile the snowpack at the crown fracture of a deep persistent slab avalanche after a fatal avalanche. Photo: Bruce Jamieson.*

Figure 1.5. *In addition to snow profiles, investigators make many observations including noting the snowpack distribution in the start zone. Photo: Chris Stethem.*

consequence, the basic use of the Avaluator takes a conservative approach, highlighting the most general indicators of increased avalanche hazard.

However, there are a lot of "it depends" when making decisions in avalanche terrain, and avalanche hazard can effectively be managed by making subtle but significant context-dependent choices at the right time. For example, consider the Avaluator Warning Sign for recent slab avalanche activity. It reads "Are there any signs of slab avalanches in the area from today or yesterday?" A team of ski guides or mountain safety employees for a park may have intentionally triggered a small wind slab on a north-facing slope. For the experienced team with many recorded observations over a large area and shared at daily safety meetings, the wind slab avalanche is not indicative of a deep slab problem, which may be critical for the day's decisions. However, being able to reliably recognize these differences and appropriately adjust backcountry terrain choices requires advanced training and extensive experience. Therefore, the Avaluator Warning Sign—developed for recreationists, most of whom go to a new area each day or weekend—interprets any sign of a slab avalanche as an indicator of increased avalanche hazard.

Readers will notice that for some accidents, one or more of the Warning Signs are shown as a "?". This indicates that the relevant observation remained unknown after we reviewed the available information. There are several reasons for this. In the early years covered by this book, the reports on avalanche accidents were much briefer than in later years, and when we contacted investigators and those present at fatal avalanches, we found memories of certain Warning Signs, such as previous slab avalanches or signs of instability, had faded.

Snow profiles and snowpacktests

With some of the accident summaries, we have included a profile of snowpack layers, usually observed near the crown or flank of the fatal slab avalanche (*Figure 1.4 and 1.5*). Since there are specialized symbols and jargon used in snow profiles, Appendix D introduces some key terminology and ideas for interpreting the snow profiles. Often, rather than reproducing a snow profile, we have described some key results from one or more snow profiles in words.

Snowpack tests such as the rutschblock test, shovel test or compression test (CAA, 2007, p. 32-41) are often observed along with the profiles at fracture lines. For quite a few of the accidents, we have described the results of these snowpack tests. The results often vary between adjacent tests in the same pit or in different pits along a fracture line. Much of the variability in the results of snowpack tests is due to variability in snow stability on the slope, and should consequently limit our confidence in any point observation of the snowpack (e.g. Haegeli and McClung, 2004; Campbell and Jamieson, 2007; Schweizer et al., 2006).

Terrain ratings

With most of the case histories, we have included a rating according to the Avalanche Terrain Exposure Scale (Statham et al., 2006; search for "avalanche terrain ratings" on www.pc.gc.ca). Like the Avaluator Warning Signs, this awareness scheme was developed for recreationists. While it was first developed for major routes, we have applied it to the slopes on which the fatal avalanches occurred.

Importance of reporting avalanches

This book and the growing database of avalanche accidents, as well as the many programs intended to help reduce the rate of avalanche accidents, rely on avalanches being reported—especially those that are triggered by or catch people. This important task is now easier due to the online reporting on the avalanche.ca website. The next volume of *Avalanche Accidents in Canada* and the Canadian Avalanche Centre's database of avalanche incidents will benefit from your reports of avalanches that involve people.

Avalanche risk

Avalanche risk is a combination of the probability of being caught and the likely consequences. Those who travel in the mountains often deal with the insidious combination of low probability and high consequence. A wide "margin of safety" helps, but some level of avalanche risk always remains when travelling on or below most snowy slopes. Where available, the regional avalanche danger is excellent baseline information for recreationists; nevertheless, avalanches on individual slopes are not predictable (Schweizer, 2008).

Reflection

Many of the elements in these individual accidents resonate with us, as people who enjoy winter mountain travel, and we expect they will with readers. Occasionally we felt our observations and actions while recreating and working in avalanche terrain have had similarities to those who were caught in and did not survive avalanches. Although we intentionally removed our emotions from the case histories, again and again while writing this book we were touched by the loss of lives, sometimes feeling, "I could have been there."

Certainly, as Jill Fredston predicted, the avalanche accidents in this volume have similarities to those in previous volumes. Just as certainly, learning vicariously from the accidents in this book is better than being caught in avalanches.

Chapter 2

First Person Account

By Rick Tams, with help from Dave Ure

On 22 April 2007, I arranged to take my Dad on a one-day snowmobiling trip into the Forester area near Radium, BC. He's 71 and also an avid rider, but hadn't been out riding at all that winter. My cousin and his 17-year-old son came with us as well. The trip from Innisfail, AB to Radium was uneventful, and we were unloaded and on the trail by late morning. We rode up to the cabin at Forester, where we stopped and ate lunch. At noon, the air temperature was about 9°C. It was a bit overcast that morning, so when we saw the sun poking out on an adjacent mountainside, we proceeded in that direction. As we rode into the area, we came across a small, safe-looking bowl, which I immediately began to ascend.

It was not a particularly difficult climb and I knew that I had been on much more challenging and intimidating slopes in the past. About half way up the bowl, just as I was about to turn around, I noticed something strange closer to the top. It was hard to detect at first, but then I saw a large crack form and I realized that an avalanche was happening. My first thought was to look for snow coming down toward me from higher up the bowl,

Figure 2.1. *"The slab of snow that broke free was about 300m wide, and I was about 100 to 150m from the top of it." Photo: Alan Harder*

but I quickly figured out that the snow I was on was moving—I was in the middle of a large slab avalanche!

The slab of snow that broke free was about 300m wide, and I was about 100 to 150m from the top of it. When something like this happens, there isn't a lot of time to analyze the situation and choose a game plan. I was still pointed up the hill and moving forward so I decided that my best choice was to try and climb up and over the top of the fracture to safety. I pinned my machine, which at first enabled a very smooth and rapid climb towards the edge of the broken slab. I kept thinking, "C'mon, I can make this," but the angled sheet of smooth white powder was turning into a fast, churning river of snow. The forward momentum I had achieved was being erased by the speed of the avalanche moving down the bowl. Although the snowmobile was wide open with all of the available track speed at my disposal, it started to feel like I wasn't getting much closer to the top.

At about that point, I hit a ridge of snow that was created by the shifting slab, and it turned me slightly to the left. I was using all of my years of experience and skill to get me out of this situation but the speed and power of the avalanche had become much more than I could even begin to control. The slight shift in direction had allowed me to gain some forward momentum with my machine, which was still pinned wide open. Afterward, those who witnessed the incident would tell me that I likely hit 80 km/h , but at the same time the avalanche was carrying me, and the snow I was on, straight down the hill at about the same speed.

I made it to within 10m of the edge of the slide and I really thought I would succeed in my plan to climb to safety. However, as the avalanche continued to take everything, including me, downhill at a very rapid rate, my machine struck a large boulder on the downhill side. Although it felt like I was making progress, the flow of the avalanche was still pushing everything down the side of the mountain and moving over top of whatever was underneath it, including that large protruding rock. The impact catapulted me off my machine and into the air about 10m.

As soon as I landed and hit the snow, I felt myself being buried while still being carried down the hill. Just as quickly as I was covered by the moving snow, I popped up on top of the avalanche, carried head first down the hill. My machine had been launched in the same direction after striking the boulder, and it caught up to me and struck the back of my legs. That impact drove my feet and legs deeper down into the snow causing my body to slow just enough to be buried again. Just as the avalanche seemed to stop, my head again emerged from the snow, and the words rang in my mind, "Thank God, I've survived."

But seconds later, one last rush of snow from above hit the back of my helmet like a ton of bricks and buried me completely one last time. My final resting spot was face down on my stomach with my body inclined towards the bottom of the hill. I was entombed in very wet and heavy snow and I remember checking to see if I had space to breathe in and out, which I did. Looking up through the opening in my helmet, I could see daylight penetrating through the layers of snow on top of me, which made me think that I wasn't buried very deeply. My first instinct was to try and simply push myself up. I remember feeling shocked when I couldn't move even just a

Figure 2.2. *"People had to take turns shovelling as they became tired quickly from digging in the heavy snow. They cleared the area around my helmet and noticed that my face was purple and that I was not breathing." Photo: Alan Harder*

Figure 2.3. *"I was unable (or perhaps just unwilling) to move from my recovery position, so I was carried over to a nearby machine where I sat to try to gain my composure. It took another hour of tireless effort by the rescuers to dig out my sled." Photo: Alan Harder*

little, so I tried again, and nothing. I concentrated and put all of my strength into trying to dislodge myself, and again, nothing. The reality started to sink in that I would never get myself out. There was no snow inside my helmet so I told myself that I should have enough oxygen to breathe, and then I started thinking of what else I had going for me. I had my beacon on, I had air, I didn't feel badly injured, and I figured I must be fairly close to the bottom of the hill and near the surface of the deposit.

I also thought the other three people in my own party would have witnessed what had happened and that they would quickly be using their own beacons to find me and dig me out. Who knows, maybe my sled or part of my body may even be visible on the surface of the snow to help mark my location. Although I knew my situation was not great, I felt confident that within a few minutes I would hear people overhead with probes and shovels moving the solid mass of snow around me. I relaxed and calmed myself the best that I could to try to save my air and my energy. I believe I lost consciousness a couple of minutes after that. Being in this calm and relaxed frame of mind was the last thing I remember until I heard people trying to revive me some time later.

There were two other snowmobilers sitting on top of a nearby ridge who witnessed the avalanche, and another six who were heading out of the area but happened to see the slide. They all came to help search for me. Luckily, everyone who responded to the avalanche was an experienced rider carrying a beacon, probe and shovel and had some knowledge of what to do. There was only one problem with the search: one of the rescuers had not switched their beacon from transmit to search mode, which resulted in them digging a trench in the wrong place while trying to locate me. Looking back, everyone agreed the extra time spent on this could have had serious consequences for me. Once all the beacons were in search mode, they were able to zero in on my signal and locate my approximate location and within a short time had hit my helmet with their shovels.

People had to take turns shovelling as they became tired quickly from digging in the heavy snow. They cleared the area around my helmet and noticed my face was purple and I was not breathing. They continued to dig down to my waist. Five large men tried to pull me to the surface, but could not even budge me. The snow had set up as hard as cement. They dug down deeper to my knees and this time were able to remove me and place me on the surface of the slide. They laid me on my back and one of the responders performed CPR. From the heroic efforts of these brave men I started breathing on my own, although I did not become fully conscious for another 8 – 10 minutes. When I finally came around I experienced the worst headache I have ever had in my life, I was sick to my stomach and my mouth was extremely dry.

I was unable (or perhaps just unwilling) to move from my recovery position, so I was carried over to a nearby machine where I sat to try to gain my composure. It took another hour of tireless effort by the rescuers—all while exposed to any more avalanches that might come down—to dig out my sled. Incredibly enough, it was in running condition and although I still felt very sick, I concluded that I would be better off riding my own machine out where I could control the pace, rather than riding behind someone else. That trip back to the trucks felt like the longest ride of my life, but two and a half hours later, I made it back out, very thankful to be alive. By the time we got back into Radium, it had been six or seven hours since it all began. With every hour that passed, I felt better and better, to the point that we decided just to drive directly home to Innisfail from Radium. My wife took me to the hospital when I got there, and after many tests, severe headaches, and total discomfort everywhere on my body for the next few days, I began to feel better. A few weeks later, I was recovered completely.

Looking back now I am amazed at how quickly everything happened and how vulnerable and powerless I felt while that wall of snow tossed me around. I also find it hard to believe just how quickly and easily I lost consciousness. I can assure you that many of my own personal paradigms shifted that day. You can also understand my gratitude to the group of individuals who unselfishly risked their own safety to come and rescue me. Without them, I wouldn't be here today. Yet, as their own worst critics, they were reminded afterward of how important time is in these situations; of how important it is for someone to assume control and start directing work and taking leadership responsibilities; of how important it is for people to work together in a unified fashion to search and rescue effectively. To me, they will always be true heroes, and will always be the ones that accepted responsibility to act once I found myself in a situation where I was unable.

I thought we were avalanche smart before my accident, but I realize now we knew very little. I look at everything in the mountains completely differently now. So what did I learn and what can I try to share with others, besides the fact that life is fragile? Well for one thing, become educated on the risks you face in the mountains. Everyone should take an avalanche course. Become very familiar with recognizing and responding to hazards, including the less obvious ones. Check the avalanche bulletin on the days preceding your trip. At the time of this accident, I didn't even know there was an avalanche bulletin!

NEVER ride alone. Learn and practice CPR. Make sure that EVERY person that rides with you carries a beacon, shovel and probe and knows how to use them. Take your beacons out into your yard and practice with them BEFORE you venture into mountainous areas. My hope is that others can learn from my experience and never have to go through what I did.

I would really like to thank everyone who risked their lives to save mine:

- Alan Harder and Duane Hildebrand of Strathmore AB
- Dan Fox of Nanton AB
- Dwayne Howatt of Calgary AB
- Todd Amlin and Reece Webster of High River AB
- Jon Creason and Kirt Laing of Airdrie AB
- Greg and Aaron Quesseth of Innisfail AB
- And my Dad, Mel Tams, also from Innisfail AB

Chapter 3

Trends and Patterns
Fatal Avalanche Accidents
Winters 1997 – 2007

According to the historical records of the Canadian Avalanche Centre, at least 766 people have perished in avalanches in Canada. The earliest known avalanche accident in Canada occurred in an Inuit settlement near Nain, Labrador, during the winter of 1782 and resulted in 22 fatalities (Liverman, 2007). While avalanche accidents in the past primarily happened to people living in, working in, or travelling on roads or railways through avalanche terrain, the majority of today's avalanche accidents occur during recreational pursuits. Since 1970, a total of 445 individuals have lost their lives in 295 different avalanche accidents in Canada. During this time period, 92% of all fatal accidents and 90% of all avalanche fatalities involved recreationists. However, non-recreational avalanche accidents do still occur and are often associated with multiple casualties.

The purpose of this chapter is to summarize the main characteristics of the fatal avalanche accidents that took place in Canada during the winters of 1997 to 2007 (between 1 October 1996 and 31 September 2007). After examining the overall trends, the discussion in this chapter will focus primarily on the examination of recreational avalanche accidents, which represent the vast majority of the accidents covered by this book. At the end of this chapter, we hope the reader has a better sense of what a typical recreational fatal avalanche accident in Canada looked like during the period covered in this book. The following lists provide brief summaries of the main results.

All fatal avalanche accidents from winters 1997 through 2007:

- A total of 155 individuals lost their lives in 105 different accidents.
- On average, there were 14.1 avalanche fatalities in 9.6 accidents per winter.
- 139 avalanche fatalities (90%) and 98 fatal avalanche accidents (93%) occurred during recreational pursuits.
- The deadliest avalanche accident occurred in **Kangiqsualujjuaq on 1 January 1999** (page 368), resulting in 9 fatalities and approximately 25 additional individuals injured.

Fatal recreational avalanche accidents from winters 1997 through 2007:

- On average, there were 12.6 avalanche fatalities in 8.9 recreational accidents per winter.
- The winter of 2003 was the most deadly recreational avalanche winter in Canadian history with 29 avalanche fatalities in 13 seperate accidents.
- Half of the fatal recreational avalanche accidents involved skiers and snowboarders; about a third involve snowmobilers.
- 76% of the fatal recreational avalanche accidents took place in British Columbia, 18% in Alberta.
- 40% of the fatal recreational avalanche accidents occurred in the Columbia Mountains and 38% in the Rocky Mountains. Only 10% were in the Coast Mountains and 2% in the Cascades.
- Only 55% of the accident parties were fully equipped with avalanche transceivers.
- 82% of the fatal avalanche accidents occurred when the regional avalanche danger rating was Considerable or higher.
- In a limited dataset with reliable avalanche activity data, two-thirds of the fatal accidents were preceded by recent slab avalanche activity.
- Based on our research, signs of unstable snow were present prior to the accident in 30% of the cases where this information was available.
- In fatal accident records with reliable precipitation and wind information, recent snowfall, drifting snow or rain contributed considerably to the existing avalanche hazard in 51% of the cases.
- Critical warming was observed prior to 25% of the fatal accidents, where this information was available.
- Among the accidents where detailed terrain information was available, 45% occurred on convex slopes and 17% of the slopes lacked toe support.
- 76% of the fatal recreational avalanche accidents occurred in complex avalanche terrain.
- Terrain traps were present in 73% of the fatal accidents.
- Three-quarters of the fatal accidents occurred on slopes facing northwest through north to southeast.
- 96% of the fatal accidents occurred in areas where the steepest sections of the slope or adjacent terrain were steeper than 30 degrees; in 72% of the accidents they were steeper than 35 degrees.
- 72% of the fatal recreational avalanche accidents were related to persistent snowpack weaknesses.
- The most common avalanche size was 3, enough snow to bury a car or sufficient force to destroy one.
- 92% of the avalanches were triggered by humans.
- The typical slab thickness was 75cm.
- 56% of fatal accidents had more than one person involved in the avalanche. On average fatal avalanche accidents typically involved two people. While one person was completely buried, the second person was either caught or partially buried without having their breathing impaired.

- Most fatal avalanche accidents only had single fatalities. However, on average every third accident resulted in at least one additional victim with serious injuries. One in five accidents resulted in multiple fatalities.
- The recreational avalanche accident with the most fatalities occurred on **Tumbledown Mountain on 20 January 2003** (page 238) and **Connaught Creek on 1 February 2003** (page 243) with seven fatalities each.

Recreational avalanche fatalities from winters 1997 through 2007:

- 88% of the victims were male.
- While the most common age group was 20 to 29 years, the age of victims ranges considerably among the different backcountry activities.
- Two-thirds of the victims were from Canada; the majority of them from BC and Alberta.
- One-third of the avalanche victims did not carry an avalanche transceiver. This percentage varies dramatically among the different backcountry activities.
- 86% of the victims were completely buried or had their breathing impaired when the avalanche stopped.
- 66% of the completely buried fatalities were found using an avalanche transceiver.
- The median burial depth of completely or partially buried avalanche fatalities with breathing impaired was 150cm.
- The median burial time of the completely or partially buried avalanche fatalities was 40 minutes.
- 74% died of asphyxia; 26% succumbed to severe traumatic injuries.

It is important to recognize that the results presented in this chapter are only descriptive and cannot be used to predict the likelihood of a fatal avalanche accident happening. While the observed patterns provide useful insights about the typical patterns in fatal avalanche accidents and it is possible to hypothesize about the underlying causes, an analysis that only includes records of fatal accidents is fundamentally unable to directly identify and quantify the risk factors associated with fatal avalanche accidents. Calculating proper estimates for these risk factors requires a dataset that also includes records of non-accident situations under a wide range of conditions. However, the general lack of detailed information about recreational backcountry usage and the lower quality of data from non-fatal avalanche accidents currently prevent a meaningful statistical analysis. Because of these limitations, it is important that the statistics presented in this chapter are only viewed within this limited context and should not be extrapolated further. Diligent reporting of all avalanche involvements is therefore an important first step for improving our understanding of what factors lead to avalanche accidents.

3.1 All Fatal Avalanche Accidents

General annual trends

The annual number of fatal avalanche accidents and avalanche fatalities are important measures for examining temporal trends in avalanche accidents (*Figure 3.1*). While the number of fatal avalanche accidents and avalanche fatalities in Canada were fairly stable in the 1980s, they experienced a marked increase in the 1990s before the numbers stabilized again in the first years of the new millennium. During the time period covered in this book, 1 October 1996 to 30 September 2007, a total of 155 individuals lost their lives in 105 different accidents in Canada. This is equivalent to 14.1 avalanche fatalities in 9.6 accidents per winter (*Table 3.1*). For comparison, the time period covered by the previous volume of avalanche accidents in Canada (Jamieson and Geldsetzer, 1996), 1 October 1984 to 30 September 1996, exhibited 10.0 fatalities in 6.6 accidents per winter.

When we compare the annual accident and fatality numbers between the winters 1985 – 1996 and 1997 – 2007, we find a 33% increase

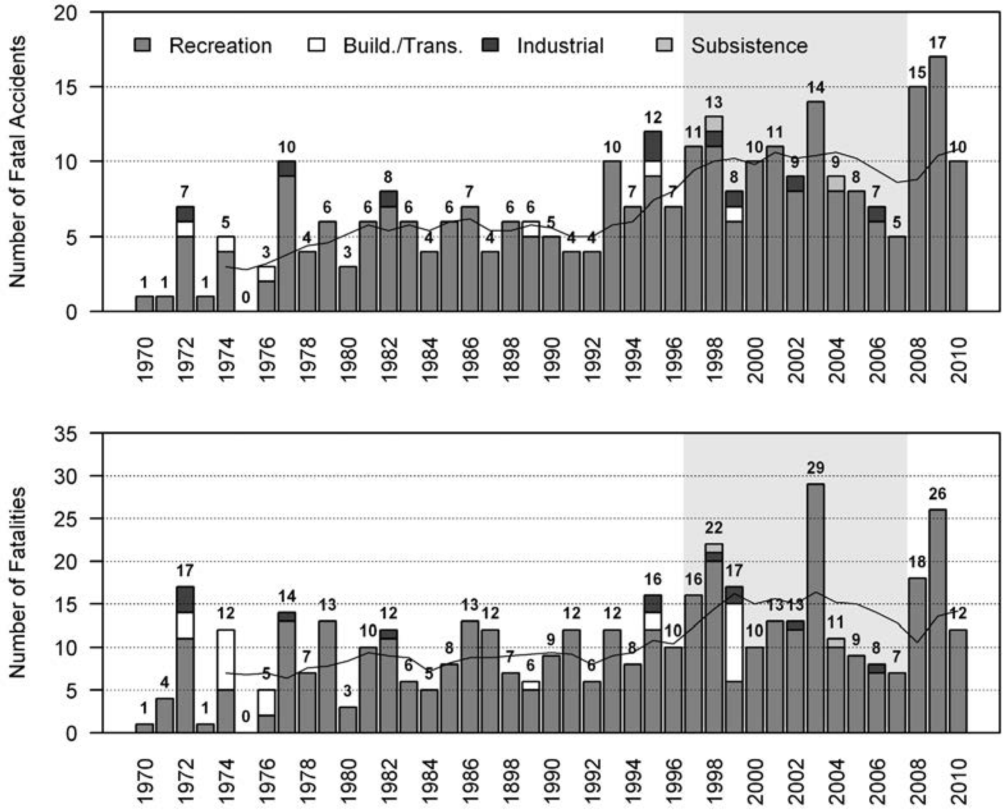

Figure 3.1. Number of fatal avalanche accidents and avalanche fatalities for the winters 1970 to 2010 separated into the four main classes: Recreation, Building or Transportation (Build./Trans.), Industrial, and Subsistence Hunting or Fishing. The solid black line marks the five-year moving average. The shaded area highlights the time period covered in this book.

Table 3.1. Total number and annual average of fatal avalanche accidents and avalanche fatalities for the winters covered by Avalanche Accidents in Canada Vol. 4 *(Jamieson and Geldsetzer, 1996) and this publication.*

Activity	Number of fatal accidents				Number of fatalities			
	1985-1996		1997-2007		1985-1996		1997-2007	
	Total	Average	Total	Average	Total	Average	Total	Average
Recreational	74	6.2	98	8.9	114	9.5	139	12.6
Buildings/Transportation	2	0.2	1	0.1	3	0.3	9	0.8
Industrial	2	0.2	4	0.4	2	0.2	5	0.5
Subs. Hunting/Fishing	0	0	2	0.2	0	0	2	0.2
Total	79	6.6	105	9.6	119	10.0	155	14.1

in fatalities and a 44% increase in the number of fatal accidents between these two time periods. This substantial increase in accident and fatality numbers is primarily related to higher numbers of recreational avalanche accidents (*Table 3.1*).

While it is difficult to reliably measure backcountry use in Canada, we estimate the growth in backcountry activities has been considerably higher (Haegeli, 2005) than the increase in avalanche fatalities. As a consequence, the numbers of recreational avalanche fatalities and fatal accidents per backcountry trip have most likely decreased over the past decade. We believe this decrease is due to increased public avalanche awareness, better avalanche information and improved rescue technologies.

Since fatal accidents in the non-recreational categories are relatively rare events, it is difficult to identify meaningful trends within the short time period covered in this book.

Different patterns in different winters

Avalanche accidents are the result of complex interactions between the seasonal snowpack, backcountry use and rescue capabilities. While backcountry use and rescue capabilities evolve only gradually over time, snow and avalanche conditions can vary dramatically from one winter to the next. As a consequence, significant variability in the number of fatal avalanche accidents and fatalities exists between years (*Figure 3.1*).

With 29 fatalities, the winter of 2003 was the deadliest winter in Canadian history for recreational avalanche accidents. While two accidents with seven fatalities each—**Tumbledown Mountain on 20 January 2003** (page 238) and **Connaught Creek on 1 February 2003** 243—resulted in an exceptionally high number of avalanche fatalities, the number of accidents during this winter, 14, was also a record high at the time. Since then, higher numbers of fatal avalanche accidents were observed in the winters 2008 and 2009.

A total of 22 individuals perished in avalanches during the winter of 1998, which is the third highest toll between 1970 and 2010. This number included 20 recreational fatalities, one industrial accident at **Sa Dena Hes Mine on 16 April 1998** (page 365); and one subsistence hunting accident at **Arctic Bay on 7 March 1998** (page 364). With 11 recreational accidents, this winter was comparable to those of 1997 and 2001. A common thread in all these winters—1997, 1998, 2001 and 2003—was that southwestern Canada experienced challenging avalanche conditions with significant persistent and/or deep persistent avalanche problems.

While the winter of 2000 was also associated with a total of 10 fatal recreational avalanche accidents, three of them occurred outside southwestern Canada.

To highlight the relationship between the seasonal snowpack and the characteristics of the fatal avalanche accidents, a detailed weather and snowpack summary is provided at the beginning of each chapter describing the fatal avalanche accidents in southwestern Canada.

General geographic location

Avalanche accidents in Canada exhibit a characteristic spatial pattern (*Figure 3.1*). Ninety per cent of the fatal avalanche accidents that occurred during the winters of 1997 through 2007 took place in British Columbia (72%) and Alberta (18%). The vast majority of the accidents in these two provinces were related to recreational activities (97%; *Table 3.2*). While recreation is also the primary cause of avalanche accidents in the other provinces and territories, non-recreational activities play a more dominant role in those areas.

3.2 Non-Recreational Fatal Avalanche Accidents

Since the characteristics and management of non-recreational avalanche accidents are considerably different, these types of acci-

Table 3.2. Number of fatal avalanche accidents in different provinces and territories separated according to activity during winters 1997 to 2007.

Activity	Western		Northern		Eastern		Total
	BC	AB	YT	NU	QC	NL	
Recreational	74	18	1	1	3	1	98 (93%)
Buildings/Transportation	0	0	0	0	1	0	1 (1%)
Industrial	2	1	1	0	0	0	4 (4%)
Subs. Hunting/Fishing	0	0	0	2	0	0	2 (2%)
Total	76	19	2	3	4	1	105

dents are discussed separately in this chapter. Between the winters of 1997 and 2007, there were a total of seven non-recreational accidents that resulted in 16 fatalities.

The only residential accident occurred in northern Quebec in **Kangiqsualujjuaq on 1 January 1999** (page 368). The local gymnasium, which served as the community centre for the New Year's celebrations, was hit by a natural size 3 avalanche shortly after midnight, killing nine people and injuring some 25 others. This was the worst accident in terms of fatalities—five of them were children between the age of 22 months and eight years—during the period covered by this book.

There were a total of four fatal avalanche accidents in industrial settings resulting in five fatalities. This category refers to accidents that occurred at outdoor work places not directly related to recreational activities. These accidents primarily took place in western Canada and included **Sa Dena Hes Mine on 16 April 1998** (page 365), **Ningunsaw Pass on 7 January 1999** (page 371), **Parker Ridge on 12 January 2002** (page 194), and **Lizard Range on 14 January 2006** (page 331). In addition to the five workers who perished in these accidents, an additional seven working individuals, including guides, died in recreational avalanche accidents between the winters of 1997 and 2007.

During the period covered by this book, there were two fatal accidents during subsistence hunting or fishing in the Canadian Arctic. Both these accidents occurred on Baffin Island; one at the northern tip of the island close to **Arctic Bay on 7 March 1998** (page 364) and the other in the southern part at **Cape Mercy on 25 January 2004** (page 384).

3.3 Recreational Fatal Avalanche Accidents

The vast majority of the avalanche accidents presented in this book occurred during recreational activities: 139 individuals perished in 98 separate accidents (Tables 3.1 and 3.2), which represents 93% of all fatal accidents and 90% of all fatalities covered in this book. On average, there were 8.9 fatal recreational avalanche accidents per winter resulting in 12.6 fatalities.

The following characterisation and discussion of the fatal recreational avalanche accidents is divided into five main sections: examining the characteristic of accident party and trip location; the general snow and avalanche conditions; the terrain characteristics of the accident location; the accident avalanche and involvement; and the fatal avalanche victims. Combined, this discussion will provide a detailed summary of what a typical fatal recreational accident in Canada looked like between the winters of 1997 and 2007.

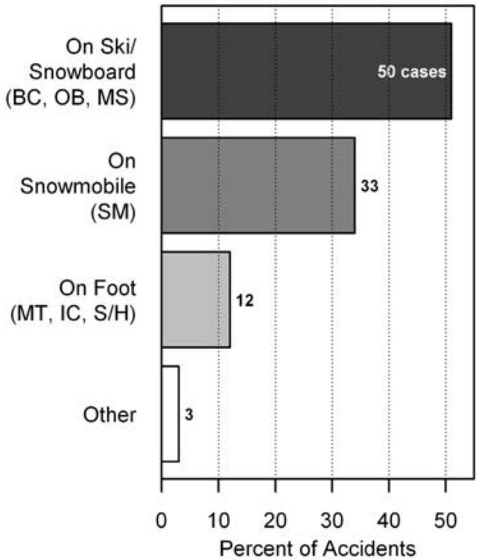

Figure 3.2. *Percentage of fatal recreational avalanche accidents per main activity during winters 1997 to 2007 (n = 98). Legend: BC: Backcountry skiing; OB: Out-of-bounds skiing; MS: Mechanized skiing; SM: snowmobile riding; MT: mountaineering; IC: ice climbing; S/H: snowshoeing and hiking; Oth: Other recreational activities.*

Characteristics of accident party and trip location

a) Backcountry activity

The majority of fatal recreational avalanche accidents from the winters of 1997 through 2007 were associated with skiing[1] (51%) or snowmobile riding (34%) (*Figure 3.2*). Skiers are commonly divided further into backcountry skiers (including snowmobile assisted), out-of-bounds skiers (including skiing in permanent and temporary closures within a ski area boundary) and mechanized skiers (helicopter and snowcat skiers) due to the significant differences in the general demographics, primary means of travel and the approach to risk management (*Table 3.3*). Individuals on foot (mountaineering, ice climbing, snowshoeing and hiking) accounted for another 12% of the fatal accidents.

When examining the number of recreational avalanche fatalities (*Table 3.3*), most of those killed in avalanches were backcountry skiers (35% or 4.5 fatalities per winter) and snowmobile riders (27% or 3.4 fatalities per winter). All skiers combined were responsible for 60% of the recreational avalanche fatalities. The activities of mountaineering, ice climbing, and snowshoeing/hiking combined were related to 11% of all recreational avalanche fatalities. This is roughly equivalent to one fatality every second winter in each of these activities. A total of three fatalities (2%) were classified as other recreational activities. These cases included two tobogganing accidents on **Whistler Mountain near Jasper on 17 May, 1998** (page 94) and in **Château Richer on 14 February, 2000** (page 376), and an accident involving children playing on a steep river bank near **Pond Inlet on 4 April 2004** (page 386).

Figure 3.3 shows the temporal development of recreational fatal accidents and the number of recreational avalanche fatalities separated by recreational activities for the winters 1997 to 2007. The relatively short time span of 11 winters and the high variability among the conditions of these winters does not allow for any meaningful trend analysis.

b) Trip location – mountain range and snow climate

The dominance of recreational activities in avalanche terrain in Alberta and British Columbia shown in Table 3.2 is also reflected in the distribution of fatal recreational avalanche accidents among mountain ranges (*Figure 3.4*). With 37 fatal accidents (38%), the Rocky Mountains saw the highest number of fatal avalanche accidents in a single mountain range. While the individual sub-ranges of the Columbia Mountains (Cariboos, Monashees, Selkirks, and Purcells) in the interior of British Columbia experienced between 5 and 19% of the accidents, a total of 39 (40%)

[1] In this chapter, the term “skiing” refers to both skiing and snowboarding. More complete definitions of the all the different activities are provided in the glossary.

Table 3.3. Total number and annual average of fatal recreational avalanche accidents and related fatalities separated for each activity between October 1997 and September 2007.

Activity	Fatal accidents		Fatalities	
	Tot.	Annual Avg.	Tot.	Annual Avg.
Backcountry Skiing	26	2.4	49	4.5
Out-of-bounds Skiing	9	0.8	13	1.2
Mechanized Skiing	15	1.4	22	2.0
Snowmobile Riding	33	2.0	37	3.4
Mountaineering	5	0.5	6	0.5
Ice Climbing	3	0.3	5	0.5
Snowshoeing or Hiking	4	0.4	4	0.4
Other Recreation	3	0.3	3	0.3
Total	98	8.9	139	12.6

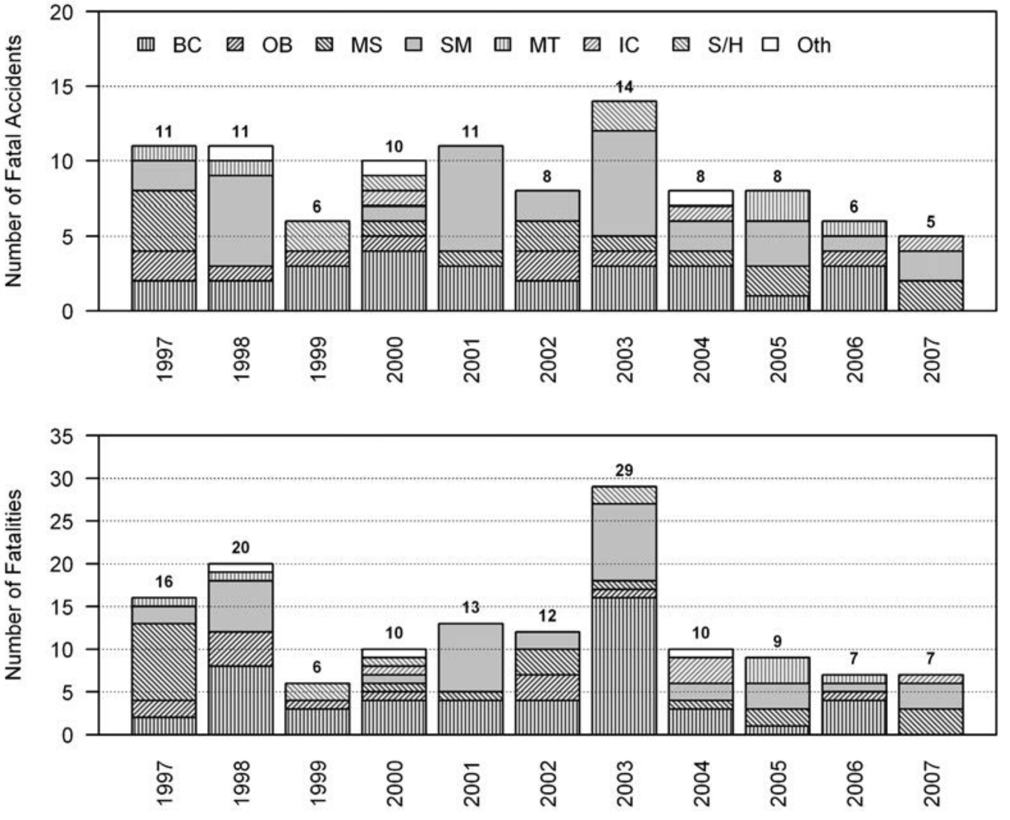

Figure 3.3. Number of fatal recreational avalanche accidents and avalanche fatalities during winters 1997 to 2007 separated into different activities. Activity abbreviations are the same as in Figure 3.2.

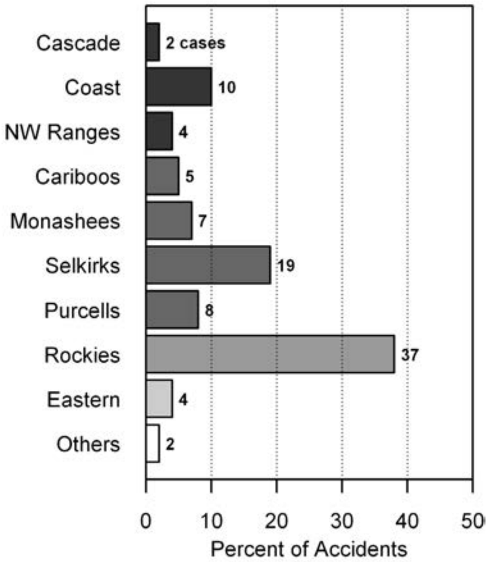

Figure 3.4. *Distribution of mountain ranges among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 98).*

accidents took place in this entire mountain range. Two percent of the accidents occurred in the Cascades, 10% in the Coast Mountains and 4% in the Northwest Ranges of British Columbia. An additional 4% of the fatal avalanche accidents took place in Eastern Canada, namely Quebec and Newfoundland. The remaining two cases that were classified as "Others" occurred in the Saint Elias Mountains (**Mt Logan on 31 May 2005**; page 388) and northern Baffin Island (**Pond Inlet on 4 April 2004**; page 386).

The observed pattern of avalanche accidents is likely the result of the combined effect of snow stability and winter backcountry recreation. Intense backcountry use and the common presence of persistent and deep persistent avalanche problems in the transitional snow climate of the Columbia Mountains naturally lead to higher numbers of avalanche accidents. While winter backcountry recreational activity is generally less intense in the Rocky Mountains, the prevalence of a shallow and weak snowpack in the continental snowpack most likely counteracts this effect. Backcountry recreation in the Cascades, Coast Mountains and Northwest Ranges of British Columbia is much more concentrated in key locations and the snowpack generally stabilizes more quickly due to the maritime snow climate of these ranges.

c) Group size

Five avalanche accidents covered in this book involved more than one group of recreationists. In the accident on **Mt Jowett on 22 March 1997** (page 62), the second group of a heli-skiing operation likely triggered the avalanche that caught the last two skiers of the first group. Similar accidents occurred on **Mt La Forme on 10 February 2002** (page 214) and **Delta Peak on 2 April 2007** (page 392). In the accident in the **Lizard Range on 13 February 2001** (page 159), a group triggered an avalanche high up in the start zone that buried members of a separate group at the bottom of the avalanche path. Due to the configuration of the local terrain, the higher group could not see the lower group and was unaware of it at the time of the accident. In the accident in the **South Chutes outside Fortress Mountain Ski Area on 14 April 2002** (page 223) two separate groups of out-of-bound skiers were caught in the same natural avalanche from above.

All other accidents involved single groups. Group size is known in 86 of the 93 single group accidents. While values ranged from 1 to 21 (*Figure 3.5*), the most frequent group size was three (19%); 50% of the groups had four or fewer members.

Five of the fatal recreational accidents involved individuals travelling alone in avalanche terrain (**Schaeffer Bowl on 12 December 1996**, page 46; **Mt Strachan on 24 December 1998**, page 110; **Mt Lady Macdonald on 13 March 2003**, page 249; **Lake Agnes on 14 March 2003**, page 250; and **Kicking Horse Mountain Resort on 7 January 2006**, page 328). Since a quick rescue is essential for the survival of an avalanche burial, the Canadian Avalanche Centre strongly recommends not travelling alone in avalanche terrain.

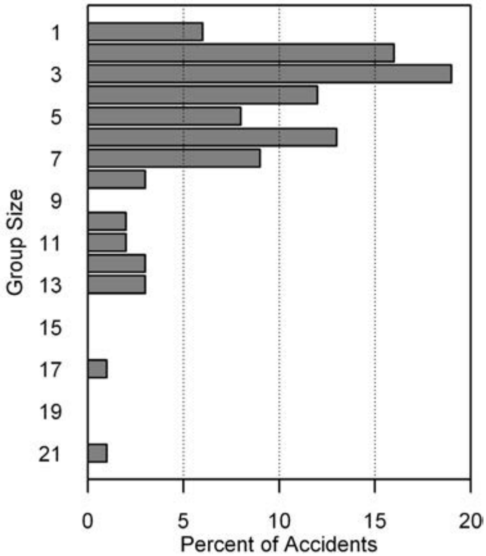

Figure 3.5. Distribution of group sizes in fatal recreational avalanche accidents during winters 1997 to 2007 (n = 86).

d) Safety equipment

Avalanche transceivers are considered essential avalanche safety equipment. Without transceivers, finding a completely buried avalanche victim becomes very time consuming and rarely results in a live recovery. Information about whether avalanche accident parties carried avalanche transceivers was available for 91 of the 98 recreational accidents. While all party members carried transceivers in 55% of the cases, in 14% of the accidents only some members had them, and in 31% none were carried at all (*Figure 3.6*).

Considerable variations in the use of avalanche transceivers were observed among the different backcountry activities. While the percentage of all accident party members carrying transceivers was high among mechanized skiers (100%; n = 15) and backcountry skiers (92%; n = 25), their use was considerably lower in snowmobile riders (38%; n = 32) and out-of-bounds skiers (13%; n = 8). Furthermore, snowmobiling is the only activity where only some of the accident party members were carrying avalanche transceivers (41%; n = 32).

No avalanche transceivers were in use in any of the accidents involving ice climbing (0%; n = 2), mountaineering (0%, n = 2), snowshoeing and hiking (0%; n = 4).

Snow and avalanche conditions

This section summarizes some of the key indicators for increased avalanche hazard. None of these indicators alone can predict whether a fatal avalanche accident will occur. However, their combined presence can provide strong evidence of increased avalanche hazard.

a) Regional avalanche danger rating

The research of Jamieson et al. (2009) shows that regional avalanche danger ratings published in the public avalanche bulletin provide excellent initial estimates of the local level of avalanche hazard.

Of the 98 fatal recreational avalanche accidents, relevant avalanche danger ratings are available for 74 cases. Twenty-two accidents did not have an avalanche danger rating as they either took place outside of the existing avalanche bulletin regions or during times when avalanche bulletins were not available. While avalanche accidents occurred during

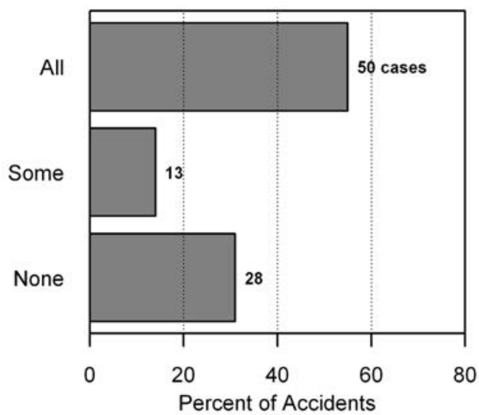

Figure 3.6. Availability of avalanche transceivers within accident party of fatal recreational avalanche accidents during winters 1997 to 2007 (n = 91).

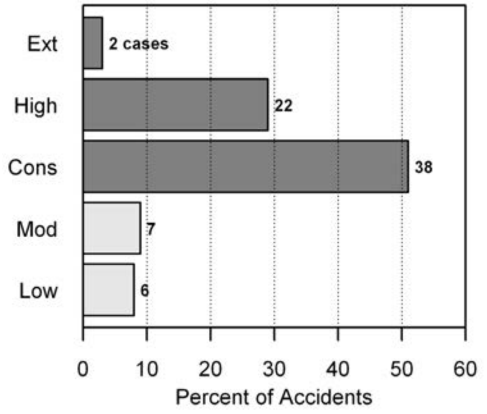

Figure 3.7. Distribution of danger ratings for recreational avalanche accidents that occurred within an avalanche bulletin area during winters 1997 to 2007 (n = 75). Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

all avalanche danger rating levels (*Figure 3.7*), the majority of them took place when the rating was at Considerable (51%) or High (29%). The observed distribution confirms the pattern observed in other studies (Greene et al., 2006) and is likely the result of the interaction between avalanche conditions and backcountry use. Moderate and Considerable are the most common danger ratings published in public avalanche bulletins in Canada (Greene et al., 2006) and while the likelihood of triggering an avalanche increases with increasing danger levels, the number of backcountry users generally decreases.

In addition, avalanche conditions under Considerable danger ratings are often particularly challenging to assess because the signs of the increased danger might be subtle and infrequent. This situation is commonly observed with persistent or deep persistent avalanche problems where the likelihood of triggering avalanches is relatively low, but the potential consequences are devastating.

b) Signs of recent slab avalanche activity

Slab avalanche activity within the last two days can provide a strong indication about the presence of an active weak layer in the snowpack. Based on all of the available information, it was possible to conclusively determine the presence or absence of recent slab avalanche activity in the vicinity of the accident site in 61 of the 98 fatal recreational accidents. According to our assessment of this limited dataset, avalanche activity was present in approximately two-thirds of the accidents (*Figure 3.8*).

c) Signs of unstable snow

Collapsing, whumpfs, cracks and drum-like sounds are all significant indicators of the presence of an active weakness in the snowpack. Low test scores and sudden fractures in snowpack tests are also signs of unstable snow, but are less reliable and hence their proper interpretation requires considerable training and experience.

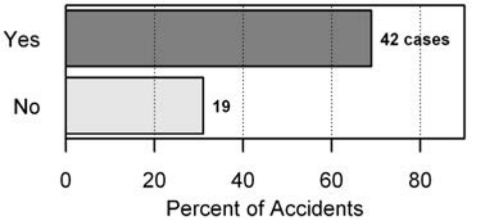

Figure 3.8. Presence of recent slab avalanche activity in the vicinity of fatal recreational avalanche accidents during winters 1997 to 2007 (n = 61). Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

While signs of unstable snow are very important indicators to observe when travelling in the backcountry, it is difficult to conclusively determine their presence or absence retrospectively without detailed accident records or personal interviews with the accident party. Of the 98 recreational accidents covered in this book, it was possible to accurately de-

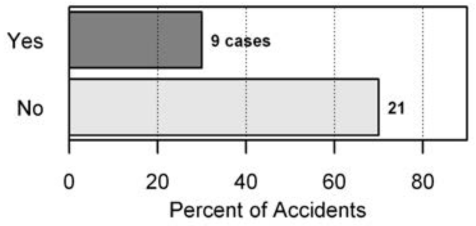

Figure 3.9. Distribution of observed signs of instability among fatal recreational accidents during winters 1997 to 2007 (n = 30). Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

termine the presence or absence of signs of unstable snow in only 30 cases. In this very limited sample, signs of unstable snow were observed in 30% of the accidents (*Figure 3.9*).

In the nine cases with confirmed signs of unstable snow, accident parties noticed whumpfs (4), cracks (4), hollow sounds (1), received low test score results (1) or observed sudden fractures their snowpack tests (1) prior to the accident. In two cases, the ski patrol reported easy releases whenever a slope was approached. Multiple signs of instability were observed in three of the nine cases.

d) Recent loading

Recent loading by snowfall, wind or rain generally results in increased avalanche hazard by putting additional load on existing weak layers in the snowpack. The Avaluator (Haegeli, 2010) recommends 30cm of new snow, wind transport or rain within the last 48 hours as a rough guideline for recognizing when recent loading starts to significantly affect avalanche hazard. Based on the available weather information, it was possible to estimate the amount of loading in the two days prior to the accident in 86 cases.

Loading contributed significantly in a total of 44 (51%) of the fatal recreational avalanche accidents (*Figure 3.10*). In the majority of cases, the loading was a combination of new snow and wind transport (26%), new snow and rain (1%), or new snow, wind transport and rain (6%). Pure loading by either new snow or wind transport alone were only identified in 10% and 8% of the cases respectively.

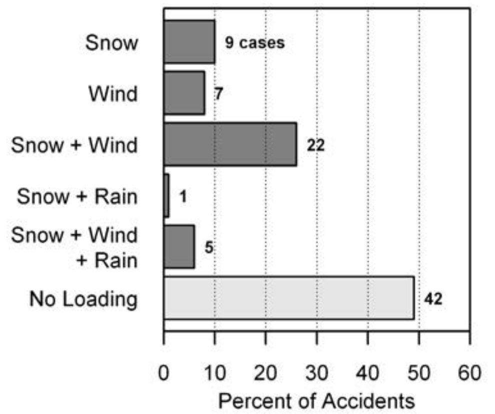

Figure 3.10. Presence of significant recent loading among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 86). Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

e) Critical warming

Rapid rises in temperature to near 0°C can significantly destabilize the snowpack and activate existing snowpack weaknesses. An upper snowpack that is getting wet due to strong sun, above freezing temperatures or rain is also an important indicator that the snowpack is losing strength quickly. Based on the available weather information, it was possible to determine the temperature situation with reasonable accuracy in 91 of the 98 fatal recreational avalanche accidents.

Critical warming was present in a total of 23 (25%) of the accidents (*Figure 3.11*). Among

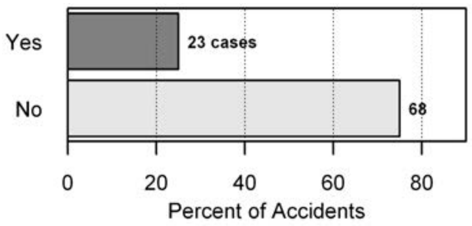

Figure 3.11. Presence of critical warming among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 91). Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

the accidents with critical warming present, air temperatures above 0°C were observed in 16 cases (70%), a rapid temperature rise in six cases (26%), rain in six cases (26%) and strong solar radiation in four cases (17%). Since more than one of these processes were present in some of the accidents, the above percentages add to more than 100%.

Terrain characteristics of accident location

a) Avalanche terrain rating

Avalanche terrain ratings (Statham et al., 2006) were developed to characterize the overall complexity of a backcountry trip with respect to avalanche hazard. Similar to the avalanche danger ratings published in avalanche bulletins, terrain ratings provide an intial, large-scale assessment of the seriousness of the intended backcountry trip.

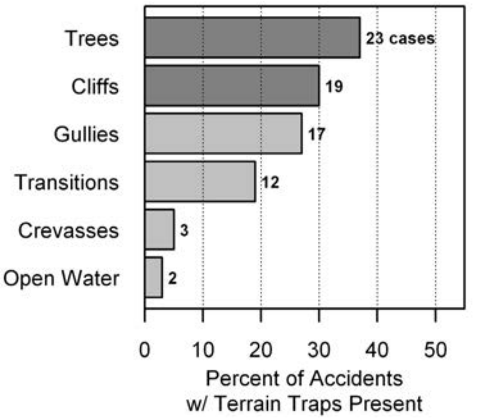

Figure 3.13. Percentage of different terrain traps observed in fatal recreational avalanche accidents with terrain traps present during winters 1997 to 2007 (n = 63; presence of multiple traps possible). Darker shading highlights terrain trap types primarily associated with increased likelihood of trauma injuries; lighter grey show terrain trap types that generally increase the severity of burial. Transitions refer to any rapid transitions in the terrain that would result in increased burial depth (e.g., depressions, benches).

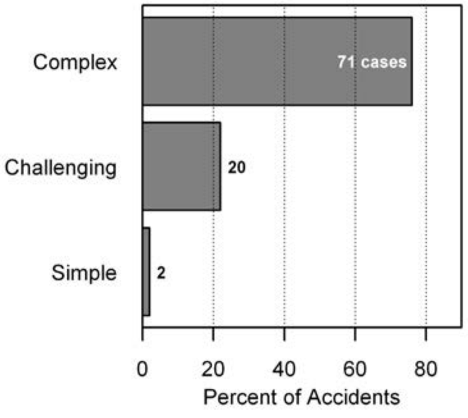

Figure 3.12. Distribution of terrain ratings among fatal recreational avalanche accidents during winters 1997 to 2007(n = 93).

Detailed terrain information about the vicinity of the accident location was available in 93 of the 98 fatal recreational accidents (*Figure 3.12*). While avalanche terrain ratings are used mainly to assess entire backcountry routes, the rating system has emerged as an effective tool for providing a general assessment of the severity of the terrain at an accident site. While fatal avalanche accidents have occurred on all types of avalanche terrain, the majority of accidents took place in complex terrain (76%). The two recreational accidents that took place in simple terrain—**Château Richer on 14 February 2000** (page 376) and **Pond Inlet on 4 April 2004** (page 386)— occurred outside of western Canada during recreational activities not typically

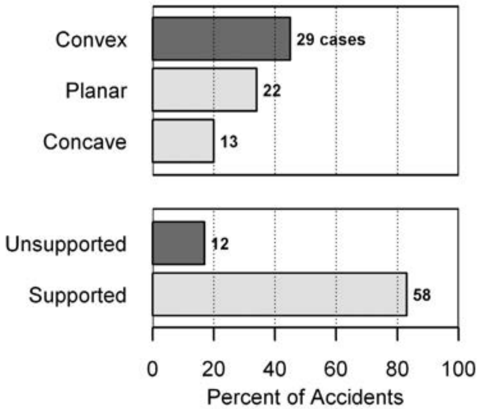

Figure 3.14. Prevalence of convex (top panel, n = 64) and unsupported slopes (bottom panel, n = 71) among recreational fatal avalanche accidents during winters 1997 to 2007. Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

associated with avalanche hazard (tobogganing and playing).

b) Terrain traps

Terrain traps are any terrain features that increase the severity of being caught in an avalanche. There are two main classes of terrain traps: a) cliffs or trees that increase the likelihood of traumatic injuries; and b) gullies, rapid terrain transitions, crevasses or open water that lead to deeper or more severe burials. Based on the available terrain information, it was possible to determine the presence of terrain traps in 86 of the 98 accidents. According to our research, terrain traps were present in 73% of the accidents (63 cases). Within the sample of accidents that had terrain traps present, trauma-related traps were present in 65% while burial-related terrain traps existed in 52% of the cases (*Figure 3.13*). The most frequently found terrain traps were trees (37%), cliffs (30%) and gullies (27%).

c) Slope shape

The general degree of convexity of a slope and its level of toe support can affect the stability of a slope, and avalanches are generally triggered more frequently on convex and/or unsupported slopes. For the 98 fatal recreational avalanche accidents, it was possible to determine the slope shape and toe support in 64 and 70 cases respectively. Based on these two limited datasets, 45% of the accidents took place on convex slopes and 17% occurred on unsupported slopes (*Figure 3.14*).

d) Forest density

It was possible to conclusively determine forest density at the site in 95 of the 98 fatal recreational accidents (*Figure 3.15*). While most of the accidents occurred on open, treeless slopes (73%) or on sparsely treed slopes (24%), three of the accidents took place in mature forest (4%).

Similar to other accident characteristics, this pattern is most likely a combination between snow stability and backcountry use patterns. The snowpack is generally more stable in dense forests than in areas with large spacing between trees. However, trees need to be closely spaced to effectively anchor the snowpack. It is important to remember that avalanches that start in open areas can eas-

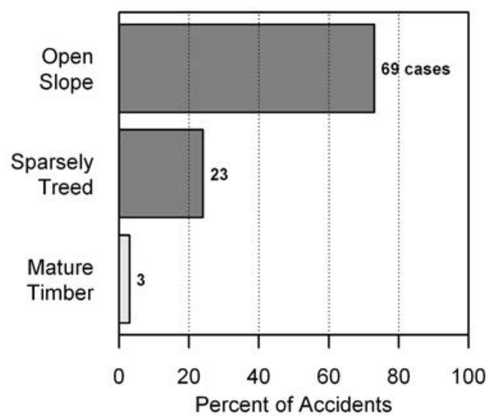

Figure 3.15. Distribution of forest density among recreational fatal recreational avalanche accidents during winters 1997 to 2007 (n = 95). Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

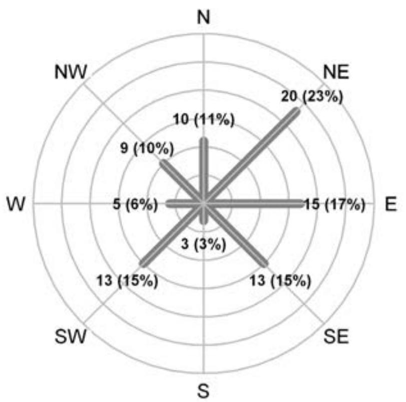

Figure 3.16. *Distribution of aspect among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 85)*

ily run into trees, which then become serious terrain traps. The second factor that likely contributes to the observed pattern is the fact that recreationists tend to prefer areas without dense timber.

Accidents that were classified to have occurred in mature timber include **Mt Strachan on 12 February 1997** (page 56), **Mt Strachan on 24 December 1998** (page 110) and **Mt Llewelyn on 18 January 2005** (page 310).

e) Aspect of start zone

The recreational accidents covered in this book are not distributed evenly across slope aspects. Most accidents occurred on slopes facing northwest through north to southeast (76%; *Figure 3.16*). This pattern is most likely the result of a combination of meteorological factors and backcountry use patterns. The development of persistent weaknesses such as surface hoar is generally less pronounced on southern and western aspects as the more intense incoming solar radiation on these aspects tends to inhibit the cumulative growth of these weak crystals over multiple days. In addition, winds in western Canada blow most often from westerly and southwesterly directions, making easterly and northerly slopes more sheltered and leading to the development of wind slabs on these aspects. In addition to these meteorological factors, the preference of backcountry recreationists for powder snow most likely contributes to the prevalence of accidents on north- and east-facing slopes.

f) Slope incline

In 79 of the 98 fatal recreational avalanche accidents, detailed information was available regarding the slope incline at the accident itself and the adjacent terrain. In four cases, avalanche victims triggered cornices on ridgelines where incline is not relevant. Among the remaining dataset of 75 cases, the highest percentage of fatal avalanche accidents (55%) occurred on slopes where the steepest sections were between 36 and 40 degrees (*Figure 3.17*). This slope angle is comparable to the steepness of a double-black diamond run at a ski resort, an incline often preferred for skiing, snowboarding and snowmobile riding.

The observed pattern is consistent with other studies showing that most human-triggered avalanches occur on slope angles with start-

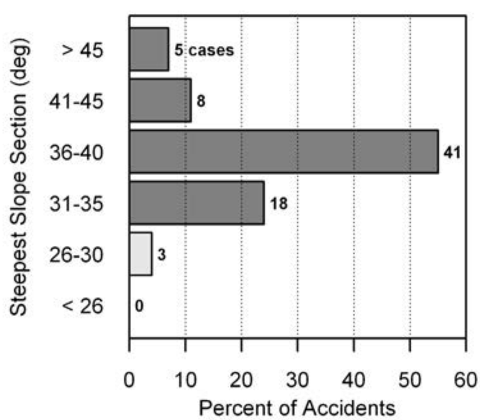

Figure 3.17. *Categorical distribution of incline of steepest slope section among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 75). Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).*

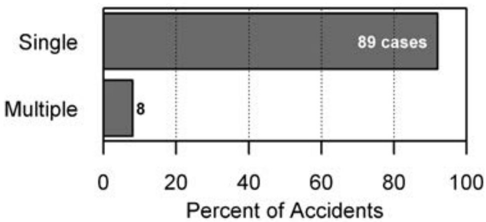

Figure 3.18. Distribution of number of avalanches directly affecting individuals in recreational fatal avalanche accidents during winters 1997 to 2007 (n = 97).

ing zones between 37 and 39 degrees (see, e.g., Jamieson, 2000; Tremper, 2008). While avalanche accidents in terrain of 30 degrees and below are rare (4%), they do exist. Fatal accidents involving low-angle terrain include **Ladybird Creek on 10 January 1998** (page 85), **Brewer Creek on 14 January 2002** (page 197), and **Mt Terry Fox on 26 March 2003** (page 262).

Characteristics of avalanches and involvement

a) Number of avalanches

Among the fatal recreational avalanche accidents covered in this book, the vast majority of accidents only included single avalanches. While one accident did not have a direct avalanche involvement (**Whistler Mountain on 3 December 1996;** page 45), in 8% of the accidents, multiple avalanches affected the victims (*Figure 3.18*).

Accidents with involvements in multiple avalanches include **Phalanx Glacier on 16 December 1996** (page 48), **Mt Jowett on 22 March 1997** (page 62), **Mt Switzer on 31 March 1997** (page 360), **Corbin Creek on 2 January 1998** (page 79), **Ladybird Creek on 10 January 1998** (page 85), **Grouse Grind Trail on 27 January 1999** (page 114), **McLean Creek on 24 February 2001** (page 167), **Bella Coola on 21 April 2006** (page 345). In the majority of these cases, the additional avalanches released sympathetically to the initial accident avalanches. In other cases, the secondary avalanches were triggered by the impact of the first avalanche or simply released independently as an additional natural avalanche.

b) Avalanche problem

Not all avalanches are the same. Avalanches can roughly be divided into eight types according to the characteristics of the associated snowpack weakness. The type of avalanche problem has strong implications on how to manage avalanche hazard during a backcountry trip.

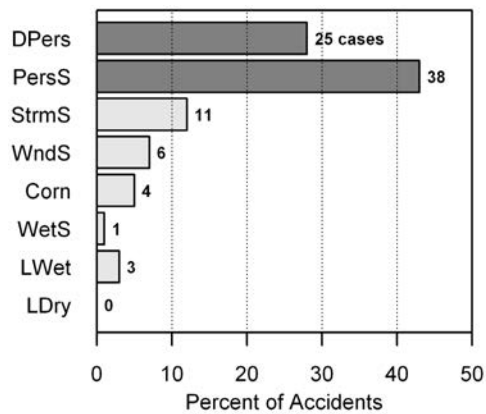

Figure 3.19. Distribution of avalanche problems among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 88). Legend: DPers: Deep persistent slab; PersS: Persistent Slab; StrmS: Storm Slab; WndS: Wind slab; Corn: Cornice; WetS: Wet slab; LWet: Wet loose avalanche; LDry: Loose dry avalanche. Dark shading highlights the values considered a warning sign by the Avaluator (see Appendix E for details).

The specific avalanche problem is known in 88 of the 98 recreational avalanche accidents (*Figure 3.19*). While most of the avalanche problems have led to fatal avalanche accidents, the vast majority of accidents are related to persistent (43%) and deep persistent avalanche problems (28%). These are particularly challenging conditions as the related snowpack weaknesses can linger for weeks and even months. The resulting avalanches are generally more difficult to anticipate, can

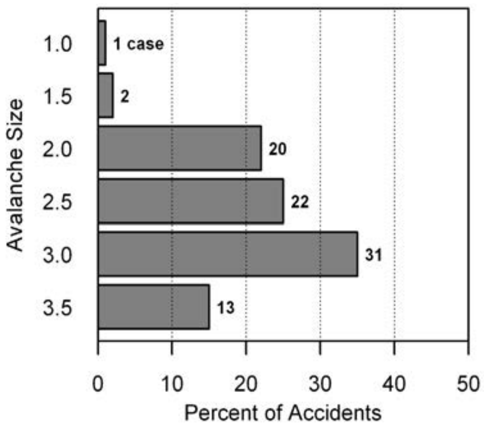

Figure 3.20. *Distribution of avalanche size of primary avalanches among recreational fatal recreational avalanche accidents during winters 1997 to 2007 (n = 89).*

be triggered from a distance, are generally bigger and occur more often on gentle terrain.

c) Avalanche size

The Canadian avalanche size classification (CAA, 2007) describes the size of avalanches according to their destructive potential, which is a function of their mass, speed, density and the dimensions of the avalanche path. While the scale defines five main size classes (see Appendix A, size classification), half-sizes are commonly used to describe the size of avalanches between two classes.

The most common avalanche size in fatal recreational avalanche accidents is size 3 (35%), which is large enough to bury or destroy a car (*Figure 3.20*). While 49% of the avalanches are of size 3 or 3.5, 47% of the avalanches are of size 2 or 2.5. These avalanches are smaller, but still large enough to directly bury, injure or kill a person.

In 3% of the accidents (3 cases), avalanches were classified as size 1 or 1.5. While avalanches of this size are generally harmless to people, they can result in serious consequences when combined with terrain traps or mountaineering routes. Fatal accidents involving small avalanches include **Mt Edith Cavell on 28 June 1998** (page 96), **Mt Strachan on 24 December 1998** (page 110) and **Cayoosh Mountain on 1 February 2004** (page 283).

d) Avalanche trigger

Avalanches that catch recreationists are usually triggered by members of the same party, whether they are on foot, on skis or on snowmobiles. In the recreational avalanche accidents covered in this book, only 8% of the fatal accidents were related to natural avalanches (*Figure 3.21*).

The high percentage of human-triggered avalanches is observed in all activities with the exception of ice climbing where all avalanches released naturally (see **Cascade Mountain on 17 December 1999**, page 133; **Mt Wilson on 13 February 2004**, page 290; and **Mt Inflexible on 5 November 2006,** page 352). Examples of other accidents with naturally triggered avalanches include **Mt Robson on 9 July 1997** (page 67), **Kokanee Lake on 13 November 1998** (page 102), **South Chutes outside Fortress Mountain Ski Area on 14 April 2002** (page 223) and **Connaught Creek on 1 February 2003** (page 243).

e) Average slab thickness

An average slab thickness was available for 55 of the 98 recreational avalanche accidents.

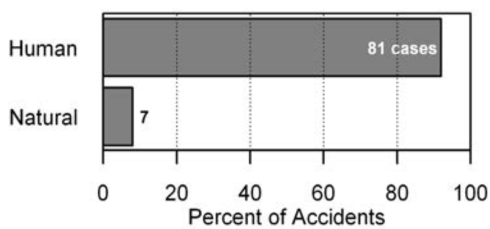

Figure 3.21. *Percentage of human-triggered and natural avalanche among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 88).*

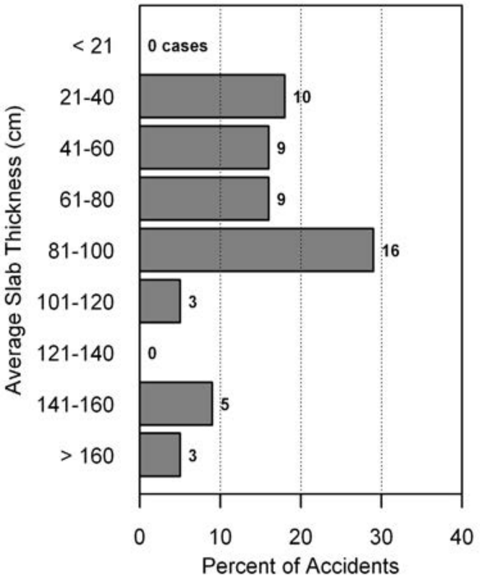

Figure 3.22. Distribution of average slab thickness among fatal recreational avalanche accidents during winters 1997 to 2007 (n = 55).

The median of the average slab thickness was 75cm with the middle 50% of the distribution ranging from 55 and 100cm. The vast majority of slabs (80%) were less than 100cm thick (*Figure 3.22*). When the trigger point is known, it is usually at a location where the snowpack is thinner than the average slab thickness (Jamieson and Geldsetzer, 1999).

The observed pattern confirms that skiers and individuals on foot or on snowmobiles rarely affect snowpack weaknesses deeper than 100cm. However, once triggered, slabs can propagate into deeper snowpack areas, resulting in larger and more destructive avalanches. The thickest slab avalanche covered in this book took place on **Mt Terry Fox on 26 March 2003** (page 262). In this accident the crown height ranged from 1m to 3.5m with an average of 2.25m.

f) Number of individuals involved in avalanche

The total number of individuals involved is known in 97 of the 98 fatal recreational avalanche accidents. In two cases, the fatalities were not caused by a direct avalanche involvement. In the accident on **Whistler Mountain on 3 December 1996** (page 45), the victim fell jumping off the crown of an old avalanche and was unable to stop himself on the hard bed surface before he fell over a cliff to his death. Similarly, the victim of the accident on **Mt Strachan on 12 February 1997** (page 56) initially fell after landing on the hard bed surface of an avalanche that had been triggered by another party member. The victim later sustained fatal injuries as she was trying to find her way back to the ski area.

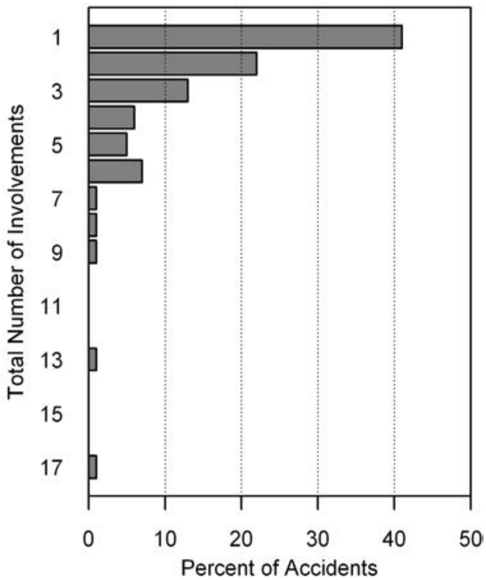

Figure 3.23. Distribution of total number of individuals involved in fatal recreational avalanche accidents during winters 1997 to 2007 (n = 95).

The number of individuals involved in a fatal recreational avalanche accident ranged from one to 17 (*Figure 3.23*). While the most frequent number of individuals involved is one, 56% of the accidents included multiple involvements (not all fatal). The two accidents with the highest number of involvements were **Connaught Creek on 1 February 2003**

Table 3.4. *Number and percentages of different degrees of burial in fatal recreational avalanche accidents during winters 1997 to 2007 (n = 91).*

Number of individuals	Caught only	Partially buried		Completely buried
		Not critical	Critical	
0	68 (75%)	65 (71%)	83 (91%)	15 (16%)
1	13 (14%)	15 (16%)	7 (8%)	53 (58%)
2	8 (9%)	9 (10%)	1 (1%)	12 (13%)
3	1 (1%)	0	0	10 (11%)
4	0	0	0	1 (1%)
5	1 (1%)	2 (2%)	0	0
6	0	0	0	0
Average	0.41	0.47	0.10	1.22

(page 243) with 17 involvements and **Tumbledown Mountain on 20 January 2003** (page 238) with 13 involvements.

g) Avalanche involvements

Avalanche involvements are generally classified into one of the following four categories:

- Caught only: individual is moved by the avalanche but not buried.
- Partially buried – not critical: individual is partially buried when the avalanche stops but the breathing is not impaired (i.e., head is still above the snow surface).
- Partially buried – critical: individual is partially buried with head under the snow surface when the avalanche stops. Breathing is impaired.
- Completely buried: individual is completely beneath the snow surface when the avalanche stops. Equipment such as skis or poles may still be visible on the surface.

The degree of burial has strong implications for the seriousness of an accident and how quickly a victim can be found.

Detailed information on the degree of burial of all involved individuals is available in 91 of the 98 fatal recreational avalanche accidents (*Table 3.4*). In this sample, the average number of people involved in the accident avalanche was 2.2. Of the individuals involved in this sub-sample, 60% were either completely buried or partially buried with impaired breathing. Another 22% were partially buried non-critically and 19% were caught only. These statistics apply only to fatal avalanche accidents, as information on non-fatal accidents was not included in this analysis.

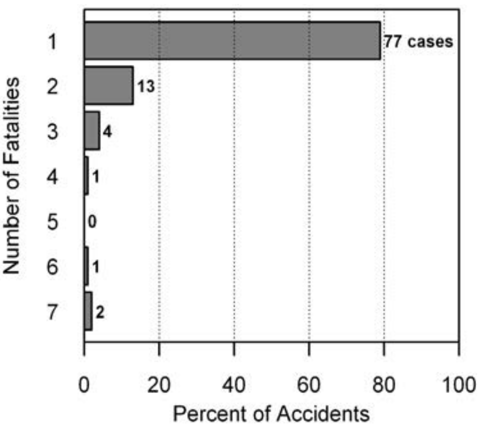

Figure 3.24. *Distribution of number of fatalities among fatal recreational accidents during winters 1997 to 2007 (n = 98).*

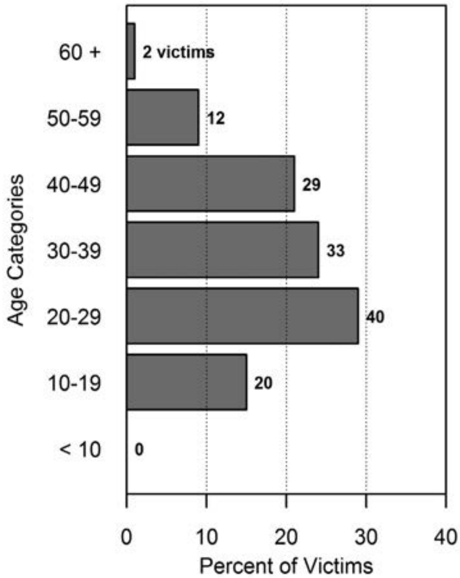

Figure 3.25. *Age distribution among recreational avalanche fatalities during winters 1997 to 2007 (n = 136).*

h) Number of fatalities and injuries

The number of fatalities within recreational accidents ranged from one to seven. While the majority of the recreational accidents resulted in single fatalities, 21% of the accidents had multiple fatalities (*Figure 3.24*). The two accidents with the highest number of fatalities are **Tumbledown Mountain on 20 January 2003** (page 238) and **Connaught Creek on 1 February 2003** (page 243) with seven fatalities each.

When individuals with injuries that required medical attention are also included in this analysis, the number of accidents with multiple victims increases by 11 percentage points to 32% (31 of 97 accidents with available information).

Characteristics of avalanche victims

The 105 avalanche accidents that occurred between the winters of 1997 and 2007 resulted in a total of 155 fatal avalanche victims. The following characterisation focuses on the 139 victims (90%) who perished in the 98 recreational accidents.

a) Gender and age

Over the period covered by this book, 88% of all recreational avalanche fatalities were male. The prevalence of male avalanche victims is likely related to the fact that the percentage of female backcountry recreationists is relatively small (see, e.g., Gunn, 2010; Tase, 2004) as well as the generally higher risk propensity of males (Byrnes et al., 1999).

The age of the victims is known for 136 of the 139 recreational avalanche fatalities. While 20-29 years was the most frequent age decade (*Figure 3.25*), the median age was 33 years and the central 50% of the age distribution was between 24 and 42 years old.

The age of avalanche fatalities differs considerably among recreational activities. The detailed study of Boyd et al. (2009) showed that avalanche victims engaged in out-of-bounds skiing and snowshoeing or hiking are considerably younger and victims in mechanized skiing are substantially older than the average.

The youngest avalanche victim in all of the accidents covered in this book was a 22-month-old child who perished during the residential

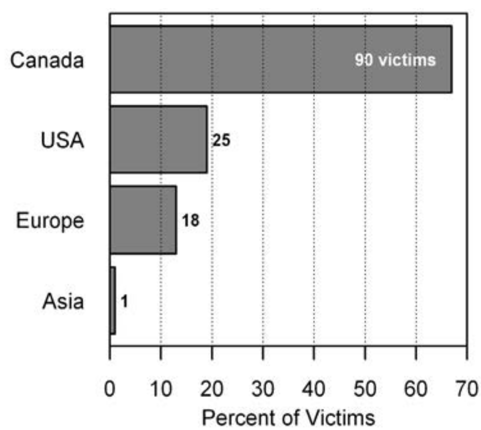

Figure 3.26. *Distribution of residence among recreational avalanche fatalities during winters 1997 to 2007 (n = 134).*

avalanche accident in **Kangiqsualujjuaq on 1 January, 1999** (page 368).

b) Residence

While the majority of recreational avalanche victims were Canadian (67%), 19% were from the United States, 13% from Europe and a single victim was from Japan (*Figure 3.26*). Due to their international clientele, the percentage of international avalanche victims is highest among mechanized skiers (90%).

Among the Canadian fatalities, most of the victims resided in British Columbia (47%) or Alberta (45%). The remaining victims with a known residence came from the Yukon, Saskatchewan, Ontario, Quebec, Nunavut and Newfoundland (*Figure 3.27*). Since three-quarters of all fatal recreational avalanche accidents took place in British Columbia (*Table 3.2*), the residence statistics show that many avalanche victims were non-locals.

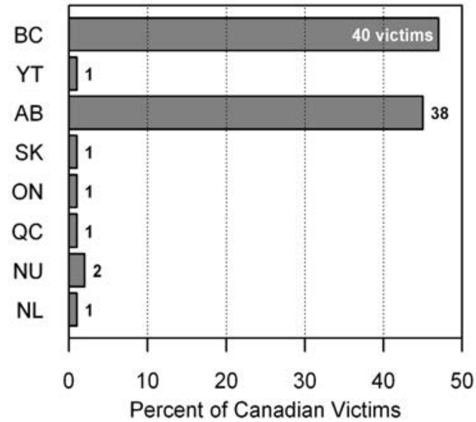

Figure 3.27. *Distribution of residence among Canadian recreational avalanche fatalities during winters 1997 to 2007 (n = 85). Legend: BC: British Columbia; YT: Yukon; AB: Alberta; SK: Saskatchewan; ON: Ontario, PQ: Quebec; NU: Nunavut; NL: Newfoundland.*

c) Rescue gear: avalanche transceiver

Since quick companion rescue offers the highest chance of surviving an avalanche involvement, carrying proper avalanche safety equipment is essential for travelling in avalanche terrain. An avalanche transceiver, shovel and probe are essential pieces of avalanche safety equipment and should be carried by all group members. Among the cases of recreational avalanche fatalities with documented information about avalanche safety gear, only 67% carried avalanche transceivers (*Figure 3.28*). This percentage varies considerably depending on backcountry activity. While the use of avalanche transceivers was high in mechanized skiing (100%) and backcountry skiing (94%), few or no avalanche transceivers were carried by victims skiing out-of-bounds (9%), mountaineering, ice climbing, snowshoeing or hiking (all 0%). The use of transceivers among snowmobile victims is in the middle of the range at 58%.

Avalanche floatation packs have recently been introduced as a new type of avalanche safety device. These consist of a folded-up single- or dual-balloon system integrated into a specially designed backpack. In the case of an avalanche, the wearer activates the balloon system by pulling a ripcord-like handle, which triggers the inflation of the balloon system from a pressurized gas cartridge. With the balloon system inflated, the victim becomes a large "particle" within the granular flow of the avalanche and naturally "floats" to the surface through the process of inverse segregation (Kern, 2000). While avalanche transceivers and probes aim to accelerate the search and extrication phase of an avalanche rescue, the primary goal of an avalanche floatation device is to prevent or limit the extent of burial of the victim. While the

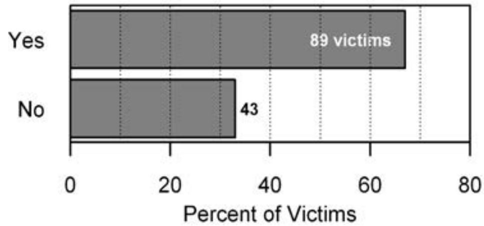

Figure 3.28. *Percentage of recreational avalanche fatalities carrying avalanche transceivers during winters 1997 to 2007 (n = 132).*

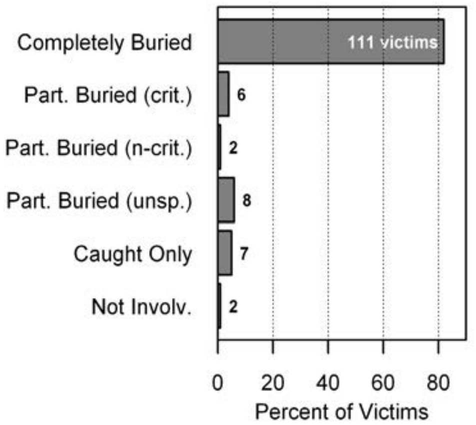

Figure 3.29. Distribution of degree of burial among recreational avalanche fatalities during winters 1997 to 2007 (n = 136). Legend: Part. buried crit.: Partially buried critical (breathing impaired); Par. Buried n-crit.: Partially buried non-critical; Part. buried unsp.: Partially buried unspecified; Not involv.: Not directly involved.

effectiveness of avalanche floatation devices has been shown using European avalanche accident data (Brugger et al., 2007), only very limited data is currently available on the use of these avalanche safety devices in Canada.

d) Degree of burial

Degree of burial is known for 136 of the 139 recreational avalanche fatalities. While a total of 86% of these individuals had their breathing impaired when the avalanche stopped (111 completely buried and six partially buried critical), 8% of the fatalities had a clear airway as they were partially buried non-critical, caught only, or not directly involved in the avalanche (*Figure 3.29*). In eight cases (6% of partially buried victims) it is unclear whether their breathing was impaired or not. Overall, these numbers indicate that it is possible to die in an avalanche even without being buried.

e) Primary search method

The best, if not only, chance to survive an avalanche burial is timely rescue by travel companions. Avalanche transceivers provide the most effective means for finding avalanche victims who are completely buried. While 66% of completely buried fatal avalanche victims were found using avalanche transceivers, a total of 14% were located by probing (two cases with improvised probes), one case by searching at the last-seen point, 5% by searching in the vicinity of visible gear, 3% by searching in the vicinity of other victims, and a final 12% were found by dogs (*Figure 3.30*). Some of these latter search methods are very time consuming and rarely result in live recoveries.

f) Burial depth

Burial depth is known in 106 of the 117 recreational avalanche fatalities who were either completely buried or partially buried with their breathing impaired (critical). While the most frequent burial depth was in the 100 to 149cm category (34%), the median of the complete burial depth distribution is 150cm with the middle 50% between 100 and 218cm (*Figure 3.31*). These statistics show that the most frequent burial depth of avalanche fatalities was roughly twice as deep as the average thickness of the initial slab. Any burials deeper than 200cm are generally associated with terrain traps that significantly increased the severity of the burial. Examples of such

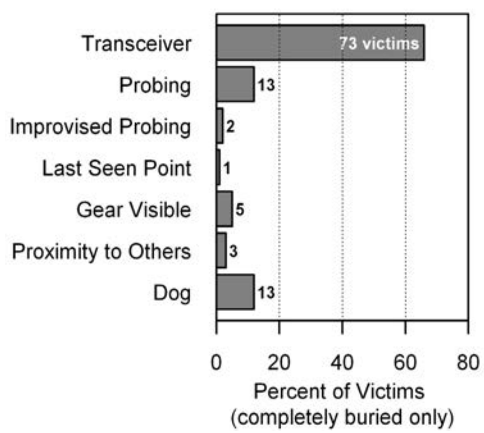

Figure 3.30. Distribution of primary search method among recreational avalanche fatalities who were completely buried during winters 1997 to 2007 (n = 110).

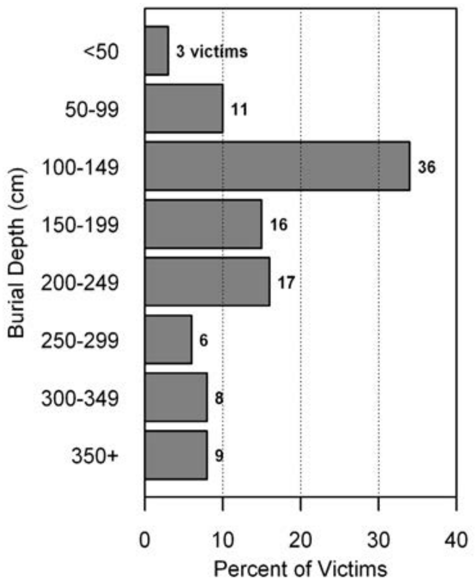

Figure 3.31. Distribution of burial depth (cm) among recreational avalanche fatalities during winters 1997 to 2007 who were completely buried or partially buried critical (n = 106).

terrain traps are rapid transitions in the terrain, gullies or crevasses.

The shallowest burial to result in an asphyxia fatality was just a few centimetres in depth on **Round Top Mountain on 31 January 1998** (page 90). Since the accident party did not carry avalanche transceivers, it took the survivors approximately 30 minutes to locate and extricate the victim. Proper avalanche safety gear would have likely made a difference in the outcome of this accident. The deepest burial covered in this book occurred on **Mt Brewer on 27 March 2003** (page 264). In this accident, a snowmobile rider was buried in a depression under 7.3m of avalanche deposit.

g) Burial duration

The chance of survival for completely buried victims in open terrain has been described in the avalanche survival curve, which displays probability of survival as a function of burial time (Brugger et al. 2001). The curve, which was calculated using data from Switzerland, can be divided into four distinct phases. While the probability of survival remains above 91% during the first 18 minutes of burial (survival phase), there is a precipitous drop to 34% between 19 and 35 minutes related to the asphyxiation of victims without an air pocket (asphyxia phase). As victims with an air pocket are able to survive longer due to the availability of oxygen, the survival drops only slightly between 35 and 90 minutes (latent phase). This phase is followed by a second drop to 7% at approximately two hours as victims with a closed air pocket often slowly succumb to asphyxia and hypothermia. Survival beyond two hours is only possible if the victim is surrounded by a large cavity or an air pocket open to the exterior.

The duration of burial was known for 75 of the completely buried and partially buried (critical) avalanche victims covered in this book (*Figure 3.32*). The median burial time is 40 minutes, which is beyond the survival and asphyxia phases of the avalanche survival curve by Brugger et al. (2001). The middle 50% of the burial durations range between 20 and 134 minutes.

Sadly, 20% of the fatalities were extricated within the survival phase of the avalanche survival curve described by Brugger et al. (2001). Only two of these 15 cases were trauma fatalities. Data currently under investigation show that under Canadian conditions, the initial drop in the survival probability (asphyxia phase) might start significantly earlier than the 19 minute threshold suggested by Brugger et al. (2001).

On a more positive note, the longest documented Canadian avalanche survival in open terrain occurred at **Château Richer on 14 February 2000** (page 376). A teenager, who

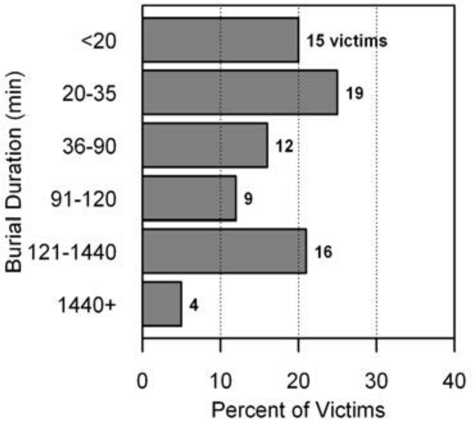

Figure 3.32. *Distribution of burial duration in minutes among recreational avalanche fatalities during winters 1997 to 2007 (n = 75) roughly divided into the survival phases described by Brugger et al. (2001). 120 minutes is equivalent to 2 hours and 1440 minutes to 1 day.*

was tobogganing with a friend when the accident occurred, survived after been completely buried in the avalanche for 300 minutes. Her friend, who was buried for approximately the same amount of time, did not survive the avalanche.

h) Cause of death

The primary cause of death is known for 133 of the 139 recreational avalanche fatalities. While 74% of the victims died of asphyxia, 26% succumbed to severe traumatic injuries (*Figure 3.33*). These numbers are consistent with the statistics presented by Boyd et al. (2009) who conducted a more detailed study on the causes of death among avalanche fatalities in Canada between 1984 and 2005.

The study highlighted that the prevalence of trauma among avalanche fatalities varies significantly between backcountry activities, ranging from 0% for snowshoeing or hiking to 42% for ice climbing. In addition, the authors showed that severe trauma likely contributed considerably to the fatal outcome of an additional 10% of the asphyxia fatalities. Overall, severe trauma therefore contributed to one in three avalanche fatalities.

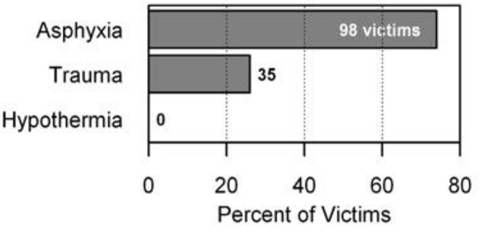

Figure 3.33. *Distribution of causes of death among recreational avalanche fatalities during winters 1997 to 2007 (n = 133).*

Chapter 4

Avalanche Accidents of Southwestern Canada **1996-1997**

Winter Summary for Southwestern Canada

- **13 avalanche fatalities in nine accidents during the main winter season, one accident in July**
- **Facet-crust combination that developed in November after a rain-on-snow event was the primary persistent weakness of the season**
- **The November facet-crust combination can be linked to accidents in all three main mountain ranges and was responsible for seven of the 13 fatalities during the main winter season**
- **With the exception of one accident during the main winter season, all avalanche fatalities were linked to persistent weak layers**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
3 Dec 1996	Whistler Mountain	South Coast Mountains	Snowboarding in Closed Area	1	Persistent Slab	11 Nov 1996	45
12 Dec1996	Schaeffer Bowl	Rocky Mountains	Backcountry Skiing	1	Persistent Slab	11 Nov 1996	46
16 Dec 1996	Phalanx Glacier	South Coast Mountains	Heli-Skiing	3	Deep Persistent Slab	11 Nov 1996	48
13 Jan 1997	Bone Creek	Monashee Mountains	Heli-Skiing	2	Deep Persistent Slab	22 Nov 1996	51
2 Feb 1997	Lang Creek	Purcell Mountains	Snowmobiling	1	Deep Persistent Slab	11 Nov 1996	54
12 Feb 1997	Mt Strachan	South Coast Mountains	Out-of-Bounds Snowboarding	1	Storm Slab		56
9 Mar 1997	Mine Creek	Cascade Mountains	Backcountry Snowboarding	1	Persistent Slab	24 Feb 1997	58
22 Mar 1997	Mt Jowett	Selkirk Mountains	Heli-Skiing	2	Persistent Slab	15 Mar 1997	62
30 Mar 1997	Lang Creek	Purcell Mountains	Snowmobiling	1	Deep Persistent Slab	11 Nov 1996	65
9 Jul 1997	Mt Robson	Rocky Mountains	Mountaineering	1	Loose Wet Avalanche		67

[1] It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.

Accumulation of snow in the mountains started in mid-October when temperatures fell below freezing for the first time. Steady accumulation of snow during the second half of October resulted in a solid snowpack by the end of the month. On 31 October, Mt Fidelity (1874m) reported a snowpack height of 65cm, which is close to average for that time of the year.

After a few days of snowfall in early November, temperatures increased dramatically on 8 November and snowfall turned to rain to mountain tops. From 9 to 13 November, Mt Fidelity reported 28mm of rain and 16cm of new snow, which created a layer of wet snow at the surface. This episode of above normal temperatures was followed by a strong push of arctic air that brought a significant drop in temperature. Temperatures at Mt Fidelity were around -10°C from 14 to 17 November and the area received approximately 15cm of new dry snow. The influence of the arctic air mass became even stronger the following days and maximum temperatures at Mt Fidelity ranged from -9.5 to -17°C under clear skies.

The combination of the latent heat stored in the wet snow layer from the rain event and the cold air temperatures produced a strong temperature gradient in the surface snow layers that promoted the development of a weak layer of faceted crystals on top of a much harder melt-freeze crust. While the facet-crust combination was most dominant in the Columbia Mountains north of the Trans-Canada Highway, it was observed with varying degrees of severity in all mountain ranges in southwestern Canada. This persistent weakness became the most prominent challenge of the 1997 snowpack and was commonly referred to as the November facet-crust combination. While the layer was dated as 11 November facets in the Coast and Columbia Mountains, it was referred to as the 14 November melt-freeze crust in the Rocky Mountains.

By 26 of November 46cm of new snow had fallen at Mt Fidelity under increasing temperatures, which promoted the formation of a slab on top of the crust-facet combination. The first related skier-triggered natural avalanche was reported on 27 November and the first natural avalanche on 1 December. The weakness remained active for the majority of the season and the last related dry-slab avalanche in the North Columbias was reported on 19 March. During that period, the November facets were responsible for avalanche fatalities in all mountain ranges in southwestern Canada: **Whistler Mountain on 3 December** (page 45) and **Phalanx Glacier on 16 December** (page 48) in the **Coast Mountains, Schaeffer Bowl on 12 December** (page 46) in the **Rocky Mountains, Bone Creek on 13 January** (page 51) in the **Monashee Mountains, and Lang Creek on 2 February** (page 54) in the Purcell Mountains. After a period of dormancy, the November facets became active again in the spring months when wet slabs released on the weakness due to the warmer temperatures and/or large cornice triggers. The last avalanche fatalities related to this deep persistent weak layer occurred in **Lang Creek on 30 March** (page 65). The weather during the first half of December was characterized by steady snowfall at normal temperatures.

The first avalanche accident of the season occurred on **Whistler Mountain on 3 December** (page 45). There was no direct avalanche involvement, but the case was classified as an avalanche accident since the victim fell over a cliff after losing control when snowboarding on the hard November crust bed surface of an old avalanche. While the northern Rockies remained fairly dry, the snowpack in the central and southern Rocky Mountains was above average. Wind transport contributed to the formation of wind slabs on lee slopes and resulted in widespread natural avalanche activity in the Banff and Kananaskis areas. After the natural avalanche activity had tapered off, the first fatal avalanche accident related to the November facets occurred at **Schaeffer Bowl on 12 December** (page 46) in Yoho National Park.

Between 1 and 15 December, total accumulation of new snow at Whistler Roundhouse (1835m) was 166cm. While moderate to strong wind from variable directions led to the development of new wind slabs, the November facets remained the primary concern. The next fatal avalanche accident on the November facets occurred in the Coast Mountains on **Phalanx Glacier on 16 December** (page 48). While the facet-crust combination was too deep to be skier-triggered in most places, the accident avalanche was triggered from a shallow area.

In the second half of December, temperatures steadily decreased as southern BC and Alberta increasingly came under the influence of the arctic air mass. The ridge of high pressure deflected the Pacific storms to the south, which resulted in generally clear skies in the northern parts of the mountain ranges and some precipitation along the border. The arctic air mass started to retreat on 28 December, which was accompanied by a dramatic increase in temperature (approximately 20°C in three days) and significant snowfall across all three mountain ranges. At Parker Ridge (2023m), for example, overall accumulation over the last three days in December was 40cm. This was the first significant snowfall in the northern Rockies since mid-November. This dense slab was now sitting on top of the low density facets and isolated surface hoar that developed during the influence of the arctic air mass. This snowpack configuration resulted in poor stability and a significant avalanche cycle across all mountain ranges in southern BC and Alberta during the first part of January.

In mid-January, the area came under the influence of a strong ridge of high pressure, which brought clear skiers, warm days and crisp nights. While the warmer temperatures were promoting the bonding at the bottom of the recent storm snow, the mid-November facet-crust combination continued to produce large avalanches. However, while no human-triggered avalanches were observed on this deep persistent weak layer in the North Columbia Mountains since 22 December, another avalanche fatality occurred related to this weak layer at **Bone Creek on 13 January** (page 51) where it was triggered from a shallow area.

While the stability of the snowpack generally improved in this period, the fair weather also resulted in the widespread development of the first persistent weak layer of surface hoar and sun crusts. These surfaces were buried by the next storm, which brought a total of 100cm of new snow at Mt Fidelity between 16 and 23 January. The considerable load of new snow resulted in a significant avalanche cycle that included the new surface hoar interface as well as the November facets.

This period was followed by another push of arctic air that resulted in the third significant cold snap of the season. This period of cold and clear weather led to the development of yet another weak layer of surface hoar and near-surface facets in the Columbia Mountains. Similar to the previous cold periods, the end of this cold snap was marked by a rapid increase in temperature, freezing levels rising to 1000 to 2500m depending on the area, and strong westerly winds. This combination of conditions resulted in a so-called "upside down" snowpack and led to widespread natural avalanche activity that involved all existing persistent weak layers. Another fatal avalanche accident involving the November facets occurred towards the end of this storm in **Lang Creek on 2 February** (page 54).

The beginning of February was characterized by an extended period of fair weather. The ridge of high pressure brought clear, cold and calm weather to all of southern BC and Alberta. Significant fluctuations in the diurnal temperatures and a temperature inversion in the Coast and Columbia Mountains provided perfect conditions for the development of a third layer of surface hoar crystals, near-surface facets and sun crusts. In the South Columbia, surface hoar up to 10cm was observed in sheltered areas adjacent to cut blocks at treeline. This surface was buried on 11 February when the next low pressure system arrived at the Coast Mountains. Within this storm, a fatal avalanche accident occurred on **Mt Strachan on 12 February** (page 56), just outside the Cypress Mountain ski area. The failure plane of the avalanche in this accident was surface hoar on a pencil-hard rain crust that developed during the warm winter storm on 29 January. This was the first fatal avalanche accident of the season that was not related to the November facets.

The storm that buried the 11 February surface hoar layer lasted until 16 February and concluded with a significant spike in temperature due to strong southerly winds in the Coast and Columbia Mountains, and Chinook conditions in the Rocky Mountains. The combination of new snow and above-freezing temperatures resulted in widespread natural avalanche activity. While conditions seemed to stabilize in the Coast and Rocky Mountains during the subsequent period of cooler temperatures (17 to 22 February), avalanche conditions remained touchy in the Columbia Mountains. Between 22 and 25 February, wet surface layers developed on southerly aspects and at lower elevations due to another period of clear weather and above normal temperatures. A gradual cooling trend towards the end of February produced a melt-freeze crust that was eventually buried around 27 February. Convective storm activity continued into March and resulted in highly spatially variable snow accumulation. The avalanche in the fatal accident at **Mine Creek on 9 March** (page 58) slid on the melt-freeze crust that developed during warm period of 22 and 25 February.

Conditions remained unsettled in March with strong winds and slightly cooler temperatures as BC and Alberta was under the influence of the arctic air mass again. Wind and storm slabs were the main concerns during this period of convective snowfall. Temperatures rose again on 17 March as a powerful "Pineapple Express" arrived in southern BC bringing significant precipitation to all mountain ranges—72cm at Whistler Roundhouse on 17 March, 41cm at Mt Fidelity and 47cm at Parker Ridge on 18 March. While this storm resulted in a distinct spike in the snowpack height at higher elevations, it also pushed freezing levels above 2000m and brought significant amounts of rain to lower elevations. The combination of warm temperatures, strong winds and heavy precipitation resulted in very poor stability and an extensive avalanche cycle with many large avalanches.

At the tail end of the storm, there was a fatal avalanche accident in the Selkirk Mountains on **Mt Jowett on 22 March** (page 62). The accident avalanche was a persistent slab that released on a layer of rounded grains and faceted crystals and slid on a sun crust that most likely developed during the period of fair weather earlier in March.

Winter conditions prevailed and March concluded with a week of unsettled westerly flow with normal temperatures, continuous snowfall and moderate to strong winds, which produced new wind slabs and large cornices. Avalanche activity remained serious and another fatal avalanche accident occurred in **Lang Creek on 30 March** (page 65). The accident investigation revealed that the accident avalanche initially failed on the crust interface created by the recent "Pineapple Express," but stepped down into deep persistent weak layer of the November crust-facet combination once the slab was in motion.

Conditions settled into a more typical spring pattern at the beginning of April. After the passing of a cold front, an extended period of fair weather with mild daytime temperatures promoted the settlement of the snowpack. However, below-normal nighttime temperatures preserved the winter character of the snowpack at higher elevations, while radiation effects were observed on solar aspects and isothermal conditions dominated the snowpack at lower elevations. At this point, cornice failures were reported to trigger avalanches on the November facets again.

More normal temperatures and the occasional rain to mountain tops in the second half promoted the final transition into a spring snowpack.

The last fatal avalanche accident of this year occurred on **Mt Robson on 9 July** (page 67) and involved a falling serac that triggered a large loose snow avalanche. While it is known that the sky was overcast and the air temperature was well above freezing at the time of the accident, detailed information about the weather prior to the accident is not available.

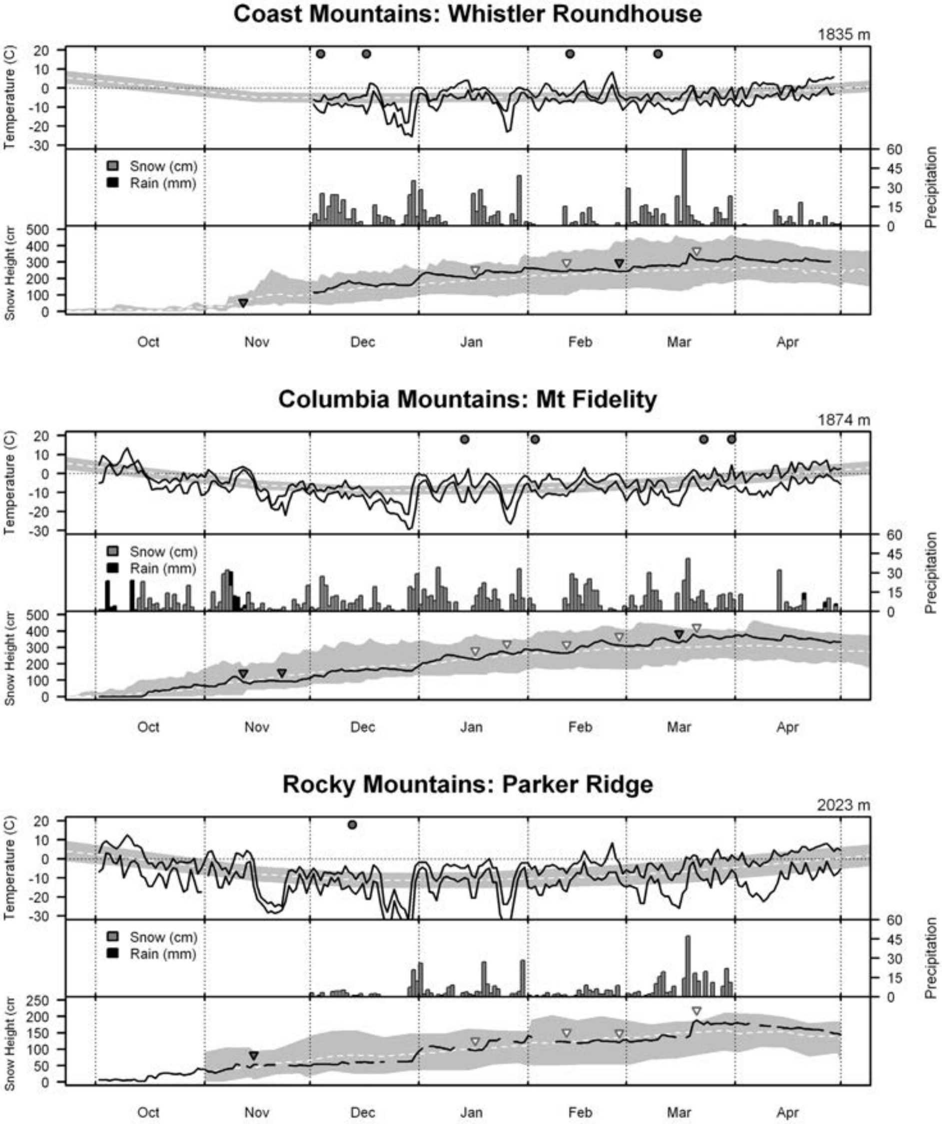

Figure 4.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 1996/1997 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanches (black triangles). Other persistent weak layers are shown with light triangles. The grey band shows minimum, average (dashed line) and maximum snowpack height measures at this location since 1976 (Whistler Roundhouse and Mt Fidelity) or 1978 (Parker Ridge).*

3 December 1996, Lift Snowboarding in Permanent Closure Whistler Mountain, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **No direct avalanche involvement**
- **Victim fell on an old bed surface, then over a cliff**

The weather on 3 December 1996 was sunny, approximately -10°C, with 10cm of fresh snow. Since the avalanche bulletins of that season did not start until 12 December, there is very little information available about the general avalanche conditions that existed at the time.

At approximately 11:20, a group of three friends disembarked from the Peak Chair on Whistler Mountain. They traversed along the northwestern ridgeline to an area known as the "Hanging Roll," a convex slope that leads to a series of cliffs above the West Bowl of Whistler Mountain. The area is within the ski area boundaries, but roped off as a permanent avalanche closure due to the seriousness of the terrain and the fact that avalanches from this area can affect secured ski runs below.

At 11:45, the group crossed over the roped-off area and one of the group members, an off-duty lift operator, started snowboarding down the convex slope. On his way down he came across the remains of a previous avalanche from avalanche safety control work in the area. After dropping over the 1m high fracture line, he lost his balance during the landing and started sliding on the hard bed surface. Most likely, the old avalanche ran on a layer of facets on top of a rain crust that developed after the considerable rain event on 11 and 12 November. Unable to stop himself on the hard bed surface, he fell over the cliff at the bottom of the convex slope and tumbled down through the old avalanche debris for about 300m before coming to rest in the West Bowl.

Two skiers who witnessed the fall quickly rushed to the site to offer their help. As they found the victim badly injured and with no pulse, one of them initiated CPR, while the other left the scene to notify the ski patrol. Ski patrollers, including a doctor, arrived at the scene at 12:20. Despite all their efforts, the victim succumbed to his injuries.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalaches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Cliffs	Unsupported convex roll	Open alpine slope

Source
- BC Coroners Service
- Whistler Mountain Ski Patrol
- InfoEx

Comment

This accident occurred in a permanent avalanche closure. These are areas within the ski area boundary that are never open for skiing or snowboarding as they contain serious hazards that may also threaten others on runs below. Skiing in permanent closures is different from skiing out-of-bounds. While most ski areas in Canada have an "open boundary" policy, people caught riding in permanently closed areas will, at minimum, have their lift privileges revoked.

12 December 1996, Backcountry Skiing Schaeffer Bowl - Lake O'Hara, Yoho National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Travelling alone without a partner**

A party of two backcountry skiers was staying at the Elizabeth Parker Hut at Lake O'Hara in Yoho National Park for a week of climbing. The accident happened on 12 December, the fourth day of the eight-day trip. At approximately 14:00, the victim skied out alone from the hut towards McArthur Pass to scout out a trail for the following day's climb. Several hours later, he had not returned, so his partner set out to search for him.

Following his friend's tracks, he came across fresh avalanche debris in an area called Schaeffer Bowl approximately 30 minutes from the hut. He found his friend buried in this avalanche with one of his ski boots sticking out. After a failed attempt to dig out his partner, he returned to the hut to notify the park wardens and the RCMP. The rescue party reached the accident site the following morning at 04:00.

The weather during the week prior to the accident was characterized by a trend towards colder temperatures and considerable amounts of new snow. Light to moderate southwesterly winds redistributed a portion of the storm snow. During the night prior to the accident, 20 to 30cm of new snow fell in the area. The public avalanche bulletin for Banff-Yoho-Kootenay National Parks published on 11 December rated the avalanche danger as Considerable in the alpine, Moderate at treeline and Low below. While mentioning "several skier and explosive triggered avalanches to size 3.0 have been observed over the past 72 hours, most of the natural activity appears to be tapering off," the bulletin still cautioned recreationists about the new storm and the significant amount of snow available for wind transport.

Since the victim was travelling by himself, little information is available about the exact sequence of events at the accident site. The subsequent avalanche investigation by Parks Canada Wardens indicates the snowpack was quite thin and faceted in that area, and the victim was most likely in the middle of the slope, triggering the avalanche from below. The start zone had an average incline of 32 degrees. The size 2 avalanche failed in a weak layer of facets immediately above the 14 November melt-freeze crust, about 70cm deep.

The victim was buried under approximately 80cm of snow in the deepest section of the debris, which was located behind a small ridge that deflected the avalanche. The victim was buried lying on his back with both his poles still on his wrists. It did not appear the victim was carried by the avalanche; it likely knocked him over and buried him on the spot.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	?	27cm in the past 24 hours	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
32°	None	Concave	Open alpine slope

Source

- BC Coroners Service
- Parks Canada records
- Parks Canada Public Avalanche Bulletin for Banff-Yoho-Kootenay
- CAC Public Avalanche Bulletin for Rocky Mountains
- Mountaineering accident database of Alpine Club of Canada
- Cyberspace Avalanche Center

Comment

Even small avalanches can lead to fatal outcomes when travelling without a partner. Since the victim was only partially buried, it is quite likely that he would have been found and extricated quickly enough to avoid the fatal outcome if he had been skiing with a partner.

Ski pole straps should generally not be used in avalanche terrain, since they act as anchors and impair a victim's ability to struggle against the avalanche.

16 December 1996, Heli-skiing
Phalanx Glacier, South Coast Mountains

Deaths	Avalanche Problem	Terrain
3	Deep Persistent Slab	Complex

- **Triggering from an area of thin snowpack**
- **One dry slab avalanche sympathetic to another**

On 16 December 1996, groups of heli-skiers were skiing on the glaciers southeast of the town of Whistler, BC. In the afternoon they moved to the Phalanx Glacier about 7km east of the town.

The heli-skiing operation had been conducting daily weather, snowpack and avalanche observations throughout the winter. On this day, a guide who was not assigned to a group of skiers was making additional snowpack observations including profiles and snowpack tests.

The avalanche bulletin, issued on 12 December by the Canadian Avalanche Association, rated the avalanche bulletin for the South Coast Region as Considerable. The bulletin also noted: "The instabilities within the storm snow have begun to tighten up, but the depth of snow overlying a weak facet layer has exceeded 1 metre in some areas. This deep instability is presently reacting to explosives and could potentially be responsible for more widespread natural or skier-triggered activity with additional loading."

From 15 November to 16 December, the area had received 1.5 to 2m of snowfall with cooler than usual temperatures. Three days earlier, the guides observed that moderate-to-hard tapping was required to fracture a facet layer on a rain crust where this layer was down 60 to 130cm. Only easy taps were required to fracture the layer in shallow areas and on moraine walls. The moderate-to-hard result on the facet-crust combination was also observed on the following day.

The lead guide landed with his group of ten guests on the Phalanx Glacier. The air temperature was -6°C. He discussed the snowpack with the guide making the snowpack observations, who noted a mostly 1-finger-hard slab overlying the softer faceted layer 100 to 110cm below the surface. One of the two guides had intentionally triggered ("ski cut") a soft slab about 20cm thick, but had not triggered the deeper weak layer of faceted crystals. The lead guide instructed his guests to ski a fair distance apart and not far from his tracks.

Morning weather summary from Whistler Mountain, 1835m
7km southwest of the Phalanx Glacier

Date	Max. Temp. (°C)	Min. Temp. (°C)	Snowfall (cm)	Snowpack (cm)	Wind speed (km/h)	Wind dir.
15 Dec	-5.0	-8.0	1	165	22-54	SW
16 Dec	-4.0	-13.0	3	164	8-26	NE

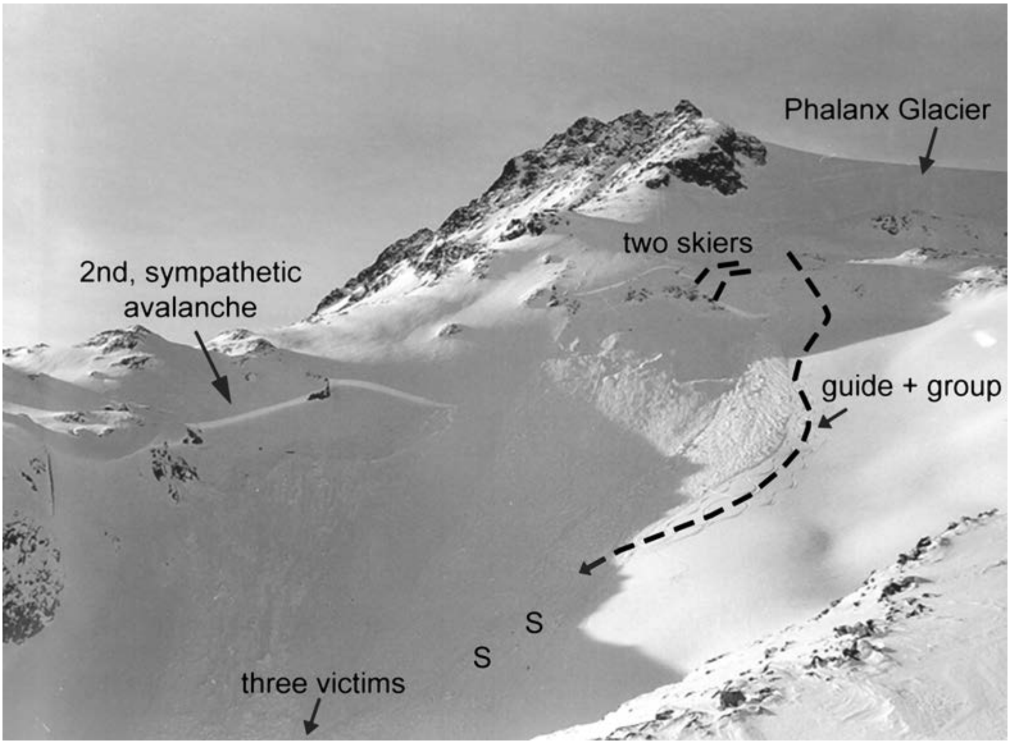

Figure 4.2. Phalanx Glacier, 16 December 1996. The first avalanche was likely triggered by the skiers who deviated to the skier's right of the guide's tracks. S – survivor. The location of the deceased skiers is just beyond the photo. Photo: Chris Stethem.

About 14:40, he skied down a gully slightly to the skier's left of a convex roll at the top of the slope. Other guests started skiing down the slope. Two guests deviated to the skier's right of the guide's tracks, encountering snow as thin as 10cm, and likely triggered the first avalanche. Some of the guests part way down the run were caught in the avalanche.

A second and larger avalanche released sympathetically to the west of the guide's tracks. The slightly bowl-shaped terrain directed this slide towards the first avalanche, which it overran in the runout zone. Two guests part way down the slope were partly buried by the first avalanche; one had minor injuries and the other was not injured. Three guests were missing.

Using the radio, the lead guide called the guide doing snowpack observations, who quickly skied to the deposit. The two guides started the transceiver search. Some guests joined the search but forgot to turn their transceivers to search mode. This caused unnecessary probing and digging, delaying the rescue. Twenty to 30 minutes after the avalanches, all three guests were recovered under about 1.6m of the deposit. All had died due to suffocation and crush asphyxia within an estimated three to five minutes. During the latter stages of the rescue, additional guides, an avalanche rescue dog and an emergency physician arrived.

The first avalanche released at 2200m on a north-facing convex open slope, which ranged in slope angle from 36° to 50° at the rocks near the crown. The crown height of the 74 m-wide dry slab avalanche averaged 50cm with a maximum of 200cm. It released on a layer of old faceted crystals on top of a rain crust. The ground was rocky.

The second avalanche released sympathetically at 2200m on a northeast-facing slope. The crown height of this 75 m-wide avalanche averaged 200cm with a maximum of 270cm. It also released on the layer of old faceted crystals on top of the rain crust. The deposit from the two avalanches was 2.5 to 4m deep and included angular blocks of snow.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes (ski-cut shallow slab)	No	Wind loading	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Convex	Alpine

Source

- BC Coroners Service
- InfoEx
- John Hetherington
- Chris Stethem

Comment

In most places the facet-crust combination was too deep to be skier-triggered. In this case, the thickness of the alpine snowpack was highly variable, and the avalanche was triggered from a thin area.

Even one searcher with a transceiver in send mode (transmitting) can confuse searchers with their transceivers in search mode, and delay the rescue. Based on the survival times estimated by the coroner, a faster search would probably not have affected the outcome.

Although it is unrelated to the deep persistent slab that killed the skiers, the skier-triggered shallow slab counts as an Avaluator Warning Sign for Slab Avalanches.

13 January 1997, Heli-skiing
Bone Creek, Monashee Mountains

Deaths	Avalanche Problem	Terrain
2	Deep Persistent Slab	Complex

- **Skier triggering from an area of thin snowpack**
- **Deep burials on a gentle slope at the base of a small cliff**

A group of 10 guests, a lead guide and a tail guide were heli-skiing in the Bone and Mud Creek valleys about 30km northeast of Blue River, BC.

The regional bulletin issued for the North Columbia Mountains four days previously rated the avalanche danger as High. It also noted: "The storm snow is not well bonded to the old surface. The crust formed mid-November, which has a layer of weak facets immediately above, is buried 1 to 2 metres down. This layer is currently at threshold and is causing a widespread [natural] avalanche cycle over the entire region. ... This instability, buried as deep as it is, often will not react to the load of one or two people, but will to larger triggers."

This large heli-skiing operation had been making and recording comprehensive weather, snowpack and avalanche observations since the start of winter.

The North Columbia Mountains were under the influence of high pressure with a temperature inversion, i.e. warm afternoon temperatures were reported in the alpine zone. A sun crust was reported on some south-facing slopes. At the weather station, elevation 1900m, located 22km to the west of where the group was skiing, there had been no snowfall for at least three days, and the air temperatures had ranged from -3 to -10°C. In the Mud Creek area, wind was moderate from the northwest on 11 January and light on 12 January.

On the day before the accident and one valley to the east, three size 2.5 to 3 natural slab avalanches were reported on north, northeast and south aspects, releasing on the November facet layer at about 2600m. Other older natural avalanches were also reported to have released on the November facet layer. There were no recent reports of human-triggered avalanches or whumpfs on this layer.

For the last run of the day, at 15:30, the lead guide selected a south-facing run that traversed under a large rock outcrop and above a smaller cliff before skiing down a slope to the east of the small cliff. He instructed the guests to ski one at a time for the traverse. The tail guide heard there had been an avalanche and moved onto the traverse at the same time as two guests were traversing.

After the lead guide arrived with the sixth guest at the base of the slope, he saw a size 1.5 slab that had been triggered, "probably by the sixth guest." He prepared to call the tail guide on the radio to advise him to ski to the west with the remaining four guests, away from the area of the small avalanche. He then saw the tail guide and two guests already traversing eastwards above the small cliff. Their tracks were slightly below the tracks from the first part of the group. A deeper slab avalanche released from the slope they were traversing and carried the tail guide and two skiers over the small cliff. The remaining two skiers were to the west of the avalanche and were not caught.

The lead guide called for assistance from the other guides and helicopters operating

Figure 4.3. *Bone Creek, 13 January 1997. Traverse tracks near thin snowpack overlying rocks. Photo: Phil Hein.*

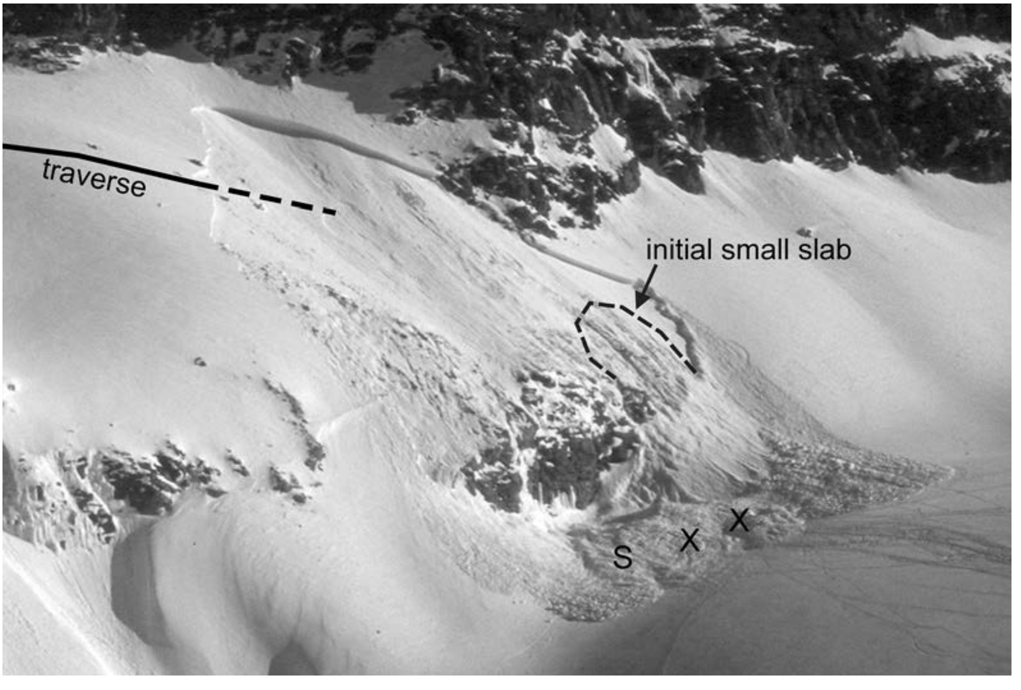

Figure 4.5. *Bone Creek, 13 January 1997. S – survivor. X – deceased. Photo: Phil Hein.*

in the area. He organized the remaining skiers in his group to search the deposit at the base of the small cliff with transceivers. All three transceiver signals were pinpointed within five minutes. Other guides and three physicians soon arrived by helicopters and joined the search. One guest was found buried under 50cm of the deposit; another under 250cm. The tail guide was also found under 250cm of the deposit.

The guest buried the shallowest survived. The deeply buried guest was flown to Blue River where he was pronounced dead; he had asphyxiated. The tail guide died in hospital six days later of brain trauma due to asphyxia.

The dry slab avalanche released at the elevation of the traverse, approximately 2500m. The slope angle in the start zone varied from 32 to 42° and averaged 37°. The crown height varied from 30 to 260cm and averaged 120cm. The crown was 130m wide. The crown and snowpack were thinner in the western part of the start zone. Where the ski tracks entered the slope, the height of the crown varied from 30cm to 65cm. The avalanche ran down the slope for 215m and fell approximately 130m vertically. On the gentle slope at the base of the small cliff, the deposit was approximately 30m long by 150m wide. The estimated average and maximum depths of the deposit were 2.5m and 5m. It was a size 3 avalanche.

After the deep slab avalanche, two cracks were observed west of the start zone, indicating that the fractures spread along the weak layer outside the start zone. No evidence of the first and smaller avalanche remained after the larger avalanche.

The fracture that released the slab spread along the top of the faceted layer that was buried around 22 November 1996. The rain crust that lay under the faceted layer in many areas of the North Columbia Mountains was not apparent at this location and elevation. The grains in the weak layer consisted of 2-3mm faceted crystals and depth hoar. Along the crown, the hardness of this layer varied from four-finger to one-finger (4F to 1F).

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	No	No	Yes on sunny alpine slopes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Cliff	Planar, but unsupported	Alpine terrain

Source

- BC Coroners Service
- InfoEx
- Phil Hein
- Marc Ledwidge.

Comment

The rescue was very efficient.

The November facet layer was too deep in many areas of the North Columbia Mountains to be skier-triggered. There had been no human-triggered avalanches reported on this layer since 22 December 1996 and prior to that, none since 12 December 1996. The second photo shows the tracks traversing where—prior to the avalanche—there were shallowly buried rocks. Investigators reported weak depth hoar around the rocks, which have been identified as likely trigger points in other accidents.

2 February 1997, Snowmobiling
Lang Creek, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **No transceivers, probes or shovels**
- **High avalanche danger**

On Saturday 1 February, a group of four snowmobilers rode in the Lang Creek area of the North Purcells, about 20km northwest of Golden, BC. On Sunday 2 February, they returned to the same area.

On the Thursday before the weekend snowmobile trip, the Canadian Avalanche Association issued a regular bulletin for the South Columbia Mountains, which include the North Purcells. The avalanche danger in the region was rated High, "going to EXTREME if forecast weather prevails with the next storm load over the weekend." The bulletin also noted: "There is an obvious storm instability in the snowpack. There were limited alpine observations but classic contributory factors to a poor stability snowpack are all there. The easy shears were already identified and all it needed was new load and warming to get everything moving. The two recent surface hoar layers will shear easily and with adequate propagation avalanches may release down to the 11 November crust. Around all the Columbia Mountains the 11 November [facet-crust combination] has had most erratic performance. One day it goes big near Valemount, the next day near Galena and then over to the Adamants, jumping all over. ... Travel in avalanche terrain should be avoided and stay on low angle terrain well away from avalanche slopes. Main trails in low angle terrain for snowmobiling and the ski areas have safe conditions."

The storm was less intense than forecast, depositing 10 or less centimetres of snow with little wind in the Columbia Mountains near the Trans-Canada Highway. On the weekend, the air temperature at treeline and in the alpine zone stayed below freezing.

On Sunday, after arriving at the headwaters of Lang Creek, the snowmobilers split into two pairs. One pair (called Riders 1 and 2 in this summary) chose a large northeast-facing slope. Rider 1, then Rider 2, climbed through open trees near the valley bottom then up an open slope to 2450m. At about 13:00, after pausing on top, Rider 1 started down and—

out of sight of his companion—triggered a large slab avalanche.

Rider 2 was initially unaware of the avalanche. After waiting for his companion to come into sight on the lower mountain, he started down the slope. He saw the avalanche and his friend's partly buried snowmobile but not his friend. When he reached the bottom about 20 other riders had gathered to help in the rescue.

Rider 1 was not wearing a transceiver and the searchers began to probe for him. After about two hours, they found him under 3 to 4 metres of the deposit, about 35m up the slope from his partly buried snowmobile. He had asphyxiated.

The dry slab avalanche released at 2400m elevation on a northeast-facing slope with an incline between 30-35°. The crown fracture was 1 to 3m high and 300m wide. It ran on the rain crust from November 1996, and was a size 3.5 avalanche.

It is unknown if the snowmobilers observed recent avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
30-35°	?	?	Alpine terrain

Source

- BC Coroners Service
- InfoEx

Comment

Had the victim been wearing a transceiver, it would have shortened the rescue but—given the burial depth—probably not changed the outcome.

The erratic deep slab avalanches on the November crust were widely spaced in the Columbia Mountains, representing one type of a low probability – high consequence scenario. Under these circumstances, the bulletin recommended a wide margin of safety.

12 February 1997, Out-of-Bounds Snowboarding Mt Strachan, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Challenging

- **No direct avalanche involvement**
- **Lack of communication within the accident party turned an inconsequential avalanche event into a fatal accident**

In the early afternoon of 12 February 1997, a group of three teenaged snowboarders were riding the Sky Chair to the top of Mt Strachan at the Cypress Mountain ski area. The group was expecting good powder snow, as this was the second day of a significant storm passing through southwestern British Columbia after an extended dry period. On 11 February, 43cm of new snow was recorded on Grouse Mountain, the neighboring ski area to the east. That night, avalanche control teams at Cypress Bowl used ski cutting under lights to secure the runs within the ski area, reporting easy releases whenever a slope was cut along the top.

The group started on a ski run called “Glades.” At the bottom, the run takes a sharp left and traverses back to the chair lift. The group left the ski area here for a few turns in untracked powder. The southwest-facing terrain starts as a gentle slope but quickly changes into a steep (49 °) gully in mature timber. The overall length of the slope is approximately 250m. At the bottom, the steepness decreases as the slope joins a larger bench in the Montizambert drainage.

As the first snowboarder entered the steeper part of the slope, he triggered a size 2 avalanche, approximately 35m wide and involving a large part of the gully the group intended to ride. The failure plane was a layer of surface hoar approximately 25cm down from the surface of the snowpack, at the interface of the current storm snow and a pencil-hard rain crust. This rain crust developed during a storm cycle in late January, which brought significant amounts of rainfall all the way to the top of the North Shore Mountains. On 29 January, 76mm of rain were reported on Grouse Mountain. This rain event resulted in a major avalanche cycle on the South Coast with lots of natural avalanche activity and numerous road closures.

Between 1 and 9 February, the weather was fair and the snowpack regained strength, with a solid crust developing on the snow surface. At the same time, the fair weather promoted the development of surface hoar on northerly aspects and in shaded locations. While the Canadian Avalanche Association rated the general avalanche danger for the south coast and Vancouver Island as Low on 10 February, the bulletin highlighted the ongoing surface hoar formation. It was this combination of surfaces that was buried at the beginning of the current storm.

After the avalanche had released, the second snowboarder entered the area and jumped over the fracture line onto the hard avalanche bed surface. At this point, it appears she lost control, took a hard fall and slid down on the avalanche bed surface through the mature timber. She eventually came to a stop on the bench not too far below the fracture line. However, since the terrain drops off sharply, there was no visual contact between her and the rest of the group, still at the top of the gully. However, they were able to hear her yell, and the two friends decided to go for help.

The victim continued down the gullies, even though she was not equipped for backcountry travel. She missed the snow-covered route of the Howe Sound Crest Trail—a trail frequently used by out-of-bounds skiers to return to the bottom of Cypress Mountain ski area—and descended more deeply into the Montizambert Creek drainage.

Within a short time, ski patrollers from Cypress Mountain and a team from North Shore Search and Rescue arrived on the ridge, and followed the avalanche path to the deposit. There they found tracks leading away from the deposit and down into the Montizambert drainage, a well-known catchment area for lost skiers. The tracks did not indicate the victim was injured at the time. The victim was eventually found in a severely hypothermic condition in the steep and rocky creek bed. She had apparently slipped off a log crossing the creek, sustaining a head injury.

Daylight was rapidly fading as a fast-response air-rescue helicopter was called in from Whistler Village to extricate the victim from the confines of the narrow creek bed. She remained in critical condition during the evacuation and CPR was conducted on the flight to the hospital. Within a few hours of arriving at the hospital the victim suffered a hypothermia-induced cardiac arrest and died.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Low	No	Yes	Ski patrol reported easy results whenever slopes were approached	43cm on 11 Feb and 10cm on 12 Feb	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Gully and trees	Convex	Mature Timber

Source

- CAA public avalanche bulletins for South Coast
- Cypress Mountain
- CAA press release
- SARNews article

Comment

In this accident, the triggering of the avalanche was just the first step in a series of unfortunate events. Particularly on the North Shore Mountains, rain crusts can be “rock solid” and create very challenging travelling conditions. In a fall, it is very difficult to stop on the hard, smooth surface and the surrounding cliffs and trees become serious terrain hazards.

The convoluted terrain, cliffs and dense forest make the North Shore Mountains a very challenging environment. Local search and rescue organizations recommend that if you are lost, the best way to safety is to retrace your tracks and to go up.

The lack of backcountry equipment might have contributed considerably to this accident. Even if "just" quickly ducking the ropes at a ski area, a beacon, shovel and probe are essential safety equipment for travelling in avalanche terrain, and one needs to be prepared to spend the night out if something goes wrong.

Better communication among the members probably would have prevented this accident. Unless it is really necessary, never leave a victim behind alone. If it is unavoidable, it is crucial that everyone, including the victim, knows exactly what the plan is.

9 March 1997, Backcountry Snowboarding Mine Creek near the Coquihalla Highway, Cascade Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Accident party did not have any avalanche rescue equipment**

On Saturday, 9 March 1997, three men were snowboarding near the Coquihalla Highway in the vicinity of Mine Creek, approximately 8km north of the toll plaza. From the road, the men had seen the avalanche path on the west side of the highway, and they hiked to it using snowshoes. They first followed a logging road, then ascended through the steep, wooded terrain on the climber's right of the path.

While one of the party stopped for something to eat approximately 50 vertical metres below the upper limits of the start zone (point A in *Figure 4.6*), the other two continued on foot to about 25 vertical metres above the start zone where they would have their lunch (point B). The start zone is a small bowl covered with sparse coniferous trees approximately 60m wide at the top, narrowing to 8 to 10m wide at the entrance of a steep chute. While the top of the start zone primarily faces east, the lower parts and the track face southeast.

After the break, at approximately 15:15, the lower individual snowboarded down following the southeasterly aspect of the start zone and into the confined chute below. He arrived at the bottom of the chute without incident and began waiting for his companions. About 15 minutes later, the other two entered the slope together on the far skier's right of the start zone (point C). As they crossed the convexity of the slope where the slope angle increases from 25 to 35 degrees, they triggered a soft slab that started carrying them down into the gully. One of the individuals managed to board for a short distance, but quickly lost his balance. However, he was able to grab onto a small tree still in the start zone (point D) and hold on as the avalanche flowed past, partly burying him. The other boarder was swept into the gully.

The avalanche, which was later classified as a size 2.5, consisted of a soft slab about 40m wide, varying in depth from 35 to 45cm. The avalanche ran for approximately 370m and all of the deposit was found in the lower portion of the track. The deposit was approximately 200m long, 3 to 4m deep and 10 to 15m wide. The air blast component of the avalanche broke small branches off short cedar trees up to a height of approximately 2m.

The rider waiting at the bottom of the gully managed to avoid the avalanche and waited for the survivor to come down to him. Once reunited, they searched the deposit for their lost partner. Even though they did not have any avalanche safety gear, they were able to locate the victim quickly due to a piece of cord or rope that they spotted on the surface of the snow (point E). They used their snowshoes and boards to dig for their partner, finding him under about 1.2m of deposit approximately 15 to 20 minutes after the avalanche occurred. One of the rescuers immediately applied CPR to the victim, but he did not respond to it. Lacking any resources to carry their friend's body out to the road, the two survivors decided to leave the accident scene and go for help. At approximately 16:45, the two survivors arrived at the Coquihalla Toll Plaza and requested assistance.

The highway staff at the toll plaza initiated a rescue involving the local avalanche technicians of the BC Ministry of Transportation and Highways (MoTH), the RCMP, BC Provincial Emergency Program, BC Ambulance Service and the BC Coroners Service. After establishing there was no additional avalanche risk at the accident site, a team of four MoTH avalanche technicians left the highway at 18:45 to recover the body of the victim. They returned to the highway with the body at 21:40.

The subsequent accident investigation revealed that the avalanche released in a layer of weak, faceted crystals above a 10cm thick knife-strength crust (*Figure 4.7*). This crust developed during the period of 24 to 26 February when the area experienced spring-like conditions. Maximum temperatures at Coquihalla Summit (1230m above sea level) during that period reached 7 °C, barely falling below freezing over night. That moist surface layer was subsequently buried by approximately 10cm of new snow on 27 February, accompanied by a considerable drop in temperature. The resulting strong temperature gradient at the interface between the old moist snow surface and the new storm snow caused the development of a crust with a layer of weak faceted crystals right on top.

The majority of the slab was deposited by two separate storms on 1 and 2 March and 6 to 8 March. Moderate snowfall at cool temperatures and moderate to strong westerly winds deposited approximately 40cm of new snow forming a slab above the layer of faceted crystals. On the morning of the day of the accident, 9 March, moderate snowfall was accompanied by strong to extreme west winds. Since the avalanche path was facing east, the deposition of blowing snow must have considerably contributed to the loading at the starting zone. The public avalanche bulletin published by the Canadian Avalanche Association for the South Coast on March 6 rated the avalanche danger as Considerable and highlighted the consistent shear at the storm snow interface.

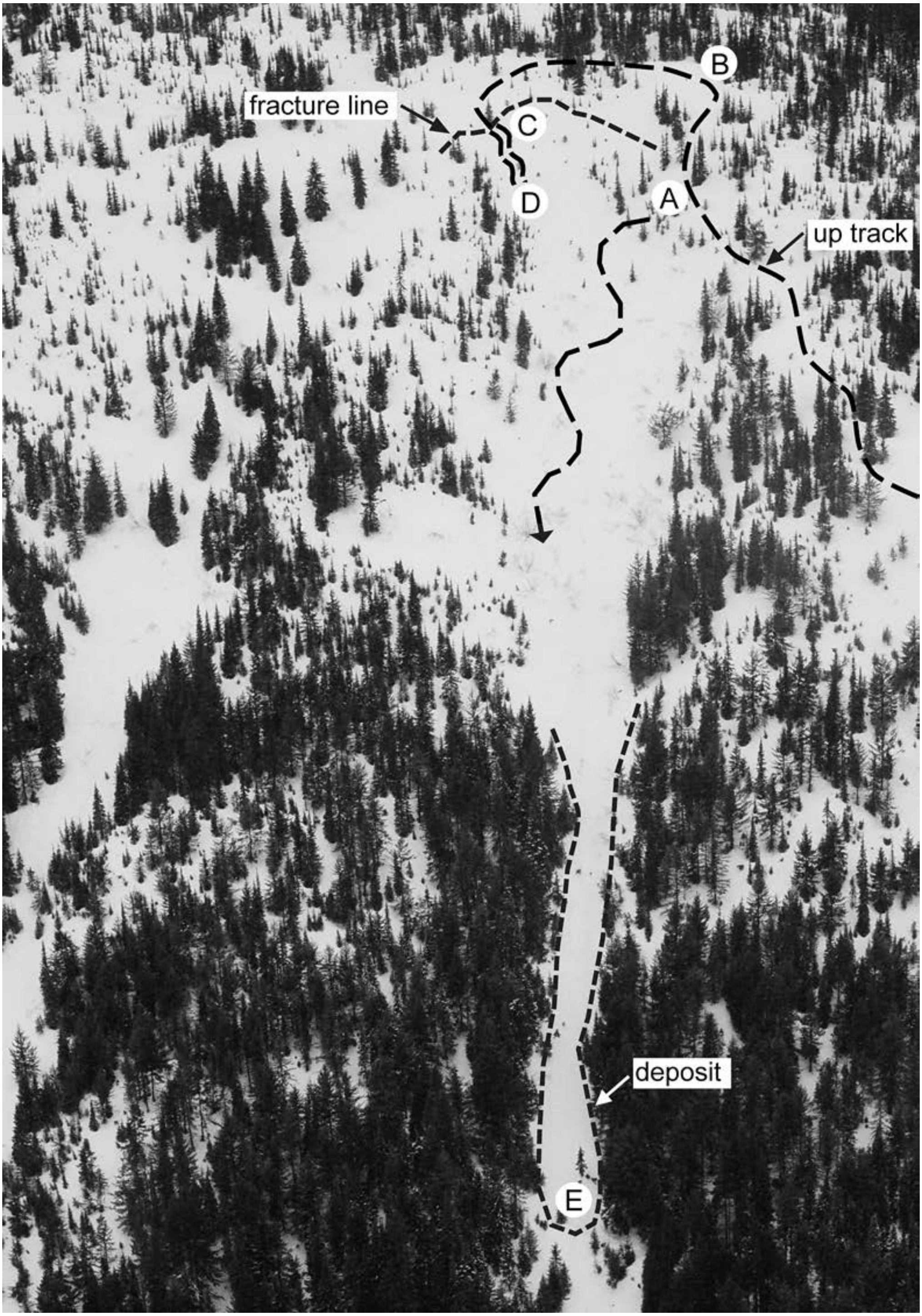

Figure 4.6. *Mine Creek, 9 March 1999. Overview of accident site. A – lunch spot of first snowboarder, B – lunch spot of second and third snowboarder, C – trigger location, D – tree where survivor was able to hang on, E – burial site of deceased victim. Photo: BC Ministry of Transportation and Infrastructure—Bill Golley.*

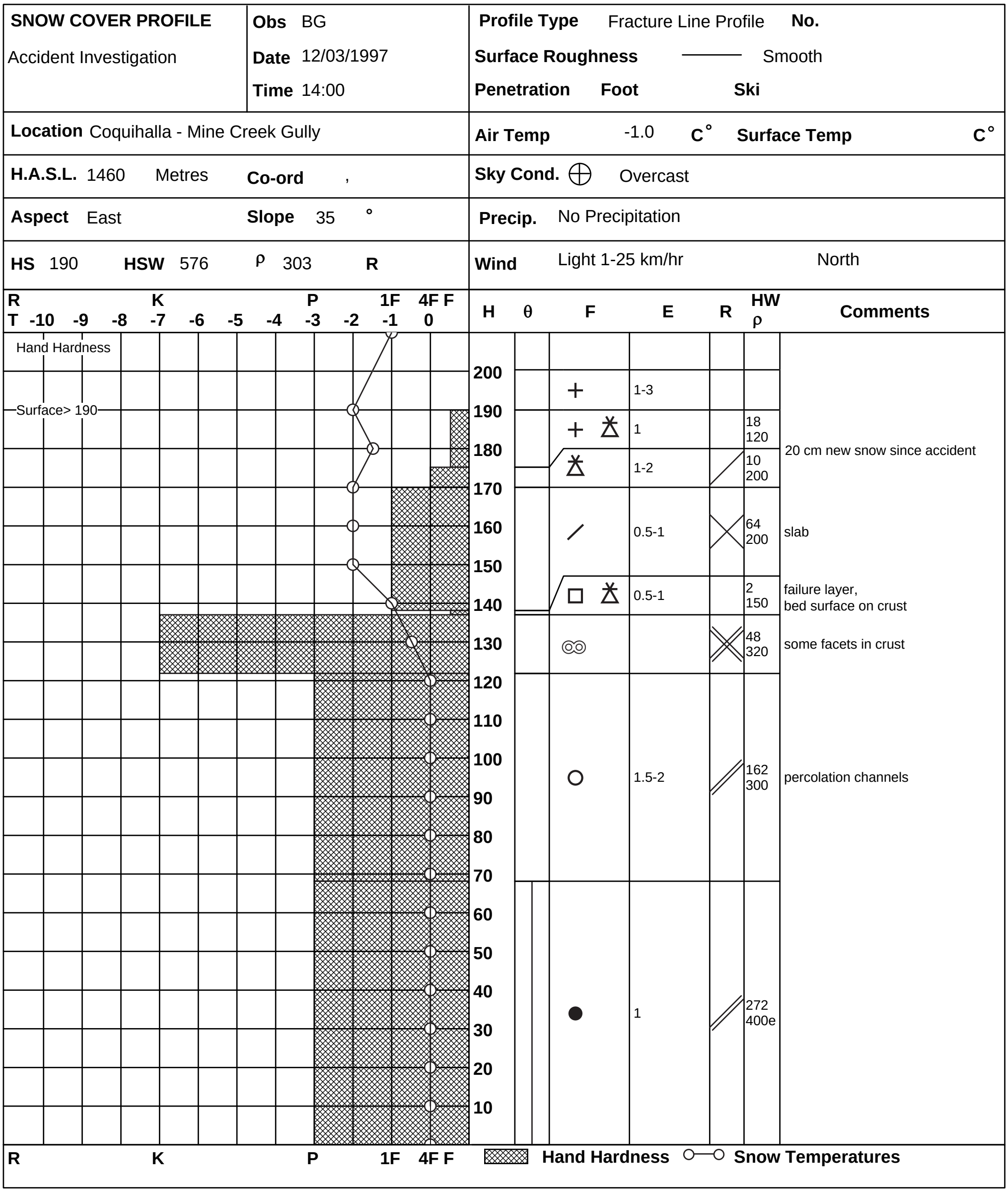

Figure 4.7. *Mine Creek, 9 March 1999. Fracture line profile taken by avalanche technicians from MoTH on 12 March 1997*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	?	30-40cm In the past 24 hours and strong winds	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Gully and trees	Convex	Path

Source
- BC Ministry of Transportation and Infrastructure
- BC Coroners Service
- Hourly weather observations at Coquihalla Summit in February and March, 1997.
- CAA Public avalanche bulletins for South Coast

Comment
In this accident, the survivors managed to quickly locate the avalanche victim due to a piece of cord on the surface of the debris. However, many avalanche victims are completely buried; searching without proper avalanche safety equipment becomes extremely ineffective. Avalanche transceivers, shovels and probes are essential safety gear when travelling in avalanche terrain.

In order to minimize the risk of multiple avalanche involvements, it is common practice to ski one at a time, while other group members wait in safe locations. This particular accident could have easily ended up with two fatalities.

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22 March 1997, Heli-Skiing
Mt Jowett, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	Complex

- **One large slab avalanche sympathetic to another**
- **Deep burials in a gully**

Two groups of about 11 guests were each skiing with a guide near the Lardeau Valley. Before 10:30, one group and then the other landed on Mt Jowett to ski a southwest-facing run.

The bulletin for the South Columbia Mountains issued on Thursday 20 March, two days before the accident, rated the regional avalanche danger as High with a reasonable expectation that the danger would drop

Weather at Galena Pass Elevation 1570m, 23km west of avalanche site					
Date	Max. Temp. (°C)	Min. Temp. (°C)	Precip. (mm)	Min. hourly wind speed (km/h)	Max. hourly wind speed (km/h)
17 Mar	-0.5	-5.0	5	1	25
18 Mar	0.5	-1.5	15	14	25
19 Mar	3.3	-0.5	18	0	30
20 Mar	2.9	-2.8	4	4	27
21 Mar	0.7	-5.0	3	3	10
22 Mar	2.2	-5.1	4	4	17

to Considerable over the weekend [22, 23 March] with cooling. The bulletin also noted: "The last storm of the winter certainly went through with a bang; every howitzer, rifle and hand charge operator was busy blowing things up and getting good results. ... Although the danger will drop if the forecast weather comes there are going to be isolated areas that may still hold the big slab that has long and deep fracture characteristics if it releases."

At this heli-skiing operation, four or five guides made daily observations throughout the winter. As shown in the table from a lower weather station 23km to the west, after a mild storm on 18 and 19 March, precipitation was light. A neighbouring heli-ski operation to the north reported rain below 2000m.

In the skiing terrain between 1500 and 3000m on 22 March, the air temperature ranged from -12 to -4°C, 4cm of new snow fell, and the wind was light from the west. On 21 March, the guides reported a remotely triggered size 3 slab avalanche on a 30° west-facing slope. It was about 90cm thick. (An avalanche is remotely triggered if the snow at the trigger point does not slide.)

The first group landed at about 2700m and skied down a southwest-facing run. Near the bottom they traversed to their right along a ramp to get to the helicopter pickup. The guide had reached the pickup site and all but two of the guests had completed the traverse and were stopped in an island of mature trees. The last two skiers were still traversing along the ramp. At about 10:30, the second group was skiing higher on the run and near the tracks from the first group. One slab avalanche released to the skier's left of the tracks from the first group, then another on the other side of the tracks. The last two guests from the first group were caught in the second avalanche. It swept them down 200 vertical metres, over two cliffs, and buried them in a gully.

A major rescue effort began, involving 17 guides from this and neighbouring operations, two physicians and an avalanche rescue dog. The recovery took about 1.5 hours for one person, and two hours for the other. They were buried 4 and 6m deep, about 17m apart. Both had died from asphyxia.

There were two avalanches that released at elevation 2400m. The height of the crown fractures varied from 30 to 100cm and averaged about 75cm. The avalanche to the skier's left was about 300m wide. The other avalanche that buried the skiers was about 500m wide and ran about 800m down the slope. It was a size 3.5.

Near the crown fractures, the snowpack was about 300cm deep. The avalanche released on a layer of 1.5mm rounded grains and faceted crystals, and slid on a sun crust. A compression test done later the same day near the crown of the first avalanche required moderate tapping to fracture the failure layer. In the area where the second group was skiing when the first avalanche was triggered, the failure layer was 30 to 50cm below the snow surface.

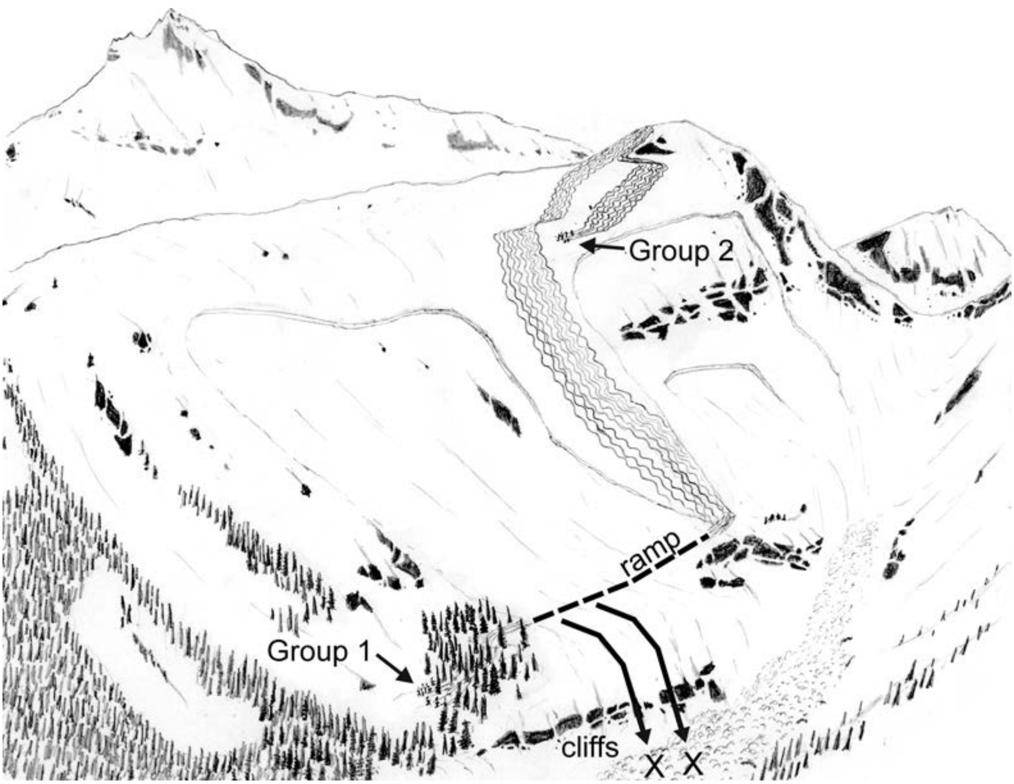

Figure 4.8. *Mt Jowett, 22 March 1997. The avalanche released while the last two guests from the first group were traversing and the second group was skiing above the main slope. X – deceased.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Cliffs and gully	?	Mostly open

Source

- BC Coroners Service
- BC Ministry of Transportation and Infrastructure weather data archive
- Chris Stethem

Comment

For people buried under four or more metres of snow, the survival rate is very low. This may be partly due to the time required to dig that deep in an avalanche deposit, and partly due to the compressive forces on the victims.

30 March 1997, Snowmobiling
Lang Creek, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **No transceivers, probes or shovels**
- **All four snowmobilers exposed in the avalanche path**

On Sunday 30 March, four friends went snowmobiling in the headwaters of Lang Creek, about 20km northwest of Golden, BC. They did not have transceivers, probes or shovels. There were other groups of snowmobilers in the area.

The day was sunny and warmer than the previous day. Nearby operations reported air temperatures in the alpine reaching freezing or a few degrees above. The snow surface became moist on south-facing slopes. The wind was moderate from the south.

Three days before the snowmobiling trip, the Canadian Avalanche Association issued a regular bulletin for the South Columbia Mountains, which includes the Purcells around Lang Creek. The avalanche danger was rated Moderate. The bulletin also noted: "Sun crusts, wind slabs and wind affected slopes are the most common surface condition in the alpine. These are sitting on a variety of deeper sun and rain crusts with fairly dense snow in between. ... Shears and deeper instabilities are not being reported but there are areas with depth hoar and these may be more of a problem with continued warming." In the two preceding days, the two closest heli-ski operations each reported wind slabs formation and several skier-controlled and natural avalanches from size 1 to 2.

At about 12:30 while the group was stopped at the base of a large, steep west-facing slope, one rider climbed up the slope. As he started down he triggered a slab avalanche, was swept down the slope and buried. The three riders at the base of the slope fled on foot. They escaped but their snowmobiles were partly buried and damaged.

Other snowmobilers in the area, including a well-equipped search and rescue group, came to help. Two riders left to get help. The others formed a line and began probing the deposit. Helicopters brought two dog teams as well as rescuers from the RCMP, Parks Canada and the ambulance service. The first dog team arrived at 15:35. Before dusk the ambulance crew was flown out. Other personnel continued searching, prepared to stay on the scene overnight. At 19:45 the victim was found by one of the search dogs, about 300m vertically below where he triggered the avalanche. He was buried 2m, about 40m up the slope from his snowmobile. Due to the long burial, resuscitation was not attempted. He had asphyxiated.

The crown fracture was at 2560m on a 35-40° west-facing slope. It was 300m wide and reached 2m in height. The avalanche fell about 300m vertically.

A witness reported an initial shallower slab avalanche and then a deeper one. The bed surface was stepped. Although no detailed fracture line profile was observed, the initial slab is believed to have released on a rain crust that formed on 20 March. The lower bed surface exposed rocks, indicating the avalanche stepped down into the weak base of the snowpack, likely sliding on the rain crust from early November. It was a size 3 avalanche.

On the day of the accident, one of the nearby heli-ski operations reported three size 2 – 3 cornice-triggered avalanches on northerly aspects; the other reported numerous size 1 – 2 avalanches due to the sun's radiation. It is unknown if the snowmobilers observed recent avalanches or other signs of instability, or if they made snowpack tests.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate	Yes	?	?	Wind loading	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Planar	Open slope

Source

- BC Coroners Service
- InfoEx
- Parks Canada report to the Canadian Avalanche Association
- Website of the Edmonton Section of the Canadian Alpine Club

Comment

Rescuers had responded to a non-fatal avalanche in a nearby drainage earlier in the day.

This fatal accident occurred within a few kilometres from another in Lang Creek on 2 February 1997.

9 July 1997, Mountaineering
Mt Robson, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Loose wet avalanche triggered by icefall	Complex

- **Icefall triggers slab avalanche which hits climbers' camp**

On 8 July 1997, a group of five mountaineers set out to climb the Kain Face route on Mt Robson in Mt Robson Provincial Park. In white-out conditions, they camped on the Robson Glacier below the dome. Apparently, they knew they were in a crevassed area below seracs (huge towers of ice between crevasses). Three climbers slept in a tent and two bivouacked nearby.

Early the next morning the sky was overcast, the air temperature was about 8°C. It was not snowing and the wind was calm.

At about 06:10, a falling serac started a large loose avalanche which hit the camp. The climbers in the tent were carried about 100m down the glacier, and not seriously injured. One of the bivouacking climbers was carried about 40m; he had broken ribs. The other was carried into a crevasse, where he landed on a snow-bridge about 12m below the surface of the glacier.

The four on the surface of the glacier searched for 1.5 hours without finding their companion. They descended to the Berg Lake Ranger Station to get help.

A ranger from Mt Robson Provincial Park flew over the area to assess the site. On the second flight, rangers landed at the toe of the avalanche and started to search upwards. Wardens from Jasper National Park responded by helicopter with two avalanche dogs. The victim was found in a crevasse not far below the suspected site of the camp. He had died of traumatic injuries.

The serac fall started the loose, wet avalanche at about 3100m on a 25 – 35° east-facing slope well above the climbers' camp. The avalanche ran out on a 10° slope at about 2800m. The deposit averaged 1m deep and reached a maximum of 2m. It was about 300m long, 75m wide and contained chunks of ice from the serac. The avalanche was rated a size 3.5.

It is unknown if the climbers heard or observed avalanches prior to the fatal avalanche.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	?	?	?	?

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
25-35° (well above climbers' camp)	Crevasse	?	Alpine

Source

- BC Coroners Service
- Parks Canada, Accidents in North American Mountaineering (American Alpine Club and Alpine Club of Canada, 1998)

Comment

The survival of a size 3.5 avalanche by 4 of 5 climbers is remarkable.

The climbers did not have transceivers. In this case, transceivers would only have made the body easier to recover.

Chapter 5

Avalanche Accidents of Southwestern Canada **1997-1998**

Winter Summary for Southwestern Canada

- **18 avalanche fatalities in 9 accidents during the main winter months**
- **Two additional fatalities outside the main avalanche season**
- **9 avalanche fatalities in three separate accidents on 2 January 1998**
- **Very mild temperatures throughout the season resulted in the rapid settlement of instabilities**
- **Small number of active surface hoar layers**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
29 Nov 1997	Near Fortress Mountain Ski Area	Rocky Mountains	Out-of-Bounds Skiing	4	Persistent Slab	15 Nov 1997	75
21 Dec 1997	Hasler Creek	Rocky Mountains	Snowmobiling	1	Deep Persistent Slab	15 Nov 1997[2]	77
2 Jan 1998	Corbin Creek	Rocky Mountains	Snowmobiling	1	?		79
2 Jan 1998	Kokanee Glacier Prov Park	Selkirk Mountains	Backcountry Skiing	6	Persistent Slab	8 Dec1997	80
2 Jan 1998	Mt Aylwin	Selkirk Mountains	Backcountry Skiing	2	Persistent Slab	8 Dec1997	84
10 Jan 1998	Ladybird Creek	Selkirk Mountains	Snowmobiling	1	Deep Persistent Slab	15 Nov 1997	85
25 Jan 1998	Stoyoma Mountain	Cascade Mountains	Snowmobiling	1	Wind Slab		88
31 Jan 1998	Round Top Mountain	Cariboo Mountains	Snowmobiling	1	Deep Persistent Slab	15 Nov 1997	90
28 Mar 1998	Ram Range	Rocky Mountains	Snowmobiling	1	Storm Slab		92
12 May 1998	Whistlers-Mountain - Jasper Tram	Rocky Mountains	Tobogganing	1	Loose Wet Avalanche		94
28 Jun 1998	Mt Edith Cavell	Rocky Mountains	Mountaineering	1	Loose Wet Avalanche		96

[1] *It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.*
[2] *Suspected*

This winter started with a mixed bag in October. After two snow storms in the first half of the month, a period of warm weather that included a significant rain event almost completely melted the existing snowpack again. However, once temperatures cooled off again, a snow storm starting on 25 October brought significant amounts of new snow to the region. By the end of the October, the snowpack at Mt Fidelity (1874m) was at 90cm, clearly above the 60cm typically observed during this time of the year.

After a few more days of snowfall in November, the arrival of a warm front on 5 November that brought 7mm of rain to Mt Fidelity marked the beginning of another warm weather period. After front passed, a ridge of high pressure established itself over BC bringing warm and dry weather to the region that lasted until 15 November. Maximum temperatures at Mt Fidelity remained above freezing for the entire period with a maximum of 8°C observed on 8 November. Due to the warm temperatures a widespread layer of wet snow developed at the surface of the snowpack. On 16 November, temperatures returned to more seasonal values and the wet layer was slowly buried by the next snow storm. At Mt Fidelity, the wet layer was first buried with 6cm of new snow on 16 November and 18cm on the following day. As the wet layer refroze, a crust-facet interface developed, which was the first significant persistent weak layer of the season. Numerous fatal avalanche accidents can be related to this weakness including near **Fortress Mountain Ski Area on 29 November** (page 75), **Ladybird Creek on 10 January** (page 85), **Round Top Mountain on 31 January** (page 90), and most likely **Hassler Creek on 21 December** (page 77).

The rest of November was characterized by continuous snowfall at seasonal temperatures. On 28 November, the Rocky Mountains received approximately 30cm of new snow with strong southwesterly winds and slowly rising temperatures. This storm significantly increased the snowpack depth in this area. The first fatal avalanche accident of the season occurred in the southern Rocky Mountains near the **Fortress Mountain Ski Area on 29 November** (page 75). The avalanche failed on a weak layer of faceted crystals above the decomposing crust layer that was formed during the period of very warm temperatures in early November.

The beginning of December was characterized by another extended dry period. While above normal temperatures were observed in the Coast Mountains, temperatures remained closer to normal in the Columbia and Rocky Mountains. This period of fair weather resulted in the development of a persistent weak layer with sun crusts on solar aspects and surface hoar in sheltered locations. In the Columbia Mountains, this development was enhanced by the wide presence of valley clouds. This snow surface was buried on 7 December when a relatively minor storm passed the region. This storm deposited 9cm of new snow at Whistler Roundhouse (1835m) and only 5cm at Mt Fidelity.

The Canadian Avalanche Association published the first avalanche bulletin for the season on 8 December. At this point, the Coast Mountains generally had a below-average snowpack due to the unusual dry periods during the fall. Besides the recent layer of surface hoar, the snowpack was well settled and exhibited good stability. As most of the storms in early December were deflected to the north, the northern Columbia Mountains exhibited an above-average snowpack, while the central and southern regions had more normal snowpack depths. The stability of the snowpack was generally good, with just enough snow covering the recent surface hoar layer. The worst conditions were found in the Rocky Mountains, which had an exceptionally thin snowpack, where wind action had caused an erratic distribution of snow patches.

After a few more clear days in the Coast and Columbia Mountains, a low pressure system from the Pacific finally brought the long awaited significant snowfall to the region. Between 14 and 17 December, 68cm of new snow were measured at Whistler Roundhouse and 74cm at Mt Fidelity. In the Rocky Mountains, the same storm brought approximately 75cm in the area of Parker Ridge (2023m) with strong westerly winds. Temperatures were initially close to the freezing point, but they returned to more seasonal temperatures as the storm progressed. While avalanche activity was limited, widespread whumpfing and cracking provided strong indications about the increased hazard related to the recently buried surface hoar layer. The avalanche fatality in **Hassler Creek on 21 December** (page 77) occurred at the tail end of this storm period. The avalanche of this accident released in a layer of faceted crystals overlying a melt-freeze crust.

While cooling temperatures prior to Christmas helped to stabilize the snowpack, the region experienced another storm with above-seasonal temperatures over the holidays. On December 28, freezing levels climbed to around 2000m in the entire region and

Whistler Roundhouse recorded 13mm of rain. While most of the precipitation was deposited in the northern part of the region, the warm temperatures and moderate to strong winds resulted in the widespread development of wind slabs and significantly stressed the existing persistent weak layers in the Columbia and Rocky Mountains. This led to a widespread cycle of avalanche activity over the New Year's holidays.

2 January was the first nice day after this storm period. Snowfall eased and temperatures started to fall dramatically as arctic air was moving into the region. On this day, the combination of sensitive avalanche conditions and increased backcountry traffic after the bad weather over the holidays led to nine individuals perishing in three separate accidents: **Corbin Creek** (page 79) in the Rocky Mountains, **Kokanee Glacier Provincial Park** (page 80) and **Mt Aylwin** (page 84) in the Selkirk Mountains. While the avalanches of the first two accidents failed on the 8 December surface hoar layer, no detailed information is available about the failure plane of the fatal avalanche in Corbin Creek.

After another brief storm between 3 and 7 January, the arctic high pressure established itself and brought the only true cold snap of the 1998 season. The arctic air mass brought clear skies, temperatures in the mid -20°C and northerly winds to the Coast and Columbia Mountains. In the Rocky Mountains, temperatures dipped down to near -40°C. This period of cold temperatures had a significant impact on the development of the snowpack. The strong temperature gradient in the upper snowpack led to the development of faceted snow crystals in the top 20 to 40cm of the snowpack. While surface hoar was growing in sheltered locations, the northerly winds resulted in widespread wind slab development in the alpine. The cold temperatures also slowed the strengthening of the existing weaknesses in the mid-pack and the November facets remained a serious concern. The next fatal avalanche accident occurred in the Selkirk Mountains in **Ladybird Creek on 10 January** (page 85). In this accident, the avalanche failed in a layer of faceted crystals under the November rain crust.

Conditions changed dramatically on 13 January when the cold snap concluded as a powerful low pressure system arrived from the Pacific. Accumulations in excess of 50cm in the first two days and gradually warming temperatures created an "upside down" storm slab on top of the weak snow surface of faceted snow crystals. This configuration led to widespread avalanche activity throughout the region. However, once the storm passed, the mild temperatures led to the rapid stabilisation of the snowpack.

After a few days of less intense snowfall, another powerful storm arrived on 23 January accompanied by temperatures close to the freezing point. The Coast Mountains received most of the snow and strong southwesterly winds produced widespread wind slab conditions. On the first day of the storm, Whistler Roundhouse reported 61cm of new snow and on 25 January a maximum wind speed of 138 km/h was observed. The resulting wind slabs became the main avalanche problem, which led to a fatal avalanche accident at **Stoyoma Mountain on 25 January** (page 88). In the interior, the storm was considerably less powerful. Mild conditions generally promoted settlement, but rain up to 1200m resulted in moist conditions at low elevations. While precipitation eased during the last few days of January as a new ridge of high pressure established itself, strong winds continued to build wind slabs in the alpine. Recent storm snow layers were bonding well, but the deeper instabilities were unaffected and remained a concern. The next avalanche fatality occurred on **Round Top Mountain on 31 January** (page 90). While the avalanche was a result of a failure on a layer of surface hoar that was likely buried after the cold snap in early January, most of the bed surface consisted of the now faceted melt-freeze crust from November.

February started with a short-lived ridge of high pressure that lead to the formation of a new layer of surface hoar in sheltered locations and sun crusts in open areas. After this short period of fair weather, the conditions in February were primarily driven by the passing of a series of Pacific disturbances. While the Coast Mountains received significant amounts of snow, the interior ranges only saw light to moderate amounts as the low pressure centres of these disturbances tracked mainly either to the north or south of the region. The three main pulses of storms occurred on 10-12, 17-18, and 20-21 February. While strong winds contributed to direct action avalanche activity during the storms, storm snow instabilities generally settled out quickly due to mild temperatures. At the same time, the early February surface hoar became more reactive as the overlaying slab was setting up. At lower elevations, the mild temperatures resulted in an isothermal snowpack. After the last storm, temperatures were cooling off again and a period of clear weather allowed the formation of the next surface hoar layer across the entire region.

The new surface hoar was buried by a storm in the first days of March. Contrary to the flow pattern earlier in the season, the storms in March arrived from a more southerly direction bypassing the Coast Mountains and bringing most of the precipitation to the southern part of the region. An arctic ridge of high pressure east of the continental divide resulted in generally colder temperatures, particularly in the Rocky Mountains, during the first few days of March. This short period of cold and clear weather resulted in another layer of surface hoar in the Coast and Columbia Mountains. The influence of the arctic air concluded on 7 March when the next warm front arrived raising the freezing levels again and bringing light rain up to 1200m.

By 19 March, continued fair weather, mild temperatures and light winds transformed the alpine snowpack in the Coast and Columbia Mountains into a spring snowpack. In comparison to other winters, this transformation occurred approximately two to three weeks earlier. At the same time, the southern Rocky Mountains experienced a major last winter storm that brought 60cm of new snow to Nakiska and 20 to 25cm to Sunshine Village.

The last snow storm in March affecting the entire region arrived with a cold front that brought temperatures below freezing again. It created a well-developed winter slab that was sitting on a variety of spring surfaces including crusts and surface hoar. This configuration resulted in widespread avalanche activity and numerous involvements were reported to the Canadian Avalanche Association. One of these involvements resulted in a fatality in the **Ram Range on 28 March** (page 92).

Early April was primarily characterized by episodes of heavy convective precipitation and breaks in between them. Surface conditions included new surface hoar, heavy powder, corn and crusts. While some of the new instabilities were of concern for backcountry travellers, the late winter mid-pack was generally well settled.

During this avalanche year, two of the fatal accidents occurred outside of the main winter months. One of them was related to a wet loose avalanche that was triggered in an isothermal snowpack by somebody tobogganing on **Whistlers Mountain in Jasper on 17 May** (page 94). The second summer fatal avalanche accident happened while a mountaineering party was descending along the east ridge of **Mt Edith Cavell on 28 June** (page 96). In this accident, one of the climbers triggered a wet loose avalanche while glissading down an isothermal snow slope in the late afternoon. He was unable to arrest himself and fell down a gully.

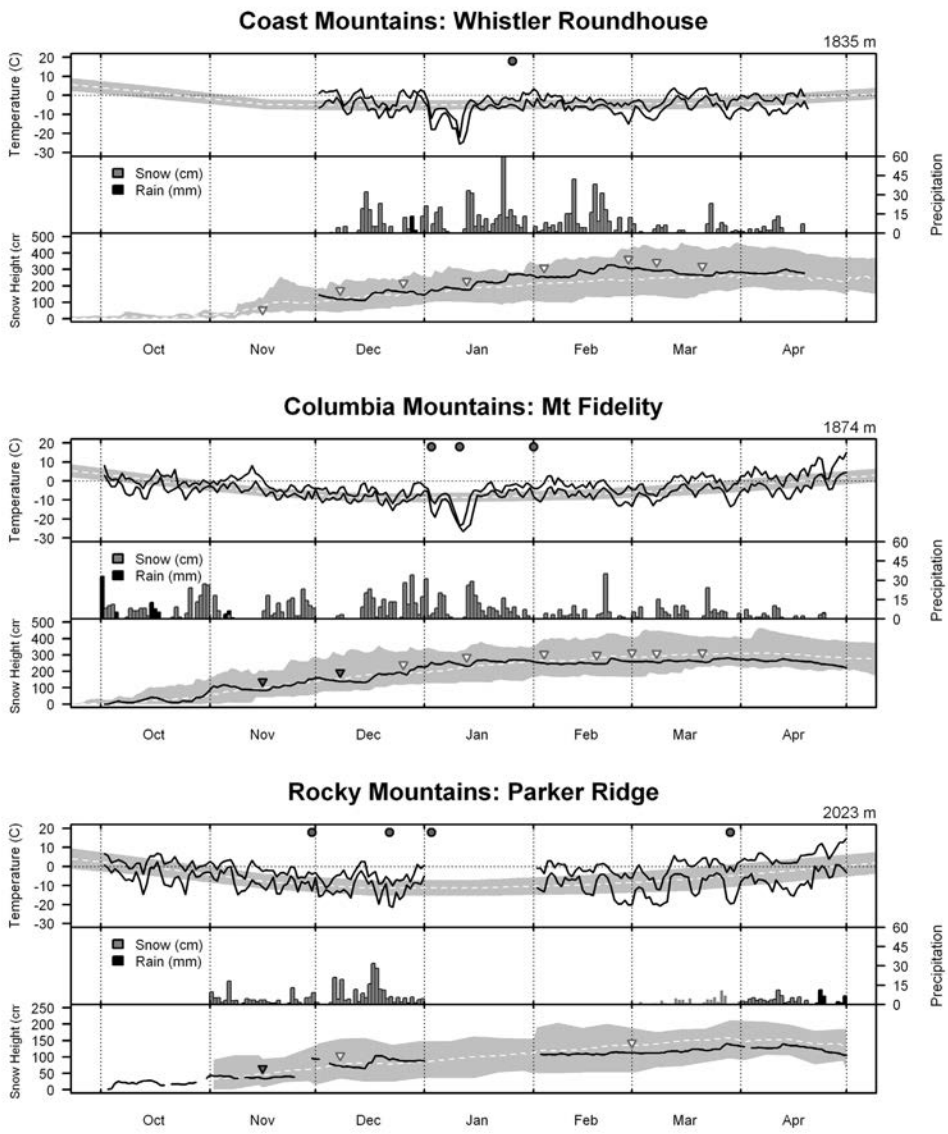

Figure 5.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 1997/1998 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanches (black triangles). Other persistent weak layers are shown with light triangles. The grey band shows minimum, average (dashed line) and maximum snowpack height measures at this location since 1976 (Whistler Roundhouse and Mt Fidelity) or 1978 (Parker Ridge).*

29 November 1997, Out-of-bounds Skiing and Snowboarding Near Fortress Mountain Ski Area, Kananaskis Country, Rocky Mountains

Deaths	Avalanche Problem	Terrain
4	Persistent Slab	Complex

- **Backcountry accessed from closed ski area**
- **Early season snowpack highly variable in depth**
- **Recent wind loading**
- **Triggered from area of thin, weak snowpack**

While staff and ski patrol of the Fortress Mountain ski area in Kananaskis Country west of Calgary were busy preparing to open the hill for the season, four teenagers arrived at the parking lot eager for some early season turns. They set out from the base on foot, carrying their skis and snowboards, and climbed the main ridge of the ski hill. They rode down a backside run of the ski area, and arrived at the base of a large, open scree slope leading up to an alpine rock face. An isolated pocket or pillow of deep snow had built up on part of the scree slope. The pillow likely looked like it held some good riding, considering that the snow around it was barely boot-deep.

The public avalanche bulletin valid for 29 November, issued by Kananaskis Country Public Safety forecasters, called for caution on steep lee or cross-loaded slopes in the alpine because they might hold wind loaded snow; however, the danger was generally Low as there was not enough snow to avalanche in most places.

The week leading up to 29 November had been windy and snowy, and temperatures were on the rise. A valley-bottom weather plot located to the west of Fortress recorded 12cm of storm snow on the morning of 29 November, which doubled the amount of snow on the ground. A further 4cm of storm snow fell through the day, and the temperature had not dropped below -2°C since the day before. Another nearby weather station located at 2540m in the alpine recorded slowly rising temperatures and moderate to strong winds over the previous week, with the highest temperatures of the second half of the month recorded on the afternoon of 29 November (-1.8°C).

It is unknown if the skiers/snowboarders were making any snowpack observations other than searching for good riding. There were no signs of avalanches in the area.

They were climbing as a group near the midpoint of the slope when they reached a small rise formed by the scree beneath the snow. Recent winds had scoured and thinned the snowpack on top of the rise to the point where it could not support the weight of the teenagers, and their boots punched through to near the base of the snowpack, starting a fracture along a weak layer of faceted snow on top of a buried crust. The fracture propagated into the thicker parts of the large pillow, reaching all the way to the base of the rock face above, releasing a large slab avalanche that swept them down the slope.

Family members reported the teenagers overdue when they didn't return home, and searchers from the ski area and Kananaskis Country Park Rangers were notified. Late in the day, they discovered tracks leading toward the ski area boundary. By that time, it was nearly dark and the weather was poor, so the search was suspended. At first light, public safety staff from Kananaskis Country searched the area by helicopter, and noticed a recent slab avalanche in the bowl beyond the ski area boundary. They searched for clues on the surface of the deposit and noticed what appeared to be a ski near the midpoint of the slope, and a part of a snowboard near the toe of the deposit. Several searchers were dropped near the deposit and made their way toward the snowboard. A Parks Canada search dog team met them there. The dog indicated near the snowboard, and one of the buried teenagers was pinpointed by probing. The dog continued to indicate in the same area, and the other three members of the group were discovered within 2m of the first. All had died in the avalanche.

The size 2.5 slab avalanche appears to have been triggered by the group from an area of thin snowpack hidden in an isolated pocket of deep snow, on a 40° northwest facing slope at 2290m elevation. It was 100m wide, and ran about 200m down the slope. The thickness of the slab ranged from 20cm on the slope near the trigger point, to almost 2m thick along the crown and upper flanks.

The avalanche slid on a weak layer of faceted crystals resting on a decomposing crust layer near the ground. The crust formed on the surface during a period of very warm temperatures earlier in November, and was buried by subsequent snowfalls. The early season snowpack was generally thin and weak throughout the area, but significant amounts had been loaded into specific terrain features by strong winds. A snow profile observed on the fracture line showed over 2.6m of snow on the ground there, while beside the pillow the snowpack was less than 25cm thick. The warming that occurred on the afternoon of the accident was not pronounced, but at high elevations temperatures were the warmest they had been for over two weeks.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Low	Yes	No	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
40°	None	Convex	Open slope

Source

- George Field
- Environment Canada - Climate Archive

Comment

Early season turns are hard to resist, especially after a snowfall. Unfortunately, large and dangerous avalanches can and do occur in the early season, even near ski resorts where it may seem safer.

In the fall when most slopes have little or no snow, dangerous avalanches can and do occur in isolated terrain features with thicker snow. Many years of experience in avalanche terrain is required to effectively assess the safety of these features.

21 December 1997, Snowmobiling
Hasler Creek, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Challenging

- **Party of three snowmobilers all caught on the same slope**

On Sunday 21 December 1997, a group of three snowmobilers was riding in the Hasler Creek area about 40km southwest of Chetwynd, BC. Including other groups, there were about 20 snowmobilers in the area. The sky was overcast, it was snowing about 1 cm/h, the air temperature was about -4°C and the wind was moderate.

There was no avalanche bulletin for this part of the Rocky Mountains in the winter of 1997-98. At the Pine Pass Snow Pillow, elevation 1386m, located 40km to the west, about 130mm of snow water equivalent had fallen in the previous week. The air temperature had ranged between -2 and -9°C. On 21 December, the air was cooler, ranging between -13 and -9°C, and about 24mm of snow water equivalent fell.

At around noon, the three snowmobilers were highmarking on a northeast-facing slope. A large slab avalanche released when one rider was crossing the upper part of the slope, one was in the middle of the slope and one was low on the slope. The two riders who were higher on the slope were caught, thrown from their machines and partly buried; they were able to free themselves from the deposit. After the avalanche, the rider who had been lowest on the slope could not be seen.

Other snowmobilers from the area came to help probe for the buried rider. In total about 15 snowmobilers were involved in the search, which lasted about three hours that day. They found the victim's snowmobile but did not locate the buried rider.

That night the RCMP and Jasper Park wardens prepared to respond with avalanche search dogs. Snow and wind delayed the response. The man was found at noon on 24 December by the search dogs. He was under 3m of snow, against a tree and about 17m upslope from his snowmobile. He had asphyxiated.

The start zone was a 35° northeast-facing rocky slope, just below the ridge at 2035m. The avalanche exposed rocks near the crown. The crown fracture of the hard slab was about 200m wide. Its average height was over a metre with a maximum height of about 3 metres. It released in a layer of faceted crystals overlying a melt-freeze crust. The deposit from the size 3 dry slab avalanche contained a few broken trees. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

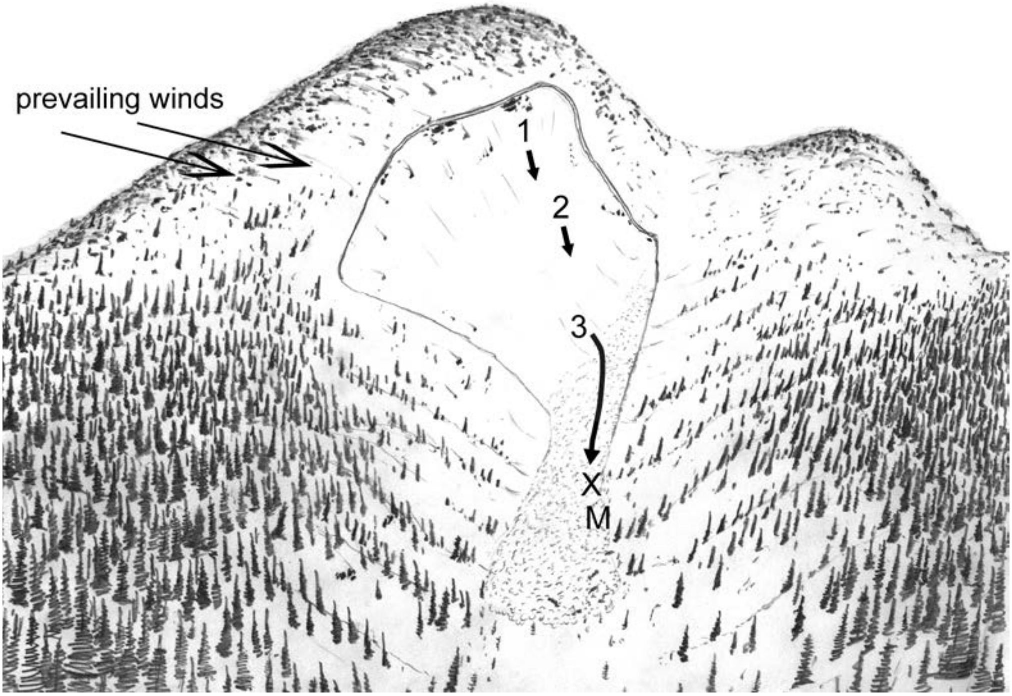

Figure 5.2. *Hasler Creek, 21 December 1997. Snowmobilers 1 and 2 high on the slope were able to escape the avalanche. X - deceased, M - machine.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Gully	Convex	Open slope

Source

- BC Coroners Service
- BC Ministry of the Environment Data Archives
- Will Devlin

Comment

Few people survive such deep burials. Transceivers would have sped the search but probably not affected the outcome.

2 January 1998, Snowmobiling
Corbin Creek, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	?	?

- **Four snowmobilers caught during highmarking**
- **A fully buried person found alive with transceivers**

On Friday 2 January, the warm storm from New Year's Day had left fresh snow in the mountains. As arctic air pushed into the area, four snowmobilers went riding at the head of Corbin Creek about 17km south of Sparwood, BC.

The previous day, the Canadian Avalanche Association issued a bulletin for the Rocky Mountain region, which includes the Corbin Creek area, rating the avalanche danger as High.

At the Morrissey Ridge Snow Pillow, elevation 1800m, located 17km south-southwest of the snowmobiling area, 30mm of snow water equivalent fell on 1 January and none on 2 January. At the Sparwood weather station, elevation 1138m, located 17km to the north of the snowmobiling area, the air temperature reached 6°C during the storm on 1 January and then plummeted to -19°C by the afternoon of 2 January. The wind was moderate to strong from the north.

The four riders were highmarking in the fresh snow. As one reached his high point and started to descend, one avalanche and then another swept down the slope burying him. His three companions lower on the slope were also caught. Two were partly buried, including one up to his chest. As these two freed themselves, they realized two of their companions could not be seen.

The two who had been partly buried used transceivers to pinpoint a signal and found a third rider alive. They could not detect a signal from the fourth rider. They began to probe for their companion.

Rescue personel arrived and joined the probing. About two hours after the avalanche, the fourth rider was found, pinned under his snowmobile and about 2.5m below the surface of the deposit. He had asphyxiated.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	?	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	?	?	?

Source
- BC Coroners Service
- Environment Canada Weather Archives
- BC Ministry of the Environment Data Archives

Comment
This is an example of transceivers being successfully used to save a life.

2 January 1998, Backcountry Skiing
Kokanee Glacier Provincial Park, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
6	Persistent Slab	Complex

- **Everyone in large group buried**
- **One victim's beacon in "search" mode**
- **Long and difficult recovery operation**

The Silver Spray cabin is located high up on the slopes of Sunrise Mountain, at about 2400m elevation in Kokanee Glacier Provincial Park, just north of Nelson, BC. A group of six backcountry skiers had arrived at the cabin by helicopter on 27 December for a week of backcountry skiing. In this group were two couples from the Nelson area, and their two friends from the coast. A cabin custodian went in to the cabin as well. The group was responsible for their own safety, but the custodian would pass along weather forecasts and avalanche bulletins, and would share snow and stability information with another cabin in the park via radio. The custodian at the Silver Spray cabin would often ski with groups staying there, but it was clear that it was not in the capacity of a guide.

After a mock rescue practice and cabin orientation on their first morning, the group explored the area close to the cabin and made some runs. For the next few days, they skied in stormy conditions, with over 25cm of heavy storm snow accumulating and building up soft slabs. On the evening of 30 December, the group at Silver Spray was informed of an avalanche involvement that morning near the other cabin in the park. A group there had triggered a size 2 avalanche at about 2000m elevation; one person was caught and partially buried but no one was hurt. The Silver Spray group had also encountered unstable conditions–they observed cracking around their skis that morning and had decided to turn around and return to the cabin.

By New Years Day a major winter storm had settled in to the area, bringing with it warm temperatures, heavy snowfall and strong winds. The skiing on 1 January was a slog with the heavy wet snow in the trees below the cabin. Winds switched to northerly overnight as cold arctic air flooded into the southern Selkirks, and the skies began to clear. On the morning of 2 January, the custodian noted that 31cm of snow had fallen in the previous 24 hours, and that an avalanche cycle had been occurring the previous day; however, the sky was clearing and the temperatures were cooling (near-freezing temperatures had been observed at treeline the previous day) and the group looked forward to a day of skiing fresh snow in the sun.

The group had been making snowpack observations and doing snowpack tests through the week as the storm snow accumulated, but had found variable results in rutschblock tests and had seen very little avalanche activity until 1 January. They were aware of several buried persistent weak layers, including a surface hoar layer from early December and a rain crust buried in November.

The Canadian Avalanche Association published a public avalanche bulletin on the evening of 1 January, which was relayed to the group at Silver Spray by radio. The custodian wrote down the details and made it available to the group. The avalanche danger would be High for 2 and 3 January, likely improving after that. The bulletin discussed a "big dump of snow to start of 1998," which was already underway in Kokanee Park. Forecasters were concerned about several weak layers buried below the recent storm snow, and mentioned that "the most dangerous layer is the December surface hoar down about 70-100cm, which in one case produced an avalanche 1km wide in the New Denver area," about 25km northwest of the Silver Spray cabin.

The big dump of snow was happening as the group read the bulletin, and by the morning of 2 January they were seeing the arrival of the cold arctic air mentioned in the weather discussion of the bulletin. The group planned to ski an area called Woodbury Glades, located on the lower slopes of Mt Woodbury, a few kilometres from the cabin. This was one of the relatively safe places to ski during bad avalanche conditions, although it was separated from the cabin area by a broad, bowl-shaped feature called Clover Basin. The plan was to traverse the lower part of the basin, staying well below the large alpine start zones at the head of the bowl.

One of the skiers decided to spend the day relaxing at the cabin, and the remaining five skiers invited the custodian to join them after agreeing to help with the chores in the evening. They skied a short distance from the cabin and stopped to dig a snow profile to check the snowpack layering and stability, then proceeded to ski one at a time down into Clover Basin to reach a low-angle bench further down. There they would regroup before starting the traverse toward their destination.

A few times during the day, the skier at the cabin tried to make contact with the group by radio, but she couldn't raise anyone. By 16:00, dusk was starting to fall and she tried the radio again. Again, the group didn't answer. She went out to have a look into the basin, and could see a set of ski tracks leading into an avalanche deposit, but couldn't make out if they emerged from the other side. At that point, she radioed the base manager for the cabin in Nelson and reported that the group of skiers was overdue.

The base manager, responsible for both cabins in the park, made contact with provincial search and rescue groups and the RCMP to notify them that there was an overdue group at Silver Spray. He also spoke with a few local guides and avalanche professionals, and asked them to be ready to assist the following day in case a rescue was required.

The skier at the Silver Spray cabin spent a long night alone, but in radio contact with the base and with the custodian from the other cabin in the park. At first light on 3 January, the base manager and another custodian made a helicopter flight toward the Silver Spray cabin, flying low over Clover Basin en route. They could see from the air that a very destructive size 3 slab avalanche had occurred there. The fracture line at the crown was almost 1km across, covering most of the width of the upper slopes of the basin. It ran through a 150m wide gap between some rocks and trees in the middle of the track, then fanned out again as it ran about 1km down the basin. It destroyed many trees in the path, and came to a stop at the bottom of the basin with a 300m wide deposit, full of broken timber and branches.

On the surface of the deposit, they could see the distinctive colour of a ski jacket or backpack. They proceeded to the Silver Spray cabin to evacuate the lone skier there, and called to the search and rescue groups staging at a nearby resort that there had been an avalanche and that people were buried.

Before any search and rescue operation could begin, explosives had to be applied to the slopes above the basin to bring down any avalanches that could threaten the rescuers. Once this was complete, two rescuers started down Clover Basin from the cabin, while others were dropped at the toe of the avalanche deposit to start searching there. On the approach, they could see a gliding traverse track that had been obliterated by the avalanche deposit. They were able to locate three of the missing skiers on the surface partially buried by the avalanche, and discovered the location of two others by following the signals from their avalanche beacons. Four had died from trauma suffered during the avalanche, and the fifth had died of asphyxiation. Four of the skiers were found near the toe of the deposit, and one was located near some small trees higher up in the track. The sixth missing skier was the hut custodian, but rescuers could find no signal from her avalanche beacon. They probed likely areas and searched with a trained rescue dog, but found no sign of her.

Late in the afternoon, all of the rescuers were removed from the scene by helicopter because of the fading light and threatening weather. On the morning of 4 January, while a significant search and rescue operation was staging at a nearby resort at Kootenay Lake, rescuers took advantage of a short window of good weather to fly up and remove the bodies of four of the skiers. They were grounded by bad weather and unable to access the site for the next two days. By the afternoon of 7 January, small groups of rescuers were able to fly to the site and do another round of explosive control to stabilize the surrounding slopes, many of which had built up large amounts of snow over the previous few days. By the morning of 8 January, the weather was clear and a coordinated rescue operation began. The body of one skier was still on the mountain, and the custodian was still missing.

With the help of many rescuers, both professional and volunteer, two search and rescue dogs and countless helicopter flights, the body of the fifth skier was removed from the site, and by early afternoon the custodian had been found, buried deeper than the others near the toe of the avalanche. She had died of severe trauma because of the avalanche. Her beacon—which had not been transmitting a signal—was found zipped under several layers of clothing but in the "receive" or search position. Given her burial depth and location in the avalanche, and the fact the beacon was still under her clothing means it was unlikely she was searching for the other skiers when a second avalanche occurred. More likely is that she inadvertently left it in the receive position after a beacon test in the morning, or that the force of the avalanche caused it to spontaneously switch positions.

The slab of the fatal avalanche was approximately 100cm thick, releasing from approximately 2600m elevation on a south-facing slope, high up in the basin. The skiers may have triggered the avalanche as they made their gliding traverse across the flat bench in Clover Basin, en route to the Woodbury Glades on the opposite side. A second, smaller avalanche also released within the basin, stopping part way down the track.

No detailed snow profiles or other measurements were made at the site; however, given the dimensions of the avalanche and reports from other local operations it is most likely that the avalanche released on the surface hoar layer buried around 8 December 1997. One rescuer noted the presence of a hard ice crust at the bed surface in the lower part of the avalanche. This could have been formed during the warm, wet storms in which rain fell at lower elevations at the end of December, or the avalanche fracture may have stepped down to a deeper weak layer above a rain crust buried in November 1997.

It is likely the heavy snow that fell toward the end of December and on 1 January had slowly settled and stiffened into a slab capable of releasing an avalanche on a number of buried weak layers in the snowpack. The critical snowpack properties appear to have been developing over a few days leading up to 2 January, as reports from nearby operations of both natural and human triggered avalanches were increasing over that period.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	Trees	Planar	Open slope

Source

- BC Coroners Service
- “In the Path of an Avalanche” by Vivien Bowers
- InfoEx

Comment

The terrain around the Silver Spray cabin was reevaluated following this accident. It was determined there were too few safe travel options during times of elevated avalanche hazard, and that there was no safe egress route from the cabin in case helicopter access was impossible. In fact, the cabin itself was at risk of avalanches from the terrain above. Because of this assessment, it was closed for winter use.

It would not have made a difference to the outcome of this avalanche, but it is always important to be sure that avalanche beacons are functioning properly and are transmitting a signal while in the backcountry. It is easy to forget to switch back to “transmit” after checking beacon function at the start of a trip.

2 January 1998, Backcountry Skiing
Mt Aylwin, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	Complex

- **Clearing weather after a storm**
- **Several persistent weak layers in the range for skier-triggering**
- **Misleading snowpack test results**

Six skiers and one dog were backcountry skiing near a rustic cabin in the Maurier Creek drainage, south of New Denver, BC. The group had investigated the layering of the snowpack and performed some snowpack tests. They decided to ski a northeast-facing bowl-like feature on the shoulder of Mt Aylwin. The group was experienced in the mountains and the local area, and several had professional avalanche training.

A remote weather station located at treeline about 20km north of Mt Aylwin recorded 22cm of new snow on 1 January and into the early morning of 2 January, on top of more than 65cm that fell between 26 and 29 December. Moderate to strong southwest winds accompanied a clearing trend with the passage of the stormy weather on the morning of 2 January, and temperatures fell from around -5°C to -12°C by the afternoon.

Two of the skiers and the dog were making their run down the bowl when a third person started skiing above, triggering a slab avalanche that overtook and buried the skiers and dog below. Members of the group were able to locate the two buried skiers within 25 minutes of the avalanche, under approximately 1m of snow on a flat bench in the path. Neither survived the burial, and the dog was not found. The avalanche was a size 2 or 2.5, and released from about 2280m elevation on a 35° slope. It was approximately 30m wide and ran for almost 400m.

The Canadian Avalanche Association's public avalanche bulletin rated the avalanche danger as High for 2 January. Forecasters were concerned about surface hoar layers buried on 8 December and 27 December. With the recent snow, many avalanches had occurred on these layers in the preceding week, including one skier-controlled slide near New Denver on 31 December that was 1km wide. The December weak layers were likely both within the top 120cm of the snowpack at Mt Aylwin, and the avalanche that buried the two skiers probably released on one of them.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	No	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Bench	Planar	Sparsely treed slope

Source

- BC Coroners Service
- BC Ministry of Transportation and Infrastructure weather data

Comment

Cool, clear days following stormy weather can make for excellent backcountry skiing but persistent weak layers lurking in the upper part of the snowpack can be overloaded by the new snow and the weight of a skier.

Point observations like snowpack tests can provide misleading results if other factors from a variety of scales are not included in a stability assessment.

10 January 1998, Snowmobiling
Ladybird Creek, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Challenging

- **Snowmobiler buried in a size 2 slow-moving slab avalanche**

On Saturday 10 January, many snowmobilers were recreating in the headwaters of Norns and Ladybird Creeks, about 24km northwest of Castlegar, BC. A group of seven snowmobilers accessed the southwest slopes at the head of Ladybird Creek. Four of them including Rider 1 had transceivers. Many were experienced.

Two days before the snowmobiling trip, the Canadian Avalanche Association issued a regular bulletin for the South Columbia Mountains, which includes the South Selkirks around Ladybird and Norns Creeks. The avalanche danger was rated High. There was a major storm from 4 to 7 January, followed by a period of cool and stable weather, with little wind. The snowmobilers were aware of the warnings from the Canadian Avalanche Association and the recent fatal avalanches in southeastern BC.

After lunch the seven snowmobilers were highmarking a southwest-facing slope. Another group of four arrived and were watching the highmarking. At about 14:30, Rider 1 made one last climb. As he was high on the slope, a deep slab avalanche released. He fell off his snowmobile and landed hard on the rocky bed surface. A second deep slab avalanche released above the first crown, carrying him down the slope. The avalanche was reported to be slow moving. When the avalanche stopped, Rider 1 could not be seen but part of his snowmobile was visible.

The riders at the base of the slope—several of whom had transceivers—soon communicated that Rider 1 had a transceiver. Those with transceivers began to search. The others began digging around the snowmobile. One person tried, with difficulty, to call for help by cell phone. About15 minutes after the avalanche, Rider 1 was located under 60 to 90cm of the deposit. He was dug out and found to be without a pulse. Resuscitation attempts were started and continued in the helicopter,

Weather at Paulson Summit Elevation 1555m, 40km west of upper Ladybird Creek					
Date	Time	Max. Temp. (°C)	Min. Temp. (°C)	Precipitation (mm)	Snowpack height (cm)
8 Jan	06:00	-8.4	-15.4	0	106
8 Jan	16:00	-9.2	-15.6	1	100
9 Jan	06:00	-16/3	-21.6	1	99
9 Jan	16:00	-10.4	-21.6	0	102
10 Jan	06:00	-14.0	-16.2	2	101

which arrived with ambulance attendants after 40 minutes. Rider 1 was pronounced dead at Castlegar Hospital. He had asphyxiated.

The crown of the deep slab avalanche was at 2255m elevation on a southwest-facing cross-loaded slope with an estimated incline of 30°. The crown height averaged 70cm and reached a maximum of 90cm. The width of the avalanche near the crown was 40m. The slab released in 1.5 – 2mm faceted crystals under the rain crust from November 1997. Rocks were exposed in the bed surface.

The avalanche ran out at 2195m. The deposit was 40m long and 20m wide. Its depth averaged 1.2m and reached a maximum of 2m. It was a size 2 dry slab avalanche. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

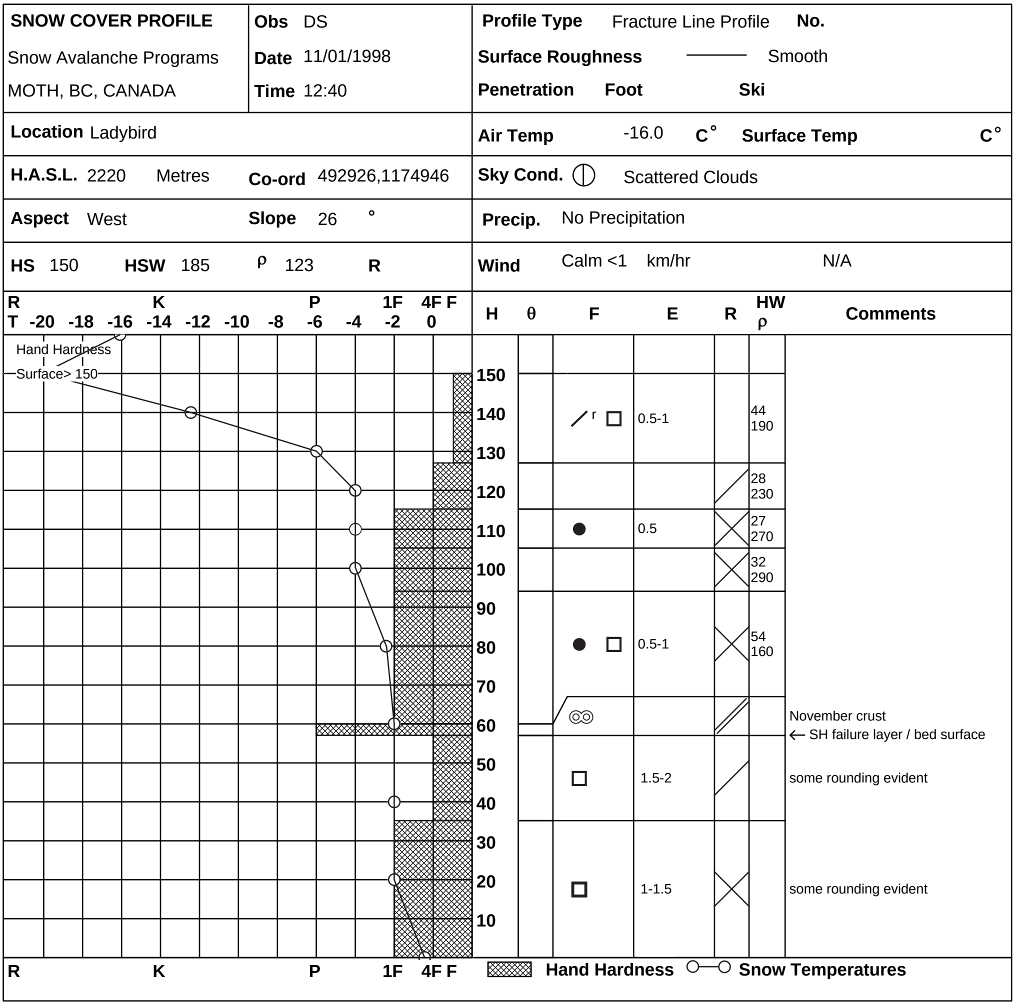

Figure 5.3. *Ladybird Creek, 10 January 1998. Fracture line profile observed one day after the accident.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
30°	None	Concave	Alpine

Source

- BC Coroners Service
- BC Ministry of Transportation and Infrastructure

Comment

During high and extreme avalanche danger, some slopes that are not considered steep enough to avalanche can surprise even experienced backcountry recreationists. A very wide margin of safety is prudent under such conditions.

Only Rider 1 was caught, suggesting the others were not exposed to the avalanche path while Rider 1 was highmarking. Consequently, all the others were able to search for the buried victim.

The search was efficient—15 minutes; however, the victim had asphyxiated.

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25 January 1998, Snowmobiling
Stoyoma Mountain, Cascade Mountains

Deaths	Avalanche Problem	Terrain
1	Wind Slab	Challenging

- **Victim did not have a transceiver**
- **Two on the slope when the avalanche was triggered**

On Sunday 25 January, a group of eight snowmobilers was riding near Stoyoma Mountain, an area located 34km southwest of Merritt, BC. One of the snowmobilers (called Rider 1 in this summary) did not have a transceiver.

At the Merritt weather station, 605m elevation, 11mm of rain fell and the air temperature ranged from -1.5 to 6.5°C. It was likely snowing where the group was snowmobiling at about 2000m. The air temperature reached 0°C during the day.

Six days before the snowmobiling trip, the Canadian Avalanche Association issued a bulletin for the South Coast, which in 1998, included this part of the Cascade Mountains. The avalanche danger in the alpine zone was rated High. The bulletin mentioned strong winds the previous weekend.

The snowmobilers were trying to find a route to the summit of Stoyoma Mountain but snow conditions were poor. After lunch about 12:45, Rider 1 climbed part way up a gully and stopped on a bench, facing uphill, to wait for the others. The next rider (Rider 2) turned above Rider 1 and had started downhill when a hard slab avalanche released on the slope above them both. Rider 2 escaped the avalanche but Rider 1 and his snowmobile were tossed about 15m down the slope and buried, with part of his snowmobile exposed.

The remaining riders began to search with transceivers and soon realized Rider 1 did not have one. They sent two riders out to get help and started to probe. Two BC Government Avalanche Technicians flew to the site at 15:40 and joined the probe line. At 15:55 the victim was probed about 5m upslope from his snowmobile. He was under 1m of the deposit. As soon as practical during the digging, CPR was started. Paramedics soon arrived on the scene by helicopter. They continued CPR on the flight to Nicola Valley General Hospital where the victim was pronounced dead. He had asphyxiated.

The hard slab avalanche released at the top of a concave chute at about 2080m, ran down the southeast-facing slope for about 35m and onto the bench. The 35° start zone had been cross-loaded by strong winds from the northeast and southwest. (The wind had scoured nearby areas to ground.)

The crown fracture was 30m wide and about 50 to 80cm in height. Many of the blocks of the pencil-hard slab had not turned over as they slid down the short slope. The deposit was noted to be moist at the time of the rescue. It was a size 2 avalanche.

The failure layer was soft (4-finger hard), consisting of stellar crystals, 3-4mm in size. A compression test caused the failure layer to fracture at the first moderate tap (total 11 taps). Prior to the avalanche, the group did not observe any recent slab avalanches or other signs of instability.

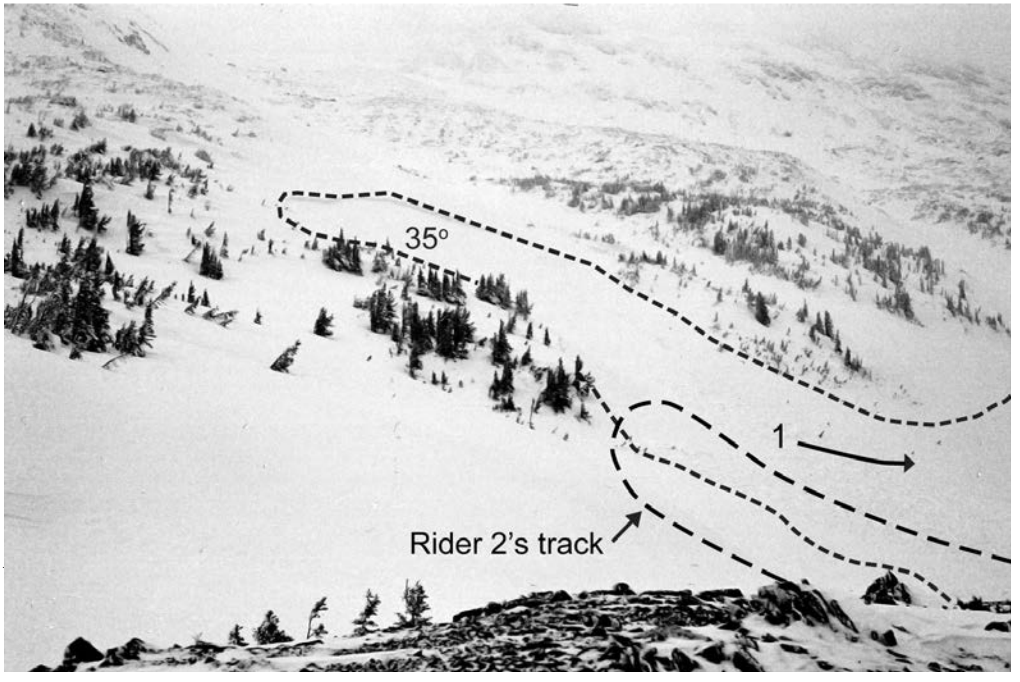

Figure 5.4. *Stoyoma Mountain, 25 January 1998. During the rescue, part of Rider 2's track was visible outside the avalanche. X – deceased. Photo: Bill Golley.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	No	No	No	No	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	None	Concave	Very sparse

Source
- BC Coroners Service
- Bill Golley
- BC Ministry of Transportation and Infrastructure report to the Canadian Avalanche Association
- Environment Canada archived weather data

Comment
The survivors had probed the area where the victim was buried. They may have missed him because he was on his side.

Companion rescues are generally faster when everyone in the group has a transceiver, probe and shovel.

31 January 1998, Snowmobiling
Roundtop Mountain, Cariboo Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Two snowmobilers exposed on one slope while highmarking**
- **No transceivers, only one probe**

On Saturday 31 January, a group of 12 snowmobilers headed to the slopes around Roundtop Mountain about 20km southeast of Barkerville, BC. Two of them had transceivers but left them in their trucks at the trailhead. They had one probe and several shovels.

Two days before the snowmobile trip, the Canadian Avalanche Association issued a regular bulletin for the North Columbia Mountains, which include the Cariboo Mountains. The avalanche danger in the region was rated Moderate. The regional bulletin summed up the recent weather and forecast: “It’s too warm for January and looks as though it will continue that way until the end of the month. There have been moderate winds mainly from the south in the higher alpine and light snow amounts through the week from 5 to 15cm on Monday, Tuesday and Wednesday. Temperature ranged in the alpine from -4 to -10°C.” At the Sliding Mountain weather station, 27km to the north-northwest, winds gusted to moderate mostly from the southwest on 29 January but were light on January 30. There was little snowfall in the preceding 48 hours.

When the 12 snowmobilers reached the north side of Roundtop Mountain they split into two groups. One group of eight went around the back so they could “drop in” to the bowl on the north side. The remaining four approached the north bowl from below. Around midday, the four were taking turns highmarking the slope. The sky was clear. The wind was calm and the temperature was about -1°C.

At 12:30, one snowmobiler (called Rider 1 in this summary) got stuck high on the slope. He freed his snowmobile and started down, when Rider 2 started up the slope. As he turned around the place where Rider 1 had been stuck, a large avalanche released. He headed for the side but was quickly bucked off his machine. He and his machine were carried through a group of small trees and buried. As Rider 1 reached the bottom, he felt the back of his machine get pushed and turned to see a large avalanche brush by him and quickly stop. The two other riders who were stopped at the base of the slope saw the avalanche descending towards them and quickly moved out of its path.

Rider 2 could not be seen as the remaining three riders began to search the surface of the deposit. The group of eight who had reached the top came down to help with the search. After about five minutes, Rider 2’s snowmobile was found. After another 30 minutes, Rider 2’s helmet was found a few centimetres below the surface of the deposit and about 5m upslope from his snowmobile. He was dug out; resuscitation was attempted but was unsuccessful. He had asphyxiated due to snow blocking his airway.

The top of the start zone is at 2010m on a 32° north-facing slope where the ground is rocky. The path continues down a 32 to 35° open slope before running through an open forest with a creek bed inclined at 10 to 15°.

The crown height averaged 100cm and reached a maximum of 215cm. The width of the slab avalanche near the crown was 245m. The bed surface was stepped. A layer of surface hoar, likely buried in early January, was found on the upper bed surface about 35cm below the snow surface. The lower bed surface on which most of the avalanche ran consisted of the now faceted melt-freeze crust from early November. The grains were 1 to 1.5mm in size.

The deposit was about 95m wide and 150m long. Its depth averaged 3m and reached an estimated maximum of over 8m. Both rounded and angular blocks as well as a few broken trees and branches were visible in the deposit. The toe of the deposit was at 1907m. It was a size 3 avalanche.

A fracture line profile and snowpack tests were observed on 3 February. The surface hoar layer, 35cm below the surface, produced easy shovel shears and a rutschblock 3 (block released while pushing down with the legs). At the top of the November crust, the shovel shear tests and the rutschblock produced no results. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate	Yes	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
32°	None	?	Mostly open

Source

- BC Coroners Service
- BC Ministry of Transportation and Infrastructure weather data

Comment

The burial was shallow, which is one factor that favours a live recovery with transceivers.

28 March 1998, Snowmobiling
Ram Range, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Complex

- **One snowmobiler without a transceiver buried in a gully**

On Saturday 28 March, seven snowmobilers accessed the slopes of the Ram Range about 43km south of Nordegg, Alberta. At least four of the snowmobilers had transceivers. They reached a northeast-facing bowl of Mt Bramwell, at the head of Onion Creek. The bowl funnels into a "choke" about 20-30m wide at the head of a gully.

Two days before the snowmobile trip the Canadian Avalanche Association issued a regular avalanche bulletin for the Rocky Mountains including the Ram Range. The avalanche danger was rated Considerable in most alpine terrain. The bulletin also noted: "New slab in the alpine is creating an instability. Field test indicate the instability is confined to the new snow layers and not overloading the weak base to failure.... Spring transition weather for the past few days with warmer temperatures and minimums to minus 5°C at 2000m and moderate to strong winds from the southwest. Trace to light snow amounts for the weekend but lots of clear sunny skies." About 10 days before the snowmobile trip, 35 to 50cm of heavy wet snow fell in the area.

At 15:30 a rider (without a transceiver) was descending the gully below the choke. He was hit by an avalanche and swept about 200m down the slope. A second rider was caught but not buried. After about 70 minutes of probing below the last seen point, he was located about 20 – 30m from the toe of the

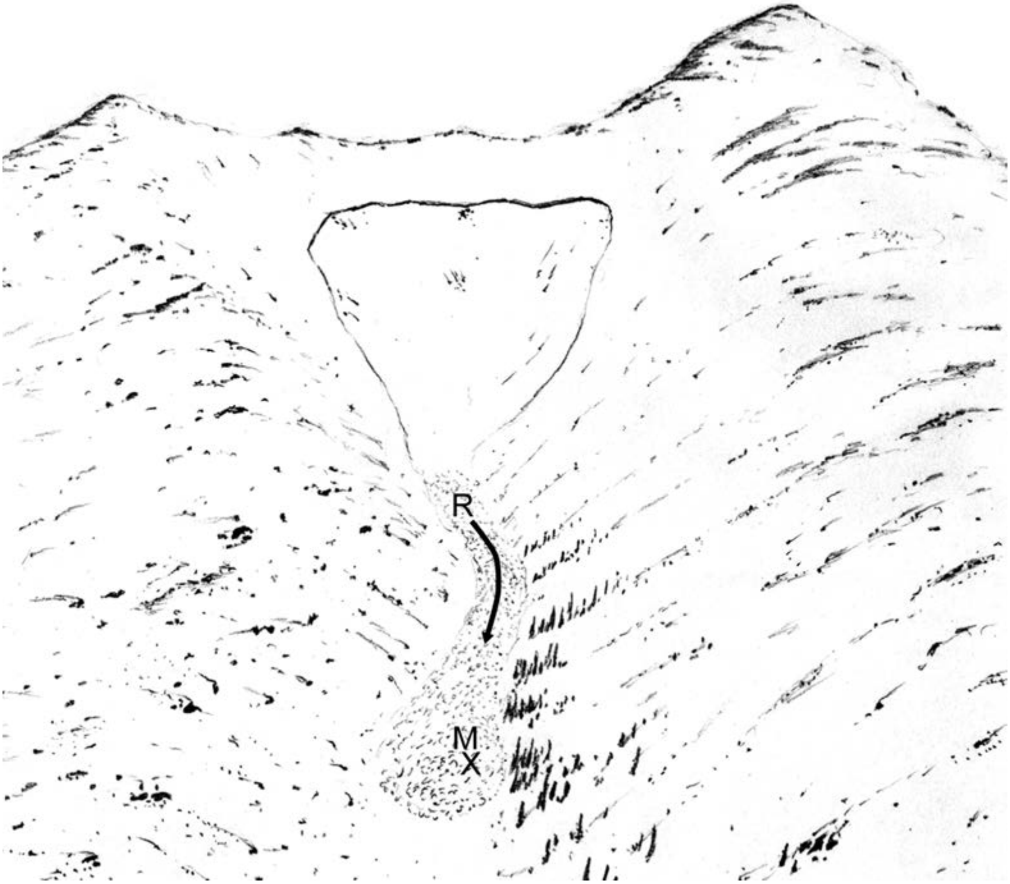

Figure 5.5. *Ram Range, 28 March 1998. R – rider when caught, X - deceased, M – machine.*

deposit, a short distance down slope from his sled. He was found dead due to a neck injury, buried under 1m of the deposit.

The 1 to 2m high crown of the slab avalanche released at about 2400m elevation on a slope that reached 40°. The slab avalanche was 250m wide near the crown. The slab consisted of snow from the storm about 10 days previously. At the choke, the avalanche deposit was estimated to be 2 to 3m deep at the side and 6m deep in the middle. The deposit was moist and ran down to 1980m. It was a size 3 avalanche. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	No	?	?	?	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
40°	Gully	?	Open Slope

Source

- Avalanche involvement report from Nordegg Ranger Station
- Patterns of death among avalanche fatalities: a 21-year review (Boyd et al., 2009).

Comment

Only two snowmobilers were caught, suggesting the others had positioned themselves outside the path when the avalanche occurred. Transceivers have been shown to reduce the search time but would not have affected the outcome in this case.

A fatal avalanche also occurred on this slope on 20 March 2003.

17 May 1998, Tobogganing
Whistlers Mountain, Jasper National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Loose Wet Avalanche	Complex

- **Tobogganing near tourist tram**
- **Unaware of risks and terrain**

Two men used the sightseeing tram to ascend Whistlers Mountain near Jasper at approximately 16:00 on 17 May 1998, with the intention of tobogganing on the upper slopes of the mountain. They hiked along the ridge to a spot above a north-facing slope at approximately 2500m elevation, and began their descent using “crazy carpets.” The slope they chose gradually steepened as they descended, and was interrupted by a 200m high cliff area and rock band just out of sight from the top.

A few centimetres of fresh snow had fallen on recent accumulations of approximately 40cm. This, combined with rain and warm temperatures, resulted in a deep isothermal snowpack.

The two descended side-by-side over the convex roll below the ridgeline for approximately 50m, where they triggered a size 2 loose wet snow avalanche. It carried both men with it through a steep gully between the large cliffs and rock bands before coming to a stop. One of the victims was relatively unhurt; however, the other sustained serious injuries while being swept through the gully. The first victim quickly evaluated his friend's injuries, and then left the site to seek help at the nearby tram station. Neither of the victims were well prepared for a day in the mountains, and carried no equipment for self-rescue. Both were impaired by alcohol and drugs.

Several members of the public witnessed the avalanche from the tram station, and they notified staff there, who in turn reported the incident to the Parks Canada Warden Service. A Warden arrived at the scene shortly after, and started CPR. Approximately 30 minutes later paramedics arrived and continued attempts to revive the victim, which were unsuccessful. At 21:00 resuscitation efforts were ceased and the victim was pronounced dead.

The size 2 loose snow avalanche started in wet snow, and was initiated by the victims as they were sliding over a convex roll above a large cliff and rock band. The avalanche was funneled through a gully in the rock band and stopped on gentler terrain below. In total it ran for approximately 250m.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	Yes	?	Yes	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
>30°	Yes (cliffs)	Convex	Alpine

Source

- Steve Blake
- Parks Canada

Comment

Avalanches can and do occur in spring and summer, especially at higher elevations where more snow often remains.

Even small loose wet snow avalanches can be very difficult to escape from once caught, and they often run a long distance down slope.

28 June 1998, Mountaineering
Mt Edith Cavell, Jasper National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Loose Wet Avalanche	Complex

- **Climber triggered wet avalanche while glissading**

Two climbers ascended the East Ridge of Mt Edith Cavell in Jasper National Park, reaching the summit about 13:00. They began descending the East Ridge and were below the steep section by 15:00. At the top of the prominent northeast-facing snow gully that parallels the less steep part of the ridge, at about 2600m, they chose to remove the climbing rope and glissade a short distance down the gully. (Glissading refers to sliding down slope while either standing—like skiing without skis—or while sitting.) Ten centimetres of fresh snow in the gully had warmed to 0°C (isothermal), and was moist or wet. While glissading, the first climber triggered a point release avalanche, which caused him to fall. He was unable to self arrest and was carried or fell down the gully for a vertical distance of about 300m.

His partner was also caught in the avalanche but was able to escape it. He scrambled down the ridge and found his partner near the bottom of the avalanche deposit at about 15:30. The fallen climber was blueish in colour and not breathing. His partner started cardiopulmonary resuscitation (CPR) but was unable to get air into the victim's lungs. After two cycles of CPR, he descended to the trailhead to report the accident by cell phone. He drove towards Jasper and met the wardens close to the town. Once the wardens had interviewed the survivor, they flew to the site by helicopter. The victim (deceased) was removed in a sling below the helicopter. The cause of death was head trauma.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	?	?	No	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Gully	?	Alpine

Source
- Parks Canada
- Accidents in North American Mountaineering (American Alpine Club and Alpine Club of Canada, 1999)
- Patterns of death among avalanche fatalities: a 21-year review (Boyd et al., 2009)

Comment
In steep terrain, even a small amount of sliding wet snow can be difficult to escape.

Chapter 6

Avalanche Accidents of Southwestern Canada **1998-1999**

Winter Summary for Southwestern Canada

- **6 avalanche fatalities in 6 accidents**
- **Slow start to the winter**
- **Large amounts of snowfall and generally mild temperatures**
- **Snowpack above normal for entire season except at the very beginning**
- **General lack of active persistent weak layers in the snowpack**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
13 Nov 1998	Kokanee Glacier Park	Selkirk Mountains	Backcountry Skiing	1	Storm Slab		102
14 Nov 1998	Abbot Pass	Rocky Mountains	Hiking	1	Wind Slab		104
24 Dec 1998	Mt Strachan	South Coast Mountains	Snowboarding in Closed Area	1	Storm Slab		110
13 Jan 1999	Wolverine Valley	Rocky Mountains	Backcountry Skiing	1	Wind Slab		112
27 Jan 1999	Grouse Grind Trail	South Coast Mountains	Hiking	1	Storm Slab		114
20 Mar 1999	Cook Mountain	Cariboo Mountains	Backcountry Skiing	1	Cornice Fall		118

[1] It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.

The start of the 1999 winter in southwestern Canada was initially slow. After a series of rain storms at the beginning of October, a ridge of high pressure parked itself over British Columbia in mid-October and brought clear skies and above normal temperatures for the rest of the month. On 22 October, the maximum temperature measured at Mt Fidelity (1874m) was 15°C. While temperatures returned to normal at the end of the month, the dry spell persisted into the beginning of November with the exception of a light dusting of snow over the last few days of October. In the Rocky Mountains where there was snow on the ground, this period of warm weather resulted in the development of the 31 October melt-freeze crust. However, the dry and warm fall primarily resulted in an exceptionally low snowpack at the beginning of this season.

Conditions changed dramatically on 12 November with the arrival of a "Pineapple Express," which brought significant amounts of new snow under high winds and temperature close to the freezing point. Mt Fidelity (1874m) reported total of 61cm of new snow during the three days of this first snow storm of the season. The two accidents at **Kokanee Glacier Provincial Park on 13 November** (page 102) and **Abbot Pass in Yoho National Park on 14 November** (page 104) were directly related to this storm. The rest of November was characterised by continuous snowfall at above normal temperatures. By the end of the month, the snowpack height at higher elevations was close to or even above typical values for the time of the year. However, the snowpack at lower levels was still below normal due to the warmer than normal temperatures.

The pattern of continuous snowfall persisted into December. At this point, the snowpack was generally well consolidated with no significant buried weaknesses. In many areas of the Rocky Mountains, the stronger upper snowpack was overlaying a weaker base from the early season. After a few days of normal temperatures, another Pacific disturbance with above-normal temperatures resulted in rising freezing levels and strong winds. On 11 December, Whistler Roundhouse (1835m) in the Coast Mountains reported 30mm of rain within 24 hours and in the South Columbia Mountains rain was occurring up to approximately 1600m. This event was followed by the only significant cold snap of the season.

A strong ridge of arctic air resulted in widespread clear skies, strong northerly winds and temperatures between -25 and -30°C. This weather pattern, generally referred to as an arctic outflow condition, produced a variety of different snow surface conditions: surface hoar in sheltered areas, faceting in the surface layers due to the strong temperature gradient, wind slabs and wind crusts in exposed places. At lower elevations these surfaces were sitting on the melt-freeze crust that developed during the rain event prior to the outflow. They were buried starting on 23 December when the next weather system from the Pacific brought significant amounts of new snow and warmer temperatures. The interface at the base of this recent storm snow was the first persistent weak layer of this season. While the avalanche in the accident on **Mt Strachan on 24 December** (page 110) failed on this interface, the avalanche was classified as a storm slab since it occurred during the first storm burying the weak layer. Heavy snowfall continued over the holidays resulting in an extensive avalanche cycle, particularly in the Columbia Mountains. The warmer temperatures, however, allowed the weakness to gain strength rapidly.

1999 started with a generally strong and above average snowpack. The New Year's weekend brought northerly flows, clear skies and no new snow. This period of fair weather resulted in the formation of facets and surface hoar crystals at the snow surface primarily in the Columbia Mountains. However, it was short lived as the onshore flow pattern re-established itself quickly and delivered the next series of strong frontal systems with heavy snowfall for most of January. While warm and wet conditions prevailed in the Coast Mountains and the South Columbias in the second week of January, the Rockies and North Columbias were under the influence of the arctic air mass, which deflected the Pacific storms further north. Strong winds and a temperature inversion in the alpine promoted the widespread development of wind slabs in the Rocky Mountains, which led to a fatal avalanche accident in the **Wolverine Valley on 13 January** (page 112).

Once the arctic air mass retreated around 14 January, all of southwestern Canada came under the influence of the Pacific frontal systems again. The next series of storms brought significant amounts of new snow. Between 18 and 21 January, the Columbias received between 20 and 30cm in the north and between 50 and 70cm in the south. During this time, the primary avalanche concern was storm snow instabilities and wind slabs, but generally above-normal temperatures promoted rapid settlement and the new instabilities disappeared quickly.

This pattern was interrupted between 23 and 26 January, when the area experienced another push of arctic air. However, the break was short-lived as another powerful frontal system reached the Coast Mountains on 27 January. The system brought heavy snowfall and strong winds, particularly to the Coast Mountains and was accompanied by a fatal avalanche accident on the **Grouse Grind Trail on January 27** (page 114). New snow accumulations at Whistler Roundhouse (1835m) were 16cm on 27 January, 67cm on 28 January and 42cm on 29 January. This brought the snowpack height to 330cm, the most snow on the ground ever measured at Whistler Roundhouse for 29 January. At this point in the season, the snowpack across most of southern BC and Alberta was between 110% and 125% of normal and remained at those levels for the rest of the season.

February and the first two-thirds of March were primarily characterized by constant snowfall at temperatures generally typical for that time of the year. A low pressure centre over the Gulf of Alaska produced a steady stream of major frontal systems that moved across BC and Alberta. The relevant avalanche problems during this time were primarily storm snow instabilities and wind slabs in exposed areas. Wind slabs were particularly dominant in the Rocky Mountains, which had an atypically strong snowpack during this season. However, shallow areas with considerable facet and depth hoar development still existed.

There were two short breaks in the storm pattern, which both resulted in the development of persistent weak layers. The first break of fair weather resulted in a surface hoar layer, which was buried around 16 February. It was primarily present in the Columbia Mountains and by the beginning of March this weak layer was buried by approximately 100cm of snow and was causing numerous avalanche involvements, but no fatalities. The second period of nice weather occurred between 6 and 11 March and produced a variety of surfaces including surface hoar, facets and sun crusts across the entire region. While the subsequent storm snow initially bonded poorly to this interface, particularly in the more northerly mountain ranges, conditions improved more quickly than with the February surface hoar layer.

Weather patterns shifted dramatically on 20 March when a ridge of high pressure formed along the Continental Divide. Rather than coming onshore, the Pacific lows were deflected either north or south and all of southern BC and Alberta remained under clear skies. This nice weather period brought exceptionally high temperatures—Mt Fidelity reported maximum temperatures of 7.5°C on 20 March and 11.5°C on 21 March—which resulted in the first true spring weekend of the season. The upper snowpack warmed rapidly with moist surface conditions reported up to 3000m on southern aspects in the North Columbias. This rapid rise in temperature contributed to a fatal avalanche accident involving a cornice failure on **Cook Mountain on 20 March** (page 118). Operations in the Rocky Mountains reported isothermal conditions on the same weekend. The warm weekend was followed by another Pacific disturbance that brought new snow and cooler temperatures. The colder temperatures helped to stabilize the weak snowpack and the new snow bonded well to the melt-freeze crust that had developed during the previous weekend.

The rest of March and April were characterized by the more typical sequence of storms and periods of clear weather. The two fair weather periods in the second half of April exhibited above normal temperatures which promoted the melting of the snowpack. However, in May temperatures dropped below normal again, which, together with the existing snowpack and the above normal precipitation, resulted in an abnormally long

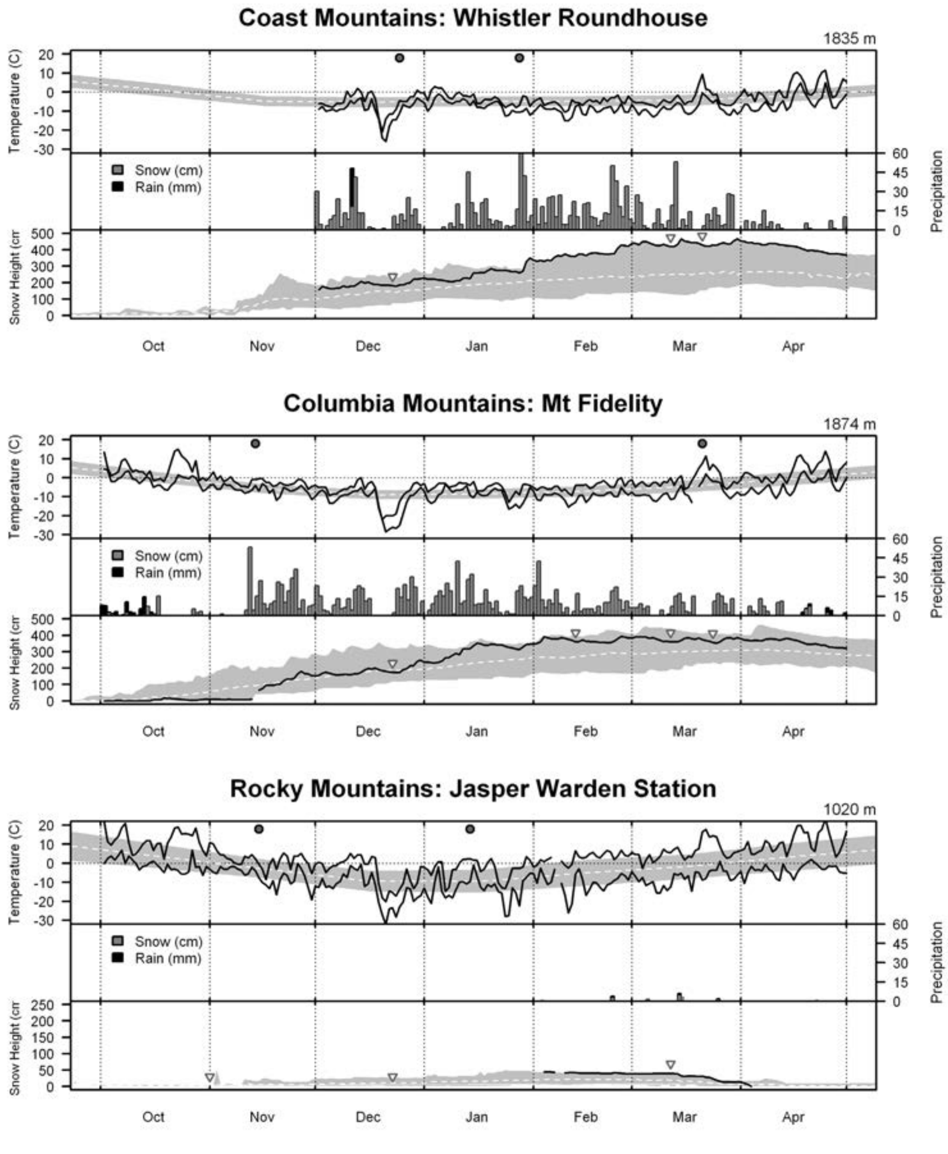

Figure 6.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 1998/1999 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanche (black triangles). Other persistent weak layers are shown with light triangles. The grey band shows minimum, average (dashed line) and maximum snowpack height measures at this location since 1976 (Whistler Roundhouse and Mt Fidelity) or 1978 (Jasper Warden Station).*

13 November 1998, Backcountry Skiing
Kokanee Glacier Provincial Park, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Complex

- **A relatively small avalanche resulted in a fatality because of a serious terrain trap**

On Wednesday, 11 November 1999, a group of six backcountry skiers drove from Rossland, BC, to Kokanee Glacier Provincial Park to enjoy some early-season skiing. They parked their cars at Gibson Lake at the south end of the park and hiked to the Slocan Chief cabin, where they were planning to spend the next few nights. The weather during the hike to the cabin was described as good. Weather records from Kootenay Pass (next page), a weather station about 80km south of Kokanee Glacier Park at a similar elevation as Kokanee Lake, show temperatures around -5°C and only a trace of new snow for that day.

The following day was marked by the arrival of a "Pineapple Express." For the area around Kokanee Glacier Provincial Park this meant a day of warmer temperatures and heavy snowfall accompanied by strong winds and drifting snow. This was the first significant snowfall event of the 1999 winter season.

As there was no improvement in the weather on Friday morning, 13 November, four members of the party decided to abort the trip and head back to their cars. Travel was slow due to the significant amounts of new snow and by 13:00 the group of four had only reached Kokanee Lake, which is about half way between the cabin and their cars at Gibson Lake. The traditional skiing exit to Gibson Lake is down the middle of Kokanee Lake, which offers some protection from the ominous avalanche threats from either side of the lake. In conditions of Considerable or High avalanche danger, even this route is usually avoided and exit from the park is via helicopter. However, at this time of the year the lake was not yet frozen and the group decided to use the summer hiking trail. The summer trail follows the shore on the western side of the lake, where the terrain is characterized by steep talus slopes that lead directly into the lake with gullies and cliffs above. As a consequence, the trail is exposed to avalanche hazard from above for the majority of the way along the lake.

Cognizant of the existing avalanche hazard, the group performed a snow stability test before committing to the exposed route along the lake. Even though they interpreted the result of the test as favourable, they decided to take extra precautions and traverse the lake area spaced apart to minimize their exposure to possible avalanches. At about 13:30, as the leader of the group was approximately two-thirds of the way towards the south end of the lake, a relatively small avalanche (size 1.5 to 2) released from a gully feature above the group. The avalanche swept the first two members of the party off the trail and into the lake. The leader ended up about 3 to 5m from shore, and managed to get his backpack off and use it as a flotation device to reach the shore. The second victim was carried much further into the lake and sank through the deposit and the thin ice with his skis, poles and pack still on. His companions on the shore encouraged him to try to swim, but he was unable as he was weighed down by his gear. During his struggles the victim floated further towards the centre of the lake where he eventually succumbed.

This event was witnessed by another party of three that had caught up to the first group

Kokanee Glacier Provincial Park, Weather data from Kootenay Pass
Elevation 1775m; comparable to Kokanee Lake

Date	Max. Temp. (°C)	Min. Temp. (°C)	HN (cm)	Rain (mm)	HS (cm)
8 Nov	-3.0	-9.0	0		18
9 Nov	-4.0	-7.0	2		20
10 Nov	-5.0	-6.5	4		23
11 Nov	-5.0	-5.5	trace		22
12 Nov	-2.0	-5.0	22		42
13 Nov	+1.0	0.0		20	N/A

just minutes prior to the accident. Moments later, this second group was caught in a second avalanche. However, nobody was injured in this incident. Both avalanches were most likely the result of the significant accumulation of new snow in the gully features above the lake during the previous day and were subsequently triggered by the rain and above-freezing temperatures during the day of the accident (refer to weather table).

While the three remaining individuals of the first accident party spent the night at the south end of the lake, the second group continued to their cars at Gibson Lake. It was approximately 21:00 when they were finally able to report the accident to the authorities. RCMP and local search and rescue teams immediately commenced organizing efforts to rescue the individuals still on the mountain and to locate the remains of the victim. Rescue specialists from Parks Canada, including a dog team, were able to access the site by helicopter on the morning of 14 November and rescued the three survivors, who were then flown to the hospital in Nelson. On the same day, the two individuals who stayed at the cabin for an extra night made their way back to their vehicle at Gibson Lake where they were met by ground search and rescue personnel.

Severe weather conditions and ice forming on the lake delayed the recovery efforts for the victim. On 17 November, after the slopes surrounding the lake had been controlled for avalanche hazard using explosives, an RCMP dive team was deployed to look for the victim, but they found no evidence. After further delay due to inclement weather and avalanche conditions, the victim's family informed the authorities that they did not want any further risk to rescue personnel, and the recovery efforts were cancelled on 19 November.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	?	?	>20cm of new snow with wind	Above freezing temp and rain

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Lake	Planar	Open slope

Source
- BC Coroners Service
- Maclean's, Nov. 23, 1998 (available from http://www.thecanadianencyclopedia.com)
- BC Ministry of Transportation Kootenay Pass
- Parks Canada
- RCMP

Comment
In this accident a relatively small avalanche resulted in a fatal outcome due to a terrain trap. Open water is particularly serious as it affects the victim's ability to fight against the avalanche and essentially prevents any rescue possibilities by party members.

Even though this was a relatively small avalanche, two skiers were involved. The distance required between individuals to avoid multiple involvements is often underestimated. Travelling in high-consequence locations such as the one described in this accident requires a very conservative approach.

14 November 1998, Hiking
Abbot Pass, Yoho National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Wind Slab	Complex

- **Hiking trip in the alpine after first significant storm of the winter that created wind slabs on top of a weak foundation**
- **Group unable to adjust their plans to the unexpected conditions**
- **No avalanche safety gear**

In mid-November 1998, three male and three female students from the University of Calgary were planning a hiking trip to Abbot Pass, where they would spend the night in the hut run by the Alpine Club of Canada. It had been a dry fall with just the occasional snowfall of less than 5cm. This little amount of snow had collected in sheltered areas and developed into a layer of sugary, faceted crystals, particularly at higher elevations. Since the group did not expect to encounter wintery conditions on this trip, they decided not to carry any avalanche safety gear.

The group left Calgary on the afternoon of Friday, 13 November with the plan to drive to the Lake O'Hara access road and hike to the Lake O'Hara campground, where they would spend the night. En route, they quickly stopped in Banff where one of the more experienced group members spoke to park wardens to get information about the existing avalanche conditions. Since Parks Canada generally does not publish public avalanche bulletins prior to 15 November, the group did not have detailed avalanche information available when planning their trip. There was approximately 20cm of snow on the ground when they left their cars in the parking lot at the start of the access road. They hiked along the access road and safely made it to the Lake O'Hara campground. Because of the snow on the ground, the group camped inside the picnic shelter.

On Saturday morning, 14 November 1998, the group left the campground around 08:00 and followed the regular summer trail that goes along the shores of Lake O'Hara and passes Lake Oesa before steeply climbing a wide scree gully leading directly to Abbot Pass. At approximately 12:30, the group was half way up the gully, where they stopped for their lunch break. While eating their lunch, the group discussed the current conditions and available options for the trip. While the most experienced group members felt it was safe to continue, two of the female members thought the conditions were quite stormy and the amount of new snow was threatening.

At this point, a group of two men descending from Abbot Hut came by the group of students. The two had spent the previous night at the hut, and mentioned that they observed cracking, whumpfing and high winds below the hut and urged the group to turn around. This information further fueled the discussion among the students whether to continue on or turn around. Since it was snowing and the weather seemed to get worse, the more experienced group members felt it unsafe to split up the group. In the end, the group agreed on a compromise, deciding to continue towards the hut for another hour and to re-evaluate the conditions at that time.

Shortly after the lunch break, at the level of the big rock outcrop in the middle of the gully (*Figure 6.2 and 6.3*), the group encountered deeper, wind-drifted pockets of snow. The snow was about 30 to 40cm deep and since travel became more difficult, three of the group members shared the task of breaking trail. In the scoured and snow-free sections, the ground was covered by a layer of ice, almost verglas in sections. At approximately 13:50, the leader of the group suddenly saw a big crack about three metres in front of her. The size 2 slab avalanche was roughly 50m wide, spanning the entire gully and engulfing the entire group. It travelled for 300m down the scree slope and when it stopped, everybody in the group was either partially or completely buried. While five of the six party members were able to free themselves, one of the female members was missing.

The group quickly gathered together to assess their injuries and to begin the search for the missing person. One of the group members sustained pelvic and internal injuries; two others had minor injuries. Since the group did not have any avalanche safety equipment, they had very limited capabilities for finding the missing person. After approximately 10 minutes, one person was sent back down to Lake O'Hara to call for help. The other four group members continued with the search for over an hour, but were unable to locate the missing individual. At this point the group decided for their own safety to leave the accident scene and to return down into the valley before darkness.

The Warden Service of Banff National Park received the distress call from the Lake O'Hara Day Use Shelter at 16:10, about two hours after the avalanche had happened. A Parks Canada helicopter, which was returning from another avalanche rescue mission in Kokanee Glacier Provincial Park near Nelson, BC, was immediately diverted to the accident location. After the helicopter did not see anybody at the avalanche site during the initial aerial search, a team of two rescuers and an avalanche rescue dog were dropped off on Abbot Pass to initiate the ground search. The helicopter then flew to the helicopter base in Lake Louise to pick up more rescue personnel.

The initial ground rescue team of two started to search the steep, snow-covered slope down from Abbot Pass. They had covered about 200m when the avalanche rescue dog found the missing individual at 17:30. The victim was buried under approximately 60cm of avalanche debris and was deceased when uncovered. Due to the closing darkness, the decision was made to leave the victim at the accident site and re-visit the scene the following morning to remove the body.

On its way back to the accident site, the helicopter spotted four of the survivors in the vicinity of Lake Oesa. The two most seriously injured individuals were flown to Lake Louise in the dark where they were picked up by an ambulance and transferred to Mineral Spring Hospital in Banff. The other two survivors were guided by the rescuers back down to the Lake O'Hara Warden Cabin where they met up with their friend who placed the rescue call. All three were then evacuated by snowmobile.

In the two days prior to this accident, the Rocky Mountains received their first significant snowfall of the 1999 winter season. While there was insufficient snow on the ground for avalanches to be a concern before 12 November, weather records in the vicinity of Yoho National Park indicate the area received approximately 30cm of new snow during this storm. In addition, considerable wind transport at higher elevations resulted in additional loading on sheltered aspects and the creation of wind slabs on a weak foundation of depth hoar and facets. The gully below Abbot Pass was such a sheltered area and the accident party triggered the wind slab that developed during that storm period.

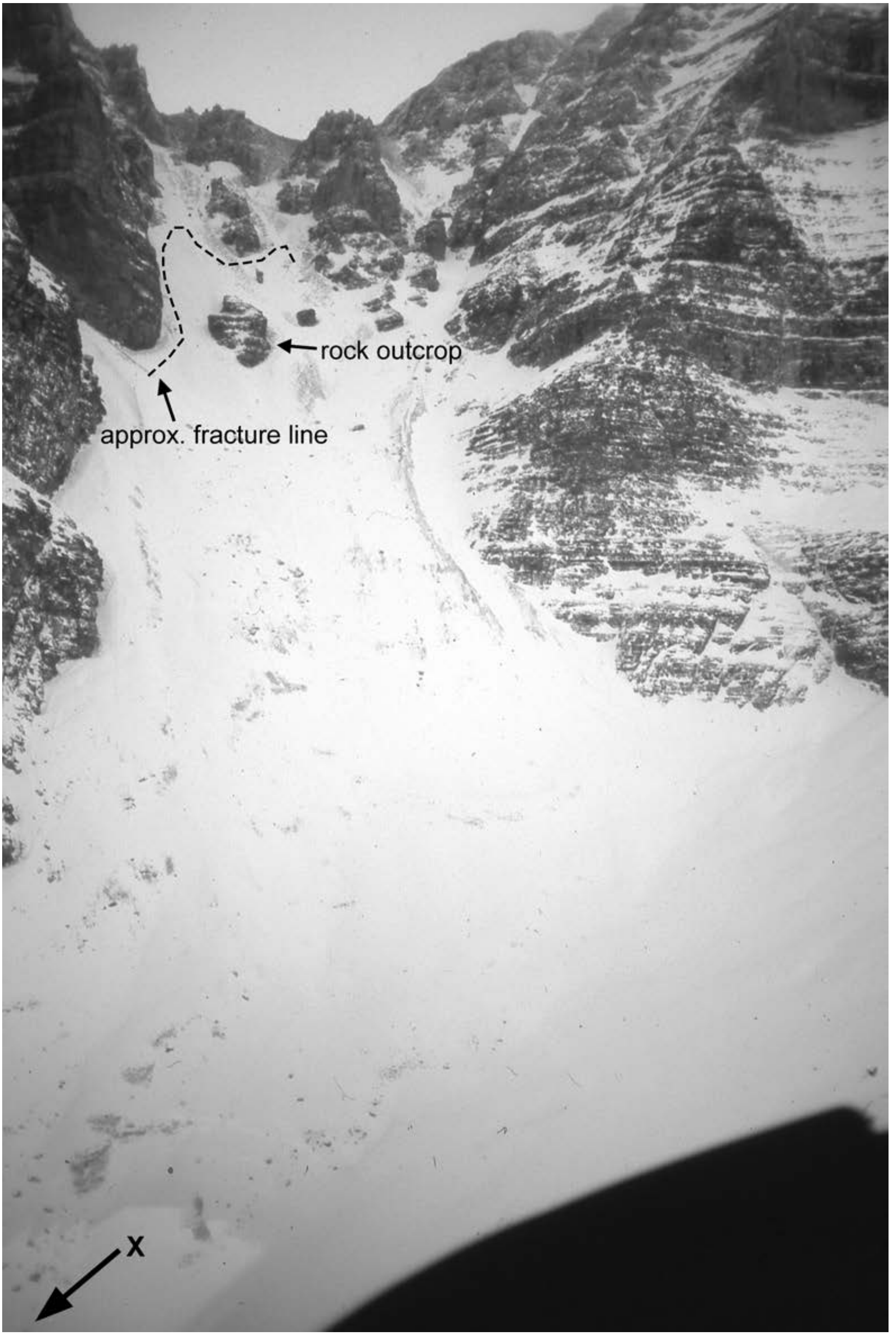

Figure 6.2. Abbot Pass, 14 November 1998. Overview of accident location. X - deceased. Photo: Parks Canada–Marc Ledwidge.

Figure 6.3. *Abbot Pass, 14 November 1998. Detailed view of start zone of avalanche. Photo: Parks Canada–Marc Ledwidge.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	No	Cracking Whumpfing	Approx. 30cm with wind	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
36°	None	Planar	Alpine

Source

- BC Coroners Service
- Parks Canada
- Member of accident party
- InfoEx
- Environment Canada – Online Climate Data for Lake Louise, Sunshine and Emerald Lake

Comment

The conditions encountered during the hike were significantly different from what the group had planned for. The inability to adjust their plans contributed considerably to the outcome of this backcountry outing.

This was the first time this group had been in the mountains together. Their insufficient understanding of each other's experience levels and diverging personal objectives created challenging decision dynamics.

Avalanche hazard starts with the first snowfall of the season. Even if planning a non-typical winter outing, such as a hiking trip, recreationists need to be prepared to manage avalanche hazard.

24 December 1998, Lift Snowboarding in Permanent Closure Mt Strachan, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Challenging

- **Significant avalanche cycle after very unusual weather conditions**
- **Victim snowboarded in a permanent closure alone and without any avalanche safety equipment**
- **The narrow creek bed turned a relatively small avalanche into a fatal event**

This accident took place on Mt Strachan, one of the two main peaks of Cypress Mountain ski area in the North Shore Mountains on the outskirts of Vancouver. The weather of December 1998 was rather unusual on the North Shore Mountains. After almost two week of continuous snowfall, a warm front had brought significant amounts of rain all the way to the mountain tops. On 16 and 17 December, the Cypress Mountain ski patrol measured 38mm of rain at their study plot.

The following six days were characterized by an arctic outflow that brought unusually low temperatures to the South Coast. At the peak of the outflow situation on 20 December, the minimum temperature at Cypress Bowl was recorded as -17°C, making it the coldest December day on record for that station, approximately 10°C below normal. The maximum temperature for this period never rose above -9°C. During this period of clear and extremely cold weather, a layer of ice 1.5cm thick developed on the surface on all aspects across the North Shore Mountains. In addition, surface hoar crystals up to 2cm developed on sheltered aspects. On 21 December, the Canadian Avalanche Association rated the avalanche danger as Low at all elevations. However, the travel advice highlighted that the developing surface layers would likely become a weak interface once buried by the next storm.

On the evening of 23 December, a new warm front ended the outflow situation, bringing 20 to 25cm of new snow at -4°C. The night shift of the ski patrol at Cypress Bowl managed the new snow instability within the ski area by ski cutting, getting lots of results. By the morning of 24 December, the total amount of accumulated storm snow was at 35cm. The day shift of the ski patrol continued to ski cut, setting off roughly 50 avalanches up to size 2.5 with crown heights ranging between 10 and 35cm. In addition, many natural avalanches were observed both in-bounds and out-of-bounds. Because of the active avalanche cycle, the lift of Cypress Bowl opened two hours later than their scheduled opening times.

Just before noon, an off-duty member of the local snowboard instructor team and his sister were snowboarding on a run called “Humpty Dumpty.” This is an intermediate ski run with a steep and heavily wooded creek basin to the skier’s right (west). Since the creek funnels into a narrow gully, the entire area is permanently closed, fenced off and clearly marked with “Avalanche Danger” and “Permanently Closed” signs. Despite the signage, the two snowboarders decided to duck the ropes and started to descend towards the creek. However, soon after they left the official ski run, the sister got stuck. Once unstuck, she hiked back up and descended on the regular ski run. She waited for her brother at the bottom of run, but when he did not appear, she thought that she must have missed him. She then took the chair lift back to the top and waited there for a few minutes. When her brother again failed to appear, she went back down the run and informed a lift operator. She then went to the parking lot where she found her brother's car still parked.

The ski patrol was eventually notified about the missing person at approximately 16:40. When scanning the Humpty Dumpty run for the missing person, patrollers found snowboard tracks at the top of the creek gully. Based on those tracks, it seems the victim did two runs into the gully. When he climbed out the second time, he triggered a size 1 avalanche, approximately 5 to 7m wide with a crown height ranging from 15 to 25cm. Similar to the other avalanche activity that day, the failure plane was the ice layer that developed during the outflow. The small avalanche pushed the victim into a hole in the open creek. The patrol followed the victim's track into the deposit, formed a probe line and found him almost immediately, buried under approximately 1.5m of snow. Initial attempts to resuscitate the victim were unsuccessful. At this time, a squad of the North Shore Search and Rescue arrived, but their attempts to revive the victim also failed. The victim was pronounced dead on the scene by a paramedic on the search and rescue team.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Low	No	Yes	Ski patrol reported easy results	> 35cm new snow	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
40°	Gully, creek	Planar	Mature forest

Source

- BC Coroners Service
- CAA public avalanche bulletins for South Coast
- Cypress Bowl Recreations Ltd.

Comment

This accident occurred in a permanent avalanche closure, areas within a ski area boundary that are never open for skiing or snowboarding as they contain serious hazards and/or have the potential to threaten others on runs below. Skiing in permanent closures is different from skiing out-of-bounds. While most ski areas in Canada have an "open boundary" policy, skiing in permanent closures is against ski area rules and ski areas will revoke lift access privileges of skiers and riders caught in these areas.

Time is of the essence in an avalanche rescue. Regardless of where you are skiing, if there are any hints about a potential avalanche involvement it is crucial to act quickly. However, the best chance of survival is through efficient companion rescue. It is recommended to always ski and board with a partner and to always carry transceiver, shovel and probe.

Managing avalanche danger is particularly challenging after a period of unusual weather. Backcountry travelers often get surprised under these conditions since the hazard patterns can be very different from regular, and avalanches can occur in uncommon locations.

13 January 1999, Backcountry Skiing
Wolverine Valley near Lake Louise
Banff National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Wind Slab	Complex

- **Trauma fatality**

This accident involved a party of two males in their 20s from the United States, on a backcountry skiing holiday in Canada. The two experienced backcountry skiers were originally planning to visit the Rogers Pass area, but decided against it due to the high avalanche danger mentioned in the public avalanche bulletin for Glacier National Park. Instead they decided to do an outing in the Wolverine Valley adjacent to the Lake Louise ski area in the Rocky Mountains.

During the first half of January 1999, the weather in the Rocky Mountains was primarily characterized by steady snowfall and continuous moderate winds, leading to the formation of a series of wind slabs on lee- and cross-loaded slopes. Between 3 and 5 January, westerly and southwesterly winds scoured much of the available loose snow off the windward slopes and created an initial set of wind slabs on easterly slopes. The two primary avalanche problems at the end of this period were a layer of faceted crystals under the recent storm snow (approximately 30cm down) and a base layer of facets and depth hoar in shallow areas. While the 31 October melt-freeze crust had started to break down, it was still evident as a distinct line in the depth hoar and facets at the base of the snowpack.

On 6 January, an arctic front arrived bringing up to 30cm of new low-density snow to the area around Lake Louise. The following day, the area received another 10cm of new snow. Despite the continuous moderate N winds, the new snow remained unconsolidated due to the low temperatures, and no new slabs were formed during that period. During the subsequent days, however, moderate westerly winds and milder temperatures in the alpine due to a temperature inversion, promoted the formation of another set of cohesive wind slabs on easterly slopes. On 10 January, the public avalanche bulletin for Banff, Yoho and Kootenay National Park stated that, in addition to the developing wind slabs, the early season melt-freeze crust near the ground was still a concern and that there had been full-depth skier triggered avalanche on this layer in shallow areas.

On the following days, the area came under the influence of a Pacific storm system and by 12 January the storm had brought another 10 to 20cm of new snow. The warm temperatures, high relative humidity and moderate westerly winds created another set of sensitive wind slabs on lee and cross-loaded features. The public avalanche bulletin of 12 January mentioned “the increased load in lee slopes has reached critical levels” and explained there is “good potential for triggering avalanches on steep lee features.” The avalanche danger was rated as Considerable in the alpine, Moderate at treeline, and Low below treeline.

The Wolverine Valley is located on the east side of the Lake Louise ski area and runs southeast to northwest. It is reached by following the trail to Skoki Lodge from the Temple Day Lodge at the bottom of the Larch area. After following the established trail for approximately 500m, the route veers to the right into the Wolverine drainage. The group initially attempted to ski up a west-facing path on the climber's left at the entrance of the Wolverine Valley. However, after digging a snow profile in the shallow windward snowpack and seeing mostly depth hoar and facets, they abandoned this plan. Instead they travelled a bit further up the valley to an area call the Tylenols on the climber's right (southern) side of the valley. Here, they dug another snow profile and were much happier with what they saw in the deeper snowpack of a lee slope.

At approximately 13:45, just as the two approached the ridgeline, they triggered a size 2.5 wind slab. Both skiers were caught by the avalanche and carried down the slope. One of them rode the avalanche all the way to the runout zone. As he was only partially buried when the avalanche came to a stop, he managed to free himself. Since he was unable to make contact with his friend, he immediately started to hike up the slope searching for him. Using his avalanche transceiver, he quickly located his missing friend higher up on the slope. He found him buried under 120cm of snow, wrapped around a tree. He initiated CPR right away, but his friend had already succumbed to the traumatic injuries sustained during the avalanche involvement. Unable to do anything more for his friend, the survivor decided to go back to the Temple Lodge in the ski area to call for help. Since he had lost his skis in the avalanche, he had to hike back to the lodge on foot through deep snow. The body of the victim was recovered by public safety wardens of Parks Canada later that afternoon.

The accident investigation by Parks Canada revealed the following details. The fatal avalanche was triggered on a northeast-facing slope at 2500m, just above treeline on the southern side of the Wolverine Valley. The slope incline at the trigger location was 38°. The slab was approximately 35m wide and the fracture line ranged between from 50 to 220cm. The pencil-hard slab failed on a layer of weak faceted crystals and depth hoar at the bottom of the snowpack that showed some evidence of the late October melt-freeze crust.

On the same afternoon as this accident, there was another involvement that took place adjacent to the Lake Louise ski area on the Dog Leg run, an out-of-bounds run near West Bowl. It was a size 2 slab avalanche (50cm deep, 80m wide and ran for 100m), triggered in a cross-loaded feature. Of the party of two, one individual was caught only while the other was partially buried. Luckily, both individuals walked away from that avalanche unharmed.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	No	Yes	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
38°	Trees	Convex	Open slope

Source

- InfoEx
- Environment Canada – Online Climate Data for Lake Louise and Skoki
- Calgary Herald (Jan. 14): Wall of snow buries skiers - Survivor's bid to revive his friend fails
- Parks Canada Public Avalanche Bulletins for Banff, Yoho, and Kootenay

Comment

In Canada, approximately one quarter of all avalanche fatalities die directly from trauma. In an additional 10% of the fatalities, trauma is a major contributor even though the victims eventually succumbed to asphyxia (Boyd et al. 2009).

27 January 1999, Hiking
Grouse Grind Trail, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Challenging

- **Front-country accident on popular hiking trail**
- **No avalanche safety gear or proper winter clothing**

The "Grouse Grind" is a strenuous three-kilometre hiking trail on Grouse Mountain in the North Shore Mountains just north of Vancouver. The trail starts to the east of the Grouse Mountain Skyride parking lot in North Vancouver and winds its way steeply up Grouse Mountain roughly parallel to the Skyride gondola. After approximately 800m of elevation gain, the trail pops out of the forest at the restaurant complex at the top station of the Skyride. Due to its proximity to the city and the easy access, it is a very popular trail and many locals use it to exercise on a daily basis.

The weather on Wednesday, 27 January 1999, was miserable—raining in the city and snowing hard in the mountain. Weather records from that morning at the top of Grouse Mountain show temperatures between -5 and -4°C, 23cm of recent storm snow accumulated over three days, heavy snowfall and strong to extreme gusts from southwest. This type of weather was a regular sight on the North Shore Mountains during the winter of 1999. The area experienced more or less continuous snowfall during most of January. On Grouse Mountain, snowpack height increased from approximately 265cm on January 6 to 437cm on 27 January, the most snow on the ground ever measured there for that day. The avalanche bulletin of the Canadian Avalanche Association on 25 January rated the avalanche danger for the South Coast and Vancouver Island as Considerable above treeline and Moderate below.

Shortly before noon, five separate hikers and a group of two, among others, left the parking lot at the bottom of the Skyride to climb the "Grind." None except the two friends knew each other and they all hiked the trail in the mature forest separately under the heavy snowfall. At approximately 13:00, Hiker 1 reached the last section of the trail. He was wearing hiking boots, nylon tear-away pants, a long-sleeve shirt and a thin cloth cap. In a small backpack he had a nylon shell, a spare T-shirt and a cell phone. As he approached the very top of the trail where the forest opens up, he was suddenly caught in an avalanche. As he was carried down, he managed to grab a tree and cling to it just above a drop off. Bruised, scared and completely soaked, he grabbed the nylon shell out of his backpack and used his cell phone to call Grouse Mountain Resort for assistance to get him off the tree. However, he did not mention that he had been struck by an avalanche.

Unknown to Hiker 1, the group of two hikers (Hiker 2 and Hiker 3) were just below him and also hit by the avalanche. Both were carried downhill. Hiker 2 hit a tree and grabbed on for life. After the snow had stopped, Hiker 2 managed to free himself but was unable to make contact with his friend. Looking for Hiker 3, Hiker 2 started to hike downhill wading through thigh-deep avalanche debris. He first came across Hiker 1, stuck on a tree about 20m off the trail. Hiker 2 asked Hiker 1 whether he had seen his friend, but Hiker 1 was unable to provide any clues.

During their conversation, multiple other hikers came up the trail but none had any information about the whereabouts of Hiker 3. Only one (Rescuer 1) actually offered his help to the two avalanche survivors. He first told Hiker 2 to stay put, so rescuers will know where to start their search and then started to descend the trail in search of Hiker 3. As he was hiking down the trail, Rescuer 1 heard moans and screams from a nearby gully. There he found another hiker (Hiker 4), who had also been caught in the avalanche and was pinned against a tree with his torso above the snow and his legs twisted around at an unnatural angle. Below Hiker 4, the legs of yet another hiker (Hiker 5) were sticking out of the snow. Using his hands, Rescuer 1 was able to uncover Hiker 5, but his airway was choked with snow and he was unconscious. However, as soon as Rescuer 1 cleared his airway, Hiker 5 took a deep breath and regained consciousness. Nevertheless, he was severely injured and moaning in pain. The moaning and screaming was now also heard by Hiker 1 and Hiker 2, who were still waiting for help higher up on the trail. By now it was approximately 13:15 and Hiker 1 used his cell phone a second time to call Grouse Mountain Resort. This time he informed them about the full extent of the avalanche accident and explained that it involved injuries and at least one person missing. At this point, Grouse Mountain Resort contacted North Shore Search and Rescue to initiate a large-scale rescue operation.

At the same time, a ski patroller from Grouse Mountain Resort—still unaware of the full extent of the accident—started to descend the Grouse Grind trail from the top of the Skyride in response to the first cell phone call for help. While looking for Hiker 1, he came across yet another hiker (Hiker 6) who was caught by the avalanche and was clinging to a tree. Hiker 6 informed the patroller about the avalanche and explained that during his involvement, he bashed into a tree and might have broken a leg. While the patroller put Hiker 6 in a rescue bag, Hiker 2 and another female hiker came up the trail and informed the patroller about the full extent of the accident below.

At the same time, Rescuer 1, who was attending Hiker 4 and Hiker 5, was hit by two additional avalanches. Both avalanches knocked Hiker 5 over and completely buried Hiker 4, who was still pinned against a tree. But each time, Rescuer 1 was able to dig them both back out again. While this was happening on the trail, North Shore SAR was setting up an incident command in the parking lot of the Grouse Mountain Sky Ride to coordinate the rescue efforts.

At approximately 14:15, a rescue team of three volunteers from North Shore SAR started to approach the accident scene from the top of the Skyride and at 14:30 they found Hiker 1 on the tree. They brought him back onto the trail, provided him with warm clothing and temporarily secured him to a tree. After a short scramble down, the rescue team then found the victims Hiker 4 and Hiker 5—together with Rescuer 1—on the far side of a steep-sided gully. At this point, Hiker 5 was buried to his waist and shivering as he was only wearing shorts. Hiker 4 was buried to his neck and screaming of pain when he was not shivering. Rescuer 1 was doing his best to comfort the two seriously injured hikers and keep them warm.

Before moving any further, the rescue team asked the ski patroller to assess the present avalanche danger in the gully. As soon as they were given the green light by the ski patroller, a few members of the North Shore SAR team started a hasty search for the still missing hiker (Hiker 3) down the gully. They found a pack, a boot and an umbrella, but no sign of Hiker 3.

As more rescuers arrived at the accident site, they started to dig out a platform to stabilize the severely injured victims. At 15:45, hypothermia kits arrived at the accident scene. Hiker 4 and Hiker 5, who had been completely excavated by now, were stabilized and moved to the platform. They were both completely stripped of their wet clothing and placed into thick sleeping bags with portable heating units next to them. At 16:00, Hiker 1 and Hiker 6, the two less seriously injured avalanche victims, were both evacuated to the top of the Skyride.

At the same time, search efforts for the missing hiker continued. By now, five avalanche rescue dog teams were searching in the gully but due to the high avalanche danger caused by the continuous snowfall and strong winds, they were temporarily pulled out of the gully. At 16:45 that precautionary measure was vindicated as another avalanche released and roared through the gully. In addition to the main search in the gully, members of the rescue team also performed a perimeter search to ensure Hiker 3 did not leave the accident scene unnoticed.

At 19:00, the first of the seriously injured avalanche victims (Hiker 5) was evacuated to the top of the Skyride in a basket stretcher with a simple rope raise. By now it had been determined that Hiker 5 had a broken pelvis, a dislocated shoulder and a concussion. The second seriously injured victim (Hiker 4), who had two broken both femurs, received a morphine shot to ease his pain before his legs were carefully straightened and stabilized with a traction splint. Similar to the first victim, he was also evacuated to the Skyride station in a basket stretcher with a rope raise, but the progress was a lot slower as he had to be stabilized every 100m due to his significant blood loss. He eventually reached the top of the Skyride at 21:30. From there, he was taken down by the gondola and placed in an ambulance at the parking lot at 21:50. Both, Hiker 4 and Hiker 5 were brought to Lions Gate Hospital in North Vancouver for further medical treatment.

Due to the avalanche danger, the search for Hiker 3 was called off for the night. At that point, the RCMP also closed the Grouse Grind trail until further notice. Continuous significant snowfall and the constant high avalanche danger at the accident site made it impossible to continue the search until 15 February, when the search for Hiker 3 resumed. Avalanche rescue dogs and search teams from North Shore SAR and other SAR teams repeatedly searched the avalanche site, but did not find any trace of the victim. On May 24, the body of Hiker 3 was finally found by a pet retriever dog brought to the accident site by one of the North Shore SAR team members. At that time, the victim was still buried under 1m of snow.

Based on the available records, the primary avalanche of this accident was a size 2.5, approximately 100m wide with a fracture depth between 25 and 30cm. The slab consisted primarily of the most recent storm snow. Most likely, the avalanche was triggered by one of the hikers at the top of the trail where the forest opens up and the terrain is characterized by small steep cliffs. From the start zone at approximately 1125m above sea level, the avalanche was channeled into a steep gully. The avalanche ran for about 200 vertical metres and the debris was deposited between 800 and 900m above sea level. The deposit was approximately 100m long, 20m wide and had an estimated average depth of 4m. Besides the main avalanche, there were numerous smaller sympathetic avalanche releases nearby. Additional avalanches also occurred during the rescue efforts due to the continuous heavy snowfall.

In total, there were six hikers involved in this accident. None were carrying any avalanche safety gear. One victim was found near the start zone (Hiker 6), two in the track (Hiker 1 and Hiker 2) and three in the runout zone of the avalanche (Hiker 3, Hiker 4 and Hiker 5). Three of the victims were injured (Hiker 4, Hiker 5, and Hiker 6) and there was one fatality (Hiker 3). Overall, the immediate rescue response on the day of the accident involved more than 60 individuals—most of them volunteers—from Grouse Mountain Resort, North Shore SAR, Coquitlam SAR and Lion's Bay SAR.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate	No	?	?	> 23cm in past two days plus strong to extreme winds	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
25-60°	Trees and gullies	Convex	Open forest

Source

- BC Coroners Service
- Grouse Mountain Resort
- CBC News (1999) Search for the body of missing hiker resumed today. Feb. 15, 1999 (retrieved from http://www.cbc.ca/news/story/1999/02/15/bc_grouse990215.html on July 18, 2009).
- Vancouver Sun (1999) Body found by Rescue Crew could be Missing Hiker. May 25, 1999 (retrieved from http://www.sarinfo.bc.ca/Library/Rescues/GrouseGrind.BC on July 18, 2009).
- Blore, S. (2000) Risk and Rescue. Canadian Geographic. March 2000.

Comment

Regardless of whether you are in the remote backcountry or close to an urban centre, trips into uncontrolled avalanche terrain require proper winter clothing and avalanche safety gear. In this accident, familiarity with the trail and the perceived closeness to rescue services might have prevented the hikers from recognizing the true seriousness of the conditions and led to casual and careless safety behaviour.

20 March 1999, Backcountry Skiing
Cook Mountain, Cariboo Mountains

Deaths	Avalanche Problem	Terrain
1	Cornice Fall	Complex

- **First spring-like weekend with dramatic temperature increase**
- **Victim triggers cornice on top of peak and falls 300m over cliff triggering an avalanche at the bottom**
- **Trauma fatality**

On Saturday, 20 March 1999, a group of friends were backcountry skiing on Cook Mountain. This peak is situated in the Cariboo Mountains, approximately 10km north of Blue River. The group reached the top of Cook Mountain shortly before noon and decided to take a rest before starting the descent. While enjoying the view, one of them started taking pictures of the group from different angles. As he walked around the group for another picture, unaware that he was moving onto the exposed part of the cornice, a 3 to 4m wide piece of the cornice broke away underneath him. The victim fell about 300m down exposed rock on the north face of Cook Mountain. The impact at the bottom of the cliff triggered a slab avalanche 40m wide and ran for approximately 300m. The victim was carried for approximately 100m from the site of impact.

After the cornice fall, the party moved back from the edge of the cliff and discussed their options. Realizing they would not be able to get to the victim themselves, they immediately sent one person ahead to the Cook Cabin to call for help on the radio. Shortly after 12:00, the distress call was received by Mike Wiegele Helicopter Skiing, a commercial heli-ski company based out of Blue River, who initiated the rescue. After the rescue call was placed, the accident party continued to ski out to their cars through the Cook Creek drainage.

Approximately 45 minutes after the accident, a helicopter from Mike Wiegele Helicopter Skiing arrived at the scene with three guides and a medical doctor. The helicopter was able to land right at the edge of the avalanche debris and the rescuers immediately picked up the beacon signal of the victim. The victim, who was completely buried under approximately 30cm of snow, was located in less than two minutes and the snow cleared from his head and torso within the next two to three minutes. CPR was started immediately by the rescue personnel and continued during the transport to the hospital in Clearwater. However, the victim had already succumbed to his injuries from the fall down the cliff face.

The week prior to this accident was characterized by intermittent snowfall and moderate winds creating wind slabs in the alpine. These wind slabs were sitting on a surface hoar interface on northern aspects and a sun crust on southerly aspects from early March. Towards the weekend, a high pressure ridge formed along the Continental Divide and brought clear skies and warm temperatures across all of British Columbia—along with a forecast for the first spring-like weekend of the season. The avalanche bulletin of the Canadian Avalanche Association published on 18 March for the North Columbia Mountains rated the avalanche danger as Moderate at all elevations, but warned recreationists of the increasing temperatures and highlighted that cornice failures were likely during the weekend. The maximum temperature at the weather station in Blue River on the day of the accident was recorded at 12.8°C and the freezing levels were reported to have reach 3000m, considerably higher than originally forecasted. With an increase of more than 10°C in three days, the temperature change leading up to the weekend was dramatic. All of the commercial operators in the area reported widespread loose snow and surface slab avalanche activity on solar aspects on the day of the accident.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate	No	Yes	?	No	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
N/A	Cliff	Unsupported	Alpine

Source

- BC Coroners Service
- CAA Public avalanche bulletin for North Columbia Mountains
- InfoEx
- Environment Canada Online Climate Data: Blue River March 1999
- Mike Wiegele Helicopter Skiing

Comment

This accident happened during a period when the snowpack was undergoing the seasonal change from winter to spring conditions. Dramatic weather changes, such as the temperature increase observed prior to this accident, have the potential to significantly destabilize the existing snowpack in this period of change. In addition, the primary avalanche concerns during spring conditions are different from the concerns during the preceding winter months, requiring backcountry travelers to change their approach for travelling in avalanche terrain.

Chapter 7

Avalanche Accidents of Southwestern Canada **1999-2000**

Winter Summary for Southwestern Canada

- **7 avalanche fatalities in 7 accidents**
- **Above-normal temperatures without any significant cold snaps**
- **Above-average snowpack despite extended dry periods**
- **Due to the generally warmer than normal temperatures, the snowpack height at lower elevations was below average**
- **Early season crust-facet combination was the dominant feature particularly in shallow snowpack areas; 4 of the 7 avalanche fatalities were related to this persistent weakness**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
7 Dec 1999	Mt Macdonald	Selkirk Mountains	Backcountry Skiing	1	Persistent Slab	17 Nov 1999	127
17 Dec 1999	Cascade Mountain	Rocky Mountains	Ice Climbing	1	Persistent Slab	17 Nov 1999	133
26 Dec 1999	Hospital Creek	Rocky Mountains	Snowmobiling	1	Persistent Slab	17 Nov 1999	136
17 Jan 2000	Tent Ridge	Rocky Mountains	Backcountry Skiing	1	Persistent Slab	17 Nov 1999	138
9 Mar 2000	Near Sunshine Village Ski Area	Rocky Mountains	Out-of-Bounds Skiing	1	Cornice Fall		141
19 Mar 2000	Wasp Creek	South Coast Mountains	Mechanized Skiing	1	Storm Slab		143
26 Mar 2000	Powder Mountain	South Coast Mountains	Backcountry Skiing	1	Persistent Slab	9 Mar 2000	145

[1] It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.

At the end of October 1999, Mt Fidelity (1874m) reported a healthy snowpack with 135cm of snow on the ground and no pre-existing weaknesses. While the more northern parts of the region generally had an above-average snowpack, very little snow was present in the southern parts of the Columbia and Rocky Mountains.

After a substantial snowstorm around 3 November that brought approximately 45cm of new snow to Mt Fidelity, temperatures warmed up dramatically. Maximum temperatures reached 9.5°C at Mt Fidelity on 6 November and 6.3°C at Parker Ridge (2023m) the day after. This rapid rise in temperatures was followed by a cold front that initially brought rain to mountain tops turning to heavy snow as the freezing level dropped. However, temperatures rose again during the subsequent period of clear weather. During this period of exceptionally warm weather, the snowpack at Mt Fidelity shrunk by about one-third from 159cm on 11 November to 118cm on 17 November, the date of the next storm. While initially bringing significant rain all the way to mountain tops, temperatures gradually dropped during the storm and the rain turned to snow. The colder temperatures during the storm turned the wet surface layers from 17 November into a solid ice crust reaching up to approximately 2000m across the entire region. The subsequent colder surface temperatures and the latent heat stored in the wet snow layer produced a strong temperature gradient, which resulted in the development of faceted snow crystals right next to the crust. This crust-facet combination developed into a major feature of this winter's snowpack and four of the fatal avalanche accidents can directly be related to this specific persistent weakness: **Mt Macdonald on 7 December** (page 127), **Cascade Mountain on 17 December** (page 133), **Hospital Creek on 26 December** (page 136) and **Tent Ridge on 17 January** (page 138).

By 25 November, the crust was buried under approximately roughly 50cm of new snow in the Coast Mountains, 65cm in the North Columbia Mountains, 45cm in the South Columbia Mountains and approximately 60cm in the Rocky Mountains. However, despite the recent significant snowfalls, the snowpack in the South Columbia and Rocky Mountains was still well below average. Strong winds in the alpine led to the development of widespread wind slabs across the entire region.

A single night of clear and cold weather on 28 November allowed the first surface hoar layer to grow in the Columbia Mountains. However, temperatures again rose dramatically with the arrival of the next warm front. The beginning of December was characterized by the passing of a series of frontal waves from the Pacific that brought continuous precipitation to the Coast and Columbia Mountains, and more intermittent snowfall periods to the Rocky Mountains. Fluctuating freezing levels, a mix of snow and rain and moderate to strong winds produced a variety of storm and wind slab instabilities. Due to the generally mild conditions, however, these instabilities stabilized fairly rapidly and the November crust and recent 28 November surface hoar remained the main snowpack concerns for the time being. The first avalanche fatality of this winter occurred in Glacier National Park on **Mt Macdonald on 7 December** (page 127) and involved the November crust.

Snowfall amounts were considerably less in the Rocky Mountains, but the moderate winds continued to scour exposed slopes and augment existing wind slabs. On 15 and 16 December, a warm front with a distinct temperature spike crossed BC and Alberta, which led to widespread natural avalanche activity in the Coast and Columbia Mountains. The warm southerly winds ahead of this front contributed to a fatal avalanche accident in Banff National Park on **Cascade Mountain on 17 December** (page 133) when a wind slab failed naturally on the November crust and swept down a popular ice climbing route.

After a brief return to seasonal temperatures, a powerful ridge of high pressure established itself over western Canada bringing clear skies and soaring temperatures across the entire region due to the inflow of warm air from the tropical Pacific. At Whistler Roundhouse temperatures did not fall below the freezing point between 21 and 28 December and the maximum temperature measured during that period was 14°C. The rapid and significant warming resulted in a dramatic weakening of the upper snowpack that generated widespread wet loose avalanche activity on southern aspects and cornice failures. At the same time, the November crust-facet combination became more susceptible to natural and human triggers as the strength of the upper snowpack deteriorated. This particularly applied to areas with a shallower snowpack. The November facets were triggered in a fatal avalanche accident that occurred near Golden in the **Hospital Creek area on 26 December** (page 136). Extensive valley fog during this period promoted the growth of the next surface hoar layer across the entire region. In the Columbia Mountains, the maximum growth of surface hoar was particularly visible as a band of white frosted trees just below treeline.

After the initial avalanche activity related to the rapid rise in temperature had passed, the warm temperatures had a positive effect by promoting the settlement of any existing instabilities in the upper snowpack. Once temperatures started to cool off again on 29 December, stability improved even further as the upper snowpack stiffened again. While the stability of the November crust-facet interface also improved during this period, it remained a serious concern. On 30 December, after approximately 10 days of clear weather, the ridge of high pressure eventually broke down and a low pressure system brought new precipitation and more seasonal temperatures to the region. The accompanying winds produced the necessary air flow to mix up the temperature inversion in the Columbia Valley and dissipate the layer of valley cloud. By 3 January, the storm had deposited between 15 and 30cm of new snow covering a wide variety of surfaces including older wind slabs, surface hoar, facets, and smooth sun crusts.

Similar to the beginning of December, the first half of January was characterized by a steady stream of low pressure systems that brought constant flow of snowfall to the region. While storm snow instabilities initially settled quickly due to the milder temperatures, they became more of a concern as temperatures dropped below seasonal averages. By 17 January, the main avalanche concerns in the Coast and Columbia Mountains were soft wind slabs in exposed areas, storm snow instabilities within the top 50cm of the snowpack, the so-called Y2K surface hoar layer buried on 28 December approximately 100 to 150cm below the surface, and the lingering November facet-crust interface. The surface hoar layer was particularly sensitive at treeline and below where the crystals were most well preserved. In the shallower snowpack of the Rocky Mountains, the period of low temperatures resulted in extensive faceting of the snowpack and the sustained winds produced widespread wind slabs. However, several involvements and a fatal avalanche accident on **Tent Ridge on 17 January** (page 138) provided a strong reminder that the November rain crust was still a serious concern.

Snowfalls became more intermittent and eventually ceased as a ridge of high pressure established itself over BC towards the end of January. This period allowed the next layer of surface hoar to grow in sheltered locations and sun crusts to develop on solar aspects. This snow surface was buried on 31 January by a powerful storm that brought heavy snowfall, rising freezing levels and strong winds. Within two days, the storm deposited between 35 and 50cm of new snow on top of the weak surface hoar interface, which produced a widespread cycle of avalanche activity at the end of January.

During the short period of fair weather between 3 and 7 February, a new layer of surface hoar formed in the Coast and Columbia Mountains, while faceting was the dominant process in the Rocky Mountains. This interface was buried on 8 February by a weak disturbance that brought unsettled conditions with a few flurries, some sun and light winds. After this episode, an arctic ridge of high pressure established itself over BC, which brought clear skies and moderately below seasonal temperatures.

This was the first and only time in this season that the entire region was under the influence of the arctic air mass for an extended period of time. Similar to the previous periods of clear weather, these conditions promoted the widespread development of surface hoar. While the sun destroyed the surface hoar on solar aspects each day, it grew continuously in shaded areas. The colder temperatures also resulted in faceting in the snow layers near the surface. At the end of this period, the Coast Mountains reported a generally well-settled snowpack. In the Columbia Mountains the two recently buried surface hoar layers remained problematic and while the November rain crust and the Y2K surface hoar were still identifiable weaknesses in the lower snowpack, they were much more of a concern in the shallower snowpack of the Rocky Mountains.

New snow arrived around 19 February with the passing of the next warm front. While the bond with the old snow surface of facets, crusts and surface hoar was initially poor, conditions improved slowly during the subsequent drop in temperature. However, a series of storms caused storm and wind slab instabilities to remain major concerns until the snowfall ceased around 5 March. In the Columbia Mountains, the most recent surface hoar layer was now 30 to 45cm below the surface and had become the most reactive persistent weakness.

While a weak ridge of arctic high pressure brought a few days of fair weather to the Coast and North Columbia Mountains and produced a melt-freeze crust on solar aspects, the southeastern parts of the region were under the influence of a small low pressure system tracking in from the United States. In the Rocky Mountains, this storm resulted in accumulations up to 30cm of new snow accompanied by westerly winds. The next fatal avalanche accident involved a cornice failure that occurred at **Sunshine Village on 9 March** (page 141).

As the ridge of high pressure broke down on 10 March, a powerful low pressure system made its way onshore. This storm was the first in a series of disturbances that sent pulses of new snow across the region. The combination of March temperatures and moderate winds created widespread wind slabs. Between 10 and 18 March, the Coast Mountains received roughly 70cm of new snow. While widespread storm-snow avalanche activity was observed in all mountain ranges, a fatal avalanche accident occurred in the Coast Mountains at **Wasp Creek on 19 March** (page 143). Heavy snowfall and strong winds from the south continued to produce widespread wind slabs in the alpine, while lower elevations received rain due to rising temperatures. By 20 March, the surface hoar layer from late February was buried by 80 to 150cm of new snow. On 22 March, a cold front brought a last pulse of snow before the weather changed into a more spring-like pattern.

The last fatal avalanche accident of the season occurred in the Coast Mountains on **Powder Mountain on 26 March** (page 145). The related avalanche involved a soft slab that failed on the melt-freeze crust buried on 9 March. The rest of the winter season was characterised by extended periods of clear weather interrupted by shorter episodes of unstable weather with snow and rain. Alternating influences of the continental arctic air mass and the maritime air mass from the Pacific resulted in dramatic fluctuations in temperature. Natural avalanche activity was primarily related to warm temperatures and solar radiation and the snowpack transformed into a well consolidated spring snowpack. All persistent weaknesses stabilized with the exception of the November crust facet interface, which was preserved deep in the snowpack. When the Canadian Avalanche Association published the last avalanche bulletin on 20 April, this deep persistent weakness had not yet sprung back to life, but still posed a concern for the release of large wet slabs as the snowpack became increasingly isothermal.

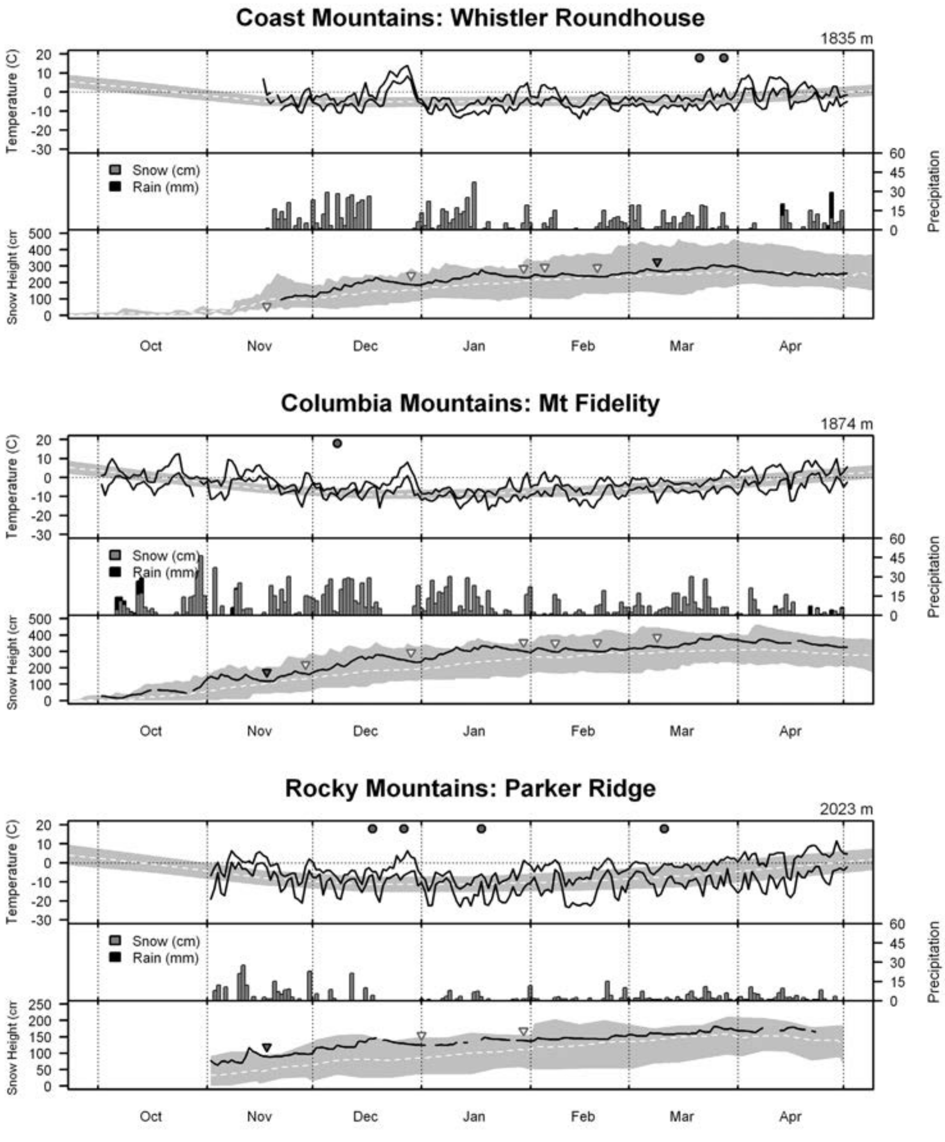

Figure 7.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 1999/2000 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanche (black triangles). Other persistent weak layers are shown with light triangles. The grey band shows minimum, average (dashed line) and maximum snowpack height measures at this location since 1976 (Whistler Roundhouse and Mt Fidelity) or 1978 (Parker Ridge).*

7 December 1999, Backcountry Skiing
Mt Macdonald, Glacier National Park, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Large avalanche released on November crust**
- **Efficient rescue led by Parks Canada, guides, and instructors**

A group of four skiers and one snowboarder arrived at the Rogers Pass Centre in Glacier National Park on the morning of 7 December to sign out for a day in the backcountry. They planned to climb up the NRC Gully area towards Shoulder Valley, and possibly into the alpine terrain on the west shoulder of Mt Macdonald. This route is located directly above the highway at the summit of Rogers Pass, and the lower part is a popular trip in the early season. One member of the group acquired the necessary permit to enter the restricted zone around Mt Macdonald, while at least one other studied the avalanche bulletin, avalanche reports, and weather forecasts. They were the first group of the day issued a permit for that area, and would be climbing ahead of anyone else. One member of the group had skied in the same area on 5 December, and most were familiar with their destination. Their permit was for seven skiers, as they were expecting two other skiers to join them later.

On the lower part of the mountain, they followed an established up-track, which traversed the thick trees beside the large, southernmost avalanche path on Mt Macdonald's west shoulder and climbed closer to the NRC Gully. Above a prominent bench at the base of the Shoulder Valley bowl, they began breaking their own trail up the rounded ridge separating the bowl from the bigger slopes of the Macdonald west shoulder. Aware of their exposure and the avalanche hazard, they used small benches and stands of trees as protection while they climbed higher through the treeline elevations, taking turns breaking trail.

As they climbed, they noted that the snow surface was becoming stiffer and more slab-like. This stiffening may have been caused by winds the previous day, and the storm snow may have also been settling and stiffening due to the warmth of the afternoon sun.

When they approached the open slopes of the alpine, they began to observe shooting cracks around their skis and small slabs about 30cm thick peeling away from rolls and switchbacks. They also experienced several whumpfs. The group discussed their options and decided to continue, but to avoid the big slopes facing into Shoulder Valley and down Macdonald's west shoulder. They spread out to reduce the exposure of the group, but their route was confined to a narrow strip of relatively safe terrain and they ended up stacked above one another along the trail.

Lower down, a group of students with their instructor on a CAA professional avalanche course had just arrived near the prominent bench. The group traversed out of the Shoulder Valley toward the paths on Macdonald's west shoulder at about 1950m elevation. A second group of students and their instructor on the same course were at about 1800m elevation in the NRC Gully. A local mountain guide was enjoying a day off and was climbing near the upper group of students. The instructors were also certified guides, and were aware of the skiers higher up on the mountain.

Reports at the Rogers Pass Centre showed 14cm of new snow in the previous 24 hours at the Rogers Pass study plot, located at 1310m near the highway, and 28cm at the Mt Fidelity research station, located about 10km west of the summit at 1905m elevation. Since the last break in the weather about a week earlier, storm snow amounts of 42cm at Rogers Pass and 45cm at Mt Fidelity had accumulated. Moderate southerly winds with strong gusts had been recorded by a remote weather station located at the north end of Mt Macdonald's west shoulder at 1900m elevation during that time. These winds are known to transport snow across west-facing upper slopes of the west shoulder, creating significant spatial variability in snowpack depth and layering there.

The avalanche bulletin issued by parks forecasters on the morning of 7 December listed the danger rating at Low below treeline, Moderate (with areas of Considerable) at treeline, and Considerable in the alpine. The trip up to Shoulder Valley and Mt Macdonald's west shoulder traverses all of these elevation bands. The bulletin warned of "faceted layers, both within and above the buried rain crust (down approximately 90cm)" that were "still a potential failure layer in specific terrain features." It was also clear that "a large degree of spatial variability in this persistent feature" was to be expected. Two surface instabilities down 25cm and 55cm would strengthen quickly, but the "deep layer will persist as a concern."

By midday on 7 December, the air temperature was -10°C at the Macdonald west shoulder weather station; however, the broken skies of the morning were clearing, and the sun was shining on the south and west facing slopes. The skiers lower down on the mountain could feel the warmth of the sun on their faces, despite the relatively cool temperature.

One member of the group of five had been in the area on 5 December, and had performed a rutschblock test on a north-facing slope in Shoulder Valley. A score of 5 suggested stability, although this was before two days of heavy snowfall had likely affected conditions on the mountain.

By about 12:30 they had climbed to 2285m elevation, and the lead skier was having difficulty finding a safe route. Three of the remaining four had caught up to him, while the fifth was about 30m below. He was working hard and had removed his hat and jacket. Another skier from the group took over the lead and tried a different approach across a small gully. The new lead skier was in the gully, making a kick-turn when the snow around him started to break up.

As the snow crumbled around the lead skier, the two nearest him noticed that only the snow in the gully was moving. Reaching out to prevent him from falling, they then saw large blocks of snow moving over the crest of the slope above them. It was a "large wall of white" and all five of them were in its path.

From an excellent vantage point across the valley, another avalanche course group watched the avalanche roar down Mt Macdonald's west shoulder. The instructor shouted a warning into his radio, hoping to alert the two other course groups in that area. The students and instructor near the NRC Gully watched as the large powder cloud, 30m above the tree tops, traveled past at an estimated 150 km/h. They immediately checked in with the course group further out on the west shoulder by radio. The avalanche had dusted them, but they were otherwise unaffected. The avalanche was likely still in motion when Glacier Park staff received word by radio that there had been a large avalanche and several skiers higher up on the mountain had certainly been involved. A search and rescue operation would be required, as all five in the lead group were indeed caught in the avalanche.

The two course groups and the guide immediately began a real-life avalanche rescue. Most of the students, along with the guide and one instructor began a beacon search down the slope toward the large deposit, while the other instructor and two students climbed toward voices and shouting they could hear above them. Meanwhile, Parks Canada wardens and avalanche staff formed an incident command near the base of the path to coordinate the rescue and available resources. They requested helicopter support and began to muster additional rescuers and gear to be flown up the mountain.

The instructor and two students climbed quickly, locating three of the skiers some distance above. Two of them had been carried down a gully feature toward Shoulder Valley; one was having difficulty breathing due to chest trauma but was conscious, while the other was entangled in some small trees and had suffered multiple injuries and broken bones, but was alert and oriented. He was climbing without a jacket on, and the force of the avalanche had torn his beacon away. It was not recovered until the next day. The third was found with a severely injured knee near the top of a stand of trees closer to the main path on the west shoulder, just as the first additional rescuers arrived by helicopter.

Shortly after the guide and students arrived, the skier suffering from chest trauma stopped breathing, lost consciousness, and his heart stopped. CPR was started immediately, but was unsuccessful. He died from severe internal bleeding because of the trauma.

The group searching down the mountain had arrived at the main deposit in the runout zone of the avalanche path, but had not located any beacon signals or victims of the avalanche. They were met at the highway by park staff, and the guide and instructor were shuttled to a staging area to be flown back up the mountain by helicopter to further assist with the rescue.

On the first helicopter flight, two additional rescuers were dropped at the location of the three skiers who were found first, to assist with treating their injuries and to search for other victims. The helicopter then dropped three more rescuers near the top of the avalanche, where they began a systematic beacon search from the top down. They discovered no signals from buried victims, and eventually came upon one of the skiers well above the other three. He had a dislocated hip and other injuries, but was otherwise alert and oriented.

The highly efficient search and rescue mission continued, as more resources and personnel arrived. The fact that the original group of rescuers carried portable radios and were able to communicate with the incident command and each other helped the operation proceed smoothly. As the rescue continued, searchers on the mountain were confident there were no beacon signals indicating buried victims; however, only four of the five people in the first group had been found, and their permit showed seven skiers. There were also at least two other groups of skiers known to be in the area. Two avalanche rescue dog teams were combing the deposit for any signs of buried people, while the rescue coordinators confirmed the whereabouts of everyone on the mountain. One of the five in the original group was ambulatory with a fractured tibia, and had been between groups of rescuers after the avalanche. He walked down the avalanche path to the highway. The two other skiers listed on the permit had arrived late and chosen another area to ski, and the other groups on the mountain eventually made their way back to the highway, unharmed. By about 15:00 everyone was accounted for, and victims were being evacuated from the mountain by helicopter–the last just as dusk arrived and daylight faded. The rescuers made their way off the mountain in near darkness. One person had died in the avalanche, and the remaining four were taken to hospital to treat their injuries.

The skier-triggered slab avalanche released from a west-southwest aspect at about 2430m elevation. It was size 3 or 3.5, and ran to

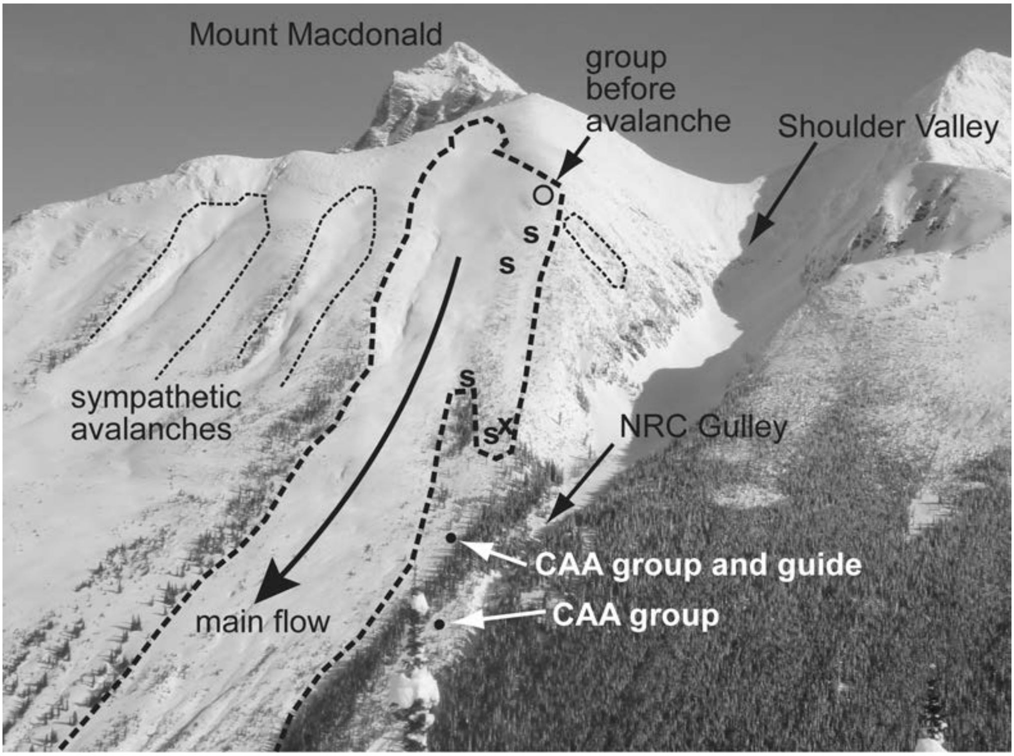

Figure 7.2. *Mt Macdonald, December 1999. S- location of survivors, X – deceased. Photo: Cameron Ross.*

1350m elevation to near the end of the path, just above the highway. The deepest part of the deposit was 3m near the main path, and some moving snow had travelled down a more southwest-facing gully near the start zone, toward Shoulder Valley. Several of the skiers had been carried down that way. The crown fracture was 250m wide, 140cm deep at its thickest, tapering down to only 5cm in places. The start zone slope was inclined at about 35°, but there were several steeper convexities and benches in the start zone and upper track. In several locations rocks protruded through the bed surface, with soft faceted snow surrounding them.

Four other avalanches released at the same time on other start zones of Mt Macdonald's west shoulder, apparently sympathetic with the fatal one.

The avalanche released on a layer of soft, faceted snow atop a hard rain crust, buried around 17 November. The crust was laminated in thin layers of alternating ice and faceted snow, corresponding to periods of rain and snow that fell between 14 and 16 November. One rescuer noted that in several places the bed surface was "stepped" between these laminations. Significant spatial variability in the snowpack is the rule on the high start zones of the west shoulder of Mt Macdonald. This is a result of the interaction between the rough but mostly planar upper slopes and the prevailing south and southwesterly storm winds. The variability in slab thickness of this avalanche, the rocks protruding through the bed surface and the variation in total snowpack depths of up to 2m in the area of the start zone attest to this effect.

The crust layers that formed in mid-November were buried by more or less continuous snowfall, with 224cm recorded at Mt Fidelity, under the influence of moderate to strong south and southwest winds. This weather pattern led to the development of a relatively homogenous, thick slab overlying the crust and the soft, faceted snow just above it. A typical fracture line profile collected at the thickest part of the slab the day after the accident shows this layering. The effects of wind, settlement, and the sun on the upper snowpack likely caused it to reach a critical stiffness and load by 7 December. One rescuer noted that by the end of the day, the snowpack along the flanks of the avalanche was very sensitive to even light loads, and large blocks would peel away and slide on the crust as he skied out.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	Cracks and whumpfs	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Trees	Planar	Sparsely treed slope

Source

- BC Coroners Service
- Parks Canada
- François Desrosiers
- Jim Bay
- Scott Davis
- Karl Klassen
- Brad White
- Eric Dafoe
- Bruce Jamieson

Comment

Many popular backcountry routes—including those very close to the highway at Rogers Pass—are not easily accessible to rescue and emergency medical resources. Proximity to the road or familiarity with terrain and the snowpack does not reduce the risk of avalanche or the consequences of an accident.

In this accident, the guides, instructors, and students who were on the mountain were in an excellent position to work together with the rescue personnel and resources of Parks Canada; this fortunate circumstance allowed for a highly efficient and coordinated rescue to be completed before dark, and probably saved several lives. All of the rescuers, including the students, acted with commendable skill and professionalism under the circumstances.

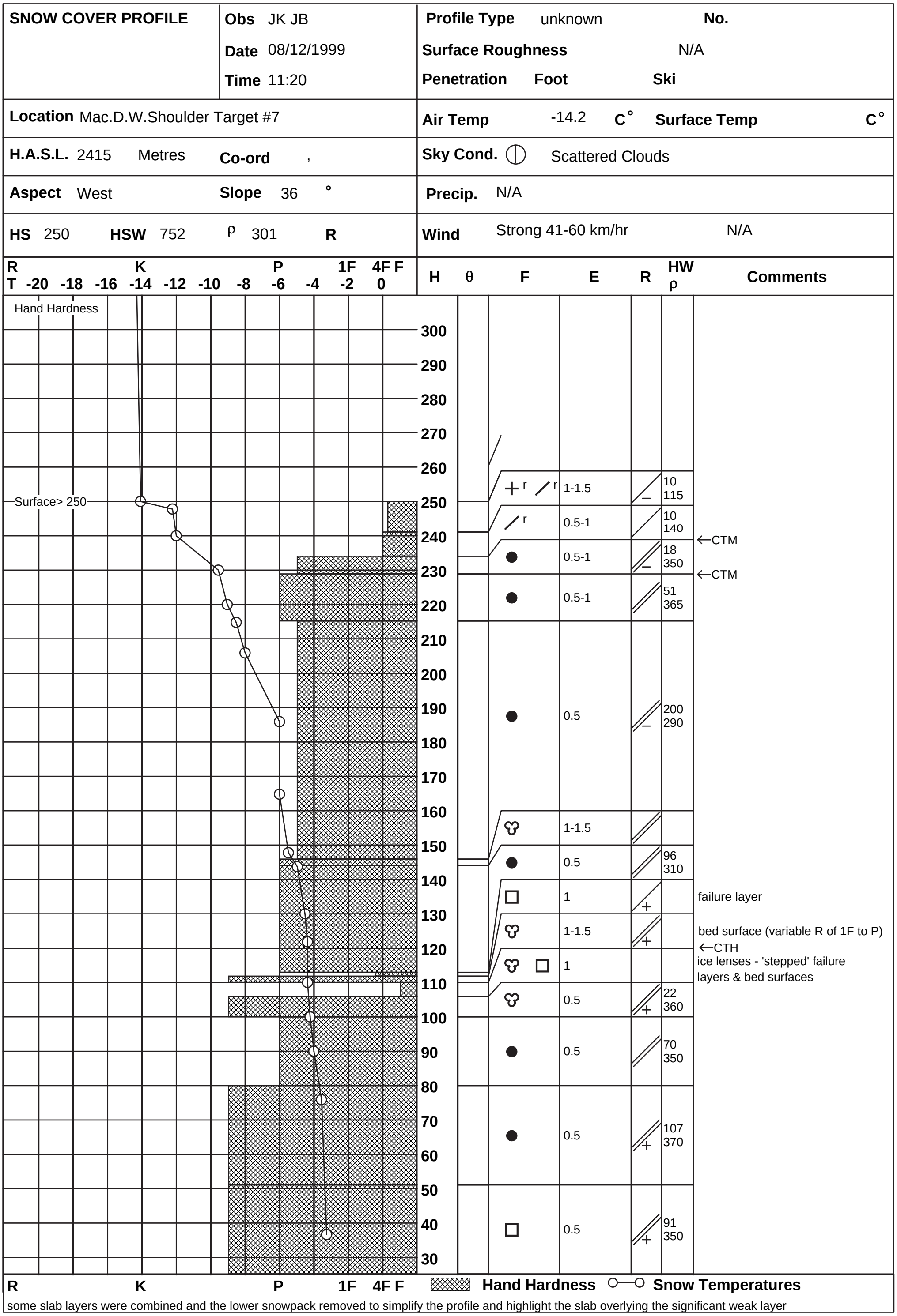

Figure 7.3. *Mt Macdonald, 7 December 1999. Fracture line profile observed one day after the accident.*

17 December 1999, Ice Climbing
Cascade Mountain, Banff National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Strong warm wind, then natural avalanche hits ice climbers**

On 17 December 1999, there were four groups, for a total of nine people, climbing the frozen waterfall on Mt Cascade near the town of Banff, Alberta. The ice climb is popular and attracts climbers of various abilities. Above its main pitches, set back in a notch, is the final pitch 12m high, which resembles a frozen curtain.

There were two accidents on this day within about 15 minutes, the second of which involved an avalanche. In the first one, a beginner climber low on the waterfall started to descend at about 13:30. He lost his balance, then fell down rock and ice steps. All but the topmost two climbers descended to assist the fallen climber, who had been killed by the fall.

The Cascade Waterfall is about 12km outside the forecast region for Banff, Yoho and Kootenay Parks. The bulletin issued on the afternoon of the 16 December for the following day rated the avalanche danger as High in the alpine zone and Considerable at treeline. The bulletin also noted: “Moderate to strong SW winds have created wind slab conditions in the alpine and to a lesser extent, at treeline. In the alpine, explosive tests and skier triggering of avalanches to size 2.5 have been observed. Failures are occurring both at the storm snow/old snow interface and deeper in the pack, on the November rain crust.” Due to wind scouring, the alpine slopes around the Banff town site, including the slopes above Cascade Waterfall looked “bony.”

By mid-day, a strong warm wind—known locally as a Chinook—was blowing and warming the upper snowpack.

The topmost two climbers had climbed the curtain. The first had rapelled, detached from the rope, and was standing on the level snow in the notch at the base of the curtain. Around this time, the accident occurred on the lower mountain, out of their sight. The second climber started to rappel and was about half way down the curtain when an avalanche released in the basin well above. He quickly swung to his right, away from the main mass of the avalanche. The climber at the base of the curtain was swept from the notch and down the main pitches, coming to rest about 10 metres from the beginner who had fallen earlier. He was also killed by the fall but not buried by the avalanche. As the avalanche plummeted down the waterfall, loose rocks were picked up which hit some of the climbers descending to help the fallen beginner.

At the time of the two accidents, Banff Park wardens were placing explosives from a helicopter to release unstable snow above the Sunshine Road. They quickly returned to Banff to get an avalanche dog team. They flew to the waterfall where they observed two victims and not enough avalanche deposit to bury people. They dropped off the avalanche dog in Banff. Rescuers were slung to the site under the helicopter to pick up the victims. Flying was difficult because of the strong wind.

Other than the two deceased victims who were slung from the site, the others who had been hit by the avalanche and rocks walked down. Several were badly bruised. One spent a week in hospital with a back injury and a suspected kidney injury.

Figure 7.4. *Cascade Waterfall, 17 December 1999. The photo was taken in a different winter when there was more ice. X - deceased. Photo: Bruce Jamieson.*

The size 2 avalanche started naturally on a southeast-facing slope at about 2130m. It likely started on the crust from 17 November 1999. Before reaching the top of the frozen curtain, it had picked up a considerable amount of broken rock. Much of the deposit piled up in the notch at the base of the curtain. Some of the flowing snow swept the climber down the main pitches of the climb

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Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	?	?	?	Strong Warm Wind

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Cliffs	Not Convex	No Trees

Source
- Parks Canada

Comment
Many frozen waterfalls in the Rocky Mountains are below avalanche bowls. The avalanche hazard must be assessed based on the bulletin, as well as weather and avalanche observations from below the starting zone.

A warm wind can effectively warm the upper snowpack, potentially reducing its stability.

Some of the climbers had observed that the slopes above the waterfall were “bony” (not holding a lot of snow) and considered the risk to be acceptable.

At least one pair of climbers became concerned by the strong warm wind and had started to descend when the avalanche struck.

26 December 1999, Snowmobiling
Hospital Creek, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **One hill climber plus two snowmobilers in the runout zone caught**
- **Only one transceiver**

On Sunday 26 December, many snowmobilers accessed the upper slopes of Hospital Creek about 10km northeast of Golden, BC. In a group of four, one snowmobiler (called Rider 1 in this summary) was more experienced than his companions. He had a transceiver but his friends did not.

The day was warm and sunny. It had not snowed in recent days and the wind was light. Three days before the snowmobiling trip, the Canadian Avalanche Association issued a regular bulletin for the Rocky Mountains in which the avalanche danger was rated High in the alpine zone and Considerable below treeline. The bulletin also noted: "Naturals to size 3 on south aspects are common in the mountain parks region, running full path on the November crust. … Natural indicators will taper off this weekend. Those who know the Rockies snowpack well are still very concerned about the crust/facet interface lurking down near the ground. The Christmas holidays are no time to deal with tragedy, so be extra cautious this weekend. Even with clear skies, wind transport and solar radiation will be constantly causing subtle changes in the balance of tensions on this persistent deep snowpack instability." At the ski touring operation to the west, the air temperature reached 6°C on the day of the snowmobile trip. Along Hospital Creek, several size 1 to 2 slab avalanches were visible on all aspects in the alpine zone.

Near the head of Hospital Creek at about 13:45, Rider 1 tried to climb up a steep, narrow southwest-facing gully. He was about half way up the gully when he triggered a slab avalanche. He disappeared in the avalanche. Two of his three companions, who were watching from the bottom, were carried and partly buried by the avalanche. They had minor injuries but were able to free themselves from the deposit. The fourth rider was not hit by the avalanche.

Since they did not have any transceivers, they sought others who did. They encountered a guided group with transceivers, probes and shovels who came to the avalanche site. Rider 1 was located about 40 minutes after the avalanche under 1.5 to 2m of the deposit. Since he did not have a pulse, they tried to resuscitate him. One of the rescuers was able to call emergency personnel with his cell phone.

Two ambulance attendants plus two avalanche technicians flew to the site. After the technicians assessed the site to be safe, the helicopter landed. The ambulance attendants loaded the victim into the helicopter and continued CPR during the short flight to Golden Hospital. Rider 1 had asphyxiated due to compression of his chest by the avalanche deposit.

The crown fracture of the dry slab avalanche was in the middle of an open 38° slope, which varied from 32 to 40°. The middle part of the gully reached 45° at the steepest part. The crown was 50 to 80cm high and 150m wide. It was a size 3 avalanche that ran about 500m down the slope. The snowpack in the area ranged from 50 to 120cm. In most areas, the November rain crust was in the middle of the snowpack.

The next day a fracture line profile was observed on the west flank of the crown where the slab was relatively thin and the snowpack height was only 52cm. Tencm of soft (fist hardness) facets and depth hoar, 3 – 6mm, overlay the November rain crust. A shovel test gave a moderate-to-hard result on the crust. In three compression tests, the facets fractured with the first moderate tap (total 11 taps). The coldest temperature in the profile was -1.7°C. Other than the slab avalanches in Hospital Creek, it is unknown if the snowmobilers observed other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	?	No	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Gully	?	Open slope

Source

- BC Coroners Service
- InfoEx
- Phil Hein

Comment

At least two of the three snowmobilers were in the runout zone while they watched their companion climb up the gully.

The combination of a transceiver, probe and shovel—carried by each person—can reduce the search time and potentially save lives.

17 January 2000, Backcountry Skiing
Tent Ridge, Kananaskis Country, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Large avalanche released on buried crust**
- **Triggered by the weight of two skiers**
- **Snowpack test indicated stability, but snow felt "spooky"**

Four skiers and a dog were backcountry skiing in the Tent Ridge area, near the Spray Lakes in Kananaskis Country. They approached the cirque at the head of the horseshoe-shaped valley, and chose a steep, treed slope to climb towards the ridge. Along the way, they dug a snow profile and performed a snowpack test. The high rutschblock score they observed was encouraging, but nonetheless the snowpack felt "spooky," which echoed the public avalanche bulletin issued by Kananaskis Country staff the previous day. It described the snowpack as "dangerously weak" requiring "only a light trigger (i.e. skier, snowboarder) to trigger failure."

The skiers proceeded to the top of the ridge at about 2400m elevation, and chose to ski a slightly steeper, sparsely treed run closer to the main slide path at the head of the valley. They started their run at around 13:30. One skier struggled with the conditions and fell, and a second skier started skiing down to offer assistance.

As the skier approached to help his partner, the slope began to fracture and slide. Everyone in the group—including the dog—was caught in the size 3 avalanche. The fallen skier was carried through the trees for about 100m, while the second skier was able to hold on to a tree and was not carried far. The rest of the group was not buried, although the dog was missing.

After the avalanche, the skier who had grabbed the tree started a transceiver search for his partner, and a short distance down slope saw her lying face-down and partially buried. It was clear she had suffered severe and fatal trauma during the avalanche, likely because of hitting trees.

The remaining three skiers (the dog was not found) skied out of the area and notified Kananaskis Country Rangers of the accident. Strong winds prevented a recovery operation until the following day.

The skier-triggered size 3 slab avalanche was approximately 300m wide, with an average slab thickness of 1m. The crown of the avalanche was about 70cm thick near the ski tracks. It ran to the bottom of the slope about 400m below, partly within the treed fringe of the path.

Approximately 15cm of new snow had fallen at the valley bottom in the previous few days, with a larger amount likely at higher elevations. It was snowing lightly on the morning of 17 January, with a few centimetres of snow having accumulated overnight. By the afternoon, winds at the ridge top were strong and gusting.

A fracture line profile observed a few days after the accident showed that the failure occurred in a thin, very weak layer of faceted crystals lying about 10cm above a thick, hard rain crust formed in November. The avalanche scoured down to the crust as it was moving. The stiff lower slab probably enhanced potential for wide fracture propaga-

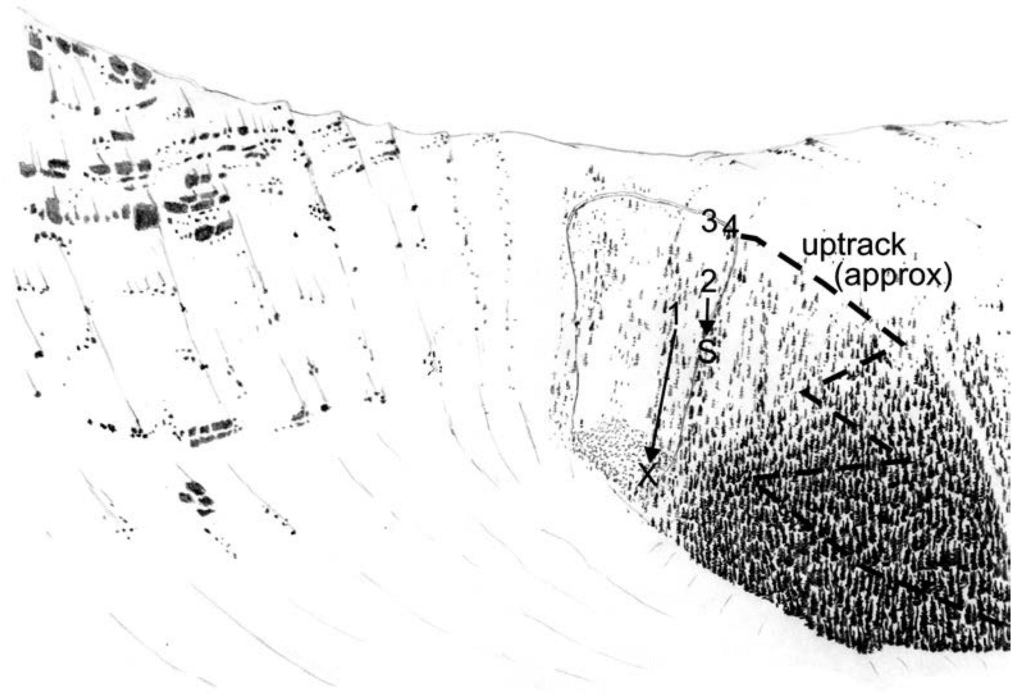

Figure 7.5. *Tent Ridge, 17 January 2000. Location of uptrack and skiers is approximate. 1 to 4 – location of skiers when avalanche released, S - survivor, X – deceased. Skiers 3 and 4 were caught by the avalanche, but not buried.*

tion, while the weight of the new snow (and the skiers) overloaded the weak layer. Two people narrowly escaped an avalanche in an adjacent drainage the previous day, which occurred on the same weak layer. Many other skier-triggered and spontaneous avalanches occurred on previous days throughout the Rocky Mountains to the west and south of Tent Ridge.

SNOW COVER PROFILE KANANASKIS COUNTRY PUBLIC SAFETY SERVICE	**Obs** BD/GF/BW **Date** 19/01/2000 **Time** 12:50	**Profile Type** Fracture Line Profile **No.** **Surface Roughness** N/A **Penetration** **Foot** **Ski**
Location Tent Ridge Avalanche Site		**Air Temp** -12.5 **C°** **Surface Temp** **C°**
H.A.S.L. 2400 Metres	**Co-ord** ,	**Sky Cond.** ◯ Clear/No Clouds
Aspect East	**Slope** 44 °	**Precip.** No Precipitation
HS 151 **HSW** **ρ** **R**		**Wind** Calm <1 km/hr N/A

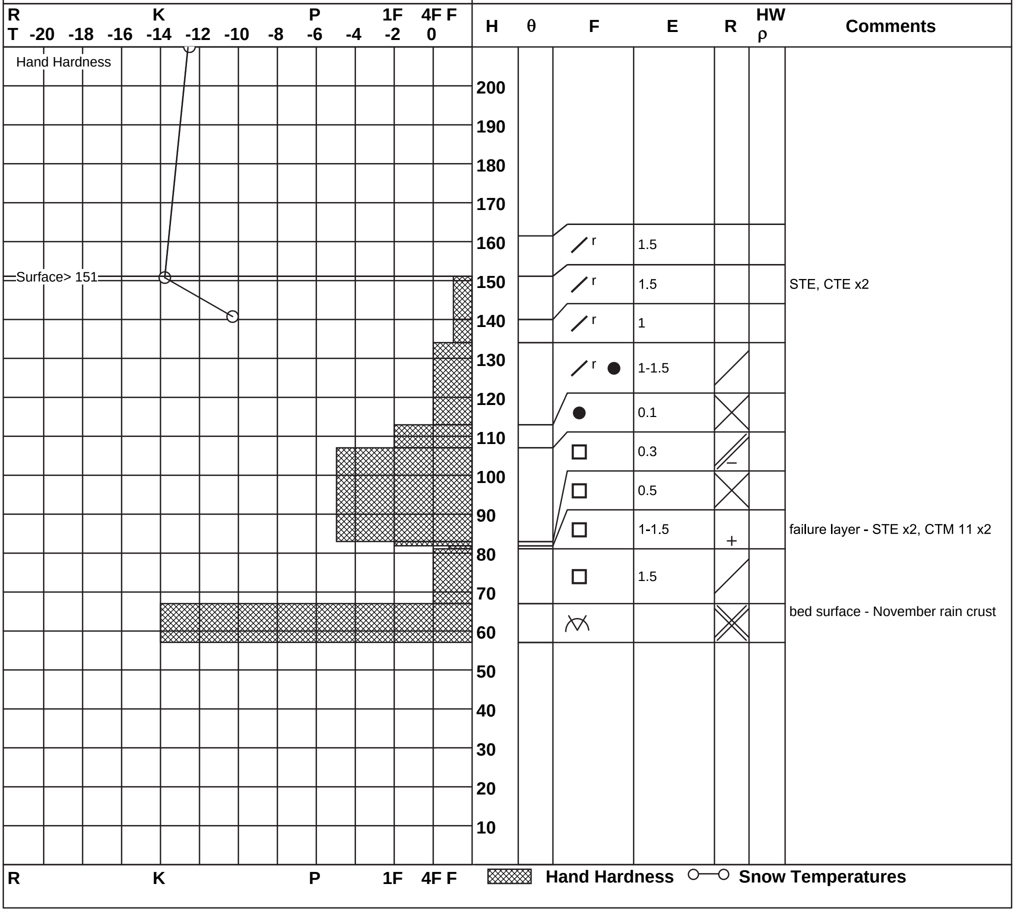

Figure 7.6. *Tent Ridge, 17 January 2000. Fracture line profile observed after the accident.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	?	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
44°	Trees	Planar	Sparsely treed slope

Source
- George Field
- Kananaskis Country Public Safety
- Brad White

Comment
Localizing the information in the public avalanche bulletin can be difficult, especially when intuition is contradicted by test results suggesting stable snow. It is always important to include all available information— including gut feelings—when making decisions in the backcountry.

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9 March 2000, Out-of-Bounds Snowboarding Near Sunshine Village Ski Area, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Cornice Fall	Complex

- **Cornice collapse and long fall**
- **Adjacent to ski area**

A group of three snowboarders met up just outside the boundary of the Sunshine Village ski area on 9 March 2000. They had crossed the ski-area boundary by climbing above the Goat's Eye chairlift and traversing around to the north, to an area known as "R2-D2 Gullies." They were planning on riding down a large chute in that area, frequented by out-of-bounds skiers and riders. They had all been to this area before, and there were many tracks visible from other skiers and riders.

The Banff-Yoho-Kootenay public avalanche bulletin issued for 9 March discussed the effects of recent wind on the formation of slabs. The danger was Considerable in the alpine.

Nearing their destination at around 10:45, they decided to climb a little higher and further around the mountain to check the views. They followed other tracks most of the way. One of the snowboarders approached the edge of a steep drop-off to get a better look at the northeast facing terrain below, while the other two waited a short distance behind where the tracks ended.

As the snowboarder peered over the edge, a small area of snow he was standing on gave way, and he disappeared from view. The remaining two, not knowing what the terrain below the edge looked like, called for him for several minutes, but heard nothing. One of them returned to the ski area to get help, while the other moved a bit higher and further along to try to get a view of the slope below. He continued calling for his friend, but still heard nothing and could not see him. After about 15 minutes, he returned to the ski area as well.

Wardens from Banff National Park were notified of the fall, and they came by helicopter to search the area below a broken cornice. The cornice was located at the top of a vertical rock headwall and cliffs. At the base of the cliffs they noticed a snowboard, and then further down the slope they noticed a helmet. Further still, almost 400m below the top of the cliff, they saw the snowboarder partly buried in the debris from the cornice and the cliffs. He had died of injuries sustained in the fall.

The area of cornice that broke away was small (1m x 1m), and was only a few metres away from some rocks poking through the snowpack. A narrow, unskiable gully cutting the cliff face was located directly below the snowboarders, such that the cornice was unsupported where it appeared to be solid ground. No part of the gully or the cliffs was visible from above.

Observers in the neighbouring National Parks noted that recent storm snow was being moved around by westerly winds and beginning to load on to north and east slopes. They had also noticed some soft-slab avalanches being triggered by cornice falls from above. Recent wind transporting snow onto north- and east-facing terrain may have expanded the cornice slightly.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	No	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
N/A	Cliffs	Unsupported	Alpine

Source

- Parks Canada
- InfoEx

Comment

Big alpine terrain, even adjacent to ski areas, requires considerable experience and skill to navigate safely.

19 March 2000, Heli-skiing
Wasp Creek, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Complex

- **Recent wind loading**

A Pemberton resident occasionally organized helicopter skiing in the mountains near Pemberton, BC. On Sunday 19 March 2000, he arranged for two groups of three skiers and snowboarders to go heli-skiing. He acted as the guide for the trip and led the first group.

At 13:55, the groups lifted from the Pemberton airport and skied on Sugarloaf Mountain and in the Wasp Creek drainage about 19km northwest of Pemberton. During their first seven runs, they ski cut (intentionally triggered) some slab avalanches about 20 to 25cm thick. They also skied over a size 2 natural avalanche. During the afternoon, the trip leader took "baby steps" into progressively more serious terrain.

On Thursday 16 March, three days before the avalanche, the Canadian Avalanche Association issued a bulletin for the South Coast Mountains. The regional avalanche danger was rated Considerable above treeline and Moderate below. The bulletin also noted: "... a series of disturbances out in the Pacific promptly began tracking onshore Thursday. Weather forecasters predict these disturbances will continue in waves approximately 24 hours apart throughout the weekend. Expect the freezing level to bounce around, but possibly climb as high as 1700m at times. A mix of wind affected snow accumulation followed by solar radiation will be the end result."

At the weather station on Whistler Peak (elevation 2180m) sustained wind speeds over 50 km/h were recorded on 18 March, mostly from the west or southwest. The alpine ski lifts were closed for the day because of wind. On 19 March, the air temperature at Whistler Peak ranged from -10 to -4°C, suggesting the snow remained dry where the groups were skiing in the alpine zone. Two neighbouring heli-ski operations reported numerous skier-controlled slab avalanches on the day of the accident, including many of size 1.5 to 2. Many recent natural slab avalanches were also observed.

The trip leader was observed to check the snow before each run. However, it is unknown if he recorded weather and snowpack observations on this or previous days of heli-skiing.

For their last run of the day at 17:35, the first group landed on the ridge at about 2170m and descended onto an east-facing slope. The trip leader asked the guests to ski about 50m apart, and then he tried to ski cut the upper part of the slope. At 17:47, he skied into a bowl, and was about 10 turns into the bowl when a slab avalanche released, sweeping him down the slope. Part way down, he appeared to be upright, and then went over a cliff and disappeared into the flowing avalanche.

The skier behind the trip leader was not caught but had observed him being caught. He yelled to the other two skiers to get away. After the avalanche stopped, these three skiers moved down the slope to begin the search.

Friends of the skiers had rented a second helicopter and witnessed the avalanche from the air. The pilot of this helicopter called the pilot of the heli-skiing helicopter, who moved the second group of heli-skiers to the deposit within three minutes. They started a transceiver search but had some difficulty pinpointing the signal from the buried leader. After they probed the victim, they dug a hole that seemed "too deep." They then re-probed the victim and refocused the digging. The trip leader's foot was uncovered about 1.6 metres below the surface. More digging revealed that the victim's body was inclined at about 30° and head downhill. His head was about 2m below the surface. Burial time was estimated to be 25 to 30 minutes. The victim's skin was bluish.

While the victim was being uncovered, guides from a neighbouring heli-ski operation arrived. Artificial respiration was started and then—when more of the victim was uncovered—CPR was applied. Paramedics arrived by helicopter. A doctor arrived and pronounced the victim dead at 19:00. The cause of death was combined smothering and mechanical asphyxia.

The dry slab avalanche released at elevation 2160m on a 38° slope. The crown fracture varied in height from 40 to 100cm and averaged 50cm. It was 220m wide and partly below a rock outcrop. The avalanche released on a weak layer of stellar crystals with some small surface hoar crystals.

The trip leader had been carried about 75 vertical metres and 210 metres down along the slope. He was buried in the upper part of the sloping deposit. The deposit ended at the bottom of a steep gully at about 1890m. The deposit was about 90m wide, 330m in length. The depth averaged 1.7m and the maximum probed depth was 3.5m. It was a size 3 avalanche.

At the accident site, investigators obtained a rutschblock score of 2 on the failure layer of well preserved 1 to 5mm stellar crystals. The compression test at several sites also produced a fracture at this level during moderate tapping (13, 18 and 19 taps). In places, 2mm surface hoar crystals were also observed in the failure layer.

In one of the three profiles, the slab included wind-stiffened snow of 1-finger hardness, favourable to spreading fractures, and resulting in wider slab avalanches. The snowpack was about 3m deep.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	No	Yes	?	Extensive wind	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Cliff, gully	Convex	Open slope

Source
- BC Coroners Service
- Scott Aitken

Comment
During the afternoon, the group increased their exposure to more serious terrain. They were not deterred by triggering some 20 to 25cm thick slabs. The fatal slab avalanche averaged 50cm in thickness.

The trip leader chose to ski late into the afternoon, reducing the time available for the unexpected events or a rescue. In this case, the rescue was not compromised by the time of day.

Digging in an avalanche deposit is time consuming. Leaving the probe in place probably would have resulted in more efficient digging for the victim, but may not have affected the outcome.

26 March 2000, Snowmobile-Assisted Backcountry Snowboarding Powder Mountain, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slabs	Complex

- **Warm afternoon**
- **Buried weak layer above a spring crust layer**

On 26 March 2000, three snowboarders were riding in the backcountry on Powder Mountain, BC, above Grizzly Lake in the Brandywine area, about 30km west of Whistler, BC. They had accessed the area by snowmobile, and were using the machine to return to the ridge top after each run down.

An automated snow survey site located at 1340m about 10km west of Powder Mountain had recorded 21mm of precipitation on 23 to 24 March, and a further 3mm on 26 March. Winds in the alpine at Whistler were mostly light from the southwest over the previous few days. Local operations had noted moist snow in the alpine on sun-affected slopes; air temperatures in the alpine were mild but mostly below freezing on the afternoon of 26 March.

The public avalanche bulletin valid for 26 March listed the danger as Considerable with areas of High for above treeline elevations. It is not known if the snowboarders consulted the bulletin.

The snowboarders were making long runs down a south/southeast-facing alpine bowl to Grizzly Lake below. All three would ride the snowmobile to the top of the run then two would snowboard down while the third drove back to the bottom for the next shuttle to the top. At around 13:30, two had started a run down the bowl together while the snowmobile descended to the lake by a different route. After only a few turns, they triggered a slab avalanche and were both swept down the slope and over a cliff.

When the avalanche stopped, one of the snowboarders was partially buried and was able to free himself within about 15 minutes. There was no sign of the other snowboarder on the surface of the deposit, so he started to search for him using his avalanche transceiver. He pinpointed the location of the buried snowboarder within five minutes, and began digging using a collapsible shovel. He uncovered the buried snowboarder's face about 1m below the surface, and discovered his lips were blue and he was not breathing.

The rescuer was having difficulty expanding the hole in the snow in order to free or attempt to resuscitate his friend, and decided to snowboard down to the lake and get help. He marked the location of the burial using a jacket. Several people raced from the lake to the burial site on their snowmobiles and began digging, while another person called 911. The buried snowboarder's face was purple and he had no pulse when he was freed from the deposit. The rescuers performed CPR for about 30 minutes, until a local SAR team arrived by helicopter, followed by a physician. They continued CPR and other first aid unsuccessfully until 16:00, when the buried snowboarder was pronounced dead.

The slab avalanche the riders triggered was a size 3, approximately 200m wide, and had apparently propagated around the bowl some distance from the trigger point. Slope angles there were between 35 – 45°, with some steeper areas. The slab was approximately 40cm thick in the area where the snowboarders were riding and up to 1.2m thick where the fracture propagated into the main bowl. The avalanche released from approximately 2255m, and stopped on a flat bench at the base of the bowl near 2040m. The deposit was 100m wide and 250m long, and averaged 2 to 3m in depth. Both of the snowboarders were buried below a small cliff at an abrupt slope angle transition, only 10m from each other.

The avalanche most likely released on a buried melt-freeze crust that formed at the surface during a period of warm weather in early March, and was subsequently covered by late winter storm snow. New snow that fell in the area over 22 – 24 March likely formed a soft slab, due to the effect of wind and warming daytime temperatures. Snowpack and stability observations from other people in the area in previous days included easy failures down 50cm and 1m, and a skier controlled size 2 slab avalanche. A slope adjacent to the one the snowboarders triggered had also recently released a natural or spontaneous avalanche, but it is not clear if they had noticed signs of fresh avalanches. It is unknown if the snowboarders were making snowpack observations or testing for stability, although investigators found no indication of any ski-cuts or profile sites. On the day of the accident, above-freezing temperatures were recorded at nearby alpine weather stations. The warm air and possibly some sun may have reduced the stiffness of the slab overlying the crust and increased the ease of triggering an avalanche as the day went on.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable (High)	Yes	Yes	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
40°	Cliff, abrupt transition	?	Alpine

Source

- BC Coroners Service
- InfoEx

Comment

Warmer slabs are easier to trigger, often making slopes that were safe for skiing or snowboarding in the morning unstable by the afternoon.

It is important to pay attention to any avalanches occurring nearby.

Chapter 8

Avalanche Accidents of Southwestern Canada **2000-2001**

Winter Summary for Southwestern Canada

- **13 avalanche fatalities in 11 accidents**
- **Exceptionally dry winter led to a shallow snowpack with continental characteristics across the entire region; snowpack height was particularly low in the South Columbia Mountains**
- **Shallow snowpack in the fall resulted in a weak foundation of facets and depth hoar that remained a concern for the entire winter**
- **Coast and Columbia Mountains experienced an exceptionally large number of persistent weak layers**
- **With one exception, all fatal avalanche accidents were related to persistent or deep persistent weak layers**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
29 Dec 2000	Pine Pass	Rocky Mountains	Snowmobiling	2	Persistent Slab	25 Nov 2000	155
6 Jan 2001	McGregor River	Rocky Mountains	Snowmobiling	1	Persistent Slab	?? Dec 2000	156
13 Feb 2001	Lizard Range	Rocky Mountains	Backcountry Skiing	2	Wind Slab		159
18 Feb 2001	Soards Creek	Monashee Mountains	Heli-Skiing	1	Persistent Slab	??Jan 2001	165
24 Feb 2001	McLean Creek	Purcell Mountains	Backcountry Skiing	1	Deep Persistent Slab	Basal layers	167
4 Mar 2001	Barnes Peak	Rocky Mountains	Snowmobiling	1	Deep Persistent Slab	Basal layers	172
17 Mar 2001	Lookout Col	Selkirk Mountains	Backcountry Skiing	1	Persistent Slab	23 Feb 2001	174
21 Mar 2001	Mt Renshaw	Rocky Mountains	Snowmobiling	1	Persistent Slab	28 Jan 2001	178
25 Mar 2001	Horsey Creek Glacier	Rocky Mountains	Snowmobiling	1	?		181
18 Apr 2001	Wild Horse Creek	Rocky Mountains	Snowmobiling	1	Deep Persistent Slab	Basal layers	182
19 Apr 2001	South of Ram Falls	Rocky Mountains	Snowmobiling	1	Deep Persistent Slab	Basal layers	185

[1] It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.

Winter conditions were slow to arrive in the fall of 2000. Only minor amounts of snowfall were recorded in October and early November. At that point, the snowpack was too shallow for the formation of avalanches except in some isolated terrain features. The weather in November was dominated by an extended period of cool and dry weather, which transformed the shallow snowpack into a weak layer of faceted snow crystals and depth hoar.
In the last week of November, the ridge of high pressure finally broke down and drifted towards the southeast. This allowed the jet stream to swing around and bring moisture from the Pacific directly into the mountains. By 30 November, the first real winter storm brought 30 to 50cm of new snow to the Coast Mountains, 50 to 70cm to the North Columbias and less to the South Columbias. While the storm deposited 35cm in the Fernie area, the majority of the Rockies experienced drier conditions.

The new snow formed a cohesive slab on a weak foundation with an interface that included facets, surface hoar and crusts. This lead to the first persistent weak layer of the season and the first widespread avalanche cycle. After a second snow storm with moderate winds in the first days of December, another ridge of high pressure established itself bringing clear skies to the region. Temperatures were exceptionally mild and a melt-freeze cycle affected solar aspects while surface hoar was growing in sheltered locations.

The subsequent “arctic outflow” situation brought a significant drop in temperature, strong northerly winds and only little low-density snow. This dry period came to an end on 14 December when a powerful storm rolled through the interior of BC and the Rocky Mountains bringing significant amounts of new snow to the mountains. The snow came in two distinct waves and had an “upside down” character due to the slowly rising temperatures. Whistler Roundhouse (1835m) reported 80cm of total storm snow, Mt Fidelity (1874m) 82cm and Parker Ridge (2023m) 22cm. The deposition of a denser slab on top of the weak foundation of facets and a layer of surface hoar resulted in a widespread cycle of natural avalanche activity. Even though the avalanche activity generally subsided on Christmas Eve, the snowpack remained fragile with lots of whumpfing and cracking reported.

While the snowpack depths were close to average in the Coast Mountains, the Columbia and Rocky Mountains reported record-low levels. Structurally, the snowpack was exceptionally weak across the entire region with a weak foundation of facets and depth hoar, an intermittent layer of surface hoar in the middle of the snowpack and a semi-consolidated upper snowpack. The continental characteristics of the early snowpack were particularly unusual for the Coast and Columbia Mountains, while the Rocky Mountains experienced an exceptionally weak snowpack as well.

The gradually receding influence of the arctic air completely vanished with the arrival of the next storm on Christmas Day. Within two days, this storm brought significant amounts of new snow and mild temperatures to the entire region. Values ranged between 15cm in the far south of the Columbias to 50cm in the North Columbias. The significant load on the weak foundation resulted in another widespread avalanche cycle with avalanches up to size 3.5 failing either in the mid-pack or in the weak base layers. The storm was followed by a period of fair weather that resulted in the development of a new surface hoar and crust layer at the surface. Avalanche hazard remained elevated during this period with widespread whumpfing and remote triggering. The first fatal avalanche accident of the season occurred in the **Rocky Mountains at Pine Pass on 29 December** (page 155). The accident avalanche released on the 25 November facet-crust combination.

With temperatures generally above normal in early January, a cold front brought significant amounts of snow to high elevations and rain below. While the mild temperatures initially promoted settlement, the considerable new load produced a widespread cycle of natural and human triggered avalanches that propagated widely, failing on all existing weak layers and in exceptionally gentle terrain. The avalanche in the fatal accident in the **McGregor River area on 6 January** (page 156) occurred towards the end of this storm period and failed on a December surface hoar layer in the mid-pack.

On 8 January, a weak disturbance buried a thin layer of surface hoar in the Columbia Mountains. The weather during the rest of January was primarily dominated by a ridge of high pressure that was solidly parked over BC. This pattern was only briefly interrupted by a storm between 18 and 21 January. The first period of fair weather was characterized by a mix of sun and clouds, mild temperatures and light winds. Valley clouds in the Columbia Mountains promoted the formation of surface hoar. This surface hoar was buried on 18 January by a storm that brought up to 35cm of new snow to the Coast Mountains and decreasingly smaller amounts to the interior ranges. The related storm slab activity was primarily limited to the Coast and North Columbia Mountains. The second fair weather period in January brought spring-like conditions to the mountains. Above freezing temperatures resulted in the formation of a crust on all aspects and new surface hoar growth was facilitated by valley clouds in the Columbia Mountains. While the warmer temperatures promoted some settlement of the upper snowpack, it had no effect on the weaker lower part of the snowpack.

On 28 January, the ridge of high pressure finally broke down and drifted southeast, allowing a series of low pressure systems to bring the long-awaited snow first to the Coast Mountains and North Columbias, and then later to all mountain ranges. Overall accumulation ranged from 100cm in the Coast Mountains and North Columbias, 50 to 80cm in South Columbias and 20 to 40cm in the Rocky Mountains. While the storm started with strong westerly winds, they became more moderate as the storm progressed. The storm resulted in a significant avalanche cycle that included natural releases as well as human-triggered avalanches. While wind slabs were the primary avalanche problem in the alpine, avalanches at and below treeline were mainly failing on the crust-surface hoar interface at the bottom of the storm snow. Some of the surface hoar avalanches were occurring on exceptionally low angle terrain. In addition, shallow snowpack areas, such as the Purcells and the Rocky Mountains, reported numerous slides that stepped down into the November facets and ran full path.

The westerly flow of the storm cycle changed on 5 February when arctic air moved into the region from the east. The push of arctic air was accompanied by northerly winds, clear skies and a significant drop in temperature. The cooler temperatures caused the surface layers to facet and therefore lose some strength. A few days later, however, a weak ridge of high pressure started to establish itself along the coast, which moderated temperatures in the Coast and Columbia Mountains. The majority of the Rocky Mountains, however, remained under the influence of the arctic air mass. The fatal avalanche accident in the **Lizard Range on 13 February** (page 159) involved a wind slab that formed during the influence of the arctic air mass.

Even though the ridge along the coast did not last for very long, there was some surface hoar development reported in the Columbia Mountains. This surface was buried by a weak disturbance on 15 February, which brought only minor amounts of new snow accompanied by strong winds. While wind slabs became the immediate avalanche problem, the wind loading also activated some of the older surface hoar layers. The fatal accident in **Soards Creek on 18 February** (page 165) occurred on one of the January surface hoar layers.

A short period of sunny skies, warm temperatures and no wind led to the development of the next layer of surface hoar and sun crusts. This layer was buried in the interior on 23 February by a somewhat unexpected storm along the arctic front, which brought up to 25cm of new snow to Columbia and Rocky Mountains. While the initial avalanche in the fatal accident at **McLean Creek on 24 February** (page 167) released at the bottom of this recent storm snow, the mass of the moving slab triggered a much larger avalanche that failed in the weak basal layer of facets and depth hoar.

After a few days of additional fair weather on the Coast and a mix of sun and clouds with occasional flurries in the interior, a powerful low pressure system with strong winds brought a more substantial amount of new snow to the region on 1 and 2 March. Avalanche activity included a variety of failure planes and increased as a result of the strong winds. The avalanche involved in the fatal avalanche accident at **Barnes Peak on 4 March** (page 172) failed in the weak basal layer of facets and depth hoar. Shortly after, 6 and 7 March were dominated by the first true heat wave of the season with rapidly rising temperatures, especially in the South Columbia Mountains (in excess of 3 °C/hr). Both Whistler Roundhouse and Mt Fidelity reported maximum temperatures of 7°C. The warm temperatures resulted in widespread avalanche activity including natural and human triggers. While many avalanches failed in the recent surface hoar layers up high, loose wet snow avalanches were reported at lower elevations where the snowpack was turning isothermal. Natural activity subsided at higher elevations with cooling temperatures, but the potential for human triggered avalanches remained.

This period of clear skies and warm temperatures resulted in the development of a crust at lower elevations and yet another layer of surface hoar in sheltered locations. This surface was buried on 12 March, when a powerful low pressure system brought heavy snow in two distinct pulses to the Coast and Columbia Mountains. While up to 120cm of new storm snow were recorded near McBride, amounts decreased rapidly further south. The South Columbias saw very little new snow, but experienced strong winds out of the southwest. A large avalanche triggered on the 23 February surface hoar resulted in another avalanche fatality at **Lookout Col on 17 March** (page 174).

On 18 March, a warm front brought rising freezing levels, heavy rains below treeline and approximately 35cm of new snow to the Coast Mountains and 50cm to the Columbia and Rocky Mountains. While the bonding with the old snow surface was reasonable, the new load significantly stressed the existing persistent weak layers in the upper snowpack. The avalanche in the fatal accident on **Mt Renshaw on 21 March** (page 178) failed on the 28 January surface hoar layer that was between 80 and 120cm below the surface.

A short period of fair weather with warm temperatures was followed by another warm front on 24 March. While rain fell up to approximately 2000m at first, freezing levels eventually dropped to around 1000m as temperatures cooled off. While the warm temperatures helped to settle the recent storm snow layers, the mid-pack was continuously losing strength, at the same time making the basal facets and depth hoar more susceptible to triggering. Temperatures in the Rocky Mountains generally remained cool as the area was under the influence of the arctic air mass. Widespread avalanche activity at various failure planes was observed with a particular focus in the North Columbia Mountains. A fatal avalanche accident occurred during this period on **Horsey Creek Glacier on 25 March** (page 181).

The end of March and beginning of April saw a series of storms pass through the area at generally lower temperature that brought considerable amounts of new snow to higher elevations. Storm snow generally bonded well with the old snow surface within a few days. By mid-month, conditions generally settled into the classic spring pattern with periods of warm weather mixed with periods of convective precipitation. Despite the stabilizing effect of the warm weather, the various surface hoar layers and the weak basal facets and depth hoar remained an avalanche concern, particularly for large triggers such as cornices and ice falls.

At the same time, the east slopes of the Rocky Mountains experienced the biggest storms of the season. Between 2 and 12 April, a series of easterly upslope storms deposited up to 1.7m of new snow in the Waterton area and about one metre in the area of the Columbia Icefield. This significant amount of new snow was sitting on the perpetually weak base of facets and depth hoar, resulting in widespread avalanche activity. The last two avalanche fatalities of this winter both occurred in the Rocky Mountains at **Wild Horse Creek on 18 April** (page 182) and south of **Ram Falls on 19 April** (page 185). In both accidents, the avalanches failed in the weak depth hoar and faceted crystals of the basal layers of the snowpack.

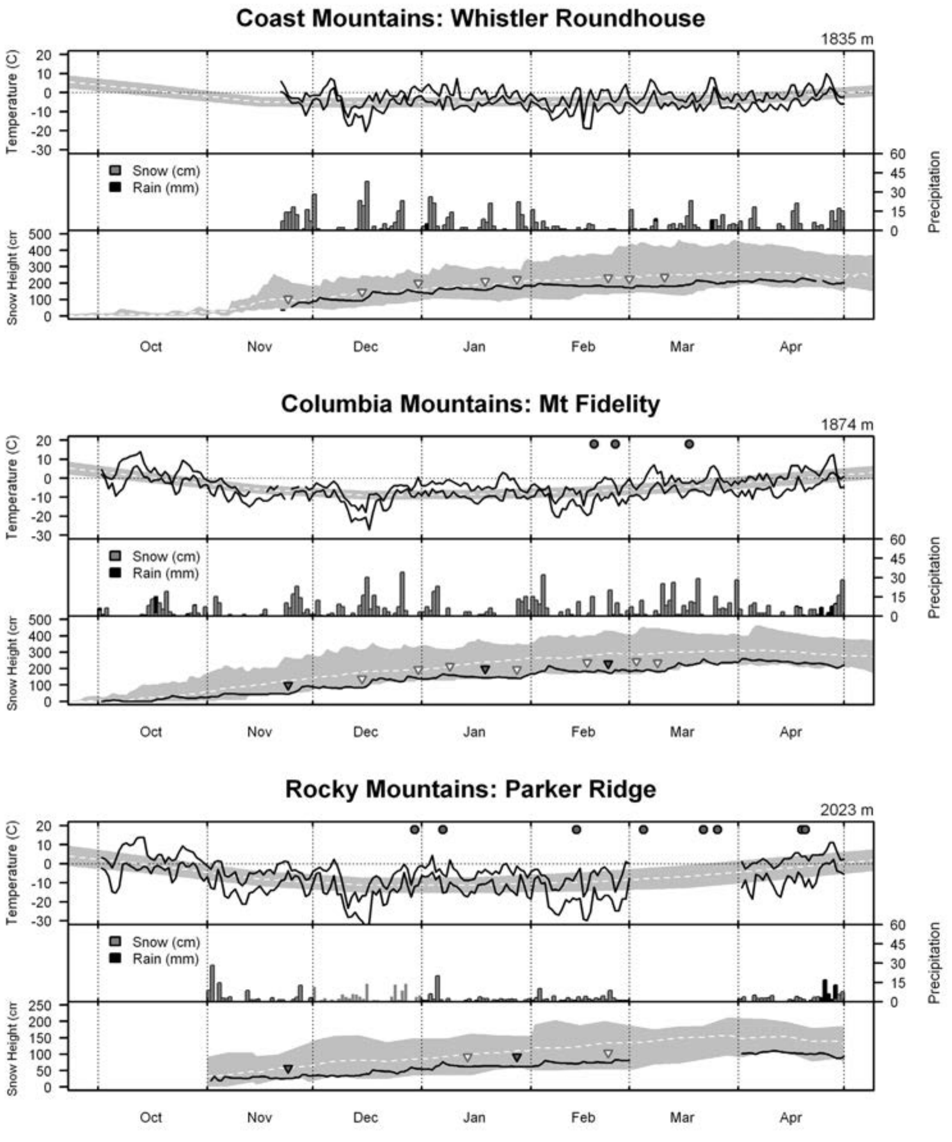

Figure 8.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 2000/2001 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanche (black triangles). Other persistent weak layers are shown with light triangles. The grey band shows minimum, average (dashed line) and maximum snowpack height measures at this location since 1976 (Whistler Roundhouse and Mt Fidelity) or 1978 (Parker Ridge).*

29 December 2000, Snowmobiling
Pine Pass, Rocky Mountains

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	?

- **Three snowmobilers in an avalanche path during highmarking**
- **One transceiver in a group of three**

On Friday 29 December, three men went snowmobiling in Honeymoon Creek about 10km southwest of Pine Pass. They had been snowmobiling in this area and near Mackenzie for about 10 years. Two of the three men usually wore transceivers; however, on this day only one did (called Rider 2 in this summary). They all had avalanche probes and shovels.

There was no avalanche bulletin for this area in the winter of 2000-01. At the Pine Pass Snow Pillow there had been no precipitation since 26 December. On 29 December, the air temperature ranged between -7.9 and -3.8°C.

At about 12:30, Rider 1 was highmarking an east-facing slope while his two companions watched from the bottom. On his third attempt, he climbed almost to the top of the slope and triggered a large slab avalanche. The two men at the bottom tried to accelerate away from the avalanche in opposite directions. Rider 2 was buried. Rider 3, who did not have a transceiver, escaped the avalanche.

When the avalanche stopped, Rider 3 could not see his friends. He called out, and got no reply. He left to contact other snowmobilers in the area, knowing a transceiver would speed the search. Rider 3 met other snowmobilers, one of whom left to contact the RCMP. The others returned to the avalanche to search for Riders 1 and 2.

About 90 minutes after the avalanche, they found Rider 2, unresponsive, under 1m of the deposit. They searched for Rider 1 until dusk and then left the area. The next day, the RCMP and local search and rescue team flew to the site by helicopter. Rider 1 was located by probing after three hours. He was under 1m of snow. Both the deceased riders had asphyxiated due to snow blocking their airways.

The crown of the dry slab avalanche released on a 37° slope at about 1660m elevation. The slab had released on the facet-crust combination from 25 November 2000. The crown fracture was 100cm in height and about 500m wide. It was a size 3 avalanche. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
37°	?	?	?

Source

- BC Coroners Service

Comment

The combination of a transceiver, probe and shovel—carried by each person—can help reduce the search time and potentially save lives.

6 January 2001, Snowmobiling, McGregor River, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Recent natural and triggered large avalanches**

On the morning of Saturday 6 January, four snowmobilers from Prince George drove north-northeast to get to the upper Torpy Valley of the McGregor Range in the Rocky Mountains. They had been enjoying snowmobiling in this area for about ten winters. The night before the trip, the four snowmobilers had discussed the avalanche hazard, and ways of surviving avalanches.

In 2001, there was no bulletin for the McGregor Range. The northern boundary of the closest bulletin region for the Rocky Mountains was 125km southeast of the McGregor Range. A regular bulletin for this region was issued two days before the snowmobiling trip by the Canadian Avalanche Association. It stated: "Virtually the entire snowpack is still primarily weak facets and depth hoar. The storm snow and the new snow from the weekend will be forming a fat wind slab at the top of the pack. Many areas still report ski penetration well into the lower facet layers. ... More snow will extend the likelihood of slab avalanches failing at the storm snow interface. Virtually every avalanche will have the potential for stepping down into the lower snowpack weakness, growing in size and potentially propagating widely if it does."

At the Hedrick Lake Snow Pillow, located at 1100m elevation and 12km to the northeast of the Upper Torpy Valley, 11mm of snow wa-

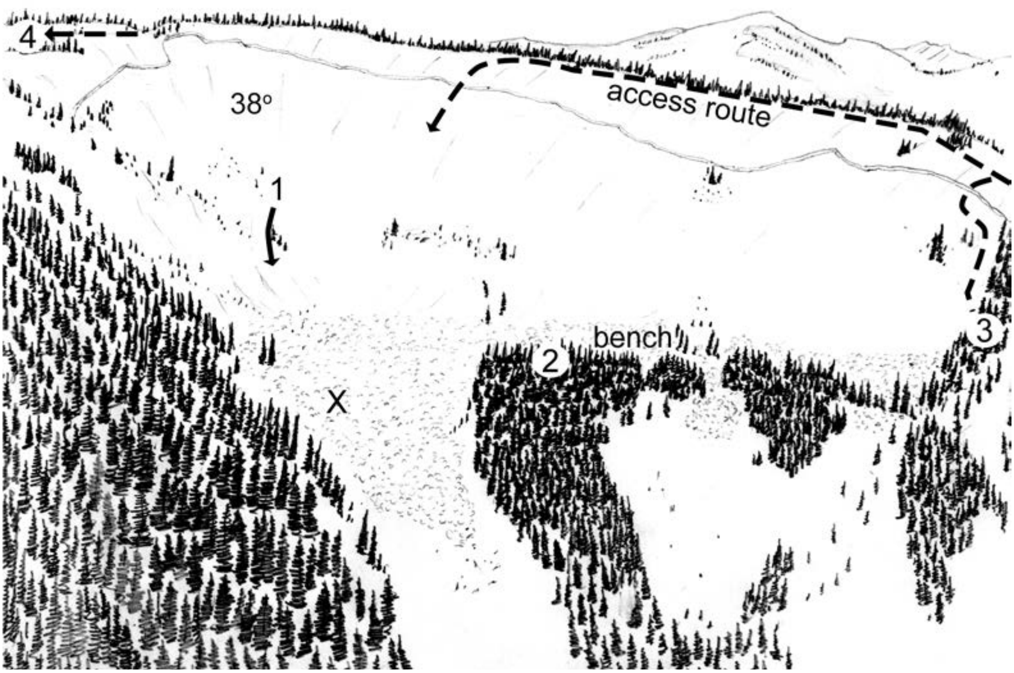

Figure 8.2. *McGregor River area, 6 January 2001. X – deceased.*

ter equivalent was recorded on 5 January and none on 6 January.

At the Sliding Mountain weather station, elevation 1675m, located 105km south of the area where the snowmobilers were headed, wind gusts had been moderate to strong from the southwest for the two days before the snowmobile trip. Such wind can efficiently transport snow onto lee slopes but it is unclear if the same winds affected the McGregor Range.

At 09:30 the four men unloaded their snowmobiles and drove 14km to reach treeline. They triggered a size 2 and a size 3 slab avalanche on their way to the ridge between the Torpy and McGregor Rivers. They also observed two other recent natural size 3 slab avalanches.

At about 12:30, one of them drove 700m along the ridge and into an east-facing bowl where he triggered and narrowly escaped a size 3 slab avalanche. About the same time, the other three snowmobilers descended from the ridge along the side of a northwest-facing starting zone. While the latter two snowmobilers were descending, the first, Rider 1, reached a bench, turned and accelerated upslope to climb the slope. He triggered a slab avalanche which swept him down the slope and buried him. The second snowmobiler, Rider 2, reached some trees on the bench and was briefly able to watch where Rider 1 disappeared in the avalanche. The avalanche deposit extended to 2m from where Rider 2 was stopped. The third rider was able to accelerate into the trees beside the path and was not caught by the avalanche.

Riders 2 and 3 started a transceiver search below where Rider 1 had last been seen in the avalanche. They were soon joined by the fourth rider. They pinpointed the signal from the buried rider within 10 minutes and began to dig. They found him under 2m of snow with his head downhill and a plug of snow in his mouth. The victim's snowmobile was on the surface of the deposit directly above

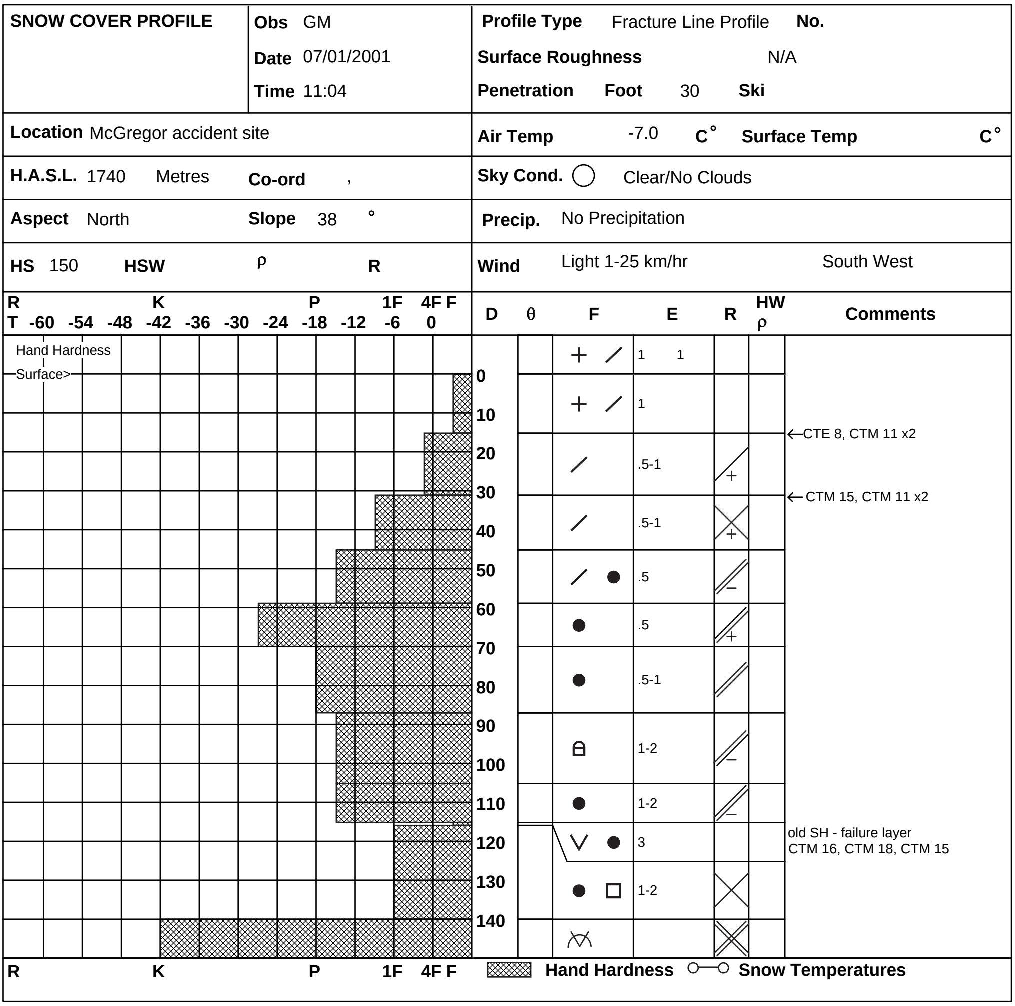

Figure 8.3. *McGregor River area, 6 January 2001. Fracture line profile observed near the crown fracture by the investigator on 7 January 2001.*

him. They were not able to revive him with 20 minutes of CPR. They left their deceased friend and drove 14km to where they could call the RCMP by cell phone. Search and Rescue and the RCMP began to respond, but due to darkness they postponed the recovery until the following day. He had asphyxiated due to snow that had blocked his airway.

The crown of the slab avalanche was at an elevation of 1740m, where the northwest-facing, convex start zone was inclined at 38°. The crown averaged 115cm in height, spanning the 500m wide start zone. The avalanche released on a layer of surface hoar crystals up to 3mm in size and rounded grains. The avalanche ran down the slope for 200m before stopping on the bench where Rider 1 started his climb. The deposit was about 350m wide, 160m long and 2m deep. It was a size 3 avalanche.

The day after the avalanche, the failure layer required moderate tapping in three compression tests before fracturing. The lower 55cm of the slab was pencil-hard. At the profile site, the failure layer was 115cm below the surface and 35cm above the ground.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Not available	Yes	Yes	?	?	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Convex	Open slope

Source
- BC Coroners Service
- BC Ministry of Transportation and Infrastructure weather data
- BC Ministry of the Environment snow pillow data

Comment

The snowmobilers continued in avalanche terrain after triggering and observing several size 2 and 3 avalanches.

The snowmobilers were equipped with transceivers, probes and shovels. The rescue was efficient and focused on the deposit below the last seen point.

13 February 2001, Backcountry Skiing
Lizard Range near Fernie Alpine Resort, Rocky Mountains

Deaths	Avalanche Problem	Terrain
2	Wind Slab	Challenging

- **Two groups in the same avalanche path unaware of each other**

On 13 February 2001, a group of five backcountry skiers was exploring the entrance to a ski run on the west side of the most northern summit (known as 2000' Peak) of the distinct ridgeline that frames Fernie Alpine Resort, at the north end of Fish Bowl. The entrance to the run is characterized by a steep west-facing cirque feature, which is prone to cross-loading by southerly winds. The cirque has an average incline between 35 and 40 degrees and is the obvious start zone of an avalanche path that quickly funnels into a gully. The path drops for approximately 600 vertical metres before it fans near the bottom of a high valley locally known as Easy Street that runs parallel to the main ridgeline. The terrain around this path is described as very steep and unforgiving.

It was a clear and sunny day with light to moderate winds from the north as an arctic ridge of high pressure was slowly drifting southeast. The days prior to this accident were characterized by overcast or broken skies, calm winds and minimal snowfall, with the last noticeable accumulation of 6cm occurring on the morning of 10 February. The public avalanche bulletin for the Rocky Mountain forecast area published by the Canadian Avalanche Association on 12 February rated the avalanche danger as Considerable in the alpine and at treeline and Moderate below. The bulletin predicted a storm to cross the area on 14 February and highlighted the possibility for the development of wind slabs if the wind picked up ahead of the storm.

Three members of the group had recently taken an introductory avalanche awareness course. To assess the local conditions before entering the ski run, the group decided to dig a snow profile adjacent to the start zone, but the test results were inconclusive. As an additional safety measure, they agreed to perform a ski cut before fully committing to the terrain. The ski cut released a wind slab, which was about 24m wide and 28cm deep (*Figure 8.4*). The bed surface was at the interface to a layer of pencil-hard faceted snow crystals, which most likely developed the extended period of fair weather in the second half of January (*Figure 8.5*). The person performing the ski cut briefly rode the avalanche before escaping to the side. The avalanche was immediately channeled into the gully feature. (*Figure 8.6*) Because there is a significant turn in the lower part of the avalanche path, the avalanche quickly ran out of sight of the group, but they did observe a large powder cloud further down in the valley. The accident investigation later classified this avalanche as a size 2.5. After this incident, the group decided to abandon their plans and returned to ski area via Liverwurst Pass and Fish Bowl.

At the same time, a group of 13 skiers from Sweden and Denmark were traversing a series of gullies behind the Fish Bowl headwall and 2000' Peak. They accessed the backcountry from the ski area by hiking to Polar Peak and skiing through Polaris Bowl. The snowpack of this winter was exceptionally shallow and the area was choked with thick alder, making backcountry travel difficult. While making their way down Easy Street, the group crossed the debris of a recent avalanche in one of the numerous gullies. Due to the rough travel conditions, the group decided to use one of the next gully features to gain some elevation in this challenging terrain.

At 14:45, the first six members of the group were hit by an avalanche from above (*Figure 8.7*). While four individuals were partially buried, two were completely buried. The trailing seven group members, who were not involved in the avalanche, immediately started to extricate the partially buried victims and to search for the complete burials using avalanche transceivers. After approximately 25 minutes, all of the victims were located and completely extricated. While one of the partially buried group members was initially not breathing when found, he recovered quickly. The completely buried skiers, two sisters, were both deceased by the time the rescuers were able to uncover them. One of them died of asphyxia; the other succumbed to trauma.

The entire accident was witnessed by a third ski party, who decided to immediately return to the ski area to notify search and rescue. In Fish Bowl, they ran into the first group of five skiers, who was still unaware of the full consequence of the avalanche. At this point they used their cell phone to call the ski area at approximately 17:20.

Fernie Alpine Resort immediately initiated the rescue and the local ski patrol leader, who was also an avalanche dog handler, was airlifted to the accident site together with a local paramedic. On arrival at the scene, it became apparent that everybody was already accounted for, so the focus shifted to the evacuation of the group. Due to approaching darkness, the helicopter was only able to land once at the accident site and to evacuate two of the survivors. The patrol leader and 11 remaining members of the accident party had to be left behind to spend the night

Figure 8.4. *Lizard Range (2000' Peak), 13 February 2001. Fracture line. Photo: Gord Ohm.*

at the accident site. At approximately 22:00 the group was joined by four ski guides from Island Lake Lodge, a nearby cat skiing lodge, who travelled on ski-touring gear to the accident site bringing tarps, blankets, brush saws, food and other overnight supplies. While two of the guides returned to the lodge, the other two remained with the group for the night. Good weather allowed two helicopters to access the accident site the following morning and by 09:15, the entire group including the two deceased was evacuated to Fernie.

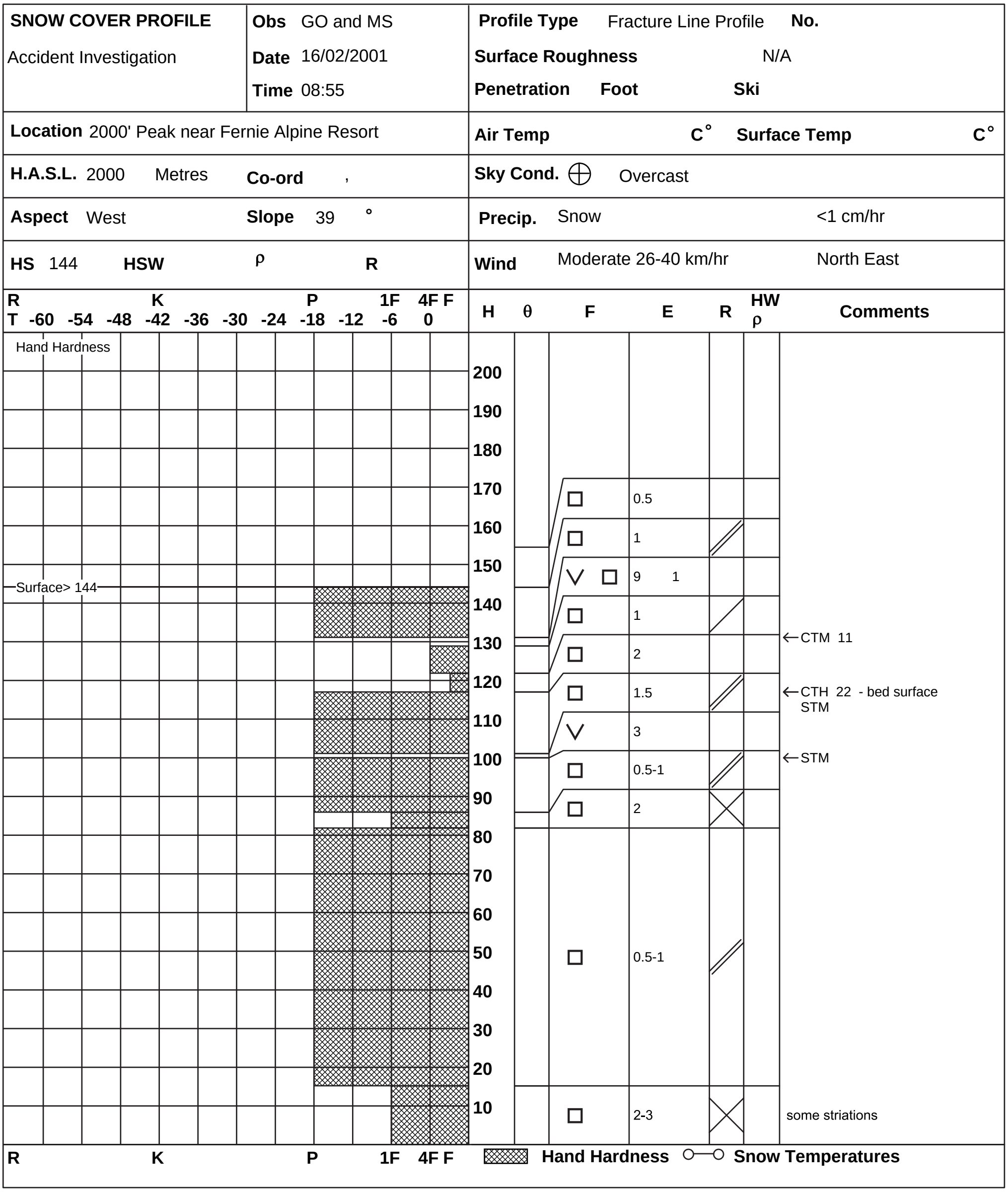

Figure 8.5. *Lizard Range (2000' Peak), 13 February 2001. Fracture line profile taken during accident investigation on 16 February 2001.*

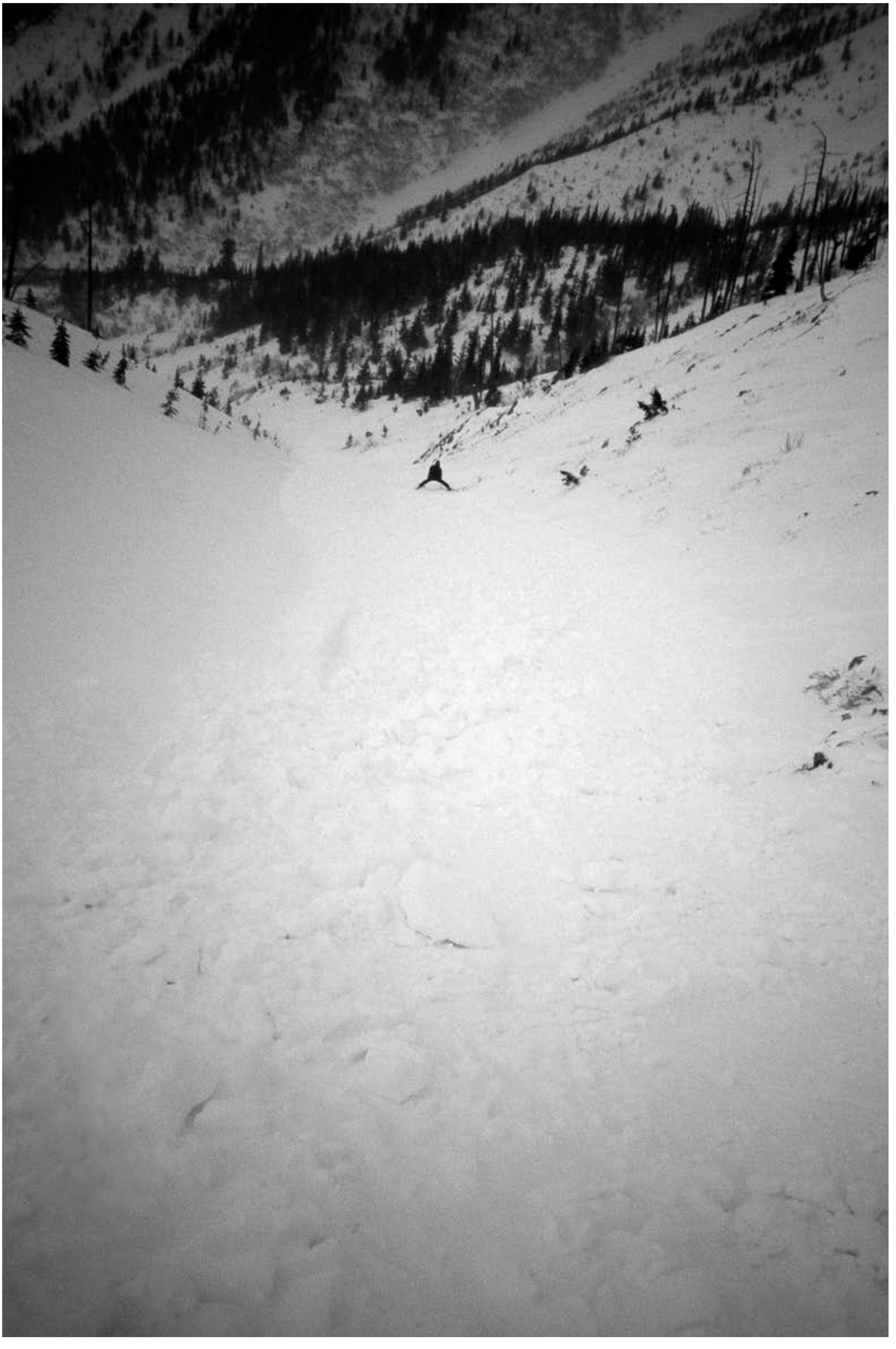

Figure 8.6. *Lizard Range (2000' Peak), 13 February 2001. Track and flank of gully which added volume to the slide. Deposit of avalanche not visible as the track turns to the left below. Photo: Gord Ohm.*

Figure 8.7. *Lizard Range (2000' Peak), 13 February 2001. Deposit at the bottom of the gully. Avalanche probe indicated burial location of one of the victims. Photo: Gord Ohm.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	No	Yes	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
39°	Gully	Planar	Open

Source
- BC Coroners Service
- CAA public avalanche bulletin for Rocky Mountains
- Island Lake Lodge
- Fernie Alpine Resort
- Gord Ohm

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18 February 2001, Heli-skiing
Soards Creek, Monashee Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Slab avalanche triggered from area of thin snowpack**

On 18 February 2001, four groups of heli-skiers were skiing in the mountains near Soards Creek about 22km west of the town of Mica Creek. The operation had been skiing in Soards Creek for the previous five days. No new snow had been reported in the previous three days. A moderate north wind (favourable to transport snow) was reported on 16 January but calm conditions were reported on 17 January. The air temperature in the previous two days had ranged from -12 to -8°C.

In the preceding two days, only one avalanche was reported: a natural size 2 dry slab avalanche, about 35cm thick at 2300m on a northeast-facing slope. Given the extensive observations by this operation, avalanching was infrequent in the preceding two days. On 16 January, the operation noted that “shears still exist on January surface hoar layers.”

The avalanche bulletin for the North Columbia Mountains issued by the Canadian Avalanche Association on 15 January for the following four days rated the regional avalanche danger as Considerable with areas of High. The bulletin also noted: "Wind loading is bringing the recently buried surface hoar layers, down about 50 and 100cm, back to life again."

After lunch, they skied a run on a southwest-facing slope and returned to ski it a second time. At 15:40, one of the four groups stopped to regroup about 100 metres from the helicopter landing. While they were standing in tracks from previous groups, the guide instructed them to follow in the tracks through a rib of trees, and stop where he stopped at some wind rolls. Out of earshot from the guide, two of the guests—called 7 and 8 in this summary—made plans to ski onto an open slope to the left of the tracks. The guide and the first five skiers arrived at the second regrouping site. The guide then looked back to observe Guest 7 ski past others—apparently with limited control—off the wind rolls and fall in a slight trough about 30m left of the regrouping site. One of the guests from the second regrouping site—called Guest 4—skied onto the untracked slope to assist the fallen skier. Guest 8 also followed Guest 7 onto the untracked slope.

A number of the guests heard and felt a whumpf and saw a crack shooting through the snowpack across the slope. A slab avalanche released higher on the open slope, sweeping Guests 4, 7, 8 and three others down the slope. About half way down the slope, the three others escaped from the avalanche or were left behind.

The guide was able to see the five skiers at the second regrouping site plus the three who had been only carried part way down the slope by the avalanche. Realizing that three skiers, 4, 7 and 8, had been carried out of sight by the avalanche, he called for help on the radio. He moved onto the deposit, searching with his transceiver. The guide quickly saw and heard Guest 8; he was caught in some trees and yelling. The guide directed some guests to assist Guest 8 in the trees. The guide then saw Guest 4 walking up from the bottom of the deposit. While continuing the transceiver search, down the slope he saw the boot of Guest 7. The guide and Guest 4 dug Guest 7 from under 30cm of snow. He was pulseless, had "irregular" pupils and bluish skin. CPR was applied for about 10 minutes until a helicopter arrived with four other guests and additional resuscitation equipment. After another 30 minutes of resuscitation efforts, Guest 7 was flown to Revelstoke Hospital, where he was pronounced dead. He had died of multiple traumatic injuries and asphyxia due to chest compression.

The crown fracture was about 36m wide and 30 to 82cm in height on a 39° slope at 2170m elevation. Due to wind loading, the snowpack was thicker and the crown generally higher on the west side.

The aspect of the bed surface changed from slightly west of south to slightly east of south. Where the slope got less afternoon sun (facing east of south) there was more surface hoar on the bed surface, which was not a melt-freeze crust. Where the slope got more afternoon sun (facing west of south), the surface hoar was smaller and more rounded, overlying two melt-freeze crusts separated by a few centimetres of 1 – 3 mm faceted crystals. The total thickness of the bed surface and the lower layers varied from 0 (exposed rock) to 86cm. On the east side of the slope where Guests 7 and 8 were caught, the snowpack was generally thinner and weaker than along the designated skiing line.

About 30 metres down the slope from the crown, the slope steepened to 48° at a rocky breakover, which was exposed in places by the avalanche. The size 2 dry slab avalanche ran down the slope for a total of 280m. The buried guest was found in the runout zone where the slope angle was approximately 22°.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes (one natural)	No	Yes (wind loading)	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Convex	Mostly Open

Source

- BC Coroners Service

Comment

In spite of the efficient rescue, the guest had suffered fatal traumatic injuries.

Given the extensive observations by this heli-ski operation, slab avalanching was infrequent. However, the single natural slab avalanche on the previous day counts as a "Yes" for Slab Avalanche since this Avaluator Warning Sign—developed for recreationists with fewer observations—refers to any sign of slab avalanches.

24 February 2001, Backcountry Skiing, Upper McLean Creek between Forster and Frances Creek, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **A group with considerable familiarity with the local terrain is caught during a winter with an unusually weak snowpack**
- **Both party members exposed themselves to the avalanche hazard at the same time resulting in two burials**

On the morning of 24 February 2001, two backcountry skiers and their dog travelled by snowmobile from near the town of Radium, BC up Forster Creek in the eastern Purcell Mountains. At about 10:30, they parked their snowmobiles below the headwall that leads up to Thunderwater Lake and started climbing on their alpine touring skis north towards Snowbird Lake. Their plan was to ski from Foster Creek up over Tunnacliffe Pass into the western branch of McLean Creek, which drains north into Frances Creek. After descending to McLean Lake, they would traverse over to the eastern upper basin of McLean Creek and ascend to another high pass that would bring them back to the Foster

Creek drainage. A 500m descent on south-facing slopes would complete the loop and get them back to their snowmobiles. This trip is a popular circuit with experienced back-country skiers from the Invermere area and one of the party members was very familiar with the terrain as he had travelled this route several times in the past.

Conditions on the morning of 24 February were cloudy and light snow had fallen the night before. A nearby heli-ski operation reported a total accumulation of approximately 20cm in the alpine with moderate winds from the south. Daytime temperatures in the alpine were approximately -10°C. The weather of the week prior was characterized by clear skies and relatively warm temperatures, which led to the widespread development of surface hoar crystals in protected areas. The avalanche bulletin of the Canadian Avalanche Association from Thursday 22 February highlighted that this weak layer would be buried by the incoming storm prior to the weekend. In addition to the discussion of the most recent weaknesses, the avalanche bulletin also included a special warning, highliting that the snowpack in British Columbia was significantly weaker than other recent winters. The avalanche danger was rated as Moderate with areas of Considerable in the alpine and at treeline.

After reaching Tunnacliffe Pass, the first high point of the trip, the party skied down to McLean Lake. During the descent, they ski cut the occasional steep rolls to test the strength of the snowpack while travelling one at a time from safe spot to safe spot. The ski cuts did not produce any results and the snowpack appeared to be reasonably settled in the basin above treeline. The group ate lunch in the middle of McLean Lake at approximately 12:30.

From the lake, the route continues over a small forested divide between the west and east forks of McLean Creek. It then drops slightly into the upper basin of the eastern fork before climbing back up to the second high pass that leads back to the Forster Creek drainage. It is at the beginning of this climb where the route encounters an unavoidable headwall, the crux of the day (*Figure 8.8*). The headwall, located near treeline, consists of a series of smaller, connected avalanche paths interspersed by several groups of trees. The slope incline ranges between 35 and 45°. The intended route was a climbing traverse through the different avalanche paths, using islands of trees for some protection.

At approximately 14:15, the group reached the edge of the last band of tall dense trees to the west of the headwall and the first skier began traversing across the more open steep slopes of the headwall (*Figure 8.8*). As he was crossing the slope, he began to sense the changing character of the snowpack as his skis were pushing through into some of the softer weak layers beneath the most recent storm snow. As he warned his partner to wait for a moment and stay back at a safe distance, a soft slab of storm snow (approx. 25 to 30cm deep) released along their ski track. They were watching the initial slab slide away from them, when the second skier suddenly noticed a second, much larger slab avalanche releasing above them. The two skiers were immediately engulfed and carried for approximately 40m before the avalanche came to a stop (*Figure 8.8*).

The skier who entered the slope first was buried facing downhill and lying on his stomach with only one of his hands close to the surface. He immediately tried to create a space around his arms and rib cage to improve his breathing, but he was already held firmly in place by the quickly hardening avalanche debris. A few seconds later, however, he felt his friend's dog—which was in the training program for becoming an avalanche rescue dog—licking his hand. This is when he realized that he was actually closer to the surface than he initially thought. He was eventually able to pull his arm down to his face, creating a hole in the snow through which he could see

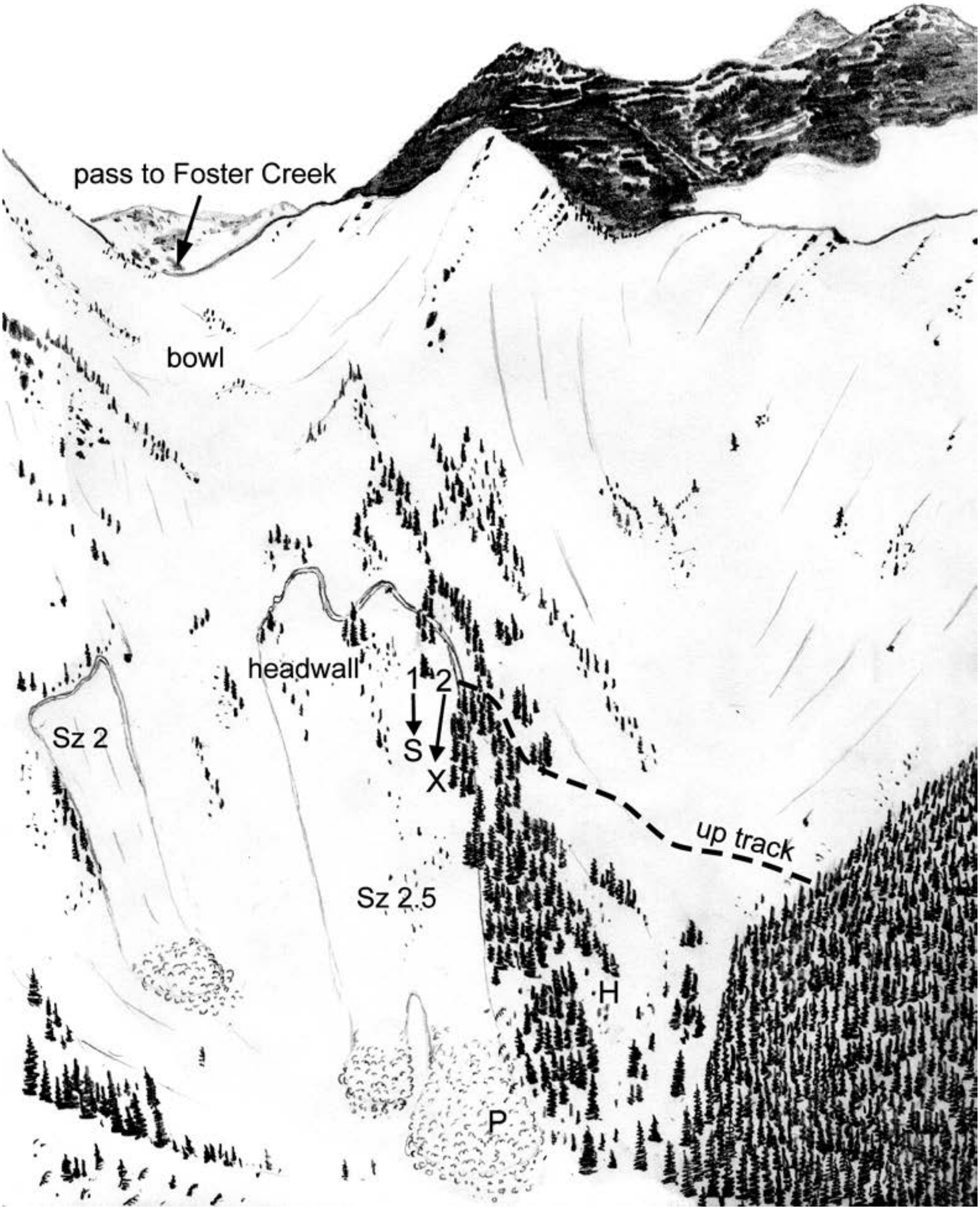

Figure 8.8. *McLean Creek, 24 February 2001. Overview of intended route and accident site. 1, 2 – location of skiers when avalanche was triggered, S – survivor, X – deceased, H – protected helicopter drop off for rescue team, P – helicopter pick-up of accident party and rescue team.*

light. Struggling for his life, he managed to free his arm more and more and after about 30 minutes he had completely freed himself from the avalanche debris using only his bare hands and one of his ski poles he found during his efforts.

Once he was free, he immediately saw the skis of his partner lying upside down on the snow surface only about two metres away from him. The skis were still attached to the body of his friend and he quickly dug down along his friend's leg with his bare hands. Once he was able to pull the shovel off his friend's backpack, it only took him another few minutes to completely uncover his friend who was found non-breathing and unresponsive. The survivor immediately initiated CPR. However, his hand were frozen solid after digging with his bare hands, so he had to alternate between doing CPR and trying to restore blood flow to his hands and fingers to allow him to work properly. At the same time, he started to call for outside help using his personal radio, but he was unable to make any contact directly from the accident location.

After 45 minutes of CPR failed to revive the victim, it became clear that further resuscitation efforts were futile. The survivor shifted his focus to reaching outside help on the radio or getting out under his own power along the originally intended route before dark. At risk of becoming hypothermic—he was quite wet from being buried without a jacket—he collected all the warm gear he and his partner had, some food and water, and started climbing towards the top of the headwall. At 16:07 he was finally able to make contact with CMH Bugaboos, a heli-ski operation close by.

Guides from CMH Bugaboos arrived at the site by helicopter at approximately 16:30. As the accident site was still threatened by considerable avalanche hazard from above, they decided to land in a small clearing away from the slopes and approach the accident site on skis (*Figure 8.8*). The ski guides met the survivor at the accident site and the victim was immediately evacuated down the avalanche debris to the base of the slope to minimize the exposure of the rescue team to the remaining avalanche hazard from above (*Figure 8.8*). The group was then picked up by the waiting helicopter and arrived at Invermere hospital at 17:15.

The subsequent accident investigation revealed that the main avalanche of this accident was a size 2.5 (*Figure 8.8*), approximately 200m wide and ran for 300m in total. The depth of the fracture line was highly variable, ranging from 60 to 200cm. While the slab released in the most recent storm snow layer in a few areas, the majority of the fracture occurred in the middle of the snowpack or near the ground. Having broken and slid on several layers, this is commonly referred to as a stepped fracture. The investigation showed that the snowpack at the incident site was highly variable and consisted of weak faceted and depth hoar crystals (*Figure 8.9*).

The initial avalanche most likely released at the most recent storm snow interface approximately 20cm below the surface. Once the initial release occurred and started moving downhill, the structural weakness at the base of the snowpack also failed. This second failure propagated up the slope above the skiers into some of the wind-loaded features, producing the avalanche that engulfed the party. The investigation also found signs of a third size 2 avalanche slightly to the east on the headwall. This avalanche most likely released sympathetically to the main avalanche of the accident, indicating that the failure propagated across the entire headwall.

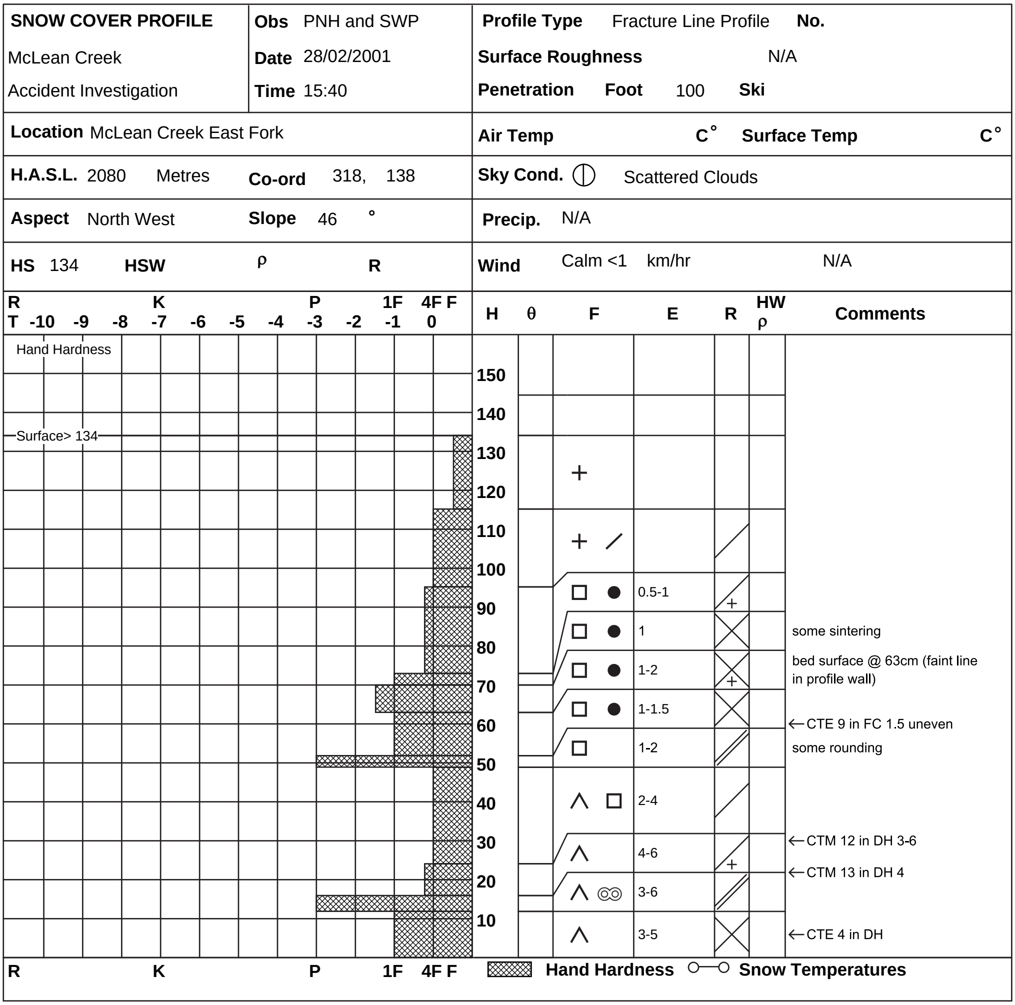

Figure 8.9. McLean Creek, 24 February 2001. Fracture line profile of main avalanche taken on 26 February 2001.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Planar	Path

Source
- BC Coroners Service
- InfoEx

Comment
In this accident a group with considerable familiarity with the local terrain is caught by an unusually weak snowpack. Winters with exceptional weather and snowpack patterns require extra caution. Unusual conditions can threaten even standard routes that are frequently travelled during normal winters.

It is very lucky that this accident did not end up with two fatalities. If it is impossible to completely avoid a suspect slope, it is recommended to expose only one person at a time to the existing hazard. The rest of the group should be waiting in a safe spot away from any avalanche hazard where they can monitor the progress of the exposed individual.

4 March 2001, Snowmobiling
Barnes Peak, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **One snowmobiler buried deeply in a terrain trap**

On Sunday 4 March, a group of six family and friends went snowmobiling in the Barnes Peak area, known locally as China Wall. This is about 22km south-southwest of Crowsnest Pass on the Alberta-BC border. In the afternoon, they were riding on an east-south east-facing slope. The upper part of the slope is a 150m-wide bowl, inclined at about 32°. Southwest winds had cross-loaded the bowl, depositing more snow on the south side. The slope narrows into a gully where the slope reaches 35° just below a convexity, before moderating to 24°. In the runout zone, the path widens and the slope angle reduces to 17°. A 4m high hump extends across the runout zone, creating a terrain trap just above it.

Three days before the snowmobile trip to the Barnes Peak area, the Canadian Avalanche Association issued a regular bulletin for the Rocky Mountains including the BC Rocky Mountains south of Crowsnest Pass. The regional avalanche danger in the alpine and treeline zones was rated Considerable. The bulletin also noted: "Wednesday's high winds were transporting large volumes of snow (100 metre plumes off ridge crests!), undoubtedly creating windslabs in all exposed areas. With significant instabilities underlying these slabs, avalanche danger has increased along with the likelihood of human triggering. Prominent instabilities are a layer of suncrust and surface hoar in the upper half of the snowpack, as well as the continued problem of an extremely weak base of facets and depth hoar."

At the Morrissey Ridge Snow Pillow, 1860m elevation and 20km west-northwest of Barnes Peak, there had only been 3cm of snowfall in the previous four days. The air temperature reached 1°C on 4 March. At the study plot, 1650m elevation, for the ski area 28km to the west, the air temperature reached -1°C and winds were light. The cat-skiing operation 35km northwest of Barnes Peak reported five slab avalanches on 3 March (a size 1 and a size 2 triggered by skiers, and three triggered by explosives). This operation reported one skier-triggered size 1 avalanche on 4 March. A nearby ski resort reported one size 1.5 avalanche triggered by an explosive on 3 March.

At about 14:00, one of the six snowmobilers (called Rider 1 in this summary) climbed up the east-southeast facing bowl, and turned down about 20m below the highest tracks on the slope. He was about a quarter of the way down the slope when an avalanche released. The crown fracture was well above him. To get away from the avalanche he tried to escape to the north but the avalanche knocked him off his machine. Four other riders were in the runout zone. They quickly started their snowmobiles and escaped to the north just before the avalanche piled into the terrain trap.

When the avalanche stopped, Rider 1's snowmobile was visible 2m from the northern edge of the deposit, but Rider 1 could not be seen. The others used their transceivers and located his signal about 10m south of his snowmobile about 12 minutes after the avalanche. Using probes, they pinpointed his location and began to dig. At least one other group of snowmobilers came to help. It took 28 minutes to dig down through 2m of the deposit and expose Rider 1's head. He did not have a pulse. An EMT in the group began rescue breathing while digging continued. They started CPR as soon as Rider 1's chest was exposed. The victim was transferred to Sparwood Hospital at about 16:00 where he was pronounced dead. He had asphyxiated.

The dry slab released on a 32° slope at the top of the bowl at 2150m elevation. The crown height averaged 100cm and reached 115cm. It was 115m wide. The failure layer consisted of 1-2mm faceted crystals and depth hoar. The avalanche ran down the slope for 550m and into the depression in the runout zone at 1840m. There were angular blocks and some broken trees in the deposit. The deposit reached 3m deep in the depression and was about 100m wide. It was a size 3 avalanche. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Depression	Convex	Mostly Open

Source
- BC Coroners Service
- Lori Zacaruk
- InfoEx

Comment
Rider 1 plus four others watching from the terrain trap were exposed to the avalanche. Those in the terrain trap narrowly escaped the avalanche.

Few people survive burials as deep as 2m.

17 March 2001, Backcountry Skiing
Lookout Col/Glacier Crest
Glacier National Park, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Multiple individuals exposed at the same time**
- **Avalanche most likely triggered from a shallow spot**
- **Moraine feature in runout zone resulting in deep burial**

On 11 March 2001, a group of eight friends from France arrived in Calgary for two weeks of self-guided backcountry skiing in western Canada. Everybody on the trip was a member of the French Alpine Club and the group had considerable experience in backcountry travel and avalanche safety. Four members of the group had even completed the leadership training of the French Alpine Club, which includes avalanche safety, safe mountain travel and first aid.

The group originally planned to spend some time in the Rocky Mountains, but due to the lack of snow in the Rockies they decided to immediately continue to the Rogers Pass area. From 13 to 16 March, the group stayed at the hotel at Rogers Pass and completed various day-trips including Balu Pass, Young's Peak via the Illicillewaet Glacier, the south face of Rogers Peak and Dome Glacier. While the Rogers Pass area received approximately 25cm of new snow in the alpine on the first day of their visit, the weather during the other days was pleasant with temperatures averaging around -5°C, traces of new snow and light southerly winds.

On the morning of 17 March 2001, the group started the day with their daily routine visit to the Rogers Pass Information Centre to get up-to-date information on the current avalanche conditions. The local bulletin published by Glacier National Park rated the avalanche danger as Considerable in the alpine and at treeline and Moderate below treeline. While the bulletin mentioned that conditions were improving slightly, it highlighted the presence of a persistent surface hoar layer approximately 40-60cm down from the snow surface, which was particularly reactive on sheltered north and east aspects. This surface hoar layer developed during an extended period of clear weather during the second half of February and was initially buried on 23 February. According to the available records, no new avalanche activity was observed within the highway corridor over the past 48 hours.

After their visit to the information centre, the group travelled up the Illecillewaet River Valley towards the Perley Rock area, their objective of the day. However, after seeing tracks in that area, they changed their plans and decided to ski Lookout Col and Glacier Crest instead. During their earlier trip to Young's Peak, they saw an uphill track towards Lookout Col and they expected to find good conditions for skiing in that area. They would make the final decision as to which side of Glacier Crest to ski down once they arrived on the top.

As the group entered the Lookout Col basin, they travelled up the normal ascent route over moderate terrain in the centre of the basin. Approximately 100m below Lookout Col, they traversed to the climber's right onto a steep slope (37 to 42 degrees) below the south end of Glacier Crest Ridge. Using switchbacks, they climbed up beneath a low saddle between minor peaks on the ridge (*Figures 8.10 and 8.11*). They then made a steep and exposed traverse just metres below the ridgeline and used the first opportunity to gain Glacier Crest ridge. While the basin is generally facing north, the upper sections of the ascent route are on northeasterly facing slopes.

Cognizant of the seriousness of the terrain, the group decided to spread out along the uphill track as a precautionary measure. As the second person arrived on the ridge crest, they suddenly heard a muffled sound and saw the start of an avalanche down into Lookout Col basin. While the two party members who were just immediately beneath the ridge crest were not affected by the avalanche, the four members who were still climbing below the saddle were all caught in the avalanche (*Figures 8.10 and 8.11*). The person at the very back of the group was at the very edge of the steep section when the avalanche was triggered. He was only moved for a few metres and remained completely on the surface. The second and third person from the back were in the middle of the steep section when the avalanche hit and were both carried for approximately 100m down slope. When the avalanche came to a stop, one of them remained completely on the surface, while the other one was buried head down with only one leg exposed. The person who was highest on the steep section of the uphill track was missing.

The two people who had been only caught immediately started to extract the partially buried individual. This victim did not sustain any injuries and right away joined the rest of the group in their search for the missing person. While they did not pick up the signal of the victim's avalanche transceiver from their original location, they eventually detected a signal as they moved towards the toe of the avalanche. It took the group approximately 15 minutes to pinpoint the exact location of the victim about 300m from where he was caught. The local topography funneled the avalanche and forced the deposit into a relatively small area behind a moraine feature (*Figures 8.11*). The victim was found deeply buried in the centre of the small deposit area at a depth of 2.3m. When they reached the victim about 30 minutes after the avalanche happened, he was unresponsive, not breathing and had no pulse. The group immediately initiated CPR to try to save their friend's life.

Three people were sent to Rogers Pass to organize help. They arrived at the Rogers Pass Visitor Centre at approximately 15:15 and reported the accident to Parks Canada staff. At 16:05 a rescue team from Parks Canada took off from Rogers Pass by helicopter and flew to the accident site. After a quick safety reconnaissance flight over the basin, the heli-

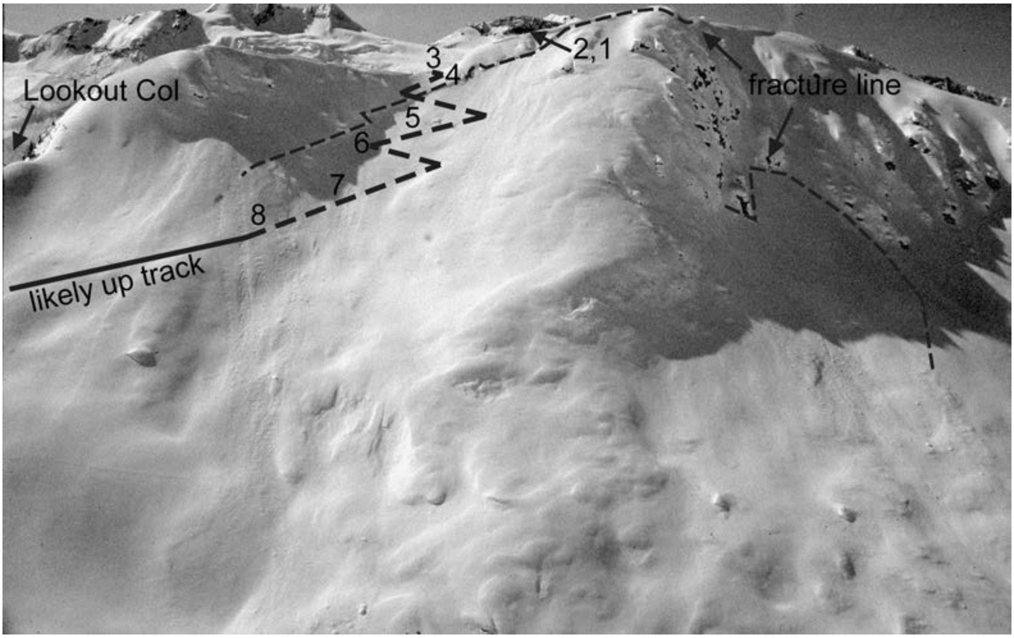

Figure 8.10. *Lookout Col/Glacier Crest, 17 March 2001. Overview of start zone with likely uptrack and location of individual party members when avalanche was triggered. Photo: Parks Canada–Bruce McMahon.*

copter landed on the avalanche debris next to the remaining members of the accident party who had continuously performed CPR on the victim. Despite their efforts, a thorough assessment of the victim by the rescue team found no evidence of breathing or a pulse. It was therefore decided to first evacuate the four survivors, followed by the victim and the rescue team. After the party members were dropped off at Rogers Pass at approximately 16:50, the victim was evacuated from the accident site using a long-line (also known as helicopter flight rescue system). At 17:30 the victim was transferred to an ambulance at Rogers Pass and transported to the hospital in Revelstoke.

The subsequent avalanche accident investigation revealed that the avalanche was approximately 180 to 200m wide and ran 300 to 350m to a moraine feature towards the bottom the basin. The avalanche was classified as a size 2.5. The accident report identified the failure layer as a layer of surface hoar crystals up to 6mm in size, which was most likely the 23 February weakness mentioned in the avalanche bulletin. The slab thickness ranged from 70 to 100cm. The report also noted that the depth of the weak layer was much shallower towards the crest of the ridgeline. It is therefore plausible that the two individuals who first arrived on Glacier Crest triggered the avalanche from a shallow spot. The muffled sound they reported was most likely the sound of the collapsing weak layer caused by the additional load of the two individuals. This sound is commonly referred to as a whumpf. The initial shear fracture in the weak layer then travelled out onto the main slope ultimately causing the avalanche.

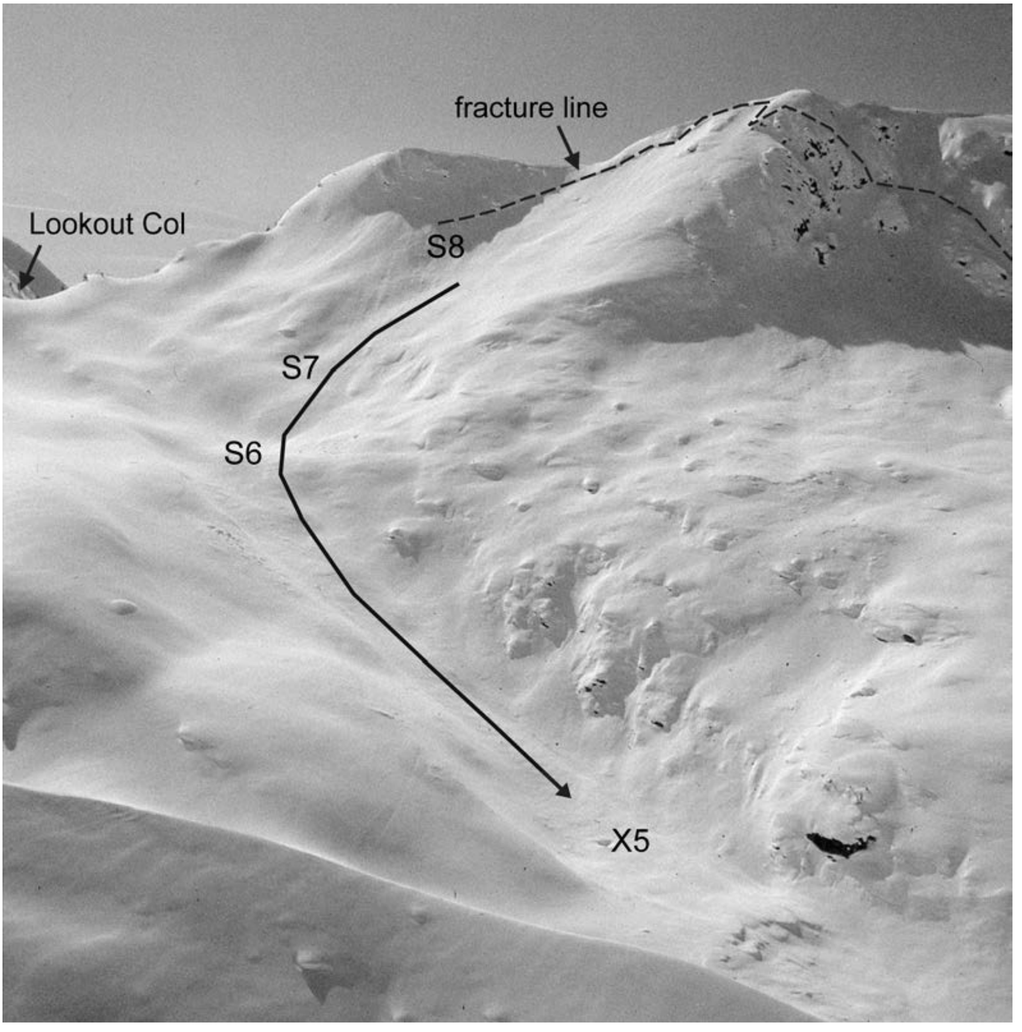

Figure 8.11. *Lookout Col/Glacier Crest, 17 March 2001. Overview of entire avalanche path with burial locations. S – survivors, X – deceased. Photo: Parks Canada–Bruce McMahon.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
37°- 42°	Moraine feature	Planar	Open alpine slope

Source

- Glacier National Park
- InfoEx
- Environment Canada – Climate data for Rogers Pass and Mt Fidelity

Comment

While the accident party decided to spread out for the final ascent to Glacier Crest, they did not consider that a large part of the group remained in the direct line of any avalanche triggered from above. The way to avoid this situation is to only allow one person at a time on the slope between the climbing track entering the slope and the ridge top.

The burial depth of 2.3m caused by the terrain trap in the runout zone, most likely contributed considerably to the negative outcome of this accident.

21 March 2001, Snowmobiling
Mt Renshaw, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Victim did not have a transceiver**
- **Triggering from thin snowpack overlying rocks**

On Wednesday 21 March 2001, a group of 12 snowmobilers left McBride, BC for the Mt Renshaw area of the Rocky Mountains. One of the riders (called Rider 1 in this summary) had left his transceiver in his hotel room because the batteries were weak. The group had ridden in the area previously. They followed a 12km groomed trail up the McKale Valley and then split into smaller groups.

In 2001, there was no regular avalanche bulletin for this region of the Rocky Mountains. However, the Canadian Avalanche Association had issued a Notice of Unusual Avalanche Conditions for the Inner Coast Mountains and Rocky Mountains. This stated, in part, that the snowpack was "unusually weak. The combination of below normal snow depth and low temperatures has produced layers of faceted grains and surface hoar with a low strength. These types of weak layers can persist for a long time, and the avalanche danger will increase with every load of new snow onto this weak base."

At a heli-ski operation about 40km to the southwest, 25cm of snow fell on 20 March with strong winds from the south and west.

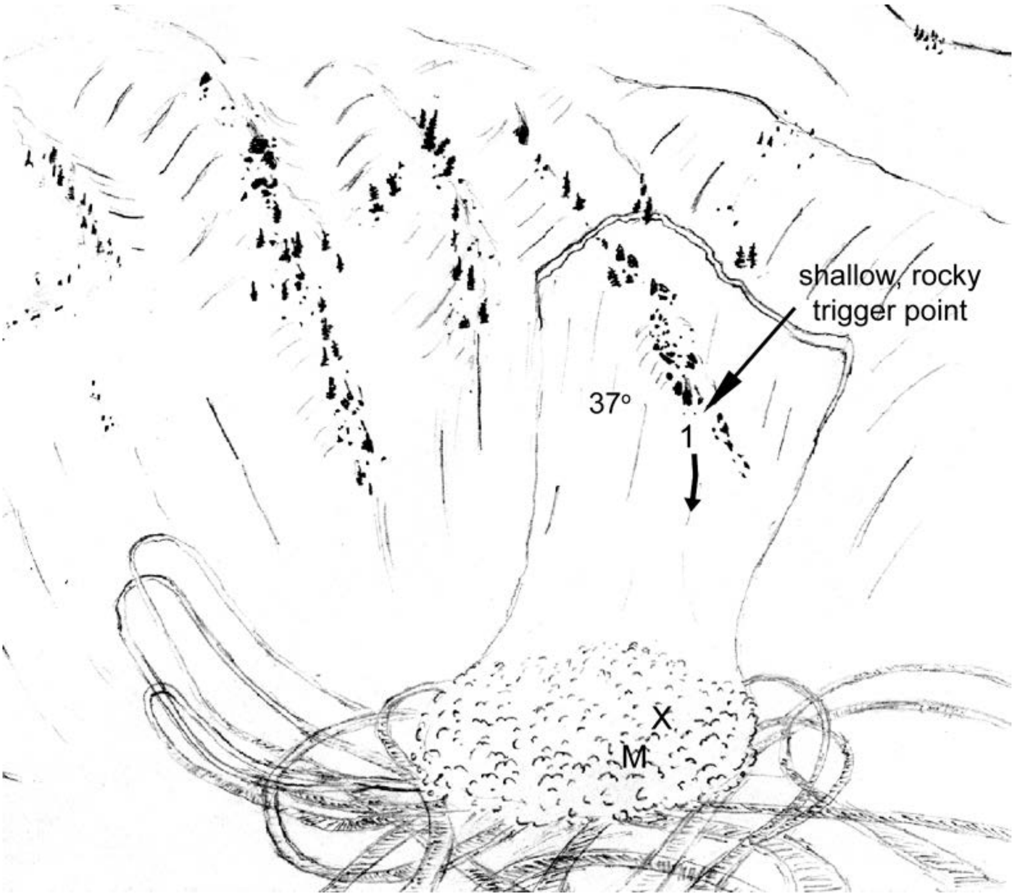

Figure 8.12. *Mt Renshaw, 21 March 2001. The avalanche was triggered where the snowpack was thin over a rocky bulge. X - deceased, M - snowmobile.*

A size 2 and a size 3 natural avalanche were reported in the alpine zone. On 21 March, an additional 10cm fell with strong wind from the south. It is not known if the snowmobilers observed avalanches or signs of instability during their approach to avalanche terrain.

At about 10:30, a group of five snowmobilers was attempting to climb a northwest-facing slope that reached 40°. It was part of a bowl that was 300m wide and 100 to 150m long. (This bowl was in the track of a larger avalanche path.) Part way up the slope, Rider 1 got stuck. He got off his snowmobile and attempted to pull it around so it was facing down the slope. An avalanche released and carried him about 60m down slope. The four others in the small group were not caught. One was sent to get help from the larger group, and the other three started the search.

All of the three searchers had transceivers but Rider 1 did not. None of them had avalanche probes so one of them drove to a group of trees and cut branches for probing. An additional ten riders in the area also came to help. About five of them had probes and shovels. The victim was found within an hour. Resuscitation was started as soon as his face was exposed. Later, Emergency Medical Responders arrived by helicopter and CPR continued. The victim was flown to McBride District Hospital, where he was pronounced dead at 13:40. He had died of asphyxia.

The slab avalanche released at 1870m where the slope was convex and about 37°. The crown fracture was 54m wide and 80 to 120cm in height. The failure layer consisted of 2mm surface hoar crystals that had been buried on 28 January. This weak layer of 1-finger hardness was sandwiched between two pencil-hard layers. Much of the slab was pencil-hard. The failure layer did not fracture in shovel tests but did fracture after 15 and 16 taps (five and six moderate taps) in compression tests. Near the crown the snowpack was 110 to 255cm in height. At the trigger point, rocks were exposed by the avalanche, indicating locally weaker snow was likely.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Convex	Open slope

Source

- BC Coroners Service
- InfoEx

Comment

Prudently, the other snowmobilers did not come to assist the person with the snowmobile stuck in the soft snow. This precaution and the position of the other riders far enough from the avalanche slope assured that only one person could be caught.

The Canadian Avalanche Centre recommends that people recreating in avalanche terrain during the winter have a transceiver, shovel and probe, and be trained in the use of this equipment.

25 March 2001, Snowmobiling
Horsey Creek Glacier, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	?	Complex

- **No transceiver**
- **Two riders caught**

On Saturday 24 March, an inexperienced snowmobiler with a new machine (called Rider 1 in this summary) met with friends and stayed overnight at a hotel in Valemount, BC. He rented a transceiver for snowmobiling on Saturday but did not do so on Sunday because he intended to drive directly home after the day of riding. On Sunday, the group parked along Highway 16, and drove their snowmobiles up the snow-covered Horsey Creek Forestry Road east of McBride, BC. In the morning, they rode for an hour or so near the Horsey Creek Glacier, where much of the terrain faces north or northeast. The sky was broken and the air temperature was a little below freezing.

There was no regional avalanche bulletin for this area in the winter of 2001. However, the Canadian Avalanche Association issued a Notice of Unusual Avalanche Conditions which mentioned “This season avalanche professionals between the Inner Coast Mountains and the Rocky Mountains have observed snowpacks that are unusually weak. The combination of below normal snow depth and low temperatures has produced layers of faceted grains and surface hoar with a low strength. These types of weak layers can persist for a long time, and the avalanche danger will increase with every load of new snow onto this weak base. The present snowpack is less stable than in most other years and remarkably different from the snowpack at the same time last year. Backcountry users will have to pay much attention to snowpack structure and strength during this winter.”

The heli-ski operation about 35km to the southwest reported moderate winds from the south and southeast on 24 and 25 March and some wind effect on 25 March. There was little snowfall reported at the heli-ski operation on these days. One cornice-triggered avalanche was reported on 25 March.

At about 12:45, Rider 1’s snowmobile became stuck in the soft snow on a slope the group had climbed and descended a number of times. He got off his machine, removed his helmet, and was trying to free his snowmobile when he triggered a slab avalanche. He was carried about 75m downslope and buried. Another rider was buried to his waist but was quickly extricated by his companions.

Rider 1’s companions quickly began to search for him with their transceivers but did not pick up a signal and realized he did not have a transceiver. They assembled their probes and began to probe systematically. After about 17 minutes, one of the probers struck him. They shoveled and found him under 1.5 to 2.5m of the deposit. He did not have a pulse so they started resuscitation. This continued for two hours until a medevac team arrived by helicopter and took over the resuscitation effort. He was pronounced dead in McBride Hospital. He had died of asphyxia. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	?	?	?	?	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	None	?	Open slope

Source

- BC Coroners Service
- InfoEx

Comment

The riders conducted an efficient companion rescue; however, the buried rider did not have a transceiver.

18 April 2001, Snowmobiling
Wild Horse Creek, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **No transceiver**
- **Three riders caught on the same slope**

On Wednesday 18 April, a group of five snowmobilers left Fort Steele, BC and drove about 17km up the Wild Horse Creek Road. They snowmobiled an additional eightkm to reach a north-facing bowl in the East Fork of Wild Horse Creek. Four of the five riders had transceivers. The weather was partly cloudy with flurries. Later in the afternoon, the air temperature at ridge top, about 2300m, reached -1 or 0 °C

The Canadian Avalanche Association issued a bulletin for the South Rockies on 12 April. It was valid until 16 April; however, there was no update until the afternoon of 18 April. The bulletin issued on 12 April rated the avalanche danger in the Alpine zone as High. The bulletin also noted that "on northerly aspects the snowpack base remains unusually weak and unconsolidated, as it has been for the entire winter."

At the Fernie Alpine Resort, 41km to the southeast, the air temperature in the study plot at 1650m had reached 7°C in the previous three days. On the afternoon of 18 April, several deep slab avalanches running to ground were visible on south- and west-facing slopes. On the west-facing slope of the bowl where the snowmobilers were riding, a 1 metre-deep slab avalanche was visible; it was about 10 days old.

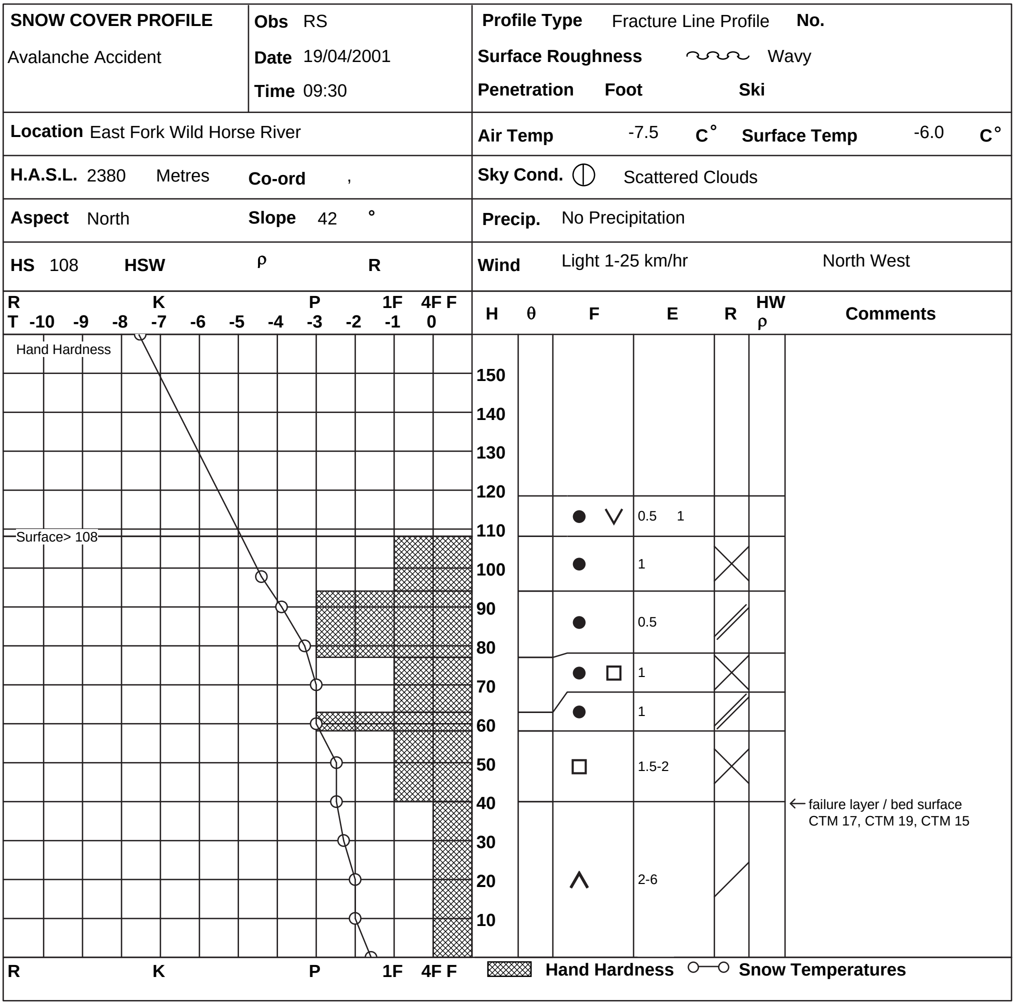

Figure 8.13. Wild Horse Creek, 18 April 2001. Fracture line profile observed by the accident investigator on 19 April 2001.

The five snowmobilers reached the bowl at about 10:45. Riders 1 and 2 rode directly up the bowl and reached the ridge at 2380m. They stopped to look around. The other three riders were unable to reach the ridge on their first attempt. Riders 3 and 4 made several climbs in the bowl. When these two riders were on opposite sides of the bowl—one climbing and the other turning down on the west flank—a large avalanche released. Rider 5 was low on the slope, and tried to accelerate away from the avalanche. He was pushed about 50m, partly buried, but able to free himself from the deposit within a few minutes. He saw a hand sticking out of the slope and began to dig out Rider 4 from the west flank, who had been carried about 250m, and was about 100m below his snowmobile. Rider 5 partly excavated Rider 4, who was breathing but had sustained a serious back injury.

Riders 1 and 2 had felt and seen the avalanche from the ridge. They knew Rider 3 was missing and that he did not have a transceiver. They assembled their probes and probed around his snowmobile, which was on the surface. Because of the difficulty in finding Rider 3 by probing and the injury to Rider 4, one person left to get help. In about 20 minutes, he reached his truck, which had a FM transmitter/receiver. He contacted a forestry worker who relayed the call for help to a helicopter in the area. The helicopter pilot contacted the RCMP. The rescue included personnel from the RCMP, the local search and rescue team, BC Ambulance Service, an RCMP dog team from Nelson, and two CARDA dog teams from Fernie, BC. Twenty-three people were at the avalanche when Rider 3 was found by probing at 15:23. He had asphyxiated under 1.3m of the deposit.

The crown fracture was just below the ridge, 150m wide on a 42 to 45° slope. The crown height varied from 35 to 110cm, and averaged 60cm. Much of the start zone was 37°. The average depth of the deposit was estimated to be 2m deep. The toe of the runout was at 2110m. It was a size 3 avalanche. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	Yes	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Concave	Open slope

Source

- BC Coroners Service

Comment

To reduce the search time and potentially increase the survival rate, the Canadian Avalanche Centre recommends that each recreationist in avalanche terrain have a transceiver, shovel and probe, and be trained in the use of this equipment.

19 April 2001, Snowmobiling
South of Ram Falls, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Victim buried in a gully**
- **2 metre-long probe and 3 metre burial**

On Thursday 19 April, a party of six snowmobilers were sledding about 8km south of Ram Falls in Bighorn Country. This is about 45km southeast of Nordegg, Alberta.

On the day before the snowmobiling trip, the Canadian Avalanche Association issued a regional bulletin for the Rocky Mountains. The avalanche danger was rated as Considerable in the alpine and Moderate below, increasing in the afternoon. The bulletin also noted: "Some reports of avalanches failing to or stepping down to the November facet layer have been submitted.... These failures generally involve the entire season snowpack, so avalanches up to size 3.5 have recently been reported. The overall trend will be for the best stability to be found in the cool mornings, with deterioration throughout the day as warming affects the snowpack."

At about 17:00, one rider made a turn low on a northeast-facing bowl. When a second rider made a similar turn, he triggered a slab avalanche and was pushed into a gully and buried. The missing rider was wearing a transceiver.

The other five riders had three transceivers and a two-metre probe. They localized the signal to an area about 8m by 8m, but had difficulty locating the victim with the probe. After 45 to 90 minutes, they struck the victim by probing the side of a large pile in the deposit. The victim was buried 3m below the surface of the deposit. He had asphyxiated.

The size 3 slab avalanche released at about 2000m on a northeast-facing slope. The crown fracture was about 100cm high and 500m wide. The slab released to ground, presumably failing on depth hoar and faceted crystals. The deposit was moist. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	?	?	?	?

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	Gully	?	Alpine

Source

- Parks Canada avalanche involvement report based on a phone interview, sketch by survivors
- Patterns of death among avalanche fatalities: a 21-year review (Boyd et al., 2009)

Comment

Few people buried more than 2m deep are found alive.

It is more difficult to pin-point a deeply buried transceiver than a shallowly buried one. Also, practice with transceivers buried more than a metre is time consuming.

In the summer of 2002, the Canadian Avalanche Association discontinued the bulletin for the Rocky Mountain region because parts of it—including the area where this accident occurred—lacked adequate weather data as well as snowpack and avalanche observations. In December 2002, they began to forecast for a new region in the South Rockies, where adequate data and observations were available.

Chapter 9

Avalanche Accidents of Southwestern Canada **2001-2002**

Winter Summary for Southwestern Canada

- **13 avalanche fatalities in 9 accidents**
- **4 of the fatal accidents related to a crust-facet combination that developed during a rain on snow event in mid-November**
- **"Pineapple Express" in early January resulted in unusual rain event in mid-season**
- **No extended cold periods until late February**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
12 Jan 2002	Parker Ridge	Rocky Mountains	Outdoor Worksite	1	Persistent Slab	16 Nov 2001	194
14 Jan 2002	Brewer Creek	Purcell Mountains	Snowmobiling	1	Deep Persistent Slab	16 Nov 2001	197
25 Jan 2002	Birkenhead Peak	Coast Mountains	Heli-Skiing	1	Persistent Slab	19 Jan 2002	200
28 Jan 2002	Mt Carlyle	Selkirk Mountains	Backcountry Skiing	3	Persistent Slab	7 Jan 2002	203
9 Feb 2002	Eureka Mountain	Cariboo Mountains	Snowmobiling	1	Deep Persistent Slab	16 Nov 2001	208
10 Feb 2002	Whistler Creek	Rocky Mountains	Backcountry Snowboarding	1	Deep Persistent Slab	16 Nov 2001	210
10 Feb 2002	Mt La Forme	Selkirk Mountains	Heli-Skiing	2	Persistent Slab	2 Jan 2002	214
18 Mar 2002	Mt Hughes	Purcell Mountains	Out-of-Bounds Skiing and Snowboarding	1	Cornice Fall and Persistent Slab	2 Feb 2002	218
14 Apr 2002	Near Fortress Mountain Ski Area	Rocky Mountains	Out-of-Bounds Skiing and Snowboarding	2	Cornice Failure or Wind Slab		223

[1] *It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.*

By the end of October, the entire region exhibited a healthy snowpack due to above-average precipitation and slightly below-normal temperatures during the fall. On 1 November, the snowpack height at Mt Fidelity (1874m) measured 124cm, roughly twice the amount of snow commonly observed at that time of year.

Snowfall decreased over the first few days of November and temperatures rose above normal as a Pacific ridge of high pressure established itself over BC. This period of clear weather ended dramatically on 13 November with the arrival of the next low pressure system from the Pacific. This powerful disturbance brought significant amounts of rain all the way to the mountains tops in the Coast and Columbia Mountains. On 14 and 15 November, Whistler Roundhouse (1835m) registered a total of 65mm of rain. Rainfall was less intense in the Columbia Mountains, where a total of 22mm was observed at Mt Fidelity. As the storm progressed through the region, temperatures dropped slightly and rain turned into snow. On 19 November, the Coast Mountains experienced another pulse of rain with 51mm measured at Whistler Roundhouse. Freezing levels in the Coast Mountains reached into the alpine again, whereas temperatures were not as high in the Columbia Mountains and precipitation fell as snow at higher elevations. While the Rocky Mountains did not experience rain to the same extent as the other two mountain ranges, the above-freezing temperatures also resulted in the development of a widespread melt-freeze crust.

After the second pulse of rain, temperatures returned to seasonal for the rest of November and the wet surface layers were buried by new layers of dry snow. This sequence of weather events created several significant crusts with adjacent layers of faceted snow crystals. The facets developed in the dry snow next to the wet snow layer, as the cooler surface temperatures and the latent heat stored in the wet snow created a significant temperature gradient. As the season progressed, this November facet-crust combination became a major feature of the 2002 snowpack and was related to numerous fatal avalanche accidents in the shallower snowpack areas of the Columbia and Rocky Mountains: **Parker Ridge on 12 December** (page 194), **Brewer Creek on 14 December** (page 197), **Eureka Mountain on 9 February** (page 208) and **Whistler Creek on 10 February** (page 210). Other than this weakness, the region had a relatively strong and well-consolidated early season snowpack at higher elevations. Snow was relatively sparse below treeline due to above seasonal temperatures.

After a quiet period towards the end of November, a warm front arriving around 1 December brought the next pulse of new snow, rising temperatures and strong winds, creating widespread wind slabs at treeline and above. A short break in the storm pattern on 5 December allowed the formation of the first surface hoar layer of the season in the Coast and Columbia Mountains. This layer was buried immediately, as the next warm front swept across the region the day after. While the initial bond to the old snow surface was weak, conditions stabilized as the upper snowpack tightened with the cooler temperatures after the storm.

The next powerful storm period was between 13 and 18 December. During this six-day period, a series of frontal systems deposited up to 200cm of snow in the Coast Mountains, 70 to 130cm in the Columbia Mountains and roughly 30 to 60cm in the Rocky Mountains. Fluctuating temperatures and strong to extreme winds resulted in the formation of stiff surface slabs and widespread avalanche activity. While most avalanches were within the storm snow in regions with a deeper snowpack, avalanches failing on the November facet-crust combination were more frequent in shallow snowpack areas. Snowfall stopped on 19 December as a blocking ridge of high pressure developed over BC. The period of nice weather was characterized by a strong temperature inversion, which meant cold and foggy valley bottoms and clear skies and warm temperatures in the alpine. The combination of no wind, cold clear nights and an abundance of moisture from the valley fog provided ideal conditions for the extensive growth of surface hoar and near-surface facets during the Christmas holidays. At the same time, sun crusts developed on solar aspects. These surfaces were buried on 1 January with the arrival of the next warm front. While much of the surface hoar was washed away by rain in the Coast Mountains, the various surfaces were just barely buried in the interior ranges.

This period of fair weather completely reversed the initial character of the snowpack in the Rocky Mountains. While the region exhibited a strong and well-consolidated snowpack at the end of October, it completely lost its strength during the second half of December due to extensive faceting. In addition, the period left a widespread layer of surface hoar, a rather unusual occurrence in the Rocky Mountains.

6 January marked the arrival of a powerful "Pineapple Express." On that day, the weather station at Whistler Roundhouse reported temperatures around the freezing point and 31mm of rain. On the same day, 9mm of rain was observed at Mt Fidelity. Above 2000m, snow accumulated under strong to extreme

southwesterly winds. The dramatic weather led to extensive natural avalanche activity with destructive wet avalanches and soft slabs running on surface hoar. Although the rapid rise in temperature and dramatic new load increased avalanche activity in the short term, this rain helped to destroy the widespread New Year's surface hoar layer at treeline and below. At higher elevations, however, this weakness was now buried under 50cm of storm snow. Temperatures cooled off after the Pineapple Express had passed and the wet surface snow turned into a widespread rain crust waiting to be buried.

In the Rocky Mountains, the warm, wet snow of the Pineapple Express was accompanied by brisk winds producing widespread touchy wind slabs on top of the old, weakened snowpack. The first fatal avalanche accident of this season occurred at **Parker Ridge on 12 January** (page 194) and involved a stiff slab that failed in a layer of weak facets above the remnants of the November melt-freeze crust. Two days later, the next fatal accident took place in the Purcell Mountains in **Brewer Creek on January 14 January** (page 197). Similar to the first accident, the related avalanche also failed in a layer of facets above the November crust.

Mid-January was characterised by relatively calm weather with cooler temperatures and minimal snowfall. In the Columbia Mountains, the simple and consolidated snowpack from early season had by now morphed into a complex mid-winter snowpack. In addition to the November crust-facet combination, which was primarily a concern in the shallower snowpack areas, the upper snowpack contained a combination of wind slabs, rain crusts, facets and two layers of surface hoar. All these weaknesses exhibited different spatial patterns and different amounts of load sitting on top of them. The elevation band around treeline was particularly sensitive with widespread whumpfing and easy test results being reported. While the interior ranges reported minor accumulations of new snow in mid-January, the sky over the Coast Mountains remained mainly clear, resulting in the development of a new layer of surface hoar.

A series of strong, low pressure systems brought steady snowfall during the second half of January. By 24 January, average storm snow accumulations were roughly 50cm in the Coast Mountains, 30 to 100cm in the Columbias and about 20cm in the Rocky Mountains. While temperatures were initially below seasonal and the snow was light, temperatures rose and wind increased as the storm progressed. This led to an "upside down" snowpack with denser slabs forming on colder and weaker snow below. Many natural and human-triggered avalanches were observed during this storm, including a fatal avalanche accident in the Coast Mountains on **Birkenhead Peak on 25 January** (page 200). The avalanche involved the recent storm snow and failed on the most recent surface hoar layer buried on 18 January.

As the arctic air mass moved into the region around 26 January, the front and main ranges of the Rocky Mountains finally received a major snowfall but the storm failed to reach the mountain ranges further to the west. As natural avalanche activity slowly subsided, the next fatal avalanche accident occurred in the Selkirk Mountains on **Mt Carlyle on 28 January** (page 203), the first nice day after the extended storm period. In this case, the large avalanche failed on the rain crust that developed during the Pineapple Express on 7 January.

After a few days of generally calm weather and cold temperatures, a series of gradually strengthening frontal systems started moving through the region on 30 January. Increasing winds resulted in the development of widespread wind slabs, primarily in the Coast and Northern Columbia Mountains. While storm snow instabilities in the upper snowpack stabilized reasonably quickly, the increasing loading started to make the deeper instabilities more susceptible to triggering. The weekend of 9 and 10 February claimed the lives of four recreationists in three different avalanche accidents. The first fatal accident occurred in the Cariboo Mountains on **Eureka Mountain on 9 February** (page 208), where a snowmobile rider triggered the avalanche in a layer of weak facets above the remnants of the November crust. The second accident happened in the Selkirk Mountains on **Mt La Forme on 10 February** (page 214) with an avalanche that failed on the 2 January surface hoar layer. The last accident of this weekend took place in Jasper National Park, in the **Whistler Creek valley on 10 February** (page 210). In this accident, the November facets were triggered from a shallow spot next to a wind-loaded area.

After an intense cold front with strong winds passed through the region on 12 February, a new ridge of high pressure moved into the region from the south. This period of clear skies, light winds and warming temperatures helped to strengthen the snowpack in the Coast and Columbia Mountains. However, the rain crusts from November and January remained serious concerns, particularly in shallow snowpack areas, and a new layer of surface hoar and sun crusts on solar aspects was being formed across the entire region.

After this taste of spring, the new surfaces were gently buried by a series of increasingly powerful storms starting on 17 February. By 23 February, the region had received between 30 and 60cm of new snow in the Coast Mountains, over 100cm in the Columbias, and about 50cm in the Rockies. While the storm started warm, temperatures slowly dropped towards the end as the influence of the arctic air mass became stronger again. Extensive avalanche activity was observed during these storms with the majority of avalanches failing within the storm snow and at the 16 February interface.

The weather at end of February and most of March was primarily characterized by a series of extreme temperature swings as the region alternately came under the influence of the maritime polar air mass from the Pacific and continental arctic air masses from the Canadian Arctic. After the first episode of below seasonal temperatures in late February, temperatures rose again at the beginning of March. The warmer weather promoted settlement and improved the stability of the significant load recently added to the snowpack. However, mild temperatures and warmer March sun also led to the development of a strong crust on solar aspect and below treeline. New surface hoar development was observed in isolated sheltered pockets. A brief dose of new snow was followed by a dramatic temperature drop on 5 March as the arctic air mass established itself across the region. Wind direction changed from southwest to northeast as the arctic front passed, which led to the formation of wind slabs in unusual locations. Prior to the passing of the arctic front, the front ranges of the Rocky Mountains experienced classic upslope storm conditions, receiving up to 40cm of new snow with strong winds on top of a still heavily faceted snowpack.

As the arctic air mass retreated to the north on 11 March, temperatures returned to normal and a series of powerful low pressure systems moved across the region bringing heavy snowfall and strong winds. The storms deposited between 30 to 50cm of new snow in the Rockies, 40 to 70cm in the Columbias and 50 to 75cm in the Coast Mountains. The new snow did not bond well with the heavily faceted snow surface that developed during the previous deep freeze. As a consequence, the storm period was accompanied by widespread storm snow and wind slab avalanche activity. However, due to the moderate temperatures, instabilities within the storm snow were settling fairly rapidly. As the arctic air started to advance again, temperatures started to drop and the unstable air mass resulted in convective flurries. While the snowpack tightened with the lower temperatures, the strong northerly outflow winds associated with the arctic air mass redistributed the surface snow into wind slabs in unusual locations. During this cold period, a fatal avalanche accident occurred on **Mt Hughes on 18 March** (page 218), in the vicinity of Kicking Horse Mountain Resort. While the accident was caused by a cornice fall, the subsequent avalanche failed on the 17 February surface hoar layer.

The cold period concluded on 21 March with a dramatic rise in temperature. Within a day, maximum temperatures measured at Mt Fidelity changed from -15.5°C to 3°C. After some initially unsettled weather, the ridge strengthened and brought spring-like conditions. The rapid rise in temperature resulted in lots of cornice failures and wet surface releases. However, due to the recent extremely cold temperatures, the warming effect did not affect the deeper instabilities in the snowpack. March concluded with another strong low pressure system that brought significant amounts of new snow primarily to the interior ranges. The surface crust at the bottom of the storm snow and new wind slabs were the dominant avalanche concerns during this storm period.

As the arctic air mass made another appearance at the beginning of April, it brought clear skies to the entire region and developed another crust at the snow surface. The influence of the arctic air finally came to an end for this season when another series of disturbances from the Pacific moved across the region. While rain was falling in valley bottoms, the alpine saw light snow with strong winds. This created a new set of wind slabs, this time on the 2 April crust interface. With 35cm of new snow in roughly two days, the Rocky Mountains experienced the largest amount of accumulation during this storm. A steady flow of weak fronts resulted in continuously unsettled weather with fluctuating freezing levels. Rain falling at lower elevations resulted in near isothermal conditions, which allowed some of the older persistent weaknesses to become active again.

The last fatal avalanche accident of the season occurred outside the Fortress Mountain ski area in an area known as the **South Chutes on 14 April** (page 223). In this accident, a natural cornice failure triggered a wind slab on the 2 April crust during the passing of a cold front. The rest of April was dominated by typical spring avalanche conditions, where overnight surface crusts provide significant strength to the snowpack in the morning hours. Then as the sun crust breaks down with daytime heating, the snowpack loses strength quickly and large wet avalanches failing on older persistent weaknesses be-

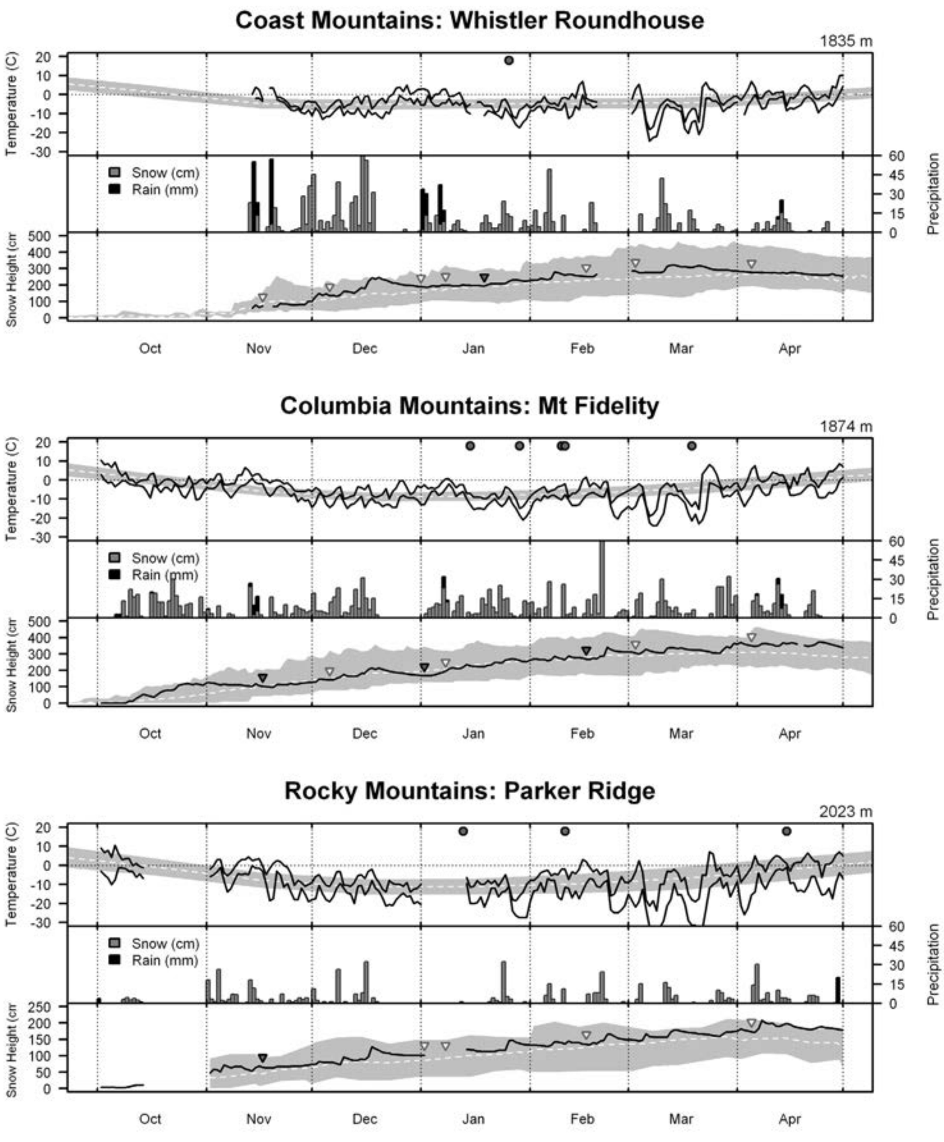

Figure 9.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 1996/1997 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanche (black triangles). Other persistent weak layers are shown with light triangles. The grey band shows minimum, average (dashed line) and maximum snowpack height measures at this location since 1976 (Whistler Roundhouse and Mt Fidelity) or 1978 (Parker Ridge).*

12 January 2002, Outdoor Worksite Parker Ridge, Jasper National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Three full burials on the same slope**

To observe a snow profile and make snowpack tests, three well-equipped wardens ski toured up to the upper south “corner” of the Parker Ridge avalanche path. This site had been used for snow studies for about 20 years to obtain supplemental information for the backcountry and highway avalanche forecasting program.

The bulletin produced the previous afternoon rated the avalanche danger in the Alpine as Considerable and included the following text: “Cold air and clear skies have settled over the region. ... Previous winds and storms have loaded east and north aspects, and created extensive windslab that has been reactive to field and explosive tests in the Marmot Basin area. ... Deeper instabilities in Jasper Park include a series of melt-freeze layers near the bottom of the snowpack, which are weakening and producing moderate to hard results. Natural activity has been limited to steep rocky exposures. Many shallow spots are faceted and weak, and depth hoar is becoming ubiquitous.”

In Jasper National Park, no fresh avalanches had been reported in the previous two days. At the 32° northeast-facing profile site at about 2225m, the air temperature was -2.3°C, the clouds were broken, and the wind was moderate from the east. The snowpack thickness was 90cm. A compression test yielded three moderate results: within the bottom 34cm of depth hoar; in a layer of faceted crystals 34cm above the ground and just under a pencil-hard layer; and in 2mm surface hoar and faceted crystals 70cm above the ground. They also observed a rutschblock test, and classified the result as “moderate.”

Partly because one member of the group was not a strong skier, they decided to take a gliding traverse down to the northwest, parallel to and above their ascent route. After traversing most of the slope, they paused on a bench at about 2100m, with one skier, A, about 50m ahead of the other two, B and C. When Skier A turned to ski down into sparse trees, the others yelled “avalanche.” The avalanche hit all three of them in two or three waves and carried them 30 to 50 metres down the slope. All three skiers were completely buried.

When the avalanche stopped, Skier B had lost his skis and was able to punch a hand to the surface, creating an opening for his face. He spat out snow, gasped and then shouted for the other two. He was able to free himself. After radioing for help he began a transceiver search and quickly picked up two signals. Wallowing thigh deep in the soft deposit, he headed upslope for what turned out to be Skier A’s signal. When he was close to Skier A’s signal, he spotted a ski sticking out of the snow and soon cleared about 50cm of snow from Skier A’s head. Noting that Skier A did not appear to be breathing, Skier B cleared snow from A’s mouth and started artificial respiration. After one ventilation, Skier A coughed and began to breathe.

Skier B left Skier A and followed the other transceiver signal towards Skier C, who was found about 28 metres away. When the transceiver indicated Skier C was close, he began to probe and hit Skier C’s pack after pushing the probe into the snow three or four times. He dug quickly through about 120cm of snow and uncovered Skier C’s head. After clearing Skier C’s mouth, he attempted ventilations

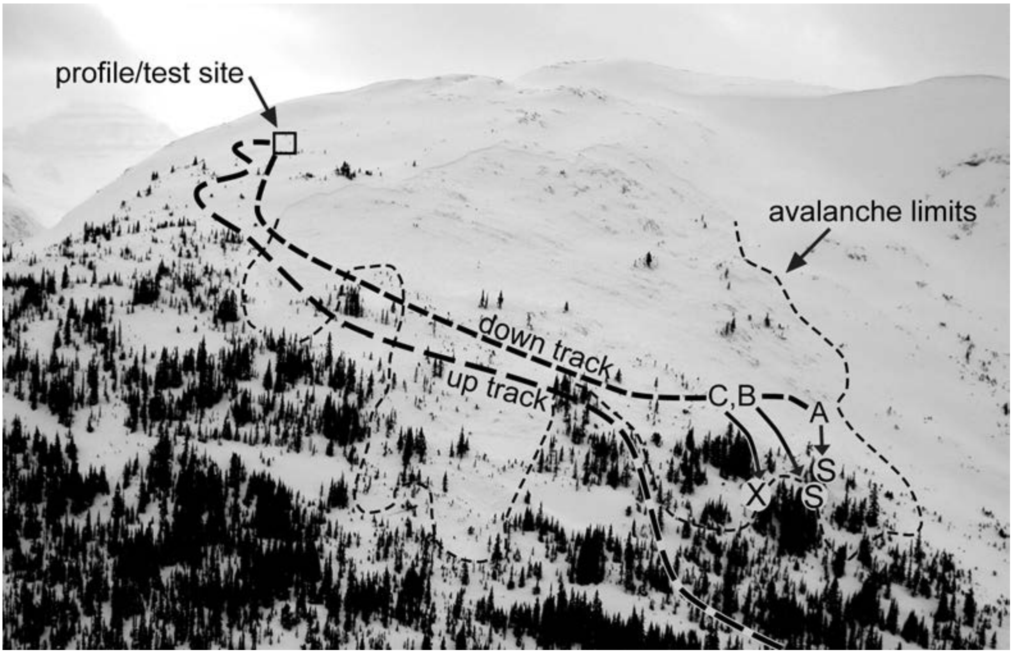

Figure 9.2. *Parker Ridge, 12 January 2002. A, B, C – position of skiers at time of avalanche. S - survivor, X - deceased. Photo: Parks Canada—Brad White.*

which successfully inflated the lungs. After more shoveling, he was able to give effective CPR.

After a period of unconsciousness and then confusion, Skier A dug himself out of the snow and—with difficulty due partly to a leg injury—joined Skier B's efforts to revive Skier C. About an hour after the radio call, an off-duty warden and companion arrived. Soon after that, the rescue team of wardens arrived in a helicopter. CPR was continued on Skier C while flying to the hospital in Banff. Skier C was not revived.

The avalanche was a size 2.5 dry slab avalanche that started at about 2230m on a north-northeast slope, inclined at 34 to 38°. The start zone is prone to wind loading. The crown fracture was about 300m wide and varied in height from 30 to 124cm (average 60cm). The avalanche released on a layer of faceted crystals (which varied from 4F to 1F in the profiles) on a pencil-hard layer of rounded facets. Investigators believe the harder layer was the remains of a rain crust that had formed in November, and that the accident party had triggered the fracture that brought the avalanche down on them. The avalanche ran for 425m along the slope, with a vertical drop of 190m. The deposit was 1 to 3m deep.

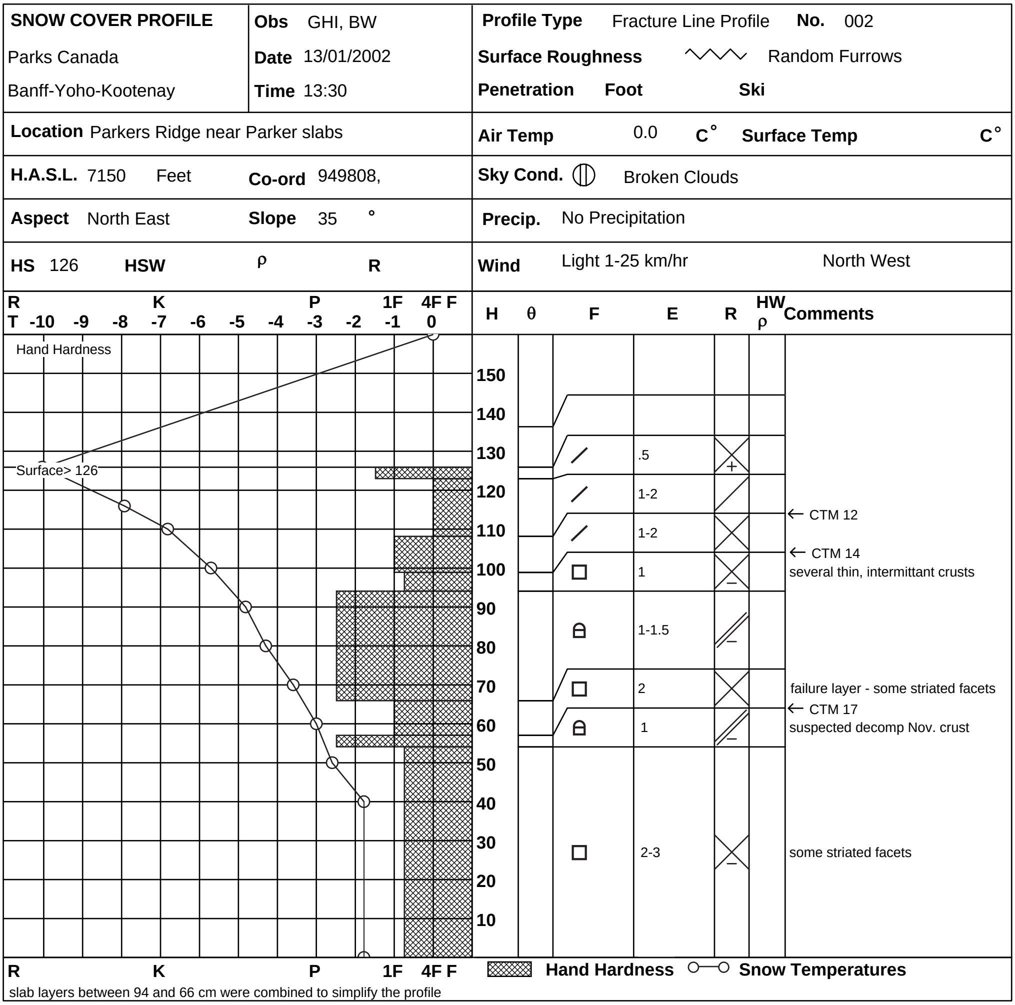

Figure 9.3. Parker Ridge, 12 January 2002. Fracture line profile observed during accident investigation on 13 February 2002.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	Yes (wind)	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Convex	Mostly open

Source

- Parks Canada Fatality Report
- InfoEx

Comment

The efficient rescue by Skier B saved the life of Skier A.

The melt-freeze crust that formed in November was no longer obvious due to the faceting process. The avalanche released on a layer of faceted crystals above the remnant of the crust. Snowpack tests on this layer varied from place to place, as indicated in the bulletin.

This is another example of triggering an avalanche from an isolated area of weak snowpack.

14 January 2002, Snowmobiling
Brewer Creek, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Short slope with terrain trap**
- **30° slope**

On Monday 14 February, a group of six snowmobilers left the Hawke Road west of Fairmont Hot Springs, BC to go riding up Brewer Creek. Snowmobile tracks indicate that while working their way up the creek, this or another group highmarked the shorter, windward slopes (mostly south-facing). A size 1.5 natural slab avalanche was visible on a lee slope of Brewer Creek. By midday they were near the head of Brewer Creek. There were high cumulus clouds, a light northwest wind and the air temperature was about -10°C. There had been no precipitation in the previous two days.

Four days before the snowmobiling trip, the Canadian Avalanche Association issued a regular bulletin for the South Columbia Mountains, including the Purcell Mountains. The regional avalanche danger at and above treeline was rated High. The bulletin emphasized wind slabs and a surface hoar layer under 50cm of storm snow. The bulletin cautioned: "Beware of slight improvements in stability luring you out into the tiger pit. After a long lazy Christmas it may be extremely tempting to sample the new powder. The whole alpine and treeline zone down to about 1500 metres should be regarded with caution."

At about 12:30 while a rider was headed north, crossing a short east-facing slope, he triggered an avalanche that swept him down the slope and into a depression at the base of the slope. The other riders located the victim by transceiver search in about 15 minutes. It took a further 20 minutes to dig him out from under 3m of the deposit. They found no pulse and tried to resuscitate him for 20 minutes. He had asphyxiated.

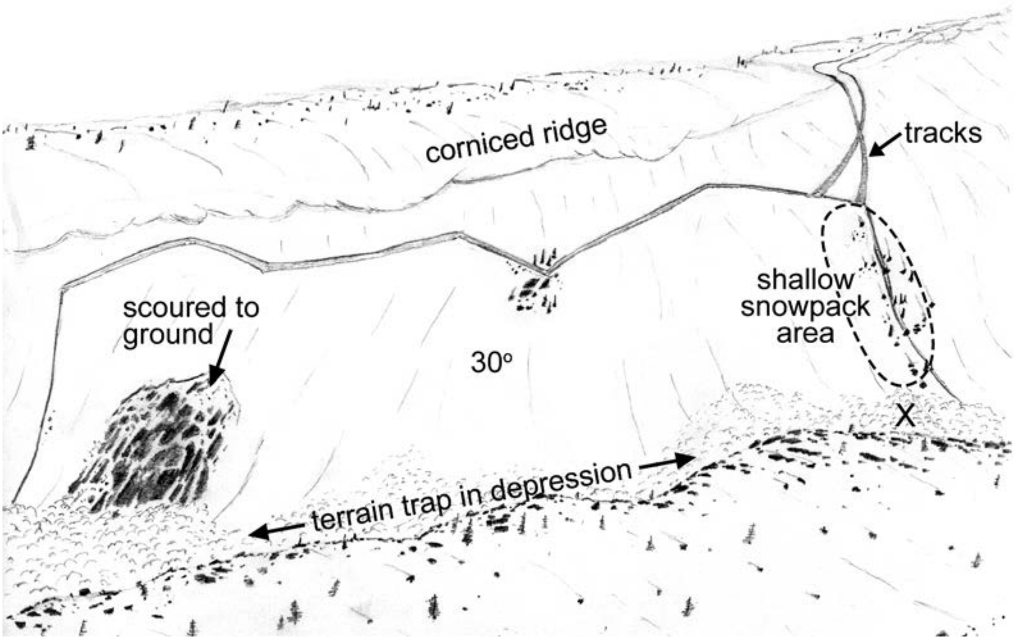

Figure 9.4. *Brewer Creek, 14 January 2002. The avalanche was triggered where the snowpack was relatively thin. X – deceased.*

The crown of the dry slab avalanche was 2 – 3m below a cornice at 2590m. The avalanche was a size 2.5, about 600m wide, with a crown height varying from 70 to 150cm. Although the snowpack height at the top of the slope was typically 160cm, it was very shallow on the climber's right side, where there is a narrow vertical band of exposed rocks and trees. The slope incline was 30°. The bed surface was the November rain crust, and part of the bed surface stepped to the ground. The avalanche ran down the slope for about 150m, where the deposit piled up at least 3m deep in front of a 7 m-high hump across the slope, perhaps an old moraine. The elevation at the bottom of the depression was estimated at 2507m. A snow profile and snowpack tests were observed the day after the accident. At the crown, there were no fractures at the failure layer for the avalanche, i.e. the faceted layer overlying the upper of two rain crusts from November 2001. In a compression test, the facets between the two rain crusts required hard tapping to cause a fracture in large depth hoar and facets. Lower on the slope, moderate tapping in a compression test caused a fracture at the failure layer comprised of 3mm depth hoar and facets.

Other than the one recent avalanche lower in Brewer Creek, it is unknown if the snowmobilers observed other signs of instability. They did not observe a snow profile or make snowpack tests.

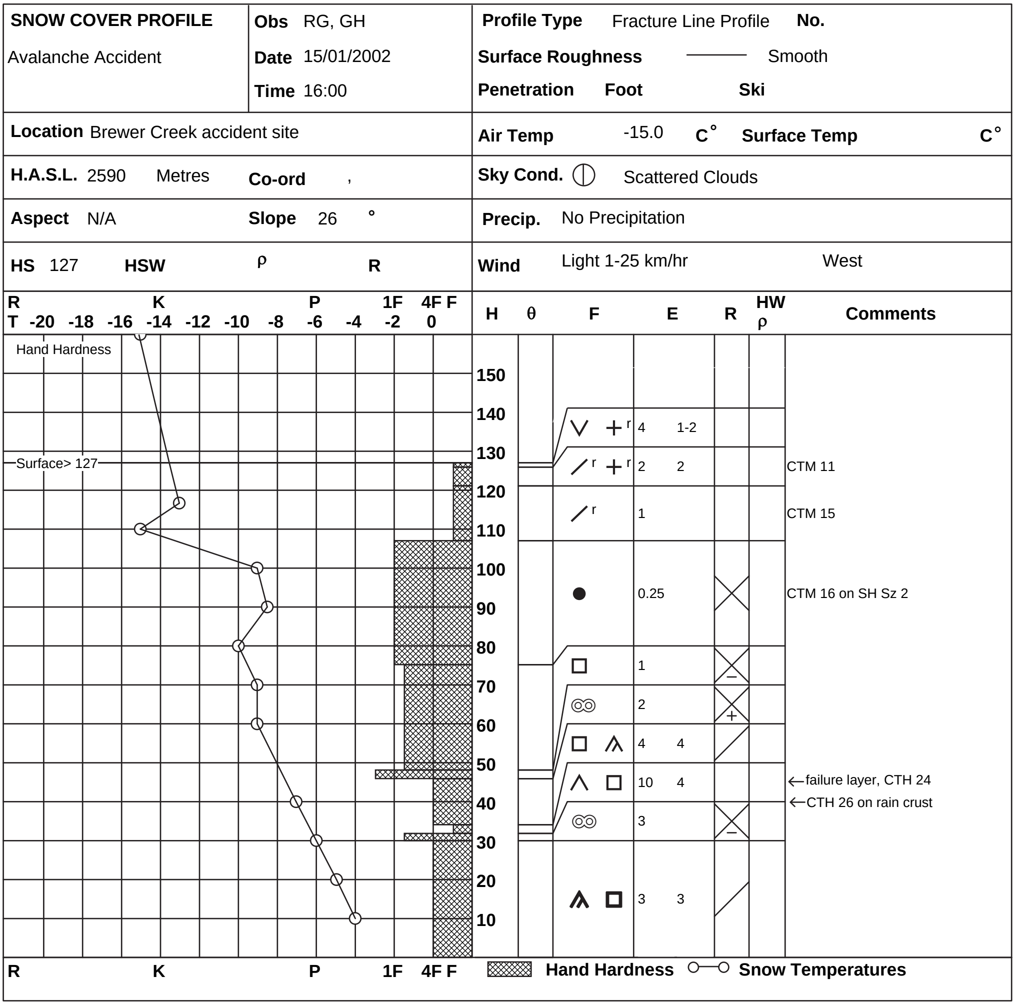

Figure 9.5. Brewer Creek, 14 January 2002. Fracture line profile observed during accident investigation on 15 February 2002.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes (one natural)	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
30°	Depression	Planar	Open slope

Source
- BC Coroners Service
- Rod Gibbons
- Graham Holt

Comment
This accident occurred on a short slope that was consistently inclined at 30°. The start zone of most fatal avalanches is steeper than 35°.

The slope was mostly lee to prevailing winds, but the snowpack was thinner near the trigger point.

The snowmobilers were well equipped and performed a companion rescue. However, the depth of the slab and the depression at the base of the short slope contributed to the very deep burial. Few people survive burials deeper than 2m.

The following winter, there was a fatal avalanche at the head of Brewer Creek, less than 2km north of this accident.

25 January 2002, Heli-skiing
Birkenhead Peak, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

On 25 January 2002, a storm in the Coast Mountains had just ended. A group of two guides and four guests flew by helicopter to go heli-skiing in the mountains northeast of Pemberton, BC. Twice, they flew toward heli-ski runs but turned back due to poor visibility. They were finally able to land on a northwest-facing slope of Birkenhead Peak for their first heli-skiing run of the day. Flurries continued after the storm and the air temperature was about -6°C.

During a clear period from 17 to 19 January, surface hoar and faceted crystals were reported to have formed on the snow surface in protected alpine and treeline sites near the Duffey Lake Road about 25km southeast of Birkenhead Peak. Also along the Duffey Lake Road, at the Blowdown mid-mountain weather station (elevation 1890m), 12 centimetres of snow fell from the night of January 19 through the afternoon of 22 January. From the morning of 23 January to 25 January, a further 56cm of snow fell and temperatures ranged between -12 and -4°C.

Two days earlier, a neighboring heli-ski operation reported that the surface slab was reactive to ski cutting, but the layer of surface hoar buried on 19 January was not mentioned. They reported a moderate compression test result in a deeper surface hoar layer but nothing on the recent surface hoar layer. On 24 January, they did not fly or make observations in the skiing terrain, likely because of the storm.

For the South Coast Mountains, the Canadian Avalanche Association issued a bulletin on 24 January rating the regional danger for the following two days as High, easing to Considerable as the storm passed. This applied to all elevation zones. The bulletin also noted: "We have a variable snowpack, a considerable storm snow load, moderate to high winds and easy shears on a variety of layers. We can expect natural and human triggered avalanches to occur on many slopes, at least until the present frontal wave passes through. After that, expect a slower recovery than normal due to the cooler temperatures and continued, albeit lighter, snowfalls."

From the landing on the ridge, the lead guide and four guests skied a gladed slope to the skier's left of a small avalanche path. The assistant guide stayed back to make snowpack observations. One of the guests fell in the first open glade—which had been observed to avalanche in other winters—and did not trigger a whumpf or avalanche. While regrouping, the lead guide probed and estimated there were 80cm of snow from the recent storm and a total of 320cm of snow on the ground. At approximately 11:35, the group traversed to their right along a bench. The guide and first guest had traversed the bench when an avalanche from above caught the last three guests in an area of scattered trees and carried them over the bench onto a 30 to 35° slope.

The guide called the assistant guide down to help with the rescue. Of the three guests caught in the deposit, one—later determined to be the middle one—was only partly buried and able to dig himself out. He noticed a hand sticking through the deposit about 50 metres below him. He helped the guide dig out this person, who was a physician and not injured. The assistant guide arrived soon after and started a transceiver search. The lead guide joined the transceiver search and soon pinpointed the signal from the third guest, who was upslope from the other two guests in the deposit. Probing indicated he was about 2m below the surface. Both guides dug and found him lying face down. While still partly buried, snow was cleared from around his helmet, which was removed. No snow was observed in his mouth. Rescue breathing (artificial respiration) was started while digging continued. One of the victim's legs was wrapped around a tree, and his ski was still attached to his boot. The helicopter arrived with oxygen and CPR was started as soon as practical. After 5 to 10 minutes of CPR, the physician pronounced the victim dead. The cause of death was crush asphyxia.

The avalanche was a size 2.5 soft slab that started on a 39° slope at approximately 1850m elevation. The crown was 50 to 100cm deep and 60m wide. The avalanche ran about 200m down the slope. The deposit was about 60m wide and 120m long.

At the fracture line, a snow profile revealed a layer of 3 – 5mm rounding surface hoar crystals 87cm below the surface. This was the failure plane for the avalanche. The upper 33cm was relatively soft (hardness F or 4F) and from 33 to 87cm it was mostly pencil-hard. A compression test yielded a hard result (23 taps) on the surface hoar layer.

A full profile observed 25m above the crown fracture revealed old faceted crystals (but no surface hoar) 81cm below the surface. At this layer, compression tests yielded hard fractures (27 and 21 taps). The rutschblock test did not result in a planar failure (RB 7). The snow height was about 270cm. The investigator reported that avalanches had occurred nearby during the storm.

Figure 9.6. *Birkenhead Peak, 25 January 2002. S - survivor, X – deceased.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	No	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Planar	Sparse trees

Source

- BC Coroners Service
- Rich Prohaska

Comment

Surface hoar layer buried on 19 January was observed in the profile at the crown fracture but not in a detailed profile 25 metres above the crown fracture. This spatial variation of surface hoar and snowpack tests in general limits the interpretation of point observations of the snowpack, including profiles and snowpack tests.

The rescue was very efficient.

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28 January 2002, Backcountry Skiing
Mt Carlyle, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
3	Persistent Slab	Complex

- **Three individuals are caught by an avalanche triggered by the fourth skier on the slope**

On Sunday, 27 January 2002, a group of eight backcountry skiers from the United States flew from Kaslo, BC, to the Mt Carlyle Lodge for a week of self-guided backcountry skiing. The lodge is situated in the Selkirk Mountains north of Kokanee Glacier Provincial Park. The group was familiar with the general area as they had spent two separate weeks skiing from the Flint Hut, which during that time was operated by the same company and located about 2.5km east, on the east side of Mt Carlyle.

After the group had settled in at the lodge, they had a meeting with the owner who was also the lodge custodian, to discuss the past weather and current snow and avalanche conditions. The week prior to their arrival was characterized by a significant storm that brought 40 to 100cm of new snow to the Southern Columbias. At the Mt Carlyle Lodge, the recorded amount of storm snow was 75cm between 21 and 27 January accompanied by strong to extreme westerly winds and a warming trend occurring on 25 and 26 January. The warming temperatures and winds during the storm resulted in the development of dense wind slabs over the colder and weaker snow surface from mid-month. This configuration led to widespread natural and human-triggered avalanche activity. On 24 January, the Canadian Avalanche Association rated the regional avalanche danger for the South Columbias as High at all the elevation bands. On 27 January, snowfall eased and temperatures dropped significantly as an arctic front passed through the area. This entire weather history was discussed during his weather briefing and the custodian explicitly warned the group of the locally persisting high avalanche hazard due to the widespread wind slab formation during the last storm.

Monday 28 January was the first calm and clear day after the storm with temperatures between -8 and -15°C. In the morning the group chose to ski right next to the lodge in an area called Sunny Side, which offers protected ski runs up to 300m long in subalpine terrain. Skiing was excellent due to the new snow and cold temperatures. Shortly before lunch, the group decided to split up. While three skiers decided to climb Mt Carlyle, the five others skied back to the lodge for lunch.

After having lunch, the group of five skied up towards the southeast ridge of a peak locally known as Misty Mountain, located approximately half a kilometre northwest of the lodge and 2km west of Mt Carlyle. When the group reached 2225m, they traversed over the ridge onto the southwest slopes under Misty Mountain. The terrain in this area is characterized by a continuous start zone that feeds into five distinct avalanche paths (*Figure 9.7*). The start zone can be described as a uniform slope above treeline interrupted by a few scattered trees. The slope angle ranges between 32 and 36 degrees, becoming increasingly steeper to the west (left in *Figure 9.7*). A distinct convexity occurs at the top of the tracks, where the slope steepens to approximately 40 degrees. Due to its exposure and shape, the area is susceptible to both cross-loading and scouring by the prevailing westerly winds. The five distinct avalanche tracks are confined by thick subalpine vegetation and much of the ground cover is talus. Smaller trees of regeneration forest encroach on the sides of all the tracks.

After climbing the ridgeline, the group stopped and traversed into a sparsely treed slope. To assess the local conditions, the group dug a snow profile to a depth of approximately 2m and performed a rutschblock test, which gave a score of five on a scale of seven. The group was confident in the test result and concluded that the snowpack was stable enough to continue. They traversed the first open slope, crossed through a narrow group of trees and stopped near the top of the second avalanche track. At this location, they decided to leave their larger packs behind and ski the slopes below them, carrying only basic rescue gear. To minimize their exposure to the existing avalanche hazard, the group took the precaution of skiing only one at a time.

At approximately 14:45, after the first three skiers of the group had skied the top of the slope individually, the fourth skier made about two turns when the entire slope released, fracturing just below the last skier of the group, who was waiting at the top. The release created a size 3.5 avalanche approximately 350m wide, involving most of the southwest facing bowl below Misty Mountain. The thick areas of mature timber on the slope divided the avalanche, funneling it into the five distinct paths. Miraculously, the skier who triggered the avalanche was able to escape, losing only his skis. While the fifth skier was not involved in the avalanche, the three skiers who had gone ahead and were waiting below were unable to get out of the way as the avalanche roared down the mountain.

The two survivors immediately switched their transceivers to receive and started the search for their friends. The search progressed very slowly due to the scale of the avalanche, complexity of the local terrain and the survivors' challenge to search the de-

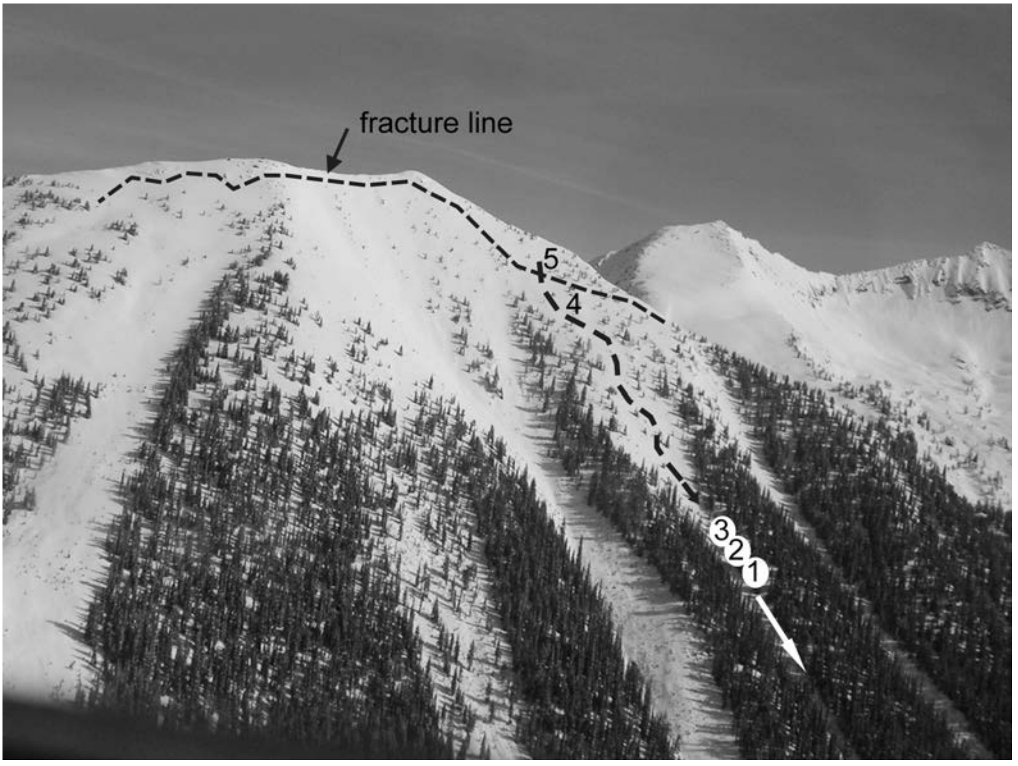

Figure 9.7. *Mt Carlyle, 28 January 2002. Upper slopes of Misty Mountain with broad start zone and five distinct avalanche paths. Numbers indicate approximate location of accident party members when avalanche was triggered. Photo: Mt Carlyle Lodge–Jeff Gfroerer.*

posit without their skiing equipment. It took over two hours before the first victim was uncovered at approximately 17:00, buried in 1.35m of “cement-like” avalanche debris and showing no vital signs when exposed. Since this victim was carrying one of the radios the group brought for the trip, the two survivors were now able to call for help. The call was heard by the custodian at the hut. However, since it was already dark and the two survivors did not see any obvious landmarks they could refer to, there was first some confusion at the lodge about where the accident had happened. After some back and forth over the radio, their location was eventually determined.

The three other skiers, who had returned to the lodge from their trip up Mt Carlyle, wanted to immediately ski to the accident site to assist their friends in the rescue efforts. However, the custodian recommended the two survivors should consider abandoning their rescue efforts, because the likelihood of live recoveries after more than two hours was very low. In addition, they were both at high risk of additional post-release avalanches, exhaustion and hypothermia. Despite the words of caution, the two survivors continued with their search efforts for the two still missing victims. To support their efforts, the custodian and group agreed to have two additional people ski to the accident site with warm tea and extra gear. To minimize the risk of additional victims, they were advised to stay in the mature timber at the edge of the first slide path and only enter the site if absolutely necessary. An extra pair of skis was brought down to the person who lost his during the avalanche to make it easier for him to move around.

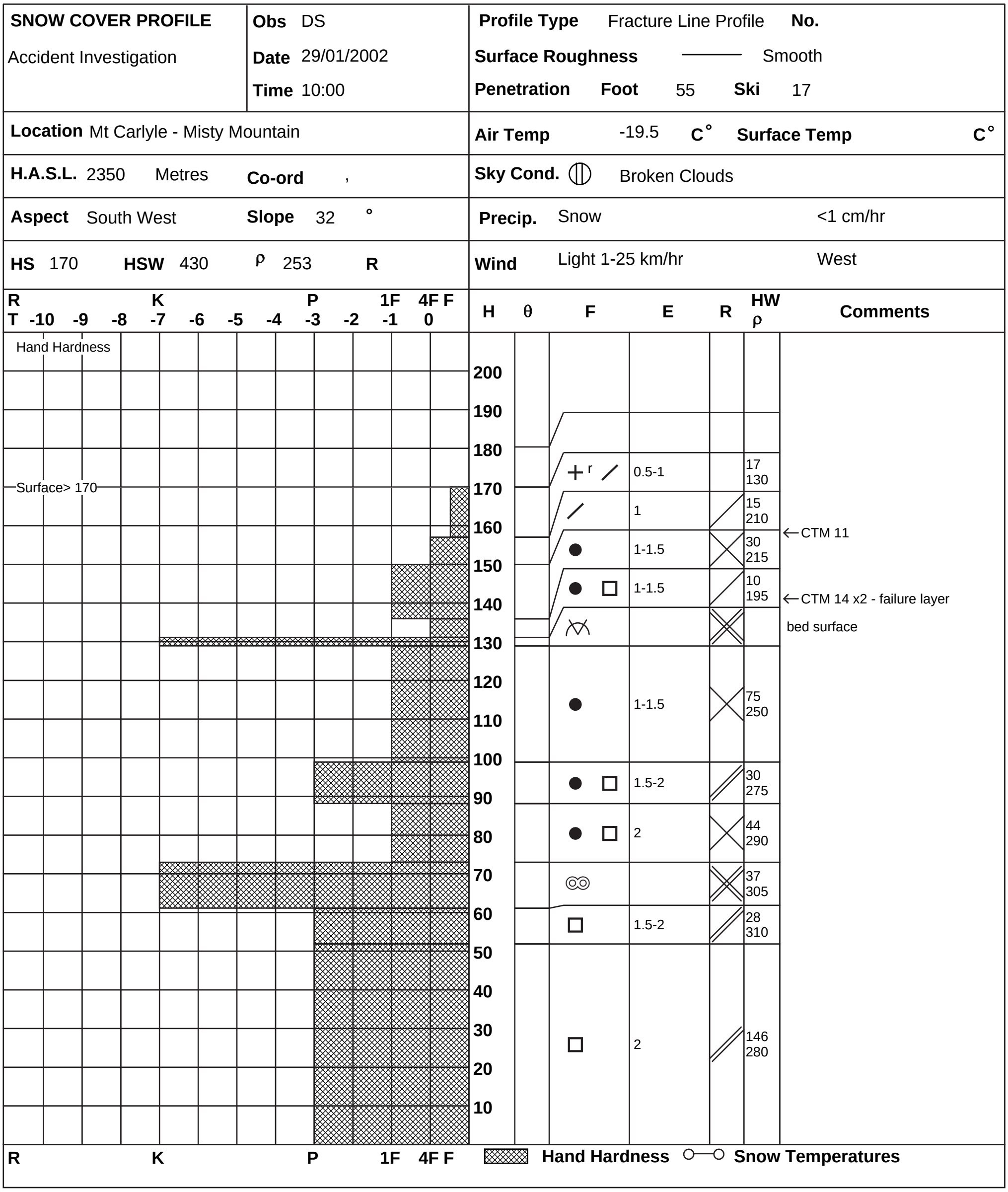

Figure 9.8. *Mt Carlyle, 28 January 2002. Fracture line profile taken during accident investigation on 1 February 2002.*

At the same time, the custodian notified the authorities about the accident and search and rescue personnel were put on stand-by in case of a late live recovery. The search efforts by the two survivors continued into the night and the second and third victims were uncovered in the runout zone at the bottom of the valley by 19:00 and 20:00 respectively. These two victims were buried 10m apart, approximately 100m below the first victim under about 1.5m of avalanche debris. By the time they were uncovered, both victims were deceased. After searching and digging for over five hours the two rescuers joined the rest of the group members waiting at the edge of the slide path and they all climbed back to the lodge arriving by 21:30.

The following morning, the bodies were extracted by the RCMP by helicopter after avalanche technicians from the Ministry of Transportation secured the accident site from further avalanche hazard using explosives.

The subsequent accident investigation revealed that the avalanche released in a layer of faceted snow crystals above the 7 January rain crust. While this rain crust was generally buried under 70 to 100cm of snow in the southern Selkirk Mountains, the fracture line profile (*Figure 9.8*) showed that this weakness was locally only covered by 35 to 40cm of snow at the time of the accident. This can be attributed to the strong westerly winds during the storm period prior to the accident, which must have scoured the starting zones above the accident site. In the more sheltered sections on the lee side of the tree bands, the slab was between 1 and 1.5m thick. The avalanche involved all five paths, but did not run into the thick areas of the mature forested flanks between the individual paths leaving some islands of safety. The avalanche ran full path and the victims were buried at the bottom of the valley in the runout zone of the second path from the east (second from the right on *Figure 9.7*). While one of the victims died of asphyxia, the other victims succumbed to traumatic injuries due to the violence of the avalanche itself or the pressure of the avalanche debris.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Convexity at bottom of starts zone	Open avalanche path

Source

- BC Coroners Service
- Owner and operator of Mt Carlyle Lodge
- CAC avalanche bulletins for South Columbia Mountain
- InfoEx
- RCMP press release

Comment

This accident highlights the challenges that spatial variability of the snowpack can pose to decision makers in avalanche terrain. The prevailing winds of the storm prior to the accident scoured the area, resulting in a much shallower burial of the 7 January rain, making it much more susceptible to human triggering.

Even though the accident party performed a rutschblock test, spatial variability within the snowpack at the slope scale generally makes the extrapolation of test results to adjacent slopes very challenging. Test results from snow profiles are only a small part of the data collection process in avalanche terrain. Stable test results should not be used to justify travelling in riskier terrain than originally planned.

Regrouping spots should be clearly outside of immediate avalanche hazard. While the accident party used the precaution of skiing one at a time, the individuals were still exposed to the existing avalanche hazard.

9 February 2002, Snowmobiling
Eureka Mountain, Cariboo Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Two people highmarking at the same time**
- **High avalanche danger**

On Saturday 9 February, six snowmobilers went riding in an area around Eureka Mountain, about 100km northeast of Williams Lake, BC. They looked at a steep southeast-facing bowl on Eureka Mountain but decided to avoid it because of the avalanche hazard and how far avalanches might run on that slope. They explored lower terrain in the area before lunch.

Two days earlier the Canadian Avalanche Association issued a regular bulletin for the North Columbia Mountains including the Cariboos where the six were snowmobiling. The regional avalanche danger was rated High in the alpine and treeline zones. The bulletin noted: “High variability in conditions, regular natural and human triggered avalanche activity pre-storm, and rapid warming combined with heavy snow in the forecast will lead to a low confidence weekend. Conservative terrain will be a good place to be. Keep a wide margin for error due to the variability.” About 100km to the east and northeast, three heli-ski operations noted that the storm snow was settling and reported only one skier-controlled size 1 slab avalanche.

After lunch the six snowmobilers returned to the bowl on Eureka Mountain. Reportedly, without seeking or discussing any additional information about the snowpack or weather, they started to highmark in the bowl. At about 13:30, two members of the group were parked on a knoll low in the runout zone; two others were stopped nearby. As the other two riders powered up the slope, approached the top and turned left, they triggered a slab avalanche at a convex roll where the snowpack was thin. One rode to the side and out of the avalanche. The other rider was swept down slope and last seen just above a small band of young trees about 20m from the climber’s left side of the avalanche. The main mass of the avalanche did not reach the knoll; however, one snowmobile was knocked over and two riders were dusted. The victim’s snowmobile was visible about 40m in front of the knoll.

The victim did not have a transceiver. The five survivors had one transceiver, one probe and three shovels. They searched near the last seen point and other likely burial sites until 16:00. The snowmobilers rode out to their vehicles and then contacted the RCMP at 17:52.

That evening and night, a rescue team was assembled including members of the local search and rescue team, a BC Government avalanche technician, and an RCMP search dog. When they flew to the site the next morning, the technician assessed the site to be safe. Within five minutes the search dog located the victim's body about 15m upslope from his snowmobile. He was face down and 40 to 60cm below the surface of the deposit. He had asphyxiated due to snow blocking his airway.

The crown fracture of the dry slab avalanche was at 2080m at a convexity near the top of a 45° southeast-facing slope. There were sparse trees in the start zone. The crown height averaged 100cm and reached 150cm. The snowpack near the crown varied in depth from 100 to 200cm due to cross-loading from some storms. The avalanche was 220m wide.

After running down an open 20 – 30° track, the avalanche ran out in a smooth runout zone, which included a gully, at 1950m. The deposit was about 220m wide and 200m long. The average depth was estimated to be 1.5m and reached over 3.5m. It was a size 2.5 avalanche.

After the body was recovered, the avalanche technician observed a snow profile near the crown and made shovel tests. The profile showed that the avalanche released in a layer of rounded faceted crystals, 1 – 2mm in size, overlying what was likely the faceted remains of the November rain crust. The shovel tests did not fracture on the failure layer.

A witness reported that, on the day of the accident, snowfall was moderate to heavy with moderate wind from the south. The air temperature was about -5°C.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
45°	Few trees	Convex	Mostly open

Source
- BC Coroners Service
- InfoEx
- Nic Seaton

Comment
There was limited avalanche rescue equipment in the group. Of the six snowmobilers, there was only one transceiver and one probe. With the proper rescue equipment and training, the survival rate for shallow burials is better than 50%.

The knoll likely reduced the impact of the avalanche on the two riders parked on top of it.

10 February 2002, Backcountry Snowboarding Whistler Creek adjacent to Marmot Basin Ski Area Jasper National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Challenging

- **Deep persistent slab triggered from a shallow area**

On the morning of 10 February 2002, a group of three snowboarders went to Marmot Basin with the intention of accessing the backcountry from the Knob Chair. Marmot Basin is located about 12km south of the town of Jasper in Jasper National Park. While one member of the group had approximately 60 days of backcountry experience from the previous winter, the other two were just starting to venture into the backcountry that winter. The group had previously used the ski hill to access the backcountry that season.

Before heading to the ski hill, the group checked the backcountry avalanche forecast of Jasper National Park. The bulletin was published on the previous day at 16:00 and rated the avalanche danger in the area at Considerable in the alpine and at treeline, and Moderate below treeline. The discussion section of the bulletin highlighted three main avalanche concerns: 1) hard wind slabs developing with the moderate to strong winds up high; 2) a reactive surface hoar layer in sheltered areas; and 3) the November rain crust and associated layers of faceted snow crystals in the bottom third of the snowpack. The bulletin further advised that any wind-loaded terrain and big open features should be regarded as suspect.

The morning of 10 February 2002 was characterized by the arrival of a low pressure system in the area. The mean temperature at the Jasper Park Warden station (1020m above sea level) rose from -7°C on the previous day to 2°C. During the day, temperatures at Marmot Basin ranged from -2.1 to -5.5°C with a slight cooling trend. There were snow flurries and moderate winds from the southwest were gusting to strong and extreme speeds at higher elevations.

The group left the ski area by late morning. They were equipped with backcountry safety equipment including beacons, shovels, avalanche probes and two-way radios. After dropping into Marmot Pass, the group did a snow stability test on a northeasterly aspect before descending further into Whistler Creek. After reaching the valley bottom safely, the group put on their snowshoes and went to find a place for lunch. After lunch, they decided there was time for another run. Looking for a suitable slope, the group decided to attempt to ride an avalanche path on the northwest flank of Marmot Mountain. This path is locally known as Ed's Alley. They made their way up the treed shoulder on the climber's left of the intended run (*Figure 9.9*). Since the snowshoes of one party member were less suited to the steeper climbing on rocky terrain, he soon started to drop behind his two partners. Eventually he fell so far behind that his two companions could no longer see him. Sometime between 14:00 and 14:30, the two individuals in the front reached the rocky outcrops at top of the intended ski run (*Figure 9.9*). They called their friend on the two-way radio and told him they would wait for him that to come up and join them. He replied that instead of climbing all the way, he intended to ride down from his present location.

Shortly after this conversation, the two friends at the top saw a slab avalanche release on the slope below them that included their intended descent line. The fracture line of the avalanche was only about 10m below them and reached across the majority of the avalanche path (*Figure 9.9*). They immediately tried to reach their friend on the radio, but there was no response. Right away, they switched their transceivers to search mode and ran down the side of the slide path to the start of the avalanche deposit. They quickly located the victim with their transceivers and pinpointed him with an avalanche probe. The victim was found face down with his snowboard and backpack on at a depth of 1.4m approximately 10 to 15 minutes after the avalanche occurred. At the time they reached his head, he was unresponsive and had no vital signs. CPR was started as soon as the victim was extracted enough to turn him on his back. Despite their efforts, they were unable to restore his pulse or breathing. After approximately 30 minutes, they decided to go for help and one of them started to build an improvised toboggan from the victim's snowboard.

At this point (approx. 14:30-15:00), the accident party heard voices in the valley below. The Whistler Creek valley is a popular ski touring destination and a trip organized by the Alpine Club of Canada (ACC) was in the valley that afternoon. Several members of the ACC trip, including a physician, joined the accident party and assisted them in their rescue efforts. While CPR on the victim had stopped for about 15 minutes prior to their arrival, it was restarted again by the ACC members. At the same time, a smaller group was sent out to call for help. At approximately 15:30, they reached the road and notified Marmot Basin staff about the accident, who alerted the Jasper National Park Warden Service. The two agencies immediately initiated a coordinated rescue response.

At approximately 16:25, CPR was stopped again as there was no sign of life by the victim. Due to the deteriorating weather and failing daylight the group felt they should head back to safety to avoid putting any of the rescuers at danger. At 16:34 two Marmot Basin staff arrived at the scene and CPR was again resumed. At 17:15, Jasper National Park Wardens and a paramedic arrived at the accident scene on foot and by helicopter. In consultation with the medical doctor on scene and a doctor from Seaton Hospital in Jasper on the radio, the paramedic pronounced the victim dead at 17:32. The body of the victim was then transported to the Marmot Ski Hill parking area by helicopter, and transferred to an ambulance at 18:00.

On the day after the accident, a team of rescue specialists from the Jasper National Park Warden Service conducted a detailed investigation of the accident. The snowpack at the accident site consisted of numerous wind slab layers typical of a cross-loaded slope (*Figure 9.10*). The avalanche was classified as a size 3, between 90 and 200m wide with a fracture line depth ranging from 53 to 173cm with an estimated average of 1m. The start zone of the avalanche faced west with an incline between 33 to 45 degrees. The avalanche debris consisted of large snow blocks that settled in three distinct bands with deposit depth of over 3m. The avalanche deposit also included some small (less than 30cm in diameter) broken timber. The victim was buried on the left side of the deposit below a narrow gully approximately 150m from the toe of the deposit (*Figure 9.9*).

In the opinion of the investigation team, the avalanche was triggered by the victim when he entered the open slope with the intent to ride it down. The trigger location was a shallow part of the snowpack in a narrow wind-loaded gully feature adjacent to the party's up track on the treed shoulder. The failure occurred at one of two locations within the snowpack: either in the layer adjacent to the November rain crust or in the layer adjacent to the ground. These layers exhibited moderate and easy shears in compression tests in two fracture line profiles (*Figure 9.10*). The rain crust developed in mid-November

Figure 9.9. *Whistler Creek, 10 February 2002. Overview of accident site. 1, 2 indicates location of survivors. The location of victim, 3, is unknown when avalanche was triggered. X – burial location of deceased.*

during a warm period when a rain event resulted in wet surface snow to mountain tops. The subsequent temperature drop and the sporadic snowfalls in the second half of the month resulted in the development of the adjacent layers of faceted crystals. The initial failure propagated up the slope for about 45 to 75 metres to where the fracture line of the avalanche was located (*Figure 9.9*).

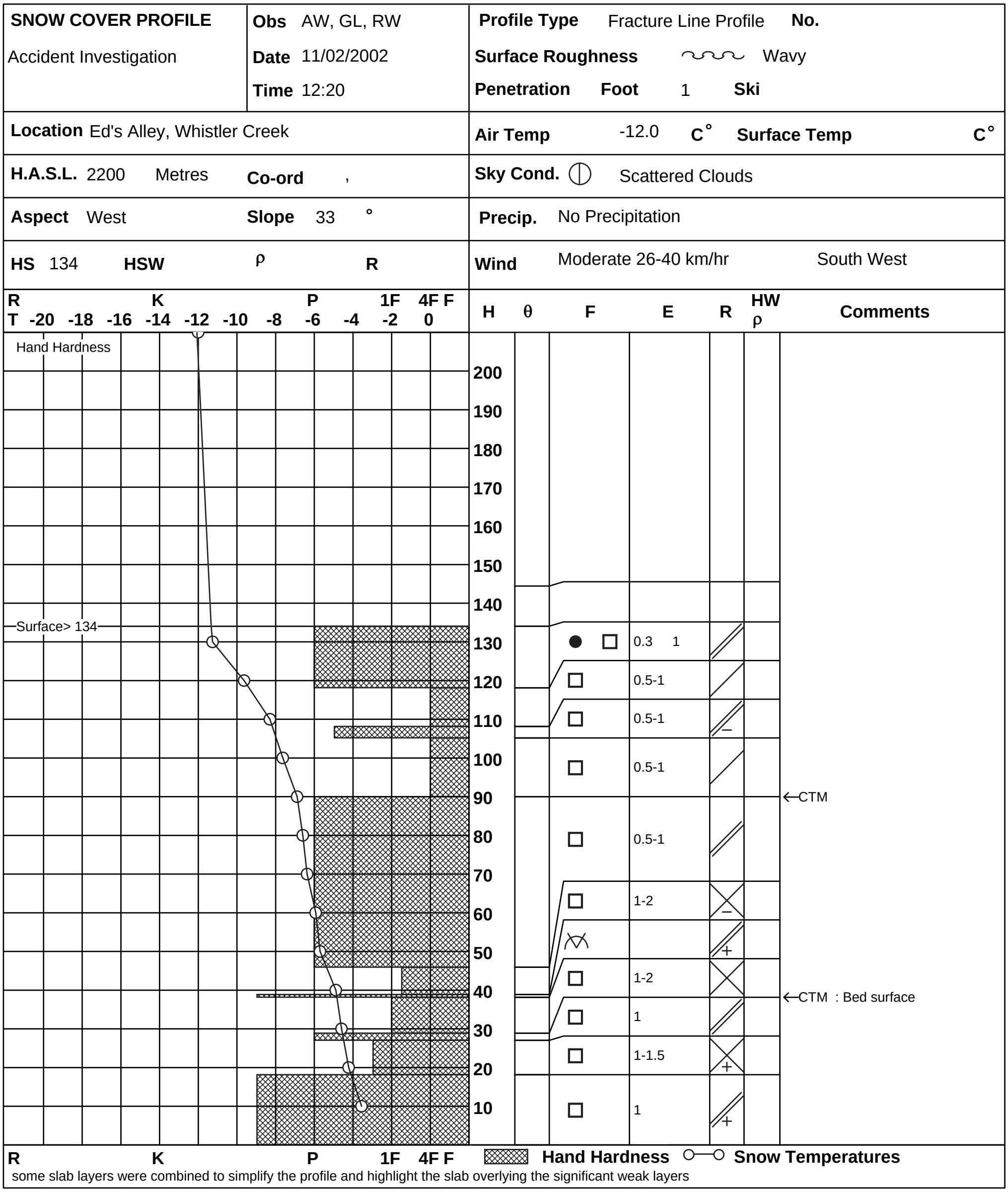

Figure 9.10. *Whistler Creek, 10 February 2002. Fracture line profile taken during accident investigation on 11 February 2002.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Gully feature, small trees	Concave	Open slope

Source

- Parks Canada
- Environment Canada National Climate Data and Information Archive for Jasper Warden Station
- InfoEx

Comment

Shallow snowpack areas such as the Rocky Mountains generally exhibit large spatial variability. While snow profiles can help to develop a better understanding of the snowpack—particularly the development of persistent instabilities—using this information to assess snow stability and extrapolate to other terrain is a complex subject requiring significant training and experience. It is recommended to always combine the information from a snow profile with all other available information and be aware of the limitations of snow profiles. Snow profile test results should not be used to justify more aggressive terrain choices.

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10 February 2002, Heli-skiing
Mt La Forme, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	Complex

On 10 February 2002, three groups of skiers were heli-skiing in the area of Mt La Forme, about 25 kilometres northeast of Revelstoke, BC. Clear weather ending on 2 January had resulted in a layer of surface hoar. The size of the crystals was quite variable and generally largest around treeline, approximately 1900m. This layer was especially variable in the alpine zone because of wind and sun effects. In this area of the Selkirk Mountains, the surface hoar layer was about 65cm below the snow surface at treeline by 9 January.

At the Mt Fidelity weather station, elevation 1900m and 22km east of Mt La Forme, 29cm of snow fell on the evening of 5 February to the morning of 7 February. After the storm ended on 7 February, avalanching decreased rapidly. By 9 February, no significant avalanches were being observed. The air temperature on 8 and 9 January was between -10 and -5°C.

On 7 February, the forecasters at the Canadian Avalanche Association published a bulletin for the next four days. It rated the avalanche danger in the alpine and treeline zones as High in the North Columbia Mountains. The bulletin also noted: "Following Tuesday's wind event, natural activity started to occur on lee slopes. By Wednesday, failures into the January 2nd layer down about 80cm were common. With rapid warming and more snow in the forecast, this will become more widespread. ... High variability in conditions, regular natural and human triggered avalanche activity pre-storm, and rapid warming combined with heavy snow in the forecast will lead to a low confidence weekend. Conservative terrain will be a good place to be. Keep a wide margin for error due to the variability. ... The weather forecast calls for significant snow and very warm temperatures to begin Saturday and last through the weekend."

After lunch the groups of heli-skiers moved to a run on the southeast slope of Mt La Forme. The first group, which consisted of 10 guests, a lead guide and a tail guide, landed at about 2450m on the shoulder of Mt La Forme. The lead guide instructed the guests to ski 50m apart, then skied the upper pitch and stopped off to the east side of the run on a small ridge. As the skiers regrouped with the guide, the tenth guest and the tail guide stopped in a small gully on the edge of the run beside the small ridge.

The guide reminded the skiers to stay 50 metres apart and skied down the next section, staying to the skier's left. The guests started to follow. By this time the second group had landed on top of the run. The guide from the second group instructed his group to ski within the tracks from the first group. They skied the uppermost moderate slope and then regrouped above the upper pitch. At 13:12, as the guide from the second group moved forward to look at his line, the slab under his skis fractured. He began to slide down the slope with most of the avalanche moving ahead of him.

Approaching the landing with the third group, the helicopter pilot saw the avalanche and called "Avalanche" on the radio. The guide from the first group was on a bench near the bottom of the run, called "Avalanche" to his guests, and headed for a small ridge while trying to watch them. He could see only the first and second guests, who were farthest down the slope. He lost sight of them as the powder cloud swept down the slope.

The last of the guests from the first group that were at or just leaving the regrouping site at the bottom of the upper pitch saw the avalanche rush by them but were not caught. The tenth guest and the tail guide who had stopped in the small gully were swept down the slope.

When the avalanche motion stopped, the second guest, tenth guest and tail guide were fully buried. The first guest was buried up his chest, and signaled to the lead guide that he was ok.

The lead guide started a transceiver search and almost immediately picked up a signal originating upslope from the partly buried guest. One of the guests from the regrouping site arrived, assembled the avalanche probe from the guide's pack, and began to probe where the guide had pin-pointed the signal. (This signal was from the tail guide.)

The two guides from the second and third groups arrived to assist in the search. The lead guide homed in on another signal (from the tenth guest), and marked the location. As the lead guide continued the search, another skier from the first group arrived and started to help with the transceiver search. This guest located the remaining signal (from the second guest). They began to dig as more skiers and guides arrived. At 13:24, the second guest was uncovered; he did not have a pulse so CPR was started. At 13:46, the tenth skier—

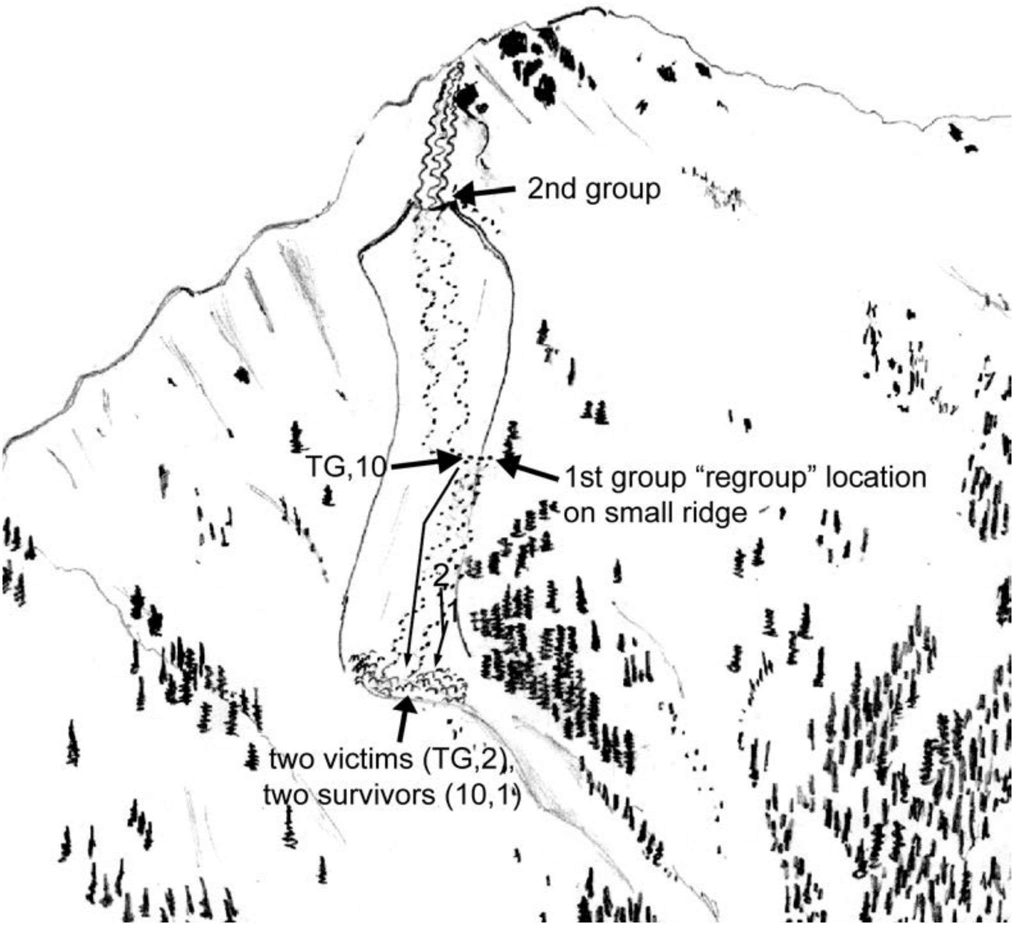

Figure 9.11. *Mt La Forme, 10 February 2002. The first (1) and tenth skier (10) survived. The tail guide (TG) and second guest (2) did not survive.*

who had used a device to facilitate breathing while buried—was uncovered. Though initially unconscious, he soon regained consciousness. The tail guide was buried the deepest and partly uncovered at 13:56. CPR was started when he was still partly buried, and continued on the helicopter flight to the hospital in Revelstoke, BC. The second guest and tail guide had asphyxiated.

The dry slab avalanche released at a convexity at elevation 2255m, where the terrain steepens from 30 – 35° to 35 – 38°. The crown fracture was about 250m wide. The minimum, average and maximum crown heights were 30, 100 and 150cm. Although much of the snowpack at the fracture line was over 300cm in depth, the eastern end extended to a rocky rib where the snow was thinned by cross winds, and weaker. Just below the fracture line, two areas of rock were exposed in the bed surface and surrounded by weak faceted snow.

The tail guide and tenth guest were carried down approximately 210 vertical metres to the bench at 1980m. The first two guests were carried a shorter distance down to the bench. The deposit on the bench was 96m wide, up to 3m in depth, and much of it was inclined at about 20°. Part of the avalanche spilled over the bench and ran down a gully to about 1800m elevation.

Profiles at and above the fracture line revealed a 1 cm-thick layer of surface hoar and faceted crystals, 1-2mm in size. This layer was buried on 2 January and was the failure layer for the fatal avalanche. Stability tests yielded hard or very hard results at the surface hoar layer. A rutschblock test failed at step 6, in a layer 50 centimetres below the surface and did not fail at the surface hoar layer (RB 7).

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Convex near crown fracture	Open slope

Source

- BC Coroners Service

Comment

The skiers on the small ridge at the regrouping site were not caught in the avalanche. The lead guide escaped the avalanche by getting to another small ridge. Although avalanches can overrun small ridges and bumps, such terrain features—sometimes called “islands of safety”—can help people avoid avalanches.

The snowpack tests done during the investigation at areas of average snowpack did not indicate that the surface hoar layer was likely to be triggered by single skiers. The avalanche may have been triggered from an area where the snowpack was thinner and weaker than average.

The slope had been cross-loaded by a recent storm, resulting in areas of thick and thin snowpack. At the time of the avalanche, the last of the skiers from the second group had arrived at the regrouping site above the upper pitch. The trigger point is unknown.

The rescue, involving guides and guests, was very efficient.

The tenth skier, who survived a deep burial, had placed the mouthpiece of a breathing aid in his mouth when he saw the avalanche approach. There is a detailed description of this event in “An AvaLung-associated avalanche survival” (Crowley et al., 2002) in the Proceedings of the 2002 International Snow Science Workshop.

18 March 2002, Out-of-Bounds Skiing Mt Hughes, outside of Kicking Horse Mountain Resort, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Cornice and Persistent Slab	Complex

- **Cornice triggers dormant persistent weak layer**
- **High consequence location**
- **Trauma fatality**

The weather in mid-March of 2002 was characterized by two significant cold snaps, between which a powerful storm deposited significant amounts of new snow. On 15 March, a local heli-skiing operation reported just over half a metre of recent storm snow in the Purcell Mountains. The snow was deposited with moderate westerly winds, which lead to the development of widespread wind slabs in the alpine. On 16 March, the discussion in the public avalanche bulletin of the Canadian Avalanche Association for the South Columbia Mountains focused primarily on instabilities in the upper half of the snowpack, including the new wind slabs, a layer of faceted snow at the bottom of the most recent storm snow, and the mid-February surface hoar layer, which was still subject to human triggering in some areas. The avalanche danger was rated as Considerable in the alpine and Moderate at treeline and below. On the weekend of 16 and 17 March, an arctic front passed over the area, which resulted in a significant temperature drop and more localized snow showers.

In the morning of Monday 18 March, a father, his two sons and a friend arrived at Kicking Horse Mountain Resort to do some out-of-bounds skiing. Their plan was to use the lifts to get to the top of the ski hill and then cross the ski area boundary to the north. The northern part of the Dogtooth Range is a popular destination among out-of-bounds skiers and snowboarders and consists of several large east-facing bowls, separated by striking ridgelines. The three younger individuals in the group were somewhat familiar with this area and wanted to show the father around. Weather observations from backcountry operations skiing in the Purcell Mountains on that day show the temperature in the alpine was between -15 and -25°C, with light snowfall and light to moderate winds from west to southwest.

The group intended to travel to Mt Hughes, which is at the northeastern end of Repeater Ridge and the most northern peak in the Dogtooth Range with a direct path back to the base of the ski resort. From the peak, they would descend the northeast bowl (*Figure 9.12*), which is characterized by steep open slopes (approximately 40 degrees) and a distinct convexity with a cliff band mid-slope on the skier's right. The bowl was generally in the lee of the prevailing winds and the ridgelines surrounding the bowl were heavily corniced.

Once the group arrived at the top of Mt Hughes (far top left in *Figure 9.12*), they discussed how to best descend through the very steep terrain. While the three young group members had some basic avalanche awareness training, the father had no formal avalanche training. They decided that one of the sons should first ski down to the flat section at the bottom of the bowl, where he could see the entire face. From there, he would provide the others with instructions by radio on how to best navigate the steep and cliffy part of the slope. The first skier took a more conservative line, along the ridgeline to the north to a saddle (centre in *Figure 9.12*). There he entered the bowl by jumping off a 1.5m section of the cornice, and skiing fall line on the skier's left of the main slope to the bottom of the bowl (right in *Figure 9.12*). Once he was set up in the flat section at the bottom of the bowl, the second person, a snowboarder, started his descent. He took a more aggressive line and rode from the very top of the ridge of Mt Hughes on the skier's right of the bowl, straight through the main rock band (left in *Figure 9.12*) and joined up with the first skier at the bottom of the bowl.

Before the father started his run, his second son, who was waiting with him at the top, advised him that it might not be a good idea to cut across the slope near the rock band. While the father first followed the descent line of the snowboarder, he then traversed to the skier's left across the slope to the top of the main cliff band. At this point he disappeared from his son's view. To keep his father in sight, the son started to slowly ski along the ridgeline to the north. Visibility was quite poor and as he approached the cornice further down, he suddenly fell into a large cavity that had developed behind the cornice, due to the mass of the cornice slowly creeping away from the ridge. Once he managed to climb back out of the hole, he realized that part of the cornice had fallen off and triggered an avalanche on the slope below. He immediately radioed his brother at the bottom of the bowl to ask whether he could still see their father on the slope, but the response was negative. The father was in fact hit by the small avalanche triggered by the cornice failure and carried through the cliff band. This small avalanche had enough mass to then cause the entire slope below the cliff band to avalanche as well.

While the two group members waiting below immediately started to search the avalanche deposit from the bottom, the second son skied down the skier's left side of the bed surface with his avalanche transceiver in search mode. He quickly found a signal and identified the general burial area of the victim. After pinpointing the exact location using avalanche probes, the two sons started to dig out the victim, who had sustained serious injuries from his fall through the cliff band and did not show any vital signs when uncovered. Due to the severe trauma to the face and head, the group had great difficulty in maintaining an open airway and performing artificial respiration. While one of the sons remained with the father at the accident site, the other two made their way back to the ski resort where they notified the authorities of the accident. A recovery team consisting of members from the local search and rescue team and staff from Kicking Horse Mountain Resort was flown to the accident site by helicopter. Although the victim was found in less than 15 minutes, he died from the extensive trauma sustained while being swept through the cliff band. The body of the victim was then transported off the mountain and taken to the hospital in Vernon for further examination.

The accident investigation, which was conducted the following day, confirmed that the avalanche was triggered by the cornice that fell onto the 39 degrees steep slope above the cliff band. The cornice was approximately 4.5m high, 9m long and 3m wide. The cornice had enough mass to trigger the 2 January surface hoar layer, a persistent weak layer that was seemingly dormant at the time. The fracture line profile (*Figure 9.13*) showed surface hoar crystals up to 5mm in size together with faceted crystals (0.5mm) as the weak layer over a knife-hard bed surface. The fracture depth of the size 3 avalanche was between 65 and 145cm. While the avalanche was approximately 90m wide at the top, it was 200m wide further down slope and involved numerous additional crowns with the 17 February sur-

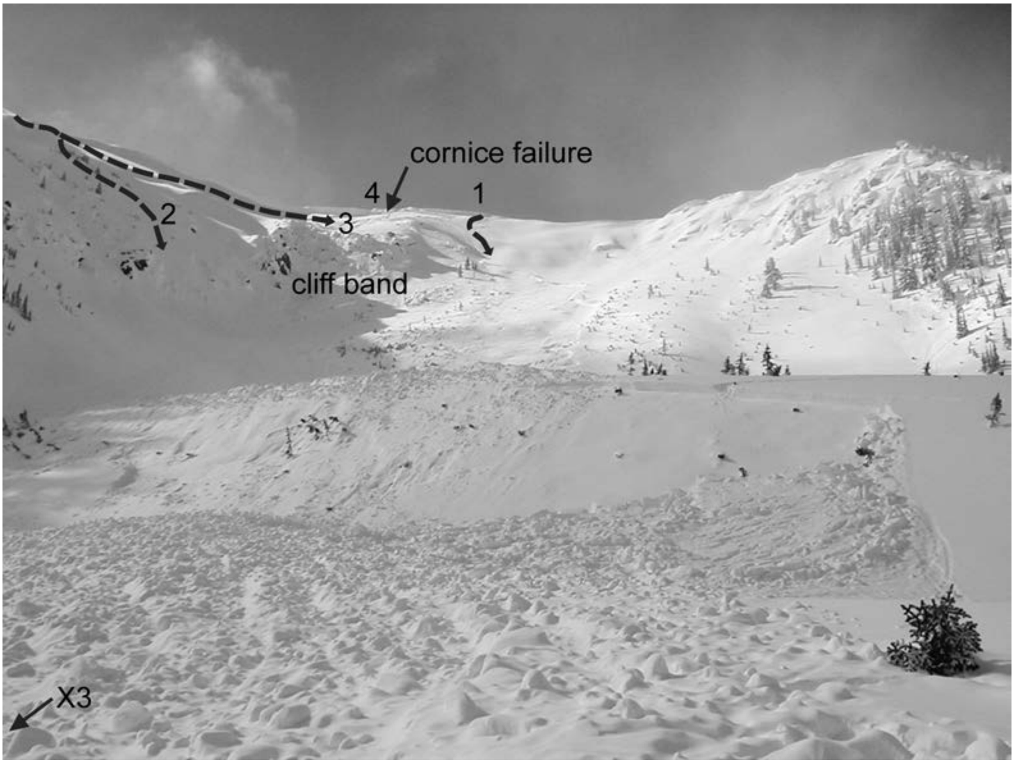

Figure 9.12. *Mt Hughes, 18 March 2002. Overview of accident site from below. 1) Approximate entry point into the bowl by skier 1; 2) Approximate start of the riding line of snowboarder 2; 3) Approximate location of skier 3 when avalanche was triggered by cornice fall; 4) Approximate location where skier 4 fell into cavity behind creeping cornice. Photo: Kyle Hale.*

face hoar as the failure layer. The avalanche ran for approximately 800m, about 90% of its full path. The victim was approximately 100m below the trigger point when the avalanche started. He was then swept through the cliff band and carried for approximately 200m before being buried under 1.5m of snow.

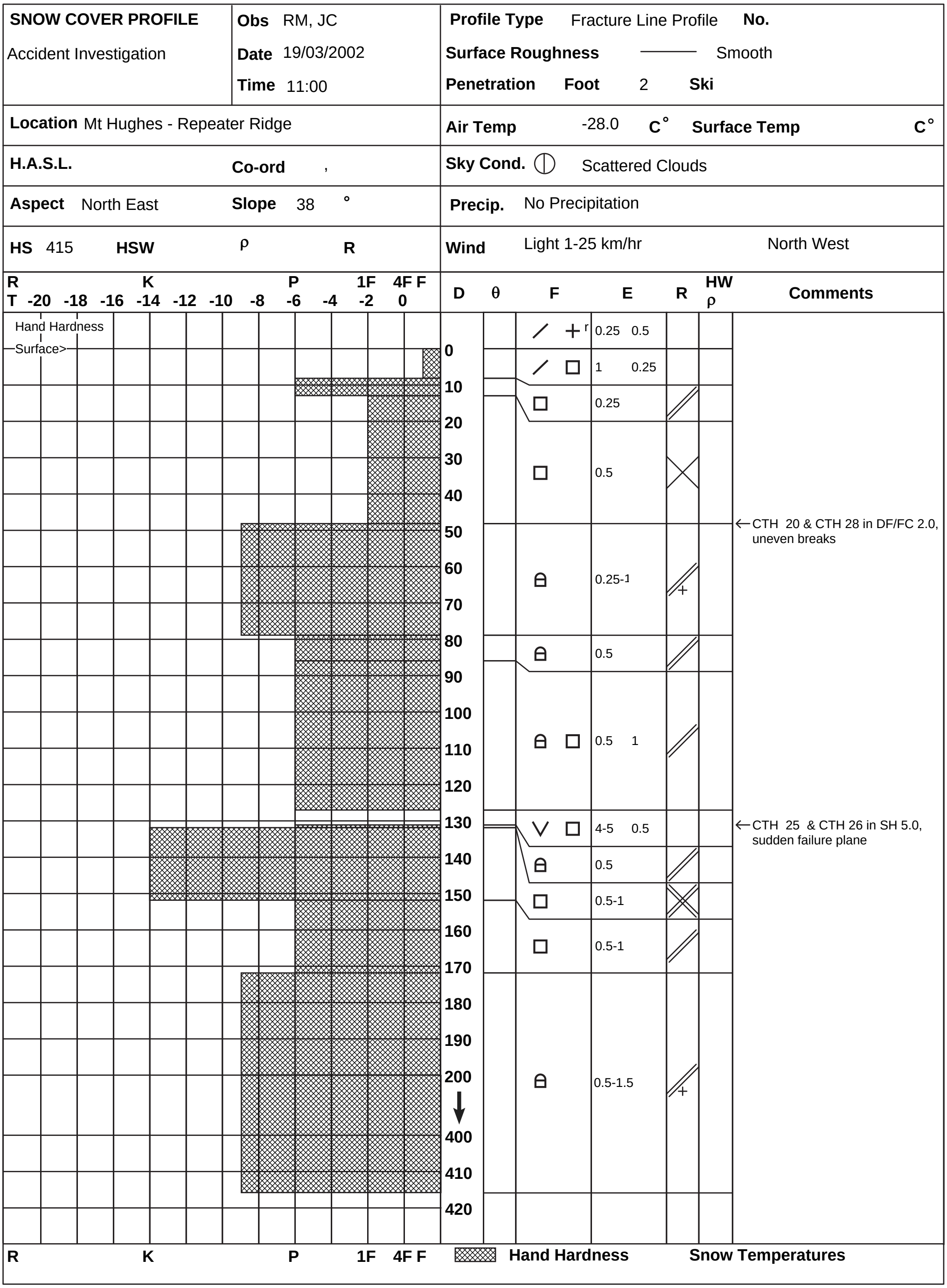

Figure 9.13. *Mt Hughes, 18 March 2002. Fracture line profile taken during accident investigation on 19 March 2002.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
39°	Cliff band	Convex and unsupported	Open alpine slope

Source

- BC Coroners Service
- Kyle Hale
- Mike Rubenstein
- Canadian Avalanche Association—avalanche bulletins for South and North Columbia Mountains
- InfoEx

Comment

Cornices are large triggers with potential to trigger persistent weaknesses deeper in the snowpack, which may not have responded to lighter triggers for a while. When travelling in areas exposed to cornices, it is crucial to always consider the potential failure of older persistent weaknesses and to make very conservative terrain choices.

In Canada, approximately one quarter of avalanche victims died of trauma regardless of how quickly they are uncovered by their partners.

14 April 2002, Out-of-bounds Skiing and Snowboarding South Chutes, Outside of Fortress Mountain Ski Area Kananaskis Country, Rocky Mountains

Deaths	Avalanche Problem	Terrain
2	Cornice or Wind Slab	Challenging

- **Natural avalanche from above**
- **Accident location in close vicinity to ski area**
- **No avalanche safety gear carried by victims**
- **One trauma fatality, partially buried**

After a week of nice spring weather with above-freezing temperatures in the southern Rocky Mountains, the weekend of 13 and 14 April was characterized by the arrival of a cold front that brought between 10 and 25cm of new snow to higher elevations, accompanied by strong westerly winds. This led to the formation of new, sensitive wind slabs and large cornices on lee slopes and in protected terrain features. At lower elevations, rain soaked much of the snowpack creating isothermal wet avalanche conditions.

On 13 April, the safety specialists of Kananaskis Country observed numerous natural avalanche releases on easterly aspects. The backcountry avalanche information report published by Kananaskis Country on 12 April rated avalanche hazard in the area as Moderate at all elevations, but warned that “rapid increases in avalanche danger to High should be expected as daytime temperatures climb above freezing and the snowpack gains heat and weakens.”

The weather at Fortress Mountain Ski Resort on Sunday, 14 April, was described as ”blizzard-like conditions” with mixed rain and snow, strong southwesterly winds with blowing snow and limited visibility. At approximately 11:20, a ski patroller spotted an avalanche as it began on a ridge called “The Hourglass” above the southwestern border of the resort. The Hourglass is part of a popular out-of-bounds area known as the South Chutes and at the time, there were two separate groups visible in that area. A group of five skiers and snowboarders had constructed a kicker about mid-way down the avalanche path and were videotaping each other doing jumps. The second group of three had just entered the slope above the other group and was crossing the avalanche path. The initial avalanche, which was either triggered by a cornice failure or wind loading, released near the top of the slope well above both parties. The small slide triggered a larger, size 3 slab avalanche approximately 40cm deep and 60m wide with a few side pockets pulling out as well. The suspected bed surface of the avalanche was a melt-freeze crust that had developed on exposed solar aspects on 2 April.

Both groups became aware of the avalanche but were unable to get out of the way in time. The avalanche ran full path and involved all members of the two groups, all in their late teens or early twenties. Since the avalanche was directly witnessed by a ski patroller, a comprehensive rescue was initiated immediately. While Fortress Ski Patrol put all resources into the rescue efforts on site, public safety specialists of Kananaskis Country organized additional rescue resources in collaboration with the Banff Warden Service and Alpine Helicopters in Canmore. At 12:00, a helicopter with sling-rescue capabilities departed from Canmore in marginal flying conditions due to the heavy snow and rain, with a public safety specialist from Kananaskis Country, and a public safety specialist and an avalanche rescue dog team from Parks Canada.

Zero visibility in extremely heavy snow almost forced the helicopter pilot to abort the mission, but after a brief flight over the accident site to assess the overall situation, the helicopter landed at the rescue staging area at 12:20. At this time, the local rescue efforts were in full swing with 20 to 30 individuals including ski patrol members, Kananaskis conservation officers, EMS personnel and additional volunteers from the public. Due to the significant residual avalanche risk to the rescuers from above, a conservation officer and a ski patroller were assigned lookout duties near the top of the slope to warn of possible additional avalanches.

The deposit of the avalanche was approximately 300m long and had an average depth of 1.5m. Of the eight individuals involved in the avalanche, none were carrying any avalanche safety gear. One person had been caught at the edge of the avalanche and was not buried at all, six were only partially buried and one person was missing. Due to the proximity of the accident site to the ski resort, there was a high possibility that others may have also been on the slope at the time of the accident, making the total number of individuals involved in the accident not completely clear at that moment.

At 12:25, paramedics on scene reported that one of the partially buried victims, found in trees near the toe of the avalanche, had succumbed to his injuries. At the same time, a second victim with injuries was brought to the patrol hut where she was prepared for a helicopter transport to the hospital in Calgary. However, due to the poor weather, the helicopter was unable to leave before 13:30. While the other five partially buried individuals did not sustain any injuries, the missing member of the first group was still not accounted for. As other day-skiers from the hill continued to come to the incident command post to report potentially missing family members and friends, there was still not complete clarity about the total number of involved individuals.

Due to concerns for potential residual avalanche danger and to create better working conditions for the avalanche rescue dog, all searchers were removed from the accident site except the dog handler and the public safety specialist from Banff National Park, who continued the search. At 13:40 the missing victim was located by the avalanche rescue dog. The victim was found head down with his head approximately 70cm below the surface and had died of asphyxia. It was soon confirmed that this victim was the last person of the original two groups on the slope. The search was continued for other potential victims, but there were no further hits by the avalanche rescue dog.

As soon as it was determined no others were missing, search efforts were stopped. The bodies of the two victims were evacuated from the accident site and all searchers were accounted for by 14:30. The rescue efforts were completed with a final sweep of the avalanche path by the two lookout posts.

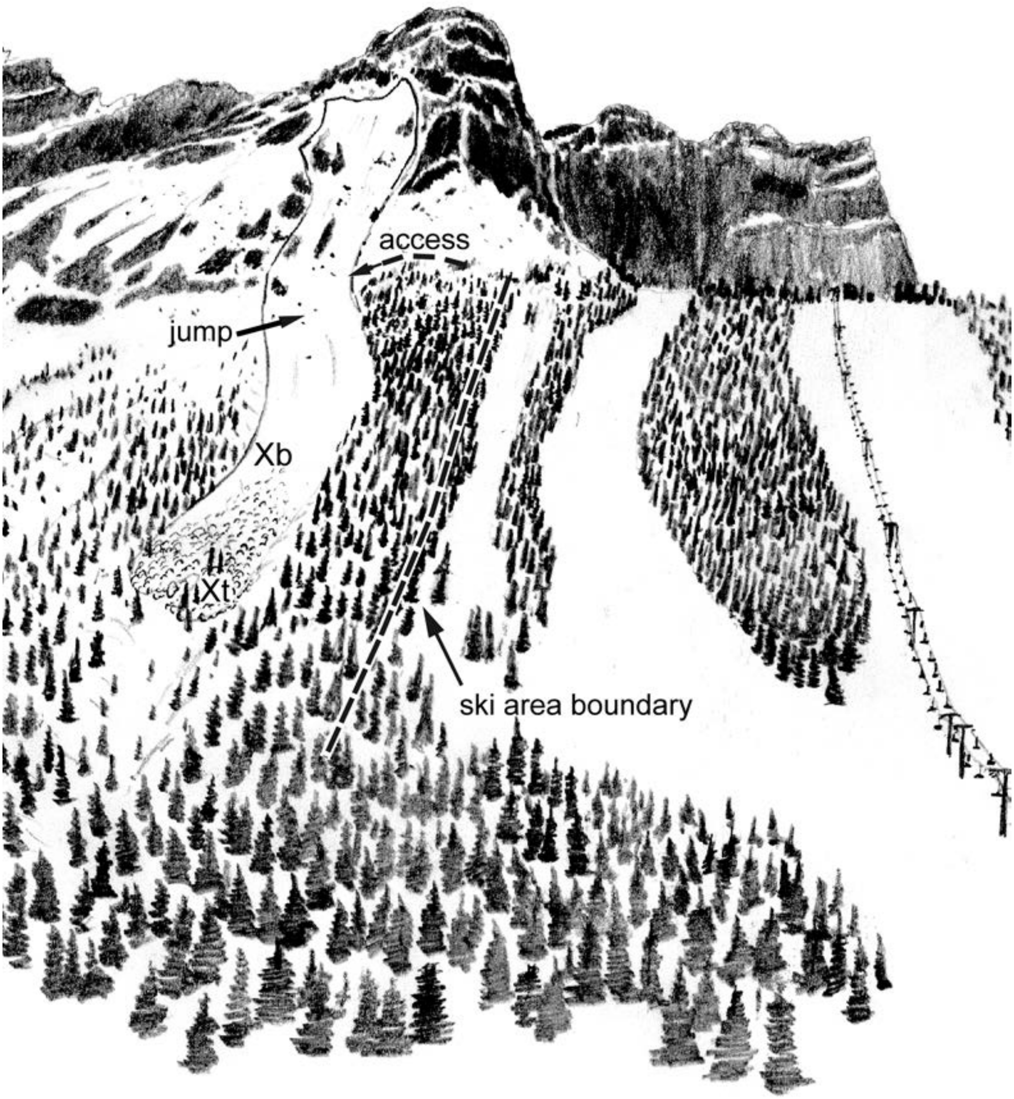

Figure 9.14. *Fortress Mountain, 14 April 2002. Overview of accident site with access from ski area. Xb – deceased (asphyxia, complete burial), Xt – deceased (trauma, partial burial).*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate (High)	No	Yes	?	10-25cm of HN with high winds rain at low elev	Wet snowpack in lower parts of the path

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees in runout	Concave	Open avalance path

Source

- InfoEx
- Kananaskis Country Backcountry Avalanche Information Report
- Banff-Yoho-Kootenay Avalanche Bulletin
- Burke Duncan
- Brad White

Comment

The proximity to secured ski runs, rescue services and other people can provide a false sense of security when venturing out-of-bounds. It is easy to become complacent, especially in commonly used areas. Regardless of the location, travelling in avalanche terrain requires a detailed assessment of the existing hazards.

When assessing avalanche risk, it is important to also include the slopes immediately above or adjacent to the location in question. Even in flat areas where triggering an avalanche is unlikely, one can be exposed to hazard from above.

None of the victims was carrying any avalanche safety gear. Even though the groups were in the immediate vicinity of the ski hill, they were in uncontrolled avalanche terrain. The use of avalanche transceivers would have likely resulted in a much quicker extrication of the second victim.

Chapter 10

Avalanche Accidents of Southwestern Canada **2002-2003**

Winter Summary for Southwestern Canada

- **29 avalanche fatalities in 13 accidents in southwestern Canada**
- **Below average and record low snowpacks until mid-March**
- **Large snow accumulations in spring**
- **November rain crust and weak layer involved in nine accidents and 23 fatalities, with many accidents in March and April**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
28 Dec 2002	Allan Creek	Cariboos Mountains	Snowmobiling	1	Deep Peristent Slab	24 Nov 2002	233
5 Jan 2003	Squaw Headwall	Monashees Mountains	Out-of-Bounds Skiing	1	Persistent Slab	25 Dec 2002	235
20 Jan 2003	Tumbledown Mountain	Selkirk Mountains	Backcountry Skiing	7	Deep Peristent Slab	24 Nov 2002	238
1 Feb 2003	Connaught Creek	Selkirik Mountains	Backcountry Skiing	7	Deep Peristent Slab	24 Nov 2002	243
13 Mar 2003	Lady Macdonald	Rocky Mountains	Hiking	1	?		249
14 Mar 2003	Lake Agnes	Rocky Mountains	Snowshoeing	1	Deep Peristent Slab	24 Nov 2002	250
17 Mar 2003	Kokanee Glacier Provincial Park	Selkirik Mountains	Backcountry Skiing	2	Persistent Slab	15 Feb 2003	253
20 Mar 2003	Ram Range	Rocky Mountains	Snowmobiling	1	Deep Peristent Slab	24 Nov 2002 [2]	257
26 Mar 2003	Fairy Creek	South Rocky Mountains	Snowmobiling	3	Deep Peristent Slab	24 Nov 2002	260
26 Mar 2003	Mt Terry Fox	Rocky Mountains	Heli-Skiing	1	Deep Peristent Slab	24 Nov 2002[2]	262
27 Mar 2003	Mt Brewer	Purcell Mountains	Snowmobiling	1	Deep Peristent Slab	24 Nov 2002	264
6 Apr 2003	Holt Creek	Purcell Mountains	Snowmobiling	1	Deep Peristent Slab	24 Nov 2002[2]	268
18 Apr 2003	Mt Ptolemy	Rocky Mountains	Snowmobiling	1	?		270

[1] *It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.*
[2] *Suspected*

Snowfall in October of 2002 was generally sparse in the Columbia and Rocky Mountains, leading to record low snowpack heights at Mt Fidelity (1874m) and Lake Louise (1524m). Winter storms began to influence the Columbia Mountains in early November, and by 19 November 2002 the snowpack at Mt Fidelity had reached its average value of about 120cm. The snowpack in the Rockies remained low throughout this period, but average values were observed at Lake Louise by the third week of November.

The tail end of this stormy period was warm and wet—rain began at Mt Fidelity on 20 November, and the temperatures stayed above freezing until the 23rd. This was a major rain event affecting all of southwestern Canada. There was little snow on the ground in the Coast Mountains, but in the Columbia and Rocky Mountains, rain fell to mountaintop elevations, soaking the snowpack at high elevations and melting it below treeline.

By 24 November clear skies and cold air returned to the Columbia and Rocky Mountains, while the Coast Mountains remained under the influence of warm air. The strong ridge of high pressure lasted for almost two weeks and by the time it broke down, all of the ranges in southwest Canada were reporting record low snowpack heights. The cold temperatures in the interior had two impacts: they resulted in the freezing of the rain-soaked snowpack at treeline and alpine elevations, and they led to the growth of surface hoar and faceted crystals on top of the smooth, hard crust. This set the stage for a snowpack weakness that persisted all season in the Columbia and Rocky Mountains. Avalanches sliding on this November rain crust and facet/surface hoar layer were involved in accidents throughout the winter and spring: **Allan Creek on 28 December** (page 233), **Tumbledown Mountain on 20 January** (page 238), **Connaught Creek on 1 February** (page 243), **Lake Agnes on 14 March** (page 250), **Ram Range on 20 March** (page 257), **Fairy Creek and Mt Terry Fox on 26 March** (page 260 and 262), **Mt Brewer on 27 March** (page 264), and **Holt Creek on 6 April** (page 268).

Around 10 December stormy weather returned to the Coast and Columbia Mountains, with some rain falling on the coast. By the third week of December the snowpack on the coast returned to normal height, but the addition of only 90cm of precipitation at Mt Fidelity could not bring the snowpack up to average levels. Neither were the Rockies seeing much of this precipitation, and Lake Louise still had a record low snowpack in the third week of December.

A short-lived ridge of high pressure, slightly below-average temperatures, and clear skies affected all ranges. In the Columbia Mountains new surface hoar began growing. Around 24 December, another Pacific storm arrived on the coast, bringing heavy snowfalls, rising temperatures, and strong winds. Very heavy snowfall in the Coast Mountains brought the snowpack to above average levels at Whistler Roundhouse. The new snow buried another surface hoar layer in the Columbia Mountains around 25 December, and avalanches began to release on it as a slab built up. The storm snow also overloaded the November crust, and an avalanche in **Allan Creek on 28 December** (page 233) claimed the life of one snowmobiler near Valemount, BC. The Rocky Mountains were receiving small amounts of snow during this time. As the storm tapered off in all ranges and temperatures warmed, rain fell at the Whistler Roundhouse on 5 January. Temperatures were near freezing and the snowpack was settling rapidly when a skier was caught in a fatal avalanche near Rossland BC, at Squaw Headwall outside **Red Mountain resort on 5 January** (page 235). The "Christmas surface hoar" was the failure layer.

A large ridge of high pressure covered most of southwestern Canada between 6 and 11 January. Cold arctic air flooded the valley bottoms in the Columbia Mountains, while warm air remained aloft, leading to inverted temperatures, thick valley fog, and the growth of surface hoar at treeline elevations. The snowpack height at Mt Fidelity remained below average despite the recent snowfalls, while on the coast the Whistler Roundhouse had a near-normal snowpack but above freezing temperatures during this period.

A weak weather system brought about 20cm of snowfall to the Coast and Columbia Mountains between 11 and 15 January, burying another surface hoar layer in many places. Lake Louise was still reporting a record low snowpack. High pressure returned with average temperatures in the Columbia and Rocky Mountains, but above-freezing temperatures at the Whistler Roundhouse. The ridge began to break down by the third week of January, as windy and stormy weather slowly returned to all ranges. A large avalanche released on the November rain crust in the Selkirk Mountains at **Tumbledown Mountain on 20 January** (page 238) in which seven people died, before the storm even gained strength. By 28 January, Mt Fidelity had received about 100cm of storm snow, yet the snowpack height remained below average. Both the Columbia and Coast Mountains received rain at the end of the storm, with large amounts falling at Whistler Roundhouse on 26 January.

A very short period of high pressure then pushed into all ranges, allowing surface hoar to grow in the Columbia Mountains. Between 29 January and 1 February, weather tracking inland from the Pacific brought about 30cm of snow to the Columbia and Coast Mountains, with strong winds and rising temperatures. Lake Louise saw some snowfall from this storm, but the snowpack there remained at a near record low. On 1 February in **Connaught Creek, Glacier National Park** (page 243), seven students died when another large avalanche released on the November rain crust. Each of the four major surface hoar layers buried since Christmas were also involved.

The first two weeks of February saw a warm high-pressure system locked into southwestern Canada, blocking storms tracking in from the Pacific. During that time, Whistler Roundhouse reported many days with above-freezing temperatures, including one day with an overnight low temperature above 0°C. Mt Fidelity had one day with above-freezing temperatures, but in general the Columbia and Rocky Mountains were experiencing warm days and cold nights under clear skies, leading to the faceting of near-surface snow layers. Both ranges were again at near record low snowpack, while the coast had slid to below average levels.

Around the middle of February, the pattern changed: it started snowing in the Coast and Columbia Mountains, and except for a few short breaks—and one longer one on the Coast in late February—it kept snowing until the end of April. The snow arrived in the Rocky Mountains by 1 March. During March it rained on six occasions at Mt Fidelity, but on the coast most of the precipitation fell as snow. The snowfall was caused by a series of major Pacific storm systems and supplemented by the more typical springtime convective showers and weaker fronts. The snowpack at Lake Louise and at Mt Fidelity reached average height by mid-March, and Whistler Roundhouse was reporting above-average snowpack levels for most of the spring. Heavy snow and rain around Canmore, AB created dangerous conditions that led to a fatal avalanche on **Mt Lady Macdonald on 12 March** (page 249). The new snow had buried a weak, faceted surface on 15 February in **Kokanee Glacier Provincial Park**, where a skier-triggered avalanche released on that layer claimed two lives on **17 March** (page 253).

This relatively fast and heavy accumulation of snow had begun to overload the November crust in early March, and a series of deadly avalanches began. First, in the Rocky Mountains one person died near **Lake Agnes on 14 March** (page 250), and another near **Ram Range on 20 March** (page 257). The very thin snowpack through much of the season, and the periods of cold clear weather probably led to faceting and weakening of the snowpack around rocks and other obstacles. As the snowpack grew through March, these weak areas became perfect locations for skiers and snowmobilers to trigger large avalanches accidentally, such as at **Fairy Creek on 26 March** (page 260), **Mt Terry Fox on 26 March** (page 262), **Mt Brewer on 27 March** (page 264), and **Holt Creek on 6 April** (page 268).

By the end of April—the typical end to the avalanche and weather reporting season—there was still snow in the Coast and Columbia Mountains, with Whistler Roundhouse at above average snowpack heights and Mt Fidelity just below average. The late-season storms had built large cornices in many ranges, including in the northwest near New Hazelton and in the south Rockies near Sparwood. At **Scallop Mountain on 31 March** (page 382) and on **Mt Ptolemy on 18 April** (page 270) snowmobilers were involved in cornice-related avalanches that took two lives. The exceptional snowfalls that began around the middle of February had taken the 2003 season from a record-low snow year in the Columbia and Rocky Mountains, and below average in the Coast, to a normal or above-average year. Unfortunately, both the low snowpack up to mid-February and the very heavy late-winter precipitation that overloaded the November crust conspired to make 2003 one of the most deadly avalanche seasons in Canadian history.

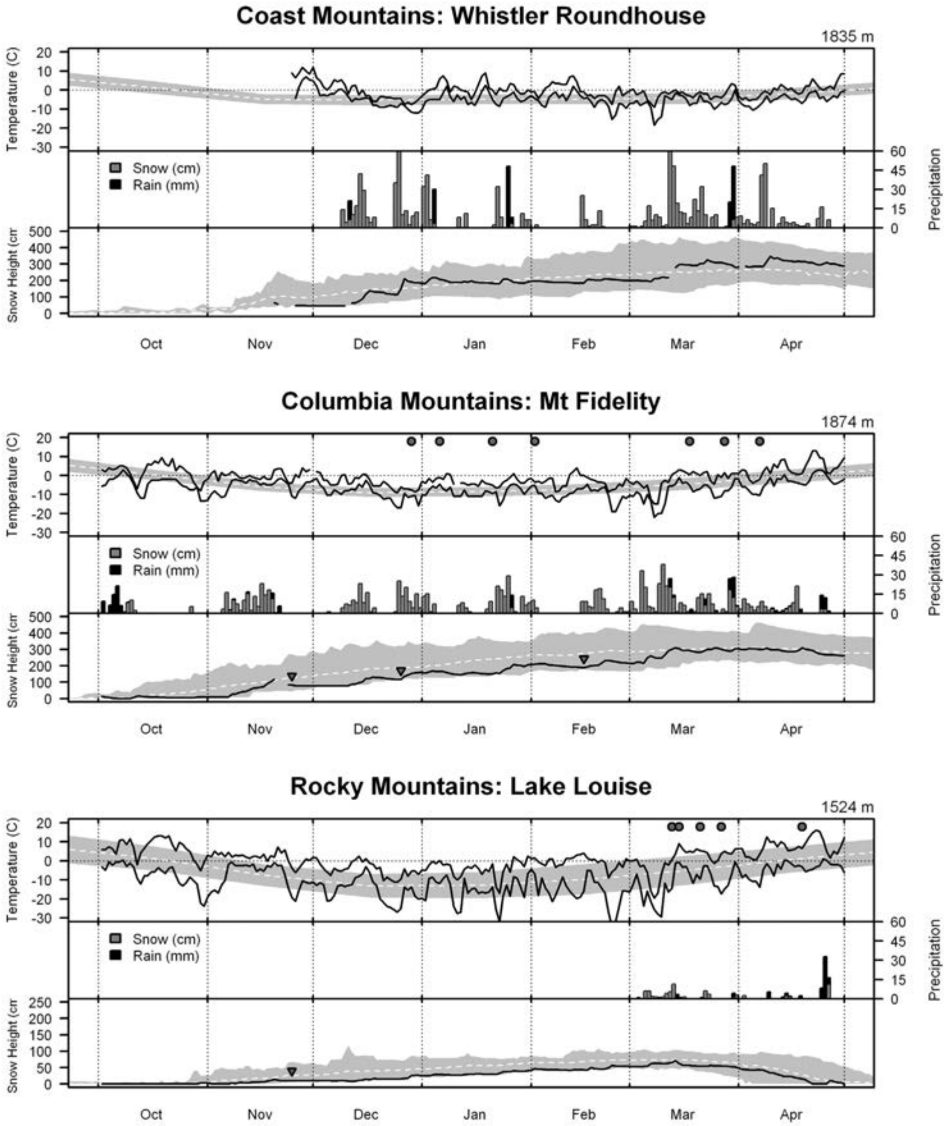

Figure 10.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 2002/2003 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanches (black triangles). The grey band shows minimum, average (dashed line) and maximum snowpack height measured at each location since 1976.*

28 December 2002, Snowmobiling
Allan Creek, Cariboo Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Two people highmarking at the same time, with a third person exposed**
- **High avalanche danger**

On 28 December, three experienced and well-equipped snowmobilers parked their truck at the Allan Creek trailhead, about 37km south of Valemount, BC. They started up Allan Creek and met four other snowmobilers. Leaving the valley, they climbed to the south and reached Oasis Bowl on Mt Sir Allan MacNab around noon.

On the previous afternoon, the Canadian Avalanche Association issued a regular bulletin for the North Columbia Mountains. The regional avalanche danger for the treeline zone where the men were snowmobiling was rated High. The bulletin also noted: "A significant layer of surface hoar was buried on Xmas day and now sits within the upper metre of the snowpack. Tests and observations indicate this layer to be very weak with avalanches failing easily at this level. As more snow accumulates and the storm snow becomes denser with wind loading, expect avalanches to continue failing on this surface hoar. Deeper in the snowpack, a layer of crust/facets/surface hoar also remains a concern, and the potential for large avalanches is significant—especially in shallow, or uneven snowpack areas. ... Widespread avalanching was observed on Thursday and is expected to continue given the weather forecast. ...This is a weekend for careful travelling in the backcountry. If the forecast snowfall materializes, then certainly the avalanche hazard will increase and travel in any avalanche terrain cannot be recommended. In the absence of additional snow over the weekend, the many slopes may not avalanche naturally but will be ripe for human triggering."

On the day before the snowmobiling trip, the heli-ski operation to the north reported 10-20cm of new snow and wind effect at treeline and in the alpine. The air temperature in the skiing terrain (1200 to 2200m) was between -12 and -6°C. The heli-ski operation to the south had observed four size 2.5 avalanches on northeast-facing slopes in the previous two days, indicating an extensive deep slab avalanche cycle.

The snowmobilers were highmarking in Oasis Bowl. The wind was calm, the sky overcast and the air temperature was about -10°C. At about 12:30, one rider was descending while another was climbing the bowl when an avalanche was triggered. The other rider from the first group was also hit. Two were completely buried and one had his hand above the surface of the deposit.

The four riders from the second group began to search. They quickly found the rider with his hand exposed and dug him out. Searching with their transceivers, they located then dug out a second rider, who was buried 60 – 90cm below the surface. It took 10 – 15 minutes to recover these two survivors. They located the signal from the third rider. Digging took longer because he was under 120 to 150cm of the deposit. He was lying with his head downhill, face down, wearing his helmet. They excavated him, removed his helmet and tried to resuscitate him. They later learned he had asphyxiated.

One of the riders in the group of four had a satellite phone and a GPS. He transmitted the coordinates and a call for help to a snowmobile shop in Valemount, who contacted the RCMP. A helicopter transported the RCMP, a representative of the BC Coroners Service and two avalanche technicians to the avalanche.

There were multiple crown fractures suggesting that several slab avalanches had released sympathetically. The elevation of the crowns was about 2130m on a 45° north-facing slope. The estimated height of the crowns was 70cm. The combined width of the avalanches was 400 to 500m. The technicians estimated that the avalanches released on the rain crust from November 2002. The toe of the deposit was at 1920m. It was a size 3. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
45°	?	Concave	Open slope

Source
- BC Coroners Service
- InfoEx

Comment
Two people were highmarking at the same time and one more was also exposed to the avalanche path.

The snowmobilers were equipped for rescue and responded efficiently, recovering two survivors.

5 January 2003, Out-of-bounds Skiing
Squaw Headwall Outside of Red Mountain Resort
Monashee Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Filming video not far from ski area boundary**
- **Videographer caught and buried**
- **No rescue equipment, high avalanche danger**

Three skiers left the boundary of Red Mountain Resort near Rossland, BC, on 5 January 2003 and headed for a nearby slope to capture some video footage.

The public avalanche bulletin issued by the Canadian Avalanche Association for the Kootenay Boundary region on 3 January described thick accumulations of storm snow and strong winds forming slabs over several buried weak layers. The danger for 5 January was High in the alpine and at treeline, and Considerable below treeline.

During the week leading up to this accident, over 65cm of storm snow fell at the nearby ski area under generally warm and very windy conditions. The new snow fell on a layer of surface hoar buried on Christmas day. Below that, the snowpack was generally thin and weak due to a dry, cold December that followed a major crust-forming rain event in November.

The skiers ascended a gentle ridge until they arrived at their objective, a steep slope called "Squaw Headwall." Two continued climbing the ridge to the top of their run, while the third (the videographer) skied down to set up the camera in a position where he could view the skiers' intended lines.

When everyone was in position and ready at approximately 11:50, the first skier started down from the ridge and jumped off a rock on the slope. The force of his landing on the slope below was enough to trigger a slab avalanche. He was able to ski to the side of the moving snow. The second skier could not see the slope or avalanche from his position, but heard calls for help from below. As he made a quick descent down the slope to skier's left of the first avalanche, he triggered a second, smaller slab. Both of the two skiers remained unaffected by the avalanches, but the videographer had been caught and was not visible on the surface of the deposit. The avalanche had travelled through a small stand of timber at the base of the slope.

Several people skiing at Red Mountain Resort witnessed the avalanches and reported the incident to the ski patrol. They were able to respond to the scene within 15 minutes of the avalanche and initiate a search for the buried videographer. None of the group involved in the accident were wearing avalanche transceivers or carrying self-rescue equipment, so the ski patrol members contacted the RCMP and local SAR team for assistance, and began probing the deposit. With the help of the SAR team, the videographer was found buried in a horizontal position with his head facing uphill, under approximately 1m of snow. He was unconscious and had no pulse. The rescue team performed CPR while moving the victim back into the ski area boundary where he was met by a helicopter and transported to hospital. He was admitted in serious condition and died the following day from head injuries sustained during the avalanche.

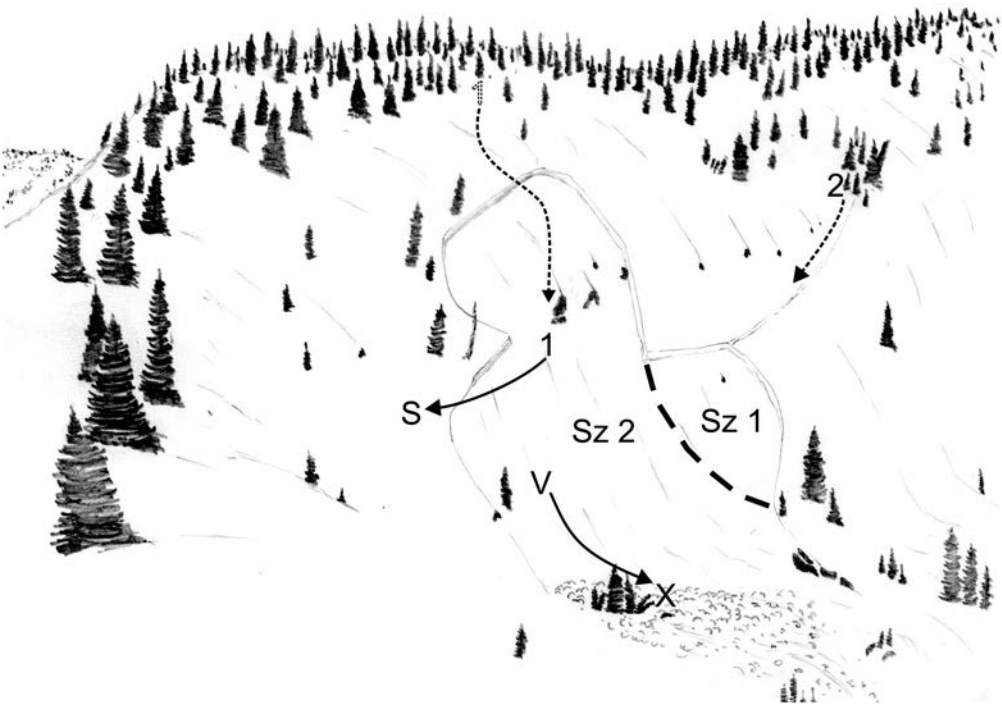

Figure 10.2. Squaw Headwall, 5 January 2003. 1, 2 - location of skiers when avalanche released, V – location of videographer when avalanche released, S - survivor, X – deceased. The size 1 avalanche was triggered by skier 2 when responding to the first avalanche.

The size 2 avalanche released from a 37° east-facing start zone near tree line at 1995m elevation. The slab area that fractured in the first avalanche was 25m across and 43m long, with an average thickness of 55cm but up to 110cm thick in places. The videographer was filming from a spot near the bottom of the fractured area, and was carried approximately 40m to a small bench in the terrain and buried adjacent to a narrow stand of timber. Most of the avalanching snow travelled another 55m down the slope. In all, the deposit was 72m long and 16m wide, with an average depth of 50cm but deeper near trees and other obstacles.

Snow profiles performed the day after the accident suggest the initial failure was in the surface hoar, but the movement of the slab scoured the snowpack down to the weak faceted snow above the November crust. On the day of the avalanche, the air temperature had warmed to near freezing under the influence of a strong inversion, leaving the skies clear and sunny. The upper part of the snowpack may have been softening with the warm temperatures, which often makes initiating fractures in weak snowpack layers much easier—especially with heavy loads like the impact of a skier landing a jump.

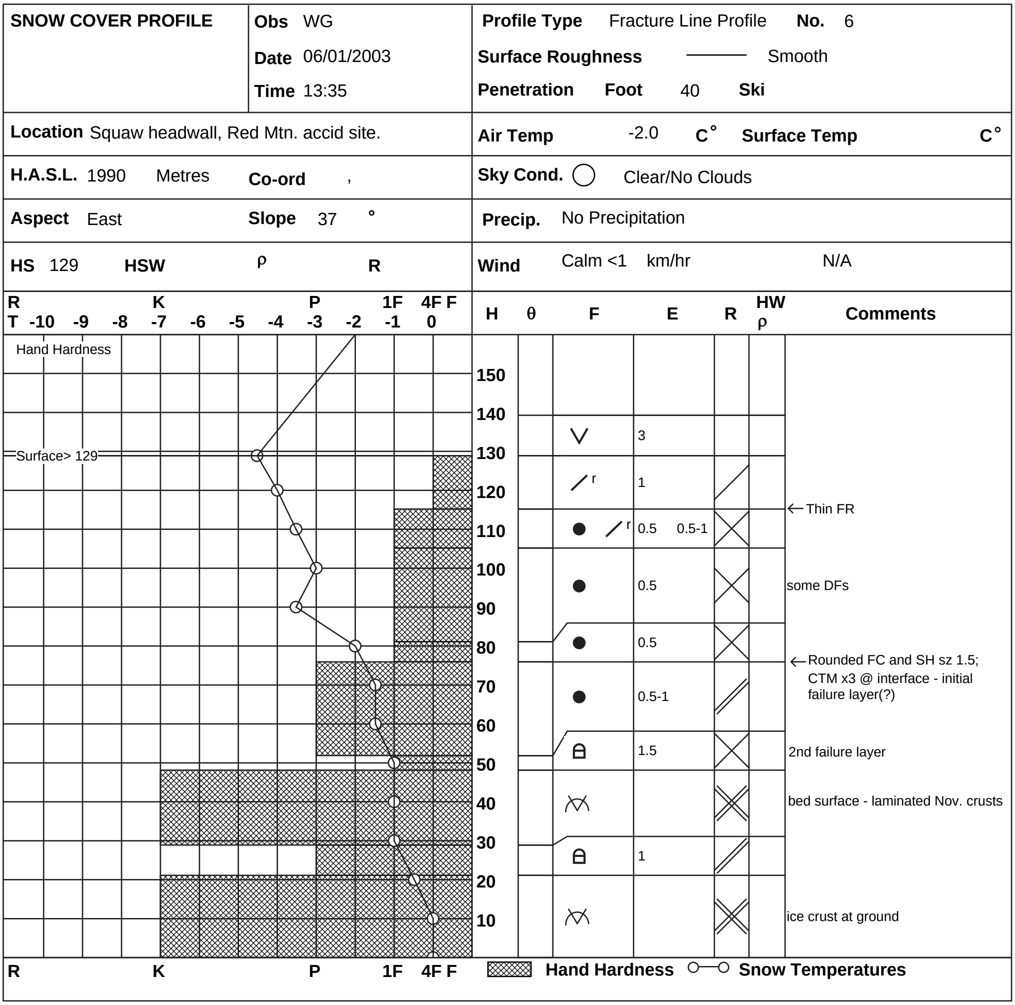

Figure 10.3. *Squaw Headwall, 5 January 2003. Fracture line profile observed one day after the avalanche.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
37°	Trees	Planar	Sparsely treed slope

Source

- BC Coroners Service
- Red Mountain Resort
- BC Ministry of Transportation
- InfoEx

Comment

Even when riding just outside ski area boundaries, it is very important to travel with the equipment for self-rescue: beacons, shovels, and probes. Outside help may take too long to arrive at the scene of an accident.

20 January 2003, Backcountry Skiing Tumbledown Mountain, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
7	Deep Persistent Slabs	Complex

- **13 backcountry skiers caught**
- **Deep slab triggered remotely**
- **Survival following long burial**

On the morning of 20 January 2003, 21 skiers left a backcountry lodge near the Durrand Glacier, about 30km northeast of Revelstoke, BC, for a day of guided ski touring. They split into two groups: the first included the lead guide, 10 guests, a professional snowboarder who was an apprentice guide, and one lodge employee; the second group, led by the assistant guide, included five guests, a second apprentice guide, and a second employee of the lodge. The first group was expected to travel faster and the second group would follow their trail some distance behind.

To start the trip they skied down from the lodge then crossed the head of a narrow valley. They then began a long uphill traverse to the west, under the south-facing slopes of Tumbledown Mountain. As they gained elevation, the trees thinned and they reached a relatively flat alpine ramp. They continued toward their first objective, a lower peak at the far end of Tumbledown's west ridge. That peak was shrouded by low clouds, and after a short break the lead guide made the decision to change objectives and ski a broad couloir called La Traviata located partway along the ridge. The second group, trailing behind, was notified of the change in plans by radio.

La Traviata couloir is a common early-winter route for groups at the lodge, although no one had yet skied this area in 2003. It is often accessed by climbing low-angle slopes further along the ridge but on this day, the group took the direct route up the couloir.

The lead guide noted some of the slopes on Tumbledown Mountain had slid during an earlier cycle. All of the guides and apprentices were likely aware of two significant weak layers buried in the snowpack throughout the Columbia Mountains. One of these layers was near the base of the snowpack and had formed following a major rain event in November.

By about 10:45, after setting a steep track with several switchbacks for the skiers to follow, the lead guide arrived near the top of the couloir. He traversed to his right toward a broad rollover east of the couloir entrance to await the rest of his group. As a few of the skiers in the lead group caught up with the guide, they felt a "whumpf" and a large slab avalanche released on a south-facing slope below their position, to the east of La Traviata. Moments later, a loud "crack" was heard, and someone yelled "avalanche!" from near the couloir. Five skiers from the first group were still climbing La Traviata and all eight in the second group were spread out further down the couloir.

The lead guide and the few skiers nearby quickly moved back toward the top of the couloir. There, they saw the crown of the large avalanche that had swept down La Traviata. The lead guide immediately reported the avalanche to the lodge by radio, and the information was passed along to a local helicopter company to initiate an external rescue plan. The lead guide and the seven guests who were above the crown fracture when the avalanche released then made their way down the bed surface of the avalanche to search for the other 13 skiers.

Four of the skiers who were in the couloir—including the apprentice guide and the lodge employee from the second group—were only partially buried by the avalanche and were excavated quickly, enabling them to assist in the search for the nine others who were buried completely. The exact timing of events is unclear, but the search was extremely efficient given the scale of the accident. Less than one hour after the avalanche, all nine had been located and uncovered. Most were not breathing or lacked vital signs, and received CPR. The assistant guide leading the second group was the only one of the buried victims to respond to resuscitation efforts; he resumed breathing only after the heavy snow was removed from his chest. He had been buried for about 30 minutes.

At about 11:40, a helicopter carrying guides from a nearby heli-skiing operation was able to land at the scene. By that time, the last of those completely buried were being pulled from the deposit. The assistant guide who was revived by CPR was fading in and out of consciousness, and was evacuated by helicopter immediately, accompanied by one of the other survivors. As more outside support arrived at the scene, including several local guides and paramedics, confusion arose regarding the number of skiers involved and how many had been rescued. This was rectified when it was realized that the guest who had departed with the assistant guide was missed in the headcount.

Thirteen skiers were caught in the avalanche in La Traviata couloir. Seven died, all of whom were buried completely by the avalanche. Of the six who survived, two were buried completely, while the other four were partially buried by the avalanche.

At the time of the avalanche, a nearby treeline weather station showed an air temperature of -5°C. Fog and low cloud lingered around many peaks in the area as a ridge of high pressure started to break down. Just 1cm of new snow was recorded at the lodge on the morning of 20 January, which was the first precipitation since the last storm ended about six days earlier. On 19 January, a local heli-skiing operation recorded moderate and strong winds from the southwest while skiing, but otherwise the weather had been fine for a few days.

The Canadian Avalanche Association published a public avalanche bulletin on 17 January for the North Columbia Mountains. The bulletin was valid until 20 January, and the danger was listed as Considerable in the alpine and treeline elevations, and Moderate below treeline. Forecasters noted "a few remotely triggered size 2.5 avalanches" in the eastern Selkirk Mountains, some triggered from a distance of more than 100m. They also stated that "widespread whumpfing continues to be observed in all areas."

The bulletin urged backcountry travelers to "be alert for remote triggering and continue to be vigilant about avoiding those tempting big steep alpine faces. Any avalanche triggered on the older weaknesses may propagate extensively into a large and dangerous avalanche event. Be aware of how stresses penetrate deeper into the snowpack as you group up."

The fatal slab avalanche on La Traviata released from an elevation of 2510m, on a 33° southwest-facing slope near the top of the couloir. The size 3 avalanche had a crown fracture about 65m wide, and slab thickness varied between 63 and 260cm. It ran approximately 350m down to flat terrain at the base of the couloir. A sharp transition from the slope to the flats probably increased the depth of the deposit; it was 185m wide but only 85m long, with measured depths ranging from 2m up to 4.5m.

Much of the couloir had released, including some of the steep adjacent terrain. The assistant guide reported that the fatal avalanche had occurred in two distinct waves. The first only partly buried him, but seconds later another rush of snow overran and buried him completely.

At least two other avalanches released just before or simultaneously with the one in La Traviata. One size 3 slab slid on a large south-facing slope below the position of the lead guide when the whumpf occurred. Its deposit covered the ascent track from both groups on the ramp below the west ridge of Tumbledown Mountain. A second size 1 avalanche released from steep rocky terrain between the two large avalanches. The sequence and triggers of the three avalanches are unclear; however, it appears the lead guide was regrouping his guests in an area of very thin, wind scoured snowpack. It is likely that the combined weight of the skiers there caused a fracture in the snowpack, which then propagated down the slopes below and around to the couloir, triggering the avalanches remotely.

Investigators spent two days following the avalanche making measurements and collecting snow profiles at the site. Their observations showed a huge amount of variability in the snowpack from one place to the next. At the highest point of the skiers' up track, near the position of the lead guide, the snowpack was only 50cm deep. There, about 35cm of faceted and depth hoar crystals rested on a strong crust mixed in with the rough, rocky ground surface. In some places closer to the crown of the fatal avalanche, snowpack depths reached 240cm. The snow profiles showed either relatively thick, stiff slabs with softer surface layers in wind-loaded areas, or thinner but still stiff slabs with several buried suncrusts on wind scoured and more solar aspects. Winds around La Traviata tend to move snow from east to west, so that snow is deposited in thick layers within the couloir

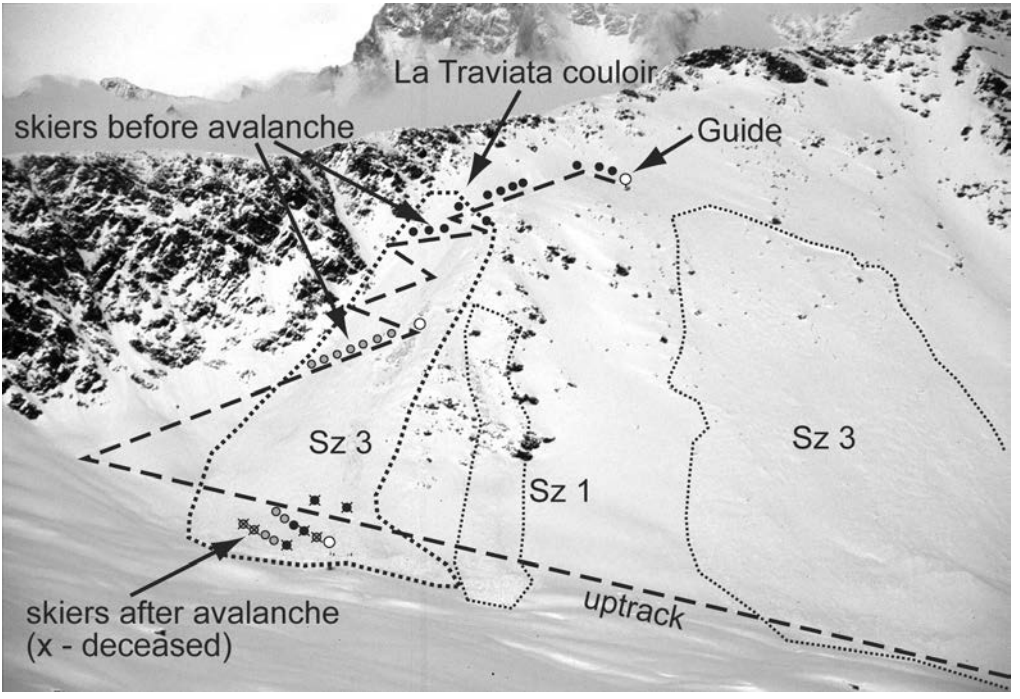

Figure 10.4. *Tumbledown Mountain, 20 January 2003. Photo: Jim Bay.*

itself, especially on the east side, leaving thinner areas in the rocky terrain to the east.

The common feature of all the profiles collected is the existence of a relatively soft, weak layer of faceted crystals a few centimetres thick, overlying a smooth and strong icy crust layer. That crust was formed at the end of a period of warm, wet weather in late November. This "November crust" was a prominent feature of the snowpack throughout the North Columbia Mountains and had resulted in many large avalanches in recent weeks, and even more as the season progressed.

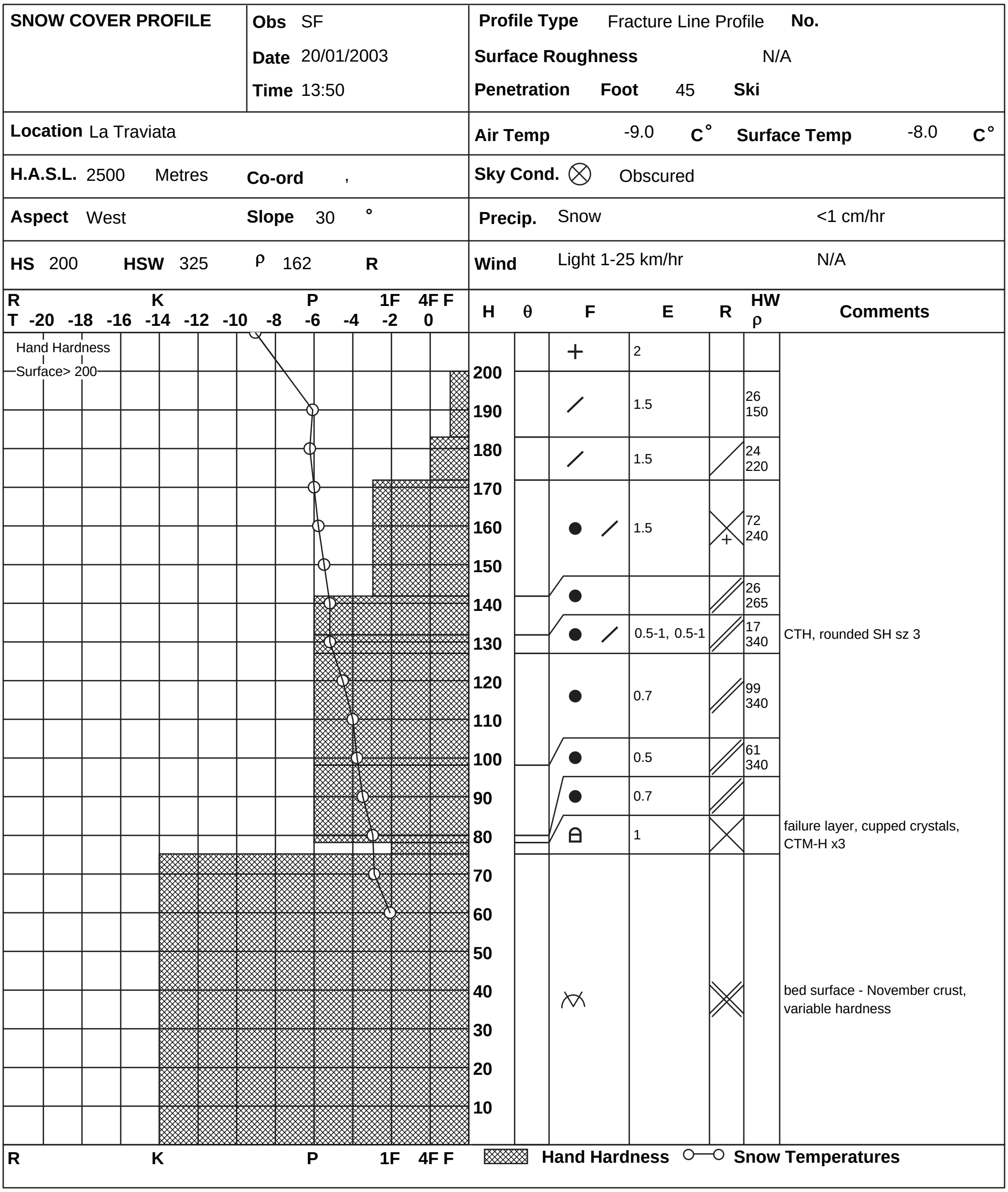

Figure 10.5. *Tumbledown Mountain, 20 January 2003. Fracture line profile from fatal avalanche showing typical snowpack layering. Significant spatial variability was noted within and surrounding the couloir that avalanched.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
33°	Abrupt transition	Convex	Alpine

Source
- BC Coroners Service
- InfoEx
- Chris Stethem
- Various media reports and magazine articles

Comment
This was the first of two high-profile avalanche accidents during the winter of 2003 that each claimed the lives of seven people. Extensive media coverage led to a heightened awareness of avalanches and the risks associated with them amongst Canadians. The ensuing discussions contributed to many changes in the way those risks are managed in Canada.

Much discussion arose surrounding the events leading up to this accident, much of which was valuable and educational, especially for the management of complex avalanche problems involving decision making, spatial variability in the snowpack, and the triggering and fracture propagation in deep slab avalanches.

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1 February 2003, Backcountry Skiing
Connaught Creek, Glacier National Park, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
7	Deep Persistent Slabs	Complex

- **14 students and 3 adults caught by large natural avalanche at valley bottom**
- **Many lives saved because of quick rescue by two witnesses and several survivors**

As part of their grade ten outdoor education curriculum, a group of 14 students from a school near Calgary were at Rogers Pass in Glacier National Park for a week of backcountry skiing. The teacher leading the group had professional avalanche training. Another teacher and a chaperone were along to help on this trip.

They had spent the morning of their first day in the mountains at the Rogers Pass Centre reading avalanche bulletins, weather forecasts, and avalanche reports. That day they skied a short distance to an area called NRC Gully, where they observed snow profiles and performed tests to learn more about the local snowpack.

On 1 February 2003—their second day in the mountains—they chose to ski up the Connaught Creek drainage toward Balu Pass, a very popular route that starts directly behind the hotel next to the Rogers Pass Centre (RPC). The trail follows the valley bottom most of the way up to treeline near Balu Pass, but it is exposed to the runouts of numerous large avalanche paths from both sides of the valley.

About 10cm of new snow had fallen in the 24 hours leading up to the morning of 1 February 2003, adding to about 20cm that had fallen at treeline over the previous two days. During that period, winds had blown strongly from the south and southwest at a treeline weather station on Mt Macdonald, located above the highway on the east side of the Rogers Pass summit. Winds there tend to be higher than at other locations, although blowing snow at mountaintops had been noted near the summit of Rogers Pass on the morning of 1 February. Blowing snow had also been noted on cheops Mountain which forms the entire south side of the Connaught Creek valley. The recent stormy weather had been mild, but temperatures remained below freezing.

The avalanche bulletin issued by Parks forecasters on 1 February was quite detailed in its description of conditions that day. It mentioned new snow which fell during a warm, windy southwest flow; storm snow totals of around 30cm which helping to stiffen a slab over a surface hoar layer, and was responsible for an extensive avalanche cycle the previous week; moderate to hard snowpack test scores on that surface hoar layer; and an instability within the storm snow itself. The bulletin highlighted that these two weak layers were the highest concern, "especially on lee slopes or near large terrain features."

Two deeper weak layers were also mentioned: "the Christmas surface hoar layer, now down approximately 125cm, is gaining strength, but still showing up with variable results in stability tests" and finally "still a concern is the deeply buried November layer which consists of a laminated crust of melt-freeze crystals sandwiched between loose faceted grains, now buried approximately 160cm." The November crust was weakest "in rocky, shallow snowpack areas and on large open slopes above 2000m, where shallow weak areas have the potential to trigger larger and deeper events." The bulletin concluded by noting "the potential for a triggered event to step down to one of the deeper instabilities."

Forecasters had identified five weak layers in the snowpack: one within the recent storm snow, three surface hoar layers buried since late December, and a frozen crust near the base of the snowpack formed by a rain event in late November, overlaid by soft faceted crystals and surface hoar. The danger rating was Considerable in the alpine and at treeline, and Moderate below treeline. The trail along Connaught Creek up to Balu Pass would be mostly below treeline, but most of the route was exposed to avalanche paths with alpine and treeline start zones.

The 14 students and three adults left the trailhead for Balu Pass at about 09:45 on 1 February after again visiting the RPC to check avalanche bulletins and conditions in the surrounding mountains. They double-checked the function of their avalanche beacons before setting out.

As they came to the first section of trail where avalanche paths from Cheops and Grizzly Mountains overlap, they began to ski-tour up in pairs, spreading out by 10-15m along the trail to reduce their exposure. Twice they regrouped for a rest during the ascent; at one of those breaks two local guides on a day off passed them.

At about 11:45 the lead teacher at the front of the group had just climbed past the bottom of "Hospital Gully" on his right. The two guides were now about 150m above the Balu Pass trail, on the opposite side of the valley from Cheops Mountain. They had branched off the

Balu Pass trail sooner than usual, as they had noticed some sloughing snow high on Cheops Mountain on the opposite side of the valley.

The two guides had just started climbing again after a short break, when they noticed a large avalanche roar down the high slopes of Cheops Mountain—heading directly for the group of students spread out along the trail below. The guides shouted a warning, and then watched through the trees as the avalanche engulfed the entire group.

Some of the powder cloud from the avalanche reached the position of the guides as it ran up the slope below them; the dense flow of the avalanche had climbed into the trees a short distance, but then turned and sped down the main valley.

At the back of the group of students, the chaperone first heard a loud "crack" from above, and then he and the second teacher saw the avalanche bearing down on them and the students ahead. They shouted a warning, and crouched in the snow to brace for the impact.

Students near the back of the group saw the avalanche and heard the warning shouted from behind them. They raced to climb out of harm's way, but the fast-moving wall of snow quickly caught all of them. The avalanche also hit the two adults at the back; when it stopped, they were both partially buried, but able to free themselves.

The two guides immediately skied back down to the Balu Pass trail. Less than two minutes after the avalanche, they were at the top of the deposit. It reached up about 40m into the trees near the base of Hospital Gully, and then stretched for over 700m down the valley below. The deposit had covered over 200m of the trail, and all 17 skiers in the high-school group had been caught.

The two guides found one student, almost completely buried near the top of the deposit, and then noticed a glove sticking out of the snow; the teacher in the lead had thrust his hand toward the surface as the avalanche came to a stop. He was beginning to lose consciousness just as one guide was able to dig down to his head and chest. The teacher indicated that he had a satellite phone in his backpack and had written down the phone number of the warden office in case of emergency. The guides left him to call for help and dig himself out of the snow. At about 11:50, only five minutes after the avalanche, he called the warden office and reported the avalanche. He provided just the basic details, and quickly joined the rescue effort. The wardens knew only that a party of 17 had been hit by an avalanche, and that 15 were unaccounted for. A large-scale response was initiated immediately.

In the meantime, the two guides began searching down the length of the deposit using their avalanche transceivers, each covering one side. They found students partially buried near the surface, and others who were buried completely; the guides made sure the students they found were breathing, and moved on. They located a number of students buried close to one another. The guides continued the search down the deposit, instructing those who had been rescued to help with probing and digging, and to provide CPR to their friends.

Near the toe of the deposit, the second teacher and the chaperone were able to free themselves from the snow. Along with two students who had been only partly buried further down the slope, they began searching the deposit for others. At a spot where a beacon signal indicated the location of a buried student, they met one of the guides as she searched down the deposit. The search continued, with the guides and those who had been rescued helping to probe and dig, as more and more buried students were located.

By about 12:30, seven students and the three adults had been found and uncovered from either partial or complete burials. These ten would be the only survivors. Some required help to breathe initially; one had suffered a broken ankle.

At approximately 12:40, a helicopter arrived in response to the call for help, carrying two guides from a local heli-skiing operation, and two wardens and three members of the park's avalanche control section. They landed near the two guides on the deposit, and were informed that several students had been located by transceiver but were still deeply buried. One student remained unaccounted for while others were continuing to search using their beacons. Most of the new rescuers joined the search and recovery efforts, while one guide and an avalanche forecaster flew up to assess the avalanche hazard to the rescuers below. Within minutes, more helicopters arrived, bringing guides, wardens, rescue dogs and first aid equipment as well as a helicopter-mounted avalanche beacon that could rapidly search the entire deposit for any additional signals. At its peak, there were 50 people working on the rescue effort.

By 13:15, six more students had been located and recovered from the avalanche. All were buried deeply, and all had died from asphyxiation. At that point, it seemed that two students had not been recovered, although a very weak beacon signal had been located near the toe of the deposit, and rescuers were digging there.

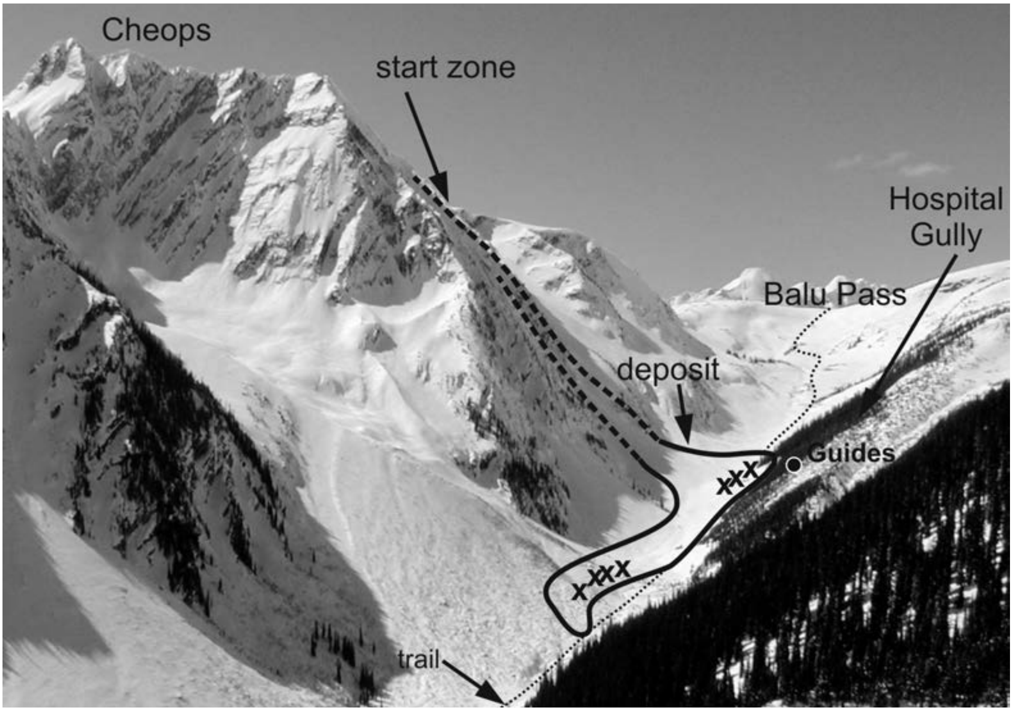
It took until after 14:00 to confirm that all of the students had been located, although not all had been recovered at that time. One of the victims found earlier had been removed from the scene by helicopter, which caused some confusion for the rescue coordinators.

With the threat of further avalanches releasing from Cheops Mountain increasing rapidly as strong winds loaded snow into the start zones, plans were made to clear the search area and apply explosives to the slopes to stabilize them. There were a large number of people—rescuers and victims of the avalanche, as well as other skiers who had arrived at the end of their day of skiing— still on the slope, and their safety was a serious concern. The avalanche control would be unnecessary, since by 15:00 all of the victims were recovered and evacuated. Rescuers were then grouped in a safe location to be flown from the site.

The slab avalanche released from a north-facing gully on the northwest aspect of Cheops Mountain. The fracture line reached up to approximately 2380m elevation, and was about 100m wide near the top. It made a series of steps down along its west flank on the rocky ridge of the gully, where it was about 2m thick. The east flank of the avalanche was against bare rock, where most of the snowpack had released. The fracture line along the east flank was up to 4m thick in a bowl feature partway down the gully. The start zone had a 45° incline, while in the bowl the slope eased to about 30°.

The avalanche was a size 3.5, and ran for a distance of about 1500m. The deposit was about 740m long, with an average width of 85m. It was 2.5m deep on average, but reached a depth of 5m in places. It hit the valley bottom near Hospital Gully at about 1700m elevation. The moving snow had turned directions several times while it flowed, once after it ran 40m up the side of the valley near Hospital Gully, and then again while it moved around alluvial fans below Cheops Mountains and flowed into the depression above the channel of Connaught Creek.

It is not entirely clear where in the snowpack the initial fracture occurred, or what the trigger was. Some professionals have suggested the group may have triggered the avalanche from below; however, most of the evidence suggests it was a naturally triggered avalanche. The guides and several rescuers noticed blowing snow along the upper ridge



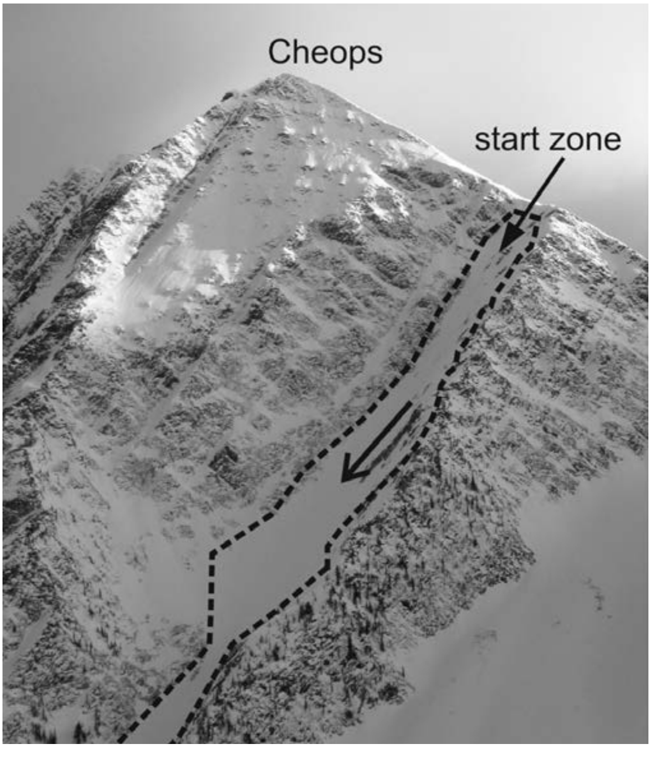


Figure 10.6. *Connaught Creek, 1 February 2003. Top photo: Students and teachers were spread out along the Balu Pass trail at the time of the avalanche. X – deceased. The start zone is hidden from view in the first photo. Photo: Phil Hein. Bottom photo: Start zone of avalanche path. Photo: Cameron Ross.*

of Cheops Mountain on the day of the avalanche. A small, loose avalanche was also noted high in the start zone. It had released below the ridgeline cornice, above the fracture line of the fatal avalanche. Either of these factors may have contributed to the start of the avalanche.

No snow profiles were collected in the start zone of the avalanche, but in the days following several profiles were observed in nearby locations. All showed the snowpack as described by the avalanche bulletin—a relatively thick, strong upper snowpack, interrupted by up to four weak layers of surface hoar crystals dating back to early December. In the lower part of the snowpack, a layer of weak, faceted crystals rested on a decomposing rain crust formed in late November. That crust was the ultimate bed surface of the avalanche, and had been responsible for a number of isolated but large releases over the preceding few weeks in the region. The presence of up to four weak layers in the upper snowpack likely contributed to the size of the avalanche on 1 February, allowing initial fractures to "step down" through the snowpack and reach the deep layer, making it possible for the moving avalanche to incorporate a significant volume of snow from its track. Most seasons, the paths on Cheops release many small avalanches, limiting the amount of snow that accumulates in the start zones; in 2003, north winds loaded them in the early season, and subsequent low snowfall amounts meant that the small avalanches did not occur, leaving the entire snowpack available to avalanche in February.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
>45°	None	Concave	Open slope

Source

- BC Coroners Service
- Rich Marshall
- Eric Dafoe
- Parks Canada

Comment

One rescuer referred to this accident as a "worst case scenario." The tragedy of it clearly had a huge impact on the survivors, the families those involved, the rescuers, and everyone who responded to the scene. But its effects were even more widely felt, reminding people in the community and across the country of the potential scale of snow avalanche hazards.

Parks Canada modified its backcountry use policies after a thorough review following this accident. Avalanche area maps and warning signs are posted at popular trailheads in the mountain parks, and new terrain rating and danger scale systems have been established. In addition, an appropriately qualified member of the Association of Canadian Mountain

Guides must now lead custodial groups travelling outside of simple terrain in national parks. Custodial groups are those organized by a formal institution, which contain at least one minor whose parents are not present.

13 March 2003, Hiking
Mt Lady Macdonald, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	?	Complex

- **Lone hiker during extreme avalanche danger**
- **Not found until June**

Sometime around 13 March 2003, a lone hiker climbed toward the summit of Mt Lady Macdonald, near Canmore, AB. He left the summit ridge above the tea house, heading toward a west-facing bowl feature above a prominent gully at about 2400m elevation.
A major spring storm was underway—20 to 40cm of new snow had fallen, and the temperature was rising rapidly with strong southwest winds. The previous night it had rained up to about 2100 to 2300m elevation, and a widespread avalanche cycle was occurring on 13 March. Size 2 and 3 loose snow and slab avalanches, involving most of the snowpack, were running at and below treeline in Kananaskis Country. Nearby in Banff National Park, wardens reported that the largest avalanche cycle of the season was underway on 13 March, with avalanches up to size 4.

The Kananaskis Country backcountry avalanche report rated the danger in the alpine and treeline at Extreme, meaning that widespread natural and human triggered avalanches were certain. Travel in the backcountry was explicitly not recommended. Kananaskis Country Public Safety officials produced a press release on 12 March highlighting the dangerous conditions.

The hiker had been reported missing and authorities were on the lookout for him, but no one knew where he had gone or what he was planning to do. It was not until early June that most of the snow had melted from the gullies on the mountain and a group of hikers reported seeing a body below the tea house in the prominent gully.

Kananaskis Country Public Safety staff approached the site by helicopter, and recovered the deceased by long-line and sling. The victim's identity was later confirmed to be that of the missing hiker. He was not dressed for travel in the mountains during bad weather, and was not carrying any rescue equipment.

No details are known about the exact sequence of events leading up to the accident, but the hiker was found partially buried in what appeared to be old avalanche debris. He was likely travelling in the bowl above the gully and was swept down and buried by an avalanche. It is not known if he triggered the avalanche or if it occurred naturally and he was overrun by it. In any case, he appeared to have made no preparations to travel in avalanche terrain in dangerous conditions.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Extreme	?	Yes	?	Yes	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	?	?	Alpine

Source
- George Field
- Kananaskis Country Public Safety
- InfoEx

Comment
This was a good time to avoid anything even close to avalanche terrain.

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14 March 2003, Snowshoeing
Lake Agnes, Banff National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Lone snowshoer in Extreme avalanche danger**

Early in the morning of 14 March 2003, a lone snowshoer set out from the Chateau Lake Louise for a trip into the backcountry. His destination was the area around Lake Agnes, a mountain lake at the base of an impressive cirque just southwest of Lake Louise proper. This is a common summertime recreational area, with trails and a tea house near the lake, but sees limited traffic in the winter. Very steep rock walls, faces, and slopes cut by a number of clefts and couloirs surround the lake and its narrow valley.

By around 07:00 or 08:00 the snowshoer would have had arrived at Lake Agnes. He would then have snowshoed across the lake towards the summer trail at the southeast end.

A major storm had been raging in the days leading up to 14 March. Up to 40cm of snow had fallen on the local mountains that week, followed by rapidly warming temperatures and heavy rain up to about 2300m elevation on 13 March. Strong southwesterly winds accompanied the storm towards the end of the week. On the morning of the 14 March, the weather was clearing but still very warm, with daytime temperatures expected to be above freezing even at alpine elevations.

The storm had triggered the largest avalanche cycle of the season in the local mountains. Many avalanches—both natural and explosive-triggered—were occurring frequently on the 12 and 13 March. Several of these were size 4, and had destroyed mature

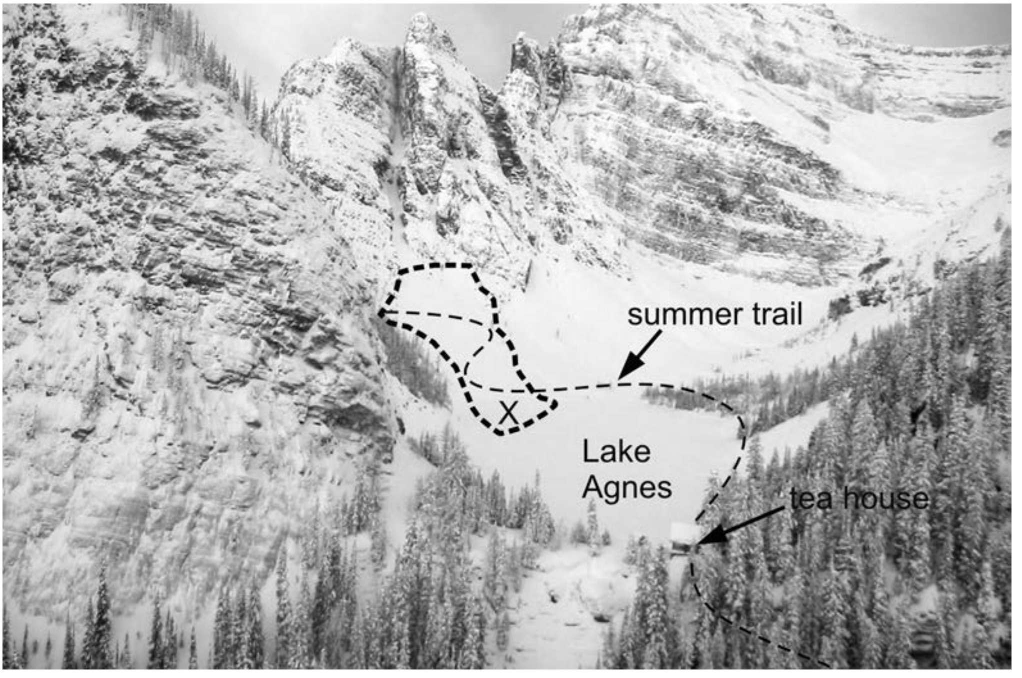

Figure 10.7. *Lake Agnes, 14 March 2003. X – location of buried snowshoer. Location of summer trail is approximate. Photo: Parks Canada.*

timber well beyond their normal runouts at the valley bottom. Both major highways had been closed temporarily during the storm, due to the avalanche hazard and to allow for avalanche control and clearing operations.

The Parks Canada Banff, Yoho, and Kootenay public avalanche bulletin issued for 14 March rated the avalanche danger at Extreme in the alpine and treeline, and High below treeline; Extreme danger means that widespread natural and human triggered avalanches are certain. The bulletin stated that travel of any kind in avalanche terrain was not recommended, including valley bottom areas normally considered safe.

The wife and young family of the snowshoer had been anxiously awaiting his return since the evening of 14 March. Just after midnight she reported him overdue. Rescuers from Parks Canada initiated a ground search along the trail toward Lake Agnes, but were turned back by darkness and the threat of avalanches.

At first light, the area around Lake Agnes was searched from the air, and a single set of tracks was discovered leading directly into the only avalanche deposit in the entire cirque. Given the ongoing avalanche hazard, rescuers had to stabilize the slopes using explosives before they could safely conduct a search on the ground. The results of the explosives were impressive: nearly every slope in the entire bowl avalanched, with large powder clouds and dense deposits covering much of the valley floor. Fresh deposits overran the original avalanche, and enough snow hit the lake to fracture its ice cover.

With the area safe for rescuers to proceed, they began a search near the first avalanche. An avalanche rescue dog quickly indicated the area of the buried snowshoer, yet a significant amount of probing was required to pinpoint his exact location. Rescuers uncovered his body from under about 2m of snow, at least 1m of which was from the first avalanche. He was not wearing an avalanche transceiver, and had died because of the burial.

The first avalanche that rescuers spotted from the air was a size 2, triggered by the snowshoer near the base of a 35 – 37° slope. The crown fracture was a short distance up the slope, below a cleft or couloir in the rock wall above the lake. The location of the tracks suggests the snowshoer may have been trying to climb up the slope to where the summer trail is shown on a map of the area. There were no other avalanches in the cirque that would have been visible to the snowshoer, but, as described in the bulletin, a major avalanche cycle was occurring in the local mountains. This means that the warning sign of recent slab avalanches would have been noticed by travellers to other nearby areas, or those who had read the avalanche bulletin.

The first avalanche released on a weak layer above the rain crust formed in November. When explosives were applied to the slopes around Lake Agnes following the accident, rescuers reported that the avalanches were breaking all the way to the ground, releasing the entire snowpack (including the November crust layer). The amount of precipitation associated with the storm, the warm temperatures and strong winds, and the amount of rain falling all conspired to overload the weak layer, weaken the stiff overlying slab, and eventually break down the crust to the point where the whole snowpack was unstable.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Extreme	Yes	Yes	?	Yes	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
37°	None	Concave	Open Slope

Source
- Marc Ledwidge
- Parks Canada

Comment
This accident occurred when the regional avalanche danger was Extreme, and travel in or near avalanche terrain was not recommended.

The area of this accident was complex terrain with significant exposure to avalanche hazard.

Self-rescue is usually not possible when completely buried in an avalanche. It is safest to travel with a beacon, shovel, and probe, and a partner who knows how to use them.

17 March 2003, Backcountry Skiing
Kokanee Glacier Provincial Park, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	Complex

- **Experienced group mindful of conditions, approaching a snowpack test site**
- **Convoluted terrain**
- **Big, out-of-sight slope triggered from below**

In the winter of 2003, the Slocan Chief cabin in Kokanee Glacier Provincial Park was in its last season of operation, about to be replaced by the new Kokanee Glacier cabin later that summer. A group of six avid backcountry skiers had booked the Slocan Chief that final winter, and had arrived on 15 March for a week of ski-touring. Members of this group knew each other well, and had climbed and skied together at backcountry huts annually for the previous decade. They arrived at the tail end of a major storm and avalanche cycle, and for their first two days had skied conservative lines in the trees.

The morning weather observations made at the cabin (approximately 2000m elevation) showed a maximum temperature the previous day of 2.5°C, with -6°C recorded at 07:30 on the morning of the 17 March. They had 9cm of snow in the previous 24 hours, with a total of 92cm cleared from the storm board. It was snowing lightly under broken skies, and the mountaintops were obscured by cloud.

An automated snow survey site located about 10km south of the cabin at 2100m elevation recorded over 190mm of precipitation (water equivalent) in the previous two weeks, with daytime temperatures hovering around freezing on 12 and 13 March. Rain fell up to about 1900m elevation during that warm period, with moist snow falling up to about 2500m elevation. For much of western Canada this was the storm of the year, and it had triggered a major avalanche cycle throughout Alberta and British Columbia.

The morning stability evaluation form completed at the cabin mentioned 110cm of settled snow resting upon a weak layer of surface hoar and faceted crystals that formed during a cold, clear period in the middle of February. The group of skiers at the cabin was aware of the major avalanche cycle that was just ending as they arrived. The stability evaluation summarized a number of avalanches reported by nearby forecasting operations. Numerous loose snow and slab avalanches had occurred in the Selkirk Mountains the previous day, including two large naturals from 2400m elevation, and two remotely triggered avalanches between 2250m and 2450m. Each of these four notable occurrences released on the weak layer of surface hoar and facets buried in mid-February.

By the morning of 17 March, avalanche activity was waning and the skiers at Slocan Chief felt the snowpack was "tightening." They were keen to explore further afield, but spent the early part of the morning observing a snow profile and performing snowpack tests along with the hut keeper. Soon after they left for a ski tour to an area near the cabin called "Grizzly Benches," located on the far side of Grizzly Bowl below the north terminus of the Kokanee Glacier. They knew that conditions could change as they traveled, and planned to do more snow studies at a higher elevation to confirm their findings near the cabin. They all agreed to turn around if they encountered an unstable snowpack during the day.

The snowpack tests the group performed near the cabin, including several rutschblocks, produced low to moderate scores that the group interpreted as "very favourable for skiing" (see Comment below).

Because of the heavy snowfall and major avalanche cycle that had occurred that week, the Canadian Avalanche Association was temporarily producing public avalanche bulletins every two days. The most recent was issued in the evening of 14 March, valid through 17 March. The avalanche danger forecast for 17 March was High in the alpine and treeline elevations, and Considerable below treeline. Forecasters discussed that stability would be improving towards the end of the forecast period, but that much caution was still required, especially on lower-angled slopes that had not avalanched during the cycle. They noted that only light loads, like a single skier, would be required to trigger many slopes and release large avalanches. The group was aware of this avalanche bulletin, and aware that their trip would take them through each of the elevation bands.

They gave the treeless expanse of Grizzly Bowl a wide berth as they traversed below it, en route to the treed benches on the far side. As usual, they spread out as they climbed, sticking to safe routes in thick timber and along ribs and ridges, avoiding steep slopes. Just before noon, the lead group of three skiers stopped to rest as they broke out of the trees at a broad, low angled bench near 2400m elevation. The remaining three caught up, then proceeded a little further along to dig a pit and do some snowpack tests.

One skier went ahead, while the other two followed. The lead skier made a curving traverse up the bench, headed for a small slope and a stand of small trees for the snow profile work. He had just made a kick-turn when the slope shuddered with a "whumpf."

The whumpf stopped them all in their tracks—the lead skier at the toe of a small slope, the two climbing with him on the bench, and the remaining three resting in a safe place a short distance away. They exchanged nervous glances, then noticed a small section of slope above them breaking loose. It was a small, manageable amount of moving snow, nothing compared to the torrent that seconds later followed a loud "boom." A large face a few hundred metres above, shielded from view at the bench, had released an avalanche.

The lead skier immediately turned downhill and moved quickly toward a small stand of trees about 50m down-slope, but before he could make it, he was overtaken by the moving snow. The avalanche pushed him in to the trees he was racing for, which he grabbed onto as tight as he could. The moving snow forced him higher up the tree, and the pressure from it caused him to lose consciousness temporarily. When the avalanche stopped, he awoke and, surprised he could breathe and was only partially buried, called out to his friends.

Meanwhile, the three skiers resting in a safe place had witnessed the avalanche but were not caught. They watched as the two skiers on the bench were caught by the avalanche, carried a short distance, and disappeared. They heard the lead skier yell from the tree that he was buried but all right and quickly began to search the deposit with their avalanche transceivers. They located the signal of one of the buried skiers, and immediately began digging him out. Shortly after they found the signal of the other buried skier and began digging for him. By this time, the lead skier had freed himself and joined the rescue effort.

About 30 minutes after the avalanche, they had uncovered one of the buried skiers under about 1.4m of avalanche deposit. He had no signs of life, and CPR was unsuccessful. The other buried skier was buried under about 3.4m of snow, and it took almost 50 minutes to fully excavate him and begin CPR. It was also too late, and CPR was unsuccessful.

The remaining four skiers decided it was best to get back to the cabin as soon as possible. By 14:00 they arrived, and used the radio to call for help. They gave the details of the accident to staff of the Provincial Park, reporting that the two victims were still in the bowl but some avalanche control might be required before it was safe to recover their bodies.

The surviving skiers were flown out to the highway by around 16:00, and avalanche technicians stabilized the surrounding slopes from the helicopter using explosives prior to landing at the avalanche site and removing the victims.

The slab avalanche was triggered from below, either when the lead skier made his kick turn or due to the combined weight of the three. It was a size 2.5, and released from a steep, northwest facing 55° slope at 2490m elevation. It was 250m wide, with an average thickness of about 1m. It ran about 200m down the slope. It crossed the 20° bench that the victims were on, and proceeded about 90m down the 25° slope below. The two skiers caught in the slide were buried just below the bench. A small stand of trees was destroyed in the track of the avalanche.

On 18 March, an avalanche technician visited the site to conduct an investigation. He found approximately 115cm of settled— but not particularly stiff— storm snow resting on a weak layer of 3 – 6mm surface hoar. Below that was a stiff layer of partly faceted crystals. The technician suspected the surface hoar was the layer buried on 15 February, which had been responsible for so much recent avalanche activity. This layer fractured with a moderate force in snowpack tests at the profile site.

The layers of settled storm snow overlying the surface hoar made for a thick but relatively soft slab. The upper, softer 60cm layer probably allowed skis to penetrate quite deeply, allowing the weight of the skiers to reach the weak layer and trigger a fracture there. The stiffer layer below, combined with the weight of the layer above, allowed the fracture to propagate to an extent that a dangerous avalanche could release. The heavy snowfall in the days prior to this avalanche likely came too quickly to allow the weak layer to adjust to the load above, leaving it in a very unstable and sensitive condition on 17 March.

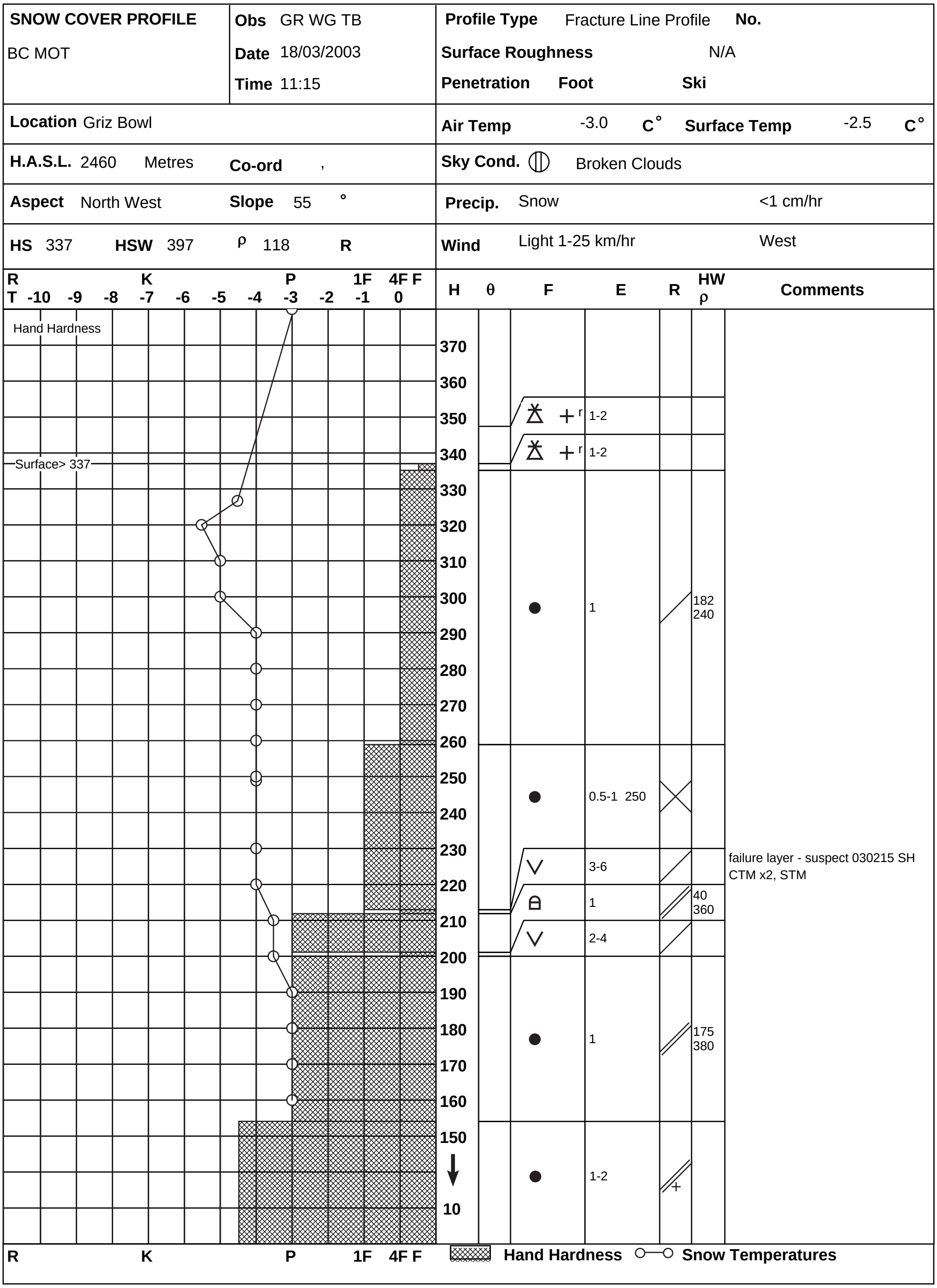

Figure 10.8. Kokanee Glacier Provincial Park, 17 March 2003. Snow profile observed one day after the accident.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	Low-moderate test scores	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
55° (start zone)	?	Unsupported	Sparsely treed slope

Source

- BC Coroners Service
- Witness report
- InfoEx

Comment

In order to stabilize, very heavy snowfalls require extra time to settle. However, if the new snow buries a persistent weak layer, that same settling can create a slab over the weak layer. It is not always easy to know when this is occurring, but the public avalanche bulletin is the best place to start if local knowledge is not available.

In convoluted terrain, it is possible to be below big slopes that are difficult to see, and sometimes they can release large avalanches triggered from gentle terrain below. Maps, terrain photos, and local knowledge can help identify the places or routes with hazard overhead.

The low rutschblock scores the group observed would generally be considered an indication of unstable snow. Many avalanche safety books explore the interpretation of snowpack tests in more detail (e.g. *Staying Alive in Avalanche Terrain*, by Bruce Tremper).

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20 March 2003, Snowmobiling
Ram Range, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Highmarking without transceivers, probes or shovels**
- **Two riders exposed**

On 20 March, two snowmobilers left the trailhead in Hummingbird Creek to access the slopes of the Ram Range about 43km south of Nordegg, Alberta. They began to highmark in a northeast-facing bowl of Mt Bramwell, at the head of Onion Creek. They did not have transceivers, probes or shovels.

There was no avalanche bulletin for this area in 2003. It is 30km from the bulletin region for Jasper National Park. The bulletin issued on the previous afternoon noted, “Over a metre of snow fell last week with strong southwest winds.”

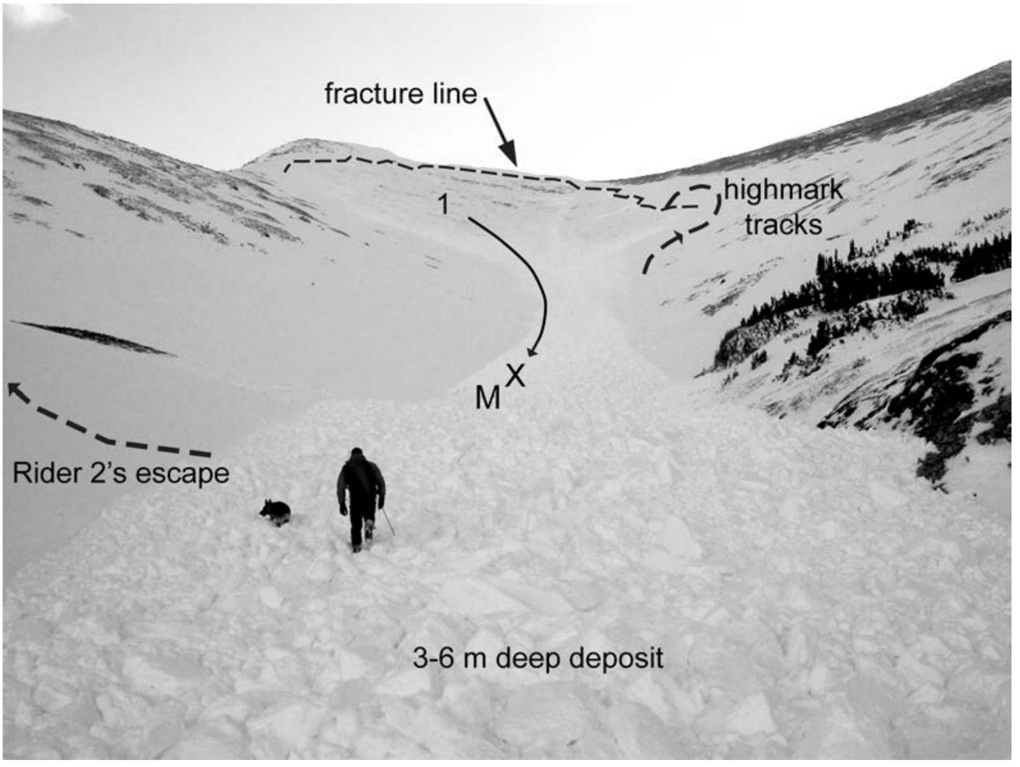

Figure 10.9. *Ram Range, 20 March 2003. Part of a highmarking track is shown just outside the avalanche. X – deceased (Rider 1), M - snowmobile. Photo: Parks Canada—Brad White.*

At about 13:40, it was not snowing, the sky was broken, a moderate wind blew from the southwest and the temperature was about -5°C. One rider (called Rider 2 in this summary) was low on the slope while his companion (Rider 1) was highmarking the bowl at the head of the gully. A large avalanche released. Rider 2 saw his companion and the snowmobile tumbling down with the avalanche. He accelerated to the side, out of the path and onto a bench. When the avalanche stopped, Rider 1 could not be seen but parts of the snowmobiler (a ski and part of the cowling) were visible.

Rider 2 hurried to his companion's snowmobile and tried digging into the avalanche deposit with his hands for a few minutes. Realizing this was ineffective, he drove his snowmobile to the trailhead, then a further 35 – 40km until he could contact authorities with his cell phone.

Rescue staff from Kananaskis Country and from Parks Canada responded in separate helicopters. The Parks Canada staff had an avalanche rescue dog. The helicopters arrived at 16:45 and 17:40. They started to probe where the dog indicated about 30m upslope from the partly exposed snowmobile but had no success before limited remaining daylight dictated their departure.

The next morning a combined team involving people from Kananaskis Country, Parks Canada, the local search and rescue team and two search dogs located the victim—about 3m above the partly exposed snowmobile. Rider 2 was found dead under 3.5m of avalanche deposit.

The crown of the dry slab avalanche was 100m wide, with an average height of 30cm and a maximum height of 70cm. It released at 2575m in shallow rocky terrain near a rock outcrop. The rescue team suspected the avalanche released on the rain crust from November 2002.

In the gully below the bowl, the deposit was 800m long, 30m wide and estimated to be mostly 3 – 6m deep. The deposit contained angular blocks. The toe of the deposit was at about 2225m. It was a size 3. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	?	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	Gully	?	Alpine Slope

Source

- Alberta Tourism Parks and Recreation
- Parks Canada

Comment

Due to the deep burial, basic rescue equipment (transceivers, probes and shovels) would not have saved the victim's life, but a transceiver would have shortened the rescue.

Triggering of deep persistent weak layers often occurs in localized areas of thin snowpack, as in the rocky terrain in the upper part of this bowl.

A fatal avalanche occurred previously in this bowl on 28 March 1998.

26 March 2003, Snowmobiling
Fairy Creek, Rocky Mountains

Deaths	Avalanche Problem	Terrain
3	Deep Persistent Slab	Complex

- **Snowmobilers parked in runout zone during hill climbing**

On Wednesday 26 March, many snowmobilers had left their trucks along the Hartley Lake Road outside Fernie, BC, to go snowmobiling near Mt Trinity and in the Fairy Creek drainage. They separated into groups in different riding areas. Although deposits from older avalanches were visible, no fresh slab avalanches were reported. Near the head of Fairy Creek, seven riders climbed into a high east-facing basin. This may have been the first time during the winter that any snowmobilers had reached this high basin.

Two days before the snowmobiling trip, the Canadian Avalanche Association issued a regular bulletin for the South Rockies rating the regional avalanche danger as Considerable in all elevation bands. The bulletin also noted: "Rapid warming may cause the near surface crust to deteriorate, causing a rise in danger. Cautious choice of terrain should allow enjoyable skiing and riding in the light powder layer above the crust. Avoid bunching up into large groups as this may overwhelm the strength of the crust. When the sun pops out, treat south aspects with additional respect. ... The lower snowpack is still weak but isolated from forces above by the midpack at treeline and above, except in shallow snow areas."

At a weather station for a cat-skiing company, 1850m elevation and about 12km south of the high basin, snowfall and wind had been light in the two days before the snowmobiling trip. The air temperature had been between -13 and -2°C. In the two preceding days at the two nearby cat-skiing operations and at the nearby lift-based resort, there had been a few slab avalanches in the storm snow and on the mid-March crust, but no deep slab avalanches and no avalanches larger than size 2.

The seven snowmobilers made a couple of short climbs low in the bowl. At about 14:00, four of them parked and watched one rider climb to the top of the slope. Two more riders arrived and were crossing the bottom of the bowl. After pausing at the top of the slope, the rider at the top of the slope started down his up track. Partway down, just above a steeper section, a crown fracture appeared in front of his snowmobile, spreading quickly across the bowl. He rode over the fracture but was able to stop himself on the bed surface, above the main moving mass of the avalanche.

As the avalanche swept down the slope, the six riders in the runout zone tried to get away. Some started their snowmobiles and at least one who was walking towards his snowmobile tried to flee on foot. When the avalanche stopped, two were partly buried (and survived). Three could not be seen. A transceiver search detected the signals from the three missing riders. Avalanche professionals from Island Lake Cat Skiing and Fernie Alpine Resort flew to the site. The first victim was recovered after 30 minutes; the last after two hours. They were found dead under 3, 4.5, and 5m of avalanche deposit. Asphyxia was confirmed for one death and suspected for the other two.

The crown fracture of the dry slab avalanche was 500m wide at 2350m elevation on a southeast-facing part of the bowl where the slope angle was 35 to 40°. The crown height ranged from 80 to 260cm and averaged

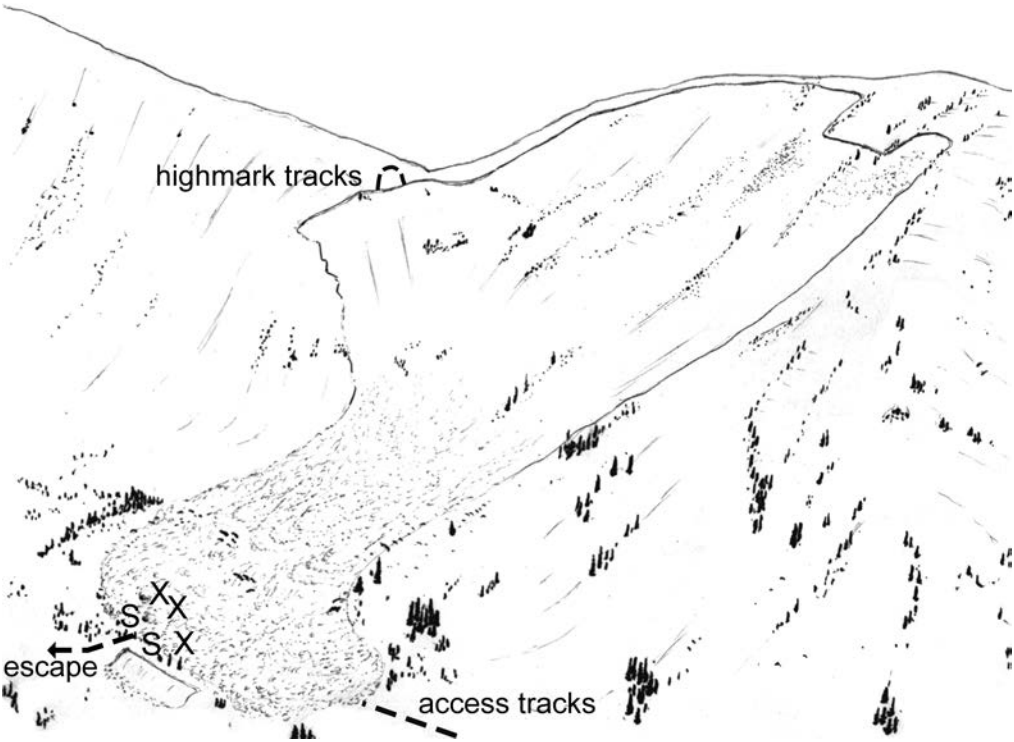

Figure 10.10. *Fairy Creek near Fernie, BC, 26 March 2003. The people who were caught were in the runout zone when the avalanche released. S - survivor, X – deceased.*

150cm. Most of the slab released in the facets on top of the November rain crust. In some places lower on the slope, the avalanche stepped down to faceted crystals next to the ground.

The avalanche ran down the slope for approximately 600m and ran out at 2050m on approximately level ground. The deposit was 200m long and 200m wide. Parts of the deposit were moist. The funneling of the bowl and transition to level ground contributed to the depth of the deposit, estimated at an average of 3m. All three victims were found in depressions where the deposit was particularly deep. It was a size 3.5 deep slab avalanche.

There were no fresh slab avalanches reported in the Fairy Creek area. It is unknown if the snowmobilers observed other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Depressions	Concave	Open slope

Source

- BC Coroners Service
- InfoEx
- Patterns of death among avalanche fatalities: a 21-year review (Boyd et al., 2009).

Comment

Although the freezing level did not reach the elevation of the avalanche, the investigator reported that solar radiation on the southeast-facing slope was strong.

There was no evidence of previous deep slab avalanches in this particular bowl.

Although deep slab avalanches had not released on the November crust in the area in the preceding few days, it remained a concern throughout much of the winter. By this time of year, avalanches on this layer were characterized by low frequency and high consequence.

It is often difficult to judge how far large avalanches can run. In this case, the vegetation was a clue that the large avalanches could run to where the snowmobilers were parked.

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26 March 2003, Heli-skiing
Mt Terry Fox, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Avalanche released on a four-month-old poorly bonded crust**

On Wednesday 26 March, a group of nine heli-skiers were skiing with a guide in the Selwyn Range about 11km northeast of Valemount, BC. After lunch they made their fifth run of the day and their second on the north-facing slope of Mt Terry Fox. The upper part of the run was glaciated.

The Robson Roadside weather station at 944 metres and 11km north-northeast of Mt Terry Fox recorded no precipitation in the preceding three and a half days. At this weather station, which is about 1500m below where the group was skiing, the temperature reached 2°C higher than the previous day. At the elevation where the group was skiing, the snow was dry. The previous day, the heli-ski operation reported one cornice-triggered size 2 avalanche at 2300m on a northeast-facing slope.

The avalanche bulletin issued by the Canadian Avalanche Association two days before the accident rated the alpine zone as Considerable with areas of High. It also noted: “Fairly widespread storm snow avalanches occurred Saturday, with some reports of stepping down to lower layers, some as deep at the November crust. ... We are in a time where the frequency of avalanches is going down, but the size of the events that do occur is increasing. ... North facing aspects will represent the greatest danger, particularly just below ridgelines and near treeline.”

The guide told the guests to wait until he was down the upper steep part (pitch) of the slope, and then ski one at a time. When he reached the bottom of this pitch, he radioed the next person to ski down. When this skier reached the regrouping site, the next skier (second guest) started down the pitch at 12:50. After he skied about 30m down a 15–25° slope, a slab avalanche released where a 25–30° convex roll crossed the slope. Then, the gentler slope above the convex roll released an avalanche. The second guest disappeared in the avalanche.

The guide informed the heli-ski base that one person had been buried in an avalanche. Then, he skied down to the helicopter and flew to the top of the run, where he led the remaining seven guests to a safe site. The guide selected four guests and led them down to the deposit, below where the missing guest had last been seen. It was about 10 minutes after the avalanche when they began searching with transceivers for the missing guest. Five minutes later, they located a signal, probed the missing guest about 2.5–3 metres deep in the avalanche deposit, and began to dig. A second helicopter with a toboggan and two additional rescuers arrived. After approximately 20 minutes of digging through the compacted deposit, the buried guest was sufficiently uncovered for artificial respiration to begin. Further digging was required before the rescuers could free the victim from the deposit and load him into the helicopter. He was pronounced dead at Valemount Health Centre. He had asphyxiated.

The slab avalanche released on a lee, north-facing slope at 2670m. There was one convexity at the crown and another lower down the slope. Most of the crown was 1–3.5m in height. The avalanche was 375m wide. Cracks extended several hundred metres laterally through the snow that did not avalanche. The slab had released in facets on top of the rain crust from November 2002, and run down the slope for approximately 500m.

It was a size 3.5 avalanche. The deposit was in three lobes, the average depth of which was estimated to be 3 to 4m. The maximum depth was estimated to be 6m.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes (one cornice triggered)	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
30°	None	Convex	Open slope

Source

- BC Coroners Service
- R.J. Kingston
- InfoEx

Comment

This avalanche was apparently triggered by the first or second guest. No skier-triggered avalanche on the crust that formed in November 2002 had been reported in the North Columbia Mountains since mid-January 2003.

Since avalanches on the November crust would likely be large, the one recent avalanche that was triggered by a falling cornice was probably not on the November crust.

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27 March 2003, Snowmobiling
Mt Brewer, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Variable snowpack in the starting zone**
- **Very deep burial**

On Thursday 27 March 2003, a snowmobile guide led 12 guests on snowmobiles to the headwaters of Brewer Creek, about 28km west of Fairmont Hot Springs. In the afternoon, they were climbing the large southeast-facing bowl of Mt Brewer.

On the afternoon before the snowmobiling trip, the Canadian Avalanche Association issued a regular bulletin for the South Columbia Mountains, which includes the Purcell Mountains. The regional danger rating at and above treeline was Considerable with areas of High danger. The bulletin also noted: "The February 15th buried surface hoar layer is down about 150cm and below that lies a series of persistent instabilities, the most serious of which is the November crust down near the ground. ... Activity is decreasing in frequency since the weekend, but any slides that are occurring are in the larger size classes. ... Your greatest concern this week may be the lingering potential for deep releases on the same persistent instabilities that have been a concern for some time now. Cornice fall and heli bombing still produces fracture lines up to 2m deep! A good bet may be deciding to stick to conservative, non-committing terrain for some time yet."

The regional bulletin summarized the weather: "Cool, cloudy conditions prevailed this week, although daytime highs at lower elevations still got to as much as plus 6. Cloudy conditions kept the nights from getting much cooler than -7. Winds were generally light out of the SW. The weather forecast predicts more of the same until the weekend..." On the afternoon of the snowmobiling trip, the heli-ski operation 30km to the north reported "a few clouds, intense solar radiation, temperature at 2700m -8 to -9°C, light wind from the northeast, nil precipitation."

Recent avalanches that had released naturally or had been triggered by snowmobilers were visible near the head of Brewer Creek. Looking at the alpine bowl from below, the left side faces east-northeast and the right side faces south. Parts of the upper bowl were wind-loaded and parts were cross-loaded. Ribs and bulges of rock were exposed, indicating variable snowpack depth and strength. Much of the bowl was about 37°.

Before snowmobiling 20km down Brewer Creek to the staging area, the guide made a final climb up the bowl at about 15:00. He entered the bowl from the south and was part way up the slope when a large slab avalanche released about 200m above him. The guide was carried about 100 vertical metres down slope and buried in a depression at the bottom of the bowl. Only one other member of the group was at the bottom of the bowl; he fled to higher ground.

One of the group drove to where there was cell phone coverage and called for help. The others moved onto the deposit and began the transceiver search. Guides from RK Helicopter Skiing flew to the avalanche at 17:40. They located the victim's transceiver signal and suspected a very deep burial. After digging a hole about 4m deep, they could not probe the victim with a 3m quick-assembly sectional probe with a pull cord. Some of the snowmobilers had screw-together sectional probes. From these, they assembled a 5m probe and probed the victim. They dug down to partly expose the victim, did not find a pulse, then left at 19:00 so the helicopter could return to the base in daylight.

The guides returned the next day with patrollers from Panorama Mountain Village and excavated the victim. He was under 7.3m of the deposit. He had asphyxiated. In the summer, the snowmobile was recovered 10m below the burial site.

The crown fracture of the dry slab avalanche was on a 37° slope at 2730m elevation. The height of the crown was 150cm in the middle and about 37cm at the flanks. Near the crown, the avalanche was 850m wide. In most places, the failure layer was the facets on the weakened remains of the rain crust from November 2002. In sheltered places, surface hoar was found on the bed surface. The rain crust was more prominent on the more southerly aspect. The snow below the bed surface was weak and the avalanche stepped down through weak facets and depth hoar to ground in many places. Near the crown the snowpack height varied from 93 to 239cm, indicative of the variable distribution of snow in this alpine bowl.

The victim was found at about 2350m. Probing at the bottom of the hole did not reach the ground so the total depth of the deposit and snowpack at that location was more than 10.3m. Part of the deposit ran down to the lake at 2330m. The runout zone was narrower than the start zone and track, contributing to the very deep deposit.

Two to four days after the avalanche, compression tests at the crown gave variable

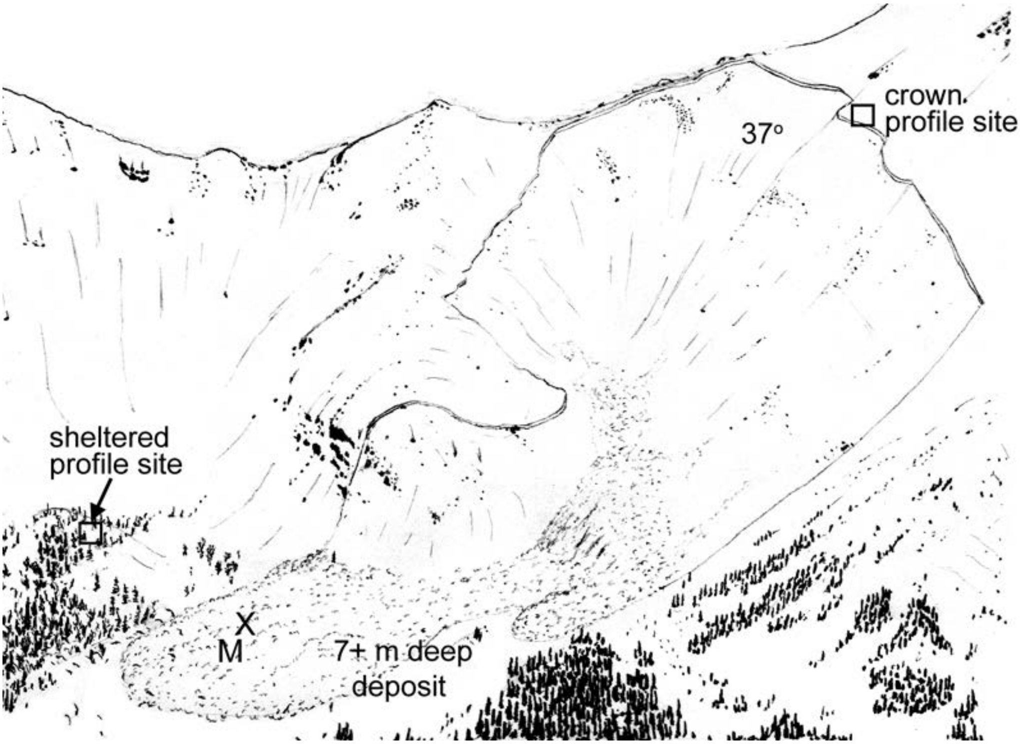

Figure 10.11. *Mt Brewer Creek, 27 March 2003. X - deceased, M – snowmobile.*

results in facet layer above or below the November rain crust. In some tests, the facets collapsed when the column was cut. In others, moderate tapping was required to cause a fracture in the facets. At a sheltered site beside the main bowl, the lower facets collapsed when the column was cut.

It is unknown if the snowmobilers noted the recent slab avalanches or if they observed other signs of instability.

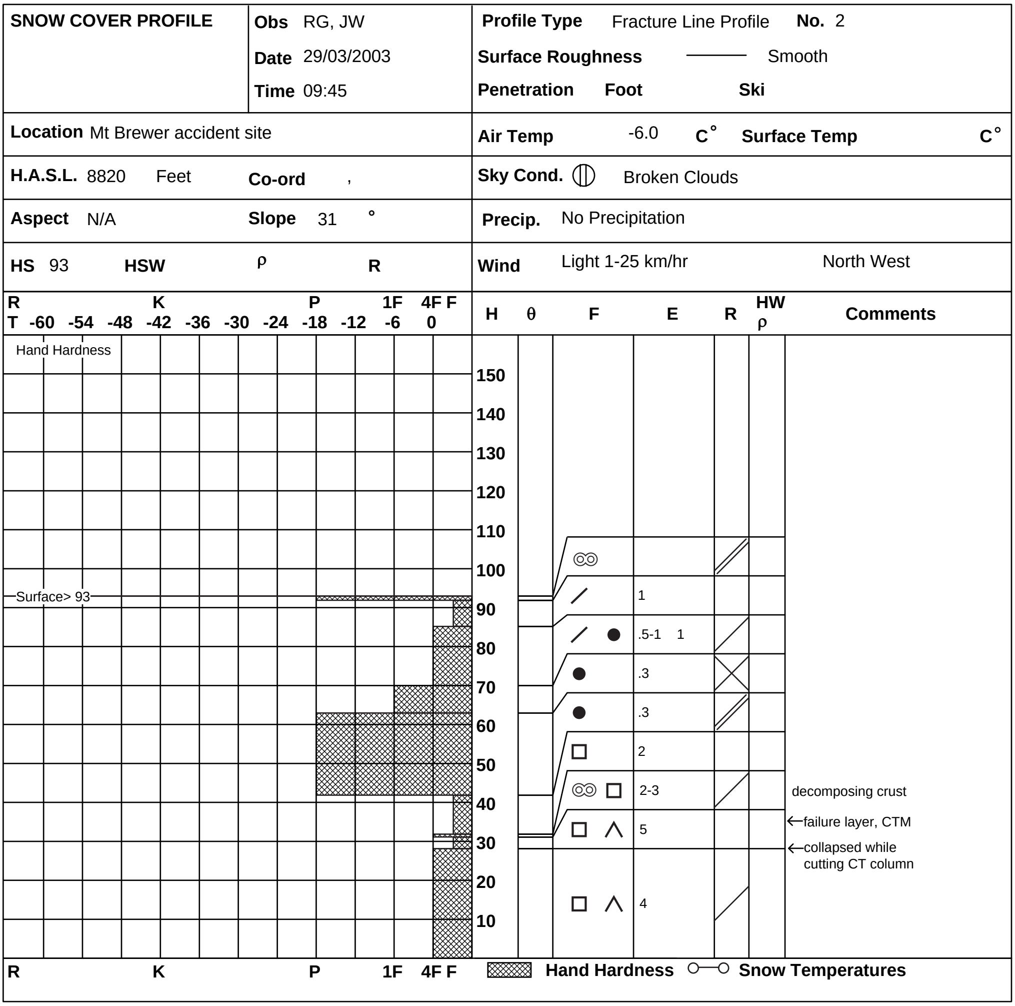

Figure 10.12. Mt Brewer, 27 March 2003. Snow profile observed at a sheltered site by investigators on 29 March 2003.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Depression	Planar	Alpine Slope

Source

- BC Coroners Service
- Rod Gibbons
- InfoEx

Comment

Given the snowpack conditions mentioned in the bulletin, a human-triggered avalanche on this large slope was likely to have high consequences.

The depth of the slab, the funneling of the large slope and the depression in the runout zone contributed to the very deep burial. Few people survive burials deeper than 2m.

This accident occurred less than 2km north of one the previous winter.

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6 April 2003, Snowmobiling
Holt Creek, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Avalanche released just after two snowmobilers freed a stuck sled**

On the morning of Sunday 6 April 2003, an Alberta man drove to Golden, BC to go snowmobiling with his aunt and uncle. The group of three headed into the Holt Creek area about 15km northwest of Golden, BC.

Two days previously, the Canadian Avalanche Association issued a regular bulletin for the South Columbia Mountains including the Purcells. The regional avalanche danger was rated Considerable in the alpine, and Moderate at and below treeline. The bulletin remarked that the danger would rise to High with daytime warming at and above treeline. The bulletin also noted: "In all areas there continues to be a concern that deeply buried weak layers will fail with significant warming or with the weight of a surface avalanche or cornice drop. ... Although air temperatures have remained relatively cool, daytime warming continues to be a concern in the form of solar radiation. This type of warming affects steep southerly slopes and rocky areas most. Stay vigilant when in and beneath this sort of terrain."

On 5 April most operations in the North Purcells reported 0 to 5cm of snow and light winds. Near the top of the Kicking Horse Mountain Resort, 2325m elevation and 10km southeast of where the threesome were snowmobiling on 6 April, there was no snowfall and the air temperature was between -12 and -8°C with light wind. Although the air remained cool in the alpine areas of Holt Creek, radiation was likely strong since some heli-ski operations to the south reported that the surface snow became moist on sunny aspects up to 1800 to 2200m.

After a few hours of snowmobiling, the three snowmobilers stopped for a break, probably around 14:00. The man from Alberta decided to climb a steep alpine slope but got his snowmobile stuck on the slope. While he was trying to free his snowmobile from the deep snow, his uncle drove up to help him. After freeing his nephew's sled, the uncle drove down the slope several metres from the up-track. As he descended, he looked over his shoulder, saw an avalanche sweeping down the slope and accelerated out of its path. The nephew had just started down when he was struck by the avalanche.

The aunt and uncle immediately started to search the deposit with their transceivers. Two other snowmobilers had witnessed the avalanche and came to help. The aunt and uncle found their nephew in about 13 minutes under 1m of the deposit. Since he had no pulse, they tried to resuscitate him. The other two snowmobilers left to get help, and contacted authorities at 14:52.

Rescuers responded by helicopter, took over resuscitation, and flew the man to Golden Hospital where he was pronounced dead about 45 minutes after his arrival. He had asphyxiated.

The slab avalanche started on a southwest-facing slope at about 2400m elevation. The crown was about 150cm high and 350m wide. One rescuer, who was familiar with the local snowpack, suspected that the avalanche released on the rain crust from November 2002 and, in places, ran to the ground. The avalanche ran about 800m down along the slope. It was a size 3 avalanche. It is unknown if the snowmobilers observed previous avalanches or other signs of instability, or if they made any snowpack tests.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High on sunny slopes	Yes	?	?	No	Yes (radiation)

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	?	?	Alpine

Source

- BC Coroners Service
- InfoEx

Comment

Although the air temperature remained cool, solar radiation was strong enough to moisten the surface snow below 1800 to 2200m. Radiation is more effective for warming the snow surface than warm air with little wind.

There are a number of incidents in which an avalanche released when one snowmobiler was helping another free his snowmobile. In this case, the two snowmobilers had just separated, so the avalanche may have been triggered by either moving snowmobile.

The companion search was efficient.

18 April 2003, Snowmobiling
Mt Ptolemy, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Cornice Fall	Complex

- **Snowmobiler fell with cornice**

Little has been reported about this accident. A group of six were snowmobiling near Mt Ptolemy along the divide of the Rocky Mountains. The ridge of Mt Ptolemy ranges in elevation from 2000 to 2700m. Much of the Alberta side of the ridge is a very steep face.

Two days before the accident the Canadian Avalanche Association issued a regular bulletin for the South Rockies. In all three elevation zones, the avalanche danger was rated Moderate with the note that conditions would deteriorate with warm daytime temperatures. The bulletin also mentioned: "The warm temperatures are especially a concern in the shallower Alberta snowpack, which has become weaker than that in the Fernie area. ... Although avalanche activity has been minimal, expect that to change if the sun starts coming out and causing intense radiation and raising freezing levels. Larger wet surface avalanches will begin occurring, cornices will fall off, and lingering instabilities will wake up. Expect avalanche danger to go to High and some larger slab avalanches to run if the weather forecast holds true."

At 1650m in the Fernie Alpine Resort, located 34km west-southwest of Mt Ptolemy, the air temperature reached 6°C on the day of the accident. At 1190m in the town of Pincher Creek, located 50km east of Mt Ptolemy, the air temperature reached 12°C.

A snowmobiler was on a cornice when it broke and fell down the steep side of the mountain into Alberta. The falling cornice started an avalanche. The snowmobiler was carried over a 300m cliff.

A helicopter and search dog were called to the scene. The victim was found under 100cm of snow about three hours after the fall. The cause of death was a head injury.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate	?	?	?	?	?

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
N/A	Cliff	Unsupported	Open slope

Source

- CTV Winnipeg (online, 20 April 2003)
- InfoEx
- Patterns of death among avalanche fatalities: a 21-year review (Boyd et al., 2009).

Comment

Cornices can be difficult to recognize from the windward side. Also, it is difficult to judge how far back from the edge a cornice might break.

Chapter 11

Avalanche Accidents of Southwestern Canada **2003-2004**

Winter Summary for Southwestern Canada

- **9 fatalities in 7 accidents in southwestern Canada**
- **Average snowpack height and weather conditions in all ranges**
- **October rain crust not a factor in accidents**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
8 Jan 2004	Albert Creek	Selkirk Mountains	Backcountry Skiing	1	Persistent Slab	25 Dec 2003	278
30 Jan 2004	Russel Creek	Selkirk Mountains	Heli-Skiing	1	Persistent Slab	22 Jan 2004	280
1 Feb 2004	Cayoosh Mountain	South Coast Mountains	Backcountry Skiing	1	Storm/Wind Slabs		283
2 Feb 2004	Norns Creek	Selkirk Mountains	Snowmobiling	1	?		288
13 Feb 2004	Mt Wilson	Rocky Mountains	Ice Climbing	3	?		290
20 Mar 2004	Mt Symons	Monashee Mountains	Snowmobiling	1	?		292
9 Apr 2004	Vice President	Rocky Mountains	Backcountry Skiing	1	Cornice Fall		294

[1] *It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.*

The winter season of 2004 is best characterized as average in most of its features. Rain in October fell on a thin snowpack, and regular snowfalls and intervening cold snaps resulted in a few persistent weak layers that were not widespread, although were involved in a number of avalanche accidents. Two fatal avalanches, located at the headwaters of **Albert Creek on 8 January** (page 278) and in the **Russel Creek drainage on 30 January** (page 280) were confirmed to have released on persistent weak layers of surface hoar. Storm snow released on a buried crust at **Cayoosh Mountain on 1 February** (page 283), while a late January surface hoar layer may have been involved in an accident at **Norns Creek on 2 February** (page 288). On 20 March on **Mt Symons** (page 292) a fatal avalanche may have released on a buried crust.

October saw significant precipitation in the Coast and Columbia Mountains, although much of it fell as rain. At Mt Fidelity (1874m) in the Columbia Mountains it rained for 13 days, with a small amount early in the month, and followed by a major rain event beginning around the 15th that fell on a snowpack only 50cm thick. At Lake Louise (1524m) it also rained around the middle of the month, although lesser amounts fell. By early November the rain-soaked snowpack was frozen and buried by a small amount of new snow when cold, clear weather settled in to all ranges. That cold period led to the faceting of the snow overlying the crust. Unlike the previous winter, this crust and weak layer did not become a major player in later avalanches, having mostly stabilized by the end of December.

By mid-November when snow started to fall again, the Rocky Mountains had an average snowpack height, while the Columbia and Coast Mountains were slightly below average. The Columbia and Coast Mountain snowpacks recovered quickly, both reaching average levels by the third week of November. At that time, Lake Louise reported a record high snowpack height of just over 50cm. Steady snowfalls and a few more significant storms continued through to early December when two short-lived ridges of high pressure brought clearing skies and cold temperatures. Surface hoar and facets formed in all ranges. Stormy weather returned to the Coast and Columbia Mountains around 8 December with average temperatures, while the Rockies near Lake Louise had no precipitation and daytime high temperatures near freezing. All ranges were at about average snowpack height by mid-December, and except for a brief period with only small snowfalls in late January, would remain there for the duration of the season.

The next high-pressure ridge settled in to the Columbia Mountains for a few days just before the Christmas period, leading to widespread surface hoar growth especially in the southern parts of the range, although in many places the surface hoar was destroyed by winds in the following days. Small amounts of snow fell on all ranges over Christmas and into the New Year, when temperatures plummeted as arctic air flooded into the mountains from the northeast. North winds and very cold temperatures affected all ranges, with light snow falling at Lake Louise but mostly clear skies in the Columbia and Coast Mountains.

At the end of the first week of January temperatures began to rise as warm, wet weather from the Pacific pushed into the mountains. Moderate snowfalls occurred in the Coast and Columbia Mountains, overloading the Christmas surface hoar layer and resulting in a fatal avalanche at **Albert Creek on 8 January** (page 278). The Whistler Roundhouse (1835m) recorded a significant rain event with temperatures just above freezing on 14 and 15 January. The south Columbia mountains and south Rockies near Fernie also had warm temperatures with rain to treeline, although in much of the northern part of the Columbia and Rocky Mountains the precipitation fell as snow with warm temperatures and strong southwest winds. Temperatures fell slightly after this—although still staying very warm—resulting in a frozen rain crust in the Coast and southern Rocky and Columbia Mountains. It continued to snow in parts of the Columbia Mountains, while Lake Louise was relatively dry with well above average temperatures.

A short period of clear weather ended around 22 January in all ranges, when new snow began burying yet another sporadic layer of surface hoar crystals, especially in the southern Columbia Mountains. Rain fell briefly in the Coast Mountains on 24 January, but it continued snowing after that, which resulted in the burial of a frozen crust, and the faceting of the new snow directly above it. By 30 January the stormy period was ending, but not before temperatures spiked along with a heavy snowfall and strong winds. On that day, in the Valhalla Range near Nelson, BC, a large avalanche released on the 22 January surface hoar layer in **Russel Creek** (page 280)burying two skiers and claiming the life of one. The avalanche that killed one snowmobiler at **Norns Creek on 2 February** (page 288) near Castlegar may have slid on this surface hoar layer as well. On **1 February at Cayoosh Mountain in the South Coast Mountains** (page 283) another fatal avalanche occurred, this time when strong winds created slabby conditions in the new snow, which then slid on one of the two crusts buried in January.

Minor disturbances affected the Coast and Columbia Mountains, bringing new snow and some windy weather during the first week of February. A strong ridge of high pressure became anchored over all ranges by about 10 February, leading to mild temperatures and clear skies. Large and widespread surface hoar grew during this period in the Columbia Mountains, while in the Coast Mountains surface hoar was found on shady aspects, and sunny slopes built up temperature crusts as the snow surface began to melt. Fine weather and a temperature inversion in the Rocky Mountains made for excellent ice-climbing, although on 13 February a large avalanche released from the upper slopes of **Mt Wilson** (page 290) near the Icefields Parkway and overran a group of climbers lower down, killing all three.

Snow arrived to all ranges by mid-February, although only small amounts fell near Lake Louise. Throughout the Columbia Mountains and South Rockies the new snow buried a significant layer of surface hoar, which most observers called the ”Valentine’s Day” weak layer. Despite being a layer of serious concern, the Valentine’s Day surface was not involved in any fatal accidents.

Stormy weather continued into early March. Small amounts reached Lake Louise, while snow turned to rain at Whistler Roundhouse on 8 March when temperatures spiked. The Columbia Mountains received most of the precipitation during this period, with heavy snow falling for about a week, and some rain reported at treeline elevations on 7 and 8 March at Mt Fidelity. Temperatures cooled in the Columbia Mountains and after a brief respite and later a one-day break, snow continued to fall until the end of March. The rain left a prominent crust buried in the snowpack, which may have been responsible for a fatal avalanche south of Revelstoke, BC at **Mt Symons on 20 March** (page 292). A series of weak disturbances affected the Coast Mountains during the second half of March, although accumulations were less than normal with warmer than average temperatures. The Rocky Mountains near Lake Louise received small amounts of snow in March.

Early April was mostly warm and dry in all ranges, and small amounts of precipitation reached all ranges by the middle of the month. Snowpack heights were well below average in the Coast and Rocky Mountains at this time, and the Columbias had also slipped to below-normal levels. By late April, clear weather in the Rockies had warm days and cool nights creating the usual diurnal freeze-thaw cycle. The warmth of the morning sun on an east-facing slope led to a cornice failure and a fatal avalanche for a ski-mountaineer at **Vice President near Field, BC on 20 April** (page 294).

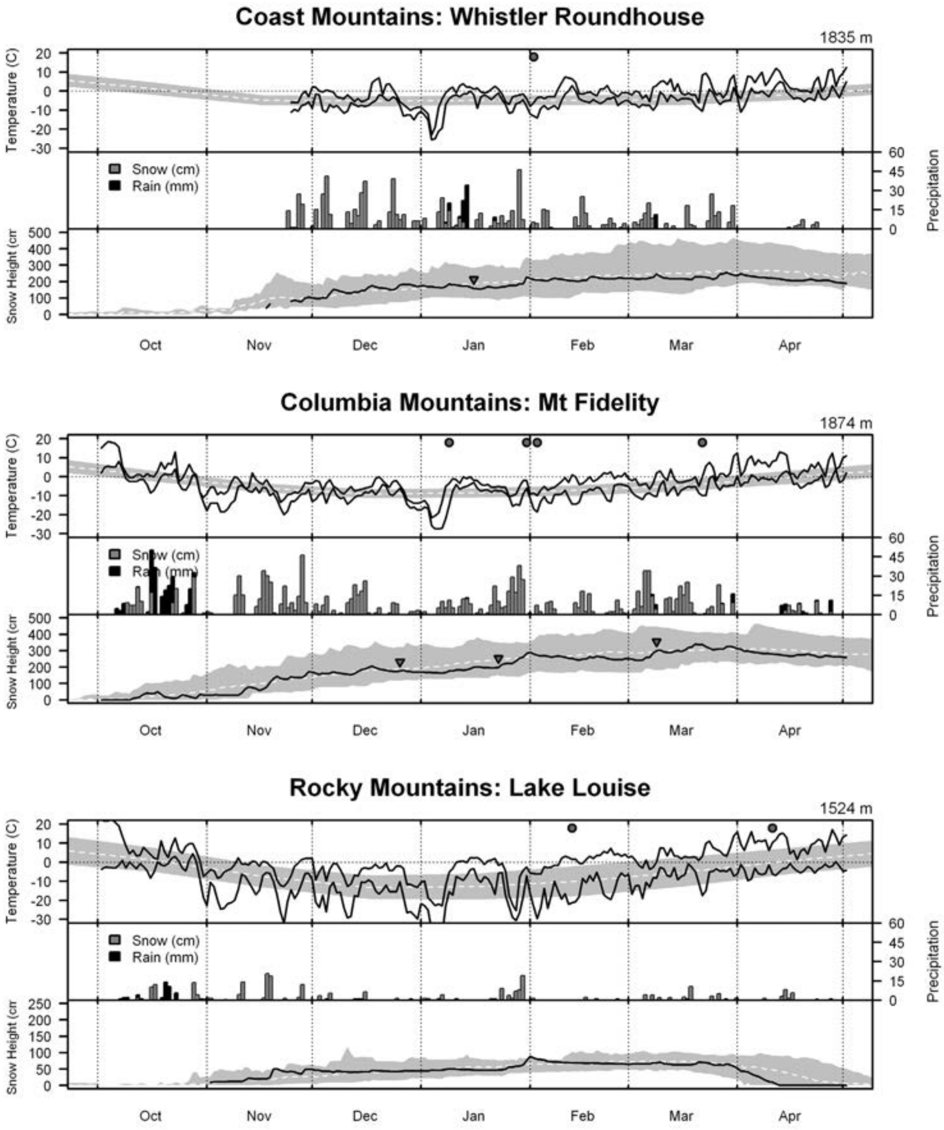

Figure 11.1. *Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 2003/2004 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanches (black triangles). The grey band shows minimum, average (dashed line) and maximum snowpack height measured at each location since 1976.*

8 January 2004, Backcountry Skiing
Headwaters of Albert Creek, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Inappropriate terrain choice by guest leads to fatal accident**
- **Trauma fatality**

This accident occurred during a week of guided backcountry skiing at the headwaters of Albert Creek in the Selkirk Mountains. The group, which included twelve guests, two mountain guides and two staff, arrived at the remote lodge on Saturday, 3 January 2004. The weather of this weekend was marked by the arrival of a ridge of arctic high pressure, accompanied by light northerly winds, clear skies and a dramatic temperature drop of about 10 °C to the mid -20's. The low temperature resulted in considerable faceting of the surface snow layers, which provided perfect conditions for enjoyable powder skiing during the first half of the week.

The snowpack at treeline was approximately 170 cm deep and the most significant feature in the snowpack was a faceted weak layer at or near the ground. This weakness was of particular concern above 1900 m, where it overlaid a melt-freeze crust that developed in late October. The second concern was a surface hoar layer that developed during a short period of clear weather just prior to Christmas. Light winds at the end of this period destroyed the surface hoar in the alpine and other exposed areas, resulting in this potential weakness being predominately distributed in sheltered areas at and below treeline. The surface hoar layer was buried on 24 and 25 December under approximately 20 cm of low-density new snow. Due to the unconsolidated nature of the storm snow, the persistently cold temperatures and insignificant amounts on new snow, the surface did not initially result in any avalanche activity.

On 6 January conditions changed when a low pressure system arrived from the Pacific and brought warm and moist air to the area. By the morning of 8 January, temperatures had risen by approximately 10 °C and the area had received 15-25 cm of new snow under the influence of southerly winds. The combination of new snow, higher temperatures and wind resulted in the development of wind slabs on northerly aspects and much more consolidated surface snow in general.

Due to the poor visibility and the challenging conditions the group limited their skiing on 8 January to conservative ski runs in the trees below the lodge. Many of these runs fan out on different aspects from a common base location where skiers put their skins back on before they start climbing again. Being cognizant of the conditions and having seen several natural avalanches on steep convex rolls above treeline, the group was skiing and climbing with caution.

Shortly before noon, five guests decided that they had enough skiing for the day and started climbing towards the lodge with one of the guides. The rest of the group, nine skiers and a guide, climbed the lower part of a west-facing ski run and stopped on a bench at treeline to take their skins off and prepare for the next run. From this bench, the ski line drops into the trees over a series of small rolls to a flat spot at the top of a small cliff band. The group had negotiated this cliff band on their way up and the plan was to retrace their steps through it on their way back down. The terrain in this area is rolling and gentle to the skier's right, but gets progressively steeper to the left, culminating in a steep convex roll which can be seen as a small cliff in the summer.

Based on his detailed local terrain knowledge, the guide chose a gentle ski line to the skier's right of a small ridgeline. Before skiing off to the re-grouping spot at the top of the cliff band, he instructed the group to follow his tracks. The first skier of the group, however, decided to go about 40 m to the skier's left of the guide's track beyond the faint ridgeline to a ski a few steeper turns. The avalanche released almost immediately as he entered the steeper section of the slope, propagating to the increasingly steeper terrain above and further to the skier's left. The victim was carried by the avalanche down the steep slide path for about 100 m before he was forced into a tree. While significant amounts of snow piled up behind the victim, his head was free of snow when the avalanche came to a stop.

An additional staff member, who was still at top of the run with the rest of the group, immediately called the guide on the radio. After deciding there was no further danger of another avalanche, she sent two people down to assist the victim. The guide and the two guests arrived at the victim within about two minutes of the avalanche happening. The guide immediately started giving mouth-to-mouth resuscitation to the victim, while the two guests started with his extrication. As soon as the victim was freed and placed on a level platform the rescuers had constructed from skis and jackets, CPR was started. A medical doctor skiing with the party arrived about five minutes after the incident and detected no vital signs. CPR was continued for about 90 minutes, but the victim succumbed to his severe traumatic injuries.

By the time the guide and two guests first arrived at the victim, the additional staff member also contacted Selkirk Tangiers, a close-by helicopter skiing company, and asked for their assistance in the rescue. Selkirk Tangiers immediately responded, sending an A-Star helicopter to the backcountry lodge to drop off a group of heli-skiers and pick up the second guide to assist in the rescue. They arrived at the accident site with oxygen and a large first aid kit within 15 minutes of the avalanche.

Rescue efforts were further assisted by a Long Ranger helicopter with long-line rescue equipment (also known as helicopter flight rescue system) operated by Selkirk Mountain Helicopters. On its way from the hangar in Revelstoke, it picked up a team of guides certified in long-line rescue techniques from Selkirk Tangiers about half-way between Revelstoke and the accident site. After a quick stop at the lodge to reconfigure the helicopter for the rescue, the Long Ranger was used to extract the victim and fly him to the backcountry lodge. There he was transferred to the A-Star and flown to the hospital in Revelstoke.

According to the subsequent accident investigation, the avalanche was a size 2, approximately 80 m wide and ran for about 100 m. The terrain was characterized by a steep convex roll with a northwesterly aspect. The avalanche was triggered from the side where the incline was 32 °, but the terrain becomes progressively steeper to the skier's left and above. The location was partly sheltered yet subject to some cross loading. The avalanche was a pencil-hard wind slab that failed on the surface hoar layer buried before Christmas and the fracture depth ranged from 20 to 100 cm.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	No	Yes	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Convex	Glade at treeline

Source

- Lodge owner and guide
- BC Coroners Service
- Environment Canada Climate Data for Mt Fidelity
- Canadian Avalanche Association public avalanche bulletins for South Columbia Region
- Glacier National Park public avalanche bulletin
- InfoEx

Comment

This accident highlights that while travelling safely in the backcountry under these conditions is possible, the margins of error are extremely narrow. Just a few metres can make the difference between safe and unsafe.

Whether guiding a group or just skiing with friends, clear communication is critical for safe travelling under challenging conditions. It is crucial that everybody in the group is completely aware of where to go next and—even more importantly—what terrain to avoid and why.

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30 January 2004, Snowcat Skiing
Russel Creek, Valhalla Range, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Long burial due to transceiver failure**

On the morning of Friday 30 January 2005, a group of 11 guests and two guides left Nelson, BC, by van to go snowcat skiing in the Valhalla Range. As is common for guided backcountry skiing, the skiers were all equipped with avalanche transceivers. The van met the snowcat at about 900 metres in the Russel Creek valley. Part way up the mountain, the cat stopped, and the skiers got out. All transceivers were checked and found to be working, and were in transmit mode as the skiers re-boarded the snow cat. The cat climbed to about 1980m on a ridge where the snow conditions were becoming unfavourable for further ascent. Before skiing the group had to remove ice from their skis and snowboards that had resulted from the rain and warm air at lower elevations.

The lead guide instructed the guests to carefully follow instructions because of the avalanche hazard. He chose a route with sparse trees that became more closely spaced during the descent. On the descent, he tried to "ski cut" (intentionally trigger) avalanches but none were triggered. The other guide skied at the back of the group. During the descent, the tail guide observed an "easy" hand shear. (Such results indicate the presence of a weak layer within the storm snow, but are not well correlated with avalanching.) At approximately 1850m, they left the trees to cross an avalanche path to reach the snowcat parked on the other side. Concerned about avalanches from the alpine start zone, the guide instructed the guests to cross the path quickly. Because the terrain was relatively flat, the guests could only slide about half way across before they stopped. Some removed their skis or snowboard to walk to the snowcat.

At the weather station where the van met the snowcat, the 24-hour snowfalls from 22 to 29 January totaled 112cm of snow. A further 23cm of 24-hour snow was observed on the morning of 30 January. The wind was observed to be "strong up high." From 25 January to the morning of 30 January, the temperature had risen slowly from -10 to -1°C. During the descent, the tail guide observed strong wind, an air temperature of -2°C, and snowfall at 1 to 2cm per hour.

On 28 January, the cat-skiing operation had observed three avalanches: a size 2 avalanche on a north aspect, another on a northwest aspect, and a size 1.5 on an east aspect. No avalanche observations were reported on 29 January.

The regional avalanche bulletin issued by the Canadian Avalanche Association on 28 January for the next two days rated the avalanche danger as High in the alpine and at treeline and Considerable below treeline. Although the elevation at which the snowcat was parked is typically below treeline, the group was crossing an avalanche path, which started well above treeline. The bulletin also noted, "The snow just keeps coming, and isn't going to stop loading weak snowpack layers at least until Friday [30 January]. ... Several small natural avalanches were reported in the storm snow. ... With continuing snowfall, a large avalanche cycle will be likely with some avalanches possibly running out into the valley bottoms."

At approximately 11:20 while the group was crossing to the snowcat, the two guides on opposite sides of the path spotted the powder cloud of a large avalanche running down the path. Both shouted a warning. The guests began to run when they, and both guides, were hit by the avalanche. Some guests reported being thrown up in the air. Some were carried 20 to 80 metres down the path. Some hit trees.

Despite being partly buried, the lead guide quickly counted heads and was able to see all but two of the guests. The tail guide called the snowcat driver, asking him to call for outside help. Within five minutes a female guest was located by a transceiver search and extricated from the deposit.

After a transceiver search organized by the lead guide began, no signal could be detected from the missing male guest. Using their avalanche probes, the group probed areas of the deposit where burial was considered likely. They also formed a line of probers to search the deposit.

After about two and a half hours, the first outside assistance arrived by helicopter. This included an avalanche dog and dog master, avalanche technicians from the provincial government, and search and rescue volunteers. The search continued until 5 February using a number of avalanche dogs and many volunteers. When the missing male guest was found under 120cm of snow, his transceiver was not transmitting. This was the reason he had not been found by thorough transceiver searches.

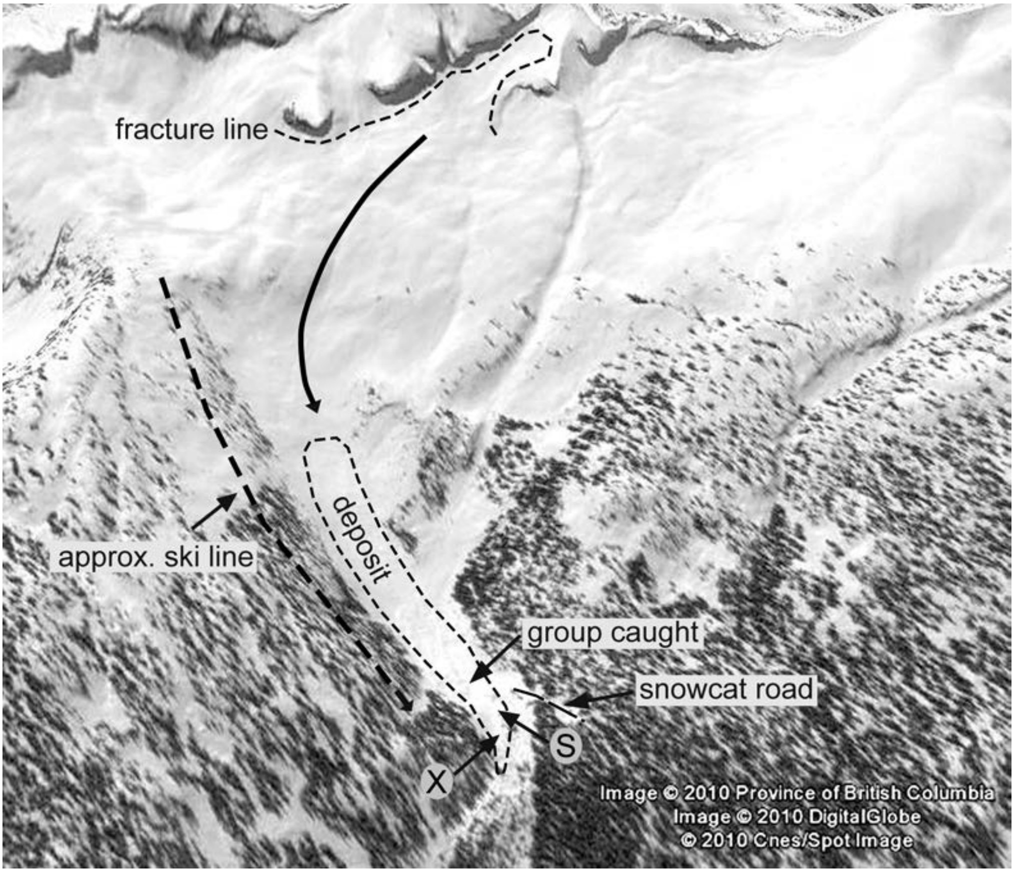

Figure 11.2. *Russel Creek, 30 January 2004. The group was traversing to the snowcat when they were hit by the avalanche. S – fully buried woman who survived, X – deceased. Image provided under the Google Earth terms of use, copyright 2010 Province of British Columbia, 2010 DigitalGlobe, 2010 CNES/Spot Image and 2010 Google.*

The transceiver began to work when it was turned off then on. He had asphyxiated.

The dry slab avalanche started on a north-east-facing 39° slope at about 2300 to 2400m, about half way between Mt Airy and Mt Spiers. The crown was approximately 30 to 100cm in height. The avalanche was about 220m wide, and ran about 1600m down the slope, stopping in a gully below where the guests were hit. The avalanche broke several large spruce trees along the sides of the path and many smaller ones in the runout. The smell from these broken trees made the avalanche dogs' search very difficult. The average depth of the deposit was about 2.5m and the maximum probed depth was 5.7m. It was a size 3.5 avalanche.

Clear periods ending on 24 December 2003 and 22 January 2004 had formed persistent weak layers of surface hoar and/or faceted crystals on the surface of many slopes in the South Columbia Mountains. (Often clear winter weather results in surface hoar in more sheltered locations and near-surface facets in areas more exposed to wind.) Snow profiles after the accident suggest the fatal avalanche released on the persistent weak layer buried on 22 January 2004.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	No	No	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Gully	Planar	Open gully

Source

- BC Coroners Service

Comment

Although the elevation of the guests would—in most places—be considered below treeline, they were crossing an avalanche path with an alpine starting zone, so the conditions and the danger rating for the alpine zone were more relevant.

Little can be learned from the critical transceiver failure because analyses by different specialists were inconsistent.

1 February 2004, Backcountry Skiing
Cayoosh Mountain, South Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Storm/Wind Slab	Complex

- **Second day after a week of continuous significant snowfall**
- **High consequence route on unsupported slope**

While the first three weeks of January were dry with little measurable snowfall in the Duffy Lake area, weather patterns changed on 24 January as the area was hit by the first of four distinct snow storms in short succession. Between 24 and 30 January, a total of 110 cm of new snow was recorded at Cayoosh Summit (Tbl. 1), a weather plot maintained by the BC Ministry of Transportation along the Duffy Lake Road. Particularly memorable was the last storm, which deposited 59 cm of new snow at this weather station on 29 and 30 January alone. During this storm, the town of Lillooet on the dryer east side of the Coast Mountains approximately 90 km east of the Cayoosh Mountain, experienced snowfall rates with accumulations of 30 cm in six hours. Moderate to strong southwesterly wind during the entire storm period resulted in the development of various wind slabs at higher elevations. These weather conditions lead to a significant widespread cycle of storm snow avalanches in the area, particularly on 29 and 30 January. The BC

Highways avalanche control program for the Duffy Lake Road reported numerous small slabs from cutbanks affecting the closed highway as well as an isolated large slab avalanche with a large powder cloud stopping only 70 m from the closed highway.

While the snowfall stopped and skies started to clear on 31 January, commercial backcountry operations in the area still reported signs of extensive storm snow avalanche activity primarily on the wind-loaded northerly to easterly aspects. As the snowpack was slowly gaining strength, the Canadian Avalanche Association downgraded the avalanche danger for the South Coast in the bulletin published in the afternoon of 31 January from High to Considerable in the alpine and at treeline, and from Considerable to Moderate below treeline. However, the bulletin mentioned that considerable variability existed and advised recreationists to make conservative terrain choices over the weekend.

Sunday, 1 February 2004, started as a cold day with clear blue skies. At 09:00 a group of three accomplished backcountry skiers left the Cayoosh Cabin to ascend the traditional route up Cayoosh Mountain via Armchair Glacier to a narrow gap that leads to a glaciated bench immediately east of the summit. Cognizant of the challenging avalanche conditions, the group assessed the snowpack by digging quick test profiles and hand pits at intervals of roughly 300 vertical metres as they were ascending the route. The observations showed surprisingly good bonding between the recent storm layers at these elevations. At approximately 12:30, the group reached the glaciated bench at 2400 m and took a break to have lunch.

At that point the group decided to ski the "Million Dollar Couloir" on the northern side of the northeast ridge of Cayoosh Mountain. Two of the party members were familiar with this run as they had skied it before. The couloir is reached by first travelling across the flat section of the northeast glacier before gaining the northeast ridge. The route continues along the exposed ridgeline for approximately 500 m before the terrain widens again close to the actual entrance to the Million Dollar Couloir. At approximately 13:30, the group reached the beginning of the narrow section of the ridgeline, which is characterized by a 40 ° east-facing slope with a sharp drop-off and large cornice to the skier's left (west) and becomes increasingly steep to the skier's right as it rolls off into a cliff band below. A large rock in the middle of the slope creates two different route options for traversing this section (*Figure 11.3*). After a brief discussion, the group decided to take the lower route, which goes below (skier's right) the large rock, approximately 1.5m wide. While this option is more exposed to the cliffs below, the group was worried that the higher track along the top of the ridge would be too close to the cornices hanging off the left (west) side of the ridge.

The group traversed the section without their climbing skins on, as there is only minimal side-stepping needed on the way. One of the party members stopped to take a couple of photos of the others approaching the ridgeline. At this point, the group was slightly spaced out with approximately 5 to 7m between each of them. After the first skier passed the rock, she started to angle the track back up towards the ridgeline. When the second skier reached the rock, she stopped in the track to wait for the photographer. As he skied up to the rock, he angled his track into the fresh snow just below her with enough room to put his back between them and put the camera back into it. His pack was half off and he was facing up hill when the slope suddenly fractured between the two of them (*Figure 11.3*).

While the first two skiers were above the fracture line, the photographer was standing on the slab with his skis across the fall line. As the snow began to move, he pressed his skis down hard in an attempt to break the slab and regain a hold on the bed surface. At this point

Weather observation at Cayoosh Summit
Elevation 1350 m

Date	Max. Temp. (°C)	Temp. Pres. (°C)	Min. Temp. (°C)	Snowfall (cm)	Snowpack (cm)
23 Jan	2.2	-0.5	-0.7	9	95
24 Jan	2.0	-2.5	-2.7	2	95
25 Jan	-0.6	-14.4	-14.4	22	110
26 Jan	-4.8	-6.9	-16.5	3	109
27 Jan	-3.4	-19.6	-19.7	14	116
28 Jan	-5.2	-5.2	-19.9	11	123
29 Jan	-0.6	-1.6	-2.8	0	118
30 Jan	2.0	-2.2	-2.4	40	152
31 Jan	-1.0	-5.5	-5.8	19	158
1 Feb	-1.6	-19.6	-19.6	0	149
2 Feb	-7.3	-15.7	-20.4	1	143

he was hit by a chunk of snow—about the size of a sofa cushion—that released above him. It caught him off balance and pushed him into the movement of the main slab. The avalanche was approximately 40 m wide and ran for 15 to 20 m carrying the victim over the edge of the cliff band to the east. The victim fell for about 125 m through the cliffs onto the slope below, where he was buried by the following avalanche debris (*Figure 11.4*). Immediately below where he landed, the falling debris triggered a second avalanche that continued to lower levels.

Since the avalanche slope was convex, the two survivors were unable to see where the victim went and the route to the deposit of the avalanche was not immediately obvious. While one of the survivors started to sidestep down on the very hard bed surface, the other survivor put on her climbing skins and ascended to a vantage point from where she would have a better view on possible route options down into the hanging valley below the cliff band (*Figure 11.3*). At that point she saw that the other survivor was getting precariously close to the cliff band, which was still out of sight for her. She alerted her friend that her intended route was a dead end and told her that she should very carefully climb back up to the ridgeline. Since time was of the essence, she did not wait for friend, but immediately continued to drop into the hanging valley and contoured along the base of the cliff to the deposit of the avalanche (*Figure 11.4*). She reached the area where the victim was buried between 15 and 20 minutes after the avalanche had happened. When she switched her avalanche transceiver to receive, she immediately picked up a signal. She also noticed a glove sticking out of the debris and as she approached the glove, the signal became stronger. She right away started to dig and uncovered the victim.

The victim was found in a folded position with his legs flat and his upper body completely bent forward under approximately 1 m of firm avalanche debris. The survivor dug the victim out enough to unfold his body and take a pulse. As there was no pulse and the victim's colour was bluish, she immediately began CPR approximately 30 minutes after the avalanche. CPR was performed for

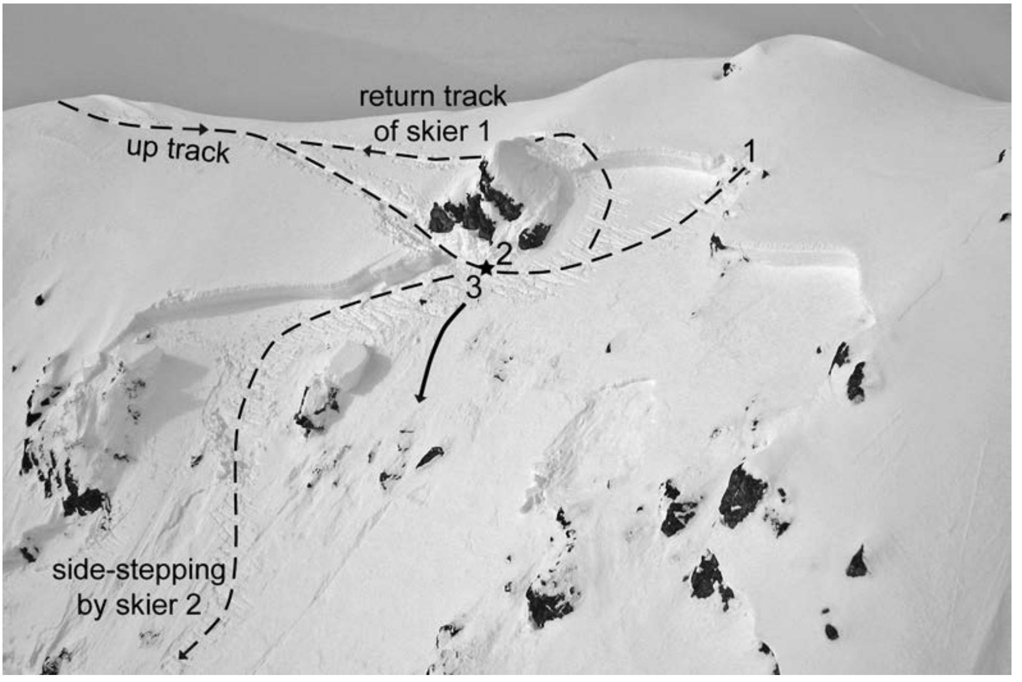

Figure 11.3. *Cayoosh Mountain, 1 February 2004. Overview of start zone. 1, 2, 3 – location of skiers when avalanche was triggered. Photo: Wayne Flan.*

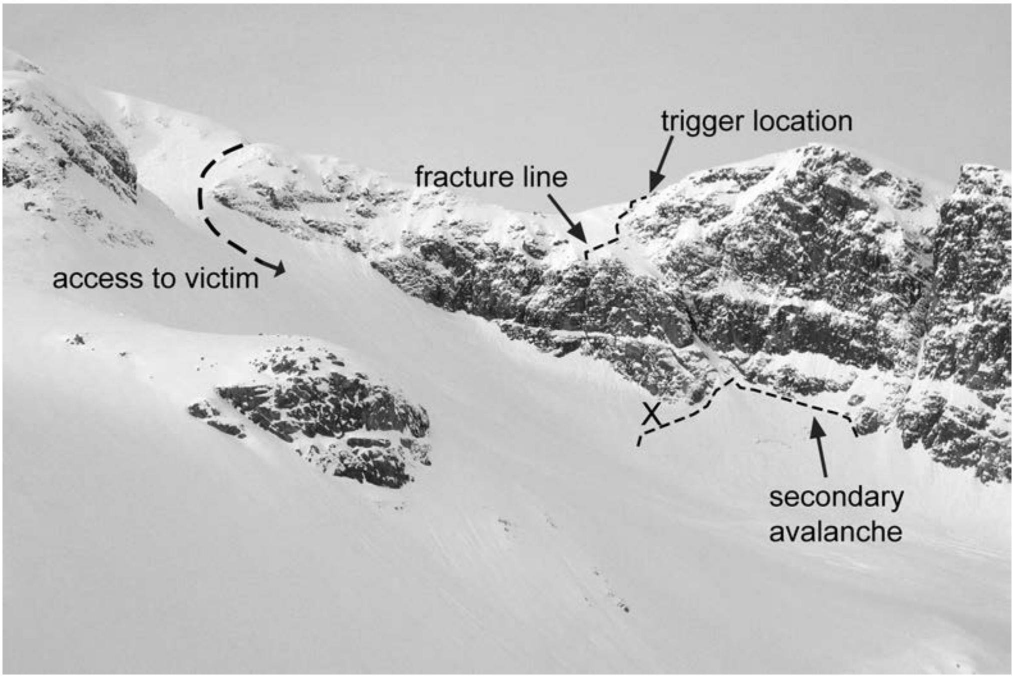

Figure 11.4. *Cayoosh Mountain, 1 February 2004. Overview of entire accident site with fracture lines of both avalanches and access route to victim. X – deceased. Photo: Wayne Flan.*

approximately 10 to 15 minutes before the second survivor arrived at the burial site. Together they continued with their rescue efforts with one person doing the breathing and the other person doing chest compressions.

At 15:30, after 45 minutes of CPR had failed to revive the victim, it became clear that further resuscitation efforts were futile and could potentially expose the two survivors to additional danger. Exhaustion was becoming a considerable risk factor and there was still significant terrain to ascend and descend to safely retreat back to the highway before dark. Before they left, they placed a tarp around the victim to protect him from the elements and planted a ski in the ground as a reference for the future recovery efforts.

They followed their route back to the cabin and skied down the logging road to the Duffy Lake Road. There they flagged down a motorist to take them to the police in Pemberton as the keys to their own vehicle were left in the victim's pocket. They reported the accident to the Pemberton RCMP detachment at approximately 19:00.

The following day, a recovery team consisting of one of the survivors, members of the local search and rescue team, the RCMP and avalanche technicians from the Blackcomb Ski Patrol flew to the accident site to evacuate the body of the victim and to conduct an accident investigation. The investigation revealed that the initial avalanche was a size 1.5, consisting of a 60 cm thick slab of storm snow that slid on a crust. Possible bed surfaces for this accident were the 15 January crust that developed during a rain event, or the 24 January melt-freeze crust that formed during a short period of warm and clear weather prior to the significant snowfall. Since the location of the avalanche was on an exposed ridgeline, it is quite plausible that the moderate to strong southwesterly winds during the storm event scoured the slope leading to a much shallower—and therefore more easily triggered—burial of the crust.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	No	Yes	No	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
40°	Cliffs	Convex, unsupported	Open alpine slope

Source

- Personal exchange with accident party
- BC Coroners Service
- British Columbia Ministry of Transportation Weather data for Cayoosh Summit
- CAA avalanche bulletins for South Coast
- InfoEx

Comment

While the accident party was cognizant of the challenging avalanche conditions and examined the snowpack during their ascent in the morning, they did not take into account that the terrain characteristics at the accident location were different from the test sites. The easterly aspect of the slope immediately below the ridgeline and its exposure to recent wind transport resulted in a locally much more unstable snowpack. While snow profiles can help to develop a better understanding of the snowpack—particularly the development of persistent instabilities—using this information to assess snow stability is a complex subject. It is recommended to always combine the information from a snow profile with all other available information and be aware of the limitations of snow profiles. Snow profile test results should not be used to justify more aggressive terrain choices.

The location of this accident was a steep and unsupported piece of terrain with the potential for high consequences if something goes wrong. Travelling in this type of terrain is unforgiving and does not allow for any assessment errors. It is best to approach terrain of this severity only after extended periods of low avalanche hazard.

While the subsequent medical examination of the victim revealed the primary cause of death was asphyxia, the victim sustained major trauma from his fall through the cliff band. This likely compromised his capability to struggle out of the avalanche and significantly reduced his ability to survive the burial. In Canada, approximately one quarter of all avalanche fatalities die directly from trauma. In an additional 10% of the fatalities, trauma was a major contributor even though the victims eventually succumbed to asphyxia (Boyd et al. 2009).

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2 February 2004, Snowmobiling
Norns Creek, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	?	?

- **Six snowmobilers stopped for lunch in an avalanche runout zone.**

Seven people from Washington State came to the mountains about 25km northwest of Castlegar, BC for recreational snowmobiling. Two days before the group went snowmobiling, the Canadian Avalanche association issued a bulletin for the South Columbia Mountains that rated the regional avalanche danger as Considerable at and above treeline. The bulletin also noted: "Winds from Friday [30 January] have loaded alpine and treeline N and E slopes. Weaknesses are reported within the storm snow 20-30, 40-70, and 60-110cm below the surface. Below the copious storm snow there is concern about a buried layer of surface hoar that is 40-110cm below the surface. This layer is more prominent as you move south. ... Many large natural and human triggered avalanches were observed Friday from all aspects. ... As danger moderates through the weekend under stable weather, users should be aware that it is most likely for deadly avalanches to occur while danger is rated as Considerable. You should wait until the snowpack improves before entering steep slopes or terrain that is threatened by avalanches from above."

The Paulson Summit Weather Station, elevation 1535m, is 33km southwest of where the group was snowmobiling. At this station, following a 48-hour storm ending in the early morning of 31 January, 26mm of snow-water-equivalent, 28cm of snowfall and moderate wind gusts were recorded. Only 5cm of snow fell on 31 January and none on 1 or 2 February. The air temperature ranged between -14 and -6°C on 2 February and the wind was light.

The seven snowmobilers stopped for lunch at the base of a bowl. They had taken off their packs. At 14:00, one rider wanted to try something with his snowmobile and headed up the mountain and out of sight of the rest of the group. Soon, one of the riders having lunch saw "the whole mountain coming down." They ran for their snowmobiles, leaving their packs. All six were hit by the avalanche. One was buried to his waist. Another was buried except for one arm; he was quickly uncovered without serious injury. One person was missing.

The group had lost their probes and shovels with their packs but had retained their transceivers. One was skilled with his transceiver and was able to help the others switch their units to receive. They localized the signal from the missing snowmobiler and began to dig with their hands and a windshield. After several hours, they found the top of a helmet. For the safety of the group, they left to get help. They got one of the snowmobiles working and sent one person to notify the RCMP.

At 07:00 the next day an avalanche technician from BC Highways flew to the site to assess the safety for the recovery team. He returned with explosives and used them to trigger a size 2.5 avalanche. On the next flight the recovery team arrived on the site. They found the missing snowmobiler with a transceiver search, probing and shoveling. He was about 215cm below the surface of the deposit, at the toe of the deposit in a flat area. He had asphyxiated due to chest compression from the weight of the avalanche deposit.

The crown fracture of the dry slab avalanche was half way down the northeast-facing avalanche path on a convex roll. The crown was 80–100cm high and about 90m wide on a 35 –40° slope. Extensive cracking of the upper snowpack was visible above the crown, indicating propagation beyond the start zone. It is unknown if the group observed any recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	?	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Convex	Open slope

Source

- BC Coroners Service
- BC Ministry of Transportation and Infrastructure weather data

Comment

One of the riders was critically buried but had an arm sticking out of the deposit. This facilitated a speedy recovery and his survival.

13 February 2004, Ice Climbing
Mt Wilson, Banff National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
3	Wet Slab	Complex

- **Avalanche started far above ice climbers on a sunny day with a temperature inversion**

Seven experienced climbers from Washington State came to the Icefields Parkway between Lake Louise and Jasper to climb frozen waterfalls in mid-February 2004. Early on 13 February, they split onto two groups to climb separate waterfalls. At about 08:30, one group of three (called Group 1 in this summary) left the Icefields Parkway to climb Midnight Rambler on the southwest-facing slopes of Mt Wilson.

On the afternoon of the previous day, Jasper National Park issued a bulletin valid for the following day that rated the avalanche danger in the alpine zone as Considerable. The bulletin also noted: "Warm daytime temperatures and sun exposure have triggered several new size 2 slab and loose snow avalanches on South aspects today. ... A mix of sun and cloud is forecast for tomorrow and temperatures are forecast to be even warmer than today. The avalanche danger on south and southwest aspects will increase with prolonged sun exposure."

There had been no substantial snowfall for a week. The sky was clear and there was no wind. The air temperature was about -15°C in the valley and -1°C in the high alpine, indicating a strong temperature inversion.

The other group of ice climbers, Group 2, finished their route early and returned to their accommodation on the David Thompson Highway. They became concerned that their friends on Midnight Rambler (Group 1) had not returned and, at about 19:00, three climbers from Group 2 went to look for Group 1. In the dark, they found Group 1's car and tracks leading up towards the route. Below the route they encountered a hard avalanche deposit in a confined gully. They called out and began to search, finding a helmet and then a rope. They followed the rope to where to it disappeared into the ice-hard deposit. They chopped with shovels and ski poles with little effect.

They returned to the Icefields Parkway to get help and arrived at the Saskatchewan River Crossing Warden Station at about 21:30. That night, a team of six with two avalanche dogs responded. With the help of one of the dogs, about an hour after midnight they found one person dead under 1m of the deposit. They returned to their base at about 02:30 on 14 February.

With a helicopter and more Parks Canada rescuers from Jasper and Lake Louise, the team set out at 07:00 the next morning. At 09:30 the second victim was found by an avalanche

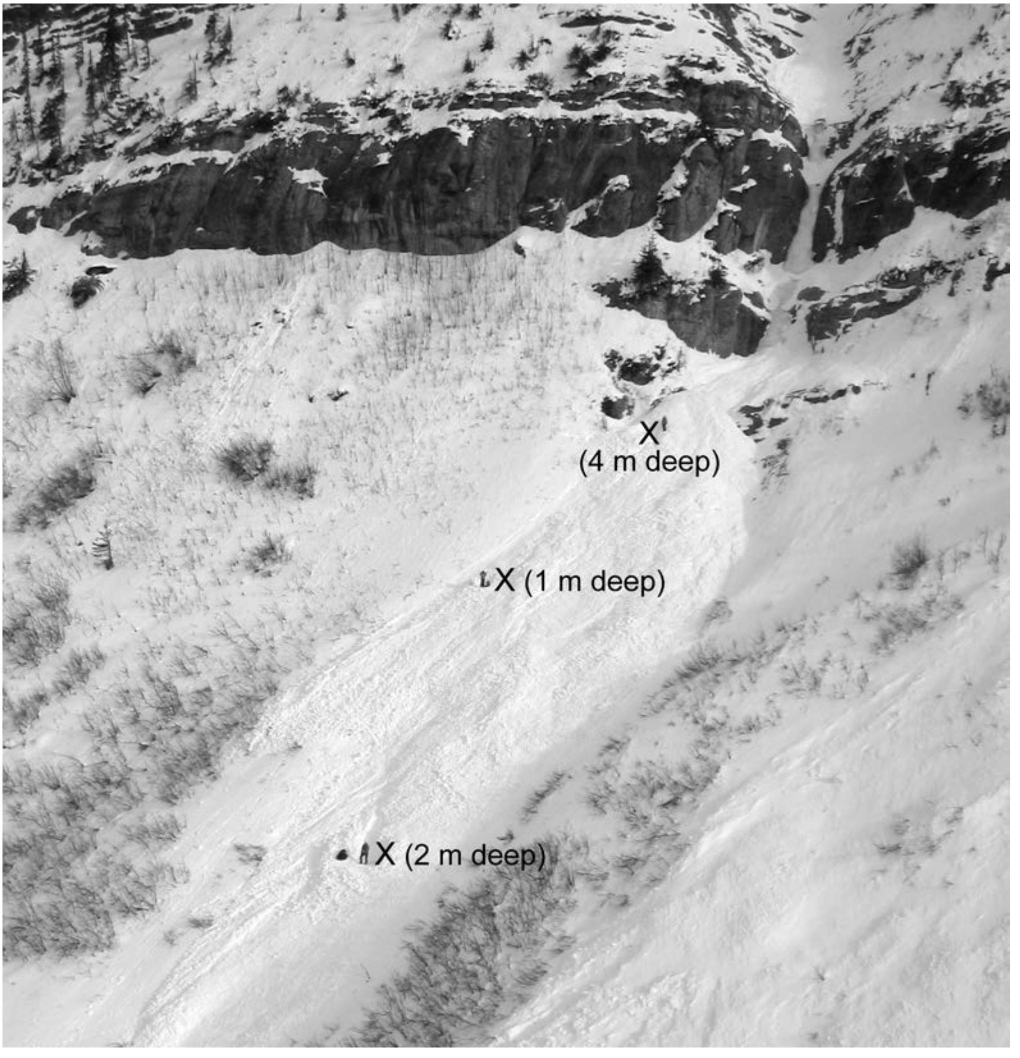

Figure 11.5. *Mt Wilson, 13 February 2004. The photo shows only the runout and the lower part of the route. X – deceased. Photo: Parks Canada—Marc Ledwidge.*

dog 2m down. At about 10:00, the third was found under 4m of the avalanche deposit by probing and following the rope. The climber buried 2m had died of multiple trauma. The other two had asphyxiated.

It was a size 3 avalanche that had started at about 2900m, well above the climbers and out of their sight. The avalanche descended about 1200m before sweeping the climbers down about 120m. Investigators estimate it occurred in early afternoon. The deposit was estimated to be 5 to 10m deep.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	?	?	?	No	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Cliffs	?	Alpine

Source

- Parks Canada
- Alpine Club of Canada Edmonton Section website
- Accidents in North American Mountaineering (American Alpine Club and Alpine Club of Canada, 2005)
- Patterns of death among avalanche fatalities: a 21-year review (Boyd et al., 2009)
- When rescuers become victims (Northwest Mountaineering Journal 6, 2009, available online).

Comment

One of the wardens involved in the rescue commented: "There was no way they would have known there was a temperature inversion." The bulletin warned about avalanches on south aspects, a mix of sun and cloud, and increased danger on south and southwest aspects with prolonged sun exposure.

The ice climbers were not wearing avalanche transceivers. The use of these units would not have affected the outcome.

20 March 2004, Snowmobiling
Mt Symons, Monashee Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Complex

- **Hill climbing with more than one snowmobiler exposed**
- **No transceiver**

On Tuesday 20 March 2004, several groups of snowmobilers were riding in the area of Mt Symons and Empress Lake in the South Monashees. The day before the snowmobiling trip, the Canadian Avalanche Association issued a regular bulletin for the South Columbia Mountains, which include the South Monashees. For the treeline zone where the riders were snowmobiling, the regional avalanche danger was rated High. The bulletin also noted: "Heavy snow and strong winds created wind slabs on north through east facing slopes down to well below treeline. In most areas the recent snow sits on a firm crust. This crust may have weak layers associated with it, either above or below, to create a dangerous combination of layers. Deeper weaknesses remain in the snowpack to 100cm. ... The potential for deeper releases exists, particularly on north and east lee slopes. Wind affected areas where pillows of new snow are deeper and stiffer should be avoided."

At the Galena Pass Weather Station, elevation 1570m, located 35km northeast of the snowmobiling area, there had been only about 3mm of precipitation since the morning of 18 March. On 20 March, the air temperature was steady at about -5°C. The wind was light and it was not snowing.

At about 11:45, a rider without a transceiver separated from his group (called Group 1 in this summary) and accelerated up a slope about 10m behind a rider from another group. When the leading rider reached the top of the slope, a slab avalanche released under his snowmobile. The second rider and two others were completely buried by the avalanche. An additional two riders were partly buried and able to dig themselves out of the deposit. Two of the buried riders had transceivers and were found alive. It was not initially recognized that a rider from another group was missing. Twenty to 25 snowmobilers, including riders from Group 1, came to help. When the riders from Group 1 realized that one of their members (without a transceiver) was missing, a line of probers was formed. After about 25 minutes of probing, the missing snowmobiler was found under 1m of the deposit. Guides from Canadian Mountain Holidays also arrived by helicopter to help with the rescue. Resuscitation continued for 90 minutes but was not successful. The victim had asphyxiated.

The dry slab avalanche released at 2100m near the convexity of a lee slope, which faced southeast. The slope reached 50° at the crown. The crown was 30m wide and 150cm in height. The size 2.5 avalanche ran down the slope for 150m.

Other riders in the area had noted a smaller avalanche to the east earlier in the day and were avoiding the steep slope where the accident occurred.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	?	Yes	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
50°	None	Convex	Open slope

Source
- BC Coroners Service
- InfoEx
- The Revelstoke Times Review (24 March 2004).

Comment
A European study (Falk et al., 1994) indicates that only about 30% of fully buried avalanche victims survive for 35 minutes. Unpublished Canadian data suggest shorter survival times. Consequently, because of the increased search time, fully buried people without a transceiver are rarely found alive.

9 April 2004, Backcountry Skiing
Vice President, Yoho National Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Cornice Fall	Complex

- **Cornice failure followed by 600 m fall and subsequent avalanche involvement**

In April of 2004, the snowpack in the Rocky Mountains had settled into the typical pattern of spring conditions. Under these conditions, the snowpack is generally held together by surface crusts that develop through the diurnal cycles of surface melting during the mild daytime hours and refreezing over night. Avalanche hazard is generally low during the morning hours when the snow surface is still frozen, but increases rapidly as solar radiation and mild temperatures weaken the surface crust during the day. Timing is the key to safe travel in avalanche terrain under these conditions.

Friday, 9 April 2004, started as another stellar day in the Little Yoho Valley with blue skies and temperatures below freezing. The previous day brought a little bit of new snow, but with 2.7 cm it was much less than originally forecast and did not significantly affect the avalanche danger. The public avalanche forecast for Banff, Yoho and Kootenay National Park from the previous afternoon rated the avalanche danger as Low at all elevations. It did, however, warn backcountry travelers of loose snow slides on steep southern aspects as the new snow warmed up, and the potential for cornice failures.

At approximately 09:30, a group of five friends from Montana left the Stanley Mitchell Hut with the goal to climb the President and the Vice President. The group arrived in the Little Yoho Valley the day before after successfully completing the Wapta Traverse. From the hut, the route to the two summits follows the drainage of the President Glacier up to President Pass. From there, both summits can be reached by bootpacking up the obvious ridgelines. On their way up the east ridge of the President, the group passed a group of three Canadians, who were also staying at the Stanley Mitchell Hut. The two groups met again at the summit of the President and exchanged a few words before heading back down to the pass to attempt the Vice President, the second objective of the day. Since not everybody wanted to climb the Vice President, the groups split up at the pass. In the end, three people from the Montana group and two Canadians were climbing together

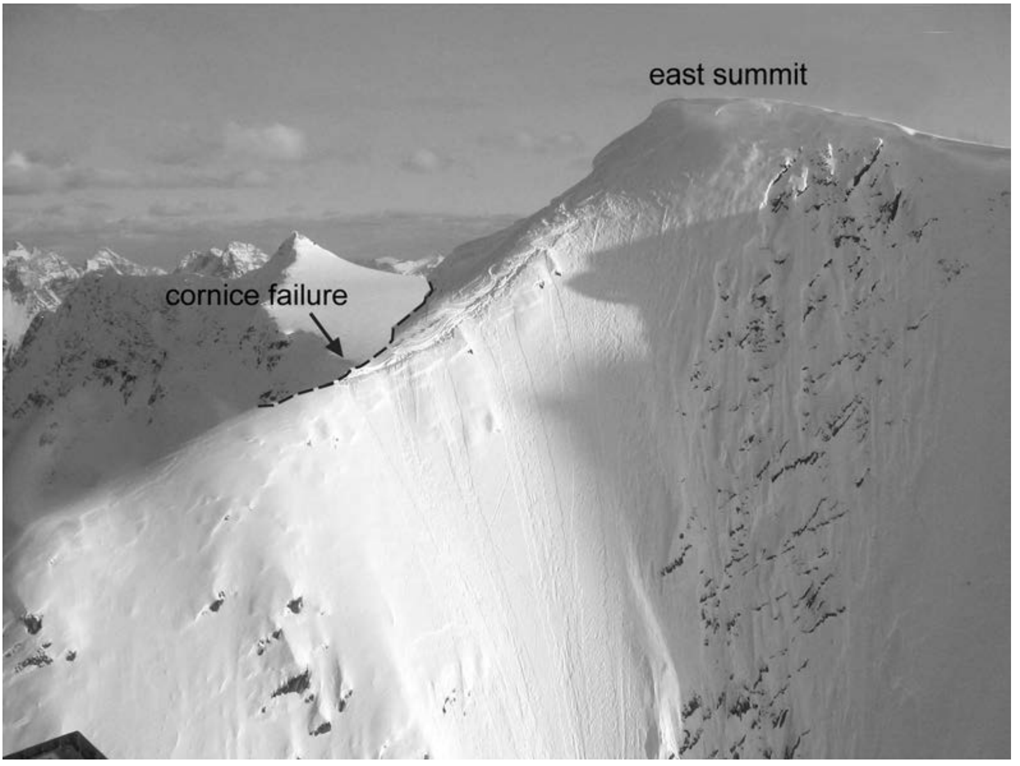

Figure 11.6 *Vice President, 9 April 2004. Location of cornice failure on north ridge of Vice President. Photo: Parks Canada—Brad White.*

towards the summit of Vice President. The remaining three individuals started their descent down the glacier towards the hut.

While looking at the intended route from the hut the previous evening, the group from Montana noticed an attractive ski line from the east summit of Vice President. The line consists of a north-northwest facing chute that drops north from the summit ridge separating the Emerald Glacier on the south from an unnamed pocket glacier on the north, east of the President Glacier. It is a steep 400 vertical metres straight down to the glacier below. To get to this ski line, however, one needs to find a safe entrance along the heavily corniced and seriously exposed north ridge of the east summit of the Vice President.

Once on the summit, one American and the two Canadians decided to attempt the inviting ski line. They skied over to the east summit and found a non-corniced entrance that would allow them to access the north ridge. At the same time, the two Americans who stayed behind on the main summit were getting ready to take some pictures, as they had an unobstructed view of the intended ski line. The three skiers then dropped onto the north ridge. The American skier first descended about 20 m and then another 15 m along the ridge in search of an entrance to the chute on the skier's left (*Figure 11.6*).

As the first Canadian skier arrived at the same spot, the first skier warned him about the potential of cornice failures. Suddenly, there was a cracking sound and a large gap appeared between the two skiers. The American skier was standing on top of the cornice as it was calving off the ridge down the east face to the skier's right. While he tried to jump to the safe side and arrest himself, he was unable to stop his fall and soon disappeared out of sight

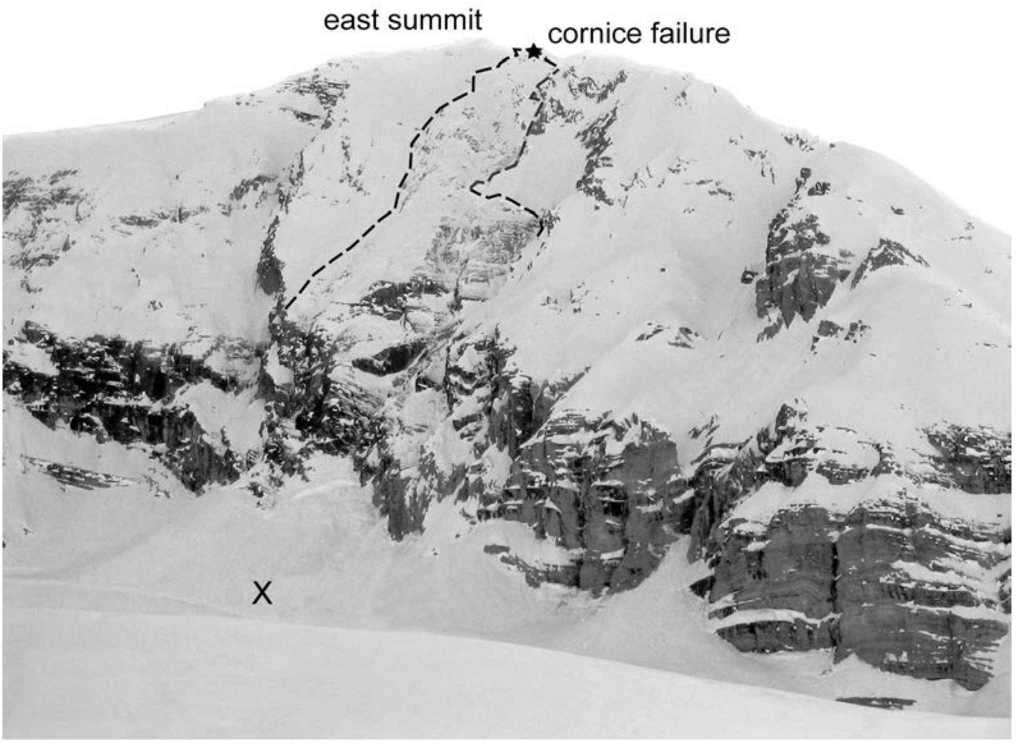

Figure 11.7. *Vice President, 9 April 2004. East face of Vice President with location of cornice failure and subsequent avalanche. Photo: Parks Canada—Brad White.*

from his two partners. The falling pieces of cornice subsequently triggered a size 3 avalanche on the face and while the two skiers at the top could see avalanche debris running out on the glacier below, there were no signs of the victim. (*Figure 11.7*)

Unable to directly descend the face where the avalanche had occurred, the two skiers decided the quickest way to get to the victim was to climb back up to the summit of Vice President, descend back to President Pass, down President Glacier and then make a high traverse to the avalanche debris around the two descending ridge lines. Once back at the summit, they broke the news about the accident to the two other American skiers who stayed behind and were unaware of what had just happened. Using their radios, they were able to immediately relay the news to the other group members who were half way down President Glacier. They quickly descended to the Stanley Mitchell Hut where the custodian used a satellite phone to call Parks Canada for assistance.
After descending President Glacier, the two Americans followed the high traverse to get to the accident site as quickly as possible, while the two Canadians continued to descend to the Stanley Mitchell Hut to gather any additional rescue material that might be needed. The Americans arrived at the avalanche site about 1.5 hours after the accident. By that time, a Parks Canada search and rescue helicopter with two public safety wardens and an avalanche rescue dog had already arrived at the site. While the victim was completely buried and not visible from the helicopter, his skis were on the surface of the avalanche debris and provided some clues about the potential burial site.

As the area was heavily crevassed, one of the safety wardens first approached the scene on the sling rope under the helicopter. Using an avalanche transceiver and a probe, he was able to quickly locate the victim in the avalanche debris while using the helicopter sling rope as a belay. Since he felt the burial site was safe, both public safety wardens and the avalanche rescue dog got off the helicopter and started excavating the victim. They found the victim under approximately 60 cm of snow, but he had already succumbed to the traumatic injuries from the fall. After the body was evacuated, the American group was also flown out, while the Canadian group returned to the Stanley Mitchell hut.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Low	No	No	?	No	?

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
N/A	Cliff	Unsupported	Open

Source

- BC Coroners Service
- Parks Canada
- InfoEx
- Canadian Avalanche Association
- Environment Canada

Comment

Failing cornices are always a concern when travelling along exposed ridgelines. This issue is more pronounced in the spring when the snowpack is steadily getting weakened by the milder temperatures. Judging cornices can be very challenging. It is often difficult to determine exactly how far the cornice overhangs the ridgeline, and failing cornices often involve more of the snow on the ridgeline than may be expected.

Chapter 12

Avalanche Accidents of Southwestern Canada **2004-2005**

Winter Summary for Southwestern Canada

- **6 fatalities in 6 accidents in southwestern Canada in the winter months**
- **“Monsoon” rains in January depleted and stabilized the snowpack**
- **Record low snowpack in Coast Mountains**
- **Very snowy in March and April, with several crust/facet layers causing avalanches**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
12 Dec 2004	Allan Creek	Monashee Mountains	Snowmobiling	1	Storm Slab		304
13 Jan 2005	Trout Lake	Selkirk Mountains	Backcountry Snowboarding	1	Persistent Slab	11 Jan 2005	305
18 Jan 2005	Mt Llewelyn	Selkirk Mountains	Heli-Skiing	1	Persistent Slab	15 Jan 2005	310
30 Mar 2005	Jersey Creek	Selkirk Mountains	Snowmobiling	1	Persistent Slab	17 Mar 2005	313
1 Apr 2005	East Tsuius Peak	Monashee Mountains	Snowmobiling	1	?		316
5 Apr 2005	Thunder River	Monashee Mountains	Heli-Skiing	1	Persistent Slab	17 Mar 2005	317
29 Jul 2005	Mt Robson	Rocky Mountains	Mountaineering	1	?		320

[1] It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.

The winter season of 2005 was atypical, with a major rain event occurring in late January in all ranges that completely melted the low-elevation snowpack in the Coast Mountains. At higher elevations and in the Columbia and Rocky Mountains the rain-soaked snowpack either avalanched to a November crust layer during the storm, or froze solid when colder weather returned. In both cases, the rain event neutralized avalanche potential on layers buried earlier in the season. Average snowpack heights were the rule throughout the winter in the Columbia and Rocky Mountains; however, the Coast Mountains had near record-low levels for most of the winter. Winter returned to an unusual extent in March and April on the coast, salvaging an otherwise dismal snow year. While several persistent weak layers were formed throughout the season, none were widespread or responsible for large numbers of fatal avalanches.

A slow start to the season left all ranges mostly snow-free until mid-October, although heavy precipitation fell as rain at Mt Fidelity (1874m) and Lake Louise (1524m) early in the month. Snow did not start to accumulate at Lake Louise until early November. Periodic snowfalls through early November brought the snowpack height in the Columbia Mountains to normal levels, and slightly below average in the Rocky Mountains. Stormy weather persisted throughout southwestern Canada through to late December.

Rain fell on about 100cm of settled snowpack at Mt Fidelity and around the Columbia Mountains at the end of the first week of November; rain also fell on the Coast Mountains, but the Rocky Mountains were mostly spared. Several days of above-average temperatures were recorded following that warm storm. The Coast and Columbia Mountains continued to receive snow following the rain, leading to the development of a buried rain crust overlaid by weak facet crystals; avalanche forecasters took note of this layer. During this period the Rocky Mountains near Lake Louise were only receiving small amounts of snow, and the snowpack height was near-record low levels throughout November.

It snowed almost continuously at Mt Fidelity until the end of December, with a few short breaks of clear weather and at least one minor rain event on 10 December. One snowmobiler died in an avalanche near Valemount, BC at **Allan Creek on 12 December** (page 304), as a result of this warm and windy storm. That same weather system brought heavy rain and very warm temperatures to the Coast Mountains, melting the low-elevation snowpack and causing the level at Whistler Roundhouse (1835m) to dip below normal, where it would stay for the following three months.

Cold, clear weather returned to all ranges at the end of December and early January, during which time the one minor disturbance brought a small amount of snow. With the fair weather, the snow surface began faceting and surface hoar grew, especially in the Columbia Mountains. After about 30cm of snow fell on the Selkirk Mountains around 11 and 12 January, burying the faceted and surface hoar crystals, clear weather returned with strong winds, building slabs that released during a fatal avalanche near **Trout Lake on 13 January** (page 305).

The cold high-pressure ridge that followed led to even more faceting of the snow surface, which was again buried during the start of a major winter storm period that affected all of the ranges. The storm brought heavy snow and rising temperatures, which had gone above zero at Whistler Roundhouse on 13 January. The above freezing temperatures reached the interior ranges by 18 January when a fatal avalanche released on the facets buried a few days before near **Mt Llewelyn** (page 310).

The series of weather systems tracking from the Pacific in mid-January culminated in a major "Pineapple Express" storm. Over 300mm of rain fell on the Coast Mountains during the third week of January, completely melting much of the below-treeline snowpack, and pushing the high-elevation snowpack to near record low levels. It rained to the mountaintops in the Columbia Mountains as well, initiating a major avalanche cycle that reactivated the crust layer buried in November. The warm weather persisted until near the end of January, when precipitation slowed and seasonal temperatures returned. The Coast Mountains lost much of their snow, while at higher elevations and throughout the Columbia Mountains the rain-soaked snowpack froze to form a strong, thick crust. The Rocky Mountains had similar conditions, although there the mountain ridges and peaks had escaped the rain, and the storm brought snow and the snowpack was average height or above.

The main effect of this "January Monsoon," as forecasters called it, was that almost all of the unstable snow in southwestern Canada either melted or avalanched. Any remaining snowpack was locked below the strong, thick rain crust, which anchored it in place and left the forecasters with little concern for stability of the lower layers. It was effectively a fresh start to the avalanche season, as earlier weak layers including the rain crust and facets formed in November were now off the books.

Following the monsoon, and except for a few intense storms in early February and March, the Coast Mountains received almost no snow for over six weeks, and temperatures were well above normal. This is typically a very stormy period, and the drought made for more than a month of record-low snowpack at the Whistler Roundhouse.

After an intense storm in early February, it was very dry in the Columbia Mountains for the next two weeks, and the snowpack height dropped below average at Mt Fidelity. The Rocky Mountains near Lake Louise received almost no snow from mid-February to late March, and saw warm, above-average temperatures.

Very warm temperatures prevailed in the Columbias, and weak disturbances tracking through the area brought small amounts of rain several times during March, especially in the very south Selkirk Mountains. Several of these rain events left prominent crusts buried in the upper snowpack, and a thin weak layer of faceted crystals formed atop the crusts in many places. An avalanche released on one buried 17 March near **Kootenay Pass, BC, on 30 March at Jersey Creek** (page 313), resulting in the death of one snowmobiler. Another avalanche in the Monashee Mountains southwest of Revelstoke, BC, near **East Tsuius Peak on 1 April** (page 316) may have failed in a on a March rain crust layer, killing one snowmobiler. In the northern Monashee Mountains near Blue River, BC, an avalanche at **Thunder River on 5 April** (page 317) failed on several of these crust-facet layers, and one heli-skier died.

When the snow started falling in the Coast Mountains in mid-March, it kept falling through to late-April, resulting in one of snowiest springs on record. By mid-April, the record low snowpack had returned to normal levels.

Small amounts of snow fell on the Rocky Mountains with normal temperatures through the spring, and average or slightly below average snowpack heights were recorded at treeline, with some alpine areas showing above average levels. By late April all ranges had settled in to a typical spring pattern of warm days and cool nights, and the spring continued as normal.

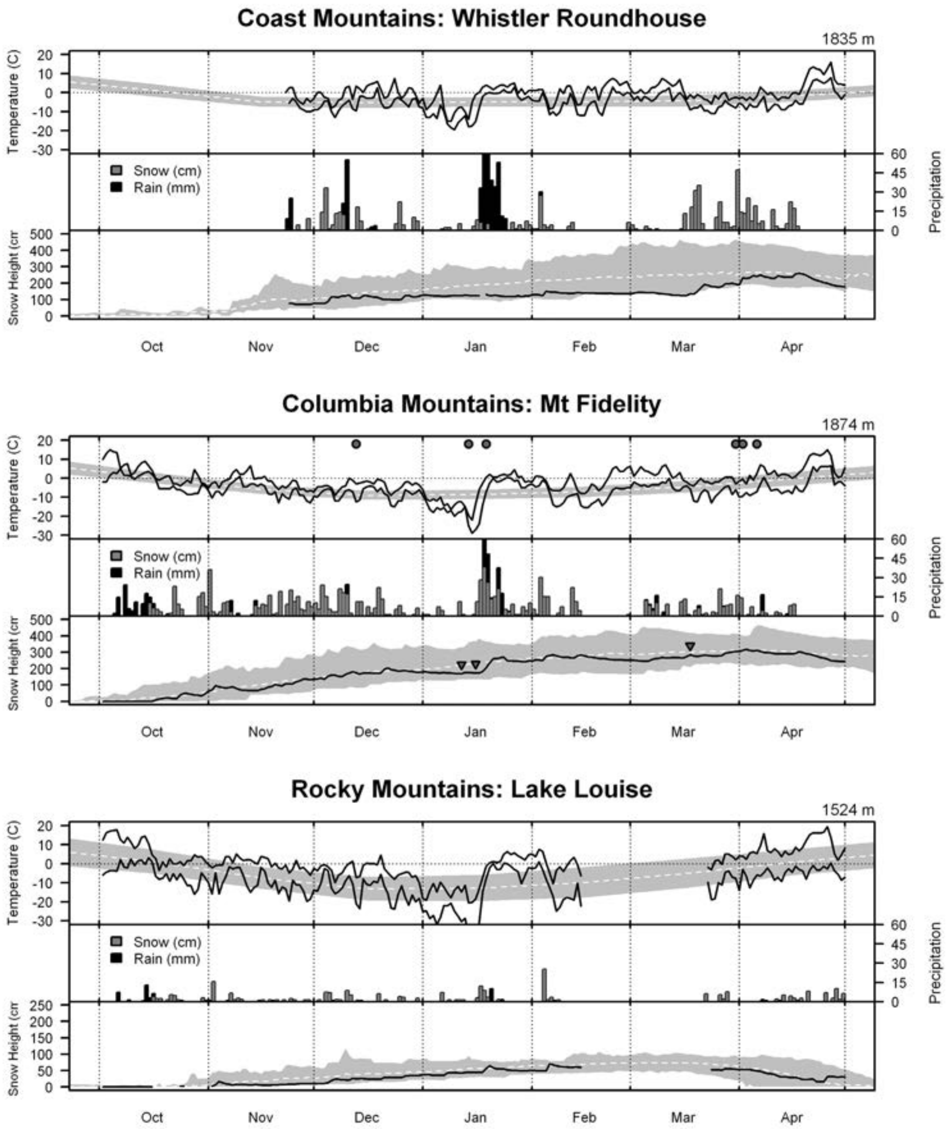

Figure 12.1*: Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 2004/2005 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanches (black triangles). The grey band shows minimum, average (dashed line) and maximum snowpack height measured at each location since 1976.*

12 December 2004, Snowmobiling
Allan Creek, Cariboo Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Complex

- **Highmarking the day after a major storm**

Early on Sunday 12 December 2004, a group of snowmobilers met in Valemount, BC and drove up the Allan Creek logging roads for recreation in the Cariboo Mountains about 25km south of Valemount, BC. At least two of the snowmobilers had been riding in the area for 20 years. A storm had ended and the weather was improving.

On 10 December, the Canadian Avalanche Centre issued a regular bulletin for the North Columbia Mountains and a Special Avalanche Warning for areas including the Columbia Mountains. The regular bulletin rated the regional danger at treeline as High on Saturday and Considerable on Sunday 12 December. The bulletin noted the "northern Monashee Mountains will see 30 to 80cm of snow and some rain." The Special Avalanche Warning cautioned: "Avalanche accidents commonly occur shortly after a storm passes because the snowpack hasn't adjusted to the additional weight of the new snow. ... we urge the public to use extra caution this weekend should they choose to travel in avalanche terrain."

From the morning of 10 to 11 December, the Chappell Creek weather station at elevation 786m and located about 25km south from where the group was snowmobiling recorded 27mm of precipitation. More than 30cm of snow was likely at the elevation the group was riding.

It is unknown if the snowmobilers observed avalanches or other signs of instability.

The snowmobilers crossed through the pass just west of Mt Milton and were high in the Camp Creek valley. Forty to sixty centimetres of snow had fallen during the storm with moderate southwest wind. The sky was now clear. The winds were light and variable. The air temperature was about -2°C.

At 13:00 they were highmarking an east-facing slope at treeline. While climbing the slope, one rider got stuck about half way up the slope. He was shovelling to free his sled when he was struck and buried by an avalanche.

The other members of his group found him by transceivers. After shoveling down through 3m of avalanche deposit, they attempted to resuscitate him. An ambulance crew arrived by helicopter at 15:15 and took over the resuscitation. The victim was transported to Valemount hospital where he was pronounced dead at 16:10. He had asphyxiated.

The dry slab avalanche released at 2080m on a convex slope that reached 38°. The crown was about 50m wide and varied in height from 30cm to over 100cm. It ran 110m down the slope. The avalanche was a size 2.5.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	No	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	?	Convex	Few small trees

Source

- BC Coroners Service
- InfoEx

Comment

Only one person was caught suggesting the other snowmobilers were, prudently, not on the same slope as the highmarker.

13 January 2005, Snowmobile-Assisted Backcountry Snowboarding Trout Lake, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Experienced rider in familiar terrain and snowpack**
- **High level of awareness of conditions**
- **Group of trauma doctors skiing nearby**

The Selkirk Mountains north of Trout Lake, BC, are remote and see little traffic in winter. Because of its remoteness and lack of crowds, a few skiers and snowboarders use snowmobiles to access excellent riding terrain via a network of forestry roads and trails that ascend many of the drainages in the area.

During the early part of January 2005, a group of four professional snowboarders, along with a cinematographer and a photographer, were in the area capturing footage of some of the steeper lines. On 13 January 2005, they had accessed an area on the east flank of Great Northern Mountain, near the head of Fissure Creek, located north of Trout Lake. By about 08:30 they arrived at “Fissure Bowl,” a small cirque near the treeline, with numerous steep descent options a few hundred metres in length. The four snowboarders rode their machines to the small peak above the cirque to prepare for their runs, while the photographer and cinematographer set up in the lower part of the bowl below to film them. Around this time, a fifth professional rider arrived. He was an experienced snowboarder who had pioneered a new technique of riding without bindings called “noboarding.” He owned a cabin at the mouth of Ferguson Creek, not far from Fissure Bowl. He knew the local mountains well, and spent three to five days riding in the backcountry each week. In fact, everyone in the area that day were experienced backcountry riders, with much informal training. One member of the group had taken a professional avalanche course, and they were confident in their ability to manage the hazards in the bowl.

The group of professional snowboarders had been riding and filming in the area around Trout Lake for the previous week or so. They noticed strong winds blowing the previous day, and a resulting increase in the avalanche hazard. The weather on the morning of 13 January was calm, clear, and cold. A heli-skiing lodge located about 10km from Fissure Bowl maintains twice-daily weather records, and the guides keep track of weather conditions encountered in the field. It had snowed lightly throughout 11 January, and by the morning of the next day, 10cm had accumulated at the lodge, located well below treeline. It had been getting steadily colder and clearing since the end of the snowfall on 12 January. Guides reported that up to 30cm of snow had fallen at higher elevations on 12 January and that light winds had increased to moderate and shifted to south and southeasterly towards the end of the storm. They reported temperatures between -18°C and -24°C on 13 January, with clear skies and a light westerly breeze; however, the snow surface was wind-affected in exposed areas, building into slabs in many places with the winds from the previous day.

Local heli-ski guides had noted that the storm snow was reactive to skier traffic, and had observed many small avalanches on the 12th and 13th. The group of snowboarders made similar observations; they had triggered numerous small avalanches on the 12th, and noted shooting cracks in the snowpack around their snowboards. At the top of Fissure Bowl, they discussed snowpack stability, but felt they didn't need to perform any snowpack tests or profiles. According to one member of the group, "It was sunny on that face, and really dangerous. We knew it was really dangerous..."

The Canadian Avalanche Centre produced a public avalanche bulletin on the afternoon of 12 January, valid for the 13th and following days. In their discussion of conditions in the South Columbia Region, forecasters described how "storm snow and soft windslabs sit on a weak faceted layer. Contained within the faceted layer are three weak layers of surface hoar. Two of these layers are buried deep enough to be a concern for avalanches." The avalanche danger was Considerable in the alpine and treeline elevation bands, and Moderate below treeline.

The noboarder was not part of the group assembled in the bowl, but was their acquaintance. He arranged with the photographer to take some photos of his run, and then raced to the top of the bowl to meet up with the other group. When he arrived there, the group was discussing route options and avalanche hazards. Without indicating his chosen run to the others, the noboarder started down the ridgeline on the riders left of the bowl and dropped in to a steep, sparsely treed dish-shaped line.

The four snowboarders watched the noboarder start his descent until he disappeared from view along the ridge. Expecting to see him re-emerge below, instead they watched a powder cloud—clearly the result of an avalanche—engulf the lower part of the bowl. The photographer stationed there saw the avalanche, and knew it had come from the slope the noboarder was riding. The group of snowboarders was in radio contact with the photographer and cinematographer; they decided the photographer would start to search for the noboarder from the bottom by climbing the avalanche deposit, while two of the snowboarders would descend and search from the top. The remaining two snowboarders were tasked with bringing the snowmobiles down the slope to the bottom of the bowl. Within five minutes of the avalanche, using their avalanche transceivers they had pinpointed the location of the noboarder buried in the deposit. The rest of the group, as well as two other riders who had just arrived, joined to help dig for the noboarder, while the photographer went for help on his snowmobile.

The noboarder was uncovered feet first, buried under about 1.4m of snow, lying almost horizontally but slightly head-down into the slope. They had to dig down about 2m to completely extricate him and expose his upper body. The noboarder had no vital signs, and had obviously suffered some trauma to his head, face, and neck. The rescuers immediately started CPR.

In the meantime, the photographer had become stuck in deep snow, and one of the other snowboarders had left the area to seek outside assistance. A short distance down the access road he came across a group of skiers and their guide awaiting a helicopter pick-up. Among them were several emergency room trauma doctors. The guide and two of the doctors were flown to the scene of the avalanche to assist. They arrived there within five minutes of meeting the snowboarder, and immediately took over treatment and resuscitation efforts. Ten minutes later another helicopter arrived with a trauma kit, including an automatic external defibrillator (AED). The AED measured pulseless electrical activity, but was unable to revive the noboarder. The two doctors continued CPR while they evacuated the victim by helicopter to hospital in Revelstoke, departing Fissure Bowl about 45 minutes after the avalanche. Once there, CPR was continued for a further 30 minutes while the noboarder was warmed; ultimately, the resuscitation efforts were unsuccessful and ceased at 11:41. The noboarder had died of asphyxiation, and had sustained just minor facial trauma in the avalanche.

The noboarder had triggered a size 2 – 2.5 avalanche near the start of his run, on a northeast facing, 42° slope at about 2300m elevation. The avalanche crown fracture was located just below the ridgeline, and the slope was slightly dish-shaped with both convex and concave sections, including a steep, thinly treed rollover with an incline of over 50°. The slab that released was 27m wide, and between 10cm and 57cm thick. It ran approximately 450m down the slope into the lower part of the bowl. In the track, it was confined to a narrow, 5m wide gully. The deposit ranged from 5m to 11m wide and was up to 3.5m deep.

Several periods of cold clear weather at the end of December and early January led to the growth of surface hoar crystals and the faceting of the snowpack near the surface. Snowfalls that occurred in the first weeks of January buried these surfaces, which then became weak layers buried within the settling upper snowpack. As the public avalanche bulletin outlined, there were several surface hoar layers buried within a faceted interval throughout the Columbia Mountains, although the character and properties of the layers varied significantly from place to place, depending on aspect, elevation, wind, snowfall amounts, and local climate effects. The storm that passed through the region on the 11th and 12th dropped up to 30cm of snow on top of what had fallen in early January, and winds blowing on the 12th had moved this new snow around, loading north and northeast slopes and building stiff windslabs in exposed places.

A snow profile observed by investigators at the fracture line of the avalanche found a snowpack depth of 177cm. There was a 35cm thick wind slab near the surface, strong enough that investigators could walk on it. Below that, a 22cm thick layer of slightly softer snow sat atop a very soft, weak layer of faceted snow. The lower interface of this layer was identified as the failure plane for the avalanche. Snowpack tests performed at the fracture line had easy fractures down 57cm from the surface, at the bottom of the weaker snow. At that location investigators found slightly larger faceted crystals showing striations, indicative of advanced faceting and weakening. On the bed surface of the avalanche, they noted scattered surface hoar crystals that were apparently absent in the snow profile; however, in a slightly more protected profile site a short distance away, the snowpack was deeper (220cm) and surface hoar was present as a weak layer at the corresponding depth.

It is possible, given the fact it was found adjacent to the profile site, that the surface hoar had been destroyed near the ridgeline by sun or wind or both, but lower down on the slope that avalanched it was present and played a role in this avalanche. Investigators noted the wind-stiffened surface extended only a short distance below the ridge, and numerous snow profiles performed by nearby forecasting operations identified surface hoar as a prominent weak layer in their upper snowpacks.

Of note is that investigators found a void in the snowpack just upslope of the fracture line, suggesting earlier in the season a cornice had been located there and was subsequently buried. Also of note is the relatively thin snowpack (177cm) at the fracture line, compared to 220cm both at a nearby sheltered location. The higher value was typical of snowpack heights observed in other parts of the Selkirk Mountains at that time. This suggests the avalanche was triggered from a locally thin area, which had seen significant wind effects, while lower down the slope the snow was softer and more plentiful, having been transported there by recent winds.

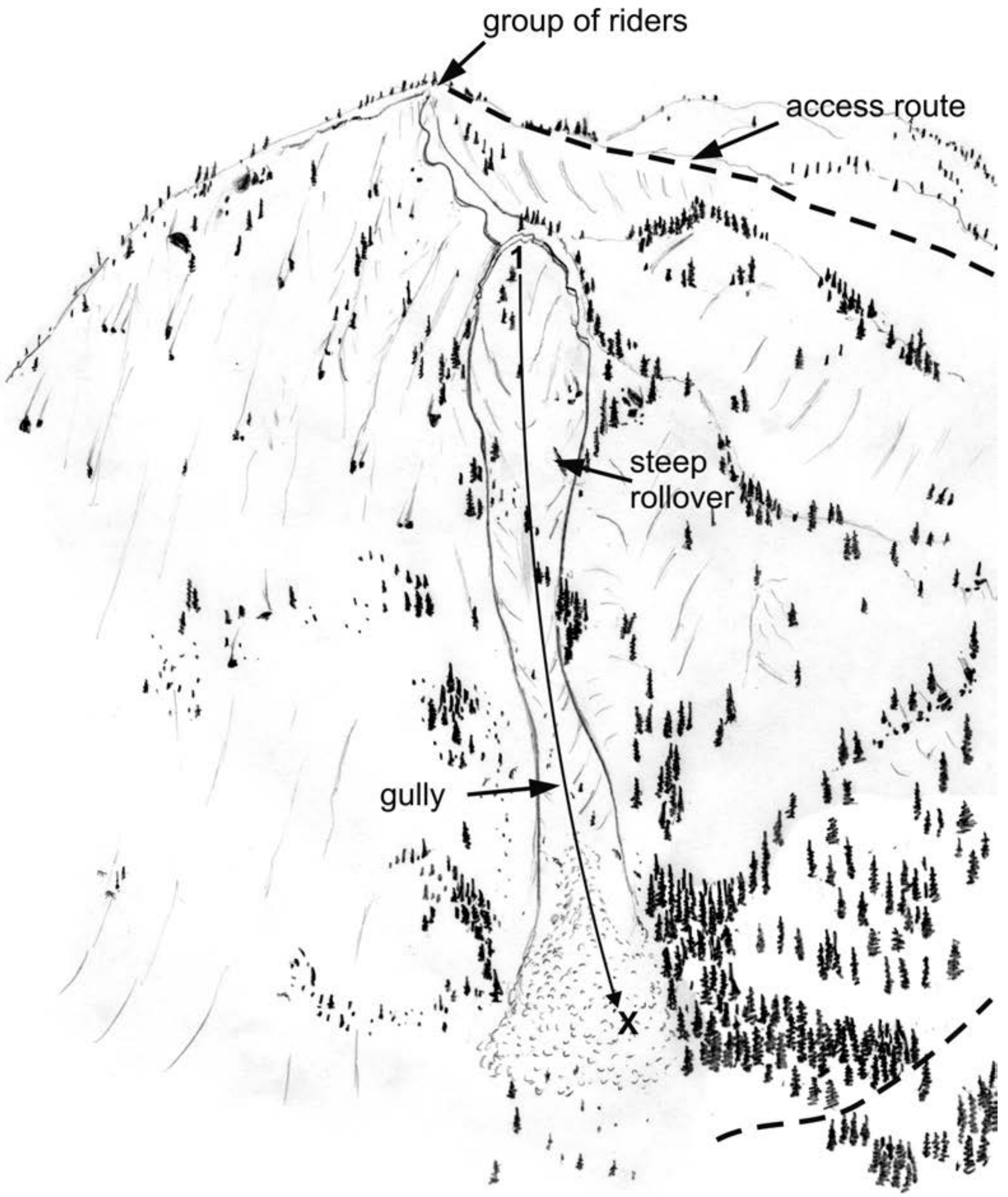

Figure 12.2 *Trout Lake, 13 January 2005. 1 – Location of snowboarder at time of avalanche; X – location of burial.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	Cracks	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees, gully	Convex, unsupported	Sparsely treed slope

Source

- BC Coroners Service
- InfoEx

Comment

Spatial variability of the slab and weak layer can be very difficult to predict, even for riders very familiar with an area. Ridge tops are places where spatial variability is the rule, making it even more difficult to determine where the weak layers and thin spots are lurking, and which routes are likely to release avalanches.

Research has shown that groups that form casually in the backcountry often have difficulty with communication and decision making, which can lead to poor terrain and travel choices.

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18 January 2005, Heli-skiing
Mt Llewelyn, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Skiers caught while skiing in mature forest**

Two groups of about nine skiers each were helicopter skiing with guides about 17km east of Revelstoke, BC. They started skiing at about 10:00 and observed recent natural slab avalanches starting on nearby slopes that were too steep for the groups to ski. The guides tried to “ski cut” (intentionally trigger) avalanches on some slopes but did not trigger any avalanches. They felt and/or heard “whumpf” sounds, which are due to collapsing weak layers in the snowpack. After observing two snow profiles, the groups moved to a nearby run, which was mostly treed. The first group skied the run without incident.

Clear weather ending on 15 January 2005 had formed faceted crystals on the snow surface and in some areas, surface hoar was reported. By the morning of 18 January, approximately 40cm of soft snow overlay the faceted layer that had formed in the clear weather.

By 11:25 on 18 January, the air temperature where the groups were skiing had risen to 0°C

Morning weather (~ 08:00) at Mt Fidelity, 1905m, 30km northeast of the accident site						
Date	Max. Temp. (°C)	Min. Temp. (°C)	Precip. (mm)	Snowfall (cm)	Wind speed (km/h)	Wind dir.
15 Jan	-22	-29	0	0	10-20	SW
16 Jan	-16	-25	0.8	1	5	Var
17 Jan	-8	-13	3.6	5	5-10	Var
18 Jan	-2.5	-5.5	31.5	28	15-25	SW

and the snow surface was moist. The wind was light from the southwest. The sky was overcast. Snowfall was light—only a flurry.

The bulletin issued by the Canadian Avalanche Centre for the day of the accident in the South Columbia mountains rated the avalanche danger as Extreme at treeline and High below treeline. The bulletin noted that "Lots of storm snow and soft and hard windslabs sit on a weak faceted layer. ... Widespread natural avalanche activity is expected as new snow accumulates."

At about 11:25, the second group started to ski a gentle narrow glade near the tracks from the first group. Below the glade they entered mature forest where it was at times difficult to link turns. The guide gave instructions not to traverse left to where the trees were farther apart. At about 1980m elevation, three guests veered left into scattered open areas, inclined at about 34°, and were struck by an avalanche. The slide had started in a small open glade above a small cliff, and ran about 50 to 70m through trees. One skier was partly buried, pinned against trees but was able to breathe. Another skier was carried about 30m down the slope through the trees. He was mostly on the surface of the deposit, but had broken a leg. The remaining skier was carried about 60m down the slope. Only one hand was visible.

The guide counted the skiers and quickly realized one skier was missing. He called for help on the radio, and started a transceiver search. The almost buried skier who was carried farthest down the slope was soon located, buried with his head down against a tree, about 60cm below the surface. He was wearing a helmet. About five minutes after the avalanche, he was extricated from the deposit. The rescuers realized he had no pulse and began CPR. Other guides soon arrived with advanced life support equipment, including oxygen and a portable defibrillator. Resuscitation efforts were not successful. There was a partial fracture and dislocation of two neck vertebrae. The cause of death was asphyxia due to chest compression.

The soft slab avalanche was a size 2, about 100m wide and started on a 38 – 40° southwest-facing slope. It released on a layer of small faceted crystals and decomposing precipitation particles that had likely formed on the snow surface during the clear weather prior to 16 January. The crown was about 40cm high. The avalanche ran down the slope for about 170m. The deposit was about 70m long, 80m wide and averaged 50cm thick.

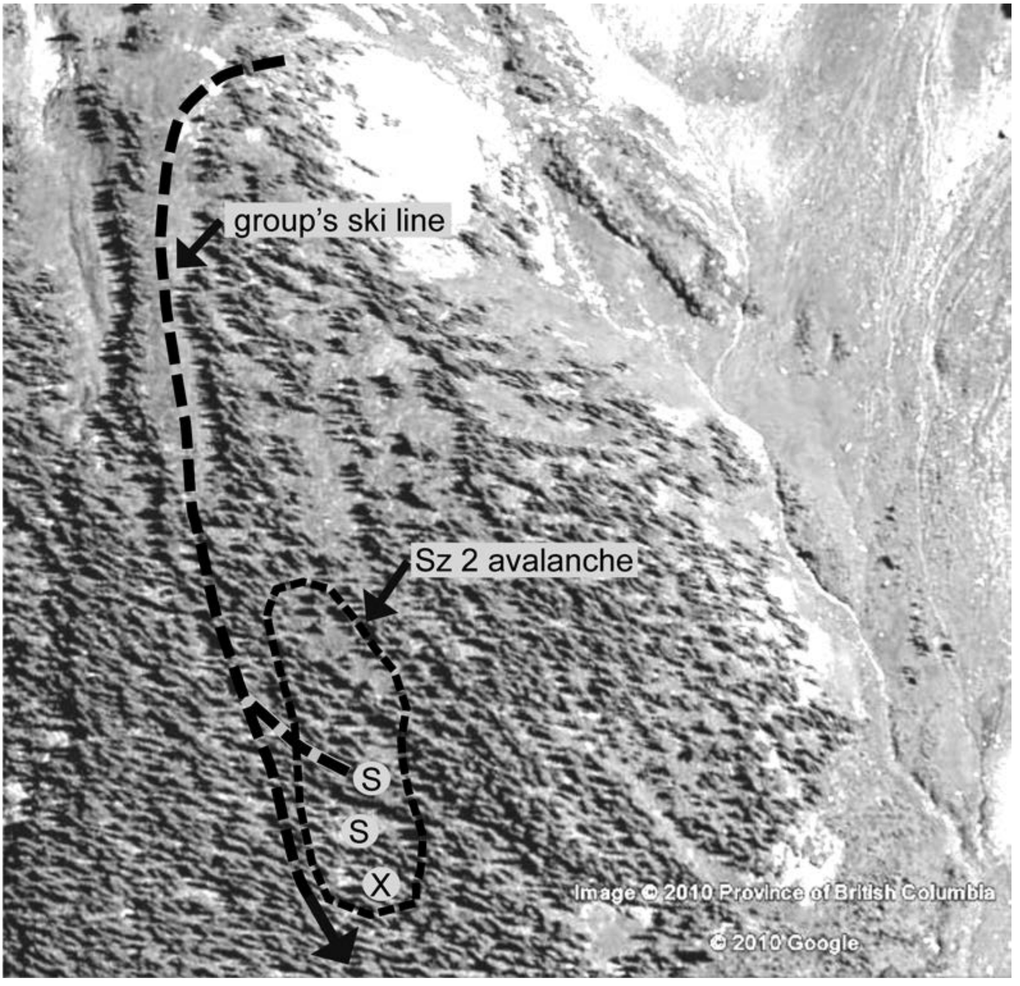

Figure 12.3. *Mt Llewelyn, 18 January 2005. The Google Earth image shows the actual tree spacing where the avalanche started and where it hit the skiers. S - survivor, X - deceased. Image copyright 2010 Province of British Columbia, 2010 Google.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	Yes	Yes	Whumpfs	Yes	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Planar	Mature forest

Source
- BC Coroners Service

Comment
Once avalanches start, they can flow through the forest, pushing skiers into trees and causing trauma.

30 March 2005, Snowmobiling
Jersey Creek, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Two snowmobilers stuck and caught on the same slope**

On Wednesday 30 March 2005, three experienced snowmobilers from Creston, BC went snowmobiling in the Jersey Creek area, about 30km west-northwest of their home town. They had read the bulletin and were equipped with avalanche transceivers, probes and shovels.

Two days before the accident, the Canadian Avalanche Centre issued a bulletin for the Kootenay Boundary Region rating the avalanche danger as Moderate at treeline where the snowmobilers were riding. The bulletin also noted: “A warm and moist storm deposited between 20 and 40cm of snow over the weekend. ... Warm temperatures are causing the storm snow instabilities within the new snow to rapidly strengthen on Monday and Tuesday. The bond of the new snow to the old surfaces is taking longer, especially on north aspects. ... A number of naturally triggered and human triggered slab avalanches were reported over the weekend. We expect the activity to taper off, but there are still a few surprises out there.”

At the Kootenay Pass weather station, elevation 1780m, located 18km southwest of the snowmobiling area, 80cm of snow had fallen in the preceding five days. Only about 22cm of this snowfall had been in the preceding two days. The air temperature had been be-

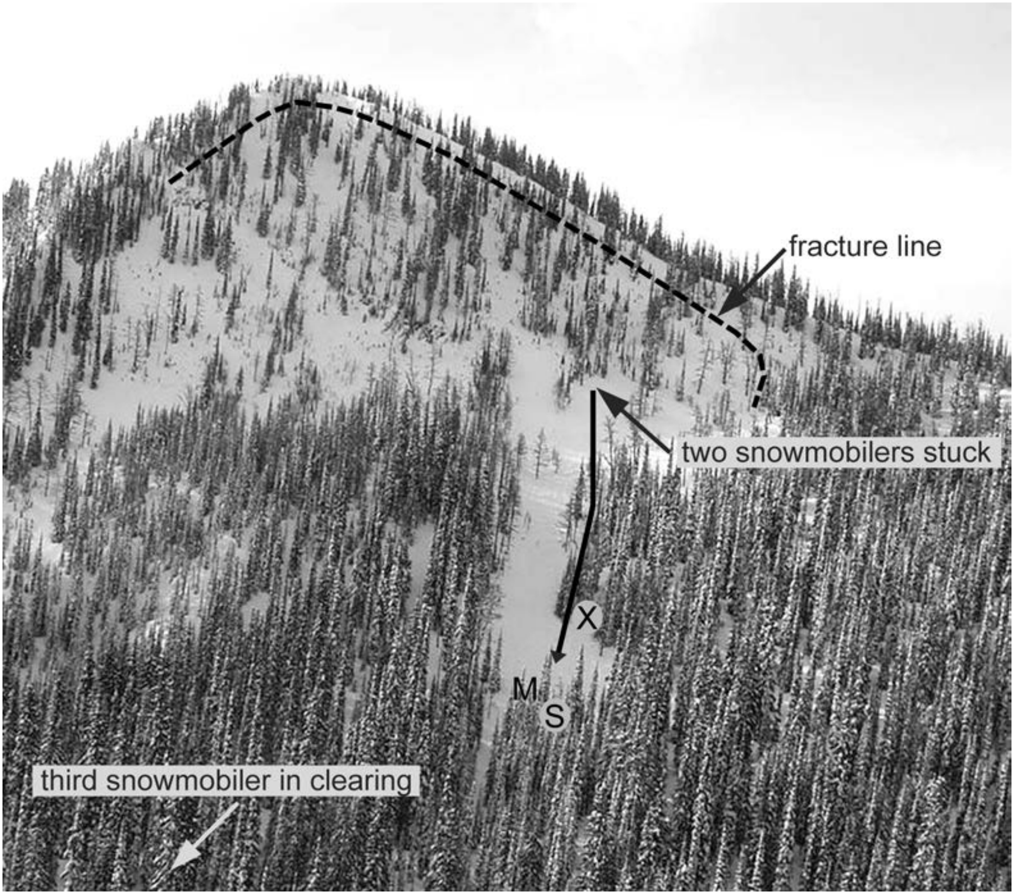

Figure 12.4. *Jersey Creek, 30 March 2005. S - survivor, X - deceased, M - snowmobile. Photo: John Tweedy.*

low freezing since the afternoon of 28 March. By noon on 30 March, the air temperature had risen slowly to -1°C. The snowmobilers did not observe any recent slab avalanches or make any snowpack observations.

The sky was clear with air temperatures between -6°C and 0°C. The group found an area where they had not previously snowmobiled. They began to highmark on a northeast-facing slope with deep soft snow. After about six runs, two of the snowmobilers got stuck near each other on the slope. At about 14:00, they were trying to dig out their snowmobiles when they were struck by a slab avalanche. They were carried down the slope through large trees at the side of the avalanche path.

After the avalanche, the rider who had been higher up the slope could not be seen. The other rider was on the surface but was bleeding from a severed kneecap due to hitting his snowmobile or a tree while being swept down the slope. After the avalanche, he blew his whistle to alert the third snowmobiler at the bottom of the slope who was in a nearby logging clear cut and not exposed to the avalanche slope.

The snowmobiler at the bottom of the slope had heard trees breaking but not been hit by the avalanche. He heard the whistle and drove his snowmobile up to his injured friend, who reported that the missing snowmobiler had last been seen farther up the slope. The uninjured rider ascended the slope and picked up, then pin-pointed the transceiver signal. To get to the buried snowmobiler, he dug down 2m, which took approximately 45 minutes. He attempted CPR for 15 minutes, without success. He then returned to his seriously injured friend and helped him down to their vehicle, and then to Creston Hospital.

Before the recovery team came to the avalanche site the next day, an BC Highways avalanche technician flew to the site by helicopter to assess the avalanche risk. The body of the snowmobiler was then recovered on a second flight. He had died of asphyxia due to compression of his chest by the avalanche deposit.

The dry slab avalanche started on a north-east-facing 40° slope at 1850m, about 100m above the stuck snowmobilers. The crown fracture was about 80cm high and 125m wide. It released on a rain crust and ran about 200m vertically. It was a size 2.5. There were sparse trees in the starting zone. The avalanche released on a rain crust that had been buried around 17 March 2005.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate	Yes	No	?	No	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35° in start zone	Trees	?	Sparse trees in path

Source

- BC Coroners Service
- John Tweedy

Comment

The snowmobilers were well equipped for avalanche rescue.

This is one of a number of snowmobiling accidents in which there was more than one rider (and more than one snowmobile) on the slope when the avalanche was triggered. In this case, one of the three snowmobilers was in a clear cut not connected to the slope and able to respond.

The uninjured rider appropriately shifted the priority from his companion who had not responded to CPR, to the one who was bleeding.

1 April 2005, Snowmobiling
East Tsuius Peak, Monashee Mountains

Deaths	Avalanche Problem	Terrain
1	?	Complex

- **Snowmobiling out of sight of companions**
- **Triggering from low in a bowl**

On 1 April 2005, a group of seven friends were snowmobiling in the Sawtooth Range of the Monashee Mountains, about 30km southwest of Revelstoke, BC.

The evening before the accident, the Canadian Avalanche Centre issued a bulletin for the South Columbia Mountains rating the regional avalanche danger as Considerable in the Alpine zone and Moderate at treeline. The bulletin also noted: "Instabilities within the storm snow are strengthening and the prime concern is the old snow to new snow interface buried 50 to 70cm deep. These layers tend to gain strength slowly and awaken when they are loaded by new snow. ... The snow that fell since last week is settling into a soft slab especially where it is slightly wind affected and on solar aspects."

In the Sawtooth Range, it had snowed on each of the several preceding days and over the previous 24 hours, 17 to 20cm of snow had fallen. Nearby heli-ski operators had reported moderate to strong winds in the preceding two days.

In the preceding days, there were reports of other avalanches. It is unknown if the snowmobilers observed other signs of instability.

At about 14:30, the group stopped on top of a small bluff. It was snowing and the clouds were low, making visibility difficult. One rider went down around the bluff, out of sight of the others. He was travelling at the base of a bowl when struck by an avalanche, likely triggered by his snowmobile. He was carried about 250m down the slope.

When he did not return, other members of his group followed his track and found his snowmobile on the surface of an avalanche deposit. They were able to locate him with their avalanche transceivers within 10 minutes. After digging down 75cm, the victim was found without a pulse. CPR was started and BC Ambulance Service was called. The ambulance service responded by helicopter and flew the victim to the hospital in Revelstoke. He could not be resuscitated. He had died of asphyxia.

The dry slab avalanche started at elevation 2130m below a rock band on a southwest-facing slope within a large bowl. The crown height was about 100cm and the width was about 200m. The avalanche ran for about 500m. It was a size 3.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	?	Yes	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35° in start zone	None	?	Open

Source

- BC Coroners Service
- Karl Klassen

Comment

The companion rescue was efficient.

5 April 2005, Heli-skiing
Thunder River, Cariboo Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

In the morning of 5 April, the two groups, each with two guides, skied a northeast-facing bowl in the Thunder River valley about 13km north of Blue River, BC. After this, they moved about 1km northwest to the adjacent bowl known as McGowan's. Both groups skied one run down the eastern side of the bowl and then one run down the western side.

Following light snowfalls from 5 to 10 March, the air temperature at the weather station at elevation 1900m, which is located 6km northeast of McGowan's Bowl, rose above freezing on 11 March. On 12 March, the wet surface at and below treeline was buried by dry snow presenting favourable conditions for faceting of the dry snow on the freezing crust. The 24-hour snowfall (HN24) as well as the 24-hour minimum and maximum air temperatures at the weather station are shown in the table.

On the previous day, the Canadian Avalanche Centre issued a regular bulletin for the North Columbia Mountains, which included this area of the Cariboo Mountains. The regional danger rating was Considerable at treeline, where the groups were skiing. The bulletin noted that "Some areas report weak facet crystals sitting on top of the [mid-March] crust which forms a very weak layer responsible for many of the large avalanches observed this weekend."

The only avalanche reported by the heli-skiing operation in the six days prior to the accident was a small slab avalanche on a south-facing slope approximately 12km northeast of the accident site. This avalanche was ski

Weather at Mt St. Anne, 06:00 1900 metres, 6 kilometres northeast of the accident site			
Date	HN24 (cm)	Max. Temp. (°C)	Min. Temp. (°C)
31-Mar	0	-4	-8
1-Apr	30	-2	-8
2-Apr	10	-2	-9
3-Apr	0	-2	-9
4-Apr	2	-4	-9
5-Apr	0	0	-7

cut (intentionally triggered) by a guide and slid on the weak layer that formed in mid-March.

A minor rib divides McGowan's Bowl into an eastern and western bowl, both of which face north. For the third run in McGowan's Bowl, Group 1 skied down a broad ridge and then regrouped above the eastern bowl. Entering the bowl where the slope was approximately 45°, the guide skied back and forth ("ski cut") across the steep upper slope of the bowl, attempting to release unstable snow before the guests and second guide skied it. No avalanche was triggered. After skiing the eastern bowl one at a time, the group stopped at the edge of the forest.

Group 2 also skied down the broad ridge but regrouped above the west bowl (*Figure 12.5*). The guide ski cut the slope without triggering any slabs, and skied down to a regrouping point in sparse trees on the middle rib dividing the eastern and western bowls. The guests started skiing one at a time down to the guide. When the seventh skier entered the slope, a slab avalanche released, carrying him down the slope, over a 30m cliff and out of sight of the skiers and guides.

Immediately after the avalanche, the guides who had observed the avalanche called on the radio for help from nearby guides who were using other helicopters. The guide from Group 2 and a guest quickly skied down beside the cliff and began a transceiver search. The second guide from Group 1 joined the transceiver search. Within approximately three minutes of the avalanche, the guides reported "pin-pointing" the transceiver signal. Approximately 30 seconds later one of the guides probed the victim under approximately 1.2 metres of snow. After an estimated five to six minutes of shoveling, the victim was partly uncovered. He had a head injury and no pulse. A doctor, who had been flown to the site with advanced life support equipment, arrived. CPR and advanced life support were provided. A faint pulse was soon detected. The victim was flown to Clearwater Hospital, stabilized, and then flown to the Royal Inland Hospital in Kamloops where he died the following day. The cause of death was asphyxia.

The soft-slab avalanche was skier-triggered in the western bowl at 1895m. The crown averaged about 95cm in height and was about 100m wide. It flowed over a cliff about 30m in height and ran down the slope for a total of 480m, with a vertical fall height of approximately 205m. Based on its destructive potential, the avalanche was a size 3. The deposit ranged from 150 to 350cm in depth. Density measurements ranged from 270 to 450 kg/m^3.

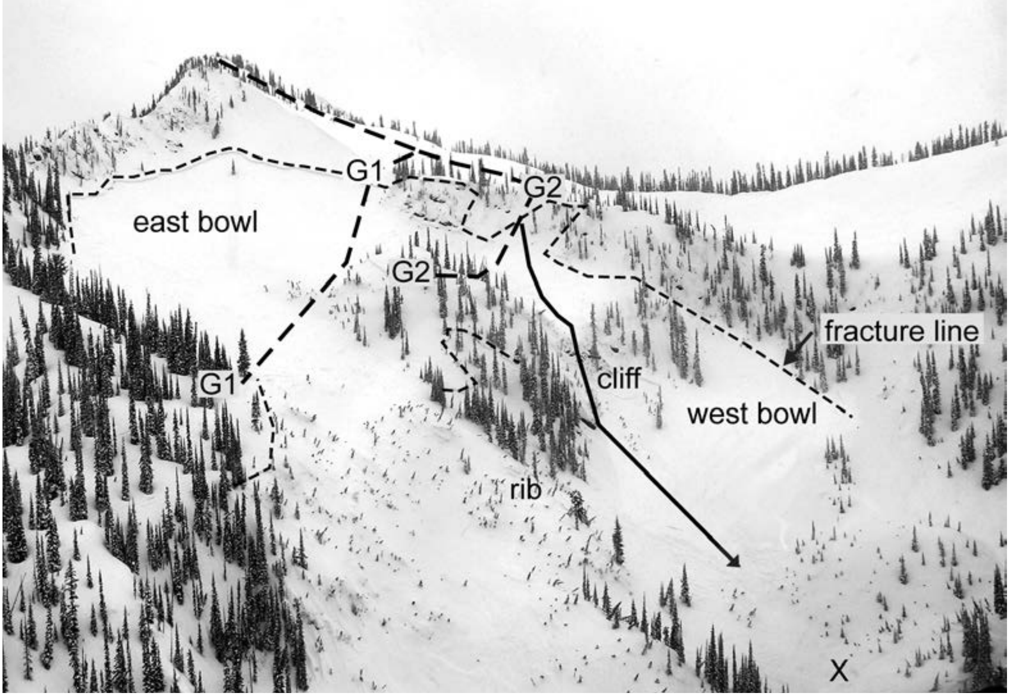

Figure 12.5. *Thunder River, 5 April 2005. When the avalanche released, all of Group 1 was at the lower location marked G1 and the guide plus six skiers from Group 2 were at the lower location marked G2. X - deceased. Photo: Karl Birkeland.*

Moments after the western bowl avalanche, the eastern bowl released. This crown was approximately 110cm high and 200m wide. It stepped down to a deeper weak layer in the snowpack, and consequently released harder snow layers. It ran down the slope for approximately 520m.

The heli-skiing operation observes many snow profiles and performs many snowpack tests daily. A profile in Wolverine Bowl less than two hours before the avalanche identified a layer of facets 100cm below the surface. A shovel test on this layer produced an "easy" fracture.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 40°	Cliff	Concave	Mostly open

Source
- BC Coroners Service
- Bruce Jamieson

Comment
On this particular slope, skiing one at a time and regrouping on the edge of forested areas prevented additional people from being caught.

In the six days prior to the fatal avalanche, only one avalanche had been reported. This was a small slab avalanche ski cut (intentionally triggered) by a guide on 4 April about 12km north of the accident site. Because the Avaluator Warning Signs are intended for recreationists with limited local observations, this avalanche counts as a Warning Sign for slab avalanches, which includes any sign of recent slab avalanches.

The rescue was very efficient.

29 July 2005, Mountaineering
Mt Robson, Mt Robson Provincial Park, Rocky Mountains

Deaths	Avalanche Problem	Terrain
2	?	Complex

On 27 July 2005, a European mountain guide and his very experienced climbing partner entered Mt Robson Provincial Park with the intent to climb the north face of Mt Robson. They were accompanied by their spouses. The climbers did not register for the route but met a park ranger at their camp on the next morning. The ranger cautioned that there might be fresh unstable snow on the north face. The weather was sunny and warm. At 17:30, the two climbers left their spouses and waded across the Robson River to approach the north face.

Heavy wet snowfalls in June and early July had extended the avalanche season into the normal climbing season. There was no avalanche bulletin available for this area in the summer of 2005.

On the night of 26 July and day of 28 July, a weather station at 944m and 9km south of the north face recorded 6mm of rain and 2mm of rain. More precipitation, likely in the form of snow, probably fell high on Mt Robson.

At 08:00 and 09:30 on 29 July, the ranger used a spotting telescope to observe the climbers ascending the glacier at the bottom of the north face. There are some large crevasses on the glacier, some of which were partly open. The ranger also observed fresh avalanches near the base of the north face. At 11:00 the ranger observed the climbers one quarter of the way up the face at about 3170m. They climbed into the cloud base. The ranger was unable to observe them subsequently that day although the cloud base remained at the same elevation.

At 07:30 on 30 July, using the spotting telescope the ranger observed two dark objects in an avalanche deposit at the base of the north face. At 15:50, an RCMP helicopter confirmed two bodies in the upper part of an avalanche deposit at approximately 3060m. The coroner authorized recovery of the bodies by the Jasper National Park rescue team, which flew to the site by helicopter. At 17:30, they recovered one of the bodies but could not recover the second one due to the weather, which was drizzling, windy and deteriorating.

On the night of 30 July and following day, at least three avalanches—including one massive avalanche—struck the site where the second body had been left. The body was likely displaced an unknown distance and may have been pushed into a crevasse. The search was abandoned. The coroner judged both victims to have died from trauma.

The deposit from the size 2.5 avalanche included some cornice chunks. The slope angle where the bodies were observed was about 15°.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	?	Yes	?	?	?

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	Crevasses	?	Alpine

Source

- BC Coroners Service
- Parks Canada
- BC Provincial Parks
- BC Ministry of Transportation and Infrastructure weather data archive

Chapter 13

Avalanche Accidents of Southwestern Canada **2005-2006**

Winter Summary for Southwestern Canada

- **8 fatalities in 7 accidents in southwestern Canada**
- **One workplace fatality**
- **Crusts buried in October and November active throughout winter**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
7 Jan 2006	Kicking Horse Mountain Resort	Purcell Mountains	Lift Snowboading in Closed Area	1	Persistent Slab	21 Nov 2005	328
14 Jan 2006	Lizard Range	South Rocky Mountains	Outdoor Worksite	1	? Slab		331
12 Feb 2006	Commonwealth Valley	Rocky Mountains	Backcountry Skiing	1	Deep Persistent Slab	19 Oct 2005	333
3 Mar 2006	Mt McBride	Selkirk Mountains	Backcountry Skiing	2	Persistent Slab	20 Feb 2006	337
5 Mar 2006	Mt Fernie	South Rocky Mountains	Snowmobiling	1	Persistent Slab	20 Feb2006[2]	341
20 Apr 2006	Deltaform Mountain	Rocky Mountains	Mountaineering	1	?		343
21 Apr 2006	Bella Coola	Central Coast Mountains	Heli-Snowboarding	1	Persistent Slab	12 Apr 2006	345

[1] It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.
[2] Suspected

The winter of 2006 was typical in terms of overall snowfall amounts, but the temporal distribution of the snowfall was abnormal. A significant rain event occurred in October, and another in November. These led to the formation of crusts and faceted crystals which were subsequently buried in the snowpack, and later failed and released fatal avalanches on 7 January at **Kicking Horse Mountain Resort** (page 328), possibly on **14 January in the Lizard Range** (page 331), **12 February at Commonwealth Valley** (page 333) and possibly on **20 April on Deltaform Mountain** (page 343). More snow and rain fell in December and January, and a long period of fair weather through much of February led to more weak layers when it started snowing again in late February and March. A weak layer of faceted crystals buried in late February was responsible for fatal avalanches on **3 March at Mt McBride** (page 337) and possibly **5 March at Mt Fernie** (page 341). Clear spring weather later in March and early April formed new weak layers, one of which led to avalanche near Bella Coola on 21 April (page) that killed one person.

Snow came early to the Coast and Columbia Mountains and the high alpine terrain of the Rockies, beginning in early October with some small storms. Around the middle of the month, a major system brought heavy snowfalls followed by rain to mountaintop in all ranges. While the low-elevation snowpacks melted, at high elevations the rain-soaked snowpack froze into a solid crust when temperatures cooled at the end of the month. A persistent series of storms began to affect all ranges at this time, leading to the burial of an "October Crust" topped with a weak layer of faceted crystals in many places. Snowpack heights were near normal for all ranges, and stayed that way as stormy weather continued through the first two weeks of November.

By mid-November things cleared up, and the third week of the month saw sunny skies with temperatures well above average. Above freezing conditions extended well into the alpine in all ranges. In the south Coast Mountains, a strong inversion led to daytime highs of 10°C above treeline. This began to shrink the snowpack everywhere and brought snowpack heights to below average. Temperatures cooled somewhat as weak storms at the end of the month were followed by arctic air flooding into the mountains from the north and east. The return to winter froze the wet upper snowpack into a thick temperature crust, particularly in the Columbia and Coast Mountains. Once buried, facets formed and this became the "November crust." Temperatures warmed somewhat, but a long, mostly dry period persisted through the first three weeks of December. Despite some small inputs of snow in the Columbia Mountains snowpacks heights were well below average in all ranges by mid-December. Surface hoar and faceted crystals covered the snow surface on sheltered aspects of all ranges.

Moisture from the Pacific finally arrived in all ranges around Christmas time. First, the Coast Range was slammed by the warm storm, bringing about 200mm of rain to Whistler Roundhouse (1835m) over seven days. Then the system pushed into the Columbia Mountains, where several days of snow were followed by rain just before Christmas, and then snow again into the New Year. The Rocky Mountains received a small amount of the snow from this storm, along with very warm and windy conditions. It continued to snow, with above-average warmth in all ranges into early January, leaving a "Christmas crust" and facets buried in the Coast and Columbia Mountains. That crust was absent in the alpine in most places. On **7 January at Kicking Horse Mountain Resort** (page 328) near Golden, BC, an out-of-bounds rider was killed when an avalanche released on the November crust.

All ranges received significant snowfall steadily through the month of January. After 60cm of snow in one day, the Whistler Roundhouse had a near-record high snowpack for that time of year. The South Rockies near Fernie, BC, received a similar amount of precipitation, leading to the release of a large natural avalanche that claimed the life of a worker in the **Lizard Range on 14 January** (page 331). A high pressure system appeared for a few days at the end of January on the coast, while a few warm and clear periods in the Columbia Mountains formed a crust and two surface hoar layers which were then buried by subsequent snowfalls. The snow resumed in all ranges through the end of January and into early February, clearing near the end of the first week. By that time the snowpack at Whistler Roundhouse was above average, while Mt Fidelity (1874m) and Lake Louise (1524m) reported average snowpack heights. February continued with seasonal temperatures and some arctic air, but little precipitation. Sunny skies and fair weather made for great riding in the mountains, although the buried crusts remained a concern in many places. One skier died in a large avalanche that released on the October crust in the front ranges of the Rockies near **Commonwealth Valley on 12 February** (page 333). By the fourth week of the month, stormy weather returned, burying a weak interface of surface hoar and facets—and in some places a crust—that formed during the dry period.

The late February storms continued into early March, bringing the snowpack height at Whistler Roundhouse to above-average levels, and to average in the Columbia and Rocky Mountains. In the south Columbia and south Rocky Mountains a brief period of clear weather in early March came in with strong winds and high temperatures. A fatal avalanche at **Mt McBride on 3 March** (page 337) near Nakusp, BC, and another at **Mt Fernie on 5 March** (page 341), released on late February weak layers buried by recent storms. Snow continued to fall in all ranges through March, with rising temperatures as spring arrived. In the Coast Range, several significant storms kept snowpack heights above average, while in the Columbia Mountains most locations slipped below average with small but regular inputs of snow. The Rocky Mountains maintained a close to average snowpack. A brief period of clear weather in the Columbia Mountains resulted in the formation of a weak layer of surface hoar crystals buried around 13 March.

A high pressure system returned to the coast for a brief period in early April under average temperatures, resulting in the formation of a surface hoar and facet weak layer. A weak but warm storm affected the Columbia Mountains during this period, bringing some light rain to treeline elevations and pushing the snowpack to below average and near record low levels. A major spring storm arrived to all ranges near the middle of April, refreshing the snowpack to average or above average heights. By late April some very warm, clear weather made for excellent mountaineering, although one person died in an avalanche following a cornice fall on **Deltaform Mountain on 20 April** (page 343) south of Lake Louise, AB. Snow was then replaced by rain, signalling the end of winter and the onset of typical spring snowpack ablation.

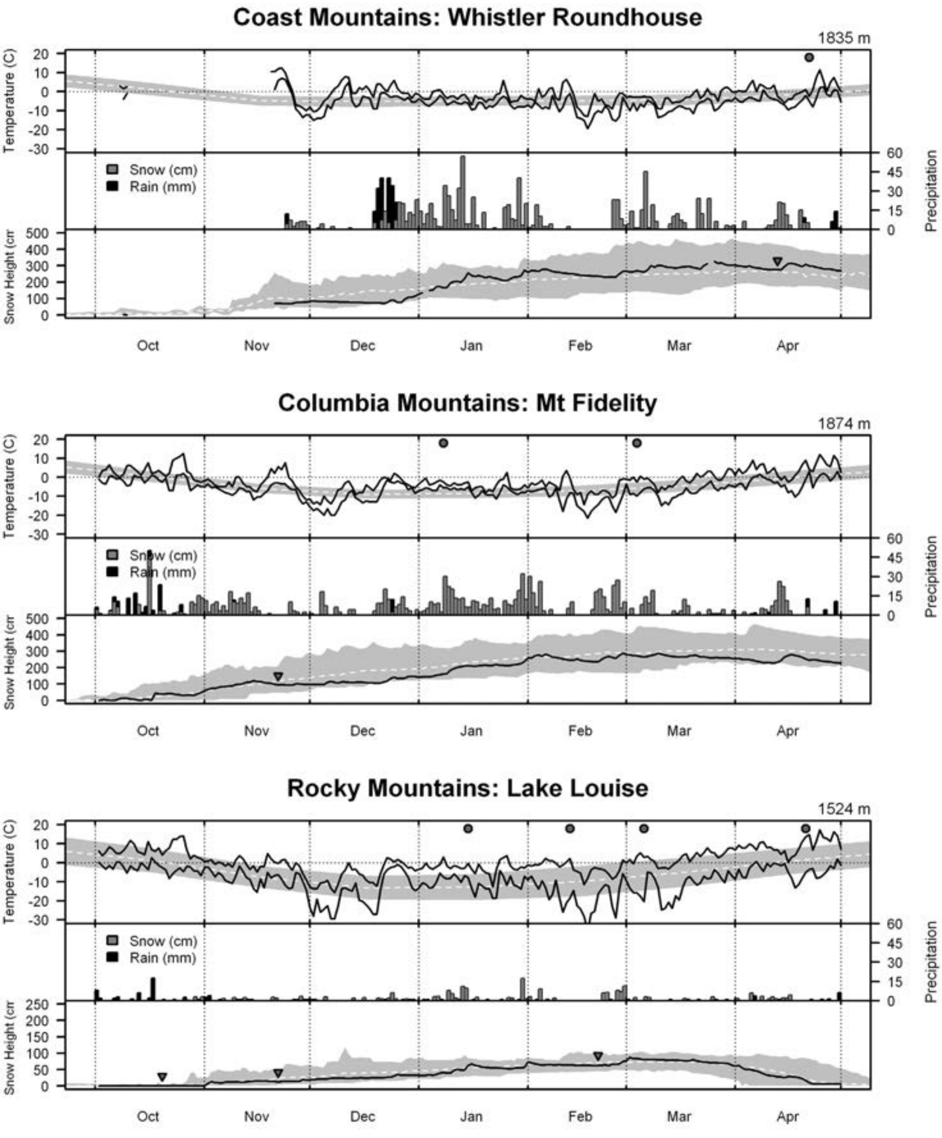

__Figure 13.1:__ Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 2005/2006 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanches (black triangles). The grey band shows minimum, average (dashed line) and maximum snowpack height measured at each location since 1976.

7 January 2006, Lift Snowboarding in Permanent Closure Kicking Horse Mountain Resort, Purcell Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Lone rider in permanently closed area of ski resort**
- **Avalanche transceiver turned off, in backpack**

A group of snowboarders was enjoying the fresh snow at Kicking Horse Mountain Resort near Golden, BC, on 7 January 2006. Around midday, one person split from the group and decided to make a run in an out-of-bounds area called "Terminator Ridge." He was an experienced backcountry traveler, and knew the local mountain well. Once on top of Terminator Ridge, there were several options available for a backcountry descent; however, the one the snowboarder chose was further along the ridge, and part of a permanently closed area within the ski-area boundary. In order to access his chosen run, the snowboarder had to cross back into the ski-area, past the rope marking the boundary. He also passed several warning signs marking the area as off limits, and subject to avalanche hazard.

The weather had been stormy in the days leading up to 7 January. The ski area had reported snowfalls of 5cm and 11cm on the preceding two days, and 10cm the morning of 7 January. Temperatures were below freezing during the storm, but had been gradually warming to a high of -1°C on the afternoon of 7 January (at approximately 2000m). Winds were predominantly from the northwest, but had switched to southwest on 6 January.

The ski area had noted isolated, small, natural, explosive- and skier-controlled avalanches over the previous few days. A nearby heli-skiing operation had also observed some whumpfing on a weak layer of faceted crystals buried about 60cm down in the snowpack. In the local mountains, the new snow was being moved around by the southwest winds, forming a soft slab.

The Canadian Avalanche Centre public avalanche bulletin issued on 6 January had forecast Considerable danger in the alpine and at treeline for 7 January. The travel advisory stated: "the main areas of concern remain wind exposed areas at tree line and above where recent winds have formed slabs. Since the winds have been predominantly from the south and west, expect to find slabs on north and east facing terrain near ridges opposite to the primary wind direction. The second (possibly more important) concern is the weak layer of faceted snow buried below the crust below 2000 – 2400m and under the storm snow above that." It is not known in the snowboarder was aware of the avalanche hazard or if he made any snowpack or weather observations.

Late in the evening of 7 January, friends of the snowboarder noticed he hadn't returned from the ski area that day. They notified the local police. The ski patrol, search and rescue volunteers, and the police initiated a helicopter and ground search at first light the following morning. Ground searchers noted a fresh avalanche on Terminator Ridge with one set of tracks leading into it, and none leading out. The tracks made a descending traverse to about 15m below the ridge top, and then disappeared into an area where a slab avalanche had released and run down to the base of the ridge.

The searchers immediately skied around to the deposit of the avalanche and began a visual and beacon search, while more rescuers landed in the helicopter. They could not find a signal. A few minutes later, another helicopter arrived on the scene with two rescue dog teams. One of the dogs quickly found a glove buried in the snow. When they looked closer, the rescuers discovered the glove belonged to the missing snowboarder, and that he was buried at the same location under about a metre of snow. He had died of asphyxiation as a result of the burial. He was wearing a backpack, in which rescuers found avalanche rescue equipment including a transceiver. It was not turned on.

The snowboarder had triggered a size 2 slab avalanche. It was 25m wide, about 70cm thick, and ran about 250m down the slope, through some small trees and over a steep, rocky area. The crown fracture near the snowboarder's entry track was at 2275m elevation, on a northeast aspect with a slope angle of 37°.

The ski patrol observed a fracture line profile on 8 January. A thin weak layer of faceted crystals found about 70cm below the surface was the failure layer for this avalanche. Investigators suspect the weak layer was part of a deteriorating melt-freeze crust buried back in November. It was sandwiched between thicker and stiffer layers of faceted crystals, with decomposing and rounded crystals from the recent snowfalls closest to the surface. Inconsistent snowpack stability test results were observed at the weak layer, mostly easy fractures but with broken or resistant character. The entire snowpack was relatively weak, but the contrast between the very soft weak layer and slightly stiffer slab and bed surface layers promoted the sequence of fractures that lead to avalanche release.

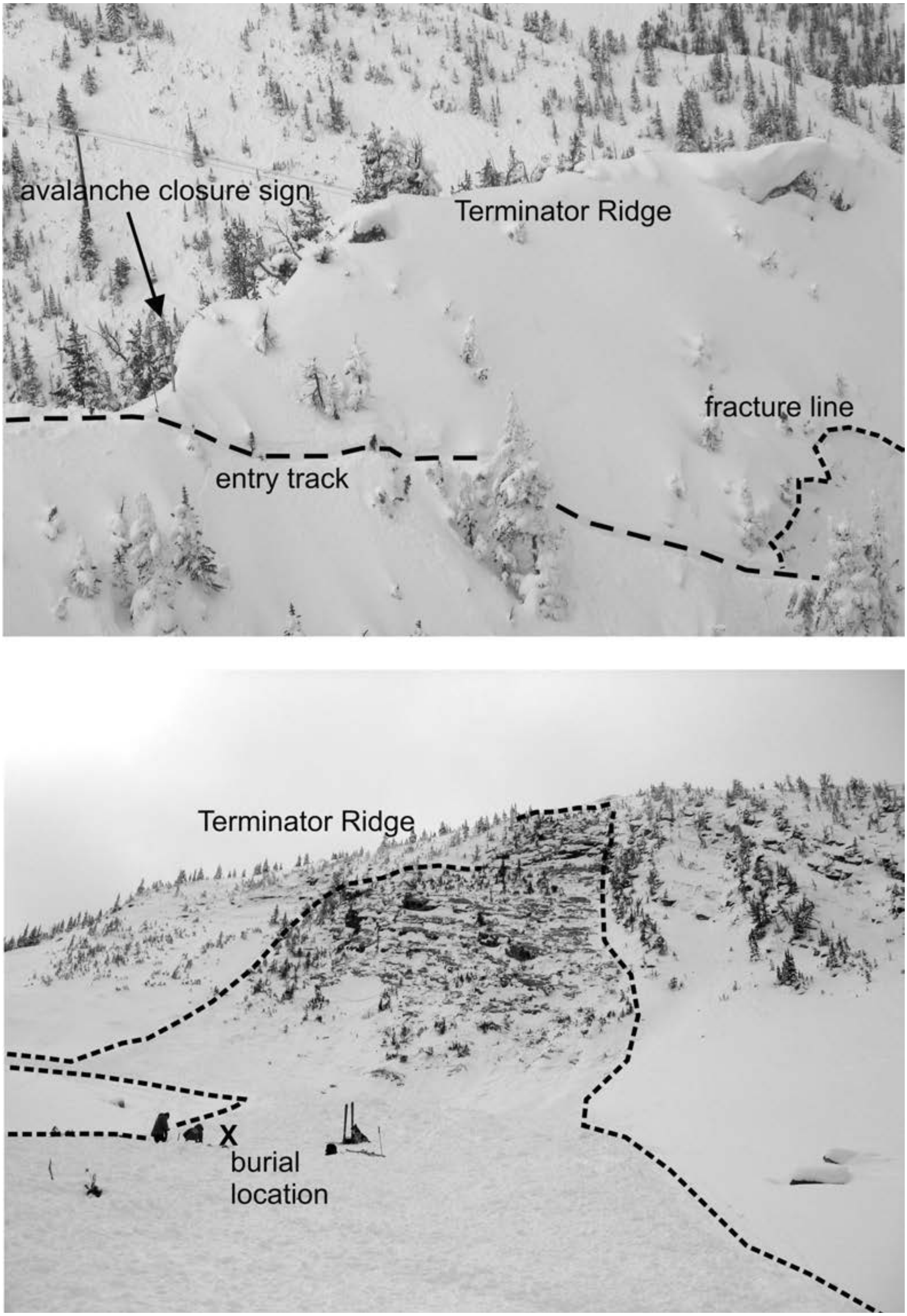

Figure 13.2 *7 Kicking Horse Mountain Resort, January 2005. Top photo shows snowboarder's line along the ridge and part of the avalanche fracture line. Lower photo shows released area and deposit. X - location of victim. Photos: Kicking Horse Mountain Resort.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	?	?	Yes (wind)	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
37°	None	Planar, unsupported	Sparsely treed slope

Source
- Mike Rubenstein
- BC Coroners Service
- InfoEx

Comments
While the freedom of the hills may beckon, riding alone in avalanche-prone areas reduces the margin of error significantly. If buried in an avalanche, it is essential that companion rescue occurs within a few minutes, which is not possible when riding alone.

Untracked snow, especially near ski area boundaries, may be tempting, but there are usually good reasons why these areas haven't been ridden. It is important to respect closed areas within and around ski areas.

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14 January 2006, Outdoor Worksite
Lizard Range, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Simple

- **An extreme avalanche ran into a snow study site**

A cat skiing lodge is located at an elevation of 1385m at the base of the Lizard Range of the Rocky Mountains. It is approximately 8km west of Fernie, BC.

A major storm started on 10 January. On 12 January, guides from the cat skiing operation triggered several avalanches from size 1 to size 3.5 on north- and east-facing slopes of the Lizard Range by placing explosives from a helicopter. A natural size 2.5 avalanche was reported in Wolverine Bowl above the Sunnyside study plot. On 13 January, the guides intentionally triggered ("ski cut") numerous size 1 to 1.5 slab avalanches. Also, several avalanches were triggered by explosives placed by hand, the largest of which was size 2.

In the bulletin for the South Rockies issued by the Canadian Avalanche Centre on 13 January, the regional avalanche danger in the alpine and treeline zones was rated High for

14 January. The bulletin also noted: "The large avalanche cycle will continue until someone shuts the tap off. ... Consider that some of the large avalanches reported went well down into their runout zones, so it's best to steer clear of large avalanche paths. ... Big avalanches were reported throughout the Fernie area up to Size 3.5, triggered naturally and by explosives. Expect the mountains to continue rumbling with avalanches Friday and Saturday with continuing snowfall ..."

Prior to each morning guides meeting, manual weather and snow measurements were conducted at two weather observation stations (study plots); one beside the lodge at 1385 m—which gets less snow than many of the avalanche start zones—and one at the Sunnyside weather station at 1600m. At 06:55 on 14 January, a tail guide left the lodge and drove a snowmobile 1.8km to the Sunnyside weather station.

At the Main study plot for Fernie Alpine Resort, located at 1645m and 9km southeast of the Sunnyside study plot, 40, 40 and 14cm of snow were recorded in the afternoon readings of the three days preceding the accident. The air temperature over these three days had ranged from -4.5 to -1.0°C.

At the cat-skiing lodge 7, 11 and 18cm of snow were reported on the mornings of 12, 13 and 14 January, respectively. The air temperature over these three days had ranged from -4.5 to -1.0°C.

On the morning of 14 January, a large natural avalanche in Wolverine Bowl above the Sunnyside study plot ran down to treeline, where it turned around mature trees and ran through the study plot, burying the tail guide and the weather observation station. She was not wearing a transceiver.

Back at the lodge at approximately 07:10, the lead guide heard a rumble from an avalanche and called the tail guide on the FM radio but did not get a reply. The lead guide notified the manager. After another unsuccessful attempt to contact the tail guide five minutes later, the manager drove a snowmobile to the study plot and reported that a large avalanche had overrun the plot. A search and rescue operation was started.

Upon arrival at the weather observation station, searchers did not detect a signal from a transceiver. A search by an avalanche rescue dog was started. The rescue team also began to search the area by forming a line and probing the avalanche deposit with probes. Others who were not part of the line probed at likely burial sites, and one of these searchers probed a box of weather instruments that had been moved by the avalanche. Further probing near the box detected the tail guide, who was located under approximately 1.5m of the avalanche deposit. After digging down to her, CPR was started. This continued during the helicopter flight to the hospital where the tail guide was pronounced dead. She had asphyxiated.

The slab avalanche released naturally (spontaneously) at about 2300m in the alpine zone on a northeast-facing slope inclined at more than 40°. The crown fracture was approximately 200 to 300cm in height and approximately 300m wide. The avalanche ran approximately 1km down the slope, flowed around mature trees and stopped just beyond the study plot. It was classed as a size 3.5 avalanche.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
High	?	Yes	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
>40°	None	Concave	Open

Source

- BC Coroners Service
- Canadian Avalanche Association
- InfoEx

Comment

No avalanches had reached the study plot during its 15 winters of use.

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12 Feb 2006, Backcountry Skiing
Commonwealth Valley, Kananaskis Country, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Experienced backcountry skiers**
- **Warm, sunny afternoon**
- **Deep weak layer**

The Commonwealth Creek Valley, in Kananaskis Country near Canmore, AB, is a common destination for backcountry skiers and snowshoers in winter. The ridgeline on the north side of the valley climbs steadily to Mt Smuts, interrupted by a large, round subpeak known as "The Fist." Several enticing bowl features feed into long avalanche paths dropping into Commonwealth Creek along this ridge. Between Mt Smuts and The Fist, two of these bowls offer particularly exciting skiing.

Just after noon on 12 February 2006, two experienced backcountry skiers from Calgary stood atop one of these slopes, just above the treeline at about 2500m elevation. They had climbed the ridge from Commonwealth Creek, making a series of switchbacks in the safety of thick trees separating two avalanche paths. Aware of the avalanche hazard on the slope they planned to ski, they decided to keep some distance apart as they began the long run to the valley bottom.

The weather was excellent for backcountry skiing; by the time they reached the top of the run, the temperature was a few degrees above freezing, the sun was out under broken skies, and there was little wind. The previous few days had been similar, with daytime high temperatures above freezing at treeline, calm winds and some clear skies.

The warmth of the afternoon sun had triggered some loose snow avalanches the day before, and similar events were occurring on this day, although the sun wasn't as strong through the clouds. They were mostly small, isolated releases from treeline elevations near trees or rocks. No slab avalanches had been observed in the area since about a week earlier, following 40cm of storm snow and a period of extreme winds.

The public avalanche bulletin issued on the evening of 11 February discussed the warming of the snowpack given the recent weather, and the resulting loose snow avalanches. Forecasters also mentioned a weak layer buried deeply in the snowpack, and that small avalanches could step down to this layer and release large slides. The danger was rated at Moderate in the alpine and treeline, and Low below treeline, with the caveat that snow stability would likely decrease by the afternoon in the alpine and at treeline if the weather stayed warm. Slopes facing the sun were highlighted as being the most suspect, with any areas of thin snowpack or protruding rocks a likely trigger point. It is not known if the skiers had read the bulletin.

Shortly after the two skiers started their run, a Kananaskis Country Public Safety Specialist doing snow studies on the opposite side of the valley heard a large avalanche occurring. He turned around to see a powder cloud fill the Commonwealth Valley, directly below the slope the skiers were descending. He quickly made his way down to the area of the avalanche deposit, where he encountered a lone skier.

She described to him how she and her partner had been skiing the slope above when they triggered an avalanche. She had been able to ski to the side and was not caught, but her partner had been carried by the avalanche through some small trees and was partly buried. She had been able to locate him quickly using her avalanche transceiver, but it was clear that he had been injured badly and needed medical attention. She was on her way to look for help, and had left two other skiers that witnessed the avalanche with her partner.

The Public Safety Specialist used his radio to call for help; a short time later, a helicopter arrived with a second Public Safety Specialist. In addition, four conservation officers who also work in the district responded. They all flew to the location of the victim by helicopter. When they arrived, the two witnesses were performing CPR on the injured skier. He was evacuated from the site on a long-line attached to the helicopter while CPR was continued, and moved to a waiting ambulance at the nearby road. Despite extensive resuscitation efforts, the skier had died from severe trauma caused by impact with trees as he was carried down the slope in the avalanche.

The deep-slab avalanche the two skiers triggered was large: it was approximately 400m wide and ran for about 1000m down the mountain, finally stopping near the valley bottom. It was a size 3.5, with slab thickness ranging from 40cm to 2m. It had released in two parts, a smaller area on the skier's left side of the path and a much larger area on the skier's right part of the bowl feature, separated by a subtle, thinly treed rib. The slope angle in the southeast facing start zone ranged between 35° and 37°; however, near the suspected trigger point—a small area of thin snowpack covering scrubby trees— the slope angle was closer to 40°. The avalanche occurred in a well-defined path, with an area of small trees in the middle part of the track. The runout zone of the path reaches the valley bottom. In fact, a group of snowshoers travelling near Commonwealth Creek, who were not carrying any avalanche rescue equipment or wearing transceivers, had narrowly missed being hit by this avalanche.

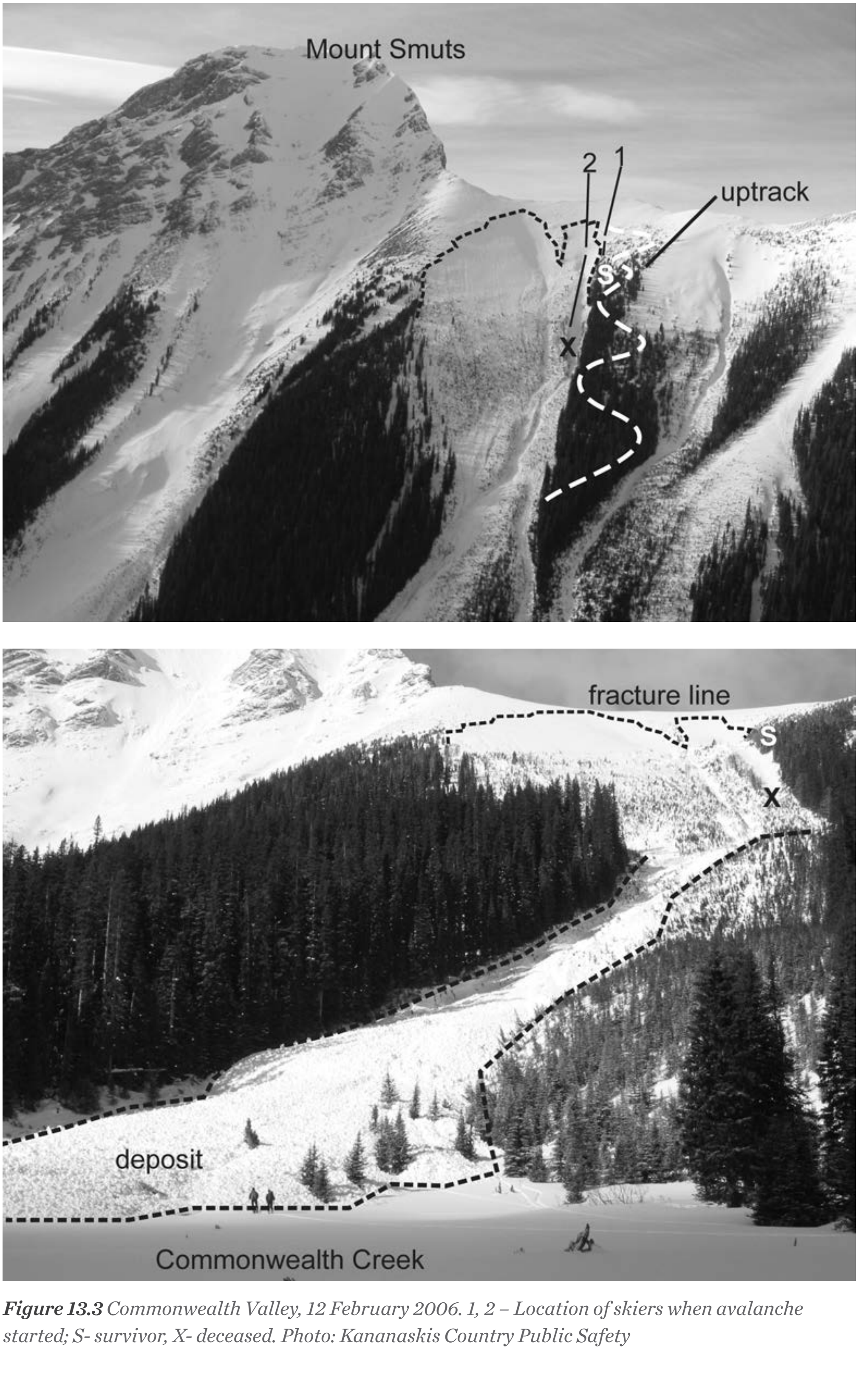

Figure 13.3 *Commonwealth Valley, 12 February 2006. 1, 2 – Location of skiers when avalanche started; S- survivor, X- deceased. Photo: Kananaskis Country Public Safety*

A few days after the accident, investigators observed several snow profiles along the fracture line. The snowpack height and layering varied considerably across the slope, although at all locations weak layers of depth hoar and faceted crystals were found in the lower snowpack near a prominent melt-freeze crust, which formed after a significant rain event the previous October. Stability tests at each profile site caused fractures not directly above the crust, but in a thicker layer of faceted crystals higher up in the snowpack below stiffer (likely wind-affected) layers of smaller faceted crystals. Photos taken of the bed surface a few days after the avalanche suggest it was triggered in this upper weak layer, but the fracture may have stepped down to the deeper weak layer near the November crust.

The start zone is cross-loaded by the prevailing westerly winds. Snow profiles and photos taken just after the avalanche highlight the significant variability in the height of the snowpack and its layering from the west or windward side of the start zone, to the east side near the trigger point. In many places in the start zone, the thin, weak snowpack covered scrub trees and rocks. These would have been difficult to detect before the avalanche, yet they make ideal locations to trigger fractures in weak layers near the bottom of the snowpack.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Moderate	Yes	No	?	No	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
40°	Trees	Planar	Open Slope

Source

- Mike Koppang
- Kananaskis Country Public Safety

Comments

Even experienced skiers can sometimes underestimate the effects of warm temperatures and spatial variability in the start zone on both the overall stability of the snowpack and the likelihood of triggering a fracture.

Deep weak layers often lie dormant for weeks or months, but when triggered usually result in large, dangerous avalanches.

Avalanche hazard is not limited to those skiing in the start zone or high in the path; a very lucky group of snowshoers narrowly avoided being hit by this avalanche near the valley bottom. Avalanche transceivers and self-rescue equipment should be carried at all times when travelling in or below avalanche terrain, and it is always wise to pay attention to what is happening on slopes above.

3 March 2006, Backcountry Skiing
Mt McBride, Valkyr Range, Selkirk Mountains

Deaths	Avalanche Problem	Terrain
2	Persistent Slab Wind Slab	Challenging

- **Fresh snow and clear weather**
- **Reverse loading by east winds**
- **Low angle slope with terrain traps**

A group of nine people were at a backcountry ski lodge, located in the northern part of the Valkyr Range of the Selkirk Mountains about 8km east of Faquier, BC, for a week of ski-touring and mountaineering. They chose a self-catered and self-guided option, preferring to take care of their own cooking and leading their own trips into the nearby mountains. The lodge is located in a broad basin near treeline, at about 2200m elevation on Naumulten Mountain. Guests at the lodge are instructed in the use of a nearby weather station, and are provided with up-to-date avalanche and weather information each day.

The group arrived at the lodge on 27 February 2006, and began the usual routine of rotating kitchen duties each day, so that most of the group could get out skiing early while a few stayed back to finish the chores. On 3 March 2006, three skiers stayed behind on kitchen duty, and then set out with a plan to spend the night camped out in the mountains. Their destination was Mt McBride, a prominent peak located about 5km south of the lodge. By mid-day, the three experienced winter mountaineers had covered a considerable distance toward their objective, and were establishing a trail up to the southwest ridge of Mt McBride, expecting to make use of it the following day en route to the summit.

As they approached the ridgeline at about 2300m elevation, they noticed the snow surface becoming stiffer and more supportive. This likely made for easier trail breaking, but also suggested that the upper snowpack was gaining a more slab-like character. They were climbing a northwest-facing slope with sparse trees and an overall incline of about 30°, often considered the lower limit for slab avalanching. There were areas of much steeper terrain leading into a prominent gully on their right as they climbed, and a more gentle approach was some distance away on their left. They were climbing as a group, with one skier breaking trail, and the other two following a short distance behind.

Records from the lodge show that on 26 February a short period of warm, humid weather at the tail end of a major storm had formed a thin, icy crust on the surface of the snowpack. Between 65cm and 75cm of new snow had fallen on the crust at treeline elevations from 27 February to 3 March. Several intervals of moderate and strong winds from the southwest had occurred during the stormy weather; however, overnight on 2 March 10cm of new snow was accompanied by 80 km/h winds from the east, the opposite of the typical direction in the local mountains. These extreme winds transported a significant amount of snow and deposited it on the lee, or west aspects below ridgelines. Clear, cold weather followed the easterly winds, and on 3 March—for the first time all week—the sun was out and there was fresh snow covering all the peaks around the lodge.

All the members of the group at the lodge that week were aware of the increasing ava-

Morning weather at Naumulten Lodge 2200m, 5km north of accident site					
Date	Max. Temp. (°C)	Min. Temp. (°C)	Sky	Snowfall 24 hour (cm)	Wind
27 Feb	-2	-4	overcast/obscured	6	Strong W
28 Feb	-2	-8	overcast/obscured	28	Light SW*
1 Mar	-2	-8	overcast/obscured	30	Strong SW*
2 Mar	-4	-10	overcast/obscured	0	Extreme E
3 Mar	-4*	-15*	clear	10	Mod NE

**estimated conditions based on records from nearby operation*

lanche hazard. In addition to having been informed of a size 2.5 remotely triggered avalanche that occurred the previous week, they had accidently triggered several avalanches themselves, as recently as 2 March, including one that resulted in a partial burial of one of the members of the group and some lost gear. A number of size 2 natural avalanches had also been noted in the area. Local heli-skiing operations had observed similar occurrences, and it is likely that many avalanches were visible from the lodge and surrounding terrain throughout the week.

While climbing towards Mt McBride, the group of three had encountered whumpfing, hollow- sounding snow, and cracking around their skis. They were well aware of the unstable snow around them, and were managing the hazard by sticking to low angle terrain. They noted a gradual improvement in the conditions as they approached the top of the ridge on the flank of Mt McBride.

The group at the lodge was provided with the pertinent public avalanche bulletins for the South Columbia Mountains. In the bulletin issued 1 March, the avalanche danger for 3 March was forecast to be High in the alpine, Considerable at treeline, and Moderate below treeline. The bulletin discussed storm snow sitting on a weak layer of faceted snow buried on 20 February, and recommended backcountry travelers to avoid steep slopes and restrict themselves to safe terrain below treeline. The group approaching Mt McBride had travelled below treeline and through the treeline band, and they were headed for the alpine.

As the lead climber of the group of three approached within 30m or so of the ridgeline, they all felt a whumpf in the snowpack and quickly realized they had triggered an avalanche. They were all caught. When the moving snow came to a stop, the skier who was in the lead found himself partially buried and with a dislocated shoulder after having been swept about 50m down the slope through some sparse trees and over a small cliff.

He was able to reset his own shoulder, and make a call for help on a satellite phone. He had to climb back up the slope a short distance, following signals on his avalanche transceiver, to find his partners; one was buried about 1m deep, the other about 2.5m, quite close together up against a small stand of trees. With great difficulty, the lone rescuer excavated his more shallowly buried partner, and began resuscitation efforts immediately.

Guides from a nearby heli-skiing operation arrived at the site by helicopter to respond to the call for help, and less than 30 minutes after the avalanche they had uncovered the

Figure 13.4 *Mt McBride, 3 March 2006. Note orientation of slope with respect to east winds, which are opposite to the prevailing pattern. 1,2,3 – Location of skiers at time of avalanche; S- survivor, X – deceased. Note low angle terrain on left, with steeper slopes dropping into gully feature on right. Photo:Will Geary.*

more deeply buried skier. Resuscitation efforts continued on both victims, but neither survived.

The skier-triggered hard slab avalanche was a size 2.5, about 100m wide and ran down the northwest-facing slope for about 250m. Its crown fracture was approximately 60cm thick, and had released from about 2290m elevation in two connected parts. In the area of the skiers and to climber's left, the slope was consistently about 30° incline, with a deposit about 1m deep; to climber's right, the slope rolled over to an incline of 40 – 50° on the side of a prominent gully feature, which confined some of the moving snow and resulted in a deposit about 2m deep. Combined, the deposit was 135m wide, contained many rigid blocks of snow, and overran the ascent tracks of the group. The two victims of the avalanche were carried only a short distance before being pushed into a stand of small trees and buried. The surviving skier was carried further down the slope into the gully feature.

The heli-skiing guides performed a fracture line snow profile on the day of the accident, and investigators did the same the following day, with consistent results. Both found the thin crust layer formed on 26 February buried beneath a slab about 60cm thick. The slab contained two very stiff layers and some softer storm snow. Below the crust, the bed surface of the avalanche was a layer of old, stiff snow topped with soft, weak, faceted snow formed during the cold weather period ending around 20 February and responsible for much of the recent avalanche activity. Snowpack tests caused collapsing fractures atop the 26 February melt-freeze crust, suggest-

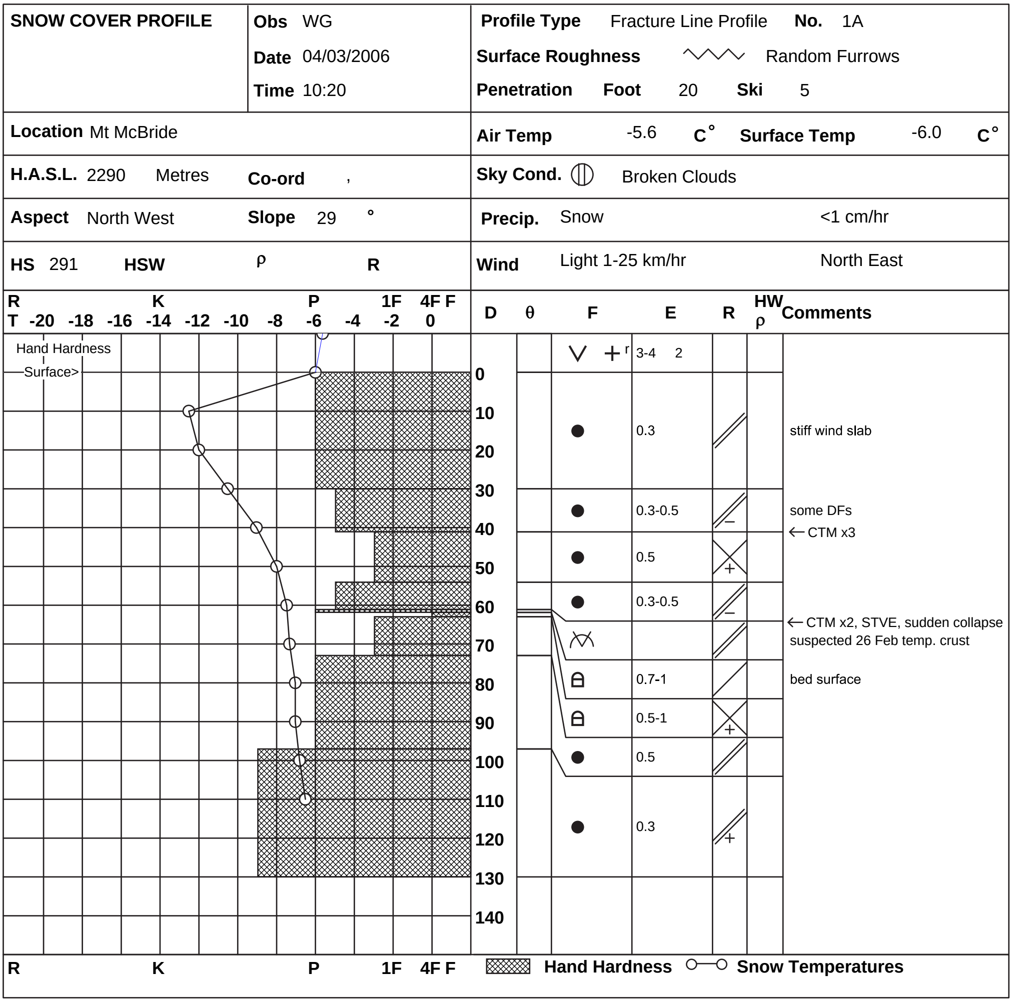

Figure 13.5 *Mt McBride, 3 March 2006. Fracture line profile observed by investigators one day after the avalanche.*

ing the initial weak layer fracture triggered by the skiers had occurred there. Once the stiff slab was in motion, it likely destroyed the crust layer and scoured the weak snow from 20 February down to the old, stiff layers.

The two stiff slab layers evident in the fracture line profile were likely wind slabs formed during periods of strong winds from the southwest (lower layer), and the east (surface layer). The profile observed on the day of the avalanche showed approximately 10cm of unsettled snow at the surface, matching the weather report from the lodge that morning. Of note is the fact that the investigators found a thick, stiff wind slab near the ridgeline in the area of the avalanche crown and trigger point, while lower down on the slope the surface was relatively loose. This suggests the east winds that had reverse-loaded the slope and formed the stiff wind slab weren't affecting the snow further away from the ridge top, and that the skiers would have been climbing through rapidly changing conditions as they approached the ridge.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	Whumpfs, hollow sounds	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
30°	Trees and cliff	Convex and unsupported	Open slope

Source

- BC Coroners Service
- Valkyr Lodge
- InfoEx

Comments

Even for skilled and experienced backcountry skiers, blue skies and fresh snow can be a powerful lure to keep going, despite the avalanche hazard and warning signs present.

Easterly winds are not typical for the Selkirk Mountains. When they do occur, snow can be transported onto slopes that would not normally be loaded by wind, and wind slabs can form in atypical places near ridgelines. These conditions can surprise even experienced people, especially when there are persistent weak layers recently buried by heavy accumulations of storm snow.

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5 March 2006, Snowmobiling
Mt Fernie, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Triggered from area of thin snowpack near rock outcrops**
- **Snowmobiler parked at the base of a slope when buried by avalanche**

At about 11:00 on Sunday 5 March, two men rode their snowmobiles up Fairy Creek just north of the town of Fernie, BC for a day of recreation. Rider 1 carried a transceiver, shovel and probe but his companion did not have a transceiver. They climbed up to an east-facing bowl on Mt Fernie with many scree slopes and few trees. They noticed old avalanches but no recent ones. Also, they observed no cracking in the snow. One of the riders tested a slope by “cutting” across it but was unable to trigger an avalanche. They began highmarking, each trying to climb successively higher up the slope with their snowmobiles than the previous attempt.

Two days previously, the Canadian Avalanche Centre issued a regular bulletin for the South Rocky Mountains, rating the regional avalanche danger in the Alpine and Treeline zones as Considerable. The bulletin noted: “The snowpack is still very weak and fragile right now. The recent storm snow, which contains two failure planes, was still giving easy shears in snowpack tests on Friday. The layer of faceted crystals buried under the storm snow is the weak zone that will be subject to human triggering for some time; definitely through this weekend."

At the main study plot for Fernie Alpine Resort, located at 1650m elevation and about 9km south of Mt Fernie, less than 4cm of snow had fallen in the preceding three days. The air temperature reached 1°C on 5 March, which was the first temperature above freezing in the preceding three days.

At 14:30, hikers in the area saw Rider 2 highmarking a steep chute in an area with thin snowpack. On a slope of at least 45°, he triggered a slab avalanche between two rock outcrops but was able to ride out of it. Rider 1 was stopped lower in the bowl below Rider 2, where he was hit by the avalanche, carried by it and buried in the deposit.

Rider 2 descended and dug out his friend's snowmobile. After 25 minutes of searching for his friend, he had not found him and left by snowmobile to get help. The local RCMP was notified at 15:27. Search and rescue volunteers, an avalanche dog and ski guides from a near-by lodge flew by helicopter to the avalanche site. They arrived at 16:30 and used the avalanche dog and transceivers to quickly locate the buried rider. He was pinned under his snowmobile about 1m below the surface of the deposit. CPR was started and continued on the helicopter flight to hospital where the victim was pronounced dead. He had asphyxiated.

The crown of the size 2 dry slab avalanche was 30 to 80cm high and about 35m wide. The avalanche started at an elevation of about 2000m, and ran about 150m down the slope.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
45°	?	?	Alpine

Source
- BC Coroners Service
- BC Provincial Emergency Program
- Fernie RCMP

Comments
The snowmobilers had not checked the Canadian Avalanche Centre's avalanche bulletin.

Estimating how far avalanches run—and hence where to stop safely at the base of a slope—is difficult. This is one of several accidents in which snowmobilers have been caught while parked at the base of a slope.

Effective companion rescue requires that every person has at least a transceiver, shovel and probe.

20 April 2006, Mountaineering
Deltaform Mountain, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	?	Complex

- **Two climbers triggered an initially shallow slab avalanche on a serious alpine climbing route**

On 19 April 2006, two climbers snowshoed into Eiffel Lake in Banff National Park, where they camped. The bulletin for Banff, Yoho and Kootenay National Parks issued on that day noted that north-facing slopes were cool and wintery but that "daytime heating is also a concern on south aspects." The danger rating for the alpine was Considerable.

At 03:30 on 20 April, they left camp to climb the Supercouloir route on the north face of Deltaform Mountain. They reached the top of the route—which is not the summit of the mountain—at about 15:00. While roped together, they began to descend into Kootenay National Park on the windward, south-east side of the east ridge. After descending about one rope length on a 35-40° slope, they triggered a slab avalanche. Climber 1, who was initially lower on the slope, recalled being pummeled by the moving snow but kept "swimming." The avalanche swept the two climbers about 900m vertically down the slope.

When the climbers and the avalanche stopped, Climber 1 was buried up to his knees. He had broken his right femur and lower left leg, and sustained a concussion and pneumothorax (an abnormal pocket of air in the chest cavity that at least partly collapses a lung). The rope was cut about a metre from his waist. He had lost his helmet, his warm gloves and the lid of his pack. He crawled about 2m and then stayed there for three nights. He did not drink or eat for the first two days, and then was able to drink some water that he melted in his water bottle. For much of the time, he hallucinated that his partner was alive and higher on the mountain. On the third day, he realized he had been hallucinating and tried to crawl from the avalanche deposit towards a lake. After crawling about a hundred metres, he was found by park wardens.

On 20 April at 04:00, the air temperature at the Bosworth Remote Weather Station (2773m) was -4.6°C. From 14:00 to 20:00, the temperature varied between 0 and -0.9°C. The Bosworth weather station is located approximately 18km north-northwest from the accident site.

The climbers had left word when they were due back but not which route they intended to climb or where they would park their vehicle. After they were reported overdue, park wardens searched parking lots in Jasper, Banff, Yoho and Kootenay National Parks for their vehicle. After finding it, the wardens flew by helicopter, searching the climbing routes on Mt Fay, Mt Temple and then Deltaform Mountain. When they spotted Climber 1—who survived—they were able to land the helicopter within about 50m of his location. A few hundred metres from Climber 1 and in another lobe of the deposit, Climber 2 was located and evacuated by helicopter. He had sustained a fatal head injury in the fall.

The slab avalanche was 15-20cm deep at the crown and about 20 metres wide. It stepped down to a lower bed surface, approximately 150cm below the snow surface. The avalanche ran 1300m down very steep gullies and over cliffs for a vertical drop of 950m. The maximum width of the avalanche in the track was 75m. The maximum width of the deposit was 250m.

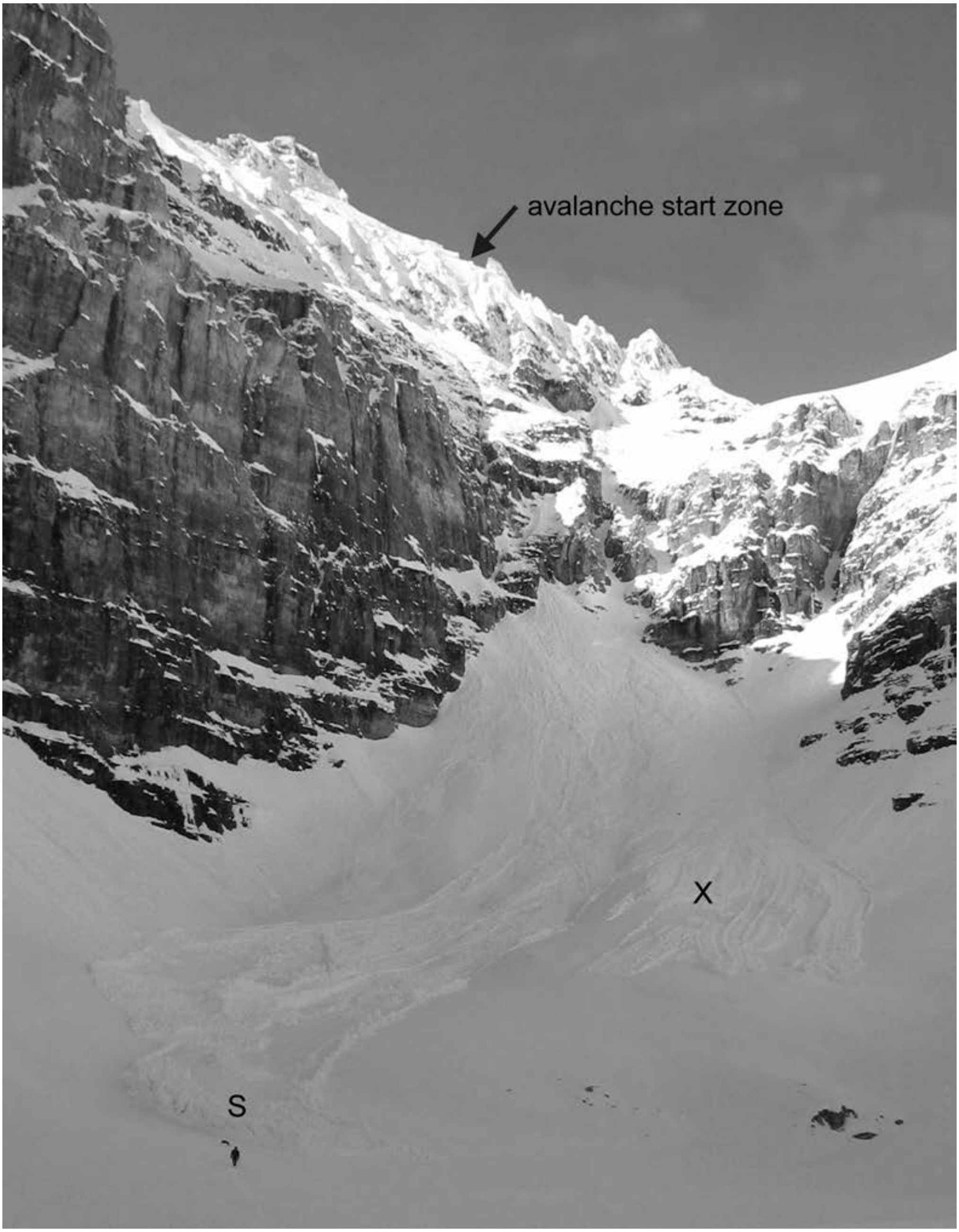

Figure 13.6. *Deltaform Mountain, 20 April 2006. S - survivor, X – deceased. Photo: Parks Canada—Brad White.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	?	?	?	?	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Cliffs	?	Alpine

Source

- BC Coroners Service
- Parks Canada

Comments

The rescue was delayed by the lack of information about where the climbers intended to park their vehicle and which route they intended to climb.

The climbers did not have transceivers but this did not affect the outcome.

21 April 2006, Heli-Snowboarding
Bella Coola, Central Coast Mountains

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Professional snowboarder caught and buried while being filmed**
- **Variable spring snowpack with limited information available for assessing stability**
- **Deep burial within a glacial crevasse**

A group consisting of two professional snowboarders, a cinematographer, photographer, and a safety person had gathered in the Coast Mountains, south of Bella Coola, BC, at a local heli-skiing operation in order to film some big-mountain riding. By 21 April 2006 they had been in the area for two weeks. Their original plan was to stay for one week, but poor flying and filming conditions led them to extend their stay, and meant that for the extra week they did not have a dedicated helicopter for their use. For the extra week the heli-skiing company would provide flights and guiding support for the group.

This heli-skiing operation is quite isolated, and had been grounded for two days in the three leading up to 21 April. On 20 April, they had acquired some limited snowpack and avalanche observations.

Several natural avalanches occurred in the area on 19 April, but these were not observed until 20 April. On the morning of 21 April, guides had performed snowpack tests and found moderate but sudden planar results on a buried weak layer. In addition, another group in a nearby area with a shallower snowpack had triggered some small skier-controlled and accidental avalanches throughout the day. No public avalanche bulletin is issued for this part of the Coast Mountains.

After several days grounded by the weather, the group was finally able to get out and do some filming on 21 April. Around midday, the two snowboarders were dropped atop a large alpine face, while the rest of the group set up on an adjacent ridge with a good view of the run. The air temperature was -7°C, with moderate westerly winds. The first snowboarder made a successful descent at around 12:25. At 12:35, the second snowboarder started down the face, and triggered a large slab avalanche. He tried to outrun the avalanche to the bottom of the slope and onto the glacier below, but a second smaller avalanche was triggered by the first, and eventually he was overtaken by the moving snow.

The rest of the group rushed to the area of the avalanche deposit and began a transceiver search. Within 10 minutes, they had pinpointed the location of the buried snowboarder with their avalanche probes. He was buried under more than 3m of snow after having been swept into a crevasse in the glacier, and covered by the deposits of both avalanches.

A second helicopter, including a guide and his group of skiers, arrived on the scene and assisted in digging for the victim. After 93 minutes of burial, the snowboarder was uncovered in a semi-vertical position, not breathing and lacking any vital signs. Resuscitation efforts began immediately.

The RCMP had been notified of the avalanche, and arrived on the scene at around 14:00. They helped evacuate the victim to hospital while CPR was continued, unsuccessfully, until around 16:40. The snowboarder had died of asphyxiation.

The snowboarder triggered the size 3 avalanche at approximately 2650m elevation, on a 45° north-facing ice headwall surrounding by rocky terrain. The slab was 120m wide, about 50 to 80cm thick, and ran for 500 to 700m down the slope. The deposit from the two avalanches was large: approximately 200 to 300m long, 120m wide, and 1 to 5m deep. It ran over bulges, benches, and crevasses in the glacier; those features increased the depth of the deposit in some places.

A period of clear weather ending on 12 April had affected the snow surface, leaving patchy areas of small faceted crystals and surface hoar. It snowed intermittently over the next nine days, with the largest amounts on 13 April and 19 April. The fresh snow from 19 April was settling into a soft slab in reports from 20 April. By the day of the accident, 30 to 50cm of settled storm snow was overlying the weak layer buried on 12 April in most places, with locally thicker slabs at higher elevations and on lee slopes. The fatal avalanche and several others the same day released on this layer. Despite limited observations, the guides were aware that the condition of the weak layer and overlying slab were variable from one run to the next, which is typical of springtime snowpacks.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	Yes	Yes	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
45°	Crevasses	?	Alpine

Source
- BC Coroners Service
- InfoEx
- Paul Berntsen

Comments
The snowboarders were trained professionals, aware of the risks, and had taken many precautions prior to riding the slope that avalanched. Despite their preparations, several factors may have influenced the outcome of this run: variability in the spring snowpack, a deep burial within a crevasse on the glacier, and possibly pressure to get some good riding on film at the end of a few weeks of lousy weather.

Chapter 14

Avalanche Accidents of Southwestern Canada **2006-2007**

Winter Summary for Southwestern Canada

- **3 fatalities in 2 accidents in southwestern Canada**
- **Heavy snowfall and few persistent weak layers**
- **One widespread layer of surface hoar released many dangerous avalanches**

List of Fatal Avalanche Accidents							
Date	Location	Mountain Range	Activity	Fatalities	Avalanche Problem	Persistent Weak Layer[1]	Page
5 Nov 2006	Mt Inflexible	Rocky Mountains	Ice Climbing	1	?		352
9 Mar 2007	Hall Mountain	Monashee Mountains	Snowmobiling	2	Persistent Slab	4 Feb 2007	354

[1] It is common practice to name persistent weak layers according to date they were buried. Burial dates presented are rough estimates, particularly for early season weak layers due to the lack of detailed weather and snowpack information.

The winter of 2007 was dominated by heavy snowfall, no major crust buried in the fall, and only one widespread persistent weak layer, buried in February and responsible for a fatal avalanche at **Hall Mountain on 9 March** (page 354) south of Revelstoke, BC. The only other fatal avalanche occurred in early fall following a period of strong winds at **Mt Inflexible on 5 November in Kananaskis Country** (page 352).

Following a slightly late start, snow began to accumulate in all ranges by mid-October. A warm storm in early November brought strong winds and snow, with rain to treeline and above across southwestern Canada; during that storm an ice climber was killed by an avalanche at **Mt Inflexible on 5 November** (page 352) in Kananaskis Country. The snow started falling in earnest by the second week of November, and it did not stop until late January. Snowpack heights at Whistler Roundhouse (1835m), Mt Fidelity (1874m), and Lake Louise (1524m) exceeded normal levels in by mid-November, and stayed above average until late spring.

By mid-January most places in all ranges were at or near a record-high snowpack when a high pressure system brought clear skies and warm temperatures to all ranges. During that period large surface hoar and faceted crystals grew at treeline and below. Some locations saw surface hoar crystals greater than 3cm in length. When the snow returned to all ranges in early February, it started slowly and was able to bury those weak crystals without destroying them. As temperatures cooled and storms intensified, many abnormal releases were observed to release on the February weak layer in the Columbia Mountains—very low angle slopes, dense forests, and creek banks were releasing dangerous avalanches. Vigilance by guides and a public awareness campaign—led by the Canadian Avalanche Centre—describing the dangers of this layer probably saved many lives. No fatal avalanches occurred during the month where that layer was most active, although there were many close calls; however, on **9 March at Hall Mountain** (page 354) south of Revelstoke, BC, two snowmobilers died when an avalanche released in a cutblock on the February surface hoar layer.

The latter part of February saw typical snowfalls occurring in all ranges, but March brought a series of major storms that kept the snowpack height above average levels in all ranges. One major rain event in early March led to an extensive avalanche cycle in the Coast Mountains. By April, the winter weather finally abated and a typical spring pattern was established.

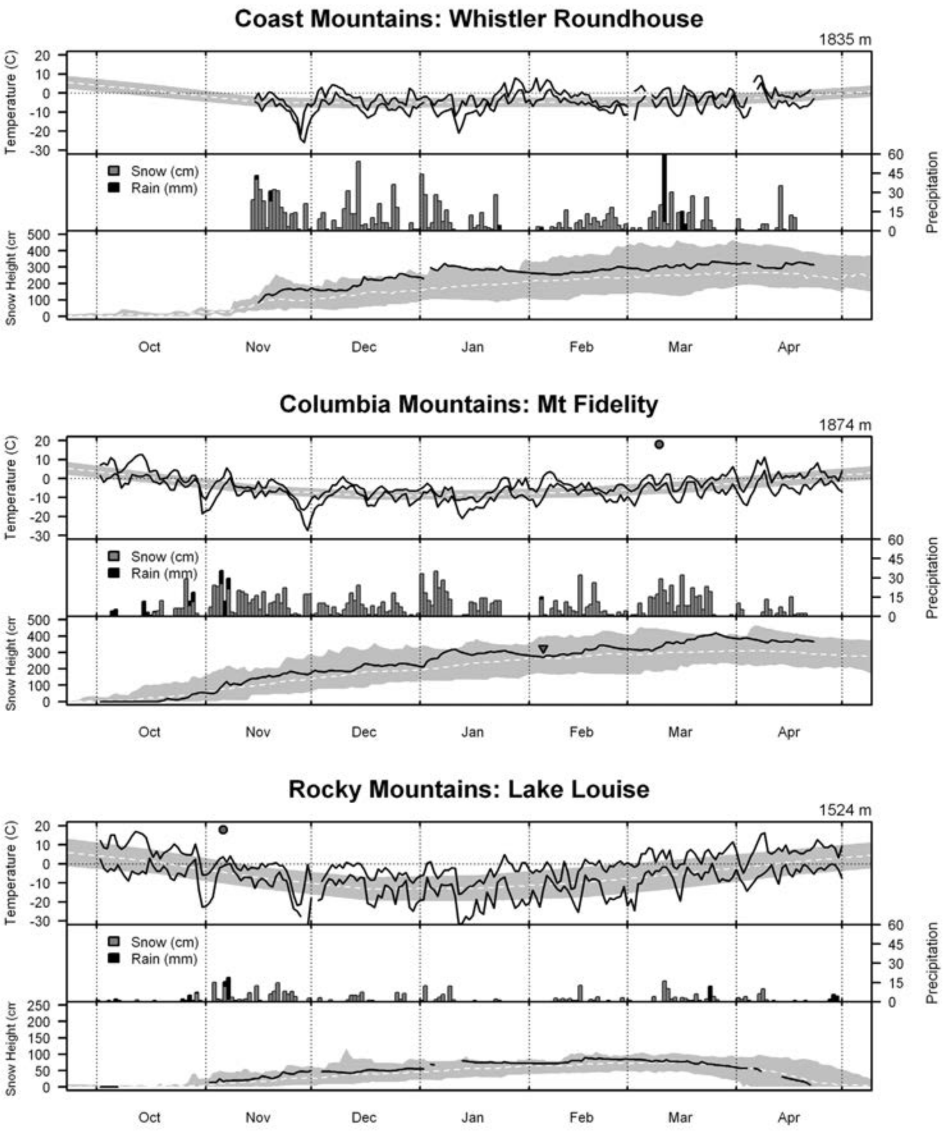

Figure 14.1: Weather and snowpack development at representative locations in the three main mountain ranges in southwestern Canada for the 2006/2007 winter season. In each chart, the top panel displays time series of daily minimum and maximum temperatures in relation to the climatological average daily minimum, maximum (grey band), and mean (dashed white line) temperatures. Circles at the top of the chart indicate fatal avalanche accidents in the specific mountain ranges. The middle panel shows daily amounts of new snow incm (grey) and rainfall inmm (black). The bottom panel displays the seasonal development of the height of the snowpack (black line) and the burial dates of persistent weaknesses involved in fatal avalanches (black triangles). The grey band shows minimum, average (dashed line) and maximum snowpack height measured at each location since 1976.

5 November 2006, Ice Climbing
Mt Inflexible, Kananaskis Country, Rocky Mountains

Deaths	Avalanche Problem	Terrain
1	?	Complex

- **One climber swept off route**

On the east side of Mt Inflexible, two climbers were climbing a frozen waterfall below an alpine cirque. They had chosen the route partly because they had observed a deposit from a recent avalanche in the gully. The avalanche danger rating for the alpine zone was Low. However, the bulletin issued the previous day cautioned that: "Pockets of unstable snow continue to persist in small features such as gullies, along ridgelines and in-between pitches of ice climbs. Avalanches that occur in these areas will likely be small but they do have the potential to carry a backcountry user over cliffbands or other similar terrain features."

At the Nakiska Ridgetop weather station at 2543m, 18km north of Mt Inflexible, wind speeds since midnight ranged from 24 to 100 km/h—favourable to wind loading. The air temperature at the weather station was approximately -1.4°C at 13:00.

At about 13:10, the climbers were in a narrow gully when an avalanche swept down the climb. The leading climber was partially protected by a rock outcrop which deflected some of the avalanche around and over him. The lower climber was carried about 20m and buried in the gully, still attached to the rope.

The climbers did not have avalanche transceivers, probes, or shovels. The surviving climber followed the rope to the vicinity of his partner and dug for approximately 45 minutes with his helmet before going for help. When Kananaskis Country rescue personnel arrived at the site, they probed where the rope entered the deposit and found the victim approximately 1.9m below the surface. The medical examiner determined that the victim died of traumatic asphyxia.

The size 2 slab avalanche released from snow pockets between cliff bands on a northeast-facing slope. Although the investigation was hampered by poor weather, a crown fracture above the waterfall was estimated to be about 50cm thick on a slope of approximately 35°. Investigators suspect a smaller point release avalanche close to the 2600m ridge may have triggered the slab avalanche, which ran about 200m. The deposit was approximately 3m deep.

When the rescuers arrived at the accident site, the air temperature was 2°C and the snow surface was moist.

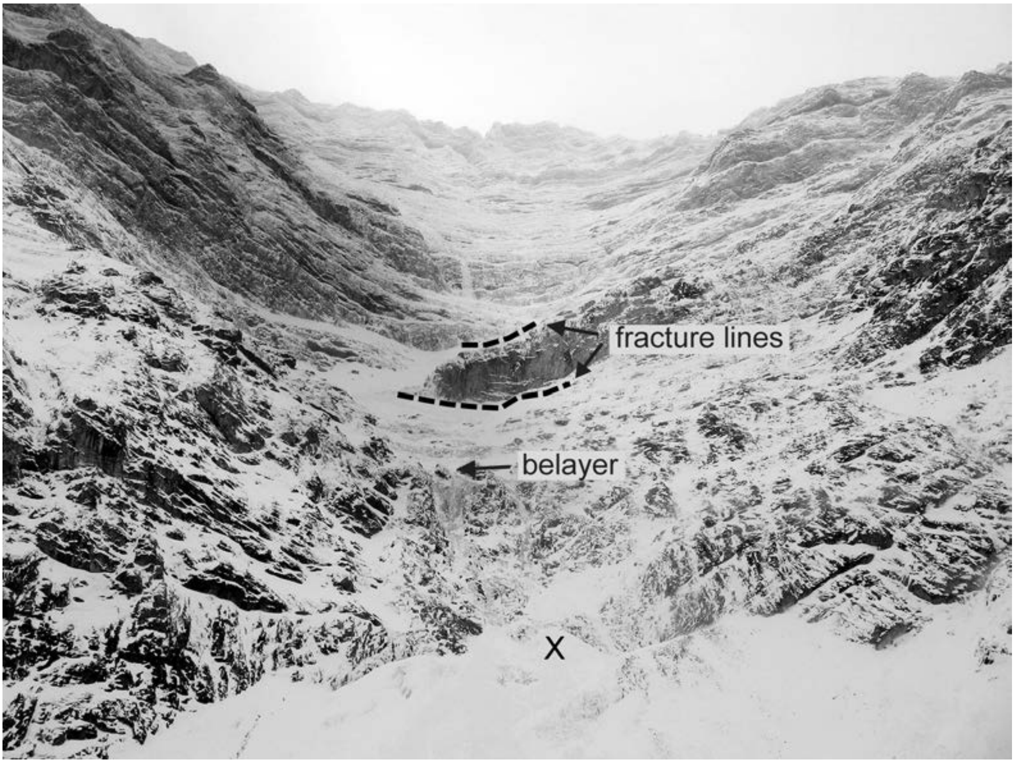

Figure 14.2. *Mt Inflexible, 5 November 2006. Dashed lines show locations of crown fractures observed after the avalanche. X deceased. Photo: Kananaskis Country Public Safety.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Low	?	Yes	?	Yes (wind loading)	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Gully, cliffs	?	Alpine

Source
- Dave Hanna
- Burke Duncan
- The victim's climbing partner

Comment
The two climbers were ascending below a cirque following recent wind loading. On the day of the accident, wind speeds were favourable for continued wind loading and the temperature

was rising to above 0°C. Since cirques like this one can funnel avalanches from many different parts of its upper reaches, the observation of a deposit did not mean other avalanches were unlikely.

9 March 2007, Snowmobiling
Hall Mountain, Monashee Mountains

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	Complex

- **Seven snowmobilers on the slope at the time of the avalanche**
- **Group equipped with rescue equipment; efficient companion rescue**

On the morning of 9 March, seven snowmobilers headed for Hall Mountain in the Monashee Moutains, which is approximately 32km south of Revelstoke, BC. All had transceivers, probes and shovels. They approached the west slopes of Hall Mountain by a road around the south end of the peak.

Two days before the snowmobile trip, the Canadian Avalanche Centre issued a regular bulletin for the South Columbia Mountains. The danger was rated Considerable below treeline. It also noted: "Avoid big, open terrain, particularly that which faces south and west. Expect avalanche danger to be somewhat elevated in the afternoons from what you found in the mornings." For this northern part of the South Columbia Mountains, the bulletin also stated that "some slab avalanches are still running ... but nothing large has been seen since the weekend."

At the Galena Pass weather station at 1570m and 23km to the east, the temperature had peaked slightly between 1 and 2°C in the previous four days. On the day of the accident, the temperature was slightly cooler, rising from -3°C in the morning to -1°C in the afternoon. Precipitation was light with 4mm of water equivalent falling on the day of the accident, 5 and 6mm on the preceding two days (one centimetre of snowfall is roughly equivalent to 0.5 to 1 millimetre of water). This precipitation could have been snow and/or rain.

While the snowmobilers were stopped for lunch near Coursier Lake west of Hall Mountain, they noticed a recent slab avalanche in a west-facing cutblock on Hall Mountain (which will be called Cutblock A in this summary). This was the only recent avalanche they observed. They decided to proceed with caution, and planned to ride near the side of cutblocks so they could escape into the forest if an avalanche occurred. The group headed for the cutblocks south of the one that had avalanched, and split onto two groups. The group that arrived in Cutblock C (two blocks south of Cutblock A) climbed it without incident, before heading for Cutblock B.
Snowmobilers 1 and 2 arrived in Cutblock B, just south of the one that had avalanched. Snowmobiler 1 climbed up the south side—10 to 15 metres from the forest—and got stuck. Snowmobiler 2 also stayed close to the forest on the south side of the cut block. He got farther up the slope than his fellow rider but "didn't like the look of the slope ahead of him" and turned into the forest.

Two of the riders from Cutblock C, Snowmobilers 3 and 4, arrived in Cutblock B and began to climb it. Snowmobiler 3 paused on a bench, and was passed by Snowmobiler 4, and

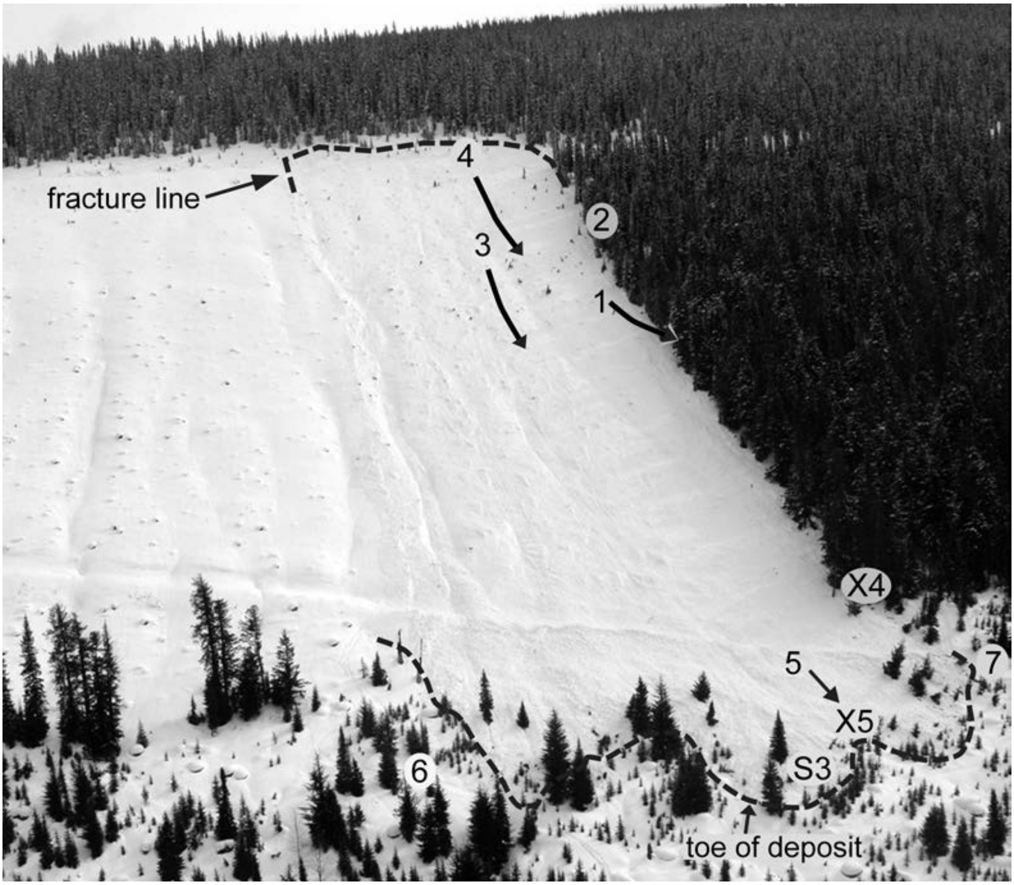

Figure 14.3. *Cutblock B on the west-facing slope of Hall Mountain, 9 March 2007. The numbers represent the snowmobilers in the narrative. S - survivor, X – deceased. Photo Bruce Allen.*

then began to follow up the slope. Snowmobiler 5 arrived, started to climb then turned downward before a second attempt. He was descending just below the road that cut diagonally across the bottom of the cutblock when the avalanche released, just as Snowmobiler 4 climbed to the road across the top of the cutblock. It was 15:55.

Snowmobilers 6 and 7 arrived at the bottom of the cutblock, saw the avalanche release, shouted out a warning and drove in opposite directions, narrowly escaping the main force of the avalanche. Snowmobiler 1 had just freed his machine when he heard a warning shout. He saw the avalanche approaching and drove down at an angle to the edge of the forest where he jumped off his sled to hide behind a large tree. The avalanche flowed around the tree, and pushed him cart-wheeling down the slope, but did not bury him.

The avalanche pushed Snowmobiler 2 a few metres further into the forest. Snowmobiler 5 was still descending the slope when the avalanche hit him from behind. When hit by the avalanche, Snowmobiler 3 retained control, rode downhill then was being buried by the avalanche when his sled hit a bent tree that bumped him to the surface as the avalanche was stopping. He was only partly buried and easily freed himself from the deposit.

Snowmobilers 1, 2 and 3 were not buried. Quickly realizing two others were missing, they switched their transceivers to receive mode and began to search. Snowmobilers 1 and 2 quickly picked up a signal, followed it,

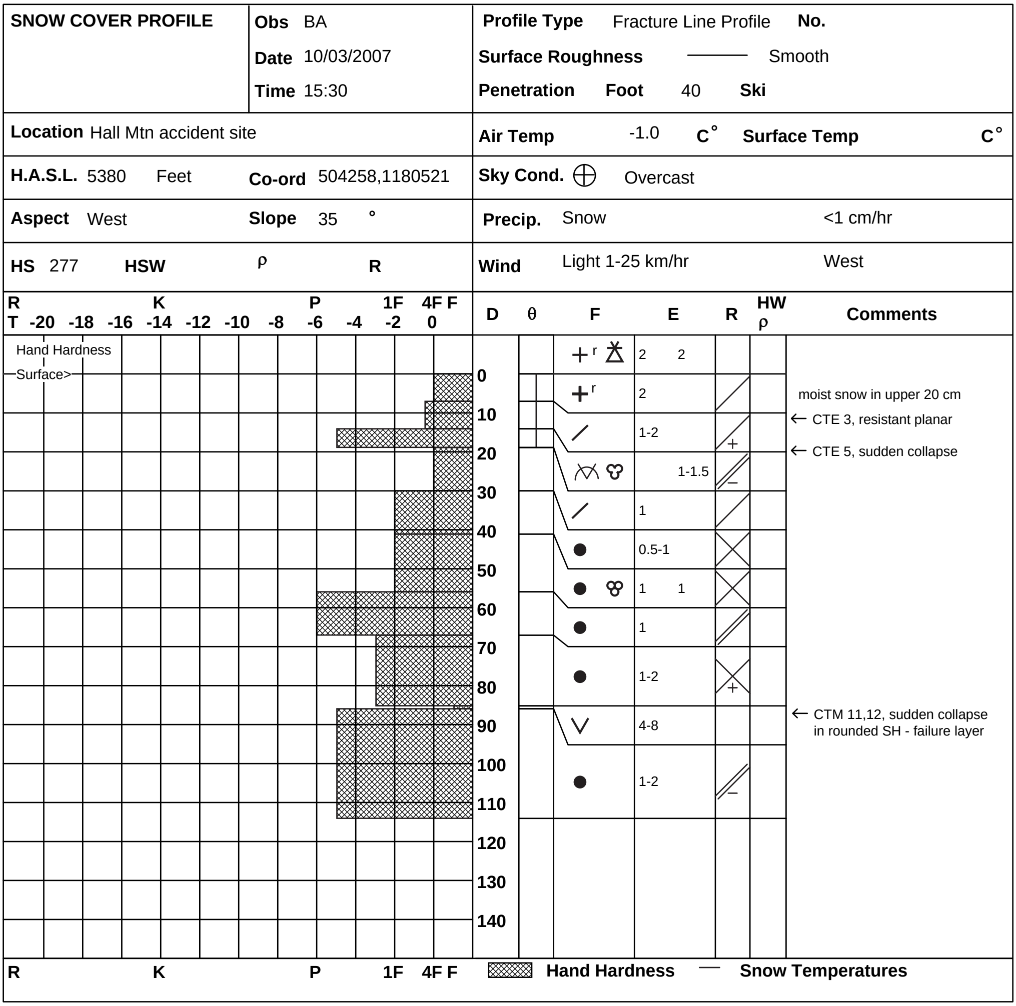

Figure 14.4. *Hall Mountain, 9 March 2007. Fracture line profile observed by the accident investigator on 10 March 2007.*

found Snowmobiler 4's sled, and determined the rider was beside it. They dug down, found his foot, dug more and found his head about 2m below the surface.

Snowmobiler 3 had been swept to the toe of the avalanche, near the bottom of the cutblock. He began a search with his transceiver, moving uphill, and quickly picked up the signal from Snowmobiler 5. Snowmobilers 3 and 6 dug down, found the victim against a tree with his head about 1m below the snow surface. They removed him from the deposit at 16:07 and began CPR.

No snow was observed in the airways of Snowmobilers 4 and 5. CPR was discontinued after 20 to 30 minutes. Snowmobilers 6 and 7 rode to their truck, then drove towards Revelstoke and called the RCMP when their cell phone picked up a signal.

The size 3 dry slab avalanche released on a surface hoar layer that was buried on 4 February 2007. The crown was about 85cm thick on a convex part of the slope with small trees and stumps. The 150m wide avalanche started at approximately 1640m on an incline of about 35°, and ran for approximately 600m along the slope with a vertical drop of approximately 300m. Several small gullies channeled some of the avalanche flow. The toe of the avalanche was in sparse trees below the open cut block where the slope angle was estimated to be 10 to 15°. Much of the deposit was 1 to 3m deep.

Near the crown fracture on the day after the accident, the 85cm thick dry slab was mostly 4-finger to 1-finger hard. Pencil hard layers were observed from 14 to 19cm and 56 to 67cm below the surface. This slab overlay a 4-8mm layer of surface hoar crystals. Compression tests at two sites near the avalanche yielded Sudden Collapse fractures after 11 and 12 taps. Light rain was reported at the avalanche site.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	Yes	?	No	Yes (light rain)

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Trees, small gullies	Convex	Cut block

Source

- BC Coroners Service
- BC Ministry of Transportation and Infrastructure weather archive

Comment

One of the snowmobilers did check the public bulletin four days before the trip. Interviews with survivors indicate that none had read the most recent bulletin. The avalanche occurred below treeline where the avalanche danger was rated Considerable. The snowmobilers did note the recent avalanche in the cut block to the north (Cutblock A), and decided to stay close to the forest to facilitate escape from an avalanche. While Snowmobiler 4 got to the edge of the forest, neither he nor Snowmobiler 5 escaped the effects of the avalanche.

Once the avalanche occurred, the companion rescue was efficient.

Cutblocks with sufficient snow and sufficient incline can produce destructive avalanches.

Chapter 15

Avalanche Accidents Outside Southwestern Canada

1996 - 2007

31 March 1997, Heli-skiing
Mt Switzer, Florence Range, BC

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	Complex

- **Shallow slab avalanche followed by deeper one**

On 31 March 1997, four groups of heli-skiers were skiing in the Florence Range, about 50km southwest of Atlin, BC. Each group had five guests and a guide. There was also another group with a separate helicopter in the area.

There was no regional avalanche bulletin for this area in the winter of 1996-97. The heli-skiing operation had been conducting daily weather, snowpack and avalanche observations throughout the winter. On 28 March, there was a 48 km/h wind from the south and flurries. On 30 March, there was no snowfall, only light winds and the temperature rose from -8 to 3°C. On 31 March, the sky was clear, the wind was light and the minimum temperature was -8°C.

Earlier in the day, the guides had made several attempts to trigger (ski cut) avalanches. One of these attempts resulted in the release of a small wind slab on a north aspect. One hand shear test yielded a moderate result for a 25-30cm wind slab. Both these results were in obviously wind-affected areas.

After several runs following lunch, one group landed at elevation 2030m to ski a north-facing glaciated run on Mt Switzer. The guide traversed out onto the slope and, as a routine precaution, tried to trigger an avalanche but did not trigger one. He then skied about 100m down the slope and stopped in the tracks from a previous group (that had started from a different landing earlier in the day). Guest 1 skied down to the guide. Guest 2 skied about 50m, fell, and a slab avalanche released above him. He was briefly upright, trying to ski out of the avalanche. The guide shouted at him to ski towards a bench on the glacier. About three seconds after the first avalanche, a second and deeper slab avalanche released to the east of the first one, about 100m down the slope from the first fracture line and about 30m above where the guide and Guest 1 had stopped. The guide shouted "avalanche" into his radio. Both guests and the guide were carried about 550m down the slope.

The other guides in the area quickly responded. The lead guide of the four groups found and uncovered Guest 2 in about seven minutes. This guest was buried about 50cm but had one ski and pole sticking out of the deposit. He soon recovered consciousness and had only a minor injury. The lead guide left him and began a transceiver search.

Another guide and some guests landed at the top of the deposit. With their transceivers on receive, they spread out 20m. About half way down the deposit, this guide and the lead guide homed in on the same signal (from the missing guide). They probed him and began to dig. Another guide arrived and located the remaining transceiver signal (from Guest 1) about 18 metres up the slope, probed him and started to dig. Guest 1 was about 1.2m deep and uncovered after about 20 minutes. The missing guide was about 3.5m deep and uncovered after about 45 minutes. Neither could be revived; they had both died of crush asphyxia.

The crown of the first avalanche was 77m wide, and averaged 50cm in height. A short distance below the crown, the avalanche

Figure 15.1. *Mt Switzer, 31 March 1997. G – guide, 1 - Guest 1, X – deceased.*

spread out 160m to the northwest above a prominent cliff band. The snow below the bed surface varied in height from 0 at exposed rocks to 80cm. The slope angle averaged 32°. The deposit below the northwest part of the crown was on a gentle slope below the cliff band.

The second avalanche (likely triggered by the first one) was 136m wide. The crown height was mostly about 110cm high except at the east end where it was 160cm high. The slope angle in its start zone was 37 to 40°. From the crown to the toe of the deposit, this avalanche ran for about 550m. Below the second and deeper crown fracture, the lower deposit, at about 1740m, was about 80m wide and 124m long. It was 4 to 7m deep. The combined size of the two avalanches was 3.5.

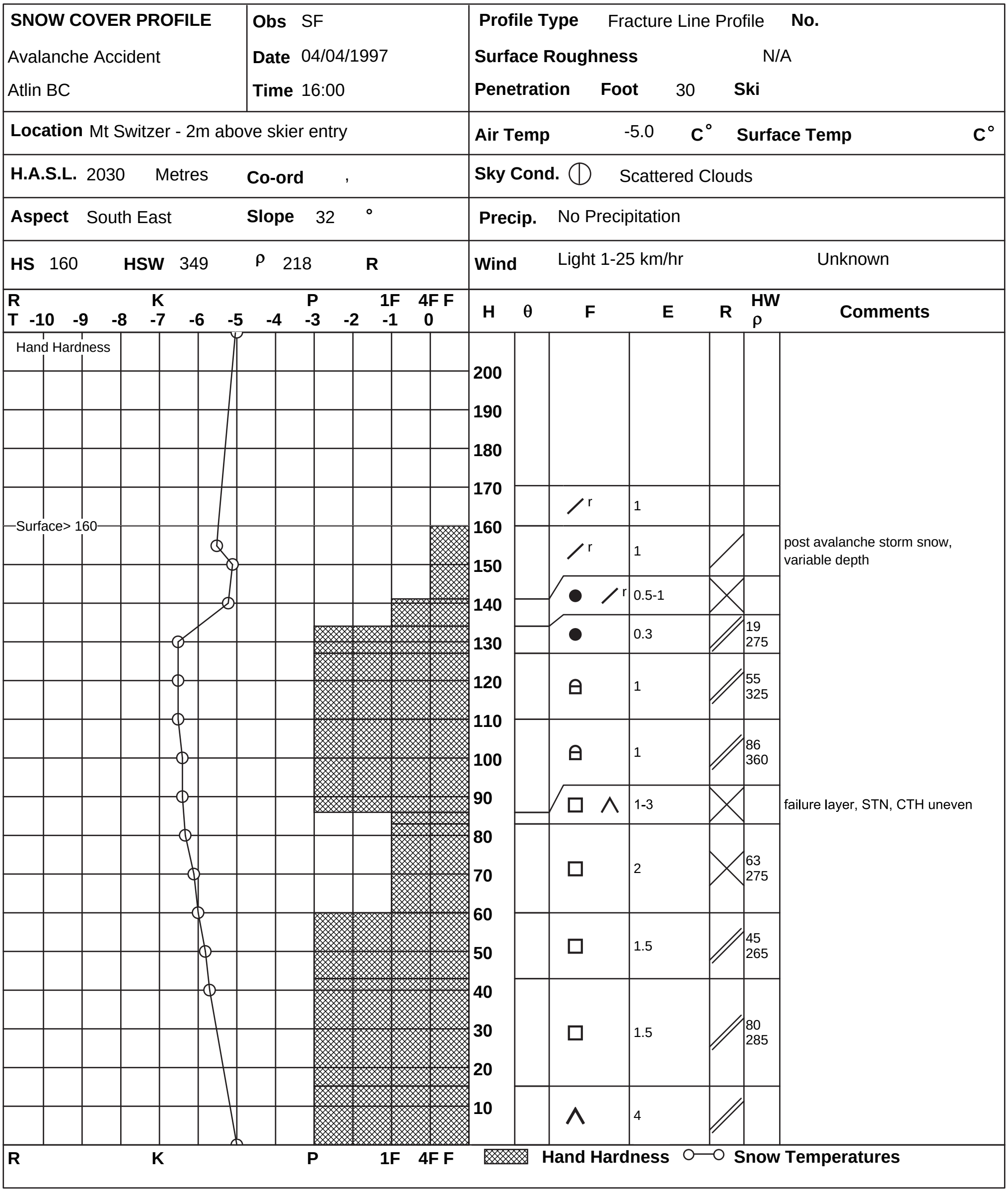

Figure 15.2. Mt. Switzer, 31 March, 1997. Fracture line profile observed four days after the accident.

Along the traverse from where the helicopter landed, there were areas where larger rocks extended up through the bed surface. The first avalanche was triggered along the traverse where the slab and snowpack thickness were variable. In three profiles, the slab varied from 7 to about 50cm in thickness, overlying a failure layer that varied from 0.7mm facets to 2 – 3mm facets and depth hoar. Shovel and compression tests required either hard force or did not fracture the weak layer. Two rutschblock tests failed at the 6th loading step (RB 6), for which skier triggering is not common.

Near the deeper crown fracture, a profile showed that the lower part of the slab, roughly the lower 50cm, was pencil-hard. This slab released in a layer of faceted crystals, 2mm in size, about 100cm above the glacier ice. Shovel tests produced no results. One compression test produced an uneven fracture during hard tapping.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	Yes (small wind slab)	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	None	Planar	Alpine

Source

- BC Coroners Service
- Scott Flavelle

Comment

Either before or after the avalanche, the deep layer of faceted crystals gave little indication of being “triggerable” by skiers. The shallower slab avalanche was likely triggered from a thin area and provided the force that triggered the deeper layer of faceted crystals.

Although it is unrelated to the persistent slab that killed the skiers, the small skier-controlled wind slab on a north aspect counts as an Avaluator Warning Sign for Recent Slab Avalanches.

7 March 1998, Hunting/Fishing
Arctic Bay, Northwest Territories (now Nunavut)

Deaths	Avalanche Problem	Terrain
1	?	?

- **Small slope triggered while hunting**

On 7 March 1998, two hunters left the hamlet of Arctic Bay, NWT (now Nunavut), and travelled approximately 10km by snowmobile to go hunting. When they arrived at a good spot above a steep creek valley, one hunter remained with the snowmobile while the other continued about 1km on foot.

At approximately 11:00, the hunter with the snowmobile heard a shout and a loud rumble. He followed his partner's tracks to the top of the valley slope where he saw that an avalanche had just occurred. He could not see his partner anywhere, and spent some time searching around the avalanche deposit. He hoped the other hunter was not involved and that he would return to the snowmobile. At approximately 15:30 the lone hunter left for Arctic Bay to get help.

The RCMP was notified of the missing hunter at approximately 20:30, and they returned to the scene to start searching for him. They found the hunter buried 1.5m below the surface after only 15 minutes of searching the avalanche deposit using lengths of copper plumbing pipe.

The size 2.5 slab avalanche was approximately 150m wide, and occurred on a short, 45° slope with a northeast aspect, just 100m above sea level. The slab was about 70cm thick, and released nearly the entire snowpack from the slope. It ran about 115m down the slope to the valley bottom. Tracks leading from the top of the slope to the crown suggest that the hunter accidently triggered the avalanche, and was carried with it. An abrupt transition at the base of the slope caused a narrow but deep deposit, including many large blocks of the slab.

Strong winds and heavy snowfall during a blizzard approximately three weeks before the accident may have loaded snow onto lee slopes and formed pockets of hard slab, leaving adjacent areas thinner and more susceptible to human triggering.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	?	?	?	?	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
45°	Abrupt transition	Convex	Above treeline latitude

Source

- RCMP

Comment

Even small slopes can produce dangerous avalanches when overloaded with unstable snow.

16 April 1998, Outdoor Worksite
Sa Dena Hes Mine, North of Watson Lake, Yukon

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Climate researchers doing fieldwork near tree line**
- **No precautions for risk of avalanche**
- **Warm sunny weather and several persistent weak layers**

Three members of a university research team—a professor and two students—were investigating climate change and tree growth in the Yukon, near Watson Lake, in the spring of 1998. They accessed many sites by helicopter, but on 16 April were working on a slope near treeline on Jewelbox Hill, at the site of the closed Sa Dena Hes Mine. Their objective was a small stand of scrub trees located on an open slope a short distance above a mine portal and access road. They approached the stand of trees using snowshoes to climb above the portal. As they stepped onto a steep slope, a large avalanche released.

The avalanche caught all three of the researchers. One student was carried a short distance and ended up on the surface, while the second was partially buried nearby. The students could see no signs of their professor.

They rushed down the mountain to the mine site to notify the mine manager (the only person working at the closed mine site) and request his assistance. The mine manager returned to the site of the avalanche via snowmobile and was able to locate the professor quickly. He was buried with his head facing downhill under approximately 1.5m of snow, with tip of his snowshoe was visible on the surface. He had been carried only a short distance down the small man-made slope above the portal and was buried by large blocks of snow. He was carrying a chainsaw in his backpack, and had apparently pitched forward under its weight when the snow started moving. He was not breathing when uncovered, and CPR was unsuccessful.

The slab avalanche released from a northeast-facing slope at an elevation of 1525m and with an incline of 32 – 40°, with the majority of the start zone area in the lower part of this range. It was size 2.5, and had stepped down through several persistent weak layers, resulting in an average slab thickness of 75cm, and width of approximately 110m. The

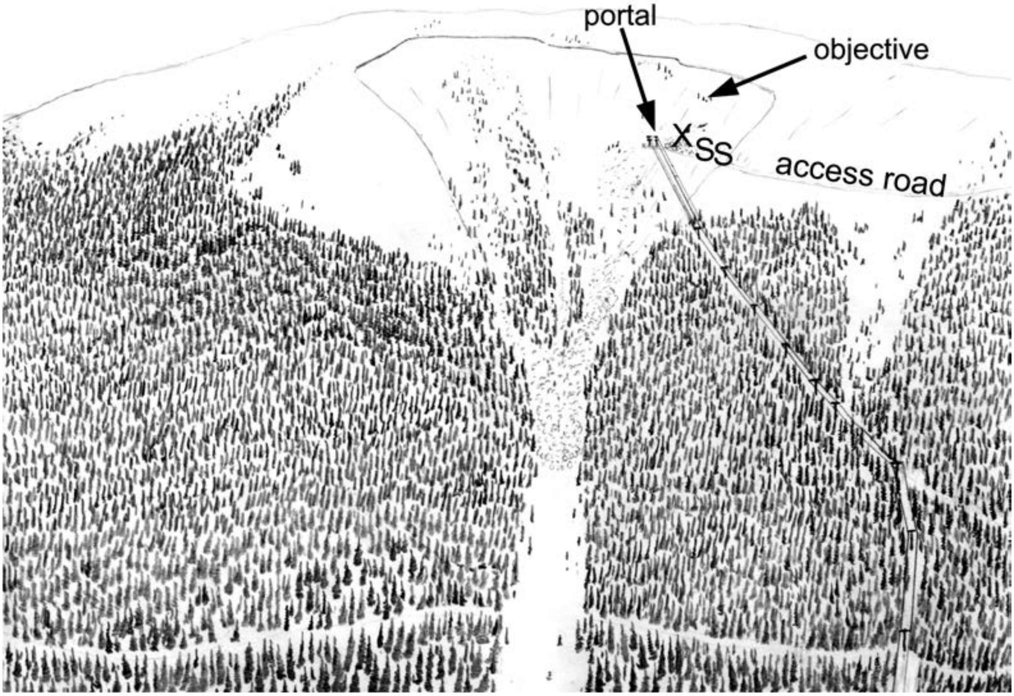

Figure 15.3. Sa Dena Hes mine, 16 April 1998. The exact location of researchers is not known, but all were above the portal and access road climbing toward their objective, a small stand of trees. S - survivor, X – deceased, approximate location after avalanche.

avalanche ran about 500m, with a moist deposit 80m wide, 300m long, and up to 4m deep. It was triggered by the weight of the researchers as they climbed above the portal. They were on a small but steep slope. On their left was a bigger slope, which is the start zone for an avalanche path that extends into the trees below. This area was identified as avalanche terrain during a risk assessment when the mine was operating, and avalanches had impacted the portal and power lines in the past.

The researchers were not making any observations of the snowpack stability during their fieldwork. In previous days, a helicopter pilot had pointed out signs of avalanche activity near other research areas, and had made some suggestions about site selection in terms of avalanche safety, although it is unknown if any recent slab avalanches were observed near the Sa Dena Hes site. Otherwise, the researchers were not carrying avalanche rescue equipment, nor did they have any avalanche training. Public avalanche bulletins are not issued for the Yukon.

The mine manager reported the weather was sunny and about 5°C at the time of the avalanche. The initial weak layer fracture occurred on a layer of 12mm surface hoar buried approximately 25cm deep, but the avalanche stepped down to an early season surface hoar layer, a layer of faceted crystals, and finally to depth hoar and facets near the ground, resulting in the release of almost the entire season's snowpack across the start zone. A snow profile observed two days after the accident showed moist snow to a depth of 40cm below surface, suggesting that at the time of the accident near-surface snowpack layers were melting due to sun and warm temperatures, making them more susceptible to human triggering.

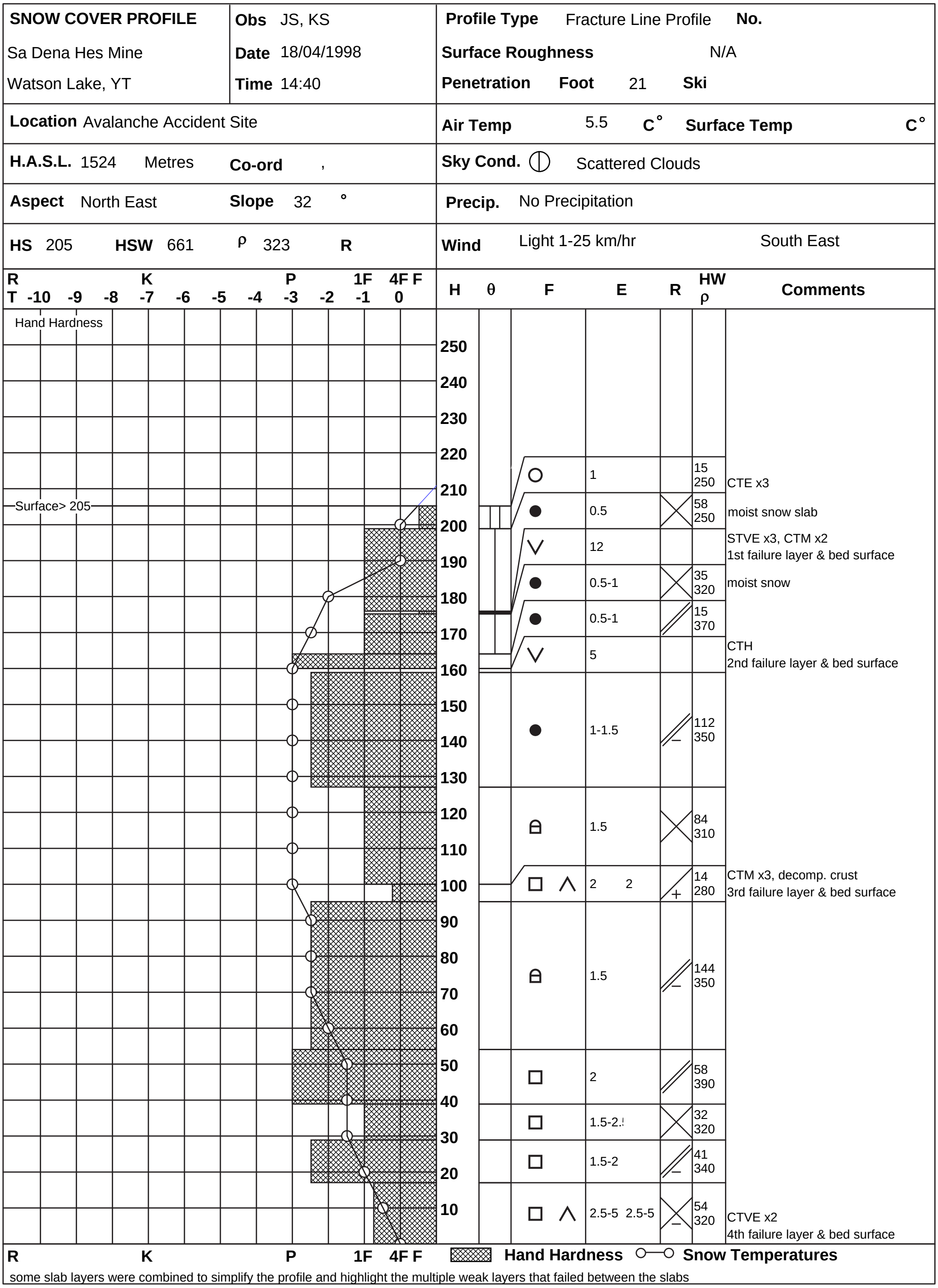

Figure 15.4 Sa Dena Hes mine, 16 April 1998. Fracture line profile observed two days after the accident.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	?	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 30°	None	Convex	Sparsely treed slope

Source

- Kirstie Simpson
- Yukon Coroner's Service

Comment

Avalanches may step down through snowpacks containing several persistent weak layers, often resulting in a much larger avalanche than triggered initially.

Anyone travelling around snow-covered mountains should be aware of the risk of avalanches and take appropriate precautions or seek expert guidance.

The Yukon Avalanche Association (YAA) was formed in 2010, with the goal of improving public safety and avalanche awareness in the Yukon, and to eventually produce a regular public avalanche bulletin.

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1 January 1999, Residential Kangiqsualujjuaq, Québec

Deaths	Avalanche Problem	Terrain
9	Persistent Slab	Complex

The town of Kangiqsualujjuaq, population 750, is located on the mouth of the George River on the Ungava Peninsula in northern Quebec. A hill, about 115m high, separates the town from the George River. In the 1990s, buildings close to the base of the hill included a church, a store and the Satuumavik School. The school gymnasium, which was attached to the school, was approximately 40m from the base of the slope. Close to the 1990s site of the gym, the lower 86m of the hill is steep enough for avalanching, averaging 38°. Cornices often form at the top of the steep section, which faces northeast towards the school.

In November 1998, rain and/or a period of mild weather had formed a melt-freeze crust in the snowpack. Freezing rain occurred between 3 and 6 December, forming another crust in the snowpack. At the end of December 1998, there was much more snow than usual on the slope above the town.

On 31 December, approximately 10cm of snow fell in the region with air temperatures around -15°C. At the nearby airport, wind speeds averaged 25 to 40 km/h between 08:00 and 10:00. In the afternoon, southwest winds gusted to 80 km/h. In the evening, south wind gusted to 70 km/h. Blizzard conditions existed. These winds would have transported the falling and recently fallen snow onto the northeast-facing slopes above the school.

The school gymnasium served as the community centre. On the evening of 31 December 1998, many people gathered for a New Year's Eve celebration, accessing the gym through the door that faced the hill. Around 1:30 am, the music was stopped as the master of ceremonies prepared to draw a door prize. Many people were inside the gym; others were outside, some starting their snowmobiles or trucks at the base of the slope.

Accompanied by a low rumble at around 1:30 am, a slab avalanche descended the slope, hitting some of the people outside the school, smashing large holes in the wood frame wall of the gym and hitting more people inside the building. The alarm bell began to ring, adding to the confusion.

Those not trapped by the avalanche began to dig with their hands for the victims but the snow had hardened immediately. The elders and community leaders calmed the people and organized the rescue. Outside the school, improvised probes were used to search for victims in the avalanche deposit, which was 3 to 4m deep. Injured people were taken to the dispensary in sleds behind snowmobiles, or in the back of pickup trucks. Uninjured children were moved to the classrooms and then home.

Nine people were killed including five children between 22 months and eight years of age. At least seven of the deceased were outside the school when the avalanche struck. Twenty-five people were injured.

In the days after the avalanche, a 1 to 1.8 m high crown fracture was observed on the slope. The 180m wide slab avalanche had gained speed on the 38° slope, run across 40m of flat ground, and hit the southwest wall of the gymnasium and southeast wing of the school. On the northwest side of the gym, the deposit extended about 35 metres past the southwest wall.

Two snow profiles on 6 and 7 January revealed weak layers of faceted snow overlying or sandwiched between a melt-freeze crust and/or an ice layer. The layers of facets were 1-finger hard while the crusts and ice layers were pencil to knife hard. While likely representative of the snowpack on the slope facing the town, these profiles were not done closer to the avalanche because the snow study team was concerned about triggering avalanches.

Figure 15.5. *Kangiqsualujjuaq, 1 January, 1999. Damaged gym and school, looking down the slope. The entrance faces the avalanche slope. Photo: Bruce Jamieson.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Wall of gym	Convex	No trees

Source

- Report: Public Inquiry into the causes and circumstances surrounding the deaths in Kangiqsualujjuaq, Nouveau-Quebec on January 1, 1999
- Bruce Jamieson

Comment

This was the most deadly avalanche affecting a residential area in Canadian history. Investigations revealed that in previous years, avalanches from the hill had reached some of the buildings close to the base of the slope. In 1993, one avalanche had reached the southwest wall of the gymnasium, partly burying a boy, who survived.

Following the 1999 avalanche, experts prepared an avalanche hazard map, which identified the zone prone to destructive avalanches, and a low-risk zone farther from the hill. The school was demolished and a new one built in the low-risk zone. The buildings close to the base of the hill, which had no basements and only simple foundations, were also moved to the low risk zone.

Like most fatal avalanches affecting residential areas in Canada, it released on a slope less than 100m high.

7 January 1999, Outdoor Worksite Ningunsaw Pass, Central Coast Mountains

Deaths	Avalanche Problem	Terrain
2	Deep Persistent Slab	Complex

- **Two workers exposed to a large slope**
- **Likely triggered from an area of thin snowpack**

On 6 and 7 January 1999, two avalanche technicians from the BC Ministry of Transportation and Highways (MoTH, now known as BC Ministry of Transportation and Infrastructure) were conducting forecasting and control work for Highway 37 near Ningunsaw Pass in northern BC. On the first day, they flew by helicopter to two sites where they observed a total of four snow profiles. Their field notes indicated good stability.

To further assess the avalanche slopes near the highway on 7 January, they prepared explosive charges to place in avalanche start zones by helicopter. They placed 10 charges resulting in a few size 2 to 2.5 avalanches—too small to threaten the highway. The last explosive was placed on Path 42.0, where it produced only a small "bomb sluff." These results provided further indication that the avalanche hazard to the highway was low. The technicians informed the pilot that they would perform more snowpack tests on Path 42.0 before skiing to the highway where their truck was parked. At 13:06 the helicopter landed on the ridge so the technicians could access the avalanche path for further snowpack tests. By radio at 13:30, they informed the district highways manager of their plans and reported the hazard to the highway was low.

Snowfall on 5 to 7 January had been light with air temperatures between -9 and -16°C. On 7 January the wind was light.

Attempts to contact them by radio started at 17:30 and continued through the evening. A highways foreman saw a deposit that he thought was fresh. He was joined by two ski guides working nearby. Together, they conducted a transceiver search in the dark but no transceiver signals were detected. After a while, they decided the deposit was not fresh.

Two other avalanche technicians from the BC MoTH drove to the area that night. In the morning, one of the technicians and two guides from Last Frontier Heli-skiing observed a fresh deposit in Path 42.0 from a helicopter. From the helicopter, they detected

Weather from the station 1km from Snowbank Path 42.0				
Date	Time	Max. Temp. (°C)	Min. Temp. (°C)	Precip. (mm)*
2 Jan	1800	-4.5	-6.8	11
3 Jan	1800	-2.4	-3.5	32
4 Jan	1800	-0.5	-2.0	15
5 Jan	1800	-9.6	-16.1	7
6 Jan	1800	-11.4	-15.3	5
7 Jan	1400	-12.9	-15.9	6

** During snowfall, 1mm of precipitation is roughly equivalent to 1cm of snowfall.*

two transceiver signals in the runout zone. At this time, a larger response involving the RCMP, an RCMP dog team and the Provincial Emergency Program was being mustered. The missing technicians were found under 70 and 100cm of snow. One had died of multiple trauma and the other from asphyxia.

The avalanche was a size 3 dry slab avalanche. The start zone faced east-northeast. The crown fracture was at a convexity where the slope angle increased from an average of 40° to 52°. The crown fracture was about 60m wide and about 600m (vertically) above the burial locations. At the crown fracture, the ski tracks were about 15 to 20m apart. The crown fracture varied from 0.5 to 1.5m in height. At the thicker part of the crown, the failure layer was a 4cm thick layer of 2mm rounded facets (1 finger hardness). This layer was sandwiched between two pencil-hard layers near the ground. At the thinner part of the crown, the failure layer consisted of 3 to 5mm faceted grains near the ground.

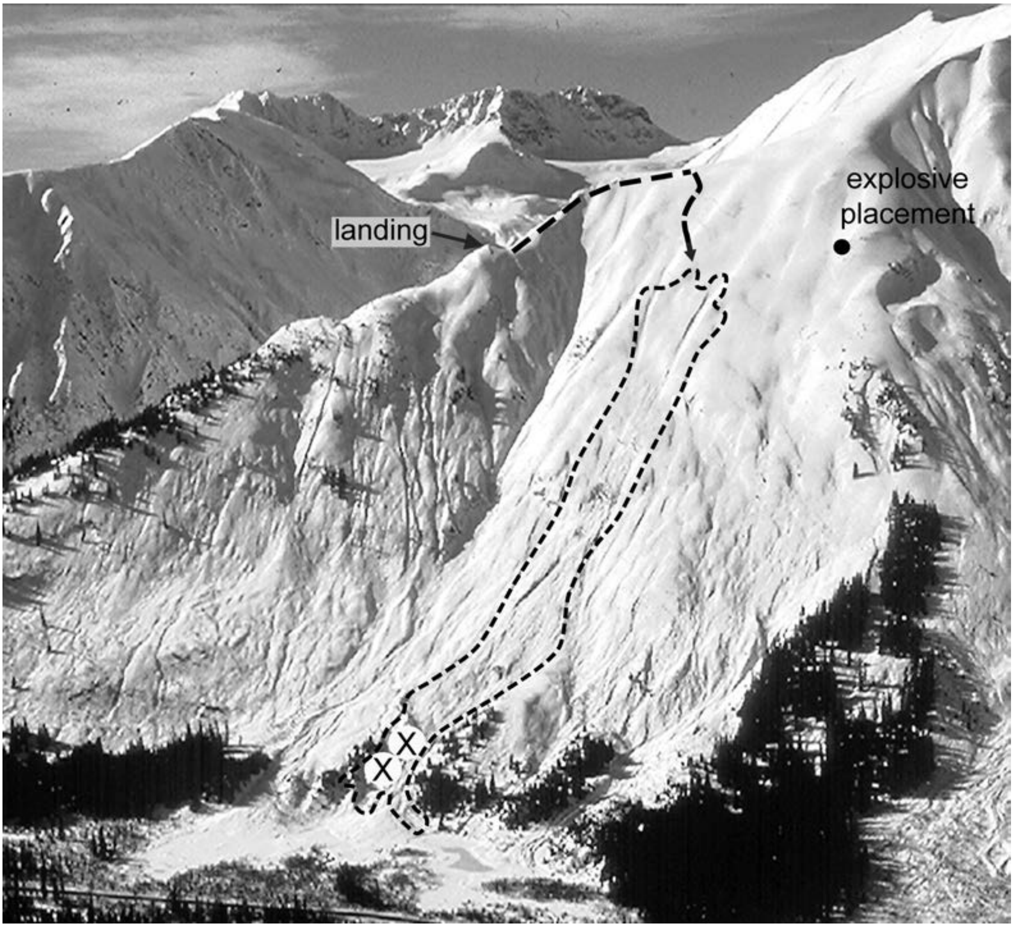

Figure 15.6. *Ningunsaw Pass, 7 January 1999. From the helicopter landing, the two workers ski toured up. They were below the crown fracture when it released. X – deceased. Photo: BC Ministry of Transportation and Infrastrucure.*

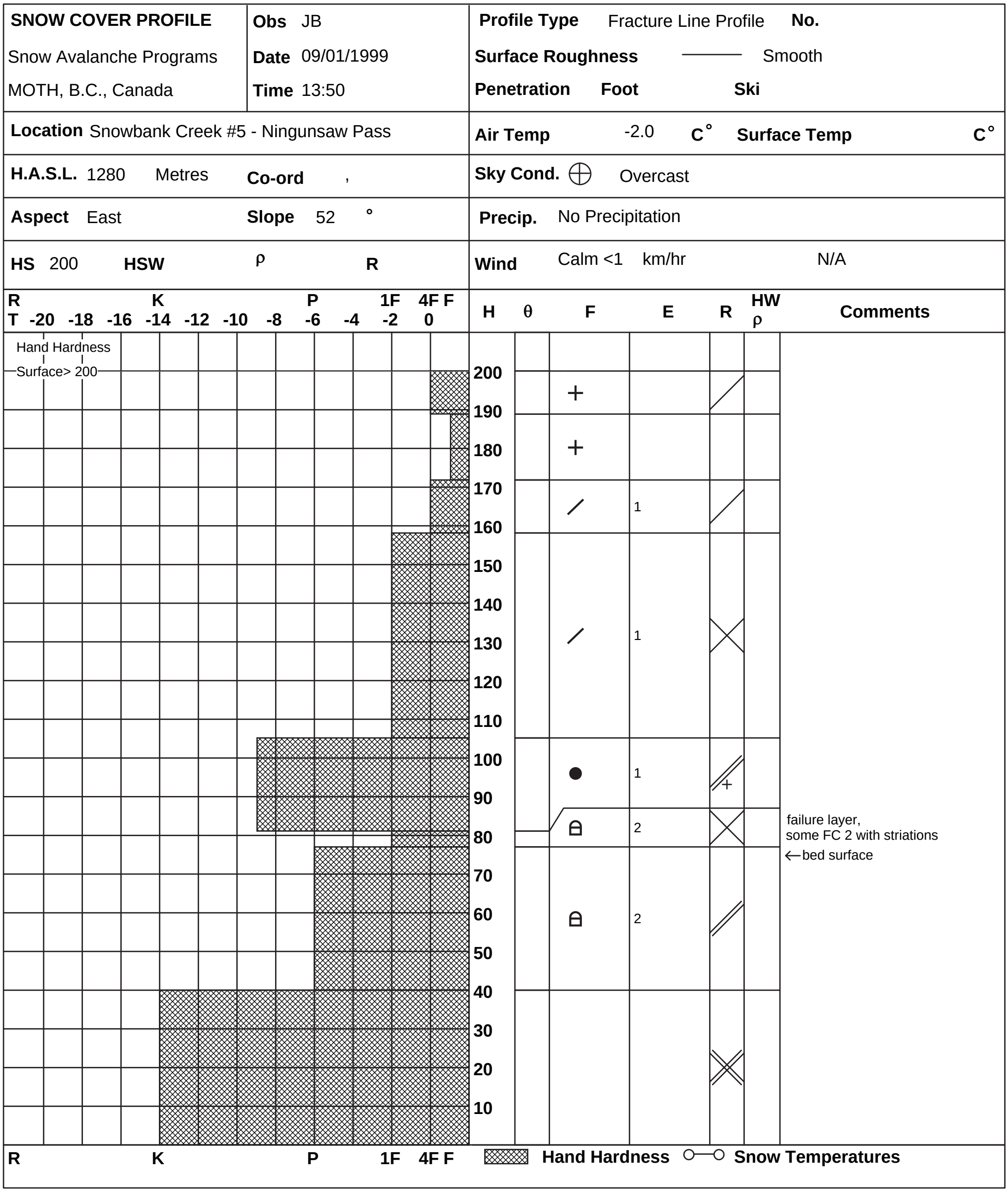

Figure 15.7. *Ningunsaw Pass, 7 January 1999. Fracture line profile near the crown fracture of the avalanche at Ningunsaw Pass.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	Yes (triggered by explosive)	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 40°	Gully	Convex	Open Slope

Source

- BC Coroners Service
- BC Ministry of Transportation and Infrastructure Involvement Report to Canadian Avalanche Association
- Doug Wilson
- Mike Boissonneault

Comment

The avalanche was likely triggered from the thinner, weaker snow near the convexity. Anticipating the location of isolated areas of weak snowpack is difficult, even for experienced avalanche workers.

This and other accidents involving avalanche workers prompted changes to workplace procedures, including call-in procedures.

14 February 2000, Toboganning
Château-Richer, Québec

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Simple

- **Avalanche on small slope following a blizzard**
- **Record burial survival time and recovery by dog**

At around 15:00 on 14 February—towards the end of the second blizzard to hit the Québec City area in four days— two teenagers left home in Château-Richer (about 30km east of Québec City) to take a walk and check out a local tobogganing area.

A major winter storm on 10 and 11 February dropped over 15cm of snow on the region, accompanied by strong to extreme winds out of the northeast, making for blizzard-like conditions with blowing and drifting snow. Another storm brought 20cm of additional snow on 14 February, again with extreme northeast winds (gusting to 130 km/h) and blizzard conditions.

The teenagers walked along a trail in the Lemoine River ravine, and arrived at a short (30 – 40m) but steep slope on the wall of the ravine. They decided to climb the slope and try to slide down. The steepness and a slippery ice crust below the storm snow made climbing difficult, and they grabbed on to trees to help them ascend. The tobogganing slope of the ravine faces approximately southwest, and drops away steeply from a broad, flat plain to the northeast. This puts the slope in the lee of a large fetch, and the extreme northeast winds that came with the storms caused a large amount of drifting and blowing snow to be deposited on the bank of the ravine.

When the teenagers were about halfway up the slope, climbing very close together, they were overcome by a wall of snow from above. The slope had avalanched, and the moving snow carried them to the bottom of the ravine. The deposit was up to 2.5m deep, piled at the base of the slope.

At around 20:30 the parents of one of the teenagers phoned police to report that they had not returned home. Shortly after, a neighbour reported having seen the teenagers headed up the trail at the base of the ravine. The father and two police officers searched the trail and the ravine but found no sign of the missing teenagers, their tracks having been obscured by the storm. At 21:00 another neighbour joined the search effort, this time with a trained hunting dog familiar with one of the missing teenagers. Very quickly, the dog indicated a spot and began digging at the snow, uncovering a glove. The police and searchers continued digging at that spot and found the two teenagers, buried next to one another in a standing position, under about 60cm of snow. Both were unconscious after having been buried for over five hours. The first to be uncovered had no vital signs, but the other was still breathing.

Ambulances arrived by 21:30 and paramedics began resuscitation efforts and first aid. Both teenagers were at the hospital by 22:00. Resuscitation of the first continued for another 20 minutes, after which the teenager was pronounced dead. The second victim was treated for hypothermia, but was otherwise uninjured and regained consciousness the following day.

Several metres of snow were deposited on the slope during the blizzards. It was likely this storm snow that avalanched, possibly sliding on a crust lower down in the snowpack that would have acted as a slippery bed surface. The slope is not very big, but big enough to release a size 2 (or larger) avalanche with a deep deposit (2.5m). The teenagers probably triggered the avalanche.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	None	?	Open slope in forest

Source

- Bernard Hétu
- Dominic Boucher
- Québec Coroner Office

Comment

At over five hours, this is the longest survival time in a recreational avalanche burial in Canada, and one of only a small number of live rescues by a dog.

Locals had never witnessed such a large avalanche on that slope in the past. Because of this accident, the municipality recognized the hazard to the ravine trail and has posted warnings.

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13 March 2000, Backcountry Skiing
Mt Vallières de St-Réal, Monts Chic-Chocs, Québec

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Challenging

- **Two skiers climbing for an extra run**
- **Severe trauma from impact with trees**

A group of six skiers was enjoying a day of backcountry skiing on Mt Vallières-de-Saint-Réal, which is within the Réserve Faunique des Chic-Chocs in the Gaspésie region of Québec. They were experienced skiers, but not expert backcountry travelers. Approximately 15 –20cm of new snow fell on 12 March, with south-southeast winds. As a cold front passed on 13 March, the temperature dropped and the winds became strong and backed to northwest. The local terrain configuration may have affected the speed and direction of the winds near the slide path. No public avalanche bulletins were available at this time.

At around 14:15 the skiers stopped for a break. Four of them decided to head back to the trailhead, while two others decided to ski one more run down a nearby north-facing slide path and meet the rest of the group later. After the group of four departed, the remaining two moved toward their chosen run and began to boot pack up to gain some elevation. They had climbed 100 to 150m when the snow crumbled around them; they were both caught in a slab avalanche.

The site of the avalanche is a broad, north-facing cirque just below the flat-topped mountain summit. The upper reaches of the cirque are just above the treeline, while lower down below treeline the slopes converge into a relatively narrow creek valley. Much of the upper, alpine part of the cirque makes the start zone of the avalanche path, while the track continues down the creek and is fringed by mature timber. Sparse vegetation grows in the lower part of the start zone, especially along its flanks.

As the avalanche slid down the mountainside, one of the skiers found himself being carried along with it. When the snow stopped moving, he was not buried, but had sustained a sprained ankle and had lost some equipment. He could see his friend further up the slope pushed into a stand of trees, near where they had been walking. He quickly climbed back up the slope, reaching his friend within approximately 10 minutes. It was obvious his friend had sustained serious injuries from hitting the trees, and he had no vital signs. CPR and rescue breathing were impossible given the extent of the injuries, and the remaining skier decided to go for help.

At around 22:15 a rescue team arrived and moved the victim towards an ambulance waiting at the trailhead. They traveled part of the way by snowmobile, which took about 40 minutes. No signs of life could be found by paramedics at the trailhead or by doctors in hospital when the victim arrived there at around 02:00 on 14 March.

The slab avalanche was approximately 10m wide, 100m long, and about 30cm thick, having released from a north or northeast aspect just above treeline. It was estimated to be a size 2. Most of the snow was deposited in the open part of the track, but some snow moved through a stand of timber, which caught the victim.

The avalanche was triggered when one or several persistent weak layers in the snowpack failed and released an overlying hard wind slab. About two weeks before the accident, the weather in the area had been well above freezing, and 10 – 15mm of rain fell, followed by about 10cm of wet snow. This would have formed a frozen crust layer, likely with weak faceted snow crystals on top. Warm, but below-freezing temperatures prevailed for the following week with a small amount of snowfall most days, but some drizzle and heavier snow on 9 March likely formed another crust/facet layer. Winds were variable through this time, with some periods of southerlies that may have been loading snow onto the north-facing slopes. Cold weather returned on 12 March, along with 15 – 20cm of snow and strong winds, forming a stiff wind slab in top of the weaker crust layers. It appears the weight of the skiers triggered a fracture in one of the weak layers, which was able to propagate and release the avalanche.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
>30°	Trees	?	Sparsely treed slope

Source

- Bernard Hétu
- Dominic Boucher
- Québec Coroner Office

Comment

Often weather events several days or weeks before a backcountry outing, can set the stage for dangerous avalanches. Forecasters who prepare the public avalanche bulletin can help identify snowpack features lurking below the surface that may have been created by previous weather events. Check www.centreavalanche.qc.ca for conditions in this area.

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18 March 2000, Backcountry Skiing
Mt Albert, Monts Chic-Chocs, Québec

Deaths	Avalanche Problem	Terrain
1	Persistent Slab	Complex

- **Warm sunny afternoon after following storm**
- **Buried crust**
- **No beacons or other rescue gear**

On 18 March 2000, a group of three was out for a day in the backcountry around Mt Albert, in the Chic Choc Mountains of Parc national de la Gaspésie, Québec. Two were climbing with snowshoes, and one was using skis. By the afternoon, they had climbed and descended one run on the west side of the Cuve des Mélèzes, a bowl-shaped cirque located just below the main plateau of Mt Albert. The weather was fine, above freezing and sunny, so they decided to do another run. They climbed to the top a second time, with plans to descend a couloir on the north aspect of the bowl. The skier had taken a recreational avalanche course, but the group did not discuss the risk of avalanches occurring in the bowl that day. They did note recent ski tracks in the area of the couloir, which may have led them to think that the risk of avalanches was low.

Prior to this day, on 15 and 16 March, 15-20cm of snow had fallen on the Mt Albert area, with strong winds blowing. A few centimetres of snow fell on 17 March, and then the weather cleared and warmed up. The sky was clear and the temperature was above freezing by the afternoon of 18 March. No public avalanche bulletin was available.

At around 14:30 the skier started down the upper slope of the cirque, but stopped after a few turns to adjust his goggles. As his partners watched from a safe place, the slope gave way, released a large avalanche, and carried the skier down the run where he disappeared in the moving snow.

The two snowshoers immediately began searching the avalanche deposit for any signs of their friend. This was difficult, as no one in the group was wearing avalanche transceivers or carrying probes and shovels. After 1 – 1.5 hours of fruitless searching, they decided to leave the area and try to get help.

A small group of trained rescuers arrived on the scene at 18:45. They did a visual search of the deposit and began probing likely burial areas, but could not locate the buried skier. After a short time, the search was called off since darkness was falling and the risk of further avalanches was a concern.

First thing the following day, an organized group of searchers, including trained rescue dogs, returned to the accident site. They conducted a systematic search of the avalanche deposit using probes. At 14:50 the skier was found, encased in hardened snow about 1.5m below the surface. He had no vital signs after being buried in the avalanche for over 24 hours, and was pronounced dead of asphyxiation in hospital later that evening.

The slab avalanche released from a north aspect at around 1000m elevation, on a 35 – 40° slope. It was approximately 300m wide, 30cm thick, and ran for about 400m to the bottom of the bowl. It was probably a size 2.5 or larger, based on the volume of snow involved and the depth of the deposit.

The skier-triggered avalanche slid on a frozen rain crust buried in the snowpack at the end of February, a little over two weeks prior to the avalanche. Several days of warm temperatures and rain and snow occurred in early March, followed by a larger storm with cold temperatures and strong winds. By that time, the upper part of the snowpack probably had the ingredients for a slab avalanche—a frozen rain crust, most likely with a thin weak layer of faceted crystals on top of it, covered by a stiff slab formed during the windy storms. Warm temperatures on the day of this accident probably softened the slab enough to allow the weight of the skier to penetrate down to the faceted crystals overlying the crust.

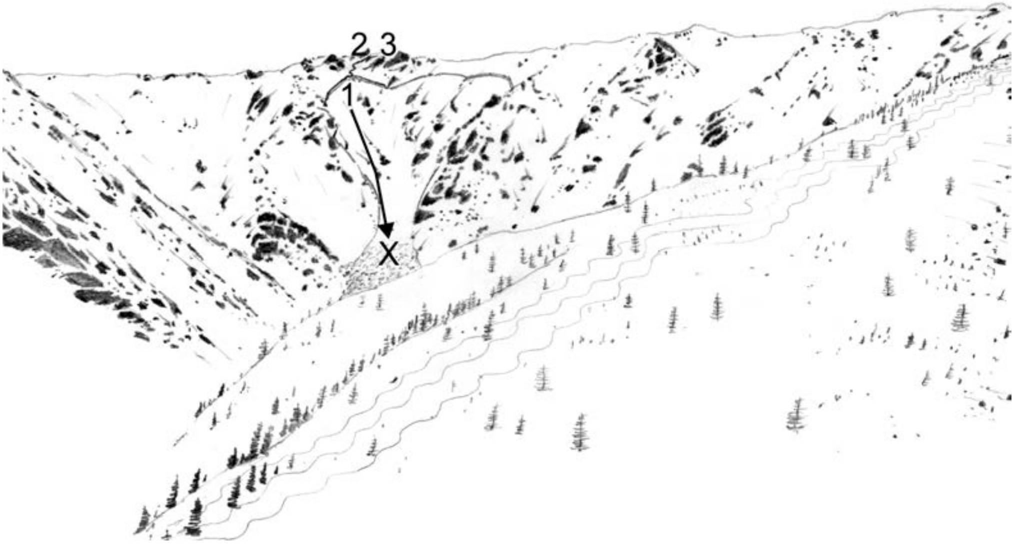

Figure 15.8. *Chic Chocs, 18 March 2000. 1 to 3 – location of skiers when avalanche released, X – deceased.*

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	?	?	Yes (wind)	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35-40°	None	?	Alpine

Source

- Bernard Hétu
- Dominic Boucher
- Stephanie Lemieux
- Québec Coroner Office

Comment

While the victim had taken an avalanche course, no one in the group was carrying avalanche rescue gear (beacon, shovel, probe).

The victim died of asphyxiation, which suggests that a quick rescue may have saved his life. This is very difficult without beacons, shovels, and probes.

The warm, sunny weather combined with a fresh snowfall makes for excellent ski touring, but is also perfect for slab avalanches, especially with a buried persistent weak layer or rain crust.

31 March 2003, Snowmobiling
Near Scallop Mountain, Omineca Mountains, BC

Deaths	Avalanche Problem	Terrain
1	Storm Slab	Complex

- **Couple drove a snowmobile off a cornice, triggering a large avalanche**
- **Rider survived long fall**

On Monday 31 March 2003, a group of 13 people were snowmobiling on the gentle south side of an unnamed peak about 4km south of Scallop Mountain, about 110km north east of New Hazelton, BC. The steep north-facing slope of this peak drains into Lion Creek, which in turn flows into the Driftwood River.

There was no avalanche bulletin for this region in 2003. On 29 March, a heli-ski operation about 170km to the west reported 20cm of snow and moderate wind from the southwest. The following day they reported rain in the subalpine and strong wind from the south.

The snowmobilers were not seeking steep terrain and did not carry avalanche transceivers, probes or shovels. During the afternoon, they enjoyed snowmobiling on the gentle south slopes. About 18:30 two members of the group were standing about 12m back from a cornice overhanging the steep north slopes. They saw a couple approach rapidly on a sled—the rear rider had his hands on the controls—and drive off the cornice. While they were briefly on the cornice, a chunk about 4m wide and 50cm thick broke off. When the snowmobile landed on the steep north slopes, a large slab avalanche released.
Some of the people from the group went to the edge of the cornice, looked down and saw the male rider and the snowmobile far below on the deposit. The man was moving around and calling for his partner. The survivors did not see how to get down onto the deposit and called for help on a satellite phone.

A helicopter arrived about 90 minutes later and picked up the man on the deposit. His partner was not visible. The snowmobilers from the south side were able to leave the mountain without further incident.

That night a small search team was assembled by phone. A CARDA avalanche dog and master were called since the victim did not have a transceiver. Because of the risk from further avalanches and unstable cornices, the leader wanted to keep the team small and experienced.

When the team flew to the avalanche site at 07:50 on 1 April, they noted that no further snow had fallen, the weather was fair and the air temperature had cooled. There was, however, further risk from cornices and unreleased snow (“hangfire”) above the search area. The small, experienced team accepted the risk and moved onto the deposit. The dog “indicated” at an area 8m from the snowmobile, but at that location the searchers only found a helmet visor.

A longer search involving more people probing in lines was required, but first the remaining avalanche hazard had to be reduced. Using the satellite phone, the search leader requested assistance from the avalanche forecasting and control team for the Kemess Mine, who agreed to help. A larger search team was assembling at the Lovell Cove logging camp on Takla Lake.

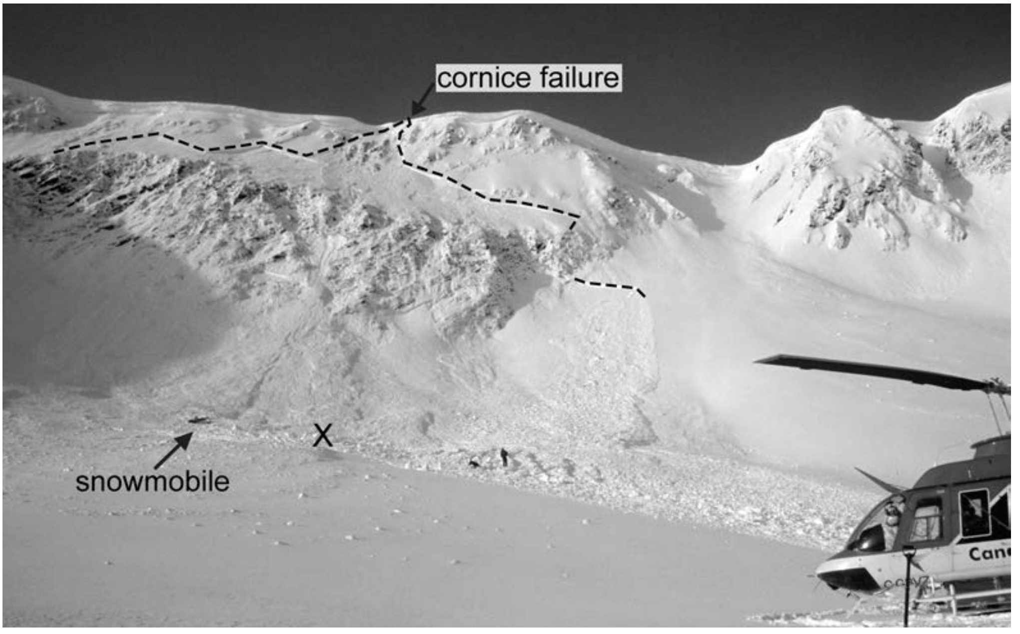

Figure 15.9. *Near Scallop Mountain, 31 March 2003. X – deceased. Photo: Christoph Dietzfelbinger.*

Explosives placed from a helicopter released a number of avalanches, none of which reached the section of the deposit where the victim was likely buried. While the larger search team was preparing to come to the site, the small team continued probing at spots they considered likely. They probed the victim at 14:37 about 30m away from the snowmobile and 1.5m from the edge of the deposit. Her head was about 1m below the surface. There was no sign of life and no air space around her face. She had asphyxiated. The body and then the searchers were lifted from the site by helicopter in daylight.

The crown of the dry slab avalanche was 50 to 100cm high and 350m wide. It started at 1800m elevation, ran down a 50 to 55° slope under the cornice over a 40° ramp, down a steep rocky step for a total of 200 vertical metres, then on to unconfined gentle terrain at about 1600m, slightly above the local treeline. Much of the deposit was estimated to be 3m deep, tapering to 1m towards the toe. There were large cornice chunks in the deposit. It was a size 3 avalanche.

No snow profile was observed near the crown or flanks because of residual avalanche risk. The rescue coordinator, who was familiar with local conditions, estimated that the slab was comprised of snow from the storm and from south winds in the two days before the accident. It is unknown if the snowmobilers observed recent slab avalanches or other signs of instability.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	?	?	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
50°	Cliffs	?	Open Slope

Source
- BC Coroners Service
- Christoph Dietzfelbinger
- InfoEx

Comment
Although the group was not intending to snowmobile in avalanche terrain, two of its members drove off a cornice into serious avalanche terrain.

The man survived a long fall and a size 3 avalanche.

The leader of the search team prudently limited the exposure of searchers to the residual hazard, and called for explosive control before allowing more searchers to be exposed.

The dog search was not successful, perhaps because the victim was wearing her partner's jacket, which smelled of diesel fuel.

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25 January 2004, Camping During Fishing Trip
Cape Mercy, Baffin Island, Nunavut

Deaths	Avalanche Problem	Terrain
1	?	?

- **Natural avalanche cycle during blizzard with unusually high temperatures**
- **Accident involves three separate avalanches; two avalanches involving the accident party and another avalanche with the ground SAR team**
- **No avalanche safety gear**

This fatal avalanche accident took place in the area of Cape Mercy, located approximately 140 km southeast of Pangnirtung at the southern tip of Baffin Island. According to the existing weather records for 25 January 2004, the area was being battered by a blizzard with snowfall and easterly winds up to 75 km per hour. The storm was accompanied by a dramatic rise in temperature of approximately 15 to 20 °C over the previous two days. In the afternoon, the temperature was hovering around the freezing point, which is unusually warm for this area and resulted in the highest temperature on record at the nearby weather stations.

In the middle of this blizzard, a group of three fishermen were camped on a lakeshore in the area of Cape Mercy. Around midnight on 24 January, an estimated size 2.5 avalanche released on the slope above, partially burying all three individuals. While two of them survived the avalanche, the third was fatally injured. After recovering from this avalanche, the two survivors relocated their camp laterally along the shore of the lake. Around 14:00 on 25 January, they were hit by a second avalanche, which pushed their camp out onto the ice of the lake. While the two survivors were partially buried again and could free themselves, the deceased was completely buried and could not be found. In addition, the group must have also lost some of their equipment to this avalanche. Only at this point did the two survivors finally call for help using their HF radio.

Under the lead of the RCMP and the Hamlet of Pangnirtung Search and Rescue Committee, a ground search and rescue team was sent immediately from Pangnirtung to the accident site to provide assistance to the survivors. Due to the adverse weather conditions, it was impossible to include helicopter support in the rescue. With the blizzard still in full force, the SAR team itself was involved in an avalanche incident en route to the accident site. Luckily, this avalanche only resulted in the partial burial of a snowmobile.

With the weather improving, the accident party was finally located by a search and rescue helicopter from Iqaluit on the following afternoon. While the two survivors immediately received initial medical attention at the site, a first search was conducted for the missing victim with the support of an RCMP search dog. However, the search was unsuccessful at that time. After the site was marked for future reference, the helicopter search team left the scene to evacuate the two survivors to Iqaluit. On 28 January, a ground search team consisting of seven Canadian Rangers and six local hunters, all from Pangnirtung, found the body of the victim in the avalanche deposit on the lake ice using probes.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	?	?	?	Yes	Yes

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	Lake	?	Open slope

Source

- InfoEx
- Parks Canada
- RCMP
- Environment Canada
- CBC News North: Avalanche death touches Pangnirtung (27 January 2004)
- Nunatsiaq.com (Jane George): Three rescued after avalanche kills companion - Survivors shaken but unhurt after Cumberland Sound ordeal (30 January, 2004)

Comment

Very little information is available about this accident, but the group did not carry any avalanche safety gear and most likely did not have any avalanche awareness training. Basic avalanche awareness might have helped to prevent this accident by either alerting the accident party to the worsening conditions or the exposed camp site. Proper avalanche safety gear might have helped to speed up the recovery of the victim on the first avalanche.

This accident occurred during a major blizzard with unusually high temperatures after a rapid temperature increase. Dramatic changes in weather conditions require the snowpack to adjust to the new conditions. Together with the snowfall and considerable transport of snow by the strong winds, the unusual weather resulted in a natural avalanche cycle.

4 April 2004, Playing on River Bank Near Pond Inlet, Baffin Island, Nunavut

Deaths	Avalanche Problem	Terrain
1	Wind Slab	Simple

- **Lee pillow on steep river bank**
- **No avalanche safety gear**

This fatal avalanche accident happened on the banks of the Salmon River during a family snowmobile outing on the afternoon of Sunday, 4 April 2004. The area, which is known as the Coal Mine, is approximately 20 km south of Pond Inlet on Baffin Island, Nunavut. The weather of that afternoon was characterized by light westerly winds, and temperatures around -22 °C.

After travelling to the area on snowmobiles, the family enjoyed themselves on the banks of the Salmon River. While playing along the toe of the steep riverbank, a number of children triggered a slab avalanche in a concave section of the slope. The avalanche, a hard slab that was about 100 m wide, 1.5 m deep and ran for approximately 10 m, completely buried an 11-year-old boy at the bottom of the slope. The deposit of the avalanche consisted of large blocks and was quite deep due to the abrupt transition at the bottom of the slope (*Figure 15.10*).

Three people had just passed the area where the avalanche happened. They immediately turned around and, while two of them began the search for the boy, the other was sent out to call for help. The local RCMP and Pond Inlet Search and Rescue received the emergency called at approximately 17:00. Within 20 minutes, numerous members of the local search and rescue team arrived at the accident scene to assist with the search. The boy was located approximately 80 minutes later using harpoons as improvised avalanche

Figure 15.10. *Pond Inlet 4 April 2004. Accident site about a month after accident. Photo: Parks Canada—Marc Ledwidge.*

probes. Two nurses were at the scene and immediately began CPR. The boy was transported directly to the local Health Centre where further attempts to revive the boy remained unsuccessful.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	No	?	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	Abrupt transition	Concave	Open slope

Source

- InfoEx
- Parks Canada
- RCMP
- Environment Canada
- CBC News North: Pond Inlet mourns avalanche victim (April 5, 2004)
- Nunatsiaq.com: Avalanche near Pond Inlet kills boy (April 9, 2004)

Comment

This avalanche occurred in a "lee pillow," a common occurrence on riverbanks. Their steepness in the otherwise flat landscape allows the deposition of considerable amounts of blowing snow. The last wind event with blowing snow prior to the accident was in the afternoon of April 1 and the early morning April 2 with wind speeds up to 54km/hr. While this event might have contributed to the accident, the lee pillow at the accident site was most likely developing throughout the entire winter.

Very little is known about this accident, but the accident party did not carry avalanche safety equipment and most likely had very limited avalanche awareness. Proper avalanche safety equipment would have most likely resulted in a much quicker recovery of the victim in this rather small avalanche.

31 May 2005, Mountaineering
Mt Logan, Kluane National Park, St. Elias Mountains, Yukon

Deaths	Avalanche Problem	Terrain
1	?	?

In late May 2005, two climbers were ascending the east ridge of Mt Logan, 5959 metres high, in Kluane National Park. A few days earlier a major storm had trapped three climbers near the summit for three days. At 2900 metres, an avalanche started a few metres ahead of one climber, missed him and carried the other climber about 450 metres down the mountain.

It took the uninjured climber about a day to find the body of his climbing partner. He did not have a satellite phone and descended to their base camp. About six days after the avalanche, the survivor caught the attention of a passing helicopter and was flown off the mountain. Staff from Kluane National Park recovered the body.

There was no avalanche bulletin for this area in the summer of 2005.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	?	?	?	?	?

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	?	?	?

Source

- www.cbc.ca
- www.whitehorsestar.com
- www.lastlinkontheleft.com

Comment

There is little detailed information available on this fatal avalanche.

10 January 2007, Heli-skiing
Deep Canoe Creek, Skeena Mountains, BC

Deaths	Avalanche Problem	Terrain
1	Deep Persistent Slab	Complex

- **Deep slab avalanche triggered by a skier during the first day of cooling after a storm**

Following heavy snowfall and wind, the bulletin issued by the Canadian Avalanche Centre on Monday 8 January 2009 warned that large avalanches in the NW Region were reported on Sunday and Monday but that “conditions should become much safer with clear, dry, and cold weather later this week” and that “cold dry, outflow conditions are forecast Wednesday” (the day of the accident).

On the four days prior to 10 January, weather had limited the heli-skiing to treeline and below. About 12 then 18cm of snow had fallen on 8 and 9 January, respectively. On Wednesday 10 January, three groups shared the same helicopter and were able to land in the alpine. Near the top of the third run the temperature was -19°C. A ski cut by the lead guide did not produce an avalanche. The groups began to ski a bowl, where the middle part of the slope was 35° and without trees. The lower and upper parts of the slope were less steep and the run out continued into small trees.

In two pits on the slope, compression tests yielded only hard results. Prior to the avalanche, the groups had descended the bowl a total of three times. At about 11:00, one of the groups was making their second run down the bowl, skiing the upper section one at a time. The guide and then one guest descended approximately half way down the slope and stopped where avalanches were unlikely. When the third guest was about half way down to the guide, a dry slab avalanche released. A powder cloud from the avalanche soon prevented the guide from seeing the guest.

Immediately after the avalanche, a beacon search was initiated but produced no signal on the first pass by the guide of the group. A visual search by the guides and helicopter pilot soon spotted a glove and ski pole from the missing skier near the bottom of the deposit. The victim was located by transceiver search. He was buried about 1m below the surface of the deposit in a small gully, and was dug out about 18 minutes after the avalanche. He was unresponsive, and was not revived with CPR. He had asphyxiated.

The 150m wide skier-triggered slab avalanche started at approximately 1700m on an east aspect on a slope of approximately 35°. The avalanche was reported to have released at the ground and the height of the crown varied from 30 to 240cm. Below the wind-loaded crown, the height of the slab, visible at the flanks, tapered substantially. The size 3.5 avalanche ran for 800m down along the slope.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Considerable	Yes	No	No	Yes	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
35°	Gully	Planar	Open Slope

Source

- BC Coroners Service
- InfoEx

Comment

Part of the crown fracture was where the groups had traversed onto the slope and where the fourth skier was getting ready to ski down. The trigger point is unknown.

10 March 2007, Snowmobiling
Northern Peninsula, Newfoundland

Deaths	Avalanche Problem	Terrain
1	Slab	?

A group of two men and nine teenagers were snowmobiling in the Blue Mountains near the community of River of Ponds on the Northern Peninsula of Newfoundland. The weather was good. They stopped their snowmobiles at the foot of a steep slope and started walking up a bowl. They were 30 to 50m from their snowmobiles when the slab avalanche struck the group. At least seven people were caught by the avalanche.

Someone called the mayor of River of Ponds by cell phone. He left immediately with others by snowmobile to the accident site, which was 25 to 30km away.

The avalanche partly buried one of the men, making his breathing difficult. He felt he was suffocating, until the teenagers freed him from the snow.

The other man was about 1m deep in a part of the deposit that was about 5m deep. Reports do not specify how he was located—perhaps he was only partly buried. He was dug out, and found to be without a pulse. The others in the group attempted to revive him with CPR. The resuscitation efforts were continuing when the rescuers from River of Ponds arrived. The victim was not revived.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	?	?	?	?	?

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
?	?	Concave	Mostly open

Source
- CBC news and radio interviews as summarized by David Liverman
- Newfoundland Geological Survey

Comment
Transceivers, probes and shovels enable faster rescues by companions.

2 April 2007, Heli-skiing
Delta Peak, Skeena Mountains, BC

Deaths	Avalanche Problem	Terrain
2	Persistent Slab	Complex

- **Use of a "balloon pack" flotation device**

On Monday 2 April, two groups of heli-skiers were skiing with guides in the Bell-Irvine Valley of the Skeena Mountains in northwest British Columbia. The air temperature was -10°C and the sky was clear with a light wind from the north. They observed two cornice falls: one which did not trigger a slab avalanche and one which triggered a size 1 avalanche on a step north-facing slope. On the previous day, a size 3 avalanche—up to two days old—was observed on an unskiable southwest-facing slope.

Three days previously, the Canadian Avalanche Centre issued a regular bulletin for the Northwest region including the Skeena Mountains. The regional avalanche danger for 2 April for all elevation zones was rated Low. A storm ending on the morning of 29 March, deposited 24cm of storm snow at the lodge (575m). No subsequent snowfall was reported through 2 April.

After observing no signs of wind-loading, a guide plus a group of five heli-skiers (guests) landed at the top (1845m) of a southwest-facing run known as Mistaya. After the group put on their skis and snowboards, the guide asked them to stay at the landing, while he skied down about 30m to a convex part of the slope near the top of the run. A quick pit dug by hand did not reveal a melt-freeze crust, which was a concern in the snowpack. The guide asked the skiers to ski one at a time, keeping about 150 vertical metres apart, while staying close to the guide's tracks. The guide skied about 450m and below the steep section turned towards a small knoll on his left, away from the base of the slope.

While the heli-skiers were descending the slope, spaced apart, a helicopter with a second group landed on top of the slope.

At about 10:25, while the first group was at the regrouping knoll, the guide from the second group skied a short distance down the slope. At the convexity, about 12 to 25m laterally from the first group's tracks, he triggered a slab avalanche but was not carried by it. The crown fracture quickly spread across the slope. The guide of the first group yelled to the guests to follow him and he quickly skied down and farther to his left. The group skied for 50 to 80m before being struck by the avalanche and carried about 500m to a transition in the slope, where the avalanche veered to the right.

The guide was wearing a balloon pack, which he activated (by pulling on a ripcord at the shoulder strap, one or two balloons on the pack are inflated rapidly to help keep the victim near the surface of a flowing avalanche). When the avalanche struck, he was farther down the slope than the guests and was carried a shorter distance. When the avalanche stopped, the guide was only partly buried, uninjured, and able to free himself from the deposit.

The guide radioed for help and started a transceiver search for the guests. The guide and skiers from the second group quickly came to assist. Other groups of heli-skiers in the area and resources from the lodge headed for the accident site.

Two were partly buried, one with head and torso under the snow, i.e. critically buried.

Both the partly buried guests survived. Three guests were fully buried. All were found quickly by transceiver search. One survived. One deceased guest, a male skier, was located by a transceiver search under 1.2 to 1.5m of snow. He had been buried 10 to 15 minutes and had no vital signs. CPR was started. When an automatic defibrillator (AED) was used, it detected no shockable heart rhythms. Efforts to revive the victim were stopped after about 45 minutes. The cause of death was asphyxia. The other deceased victim, a female snowboarder, was buried 40cm to 1.5m deep. She was found unresponsive after about 15 minutes, still attached to her snowboard with both legs broken. Also in this case, CPR and the AED did not revive the victim. Revival efforts were stopped after about 60 minutes.

At the trigger point, the slab was about 70cm thick. The crown fracture was 650 to 810m long and varied from 40 to 190cm in height. The avalanche dropped almost 600m vertically over a slope distance of 1.5km. The deposit was 180m wide and in places deeper than 3.2m. The dry slab avalanche was a size 3.5.

The slab slid on a weak layer of faceted crystals overlying a melt-freeze crust about 70cm below the surface. The crust likely formed when the wet snow surface froze during cooling on 7 March. Rain had been reported to an elevation of about 1600m.

After the avalanche, rutschblock tests yielded scores of 3 and 4 near the trigger point. Near where the first group entered the slope, two rutschblock tests both gave scores of 7. Snow profiles at the trigger point and crown revealed snowpack depths of 133 and 165cm, respectively.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
Low	Yes	Yes	?	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	?	Convex	Mostly Open

Source

- BC Coroners Service
- InfoEx

Comment

The small cornice-triggered avalanche counts as an Avaluator Warning Sign for slab avalanches, which includes any recent sign of slab avalanches. These Warning Signs were developed for recreationists who make fewer observations than heli-skiing operations.

This use of a balloon pack in this accident and others prompted discussion on this technology within Canada. In this case, the guide had difficulty pulling the trigger because the avalanche pulled his ski poles back and he was wearing wrist straps. Following this accident, the operation began providing balloon packs to all their guests. In the training, pulling the trigger early and not wearing wrist straps are emphasized. Swiss and Austrian data on the use of balloon packs and other rescue devices are summarized in Brugger et al. (2007).

Fatal avalanche accidents are rare when the regional danger rating is Low.

Chapter 16

Bugaboo Creek
12 March 1991

This accident was excluded from *Avalanche Accidents in Canada, Volume 4 – 1984-1996* because of a court case ongoing at the time that book was published. The judgement is available online by searching for "Bay Street Court Decision."

12 March 1991, Heli-skiing
Bugaboo Creek, Purcell Mountains

Deaths	Avalanche Problem	Terrain
9	Persistent slab	Complex

- **Triggering from area of thinner snowpack in a cross-loaded start zone**

On 12 March 1991, four groups of heli-skiers were skiing with guides in the Bugaboos of the Purcell Mountains. In the morning, the groups skied mostly north-facing runs. Although the guides had discussed the potential for wind effect at the morning meeting However once in the field, there was a noticeable lack of wind effect. One of the guides, who was not guiding a group, skied around seeking wind-affected areas. He only ski cut (intentionally triggered) a shallow wind slab the width of his skis on a steep slope located low in a glaciated bowl known for down-flowing wind. Otherwise the guides noticed no signs of instability in their extensive observations. There was no regional avalanche bulletin for this area in 1991.

During the afternoon, two groups finished skiing and flew back to the lodge by helicopter. The other two groups continued skiing. The first of the two remaining groups landed at about 2500m to ski a west-facing run known as Bay Street. Initially, they skied to the north down a shoulder before regrouping above a west-facing avalanche path. In the bowl to the north of the run, the guide noticed that a cornice had fallen but not released an avalanche—a sign of slab stability. He led his group down through some trees to the skier's right side of the avalanche path. They entered the path, skiing one at a time close to the trees on their right, with each person making fresh tracks. They regrouped below the start zone on the skier's right side of the path and then skied to the bottom of the run. While waiting for the helicopter, the guide radioed the upper group to say the skiing was great. The sky was partly cloudy. It was not snowing. The wind was light from the southwest. The air temperature was about -14°C.

Weather at lodge,
elevation 1500m, 5km north-northwest of accident site

Date	Time	Max. Temp. (°C)	Min. Temp. (°C)	HN12 (cm)	HNS (cm)	Wind
9 Mar	AM	-1.5	-17.0	0.1	117	Calm
9 Mar	PM	1.0	-9.0	0.1	117	L-SW
10 Mar	AM	-0.5	-4.5	2	118	Calm
10 Mar	PM	-1.0	-5.0	10	125	L-SW
11 Mar	AM	-2.5	-12.5	4	125	Calm
11 Mar	PM	-4.5	-12.5	0.1	127	L-SW
12 Mar	AM	-5.0	-11.0	1	122	Calm
12 Mar	PM	0.0	-11.0	0	119	-

The second of the two remaining groups had twelve skiers plus a guide. They followed a similar line down the shoulder and regrouped above the path at about 16:00. They also skied through the trees beside the path before entering it. The guide told the guests to ski in the tracks next to the trees and that she would stop where they could spread out. She and the first five guests skied within 5 to 10m of the trees. As the next two skiers swung wide of the tracks, the guide stopped and called to them to return to the tracks. As the two skiers approached the five skiers grouped near the guide, they felt a large whumpf. The guide told the guests to ski into the trees but before they could move they were caught in an avalanche. The guide and five skiers at the regrouping site plus four who were skiing above were swept downslope. Three guests near the top of the slope were not caught.

When the avalanche stopped, the guide had been carried about 400 vertical metres down the path and only had an arm sticking out of the deposit. She was injured but able to dig herself out of the deposit. The nine guests had been carried 200 to 850 vertical metres. Three guests were partly buried. Six were completely buried and located by transceiver search within 45 minutes. All had died from trauma and not from asphyxia.

The hard slab avalanche released on a slope inclined at 37 to 42°. The aspect of the start zone wrapped from west-southwest to west-northwest. The start zone was cross-loaded by prevailing winds, resulting in a thinner snowpack on the side where the skiers entered the slope. The most recent snow had fallen with no wind effect and was evenly distributed across the slope.

The 90m wide crown varied in height from 40 to 190cm. The snowpack height near the crown varied from 120 to 360cm. The highest point of the crown was at 2390m. The bed surface stepped down to a depth hoar layer in places. The main part of the deposit was about 80m wide and estimated to be 3m deep. The toe of the deposit was at 1560m.

In the second week of March 1991, there was a buried surface hoar/crust layer that was of concern, which had been observed to produce avalanches on southwest and east-facing slopes. However, there was little evidence of the surface hoar layer in the investigators' profiles, most of which showed that the slab avalanche released in a layer of rounded faceted crystals about 2mm in size, which originated from a faceted layer that formed in December. The facet layer varied from fist-hard (soft) to 1-finger-hard. In places, the bed surface was a melt-freeze crust, which also varied in hardness.

Snowpack tests varied widely. Shovel tests ranged from no result at the failure layer to very easy in the deeper layer of depth hoar. A rutschblock test released a 20cm slab with the leg push (RB 3), a 50cm slab after three jumps (RB 6), but did not release at the failure layer (RB 7).

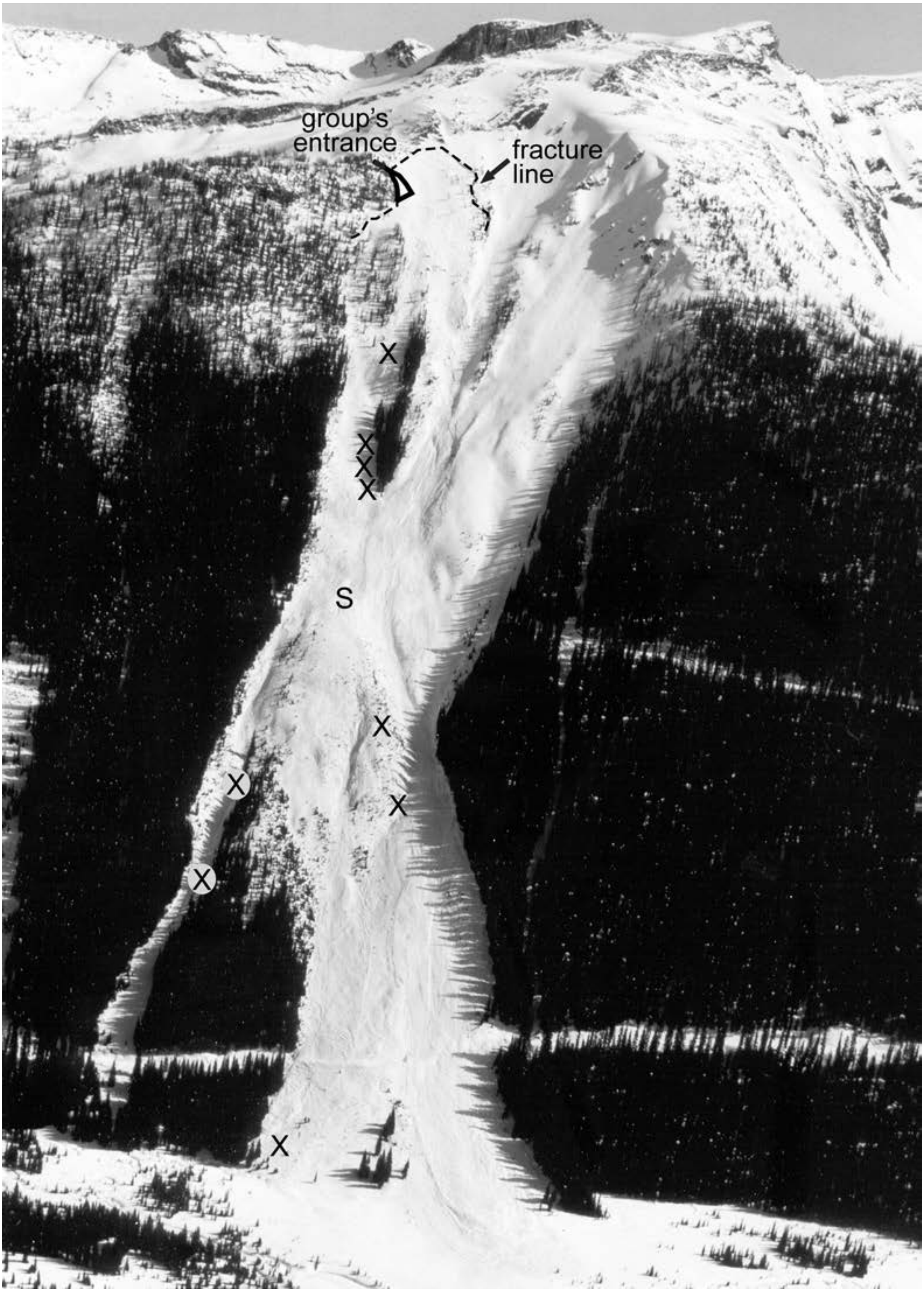

Figure 16.1. Bugaboo Creek, 12 March 1991. The triangle shows the where the second group entered the slope and where they were when the avalanche released. S- survivor. X – deceased. Photo: Chris Stethem.

Avaluator Warning Signs

Avalanche Conditions					
Regional Danger Rating	Persistent Avalanche Problem	Recent Slab Avalanches	Signs of Instability	Recent Loading	Critical Warming
N/A	Yes	One small wind slab	No	No	No

Terrain Characteristics			
Incline	Terrain Trap	Slope Shape	Forest Density
> 35°	Trees	Planar	Open slope

Source

- BC Coroners Service
- Chris Stethem

Comment

Earlier in the day, a guide triggered an isolated shallow wind slab avalanche while looking for wind affected snow. Although not relevant to the persistent slab avalanche that killed the skiers, it counts as an Avaluator Warning Sign for Slab Avalanches, which—because it is intended for recreationists with limited local observations—includes any sign of recent slab avalanches. For this heli-skiing operation which had extensive observations over their tenure throughout the winter, no avalanches had been reported on the December facet layer since early February.

The lack of wind in the area resulted in an even distribution of snowfall from the two previous days. Relative to the snowpack height, there was more recent loading by snowfall where the groups skied on the skier's right side of the run than on the skier's left, which did not release.

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Appendix A **Glossary**

Arctic air mass: Very cold and dry body of air that develops over the Canadian arctic, northern British Columbia and Alberta. The winter weather in the Rocky Mountains is primarily affected by this air mass.

Arctic outflow (arctic outbreak): Strong northerly and northeasterly valley winds on the west side of an arctic ridge of high pressure that advances into southern British Columbia toward the Pacific.

Avalanche Terrain Exposure Scale (ATES; Statham et al., 2006):
Uses three different classes to describe the overall exposure of a backcountry trip to avalanche hazard. The table below describes the basic characteristics of the three different classes.

Description	Class	Terrain Criteria
Simple	1	Exposure to low angle or primarily forested terrain. Some forest openings may involve the runout zones of infrequent avalanches. Many options to reduce or eliminate exposure. No glacier travel.
Challenging	2	Exposure to well defined avalanche paths, starting zones or terrain traps; options exist to reduce or eliminate exposure with careful route finding. Glacier travel is straightforward but crevasse hazards may exist.
Complex	3	Exposure to multiple overlapping avalanche paths or large expanses of steep, open terrain; multiple avalanche starting zones and terrain traps below; minimal options to reduce exposure. Complicated glacier travel with extensive crevasse bands or icefalls.

Avalanche character/problem (Atkins, 2004; Haegeli et al., 2010):
Describes the specific characteristics of a given avalanche hazard situation. There are roughly eight different types of avalanche problems. Their character has direct implications about the type of terrain to favour or avoid, the likely size of avalanches, which observations are most useful, and how long the problem is likely to persist. The following table provides short descriptions of each of the eight avalanche problems types.

Loose Dry Avalanche	Loose dry avalanches are usually confined to surface layers, and therefore are often small. They contain loose cohesion-less dry powdery snow. They start from a point and gather mass progressively in a fan-like shape. Small loose dry avalanches are often referred to as "sluffs" or "point releases."
Loose Wet Avalanche	Like loose dry avalanches, loose wet avalanches are usually confined to surface layers, and are therefore often small. However, because of their high density, loose wet avalanches contain greater mass and are much more difficult to fight against than loose dry avalanches. They contain cohesion-less wet slushy snow, and like loose dry avalanches, they start from a point and gather mass progressively in a fan-like shape. They are also sometimes called "point releases."

Wind Slab	Wind slab avalanches are caused by a cohesive slab of wind-deposited snow overloading the bond to an underlying weak layer or interface. Wind slabs consist of snow crystals broken into small particles and packed together by the wind. These wind-deposits, often referred to as "pillows," are usually smooth and rounded and sometimes sound hollow. The moving snow as well as the debris can include hard and soft chunks of slab. Wind slabs can be created on lee (downwind) slopes and in cross-winded areas where the winds blow across the terrain. They are commonly found behind and below features that act as a natural wind-fence, such as bands or isolated stands of trees, ridges, ribs, etc.
Storm Slab	Storm slab avalanches are caused by a cohesive slab of new snow overloading the bond to an underlying weak layer or an interface within the storm snow. However, these slabs are often quite soft compared to other slab types and this can fool people into underestimating the potential for a slab avalanche. The moving snow often involves a significant powder cloud and the avalanche debris tends to be soft and powdery. Storm slab avalanches tend to release below the trigger, making it somewhat easier to escape if you trigger one. During and shortly after large storms involving rapid accumulations of significant new snow amounts, storm snow avalanches can be very large and destructive.
Wet Slab	Wet slab avalanches are caused by a thick cohesive slab of snow losing its bond to an underlying thin weaker layer or interface after becoming damp, moist, or saturated with water. The moving snow is a dense, mushy mass often composed of large rounded lumps, and there is no powder cloud. Wet slab avalanches are slow moving, tend to flow in channels and are easily deflected by irregularities in the terrain. The deposited debris commonly has channels and ridges on the surface. Wet slabs are often highly destructive due to great mass created by the high water content of the snow.
Persistent Slab	Persistent slab avalanches are caused by a cohesive slab of snow losing its bond to an underlying weak layer. This type of weak layer strengthens very slowly or not at all over time. They can remain unstable and primed for human triggering for several weeks after burial and often catch backcountry recreationists when they least expect it on clear and calm days. Persistent slab avalanches are tricky to manage because they can often be triggered by light loads with very little warning and they tend to release above the trigger, making it difficult to escape if you are the trigger.
Deep Persistent Slab	Deep persistent slab avalanches are caused by a thick and hard cohesive slab of snow losing its bond to an underlying weak layer that is very deeply buried in the snowpack, often on or near the ground. They are highly unpredictable and destructive; essentially not survivable. It's common for persistent deep slab avalanches to become dormant for extended periods of time then "wake-up" again when the weather changes or later in the season, especially when warm spring weather arrives. When active, they often occur without warning or with light triggers. In dormant phases, they may require heavy triggers such as snowmobiles, cornice falls or smaller avalanches from above or on the slope stepping down to deeper layers.

Avalanche cycle: A period of avalanches associated with a storm or warm weather. For snow storms, the cycle typically starts during the storm and ends a few days after the storm.

Avalanche danger: See Appendix C.

Avalanche season/winter: The period from 1 October to 30 September. For example, an avalanche that occurred in December of 1999 would be in the 2000 season/winter.

Avalanche transceiver/beacon: An electronic device worn by travelers in avalanche terrain. In "transmit" or "send" mode, it constantly emits a radio signal which is stronger at close range. If someone with a transmitting transceiver is buried, the other members of the group can switch their transceivers into "receive" or "search" mode and follow a search pattern that locates the strongest signal. The person is then found by probing and shoveling.

Avaluator: Decision aid promoted by the Canadian Avalanche Centre that can assist winter backcountry users to make informed decisions when planning for and travelling in avalanche terrain. The Avaluator provides guidance about what observations to make, how to fit them together to assess the existing risk and what level of training and experience is required to safely travel in avalanche terrain under the given conditions.

Avaluator Trip Planner: Assists users of the Avaluator when planning a trip into avalanche terrain. It combines the current avalanche danger rating with the avalanche terrain rating of the intended trip to derive an expected risk level using a coloured chart. The different colours on the chart provide guidance on the necessary training and experience required to safely travel in avalanche terrain under the expected conditions. An online version of the Avaluator Trip Planner can be found at www.avalanche.ca/avaluator.

Avaluator Warning Signs: Refers to the field observations and terrain characteristics included in the Avaluator slope assessment tool. Please refer to Appendix E for the definitions of the individual warning signs.

Backcountry skiing/snowboarding: Skiing or snowboarding on uncontrolled slopes in the backcountry where the primary means of access are climbing skins, snow shoes or snowmobiles.

Bed surface: The surface on which a slab avalanche slides. Not to be confused with failure plane, failure layer, or weak layer.

CARDA: Canadian Avalanche Rescue Dog Association.

Compression test (CAA, 2007): Small-column snowpack test used to identify weak snowpack layers in the upper snowpack and provide an indication of their triggering potential. A shovel blade is placed on top of the column. Manual taps are applied with increasing force, which can cause the layers within the column to fracture. "Fracture character" may be an indicator of propagation potential. May be recorded as, for example: "CTE (SP)" for compression test easy, sudden planar fracture character. See also "Fracture character."

Term	Description	Data Code
Very Easy	Fails during cutting	CTV
Easy	Fails before 10 light taps using finger tips only	CTE
Moderate	Fails before 10 moderate taps from elbow using finger tips	CTM
Hard	Fails before 10 firm taps from whole arm using palm or fist	CTH
No Failure	Does not fail	CTN

Cornice: An overhanging build-up of snow, usually on the lee side of ridges. Moderate or strong winds often create a vortex on the lee side and deposit snow at the very top of the lee slope. Cornices generally form faster during periods of high humidity.

CPR: Cardio-pulmonary resuscitation. An emergency procedure for people in cardiac or respiratory arrest. Involves rhythmic chest compressions to restore blood circulation, and often artificial respiration to ventilate the lungs.

Cross-loaded: When wind blows across a cross-loaded slope, snow is picked up from windward ribs and deposited in lee pockets, often resulting in areas of thick and thin slab. Some unexpected avalanches are triggered from areas where the slab is thin.

Crown: the upper tension fracture of a slab avalanche, through the thickness of the slab and perpendicular to the bed surface. The crown is usually oriented across the slope, but may be curved or jagged. The crown surface marks the upslope fracture line of the avalanche.

Crust: Above-freezing temperatures, direct sun, and rain tend to result in moistened or wetted surface of the snowpack, forming a hard, often smooth layer called a temperature, sun, or rain crust once frozen. Once buried by subsequent snowfalls, these crusts tend to make ideal bed surfaces for future avalanches. Often a weak layer of faceted crystals forms above, within, or below buried crusts during or after their burial, creating a potential failure layer.

Depth hoar: An advanced, generally larger, form of faceted crystal. Depth hoar crystals are striated, and in later stages form hollow shapes. Cup-shaped crystals are a common form of depth hoar. This type of crystal can form at any level in the snowpack but is most commonly found at the base of shallow snowpacks following periods of cold weather, and may form a persistent weak layer. See also “Facets/faceted crystals.”

Direct action avalanches: Avalanches that occur during precipitation or wind loading.

Failure plane/layer: The fracture that releases a slab avalanche spreads along a weak snowpack layer called the failure plane or layer. The bed surface usually lies immediately below the failure plane. Failure planes or layers are usually noticeably weaker than the slab and bed surface. See also “propagation” and “weak layer.”

Facets/faceted crystals: In response to a sufficiently strong temperature gradient within the snowpack, snow crystals grow flat faces (facets) by a process known as kinetic growth or simply faceting. Growth of facets occurs at the expense of bonds between crystals, usually resulting in the weakening of a layer. Facets commonly form during periods of cold weather near the snow surface or in thin snowpack areas. Once buried, layers of facets are slow to gain strength, and usually form a persistent weak layer.

Flanks: The side fractures of a slab avalanche, through the thickness of the slab and perpendicular to the bed surface. The flanks are usually oriented parallel with the fall-line of the slope, but may be curved or jagged.

Fracture character (CAA, 2007): For small column snowpack tests[1], observations of the character of a fracture provide additional insight into the likelihood of skier-triggering and propagation potential of the snowpack.

Fracture Character Major Class	Code	Description Sub Class	Code	Fracture Characteristics
SUDDEN (Pops and Drops)	SDN	**Sudden Planar** (pop, clean & fast fracture)	SP	A thin planar[2] fracture suddenly crosses column in one loading step AND the block slides easily[3] on the weak layer
		Sudden Collapse (drop)	SC	Fracture crosses the column with a single loading step and is associated with a noticeable collapse of the weak layer
RESISTANT (Others)	RES	**Progressive Compression** (step by step "squashing" of a layer)	PC	A fracture of noticeable thickness (non-planar fractures often greater than 1cm), which usually crosses the column with a single loading step, followed by step-by-step compression of the layer with subsequent loading steps
		Resistant Planar	RP	Planar or mostly planar fracture that requires more than one loading step to cross column and/or the block does NOT slide easily*** on the weak layer
BREAK[4] (Others)	BRK	**Non-planar break**	BRK	Non-planar, irregular fracture

[1] *"Small Column Snowpack Tests" refer to snowpack tests performed on an isolated column of snow where the objective is to load the column until a fracture (or no fracture) occurs. Typical small columns are less then*
50cm x 50cm in cross section.
[2] *"Planar" based on straight fracture lines on front and side walls of column*
[3] *Block slides off column on steep slopes. On low angle slopes, hold the sides of the block and note resistance to sliding.*
[4] *For tests which result in no fracture of the column, record as No Fracture (NF)*

Fracture line: The outline of the released part of the slab, defined by the crown and flanks.

Front: Boundary between two air masses differing in temperature and humidity. Depending on whether warmer or colder air is advancing, the fronts are referred to as warm or cold fronts respectively. Fronts are associated with active weather, including precipitation, wind and temperature changes. Cold and warm fronts exhibit distinct weather patterns.

Highmarking: Activity in which snowmobilers ride up a steep slope, trying to reach the highest possible point. When the machine slows at the top of the run, the rider turns and heads back down. Subsequent riders may try to go higher.

Hill climbing: Similar to highmarking, where the objective is to ride all the way to the top or crest of a large, steep slope.

Ice climbing: Climbing of steep frozen waterfalls using crampons and technical ice axes. While this activity does not necessarily take place in avalanche terrain directly, icefall climbs are often exposed to an avalanche hazard from above.

InfoEx: Industry-supported avalanche and weather information exchange, in which operations engaged in avalanche forecasting and control share local observations, in exchange for access to those from other operations. The InfoEx is not available to the public, but is widely used by professionals and allows them to track daily snowpack and weather changes throughout western Canada.

Inversion (temperature inversion): An increase in temperature with height inhibiting vertical motion of air. Commonly observed under arctic high pressure systems with clear skies, warmer temperatures in the alpine and colder temperatures in valley bottoms. Often association with the development of valley clouds or fog as moisture gets trapped in the valley bottoms.

Isothermal snowpack: Refers to a snowpack with no variation in temperature through its thickness. Almost exclusively used to describe snowpacks which are entirely at 0°C during melting. Isothermal snowpacks have usually lost most of their strength and cohesion.

Low pressure system (disturbance): A storm system with counter clockwise (cyclonic) air flow around a centre of low atmospheric pressure at the surface in the mid and high latitudes. Develops along the boundary between two air masses and is associated with a leading warm front and a trailing cold front.

Mechanized skiing: Skiing or snowboarding on uncontrolled slopes in the backcountry in organized groups under the direction of a ski guide. The primary means of transportation between runs are helicopters or snow cats.

Median: The median describes the numeric value in a set of numbers (sample) that separates the higher half from the lower half. It is the middle measurement in an ordered set of data. The median is different from the mean which describes the average value of a sample.

Mountaineering: Traditional climbing of a mountain peak without the use of skis.

Out-of-bounds skiing: Skiing or snowboarding on uncontrolled slopes outside, but close to the ski area boundary, primarily using ski lifts and possibly short hikes for access. In this book, this category also includes accidents that occurred in permanent closures within ski area boundaries.

Pacific air mass: Moderately cool and moist body of air that develops over the mid-latitudes of the Northern Pacific. The winter weather in the Coast Mountains is primarily affected by this air mass.

Persistent weak layer: A weak layer that persists in the snowpack for many weeks or months. Usually composed of surface hoar, faceted crystals, or depth hoar. Most avalanche accidents involve persistent weak layers.

Pineapple Express: Weather pattern characterized by a strong flow of warm and humid air that originates from the tropical waters in the vicinity of the Hawaiian Islands towards southern British Columbia.

Propagation: The progressive spreading of a fracture or crack. Usually refers to failure or fractures in weak snowpack layers that release slab avalanches. Relatively thick, stiff slabs with large weak-layer crystals are associated with extensive propagation and therefore with relatively wide and large slab avalanches.

Ridge of high pressure: Elongated area of high atmospheric pressure. Generally associated with clear skies and no precipitation.

Rounded grains/rounds: Under sufficiently low temperature gradients, branched and angular crystals decompose into more rounded shapes called rounded grains or rounds. Rounding tends to build bonds between grains, and usually results in the strengthening of layer.

Rutschblock test/score: Large-column snowpack test used to identify weak snowpack layers in the upper snowpack and provide an indication of their triggering potential. A large column of snow is progressively loaded by a skier until a weak layer fracture is observed. Scores are reported by loading step. "Release type" may be an indication of propagation potential, where the whole block (WB) or most of the block (MB) slides. Edge of block (EB) fractures may indicate fracture resistance. May be recorded as, for example: "RB4 (MB)" for rutschblock score 4, most of block (CAA, 2007, pp. 33).

Field Score	Loading step that produces a clean shear failure	Data Code
1	The block slides during digging or cutting, or anytime before the block is completely isolated.	RBI
2	The skier approaches the block from above and gently steps down onto the upper part of the block (within 35cm of the upper wall).	RB2
3	Without lifting the heels, the skier drops from straight leg to bent knee position, pushing downwards and compacting surface layers.	RB3
4	The skier jumps up and lands in the same compacted spot.	RB4
5	The skier jumps again onto the same compacted spot.	RB5
6	For hard or deep slabs, remove skis and jump on the same spot. For soft slabs or thin slabs where jumping without skis might penetrate through the slab, keep skis on, step down another 35cm (almost to mid-block) and push once then jump three times.	RB6
7	None of the loading steps produced a smooth slope-parallel failure.	RB7

Settlement: Process of natural compaction and stiffening of snowpack layers under their own weight or weight of layers above. Settlement can transform soft storm snow into a slab. The transition is gradational, depending on thickness, weak layer properties, and other factors. The term settlement is often incorrectly used to describe a "whumpf."

Size classification (avalanche; CAA, 2007): The Canadian avalanche size classification is based on destructive potential of an avalanche.

Size	Destructive Potential (definition)	Typical Mass	Typical path length
1	Relatively harmless to people	<10 tonnes	10 m
2	Could bury, injure, or kill a person	10^2 tonnes	100 m
3	Could bury and destroy a car, damage a truck, destroy a wood frame house, or break a few trees	10^3 tonnes	1000 m
4	Could destroy a railway car, large truck, several buildings, or a forest area of approximately 4 hectares	10^4 tonnes	2000 m
5	Largest snow avalanche known,. Could destroy a village or a forest area of approximately 40 hectares	10^5 tonnes	3000 m

*Half sizes are not defined but may be used by experienced practitioners for avalanches that reach midway between defined size classes (e.g. size 2.5)

Skier's right/left: Refers to the direction relative to a person facing downhill. Alternatively, *climbers' right/left* or *looker's right/left* are relative to a person facing uphill.

Slab: One or more cohesive layers of snow that act as a unit.

Sling rescue: A rescue method in which a rescuer on a long-line below a helicopter picks up a victim. The official term for this is HETS (Helicopter External Transport System)

Sluff: A small loose snow avalanche.

Snowmobile riding: Using a snowmobile to travel in uncontrolled backcountry areas.

Snowpack test: Any formal or ad hoc method of testing snowpack stability when travelling in avalanche terrain. Usually involves isolating a column or block of the snowpack and applying some force to it. Common methods include hand tests (quick method often used by guides while skiing), pole tests, compression tests, rutschblock tests, etc.

Snowshoeing or hiking: Hiking on uncontrolled slopes in the backcountry with or without the use of snowshoes.

Stepped down: A slab avalanche is said to have stepped down if the motion of the initial slab causes lower weak layers to fracture, resulting in a second bed surface deeper in the snowpack. A step in the bed surface is usually visible.

Storm snow: The snow that falls during a period of continuous or consistent snowfall.

Surface hoar: Crystals, often shaped like feathers, spikes, or wedges, that grow upward from the snow surface when air just above it is cooled to the dew point. Surface hoar is the winter equivalent of dew. It grows most often when the wind is calm or light on cold, relatively clear nights, but may also grow on shady slopes during the day. Once buried, layers of surface hoar are slow to gain strength, and usually form a persistent weak layer.

Temperature gradient: The temperature gradient is the change in temperature with depth in the snowpack. Gradients greater than 1°C per 10cm of depth are often associated with faceting and sometimes weakening of layers, whereas lower gradients are usually associated with rounding of grains and strengthening.

Terrain trap: Any terrain features that have the potential to increase the severity of being caught in an avalanche. Examples include gullies, cliffs, crevasses and trees.

Thin spot: Refers to a relatively small area of shallower or thinner snowpack where it may be easier for the weight of a skier or snowmobiler to trigger a weak layer fracture that leads to a slab avalanche. Thin spots may be difficult to avoid, as they are often not noticeable from the surface.

Verglas: In mountaineering, rock that has been glazed with ice.

Whumpf: The sound of a fracture propagating along a weak layer within the snowpack. Whumpfs are often indicators of instability in the snowpack. Whumpfs that occur on slopes steep enough to slide usually result in a slab avalanche.

Wind-loaded: Terrain on which the wind has deposited additional snow. Slopes on lee sides of ridges are often wind-loaded.

Wind slab: One or more stiff layers of wind-deposited snow. Wind slabs usually consist of snow crystals broken into small particles by the wind and packed together.

Appendix B **Resources for Recreationists**

Selected Books

Daffern, T. (2009). *Backcountry Avalanche Safety for Skiers, Climbers, Boarders and Snowshoers*, third edition. Rocky Mountain Books, Calgary, Canada, 208 pp.

Fredston, J.A. & Fesler, D. (1999). *Snow Sense: A Guide to Evaluating Avalanche Hazards*, fifth edition. Alaska Mountain Safety Center, Anchorage, Alaska, USA, 120 pp.

Ferguson S.A. & LaChapelle, E.R. (2003). *The ABCs of Avalanche Safety*, third edition. The Mountaineers Books, Seattle, USA, 140 pp.

Haegeli, P. (2010). *Avaluator: Avalanche Accident Prevention Card*, second edition. Canadian Avalanche Centre, Revelstoke BC, 30 pp.

Haegeli, P., Atkins, R., and Klassen, K., 2010. Decision making in avalanche terrain-a field book for winter backcountry users. Canadian Avalanche Centre, Revelstoke BC, 64 pp.

Jamieson, B. (2000). *Backcountry Avalanche Awareness*, seventh edition. Canadian Avalanche Centre, Revelstoke, BC, Canada, 78 pp. Sixth edition available in French as Sensibilisation aux Avalanches en Montagne. Translated by M. Perron and M. Thibaudeau. Also available in Swedish.

Jamieson, B. & Geldsetzer, T. (1996). *Avalanche Accidents in Canada, 1984-96*. Canadian Avalanche Centre, Revelstoke, BC, Canada, 193 pp. Available online at www.avalanche.ca. Also available in French as *Avalanches au Canada, 1984-1996*. Translated by M. Perron and M. Thibaudeau

Jamieson, B. & McDonald, J. (1999). *Free Riding in Avalanche Terrain, A Snowboarder's Handbook*. Canadian Avalanche Centre, Revelstoke, BC, Canada, 74 pp. Also available in Japanese.

Jamieson, B., Svederus, D. & Zacaruk, L. (2007). *Sledding in Avalanche Terrain: Reducing the Risk,* second edition. Canadian Avalanche Centre, Revelstoke, BC, Canada, 74 pp.

Logan, N. & Atkins, D. (1996). *The Snowy Torrents — Avalanche Accidents in the United States 1980-86*. Colorado Geological Survey, Special Publication 39, 275 pp.

McClung, D.M. & Schaerer, P.A. (2006). *The Avalanche Handbook,* third edition. The Mountaineers Books, Seattle, 288 pp.

Schaerer, P.A. (1987). *Avalanche Accidents in Canada III, A Selection of Case Histories, 1978-1984*.National Research Council of Canada, Institute for Research in Construction, Paper No. 1468, NRCC Publication 27950. Available online.

Stethem, C.J. & Schaerer, P.A. (1979). *Avalanche Accidents in Canada I, A Selection of Case Histories of Accidents, 1955 to 1976*. National Research Council of Canada, Division of Building Research Paper 834, NRCC Publication 17292. Available online.

Stethem, C.J. & Schaerer, P.A. (1980). *Avalanche Accidents in Canada II, A Selection of Case Histories of Accidents, 1943 to 1978*. National Research Council of Canada, Division of Building Research Paper 926, NRCC Publication 18525. Available online.

Tremper, B. (2008). *Staying Alive in Avalanche Terrain*, second edition, The Mountaineers Books, Seattle, Washington, USA, 318 pp.

Selected DVDs

The Fine Line, Rocky Mountain Sherpas, www.rockymountainsherpas.com

Time is Life - Medical Training in Avalanche Rescue, www.time-is-life.org

White Risk, WSL Institute for Snow and Avalanche Research SLF, www.slf.ch

Selected Websites

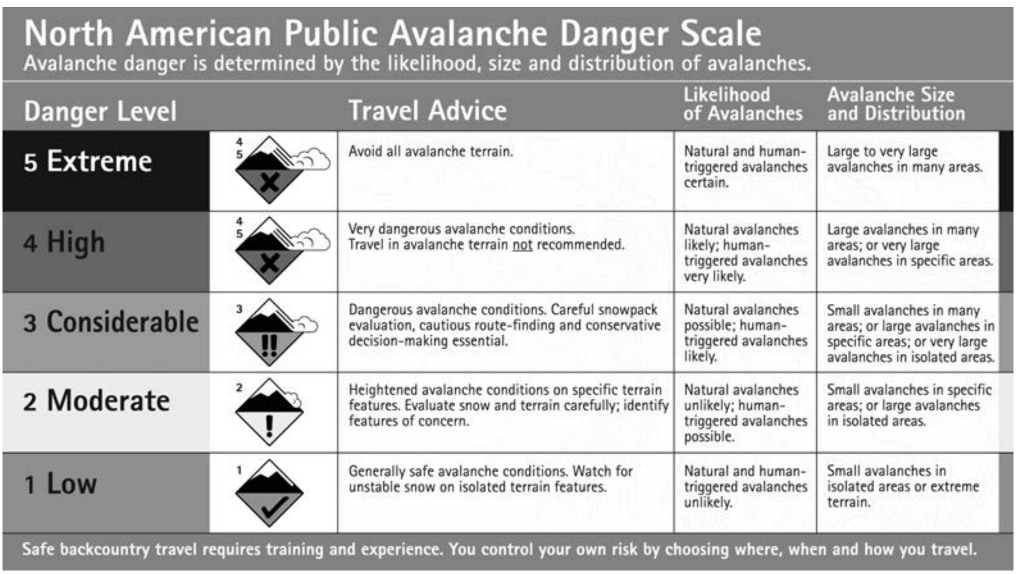
Canadian Avalanche Association, www.avalanche.ca

American Avalanche Association, www.avalanche.org

Appendix C **Canadian Avalanche Danger Scale**

Canadian Avalanche Danger Descriptors (1996)		
Danger Level (& Color)	**Avalanche Probability and Avalanche Trigger**	**Recommended Action in the Backcountry**
…WHAT…	…WHY…	…WHAT TO DO…
LOW (green)	Natural avalanches very unlikely. Human-triggered avalanches **unlikely**.	Travel is generally safe. Normal caution advised.
MODERATE (yellow)	Natural avalanches unlikely. Human-triggered avalanches **possible**.	Use caution in steeper terrain on certain aspects (defined in accompanying statement).
CONSIDERABLE (orange)	Natural avalanches possible. Human-triggered avalanches **probable**.	Be increasingly cautious in steeper terrain.
HIGH (red)	Natural and human-triggered avalanches **likely**.	Travel in avalanche terrain is not recommended.
EXTREME (red with black border)	Widespread natural or human-triggered avalanches **certain**.	Travel in avalanche terrain should be avoided and travel confined to low angle terrain well away from avalanche runouts.

The Canadian Avalanche Danger Scale was introduced in 1994, and was in use for the period covered by this book. The danger scale system was developed in Europe in 1993 and adopted by both Canada and the United States. However, different descriptors of the danger levels were developed in each country.



North American Public Avalanche Danger Scale

Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level		Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	4 5	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	4 5	Very dangerous avalanche conditions. Travel in avalanche terrain not recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	3	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	2	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	1	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

In 2005 a group of Canadian and American avalanche forecasters and researchers began to revise their separate systems with the goal of improving clarity and developing a single standard for both countries. In the spring of 2010 the North American Public Avalanche Danger Scale was introduced. Incorporating icons and information on the likelihood, size and distribution of avalanches, this new scale aims to better communicate avalanche danger to the user.

Appendix D **Graphical Snow Profile Interpretation**

Introduction

The following description of graphical snow profiles is a basic overview of their purpose, techniques, plotting, and interpretation. It is cursory at best, and not intended to replace formal training and experience. This brief description will help familiarize readers of this volume with the features of snow profiles, so that they might gain some insight from those included with the accident summaries. For a more detailed treatment of snowpack layering and evolution, snow profiles, and what they mean please refer to the resources and references listed at the end of this appendix.

Purpose of Snow Profiles

The majority of the snow profiles presented in this volume were observed by investigators on the days following an avalanche accident, from a site at or near the fracture line or crown of the avalanche. These "fracture line profiles" seek to document the snowpack layering and other features that may have contributed to the triggering and release of the avalanche. With the benefit of hindsight and observations of the avalanche, it is usually practical to identify the slab, weak layer, and bed surface involved. A careful study of the common threads found in fracture line profiles can provide the forecaster, guide, or recreationist with the ability to identify unstable snowpack configurations observed in "full" or "test" profiles. In fact, recent research has identified the characteristics of snowpack layering more likely to be found on slopes where human-triggered avalanches have occurred (see Jamieson and Schweizer, 2005; Schweizer and Jamieson, 2007).

Field Techniques

The snow profile begins with the choice of a suitable location. For fracture line profiles, safety of the observer is paramount. The profile may be observed along the flanks or crown of an avalanche. If this is not possible, a nearby safe area where similar snowpack conditions are expected is acceptable, although correlations with the snowpack that avalanched may be limited or unknown.

The observation face for a fracture line profile is a vertical section through the snowpack, located at least 1m back from the crown or flank of an avalanche and excavated deeper than the bed surface of the avalanche. Full or test profiles are often performed nearby, or in other safe locations. The bed surface, failure layer, and all other important snowpack layers are identified in the observation face, and their depth and features are described. The total depth of the snowpack is measured by probing or digging to ground. The slope angle of the bed surface is determined, and the location of the profile relative to the avalanche outline is described in detail. Often, time constraints or other considerations limit the observations to these main features.

Graphical Snow Profiles

The snow profiles that accompany many accident summaries in this book are graphical representations of the details and layering of the snowpack, presented in a format that allows for visual interpretation of the complete profile at a glance. They also contain the finer details of layer properties for those interested readers. In some cases, the profiles have been simplified for this volume, but the format used here is the standard for snow observations in Canada and elsewhere, and all relevant information was retained. A brief description of the features of a graphical snow profile follows, using *Figure D.1* as a guide.

The header or title bar (A) contains information about the location, date, time, observers, weather, etc. Some more technical information, such as elevation, slope incline, and foot penetration are included.

The main graphical section, on the left side of the profile (B), has two axes. The horizontal axis measures temperature and layer resistance, while the vertical axis measures the depth in the snowpack of the observed features. In some profiles of the snowpack, the depth scale may have zero at the bottom, with height increasing upwards; for others, zero may be at the surface, with depth increasing downwards. The height of the surface may be indicated in the left hand part of the graphical section to highlight cases where the lower snowpack was not profiled. In either case, the resulting graphic is a scaled vertical cross-section through the snowpack, showing each of its layers and their pertinent details.

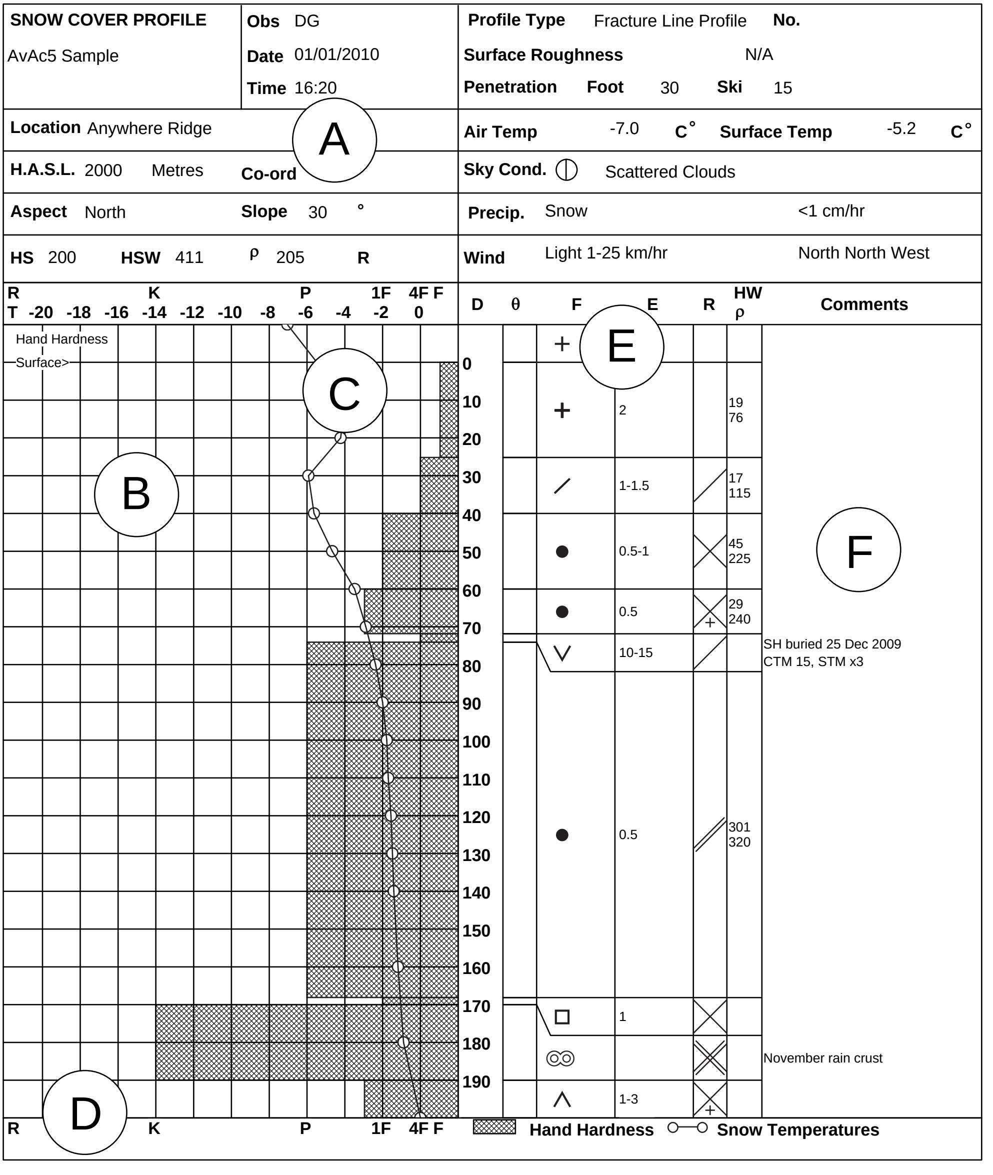


Figure D.1. *Hypothetical graphical snow profile, labeled to match description in text.*

The temperature of the snowpack is generally recorded at the surface, and then at intervals of 10 or 20cm. It is recorded on the graph using a set of dots connected by a line (C); the temperature scale is found on the upper horizontal axis, with the freezing point of water at the right, and temperatures decreasing to the left. The absolute temperature of a snowpack layer may be less important than the temperature gradient, or change with depth in snowpack. Very high temperature gradients, even over a short depth interval, promote the faceting of snow crystals and the weakening of bonds between them, whereas low temperature gradients promote rounding and strengthening.

The resistance or hardness of each layer is recorded on the graphical snow profile as a horizontal bar, with its length corresponding to the hardness scale on the horizontal axis (D). This is a good proxy for the relative stiffness of the layers. The horizontal scale is sometimes marked in force units (Newtons), although in the field and on the profile, "hand hardness" is used as a simple index. In addition, the hardness is assigned a code (*Table D.1*), which is included in the R column (E). For each layer, the observer records the object that can be pushed into the snow with moderate effort, parallel to layer boundaries.

Table D.1. *Resistance or hand hardness chart.*

Object	Profile Code	R Code
Fist in glove	F	
Four fingers in glove	4F	/
One finger in glove	1F	╳
Blunt end of pencil	P	//
Knife blade	K	⋇
Too hard to insert knife	I	▬

Note that slight variations in hardness are often indicated using "+" (slightly harder than) or "-" (slightly softer than) symbols. The hardness axis is usually on the bottom of the snow profile and is a non-linear scale, corresponding to the relative surface area of the objects used to determine hand hardness.

The right hand columns of the profile (E) provide additional detail about each layer. The liquid water content of the layer is recorded in the θ column, as dry (D or blank), moist (M or I), wet (W or II), very wet (V or III), and saturated (S or IIII). The grain form or type of snow crystal is recorded using basic symbols (*Table D.2*) in the F column.

Table D.2

Grain form	Abbreviation	Symbol
Precipitation particles	PP	∗
Decomposing and fragmented particles	DF	/
Rounded grains	RG	●
Faceted crystals	FC	□
Depth hoar	DH	∧
Mixed forms (rounded facets, faceted rounds)	MX	⍝ ⛉
Wet grains	WG	○ ⚘
Surface hoar	SH	∨
Ice Masses	ICE	▬
Surface deposits and crusts	MFC	⍱

A more detailed international classification system may be used. Please see Fierz et al. (2009) for details. Note that the grain form of the snow surface is often recorded as the uppermost layer; however, no hardness is assigned to the surface. The typical size or extent of snow crystals in each layer is recorded in the E column. Grains are measured in millimetres, and the entry may refer to a range (e.g. 0.5 –1) or several distinct sizes (e.g. 0.5/2 for the size of the first/second grain type).

The density of layers is often measured in the field, and is recorded in the ρ column. Field measurements are converted to kg/m^3 for the graphical profile. Note that newly fallen snow has a typical density between 50 and 150 kg/m^3. Very dense snowpack layers may have a density of over 400 kg/m^3, whereas the maximum density of ice layers is approximately 920 kg/m^3.

Any comments or the results of snowpack tests are recorded in the rightmost column of the profile (F). Often a more detailed description of the profile site is included below the graphic section. For fracture line profiles the bed surface and failure layer should be identified there as well. Abbreviations for snowpacks tests are usually used—see the glossary chapter for a description of these.

Snow Profile Interpretation

Aside from simply documenting the conditions that existed at the time of an avalanche, the goal of a snow profile is often to identify and characterize unstable snowpack configurations. For slab avalanches, one must have a relatively thick, stiff slab overlying a relatively thin, soft weak layer, which in turn rests on a stiff or smooth bed surface; however, many stable snowpacks also have these three required elements. Ultimately, we seek to differentiate between stable and unstable snowpacks, which becomes less difficult with training and experience.

Research on many snowpacks involved in human-triggered avalanches has shown that critical ranges exist for at least three layer properties and three interface properties which, taken together, have some—although not perfect—predictive power for slope stability. Inexperienced observers can identify these critical properties just as well as those with more experience, yet final decisions on stability require skilled interpretation of many observations beyond any point observation of the snowpack (snow profile or snowpack test).

For weak layers, the key properties are large grain size (>1mm), low hardness, and persistent grain forms. For interfaces between a slab and weak layer, a difference in grain size greater than 0.5mm and a difference in hardness of greater than a single step in penetration resistance indicates instability. Skier triggering is most frequent with a depth to the interface between 20cm and 85cm. Some of these properties are associated with a relatively weak layer, and others seem to enhance the ability of the slab-weak layer system to propagate fractures once initiated. The hypothetical snowpack profiled in *Figure D.1* contains several weak layers at different depths, and many features that might suggest instability.

Further Resources:

Canadian Avalanche Association, 2007. *Observation Guidelines and Recording Standards for Weather, Snowpack and Avalanches*. Canadian Avalanche Association, Revelstoke, BC.

Fierz, C., Armstrong, R.L., Durand, Y., Etchevers, P., Greene, E., McClung, D.M., Nishimura, K., Satyawali, P.K. and Sokratov, S.A. 2009. The International Classification for Seasonal Snow on the Ground. IHP-VII Technical Documents in *Hydrology* 83, IACS Contribution 1, UNESCO-IHP, Paris.

Jamieson, B. and Schweizer, J., 2005. Using a checklist to assess manual snow profiles. *Avalanche News*, Canadian Avalanche Association, Revelstoke, BC, Volume 72, p.57-61.

McClung, D., and Schaerer, P., 2006. *The Avalanche Handbook*. The Mountaineers, Seattle, WA.

Schweizer, J. and Jamieson, B., 2007. A threshold sum approach to stability evaluation of manual snow profiles. *Cold Regions Science and Technology*, Volume 47, Issue 1-2, p.50-59.

Tremper, B., 2008. *Staying Alive in Avalanche Terrain*. The Mountaineers, Seattle, WA.

Appendix E **Avaluator Warning Signs and Terminology**

The following table gives explanations of the warning signs as used in this book. The specific definitions of the warning signs, the weighting applied to the different signs, and the interpretation and decision guidance derived from the combined signs (i.e. Caution, Extra Caution or Not Recommended) are discussed in detail in the Avaluator booklet (Haegeli 2010).

AVALANCHE CONDITIONS	
Regional Danger Rating	The danger rating for the applicable elevation zone, i.e. Alpine, Treeline or Below Treeline, as issued by a regional forecast centre such as the Canadian Avalanche Centre, National Park or Kananaskis Country. See Appendix C for the danger ratings in use during the years covered by this book. Considerable danger or higher is considered a warning sign.
Persistent Avalanche Problem	Is there a persistent weak layer or deep-slab problem in the snowpack? See the glossary for types of avalanche problems.
Slab Avalanches	Any sign of slab avalanches in the area from the current or previous day is considered a warning sign.
Signs of Instability	Whumpfs, shooting cracks or drum-like sounds are considered a warning sign.
Recent Loading	Snowfalls of roughly 30cm or more within 48 hrs, or any rain or wind-transported snow are considered a warning sign.
Critical Warming	Either a recent rapid rise in temperature to near 0°C, or wetting of the upper snowpack due to strong sun, above-freezing air temperatures or rain is considered a warning sign.

TERRAIN CHARACTERISTICS	
Slope Steepness	The steepest part of the slope where the people were, or of immediately adjacent slopes. Slopes over 30°, especially over 35°, are considered a warning sign. The steepness of the immediately adjacent slopes is considered because of remote triggering.
Terrain Traps	Any terrain feature that increases the consequences of being caught in an avalanche such as, gullies, trees or cliffs is considered a warning sign.
Slope Shape	Convex or unsupported slopes are considered a warning sign. Concave or planar slopes are not.
Forest Density	Anything but closed forest is considered a warning sign. This includes the alpine (no trees) and sparsely treed or open forest (cut-block, burn, glades with widely spaced trees).

Index of Avalanche Accidents by Activity

Backcountry Skiing/Snowboarding

Out-of-bounds Skiing/Snowboarding

Mechanized Skiing/Snowboarding

Snowmobile Riding

Mountaineering

Ice Climbing

Snowshoeing or Hiking

Other Recreation

Outdoor Worksite

Buildings/Transportation

Subsistence Hunting/Fishing

Index of Avalanche Accidents by Date

About the Authors

Bruce Jamieson started ski touring in 1974 and soon became fascinated with snow avalanches. From 1980-86 he worked on avalanche forecasting and control programs for ski resorts. Graduate school, consulting, hazard assessments and teaching avalanche courses followed. He was president of the Canadian Avalanche Association from 1992 to 1995. During the summers of 2002 and fall of 2008 he was a guest researcher at the Swiss Federal Institute for Snow and Avalanche Research. His three short books on backcountry avalanche safety are used as student manuals for the Canadian Avalanche Centre's Avalanche Skills Training courses. As part of the NSERC Research Chair in Snow Avalanche Risk Control at the University of Calgary, he works with a team of graduate students and technicians on field studies of snow and avalanches.

Pascal Haegeli grew up in Switzerland and was first introduced to avalanches when he went to a backcountry skiing camp in junior high school. He was immediately hooked by the experience and wanted to learn more about snow and avalanches. After graduating with a Masters in Climatology in 1998, he moved to Canada to pursue graduate research in Atmospheric Science at UBC. In 1999, he decided to better align his interest in science with his passion for backcountry skiing and changed his research focus to avalanches. Since the completion of his PhD in 2004, he has been working as an independent research consultant in the Canadian avalanche community. His research interests include both the physical and human aspects of avalanche safety. In an attempt to capture the existing expertise in the avalanche community and make it more accessible to recreationists, Pascal has developed the Avaluator and more recently co-authored Decision Making in Avalanche Terrain, a field book for winter backcountry users. Besides his work as a consultant, Pascal is currently an adjunct professor at Simon Fraser University in Burnaby, BC, where he works on various avalanche challenges with graduate students. Whenever there is time, he enjoys the mountains, focusing more on turns and a little bit less on research.

Dave Gauthier first came to the mountains of western Canada as a teenager, for a season-long sabbatical in Rossland, BC after finishing high school in Ottawa. Following undergraduate and Master's degrees in geology from Lakehead University in Thunder Bay, he returned west, this time to Fernie. There he discovered the freedom—and dangers—of the backcountry, and began to wonder about avalanches. Luckily, he found like-minded people at the University of Calgary, and graduated with a PhD in snow science and avalanche research in 2007. Along the way Dave has been very fortunate to have lived and worked with many amazing people—researchers, guides, technicians, forecasters, friends—whose generosity with time, knowledge, experience, and opportunity has not gone unnoticed. Today, he is based in Thunder Bay and wears both academic and professional hats, with a continued focus on avalanches and more recently on rock fall hazards. From there, with the help of the internet and frequent-flyer miles, Dave stays in touch—literally and figuratively—with the mountains and the snow.

Avalanches affect Canadians from coast to coast to coast.

In the period covered by this book, 155 people lost their lives in 105 avalanche accidents across the country—from Newfoundland to Baffin Island to BC's North Shore Mountains.

The authors are avalanche researchers and experienced backcountry travellers. After examining each of these tragedies, they offer the reader a comprehensive and concise analysis of the circumstances and decisions behind these accidents.

Travelling in avalanche terrain involves risk. Backcountry users of all types can reduce their risk with training and education. This book is a good place to start, by learning from the experiences of others.

About the Canadian Avalanche Association

The Canadian Avalanche Association is the organization that serves and supports the diverse community of professional avalanche workers and operations in Canada. The CAA has close to 1000 members, and delivers a variety of professional-level training courses to approximately 700 students each year.
www.avalanche.ca