



Persistent Weak Layers and the Winter of 2007-2008

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This winter, backcountry users in western Canada are faced with a particular problem—a persistent weak layer in the snowpack of many popular mountainous areas. This discussion is intended to help you better understand how these layers formed and the challenges related to managing this type of risk. This article is not intended to provide answers to all the questions you might have. Instead, it provides general guidance and some tips to help you ask the right questions and gather information that can help you make an informed decision.

I must stress there is no 100% guarantee of safety in the mountains. You could be caught in an avalanche, injured, or killed even if you follow every piece of advice in this discussion and “do everything right.” This being said, in at least half of the avalanche fatalities to date this season, the victims were either not equipped with appropriate rescue gear or did not heed clear warnings. Many avalanche accidents are preventable—it’s up to you to get the training, information, and appropriate equipment to properly manage your risk if you choose to go into the mountains.

What’s the problem?

A persistent weak layer (PWL) is so called because it does not strengthen over time, and in some cases it even becomes weaker over time. A PWL can remain unstable for weeks or even months and is often the cause of avalanches long after it originally forms and is buried.

A PWL often results in what is referred to as a “deep slab instability”—a deeply buried weak layer beneath a thick slab or slabs of snow comprised of accumulated snow from numerous storms. Deep slab avalanches are generally large and highly destructive due to their size and mass. A PWL that formed in the fall of 2002 and the resultant deep slab instability was the underlying cause of most of the 29 fatalities that occurred in the winter of 2002-2003 (the worst avalanche season in recent years), including two large avalanches that each killed seven people in the Selkirk Mountains.

A variety of crystal forms can contribute to a PWL, but the current concern is a “facets on crust” layer. Back in the early days of the season, rain saturated the surface of the snowpack (this is called a “rain on snow event”). As or shortly after that wet layer froze, facets (sugary snow grains) formed on top of the icy rain crust. Now, that layer of facets has become a PWL.

This year’s facet on crust PWLs are known or strongly suspected as the cause behind nine of 11 avalanche fatalities to date, spanning a time frame from December 8, 2007 to January 16, 2008 and occurring in the Alberta Rockies, the Cariboo Mountains, and the

southern Monashee Mountains. The most active period to date was the first week of January when numerous fatal accidents made avalanches front page news. The untold story are the many close calls involving this year's PWLs that didn't make the news starting in mid-November and, as of this writing, continuing to January 24th, occurring in practically all the mountain ranges of BC and Alberta. You can see reports about many of these close calls on the Canadian Avalanche Centre's Discussion Forums at: <http://www.avalanche.ca/default.aspx?DN=586,558,3,Documents>.

Experience has shown that PWLs go through cycles where periods of high avalanche activity are interspersed with periods during which few avalanches occur. When, where, and why these cycles occur can be difficult to predict with a high degree of accuracy and are not fully understood. Unstable periods are often related to changes weather factors such as increased wind, snowfalls, rain, temperature changes (especially from cold to warm), and solar radiation. A PWL that has produced avalanches and then shows signs of stability is generally treated with scepticism by knowledgeable practitioners, most of whom describe such a layer as dormant rather than stable, the assumption being (as Monty Python once said): "...it's not dead, it's just sleeping."

Where is the problem?

One or more rain on snow events occurred in pretty much all the mountain ranges of BC and Alberta in the fall of 2007. It is common practice to name a PWL according to the date on which it is buried by subsequent snowfalls. To date this year, rain on snow events occurred:

- Near the end of October at most elevations and on all aspects in most BC and Alberta mountain ranges. This layer is generally referred to as October 31st or the Halloween crust, although it is dated as early as October 27th in some areas.
- Around the third week of November at most elevations and all aspects in practically all BC and Alberta mountain ranges. This one is referred to as November 24th, plus or minus a few days.
- In early December on all aspects to treeline or just above treeline in most BC ranges. This most recent layer is commonly known as December 5th although it might be anything from December 3rd to 10th, depending on where you are.

The October layer, while quite widespread in BC and Alberta is not a great concern in most of BC at this time. It is, however, considered a problem in the Alberta Rockies. The November layer was considered a potential problem in many ranges but in most areas of BC it seems to no longer be a significant concern. At this time, however, it remains an issue in parts of the Alberta Rockies and perhaps in isolated areas in BC that have a snowpack of less than about 150cm on average. The December layer did not occur in the Alberta Rockies but is widespread in BC. That said, there are numerous areas where these layers either do not exist or, if they do, have shown no signs of instability from the outset.

Following is a breakdown of the regions where this year's facets on crust PWLs are more prevalent. I must stress that this is a very general overview and local anomalies are a certainty. Please note that in areas where a professional avalanche control program is in place, the problems associated with these layers are significantly or wholly mitigated; this includes for example, transportation corridors and ski areas. On a regional scale, October and November PWLs are currently considered prevalent at all elevations in:

- The entire east slope of the Alberta Rockies from the US Border to at least Jasper and probably to Grande Cache.
- Limited information indicates the November layer was a concern in the North Rockies but its current state there is uncertain.

The December layer is considered a greater problem around treeline and in open areas below treeline in:

- The west side of the southern Rockies from around Elkford (and maybe a little farther north) to the US Border, including the Fernie area.
- The Boundary region east of Osoyoos, west of Kootenay Pass, and south of Castlegar. The mountains around Rossland have been described the "epicentre" of the December PWL.
- The Monashee and Selkirk Mountains south of a line running more or less from Vernon to Nakusp.
- The Purcell Mountains.
- Inland regions of the South Coast Mountains.

- Limited information suggests this layer is of concern in the North Rockies, especially in the eastern parts of the region where the snowpack is shallow.

Even in areas noted above, there are locations where PWLs are less of an issue or perhaps not an issue at all. Knowledgeable local experts (e.g. guides, ski patrollers, and avalanche professionals) who have been tracking and testing the snowpack throughout the winter and who use a recognized snow stability analysis and forecasting process to assess hazard and manage risk, will know if PWLs are an issue in their area or not. Unless you have credible local knowledge and are certain a problem PWL does not exist, it's probably wise to assume there is an issue in the above areas.

The potential for triggering a deep slab instability on a PWL is greater in:

- Shallow snowpacks (less than 200cm on average).
- Variable depth snowpack areas (shallow areas interspersed with deep areas on the same slope).
- Rocky slopes.
- Slopes with small, isolated trees sticking out.
- Complex slopes. (check out terrain classification at: <http://www.avalanche.ca/default.aspx?DN=599,428,4,558,3,Documents>)
- Steep, convex, unsupported features.

How do this year's layers look and feel?

A facets on crust PWL is characterized by a layer of firm or frozen snow with weaker facets above and/or below it. The firm layer is generally hard to very hard, sometimes even an ice layer, anywhere from perhaps a centimetre or two in thickness to 10cm or more. If you poke the firm layer, it will be difficult or impossible to push a single, gloved forefinger into it. The facet layer is soft or very soft, is typically thinner than the crust, and can be as thin as a few millimetres. It's difficult to assess the hardness of thin facet layers but they are often relatively easy to see (a darker, sometimes bluish line in the wall of a hole dug in the snow). Under 8-10x magnification on a dark background, facets look like sugar crystals and the grains separate easily when removed from the snowpack.

A problem PWL, or one that is likely to become a problem, usually displays a certain "fracture character" when tested. The layer will generally produce a "pop" (sudden planar) or "drop" (sudden compression) fracture when tested using the Compression (CT) Test. In Rutschblock (RB) tests it often results in a whole block (WB) or most of block (MB) failure. In the case of PWLs, most avalanche professionals weight the pops and drops or WB/MB fracture characteristic more than the amount of force it takes to create the fracture in the first place. That is, even if it takes a lot of force to make the layer fail, if the layer pops/drops or produces a WB or MB failure, these layers are still considered significant.

One of the problems with the CT and RB tests is they only work when the PWL is less than 150cm below the surface. In many areas, this season's PWLs are already buried deeper than 150cm and assessing them requires more complex tests that provide less definitive answers. Testing, assessing, analyzing, and predicting the behaviour of very deep instabilities falls into the realm of highly experienced professionals who have seen many similar problems in the past and who can combine technical and scientific information with their broad knowledge and intuition in the analysis of these layers.

You can learn how to do CT or RB tests in avalanche courses or from an experienced, professional avalanche practitioner. You can find out more about training at: <http://www.avalanche.ca/default.aspx?DN=350,579,558,3,Documents>. Read more about pops, drops, CT and RB tests at: http://www.mec.ca/Main/content_text.jsp?FOLDER%3C%3Efolder_id=2534374302881865

How long will these layers persist and what will make the problem go away?

Most PWLs will perform (produce cycles of high avalanche activity) several times throughout a winter, with dormant periods lasting as long as several weeks. However, even in dormant phases, these layers can and do produce large, destructive avalanches.

In my opinion, it's almost certain that, where this year's layers are prevalent, they will persist for the remainder of the season. That said, just because a layer is there, does not necessarily mean it will wake up again and even if it does become active again, it may not produce as widespread a problem as we experienced in early January.

As to what it will take to make these layers go away, there is no definitive answer. A heavy rain event, while it would probably produce a major avalanche cycle in the short term, would likely create a very strong overlying layer of icy snow which, much like a bridge, would support further loads and minimize or eliminate the chance of a PWL below from failing. At the moment however, there is no such event on the horizon according to current long term weather forecasts. Otherwise, the only thing that will improve this kind of layer is if the crust becomes softer and/or the facets become harder and the whole combo becomes more homogeneous with the surrounding layers. There are some indications that this may be occurring with the December layer in some areas. However, this idea is based on limited data from isolated locations and should not be considered a general trend at this time.

If the layer is dormant, when will it wake up?

First of all, dormant is a relative term. A common pattern with PWL avalanche activity is a gradual decline in the frequency of avalanches. However, the avalanches that do occur tend to be larger. When and where the "low frequency/high consequence" avalanches will occur during a dormant spell is extremely difficult to predict and wondering when a dormant layer will reactivate causes sleepless nights for avalanche forecasters world-wide.

In addition to the difficulty of predicting the low frequency events, it can also be hard to predict when a new cycle of high avalanche activity will start. It's prudent to pull back and wait a few days to see what happens if:

- It starts raining.
- More than 20-30cm of new snow accumulates in a 24 hour period (perhaps less if the snow feels heavy or is associated with winds and/or warm temperatures).
- Wind is drifting snow onto slopes where PWLs are likely to exist.
- Temperatures rise rapidly (more than 3°C in a period of one hour), especially if it's -10 or warmer.
- Temperatures are near, at, or above 0°C.
- Solar radiation is strong.
- The snow is softening or becoming moist/mushy.
- Large triggers (e.g. cornice fall, avalanches from above, icefall, etc.) may affect a slope containing a PWL.

It's always a good idea to check the avalanche forecasts issued by the Canadian Avalanche Centre (<http://www.avalanche.ca/default.aspx?DN=5,4,558,3,Documents>) regularly to see if there is information there that indicates the layer is coming alive or is expected to wake up. Another place to look is in the CAC Discussion Forum (<http://www.avalanche.ca/default.aspx?DN=586,558,3,Documents>) where people who have been out in the mountains discuss their observations and post incident reports.

Some of the most destructive avalanche incidents in Canadian history are related to the end of a PWL lifespan. This is often in late winter or early spring when a PWL is dormant. After a long period of time where little or no avalanche activity on the PWL has been noted, people get lulled into sense of complacency or develop increasing confidence and are then caught by surprise (often in March) when an isolated but very large avalanche event catches the unwary by surprise. I recall a PWL in the 1990s that formed in November, went through several active periods through late spring, then wasn't heard from again until it was suspected as the weak layer in an avalanche that killed a mountaineer in August of the following year.

How do I manage risks associated with PWLs and deep slab instability?

Deep slab instabilities associated with PWLs are among the most difficult of all avalanche problems to assess, predict, and manage. Even with extensive training and nearly 30 years professional experience, I struggle with the combination of “low probability-low frequency/high consequence.” That is, it’s often difficult to trigger a deeply buried instability and the frequency of avalanches is low, but the consequences if caught in a deep slab avalanche are very serious due to the size and mass of the slide. The answer lies in making decisions based on what you know about a slope, its history of avalanche activity over the season, slope use patterns (e.g. compaction), and/or stabilization (avalanche control) measures. In the absence of knowledge the only reasonable way to manage your risk is by leaving a wide safety margin wherever a PWL is known or suspected.

It’s important to be aware of the potential risks so you can make an informed decision when determining whether the risks are acceptable to you and your party. There are a number of steps you can take to ensure you are making an informed decision:

- Examine your own motivation and that of others in your group. Check out this article:
http://www.mec.ca/Main/content_text.jsp?FOLDER%3C%3Efolder_id=2534374302881868
- Assess the training and experience of your party.
- Use a decision making process or tool like the Avaluator™ to aid in trip planning (<http://www.avalanche.ca/default.aspx?DN=428,4,558,3,Documents>).
- Ensure all members of the party play an active role in all aspects of planning, preparation, and execution of the trip.
- Talk to the others in your party. Listen to what they have to say. Respect their concerns. Make sure lines of communication remain open between all members of the party at all times.
- Use the information in this discussion and from regional avalanche forecasts to assess general conditions for the area where you will be.
- Talk to credible local experts such as guides, ski patrollers, avalanche professionals, etc. to get a handle on local conditions.
- Watch for signs of instability while travelling, such as whumpfung, cracking, and avalanches on similar slopes. These observations give you a clear signal that things are at a critical state. However in the case of a known or suspected PWL, the absence of whumpfung or avalanches should never be interpreted as evidence that a layer is not active.

PWLs are associated with high uncertainty and low confidence. With PWLs I don’t ask: “Will it slide?” I do ask: “If it slides, what will happen to me or my partners?” This approach leads to greater margins for error, which in my opinion, is the best way to manage risk at times and places where confidence is low. With PWLs and deep slab instability, I am extremely careful in choosing what terrain I use and how I manage my groups in that terrain. Here are some general tips for managing risk at any time and some specific ideas for dealing with the existing PWL problems identified in this discussion:

- Take a more conservative overall approach in areas where this year's PWLs are more prevalent (see "Where is the problem?" above).
- Use a slope assessment tool or process like the Avaluator Obvious Clues™ card to assess each slope before you expose yourself to avalanche terrain (<http://www.avalanche.ca/default.aspx?DN=673,428,4,558,3,Documents>).
- Take a more conservative approach at elevations from just above treeline to treeline and in open areas below treeline.
- Avoid travelling in avalanche terrain where the snowpack is shallow (less than 200cm on average).
- Avoid avalanche terrain where the snowpack depth is variable (shallow areas mixed with deep areas).
- Avoid slopes that have rocks and scattered trees sticking out of the snow.
- Avoid steep (steeper than a set of stairs in your house) unsupported terrain features especially if there is a pronounced convexity (roll).

- Eliminate or minimize exposure to terrain traps, such as:
 - Depressions
 - Gullies
 - Creekbeds
 - Sudden transitions from steep to flat (lakeshores, benches, roadcuts, etc.).
 - Slopes where an avalanche might carry you:
 - Over a cliff.
 - Into trees.
 - Against obstructions such as rocks or boulders.
- Stay on low angle slopes that are less than 30° incline (less steep than a set of stairs in your house).
- Stay on simpler terrain
(<http://www.avalanche.ca/default.aspx?DN=599,428,4,558,3,Documents>).
- Avoid avalanche start zones and tracks if possible.
- If you must travel in or through start zones or tracks, go one at a time from safe spot to safe spot.
- Spread out when travelling in or through avalanche runout zones.
- Regroup only in safe areas where avalanches will not start or run through/over:
 - High points.
 - Ridges above start zones.
 - Dense timber well away from the track or runout zone.

Some references for further reading:

If you are unfamiliar with the terminology used in this discussion, check out:

<http://www.avalanche.org/~uac/encyclopedia/index.htm>

You can learn more about facets on crust layers, PWLs, and deep slab instabilities in the following technical articles:

- Formation of Refrozen Snow Layers and Their Role in Slab Avalanche Release by Dr. Bruce Jamieson. Published in the Review of Geophysics, 44 (paper number 2005RG000176). Available online at:
<http://www.agu.org/pubs/crossref/2006/2005RG000176.shtml>
- Terminology and Predominant Processes Associated with the Formation of Weak Layers of Near-Surface Faceted Crystals in the Mountain Snowpack by Karl W. Birkeland. Published in Arctic and Alpine Research, Volume 30, Number 2 1998 . Available online at: [http://links.jstor.org/sici?sici=0004-0851\(199805\)30%3A2%3C193%3ATAPPAW%3E2.0.CO%3B2-H](http://links.jstor.org/sici?sici=0004-0851(199805)30%3A2%3C193%3ATAPPAW%3E2.0.CO%3B2-H)
- Characterization of a Deep Slab Avalanche Cycle by Ethan Green and Greg Johnson. Published in the Avalanche Review, Volume 21, Number 2. Available online at: http://www.americanavalancheassociation.org/pdf/deep_slab.pdf