DEEP SLAB

AVALANCHE CYCLE IN NORTHWEST WYOMING:

Analysis using historical loading thresholds

BY PATRICK WRIGHT

During mid-December 2016, the mountains of northwest Wyoming experienced a major deep-slab cycle with large avalanche events running on an October rain crust (*Figure 1*). The following analysis provides a timeline of conditions leading up these events. In addition, peak loading and settlement rates are compared to historical thresholds. With near-record loads and well-defined sliding and weak layers at the base of the snowpack, December 2016 proved to be both an intriguing and intimidating period for deep slab activity in the region.

Early season snowpack

Four storm systems in October resulted in precipitation at 200-300% of the 30-year average and set precipitation records at multiple recording stations in western Wyoming. These storms were progressively warmer, ending with rain to an elevation of 11,000' during the last week of October. A cold front on October 30 brought lower temperatures and 7" of new snowfall to the Teton region. The first half of November was mostly dry and warm under a high pressure ridge, resulting in melt of the snowpack to bare ground on southern aspects below 10,500'. On east, north, and west aspects above 9,000' (and to 8,000' on well-shaded north aspects) the October rain crust persisted, with overlying snow becoming faceted. The rain crust was found to be up to 16" thick on north aspects.

Snow began to fall in the Teton region beginning on November 16. By November 24 three storms had resulted in total snow depths at the high elevations ranging 10-30". Initial avalanche activity on the October rain crust did not occur until November 27-30. Rapid loading on November 28 and sustained winds resulted in both natural and artificial triggers of 15-30" soft slab events running on the rain crust.

Isolated deep slab events during early December

A storm system during December 3-5 resulted in 10-20" of new snow with an upside-down density structure. This system produced multiple natural soft slab events (24"-42" depth) throughout the Tetons, with three reported high-elevation deep hard slab events (60" depth). Deep events were also triggered with explosives on December 6 at Jackson Hole Mountain Resort (JHMR). Although these are in-bounds slide paths, an early-season backcountry snowpack existed at JHMR during this time. These events coincided with a rapid increase in multi-day cumulative snow water equivalent (SWE) at the Mid-Mountain study plot at JHMR. In particular, the 10-day cumulative SWE increased from an already heightened baseline load

Editor's Note: I had already grabbed a stack of Mark White's characteristically high drama and high resolution photos of the Birthday Chute when Patrick Wright's piece about further research on the Deep Slab problem came in. As a literary matchmaker, the fit seemed perfect, and Drew's musings on decision-making dovetail nicely into the rest of this issue's closer look at uncertainty.

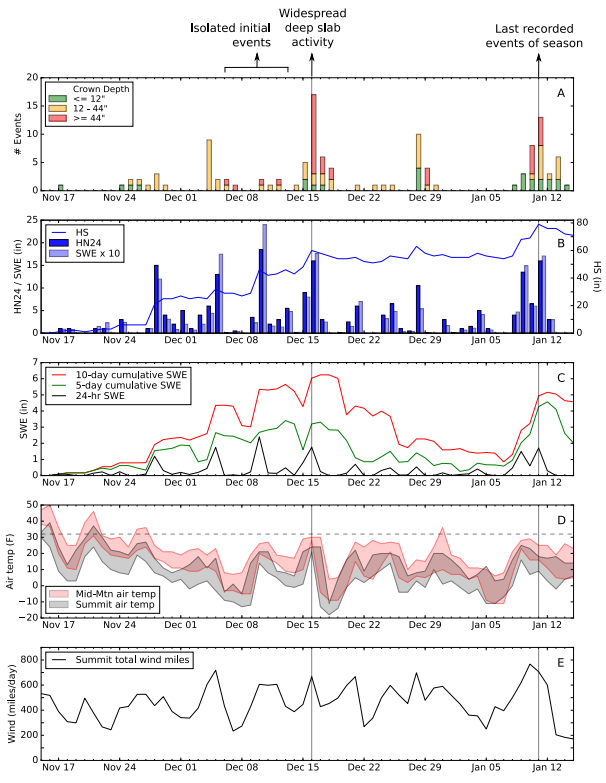


FIGURE 2: Weather and snow conditions leading up to mid-December deep slab cycle. Recorded avalanche events for the backcountry are shown in Panel A, with colors corresponding to crown depth. Received 24-hr precipitation at the Mid-Mountain study plot at JHMR (8,180') is shown as SWE x 10, alongside 24-hr new snow totals (HN24) and total snow depth (HS) (Panel B). This display allows quick estimation of new snow density, where new snow and SWE bars of equal height indicate 10% density. Multi-day cumulative SWE totals at the Mid-Mountain plot (Panel C) demonstrate major loading peaks during December. Air temperature is shown as previous 24-hr maximum and minimum at the Mid-Mountain plot and the Summit of Rendezvous Peak (10,450') (Panel D).

FIGURE 1: A deep slab avalanche on the east face of Peak 10,406' in the southern Teton Range, Wyoming. This event likely occurred on December 16, 2016, with an estimated crown depth of 62" (HS-N-R3-D3.5). *Photo Bridger-Teton Avalanche Center*

reached with the late November storm. The peak 10-day SWE was 4.35", significantly above the historical 10-day median for days with deep slab events (2.99") (Wright et al., 2016). This system was also accompanied by very strong winds (719 miles of wind at Rendezvous Peak summit).

A second storm system during December 9-10 resulted in additional isolated deep slab events. An impressive 24" of new snow with 3.4" of SWE was recorded at Rendezvous Bowl on December 10 accompanied by 606 miles of wind at Rendezvous Peak summit. 5-day cumulative SWE at Mid-Mountain increased to maximums only slightly higher than those reached on December 5, while 10-day totals again added to previously received loads, rapidly increasing to a new season maximum of 5.34". Light to moderate snowfall and strong winds continued through December 13. Although deep slab events were somewhat isolated during this period (*Figure 2*), significant events occurred on Cody Peak, Mt. Taylor, and Breccia Peak.

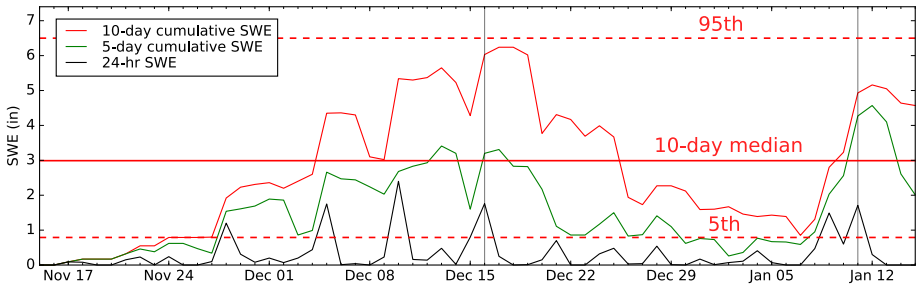


FIGURE 3: Panel C from Fig. 2, shown with the distribution of historical 10-day cumulative SWE totals for days with deep slab events (N=501, 1974 - 2016) (Wright et al., 2016). The historic median (solid line) is shown along with the 5th and 95th percentiles (dashed lines) of the distribution. Note that the three major peaks in the cumulative 10-day SWE totals for December 2016 all fall within the upper half of the historic distribution, with the loading peak reached December 17-18 almost reaching the 95th percentile.

Widespread deep slab activity during December 14-16 storm

A major storm from the mid-Pacific arrived with a warming trend during the night of December 14-15. By December 16 the Teton region received up to 30" of new snow with over 3" of SWE accompanied by strong winds. 5-day cumulative SWE totals at Mid-Mountain rebounded back to the levels achieved during December 11-13. The 10-day SWE increased to a new season maximum of 6.24". Snowpack settlement was at 4-6"/day during the storm and remained elevated at 2-5"/day during December 17-18.

The December 14-16 storm event exceeded loading thresholds for many high-elevation slide paths, with widespread activity reported when skies cleared on December 17. Natural activity occurred in major slide paths throughout Grand Teton National Park and the southern Tetons with crown depths ranging 48"-72". These events occurred during active loading with no known events after December 16, despite high settlement rates in the day following the storm. The received water content during this storm (2.81" during 12/15-12/17) amounted to 33% of the existing water content in the snowpack overlying the rain crust (8.62" received since November 16).

The continuous snowfall since late November created significant loading on the snowpack that is among historic highs. 10-day SWE totals greater than those achieved on December 17, 2016 (6.24") have only occurred in 8 other seasons since 1974.

Last reported deep slab events of 2016-17 season

On December 23 a human-triggered cornice collapse outside the Grand Targhee boundaries resulted in the fatality of a snowboarder who was carried over a 500 ft cliff. On Dec. 29 four 22-lb heli-bombs were deployed to provide rescuer safety, resulting in a deep slab event (72" depth). Snowfall events had continued throughout late December, yet there was an overall decreasing trend in multi-day cumulative SWE totals during this period, and a lack of any continued activity on the October rain crust.

The last deep slab events of the season occurred with significant storm loading during January 8-12. Two events were recorded on January 11 in Prater Canyon in the Salt River Range (N aspect, 9,700'), and Treasure Bowl on Table Mountain (NE aspect, 10,800'). It should be noted that large events (up to 60" depth) reported on January 12, 2017 are considered deep slab events, but did not run full-depth to the persistent October surface and are not considered as part of the persistent deep slab cycle. After six days of clear and cold weather with no deep slab activity, the "Persistent Deep Slab" problem was dropped from the Bridger-Teton Avalanche Center bulletin on January 17.

Conclusions: December 2016 in a historical context

The early season snow structure in northwest Wyoming was primed for deep slab avalanches at high elevations with a distinct sliding and weak layer. In addition, we experienced near-record levels of load on the snowpack during December. This was a good season to stay away from upper elevation steep terrain and also a great case study to try and learn something more about deep slab failure.

The period with deep slab activity during mid-December showed 3-day cumulative SWE levels at the Mid-Mountain study plot at JHMR nearly peaking with the first major December storm, then reaching similar peak values with each consecutive storm. The 5-day totals showed a slightly more increasing trend as the December storms progressed. The 10-day totals, however, best reflected the peak in cumulative loading resulting from the December 14-16 storm, and best coincided with widespread deep slab activity (*Figure 2*). For a persistent deep slab problem, 3-day and 5-day cumulative SWE totals may not reflect long-enough loading periods, whereas the 10-day totals may be a better way to visualize and track the increased load. Depending on the storm system, an even longer multi-day window could be useful.

Utilizing data collected at JHMR since 1974, historic trends in multi-day SWE for days with deep slab events provide context for the SWE totals received in 2016. The 3 major peaks in the 10-day cumulative SWE totals for December 2016 all fall within the upper half of the historic distribution for the Mid-Mountain plot, with the 10-day loading peak reached during December 17-18 almost reaching the historic 95th percentile (*Figure 3*). If there is potential for deep slab avalanches, multi-day SWE totals that exceed the historic median are likely an indicator of loads that may be close to threshold levels.

Settlement rates were also a good indicator, with many days of elevated settlement (3-6"/day) leading up to the major deep slab activity. These rates were mostly greater than the historic median settlement values for days with deep slab events (3"/day).

It is significant that there were only three deep slab events recorded after December 16, despite continued gradual loading during late December and early January followed by rapid loading on January 12 with 10-day SWE totals almost equivalent to the mid-December peak. With increasing snow depths in late December and early January, loading events had a diminishing impact on weak layers at the snowpack base and the deep slab gained strength. In addition, the problem layers (ice crust and facets) likely had time to "heal" (increased bonding with the crust and rounding of facets). At the time of this writing, a historic storm system impacted northwest Wyoming resulting in 10-day SWE totals of 11.9" on February 11, 2017. These water totals are almost equivalent to the highest storm totals ever received at the JHMR study plots, only slightly less than a 12-day SWE total of 12.75" received during February 1986. Despite this massive loading event, there were no additional deep slab avalanches.

Although in retrospect the end of the December 2016 deep slab cycle can be reconciled, it is often challenging to forecast the close of a deep slab cycle. Dropping the deep slab problem was largely guided by a lack of activity on the problem layer after it had been heavily loaded during January 9-11. Reduced settlement rates were an additional indicator of stability with many days of 1-2"/day occurring during January 12-17. Although forecasting the timing of deep slab cycles will remain a challenging task, analysis of cumulative multi-day precipitation totals in a historical context can provide a baseline range for expected loading thresholds. January and February of 2017 also demonstrate a historical trend for the northwest Wyoming snow climate: large loading events that occur later in the season with increased snowpack depth do not necessarily result in continued deep slab avalanches. This reinforces the importance of monitoring the condition and depth of problem layers and the character of the overlying slab, which will be unique season to season. ▲

References

Wright, P. J., B. Comey, C. McCollister, and M. Rheam (2016), Deep slab instability: loading, temperature, and settlement rate thresholds related to failure - Part II, Proceedings of the 2016 International Snow Science Workshop, Breckenridge, CO, USA.

Patrick Wright has spent summers since 2011 doing field work on the Greenland Ice Sheet and received M.S. degrees in Atmospheric Science (University of Houston, 2012) and Glaciology (University of Montana, 2015). He is currently on the Jackson Hole Ski Patrol, and is co-owner of Inversion Labs, completing data analysis and instrumentation design for the earth sciences.

DEEP SLAB

in the BIRTHDAY CHUTES

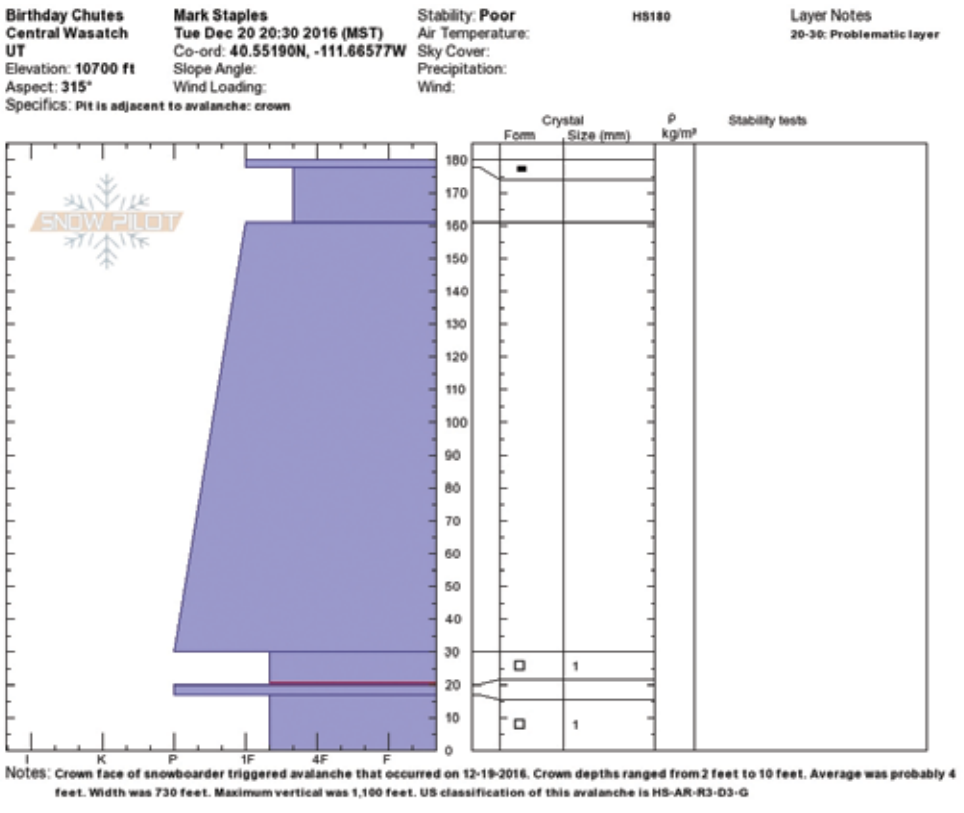
Close-up of the crown in the Birthday Chutes on December 19, 2016. *Photo Mark White*

We were finishing up a full day tour and decided to drop into Birthday Chutes to get back to White Pine Trailhead. We had been on all aspects during the day and the only red flags we saw were warming on the south slopes and some wind loading mostly on east faces. The top of the northwest side of the Red Top Mountain was scoured and cornices were formed on the east side of Temptation Ridge. We saw no signs of wind loading into Birthday Chutes so we decided to drop in. The snow surface was very soft and seemed safe. After my partner rode the top couple hundred feet, he moved over close to the trees on the skiers left of the chute. As I started forward into the chute I saw snow start moving slowly about two feet in front of my board. I immediately dove back and grabbed a small tree. The slide picked up a ton of speed and propagated way farther west than I thought possible. The crown broke all the way to the ground from the top. The slide went all the way to the hill on the west side of Columbine Bowl where a couple hundred foot cloud of snow shot into the air. I immediately radioed my partner but the radio kept shutting off due to the cold. I tried calling him but his phone was off, I could not find a safe route to the debris pile so I called 911 and asked for rescue crews. My partner was able to dig out his feet and call 911.

—a member of the party involved

INVESTIGATION:

Avalanche: White Pine
Observer Name: Mark Staples
Observation Date: Monday, December 19, 2016
Occurrence Date: Monday, December 19, 2016
Occurrence Time: 5:00pm
Region: White Pine
Location Name or Route: Birthday Chutes, White Pine
Elevation: 11000
Aspect: North
Slope Angle: 38
Trigger: Snowboarder
Trigger: additional info: Unintentionally Triggered
Avalanche Type: Hard Slab
Avalanche Problem: Deep Slab
Weak Layer: Depth Hoar
Width: 700
Vertical: 1000
Carried: 1
Caught: 1
Buried—Partly: 1



FORECASTER NOTES:

Weather and Snow information: From December 14 to December 16, the Alta Guard Station three miles NNE of the avalanche site, received snow containing 2.5 inches of snow water equivalent. On Thursday, December 15 and Friday, December 16, winds at 11,000 feet averaged 31 mph and gusted 47-62 mph from the southwest. By late Dec 16, winds at 11,000 feet were averaging 50 mph gusting to 75 mph from the WNW. Those winds were a significant factor in this avalanche for two reasons:

First, winds easily doubled the load on this slope with wind-blown snow adding significant stress to faceted snow at the ground. Faceted snow is very tricky. It can support a tremendous load without fracturing and producing an avalanche. However, as soon as a very small crack or failure is started, it can quickly fracture across the entire slope. The snowboarder who triggered this avalanche likely rode over a thin spot of the slab where he initiated a crack in the faceted snow layer which fractured and released the slab.

Second, winds built a slab that connected across both chutes. This stiff, cohesive slab is what helped carry the fracture across both chutes and fracture over such a wide area.

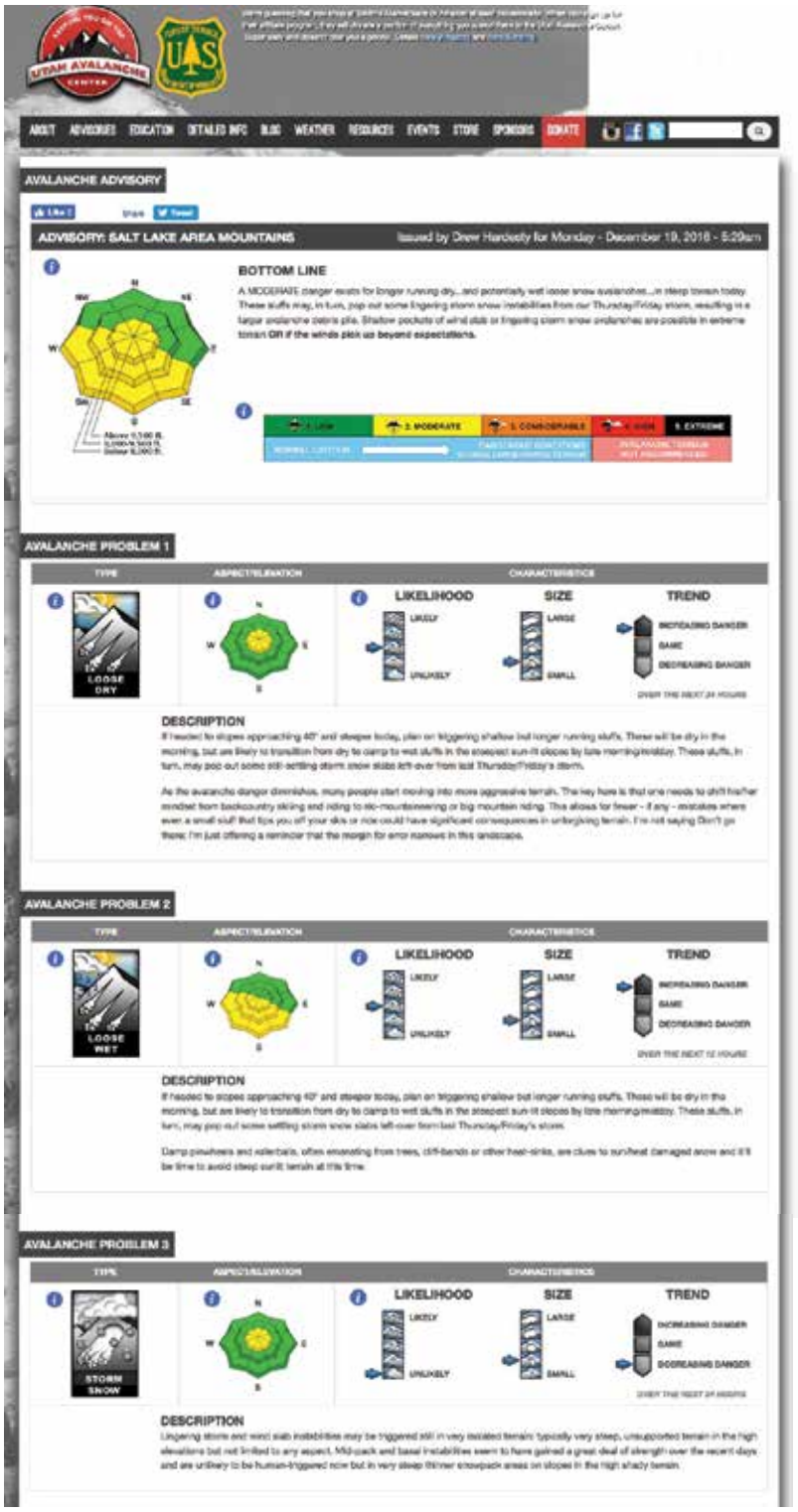
Snow that formed the weak layer in this avalanche fell in the fall and was preserved on this slope because of the high elevation and northerly aspect while snow melted off other slopes. This snow metamorphosed and became weak, faceted snow crystals. See the photo below from video footage taken on November 14, 2016. Notice that other aspects exposed to more sun did not have snow on the ground.

Avalanche information: This party had been reading the avalanche advisory for most of the season. On the day of the avalanche, they had been looking for signs of instability during their tour in Mineral Basin, in Mary Ellen Gulch, over Silver Creek Peak, over American Fork Twin Peaks, and over Red Top Mountain. They noted warming on south aspects and were carefully monitoring wind speeds and direction. Winds were relatively light in the Birthday Chutes and not depositing snow at the time. Unfortunately, winds on Thursday, December 15 and Friday, December 16 heavily loaded this slope.

The person who was caught in this avalanche initially made three or four turns, thought he heard something, began traversing to the looker's right, and made five or six turns before the avalanche broke. He never saw the avalanche coming and said that it felt like he was hit by a freight train. The person on top of the ridge had to jump back to avoid being caught. He commented that the avalanche did not make any noise when it fractured and seemed to pull away very slowly for the first 50 feet before accelerating.

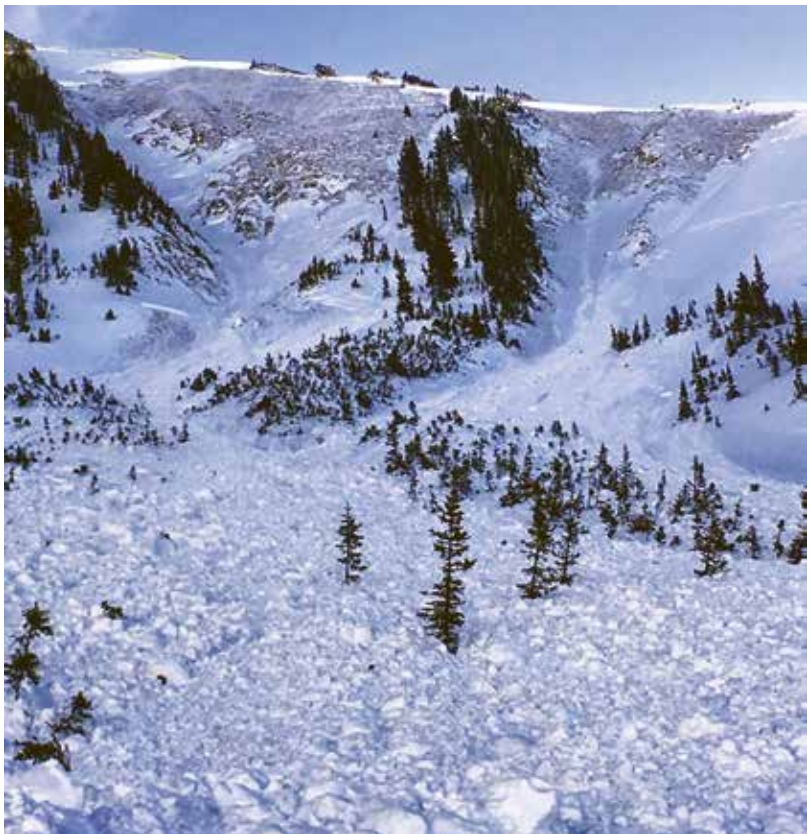
This avalanche was approximately 730 feet wide, four to five feet deep on average with a minimum of three feet and a maximum of 10 feet deep. It ran 1,100 feet vertical. U.S. classification is HS-AR-R3-D3-G.

Rescue: This avalanche occurred at about 5 p.m. Once the avalanche happened, this party was in a very difficult situation especially with the fading daylight. They both had radios with dead batteries from being on all day, thus



The avalanche broke on old facets at the ground. Crown depth averaged 4-5 feet with a maximum of 10 feet and minimum of 3 feet. It was 730 feet wide and ran 1,100 feet vertical. *Photo Mark White*

View up from the huge debris field. *Photo Mark White*



they were not able to communicate. They could not see each other either. Both feared that the other had been caught and was buried.

The person on top of the ridge was unsure he could descend safely to his partner whom he thought was dead. Because of the late hour and what he thought was an unsafe situation, he decided to call 911. He was on top of the ridge for about an hour and a half in the dark. When his phone battery died, he finally descended a ridge and the White Pine drainage ultimately reaching the White Pine trailhead. The whole time he thought his partner was buried and dead. It wasn't until reaching the parking lot and talking with Search and Rescue personnel that he discovered his partner was alive.

The person caught in the avalanche survived and amazingly was not injured. When the avalanche stopped, he was on top of the debris only buried to his knees with his face down. As he looked up, he saw a powder cloud of airborne snow roll over top of him. Because he and his partner had not explicitly discussed a plan for riding this chute, he assumed the worst. Also, he was unable to communicate with his partner due to dead radio batteries and figured his partner was buried. He also contacted 911. For the next hour and a half he searched the debris field with an avalanche transceiver. Ultimately a helicopter was sent to the scene and transported him to Alta.

Forecaster comments: On the day of the avalanche the danger was rated Moderate at this elevation. The avalanche problems listed in that day's advisory were Loose Dry avalanches, Loose Wet avalanches, and Storm Snow avalanches.

This was a difficult situation for all involved including Search and Rescue who received two separate calls from someone stating that their partner was buried in an avalanche. Sorting the details in these events can be very difficult. For the two people involved, it was also a very difficult and confusing situation as well. This event highlights how difficult avalanche rescue can be and that many events can happen at the end of the day in darkness. Luckily no one was buried. This emphasizes the need to practice companion rescue skills and be familiar with terrain because many avalanches occur under difficult conditions. If you are in unfamiliar terrain, that can be an additional risk factor.

Deep slab avalanches are by far the most difficult avalanche problem to deal with. Even professional operations armed with explosives struggle with these types of avalanches. Because the weak layer is buried deeply under a thick, hard slab of snow, impacting the weak layer with enough force to trigger an avalanche is not easy to do. There's a decent chance this party could have descended the chute without triggering this avalanche.

Information from this report comes from a visit to the avalanche by Mark Staples, Greg Gagne, Mark White and two members of the Snowbird Ski Patrol on December 20, 2016 as well as a phone interview with the two people involved in the avalanche.

This report was compiled by Utah Avalanche Center Director Mark Staples with help from other UAC staff.

A big chunk from a dense hard slab. *Photo Mark White*

#nothingbadhappened

Saturday, December 24, 2016
Drew Hardesty

I cribbed the name from an essay by Iain Stewart-Patterson, a mountain guide and faculty staff member of Thompson Rivers University in British Columbia. His dissertation: *The Role of Intuition in the Decision Process of Canadian Ski Guides*. You can find his essay in issue 34.4 of *The Avalanche Review*, the publication of the American Avalanche Association.

I imagine most of you reading this are familiar with the very close call in the Birthday Chutes from last Monday. I've added Mark White's photos and the full accident investigation report by Mark Staples, Greg Gagne, Mark White, and Snowbird ski patrol can be found before these companion essays. Long story short, a party of two triggered a very large avalanche to the ground in mid-White Pine canyon of Little Cottonwood. One of the two was caught and carried for over 500' and was uninjured.

That night, we received an email from a backcountry skier who that same day had skied the northwest face of Red Baldy—the steep open face lording over upper White Pine canyon in LCC and sitting just up-canyon from the Birthday Chutes. As I respect and value his self-reflection, I thought it might be of interest to share his email and my thoughts back to him.

Hello UAC,
I'm wondering if someone would help me analyze my decision to ski Red Baldy on the day that the Birthday Chutes slid.

In hindsight, I still feel it was a reasonable decision. But if someone is inclined, I'd like to know if you see any mistakes in my process, so I could avoid repeating them.

Before I hit the snow:

- I'm a regular bc skier
- carrying beacon, shovel, probe and 10 essentials
- familiar with the terrain
- familiar with the weather and this season's snow in the central Wasatch, but not upper White Pine
- had a goal—NW Red Baldy—but not set in stone
- Strategy for making good decisions under stress: go w/ the most conservative judgment
- read weather and avy reports from UAC and other sources that morning and each day since the most recent storm
- was on a similar aspect and elevation the day prior, Argenta.

On the approach:

- looking around a lot/keeping awareness focused on physical environment
- specifically looking for signs of recent avalanches, sun and wind effects, effects of prior skiers' travel
- observed no signs of recent avalanches, only infrequent sightings of point releases below cliffs, trees; no cracking or collapsing on skin up
- Looked at the BDays from the summer road skin track: suspected it would be loaded in parts and scoured in others—could see westerly winds transporting snow up high—sensitive and have the potential to slide leaving no easy escape.
- no noticeable effect from sun on snow

On Red Baldy:

- wind was stiff and swirling with a slightly west prevailing direction above the forest at the base of RB.
- NW face had up to half a dozen faint, wind buffed ski tracks, some starting just under the ridge line rocks, others going only half way up the face, and running down the center of the face. No sluffing seen near any of the old ski tracks.
- NW face showed only small, isolated areas of wind loading. Mostly, swirling wind transporting snow in all directions. The only drifts encountered were avoided by changing the path of the skinner.
- just below the top of the NE ridge, I traversed west below the ridge line rocks. Rocks above were scoured and not holding much snow. Transitioned in a rock outcropping mid-way across the NW face
- First turn was a fast, left cut to the bottom of the summit rocks. Looked over the shoulder for trailing snow. 2nd turn was the same, traveling over to the rocks that form the skier's left boundary of the face.
- Skied the far skier's left (west) side of the face reasoning it would've been sheltered from prevailing westerly winds and sun by the rocks.
- Looking back up at my tracks from the flat, nothing slid or even sluffed. One and done.

Lastly, while the Red Baldy face and the BDays are a similar aspect and elevation and location, while planning my tour I felt RB would be in different and safer condition than the BDays b/c of the contour of the terrain—a flat, open face versus funneling gully chutes—and that the line I planned to ski, the far west side abutted by the rocks, would be sheltered from wind effect whereas the BDays were hammered.

Thanks for helping me cover my blind spots, if you can!

Thanks for writing in. We've all had our close calls out there and we've all had times when we got back to the car and realized that maybe we got away with something. I appreciate your self-reflection and awareness of how you "go about the work" in order to make good decisions and avoid the avalanche problem. Seems you're as diligent as they come in regards to your approach to the mountains. Sometimes, however, we feel like we do everything right and then still something bad happens. (It's driven me to read more of the Old Testament over the past couple of years, but I digress.) After a well-publicized avalanche fatality in the Tetons a few years ago, I wrote at length about it for *Backcountry Magazine*; here's the link: **backcountrymagazine.com/stories/mountain-skills-understanding-the-avalanche-problem/**.

The avalanche in the Birthday Chutes may have been one of the most surprising avalanches that I've seen in almost 20 years of avalanche forecasting. I know that I'm not alone in that sentiment. As far as I know, only a few avalanches ripped to the ground during the storm with only one or two that stepped to the ground (on Saturday) with explosive control work. These were of similar aspect and elevation, but there are times when we feel that while storms, explosives, very large cornice fall, etc may trigger deep slabs, a single skier on the slope will not. Or it's very unlikely that they will. I made a slight mention of this on that Monday mostly in the fine print of Storm Slab in the advisory. **Still, certainty is the enemy of wisdom, and this is what makes this profession or pursuit so compelling. Risk and uncertainty are always a part of mountain travel.**

At some point, one must decide (or not) that the poor structure is now dormant. Recent human triggered slides? Cracking? Collapsing? Tests? These are all part of the calculus. It's my personal view that none of this type of information was evident. It was conveyed to me that the Birthday Chutes avalanche took out previous tracks on the slope, but I can't confirm this. What I do know is that depth hoar has bedeviled avalanche practitioners since before it was even called depth hoar...and it will continue to do so. You simply cannot trust it. When you enter this terrain with this type of snowpack, you're playing the game...and it's just a matter of odds—or risk—and then it's a matter of understanding your own level of acceptable risk. 1:10? 1:1,000? 1:10,000? Most of us are prematurely grey because we are tasked with helping the public reduce their odds or exposure.

But before I get back to your original question I want to say that I particularly appreciated your use of the term hind-sight...because in my view, the hind-sight bias is nearly always damning because the outcome is already known—How could this person miss all of the obvious clues leading up to the incident? My opinion is that if you could go back and re-live that Monday 100 times and ski Red Baldy, you would come back to the truck at the end of each of those days.

—Drew Hardesty

20/40 HINDSIGHT

TOP: Investigating a big slide can be sobering, but less so when no-one is caught or injured.
BOTTOM: Hard wind slab reached uphill as far as it could. *Photos Mark White*

BY DREW HARDESTY

All too often, we find ourselves unable to predict what will happen; yet after the fact we explain what did happen with a great deal of confidence. This "ability" to explain that which we cannot predict, even in the absence of additional information, represents an important, though subtle, flaw in our reasoning. It leads us to believe that there is a less uncertain world than there actually is, and that we are less bright than we actually might be. For if we can explain tomorrow what we cannot predict today, without any added information except the knowledge of the actual outcome, then this outcome must have been determined in advance and we should have been able to predict it. ***The fact that we couldn't is taken as an indication of our limited intelligence rather than of the uncertainty that is in the world.***

—Daniel Kahneman/Amos Tversky

The Event

On December 19, 2016, two young backcountry riders exited the Snowbird access gates to enter the backcountry. They skied one steep line and then paused above the Birthday Chutes of White Pine Canyon. The Birthday Chutes sit at just over 11,000' and face north-northwest. They had seen one other avalanche from two days prior on their tour. They had observed no cracking or collapsing of the snowpack. Many, many steep lines in similar, representative terrain had been ridden with impunity. The small depth hoar crystals at the base of the snowpack—long suffering holdouts from the late fall storms—had been dormant or asleep to human triggering for weeks. Snow tests had indicated that the snowpack was stable or that the snow was too deep to allow for triggering a full-depth release. The avalanche danger for the day was rated as Moderate, though the fine print relayed that, "Basal instabilities seem to have gained a great deal of strength over the recent days and are unlikely to be human-triggered now but in very steep thinner snowpack areas on slopes in the high shady terrain."

You can imagine what happened next. Person A drops in, makes 10 turns and sees the snowpack come alive around him. Person B, still near the top, imagines an earthquake has occurred as the earth itself cracks open 6-10' deep right at his feet. He later recalled diving back to grab a tree to avoid being engulfed and swept down the mountainside. Person A rockets 500' down the slope, getting bashed and hammered by hard slab blocks almost twice his size. When the enormous pile of debris finally comes to a rest, Person A stands up, dusts himself off, and walks away.

Using the United States avalanche classification system, this avalanche is described as an HS-ASu-3.5-O or a hard slab unintentionally triggered by a skier that broke to the ground. Its destructive force could have taken out a something between a large vehicle and a house. (It was 4-10' deep and 700' wide.) The subscript "u" de-

This was a low likelihood event (see Drew's blog) that had high **potential** consequences but low **actual** consequences. Is that the definition of luck? *Photo Mark White*

notes unintentional. It should really denote unpredictable or unmanageable. In the aftermath, everyone looked back at the events leading up to the avalanche to try to understand what went wrong. "Facets were on the ground," some said; others said "There was way too much wind 48 hours before. Of course the Birthday Chutes are suspect with this set-up: How could you not have seen this coming?"

Expert Intuition

In their powerful, collaborative essay *A Failure to Disagree,* the world renowned behavioral psychologists Gary Klein and Daniel Kahneman describe the circumstances that may enable one to develop something called expert intuition. They argue that two fundamental criteria must exist:

1. The environment must be one of high validity.
2. The individual has an adequate opportunity to learn the environment (they recommend roughly 10,000 hours).

High validity refers to a stable relationship between cause and effect. Children learn early on. In fact, they become experts at not putting their hand on a hot stove-top. The stove coils are red, they are hot, you put your hand on them, you get burned. There is a direct correlation between the hot coils and the immediate pain of your hand on the stovetop. Klein calls this "recognition-primed decision making" (RPDM). We see a situation, our cerebral hard drive searches for a similar situation from past experience, and we follow the course of action that produced a favorable outcome or avoided a terrible outcome from the previous times.

A Wicked Environment: The Subconscious Mind Does Not Know Death

But what if we are in an environment that is not highly valid, or one that promotes the illusion of validity? An environment where we are actually getting feedback, but learning the wrong lessons? Imagine the rooster looking over his shoulder, the sunrise behind him on the horizon, and—in a cocky way—saying, "You're welcome." What about inconsistent feedback? And finally, what if the lesson is both surprising and tragic? The business and statistics researcher Robin Hogarth has a name for this: A *wicked* environment. A wicked environment is one where feedback may be X until it's Y, and Y may be death. For most of us, this can be viewed with a great deal of skepticism, because the subconscious mind does not know death. To wit: who among us has died and returned with great enlightenment?

The Role of Expert Intuition in Low Probability, High Consequence Events

The risk management consultant Gordon Graham parcels out four different situations:

- Low Probability, Low Consequence
- High Probability, Low Consequence
- High Probability, High Consequence
- Low Probability, High Consequence

In avalanche terms, the first situation might be a LOW avalanche danger day. The second situation is arguably a MODERATE to CONSIDERABLE avalanche danger day, but with avalanche types where avalanche professionals may develop expert intuition: storm slab, wind slab, loose wet and dry snow avalanches. The third situation may best describe a HIGH or EXTREME avalanche danger. The fourth situation, however, is, as Graham writes, when "the bells of Saint Mary ought to be going off in your head."

The Low Probability, High Consequence environment. An environment where ski cuts in one place produce an avalanche in another. Or the 5th or 25th person on the slope brings the whole face down. Or walking in the drainage, one collapses the slope and pulls the whole mountain of snow on top of them. The argument here is that with these types of avalanches—deep slab, persistent slab, wet slab, glide avalanches—and particularly the first and the last—these types of avalanches fall neither into a high validity environment nor the one where we can gain the figurative 10,000 hours. This helps to explain why—in Utah anyway—an estimated 95 percent of the avalanches are of the type where we can hypothetically develop expert intuition...but the second kind account for more than 70 percent of our avalanche fatalities, well illuminating the stark contrast between the high probability low consequence events…and their opposite.

> *The question is not whether these experts are well trained…the question is whether their world is predictable.*
>
> —Daniel Kahneman/Amos Tversky

But back to the Birthday Chutes. In the end, we may try to reverse-engineer a problem to try to make sense of the world because an uncertain world—one that we don't fully understand—can be a frightening and humiliating place. So that "after the fact we (may) explain what did happen with a great deal of confidence." The confidence that comes with hindsight. The problem, however, is that we may be taking home lessons to understand the world, but sometimes they may be the wrong ones. ▲

Drew Hardesty has been an avalanche forecaster with the Utah Avalanche Center since 1999/2000 and spends his summers in Grand Teton National Park.