THE Avalanche REVIEW

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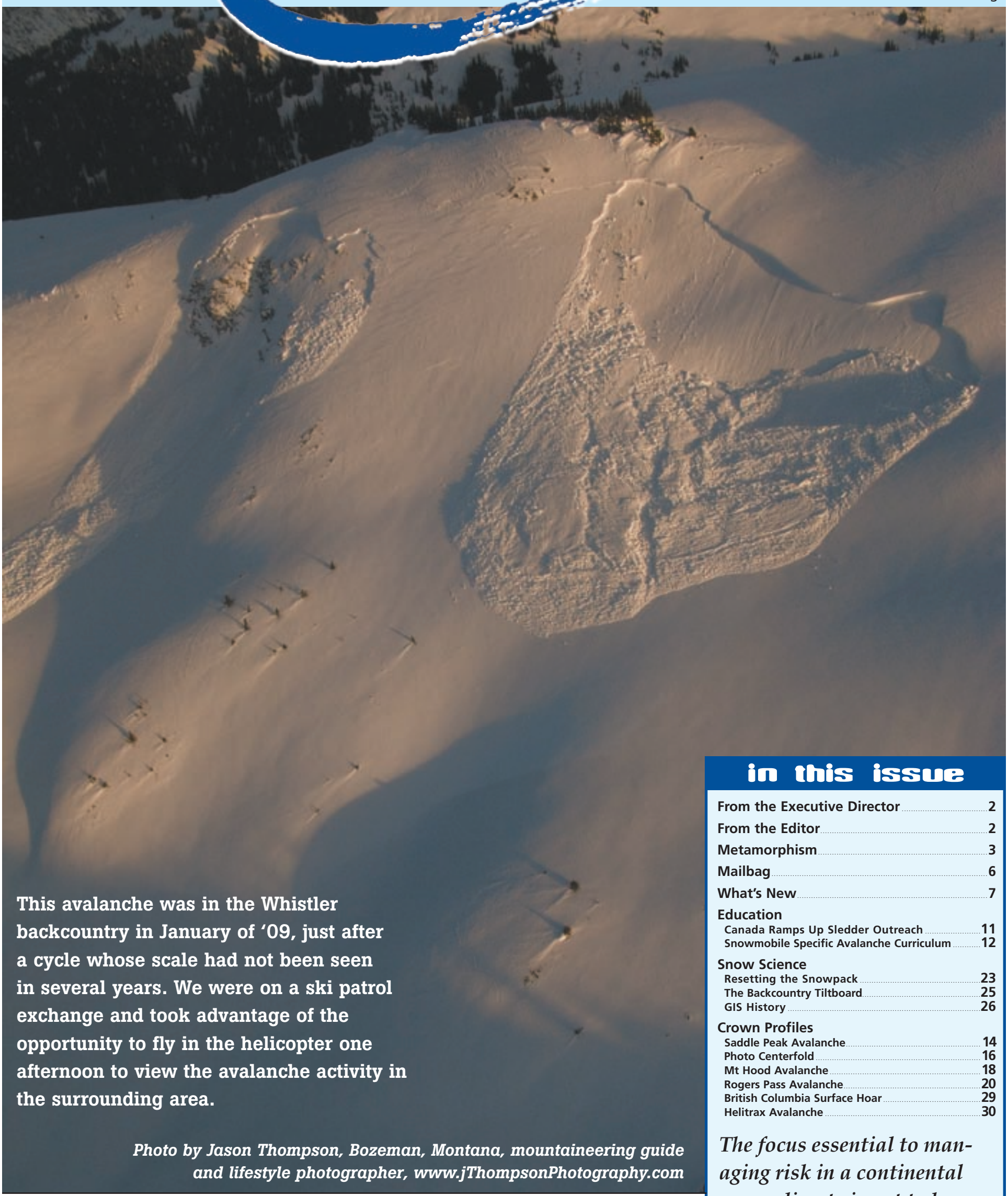

This avalanche was in the Whistler backcountry in January of '09, just after a cycle whose scale had not been seen in several years. We were on a ski patrol exchange and took advantage of the opportunity to fly in the helicopter one afternoon to view the avalanche activity in the surrounding area.

Photo by Jason Thompson, Bozeman, Montana, mountaineering guide and lifestyle photographer, www.jThompsonPhotography.com

The Avalanche Review
P.O. Box 2831
Pagosa Springs, CO 81147

in this issue

The focus essential to managing risk in a continental snow climate is not to be taken lightly. It demands, as an old mountaineer said, "sensible self-denial" and a little bit of luck.

—Mike Friedman, *Managing Risk*, p31

THE Avalanche REVIEW

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The mission of the AAA is:

A. To provide information about snow and avalanches;

B. To represent the professional interests of the United States avalanche community;

C. To contribute toward high standards of professional competence and ethics for persons engaged in avalanche activities;

D. To exchange technical information and maintain communications among persons engaged in avalanche activities;

E. To promote and act as a resource base for public awareness programs about avalanche hazards and safety measures;

F. To promote research and development in avalanche safety.

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Layout & Design: Karen Russell, Fall Line Design, (208) 354-6500, karen@FallLineDesign.com.

from the executive director

Join AAA Governing Board, Help Make Important Calls

Mark Muller is busy on the phone even in Europe. Photo taken by Craig Sterbenz at the Jakobshorn during ISSW 09 in Davos last fall. *Photo by Craig Sterbenz*

As I write this, another strong storm is moving into southern Colorado. It's hard to imagine right now that we won't see this in print until early April. Spring seems so far away.

We are seeking interested governing board candidates for this fall's election. Your Association continues to improve and expand. The new avalanche.org is an example of our improvement, and our membership continues to grow with over 50 new membership applicants for review and ratification this spring. Both of these examples are due to the hard work and dedication of AAA's governing board.

We are strong financially and the board is dedicated to providing quality benefits to our members. Several of the governing board members who have served for many years wish to step down. Governing board elections are held in even numbered years for executive board and section representative positions. Some of these positions will be open. Members will receive ballots this summer for this bi-annual election. The governing board seeks willing individuals who are interested in serving the avalanche community and advancing our profession.

Earlier I wrote that we are strong financially. How do we want to use this money? Our primary product is and will continue to be *The Avalanche Review*. We provide practitioner and academic research grants and have begun to co-sponsor regional continuing education seminars – to name several other efforts. As a nonprofit organization, we are required to explain in detail our activities to the Internal Revenue Service. The IRS doesn't really care about the size of our bank account; they want to know what we do with those funds. We are in a financial position to expand our reach to benefit the membership and the avalanche community in general. What we do and how we do it will be a responsibility of the new board. Our new board members will be a big part of the effort.

Has your winter been quiet? We've seen tragedy once again visit our colleagues. Many areas in the West have fragile snowpacks that have yet to be seriously loaded. We have many weeks to go. I hope that avalanches stay out of the news and that we all arrive together at season's end: healthy, happy, and fulfilled.

ISSW 2010 is coming to Squaw Valley in the Sierra, October 17-22. Our annual membership meeting will take place there, and our new governing board members will be introduced. I look forward to seeing many of you there.

—Mark Mueller, AAA executive director

Lynne Wolfe enjoys a spot of tea on her birthday – a bitterly cold day in Columbia Bowl, Teton Pass. *Photo by Erika Eschholtz*

from the editor

Everybody loves a good story, especially one that is told well, comes with great photos, and helps a bit of science to get translated into practice. This issue has all that and more, of course. Our theory comes in with a discussion of resetting the snowpack from practitioners who work in maritime, intermountain, and continental snowpacks; Lisa Portune of the Chugach then takes theory into practice describing one big storm's weather and images.

More case studies give us insight into circumstances and decision-making processes leading up to accidents on Rogers Pass and in the San Juans; the participants' hindsight and analysis give us tools for the future. A huge avalanche on Saddle Peak, just outside the Bridger Bowl boundary, leaves me appreciating the role of luck. As Doug Chabot states, we usually only get one free lesson and this was it. It also raises several difficult questions: How do we educate sidecountry enthusiasts, and on a larger scale, is it possible to change human behavior when a resource is scarce?

At Mt Hood, the role of luck is once again paramount, as another record-breaking avalanche gouges the ski area top to bottom after closing. In British Columbia, Wren McElroy documents the formation and burial of several layers of surface hoar, then shows that as these surface hoar layers are buried deeper, they are more difficult to trigger but deliver dramatic results. Forecasting with these conditions is challenging; recreating in these circumstances even more challenging. At press time, two snowmobiler-triggered avalanches and one heli-ski avalanche have had fatal consequences. Is it even possible to have a "reset" in these circumstances, or do we simply wait for spring? Patience is a difficult human virtue; does it always come with age and experience?

Finally, we have a second installment of photos from TAR correspondents across the map. Thank you for sending us these views of your worlds. We really appreciate it and encourage you to keep us informed, sharing your problems and solutions; the larger TAR audience can learn from both your steps and missteps – and offer insight if appropriate.

This April issue marks the conclusion of volume 28, the 28th year of *The Avalanche Review*. We'll pick up again late summer, preparing for the ISSW issue, TAR 29/1; deadline for submissions August 1. We hope to see you in Squaw Valley; don't forget to take advantage of early registration prices before the end of April *(see specifics on page 5)*. I for one will be glad to see the tail end of El Niño; hopefully this winter's low snow totals coupled with bark beetle devastation don't translate into a smoke-filled summer.

—Stay in touch, Lynne Wolfe

submissions

Write it up ; sent it to us. *The Avalanche Review* is only as good as the material you send:

- Snapped any photos of a crown or of avalanche workers throwing bombs, teaching classes, or digging holes in the snow?
- Learn something from an accident investigation?
- Developing new tools or ideas?
- Pass along some industry news.

SUBMISSION DEADLINES

Vol. 29, Issue 1 ..... 08/01/10
Vol. 29, Issue 2 ..... 10/01/10
Vol. 29, Issue 3 ..... 12/01/10
Vol. 29, Issue 4 ..... 02/15/11

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ISSW 2009 Proceedings Now Online

The Proceedings from ISSW 2009, Davos, are now available as downloadable pdfs at the following links:

Proceedings: **www.wsl.ch/publikationen/pdf/9854.pdf**
Abstracts: **www.wsl.ch/publikationen/pdf/9893.pdf**

metamorphism

Steve Baugh Bowl, just out of bounds at Grand Targhee Resort in Alta, Wyoming, was triggered on January 6, 2010, by four skiers jumping in unison on the flats above the peak of the crown. More than an inch of water in 24 hours came in strong from the southwest on top of a cold cocktail of surface hoar and near-surface facets, initiating a widespread avalanche cycle throughout the Tetons.

Hard slab created in the same storm broke well above Jackson Hole Ski Patroller Mark Wolling after he threw two hand charges in Cheyenne Bowl. The ensuing avalanche stepped down to the early-season depth hoar, burying him five to six feet deep. He was quickly located and extracted, but did not survive his injuries. *Photo by JB Harris of Ririe, Idaho*

Mark "Big Wally" Wolling Dies after January Avalanche at Jackson Hole

Big Wally in the tram, anticipating the goods, circa1980. *Photo by Bob Woodall*

Mark "Big Wally" Wolling died Saturday, January 9, 2010, after having been buried in an avalanche on January 6, in Cheyenne Bowl while on ski patrol duty for Jackson Hole Mountain Resort. He was 58. The following was provided by his family.

He is survived by parents Spence and Millie Wolling of St Louis; sisters Barb, of Perry, Iowa, and Sue, of Eugene, Ore.; and long-time companion Marianne Hammersley, of Wilson.

Big Wally lived in the Jackson Hole area since 1973. He worked on the Jackson Hole Mountain trail crew for many years, and was a member of the ski patrol beginning in 1989. He was a passionate outdoorsman who enjoyed not only skiing but also paragliding, mountain biking, kayaking, and going exploring with his springer spaniel, Sir Charles, "Charlie."

Big Wally on the job, performing avalanche control at Jackson Hole Mountain Resort in 1998. The ski resort renamed the Bivouac Woods run "Wally World" in honor of the long-time Jackson patroller. Wolling is know to have described Wally's World as "a state of mind, where the fun never stops and all your dreams come true." *Photo by Jonathan Selkowitz*

Along with many friends, he coordinated the 2009 Goatstock Festival, a benefit for Jimmy Zell held at Wally's home in Redtop Meadows. The "Hole Family" will remember Wally's adventuresome spirit, generous heart, and larger-than-life smile.

Sunrise in the Mountains

Story & photos by Zahan Billimoria

When I met Wray I was working and had a young one at home, so we would head up to Targhee in the twilight and rally the 2000' up Fred's Mountain, arriving home by daybreak. Wray didn't have winter work in those days, so after the warm up, he would saunter off to Teton Pass where he would find a few other partners to burn through.

The next fall Wray convinced me we could do a Taylor lap and still be home by 8:30am. The first few times the 3300' climb would cause me to miss breakfast with the family, but soon we had it down: bags packed and skins on the night before, drive in your boots, eat in the car, no breaks, and then the summit – and coffee.

Wray was driven by raw passion for the mountain experience. Uncluttering the mind, unleashing the human spirit in the brutality of winter in the Tetons, offering up every kilojoule of energy to climb these sacred mountains – that was the experience we sought, and found.

Windslab, suncrust, blower powder, boilerplate, stormy nights, and blinding sunrises, penetrating cold and sweat. Howling winds, and calm. Those were the blessings of the mountains, and Wray accepted each with total and complete gratitude. Our bodies became leaner, our minds clearer with the passing of every daybreak, and then Wray wanted to do another lap. One Taylor sometimes became two, and occasionally three.

When I faltered, Wray would go anyway. When he faltered, I would sleep in.

Wray never made a lot of money, nor did he really care to. He sought meaning before recompense in his work. When I visited his room last week I was struck by how few possessions he left behind. He lived out a simple ethos of going higher with less. Wray was a keen observer of nature, particularly of the small things. He could identify bird song, find berries, track animals, and he could read snow like a book.

What I'll remember most is the experience of connecting with the natural world as night turned to day through all the moods and conditions of the high country. Good conditions were a bonus – but to experience the mountains in their rawest moments, to feeling the sting of the arctic wind on my face, to button down the snaps and push onwards through the eye of a raging storm, that was to experience life fully. This was Wray's legacy, not mine – but I'll be sure to make it mine now that he is gone.

I have no regrets, we lived fully. Goodbye Big Wray.

Zahan Billimoria *is a mountain guide and avalanche educator who lives in the Tetons with his wife and two children. Zahan had the great fortune of being an early morning ski partner of Wray Landon's for many years.*

Wray boots up the Newc couloir on the north face of Buck Mountain in the Tetons.

Ski partners and friends in the mountains (l-r): Zahan and Wray.

An Account of Wray Landon's Last Ski Descent: South Face of the South Teton

Story by Nate Brown

Saturday afternoon I spoke with Wray about the plans for the following day. Wray said that he was still feeling a little under the weather and that our previous plan may be too much for the weekend. Wray's good friend Brady Johnston was on board to go on Sunday. I was looking forward to meeting Brady. I had heard his name a few times and knew that he was a very strong athlete as well. We settled on meeting at Wray's apartment at 5am Sunday and finalizing a plan that morning.

At the trailhead we were getting our stuff together, and we settled on skiing the Amora Vida couloir on the South Teton and maybe going over to ski Buck Mountain after that. This would be an impossible itinerary for some, but no big deal for Wray. At 6am we left the parking lot at a fast pace (slow for Wray) and kept that pace the whole morning. Wray was out front the whole way. I now know that being ahead of Wray was next to impossible.

We reached the summit of the South Teton at 10:45am. Wray had his down coat on almost the entire time. He was such a fit guy that this pace seemed slow for him. We spent about 15 minutes on the summit eating food, drinking water, and as is customary, I called my wife to let her know how the day was going. We talked about our options, the southeast couloir, the Amora Vida, or the South Face. We all skied up to the southeast couloir and had a look. Decided to move along to ski the Amora Vida instead.

Brady skied the upper pitch – a 50-degree access slope to the larger, hanging face. He skied it hard, trying to make it slide. He then skied under the rocks to the safety zone at the Amora entrance #1, jumping up and down on the slope trying to make it slide along the way to the zone. I skied next. Wray skied up to us last.

The next pitch puts you out on the hanging face for about 12 turns before you get to the entrance to the Amora Vida. Brady skied first. Wray yelled down to Brady, "Are you sure that is the entrance; I think this is it." Brady yelled up, "Yeah, this is it for sure." Without any hesitation or conversation, Wray began skiing to Brady. I was in a "safe" spot watching Wray ski. After Wray made about four turns, I felt the earth move under my feet. Then I was on my hip on a moving block of semi-hard snow. I luckily stepped off onto the bed surface and tried to watch Wray. I could see the Class V river of snow flowing toward Brady, and I yelled, "AVALANCHE."

I knew right then that Wray had very slim chances of making it. A 2'-deep blanket of snow that covered the whole hanging South Face of the South Teton had just slid off the cliff band at the bottom of the face, and Wray was swept up in the madness. I immediately skied down to Brady, and he already had his beacon out. We skied back and forth searching the bed surface, hoping desperately that we would find Wray above the cliff band. About 100' above the brink we found Wray's ski. Still no beacon signal. Brady and I stopped on the edge of the cliff, took our skis off, and looked over the edge.

I said to Brady, "I think Wray is dead." As we were scanning the debris on the snow 1500' below us, we both thought we could see Wray. Arms outstretched, silent, still.

At this point, Brady and I were standing at the lower toe of what is like a massive altar in the sky, in a place that surely no skier has ever thought to go. The direct line to Wray would involve 1500' of rappelling with a rack and a rope. We had neither. Our only way to get to Wray was back up to the entrances of two couloirs going either east or west off the massive altar.

I called the Teton County Sheriff's Department dispatch and asked to be transferred to the National Park for a rescue. Almost immediately I was explaining the facts to a park ranger who would be the ground man for the rescue. I told him our plan to get to the Amora Vida and get to Wray. He told me to be patient, and that they were on their way.

We stood there trying to grasp the gravity of the last five minutes. The horror was there, but this was not the time to lose our cool. Immediately we started formulating a plan. Right away we hastily decided that we would boot pack back up the 1000 vertical feet to the Amora Vida and get to Wray. We both had a burning desire to get to Wray.

We began the climb back up the face – at this point the only way off was up. I am grateful we had the time to think while climbing. I was pondering our options and concerned about skiing a similar aspect at a similar elevation after the massive avalanche that had just wiped this huge face clean. We arrive at the entrance of the Amora Vida.

I said to Brady, "I really don't think it is a good idea to just ski in to this thing." Brady seemed to be thinking the same thing. "What should we do with Wray's ski?" I asked. Brady said, with tears in his eyes, "I really want to leave it here. I'll come back and leave a plaque with it." He jammed the now-useless ski in to a pile of rocks – high in the sky. We decided to continue another 700 vertical feet to the summit and wait for the helicopter to arrive before contacting the SAR ranger again. More climbing, more reflection. A phone call to my wife explaining our situation and the tragic news. While we were hiking, I asked Brady about Wray's family. Such loss. Such tragedy. I could not help feeling complicit. I still can't help it.

Just below the summit, we could hear a helicopter far off to the west. The SAR team was close. A few minutes later, they were hovering a few hundred feet away. Brady gave the hand-on-the-head "we are okay" signal and they were pointing to the north. As soon as they flew away, I called the Park SAR ground man. He told me that SAR wanted us to go down Garnet Canyon and clear the upper face so that they could do some control work.

I was both relieved and disturbed to know that we would not be descending into Avalanche Canyon. We ate some food, drank some water, and started skiing back down Garnet. Two hours later, we were at the car. I called the SAR ranger again, and we agreed to meet the following day to discuss the event. I knew it would be a long time…if ever…

This story first appeared on MountainProject.com

Nate Brown *grew up skiing the back-country snow and climbing the rocks of the Wasatch Range in Utah. He now resides in Wilson, Wyoming. He is a full-time husband and carpenter and a part-time skier/climber who gets out as much as possible.*

Backcountry Skier Dies in Avalanche on South Teton

Submitted by Jackie Skaggs, Grand Teton National Park public affairs officer

Grand Teton National Park (WY): A backcountry skier triggered an avalanche on the South Teton that swept him to his death on the morning of Sunday, February 21.

Wray Landon, 30, of Driggs, Idaho, and recently of Jackson, Wyoming, skied with two companions to the summit of the South Teton via Garnet Canyon and the Northwest Couloir early Sunday morning. They were descending the southeast face of the peak when Landon set off a 2' crown avalanche approximately 300' below the 12,514' summit. The avalanche carried Landon over 2,000 vertical feet of slope and cliff bands before he came to a rest about a thousand feet above Lake Taminah in upper Avalanche Canyon; the avalanche debris continued about 800' further before stopping. Landon and his companions were experienced with backcountry travel in the Teton Range and prepared with the appropriate equipment for a mountain excursion.

Landon's ski companions, Nathan Brown and Brady Johnston, made a 911 call to report the incident at 11:35am, and the Teton Interagency Dispatch Center received notice from the Teton County Sheriff's office shortly after. Park rangers immediately summoned the Teton County Search and Rescue contract helicopter to assist with the rescue operation. An aerial reconnaissance flight was conducted at 1:15pm during which rangers were able to determine that Landon was deceased, although not buried by the avalanche debris. In order to reach Landon, who was lying in an exposed avalanche-prone area, four rangers were flown via helicopter to a landing zone near Snowdrift Lake (elevation 10,006') from which a recovery operation could be staged. Three Teton County Search and Rescue personnel were flown into the location, and they conducted aerial avalanche control using explosives to stabilize slopes above the route rangers intended to ski in order to reach Landon.

After the avalanche control work was completed, four rangers traversed a steep slope below an area of cliff bands and couloirs. While two rangers acted as safety spotters, watching for additional avalanche activity, two rangers prepared Landon for aerial evacuation. Landon was airlifted by a long-line to the valley floor at 4:45pm. Landon's two companions skied out of the backcountry on their own, and the rescue personnel were evacuated by air, completing their operation at 5:30pm.

The avalanche condition rating that day was listed as "moderate" for mid-level and high elevations below 10,500'. The Bridger-Teton National Forest Avalanche Center does not forecast areas above 10,500', and park rangers remind skiers and climbers that conditions on the higher peaks can be vastly different above the Bridger-Teton forecast zone. A moderate rating means that areas of unstable snow exist, and human-triggered avalanches are possible. The general avalanche advisory warns that pockets of dense surface slab up to 30" deep rest upon buried surface hoar and sun crusts at the mid- and upper elevations, and the possibility persists for backcountry travelers to trigger these slabs in steep, avalanche-prone terrain.

From Steve Romeo on skiing the SW face of the South Teton the day before Wray Landon's accident (Feb 20, 2010): We didn't dig a pit…because it seemed like everything was capped off with a sun crust. Last thing I thought was that it could slide. Usually a suncrust signals stability, shitty skiing, but stability in my book. I think Wray just must have hit the money spot…and the slab that released looked pretty isolated. *Photo courtesy Teton AT*

South Teton Route Description and Conditions

Story by Lynne Wolfe

This ski route on the south face of the South Teton is difficult to assess and difficult to control "top down" because of the exposure and width, and because the skier comes in from Garnet Canyon (a different aspect). It is a steep, rounded, start-zone face, a cross-loaded rocky sunlit surface with a 1500' cliff at the bottom.

After some control of the southeast couloir route on February 21, the team of three decided on their original objective; the south face to the Amora Vida couloir, which is a southwest aspect.

On top of the south face the first skier "floated" lightly to a safe spot after attempting some ski cuts as control work.

After six to eight turns the second skier triggered a new surface slab with a minor surface crust on a faceted crust shear bed. The avalanche entrained the victim in mid-slab. The slide slightly channelized and rapidly gained speed on the very steep slope before going airborne over a 180m overhanging cliff.

According to Steve Romeo of Teton AT, the previous day's conditions in this spot were rock-hard surface crust. Overnight windloading of 2-10cm of new snow from the north and east (unusual directions for this area) and an early morning dose of sun seemed to have created a surface windslab that was susceptible to triggering. Weak layer was a layer of buried near-surface facets from a cold period mid-February on top of a pencil-hard crust. Elsewhere in the range this weak layer can be found intermixed with surface hoar as well, but at 12,200' its presence was doubtful.

This photo found on Wray Landon's camera shows Brady Johnston out in front on the south face of the South Teton, making a few ski cuts to test stability and pull out to skier's right before Landon dropped in.

The avalanche was classified as an SS-ASu-D2-R3-O. Crown height was 20-35cm, 30-40m wide, and the slab itself was 30m deep from crown to stauchwall.

Thanks to Greg Collins, Brady Johnston, and Steve Romeo for condition information.

Take-home: *From Lou Dawson*

The craft of avalanche safety requires much thinking and acting outside your day-to-day routines. It's easy to learn how to evaluate snowpack safety, especially when you live near or in the areas you ski. But what you do with your evaluation is a whole other story. My advice is to be radical. If you live and play in a mid-continental snowpack (or for that matter, in any snow climate), be willing to dial your expectations and resulting actions back so far you may hardly feel like you're "skiing," in the sense of modern climbing for turns. But you'll stay alive so that when it does get good, and it will, you'll be there to enjoy it.

—From WildSnow.com on February 25, 2010. Used by permission.

mailbag

Brooks-Range Correction from Craig Dostie—

From: "CDostie" <cdostie@earnyourturns.com>
Subject: Brooks Range correction
Date: March 4, 2010 9:24:24 AM MST
To: <lwolfe.avalanchereview@gmail.com>

Lynne, Please print the following correction in the next issue of TAR regarding the information in the sidebar on Brooks Range products. The specs on the Snow Density gauge were pretty unbelievable. Not sure exactly where those came from, probably a combination of a typo and a misunderstanding with the original description.

It said, accurate to 0.1% from 0% to 60% in 1% increments. It should have said the scale ranges from 0% to 60% in 5% increments. The ability to accurately interpret the scale to +/- 1% is reasonable, but it is not expressed, only implied.

Craig Dostie

Correction from Ron Perla—

From: riperla
Subject: Feb 2010 Avalanche review, bottom page 14
Date: February 24, 2010 5:15:14 PM MST
To: art.judson
Cc: lwolfe.avalanchereview@gmail.com

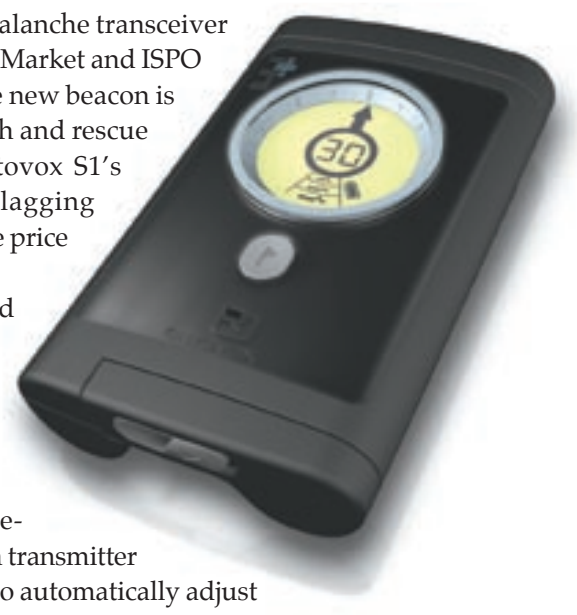
My issue finally arrived, and I now see the photo: very nice, thanks for giving me credit, but in fairness the photo credit should be Art Judson.

The problem with the caption submitted by Rod Perla is that those who know me well may wonder just how much is based on fact. Gretchen, who knows that I solo climb and that once sprayed myself accidentally, told me that she knew it didn't exactly happen that way. R.I.P.

The Avalanche Review deeply regrets any errors, which are solely its responsibility.

what's new

Ortovox Debuts 3+ Transceiver



Ortovox introduced a new avalanche transceiver at the Outdoor Research Winter Market and ISPO tradeshows. Dubbed the 3+, the new beacon is an incredibly capable avy search and rescue tool that brings its sibling Ortovox S1's proven signal masking and flagging technology down to a mid-range price point, in the mid-$300s.

Housed in a sleek, space-aged case, the Ortovox 3+ features a unique direction and distance display as well as a new hash-mark system for pinpoint searching. Especially noteworthy is the fact that the 3+'s three-antenna design is equipped with transmitter technology that allows the unit to automatically adjust polarity for optimal reception by searching beacons. The 3+'s power-management system makes the unit meet all industry standards while running on one AA battery. The 3+ can track up to three buried victims, and its operating software is fully and easily updatable.

"What is paramount for people to understand is that the 3+, with its new transmitter technology, is the first beacon ever that actually makes your buddies' transceivers work better – especially older single and double antenna units," claims Marcus Peterson, general manager of Ortovox USA.

For more info, contact Marcus Peterson at ortovoxusa@aol.com or 603-746-3176

A Quick Note on Avalanche Beacon Battery Meter Numbers

Story by Jonathan Shefftz

Once upon a time, beacons had only very rudimentary battery strength indicators, but now all modern designs provide a numerical indicator. However, this is somewhat in the realm of spurious precision.

Why? Well, first off, I just love using the phrase "spurious precision" whenever I have the slightest excuse. More importantly, assigning a specific number to a given set of batteries requires some interpretation, which varies by beacon model.

Why's that? Let's back up a second and review the official spec for battery life: "at least 200 hours of transmitting at a temperature of +10°C and subsequent receiving for one hour at a temperature of -10°C."* Many beacons substantially exceed this spec, but either, that's an impressively long operating time.

Backing up even further, some of the variables involved in remaining battery life for any kind of device can include:

- The temperature of the device.
- The temperature of the batteries.
- The temperature history of the batteries.
- The capacity remaining algorithm in the unit.
- The calibration of the capacity circuit in the device.
- The lot characteristics of the batteries.
- The particular voltage/current needs of the device.

Furthermore, a device when assessing batteries can measure just voltage, measure voltage as a function of load, measure battery source impedance using an occasional current pulse, calculate total charge withdrawn from the batteries, and still others…

Bringing all of this back to avalanche beacons: for a given voltage on a controlled bench test, different beacon models have had their battery meter figures test out anywhere from 0% all the way to 71%. I'm not going to provide the test results, because I don't want to encourage any behavior along the lines of, "Hey, it's okay that my Brand X beacon is flashing 0%, because I saw this table in TAR," but suffice it to say that at least one beacon model in particular is very pessimistic, just like some cars might show you running on empty even when you're still going to be okay for awhile. (Remind me sometime to tell you that story about when my wife and I returned from skiing at Tioga Pass by driving to Tahoe via Monitor Pass and…no wait, don't ask me to remind of you that story!)

Wrapping up, here are the specific recommendations I give to my students in avalanche-safety classes. (And I even follow them myself – how's that for lack of instructor hypocrisy?)

1. First and foremost, although every beacon owner should already know this one by now, no note on avalanche beacons is complete without the long-time admonition to use only regular alkaline batteries. That means no rechargeable batteries (of any kind) and no lithium batteries. Also stay away from batteries whose names are a bit too intriguing (e.g., Duracell PowerPix), which are often *not* standard alkaline chemistry.

2. For your particular unit, keep an eye on its typical battery consumption patterns: i.e., how much of a drop in percentage over the course of the day, how much rebound in percentage after the unit has been turned off then back on, and how much any of this varies depending on how fresh the batteries are. Also, although many of the latest designs have some impressive companion check modes for frequency drift and related functionality, a reality test for how well your partners' beacons in regular search mode can actually receive your signal is always a worthwhile diversion.

3. As for what to bring to the field:
   a) Bring extra sets of three AAA batteries and two AA batteries in your car (or trailhead bag, wherever it resides) just in case someone (why, maybe even you!) shows up at the trailhead short on battery strength.
   b) On daytrips, replace batteries when below 50%.
   c) On multi-day trips, start off with a fresh set of batteries.
   d) On multi-day trips where you might do some beacon searching practice during downtime, bring an extra set of batteries.

4. Once you reluctantly concede sometime during the summer that ski season is over, remove the batteries from your beacon for the off season (which should be blessedly short). This will eliminate the chance of a corrosive leak from your $1 set of batteries ruining your $450 beacon, and also some beacons have a non-negligible battery draw even when off. Plus it's a nice end-of-season and beginning-of-season ritual too.

For your particular unit, keep an eye on battery consumption patterns

**This battery life spec can be found in ETSI EN 300 718-1, V1.2.1 (2001-05), "Electromagnetic compatibility and Radio spectrum Matters (ERM); Avalanche Beacons; Transmitter-receiver systems; Part 1: Technical characteristics and test methods," if you want some fascinating night time reading – and yes, Parts 2 and 3 are just as good – in particular section 4.2.5, "Operating time."*

Jonathan Shefftz is an AIARE and NSP avalanche instructor who, as a consulting economist, has no professional training in electrical engineering but sure has been putting in lots of fresh batteries lately for all the gizmos his wife Andrea has been buying for their newborn daughter Micayla. He is thankful for the input from Bo Duris (a fellow NSP avy instructor) and Paul Terwilliger (a recent CAA Pro L1 grad), who actually know something about electrical engineering.

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Editor's note: The I/O bio women's Pilot Suit (shown at right) is one of the best new wool products on the market (and I even paid retail for it). Soft and warm, but with all the right features: thin hood, thumb loops, and the always-critical but often missing "split-P" zipper.

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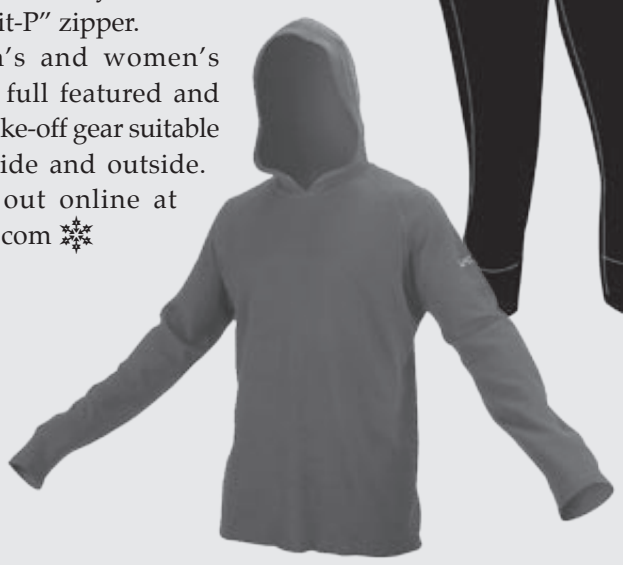


ISSW 2010 Update

Story by Russ Johnson

As I'm sure everyone is now aware ISSW 2010 will be held at Squaw Valley, October 17-22, 2010. Most info is available at issw2010.com, so the following are just a couple of additional notes.

Our keynote speaker for the banquet Thursday evening is Andrew McLean, a well-known ski mountaineer with multiple first descents from Antarctica to Alaska, from North America to Europe and Tibet. He is equally well known for his interesting and informative talks laced with humor and wonderful photography. For a revealing insight into Andrew's mountaineering philosophy I recommend his interview on sierradescents.com. Seating at the banquet will be limited, so be sure to sign up for the banquet when you register.

As promised, we have arranged airport transportation service with North Lake Tahoe Express; check issw2010.com for details. This service is complimentary for those staying at The Resort at Squaw Creek *(see lodging and package rates on page 5)*. The service is also available to others at a reduced rate, so you shouldn't need to rent a car if you fly into Reno.

We've tried to make this ISSW very affordable; take advantage of the early bird rates if you can. Go to issw2010.com for early registration discounts and while you're at it, check the activities page for an in-depth and inspiring look at the range of possibilities for October 20. *—Russ Johnson is the chair of ISSW 2010.*

The Avalanche Review extends our deepest condolences to Russ on the recent tragic loss of his son CR Johnson in a ski accident.

French and Canadian Governments Weigh in on Avalanche Airbag Use

Story by Bruce Edgerly

So you think the United States has a litigious society? Try France.

At the ICAR (International Commission on Alpine Rescue) annual meeting this year in Zermatt, delegates from the French avalanche agency, ANENA, announced a precedent-setting verdict in a wrongful death lawsuit involving an avalanche technician at the French resort, Ste Foy Tarentaise. The court tribunal awarded 40,000 euros to the parents of Eric Peymirat, who was killed in an avalanche in January of 2004 while performing control work.

The tribunal cited the book, *Dans le Secret des Avalanches*, by former ANENA director François Sivardière, which states that 95% of avalanche victims deploying avalanche airbags have remained at least visible on the snow surface – and survived. The tribunal also cited a witness who said Peymirat would have had plenty of time to deploy an airbag. The written verdict declares the ski area to be "inexcusably at fault" by not providing Peymirat with an airbag.

Meanwhile, in Canada, the Coroners Service of British Columbia has recommended that commercial guiding operations consider using avalanche airbags. The report cites a successful airbag deployment several years ago in northern British Columbia: a heli-skiing guide who deployed his airbag not only stayed on the surface and survived, he was then able to rescue a buried guest who was not using an airbag.

Both of these cases suggest that the writing is indeed on the wall that avalanche airbags will become standard safety equipment in the years to come, in both Europe and North America.

***Bruce Edgerly** is co-founder and vice president of Backcountry Access, Inc. (BCA).*

Historic 1910 Wellington Tragedy

This spring marked a significant anniversary: the 100th anniversary of the largest avalanche tragedy in US history. Ninety-six persons died on March 1, 1910, when two trains were swept off the tracks during an epic, multi-day Cascade storm at Wellington, Washington. *Northwest Disaster, Avalanche and Fire*, by Ruby El Hult includes a great account of the accident. A shorter report can be found in the first volume of *The Snowy Torrents*, Dale Gallagher, editor.

BCA Announces New Products

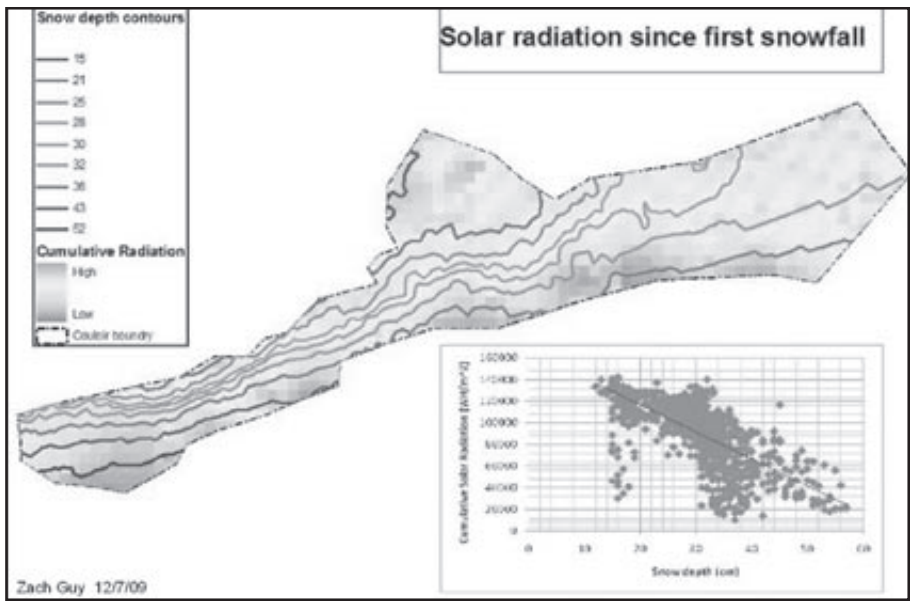
Avalanche equipment manufacturer Backcountry Access, Inc. (BCA) recently unveiled two new products: the Tracker2 avalanche beacon and Float 30 avalanche airbag.

The Tracker2 reinforces the Tracker DTS with a third antenna (for increased accuracy at close range), even faster processing speed, greater receive range, and "out of the box" simplicity. "This is the beacon you want your touring partner to carry," said BCA Vice President and co-founder Bruce Edgerly. "No bells and whistles, just raw simplicity and speed. In a stressful situation, that's what people want." Suggested retail is $335.

The company is poised to revolutionize another category with its Float 30 avalanche airbag. This 30-liter backpack includes a compact compressed air system. When the user pulls a trigger on the right shoulder strap, a 150-liter airbag inflates behind the user's head and shoulders. This helps protect the victim from trauma and helps keep him or her on top of the flowing avalanche debris. Similar systems have been proven extremely effective in Europe, but have not been widely adopted in North America due to high prices and complicated refilling logistics. The Float 30 is priced at $500 and the cylinder can be exchanged or refilled at BCA and a network of retailers, SCUBA and paintball shops.

"We've done our homework and found that the biggest challenge in avalanche rescues is no longer the beacon search," Edgerly said. "The vast majority of time is spent digging for the victim. By reducing or eliminating the burial depth, then you dramatically increase the chances of survival. Our mission is to save lives, not just pump beacons."

For more info, contact BCA at info@backcountryaccess.com or 303-417-1345.



GIS Conference Set for April 22

A one-day mini-conference will be held on Thursday, April 22, during the 2010 Intermountain GIS Conference in Bozeman, Montana. The Use of Geographical Insormation Sciences (GIS) in Snow and Avalanche Sciences will feature a tour of the MSU Subzero Science and Engineering Research Facility (www.coe.montana.edu/ce/subzero) and will cover the following topics:

- Open Source GIS
- Avalanche Runout Probability
- Surface/Snowpack Energy Modeling
- Avalanche Atlas Creation
- Forecasting
- Visualization of Snowpack Conditions
- Modeling Spatial Patterns in Couloirs
- Avalanche Path Statistics
- Analyzing Surface Hoar Distribution
- History of the use of GIS in snow and avalanche sciences

The cost for the one-day registration is $90 for Montana Association of Geographic Information Professional (MAGIP) members and students. The fee is $110 for non-members. For information about student scholarships, go to www.magip.org/IntermountainScholarships2010.

Go to www.magip.org/Intermountain for more information and updates, or contact Tara Chesley-Preston at tara.chesley@gmail.com.

Small Unmanned Aircraft Tested for Use in Avalanche Control

Story and photos by Ed McCormack and John Stimberis

Because of their newsworthy use by the military, many of us are aware of unmanned aircraft. As spinoffs from these defense applications, civilian versions of these aircraft are increasingly affordable, capable, and easy to operate. Commercially available unmanned aircraft systems (often known as UASs) are small enough to be launched off a vehicle or from a road but can carry payloads, video cameras, and sensors and are able to use global positioning systems to autonomously fly pre-set flight plans.

Recognizing the possible potential of UASs, in 2006 and 2007 researchers at the University of Washington (UW) and avalanche control staff from the Washington State Department of Transportation (WSDOT) evaluated two commercially available small UASs – one fixed wing and one rotary wing (a helicopter) – as a potential avalanche-control tool. We concluded that UASs did have some potential, with the rotary wing version showing the most promise.

Our tests involved a series of flights centered on State Route 20 in the North Cascade Mountains of north-central Washington State, where WSDOT annually conducts spring snow-clearing operations. This area was chosen because of the remoteness, low traffic flows, elevation, and the availability of large avalanche paths. We explored the UAS's capabilities to:

- Survey terrain surrounding the roadway, avalanche paths, and starting zones
- Inspect avalanche control target zones for people before the use of explosives for avalanche control
- Deliver avalanche-control explosives
- Operate in mountainous terrain and weather

We selected the two UASs because they were affordable (less than $250,000 for the aircraft and the ground control station), could be transported in a standard vehicle, and could be launched and retrieved from or next to a roadway.

The fixed-wing aircraft we tested was the MLB BAT. This 24-pound aircraft has a 72" (200cm) wingspan and can carry a 5-pound (2.2kg) payload. The aircraft's pan-tilt video provided a clear real-time image of the snow coverage on the roadway and the surrounding terrain. The test also highlighted some issues that may affect the use of fixed-wing aircraft. The BAT required a 100' (30m) straight stretch of roadway to land, which may limit its use in some areas. The mountainous terrain and weather also created some flight limitations.

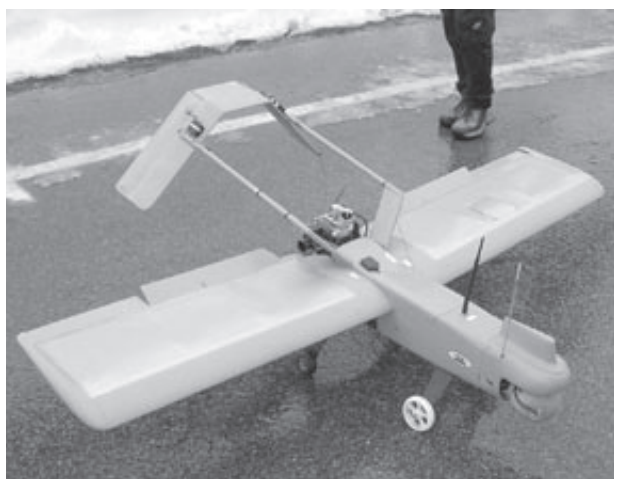
The rotary wing aircraft was a Yamaha RMAX. This aircraft, which was originally designed for crop spraying, weighs 205 pounds (93kg) and can carry a 65-pound (29kg) payload, as well as a pan-tilt video camera. The test flights demonstrated the aircraft's ability to autonomously follow a road at varying heights by using preprogrammed waypoints. We designed this exercise to simulate a reconnaissance before the start of snow-clearing operations on the road. The ability of the aircraft to hover above areas of interest provided a stable platform that made camera use extremely effective.

We also evaluated the ability of the RMAX to survey terrain away from a roadway. The idea was that avalanche-control personnel could view the real-time video to find backcountry travelers who may be at risk if WSDOT was performing avalanche control. However, in viewing the video output, we were generally unable to locate a person stationed in visually complex, rocky, and vegetated terrain above the road. If we had had infrared sensor equipment, such as that used by search and rescue operations, we may have been more successful.

Other test flights demonstrated the ability of the RMAX to accurately (within 3.5' or 1m) drop 8-pound (3.6kg) dummy avalanche charges at predetermined heights to preselected GPS locations. The charges were rigged with a pull-wire fuse hooked to a lanyard that successfully ignited as the charges were dropped.

In general, we concluded that the functionality of the UASs would allow someone to operate them for avalanche-control operations, reconnaissance missions, or search and rescue missions without major organizational additions. However, the life span and reliability of UASs are not well demonstrated, and these issues are important in relation to the equipment costs for replacement and the consequences of a crash. The capabilities of the aircraft in rugged, windy, or cold conditions are also a concern. These problems may be reduced in the future as UASs become more reliable, or more all-weather capable, or less expensive and thus more expendable.

One other notable limitation to flying a UAS is institutional; this is principally linked to the requirement to obtain FAA authorization to fly in order to comply with strict "see and avoid" air space collision-avoidance rules. Unfortunately, the process is time consuming and restrictive. However, both technical and organizational solutions are being considered. UASs used for avalanche control and other uses generally would operate in sparsely populated areas, which would reduce the challenges in obtaining FAA authorization to fly.



During trials conducted in Washington's North Cascades, the Yamaha RMAX rotary wing unmanned aircraft, top, showed the most potential for use in avalanche-control work. The Yamaha weighs 250 pounds and can carry a 65-pound paylod. Weighing in at just 24 pounds, the fixed-wing MLB BAT, above, can carry a 5-pound payload.

As funding permits, we are planning a new set of tests. We hope to further explore the operational capabilities of the rotary wing UAS in winter conditions. We also will explore the use of unmanned aircraft as a low-cost aerial platform for sensor technologies such as LIDAR, infra-red, and perhaps RECCO or traditional avalanche-transceiver technology. If you would like more information on this topic, please feel free to contact either author.

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education

CAC Ramps Up Sledder Outreach

Story by Mary Clayton

After last winter's unprecedented number of snowmobiler avalanche deaths, the Canadian Avalanche Centre (CAC) is counting on the sledding community to become more engaged with the many avalanche safety programs and services available to them. In the fall of 2009, the CAC committed considerable resources and efforts to a wide range of outreach events, speaking directly to snowmobilers and hopefully making some good connections.

"In the past we've worked primarily through the clubs and organizations," explains CAC Operations Manager John Kelly. "We need to build multiple links with the sled community so we are also concentrating more on the grassroots focus. Amber Wood and Lori Zacaruk are our sledding outreach team and they've been invaluable for their great network of contacts, connections they've made over the past few years of travelling around and giving evening and weekend avalanche-awareness courses."

Working with her contacts in Edmonton and Calgary, Lori created an evening event in both cities focusing on last year's snowpack. The purpose was not to dissect any of the fatal accidents of last year. Rather, the aim of CAC Forecaster Greg Johnson, who led the discussions, was to give the audience a short rundown of the persistent weak layers of 2008/09 and their effect on snowpack stability over the course of the season. Lori and Greg also showed videos of sledders triggering slides, bringing the conversation around to terrain selection.

Close to 50 people attended the Calgary evening, but the show really took off in Edmonton, where some 140 people gathered to hear the talk and participate in the discussion. "It was a great evening, the highlight of all my speaking engagements this fall," said Greg. "Many members of the audience had lost friends in avalanches, and one woman lost her husband last year. It was intense." Although the format was the same in the two cities, Greg reports the Edmonton audience was much more engaged and the discussion was "amazing."

Jeremy Hanke is another sledding contact who's become very involved. Many CAA members were introduced to Jeremy at last year's AGM, when he and Wren McElroy gave a presentation at the public and technical meetings on the challenges of avalanche awareness with snowmobilers. Jeremy is a very experienced and accomplished rider and, as an avalanche survivor, he is also very keen to work with and help the CAC get the message out.

In addition to speaking at our sledder-focused Basic Awareness Workshops (BAWs) in Prince George and Grande Prairie, Jeremy also spoke at an avalanche-awareness evening organized by the Vernon Search and Rescue at the end of November. Working with a local snowmobile dealer, the Vernon SAR group screened a new sledding movie and asked the CAC to provide a speaker for the evening.

CAA Curriculum Specialist Wren McElroy and Jeremy were the speakers, and Wren noted the audience seemed to appreciate the significance of a professional avalanche worker and a sledder working together to raise awareness. Feedback from the presentation was very good, with audience members approaching Jeremy later to ask about avalanche education.

Of course, not everything always goes according to plan and we're regularly reminded that much work remains to be done on this issue. While the Prince George and Grande Prairie BAWs were very successful, workshops in Fernie, Calgary, and Vancouver all received negative feedback from the few snowmobilers who attended. This feedback reflected the perception that education delivered by and aimed at skiers is not relevant for snowmobilers. While we strongly feel this isn't entirely true, we recognize that perception is reality. Next year, our BAWs will be further refined and tailored for specific user groups.

Another disappointment this past fall was a talk organized by Teck Coal in Sparwood, a company that lost four employees in the Harvey Pass accident of December 2008. Greg Johnson was planning to present and lead a discussion similar to those he gave in Calgary and Edmonton. Teck (also a long-time CAC sponsor) prepared for an audience of 100; five showed up.

Despite these setbacks, we are making headway. We have seen a marked increase in demand from snowmobiling groups for evening presentations or day-long workshops. Lori Zacaruk and Amber Wood report a significant increase in support from dealers promoting classes in their communities, and CAC forecasters are hearing directly from more snowmobilers than ever before.

While we would all like to see snowmobile avalanche safety on the fast track towards improvement, cultural change is a slow road. Our aim is to shorten up the learning curve for sledders with avalanche-safety knowledge and practices that have been developed over time for other user groups. We'll keep working the grassroots with the belief that together, we're growing something special.

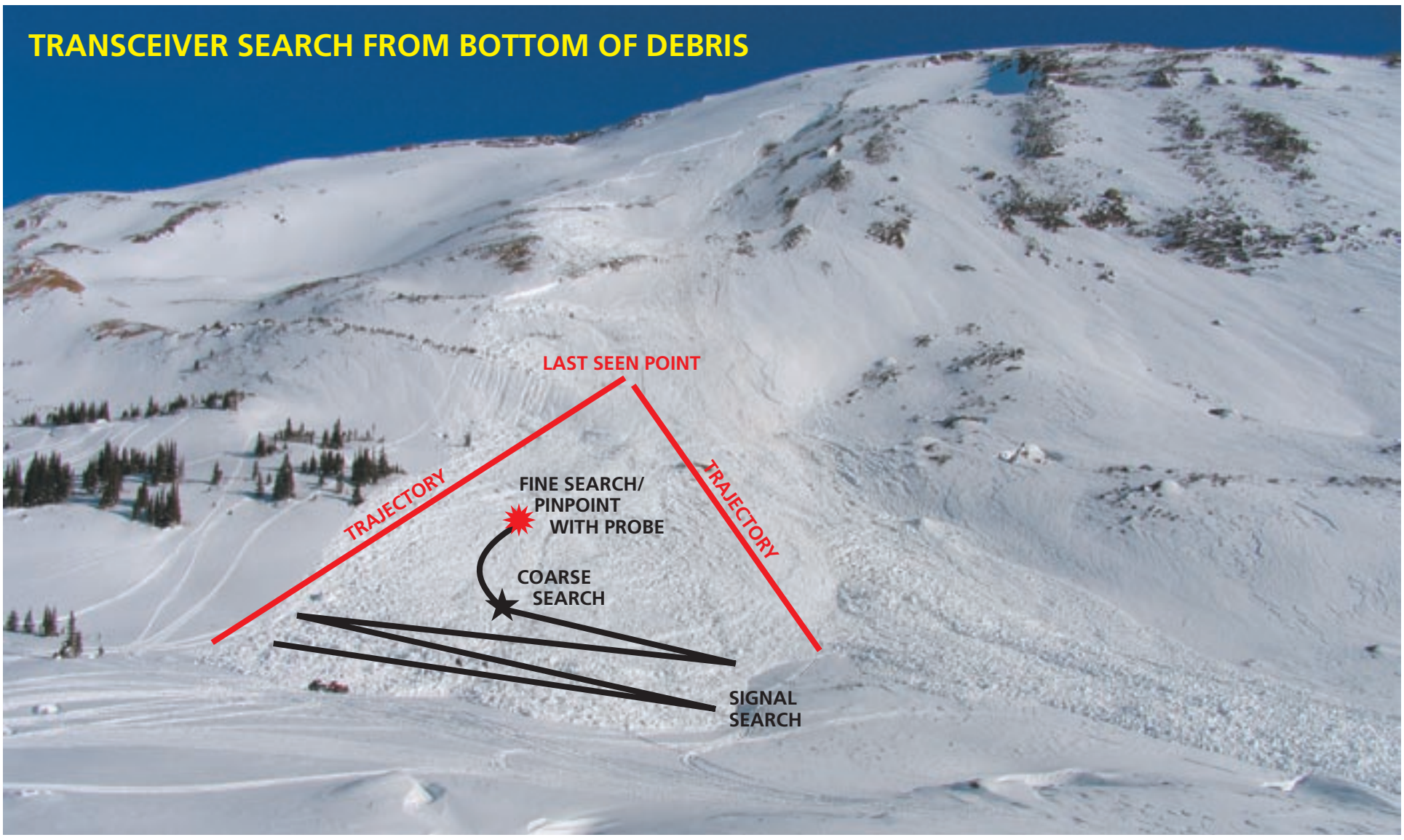
Mary Clayton *is the communications director for the Canadian Avalanche Centre.*

EDITOR'S NOTE:

At press time *The Avalanche Review* learned of a large avalanche that occurred on March 13 on Boulder Mountain outside of Revelstoke, BC, as part of the annual Big Iron Shoot-out snowmobile festival. Two people were killed, 20+ sent to the hospital, and many people and sleds were buried. Companion rescue was swift and generally effective; many participants possessed and knew how to use rescue gear.

Many questions remain as to why so many people were parked right beneath such a large path with an avalanche warning from the CAC in place, due to a large storm on top of a fragile snowpack. We hope that this incident gives further impetus and impact to the CAC's snowmobiler outreach.

The Avalanche Review extends our condolences to the families and friends of those caught in the avalanche.



All backcountry travelers should be able to effect a rescue from either the top or the bottom of the path. In this diagram, sledders imagine the trajectory of the sled in the debris.
Photo courtesy Canadian Avalanche Association

Advanced Avalanche Education Developed for Snowmobilers

Story by Sean Wisner, Mike Buck, and Sarah Carter

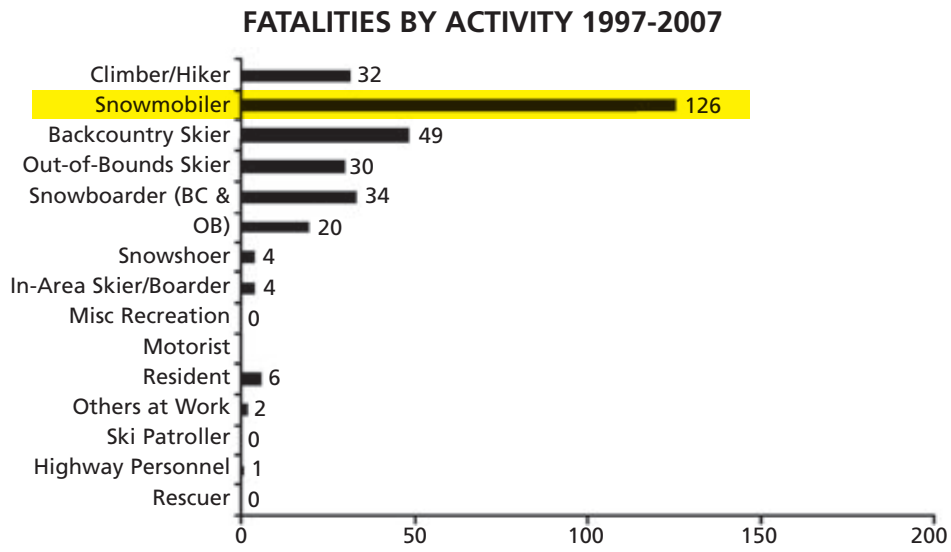
A new era of avalanche education was born when the Alaska Avalanche Information Center (AAIC) recently hosted Alaska's first nationally recognized American Institute for Avalanche Research and Education (AIARE) Level I avalanche course focused specifically for backcountry snowmobilers. The course was held February 5-7, 2010, in Valdez, Alaska, with the field components presented in the spectacular setting of Thompson Pass and the Tsaina Glacier Valley.

Snowmobilers in Alaska continually lead the statistics for avalanche fatalities in the United States. As this disturbing trend only gets worse, snowmobile-specific courses taught by experienced, progressive snowmobilers becomes imperitive.

In the past, snowmobilers who took the initiative to enroll in an avalanche class higher than awareness level stuck out like a sore thumb. They often became a logistical conundrum in the field and were sometimes alienated by the skier-oriented snow, terrain, and travel assessment/technique. They were asked to strap on a pair of skis or snowshoes (not their first choice of travel tools), then required to chase the class around the hills – which often made delivery of instruction challenging for instructor and student alike. Instructors on skis approach the terrain quietly and slowly, covering a limited amount of ground each day. But for these students, this is perhaps the first and last time they will don a pair of snowshoes/skis in their life to hear subtle changes in snow conditions while walking quietly through the mountains. Statistical trends in the US illustrate that this approach has not been effective. An educational paradigm shift was clearly needed.

Utilizing AIARE Level I guidelines as the curriculum backbone, the AAIC course addresses issues of terrain selection, travel techniques, slope-stability testing, group dynamics, and observational guidelines specific to backcountry users traveling on snowmobiles. The 30-hour course was taught on snowmobiles by active snowmobilers who speak the user group's lingo. Classroom components include:

- Introduction to AIARE and AAIC's mission
- Goals and objectives of Level I avalanche education
- The "anatomy of a decision" and the AIARE decision-making framework
- Detailed analysis of case studies pertaining to snowmobile-triggered avalanche fatalities in Alaska and the US, with specific emphasis on a human-triggered avalanche fatality in April 2009 on Thompson Pass near Valdez
- Basics of avalanche types and characteristics
- Avalanche-terrain recognition
- Formation of layers in mountain snowpack and snow-crystal metamorphism
- Review of the North American Danger Scale and how it relates to avalanche bulletins and forecasts
- Observing obvious clues and specific observational techniques that can be used while riding a snowmobile
- Tabletop exercises using the AIARE observation checklist
- Snowmobile trip planning and preparation
- Thorough overview of human factors and heuristic traps
- Terrain selection and travel techniques specific to snowmobiling
- Snowpack stability tests, both in the pit and on the go
- Snowmobiler companion-rescue techniques



The main course focus was selection of terrain appropriate for conditions. Participants conducted several tabletop route-finding scenarios and trip-planning exercises before heading into the field. Considerable time was spent reviewing the avalanche size table, reporting guidelines, and language used by avalanche professionals. Because snowmobilers have the capability to cover tremendous amounts of terrain in a single outing, they can be one of our greatest assets in developing public avalanche bulletins; we all gain when snowmobilers make and communicate quality observations.

Field sessions focused on decision-making in avalanche terrain: communication techniques while on a snowmobile, route-finding exercises involving simple and challenging avalanche-terrain features, weather observations, recent avalanche observations, snow-stability tests both on and off the machine, and complex companion-rescue exercises.

Using snowmobiles for travel, 30-minute route-finding exercises took place on slopes that would compose the venue for an entire ski course day. The all-day field component on the third day of the course consisted of a ride covering three distinct snow climate zones, so participants were able to observe the maritime snowpack, traverse the intermountain region, and finish in a continental snowpack. This is typical of an outing for snowmobilers in this region of Alaska who often cover well over a 100 miles per day.

Another significant curriculum difference involves companion-rescue techniques. The majority of snowmobile-related avalanche accidents involve a person climbing a hill and triggering a slide while their companions wait at the bottom. So instead of starting from the last-seen point and traveling downhill, most snowmobilers will approach the debris from the bottom to perform an initial search. This is significantly different from the current search techniques developed by skiers involving only top-down search pattern. Skiers should learn these techniques as well, as anyone skiing a slope one at a time should be prepared for those at the bottom to effect a rescue.

AAIC developed a diagram to visually demonstrate this technique *(shown at the top of the page)*. Recommendations suggest groups avoid congregating in runout zones, position their machines for hasty retreat, and not assist those stuck in avalanche

Strategic shoveling is the same for all disciplines: leave the probe in place and plan to make a hole whose diameter is determined by the burial depth. Many riders are found within two meters of their sleds. *Photo by Michel Freiderich*

In Alaska, crevasse-rescue equipment is worn by all avalanche-course participants traveling across glaciers on snowmobiles. Participants are taught traditional snowpack stability tests in addition to snowmobile-specific tests. *Photo by Michel Freiderich*

start zones. The victim's companions are taught to spot the last-seen point of the caught rider, calculate the downward trajectory, and begin their primary search pattern from the toe of the debris directly below the last-seen point.

Participants learned subtle differences in companion rescue and what to do if they personally are caught in an avalanche. More often than not, the snowmobiler will be traveling uphill when the avalanche occurs. If a rider is carrying some speed in an uphill trajectory when the slab fails, they should make every attempt to ride off the top of the moving slab. However, if they have already made the turn and are traveling back down the slope when the slab fails, they should proceed similarly to a skier and attempt to ride off the slab at a 45-degree angle to the side. If they are at the bottom of the slope when the slide occurs and have their machine pointed in the correct direction, an attempt should be made to outrun the avalanche. Instructors need to remember that snowmobiling is both an uphill and a downhill activity, and the additional 150 horsepower can be helpful when an avalanche occurs.

Snowmobile slope-stability testing includes different techniques than those used by skiers or snowboarders. Although compression tests, hand shears, and extended column tests were demonstrated to the students in the pit, the main focus was on representative slope-stability tests that can be performed while riding a snowmobile. Although these tests are not yet quantifiable, they are extremely effective at finding and identifying weak layers within the snowpack.

The following snowmobile-specific slope-stability tests should only be demonstrated on small, lower-consequence slopes (in the 30- to 40-degree range) and must be performed by competent snowmobile riders in order to be effective:

- **Looping Slope Test**
- **Downhill Traverse Test**
- **Rollover Ride-Out Test**
- **Rip Saw Cut Test**
- **Parallel Rip Saw Cut Test**
- **Impact Test**
- **Rollover Rip Saw Cut Test**

Part of several stability tests, the Rip Saw technique incorporates the process of leaning the snowmobile into the slope and counter-steering with the downhill ski in the air, causing the track to cut deeply into the slope. Riders should practice and master this skill in order to obtain quality results.

The most basic test used in backcountry snowmobile travel for stability evaluation purposes is the **Looping Slope Test**, performed by looping up, across, and down a slope in a half moon crescent shape in an attempt to trigger a slope release. When successful in triggering a release, this test indicates significant snowpack instability.

The **Downhill Traverse Test** starts from the top of a slope, riding at a 30- to 45-degree angle across the face with some speed. The rider must not carve into the surface when performing this test. Slab release while performing this test will identify weak layers, sensitivity, and slab property.

The **Rollover Ride-Out Test** starts from the top of the slope riding straight down at a slow speed, intermittently braking during the decent. This test is performed when stability is suspected to be poor to fair. Horizontal slab propagation from the machine indicates both weak layer and slab properties. Pushing powder snow in front of the machine means little; this is not an indicator of instability.

The **Rip Saw Cut Test** traverses the uphill track starting from the bottom and angles across the slope at a 30- to 45-degree angle. It is imperative to maintain track speed and counter-steering during this test, leaving a trench across the slope face. This test will provide data on deeper instabilities and weak layers in the snow pack by putting significant stress on the slope.

The **Parallel Rip Saw Cut Test** is performed from the bottom of a slope. The tester rides up the slope, then turns 90 degrees and rides across the slope parallel to the bottom. Multiple cuts are made parallel to one other, 4-10' apart starting low, with each subsequent cut made above the previous cut. Data is obtained from cutting above unsupported snow. If poor stability is suspected, the test should be reversed, cutting the slope from top to bottom. If any result is observed, both methods should be performed. Inspection of the results is required to assess the stability of the snowpack.

The **Impact Test** is performed from the top down. The tester should carry enough speed to make a small jump from the top of the hill onto the slope below. This test is best performed on a slope with a flat top and convex rollover. A small cornice will often assist the tester. It is important to learn this technique from an experienced rider due to the potential for back injury when performed incorrectly.

The **Rollover Rip Saw Test** is performed from the top of a slope, preferably with a convex rollover. The tester begins the approach parallel to the horizontal convexity, drops just over the edge with a ripsaw cut along the apex of the rollover, and completes the test back on top of the test slope. Similar to ski-cutting convex rolls, this is an effective test to determine the stress in the snowpack at potential trigger points.

During slope-stability test instruction, participants were taught to examine the properties of any released slabs. The fracture, slab, weak layer, and bed surface are clues riders will use to make subsequent decisions on terrain and route selection for the day.

Instructor Mike Buck demonstrates snowmobile slope-stability testing, including the rip saw technique (above). It is easier to teach a good rider to be an avalanche instructor than to teach an avalanche instructor to ride a snowmobile. *Photos by Michel Freiderich*

The keys to a successful AIARE snowmobile-specific Level I avalanche course are the instructors. It is easier to teach snowmobile riders to be avalanche instructors than it is to teach avalanche instructors to be good snowmobile riders. Snowmobile riders need to be cultivated early and provided with the tools to become effective avalanche educators. Teaching an avalanche class to a snowmobiler traveling on snowshoes is just as ineffective as a course led by an instructor who cannot ride the snowmobile proficiently enough to effectively demonstrate slope-stability testing techniques or make proper terrain selections. To maintain credibility with this user group, instructors for these courses must have extensive riding abilities and experience. We believe that minimum experience standards will need to be specified for snowmobile instructors, similar to the standards that have been set for skier-specific courses.

The AAIC is focusing efforts on snowmobile safety in an attempt to break the disturbing trend of snowmobile-related avalanche fatalities. We submit that the industry as a whole should strive to provide quality education to all outdoor enthusiasts – especially to those in the highest fatality category. For more info, contact the Alaska Avalanche Information Center at alaskasnow.org@gmail.com.

Sean D Wisner *is a professional member of the American Avalanche Association and currently holds the position of executive director for the Alaska Avalanche Information Center.* ***Mike Buck*** *has been snowmachining in the Valdez area for over 30 years and is an assistant AIARE instructor. Mike holds a masters degree in education; he was instrumental in developing the snowmachine-specific curriculum for this course.* ***Sarah Carter*** *is a professional member of both the AAA and the Canadian Avalanche Association. She is an AIARE instructor and course leader, and she currently holds the position of education director for the Alaska Avalanche Information Center.*

above: Albert Swanson was in the right place at the right time to capture the powder cloud from a huge human-triggered avalanche on February 16, 2010. *Photo by Alfred Swanson*

below & top of next page: The scale of this avalanche on Saddle Peak is impossible to fully comprehend from a photo. The crown face was nearly 5' tall and almost 1000' wide. The avalanche ran about 2000' vertical down one of the most popular and heavily skied slopes on Saddle Peak. *Photos by Alex Marienthal*

Saddle Peak Avalanche

Submitted by Doug Chabot, GNFAC

From the Gallatin National Forest Avalanche Center Avalanche Advisory for Wednesday, February 17, 2010:

Yesterday morning at 11am, a person triggered a large avalanche on Saddle Peak. Extreme luck was involved as no one was caught. A cornice the size of a VW van broke as a skier walked towards the edge of the ridge at the summit. The block slid downhill and triggered the avalanche. It broke 3-6' deep and went 1,000'+ wide, wiping out hundreds of ski tracks from Monday. A powder cloud was seen by most people at the ski area. Our photos page on the Web site is filled with pictures more vivid than words can describe.

Take a hard look at the photos. If you skied off the summit on Monday and find that your tracks are now obliterated, I'm asking, "What did you do to arrive at the decision to ski that slope?" Now that it slid there's no real argument about whether it was stable or not. It wasn't. But hundreds thought it was good to go. Perhaps I would have been one of them. But I know I'd want to puke looking at those photos, knowing how close I would have been to dying.

Seeing other tracks in fresh powder is commonly mistaken as a sign of stability, but it's not. Folks think that slopes that get skied often are safer because the weak layer gets broken down and compacted by the tracks. But in this case the weak layer was impervious to tracks because it was preserved under a supportable hard slab. Supportable until yesterday.

Three inches of snow-water equivalency fell in under 48 hours. Strong winds created drifts, adding even more weight. And facets hibernating deep in the pack finally couldn't hold up any more snow. That's what happened.

We are extremely lucky. I could just as easily be writing my condolences to 15 families this morning. Many people would have died if the slope slid the day before or a few hours later. Most days skiers are stacked on top of one another, exposed to avalanches from above. Luckily it was triggered early in the day with few skiers around. Consider this avalanche the one and only free wake-up call we'll ever get. There's a lot to learn. The slope slid on a beautiful day with many tracks on it. It was undeniably unstable yet provides us with an opportunity to re evaluate how we ski, make decisions, and travel in the sidecountry.

Wake-Up Call in Montana

Story and photos by Alex Marienthal

It was a bluebird day. The temperature was around 27 degrees in the shade, and the sun was sitting higher than it has in past months making the south-facing slopes hold spring-like conditions, while the north-facing slopes were still soft from 23" of snowfall over the previous three days. The air was calm on the predominantly east-facing Bridger Bowl, but up on the ridgeline winds were westerly between 25 and 35mph.

We were hiking along the ridge toward Saddle Peak around 11am to ski inside the south boundary of the ski area were the snow was still looking fresh for a Tuesday after a large weekend storm. Before we crested a rocky spot on the ridgeline that blocked our view of the peak, I heard yelling from behind me. It wasn't the excited, "This snow is blower and we're stoked," kind of yell. It was more like, "Something might be wrong, everybody look!"

I turned to look down the slope where a large cloud of snow was moving away from us. When I realized the likely magnitude and possibility of an avalanche, I moved faster than I ever have with ski boots on and skis on my shoulder to get a better view. The first evidence was the debris in the runout zone where small trees stood, possibly 10- or 20-years old. Then I saw the crown about 1700' above the toe of the debris. It was 5-7' deep and extended 1000' across an E-NE aspect. Skiers were lined up on the ridgeline above where it fractured, and those who hiked blindly continued to exit the gate. I felt sick.

Before it happened the situation out there looked scary. Warm and windy with 3" of snow-water equivalent (SWE) over the last three days. The day after the avalanche Karl Birkeland and Mark Staples of GNFAC investigated the crown and discovered that there was 5" of SWE on top of the weak layer, which was below a hard wind slab that had been pointed out in December. This hard layer was protecting the weak base from skier compaction. It also prevented any small avalanches while the load grew to its tipping point, and the skiers who made hundreds of tracks down the face of the slope gained increasing confidence in side-country stability with every lap.

We got away very lucky. I hope people evaluate what the situation was, think about what they would have done, or what they were doing, and consider how that may change in the future. This is exciting new terrain we are dealing with, and it will be out there for many seasons to come. Some seasons will provide stable steep powder skiing, while others may restrict us to spinning lift laps and low-angle tours with our friends.

A friend of mine made a good point when he said, "The peaks will always be there next year." This season is one to be conservative. A weak base from the start has made anything a possibility, and many natural avalanches have warned of deep instabilities (the type that may not be affected by skier compaction or ski cuts). The risks and rewards of skiing sidecountry powder become a lot clearer after a day like this, and relying on luck in that high risk of a situation is hardly worth the turns. Stay safe.

Alex Marienthal *was born and raised in Gold Hill, Colorado, in the mountains west of Boulder. He has spent countless hours skiing in southwest Montana and has climbed and skied many of the peaks in the area while earning a bachelors degree in snow science and a minor in statistics at Montana State University.*

Notes on Saddle Peak Avalanche

Doug Richmond, 32-year veteran patroller at Bridger Bowl, snow safety director from 1996-2008:

A lot of people learned from this lucky episode. We still have lots of people asking questions and saying they are re-thinking their OB (out-of-bounds) skiing. However, skiing continues in that region, including more than one at a time on adjacent wind-loaded slopes. So some are not more cautious. Biggest lessons I am blabbing to those who ask:

- Cornice and pillow loading is almost always there, and it should be respected.
- The vast runout zone, including "Going Home Chute," is no place to loiter.
- People hiking out behind you present a serious hazard when you cross below them.

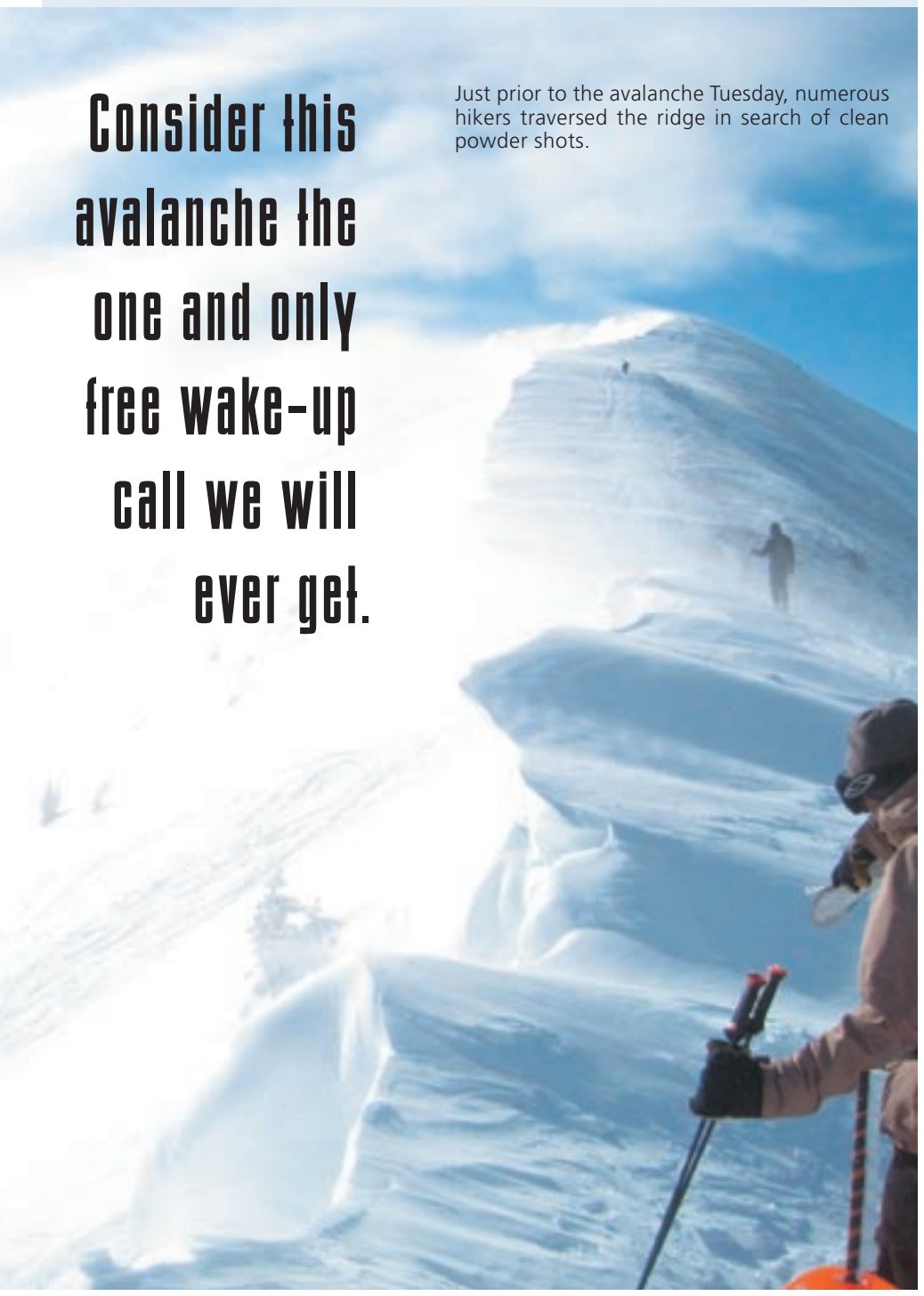
We are very lucky that we aren't attending memorials. Ten minutes either way, and it would have been a different story.

Fay Johnson, Bridger Bowl ski patrol director:

I agree with Richmond's statements. I think this event was an eye opener for some, but by no means all. I'd hate to think it would actually take one or more fatalities to really get people's attention.

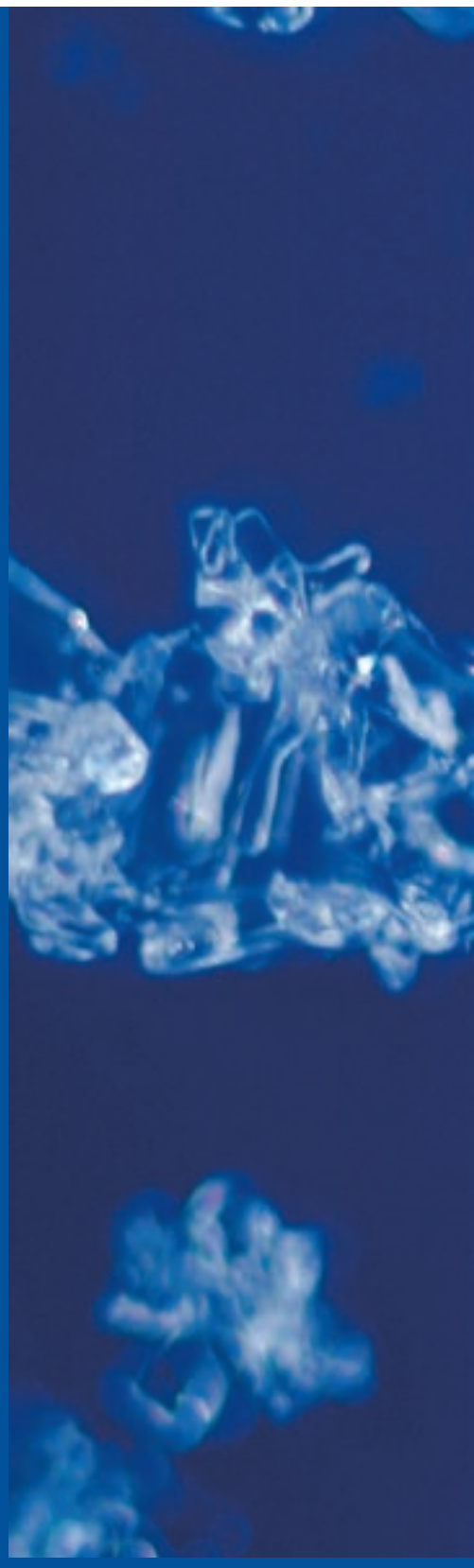
This did not change our approach to how we manage our in-bounds stuff. It was a good exercise in having to wait for all of the other backcountry skiers who were out there and conducting the hasty search to get low enough on the path before we sent other rescuers in – not wanting anyone above on the slope as additional triggers, etc.

The GNFAC presented a Saddle Peak avalanche question and answer session at the Bozeman Public Library on March 4, 2010. According to Doug Chabot, it went quite well, with a full house and lots of interest and learning.



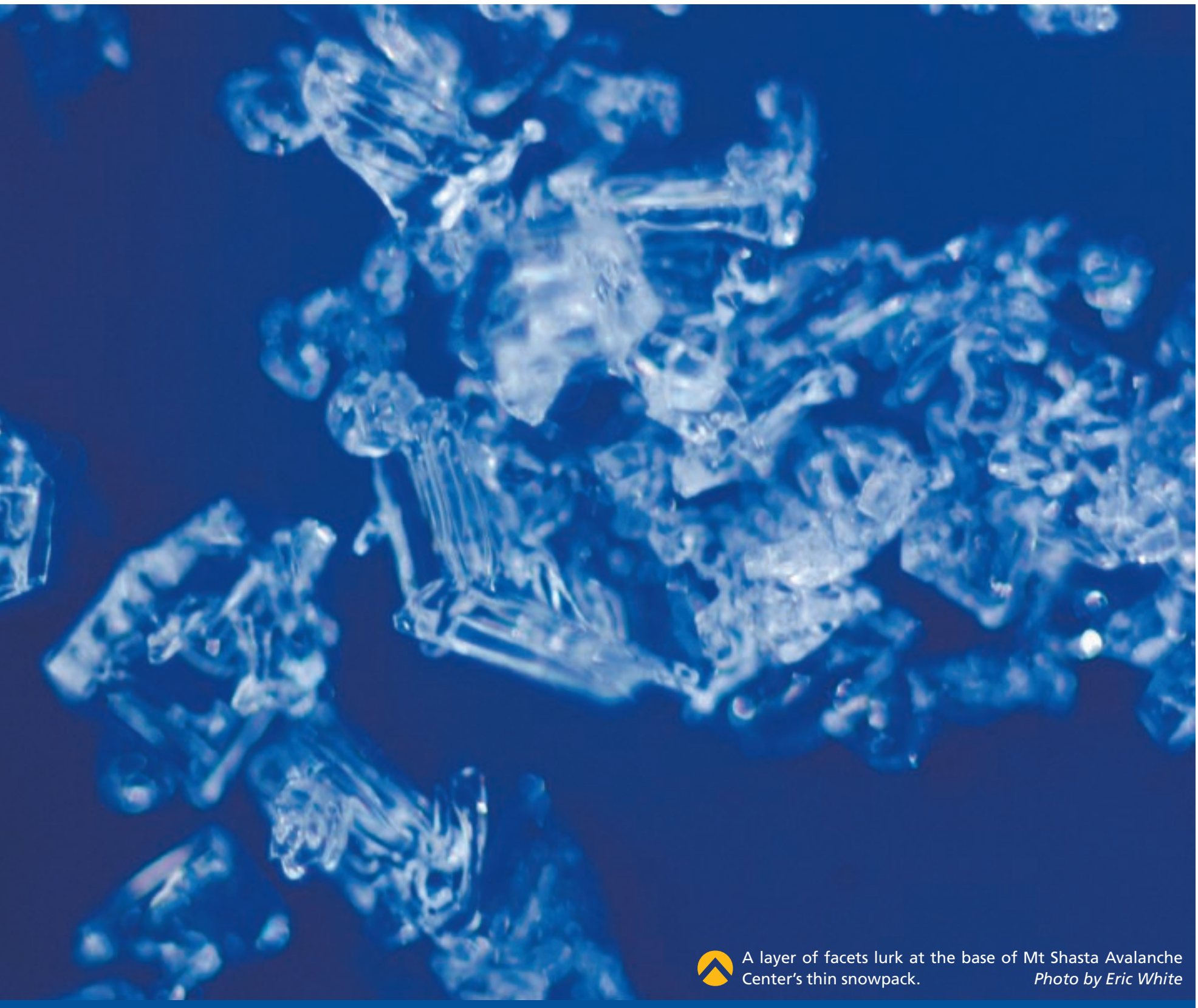
Just prior to the avalanche Tuesday, numerous hikers traversed the ridge in search of clean powder shots.

Photo Centerfold



Snowkiting in the Pisa Range, South to the top of Mt Pisa – didn't put my

It's been an active season here in the San Juans. We had quite a storm for about three days (February 18-21) with high S-SW winds and, though storm totals were variable in the region, about 2-4' of snow and 2-4" of water equivalent. Impressive natural cycle. We [Helitrax] flew on February 22 and shot the Ophir Road. We got excellent results on multiple paths. This sequence shows the West St Louis running and hitting the road. The slide was SS-AH-R4D3.5-O, about 2' deep, 300' wide and 2000' vertical. It put 6'x200' across the road. *Photos by Mark Rikkers*



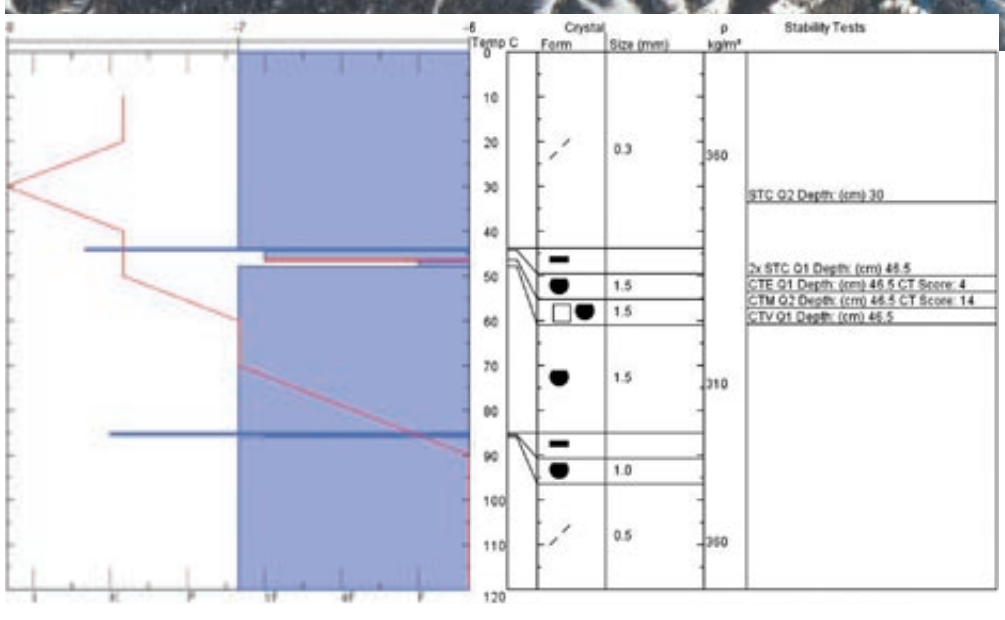
A layer of facets lurk at the base of Mt Shasta Avalanche Center's thin snowpack. *Photo by Eric White*

Island, New Zealand, August 2009.One day we kited 66km kite down once! Touring has taken on a new meaning ;-)
Photo by Laura Adams

This is Andy Gleason and myself [HP Marshall] making radar measurements in steep terrain beneath a cornice to map the snow stratigraphy in an avalanche starting zone (with Yukon my Alaskan husky too) at ~13,000' in Senator Beck Basin in southwest Colorado. Radar is on the pole between the two skiers. *Photo by James McCreight*

On January 17, 2010, an avalanche originating above Super Bowl slid down Clark Canyon then into Heather Canyon – almost all the way to the Heather chairlift. The deposition zone is hundreds of yards long and 15-30' deep. *Top photos by Steve Warila*

below: Mt Hood Meadows ski area, with Wy'east Face at top of photo.

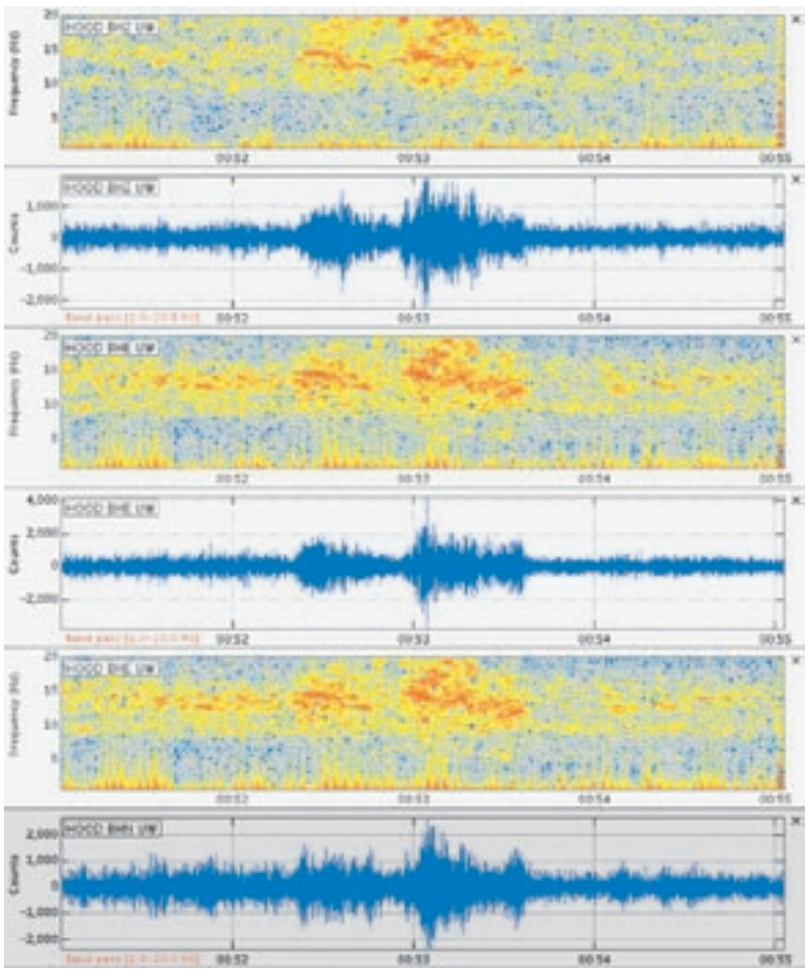


Snow Pit Profile — Observer: **Nicholi Stoyanoff**
WyEast face — **Fri Jan 22 16:00:00 PST 2010**
Cascade, OR — Co-ord: **W N**
Elevation (ft) **9880** — Slope: **35**
Aspect: **130** — Wind loading: **yes**
Activities: **Recent act on sim slopes. Recent act on diff slopes.**
Notes: **See attached notes.**

Stability on similar slopes: **Poor**	Stability Test Notes:	Layer notes:
Air Temperature: **-10.6 C**	**46.5: sp**	**46.5-48: faceted mltforms**
Sky Cover: **sky 4/8 to 8/8 covered**	**46.5: sp, popped**	**48-85: faceted mltforms**
Precipitation: **Snow < 0.5 cm/hr**	**46.5: failed under cr**	**86-120: end obs**
Wind: **E Light Breeze**		

Crown profile from the event on 20100117:
47-48.5 layer was pouring out of the pit wall, very non-cohesive. We feel the slide initiated and failed at 46.5, and once it started to build energy and mass, it stepped down to the crust at 85.

The photos at right give a patchwork impression of the huge river of debris. The avalanche fell a 2.75-mile slope distance and 5385' of vertical, leaving a nearly two-mile path of destruction through the ski area. The deposit was an average of 200' wide, 1500' long and 15' deep with areas close to 30' deep. *photo 1 by Steve Warila, photo 2 by Matthew Aimonetti, photos 3-4 by Nicholi Stoyanoff*



The avalanche even left a seismic signature on the Hood geophones.

Avalanche Shakes Up Mt Hood Meadows

Story by Nicholi Stoyanoff

Distracted is a good way to describe the way I felt that morning. I found myself staring at the powerful aftermath of a large avalanche that started above and traveled well into our permit area. The track had gouged down to earth in multiple spots and lead to a debris pile that seemingly had no end. It is one thing to look at pictures of a large event that has happened in the past, it is entirely another to climb through the deposit and smell the freshly snapped trees stuck in the debris, reluctantly accepting the reality of it all.

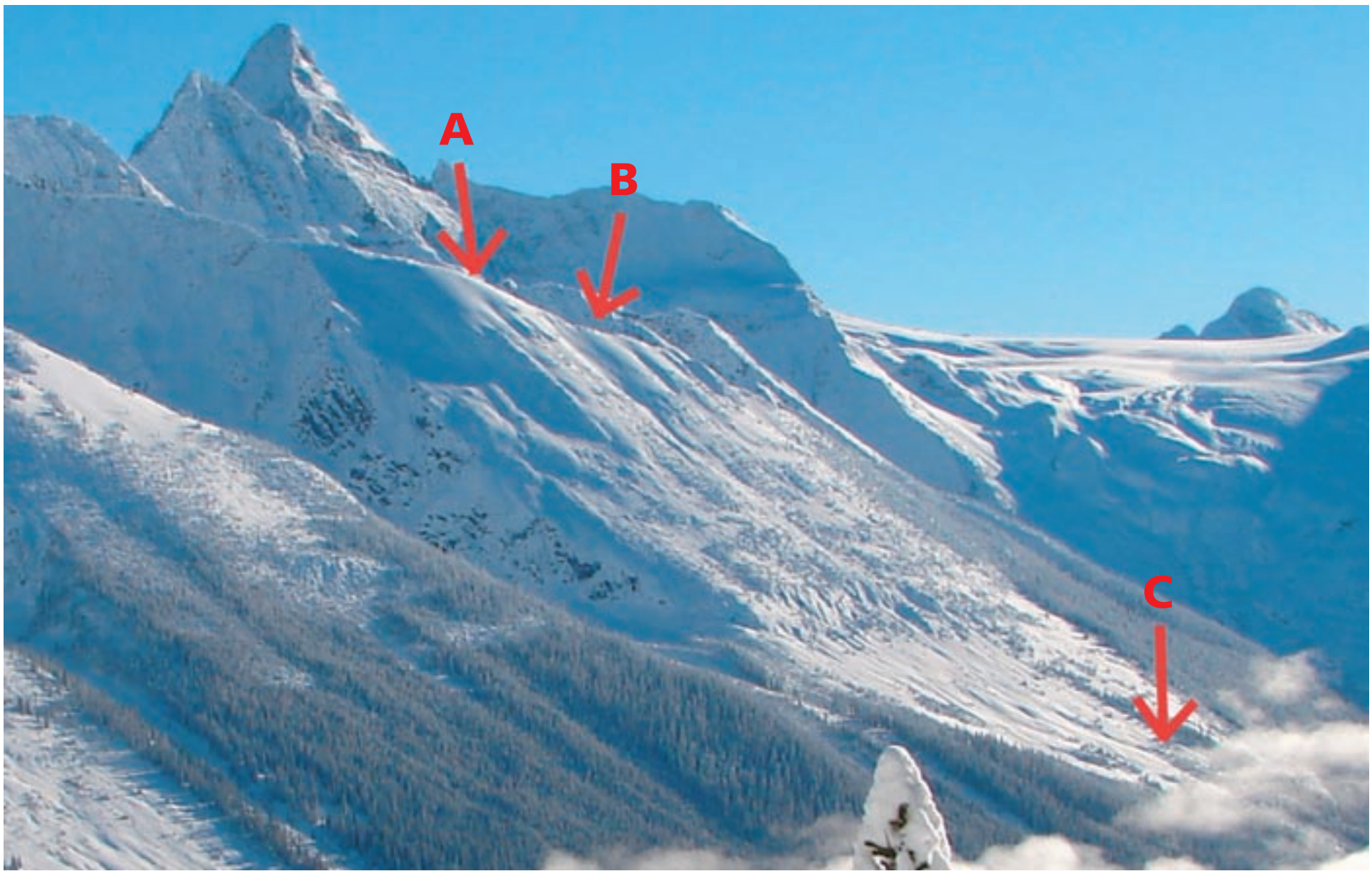
This natural hard slab (HS-N-R4-D4-O) occurred only a couple of hours after sweeps on January 17 but wasn't discovered until the next morning during normal avalanche-reduction routes. The crown depth ranged from 2' to 10' deep and was almost three-quarters of a mile wide. It ran from 10,650' on Wy'East Face to 5265' in the Heather drainage for a 2.75-mile slope distance and 5385' of vertical; leaving a nearly two-mile path of destruction through the ski area. The deposit was an average of 200' wide, 1500' long and 15' deep with areas close to 30' deep.

Attempting to draw a correlation between the observed weather at the base area station (5250') and the top of Wy'East face (10,650') can often be a challenge. A little wet snow fell on January 9 and 10 at elevations above 8000', with increased warming and a small spattering of rain followed by rapid cooling on the 11th, a thin water ice crust had formed but was quickly buried by new snow. Then 2" of water equivalent for only 15.5" of snow spread out over the next six days in the base area. The top weather station at 6600' recorded average winds from the 9th through the 18th as 12mph out of the southwest. Temperatures at the top station for the 12-hour period preceding the event also revealed no significant spikes or trends. For Mt Hood, a fairly typical storm.

The crown profile revealed a 1.5cm-thick failure plane of fist-hard faceted melt forms sitting just below the ice lens from the 11th. The failure plane freely poured from the layer into the pit. Loaded on top of that whole structure was one-finger plus hard slab.

Since 1976 there have been 16 recorded natural events size R4 or bigger that have traveled through the Clark drainage; six of those events have reached the confluence of Heather and Clark Canyons or made it well past. If history itself has created a strong desire to know more about what causes these events to happen, then the reality of this event will continue to keep me distracted seeking the reasons why.

Nicholi Stoyanoff *works as snow safety at Mt Hood Meadows Ski Resort. He is constantly pondering how to surf turns on water, in whatever form found.* ❄



Point A on Avalanche Crest *(see topo map on next page)* indicates where skier Robert Quade triggered the avalanche. Point B shows the location from which the video and pictures were shot, and point C indicates the terminus of the slide debris. Following the sunny ridge between the red arrows, the avalanche developed into a size 2 by the time it reached the steep bench in the middle. *Photo by Robert Quade*

Several Perspectives on a Day at Rogers Pass

Story by Sharon Bader, Adrian Bostock, Lee Lau, Robert Quade, and Tyler Wilkes

A random accrual of ski buddies led to a ski tour day on Avalanche Crest, an obvious path and stunning line that drops down to the Trans-Canada Highway just west of the Glacier Park visitors' center. Making decisions in a large group can be challenging, especially with a group of mixed abilities and risk tolerances. These backcountry travelers apply 20/20 hindsight and remarkable self-awareness (albeit after-the-fact) to the proceedings of January 9, 2010. Check out their video of the actual event at http://vimeo.com/8681416.

Lee Lau: On a three-day trip to Rogers Pass in January of 2010, Sharon, Gav, Tyler and I were looking for snow and big lines. Revelstoke local Robert and another old friend from Salmon Arm, Adrian, joined us for a day of turns on Avalanche Crest.

Tyler Wilkes: West-facing pit about 100m below on the ridge gave moderate results. Clearly the crust/surface hoar was sheltered from the wind in some areas and not others, so it's very unpredictable at higher elevations. Luckily our buddy skied onto the tree anchor easily and stayed out of the slide – but it could have been ugly.

The video of the slide can be found at http://vimeo.com/8681416.

Robert Quade: I'm the skier in that video. I do feel fairly lucky and also pretty stupid about the whole thing. I had done a number of stability tests on the way up that made me feel pretty good, but a simple handpit on that slope would have shown me the easy Q1 shear, surface hoar on sun crust. We had expected super touchy surface hoar at treeline, but not on an exposed ridge in the alpine.

The turn that initiated the slab was MUCH harder than my turns before it, my thinking is that the extra force was enough to get it to pop. Not to say it wouldn't have gone anyway.

Midway through that turn I noticed a few things were off. The snow was much deeper there and the turn felt a little strange – mostly I just had a feeling that something was wrong. I was already skiing towards the mini tree island and decided it was a great impromptu place to stop. I had no clue that I had triggered the slide until just before it knocked me off of my feet. At that point I let myself get pushed onto the trees, put an edge against them, and held my ground.

The initial size 1 ran for 400m down a gully before hitting a slightly steeper bench at treeline. When it got there, the slide propagated big time, and it turned into a solid size 2, running for another 200-300m before stopping just above the mature trees.

The debris deposition wasn't that deep, probably not enough to totally bury me. The ride down had a number of sharp pointy things that stood a good chance of messing up my day. Thankfully I got to watch it all from the top.

Lee can be heard at the end of the video telling me that I can traverse back to the group, but there was a slightly different aspect between us that didn't slide. I wasn't eager to cross it, and the remainder of my group didn't want to ski down it. By far the smartest and safest option was for me to ski the rest of the run solo and for the group to find another way down. I think they picked one of the slopes I had previously booted a cornice onto. Lee was able to see my entire run top to bottom. I had some great turns down it just beside the track and stopped at the bottom to poke around a bit. I then hit the trees and proceeded back to the car to wait.

I think staying calm in bad situations is one of the best traits anybody can look for in a backcountry partner. Certainly it helped keep me out of trouble and also allowed my group to leave me and go somewhere safer. I'm grateful I was skiing with like-minded people who didn't overreact.

The photo at the top of this page points out where I dropped in, where the video/pictures were shot from and where the slide stopped. My line and the avy basically follow the sunny ridge between the red arrows. The steep bench in the middle is where it turned into a size 2.

Please don't tell my mother, she sleeps better at night not knowing these things. Questions? Comments?

Robert Quade: On our climb up the ridgeline, I stopped and dug a pit. The SH scored ECTN, ECTN, CTM12 Q2 (if memory serves). I also booted two different cornices off, neither weighed more than 50lbs though. All of these tests were on perfectly representative slopes. With all of that, I felt we had a pretty good handle on stability. Lee and I put stability at fair with moderate-considerable danger.

As I was skinning up the slope that I skied, I gave a couple good stomps on my kick turns and poked around a bit. I subsequently found out that one of our group had started to follow me, but his quick handpit made him back off. He was a self-proclaimed chicken, so I'm not certain if I would have done anything differently had I known.

In hindsight, essentially the one lesson I took from this was to dig more handpits. They're easy, fast, and give decent information. I regret not doing a crown profile, but I wasn't exactly in the greatest spot.

Ultimately, I put too much stock into my previous tests and should have more thoroughly checked out my line before dropping in. A slight difference in slope angle and aspect made all the difference it seems.

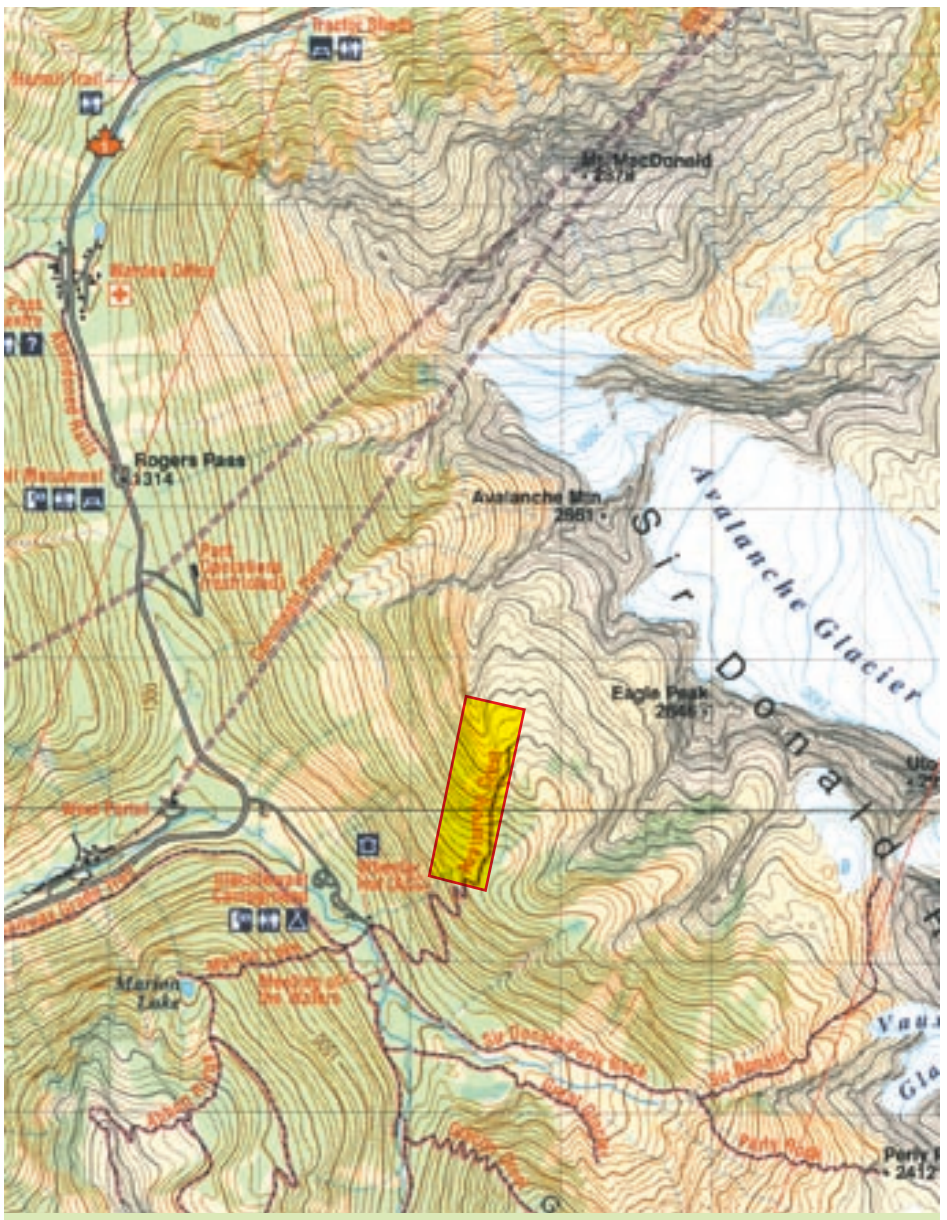
The other mistake that I made was forgetting about the sun crust. I had been skiing a similar aspect for a few days prior to that. On the way up I had intended to take us to a more open northwest-facing shot because I knew the crust disappeared north of 270 degrees. The rest of the group decided not to ski that shot, and I simply spaced out about the crust when we dropped in.

Adrian Bostock: Self-proclaimed chicken shit here.

The biggest lesson to take way from this is one that has not been touched on: group dynamics. They play a huge role in the

Continued on page 22 ➡

Lee Lau and Sharon Bader captured this time-lapse sequence of Robert Quade dropping into his shot, triggering the deeper, more sensitive pocket which then flowed past him.



The Avalanche Crest ridge *(highlighted, above)* runs east/west, and the ski shot drops dramatically down to the road.

Backcountry Avalanche Hazard Reports

Issued: Saturday, January 9, 2010 08:00

Bulletin Area: This bulletin covers the areas adjacent to the Trans Canada Highway corridor in Glacier National Park and the drainages directly accessed from this corridor.

Danger Rating:

	SATURDAY	SUNDAY	MONDAY
Alpine	3-Considerable	3-Considerable	3-Considerable
Treeline	3-Considerable	3-Considerable	3-Considerable
Below Treeline	2-Moderate	2-Moderate	2-Moderate

Synopsis: Approximately 50cm of storm snow is settling on a layer of surface hoar which is highly variable over elevation and terrain in regard to layer thickness and sensitivity. This layer is most reactive at and near treeline. On steep southeast to southwest aspects the surface hoar sits on top of a thin sun crust. While the instance of naturally occurring avalanches on this layer has diminished, the combination of settling storm snow and the lingering nature of the weak layer make backcountry conditions highly susceptible to human triggering. Caution is advised particularly at treeline when entering sheltered areas, steep open slopes with convex features and avoid gullies and terrain traps.

In the alpine, rising winds and additional new snow will increase the possiblity of windslabs near ridgecrests today and through the weekend.

Highlights of recent snowpack investigations on a variety of aspects at and below treeline include rutschblock scores of 1 and 2 with the whole block failing down 35 to 45cm on the surface hoar layer. The existence of suncrust under the surface hoar was noted on the SW facing slope on Grizzly Shoulder.

Avalanche Activity: Natural activity has been minimal for the past few days, however some natural activity may be possible today with the rising winds.

At and near treeline, many reports of skier-controlled and accidental avalanches have been observed or reported over the past week. Failure depths were 35 to 40cm and involved the December 29 surface hoar or surface hoar/crust combination. Avalanche sizes were reported as 1.0 to 1.5 with crown widths up to 40m and running to 40m in length.

GLACIER NATIONAL PARK – the next day
Issued: Sunday, January 10, 2010 08:00

Avalanche Activity: Several natural avalanches, size 2, occurred yesterday from steep north-facing start zones in association with the rising winds. These events stopped at the top of normal runouts. Similar natural activity is possible today.

Skier-triggered avalanches are continuing with increasing frequency on the December 29 surface hoar 30 to 50cm deep with three events reported yesterday. On a west aspect of Avalanche Crest at 2300m a slab was triggered near the ridgeline that subsequently initiated a wider slab at 1800m. The bed surface was surface hoar on a suncrust, and the avalanche, size 2-2.5, ran 600m to the bench below.

ROGERS PASS

continued from page 20

backcountry and go largely ignored.

We were a large group (six). Of those six, I had only met three before. We had zero ability to read each other or to know whose judgment to trust, though it was pretty obvious from the start that Robert and I were at opposite ends of the spectrum when is comes to acceptable risk.

I don't blame Robert for not trusting my opinion. I was feeling very gun-shy. Even though I had 25 or so days touring under my belt to the west, I had not skied the pass yet this year. In the week leading up to this we had seen much avalanche activity. A couple of my friends had gone for rides. I really was not feeling it. Even I was questioning my decision to back down considering how sure Robert was. But there was no way in hell I was going to ski that slope. Nothing about it seemed right to me. The quick hand shear I did was the straw that broke the back (sorry for the cliché).

Robert was pretty sure of what he wanted to ski; I was willing to look at it but more than willing to turn back. The rest of the group fell into two camps split along those lines. Some did not even want to look at the line. That sort of forced the decision to not carry on along the ridge and to drop in sooner then planned. The decision happened quickly and with a huge amount of compromise.

Just wanted to add my observations to the pot. While Robert was busy charging up the ridge, I had a small slab pop under my skis on a convex roll and slip on a very smooth surface. Lots of collapses along the ridge following Robert's skin track.

Something I've noticed a lot is that the first guy seldom gets any reaction along the skin track; it's the next two people along who really gather the info. I've been in this situation before where I have been setting skin track, keen to ski something, and the people behind me have been noticing collapses. Gone ignored, those days have all ended with someone going for a ride.

Lee Lau: Obviously there's some self-appraisal going on about decision-making after this exercise, and I'm going to put them in bullet points.

- This is a good case study for group dynamics and heuristics. Adrian already described the composition of the group. Let me add that of the six in the group, myself and Robert are used to wearing the expert halo. Can't speak to Adrian and the group with which he skis. Sharon is as knowledgeable as me but less pushy/verbal. Tyler is less experienced but not afraid to voice an opinion. Gavan is least experienced and admitted that he followed.

- I was overly reliant on Robert's previous experience in skiing that very same general area of terrain only two days before – I was generally deferential to him. I was also aware that Robert is very capable and in my opinion not ego driven or goal driven, so tended to defer to his judgment in the Rogers Pass area.

- I was also overly reliant on good stability results we had skiing a big, steep SE aspect (Lone Pine) from the day before. I (incorrectly) extrapolated from the relatively stable snow in the alpine of Lone Pine that the sun crust and surface hoar combination would also be benign on the west aspects of Avalanche Crest.

  For those two reasons I also failed to put importance on Adrian's sudden planar handpit test on that very slope Robert skied. In retrospect that was a glaring error given that this was perhaps about as representative a test as one could do.

- I wasn't too crazy about the slope Robert wanted to ski (poorly anchored, convex, long way down) and refused to follow his skin track onto the ridge proper. I rationalized that decision verbally to the group and to Robert by saying I would take pictures and spot him. I also said that I didn't want to let him ski the route solo and would follow him down the slope later.

  Thinking back on it, perhaps I was a psychological enabler in that I half-supported Robert's decision, but for reasons that were poorly thought out. Honest self-examination is that I wasn't doing that for macho reasons. I have skied much steeper and more demanding terrain, so I can't say there was any desire to prove myself. I can't think of why I wasn't more willing to follow Adrian and Tyler's openly verbalized desire to not ski the slope that slid and just back down the ridge.

This was a very intense experience I personally do not want to repeat. Thanks to Wilkes for shooting the video, for Robert and Adrian articulating their thoughts, and to the peanut gallery for providing an audience.

Tyler Wilkes: I am group member four. I've only been splitboarding for three seasons, so I am on the inexperienced list from the group. Although I like to think that in my three seasons (approximately 100 ski days) I have experienced quite a number of different places and conditions across British Columbia (i.e., last year on the coast). From my point of view, here is what I saw:

- Nobody in the group was very confident in the snowpack in that area.

- Robert did a very good job of analyzing the snowpack on a representative slope. On the actual slope that slid, he analyzed the terrain well and knew exactly where his safe spots were. I think he did everything in his power to mitigate risk on that slope (other than not skiing it).

- In the short distance (100-200m) along the ridge between where the pit was dug and the slope that slid, I felt collapses and watched Adrian's handpits. I sided with the more conservative choice based on that data, my own observations, and the fact that I have known Adrian for five years and met Robert the day of the trip.

- When Robert made the decision to climb the extra 50m up to where he started the slide, Lee and Gavan decided not to do the extra climb but would ski behind him. The other three of us agreed to head back down the ridge to a lower-angle slope that was less of a terrain trap so that the risk was much more manageable. In fact, my exact reasoning was, "I would rather ski a lower-angle slope more aggressively and with less uncertainty than ski a better (steeper) line and take an unnecessary risk knowing I could have made a safer decision."

- There was no disagreement in the group at all. Everybody made his or her own decision. I think we all handled the situation extremely well.

- Being a less experienced member of the group, I made a decision for myself and did not try to convince Lee, Gavan, or Robert to change their decision. Obviously hindsight is 20/20, and perhaps the conservative group could have done more to sway opinions. On the other hand, all three of them could easily have skied the slope and had the run of a lifetime and maybe the conservative group would have followed. Who knows?

What did I learn from it all? Trust your knowledge and your instincts. Don't be afraid to voice your opinion in a group. Don't just follow blindly, even if you are following experienced people.

Robert Quade digs a test pit just north of the Avalanche Crest ridgeline. The Trans-Canada Highway runs far below him. *Photo by Sharon Bader and Lee Lau*

Sharon Bader *has been ski touring since 1991. She is an avid outdoorsperson who enjoys the challenges and serenity the mountains offer. You will find her on her skis in the winter and mountain bike in the summer.*

Adrian Bostock *is a fourth-generation Salmon Arm dirtbag who earns adventure funds planting trees for the forest industry. He has mountain biked extensively throughout the BC and Alberta backcountry, as well as the dirtier parts of Asia. After spending his early 20s in Lake Louise he is currently picking away at west Monashee pow stashes. He is a fan of early mornings, whiskey, and knee socks.*

Lee Lau *is an avid skier and outdoorsman who embarks on many adventures with his loving and sometimes concerned wife, Sharon. He has over 15 years of experience backcountry skiing and dabbles in mountaineering. In the "off-season" he is occasionally found working in his day job as an intellectual property lawyer when he is not mountain biking. As a resident of Vancouver and Whistler, British Columbia, Lee's playground extends mainly to western Canada, including southwest BC and the Selkirks.*

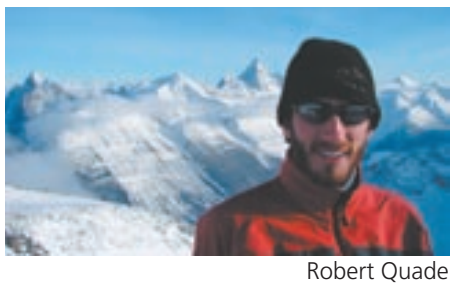
Robert Quade *is 26-years old and has been in Revelstoke for the past two years. This is his seventh season since touring became his primary passion, and this is the biggest unintentionally triggered slide he has been involved with during that time.*

Tyler Wilkes *is a 23-year-old university student who was born and raised in Vancouver, BC. He has been snowboarding over 15 years and has three years of backcountry experience, mostly in the Coast Mountains and Rogers Pass.* ❄

Sharon Bader

Adrian Bostock

Lee Lau



Robert Quade

Tyler Wilkes

snow science

How Does An Avalanche Cycle Affect Future Snowpack Instability?

Perspectives from Mike Richardson, Randy Spence, Nick Armitage, and Peter Carvelli

The following questions appeared on an Internet bulletin board for recreational backcountry skiers, and they are a common topic of discussion among both avalanche professionals and recreational backcountry skiers alike.

Does widespread avalanching effectively "reset" the snowpack by clearing out the weak layer?

Are thick layers such as surface hoar, depth hoar, and graupel readily cleaned up by widespread avalanching?

Are harder or thinner layers, such as crusts, less easily cleaned up by widespread avalanching?

Natural avalanches on Fan Mountain, Madison Range near Big Sky, Montana: January 6, 2010. *Photo by Randy Spence*

Mike Richardson discusses the scientific and human aspects:

The size of the forecast region is the most important factor, with precise answers only available for very small areas. However, even for small areas, the chaotic interaction between terrain and weather makes it difficult to predict the effects of widespread avalanching on future snowpack instability. The following scenario, which is just one possibility out of many, hints at the overall complexity of this forecasting problem.

Instability will persist when a bed surface composed of faceted crystals is immediately reloaded during a storm. On the other hand, future snowpack instability on that slope will be very different if the faceted crystals exposed by avalanching are subjected to multiple melt/freeze cycles prior to the next storm. Melt/freeze activity is often limited by aspect, so it is possible for the faceting process to continue on cold aspects, while faceted crystals on warm aspects undergo rounding as a result of melt/freeze metamorphism. In this highly general scenario, the weather builds new patterns of snowpack instability that are difficult to uncover without careful observations.

Therefore, for most recreational skiers, knowledge of a recent avalanche cycle is a very general and imprecise piece of information. General information often has a dangerous and unwarranted influence on individual or group beliefs about the presence of instability and its parameters. Without abundant information, expert knowledge, and significant experience *(Randy and Nick provide great examples of this)*, a recent avalanche cycle should not exert undue influence on recreational travel choices and decision-making at any operational scale. More than anything, incremental changes to the snowpack caused by synoptic scale weather events will alter the characteristics of the danger but won't eliminate it.

The chaotic relationship between terrain and weather is a primary source of uncertainty.

- Incremental changes to the snowpack are a primary source of uncertainty.
- Avalanches remove weak snow from some, but not all, slopes.
- Avalanches may or may not remove all the weak snow from a specific slope.
- Use multiple sources of information to determine the likelihood of avalanche formation.
- An avalanche cycle over a large area certainly does not mean a specific slope is safe.
- Proactively managing uncertainty is essential to safe decisions.

Randy Spence answers:

My perspective is from the point of view of ski area operations and avalanche-hazard reduction.

On Lone Mountain at Moonlight Basin and Big Sky it is very common to receive larger than average snow events in October and November followed by a prolonged cold and dry period of weather. This scenario sets up an early season snowpack that is composed of slabs and weak layers (the shit sandwich) with the slabs bridging or protecting the weak layers from the effects of skier compaction once the areas have been opened for the season.

The winter snowfall patterns in the Madison range are of many small precipitation events that allow for a gradual buildup of additional, thicker slabs over the top of the sandwiches. With these events coming so gradually, we tend toward developing a snow surface that can be skied and opened to the public while giving the forecasters nightmares about when we will overload the bridge and begin a widespread cycle of avalanches that do reach down into the sandwich.

The sheer size of many of the paths on the Big Sky side of Lone Mountain and the lack of reliable early season access makes boot packing of some areas difficult if not impossible.

On the Moonlight side, we deal with two regions:

The ***Headwaters*** area paths generally face a northerly aspect and are confined gullies. The gullies develop bridged slabs, yet skier compaction and explosives testing seem to disrupt the size of most slabs and tend to reduce the number of large, widespread events and failures. The sandwich is present in pit data until late February of most years and can persist through the entire season in other years.

The ***North Summit*** complex is 1000' higher in general elevation and while it also faces north, the area is subject to much more wind. The slab areas are wider and less confined and we tend to experience many more repeat performances within that area.

Broadly speaking, once we overload the slab and begin to experience the onset of an avalanche cycle it may continue for days or a week or more with some paths running piecemeal or failing completely and running huge. In the aftermath of each event we try to reopen the terrain as soon as it may be safely navigated by our skiers. The local skiers have a high tolerance for skiing over rocks and will then affect the weak faceted layers that remain and begin to build a stronger basal structure that will support a pretty good load.

One trick when dealing with this kind of situation is to have the memory of an elephant and be able to recall what areas have cleaned out and what areas haven't. Or, if you have the memory that I do, you can use digital images to record each event and track them accordingly. Big Sky has used this technique with good success.

At Moonlight Basin we occasionally use what I call the five-card draw method. That is to get to the point where you begin to become concerned about failure of your supports and can somewhat accurately predict the arrival of the next series of storms. Then force as much failure as possible through larger shots and, in effect, keep your ace and draw four new cards.

Once you have your new hand you are pretty well stuck with it. Getting patrollers and tolerant locals to mix any new snow with the older remains of the sandwich is the key part. This may involve the nerve-wracking process of keeping some areas closed while allowing traffic into adjacent areas you are trying to heal.

In effect, this is a reset of the existing snowpack. The theory does apply for smaller and more confined avalanche paths within the boundaries of operational ski areas.

Attempting to apply the same theory to uncompacted and uncontrolled avalanche terrain is akin to comparing apples to oranges and may lead to a very unpleasant surprise.

Nick Armitage, Big Sky avalanche forecaster, adds the following:

I think this conversation often comes up with recreationists looking for a silver bullet in slope-by-slope forecasting. This probably goes without saying but…silver bullets are a red flag in avalanche forecasting. Mike covers all the variables of this issue well, but to summarize, "It just depends."

As a generalization, I think the professional avalanche community would agree that avalanching usually clears out weak layers. They are fragile by nature. So, I respond to this question with a question to the avalanche community and those more qualified

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SNOWPACK HISTORY

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to speculate on this topic: What are the forecasting challenges/solutions when avalanching does not "reset" or increase stability?

Two examples come to mind. First, the scenario much of the mountain West has been dealing with this season: multiple persistent weak layers. We dealt with several large paths that would avalanche, reload, and then have a similar avalanche a week or two later on another layer deeper in the pack. This piecemeal effect gave us a challenge within the challenge this season. With several 7+ cm thick weak layers, there was no single "bad guy" that we were going after. We just did not like our wimpy snowpack in many ways. Our approach has included regular explosives testing with varied shot placements, ski tracks, and regular status checks (snowpits).

The second scenario, which we are familiar with at Big Sky, involves a prominent sun and/or rain crust that commonly forms in October or November. We will trigger full-width 2-3m deep slabs, and then it will happen again on the same bed surface days or weeks later. This issue addresses the third question asked of this discussion relating to bed surfaces and their interface with the layers sitting on them. As Randy stated, patrol attention, explosives, and public traffic are the tools that get us past these recurring slides. The challenge in forecasting and managing these layers involves timing in accessing that crust as new snow is being deposited. The mere existence of such a bed surface means the "reset" does not automatically apply. As a new forecaster I look forward to future discussions on these issues.

Peter Carvelli answers:

Skiing in central Colorado means living with weak faceted snow layers every year, so this season is not unprecedented. A shallow snow cover is a primary ingredient for growing facets. Clear skies and relatively cold temps are the other major contributing ingredients for facet growth. This early season, infrequent storms and cold clear periods between storms were the norm for the mountain West, not just Colorado, so facet layer development affected many regions.

When we talk about metamorphism, we generally think in terms of change beneath the surface (think depth hoar or settlement/rounding), BUT it is the snow surface that undergoes the most significant change. It is my belief that surface facets, not depth hoar, are a primary failure layer in the continental climate. That said, surface hoar and buried stellars also are significant weak layers – graupel less so here.

What is required for slab release? A slab, a weak layer (crack-propagation pathway), some people might add a stiff substructure (bed surface), a propagating crack, and an overcoming of the frictional force between slab and substructure post collapse. Destructive avalanching can occur when a substantial slab quickly overlays a weak old surface. This combination doesn't always produce spontaneous avalanches, or may produce them in some paths but not others, or in a lot of paths but not all of them.

Then what? Are the released paths safe? Are the loaded paths unsafe?

How does one define the term "widespread avalanching?" Does it mean 20, 40, 60, or 80% of an area has released? Does it account for all aspects and

Resetting the Snowpack, Alaska-style

Story and photos by Lisa Portune

This photo of Tincan shows a skier-triggered slide from Saturday, February 6, 2010. The guy was partially buried but dug himself out. We watched the whole thing happen, as we had a sneaking suspicion something was going to pop. This slope now has 7.5' (yes, that's FEET) on top of the old bed surface.

There were a few small avalanches in this bowl on Tincan prior to the one pictured above, but nothing significant – not really a repeat offender. (Funny, we actually have a slide path on the motorized side called "Repeat Offender.")

The avalanche happened on February 6, 2010, the day after we got 12" snow/1" SWE burying a layer of surface hoar on a thin crust. It kept snowing for a few days after, and then the El Niño firehose let loose starting February 9. We got a full-on shellacking to say the least: 10 days of horizontal rain below 1000', gale- to storm-force east winds, 7.5' of snow, 9" of water. The Girdwood Valley got a bit more than Turnagain Pass (10-14' of snow above 1500').

Skies cleared up for one day in the middle of the storm, which unfortunately was the Saturday of a holiday weekend (February 13). By the end of the day three people were dead in two separate avalanches. The body of one of the victims was just recently recovered on Monday, February 22. Search crews had to wait for the storm to subside, and then it took three days of probing to find him.

The storm and the snowpack hit critical mass on February 18 – the first day we have ever issued an Extreme danger rating. Once skies cleared on the 20th, we got to survey the aftermath, and it was a sight to behold – some of the biggest naturals I have ever seen. So, in a nutshell, we have completely reset our entire snowpack.

For a photo gallery of the naturals, go to www.cnfaic.org/fotogallery.php.

***Lisa Portune** is an avalanche forecaster for the Chugach National Forest Avalanche Forecast Center.*

An aerial view of Tincan shows the bowl (left, with all the ski tracks) where the slide happened.

elevation zones? Full paths or partial? How about sub paths, open pitches, and terrain traps?

We can address what happens when a specific path avalanches. The slab is removed, the weak layer is removed, destroyed, altered, and the bed surface and snow substrate are thoroughly tested for stability.

What happens next is dictated by weather. An avalanched path is back to a shallow snow cover. Is the next storm a few centimeters or a meter? Following the storm is there a clear and cold period, or is it back to snow and cloud cover? Are we seeing another cycle of facet growth and new slab? SH and slab? Or a regime of continuous snowfall resulting in a thick well-settled layer of consolidated rounded grains with no significant interfaces?

In unreleased areas, as a weak layer is buried, it generally becomes more difficult to elicit failure (start a crack propagating). In order to start a crack in the weak layer, the weak layer must first be deformed. As the distance between load (skier) and weak layer increases, and as the slab stiffens or densifies, probability of deformation decreases. On the flip side, a release will likely be more destructive with increasing slab mass. At the margins the slab may thin enough for a load to deform a weak layer. A terrain feature or change in slope angle may increase probability of weak layer deformation with load.

With SH involved, a weak layer may lie dormant and become susceptible to deformation and failure with increasing slab mass.

In spring, initial warmup may bring wet slab releases, which seem to be dependant on buried weak layers losing strength.

A digression into the real questions here, which revolve around risk, risk appetite, probability, reward, pertinent information, knowledge acquisition, decision-making, personal responsibility, uncertainty, and NOWcasting:

Probability can be defined as the likelihood of an event occurring, in this case an avalanche. ***Risk*** is then defined as the probability of an event occurring with consequence. ***Risk assessment*** can be defined as an attempt to gather any and all pertinent information, with analysis of that information to predict a reasonably accurate probability of an event occurring (an avalanche) right here and now when interacting with the system (this snow-covered slope). ***Uncertainty*** may be defined as the probability of an incorrect assessment. ***Risk appetite*** is an individual's tolerance for risk and includes a clear understanding of consequence. ***Decision-making*** involves combining a good risk assessment, a clear understanding of risk appetite and reward, and a knowledge of the meaning of uncertainty in order to reach a go/no-go decision. ***Personal responsibility*** means just that, taking ownership of a decision with consequence.

Knowledge acquisition begins with a first day of skiing and accumulates over the years. It also starts with the first snowfall of each season, obviously includes terrain and is a tremendous resource.

NOWcasting differs from risk assessment slightly as it involves building an understanding of what's happening NOW, starting from awakening this day. Do I have a good feeling today? Who am I going with? Where? What's the goal? Alternatives? Recent wx? Today's wx? New load? How great? Wind? Direction, how long, how strong? Aspect? Snowpit info? Many or few? Signs of recent avalanching? Signs of instability? Slope angle? What's above? What is below? What time of year? What time of day? Terrain features? Traps? Elevation band? Treed or open? Weak layers? Stability tests?

All this stuff and more, weighted accordingly…continually assessed and updated and updated and assessed…

Now back to the questions at hand:

Resets may be possible in a given, observed path, but the reset may be a less stable configuration than the original snow cover, depending on wx events. Widespread avalanching simply increases the uncertainty of a risk assessment. True resets only happen seasonally, with snow melt in the spring and snow accretion during the fall and winter months. Any weak layer that fails and results in avalanching is effectively destroyed and will not likely contribute to another round of avalanching. The same cannot be said for the bed surface or the avalanche path itself. Weak layers below the bed surface are also very unlikely to fail except under extreme conditions.

To sum it up, two rules of thumb apply to all snow-related decision-making:

1. The snow is a lot smarter than we are. *—Contuli*
2. There are no rules of thumb. *—Perla*

Decisions have to be made in the field, using the information available, processed in a reasonable fashion as objectively as possible. They could still be wrong, or right. Try to make good ones.

Mike Richardson *is a software developer and cookie-enthusiast based in the Pacific Northwest. He can be reached at mike@scenomics.com.*

Randy Spence *is the ski patrol director at Moonlight Basin in Big Sky MT. When not ski patrol directing, he can be found on a mountain bike. He can be reached at rspence@moonlightbasin.com*

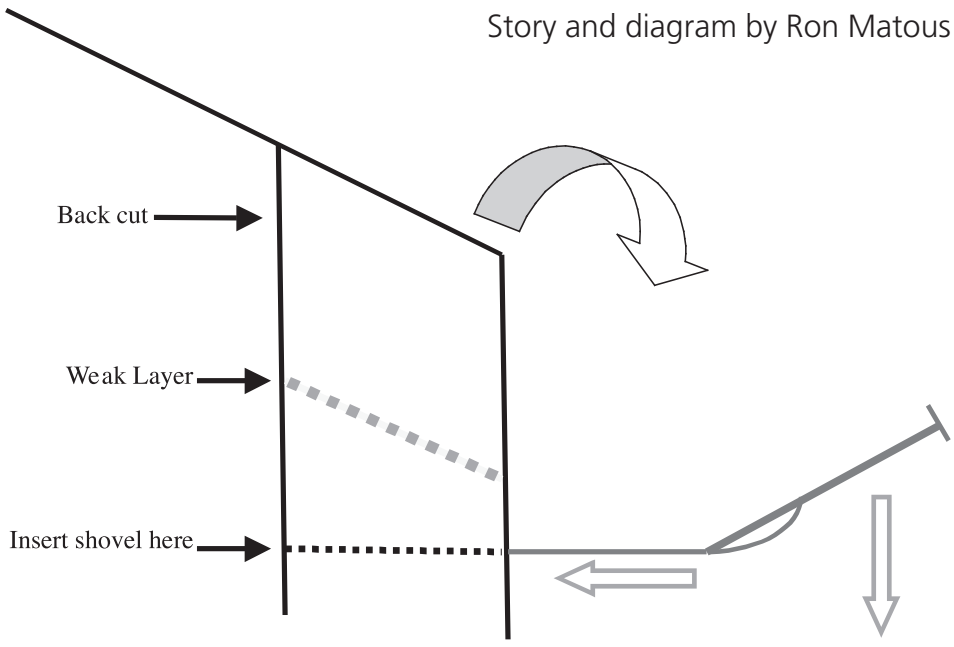
As an avalanche forecaster at the Big Sky Resort, ***Nick Armitage*** *tells TAR he is trying to fill "big" ski boots on a big mountain. His summers are now spent skipping through the hills as a Jenny Lake Ranger in Grand Teton National Park.*

Peter Carvelli *is a ski patroller at the Highlands. He can be reached at pcarvelli@aspensnowmass.com*

The Backcountry Tiltboard:

Another possibly useful, possibly confusing quantification of an old hand's simple observational trick

Story and diagram by Ron Matous



Sometime in the past few years I became somewhat intrigued by a paragraph which appeared in the last two editions of *The Avalanche Handbook* concerning certain researchers' use of a "tilt board" to test bonding between layers. The contraption involved was a bulky and heavy framework of wood and metal attached to a ski base that allowed one to elevate and then tilt a block of snow, tapping on it all the while until a shear failure occurred. My suspicion is that most practitioners looked at the photo, read most of the paragraph describing it, and then put it down with a yawn – relegating it to the same backcountry status as three sections of ram penetrometer: too heavy, too bulky, too time-consuming to use with clients (or even good friends) when skiing was the object.

I have yet to run into even those few readers who might have thought about the last sentence:

"A rough tilt board test can be done with a test profile…A block of soft snow is held on a slightly inclined shovel, the shovel is tapped, and the snow block observed for shear failure."

This, of course, has become known in some form or another as the "burp-the-baby test," though often the baby is not merely burped but slapped senseless (apologies to the politically correct out there). It seems to me that surely by now someone besides me has come up with the following technique (see diagram 1, the only one you get), which requires absolutely no additional equipment other than a second person for accuracy.

Note: this will only work, realistically, with obvious weak layers like surface hoar or an ice interface and where that layer is not buried so deeply that the full weight of the column above won't fall on your head.

1. Measure out and isolate your standard 30x30cm column, with the exception of the backcut: that only needs to go some 20-30cm below the weakness.
2. Insert a shovel right-side up so that the blade is horizontal (straight in) at a point 10-15cm below the layer. This allows you room to have one hand helping to support the block.
3. With an inclinometer-laden assistant by your side, slowly tilt the block towards you, while resting the heel of the shovel on the column below to prevent too much movement. I found that I like to tap the shovel handle as I go with the tilting hand (not the supporting hand, which should in no circumstances obstruct the block or weak layer), for the same reasons that people tap the tilt board, although in the case of an "official" tilt board, the angle doesn't change.
4. At the moment when the block slides off of the weak layer and into your face, hold still and have your partner measure the slope angle of the sliding surface remaining on the shovel (that's what that 10-15cm of extra was for). Record that angle (or just remember it) along with the original slope angle where your pit was dug. To my mind, the difference says something (what?) about how much steeper things would need to be in order to be naturally unstable. No significant failure (i.e., the whole column topples over on your head) is recorded as: L. Failure in cutting the block indicates that you're already on an unstable slope: X.
5. So: Do I have any data that this might contribute to an understanding of instability? No. Do I have a gut feeling that it could? Yes. I just haven't done enough of them yet.

If anyone has further feedback on this or other attempts to quantify the same thing, I'd love to hear it: rmatous@wyom.net.

Ron Matous *is a AAA-certified avalanche instructor who has guided in many winter capacities, been a ski patrolman, taught avalanche classes of all levels, trained winter Outward Bound and NOLS students, and – as his mug shot illustrates – spent way too much time above 20,000' while working and traveling in various snowy ranges worldwide.*

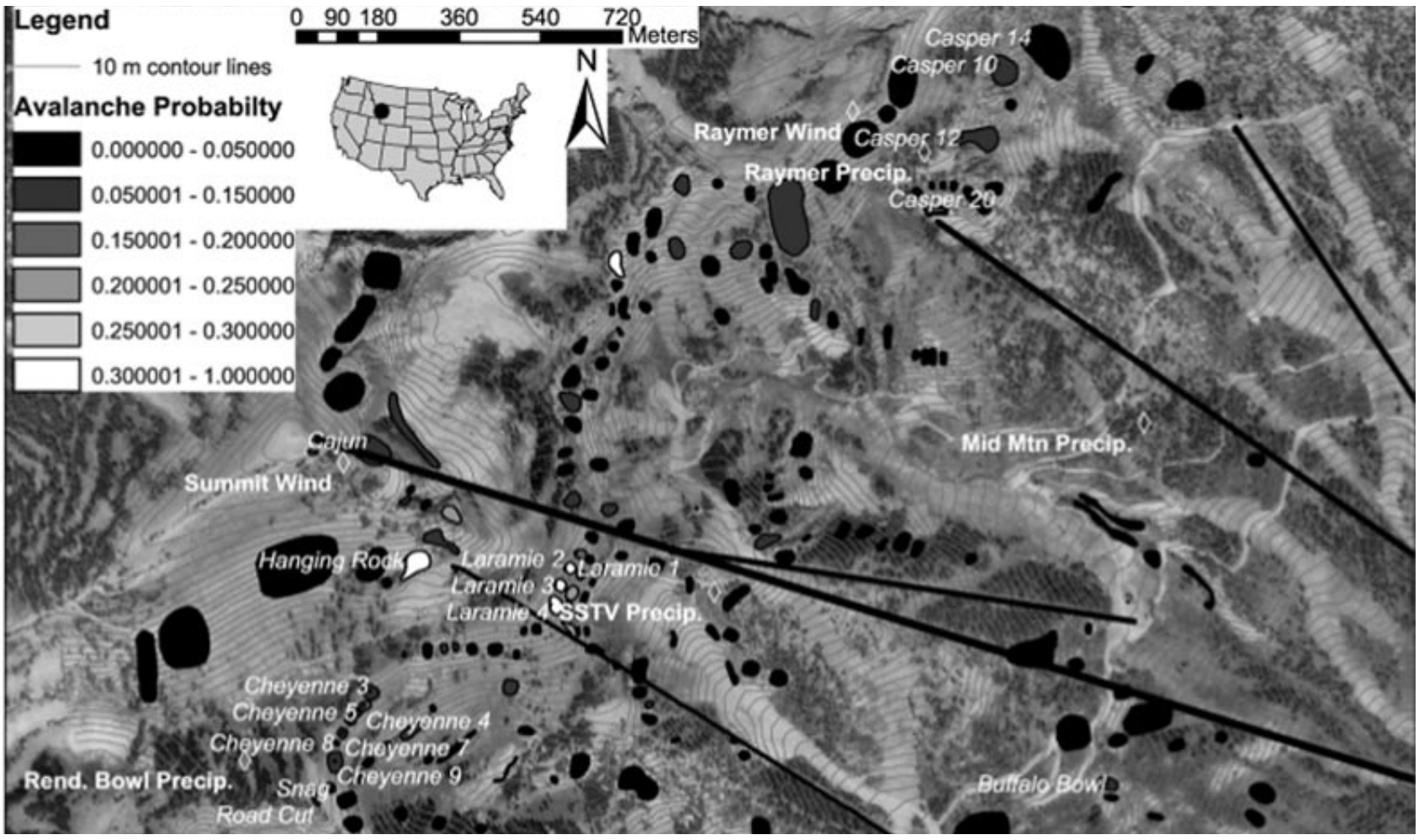


Figure 1: Graphic output of avalanche-probability model. Avalanche probability is shown for individual starting zones in Jackson Hole Mountain Resort, Wyoming. Probability is determined based on terrain and current daily weather and snowpack parameters using a nearest neighbors approach, which compares current conditions to over 10,000 historical days to find what type of outcomes were created on historical days with similar weather and snowpack properties. GIS facilitates the management and display of all the data used for this type of analysis. *McCollister, et al., 2002*

Geospatial Science and Snow-Avalanche Research

Story by Alex Marienthal, Jordan Mancey, Zachary Guy, Frederick Rains, and David Schwab • Edited by Alex Marienthal and Jordan Mancey

The use of geographic information systems (GIS) and geospatial sciences in snow and avalanche research has come a long way over the last half-century. Increased availability of geospatial data coupled with decreasing costs of computing software and more power has enabled more snow scientists to use geospatial sciences in their research. In the fall of 2009 five students at Montana State University compiled a research paper to review studies that have incorporated GIS and geospatial sciences in snow-avalanche studies and to discuss the influence of GIS to suggest directions for the use of geospatial sciences in future snow-avalanche research.

We explored the topics of avalanche mapping, avalanche forecasting, spatial variability, snow distribution, and water in the snowpack. We searched for articles relating to these topics in a number of popular scientific journals from the last 20 years, as they are all of fundamental importance to understanding, forecasting, and modeling avalanches. A "web of science" approach was used by checking the references of all reviewed articles for other articles that potentially used geospatial sciences for snow-avalanche research. The literature review did not encompass every study that has linked snow science and GIS. However, an attempt was made to include all research related to significant topics in snow-avalanche science over the last two decades.

Snow-avalanche research incorporates a broad range of geospatial properties, so it is appropriate to narrow the definition of GIS and geospatial sciences as it is used in this review. This study focuses on research that uses GIS and computer software to collect, manage, analyze, or display geospatial data that has a traditional or potential component related to snow-avalanche research. Specifically, this article will focus on the evolution of geospatial data management capabilities, and how geospatial sciences are essential to past and future research in forecasting, modeling, and mapping snow avalanches and related phenomena.

Some of the earliest geospatial sciences used for snow-avalanche research includes the creation of avalanche hazard maps and avalanche atlases for towns and transportation

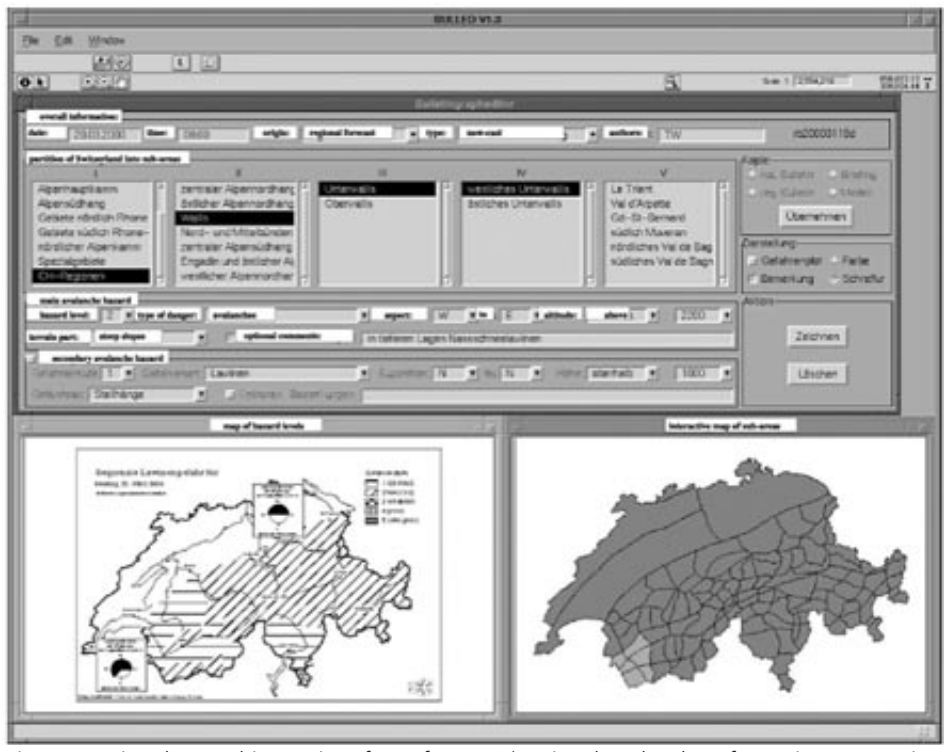


Figure 2: Using the graphic user interface of RAIFoS (Regional Avalanche Information Forecasting System) in Switzerland, items are chosen from the menus to determine danger over an area from a given day.

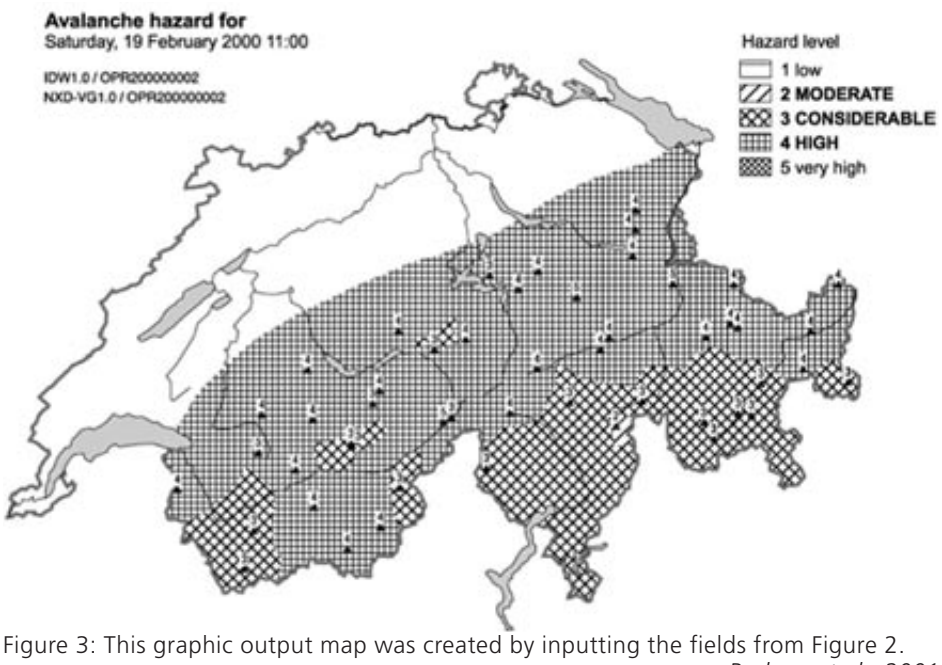


Figure 3: This graphic output map was created by inputting the fields from Figure 2. *Brabec, et al., 2001*

corridors in Norway, Switzerland, and Colorado *(Armstrong, 1976; Borrel, 1992; Frutiger, 1980; Hestnes and Lied, 1980; Ives and Plam, 1980; Miller et al., 1976)*. At the same time hazard maps and atlases were created, topographic maps at scales typically between 1:24,000 and 1:100,000 were used to define terrain parameters, such as slope, aspect, elevation, alpha angles, and curvature of avalanche paths, for modeling runout distance and risk to people and structures *(Bakkehoi et al., 1983; Bovis and Mears, 1976; Frutiger, 1990; Hestnes and Lied, 1980; Lied and Bakkehoi, 1980; McClung and Lied, 1987)*. Terrain parameters for similar studies are modernly defined using a GIS and a digital elevation model (DEM) with a typical grid resolution between 5m and 100m *(Gruber and Bartelt, 2007; Delparte et al., 2008; Forsythe and Wheate, 2003; Maggioni and Gruber, 2003)*. DEMs are essentially map layers of grid cells with an attached value for the elevation at the center of each cell. Various studies have used DEMs to model runout distance in combination with known, or potential, locations of avalanche paths using GIS software in order to map risk and potential hazard in settlements *(Cappabianca et al., 2008; Gruber, 2001; Gruber and Bartelt, 2007; Keylock et al., 1999; Maggioni and Gruber, 2003)*.

Modern digitization of avalanche atlases and hazard maps combined with computer-literate practitioners has enabled the establishment of easily manageable and updateable databases that hold records of avalanche events, spatial representations of avalanche paths, and are critical for the creation and validation of models, which may aid in future understanding and forecasting of snow avalanches *(Borrel, 1992; Jaedicke et al., 2008; Jaedicke et al., 2009; Schmidt and Hartmann, 1988)*. Models and databases can be used in combination with meteorological data to correlate temporal patterns between avalanche activity and weather or snowpack properties at daily to seasonal scales *(Jaedicke et al., 2008;*

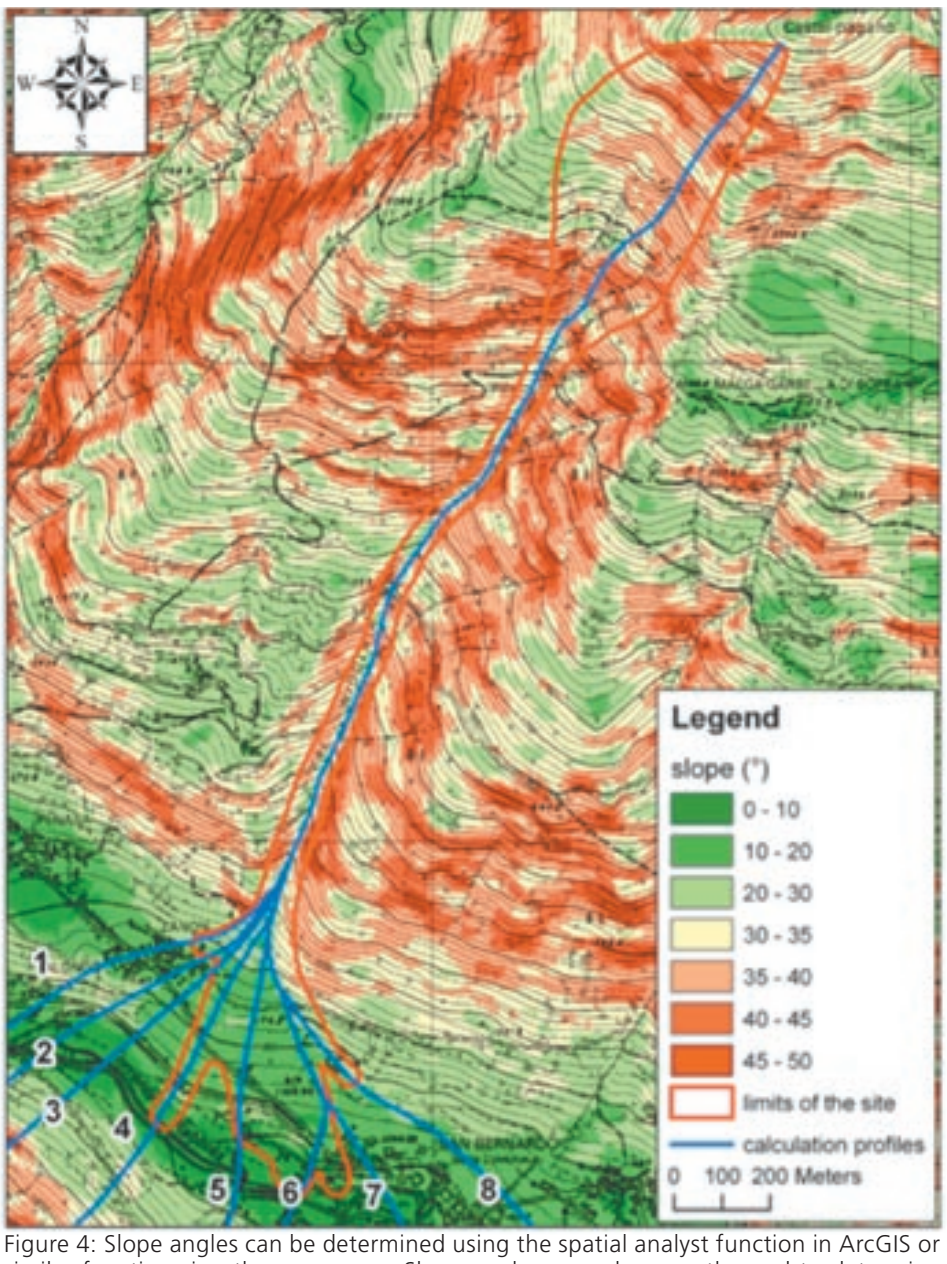


Figure 4: Slope angles can be determined using the spatial analyst function in ArcGIS or similar functions in other programs. Slope angles are subsequently used to determine potential for, and characteristics of, avalanches occurring in areas of concern. The red outline indicates the currently known limits of the avalanche path, and the blue lines are profiles used for calculating risk. *Cappabianca, et al., 2009*

Schmidt and Hartman, 1988).

Early programs, such as SnowBase software used at Alta Ski Resort, Utah, were used for management of meteorological data, snow stratigraphy data, and avalanche occurrence. The database was used to model conditions with an output of snow cones, which show a variety of parameters stratified by aspect and elevation in polar graphs, and snow roses, which show wind patterns and snow loading considerations on different aspects and elevations *(Atkins, 1992; Tremper, 1992)*. Snow cones and snow roses are still used by avalanche forecast centers, and also show danger ratings for given mountain ranges.

GIS has been a valuable interface for managing historic records along with spatial data to create models. Historic data of meteorological conditions, collected at remote weather stations, and snowpack properties, such as stratigraphy profiles showing hardness, strength, and grain properties of each layer, collected by researchers and ski patrol, have been useful in linking weather patterns and snowpack properties with past records of individual avalanche events or cycles *(Brabec, 2001; Brabec and Meister, 2001; Bovis, 1977; Gassner et al., 2000; Giraud, 1992; Hendrikx, 2004; Hendrikx et al., 2005; McCollister et al., 2002; McCollister et al., 2003, Purves et al., 2003; Rashpal, 2002)*. Regions that have long records, such as the mountainous regions of Europe, have found this approach to be helpful in identifying weather patterns leading to avalanche events and cycles. In France, forecasts cover approximately 5000 km2 and began daily recordings of snowpack and meteorological data in 1971, and in 1986 initiated a computerized system *(Garreaud, 1990)*. Weather data (i.e., snowfall, wind direction, wind speed), weekly snowpack profiles, and all avalanche activity were recorded three times daily. The GIS assisted in statistical calculations using a nearest neighbor approach in which present meteorological conditions were compared to days in the past with similar conditions to determine avalanche probabilities using a daily historical record of ~4000 meteorological days and 400 snowpack profiles from past winters. Hazard estimations derived from historical patterns can be incorporated in a graphical snow cone format where risk and natural avalanche type are displayed for different aspects and elevations. Forecasts derived using these types of data with a probabilistic approach are only useful in conjunction with local expert knowledge of snow climate and terrain characteristics, and are not solely used to create forecasts. However, they are an aid in forecasting and correlation of weather and snow property patterns that lead to avalanche events and cycles.

Historical records are unfortunately limited to areas of settlement and activity, and therefore do not provide a continuous spatial or temporal record of activity. In remote regions where the availability of historical data is limited, remote sensing applications and digital terrain analyses using GIS have been tested to develop databases of avalanche events, and collect weather and snow distribution data *(Bitner et al., 2002; Bühler et al., 2009; Cartwright, et al., 1990; Forsythe and Wheate, 2003; Gruber and Haefner, 1995; Hall et al., 2002; Hendrikx et al., 2005; Klein et al., 1998; Maggioni and Gruber, 2003)*. The purpose of these remote applications is to obtain data about locations that have limited observations of weather, snowpack properties, and avalanche events due to remoteness, limited accessibility, and/or hazardous conditions.

Studies focusing on distribution of snow properties (i.e., snow depth, SWE) and spatial variability have recently benefited from technological advancements in remote sensing and GIS capabilities. Improved modeling and data collection capabilities of snow property distribution and spatial variability may aid in improved forecasting models. Prior to the mid 1980s interpolating values between remote weather stations or test sites was the norm for providing relatively accurate values for snow depth, or snow water equivalent (SWE) across a region and remains a primary tool in many regions across the world today. Over the course of the last fifty years the availability of land-based remote sensing equipment and aerial/satellite imagery has increased dramatically along with computer processing capabilities and software. Snow cover maps have been produced using data collected from remote sensing equipment by the National Oceanic and Atmospheric Association (NOAA) (Hall et al., 2002), the National Operational Hydrologic Remote Sensing Center (NOHRSC), the National Environmental Satellite, Data, and Information Service (NESDIS), and the National Aeronautical and Space Administration (NASA).

Remote sensing technology has also assisted in creating snow transport models, quantifying radiation input and output over a surface, interpolating SWE, and exploring terrain properties associated with surface hoar formation *(Corripio et al., 2004; DeBeer and Pomeroy, 2009; Deems et al., 2002; Liston et al., 2007; Molotch, 2009; Schaper et al., 1999; Schauffhaser et al., 2008; Schweizer and Kronholm, 2007; Tesche and McNally, 1988)*. Also, snow cover area, grain size, albedo, and surface water content were all calculated from remotely sensed data over an area covering nearly all of the Sierra Nevada *(Dozier et al., 2009)*. The ability to model and remotely collect data for the distribution of snow properties may aid in more robust correlations between snow properties and avalanche events in the future.

DEMs derived from remotely sensed data and made available by the United States Geologic Survey (USGS) in varying resolutions have been a significant tool in mapping and modeling of snow properties. Many snow distribution models use terrain parameters, derived from DEMs, as inputs to predict a value (i.e., snow depth, SWE, albedo) at an unobserved location. The accuracy of DEMs is a major limitation in models. Studies have found decreased modeling accuracy with lower resolution DEMs *(Wu et al., 2008)* as analysis is limited by the lowest resolution data. For example, Prokop *(2008)* acquired terrestrial laser scanner data with 9cm resolution, but the correlation analysis was limited by the 5m resolution of the modeled airflow. Measurement errors associated with data collection equipment can also create uncertainties. These uncertainties can often be accounted for if the measurement error can be defined. Furthermore, incomplete records of historical avalanche events can create problems when correlating weather events with avalanche events. In efforts to obtain more complete avalanche

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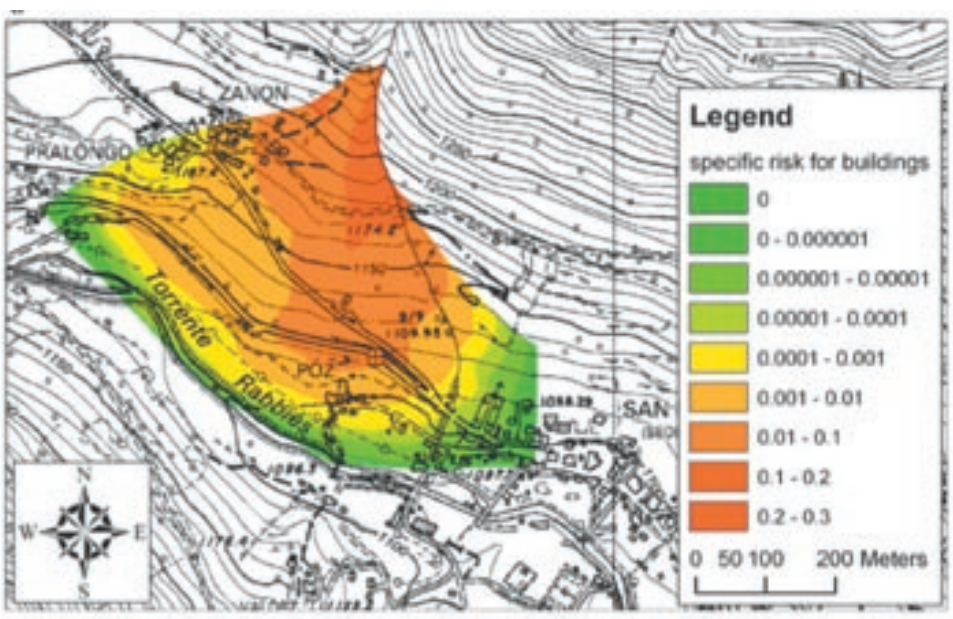
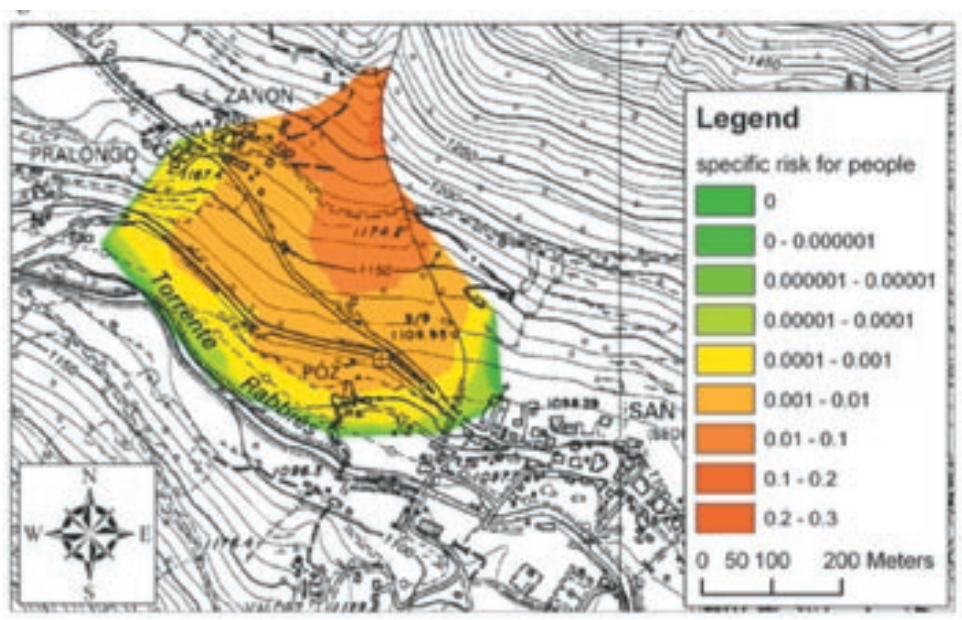
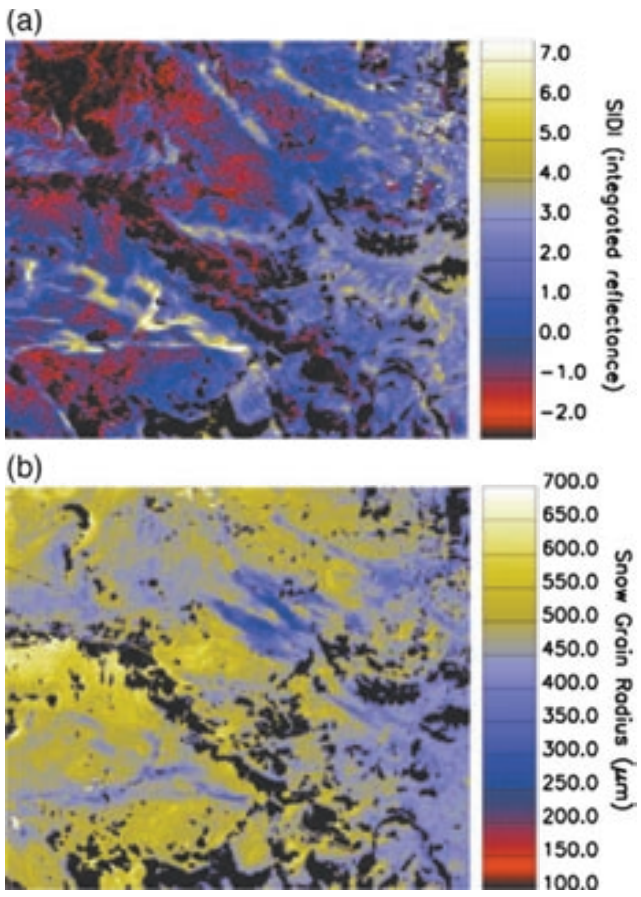
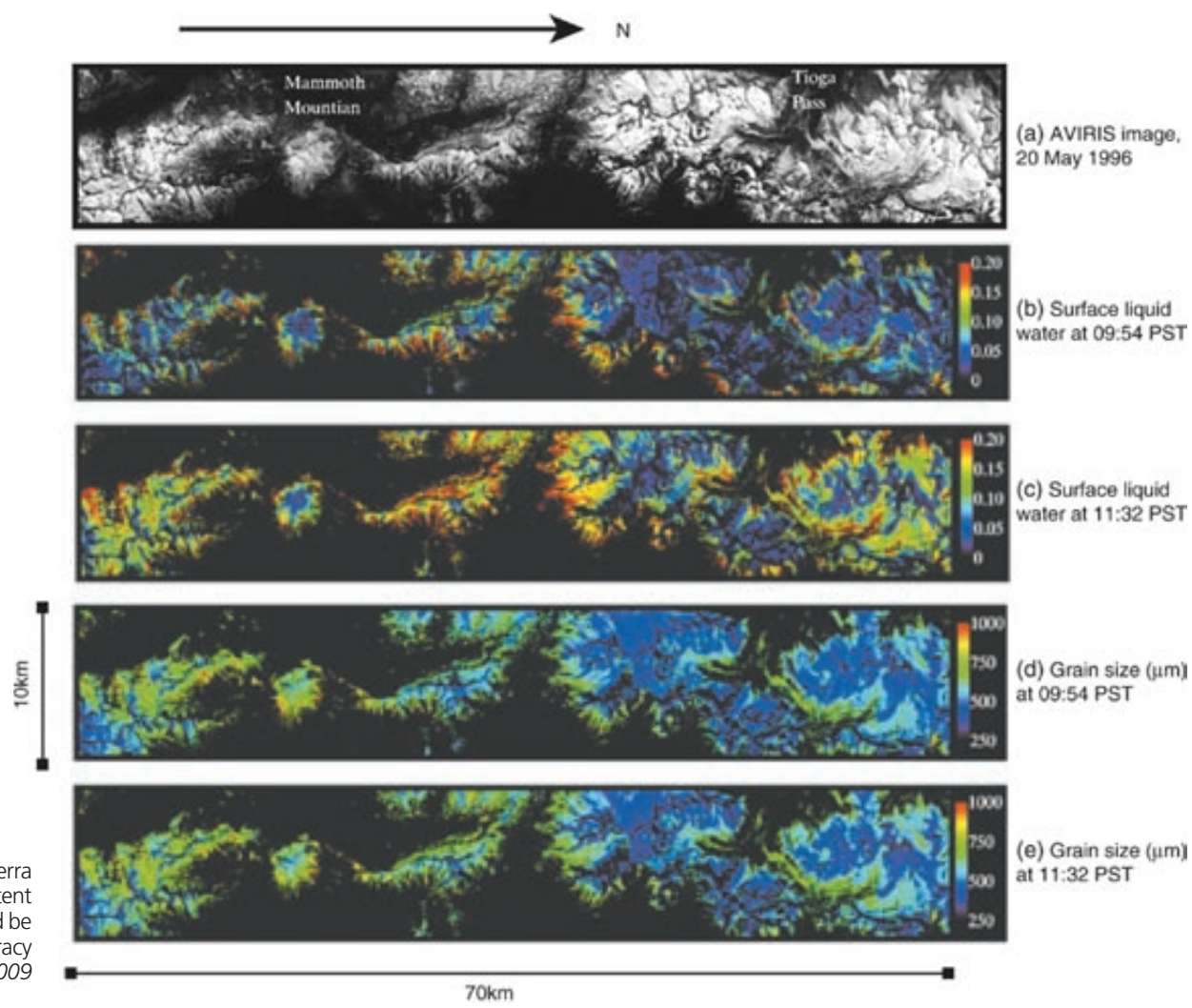




Figures 5 & 6: Specific risk is shown for buildings and people as calculated based on model simulations that use parameters such as slope, release depth, runout distance, and likelihood of people or buildings being in the area. Specific risk is higher for buildings because they are permanently located in the runout, while people may be removed for safety.
Cappabianca2, et al., 2009 and Cappabianca3, et al., 2009





Figures 7-8: Output of snow-surface properties in an area of the Sierra Nevada. Snow-cover area, grain size, albedo, and surface-water content were determined using remotely sensed satellite data. These data could be used as variables in future modeling given they meet acceptable accuracy requirements and are cost effective to collect. *Dozier 2009, Dozier2 2009*

GIS HISTORY

continued from previous page

observations some areas such as Little Cottonwood Canyon, Utah, and Teton Pass, Wyoming, use infrasonic avalanche monitoring systems. These represent an electronic "trip wire" to remotely locate avalanche occurrence, which are then automatically input to a GIS and displayed on a time graph and hillshade view to locate the temporal and spatial occurrence *(Yount et al., 2008)*.

Although accuracy of data may limit the accuracy of results, data quality and completeness has improved and will likely continue to improve with easier data management and collection capabilities. DEMs have improved from 30m to sub-meter accuracy with Light Detection and Ranging (LiDAR) data. GPS units are now capable of delivering locations with 1cm accuracy. Terrestrial scanning lasers can measure snow depths with accuracy below 10cm *(Prokop, 2008)*. An improvement in accuracy, completeness, and resolution of data will both promote more studies using GIS and increase the significance of these studies.

The combination of snow and geospatial science was once limited simply to maps of known avalanche areas before technological advancements allowed for user-friendly data management and easily updateable documents on a computer interface. Advancements in GIS technology, improved data resolution, establishment of avalanche atlases and databases, and sophisticated remote sensing and satellite technology combined with an increase in computer literate researchers and practitioners supports a promising future of robust and efficient research in the field of snow-avalanche science.

For a full manuscript of the original research or full reference list contact Alex Marienthal: alexm1417@hotmail.com, 303-827-4788.

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Alex Marienthal *was born and raised in Gold Hill, Colorado, in the mountains west of Boulder. While working towards his college degree he spent countless hours skiing in the backcountry of southwest Montana and has climbed and skied many of the peaks in the area. Alex earned his bachelors degree with honors in snow science and a minor in statistics in December 2009. He is currently enjoying skiing at Bridger Bowl or in the mountains of southwest Montana.*

While discovering the secrets of the world during his completion of a bachelors degree in physical geography at Montana State University, ***Jordan Mancey*** *skied off summits, kayaked Class 5 whitewater, and climbed world-class ice and rock in the mountains of southwest Montana. He can currently be observed skiing cold smoke powder, ice-climbing nude, digging snow pits, and consuming malted beverages.*

A classic surface hoar avalanche in British Columbia, breaking into lower-angle terrain and pulling out everywhere the surface hoar remained tall before being buried.

Surface Hoar Develops in British Columbia

Story and photos by Wren McElroy

Currently in British Columbia we are dealing with five significant surface hoar layers from February 22, February 5-8, January 29, January 24, and December 29. The 100222 surface hoar is now buried 10-20cm down. The 100208 is down 30-60cm, varying by location. On the north to east aspects there was significant surface faceting in January, where ski cutting caused much sloughing running far and fast.

We have had relatively little wind through January and February, so the surface hoar is present into the alpine in many areas. This has changed as the recent systems have been coming in with L-M winds transporting the recent storm snow and creating soft slabs on the lee features. Generally high temperatures and humidity are also contributing to slab formation.

These photos were taken February 18 on a CAA Level 1 course taught by me and Ian Tomm. Selkirk Tangiers Heli Skiing gave us a lift north of Revelstoke near Sail Mountain in the Caribou Basin.

The layers in the profile shot show the February 22 on the surface, the February 8, and the January 24-29 sandwich. We have had little bits of snow in small accumulations keeping the surface hoar well preserved.

The avalanches in the photos were heli-controlled (helicopter touching up and down on the ridge features). They were size 2-3 with widespread propagation, NE aspects 2000m failing on the 100208 and stepping down to the 100124/29 layers. The smaller ski cuts were failing on the 102008. Industry reporting noted avalanches on terrain as low angle as 20 degrees. South aspects have had facet/crust combos, some with surface hoar as well.

The guiding industry has had its work cut out for it with very limited terrain to access.

Wren McElroy *is the Canadian Avalanche Association's Industry Training Program curriculum specialist.*

Poster Pitch Produces Pocket Avalanche in the San Juans

Photos and captions compiled by Mark Rikkers

Upper Waterfall Canyon is a standard portion of Helitrax's south terrain in Low and Moderate hazard. The small red outline indicates the location of the avalanche. The remotely triggered pocket avalanche on Poster Pitch, in Upper Waterfall Canyon between Yellow Mt and Pilot Knob, was on an ENE aspect from 12,800' ASL. The avalanche hazard on this day (January 8, 2010) was rated Moderate.

Shaken but not Stirred

Story by Peter Shelton

On January 8, 2010, Helitrax dropped a group of skiers off on the shoulder of Pilot Knob for a run into Waterfall Canyon. It was a placid day: blue sky, very little wind. The powder was old and settled, wind-affected in places; it hadn't snowed in a while.

Long-time Ophirian Mark Rikkers was the guide. He decided, along with the other guides and the dispatcher, to ski Poster Pitch. His would be the first commercial group down that run this season. But it was not the first time it had been skied. In fact, earlier that morning, a cadre of "heli-hitchers," including Helitrax founding members Mike Friedman and Mark Frankmann, had dug a snow pit there, before themselves skiing down Poster Pitch and thence to Ophir. Their pit revealed moderate weakness in the snowpack, a totally expectable – if typically ambiguous – hazard rating for the San Juans in January.

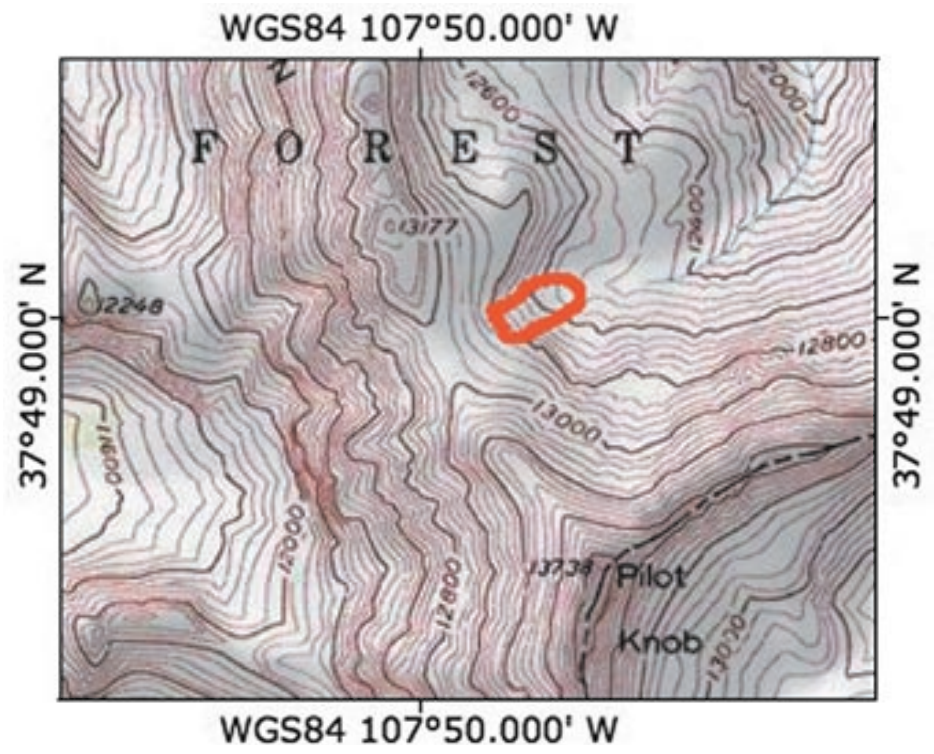
Using standard protocol, Rikkers had his clients ski the first pitch one at a time. One of them, an Australian man, stopped off to the side to take a picture of his wife skiing by. Hers was the eighth track marking the hill. Then, as she passed him, 30' away, the snow above and all around the man fractured to the ground and swept him down the fall line.

Rikkers was moving almost as soon as the Aussie man was. "I was watching him the whole way, skiing and talking on the radio. He was never buried. He was never under the snow. He lost both skis, but he ended up on top. I did help him dig one arm out."

Rikkers called in the helicopter and stomped out a landing pad below the debris, which was littered with chunks of hard slab. (Blocks the size of La-Z-Boy recliners remained near the fracture line.) They flew the man down to Telluride, where he was treated for a slight ankle injury, perhaps an Achilles strain. In classic Aussie good humor, he declared himself "shaken but not stirred."

Everybody at Helitrax was shaken. Theirs is an exemplary safety record over 28 years of skiing in arguably the trickiest snowpack in North America. In fact, their only serious accident happened in 1994, and it didn't involve an avalanche. That was the infamous Christie Brinkley crash, when the helicopter with Mrs. Billy Joel aboard went down, mysteriously and hard, on Pilot Knob just the other side of the ridge from Poster Pitch.

Only two clients have ever tangled with avalanches. The first incident happened up in Hope Lake Basin on a run they now call Lucky Bob's, after a customer who triggered a slide but managed to ski safely out to the side. Poster Pitch is the second, and the only time someone has taken a ride.



Helitrax director Aaron Rodriguez sent email word out to the snow-and-avalanche community that same night, with photos of the scene, and Rikkers later put together detailed diagrams and analysis. They cancelled skiing for the next day and flew up to do a fracture-line profile on the slide. They also threw 24 three-pound explosives into likely start zones with no results whatsoever.

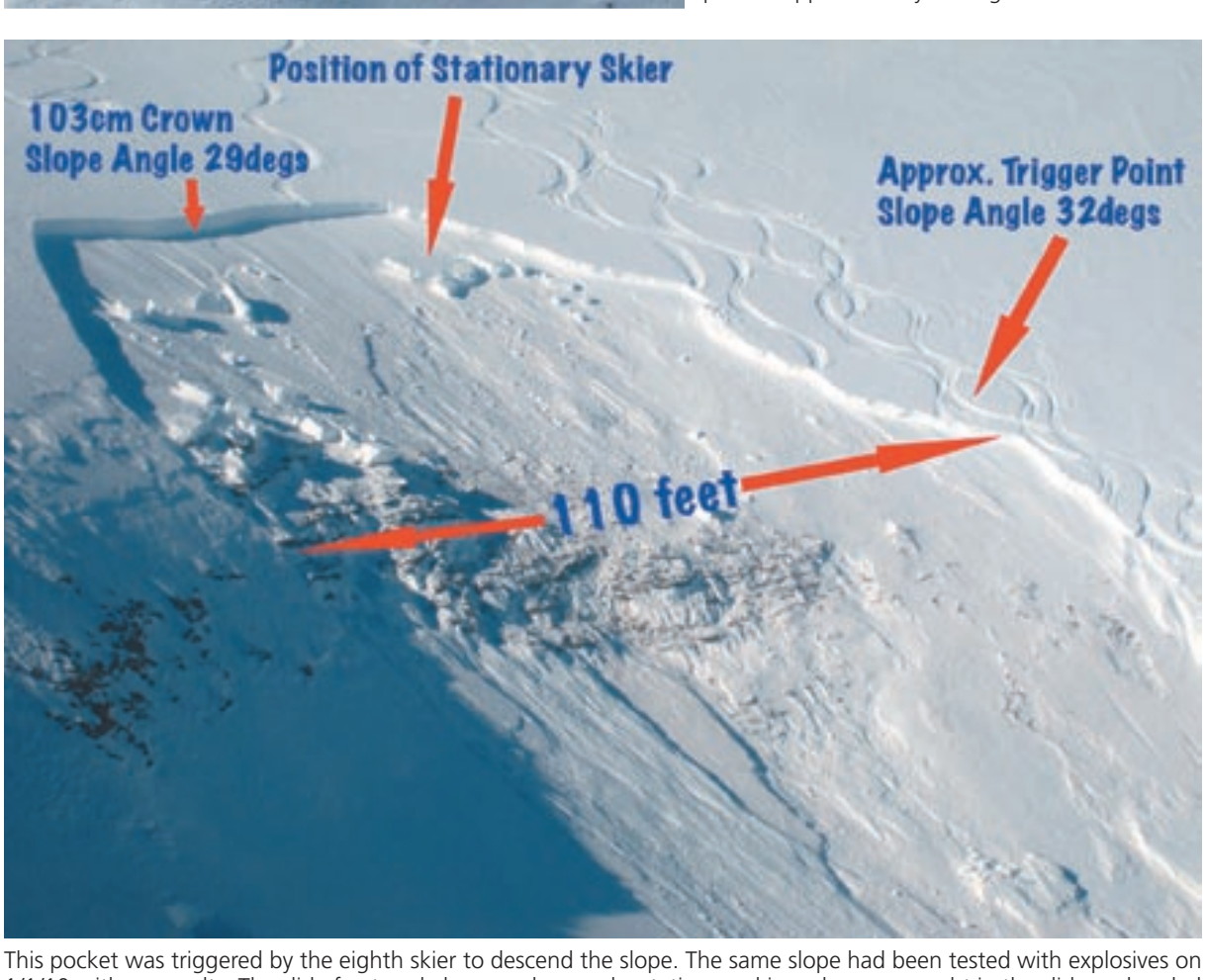
It was clear at the site that the avalanche had been triggered remotely. That is, the pressure of a ski turn (the wife's) in softer snow off to the side had caused the nearby hard slab, where her husband was standing, to break free. She wasn't caught, nor did the snow she was skiing in move.

Senior guide Speed Miller, who has been out on skis almost every winter day these last 28 years, had never seen an avalanche that high on the pitch before. The slope angle at the fracture line was only 29 degrees. Steep enough to slide, obviously, but significantly shallower than the most common failure angle of 38 degrees.

"We knew there were little pockets of tension in the snow," Miller told me. They had, in fact, bombed this very slope the previous week with a five-pounder without results. Hard slabs, which form from densely-compacted, wind-driven snow, are notoriously difficult to gauge. They may be hidden under layers of softer snow. They may be stable enough to support Hannibal's elephants. They may be as brittle as a hair trigger. And they may, as in this case, lurk on only a small portion of a large terrain feature.

Continued on page 32 ➡

At its deepest and widest, the dimensions were 3' x 110'; the vertical fall was 275'. The slide is classified as HS-ASr-R2-D2-O/G. There were areas in which this avalanche ran on a bed surface 65cm above the ground, and other areas where it ran to ground (with flanks only 50cm deep and no sign of the hard slab). The depth and snow stratigraphy in this area was definitely variable. The slope angle at the deepest point of the crown, very close to where the skier was standing when the avalanche released, was only 29 degrees. The slope angle at the trigger point is approximately 32 degrees.



This pocket was triggered by the eighth skier to descend the slope. The same slope had been tested with explosives on 1/1/10 with no results. The slide fractured above and around a stationary skier, who was caught in the slide and ended up on the surface. The skier was evacuated to the medical clinic and sustained a minor ankle strain.The slope angle at the deepest point of the crown, very close to where the skier was standing when the avalanche released, was only 29 degrees. The slope angle at the trigger point is approximately 32 degrees.

Managing Risk in a Continental Snow Climate

Story by Mike Friedman

I was asked to write a few words about deep-slab instability in a continental snow climate by way of an introduction to Peter Shelton's excellent recap of a close call. Heli-ski operations, by their very nature, must tangle with wide-ranging forecasting problems, evaluating hazard over hundreds of square miles in the context of "pushy" guest expectations. Add into this equation an inherently weak snow structure and you've stepped into a demanding mountain-guiding scenario. Heli-ski guiding is essentially a mountaineering problem, where route finding and backcountry protocol are the default skills that protect guides and clients after thoughtful run selection leaves them standing in a remote landing zone. The key is to know where you are heading and why before the helicopter takes off with the first load of riders.

Forecasting in a continental snow climate requires a determined effort on the part of guides to recognize developing conditions of deep snowpack instability which may present themselves as a subtle, delayed-action hazard. Gathering direct evidence, in the form of snowpits, is always a first step and a helpful ongoing exercise. But once the major weaknesses have been identified – typically a basal layer of depth hoar and near surface facets sandwiched between subsequent storms – you've got your problem.

With each change in the weather, a heli-ski company must re-evaluate the current trend of instability and arrive, hopefully by consensus, at the correct choice of ski terrain. This discussion includes a characterization of the permit area's overall slab sensitivity, depth of critical weakness(es), as well as unusual events which may indicate particular areas of concern (i.e., sudden temperature changes, wind loading, reported collapses). What we're seeking is a well-informed opinion on the overall trend or pattern. Then one can consider terrain choices and begin to develop a skiing circuit.

In this endeavor, a heli-ski operation always falls back on its inventory of low-angle skiing – slope angle being the only variable we can measure with any certainty. Given the persistence of these weak layers and tendency for deep slabs to retain their ability to propagate for prolonged periods of time, decision-making requires considerable self-discipline.

The overriding key to survival in a continental snow climate is communication and transparency. Those of us who call this weak snowpack our home have become comfortable sharing observations and opinions quite openly. It's true, there's no such thing as a stupid question. And the most seemingly trivial observation can be the clue to unlocking a particular lurking problem. The Canadians deserve a lot of credit for developing the INFOEX system, for surely this network has resulted in avoiding many incidents both in the backcountry and within ski resorts.

It gives me great satisfaction to see another generation of Helitrax guides take on this daunting challenge. The San Juan Mountains are a majestic range that come into their own when buried under a blanket of snow. We older guides can contribute an opinion, tempered perhaps by experience. Still, the focus essential to managing risk in a continental snow climate is not to be taken lightly. It demands, as an old mountaineer said, "sensible self-denial" and a little bit of luck.

Mike Friedman *was an original founder of Telluride Helitrax. He is also a long-time Exum guide; recently he has been developing a Via Ferrata for the Amangiri Resort near Lake Powell.*

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"That was one of the lessons we took from our day-after discussion," Rikkers said. "That spatial variability – the idea that you may have a completely different snowpack 20 feet away – is a reality. The other thing is the idea of persistent weaknesses [the slide ran on a layer of old, fragile, faceted grains near the ground]; they are just that: persistent."

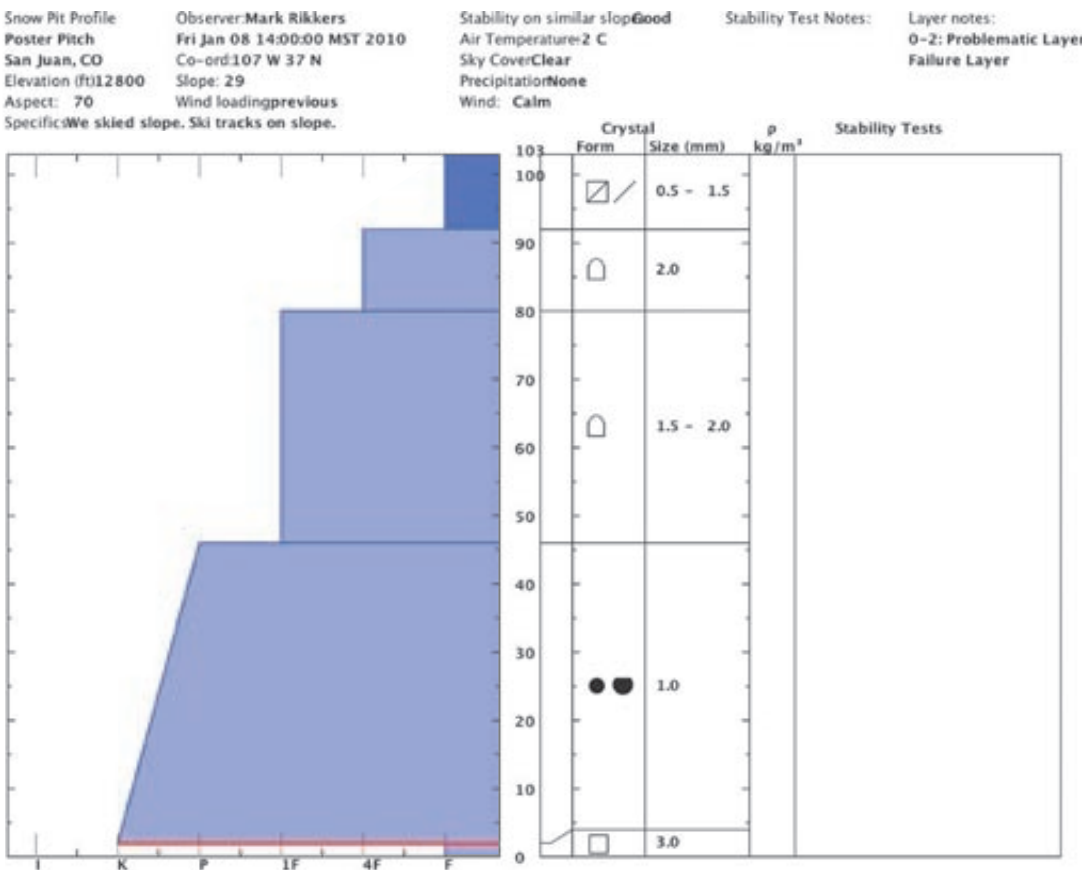
"We were lucky," Speed mused. "We didn't get somebody severely injured or buried. Eventually, someone would have hit that sweet spot," and the results might have been worse.

"Yeah, we dodged a bullet," Friedman told me. (An occasional guest guide and consultant, Mike is no longer a Helitrax principal.) "It was the perfect wake-up call. It's a reminder of how complex and amazing snow is. And snow is the most complex element in nature – that is not an understatement. It's incredibly tricky: A soft slab can propagate into and cause a knife-hard slab to fracture! It continues to teach us lessons.

"One lesson is, history repeats itself. If you're in the game long enough, it will come around again with the same sense of awe and surprise."

Peter Shelton's *blog can be found at peterhshelton.wordpress.com*

Author and Helitrax guide Mark Rikkers in his native habitat (above): A week previous to this slide, we bombed this very slope, and others close by, with NO results. In the week that followed there was no new snow. Before performing the FLP on January 9, we did extensive explosives testing (24 3# rounds) on a variety of aspects near and above treeline, including several shots in the immediate vicinity of this slope, with NO results. Fairly large hard slab blocks remained near the crown, indicative of relatively low slope angle.



left: The fracture line profile (done 1/9/10) shows a very hard slab resting above a 2cm layer of cohesionless 3mm advanced facets. Where we dug the FLP, at the deepest part of the crown, the slide did not run to ground, but it did run to ground in other areas. In this spot, the slide ran on a pencil-hard windcrust bed surface that had 65cm of 4F semi-sintered facets below it. While the 44cm hard slab didn't exist along the skier's left flank of the slab, the same 2cm layer of facets that failed did, right at the ground.