the avalanche journal

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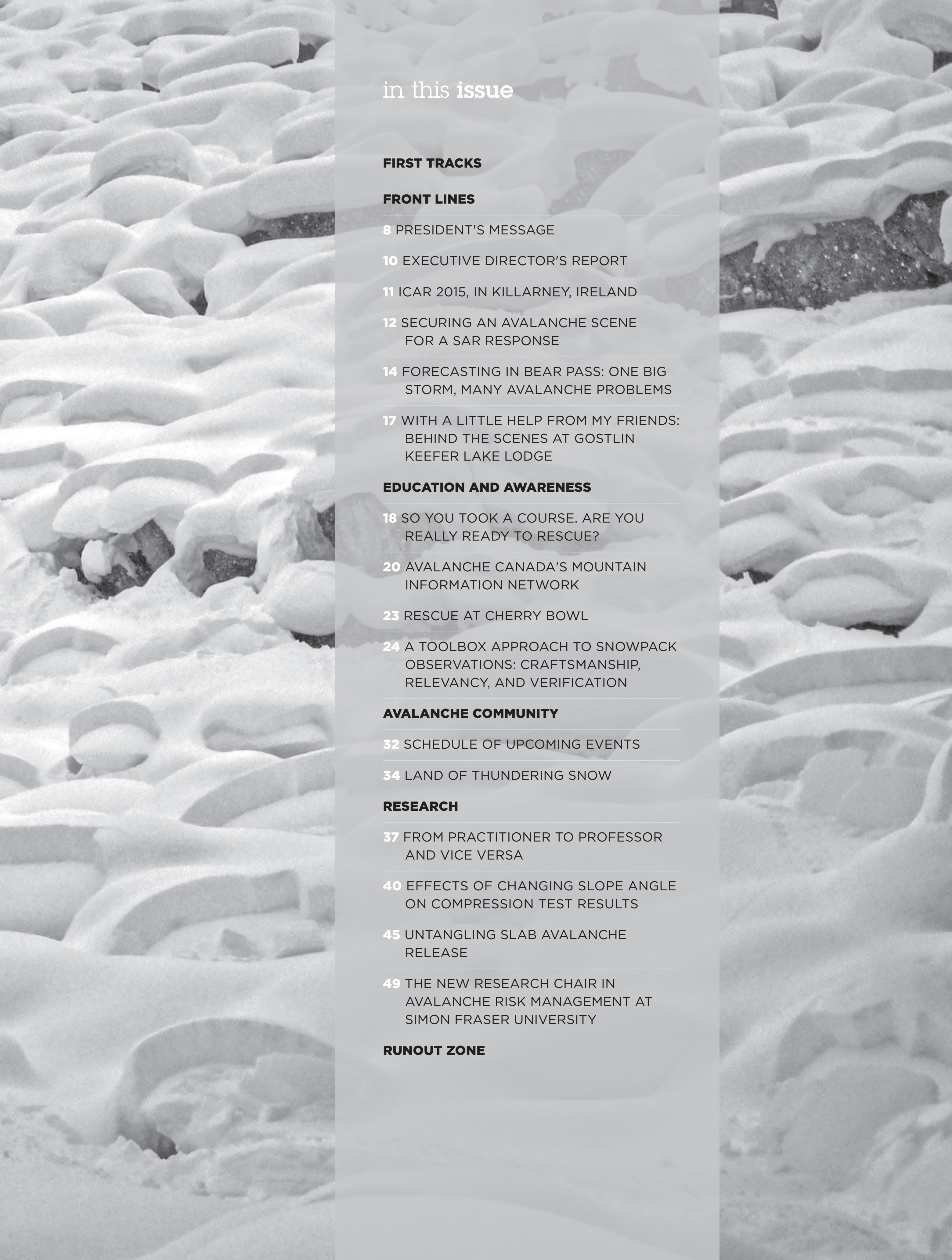
CONTENTS
WINTER 2015

COVER FELIX CAMIRE // **CONTENTS** MICHAEL CATTIE



in this **issue**

Hands **On**

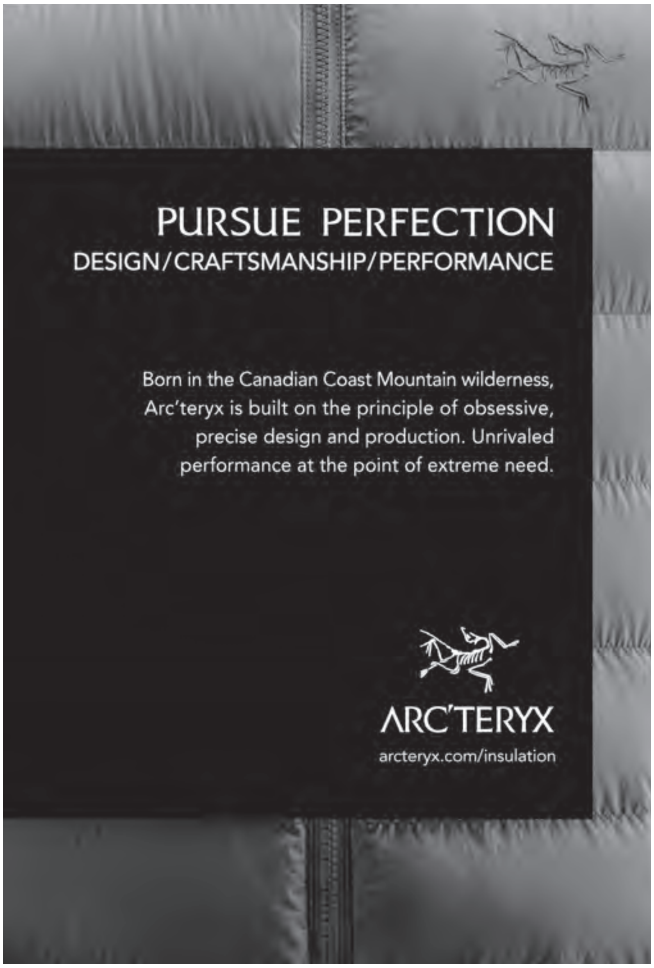
Karilyn Kempton
Managing Editor

DURING A HUT TRIP to Blanket Glacier Chalet this holiday season we were blessed with perfect powder, bomber stability, cool temperatures and great visibility. When you plan for a trip in advance you're truly at the mercy of Mother Nature, and you could end up with comically bad conditions with no real recourse, so you just make do. But it really doesn't get any better than what we got, and the group took advantage of it by skiing some seriously steep lines that have seen little, if any, traffic. It was the December to remember for many operations, with incredible snow quality and stability providing excellent guest experiences. I hope lots of you were also able to get out there and get some powder in your faces, whatever your mode of transportation.

This issue of *The Avalanche Journal* was compiled in the lead up to the holiday season and right after, and it's as stuffed as you probably felt after Christmas dinner. I know you'll enjoy Colin Zacharias' piece breaking down how to interpret snow stability test results, which dovetails nicely with Karl Birkeland's article on performing CTs on mellower terrain. Thanks to Dr. Colin Johnson who was inspired by Bruce Jamieson's retrospective in the last issue and wrote his own. Karl Klassen gives his insight on crowd-sourced avalanche data in Canada and Bree Stefanson takes us through a big storm cycle in Stewart. Thanks to all contributors.

I'm looking for more hands-on, technical articles that could help your fellow members. What kind of training does your team do? Have you started using new tests or tools that make a big difference? How are you evolving and improving? What new questions are you trying to answer, and how are you doing so? Let us know. Send any submissions, comments or questions to editor@avalancheassociation.ca. As always, I welcome any feedback, and gratefully accept any photos you'd like to send along!

Karilyn Kempton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Contributors

ALEC VAN HERWIJNEN
After growing up and going to university in the flatlands (Belgium and Holland), Alec decided it was better to move to the mountains to learn about snow. A PhD thesis (Calgary) and two postdocs (Davos and Bozeman) later, he now leads the "Avalanche Formation" research group at the SLF. Alec enjoys digging in snow almost as much as he does skiing it.
45 UNTANGLING SLAB AVALANCHE RELEASE

BENJAMIN REUTER
Ben recently obtained his PhD on the spatial variability of snow and is currently a postdoc at the SLF in Davos. Besides performing countless SMP measurements, he also found the time to become a fully certified mountain guide. Ben likes both snow and rocks, with and without his fat skis.
45 UNTANGLING SLAB AVALANCHE RELEASE

JÜRG SCHWEIZER
After graduating in environmental physics and completing a PhD in Glaciology, Jürg joined the Swiss Federal Institute for Snow and Avalanche Research SLF. He still has fond memories of his one-year stay in Canada (1995-96). He has made numerous research contributions in snow mechanics, avalanche formation and forecasting, was responsible for the education of avalanche professionals and has been an expert witness in many court cases. He is presently the head of SLF.
45 UNTANGLING SLAB AVALANCHE RELEASE

JEFF GOSTLIN
Jeff Gostlin has been in the ski industry for 17 years, first as a ski patroller and then as a ski guide at Selkirk Wilderness Skiing, Highland Powder Skiing and Kingfisher Heliskiing. Last year he started Keefer Lake Lodge, which he calls a "dream come true" and looks forward to many more years. He has four beautiful daughters at home.
17 WITH A LITTLE HELP FROM MY FRIENDS: BEHIND THE SCENES AT GOSTLIN KEEFER LAKE LODGE

COLIN ZACHARIAS
Colin Zacharias has been employed in the avalanche and guiding industries since 1980. Colin works primarily as an operational consultant and educator. He lives on BC's west coast in Tofino.
24 A TOOLBOX APPROACH TO SNOWPACK OBSERVATIONS: CRAFTSMANSHIP, RELEVANCY, AND VERIFICATION

BREE STEFANSON
This is Bree's third season in the Bear Pass. Prior to this, she worked in the MOTI Northwest Regional Program based in Terrace. She has also worked on a few industrial avalanche projects and got into the industry patrolling at Castle Mountain Resort.
14 FORECASTING IN BEAR PASS: ONE BIG STORM, MANY AVALANCHE PROBLEMS

front lines

in this **section**

// TROY GRANT

CAA President's Message

THE PUBLIC IS WATCHING: LET'S SEND THE RIGHT SIGNALS

Aaron Beardmore
CAA President

OUR ACTIONS SHAPE the public view of avalanche practitioners—during morning meetings, in the middle of a control mission or even on the way home from work after a series of choices challenged your work day. I don't think we allot a magic time to considering public perception, and yet as practitioners and CAA members, realizing how our actions shape public perception is central to our collective future.

Consider the CAA's vision statement from our strategic plan: "The Canadian public has the highest degree of confidence in the avalanche safety programs and services delivered by CAA members." This vision, aspirational in nature, has yet to be fulfilled. By design, our vision is an ideal state, something we work towards over time. Our strategic plan acts as a road map towards this vision, requiring additional refinements the closer we get. The CAA Board of Directors created the vision and strategic plan by listening to CAA members and external experts, communicating with other professions and studying modern professional self-regulation. Below are some thoughts on how the public perceives different professions, some further rationale for self-regulation, and actions you can take to help the CAA establish a self-regulatory model.

PUBLIC TRUST IN PROFESSIONS

The public is paying attention to professional groups. In 2012, the polling firm Ipsos Reid gauged public trust in professions. They found the public understands professions and judges those professions according to their perceptions. In some cases, the public views some professions as seeking "to protect their colleagues and hide the truth from the public in times of uncertainty." (Bertkau, Halpern and Yadla 2005). Trust, or lack thereof, varies greatly across groups the public view as professions.

Professions at the top of the list are perceived to place the public's interest over their own and professions towards the bottom of the list are perceived to place their own interests ahead of the public. As an emerging profession of avalanche practitioners, we need to make choices both at the individual and organizational level to maintain and *increase* trust to work towards achieving our vision. We all have a role in shaping public trust so that CAA members might be ranked near the top of this list.

PROFESSION	% OF GENERAL PUBLIC VIEWING PROFESSION AS TRUSTWORTHY
Firefighters	88
Farmers	71
Teachers	65
Daycare workers	56
Plumbers	40
Church leaders	33
Lawyers	25
Bloggers	9
Car salespeople	6

IPSOS REID RANKED THE PROFESSIONS VIEWED AS TRUSTWORTHY BY THE PUBLIC.

PROTECT THE PUBLIC: FAR FROM NEW, BUT STILL EVOLVING

As far back as the mid 1800s, dentists in Canada stated that "for the protection of the public, that there should by enactment be established a certain standard of qualification for each practitioner" (Adams 2013). Self-regulatory philosophy has also evolved over time. Some of the clearest and most modern thinking on professional self-regulation suggests that evolving professions must be very responsive and publicly accountable to retain public trust (Randall 2000). Not doing so has the potential to attract harsh public criticism and oppressive outside involvement from government and other bodies with little understanding of our profession. Placing duty on the public interest rather than self-interest by being responsive, accountable and transparent will also help us get one step closer to achieving our vision.

YOUR PART

I began by providing some examples of your role in shaping public confidence in our profession. I hope you will continue to take advantage of resources that increase your sense of professionalism in general, and your competency as a CAA member. I encourage all CAA members to take a look at some of the resources I have listed at avalancheassociation.ca/?page=Self-Regulation describing the evolution of professionalism as a concept and ways to increase public confidence. In particular, read the paper by Glen E. Randall who illustrates the merits of professional self-regulation exceptionally well. A natural corollary step is review the CAA's Code of Ethics found on the governance page of our website. Like all CAA Members, I am looking forward to the release of our *Technical Aspects of Snow Avalanche Risk Mitigation.* Please use and promote our new guidelines. Lastly, please take full advantage of all available continuing professional development opportunities to maintain and increase your competency. We will not achieve our vision of full confidence from the public tomorrow, but if we all take these steps as members, we'll be that much closer.

Aaron Beardmore, CAA President

Professionalism aligns with Goal 1 of the CAA's Code of Ethics: "CAA's Professional Path." For more information, visit avalancheassociation.ca/?page=Strategic_Plan.

Adams, Tracey L. "Professional Self-Regulation and the Public Interest in Canada." Paper presented at the ISA Rc52 Interim Conference on Challenging Professionalism, Lisbon, Portugal, November 29, 2013. Retrieved at http://pascal.iseg.utl.pt/~socius/interim/?download=adams-public.pdf.

Randall, Glen E. "Understanding Professional Self-Regulation." Retrieved at http://www.collegeofparamedics.sk.ca/docs/about-us/understanding-prof-self-regulation.pdf.

Bertkau, Anne, Jaclyn Halpern and Sanjay Yadla. "From the Editor: The Privileges and Demands of Professional Self-Regulations." *American Medical Association Journal of Ethics* Vol. 7:4 (2005). http://journalofethics.ama-assn.org/2005/04/fred1-0504.html.

Joe Obad
CAA Executive Director

CAA Executive Director's Report

PEEKING THROUGH A SCANDINAVIAN TIME MACHINE

A community is like a ship; everyone ought to be prepared to take the helm. - Henrik Ibsen

IN DECEMBER 2014, THE SWEDISH Environmental Protection Agency (SEPA) brought me and InfoEx Manager Stuart Smith to Jamptland County to provide training for InfoEx Sverige. The trip was part of the service agreement announced in an eNews this fall for the CAA to license InfoEx software to Sweden to support avalanche-related data exchange amongst their emerging network of private operations, government avalanche warning service and paid observers.

Leading up to this trip I reviewed some historic slides about the CAA and InfoEx for a presentation to SEPA and their partners. Clair Israelson was good enough to come into the office and to review some CAA material related to InfoEx and the evolution of the CAA.

"We were so hungry to learn from each other and share. We wanted to talk and connect with other avalanche professionals, but until the CAA was established we didn't have a dedicated forum for avalanche practitioners," Clair said excitedly, reflecting on the late 1970s and early 80s. "Even then, communicating things in a timely way was a huge hurdle until the fax came along, and with it the first InfoEx."

What struck me in Clair's reminiscing was the passion of practitioners of the day to communicate and exchange data, information and practices in the absence of established forums we've come to know so well today, like the CAA's spring meetings, InfoEx, *The Avalanche Journal* and various other fora like the ACMG's Informalex and Mountain Conditions Report, and even Avalanche Canada's Mountain Information Network.

A few flights later, Stuart and I were battling to keep our jet-lagged eyes open in various training sessions for our Swedish colleagues wrestling for the first time with InfoEx quirks well-known to CAA members: observation entries, reports and workflows. These tasks were just one small part of rebooting the Swedish avalanche community for which they had a dedicated *kongress*.

Maybe it was the sleep deprivation or the stomach full of reindeer, but in this group of aspiring Swedes I felt like we had a glimpse through time back to the early days of the CAA. Here was a community defining new standards; borrowing from friends abroad; adapting to their own context; sorting out what should be public and private; determining how to fund national avalanche initiatives for professionals and the public. The talks were mainly in Swedish but seeing leaders emerge to take on foundational tasks as Ibsen describes didn't always require my Google translate app. Stuart and I were humbled by the twin honours of representing the CAA and witnessing this Swedish avalanche renaissance.

After some more training sessions, reindeer and schnapps from our hosts, we were back on flights home. Our Swedish friends, led by SEPA's indomitable Per-Olov Wikberg, were well on their way. But Clair's comments about the hunger to know, connect and advance still rang in my ears. If a community is built by the hunger to connect and share, what happens to that hunger when sharing and connecting become institutionalized?

Well, I'm happy to say for the most part the passion and commitment of CAA members has not waned, but has been channeled into a variety of projects which have advanced professional avalanche practice. This past year the CAA completed several projects and continues to move on others concluding in 2016. Our revisions to ITP's primary AvSAR course were completed by a dedicated team of curriculum developers and instructors this fall. As the first course developed based on the Competency Profile presented to the CAA membership in May 2015, the AvSAR course has so far received generally positive reviews from students and instructors alike, and is rapidly becoming one of our most sought after courses.

The Competency Profile itself has offered a platform for analyzing ITP courses to see how curriculum should be modified in the future, as well as offering the competency work group a basis for beginning to look at methods of competency assessment.

On other fronts, the *Framework for Avalanche Risk Assessment and Mitigation* project will wrap up this spring. The first document for practitioners, *Technical Aspects of Snow Avalanche Risk Management*, is currently being translated, and the companion piece for land managers will follow shortly. Together these new guidelines will enable practitioners to assess and mitigate risk, while helping risk-owning land managers to define and address their due diligence.

Certainly, CAA members have stayed hungry to advance avalanche practice in Canada, but to riff again on Ibsen the CAA needs a little bit of leadership and hunger from every CAA member to advance the Association. We don't have as much heavy lifting to do as our Swedish friends, but there is still lot of work ahead for ITP, InfoEx and the many functions of the Association. Our board, committees and staff and other institutional veneers may lull some members into thinking their help isn't required. But there are enough gaps that the Association still needs your help. I encourage you to consider what areas you wish to advance and approach the Board or me with your interests. As always, I welcome any feedback from members. Warm wishes for a safe and happy 2016 to all of you!

Joe Obad, CAA Executive Director

The Competency Profile mentioned above aligns with section 1.6 of the CAA's 2014-16 Strategic Plan. To read more, visit avalancheassociation.ca/?page=Strategic_Plan.

ICAR 2015 in Killarney, Ireland

Kyle Hale

From October 13-17, 2015, I had the honour of attending the annual International Commission on Alpine Rescue (ICAR) Congress as the CAA and Parks Canada delegate to the avalanche commission. The 2015 ICAR Congress was hosted in Killarney, Ireland with over 400 delegates from 33 member countries. This was my first exposure to the organization, so I had my hands full getting up to speed on previous work done by the avalanche commission and understating the process and structure of ICAR.

The avalanche commission is led by its president Dominique Létang and consists of two sub commissions, one concentrating on avalanche prevention and the second on avalanche rescue dogs. During the conference, the avalanche commission had the opportunity to meet for several days and was fortunate to hear several great presentations on operational avalanche rescue tasks from around the world.

Much discussion this year was centered on the establishment of a best practice for probing methodology. It is clear that probing methodology differs greatly from country to country. This simple search strategy has been used in many European countries for generations and is very rooted in local culture and tradition. Some counties with large volunteer SAR systems expressed concerns about retraining SAR personnel if new techniques were to be adopted. Manuel Genswein's Banff ISSW 2014 paper "Slalom Probing – A Survival Chance Optimized Probe Line Search Strategy" framed the majority of the conversation. The best practices for probing in Canada are well established in the CAA AvSAR manuals and curriculum. The recent addition of the slalom probe as a best practice for a course probe strategy is reflected in the newest CAA AvSAR course curriculum.

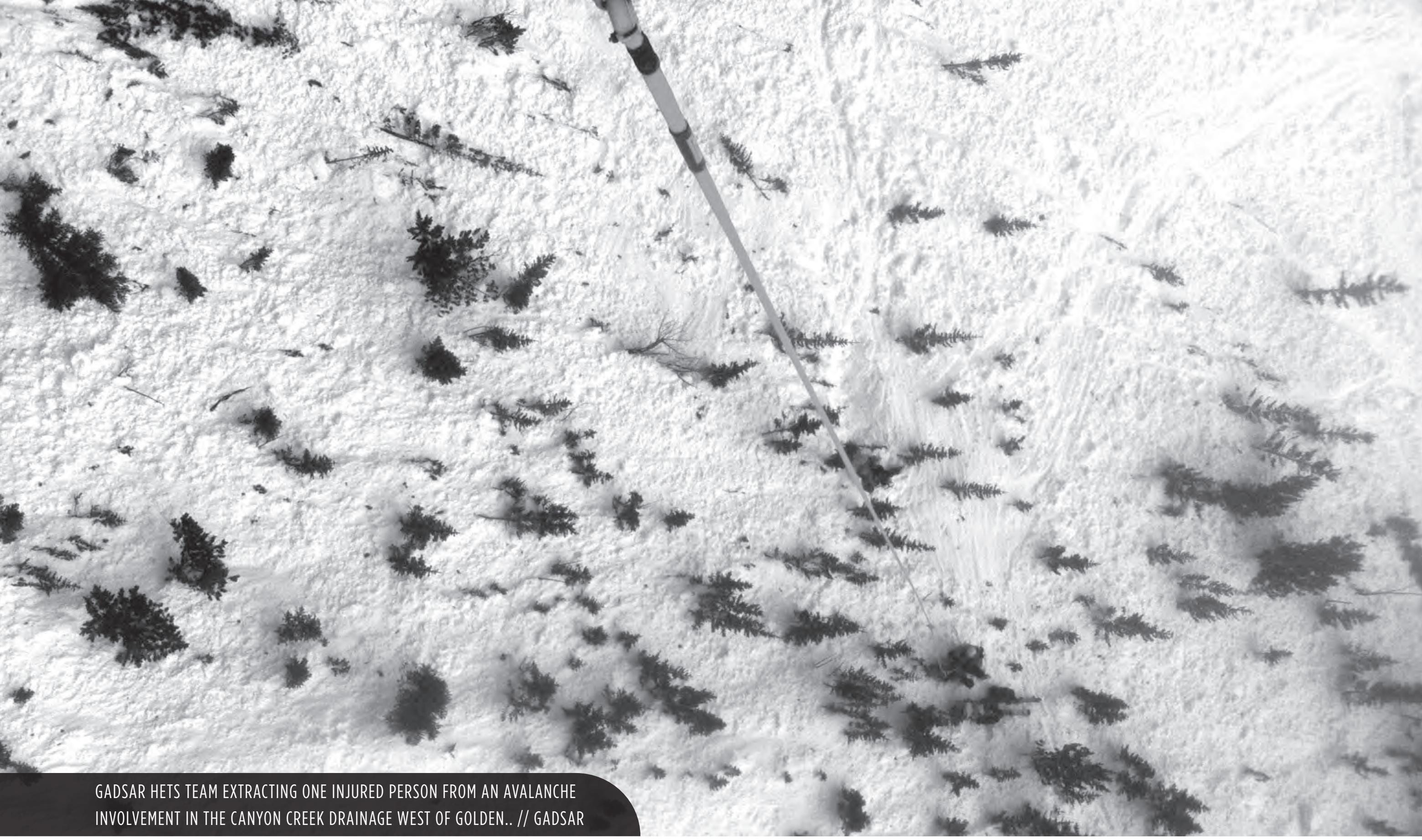
Another interesting development is collaboration between ICAR and the UIAA (International Climbing and Mountaineering Federation) on the development of a certification standard for avalanche rescue shovels and probes. UIAA is currently conducting research to develop laboratory testing standards for avalanche safety equipment.

Canadian avalanche professionals were well represented and active in the avalanche sub committees. This year the avalanche prevention sub commission met in advance of the conference, and Joe Obad and Karl Klassen attended and contributed to the commission. The sub commission passed a recommendation last January: "Be Searchable." The recommendation encourages mountain recreationists to utilize equipment that makes them more searchable for rescuers. ICAR is currently working to promote that recommendation to the public. Jennifer Coulter represented the Canadian Avalanche Rescue Dog Association and attended the Avalanche Rescue Dog sub commission. This was the first time Canada had a formal representative attend this sub commission.

Moving forward, I will continue to represent the CAA at ICAR and I look forward to your engagement. You can find more information about how ICAR works through their website at alpine-rescue.org/. If you have any questions or comments regarding ICAR please contact me directly at kyle.hale@goldeneoc.ca.

BRIAN WEBSTER OF PARKS CANADA PERFORMING CPR // KYLE HALE

PATIENT TRANSPORT AT THE FIELD DAY CPR TRAINING STATION // KYLE HALE



GADSAR HETS TEAM EXTRACTING ONE INJURED PERSON FROM AN AVALANCHE INVOLVEMENT IN THE CANYON CREEK DRAINAGE WEST OF GOLDEN.. // GADSAR

Securing an Avalanche Scene for a SAR Response

Adam Sherriff, Golden and District Search and Rescue

AN ORGANIZED AVALANCHE RESCUE can be a complex response involving multiple agencies, with varying levels of experience and degrees of operational risk. When rescue groups come together to respond to an avalanche accident, it is essential that we all speak the same language and operate under the premise that our overriding rule is rescuer safety. Multiple factors may complicate or hasten the rescue response, such as time of day, survivability of the patients, amount of detailed information, available resources, relationships between the rescuers and the patients, weather, and media and/or family pressures. Each one of these factors can influence team decisions and potentially increase the risk the team is willing to expose themselves to. For the safety of the rescuers, we must take steps to ensure that the rescue plan remains within the operational risk band prior to performing the rescue. These steps are put into motion starting from the report of the incident.

Avalanche Report:

- How many people are involved?
- Are they wearing appropriate PPE?
- How long ago did the accident happen?
- Are they performing companion rescue?

SAR mobilization:

- Who is available to respond? What are their levels of training?
- What is the type of terrain? What are the travel requirements?
- Where is staging? Is there a helicopter available?

In the first minutes of a SAR team avalanche response, the answers to the questions above create the foundation of the response and how it will be safely conducted. Acquiring as much information as possible prior to responding allows us to select the highest trained personnel for the specific accident and build on that. To conduct a SAR response in avalanche terrain, at least one member of the team must be trained to the CAA Avalanche Operations Level 2. Golden and District Search and Rescue is a volunteer group and approximately 30% of our members possess a CAA Level 2 and work in the avalanche industry (including ski

SAR RECONNAISSANCE FLIGHT TO ASSESS OVERHEAD HAZARD FOR CANYON CREEK DRAINAGE AVALANCHE INVOLVEMENT // GADSAR

patrollers, avalanche technicians and ski guides). Often the initial stages of a rescue are quite hectic and this strong foundation will lead to safer and more informed decisions as the rescue response evolves.

Assessing the scene, we ask more questions (from a helicopter, if available):

- What's the location of patients? Are they on the surface or buried?
- What was the avalanche trigger? Was it natural or human triggered?
- Is there potential for a secondary avalanche? How much hang fire is there? Are there overlapping avalanche paths?
- What's the rescuer access/egress? What is the overhead exposure?

Now that we have a picture of the accident scene, we must take steps to perform the rescue while keeping the rescuers within the operational risk band. In a straightforward rescue the scene assessment would reveal that the avalanche rescue scene is not threatened by secondary avalanches, has simple access and little overhead exposure throughout the SAR response. Unfortunately this is rarely the case, and mitigation measures must be used to keep the rescuers safe. Mitigating the team's exposure, vulnerability or the overhead hazard allows us to perform structured responses to avalanche accidents. The options listed below are examples of how GADSAR can make changes to a response plan based on the findings at the scene.

Hazard:

- Can we mitigate hazard with explosives?
- It is acceptable with other mitigations?

Exposure:

- Send a small strike team to perform a quick rescue of patients on surface and patients with a high percentage of survivability. Other team members act as lookouts and prepare rescue gear.
- Utilize dog teams to search large areas. Reduce the amount of rescuers exposed.
- Reduce the search area to specific zones until further hazard mitigation has been taken.
- Perform a HETS rescue.

Vulnerability:

- Search the area with an external helicopter transceiver.
- Fly to the scene rather than over-snow transport.

Multiple mitigation options may be available depending on the scene and each must be weighed against each other to see which is the safest and most effective. On occasion, reducing the exposure or vulnerability is not enough to ensure the safety of the rescuers and a full hazard mitigation plan using explosives may be required to safely allow rescuers to access accident scenes to search.

Once the risk mitigation plan has been established and all team members have been briefed, the scene can be deemed "secure" based on the plan for the specific operation. A secure scene is not always a scene free of hazard, but is a scene that, combined with the SAR team's rescue plan, keeps the rescuers within the operational risk tolerance. As the rescue moves into its next operational period, hazards must be reassessed and new mitigation actions may be required to keep the scene secure for the next phase of the rescue.

Forecasting in Bear Pass: **One Big Storm, Many Avalanche Problems**

Bree Stefanson

I MOVED TO STEWART SEVERAL YEARS AGO to work in the BC Ministry of Transportation and Infrastructure Bear Pass Avalanche Program. The afternoon before my first day of work was my first time driving Highway 37A. My jaw dropped and my neck strained as my eyes tried to take in the complexity of the avalanche paths surrounding my truck. Within the first few hours on the job, I was in a helicopter finding out where my targets were and when to deploy the charges. Each of the sixty 25kg bags that went out of the door created avalanches, including numerous showy size 3s and a handful of movie-quality size 4s. It was like nothing I had ever seen. The large paths have a vertical fall of over 2,000m and avalanches can travel upwards of four kilometres before the mass crosses the highway. The mid-sized paths were a couple hundred metres higher than the vertical fall of Castle Mountain Resort, where I had worked as a ski patroller. The smaller paths can bury a vehicle or push one into a lake.

The pass taught me a lot my first season. For example, the center of an approaching low-pressure system can slip a little south and surprise you by sneaking in the backdoor with outflow winds. Amazingly, the large avalanche paths can retain what seems to be an infinite amount of load and are capable of producing size 5 avalanches. An impressive display of nature, the large avalanches command respect for the potential damage they can produce. It was hard not to get caught up in focusing on the large paths, but the "small" paths can still put a size 3 on the road. Also, the importance of clear, timely communication to the public became paramount when living in a community that becomes isolated once the road closes.

Coming into my second season I had a better idea of what to look for and what to expect. I also knew that I had just experienced an "average" season and hadn't seen anything "above average." I had come to appreciate the forecasting process which was well-established within the program. This process assesses the overall avalanche hazard for an unmodified snowpack and then applies that assessment to each individual path throughout the forecast area, taking significant occurrences into account. The paths are then individually ranked on the Ministry's five level hazard scale to identify the paths of concern and dictate specific operational procedures that the maintenance contractor is required to follow while working within the avalanche area.

The 2014-15 season started warm and wet with average amounts of precipitation, but freezing levels were often above 1,000m. In the alpine, a significant instability was buried in the fall, and by Christmas a hard slab had developed over top. When we issued a Future Planned

FRACTURE PROFILE ON ORE MOUNTAIN // MOTI

EXPLOSIVE CONTROL EAST STROHN // MOTI

Event notifying our stakeholders that the highway would be closed for avalanche control, you can only imagine the feedback we got from surprised locals, as there wasn't a flake to be found in town. The control mission was successful, with avalanches to size 4 crawling over nearly bare ground and terminating within 200m of the highway. This mission greatly reduced mass from our alpine start zones, and even though we had large deposits visible from the road, no one in town was buying my story.

The first time I heard the term "atmospheric river," a significant storm that was forecast to track well to the south had shifted its course and was headed towards Stewart. The millimetres were stacking up on the XTs and we were all trying to forecast the effects of 100mm in a 30-hour period on our snowpack. We compared the various forecast models, attempting to pinpoint the peak of the storm. We applied the forecast to our current snowpack and attempted to hypothesize the timing and character of the expected avalanche cycles. Our theory was that there would be too much rapid loading for the paths to retain significant mass, and the paths would shed during peak loading. We anticipated the freezing levels to rise and induce a secondary wet cycle as the snowpack became saturated. With saturated runout zones, deposits from large avalanches initiating later in the storm would slow down, ideally stopping above the road. We planned a

control mission for the peak of the storm, targeting rain-saturated paths below treeline. This closure would also empty the road of travelling public, allowing us to get a handle on the avalanche character and where the deposits were actually stopping without added pressure.

The storm was intense, starting with 3-5mm H2OE per hour, steady for hours. Twelve hours into the storm, snow levels were above 1,100m and precipitation rates had reached up to 7.4mm an hour. I was relieved once the road was closed for control, as the large paths were retaining their mass.

Fortunately, the ceiling was high enough to access the below treeline start zones and the snowpack was saturated enough to release wet loose and slab avalanches. After a three-hour mission, our BTL concerns were mitigated and we had plenty of daylight to fly through the pass to observe the natural occurrences. Sure enough, as we flew by, we saw every large alpine and mid-elevation path had healthy deposits below them, with all deposits stopping above the highway. We ran through our path hazard avalanche risk table and all of our paths of concern had released, with any residual hazard still falling well within our operational risk band. We made the call to open the road and continued to monitor avalanche activity.

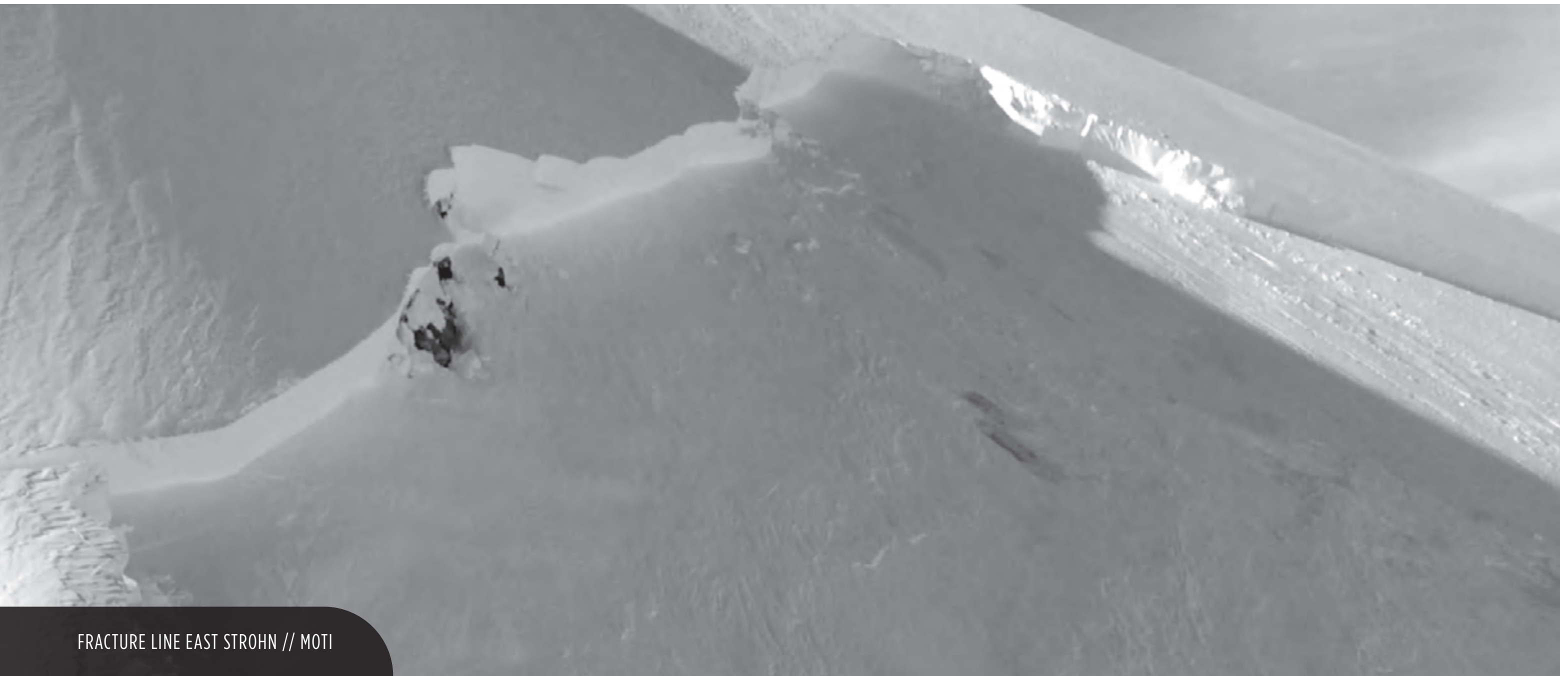
The storm ended as fast as it came. When it was all said and done, Stewart had received 146mm over a couple of days with 110mm falling within a 24-hour period. This exceeded by twice as much the previously recorded maximum precipitation amount for a 24-hour period in Stewart in March.

At first light I drove through the pass with the clear morning sky showing crowns throughout the pass. By 10:00 a.m., the wind increased, grabbing all the new snow available for transport and quickly erasing the crowns.

Fortunately, the weather continued to improve and conditions were favourable for control the following day. We spent most of our mission above the treeline, producing numerous size 3 to 3.5 avalanches and a few size 4s. The deposits of these reloaded paths easily traveled over the debris piles produced during the storm, with some just stopping shy of the road. The avalanches were stunning. They were dry and moving fast until they hit the saturated snow, where they'd push a slow moving finger of wet mass through the run-out zone. It was impressive to see the power of the airblasts from the two plunging avalanches that dusted the road.

Following the mission, I drove through the pass to capture the toe distance mass of the deposits, and I reflected on the storm, the natural cycles and the control missions. I thought about the various avalanche path characteristics over the elevation bands and the many avalanche problems I had just seen. In one storm there was storm slab, persistent slab on surface hoar, large plunging, loose dry, loose wet, and wet slab, as well as the potential for large avalanches to detach huge fins of glacial ice amplifying the deposit size. I was glad that we had eliminated the deep slab problem formed earlier in the season as it had become active in slopes adjacent to the forecast area, and this would have increased the magnitude of the impacts to the highway during the storm.

The Bear Pass is a wild place to work during a significant storm event, and the area provides a fabulous opportunity to learn a lot about avalanches. I am grateful to have seen an event like this and to have had such a solid team to work with through the season. I'm now in my third season in the pass and from the deposits I've seen in the archived photos, all I really know is that I have a whole lot more to learn.



FRACTURE LINE EAST STROHN // MOTI

With a Little Help From My Friends: Behind the Scenes at Gostlin Keefer Lake Lodge

Jeff Gostlin and Felix Viau

ONE OF THE BIGGEST CHALLENGES of starting a mechanized ski operation is safety, both on and off the snow. Obviously finding the best ski lines is one thing, but efficient terrain management is another. Cat ski roads need to be in the right places for easy turn around and in the proper place to minimize exposure to natural hazards like avalanches.

This is where the team at the brand new Gostlin Keefer Lake Lodge has had an advantage right from the start. The tenure is adjacent to Kingfisher Heliskiing, and forms part of what Kingfisher has been skiing over the past few years. Kingfisher Owner and guide Matt “Pinto” Devlin has been working withGostlin Keefer Lake Lodge owner Jeff Gostlin right from the beginning, sharing information about the skiable terrain and how it has reacted in the past to different weather and avalanche patterns. Matt’s extensive winter and summer knowledge of the area helped to create a road system that primarily avoids exposure to avalanche hazards as much as possible.

Devlin and Gostlin, with the help of Kingfisher guide Felix Viau and a few other dedicated chainsaw operators, mapped the roads on both web-based and topographic maps to highlight avalanche hazard areas. The complexity of some of the micro terrain revealed small pockets that could produce size 1 to 2 avalanches on the roads. We determined that exposure can be controlled on a regular basis by ski cutting to ensure that there is never enough of a snow build up.

Other roads were built with small pullouts above hazardous slopes where the road-building cat can easily push snow onto the start zone to initiate failure of weak layers. Supervision by other guides is key to ensure that no person ever works alone in that kind of situation. Avoidance will be the main strategy for areas that are able to produce larger avalanches. Fortunately, there are very few places that cannot be entirely avoided when necessary.

Another advantage for both organizations is our close relationship. A big part of the avalanche program and Emergency Rescue Plan for both companies is based on the help can provide each other. We also share weather and snowpack data, as well as avalanche observations and near misses—key for both companies to ensure the best terrain selection for skiers and to avoid hazards.

We appreciate knowing that friends are close by skiing with their own guests, and that they can drop everything and help in case something goes wrong. We are working together as professionals, thinking of the well-being of others around us—in our minds, every operation should put this kind of cooperation at the forefront of their safety program. You can’t control Mother Nature, but together we can ensure that our guests have a safe, enjoyable ski day, regardless of conditions. Be safe out there.

GOSTLIN KEEFER LAKE LODGE

So You Took a Course. Are You Really Ready to Rescue?

Emily Grady

BY THE TIME YOU READ THIS, the CAA's Industry Training Program will have completed a redevelopment of its Avalanche Search and Rescue (AvSAR) Response course, and conducted courses in Revelstoke, Whistler, and Jasper.

RATIONALE FOR CHANGES

We designed the 2014 version of the AvSAR course to address a perceived shortfall in new worker skills. That redesign was done with the help of Manuel Genswein. The development of the CAA's Competency Profiles for CAA Members document provided emergency response competencies (Section 8 of the P1 and P2 competency profiles) which complemented the 2014 course redesign.

The 2015 AvSAR curriculum project further aligns the course with the entry-to-practice requirements of a worker at the P1 level as laid out in the Competency Profile. We have accomplished this by altering the course goals and learning objectives, creating a new student manual, and most importantly, developing assessment methods that accurately evaluate skills (this is also known as "authentic assessment"). Employment-oriented education and training need to provide a connection between learning and the ability to use that knowledge in the real world. Practical assessment tools, such as the snow profile exam on the Avalanche Operations Level 1 course, prepare graduates with the skills they need to be entry-level avalanche workers.

THE ASSESSMENT PROCESS

Student learning assessment on the AvSAR course is broken into two parts: theory and practical skills. The theory portion is assessed at the end of the course with a final written exam. This exam has a combination of multiple-choice, matching and short answer questions. Learners must achieve a mark of 71% or higher in order to pass the written exam and to receive an AvSAR theory certificate.

During the AvSAR course, students are provided with written and/or verbal feedback as they practice avalanche rescue skills during the outdoor field stations. Students are also provided with the practical skills marking rubrics in order to help prepare for the practical skills assessment. This assessment can take place during either the Avalanche Operations Level 2 Module 2 *or* the AvSAR practical skills exam.

The AvSAR practical skills exam will be offered as an additional day at the end of AvSAR courses, mainly to accommodate students not intending to pursue the Avalanche Operations Level 2 program. In either case, the practical skills assessment involves three evaluation sites where students are randomly assigned to one of the sites. In other words, students must train for *all* exam scenarios but will only be assessed on *one* of them. For example, one exam scenario examines a student's ability to apply an alternate search strategy for multiple burials, which includes being able to explain transceiver interference issues, applying effective search techniques, developing appropriate logistical, organizational and search tactical conclusions based on a mental map, and employing effective probing techniques.

Retests after the course will consist of another scenario selected at random. Upon successful completion, students receive an AvSAR practical skills certificate.

RATIONALE FOR ASSESSMENT

Providing students with a meaningful evaluation of their practical skills is unrealistic in a three-day AvSAR course, given the instructor to student ratios. Introducing and practicing a skill on the second day and then testing it the following day sets many learners up for failure. By clearly setting out the assessment expectations during the AvSAR course and then providing students with ample opportunity to practice, we can assess learners at a higher level, as per the DACUM course goals. The CAA is striving toward assessing member abilities more rigorously, and this is an important step. In the last issue of *The Avalanche Journal*, CAA President Aaron Beardmore explained the difference between formative and summative assessment in his President's Message. Whereas formative assessment looks at a student's development at a certain time, summative assessment evaluates student learning at the end of an instructional period by comparing it against a benchmark—which, in this case, is the competency profile.

We are excited to move forward with these new methods, which align with the emergency response portion of the CAA's competency profile, and address the need for more advanced avalanche rescue skills in avalanche workers. For course details, click on the training tab at avalancheassociation.ca.

AVSAR CORE INSTRUCTOR TEAM FROM LEFT TO RIGHT: BRAD WHITE, KYLE HALE, JORDY SHEPHERD, WALTER BRUNS, JOHN BUFFERY, GARTH LEMKE, EMILY GRADY (PROJECT MANAGER), SYLVIA FOREST AND ROB WHELAN // BRAD WHITE

THE FIRST BATCH OF STUDENTS TAKING THE COURSE AT REVELSTOKE MOUNTAIN RESORT // TOMOAKI FUJIMURA

Avalanche Canada's Mountain Information Network: **Promoting Convergence in the Canadian Avalanche Data Stream**

Karl Klassen

CANADA HAS A LONG HISTORY of national standardization in the avalanche industry. This includes the realm of data exchange, the ultimate result of which is InfoEx, considered by many to be the most comprehensive avalanche database in the world. However, InfoEx is available only to qualified professionals who pay for a subscription, which leaves the public and a portion of the professional community without an avalanche information exchange system.

In response to the need for a public avalanche information exchange system, Avalanche Canada created the Mountain Information Network (MIN). Jointly funded by TECTERRA (the funding agency behind the InfoEx upgrade), MEC and Recreation Sites and Trails BC, and built by the geomatics development company Tesera Systems Inc., the MIN has transformed Avalanche Canada's Public Avalanche Warning Service from a provider of information to an information gathering and sharing operation.

"Whenever I felt a little overwhelmed, I'd remind myself about multi-billion-dollar Apple Corporation's first version of its mapping app—remember that dog?"

The first phase of the MIN, launched in December 2014, re-developed Avalanche Canada's existing mobile app to include data sharing. The app's Quick Report function provides an easy-to-use interface that allows fast and efficient input, uploading, and sharing of observations in real-time (if connected at the time of posting) or near real-time (i.e., uploaded as soon as a connection is established) on a geographical interface. Users not only see the data, but can visualize on a map where the data is coming from. In addition to the mobile app, the MIN was duplicated on the web so users could submit information from and view reports on avalanche.ca.

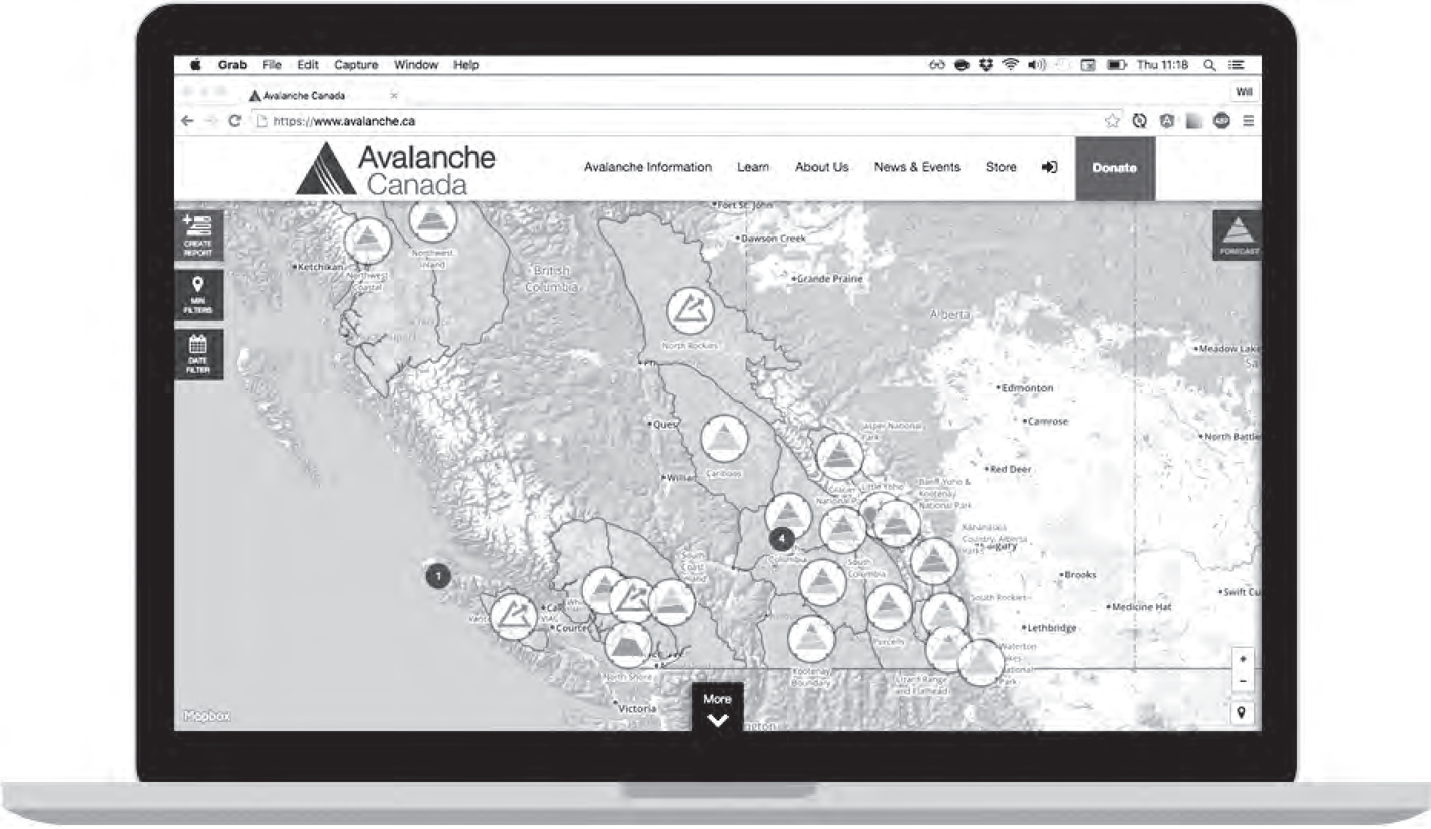
The MIN of 2014-15 garnered both praise and criticism. The general public appreciated how simple and easy it was to input, share, and view information. AvCan forecasters liked it because it augmented existing sources of information such as InfoEx and provided new information that filled gaps in our data streams, both at data-sparse times and in data-scarce regions.

Criticism revolved around two main issues: "it's buggy" and "it's too basic." As the project progressed, I took the issue of bugs in stride, knowing that a small, non-profit, NGO with limited funds and resources would be challenged to put out a perfect app on the first version. Whenever I felt a little overwhelmed, I'd remind myself about multi-billion-dollar Apple Corporation's first version of its mapping app—remember that dog? After a number of updates, the most recent following Apple's release of iOS 9, which impacted the MIN photo upload functions, the Avalanche Canada mobile app is now a functional tool.

The second criticism came from more advanced users who felt the "simplistic" questions and pre-set answers in the Quick Report were too basic with little value. In answer to this I make the following points:

- The MIN is meant to appeal a broad range of users, including those who have little or no training.
- It's hoped the MIN will draw in user groups who have traditionally been disengaged from avalanche safety.
- The questions and answers were carefully designed and worded to make them interesting and accessible to a broad variety of users.
- Answers to the questions offer an opportunity to share simple, non-technical information with other users, thereby drawing people into avalanche awareness.
- At the same time, answers provide pertinent data to AvCan forecasters. With minimal reading between the lines you can easily glean information about surface conditions, weather, snowpack, avalanche activity, and decision-making in avalanche terrain—the same data we all look for in professional data sources.

Further to the "it's too simple" feedback, I'm very pleased to announce that AvCan has recently launched phase two



CHECK OUT THE NEW MIN FEATURES AT AVALANCHE.CA/MOUNTAIN-INFORMATION-NETWORK.

of the MIN. This update allows technical weather, snowpack, and avalanche data exchange on a geographical interface with improved data visualization. The catchphrase "InfoEx for the people" was tossed around and quickly shelved, but that's actually a good description of where the MIN is going. In addition, an incident reporting section allows users to share the learning opportunities generated by close calls. At avalanche.ca you see more data on the map than in the past, and you can create a full technical MIN report by clicking the red "Create Report" tab in the upper left corner. After completing a MIN report, it's easy to share on social media. For this winter, creating technical reports is possible only on the web.

When funding becomes available, further development of the MIN will be undertaken. This includes:

- Updating the mobile app to allow visualization of the new MIN reports.
- Assessing if creating advanced technical reports from a mobile device is practical, affordable, and desirable, and update the mobile app to allow full technical input functionality if appropriate.
- Adding weather stations to the map.
- Adding weather forecast information to the map.
- Displaying basic observations (e.g., snow, wind, and temperature) on the map at MIN report locations.
- Making snowpack modelling information available. This includes modelled snow profiles and surface hoar layers.
- Charting and graphing functions.
- Terrain maps and trip information.
- Decision making support tools (e.g., a new version of the online trip planner).

Throughout the process of building the MIN, I've been asked why we don't simply adopt one of the information exchange platforms that already exist instead of building our own system. AvCan did in fact contemplate collaborating or partnering with developers of existing systems. Following are some of the factors we considered, questions we asked, and specifications we established to help us decide if we should build our own or buy in to another system:

1. A system dedicated to public safety should be free to all users at all levels. There should be no hidden costs or "in-app" purchases or upgrades.
2. There should be some reasonable expectation that once started, this vital public safety service will continue to be available without regard for economic considerations.
3. Public safety information should not be a slave to market forces, which can add or increase costs or even drive companies out of the market or out of business completely.

4. A system dedicated to improving public safety should not rely on individual developers (even if those individuals' motives are altruistic) who can drop out of the business at any time for any reason.
5. Many of the existing applications have been built by private individuals or companies who are actively pursuing market share to create revenue and ultimately make a profit in the avalanche data exchange realm. History has proven that making a buck in the avalanche data exchange world is not an easy task and at least one previous attempt by private enterprise to provide this vital service resulted in a failed program that left the public and many commercial operations and professionals, who sank hard-earned dollars into the system, without a viable alternative.
6. Effective avalanche data exchange platforms should allow simultaneous geographical visualization of raw data and avalanche forecasts.
7. As much as possible and practical, systems used in Canada (even public ones) should be OGRS compliant.
8. Sharing avalanche information plays a role in developing a culture of avalanche safety in Canada. This requires a data system that's a two-way discussion, which:
   a. Allows an exchange of information at a number of technical levels from simple (e.g., just a photo or a quick report) to technical (i.e., professional level weather, snowpack, and avalanche data), and
   b. encourages engagement from and between anyone, regardless of their training, skill level or experience—professionals and the public alike.
9. There's a trend of increasingly complex applications and systems that offer a seemingly endless menu of options and customization and we felt this was not the right solution for AvCan or our users. The consensus was that public avalanche safety is best served by a system that allows fast and easy input, upload, sharing, and simple but effective visualization of key, relevant data.

After considering these factors, it was clear there were no suitable existing applications available and it was obvious that we should build something from scratch that met as many of these requirements as possible—if not immediately, then in the long term.

Personally, I believe that too many applications all trying to do the same thing creates a scattered and divergent set of data streams that forces users to look for various data in numerous places and leads to user fatigue. If we're talking about music apps or games, user fatigue isn't a big deal. But when we're talking public safety, user fatigue that causes people to stop looking for information means eventually someone misses something important at a critical time, which results in an accident that could have been avoided.

I accept that other applications are out there and more are probably coming, but I hope that in Canada, avalanche data information and exchange systems will converge rather than diverge. Clearly, InfoEx is the system for commercial operations and industry. I believe the MIN is the simplest and best avalanche data sharing option in Canada, both for the public and for professionals who want to share publically or who don't qualify for or aren't able to access InfoEx.

I invite anyone who wants to share avalanche data in a public exchange to join the Mountain Information Network. Please help Avalanche Canada improve and expand the system by sending your thoughts, ideas, constructive criticism and questions to kklassen@avalanche.ca.

Rescue at **Cherry Bowl**

Mary Clayton

STORY-TELLING IS ONE OF OUR OLDEST and most effective forms of communication. Humans are hard-wired to respond to stories; they help us make sense of the world and our place in it. When we at Avalanche Canada heard the story of an amazing avalanche rescue—a story that defies all odds—we knew we had to tell it to a wider audience.

This rescue took place in the backcountry near Terrace, BC. Cherry Bowl is a spectacular feature, about an hour's skinning from the Shames Mountain Ski Resort. On a sunny day in March, 2013, two groups of four skiers headed in the direction of Cherry Bowl. One group, visitors from Whitehorse, were intent on hitting this choice line. The other group, locals from Terrace who were a bit more wary of the conditions that day, were out for a ridge walk.

The Whitehorse group had some great turns, but while they were in transition at the bottom of the bowl, they were hit by a size 3.5 avalanche. One of them miraculously managed to stay on the surface but the other three were buried, all at least 1.5m deep. The Terrace group, still high on the ridge, saw the slide and immediately went into action, performing an incredible rescue that saved three lives.

What really makes this story special is the fact that the Terrace group had very recently taken a companion rescue skills course. All avid backcountry skiers, they had taken it upon themselves to hone their skills for the season. Who could have known what a difference that training would make?

When Avalanche Canada forecasters first heard about this accident, they immediately recognized its incredible potential as a learning tool. We were all still buzzing about "Snow Fall", the Pulitzer-prize winning online feature published by *The New York Times* in late 2012 that tells the story of a fatal avalanche accident near Stevens Pass in Washington. Snow Fall is definitely an inspiration for digital storytelling and if you haven't seen it yet, do yourself a favour and take the time to explore.

We wanted to do something similar—create an interactive site that allows the user to experience and explore different aspects of the story. We began by connecting with a US production team, Tinhouse Creative. They were in Terrace in early 2014 and taped amazing interviews with every person involved in the accident. We contracted them to produce a short, eight-minute video that we could use to raise money for this project.

Over the winter of 2014-15 we used this video to drum up support for the project and thanks to a number of sponsors, by the spring of 2015 we were in business. Work began over the summer to develop the site and as this issue of *The Avalanche Journal* goes to press, we are in the final stages of coding.

We are all very excited to get this project online and we're counting the days to get it finished. There will be an announcement when the site goes live, so watch for that soon.

Thanks to these sponsors, Avalanche Canada is able to bring this project to life.

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A Toolbox Approach to Snowpack Observations: Craftsmanship, Relevancy and Verification

Colin Zacharias

THE WEIGHT OF EVIDENCE

Every winter day we make snowpack observations and extrapolate from observation sites to nearby terrain. Most days, for most avalanche problems, this extrapolation process works and we make key decisions from comparatively few *quality* bits of information. But it is easy to lose confidence in our abilities when conditions become unfamiliar or our information becomes scarce.

Outside of current avalanching and other alarm signs, and especially during periods of high snowpack variability, experienced observers tend to steer away from drawing quick conclusions from a few snowpack observations. They recognize that one test is just one observation, and to counter possible extrapolation errors they ensure that over the critical timeframe key information is supported and verified.

On the other hand, inexperienced observers may apply too much importance to a persuasive snowpack test result or a single avalanche occurrence and be subject to a confirmation bias. Experienced forecasters, even with a decent amount of information, recognize that at times their best is still in the end just that.

Karl Klassen, Avalanche Canada Public Avalanche Warning Service Manager and mountains guide, recently reminded me with a nice touch of irony that while our data ⇨ information ⇨ knowledge ⇨ wisdom hierarchy (Zeleny 1987) fits into a neat little package, it can also backfire. Depending on the quality and quantity of the data set, its relevancy, and our ability to interpret the info, data *isn't* information and information *isn't* knowledge, and if one thing is certain, wisdom is a different kettle of fish.

There are times when logistics make it difficult to add weight to the evidence. Poor weather or difficult travel conditions, for example, may prevent access to terrain or study sites. Yet even then assumptions are made and conclusions derived. As Dr. Bruce Jamieson notes in his mountain snowpack presentation for the ITP Level 2 Module 1, "inaccurate assumptions can have serious consequences" when it comes to spatial variability in the mountain snowpack. Decisions made from a deficit or even partial deficiency of information required to understand the avalanche problem are considered uncertain in light of an applied risk management strategy (as defined by ISO 31000). In the avalanche world we are okay with uncertainty—so long as we know what we don't know. We understand that as the measure of uncertainty increases so does that long arm of caution when planning to reduce the risk.

In today's avalanche world in Southern BC and Alberta, professionals rely on a daily information exchange to help manage the complexity of snowpack/terrain variability, to provide a "heads up" early warning system or a nearest neighbor confirmation— "yes, they're seeing what we're seeing." Each day we scan through thousands of bits of data and information on the InfoEx, then go into the field and gather more, aggregate the data into information packets, and analyze and communicate patterns that we refer to as hazard factors.

This article, along with the "How Useful Is the Evidence?" table below, was developed in the fall of 2011 as part of an Avalanche Operations Level 2 Module 3 training course handout to help learners apply the notion of strength and weight to field observations, to use a checklist style verification process, and to encourage quality craftsmanship and a thorough approach when analyzing and discussing snowpack factors. It may help the

HOW USEFUL IS THE EVIDENCE?	
Strength Persuasive nature of evidence	• Does the test identify instability? • Does the type of test apply to and help identify the current avalanche concern?
Weight Quality and quantity of evidence	• Is the observation site representative? (Relates to weak layer distribution and sensitivity, and the current problem) • Is the observer skilled at performing the test and interpreting the result? • Is there enough representative data to accurately extrapolate?
Verification Repeatable results	• Has the test been verified with similar or complementary additional tests? • Has the observation or test been confirmed using similar findings from "nearest neighbour" professionals?

FIG. 1: FROM CAA L2M3 HANDOUT

learner to recognize whether or not their evidence drawn from snowpack tests is helpful to their decisions.

CRAFTSMANSHIP AND CONSISTENCY

"Jeez…. the weather and snowpack vary enough; can't we all just do the same damn observation the same damn way?"

Regional and operational consistency with technique, application and interpretation ensures the quality of data gathered, recorded and communicated. On professional level avalanche training courses, instructors inform that practice, technique, and a meticulous day-to-day consistency with observations, recording and communication should never be undervalued, nor should the scope of the task be underestimated:

- Ensure that there is an objective for each snowpack test. The early morning safety meeting agenda usually includes assessing the day's avalanche problem and identifying gaps in knowledge. Know what you're looking for prior to looking.
- Select relevant sites for field test sites using experience and the seasonal observation of how the snow is layered over the terrain. Once sites have proven their worth, they are repeatedly used season to season.
- Conduct tests skillfully using standardized, practiced techniques. Observers use established guidelines when conducting, recording, and communicating weather, snowpack and avalanche observations; these come from *Observation Guidelines and Recording Standards for Weather, Snowpack and Avalanches* (OGRS) and *Snow, Weather, and Avalanches: Observation Guidelines for Avalanche Programs in the United States* (SWAG).
- Ensure consistency within an operation by having employees conduct observations side by side. Discuss technique and compare interpretation during preseason staff training.

THE RIGHT TOOL FOR THE RIGHT JOB

The CAA's OGRS and the AAA's SWAG provide guidelines for how to conduct and record weather, snowpack, and avalanche observations. Other than a few comments about the observed limitation of certain tests, these guidelines deliberately offer little information on how to apply or interpret the observations as they relate to an avalanche problem or forecast. This knowledge and proficiency is gained through other means, including research articles, professional avalanche training, and on the job training and mentorship.

Of course there isn't any single test that will reveal exactly what you need to know about snow. Yet every decade or so it seems that guides and forecasters have a new favourite "go to" decision making aid they default to when investigating the current avalanche problem. First it was the Rutschblock test (RB), then the compression test (CT)—or the other way around depending on your region—and now it's the extended column test (ECT). In a helpful 2010 article "Which Obs for Which Avalanche Type?" Bruce Jamieson and others conducted a field study that did an excellent job of directing attention to those observations that best identify each avalanche concern. The combination of determining the avalanche problem prior to departure (Atkins 2004) and having a good idea about which field observations and tests will best identify the problem is a good start when choosing the right tool for the right problem. The AIARE Avalanches and Observations Reference included below (published in the AIARE Field Book and instructor materials) was inspired by the aforementioned article and is a useful field reference to help learners target those concerns described in the daily avalanche advisory.

MANAGING FALSE STABLE AND FALSE UNSTABLE RESULTS

Doug Chabot, forecaster at the Gallatin National Forest Avalanche Center, brings up a good point in a recent blog post:

"Snowpit tests are used to show instability, not stability. Never stability. Snowpits (and snowpack tests) do not give the green light to ski; they just give us the red light to not ski. An unstable test result is always critical information. A stable test result does not mean the snow is stable a hundred feet away."

Chabot's advice points to the quandary many backcountry recreationists face when analyzing snowpack factors: a test result illustrating unstable snow urges cautious risk reduction, but what does a "no result" mean? Yet estimating where the snow is strong *and* where the snow is weak is an important

<table>
<tr><th colspan="4">HOW USEFUL IS THE EVIDENCE?</th></tr>
<tr><th>AVALANCHE PROBLEM</th><th>CRITICAL OBSERVATIONS</th><th>FIELD TESTS AND RELEVANT OBSERVATIONS</th><th>IMPORTANT CONSIDERATIONS</th></tr>
<tr><td>LOOSE DRY</td><td>• Fan-shaped avalanches; debris fine.
• Loose surface snow ≥12” (30 cm) deep.</td><td>• Boot/ski penetration ≥12” (30cm).
• Slope tests/cuts result in sluffs.
• Loose snow surface texture (as opposed to wind-affected, refrozen, or other stiff snow textures).</td><td>• Can be triggered by falling snow, cornice fall, rock fall, a brief period of sun, wind, or a rider.
• Sluffs can run fast and far.</td></tr>
<tr><td>STORM SLAB</td><td>• Natural avalanches in steep terrain with little or no wind.
• ≥12” (30cm) snowfall in last 24 hours or less with warmer heavier snow.
• Poor bond to old snow; slab cracks or avalanches under a rider’s weight.</td><td>• Observe storm snow depth, accumulation rate and water equivalent.
• Observe settlement trend: settlement cones, boot/ski penetration, measured change in storm snow (>25% in 24 hours is rapid).
• Tests show poor bond with underlying layer (tilt and ski tests). ID weak layer character.
• Denser storm snow over less dense snow (boot/ski penetration, hand hardness).</td><td>• Rapid settlement may strengthen the snowpack, or form a slab over weak snow.
• When storm slabs exist in sheltered areas, wind slabs may be also present in exposed terrain.
• May strengthen and stabilize in hours or days depending on weak layer character.
• Potential for slab fracturing across terrain can be underestimated.</td></tr>
<tr><td>WIND SLAB</td><td>• Recent slab avalanches below ridge top and/or on cross-loaded features.
• Blowing snow at ridge top combined with significant snow available for transport.
• Blowing snow combined with snowfall; deposition zones may accumulate 3-5x more than sheltered areas.</td><td>• Evidence of wind-transported snow (drifts, plumes, cornice growth, variable snow surface penetration with cracking).
• Evidence of recent wind (dense surface snow or crust, snow blown off trees).
• ≥Moderate wind speeds observed for significant duration (reports, weather stations and field observations).</td><td>• Often hard to determine where the slab lies and how unstable and dangerous the situation remains.
• Slope-specific observations, including watching wind slabs form, are often the best tool.
• Strong winds may result in deposition lower on slopes.
• Commonly trigged from thin areas (edges) of slab.
• Wind transport and subsequent avalanching can occur days after the last snowfall.</td></tr>
<tr><td>LOOSE WET</td><td>• Rain and/or rapid warming.
• Air temp >0°C for longer than 24 hours (cloud cover may prevent nighttime cooling).
• Pinwheels or roller balls.
• Fan shaped avalanches; debris lumpy and chunky.</td><td>• Observed and forecast temp trend.
• Temps (air, surface, T20)/freezing level indicate near-surface snow temps at 0ºC.
• Note slopes receiving/will receive intense radiation.
• Wet snow surface; water visible between the grains with a loupe, may be able to squeeze water out with hands.</td><td rowspan="2">• Timing is critical. Danger can increase quickly (minutes to hours).
• No freeze for multiple nights worsens condition. However, nighttime freeze can stabilize.
• Gullies and cirques receive more radiation and retain more heat than open slopes.
• Shallow snow areas become unstable first, may slide to ground in terrain with shallower, less dense snowpack.
• May initiate from rocks or vegetation.
• Can occur on all aspects on cloudy days/nights.
• Conditions may also include cornice fall, rock fall or increased icefall hazards.
• Snow temp of slab at or near 0°C.
• Loose wet snow slides can occur just prior to wet slab activity.
• Possible lag between melt event and wet slab activity.</td></tr>
<tr><td>WET SLAB</td><td>• Rain on snow, especially dry snow.
• Current or recent wet slab avalanches: debris has channels/ ridges, high water content, may entrain rocks and vegetation.
• Prolonged warming trend, especially the first melt on dry snow.</td><td>• Consider Loose Wet Snow observations.
• Observed melting snow surface (rain or strong radiation) of a slab over weak layer.
• Tests show change in strength of weak layer due to water and/or water lubrication above crust or ground layer.
• Identify the depth at which the snow is 0ºC.
• Monitor liquid water content and deteriorating snow strength using hardness and penetration tests.
• Nearby glide cracks may be widening during rapid warming.</td></tr>
</table>

AVALANCHE PROBLEM	CRITICAL OBSERVATIONS	FIELD TESTS AND RELEVANT OBSERVATIONS	IMPORTANT CONSIDERATIONS
PERSISTANT SLAB	• Bulletins/experts warn of persistent weak layer (surface hoar, facet/crust, depth hoar). • Cracking, whumpfing.	• Profiles reveal a slab over a persistent weak layer. • Use multiple tests that will verify the location of this condition in terrain. • Small column tests (CT, DT) indicate sudden (Q1) results; large column tests (ECT, PST, RB) show tendency for propagating cracks.	• Instability may be localized to specific slopes (often more common on cooler N/NE aspect) and hard to forecast. • Despite no natural occurrences, slopes may trigger with small loads—more likely when the weak layer is 8-36" deep (20-85cm). • Human triggered avalanches are still possible long after the slab was formed.
DEEP PERSISTANT SLAB	• Remotely triggered slabs. • Recent and possibly large isolated avalanches observed with deep, clean crown face.	• Profiles indicate a well preserved but deep (≥1m), persistent weak layer. • Column tests may not indicate propagating cracks; DT and PST can provide more consistent results. • Heavy loads (cornice drop or explosives test) may be needed to release the slope—large and destructive avalanches result.	• May be aspect/elevation specific—very important to track weak layer over terrain. • Slight changes, including moderate snowfall and warming, can re-activate deeper layers. • May be dangerous after nearby activity has ceased. • Tests with no results are not conclusive. • May be remotely triggered from shallower, weaker areas. • Difficult to forecast and to manage terrain choices.
CORNICE	• Recent cornice growth. • Recent cornice fall. • Warming (solar, rain at ridge tops).	• Note rate, extent, location and pattern of cornice growth and erosion. • Photos tracking change over time.	• Cornices often break further back onto ridge top than expected. • Can underestimate sun's effect on the back of cornice when traveling on cool, shaded aspects.

FIG. 2: FROM AIARE INSTRUCTOR MATERIALS AND FIELD BOOK, 2012.

skill—particularly for guides committing clients to terrain. Determining stability or the "likelihood that avalanches will *not* occur" involves a detailed process of gathering evidence, drawing a big picture perspective and not leaping to conclusions from a single observation or test result.

Knowing the sites that information is coming from, having a systematic or "toolbox approach" to clue gathering (see Fig. 3), and observing the terrain and trends over time are all crucial links in the chain of gathering information and applying it to a hazard analysis. And knowing to what degree those links are missing and then defining the information deficit (whether the uncertainty is weak layer location and distribution, character and sensitivity, or slab characteristic and estimation of destructive potential) is all part of guide and forecaster daily discussion. In addition to the strength, weight and verification checklist provided in Fig. 1, the following points may help when interpreting the day's investigations.

- A seasonal perspective of where the terrain has historically formed stronger and weaker snow is important. Basal facet development tends to repeat itself in seasonal trends. While near-surface persistent weak layers tend to have a broader distribution, sun or wind effect can result in feature scale variability in weak layer character. For example, DF (decomposed and fragmented snow grain) layers can be unstable locally but may not be problematic on a drainage scale. Expect a higher incident of false stable test results when observing locally unstable layers like DFs, graupel or sun crust/DF interfaces.
- One of the best tools for determining the nature of snowpack variability is to simply observe and memorize how the current snow surface or near surface condition changes over the terrain. Knowing the extent of surface hoar, facet, crust, or graupel formation and the distribution of storm snow and wind redistribution of snow helps to form a baseline when later estimating snowpack strength. Imagine yourself a heli ski guide with the opportunity to travel over 10s or 100s of kilometres of terrain on any given day. Using your eyes, your skis, and a few quick penetration and hand tests provides insight into what to expect when the snow surface becomes a buried weak layer. "Quick tests," while not subject to the same formal research as standard tests, still provide helpful information to an approximate depth of 45cm (Schweizer and Jamieson 2010).
- A checklist sum of snowpack structural properties (a.k.a. "yellow flags" or the Snowprofile Checklist (Jamieson and Schweizer 2005)) provide valuable clues about which layer interface is most likely to result in a localized failure/fracture. However, as the checklist sum has a tendency to overestimate

instability (false unstable=false alarm), further tests are conducted to determine propensity for propagation (Winkler and Schweitzer 2008). The combination of CTs (with fracture character) and the profile checklist sums provide an excellent tool to determine which layer is worth testing prior to a propagation saw test (PST) or ECT propagation propensity test.
- The large column snowpack tests that employ taps or jumps to apply a load to the slab (e.g., the ECT and RB) may still indicate a "no result" when a significant weak layer is buried approximately 1m or deeper—and/or when stiffer snowpack layer characteristics (e.g., a crust) reduce the likelihood that surface taps are affecting the deeper weak layer. The cautionary note is that skier triggering of a layer of this depth may still occur from shallower or weaker area (see case history below). In this scenario, one would not use the ECT or RB as the sole observation tool. It may be more prudent to identify the deeper weak layer with a CT or deep tap test (DT) and if a sudden fracture is observed choose to conduct a PST (or choose a shallower location for an ECT) to observe propensity for crack propagation in the layer. The combination of the small column test (which may err on false unstable but identifies fracture character) combined with a large column test (testing for propagation propensity) both reduces the likelihood of a missed observation and provides more information with a verified result. This "toolbox approach" may help interpret a potential "no result" or a false stable result.

The 2010 Schweizer and Jamieson article "Snowpack Tests for Assessing Snow-Slope Instability" provides an updated, excellent perspective directed at a general audience on snowpack test use and limitations. The following summary points have been paraphrased from the article:

- A good test method should predict stable and unstable scenarios equally well.
- Column tests are particularly helpful for assessing persistent slab conditions.
- Small column tests (CT and DT test) are useful for identifying weak layers and likelihood of initiation but have a tendency to overestimate instability (false unstable) conditions. Observing fracture character improves, to a degree, the interpretation of the test results. These tests are a better indicator of layer character than instability.
- Large column tests are better at predicting propensity for fracture propagation than small column tests, particularly when used in combination with other large column tests. Comparative studies suggest that the RB, ECT, and PST have comparable accuracy.
- With large column tests, repeated test results in the same location are useful but the tests repeated on similar, nearby slopes add value.
- Each test has a margin of error. Even with very experienced observers an error rate of 5-10% is to be expected. Site selection and interpretation require experience.

A TOOLBOX APPROACH TO INVESTIGATING LAYERS OF CONCERN

The Toolbox Approach in Fig. 3 may help students avoid the relatively high number of false predictions that occur due to a combination of several factors, such as extrapolation from single tests and high snowpack variability. The diagram supports a dialogue encouraging students to take a step-by-step approach and observe clues from a combination of tests and observation methods. For example, the combination of both the "yellow flags" checklist sums and fracture character in compression tests provide clues, not confirmation about whether or not a "propagation likely" scenario exists, which is then verified with a large column test that is suitable for testing within limitations posed by the particular snowpack structural properties. Understanding test limitations, matching the test to observed structural properties and verifying observations with complementary tests may improve the ability to interpret the test results and reduce false stable or false unstable predictions. I created this diagram and instructional method five years ago and have included it on the L2M3 and American professional level courses.

A CAUTIONARY TALE

Backcountry winter travelers are always encouraged to make weather and snowpack observations in the field, and when possible identify on a drainage and slope scale what the public avalanche advisory describes for the region or range. For the most part, this is an effective risk management strategy. However, there have been a number of close calls, incidents and avalanche accidents with backcountry users increase their risk by not managing exposure when gathering information or misinterpreting the observations they collect. In December 2007, a fatal avalanche accident occurred on Tent Ridge in Kananaskis Country when two backcountry skiers were killed conducting a snow profile in the start zone of an avalanche path. Older examples of riders conducting tests on or very near the slope and being subsequently killed include Wawa Bowl, AB, and Mt. Neptune, BC in 1984, Thunder River, BC in 1987, and White Creek, BC in 1993. More recent incidents include Ningunsaw Pass, BC in 1999 and in Twin Lakes, CO in 2014, where a group of seven dug a profile and conducted eight CTs on a slope before choosing to ski it (see CAIC Incident Report for more information).

There are also several examples of "close calls" where test results gathered and extrapolated to chosen terrain illustrated one problem but not the primary concern. A recent example occurred in December 2013 in Hope Creek, BC involving two backcountry skiers. This is an unfortunate example where

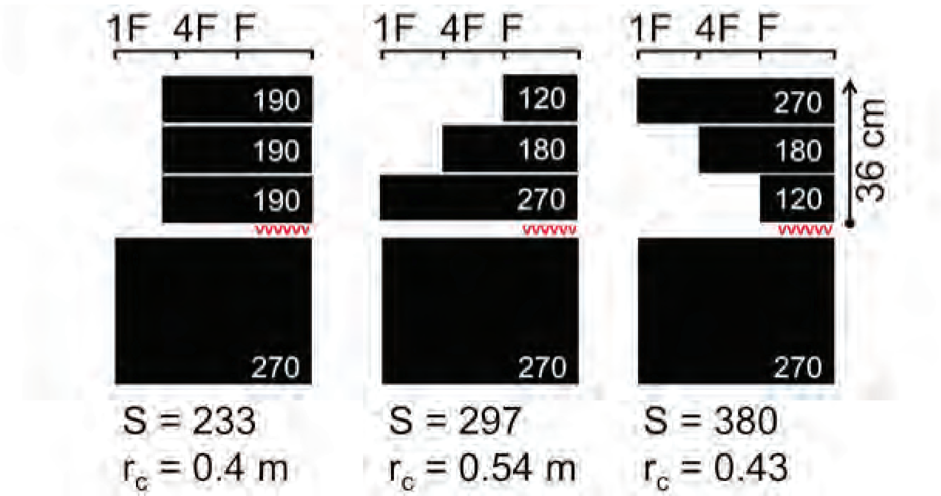


FIG. 3 THE TOOLBOX APPROACH: VER. 6, ZACHARIAS 2015

a combination of well-intentioned observations formulated a confirmation bias and decision making trap. The rider's observations prior to descending the slope included three existing ski tracks on the slope, 15cm recent snow, light winds, -3°C and no recent avalanches. The group conducted several tests with the following results: CTM16 (SC), ECTP 23, and "numerous ski cuts in the start zone," all revealing a significant surface hoar layer (size 7-10mm) 40cm deep but nothing deeper. A DT also revealed no results on deeper layers. The group decided that the surface hoar layer was manageable and to ski the slope one at a time. Rider 1 skied the slope with no problems and stopped 400m below, adjacent to the path trim line. Unfortunately, Rider 2 triggered the slope after landing an air low down in the start zone. The resulting D3 avalanche fractured 100m wide on basal facets 80-120cm deep and well below the surface hoar layer. The fast moving avalanche debris caught Rider 1 on the path's edge before he could scramble to safety. Both involved were carried approximately 700m downslope. Both were buried and badly injured but were able to self extricate, call for help, and were successfully rescued (Editor's Note: read a first-hand account of this avalanche by Billy Neilson in *The Avalanche Journal* Volume 106).

Those involved generously provided the CAA occurrence report with snowpack observations and insight into what gave them confidence to venture onto this particular slope. This event is a helpful wake-up call as we can all place ourselves in their decision making shoes. In hindsight, it is revealing to examine the Kicking Horse Mountain Resort local forecaster's public video statement issued on Vimeo on December 13, 2013 for the nearby backcountry terrain. The forecaster warned there is a "basal weakness at the bottom of the snowpack that is still reactive," and "skier triggered size 3 avalanches have occurred," and "avalanches had triggered larger slopes sympathetically," and that "now is the time to be very mindful of slope history." He went on to emphasize "without that degree of confidence that an avalanche has happened [on your slope of interest], you are really rolling the dice hopping onto big terrain." This incident—though occurring over one week after the video statement—illustrates that when it comes to managing deeper persistent slabs, the careful observations and good well-learned techniques of the backcountry travelers were not sufficient to protect them from the lingering hazard. It also reveals the big-picture perspective of the forecaster, who clearly warned of the more serious basal concern. Experience with this type of problem, experience monitoring unstable snow in a shallower snow climate, experience matching specific tests to specific problems, and experience managing false stable results and prioritizing the key concerns are all factors that may have given the experienced forecaster a different perspective than the backcountry riders. In this case, the knowledge of how the snowpack lay over the terrain held more weight than even a series of test results, all of which drew attention to a secondary problem that, while significant, was less so than what lurked below.

The bottom line is snowpack tests used to predict instability, while valuable when employed appropriately, are not foolproof. As Schweizer and Jamieson state obviously and importantly in the aforementioned 2010 article, "decisions about traveling in terrain should not be based solely on stability (snowpack) test results."

REFERENCES

American Avalanche Association and USDA Forest Service National Avalanche Center. 2010. *Snow, Weather and Avalanches: Observation Guidelines for Avalanche Programs in the United States.* 2010. Pasoga Springs, CO: AAA. http://www.avalanche.org/research/guidelines/pdf/Introduction.pdf

Atkins, Roger. 2004. "An Avalanche Characterization Checklist for Backcountry Travel Decisions." *Proceedings of the 2004 International Snow Science Workshop*. Jackson Hole, WY. http://arc.lib.montana.edu/snow-science/objects/issw-2004-462-468.pdf.

Avalanche Canada Incident Report Database. Golden, Hope Creek Draining, Privateer Mountain. December 29, 2013. http://old.avalanche.ca/cac/library/incident-report-database/view.

Campbell, Cam. 2008. "Testing for Initiation and Propagation Propensity." *Canadian Avalanche Association Level 2 Module 3 Lecture*.

Canadian Avalanche Association. 2014. *Observation Guidelines and Recording Standards for Weather, Snowpack and Avalanches*. Revelstoke: CAA. www.avalancheassociation.ca/resource/resmgr/Standards_Docs/OGRS2014web.pdf

Chabot, Doug. "Another viewpoint on a Backcountry Magazine article." *Gallatin National Forest Avalanche Center Blog*, November 6, 2015. http://www.mtavalanche.com/blog/another-viewpoint-backcountry-magazine-article

Colorado Avalanche Information Center. Colorado, Star Mountain. February 15, 2015. https://avalanche.state.co.us/caic/acc/acc_report.php?acc_id=526&accfm=inv

Gauthier, Dave, Cameron Ross, and Bruce Jamieson. 2008. "How To: The Propagation Saw Test." *University of Calgary Applied Snow and Avalanche Research*. October 2008. http://www.ucalgary.ca/asarc/files/asarc/PstHowTo_Ross_Oct08.pdf.

Jamieson, Bruce. 2009. "Mountain Snowpack and Spatial Variability." Canadian *Avalanche Association Level 2 Module 1 Lecture*.

Jamieson, Bruce. 2003. "Risk Management for the Spatial Variable Snowpack." *Avalanche News 66* (Fall 2003): 30-31.

Jamieson, Bruce and Jürg Schweizer. 2005. "Using a Checklist to Assess Manual Snow Profiles." *Avalanche News 72* (Spring 2005): 57-61.

Jamieson, Bruce and Torsten Geldsetzer. 1996. Avalanche *Accidents in Canada Volume 4: 1984-1996*. Revelstoke: Canadian Avalanche Association.

Jamieson, Bruce, Jürg Schweizer, Grant Statham and Pascal Haegeli. 2010. "Which Obs for Which Avalanche Type?" *Proceedings of the 2010 International Snow Science Workshop*. Squaw Valley, CA. http://arc.lib.montana.edu/snow-science/objects/ISSW_O-029.pdf

Klassen, Karl. 2002. *American Institute for Avalanche Research and Education Level 2 Student Manual*. 2002 Version.

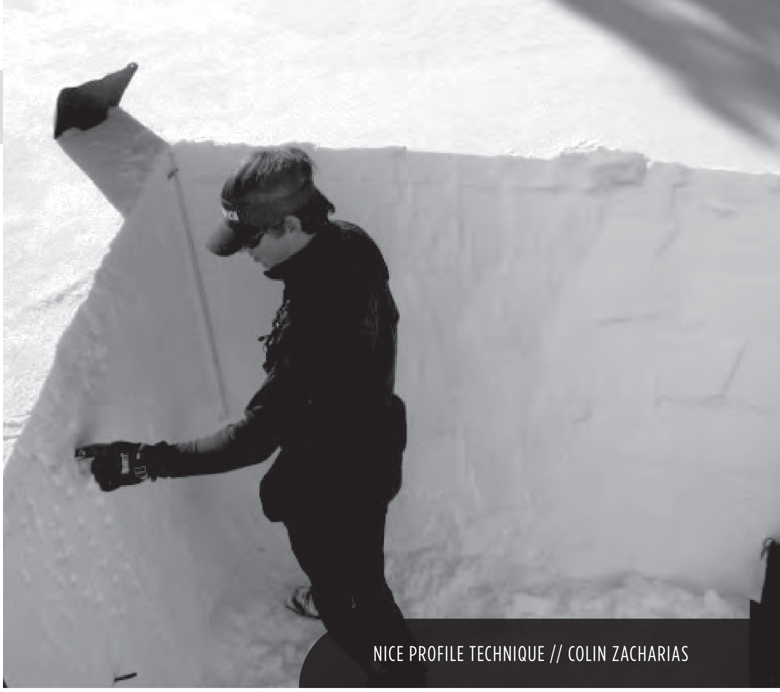
Ross, Cameron, and Bruce Jamieson. 2008. "Comparing Fracture Propagation Tests and Relating Test Results to Snowpack Characteristics." *Proceedings of the 2008 International Snow Science Workshop*. Whistler, BC. http://arc.lib.montana.edu/snow-science/objects/P__8177.pdf.

Schweizer, Jürg and J. Bruce Jamieson. 2010. "Snowpack Tests for Assessing Snow-Slope Instability." *Annals of Glaciology* 51(54): 187-194.

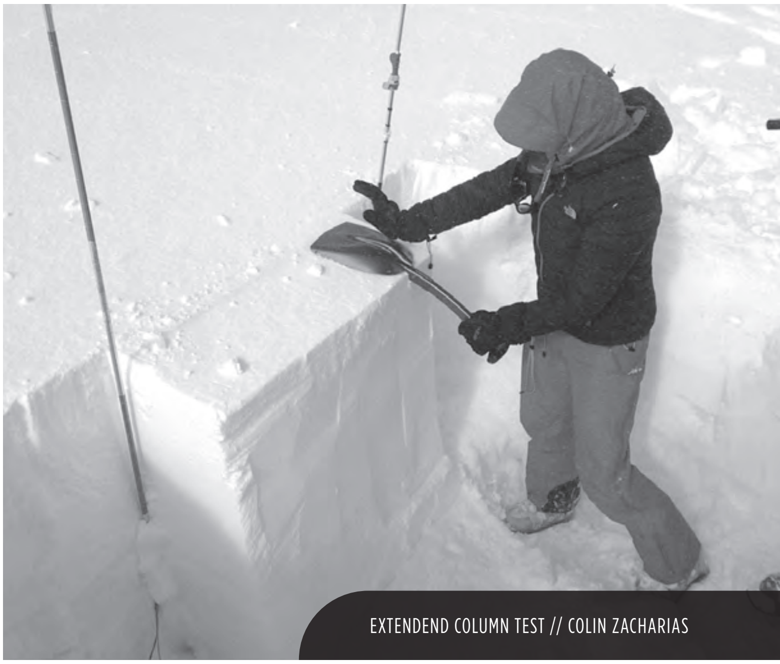
Simenhois, Ron and Karl Birkeland. 2007. "An update on the Extended Column Test: New Recording Standards and Additional Data Analyses." *The Avalanche Review 26(2)*.

Zeleny, Milan. 1987. "'Management Support Systems: Towards Integrated Knowledge Management." *Human Systems Management* 7: 59–70.

"Skiers Died Testing for Avalanche." *The Calgary Herald*, December 11, 2007. Accessed December 10, 2015. http://www.canada.com/story.html?id=75d72a3c-c743-4c65-a0c2-a18728813217.



NICE PROFILE TECHNIQUE // COLIN ZACHARIAS



EXTENDEND COLUMN TEST // COLIN ZACHARIAS

PROPOGATION SAW TEST // MIKE CONLAN

Schedule of Upcoming **Events**

WILDERNESS MEDICAL SOCIETY'S 24TH WILDERNESS & MOUNTAIN MEDICINE CONFERENCE
February 18-24, 2016
Park City, Utah
Leading-edge information in avalanche rescue, cold injuries, high-altitude illnesses, expedition/travel medicine and more.
For more information:
wms.org/conferences/parkcity16

84TH ANNUAL WESTERN SNOW CONFERENCE
April 18-21, 2016
Grass Valley, California
The theme of this year's conference is "Snow Drought and Hydrologic Impacts."
For more information:
westernsnowconference.org/meetings/2016

HELICAT CANADA ANNUAL GENERAL MEETING
May 2, 2016
Penticton, BC
For more information: helicat.org

CAA SPRING CONFERENCE AND ANNUAL GENERAL MEETING
May 2-6, 2016
Ramada Inn & Suites and Penticton Trade & Convention Centre, Penticton, BC
Join us for the AGM, meetings, case study and research presentations and discussions about the Canadian avalanche industry.
For more information:
avalancheassociation.ca

CANADA WEST SKI AREAS ASSOCIATION 2016 SPRING CONFERENCE
May 3-5, 2016
Whistler, BC
For more information: cwsaa.org

INTERNATIONAL CONFERENCE ON SNOW ENGINEERING
June 14-17, 2016
Nantes, France
Bringing together research and operational communities to discuss scientific, engineering and operational issues related to snow and ice.
For more information: snoweng2016.org

GEOVANCOUVER 2016
October 2-6, 2016
Vancouver, BC
This year's theme is "History and Innovation," recognizing historical achievements and highlighting new innovations.
For more information:
geohazardassociation.org/event/geovancouver-2016

ISSW 2016
October 3-7, 2016
Breckenridge, Colourado
Facilitating the interdisciplinary exchange of ideas and experiences between snow science researchers and practitioners.
For more information: issw.net

avalanche community

in this **section**

// MARK KLASSEN

Land of **Thundering Snow**

John G. Woods, Volunteer Researcher, Revelstoke Museum & Archives and **Cathy English**, Curator, Revelstoke Museum & Archives

THE VIRTUAL MUSEUM OF CANADA'S newest exhibit features Canada's avalanche history and snow safety, and officially launched in English and French at the end of September (find it at landofthunderingsnow.ca). Funded by the Canadian Museum of History and supported by many partners, this culmination of three years of research, writing, design and programming was a landmark moment for the Revelstoke Museum & Archives—our largest single project in the Museum's history and the first nationwide public exhibit to look at the topic of avalanches from a museum's perspective.

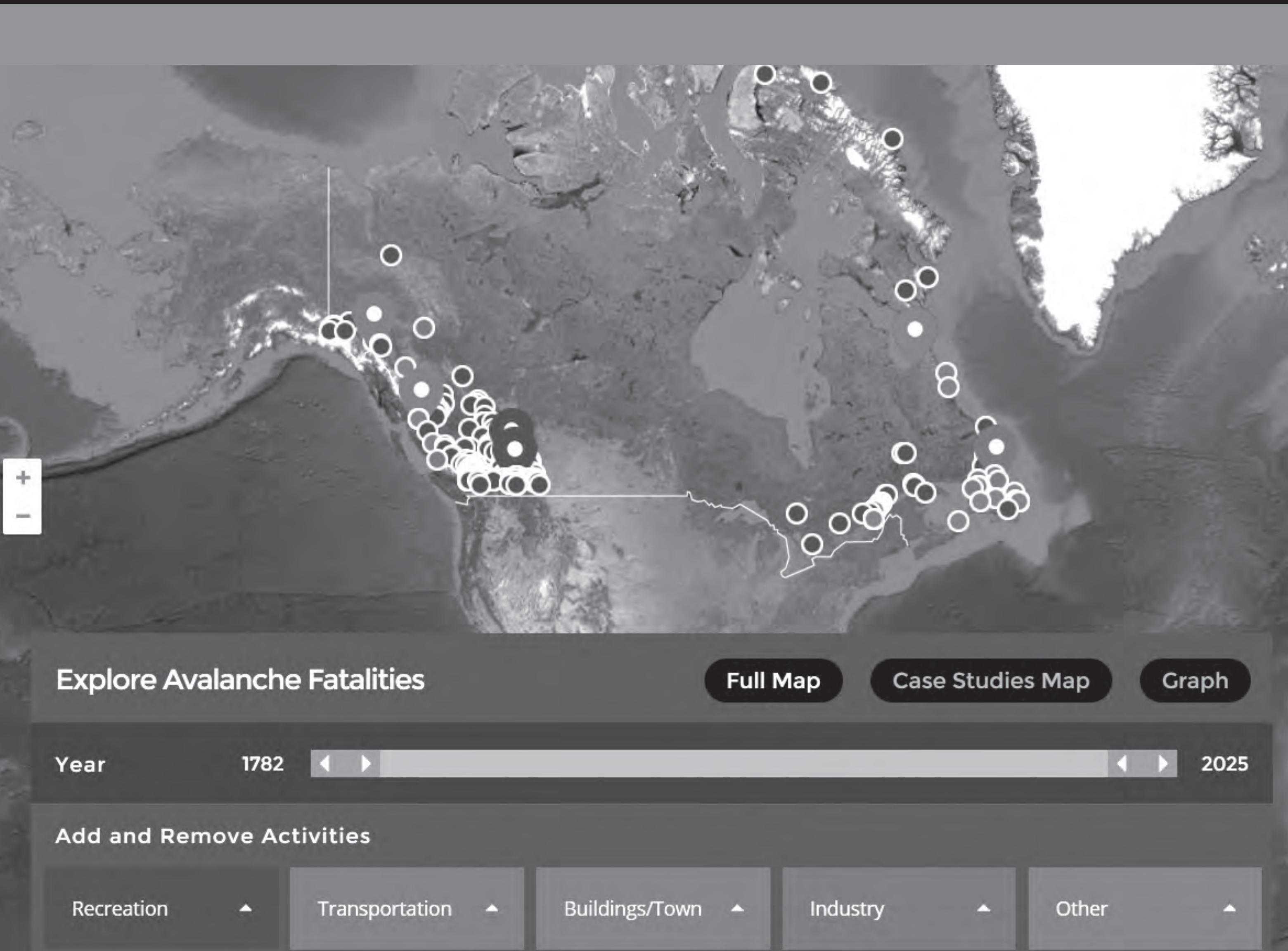
A map of Canada's known snow avalanche fatality locations is the centerpiece of the exhibit and elicits a common reaction: "I didn't know that fatal avalanches happened in places like Quebec and the Maritimes." Building on the CAA's *Avalanche Accidents in Canada* publications and Avalanche Canada's online incident report database, the Land of Thundering Snow project dug into historical accounts and added newly-documented avalanches and refinements to the historical records.

Capitalizing on the dynamic potential of the web, the interactive map allows visitors to display the records for specific time-periods and for a variety of historically important categories such as mining, transportation, and recreation-related. To give a quantitative perspective of the fatal records, a graph view is available (also with user-selected categories and date ranges). When a user clicks an individual fatality marker on the map, a popup box gives the incident date, approximate location, and number of deaths. The histories of seven incidents are treated in depth including photographs, videos and sound recordings.

Other parts of the website take viewers behind the scenes of avalanche research and control programs, into the nature of avalanche behaviour and avalanche ecology in the mountains, and introduces them to avalanche safety at home and in their travels.

While the exhibit is designed for general audiences, special resources are available to teachers to help them integrate avalanche studies in their social studies and science programs. Already, Social Studies teacher Lissa Cancilla-Sykes at the Revelstoke Secondary School has used the website to stimulate a discussion forum in her Grade 9 class. Her students were surprised by the wide-spread occurrence of avalanches across Canada. Several mentioned that the safety messages really hit home after they learned about the power and speed of avalanches from the exhibit. They also singled out the case studies of Michel Trudeau (November 13, 1998) and the Connaught Creek school trip disaster (February 1, 2003) as particularly thought-provoking.

During the research phase of the Land of Thundering Snow project,



the professional avalanche community and Avalanche Canada were unfailing in their support for interviews, artifacts, documents, photographs and videos. This not only was essential to the development of the website, but has now left an historical legacy in our archives. Our additional partners included Okanagan College, the Revelstoke Railway Museum and Parks Canada.

In a final segment of the website "Only the Beginning," we acknowledge that the synthesis of Canadian avalanche history is still in its infancy and encourage anyone with new or better information on fatality records to share them with us. The website is scheduled to be online for the next five years, and we have the ability to update the map to reflect new and better information as it becomes available.

Already we've been contacted by a museum on the British Columbia coast that believes they have better coordinates for one or more of the mapped locations and we've opened a dialogue with them to establish a revision to these records. We also would like to invite readers of *The Avalanche Journal* to contact us with any new information or data discrepancies they notice. Please contact Cathy English at curator@revelstokemuseum.ca. And, if you are passing through Revelstoke, we invite you to drop by and see our new indoor exhibit of photographs and artifacts complementing the website.

research

in this **section**

// JASON HUMMEL

From Practitioner to Professor and Vice Versa

Dr. Colin Johnston

BRUCE JAMIESON'S RECENT ARTICLE "ASARC: The Prequel" in Volume 110 of *The Avalanche Journal* alludes to his somewhat unusual path from avalanche practitioner prior to 1986 to two-time graduate student in the civil engineering department at the University of Calgary. As a prospective graduate student, he needed a professor to supervise his academic program, preferably one with an academic background in avalanche research and funds to sustain him at or above the poverty level characteristic of grad student remuneration in Canadian universities. I had neither when Bruce somehow ended up in my little piece of the ivory tower early in 1986, having apparently gleaned intelligence from sources unfamiliar with the norms of university graduate study that I might be able to help him achieve his goal of a MSc degree based on avalanche research.

At the time, my avalanche background was entirely nonacademic. I had been with the Lake Louise volunteer ski patrol from 1968-81, where I became involved with instructing avalanche awareness and rescue training to other patrollers. Luckily, it also included wonderful instructor-mentoring backcountry trips with Parks Canada's Clair Israelson and patrollers Brad Geisler and Peter Spear, which had taught me the basics of Rockies snowpack structure and stability. It even included a real avalanche incident when my patrol group leader Peter triggered a slide and was partially buried after ski cutting a slope convexity in the Teepee Town area at Sunshine Village, soon after a snow pit profile had revealed the classic Rockies slab overlaying depth hoar. Fortunately, he resurfaced and I narrowly avoided having to lead my first rescue search.

Not surprisingly, Bruce's arrival in 1986 revitalized my hitherto nonacademic interest in avalanche phenomena which had lapsed since quitting the ski patrol in 1981. His practitioner experience at Fernie and Nakiska, his intent to pursue a possible source of funding with the Alberta government, and his planned collaboration with Parks Canada's Clair Israelson, whose expertise I held in high regard, were very persuasive in getting me academically involved in his proposed avalanche research project.

So the winters of 1986-87 and 1987-88 found me periodically leaving the comfort of my office and the convenience of my research laboratory a mere floor below for days as a snow pit serf in Wolverine Valley, a short snowmobile ride from Temple warden station. There, we learned how to determine the tensile strength of snowpack layers using a setup quite similar in principle to one I had used to research the tensile strength of various concretes. These were the first of many days when I began to learn the skills of the snowpack practitioner from Bruce, and the realities of testing a material formed entirely by nature with totally uncontrollable structure and properties. What a contrast to my concrete technology research over the previous 19, years conducted with entirely prescriptible materials under controlled lab conditions.

During this time, Bruce the student was undergoing the academic torture tests imposed by the engineering coursework needed to fulfill his degree requirements, much of which was largely unrelated to snow or avalanches, or to his undergraduate math and physics background. Nevertheless, his rigorous work ethic resulted in completion of a thesis and coursework in an unusually short time of about 16 months, ending in December 1988—a supervisor's dream in terms of quality and productivity, and not typical of most of my other graduate students.

In 1988, two very significant events occurred that were to influence Bruce's and my involvement in avalanche research over the next decade. First, Mike Wiegele offered a collaboration that would facilitate and partially fund future research at his heli ski operation in Blue River, BC. Second, the federal government had recently initiated a policy specifically aimed at promoting research collaborations between universities and industry called the Collaborative Research and Development (CRD) program. The rumour was that just about any proposal could qualify as long as the private sector participant provided significant funding, and the Natural Sciences & Engineering Research Council (NSERC), along with

BRUCE JAMIESON CONDUCTING SHEAR FRAME TEST // COLIN JOHNSTON

the university, approved a professor as principal investigator to supervise the project. So the proposed collaboration seemed to fit this new government initiative, and we decided to proceed with a grant application. Since the NSERC bureaucracy in Ottawa had little awareness of avalanche issues, writing a convincing grant application was challenging given that my previous 21-year academic track record in research was devoid of avalanche-related work. However, Bruce's recent academic achievements along with strong letters of support from Mike Wiegele, Clair Israelson, Peter Schaerer and Chris Stethem on behalf of the Canadian Avalanche Association eventually resulted in approval of a three-year NSERC-CRD grant starting in November 1989.

So the winters of 1989-90, 1990-91 and 1991-92 found Bruce working full-time at Blue River, ably assisted by technicians Mark Shubin, Jill Hughes, Ken Hammill and others. While working a normal teaching load in Calgary, I visited the project periodically to become familiar with all aspects of the field work and the personnel and operations at Mike Wiegele Helicopter Skiing. I learned much about snowpack profiles, shear frame and rutschblock testing, as well as some of the unique problems associated with working at our main study area on Mount St. Anne. I experienced the frustration and back-breaking toil of getting three researchers and one snowmobile up the access road after heavy overnight snow. I learned how to survive the long ski road to valley bottom at the end of each day, even when it meant sharing it with resident moose, or on one occasion using climbing skins to ski downhill without crashing in frozen snowmobile tracks bordering breakable crust. And there was the time we needed the services of a local trained rescue dog and his handler, fortunately not to recover a researcher, but to retrieve a lost field book full of valuable data that had been covered by a recent snowfall.

I also relished the occasional opportunities to learn about heli skiing in varied terrain and snow conditions ranging from powder to soft slab, corn snow, breakable crust and sun-drenched slush. An unforgettable terrain learning experience occurred when a guide instructed our group to ski one at a time across a slope without lingering. Unfortunately, the guest preceding me fell halfway across and had difficulty getting up, so after waiting a while I decided to assist. But just as he was about to undo his skis I became aware of a nearby hole in the snow with darkness below. Clearly we were on a snow bridge, so I insisted that he not undo the skis and between us we somehow got him up on his skis and away from that ominous black hole.

During these skiing opportunities and in the daily guides' meetings I learned about their approaches to stability evaluation, terrain selection and operational decision making. Initially, I think they regarded us ivory tower types as a curiosity irrelevant to their daily operations, but as the years passed Bruce gradually managed to integrate the daily research data into their guiding discussions. And as news of the research spread, others became interested.

In 1992, with the expiry of our first three years of funding imminent, Colani Bezzola and Mark Kingsbury from Canadian Mountain Holidays (CMH) decided to support the research program. So we wrote a new three-year NSERC-CRD grant application based on adding field work and research staff at CMH Bobbie Burns Lodge, where we were ably assisted by technicians James Blench, Brian Gould, Sue Gould and others. It also included continuation of the field work in Blue River and periodic field work in Jasper, Yoho, Banff and Glacier National Parks. That meant more places to visit, more field staff, and more accounts to administer to ensure everyone got paid correctly with all eligible expenditures attributed to the appropriate accounts. And then there were the supervisory tasks associated with NSERC's wish to have graduate study associated with the new grant, which meant Bruce somewhat reluctantly registering as a PhD student and surviving the various academic torture tests involved. Despite these challenges, a punishing field work schedule and my numerous supervisor queries on initial thesis drafts, he produced a final PhD thesis in 1995 which, to my great satisfaction, the external examiner from an American university deemed the best he had ever read. During this period we welcomed a collaborative visit by Jürg Schweizer from the Swiss Federal Institute for Snow and Avalanche Research Institute (SLF) in Davos. He spent a year working with us in Calgary, which started an ongoing collaboration with several SLF researchers.

Sometime prior to 1995, Mark Kingsbury in his dual roles as president of CMH and the BC Helicopter and Snowcat Skiing Operators Association had championed our research with other association members. As the second NSERC-CRD

COLIN RELISHING THE OCCASIONAL OPPORTUNITIES TO LEARN ABOUT HELI SKIING // COLIN JOHNSTON COLLECTION

grant was about to expire, this timely involvement became the basis for a third successful three-year grant application with 22 industry supporters and the CAA covering winters 1996, 1997 and 1998. And, of course, grants administration became yet more complex and occasionally frustrating, like when the Ottawa bureaucracy, after a random audit, rejected an expense claim for purchase of newer, more advanced avalanche transceivers for my grant employees, a decision that was quickly reversed when I threatened to immediately terminate the project. An idea of the scope of the work during this period is conveyed in an October 1997 research update for winter 1996-97 which reports 380 person-days of field work by research staff plus tests done by Parks Canada avalanche control staff, resulting in over 204 profiles, 528 compression, 120 rutschblock and 240 shear frame tests. It also introduced the new name ASARC (Applied Snow and Avalanche Research) for the project.

During the six years between 1992 and 1998, I visited many of the field locations, met many interesting practitioners, and learned much more about backcountry terrain and the dangers and challenges faced daily by the research staff. There were days of satisfying accomplishment, such as helping Bruce and our master shoveler Mark Shubin complete a set of 49 rutschblock tests within a day to determine the test's variability on a slope judged to have a uniform snowpack. Or the day Bruce, Peter Schaerer and I flew to a remote slope that had recently avalanched and performed shear frame and rutschblock tests adjacent to the crown fracture in order to generate test data representative of real avalanche conditions. Observing the released rutschblocks speeding down the steep slope—appropriately named Freefall—and then crashing into the forest below made me wonder whether I would make it down the steep hard bed surface to the helicopter landing zone without following the rutschblocks.

There were also frustratingly unproductive days when Mother Nature was uncooperative, such as the day Bruce, Peter and I skied a variety of terrain when the stability was judged "bombproof" and weak layers suitable for testing were almost impossible to find. Finally, my accompanying experts decided to dig a pit on a steep slope where I noted a significant cliff not far below, and fervently hoped that the "bombproof" assessment was correct. Then there was the day Bruce and I had arranged to join Yoho Park warden Terry Willis and his two snowmobiles for a day of field work in the Lake O'Hara area when the morning temperature in the parking lot was about -35°C and the day's high was -28°C. This was a low-productivity day for snowpit work as most of the time was spent thawing our bodies by the fire in the warden hut—but on the plus side I learned to drive a snowmobile. And there was the day Bruce and I visited our study slope at Bow Summit only to find a snowpack faceted from top to bottom and totally unsuitable for rutschblock or shear frame testing.

For me personally, there were particularly memorable events, including participation in the May 1996 International Glaciological Society conference in Chamonix and the post-conference trip to the SLF in Davos hosted by Jürg Schweizer and Paul Fohn, followed a few months later by the 1996 International Snow Science Workshop in Banff where I chaired the papers committee.

As I had committed to early retirement in 1997 in response to the Klein government's 1994 deficit-slaying crusade which resulted in about 300 academic and support staff retirements at the U of C, my role as Principal Investigator ended with the 1995-98 NSERC-CRD grant. So, in order for the research to continue I recommended that the newly minted Dr. Jamieson be appointed an Adjunct Professor, making him eligible to apply for future NSERC funding in his own name. Thus, the accomplished practitioner finally became a professor, and I, his former professor supervisor, acquired at least some of the avalanche practitioner's knowledge and skills.

The Effects of Changing Slope Angle on Compression Test Results

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ABSTRACT: Conducting stability tests in avalanche terrain is inherently dangerous since it exposes the observer to the potential of being caught in an avalanche. Recent work shows that such exposure may be unnecessary since the results of extended column tests (ECTs) and propagation saw tests (PSTs) are largely independent of slope angle, allowing for data collection in safer locations. Conversely, some past work shows that compression tests (CTs) are slope angle dependent. In this paper, we test the effect of slope angle on CTs using similar methods as the recent ECT work. We collected field data on three separate days with persistent weak layers in Montana and California. Our slopes exhibited gradual changes in steepness, allowing us to sample a variety of slope angles with minimal snow structure changes. We also employed a second method to reinforce our results. Utilizing the SnowPilot dataset, we analyzed the difference between propagating ECTs and CTs on the same layer, and compared that difference with slope angle. Our fieldwork shows that the CT test results either did not change or increased slightly with increasing slope angle. Further, the SnowPilot data demonstrate that the difference between ECTs and CTs is not statistically dependent on slope angle, reinforcing conclusions from our field work. Our results have significant theoretical implications, but the practical implications are even more important since this work suggests that, in addition to ECTs and PSTs, CTs can be conducted in safer low-angle terrain.

1. INTRODUCTION

In March, 2014 a group of backcountry skiers in Montana travelled onto a steep slope to assess the avalanche conditions. Their initial observations indicated unstable conditions, but they moved further down the slope to see if similar conditions existed as it steepened. Tragically, they triggered a slide that killed one person. This accident graphically demonstrates the danger of conducting stability tests in avalanche terrain when conditions are unstable. The consequences of a mistake in these situations can clearly be severe.

Though conducting tests on slopes safe from avalanches will minimize risk to observers, conventional wisdom has been that it is necessary to get into steep terrain to get good data. Recent research on some tests runs contrary that conventional wisdom. For example, Gauthier and Jamieson (2008) and McClung (2009) both show that propagation saw test (PST) cut lengths are similar, or shorter, in lower angled terrain in comparison to steeper slopes. Further, Birkeland et al. (2010) and Simenhois et al. (2012) found that the number of taps required to initiate fracture for extended column tests (ECTs) that propagate completely across the column (ECTPs) is similar or perhaps actually decreases slightly in lower angled terrain as long as the snow structure remains consistent across a slope. This was true for both persistent (Birkeland et al. 2010) and non-persistent (Bair et al. 2012; Simenhois et al. 2012) weak layers.

The compression test (CT) has been used for more than 35 years. Its popularity continues to the present; it was the second most utilized test among SnowPilot users behind the ECT during the 2011-12 winter (Birkeland and Chabot, 2012). Jamieson (1999) found a significant trend in CT test results with changing slope angle in seven of 11 datasets (64%), and suggested a decrease of approximately one tap in CT score for every 10 degree increase in slope angle. Data collection for this work differed from that with the ECT. The 11 slopes used for the CTs were sampled in two to four locations with varying slope angles, with multiple tests

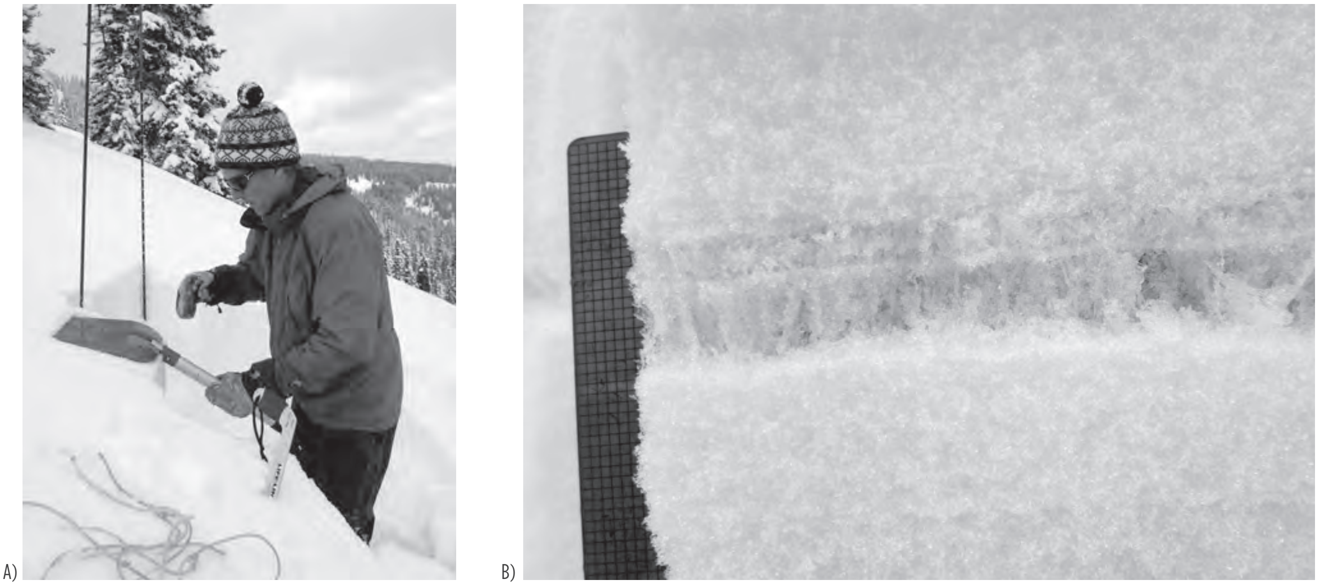

FIG. 1A: (A) COLLECTING CT AND ECT DATA (DATASET 1) ON VARYING SLOPE ANGLES AT OUR LIONHEAD STUDY SLOPE IN MONTANA. FIG. 1B: HERE OUR TESTS FRACTURED ON A BURIED LAYER OF SURFACE HOAR WITH CRYSTAL SIZES RANGING FROM 6 TO 15MM. THE GRID SIZE ON THE SNOW CARD IS 1 MM.

at each sampling location, while the ECT work sampled at multiple (more than 20), closely spaced locations with varying slope angles. Though the CT work runs counter to that with the ECT, the methods differed and the reported change of one tap for every 10 degrees is small given the potential variability of CT results.

The purpose of this paper is to utilize the techniques and methods of Birkeland et al. (2010) to test the effect of slope angle on CT results. Additionally, we analyze a large amount of data from SnowPilot (Chabot et al. 2004) to compare the difference between ECTs and CTs with changing slope angle. Since ECT results are largely independent of slope angle, the relationship between the difference between ECTs and CTs and slope angle can provide additional information about the slope angle dependence of CT results.

2. METHODS

2.1 Field sites

We used three different slopes for our fieldwork. Our first slope was the same Lionhead study site in southwest Montana that Birkeland et al. (2010) utilized for their ECT study. On this slope we collected 22 side-by-side CTs and ECTs fracturing on surface hoar on slope angles ranging from 17 to 30 degrees (Fig. 1). When we tried to access terrain in the low 30 degree range we collapsed the slope and triggered a small avalanche below our study site, attesting to the unstable condition on that sampling day.

Our two other slopes are located in California's Eastern Sierra Range. On these slopes our CTs fractured on depth hoar. We conducted eight CTs on the first slope with slope angles ranging from seven to 24 degrees, and 14 CTs on the second slope with slope angles from zero to 38 degrees.

For this work we specifically sought out uniform slopes. This limited the amount of data we could collect, but we felt this provided optimal datasets for testing the effect of slope angle on CT tests.

2.2 Snowpack structure for field data

The snowpack structure differed between our datasets. The tests in our first dataset fractured on surface hoar buried beneath a recently deposited slab, while the CTs in our other two datasets fractured on depth hoar. The depth hoar for Dataset 2 was dry, while the depth hoar for Dataset 3 was slightly moist (Table 1). We dug one manual pit for each field day following the techniques outlined in Greene et al. (2010).

2.3 Test procedure for field data

A single observer conducted every test in each of our three datasets for consistency. We followed standard procedure for the CT (Greene et al. 2010). Also, at our first slope we conducted our tests side-by-side with ECTs (Simenhois and Birkeland 2009). Prior to each test, we sighted up the snow surface with a Suunto clinometer, measuring the slope angle to an estimated accuracy of ±1°. In most cases tests were immediately upslope, or within one metre, of one another. We did this for ease of testing, as well as to minimize any spatial changes in the snow structure.

2.4 SnowPilot data analysis

Because our field data are somewhat limited, we utilized data from SnowPilot (Chabot et al. 2004) to further address our research question. In particular, since previous research

Dataset	Mountain Range	N	θ [deg]	h [m]	Std Dev h [m]	ρ [kg-m^{-3}]	F	E [mm]
1	Henry, Montana	22	17 - 30	0.47	0.012	128	Surface hoar	6 – 15
2	Sierra, California	8	7 – 26	0.87	0.066	NA	Depth hoar	2 – 4
3	Sierra, California	14	0 – 38	0.57	0.040	NA	Depth hoar	2 – 4

TABLE 1: GEOGRAPHICAL LOCATION AND SNOWPACK CHARACTERISTICS AT FIELD SITES. N: NUMBER OF TESTS, θ: RANGE OF SLOPE ANGLES SAMPLED, h: AVERAGE SLOPE NORMAL SLAB THICKNESS FOR ALL THE EXPERIMENTS, STD DEV h: STANDARD DEVIATION OF H FOR ALL EXPERIMENTS, ρ: AVERAGE DENSITY OF THE SLAB MEASURED AT THE SITE OF THE SNOW PROFILE, F: WEAK LAYER CRYSTAL TYPE, E: WEAK LAYER GRAIN SIZE. NA = DATA NOT AVAILABLE FOR THAT DATASET.

suggests that the number of ECT taps is approximately independent of slope angle (Birkeland et al. 2010; Simenhois et al. 2012), testing if the relationship between CTs and ECTs varies by slope angle will give us additional information about the relationship between CTs and slope angle.

In SnowPilot we looked for cases where CTs and ECTs fractured on the same layer and where ECTs fully propagated (ECTP). We had 534 total test pairs on slope angles from zero to 45 degrees. We graphed the data and tested for the existence of statistically significant ($p<0.05$) linear trends.

3. RESULTS AND DISCUSSION

3.1 Field data

In all three of our field datasets the number of CT taps remained relatively constant or increased slightly with increasing slope angle (Fig. 2), paralleling previous work with the ECT (Birkeland et al. 2010). A side-by-side comparison of ECTs and CTs in Dataset 1 shows no trend between the difference between ECTs and CTs and slope angle (Fig. 3).

Our results differ from those of Jamieson (1999). We believe the primary reason for this discrepancy lies in our differing methods of data collection. While Jamieson (1999) conducted multiple tests at two to four locations per slope, each of our tests is considered individually and we conducted all our tests in close proximity on relatively uniform slopes with a changing slope angle. A particular strength of our data is the nature of our slopes, which yielded consistent results. The average standard deviation in CT taps for our datasets was just 1.34 (Dataset 1=0.83, Dataset 2=1.19, Dataset 3=1.99). In comparison, Jamieson's average standard deviation was double that at 2.26 (range 0.5-4.0). We believe that our data collection techniques are better able to capture relatively subtle variations in CT scores with slope angle.

The practical implications of our work do not differ much from those of Jamieson (1999). Our work confirms that low angle slopes work well for data collection. Likewise, Jamieson's (1999) conclusion that there may be a one tap decrease for every 10 degree increase in steepness means that practitioners can conduct CTs on safer 25 degree slopes rather than more dangerous 35 degree slopes and still expect quite similar results.

3.2 SnowPilot data

A plot of the difference between ECT and CT results versus slope angle shows a great deal of scatter and no statistically significant trend (Fig. 4). A least squares linear fit to the data has a slightly downward trend, but it is not plotted since the fit is not significant at the 5% level ($p=0.19$).

The scatter in these data contrasts sharply with the low scatter in our Montana field data (Fig. 3). However, the Montana data were collected on one fairly uniform slope with a well-defined weak layer, while the SnowPilot data represent data from a broad range of observers, snow climates, slopes, slabs, and weak layers. Still, if a relationship exists between the difference between ECTs and CTs and slope angle, we expect that it would be reflected in this large ($n=534$) dataset.

4. CONCLUSIONS

This research utilized two independent methods to test the slope dependence of CT results. Our first method was field-based and followed Birkeland et al. (2010), and our second method utilized SnowPilot data. Our field data show that the number of CT taps are constant, or increase slightly as slopes steepen. The SnowPilot data reinforce these results by showing that the difference between ECT and CT tests is not statistically dependent on slope angle ($p=0.19$).

Our results differ from those presented by Jamieson (1999), who found that CT scores decreased slightly as slope angle increased. While Jamieson collected multiple tests from two to four locations, we sampled up to 22 per slope and did one test at each location. The slopes we tested had considerably less variation than those tested by Jamieson (1999).

Our results also contradict laboratory tests which showed a decrease in sample strength with increasing slope angle for small (≤20cm in length) samples with weak layers of surface hoar, depth hoar, and facets (Reiweger and Schweizer, 2010; Reiweger and Schweizer 2013). One explanation for the discrepancy might be a geometrical effect of the CT with changing slope angle. Alternatively, it could have something to do with the difference between methods utilized (lab vs. field work and the way the loading method for the snow). Currently, the exact reason for the difference in our results is unclear.

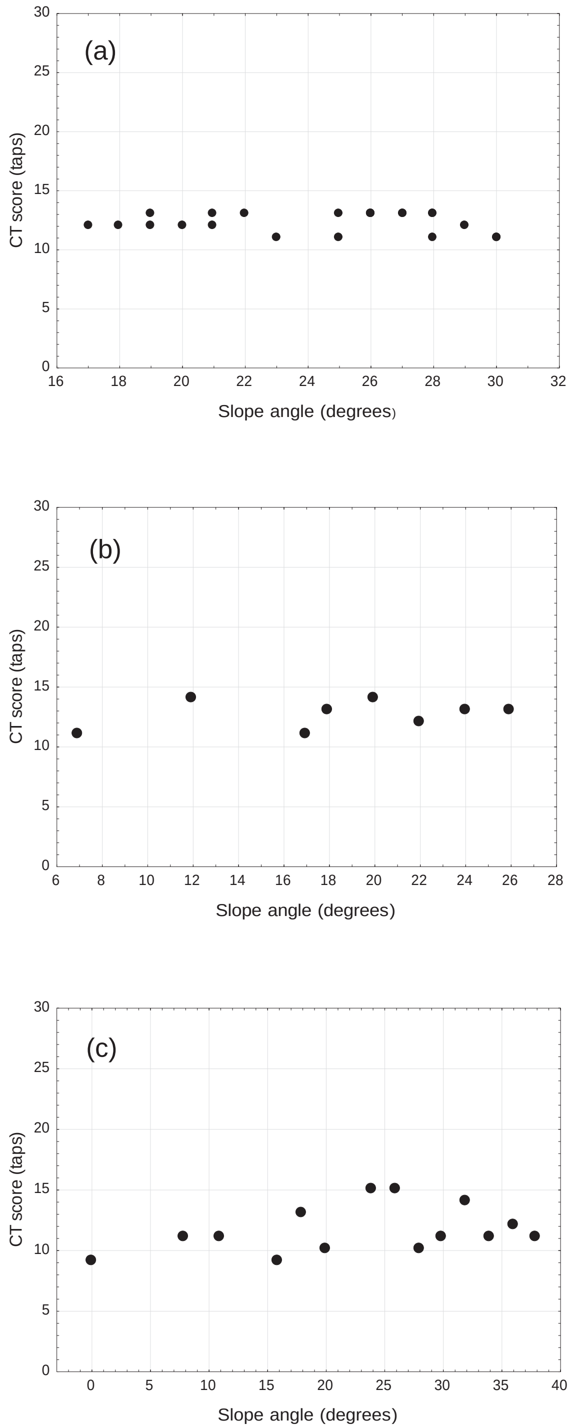

FIG. 2: FIELD DATA COMPARING CT RESULTS TO SLOPE ANGLE FOR (A) DATASET 1, (B) DATASET 2, AND (C) DATASET 3. NONE OF THE DATASETS SHOW A STATISTICALLY SIGNIFICANT TREND (p-VALUES: (A) = 0.67, (B) = 0.44, (C) = 0.21).

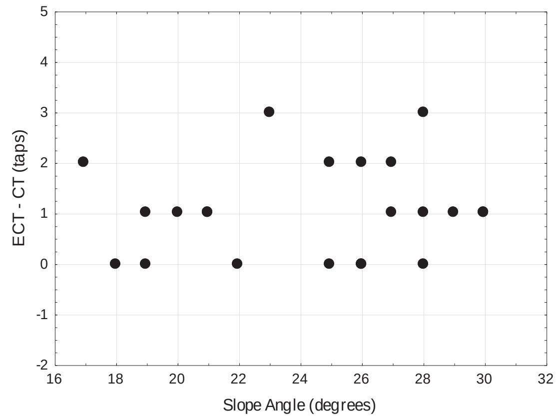

FIG. 3: THE DIFFERENCE BETWEEN SIDE-BY-SIDE CTs AND ECTs FROM DATASET 1 DO NOT SHOW ANY STATISTICALLY SIGNIFICANT RELATIONSHIP WITH SLOPE ANGLE (p-VALUE=0.64). THROUGHOUT THE RANGE OF SLOPE ANGLES IT TOOK BETWEEN ZERO AND THREE ADDITIONAL TAPS TO FRACTURE ECTs IN COMPARISON TO CTs AT THIS SITE.

Given that CTs, ECTs, and PSTs all show slope angle independence in their scores (Gauthier and Jamieson, 2008; McClung 2009; Birkeland et al., 2010; Heierli et al. 2011; Bair et al. 2012; Simenhois et al. 2012), we suggest that crack initiation (measured by the CT), and crack propagation (measured by the ECT and PST) have little dependence on slope angle over the range of an-gles investigated.

The primary practical consideration of our results is that tests on safer, lower-angled terrain are useful since CTs have similar or perhaps lower scores in lower angled terrain. This result is similar to results previously reported for the ECT (Birkeland et al. 2010) and the PST (Gauthier and Jamieson 2008).

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The Gallatin National Forest Avalanche Center provided logistical support and assistance for the Montana field work. Mark Kahrl developed SnowPilot and queried the database for this paper. Sue Burak helped with field work in the Sierra.

REFERENCES

Bair, E.H., R. Simenhois, K.W. Birkeland and J. Dozier. 2012. "A field study on failure of storm snow slab avalanches." Cold Regions Science and Technology 79-80: 20-28.

Birkeland, K.W. and D. Chabot. 2012. "Changes in stability test usage by SnowPilot users." Proceedings of the 2012 International Snow Science Workshop, Anchorage, Alaska. http://arc.lib.montana.edu/snow-science/objects/issw-2012-1065-1068.pdf.

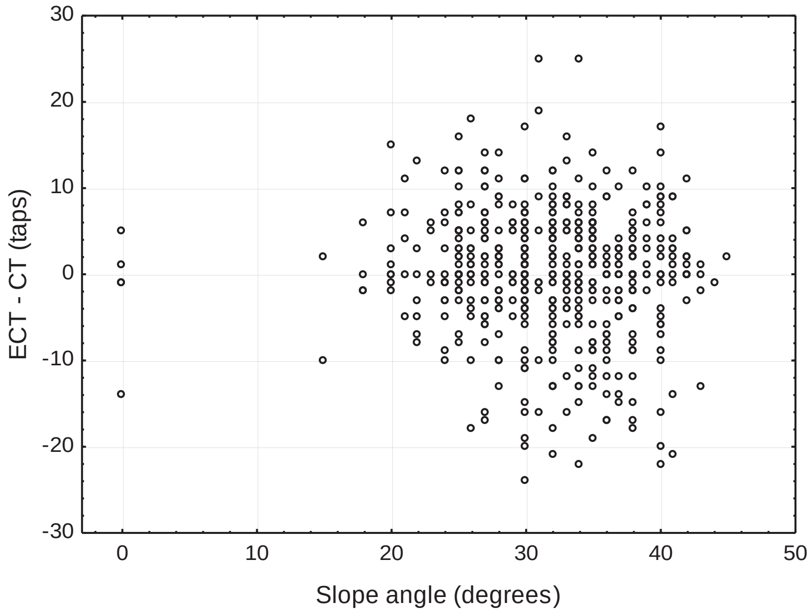

FIGURE 4: A SCATTERPLOT OF 534 PAIRS OF CTs AND ECTs FROM THE SNOWPILOT DATASET DOES NOT SHOW A STATISTICALLY SIGNIFICANT RELATIONSHIP BETWEEN THE DIFFERENCE BETWEEN ECT AND CT RESULTS AND SLOPE ANGLE (p=0.19). THIS PROVIDES FURTHER EVIDENCE THAT CT RESULTS ARE LARGELY INDEPENDENT OF SLOPE ANGLE.

Birkeland, K.W., R. Simenhois, and J. Heierli. 2010. "The effect of changing slope angle on extended column test results: Can we dig pits in safer locations?" In: R. Osterhuber and M. Ferrari (Editors), 2010 International Snow Science Workshop, Squaw Valley, California: 55-60.

Chabot, D., M. Kahrl, K.W. Birkeland, and C. Anker. 2004. "SnowPilot: A "new school" tool for collecting, graphing, and databasing snowpit and avalanche occurrence data with a PDA." In: K. Elder (Editor), International Snow Science Workshop, Jackson Hole, Wyoming: 476.

Gauthier, D. and J. B. Jamieson. 2008. "Fracture propagation propensity in relation to snow slab avalanche release: Validating the propagation saw test." Geophysical Research Letters 35(L13501): doi: 10.1029/2008GL034245.

Greene, E.M., D. Atkins, K.W. Birkeland, K. Elder, C.C. Landry, B. Lazar, I. McCammon, M. Moore, D. Sharaf, C. Sterbenz, B. Tremper, and K. Williams. 2010. "Snow, Weather and Avalanches: Observation guidelines for avalanche programs in the United States." Pasoga Springs, Colorado: American Avalanche Association.

Heierli, J., K.W. Birkeland, R. Simenhois and P. Gumbsch. 2011. "Anticrack model for skier triggering of slab avalanches." Cold Regions Science and Technology 65(3): 372-381.

Jamieson, J.B. 1999. "The compression test - after 25 years." The Avalanche Review 18(1): 10-12.

McClung, D.M. 2009. "Dry snow slab quasi-brittle fracture initiation and verification from field tests." Journal of Geophysical Research - Earth Surface 114: F01022, doi:10.1029/2007JF0000913.

Reiweger, I. and J. Schweize. 2010. "How snow fails." In: R. Osterhuber and M. Ferrari (Editors), 2010 International Snow Science Workshop, Squaw Valley, California: 204-206.

Reiweger, I. and J. Schweizer. 2013. "Weak layer fracture: facets and depth hoar." Cryosphere 5: 1447-1453.

Simenhois, R. and K. W. Birkeland. 2009. "The Extended Column Test: Test effectiveness, spatial variability, and comparison with the Propagation Saw Test." Cold Regions Science and Technology 59: 210-216.

Simenhois, R., K.W. Birkeland, and A. van Herwijnen. 2012. "Measurements of ECT scores and crack-face friction in non-persistent weak layers: What are the implications for practitioners?" 2012 International Snow Science Workshop, Anchorage, Alaska. http://arc.lib.montana.edu/snow-science/objects/issw-2012-104-110.pdf.

Untangling **Slab Avalanche Release**

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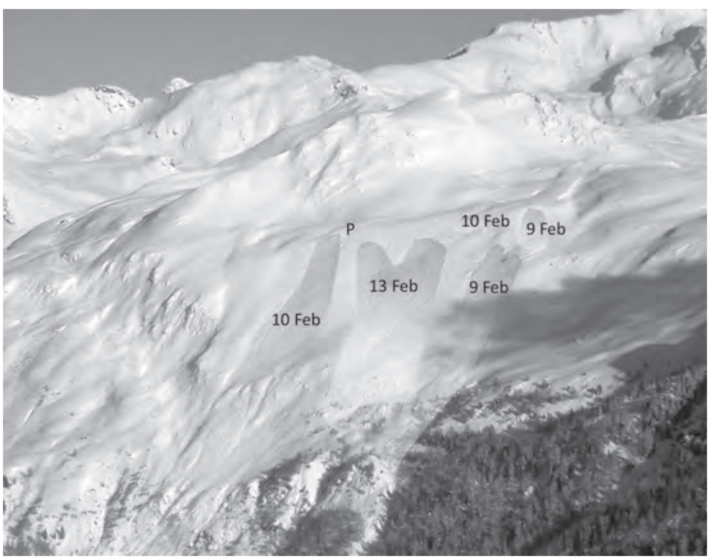
Between February 10-13, 2013, several slab avalanches were triggered by skiers on the west flank of Hüreli, a popular freeride spot above Davos, Switzerland. Cracks easily propagated in a weak layer below a wind slab. Four cold days later, we returned to the scene and dug a snow pit. Highly motivated to capture propagating cracks on tape we were very disappointed to see that our PSTs were not propagating. Signs of instability were lacking too. What was going on? Nothing seemed to have changed—at least in the weather plots.

Canadian research has shown that weak layer strength only slowly changes with time when no additional load is applied. So is it the changes in the slab that made the difference? We know that layering is vital for avalanching. In a Black Forest cake, the chocolate and whipped cream layers are very different. If the cake is fresh, the whipped cream is pushed out under your spoon, but when the cake is stored in the fridge for a few days, hardness differences vanish and your spoon runs through the cake smoothly. The same can happen to the snowpack when it is cooled: surface layers start to facet and lose strength and skiing can become really fun with fast snow and lots of sluffing in steep terrain. This is exactly what happened to the snow around Davos in mid-February 2013.

The start of a snow slab avalanche is commonly interpreted as a sequence of fractures. After an initial failure is created, crack propagation through the weak layer occurs before a tensile fracture at the crown arrests this process and the slab is detached. The two most important processes are called failure initiation and crack propagation. In the field it is very difficult to observe both processes independently, but in fracture models we can do exactly that. Looking at the processes separately allows us to investigate the influence of snow cover properties, understand how the processes interact and finally control snow instability.

Failure initiation is best described by the balance of stress (force per unit area) and strength. Crack propagation is best described by the balance of the fracture energy required to break the weak layer and the deformation energy supplied by the slab to advance the crack. Clearly, both slab and weak layer properties are



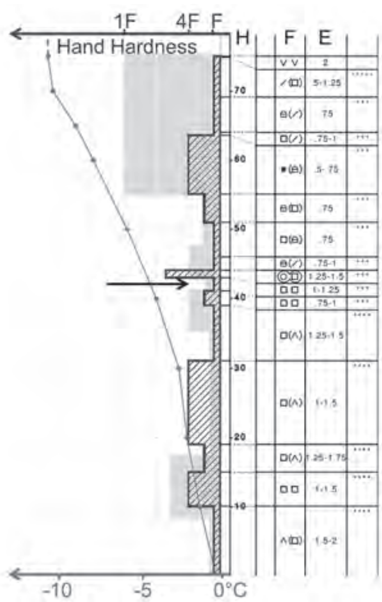


FIG. 1: THE WEST FLANK OF HÜRELI. THE SLAB AVALANCHES RELEASED BETWEEN FEBRUARY 10 AND 13, 2013 AND ARE HIGHLIGHTED. SNOW PIT LOCATION INDICATED WITH "P". THE SNOW PROFILE WAS RECORDED ON FEBRUARY 17. SINCE FEBRUARY 11 (ORANGE HARDNESS PROFILE) THE SLAB HAS BECOME SOFT DUE TO NEAR-SURFACE FACETING, AND PST RESULTS WERE ALL SLAB FRACTURES.

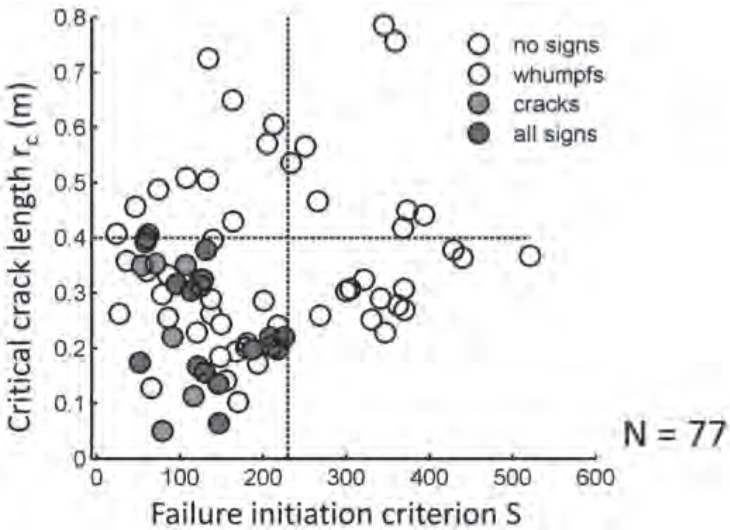


FIG. 2: THE FAILURE INITIATION CRITERION AND THE CRITICAL CRACK LENGTH, AS MEASURES FOR THE PROPENSITY OF FAILURE INITIATION AND CRACK PROPAGATION, CONTRASTED WITH THE PRESENCE OF SIGNS OF INSTABILITY IN THE AREA FOR 77 CASES WITH VARYING STRATIGRAPHY. DASHED LINES INDICATE THRESHOLD VALUES. (REUTER ET AL. 2015).

of fundamental importance if we want to describe failure initiation and crack propagation in a quantitative manner. Unfortunately, manual snow profiles often do not provide us with the necessary physical snow properties, such as the effective elastic modulus of the slab or the specific fracture energy of the weak layer. Luckily, there is an alternative. With the snow micro-penetrometer (SMP) it is possible to derive all the necessary quantities to develop criteria for failure initiation (S) and crack propagation (rc).

Over the past few seasons, we have collected several hundreds SMP profiles with one major goal: derive snow instability. Press a button, measure an SMP profile and get the answer to the question: What would a rutschblock, a CT, an ECT or a PST tell me if we had dug one here? A noble goal indeed, but we still have a little way to go. Thanks to recent developments, the micro-mechanical properties of snow can be derived from the SMP signal and after some calculations and computer simulations, the rutschblock or CT score and critical crack length can be derived. While there are still countless buttons to push and numbers to crunch, we are now able to derive criteria for failure initiation and crack propagation from SMP signals.

Contrasting signs of instability in the area, such as whumpfs, shooting cracks and recent avalanches, with the propensity of failure initiation and crack propagation we calculated from the SMP signals brought some interesting insights (Fig. 2). The first thing that strikes us in Fig. 2 is that all the coloured circles (snow pits with signs of instabilities)

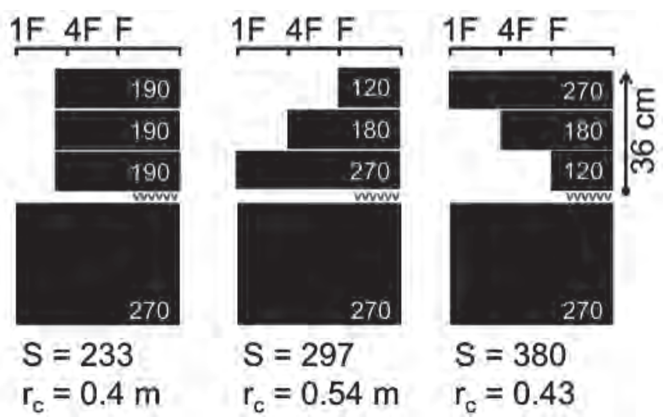


FIG. 3: EXEMPLARY SNOW STRATIGRAPHY REPRESENTED BY SLAB AND BASAL LAYERS (BLACK BARS) DISRUPTED BY A CRITICAL WEAKNESS (TRIANGLES). BELOW VALUES OF FAILURE INITIATION (S) AND CRACK PROPAGATION (r_c) ARE SHOWN FOR THREE LAYERINGS DIFFERING BY HAND HARDNESS (SCALE AT THE TOP), AND DENSITY (WHITE NUMBERS IN KG/M^{-3}). THE PROFILES HAVE THE SAME DENSITY AND HARDNESS AVERAGES.

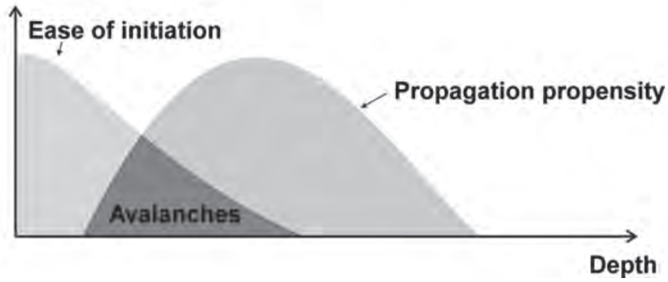


FIG. 4: SCHEMATIC REPRESENTATION OF THE INFLUENCE OF WEAK LAYER DEPTH ON FRACTURE INITIATION AND FRACTURE PROPAGATION. IN OVERLAPPING AREA, CONDITIONS FOR AVALANCHING ARE FAVORABLE.

are located in the lower left corner. Obviously, both the critical crack length and the failure initiation criterion were low when signs of instability were present. In other words, signs of instability were mainly observed when it was relatively easy to initiate a failure and relatively short cracks would already propagate. Based on the data shown in Fig. 2 we can derive two instability thresholds. Unstable snow conditions were typically present for a failure initiation criterion of S≤230, which translates approximately to the split between rutschblock scores 3 and 4, and for a critical crack length rc≤40 cm in PSTs. When both criteria were fulfilled, the chances of observing signs of instability were highest. One criterion is not sufficient to adequately separate situations with and without signs of instability, confirming the importance of both criteria for snow instability evaluation.

The variations observed in Fig. 2 are in large part due to differences in the layering, (e.g., thickness, density, stiffness, and strength). Accounting for the sequence of the layers in the slab is crucial to obtain realistic estimates of snow instability criteria. Using average values for the slab, for instance a mean density or hardness, can result in poor estimates, since the mechanical behavior of the slab is not adequately reproduced. To highlight this fact, we calculated S and rc for three idealized slabs (Fig. 3).

The three exemplary slabs all have the same mean properties with respect to density, hardness and stiffness. However, the two cases on the right, with more pronounced layering in the slab, have higher values of the instability criteria than the homogeneous case on the left. Actually, the layering has some positive aspects to it, too. We know that hard layers spread the force exerted by a skier—the so-called bridging effect—and there is less stress at the depth of the weak layer. Also, harder layers tend to be stiffer, which decreases the amount of deformation during the onset of crack propagation, and hence less energy is available and the initial crack has to be longer for it to start spreading. Comparing the profile in the centre with the one on the right, we find opposite effects on the failure initiation and the crack propagation propensity. The configuration with easier failure initiation in the centre is more resistant to crack propagation. Conditions favorable for failure initiation do not necessarily support crack propagation—and vice versa. For example, a thick and dense slab provides a lot of energy for propagation and tends to support crack propagation, whereas it is hard to initiate a failure in a deeply buried weak layer (Fig. 4). As the depth of the weak layer increases, stiffness and density of the slab generally increase as well. Hence, from a failure initiation point of view, snowpack conditions are becoming less favourable, but from a crack propagation point of view snowpack conditions are becoming more favourable. At the overlap of the two curves in Fig. 4, when the weak layer is not buried too deep, snowpack conditions are best suited for avalanche release.

Untangling snow instability means to focus on the avalanche release processes, the most prominent of which are failure initiation and crack propagation. They are closely tied together and both eventually control the avalanche release probability. Returning to the Hüreli, it is obvious now that "low temperatures did not preserve the danger"—near-surface faceting took away the slab's energy needed for crack propagation. Thus, whenever we evaluate snow instability, we must keep in mind avalanche release mechanisms: is there a weak layer, how is the slab above it, can we initiate a failure and will the crack propagate?

THE SNOW MICRO-PENETROMETER

Despite well-defined observation standards, snow hardness remains observer dependent. Clearly, hand hardness index depends on the size of your fingers, your strength and perhaps your pain tolerance. The oldest and best known objective measurement device is the Swiss rammsonde, which was developed during the 1930s, and the most recent example is the SP1 from Avatech (Lutz and Marshall 2014). For research purposes, the most precise instrument is the snow micro-penetrometer (SMP), which has been developed

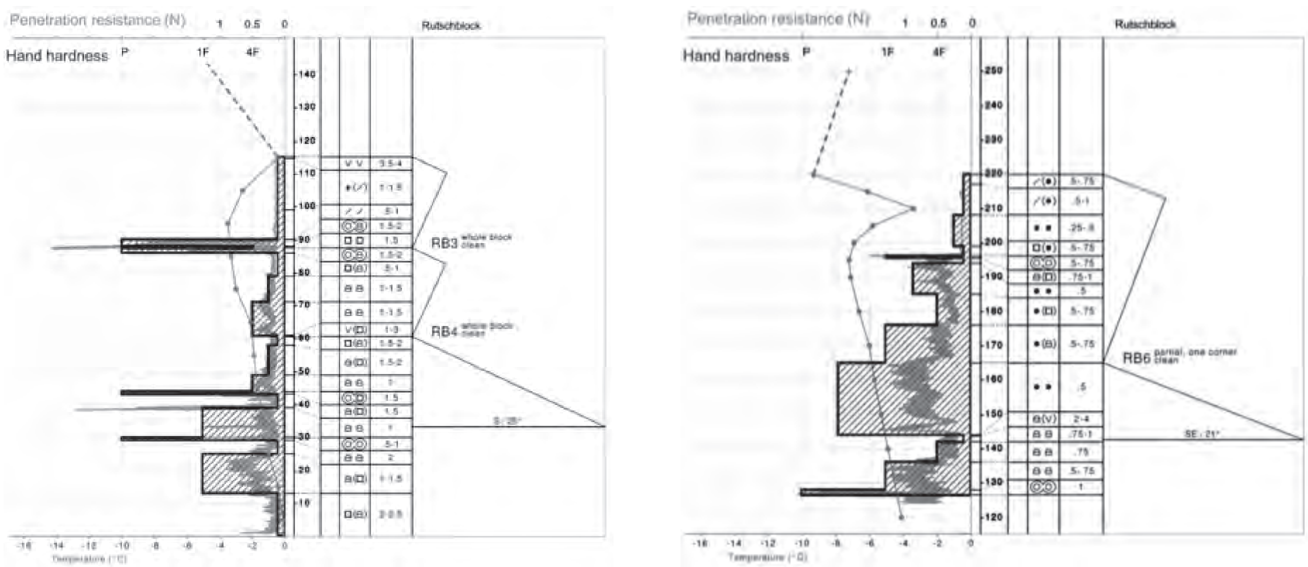


FIG. 5A: SNOW PROFILE FROM FEBRUARY 26, 2015 AT STEINTÄLLI, DAVOS, 2320M, S, 25°. FIG. 5B: SNOW PROFILE FROM THE SAME DAY, BUT AT CHILCHERBERG, DAVOS, 2480M, SE, 21°. BOTH CONTAIN TRADITIONAL PARAMETERS, SUCH AS HAND HARDNESS, GRAIN TYPES AND SIZES, AND SNOW TEMPERATURE, BUT ALSO CONTAIN THE PENETRATION RESISTANCE MEASURED WITH THE SMP.

and improved since the mid-1990s. The SMP can be used to obtain an incredibly detailed hardness profile of the snow cover, with 250 hardness measurements per mm. It can therefore easily be used to compare human fingers to objective snow measurements.

In Fig. 5 we present last year's winners of the "man against machine contest" during the 2015 International Advanced Training Course on Snow and Avalanches in Davos. As in chess the machine is not only faster but also more accurate. Still, humans are quite good at identifying hardness differences, but with our tactile senses we often overestimate the absolute value of the hardness of snow layers.

The SMP was not just developed to calibrate fingers of snow nerds. Snow researchers were primarily interested in obtaining objective measurements of the microstructure of snow, because, let's admit it, our fingers are a bit rough to carefully sense the fragile ice structures which make up the snow cover. The SMP has kept many snow scientists off the street, both sides of the Atlantic. Endless nights counting signal peaks, head scratching and the occasional cursing have provided us with increasingly reliable methods to interpret SMP signals. This provided the community with a more thorough understanding of what we measure in terms of microstructure. After all this preparatory work, the road was paved to derive snow instability.

REFERENCES

Lutz, E.R. and H.P. Marshall. 2014. "Validation study of AvaTech's rapid snow penetrometer, SP1." In: P. Haegeli (Editor), Proceedings of the 2014 International Snow Science Workshop. Banff, AB: Alberta, Canada, pp. 843-846.

Reuter, B., Schweizer, J. and Alec van Herwijnen. 2015. "A process-based approach to estimate point snow instability." The Cryosphere 9: 837-847.

Van Herwijnen, A. and J. B. Jamieson. 2007. "Snowpack properties associated with fracture initiation and propagation resulting in skier-triggered dry snow slab avalanches." Cold Regions Science and Technology 50(1-3): 13-22.

The New Research Chair in Avalanche Risk Management at Simon Fraser University

Dr. Pascal Haegeli

IT HAS BEEN A LONG TIME COMING and I am very excited to announce to the Canadian avalanche community that a new Research Chair in Avalanche Risk Management was formally established at Simon Fraser University (SFU) this fall. The Research Chair is in SFU's Faculty of Environment and it is housed in the School for Resource and Environmental Management (REM). The goal of the Research Chair is to conduct interdisciplinary research at the interface between the natural and social sciences to help improve avalanche safety in Canada. But before I get too much into the details of my research ideas, I would like to step back and provide a bit of background about how we got here.

The close collaboration between academic avalanche researchers and practitioners in Canada is unique and has resulted in first-class applied research programs at the University of British Columbia (UBC) and the University of Calgary. However, after many productive years of Canadian avalanche research, the recent retirement of Dave McClung from UBC and Bruce Jamieson's slowing down of the ASARC program put a big question mark on the future of avalanche research in Canada. Since neither UBC nor the University of Calgary had succession plans for their avalanche research programs, there was an opportunity to build something new.

Traditionally, avalanche research programs have mainly employed snow science and engineering approaches, and the results of this research have substantially deepened our understanding of the avalanche phenomenon. Over the last 10 years, however, there has been an increasing awareness that a better understanding of the human factors is critical for preventing avalanche accidents. While studies on human factors were conducted here and there, no research program has primarily focused on this aspect of avalanche safety.

During my work as an avalanche safety research and development consultant, I had become increasingly interested in human factors research. I was fortunate to be formally trained in social science research methods as a PostDoc under the supervision of Wolfgang Haider at SFU between 2006 and 2008. Wolfgang and I continued to work closely together and I had the pleasure to supervise a number of his graduate students on avalanche safety related research projects. During these collaborations Wolfgang and I started to talk about the possibility of an interdisciplinary avalanche Research Chair at SFU. In the summer of 2011, we pitched the idea to John Pierce, the Dean of the SFU Faculty of Environment at the time. John was immediately intrigued by the idea since a community-supported Research Chair resonated well with SFU's vision to become the most engaged university. At the same time, I discussed the idea with key players in the Canadian avalanche community and also received broad support. After four years of fundraising and negotiating, we finally had all of the necessary pieces in place to start the new Research Chair in Avalanche Risk Management at SFU last September. SFU contributed a regular tenure-track position for the Chair, which is very exciting as it provides long-term security for avalanche research in Canada. The five-year term of the Research Chair is funded by generous contributions from CP, HeliCat Canada, Avalanche Canada and Avalanche Canada Foundation, and the Canadian Avalanche Association. I am proud to have such broad support from both the professional and public avalanche communities.

The new Research Chair aims to

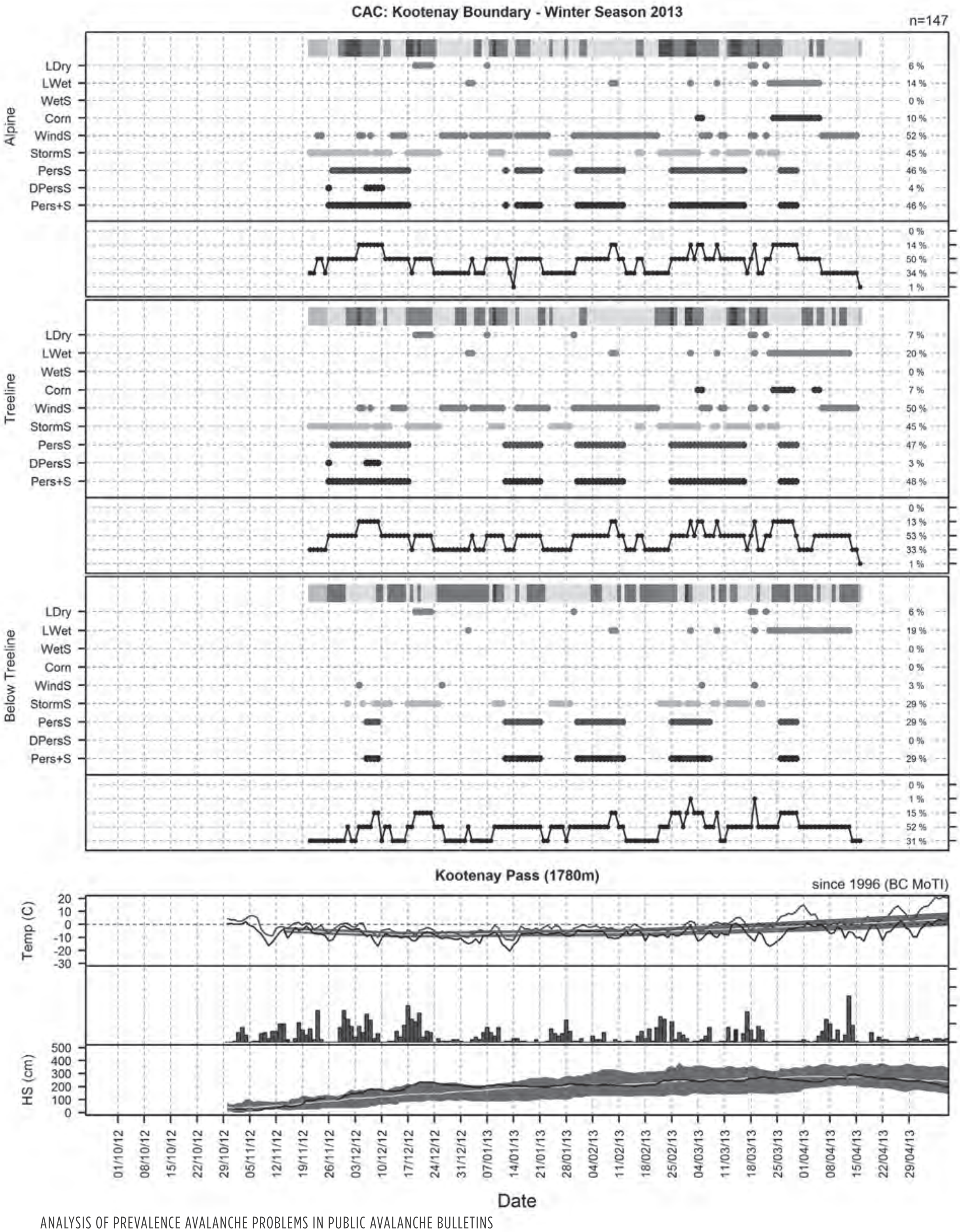
PASCAL IN HIS OFFICE AT SFU // PASCAL HAEGELI COLLECTION

complement traditional avalanche research by combining the natural science understanding of the avalanche phenomenon with human factors research. While any avalanche safety research needs to be grounded in natural science, there is a lot we can learn from other research fields like risk analysis, decision-making science, cognitive psychology, sociology, accident analysis, risk communication, geographic information science and public health. Incorporating theories and methods from these research fields can provide valuable additional perspectives for examining avalanche safety challenges. A successful research program in avalanche risk management also depends critically on a close collaboration with avalanche practitioners, the true experts in this field. The Canadian avalanche community has thousands of years of collective practical experience travelling in avalanche terrain and knows best where challenges exist.

My goal is to build on the tradition of collaborative avalanche research in Canada and develop an engaged interdisciplinary research program where we can all learn from each other. I see my role as a bridge builder who can span the gap between the natural and social sciences as well as academic researchers and practitioners to effectively study avalanche risk management practices and develop evidence-based tools that help both avalanche professionals and amateur recreationists make better informed decisions.

I have the pleasure to start my work as the Research Chair at SFU with a great team of students. Scott Thumlert, a PhD graduate from Bruce Jamieson's ASARC program and assistant ski guide joined me a year ago as a PostDoc in anticipation of the new Research Chair. Scott's work is funded through a MITACS grant in collaboration with Mike Wiegele Helicopter Skiing. Scott's research expertise and practical insights from guiding are valuable assets for the research program. Reto Sterchi joined me from Switzerland as a PhD student this fall. Reto has a master's degree in geography and worked as a natural hazards consultant in an engineering company for several years. Bret Shandro started with me as a master's student this fall as well. Bret has a degree in civil engineering and is coming from Revelstoke, BC. Together, we are the SFU Avalanche Research Program—SARP for short.

Consistent with the collaborative research approach, the SARP research priorities are developed in consultation with the supporters of the Research Chair. The initial research projects focus on two key areas: a) the conceptual model of avalanche hazard, and b) the use of terrain to minimize the physical risk from avalanches when travelling in avalanche terrain. The conceptual model of avalanche hazard presented by Grant Statham and colleagues at the 2010 ISSW in Squaw Valley articulated the previously undescribed assessment pathway between weather, snowpack and avalanche observations and avalanche hazard. The components specified in the conceptual model—avalanche character, likelihood of triggering, expected destructive size potential avalanches, etc.—are important inputs for making an informed decision about how to effectively manage avalanche risk under the current condition. Due to its practical value, the conceptual model quickly gained support in the community and in the winter of 2011-12, the production and presentation of public avalanche bulletins in Canada were redesigned to follow the conceptual model. In the winter of 2013-14, the conceptual model was also introduced into the InfoEx. After a few years of operational use, it is now time to look at the collected assessment data in more detail. Based on avalanche bulletin data from Avalanche Canada and Parks Canada, Bret will examine differences in the prevalence of avalanche problems and their characteristics among forecast regions in western Canada and from year to year. Bret's goal is to develop a risk management-focused avalanche climatology that is more informative than the traditional maritime, continental and transitional classification. The results of this research will pave the way for the development of forecast models for avalanche problems.



ANALYSIS OF PREVALENCE AVALANCHE PROBLEMS IN PUBLIC AVALANCHE BULLETINS

SCOTT THUMLERT (LEFT), BRET SHANDRO (MIDDLE) AND RETO STERCHI (RIGHT) MAKE UP THE REST OF THE SFU AVALANCHE RESEARCH PROGRAM TEAM—SARP FOR SHORT

As we all know, terrain selection is the primary means for managing the physical risk from avalanches when travelling in the backcountry. This process is primarily experience-based, relies considerably on non-explicit and non-formal knowledge, and employs intuitive decision practices. Surprisingly, very little research has been conducted to systematically examine what type of terrain is appropriate under different hazard conditions. To study terrain selection in detail, SARP has teamed up with seven mechanized backcountry skiing operations (Northern Escape Heli Skiing, Mike Wiegele Helicopter Skiing, CMH Galena, CMH Revelstoke, Selkirk Tangiers Heli Skiing, Monashee Powder Snowcats and Whistler Heli-Skiing). Small GPS tracking units are used to record the terrain choices of lead guides in participating operations at high resolution under a wide range of different conditions. The combined ski run tracks of all participants provide a detailed record of the terrain choices and risk management practices used within our community. In combination with raw weather, snowpack and avalanche observations, and avalanche hazard assessment information, these GPS tracks provide an extremely rich dataset that opens the door for examining a wide range of research questions around avalanche risk management during backcountry travel. Most generally, this research aims to extract the rules underlying terrain selection and quantify the professional practice norms that have evolved over the past 50 years, but remain undescribed. Last winter's pilot studies at Northern Escape Heli Skiing and Mike Wiegele Helicopter Skiing revealed promising results and allowed us to build the infrastructure necessary for handling this type of data. Scott and Reto will focus primarily on this research topic.

These are exciting times! Following Dave McClung and Bruce Jamieson is a tall order, but I am very excited and deeply honoured to have your trust to fulfill this important role in the Canadian avalanche community. I am looking forward to working with you to improve avalanche safety in Canada and beyond. I strongly believe that the proposed interdisciplinary and collaborative approach will allow us to develop innovative solutions to address today's avalanche safety challenges. If you have any research ideas, questions or comments, I would love to hear from you. You can reach me at pascal_haegeli@sfu.ca. You can also follow SARP on Facebook at facebook.com/avalancheresearch and learn more about the research program at avalancheresearch.ca.

There are many individuals who have championed this Research Chair along the way and we would not be here without them. I would like to thank everybody for their support, and in particular Mark Seland (formerly with CP), Heather Woods (CP, Coordinator Community Investment), Rob Rohn (President, HeliCat Canada), Ian Tomm (Executive Director, HeliCat Canada), Gordon Ritchie (President, Avalanche Canada Foundation), Kevin Seel (President, Avalanche Canada), Gilles Valade (Executive Director, Avalanche Canada), Aaron Beardmore (President, Canadian Avalanche Association), Joe Obad (Executive Director, Canadian Avalanche Association), John Pierce (SFU, former Dean of Faculty of Environment), Ingrid Leman Stefanovic (SFU, Dean of Faculty of Environment), Wolfgang Haider (SFU, former Director of REM), Phil Gerard (former SFU, Faculty of Environment), Wanda Dekleva (SFU, Faculty of Environment), Bruce Jamieson (University of Calgary), Jürg Schweizer (WSL Institute for Snow and Avalanche Research SLF), Hermann Brugger (EURAC) and Dave McClung (UBC).

On behalf of the entire SARP team, best wishes and have a safe season.

Flakes

ROB BUCHANAN