# Puzzling Over Propagation Propensity

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"So, what do *you* think will happen?" Bruce Jamieson has asked me a lot of questions in the past year and half since I've been one of his students, but never like this. Something about this question was different. I'm not sure if it was the way he asked it or the quizzical look he gave me when asking it, but I had the distinct feeling that he didn't know the answer. And neither did I.

I could have told him what I *hoped* would happen, but he wanted to know what I thought would happen. I knew my answer needed to be a good one, considering we had spent the better part of the day digging two parallel trenches about three metres long and more than two metres deep on the flats of Cheops Bench, at Rogers Pass in Glacier National Park. Between the trenches sat a smooth 30 cm wide by 200 cm tall by 285 cm long "beam" with a one cm-thick surface hoar layer about 170 cm below the surface (Figure 1). It was 1500 hrs and my field book was empty.

Bruce asked his question on January 28 of this year, but my mind quickly jumped back to February 19, 2000. That was the day Crane Johnson and several ASARC staff and students triggered a whumpf in a flat meadow near Bow Summit and successfully measured the speed of the propagating collapse. It wasn't a novel idea to associate collapse with propagation in whumpfs, but Crane's description of how the collapse propagated was new.

His model required vertical collapse in the weak layer, and described how a "bending wave" could develop in the slab, shearing or crushing the weak layer as it travelled along. What's most interesting is that he showed the types of slabs and weak layers most often associated with whumpfs looked a lot like the ones associated with remotely triggered avalanches. This explains why most of us to look up, not down, when we trigger a whumpf with even a small slope above us.

*Looking down at the "big beam" on Cheops Bench. The beam was 30 cm wide, 285 cm long, and excavated to a depth of about 2 m. The 060126 surface hoar layer was 170 cm below the surface. I'm deep in the trenches taking a close look at the weak layer in the area that the saw passed through. The collapse ran toward the camera.*

*This photo was taken before one of Alec van Herwijnen's fracture speed tests. The markers are rubber corks, and the weak layer is in between the two rows. He filmed the propagating fractures with a high-speed video camera, capable of capturing 250 frames per second.*

I think a lot of Crane's inspiration came from seeing propagating fractures in a weak layer while performing his version of the cantilever beam test. With a specially-made saw that made a five cm-thick cut, he'd undercut the slab in a "beam" of snow until the slab finally overhung too far and broke. He was searching for information about flexural stiffness in the slab to improve his understanding of how they bend. His super-thick saw was cutting along a weak layer, so he was able to see that every now and again the weak layer progressively collapsed ahead of his saw before the slab broke. In the touchiest of layers, the weak layer collapse would run right to the end of the beam and stop at the pit wall.

But what does this have to do with my big beam on Cheops Bench? After all, my goal is to develop a practical field test related to fracture propagation propensity and apply it to regular skier-triggered avalanches, not these oddball whumpfs and remotes that Crane was so keen on. The beam that Bruce asked about certainly wasn't practical, and I wasn't chasing whumpfs.

Bruce was still staring at me, waiting for my answer, so I stalled with a drawn out "Well…," and returned to my academic soul-searching. Again, I started by thinking about propagation speed. Alec van Herwijnen spent a great deal of time in the past few years measuring propagation speeds. He used a really fast video camera to record propagation in stability tests, Crane's cantilever beam test, and on skier-tested slopes. To do this, he filmed and tracked the movement of a series of markers placed in the slab above the weak layer in the side wall of the stability and beam tests, or in a trench in a small slope while it was being ski-cut (Figure 2).

*"I asked what he thought would happen if I drove a hypothetical bulldozer around one end of the ground floor and started knocking pillars over."*

When he analyzed the results, Alec found that in almost every case the markers moved down, one after the other, before they moved parallel to the slope individually or together when the slab started to slide. He calculated a propagation speed based on how much time passed between the onset of movement in each of the markers and how far apart the markers were. The speeds he calculated were very close to the same speed Crane measured at Bow Summit, and were quite a bit lower than he expected.

Alec observed progressive vertical movement in the slab before any slope parallel movement almost every time, in thin layers, thick layers, on the flats, on slopes, in stability tests, cantilever beam tests, and ski cuts. Even in Compression Tests with sudden planar fracture character, where we don't see any vertical movement of the slab, the video footage revealed there was at least a small component of collapse.

These things suggest, quite strongly in my mind, that there is a very real connection between fracture propagation in whumpfs, remotes and run-of-the-mill slab avalanches. The difference seems to be less in the fracture process than in the scale. Finding collapsing weak layers and slab bending in most cases may just depend on how closely you look.

Back on Cheops, Bruce waited patiently while I mulled it over. Another glance at our beam took me on one more ride down memory lane, this time to Mt. Ste. Anne near Blue River, BC. In the spring of 2005, esteemed ASARC technician Ken Matheson and I were struggling over another prototype propagation test. The layers weren't co-operating, the drop-hammer apparatus was cumbersome at best, and Ken was ready for a new direction.

I had been waxing philosophical over lunch about parking garages and the not-so-obvious similarity between them and the snowpack we were neck deep in. At that point I was familiar with Crane's results and had just read Alec's thesis, but I was stuck on concrete slabs held up by thin pillars. I told Ken about this hypothetical parking garage, about 30 m wide and 300 m long, with one slab floor held above the ground floor in the standard way these things are constructed.

I asked what *he* thought would happen if I drove a hypothetical bulldozer around one end of the ground floor and started knocking pillars over. Would the second floor come crashing down? At some point, of course it would. Would it only crash down above the pillars I had destroyed? Maybe. Would the collapsing slab drag more of the slab with it, causing a few extra pillars to break? Would the progressive collapse start at my dozer and run the whole 300 m and bring the whole garage down? Is this starting to sound familiar?

Ken was game, so we isolated a 30 cm across-slope by 3 m down-slope column of snow, and started knocking over pillars of weak layer. We did this with the back of a 3-mm thick regular snow saw, dragging it through the weak layer in the column starting at the upslope end. Bruce was well aware of what Ken and I observed that day. He knew that on the first test we cut about 50 cm of weak layer when suddenly, with a distinct "POP," the weak layer fractured from our saw to the end of the column. He knew that with some amazement we watched the 85-cm thick slab slide right off and landed on the slope below our pit. He also knew, that in the 100 or so tests like this that we did last year, we sometimes saw propagation in the weak layer to the end of the column, sometimes to a crack through the slab, and sometimes to an indistinct point where there was no obvious reason for the fracture to arrest.

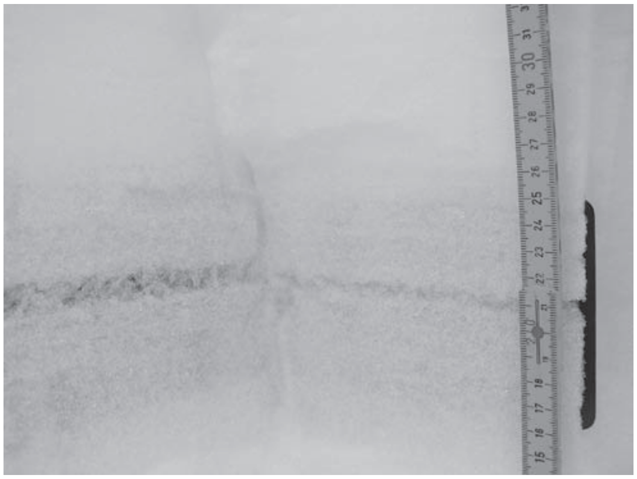
Bruce knew we had tested many different layers and column lengths, and had shown we needed a slab *and* a weak layer to get good propagation. He was as convinced as I was that we were sampling propagation and arrest away from and unrelated to the initiation condition or the trigger. We were watching a bull dozer try to topple a parking garage by knocking over a few of the supports.

Most importantly, Bruce thought that maybe weak layer and slab combinations, possessing what we call "high fracture propagation propensity," might be enticed to collapse fully with just a small portion of the weak layer support removed. Those with low or no propagation propensity might never fall down, or might fall bit by bit as the weak layer pillars are destroyed with the saw. With high propagation propensity you'd expect big avalanches, I guess, but I'm getting a little ahead of myself here. Bruce is waiting for his answer and I can't stall much longer.

*"'It went to the end,' I noted casually, disguising my amazement."*

"Well," I continued, "I'm going to cut about 50 cm of the weak layer with the back of my saw, and then it's going to run right to the end." I think Bruce agreed with me, but I didn't mention that secretly what I *thought* would happen and what I *hoped* would happen were the same thing. At the very least, if my prediction was correct we wouldn't have wasted all day digging a truly monstrous pit on the flats. In the spirit of true scientific ideals, I justified our time by mentioning whatever happened we would learn *something* about propagation.

"What happened?!"



*The collapsed 060126 surface hoar layer on the right and the intact layer on the left. We took this photo at the end of the beam on Cheops Bench after the test. A vertical saw-cut separates the isolated beam from the rest of the pit.*

I was still trying to figure it out myself when Bruce shouted this one through the beam. We were on opposite sides, only 30 cm apart, but in our own little worlds in the segregated trenches on either side of the beam. I had placed the saw in the weak layer, and Bruce had kept it on track on his side while I dragged it through the layer on mine.

"It went to the end," I noted casually, disguising my amazement. It must have been quite the sight, the two of us on all fours scrambling along the floors of our respective trenches, following a formerly 1-cm thick – now 4-mm thick – surface hoar layer for about 230 cm until it abruptly became 1-cm thick again beyond the extent of our isolated beam (Figure 3). I had predicted that we'd cut 50 cm of weak layer before the dynamic progressive collapse we call propagation would take over and run the length of the beam. I was wrong. We had to cut 58 cm.

Given the preamble that led to this prediction, the outcome doesn't seem that surprising. What I think *is* somewhat surprising is that we had arrived at propagation with a very thin saw, on the flats, without jumping or pounding on the end of the beam, and without slope parallel shearing that seems to be required for propagation on the slopes. However, what we observed looked almost exactly like what I saw a week later, when I repeated this very experiment on a 30º slope in a similar snowpack on Mt. Fidelity. I cut the weak layer from the upslope end of the beam, and got about 45 cm into it when, with a half "pop" and half "whumpf" sound the weak layer collapsed from my saw to the end of the beam, about 240 cm away.

"What does this mean?" Bruce inquired. It was 1530 hrs now on Cheops Bench, and we really had to make tracks to be at the highway before 1600 hrs. I hope this last question Bruce asked was meant to be rhetorical, because I never did answer it. I couldn't answer it then, and I can't answer it now. Don't get me wrong, I've got some ideas. I know what I *hope* it means, and I know what I *think* it means. I hope it means we are getting closer to understanding how fracture and failure propagation in weak snowpack layers works, and I think it means we're on a road that will lead to a practical field test for propagation propensity. But I don't *know* these things, and I don't know for sure how all this relates to avalanches. Or parking garages.

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For his PhD in Civil Engineering Dave Gauthier is studying propagating, fractures in weak snowpack layers. Along with observations of fractures initiating, propagating, and arresting, Dave is working towards the development of a practical field test for fracture propagation propensity. Dave studied Geology at Lakehead University in Thunder Bay, Ont., where he received his HBSc and MSc degrees. After a few winters in Fernie, all roads led to Calgary. Currently, all roads lead to Rogers Pass between December and April, and the Canoe Meadows parking lot for the remainder of the year.