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Avalanche survival strategies for different parts of a flowing avalanche: Merging theory and practice to increase your odds

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Note from KB: Dale Atkins' and Marty Radwin's presentations at the seminar in Jackson Hole got me thinking about survival strategies for people caught in avalanches. Clearly there are many things we do not know. I was curious about what we did know about granular flow, swimming, and surviving avalanches. I started by calling granular flow expert Michel Louge from Cornell, and he gave me some valuable insights, but admitted that we don't really know if swimming in an avalanche is helpful, but we also cannot say that it is not helpful. In fact, there may be some times when swimming – or rather struggling – could be beneficial. I next contacted Perry Bartelt from the Swiss Federal Institute and he helped me to better understand avalanche dynamics and how surviving an avalanche might well depend on what part of the avalanche you are in. About that same time Theo Meiners, who runs Alaska Rendezvous Guides Heliski, sent me a hand-drawn picture of how to survive an avalanche based on his experiences and the experiences of many of the people he knew. Theo's drawing showed different strategies for different parts of the avalanche. Interestingly, several parallels existed between Perry's theories and Theo's experiences. It was a perfect example of merging of theory and practice, and from it came this short article.

Introduction

Avalanche survival is currently a hot discussion topic among many avalanche professionals. Dale Atkins' recent comments that swimming may lead to dying in avalanches received wide media coverage, and his article in *The Avalanche Review* (Atkins, 2007) gave the avalanche community something to chew on. Was the long-established dogma of swimming in avalanches actually wrong? Has the avalanche community been misleading the public for many years about how to best survive an avalanche?

Of course, the best way to survive an avalanche is to not get caught. However, once you are caught, what is the best survival strategy? Dale brought out several interesting points, the most important of which is that many avalanche victims are found with their hands well away from their faces. This suggests they were unable to create an air pocket, which is critically important for surviving under the snow for any length of time. Dale suggests that the process of "swimming" does not allow people to get their hands in front of their faces quickly enough as the avalanches come to a stop. The idea that avalanches stop quickly is well established in our understanding of avalanche dynamics, and we need to emphasize to the public that people must to try to get an air pocket well before the avalanche comes to a stop.

However, other parts of Dale's message do not resonate for many. Once knocked off our feet, are we really better off simply trying to guard our airway for the entire ride? Or, are there things we can do to increase our chances of survival?

A practical view

Alaska's Chugach Range has served as a testing ground for guiding heli skiers in extreme terrain. Guiding the area has been a learning process resulting in no small number of avalanche involvements, and the survivors have swapped stories and devised optimal survival strategies. Though every avalanche is different, and each avalanche may require a different approach, some common strategies have emerged. These have been compiled by Theo Meiners (Figure 1) and are discussed below.

These guidelines apply to SS/AS or AR/D2,3,4 and R2,3,4 avalanches without secondary exposure or terrain traps. Field observations show similar flow patterns for many avalanches. Failure/release is followed by laminar flow, then as the stauchwall appears there is a violently turbulent zone as the sliding snow and blocks roll over the stauchwall. The snow then exits this turbulent zone, flows as a mostly laminar flow (depending on the terrain over which it is traveling), and begins its deposition phase. The head of the slide continues to subduct as it compacts and entrains the snow on slope while rolling forward. Depending on where you are in the slide, there are different possibilities for escape off the avalanche before you have to go full ride. The strategies are:

1) Ski or board away fast.
2) Self arrest on bed surface.
3) If knocked downhill with skis /snowboard still on, use your skis as brace and spin on hip/bed surface to get skis downhill (like a kayaker using a paddle) and stand and ski away (even if you are in a lot of snow this method works in initial phase).
4) If ejected from skis use back stroke/log roll combination to fight for flank and self arrest on to flank or bed surface. The main thing to do is to fight. Any resistance at all will slow your progress as slide accelerates away from you.
5) If you are in an area of turbulence, do your best to go with the flow. Maintain white water position with feet down hill. After going through the turbulent area you may emerge before the deposition area. Assist the currents of the avalanche with back stroke action once you are through the turbulent area. Continue to try to back stroke and log roll to get to the flanks and self arrest.
6) Do whatever you can to avoid head of slide as it is subducting and will pull you down and under the slide. Absolutely do not swim forward of head if you can help it.
7) Use essential equipment for surviving/escaping capture. This includes a helmet to help prevent a head shot and the resulting confusion, an Avalung to maintain breathing and to keep you from gagging (thereby helping to prevent panic), the usual transceiver/probe/shovel combination, and of course trusted partners. Never say die and never go Gumby; you have a lot to teach others from this experience!

A theoretical view

Recent research is leading to an improved understanding of avalanches in motion. Much of this research is focused on better understanding avalanche runout, but it can also help us devise appropriate survival strategies for avalanches. Like the experience-based answers provided above, theory about avalanche motion also suggests that the best survival strategy in an avalanche depends – at least in part – on where in the avalanche you happen to be. Our discussion focuses on what we know about the flow in the different parts of the avalanche, and how you can use that knowledge to increase your odds of surviving an avalanche if you are caught.

Much of our theoretical understanding of avalanche dynamics has been derived from full-scale experiments recently performed at the Swiss Vallée de la Sionne test site (Amman, 1999). Actual measurements of avalanche velocity clearly support the division of an avalanche into turbulent and laminar flow regions, as depicted above by Theo. Consider the figure below showing the distribution of avalanche velocity in a medium-sized mixed flowing / powder avalanche which spontaneously released after a heavy snowfall period in 2005 (Figure 2). The velocity profiles (the distribution of velocity over the avalanche height) are depicted at different times starting after the leading edge of the avalanche has passed the sensors. In this particular measurement, the velocities 10 s after the leading edge has passed are still quite high at over 30 m/s (67 mph). Thirty seconds later, in the tail of the avalanche, the flow velocity has decreased to less than 10 m/s (22 mph). Wait another ten seconds and the avalanche tail has basically stopped.

These velocity measurements provide useful insights into the flow behavior of avalanches and possible survival strategies. For example, in the turbulent front zone, the velocities at the top surface are much larger than the velocities at the bottom. This is the dangerous subducting zone. In this zone, velocity fluctuations and random flow patterns exist. A skier caught in this region will be probably be taken by the rolling motion of the avalanche. Because the velocity gradients (the difference in velocity as a function of height) are large, it is unlikely that any swimming strategies will be helpful as the tremendous shear forces (several tons per square meter) will prevent the avalanche victim from making any useful or concentrated movement. Clearly, this is the part of the avalanche we would like to avoid, if at all possible.

At the tail of the avalanche, the situation appears much better. The measurements reveal that an avalanche stops at the tail. As the avalanche elongates, mass is withdrawn from the front and deposits even on steep slopes. The avalanche essentially "runs out". The velocity gradients and fluctuations at the tail are much smaller than at the front (for more technical details, see Bartelt *et al.*, 2007). An avalanche victim caught at the tail, or who manages to work their way back to this part of the avalanche, has a fighting chance. They clearly should do everything in their power to arrest on the bed surface or reach the flanks of the flow.

What determines the size of the turbulent and laminar regions of an avalanche? Quite simply it is the amount of snow, or mass of the avalanche. Avalanches with larger release zones, or avalanches that can entrain the snowcover and therefore continually grow, will easily generate dangerous turbulent fronts. These monsters simply have more potential energy that they can convert to velocity and turbulent motions, and will have proportionally smaller tail regions. Conversely, smaller avalanches will have a proportionally larger tail and this will cause them to stop more quickly.

Merging theory and practice

Merging theory and practice can sometimes be messy business. However, in this case clear parallels exist between our scientific understanding about avalanche dynamics gathered from sophisticated instrumentation and the knowledge that some practitioners have gathered through experiencing avalanches from the inside looking out. First, avalanches consist of several parts and what you can do to increase your odds of surviving the slide depends – at least in part – on what part of the avalanche you are in. Second, practice tells us that we should do whatever we can to try to let as much snow go by us as possible, whether that is skiing to a side of the avalanche where less snow is releasing, digging into the bed surface, or climbing uphill over blocks. Doing this helps to put us in what an avalanche dynamics specialist would call the "tail" of the avalanche, and theory suggests that this is a much more manageable – and survivable – place to take a ride. Third, practice tells us that being at the head of the avalanche is bad news. Here we are likely to get sucked under and thrashed around violently. This rather unpleasant observation is also borne out by data collected from moving avalanches which shows that the leading edge of the avalanche is where there are tremendous subducting forces and wildly turbulent flow patterns that make swimming either difficult or impossible. If you are getting thrashed around in this zone you might be best just trying to protect your airway if that is at all possible.

Of course, when we teach others about avalanches we don't want to focus on how to survive an avalanche. Instead, we need to emphasize the importance of *not getting caught* in an avalanche. Still, having a viable plan might save the life of a person who unintentionally does get caught in a slide. Clearly, each avalanche will be somewhat unique and different strategies might work in different avalanches. However, we believe that the strategies and ideas discussed in this article can form part of a useful plan for surviving avalanches.

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<u>Short bios</u>

Karl Birkeland is the avalanche scientist for the Forest Service National Avalanche Center, and is based in Bozeman, Montana. He's been trying to control, forecast, and study avalanches for the past 25 years. Karl enjoys mucking around in the snow in the winter when he isn't chasing his two young daughters around Bridger Bowl.

Perry Bartelt is head of the research unit "Snow avalanches, debris flows and rockfalls" at the Swiss Federal Institute for Snow and Avalanche Research (SLF). Although clearly a theoretician, Perry can and even enjoys writing computer models that actually work on real problems.

Theo Meiners is the owner and lead guide for Alaska Rendezvous Lodge and Heliski Guides, which he has operated for the past eight seasons. For the five seasons prior to that, he was a lead guide for Doug Coombs at Valdez Heliski. When it's too dark in Alaska he spends his time guiding at Jackson Hole Mountain Resort. Theo has been skiing and guiding in the Alaska's Chugach Range, Colorado's Elk Mountains, Wyoming's Teton Range, and the Andes in Chile. Without dummies to experiment witht, and with poor technical help, he and his colleagues have managed to blunder through many an experiment of merging science with practice as they passively and personally mitigate avalanche hazard.

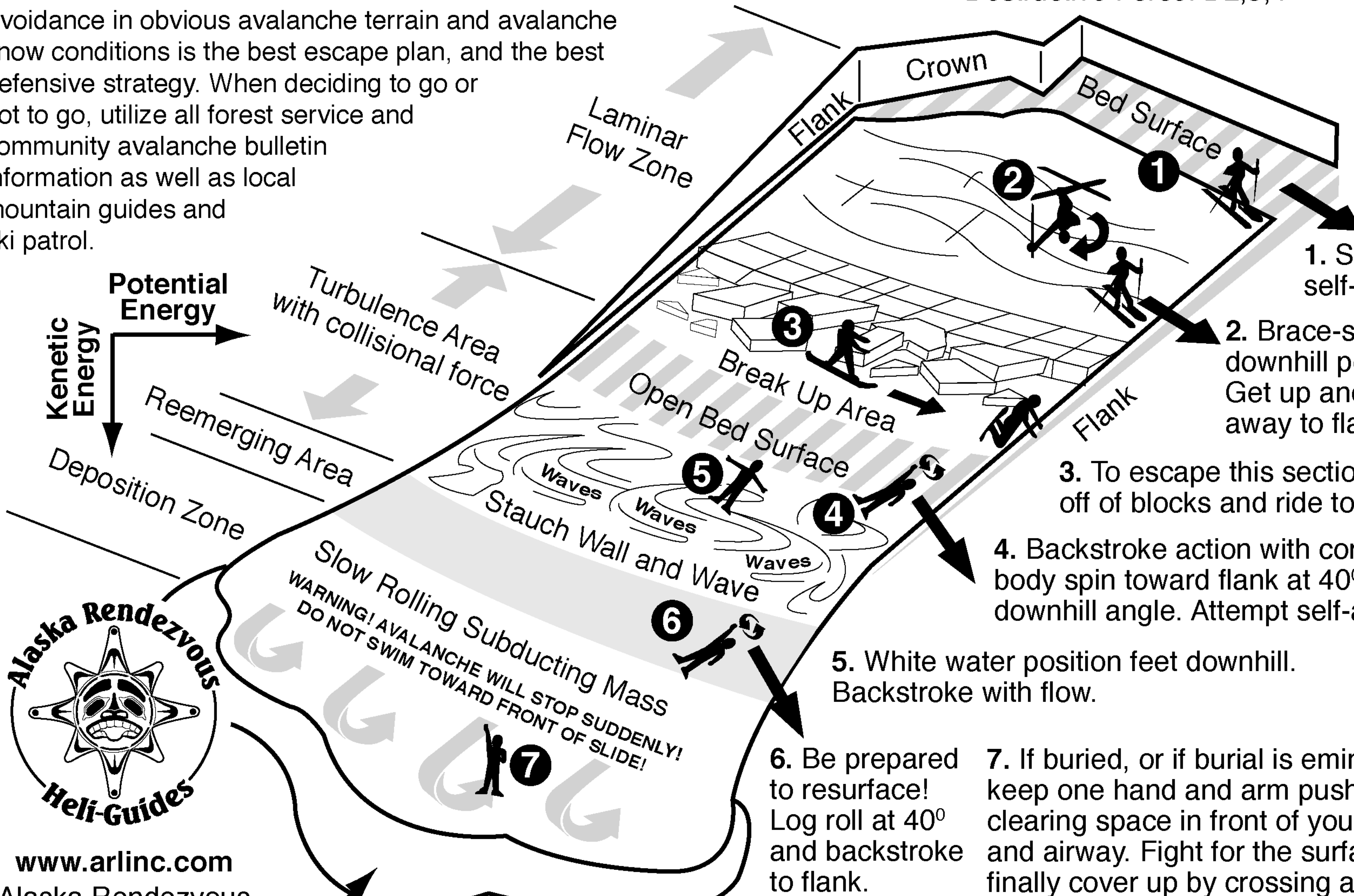
Escape From Capture!

These are your escape opportunities in powder slab avalanches

This scenario assumes that there are no terrain traps or double exposure.

Triggers: SS/AS/AR• Run: R2,3,4
Destructive Force: D2,3,4

Avoidance in obvious avalanche terrain and avalanche snow conditions is the best escape plan, and the best defensive strategy. When deciding to go or not to go, utilize all forest service and community avalanche bulletin information as well as local mountain guides and ski patrol.



Compacted Base (Not bed surface)

1. Ski off or self-arrest

2. Brace-spin to downhill position. Get up and ski away to flank

3. To escape this section, push off of blocks and ride to flank.

4. Backstroke action with corkscrew body spin toward flank at 40⁰ of downhill angle. Attempt self-arrest.

5. White water position feet downhill. Backstroke with flow.

6. Be prepared to resurface! Log roll at 40⁰ and backstroke to flank.

7. If buried, or if burial is eminant, keep one hand and arm pushing and clearing space in front of your face and airway. Fight for the surface and finally cover up by crossing arm over to opposite shoulder and grab pack strap or collar on jacket. Stay balled up and remain calm. Wait for help.

DO NOT SWIM FORWARD TOWARD THE FRONT OF THE SLIDE!

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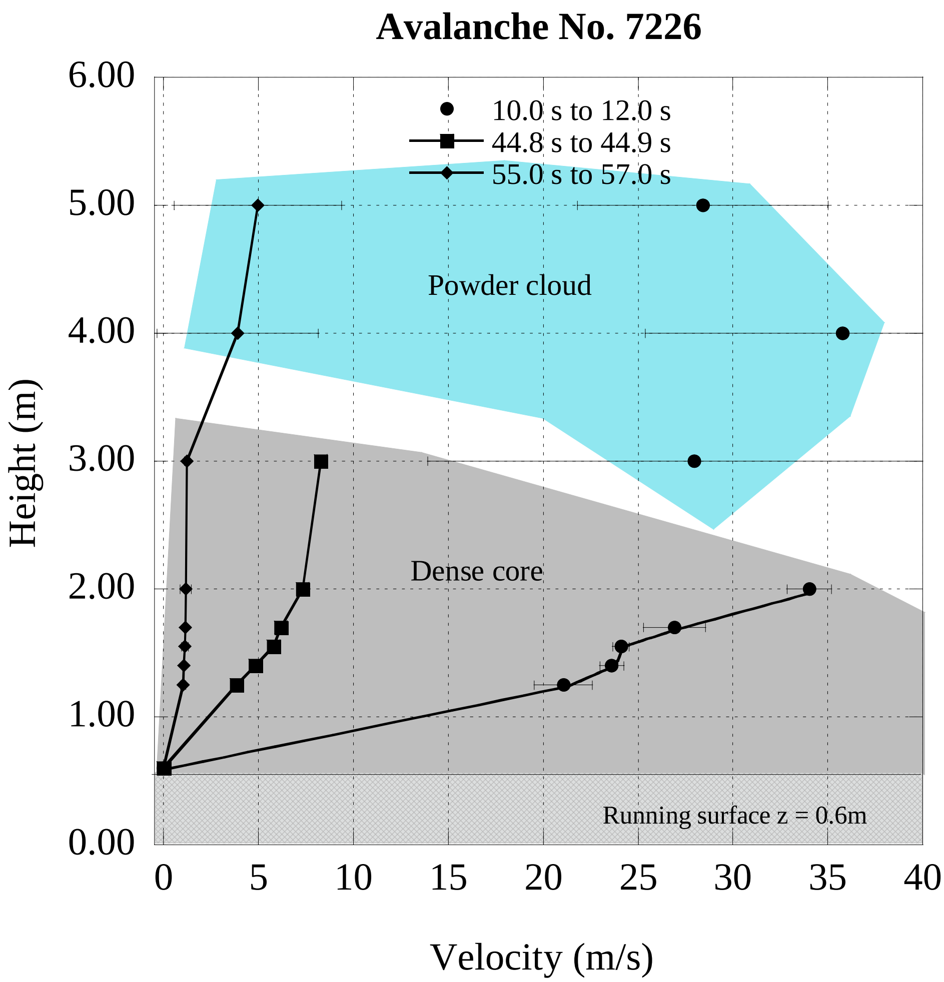

Figure 2: Distribution of avalanche velocity with height for three different time periods for a medium sized mixed flowing/powder avalanche from the Swiss Vallée de la Sionne test site.