AVALANCHE SURVIVAL STRATEGIES FOR DIFFERENT PARTS OF A FLOWING AVALANCHE

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ABSTRACT: Swimming in avalanches has recently been questioned, with detractors stating that "swimming leads to dying". Since no direct scientific evidence exists to either refute or support the idea of swimming, we combine the practical experience of avalanche survivors with our emerging knowledge of avalanche dynamics to arrive at possible survival strategies for different parts of flowing avalanches. Practical experience and avalanche dynamics theory are largely consistent and suggest the following strategies: 1) Once an avalanche is released, every effort must be made to get off the moving slab, 2) After being caught, the victim must do everything possible to try to get toward the back, or tail, of the avalanche since this is where avalanches run out of mass and where a victim is more likely to be left behind by the slide, 3) Experience shows that in some avalanches a backstroking and log rolling motion may help the victim stay near the surface and move toward the flanks of the avalanche, and 4) If at all possible, the head of the avalanche should be avoided since the turbulent flow and large forces in this area increase the odds of injury and deep burial. Though it cannot be definitively proven, experience and avalanche dynamics theory suggest that swimming – or as some call it, "struggling" – is part of a viable strategy for surviving an avalanche once you are caught.

KEYWORDS: avalanche survival strategies, avalanche rescue, avalanche dynamics

1. 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. Is 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? Atkins (2007) 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. The process of "swimming" may not allow people to get their hands in front of their faces quickly enough as the avalanches come to a stop (Atkins, 2007). The idea that avalanches stop quickly is well established in our understanding of avalanche dynamics, and avalanche educators need to emphasize the importance of trying to establish an air pocket well before the avalanche comes to a stop.

However, other parts of Atkins' (2007) 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? Should we be "swimming", or as Radwin (2008) calls it, "struggling"? To further our understanding of optimal strategies for surviving a flowing avalanche, this paper offers: 1) a practitioner's view of the problem, 2) a theoretician's discussion of our current knowledge of avalanche dynamics, 3) a few key case studies from people who have survived rides in avalanches, and 4) an attempt to merge the theory and practice of avalanche survival. This paper is an updated version of a paper we previously published (Birkeland et al., 2008).

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2. 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 (Figure 1). The strategies below have been compiled by the second author (T. Meiners) and are discussed in more detail below.

These guidelines apply to SS/AS or AR/D2,3,4 and R2,3,4 avalanches without secondary exposure or terrain traps (Greene et al., 2004). 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. After triggering a slide, the strategies (in order) are:

1) Ski, board or snowmobile away and off the moving slab fast.
2) If that is not possible, try to self arrest on bed surface.
3) If knocked downhill with skis /snowboard still on, use your skis to help swing you around. In other words, dig into the bed surface on your hip using hands, ski poles, etc. As your hips slow your skis will catch the faster moving snow and spin your feet downhill. At that point you quickly stand and ski away (even if you are in a lot of snow this method works in the initial phase).
4) If ejected from skis use back stroke/log roll combination to fight for flank and self arrest onto 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. You want to get as far toward the edge or the back of the slide as possible.
5) If you are in an area of turbulence, do your best to go with the flow. Maintain whitewater 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 the head of the slide as it is subducting and will pull you down and under the slide. Absolutely do not swim forward of the 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. Do not give up; you have a lot to teach others from this experience!

3. 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. Consider 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

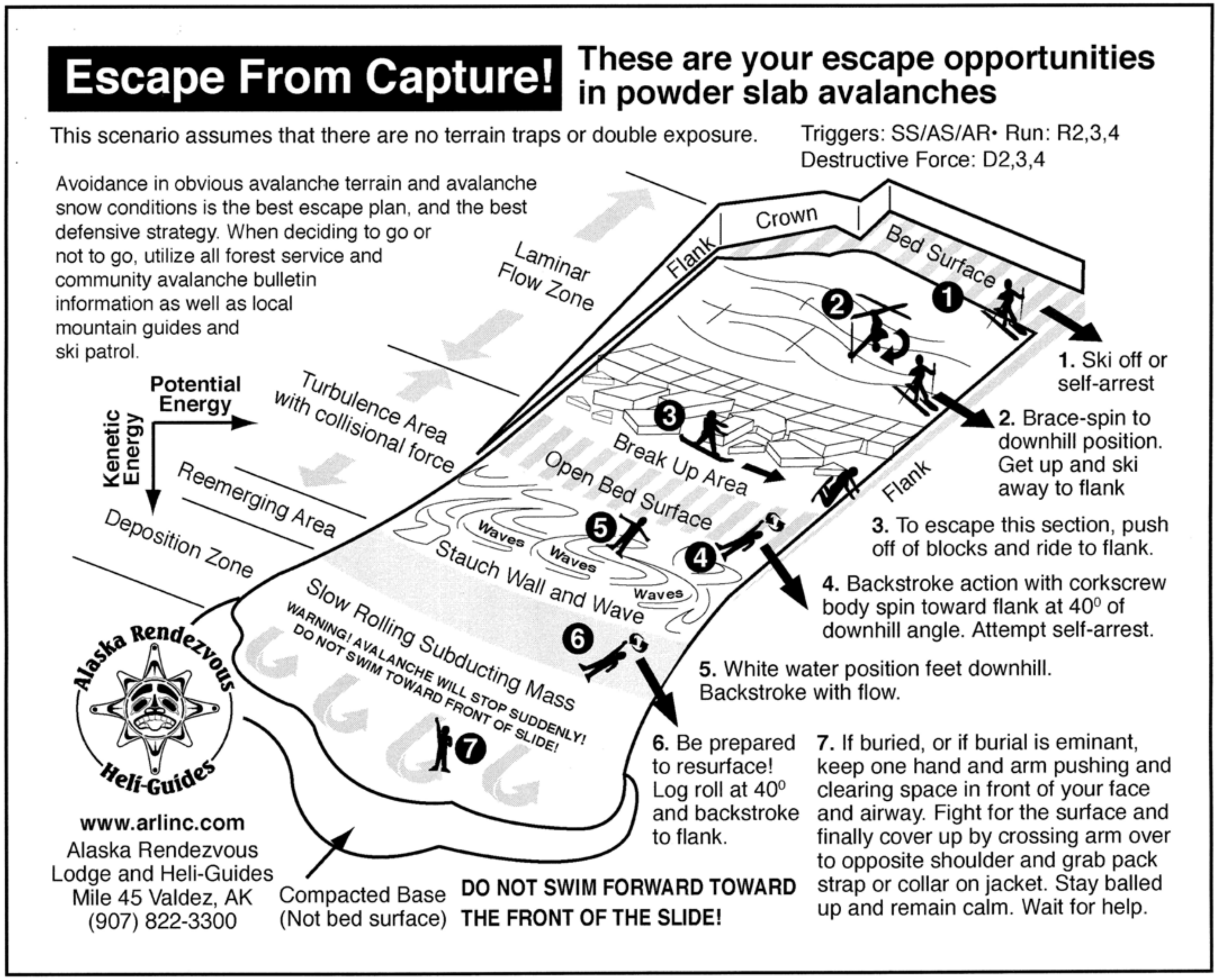

Figure 1: Alaska Rendezvous Heli-Guides safety card explaining and illustrating the survival strategies discussed in this paper.

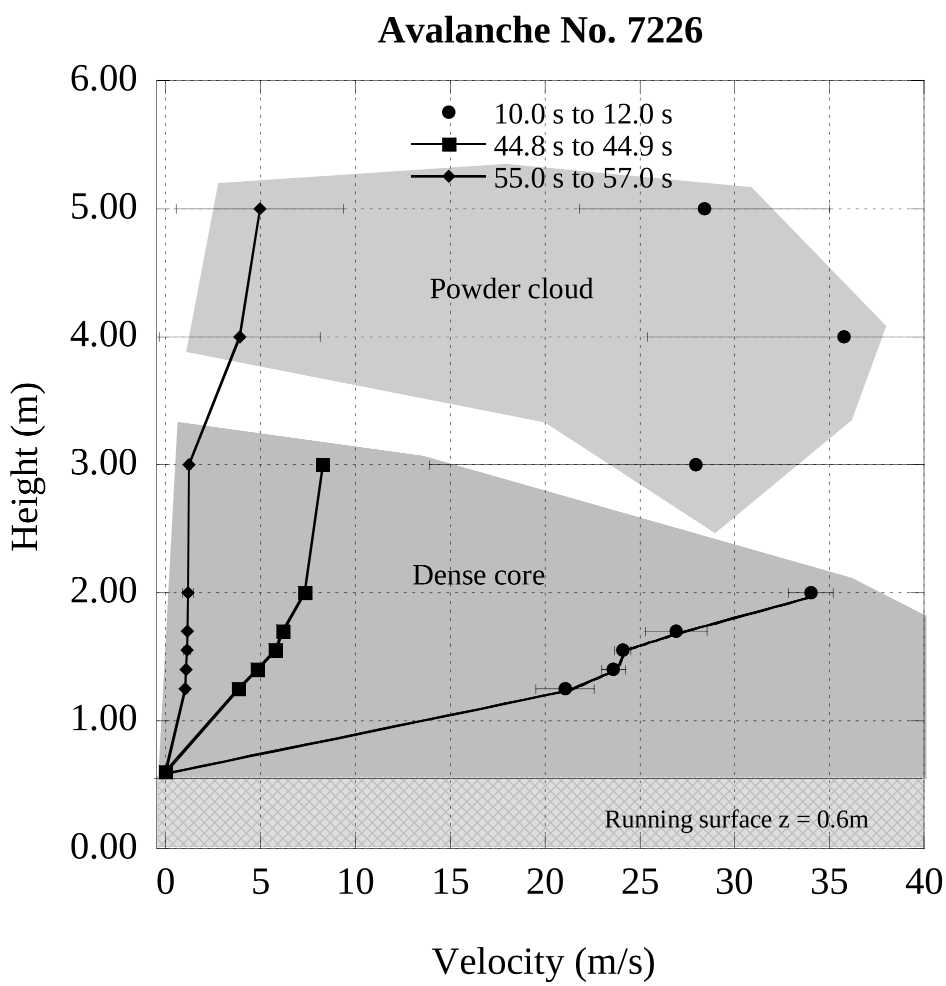

Figure 2: Distribution of avalanche velocity with height for three different time periods for a medium sized mixed flowing/powder avalanche from the Swiss Vallée de la Sionne test site.

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 person 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.

4. CASE STUDIES

As pointed out by Atkins (2007), people who die in avalanches cannot tell us what sort of survival strategy they attempted. However, we can talk to people who have survived avalanches to better understand some of the different survival strategies that worked (or did not work) for their particular avalanche. Such case studies emphasize that each avalanche is somewhat unique. Though we can provide general guidelines, the best strategy for surviving an avalanche likely varies somewhat with the avalanche. Our first two case studies illustrate the effectiveness of some of the techniques discussed in this article, while the third illustrates the importance of improvising and doing whatever is necessary to get out of the avalanche.

Case study 1. The second author of this paper (T. Meiners) has been personally involved in a number of avalanches, and many of his experiences form the basis for the practical aspects of this paper. We will describe one particular avalanche that illustrates the importance of using the techniques described to survive an avalanche capture. In early April of 2000 he was guiding a group in Alaska's Chugach Range. After digging a pit and doing a few ski cuts, he decided to ski down a slight ridge between two ravines. At the mid-slope level he felt the snow collapse and saw the snowpack cracking as he trigged an avalanche that was estimated to be D3.5 in size.

Once the avalanche initiated, his radio mic was immediately cued by the helicopter pilot who was watching from below, so he knew the slide was huge and that he was in the middle of the slab. Since he was mid-slope, he had plenty of speed. His first tactic was to try to escape by speeding through multiple stauchwall sets and heading to the left flank. He did not make it as the snow folded under his skis, swallowing him with a violent ski crash. Sliding rapidly headfirst and buried, he used the technique of digging into the bed surface with his arms and poles near his hip which brought his skis around in seconds. Standing quickly, he was up again and skiing fast on the bed surface between blocks and sliding snow. However, he was overtaken again because his speed this time was roughly the same as the sliding snow and his traverse was not steep enough. He was pushed over again and was under the snow sliding headfirst on the bed surface. At this point he once more used the technique of digging into bed surface with his arms so that his skis caught the snow and spun him around. Standing up – now with only one ski – he made a steep straight run for the left flank and witnessed alders and small aspen trees popping up out of the snow as the full depth avalanche released the winter's snow load off of them. As the trees sprung upward he crashed into the trunk and branches of one and was held above the snow by the tree as he watched volumes of snow release from above and sympathetically on the adjacent slopes. The helicopter was pummeled by wind blast, and the slide left behind three piles of debris up to 5 m deep each.

This avalanche demonstrates the importance of doing everything you can to get toward the back and/or side of a moving avalanche. In this case, digging into the bed surface allowed the victim's skis to rotate under him so he could then stand up and use those skis to try to get toward the side of the avalanche. The point is to never say die and to keep fighting for a way out from the destructive force of the avalanche and the threat of burial. Relaxing and going with the flow would not have been a good option with this avalanche.

Case study 2. In November, 2007 a ski patroller from the Big Sky area attended a presentation on the self-rescue techniques presented in this paper. He was subsequently caught in an avalanche about 1 m deep and 125 m wide in January, 2008 while backcountry skiing in Montana's southern Madison Range. After being swept off his feet and losing one ski he could feel his other ski dragging him down. He vigorously kicked his remaining ski off, got rid of his poles, and started backstroking at a 45 degree angle. This was not working as well as he hoped, so he began log rolling and backstroking and managed to slowly work himself toward the back and side of the avalanche where he eventually managed to grab a small tree, allowing the rest of the debris to pass by. He lost all of his gear except for a ski and his backpack.

He sustained some relatively minor injuries (including a cut on his leg requiring 14 stitches) but, in his words, the “log roll technique definitely saved me from a longer ride”, and the survival strategies discussed in this paper “worked like a charm”.

This case study illustrates the importance of taking an active role in the avalanche. The gear being used by the victim was swept away and buried. However, the victim actively fought to stay toward the tail and the side of the avalanche and was not buried, nor was he carried up to the violent leading edge of the slide.

Case study 3. Glude (2008) describes being caught in a large (D3-4) avalanche. A skier uphill from him triggered the slide and he dug in prone on the slope as the avalanche approached at an estimated 40 m/s. Picked up by the slide, he received a first hand experience of the dynamics at the leading edge of the slide. Matching what we know about avalanche dynamics, during this part of the slide the rotational forces were so strong he had no opportunity to protect his airway or to even retract his outstretched arms. As the avalanche began to slow he could move again, and he waited until his head was toward the top of the rotation. At this point he gave two thrusts with his feet, which still had his snowboard attached. He felt these thrusts propel him upward in the snow an estimated 0.7 to 1 m each time, with the final time popping him out on the surface.

In this case, many of the strategies outlined in our paper would not be effective. The extreme rotational forces at the leading edge made movement or struggling impossible. However, once the slide slowed down enough to allow the victim to move, he improvised an effective strategy to help to push him up through the debris. He feels strongly that it was these motions, and not any inverse grading effect, that brought him to the surface. This case study illustrates the importance of continuing to actively struggle and improvise to increase the probability of your survival.

Our case studies match up well with our knowledge of avalanche dynamics, and they also help to illustrate that some of the techniques outlined in this paper are effective in some avalanches. One key component that is common throughout these case studies is that – when possible – the victims took an active role in the avalanche, fighting to get closer to the snow surface, to side of the slide, or to the tail of the avalanche.

5. 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. Our case studies demonstrate that 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.

Acknowledgements

We thank Bill Glude and Ben Anderson for providing detailed accounts of their avalanche experiences for us.

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