COLORADO GEOLOGICAL SURVEY

ROCK TALK

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AVALANCHE FORMATION AND RELEASE

Properties of Snow

Snow is a very interesting and complex substance. It is comprised of ice, water vapor, and sometimes water. Its physical and mechanical properties often show great variability over short distances and from one day to the next. There are two important reasons for this.

First, snow in nature exists close to its melting point (mostly in the range of -15 to 0°C), and this causes some interesting behavior. Snow is a visco-elastic material. This means it can behave viscously—more like a liquid than a solid, and does so especially near 0°C by slowly settling, densifying, creeping downhill, bending, or showing other modes of deformation. Or it can behave elastically—more like a solid than a liquid—by holding its shape rigidly under strain and storing strain energy until it cracks under too much strain.

The second cause of variation in the snow cover and its properties is the weather itself. The snow cover is easily affected by wind, sun, and temperature changes, so that the snow is different from one slope to another, from one elevation to another, and even from one side of a tree to the other. These differences can be both in physical properties such as depth, layering, density, and grain type and bonding, and in mechanical properties such as strength and tendency for either viscous deformation or elastic fracture.

Stress in the Snow Cover

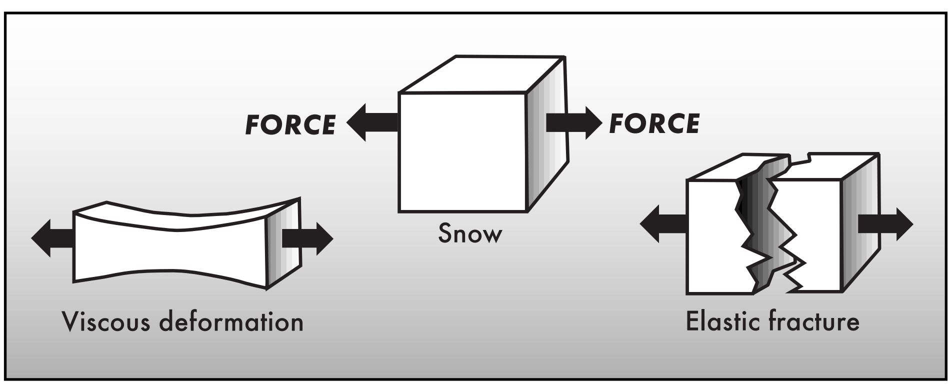
Gravity is always pulling snow downslope, causing it to deform and putting it under stress. Most of the time, however, the strength of the snow is enough to prevent avalanches. For an avalanche to release, stress must equal (and thereby nullify) strength in a layer of the snow layer. This happens when stress increases or when strength decreases. Increases in stress can be obvious, such as prolonged snowfall and blowing snow that add weight to the snow cover, or can be subtle, such as the downslope creep of a slab layer under warming temperatures. Decreases in strength can occur from metamorphism, which can turn a buried layer of snow into poorly-bonded faceted grains, or from thaw, in which melt water dissolves the bonds that gives the snowpack its strength.

Ingredients of a Slab Avalanche

In the October, 1998 issue of *Rock Talk*, an article titled “An Avalanche Primer” introduced the four ingredients of a slab avalanche. These are a slope, slab, weak layer, and trigger. Lets look at these ingredients in a little more detail.

SLOPE: Avalanche release is closely correlated to slope angle. Most avalanches occur on slopes of 30–45 degrees, because these are the angles where the balance between strength and stress is most critical. The adjacent graph shows the percent of avalanches

Continued on page 2



When force is applied, snow may deform and stretch in a viscous manner, or it may act like a solid and fracture.

INSIDE THIS ISSUE

Focus on Avalanches

Field Notes from the Director

The Colorado Statues recognize avalanches as a geologic hazard and C.R.S. 34-103(k) charges CGS to "promote safety by reducing the impact of avalanches on recreation, industry and transportation in the state through a program of forecasting and education conducted by the Colorado Avalanche Information Center." The CAIC mission statement repeats this legislative charge.

The goals are obvious: to reduce accidents and the number of people injured and killed and to keep Colorado's highways as avalanche-free as possible. But using accident statistics alone as a measure of success is not definitive. Winters vary in intensity, with varying numbers of avalanches and level of danger; we cannot know if we have successfully persuaded people to postpone backcountry trips during times of high danger and thus reduce accidents; and we cannot reduce the incidence of accidents for those who frequently take undue risks.

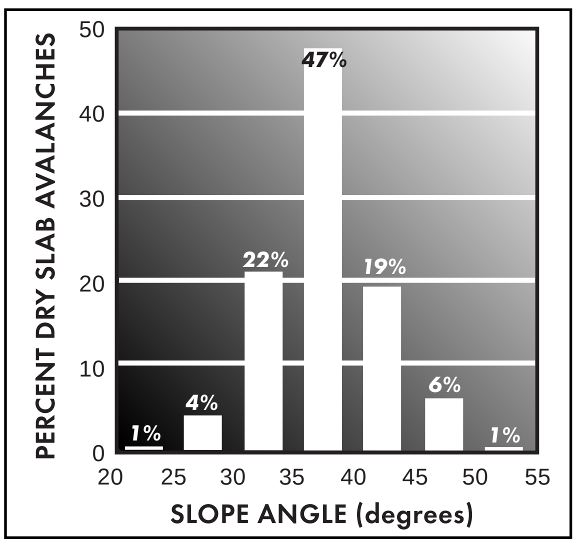
A declining fatality rate would be definitive. Avalanche deaths, however, have remained steady for a decade, at six per year. But backcountry use has increased several times during the

Continued on page 7

releasing at different slope angles (based on a sample of 200 avalanches): 47 percent release on slopes of 35–40 degrees, 88 percent on 30–45 degrees, and 98 percent on 25-50 degrees.

SLAB: A slab is a cohesive layer of snow that is under stress as gravity tries to pull it downslope. Cohesion is key, for that is the property that allows the snow layer to act as a block and to store strain energy as gravity tugs on it. The slab becomes the stuff of the avalanche once it releases. Without slab, all avalanches would be cohesionless point releases-mostly small and harmless avalanches, a circumstance that would make the Colorado Avalanche Information Center unnecessary.

Slab snow can vary greatly in feel and appearance. It can have a density less than 100 kg/m^3 (10 percent) and therefore be soft and fun to ski through, or it can have a density greater than 400 kg/m^3 (40 percent) and appear bulletproof, such that a ski edge barely cuts it. Slab by itself is not a dangerous condition: it all depends on what is underneath.



Percentage of avalanches vs. slope angle (from The Avalanche Handbook)

WEAK LAYER: For a slab to be dangerous, it must be sitting on a layer that may not hold the slab in place; in other words, a weak layer. Weak layers fail either by shear (slippage), such as any slick snow surface, or even the ground, that affords a poor bond to the slab layer and allows it to slip downslope; or by collapse, such as a layer of poorly-bonded snow grains that cannot support the weight of the slab. Once the weak layer fails, the slab is only anchored by snow bonds around its perimeter, especially at the top and sides. Tensile stress becomes critical at these points and often results in tensile failure, fracture and avalanche release.

Since slab is almost universally present, avalanche forecasters look for potential weak layers beneath the slab that will lead to a dangerous combination. They do this by digging snow pits (only in safe areas) and measuring the density, hardness, shear strength, and compressive strength of the various snow layers. These data help determine stability.

Weak layers have two origins: one, they were once a surface snow layer, such as a slick ice crust or a layer of feathery surface hoar, that became buried by the next storm's snow; or two, they form from metamorphism inside the snow cover that gradually erodes the strength of a layer, such as depth hoar.

TRIGGER: A trigger is the additional load of new snow, falling cornice, animal, person, or explosive charge that releases the avalanche. The trigger starts a rapid domino effect: it tips the balance of stress over strength, which causes the weak layer to fail, which increases tensile stress in the slab, which causes tensile cracks to shoot through the slab, which breaks all the anchors, which sets the avalanche in motion.

The size of the trigger is intimately related to avalanche stability. The more unstable the snow, the smaller the trigger required. Snow that is unconditionally unstable requires no external trigger: It avalanches from natural forces, and is thus called a natural avalanche. Snow that is conditionally unstable requires an external trigger applied to a vulnerable spot in the slab. Again, depending on the degree of instability, a single person may be an adequate trigger, while slightly more stable snow might require a snowmobile or five people skiing. Avalanche control teams sometimes take out all the guesswork by using very large explosives (more than 10 kg of TNT) to release avalanches on otherwise strong slopes. Snow that is unconditionally stable will resist even the largest of triggers (except perhaps earthquakes) and remain on the mountainside.

Slab Avalanche Release

Avalanches release when the unstable snow cover—comprised of a slab layer on top of a weak layer—is stressed to the point that it can no longer hold itself in place and it fails. This may happen almost instantaneously, or it may happen in a progressive failure of one small area at a time, with minutes to hours passing before release. A tug-of-war analogy is useful in understanding how this might happen.

A weak layer-buried surface hoar

–PHOTO FROM SP 48

In unstable snow, stresses are approaching the strength of the weakest layers. Because of, say, load from new snow or from a skier, the stress at a point may become equal to the strength, and the snow will fail at that point, meaning that the strength goes to zero. It is as though a member of your tug-of-war team lets go of the rope. If the rest of your team is strong enough, they can hold the rope and they haven't yet lost. But if they are not strong enough, the team will fail, either at once or in a chain reaction of one member at a time. In the snow cover, there may be enough overall strength to compensate for failure at one point, and the avalanche will not release—though there may be local movement or collapse. But if the surrounding snow is not strong enough, the area of snow next to the initial failure point fails, followed by another area, and so on until a large enough area of the slab has broken loose from its underpinnings. Tensile cracks then shoot through the slab, releasing elastic energy, which drives the cracks even further. The result can be an avalanche that releases a slab area a thousand or more times larger than the original failure area. Indeed, an unstable snowpack is like a house of cards, in which a tiny failure leads to a great catastrophe. –Knox Williams

Blocks of snow showing released tension in a slab avalanche

AVALANCHE HOTLINES

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FORECASTING FOR COLORADO'S HIGHWAYS

The task of keeping our mountain highways clear throughout the winter is daunting enough, even without avalanches roaring down from above. That's why the Colorado Department of Transportation (CDOT) and the Colorado Avalanche Information Center (CAIC) teamed up to keep road closures to a minimum and make the highways safer for winter travel.

The CAIC acts in an advisory capacity by issuing avalanche forecasts and, when necessary, making recommendations for avalanche control missions. CDOT makes the final decision on what action to take, as we'll see in an example below.

The avalanche threat to transportation is nothing new. In the early mining days avalanches clogged narrow mountain roads, causing delays and creating a general nuisance for those charged with keeping the thoroughfares open. And yes, accidents occurred. Today avalanches still cause delays and accidents still occur, but we are facing the problem differently — head-on and aggressively. Let's take a closer look at how the program evolved and what the job entails.

A Brief History

Since the 1950s, avalanches on Colorado's highways have caught numerous vehicles, injured several people and killed seven. While CDOT had dealt with the problem by implementing road closures and using explosives, it wanted to take a more formal approach based on "scientific" avalanche forecasting.

In 1992, CDOT approached the CAIC and asked if we would join them in the battle against avalanches. Up to the challenge, we readily accepted. Funding was provided for avalanche forecasters, remote weather instrumentation and other equipment, and the development of a formal avalanche safety program for plow drivers.

A pilot program began in Silverton for the 1992–93 winter. Following a successful first season, the Pagosa Springs and Eisenhower Tunnel forecast offices were set up. In 1994 a fourth office was created in Carbondale to complete the network. Today, six forecasters closely monitor some 450 avalanche areas that threaten Colorado's mountain highways.

The Forecaster's Role

It's a big responsibility. How do they do it? Avalanche forecasting can appear to be as much art as it is science. While technology offers valuable tools (instruments, computers) these only help so much. The forecaster must be skilled, knowledgeable and experienced. Here are a few highlights from the forecaster's list of duties:

- **Gather the latest data** from remote weather instruments, several snow study plots, nightshift plow driver input, and the updated weather forecast from the CAIC headquarters in Boulder.
- **Monitor daily weather patterns** to determine adverse effects on snowpack stability.
- **Monitor the snowpack** by digging snowpits and performing tests that help verify snowpack stability.
- **Provide twice-daily avalanche forecasts** via fax, and e-mail to multiple CDOT offices.
- **Make recommendations** for road closures or avalanche control work when necessary.
- **Participate in CDOT avalanche control missions** to observe results and assist as necessary.
- **Maintain daily logs** of weather data, avalanche events and other observations.
- **Provide avalanche safety and rescue training** to CDOT personnel, AND ...
- **Be available** for callout day or night to respond to any avalanche situation.

Case Study of a Storm Event

Here is a typical forecasting example with excerpts from the report by Mark Mueller, CAIC forecaster for Wolf Creek Pass.

The situation: "A much anticipated storm cycle began at Wolf Creek Pass on 2/9/00, and continued through 2/14/00. Snowfall during this period was measured at only 15 in., but this fell on a shallow, fragile snowpack. Aided by moderate winds, drifted accumulations were observed to be two to three times the measured amount."

The thinking: "Snowpack stability tests, both before and early in the storm, indicated avalanches were likely. Fortunately, mild winter weather had left most highway avalanche paths without sufficient snowpack to support avalanche flows to the highway."

The action taken: "Nevertheless, I recommended avalanche control to test the stability of the snowpack with its new stress overburden, and to eliminate avalanche problems where instability might exist."

The results: "Avalanche control by the CDOT Avalanche Control Team on the west side of Wolf Creek and by Wolf Creek Ski Area personnel at the Alberta slide on 2/14/00 released two medium-sized avalanches into the fragile basal layers. Four small avalanches involving only new snow accumulations were also released during control. No avalanches reached or came close to the highway." Mark also added, "...the control mission confirmed the analysis of the evolution of this winter's snowpack made by gathering data at study sites and interpolating to nearby avalanche paths."

Program Success

This year will be the ninth winter for the alliance between CAIC and CDOT. We believe it has been very successful as evidenced by the following statistics. In the 1970s, 64 people were involved in highway-related avalanches, 53 people in the 1980s, and only 24 in the 1990s. And this is with much-increased traffic over the years. People in nearby communities have also expressed satisfaction with shorter road closures.

—Nick Logan

HOW TECHNOLOGY IS HELPING AVALANCHE FORECASTERS

Technology has been a boon to all scientific fields, but for the avalanche forecaster, technology has provided only marginal results. A 1990 National Research Council Report on avalanches defined avalanche forecasting as "an art based on experience, intuition, and processed-oriented reasoning that is difficult to learn, teach and transfer to different regions." In recent decades forecasters have tried using various computer-based statistical and dynamical models, but these computer forecasts performed no better—and usually worse—than an experienced forecaster using intuitive or conventional methods.

The problem, as avalanche scholar Colin Fraser wrote more than 30 years ago, is that "avalanches are notoriously unwilling to follow expected rules of behavior." While technology has fallen short in providing an answer to "What will slide today?", forecasters are using new technologies as tools for more accurate forecasts. Today forecasters at the Colorado Avalanche Information Center are embracing new technologies to gather weather and snow pack data and disseminating forecasts to a growing and needing audience. These include:

Automated Weather Data Collection

The Center has established a network of remote, high-elevation weather stations near the summits of Red Mountain, Lizard Head, Wolf Creek, Loveland, Berthoud and McClure passes. In addition to these stations the Center has access to similar stations located at several ski areas. The stations can provide the forecasters real-time data any time of day or night.

Nick Logan and Cathy Fraser at weather station on Loveland Pass

This allows forecasters to detect changes in weather conditions in a timely manner that might worsen avalanche conditions.

Geographic Information Systems

The cliché "a picture is worth a thousand words" rings true with GIS, and the Center is just starting to tap the potential for GIS to assist avalanche forecasters. Currently, the Center uses GIS to map avalanche paths affecting state highways. This winter the Center plans to use GIS to display their avalanche danger ratings visually on its web site, and in the near future the Center hopes to use GIS to display avalanche occurrences, snow-drifting patterns and even the output from a Nearest Neighbors program.

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continued on p. 11

Nearest Neighbors Model

This winter to help forecasting along Colorado's highways, the Center will implement a nearest-neighbors computer model. This method assumes that for given weather and snow conditions, avalanche activity will be similar. By querying weather and avalanche occurrence databases this model will provide forecasters with a list of avalanches that occurred on the 10 days in the past 30 years most similar (nearest neighbors) to the day being considered. The method will aid forecasters by identifying similar conditions in previous years and providing a list of avalanche occurrences.

Snowpro

Digging holes in the snow and examining the snowpack stratigraphy can reveal vast amounts of information regarding the strength and weakness of the snow, but communicating these findings have never been easy. Deciphering an observer's notes sometimes leads to confusion or even wrong conclusions. Snowpro, a Canadian software program, standardizes snowpit data and displays it visually in an easy to use format. This year the Center's staff and contracted observers will be using the software to submit snow pit reports. This will ensure the right information is easily and readily available.

Internet (World Wide Web and E-mail)

In the past few years the Internet has provided forecasters and the Center's users with the opportunity to exchange data and disseminate forecasts like never before. The potential is limitless. Soon new software will allow forecasters to collect, display and interpret vast amounts of data faster than ever before. The Internet will be the avenue to collect and disseminate real-time data on wind, snowfall, temperature, snowpack, and avalanches to our users, such as ski areas, CDOT, and the public. The Center's forecast and real-time data will make every user a better decision-maker.

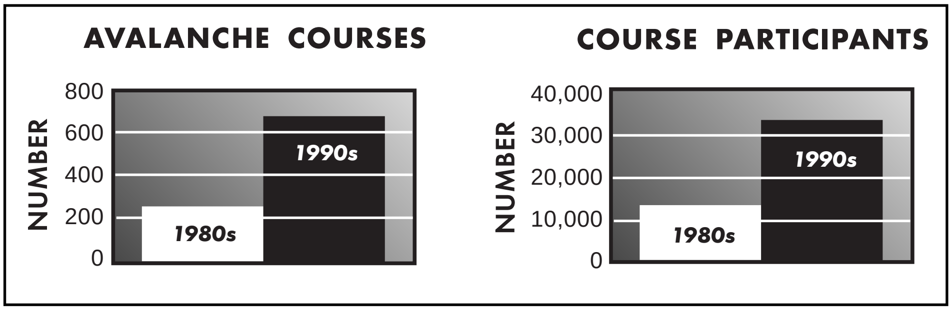
Today forecasters at the Colorado Avalanche Information Center are combining new technologies to produce more accurate and timely forecasts. When united with time-tested conventional forecast methods, new technologies produce a synergistic effect on avalanche forecasting that will go a long ways in saving lives and protecting property in this nation's most avalanche-prone state.

—Dale Atkins

AVALANCHE TRAINING SAVES LIVES

In contrast with the rest of the United States, the average number of avalanche fatalities in Colorado has increased only slightly in recent years. This is notable in the light of our greatly increased backcountry use. In the 1980s Colorado averaged five fatalities per year. In the 1990s the average was six, an increase of 20 percent. In comparison, the average for the U.S. was 14 fatalities in the 1980s and 23 fatalities in the 1990s, a sharp increase of 64 percent.

Colorado's avalanche training was expanding at the same time. In the 1980s the CAIC conducted 256 courses that reached 12,967 people. In the 1990s that jumped to 683 courses in which 32,409 people benefited. These are increases of 167 percent and 150 percent, respectively. We believe avalanche education is key in keeping Colorado's statistics down. The charts above compare the number of courses and participants in both decades.



Growth in the CAIC's education outreach by decade

Both physical and human factors are involved in an avalanche accident. We teach people how to recognize both and how to make sound decisions accordingly when traveling in the backcountry. Here are some examples of how this is done.

Teaching Physical Causes

The four ingredients of an avalanche are a steep slope, a slab, a weak layer and a trigger. We teach the students how the physical causes of avalanches, which include weather, snowpack, and terrain, interact to form the ingredients of an avalanche.

Teaching Human Causes

Even when the physical dangers are obvious, prudent decision-making can be overshadowed by adverse human factors. Among these are attitude (anti-authority, invulnerability, impulsivity, etc.), poor communication, over confidence, complacency, fatigue and stress. Therefore, the CAIC incorporates the human aspect into avalanche training.

Using Scenarios to Teach Decision-Making Skills

Interactive scenarios are effective in teaching people to "think avalanche" and interact in a typical backcountry situation. In one example, the class is divided into small workgroups for the "Dilemma Pass" scenario in which some backcountry travelers find themselves at the base of a pass near the end of an all-day, one-way tour. Darkness is approaching and they must make a decision: turn back, stay put for the night, or continue over the pass to meet a friend waiting for them at the trailhead. Each group may ask questions about the terrain, weather or snowpack to help them make their decision. They then have 15 minutes to discuss the situation, come up with an answer and explain what they are going to do and why. There is really no right answer but the exercise teaches people two things. First, how group dynamics can influence decision-making, and second, what the most important factors are to consider when making such a decision. Getting classroom experience on this level is a positive step toward developing safe field skills. The CAIC uses backcountry, highway and ski patrol scenarios to enhance the different types of courses.

Conclusion

Is avalanche awareness training beneficial? The statistics shown earlier speak for themselves. There are other positive indicators too. I received a call at the Avalanche Center one day from someone reporting an avalanche: "We thought the slope could slide so we decided to ski down one-at-a-time like we learned in your course. It's a good thing we did. The second skier triggered an avalanche but he was the only guy caught and the rest of us were able to get him out." Another instance occurred last winter on Red Mountain Pass. A group of people had just completed the Silverton Avalanche School and avalanche safety was fresh in their minds. On a day tour, they worked their way to the top of a steep slope they thought would make a great run down only to turn around when they got there. "Something just

Field Notes continued from page 2

decade, so that a death rate that is not rising can be viewed as a positive statistic. There is, however, another way we can show positive progress in attaining our mission, and that is by the growing number of people who use our services. For example, there has been dramatic growth in the number of people receiving CAIC daily forecasts via hotlines, e-mail, and web site: 160,000 in 1997–98, 212,000 in 1998-99, and 356,000 in 1999–2000. In education, approximately 28,000 people have attended our avalanche talks and seminars in the last eight years. The majority of these are the public seeking avalanche awareness, but CAIC serves others as well. For example, in 1999–2000 CAIC avalanche experts gave 22 talks to CDOT maintenance personnel, providing them with valuable knowledge to improve their safety while on the job.

We believe that with timely, accurate forecasts of avalanche danger and a growing population of avalanche-aware recreationists our mission of improved avalanche safety is being fulfilled.

didn't seem right. From our observations we thought the slope could avalanche so we changed our plan and took a different route." The next morning a large, natural avalanche released on the slope they almost skied. Proper training and good decision-making averted this group from sure tragedy. These are the stories that make an avalanche forecaster/educator feel good. —Nick Logan

How Rescue Technology Is Saving Lives

Every winter avalanches claim about 26 lives in the United States. In Colorado, on average, six die. Most buried avalanche victims die from suffocation, and time is their enemy. If found in the first 15 minutes almost 9 in 10 buried victims will survive; however, the cruel reality is that most rescues take much longer than one-quarter hour. Using conventional rescue equipment it is not easy or fast to search an avalanche area that typically might be a football field in size. Survival statistics tell a grim tale: After a 30-minute burial, only half of the victims survive; and by 45 minutes, survival plummets to one-in-four. Survival does not favor the buried victim; however, in the past several years three new technologies have been developed that will help people be found faster, live longer under the snow, or even prevent burial.

Digital avalanche rescue transceiver (beacon)—PHOTO FROM BACKCOUNTRY ACCESS

Digital Avalanche Rescue Transceivers (aka Beacons)

The conventional analog transceiver was developed as a personal rescue device in the late 1960s and changed very little during the next three decades. A little larger than a deck of cards, the transceiver transmits a signal that companions receive on their own units. The closer the buried unit, the louder the signal, but these beacons are not directional. Therefore, a search pattern using right-angle brackets was the only method guaranteed to zero in on the buried unit. To become fast required lots of practice.

Everything changed in 1997 with the development of digital transceivers, which use a computer chip to capture the signal and present the information in a user-friendly format. The biggest improvement has been the addition of distance displays and directional arrows that help steer the user to the buried unit. Also these new units use changes in tone and/or frequency of beeps (rather than louder volume) to alert searchers that they are getting closer. Experience has shown the new beacons to be significantly faster and easier to use than conventional transceivers.

AvaLung™

Snow is mostly air; even the heaviest avalanche debris is still 40 percent air. But for the buried victim it is difficult to draw the air out of the snow, and even more troubling is that victim must re-breathe exhaled CO_2 causing asphyxia. In concentrations slightly higher than found in ambient air, CO_2 can quickly become deadly.

With technology developed by a Denver doctor, the AvaLung™ became available in 1999 and can prolong survival time. The AvaLung™ is a device built into a vest. A flexible plastic mouthpiece is located near the garment's collar. If caught in an avalanche the user must insert the mouthpiece and breathe through it. A membrane (AvaLung™ System) built into the front of the vest makes possible the inhalation of air from the surrounding snow and exhalation to the rear of the vest. The separation of inhaled from exhaled air leads to the ingenious trick of avoiding asphyxia by preventing the buildup of deadly CO_2 in the

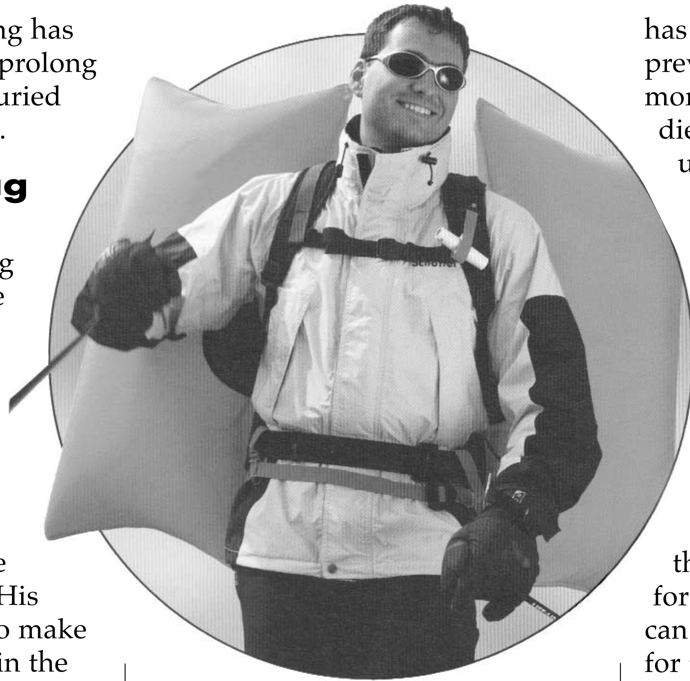

Dale Atkins wearing the AvaLung™

inhaled air. Extensive testing has shown the AvaLung™ can prolong survival time of a totally buried person by 15 to 60 minutes.

Avalanche Airbag System

Perhaps the most promising avalanche rescue tool is the Avalanche Airbag System (ABS), because it can prevent burial. A German forester first conceived of the product in the 1970s when he noticed larger trees stayed on the surface of avalanches while smaller trees were buried. His idea was to use a balloon to make a person the largest object in the avalanche, so that the flowing snow would force the person to the top. The same principle can be applied to a bowl of mixed nuts. Shake the bowl and the larger nuts (like whole cashews) rise to the top. This principle of inverse segregation is sound and well known in particle flow dynamics and is also at work in avalanches.

It has only been in the last few years that another German entrepreneur developed a practical airbag that can and does save lives. Integrated into a backpack, the ABS uses two 75-liter airbags that are inflated in two seconds when the user pulls a small handle on the pack's shoulder strap. Extensive testing by the Swiss Federal Institute of Snow and Avalanches has found the ABS to work well at preventing most burials. Furthermore until last spring no one had died in more than 35 documented uses. However, no device is perfect: This spring a user died when he was buried by a second wave of snow. The ABS is now available in Europe and Canada and will likely be available in the U.S. by 2002.



Avalanche Airbag System—PHOTO BY ABS

These new rescue technologies are promising to those who work and play in avalanche country. However, there is a serious caveat. If used for the right reasons, technology can and will save lives, but if used for the wrong reasons, technology can create an illusion of safety that will lead to riskier actions, perhaps ending in death. New technology thus poses a unique challenge to the education efforts of the Colorado Avalanche Information Center. The Center advocates good judgment that should not be compromised by tools, tricks or techniques. The wise carry all the devices that can save a life, but they travel and make decisions as if they left their devices at home.

—Dale Atkins

A DAY IN THE LIFE OF AN AVALANCHE FORECASTER

Somewhere in the distance a telephone rings. It is very faint and I wonder why no one is answering. Suddenly something that sounds remarkably like an air raid siren bolts me out of a deep and short-lived sleep. It is my number two alarm and it is 2:05 am Monday. My next two-day shift at the Colorado Avalanche Center is set to begin in 2.5 hours. However, I need to get out of bed, sweep 6 in. of new snow off the deck, restock the fireplace and fix a cup of tea before the 1.5 hour drive from Breckenridge to Boulder.

Dale's (Atkins) weather forecast from yesterday looks to be right on for the Summit County area. He had called for 4–8 in. of new snow, and with 4 more hours till sunrise it looks like the high end of his forecast was going to materialize. In Breckenridge there is no wind, but on my drive back from the Telluride Avalanche School just 6 hours earlier there had been significant snow drifting on Vail Pass. It was beginning to look like a busy two days in Boulder.

Driving over Loveland Pass I stop at the summit for a quick reconnoiter of the wind, temperature and snow. This little habit gets me warmed up for the two-day shift and gives me a last-minute, first-hand view of current avalanche conditions before I settle into the office for the next two days. Once there I will use the computer—my best friend—to check the data from our remote weather station on Loveland Pass to confirm my personal weather observation.

After a quick stop at King Soopers I arrive at the CAIC office in the David Skaggs Research Building. One good thing about getting to work at 4:30 am is that you always get the prime front row parking spot.

Each of our four forecasters has their own routine. I prefer to get to the office about 4:30 so I can ease into the day. The official CAIC start time is 5 am. Some days that's fine, but with today's new snow and wind there are many decisions to make in the next hour and a half, one of which will be the call on an avalanche warning. There were no avalanche warnings in place yesterday so the first thing I do is check the Hazard and Decision Chart that Dale completed yesterday to get an idea of what he was thinking.

At the same time I can tell if it will be a crazy day just by checking the answering machine. If there are more than a half dozen messages you hit the floor running. Today there are only three, so the day begins at a jog.

Colorado is a big state, and I need to analyze data from all areas. For the last five days, I had been able to check the snowpack at a few areas around the state. On my way to the Telluride Avalanche School this last weekend, Halsted Morris, Denny Hogan and I had taught a two-day avalanche seminar in the Flat Tops for the local snowmobile club from Rifle. We found a very pronounced surface hoar layer a foot down in the snowpack. This layer provided very dramatic results for our students while we performed our stability tests on the snowpack. It looked like all that was needed to get a good avalanche cycle going was about a foot of new snow with some good wind. In Telluride the surface hoar layer had been less pronounced but still insidious.

The information from my trip through the central and southern mountains of Colorado, plus the 6 in. of new snow on the deck when I left Breckenridge, would be added to Dale's notes from the previous day to help formulate today's avalanche danger rating.

After checking phone, fax and e-mail for more data, I dial up our remote weather stations to download the overnight numbers. Next I move out to the National Weather Service (NWS) work station to pull up even more weather data. The first weather and avalanche forecast is due in 1 hour and 15 minutes. It is time to rock and roll.

Scott Toepfer writes the forecast on the computer while Nick Logan checks his spelling

The data from the NWS computers are a big part of my weather and avalanche forecast for the next 24–36 hours. This forecast will go first to ski patrols and the CAIC's team of highway forecasters at four mountain offices. It does not look good from an avalanche safety standpoint. Dale felt this storm could bring us to our second avalanche warning of the year, and it looks like his forecast was pretty much right on the money. A series of storms are lined up into the Pacific Ocean, all looking to track right into Colorado and worsen an already tender situation.

Once I have my weather data I head back into the CAIC office to write my forecast on the computer. My deadline for this initial forecast is a 6 am release via e-mail and fax. It is now 5:40 am. In the next 15 minutes Kevin Heineken from Aspen Highlands and John Brennan from Snowmass send in their weather reports, and this gives me a clearer picture of winds and the water content of the new snow in the Aspen area—more vital information in building my avalanche forecast. Already I am leaning towards an avalanche warning for the Elk Mountains around Aspen, but I don't have to make that decision just now.

The storm that brought 6 in. to Summit County has been hitting the Elk Mountains with much greater force. Doug Bitterman, one of CAIC's eight backcountry observers, reports 12 in. of new snow in Ashcroft just outside Aspen. Doug runs the Ashcroft Touring Center and when it snows he starts grooming trails about the same time I arrive at the Boulder office. Doug reports that he will keep the upper trails closed due to the threat of avalanches. On the walk out to his snowcat at 4 am he heard what sounded like a large avalanche up the valley from his house.

It's 6 am and out goes the first forecast to the ski industry and our highway forecasters. It mentions that a warning looks likely for the central mountains. But there is no time to rest. I check phone messages for new data and rework the forecast for public use. This second forecast will go onto our five public hotlines, to our Friends of the CAIC by e-mail, to several fax destinations, to a couple of radio stations, and onto our web site. In the next hour I read the forecast six times onto the hotline phones and a live radio feed, customizing the wording for the area of coverage of each hotline.

All that talking gets me pretty dry in the throat so it is time for lunch; after all it's 8 am and I've been running hard for 3.5 hours. I suddenly feel the weight of responsibility and realize I had better be right. This morning thousands of people will read my forecast from their e-mail or our web site, or will hear my voice over the hotlines or radio. Many will plan their day on what I have said. My experience—and the data—tell me I am right.

After my break I head back into the office to look at all the incoming data that has arrived over the last several hours. I also load visible satellite imagery, upper air data, and other current information onto the NWS work stations for quick reference as I make the decision to issue an avalanche warning for the central mountains. All the data points to an active avalanche cycle for the next 24 hours, at least.

The incoming data from our observers must be written into our log book, so after getting caught up on that, I write the avalanche warning. This will go out on the NWS weather wire and is available to all media outlets. I will also put it on our web site. By 11 am I have issued the avalanche warning and start to answer calls from several news reporters, ski patrollers and our highway forecasters.

Sometime after 11 am the new weather models begin to filter into the NWS work stations, so it is time to start putting together the afternoon update. This forecast is specifically tailored for our four highway forecast crews. These guys are out in the snow and do their own avalanche forecasting for specific highway corridors, but they use our weather forecasts to help come to an avalanche danger rating for each mountain pass.

I get this forecast out at 2 pm and then immediately begin reworking it into a backcountry

Publications continued from page 6

Miscellaneous Investigation 56
The Snow Booklet: A Guide to the Science, Climatology and Measurements of Snow in the United States $15.00

Special Publication 7
Colorado Avalanche Area Studies and Guidelines for Avalanche-Hazard Planning $8.00

Special Publication 39
The Snowy Torrents: Avalanche Accidents in the U.S., 1980–86 $16.00

Special Publication 48
Avalanche Wise: Your Guide to Avalanche Safety in Colorado $2.50

Upcoming Events Involving CGS

October 8–14
Earth Science Week, free public field trips, Vince Matthews, (303) 866-3028

February 26–28
Society for Mining, Metallurgy, and Exploration (SME) Annual Meeting, exhibit, participants, Jim Cappa, (303) 866-3293

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THIS ISSUE
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AWARD

Dale Atkins, CAIC avalanche forecaster, was recognized for **"Outstanding contribution to Mountain Safety Education"** by the Mountain Rescue Association in June in Nordegg, Alberta, Canada.

forecast for our afternoon Friends of the CAIC e-mail update. I scan the log book for fresh avalanche reports, write this into the stability discussion, and then zap it electronically to 350 Friends who subscribe to this bonus service.

It is now 2:45 pm, my energy is sagging, so it's time for a quick snack. After a little brain food, I rewrite the afternoon avalanche warning, adding snowfall numbers and an avalanche count for the day. Several avalanche technicians from the Aspen ski areas, from Crested Butte, and from the Summit County areas have called this afternoon with results from control work and from natural releases in the backcountry. The avalanche warning for the Elk Range has been verified with over 100 avalanches being reported. This information goes into my warning bulletin, which I send out a few minutes after 4 pm and which extends the warning into Tuesday.

It's been a long a day and it's still not over. Now I turn to the Hazard and Decision Chart. This is a summary of everything that happened today, and step by step I fill out the page with the important data that dictated my decision-making. And still the phone keeps ringing.

Several highway forecasters and patrollers from the southern and northern mountain areas are getting excited as the storm intensifies; we may be on our way to a statewide avalanche warning. But that is a problem for tomorrow's forecast. It's almost 5:30 pm and I will be back Tuesday morning at 4:30. But first I think I deserve a cold beer and a big dinner.

–Scott Toepfer

FAREWELL KATIE!

Katie KellerLynn, former Outreach Coordinator for CGS, giving her final Outreach presentation in Rocky Mountain National Park to summer students working in various agencies as part of the Youth in Natural Resources program. We wish Katie success in her new career with the Geological Society of America.

Colorado Science and Engineering Fair Winners

The Colorado Geological Survey is proud to announce the winners of the Junior and Senior "Best Earth Science Project" at the 45th Annual Colorado Science and Engineering Fair. **EMILY ROSA** from Liberty Common School in Loveland was selected in the Junior Division for her project "Geodesy-Measuring the Earth with Original Instruments." **EVAN BURGESS** of Fairview High School in Boulder was selected in the Senior Division for his project "Predicting Avalanche Risk."

ROCKTALK

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