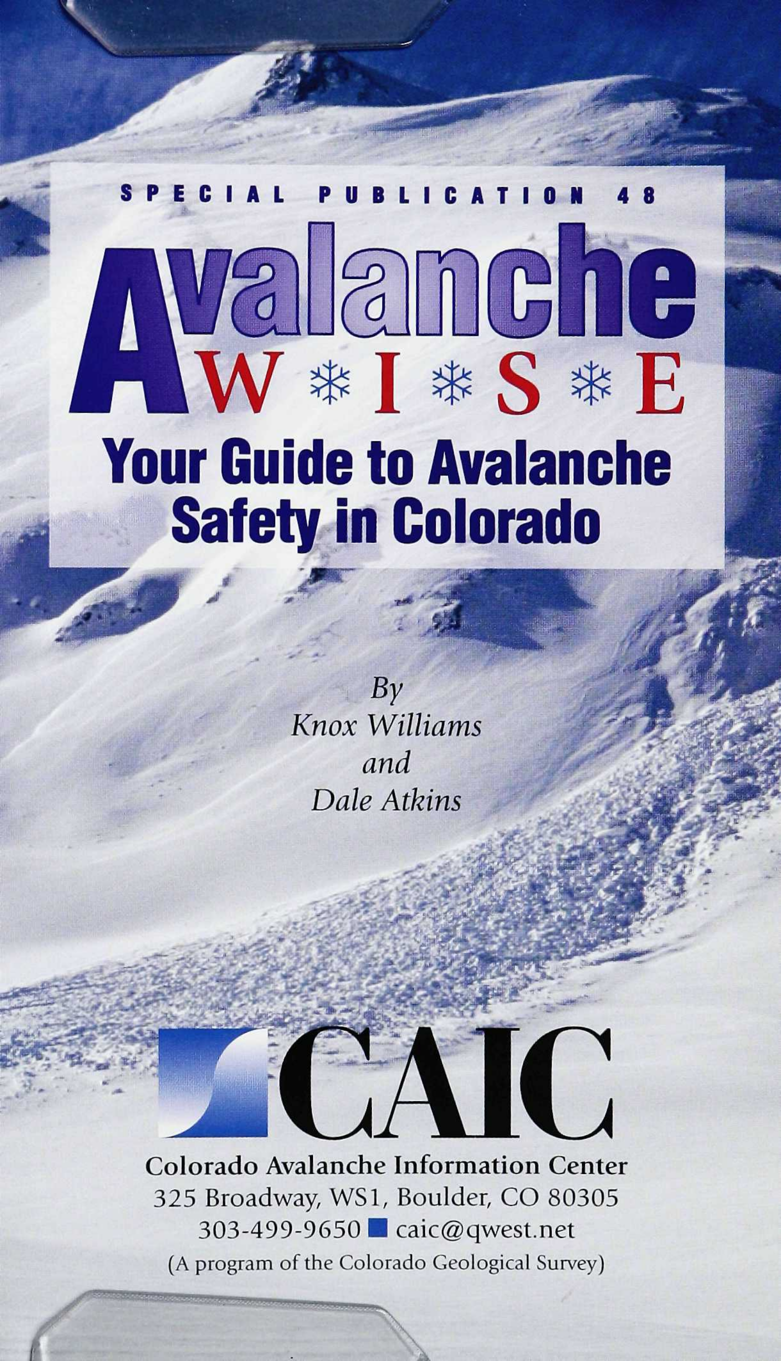


SPECIAL PUBLICATION 48

Avalanche WISE

Your Guide to Avalanche Safety in Colorado

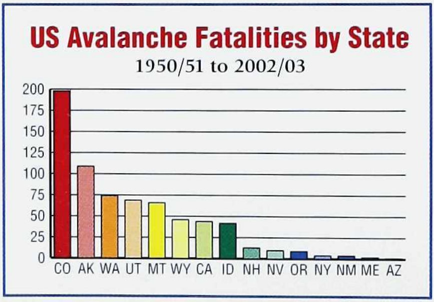
By
Knox Williams
and
Dale Atkins

CAIC
Colorado Avalanche Information Center
325 Broadway, WS1, Boulder, CO 80305
303-499-9650 ■ caic@qwest.net
(A program of the Colorado Geological Survey)

What's Special about Colorado Avalanches?

Nowhere else in the United States are avalanches more deadly than in Colorado. The reason can be found in the Colorado snowpack. Located furthest from the oceans, the Colorado mountains usually have a shallower and colder snowpack than other western states. And in cold, shallow snowpacks there are physical processes at work making them more avalanche prone (see Snowpack Factors). The mountains west of Colorado (e.g., Utah's Wasatch, California's Sierras, and Washington's Cascades) see numerous and large avalanches during storms but few avalanches between storms. That's because the deep, dense snowpack becomes very strong after storms end. That is not true in Colorado, where the cold, shallow snowpack is much slower to gain strength, and can sometimes lose strength, in the clear weather between storms.

Each winter in Colorado, avalanches catch 100 or more unsuspecting victims. Of these, about six will suffer serious injury and six will die. The avalanche doesn't care if you are an expert or novice: athletic skills won't help you. The way to fight back is with knowledge and snow skills. This booklet will keep you avalanche wise in Colorado.



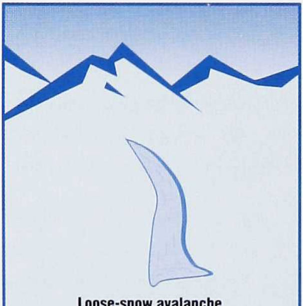
Contents

Avalanches

An avalanche is a mass of snow sliding down a mountainside. It is estimated that 20,000 avalanches—also called snowslides—fall every winter in the Colorado mountains. They come in all sizes. Small avalanches may fracture 1–2 feet deep and 50–100 feet wide, and travel at 30 mph; medium avalanches may break 3–6 feet deep and 200–500 feet wide, and move at 50–60 mph; large avalanches can be 6–10 feet deep, thousands of feet wide, and roar along at more than 100 mph.

Types

There are two types of avalanches: loose-snow and slab.



Loose-snow avalanche

Loose-snow avalanches occur in a snow cover that lacks cohesion, such as freshly fallen snow that has not bonded or wet snow that has lost its cohesion because of thaw. Also called point-releases, loose-snow avalanches start at a point and fan out as the mass of loose grains slides downhill. Though numerous, they are usually small in size and seldom cause injury or damage.

Slab avalanche

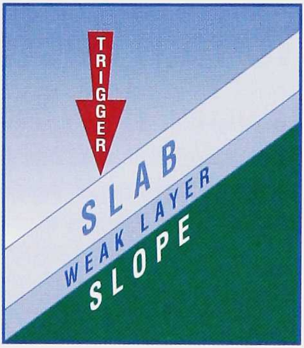
Slab avalanches occur when the snow cover has bonded into a cohesive slab layer. The slab can hold itself in place until the downhill stress exceeds its strength. When a slab fails under too much stress, cracks shoot through the slab and it breaks loose from its final anchors at the top, sides and bottom. Slab avalanches are very dangerous because they can move large amounts of snow at great speed. Almost all harmful avalanches are slab avalanches, but they need not be large to be dangerous: even small avalanches can be killers.

Both loose-snow and slab avalanches can release in dry, damp, or wet snow covers.

Ingredients

There are four *ingredients* of a slab avalanche:

- a steep slope
- a slab
- a weak layer
- a trigger



When these ingredients are present, avalanches are possible, if not likely. A *slope* must be steep enough to create a tenuous balance between stress and strength, and that almost always means slopes of 25–50 degrees. A *slab* is the stuff of the avalanche. A *weak layer* must lie underneath the slab and be prone to collapse or slippage (shear failure). A *trigger* is the additional load of new snow, falling cornice, animal, person, or explosion that tips the balance of stress over strength.

A *natural avalanche* releases spontaneously without an external trigger. For this to occur, stress must increase from natural load such as falling or blowing snow, or strength must decrease from internal changes (e.g., snow metamorphism or increased creep), or both. An *artificially triggered avalanche* releases from the added stress of an external trigger, and the more unstable the snow, the smaller the trigger required.

Two facts about triggers warrant extra emphasis:

- Most avalanche victims trigger their own avalanche.
- Slab avalanches can be triggered from gentle—or even flat—slopes that lie to the side or below steep slopes.

When trying to make predictions, it is helpful to look at three factors that can put the necessary ingredients in place: *terrain, weather, and snowpack*. Let's look closer at these factors.

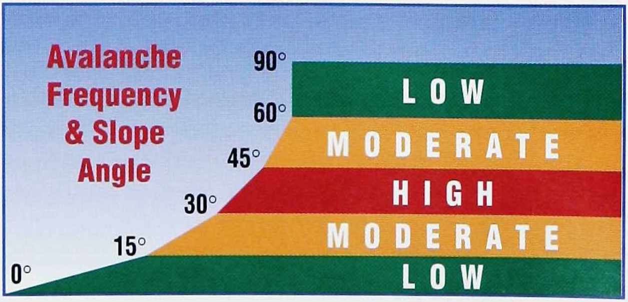
Terrain Factors

"Can the Terrain Cause an Avalanche?"

You can reliably avoid avalanches by avoiding avalanche terrain. Slope angle, aspect, anchors, and elevation are the terrain elements that can cause avalanches.

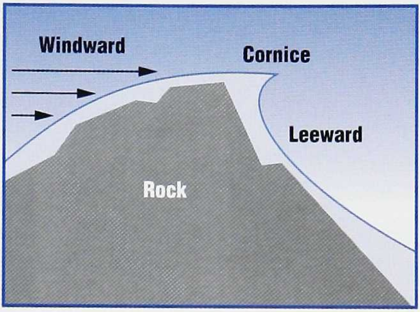
Slope Angle

Steepness is the most important terrain factor leading to avalanches because as angle increases, so does the stress acting on the snowpack. Most avalanches (about 90%) release on slopes of 30–45°.



Aspect

How a slope faces relative to the wind and sun is also important. Slopes facing away from the wind—leeward slopes—produce more avalanches than windward slopes. Wind strips snow from windward slopes and deposits it as a slab layer on leeward slopes.



Slopes facing away from the sun (north aspects) have a deeper and colder (weaker) snowpack that is more apt to cause avalanches than south aspects. However, slopes facing the sun (south aspects) can be more prone to wet avalanches during periods of thaw, and can produce dry avalanches when loaded by a north wind.

Anchors

Bushes, trees, or rocks tend to anchor the snow but do not necessarily prevent avalanches. Once started, though, avalanches can easily flow through trees and rocks.

Elevation

Avalanches can start at any elevation, if the necessary ingredients are present. But higher elevations, especially above timberline, are more favorable for avalanche formation. Heavier snowfall (more load), stronger winds (more slab buildup on leeward slopes), colder temperatures (weaker snow), and fewer anchors above timberline create a favorable terrain environment for avalanches.

Weather Factors

"Is the Weather Making the Snow Unstable?"

Snowfall

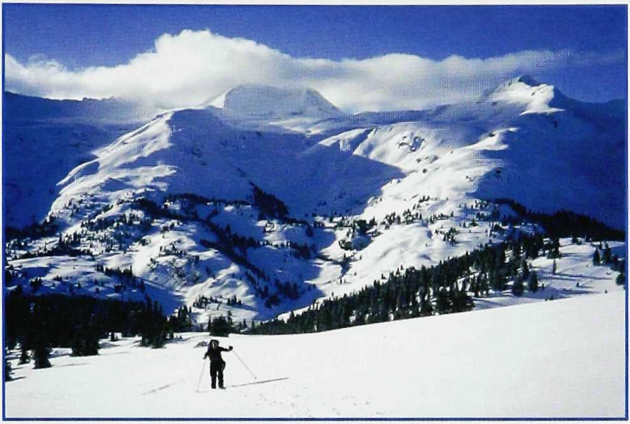
Most avalanches release during or shortly after a storm. This is because accumulating snowfall is adding another slab layer to the snow cover. This layer itself may be unstable or adds weight to the layers below. There is no rule of thumb on how much new snow is required for dangerous conditions, but the greater the accumulation, the greater the stress.

Snowfall Intensity

The more intensely snow falls, the more rapidly the avalanche danger increases, because the snowpack has less time to adjust to the load. For example, 12 inches of snow falling in 6 hours is far more dangerous than 12 inches in 24 hours.

Wind

The avalanche danger can quickly worsen on leeward slopes when winds are strong enough to cause blowing snow. That usually means winds of 15 mph and stronger. Even on sunny days winds can strip snow from windward slopes and deposit that snow onto leeward slopes at rates far greater than snow falling from clouds. Blowing snow also causes cornices to grow along ridge lines, further increasing the danger on lee slopes below.



Temperature

Storms that start cold and end warm cause heavier new snow to fall on colder, lighter snow, which creates unstable conditions. Very cold temperatures keep the snow brittle and maintain instabilities in the snow cover. Cold temperatures combined with a shallow snow cover can weaken the snow through metamorphic processes (see Snowpack Factors). On the other hand, mild temperatures cause the snowpack to settle and get stronger. A sustained temperature rise, however, is often a danger sign because it can lead to higher stress via snow creep, or can cause thaw instability.

Thaw

When warm temperatures lead to thaw, melt water can percolate though the snowpack. This weakens the snow by dissolving bonds between snow grains and between layers of snow. Thus, wet snow is often unstable, such that a smaller trigger can set it in motion.

Snowpack Factors

"Can the Snow Slide?"

Detecting weak layers and making the proper stability evaluation is perhaps the most important avalanche skill.

Layering

The snowpack builds in layers, and the key to knowing if it will slide comes from testing the strength of the layers and bonds between layers. The Colorado snowpack consists of many different snow layers, each the result of a weather event or metamorphic change. Some of the layers will be strong, and some will be weak, providing fragile support to the layer above.

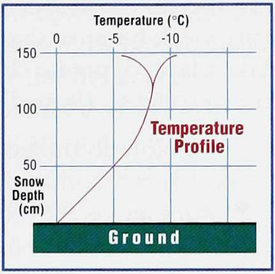
Slabs vary greatly from very soft (good powder) to extremely hard (bulletproof). Slab snow can be found almost everywhere and by itself is not dangerous. To be dangerous, it must be under tension and lie atop a weak layer.

Weak Layers

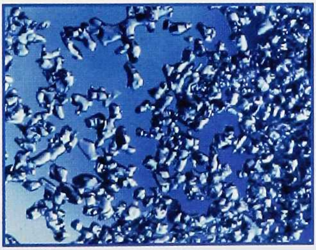
A weak layer can be several feet thick or paper thin, but is one which, when loaded, is prone to collapse or slippage (shear). Weak layers can form as a previous surface layer that gets buried, or can form from the metamorphism of an internal layer (see Snow Metamorphism.) Examples of previous surface layers are hard crusts or ice layers, low-density snow layers, and surface hoar. Surface hoar is a layer of loose feathery crystals that form during periods of cold and calm conditions. Once buried, these layers act as weak layers sandwiched between the old snow surface below and the new slab layer above.

Snow Metamorphism

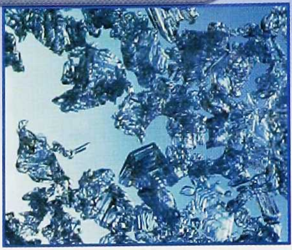
The snow grains making up the mountain snowpack can change over days, weeks, and months because of temperature influences. There are two types of metamorphism that change the shape of the snow grains in a layer of the snowpack and strength of that layer. The two types are called *equilibrium metamorphism*, which strengthens the snowpack, and *kinetic metamorphism*, which weakens the snowpack.



The type of metamorphism is dictated by the change in temperature from top to bottom of the layer. If the change is small (less than 1 °C per 10 cm, or in deep layers, less than 10 °C per meter), then equilibrium metamorphism will take place. This is common in a deep snow cover and/or in mild temperatures, such as in the Sierras. If the change is large (more than 1 °C per 10 cm, or 10 °C per meter), kinetic metamorphism will take place. Kinetic metamorphism is common in a shallow snow cover with cold temperatures (as in the Colorado mountains) but can also occur near the surface from diurnal temperature changes or from prolonged periods of cold weather.



Equilibrium Metamorphism. When a small temperature gradient exists, the snow grains will slowly become smaller and rounder. (Indeed, you will often hear the term *rounds* to describe these grains.) They will also bond (sinter) to the grains they touch. The result is a dense and strong layer of snow that is unlikely to produce avalanches unless a weak layer is beneath it or it loses its strength because of thaw.



Kinetic Metamorphism. When a strong temperature gradient is present, the snow grains grow larger and more angular. We call these *faceted grains* because of their many faces and sharp angles. (You will also hear the term *squares* to describe them.) Well-developed faceted grains are also called *depth hoar or sugar snow*. These grains are very weak because they bond poorly to one another. Like a layer of potato chips, they are prone to shear failure or collapse. (Buried surface hoar acts the same way.)

In the Colorado snowpack, a layer of depth hoar at the ground is very common. This layer can be more than a foot thick and is the cause of many avalanches. On the other hand, the mere presence of a layer of depth hoar does not mean the slope is dangerous. To determine the likelihood of avalanches, you must test the slope (see Field Tests) to see how it acts under stress.

Variability of Weak Layers

Snow structure and stability can change from slope to slope and can change significantly over short distances on the same slope. Subtle differences in windloading, aspect, slope angle, snow depth and topography all affect the snow structure and stability. The variability in stability across a slope is the reason that sometimes it is the second, third, tenth or even twentieth person on a slope who triggers the avalanche.

To detect weak layers and learn how widespread they are, you will need to dig several snowpits. You may find very different results in snowpits dug 100 feet apart. Data from snowpits can help you make good (and bad) decisions. Since stability may vary across a slope, don't trust your life to a single snowpit. Use snowpit data to complement other field observations.

Detection of Weak Layers

In a snow pit, weak layers can usually be seen or found by stability tests like the shovel shear, compression, Rutschblock, and slope test (see Field Tests). Use the results cautiously. Snow structure and stability can change significantly over short distances and from slope to slope, so frequent tests may be needed.

You should dig snow pits on a slope similar to the one in question. Snow conditions (snow cover and windloading) and terrain characteristics (aspect, elevation, steepness and ground cover) should be like the slopes you are headed for. Don't dig in snow disturbed by ski or snowmobile tracks, or in drifted snow around trees, bushes, and rock outcrops. Lastly, be sure your spot is safe. Triggering an avalanche while digging a snowpit gives meaningful data, but the consequences are potentially lethal.

Dig your pit just deeper than the suspected weakest layer. Generally, a 4- to 5-foot pit is sufficient, but probe the floor of the pit to check for weak layers deeper in the pack. Dig deeper if soft (weak) layers are detected or suspected.

Smooth the pit wall across the fall line of the slope and one side wall. You can see thick weak layers, and can detect thin and indistinct weak layers by brushing or poking with your hand. You can find less obvious weak layers by drawing a credit card down the pit wall and marking the changes in resistance. Finally, you can use several different field tests to find paper-thin weak layers that cannot be seen or felt but are just as dangerous. Remember: the presence of weak layers does not equate to instability. The snow must be tested.

Field Tests

In this section, we show you four ways to test the snow. The *shovel shear test* is good for finding weak layers (but not a good test of stability). The *compression test* and *Rutschblock test* are good for judging stability. Finally, *slope tests* are safe ways to see if you can trigger a small avalanche.

Shovel Shear Test

To perform this test, first isolate a column of snow in the pit wall. The dimensions of the column are the width of your shovel blade on all sides, or about 1 foot square. Use a snow saw, ski tail, or shovel to cut the column on all sides so that it is free standing. Cut the sides to the bottom of the pit and cut the back about 2 feet (60 cm) deep. (Don't cut down into depth hoar or the column will simply fall over.)

Carefully insert the shovel behind the column and with both hands pull in the direction of the slope. If a block of snow pops out with a smooth surface on the bottom, it is a shear failure. The force necessary to cause the shear can be ranked as *very easy, easy, moderate, or hard*.

The test should be performed several times and works best when the weak layer is within 6 inches (15 cm) of the bottom of the shovel.

For years back-country travelers and even avalanche workers have incorrectly used the shovel shear test to estimate snow stability. This test is very good for finding weak layers, but it is a poor test of snow stability.

Compression Test

This test is a very good way to find weak layers and to judge the strength of those layers. Start by isolating a column of snow exactly like the shovel shear test. Place the shovel blade upside down on top of the column and compress any very soft snow until the blade lies firmly on top. Hold the shovel handle with one hand while your other hand becomes a hammer. Your goal is to hit the shovel and cause a block of snow to shear loose or appear as a distinct break on the smooth side of the column. Stop the test whenever failure occurs.

Start with 10 taps with your finger tips on the shovel using only your wrist as a hinge. If no failure occurs, tap harder 10 times with the palm of your hand and using your elbow as a hinge. If still no failure, apply 10 even harder hits using your fist and keeping your arm straight and swinging from the shoulder.

Interpretation is as follows:

- A *very easy* shear if the column breaks while cutting it out.
- An *easy* shear with wrist taps.
- A *moderate* shear with elbow taps.
- A *hard* shear with arm hits.

Very easy and easy failures tend to be associated with human triggered avalanches.

Rutschblock Test

A better test for the back-country traveler to judge snow stability is the Rutschblock. In very simple terms you are testing for a small slab avalanche by applying force in seven steps. To be meaningful the Rutschblock must be done on slopes of 25° and steeper.

Once the lower wall of the Rutschblock is shoveled away, the sides and upper wall can be dug out, or cut with a snow saw, light cord, or the tail of a ski or snowboard leaving a large isolated block of snow. The dimensions of the Rutschblock are the length of a ski across the slope and the length of a ski pole up the slope.

Force is added by a skier, snowboarder, or snowshoer stepping onto the block. Failure occurs when the block moves. (Even a snowmobile can be driven across the back of the block to trigger a failure.) Movement can be subtle, so it's wise to have someone watching the block. Listed below are the Rutschblock scores and what they mean:

1. The block fails when digging or cutting.
2. Fails when stepping onto the upper part of the block.
3. Fails with a downward knee thrust.
4. Fails with one jump.
5. Fails with two hard jumps.
6. Fails with three or more hard jumps.
7. Block crumbles or does not fail at all.

Rutschblock numbers 1, 2, & 3 indicate an *easy* shear and triggered avalanches are probable or even likely; 4 & 5 indicate a *moderate* shear and triggered avalanches are possible; and 6 & 7 indicate similar slopes are generally stable and triggered avalanches are unlikely but not impossible.

Experience has shown three important points about the Rutschblock test that should be considered:

- For each 10° increase in slope angle the score decreases by one step.
- The test is less reliable when done near the top of a slope.
- It only tests weak layers no deeper than about 5 feet (1.5 m). If deep slab instability is suspected, stay off the slope.

Slope Tests

Small slopes (without terrain traps) can quickly be tested by experienced people traversing across the slope. This can be done with skis, snowboard or snowmobile. Choose small, steep slopes where a slide will not endanger the tester. Cut across the slope to see if you can trigger a small slab. Small cornices can also be knocked down (kicked off).

Human Factors

"What is my attitude?"

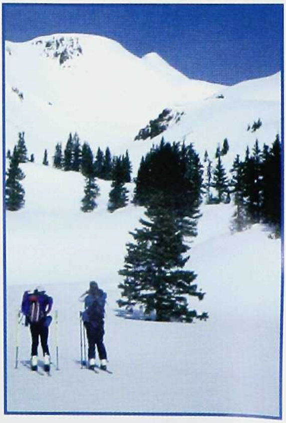
Most avalanche victims trigger the slide that catches them. Therefore, most avalanche accidents are preventable. Accidents usually occur because of ignorance, arrogance, overconfidence, or distractions.

- Ignorance can be overcome by avalanche education.
- Arrogance can be overcome by checking your attitude at the trailhead and recognizing that even you can make a mistake.
- Overconfidence can be overcome by expecting the unexpected.
- Distractions can be overcome by always focusing on the terrain, weather, and snowpack factors available to you.

Attitude

Recognize and overcome these common mistakes:

- Exceeding your skill level because of peer pressure.
- Taking unwarranted risk to achieve goals.
- Being too tired to make good judgments.
- Traveling too fast or taking shortcuts because you are cold, hungry, or late.
- Rushing for first tracks.
- Thinking your athleticism or gear will let you survive an avalanche.



Minimizing Risk and Surviving Avalanches

Avalanche safety and survival is a matter of knowledge and skill. Knowledge tells you what to do and why, and skill lets you do it. You can avoid avalanches altogether only by recognizing and avoiding avalanche terrain. But this recommendation is not practical for many people who enjoy the challenge and rewards of back-country adventure.

We support the philosophy that risk has its rewards. Taking risks, however, must be tempered by good judgment. In avalanche terrain, you should do everything to minimize risk. You do this with observations, knowledge, and good travel habits, and you improve your odds of survival by carrying rescue gear.

Rescue Gear

Beacons and shovels should be mandatory for you and your back-country companions. There are several good beacons available, they are all compatible, and though expensive, they are proven life savers—though you should not take extra risk because you are wearing a beacon. You and your companions should practice with your beacons often.

Probes are valuable because they may speed up a beacon rescue; they become mandatory when victims do not have beacons.

Lastly, a slope meter is an excellent tool to help identify avalanche paths.

Avalanche Paths

Avalanches run repeatedly in the same areas. Avalanche paths can be identified by slope angle (usually 30° or steeper in the starting zone), swaths through the trees, or damaged trees in the track and runout.

Terrain Traps

Small avalanches can quickly turn deadly when they pile into narrow gullies or creek bottoms, or spill over cliffs, or into dense timber or rock outcrops.

Unstable Snow

Recent avalanches, shooting cracks, collapsing snow, and "whoomphing" or hollow, drum-like sounds are excellent clues of unstable snow. Weather clues to watch for are recent snowfall, blowing snow, strong temperature rise, or a melting snowpack.

Snow Pits

When in doubt, dig pits and perform stability tests on a variety of slope aspects and elevations. (See Field Tests.)

Timing

Avalanche danger can vary from one day to the next. Avoid back-country travel when you know the danger is high or extreme. You should travel in steep terrain only when you feel the danger is low.

Flexibility

Live by the following rules of good judgment:

- Be flexible to where and when you go into the back-country…and come out. Use the hotlines to help plan trips.

- Don't take undue risk to keep a self-imposed deadline. Avalanches don't care that you have to be home by 5 o'clock.
- Avoid steep slopes when the snow cover is unstable. Ski a less-steep slope.

"What are the Consequences of Getting Caught in an Avalanche on This Slope?"

Ask yourself this question if unstable conditions exist or if you have any doubt as to conditions. If an avalanche could bury you, avoid the slope. Look for alternate safe routes. Sometimes the only safe alternative is to retreat and try it another day.

Safe Travel Habits

If you decide to "go for it" because you feel conditions warrant it, then cut your risk to a bare minimum with the following precautions:

- Travel with skilled and practiced companions. Your life may depend on their actions.
- Carry and know how to use slope meters, beacons, shovels, and collapsible probes.
- Check beacons at the trailhead, or each morning.
- Safest routes are broad valleys, ridge tops, or windward sides of ridges. Avoid narrow valleys, cornices, and lee slopes.
- Lower-angle slopes are safer than steeper slopes, but when unstable conditions exist gentle slopes may be overrun by avalanches releasing on steep slopes above.
- Cross, climb, or descend suspect slopes one at a time.
- Cross as high as possible.
- Don't travel above your partner.
- Don't stand below your partner.
- Stay in sight of your partner.
- Wait and watch from protected areas.

- Use ridges, rock outcrops, and dense timber for protection. (But in very weak snow, avalanches can release next to rocks, brush, and trees, so avoid shallow snow areas where slabs may be thin and easily triggered.)
- Keep to the edges of open slopes and gullies.
- Be prepared to ditch a heavy pack, poles, skis, or snowmobile if caught.
- Minimize the time you are exposed. Stop to rest, eat, or camp in avalanche-free areas.

Survival Tips and Rescue Procedures

Once caught in an avalanche, your survival may depend on luck, for the forces you will be fighting are strong. Nonetheless, your goal is to stay on top. The following tips may save your life or your companion's.

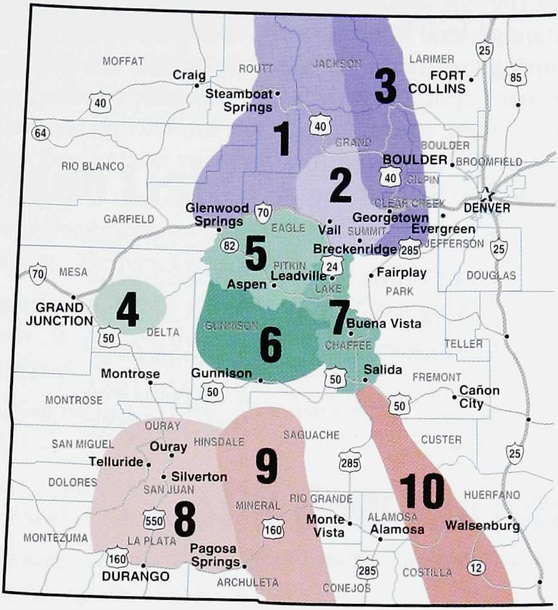
If you are caught...

- ✔ Escape to the side or grab a tree, or outrun the slide with your snowmobile.
- ✔ If knocked down, discard heavy pack, poles and skis. Get clear from your snowmobile.
- ✔ Fight the avalanche by swimming.
- ✔ Form an air pocket with your hands before the snow stops.

If you are a rescuer...

- ✔ Watch the victim closely.
- ✔ Search downslope from the last-seen area.
- ✔ Use your beacon and watch for clues.
- ✔ If no beacons, spot probe, then coarse probe likely burial areas.
- ✔ Do not go for help prematurely. Keep all rescuers on site for as long as possible.
- ✔ Treat victim for suffocation, impact injuries, shock, and hypothermia.

Avalanche Zones of Colorado



Region	Zone	
Northern Mountains	1	Steamboat
	2	Vail—Summit County
	3	Front Range
Central Mountains	4	Grand Mesa
	5	Aspen
	6	Crested Butte
	7	Sawatch
Southern Mountains	8	Western San Juans
	9	Eastern San Juans
	10	Sangre de Cristos

Avalanche Hotlines

The following hotlines provide the most recent weather, snow, and avalanche conditions for the Colorado mountains. They are updated daily in the winter months. They contain general information which you should use for planning your trip. But you can easily find different snowpack conditions than mentioned in the hotlines. That is where your back-country knowledge and skills come in. Be prepared to alter your route (and your behavior) to fit the situation.

Denver/Boulder	303-275-5360
Fort Collins	970-482-0457
Colorado Springs	719-520-0020
Summit County	970-668-0600
Aspen	970-920-1664
Durango	970-247-8187

Internet Web Site

http://geosurvey.state.co.us/avalanche

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Beating the Odds. 1996. YAK Alpine Enterprises, Calgary, AB, Canada, 48 min.

Riding Safely in Avalanche Country. 1998. USFS National Avalanche Center, Ketchum, ID, 28 min.

Winning the Avalanche Game. 1993. Wasatch Interpretive Assoc., Salt Lake City, UT, 58 min.

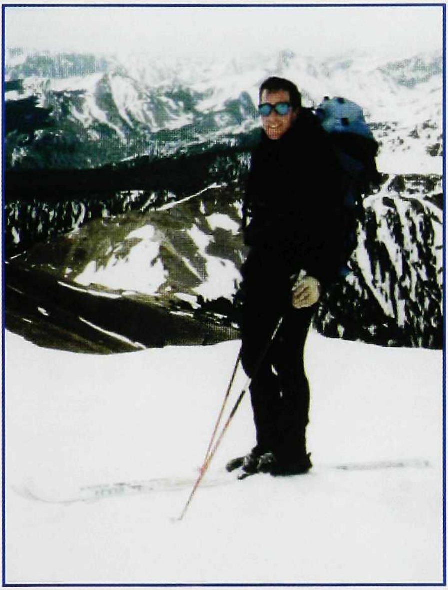
*These books and videos can be ordered from:
Colorado Geological Survey Publications
1313 Sherman Street, Room 715
Denver, CO 80203
303-866-2611
http://geosurvey.state.co.us

Acknowledgement

The authors wish to thank Jill Fredston and Doug Fesler for their contributions to avalanche education and especially their excellent book *Snow Sense*. We patterned the style of *Avalanche Wise* after *Snow Sense*, because we could not improve on that style.

Avalanche Danger Scale

Danger Level	Avalanche Probability and Trigger	Degree and Distribution of Danger	Recommended Action in the Back-country
Low (green)	Natural avalanches very unlikely. Human triggered avalanches unlikely.	Generally stable snow. Isolated areas of instability.	Travel is generally safe. Normal caution is advised.
Moderate (yellow)	Natural avalanches unlikely. Human triggered avalanches possible.	Unstable slabs possible on steep terrain.	Use caution in steeper terrain on certain aspects (defined in bulletin).
Considerable (orange)	Natural avalanches possible. Human triggered avalanches probable.	Unstable slabs probable on steep terrain.	Be increasingly cautious in steeper terrain.
High (red)	Natural and human triggered avalanches likely.	Unstable slabs likely on a variety of aspects and slope angles.	Travel in avalanche terrain is not recommended. Safest travel is on windward ridges or lower-angle slopes without steeper slopes above.
Extreme (red with black border)	Widespread natural and human triggered avalanches certain.	Extremely unstable slabs certain on most aspects and slope angles. Large destructive avalanches possible.	Travel in avalanche terrain should be avoided, and confined to low-angle terrain well away from avalanche path runouts.



Avalanche Wise is funded by the family and friends of Ethan Morris Gell, 1961–1995.

With a special interest in avalanches, Ethan worked as a ski patroller at Beaver Creek Resort, Colorado. He died of a congenital heart defect.

The above photograph of Ethan was taken by Dorothy J. Howard on Memorial Day weekend, 1994, while on Mt. Sopris, Colorado.

CAIC

STATE OF COLORADO
Bill Owens, *Governor*

DEPARTMENT OF NATURAL RESOURCES
Greg E. Walcher, *Executive Director*

DIVISION OF MINERALS AND GEOLOGY
Ronald W. Cattany, *Director*

COLORADO GEOLOGICAL SURVEY
Ronald W. Cattany, *Interim Director*

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