UNDERSTANDING AVALANCHES • EVALUATING AVALANCHE HAZARD • KNOW BEFORE YOU GO: PLANNING A TRIP • USING THESE SKILLS IN THE FIELD • RESCUING A COMPANION IN AN AVALANCHE • TRAVELING SAFELY IN AVALANCHE TERRAIN

CHAPTER 17
AVALANCHE SAFETY

Mountaineers seek the freedom of the hills, and no freedom is harder to earn than that of the snowy hills. In North America, according to the Colorado Avalanche Information Center, avalanches kill more winter recreationists than any other natural hazard: 34 in 2012, 24 in 2013, 35 in 2014, 11 in 2015, and 29 in 2016. Nearly all avalanches that involve people are triggered either by the victims themselves or by a member of their party. According to avalanche expert Bruce Tremper, about 90 percent of avalanche victims trigger their own slide.

Climbers, backcountry skiers, snowmobilers, and snowshoers are prime victims of avalanches. Better mountain gear and changing trends in backcountry recreation are leading more and more people to have fun where there are avalanche-prone slopes. The high level of risk to climbers and backcountry skiers can be explained by two factors:

1. Climbers' and backcountry skiers' destinations are often in avalanche terrain; therefore they spend more time exposed to risk of involvement in an avalanche.

2. Climbers' and backcountry skiers' routes to their destinations often cross avalanche-prone areas where human triggering is possible or even likely.

Reaching a climbing objective often involves traveling on steep and exposed avalanche start zones (see "Understanding Avalanches" below). When choosing route options, climbers must contend with the challenges of evaluating avalanche hazard. Early start times, really fast travel, and brute ambition are not enough to evade all avalanches. Avalanche hazard, unlike high-mountain exposure and severe weather, is not always obvious.

However, avalanches are not a mysterious phenomenon. Avalanche education can help backcountry travelers make better decisions about safe snow travel. This chapter introduces the subject of avalanches, reviews some of the ways that snow travelers can evaluate hazards and minimize risk, and explains methods of searching for avalanche victims. This material is not intended to be comprehensive. For a more complete understanding of the subject, consult specialized publications (see Resources) and take a level 1 course offered by the American Institute for Avalanche Research and Education (AIARE), or equivalent, to learn how to make informed decisions in avalanche terrain. For an explanation of the formation of avalanches and an assessment of dangers associated with various forms of snow, see Chapter 27, The Cycle of Snow.

UNDERSTANDING AVALANCHES

Most avalanche victims are involved in small to medium-sized slides. Imagine a snowfield the size of a couple of tennis courts; it is poised on a slope, with weak layers hidden beneath the surface. A climber or skier enters the scene, and the additional load causes a failure: *crack!* The slab is off and away. The snow breaks and shears along the bed surface (the ground, ice, or hard snow layer that forms the sliding surface) between the weak layers, and across the top of the snowfield a fracture line marks the point where the tension holding the snow failed. Below the avalanche start zone (typically a 25- to 50-degree slope), the slab breaks up, and the churning snow accelerates down the avalanche track and into the runout zone, where a change in the terrain stops the moving snow and the dense deposit accumulates and buries victims, on average, 3 to 4 feet (about 1 to 1.3 meters) deep. Because the motion is sudden, it has an unbalancing effect; the suddenness, speed, and power of the avalanche typically sweep victims off their feet or skis, sometimes hurtling them into bad terrain or forcing them through confined tracks and burying them deeply in a cement-like medium tightly packed in a terrain trap.

Many avalanches create a destructive force capable of breaking trees, crushing a car, or wiping out a small cluster of buildings. Avalanche movement is varied; imagine slow lava, flowing white water, or 220-mile-per-hour (350- kilometer-per-hour) airborne turbulent masses.

When the following three elements coincide, an avalanche can occur:

1. **Unstable snow.** The snow is loose (for example, powder, which is part of the allure of a climbing, snowshoeing, or skiing trip) or the snow layers are poorly bonded.
2. **Steep terrain.** The slope angle is steep enough to produce a slide.
3. **Trigger.** Something initiates the failure of the bonds holding the snowpack in place.

Natural avalanches may occur when new snow deposited by storms loads the previous layers of snowpack, adding more stress and triggering an avalanche. A skier or climber may add sufficient stress to trigger a slide, as can falling chunks of snow, ice, or rock. The two principal types of avalanches that climbers encounter in a typical spring and summer climbing season are slab avalanches and loose-snow avalanches. (See "The Formation of Snow Avalanches" in Chapter 27, The Cycle of Snow.)

SLAB AVALANCHES

Slab avalanches are very dangerous to skiers, snowshoers, and winter climbers and scramblers. They are formed by a cohesive stronger snowpack layer forming over a weaker layer (see "Terrain" in the next section). A slab avalanche occurs when the slope fails first in compression (the *whumph* sound that climbers sometimes hear) and then in tension (the breaking of the slab that allows the slab to begin moving). A large area of snow (the slab) begins to move simultaneously and often breaks up into large plates and blocks of snow. Slab avalanches can strip snow all the way to the ground or can involve only the top layer(s) of poorly bonded snow. Wet springtime slab avalanches occur when the intense warming of long spring days and higher sun angles softens layers in the existing snowpack that formed during the winter; wet slab avalanche conditions are very sensitive to the slope aspect, time of day, and temperature.

LOOSE-SNOW AVALANCHES

Loose-snow avalanches, which can consist of wet or dry snow, originate from a single point of release. They often look like an inverted V as they spread out and move downslope. They often move relatively slowly compared with slab avalanches. Wet loose-snow avalanches (common in spring) can overload a slope and cause failure in an underlying slab, resulting in a large and dangerous slab avalanche.

EVALUATING AVALANCHE HAZARD

The interaction of three crucial variables—unstable snow, terrain, and a trigger—determines whether or not an avalanche is possible (fig. 17-1). What is the layering of the snow? Is the terrain capable of producing an avalanche? Could I or one of my party be the trigger? Could a change in the weather trigger an avalanche? (See “Avalanche Triggers” in Chapter 27, The Cycle of Snow.)

Evaluating avalanche hazard is both an art and a science. It takes years of experience to become good at evaluating hazard. Local knowledge and experience reading the weather and snowpack typical of each of the world’s mountain ranges is vital to achieving a high degree of competence at predicting when and where avalanches are likely to occur. Many regions offer detailed avalanche and mountain weather forecasts, explaining what (if any) weak layers exist, what the current avalanche problems are, and what terrain to avoid (see www.avalanche.org to find forecast websites near your objective).

Forecasting is not an exact science and weather does not always unfold as predicted, so it is vital to understand the logic behind the forecast and to confirm that the conditions in the field match the conditions predicted by the forecast. In addition, forecasts are often generalized to cover large geographical areas, so it is also vital to confirm that local conditions on your route match the forecast.

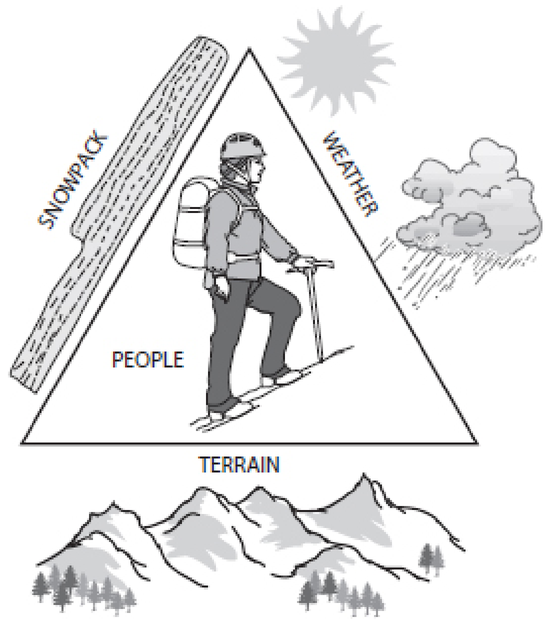


Fig. 17-1. Avalanche hazard triangle: terrain, snowpack, and weather—with the added variable of backcountry travelers.

The composition of the current snowpack can to a large extent be inferred based on the weather history. Online spreadsheets that provide hourly snapshots of data such as wind speed, wind direction, temperature, rates of precipitation, and so on can give a very good idea of whether the snowpack in a particular area is likely to be stable or not. If this data is no longer available once climbers are out in the field, they need to observe and record their observations in order to form their own accurate forecasts.

Climbers in an unfamiliar area need to make conservative decisions about where to travel. When climbing in remote areas, where professional forecasts are unavailable, climbers need to become their own forecasters, which requires a high degree of competence at evaluating the snowpack and analyzing the available weather data. Even when professional avalanche forecasts are available and you are climbing in familiar mountains, it is important to make these same weather observations, as well as to continually study and test the snowpack, in order to confirm that the forecast you are depending on really corresponds to the conditions you are encountering.

TERRAIN

Understanding avalanche terrain is the key to safe travel in snowy mountains. Of the three variables in Figure 17-1, the weather cannot be controlled, and an unstable snowpack can persist over large areas for long periods, but climbers can always choose to travel in terrain that will not generate an avalanche. Choosing safe terrain based on an understanding of the local conditions is the central concept of safe travel in avalanche country.

Learning to recognize avalanche terrain is the first step in the process of evaluating avalanche hazard. The steepness of a slope, its aspect (which direction it faces), and the slope's shape and natural features (its configuration) are all important factors in determining whether a slide can occur on a particular slope.

Slope Angle

Of all of the terrain factors, the steepness, or slope angle, is the most important. Slab avalanches commonly occur on slopes with starting-zone angles between about 30 and 45 degrees, but slab avalanches occasionally occur on slopes of less than 30 and greater than 45 to 55 degrees (fig. 17-2). Slopes steeper than about 50 to 60 degrees tend to sluff snow constantly, and slopes of about 25 degrees or less are generally not steep enough or require highly unstable snow before they can slide.

It is difficult to estimate the angle of a slope just by looking at it. Use a clinometer to measure slope angles in the field. Simple plastic models are available, and many compasses have clinometers built into them (see Chapter 5, Navigation, for a discussion of clinometers and how to measure slope angle). Learn to measure slope angle accurately on topographical maps; special scales make it easy to measure slope angle directly from the map based on the spacing of contour lines (fig. 17-3).

The angle of the slope the climbers are on is not the only concern, because an avalanche could start from an adjacent slope. A party does not have to be climbing or skiing on a slope for it to avalanche. This is a very important concept: All of the snow is connected. Climbers can be traveling on a gentle slope or a snow-covered road, and if the snowpack is unstable enough, they can trigger a slide on the steeper slope above them, even though they are not on a steep slope. All of the snow is connected, remember? It is critical to know what is above you as you travel. Because adjacent terrain is often out of view or obscured by the weather, study a topographical map to identify sources of hazard that may lie above or below your route.

Slope Aspect

The direction a slope faces—its slope aspect—determines how much sun and wind the slope gets, which indicates a great deal about its avalanche potential. Here is how it works in the northern hemisphere (it is the opposite on mountains south of the equator).

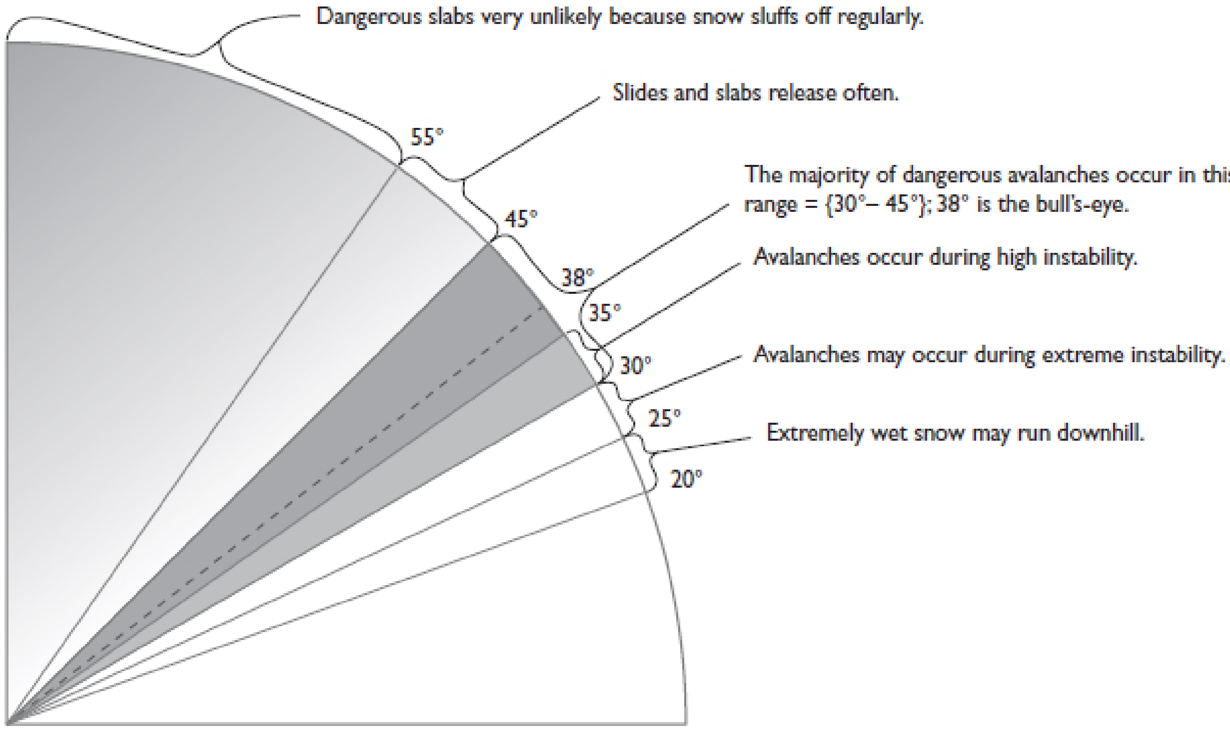


Fig. 17-2. Steepness of the slope—slope angle—is the most important of all terrain factors affecting avalanches. Most avalanches occur on slopes ranging from 30 to 45 degrees.

South-facing slopes. Snow settles and stabilizes faster on slopes that receive more sun than it does on north-facing slopes. In general (with plenty of local exceptions), this may make south-facing slopes somewhat safer in winter. They tend to release avalanches sooner after a storm, so if they are avalanching, it is an indication that slopes facing in other directions may soon follow their lead. As warmer spring and summer days arrive, south slopes become prone to wet-snow avalanches, and north-facing slopes may be safer.

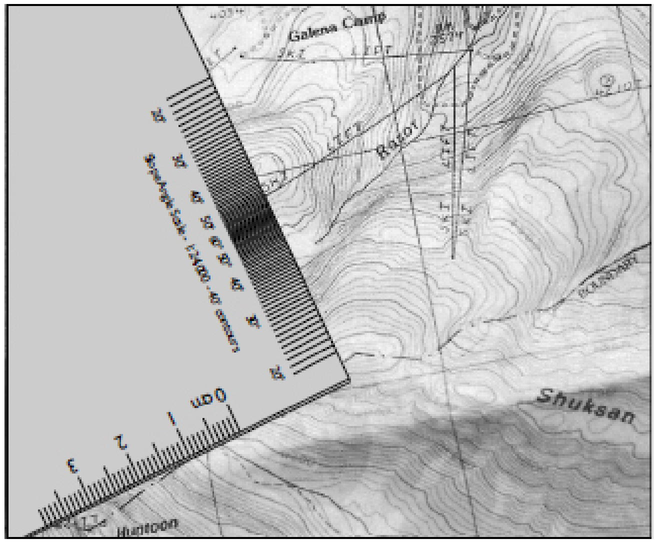


Fig. 17-3. Measuring slope angle based on contour lines using the 1:24,000 scale in the American Institute for Avalanche Research and Education (AIARE) Field Book.

North-facing slopes. On slopes that receive little or no sun in the winter, consolidation of the snowpack takes longer. Colder temperatures within the snowpack create weak layers. Therefore, in general (again, with local exceptions), north slopes are more likely to slide in midwinter. In spring and summer, as south slopes become dangerously wet, look to the north side for firmer, safer snow.

Windward slopes. Slopes that face into the wind tend to be safer than leeward slopes. Windward slopes may be blown clear of snow, or the remaining snow may be compacted by the force of the wind.

Leeward slopes. Slopes that face away from the wind are particularly dangerous because of windloading, which happens when the wind transports snow rapidly from a wind-exposed area of the slope to a less wind-exposed leeward area of the slope. A slope can become “top-loaded” by wind blowing snow over the top of a ridge crest and depositing it on the lee side, or it can become “cross-loaded” by the wind blowing across the slope and depositing the snow in gullies between ridges. Leeward slopes collect snow rapidly when even moderate winds move snow from windward slopes onto the leeward side. The results are the formation of cornices on the lee side of ridges, snow that is deeper and less consolidated, and the formation of wind slabs ready to avalanche.

Be especially aware that in some areas, such as the passes in Washington State’s North Cascades, the wind very often shifts direction with the onset of a storm, and what a climber thought was the windward slope may then become the leeward slope. It is quite common to have the wind blow the snow that was deposited by the last storm on the north and east aspects onto the south and west aspects as a storm approaches these mountains from the southwest. This makes the west and southwest aspects temporarily the leeward slopes, and avalanche conditions become dangerous on those slopes. As the storm moves onshore from the Pacific Ocean and into the Cascades, the wind then shifts to blowing from the west and southwest and begins to redeposit the snow on the now leeward north and northeast aspects, the "traditional" dangerous leeward slopes.

Slope Configuration

Smooth slopes—those that, beneath the snow, are covered with grass or smooth rock slabs—generally do not anchor the snow well, and thus provide a good bed surface for a slide. Trees and rocks may serve as anchors that tend to stabilize the snow—at least until the snow covers them. But, in general, to act as effective anchors, the trees and rocks need to be so close together that it can be difficult or impossible for a climbing party to move through them. After these trees and rocks are buried by snowfall, they can actually become a source of weakness in the snowpack: as foreign bodies, the trees and rocks can inhibit or interfere with the bonding of the snow layers. Slides are less likely to originate in a dense forest, but they can run through dense forest from above. Forested slopes avalanche less often, not because the trees hold the snow in place, but because snow falling from treetops will often speed up the stabilization of fresh snow after a storm or because tree cover may inhibit the formation of surface hoar (a potential cause of weak layers in the snowpack). In addition, an established forest provides historical evidence that very large slides do not often occur in the forested terrain.

The shape of a slope also affects the hazard level. Snow on a slope that is straight, open, and moderately steep presents the most obvious danger. Snow on a convex slope, under tension as it stretches tightly over the bulge in the terrain, is more prone to avalanche than snow on a concave slope (fig. 17-4). Fracture lines frequently occur at or just below a convex area. Ridges are often the safest route up a mountain where avalanches may be a problem, because they present a lower-angle path and keep climbers off open slopes; however, on ridges be wary of overhanging cornices or adjacent wind slabs.

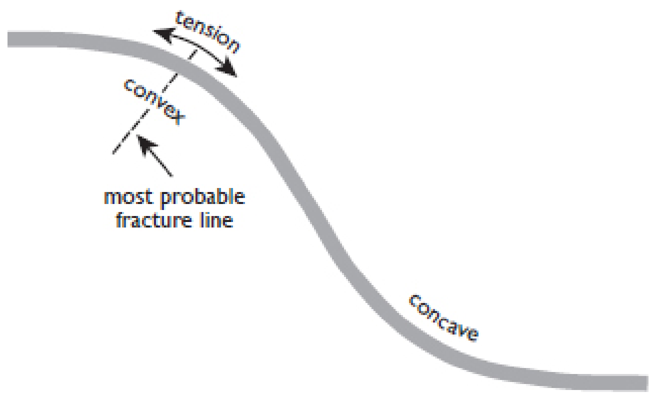


Fig. 17-4. Convex and concave slope configurations.

Terrain Traps

The term “terrain trap” describes hazardous terrain that increases the consequences of being buried or injured if a climber is caught in an avalanche. These traps can be found in a wide variety of terrain, including cliffs below the route that a snowslide might carry you over or a grove of trees that might injure you if a slide sweeps you into them. It is particularly important to be aware of terrain configurations that will concentrate or funnel an avalanche into a smaller runout zone so that a person caught in the slide is buried very deeply. Even a relatively small and shallow snowslide that might be harmless on an open slope can bury and kill a climber if it flows into a narrow gully. Many ice climbing routes follow gullies that, though they may be too steep to be a source of avalanches, are routinely swept by powerful avalanches generated higher on the mountain. Other examples of deadly terrain traps include buried streams, glacier crevasses, valleys, and flat roadways cutting across a slope.

SNOWPACK

The typical snowpack is composed of a series of distinct layers deposited by each storm and characterized by relative strength, hardness, and thickness. The depth and distribution of weak layers within the snowpack are significant factors in determining the stability of the snowpack. Climbers must determine the composition of the snowpack—its configuration.

Bonding Ability

Throughout the winter, the snowpack accumulates layer by layer with each new precipitation, temperature, and wind event. A snowpack has both strong and weak layers. Strong layers tend to be cohesive—denser layers composed of small, round snow grains packed closely together and well bonded to each other. Weak layers tend to be less dense, composed of poorly bonded grains. These weak layers often appear loose or "sugary." Because weak layers prevent strong layers from bonding with one another, it is important for the backcountry traveler to know the relationship of these layers. Remember, the snow slab that becomes a slab avalanche is a stronger layer of snow on top of a weaker layer of snow; where slab avalanches are suspected, the backcountry traveler may dig snow pits and probe the snow looking for strong-over-weak layers in the snowpack.

Sensitivity to Stress

The snowpack exists in a balance between its strength and the stresses placed upon it. When the snow's strength is greater than the stresses, the snow is stable. Fortunately, this is most often the case; otherwise, snow would never stay on a hillside. But sometimes the balance between strength and stress is almost equal, and then the snowpack is unstable. Avalanches occur only when and if the snowpack is unstable. For an avalanche to occur, something must disturb the balance so that the stress on or within the snowpack exceeds its strength. The snowpack can adjust to only a limited amount of stress and only at a certain rate of speed. Add another stress such as a rapid load of precipitation, a sudden increase in temperature, windblown snow, or the weight of a climber or skier, and an avalanche could be triggered.

WEATHER

Before and during any backcountry trip, study the weather closely. Heavy precipitation, high winds, or extreme temperatures mean changes in the snowpack. Be prepared to look critically at the snow to see how the snowpack has been affected by recent weather. The snowpack adapts poorly to sudden changes, so rapid turns in the weather contribute to instability of the snowpack. The snowpack can bend and adapt when forces are applied slowly, but sudden stress can cause it to break (see "The Formation of Snow Avalanches" in Chapter 27, The Cycle of Snow).

In some climates, such as maritime areas, the storm snow typically stabilizes within 72 hours, so climbers may need to look at weather data for a week or two prior to their trip, in order to determine how the snowpack has evolved since the last time it was stable. Even in a maritime mountain range, persistent weak layers do sometimes occur, however, requiring climbers to consider a hazard caused by weather events from much earlier in the season. In colder mountain climates with shallower snowpacks, persistent weak layers are the norm and climbers almost always need to consider the weather history and snowpack evolution through the entire avalanche season. It is especially important when climbers are in an unfamiliar part of the world to study the ways that weather and snowpack interact; the typical avalanche problems can be very different from place to place. Weather and snow pack formation is covered in greater depth in Chapter 28, Mountain Weather.

Precipitation

Both forms of precipitation—either solid (snow and hail) or liquid (rain)—add to stress on the snowpack. Avalanche danger increases rapidly with snowfall of 1 inch (2.5 centimeters) or more per hour. The threshold of 12 inches (30 centimeters) or more in a day is critical. If a heavy load of new snow accumulates too quickly for the strength of the existing snowpack, an avalanche may result.

Rain can percolate into the snow, weakening bonds between layers. Rain tends to lubricate the layers, making it easier for a slide to start. Rain adds significant weight, and it may also rapidly warm the snowpack. Avalanches can be triggered very quickly after rainfall begins.

With either rain or new snow, consider these questions: How well does new snow bond with the snowpack? How big a load does it represent? The weight of the water in rain or new snow is the primary contributor of stress on the snowpack.

Wind

The high winds that transport snow from windward slopes and deposit it on leeward slopes break the interlocking bonds between snow crystals. These particles, once they are made smaller, pack closely together, forming firm cohesive slabs that fracture efficiently, resulting in avalanches. A wind slab is a typical strong layer, ready to slide as a unit when it breaks free of a weaker underlying layer. High winds also shape the cornices that overhang lee slopes (fig. 17-5a and b). Cornices can break and fall, sometimes triggering an avalanche (fig. 17-5c). Be aware that when winds blow from one direction and then later from another direction, it is sometimes possible for wind slabs to form on both sides of a ridge. Local terrain features can force prevailing winds to blow in atypical directions as well. Always study weather over a sufficient span of time and make observations in the field rather than going by simple assumptions.

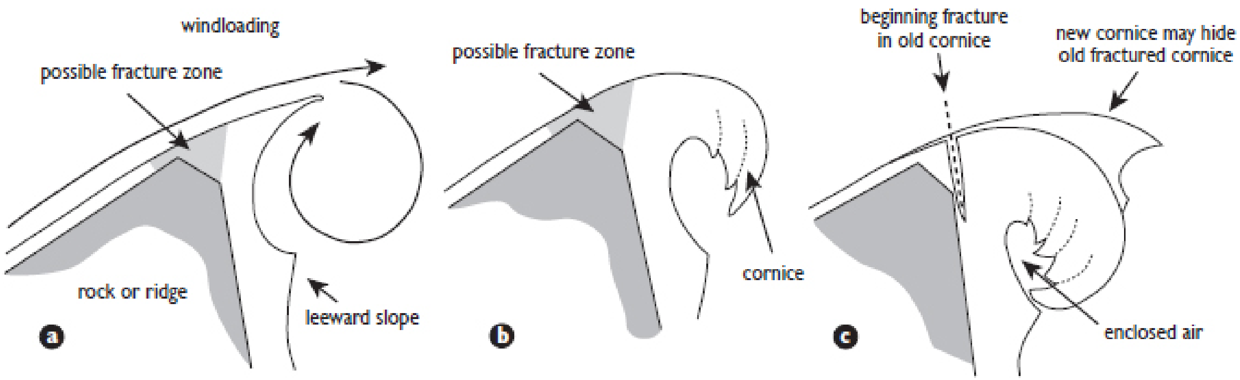


Fig. 17-5. How cornices form: a, wind blows snow beyond the edge of a ridge; b, successive storms build up layers and extend snow farther away from ridge; c, original cornice becomes fully enclosed and a new cornice begins on top of it.

Temperature

Significant differences in temperature between the ground and the snow surface promote growth of highly faceted snow crystals (depth hoar, or “sugar snow”) that cannot support much load. This temperature differential and the resulting sugar snow are especially common early in the season, notably in interior, snowy climates such as that of the Rocky Mountains or in the drier and colder parts of the North Cascades like the Washington Pass area. Less severe temperature gradients and a deeper snowpack act as insulation that may allow this snow to stabilize. But highly faceted snow can persist as a dangerous underlying layer well into the snow season or until avalanches release it.

Another persistent weak layer, similar to dew, is surface hoar. It is found in all mountain ranges. The conditions that encourage its growth are cold, clear nights with little to no wind at the snow surface and a source of moisture nearby such as a stream or lake. When the thin, feathered crystals of surface hoar are covered by subsequent snowfall, they can form weak layers that—like sugar snow—increase avalanche hazard.

Melt-freeze crusts form from sun or rain on snow followed by rapid cooling, resulting in a dense icy layer with poor bonding characteristics.

These crusts may persist for a long time before they break down, leaving a smooth, hard bed surface ready to be reloaded by the next storm.

Temperature affects snow stability, especially that of new snow, in complicated ways. Warm temperatures accelerate settling, causing the snowpack to become denser and stronger and, thus, over the long term, more stable. But rapid, prolonged warming, particularly after a cold spell, initially weakens the snow cover, making it less stable and more susceptible to human-triggered failure. The snowpack remains unstable until temperatures cool down. Cold temperatures make dense snow layers stronger but are unlikely to strengthen weak layers of new, low-density snow. Cold temperatures also tend to preserve such weak layers, extending the time that they may remain a hazard.

KNOW BEFORE YOU GO: PLANNING A TRIP

It is up to all climbers to gather important data before they head into avalanche terrain. There are many ways to minimize the risk of avalanches and to increase the chances of survival if one hits. In addition to evaluating avalanche hazard during a trip, climbers can also reduce avalanche risk by the things they do before they head into the mountains. See "Organizing and Leading a Climb" in Chapter 22, Leadership.

Take a class: a level 1 avalanche course is critical to climbers' learning how to make good decisions about safe travel in avalanche terrain. Reading this chapter provides an introduction to decision making in avalanche terrain. After taking an avalanche course, climbers should be able to identify avalanche terrain; identify basic snow grain types, weak layers, and strong layers; perform field tests to look for instability in the snowpack; recognize weather and terrain factors contributing to instability; perform rescue through fast and efficient transceiver use; and apply safe travel techniques. There is no such thing as too much avalanche education.

CHECK WEATHER AND AVALANCHE FORECASTS

It is obvious advice, but check the weather and avalanche forecasts before a trip. Most local avalanche centers, such as the Northwest Avalanche Center (see Resources), issue avalanche warnings throughout the winter. Before heading out, check the avalanche bulletin for the area the party plans to visit, and use this forecast to make decisions about where it might be safe to travel.

If possible, study the weather trends and snowfall history of the area, which provide information about the snowpack. Talk to people with local knowledge of the intended route, including any ranger who may be responsible for that area. Often, detailed trip reports can be found on websites that post beta gathered by climbers, skiers, and others. Do not be afraid to rethink well-laid plans if crucial new pretrip information is uncovered.

TIPS FOR SELECTING A SAFE ROUTE

Travel safely in the backcountry by seeking routes that limit the party's exposure to danger. The following guidelines are based on some of the important considerations discussed in this chapter:

- **Favor windward slopes,** which tend to be more stable.
- **Avoid leeward slopes** where winds have deposited snow slabs.
- **Choose the lowest-angle slopes** that avoid 30 to 45 degrees and will get the party to its objective.
- **Favor the edges of slopes,** where avalanches are less likely and safer terrain is closer in case one does occur.
- **Be particularly cautious of slopes of 30 to 45 degrees;** use a clinometer to identify them. The majority of avalanches occur on slopes close to 38 degrees.
- **Be suspicious of convex rollovers;** they are likely trigger points for avalanches.
- **Be careful of shaded slopes** in winter and the very warm, sunny slopes of spring.
- **Avoid gullies and other terrain traps,** which can be chutes for large quantities of snow that can deeply bury climbers or sweep them away.
- **Keep aware of the runout zone** below snow slopes and gullies, especially avoiding areas with cliffs below.
- **Avoid camping in valleys** or any other place that can be exposed to avalanche danger from above (fig. 17-6).
- **Develop "avalanche eyeballs"** by continually evaluating avalanche danger and its potential consequences.

Climbers can also improve their safety margin by taking the normal precautions called for on any climbing trip or ski tour: studying maps, Google Earth, and photos of the area; researching alternative routes; preparing for an emergency bivouac; and identifying possible retreat routes. Determine the route—including its slope aspects, elevations, slope sizes and shapes, and exposure—and identify the probable locations of hazards. See the “Tips for Selecting a Safe Route” sidebar.

It is an excellent idea to include a safe alternate destination in every trip plan. Having a safe option already picked out and planned for helps defeat the momentum that so often leads people to plunge ahead in dangerous conditions, instead of making a rational decision to go elsewhere.

Trip planning is much more effective if all climbers in a party use a small field book to note weather and snowpack data and forecasts, route plans, emergency contact information, and so forth. The same book can be used to note snowpack and weather observations in the field, which is a huge help in tracking how well the conditions encountered support the avalanche forecast upon which the initial trip plan was based. The *AIARE Field Book* provides a standardized format for this purpose, with a “Trip Plan” form on one page and a “Field Observations” form on the adjacent facing page (fig. 17-7). This useful little book also provides basic reference tables and checklists for travel in avalanche terrain. (For more information or to contact AIARE, see Resources.)

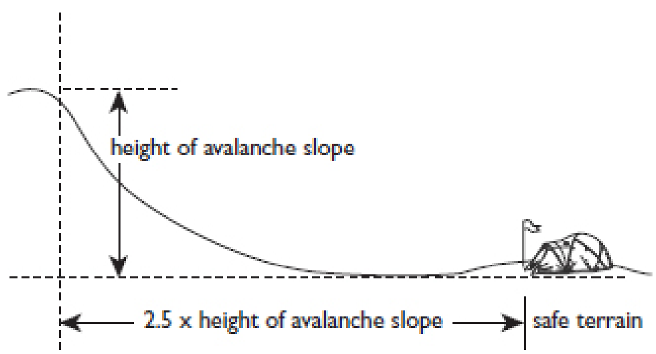
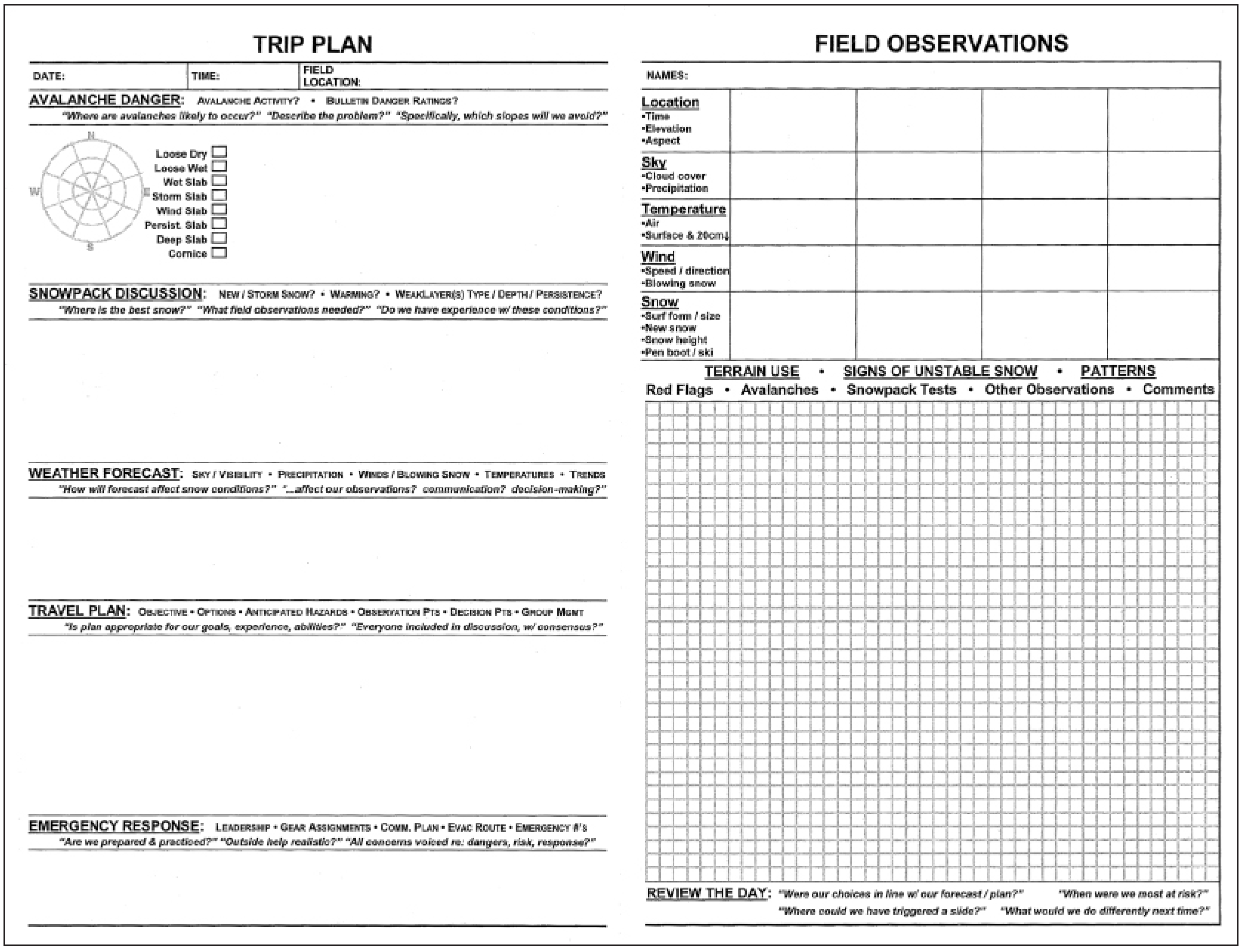


Fig. 17-6. Calculation to arrive at a safe camping zone: the formula requires that the climber accurately determine the full extent of the applicable avalanche slope, but it gives a good idea of where safe terrain can be found below avalanche-prone slopes. Narrow valleys may not have a safe zone.



TRIP PLAN

DATE: | TIME: | FIELD LOCATION:

AVALANCHE DANGER: Avalanche Activity? • Bulletin Danger Ratings?
"Where are avalanches likely to occur?" "Describe the problem?" "Specifically, which slopes will we avoid?"

N
W
E
S

Loose Dry
Loose Wet
Wet Slab
Storm Slab
Wind Slab
Persist. Slab
Deep Slab
Cornice

SNOWPACK DISCUSSION: New / Storm Snow? • Warming? • WeakLayer(s) Type / Depth / Persistence?
"Where is the best snow?" "What field observations needed?" "Do we have experience w/ these conditions?"

WEATHER FORECAST: Sky / Visibility • Precipitation • Winds / Blowing Snow • Temperatures • Trends
"How will forecast affect snow conditions?" "...affect our observations? communication? decision-making?"

TRAVEL PLAN: Objective • Options • Anticipated Hazards • Observation Pts • Decision Pts • Group Mgmt
"Is plan appropriate for our goals, experience, abilities?" "Everyone included in discussion, w/ consensus?"

EMERGENCY RESPONSE: Leadership • Gear Assignments • Comm. Plan • Evac Route • Emergency #'s
"Are we prepared & practiced?" "Outside help realistic?" "All concerns voiced re: dangers, risk, response?"

FIELD OBSERVATIONS

NAMES:

Location •Time •Elevation •Aspect				
Sky •Cloud cover •Precipitation				
Temperature •Air •Surface & 20cm↓				
Wind •Speed / direction •Blowing snow				
Snow •Surf form / size •New snow •Snow height •Pen boot / ski				

TERRAIN USE • SIGNS OF UNSTABLE SNOW • PATTERNS
Red Flags • Avalanches • Snowpack Tests • Other Observations • Comments

REVIEW THE DAY: "Were our choices in line w/ our forecast / plan?" "When were we most at risk?"
"Where could we have triggered a slide?" "What would we do differently next time?"

Fig. 17-7. "Trip Plan" and "Field Observations" forms, reproduced from the AIARE Field Book.

In areas where professional avalanche forecasting is available, climbers should take forecast warnings very seriously. It is never a good idea to enter terrain the forecast declares to be unsafe. In addition, it is important that climbers keep a sharp eye out for unsafe conditions even in areas the forecast has not singled out for extra caution.

The trend in avalanche forecasting is to present the forecast hazards in terms of one or more "avalanche problems," as shown in Table 17-1, excerpted from the *AIARE Field Book*.

For each of the typical "avalanche problems" listed in Table 17-1, there are lists of red-flag observations as well as specific tests and other practical considerations that can help in choosing safe terrain. Note that several of these avalanche problems may exist in the same area and/or at the same time. It is also possible for changing conditions to cause one avalanche problem to morph into another, as when a wind slab warms up and becomes a wet wind slab.

AVALANCHE EDUCATION

The American Institute for Avalanche Research and Education (AIARE) is a nationally recognized curriculum for avalanche educators in the United States, South America, and Europe. The mission is to "save lives through avalanche education" with avalanche training courses reflecting the latest knowledge, research, and ideas in avalanche safety for backcountry travelers. AIARE's goals include increasing public awareness of avalanches and avalanche safety; providing high-quality avalanche education to enhance public awareness and safety; and developing an international network of professional avalanche educators.

TABLE 17-1. AVALANCHES AND OBSERVATIONS REFERENCE

CRITICAL (RED-FLAG) OBSERVATIONS	FIELD TESTS & RELEVANT OBSERVATIONS	IMPORTANT CONSIDERATIONS
THE PROBLEM: LOOSE DRY SNOW		
▪ Fan-shaped avalanches: fine debris ▪ Loose surface snow 12 inches (30 cm) deep	▪ Boots or skis penetrate 12 inches (30 cm). ▪ Slope tests and cuts result in sluffs. ▪ Snow surface texture is loose (as opposed to wind-affected, refrozen, or other stiff snow textures).	▪ Loose-snow avalanche can be triggered by falling snow, cornice fall, rockfall, brief periods of sun, wind, or a rider. ▪ Sluffs can run fast and far. ▪ Small slides are dangerous with terrain traps and/or cliffs.

		▪ Sluffs can trigger slabs in certain conditions.
THE PROBLEM: LOOSE WET SNOW		
▪ Rain and/or rapid warming ▪ Air temperature >32°F (>0°C) for longer than 24 hours (cloud cover may prevent nighttime cooling) ▪ Pinwheels or roller balls ▪ Fan-shaped avalanches: debris lumpy and chunky	▪ Compare observed and forecasted temperature trend. ▪ Temperatures (air, surface, 20 cm deep) and freezing level indicate near-surface snow temperatures at 32°F (0°C). ▪ Note slopes receiving or that will receive intense radiation. ▪ Snow surface is wet: water visible between the grains with a loupe; may be able to squeeze water out with hands.	▪ Timing is critical: danger can increase quickly (minutes to hours). ▪ No freeze for multiple nights worsens conditions; however, nighttime freeze can stabilize conditions. ▪ Gullies and cirques receive more radiation and retain more heat than open slopes. ▪ Shallow snow areas become unstable first—may slide to ground in terrain with shallower, less-dense snowpack. ▪ Loose-snow avalanche may initiate from rocks or vegetation. ▪ Loose-snow avalanche can occur on all

		aspects on cloudy days and nights. ▪ Conditions may also include cornice fall, rockfall, or increased icefall hazards.
THE PROBLEM: WET SLAB		
▪ Rain on snow, especially dry snow ▪ Current or recent wet slab avalanches: debris has channels and/or ridges, high water content; may entrain rocks and vegetation ▪ Prolonged warming trend, especially the first melt on dry snow	▪ Consider loose wet snow observations. ▪ Melting snow surface (rain or strong radiation) of a slab is observed over weak layer. ▪ Tests show change in strength of weak layer due to water and/or water lubrication above crust or ground layer. ▪ Identify depth at which snow is 32°F (0°C). ▪ Monitor liquid water content and deteriorating	▪ Snow temperature of slab is at or near 32°F (0°C). ▪ Loose wet snow slides can occur just prior to wet slab activity. ▪ Possible lag can occur between melt event and wet slab activity.

	snow strength using hardness and penetration tests. ▪ Nearby glide cracks may be widening during rapid warming.	
THE PROBLEM: STORM SLAB		
▪ Natural avalanches in steep terrain with little or no wind ▪ At least 12 inches (30 cm) snowfall in last 24 hours or less with warmer, heavier snow ▪ Poor bond to old snow: slab cracks or avalanches under a rider's weight	▪ Observe storm snow depth, accumulation rate, and water equivalent. ▪ Observe settlement trend: settlement cones, boot or ski penetration, measured change in storm snow (more than 25% in 24 hours is rapid). ▪ Tests show poor bond with underlying layer (tilt and ski tests). ▪ Identify weak layer character.	▪ Rapid settlement may strengthen the snowpack or form a slab over weak snow. ▪ When storm slabs exist in sheltered areas, wind slabs may also be present in exposed terrain. ▪ Storm slab may strengthen and stabilize in hours or days depending on weak layer character. ▪ Potential for slab fracturing across terrain can be underestimated.

	▪ Denser storm snow is observed over less-dense snow (boot or ski penetration, hand hardness).	
THE PROBLEM: WIND SLAB		
▪ Recent slab avalanches below ridgetop and/or on cross-loaded features ▪ Blowing snow at ridgetop combined with significant snow available for transport ▪ Blowing snow combined with snowfall: deposition zones may accumulate three to five times more than sheltered areas	▪ Evidence of wind-transported snow (drifts, plumes, cornice growth, variable snow surface penetration with cracking) is observed. ▪ Evidence of recent wind (dense surface snow or crust; snow blown off trees) is observed. ▪ Moderate (or stronger) wind speeds for significant duration are observed (reports,	▪ Often it is hard to determine where the slab lies and how unstable and dangerous the situation remains. ▪ Slope-specific observations, including watching wind slabs form, are often the best tool. ▪ Strong winds may result in deposition lower on slopes. ▪ Avalanches are commonly triggered from thin areas (edges) of the slab. ▪ Wind transport and subsequent avalanching can occur days after last snowfall.

	weather stations, field observations).	
THE PROBLEM: PERSISTENT SLAB		
▪ Bulletins or experts warn of persistent weak layer: surface hoar, facet and crust, depth hoar. ▪ Cracking and/or whumping	▪ Profiles reveal a slab over a persistent weak layer. ▪ Use multiple tests that will verify location of this condition in terrain. ▪ Small column tests (compression test) indicate sudden results; large column tests (extended column test, propagation saw test, Rutschblock test) show tendency for propagating cracks.	▪ Instability may be localized to specific slopes (often more common on cooler north and northeast aspects) and hard to forecast. ▪ Despite no natural occurrences, slopes may trigger with small loads—more likely when weak layer is 8–36 inches (20–85 cm) deep. ▪ Human-triggered avalanches are still possible long after slab formed.
THE PROBLEM: DEEP SLAB		
▪ Remotely triggered slabs	▪ Profiles indicate well preserved but	▪ Avalanches may be aspect or elevation specific: it is very

▪ Recent and possibly large isolated avalanches with deep, clean crown face	deep (≧3 feet [1 m]), persistent weak layer. ▪ Column tests may not indicate propagating cracks; propagation saw test can provide more-consistent results. ▪ Heavy loads (cornice drops or explosives test) may be needed to release the slope—large and destructive avalanches result.	important to track a weak layer over terrain. ▪ Slight changes, including moderate snowfall and warming, can reactivate deeper layers. ▪ Terrain may be dangerous after nearby activity has ceased. ▪ Tests with no results are not conclusive. ▪ Avalanches may be remotely triggered from shallower, weaker areas; it is difficult to forecast and manage terrain choices.
THE PROBLEM: CORNICES		
▪ Recent cornice growth ▪ Recent cornice fall ▪ Warming: solar, rain at ridgetops	▪ Note rate, extent, location, and pattern of cornice growth and erosion. ▪ Observe photos tracking change over time.	▪ Cornices often break farther back onto ridgetop than expected. ▪ Sun's effect on back of cornice can be underestimated during travel on cool, shaded aspects.

Source: AIARE.

Focusing on the relevant avalanche problems makes it easier for a team to concentrate on avoiding the most dangerous terrain, as well as on making more relevant observations; however, the potential for discovering additional avalanche problems should never be ignored. Choosing safe terrain based on an understanding of specific avalanche problems can also help prevent a tendency to rely too much on the generalized "Danger Level" categories used by forecasters. In North America the North American Public Avalanche Danger Scale (fig. 17-8) provides an overall rating of avalanche danger levels; similar danger scales are used in other parts of the world. It is crucial to realize that even when the overall danger is moderate or even low, potentially deadly avalanches can occur in specific terrain and conditions. Studying the relevant avalanche problems is one way to stay focused on avoiding these specific danger areas.

North American Public Avalanche Danger Scale

Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level	Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	Very dangerous avalanche conditions. Travel in avalanche terrain not recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

Fig. 17-8. North American Public Avalanche Danger Scale.

CONSIDER HUMAN FACTORS

In evaluating avalanche hazard, a prime component is the human factor. The judgments that mountaineers make affect the level of risk they face. In terms of avalanche safety, the term "human factors" has come to represent the whole constellation of psychological foibles and mental shortcuts that lead people to make poor decisions when they encounter hazardous conditions. In hindsight, most avalanche survivors can point to various human factors that were the pivotal causes in the chain of events leading up to the mishap. It is worth studying troublesome human factors in more detail than is covered here (see Chapters 22, Leadership, and 23, Safety). A few of the more common human factors include these:

- **Peer pressure:** Feeling that you must do the same things as others so that they will like you.
- **Overconfidence:** Having too much confidence in your ability or assessment of a situation.
- **Familiarity:** The tendency to assume that familiar places are safe places.
- **Rule-following:** Using rules of thumb instead of careful thought.
- **Momentum:** The tendency to just keep going rather than considering alternatives.
- **Euphoria or hypoxia:** The heightened state of physical excitement that comes with strenuous exercise in a thrilling environment, which can have an insidious negative impact on clear thinking.
- **Large group size:** The tendency for large groups to inhibit communication and thus replace good decision-making processes with the herd mentality.
- **"Expert halo":** The tendency for people to blindly follow a leader or, even worse, to blindly follow tracks left in the snow by a group of strangers.

Communication

Good communication—and participation by all members in the group—is the most effective way to promote good decision making and to reduce the bad effects of those unavoidable human factors. Before setting off into the backcountry, a party should agree on a process for making decisions as a group. The party should agree on its goals, acceptable level of risk, and understanding of the hazard data each member has been collecting. Consider and discuss the party's tolerance for risk and its degree of commitment to a climbing objective even in the face of hazard. Determine how willing the group is to look objectively at information on terrain, the snowpack, and weather.

Fig. 17-9: Good communication keeps the group focused on important observations and evaluations of avalanche hazards, terrain, snowpack, and weather.

Many parties allow their desires to cloud the hard facts. Most avalanche victims were aware of the hazard but chose to interpret the information in such a way that an accident occurred. An unsafe attitude can be fatal. Good communication defeats human-factor trouble by keeping the group focused on important observations and evaluations, by providing a valve to release social pressures and by recruiting all the eyes and minds in a group instead of depending on one person to think of everything. For instance, sharing the tasks of making observations can allow a group to gather more data while also moving faster.

Parties make the best decisions when they work together to make a travel plan and gather data, then reevaluate the plan as a group once they are in the field (fig. 17-9). Groups that take each person's thinking into account usually make better decisions than individuals. All climbers in the party have an obligation to express their concerns clearly and freely, even in the face of differing opinions. When the party faces the risk of fatalities, it is essential that every climber be ready and able to communicate prudent reservations with the rest of the group.

It is particularly important to avoid the powder fever that so often takes over on the first blue-sky day after several days of storm and a couple of feet of new snow. Each person must understand the possible consequences of decisions and any alternatives. Everyone should understand any assumptions underlying the decision to enter avalanche terrain, including assessments of the party's risk tolerance and its ability to deal with an avalanche.

The decision-making process should be based on group discussion and should cover these areas:

1. Identify potential hazards.
2. Collect, evaluate, and integrate information continuously during trip.
3. Consciously explore assumptions, the consequences of a particular decision, and all alternatives to that decision.
4. Make a decision—but be willing to reevaluate based on new information.

It can be very useful to formalize this decision-making process by identifying one or more places along a route where decisions may need to be made and marking these down in the trip plan or on a map, to ensure that the group takes time to reevaluate conditions and discuss options as a team.

Technical Skill Level

How skilled are members of the party at snow travel and at evaluating avalanche hazard? Are the party's overall mountaineering skills high? Just average? Low? In theory, a balanced party of able, experienced mountaineers can be expected to do well at avoiding avalanches and at responding efficiently if one strikes. In fact, experienced and knowledgeable climbers are caught by avalanches every year, and this is nearly always largely due to errors of judgment because of human factors and not because the party was unaware of the hazard. A relatively untested party, or one whose members have a great difference in experience and skill levels, must be extra conservative in its decisions.

Strength and Equipment

What shape is the party in? Decide whether members of the group are strong and healthy enough to go on a demanding and possibly hazardous trip. How well equipped is the party to deal with an avalanche? Determine whether the party is adequately prepared, with shovels, rescue transceivers, avalanche probes, first-aid supplies, and other gear that would be needed in case all precautions fail and the party is involved in an avalanche.

USING THESE SKILLS IN THE FIELD

Once climbers have learned (and practiced) the fundamentals of avalanche safety, they must use these skills in the backcountry. Identifying avalanche terrain or suspect weather patterns is not enough; climbers must know how to put it all together. This section helps prepare climbers for making decisions and taking action in the backcountry. As with other aspects of avalanche safety, practice the techniques before you end up in hazardous terrain or are involved in an avalanche rescue.

OBSERVING SNOW CONDITIONS

Climbers should understand the terrain they are heading into before they get there and include in the trip plan where and when the most relevant observations might be made. Look at conditions on similar terrain as soon and as often as possible. Observe the big picture first: on the road, up the trail, at camp, out on the terrain. Then fit the party's plans and situation into that picture. Use this perspective to decide where the party might test the snow for its stability and what tests will be used, and also use this perspective to aid the party in avoiding avalanche hazard.

There is often tremendous variability in the snowpack from place to place. This means that testing the snow in one place does not mean the snow is stable anywhere else. For this reason, snow stability tests should be used to gain a general understanding of local conditions and to look for any unexpected signs of danger—but snow stability tests should *not* be used to predict the stability of adjacent slopes. In other words, if the overall conditions lead a party to conclude that a slope may be dangerous, then the climbers should never change that forecast based on field tests that happen to show a stable result. On the other hand, if the party's forecast was for good stability and a local test of the snowpack uncovers unstable conditions, the climbers should assume that other unstable areas may exist on similar slopes.

To travel safely in the backcountry, climbers must be able to recognize unstable conditions. Generally, when unstable snow conditions exist, the majority of results from observations and tests will confirm that conditions are unstable on certain slope aspects, at certain elevations, and within a certain range of slope angles. Because there will be some uncertainty, particularly when the weather is changing, an extra margin of safety is required. Always make observations, looking for obvious signs of instability. Use the major clues shown in Table 17-1 in the preceding section.

Snowpack Observation Techniques

It is often more practical to make many quick tests and observations of the snowpack as a climbing party maintains steady forward progress than it is to stop and carry out scientific snow stability tests or dig full-scale snow pits (fig. 17-10) to gather detailed observations from a single location. Nevertheless, it is a very good idea for those who travel in avalanche terrain to familiarize themselves with the range of stability tests and snow observation techniques that professional forecasters use to understand the snowpack.

Full descriptions of these tests are beyond the scope of this text, and they are much better learned in the snow by taking an avalanche course. Learning how to carry out these tests provides the backcountry traveler with tools for looking deeper into the snowpack and understanding how weather affects the snow. Knowing how to conduct these tests will also help climbers understand the basis for avalanche forecasting. It is a very good idea to practice these tests and dig snow study pits, when time allows, for the knowledge you can gain. Comparing what you actually find in the snow to the data and discussion gleaned from avalanche forecast reports can yield a much deeper understanding of avalanche hazard. Stability tests can also be a useful way to look for unexpected danger in the snowpack, but they have limited value in decision making since one or more tests that indicate a stable snowpack can never be used as a basis for entering avalanche terrain in questionable conditions.

Fig. 17-10. Evaluating layers in a correctly constructed snow pit.

A well-equipped climbing party may carry tools to evaluate the snowpack. A snow study kit with a snow crystal card, a clinometer, and a snow saw help in analysis of slopes and the snowpack. Climbers well-educated in avalanche safety should understand the procedures and terminology used in the extended column test (ECT; fig. 17-11), Rutschblock test (RB), compression test (CT), propagation saw test (PST), and any other tests commonly performed by professional forecasters in their part of the world. It also pays to learn the correct methods used in making snowpack observations, as well as the standardized ways of noting the data from these tests and observations. Full profiles are dug in the snow to allow a close inspection of the layers in the upper 3 feet (1 meter) of the snow. They allow a detailed look at the snowpack, but they are time-consuming to do properly and represent only a single sample in a vast landscape. In the United States, level 2 avalanche courses cover this material and introduce people to the basics of snow science and forecasting.

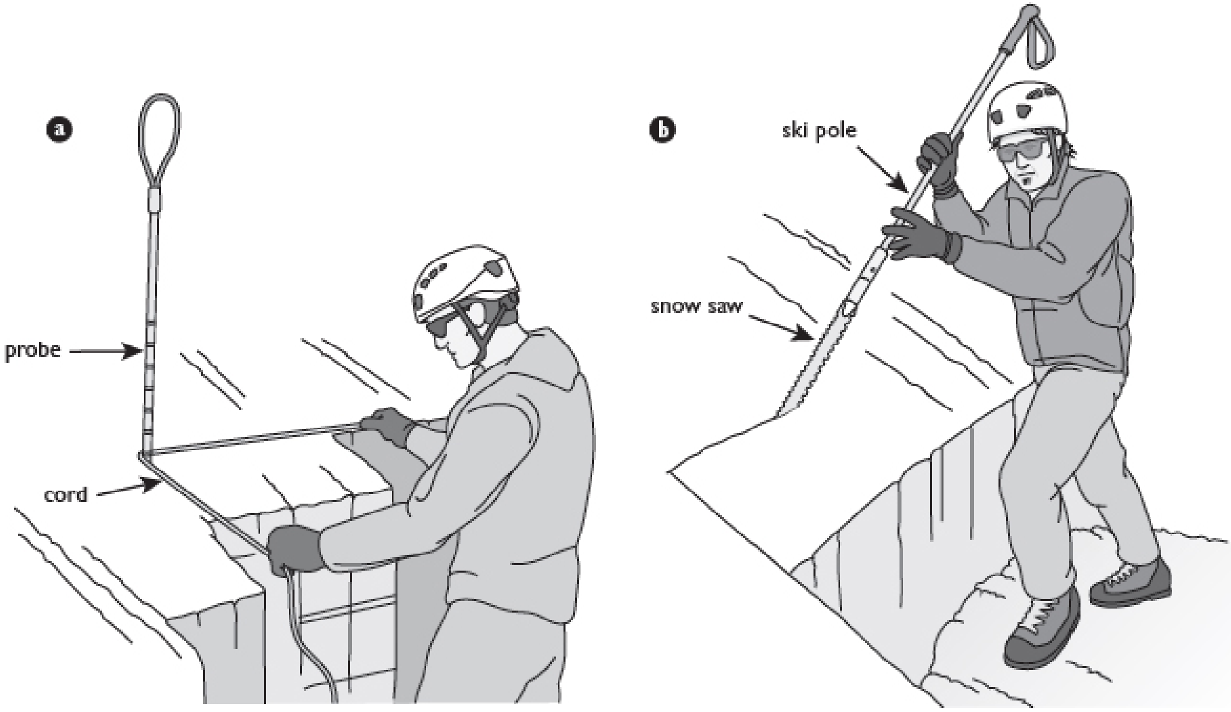


Fig. 17-11. Isolating the snowpack column for an extended column test: a, using a probe and cord to cut a column; b, a snow saw on a ski pole to cut a column.

Test profiles, quickly scooped in the snow by hand or shovel, can give an idea of what is going on in the near-surface layers of the snowpack. It is a good idea to regularly push your ski pole or ice-axe spike into the snow as you travel along to feel for weaker and stronger layers. If the snow is very soft, push the basket end of a ski pole smoothly into the snow; then pull it slowly out, trying to feel any hard or soft layers. It may be possible to reach down into the ski-pole hole and feel the snow layers with your fingers. In most other snow, remove the basket or use the handle end of the ski pole to penetrate the snow. Usually only the top 39 to 48 inches (100 to 120 centimeters) of snow needs to be observed in assessing snowpack stability because the stresses generated by a climber or skier generally will not penetrate more than about 33 or 34 inches (85 centimeters) into the snow.

Regularly making these test-profile observations and discussing them with party members reinforces an awareness of avalanche hazard and preparedness. These informal tests will not give information on the bonding of snow layers and they will miss thin shear planes, but they can reveal gross discontinuities in the snowpack structure that suggest instability.

MAKING DECISIONS IN THE FIELD

Making a decision about whether or not to enter avalanche terrain can be a vexing problem. The variables that go into the decision can be complex and often seem contradictory. Add to this that social and time pressures can make it hard to think calmly, and it is easy to see how people often make the wrong decision and enter unsafe terrain when they shouldn't.

It is often best to think in terms of the party's levels of certainty, instead of agonizing over the particulars in an attempt to come up with a simple decision of "go" or "no go." Take a hard look at the information available and then determine whether or not there is enough information to make a safe decision *based on the available data and the skill and experience of the party.* If you look at the information available to you and cannot decide whether the terrain is safe, then there is simply too much uncertainty to proceed safely. In this situation, it is best to choose to travel on alternative terrain that you are certain will be safe for your party in the conditions. Be sure that every trip plan includes a safe alternate destination.

When a party encounters potential hazard along the way, ask these questions:

1. Do current observations still support the assumptions behind the trip plan?
2. Is the snow unstable?
3. Could I be a trigger?
4. Is the weather contributing to instability?
5. What are the alternatives and their possible consequences?

To respond effectively to these overall questions, the party should come up with answers to a series of secondary queries about the big picture—terrain, snowpack, weather, the climbing party itself—thinking holistically and applying concrete observations and information.

USING SAFE TRAVEL TECHNIQUES

Even after a party has made every effort to choose terrain that is safe in the existing conditions, it can be a good idea to use travel techniques designed to add a layer of safety when crossing a potential avalanche slope. The task is to travel with the least danger of disturbing the slope and to minimize the consequences of a possible avalanche.

Prepare Clothing and Gear

Just as during travel on a crevassed glacier, it may make sense to put on a hat, mittens, and warm clothing and to zip up clothing. Undo ski-pole straps. Use releasable bindings on skis or snowshoes, and remove the safety straps that connect boots to the bindings. (Skis and snowshoes spread a person's weight over a relatively large area, putting less strain on the slope than boots do.) Stow all essential gear securely inside packs, including vital avalanche rescue tools such as shovel and probe; if these are strapped to the outside of the pack, they will likely be torn away and lost in an avalanche, just when they are needed most. If you are using an airbag, such as an AvaLung, make sure it's ready to deploy.

Choose a Safe Line of Travel

When the route lies up a slope (and the party is walking, not skiing), head straight up the fall line instead of switchbacking, which can undercut the snow. However, a straight line up the mountainside may not be as safe as a more meandering route that seeks out lower-angle terrain and avoids convex rollovers and exposure to terrain traps. Always look ahead and make use of topographical maps to avoid routes that dead-end in unsafe terrain. The route should follow a line as high on the slope as practical. It may be possible to hug cliff bands at the top of the slope. Choosing the most efficient and safe line up a mountainside while setting a skin track is an advanced skill in which experienced ski mountaineers take great pride. The fastest line is never the steepest one.

Stay Together

On a tricky traverse, only one person moves at a time, and everyone else watches from safe places, ready to shout if a slide starts. (Alternatively, the group may spread out and travel far apart simultaneously, but within view of each other.) Cross with long, smooth strides, being careful not to cut a trench across the slope. Each climber follows in turn, stepping in the leader's footprints or skiing in the same track. Everyone listens and watches for an avalanche. It is not always best practice to spread out or travel one at a time: in very low visibility it is often safer to stay close together. Never let any member of a group out of sight of others. The best way to ensure this is to pair people up to look after each other; using the buddy system can prevent an individual from getting separated from the group, or buried, without anyone noticing. Move from one position of safety to another, minimizing the potential exposure period. Do not fall; falling puts a sudden load on the snowpack. On an avalanche-ready slope, the impact of a falling body can be like the detonation of a little bomb. Be aware of other parties; try not to travel or ski above others moving up the slope.

Rope Up or Not?

Think twice before roping up on questionable slopes. Decide whether the risk of the slope avalanching is greater than the risk of a climber falling, because roping up can risk the belayer being pulled into an avalanche. If the party chooses to use a rope, belay directly off the anchor; the belayer should not tie in to the rope, to avoid being pulled into an avalanche. If there are no solid anchors from which to belay, it may be better to go unroped.

SURVIVING AN AVALANCHE

Climbers must think ahead about what they would do in the event of an avalanche, because after one starts, there is no time. While traveling, keep an eye out for escape paths.

If you are caught in an avalanche, do not give up. Fight to survive. Try to get off the moving snow. Yell to your climbing partners. Jettison any gear you want to get rid of, including skis and ski poles. It is a good idea to keep your pack on to protect your back and neck. Larger objects tend to be transported to the surface of avalanche debris; the pack may help keep you near the surface, and it may help protect you from trauma. If you survive the traumatic forces of the avalanche, you will need the clothing and equipment in the pack.

At the start of an avalanche, try to stop before being swept away. Grab a rock or tree, or dig your ice axe or a ski pole into the snow, and hold on. If that does not work, try to stay on the surface by using swimming motions, flailing your arms and legs, or by rolling. Try to move to the side of the slide.

If your head goes below the surface, close your mouth to avoid being suffocated by snow. As the avalanche slows, thrust upward. If you are buried, try to make a breathing space by putting an elbow or hand in front of your face. Inhale deeply before the snow stops, in order to expand your ribs; as the snow closes around you, you won’t be able to move. Do not shout or struggle. Relax. Try to conserve oxygen and energy. Your climbing partners should know what to do, and they will begin rescue efforts immediately.

RESCUING A COMPANION IN AN AVALANCHE

The mountaineer's primary emphasis should be on avalanche evaluation and safe travel. Rescue skills are very important, but it is vital to keep in mind that they cannot keep you safe; self-rescue is the last resort, to be used when you have failed to stay safe. Every party needs avalanche rescue skills and equipment, but these are no substitute for the ability to make sound judgments that promote safe travel in avalanche terrain. If an avalanche does occur, this section covers what to do. Also, Resources, at the back of the book, lists several widely available books about avalanche rescue, as well as online resources such as www.avalanche.org, a comprehensive website run by several avalanche research organizations that provides international statistics, links to avalanche courses, and links to avalanche information centers.

When buried in a snow avalanche, people very seldom live long enough to be rescued by people who are not close by when the accident occurs. It can often take hours, or even days, to bring in rescuers from outside to the scene of an avalanche. A victim who survives the physical trauma of an avalanche almost always depends on companions to dig him or her up quickly, before the victim suffocates or dies of hypothermia.

THE WELL-PREPARED PARTY

A climbing party's level of preparedness is an important factor in minimizing avalanche hazard. A well-prepared party has the training and practice, conditioning, equipment, and critical judgment to evaluate avalanche hazard and to respond effectively to an avalanche if one occurs. Each climber should carry a digital triple-antenna avalanche rescue transceiver, shovel, and commercial avalanche probe 104 inches (265 centimeters) or longer to perform a rescue, and they must have developed the skills to use them. They know that seconds—not minutes—count should an avalanche occur.

The well-equipped party may carry new products to help avalanche victims survive, including the Black Diamond AvaLung II and avalanche air bags. Research and try out any avalanche safety item before relying on it in the backcountry.

AVALANCHE RESCUE TRANSCEIVERS

The digital avalanche rescue transceiver, often called an *avalanche beacon*, is the principal tool for finding buried victims. Rescue depends on each member of the party carrying a transceiver. A rescue transceiver can be switched to either transmit or receive signals. Digital transceivers convert the analog signal to a digital readout, and they typically provide both audible and visible signals in the receive (search) mode. The international standard frequency for avalanche transceivers is 457 kilohertz; transceivers that work at 2,275 hertz are obsolete and should not be used.

Continued progress in the avalanche safety field has produced transceivers with increasingly sophisticated digital processor capabilities. Older analog and newer digital transceivers are compatible, and both types use the 457-kilohertz standard frequency. But modern digital transceivers are much more effective than the old analog versions. Use a modern digital transceiver with three or four antennas. The recommended transceivers for backcountry travelers and climbers operate exclusively at 457 kilohertz and use three or more antennas for the most accurate readings and fastest search. It is not necessarily an advantage to use the models with the most features, which can be confusing in an emergency; the current simple transceiver models can be excellent.

A valuable feature of newer digital transceivers is their ability to quickly separate and isolate signals in a multiple-burial scenario in which two or more victims have been buried. Some people argue that multiple-burial scenarios are rare; however, they do occur, and even in a single-victim burial if a searcher inadvertently reverts to transmit, it is very useful to have a transceiver that can let searchers know whether multiple transceivers are in transmit mode.

The various models do not have consistent features or controls, so it is important to study the instructions that come with the receiver, and it is not a bad idea to learn something about how your companions' transceivers work in case you need to use one in an emergency. All members of a party must know how to use the transceivers correctly. This skill requires regular practice, so practice before and during every season. The same thinking applies to phones or other communication devices: all team members should know how to turn on all devices and call for help.

Preparing to Travel

At the trailhead and at the beginning of each day, the group should verify that all transceivers can transmit and receive signals properly. Fresh batteries usually last for about 300 hours (a lot less time when used in search mode), but carry extras in case the signal from any transceiver weakens. Test the battery life of your transceiver while practicing search methods. Always check the charge level before you head out and try to determine where on the battery-level-indicator scale you need to change the batteries in order to ensure that there will always be enough power left to carry out a search in an emergency.

Strap the transceiver around your neck and torso. Carry it under clothing, just outside your innermost garment, to keep it from being lost in an avalanche. Do not carry it in your pack. Carrying the transceiver inside a secure zipped front pants pocket has also been determined to be safe, but use a leash to secure the device to you as well. During the climb, leave transceivers on, set to the transmit mode. When you are staying overnight in a snow cave or in an avalanche-prone area, consider leaving the transceiver on, set to transmit, even at night.

Cellular phones, radios, GPS devices, MP3 players, and other electronics have been shown to interfere with the function of avalanche transceivers. Consider turning such devices off (or putting them in “airplane mode”) if they are not needed for travel or communication; if they are turned on, keep them 12 to 20 inches (30 to 50 centimeters) away from where the transceiver is stowed on your body. For instance, you might carry a radio in the top pocket of your pack if the transceiver is low on your torso.

FIRST STEPS IN A RESCUE

Climbers may need to consciously control their feelings of shock and anxiety in order to be effective at trying to find the missing person(s).

Identify the Area Where the Victim Was Seen Last

The rescue effort starts even before the avalanche has stopped. In the shock of the moment, the first step in a successful rescue is a tough one: pay attention to the point where a victim is last seen. Identify the area to be searched based on this last seen area. Do a head count to make sure you know how many are missing.

Select a Search Leader

Choose a search leader to direct a thorough and methodical rescue effort. Before entering the search area, the leader considers the safety of the search party: evaluate the potential for other slides in the area, choose a safe approach to the search area, and designate an escape path in case of another avalanche. It is usually easier to move downhill while searching. The leader assigns tasks to make the best use of the available people. If the search party is large enough, the leader should stand back and avoid hands-on participation in the rescue process, which can narrow the leader's focus and prevent effective leadership. Only enough people to cover the search area are needed to proceed with the initial transceiver search.

If someone is available, it is often a good idea to have that person make an initial call to alert outside rescuers to the situation, even to simply report the ongoing search and the party's location and arrange to call back. It can take a long time to mount a search by outside search and rescue organizations, and in the event that a trauma victim needs evacuation, the leader should start this process right away. Sometimes, with a long downhill search zone, there may not be a signal at the bottom of the slope, so it might be a long time before the call can be made if it is postponed too long. On the other hand, if everyone is needed to carry out an effective companion rescue, it may be best to postpone the call for help until after the victim is recovered.

Do Not Go for Help

A critical principle of avalanche rescue is this: Do not send anyone for help. Stay and search. Survival depends on locating the victim quickly. A person located in the first 15 minutes has an approximately 90 percent chance of survival if he or she survived the avalanche and did not hit rocks or trees or suffer trauma. The probability of survival drops off rapidly after that time. After 90 minutes, the probability of survival is approximately 25 percent. Wait until after the victim is unburied or after search efforts turn out to be futile to send someone for help.

Prepare to Search

Once a search begins, unstrap the transceiver and bring it out for rescue work; all rescuers must switch their transceivers to the receive mode to locate the transmission from a victim. It is critically important that every searcher switch to receive; if a searcher's transceiver is left in the transmit mode, searchers will waste valuable time receiving this signal rather than the victim's signal.

Each searcher listens for beeps and watches an optical display to detect the buried victim. A rescuer should be able to locate the buried victim in less than 5 minutes once a signal has been acquired. It is essential to practice using rescue transceivers to ensure that searchers have the best chance of locating victims before they suffocate.

Commence Searching

Work rapidly but efficiently. Don't forget to search with your eyes. Try to determine if anyone can point out the last place the victim was seen, then move quickly into the transceiver search. Searchers should remember to look for items of clothing or other clues and consider the location of terrain traps where a person might be lodged. Searchers not needed for the transceiver search should quickly follow the transceiver searchers while deploying their probes in readiness. All searchers should keep their packs and all emergency gear with them if they can.

THREE PHASES OF A SEARCH WITH A MODERN DIGITAL TRANSCEIVER

The digital transceiver search for an avalanche victim or victims occurs in three phases: coarse, fine, and pinpoint.

Phase 1: Coarse Search

In the coarse search phase, a signal has not yet been detected. The searchers start from the victim's last-seen point and fan out no more than 65 feet (20 meters) apart—about the effective range of a modern digital transceiver (with an overlap for an extra margin of safety)—across the slope, each moving straight down the fall line with their transceivers in receive mode until a signal is picked up (fig. 17-12a). If there is no clear last-seen point, then the searchers much check the entire slope. *Note:* A lone searcher must switchback down the slope with no more than 65 feet (20 meters), the effective range of the transceiver, between switchbacks (fig. 17-12b).

Once a signal is detected, some searchers can move to the fine search while other rescuers prepare to dig out the victim. If there is more than one victim, the rest of the rescuers continue the coarse search until all are found. Modern transceivers should allow a continued search without any need to turn off the recovered victim's transceiver. Try to avoid turning anyone's transceiver off if at all possible, in case another avalanche comes along.

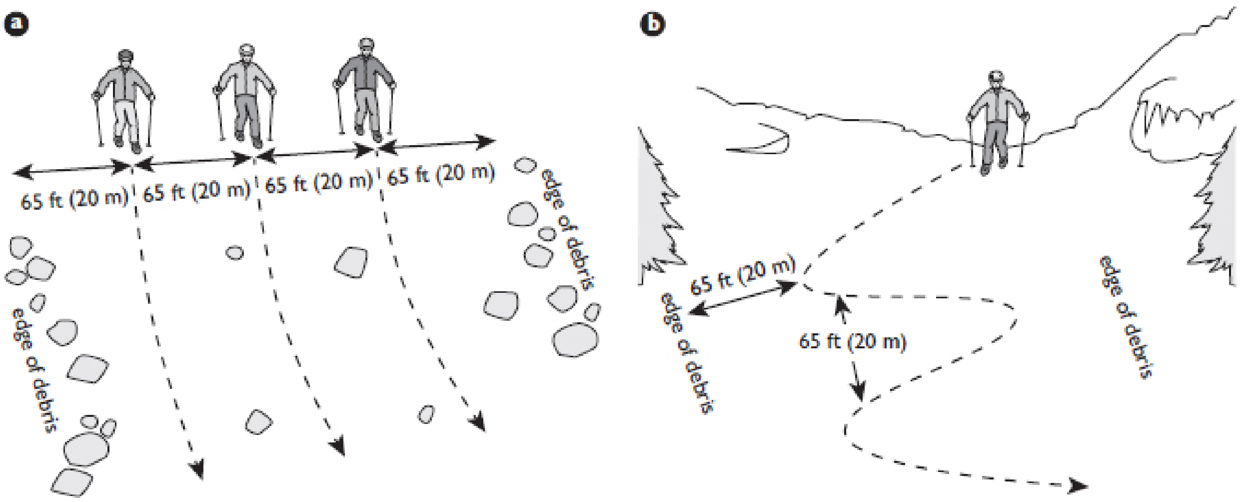


Fig. 17-12. Paths taken during a coarse search phase: a, multiple searchers; b, single searcher. Space the search paths closely enough to stay in range of the victim's transceiver.

Phase 2: Fine Search

The fine search phase begins when the searchers detect a signal. Use the directional lights and distance meter on the transceiver to follow the signal to roughly where the victim is buried. This will often be a curved path, as the transceiver is following the induction line. The induction line follows a curved path because the radio signal transmissions from the victim's transceiver are propagated outward in a curved shape.

Move as quickly as is practical during this phase. The digital distance readout on a transceiver is not ultraprecise, but it gives a good idea of the distance to the victim's transceiver beneath the snow. After practicing searches with your transceiver, you will begin to get a good idea what the distance readings mean and you will become familiar with the range of curves that search lines may follow. This experience will greatly improve your search times, and such practice can teach you how best to pace yourself to get through the search quickly but without moving so fast that you outpace the transceiver's processor or make mistakes that waste time.

Phase 3: Pinpoint Search

Once a searcher is within roughly 10 feet (3 meters) of the victim, the pinpoint search begins, and the searcher slows down even more, and moves the transceiver as close as practical to the surface of the snow. At this point it is usually best to remove skis to make it easier to get right down on the snow and move with precision. You will need to take skis off in order to dig, in any case.

Search along a straight line to try to pinpoint the victim more closely (fig. 17-13a). Ignore the transceiver's directional arrows and audible signals from this point on (some beacons switch them off automatically at this stage) and use only the distance indicator numbers to find the point along this straight line that is closest to the victim. As you move along the line, maintain a steady speed, not too fast, and keep the transceiver oriented exactly the same way—do not swing it back and forth or orient it at different angles, which will reduce the precision of the distance readout. It is critically important to practice with your transceiver, since there are subtle differences in operation and sensitivity between the various models.

At some point along the line, you will see the distance numbers dip to a low point and then start to climb again. Make a mark in the snow at the first point where the distance number went up again and then move back along the line (without changing the transceiver orientation) at the same steady pace until the number dips low and rises to the same higher number again, then mark this point. Now you have two marks along your straight line. Precisely mark the midpoint of the span between the marks. This is the point along your first line where you are closest to the victim, but you may not yet be directly above the victim.

Now strike a line exactly perpendicular to your original line that crosses it at this close-to-the-victim point (fig. 17-13b). Follow along this second line in either direction (again, with the transceiver in the same orientation it has been in all along) until you again find the lowest distance reading by marking the two points where the reading first rises above the low and then marking their midpoint. The victim should be below this mark.

Probe at this point and *be sure to probe perpendicular to the snow surface* instead of straight up and down (fig. 17-14). The shortest distance from the closest point detected by a transceiver will be along a line perpendicular to the snow surface; probing on a plumb line from this point can easily miss a buried person.

Commercial avalanche probes work far better than any other alternative. However, to find a buried victim, use whatever is at hand as a probe, including commercial avalanche probes, ski poles, ice axes, or wands. Carry a real avalanche probe and a sturdy metal shovel. Ski-pole probes and plastic shovels have a reputation for failing.

If you have done a good job, you will often strike the victim with this first probe, even with a deep burial. Less-proficient searchers may have to continue probing in a spiral pattern outward from this point, moving in 10-inch (25-centimeter) increments out from the closest point found in the transceiver search. Take care to keep the angle of your probe very consistently parallel to previous probes so as not to miss the victim due to sloppy probing. Probe down to a depth of 61/2 feet (2 meters). People are sometimes buried more deeply but in these cases they are less likely to survive long enough to be dug out. As soon as the person is located, leave the probe in place, touching the victim, and begin digging.

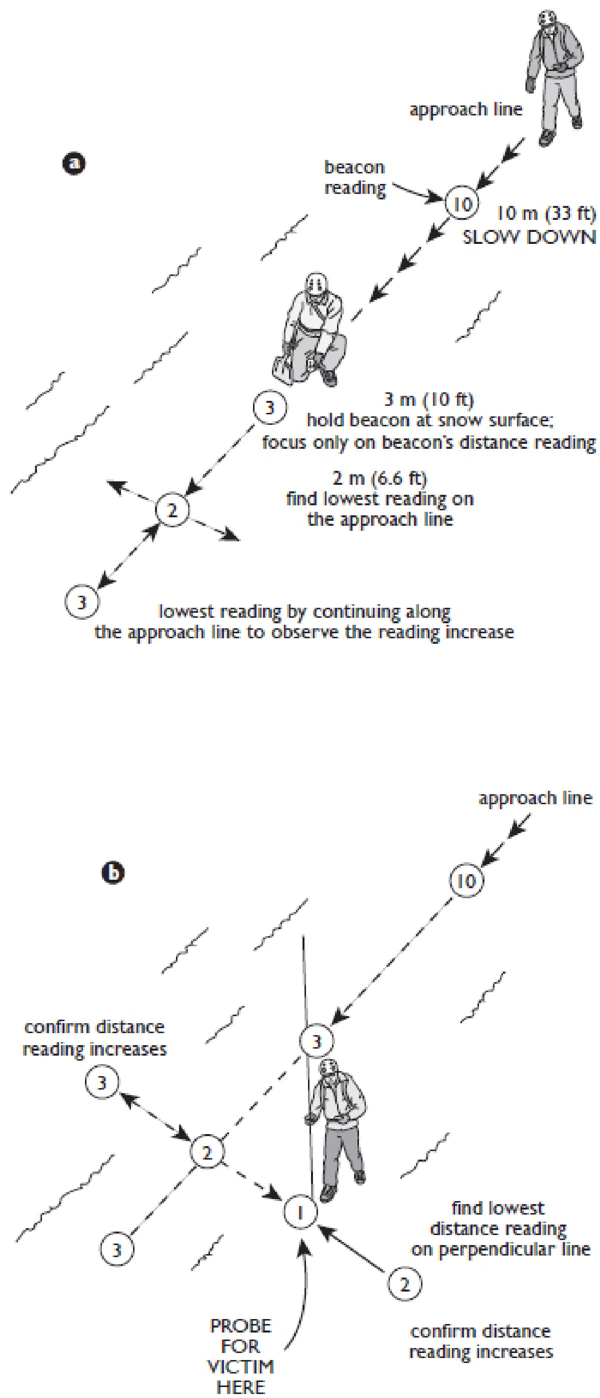


Fig. 17-13. Steps of a pinpoint search: a, When beacon reads 33 feet (10 meters), slow down. Continue until the beacon displays a higher distance reading. Mark this point, then return along the line past the lowest reading and back until the reading rises again, and mark this point; b, Now strike a new line perpendicular to the approach line at the midpoint between these marks. Repeat the process to find the closest point to the victim along this second line, and probe for the victim here.

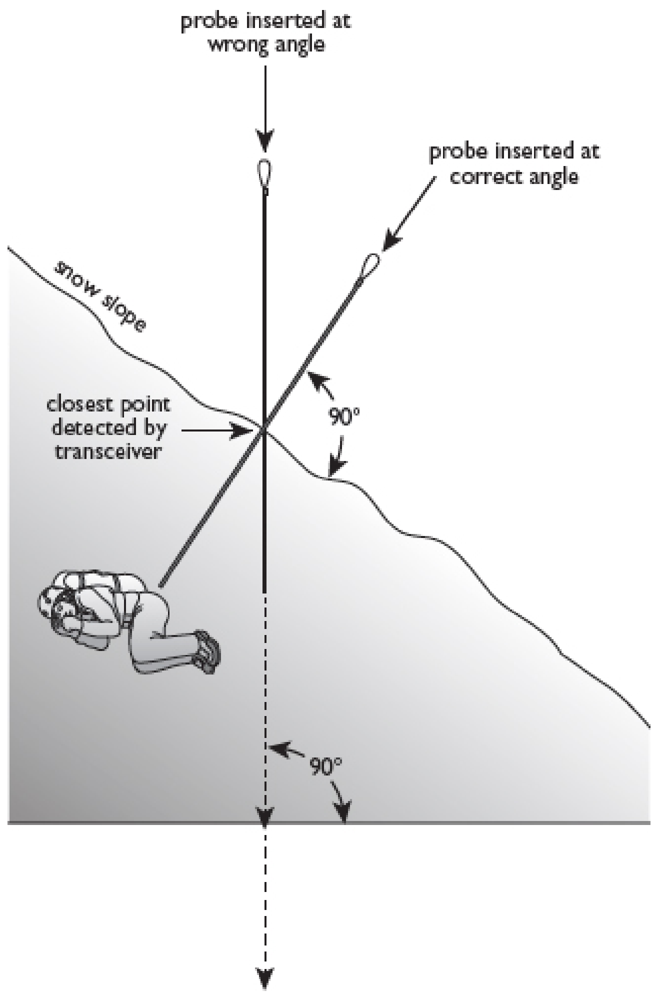


Fig. 17-14. After locating victim with a beacon, insert probe perpendicular to the slope. Inserting probe on a plumb line may easily miss the victim.

PROBE SEARCHES

Probing is a slow and uncertain mechanical process, but it may be the only alternative if rescue transceivers fail to locate a victim or if the party is traveling without transceivers. Probe first at likely areas: near pieces of the victim's equipment, at the points of disappearance, and around trees and rocks. Probing in a group is a skill that must be practiced before it is needed. It is hard work involving discipline and concentration. In the backcountry, there may not be enough people to carry out formal probe procedures. Systematic probing involves a group of people working in a line, with probes always held plumb and probing in unison in a grid pattern so as not to miss the victim.

EFFICIENT SHOVELING AND RECOVERY

After locating the victim using the pinpoint search, take care to avoid injuring the victim with probes or shovels or otherwise endangering the person being rescued. Some victims report that the most terrifying part of their avalanche experience was having their air space trampled on as they were being rescued. Nevertheless, don't hold back: dig as fast as you can while following a systematic and efficient process and working as an organized team. Practicing efficient shoveling methods with your climbing team is a very valuable exercise that has certainly saved lives.

Expect to work very hard: snow in an avalanche undergoes a transition as it slides, and it sets up like concrete when it finally comes to a stop and settles. Digging out the victim is the hardest and most time-consuming part of companion rescue. The goal in any recovery effort is to first uncover the victim's face and chest to get an airway established.

Start shoveling on the downhill side, away from the victim at a distance of approximately one and a half times the estimated depth of the probe to the victim. Move snow downhill. Excavate either in steps or at an angle to the victim, rather than straight down (fig. 17-15). The search leader should organize the shovelers so that one person at a time spearheads the shoveling; the others should hang back and extend the digging area while also sweeping the lead digger's snow piles and chunks out of the way. Diggers should take turns in the lead position, rotating very frequently to avoid slowing due to fatigue. The goal is to keep a wide area open behind the lead digger where snow can rapidly be cleared away. This method is much faster than tunneling straight down, even though it moves more snow, plus an open and relatively level area may be very important if the rescuers need to extract and treat a trauma victim.

As the victim is uncovered, check to see that the person's mouth is not filled with snow and that there are no other obvious obstructions to breathing. Clear snow away from the victim's chest to allow room for it to expand and take in air. Be prepared to start cardiopulmonary resuscitation (CPR); the person need not be fully extracted from the snow before CPR begins. Be aware that suddenly moving a burial victim may cause cardiac failure as cold blood from the extremities moves to the heart (read more about "afterdrop" in "Hypothermia" in Chapter 24, First Aid). Make the person as warm and comfortable as possible, and be prepared to treat for hypothermia and injuries (see Chapter 24, First Aid).

Once it is determined that the rescued individual does not need urgent care, continue to search for any other buried victims.

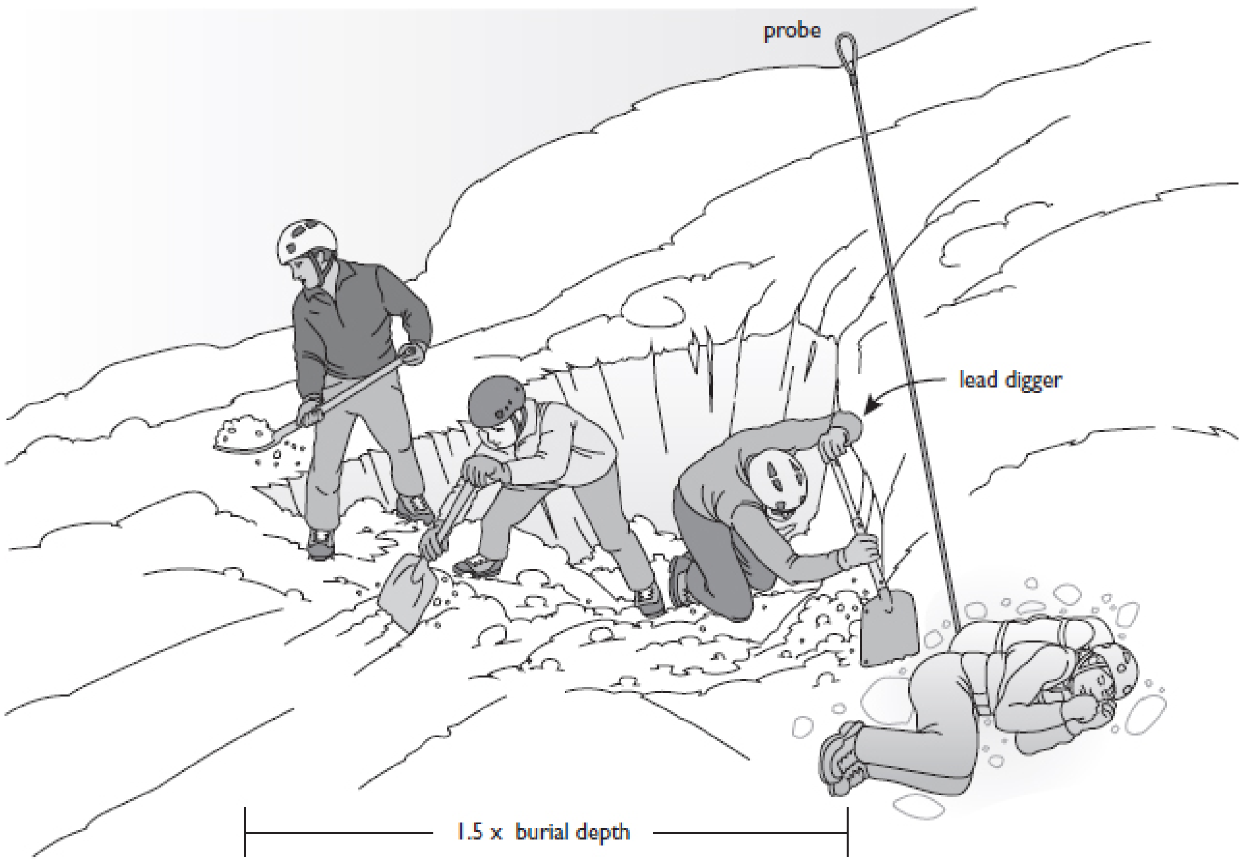


Fig. 17-15. Digging out a fully buried avalanche victim, shoveling at an angle on the downhill side from victim's estimated location.

TRAVELING SAFELY IN AVALANCHE TERRAIN

Snow is a constantly changing medium. Safe travel in avalanche terrain requires preparation, constant reassessment of conditions, and alertness. Here are some points to remember:

- **Continually assess the stability of the snow.** What is the relative level of avalanche hazard? Start with pretrip research and continually reassess throughout the climb.
- **Practice safe travel techniques in avalanche-prone areas.** Always choose the safest path of travel and consider crossing avalanche-prone slopes one person at a time.

- **Carry the necessary rescue gear in avalanche terrain.** Carry avalanche transceivers, probes, shovels, and a first-aid kit, and be trained in their proper use.

Unfortunately, many climbers consider avalanche safety an abstruse specialty of more concern to skiers and winter mountaineers than to the average climber, so they may not bother to make a thorough study of the subject. Yet avalanches can and do occur year-round in many mountain ranges. There is no question that anyone who travels on steep snow, at any time of year, will benefit greatly from avalanche safety training. The study of snow and avalanches is fascinating, as well as useful; the more you learn the more interesting the topic becomes. The knowledge gained turns out to overlap with many other topics in mountaineering. In particular, the emphasis modern avalanche training puts on planning and decision making is valuable and directly applicable to all backcountry travel. The cycle of snow is both an art and a science that you can study for a lifetime. Avoiding avalanches is only one of many benefits of such study. Understanding snow and mountain weather is vital—even outside avalanche terrain—to truly gaining the freedom of the hills.