Avalanches: A novice guide

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Avalanches are very complex phenomena and are certainly one of the major natural hazards in mountain areas. Thousands of avalanches happen every year without causing any casualties or damage, however in the European Alps about 150 people are killed every year by snow avalanches, with smaller numbers also killed in less tourist-developed regions like Scotland and Scandinavia. In the US, 434 people have been killed since 1950, most of whom are ski-tourers (27%) and climbers (26%). Most of the victims of avalanches are therefore knowledgeable and experienced mountain travellers, but the fact is that mountain experience does not necessarily convey knowledge or experience of avalanche safety. Additionally avalanches also damage ski lifts, roads, building, power lines, forests, etc. In developed areas avalanche control is often used to minimize hazard, this may be by controlled release of snow by explosives, retaining structures and fences, or reinforced buildings and structures. The other method of reducing risk, and in the back-country the only method, is avalanche forecasting, this can be based on scientific analysis of meteorology, thermodynamics, slope geometry etc., but personal experience is very important.

Avalanches are classified as dense flow avalanches (DFAs) or powder snow avalanches. DFAs comprise a wide range of phenomena ranging from cold and dry slab avalanches to very wet avalanches with various sizes involving a few tons of snow up to catastrophic events involving moving snow of several hundred thousand tons. In contrast to the deadly DFAs, powder snow avalanches are suspended ice particles in air. They form on top of flow avalanches when the snow is cold and dry as is often the case in Scandinavia. The suspended ice particles may reach up to 100 m in height and a kilometre in length, though the density of particles is quite low, the flow can reach very high speeds up 100 m/s and give a great pressure to objects in their path.

Avalanche Risk Factors

For the back-country telemark skier, skiing in areas with few or no avalanche control measures, it is important to be aware of potential avalanche risk, and also to know what to do should a member of the party be caught in an avalanche. When viewing a slope that has to be negotiated the following criteria should be assessed, and due caution in route planning or avoidance of the slope should be considered:

- Weather conditions, most avalanches happen during or soon after storms, the extra weight of a ski may be enough to break the bonds between the snow layers, and travelling during a storm when weight is constantly being added to the surface is not often a good idea. In general the windward side of a mountain offers the safer avalanche route than the more comfortable downwind side where snow accumulates faster. Melting or rain caused by warm weather also often leads to the release of many avalanches as the snow pack becomes lubricated.
- Topography and slope angle of the avalanche starting zone, slopes between 28 and 45 are most dangerous, steeper slopes shed snow quickly and are unlikely to produce large dangerous avalanches.
- Slope shape and morphology: presence of bowls, gullies which could channel a flow.

- Rugosity of the slope due to rock type, vegetation, obviously open slopes smooth slopes provide little restraint in the path of an avalanche building up speed and force.
- Evidence of previous avalanche activity, look for damage to tree trunks and branches, snow piled up on the uphill sides of trees, trees bent over in a downward direction and for factors which involve the entire avalanche path such as anomalous altitudinal variations in vegetation type, debris in the avalanche run out zone, fracture lines in the snow surface, etc.
- Aspect of the slope, different slope orientations imply differences in the incoming solar radiation, and more importantly in Scandinavia, the orientation of the slope relative to the prevailing wind direction controlling snow drift deposits, both of which changes the snowpack and therefore the type of avalanche produced.

Snowpack Structure

Avalanches that occur during storm activity or soon after are called direct action avalanches and the sliding surface is the boundary between the old and the new snow. However the snow will form new bonds with the underlying snow over a period of days, the timing depends on temperature, the warmer it is the faster the crystals can bond together, but in very cold conditions this may take much longer. However the processes that create bonds between snow crystals can also lead to formation of weakly bonded layers within the snowpack, this weak layer can then lead to sliding and a delayed action avalanche. The general likelihood of an avalanche can be investigated by studying the snow pack structure. This is done regularly at ski resorts and can be done quite quickly and easily in the backcountry by skiers. Of course a shovel is required, but this is required anyway for travel in an avalanche area. A pit dug in the snow should be in a similar (but safe location) as the avalanche starting slope so that snow structures are similar. Slab avalanches occur when a weak layer of snow can no longer support the weight of the overlying snow and fractures. In polar regions this is usually the result of depth hoar formation. Depth hoar is snow that has grown into large faceted crystals often in a series of stacked cup-shapes, the crystals have very few bonds between them and so make a structurally weak layer. Other weak layers may occur over melt layers or wind crusts in the snow. A pit dug in the snow should be made with one side undisturbed by walking etc. When the ground is reached, the undisturbed side can be cleanly sliced by smooth passes of the shovel down the side wall. Visual examination can reveal any melt layers or wind-crusts and crystals from each of the layers can be removed by hand. The strength of each layer can be easily judged by rubbing or poking a finger in the layer. Depth hoar should be fairly easy to spot, and is most dangerous when it overlain by heavy consolidated snow. Depth hoar layers tend to form in the snow as a result of very low air temperatures while the snow pack is relatively thin and the ground warm, much of snow pack in Lapland and Alaska is depth hoar by spring after the low winter temperatures. Usually a snowpack composed of mainly depth hoar is not dangerous, just a nuisance as the snow is weak and travel very difficult due to constant sinking into the pack, however layers of depth hoar overlain by newer snow is dangerous as slopes may remain unstable for months before the depth hoar crystals changes into a more consolidated form. In general if the terrain seems to present avalanche hazard several pits should be dug to ascertain the local scale changes in snow pack caused by micro-climate variations. In spring-time or thaw conditions, a hand thrust into the snow is a good quick way of checking the water content of the snowpack.

Travelling in Avalanche Zones

If a party of skiers has to cross an avalanche slide slope there are several techniques to minimize risk. Travel along ridges that are not exposed to avalanches from slopes above, it is safer to follow a ridge around a cirque than to cross the bowl. Concave slopes and bowls are

safer as they have less stress than convex slopes. Narrow gullies with steep sides should be avoided as they can quickly fill with snow in even a small avalanche. If you have to cross a slope steeper than 25° choose the part of the slope to cross that has the shortest lengths of dangerous ground, or the most protected regions on the route so that the time spent in the avalanche path is reduced. The group should wait together at the edge of a the danger area in a protected place such as within large trees, bear in mind that powder snow avalanches can extend well beyond the slab avalanche region. If wearing a pack undo the waist belt so that the pack can be abandoned quickly, similarly with the ski safety straps and ski pole straps, zip up outer-clothing to conserve warmth if you become buried in snow. One person at a time should cross the slope choosing a line directly across the slope, avalanches travel very quickly, it is impossible to out run or ski them, so spend as little time on the slope as possible. The other members of the party should all watch the person crossing until they are safe, this is the only way to keep track of anyone swept away, and vitally important in pinpointing the spot to being a search. When the person has safety crossed the slope, they should again wait in a safe place and watch the other members of the party cross also. Try and ski the same tracks to minimize disturbance to the snowpack. If cracks appear or the surface suddenly drops down all around, the snow is unstable and safety should be gained as quickly as possible, most safely by retreat along the ski tracks.

Avalanche Survival

If an avalanche occurs while on the slope try and get out to the side of the avalanche track as quickly as possible, if you are caught by the slide, try and get rid of the pack, and keep near the surface of the slide using swimming motions. As the slide comes to a rest try and keep your arms in front of your face and make a breathing space in front of your face. Most people in an avalanche die with 45 minutes - of asphyxiation, not cold or trauma injuries. On the other hand 90% of people survive if recovered in 15 minutes, it therefore vital that members of the victim's party effect a speedy rescue.

It is most important that other members of the party watch the person being swept down the slope in the avalanche and continue to watch while they go as quickly as possible to the place where the person was last seen. If the person is only partly buried than the usual mountain accident procedures can used to treat injuries etc. If the person is completely buried then an efficient search operation is the only way to save them. The lost person will be somewhere down slope of the last place they were seen on the surface. It is most unlikely that the person will be able to move to free themselves, but they can perhaps hear voices and shout for help. Marking the place where the person was last seen a quick search should be made of the snow surface for any signs of clothing that may indicate the location of the body. Call and listen for any cries as well. Assuming that no avalanche beacons were being used the search must rely on probing the snow using ski poles without baskets, feeling for any impenetrable objects. Begin in a line of people from the last sighting down the fall line of the avalanche. Of course if the person is located then recover them as quickly as possible by digging. The most likely cause of death is lack of oxygen, but this can take a long time so it is important not to give up the immediate search too quickly, people have survived burial for several hours, but chances of survival fall quickly so all the members of the party must search for at least an hour before going for outside help.

By far the best thing to help with avalanche survival is possession and knowledge of use of avalanche transponders or beacons as they are called. These are small lightweight radios that should be worn inside clothing so that they cannot be ripped off the body during an

avalanche. At the start of a trip all the party should put on their beacons, check that batteries are OK and set their beacons to transmit. The world-wide standard frequency for these radio transmitters is now 457 kHz, but in the US a lower frequency was used until very recently, do not be tempted to buy one of the old beacons at any price. It is of course important that all members of a party are wearing beacons and that they all work on the same frequency. After an avalanche the rescuers set their transponders to receive and maximum sensitivity and listen for the tone from the buried person's transmitter.

To carry out a search, begin from the last sighting place, analogue quartz watches can interfere with the signal and should be removed. The avalanche must be stopped before a search can safely begin, if there is likely to be more danger, one person in the group can act as a lookout to warn of impending danger. Starting from the point where the victim was last sighted, the party should fan out over the width of the debris with their beacons set to the maximum range walk down slope listening to the sound, and looking for any signs on the surface of clothing or equipment. If there is only one searcher a zig-zag pattern should be made down the slope. When a searcher hears a signal from their beacon notify the others and find the orientation of the beacon that gives the loudest signal and keep the beacon in that orientation for the rest of the search. Walk down slope and wait for the signal maximum to come. Then walk across slope perpendicular to the first direction and again listen for the signal to become louder (the right direction), or quieter (the wrong way, go back and walk the other way), walk until the signal reaches a maximum, turning down the range of the receiver as necessary. Then turn again 90° and find another maximum. The person should then within a few square meters of the your location. The final search should be made as calmly as possible by the leader who finds the exact region where the signal is strongest, when this area is less than a metre in diameter dig as fast as possible.

Practice in the art of avalanche rescue is a very effective way of becoming confident and efficient in a real rescue situation, the time taken to locate a beacon can be reduced to as little as 3 minutes after some practice. Similarly practice in studying snow structure and assessing slope safety and route planning can all significantly add to one's life expectancy in avalanche prone regions.

Equipment

Avalanche beacons cost about $300, shovels about $50. Every member of a party in an avalanche area should carry both items, if you don't have a shovel its the same as saying you can rescue me, but I won't rescue you, the same is true of cheap avalanche transponders that only transmit. Shovels are also useful for digging snow pits and excavating snow caves. Ski poles that can be used as probes in avalanche debris are useful, especially if no avalanche beacons are used.