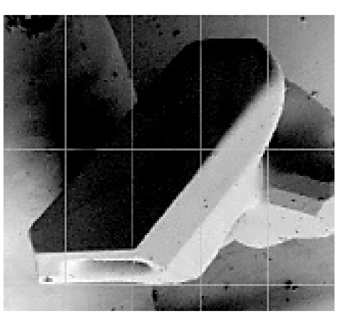
FACETING

Reprinted with permission from Ian McCammon
Faceting is a metamorphic process that produces angular, weakly-bonded snow. Once buried, facets can produce dangerous weak layers. Facets rate second only to surface hoar as the most frequent killer of professionals and knowledgeable recreationists.

Facet Formation

Facets form when a snow grain is surrounded by a steady flow of water molecules (water vapor). Under these conditions water molecules tend to leave (sublimate) from the top of the crystal while being deposited on the bottom of the crystal above. Molecules can leave the top of a crystal almost anywhere giving it a rounded appearance. Molecules being deposited on the crystal however can only do so in certain places determined by the energy of the molecules (the ambient temperature) and the number of molecules present (the vapor pressure)[1]. The result is that the top of the snow crystal gradually gets smaller and more rounded, while the bottom becomes larger and more angular (see figure below).

A scanning-electron microscope (SEM) photo of a snow grain in the early stages of faceting.



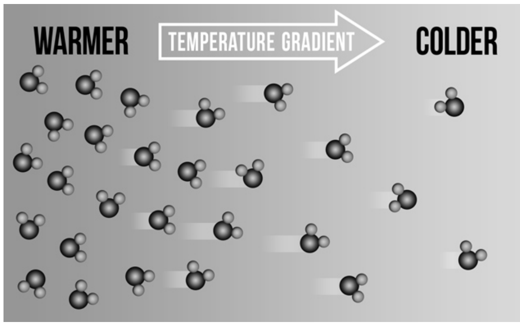
Vapor flow was from bottom, producing an angular lower edge and rounded upper edge. (Photo by W. Wergin, USDA)

An important consequence of the faceting process is that water molecules are free to leave snow crystals from areas near inter-grain bonds, but tend to be deposited only on crystal surfaces. The result is that bonds gradually decay, giving rise to the familiar crisp and sugary texture of faceted snow. Faceting is accelerated when the grain sizes are small and when there are large pore spaces around grains.

The faceting process is often called KINETIC METAMORPHISM because ice crystals are moving away from their equilibrium state. Faceted grains are also called SQUARES or SQUARE GRAINS. Older terms for faceting include TEMPERATURE GRADIENT or TG METAMORPHISM and CONSTRUCTIVE METAMORPHISM. These terms have been abandoned as being inaccurate, confusing or both.

Temperature Gradient

We've seen that the faceting process is driven by a steady flow of water molecules past ice crystals in the snowpack. But where does this flow come from? It turns out that molecules with higher energy tend to move toward areas where they can have less energy. Much like people escaping the frantic pace and overcrowding of the city by moving to the country, water molecules tend to move from areas that are crowded and energetic to areas that are less populated and quieter[2]. As shown in the figure below the result is a net movement from warmer regions of the snowpack to regions that are colder. On a macroscopic level, we measure the molecular flow rate for the population difference or the energy difference as a temperature gradient.



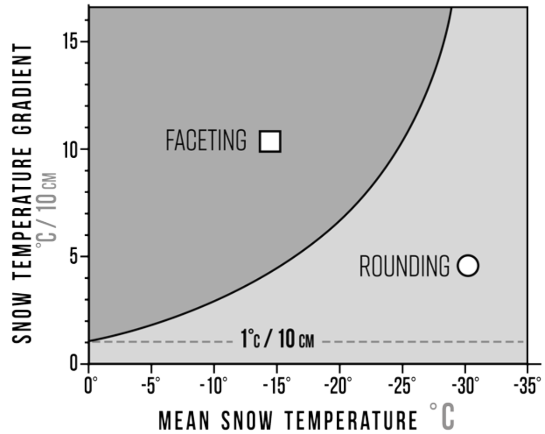
Temperature gradients produce a tendency of water vapor to move from crowded, energetic (warm) areas to areas less populated, quieter (cold) areas.

Below a certain temperature gradient (flow rate), there are not enough water molecules passing by to overcome the random exchange of water vapor within and between ice grains. Under these conditions, rounding and sintering are the dominant processes between grains. But when the gradient is higher, the flow of molecules overwhelms random exchange, causing facets to grow and bonds to decay, eventually producing weaker snow.

At 0°C, the critical temperature gradient at which faceting begins to take over is about 1°C per every 10cm of vertical height in the snowpack. But as temperature decreases, there is less free water vapor between snow grains, and the critical gradient for faceting increases. The figure below shows the general relationship between the critical faceting gradient and ambient snowpack temperature.

The bottom line is that faceting slows down dramatically as the snowpack cools. Below about -40°C, faceting stops altogether and the snowpack begins to sinter and round, but at such a slow rate to be almost imperceptible.

Faceting occurs in the snowpack whenever there are sufficient gradients to sustain it. Faceting near the ground often produces DEPTH HOAR: faceting near the snow surface produces NEAR SURFACE FACETS. All present significant hazards when buried.



The critical temperature gradient for faceting increases as overall ambient snow temperature drops.

Depth Hoar Formation

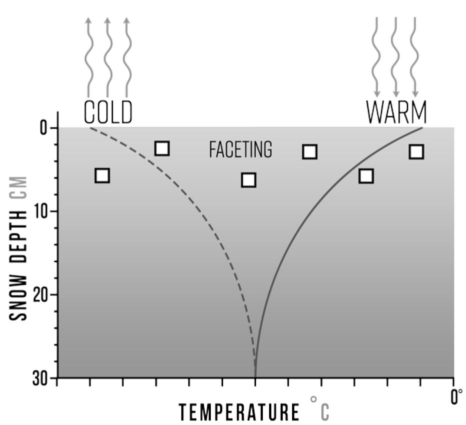
In most of North America, the temperature of the ground remains near 0°C throughout the winter. As a result, any snow on the ground acts as a thermal buffer between the cold air above and the warm ground below. Cold air temperatures and a thin snowpack thus gives rise to steep temperature gradients and produce the weakly-bonded large snow grains familiar as DEPTH HOAR.

Two factors combine to give depth hoar its unique appearance and properties. First, the relatively warm ground produces an ample supply of water vapor in the lower snowpack, promoting rapid faceting. Second, temperature gradients generally persist for as long as the air above a thin snowpack remains cold, so the faceting process can go on for days or weeks. Under such conditions, the bonds between crystals weaken, and crystals become striated and eventually hexagonal and cup-shaped. Because the air above the snow can remain cold for days or weeks, temperature gradients can persist for a long time, providing plenty of time for facets to grow large and for bonds to decay.

Once depth hoar is buried, it bonds very slowly once the temperature gradient eases. Large crystals of mature depth hoar may take a long time to re-bond, and can linger as a dangerous weak layer in the snowpack for many months.

Diurnal Recrystallization

In deeper snowpacks, daily fluctuations of snow surface temperatures can create gradients that produce faceting. As shown in the diagram below. Cold nighttime temperatures result in a cool snow surface, driving faceting in much the same way as in depth hoar formation. Warmer daytime temperatures, on the other hand, warm the snow surface and reverse the gradient, causing further faceting[3].

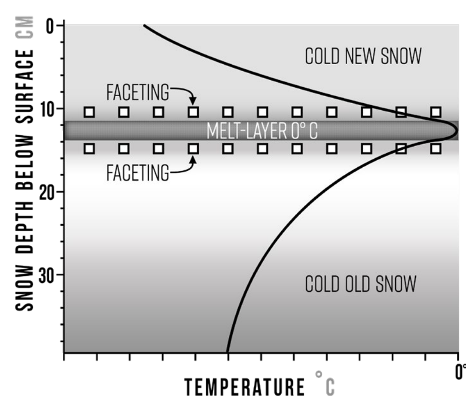


Diurnal recrystallization is produced by daily fluctuations in the snow surface temperature.

Diurnal recrystallization is a boon to skiers, since heavy wet snow that starts out as poor skiing often "dries out" and improves in a day or so of dry, cold weather. The downside of this is that once buried, diurnal recrystallized snow can produce very persistent weak layers that are often accompanied by surface hoar at their upper boundaries.

Melt Layer Recrystallization

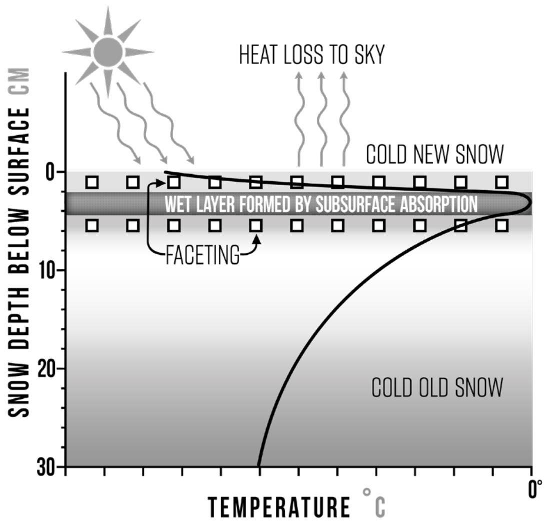
If rain or sun produces a warm snow surface which is subsequently buried by cold snow, a temperature gradient can form both above and below the melt layer (see figure Below). Once the melt layer freezes into a crust, it forms a nice bed surface for the poorly bonded slab above to slide on. It's important to note that new snow may bond well initially to the melt layer, only to become dangerous once this layer has been buried for a few days.



Melt layer recrystallization occurs when a warm surface layer is buried by cold new snow.

Radiation Recrystallization

At inland elevations above 10,000 feet, the air is very dry and imparts little heat to the snowpack through conduction. Under these conditions, the surface of the snow can cool significantly by radiating heat to the sky. If the sun is shining on the snow, however, some of the sun's radiation penetrates the snow surface and is absorbed in the top one or two centimeters of snow (see figure below). The result is a thin melt layer or crust that has a temperature gradient on either side of it – prime conditions for faceting. Once buried, this faceting can be remarkably persistent and treacherous, since it tends to form on sunny high-elevation slopes that many people assume are safe.



Radiation recrystallization occurs when solar radiation penetrates low-density new snow while the snow surface loses heat to the sky.

Red Light Conditions

Faceting in the snowpack are rarely dangerous until they become buried. Recognizing when they form is an important part of anticipating future instabilities.

Depth Hoar: Λ

Thin snowpack and cold temperatures.

Diurnal Facets: ⧄

Warm sunny days and cold clear nights.

Melt Layer Facets: ⧄

Cold new snow on recent rain or sun crust.

Radiation Recrystallization: ⧄

High elevation sun on low-density snow.

References

Tremper, B. 2011, Stay Alive in Avalanche Terrain, Mountaineers, Seattle

McClung, D. & Schaerer, P. 1993, The Avalanche Handbook, Mountaineers, Seattle

Endnotes

[1]Deposition of water on the lower edge of a faceted crystal is governed by the same process that form snow in the atmosphere at low humidity.

[2]This principal is formally known as the first law of thermodynamics.

[3]Strictly speaking, a reverse temperature gradient also reverses the direction of molecular flow, so facets now form on the upper surface of diurnal crystals. In reality, water vapor must compete with rising air in the snowpack, resulting in a slower faceting process during the day.