SNOWPACK BASAL LAYER FACETS IN THE SIERRA NEVADA

Randall Osterhuber
UC Berkeley, Central Sierra Snow Laboratory
PO Box 810 Soda Springs California 95728 USA
(530) 426-0318, (530) 426-0319 fax, randall@sierra.net

ABSTRACT: Though California's Sierra Nevada generally experiences deep snowpacks and modest mid-winter air temperatures, faceted snow grains do form and persist. The most pronounced and persistent facets have been found as basal layers of the winter and spring snowpack—snowpacks often several meters deep. Formation of these grains occurs early winter when snow depths are slight and air temperatures are low. This examination describes the basal layer snows at several locations in California's Sierra Nevada and the Carson Range of Nevada (above the north shore of Lake Tahoe) during Winter 2006, and discusses the implications of these weak layers to avalanche potential. Also investigated are recent spring avalanche cycles in the Sierra Nevada during which wet slab avalanches released at ground level. The failure layer of these avalanches are thought to be old, wetted, faceted grains.

Keywords: facets, depth hoar, wet slab avalanche

1. INTRODUCTION

Influenced by a strong westerly flow off the Pacific Ocean, the seasonal snow cover of the Sierra Nevada is considered a maritime snowpack. Deep, dense, and warm are the characteristics of Sierra Nevada snows. At the Central Sierra Snow Laboratory (CSSL, 39.32884° N, 120.37247° W), a field station of the University of California, Berkeley just west of Donner Pass, average maximum snow depth is 3.1 meters and average maximum snowpack density is 425 kg/m^3. Average minimum air temperature at the CSSL during December, January, and February hovers around -7° C. Once snowpack depth exceeds approximately 1.5 meters, snow temperatures of the basal layers remain just below the melt point for the remainder of the season.

Avalanche cycles in the Sierra are often a consequence of poor initial bonding between newly fallen snow and the old snowpack surface. Weak interfaces like this rarely persist, and within a couple days after snowfall avalanche potential tends to decrease substantially as bonding increases. There are, of course, avalanche cycles that demonstrate exceptions to this. One such exemption is the formation—and persistence—of weak, deep, grains within the snowpack. These weak grains have been observed to form during the early winter (Figure 1), especially when early season snowfall and snowpack depths are less than average. Such was the case during December 2005.

While many mountain ranges in the interior American West have regular avalanche cycles ascribed to deeply buried faceted snow layers, the Sierra Nevada generally does not. But with conditions favorable to faceted snow growth during the start of many a winter, it is perhaps not for lack of faceted snow. The persistence of weak snow, especially as snowpack basal layers, has not been well documented in the Sierra Nevada either during a particular winter or across several

Figure 1. Basal layer faceted grains, Mammoth Mountain, December 2005. Photograph by Walter Rosenthal.

winters. This may be mainly due to the difficulties and time-consuming task of digging deep snowpits to the ground in order to identify the basal layering. During Winter 2006, observations of the basal snowpack layers were made at 35 different locations throughout the Sierra Nevada and

Carson Range. Twenty-six of these sites revealed faceted grains as the basal layer snows. The earliest observation was on December 10, 2005; the last on June 20, 2006. Of these 35 observations, 20 were done from north and northeast facing snowpits, two from southeast facing snowpits, and 13 others from sites with extracted snow cores. It should be noted that the observations of basal layer snows was not in itself any kind of research objective of this author, but rather a consequence of digging snowpits for avalanche hazard assessment, state-sponsored snow surveys, peripheral snow hydrology research, and during field teaching sessions of both Level 1 and Level 2 avalanche safety courses.

2. OBSERVATIONS

Observations from several "linked" early season snowpits revealed substantial layers of faceted snow composed of large (> 2 mm), poorly bonded grains. On December 10, 2005, the bottom 40 cm of a 125 cm deep snowpack (39.29649º N, 119.94073º W) was found to consist entirely of large, faceted grains "fist" hard. This particular layer extended laterally across a 35° north-facing slope for at least 10 meters surrounding the initial snowpit location. However, no mechanical failures could be initiated within this layer even after numerous bonding tests including compression tests, shovel shear tests, a rutschblock, and ski cutting. Though the snowpit examination suggested little strength within this layer, it is not clear as to why failure could not be initiated. It is assumed the anchoring across the slope was substantial enough to support and/or bridge the weak snow layers. These weak, faceted grains observed in early December 2005 persisted as basal layers of the snowpack through the winter and early spring, despite numerous rain storms, ever-deepening snowpacks, and warm, stable, deep-layer snow temperatures.

The CSSL recorded 604 mm of rainfall during December 2005, from five separate precipitation events. The warmest of these storms, just after Christmas, had a snowline of at least 2750 m. Snowpack outflow measuring devices at the CSSL indicated the majority of this rain went through the snowpack, as often is the case during hard rainfall on relatively shallow snows. (Snowpack depth at the CSSL December 1 was 24 cm; on December 31, 91 cm.) The faceted basal layer grains evidently survived this through-flow.

Ten separate snowpits were dug to the ground in the Carson Range of Nevada, above the north shore of Lake Tahoe. This area is accessed from Nevada State Route 431 (the Mt. Rose Highway) and is a popular destination for many devotees of winter recreation including backcountry skiers and snowmobilers. The area encompasses some of the highest elevation terrain (up to 3285 m) around the Lake Tahoe Basin, and because it is 35 km east of the Sierra Nevada crest, tends toward colder and drier snows. On February 3, 2006, snow depth at a pit location (39.24204º N, 120.25983º W) here was 390 cm, the bottom 12 cm being moist/wet, old, faceted grains to 4 mm in size, "fist+" hard. This layer's temperature was measured at –0.5º C. This particular snowpit location was about 500 m from the snowpits of December 10, 2005, and within 600 m of six other snowpits (dug between December 2005 and March 21, 2006), all of which revealed mature faceted grains as basal snowpack layers. This area was last visited, and a snowpit dug, on June 20, 2006. Snow depth then was 216 cm, snowpack temperature was measured uniformly at –0.5º C except for the top couple centimeters which were 0º C. The bottom 60 cm consisted of large (to 8 mm), rounded, very wet grains; the bottom 2 cm of the pack a hard ice layer. Average snowpack density was 523 kg/m^3. No shear plane less than "hard" could be singled out and no evidence of faceted grains could be identified in any layer.

In addition to the Carson Range, ten other observations in the Tahoe Sierra Nevada (proper) revealed faceted basal layer snows, including three snowpits from the Alpine Meadows ski area and two from the Sugar Bowl ski area. Snowpack depths ranged from 62 to 200 cm; thickness of the faceted grains ranged from 3 to 20 cm. The five ski area observations were all during December, after which their records show no snowpits to the ground.

In early January 2006, two snowpits were dug on SE aspects, one near the Alpine Meadows ski area (90 cm deep, aspect 150º) and one near Mammoth Mountain ski area (206 cm deep, aspect 110º). Neither of these snowpack profiles revealed any faceted snows.

During a 9-day (March 24 - April 1, 2006) snow survey trip in the upper watershed of the Kern River in the southern Sierra Nevada, mature, faceted grains were discovered as the basal layer snows (Figure 2) at six of thirteen measurement

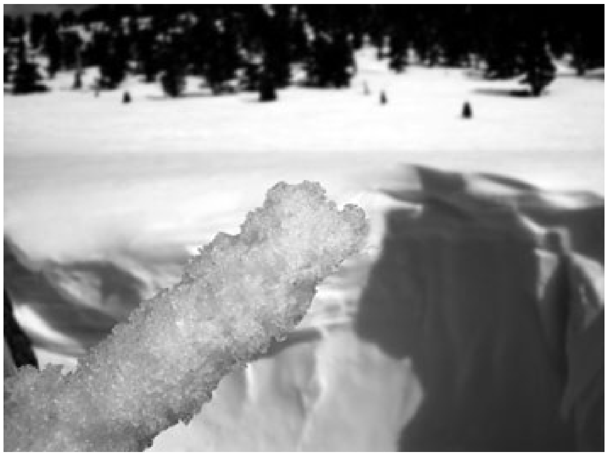

Figure 2. A sample of faceted basal layer grains extracted with a snow corer, March 2006. The core is about 5 cm in diameter. Photograph by Randall Osterhuber.

sites. The faceted snows were found as high as 3300 m and as low as 3018 m elevation. All these sites were on relatively flat ground with only modest (<10º) slope angles. These snow layers were easily extracted with a snow corer and subsequently examined. Though layer thickness could not be accurately assessed due to compression of the snow sample by the cutting action of the corer, all layers exceeded 10 cm in thickness. Total snow depth at these sites ranged from 70 to just over 200 cm; average snowpack density was 330 kg/m^3. Snow temperature was not measured. The faceted grains were removed from the bottom of the snow corer and found to be reasonably well bonded, at approximately "1 finger" hardness.

3. SPRING AVALANCHES

During the springs of 2005 and 2006, several large wet slab avalanches that released to the ground were reported by skiers in the central and southern Sierra Nevada.

On May 22, 2005, at about 1100, a large wet-slab avalanche released on a NNE facing slope at 3500 m elevation on Black Mountain (38.03867º N, 119.27870º W) above the Virginia Lakes Basin in the central Sierra Nevada (Figure 3). The Virginia Lakes Basin is a popular backcountry ski destination, especially during the spring when a paved access road is plowed and/or melted free of snow. On that particular morning, at least a dozen skiers were in the vicinity of the slide when it occurred; at least seven people had skied down or across the slope prior to its fracturing. Two skiers had started descending the slope prior to avalanching, but then cut across skier's left to find "better snow." The snows at the site were described as "rotten," "collapsing," "hollow," but the skiers observed "no large-scale whumfing." The avalanche ran to the ground on talus and scree.

During April 2006, a large wet slab avalanche ran to the ground on Victoria Peak (38.16756º N, 119.42291º W) outside of Bridgeport, California, and under Peak 11,899' (32.52509º N, 118.84062º W), southeast of the town of Mammoth Lakes.

On a subsequent snow survey trip during May 2 and 3, 2006, large wet slab avalanches that had run to the ground were observed in the upper Kern River watershed. By this time, the Sierra Nevada had been under clear, warm, stable weather for about a week.

Though it is not known what the failure layer of these springtime to-the-ground avalanches were, old faceted grains that became wetted by melt water are a distinct possibility.

Figure 3. Photograph by Jeanne Oakeshott.

4. DISCUSSION

Spring avalanches in the Sierra Nevada typically subscribe to the domain of surface releases (sometimes sizable). The most common spring avalanche scenario that involve releases to the ground is when snowpacks, resting on smooth granite slabs, are undercut from percolating melt water. This occurs frequently in Desolation Wilderness (SW of Lake Tahoe) and within the snow zone of Yosemite National Park. If weak, faceted snows do form near the bottom of the snowpack, it appears they can persist into the melt season and/or be present during mid-winter rain storms—not uncommon during any month of the

Sierra Nevada winter. Both scenarios could offer a wet- /weak-grain failure layer underlying full-season, full-depth snowpacks. The basal layer facets of the snowpack observed around the Lake Tahoe Basin remained in tact after several powerful early season rain events. Previous observations prove that once vertical flow fingers have been established in a snowpack, great amounts of free water can be transported through while leaving large areas of the ice matrix untouched and dry. This may have been the case during December 2005.

The snowpits of December 10, 2005 (mentioned above) were the only observations made by this author of basal layer facets that extended spatially across a specific snow slope. Though faceted layers were identified at several other locations, their continuity across any one slope, area, or region is not known. The springtime avalanches discussed here may represent extreme cases of locally continuous weak basal snows.

If basal layer facets are common—if not typical—in Sierra Nevada snowpacks, why are more releases to the ground not observed? One possibility is that the substantial combined strengths of the overlaying snowpacks are great enough to support itself. That, shared with the bridging of weak basal snows from contact-to-contact/anchor-to-anchor point may be sufficient to avoid full-profile avalanching. Also, as observed from the extracted snow cores, bonding among the faceted grains does occur. Though weak compared with the other high-density layers of the snowpack, this may also be sufficient to overcome decreasing snowpack strength induced by warm weather.

Systematic research is needed to establish the formation, presence, strength, and mid- /late-winter metamorphism of deep layer faceted grains in the Sierra Nevada.

5. ACKNOWLEDGMENTS

Many thanks to Susan Burak, Paul Cushing, Mike Kennett, Gary Murphy, Jeanne Oakeshott, Joe Pace, Jimmy Roberts, Walter Rosenthal, Russ Viehmann, and Jim Zaloga, for their contributions of discussion, observation, field assistance, and data.

6. REFERENCES

Andrews, J. 2004. Faceted Snow and Deep Slab Instabilities in the Maritime Climate of the Cascades. *Proceedings of the International Snow Science Workshop*, Jackson Hole, Wyoming, September 2004. p.239-243.

http://www.esavalanche.org/IndexNew.htm

http://www.esavalanche.org/ESAC/Documents/ESAC_AnnualReport_2005-2006.pdf

Reardon, B. 2004. Forecasting for Natural Avalanches During Spring Opening of the Going-to-the-Sun Road, Glacier National Park, USA. *Proceedings of the International Snow Science Workshop*, Jackson Hole, Wyoming, September 2004. p.565-581.

www.wrcc.dri.edu/weather/cssl.html

www.wrcc.dri.edu/weather/slide.html