NEAR-SURFACE FACETED CRYSTALS AND THEIR EFFECT ON SNOW STABILITY, RED MOUNTAIN PASS CORRIDOR, COLORADO

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ABSTRACT

Avalanches may be important hydrologically if avalanche deposits alter the timing and volume of runoff. Avalanches often fail from a weak layer such as surface hoar, graupel, or faceted crystals. One important type of faceted crystal, called near-surface faceted crystals, form in the near-surface layers. During the 1997/98 winter, a study of near-surface faceted crystals was conducted along the Red Mountain Pass corridor, Colorado. Six types of near-surface faceted crystals were differentiated: small faceted crystals, radiation recrystallization grains, faceted precipitation crystals, near-surface hoar, faceted partly-decomposed precipitation crystals and needles. A particularly well-developed near-surface facet layer that evolved in December acted as the dominant weak layer in the study area for seven weeks. Observation of 14 avalanches showed that 79% of the failures occurred on near-surface faceted layers. The majority of stability test failures occurred on near-surface faceted layers. Understanding the growth of near-surface faceted crystals and their effect on snow stability is important for avalanche forecasting.

INTRODUCTION

Avalanches can affect the local hydrologic regime by concentrating snow mass and by moving snow to lower elevations which may have an increased ambient temperature (de Scally, 1993). Avalanched snow can add mass to glaciers, dam rivers for short periods and increase mudflow and debris flow.

Slab avalanches initiate from a weak layer made up of poorly bonded grains such as surface hoar, graupel, or faceted crystals. Faceted crystals have flat faces resulting from rapid growth (Colbeck et. al., 1990). One important type of faceted crystal forms in the near-surface layers, called near-surface faceted crystals.

Birkeland (1998) suggested three processes which form near-surface faceted crystals: radiation recrystallization, melt layer recrystallization and diurnal recrystallization. Previous research has identified several types of near-surface faceted crystals. In Japan, Akitaya (1974) observed both skeleton-type and solid-type hoar crystals in the near-surface layers. Fukuzawa and Akitaya (1993) observed faceted crystal growth at 1 cm depth by diurnal recrystallization that formed 0.29 mm hoar crystals and by melt-layer recrystallization that formed 0.39 mm hoar crystals. Fukuzawa and Akitaya also concluded that new snow crystals can change to hoar crystals in one night.

Birkeland (1998) differentiated four types of near-surface faceted crystals: small grained beginning facets (<0.5 mm), medium to large grained (≥1.5 mm) advanced facets, needles with facets, and stellar crystals with faceted crystal branches. Birkeland et. al. (1998) also observed that 59% of 51 backcountry avalanches in southwest Montana failed on near-surface faceted layers.

Avalanche research in the San Juan Mountains indicated that most avalanche weak layers faceted within the near-surface layers before burial (Armstrong and Ives, 1976). They also noted that the principle weak layers were most often thin crusts associated with a thin facet layer (probably radiation recrystallization crust and grains). Although these observations were made, few details of the formation and character of these layers at the surface were taken.

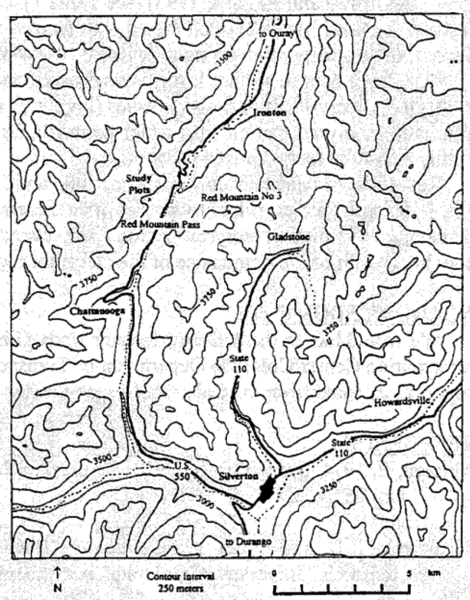

Figure 1. Map of the Red Mountain Pass corridor.

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Paper presented Western Snow Conference 1998

METHODS

An observational study on near-surface faceting was conducted along the Red Mountain Pass corridor in southern Colorado between Dec 23, 1997 and April 3, 1998 (Figure 1). Three study plots (north, south and level) at Red Mountain Pass were used for continuous monitoring of selected near-surface faceted layers. Four secondary areas were used for spatial comparison of the growth of near-surface faceted crystals and their effect on stability. Avalanche fracture line profiles were observed along the corridor. Crystals selected in Silverton were photographed through 40 and 100 power microscope lenses. The terms crystal, grain, and particle are used interchangeably.

RESULTS

During the study period there were 25 near-surface faceting cycles, each forming a recrystallized layer from the surface to variable depths. It was found that these layers form during low precipitation periods between storm events.

Six different types of near-surface faceted crystals were observed: small faceted crystals, radiation recrystallization grains, faceted precipitation crystals, near-surface hoar, faceted partly decomposed precipitation crystals and needles (Table 1).

Stability test data showed that near-surface faceted crystals were the dominant weak layer. From 14 observed avalanches, 79% failed on buried near-surface faceted layers. Seven of these weak layer failures occurred on a well-developed near-surface facet layer from December, which acted as the dominant weak layer in the area for seven weeks. Only three avalanches failed on radiation recrystallization layers. Stuffblock and rutschblock results showed that 52% of the dominant weak layer crystals to be near-surface in origin.

DISCUSSION/CONCLUSIONS

Crystals observed in this study were similar to those observed by other researchers (Akitaya, 1974; Birkeland, 1998; Fukuzawa and Akitaya, 1993) (see Table 1). Diurnally recrystallized snow appeared most often as small faceted crystals (Figure 2) often mixed with faceted precipitation crystals (Figure 4) and faceted partly decomposed precipitation crystals (Figure 6). Near-surface hoar (Figure 5), similar to Fukuzawa and Akitaya's (1993) "depth hoar in surface layer," was most often associated with near-surface crusts, but was rarely observed in diurnally recrystallized snow. Needles (Figure 7) were most often observed within the recrystallized layer above a radiation recrystallization crust which contrasts Birkeland's (1998) observations in Montana of their appearance within diurnally recrystallized snow.

Results from this study confirm Armstrong and Ives (1976) observation that the principle weak layers along the Red Mountain Pass corridor are faceted in the near-surface layers between precipitation events. The low relative percentage of radiation recrystallization weak layers contrasts Armstrong and Ives (1976) findings. This difference may be a result of the dominance of the December weak layer.

ACKNOWLEDGMENTS

We would like to thank Denny Hogan; Andy Gleason, Doug Lewis and Knox Williams, Colorado Avalanche Information Center/Colorado Department of Transportation; Scot Jackson for the use of his cold lab. Financial support has come from the Colorado Mountain Club Foundation and the American Alpine Club.

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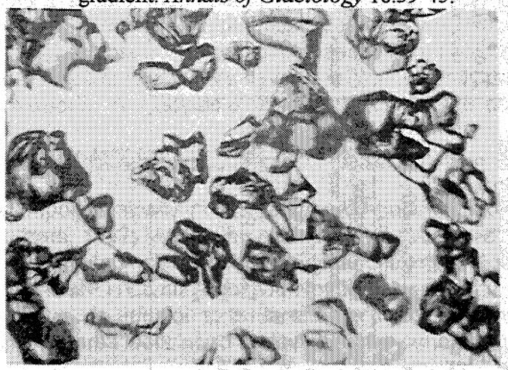

Figure 2. Small faceted crystals

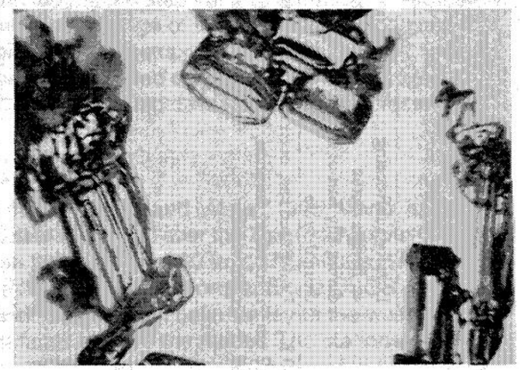

Figure 3. Radiation recrystallization grains

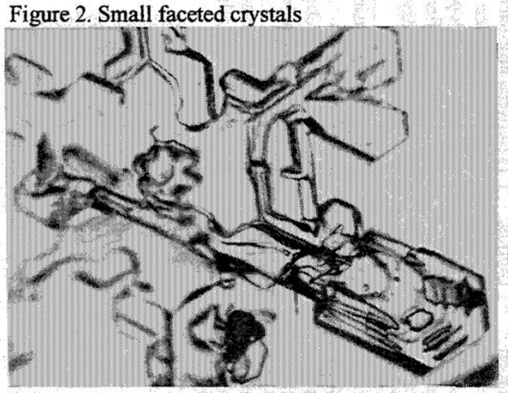

Figure 4. Faceted precipitation crystals

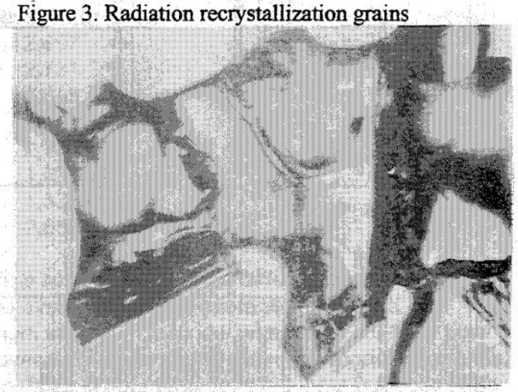

Figure 5. Near-surface hoar

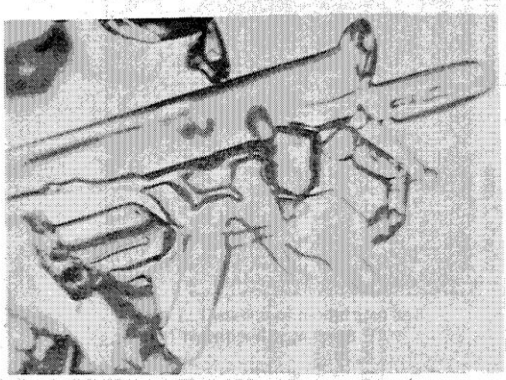

Figure 6. Faceted partly decomposed precipitation crystals

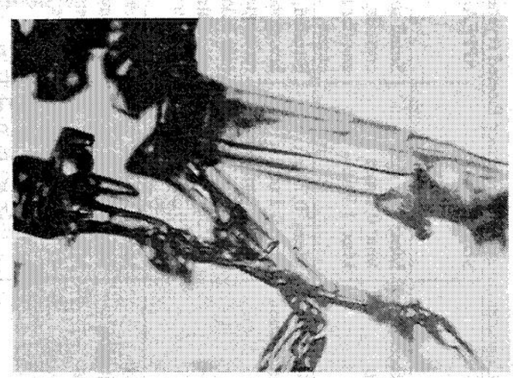

Figure 7. Needles

Table 1. Characteristics of near-surface faceted crystals along the Red Mountain Pass Corridor, San Juan Mountains, Colorado, December 23, 1997-April 3, 1998.

NAME	SIZE	APPEARANCE	PROCESS	PLACE OF FORMATION	WEATHER FOR FORMATION	DURATION FOR FORMATION	EFFECT ON STRENGTH
Small faceted crystals	Mean: 0.5 mm Min: 0.1 mm Max: 1.7mm	Small solid type faceted crystals, irregular angular shapes, sharp edges	Diurnal, melt-layer, radiation	In subfreezing near-surface layers	Locally subfreezing air temperatures during any part of the diurnal cycle	Several hours, size increases with time	Dominant weak layer crystal type
Radiation recrystallization grains	Mean: 0.7 mm Min: 0.1 mm Max: 3 mm	Striated, half and full hexagons, cup-shaped, rectangular to needle (see below), always associated with a stronger layer just below	Radiation	Sunny aspects, in top 0.8 cm (mean), above a 2.2 cm (mean) melt-layer crust	Undiffused sun, even if for short duration, calm winds	>30 minutes, subsurface melting can occur within minutes of sun	Significant contributor to instability
Faceted precipitation crystals	Mean: 1.7 mm Min: 0.1 mm Max: 4.0 mm	3D facets on crystal tips, sometimes striations, stellars may become plate-like	Diurnal, radiation, melt-layer	Usually in top few cm of snowpack	Mostly clear, cold	Several hours during cold clear conditions, rarely last more than several days unless buried	Often associated with other types of near-surface faceted weak layer crystals
Near-surface hoar	Mean: 1.0 mm Min:0.2 mm Max: 3.0 mm	Similar to radiation recrystallization grains, striated, half and full hexagons, rarely cup-shaped	Diurnal, melt-layer	1) Between near-surface crusts, 2) within near-surface crusts, 3) top 2 cm on shady slopes after several snowfree days	1) Cold mostly clear nights, 2) clear to mostly clear nights for crusts to freeze, 3) local subfreezing conditions	1) Several days, 2) overnight, 3) several days	Significant contributor to instability
Faceted partly decomposed precipitation crystals	Mean: 0.9 mm Min: 0.2 mm Max: 2.0 mm	Show some original structure: 60 degree angles, branch parts	Diurnal, radiation, melt-layer	Typically as a transition form from faceted precipitation particles to small faceted particles	Conditions for subfreezing near-surface snow	Several hours to weeks	Minor contribution to instability
Needles	Mean length:1.2mm Min length: 0.2 mm Max length: 3.0 mm Mean width: 0.2 mm	Elongated, usually, striated, sometimes glassy, rarely capped on one end	Usually radiation, rarely diurnal	Generally with radiation recrystallization grains, also with diurnal recrystallized snow	Same as for radiation recrystallization crystals	1 day	No observed effect on instability