THE TEMPORAL VARIATIONS OF NEAR-SURFACE FACETED CRYSTALS, RED MOUNTAIN PASS CORRIDOR, COLORADO.

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ABSTRACT

Avalanches are an important natural hazard. Slab avalanches initiate when a more cohesive layer lies over a less cohesive weak layer and the stresses on the slab exceed the weak layer's strength. Weak layers are commonly composed of surface hoar, graupel, or faceted crystals. One important type of faceted crystal forms 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 between Silverton and Ouray, Colorado. This study examines temporal variations in selected near-surface faceted layers at three study plots at Red Mountain Pass. The north-facing site retained lower strength faceted crystals throughout the study period while the other sites evolved into higher strength crystals. Stuffblock stability tests indicated an increase in stability on the north-facing site, yet the south-facing site lost strength toward the end of the study period.

INTRODUCTION

Avalanches are a serious hazard to people and structures in mountainous regions. For example, 26 people died from avalanches in the United States during the 1997/1998 snow year (CSAC, 1998). Slab avalanches initiate when a more cohesive layer lies over a less cohesive weak layer and the stresses on the slab exceed the weak layer's strength. Example weak layers may be surface hoar, graupel, or faceted crystals. Faceted crystals are poorly bonded together and weak in shear strength (McClung and Schaerer, 1993). These characteristics make it possible to use faceted crystals as an indication of less stable snow relative to other, more well-bonded crystal forms such as mixed forms or rounded grains. Depth hoar is one type of faceted crystal that forms in the basal layers of the seasonal snowpack, and has been studied in detail. Another important type of faceted crystal forms in the near-surface layers of the snowpack, called near-surface faceted crystals. Birkeland (1998) suggested three processes which form near-surface faceted crystals: radiation recrystallization, melt layer recrystallization and diurnal recrystallization. Examples of the resulting crystals include small faceted crystals (Figure 1) and radiation recrystallization grains (Figure 2) (Birkeland, 1998; Stock et. al., 1998).

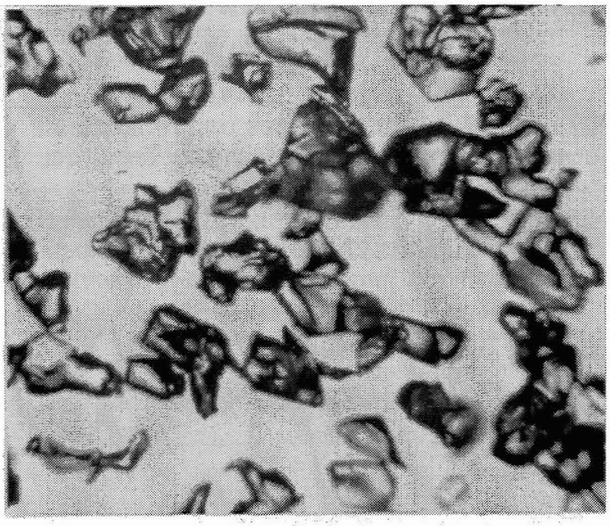

Figure 1. Small faceted crystals from Silverton, Colorado. April 1, 1998. Field of view is 2.1 x 1.7 mm.

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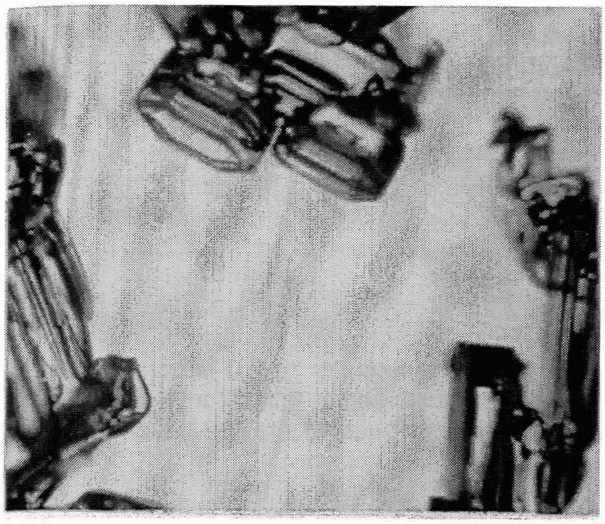

Figure 2. Radiation recrystallization crystals, Silverton, Colorado. March 2, 1998. Field of view is 2.9 x 1.5 mm.

Faceted crystals are known to be persistent weak layers in that they remain weak for longer than several days after burial (Birkeland, 1998; Armstrong, 1985). For example, Armstrong (1985) observed that once a weak depth hoar layer has formed within a starting zone in the San Juan Mountains only a significant avalanche cycle can eliminate this weak layer. Similarly, Birkeland et. al., (1996) observed an avalanche on a buried near-surface faceted layer 90 days after its burial.

Temporal studies of buried layers of faceted snow are scarce. In the Front Range of Colorado, Dexter (1986) looked at metamorphic patterns on a north and south-facing study plot at 3250 m. The north-facing site had a longer faceted crystal to rounded grain transition than the south-facing site. Wet grains dominated the south-facing site by mid-March and the north-facing site by late April. Armstrong (1985) studied a well-developed depth hoar layer at Red Mountain Pass, Colorado. Low strength persisted through the winter, but as melt began the surface tension of free water produced a temporary increase in strength only to reduce again as increasing amounts of liquid water appeared in the layer. Fierz (1998) followed a well-developed diurnally recrystallized layer in the Swiss Alps. This weak layer persisted for over two months and resulted in several fatal skier-triggered avalanches. For several months the crystal character and snow temperatures were measured for the layer, but these observations were at a single location and did not include stability observations.

Avalanche research in the San Juan Mountains has shown faceted crystals to be the dominant crystal type associated with avalanche weak layers (Armstrong and Ives, 1976). Armstrong and Ives (1976) also noted that most weak layers faceted within the near-surface layers before burial. Despite these observations, few details of the characteristics of near-surface faceted layers were subsequently made.

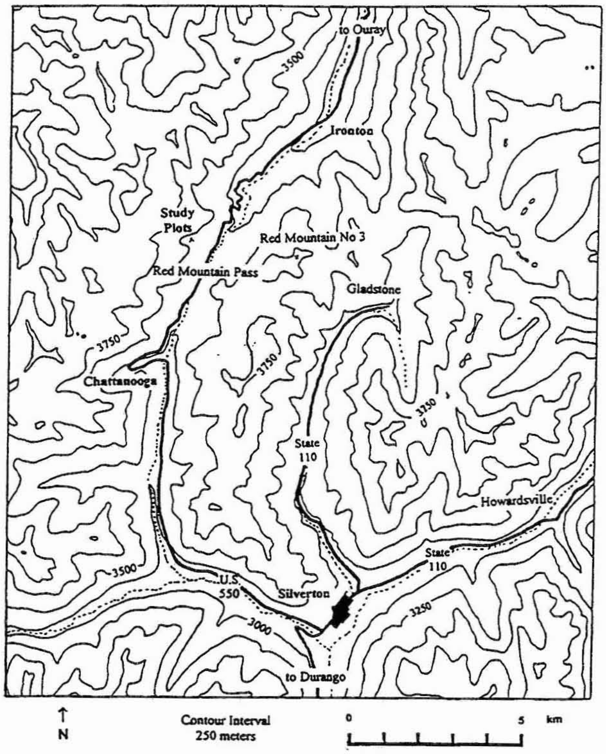

Figure 3. Map of the Red Mountain Pass corridor, Colorado, showing the study plots at Red Mountain Pass.

METHODS

An observational study of near-surface faceting was conducted along the Red Mountain Pass corridor in southern Colorado (Figure 3) between Dec 23, 1997 and April 3, 1998. Three study plots (Table 1) at Red Mountain Pass (3365 m) were used for continuous monitoring of selected near-surface faceted layers. Once buried, near-surface faceted layers are difficult to differentiate. To track the layers through time, observations were made in localized areas (<20m^2) to minimize spatial variation, and marked strings were laid on the snow surface for future reference before selected layers were buried. Pits were progressively dug following the strings across the study plots. About once a week, snowpack observations were taken in the top 30 cm of the snowpack and at each of the reference strings according to the guidelines in Colbeck et. al (1990). These observations included crystal type and size, hand hardness, density and temperature. Stuffblock stability tests (Birkeland et al., 1996) were used to test the strength of the layers.

Table 1. Aspect and slope angles for the Red Mountain Pass study plots

Site	**Aspect**	**Slope Angle**
South-facing	180°	28°
Level	NA	0°
North-facing	43°	33°

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.

String #1 was laid on the snow-surface of a well developed near-surface faceted layer which originated prior to the study period, and was buried on Dec 24, 1997. By late April, string #1 was buried 127 cm at the south-facing site, 99 cm at the level site, and 123 cm at the north-facing site. This layer was the dominant weak layer in the region during the study period and has been chosen for analysis.

The south-facing site changed to mixed forms by mid-January, and wet grains by mid-March (Figure 4). The level site changed to mixed forms in early March, while the north-facing site remained faceted through the study period.

The time-series of averaged stuffblock values and hand hardness at the south-facing site (Figure 5) show an initial increase in snowpack stability and strength during January, but decreased during the remainder of the study period. The north-facing site shows an increase in both stuffblock and hand hardness with time (Figure 6).

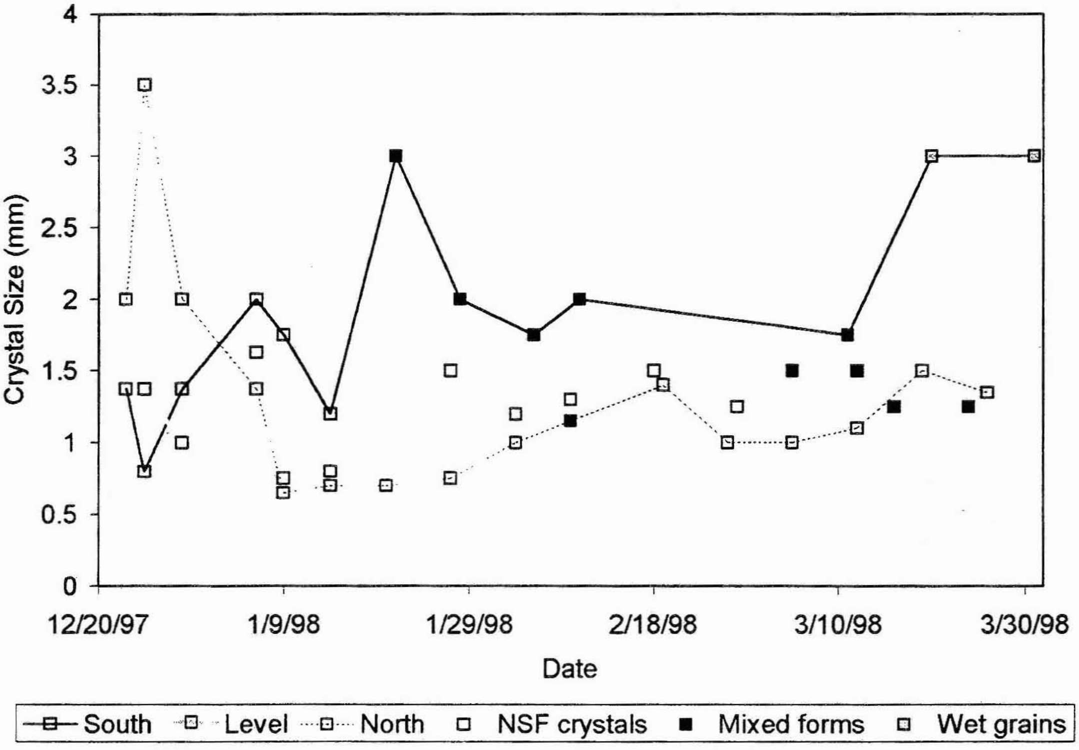

Figure 4. String #1 data from the south, level, and north-facing sites showing changes in crystal size and type.

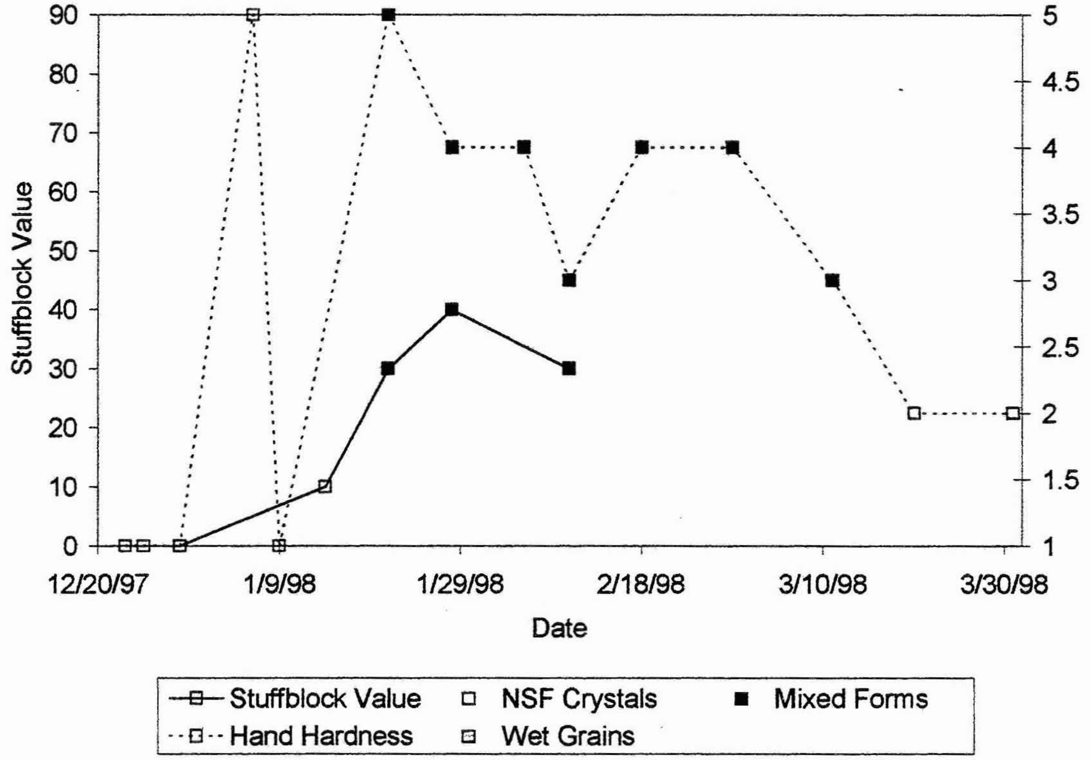

Figure 5. South-facing site stuffblock and hand hardness values.

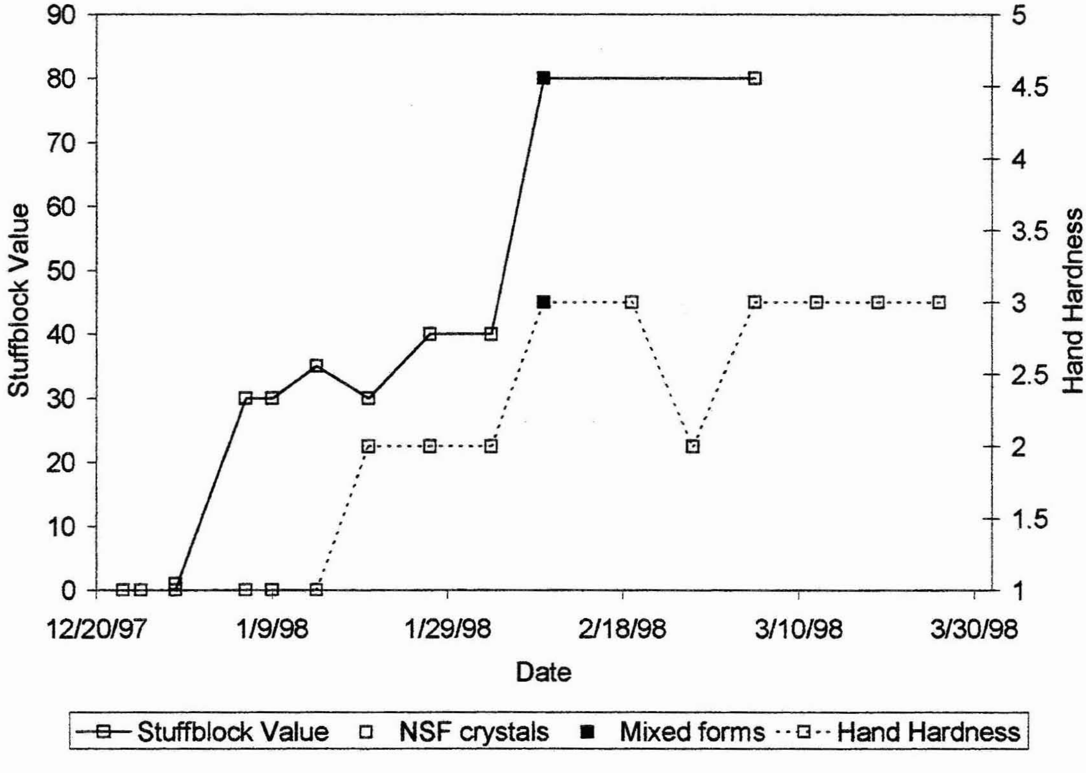

Figure 6. North-facing site stuffblock and hand hardness values.

DISCUSSION/CONCLUSIONS

The three study plots showed marked differences in crystal type trends during the study period (Figure 4). The transition dates we observed from faceted forms to mixed forms to wet forms are consistent with Dexter's (1986) observations despite the geographical differences.

The transition from relatively weaker faceted crystals to stronger mixed forms at the south-facing site (Figure 4) is represented by an increase in both stuffblock and hand hardness during January (Figure 5). The two hand hardness values of 5 in early January (Figure 5) are probably anomalous due to ice columns from flow fingers. As the south-facing site crystal type changed from more well-bonded mixed forms to less well-bonded wet grains, stuffblock and hand hardness decreased indicating a loss in strength. This loss in strength may initially be due to accelerated faceted crystal growth between melt-freeze crusts, and may have further weakened as the layer becomes isothermal at 0°C in March. This final observation is similar to Armstrong's (1985) observation of a loss in strength from increasing amounts of liquid water in late April.

At the north-facing site, the layer represented by string #1 remained faceted throughout the study period (Figure 4) resulting in a slow increase in stability and strength (Figure 6). This layer was the most persistent of the observed weak layers, resulting in numerous avalanches in the area. 50 days after the layer's burial, a snowboarder-triggered avalanche occurred 1 km away from the study plot, on a 36°, northeast-facing slope, at 3,380 m.

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