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VEGETATIONAL AND GEOMORPHIC CHANGE ON SNOW AVALANCHE PATHS, GLACIER NATIONAL PARK, MONTANA, USA

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Abstract.— Six subalpine snow avalanche paths studied in 1975 were revisited in the summer of 1983, with the purpose of examining geomorphic and vegetational change that may have occurred during this eight-year period. Repeat photography and field reconnaissance were used to assess vegetational and geomorphic change. Vegetational responses to avalanches were apparent on several of the avalanche paths, generally by an increase in brush cover. Geomorphic changes were not apparent, suggesting that avalanches need not be geomorphically effective to initiate substantial vegetative disruption.

Long-term records of geomorphic and vegetational change in subalpine and alpine environments of North America are scarce, because of the limited period of historical settlement and problems of inaccessibility. Recent studies have reported geomorphic change on alpine debris slopes based on periods of observation ranging from 7 to 15 years (Gardner 1979, 1982, 1983a, Luckman 1981). Subalpine slopes, however, have been relatively ignored in long-term studies.

In 1975, Butler examined the general vegetative conditions and geomorphic processes active on 12 subalpine avalanche paths in Glacier National Park, Montana, USA (Butler 1979). The intent of the study presented here is to describe the geomorphic and vegetational changes that took place on six of these snow avalanche paths during the eight-year interval from 1975 to 1983. The occurrence and synchroneity of large-scale destructive avalanches were of particular interest.

Sites MV3, MV4, SN5, SN6, SN7, and SN8 were revisited in 1983 (Fig. 1). MV3 and MV4 had also been revisited briefly in 1981. These paths all impinge on either a highway (MV3 and MV4 in the McDonald Creek Valley), a heavily used foot trail (SN6, SN7, and SN8 in the Snyder Creek Valley), or a popular backcountry campsite (SN5 in the Snyder Creek Valley), and thus major avalanche events are noted by National Park personnel. These six avalanche paths were selected for further study because: (1) some had tree-ring and/or highway and trail crew maintenance records of avalanche frequency and magnitude (MV3, MV4, SN5, and SN7); (2) some were encountered enroute to the above paths and had similar characteristics of vegetation and site conditions (SN6 and SN8); and (3) time limitations restricted revisitation to the most easily accessible paths. Detailed site descriptions of the six revisited paths may be found in Butler (1979).

Tree species present on the drier avalanche paths of the Snyder Creek Valley include *Abies lasiocarpa* and a few *Pseudotsuga menziesii*, whereas the paths of the McDonald Valley support *Betula papyrifera* and *Picea engelmannii*. Flexible-stemmed shrubs and small trees, able to withstand avalanche impact pressures of up to about 10 t m^{-2}, include *Acer glabrum*, *Alnus* spp., *Sorbus scopulina*, and *Crataegus douglassii*. *Acer* and *Alnus* are most common (Butler 1979). Smaller, flexible berry bushes (e.g., *Vaccinium*) are also common.

Methods

Repeat Photography

Repeat photography allows qualitative assessment of geomorphic and vegetational changes that may occur over a given interval. Photographs taken during field work in 1975 were repeated in 1981 for MV3 and MV4 and on all six sample paths in 1983. Photographs were taken looking up-path from the farthest down-path point (in the case of SN5,

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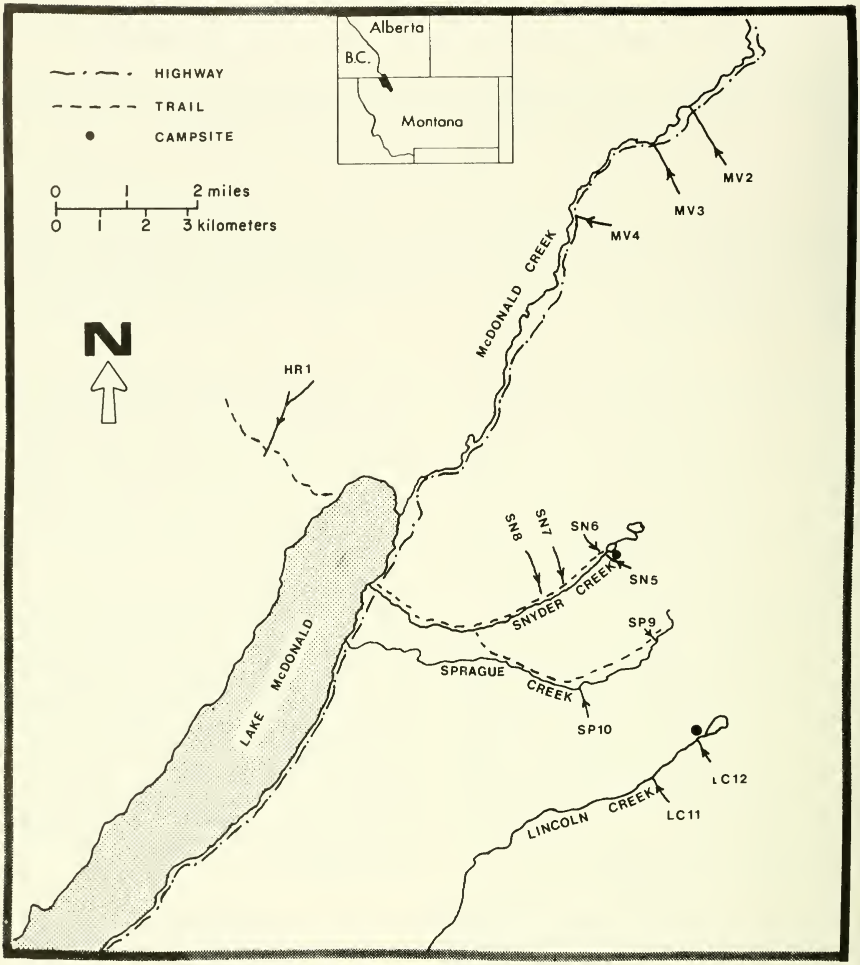

Fig. 1. Map of the study area in the central portion of Glacier National Park, Montana, showing the location of the avalanche paths mentioned in the text. The inset map shows the location of Glacier National Park in relation to Montana and the Canadian–USA border.

heavy brush cover dictated that photographs be taken about 100 m from the path, on the opposite valley side). Figure 2 illustrates a typical subalpine avalanche path (SN8) as it appeared in 1983.

Dendrogeomorphology

Butler (1979) tagged 30 trees in the runout zone of path SN7 in 1975. Relocation of these trees and assessment of their condition would indicate whether a large-scale destructive avalanche had occurred during the interval between visits. Additional tree-ring dating of high magnitude avalanche events had been planned for paths SN5, SN6, and SN8. Access to Snyder Creek drainage was closed, however, on 24 June 1983, because of the presence of two families of grizzly bears (*Ursus arctos horribilis*). The drainage was

Fig. 2. Left, View up-path on path SN8 in 1975. Right, View up-path on path SN8 in 1983. Notice the increase in alder in the runout zone and growth of subalpine fir and Engelmann spruce in the upper reaches of the path.

not opened again during the field season. Prior to the closing of the valley five cross-cut samples from avalanche-damaged trees at the base of path SN8 were collected for dendrogeomorphic analysis.

Historical and Observational Records

The *Hungry Horse News*, a weekly newspaper published in Columbia Falls, Montana, regularly records information on avalanches that close highways in the Glacier National Park area. Reports and photographs from the newspaper were used to assess large-scale avalanche frequency on paths MV3 and MV4. Trail crew and highway personnel provided additional observations of avalanche events, from both direct observation and observation of avalanche debris in backcountry areas.

Results

The data on avalanche occurrences provided the context in which to assess any geomorphic and vegetational changes as revealed by site examination and repeat photography. The following section presents specific results from each of the six avalanche paths; this is followed by a discussion of the geomorphic and vegetative implications of the study.

Path MV3 continues to annually experience snow avalanches that descend to Going-to-the-Sun Highway, as revealed through conversations with park personnel. Photographs taken in 1975, 1981, and 1983 revealed snow cover in the avalanche path but essentially no vegetational or geomorphic change. Individual trees along the sides of, and within, the path are identifiable in photographs from each year, illustrating that no new high magnitude avalanches have occurred since 1975. On other avalanche paths in the park, post-1975 avalanches have extended both the longitudinal and transverse trimlines along path margins (Butler and Malanson 1985, in press). No major geomorphic change is detectable on path MV3; the stream channel within the path has remained stationary, no deposits of fresh rock debris were detected in the runout zone in 1981 or 1983, and no new erosional scouring has been identified.

Path MV4 has experienced avalanches that reached the lower portions of the runout zone in all but two years since 1975. Vegetational characteristics have remained remarkably similar during the years between 1975 and 1983, with *Acer glabrum* and *Alnus* spp. continuing to dominate the path. Trees seen along the margins of the path in 1975 were again identifiable in 1981 and 1983, indicative of no major high magnitude event during the intervals between visits. Individual boulders photographed in the runout zone in 1975 were reidentified in the same positions in 1981 and 1983, and no noticeable addition of clasts has occurred.

In contrast to conditions in the McDonald Creek Valley, three of four paths reexamined in the Snyder Creek drainage have undergone extensive vegetational change since

1975. Only path SN7 appears little changed. The tagged trees at the base of the runout zone of path SN7 were successfully relocated. No new avalanche damage was discernible, and the very presence of the same trees indicates an absence of high-magnitude avalanche events. Small subalpine firs (*Abies lasiocarpa*) within the runout zone and lower track were also relocated by repeat photography. Shrubs (primarily *Acer glabrum*) experienced no increase in number and grew very little. Geomorphic changes were not apparent anywhere on the path.

Path SN5 has experienced at least one large avalanche since 1975. Trail crew personnel encountered vegetative destruction and deposition at the Snyder Lake backcountry campsite (Fig. 1) in the early summer of 1979 (J. Oelfke, pers. comm., February 1983). The destruction of trees was attributed to a large avalanche event during the 1978–1979 avalanche season. Vegetation encountered in 1983 was very dense, with a large increase in *Alnus* spp. over what had been present in 1975. The increase in deciduous shrubs suggests that 1978–1979 was not the only avalanche winter since 1975, because such flexible shrubs are themselves indicators of a continued avalanche frequency of every one to three years (Schaerer 1972, Butler 1979); coniferous succession on disturbed areas in the park occurs if the disturbance ceases (Parker 1982). Grizzly bears are known to prefer the shrub and berry habitat of avalanche paths (Martinka 1972), and the increase in shrubs (and berry bushes) may be partially responsible for the presence of grizzlies in 1983. This dense shrub cover that developed between 1975 and 1983 effectively precluded useful repeat photography. Gross morphology of the track and runout zone remained unaltered from their 1975 appearance.

Conditions on path SN6 were very similar to that described for SN5, with a dramatic increase in size of *Acer glabrum* and *Alnus* spp. masking any geomorphic change that may have occurred. No data were available on avalanche frequency because of the drainage closure on 24 June 1983. The level of brushiness suggests, however, that avalanches have been frequent.

Path SN8 experienced a great deal of vegetational change during the eight years between visits; yet it apparently remained geomorphologically static. No fresh clasts were located in a reconnaissance of the runout zone, the small stream channel in the path had not shifted position, nor were other changes apparent in repeat photography comparisons. Repeat photography was difficult, however, because of the profusion of alder (*Alnus* spp.) that had grown since 1975, obscuring the view up-path (Fig. 2). Cross-sections from avalanche-damaged Engelmann spruce (*Picea engelmannii*) and subalpine fir located in the runout zone all recorded evidence of trauma (reaction-wood growth, corrasion scars, and severely suppressed rings) from the avalanche seasons of 1978–1979, and 1981–1982. The only firm dendrochronologic data suggesting avalanche-induced trauma prior to 1975 were for 1965–1966. These data suggest that avalanches have reached the runout zone in the last eight years more frequently than in the previous 25 years, probably accounting for the increase in alder, as well as *Vaccinium* bushes. The path has become, because of increased avalanche frequency, prime grizzly habitat; recently clawed trees and fresh scat attested to the presence of grizzlies in the path in June 1983.

Discussion

Dendrochronologic data indicate that a major avalanche event occurred on path SN8 during the 1978–1979 avalanche season. This date is correlative with the destructive campsite event on path SN5, as well as with other major avalanches in the park that occurred in February 1979 (Panebaker 1982, Butler and Malanson 1985, in press). Previous work (Butler 1979) that suggested that no path-to-path synchroneity of avalanche events occurred in the central portion of Glacier National Park may be partially in error; work is continuing on this topic.

Observations of geomorphic change based on field examinations and repeat photography indicate that no differences developed in gross path morphology between 1975 and 1983. On a small scale, individual clasts identifiable in photographs taken in 1975 remained in the same locations in 1981 and 1983, again indicative of an absence of geomorphic change. Snow avalanches that occur on the same paths apparently do not come into effective erosional contact with the ground surface. This conclusion was suggested in previous work, which stated that snow-on-snow avalanches prevented damage to lower portions of trees on avalanche paths (Butler 1979:26). Recently, Gardner (1983b) has shown that even avalanches that move over snow-free and thawed surfaces may have no erosional impact, a result of a protective layer of snow deposited by a moving avalanche. In spite of the geomorphically ineffective avalanches that occurred during the study period, vegetative damage was sustained on several paths, and shrub density increased. Snow avalanches need not be in effective geomorphic contact with the ground surface to produce vegetative responses. Research will continue in Glacier National Park to further examine the question of the geomorphic effectiveness of subalpine snow avalanches.

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