AVALANCHE ECOLOGY AND LARGE MAGNITUDE AVALANCHE EVENTS – GLACIER NATIONAL PARK, MONTANA, USA

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ABSTRACT: Large magnitude snow avalanches play an important role ecologically in terms of wildlife habitat, vegetation diversity, and sediment transport within a watershed. Ecological effects from these infrequent avalanches can last for decades. Understanding the frequency of such large magnitude avalanches is also critical to avalanche forecasting for the Going-to-the-Sun Road (GTSR).

In January 2009, a large magnitude avalanche cycle occurred in and around Glacier National Park, Montana. The study site is the Little Granite avalanche path located along the GTSR. The study is designed to quantify change in vegetative cover immediately after a large magnitude event and document ecological response over a multi-year period. GPS field mapping was completed to determine the redefined perimeter of the avalanche path. Vegetation was inventoried using modified U.S. Forest Service Forest Inventory and Analysis plots, cross sections were taken from over 100 dead trees throughout the avalanche path, and an avalanche chronology was developed.

Initial results indicate that the perimeter of this path was expanded by 30%. The avalanche travelled approximately 1200 vertical meters and 3 linear kilometers. Stands of large conifers as old as 150 years were decimated by the avalanche, causing a shift in dominant vegetation types in many parts of the avalanche path. Woody debris is a major ground cover up to 3 m in depth on lower portions of the avalanche path and will likely affect tree regrowth. Monitoring and measuring the post-avalanche vegetation recovery of this particular avalanche path provides a unique dataset for determining the ecological role of avalanches in mountain landscapes.

1. INTRODUCTION

Snow avalanches threaten human life, property and infrastructure in mountainous areas worldwide. A class 5 avalanche is the largest magnitude avalanche based on the United States classification scale (Greene et al., 2004). This type of avalanche is capable of destroying buildings, gouging the landscape, and redefining the topographic parameters of existing avalanche paths. Understanding impacts and consequences of large magnitude avalanches is important because extreme weather events that can trigger them may become more common in the context of climate change. At Glacier National Park, Montana, USA, understanding large magnitude avalanches is also critical to avalanche forecasting for the annual spring opening of the Going-to-the-Sun Road (GTSR), where machine operators work below and within avalanche paths (Reardon and Lundy, 2004).

Large magnitude snow avalanches occur rarely but are a major ecological disturbance in mountain landscapes with consequences that last for decades or centuries (Bebi et al., 2009). Large magnitude avalanches move sediment, plants and nutrients from alpine zones near ridge tops to valley bottoms, influencing biogeochemical cycling (Butler et al., 1992). Avalanches damage or remove forest cover in mostly linear paths that then host a larger array of herbaceous plants and increase montane biodiversity. These avalanche paths can then act as natural firebreaks to forest fires, changing fire dynamics and creating more complex vegetation mosaics (Malanson and Butler, 1984). The florally diverse paths are critical habitat for wildlife species, including threatened and keystone species such as grizzly bears (Mace and Waller, 1997). Large magnitude avalanches can deposit debris in streams, changing habitat for fish species and other aquatic organisms. Lastly, after the initial large magnitude avalanche occurs and for up to two years, the snow deposits at the base of avalanche paths act as a temporary hydrologic reservoir by releasing water slowly through the dry season (Bebi et al, 2009).

The GTSR in Glacier National Park is positioned mid-track near the Continental Divide and is subjected to frequent avalanches

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(Reardon and Lundy 2004) (Figure 1). In January 2009 a large magnitude avalanche cycle occurred in Glacier National Park, Montana, following a rapid increase in temperatures resulting in rain-on-snow on the lower portion of the avalanche path and heavy, wet snow on the upper portion of the path (Figure 2).

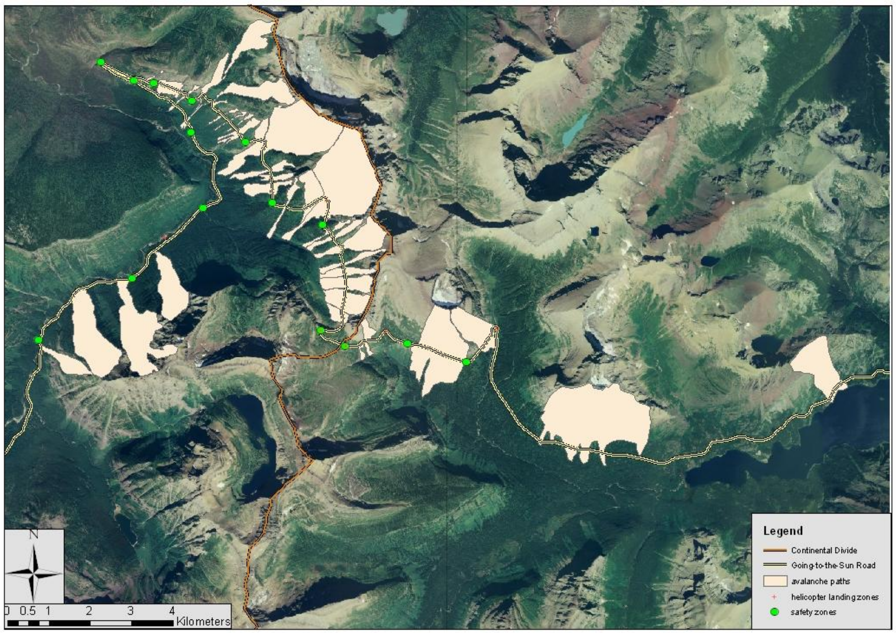

Figure 1. Overview of avalanche paths affecting the Going-to-the-Sun Road (GTSR), Glacier Park, Montana

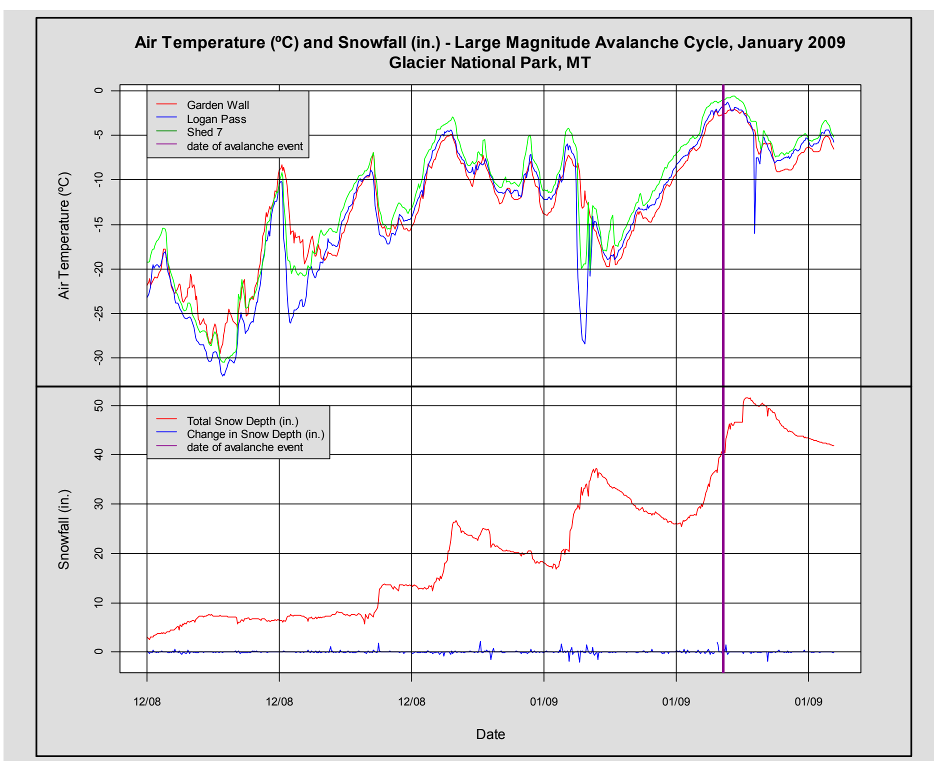

Figure 2: Weather conditions preceding the large magnitude avalanche cycle, Glacier National Park, January 2009.

The initial investigations occurred in April 2009 during forecasting operations for the annual spring plowing of the GTSR. The avalanche, designated the Little Granite avalanche path, was estimated to have descended 1200 m from the start zone near the crest of the Garden Wall and travelled approximately 3 km to end in valley bottom forests near Upper McDonald Creek (Figure 3).

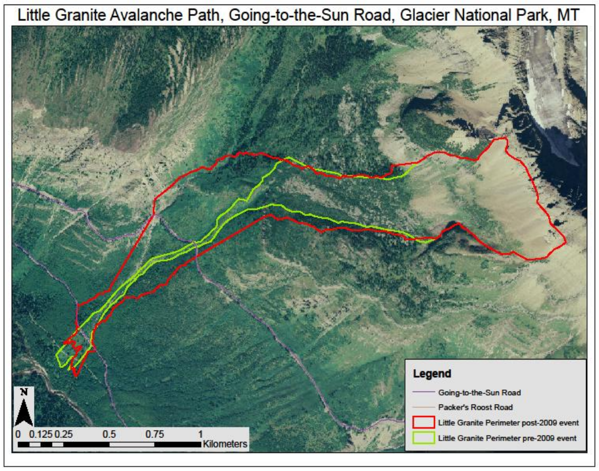

Figure 3. Path perimeters of Little Granite avalanche path before and after January 2009 release.

The massive avalanche had so much momentum that it traveled approximately 1.6 km across a nearly level bench, shearing off a mature forest, before reaching a rollover where it split into separate paths (Figure 4). Part of the GTSR roadway and historic rock wall was destroyed and a massive debris pile of trees and snow, 10 m high, required several days for heavy equipment to establish an opening through to facilitate the spring plowing.

Figure 4. The Little Granite Slide bulldozed a linear path through an established forest.

The meteorological conditions that caused release of the avalanche in the Little Granite avalanche path also caused numerous other major avalanches throughout the park and surrounding mountains. However, the early discovery of this path and its ease of access on the GTSR made this an ideal site for further investigation and to acquire baseline data on large magnitude avalanches, their frequency, and their ecological impacts. The specific objectives were to:

- Establish the new spatial extent of the path
- Establish the power of the avalanche via standardized tree damage assessments
- Establish the extent of vegetation disturbance post-event
- Establish frequency of occurrence of large magnitude avalanches through dendro-morphological methods
- Establish a vegetation monitoring program to document the impacts to plant diversity and phenology and the rates of ecological recovery to pre-disturbance states

2. METHODS USED AT LITTLE GRANITE AVALANCHE PATH

The initial avalanche investigation was to field map the entire avalanche perimeter from the headwall to the valley bottom using a Trimble Geo XH Global Positioning System (GPS) with an external antenna that provided +/- 0.2 m accuracy. A line-of-sight estimation was made for two steep and unstable sections that required roped climbing. This perimeter was digitized in a Geographic Information System using ESRI ArcGIS 9.1 software, a 10 m Digital Elevation Model (DEM) and USDA Farm Services Agency National Agriculture Imagery Program (NAIP) 2005 imagery.

A digital vegetation classification map of Glacier National Park was overlain on the path perimeter to establish polygons of different vegetation types contained within the path. A buffer of 40 m outside the avalanche path was also mapped to establish plots that will provide for comparisons of vegetation change within the path and immediately outside of it.

Damaged and dead trees were surveyed along transects within plots and categorized according to a damage index (n=33)

(Molina et al., 2004). Damaged and dead trees were also sampled by either taking tree cores with an increment borer outside the avalanche path (n=15) or cross sections taken with chain saws from different parts of the path (n=135) to sample the age distribution of trees killed or damaged. Some of the cross sections were >1 m in diameter. Cores and cross sections were examined with standard dendrochronological techniques (Stokes and Smiley, 1968) to cross-date all samples, determine tree age distribution, and to record frequency and dates of previous avalanche caused damage.

Repeat photography sites were established at multiple points in the avalanche path to visually record rates of vegetation and other change through time. Vegetation composition was surveyed in plots (n= 24) established throughout the vertical and lateral extents of the avalanche path in each of the 5 vegetation classes. These plots were closely modeled along the U.S. Forest Service's Forest Inventory and Analysis (FIA) plots (USDA Forest Service, 2010) and can therefore be related to rates of vegetation change in the surrounding region (Figure 5). The relative occurrence of 5 major plant phenological types were recorded. These were:

- Northern Rocky Mountain Avalanche Shrubland
- Rocky Mountain Alpine Meadow
- Rocky Mountain Subalpine (cool) Deciduous Broadleaf and Mixed Forest
- Rocky Mountain Subalpine Mesic Conifer Forest and Woodland
- Rocky Mountain Wet Meadow and Snowbed

The repeat photographs and vegetation monitoring are designed to be repeated annually. The path perimeter will only be re-mapped in the event of changes caused by future avalanches.

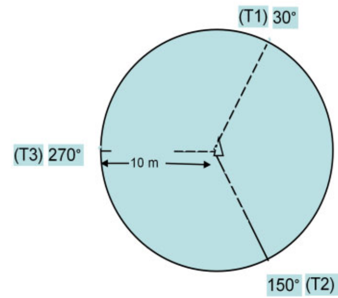

Figure 5. Modified FIS plots used for documenting vegetation change in avalanche paths.

3. RESULTS

Field mapping the entire perimeter of the Little Granite avalanche path revealed that it had significantly expanded the existing path area (Figure 3), killing trees up to 150 years old and transforming the structure and distribution of vegetation within the new path dimensions. The area for the Little Granite avalanche path increased from 61 hectares to 95 hectares. The avalanche descended a vertical distance of 1200 m through 5 vegetation classes from the high alpine tundra to mesic riparian forests (Figure 6). The avalanche traveled 3 km from the upper starting zone of the avalanche path to the bottom reaches of the runout zone.

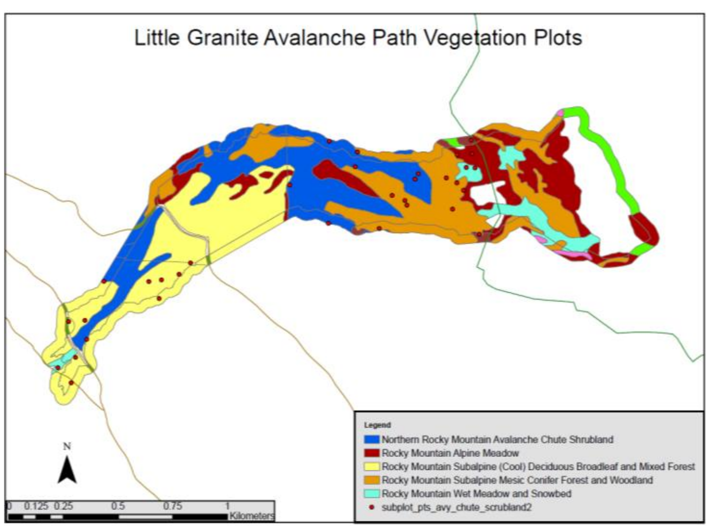

Figure 6. Distribution of vegetation impacted by Little Granite avalanche path, Glacier National Park.

Hundreds of trees were carried to the runout zone. The impact force of this avalanche caused many trees 35-100 cm in diameter to be uprooted and transported nearly 2.5 km. Of the 135 sampled trees in the path, 65 percent were uprooted and transported. The mean diameter of sampled downed woody vegetation was 35 cm and average length was 420 cm.

In the first growing season post-large magnitude avalanche, the vegetation classes within the path changed. Initial monitoring results show that the largest difference was the reduction in conifer forests. Qualitatively, vegetation damage in the Northern Rocky Mountain Avalanche Chute Scrubland class, along with the area reduction in the forest classes, served to create an open canopy environment that will favor herbaceous plant species in the intermediate future.

Repeat photographs (n=8) were taken from three camera stations in the summer of 2009 after the large magnitude release and show a robust growth of herbaceous and shrub species in all photographs except in the runout zone, which is now dominated by piles of downed trees that were transported from higher elevations within the avalanche path.

Figure 7. Repeat photography camera station showing piles of woody debris near the lower GTSR and herbaceous vegetation growing through the debris after large magnitude avalanche.

Avalanche impacts to the alpine vegetation in the starting zone were largely undetectable. Only minimal damage occurred in the shrubland vegetation class with slide alder (*Alnus sinuata*) rebounding during the first growing season to create a 3 m high canopy where it had already previously been established. Relatively little bare soil was created from this avalanche, nor was there much transport of rock debris. Most soil transport was in association with the root wads of the trees carried downslope.

4. DISCUSSION AND FUTURE RESEARCH

The expansion of the Little Granite avalanche path, the documented impact forces on trees and infrastructure, the destruction and transport of hundreds of trees, and the alteration of vegetation classes within the confines of the new path perimeter all confirm that this was a Class 5 avalanche event (Greene et al, 2004). This avalanche was one of many during a single, albeit relatively rare, avalanche cycle and illustrates the landscape-level effects of snow avalanches at Glacier National Park. The ecological impacts we've documented with the establishment of this study and partially reported in this paper for this large magnitude event underscore the significant role that snow avalanches play in mountain ecosystems by regularly disturbing montane vegetation, particularly forests. The resulting habitats are of great value to wildlife and may be maintained if avalanches are frequent enough. This paper presents our initial efforts in a long-term ongoing monitoring program that will document avalanche frequency for a representative path by developing the avalanche chronology that will characterize the significance of the January 2009 avalanche cycle.

The ongoing vegetation plot monitoring and repeat photography will provide a rate of ecological recovery by documenting the shifts in vegetation through time. By understanding the temporal contexts of both the disturbance event (the destructive avalanche) and the recovery rate of the vegetation, we can understand two important drivers of high-elevation vegetation mosaics that, in turn, influence other mountain ecosystem dynamics such as fire and hydrology.

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DISCLAIMER

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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