FIELD OBSERVATIONS AND MAPPING OF AN AVALANCHE EVENT IN SECOND CREEK, BERTHOUD PASS, COLORADO

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ABSTRACT: Debris from a recent large avalanche event was observed in the runout zone in Second Creek, Berthoud Pass, Colorado. The debris extent and the amount of forest destruction were notable with both broken boles and uprooted and transported trees. On-site measurements of the alpha angle were surprisingly low at 17 degrees, based on clinometer measurements from the toe of the runout debris to the obvious crown. While alpha angles as low as 14.8^{o} have been reported in Colorado, the mean alpha angle in this snow climate is 22.1^{o}. Observers returned to the site during summer months to map terrain, core trees, collect thin sections (cookies), and map debris deposition locations. Measurements were analyzed to look at return periods for path locations and to map runout extent in the basin. The basin receives frequent wintertime backcountry use from skiers, snowboarders, and snowshoers. A backcountry hut has recently been constructed in the basin, extending daytime use in the area and increasing multi-day overnight use. Two more large avalanches have been documented in the area close to the hut and informational mapping of hazardous areas and observed runout extents, along with daily avalanche and weather forecasts will be valuable to recreational users.

KEYWORDS: avalanche runout, alpha angle, zoning, hazard

1. INTRODUCTION

Avalanche runout distances have been of great interest to society from the time of first settlement in mountain areas of the world. Concern over avalanche runout dates back more than 500 years in Europe and more than a century in North America. Early interest focused on observations of extent and information was passed on between generations based on experiences of past death and destruction.

As greater numbers of people and infrastructure moved into avalanche terrain, it was necessary to change from reactive response to predictive capabilities to address problems before they occurred. In the last few decades there has been a large amount of research relating terrain, vegetation, ground cover, snowpack properties and flow dynamics to runout distance in objective ways.

Burrows and Burrows (1979) published the first comprehensive treatment of dendrochronological methods to map and date avalanche occurrence and extent. Many subsequent studies have built on the methods they presented. Terrain-based estimates of runout distance were first developed by Leid and Bakkehoi (1980) using long-term records of events in Norway coupled with terrain analyses. They defined a metric for avalanche path study and comparison referred to as the alpha angle.

Alpha angles are defined as the vertical angle from the most distant point where avalanche debris is deposited to the release point of an avalanche. This value is the mean path angle. The alpha angle is the most objective measure of runout distance and is useful for comparison with other paths, other climates, and for engineering and planning purposes. The two critical points (release and deposit) may be observed and are often well known in mountain areas that have been populated for long periods. The release point may also be determined by terrain analysis or by observation from experienced personnel. Determination of deposit locations is greatly facilitated by observing damage to tree in forested runout zones, and may also be aided by other destruction, visual, and historical evidence.

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Mears (1984) details extreme avalanche runout distances and alpha angles of the Colorado continental radiation climate, terrain and snowpack. His results show the lowest alpha angles in the range of 14.8° to 18.1°. In 1988, Mears published another paper where he looked at a larger sample size (130) of extreme paths in Colorado and found a mean alpha angle of 22.1°.

We observed a recent avalanche event in Second Creek, located on the north side of Berthoud Pass between Empire and Winter Park, Colorado. It is an east-facing basin and the starting zone receives considerable lee-side loading from consistent, strong westerly winds. The starting zone is located above tree line and the snowpack is cold and relatively low density producing soft slab avalanches. These are all characteristics that Mears (1980) found contributed to paths capable of producing extreme runout distances. Large cornices are found in the starting zone every winter and the basin produces multiple avalanche events each year. We believe the event we observed was a recent direct action avalanche because we observed it during a multi-day stormy period and debris was still easily visible. Two details struck us when we skied into the runout zone. First, was the extent of the debris. Deep deposits were located a long distance across a low angle runout zone and debris was located in thick trees where it had to travel upslope in some places to reach its terminal point. Second, the avalanche inflicted considerable damage on the vegetation in the runout zone, breaking and uprooting trees. We observed the maximum extent of the avalanche debris and recorded the alpha angle using a Suunto clinometer capable of measuring to the nearest degree. Again, we were struck by the low alpha angle of 17° and we determined that the path and the event warranted further attention and analyses.

2. STUDY SITE

Second Creek is located on the north side of Berthoud Pass, on US Highway 40 between Empire and Winter Park, Colorado. The path is an



Fig.1: Image of avalanche path in Second Creek, Berthoud Pass, Colorado. Line shows approximate line of travel for the observed and extreme events for this path. Approximate crown, 2012 maximum runout distance, and historical path maximum runout distance are indicated. Image is from Google Earth, 23 September, 2011 acquisition.

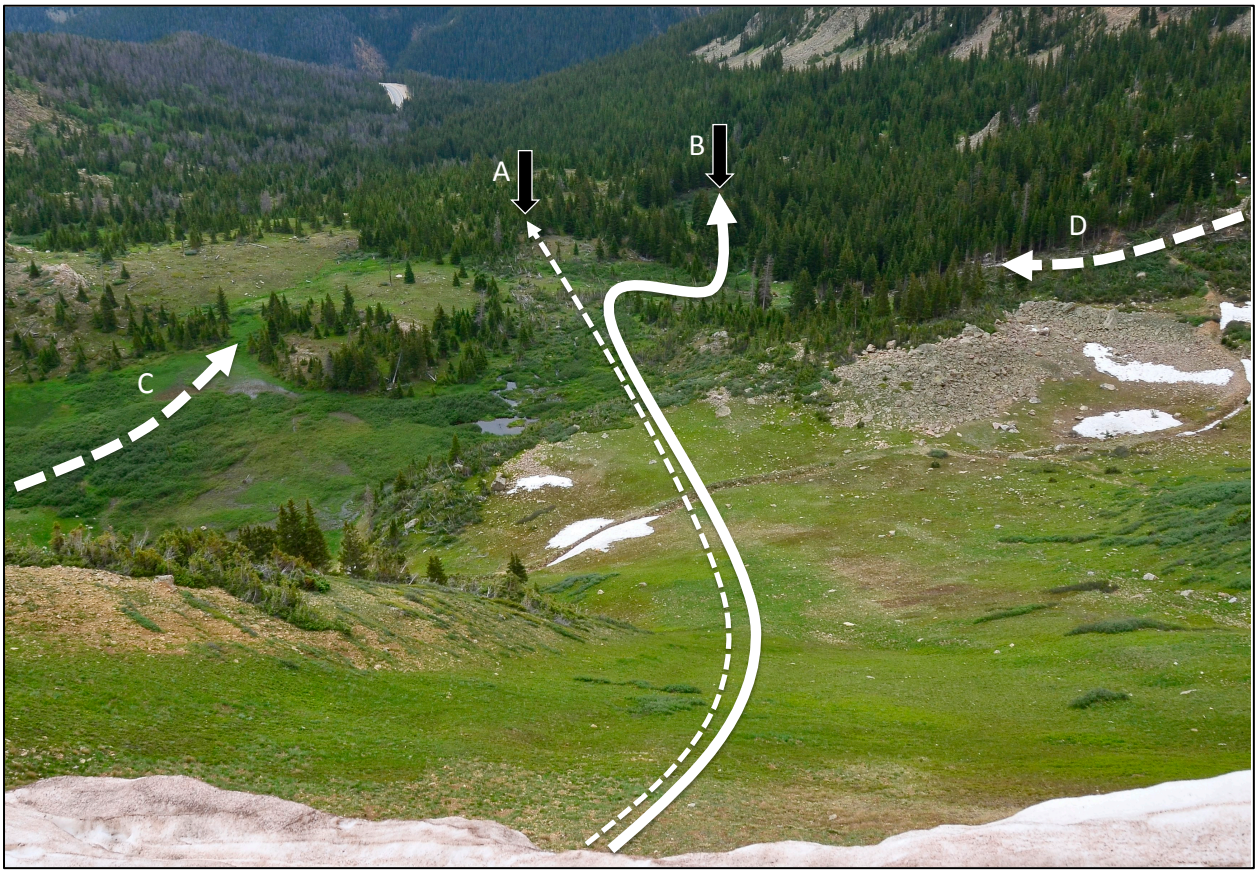

Fig. 2: Avalanche path from the top of the starting zone. Point A and the narrow dashed line represent the 2012 flow and extent. Point B and the solid line represent the approximate historical maximum flow-line and terminal extent. Dashed lines C and D represent two of the many paths that converge from the ridgeline into the bottom of this cirque. Path D is a probable path that contributes to the maximum runout distance and may in fact be the most important path in contributing to the historical maximum runout distance.

east-facing cirque with alpine portions dominated by herbaceous vegetation and some krummholz (Fig 1 and 2). Subalpine portions are dominated by Engelmann spruce (Picea *engelmannii*), lodge-pole pine (Pinus *contorta*), and subalpine fir (Abies *lasiocarpa*). Willow (salix) and other shrubs are present and followed preferred distribution related to water and soil properties. The avalanche path addressed in this study is located between 3500 and 3300 m a.s.l. and consists of a relatively steep (~40°) starting zone and track that delivers snow to the runout zone, which contains several benches or flat areas punctuated by short, steep slopes.

3. WEATHER

The 2012 event occurred during a winter storm that included precipitation and wind. Data from the Berthoud Summit SnoTel site suggests that about 20 mm of water was deposited during 23 February, two days prior to our observations. Redistribution and lee-side drifting into the starting zone were likely significant. The terrain, weather and hazard were too extreme to conduct a fracture line profile or to approach the starting zone when the event was discovered. The crown appeared to be approximately 2 m deep.

4. METHODS

Dendrochronological techniques were used to date individual avalanche events, determine the age of trees removed in the 2012 event, and to look at extreme event extent. Trees with obvious avalanche scaring were cored (Fig 3 and 4), as well as trees within the path that potentially contained event information such as hidden scars or reaction wood (Fig. 5 and 6). Cookies were removed from dead trees that were broken or uprooted (Fig. 7). Terrain factors including path

profile and alpha angle were quantified using Google Earth to get rough approximations, which were confirmed with field data.



Fig.3: Large scar on upslope side of subalpine fir bole in the runout zone.



Fig. 4: Uprooted and broken trees in the runout zone from the observed 2012 event.



Fig. 5: Field check for reaction wood and scars in core extracted from living tree in the runout zone.



Fig. 6: Coring a tree in the runout zone. Note the lack of branches on the upslope side of the tree clump and note the lack of mature trees in the path above. This tree was located near the 2012 runout maximum.

5. RESULTS

Results presented here are preliminary. Further analysis using more sophisticated tools such as GIS and possible flow modeling are planned. The basic results presented herein are fairly robust and we do not expect the future work to change runout extent or the alpha angle significantly.

5.1 Slope profile

We used Google Earth to plot a vector of the avalanche flow path from an approximated release point in the starting zone to measured locations of runout distances. We marked the locations of both the 2012 maximum runout and the historical maximum runout based on observation from tree damage. Elevations were taken from the vector at 10 m distances along the flow line. Elevations and distances were plotted in Fig. 8. Calculations of alpha angels for both the 2012 event and the historical maximum were calculated using these

same data. It is recognized that the elevations and locations acquired by this method are subject to error, however, these results corresponded closely with our field observations.

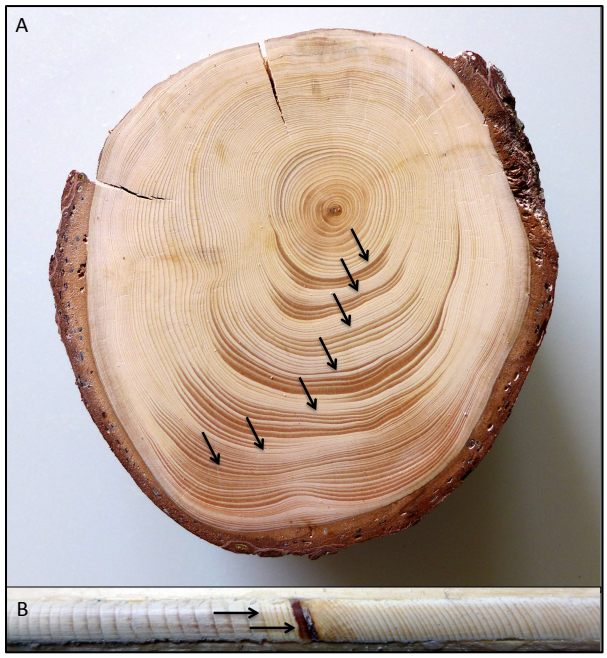

Fig. 7: A) Cross section (cookie) from subalpine fir destroyed and transported in the runout zone. Arrows mark some of the years of a significant impact events on the tree, followed by a series of dark rings called reaction wood, which represent the trees attempt to recover. The cookie is oriented such that impact came from the direction of the top of the image. It appears that the large events impacted the tree approximately every decade. B) Tree core taken from the historic maximum runout position. The left hand arrow shows the beginning of a period of reduced growth. The right hand arrow shows the location and year of the scaring event that left the dark scar line. Center of the tree (pith) and core are toward the left side of the core image. Both tree bark and impact directions are from the right side of the core image.

5.2 Alpha Angle

Our initial observation of the 2012 event alpha angle in the field was 17° using a Suunto clinometer. This value was confirmed later in the field both from the runout terminus and the starting zone. The value was also confirmed with the simple terrain analysis using Google Earth.

The extreme event or historical maximum alpha angle was measured to be 15.5° in the field with the clinometer. The extreme runout position was determined in the field by careful observation of a group of trees that exhibited upslope damage consistent with snow avalanches, rather that rockfall or other disturbances.

6. CONCLUSIONS

This avalanche path has produced large events three out of the last three winters. Two of the years (2012 and 2014) have produced events that caused significant destruction of portions of well-established mature forest. We believe that this basin and the observed alpha angles resulting from its avalanche paths are significant, and represent an important end member in the Colorado avalanche database.

Mears (1984) lists ten Colorado avalanche paths with extreme runout distances based on similar dendrochronological techniques that we used. From the data set of the ten lowest alpha angles in Colorado, the lowest value Mears identified was 14.8°, the mean alpha was 16.8°, and the maximum was 18.1°. (Note that Mears makes no claim that these are in fact the actual ten lowest out of Colorado's more than 1000 avalanche paths, but they are certainly representative of the extremes.)

The path we studied produced an observed alpha angle of 17° from a single event in 2012. This value places the path near the mean of Mear's top-ten list. Our dendrological methods and summertime field observations strongly suggest that the path is capable of producing events that continue further downslope to a distance that yields an alpha angle of 15.5°. This value would place the path in Mear's list as the second lowest observed alpha angle. This path still contains a great deal of interesting information, which we will pursue.

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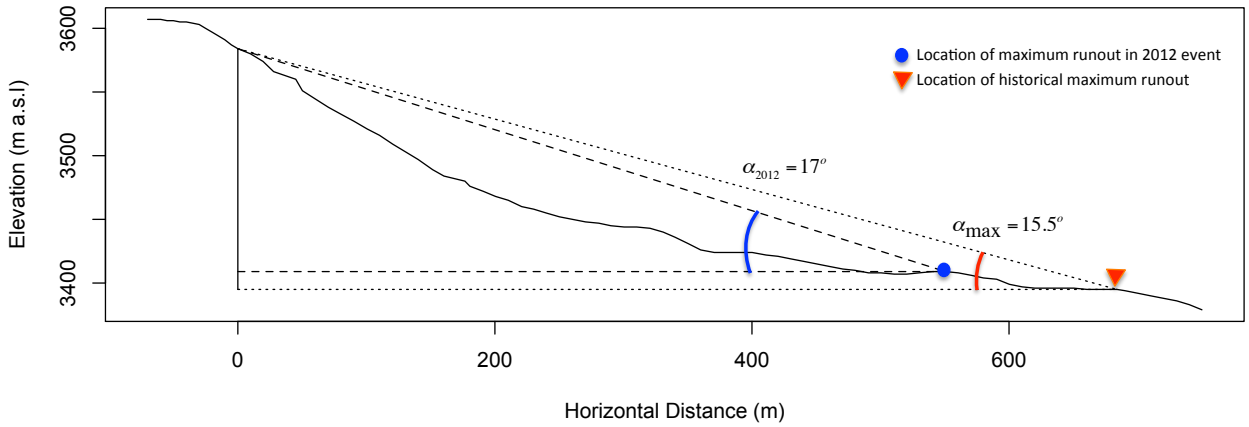

Fig. 8: Slope profile of avalanche path with alpha angles for the 2012 and historical maximum runout distances. Topographic data taken from Google Earth.

REFERENCES

Burrows, C. and V. Burrows, 1976: *Procedures for the study of snow avalanche chronology using growth layers of woody plants*. INSTAAR Occasional Paper No. 23, University of Colorado, 54 pp.

Leid, K. and S. Bakkehoi, 1980: Empirical calculations of snow-avalanche runout distances. *Journal of Glaciology*, 26(94), 165-177.

Mears, A., 1984: Climate effects on snow avalanche travel distances. Proceedings of the *International Snow Science Workshop*, Aspen, CO, 80-83.

Mears, A., 1988: Comparisons of Colorado, E. Sierra, Coastal Alaska, and Western Norway Avalanche Runout Data, Proceedings of the *International Snow Science Workshop*, Aspen, CO, 232-238.