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TERRAIN AND VEGETATION OF SNOW AVALANCHE SITES AT ROGERS PASS, BRITISH COLUMBIA

BY

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LE TERRAIN ET LA VEGETATION SUR L'EMPLACEMENT DES AVALANCHES DE NEIGE A ROGERS PASS EN COLOMBIE BRITANNIQUE

SOMMAIRE

L' auteur décrite trois types de terrain où se produisent des avalanches. On a découvert que la fréquence moyenne des avalanches est d'abord fonction de l'inclinaison moyenne du couloir et secondairement de sa forme. La rugosité, la couche du ter [illegible] ible influence. [illegible] épinettes et de [illegible] es arbres et le [illegible] des avalanc [illegible]

Chapter 5-3

TERRAIN AND VEGETATION OF SNOW AVALANCHE SITES AT ROGERS PASS, BRITISH COLUMBIA.

P. A. Schaerer

The Division of Building Research of the National Research Council of Canada is engaged in a study of snow avalanches at Rogers Pass where the Trans Canada Highway crosses the Selkirk Mountain range in British Columbia. The location was chosen because numerous avalanches reach the valley every winter and the control of them is an important part of the maintenance of the highway.

The terrain and the climate at Rogers Pass are typical for the mountains of the southern interior of British Columbia. The elevation of the narrow valleys is between 900 and 1320 m (2950 and 4350 ft) and the mountains rise to 3000 m (9850 ft) above sea level. The average annual precipitation at Rogers Pass, at elevation 1320 m (4350 ft), is 1.30 m (51 in); 0.80 m (32 in) of it falls in the form of snow.

Avalanches start to slide at elevations of between 1500 and 2300 m (5000 and 7500 ft) and run out on the alluvial fans and talus slopes in the valleys. Most avalanche site areas are between 50,000 and 200,000 m^2 (540,000 and 2,150,000 ft^2).

PROBLEM

Two of the objectives of the study are to obtain information to facilitate identification of avalanche sites and to estimate the magnitude and the frequency of occurrence of avalanches from features of terrain and vegetation. The formation of avalanches is the result of terrain factors such as slope and ruggedness and is also influenced by the weather (e.g., snowfall, wind, temperature). The various parameters are interrelated and it is often difficult to isolate their influence.

The present studies are concerned with avalanches large enough to be significant to traffic, to structures in their path, and to hydrology, geomorphology, and forestry operations. Large avalanches develop when the terrain and the snow condition in the track below the starting point permit a large amount of snow to be removed. There are many other small avalanches that are significant only to avalanche hazard forecasting and skiing safety.

TYPES OF AVALANCHE TERRAIN

The three following characteristic types of terrain where avalanches develop can be found at Rogers Pass and in other areas of southern British Columbia.

Cliff

The important characteristic here is one or more steep outcrops of bedrock in a slope covered with loose rock, grass, or shrub (Figure 1). Snow starts to slide on or just below the steep parts of the terrain and then sets more snow into motion on the slope below. The rock outcrops have surface slope angles greater than 42° and in order for avalanches to grow to a large size the slope immediately below the starting point must have an incline of 28° or more. Cliff-type terrain can usually be recognized by its lack of vegetation and can be identified on black and white air photographs as horizontal bands in a light tone.

Gullies

Gully-type sites consist of a V-shaped main gully with numerous branches of steep-sided gullies (Figure 2). There is usually no well defined avalanche starting zone. Avalanches may start in any one of the gullies and, when descending into the main channel, set into motion the unstable snow on the steep gully sides.

The various side gullies often produce avalanches independently and at different times. Several avalanches may be observed at short intervals when weather conditions are favorable for their formation.

Lee Slopes

This type of terrain can be found on the leeward side of mountain ridges where large amounts of wind-transported snow are deposited (Figure 3). The slope need not have any steep sections, such as cliffs, but in order to produce large avalanches it would appear that the incline should be more than 28°. Avalanches usually fracture close to the ridge in the convex part of the slope just above the deepest accumulation of snow.

The 67 avalanche sites investigated at Rogers Pass could be categorized as follows: 36 cliff sites; 15 gully sites; 9 lee slope sites; 5 combinations of cliff and lee slope sites; and 2 combinations

Figure 1 - Cliff type site. Avalanches start to slide at the two sharp drops of slope.

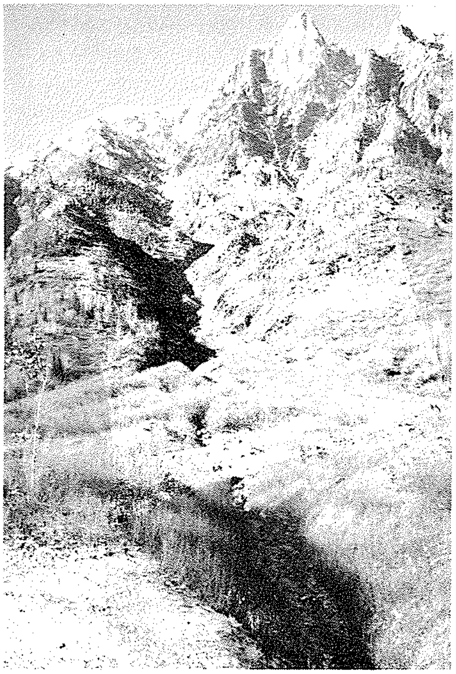

Figure 2 - Gully type avalanche site.

Figure 3 - Lee slope site. The direction of the prevailing wind is from the right-hand side; avalanches start to slide on the slopes in the shade.

of gully and lee slope sites.

The cliff and lee slope avalanches are either funnelled into a channel or may continue to slide over an open slope. The gully type is by its nature associated with a channelled track.

INFLUENCE OF TERRAIN ON THE FREQUENCY OF AVALANCHE OCCURRENCE

The number of times that avalanches will occur is determined more by climate (i.e., frequency and magnitude of snowfalls, temperatures that remain close to 0°C, and direction and speed of wind) than by terrain characteristics. Conclusions about how much terrain influences avalanche occurrence can only be drawn in conjunction with the climate.

The slope incline appears to be the most important parameter relevant to the frequency of occurrence of avalanches. Other parameters are the shape of the track, its ruggedness, vegetation cover, and exposure to wind and sun.

The avalanches close to the highway at Rogers Pass have been recorded since 1953. In Figure 4 the average number of medium and large size avalanches are plotted against the average

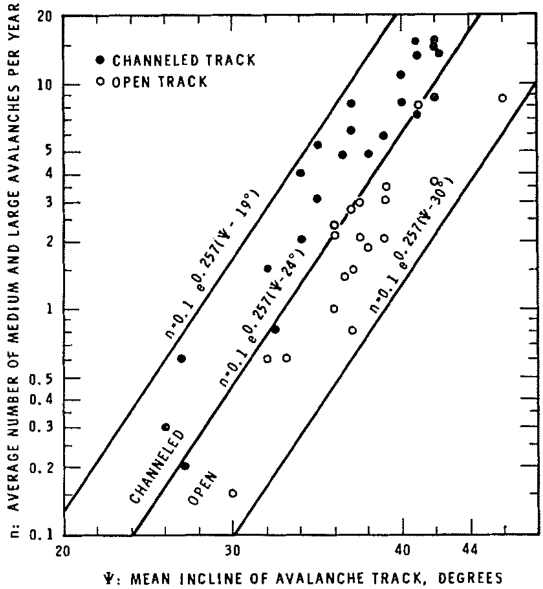

Figure 4 - Relation between frequency of occurrence of avalanches and incline of terrain.

slope angle of the avalanche track for the cliff-type and lee slope-type sites. Gully sites could not be included in the analysis because, at most of them, avalanches were controlled by artillery. Use of artillery produces smaller, more frequent avalanches than would occur under natural conditions. The incline was measured over the full length of the track between the usual starting zone and the beginning of the outrun zone, and the analysis included only those avalanches that were large enough to run over the full length of the track.

The graph shows that in order to produce large avalanches a steeper incline is necessary on open slopes than in channels such as valleys, gullies and troughs. One important reason for the difference is that channels tend to have many small avalanches and the snow deposited by them forms a smooth sliding surface. Loup and Lovie (1967) also report a remarkable difference in the frequency of avalanches between gullies and open slopes.

Exposure to wind and sun, variations of the incline, ruggedness of the terrain and ground cover are responsible for the scatter of the points in Figure 4. It is not yet possible to analyze the influence of terrain characteristics. The method of slope angle distribution, recommended by Strahler (1956), appeared to be promising. The surface slope angles were determined with the aid of topographic maps of scale 1:5000 and contour intervals 7.5 m (25 ft) for 40 to 100 random points in 34 avalanche sites. It was not possible, however, to establish a relation between the frequency and size of the avalanche and the variance of the slope angles. Avalanche activity appeared to be unrelated to the maximum slope or to the percentage of terrain steeper than a threshold angle, e.g., 42° which is the maximum angle of repose of talus. It was only the average slope angle of the track that correlated with the frequency of the avalanches.

From observations made over a twelve-year period it was found that avalanches lose speed on an open snow surface when the incline is less than 28°. They begin to deposit their snow when the talus slopes and alluvial fans of the outrun zones are flatter than this critical angle. Depending on the speed attained in the track, and their mass, avalanches may run much further and sometimes climb the opposite side of the valley.

TREE GROWTH AS AN INDICATOR OF AVALANCHE FREQUENCY

Avalanches have a significant destructive effect on forests. Their tracks can easily be recognized in the mountain area of southern British Columbia by the scars on heavily forested slopes. The dominant species of trees at Rogers Pass are Engelmann Spruce (Picea engelmanni), Western Hemlock (Tsuga heterophylla), and Western Red Cedar (Thuja plicata). Open areas in the forest are covered mainly with Mountain Alder (Alnus tenuifolia). The upper treeline is generally at the 2000 m (6600 ft) elevation.

The age of the trees in the outrun zones of avalanches is sometimes assumed to be equal to the number of years that have passed since the last large avalanche. This is true only for sites where avalanches happen so rarely that when one does occur large areas of mature timber are destroyed. At such sites seedlings begin to grow in the cleared area a year later and a young forest with numerous trees of equal age then appears. At sites with more frequent avalanches the trees are destroyed whenever they have reached a certain critical age and height; the result here is a growth of small trees with variable age.

A study of the height and age of trees in avalanche outrun zones was made at Rogers Pass and other areas. Such observations must be interpreted with caution, however, because not only avalanches but also soil conditions, climate, and exposure influence the growth of trees. Trees must be selected that are fully exposed to avalanches and not protected by boulders or a ridge of terrain. It should also be mentioned here that avalanches usually slide over the snow surface in the outrun zone and remove very little of the previously deposited snow.

The most interesting conclusion of the tree study was that it is the height rather than the age of the trees that determines how it reacts in avalanches; the reaction varies between the species. Height and age of trees are related however, e.g., the spruce trees at Rogers Pass grow at an average rate of 20 cm (8 in) per year, and the hemlocks at about 8 cm (3 in).

Engelmann Spruce is found most frequently in avalanche sites. Its chance for survival in avalanches is small when it is taller than 3.5 m (11.5 ft). Larger trees are usually broken or uprooted. Spruce trees shorter than 3.5 m (11.5 ft) are flexible enough to bend under the impact of the avalanche, and trees shorter than about 1.5 m (5 ft) are buried in the natural snow cover and are well protected.

Western Hemlock that are exposed to avalanches are usually broken near the snow surface, 1.2 to 2.0 m (4 to 6.5 ft) above ground. When the tree trunk does not break the trees are stripped of their needles and branches and then decline.

Western Cedar was found unsuitable as an indicator of avalanche activity, because of a great variation in the rate of growth and strength. Some cedars are observed to survive avalanches year after year and grow 8 m (26 ft) high and others, with equal exposure, break when they are only 3 m (10 ft) high.

Because spruce survives avalanches better and grows more rapidly than hemlock, forests at sites where avalanches have not occurred for 30 to 50 years contain mainly large spruce trees with only a few small hemlock trees. A stand of mixed spruce and hemlock of equal height and ages would indicate that no avalanches had reached its location for 100 or perhaps more years.

The studies on trees in avalanche sites enabled the following categories to be established:

(a) Alder and willow brush (no coniferous trees higher than 1.5 m (5 ft). Large avalanches occur frequently, usually once per year.

(b) Few large trees, no branches on the side facing the avalanche below 8 m (26 ft) above ground, few small trees. Avalanches occur once every one to three years. They produce mainly windblast and deposit snow not deeper than 1.0 m (3.3 ft).

(c) No large trees and no dead wood from large trees; spruce trees 3.5 to 4.5 m (11.5 to 15 ft) high and hemlock 1.5 to 2.0 m (5 to 6.5 ft) high, damaged branches and bark. Large avalanches occur about once every three to ten years and deposit deep snow.

(d) Broken large trees and dense growth of small trees. Large avalanches have occurred not more frequently than once in ten years and probably not even once in thirty years.

CONCLUSION

Avalanche sites can be identified from features of terrain and vegetation. There are numerous parameters that determine the frequency of occurrence and the size of avalanches. An idea of the average frequency of avalanches can be obtained from the average incline of the avalanche track and the type and height of trees in the outrun zone. General classifications could be established for the Rogers Pass area and it is expected that they could be extended to other areas in Western Canada.