THE AVALANCHE DEFENCE ON THE TRANS-CANADA HIGHWAY AT ROGERS PASS

By

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SUMMARY

The Trans-Canada Highway is to be constructed over Rogers Pass in Glacier National Park, B. C. About twenty-four miles of the highway which includes the Pass is threatened by avalanches. In 1953 an avalanche survey was organized to obtain the information required for the design and construction of the highway defence works and for the future avalanche warning service. Avalanches reaching the proposed highway route were surveyed and recorded. For each avalanche site a defence was chosen according to the size and frequency of the avalanche. Snowsheds will be used for protection against the large and frequent avalanches. Earth mounds and dams will be constructed at the sites of smaller avalanches. No protection was planned for those avalanches sites that threaten the highway only once in every three to five years.

The Selkirk Range is one of the more formidable obstacles to ground transportation between British Columbia and the rest of Canada. Within the Selkirk Range is beautiful Glacier National Park, still largely a virgin wilderness (Fig. 1). In the Park, near the town of Glacier, is Rogers Pass. The discovery of this Pass in 1881 by Major A. B. Rogers during his survey for the Canadian Pacific Railway Company established for this company the route over which the first railway link between Eastern Canada and the West Coast was completed in 1885.

The Pass never was hospitable to the railway during its construction or later use. The tracks crossed numerous paths of snow avalanches, which required the construction of sheds with a total length of 5 miles. But even the sheds could not protect the railway line completely and eventually the railway decided to build an alternative line.

In 1916, the construction of the 5-mile-long Connaught tunnel through Mt. MacDonald was completed and the railway line through the Pass abandoned. For about 40 years the Pass was left to nature and the old railway line fell into decay. In 1956 the decision was made to use the Pass as the route through the Selkirks for the first Trans-Canada Highway (Figs. 2 and 3).

Snowfall at Rogers Pass

Glacier is one of the highest snowfall areas in Canada. The average total snowfall for the winter measured over a twenty-year period at the west end of Rogers Pass is 342 inches. The maximum total snowfall measured during the winter of 1953-54 was 680 inches. Snowfall begins usually at the end of October and ends at the end of April. There are no yearly recurring periods of maximum snowfall intensity. Snowfalls have been recorded on every day in one month and periods of two weeks' duration have occurred without snowfall. During winters of light snowfall two storms may occur yielding 12 inches of snow in a 24-hour period. For winters of heavy snowfall, eight to ten such storms may occur. Only occasionally is there a snowfall which contributes more than 18 inches of snow in a 24-hour period.

Storms with a high rate of snowfall are usually of short duration. In the records that have been studied, no storm was recorded which yielded 12 inches of snow in a 24-hour period for more than 3 consecutive days. The maximum snowfall for a 5-day period was just under 70 inches.

It is possible that once in 25 to 30 years, a winter with very heavy snowfall could occur when the above-mentioned snowfall amounts are exceeded. On both 22 and 26 January of 1935, 35 inches of snow in a 24-hour period were recorded but this extreme rate has not been observed since.

The temperature during a snowstorm normally ranges between 24°F to 32°F. There is usually no drop in temperature immediately after a snowfall. Most of the snowfalls are accompanied by southerly and westerly winds with variable speed.

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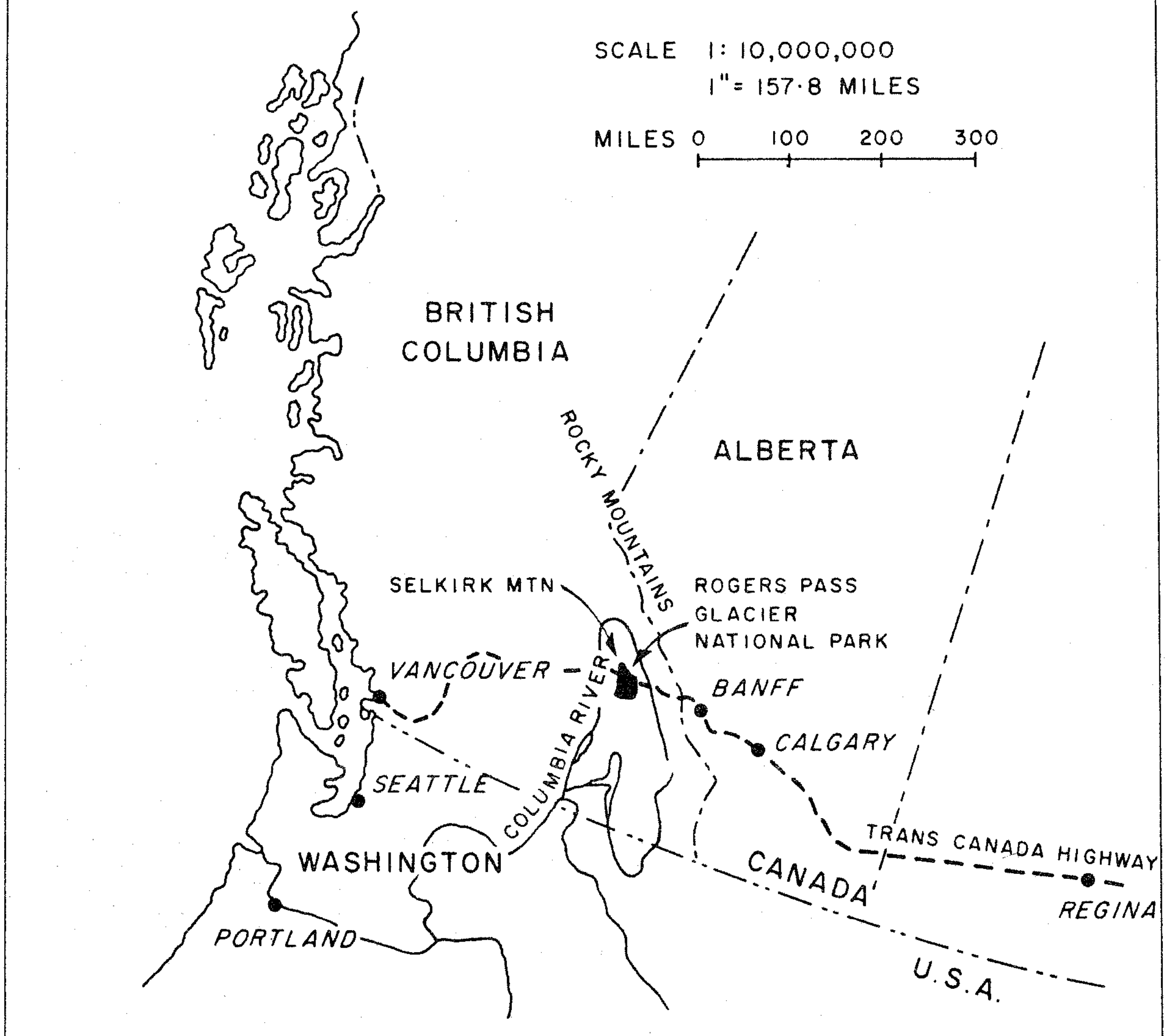
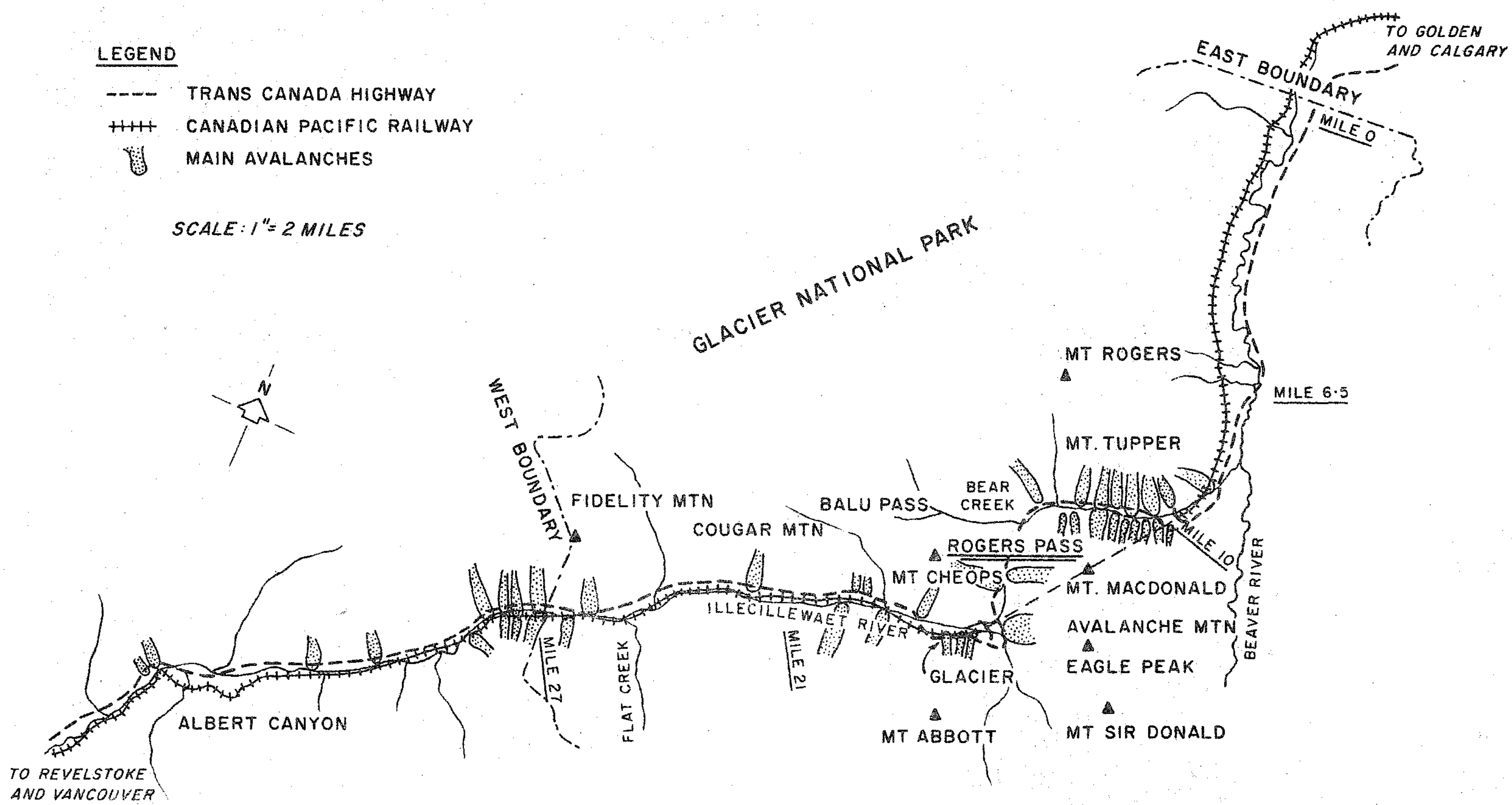


WESTERN CANADA

FIGURE 1

Sketch map of Western Canada showing the location of Glacier National Park



ROGERS PASS WITH MAIN AVALANCHES

FIGURE 2

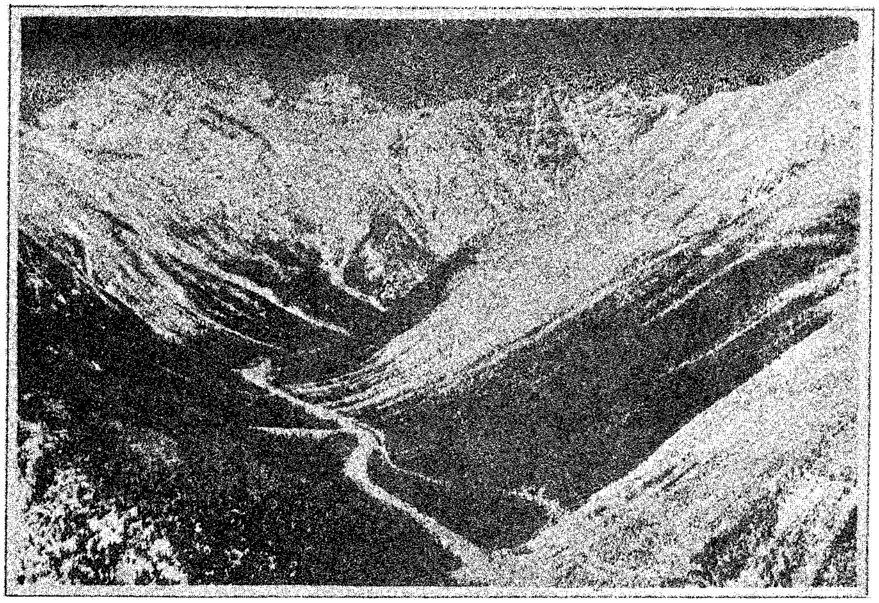


Figure 3. The summit of Rogers Pass with the abandoned railway grade on the right side and the cleared right-of-way of the highway on the left. In the background, Mt. Roger is on the left; Mt. Tupper on the right. (Photograph: Bruno Engler)

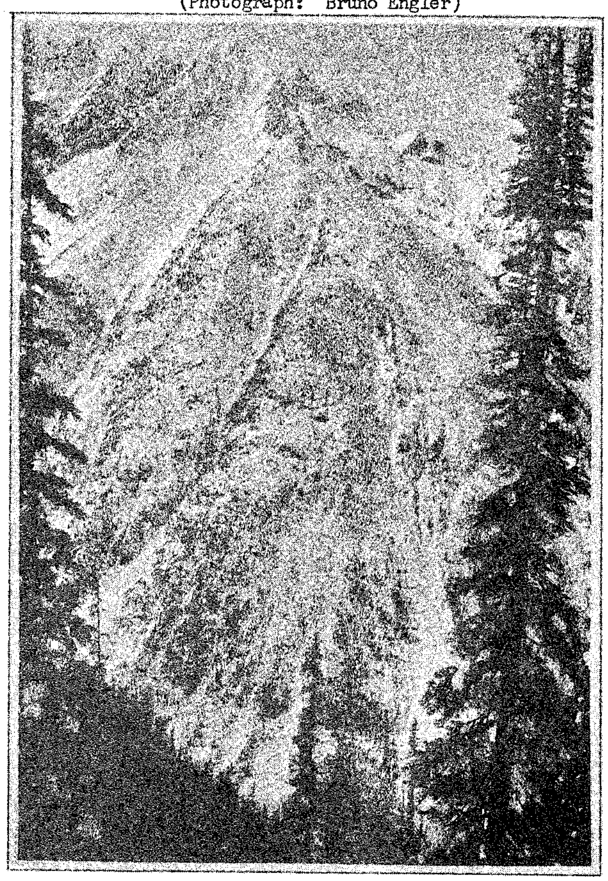


Figure 4. East ridge of Mt. Tupper with avalanche paths. The highway is located at the bottom of the photograph. (Photograph: Bruno Engler)

The Avalanche Survey

The Department of Public Works of Canada is responsible for the design and construction of the Trans-Canada highway through Glacier National Park. In 1953, the Department of Public Works began to make observations on the avalanche activity in the Rogers Pass area. Since 1957, the National Research Council of Canada through its Division of Building Research has assisted with these observations.

After the initial studies on the Rogers Pass route and the first reconnaissance work for the highway, a closer survey of the avalanches was organized. During the three winters between 1953 and 1956 occasional trips were made over the Pass, and the location and size of the avalanches that had occurred were recorded. Since 1956 observations on the avalanches, snow conditions, and weather have been made in the winter by a crew located at Glacier. It was the responsibility of this crew to:

(1) Survey and record the time of occurrence and the location of all the avalanches near the proposed highway route.
(2) Recommend the most economical defence for each avalanche and to locate and assist in the design of the defence structures.
(3) Collect experiences in forecasting the avalanches which would be of value for the future avalanche warning service.

The avalanches that occurred were surveyed on frequent trips along the proposed highway route and the location of each avalanche reaching the highway line was plotted on location plans. The accumulation area, the slide path, and the terminus of some important avalanches were traced on to photographs. In an average winter about 120 avalanches come close to the future highway, and have to be surveyed and recorded.

The Avalanches in the Rogers Pass Area

The section of the proposed highway threatened by avalanches is 24 miles long. The most active avalanches are concentrated in two sections:

(1) Below Mt. Tupper between mile 10 and 13 (from the eastern boundary of the Park) (Fig. 4).
(2) On a 1½ mile section just outside the western boundary of the Park.

Avalanches reach the highway at both sections during and after every significant snowfall and particularly after snowfalls of more than 10 inches accompanied by wind. Between these two sections and west of the second, the avalanches are more scattered and reach the highway under bad conditions only. Dangerous avalanches can occur at these sites after snowfalls of more than 24 inches total and during the snowmelt period.

There are two avalanche periods each year. In the first period between the beginning of November and the end of February the avalanches are mainly caused by snowfalls and wind, and most of the avalanches are of dry snow. The second avalanche period begins with the month of April and ends about the middle of May. The avalanches during this period are caused by the snow melt and are of wet snow. In the month of March, between the two periods, the avalanche activity is generally low.

Avalanche Defence

It was recognized from the survey that it would be impossible to obtain for the highway 100 per cent protection from avalanches using protective structures. Sheds could be built at those sites where the path is well defined and avalanches threaten traffic on the average more than once every winter. At other sites, earth mounds, benches, and diverting dams could be constructed which would impede and divert the avalanche. Such structures do not offer complete protection normally but will retain most of the avalanches that occur and certainly reduce the amount of snow reaching the highway. There are numerous avalanches for which, because they occur infrequently or the cost of protection measures is unreasonably high, no defence structures could be planned. Under unfavourable conditions, these avalanches would deposit snow on the highway.

The avalanches were divided into different classes according to the defence most suitable. The classes of avalanche and the defence proposed are as follows:

Class 1 Avalanches. - This class includes the avalanches that occur frequently and reach the highway one or more times each winter. At these sites it is proposed to protect the highway with snowsheds. Eight snowsheds with a total length of 4500 feet have been recommended. The decision as to the type of construction is still to be made. It is expected that one shed with a length of 300 feet will be constructed in the summer 1960 and the other sheds one year later.

Unfortunately, most of the sheds have to be built in the terminal zone of the avalanche, where the avalanche snow will accumulate to a great depth on the shed roof. The maximum design load used was 1000 lb/sq. ft. for the vertical component and a 350 lb/sq. ft. for the horizontal. A lighter type of shed to be built in the path of smaller avalanches was designed for a vertical load of 500 lb/sq. ft. and a horizontal load of 200 lb/sq. ft. To minimize the length of the shed the avalanches will be confined by earth dams. The dams will be 20 to 25 feet high. In two of the avalanche paths it was possible to dig trenches, 45 feet deep and 150 feet wide at the bottom, which form a channel for the avalanches. The earth excavated from the trenches was used for the construction of fill for the highway (Fig. 5). The trenches were completed before the winter 1959-60; observations during this winter have shown that the channels were successful in confining the avalanches to a narrow section of the proposed highway.

Class 2 Avalanches. This class includes the avalanches that occur frequently but where the mass of the sliding snow is small and most times the avalanche stops before reaching the highway. In the avalanche paths of this Class the highway is protected by less expensive earth structures, such as diverting dams and mounds.

The mounds are between 15 and 25 feet high with a distance of 60 to 80 feet between centres. The size and the arrangement of the mounds depends on the local conditions, such as normal size of the avalanches and the inclination of the avalanche path. One group of mounds was built in the summer 1957 (Fig. 6). Observations during the past three winters have shown that the mounds have a protective capacity of three avalanches per winter. After three avalanches had occurred the space between and above the mounds was filled with avalanche snow and the defence became ineffective. This would indicate that mounds are not suitable in places where more than three avalanches per winter are expected.

Another form of earth structures are benches which are built across the avalanche path. It is obvious that the bench will soon fill with snow and that only small and slow avalanches will be stopped by them. The capacity of the bench can be improved if a dam of snow is built on the edge of the bench. This dam, about 10 feet high, can be built by bulldozers using the snow from snowfalls and avalanches. Benches must be at least 90 feet wide to be effective. In most cases it will be more economical if mounds are built instead of benches. In Rogers Pass benches will be effective in stopping avalanches at a few sites only. The benches now in use are either natural or are the abandoned railway grade, requiring only little improvement.

Class 3 Avalanches. This class includes avalanches that occur only under severe conditions and not more frequently than once in two years. The avalanches may deposit a large amount of snow on the highway. Because of the low frequency of these avalanches, the high cost for defence structures is not justified.

The amount of snow deposited by these avalanches may, however, create some snow-clearing problems that could delay the opening of the highway after the hazard has decreased. Earth mounds will be constructed where the local conditions make them feasible. It is not expected that the mounds will stop the avalanches completely, but they should retain a great part of the heavier snow sliding at the bottom of the avalanche. The accompanying cloud of light snow will not be affected by the mounds and will probably reach the highway but it should not deposit much snow. In many cases it should be possible to re-open the highway by snowplows. The mounds should be effective for ground avalanches of heavy wet snow carrying rock and timber. This type of avalanche is the most difficult to remove from the highway.

Class 4 Avalanches. This class includes avalanches that occur under severe conditions only and not more frequent than once in two years. The snow that would reach the highway from these avalanches would usually be airborne and little would be deposited on the highway. No special protection is planned for avalanche paths of this class.

Avalanches from the unprotected sites need not occur on the same day or even in the same period during the winter. Often snow from one only will reach the highway during a 24-hour period. At the unprotected sites it is estimated that 25,000 cubic yards from six avalanches within two days would be the maximum amount of snow that would have to be removed from the highway. This amount may be exceeded under extremely bad conditions that could occur once in 20 to 30 years.

Other Methods of Avalanche Defence

Many avalanches of Class 3 and Class 4 can be controlled by gunfire. It is not yet known which type of weapon will be used in the future. Successful trials were made with the 4.2-inch mortar, the 75-mm howitzer and the 105-mm howitzer. The 105-mm recoilless gun, being used for the avalanche shooting in the United States, is not suitable for the conditions in Rogers Pass. The angle of elevation required to reach the high elevated targets is too high.

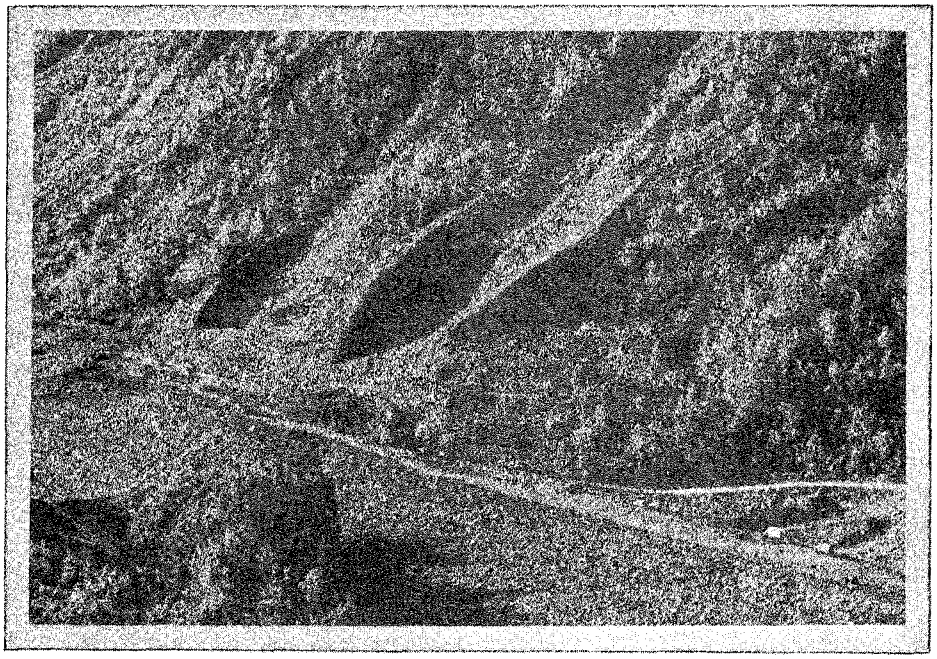


Figure 5. Dams and excavated channels for the avalanches at Mt. Tupper

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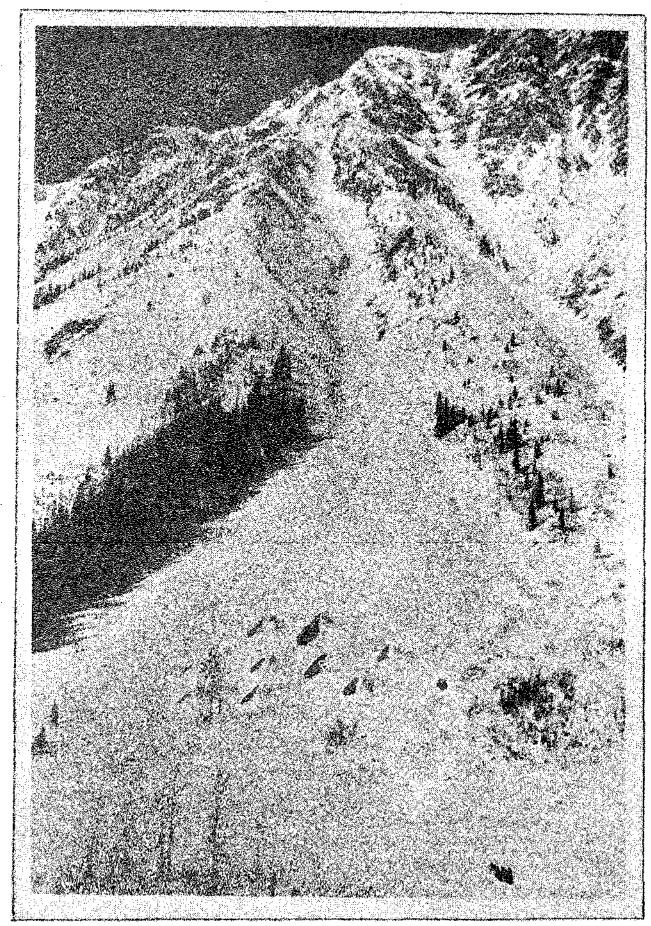

Figure 6. Earth mounds at the bottom of an avalanche path. (More mounds are to be built on the right side.)
(Photograph: Bruno Engler)

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Other methods of avalanche defence, such as supporting structures in the accumulation area, wind baffles, snow fences, and breaking structures of steel cables were studied for the different avalanche paths. All these structures proved to be either too expensive or not effective. Supporting structures built in the accumulation area of the avalanches are considered the best and safest method of defence, but they were found to be more expensive than sheds.

Organization of the Avalanche Warning

Since the highway will not be protected against all avalanches but will be closed when avalanches are likely to occur in unprotected areas, an effective warning service is essential. The avalanche hazard forecast, the control of traffic and operation of the completed highway through the National Park will be the responsibility of the National Parks Branch of the Department of Northern Affairs and National Resources.

During the survey and construction of the highway, an observatory with a snow test plot was located at the summit of Rogers Pass, altitude 4350 feet. Daily snow and weather observations were taken there. A second observatory was constructed on Mt. Abbott at 6800 feet, the altitude where most of the large avalanches originate. This observatory was visited about once each week and the snow profile studied. Occasionally an observer stayed at the Mt. Abbott observatory during a snow storm and reported snow and weather conditions by radio to the main camp at Glacier.

A test plot and observatory were established also at the summit of Balu Pass, about 3 miles west of the snow plot at the summit of Rogers Pass. The altitude of this site is about 6900 feet. The access to this site was not always safe and so observations were not made as frequently as at the other sites. In the fall of 1959, special wind telemetering equipment developed by the Division of Radio and Electrical Engineering of the National Research Council was installed at the Balu Pass observatory. Information on wind speed and direction is transmitted by radio to the base camp at Glacier. Some difficulties were encountered in the use of this equipment during the first winter of field trials but these have been largely overcome.

During the past four winters, continuing observations have been made at the test plots and observatories and using the methods practiced by the U. S. Forest Service, Swiss Avalanche Service and others, the avalanche hazard was forecasted as if the highway were in operation. The information collected and experience gained during the past four years will be made available to the Department responsible for the avalanche prediction and traffic control of the future highway.

Avalanche Hazard Forecasting

The studies on the conditions contributing to the avalanche hazard showed that the avalanches were caused by the same factors as have been observed elsewhere, for example Switzerland. The studies show the following facts:

(1) A snowfall of more than 10 inches of new snow creates a moderate avalanche hazard and avalanches may occur at areas now protected by snowsheds or other defence structures. A continuous snowfall of 30 inches or more with little or no wind may cause large avalanches in unprotected areas. With strong winds large avalanches occur before this amount of new snow is deposited. The density of the new snow has a major influence. The average density of the new snow is 0.082. New snow with a density lower than 0.07 is more likely to cause avalanching.

(2) The wind has an important influence on the build-up of the avalanche hazard for most of the avalanche paths. The direction of the prevailing wind determines whether certain avalanches will occur. The wind creates local snow accumulations on the lee side of mountain ridges. The "windslab" common in the United States avalanche areas was observed only occasionally.

(3) The temperature has to be observed during and after a snowfall and during the snow melting period. It was found that avalanches occur during the snow melting period on the first or second day with a mean daily temperature of 32°F and above. Before any such avalanche occurs, however, the temperature between the ground and the surface of the snow must have reached 32°F.

(4) The snowfalls are well distributed over the winter and the relatively high temperatures create a stable snow cover on the ground. Not many unstable layers with metamorphized crystals could be observed. In the winter months an avalanche caused by the fracture of an internal unstable snowlayer is rarely observed. It is only in spring that big avalanches start to slide on internal unstable layers.