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AVALANCHES AND FOREST COVER IN THE NORTHERN CASCADES.

BY

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AVALANCHES AND FOREST COVER IN THE NORTHERN CASCADES.

KINDS OF AVALANCHES.

In any mountainous region where the slopes are steep and the snowfall is heavy there is likelihood of avalanches. Avalanches, or snowslides, are masses of snow which, becoming dislodged from the upper slopes of a mountain side, slide or fall into the lower country. Because of the enormous amount of damage they do to everything in their path, whether forest, railroad structure, or habitation, avalanches must be looked upon as calamities in a class with floods, hurricanes, and great conflagrations.

Avalanches are of several distinct types—dust avalanches, glacier avalanches, ground avalanches, and top avalanches. Dust avalanches, so called because they fill the air along their course with a mass of fine snow, are composed of very dry snow, and start usually at high altitudes during very cold weather. Glacier avalanches, as the name suggests, are the masses of ice or compact snow that break loose from glacier and *névé* fields in very precipitous country, usually during the warm weather of summer. Ground avalanches are formations, generally of wet snow, which slide over the ground. They occur when the snow has become excessively heavy from a thaw or rain, or the surface of the ground slippery, and are therefore most frequent in late winter and early spring. Ground avalanches often accumulate in their course great quantities of earth, rock, and forest débris. Top avalanches are in most respects similar to ground avalanches, except that they slide over a crust of older snow, instead of over the ground. Where a top avalanche breaks through the crust and slides on the surface of the ground it becomes a ground avalanche. Every gradation between these four types may be found, and a single avalanche may have the characteristics of two or more of the types.

Dust and glacier avalanches usually originate on the higher mountains above the zone of tree growth, and either because of their remoteness from human habitation or because of their character are not of great economic importance. Ground and top avalanches, on the other hand, originate wherever the snowfall is sufficient, sometimes at comparatively low altitudes, and may extend down into the lower valleys, causing great damage.

AVALANCHES IN THE NORTHERN CASCADES.

In the Cascade Mountains of Washington thousands of avalanches occur each winter. The existence of many of them, however, is not known until perhaps the following summer, when a hunter or sheep herder finds a mass of melting snow and débris at the foot of a slope, and sees its deforested track on the mountain side. It is only those avalanches that destroy life or property, or that cross transmountain railroads, that are likely to be recorded or are observed soon after they occur.

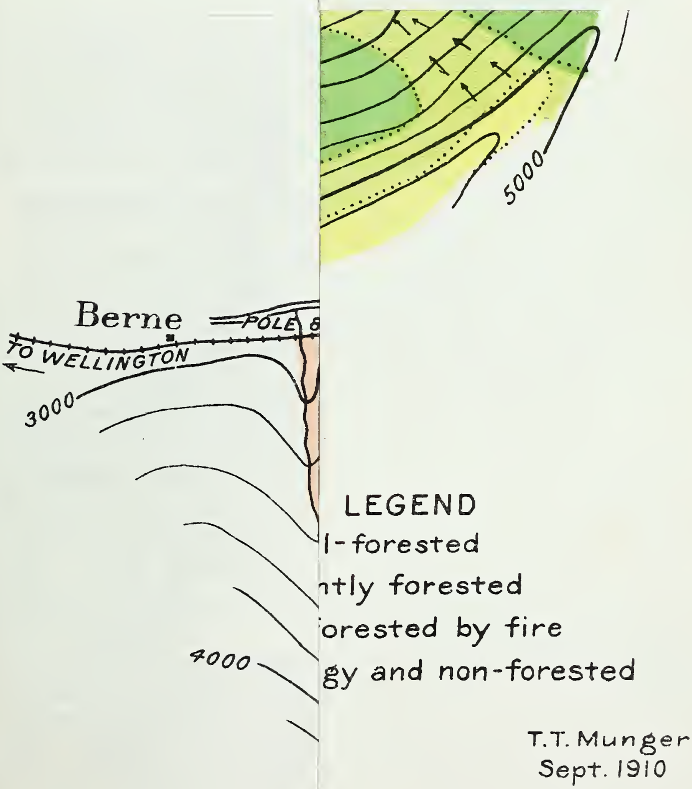
During the late winter of 1910 there were many extremely large avalanches in the Cascades, which altogether did damage to the amount of many hundreds of thousands of dollars. Several of them resulted in the loss of human life, and the most disastrous swept two trains off the mountain side and killed a hundred persons. In the 3 miles below the station of Berne, Wash., at least 11 avalanches crossed the railroad tracks in the late winter of 1910, aggregating a width of 1.05 miles. This number is not unusual in similar valleys in the Northern Cascades.[1]

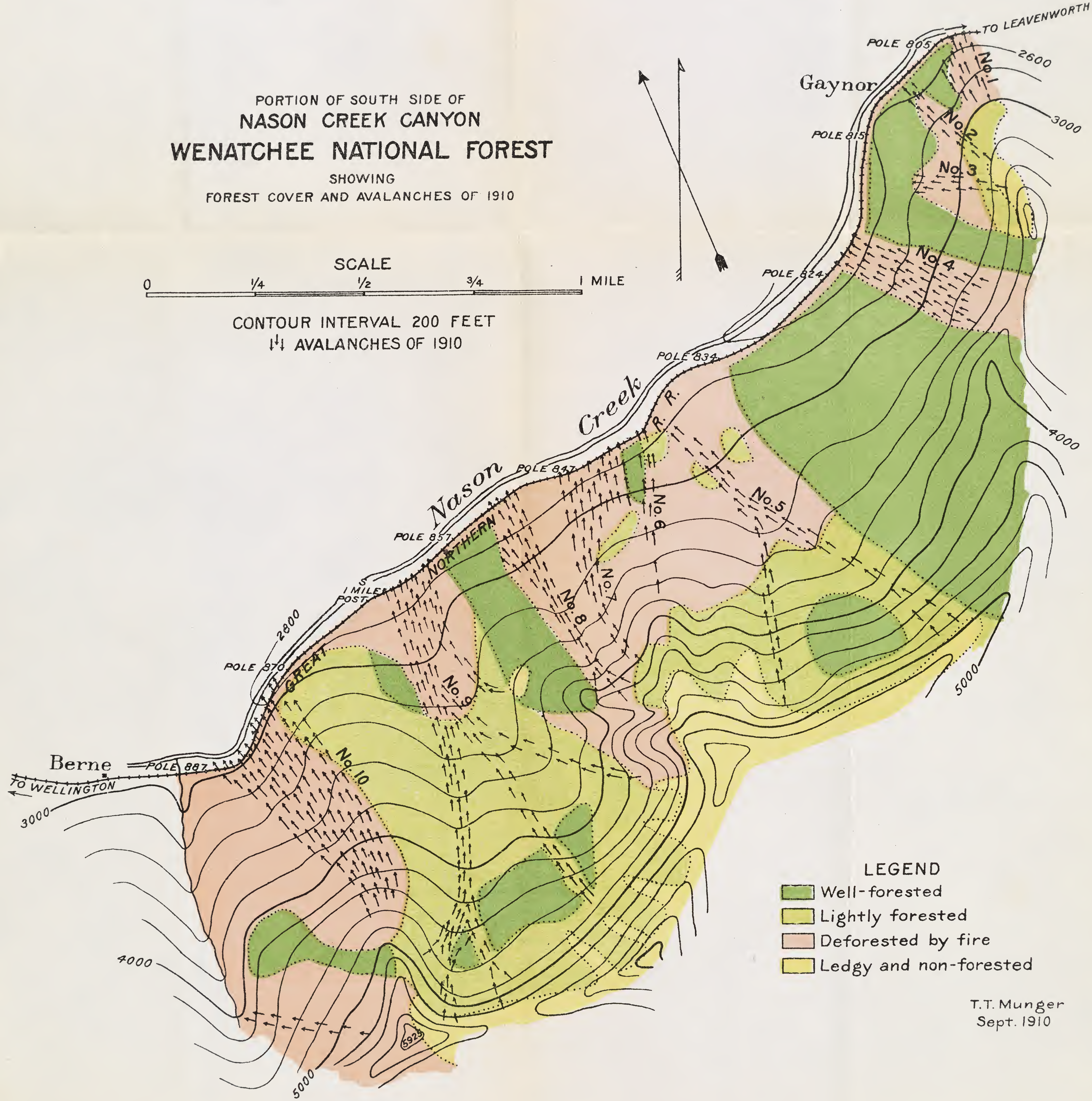
Throughout the region, wherever avalanches occur, there is a widespread and general conviction that they are more prevalent and more severe on mountain sides which have been deforested than upon slopes which still bear a good growth of trees. To determine, therefore, to what extent, if any, the forest cover prevents the formation of avalanches or lessens their severity, a field study was made while the evidences of the 1910 slides were still fresh. The results of that study are given in this circular.

CHARACTER OF THE REGION STUDIED.

In addition to general observations over a wide region, a detailed study was made on a representative piece of mountain country where avalanches have always been frequent, and where they were unusually severe in February and March of 1910. This area, shown on the accompanying map (Pl. I), embraces parts of the valleys of the Wenatchee River and Nason Creek, east of the main divide of the Cascade Mountains, in Chelan County, Wash. The topography is rugged and irregular, and cut by many canyons and gullies. In some places the slopes for hundreds of feet are ledgy and have a gradient of 100 per cent; in other places they are gentle. In general, the slopes rise from 2,000 to 4,000 feet above the bottom of the main canyons and are concave in outline—steep (about 80 per cent) toward their tops, gentle (about 30 per cent) toward their bases, with an

[1] For full discussions of many of the important avalanches, and of the weather conditions which caused them, see "Avalanches in the Cascades and Northern Rocky Mountains during the Winter of 1909–10," by E. A. Beals, "Climatological Service of the Weather Bureau, District No. 12, June, 1910."


5000
Berne
POLE
TO WELLINGTON
3000
4000
LEGEND
l-forested
ntly forested
forested by fire
gy and non-forested
T.T. Munger
Sept. 1910


PORTION OF SOUTH SIDE OF
NASON CREEK CANYON
WENATCHEE NATIONAL FOREST
SHOWING
FOREST COVER AND AVALANCHES OF 1910
SCALE
0
1/4
1/2
3/4
1 MILE
CONTOUR INTERVAL 200 FEET
AVALANCHES OF 1910
TO LEAVENWORTH
POLE 805
Gaynor
POLE 815
POLE 824
POLE 834
Nason Creek
POLE 847
POLE 857
1 MILE POST
POLE 870
Berne
POLE 887
TO WELLINGTON
GREAT NORTHERN R. R.
No. 1
No. 2
No. 3
No. 4
No. 5
No. 6
No. 7
No. 8
No. 9
No. 10
2600
2800
3000
4000
5000
5925
LEGEND
Well-forested
Lightly forested
Deforested by fire
Ledgy and non-forested
T. T. Munger
Sept. 1910

intermediate grade throughout the middle and longest part of the slope.

Most of the mountain slopes were originally forested, even in extremely steep and rocky situations. Where they are still forested, the timber on the lower slopes is large and dense, becoming smaller and scattered toward the tops of the ridges. Practically all the region has been burned over during the last 20 or 30 years, and vast stretches of virgin timber have been destroyed. On fully one-half of the area examined in detail the timber had been killed by fire within recent years. Most of the fires originated at the base of the slopes and swept up to the crest of the ridges, killing a belt of timber from one hundred to many hundred feet wide. Most of the land burned over once is restocking with a thrifty stand of young timber, but much the larger part of that burned over a second or third time is thoroughly denuded of all vegetation except a few bushes and weeds. (Pl. II, fig. 2.)

The annual snowfall is very heavy and increases rapidly with increase in elevation. At Cascade Tunnel, at an elevation of 3,379 feet, as much as 35 feet of snow falls in the course of the winter. On the highest ridges there is probably 10 feet more. This heavy snowfall, combined with a climate which promotes alternate melting and crusting of the snow on the long, steep slopes, is exceedingly provocative of avalanches.

CHARACTER OF AVALANCHES IN THE REGION STUDIED.

The avalanches of the region studied are either ground avalanches or top avalanches, and more often a combination of both. Some of them start as a slide of new snow on a crust of old snow, but as they gain volume and momentum scrape off and carry along all the snow in their path, exposing the ground. They should not be confused, however, with landslides. They are distinctly slides of snow and most of them do not even bare the ground. They therefore carry with them but little earth or rock, but where they pass through forests or burns they frequently accumulate quantities of logs, snags, and branches, and even entire trees. Since they do not commonly extend to the ground at their places of origin, the ground surface, or the character and dip of the bed rock, have here practically no effect on their formation.

For purposes of description these ground and top avalanches of the Northern Cascades may be grouped into two classes, according to their physiographic situation, namely, canyon slides and slope slides. Though the typical canyon slide is very different in character and origin from the typical slope slide, every intermediate stage between the two may be found.

A canyon slide is one which originates on the steep and rocky cliffs at the head of a canyon or gulley, and follows down the depression as a compact, narrow body of snow, constantly increasing in volume as it descends. It is often composed of a number of little slides which come off the steep, rocky sides of the canyon, and, converging, follow down the main canyon as in a trough, usually at great velocity. A canyon slide, though narrow along the major part of its course, may widen out in fan form to several hundred feet when it strikes the valley. The great majority of the avalanches of the Northern Cascades are canyon slides.

A slope slide consists of a wide, shallow, rather slowly moving mass of snow, which breaks loose from the snow mantel higher up the mountain side, and which, starting to slide, involves the snow of the whole side hill, and slips down the slope without converging into a canyon. It may be likened, in fact, to a mass of wet snow sliding in a body off the roof of a large building after a sudden thaw. Slope slides are usually shorter than canyon slides, and their snow less solidly packed. In comparison with canyon slides they are short and wide, instead of long and narrow. Their velocity usually is not great, but the enormous weight of the wet snow gives them great momentum and crushing power.

In many of the side canyons and gullies of the Northern Cascades, avalanches of the canyon slide type are of annual occurrence, and their track is plainly marked by a strip along the bottom of the gullies on which only herbage and brush grow. The steepest, rockiest slopes are those at the heads of these gullies, and are therefore the places at which snowslides are most likely to start. In one stretch of 11 miles along the main canyon of the Wenatchee River 35 distinct avalanches slid off the mountain side into the river, in the latter part of the winter of 1910. Practically all of these were canyon slides, and most of them came down well-worn avalanche slideways. Canyon slides can only be considered the unavoidable results of steep, rocky slopes and heavy snowfalls.

THE RELATION OF FOREST COVER TO THE FORMATION OF SLOPE SLIDES.

Since the place of origin of canyon slides in the Cascades is usually high up on the mountains above timber line, or on precipitous, rocky, and almost treeless slopes at the heads of canyons, the forest cover exerts but little influence upon their formation. But the occurrence of slope slides, on the other hand, seems to have an intimate relation to the character of the forest cover. In order to illustrate by concrete examples the nature of slope slides, and their relation to forest cover, a description is given of two characteristic and important slope slides of the region which occurred in February and March, 1910.

THE BERNE SLIDES.

The course of these avalanches was down the northern slope of a big conical hill, 6,000 feet in altitude, and rising 3,000 feet above its base, at Nason Creek, near Berne, Wash. The surface of this slope is fairly regular and smooth, with an average gradient of about 67 per cent. Its steepest part toward the summit has for a short distance a gradient of 85 per cent. The hillside was originally covered with a fine stand of timber, which was killed by a fire about 25 years ago. Since then, other fires have run over the slope and rendered its denudation even more complete. (Pl. III, fig. 1.) Excepting in a few places where there is a young growth of saplings, the hill is now almost completely bare.

The avalanches originated at an elevation of over 5,000 feet on a thoroughly deforested part of the slope. Two of them occurred within a period of three days. Where they crossed the railroad they covered the tracks for a distance of a third of a mile with snow and logs, sometimes to a depth of 80 feet, besides filling the canyon of Nason Creek, which is here 60 feet below the shelf on which the railroad runs.

Slides at this place could not have occurred previous to the deforestation of the slope, since if they had there would have been no mature timber on the slope, which until the relatively recent fires was well forested.

THE WELLINGTON SLIDE.

This avalanche was the most serious in its consequences of any that occurred in the winter of 1910, though by no means the largest. Early on the morning of March 1 it slid down the hillside close to the station of Wellington, sweeping two trains from the siding where they were stalled, and carrying them into the gulley a hundred feet below. The path of this avalanche was down a hillside which was originally well covered with a heavy stand of timber, and which was severely burned over in 1893 by a fire which completely killed the forest. Twice since then fire has run over the slope, so that at the time of the avalanche it was bare, except for a few logs, some stubs, and a very little brush. (Pl. II, fig. 1.) The slope is exceedingly regular and smooth, is devoid of ledges, and is crossed by but one small gulley. The avalanche originated at an altitude of about 3,800 feet, on a grade of about 75 per cent. Here a great mass of wet, heavy snow, several hundred feet wide, broke loose from the adjoining snow mantle along a contour line, and slid rather slowly down the slope. The whole length of its course was not over 1,600 feet, yet where it crossed the railroad near its terminus it was 1,000 feet wide. Its length, therefore, was not very much greater than its width. It descended about 950 feet along an average gradient of 69 per cent. This was the first slide that has been known to occur on the slope, for it has been but a few years since it has been deforested sufficiently to allow the snow to slide. Even then, it took exceptional weather conditions to promote it. The immediate cause was said to be a small canyon slide which came down a gulley at the extreme eastern end of the slope, and by lateral pressure, or by the tension which it released, started the wet snow on the entire 40-acre slope to sliding. This avalanche was distinctly a slope slide. The hillside down which it descended is not particularly steep nor long, but it is a uniform, smooth slope on which there is practically no mechanical obstruction, either tree or brush, to prevent the sliding of the snow.

These two typical avalanches illustrate forcibly the difference between slope slides and canyon slides. The first are not of periodic occurrence, nor are their paths well-worn slideways. Slope slides are now occurring on mountain sides in the Northern Cascades where no avalanches have been known before. The inevitable conclusion is that they are occurring not because the slopes are rugged and the snowfall heavy, but because the protective forest cover has been removed. There are a number of facts which substantiate this conclusion.

(1) If avalanches had been occurring on slopes such as those at Wellington and Berne periodically, or even occasionally, for centuries, as they have on the canyon slideways, there would have been no heavy forest of large trees on these slopes as there certainly was until the fires of recent years destroyed it.

(2) Avalanches in the Northern Cascades are much more numerous on deforested slopes than on forested ones, in spite of the fact that more than one-half of the land is forested. In the area selected for detailed study the paths of the 11 avalanches of 1910 cover 19 per cent of the total area mapped. Of these avalanche paths, 73 per cent are on deforested slopes and 27 per cent on forested slopes, though there are 3 acres of forested land to every 2 acres of deforested slopes.

In Switzerland, where a record has been kept since 1872 of 10,000 avalanches, it has been found that only 6 per cent originate on timbered or brush areas, the remainder starting on deforested or nonforested land.

(3) In the region examined there are many forested slopes as steep as the deforested slopes on which avalanches started. No slope slide started, however, where the mountain side was timbered, and all of the canyon slides originated either on deforested slopes or on those naturally bare.

(4) It is obvious that standing trees tend to hold the snow blanket in place mechanically, as nails hold a shingled roof.

(5) The forest promotes climatic conditions which are less favorable to the starting of slides than are conditions in the open. The

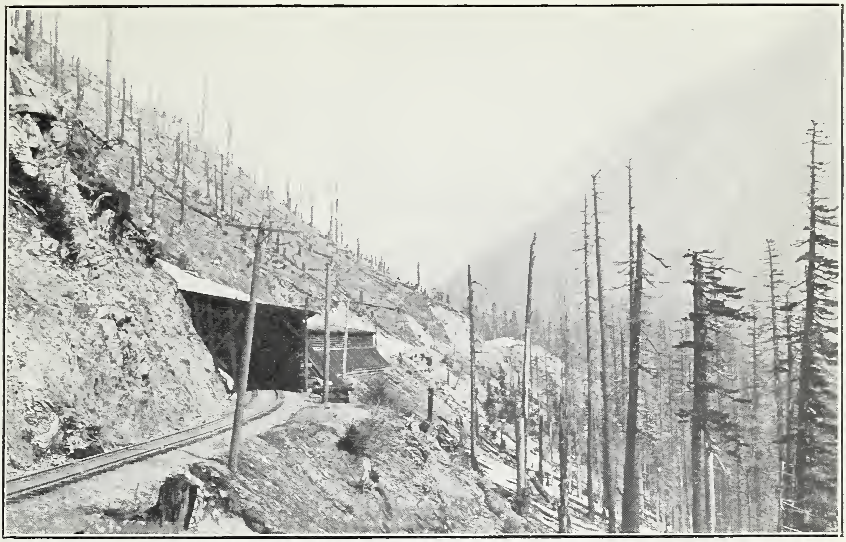


FIG. 1.—THE WELLINGTON AVALANCHE, WHICH KILLED 100 PERSONS, OCCURRED ON THIS SLOPE, THE FOREST ON WHICH HAD BEEN DESTROYED BY FIRE.

[After J. D. Wheeler.]

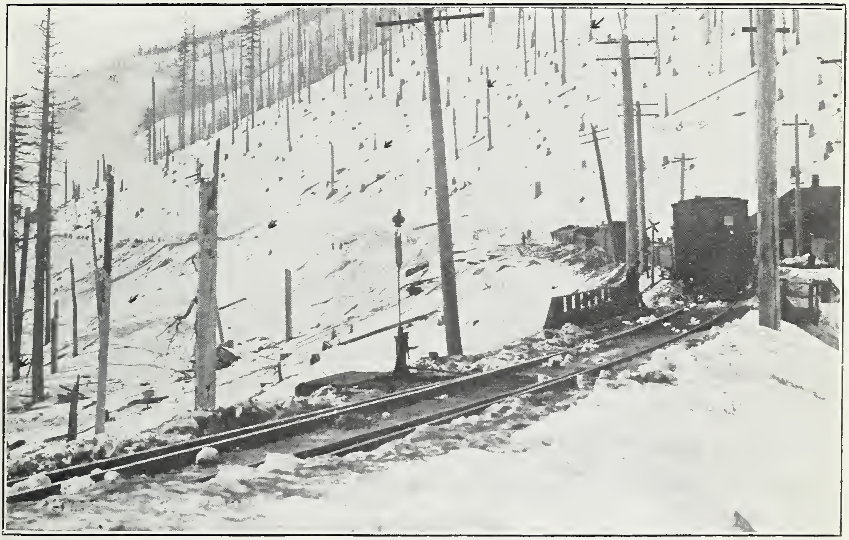


FIG. 2.—CHARACTERISTIC TOPOGRAPHY OF THE NORTHERN CASCADES, SHOWING DEFORESTED CONDITION OF MANY OF THE SLOPES.

[After J. D. Wheeler.]

[Down the slope in the foreground avalanches are of almost annual occurrence.]

FIG. 1.—CLEARING SNOW AND DÉBRIS FROM THE RAILROAD TRACKS AFTER THE BERNE SLIDE, WHICH CAME FROM THE DEFORESTED HILLSIDE ON THE RIGHT AND COVERED THE TRACK FOR A THIRD OF A MILE.

[After J. D. Wheeler.]

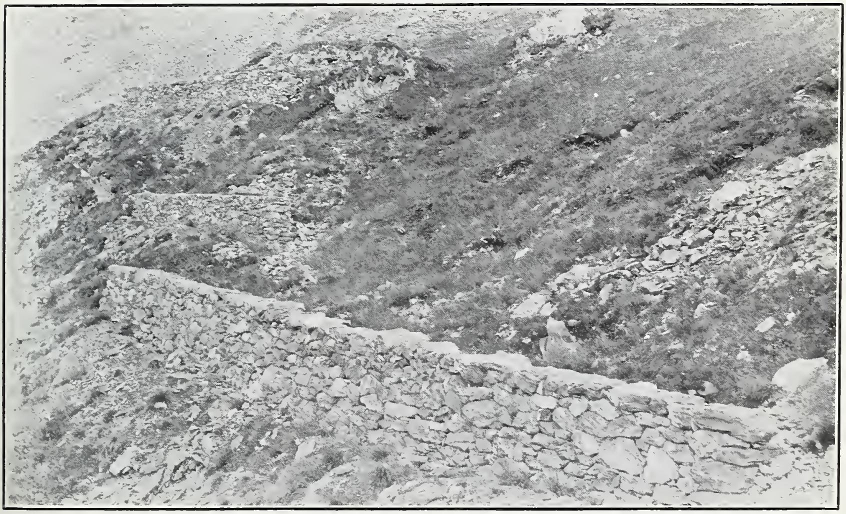


FIG. 2.—WALLS BUILT TO PREVENT THE STARTING OF AVALANCHES IN THE FRENCH ALPS.

[These walls are about 4 feet aboveground and 1.5 feet underground, and constructed at such an angle as to withstand great pressure from above.]

falling of large drops of water and chunks of snow from the crowns of trees during a thaw tends to cement the whole snow mass together when it freezes at night. The extremes of temperature on the ground, moreover, are less in the forest than in the open, and therefore a less slippery crust, and often a smaller amount of crust, is formed in the forest than in the open.

THE EFFECT OF FORESTS IN CHECKING AVALANCHES.

Instances have been recorded where an avalanche striking a body of trees 10 to 25 inches in diameter has mowed them down and continued practically unchecked. Standing timber, however, has a very retarding influence on avalanches, simply because of the physical obstruction of the trees to the passage of the snow. Large avalanches traveling at high speed and carrying much débris may knock over and break down a great amount of timber before they are stopped, but each tree encountered absorbs some of the momentum of the avalanche. Small slides are often stopped short by a body of timber. In the Northern Cascades, where the snows are very deep, trees less than 12 to 15 feet high apparently offer little resistance to the progress of an avalanche. Above that size their resisting power seems to be about in proportion to their diameters.

Forests undoubtedly tend to check the advance of an avalanche, but they do so at great expense to themselves. Periodic avalanches in the same place will in time destroy all the forests within their reach, for it is impossible for timber to develop and survive in the path of many and severe slides. The rôle of the forest in lessening the severity of an avalanche when it has started is not great. The chief influence which forests exert on avalanches is at their place of origin, and not after they have gained headway. Forests can not be considered as effective barriers against avalanches, but they may be considered as a decided preventive influence.

PROTECTION FORESTS IN THE ALPS.

The rôle which forests play in preventing the formation of avalanches is well recognized in Europe. In Switzerland avalanches have for centuries been a hindrance to the full development of the country, and it has been the special aim of the Swiss Government to keep unbroken the forest cover on the mountains and to extend the natural limits of the forests as high up on the slopes as possible. As early as 1342 "bann" forests, or protection forests, were created by official proclamation to prevent the destruction of the cover on steep slopes where avalanches might occur if the slopes were bared. These protection forests are now administered under a system which insures the continuance of a solid forest cover over the slopes where trees can be made to grow. Denuded slopes are reforested, and there is a provision in law which enables the Government to purchase privately owned lands needed for protective purposes. A similar policy of forest management as a means of preventing avalanches is practiced in other European countries.

Many of the places where avalanches originate are at too high an altitude or are too rocky for tree growth. In Switzerland, in such places, walls of stone or wood (Pl. III, fig. 2), terraces, ditches, or rows of posts are constructed as a barrier against the sliding of snow. Such structures are, of course, useful only at the very starting point of a slide. Already hundreds of thousands of dollars have been spent by the Swiss Government in the construction of works of this kind. In some places these walls and barriers are temporary in character, and are intended to prevent snowslides only until the forest which is planted under their protection has grown to suitable size.

PREVENTIVE MEASURES IN THE NORTHERN CASCADES.

The destructive effects of avalanches will be felt more and more keenly in the Northern Cascades as the region develops and an increasingly greater amount of property is exposed to destruction. Moreover, in many parts of the Cascades, through the medium of forest fires, more and more slopes are coming to a condition favorable to the formation of avalanches. Although most of the region is now given protection from fires and their frequency is on the decline, on many of the areas burned over from 15 to 20 years ago the remains of the former forests are only now becoming sufficiently decayed to make easy the sliding of snow. The second-growth forest, if there is one, has not grown to a size to be of use in preventing the formation of slope slides. It is likely, therefore, that in spite of the protection from fire conditions effecting the formation of avalanches will not better themselves for some years at least.

In the Northern Cascades the problem of protection from avalanches is at present very different from what it is in Europe. Abroad, where the value of the land and the property endangered is enormous, it is expedient to spend large sums of money for their safeguarding. Measures which are practical in other countries, however, are utterly impracticable in the Northern Cascades. Such costly wooden and stone structures as are built on the slopes in Switzerland are not possible under the economic conditions which at present obtain here, while the great depth of the snow would make them even more costly and less effective than in Europe. In the Northern Cascades the region which is exposed to avalanches is still, for the most part, a wilderness, and the property threatened is chiefly that of transmountain railways.

The surest way to avoid the destruction of property is, of course, to avoid placing it in any location where it can possibly be reached by avalanches. This policy is followed by the railroads in placing their lines in the least dangerous places, and by building sheds where-ever slides are likely to reach the track. Canyon slides are perhaps easier to avoid than slope slides, since the former follow definite slideways down narrow gullies and are almost annual in occurrence, while the latter occur in unexpected places in exceptional seasons and are often very wide. It is not always possible, however, to avoid placing property, especially railroads, in the path of avalanches. Sheds and other structures are temporary, costly, and not altogether satisfactory. Hundreds of thousands, if not millions, of dollars have been spent by the railroads in protecting their lines from avalanches and in clearing their tracks from débris, but so far all attention has been paid to keeping property out of the way of avalanches, and no effort has been made to prevent their occurrence.

Whatever preventive measures are undertaken in the Northern Cascades will of necessity be slow in operation, and the next generation will benefit by them more than the present. With canyon slides preventive measures other than reforestation are not practical in the Northern Cascades. If the heads of the canyons and gullies where these slides originate could be forested the number of slides would be much reduced, but usually the slopes where they start are too precipitous and rocky or at too high an elevation for the development of a well-stocked forest. Avalanches of the slope-slide type, however, are unnecessary and preventable, and their frequency can be greatly lessened by the observance of four principles, the purpose of all of which is to maintain a protective forest cover on the steep slopes. These principles are:

(1) Proper care of the area now forested. The fundamental requirement here is absolute fire protection. Fires on slopes such as that at Wellington are far-reaching in their consequences, and the damage they do is many times greater than the value of the timber destroyed or of the cost of protecting the slope from fire for a century. In this region where forest fires are very severe and hard to control, where reforestation is not easy, and where the destruction of the forest cover is attended by such disastrous consequences, the protection of the forest should be doubly secure.

(2) Exclusion of grazing. Although very little of the Northern Cascade region where snowslides are prevalent is grazed by sheep, none of it should be. Sheep tend to retard the vegetation, and on these steep mountain slopes with their tendency to soil erosion, as well as to avalanches, all vegetation, both arborescent and shrubby, is important for a protective cover.

(3) Careful cutting of timber on steep slopes. Within the whole mountain region where avalanches are likely to occur, slopes with a gradient of over 50 per cent should be handled as protection forests—that is, no logging or cutting over large areas should be done, unless it be in the nature of a selection cutting by which only a part of the stand is removed and the continuity of the forest cover is kept unbroken.

(4) Reforestation of the denuded areas. With thorough protection from fire, most of the deforested slopes of the region will in time reforest naturally. Many of the slopes burned over from 15 to 20 years ago would now be bearing a good stand of trees if repeated fires had not kept them bare. It will be a slow process for a forest to develop in the face of occasional avalanches which tend to break off the young trees, but since slope slides occur only in exceptional seasons, the reestablishment of a forest where only slope slides are to be feared is by no means impracticable.

Certain areas can not reforest naturally, but should be restocked artificially. These areas are either on thin soiled, rocky ridges, or in the midst of large burns remote from seed trees. Much of the land on which slides have been very serious, and on which artificial reforestation is most needed, is owned by the railroads or by the State. These lands are so intermixed with those administered by the Federal Government that the beneficial effects of reforestation on one class would be almost nullified, unless the adjoining territory were also restocked. It is therefore especially desirable that there should be the closest cooperation in reforesting and in keeping well forested the mountain sides on which, in their present condition, avalanches may start.

Approved.

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *August 20, 1911.*

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