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TRAIL CONDITIONS ALONG A PORTION OF THE GREAT DIVIDE TRAIL ROUTE, ALBERTA AND BRITISH COLUMBIA ROCKY MOUNTAINS

by

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TRAIL CONDITIONS ALONG A PORTION OF THE GREAT DIVIDE TRAIL ROUTE, ALBERTA AND BRITISH COLUMBIA ROCKY MOUNTAINS

Abstract

The proposed route of the Great Divide Trail in the Rocky Mountains of southern Alberta and British Columbia consists of a number of trails which have been built over the years to accommodate foot and horse traffic. The condition of parts of existing trails is poor mainly due to trampling of wet areas and to subsequent erosion by running water. The degree of damage is a function of trail slope and orientation, soil type and groundwater conditions, all of which factors must be considered in proper planning of trail routes. Precautions should be taken in constructing trail to avoid wet areas, to prevent water from running down the trail, to avoid areas with unsuitable vegetative and soil cover, and to provide separate trails for foot and horse traffic.

INTRODUCTION

The Continental Divide region of the Rocky Mountains of southwestern Alberta and adjacent British Columbia provides some of the most spectacular alpine scenery in North America. Set in a largely undeveloped wilderness area, much of which lies within several National and Provincial Parks, the Divide area is visited every summer by a growing number of hikers and trail riders for its scenic beauty. Consequently, over the years a number of trails have been developed along the Divide for both foot and horse traffic, which, if linked to form a continuous Great Divide Trail, would extend from the International Boundary in the south to Mount Robson Provincial Park in the north, a distance of 350 miles.

The length of new trail to be built for this purpose is not great, but the condition of parts of existing trails is poor owing to a number of factors. Therefore, the National and Historic Parks Branch requested the Canadian Wildlife Service to undertake a survey of the proposed route of the Great Divide Trail with a view to locating the trail where it would cause minimum environmental damage and yet fulfill the purpose for which it is to be constructed.

The study on which this report is based was carried out in the summer of 1971 at the request of the Canadian Wildlife Service. It deals with that portion of trail between Haiduk Lake and Wonder Pass along the western boundary of Banff National Park, adjacent to the Alberta-British Columbia boundary (Fig. 1). This section of trail has been used by hikers and pack trains for more than fifty years and provides examples of good and poor trail. The route was examined in early August, 1971, during which time fieldwork was concentrated on identifying the soil and drainage factors associated with the trail's condition with a view to compensating for existing damage or preventing further damage to the environment.

Acknowledgements

Thanks are extended to Drs. G.B. Mellon, R. Green and L.A. Bayrock who reviewed the manuscript, provided much fruitful discussion, and suggested many useful changes.

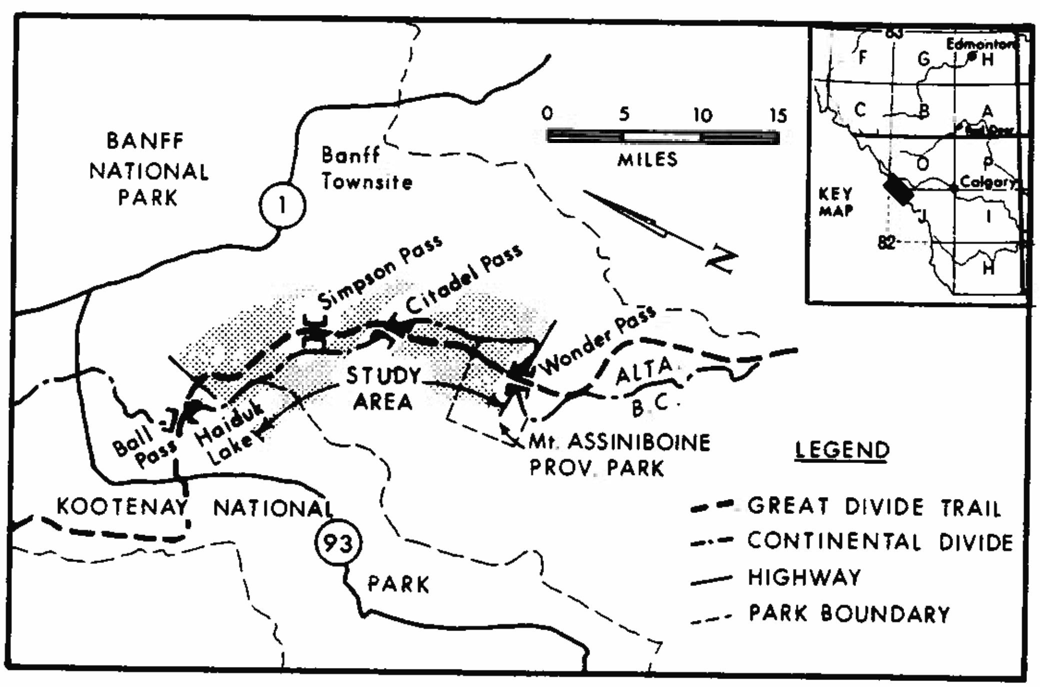


Figure 1. Location of study-area

PROCEDURE

Observations were made at 500-foot intervals along the trail to locate and precisely delimit trail damage. Notes were made on thicknesses and types of surficial deposits, bedrock lithology, local topography and aspect, groundwater and surface water drainage; the proximity, extent and meltwater effects of snowbanks, and vegetation. Soil pits were dug at selected sites, profiles described in detail, and samples taken for analysis in order to characterize soil types over large areas.

The trail was then classified into damaged and undamaged lengths so that observed hydrologic, geologic and pedologic conditions could be related to the trail condition.

SUBSOIL COMPOSITION AND TRAIL CONDITION

The proposed route of the Great Divide Trail traverses a variety of alpine and subalpine terrains which have complex topographic, soil, water and vegetative conditions. The subsoil (or parent) materials on which the trail is built or will be built vary widely in composition but can be grouped into four classes:

(1) alluvium - silt to fine sand, transported and deposited by streams

(2) till - mainly clay, sand and boulders transported and deposited by glaciers

(3) colluvium - broken bedrock material, usually coarse and angular derived from bedrock by mass wasting

(4) bedrock - mainly quartzite, sandstone, limestone and shale.

All four materials to some extent have a weathered mantle (soil) and a vegetative mat. Soils weathered from alluvium, till and colluvium may contain a volcanic ash layer. Table 1 gives the percentages of the trail which pass over these four classes of materials.

Approximately 20 per cent of existing trail along the route between Haiduk Lake and Wonder Pass was classed as damaged during the 1971 survey. Trail was considered damaged if it was deeply rutted or markedly V-shaped; if it contained loose boulders,

Table 1. Percentages of Great Divide Trail Route Underlain by Different Types of Parent Materials

Parent Material	Percentage of Trail
Alluvium	12.9
Till	45.0
Colluvium	21.5
Bedrock	20.6

cobbles, stones or roots from which soil had been trampled down or eroded; or if it contained deep mud or quicked ground which was churned by traffic. Multiple trails which converge to form a broad band of loose, vegetation-free soil also was considered damaged. Table 2 gives the percentage of undamaged and damaged trail observations over specific parent materials. Note that proportionally more trail overlying alluvium and till is damaged than trail overlying colluvium and bedrock. The weathered mantle or soil developed on these materials reflects their properties, and the limitations of the derived soils have for trail use are discussed below.

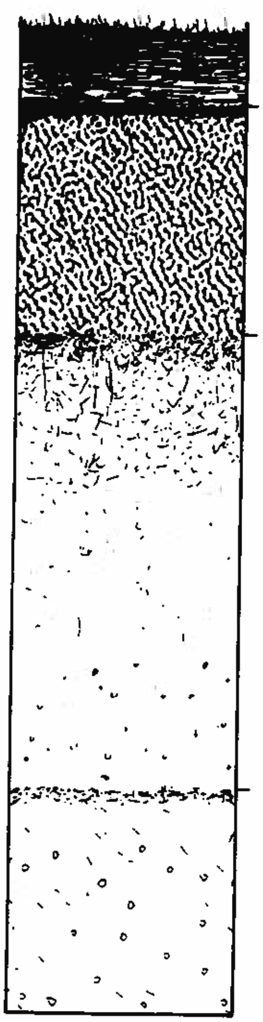
Table 2. Proportions of Damaged Trail Developed on Different Types of Parent Materials

Parent Material	Per Cent Undamaged	Per Cent Damaged	Number of Observations
Alluvium	65.0	35.0	40
Till	68.0	32.0	140
Colluvium	94.0	6.0	67
Bedrock	100.0	0.0	64
		Total Observations	311

SOIL INVESTIGATION

Introduction

Soils are developed from the alteration of bedrock and derived unconsolidated deposits by climate, vegetation and topography. Over a period of time a soil acquires more or less distinct layers or horizons which reflect the interaction of the above soil-forming agents. A cross section of the soil horizons from the surface down to the unweathered parent material is called a soil profile, shown schematically in figure 2. Some characteristics used to describe soil horizons are color, texture, structure, consistence, acidity, root content and organic content, and terms such as topography class, stoniness and soil drainage relate the soil characteristics to the landscape.



L, F, H - Organic horizon: may be subdivided into: L (raw organic matter), F (partially decomposed organic matter), H (decomposed organic matter).

A - A mineral horizon at or near the surface. It may have a humus accumulation (Ah), or a horizon from which clay, iron, and humus have been leached (Ae).

B - Mineral horizons: (1) may have an enrichment of clay (Bt), iron (Bf), or organic matter (Bh); or (2) characteristic columnar structure and significant amount of exchangeable sodium (Bn); or (3) altered to give a change in color or structure (Bm). Usually lime and salts have been leached out of this horizon.

C - Mineral horizon: comparatively unaffected by the soil forming process operative in the A and B horizons except for gleying (Cg) and the accumulation of calcium or magnesium carbonates (Ck) or soluable salts (Cs).

Figure 2. Schematic soil profile and horizon description.

For this study soils are described and classified according to the proposed system of the National Soil Survey Committee of Canada (1970). Detailed descriptions of typical soil profiles along the Great Divide Trail route are given in Appendix A, and analyses of selected horizons from these profiles are tabulated in Appendix B. Locations of sampling localities are indicated on the map at the back of the report.

Soil Limitations for Trail Use

Soil properties can be used to interpret the limitations of a soil for uses such as hiking trails, camping areas, picnic grounds and building sites.

Soil texture limits trail use. Soils with high silt content are especially susceptible to erosion by running water and once wet can support only limited traffic. Soils with high clay content dry slowly after wetting, and sandy soils are unstable when dry. A soil with a mixture of clay, silt and sand - such as a loam or sandy loam - is best suited for trail use.

Soil wetness severely limits soils for trail use, especially as the season of maximum wetness usually coincides with the season of maximum use. Wet soils or soils with a fluctuating water table have a structure and texture which simply cannot support traffic. In contrast, thin soils underlain by bedrock have few limitations for trail use, can withstand heavy traffic without eroding and, obviously, do not have the potential for deep gullying.

The structure of alpine soils is usually weak - they tend to break down easily - and thus a compact well-rooted turf is important in preventing soil erosion. The fibrous, densely rooted turf found in many alpine areas does not form under snowbed areas or slopes exposed to strong winds, and these areas should be avoided except where such areas are bedrock. Where turf has been worn away or removed from the trail, the remaining turf still provides protection for soil adjacent to the trail, and every effort should be made to leave the vegetation intact. Vegetation cover is especially important to soils that contain loess. Loess is a wind-deposited silt usually found near or at the soil surface where it is easily eroded by water and wind once vegetation is removed.

The foregoing soil limitations are summarized for the Great Divide Trail route in table 3, together with parent material, texture, drainage class and observed trail damage.

CAUSES AND EFFECTS OF TRAIL DAMAGE

The causes of trail damage along the Great Divide Trail route are trampling by horse and foot traffic and subsequent erosion by running water. The degree of damage is a function of trail slope and orientation, soil type and groundwater conditions, all of which must be considered in planning trail routes to prevent or minimize damage to the terrain. This is especially true in an alpine or subalpine environment where disturbance of fragile soil and vegetative cover is difficult or impossible to repair.

Damage by Trampling

Trampling of wet sections of the trail by horses and humans is the initial cause of trail damage (Plate 1). The thin but coherent vegetative mat which helps bind the underlying soil is breached or worn away by constant use, and relatively unconsolidated surficial materials are thus exposed to churning and compaction, and to the effects of running water and wind.

The most severe effects of trampling are found in areas of groundwater discharge, i.e., where the trail is located over or a short distance downslope from a spring or seepage area. The supply of moisture provided by groundwater discharge throughout the short summer season saturates the soil over which the trail is built and makes it extremely susceptible to trampling. The effects of trampling are similar during the spring when the soil is partially thawed and saturated with meltwater.

Most trampling effects were observed along streambanks, slopes and in enclosed basin structures (Plate 2). By simply locating the trail above springs or discharge areas and by avoiding enclosed basin structures, this type of damage can be avoided.

Table 3. Soil Types and Parent Materials Underlying a Section of the Great Divide Trail and Their Susceptibility to Trail Damage

No.	Classification	Parent Material	Texture	Drainage Class	Trail Damage	Limitations for Trail Use
33-1	Orthic Humic Gleysol	alluvium	silty clay loam	very poorly drained	severe	severe
41-1	Orthic Humic Gleysol	till	silty clay loam	very poorly drained	severe	severe
24-1	Rego Humic Gleysol	alluvium/ till	silt	very poorly drained	considerable	severe
24-2	Cumulic Regosol	till	silty loam	poorly drained	considerable	moderate
26-1	Lithic Humic Gleysol	alluvium/ colluvium	silty loam	poorly drained	considerable	moderate
45-1	Orthic Regosol	till	loam	rapidly drained	considerable	moderate
75-1	Alpine Dystric Brunisol	alluvium/till	silty loam	poorly drained	considerable	moderate
53-1	Alpine Dystric Brunisol	till	sandy loam	well drained	slight	slight
56-1	Alpine Dystric Brunisol	ash/colluvium bedrock	loamy sand	well drained	slight	slight
66-1	Degraded Eutric Brunisol	colluvium/ till	loam	well drained	slight	slight
43-1	Alpine Eutric Brunisol	till	sandy loam	well drained	slight	slight
26-2	Orthic Regosol	till	loam	moderately well drained	very slight	none
67-1	Degraded Eutric Brunisol	alluvium	silty loam to v. fine sand	moderately well drained	none	none
10-1	Alpine Dystric Brunisol	till	loam	well drained	none	none
28-1	Dystric Brunisol	till	sandy loam	well drained	none	none
42-1	Orthic Regosol	till/colluvium	loam	rapidly drained	none	none

Damage by Running Water

Running water is the principal agent of observed trail erosion. Water running across, along or in close proximity to the trail erodes fine particles, exposes roots and rocks, and undercuts vegetation adjacent to the trail (Plate 3). Table 4 shows the percentage of observations of trail erosion by running water on various parent materials.

Table 4. Trail Erosion by Running Water on Different Parent Materials

Parent Material	Percentage Eroded by Running Water	Number of Observations
Alluvium	22.5	40
Till	32.0	140
Colluvium	3.0	67
Bedrock	4.7	64
	Total Observations	311

Sand and silt removed by running water normally are deposited downslope and thus create ideal conditions for further damage by trampling. In places much of the trail has become so rutted that new trails have been worn parallel to the old (Plate 4). In extreme but not uncommon cases, streams have abandoned their channels and now flow down parts of the trail (Plate 5).

Several stages of trail erosion by running water are shown schematically in figures 3 to 8, where the trail is situated on unconsolidated glacial or alluvial sediments overlain by a thin turf layer. This type of trail erosion leads to expensive maintenance, reconstruction or rerouting of trail, and to unpleasant hiking and riding.

Sources of Water

Streams, snowmelt and springs are the sources of running water. Intermittent and permanent streams have damaged portions of the trail where the stream has intersected or run down the trail and where culverts are too small or absent. Trail must be

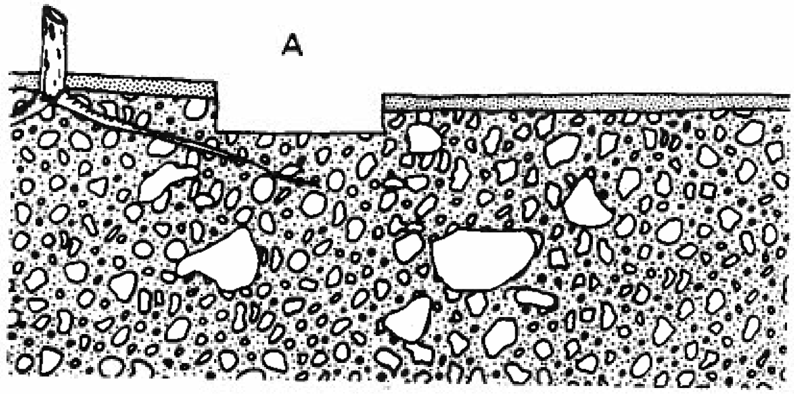


Figure 3. Original condition. Trail (A) is constructed by removing turf overlying till.

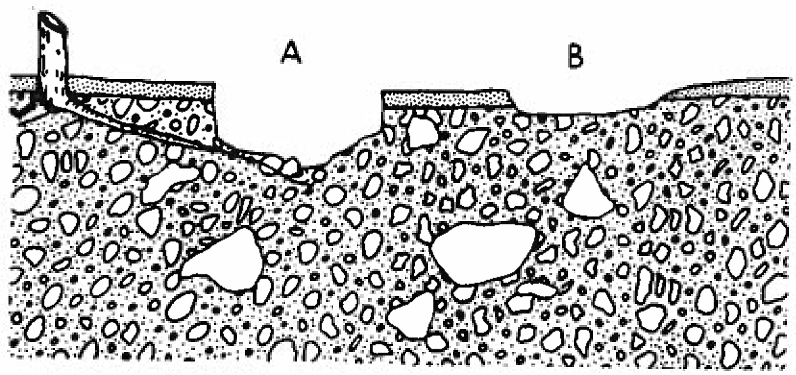


Figure 4. Trail slightly eroded by running water partly exposing pebbles and small boulders. Trail becomes difficult to walk or ride on and is partly abandoned. New trail (B) worn parallel to old.

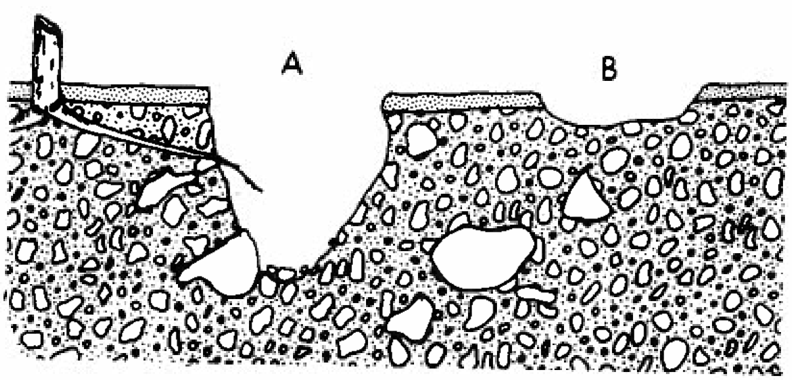


Figure 5. Trail deeply eroded by running water exposing large tree roots and boulders. Loose rocks in trail making walking and riding difficult or impossible. Trail is abandoned for new trail where undercutting of turf begins.

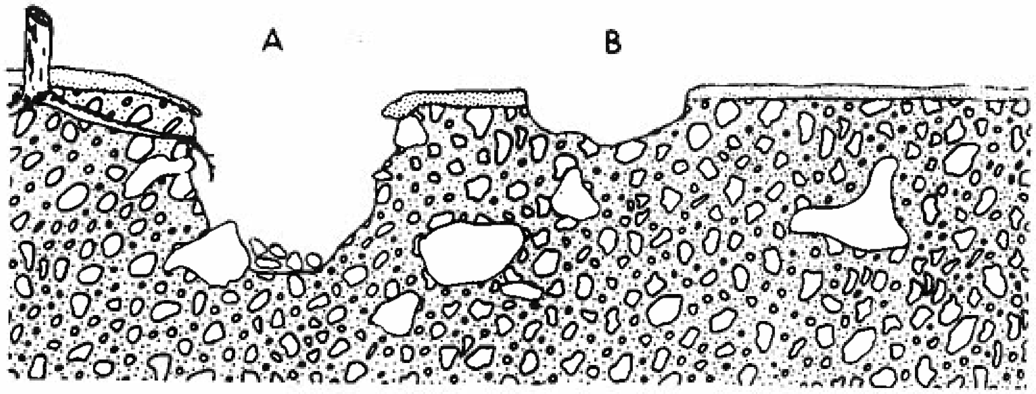


Figure 6. Trail further eroded. Vegetation and root mat is undercut, collapses, and is washed away. More boulders washed into rut, and additional roots exposed. Second trail begins to erode.

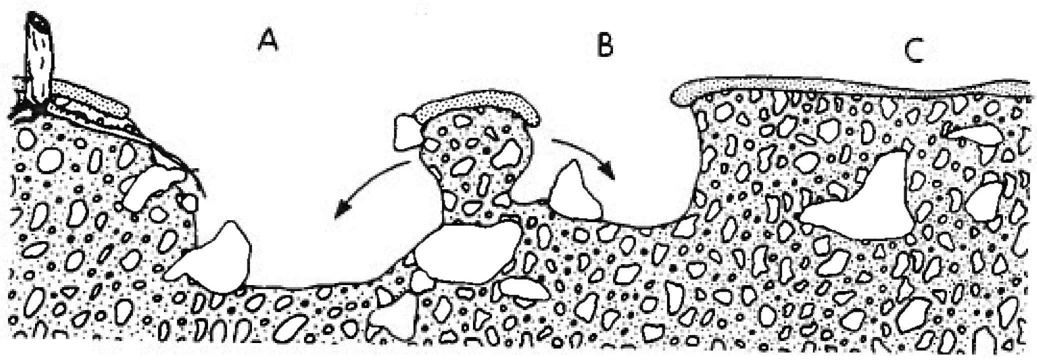


Figure 7. Second trail eroded to similar stage as old trail. Turf bank separating the two trails is further undercut, becoming unstable. Third trail (C) begins.

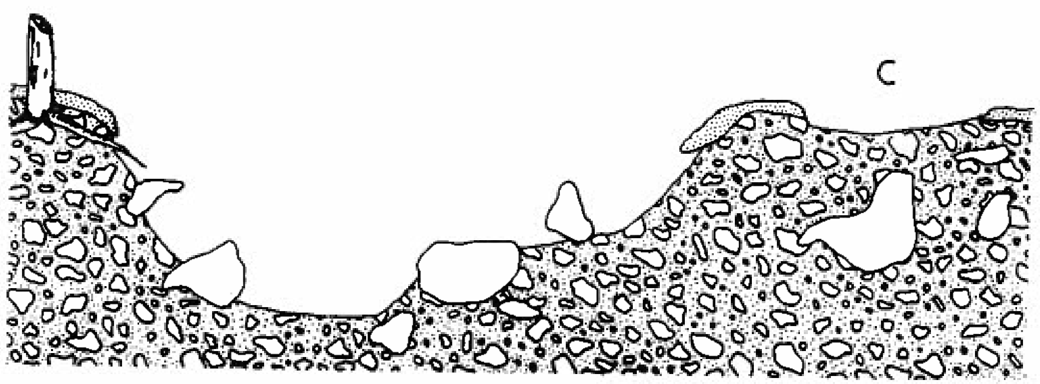


Figure 8. Turf bank collapses and is washed out by running water leaving large rut. Third trail begins to erode.

constructed so that streams are not diverted or interrupted, and culverts must be large enough to accommodate the highest flood stages of the stream.

Snowmelt provides a large quantity of runoff during spring and early summer. Fortunately, much of this water runs off over frozen soil, causing little erosion. However, where the trail provides a channel for the runoff, erosion can occur. Snowbanks that persist into the summer provide water that can erode the trail or make the trail susceptible to damage by trampling. Snowbanks also inhibit or prevent the growth of vegetation, and the lack of vegetation and its root mat enables running water to erode soil easily.

Similarly, springs supply running water throughout the season of trail use, and, without exception, portions of the trail located below springs have been damaged. Thus, areas adjacent to snowbanks or downslope from springs and seepages should be avoided in constructing trail.

Trail Orientation and Slope

Trail orientation and slope determine whether water will run down the trail. Obviously, a trail extending straight downslope will provide an ideal channel for water, whereas a trail extending across slope (i.e., parallel to the contours) will not provide a suitable channel. Much of the erosion observed along the route of the Great Divide Trail between Haiduk Lake and Wonder Pass is of the type shown schematically in figure 9 where the trail runs straight downslope. In this case the trail provides an ideal channel for running water, erosion taking place along the upper reaches of the slope and deposition at the base.

In figure 10, although the trail angles across the slope, some runoff is channelled down the trail, causing erosion in areas above stream intersections with concomitant deposition along the watercourses below.

Figure 11 and plate 6 show the effects of poorly constructed switchbacks which have been built in some areas. For example, in figure 11, the bends are not sufficiently sharp to compensate for running water, and the straighter, downslope portions of the trail have been eroded.

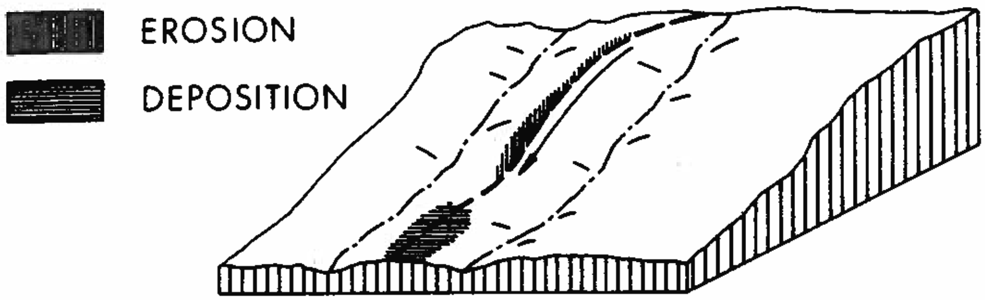


Figure 9. Effect of slope on trail erosion. Trail extends straight downslope, providing an ideal channel for running water.

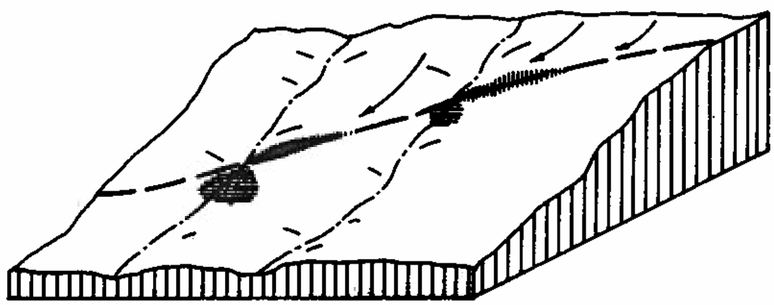


Figure 10. Effect of slope on trail erosion. Although trail angles across slope, some runoff is channelled down the trail. Each section of trail above stream intercourses is eroded and the sediment deposited in the stream bed below.

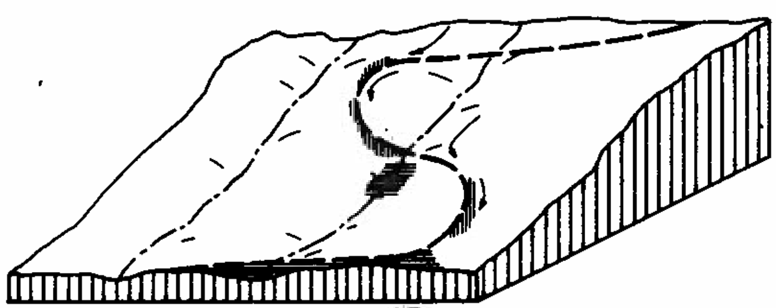


Figure 11. Effect of switchbacks on trail erosion. Poorly constructed switchbacks permit erosion by running water similar to that shown in figure 10.

Generally, the steeper the slope, the greater the potential hazard for erosion by running water; however, the greatest amount of erosion observed occurred on an alluvial plain with a slope of only 2 to 5 degrees. This indicates that soil texture - relative proportions of sand, silt and clay in the soil underlying the trail - is equally important in planning trail routes.

Soil Texture

Silt-sized material is easily transported by running water, and therefore, soils with high silt content are highly susceptible to erosion. From Og Lake to Wonder Pass a series of alluvial plains exist, consisting of silt beds over till. Although the slopes of these plains are low (2 to 5 degrees), the most extensive erosion by running water is found here.

The plain immediately south of Og Lake (Plate 7) provides a good example of the potential hazards to be found in such areas. The original trail was built straight across the plain, i.e., parallel to the regional slope, being located close to one of the meanders of Og Creek (Fig. 12). With time, horse and foot traffic compacted the soil until a rut was worn. At the same time, Og Creek gradually eroded the outside meander bank and cut into the trail rut, which provided a more direct route downslope, and streamwater flowed down the trail (Fig. 13). Subsequent annual erosion has removed so much material from the original rut that the trail is now the major channel of Og Creek (Plate 8). The new trail, built immediately to the west of and parallel to the original trail, soon will be incorporated as Og Creek erodes laterally (Fig. 13).

This type of trail damage has occurred to a lesser degree in each of the alluvial plains between Og Lake and Wonder Pass. In each case, placing of the trail on the side slopes above the plain would avoid such damage (Fig. 14 and Plate 9).

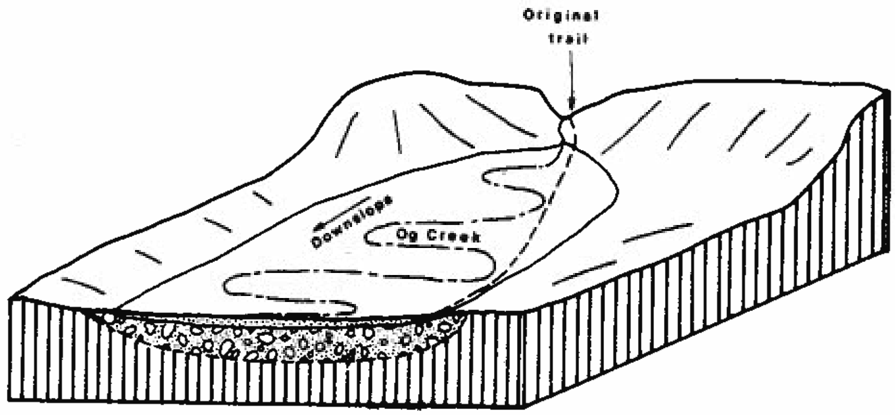


Figure 12. Location of original trail through alluvial plain just south of Og Lake.

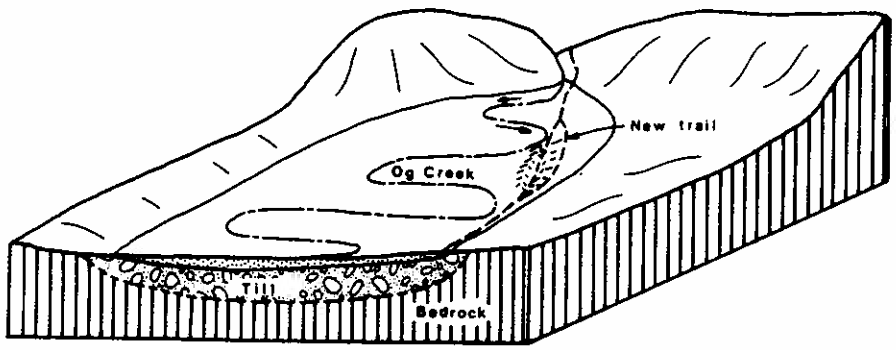


Figure 13. Trail is eroded by water creating a deep rut adjacent to meander in stream bed. New trail developed along lip of rut.

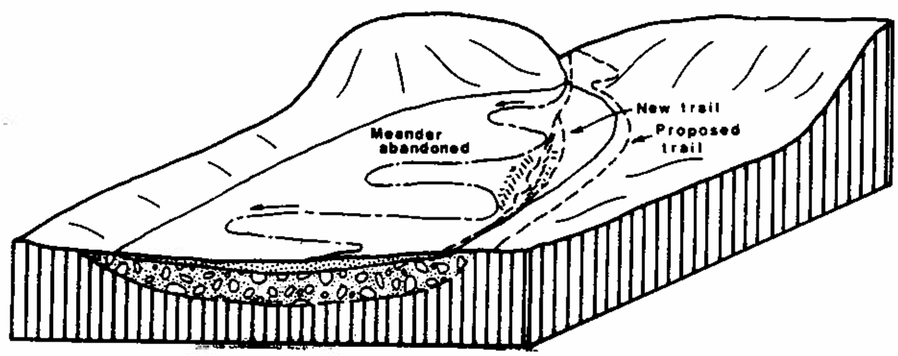


Figure 14. Stream bed is breached by erosion and rut becomes a major channel of Og Creek. The preferred site for a trail through this area is on high ground above the easily eroded alluvial plain.

CONCLUSIONS

(1) Trampling by horse and foot traffic is the initial cause of trail damage. Trail damage is particularly noticeable in wet areas adjacent to lakes, streams, snowbanks, and groundwater discharge features.

(2) Subsequent erosion by running water is the principal cause of trail damage. Where damage is sufficient to inconvenience horse and foot traffic, new trails are worn parallel to the old trail, creating in places a continually broadening series of unsightly ruts in the landscape.

(3) Trail orientation and slope are important in preventing or controlling damage by running water.

(4) Soils with high silt content are highly susceptible to erosion by running water.

RECOMMENDATIONS

(1) <u>Prevent water from running down the trail.</u>

(a) Streams should have adequate culverts, bridges or stepping stones.

(b) Switchbacks should be used on steep slopes, and water should be diverted from each switchback section so that the bends will not be eroded. Switchback bends should be sharp, and rocks, logs, small cliffs, trees and shrubs should be used to block short cutting by users. Users must be educated to use switchbacks and not to cut corners. (Signs such as those on Parker's Ridge trail, Banff National Park, could be erected at key locations to demonstrate the proper use of switchbacks.)

(c) Water bars should be used to divert water from steep portions of the trail.

(d) Trails should not be constructed running straight downslope.

(e) Trails should be constructed so that they will not cause rerouting of streams.

(2) <u>Avoid wet areas.</u>

(a) Avoid springs, seepage areas, streambanks, lake shores and snowbanks. Locate the trail on well-drained soil exposed to the sun.

(b) Corduroy unavoidable wet areas. The corduroy must be flat planks. Puncheon or small diameter logs will be removed or avoided by horse traffic.

(c) Locate trail upslope from springs, seepage areas and snowbanks.

(3) Avoid alluvial plains.

(4) Make use of ridges, coarse talus slopes and bedrock for sections of the hiking trail.

(5) Maintain vegetation cover wherever possible.

(6) Keep horse and foot traffic separate.

Horse and hiking trails require different standards of construction, are for different purposes, and are incompatible unless high standards of trail construction and maintenance are provided. Some differences are:

(a) width of clearing required

(b) height of clearing required

(c) width of tread required

(d) bridge, culvert and corduroy requirements

(e) trail route: soft ground *versus* hard ground.

(7) Make use of southerly and westerly exposed slopes for the trail.

These slopes are clear of snow earlier in the season and drier than northerly or easterly exposed slopes.

(8) Plan alternative trail routes in places.

(a) Explore the possibility of rotating trail traffic where two or more alternative routes exist.

(b) Explore the possibility of alternative routes for different seasons to avoid seasonally wet or snowdrifted areas.

(9) Update information.

The Warden's Manual (issued to National Parks wardens) under a section entitled "Trails"[1] refers to the following practice,

> "Where there is an abundance of water and the soil is an impervious clay mixed with gravel, a good trail can be secured by turning the water down the trail, until the clay is washed from the gravel and a solid gravel tread remains."

This practice should be abandoned for the following reasons:

(a) once water is diverted down the trail it may not be possible to reroute it to its original course

(b) it may not be possible to control the extent of soil erosion

(c) it will unnecessarily silt streams

(d) wet areas are unsuitable for trail routes.

(10) Consult earth scientists when planning or locating trails.

Many of the terrain conditions discussed above can be assessed from aerial photographs by soil scientists and geologists. This information will provide a suitable basis for ground surveys which, in turn, will provide the detailed information on soil types, parent materials and drainage necessary to locating the trail correctly. Alpine soils are highly variable in distribution, composition and texture, and their suitability for trail use is best assessed by soil scientists.

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[1] The section on "Trails" is based on Chapter 3, titled "Trail Building", in Western Fire Fighters Manual, R.S. Shelley, 1942, published by the Western Forestry and Conservation Association.

BIBLIOGRAPHY

Bellamy, D., J. Radforth and N.W. Radforth (1971): Terrain, traffic and tundra; Nature, Vol. 231, p. 429-32.

Canada Department of Agriculture (1970): The System of Soil Classification for Canada; Queen's Printer, Ottawa, Ontario, 249 pages.

Marr, J.W. and B.E. Willard (1970): Persisting vegetation in an alpine recreation area in the southern Rocky Mountains, Colorado; Biol. Conservation, Vol. 2, p. 97-104.

Montgomery, P.H. and F.C. Edminster (1966): Use of soil surveys in planning for recreation, in Soil Surveys and Land Use Planning (ed. L.J. Bartelli et al.); Soil Sci. Soc. America and Amer. Soc. Agron., p. 104-12.

Willard, B.E. and J.W. Marr (1970): Effects of human activities on alpine tundra ecosystems in Rocky Mountain National Park, Colorado; Biol. Conservation, Vol. 2, p. 257-65.

APPENDIX A

DESCRIPTIONS OF SOIL PROFILES

Profile number:	JR-71-10-1
Location:	Healy Pass 51°05'30, 115°52'15
Landform:	till plain
Elevation:	7400 ft., slope = 17%
Aspect:	270°
Soil drainage:	well drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	*Antennaria lanata*, *Castilleja mineata*, *Cassiope tetragona*, *Phyllodoce empetriformis*
Trail damage:	none
Remarks:	little trail damage on well-drained soil on till.
Soil classification:	Alpine Dystric Brunisol
Parent material:	till

Horizon	Depth (inches)	
A_h	0- 1.0	Brown (10YR4/3,d) loam; weak, fine granular; loose; plentiful, fine, random roots; pH 5.1.
B_m	1.0- 5.0	Dark yellowish brown (10YR4/4,m) loam; weak, fine granular; loose; abundant, fine, random roots; pH 5.6.
C	5+	Yellowish brown (10YR5/4,m) loam; abundant, fine, random roots to 14 inches; pH 5.5.

Profile number:	JR-71-24-1
Location:	1/2 mile south of Warden's Cabin, Egypt Lake 51°06'30, 115°53'45
Landform:	till plain
Elevation:	6650 ft., slope = 1%
Aspect:	none
Soil drainage:	very poorly drained
Groundwater showings:	seepage, springs
Depth to water table:	15 inches
Vegetation:	_Salix_ spp., _Carex_ spp.
Trail damage:	considerable
Remarks:	this profile is typical of severely damaged areas due to high moisture levels in drainage and seepage areas.
Soil classification:	Rego Humic Gleysol
Parent material:	alluvium/till

Horizon	Depth (inches)	
A_{hg1}	0- 4.0	Dark reddish brown (5YR2/2,m) silt; weak, fine granular; nonsticky; abundant, fine and medium roots; clear, smooth boundary; pH 5.6.
A_{hg2}	4.0- 8.0	Black (10YR2.5/1,m) silt; weak, fine granular; nonsticky; few fine, vertical roots; 5 per cent coarse fragments; clear, wavy boundary; pH 6.0.
IIC_g	8.0-10.0	Dark yellowish brown (10YR3/4,m) silt; amorphous; nonsticky; few fine, vertical roots; large boulders; clear, broken boundary.
$IIIC_g$	10+	Black (10YR2.5/1,m) silt; amorphous; nonsticky.

Profile number:	JR-71-24-2
Location:	1 mile south of Egypt Lake turnoff 51°06'10, 115°53'10
Landform:	till plain
Elevation:	6850 ft., slope = 18%
Aspect:	270°
Soil drainage:	poorly drained
Groundwater showings:	seepage at surface
Depth to water table:	at surface
Vegetation:	*Carex* sp.
Trail damage:	considerable
Remarks:	soil subject to downslope movement as well as wash deposition; soil wet all year but not reduced.
Soil classification:	Cumulic Regosol
Parent material:	till (modified by wash)

Horizon	Depth (inches)	
A_h	0- 3.0	Dark yellowish brown (10YR4/4,m) silt loam; weak, fine granular; friable; abundant, fine, random roots; clear, smooth boundary; pH 5.5.
C	3.0- 4.5	Brown (10YR4.5/3,m) silt loam; weak, fine granular; friable; few fine, random roots; 5 per cent coarse fragments; abrupt, smooth boundary; pH 5.8.
A_{hb}	4.5- 6.0	Very dark grayish brown (10YR3/2,m) silt loam; weak, fine granular; very friable; few fine, random roots; 10 per cent coarse fragments.
C	6.0-13.0	Dark grayish brown (10YR4/2,m) silt loam; weak, fine granular; friable; few fine, vertical roots, 10 per cent coarse fragments.

Profile number: JR-71-24-2 (continued)

Horizon	Depth (inches)	
C+A_{hb}	13.0-18.0	Dark grayish brown (10YR4/2,m) and very dark grayish brown (10YR3/2,m) sand and silt loam; weak, fine granular; friable; few fine, vertical roots to 16 inches.
C	18+	Dark grayish brown (10YR4/2,m) silt; weak, fine granular; friable.

Profile number:	JR-71-26-1
Location:	1500 ft. north of Healy Pass summit 51°05'40, 115°52'20
Landform:	mountain
Elevation:	7500 ft., slope = 1 - 2%
Aspect:	none
Soil drainage:	poorly drained
Groundwater showings:	seepage and springs nearby
Depth to water table:	10 inches
Vegetation:	*Antennaria* sp., *Carex* sp.
Trail damage:	considerable
Remarks:	good example of considerable damage to thin alluvial deposits in discharge areas.
Soil classification:	Lithic Humic Gleysol
Parent material:	alluvium/colluvium

Horizon	Depth (inches)	
A_{hg}	0- 5.0	Very dark gray (10YR3/1,m) silt loam; weak, fine granular; very friable; abundant, fine, random roots; clear, wavy boundary; pH 5.1.
B_{fg}	5.0- 7.0	Yellowish red (5YR4/6,m) silt; amorphous; very friable; few fine, vertical roots; pH 5.5.
C_g	7.0-12.0	Dark brown (7.5YR3/2,m) loam; weak, fine granular; friable; few fine, vertical roots.
R	12+	Bedrock.

Profile number:	JR-71-26-2
Location:	Simpson Pass area 51°05'10, 115°51'50
Landform:	mountain
Elevation:	7100 ft., slope = 5%
Aspect:	180°
Soil drainage:	moderately well drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	_Larix lyallii_, _Picea engelmanni_
Trail damage:	very slight
Soil classification:	Orthic Regosol
Parent material:	till

Horizon	Depth (inches)	
turf	0- 1.5	Compact rootbound turf; pH 5.8.
A_h	1.5-10.0	Very dark brown (10YR2/2,m) loam; weak, fine granular; very friable; plentiful, fine, vertical roots; 25 per cent coarse fragments; clear, smooth boundary; pH 5.8.
C	10+	Yellowish brown (10YR5/4,m) loam; weak, fine granular; friable; few fine, vertical roots; 70 per cent coarse fragments; pH 6.0.

Profile number:	JR-71-28-1
Location:	north of Simpson Pass 51°04'45, 115°49'50
Landform:	till plain
Elevation:	7050 ft., slope = 6%
Aspect:	90°
Soil drainage:	well drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	<u>Larix</u> <u>lyallii</u>, <u>Picea</u> <u>engelmanni</u>, <u>Abies</u> <u>lasiocarpa</u>
Trail damage:	none
Remarks:	located in channel eroded by stream; however, no alluvial deposition here. Trail standing up very well.
Soil classification:	Dystric Brunisol
Parent material:	till

Horizon	Depth (inches)	
A_h	0- 1.5	Very dark brown (7.5YR2/2,m) compact rootbound turf; abrupt, smooth boundary.
B_m	1.5- 6.0	Brown (10YR4/3,m) sandy loam; weak, fine granular; very friable; abundant, fine, random roots; 60 per cent coarse fragments; clear, smooth boundary; pH 6.3.
C	6+	Dark yellowish brown (10YR3/4,m) silt loam; moderate, fine granular; very friable; few fine, vertical roots; 70 per cent coarse fragments; pH 7.2.

Profile number:	JR-71-33-1
Location:	north of Twin Cairns 51°04'45, 115°48'20
Landform:	alluvial plain
Elevation:	7480 ft., slope = 0.5 - 1%
Aspect:	none
Soil drainage:	very poorly drained
Groundwater showings:	discharge area with considerable seepage
Depth to water table:	less than 1 foot
Vegetation:	_Carex_ _eleusinoides_
Trail damage:	severe
Remarks:	trail must avoid such areas. Gravelly wash on surface; _Carex_ growing in clumps covering about 50% of the surface.
Soil classification:	Orthic Humic Gleysol
Parent material:	alluvium

Horizon	Depth (inches)	
A_{hg}	0- 1.5	Very dark gray (2.5Y3/0,m) silty clay loam; moderate medium subangular; blocky, sticky; plentiful fine vertical roots; less than 5 per cent coarse fragments; clear, irregular boundary; pH 6.1.
B_g	1.5- 8.0	Light olive brown (2.5Y5/4,m) silt loam; common fine, distinct yellowish brown (10YR5/6,m) mottles; massive, firm; very few fine, vertical roots; less than 5 per cent coarse fragments; gradual, smooth boundary; pH 7.8.
C_g	8+	Gray (5Y6/1,m) silt loam; many coarse, prominent yellowish brown (10YR5/6,m) mottles; massive, slightly sticky, very few fine, vertical roots; less than 5 per cent coarse fragments; pH 8.0.

Profile number:	JR-71-41-1
Location:	east of Twin Cairns 51°04'30, 115°47'35
Landform:	till plain
Elevation:	7610 ft., slope - 1 - 2%
Aspect:	none
Soil drainage:	very poorly drained
Groundwater showings:	considerable seepage
Depth to water table:	at the surface
Vegetation:	*Eriophorum angustifolium*, *Carex* spp.
Trail damage:	severe - this area must be avoided!
Soil classification:	Orthic Humic Gleysol
Parent material:	water-worked till

Horizon	Depth (inches)	
peat	(4)	Dark reddish brown (5YR3/3,m) slightly decomposed masses and sedge material; abrupt, smooth boundary; pH 5.1.
A_{hg}	0- 4.0	Very dark gray (2.5Y3/0,m) silty clay loam; few fine, faint mottles; amorphous, sticky; plentiful fine, vertical roots; gradual, smooth boundary; pH 7.2.
B_{g1}	4.0- 8.0	Gray (2.5Y5/0,m) clay; few fine, faint light olive brown (2.5Y5/4,m) mottles; amorphous, very sticky; very few fine, vertical roots; gradual, wavy boundary; pH 4.7.
B_{g2}	8.0-20+	Olive gray (5Y4/2,m) clay loam; many medium prominent dark yellowish brown (10YR4/4,m) mottles; amphorous, very sticky; pH 7.4.

Profile number:	JR-71-42-1
Location:	200 yards north of Rock Isle Lake, B.C. 51°04'30, 115°47'35
Landform:	drainage channel in till plain
Elevation:	7440 ft., slope = 27%
Aspect:	130°
Soil drainage:	rapidly drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	*Pulsatilla occidentalis*
Trail damage:	none
Remarks:	considerable downslope soil movement in this area, but trail stands up very well in this material.
Soil classification:	Orthic Regosol
Parent material:	till and colluvium

Horizon	Depth (inches)	
A_h	0- 7.0	Dark brown (10YR4/3,m) loam; upper 1 inch is densely rooted turf; lower portion has inclusion of C and buried turf; weak, fine granular; friable; plentiful fine vertical roots; large boulders present; clear, wavy boundary; pH 5.5.
A+B+C	7.0-16.0	Yellowish brown (10YR5/6,m) and very dark grayish brown (10YR3/2,m) and yellowish brown (10YR5/4,m) loam; weak, fine granular; friable; very few fine, random roots; gradual, wavy boundary.
C	16+	Yellowish brown (10YR5/4,m) stoney clay loam; moderate fine subangular; blocky, friable; abundant boulders.

Profile number:	JR-71-43-1
Location:	east of Rock Isle Lake, B.C. 51°03'45, 115°45'01
Landform:	till plain
Elevation:	7370 ft., slope = 8%
Aspect:	225°
Soil drainage:	well drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	<u>Antennaria lanata</u>
Trail damage:	slight
Remarks:	trail stands up very well in similar areas, even with extreme heavy use.
Soil classification:	Alpine Eutric Brunisol
Parent material:	till

Horizon	Depth (inches)	
A_h	0- 3.5	Upper 2 inches of horizon dark gray (10YR4/1,d) turfy; dark brown (10YR3/3,d) sandy loam lower portion; weak, fine granular; friable; abundant fine, random roots; clear, wavy boundary; pH 4.9.
B_m	3.5- 6.0	Strong brown (7.5YR5/6,m) silt loam; weak, fine granular; soft; abundant fine, random roots; 50 per cent coarse fragments; clear, wavy boundary; pH 5.6.
BC	6.0-12.0	Very dark grayish brown (10YR3/2,m) gravelly sandy loam; moderate medium granular; friable; plentiful fine, random roots; 70 per cent coarse fragments; abrupt, wavy boundary; pH 7.6.
R	12+	Bedrock.

Profile number:	JR-71-45-1
Location:	east side of Quartz Ridge 51°02'50, 115°46'25
Landform:	terraced ridge on side of mountain
Elevation:	7420 ft., slope not measured
Aspect:	90°
Soil drainage:	rapidly drained (but snowbed area)
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	<u>Saxifraga</u> <u>lyallii</u>
Trail damage:	considerable
Remarks:	meltwater from snowbed areas has caused moderate erosion of trail on steep slopes.
Soil classification:	Alpine Eutric Brunisol grading to Orthic Regosol
Parent material:	till

Horizon	Depth (inches)	
A_h	0- 2.0	Very dark gray (10YR3.5/1,m) loam; weak, fine granular; very friable; abundant fine, vertical roots; very weakly effervescent; 50 per cent coarse fragments; clear, broken boundary; pH 7.1.
B_m	2.0- 6.0	Dark yellowish brown (10YR4/4,m) and yellowish red (5YR4/6,m) loam; moderate, fine subangular; blocky, friable; very few fine, random roots; very weakly effervescent; 30 per cent coarse fragments; diffuse, smooth boundary; pH 7.7.
C	6.0-10.0	Yellowish brown (10YR5/4,m) loam; weak, fine granular; friable; very weakly effervescent; pH 7.7.
R	-	Bedrock.

Profile number:	JR-71-53-1
Location:	north of Citadel Peak 51°01'06, 115°44'15
Landform:	mountain
Elevation:	7400 ft., slope = 10%
Aspect:	180°
Soil drainage:	well drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	_Abies lasiocarpa_, _Picea englemanni_, _Larix lyallii_, _Salix barratiana_
Trail damage:	slight
Remarks:	bedrock within 3 to 5 feet of surface.
Soil classification:	Alpine Dystric Brunisol
Parent material:	till

Horizon	Depth (inches)	
turf	0- 1.5	Very dark brown (10YR2/2,m), very compact root-bound sod.
loess	1.5- 2.0	Light gray (10YR6/1,m).
A_h	2.0- 3.5	Dark brown (7.5YR3/2,m) fine, sandy loam; weak, fine granular; very friable; abundant fine, random roots; 5 per cent coarse fragments; clear, broken boundary; pH ?
B_m	3.5- 5.0	Brown (7.5YR4/4,m) sandy loam; weak, fine granular; very friable; abundant fine, vertical roots; pH ?
C	5+	Brown (10YR4/3,m) sandy loam; roots to 18 inches; 70 per cent coarse fragments (channery shales) pH ?

Profile number:	JR-71-56-1
Location:	1 mile south of Citadel Pass 51°00'45, 115°41'45
Landform:	mountain
Elevation:	7400 ft., slope = 3%
Aspect:	180°
Soil drainage:	well drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	*Pulsatilla occidentalis*
Trail damage:	slight
Remarks:	slight erosion by running water on slopes.
Soil classification:	Alpine Dystric Brunisol
Parent material:	volcanic ash/colluvium/bedrock

Horizon	Depth (inches)	
turf	0- 1.0	Compact rootbound sod.
A_{he}	1.0- 2.0	Dark brown (10YR3/3,d) loamy sand; weak, fine granular; very friable; gradual, smooth boundary; pH 5.9.
B_m	2.0- 8.0	Yellowish brown (10YR5/6,m) and bright yellow (10YR7/6,d) very fine sand (volcanic ash); weak, fine granular; very friable; gradual, smooth boundary; pH 6.8.
C	8+	Dark brown (7.5YR4/4,m) gravelly loam; amorphous; friable; pH 7.4.

Profile number:	JR-71-66-1
Location:	south of Og Lake 50°56'25, 115°38'00
Landform:	mountain
Elevation:	6850 ft., slope = none (crown of ridge)
Aspect:	none
Soil drainage:	well drained
Groundwater showings:	none
Depth to water table:	unknown
Vegetation:	_Salix_ spp., _Symphoricarpos albus_, _Phyllodore glandulifora_, _Achillea millefobium_
Trail damage:	slight
Remarks:	very firm clods formed in the C horizon under the trail.
Soil classification:	Degraded Eutric Brunisol
Parent material:	colluvium/till

Horizon	Depth (inches)	
turf	0- 1.0	Compact rootbound sod.
A_e	1.0- 3.0	Brown (7.5YR5/2,m) and pinkish gray (7.5YR7/2,d) loam; weak, fine granular; loose, pH 5.7.
B_m	3.0- 6.0	Dark yellowish brown (10YR4/4,m) and light yellowish brown (10YR6/4,m) heavy loam; weak, fine granular; very friable; pH 6.0.
C_k	6+	Reddish brown (5YR5/3,m) and very pale brown (10YR8/3,d) silty clay; strong, coarse blocky; very firm; strongly effervescent; pH 7.4.

Profile number:	JR-71-67-1
Location:	north of Assiniboine Park 50°56'00, 115°37'50
Landform:	alluvial fan
Elevation:	6800 ft., slope = 9%
Aspect:	not recorded
Soil drainage:	moderately well drained
Groundwater showings:	may be seasonal seepage
Depth to water table:	unknown
Vegetation:	<u>Antennaria lanata</u>, <u>Potentilla fruticosa</u>, spp. of <u>Gramineae</u> family
Trail damage:	none
Remarks:	locality is on a hummock occurring on the fan.
Soil classification:	Degraded Eutric Brunisol
Parent material:	alluvium

Horizon	Depth (inches)	
A_h	0- 2.0	Black (7.5YR2/1,m) silt loam; weak, fine granular; compact rootbound turf; abrupt, broken boundary; pH 5.8.
B_m	2.0- 8.0	Dark brown (7.5YR4/4,m) very fine sand (may be volcanic ash); amorphous; very friable; abrupt, smooth boundary; pH 6.8.
C_k	8+	Brown (10YR4/3,m) sandy loam; amorphous; friable; 60 per cent coarse fragments; weakly effervescent.

Profile number:	JR-71-75-1
Location:	north of Wonder Pass 50°33'50, 115°36'10
Landform:	till plain
Elevation:	7450 ft., slope = 6%
Aspect:	250°
Soil drainage:	poorly drained
Groundwater showings:	seasonal seepage
Depth to water table:	shallow
Vegetation:	Carex spp., Antennaria lanata
Trail damage:	considerable damage by trampling
Remarks:	pit dug in seepage area; not wet in August but wet earlier in season.
Soil classification:	Alpine Dystric Brunisol
Parent material:	alluvium/till

Horizon	Depth (inches)	
turf	0- 1.5	Very compact rootbound sod.
A_h	1.5- 4.5	Very dark grayish brown (10YR3/2,m) silt loam; weak, fine granular; friable; pH 4.9.
AB	4.5- 5.5	Brown (10YR4/3,m) silt loam; weak, fine granular; friable.
B_m	5.5- 9.0	Dark brown (7.5YR3/4,m) silt loam; weak, fine granular; very friable; pH 5.3.
B_m+A_h	9.0-13.0	Mechanical mixture of B_m and A_h.
C	13+	Olive (5Y4/3,m) silty clay loam; few fine, faint mottles; amorphous; firm; pH 5.3.

APPENDIX B

ANALYSES OF SELECTED SOIL HORIZONS

Profile	Horizon	pH[1]	%O.M.[2]	Texture[3]
10-1	A_h	5.1	14.9	L
	B_m	5.6	6.4	L
	C	5.5	-	L
24-1	A_{hg1}	5.6	22.5	Si
	A_{hg2}	6.0	15.5	Si
24-2	A_h	5.5	15.1	SiL
	C	5.8	-	SiL
26-1	A_{hg}	5.1	16.8	SiL
	B_{fg}	5.5	7.4	Si
26-2	A_h	5.8	8.6	L
	C	6.0	-	L
28-1	B_m	6.3	2.6	SL
	C	7.2	-	SiL
33-1	A_{hg}	6.1	2.0	SiCL
	B_g	7.8	-	SiL
	C_g	8.0	-	SiL
41-1	Peat	5.1	55.9	-
	A_{hg}	7.2	13.0	SiCL
	B_{g1}	4.7	6.9	C
	B_{g2}	7.4	0.3	CL
42-1	A_h	5.5	9.8	L
	AB_1	5.3	4.4	L
	AB_2+AB_3	6.1	3.8	CL

43-1	A_h	4.9	23.2	SL
	B_m	5.6	14.0	SiL
	BC	7.6	1.1	gv.SL
45-1	A_h	7.1	4.8	L
	B+C	7.7	0.8	L
56-1	A_{he}	5.9	13.8	LS
	B_m	6.8	6.7	VFS
	C	7.4	-	gv.L
66-1	A_e	5.7	5.5	L
	B_m	6.0	5.7	HL
	CK	7.4	-	SiC
67-1	A_h	5.8	17.2	SiL
	B_m	6.8	3.7	VFS
68-1	A_h	5.2	15.9	LS
	B_m	5.7	7.9	VFS
	C	6.2	-	L
75-1	B_m	5.3	6.9	SiL
	C	5.3	-	SiCL

[1] Saturated paste method (H_2O).

[2] Wet oxidation of organic carbon ($K_2Cr_2O_7 - H_2SO_4$).

[3] Field texture.

Hikers on trail in a high alpine meadow.

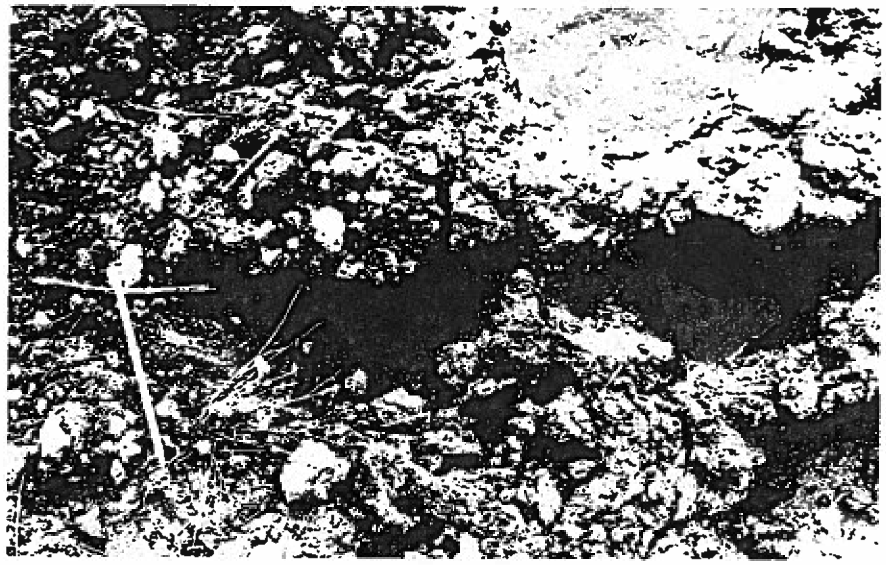

PLATE 1. Complete destruction of vegetation by trampling. Note pencil for scale.

PLATE 2. Abrupt rut entrenchment associated with an enclosed basin.

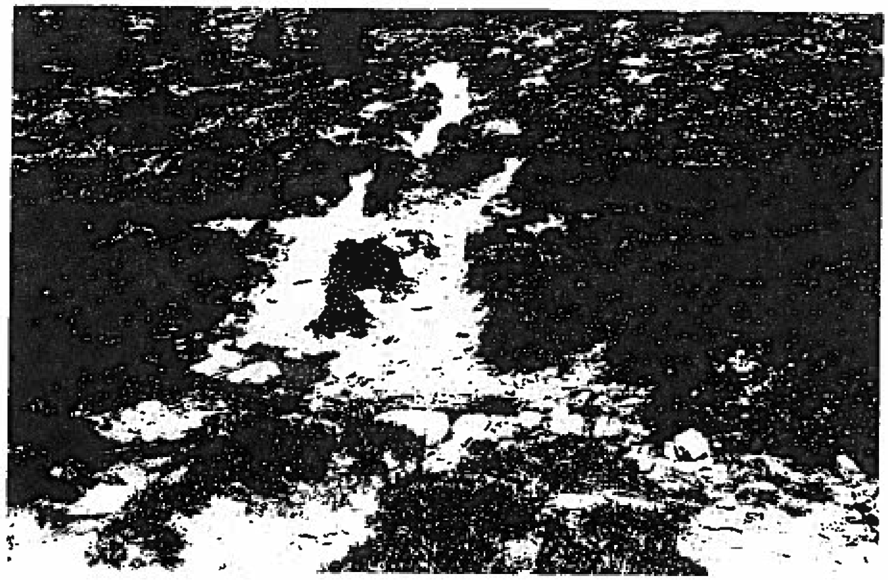

PLATE 3. Trail damaged by running water.

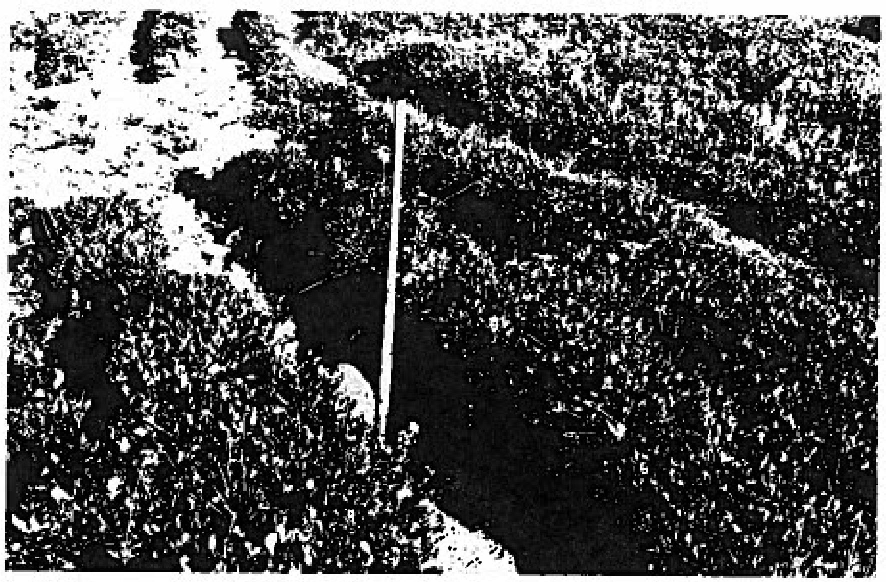

PLATE 4. New trails worn parallel to old trails.

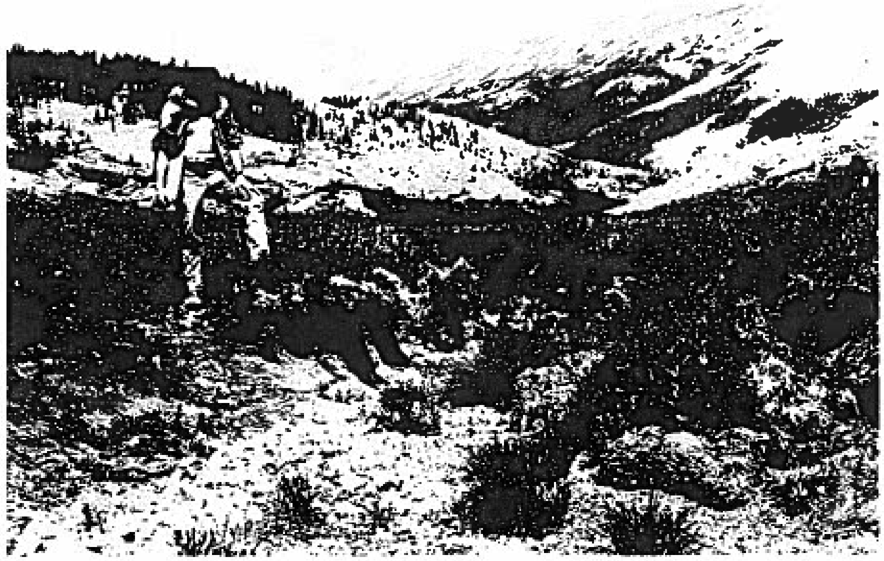

PLATE 5. Trail completely destroyed by running water.

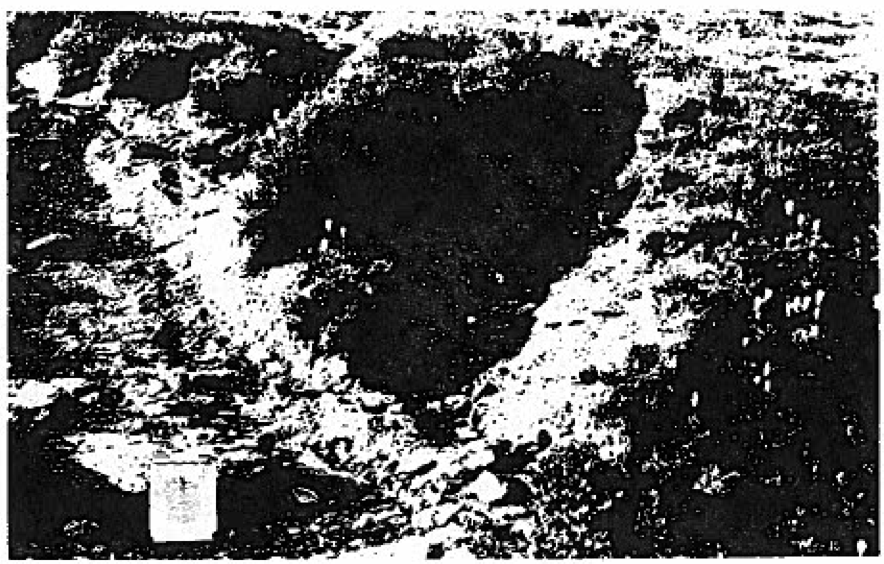

PLATE 6. Poorly constructed switchback leads to trail erosion by running water.

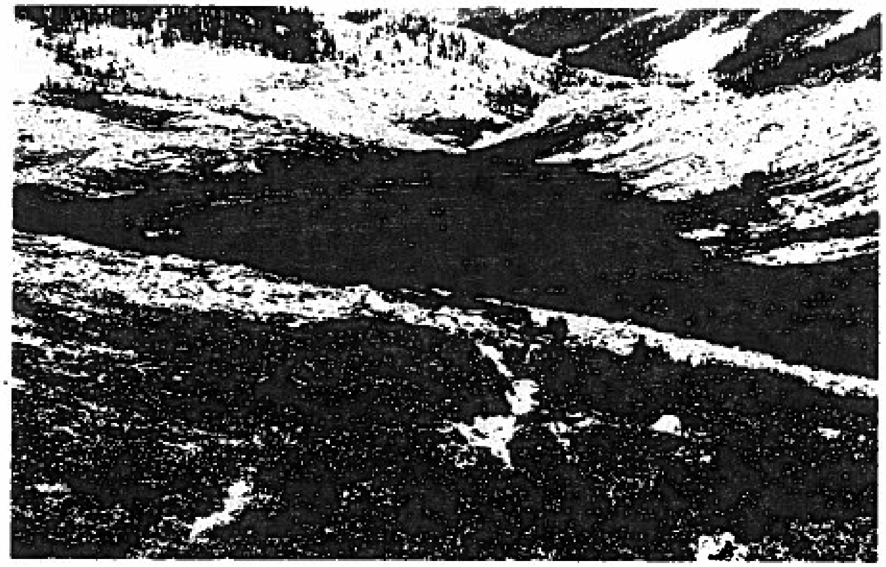

PLATE 7. Alluvial plain immediately south of Og Lake which has undergone extensive soil erosion. Original trail extended through the plain at the left of the photograph.

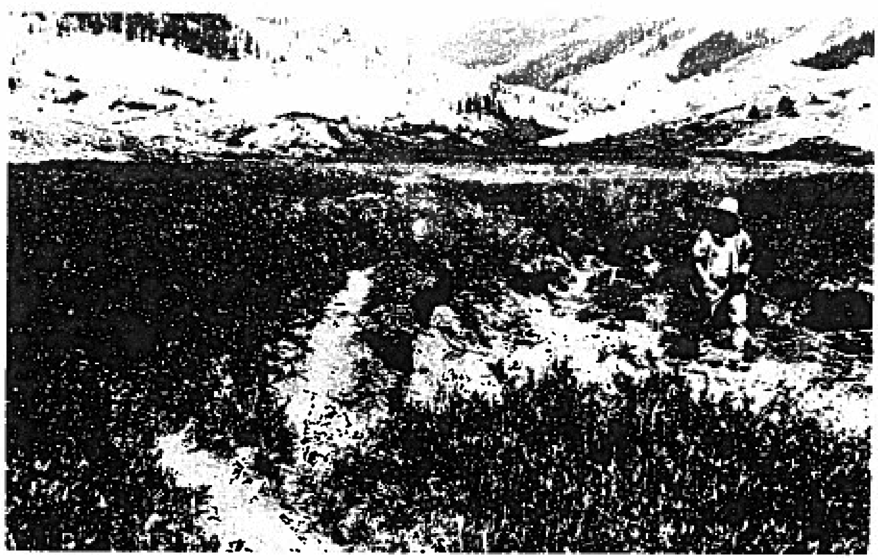

PLATE 8. Hiker walking in the major channel of Og Creek developed by erosion of the original trail rut.

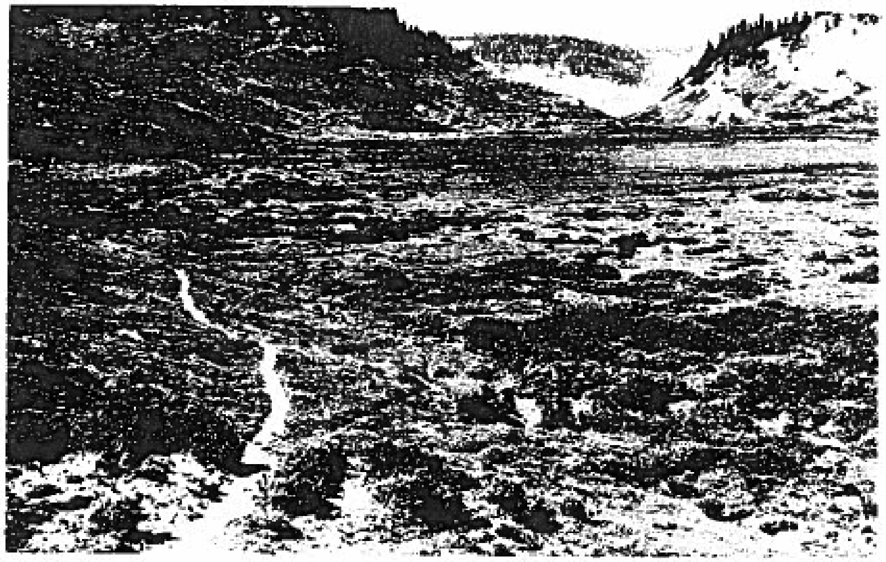

PLATE 9. Trail in good condition on side slopes above an alluvial plain.

SUBSOIL MATERIALS, TRAIL CONDITION, AND SAMPLING LOCALITIES ALONG A SECTION OF THE GREAT DIVIDE TRAIL, SOUTHERN ALBERTA AND BRITISH COLUMBIA