

CLASSIFICATION SYSTEM FOR THE SOILS OF
MOUNT RAINIER NATIONAL PARK

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LIST OF ILLUSTRATIONS

| Figure | Page |
|---|------|
| 1. Source, age, and characteristics of major soil forming tephras | 13 |
| 2. Tephra Yn | 18 |
| 3. Tephra W | 18 |
| 4. Tephra C | 22 |
| 5. Tephra D | 22 |
| 6. Tephra L | 23 |
| 7. Outline of classification groups | 46 |
| 8. Identification of sampling plots | 47 |
| 9. Representative soil-landform sequences | 48 |
| 10. Major identification characteristics and limitations | 77 |

TABLE OF CONTENTS

| | Page |
|---|------|
| INTRODUCTION | 1 |
| FACTORS IMPORTANT IN SOIL FORMATION | 4 |
| Climate | 4 |
| Glaciation | 6 |
| Post-Glacial Volcanic Activity | 8 |
| Lahars | 25 |
| CLASSIFICATION | 35 |
| Logic of Classification | 35 |
| Introduction to the Classification System | 38 |
| Description of Classification Groups | 45 |
| CONCLUSION | 74 |
| LITERATURE CITED | 79 |

INTRODUCTION

The classification of the soils of Mount Rainier National Park is a result of a forest vegetation-soils survey conducted during the summer of 1975 under the direction of Dr. Jerry Franklin of the U.S. Forest Service. The survey consisted of plot analysis of the forest vegetation in 235 sites scattered throughout the Park. On most of these plots a description was made of the representative soil, the landform, and the vegetation grouping. Because of the widespread, random scattering of these plots, the plot analysis probably contained a good representation of the soils in the Park.

Soil formation involves the following factors: parent material, topography, vegetation, climate, and time (Birkland, 1974, p. 125). Through the interaction of these factors on soil forming processes, a soil will develop certain characteristic features on a particular site. Similar soils will be found where soil forming factors are similar. In Mount Rainier National Park soil forming factors are complex. The parent materials in which these soils form are depositional. Research has been conducted by the U.S. Geological Survey to determine the origin, properties, and age of these parent materials. This deposition has been the result of volcanic pyroclastic eruptions, mudflows,

glacial activity, and landslides. Much of this material has been redeposited by colluvial and alluvial processes.

Topography is a major factor in the deposition of parent materials in the Park. The aspect of the slopes affects the micro-climatic conditions under which the soil develops. Slope steepness affects the drainage and erosional characteristics of the soil. These topographic features are extremely variable in the Park.

The climatic factor influencing soil formation is a product of both the regional weather patterns and the micro-climate as affected by topography. The micro-climate is affected by elevation, aspect, slope, and landform sequence. Vegetation variability is also extreme. It is both an active factor in soil formation and a product of these complex factors. Vegetation stabilizes the surface against erosion and increases the infiltration of water into the soil. It also contributes the organic matter to the soil and recycles soil nutrients thus affecting the chemistry of the soil.

The morphologic expression of these factors is a product of the nature of each factor and of time. Morphologic features develop over a period of time. In the Park, surface deposits of many different ages exist. The morphologic features which develop in each parent material are a product of its age and each of the other soil forming factors.

Using the data available from the U.S. Geological Survey research, climatic data, and the data accumulated through this field survey, it was possible to make inferences about the soil forming factors involved in individual soils. In this way soils which have undergone similar formation processes were identified for classification.

Since different soils behave differently when used or managed, it becomes a management "tool" to relate soil to behavior. The primary objective of this report is to devise a classification system that identifies a class of soils in terms of characteristics related to land use and management in a national park.

FACTORS IMPORTANT IN SOIL FORMATION

Climate

The effective climate in any locality in the Park is controlled by a complex of factors which includes regional weather systems, relief and topography, and orographic effects of the 14,410 foot volcano. The climatic patterns are simple regionally; winds are westerly and most of the precipitation falls during the period from October through March. Winds tend to be from the west or northwest during the wettest months, November through March, and west or southwest during the driest months, May through August.

The Park exhibits topographic extremes in elevation, slope, and aspect. The closed canopy forest ranges from 1500 feet at the Carbon River entrance to generally above 5000 feet. There exists a broad range in amount, type, and availability of precipitation throughout the forested region. The climatic data recorded at Paradise Park and Longmire from 1920 to 1959 give some indication of this range. Longmire, 2672 feet in elevation, is in a low valley bottom, whereas Paradise Park, 5400 feet in elevation, is above the forest limits. Paradise Park consistently has lower temperatures, higher total precipitation, more snow fall, and a longer season of snow pack than does Longmire (U.S. Dept. of Commerce, n.d.).

Site specific climatic conditions can be inferred from these data through knowledge of the effects of elevation, aspect, slope, and landform. Certain landforms act as catch basins for gravitational or wind influenced snow drifts, whereas others act as troughs for cold air drainage from upper elevation snow fields and glaciers and thereby maintain a more alpine temperature regime than the adjacent slopes. Both are areas of late snow melt and more moist soil conditions. Aspect and slope have considerable effect on the amount and intensity of radiation available to any land area and must be considered with landform in describing a micro-climate. The tendency for clouds to accumulate as fog in the lower valleys during the late summer months also affects the moisture regime in these areas.

The effects of Mount Rainier have not been documented, but they can be inferred from the fact that it is a physical barrier to passage of weather systems and creates an orographic modification of the basic weather patterns. As moist air rises it cools and loses increasing amounts of moisture. Then as it crosses a barrier and flows downward again it becomes warmer and drier. In this way the mountain and its higher east-west facing ridges create rainshadows on the eastern side of the mountain. Rainshadow intensity varies due to the changing wind direction during the wet season, but generally is more pronounced to the southeast and increasingly less pronounced to the northeast.

The effect is that the northwest sector of the Park has the highest precipitation and the southeast the lowest.

These combined regional and micro-climatic influences result in a variety of soil temperature and moisture regimes which cause differences in vegetational growth. In some areas soils become dry every summer whereas in others the soils remain moist except during the driest years. The moisture regime has an important influence on many aspects of the soil including stability, development, and organic matter accumulation.

Glaciation

During the Pleistocene period glaciers of alpine origin covered most of the Cascade region including the area of Mount Rainier National Park. Through a series of alternate advances and retreats, layers of glacial material were deposited as till and outwash. These deposits have been given the generalized name, drift, with the extent of the drift correlating to the extent of the glaciation. Although there are several layers of drift material, two will be discussed as possible soil parent materials. These are the drifts associated with the last two major Pleistocene glaciations, Salmon Springs and Fraser. The drifts have been named the Hayden Creek drift and the Evans Creek drift, respectively (Crandell and Miller, 1974).

Most extensive was the Salmon Springs glaciation which probably blanketed the entire Park. Drift material

from this advance has been found extensively enough to estimate its deposition throughout the Park except on some upper slopes and associated ridges on which icecap scouring occurred instead of deposition. This drift has been dated at more than 45,000 years BP (Crandell and Miller, 1974, p. 18).

The last extensive glaciation was the Fraser glaciation which deposited the Evans Creek drift and occurred about 15,000 to 20,000 years BP. This drift material was deposited in the valley and cirque basin drainages throughout the Park and, although much more restricted in both elevation of advance and glacier depth, was probably deposited in most of the forested areas.

Several more recent glaciations have occurred including two of Holocene origin, the last of which reached its greatest advance about 1860 (Crandell and Miller, 1974, p. 50). Based on observations made during this study, the effects of these advances on the forest soils appear to be limited to lateral and terminal moraines near the upper limits of forest growth in each of the major glacial valleys draining Mount Rainier.

In terms of an actual forest soil study of the Park, glacial deposition appears to be of relatively minor concern. The reason for this stems from the landforms involved and the more recent depositions of different origins. Most of the forests are on lower ridges, benches, slopes, terraces, and valley bottoms of the major drainages. The

slopes are generally steep and unstable. The benches have been depositional sites for upslope colluvial and alluvial deposits of glacial, residual, or volcanic origin. This means that the soils formed on these landforms may contain some glacial materials but are dominated by fluvial, colluvial, or eolian transport processes. The valley bottoms and terraces have probably been the major sites of till and outwash but have more recently been the sites of major mudflow activity and continuing alluvial depositions, as well as accumulation sites for tephra and colluvial deposits. Therefore, glacial depositional material as a discrete layer or parent material is probably buried deeply by these other deposits.

Post-Glacial Volcanic Activity

Many volcanic pyroclastic eruptions have occurred during the post-glacial period and have contributed to the post-glacial deposits which make up the soil forming materials in the Park. Donal Mullineaux of the U.S. Geological Survey has identified 22 post-glacial deposits, eleven from Mount Rainier, ten from Mount St. Helens, and one from Mount Mazama (Mullineaux, 1974, p. 2). Most of these have been minor and of little consequence to soil formation, but a few have caused major deposits and appear from this study to form the bulk of the soil parent material throughout much of the Park.

Mullineaux (1974) used the term tephra with reference to either pyroclastic ejected fragments of volcanic eruption or deposits of these fragments. Two of these are vesicular, pumice to a high degree, and scoria to a lesser degree. Scoria is also darker in color due to a higher content of iron-magnesium minerals but less silica. The other two, lithic and crystalline fragments, are nonvesicular. He used three terms to qualify tephra fragment size: ash, grains less than 0.4 cm in diameter; lapilli, fragments 0.4 to 3.2 cm in diameter; and blocks or bombs, fragments greater than 3.2 cm in diameter. We found that pumice ash fragments form the bulk of the tephra in the forest soils. However, lapilli are frequently present in certain tephra layers creating a gravelly soil. In certain sites near Mount Rainier, soils were found with a tephra several centimeters in thickness composed entirely of lapilli and bombs. The behavior and morphology of soil is thereby affected by the fragment size in an individual tephra layer.

Mullineaux listed several factors that contributed to the depositional nature of tephra. Most important among these are the prevailing wind direction and velocity at the time of eruption, the volume of the tephra ejected, the force of the eruption, and the particle size distribution of the tephra. Tephra tends to be distributed within a lobe downwind from the volcano. The lobe has a central axis and both particle size and depositional thickness

decrease with distance from the volcano and distance from axis of the lobe. This lobe effect decreases as the distance to the tephra source increases, with the result that tephra from a distant volcano such as Mount Mazama, 500 km to the south, is almost uniformly deposited throughout the Park. Tephras of Mount Rainier radiate as lobes from the crater. A result we found to be important in soil formation is that the Rainier tephras have been restricted almost entirely to areas east of the volcano by the prevailing westerly winds.

Each tephra layer seems to differ in its influence on the soil. Mullineaux stated that many of the older Mount Rainier tephras were volumetrically small deposits set down as thin layers. These appear to have become incorporated into a mixed soil mass rather than remaining a discrete layer. We found that larger deposits originating from both Mount Rainier and Mount St. Helens often were found to have been reworked into deep, well defined layers exerting considerable influence on the soil and often showing differential development and horizonation within the individual layer. Often tephras differ in texture and mineral composition and thus influence development of a soil by affecting water flow, weathering rate, and soil stability.

According to Mullineaux (1974), exotic tephras have a higher silica content which explains their presence on

Mount Rainier. This is because siliceous magma eruptions are more explosive and will spread farther from the source volcano. Therefore the more siliceous tephra would tend to reach a distant volcano, e.g., Mount Rainier. Mullineaux indicated that the tephra grains have been little affected by weathering except for the weathering rinds on older lapilli. We did observe that iron oxide deposits have altered the color of most layers and in some places formed iron concretion layers.

Twenty-two post-glacial tephra deposits have been identified. Of these only a few have been of sufficient volume and broad distribution to cause more than an incidental influence on the soil as typical of a discrete layer. From Mullineaux' data it can be seen that the most important among these have been the exotic tephtras which, due to the distance of their origin, have been deposited over most of the Park with some uniformity in thickness and grain size. These are the tephtras correlated with Mount Mazama, tephtra O, and with Mount St. Helens, tephtras W and Y. Most of the Mount Rainier tephtras have been small in volume with the exception of tephtra C which had both a large volume and wide distribution. It appears to be a widespread soil forming material.

Tephtra deposits of Mount Rainier origin are easily distinguished from exotic tephtras and other soil materials by a combination of characteristics. The most notable are

the distributional pattern and the grain size. Both the grain size and the thickness of the layer decrease with distance from the volcano and from the lobe axis. Unlike deposits of exotic tephra, most Rainier tephras contain lapilli wherever found in the Park. Mullineaux found that the Rainier tephras are usually more darkly colored and more altered by weathering than the exotics because they are higher in iron and magnesium and lower in silica. Colors range from brown to reddish brown or yellowish brown depending on the original color, the age, and the degree of weathering. Prevailing winds have resulted in each Rainier tephra being distributed within a lobe east of the volcano. The area of deposition is somewhat different for each of these tephras, reflecting the velocity and direction of the wind and the volumes of the ejected tephra.

The soil may not be entirely composed of tephra. Mullineaux found layers of dark lithic sand are found between tephra layers. The origin of these lithic sands is unknown, and they may be tephra or windblown mineral particles. We found that in places these lithic layers form a major component in the soil but usually they occur in thin bands suggesting that they are tephras.

Figure 1 is a table of characteristics which identify each of the tephras considered important soil parent materials in the Park (Mullineaux, 1974, p. 14).

| Tephra unit | Source volcano | Approximate age (yr) | Average range thickness (cm) | Principal distribution in Park | Common field recognition features |
|-------------|----------------|----------------------|------------------------------|--------------------------------|---|
| W | St.Hlms | 450 | 0-8 | Most of Park | White sand ash near surface |
| C | Rainier | 2200 | 0-30 | E. 2/3 | Brown ash, lapilli near surface |
| P | St. Hlms | 2500-3000 | 0-2 | Most of Park | White to light gray sand-size ash |
| | | | 0-2 | E | White to light gray undistinctive |
| | | | 0-1 | SE | Brown coarse ash |
| | | | 0-1 | | |
| Yn | St. Hlms | 3400 | 2-30 | Entire Park | Yellow brown, coarse ash |
| D | Rainier | 6000 | 0-15 | NE to SE of summit | Reddish-brown bombs and lapilli |
| L | Rainier | 6400 | 0-20 | E to SE of summit | Yellowish-brown pumice, uniform size |
| O | Mazama | 6600 | 2.7 | Entire Park | Reddish-yellow to pale yellow silt-size ash |

Fig. 1.--Source, age, and characteristics of major soil forming tephras

Each of these tephra layers will be described briefly in this section. The exotic tephras from Mount Mazama and Mount St. Helens have a wider distribution than the Rainier tephras and are less affected by weathering. With the exception of Mazama tephra 0, they are of more recent origin than all but one Rainier tephra and thus important in the upper horizons of the soil.

Tephra 0--Mount Mazama

This is the most widely distributed and easily recognized tephra throughout the Northwest. Mount Mazama (Crater Lake) was located about 500 km south of Mount Rainier. Because of this distance, the tephra deposit is composed of silt size ash and is distributed throughout the Park (Mullineaux, 1974, p. 28), although local variation occurs. The average thickness is 4 to 5 cm. Mullineaux lists the following properties as useful in field identification: the yellow orange color, the silty texture, and the stratigraphic position within the soil. The grains are pumice and crystal fragments. Neither fragment type has been strongly weathered, although coatings of iron oxide have altered the color.

From our study the 0 layer appears to be an important soil constituent throughout the Park. It is found as a stable, intact layer in the lower parts of the soil profile, 60-80 cm below the surface; in many sites it is frequently the only fine textured horizon. As such it

probably exerts considerable influence on the internal drainage not only of the immediate soil but soils downslope as well.

Tephra Y--Mount St. Helens

This tephra set consists of several individual layers. One of these layers, tephra Yn, is the most voluminous and widely distributed tephra in the Park. Mullineaux identified the other layers in a few locations where disturbance was minimal, but we did not identify them as discrete layers within the forest regions. Where he found them they were usually less than 1 cm in thickness and mixed with other tephtras. The descriptions of tephra Y will be of tephra Yn.

Mount St. Helens is located 85 km south southwest of Mount Rainier. From this distance there is considerable lobe effect in the distribution of the tephra throughout the Park noticeable in differences in grain size and deposition depth. Since the axis of the main lobe is west of the Park boundary, tephra thickness and grain size decrease to the east and north. Tephra Y is the most voluminous tephra in the Park and has been found in every area of the Park as shown in Fig. 2 (Mullineaux, 1974, p. 38).

Identification of tephra Y in the field is usually easy. Mullineaux describes it as a coarse sand size, pumice ash with colors ranging from yellow to brown depending on site conditions. Because of its texture, it has

been subjected to colluvial and alluvial reworking resulting in a wide range of layer thicknesses.

Tephra Y is the most important single soil forming parent material throughout the Park. It is the only tephra other than tephra O in the northwest corner of the Park and accounts for much of the soil material in that area. We found tephra Y as the dominant soil layer in much of the western half of the Park where it occurred as a coarse horizon 10 to 30 cm thick 20 to 50 cm beneath the soil surface. In this position it has a major influence on the moisture retention of the soil, which affects both vegetation growth and soil development. In some sites it forms a dry, loose, practically unstained layer, whereas in others it is cemented into an impervious iron pan.

Tephra W--Mount St. Helens

This is the most recently deposited tephra forming a distinct layer in the Park. Although its distribution within the Park is more limited and its volume less than that of tephra Y, it was found to be important as a soil layer throughout the south and east areas of the Park. Much of its importance appeared to be derived from its position as the top soil mineral layer throughout its area of distribution.

The layer forms a lobe across the southeastern corner of the Park resulting in a steady decrease in average depositional depth both to the north and west. This

distributional pattern is shown in Fig. 3 (Mullineaux, 1974, p. 36). Because of the grain size which Mullineaux found to be 0.3-0.5 mm in diameter, the layer has been re-worked to such an extent that we found deposits 8 to 15 cm or even up to 30 cm common throughout the eastern forest areas. We found tephra W on all but the most unstable sites throughout its distribution range.

As a soil parent material, tephra W, a light gray, medium to coarse sand, is found just beneath the duff layer though in some sites a layer 1 cm in thickness of fine, dark gray sand of post-W origin may be over it. As a soil material tephra W is loose and has little moisture retention capacity. In some sites it is essentially unaltered, whereas in others the lower portions of the layer are stained various values of brown. In stable areas we found that it overlies one or more distinctive tephra beds; however, on many slopes it overlies mixed materials of colluvial origin. As such it can be used as an indicator of only recent slope stability. It also has been used as an indicator of alluvial and mudflow depositional history.

From the results of this survey the importance of tephra W as a soil material appears to vary with the thickness of the layer and the type of underlying material. It is a rapidly drained horizon and where it occurs in deposits 20 cm or more, it appears to present a drought barrier to root growth for many herbs and shrubs. Often

St. Helens Tephra Yn
average thickness cm

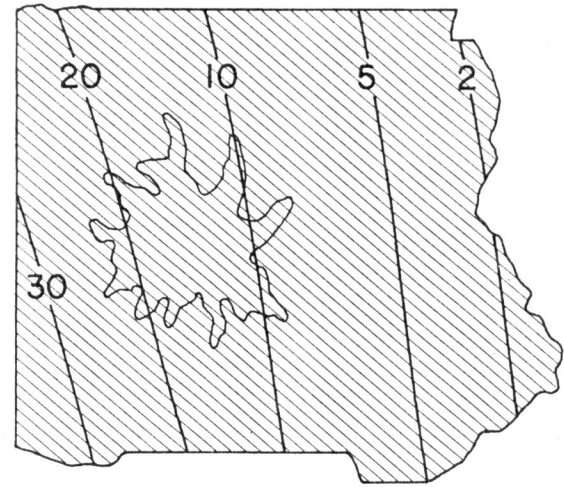


Fig. 2.--Tephra Yn

St. Helens Tephra W
average thickness cm

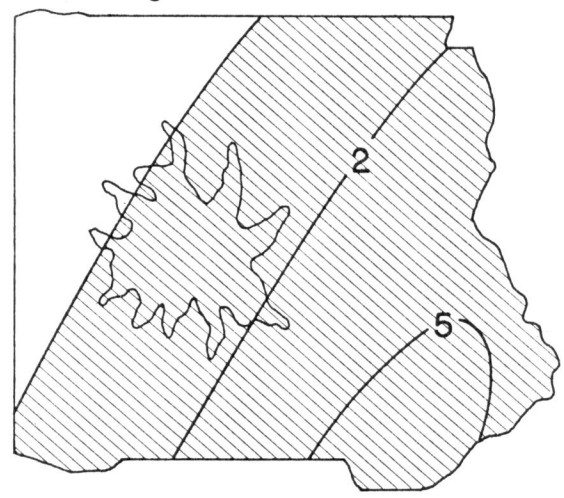


Fig. 3.--Tephra W

in sites where it is found over a loamy layer a thin iron depositional zone occurs suggesting lateral moisture drainage. Tephra W often occurs over a sandy colluvial layer forming a rapidly drained, early drying soil with essentially no indications of soil development.

Tephra P--Mount St. Helens

Mullineaux (1974) found that tephra P is a tephra set composed of four thin discrete units: two light gray, sand layers over a white, silt layer, with a brown sand layer at the base. The distribution of the two upper layers is similar to that of tephra W, but that of the lower layers is restricted to the eastern parts of the Park. All of these layers are less than 1 cm in thickness and are composed primarily of lithic particles. Forest soils such as those examined in this survey are commonly subjected to some mixing action from tree and shrub rooting and rodent activity. A layer as thin as tephra P could easily be obscured through this mixing action. Occasionally we found a fine sandy layer was present in the correct stratigraphic position, but more commonly a brown loamy sand with gray, fine sandy inclusions making up 50 percent of the layer was found. Both of these layers were thought to be tephra P at least in part.

The influence of this tephra on the soil is indeterminate since it is difficult to identify as a discrete layer.

Tephra C--Mount Rainier

This is the most recent, largest, and most widespread of the post-glacial Rainier tephras. We found it as a discrete layer throughout the forest areas east of the summit from the north to the south Park boundaries. The distributional pattern is shown in Fig. 4 (Mullineaux, 1974, p. 46). Within a narrow lobe east of the crater and farther along the axis of the lobe, the tephra forms a thick layer of coarse ash, lapilli, and bomb fragments. Without reworking, according to Mullineaux, the layer in these areas would be 15 to 30 cm in thickness but very few sites have escaped some disturbance. We found local deposits that ranged from a few centimeters to half a meter. The texture of the tephra became increasingly finer with distance from the volcano, and in the southeast extremes of the Park we found it as a loamy, fine sand with a few scattered lapilli.

The layer is easily recognized in the field because of its position immediately beneath tephra W in the soil profile. It is brown color and contains unweathered lapilli. On many lower slopes and toeslopes that we examined this layer was thickened by colluvial movement. These materials included nontephra gravels and other older tephras. However, the mixed layer was dominated by the characteristics associated with tephra C.

In the eastern half of the Park tephra C appears to have more overall importance as a soil parent material than

either tephras W or Y. Because it is a local tephra, it varies considerably in texture and thickness. We found that in most areas of its distribution range tephra C is a brown, loamy or gravelly sand, depending on the amount of lapilli present, from 10 to 20 cm thick underlying a coarser tephra W which is up to 15 cm thick. Beneath tephra C is a layer of fine sand 6 to 10 cm thick, which may be tephra P or a lithic band. In this position tephra C is a B2 horizon having undergone some color alteration and slight structural development. Often a thin portion directly beneath tephra W has been darkly stained and slightly cemented by iron deposits resulting from lateral water flow.

Tephras D and L--Mount Rainier

These are the other major post-glacial tephras, although neither compares to tephra C in volume or area of distribution. According to Mullineaux (1974), these tephras have similar yellow to brown color but differ in the types of fragments present. Tephra D is primarily pumice and scoria lapilli throughout its range in the Park, and tephra L is composed of highly vesicular pumice of all sizes. The lapilli of tephra D have been noticeably weathered.

The distribution of these tephras can be seen in Figs. 5 and 6 (Mullineaux, 1974, p. 46, 43). We made a single field identification of each of these tephras. Tephra D was tentatively identified near the upper Chinook Creek and tephra L, tentatively, near the Ohanapecosh

Rainier Tephra C
average thickness cm

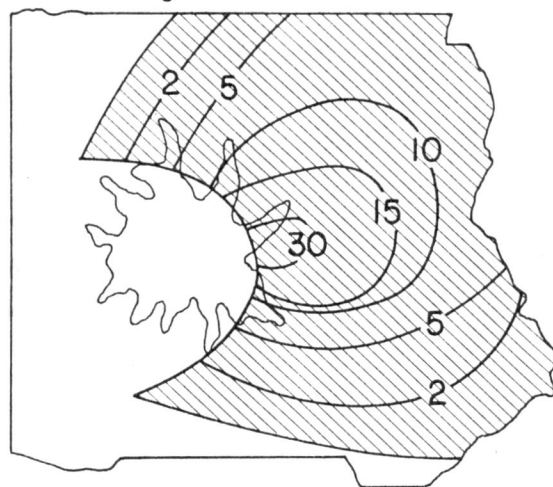


Fig. 4.--Tephra C

Rainier Tephra D
average thickness cm

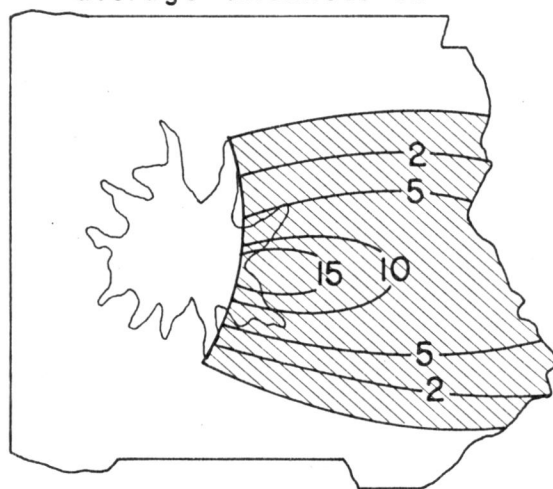


Fig. 5.--Tephra D

Rainier Tephra L
average thickness cm

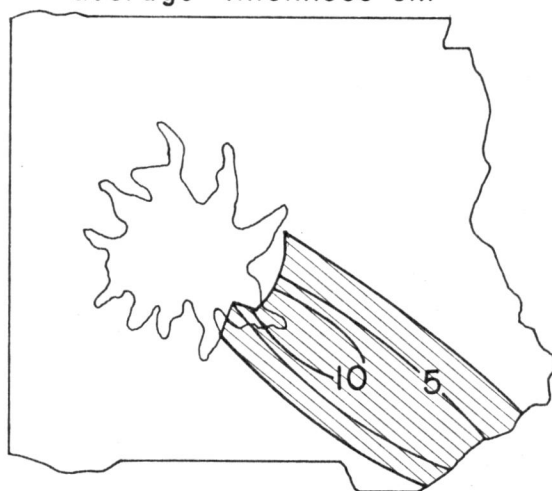


Fig. 6.--Tephra L

campground. These were both thin layers 2 to 3 cm thick and were deeply buried in the soil profile. In most forest areas these tephras appear to be major components of the colluvially mixed layers that often occur beneath tephra C.

Tephras X, B, H, F, S, N, A,
and R--Mount Rainier

These are, for the most part, minor tephras limited in extent and in volume. Tephra F, which is the only Rainier tephra dominated by clay particles, has an extended distribution to the northeast. It is thought by this observer to be important as a fine component of colluvium throughout its range of distribution and as a deep soil layer along the axis of its lobe.

Tephras, H, B, N, S, and X have been found as small deposits near the volcano but probably do not extend into the forest. Mullineaux dates tephra X to have been deposited in the early 19th century. Tephras R and A both have a wide distribution (Mullineaux, 1974, p. 59, 61) and are probably incorporated in the forested soils. The deposition of tephra A was probably too light to have any influence on the soil. Tephra R was of the same approximate volume as tephra F (Mullineaux, 1974, p. 17) and may be a functioning part of the soil as a deep layer or a colluvial soil component. We identified none of these tephras in the field, and little is known of their influence in the soil.

Lahars

Although representing only a small areas of the Park, perhaps the most important soil parent material from a management point of view is the lahar. Lahars are found in areas of the Park often most accessible for development of roads, trails, campgrounds, and picnic areas. These are also areas of special interest in vegetation and soil studies because they are often of datable origin and support a primary growth cycle.

Lahars result from a rapid flowage of water activated rocks and finer particles containing less than 20 percent water and are associated with volcanos. Dwight Crandell (1971) has grouped lahars into two main categories: debris flows in which 50 percent or more of the materials are larger than sand, and mudflows which include most of the post-glacial Rainier lahars. A lahar results in a mixed deposit of rock up to 10 feet in diameter, sand, and finer particles, and is often difficult to distinguish from till, fluvial deposits, colluvium, or landslide materials. The main distinguishing feature of the lahar is a tendency toward vertical gradation in which the average particle size increases with depth.

Another feature Crandell notes of the lahar is its depositional pattern. Once set into motion the debris flows as a loosely organized mass, often filling valleys to depths of several hundred to a thousand feet. As the mass flows, a

thin layer is deposited along the valley walls and floor until the valley becomes wider and less steep. As this happens the rate of flow decreases slowly, resulting in a shallower flowing mass and deeper debris deposition on valley floors and terraces. The depth of deposition and the extent of area involved are determined by the velocity and volume of the mudflow and the form of the valley. The flow is usually laminar, essentially like a rug unrolling, and has little erosional capability. In many instances, mudflow material may be observed lying on a thin and apparently undisturbed ash layer (Crandell, 1971, p. 24).

Lahars may result as a direct or indirect consequence of volcanic activity or as an unrelated incident. An eruption may create rock avalanches which dam a river. The river can, in turn, erode the debris and sweep it downslope as a lahar. This process may also occur independent of an eruption. Another mechanism involves the saturation of loose rock debris on steep slopes by rain and melting snow. Glacial impoundment of water and sudden release either because of atmospheric conditions or volcanic heat can also cause a lahar. Most of the post-glacial lahars associated with Mount Rainier have resulted from independent mechanisms, although one of the tephra layers has been associated with the largest of the lahars, the Osceola mudflow, which is dated at approximately the same time as Rainier tephra F (Crandell, 1971, p. 33).

The importance of lahars both as a soil material and as a management problem varies from valley to valley. Each of the major Rainier glacier valleys has been the site of post-glacial mudflows but both the size and frequency of the lahars differ greatly. The effects of lahars on the soils of each of these drainages will be examined briefly.

White River Drainage

This drainage was the site of the Osceola mudflow, the largest post-glacial Rainier mudflow and one of the largest in the world. Crandell (1971) has dated the Osceola mudflow by the use of carbon 14 and stratigraphic position to approximately 5700 years BP (before present). It swept down both the White River and the West Fork of the White River, leaving deposits which underlie the present river beds and terraces, and formed veneers on lower valley walls up to 150 m above the original river beds. These valley bottom deposits have been found through drilling to exceed 60 m in thickness near the north Park boundary. The flow then followed the White River valley to its junction with the Puyallup River just east of the city of Puyallup, leaving deposits as much as 22 m thick in the broad lowland valleys.

The Osceola is the extreme example of a mudflow in terms of mass and range of distribution. Although it is important in King County as a distinctive parent material, it has been removed or buried by more recent glaciation and

outwash, or by more recent deposits of mudflow, tephra, fluvial deposits, or colluvial materials originating within the Park. It has had tremendous influence on the landscape by filling and broadening the valley floor and building up terraces above the river flood plain.

Of more importance in a current soil study is a series of at least four interbedded lahars and as many fluvial deposits designated collectively by Crandell as the post-Osceola lahar assemblage. This assemblage buried the Osceola deposits on the floodplain and formed a series of terraces 3 to 15 m above the floodplain above the mouth of Fryingpan Creek, and one terrace several feet above the floodplain as far north as the Park boundary. All of these terrace deposits are overlaid with tephra W but not tephra C, indicating an age between the two. The assemblage deposits form most of the soil materials in these sites, and exposed boulders several feet in diameter litter much of the surface. Deposits have been found on terraces 25 m above the floodplain, but these have been buried by more recent colluvial deposits. One post-Osceola lahar has been found in the West Fork valley. It overlies tephra Y material but is older than tephra C and it is exposed in only a few sites.

The Greenwater Lahar, which is pre-Osceola but post-tephra O, should be mentioned not because of its importance as a soil material but because of landforms associated with

it. These are exposed mounds along the Fryingpan Creek composed of large rocks mixed with sand and smaller rocks. The mounds have dimensions ranging from 1 to 11 m in height and 3 to 60 m in diameter. Except for the material exposed in these mounds this lahar has been buried by the Osceola and subsequent deposits,

Nisqually River Drainage

The major lahar of this drainage was the Paradise lahar which Crandell has placed in the same approximate date range as the Greenwater lahar, between tephras D and O. This lahar flowed through Paradise valley, reaching a maximum height of 180 m above the valley floor and then continued through the Nisqually valley, possibly as far as the Park entrance gate. Deposits have been found up to 30 m high on slopes of the Kautz Creek valley. Although not of the magnitude of the Osceola mudflow, it still forms much of the shallow subsurface soil material on higher valley walls where it has not been buried by colluvial deposits. The deposits form a rather shallow layer even where found in road cuts along the valley floor and river cut exposures, averaging only 0.3 to 1.5 m in thickness but occasionally reaching 4 m. Most areas in which this lahar material was near enough to the surface to be of importance in the soil were not included in this study.

Crandell has identified a number of lahars of widely varying size and distribution which have occurred

throughout this drainage. These have been designated by relative age: assemblage A which predates tephra O, assemblage B which includes the Paradise mudflow and predates tephra Y, assemblage C occurring between tephras W and Y, and a post-W group, assemblage D. These assemblages include layers of lahar and fluvial deposits often many feet thick and have been found on both river terraces and the floodplain. Although each contributes to the general floodplain and terrace landform, only assemblages C and D and the smaller Paradise mudflow form surface materials.

Assemblage C consists of mixed and layered fluvial and lahar deposits which form a series of terraces 6 to 25 m above the present Nisqually floodplain in the upper valley and cap similar terraces as far downstream as Longmire. In many of these areas it remains the subsurface materials beneath tephra W. This is probably the material covering the terrace where Cougar Rock campground is located. On lower terraces adjacent to the present floodplain, assemblage C has been buried by assemblage D, which forms the surface soil. These areas covered by assemblage D include the Longmire Park headquarters area, where the oldest tree dates to the 1860's, and the Longmire campground, in which the oldest tree is approximately 400 years old. Crandell found that smaller lahars have occurred in the upper part of the valley in the past few decades, in October of the years 1932, 1934, 1947, and 1955.

Kautz Creek Drainage

Kautz Creek is a small drainage entering the Nisqually a few miles east of the southwest Park entrance gate. Although not one of the major drainages from the mountain, it was the site of a major mudflow in October, 1947 (Crandell, 1971, p. 46), and has had a series of both post-Y and post-W lahars which in places show 23 m of exposure in creek bank cuts. The 1947 lahar deposited material over much of the terrace area adjacent to the floodplain, burying trees with up to 5 m of sediment before coming to a halt at the creek intersection with the Nisqually River. Higher terraces along the creek are underlain by older mudflow material, though this material has been since buried by ash and other deposits.

Tahoma Creek, North and South Puyallup River Drainages

These three valleys which drain the west flanks of Mount Rainier have been the areas of greatest post-glacial lahar activity. At least nine lahars have occurred in one or all of these drainages since the deposition of tephra Y approximately 3600 years BP. Three of these lie stratigraphically above tephra W, which is less than 450 years old.

The oldest of the post-Y lahars is known as the Round Pass mudflow which Crandell has dated at approximately 2800 years BP. It has been found in the Tahoma valley to

within 1 mile of its mouth at the Nisqually River, and evidently followed both branches of the Puyallup River to their junction west of the Park continuing down the Puyallup valley as much as 16 km beyond the Park boundary. The most interesting fact about this particular mudflow and the source of its name is its deposition on and above Round Pass more than 300 m above the Tahoma Creek. It forms the shallow subsoil to a depth of 2 m in much of these upper reaches, having been buried in some places by only a thin tephra W or thin colluvial deposit. It is also found up to 30 m above the South Puyallup River nearly 4 km downstream from Round Pass.

Two other mudflows have been correlated to deposits found in all three valleys. The first of these, known as the 1000-year-old mudflow, was relatively small and has been buried by subsequent lahars. The second, the Electron mudflow, was perhaps the major lahar of this area, since it appears to have been the most extensive in debris volume and area covered. It followed essentially the same route as the Round Pass mudflow, although with a much different pattern of flow and deposition of material. Its maximum height was probably 200 m below that of the Round Pass mudflow in the area of the pass itself, and continues this relative position for several miles. The Electron mudflow, however, was a more sustained flow and continued beyond the Cascade range into the Puyallup lowlands where it covered deposits of the

Osceola mudflow near the junction of the White and Puyallup Rivers. For the most part, its deposits have been buried, except for some of the higher terraces, by more recent lahars occurring in each of these valleys (Crandell, 1971).

Crandell found that the Tahoma Creek was the site of flood-induced lahars in 1967, 1968, and 1970, each of which affected the upper-forested areas of the valley, including the picnic area. Crandell estimated the most recent major lahar of this valley by tree ring count to have occurred at least 435 years ago but after the deposition of tephra W. Deposits of this lahar have been found 60 m above the creek in the upper valley and are several feet thick.

Crandell also found that both the South and North Puyallup Rivers have been the sites of post-W lahars, four on the South River and one of the North River. The lower terraces above these rivers are capped with lahar deposits up to 8 feet thick and littered with surface boulders several feet in diameter. Especially prominent is the deposit on the lower terrace. Forty feet above the South Puyallup the lahar forms the top and subsoil material. He dated the North River lahar by tree ring counts as approximately 400 years old. The dates of the most recent South River lahars have not been determined, but they are probably more recent. In this study these lahars were found to support a midsuccessional forest in which most of the seedlings and small trees are of the climax species, silver fir.

Mowich and Carbon River Drainages

These are perhaps the largest drainages in the Park but have been the sites of very limited lahar activity. Only one has been found in the Carbon River valley, and apparently it is of very limited distribution. It has been found in only one site, opposite Chenuis Falls about 3 miles east of the entrance station and is of pre-Y origin. Crandell found three lahars in the South Mowich valley, one pre-Y, one post-Y but pre-W, and one post-W. These are found on terraces 9 to 18 m above the present floodplain. The two post-Y deposits form the main surface materials, while the pre-Y deposits form subsurface soil material beneath tephra Y in areas where it has not been buried by more recent lahars.

Ohanapecosh River Drainage

Limited lahar activity has occurred in this river valley. Crandell found two lahars, one underlying tephra O and fluvial deposits, and the other underlying tephra Y. Neither has been traced to the lower reaches of the river, but it is probable (based on the results of this study) that the latter is located on the low terrace below the Ohanapecosh Ranger Station possibly as far as the Park boundary. This has not been documented, however.

CLASSIFICATION

Logic of Classification

The purpose of a system of classification is best expressed by John Stuart Mill in his treatise, A System of Logic, as follows:

Classification . . . is a contrivance for the best possible ordering of ideas of objects in our minds; for causing ideas to accompany or succeed one another in such a way as shall give us the greatest command over our knowledge already acquired and lead most directly to the acquisition of more. (Mill, 1874, p. 34)

Thus, the purpose of classification is to organize knowledge of the properties of a system in order to best utilize and extend this knowledge. A second important aspect of a classification system is the need for an objective towards which the grouping of properties is directed. Very seldom will one classification system serve more than one purpose equally well (Cline, 1967, p. 38).

In the same treatise, Mill lists five basic predictables or distinctions which must apply to a grouping. These are: "a genus, a species, a differentia, a proprium, an accidens" (Mill, 1874, p. 77). The first two of these refer to levels of identification and will be discussed later. The others refer to the three sets of differentiating characteristics implied in a grouping.

Differentia refers to the characteristics used to distinguish groups. These should be the properties making the most precise and important statements about a group for the objectives. Marlin Cline, in his paper "Basic Principles of Soil Classification" (1967) points out that properties of individuals generally represent a continuum of expression in which each group represents a segment of a continuous series. The definition of a group requires the determination of a modal individual exhibiting the value of property expression most common to the group. The variation allowable within a group is determined by the degree of similarity with this mean expression, for at some point along the continuum expression of the property becomes more similar to the mean of the adjacent group. Such a point defines the group boundary. A class can then be defined as an aggregation of individuals or groups selected for similar properties and distinguished from all other groups within the population by differences in expression of these properties.

A proprium is a secondary group of properties consequential to and inseparably associated with the differentia, the accessory characteristics. These are properties which may be an effect or an interpretation of a particular differentia. They are constantly associated with it and can be inferred once the differentia has been identified in an individual.

The last grouping, what Mill calls the accidents, refers to those properties which vary independently of the differential and are not necessarily present throughout the class. The grouping makes no definitive statement about the class since they are nonessential and are either sporadically present or not unique to the group. Although these are the accidental characteristics of a class, in a multileveled system they often can be used to define lower more homogeneous groups.

It can be seen now that a well constructed grouping can be defined not only by the primary differentiating characteristics, but also by the accessory characteristics associated with these.

The first two terms of Mill's predictables, genus and species, refer to levels within a classification system; genus designates the larger and more general class, species the more specific. Subdividing a class or genus into species allows many more relationships to be shown, because groupings can be made on the basis of more homogeneous differentia. In this way a series of abstract levels can be designed in which the highest level makes the fewest and most general statements about the individuals of the population, and each successive lower level makes more specific statements. In a multileveled system, classes at each successively lower category must include the differentiating and accessory characteristics defining all of the higher

groups of which it is a member, plus the characteristics forming the basis of this lower separation. Thus we have a tight, logical system in which each successively lower category includes the characteristics of that and each higher category, in which each individual is included in a group at all levels, and in which each successively higher category makes more important statements about the individuals being classified. Furthermore, a name used at any categorical level brings to mind a group of differentiating and accessory characteristics applicable to the individuals at that level of abstraction. If properly constructed, the system also provides a means of inferring knowledge about untested individuals by establishing both primary characteristics and all of the accompanying and related secondary characteristics.

Introduction to the Classification System

Purpose

Various systems of soil classification have been used as a basis for developing management units within the general geographic area that includes Mount Rainier National Park. Land bordering the Park which is under Forest Service management has been classified to meet the needs of their management systems and their budget limitations. Since the Forest Service objective is multi-use, their system of classification identifies soil properties

important to these goals (U.S. Forest Service, 1972). Weyerhaeuser Company has engaged in land classification activities in areas west and north of the Park. Their system is designed to identify soil properties important to timber operations (Steinbrenner and Gehrke, 1964).

The type of classification system needed for the management of a land unit is dictated by the management objectives. With an objective of management for timber a classification system should identify properties important to growth, harvest, reproduction, and access. Properties such as the stability of a slope under use by harvesting machinery, the mass failure potential under moisture conditions introduced by clearcutting, and the fertility of a soil as it relates to tree growth need to be identified. A different classification system would be needed for different objectives.

To design a classification system for the soils of Mount Rainier National Park, the management objectives of the system must first be identified. The objectives upon which this classification system is based are: (1) to protect the natural setting; (2) to provide limited recreational opportunities including trails, backcountry campgrounds, auto campgrounds, and picnic sites. A system of soil classification should be constructed in such a way as to facilitate management options in meeting these objectives.

Five soil forming factors are recognized in the study of soil: parent material, topography, climate, vegetation, and time. In the Park two of these, parent material and topography, dominate soil formation and together they provide a reasonable basis for grouping the soils. Landscapes generally are severely sloping which creates an environment for deposits of colluvial and fluvial origin. In addition, much of the mineral soil is of recent volcanic origin. Since the types of deposits at any particular location are related to stability of the landform, and the combinations of landforms and parent materials determine the degree of soil development, these factors seem to be the most logical source of differentia for classification. Although parent materials and landforms represent continuums throughout the Park with many transition zones, these differentiations can be made for the purposes of classification by interpreting their individual expression as it relates to stability under prescribed uses.

The presence of a parent material on a geomorphic surface gives the soil morphologic features. A reasonable interpretation of the processes responsible for these features can be made through examination of the soil profile. Soils which have been acted on by similar processes have similar identifiable features. Certain interpretations of soil features such as stability and drainage affect the ways in which a soil can be used. Through identification

of those soil features that have interpretational value for management, soil classes can be made. A three-level system has been designed to classify these soils. The differentiating characteristics that are used from highest to lowest category level are parent material, landform, and genetic development. Landform is used as a criterion because it represents the geomorphic origin of soil forming materials. Landform groups represent similar natural processes and should behave similarly under management.

The purpose of classification then is to identify classes of soils which have parent materials, landform features, and morphologic features that are similar and which behave similarly under use such as Park style recreation. This should enable management decisions to be based on predictable reactions of an individual site so that any type of use can be planned from a basis of prior knowledge. For these uses many additional factors including scenic quality, vegetation sensitivity, water availability, and the nature of the bedrock must be considered. However, soil is the primary limiting factor for these uses and should be the first consideration because it is directly related to construction, maintenance, and degradational consequences for a given use.

Implicit in this classification is the identification of areas of severe limitations to use. The major limitations are slope stability, drainage, erosion, and

soil compaction, along with certain accidental hazards such as rock fall, flooding, or mudflow. For moderate use limitation corrections are possible at some expense, and this classification system should indicate those areas that should be avoided wherever possible.

The Park Service should maintain records describing the use of individual soils and the behavior encountered. In this way the classification system can be tested and refined into a valuable management tool for long range predictions of behavior related managerial goals.

Parent Materials

Four basic parent materials have been identified: volcanic tephra, mudflow, colluvium, and alluvium. There has been much mixing of parent materials because of the nature of these types of depositions. Colluvial layers occur over and under identifiable tephra layers, tephra layers occur over alluvium and mudflows, and some tephra layers are mixed with colluvium. Moreover, there is no clear distinction between colluvial and alluvial deposits. Nonetheless, subjective separations can be made which will serve the management goals. A soil consisting of tephra over colluvium can be classified according to its expected behavior under management. The same decision can be made for other complexes of parent materials.

The presence of identifiable tephra layers is usually an indication of slope stability. However, many

soils are composed primarily of a thick undifferentiated colluvial mixture overlaid by tephra W. In these instances the tephra indicates temporary stability and the soil would be placed in a colluvial group based on prediction of its behavior under long-term management. It is stabilized temporarily by vegetation and removal of the vegetation would cause renewal of the erosional cycle. A soil in which tephra C was found overlying colluvium would be considered more stable and grouped accordingly as a tephra. These are the kinds of interpretations that are a primary function of this classification and will be the basis for establishing groups according to parent material.

Colluviums are materials which have been redeposited downslope by gravity. They are usually identifiable by the lack of layering and by the undifferentiated mixture of tephras and mineral debris from other sources. Soils formed in these materials are generally mixtures of sands, angular gravels and cobbles either of extrusive volcanics or granitics, and an assortment of lapilli weathered to various degrees. Colluviums seem to be primarily associated with two types of landforms, steep slopes which are subject to soil slippage, and depositional toeslopes. Management of both is similar and for the purposes of the classification system both are classified as colluvial slopes. Colluvial soils are the least stable although certain sites can be used without causing problems.

Alluvial materials are the dominant soil forming materials on floodplains and adjacent terraces that are called alluvial flats elsewhere. These kinds of materials are recognized by the presence of water rounded cobbles and gravels. Usually these soils are layered or undifferentiated gray sands showing very little development. They often have a thick organic horizon which supports luxuriant vegetative growth in these areas. There are slopes on which alluvial and colluvial soils form a continuum indistinguishable. For purposes of management these sites have the same restrictions for use; they are unstable areas.

Mudflow soils have been identified as a group not because of unique behavioral characteristics, but because they indicate areas of special hazards.

Landforms

The landforms used as the basis for the second categorical level represent broad, simple groups. Unbroken slopes form a group. Other groups are ridgetops, benches and terraces, and alluvial flats. There has been no attempt to subdivide these groups further due to the limited scope of this inventory. Landforms together with the differentia provided by the lowest category should provide an adequate number of groups as a trial classification system.

Genetic Development

The lowest category is properties related to degree of development of soil morphology as determined by field

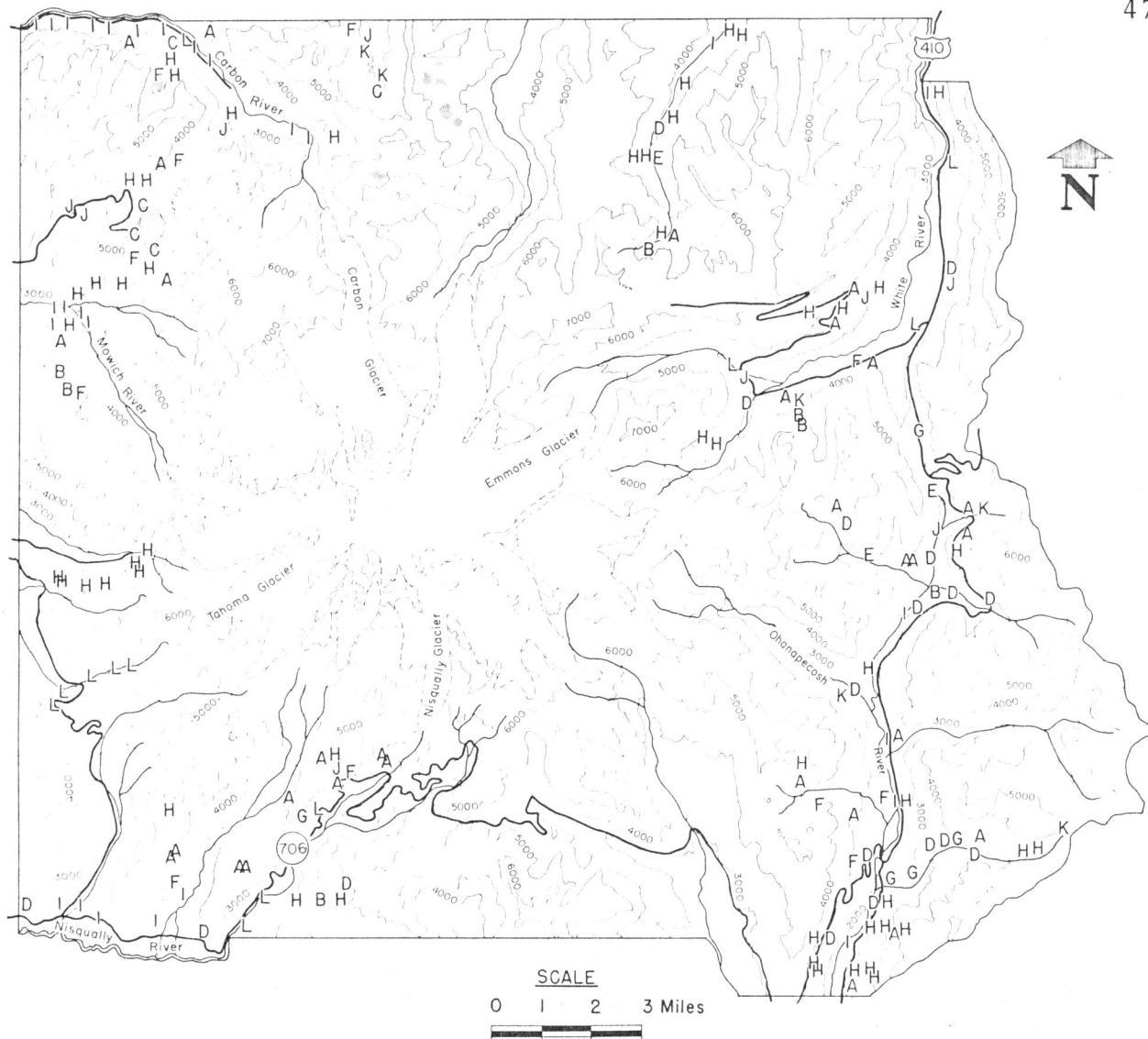
observation and recorded by standard description (National Co. of Soil Science) of the soil profile. Genetic development is a function of the soil forming factors. Vegetation may stabilize soil and contributes to production and cycling of organic matter. Some of the organic acids are important in facilitating the movement of iron oxides through the soil (Birkland, 1974, p. 105). Time is important even though all surface materials are young geologically. Different aged surfaces exist for each of the parent materials, and degrees of soil development are related in part to the age of deposition. This is especially important in determining relative stability of colluvial surfaces or use potential for alluvial areas. Results of these factors may be read in the development of soil horizons, whereas individual factors may affect the potential of the soil for use. The most important interpretations drawn from soil development are those of surface stability and internal drainage, both of which strongly influence management decisions.

Description of Classification Groups

An outline of these groups is shown in Fig. 7. Figure 8 shows the location and type of each soil examined during the study. Some general relationships of these soil landform groups are shown in Fig. 9.

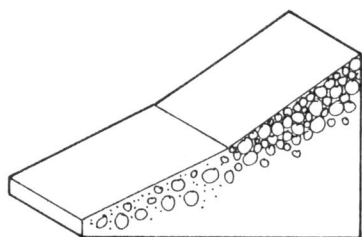
- 1 Tephra
 - .1 Slope
 - .01 Minimal development
 - .02 Weak iron pan
 - .03 Strong iron pan
 - .2 Bench
 - .01 Minimal development
 - .02 Weak iron pan
 - .03 Strong iron pan
 - .3 Ridgetop
- 2 Colluvium
- 3 Alluvium
 - .1 Flats
 - .2 Bench
 - .3 Slope

Fig. 7.--Outline of classification groups

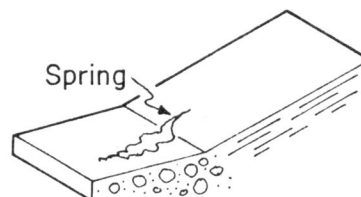


- A = Tephra, Slope, Minimal Development
- B = Tephra, Slope, Weak Iron Pan
- C = Tephra, Slope, Strong Iron Pan
- D = Tephra, Bench, Minimal Development
- E = Tephra, Bench, Weak Iron Pan
- F = Tephra, Bench, Strong Iron Pan
- G = Tephra, Ridge
- H = Colluvium
- I = Alluvium, Flat
- J = Alluvium, Bench
- K = Alluvium, Slope
- L = Mudflow

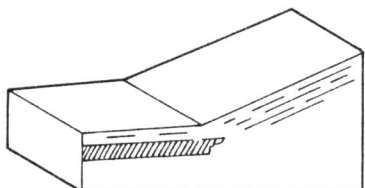
Fig. 8.--Identification of sampling plots



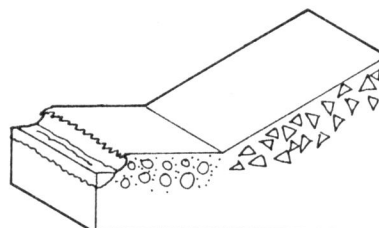
A. Talus to Alluvial Slope
(3.3)



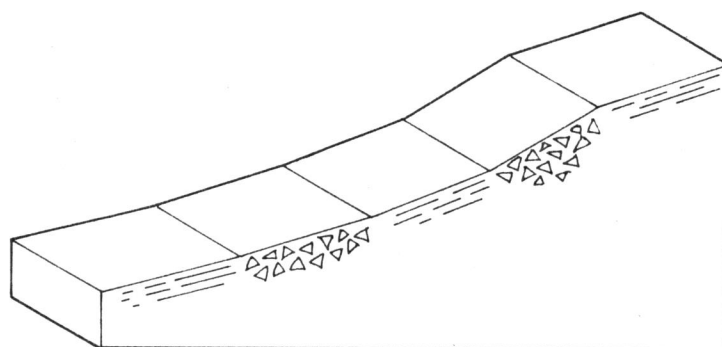
B. Tephra (1.11) to Alluvial
Bench (3.2)



C. Tephra (1.11) to Tephra
(Iron Pan) Bench (1.23)



D. Colluvial Slope (2.0) to
Alluvial Flat (3.1)



E. Tephra Bench (1.21) to Steep Colluvial (3.0)
to less Steep Tephra (1.11) to Colluvial
Toeslope (3.0) to Tephra Bench (1.21)

Fig. 9.--Representative soil-landform sequences

Group 1: Tephra Soils

Class .1: Unbroken Slopes

This group consists of ash soils which form a continuum with soils developed in colluvial materials. Both tephra and colluvium materials are generally present, and they both have been placed in this group because a well defined layer of tephra occurs above the colluvium. In some cases the layers of tephra have been reworked but the individual layers can be differentiated by texture, color differences, and presence or absence of lapilli. If present, gravels and cobbles are no more than 1 to 2 percent by volume.

Many possible combinations of layers exist in these soils because of the nature of tephra distribution, the presence of lithic layers between tephra layers, and the activity of various mixing processes on the soils. The amount of layering and the grade of texture influence water movement and retention characteristics of the soil and thus the genetic development. It is possible to find layers of different degrees of structural development separated by massive or single grained layers, or layers with an iron stained coloration over or under unaltered layers. For these reasons the continuum in terms of genetic development in these soils is extremely complex. Separation has been attempted on the basis of major horizon features of the profile taken as a whole and the implications for the behavior of the soil.

Stability of the soil under management depends on the slope, the rooting density through the soil, the amount of moisture the soil will retain or transmit, the consistence of individual layers, the internal drainage as affected by induration or compaction within the horizons, and the aspect as it affects the moisture regime.

The only managerial use for these soils is trails. On the basis of degree of development of genetic horizons this group has been divided into three subgroups.

Subclass .01: Minimal development. These soils are found on slopes that range from 40 to over 70 percent, and with elevations that range from 3000 to 5000 feet on nearly all aspects. In general these soils occur within a broad belt of climax Abies amabilis, silver fir, and Tsuga heterophylla, western hemlock. Other tree species such as Abies procera, noble fir, Pseudotsuga menziesii, Douglas-fir, and Chamaecyparis nootkatensis, Alaska cedar, occur but seem to be site specific accidentals.

These soils are well drained and are formed in layers of sands and loamy sands, often over cobbly colluvium. Most layers are apparently structureless, but some are massive and break into very friable, weak, subangular blocks. Certain tephra layers, e.g., W and Y, are usually loose and single grained. Geographically, sites where tephra Y forms a thick, loose layer are in the western third of the Park. The areas where tephra C has these traits are in the upper

forested regions of the drainages originating in the north-east section of the Park. Tephra W is found in thick deposits occasionally in the southeast extremes.

Because of variations in layering, trails in these soils must be designed for specific sites. However, the following generalizations can be made: (1) thick incoherent layers are likely to occur on slopes over 60 percent, so these slopes should be examined with caution; (2) dense shrub cover is a good indicator of high rooting density which will increase slope stability; (3) north aspects should be more stable than southern aspects because higher levels of moisture retention during the summer intensifies shrub growth and soil structure. Soils in the areas mentioned above with respect to loose sandy layers, especially those in areas of tephras Y and C, have the potential for slumping. Some method of slope fortification should be used in these instances.

Principal problems expected on these sites are those caused by soil slumping along the trail sides. By avoiding the potential problem areas and avoiding the steeper slopes, these soils should be no particular problem in trail building or maintenance.

The following is a representative profile of this group.

| | | |
|--------|----------|---|
| 01 | 6-4 cm | Litter |
| 02 | 6-0 cm | Duff; abundant medium and fine roots; smooth, abrupt boundary to |
| A21 | 0-3 cm | Dark gray (moist) fine sand (post-W tephra); loose; fine and medium roots abundant; smooth, abrupt boundary to |
| IIA22 | 3-9 cm | Mixed brown and gray (dry) coarse sand (tephra W); loose grained; fine and medium roots common; occasional sub-angular cobbles; wavy, clear boundary to |
| IIIBir | 9-25 cm | Brown (moist) loamy sand (tephra C) with fine distinct areas of dark gray fine sand; massive breaking to loose weak, moderate subangular blocks, very friable; few roots; 5 percent lapilli, occasional subangular cobble; smooth clear boundary to |
| IVC1 | 25-32 cm | Dark gray sand (moist) with common fine distinct brown mottles; massive breaking to loose and very weak sub-angular block, very friable; few roots; 10 percent lapilli; smooth abrupt boundary to |
| IVC2 | 32-68 cm | Mixed brown, dark gray, and yellowish brown very coarse sand (tephra Y); loose; very few roots to none; occasional cobble |

Subclass .02: Weak iron pan. Soils of this group were found on slopes ranging from 40 to 70 percent at elevations above 4000 feet on upper and mid slopes or at lower elevations on lower slopes of cold drainage basins. On these positions the soils are subject to late snow cover and remain saturated much of the year. The aspects are generally northerly, but exceptions are found in sheltered positions and at higher elevations. The usual vegetation on these soils includes silver fir, both western and mountain hemlock, and Alaska cedar, a tree which indicates cold wet sites. The understory is usually dominated by huckleberry, Vaccinium

menbranaceae. Herbaceous cover varies from 2 to 20 percent. These soils were found in all sections of the Park although they are not a well represented soil. They represent a colder wetter environment than soils of subclass .01.

This soil is poorly drained as indicated by the presence of iron concretions. Lateral downslope flow is a property of these soils caused by textural stratification, slope, and position on the slope. The layer with iron is a result of textural change and its effect on vertical and lateral moisture movement percolation. The soil is average in perviousness for this tephra group. Water moves through this soil in large enough quantity to maintain moisture adequate for growth throughout the summer. In the soils that were examined no horizons were saturated after the snow melted and the shrubs and herbs had leafed out.

This group includes less variation than group .01, probably because the soils have smaller distribution and have more easily defined properties. Behavioral expectations under trail use are less complex. The major limitation of these soils is moisture; otherwise they are stable as a group even on severe slopes. Lateral drainage could cause saturation and slumping along trail cuts and, when combined with snow melt, could cause severe gullying in steep areas. The trails will probably be muddy for a time after snow melt, and use in this state would increase compaction and runoff. Potential for slumping will increase

with slope, and gullies will increase both with trail gradient and early use.

The following is a representative profile of this group.

| | | |
|--------|----------|---|
| 01 | 7-5 cm | Litter |
| 02 | 5-0 cm | Duff; roots abundant, all classes |
| A2 | 08- cm | Gray (dry) coarse sand (tephra W); loose grain; roots common especially at the 02/A2 boundary; smooth abrupt boundary to |
| IIB2ir | 8-11 cm | Dark reddish brown (moist) sandy loam with 50 percent lapilli (tephra C); weakly cemented; few roots; smooth abrupt to |
| IIB3 | 11-25 cm | Yellowish brown (moist) loamy sand with 50 percent lapilli and bombs (tephra C); massive breaks to loose, friable; roots common; smooth abrupt boundary to |
| IIIC1 | 25-44 cm | Dark yellowish brown (moist) loamy, fine sand with common gray mottles; massive breaks to loose and weak sub-angular block, friable; few roots, smooth abrupt boundary to |
| IVC2 | 44-54 cm | Yellowish brown coarse sand (tephra Y); loose; very few roots. |

Subclass .03: Strong iron pan. This is a small but distinct group of soils found only at elevations above 4300 feet in the northwestern section of the Park. Slopes ranging from 40 to 60 percent were sampled on both southern and northern aspects. These sites are the wettest and coldest extremes for the slope group, and they are found in areas of both heavy precipitation and late snow melt. The vegetation represents the coldest, wettest sites in the forest. Trees include silver fir, mountain hemlock, and Alaska cedar, and the understory included alpine

rhododendron and the huckleberry species Vaccinium membranaceum. The herb cover on the sampled sites is moderate to high, 10 to 60 percent.

These soils are primarily composed of tephra Y, a coarse to very coarse sand, overlying or underlying loam or fine sand. The soils are poorly drained internally due to the induration and layering. Their tendency to remain saturated for much of the year causes lateral flow down-slope.

These slopes are stable and, when used for trails, slumping or sliding should be a minor problem. However, poor drainage makes this an undesirable soil for trail use. These areas open up late and are subject to lateral flow which without drainage controls could cause severe erosion when the trail becomes a stream. Where the trail turns sharply or grades away from the hillside the possibility exists for downslope gully formation. Exceptions may be found in areas where the indurated layer is thick enough to form the trail bed, and the trail gradient is gentle enough to inhibit runoff.

The following is a representative profile of this group.

| | | | |
|----|-------|----|--|
| 01 | 17-15 | cm | Litter |
| 02 | 15-0 | cm | Duff; abundant roots of all sizes |
| A2 | 0-8 | cm | Dark grayish brown (moist) loamy coarse sand (tephra Y); loose; roots common, abundant at 02/A2 boundary; smooth clear boundary to |

| | | |
|---------|----------|--|
| B1 | 8-11 cm | Brown (moist), loamy coarse sand; loose ; roots common; wavy clear boundary to |
| B21 | 11-18 cm | Dark reddish brown (moist) coarse sand; loose grain; roots common; wavy clear boundary to |
| IIB22ir | 18-49 cm | Very dusky red (wet) sandy loam; massive, firm to hard; partially indurated; very few roots; overlies boulder. |

Class .2: Benches and Terraces

Benches and terraces are often positions of colluvial and alluvial deposition from reworked tephra. These soils are made up of both colluvial and eolian deposits of tephra covered by or interlaid with gravelly undifferentiated deposits which give them unique behavior and genetic characteristics.

As in Class 1, the variations in parent material caused by layering and mixing are too large to use as the basis for separation of subclasses in this group. Therefore, subclasses have been established on definitive genetic differences. These soils, by the nature of the landform, have the potential to support several uses. The genetic separations are based on differences which are identifiable and significant for these uses which include trails, campsites, and picnic areas.

Subclass .01: Minimal development. These soils were found on benches and terraces with slopes varying from 2 to 35 percent. They were found at all elevations but predominant from 2500 to 4000 feet. Aspects vary but generally

do not include the northern slopes. Most of the sites on which they were found were in the southeastern section of the Park, and none were in the northwest section. The vegetation usually includes silver fir and western hemlock with an understory of mixed huckleberries, V. membranaceum, V. alaskaense, V. parvifolium, and V. ovalifolium, and various herbs. In a few sites at high elevations or in cold drainages, Alaska cedar and mountain hemlock were found but these were exceptions.

These soils are similar to those described for slope subclass 1. They are well drained with no layers impairing drainage. There is little structural development and little iron coloration. These soils are usually coarse textured sands and loamy sands containing high percentages of lapilli and often have a gravelly subsurface. Generally the soil has moderate coherence throughout the profile because of the moderate compaction of the tephra layers and the density of the roots.

The uses these soils are capable of supporting are determined by slope steepness and vegetation sensitivity. There are no restrictions to trail building but the time of snow melt should be considered before construction. Those benches near the bottom of cold drainages open late in the summer, whereas those found on upper slope positions may provide several months of use. The more level of these sites should be ideal for picnic and camping sites, since

the soils are well drained, not stoney, and not subject to hazardous problems. The limiting factor in their use is the sensitivity of the vegetation to trampling and the subsequent accelerated erosion on sloping sites. Sites of dense shrub cover should withstand more use and be more resistant to erosional problems than those with a sparse shrub cover but dense herbaceous cover. Vegetation sensitivity generally increases as the growing season shortens and becomes a limiting factor at high elevations or in cold drainages. Intensive use may cause soil compaction around trees and tree roots. This problem can be minimized by proper design of facilities.

The following is a representative profile of this group.

| | | |
|-------|----------|---|
| 01 | 3-2 cm | Litter |
| 02 | 2-0 cm | Duff; abundant roots |
| A2 | 0-1 cm | Dark gray (moist) fine sand (post-W tephra); loose; abundant roots; intermittent abrupt boundary to |
| IIA2 | 1-7 cm | Gray (dry) coarse sand (tephra W); single grain; roots common; smooth abrupt boundary to |
| IIIB2 | 7-9 cm | Dark yellowish brown (moist) fine sand; massive breaks to loose; roots common; occasional fine gravel; smooth abrupt boundary to |
| IVB22 | 9-18 cm | Strong brown (moist coarse sand with 20 percent lapilli and bombs; massive breaks to loose, very friable; very few roots; smooth abrupt boundary to |
| VC1 | 18-33 cm | Dark gray and gray (moist) fine sandy loam; massive breaks to structureless, friable; very few roots; smooth abrupt boundary to |
| V1C2 | 33-43 cm | Yellow coarse sand (tephra Y); massive breaks to single grain, very friable; very few roots; smooth abrupt boundary to |

VIC3 43-73 cm Mixed dark brown, dark yellowish brown, and reddish yellow (moist) silt loam; few small lapilli; massive breaks to structureless; very few roots.

Subclass .02: Weak iron pan. This soil represents average drainage conditions between the minimally developed and the strong iron pan subclasses, but in this study was too poorly represented to generalize. The two identified sites of this group which were sampled were in low benches in cold drainages where snow cover is heavy and of long duration. The elevations were both near 3800 feet and slopes were both 17 percent. No other generalizations are possible. Management would be the same as for wet extremes of subclass .01 since drainage is somewhat impeded and the sites are snow covered late into the summer.

Following is a representative profile of this group.

- 01 4-3 cm Litter
- 02 3-0 cm Duff; roots abundant
- A2 0-3 cm Gray coarse sand (tephra W); single grain; roots common; irregular boundary to
- IIB21ir 3-6 cm Dark reddish brown (moist) loamy sand (tephra C) with small iron concretions; massive breaks to structureless, firm to very firm; very few roots; irregular clear boundary to
- IIB22 6-19 cm Dark yellowish brown (moist) loamy coarse sand (tephra C) with 10 percent lapilli; weak medium to coarse subangular block, very friable; roots few, wavy clear boundary to
- IIIB3 19-36 cm Yellowish brown (moist) fine sandy loam with distinct common mottles, dark brown; moderate coarse subangular

IVC 36-53 cm block, friable; 5 percent lapilli and 5 percent angular gravels; very few roots; wavy abrupt boundary to Pale brown (moist) very coarse sand (tephra Y); single grain; very few roots

Subclass .03: Strong iron pan. These soils are similar to the strong iron pan subclass on slopes but represent a more extreme degree of this development. They too are usually found in the northwest area of the Park. These soils are found on benches with slopes up to 35 percent and on flat terraces. Both elevation and aspect vary but most are between 3500 and 5000 feet. Vegetation on these soils varies somewhat with elevation. Above 3000 feet Alaska cedar is present, as are silver fir, western hemlock, and mountain hemlock. Huckleberries occupy the shrub layer, often with white rhododendron at higher elevations. The herb coverage was usually 20 to 40 percent.

The most distinctive feature of these soils is their poor drainage. They occupy sites most likely to have an extremely late snow cover and remain saturated most of the year. The iron pan is both the result and cause of lateral drainage through the soil. Accurate descriptions of these soils were difficult because lateral flow filled the soil pits.

Poor drainage poses a severe limitation on use, regardless of slope. Trail use will probably result in soil slumping from the trail cuts and subsequent trail erosion

on the steeper sites. On the more level sites the wet conditions of the soil will probably encourage hikers to make new trails thus damaging the vegetation and reducing the scenic quality of the area. Where these soils must be crossed these problems should be compensated for through construction of walkways. No consideration should be given to alternate uses such as camping or picnicking on these sites.

Following is a representative profile of this group.

| | | |
|------|----------|---|
| 01 | 6-4 cm | Litter |
| 02 | 4-0 cm | Duff; saturated; abundant roots |
| A2 | 0-7 cm | Gray (wet) very coarse sand (tephra Y); loose; roots abundant, more so at 02/A2 boundary; smooth clear boundary to |
| B1 | 7-18 cm | Mixed light brownish gray and dark yellow brown (wet) very coarse sand; loose grain; roots common; smooth gradual boundary to |
| B2ir | 18-36 cm | Dark brown (wet) very coarse sand; massive breaks to structureless, friable becoming firm with depth; very few to no roots. |

Class .3: Ridge Tops

A few plots were taken on or just off of sloping ridges. There are too few examples from the study for generalizations, and no subgroups have been made. Guidelines for use can be constructed on the basis of the soils observed and the nature of the landforms. All these sites have a high erosion potential if the protective vegetation cover is damaged. Any use of these areas should be based

on slope and drainage and should be of the kind to minimize damage to vegetation. Ridges are areas of runoff and the highest rate of soil removal. Trails built on a sloping ridge crest will tend to activate this natural process and become gulleys. If use is necessary, the construction should be done in such a way as to eliminate water flow. Wherever possible, ridge crests should be avoided unless the slope is minimal. A sideslope alternative would be preferable. These areas will probably not be attractive as camping sites because of the lack of water, but such use should be strongly discouraged.

Group 2: Colluvial Soils

This is the dominant soil group in the Park. These soils occur on slopes at all elevations and predominantly southern aspects. Although exceptions were found, these soils seemed to occur on slopes of greater than 55 percent and to occur with increasing frequency as steeper slopes were sampled.

Vegetation varies due to the elevation and aspect differences represented, but a vegetation type can be described with the major variations found. On the lower elevations the vegetation is dominated by western hemlock and Douglas-fir with a shrub layer of salal, Oregon grape, and sometimes vine maple. The herb cover is approximately 10 percent, mainly vanilla leaf. At higher elevations silver fir becomes the dominant tree species with western

hemlock, and the shrub layer is dominated by mixed huckleberry species and Oregon grape. The herb cover is essentially the same as at the lower elevations. Near the extreme high elevations beargrass becomes the dominant understory species, and mountain hemlock and Alaska cedar are sometimes present with the silver fir. The percentage of cover of understory vegetation tends to decrease as the slope increases.

Certain sites were found in which water channels or springs created an extremely wet site on these steep slopes. These appeared to be slide areas with coarse, cobbly, boundary soil supporting a lush herbaceous cover of 100 percent or more. Vine maple and devils club were found on these sites also.

No subgroups have been made for this group because no meaningful boundaries could be found. There appears to be a continuum from soils that are totally undifferentiated, cobbly, gravelly sands to soils with two or three colluvial and tephra layers with a slightly differentiated B horizon based on weak color and structure.

This group includes mixed colluvial soils composed of tephra, angular and subangular cobbles and gravels, and material of unknown origin. There is minimal layering, and where it exists the layers are mixed. Notable exceptions are found in soils with an unmixed tephra W surface layer or tephra Y sublayer, but these layers do not change the

basic soil behavior. They are unstable, rapidly drained, coarse, unconsolidated, mixed soils.

The soil profile is made up of loose to weak compacted layers. Gravels and cobbles often tend to increase with depth but may be 40 percent or more in the upper horizons and scattered on the surface. Little genetic development has taken place, so there is a minimum of horizonation, although color differences exist in profiles composed of more than one deposit. There is often a high percentage of lapilli in areas of Rainier tephra deposition. These soils were generally much drier than tephra soils in comparable sites sampled concurrently.

Use of these soils in trail building depends on the slope and the care taken during construction. It should be expected that these soils will move if disturbed and that many walls and continual maintenance are necessary. Slumping soil, rock slides, and possible mass failure are potential problems of these soils and will tend to increase in frequency with slope. In areas of heavy shrub cover the rooting should provide some protection and increase the use capacity. Steeper slopes should be avoided if at all possible because of the potential for severe maintenance and possible safety problems. Where areas of this type are in use, they should be carefully observed for indications of structural failure and soil or rock slippage to maintain safety.

Following is a representative profile of this group.

| | | |
|-------|---------|---|
| 01 | 9-7 cm | Litter |
| 02 | 7-0 cm | Duff; roots common |
| A21 | 0-2 cm | Dark gray (moist) fine sand (post-W tephra); loose; roots common; smooth abrupt boundary to |
| IIA22 | 2-5 cm | Mixed gray and yellowish brown (moist) coarse sand (tephra W); single grain; roots common; irregular abrupt boundary to |
| IIIB | 5-60 cm | Yellowish brown (moist) gravelly sand; 25 percent lapilli and angular gravels increasing with depth; loose; roots abundant to 40 cm grade to few. |

Group 3: Alluvial Soils

Class .1: Alluvial Flats

Alluvial flats are the flat valley bottoms adjacent to the unvegetated floodplains of the major rivers. They are found in wide valley areas in which the river gradient becomes less severe and river deposition dominates over downcutting. Through centuries of alluvial deposition and vegetation succession, alluvial flats have been built up above the active floodplain and now support a dense forest flora. These areas tend to parallel the river gradient through the valley and to slope gently away from the river because of the bank building process at the river edge. They are bounded on the opposite side by the valley wall and are often bordered by a drainage area at the slope edge. Frequent channels draining the sideslopes cut across the flats winding towards the river.

These wide valley bottoms are usually at low elevations and have the most moderate temperature conditions within the Park. The lateral flow through alluvial flats towards the river and drainage channels create high water table conditions much of the year. These are also the areas in which clouds accumulate as fog during the late summer months, increasing available moisture and reducing evaporation and transpiration rates. For these reasons the alluvial flats support the most dense, luxuriant, and diverse flora in the Park. On these sites are found the largest specimens of red cedar, Douglas-fir, and western hemlock, as well as the most complex groupings of herbaceous species.

Differential deposition seems to have occurred across the flat creating a complex of soils including skeletal, cobbly sand, coarse undifferentiated sand, and layered multi-textured sand. The deposition has also resulted in a pattern of mounds and depressions. These small elevation differences alter moisture conditions sufficiently to influence vegetation composition and soil development. Thus there are areas of strong A1 soil development, areas of thick organic development but no A1 horizon, areas of mottled or indurated horizons, and areas of no observable development, each with a slightly different understory composition. The total complex of textural and developmental variations may be present in a very small area.

Because of the variability in this group, site data will be needed for any planned use. These are guidelines which will be useful in determining the use potential of a site.

These areas have the appearance of being ideally suited for multiple uses because they possess scenic quality, water, and accessibility. However, many drainage related problems severely limit most uses. Drainage patterns of the soil can be inferred from examination of the soil profile. In some areas mottling and induration occur, indicating the presence of high water tables much of the year. Most of the soils are composed of layered or un-layered deposits of coarse sand which is rapidly drained. Either of these soils is poorly suited for use with open pit toilets or septic tank sewage systems because of the potential for lowering the quality of the groundwater and river.

Surface moisture and drainage should be evaluated in determining usability of a site for trails. Areas of high moisture retention, often indicated by the presence of a thick organic horizon or an A1 horizon, are also areas of fragile vegetation. Trails in these areas would be wet most of the year, encouraging hikers to make new trails through the plants and thus possibly to destroy a unique ecosystem. Display of these areas is highly desirable but must be done in a carefully controlled manner.

Protection of the ecosystem and water quality should be major considerations in decisions concerning use of alluvial flats. The most usable sites are those high enough above the river to be unaffected by water tables and to have enough soil depth to ensure adequate filtration of sewage. The presence of subsurface layers of fine texture would increase the filtration capacity of the soil and thus the site usability. These areas are the most likely to have drier habitat shrubs (i.e., blueberries) as a major understory species and a more common kind of herb cover. Although not common, these areas exist in enough locations to make them a practical alternative for development in order to protect the vegetation of the wetter alluvial flats.

Two representative samples of soils on alluvial flats have been included to give a sample of the diversity of the group. The first illustrates both a well developed A1 horizon from an area rich in herbs and a B horizon somewhat indurated by an iron pan which is an indication of drainage restriction. The second is of a soil of coarse almost uniform texture and little genetic development.

| | | |
|------|----------|---|
| 01 | 3-2 cm | Litter |
| 02 | 2-0 cm | Duff; medium and fine roots abundant |
| A1 | 0-18 cm | Very dark brown (moist) fine sand; moderate fine and medium crumb, very friable; medium and fine roots common; occasional subangular gravel; wavy clear boundary to |
| IIA3 | 18-38 cm | Dark yellowish brown (moist) fine sandy loam with fine faint mottles red brown; massive breaks to moderate |

| | | |
|------|----------|---|
| | | coarse subangular block, friable to firm; few roots; smooth abrupt boundary to |
| IIB2 | 38-50 cm | Brown cobbly gravelly fine sandy loam, 75 percent water rounded cobbles and gravels; structureless; very few roots; |
| 01 | 3-2 cm | Litter |
| 02 | 2-0 cm | Duff; fine roots abundant |
| A1 | 0-3 cm | Very dark grayish brown (moist) fine sand; massive breaks to moderate medium crumb, friable; fine roots common; smooth clear boundary to |
| B | 3-14 cm | Dark yellowish brown (moist) fine sand; massive breaks to moderate coarse subangular block, very friable; fine roots common; smooth clear boundary to |
| IIC | 14-63 cm | Dark gray (moist) sand; massive breaks to single grain; few fine and medium roots. |

Class .2: Alluvial Benches

These are wet benches where runoff water, springs, or ephemeral streams have deposited layers of fine textured soil materials which are often mixed or interlaid with coarser tephras. Frequently they have an A1 horizon or a thick organic horizon and remain saturated most of the year by lateral flow just beneath the surface. The understory vegetation usually includes devils club as a dominant shrub. On these sites Alaska cedar with silver fir and western hemlock are dominant. There seems to be no predictable pattern of occurrence of these sites.

Soils materials on these sites vary depending on the type of deposit but most include layers that have sticky, plastic consistency and are strongly mottled or gleyed.

Lateral moisture drainage saturates these soils most of the year.

Limitations on the use of these sites are so severe that they should be avoided or crossed by bridge or boardwalk.

The following is a representative profile of this group.

| | | |
|-----|----------|---|
| 01 | 4-3 cm | Litter |
| 02 | 3-0 cm | Duff; medium and fine roots abundant |
| A1 | 3-0 cm | Very dark brown (wet) sandy loam; weak medium crumb, on sticky and slightly plastic; fine and medium roots common; smooth clear boundary to |
| B21 | 3-6 cm | Dark brown (wet) sandy loam; moderate medium subangular block; slightly plastic and nonsticky; medium and fine roots common; smooth clear boundary to |
| B22 | 6-11 cm | Very dark grayish brown (wet) sandy loam with distinct fine mottles, reddish brown; moderate medium subangular block, slightly plastic and nonsticky; medium and fine roots common; wavy abrupt boundary to |
| B23 | 11-12 cm | Brown sandy loam iron stained; varies from 1-3 cm; structureless; slightly plastic and nonsticky; irregular abrupt boundary to |
| B24 | 12-30 cm | Very dark grayish brown (wet) sandy loam; moderate medium to coarse subangular block; slightly plastic and very slightly sticky; common roots; smooth clear boundary to |
| IIC | 30-70 cm | Dark gray brown sand (wet) with dark yellowish brown sand; 10 percent fine gravel; layer saturated; few roots. |

Class .3: Alluvial Slopes

These soils are similar to those on alluvial benches. Alluvial soils examined in this survey were found

on east facing slopes and occurred downslope of areas of rapid runoff such as talus slopes. These soils contain either layers of fine materials or layers of mixed coarse and fine materials and are subject to saturation by surface and subsurface moisture and lateral flow. Those examined were found on slopes of 45 to 55 percent through a wide range of elevations. The sites were densely herb covered and often had devils club and Alaska cedar, both indicators of extreme moisture. Some of these soils had a thick organic horizon or an A1 horizon, but the number of samples was too few to base any subgroups on these properties.

Limitations to use of these soils is more severe than for alluvial benches. The same moisture problems exist and because of slope steepness, erosion could be a serious problem.

The following is a representative profile of this group.

| | | |
|-----|---------|--|
| 02 | 4-3 cm | Litter |
| 01 | 3-0 cm | Duff; medium and fine roots abundant |
| A21 | 0-2 cm | Very dark grayish brown (moist) loamy sand; loose; fine roots common; smooth clear boundary to |
| A22 | 2-9 cm | Dark yellowish brown (moist) grayish fine sand and loamy fine sand; loose; roots common; irregular abrupt boundary to |
| B | 9-42 cm | Dark yellowish brown (moist) loamy, fine sand with pockets of brown medium sand in upper parts of horizon; massive breaking to structureless, friable; few roots; wavy gradual boundary to |

C 42-55 cm Brown (moist) and grayish brown mixed loamy fine sand; 8 percent angular gravels; massive breaks to structureless, friable; few roots.

Group 4: Mudflow Soils

This group includes soils where the surface or shallow subsurface materials are of mudflow origin. The areas of occurrence are discussed in the section on lahars. These soils may have tephra W or alluvial or colluvial deposits as a surface covering. Inclusion of soils in this group depends more on the accidental characteristics of location and of hazards presented by mudflow potential than on actual soil characteristics, although in areas of surface mudflow soils, certain characteristic properties are observed. These soils are usually a totally undifferentiated, unaltered lithic gray sand of an almost concrete appearance. Rocks and boulders of all sizes up to perhaps 10 feet in diameter litter the surface and are found throughout the soil. The trees are the same as would be expected on any soil in the same location, though smaller, but the understory is unique. There is a scattered shrub layer of blueberries and essentially no herb cover. The ground is instead covered with moss.

In other areas in which tephras or other deposits cover the mudflow materials the sites may usually be identified by the presence of rounded rocks and boulders on the surface and beneath the surface soil layers.

The use of mudflow areas is limited by the mudflow hazard. The history of mudflows has been discussed and should be of use in determining how to manage these areas and what kinds of precautions to observe.

CONCLUSION

The classification system which has been developed for the soils of the Park has been designed to protect the landscape and to provide recreational opportunities. This classification system is designed to identify classes of soils with similar behavior. This provides a manager with a reliable determination of the best long range uses for each soil. Such a system is important in land management because it identifies those soils most suited for specific uses and those with the most severe limitations.

For the purposes of this classification system, soil-landform features which could be easily recognized and best serve the objectives were used as the basis for grouping. These were the parent materials in which the soils formed, the landforms which determine the morphologic expression of the soil forming factors. These soil-landform features provide information from which to base interpretations important in long term management. The groups have been designed to identify soils with similar stability, drainage, erosion, and hazard characteristics. Those in which one or more of the characteristics limit the use potential have been grouped accordingly. Use of soils with these limitations would be incompatible with the first objective: to protect the landscape.

The use potential differs for each group. The group determined to have the broadest use potential was the tephra, bench, minimal development group for which neither slope nor drainage were judged to be limiting. These soils should support campgrounds, picnic areas, and hiking trails. The tephra, slope, minimal development group (p. 50), the more gently sloping soils of the colluvium group, and the tephra, slope, weak iron pan group (p. 52) were judged to be suited for hiking trails. The other groups of soils were found to have severe limitations to all uses without provision for corrective construction. Soils of the colluvium group (p. 62) on steep slopes tend to be unstable as do the soils of the alluvial slopes group (p. 70). All of the alluvial soils have the potential for drainage limitations although by careful site analysis certain alluvial flat soils (p. 65) can be found that will support some uses. Those soils with well developed iron cementation horizons (p. 54, 60) are severely limited for any use because of poor drainage and potential erosion. Erosion is also a limitation for use of sloping ridgetop soils (p. 61). Vegetation destruction was considered a major limitation on many of the level or gently sloping sites in which poor drainage was indicated. These sites support a complex, unique flora which is sensitive to trampling and should be protected for this reason. A few sites are limited because of the potential for certain hazards. Some areas have been sites of

mudflow activity in recent years and the possibility for reoccurrence exists. The possibility for flooding exists on a few of the alluvial flat areas. The toeslope areas which have been grouped with the colluvium group are areas of possible rock fall as are some of the steeper colluvium sites. Figure 10 provides a matrix interpretation of some of the major features of the groups and their limitations.

This classification system has been subjectively constructed on the basis of field observation of the soils and has not been tested. If it is to become a useful tool for Park management, records should be kept to determine how each group reacts to management and these results should be represented by the construction of maps. In this way the system can be refined, expanded, and corrected where necessary and a classification best suited for the long-term needs of the Park can be developed.

| | 1.11 | 1.12 | 1.13 | 1.21 | 1.22 | 1.23 | 1.30 | 2.0 | 3.1 | 3.2 | 3.3 |
|---------------------------|------|------|------|-------|------|------|------|-----|-----|-----|-----|
| <u>Slope</u> | | | | | | | | | | | |
| 0-10 | | | | x | | x | | | x | | |
| 10-35 | | | | x | x | x | x | | | x | |
| 35-60 | x | x | x | | | | | x | | | x |
| 60- | x | x | | | | | | x | | | |
| <u>Specific aspect</u> | | | | | | | | | | | |
| N | N,S | N | A11 | S,E,N | A11 | N,S | A11 | S | A11 | E | A11 |
| <u>Specific Park area</u> | A11 | A11 | NW | SW | A11 | NW | A11 | A11 | A11 | A11 | A11 |
| <u>Vegetation</u> | | | | | | | | | | | |
| Silver fir | x | x | x | x | | x | | x | | x | x |
| Western hemlock | x | | | x | | x | | x | x | x | |
| Douglas fir | | | | | | | | x | x | | |
| Red cedar | | | | | | | | | x | | |
| Mountain hemlock | | x | x | | | x | | | | | |
| Alaska cedar | | x | x | | | x | | | | x | x |
| Huckleberry | x | x | x | x | | x | | x | | | |
| Devils club | | | | | | | | | x | x | x |
| White rhododendron | | | x | | | x | | | | | |
| Low herb cover | x | | | | | | | x | | | |
| High herb cover | | | x | | | x | | | x | x | x |
| Moderate herb cover | x | x | x | | | x | | | | | |

Fig. 10.--Major identification characteristics and limitations

| | 1.11 | 1.12 | 1.13 | 1.21 | 1.22 | 1.23 | 1.30 | 2.0 | 3.1 | 3.2 | 3.3 |
|------------------------------|------|------|------|------|------|------|------|-----|-----|-----|-----|
| <u>Soil</u> | | | | | | | | | | | |
| Well layered | x | x | x | x | | | x | | | x | x |
| Coarse Textured | x | | | x | | x | x | x | x | | |
| Fine textured layers | | x | x | | x | x | | | | x | x |
| Cobbly | | | | | | | | x | x | | |
| Weak iron pan | | x | | | x | | | | | | |
| Strong iron pan | | | x | | | x | | | | | |
| <u>Drainage limitations</u> | | | | | | | | | | | |
| None | x | | | x | | | x | x | | | |
| Moderate | | x | | | x | | | | x | | |
| Severe | | | x | | | x | | | x | x | x |
| <u>Stability limitations</u> | | | | | | | | | | | |
| None | | | x | x | x | x | x | | x | x | |
| Moderate | x | x | | | | | | x | | | |
| Severe | | | | | | | | x | | | |
| <u>Erosion limitations</u> | | | | | | | | | | | |
| None | x | | | x | | | | x | x | | |
| Moderate | | x | | | x | x | | | | | |
| Severe | | | x | | | | x | | | x | x |

Fig. 10--Continued

LITERATURE CITED

- Birkland, Peter W. 1974. Pedology, weathering and geomorphological research. New York: Oxford University Press, Inc.
- Cline, Marlin G. 1949. Basic principles of soil classification, p. 38. In Selected papers in soil formation and classifications, ed. by J. V. Drew. Madison, Wisconsin: Soil Science Society of America, Inc.
- Crandell, Dwight R. 1971. Postglacial lahars from Mount Rainier National Volcano, Washington. U.S. Geol. Surv. Prof. Paper 667.
- Crandell, Dwight R., and Robert D. Miller. 1974. Quaternary stratigraphy and the extent of glaciation in the Mount Rainier National Park region, Washington. U.S. Geol. Surv. Prof. Paper 847.
- Mill, John Stuart. 1874. A system of logic, 8th edition, Vols. I and II. London: Longmans, Green and Co.
- Mullineaux, Donal R. 1974. Pumice and other pyroclastic deposits in Mount Rainier National Park, Washington. U.S. Geol. Surv. Bulletin 1326.
- Steinbrennar, E. C., and F. E. Gehrke. 1964. Soil survey of the Vail Tree Farm. Everett, Washington: The Weyerhaeuser Co.
- U.S. Department of Commerce, Weather Bureau. n.d. Mount Rainier National Park, Washington. U.S. Department of Commerce, Weather Bureau, in cooperation with the Washington State Department of Commerce and Economic Development, Climatology of the United States.
- U.S. Forest Service, Pacific Northwest Region. 1972. Soil resource inventory Snoqualmie National Forest. Washington, D.C.: U.S. Forest Service.