
SOILS OF GLACIER NATIONAL PARK



Prepared for:

National Park Service
Glacier National Park
West Glacier, MT 59936



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HOW TO USE THIS REPORT

This report includes a variety of information about soil distribution, characteristics and management. Here are some hints for how to use it.

IF YOU ARE INTERESTED IN GENERAL SOIL INFORMATION FOR GLACIER PARK:

- Review the **introduction** and **general soil features sections**. Review any specific areas of interest such as soil classification, vegetation, productivity, trail construction or erosion.

IF YOU ARE INTERESTED IN SOIL PROPERTIES AT A SPECIFIC SITE:

- Locate your site on the map provided in this report or on the more detailed 1:24,000 scale maps available through the park GIS coordinator.
- Note the indicated soil mapping unit and surrounding mapping units illustrated on the map.
- Review these mapping units and the individual soils they contain. Compare the topographic, vegetation and other features of your site with those of the map units and individual soils.
- Note the *minor soils-inclusions* section of the map unit description to identify other possible soils at your site.
- Review the properties and management interpretations for each individual soil for additional information. Check the references for more detailed project soil reports.

IF YOU ARE DESCRIBING SOILS AT RESEARCH OR PROJECT SITES

- Use the guides provided in Appendix A to refine your soil identification and description for the specific site.
- Query local soil scientists with questions about your soil identification, distribution and management.

REMEMBER!

Individual areas depicted on soil maps (delineations) are grouped and described together as mapping units. Mapping unit descriptions outline the average composition of major and minor soils in the entire group of delineations. The relative proportions of major and minor soils varies for each individual delineation. Not all delineations have all the minor soils indicated in the mapping unit descriptions. Delineations attempt to separate areas with contrasting soils but often must be drawn along subtle gradients. Be especially aware of the potential for soil variation near delineation boundaries.

ACKNOWLEDGMENTS

This project would not have been possible without the support and cooperation of Glacier Park personnel, especially Richard Menicke who provided technical assistance and guidance throughout the project. Carl Key, Jack Potter, Dave Lange and Jim Tilmant also were helpful in identifying resources and determining potential uses for the information. We would also like to thank the ranger and backcountry permit staffs for facilitating our fieldwork. Paul Carrara of the USGS participated in philosophical discussions of ancient geologic events which helped confirm many events important to local soil genesis. Chuck Gordon and Wade Bott of the NRCS also provided valuable comments as did Pete Biggam of the National Park Service.

1.0 INTRODUCTION

Soil is the basic resource upon which many others depend. Soil supports buildings, roads and trails. It produces vegetation essential for wildlife food and cover. Glacier National Park has a spectacular variety of interesting and important soils whose history includes ancient seas, glaciers, volcanoes and floods. Park managers, researchers and visitors can all benefit from a better understanding of soil.

The goal of this project was to provide basic soil information for park personnel and others about the general characteristics, distribution and management of park soils. It highlights the most important soil features which research and management should evaluate for individual project sites. This inventory covers the entire park. It generally follows the format of an Order 3 soil survey according to USDA National Cooperative Soil Survey Program standards but also borrows from the US Forest Service landtype system and the Canadian soil inventory program. Mapping unit and general soil descriptions are presented along with information on common park uses. Data is available in both digital and hard copy formats.

2.0 METHODS

This soil inventory was completed over a six year period as part of an on-going effort to complete a park-wide soil inventory (see Appendix C). To accomplish the task within these constraints, soil properties were emphasized that most relate to future management and research activities. These properties include soil parent material, horizonation, depth, texture, rock content and available water holding capacity. Less effort was made than typical in a 3rd Order soil survey to distinguish slope classes, aspect differences and some elevation relationships which can be derived from the existing digital terrain model of Glacier Park.

SOIL INVENTORY CHARACTERISTICS:

- Similar to an Order 3 Soil Survey.
- 1:24,000 Scale
- Map units are mostly complexes of two or more soils but some are single-soil units (consociations)
- Delineations are as small as 5-10 acres and as large as several thousand acres
- Soil and map units are named to illustrate important characteristics to non-soil scientists
- Emphasis on Landscapes (similar to landtypes).
- Emphasis on park interests (basic resource knowledge especially relationships to vegetation, revegetation, weed invasion, trail and road

construction, erosion and sewage disposal, natural resource education).

SOIL INVENTORY LIMITATIONS:

- Tremendous variation in rock types, surficial geology, topography, and resulting soil features especially depth, texture, rock content, drainage, genesis and classification
- Most of the area is extremely rugged and inaccessible except by infrequent trails
- Short field season due to snow
- Need for extra sensitivity to the resource and park visitors
- Mapping base is USGS quad maps and orthophotos
- Stereo photos are 1968 Black & White with extreme distortion due to topography
- Budget is \$.07/acre
- Fieldwork conducted with shovels - no backhoe pits
- Few detailed soil descriptions - many notes
- Little soil chemical, moisture or temperature data except from other surveys in surrounding areas

The first year's effort used an expert system coupled with a GIS to produce a draft soil map of the McDonald drainage (Dutton 1995). This map was verified and edited through fieldwork. The methods used to produce this map are described in Axing, Dutton and others (1995).

For the subsequent mapping effort, an initial soil map was produced using air photo interpretation in combination with several information layers. These layers included topography, surficial geology, bedrock geology, and wetlands.

Initial soil maps and draft mapping units were examined in the field and adapted as needed. Final soil maps were compiled on 1:24,000 orthophotos and examples are included in Appendix D.

Fieldwork was conducted on foot using shovels, which presents significant limitations in a short field season. Most soil observations were made to a depth of 2-3 feet. Roadcuts, trailcuts, stream banks, slump scarps, bear-marmot-ground squirrel diggings, tree well and similar features were observed whenever available.

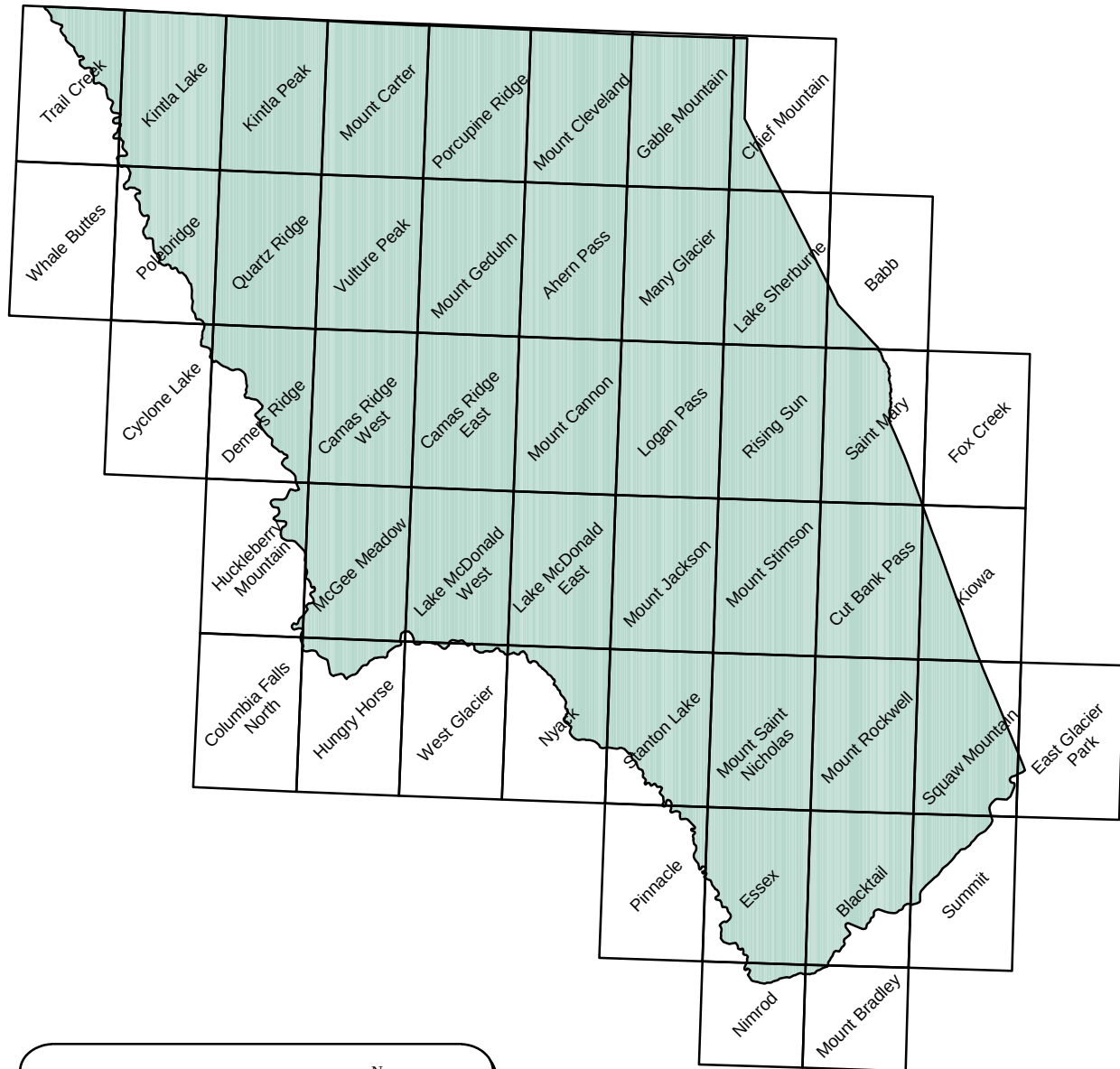
Soils were described according to the USDA Soil Survey Manual (1993). Terms used throughout this report such as gravel, cobble, sandy loam, moderately deep and others have specific definitions. A glossary has been provided for many soil and geologic terms with references to other technical sources.

Soil colors are described using Munsell Color Charts in the moist condition. Guides for identifying important

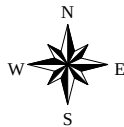
soil and geologic features are presented in Appendix A.

Soils in this report have been classified using Keys to Soil Taxonomy (1998). These classifications were made based on field observations and experience in surrounding areas combined with chemical data from adjacent areas. This project did not emphasize soil classification due to the tremendous number of potential taxonomic classes in the park. The cost of sampling, laboratory analysis, data interpretation and correlation is substantial for this effort. This project identifies similar soils and landtypes from surrounding mapping programs where available. Information on these similar soils and landtypes are available from Natural Resources and Conservation Service, Forest Service and Canadian Park Service sources.

Figure 1.
Study Area Location
Glacier National Park



Project#: 599-065
Date: January 2001
Location: Glacier National Park
Project Manager: B. Dutton
Drawn By: M. Arthur



5 0 5 10 15 Miles



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USGS 7.5 Minute Quadrangles

Use and management ratings generally follow those of the National Soil Survey Handbook (USDA 1993). Most individual soils of Glacier Park are rated as having severe limitations for many common uses. These severe ratings are mainly due to steepness, shallow bedrock, high rock content and high clay content. For example, the soils most common in existing park campgrounds are rated as having severe limitations for camp areas. It is important to note that these severe limitations do not preclude use for that purpose but warn that soil characteristics must be considered carefully in planning and design. Such uses may require greater care and cost and may result in greater environmental impacts.

3.0 SOILS OF GLACIER PARK

The soils of Glacier Park include a variety of parent materials, climates, topography, vegetation and ages. These soils are discussed in five major groups including alluvial soils, wet soils, glacial and landslide soils, and bedrock soils from both limestone and from quartzite or argillite (Table 1). The general distribution of these soil groups is illustrated in Figure 2.



Forest Soil with bright brown volcanic ash surface from the Mt. Mazama eruption (Crater Lake) 7000 years ago.

TABLE 1. SOIL GROUP ACREAGE AND PROPORTION OF THE PARK

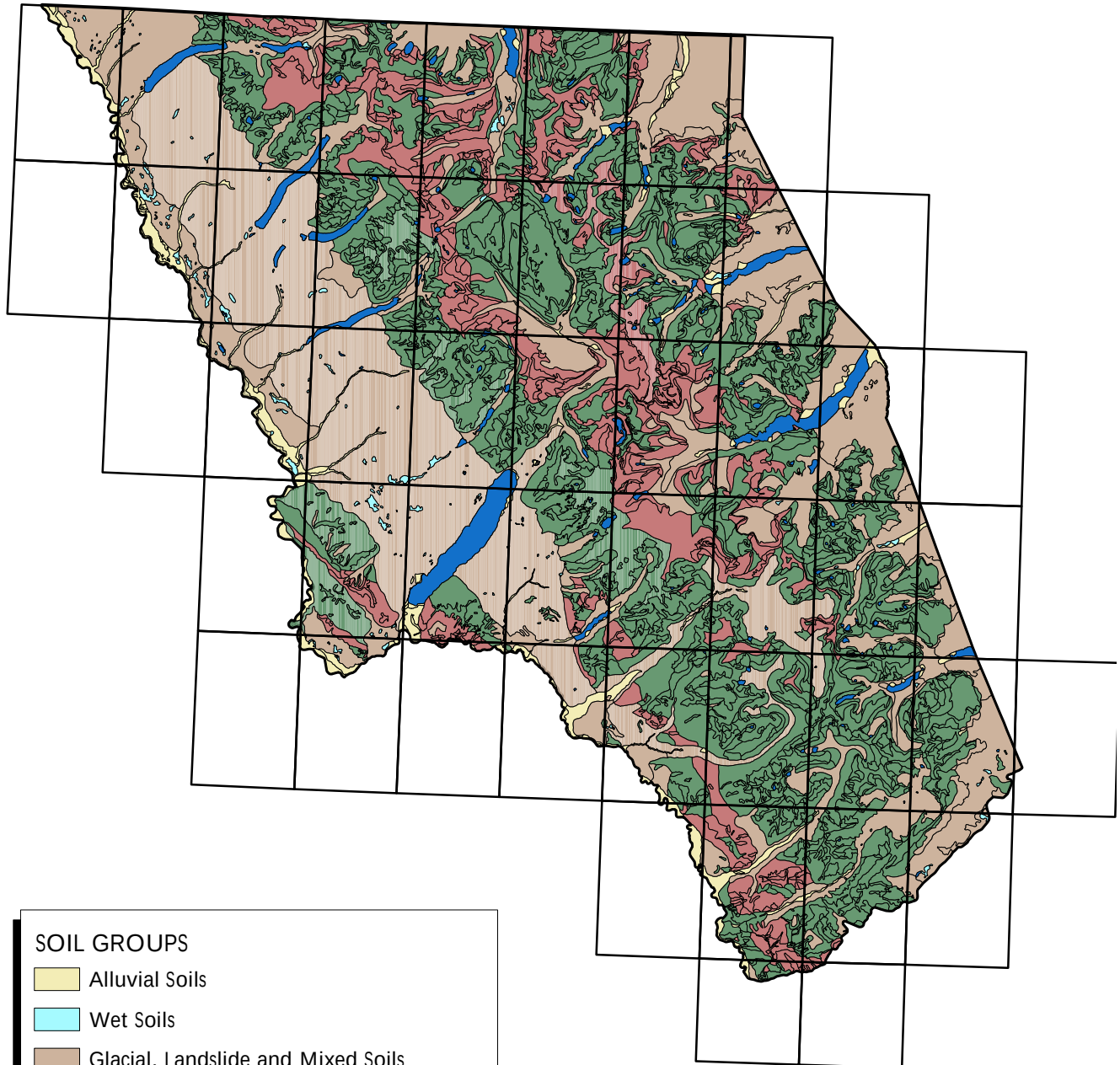
SOIL GROUP	ACRES	AREA
ALLUVIAL SOILS	27,682	3%
WET SOILS	4,686	<1%
GLACIAL & LANDSLIDE SOILS	397,015	39%
BEDROCK SOILS: QUARTZITE AND ARGILLITE	411,652	41%
BEDROCK SOILS: LIMESTONE	145,828	14%
WATER	26,709	2%
TOTAL	1,013,572	100%

Soils developed in response to geologic history and other factors as discussed in Section 5.0. Some important events and processes are listed below.

Chronology of Soil History in Glacier:

1. **Deposition** of sand, silt, clay and lime in a Precambrian sea extending west, north and south of current Glacier Park.
2. **Hardening** of these sediments into quartzite, argillite, limestone, sandstone and shale.
3. **Uplift** of these rocks and faulting (especially the Lewis Overthrust)
4. **Erosion** of the uplifting mountains to fill valleys with sediment and build large, high terraces extending eastward from the mountain front.
5. **Glaciation** which reformed the landscape and scoured loose soil and rock from some higher areas, depositing it in the lower valleys and outside the park.
6. **Intense frost action** on the unglaciated areas to weather soil and create frost features like stone stripes and polygons.
7. **Sorting and reworking** of glacial materials by melt-waters during and following glaciation.
8. **Eruption** of Cascade range coast volcanoes including Mt. Mazama (Crater Lake), Mt. St. Helens and Glacier Peak.
9. **Wind deposition** of volcanic ash, glacial flour and other material.
10. **Mass wasting** of soil materials downhill by landslide, slump, block-fall and soil creep.
11. **Development of floodplains** and alluvial fans along current streams.
12. **Formation of beach deposits** around lakes.
13. **Formation of wet soils** in depressions and near water sources.
14. **Growth of vegetation** and corresponding effects on soils including organic matter additions, surface mixing, surface leaching and aeration.
15. **Construction by mankind.**

Figure 2.
General Distribution of Soil Groups
Glacier National Park



SOIL GROUPS

-  Alluvial Soils
-  Wet Soils
-  Glacial, Landslide and Mixed Soils
-  Bedrock Soils - Quartzite and Argillite
-  Bedrock Soils - Limestone
-  Water

0 5 10 Miles



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Date: January 2001
Location: Glacier NP

Project Manager: B. Dutton

Drawn By: M. Arthur

3.1 SOIL FEATURES AND DISTRIBUTION

Soils occur as a continuum across the landscape, not as distinct individuals. This project selected and described representative soil profiles because it is difficult to describe and map the entire range of variation. Few places have such dramatic variation in soil characteristics within such short distances as Glacier Park. Park soils vary from very shallow to very deep, from sand and rock to clay, from light to dark, from green to red to tan to gray, from level to steep and from good to poor for potential uses.

Although soil characteristics are tremendously varied across the park, there are some important features common to many of these soils such as:

- bright brown soil colors
- wind-blown deposits, especially volcanic ash in the surface soil
- loamy soil textures - a mixture of windblown materials and rock weathering products
- tremendous variation in depth to bedrock over short distances in many units
- tremendous variation in climate, topography, vegetation, age, and other features over short distances

The loamy textures and bright brown colors are strongly influenced by wind-blown deposits. These wind-blown deposits are dominated by volcanic ash from the eruption of Mt. Mazama 7000 years ago and from other West Coast volcanoes. These eruptions have provided six inches of ash or more to most local surface soils. This ash was eroded from some sites, especially those with little vegetation and steep slopes. On most sites, the ash has been incorporated into the surface layer by wind thrown trees and animal burrowing. Ash has also been transported into the subsoil by water movement. As a result of ash influence, many Glacier park soils have loamy textures and the bright brown color of weathered ash. This is especially notable since many rocks in Glacier have red or green colors and weather to sandy textures.

Figures 3 and 4 illustrate the general distribution of soil mapping units in the park. These data are also available as overlays of 1:24,000 USGS quadrangles and as digital files through the National Park Service GIS coordinator in West Glacier. Table 2 lists the soils and mapping units identified in this study along with the acreage and proportion of the entire area each represents.

3.2 MAP UNIT AND SOIL DESCRIPTIONS

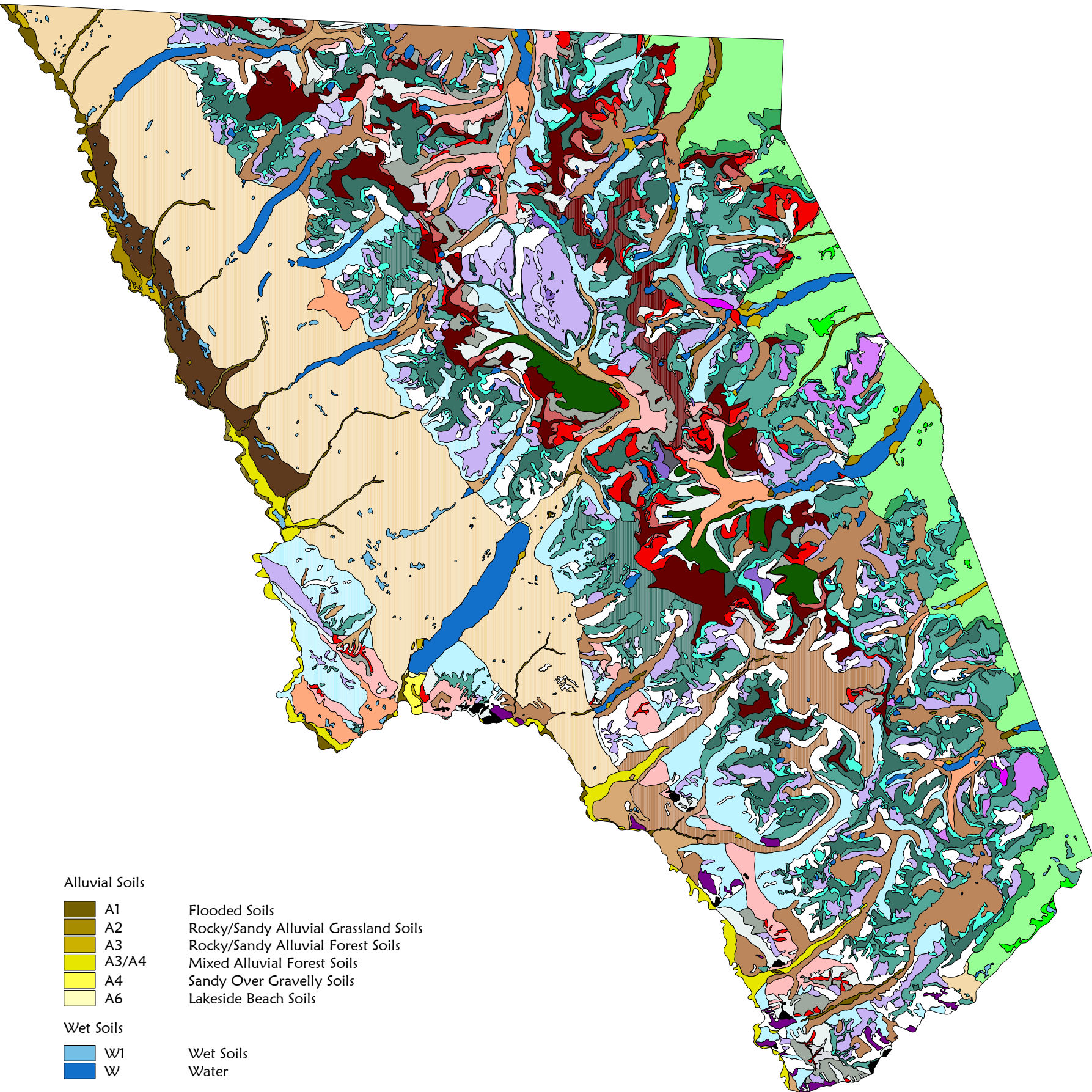
Twenty-six individual soils were identified for mapping purposes in this study. These soils represent the majority of the area but microsites may have other soils not described here. Forty-eight mapping units were identified including those dominated by one soil as well as those with many soil components. Five non-soil mapping units were used including rock outcrop, talus and water. The major and minor components of each mapping unit are described. Table 3 illustrates the general characteristics of mapping units in this report.

It is important to remember that soil properties vary dramatically across the landscape in Glacier Park. The 26 soils identified for mapping were selected to represent the entire range of soil characteristics that occur. Soils other than those described do occur and should be expected.

It is important to recognize the difference between **individual soils** (taxonomic units), individual **soil delineations** on maps and soil **mapping units**. Individual soils are identified and described within one taxonomic class (Soil Taxonomy 1975). These individual soils share important features of texture, depth, drainage, and use potentials. Soil delineations on a soil map show areas of land with similar soil patterns. The lines separate areas with contrasting patterns. Rarely does one soil occupy an area large enough to map at a scale of 1:24,000. Soil delineations are either dominated by one soil or by more than one (complexes). In either case there are also additional soils that occur in smaller amounts. No two soil delineations have the same exact mixture of soils. Each delineation does not have every minor soil listed in the map unit description and the relative composition of major soils may also vary. It is essential that users of this soil inventory review the components of soils mapping units in their area of concern to confirm that they accurately identify the correct soil at their project site.

Figure 3. Soil Types

Glacier National Park



Alluvial Soils

A1	Flooded Soils
A2	Rocky/Sandy Alluvial Grassland Soils
A3	Rocky/Sandy Alluvial Forest Soils
A3/A4	Mixed Alluvial Forest Soils
A4	Sandy Over Gravelly Soils
A6	Lakeside Beach Soils

Wet Soils

W1	Wet Soils
W	Water

Glacial, Landslide and Mixed Soils

G1	Poorly Developed Soils - Recent Glacial Moraines
G2	Silty Clay Loam Glacial Forest Soils - Wide Valley Bottoms
G2/G3	Mixed Glacial Forest Soils
G3	Loamy Glacial Forest Soils - Valleys
G3/C3	Mixed Glacial & Colluvial Soils
G3/A3/G2	Mixed Glacial Forest & Alluvial Soils
G4/G5	Mixed Conifer & Aspen Forest Soils
G6	Clay-Rich Grassland Soils
G7	Deep, Rocky Colluvial & Landslide Soils
G8	Loamy Limestone Glacial Forest Soils

Bedrock Soils - Limestone

LC1	Rock Outcrop
LC1/LC4	Rock Outcrop & Shallow Limestone Soils
LC2	Talus
LC3	Deep Colluvial Forest Soils on Limestone
LC3/LC5	Deep & Moderately Deep Limestone Soils
LC4/LC6	Shallow & Alpine Limestone Soils
LC5/LC4	Moderately Deep & Shallow Limestone Soils
LC6	Alpine Meadow Soils on Limestone
LC9/LC5	Shallow Grassland & Moderately Deep Limestone Soils

Bedrock Soils - Quartzite and Argillite

C1	Rock Outcrop
C1/C4	Rock Outcrop & Shallow Soils
C2	Talus
C3	Deep Colluvial Forest Soils
C3/C5	Deep & Moderately Deep Colluvial Soils
C4/C6	Shallow & Alpine Meadow Soils
C5/C4	Moderately Deep & Shallow Colluvial Soils
C6	Alpine Meadow Soils
C7/C1	Mixed Rock Outcrop & Ice-Patterned Soils
C8	Deep Colluvial Grassland Soils
C9/C5	Mixed Shallow Grassland & Moderately Deep Soils

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5 0 5 10 Miles



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TABLE 2. ACREAGE AND PROPORTION OF PARK FOR MAPPING UNITS

MAP UNIT	MAP UNIT NAME	ACRES	AREA (%)
	ALLUVIAL SOILS		
A1	FLOODED SOILS - FLOODPLAINS AND LOW TERRACES	10,867	1.0
A2	ROCKY/SANDY ALLUVIAL GRASSLAND SOILS - FANS AND HIGH TERRACES	2,868	0.3
A3	ROCKY/SANDY ALLUVIAL FOREST SOILS - FANS AND HIGH TERRACES	3,699	0.4
A3/A4	A COMPLEX OF A3 AND A4	9,214	0.8
A4	SANDY OVER COBBLY ALLUVIAL SOILS	834	0.1
A6	LAKESIDE BEACH SOILS	200	<0.1
	WET FEATURES		
W1	WET SOILS – DEPRESSIONS, STREAMSIDES, TOESLOPES	4,686	<1
W	WATER	26,709	<1
	GLACIAL, LANDSLIDE AND MIXED SOILS		
G1	POORLY DEVELOPED SOILS – RECENT GLACIAL MORAINES	282	<0.1
G2	SILTY CLAY LOAM GLACIAL FOREST SOILS - WIDE VALLEY BOTTOMS	177,044	17.6
G2/G3	A COMPLEX OF G2 AND G3	12,409	1.2
G3	SANDY GLACIAL FOREST SOILS - VALLEYS	10,958	1.1
G3/A3/G2	A COMPLEX OF G3, A3 AND G2	14,948	1.4
G3/C3	A COMPLEX OF G3 AND C3	92,244	9.0
G4	CLAY-RICH CONIFER FOREST SOILS - MORAINES AND LANDSLIDES	*	*
G4/G5	A COMPLEX OF G4 AND G5	67,307	6.7
G5	CLAY-RICH ASPEN FOREST SOILS - MORAINES AND LANDSLIDES	*	*
G6	CLAY-RICH GRASSLAND SOILS - MORAINES AND LANDSLIDES	1,757	0.2
G7	DEEP, ROCKY COLLUVIAL AND LANDSLIDE SOILS - THRUST FAULT ZONE	8,423	0.8
G8	LOAMY LIMESTONE GLACIAL FOREST SOILS - VALLEYS	11,644	1.2
	BEDROCK SOILS - QUARTZITE AND ARGILLITE		
C1	A COMPLEX OF C1 AND C4	85,782	8.5
C1/C4	TALUS – QA	76,051	7.5
C2	TALUS – QA	29,153	2.9
C3	DEEP COLLUVIAL FOREST SOILS - LOWER MOUNTAIN SLOPES	80,629	8.0
C3/C5	A COMPLEX OF C3 AND C5	63,751	6.3
C4	SHALLOW SOILS - SCOUR AREAS AND NEAR ROCK OUTCROPS	*	*
C4/C6	A COMPLEX OF C4 AND C6	4,943	0.5
C5	MODERATELY DEEP SOILS - SCOURED MOUNTAIN SLOPES	*	*
C5/C4	A COMPLEX OF C5 AND C4	58,888	5.8
C6	ALPINE MEADOW SOILS	1,711	0.2
C7	ICE-PATTERNED SOILS - PATTERNED GROUND ON MOUNTAINS	*	*
C7/C1	A COMPLEX OF C7 AND C1	7,295	0.7
C8	DEEP COLLUVIAL GRASSLAND SOILS - LOWER MOUNTAIN SLOPES	609	0.1
C9	SHALLOW GRASSLAND SOILS	*	*
C9/C5	A COMPLEX OF C9 AND C5	2,839	0.3
	BEDROCK SOILS - LIMESTONE		
LC1	ROCK OUTCROP – LIMESTONE	47,678	4.7
LC1/LC4	A COMPLEX OF LC1 AND LC4	16,775	1.7
LC2	TALUS – LIMESTONE	9,224	0.9
LC3	DEEP COLLUVIAL FOREST SOILS ON LIMESTONE - LOWER MOUNTAIN SLOPES	25,853	2.5
LC3/LC5	A COMPLEX OF LC3 AND LC5	23,195	2.3
LC4	SHALLOW LIMESTONE SOILS - SCOUR AREAS AND NEAR ROCK OUTCROPS	*	*
LC4/LC6	A COMPLEX OF LC4 AND LC6	2,859	0.3
LC5	MODERATELY DEEP LIMESTONE SOILS - SCOURED MOUNTAIN SLOPES	*	*
LC5/LC4	A COMPLEX OF LC5 AND LC4	18,593	1.8
LC6	ALPINE MEADOW SOILS ON LIMESTONE	452	<0.1
LC9	SHALLOW GRASSLAND SOILS ON LIMESTONE	*	*
LC9/LC5	A COMPLEX OF LC9 AND LC5	1,199	0.1
	TOTAL	1,013,572	100

* These soils are not mapped alone, only in complex with other soils as indicated.

TABLE 3. MAPPING UNIT GENERAL DESCRIPTIONS

MAP SYMBOL	MAP UNIT NAME	LOCATION	SOIL COMPONENTS	VEGETATION
ALLUVIAL SOILS				
A1	FLOODED SOILS	Floodplains and low terraces	Well to poorly drained sandy and gravelly soils formed in alluvium from mixed rock sources.	Riparian including cottonwood, aspen, willow, dogwood, alder, sedges, spruce.
A2	ROCKY/SANDY ALLUVIAL GRASSLAND SOILS	Alluvial fans, high stream terraces and glacial outwash terraces	Well-drained sandy and gravelly soils formed in alluvium from mixed rock sources.	Grassland including fescue, wheatgrass, needlegrass, lupine, shrubby cinquefoil
A3	ROCKY/SANDY ALLUVIAL FOREST SOILS	Alluvial fans, high stream terraces and glacial outwash terraces	Well-drained sandy and gravelly soils formed in alluvium from mixed rock sources.	Conifer forest dominated by lodgepole pine, subalpine fir, grand fir and spruce. Some larch, white pine, cedar and hemlock.
A3/A4	MIXED ALLUVIAL FOREST SOILS	Alluvial fans, high stream terraces and glacial outwash terraces	Well-drained sandy and gravelly soils formed in alluvium from mixed rock sources. Some profiles have rock-free sandy surface layers.	Conifer forest dominated by lodgepole pine, subalpine fir, grand fir and spruce. Some larch, white pine, cedar and hemlock.
A6	LAKESIDE BEACH SOILS	Along shores of the larger lakes.	Well-drained sandy and gravelly soils formed in beach deposits of uniform-size gravel.	Conifer forest dominated by lodgepole pine, paper birch, subalpine fir, grand fir and spruce. Some larch, white pine, cedar and hemlock.
WET SOILS				
W	WATER			
W1	WET SOILS	Potholes, flood plains, lake margins, seeps	Somewhat poorly to very poorly drained mineral soils.	Riparian / Wetland including sedges, bulrush, cattails, canary reedgrass, willows
GLACIAL, LANDSLIDE AND MIXED SOILS				
G1	POORLY DEVELOPED SOILS	Very recent glacial moraines	Well drained, poorly developed, stony sandy loam soils formed in glacial drift from recent ice advances	Scattered native invader forbs and grasses including alpine Timothy
G2	SILTY CLAY LOAM GLACIAL TILL SOILS	Ground moraines in wide glaciated valleys dominated by silty clay loam glacial till and volcanic ash.	Well-drained soils with silt loam or loam surface layers high in volcanic ash over silty clay loam glacial drift subsoils.	Conifer forest including subalpine fir, lodgepole pine, spruce, larch, hemlock, cedar, white pine, Douglas-fir
G2/G3	MIXED GLACIAL SOILS	Ground moraines in wide glaciated valleys dominated by silty clay loam to sandy loam till and volcanic ash.	A complex of well-drained soils with silt loam or loam surface layers high in volcanic ash over sandy loam to silty clay loam glacial drift subsoils.	Conifer forest including subalpine fir, lodgepole pine, spruce, larch, hemlock, cedar, white pine, Douglas-fir
G3	SANDY GLACIAL TILL SOILS	Ground moraines with silty clay loam or sandy loam glacial drift and volcanic ash.	Well-drained soils with silt loam or loam surface layers high in volcanic ash over sandy loam glacial drift subsoils.	Conifer forest including subalpine fir, lodgepole pine, spruce, larch, hemlock, cedar, white pine, Douglas-fir
G3/C3	MIXED GLACIAL AND COLLUVIAL SOILS	Ground moraines with silty clay loam to sandy loam glacial drift and colluvial toeslopes with loam or sandy loam colluvium. Volcanic ash in surface.	A complex of well drained and moderately well drained soils with silt loam or loam surface layers high in volcanic ash. Those soils formed in colluvium have very gravelly sandy loam subsoils. Those formed in glacial drift have very gravelly silty clay loam to loam subsoils.	Conifer forest including subalpine fir, spruce, lodgepole pine, Douglas-fir, white pine, western larch.
G3/A3/G2	MIXED GLACIAL AND ALLUVIAL SOILS	Outwash terraces, kame terraces and ground moraines in wide glaciated valleys with a mixture of silty clay loam to sandy loam drift and alluvium. Volcanic ash in the surface.	A complex of well-drained soils with sandy loam to silt loam surface layers with volcanic ash over sandy loam to silty clay loam glacial drift subsoils.	Conifer forest including subalpine fir, lodgepole pine, spruce, larch, hemlock, cedar, white pine, Douglas-fir.
G4/G5	CLAY-RICH CONIFER AND ASPEN FOREST SOILS	Clay-rich moraines and landslides on clay-rich moraines.	Well drained to moderately well drained silty clay loam to clay soils formed in clay-rich glacial drift.	Conifer forest including subalpine fir, spruce, Douglas-fir, lodgepole pine, western larch.

TABLE 3. (CONT.)

MAP SYMBOL	MAP UNIT NAME	LOCATION	SOIL COMPONENTS	VEGETATION
G6	CLAY-RICH GRASSLAND SOILS	Clay-rich moraines and landslides on clay-rich moraines.	Well drained silty clay loam to clay soils formed in clay-rich glacial drift.	Grassland including fescue, wheatgrass, needlegrass, lupine, shrubby cinquefoil
G7	ROCKY COLLUVIAL AND LANDSLIDE SOILS	Slopes and landslides near the overthrust zone.	Well drained sandy loam or loam soils with high rock contents and often stony surfaces formed in colluvium or landslide deposits.	Mixed fescue grassland and scattered shrubs and conifer trees.
G8	LIMESTONE GLACIAL FOREST SOILS	Silty clay loam glacial moraines in limestone areas.	Well drained soils with silt loam or loam surface layers high in volcanic ash and very gravelly silty clay loam to loam subsoils.	Conifer forest including subalpine fir, spruce, lodgepole pine, Douglas-fir, whitebark pine, western larch.
BEDROCK SOILS - QUARTZITE AND ARGILLITE				
C1	ROCK OUTCROP - QUARTZITE AND ARGILLITE	Mountain tops, ridges, ice-scoured slopes	Mostly rock outcrop including cliffs, scoured rock surfaces and limited talus.	Scattered plants in cracks and soil inclusions.
C1/C4	ROCK OUTCROP AND SHALLOW SOILS	Mountain tops, ridges and upper slopes	A complex of rock outcrop and shallow, well-drained, soils with very to extremely gravelly loam or sandy loam textures throughout.	Shallow soil: scattered, mostly alpine forbs, grasses, and shrubs. Conifer krumholtz.
C2	TALUS - QUARTZITE AND ARGILLITE	Below rock cliffs and rock outcrops	Unconsolidated rock fragments and limited soil material.	Mostly non-vegetated.
C3	DEEP COLLUVIAL FOREST SOILS	Lower to mid-mountain slopes especially toeslopes.	Deep, well-drained soils with loam or silt loam surface layers high in volcanic ash and very gravelly to extremely gravelly loam or sandy loam subsoils.	Conifer forest ranging from Douglas-fir to subalpine fir. Seral vegetation including lodgepole pine, shrubs, forbs and grasses.
C3/C5	DEEP AND MODERATELY DEEP COLLUVIAL FOREST SOILS	Cirque basins and lower glaciated trough walls	A complex of deep and moderately deep, well-drained soils with loam or silt loam surface layers high in volcanic ash and very gravelly to extremely gravelly loam or sandy loam subsoils.	Subalpine fir, lodgepole pine, spruce, huckleberry, beargrass.
C4/C6	SHALLOW SOILS AND ALPINE MEADOW SOILS	High elevation sites.	A complex of shallow, well-drained soils and alpine meadow soils.	Shallow soil: stunted conifer trees. Meadow: grasses, sedges, forbs.
C5/C4	MODERATELY DEEP AND SHALLOW COLLUVIAL SOILS	Upper mountain slopes and trough walls	A complex of moderately deep and shallow, well-drained soils with loam or silt loam surface layers high in volcanic ash and very gravelly to extremely gravelly loam or sandy loam subsoils. Fractured bedrock below.	Subalpine fir, whitebark pine, spruce, lodgepole pine, grouse whortleberry, elk sedge.
C6	ALPINE MEADOW SOILS	Cirque basins and lower, less steep alpine slopes	Shallow to moderately deep, well-drained soils with loam surface soils and loam or sandy loam subsoils. Rock content increases throughout with fractured bedrock in the lower profile.	Alpine forbs, grasses, sedges and shrubs.
C7/C1	ICE-PATTERNED SOILS	Wide alpine ridges and plateaus, and upper mountain slopes	A complex of ice-patterned soils and rock outcrop (including solifluction lobes, frost boils, sorted stone stripes and sorted polygons).	Alpine forbs, grasses and sedges.
C8	DEEP COLLUVIAL GRASSLAND SOILS	Lower to mid-mountain slopes.	Deep, well-drained soils with loam or silt loam surface layers and very gravelly to extremely gravelly loam or sandy loam subsoils.	Grassland including fescue, wheatgrass, needlegrass, lupine, shrubby cinquefoil

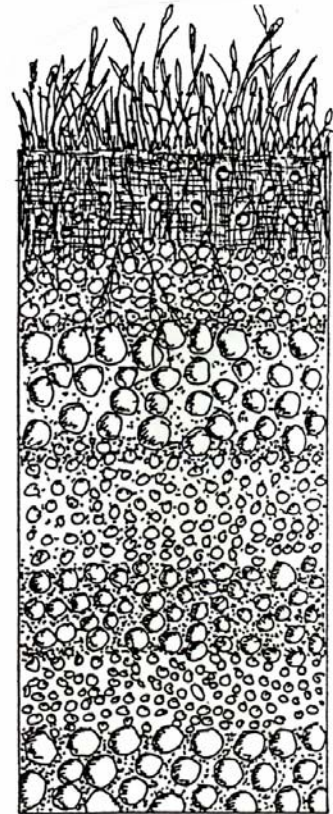
TABLE 3. (CONT.)

MAP SYMBOL	MAP UNIT NAME	LOCATION	SOIL COMPONENTS	VEGETATION
BEDROCK SOILS - LIMESTONE				
C9/C5	SHALLOW GRASSLAND SOILS AND MODERATELY DEEP COLLUVIAL SOILS	Lower elevation mountain slopes on south aspects	A complex of well-drained, shallow grassland soils and moderately deep colluvial soils. Both have loam or silt loam surface layers and very gravelly to extremely gravelly loam or sandy loam subsoils. Fractured bedrock below.	Shallow soil: grasses and scattered shrubs. Moderately deep soil: Douglas fir, subalpine fir, lodgepole pine, and shrubs such as serviceberry, huckleberry, ceanothus, spirea and others.
LC1/LC4	ROCK OUTCROP AND SHALLOW SOILS ON LIMESTONE	Mountain tops, ridges and upper slopes	A complex of rock outcrop and shallow, well-drained, soils with very to extremely gravelly loam or sandy loam textures throughout.	Shallow soil: scattered, mostly alpine forbs, grasses, and shrubs. Conifer krumholtz.
LC2	TALUS – LIMESTONE	Below rock cliffs and rock outcrops	Unconsolidated rock fragments and limited soil material.	Mostly non-vegetated.
LC3	DEEP COLLUVIAL FOREST SOILS ON LIMESTONE	Lower to mid-mountain slopes especially toeslopes.	Deep, well-drained soils with loam or silt loam surface layers high in volcanic ash and very gravelly to extremely gravelly loam or sandy loam subsoils.	Conifer forest ranging from Douglas-fir to subalpine fir.
LC3/LC5	DEEP AND MODERATELY DEEP COLLUVIAL SOILS ON LIMESTONE	Cirque basins and lower glaciated trough walls	A complex of deep and moderately deep, well-drained soils with loam or silt loam surface layers high in volcanic ash and very gravelly to extremely gravelly loam or sandy loam subsoils.	Subalpine fir, lodgepole pine, spruce, huckleberry, beargrass.
LC4/LC6	SHALLOW SOILS AND ALPINE MEADOW SOILS ON LIMESTONE	High elevation sites.	A complex of shallow, well-drained soils and alpine meadow soils.	Shallow soil: stunted conifer trees, shrubs. Meadow: grasses, sedges, forbs.
LC5/LC4	MODERATELY DEEP AND SHALLOW LIMESTONE SOILS	Upper mountain slopes and trough walls	A complex of moderately deep and shallow, well-drained soils with loam or silt loam surface layers high in volcanic ash and very gravelly to extremely gravelly loam or sandy loam subsoils. Fractured bedrock below.	Subalpine fir, whitebark pine, spruce, lodgepole pine, grouse whortleberry, elk sedge.
LC6	ALPINE MEADOW SOILS ON LIMESTONE	High elevation sites.	Well-drained alpine meadow soils.	Grasses, sedges, forbs sometimes with scattered, stunted shrubs and trees.
LC9/LC5	SHALLOW GRASSLAND SOILS AND MODERATELY DEEP COLLUVIAL SOILS ON LIMESTONE	Lower elevation mountain slopes on south aspects with limestone bedrock.	A complex of well-drained, shallow grassland soils and moderately deep colluvial soils. Both have loam or silt loam surface layers and extremely gravelly sandy loam subsoils. Fractured bedrock below.	Shallow soil: grasses and scattered shrubs. Moderately deep soil: Douglas fir, subalpine fir, shrubs such as serviceberry, huckleberry, ceanothus, spirea and others.

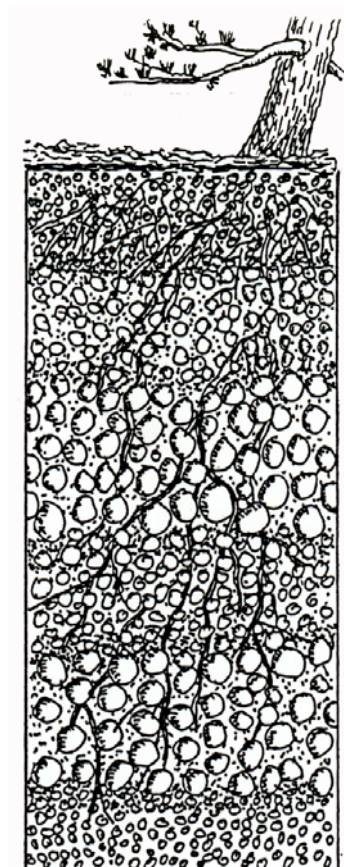
3.2.1 ALLUVIAL SOILS

Alluvial soils are those formed in deposits left by streams. These include soils recently deposited by current streams and those deposited by glacial outwash streams at the end of the last ice age. Alluvial soils are mapped across 27,682 acres (3%) of the park (Figure 2) but also occur as inclusions along streams running through most other units. These included areas are too small to delineate at the mapping scale used in this report.

The most common characteristics of these alluvial soils are their coarse textures, rapid permeability and low water and nutrient holding capacities. Streams carry fine clay and silt particles away leaving layers of sandy and rocky soil. The tumbling action of streams leaves rocks rounded and smooth. Alluvial soils near current streams, may be flooded or have shallow groundwater tables (seasonal or permanent).



Rocky alluvial soil along McDonald Creek.



A1 FLOODED SOILS

FLOODPLAINS AND LOW TERRACES

This unit is mapped across 10,867 acres along streams in valley bottoms throughout the park. It consists of flood plains and low stream terraces with deep sandy and gravelly alluvial soils. Vegetation is a mosaic including riparian tree, shrub, forb, grass and sedge communities as well as moist conifer forest types. Elevations are mainly 3000-5500 feet. The topography includes nearly level stream terrace surfaces with short, steep terrace edges and occasional old channels. Most slopes are 0 to 10 percent. Mean annual precipitation is 30 to 60 inches.

GEOLOGY

The parent material is gravelly and sandy alluvium deposited by streams in recent time. Rock types are predominantly quartzite and argillite with some limestone and occasional fragments of granitic rock. Rocks are well-rounded cobbles and gravels. These alluvial deposits are usually sorted into layers of similar-size fragments. There is tremendous vertical and horizontal variability in these deposits.

MAJOR SOIL (85% of unit):

A1 FLOODED SOILS

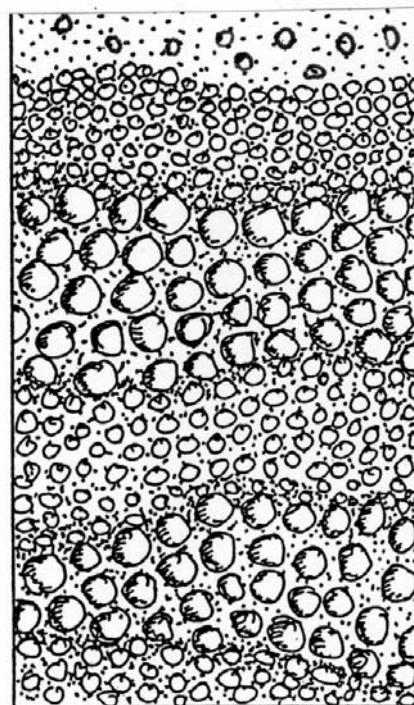
Frequently flooded, moderately well drained to poorly drained alluvial soils with highly variable profiles dominated by gravelly and sandy textures. Most profiles contain abundant, well-rounded gravels and cobbles. Rock content often increases significantly with depth. There is very little evidence of soil development due to the young age of these soils. Available water holding capacity is usually very low; .25 to .5 inch in the surface foot and 1.25 to 2.5 inches to a depth of five feet.

A1 PROFILE DESCRIPTION

These profiles are extremely variable, both horizontally and vertically due to depositional history. Very little profile development has occurred and most of the differences seen throughout the vertical profile is due to deposition. Most layers have very light colored, very sandy textures (sand, loamy sand). Rock content is usually very high

(extremely gravelly) but occasional discontinuous layers of relatively rock-free sandy soil may also occur. Rock-free surface layers sometimes are present especially in swales and backwater sloughs. Very thin, dark organic-rich layers may occur between other layers. The depth to bedrock is many feet.

A1 PROFILE ILLUSTRATION



SOIL CLASSIFICATION

Most soils in this unit are frequently flooded and are classified as Cryofluvents. Where they are wet for most of the year they are classified as Cryaquents.

VEGETATION

Vegetation is a mosaic dominated by riparian shrub and forest communities. Common shrubs and trees include willow (*Salix spp.*), dogwood (*Cornus stolonifera*), alder (*Alnus spp.*), silverberry (*Elaeagnus commutata*), gooseberry (*Ribes spp.*), cottonwood (*Populus trichocarpa*), aspen (*Populus tremuloides*) and spruce (*Picea engelmannii*). Conifer trees occur on the older portions of these units, especially spruce (*Picea engelmannii*),

Douglas-fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies lasiocarpa*). Other common plants include forbs, sedges (*Carex spp.*), rushes (*Juncus spp.*), and grasses especially reed canarygrass (*Phalaris arundinacea*). Non-vegetated recently flooded areas are common.

MINOR SOILS - INCLUSIONS

(15% of unit):

- **Soils which are rarely flooded** on higher portions of the unit.
- **Soils with dark loam or silt loam surface layers**, usually in old meander channels.
- **Recent, non-vegetated flood deposits** dominated by gravel, cobbles and sand.

INTERPRETATIONS

Productivity and revegetation potentials for these soils are generally low due to the sandy texture, high rock content and low water and nutrient holding capacity. Organic matter content is low and often varies irregularly with depth. Productivity and revegetation are much better where shallow seasonal groundwater occurs near the surface.

This unit has a low potential for **road** and **trail** construction due to flooding and a seasonal high water table over much of the unit. This unit is a good source of gravelly and sandy soil material for road or trail construction.

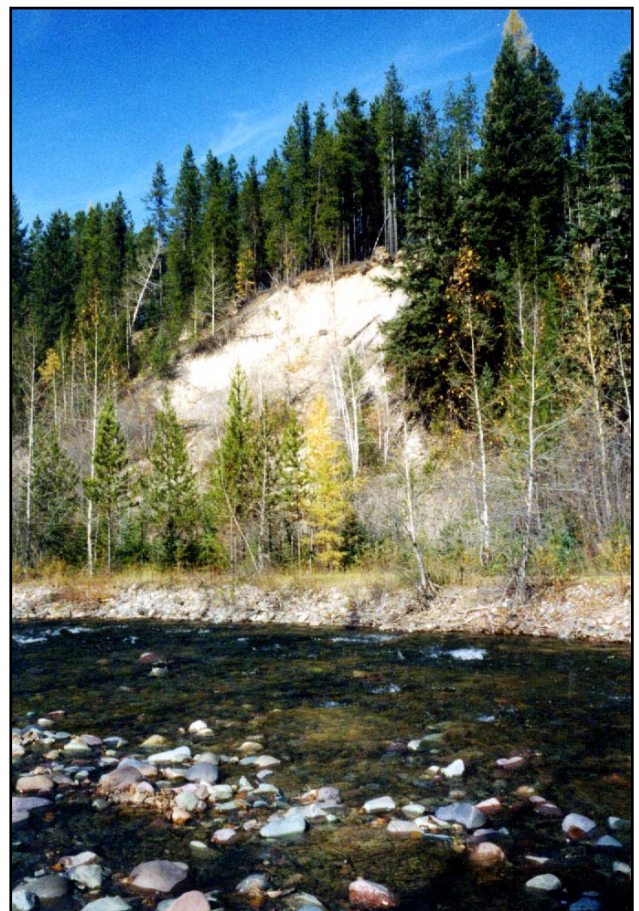
This soil is highly susceptible to **weed infestation** when disturbed. Disturbance is common due to flooding. Weed infestation is most related to: the availability of disturbed soil, soil texture (rocky and sandy), open canopy conditions, a weed seed source and elevation. The most common weeds are spotted knapweed and goatweed.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential overall. However, sandy rock-free layers have a high erosion potential.

This unit is rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems. Flooding, very rapid permeability and seasonal high groundwater limit sewage disposal options on these sites.



Alluvial soils on a low terrace along the Camas Creek Floodplain.



Alluvial soils on a low terrace along the north fork of the Flathead River.

A2 ROCKY AND SANDY ALLUVIAL GRASSLAND SOILS FANS AND HIGH TERRACES

This unit is mapped across 2,868 acres along streams and near the confluence of streams. It mainly occurs on glacial outwash terraces, alluvial fans and high stream terraces with deep sandy, gravelly and loamy alluvial soils. Vegetation is mainly fescue grassland with scattered shrubs and trees. Elevations are 3500-5000 feet. Slopes are 2 to 20 percent. Mean annual precipitation is 30 to 40 inches.

GEOLOGY

The parent material is gravelly, sandy and loamy alluvium. The outwash terraces were deposited by glacial outwash streams at the end of the last ice age. The alluvial fans and high terraces were deposited by current streams since deglaciation. Rock types are predominantly quartzite and argillite with some limestone and occasional fragments of granitic rock. Rocks are well-rounded gravels and cobbles. Some of the fine soil material was deposited by wind and includes volcanic ash.

MAJOR SOIL (85% of unit):

A2 ROCKY AND SANDY ALLUVIAL GRASSLAND SOILS

These deep, well-drained grassland alluvial soils have a very dark surface layer. They are dominated by loam or sandy loam textures with abundant, well-rounded gravels and cobbles. Rock content increases significantly with depth. Available water holding capacity is moderate; .5 to 1 inch in the surface foot and 2 to 3 inches to a depth of five feet.

Where this soil is mapped near Sullivan and Hidden Meadows, it has silt loam or loam textures and may have few rock fragments in the upper profile. Where this soil is mapped along the eastern border of the park it may have a subsoil layer enriched with calcium carbonate (lime).

A2 PROFILE DESCRIPTION

SURFACE - Very dark brown to very dark grayish brown loam or sandy loam with 10-20% rock 10-14 inches thick (A horizon).

SUBSOIL - Brown or dark grayish brown, very gravelly loam or sandy loam with 35-60% rock fragments 15-35 inches thick (Bw horizon).

SUBSTRATUM - Brown, extremely gravelly sandy loam with 60-80% rock fragments (C horizon). The depth to bedrock is many feet.

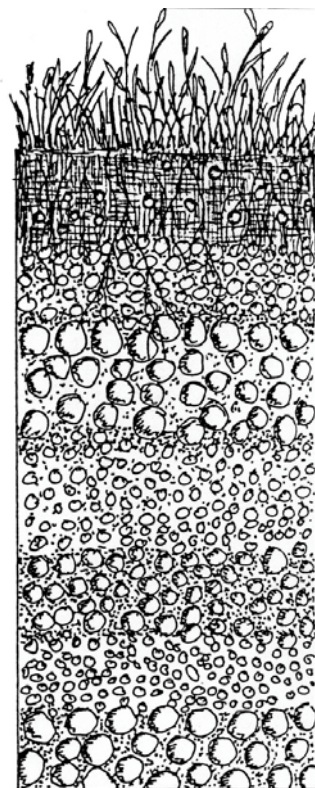
SOIL CLASSIFICATION

Most soils in this unit are classified as loamy-skeletal, mixed Typic Haplocryolls.

VEGETATION

Vegetation is mainly fescue grassland dominated by rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), Richardson's needlegrass (*Stipa richardsonii*), prairie junegrass (*Koeleria cristata*), sticky geranium (*Geranium viscosissimum*) and lupine (*Lupinus spp.*). Scattered shrubs include shrubby cinquefoil (*Potentilla fruticosa*), chokecherry (*Prunus virginiana*), serviceberry (*Amelanchier alnifolia*), mountain big sagebrush (*Artemesia tridentata-vaseyana*) and rose (*Rosa woodsii*).

A2 PROFILE ILLUSTRATION



MINOR SOILS - INCLUSIONS (15% of unit):

- Well-drained soils with silty clay loam or clay loam subsoils (**G6**) usually near the unit border.
- **Well-drained soils with very thick dark surface layers** in concave areas and on toeslopes. Some of these have thick, rock-free surface layers (Pachic Haplocryolls).
- Non-vegetated flood deposits (**A1**) along current streams and overflow channels.

INTERPRETATIONS

Productivity and revegetation potentials for these soils are moderate to high overall but decreases in the subsoil due to higher rock content and lower water and nutrient holding capacity. Organic matter, microbial activity and available nutrient levels also decrease rapidly with depth.

This soil is well suited to **road and trail** construction due to a high subsoil rock content and good drainage.

This soil is highly susceptible to **weed infestation** when disturbed. Weed infestation is most common with: disturbed soil, (especially rocky and sandy textures), open canopy conditions, a weed seed source, south aspects and lower elevations. Weeds are more successful on exposed subsoils. Soil disturbance by animal burrowing is very common in this unit.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential.

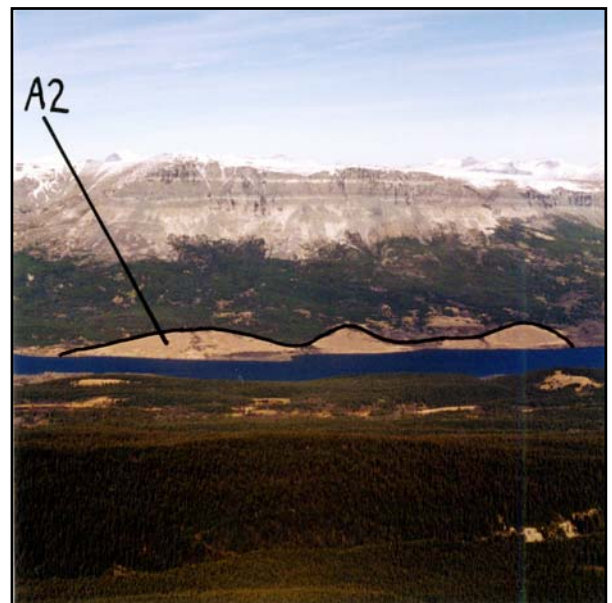
This soil is rated as having moderate potential for **waste disposal** using traditional septic tank and drainfield systems. Gravelly, sandy subsoils have rapid permeability and provide poor wastewater filtration. Water quality impacts are a concern especially if groundwater or surface water distances are small.

Soil education highlights include:

- The dark, high-organic matter content grassland surface soil. This is the zone of most intense biological and chemical activity.
- The grassland vegetation resulting from the coarser soil textures than surrounding soils with aspen (*Populus tremuloides*) and conifer vegetation.
- Animal burrows and exposed subsoil material, often with invader weeds. Animal mixing of surface soil layers.



Grassland alluvial soil with dark surface layer and white lime accumulation in subsoil.



Grassland alluvial soils on alluvial fans at Two Dog Flats.

A3 ROCKY AND SANDY ALLUVIAL FOREST SOILS FANS AND TERRACES

This unit is mapped across 3,699 acres along streams and near the confluence of streams. It consists of alluvial fans and stream terraces with deep sandy and gravelly alluvial soils. Vegetation is mainly conifer forest, especially lodgepole pine (*Pinus contorta*). Elevations are 3000-5500 feet. Slopes are 2 to 20 percent. Mean annual precipitation is 30 to 60 inches.

MAJOR SOIL (85% of unit):

A3 ROCKY AND SANDY ALLUVIAL FOREST SOILS

These deep, well-drained forest alluvial soils usually have a thin, light colored surface layer. They are dominated by sandy loam or loam textures in the surface and sandy loam to sand in the subsoil. There are abundant, well-rounded gravels and cobbles throughout these soils and rock content increases significantly with depth. Available water holding capacity is low; .5 to .75 inch in the surface foot and 2 to 3 inches to a depth of five feet.

A3 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1-2 inches thick (O horizon). Brown or grayish brown gravelly to very gravelly sandy loam or loam with 20-40% rock 10-14 inches thick (A horizon).

SUBSOIL - Brown, very gravelly to extremely gravelly sandy loam with 40-70% rock fragments 15-35 inches thick (Bw horizon).

SUBSTRATUM - Brown, extremely gravelly sandy loam, loamy sand or sand with 60-80% rock fragments (Bw or BC horizon). The depth to bedrock is many feet.

GEOLOGY

The parent material is gravelly, sandy and loamy alluvium. The alluvial fans were deposited by current streams in recent time. The high terraces were deposited by glacial outwash streams at the end of the last ice age or by current streams since de-glaciation ended. Rock types are predominantly quartzite and argillite with some limestone and occasional fragments of granitic rock. Rocks are well-rounded gravels and cobbles. Some of the fine soil material was deposited by wind and includes volcanic ash.

Soils of Glacier National Park
Land & Water Consulting, Inc./B. Dutton and others/01-08-2001

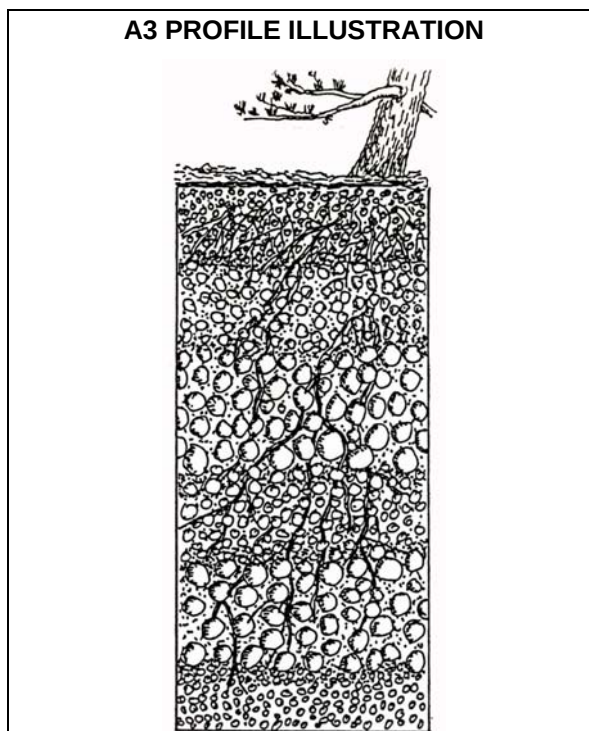
SOIL CLASSIFICATION

Most soils in this unit are classified as loamy-skeletal, mixed Typic Dystrocrypts. Very sandy profiles are classified as sandy-skeletal Typic Dystrocrypts.

VEGETATION

Vegetation is mainly conifer forest dominated by lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*). Grand fir (*Abies grandis*), white pine (*Pinus monticola*), hemlock (*Tsuga heterophylla*) and cedar (*Thuja plicata*) also occur in small amounts. The understory includes queen's cup beadlily (*Clintonia uniflora*), pinegrass (*Calamagrostis rubescens*), dwarf huckleberry (*Vaccinium cespitosum*), blue huckleberry (*Vaccinium globulare*), Oregongrape (*Berberis repens*), beargrass (*Xerophyllum tenax*) and other plants.

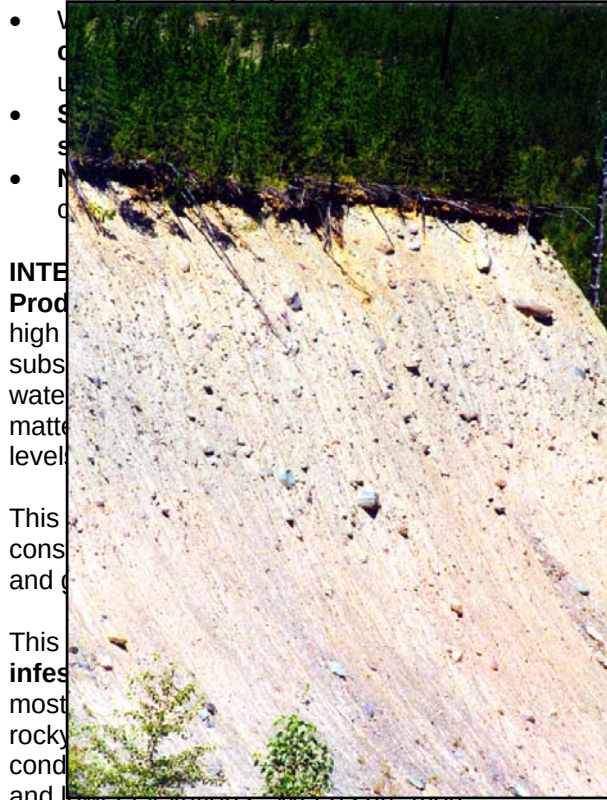
A3 PROFILE ILLUSTRATION



MINOR SOILS - INCLUSIONS

(15% of unit):

- Well-drained **soils with a rock-free sandy loam surface layer** over a cobbly and sandy subsoil (**A4**).



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Alluvial forest soil along the middle fork of the Flathead River.

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has a moderate erosion potential.

This soil is rated as having moderate potential for **waste disposal** using traditional septic tank and drainfield systems. Gravelly, sandy subsoils have rapid permeability and provide poor wastewater filtration. Water quality impacts are a concern especially if groundwater or surface water distances are small.

Soil education highlights include:

- The layer of organic litter on the soil surface which protects it from erosion.
- The high rock content which results in low water and nutrient holding capacity.
- The rocks are a mix of types carried from various parts of the drainage.
- Animal burrows and exposed subsoil material, often with invader weeds. Animal mixing of surface soil layers.



Rocky alluvial forest soil on a high glacial outwash terrace near Many Glacier.

OTHER MAPPING UNITS

A3/A4 MIXED ALLUVIAL FOREST SOILS FANS AND TERRACES

Mixed alluvial forest soils are mapped as a complex over 9,214 acres of the park. This mapping unit occurs mainly on outwash and more recent terraces of the North Fork of the Flathead River. It is dominated by sandy alluvium with a rock-free surface layer. Flooded soils, rocky alluvial soils and wet mineral soils are other components of this unit. Vegetation is dominated by conifer forest. Elevations are 3100-5000 feet. The overall topography is nearly level to moderately steep with most slopes in the 2 to 10 percent range. Mean annual precipitation is 30 to 60 inches.

MAJOR SOILS - COMPLEX

This unit is a complex of two main soils but includes others in minor amounts. The most common is the Rocky, Sandy Alluvial Forest soil (A3) that occupies approximately 40% of the unit. The other most common soil is the Sandy Over Rocky Forest Alluvial Soil (A4) which occupies approximately 40% of the unit.

VEGETATION

Vegetation is mainly conifer forest dominated by lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*). Grand fir (*Abies grandis*), white pine (*Pinus monticola*), hemlock (*Tsuga heterophylla*) and cedar (*Thuja plicata*) also occur in small amounts. The understory includes queen's cup beadlily (*Clintonia uniflora*), pinegrass (*Calamagrostis rubescens*), dwarf huckleberry (*Vaccinium cespitosum*), blue huckleberry (*Vaccinium globulare*), Oregongrape (*Berberis repens*), beargrass (*Xerophyllum tenax*) and other plants.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Soils with rock-free silt loam surface layers.**
- **Wet mineral soils (W1)** in depressions, near water, toeslopes.
- **Flooded Alluvial soils (A1)** near streams.

A4 SANDY OVER COBBLY ALLUVIAL FOREST SOILS TERRACES AND FANS

This soil is mapped alone on only 834 acres near West Glacier. Most of this soil is mapped in complex with the A3 unit. It mainly occurs along the forks of the Flathead River. It includes glacial outwash terraces and more recent alluvial fans and terraces with deep sandy and gravelly alluvial soils. Vegetation is mainly conifer forest, especially lodgepole pine (*Pinus contorta*). Elevations are 3000-5000 feet. Slopes are 2 to 20 percent. Mean annual precipitation is 30 to 60 inches.

A4 SANDY OVER COBBLY ALLUVIAL FOREST SOILS

These deep, well-drained forest alluvial soils usually have a thin, light colored surface layer. They are dominated by sandy loam textures in the surface and sandy loam to sand in the subsoil. The surface layer has few or no rock fragments to a depth of 10-30 inches. Rock fragments are abundant below and consist of well-rounded gravels and cobbles. Where mapped near West Glacier this soil may have a silt loam or silty clay loam surface layer. Available water holding capacity is low; .5 to 1 inch in the surface foot and 2 to 4 inches to a depth of five feet.

A4 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1-2 inches thick (O horizon). Brown or grayish brown sandy loam or loam with 20-40% rock 5-10 inches thick (A horizon).

SUBSOIL - Brown sandy loam with 5-25 inches thick (Bw horizon).

SUBSTRATUM - Brown, extremely gravelly sandy loam, loamy sand or sand with 60-80% rock fragments (Bw or BC horizon). The depth to bedrock is many feet.

GEOLOGY

The parent material is gravelly, sandy and loamy alluvium. The alluvial fans were deposited by current streams in recent time.

The high terraces were deposited by glacial outwash streams at the end of the last ice age or by current streams since de-glaciation ended. Rock types are predominantly quartzite and argillite with some limestone and occasional fragments of granitic rock. Rocks are well-rounded gravels and cobbles. Some of the fine soil material was deposited by wind and includes volcanic ash.

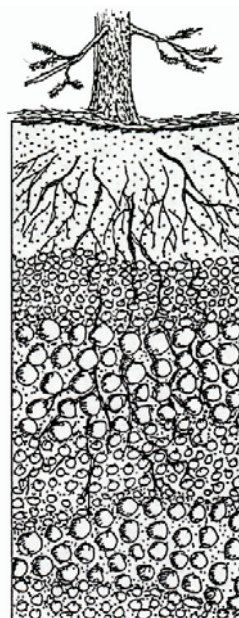
SOIL CLASSIFICATION

Most soils in this unit are classified as loamy-skeletal, mixed Typic Dystrocrepts. Very sandy profiles are classified as sandy-skeletal Typic Dystrocrepts.

VEGETATION

Vegetation is mainly conifer forest dominated by lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*). Grand fir (*Abies grandis*), white pine (*Pinus monticola*), hemlock (*Tsuga heterophylla*) and cedar (*Thuja plicata*) also occur in small amounts. The understory includes queen's cup beadlily (*Clintonia uniflora*), pinegrass (*Calamagrostis rubescens*), dwarf huckleberry (*Vaccinium cespitosum*), blue huckleberry (*Vaccinium globulare*), Oregongrape (*Berberis repens*), beargrass (*Xerophyllum tenax*) and other plants.

A4 PROFILE ILLUSTRATION



INTERPRETATIONS

Productivity and revegetation potentials are high in the surface soil and moderate in the subsoil due to higher rock content and lower water and nutrient holding capacity. Organic matter, microbial activity and available nutrient levels also decrease rapidly with depth.

This soil is well suited to **road** and **trail** construction due to a high subsoil rock content and good drainage.

This soil is highly susceptible to **weed infestation** when disturbed. Weed infestation is most common with: disturbed soil (especially rocky and sandy textures), open canopy conditions, a weed seed source, south aspects and lower elevations. Weeds are more successful on exposed subsoils.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential.

This soil is rated as having moderate potential for **waste disposal** using traditional septic tank and drainfield systems. Gravelly, sandy subsoils have rapid permeability and provide poor wastewater filtration. Water quality impacts are a concern especially if groundwater or surface water distances are small.

Soil education highlights include:

- The layer of organic litter on the soil surface which protects it from erosion.
- The high rock content which results in low water and nutrient holding capacity.
- The rocks are a mix of types carried from various parts of the drainage.
- Animal burrows and exposed subsoil material, often with invader weeds. Animal mixing of surface soil layers.

A6 LAKESIDE BEACH SOILS SHORES OF LARGE LAKES

This soil is mapped across approximately 200 acres along the shoreline of Lake McDonald. It consists of low beach terraces with deep sandy and gravelly soils. This soil also occurs around other lakes but not in areas large enough to delineate at this scale. Vegetation is dominated by moist conifer forest types dominated by lodgepole pine (*Pinus contorta*), grand fir (*Abies grandis*) and other conifers. The immediate shoreline is not vegetated and is not considered soil. Elevations are mainly 3100-3200 feet. The topography includes nearly level beach terrace surfaces with short, steep terrace edges facing the lake. Most slopes are 0 to 10 percent. Mean annual precipitation is 30 to 60 inches.

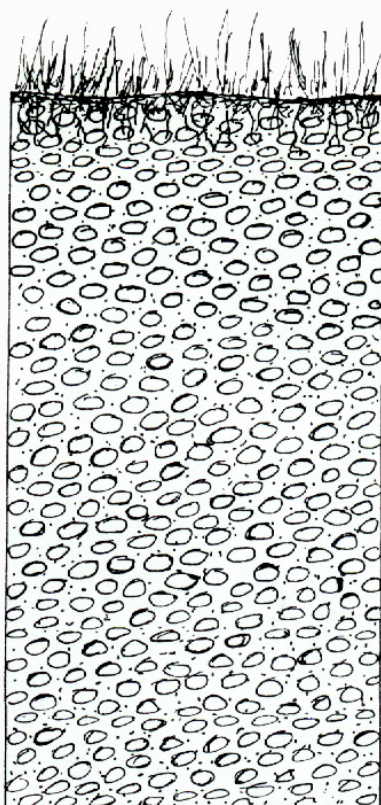
GEOLOGY

The parent material is dominated by gravel size rounded rocks all of which are similar in size (approximately 1-2 inch diameter). These rocks have been worked by wave action in recent time. Rock types are predominantly quartzite and argillite with some limestone and occasional fragments of granitic rock.

MAJOR SOIL (90% of unit):

A6 BEACH SOILS

Rarely flooded, well drained soils dominated by gravel of uniform size. The fine soil material is sandy in texture. There is limited evidence of soil development due to the young age of these soils. Available water holding capacity is usually very low; .25 to .5 inch in the surface foot and 1.25 to 2.5 inches to a depth of five feet.



Soils of Glacier
Land & Water

A6 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1 inch thick (O horizon). Pale brown or dark yellowish brown very gravelly loamy sand or sandy loam with 50-60% rock 1-3 inches thick (A horizon).

SUBSOIL - Brown, very gravelly loamy sand with 50-70% rock fragments 10-15 inches thick (C or BC horizon).

SUBSTRATUM - Brown, extremely gravelly loamy sand or sand with 50-70% rock fragments (C horizon). The depth to bedrock is many feet.

SOIL CLASSIFICATION

Most soils in this unit are classified as Typic Cryorthents unless there is a definite B horizon in which case they are classified as Typic Dystrocryepts.

VEGETATION

Vegetation is dominated by conifer forest especially grand fir (*Abies grandis*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*). Almost every other conifer

species is present except alpine larch (*Larix lyallii*), mountain hemlock (*Tsuga mertensiana*) and limber pine (*Pinus flexilis*). Riparian trees, shrubs and forbs are also present especially near the shoreline. Common shrubs include willow (*Salix spp.*), dogwood (*Cornus stolonifera*), alder (*Alnus spp.*) and huckleberry (*Vaccinium spp.*). A non-vegetated area is present along the shoreline.

MINOR SOILS - INCLUSIONS

(15% of unit):

- **Soils which are rarely flooded** on higher portions of the unit.
- **Wet mineral soils (W1)** in depressions and near water.

INTERPRETATIONS

Productivity and revegetation potentials for these soils are generally moderate. The sandy texture and high rock content give these soils low water and nutrient holding capacities, however, they are in a high precipitation zone. Organic matter content is low.

This unit has a high potential for **road** and **trail** construction due to its rocky and sandy nature. This unit is a good source of gravelly and sandy soil material for road or trail construction but the lakeshore location may make removal a significant visual impact. This soil has special significance to backcountry campers despite its small extent. Many lakeshore backcountry campgrounds on the larger lakes are located on this soil which provides an excellent, well-drained site.

This soil is highly susceptible to **weed infestation** when disturbed. Weed infestation is most related to: the availability of disturbed soil, soil texture (rocky and sandy), open canopy conditions, a weed seed source and elevation. The most common weeds are spotted knapweed and goatweed.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a low to moderate erosion potential overall due to the high rock content.

This unit is rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems. The very rapid permeability and proximity to groundwater limit sewage disposal options on these sites.



Beach soil along the McDonald Lake shoreline.



Uniform size gravels in beach soil.

3.2.2 WET SOILS

Approximately 4,686 acres of wet soils are mapped as discrete units in this park (<1%). Many additional wet soil areas occur but are too small to delineate at this map scale. Wet soils are extremely important despite their small extent. Wet soils provide important habitat for waterfowl and other wildlife. They filter sediment and other pollutants from runoff and store water for late season stream flows. Wet soils also contain historical records of past vegetation (pollen) and volcanic activity (ash).

For the purpose of this report, wet soils are defined as those that have shallow water tables at or near the surface for part of the year (somewhat poorly drained soils) and for the entire year (poorly drained and very poorly drained soils). These soils are classified as hydric in the USDA soil classification system and have features such as gleyed colors (grayish colors indicating oxygen-deficient conditions), dark, organic-rich layers, and oxymorphic features or mottles (rust spots indicating alternating reducing and oxidizing conditions). Although many soils in the park are 'wet' or saturated during a brief period at snowmelt, they dry out quickly and are not considered wet soils in this report.

As soils become increasingly wet, soil properties change in a somewhat predictable manner. First, wetness inhibits organic matter decomposition so the organic matter content increases, especially in the surface layer where roots concentrate. This gives the soil a very dark, often almost black color in the surface layer. If the high water table is seasonal and the soil is subject to alternating oxidizing and reducing conditions, rust mottles can form. Iron concentrates under reducing conditions and then these concentrations oxidize (rust).

If the high water table is persistent throughout most or all of the year, the soil acquires a grayish (gleyed) color instead of the brownish colors of well-drained soils. If wetness persists throughout the soil profile and at the surface for long periods, organic matter will accumulate to form an actual organic soil such as peat or muck. Since many wet site plant roots release oxygen

around their roots, wet soils may also have oxidized rhizospheres (rust spots around roots).

GENERAL SOIL WETNESS RELATIONSHIPS

DRIER			WETTER	
Brown Colors	Black Colors	Rust Mottles	Gley Colors (gray)	Organic Soils
DRAIN CLASS				
Well	Moderately well	Some-what poorly	Poorly	Very poorly
TAXON				
Typic	Oxyaquic subgroup	Aquic subgroup	Aquic suborder	Histosols

Vegetation is also a good indicator of wet soils. Vegetation which reflects wetter conditions than the surrounding can be an initial indicator of wet soils. For instance, devil's club (*Oplopanax horridum*) often grows on wet soil inclusions within glacial till landscapes. Some vegetation itself reflects wet conditions including many sedges (*Carex spp.*), rushes (*Juncus spp.*), cattails (*Typha latifolia*) and other plants. Other plants such as aspen (*Populus tremuloides*), cottonwood (*Populus trichocarpa*) and spruce (*Picea engelmannii*) may, but do not always indicate wet conditions.

No organic (Histosol) soils were observed during this inventory. All wet soils observed had sufficient mineral content to classify as mineral soils. Most wet soils contained layers of volcanic ash that have been correlated to eruptions of Mt. Mazama (Crater Lake), Mt. St. Helens, Glacier Peak and other west coast volcanoes. Many alpine soils were saturated during the early growing season but dried completely by mid-summer. Some wet soils were caused by water tables perched on impermeable layers. These layers included compacted till and clay-enriched materials. These soils have mainly been classified in the oxyaquic or argiaquic subgroups to indicate their elevated wetness status.

W1 WET MINERAL SOILS DEPRESSIONS, STREAMSIDES, TOESLOPES

This unit is mapped across 4,686 acres of wet soils throughout the park. It includes a variety of wet soils that have shallow water tables at or near the surface for at least part of each year. Wetness is the dominant feature of these soils and the main influence on soil properties. Vegetation is mainly riparian shrubs, sedges (*Carex spp.*), rushes (*Juncus spp.*) and forbs but also may include deciduous and conifer trees. Elevations are mainly 3000-7000 feet. Slopes are 0 to 5 percent. Mean annual precipitation is 30 to 100 inches.

GEOLOGY

The parent material is varied including alluvium, glacial drift, landslide deposits, windblown materials, residuum and colluvium. Where the deposit is till, alluvium, residuum or colluvium, they usually contain quartzite and argillite rock fragments. Limestone and other rocks occur locally. Glacial drift deposits may or may not have rocks. Rocks are also lacking in windblown deposits. These areas are usually classified as fens. Cores have been taken from some of these sites and examined to reveal the vegetative, climatic and volcanic ashfall history of the past 10,000 years (Carrara 1990).

SOIL CLASSIFICATION

Most soils in this unit are classified as Cryaquolls where the surface is dark or Cryaquepts where it is not. Fine loamy, coarse loamy and loamy skeletal particle size families are most common.

MAJOR SOIL (90% of unit):

W1 WET SOILS

These poorly to very poorly drained soils have very dark, organic-rich silty or loamy surface layers. Subsoils are usually grayish with silt loam to sandy loam textures. These soils often have vertical stratification into layers of distinct color, texture, organic content and rock content. Some profiles contain thin, dark layers of partially decomposed buried organic materials. Mottles and gley colors are present in many subsoils. Gravelly subsoil layers are present in some profiles. Available water holding capacity is usually very high

due to the high silt and organic content; 2 inches in the surface foot and 8-10 inches to a depth of five feet.

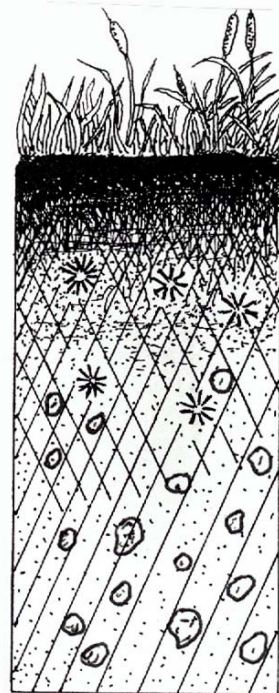
W1 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed plant litter 1-2 inches thick. (O Horizon) The surface soil is very dark gray or very dark grayish brown silt loam with 0-20% rock (6-12 inches thick). The surface layer usually has significant volcanic ash and may have a turf-like root mat. (A Horizon)

SUBSOIL - Dark grayish brown to dark gray, silt loam with 0-20% rock fragments (5-10 inches thick). Yellowish red mottles and oxidized root channels are common in most profiles. (Bg Horizon)

SUBSTRATUM - Gray to light brownish gray silt loam to sandy loam with 10-30 percent rock fragments. Some profiles have thin discontinuous layers of sand or extremely gravelly sand. (Cg Horizon) The depth to bedrock is many feet.

W1 PROFILE DESCRIPTION



VEGETATION

Vegetation on these wetland soils is often a mosaic of riparian and wetland species. Some areas may be dominated by one plant. Wetland mosaics often include a wide mix of shrubs, sedges (*Carex spp.*), grasses and forbs. Deciduous trees such as cottonwood (*Populus trichocarpa*), birch (*Betula spp.*) and aspen (*Populus tremuloides*) as well as conifers such as spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) often grow on slightly drier microsites within these units. Shrubs include a variety of willows (*Salix spp.*), dogwood (*Cornus stolonifera*), alder (*Alnus spp.*), silverberry (*Elaeagnus commutata*) and gooseberry (*Ribes spp.*). Other common plants are forbs such as large-leaved avens (*Geum macrophyllum*), horsetails (*Equisetum spp.*), mint (*Mentha spp.*) and cattails (*Typha latifolia*). Reed canarygrass (*Phalaris arundinacea*) and other grasses as well as rushes (*Juncus spp.*), beaked sedge (*Carex rostrata*) and other sedges (*Carex spp.*) are also common. Plants which dominate wet soils as almost monocultures include cattails (*Typha latifolia*), bulrush (*Scirpus spp.*) and beaked sedge.

MINOR SOILS - INCLUSIONS

(10% of unit):

- Soils with better drainage on slightly higher microsites. (Aquic, Oxyaquic and Typic subgroups of Cryepts, Orthents and Cryolls).
- Organic soils (Histosols).
- Frequently flooded soils (A1) near stream channels.
- Wet soils with high clay contents (Argic Cryaquolls).
- Open water.

INTERPRETATIONS

Productivity and revegetation potentials for these soils are very high due to the high water table, high organic content, silty soil texture and high nutrient holding capacity.

This unit has a low potential for **road** and **trail** construction due to wetness, silty texture and low rock content.

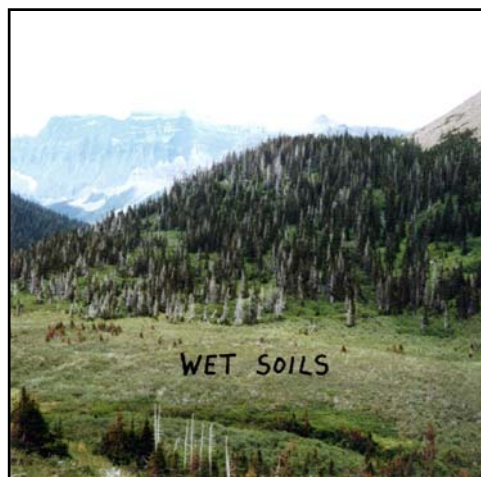
This soil is moderately susceptible to **weed infestation** when disturbed. Canada thistle is a special problem on some sites.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a low erosion potential when disturbed due to nearly level slopes. These sites revegetate quickly.

This unit is rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to wetness and the potential for water quality impacts.



Wet soils with shrub vegetation near Many Glacier.



Wet alpine soils with sedge and forb vegetation near Iceberg Lake.

3.2.3 GLACIAL, LANDSLIDE, AND MIXED SOILS

Glacial, landslide and mixed soils are mapped across 397,015 acres (39%) of the park (Figure 2). These soils formed in glacial till (material carried by ice or pushed by ice) or glacial drift (a mixture of semi-sorted till, outwash and lake deposits). Since glacial ice can transport a wide variety of materials and sizes, these soils contain a heterogeneous mixture of all rock sizes as well as sand, silt and clay. Rocks are semi-rounded from transport by ice. Volcanic ash has been added to the surface of these soils by a number of west coast volcanoes.

Glacial, landslide and mixed soils cover over one-half of the park. Most of these soils are derived from a mixture of rock types dominated by Precambrian quartzite and argillite (very old, hard sandstone and hard mudstone). These rocks usually weather to soils with sandy loam textures. However, in this area wind deposits, especially, volcanic ash has added sufficient silt particles to produce loam soil textures.

A small portion of the till soils (<1% of park) are derived mainly from Precambrian limestone bedrock. The addition of volcanic ash has not changed these limestone textures since they are already silty and loamy. Because the Precambrian limestone does not have a very high lime (calcium carbonate) content and since the climate is moist, these soils do not usually have significant accumulations of lime. However, some profiles have lower horizons with pH levels of 7.5 - 8.0 and weak to moderate reaction to dilute hydrochloric acid. These limestone till soil features have important effects on vegetation.

Local glacial soils have loam or silt loam textures, moderate rock contents and relatively high moisture and nutrient holding capacities.

Glacial landscapes have complex soil distributions, often represented by a mosaic of soil texture, rock content and ash surfaces as well as random inclusions of rock outcrop, shallow soils, alluvial soils, wet soils and others. Conditions may change rapidly across

short distances and require very site-specific investigation to evaluate soil relationships with other resources or uses.



G 1 POORLY DEVELOPED SOILS RECENT GLACIAL MORAINES

This unit is mapped across 282 acres just below current glaciers and large snowfields in cirque basins. It includes bouldery glacial drift deposited by small advances of existing glaciers in the last 10,000 years. Very little soil development is present in these deposits. Vegetation is sparse and dominated by alpine invader forbs and grasses. Elevations are mainly 6000-8000 feet. Slopes are mainly 25 to 65 percent. Mean annual precipitation is 70 to 100 inches.

GEOLOGY

The parent material is stony sandy loam glacial drift derived from quartzite and argillite rock. Rock fragments are semi-rounded and not sorted by size.

MAJOR SOILS (95% of unit):

Young, deep, well drained soils with little profile development. Many sites have a rock pavement caused by erosion of the fine soil particles. There is a slight darkening of the surface few inches but little other profile differentiation. Most of these materials are extremely stony sandy loam. Extremely stony loamy sand or sand textures are also common, especially in the deeper layers. Available water holding capacity is usually low due to the high rock and sand content; .25-.5 inches in the surface foot and 2-3 inches to a depth of five feet.

G1 PROFILE DESCRIPTION

SURFACE (A Horizon)

Intermittent surface rock pavement of stones, cobbles and gravels several inches thick.

Intermittent slight darkening of the surface few inches beneath the rock pavement especially where vegetation is denser.

SUBSTRATUM (C Horizon)

Extremely stony sandy loam and loamy sand soil material throughout the soil profile, usually becoming slightly coarser with increasing depth. The depth to bedrock is many feet.

Since these soils are very young and in a very cold climate, they show little profile development.

G1 PROFILE ILLUSTRATION



SOIL CLASSIFICATION

Most soils in this unit are classified as Typic Cryorthents. Loamy-skeletal and sandy-skeletal particle size families are most common.

VEGETATION

Vegetation is scattered individual plants dominated by alpine invader species. Common plants include alpine bluegrass (*Poa alpina*), alpine Timothy (*Phleum alpinum*), glacier lily (*Erythronium grandiflorum*), fireweed (*Epilobium spp.*), phacelia (*Phacelia spp.*), shrubby penstemon (*Penstemon fruticosus*) and Parry's rush (*Juncus parryi*).

MINOR SOILS - INCLUSIONS

(5% of unit):

Soils with color differentiation especially dark surface layers and developed brown subsoils which are less steep and more vegetated (Cryochrepts). Rock outcrop. Talus.

INTERPRETATIONS

Productivity and revegetation potentials for these soils are very low due to high rock content, coarse texture and resulting low nutrient holding capacity. The very cold climate and late snow cover also limits productivity and revegetation. Revegetation is significantly impeded by the rock pavement on the surface.

This soil material is well-suited to **road** and **trail** construction due to good drainage and coarse texture but most of these moraines have steep slopes and are snow covered most of the year which seriously restricts roads and trails.

This soil has a low susceptibility to **weed infestation** when disturbed due to the high elevation, cold climate and late snow cover.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to steep slopes. However, the rock pavement reduces the risk of further erosion.

This unit is rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to steepness, coarse texture, late snow cover and the potential for water quality impacts.

G2 SILTY CLAY LOAM GLACIAL SOILS

WIDE GLACIATED VALLEY BOTTOMS

This is the most common soil in the park and is mapped alone across 177,044 acres in the wide north fork valley. It is also mapped in complex with other glacial soils. It is dominated by ground moraine with a surface layer of volcanic ash-rich wind deposits. It occurs in complex with a variety of similar and contrasting soils. Vegetation is dominated by very productive moist conifer forests. Elevations are mainly 3000-5000 feet with some units ranging up to 6000 feet east of the divide. The overall topography is undulating with most slopes in the 5 to 25 percent range. Pit and mound micro-topography is common from tree wind throw. Mean annual precipitation is 40 to 80 inches.

GEOLOGY

The parent material is mainly glacial drift with very stony silty clay loam to sandy loam textures. The glacial drift appears to contain clay-rich, Tertiary-age sediments. These glacial materials are overlain by volcanic ash-rich wind deposits. Rock fragments are semi-rounded and are not sorted by size. Rock types are predominantly quartzite and argillite with small amounts of limestone and occasional fragments of granitic rock.

MAJOR SOIL (75% of Unit):

G2 SILTY CLAY LOAM GLACIAL TILL SOILS

This soil is deep, moderately well-drained and formed in silty clay loam glacial drift with an ash-rich surface layer. It has a silt loam or loam surface layer with 0-15% rock content. The subsoil is silty clay loam or clay loam with 5 - 50% rock. Rocks are semi-rounded gravels and cobbles with occasional stones and boulders. Rock content generally increases with depth. Available water holding capacity is high due to silt and clay content; 2 inches in the surface foot and 7-8 inches to a depth of five feet. The upper soil profile is saturated during and after snowmelt for a significant period. Some profiles have occasional weak subsoil mottling.

G2 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 2-3 inches

thick (O horizon). The upper surface soil has a thin grayish brown to pinkish gray colored layer of loam or very fine sandy loam with few rocks 1-2 inches thick (E horizon). The lower surface soil is mainly brown to dark yellowish brown silt loam or loam 6-12 inches thick with 0-15% rock fragments including gravel, cobbles, stones and boulders (Bs horizon). Significant volcanic ash influence is apparent.

SUBSURFACE - Brown gravelly loam or silty clay loam 6-20 inches thick with 10-30% rock (Bw horizon).

SUBSOIL - Brown or yellowish brown, very gravelly silty clay loam 12-24 inches thick with 25-45% rock fragments (Bt horizon).

SUBSTRATUM - Light brown or brown, very gravelly loam or sandy loam with 30-60% rock fragments (C horizon). The depth to bedrock is many feet.

G2 PROFILE ILLUSTRATION



VEGETATION

Vegetation is mainly moist subalpine fir climax forest with small areas of cedar (*Thuja plicata*) and hemlock (*Tsuga spp.*). Trees are mainly subalpine fir (*Abies lasiocarpa*), larch (*Larix spp.*), Douglas-fir (*Pseudotsuga menziesii*), spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*) with smaller amounts of grand fir (*Abies grandis*), white pine (*Pinus monticola*), cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) and cottonwood (*Populus trichocarpa*). Shrubs include gooseberry (*Ribes spp.*), devil's club (*Oplopanax horridum*), buffaloberry (*Shepherdia canadensis*), alder (*Alnus spp.*), menziesia (*Menziesia ferruginea*), and many others. Forbs include queen's cup beadleily (*Clintonia uniflora*), starry Solomon's seal (*Smilacina stellata*), bedstraw (*Gallium triflorum*), false hellebore (*Veratrum viride*), twinflower (*Linnaea borealis*), bunchberry dogwood (*Cornus canadensis*), wild sarsaparilla (*Aralia nudicaulis*) and many others. Grasses include bluejoint (*Calamagrostis canadensis*) and blue wildrye (*Elymus glaucus*).

SOIL CLASSIFICATION

This silty clay loam till soil is classified as an Oxyaquic Haplocryalf. Some profiles in drier landscape positions may be classified as Typic Haplocryalfs. The particle size family is mainly fine loamy but loamy skeletal profiles also occur.

MINOR SOILS - INCLUSIONS

(25% of unit):

- **Sandy glacial soils (G3)**
- **Wet mineral soils (W1)** in depressions and near open water.
- Well-drained **rocky and sandy alluvial soils (A3)**.
- **Floodplain and low terrace soils (A1)** along streams.
- Similar **soils with thick, low-density ash surfaces** (Andic Haplocryalfs or Andic Dystrocryepts) in concave areas.
- **Loamy soils with low rock content** (Coarse loamy Typic Dystrocryepts).
- **Beach soil deposits (A6)** dominated by small uniformly-sized gravels around large lakes.
- **Bedrock soils** near rock outcrops.

INTERPRETATIONS

Productivity and revegetation potentials are very high due to the fine texture and low rock content which result in very high moisture and nutrient holding capacity.

This soil is rated low for **road** and **trail** construction due to silty textures, periodic wet conditions and few rocks in the surface. Trail erosion is common and is often 6-10 inches deep. Special construction techniques are usually required to ensure a dry trail surface.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the silty surface soil texture and few rocks.

This soil is rated as having a high potential for **waste disposal** using traditional septic tank and drainfield systems due to the medium texture, low rock content and resulting high water and nutrient holding capacity.

Soil education highlights include:

- The volcanic ash-rich surface layer resulting mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- The undulating glacial till landscape and presence of glacial erratics (large boulders).
- Soil horizons, especially the surface litter layer which protects the soil from erosion.
- The tremendous productivity of this unit, especially the size and diversity of trees and the abundant understory.

OTHER MAPPING UNITS

G2/G3 MIXED GLACIAL SOILS WIDE GLACIATED VALLEY BOTTOMS

This unit is mapped across 12,409 acres in wide glaciated valley bottoms. It is dominated by ground moraine with a surface layer of volcanic ash-rich wind deposits. Alluvial soils, scoured bedrock and wet mineral soils are other important components of this unit. Vegetation is dominated by very productive moist conifer forest types. Elevations are 3000-6000 feet. The overall topography is undulating with most slopes in the 5 to 25 percent range. Pit and mound micro-topography is common from tree wind throw. Mean annual precipitation is 40 to 80 inches.

GEOLOGY

The parent material is mainly glacial drift with very stony silty clay loam to sandy loam textures. Both materials are overlain by volcanic ash-rich wind deposits. Rock fragments are semi-rounded and not sorted by size in the glacial drift. Rock types are predominantly quartzite and argillite with some limestone and occasional fragments of granitic rock. Also present in this unit is extremely gravelly sandy loam alluvium and outwash on stream terraces.

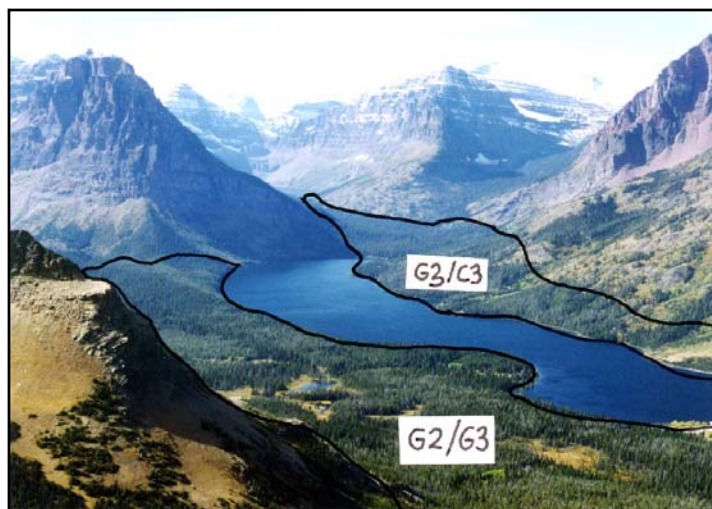
MAJOR SOILS - COMPLEX

This unit is a complex of two main soils but includes many others in smaller amounts. The silty clay loam glacial soil (G2) occupies approximately 40% of the unit. The sandy loam glacial till soil (G3) occupies approximately 40% of the unit. There is considerable variation in topography, vegetation, drainage, horizonation, and other soil related features.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Wet mineral soils (W1)** in depressions and near open water.
- Well-drained **rocky and sandy alluvial soils (A3)**.
- **Floodplain and low terrace soils (A1)** along streams.
- Similar **soils with thick, low-density ash surfaces** (Andic Haplocryalfs or Andic Dystrocryepts) in concave areas.
- **Loamy soils with low rock content** (Coarse loamy Typic Dystrocryepts).
- **Beach soil deposits** dominated by small uniformly-sized gravels around large lakes.
- **Bedrock soils** near rock outcrops.



Foreground: Complex of silty clay loam (G2) and sandy (G3) glacial soils.

Background: Complex of sandy glacial soils (G3) and deep colluvial soils.

G3 SANDY GLACIAL SOILS

WIDE GLACIATED VALLEY BOTTOMS

This soil is mapped alone across 10,958 acres in narrow, glaciated valleys. It is also mapped in complex with other glacial soils. It is most common on glaciated valley bottoms, on troughwalls and in cirque basins. The soil material is dominated by sandy glacial drift with a surface layer of volcanic ash-rich wind deposits. It occurs alone and in complex with a variety of similar and contrasting soils. Vegetation is dominated by moist conifer forest. Elevations are 3500-7500 feet. The overall topography is undulating to moderately steep with most slopes in the 15 to 45 percent range. Pit and mound micro-topography is common from tree wind throw. Mean annual precipitation is 40 to 75 inches.

GEOLOGY

The parent material is mainly glacial drift with very stony sandy loam to loam textures. These materials are overlain by volcanic ash-rich wind deposits with silt loam or loam textures. Rock fragments are semi-rounded and not sorted by size. Rock types are predominantly quartzite and argillite with small amounts of limestone and occasional fragments of granitic rock.

MAJOR SOIL (85% of unit):

G3 SANDY GLACIAL TILL SOILS

This soil is deep, well-drained and formed in loam and sandy loam glacial drift with an ash-rich surface layer. It has a sandy loam or loam surface layer with 0-15% rock content. The subsoil is very gravelly sandy loam or loam with 35 - 60% rock. Rocks are semi-rounded gravels and cobbles with occasional stones and boulders. Some surface layers are stony or bouldery. Otherwise, rock content generally increases with depth. Available water holding capacity is high due to silt and clay content; 1.5-2 inches in the surface foot and 5-7 inches to a depth of five feet.

G3 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 2-3 inches thick (O horizon). The upper surface soil has a thin grayish brown to pinkish gray colored layer of sandy loam or loam with few rocks 1-2 inches thick (E horizon). The lower surface

soil is mainly brown to reddish brown sandy loam or very fine sandy loam 6-12 inches thick with 0-20% rock fragments including gravel, cobbles, stones and boulders. Significant volcanic ash influence (Bs horizon).

SUBSURFACE - Brown to reddish brown, gravelly sandy loam or very fine sandy loam 6-18 inches thick with 10-30% rock (Bw).

SUBSOIL - Brown, very gravelly sandy loam 12-24 inches thick with 30-50% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, very gravelly sandy loam or loamy sand with 40-60% rock fragments (C horizon). The depth to bedrock is many feet.

G3 PROFILE ILLUSTRATION



VEGETATION

Vegetation is mainly moist subalpine fir climax forest. Trees are mainly subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*). Douglas-fir (*Pseudotsuga menziesii*), white pine (*Pinus*

monticola), cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) and larch (*Larix spp.*) occur at lower elevations. Whitebark pine (*Pinus albicaulis*) and alpine larch (*Larix lyallii*) occur at higher elevations. Common shrubs include blue huckleberry (*Vaccinium globulare*), grouse whortleberry (*Vaccinium scoparium*), buffaloberry (*Shepherdia canadensis*), alder (*Alnus spp.*), menziesia (*Menziesia ferruginea*), and many others. Forbs include queen's cup beadlelily (*Clintonia uniflora*), starry Solomon's seal (*Smilacina stellata*), bedstraw (*Gallium triflorum*), beargrass (*Xerophyllum tenax*), false hellebore (*Veratrum viride*), twinflower (*Linnaea borealis*), bunchberry dogwood (*Cornus canadensis*), Hitchcock's woodrush (*Luzula hitchcockii*), and many others. Other plants include elk sedge (*Carex geyeri*), bluejoint (*Calamagrostis canadensis*) and western fescue (*Festuca occidentalis*).

SOIL CLASSIFICATION

This loamy till soil is classified as a loamy-skeletal, mixed Typic Haplocryept.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Wet mineral soils (W1)** in depressions and near open water.
- Well-drained **rocky and sandy alluvial soils (A3)**.
- **Floodplain and low terrace soils (A1)** along streams.
- **Rock outcrop and associated shallow soils (C1, C4)** in convex landscape positions.
- Similar **soils with thick, low-density ash surfaces** (Andic Haplocryalfs or Andic Dystrocryepts) in concave areas and less steep areas.

Loamy soils with low rock content in sorted glacial drift (Coarse loamy Typic Dystrocryepts).

INTERPRETATIONS

Productivity and revegetation potentials are high to moderate depending on elevation, aspect and other factors. The high productivity is due to the loamy texture and moderate rock content which result in high moisture and nutrient holding capacity.

This soil is rated moderate for **road** and **trail** construction due to loamy textures, periodic

wet conditions and low rock content in the surface. Trail erosion is common and is often 6-10 inches deep.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the loamy surface soil texture and limited rocks.

This soil is rated as having a high potential for **waste disposal** using traditional septic tank and drainfield systems due to the medium texture and moderate rock content resulting in high water and nutrient holding capacity.

Soil education highlights include:

- The volcanic ash-rich surface layer resulting mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- The undulating glacial till landscape and presence of glacial erratics (large boulders).
- Soil horizons especially the surface litter layer which protects the soil from erosion.
- The productivity of this unit, especially the size and diversity of trees and the abundant understory.

OTHER MAPPING UNITS

G3/A3/G2 MIXED GLACIAL AND ALLUVIAL SOILS NARROW GLACIATED VALLEYS

This unit is mapped across 14,948 acres on the glaciated valley bottom near the north fork of the Flathead river. It is a mixture of ground moraine and glacial outwash terraces. The surface of both materials contain volcanic ash-rich wind deposits. Wet mineral soils are another important component of this unit. Vegetation is dominated by conifer forest types. Elevations are 3200-4200 feet. The overall topography is nearly level to gently sloping with most slopes in the 2 to 20

percent range. Short, steep terrace edges occur throughout this unit (40-60%). Pit and mound micro-topography is common from tree wind throw. Mean annual precipitation is 40 to 80 inches.

GEOLOGY

The parent material is a mosaic of glacial drift deposited on the valley floor which was then reworked by outwash streams. In some cases, the existing glacial drift was simply reshaped, in other cases, it was sorted and stratified. In some cases, alluvium has been deposited over the glacial till. The glacial drift has very stony silty clay loam to sandy loam textures. The alluvium has very to extremely gravelly sandy loam or loamy sand textures. Both materials are overlain by volcanic ash-rich wind deposits. Rock fragments are semi-rounded in drift and angular in colluvium. Neither material has rocks sorted by size. Rock types are predominantly quartzite and argillite with occasional limestone or granitic rock fragments. Also common in this mapping unit is extremely gravelly sandy loam alluvium on stream terraces.

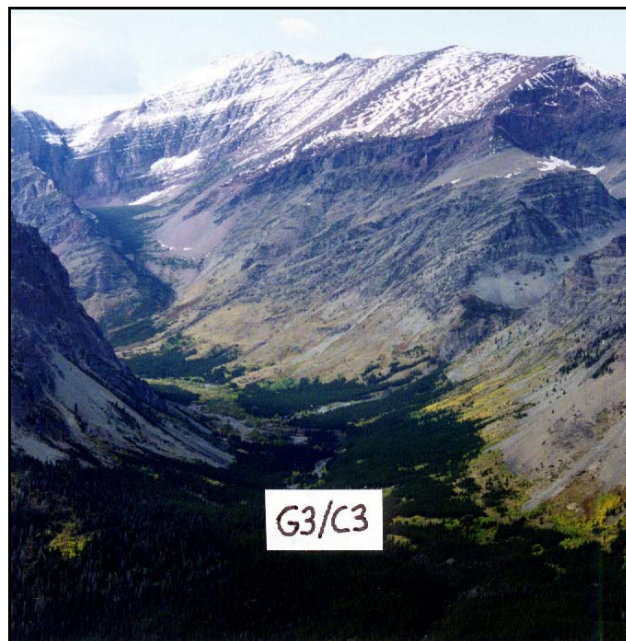
MAJOR SOILS - COMPLEX

This unit is a complex of three main soils but includes others in smaller amounts. There is considerable variation in topography, vegetation, drainage, horizonation, and other soil related features. Two major soils formed in glacial till with a silty clay loam to sandy loam texture. The third major soil (A3) formed in sandy alluvium. All have a surface layer with volcanic ash influence and each occupies 30 percent of the unit. Other soils that occur in this mapping unit are wet soils, alluvial soils, bedrock soils, floodplain soils and shallow soil areas with rock outcrops.

MINOR SOILS - INCLUSIONS

(10% of unit):

- **Wet mineral soils (W1)** in depressions and near open water.
- **Floodplain and low terrace soils (A1)** along streams.
- **Rock outcrop and associated bedrock soils** in convex landscape positions and near rock outcrops.
- Similar **soils with thick, low-density ash surfaces** (Andic Haplocryalfs or Andic Dystrocryepts) in concave areas and less steep areas.
- **Loamy soils with low rock content** in sorted glacial drift (Coarse loamy Typic Dystrocryepts).



Complex of sandy glacial soils (G3) and deep colluvial soils (C3).



Sandy loam glacial forest soil (G3) near Lunch Creek.

- **G3/C3 MIXED GLACIAL AND COLLUVIAL SOILS**
NARROW GLACIATED VALLEYS

This unit is mapped across 92,244 acres in narrow glaciated valley bottoms, trough walls and toeslopes. It is a mixture of ground moraine and colluvial mountain slopes. The surface of both materials contain volcanic ash-rich wind deposits. Alluvial soils, scoured bedrock and wet mineral soils are other important components of this unit. Vegetation is dominated by conifer forest types. Elevations are 4000-7000 feet. The overall topography is undulating to steep with most slopes in the 20 to 45 percent range. Pit and mound micro-topography is common from tree wind throw. Mean annual precipitation is 40 to 80 inches.

GEOLOGY

The parent material is a mosaic of glacial drift and colluvium deposited on the valley floor and adjacent lower trough walls. The glacial drift has very stony silty clay loam to sandy loam textures. The colluvium has very to extremely gravelly sandy loam or loam textures. Both materials are overlain by volcanic ash-rich wind deposits. Rock fragments are semi-rounded in drift and angular in colluvium. Neither material has rocks sorted by size. Rock types are predominantly quartzite and argillite with occasional limestone or granitic rock fragments. Also common in this mapping unit is extremely gravelly sandy loam alluvium on stream terraces.

MAJOR SOILS - COMPLEX

This unit is a complex of two main soils but includes others in smaller amounts. There is considerable variation in topography, vegetation, drainage, horizonation, and other soil related features. One major soil (G3) formed in sandy glacial drift and the other (C3) in sandy colluvium. Both have a surface layer with volcanic ash influence and each occupies 40 percent of the unit. Other soils that occur in this mapping unit are wet soils, alluvial soils, bedrock soils, floodplain soils and shallow soil areas with rock outcrops.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Wet mineral soils (W1)** in depressions and near open water.
- Well-drained **rocky and sandy alluvial soils (A3)**.
- **Floodplain and low terrace soils (A1)** along streams.
- **Rock outcrop and associated bedrock soils** in convex landscape positions and near rock outcrops.
- Similar **soils with thick, low-density ash surfaces** (Andic Haplocryalfs or Andic Dystrocryepts) in concave areas and less steep areas.
- **Loamy soils with low rock content** in sorted glacial drift (Coarse loamy Typic Dystrocryepts).



Complex of sandy glacial soils (G3) and deep colluvial soils.

G4 CLAY-RICH CONIFER FOREST SOILS

GLACIAL MORAINES AND LANDSLIDES

This soil is not mapped alone but in complex with other glacial soils. It is most common on lateral moraines and landslides near the eastern border of the park. The soil material is dominated by glacial drift or landslide deposits. It occurs in complex with a variety of similar and contrasting soils. Vegetation is dominated by conifer forest. Elevations are 4500-6500 feet. The overall topography is moderately sloping to steep with most slopes in the 15 to 45 percent range. Glacial potholes and rotational slump depressions form significant concave features across this landscape. Mean annual precipitation is 30 to 60 inches.

GEOLOGY

The parent material includes glacial drift or landslide deposits with clay loam or silty clay loam textures. The surface materials contain volcanic ash-rich wind deposits with silt loam or loam textures. Rock fragments are semi-rounded and not sorted by size. Rock types are dominated by Precambrian quartzite and argillite with small amounts of limestone. Occasional fragments of Cretaceous shale and sandstone are also present.

CLAY-RICH CONIFER FOREST SOILS

This soil is deep, well-drained and formed in clay loam and silty clay loam glacial drift or landslide deposits. The landslides are mainly in glacial drift materials. The surface soil contains volcanic ash-rich wind deposits. It has a silt loam or loam surface layer with 0-15% rock content. The subsoil is gravelly or very gravelly clay loam or silty clay loam with 35 - 60% rock. Rocks are semi-rounded gravels and cobbles with occasional stones and boulders. Rock content generally increases with depth. Available water holding capacity is high due to the silt and clay content; 1.5-2 inches in the surface foot and 6-8 inches to a depth of five feet.

G4 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1-2 inches thick (O horizon). The upper surface soil is a discontinuous, thin, very dark grayish brown

colored layer of silt loam or loam with few rocks 0-2 inches thick (A horizon). The lower surface soil is mainly brown or dark grayish brown clay loam or silty clay loam 6-12 inches thick with 0-20% rock fragments including gravel, cobbles, stones and boulders (E horizon).

UPPER SUBSOIL - Brown to grayish brown, gravelly to very gravelly clay loam or silty clay loam 10-25 inches thick with 15-40% rock (Bw or Bt horizon).

LOWER SUBSOIL - Gray, grayish brown or brown, very gravelly clay loam or silty clay loam with 30-55% rock fragments (Bw or Bt horizon). The depth to bedrock is many feet.

G4 PROFILE ILLUSTRATION



VEGETATION

Vegetation is mainly subalpine fir climax forest. Trees are mainly lodgepole pine (*Pinus contorta*), subalpine fir (*Abies lasiocarpa*) and spruce (*Picea engelmannii*). Douglas-fir (*Pseudotsuga menziesii*) occurs at lower elevations. Common shrubs include blue huckleberry (*Vaccinium globulare*), dwarf huckleberry (*Vaccinium cespitosum*), grouse whortleberry (*Vaccinium scoparium*), buffaloberry (*Shepherdia canadensis*), alder

(*Alnus spp.*), *menziesii*, and many others. Forbs include queen's cup beadlily (*Clintonia uniflora*), cow parsnip (*Rubus parviflorus*), fireweed (*Epilobium spp.*), starry Solomon's seal (*Smilacina stellata*), bedstraw (*Gallium triflorum*), beargrass (*Xerophyllum tenax*), false hellebore (*Veratrum viride*) and many others. Other plants include elk sedge (*Carex geyeri*), bluejoint (*Calamagrostis canadensis*), California brome (*Bromus californica*) and western fescue (*Festuca occidentalis*).

SOIL CLASSIFICATION

This silty clay loam till soil is classified as a loamy-skeletal, mixed Typic Cryoboralf.

INTERPRETATIONS

Productivity and revegetation potentials are high due to the high silt and clay content and the moderate rock content which result in high moisture and nutrient holding capacity.

This soil is rated low for **road** and **trail** construction due to silty textures, periodic wet conditions and low rock content in the surface. Trail erosion is common and is often 6-10 inches deep.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the loamy surface soil texture and limited rocks.

This soil is rated as having a moderate potential for **waste disposal** using traditional septic tank and drainfield systems due to the fine soil texture moderate rock content resulting in high water and nutrient holding capacity as well as somewhat slow permeabilities. Many areas of this soil are too steep for traditional waste disposal.

Soil education highlights include:

- The undulating glacial till landscape and presence of glacial erratics (large boulders).
- Soil horizons especially the surface litter layer which protects the soil from erosion.
- The productivity of this unit, especially the size and diversity of trees and the abundant understory.

- Hummocky terrain and depressions from rotational slumps

MAPPING UNITS

G4/G5 CLAY-RICH CONIFER AND ASPEN FOREST SOILS GLACIAL MORAINES AND LANDSLIDES

This unit is mapped across 67,307 acres on lateral moraines and landslides. Wet mineral soils, deep colluvial forest and grassland soils, and fresh landslide headwalls are other important components of this unit. Vegetation is dominated by conifer and aspen forest types. Elevations are 4000-5500 feet. The overall topography is moderately sloping to steep with most slopes in the 15 to 45 percent range. Glacial potholes and rotational slump depressions form significant concave features across this landscape. Mean annual precipitation is 30 to 60 inches.

MAJOR SOILS - COMPLEX

This unit is a complex of two main soils but includes others in smaller amounts. The most common is the clay-rich conifer forest soil (G4) which occupies approximately 60 percent of the unit. This soil is most common on the convex portions of the unit and the upper slopes. The other major soil is the clay-rich aspen forest soil (G5) which occupies approximately 25 percent of the unit. This soil is most common on concave areas and toeslopes or near seeps and springs.

MINOR SOILS - INCLUSIONS

(15% of unit):

- **Silty or sandy glacial soils (G2, G3)**
- **Clay-rich grassland soils (G6)** on steep south aspects, especially convex sites.
- **Wet mineral soils (W1)** in depressions and near open water.
- **Similar soils with low rock content** (Coarse loamy Typic Cryochrepts).
- **Loamy and rocky soils** formed from Cretaceous bedrock in the extreme northeast and southeast corners of the park.

G5 CLAY-RICH ASPEN FOREST SOILS

GLACIAL MORAINES AND LANDSLIDES

This soil is not mapped alone but in complex with other glacial soils. It is most common on lateral moraines and landslides near the eastern border of the park. The soil material is dominated by glacial drift or landslide deposits. It occurs in complex with a variety of similar and contrasting soils. Vegetation is dominated by aspen forest. Elevations are 4500-6500 feet. The overall topography is gently sloping to steep with most slopes in the 10 to 35 percent range. This soils is most common on concave landscape positions especially large glacial potholes and rotational slump depressions. It is also common on toeslopes, seep areas and where slope gradient decreases. Mean annual precipitation is 30 to 60 inches.

GEOLOGY

The parent material includes glacial drift or landslide deposits with clay loam or silty clay loam textures. The surface materials contain volcanic ash-rich wind deposits with silt loam or loam textures. Rock fragments are semi-rounded and not sorted by size. Rock types are dominated by Precambrian quartzite and argillite with small amounts of limestone. Occasional fragments of Cretaceous shale and sandstone are also present.

CLAY-RICH ASPEN FOREST SOILS

This soil is deep, well-drained and formed in clay loam and silty clay loam glacial drift or landslide deposits. The landslides are mainly in glacial drift materials. The surface soil contains volcanic ash-rich wind deposits. It has a silt loam or loam surface layer with 0-20% rock content. The subsoil is gravelly or very gravelly clay loam or silty clay loam with 15-45% rock. Rocks are semi-rounded gravels and cobbles with occasional stones and boulders. Rock content generally increases with depth. These soils have darker surface layers and colors that are slightly more gray in color than surrounding conifer and grassland soils. Many profiles have occasional rust mottles and reduced, grayish matrix colors. Available water holding capacity is high due to the silt and clay content; 1.5-2 inches in the surface foot and 6-8 inches to a depth of five feet.

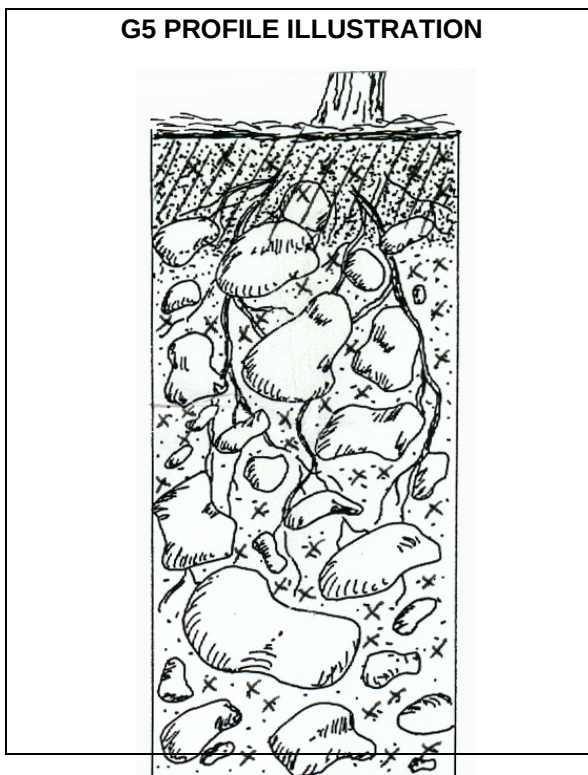
G5 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1-2 inches thick (O horizon). The surface soil is black or very dark grayish brown silt loam or loam with few rocks 5-7 inches thick (A horizon).

UPPER SUBSOIL - Grayish brown or dark grayish brown, gravelly to very gravelly clay loam or silty clay loam 15-30 inches thick with 15-40% rock (Bt horizon). This horizon sometimes has mottles.

LOWER SUBSOIL - Gray or grayish brown, gravelly or very gravelly clay loam or silty clay loam with 20-45% rock fragments (Bt horizon). The upper portion of this horizon often has mottles, and reduced matrix colors, but gley is rare. The depth to bedrock is many feet.

G5 PROFILE ILLUSTRATION



VEGETATION

Vegetation is mainly aspen forest with a very lush forb and grass understory. Trees are mainly aspen (*Populus tremuloides*) with scattered lodgepole pine (*Pinus contorta*),

subalpine fir (*Abies lasiocarpa*) and spruce (*Picea engelmannii*). Occasional Douglas-fir (*Pseudotsuga menziesii*) occur at lower elevations. Common shrubs include snowberry (*Symphoricarpos albus*), buffaloberry (*Shepherdia canadensis*), gooseberry (*Ribes spp.*), dogwood (*Cornus stolonifera*), woodsrose (*Rosa woodsii*) and alder (*Alnus spp.*). Forbs dominate the understory especially cow parsnip (*Rubus parviflorus*), fireweed (*Epilobium spp.*), starry Solomon's seal (*Smilacina stellata*), bedstraw (*Gallium triflorum*), false hellebore (*Veratrum viride*), sweet-cicely (*Osmorhiza chilensis*), angelica (*Angelica arguta*) and many others. Other plants include bluejoint (*Calamagrostis canadensis*), California brome (*Bromus californica*), blue wildrye (*Elymus glaucus*) and Timothy (*Phleum pratense*). The distribution of aspen (*Populus tremuloides*) in contrast with surrounding conifer forest and grassland vegetation has been studied by Lynch (1955). Aspen appears to be most common where excess moisture is available. This occurs in depressions, on toeslopes and near seeps or springs. Overall, aspen seems most common on concave landscape positions and less common on convex sites.

SOIL CLASSIFICATION

These soils are classified as Argiaquic Cryoborolls. Most are in the loamy skeletal family with some in the fine-loamy family.

INTERPRETATIONS

Productivity and revegetation potentials are high due to the high silt and clay content and the moderate rock content which result in high moisture and nutrient holding capacity.

This soil is rated low for **road** and **trail** construction due to silty textures, periodic wet conditions and low rock content in the surface. Trail erosion is common and is often 6-10 inches deep.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the loamy surface soil texture and limited rocks.

This soil is rated as having a moderate potential for **waste disposal** using traditional septic tank and drainfield systems due to the fine soil texture moderate rock content resulting in high water and nutrient holding capacity as well as somewhat slow permeabilities. Many areas of this soil are too steep for traditional waste disposal.

Soil education highlights include:

- The undulating glacial till landscape and presence of glacial erratics (large boulders).
- Soil horizons especially the surface litter layer which protects the soil from erosion.
- The productivity of this unit, especially the size and diversity of trees and the abundant understory.
- The dark surface layer created by the lush understory and shallow concentration of roots.
- The correlation of soil and vegetation in the surrounding landscape resulting in aspen vs. conifer vs. grassland vegetation.
- Landslide topography (depressions, hummocks)



Complex of clay-rich conifer forest soils (G4) and clay-rich aspen soils (G5).

G6 CLAY-RICH GRASSLAND SOILS GLACIAL MORAINES AND LANDSLIDES

This unit is mapped across 1,757 acres on lateral moraines and landslides along the eastern border of the park. The soil material is dominated by glacial drift or landslide deposits. It also occurs as an inclusion in other mapping units. Vegetation is dominated by fescue grassland. Elevations are 4500-6500 feet. The overall topography is gently sloping to steep with most slopes in the 10 to 35 percent range. This soil only occurs on south aspects. It is most common on convex, mid to upper slope positions. Mean annual precipitation is 30 to 45 inches.

GEOLOGY

The parent material includes glacial drift or landslide deposits with clay loam or silty clay loam textures. The surface materials contain volcanic ash-rich wind deposits. Rock fragments are semi-rounded and not sorted by size. Rock types are dominated by Precambrian quartzite and argillite with small amounts of limestone. Occasional fragments of Cretaceous shale and sandstone are also present.

MAJOR SOIL

This soil is dominated by a clay-rich grassland soil with a very dark surface layer. It occupies approximately 75% of this mapping unit. Other components of this mapping unit are clay-rich conifer and aspen forest soils (G4 and G5).

G6 - CLAY-RICH GRASSLAND SOILS

These soils are deep, well-drained and formed in clay loam and silty clay loam glacial drift or landslide deposits. The landslides are mainly in glacial drift materials. The surface soil contains volcanic ash-rich wind deposits. It has a loam or gravelly loam surface layer with 10-25% rock content. The subsoil is gravelly or very gravelly sandy clay loam or clay loam with 25-55% rock. Rocks are semi-rounded gravels and cobbles with occasional stones and boulders. Rock content generally increases with depth. Available water holding capacity is high due to the silt and clay content; 1.5-2 inches in the surface foot and 6-8 inches to a depth of five feet.

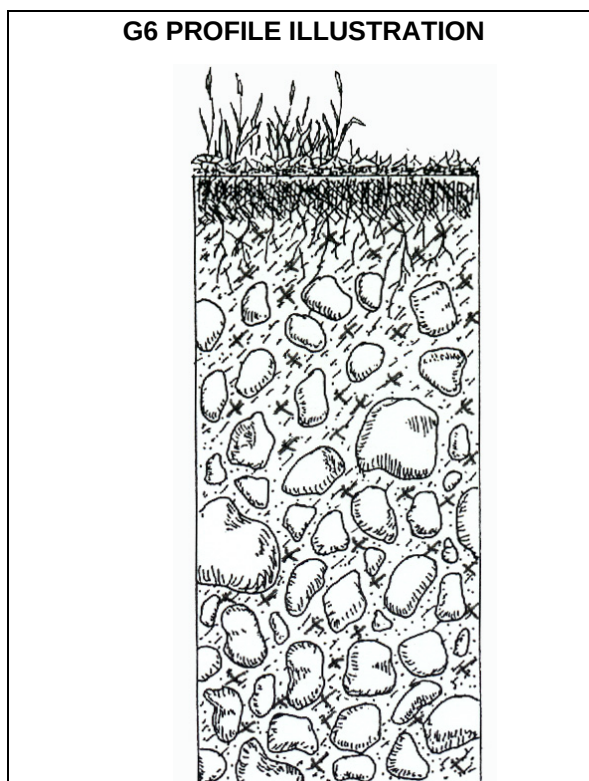
G6 PROFILE DESCRIPTION

SURFACE - The surface soil is very dark grayish brown loam or gravelly loam with 10-20% rocks, 5-9 inches thick (A horizon).

SUBSOIL - Grayish brown or dark grayish brown, gravelly to very gravelly clay loam or sandy clay loam 10-20 inches thick with 20-40% rock (Bt horizon).

SUBSTRATUM - Gray or grayish brown, very gravelly sandy clay loam or clay loam with 30-55% rock fragments (Bt horizon). The depth to bedrock is many feet.

G6 PROFILE ILLUSTRATION



VEGETATION

Vegetation is mainly fescue grassland dominated by rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), Richardson's needlegrass (*Stipa richardsonii*), timber oatgrass (*Danthonia intermedia*), prairie junegrass (*Koeleria cristata*), sticky geranium (*Geranium viscosissimum*) and lupine (*Lupinus spp.*). Scattered shrubs include shrubby cinquefoil (*Potentilla uticosa*), chokecherry (*Prunus virginiana*), horizontal juniper (*Juniperus horizontalis*), serviceberry (*Amelanchier*

alnifolia) and rose (*Rosa woodsii*). Other plants include rock alumroot (*Heuchera cylindrica*), phacelia (*Phacelia spp.*), elk sedge (*Carex geyeri*), kinnikinnick (*Arctostaphylos uva-ursi*), and wild buckwheat (*Eriogonum umbellatum*).

The dry grassland vegetation results mainly from the south aspect, convex microtopography and other factors.

SOIL CLASSIFICATION

These soils are classified as Argic Cryoborolls. Most are in the loamy skeletal family.

MINOR SOILS - INCLUSIONS

(15% of unit):

- **Clay-rich grassland soils (G6)** on steep south aspects, especially convex sites.
- **Clay-rich conifer forest soils (G5)** near the lower boundary of the unit.
- **Wet mineral soils (W1)** in depressions and near open water.
- **Talus (C2)** near the upper boundary.
- **Loamy and rocky soils** formed from Cretaceous bedrock in the extreme northeast and southeast corners of the park.

INTERPRETATIONS

Productivity and revegetation potentials are moderate due to moderate moisture and nutrient holding capacity and dry climate. Productivity is also reduced by wind exposure and high evapotranspiration.

This soil is rated low for **road** and **trail** construction due to high clay and silt content and low rock content.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the loamy surface soil texture and limited rocks.

This soil is rated as having a moderate potential for **waste disposal** using traditional septic tank and drainfield systems due to the fine soil texture and moderate rock content resulting in high water and nutrient holding capacity as well as somewhat slow permeabilities. Many areas of

this soil are too steep for traditional waste disposal.

Soil education highlights include:

- The undulating landslide landscape.
- The proximity to the Lewis overthrust.
- The dark surface layer created by the grassland vegetation and shallow concentration of roots.



Clay-rich grassland soils on lateral moraine.



Clay-rich soil on glacial moraine near Marias Pass.

G7 ROCKY COLLUVIAL AND LANDSLIDE SOILS SLOPES AND LANDSLIDES NEAR THE OVERTHRUST ZONE

This unit is mapped across 8,423 acres on mountain slopes and landslides. It occurs immediately downhill from the Lewis overthrust along the eastern border of the park. The soil material is dominated by colluvial or landslide deposits. Vegetation is dominated by fescue grassland and scattered shrubs or conifer trees. Elevations are 5500-7000 feet. The overall topography is strongly undulating to steep with most slopes in the 10 to 50 percent range. It is most common on convex, mid to upper slope positions. Mean annual precipitation is 40 to 50 inches.

GEOLOGY

The parent material includes colluvium and landslide deposits with very gravelly or stony sandy loam or loam textures. Rock fragments are angular to semi-rounded and are not sorted by size. Rock types are dominated by Precambrian quartzite and argillite with small amounts of limestone. Occasional fragments of Cretaceous shale and sandstone are also present. Some surfaces are stony or bouldery.

MAJOR SOIL

The major soil in this unit is rocky and sandy. It has grassland vegetation or seral stages of conifer forest dominated by grasses and shrubs with scattered small trees. This soil occupies approximately 65% of the mapping unit. Also included in this unit are talus (C2), deep colluvial forest soils (C3) and clay-rich grassland, conifer and aspen soils (G6, G4 and G5).

G7 - ROCKY COLLUVIAL AND LANDSLIDE SOILS

These soils are deep, well-drained and formed in sandy loam and loam colluvium and landslide deposits immediately below the Lewis overthrust. They have gravelly or very gravelly loam or sandy loam surface layers with 20-50% rock content. The subsoil is very gravelly or extremely gravelly sandy loam or loam with 40-75% rock. Rocks are angular to semi-rounded gravels and cobbles with occasional stones and boulders. Rock content generally increases with depth. Available water holding capacity is low due to the high sand and rock content; .5-1 inch in the surface foot and 3-4 inches to a depth of five feet. The surface is stony or bouldery in small areas.

G7 PROFILE DESCRIPTION

SURFACE - The surface soil is very dark brown very gravelly sandy loam or loam with 20-50% rocks, 4-6 inches thick (A horizon).

SUBSOIL - Dark yellowish brown, gravelly to very gravelly sandy loam or loam 8-12 inches thick with 20-40% rock (Bw horizon).

SUBSTRATUM - Brown, very gravelly to extremely gravelly sandy loam 50-70% rock fragments (C horizon). The depth to bedrock is many feet.

G7 PROFILE DESCRIPTION



VEGETATION

Vegetation is mainly fescue grassland dominated by rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), Richardson's needlegrass (*Stipa richardsonii*), timber oatgrass (*Danthonia intermedia*), prairie junegrass (*Koeleria cristata*), sticky geranium (*Geranium viscosissimum*) and lupine (*Lupinus spp.*). Scattered trees and shrubs include subalpine fir (*Abies lasiocarpa*), whitebark pine, Engelmann spruce (*Picea engelmannii*), shrubby cinquefoil

(*Potentilla fruticosa*), redstem maple (*Acer glabrum*), horizontal juniper (*Juniperus horizontalis*), serviceberry (*Amelanchier alnifolia*) and rose (*Rosa woodsii*). Other plants include rock alumroot (*Heuchera cylindrica*), phacelia (*Phacelia spp.*), elk sedge (*Carex geyeri*), kinnikinnick (*Arctostaphylos uva-ursi*), and wild buckwheat (*Eriogonum umbellatum*).

SOIL CLASSIFICATION

These soils are classified as Typic Cryoborolls or Typic Cryochrepts. Most are in the loamy skeletal family.

MINOR SOILS - INCLUSIONS

(15% of unit):

- **Clay-rich grassland soils (G6)** on steep south aspects, especially convex sites.
- **Wet mineral soils (W1)** in depressions and near open water.
- **Similar soils with low rock content** (Coarse loamy Typic Cryochrepts).

INTERPRETATIONS

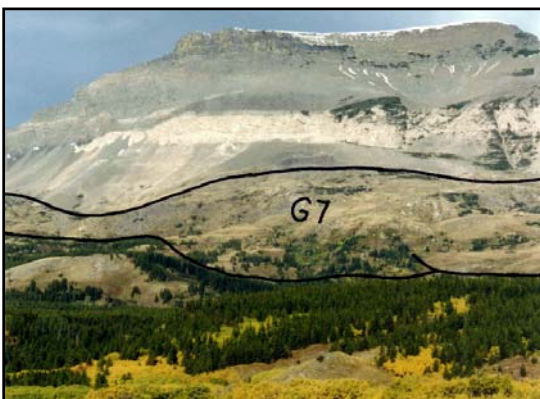
Productivity and revegetation potentials are low to moderate due to the high rock and sand content which results in low moisture and nutrient holding capacity. This soil is further limited by the extreme environment of cold and wind on these very exposed sites.

This soil is rated moderate for **road and trail** construction due to rock and sand content. This soil has a moderate to low susceptibility to **weed infestation** when disturbed due to cold climate. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

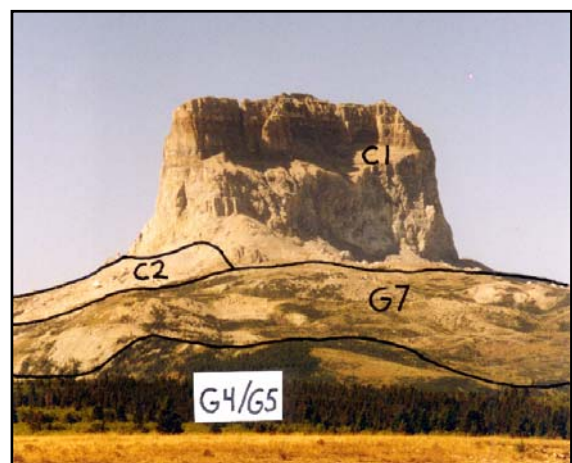
Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential when disturbed due to the loamy surface soil texture and limited rocks. This soil itself is rated as having a high potential for **waste disposal** using traditional septic tank and drainfield systems due to the fine texture and low to moderate rock content resulting in high water and nutrient holding capacity. However, most areas of this soil are too steep for traditional waste disposal.

Soil education highlights include:

- The undulating glacial till landscape and presence of glacial erratics (large boulders).
- The productivity of this unit, especially the density of plant species.
- The dark surface layer created by the grassland vegetation and shallow concentration of roots.
- The correlation of soil and vegetation in the surrounding landscape resulting in aspen vs. conifer vs. grassland vegetation.



Colluvial and landslide soils (G7) below the Lewis Overthrust near Marias Pass.



Talus (C2), Colluvial and landslide soils (G7), and Clay-rich soils (G4/G5) at Chief Mountain.

G8 LIMESTONE GLACIAL TILL FOREST SOILS WIDE GLACIATED VALLEY BOTTOMS

This unit is mapped across 11,644 acres on wide glaciated valley bottoms, on troughwalls and in cirque basins where the local bedrock is limestone. The soil material is dominated by glacial drift with a surface layer of volcanic ash-rich wind deposits. It occurs in complex with a variety of similar and contrasting soils. Vegetation is dominated by moist conifer forest. Elevations are 3800-7000 feet. The overall topography is undulating to moderately steep with most slopes in the 15 to 45 percent range. Pit and mound micro-topography is common from tree wind throw. Mean annual precipitation is 40 to 80 inches.

GEOLOGY

The parent material is mainly glacial drift with very gravelly clay loam or loam textures. These materials are overlain by volcanic ash-rich wind deposits with silt loam or loam textures. Rock fragments are semi-rounded and not sorted by size. Rock types are predominantly Precambrian limestone with small amounts of quartzite and argillite.

MAJOR SOILS (80% of unit):

The major soil in this unit is deep, slightly clayey and supports conifer forest vegetation. Also included in this unit are small areas of wet soils, alluvial soils, rock outcrop, shallow soils and other glacial soils.

LOAMY LIMESTONE GLACIAL TILL SOILS

This soil is deep, well-drained and formed in loam and clay loam glacial drift with an ash-rich surface layer. It has a loam, or silt loam surface layer with 0-15% rock content. The subsoil is very gravelly loam or silty clay loam with 35 - 60% rock. Rocks are semi-rounded gravels and cobbles with occasional stones and boulders. Some surface layers are stony or bouldery. Otherwise, rock content generally increases with depth. Available water holding capacity is high due to silt and clay content; 1.5-2 inches in the surface foot and 5-7 inches to a depth of five feet.

G8 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 2-3 inches thick (O horizon). The upper surface soil has a thin grayish brown to pinkish gray colored layer of loam or silt loam with few rocks 1-2 inches thick (E horizon). The lower surface soil is mainly brown to reddish brown loam or very silt loam 4-8 inches thick with 0-25% rock fragments including gravel, cobbles, stones and boulders. Significant volcanic ash influence (Bs horizon).

SUBSURFACE - Brown to reddish brown, gravelly silt loam or very fine sandy loam 6-18 inches thick with 10-30% rock (Bw).

SUBSOIL - Brown or grayish brown, very gravelly clay loam or loam 12-24 inches thick with 30-50% rock fragments (Bt horizon).

SUBSTRATUM - Grayish brown or brown, very gravelly clay loam or loam with 40-60% rock fragments (C horizon). The depth to bedrock is many feet.

G8 PROFILE ILLUSTRATION



VEGETATION

Vegetation is mainly moist subalpine fir climax forest. Trees are mainly subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*). Douglas-fir (*Pseudotsuga menziesii*), white pine (*Pinus monticola*), cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) and larch (*Larix spp.*) occur at lower elevations. Whitebark pine and alpine larch (*Larix lyallii*) occur at the highest elevations. Common shrubs include blue huckleberry (*Vaccinium globulare*), grouse whortleberry (*Vaccinium scoparium*), buffaloberry (*Shepherdia canadensis*), alder (*Alnus spp.*), menziesia (*Menziesia ferruginea*), and many others. Forbs include queen's cup beadiily (*Clintonia uniflora*), starry Solomon's seal (*Smilacina stellata*), bedstraw (*Gallium triflorum*), beargrass (*Xerophyllum tenax*), false hellebore (*Veratrum viride*), twinflower (*Linnaea borealis*), bunchberry dogwood (*Cornus canadensis*), Hitchcock's woodrush (*Luzula hitchcockii*), and many others. Other plants include elk sedge (*Carex geyeri*), bluejoint (*Calamagrostis canadensis*) and western fescue (*Festuca occidentalis*).

SOIL CLASSIFICATION

This loamy till soil is classified as a loamy-skeletal, mixed Typic Cryoboralf. Where the subsoil has less clay is classified as a loamy-skeletal, mixed Typic Cryochrept.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Wet mineral soils (W1)** in depressions and near open water.
- **Floodplain and low terrace soils (A1)** along streams.
- **Rock outcrop and associated bedrock soils** in convex landscape positions and near rock outcrop.
- Similar soils with thick, low-density ash surfaces (Andic Cryoboralfs or Andic Cryochrepts) in concave areas and less steep areas.
- **Loamy soils with low rock content** in sorted glacial drift (Coarse loamy Typic Cryochrepts).

INTERPRETATIONS

Productivity and revegetation potentials are high to moderate depending on elevation, aspect and other factors. The high productivity is due to the loamy texture and moderate rock content which result in high moisture and nutrient holding capacity.

This soil is rated moderate for **road** and **trail** construction due to loamy textures, periodic wet conditions and low rock content in the surface. Trail erosion is common and is often 6-10 inches deep.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the loamy surface soil texture and limited rocks.

This soil is rated as having a high potential for **waste disposal** using traditional septic tank and drainfield systems due to the medium texture and moderate rock content resulting in high water and nutrient holding capacity.

Soil education highlights include:

- The volcanic ash-rich surface layer resulting mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- The undulating glacial till landscape and presence of glacial erratics (large boulders).
- Soil horizons especially the surface litter layer which protects the soil from erosion.
- The productivity of this unit, especially the size and diversity of trees and the abundant understory.

3.2.4 BEDROCK SOILS - QUARTZITE AND ARGILLITE

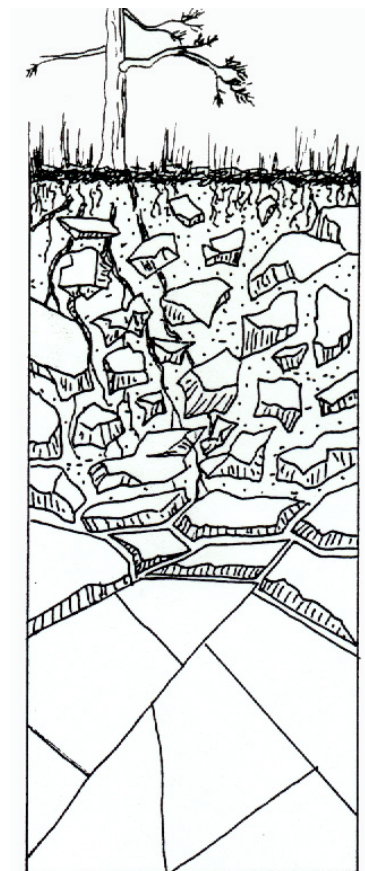
These are the most common soil in the park. They have weathered from bedrock either in place (residual soils) or from bedrock materials that are slowly creeping downhill under the influence of gravity (colluvial soils). Bedrock is slowly weathered into soil by expansion and contraction, ice wedging and other processes. These weathering processes produce rocks that are angular and sharp-edged with rock content increasing with depth. Volcanic ash has been added to the surface of these soils by a number of west coast volcanoes.

About 411,642 acres (41 percent) of the park is mapped as Precambrian quartzite and argillite bedrock soils. These rocks are very old, very hard sandstone and mudstone that weather to soils with sandy loam textures. However, in the park volcanic ash has added sufficient silt particles to produce loam soil textures in the upper profile. Very minor areas of other rock types occur in quartzite/argillite units including limestone and granodiorite. These other rocks weather to soils with similar textures to quartzite and argillite but have subtle differences in chemistry that may be important to some investigators.

Two of the most important features of bedrock soils are depth to bedrock and rock content. These features change rapidly across the bedrock soil landscapes of the park glaciation and other erosion processes. Glaciers left a complex mosaic of rock outcrop and shallow soils in scour areas with moderately deep and deep soils in deposition areas. Gravity has since moved these materials downslope to accumulate in toeslope positions. Bedrock depth may change rapidly across short distances and require very site-specific investigation to evaluate soil relationships with other resources or uses.



Shallow soil (C6) at Logan Pass parking area.



C1 QUARTZITE/ARGILLITE ROCK OUTCROP

Quartzite/argillite rock outcrop is mapped alone across 85,782 acres (8.5%) of the park. Rock outcrop is most common on mountain tops, cirque headwalls and ridges. Other common locations are scoured portions of glacial trough walls and valleys as well as the eroded portions of avalanche chutes. Rock outcrops are more frequent in the harder, most resistant layers of quartzite and argillite. Talus, shallow soils, frost affected soils and alpine meadow soils are other important components of this unit. Vegetation is limited to lichens and scattered plants capable of survival in fractures. Elevations are 4500-10,466 feet. The topography ranges from vertical cliffs to nearly level rock ledges and scoured sites. Mean annual precipitation is 40 to 100 inches.

GEOLOGY

Rock types are Precambrian quartzite (hard sandstone) and argillite (hard mudstone) which occur as inter-bedded layers. These rocks were deposited, uplifted and faulted then eroded by ice, water, wind, temperature and other forces. The differential hardness of rock layers often results in undulating microtopography on the current rock surface.

VEGETATION

Vegetation on the rock outcrop portion of this unit is limited to lichens and the few scattered plants that manage to survive in fractures. The vegetation viewed on these landscapes is mainly restricted to the inclusions of shallow soils.

MAJOR COMPONENT

Rock outcrop occupies 85% of this unit.

MINOR COMPONENTS - INCLUSIONS

(15% of the unit)

- **Talus (C2)**, usually below cliffs and other rock outcrops. Talus was usually, but not always delineated separately from rock since it was delineated by Carrara (1990) and is available as a layer in the Glacier GIS system.
- **Shallow soils (C4)**, usually in concave areas, concave areas and on less steep slopes. Vegetation varies dramatically due to moisture and elevation from grassland species at low elevation dry sites to alder (*Alnus spp.*) and sedge where moisture is concentrated from adjacent sites.

- **Alpine meadow soils (C6)** at high elevation moist sites.

INTERPRETATIONS

Most uses are severely restricted by the lack of soil material. Although ideal for rock quarries, these sites are extremely difficult to reclaim to a natural appearance.

OTHER MAPPING UNITS

C1/C4 - QUARTZITE/ARGILLITE ROCK OUTCROP AND SHALLOW SOILS

This unit is mapped across 76,051 acres of the park. It has similar distribution, geology, and environment to the C1 mapping unit. Rock outcrop (C1) cover 60% and shallow soils (C4) cover 25% of this unit. The shallow soils are found at concave areas, less steep sites and toeslopes.

VEGETATION

Vegetation is extremely variable on the shallow soil portion of this mapping unit. Alpine grasses and forbs and grass-like plants are common at the highest elevation. Stunted and wind-formed (krumholtz) shrubs and conifers may also occur. Grassland vegetation may dominate on low elevation south aspects. Alder, sedge and moist site forbs occur where north aspects or drainage from above provide better moisture conditions.

MINOR COMPONENTS - INCLUSIONS

(15% of the unit)

- **Talus (C2)**, usually below cliffs and other rock outcrops.
- **Alpine meadow soils (C6)** at high elevation moist sites.
- **Deeper soils (C5 and C3).**

C2 QUARTZITE/ARGILLITE TALUS

Quartzite/argillite talus is mapped alone or in combination with shallow soils across 29,153 acres (2.9%) of the park. Talus is most common immediately below rock outcrops especially cliffs and cirque headwalls. In some cases, talus follows the less resistant layers while rock outcrops persist in the harder, most resistant layers of quartzite and argillite. Rock outcrop, alpine soils and shallow to deep colluvial soils are other important components of this unit. Vegetation ranges from almost none to significant coverage of mainly forbs, grasses and grass-like plants. Elevations are approximately 5000-10,466 feet. The topography is steep mountain slopes below rock cliffs. Mean annual precipitation is 40 to 100 inches.

GEOLOGY

Rock types are Precambrian quartzite (hard sandstone) and argillite (hard mudstone) which occur as inter-bedded layers. These rocks have been fractured and dislodged by temperature, water, ice, gravity and other factors. These processes continue today resulting in many small deposition events which form a mosaic of surface ages. Most talus contains more soil-sized particles than the surface appearance would suggest. The source of these soil materials includes rock weathering products but wind deposits, especially ash are significant contributors.

VEGETATION

Where talus is large and composed of hard rocks, very little vegetation may be present. However, on many talus areas vegetation coverage is significant. Vegetation is highly variable due to elevation and moisture conditions but is usually dominated by forbs, grasses and grass-like plants. Occasional young, stunted shrubs and trees may be present. The mosaic of deposits which make up talus slopes are continually being disturbed or replaced. This multi-aged surface results in a multi-aged vegetation. Vegetation coverage ranges from almost none on new deposits to over 75% on older, more stable sites.

Species vary dramatically according to elevation and moisture. Trees include subalpine fir (*Abies lasiocarpa*), and whitebark pine with occasional alpine larch (*Larix lyallii*) and lodgepole pine (*Pinus contorta*). Shrubs include shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*), blue

huckleberry (*Vaccinium globulare*) and grouse whortleberry (*Vaccinium scoparium*) at higher elevations and woodsrose (*Rosa woodsii*), serviceberry (*Amelanchier alnifolia*), mountain maple (*Acer glabrum*) and others at lower elevations. Forbs include sitka valerian (*Valeriana sitchensis*), American bistort (*Polygonum bistortoides*), small-flowered woodrush (*Luzula parviflora*), arrowleaf groundsel (*Senecio triangularis*), western St. John's Wort (*Hypericum formosum*), sibbaldia (*Sibbaldia procumbens*) and many others. Other plants include alpine Timothy (*Phleum alpinum*), black sedge (*Carex nigricans*), Parry's sedge (*Carex parryana*), and Parry's rush (*Juncus parryi*).

Some talus slopes collect and route moisture to their base resulting in riparian vegetation such as aspen (*Populus tremuloides*), cottonwood (*Populus trichocarpa*), birch (*Betula spp.*), alder (*Alnus spp.*), dogwood (*Cornus stolonifera*), sedges (*Carex spp.*) and others.

MAJOR COMPONENT (85% of unit):

C2 TALUS

Talus is distinguished from soil by the lack of soil formation (pedogenic horizons). However, there is often horizontal stratification representing successive depositions. The surface of many areas is often covered with cobbles and stones. Where rock content in the surface is low enough to allow vegetation to grow, the surface soil has a thin dark brown layer one to 3 inches thick. This layer has a very gravelly loam texture. Below this depth the soil is brown extremely gravelly loam. Rock content may be as low as 50% in the surface but is usually 80-90% throughout.

PROFILE DESCRIPTION

SURFACE

Intermittent surface layer of stones, cobbles and gravels 6-12 inches thick.

SUBSURFACE

Intermittent darkening of the surface few inches beneath the surface rock layer especially where vegetation is most dense. Very to extremely gravelly loam or sandy loam. (A horizon)

SUBSTRATUM

Extremely stony sandy loam. The depth to bedrock is usually many feet except near rock outcrops.

Available water holding capacity is very low due to the high rock content; .25-.5 inches in the surface foot and 1-3 inches to a depth of five feet.

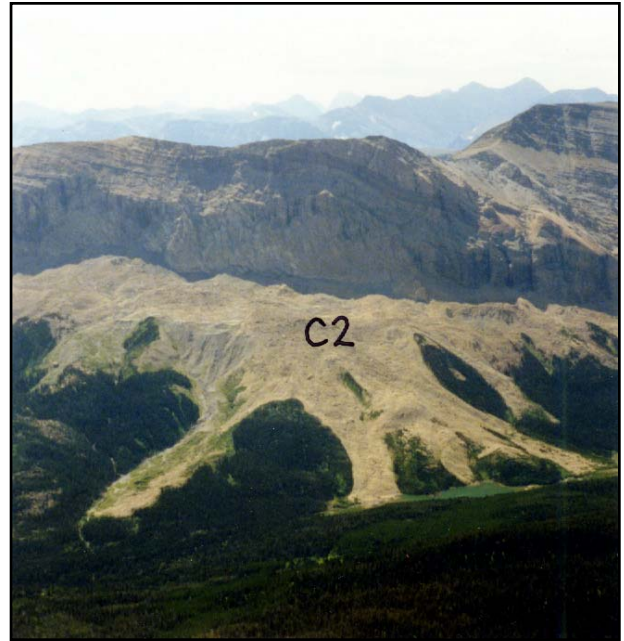
MINOR COMPONENTS - INCLUSIONS

(15% of the unit)

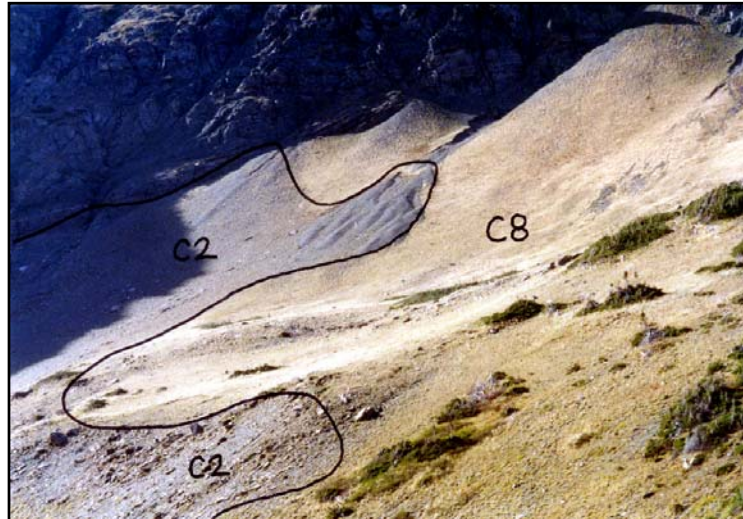
- **Rock outcrop (C1)** as cliffs, ridges and other features.
- **Poorly developed soils (G1)** on recent glacial moraines.
- **Shallow to deep colluvial soils (C3, C4, C5)** on older, more stable areas. Vegetation coverage is usually near 100% on these soils.
- **Alpine meadow soils (C6)** at high elevation sites with older, more stable surfaces such as toeslopes.

INTERPRETATIONS

Most uses are severely restricted by the instability of talus, lack of soil material and potential for snow avalanche.



Quartzite/Argillite Talus on Wynn Mountain.



Quartzite Argillite Talus (C2) and Deep Colluvial Grassland Soils (C8) near Two Medicine Lake.

C3 DEEP COLLUVIAL FOREST SOILS

LOWER MOUNTAIN SLOPES

This unit is mapped across 80,629 acres (8%) mainly on lower to mid mountain slopes. It is dominated by colluvium with a surface layer containing volcanic ash-rich wind deposits. Shallow to moderately deep soils, glacial soils, alluvial soils, scoured bedrock and wet mineral soils are other components of this unit. Vegetation is dominated by conifer forest types. Elevations are 3500-7500 feet. The overall topography is moderately steep to steep with most slopes in the 25 to 60 percent range. Mean annual precipitation is 40 to 80 inches.

GEOLOGY

The parent material is dominated by colluvium with extremely gravelly sandy loam or loam textures. The surface is a loamy mixture of volcanic ash-rich wind deposits and the underlying soil. Rocks are angular and predominantly quartzite and argillite.

MAJOR SOIL (80% of unit):

C3 DEEP COLLUVIAL FOREST SOILS

This soil is deep, well drained and formed in deep rocky and loamy colluvium with an ash-rich surface layer. The surface layer is loam or sandy loam with 0-20% gravels. The subsoil is very gravelly to extremely gravelly loam or sandy loam. Rocks are angular gravels and cobbles with occasional stones. Rock content increases with depth. Available water holding capacity is moderate due to the loamy texture and high rock content; 1-1.5 inches in the surface foot and 4-6 inches to a depth of five feet.

SOIL CLASSIFICATION

These deep, colluvial forest soils (C3) are classified as a loamy-skeletal, mixed, Typic Dystrocrepts.

C3 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 2-3 inches thick (O horizon). The upper surface soil has a thin grayish brown to pinkish gray colored layer of gravelly loam with 10-25% rocks 1-2 inches thick (E horizon). The lower surface soil is brown to reddish brown gravelly loam 6-12 inches thick with 20-40% rock fragments including gravel, cobbles and stones. Significant volcanic ash influence (Bs or Bw horizon).

SUBSURFACE - Brown to reddish brown, very gravelly loam or sandy loam 6-18 inches thick with 30-50% rock fragments (Bw).

SUBSOIL - Brown, extremely gravelly sandy loam or loam 12-24 inches thick with 55-65% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, extremely gravelly sandy loam or loam with 60-70% rock fragments (C horizon). The depth to bedrock is many feet.

C3 PROFILE ILLUSTRATION



VEGETATION - C3

Vegetation is mainly moist subalpine fir climax forest. Trees are mainly subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*), larch (*Larix spp.*), lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*) with smaller amounts of white pine (*Pinus monticola*), cedar (*Thuja plicata*), and

western hemlock (*Tsuga heterophylla*). Shrubs include blue huckleberry (*Vaccinium globulare*), buffalo berry, Utah honeysuckle (*Lonicera involucrata*), menziesia (*Menziesia ferruginea*), and many others. Forbs include queen's cup beadlily (*Clintonia uniflora*), thimbleberry (*Rubus parviflorus*), twinflower (*Linnaea borealis*), dogwood (*Cornus stolonifera*), beargrass (*Xerophyllum tenax*) and many others. Grasses include pinegrass (*Calamagrostis rubescens*), western fescue (*Festuca occidentalis*) and mountain muhly (*Muhlenbergia glomerata*).

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Wet mineral soils (W1)** in depressions, near water, toeslopes.
- **Alluvial soils (A1, A2, A3)** near streams.
- **Rock outcrops (C1)**
- **Moderately deep (C5) and shallow soils (C4)** near scoured bedrock areas.
- **Soils with silty clay loam subsoils (G2)** on the less steep slopes (Oxyaquic Haplocryalf).
- **Deep grassland colluvial soils (C8)** on south aspects (Cryolls).
- Similar soils with thick, low-density ash surfaces on the less steep slopes (Andic Dystrocryepts).

INTERPRETATIONS

Productivity and revegetation potentials for these soils are moderate due to the loamy texture and high rock content.

This soil is rated moderate for **road** and **trail** construction due to loamy textures and few rocks in the surface. Trail erosion is common on this soils and is often 3-6 inches deep.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the silty surface soil texture and few rocks. The subsoil is much less erosive and the high rock content creates a natural armor layer as soil fines are eroded.

These soils are rated as having a moderate potential for **waste disposal** using traditional septic tank and drainfield systems due to their

medium texture and high rock content. Slopes over 15% severely limit waste disposal.

Soil education highlights include:

- The volcanic ash-rich surface layer resulting mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- Soil horizons especially the surface litter layer which protects the soil from erosion.
- The angular rocks that suggest they have resulted from physical weathering and have not been transported far.

OTHER MAPPING UNITS

C3/C5 DEEP AND MODERATELY DEEP COLLUVIAL FOREST SOILS CIRQUE BASINS AND LOWER MOUNTAIN SLOPES

Deep and moderately deep colluvial forest soils are mapped as a complex over 63,751 acres (6.3%) of the park. This mapping unit occurs mainly in cirque basins and on lower to mid mountain slopes. It is dominated by colluvium with a surface layer containing volcanic ash-rich wind deposits. Shallow soils, glacial soils, alluvial soils, wet mineral soils and scoured bedrock are other components of this unit. Vegetation is dominated by conifer forest types. Elevations are 4000-7000 feet. The overall topography is moderately steep to steep with most slopes in the 20 to 50 percent range. Mean annual precipitation is 50 to 90 inches.

MAJOR SOILS - COMPLEX

This unit is a complex of two main soils but includes others in minor amounts. The most common is the deep forested colluvial soil (C3) which occupies approximately 50% of the unit. The other most common soil is moderately deep to fractured bedrock (C5).

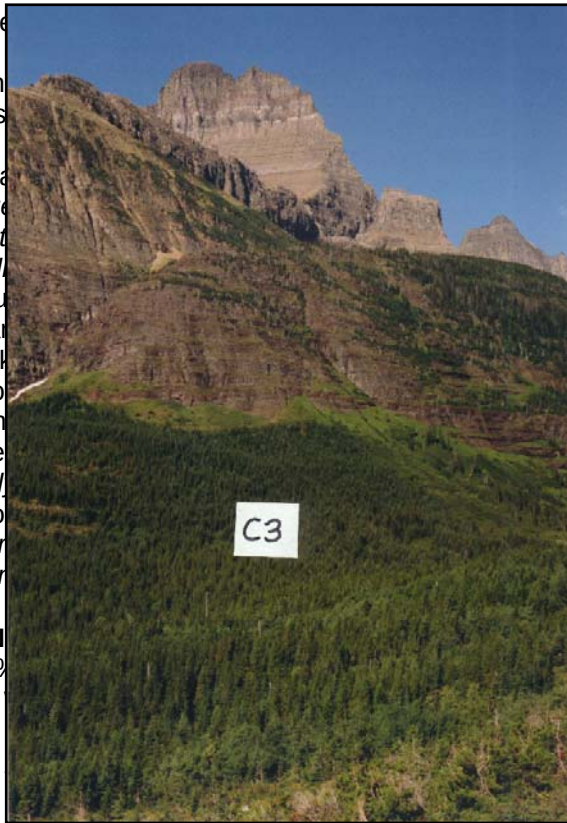
VEGETATION

Vegetation is dominated by cool to cold conifer forest. Vegetation in this unit is on the cooler end of the spectrum described for the individual soils. Seral (pre-climax)

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SHALLOW COLLUVIAL FOREST SOILS (C3) below

- Deep Colluvial Forest Soils (C3) below quartzite/argillite rock outcrop.
- (G4) on the less steep slopes (Haplocryalts)
- Similar soils with thick, low-density ash surfaces on the less steep slopes (Andic Dystrocryepts)



Deep Colluvial Forest Soils (C3) on lower mountain slopes in Many Glacier area.

C4 SHALLOW SOILS NEAR BEDROCK OUTCROPS AND SCoured MOUNTAIN SLOPES

This soil is not mapped alone but in complex with rock outcrop, moderately deep soils and alpine meadow soils. It is an important minor component of many other mapping units. These soils are mainly near rock outcrops and sites where soil has been eroded by ice, wind, water and gravity. Vegetation is highly variable due to bedrock depth, surface rock content, aspect and elevation. Many sites have a mosaic of stunted conifer forest and mixed shrub/forb/grass communities. Elevations are 3,500-10,466 feet. The topography ranges from steep mountain slopes in the 25-60 percent range to nearly level glacially scoured areas. Mean annual precipitation is 40 to 100 inches.

GEOLOGY

The parent material is mainly loam or sandy loam colluvium with abundant rock content and bedrock within 1-2 feet. Rock fragments are angular quartzite and argillite gravels and cobbles. Some of the fine soil material was deposited by wind and includes volcanic ash.

C4 - SHALLOW SOILS

This soil is shallow, well drained and formed in quartzite/argillite colluvium. The surface layer is gravelly to very gravelly loam or silt loam. The subsoil and substratum are extremely gravelly loam or sandy loam. Rock content increases with depth becoming fractured bedrock at 1-2 feet. Available water holding capacity is very low due to the high rock content and limited depth; .5-1 inch in the surface foot and 1.5-2 inches total to the depth of fractured bedrock.

C4 PROFILE DESCRIPTION

SURFACE - Brown to dark brown very gravelly loam 3-6 inches thick with 30-60% rock fragments. Rocks are mainly angular gravels and cobbles (A horizon).

SUBSOIL - Brown extremely gravelly loam 3-6 inches thick with 50-70% rock fragments (Bw horizon). Rock fragments are quartzite and argillite angular gravels, cobbles with some stones.

SUBSTRATUM - Brown or light brown, extremely gravelly loam or sandy loam with 60-90% rock fragments (BC horizon). Rock

fragments are quartzite and argillite angular gravels, cobbles with some stones. The total depth to fractured bedrock is 2-4 feet.

FRACTURED QUARTZITE AND ARGILLITE BEDROCK (R layer)

C4 PROFILE ILLUSTRATION



VEGETATION - C4

Vegetation is mainly either stunted, wind-form conifer forest in the alpine fir series or seral communities dominated by shrubs, grasses and forbs. South aspects and recent avalanche slopes often have less trees and more shrubs, grasses and forbs. Trees are mainly subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*) with smaller amounts of spruce (*Picea engelmannii*), common juniper (*Juniperus communis*) and whitebark pine. Shrubs include kinnikinnick (*Arctostaphylos uva-ursi*), blue huckleberry (*Vaccinium globulare*), spirea (*Spirea spp.*), serviceberry (*Amelanchier alnifolia*), shrubby cinquefoil (*Potentilla fruticosa*) and others. Other plants include beargrass (*Xerophyllum tenax*), phacelia (*Phacelia spp.*), alumroot

(*Heuchera cylindrica*), Indian paintbrush (*Castilleja spp.*), sweetvetch (*Hedysarum sulphurescens*), sitka valerian (*Valeriana sitchensis*), elk sedge (*Carex geyeri*) and many others. Low elevation sites on south aspects may be dominated by bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*) and other grasses.

SOIL CLASSIFICATION

This shallow soil (C4) is classified as a mixed Lithic Dystrocrept.

INTERPRETATIONS

Soil depth and high rock content are the main factors affecting interpretations for these soils.

Productivity and revegetation potentials are low for this shallow soil due to the low moisture and nutrient holding capacity as well as the cold climate.

This shallow soil is rated low for **roads** due to limited depth.

This soil has a moderate to low susceptibility to **weed infestation** when disturbed due to high elevation and cold environment. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential when disturbed.

These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to limited soil depth.

Soil education highlights include:

- The bright brown topsoil color due in part to volcanic ash, mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- Stunted tree and other vegetation growth.
- The presence of shallow and rocky soil indicator plants such as phacelia (*Phacelia spp.*), alumroot (*Heuchera cylindrica*), sweetvetch (*Hedysarum sulphurescens*) and others.

MAPPING UNITS

C4/C6 SHALLOW SOILS AND ALPINE MEADOW SOILS HIGH ELEVATION SITES

This mapping unit covers 4,943 acres (0.5%) at the higher elevations throughout the park. It is dominated by glacially-scoured cirque basins and mountain slopes that have developed alpine meadow soils in the more moist areas and shallow colluvial soils on the drier soil areas. Vegetation is a mosaic of alpine meadow communities where the surface soil has fewer rocks and drier mixed tree/shrub/forb/grass communities where the soil is rockier. Elevations are 5000-9500 feet. The topography ranges from cirque basins to moderate mountain slopes in the 10-40 percent range. Mean annual precipitation is 60 to 90 inches.

MAJOR SOILS - COMPLEX

This unit is mapped as a complex of two main soils but includes others in limited areas. The most common soil (C4) is shallow to fractured bedrock and occupies 40 percent of the unit. The other common soil (C6) is an alpine soil which make up approximately 30 percent of the unit. In some cases (West Flattop Mountain) the two soils occur as strips across the landscape for up to a mile. This strip pattern may begin as differences in the hardness of the sedimentary rock layers. The harder layers form slightly higher convex ridges and the softer layers form shallow concave strips. Wind deposited soil material, especially volcanic ash has accumulated in the concave strips.

VEGETATION

Vegetation in this unit is dominated by the colder climate species. Both stunted, wind-form conifer forest in the alpine fir series and seral communities dominated by shrubs, grasses and forbs are present. Trees are mainly subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*) and spruce (*Picea engelmannii*) with smaller amounts of common juniper (*Juniperus communis*) and whitebark pine. Shrubs include shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*), blue huckleberry (*Vaccinium globulare*) and grouse whortleberry (*Vaccinium scoparium*). Forbs include sitka valerian (*Valeriana sitchensis*), American bistort (*Polygonum bistortoides*),

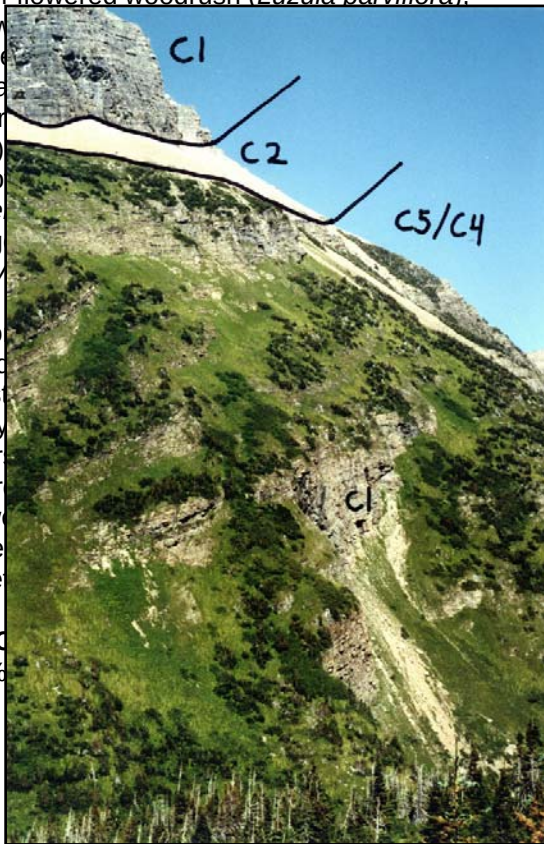
small-flowered woodrush (*Luzula parviflora*).

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Quartzite/Argillite Rock outcrop (C1), Talus (C2), Moderately deep soils (C5) and Shallow soils (C4).



This photo illustrates a shallow soil (C4) supporting conifer forest on the left and an alpine meadow soil (C6) supporting forb/grass vegetation.

C5 MODERATELY DEEP COLLUVIAL

SOILS

SCOURED MOUNTAIN SLOPES AND TROUGH WALLS

This soil is not mapped alone but in complex with shallow or deep soils. It is an important minor component of many other mapping units. These soils are on sites that have been eroded by ice, wind, water and gravity. They are also on sites where soil formation from bedrock is very slow. Vegetation is highly variable due to bedrock depth, surface rock content, aspect and elevation. Many sites have a mosaic of stunted conifer forest and mixed shrub/forb/grass communities. Elevations are 4,500-10,466 feet. The topography ranges from steep mountain slopes in the 25-60 percent range to nearly level glacially scoured areas. Mean annual precipitation is 40 to 100 inches.

GEOLOGY

The parent material is mainly loam or sandy loam colluvium with abundant rock fragments and bedrock within 2-4 feet. Rock fragments are angular quartzite and argillite gravels and cobbles. Some of the fine soil material was deposited by wind and includes volcanic ash.

C5 - MODERATELY DEEP COLLUVIAL SOILS

This soil is moderately deep, well drained and formed in quartzite/argillite colluvium. The surface layer is brown very gravelly loam. The subsoil is very gravelly loam or sandy loam. The substratum is extremely gravelly loam or silt loam. Rock content increases with depth becoming fractured bedrock at 2-4 feet. Available water holding capacity is low due to the high rock content and limited depth; 1 inch in the surface foot and 2-3 inches total to the depth of fractured bedrock.

C5 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1 inch thick (O horizon). This litter layer is absent from some sites, especially where there are few trees. The upper surface soil has a discontinuous light brown to pinkish gray layer of very gravelly loam or silt loam 0-1 inch thick with 25-50% gravels and cobbles (E horizon). This layer is most common under dense conifer vegetation. The lower surface soil is mainly brown very gravelly loam 6-10 inches thick with 25-50% rock fragments (Bs horizon). Rock fragments

are mainly gravels and cobbles with occasional stones.

SUBSOIL - Brown, extremely gravelly loam 6-18 inches thick with 30-50% rock fragments (Bw horizon).

SUBSTRATUM - Brown, extremely gravelly loam or sandy loam with 65-90% rock fragments (BC horizon). The total depth to fractured bedrock is 2-4 feet.

FRACTURED QUARTZITE AND ARGILLITE BEDROCK (R layer)

C5 PROFILE ILLUSTRATIONS



VEGETATION - C5

Vegetation is mainly stunted subalpine fir climax forest. South aspects and avalanche slopes have mixed shrub/grass/forb communities. Common trees are subalpine fir (*Abies lasiocarpa*) and lodgepole pine (*Pinus contorta*) with smaller amounts of spruce (*Picea engelmannii*), common juniper (*Juniperus communis*) and whitebark pine. Douglas-fir (*Pseudotsuga menziesii*) is common at the lower elevations. Shrubs include kinnikinnick (*Arctostaphylos uva-ursi*), blue huckleberry (*Vaccinium globulare*), spirea (*Spirea spp.*), serviceberry (*Amelanchier alnifolia*), shrubby cinquefoil (*Potentilla fruticosa*), chokecherry (*Prunus virginiana*), alder (*Alnus spp.*) and others. Forbs include beargrass (*Xerophyllum tenax*), arnica (*Arnica spp.*), sitka valerian (*Valeriana sitchensis*) and many others. Sedges (*Carex spp.*) include elk sedge (*Carex geyeri*).

SOIL CLASSIFICATION

This moderately deep soil is classified as a loamy-skeletal, mixed Typic Dystrocrypts.

INTERPRETATIONS

Soil depth, high rock content and slope steepness are the main factors affecting interpretations for this soils.

Productivity and revegetation potentials are moderate due to the low moisture and nutrient holding capacity.

Both soils are rated low for **roads** due to limited depth. The moderately deep soil is rated moderate and the shallow soil low for **trail** construction due to depth. The soil material itself would be rated moderate to high if bedrock depth were ignored.

This soil is has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. Both soils have a moderate erosion potential when disturbed. These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to limited soil depth.

Soil education highlights include:

- The bright brown topsoil color due in part to volcanic ash. Ash is mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- The presence of rocky soil indicator plants such as phacelia (*Phacelia spp.*), alumroot (*Heuchera cylindrica*), sweetvetch (*Hedysarum sulphurescens*) and others.

MAPPING UNITS

C5/C4 MODERATELY DEEP AND SHALLOW COLLUVIAL SOILS SCoured MOUNTAIN SLOPES AND TROUGH WALLS

This unit covers 58,888 acres (5.8%) throughout the park. It is dominated by glacially-scoured mountain slopes that have developed shallow and moderately deep colluvial soils since deglaciation. Vegetation is a mosaic of mostly stunted conifer forest and mixed shrub/forb/grass communities. Elevations are 4000-8000 feet. The topography is mainly steep mountain slopes in the 25-60 percent range. Mean annual precipitation is 40 to 80 inches.

MAJOR SOILS - COMPLEX

This unit is mapped as a complex of two main soils but includes others in limited areas. The most common soil (C5) is moderately deep to fractured bedrock and occupies 45 percent of the unit. The other common soil (C4) is shallow to fractured bedrock and occupies 30 percent of the unit.

MINOR SOILS - INCLUSIONS

(25% of unit):

- **Rock outcrop (C1)** on convex areas.
- **Deep colluvial soils (C3)** on lower slopes.
- **Talus (C2)** below rock outcrops.

C6 ALPINE MEADOW SOILS MOUNTAIN SLOPES AND CIRQUE BASINS

This soil is mapped alone on only 1,711 acres. Most of this soil is mapped in complex with shallow soils (C4). It is most common in alpine meadows, on mountain slopes and in cirque basins. It is dominated by residuum and colluvium with a surface layer containing volcanic ash-rich wind deposits. Scoured bedrock, shallow to moderately deep colluvial soils and wet mineral soils occur in the landscape with alpine meadow soils. Vegetation is dominated by alpine forbs, grasses and grass-like plants with scattered shrubs and stunted conifer trees. Elevations are 5000-8000 feet. The overall topography is undulating to moderately steep with most slopes in the 15 to 45 percent range. Mean annual precipitation is 70 to 100 inches.

GEOLOGY

The parent material is dominated by residuum and colluvium with loam textures and increasing rock content with depth. The surface is a loamy mixture of volcanic ash-rich wind deposits and the underlying soil. Rocks are angular quartzite and argillite.

C6 - ALPINE MEADOW SOILS

This soil is moderately deep to deep, well drained and formed in rocky and loamy residuum or colluvium mixed with ash-rich wind deposits. The surface layer is loam with 0-25% gravels. The subsoil is very gravelly to extremely gravelly loam. Rocks are angular gravels with occasional cobbles and stones. Rock content increases with depth. Available water holding capacity is moderate due to the loamy texture and high rock content; 1-1.5 inches in the surface foot and 3-4.5 inches to a depth of four feet. Soil depth varies within this mapping unit from shallow to deep but the upper soil profile has relatively similar characteristics. Multiple soils were not separated based on depth due to the limited area of these soils.

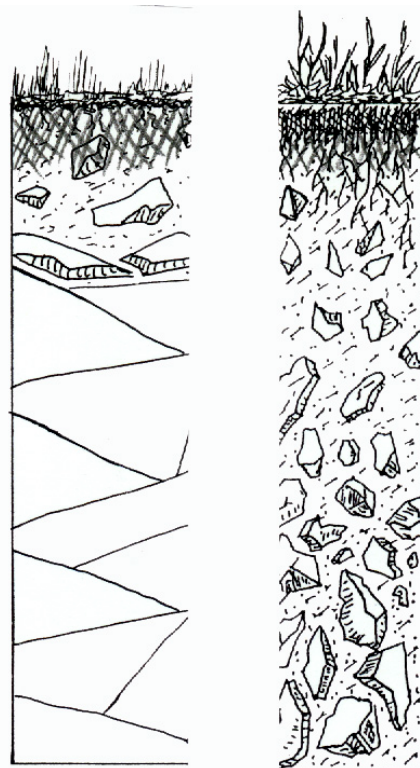
C6 PROFILE DESCRIPTION

SURFACE - The surface soil is dark brown loam with 0-20% rocks 4-6 inches thick (A horizon). Rock fragments are mainly gravels with occasional cobbles and stones. Significant volcanic ash influence. The surface layer often has a turf character caused by dense roots in the upper 2-6 inches.

SUBSOIL - Brown, very gravelly loam 7-15 inches thick with 35-65% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, extremely gravelly loam or sandy loam with 60-80% rock fragments (BC or C horizon). The depth to bedrock is mainly 20 to 40 inches.

C6 PROFILE ILLUSTRATION



VEGETATION - C6

Vegetation is dominated by alpine forbs, grasses sedges (*Carex spp.*) and rushes (*Juncus spp.*). Scattered, stunted trees and shrubs occur, usually where the surface soil has higher rock content. Trees include subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*), and whitebark pine with occasional alpine larch (*Larix lyallii*) and lodgepole pine (*Pinus contorta*).

Shrubs include shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*), blue huckleberry (*Vaccinium globulare*) and grouse whortleberry (*Vaccinium scoparium*). Forbs include sitka valerian (*Valeriana sitchensis*), American bistort

(*Polygonum bistortoides*), small-flowered woodrush (*Luzula parviflora*), arrowleaf groundsel (*Senecio triangularis*), western St. John's Wort (*Hypericum formosum*), sabbaldia (*Sibbaldia procumbens*) and many others. Other plants include alpine Timothy (*Phleum alpinum*), black sedge (*Carex nigricans*), Parry's sedge (*Carex parryana*), and Parry's rush (*Juncus parryi*).

SOIL CLASSIFICATION

These soils are classified as a loamy-skeletal, mixed, Typic Dystrocryepts.

MINOR SOILS - INCLUSIONS

(25% of unit):

- Wet mineral soils in depressions, near water, toeslopes (W1)
- Rock outcrops
- Shallow soils (C4) near scoured bedrock areas.
- Similar soils with low-density ash surfaces (Andic Dystrocryepts)

INTERPRETATIONS

Productivity and revegetation potentials for these soils are low to moderate due to the limited soil depth, high rock content and cold climate.

This soil is rated low for **road** construction and moderate for **trail** construction due to loamy textures, low rock content in the surface and bedrock within 40 inches of the surface in some profiles.

This soil has a low susceptibility to **weed infestation** when disturbed due to the cold climate.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the silty surface soil texture and few rocks. The subsoil is much less erosive and the high rock content creates a natural armor layer as soil fines are eroded. These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to their high rock content, limited depth and cold climate. Slopes over 15% severely limit waste disposal.

Soil education highlights include:

- The presence of volcanic ash resulting mainly from the eruption of Mt. Mazama (Crater Lake Oregon). Also the bright brown

soil color resulting from ash weathering.

- The turf-like root concentration in the surface few inches. This is where the nutrients, water and biological activity are.
- The angular rocks that suggest they have not been transported far but have been moved upward and mixed in the surface soil by frost action, animal burrowing and other methods.



Alpine meadow soil near fifty mountain camp.

C7/C1 ICE-PATTERNED SOILS MOUNTAINTOPS AND SLOPES

Ice patterned soils are mapped in complex with rock outcrop over approximately 7,295 acres (0.7%) of the park. They occur mainly on wide mountain tops and upper mountain slopes. The parent material is residuum and colluvium that has been subjected to intense frost action. Scoured bedrock, alpine meadow soils and shallow to deep colluvial soils are other important components of this unit. Vegetation is dominated by alpine grasses, forbs and shrubs. Elevations are 6000-8000 feet. The overall topography is gently sloping to moderately steep with most slopes in the 10 to 30 percent range. Mean annual precipitation is 50 to 80 inches.

Most of these soils have been mapped by Carrara (1990) as solifluction deposits. They have also been studied by Butler and Malanson (1989) who provide additional information on their development and morphology.

MAJOR SOIL - COMPLEX

This unit contains a variety of soils affected by intense frost action during glaciation and since deglaciation ended. They occur in complex with rock outcrop and a variety of minor soils. The frost features include turf banked terraces (or terracettes), *Dryas*. "spotted tundra", sorted and unsorted stone stripes, ice wedge polygons, frost boils and others. These frost features occupy approximately 60 percent of the unit. Rock outcrop occupies approximately 20 percent of the unit. The remainder of this mapping unit includes colluvial soils that are shallow to deep.

C7 - FROST AFFECTED SOILS

(60% of unit): These soils vary in their morphology depending on their age, history and other factors. The most common examples are shallow, well drained and formed in rocky, loamy colluvium. The surface topography forms miniature terraces (terraces) that are 1-2 feet wide. The nearly level terrace surface layer is often covered with a layer of almost pure gravel 2-3 inches thick. The steep terrace side has a thick, turf-like vegetative cover dominated by *dryas* (*Dryas spp.*). The surface soil below this gravel layer is gravelly or very gravelly silt loam or loam with 20-30 percent rock. The subsoil is very gravelly to extremely gravelly loam or sandy loam. Rocks are angular gravels and cobbles with occasional stones. Rock content increases with depth.

Available water holding capacity is low due to the shallow depth to bedrock and high rock content; 1-1.5 inches in the surface foot and 2-3 inches to the depth of bedrock.

There are no clear conventions for describing these soils. Since the vegetation occurs on the steep sides of the terraces, there has been debate concerning whether it is more appropriate to describe the soil profile from the side. These ice-patterned soils are highly variable and the profile description presented below is for a turf-banked terrace soil. It has been described vertically from the surface downward.

C7 PROFILE DESCRIPTION

SURFACE - The surface soil is covered by a layer of gravel-size rock 3 inches thick. The surface soil is brown gravelly silt loam with 20-35% rocks 2 inches thick (A horizon).

SUBSOIL - Yellowish brown, very to extremely gravelly loam 4-7 inches thick with 55-75% rock fragments (Bw & BC horizon).

FRACTURED BEDROCK - Quartzite and argillite bedrock (R horizon).

VEGETATION - C7

Vegetation is mainly alpine forbs, grasses and shrubs. A few, scattered, krumholtz conifer trees may also be present. *Dryas* (*Dryas spp.*) is the dominant plant on turf-banked terraces and "spotted tundra". Other shrubs include shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*) and grouse whortleberry (*Vaccinium scoparium*). Forbs include sitka valerian (*Valeriana sitchensis*), American bistort (*Polygonum bistortoides*), small-flowered woodrush (*Luzula parviflora*), arrowleaf groundsel (*Senecio triangularis*), western St. John's Wort (*Hypericum formosum*), sabbaldia (*Sibbaldia procumbens*) and many others. Other plants include alpine Timothy (*Phleum alpinum*), black sedge (*Carex nigricans*),

Parry's sedge (*Carex parryana*), Parry's rush (*Juncus parryi*).

GEOLOGY

The parent material is dominated by residuum with gravelly silt loam to extremely gravelly sandy loam or loam textures. The surface contains wind deposited material including volcanic ash. Rocks are angular quartzite and argillite.

SOIL CLASSIFICATION

These soils do not fit well into the current soil classification system. Where they are shallow to bedrock, these frost affected soils (C7) are classified as Lithic Cryochrepts. Where they are moderately deep to deep they are classified as Typic Cryochrepts.

C1 - QUARTZITE/ARGILLITE ROCK OUTCROP

Quartzite/argillite rock outcrop makes up approximately 20 percent of this mapping unit and is described elsewhere in this report.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Talus (C2)** - below rock outcrops
- **Alpine meadow soils (C6)**
- **Shallow (C4), moderately deep (C5) and deep (C6) colluvial soils.**

INTERPRETATIONS

Productivity and **revegetation** potential for the ice patterned soil is low due to the shallow bedrock, high surface rock content and cold, windy climate. Plant species selection is critical to successful revegetation.

This soil is rated low for **road** and **trail** construction due to the shallow depth to bedrock.

This soil has a low susceptibility to **weed infestation** when due to the high elevation and extremely cold climate. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential when disturbed due to the silty surface soil texture. The subsoil is much less erosive and the high rock content creates a natural armor layer as soil fines are eroded. These soils are rated as having a low potential for **waste disposal** using

traditional septic tank and drainfield systems due to their shallow depth.

Soil education highlights include:

- Ice features including turf-banked terraces, stone stripes, ice-wedge polygons, *Dryas* "spotted tundra".
- The angular rocks that suggest they have not been transported far.



Turf-banked terraces near Scenic Point.



Turf-banked terraces viewed from below on East Flattop Mountain.

C8 DEEP COLLUVIAL GRASSLAND SOILS

LOWER MOUNTAIN SLOPES

This unit is mapped across 609 acres mainly on lower to mid mountain slopes. It is dominated by colluvium. Scoured bedrock, shallow to moderately deep colluvial soils, glacial soils and wet mineral soils are other components of this unit. Vegetation is dominated by grasses and shrubs with scattered forest. Elevations are 4500-6000 feet. The overall topography is moderately steep to steep with most slopes in the 25 to 60 percent range. Mean annual precipitation is 30 to 40 inches.

MAJOR SOIL

This unit is dominated by a loamy colluvial grassland soil with a dark surface layer. It occupies approximately 80 percent of the unit. Other components of this mapping unit are soils with thinner dark surface layers, soils that are shallow to moderately deep, talus and rock outcrops.

C8 - DEEP COLLUVIAL GRASSLAND SOILS

(75% of unit): This soil is deep, well drained and formed in rocky, sandy and loamy colluvium. The surface layer is gravelly or very gravelly loam or sandy loam with 25-40% gravels. The subsoil is very gravelly to extremely gravelly loam or sandy loam. Rocks are angular gravels and cobbles with occasional stones. Rock content increases with depth. Available water holding capacity is moderate due to the loamy texture and high rock content; 1-1.5 inches in the surface foot and 4-6 inches to a depth of five feet.

C8 PROFILE DESCRIPTION

SURFACE - The surface soil is dark brown gravelly loam with 20-35% rocks 6-10 inches thick (A horizon).

SUBSOIL - Brown, very to extremely gravelly sandy loam or loam 12-24 inches thick with 55-65% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, extremely gravelly sandy loam or loam with 60-70% rock fragments (C horizon). The depth to bedrock is many feet.

VEGETATION

Vegetation is mainly fescue grassland dominated by rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), bluebunch

Soils of Glacier National Park
Land & Water Consulting, Inc./B. Dutton and others/01-08-2001

wheatgrass (*Agropyron spicatum*), Richardson's needlegrass (*Stipa richardsonii*), timber oatgrass (*Danthonia intermedia*), prairie junegrass (*Koeleria cristata*), sticky geranium (*Geranium viscosissimum*) and lupine (*Lupinus spp.*). Scattered shrubs include shrubby cinquefoil (*Potentilla fruticosa*), chokecherry (*Prunus virginiana*), horizontal juniper (*Juniperus horizontalis*), serviceberry (*Amelanchier alnifolia*) and rose (*Rosa woodsii*). Other plants include rock alumroot (*Heuchera cylindrica*), phacelia (*Phacelia spp.*), elk sedge (*Carex geyeri*), kinnikinnick (*Arctostaphylos uva-ursi*), and wild buckwheat (*Eriogonum umbellatum*).

The dry grassland vegetation results from the south aspect, well-drained and porous soil and other factors.

GEOLOGY

The parent material is dominated by colluvium with extremely gravelly sandy loam or loam textures. The surface contains wind deposited material including volcanic ash. Rocks are angular quartzite and argillite.

C8 PROFILE ILLUSTRATION



SOIL CLASSIFICATION

These deep, colluvial grassland soils (C8) are classified as a loamy-skeletal, mixed, Typic Cryoborolls.

MINOR SOILS - INCLUSIONS

(20% of unit):

- Talus (C2) -below rock outcrops
- Rock outcrops (C1)
- Moderately deep (C5) and shallow soils (C4) near scoured bedrock areas.

INTERPRETATIONS

Productivity and revegetation potentials for these soils are moderate due to the loamy texture and high rock content. Plant species and planting date are critical to rapid, successful revegetation.

This soil is rated high for **road and trail** construction due to the high rock content, good drainage and porous (loamy and sandy) subsoil.

This soil has a high susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential when disturbed due to the silty surface soil texture. The subsoil is much less erosive and the high rock content creates a natural armor layer as soil fines are eroded.

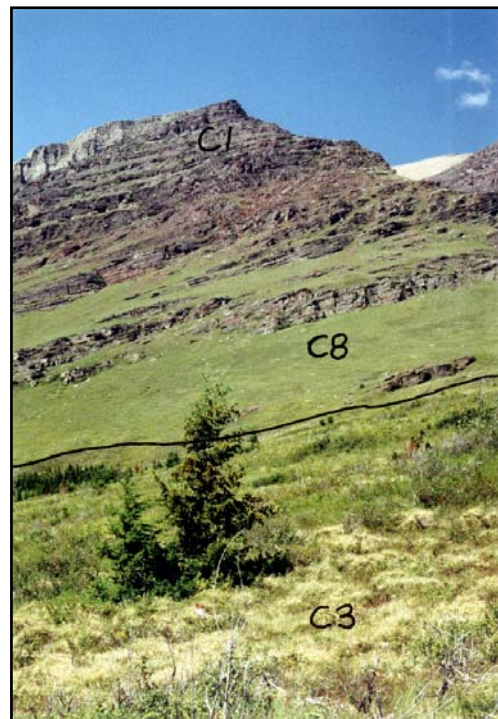
These soils are rated as having a moderate potential for **waste disposal** using traditional septic tank and drainfield systems due to their medium texture and high rock content. Slopes over 15% are rated as having a low potential.

Soil education highlights include:

- The dark, high-organic matter content grassland surface soil. This is the zone of most intense biological and chemical activity.
- The grassland vegetation resulting from the coarser soil textures than surrounding soils with aspen (*Populus tremuloides*) and conifer vegetation.
- Animal burrows and exposed subsoil material, often with invader weeds. Animal mixing of surface soil layers.
- The angular rocks that suggest they have not been transported far.



Deep colluvial grassland soils on Appistoki Peak.



Quartzite/Argillite Bedrock (C1), Deep colluvial grassland soils (C8) and Deep colluvial forest soils (C3) on Altyn Peak.

C9 SHALLOW GRASSLAND SOILS LOWER MOUNTAIN SLOPES

This unit is not mapped alone but in complex with moderately deep soils. It occurs mainly on steep, lower mountain slopes with south aspects. It is dominated by residuum and colluvium. Scoured bedrock, shallow to moderately deep colluvial soils and glacial soils are other components of this unit. Vegetation is dominated by grasses with scattered shrubs and stunted trees. Elevations are 3200-5500 feet. The overall topography is steep to very steep with most slopes in the 35 to 70 percent range. Mean annual precipitation is 30 to 40 inches.

GEOLOGY

The parent material is dominated by residuum and colluvium with extremely gravelly loam or sandy loam textures. The surface contains wind deposited material including volcanic ash. Rocks are angular quartzite and argillite.

SHALLOW GRASSLAND SOILS

This soil is deep, well drained and formed in rocky, sandy and loamy colluvium weathered from quartzite and argillite. The surface layer is gravelly or very gravelly loam with 25-40% gravels. The subsoil is very gravelly to extremely gravelly loam. Rocks are angular gravels and cobbles with occasional stones. Rock content increases with depth and fractured bedrock is present at 1-3 feet. Available water holding capacity is low due to the high rock content and limited depth; 0.5-1 inch in the surface foot and 1.5-2 inches to the depth of fractured rock.

C9 PROFILE DESCRIPTION

SURFACE - The surface soil is very dark brown gravelly loam with 30-50% rocks 6-10 inches thick (A horizon).

SUBSOIL - Brown or dark brown, very to extremely gravelly loam 6-24 inches thick with 50-75% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, extremely gravelly loam or sandy loam with 60-90% rock fragments (C horizon). The depth to fractured bedrock is 1-3 feet.

C9 PROFILE ILLUSTRATION



SOIL CLASSIFICATION

These shallow grassland soils (C9) are classified as Lythic Haplocryolls.

VEGETATION

Vegetation is mainly grassland dominated by bluebunch wheatgrass (*Agropyron spicatum*), elk sedge (*Carex geyeri*), rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), Richardson's needlegrass (*Stipa richardsonii*), timber oatgrass (*Danthonia intermedia*). Scattered shrubs include shrubby cinquefoil (*Potentilla fruticosa*), chokecherry (*Prunus virginiana*), horizontal juniper (*Juniperus horizontalis*), serviceberry (*Amelanchier alnifolia*) and rose (*Rosa woodsii*). Other plants include rock alumroot (*Heuchera cylindrica*), phacelia (*Phacelia spp.*), kinnikinnick (*Arctostaphylos uva-ursi*), and wild buckwheat (*Eriogonum umbellatum*).

The dry grassland vegetation results from the south aspect, well-drained and porous soil and other factors.

INTERPRETATIONS

Soil depth and high rock content are the main factors affecting interpretations for these soils.

Productivity and revegetation potentials are low for this shallow soil due to the low moisture and nutrient holding capacity.

This shallow soil is rated low for **roads** due to limited depth.

This soil has a moderate to high susceptibility to **weed infestation** when disturbed due to low elevation and south aspect. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential when disturbed.

These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to limited soil depth.

Soil education highlights include:

- The dark, high-organic matter content grassland surface soil. This is the zone of most intense biological and chemical activity.
- The grassland vegetation resulting from the hot, dry aspect and shallow depth.
- Animal burrows and exposed subsoil material, often with invader weeds.
- Animal mixing of surface soil layers.
- The angular rocks that suggest soil materials have not been transported far.

MAPPING UNITS

C9/C5 SHALLOW GRASSLAND SOILS AND MODERATELY DEEP COLLUVIAL SOILS SCoured MOUNTAIN SLOPES AND TROUGH WALLS

This unit covers 2,839 acres (0.3%) in the southern portion of the park. It is dominated by glacially-scoured mountain slopes that have developed shallow and moderately deep colluvial soils since de-glaciation. Vegetation is a mosaic of grassland and mostly stunted conifer forest. There is a mixture of grass, shrub and tree communities. Elevations are 3200-5500 feet. The topography is mainly very steep mountain slopes in the 35-70 percent range. Mean annual precipitation is 30 to 40 inches.

MAJOR SOILS - COMPLEX

This unit is mapped as a complex of two main soils but includes others in limited areas. The most common soil (C9) is shallow to fractured bedrock and occupies 50 percent of the unit. The other common soil (C5) is moderately deep to fractured bedrock and occupies 40 percent of the unit.

MINOR SOILS - INCLUSIONS

(25% of unit):

- **Rock outcrop (C1)** on convex areas.
- **Deep colluvial soils (C3)** mainly on lower slopes and far from rock outcrops.
- **Talus (C2)** below rock outcrops.



Shallow grassland soils (C9) on steep south aspects above the Middle Fork of the Flathead River.

3.2.5 BEDROCK SOILS - LIMESTONE

Approximately 14 percent of the park is underlain by Precambrian limestone bedrock yielding soils with light brown colors and silty or loamy textures. The addition of volcanic ash has not changed these limestone textures. Since the Precambrian limestone does not have a very high lime (calcium carbonate) content and since the climate is moist, these soils do not usually have significant accumulations of lime. However, some profiles have lower horizons with pH levels of 7.5 - 8.0 and weak to moderate reaction to dilute hydrochloric acid. These limestone soil features have important effects

on vegetation and other environmental components.

In general, vegetation on limestone soils in the park is slightly sparser and reflects slightly drier conditions than adjacent quartzite/argillite soils. Height growth, especially of trees is somewhat reduced. Lodgepole pine (*Pinus contorta*) is less common on limestone and less vigorous where it does occur. Douglas-fir (*Pseudotsuga menziesii*), common juniper (*Juniperus communis*), dryas (*Dryas spp.*) and blue clematis (*Clematis columbiana*) are examples of plants that are more common on limestone. Limestone effects on vegetation are often subtle in Glacier.

LC1 LIMESTONE ROCK OUTCROP

Limestone rock outcrop is mapped alone across 47,678 acres (4.7%) of the park. Limestone rock outcrop is most common on mountain tops, cirque headwalls and ridges along the continental divide and higher mountain tops. Other common locations are scoured portions of glacial trough walls and valleys as well as the eroded portions of avalanche chutes. Rock outcrops are more frequent in the harder, most resistant layers. Talus, shallow soils, and alpine meadow soils are other important components of this unit. Vegetation is limited to lichens and scattered plants capable of survival in fractures. Elevations are 4500-10,466 feet. The topography ranges from vertical cliffs to nearly level rock ledges and scoured sites. Mean annual precipitation is 30 to 100 inches.

GEOLOGY

Rock types are Precambrian limestones which occur as inter-bedded layers. These rocks were deposited, uplifted and faulted then eroded by ice, water, wind, temperature and other forces. The differential hardness of rock layers often results in undulating microtopography on the current rock surface.

VEGETATION

Vegetation on the rock outcrop portion of this unit is limited to lichens and the few scattered plants that manage to survive in fractures. The vegetation viewed on these landscapes is mainly restricted to the inclusions of shallow soils.

MAJOR COMPONENT

Limestone rock outcrop occupies 85% of this unit.

MINOR COMPONENTS - INCLUSIONS

(15% of the unit)

- **Talus (LC2)**, usually below cliffs and other rock outcrops. Talus was usually, but not always delineated separately from rock since it was delineated by Carrara (1990) and is available as a layer in the Glacier GIS system.
- **Shallow soils (LC4)**, usually in concave areas, concave areas and on less steep slopes. Vegetation varies dramatically due to moisture and elevation from grassland species at low elevation dry sites to alder (*Alnus spp.*) and sedge where moisture is concentrated from adjacent sites.
- **Alpine meadow limestone soils (LC6)** at high elevation moist sites.

INTERPRETATIONS

Most uses are severely restricted by the lack of soil material. Although ideal for rock quarries, these sites are extremely difficult to reclaim to a natural appearance.

OTHER MAPPING UNITS

LC1/LC4 LIMESTONE ROCK OUTCROP AND SHALLOW SOILS

This unit is mapped as a complex across 16,775 acres of the park. It has similar distribution, geology, and environment to the LC1 mapping unit. Rock outcrop (60%) and shallow soils (25%) are the major components of this unit. The shallow soils are found at concave areas, less steep sites and toeslopes.

VEGETATION

Vegetation is extremely variable on the shallow soil portion of this mapping unit. Alpine grasses and forbs and grass-like plants are common at the highest elevation. Stunted and wind-formed (krumholtz) shrubs and conifer trees may also occur. Tree species include subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*) and whitebark pine. Lodgepole pine (*Pinus contorta*) may occur on some sites but is generally shorter and less dense than on adjacent non-limestone soils. Grassland vegetation may dominate on low elevation south aspects. Alder (*Alnus spp.*), sedge and moist site forbs occur where north aspects or drainage from above provide better moisture conditions.

MINOR COMPONENTS - INCLUSIONS

(15% of the unit)

- **Talus (LC2)**, usually below cliffs and other rock outcrops.
- **Alpine meadow soils (LC6)** on less steep, high elevation, moist sites.
- **Moderately deep (LC5) and deep soils (LC3)** on lower slopes and less steep areas.

LC2 LIMESTONE TALUS

Limestone talus is mapped alone or in combination with shallow soils across 9,224 acres of the park. Talus is most common immediately below rock outcrops especially cliffs and cirque headwalls. In some cases, talus follows the less resistant layers while rock outcrops persist in the harder, most resistant layers. Rock outcrop, alpine soils and shallow to deep colluvial soils are other important components of this unit. Vegetation ranges from almost none to significant coverage of mainly forbs, grasses and grass-like plants. Elevations are 5000-10,466 feet. The topography is steep mountain slopes below rock cliffs. Mean annual precipitation is 40 to 100 inches.

GEOLOGY

Rock types are Precambrian limestone. These rocks have been fractured and dislodged by temperature, water, ice, gravity and other factors. These processes continue today resulting in many small deposition events which form a mosaic of surface ages. Most talus contains more soil-sized particles than the surface appearance would suggest. The source of these soil materials includes rock weathering products but wind deposits, especially ash are significant contributors.

VEGETATION

Where talus is large and composed of hard rocks, very little vegetation may be present. However, on many talus areas vegetation coverage is significant. Vegetation is highly variable due to elevation and moisture conditions but is usually dominated by forbs, grasses and grass-like plants. Occasional young, stunted shrubs and trees may be present. The mosaic of deposits which make up talus slopes are continually being disturbed or replaced. This multi-aged surface results in a multi-aged vegetation. Vegetation coverage ranges from almost none on new deposits to over 75% on older, more stable sites.

Species vary dramatically according to elevation and moisture. Trees include subalpine fir (*Abies lasiocarpa*), and whitebark pine with occasional alpine larch (*Larix lyallii*) at higher elevations and Douglas-fir (*Pseudotsuga menziesii*), or common juniper (*Juniperus communis*) at lower elevations. Shrubs include dryas (*Dryas spp.*), shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*), blue huckleberry (*Vaccinium globulare*) and grouse whortleberry (*Vaccinium scoparium*) at higher elevations and dryas (*Dryas spp.*), woodsrose (*Rosa woodsii*), serviceberry (*Amelanchier alnifolia*), mountain maple (*Acer glabrum*) and others at lower elevations. Forbs include sitka valerian (*Valeriana sitchensis*), American bistort (*Polygonum bistortoides*), small-flowered woodrush (*Luzula parviflora*), arrowleaf groundsel (*Senecio triangularis*), western St. John's Wort (*Hypericum formosum*), sibbaldia (*Sibbaldia procumbens*) and many others. Other plants include alpine Timothy (*Phleum alpinum*), black sedge (*Carex nigricans*), Parry's sedge (*Carex parryana*), Parry's rush (*Juncus parryi*) and many others.

Some talus slopes collect and route moisture to their base resulting in riparian vegetation such as aspen (*Populus tremuloides*), cottonwood (*Populus trichocarpa*), birch (*Betula spp.*), alder (*Alnus spp.*), dogwood (*Cornus stolonifera*), sedges (*Carex spp.*) and others.

MAJOR COMPONENT

Talus occupies 85% of this unit. Talus is distinguished from soil by the lack of pedogenic horizons. However, there is often horizontal stratification representing successive depositions. The surface of many areas is often covered with cobbles and stones. Where rock content in the surface is low enough to allow vegetation to grow, the surface soil has a thin dark brown layer one to 3 inches thick. This layer has a very gravelly loam texture. Below this depth the soil is brown extremely gravelly loam. Rock content may be as low as 50% in the surface but is usually 80-90% throughout.

Available water holding capacity is very low due to the high rock content; .25-.5 inches in the surface foot and 1-3 inches to a depth of five feet.

LC2 PROFILE DESCRIPTION

SURFACE - Intermittent surface layer of stones, cobbles and gravels 6-12 inches thick.

SUBSURFACE - Intermittent darkening of the surface few inches beneath the surface rock layer especially where vegetation is most dense. Very to extremely gravelly loam or sandy loam. (A horizon)

SUBSTRATUM - Extremely stony sandy loam.

The depth to bedrock is usually many feet except near rock outcrops.

MINOR COMPONENTS - INCLUSIONS

(15% of the unit)

- **Rock outcrop (C1)** as cliffs, ridges and other features.
- **Poorly developed soils (G1)** on recent glacial moraines.
- **Shallow to deep colluvial soils (C3, C4, C5)** on older, more stable areas. Vegetation coverage is usually near 100% on these soils.
- **Alpine meadow soils (C6)** at high elevation sites with older, more stable surfaces such as toeslopes.

INTERPRETATIONS

Most uses are severely restricted by the instability of talus, lack of soil material and potential for snow avalanche.

LC3 DEEP COLLUVIAL FOREST SOILS ON LIMESTONE LOWER MOUNTAIN SLOPES

This unit is mapped across 25,853 acres of the park, mainly on lower to mid mountain slopes. It is dominated by colluvium with a surface layer containing volcanic ash-rich wind deposits. Shallow to moderately deep soils, glacial soils, alluvial soils, scoured bedrock and wet mineral soils are other components of this unit. Vegetation is dominated by conifer forest types. Elevations are 3500-7000 feet. The overall topography is moderately steep to steep with most slopes in the 25 to 60 percent range. Mean annual precipitation is 40 to 80 inches.

GEOLOGY

The parent material is dominated by limestone colluvium with extremely gravelly sandy loam or loam textures. The surface is a loamy mixture of volcanic ash-rich wind deposits and the underlying soil. Rocks are angular and predominantly limestone with minor amounts of quartzite and argillite. Rocks are mainly light tan or brown colored. Occasional rocks effervesce with dilute hydrochloric acid and some have lime coatings.

MAJOR SOIL

This unit is dominated by a loamy colluvial forest limestone soil that has a surface layer with volcanic ash influence. It occupies approximately 80 percent of the unit. Other soils that commonly occur in this mapping unit are shallow to moderately deep soils, limestone rock outcrops and glacial soils.

LC3 - LOAMY DEEP COLLUVIAL FOREST LIMESTONE SOILS

(80% of unit): This soil is deep, well drained and formed in deep rocky and loamy colluvium with an ash-rich surface layer. The surface layer is loam or sandy loam with 0-20% gravels. The subsoil is very gravelly to extremely gravelly loam or sandy loam. Rocks are angular gravels and cobbles with occasional stones. Rock content increases with depth. Available water holding capacity is moderate due to the loamy texture and high rock content; 1-1.5 inches in the surface foot and 4-6 inches to a depth of five feet.

LC3 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1-2 inches thick (O horizon). The surface soil has a very

dark brown colored layer of gravelly loam with 15-35% rocks 2-4 inches thick (A horizon).

SUBSURFACE - Brown to reddish brown, very gravelly loam or sandy loam 6-18 inches thick with 30-50% rock fragments including gravel, cobbles and stones. Significant volcanic ash influence (Bw horizon).

SUBSOIL - Brown, extremely gravelly loam or sandy loam 12-24 inches thick with 55-65% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, extremely gravelly sandy loam or loam with 60-70% rock fragments (BC horizon). The depth to bedrock is many feet.

LC3 PROFILE ILLUSTRATION



VEGETATION - LC3

Vegetation is subalpine fir climax forest. These limestone soils generally have vegetation which reflects slightly drier conditions than on adjacent quartzite and argillite soils. Plants, especially trees are shorter and have lower coverages.

Trees are mainly subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*) and spruce (*Picea engelmannii*). Whitebark pine and lodgepole pine (*Pinus contorta*) occur on some sites. Shrubs include serviceberry (*Amelanchier alnifolia*), mountain maple (*Acer glabrum*), blue huckleberry (*Vaccinium globulare*), buffalo berry, Utah honeysuckle (*Lonicera involucrata*), menziesia (*Menziesia ferruginea*), dryas (*Dryas spp.*) and many others. Forbs include queen's cup beadlily (*Clintonia uniflora*), blue clematis (*Clematis columbiana*), thimbleberry (*Rubus parviflorus*), twinflower (*Linnaea borealis*), dogwood (*Cornus stolonifera*), beargrass (*Xerophyllum tenax*) and many others. Grasses include pinegrass (*Calamagrostis rubescens*), western fescue (*Festuca occidentalis*) and mountain muhly (*Muhlenbergia glomerata*).

SOIL CLASSIFICATION

These deep, colluvial forest soils (LC3) are classified as a loamy-skeletal, mixed, Typic Eutrocrypts.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Wet mineral soils (W1)** in depressions, near water, toeslopes.
- **Alluvial soils (A1, A2, A3)** near streams.
- **Rock outcrops (LC1)**
- **Moderately deep (LC5) and shallow soils (LC4)** near scoured bedrock areas.
- **Soils with silty clay loam subsoils** on the less steep slopes (Haplocryalfs).
- **Deep grassland colluvial soils** on south aspects (Typic Haplocryolls).
- Similar soils with thick, low-density ash surfaces on the less steep slopes (Andic Dystrocrypts).

INTERPRETATIONS

Productivity and revegetation potentials for these soils are moderate due to the loamy texture and high rock content. This soil is rated moderate for **road** and **trail** construction due to loamy textures and few rocks in the surface. Trail erosion is common on this soils and is often 3-6 inches deep.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the silty surface soil texture and few rocks. The subsoil is much less erosive and the high rock content creates a natural armor layer as soil fines are eroded.

These soils are rated as having a moderate potential for **waste disposal** using traditional septic tank and drainfield systems due to their medium texture and high rock content. Slopes over 15% severely limit waste disposal.

Soil education highlights include:

- The volcanic ash-rich surface layer resulting mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- Soil horizons especially the surface litter layer which protects the soil from erosion.
- The angular rocks that suggest they have not been transported far.

OTHER MAPPING UNITS

LC3/LC5 DEEP AND MODERATELY DEEP COLLUVIAL FOREST SOILS CIRQUE BASINS AND LOWER MOUNTAIN SLOPES

Deep and moderately deep colluvial forest limestone soils are mapped as a complex on 23,195 acres of the park. This mapping unit occurs mainly in cirque basins and on lower to mid mountain slopes. It is dominated by limestone colluvium with a surface layer containing volcanic ash-rich wind deposits. Shallow soils, glacial soils, alluvial soils, wet mineral soils and scoured limestone bedrock are other components of this unit. Vegetation is dominated by conifer forest types. Elevations are 3500-7000 feet. The overall topography is moderately steep to steep with most slopes in the 20 to 50 percent range. Mean annual precipitation is 50 to 90 inches.

MAJOR SOILS - COMPLEX

This unit is a complex of two main soils but includes others in minor amounts. The most common is the deep forested colluvial soil (LC3) which occupies approximately 50% of the unit. The other most common soil is moderately deep to fractured bedrock (LC5).

VEGETATION

Vegetation is dominated by cool to cold conifer forest. These limestone soils generally have vegetation which reflects slightly drier conditions than on adjacent quartzite and argillite soils. Plants, especially trees are shorter and have lower coverages. Seral vegetation may be dominated by shrubs, forbs and grasses following disturbances such as fire. Conifer trees dominate the vegetation but may be stunted by the cold climate, wind exposure, high soil pH and limited bedrock depth. Trees include subalpine fir (*Abies lasiocarpa*) and spruce (*Picea engelmannii*) with occasional alpine larch (*Larix lyallii*), lodgepole pine (*Pinus contorta*) and whitebark pine. Shrubs include shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*), blue huckleberry (*Vaccinium globulare*), menziesia (*Menziesia ferruginea*), alder (*Alnus spp.*), grouse whortleberry (*Vaccinium scoparium*) and dryas (*Dryas spp.*). Other plants include elk sedge (*Carex geyeri*), blue clematis (*Clematis columbiana*), sitka valerian (*Valeriana sitchensis*), American bistort (*Polygonum bistortoides*), small-flowered woodrush (*Luzula parviflora*), beargrass (*Xerophyllum tenax*), arrowleaf groundsel (*Senecio triangularis*), and many others.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Wet mineral soils (W1)** in depressions, near water, toeslopes.
- **Alluvial soils (A1, A2, A3)** near streams.
- **Rock outcrops (LC1)**
- **Shallow soils (LC4)** near scoured bedrock areas.
- **Soils with high subsoil clay contents** on the less steep slopes (Haplocryalfs)
- Similar soils with thick, low-density ash surfaces on the less steep slopes (Andic Dystrocryepts)

LC4 SHALLOW LIMESTONE SOILS NEAR BEDROCK OUTCROPS AND SCOURED MOUNTAIN SLOPES

This soil is not mapped alone but in complex with rock outcrop, moderately deep soils and alpine meadow soils. It is an important minor component of many other mapping units. These soils are mainly near rock outcrops and site where soil has been eroded by ice, wind, water and gravity. Vegetation is highly variable due to bedrock depth, surface rock content, aspect and elevation. Many sites have a mosaic of stunted conifer forest and mixed shrub/forb/grass communities. Elevations are 3500-10,000 feet. The topography ranges from steep mountain slopes in the 25-60 percent range to nearly level glacially scoured areas. Mean annual precipitation is 40 to 100 inches.

GEOLOGY

The parent material is mainly loam or sandy loam colluvium with abundant rock content and bedrock within 1-2 feet. Some of the fine soil material was deposited by wind and includes volcanic ash. Rocks are angular and predominantly limestone with minor amounts of quartzite and argillite. They are mainly light tan or brown colored. Occasional rocks effervesce with dilute hydrochloric acid and some have lime coatings.

LC4 - SHALLOW SOILS

This soil is shallow, well drained and formed in limestone colluvium. The surface layer is brown gravelly to very gravelly loam or sandy loam. The subsoil and substratum are brown or pale brown, extremely gravelly loam or sandy loam. Rock content increases with depth becoming fractured bedrock at 1-2 feet. Available water holding capacity is very low due to the high rock content and limited depth; .5-1 inch in the surface foot and 1.5-2 inches total to the depth of fractured bedrock.

LC4 PROFILE DESCRIPTION

SURFACE - On some sites with conifer forest the surface is covered with a layer of partially decomposed forest litter 1-2 inches thick (O horizon). The surface soil is brown very gravelly loam 3-6 inches thick with 30-60% rock fragments (A horizon). Rock fragments are limestone angular gravels, cobbles with some stones..

SUBSOIL - Brown extremely gravelly loam 3-6 inches thick with 50-70% rock fragments (Bw horizon).

SUBSTRATUM - Brown or light brown, extremely gravelly loam or sandy loam with 60-90% rock fragments (BC horizon). The total depth to fractured bedrock is 2-4 feet.

FRACTURED LIMESTONE BEDROCK (R layer)

LC4 PROFILE ILLUSTRATION



VEGETATION - LC4

These limestone soils generally have vegetation which reflects slightly drier conditions than on adjacent quartzite and argillite soils. Plants, especially trees are shorter and have lower coverages. Vegetation is mainly either stunted, wind-form conifer forest in the alpine fir climax series or seral communities dominated by shrubs, grasses and forbs. South aspects and recent avalanche slopes often have less trees and more shrubs, grasses and forbs.

Trees are mainly subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*) and spruce (*Picea engelmannii*) with smaller amounts of common juniper (*Juniperus communis*) and whitebark pine. Shrubs include kinnikinnick (*Arctostaphylos uva-ursi*), blue huckleberry (*Vaccinium globulare*), spirea (*Spirea spp.*), serviceberry (*Amelanchier alnifolia*), shrubby cinquefoil (*Potentilla fruticosa*) and others. Other plants include beargrass (*Xerophyllum tenax*), phacelia (*Phacelia spp.*), alumroot (*Heuchera cylindrica*), blue clematis (*Clematis columbiana*), Indian paintbrush (*Castilleja spp.*), sweetvetch (*Hedysarum sulphurescens*), sitka valerian (*Valeriana sitchensis*), elk sedge (*Carex geyeri*) and many others. South aspects at low elevations may be dominated by bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), arrowleaf balsamroot and other dry site vegetation.

SOIL CLASSIFICATION

This shallow soil (C4) is classified as a mixed Lithic Eutrocryept.

INTERPRETATIONS

Soil depth and high rock content are the main factors affecting interpretations for these soils.

Productivity and revegetation potentials are low for this shallow soil due to the low moisture and nutrient holding capacity as well as the cold climate.

This shallow soil is rated low for **roads** due to limited depth.

This soil has a moderate to low susceptibility to **weed infestation** when disturbed due to high elevation and cold environment. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential when disturbed.

These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to limited soil depth.

Soil education highlights include:

- The bright brown topsoil color due in part to volcanic ash. As is mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- Stunted tree and other vegetation growth.
- The presence of shallow and rocky soil indicator plants such as phacelia (*Phacelia spp.*), alumroot (*Heuchera cylindrica*), sweetvetch (*Hedysarum sulphurescens*) and others.

MAPPING UNITS

LC4/LC6 SHALLOW SOILS AND ALPINE MEADOW SOILS HIGH ELEVATION SITES

This mapping unit covers 2,859 acres at the higher elevations throughout the park. It is dominated by glacially-scoured cirque basins and mountain slopes that have developed alpine meadow soils in the more moist areas and shallow colluvial soils on the drier soil areas. Vegetation is a mosaic of alpine meadow communities and drier mixed tree/shrub/forb/grass communities. Elevations are 5,000-10,000 feet. The topography ranges from cirque basins to moderate mountain slopes in the 10-40 percent range. Mean annual precipitation is 60 to 90 inches.

MAJOR SOILS - COMPLEX

This unit is mapped as a complex of two main soils but includes others in limited areas. The most common soil (C4) is shallow to fractured bedrock and occupies 40 percent of the unit. The other common soil (C6) is an alpine soil which make up approximately 30 percent of the unit.

VEGETATION

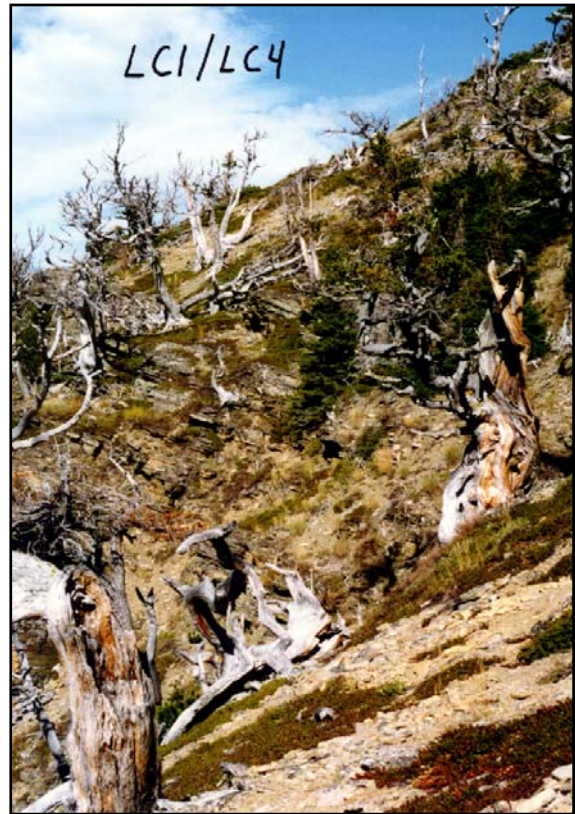
These limestone soils generally have vegetation which reflects slightly drier conditions than on adjacent quartzite and argillite soils. Plants, especially trees are shorter and have lower coverages. Vegetation in this unit is dominated by the colder climate species. Both stunted, wind-form conifer forest in the alpine fir series and seral communities dominated by shrubs, grasses and forbs are present. Trees are mainly subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*) and spruce (*Picea engelmannii*) with smaller amounts of common juniper (*Juniperus communis*) and whitebark pine (*Pinus albicaulis*). Shrubs include shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*), blue

huckleberry (*Vaccinium globulare*) and grouse whortleberry (*Vaccinium scoparium*). Forbs include sitka valerian (*Valeriana sitchensis*), American bistort (*Polygonum bistortoides*), small-flowered woodrush (*Luzula parviflora*), arrowleaf groundsel (*Senecio triangularis*), western St. John's Wort (*Hypericum formosum*), sibbaldia (*Sibbaldia procumbens*) and many others. Other plants include phacelia (*Phacelia spp.*), alumroot (*Heuchera cylindrica*), alpine Timothy (*Phleum alpinum*), elk sedge (*Carex geyeri*), black sedge (*Carex nigricans*), Parry's sedge (*Carex parryana*), Parry's rush (*Juncus parryi*) and many others.

MINOR SOILS - INCLUSIONS

(20% of unit):

- **Rock outcrop (LC1)**
- **Moderately deep and deep colluvial soils (LC5, LC3)** on toeslopes and less steep areas.
- **Wet mineral soils (W1)** in depressions, near water, toeslopes.



Complex of limestone rock outcrop and shallow limestone soils near Poia Lake.

LC5 MODERATELY DEEP LIMESTONE COLLUVIAL SOILS SCoured MOUNTAIN SLOPES AND TROUGH WALLS

This soil is not mapped alone but in complex with shallow or deep soils. It is an important minor component of many other mapping units. These soils are on sites that have been eroded by ice, wind, water and gravity. They are also on sites where soil formation from bedrock is very slow. Vegetation is highly variable due to bedrock depth, surface rock content, aspect and elevation. Many sites have a mosaic of stunted conifer forest and mixed shrub/forb/grass communities. Elevations are 3500-10,000 feet. The topography ranges from steep mountain slopes in the 25-60 percent range to nearly level glacially scoured areas. Mean annual precipitation is 40 to 100 inches.

GEOLOGY

The parent material is mainly loam or sandy loam limestone colluvium with abundant rock fragments and bedrock within 2-4 feet. Some of the fine soil material was deposited by wind and includes volcanic ash. Rocks are angular and predominantly limestone with minor amounts of quartzite and argillite. They are mainly light tan or brown colored. Occasional rocks effervesce with dilute hydrochloric acid and some have lime coatings.

LC5 - MODERATELY DEEP LIMESTONE SOILS

This soil is moderately deep, well drained and formed in limestone colluvium. The surface layer is brown gravelly or very gravelly loam or sandy loam. The subsoil is very gravelly loam or sandy loam. The substratum is extremely gravelly loam or sandy loam. Rock content increases with depth becoming fractured bedrock at 2-4 feet. Available water holding capacity is low due to the high rock content and limited depth; 1 inch in the surface foot and 2-3 inches total to the depth of fractured bedrock.

LC5 PROFILE DESCRIPTION

SURFACE - The soil surface is covered by partially decomposed forest litter 1 inch thick (O horizon). This litter layer is absent from some sites, especially where there are few

trees. The upper surface soil has a thin dark very dark grayish brown layer of very gravelly loam or sandy loam 2-4 inches thick with 25-50% gravels and cobbles (A horizon). The lower surface soil is mainly brown very gravelly loam 3-6 inches thick with 25-50% rock fragments (Bw horizon). Rock fragments are mainly limestone gravels and cobbles with occasional stones.

SUBSOIL - Brown, extremely gravelly loam 12-30 inches thick with 30-50% rock fragments (Bw horizon).

SUBSTRATUM - Brown, extremely gravelly loam or sandy loam with 65-90% rock fragments (BC horizon). The total depth to fractured bedrock is 2-4 feet. **FRACTURED LIMESTONE BEDROCK** (R layer)

VEGETATION - LC5

These limestone soils generally have vegetation which reflects slightly drier conditions than on adjacent quartzite and argillite soils. Plants, especially trees are shorter and have lower

coverages. Vegetation is mainly stunted subalpine fir climax forest. South aspects and avalanche slopes have mixed shrub/grass/forb communities. Common trees are subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*) and spruce (*Picea engelmannii*) with occasional lodgepole pine (*Pinus contorta*) and whitebark pine (*Pinus albicaulis*). Shrubs include kinnikinnick (*Arctostaphylos uva-ursi*), blue huckleberry (*Vaccinium globulare*), spirea (*Spirea spp.*), serviceberry (*Amelanchier alnifolia*), shrubby cinquefoil (*Potentilla fruticosa*), chokecherry (*Prunus virginiana*), alder (*Alnus spp.*) and others. Forbs include blue clematis (*Clematis columbiana*), beargrass (*Xerophyllum tenax*), arnica (*Arnica spp.*), sitka valerian (*Valeriana sitchensis*) and many others. Sedges (*Carex spp.*) include elk sedge (*Carex geyeri*).

LC5 PROFILE ILLUSTRATION



SOIL CLASSIFICATION

This moderately deep soil is classified as a loamy-skeletal, mixed Typic Dystrocryept.

INTERPRETATIONS

Soil depth, high rock content and slope steepness are the main factors affecting interpretations for this soils.

Productivity and revegetation potentials are moderate due to the low moisture and nutrient holding capacity.

Both soils are rated low for **roads** due to limited depth. The moderately deep soil is rated moderate and the shallow soil low for **trail** construction due to depth. The soil material itself would be rated moderate to high if bedrock depth were ignored.

This soil has a moderate susceptibility to **weed infestation** when disturbed. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. Both soils have a moderate erosion potential when disturbed.

These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to limited soil depth.

Soil education highlights include:

- The bright brown topsoil color due in part to volcanic ash. Ash is mainly from the eruption of Mt. Mazama (Crater Lake Oregon).
- The presence of rocky soil indicator plants such as phacelia (*Phacelia spp.*), alumroot (*Heuchera cylindrica*), sweetvetch (*Hedysarum sulphurescens*) and others.

MAPPING UNITS

LC5/LC4 MODERATELY DEEP AND SHALLOW LIMESTONE SOILS SCoured MOUNTAIN SLOPES AND TROUGH WALLS

This unit covers 18,593 acres throughout the park. It is dominated by glacially-scoured mountain slopes that have developed shallow and moderately deep colluvial limestone soils since de-glaciation. Vegetation is a mosaic of mostly stunted conifer forest and mixed shrub/forb/grass communities. Elevations are 3,500-10,000 feet. The topography is mainly steep mountain slopes in the 25-60 percent range. Mean annual precipitation is 40 to 80 inches.

MAJOR SOILS - COMPLEX

This unit is mapped as a complex of two main soils but includes others in limited areas. The most common soil (LC5) is moderately deep to fractured limestone bedrock and occupies 45 percent of the unit. The other common soil (LC4) is shallow to fractured limestone bedrock and occupies 30 percent of the unit.

MINOR SOILS - INCLUSIONS

(25% of unit):

- **Rock outcrop (LC1)** on convex areas.
- **Deep colluvial soils (LC3)** on lower slopes.
- **Talus (LC2)** below rock outcrops.

LC6 ALPINE MEADOW LIMESTONE SOILS

MOUNTAIN SLOPES AND CIRQUE BASINS

This soil is mapped alone on only 452 acres. Most of this soil is mapped in complex with shallow limestone soils (LC4). It is most common in alpine meadows on mountain slopes and in cirque basins. It is dominated by limestone residuum and colluvium with a surface layer containing volcanic ash-rich wind deposits. Scoured limestone bedrock, shallow to moderately deep colluvial soils and wet mineral soils are other components of this unit. Vegetation is dominated by alpine forbs, grasses and grass-like plants with scattered shrubs and stunted conifer trees. Elevations are 5500-7500 feet. The overall topography is undulating to moderately steep most slopes in the 15 to 45 percent range. Mean annual precipitation is 80 to 100 inches.

GEOLOGY

The parent material is dominated by limestone residuum and colluvium with loam textures and increasing rock content with depth. The surface is a loamy mixture of volcanic ash-rich wind deposits and the underlying soil. Rocks are angular and predominantly limestone with minor amounts of quartzite and argillite. They are mainly light tan or brown colored. Occasional rocks effervesce with dilute hydrochloric acid and some have lime coatings.

LC6 - ALPINE MEADOW LIMESTONE SOILS

This soil is moderately deep to deep, well drained and formed in rocky and loamy colluvium mixed with ash-rich wind deposits. The surface layer is loam with 0-25% gravels. The subsoil is very gravelly to extremely gravelly loam. Rocks are angular limestone gravels with occasional cobbles and stones. Rock content increases with depth. Available water holding capacity is moderate due to the loamy texture and high rock content; 1-1.5 inches in the surface foot and 3-4.5 inches to a depth of four feet. Soil depth varies within this mapping unit from shallow to deep but the upper soil profile has relatively similar characteristics. Multiple soils were not separated based on depth due to the limited area of these soils.

LC6 PROFILE DESCRIPTION

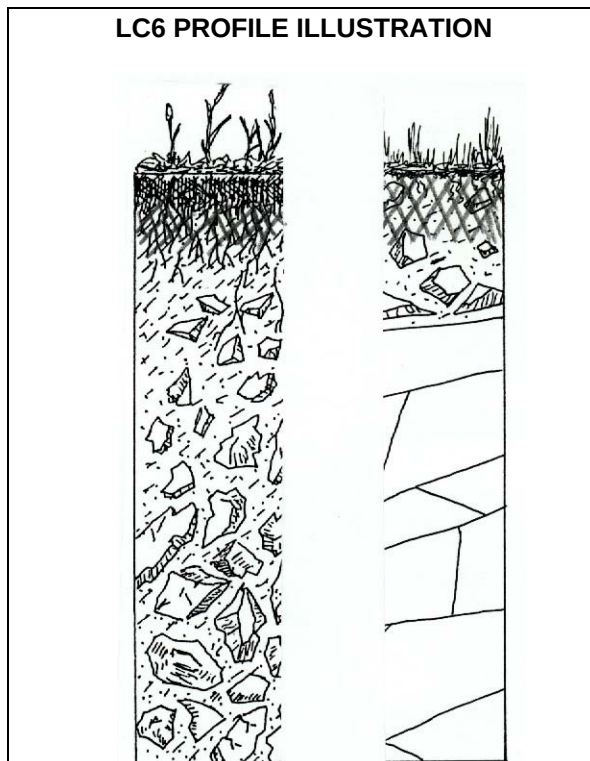
SURFACE - The surface soil is dark brown loam with 0-20% rocks 4-6 inches thick (A horizon).

Rock fragments are mainly gravels with occasional cobbles and stones. Significant volcanic ash influence. The surface layer often has a turf character caused by dense roots in the upper 2-6 inches.

SUBSOIL - Brown, very gravelly loam 7-15 inches thick with 35-65% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, extremely gravelly loam or sandy loam with 60-80% rock fragments (BC or C horizon). The depth to bedrock is mainly 20 to 40 inches.

LC6 PROFILE ILLUSTRATION



VEGETATION - LC6

These limestone soils generally have vegetation which reflects slightly drier conditions than on adjacent quartzite and argillite soils. Plants, especially trees are shorter and have lower coverages. Vegetation is dominated by alpine forbs, grasses sedges (*Carex spp.*) and rushes (*Juncus spp.*). Scattered, stunted trees and shrubs occur, usually where the surface soil has higher rock content. Trees include subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*), and whitebark pine (*Pinus albicaulis*) with occasional alpine larch (*Larix lyallii*) and lodgepole pine (*Pinus contorta*). Shrubs include

shrubby cinquefoil (*Potentilla fruticosa*), shrubby beardtongue (*Penstemon fruticosa*), blue huckleberry (*Vaccinium globulare*) and grouse whortleberry (*Vaccinium scoparium*). Forbs include sitka valerian (*Valeriana sitchensis*), American bistort (*Polygonum bistortoides*), small-flowered woodrush (*Luzula parviflora*), arrowleaf groundsel (*Senecio triangularis*), western St. John's Wort (*Hypericum formosum*), sibbaldia (*Sibbaldia procumbens*) and many others. Other plants include alpine Timothy (*Phleum alpinum*), black sedge (*Carex nigricans*), Parry's sedge (*Carex parryana*), Parry's rush (*Juncus parryi*) and many others.

SOIL CLASSIFICATION

These soils are classified as a loamy-skeletal, mixed, Typic Eutrocryepts.

MINOR SOILS - INCLUSIONS

(25% of unit):

- Wet mineral soils in depressions, near water, toeslopes (W1)
- Rock outcrops
- Shallow soils (LC4) near scoured bedrock areas.
- Similar soils with low-density ash surfaces (Andic Dystrocryepts)

INTERPRETATIONS

Productivity and revegetation potentials for these soils are low to moderate due to the limited soil depth, high rock content and cold climate.

This soil is rated low for **road** and moderate for **trail** construction due to loamy textures, low rock content in the surface and bedrock within 40 inches of the surface in some profiles.

This soil has a low susceptibility to **weed infestation** when disturbed due to the cold climate. **Erosion** will occur whenever the surface vegetation and plant litter is removed. This soil has a high erosion potential when disturbed due to the silty surface soil texture and few rocks. The subsoil is much less erosive and the high rock content creates a natural armor layer as soil fines are eroded.

These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to their high rock content, limited depth and cold climate. Slopes over 15% severely limit waste disposal.

Soil education highlights include:

- The presence of volcanic ash resulting mainly from the eruption of Mt. Mazama (Crater Lake Oregon). Also the bright brown soil color resulting from ash weathering.
- The turf-like root concentration in the surface few inches. This is where the nutrients, water and biological activity are.
- The angular rocks that suggest they have not been transported far but have been moved upward and mixed in the surface soil by frost action, animal burrowing and other methods.

LC9 SHALLOW GRASSLAND SOILS LOWER MOUNTAIN SLOPES

This unit is not mapped alone but in complex with moderately deep soils. It occurs mainly on steep, lower mountain slopes with south aspects where the bedrock is limestone. It is dominated by limestone residuum and colluvium. Scoured bedrock, shallow to moderately deep colluvial soils and glacial soils are other components of this unit. Vegetation is dominated by grasses with scattered shrubs and stunted trees. Elevations are 3200-5500 feet. The overall topography is steep to very steep with most slopes in the 35 to 70 percent range. Mean annual precipitation is 30 to 40 inches.

GEOLOGY

The parent material is dominated by residuum and colluvium with extremely gravelly loam or sandy loam textures. The surface contains wind deposited material including volcanic ash. Rocks are angular limestone argillite.

SHALLOW LIMESTONE GRASSLAND SOILS

This soil is deep, well drained and formed in rocky, sandy and loamy colluvium weathered from limestone. The surface layer is gravelly or very gravelly loam with 25-40% gravels. The subsoil is very gravelly to extremely gravelly loam. Rocks are angular gravels and cobbles with occasional stones. Rock content increases with depth and fractured bedrock is present at 1-3 feet. Available water holding capacity is low due to the high rock content and limited depth; 0.5-1 inch in the surface foot and 1.5-2 inches to the depth of fractured rock.

LC9 PROFILE DESCRIPTION

SURFACE - The surface soil is very dark brown gravelly loam or silt loam with 30-50% rocks 5-9 inches thick (A horizon).

SUBSOIL - Brown or dark brown, very to extremely gravelly loam 6-18 inches thick with 50-75% rock fragments (Bw horizon).

SUBSTRATUM - Light brown or brown, extremely gravelly loam or sandy loam with 60-90% rock fragments (C horizon). The depth to fractured bedrock is 1-3 feet.

LC9 PROFILE ILLUSTRATION



SOIL CLASSIFICATION

These shallow limestone grassland soils (LC9) are classified as Lythic Haplocryolls.

VEGETATION

Vegetation is mainly grassland dominated by bluebunch wheatgrass (*Agropyron spicatum*), elk sedge (*Carex geyeri*), rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), Richardson's needlegrass (*Stipa richardsonii*), timber oatgrass (*Danthonia intermedia*). Scattered shrubs include shrubby cinquefoil (*Potentilla fruticosa*), chokecherry (*Prunus virginiana*), horizontal juniper (*Juniperus horizontalis*), serviceberry (*Amelanchier alnifolia*) and rose (*Rosa woodsii*). Other plants include rock alumroot (*Heuchera cylindrica*), phacelia (*Phacelia spp.*), kinnikinnick (*Arctostaphylos uva-ursi*), and wild buckwheat (*Eriogonum umbellatum*).

The dry grassland vegetation results from the south aspect, limestone bedrock, well-drained and porous soil and other factors.

INTERPRETATIONS

Soil depth and high rock content are the main factors affecting interpretations for these soils.

Productivity and revegetation potentials are low for this shallow soil due to the low moisture and nutrient holding capacity.

This shallow soil is rated low for **roads** due to limited depth.

This soil is has a moderate to high susceptibility to **weed infestation** when disturbed due to low elevation and south aspect. Weed infestation is most common with disturbed soil, rocky and sandy soils, open canopy conditions, a weed seed source, south aspects and low elevations.

Erosion will occur whenever the surface vegetation and plant litter is removed. This soil has a moderate erosion potential when disturbed.

These soils are rated as having a low potential for **waste disposal** using traditional septic tank and drainfield systems due to limited soil depth.

Soil education highlights include:

- The dark, high-organic matter content grassland surface soil. This is the zone of most intense biological and chemical activity.
- The grassland vegetation resulting from the hot, dry aspect and shallow depth.
- Animal burrows and exposed subsoil material, often with invader weeds.
- Animal mixing of surface soil layers.
- The angular rocks that suggest soil materials have not been transported far.

MAPPING UNITS

LC9/LC5 SHALLOW GRASSLAND SOILS AND MODERATELY DEEP COLLUVIAL SOILS ON LIMESTONE SCoured MOUNTAIN SLOPES AND TROUGH WALLS

This unit covers 1,199 acres in the southern portion of the park. It is dominated by glacially-scoured mountain slopes that have developed shallow and moderately deep colluvial soils since de-glaciation. Vegetation is a mosaic of grassland and mostly stunted conifer forest. There is a mixture of grass, shrub and tree communities. Elevations are 3200-5500 feet. The topography is mainly very steep mountain slopes in the 35-70 percent range. Mean annual precipitation is 30 to 40 inches.

Soils of Glacier National Park
Land & Water Consulting, Inc./B. Dutton and others/01-08-2001

MAJOR SOILS - COMPLEX

This unit is mapped as a complex of two main soils but includes others in limited areas. The most common soil (LC9) is shallow to fractured bedrock and occupies 50 percent of the unit. The other common soil (LC5) is moderately deep to fractured bedrock and occupies 40 percent of the unit.

MINOR SOILS - INCLUSIONS

(25% of unit):

- **Rock outcrop (LC1)** on convex areas.
- **Deep colluvial soils (LC3)** mainly on lower slopes and far from rock outcrops.
- **Talus (LC2)** below rock outcrops.

4.0 SOIL USE AND MANAGEMENT

This section describes use and management considerations for some of the most common concerns of park personnel. Additional information may be inferred from soil characteristics presented for individual soils. Guides for identifying important soil features related to use and management are presented in Appendix A.

Table 4 summarizes the general suitability of these soils for common uses. Classes are high, medium and low suitability and are usually based on surface soil texture, flooding, wetness, slope steepness and other factors. Waste disposal classes are based on both surface and subsoil textures as well as the other factors listed above. These classes are designed to provide a quick reference of the overall soil suitability. Review discussions for individual soils for a more detailed discussion of specific use and management concerns. Additional information on soil limitations for use and management are presented in the National Soils Handbook (USDA 1993)

4.1 PRODUCTIVITY AND REVEGETATION POTENTIAL

Productivity and revegetation potential is most related to soil depth, texture and rock content with higher ratings for increased depth and lower rock/sand contents. The greater the depth and the lower the rock/sand content, the higher the water and nutrient holding capacities. Increased organic matter content also increases productivity. Wetness is another important factor. Non-soil factors also play a dramatic role on productivity and revegetation potential especially climate. Lime accumulations in the subsoil of limestone-derived soils can reduce productivity and revegetation potential at least in these layers.

4.2 ROAD AND TRAIL CONSTRUCTION

Road and trail construction are most related to soil depth, texture, rock content, organic content and wetness. Soil depth must be sufficient to allow construction over varied terrain. Higher rock and sand contents provide structural stability, less compaction and better drainage. Low fine sand, silt and clay contents

are preferred to reduce dust, compaction, ponding and drainage problems. However, these same characteristics reduce the ease of revegetation for soil disturbed by construction.

The alluvial soils are the only ones rated high for road and trail construction. In general, most soils in the park drainage have limitations for road and trail construction due to fine textures and few rocks in the surface. Most trails illustrate this point since they have been incised 6-12 inches by erosion. Through this process, a trail will erode until it accumulates enough rock fragments to 'armor' itself from further erosion.

These same fine-textured surface soils are very susceptible to compaction and the reduced infiltration capacity that results. This causes water to pond on the surface and create a muddy trail condition. Many of the soils in the park have subsoils that are much more suitable for roadway and trail construction (especially the alluvial and bedrock soils).

It is also a general rule that soils on steeper slopes have more favorable texture, rock contents and drainage characteristics. Trails should avoid most concave and flat slopes especially toeslopes where excess moisture accumulates. Trail construction should also consider snow distribution and other factors. The dark brown color of some surface soils and bright brown color of volcanic ash influenced soils can be used as an indication of potential trail maintenance problems.

Another important consideration for roads and trails is capillarity. Water is drawn upward through soil pores as much as 2-3 feet due to capillarity. When constructing roads and trails across wet sites it is important to provide a barrier to this capillary rise. Barriers may be a thin layer of sand, sand and gravel, geotextile fabric or other material that performs the same function.

Trail summary:

- choose convex microtopography not concave
- avoid black surface soils, mottles, gley or other wetness indicators
- avoid low rock content soils
- use wet vs. dry vegetation indicators
- take the high ground whenever possible

4.3 EXOTIC PLANT INVASION POTENTIAL

Exotic plant (weed) invasion potential is a factor of soil and other environmental conditions. The most important factors which increase exotic plant invasion potential are:

- the amount of soil disturbance - more disturbance results in more invasion
- the amount of sunlight - more sunlight results in more invasion especially knapweed
- soil texture and rock content - sandier soils and higher rock contents result in more weed invasion
- elevation - less weed invasion at the higher, colder elevations especially above 6000 feet
- aspect - there is a higher invasion potential on southerly aspects (aspect is also related to vegetation and canopy)
- climate - most weeds are favored by dry conditions
- weed source - there must be weed seed or plant sources available for invasion to occur

The soils most susceptible to weed invasion in the park are the sandy and gravelly alluvial soils. The floodplain soils are especially susceptible due to regular disturbances which leave bare soil exposed. The least susceptible soils are those at high elevations (>6000 ft) and all wet soils since weeds do not compete well in these environments. All other soils are roughly equal in their weed invasion potential with the most important factors being the amount of disturbance and sunlight.

Soil factors most related to potential pesticide movement are texture, rock content, depth and organic matter content. Very sandy, rocky, shallow or low organic matter soils may not retain applied herbicides for a long enough period to allow degradation.

4.4 EROSION POTENTIAL

Erosion in the park is most dependent on the amount of bare soil exposed. Most of these soils have a surface layer of plant litter, especially under conifer forests. This litter layer is extremely protective against erosion. Most erosion in forested landscapes comes from road cuts and unpaved roadways or from recently burned areas. Many local soils have highly erosive surface layers with moderately erosive

subsoils due to higher subsoil rock content. Sandy soils are the most easily eroded by water. Silty soils are the most easily eroded by wind. Rocky soils will armor themselves as fines are removed leaving a rock pavement surface. Slope steepness and length can be controlled on roads, trails and other disturbed sites. The spacing and location of water bars or other cross-drains is an effective method of preventing serious trail erosion.

In general, soil erosion by water is dependent on a series of factors including:

1. **Climate** - determines amount of rainfall, timing of rainfall and indirectly the amount of vegetation present to protect the soil surface. The moist climate across much of the park and the relative small storm sizes restrict climatic erosion events to relatively infrequent occurrences. Climate cannot usually be manipulated to reduce erosion.
2. **Slope Steepness** - steeper slopes have more erosion. The park has a wide range of slope steepness. Slope steepness cannot usually be manipulated to reduce erosion.
3. **Slope Length** - the longer the slope, the more surface to collect and concentrate water. Slope length is commonly manipulated to reduce erosion. Long slopes can be broken up into shorter sections using cross-drains and other methods on roads and trails.
4. **Soil Erodibility** - is the ease at which soil particles are dislodged and transported. Soils with low clay content are usually the most erosive. Clay is the "glue" that holds soils together into particles too large to be transported. Most soils in the park have silty, loamy or sandy surfaces that are highly erosive when exposed.

TABLE 4. SOIL MANAGEMENT INTERPRETATIONS BASED ON HIGH, MEDIUM OR LOW POTENTIAL

SYMBOL	SOIL/PARENT MATERIAL	PRODUCTIVITY/ REVEGETATION	ROADS	TRAILS	WEED INVASION	EROSION	WASTE DISPOSAL
	ALLUVIAL SOILS						
A1	FLOODPLAIN SOILS	L	L	L	H	M	L
A2	ALLUVIAL GRASSLAND SOILS	M-H	H	H	H	M	M
A3	ALLUVIAL FOREST SOILS	M-H	H	H	H	M	M
A4	SANDY/COBBLY ALLUVIAL FOREST SOILS	M-H	H	H	H	H	M
A6	BEACH SOILS	L-M	H	H	M	M	L
	WET SOILS						
W1	WET SOILS	H	L	L	M	L	L
	GLACIAL SOILS						
G1	POORLY DEVELOPED GLACIAL SOILS	L	H	H	L	H	L
G2	GLACIAL SOILS-SILTY CLAY LOAM	H	L	L	M	H	H
G3	GLACIAL TILL SOILS-LOAM	M-H	M	M	M	H	H
G4	CLAY-RICH CONIFER FOREST SOILS	H	L	L	M	H	M
G5	CLAY-RICH ASPEN FOREST SOILS	H	L	L	M	H	M
G6	CLAY-RICH GRASSLAND SOILS	M	L	L	M	H	M
G7	COLLUVIAL AND LANDSLIDE SOILS	L-M	M	M	L	M	H
G8	LIMESTONE GLACIAL TILL SOILS	M-H	M	M	M	H	H
	BEDROCK SOILS - QUARTZITE & ARGILLITE						
C1	QA ROCK OUTCROP	L	L	L	L	L	L
C2	QA TALUS	L	L	L	L	L	L
C3	DEEP QA COLLUVIAL FOREST SOILS	M	L	L	M	H	M
C4	SHALLOW QA SOILS	L	L	L	L-M	M	L
C5	MODERATELY DEEP QA SOILS	M	L	M	M	M	L
C6	ALPINE MEADOW SOILS	L-M	L	M	L	H	L
C7	ICE-PATTERNED SOILS	L	L	L	L	M	L
C8	COLLUVIAL GRASSLAND SOILS	M	H	H	H	M	M
C9	SHALLOW GRASSLAND SOILS	L	L	L	M	M	L

TABLE 4. (Cont.)

SYMBOL	SOIL/PARENT MATERIAL	PRODUCTIVITY/ REVEGETATION	ROADS	TRAILS	WEED INVASION	EROSION	WASTE DISPOSAL
	BEDROCK SOILS - LIMESTONE						
LC1	LIMESTONE ROCK	L	L	L	L	L	L
LC2	LIMESTONE TALUS	L	L	L	L	L	L
LC3	DEEP COLLUVIAL FOREST SOILS	M	M	M	M	H	M
LC4	SHALLOW LIMESTONE SOILS	L	L	L	L	M	L
LC5	MODERATELY DEEP LIMESTONE COLLUVIAL SOILS	M	L	M	M	M	L
LC6	ALPINE MEADOW SOILS - LIMESTONE	L-M	L	M	L	H	L
LC9	SHALLOW LIMESTONE GRASSLAND SOILS	L	L	L	M	M	L



Soil characteristics help determine the best locations for park facilities.



Soil characteristics are important factors in weed invasion and weed control methods.

5. Many subsoils have high rock contents which reduces erosion potential and provides 'armor' to prevent serious erosion. Soil erodibility cannot be manipulated to reduce erosion.
6. **Cover** - is the most important factor of erosion potential in the park. The surface litter layer and dense plant growth protects the soil from raindrop impact and from concentrated overland flow. Cover is removed by construction activities, intense visitor use, animal activity, fire and other factors.

4.5 WASTE DISPOSAL

Soil features most important to waste disposal are depth, texture, rock content and slope steepness. Most onsite wastewater treatment including subsurface drainfields or land application sprayfields are based on the ability of soil microbes to uptake and immobilize or transform potential pollutants. The ideal soils for these applications are those that absorb wastewater and retain it in the upper soil layers for a sufficient period to allow for microbial treatment. Very sandy and rocky soils do not retain wastewater for sufficient periods. Shallow soils do not have a sufficient volume of soil for adequate treatment and wastewater may migrate along bedrock contacts.

4.6 SOIL-VEGETATION RELATIONSHIPS

This inventory was not designed to evaluate soil-vegetation relationships but some general comments are provided to help future vegetation researchers evaluate soil features important to their investigations.

Vegetation differences across the landscape and across individual sites can often be explained by soil differences. However, it is also important to evaluate the potential influences of elevation, aspect, slope position, avalanches, fire, flooding and other disturbance factors. When vegetation differences are observed, soil features should be evaluated, especially wetness, rock type, rock content, texture and depth.

Many instances of slightly drier vegetation or slightly moister vegetation than the surroundings

can be observed. In most cases, shallower soil depth results in slightly drier vegetation. An exception is where shallow soil perches groundwater following the bedrock surface from upslope areas. Drier soil conditions may also be caused by higher rock and sand contents along with corresponding lower silt and clay contents. Instances of more moist vegetation than the surroundings can also result from soil changes. Many wet soils and wet community types such as devil's club (*Oplopanax horridum*) occur where high clay content subsoil perch groundwater near

the surface. Remember that other factors can also cause increased wetness such as potholes, toeslope positions and drainageways.

Wetness influences vegetation by restricting the germination and growth of certain plants and encouraging others which are adapted to the wet environment. As wetness increases, conifers decrease and become restricted to drier, slightly elevated microsites and riparian shrubs become dominant. With increased wetness, riparian shrubs decrease and the vegetation becomes dominated by sedges (*Carex spp.*), rushes (*Juncus spp.*), wet grasses and forbs.

Rock type, especially limestone versus others, has an important influence on vegetation due to effects on pH, calcium carbonate content, soil texture and other features. These influences are somewhat less dramatic with Glacier park soils since the Precambrian limestone formations are only moderately calcareous and because the high rainfall leaches weathered carbonates from the upper soil profile. Limestone soils also usually weather to higher silt contents than other rock types resulting in higher water and nutrient holding capacities than other rock types.

Vegetation investigators should be careful to note and document the occurrence of limestone. In general, vegetation on limestone soils in the park is slightly sparser and reflects slightly drier conditions than adjacent quartzite/argillite soils. Height growth, especially of trees is somewhat reduced. Lodgepole pine (*Pinus contorta*) is less common on limestone and less vigorous where it does occur. Douglas-fir (*Pseudotsuga menziesii*), common juniper (*Juniperus communis*), dryas (*Dryas spp.*) and blue clematis (*Clematis columbiana*) are examples of plants that are more common on limestone. Limestone effects on vegetation are often subtle in Glacier. Rock content, especially in the

surface soil has a dramatic influence on vegetation. Grasses and forbs usually compete more effectively on soils with low rock contents in the surface. Woody plants including trees and shrubs usually compete more effectively on soils with high rock contents in the surface or with shallow fractured bedrock. This relationship can be viewed throughout the area with woody plants concentrated near rock outcrops and grass/forb communities concentrated away from outcrops. Woody plants have the ability to send down deep and extensive root systems into fractured bedrock and therefore access a sufficient volume of soil to obtain water and nutrition. Grasses concentrate their root systems in the surface foot of the soil. Once their root systems are developed, it is difficult for woody plants to invade and compete on these soils.

The soil/vegetation sequence described in the C4/C6 map unit description is another example of this relationship. In that case, a striped effect has been created at some alpine landscapes with trees on the rocky shallow soils and grass/forb communities on the shallow soils with

relatively low surface rock content. The photo below illustrates this relationship on West Flattop Mountain. On the left side of the photo is a shallow bedrock soil (A4) supporting conifer forest and on the right side is an alpine meadow soil (A6) supporting forb/grass vegetation.



This photo illustrates a shallow soil (C4) supporting conifer forest on the left and an alpine meadow soil (C6) supporting forb/grass vegetation.

4.7 SOIL EDUCATION

The soils of glacier park offer a wide variety of educational opportunities. Examples of interesting soil features and events are listed below.

- Volcanic ash from west coast volcanoes form part of the surface soil throughout the park and can be seen as a distinct bright brown layer in many roadcuts.
- Soil properties - layers, colors, textures, rocks, are important features to users.
- Landscape-Soil-Vegetation-Hydrology-Wildlife interactions are everywhere.
- Wet fen/bog soils and the cores taken from them have revealed past vegetation, eruptions and climates.
- Frost features - frost boils, stone nets, ice wedge polygons, stone stripes, dryas (*Dryas spp.*) terraces indicate a history of intense ice action between glaciations and on unglaciated sites.
- Soil formation has left a sequence of layers called horizons (O, A, E, Bt, Bh).
- Soil erosion is prevented by the forest litter layer.
- Weed infestation and soil disturbance are directly related.
- Plant and soil relationships.
- Animal and soil relationships.
- Beach soils have formed around local lakes.
- Geologic soil materials and how to identify-ash, till, alluvium, bedrock soils.



Soils can be fun and education can help citizens make better decisions about natural resources in their lives.

5.0 SOIL GENESIS AND CLASSIFICATION

An understanding of soil genesis can help explain soil distribution and properties. Proper soil classification can provide insight about soil formation and also allow communication among soil professionals and others.

5.1 SOIL GENESIS

An understanding of how soils form (soil genesis) is important in explaining and predicting the distribution of soil types across landscapes. Some knowledge of soil genesis is also needed for understanding variations in soil properties within small masses of individual soil types. Soil formation is understood as a combination of processes that progressively transform inert geologic deposits into complex living systems. These soil forming processes respond to environmental conditions--classically listed as the five soil forming factors.

Modern soil classification systems are hierarchical and based primarily on measurable properties of the soils themselves. The groupings using in Soil Taxonomy (1975) reflect similarities in soil layers (horizons), physical and chemical properties. Taxonomy was designed to help in the production of soil surveys, and the interpretation of soil survey information. This complicated system allows for precise communication among professionals.

Parent Material is used for both bedrock and surficial deposits. Most surficial deposits in the park are not derived exclusively from underlying bedrock--they include transported sediments. Sediments may have been moved by glaciers (drift, till, outwash), water (alluvium), wind (volcanic ash, loess), or gravity (talus, landslides, colluvium).

The Lewis over thrust is a prominent feature that affects soil patterns. Older hard rocks were thrust east and up over softer younger rocks. The harder rocks are mostly quartzite and argillite with limestones and other rocks less common. These rocks typically weather to very gravelly sandy loams, the limestone derived soils have more alkaline subsoils than most other soils. The rocks beneath the over thrust are mostly soft shales that weather to unstable clay rich soils.

Today's landscape was mostly formed during and just after the great ice ages. Glacial erosion dominated at higher elevations and along trough walls: deposition of drift dominated valley floors. Hummocky ground moraines cover many middle elevation valley floors, outwash terraces are more common in the lower valleys. At the end of the great ice ages the high country contained many scoured and over-steeped bedrock slopes. At the same time lower valleys were choked with outwash.

In recent (post glacial) times, the largest streams have cut new floodplains down through the outwash choked lower valleys. This has left remnants of the old ice age valley floor as isolated high terraces. Smaller tributaries have build alluvial fans, some on top of high terraces and other graded to modern stream levels. Many of the over-steepened bedrock slopes have collapsed into talus cones and similar colluvial landforms. Avalanches and debris flows have created numerous small to medium sized landforms. Landslides have affected most of the clay rich soils formed on the soft shales beneath the overthrust.

The entire park has been covered in recent times with volcanic ash from Oregon and Washington, and dust from other sources. However these wind deposited materials have subsequently been eroded or mixed up with other sediments in most areas. Where relatively tick and unmixed volcanic ash has been preserved it allows unique types of topsoils to form.

Topography is critical to the development of soil-landscape patterns. Topography and climate interact at many scales to control surfaces processes, biology and soil formation. On a local scale topographic position controls the balance of erosion and sedimentation, biomass accumulation and soil drainage. Exposed convex sites tend to be harsh and unproductive, prone to erosion, and droughty with shallow soils. Concave sites tend to collect organic debris, nutrients, water and fine sediments from surrounding areas. They are usually productive and have deep highly organic moist or wet soils.

Topographic position is also related to soil surface stability and geomorphic energy. In places where geomorphic energy is focused (floodplains, avalanche paths, very steep slopes) soils tend to be unstable, young and poorly developed. At broader scales topography is the dominant controlling variable for climate and vegetation distribution. Elevation, aspect, slope gradient, rain shadows, summer shading and snowmelt patterns are all important contributing variables.

Climate controls the biological potential of individual sites as well as the physical and chemical processes of soil genesis. Precipitation drives leaching, erosion and sedimentation at soil surfaces. Intense leaching in high precipitation zones depletes nutrients and acidifies soils. The seasonal distribution of available soil water and moderate soil temperatures are critical biologic factors. Temperature controls the rates of chemical reactions, and is especially important in microbial processes. Rapid temperature fluctuations on high, windswept ridges drive the intense frost action which creates unique soil landscape patterns.

Organisms involved in soil genesis include plants, animals and microbes. The relationships between soils and dominant plants are most obvious, and probably most important. Different vegetation types are known to have distinct effects on soil formation. Grasslands form deep dark and fertile topsoils. Coniferous forests form acidic litter layers and less fertile, more acidic soils of several types. Desert and drier alpine vegetation types add little soil organic matter and leave bare ground susceptible to erosion. Animals disturb, mix and aerate soils. Microbes decompose organic debris, form humus and play critical roles in nutrient retention and nutrient recycling. Distinctive microbial communities are associated with different vegetation and soil types.

Time of soil formation affects how far a soil has evolved from its initial parent material conditions. The park contains only young soils which appear to have formed since the end of the last great ice age. The older soils are about seven to ten thousand years old and have developed deeply with many individual horizons. These are on gentle stable slopes in valley bottoms and terraces. The youngest and least developed soils are in geomorphically native areas such as floodplains, beaches, avalanche chutes, and recent landslide

deposits. Such soils may be deep to bedrock, but have not developed deep or distinctive horizons.

5.2 SOIL CLASSIFICATION

Soils have been classified with the latest revision (1998) of Soil Taxonomy (1975) based primarily on field observations of morphology. Rigorous classification in this system requires extensive laboratory data and field monitoring of soil climates. These activities were beyond the scope of this project. Attempts are currently being made to coordinate an effort to generate more of these kinds of data. Although most areas surrounding the park have some type of completed soil survey few relevant laboratory data have been found.

Due to the limited data available, all classifications presented in this report should be considered provisional. Most soils are classified to the subgroup or family level. Efforts to establish new soil series have not been made. Classifications were estimated using the experience of the principal investigators and information from surrounding inventories (Appendix B). These surrounding inventories provide a variety of useful information related to park soils. Taxonomic purity was not the primary concern in developing the current legend. As new data becomes available, taxonomic refinements are expected. Table 5 lists preliminary soil classifications for Glacier National Park.

For the purpose of this inventory, all soils in the park were considered to have a *cryic* soil temperature regime (mean annual temperature at 50cm 0-8° C and mean summer temperature <15° C). Some sites may have frigid temperature regimes (mean annual temperature at 15cm 0-8° C and mean summer temperature >15° C). These sites are mainly located on steep south aspects at the lowest elevations(<5500). These sites have good air drainage, are above cold air drainage effects and usually have grassland or dry conifer forest vegetation.

TABLE 5. PRELIMINARY CLASSIFICATION OF PARK SOILS

MAP UNIT	SOIL	CLASSIFICATION
	ALLUVIAL SOILS	
A1	FLOODED SOILS	Cryofluvents, Cryaquents
A2	ROCKY/SANDY ALLUVIAL GRASSLAND SOILS	loamy-skeletal, mixed Typic Haplocryolls
A3	ROCKY/SANDY ALLUVIAL FOREST SOILS	loamy-skeletal, mixed Typic Dystrocryepts, sandy-skeletal Typic Dystrocryepts
A4	SANDY OVER COBBLY ALLUVIAL SOILS	loamy-skeletal, mixed Typic Dystrocryepts, sandy-skeletal Typic Dystrocryepts
A6	LAKESIDE BEACH SOILS	Typic Cryorthents, Typic Dystrocryepts
	WET FEATURES	
W1	WET SOILS	Cryaquolls, Cryaquepts
	GLACIAL, LANDSLIDE AND MIXED SOILS	
G1	POORLY DEVELOPED SOILS	Typic Cryorthents
G2	SILTY CLAY LOAM GLACIAL FOREST SOILS	Oxyaquic Haplocryalf, Typic Haplocryalfs
G3	SANDY GLACIAL FOREST SOILS	loamy-skeletal, mixed Typic Haplocryepts
G4	CLAY-RICH CONIFER FOREST SOILS	loamy-skeletal, mixed Typic Cryoboralfs
G5	CLAY-RICH ASPEN FOREST SOILS	Argiaquic Cryoborolls
G6	CLAY-RICH GRASSLAND SOILS	Argic Cryoborolls
G7	DEEP, ROCKY COLLUVIAL AND LANDSLIDE SOILS	Typic Cryoborolls, Typic Cryochrepts
G8	LOAMY LIMESTONE GLACIAL FOREST SOILS	loamy-skeletal, mixed Typic Cryoboralfs, loamy-skeletal, mixed Typic Cryochrepts
	BEDROCK SOILS - QUARTZITE AND ARGILLITE	
C3	DEEP COLLUVIAL FOREST SOILS	loamy-skeletal, mixed, Typic Dystrocryepts
C4	SHALLOW SOILS	mixed Lithic Dystrocryepts
C5	MODERATELY DEEP SOILS	loamy-skeletal, mixed Typic Dystrocryepts
C6	ALPINE MEADOW SOILS	loamy-skeletal, mixed, Typic Dystrocryepts
C7	ICE-PATTERNED SOILS	Lithic Cryochrepts, Typic Cryochrepts
C8	DEEP COLLUVIAL GRASSLAND SOILS	loamy-skeletal, mixed, Typic Cryoborolls
C9	SHALLOW GRASSLAND SOILS	Lithic Haplocryolls
	BEDROCK SOILS - LIMESTONE	
LC3	DEEP COLLUVIAL FOREST SOILS ON LIMESTONE	loamy-skeletal, mixed, Typic Eutrocryepts
LC4	SHALLOW LIMESTONE SOILS	mixed Lithic Eutrocryepts
LC5	MODERATELY DEEP LIMESTONE SOILS	loamy-skeletal, mixed Typic Dystrocryepts
LC6	ALPINE MEADOW SOILS ON LIMESTONE	loamy-skeletal, mixed, Typic Eutrocryepts
LC9	SHALLOW GRASSLAND SOILS ON LIMESTONE	Lithic Haplocryolls

No andic subgroups have been identified as major soils although they have been observed at individual sites. Most of the park has had significant mixing of surface soil materials resulting in densities higher than those allowed for andic classification.

No umbric epipedons have been identified in this survey although they may occur on some sites. All dark surface soil layers that may be umbric have been classified as mollic epipedons due to limited pH sampling and data from surrounding inventories.

Although most soils in this inventory have been classified as well-drained, many have restrictive layers that slow the drainage of snowmelt, spring runoff and rainfall. These conditions do not quite fit the moderately well drained or somewhat poorly drained definitions. They do however fit the new Oxyaquic and Argiaquic subgroups which are defined as having a month of saturated conditions in the upper soil.

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7.0 GLOSSARY

This glossary defines many of the technical terms used in this report. For additional information see:

Soil Science Society of America. 1996. Glossary of Soil Science Terms. SSSA 667 S. Segoe Rd. Madison, WI. 134p. *Note: a copy of this glossary was donated to the Glacier Park library by Land & Water Consulting.*

USDA Natural Resources Conservation Service. 1993. Soil Survey Manual. USDA Ag. Handbook No. 18. 437p.

USDA Natural Resources Conservation Service. 1994. Soil Survey Handbook (part of Landform and Geologic Terms). Ag. Handbook No. 436. 754p. 629 "Glossary"

Aeolian. Deposited by wind, includes volcanic ash, in Glacier these deposits are usually dominated by silt-size particles.

Alluvial fan. The fan-like deposit of a stream where it issues from a gorge upon a plain or from a tributary stream near or at its junction with its main stream. Profile slope shape is straight, and plan slope is convex. Stream pattern is fine and braided, with weak dissection.

Alluvium. Unconsolidated clastic material, such as sand, gravel, silt, or clay, or various mixtures of these, deposited on land by streams.

Available water capacity (available moisture capacity). The capacity of soils to hold water available for use most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil.

Boulders. Rock fragments larger than 2 feet (60 centimeters) in diameter or >60 cm in length.

Cation-exchange capacity. The total amount of exchangeable cations that a soil can absorb, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. The term, as applied to soils, is synonymous with base-exchange capacity, but is more precise in meaning.

Cirque. Semicircular, concave, bowl-like areas that have faces primarily resulting from glacial ice and snow abrasion.

Cirque basin. The semi-circular bowl-like part of a cirque. Profile and plan slope are concave. Slope gradients are less than 30 percent.

Stream pattern is fine and dendritic with weak dissection.

Clay. As a soil separate, the mineral soil particles less than 0.002 mm in diameter. Also see texture, soil.

Coarse fragments. Mineral or rock particles larger than 2 mm in diameter. A synonym is "rock fragments".

Cobble (or cobblestone). A rounded or partly rounded fragment of rock 3 to 10 inches (7.6 to 25 cm) in diameter.

Colluvium. Soil material, rock fragments, or both, moved by creep, slide, or local wash and either on or deposited at the base of slopes.

Complex, soil. A map unit of two or more kinds of soil and/or miscellaneous areas in such an intricate pattern or so small in area that it is not practical to map them separately at the selected scale of mapping. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas.

Consociation, soil. A kind of soil map unit dominated by a single soil taxon or miscellaneous area and similar soils. At least half of the pedons in each delineation are of the same soil components that provide the name of the map unit. The remainder is largely of similar soils.

Contrasting soils. Soils with significant differences in properties that result in differences in interpretations for common uses. These soils are usually separated in mapping or are identified as inclusions.

Cryic. A soil temperature regime that has mean annual soil temperatures of >0 degrees C but <8 degrees C and relatively cool summer temperatures. See Frigid.

Delineation. An individual instance of a map unit on a map. A delineation may have only one map unit defining it. See Map unit.

Drainage Classes. Natural drainage class refers to the frequency and duration of wet periods under conditions similar to those under which the soil developed. Alteration of the water regime by man, either through drainage or irrigation, is not a consideration unless the alterations have significantly changed the morphology of the soil. The classes follow:

Excessively drained - Water is removed very rapidly. The occurrence of internal free water commonly is very rare or very deep. The soils are commonly coarse-textured and have very high hydraulic conductivity or are very shallow.

Somewhat excessively drained - Water is removed very rapidly. The occurrence of internal free water commonly is very rare or very deep. The soils are commonly coarse-textured and have high saturated hydraulic conductivity or are very shallow.

Well drained - Water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons. The soils are mainly free of the deep redoximorphic features that are related to wetness.

Moderately well drained - Water is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence commonly is moderately deep and transitory through permanent. The soils are wet for only a short time within the rooting depth during the growing season, but long enough that most mesophytic crops are affected. They commonly have a moderately low or lower saturated hydraulic conductivity in a layer within the upper 1 m, periodically receive high rainfall, or both.

Somewhat poorly drained - Water is removed slowly so that the soil is wet at

a shallow depth for significant periods of the growing season. The occurrence of internal free water commonly is shallow to moderately deep and transitory to permanent. Wetness markedly restricts the growth of mesophytic crops, unless artificial drainage is provided. The soils commonly have one or more of the following characteristics: low or very low saturated hydraulic conductivity, a high water table, additional water from seepage, or nearly continuous rainfall.

Poorly drained - Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods. The occurrence of internal free water is shallow or very shallow and common or persistent. Free water is commonly at or near the surface long enough during the growing season so that most mesophytic crops cannot be grown, unless the soil is artificially drained. The soil, however, is not continuously wet directly below plow-depth. Free water at shallow depth is usually present. This water table is commonly the result of low or very low saturated hydraulic conductivity of nearly continuous rainfall, or of a combination of these.

Very poorly drained - Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. The occurrence of internal free water is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly level or depressed and frequently ponded. If rainfall is high or nearly continuous, slope gradients may be greater.

Effervescence. Reaction of soil to dilute (about 1 normal) HCl.

- e - slightly effervescent - bubbles are readily observed.
- es - strongly effervescent - bubbles for a low foam.
- ev - violently effervescent - thick foam "jumps" up.

Flood plain. A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

Glacial till. Unsorted, nonstratified glacial material consisting of clay, silt, and sand, and boulders transported and deposited by glacial ice.

Glacial trough valley bottom. The floor and lower side slopes of a glacially eroded valley. The valley profile is commonly U-shaped. Profile slope is concave and plan slope is straight. Slope gradients are less than 30 percent. Stream pattern is arboreal, with weak dissection.

Glacial trough valley wall. The steep side slopes of a glacially eroded valley. The valley profile is commonly U-shaped. Profile slope is concave and plan slope is straight. Slope gradients are greater than 30 percent. Stream pattern is parallel, with weak to moderate dissection.

Glaciolacustrine deposits. Material ranging from fine clay to sand derived from glaciers and deposited in glacial lakes mainly by glacial melt water. Many deposits are interbedded or laminated.

Gleyed Soil. Soil that formed under poor drainage, resulting in the reduction of iron and other elements in the profile and in gray colors and mottles.

Gravel. Rounded or angular rock fragments as much as 3 inches (7.5 cm) in diameter. An individual piece is a pebble.

Horizon, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes.

Inclusion. A soil or miscellaneous land area within a delineation of a map unit that is not identified by the map unit name; i.e. is not one of the named component soils or named miscellaneous area components. Such soils or areas are either too small to be delineated separately without creating excessive map or legend detail, occur too erratically to be considered a component, or are not identified by practical mapping methods.

Landslide. A general term meaning the rapid downhill movement of a mass of material (some combination of soil and loose rock), generally when wet or saturated. The speed and distance of movement as well as the amount of soil and rock material vary greatly.

Landslide scarp. The erosional part of an earthflow or other kind of landslide. This is often a very steep scarp or cliff. Slope is greater than 30 percent. Stream pattern is parallel. Dissection is weak.

Limestone. A sedimentary rock consisting chiefly of the mineral calcite with or without magnesium carbonate. Common impurities include chert and clay.

Loess. Fine-grained material, dominantly of silt-sized particles, deposited by wind.

Mass wasting. A general term describing the dislodgment and down-slope transport of soil and rock material under the direct application of gravity. In contrast to other erosion processes, the debris removed by mass-wasting processes is not carried within, on or under another medium possessing contrasting processes. It includes slow displacements such as creep and solifluction and rapid movements such as landslides.

Map unit. A conceptual group of one to many delineations identified by the same name in a soil survey that represent similar landscape areas comprises of either: (1) the same kind of component soil, plus inclusions, or (2) two or more kinds of component soils, plus inclusions, or (3) component soils and miscellaneous areas, plus inclusions, or (4) two or more kinds of component soils that may or may not occur together in various delineations but all have similar, special use and management.

Mineral soil. Soil that is mainly mineral material and low in organic material. Its bulk density is more than that of organic soil.

Moraine. A non-stratified accumulation of silt, sand, clay, stones, and other debris deposited by a glacier. It usually contains a wide mixture of these materials, as opposed to glaciofluvial deposits. Some types are terminal, lateral, medial, and ground.

Mottles. Variation in color of sediment, regolith, or rock as represented by localized spots, patches, or blotches of color, or shades of color. This includes colors formed by geologic processes (e. g. hydrothermal processes), and excludes colors in soils that are due to changes in redox states from soil-forming processes (see Redoxymorphic concentrations).

Munsell notation. A designation of color by degrees of the three simple variables = hue,

value, and chroma. For example, a notation of 10YR6/4 is a color hue of 10yr, value of 6, and chroma of 4.

Parent material. The unconsolidated organic and mineral material in which soil forms.

Ped, soil. A naturally occurring soil aggregate, which gives structure to soils exposed in soil profiles.

Periglacial. Said of the processes, conditions, area, climates, and topographic features at the immediate margins of former and existing glaciers and ice sheets, and influenced by the cold temperatures of the ice.

Profile, soil. A vertical section of the soil extending through all its horizons and into the parent material. See *soil profile*.

Reaction, soil. A measure of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degree of acidity or alkalinity is expressed as pH.

Ultra acid	below 3.5
Extremely acid	3.5 to 4.4
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Slightly acid	5.6 to 6.5
Neutral	6.6 to 7.3
Slightly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	9.1 and higher

Residuum (residual soil material).

Unconsolidated, weathered, or partly weathered mineral material that accumulated as consolidated rock disintegrated in place.

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 mm in diameter. Most sand grains consist of quartz. Also see Texture, soil.

Sedimentary rock. Rock made up of particles deposited from suspension in water. The chief kinds of sedimentary rock are conglomerate, formed from gravel; sandstone, formed from sand; shale, formed from clay; and limestone, formed from soft masses of calcium carbonate. There are many intermediate types. Some wind-deposited sand is consolidated into sandstone.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.005 millimeter). See Texture, soil.

Similar soils. Soils that may have slight differences in properties or classification but which have similar interpretation ratings for common uses. May be mapped as named or unnamed inclusions.

Slump. a) A mass-movement process characterized by a landslide involving a shearing and rotary movement of a generally independent mass of rock or earth along a curved slip surface (concave upward) and about an axis parallel to the slope from which it descends, and by backward tilting of the mass with respect to that slope so that the slump surface often exhibits a reversed slope facing uphill. b) The landform or mass of material slipped down during, or produced by, a slump.

Soil. The collection of natural material on the earth's surface containing living matter and supporting or capable of supporting plants. Its upper limit is air or shallow water. At its margins it grades to deep water or to barren areas of rock or ice. Its lower limit to the non-soil beneath is perhaps the most difficult to define. Soil includes the horizons near the surface that differ from the underlying rock material, as a result of interactions through time of climate, living organisms, parent materials, and relief. In a few places where it contains thin-cemented horizons that are impermeable to roots, soil is as deep as the deepest horizon. More commonly, soil grades at its lower margin to hard rock or to earthy materials virtually devoid of roots, animals, or marks of other biologic activity, which generally coincides with the common rooting depth of native perennial plants.

Soil classification. The systematic arrangement of soils into groups of categories on the basis of their characteristics. Broad groupings are made on the basis of general characteristics and subdivisions on the basis of more detailed differences in specific properties. The soils classification system used in this survey is from the Soil Survey Staff, Soil Conservation Service (1975).

Soil depth. The thickness of the soil mantle over bedrock or a root-limiting layer; i.e., very shallow is 4 to 10 inches (5 to 25 cm) thick, shallow is 10 to 20 inches (25 to 50 cm) thick, moderately deep is 20 to 40 inches (50 to 100

cm) thick. If none of these modifiers are used, soil is greater than 60 inches (150 cm) thick. No modifier is defined for soils 40 to 60 inches (100 to 150 cm) thick.

Soil profile. The sequence of natural layers, or horizons, in a soil. The profile extends from the surface downward either into the unconsolidated material in which the soil formed (regolith) or to hard bedrock. The unconsolidated material or bedrock is devoid of roots and other living organisms and has not been changed by other biologic activity.

Soil separates. Mineral particles less than 2 mm in equivalent diameter and ranging between specified size limits. The names and sizes of separates recognized in the United States are as follows:

Separate	mm Diameter
Very coarse sand	2.0 to 1.0
Coarse sand	1.0 to 0.5
Medium sand	0.5 to 0.25
Fine sand	0.25 to 0.10
Very fine sand	0.10 to 0.05
Silt	0.05 to 0.002
Clay	less than 0.002

Stones. Rock fragments 10 to 24 inches (25 to 60 cm) in diameter if rounded or angular rock fragments, not prominently flattened in the indicated size-class.

Stratified. Arranged in or composted of strata or layers.

Subsoil. The part of the soil beneath the surface horizon(s) or surface layer.

Subsurface layer. A subdivision of the surface layer.

Surface layer. The horizon(s) directly under the soil surface.

Talus. Rock fragments of any size or shape, commonly coarse and angular, derived from and lying at the base of a cliff or very steep, rock slope. The accumulated mass of such loose, broken rock formed chiefly by falling, rolling, or sliding. See scree.

Terrace. An old flood plain, ordinarily flat or undulating, bordering a river, a lake, or the sea.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil,

excluding particles greater than 2 mm in diameter. The basic textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse", "fine", or "very fine". The textural classes may be modified by the addition of suitable adjectives when coarse fragments are present in substantial amounts (e.g. gravelly, very stony, extremely cobbly).

Sand - Soil material that contains 85 percent or more of sand; percentage of silt, plus 1.5 times the percentage of clay, shall not exceed 15.

Loamy sand - Soil material that contains at the upper limit 85 to 90 percent sand, and the percentage of silt plus 1.5 times the percentage of clay is not less than 15; at the lower limit it contains not less than 70 to 85 percent sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

Sandy loam - Soil material that contains either 20 percent clay or less, and the percentage of silt plus twice the percentage of clay exceeds 30, and 52 percent or more sand; or >7 percent clay, <50 percent silt, and between 43 percent and 52 percent sand.

Loam - Soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and <52 percent sand.

Silt loam - Soil material that contains 50 percent or more silt and 12 to 27 percent clay or 50 to 80 percent silt and <12 percent clay.

Silt - Soil material that contains 80 percent or more silt and <12 percent clay.

Sandy clay loam - Soil material that contains 20 to 30 percent clay, <28 percent silt, and 45 percent or more sand.

Clay loam - Soil material that contains 27 to 40 percent clay and 20 to 45 percent sand.

Silty clay loam - Soil material that contains 35 percent or more clay and 46 percent or more sand.

Silty clay - Soil material that contains 40 percent or more clay and 40 percent or more silt.

Clay - Soil material that contains 40 percent or more clay, <45 percent sand, and <40 percent silt.

Toeslopes. The base of a slope or hillside. Usually less steep and having deeper soil and more moisture.

Water-holding capacity. See Available water capacity.

APPENDICES

A IDENTIFYING GEOLOGIC AND SOIL FEATURES

B SIMILAR SOILS FROM SURROUNDING SOIL INVENTORIES

C HISTORY OF SOIL INVENTORY IN GLACIER PARK

D EXAMPLE SOIL MAP SHEETS BASED ON 1:24,000 ORTHOPHOTOS

APPENDIX A. IDENTIFYING GEOLOGIC AND SOIL FEATURES

GEOLOGIC FEATURES

You don't need to be a soil scientist or geologist to recognize the major kinds of soil parent material. To determine the soil parent material, look at:

- an excavation at the site (dig it yourself)
- the nearest roadcut, windthrow pit, animal burrow
- surface feature clues (flat or steep, and smooth slopes or lumpy, boulders, etc.)
- the landform

Parent material (what the soil is formed from) is the most important soil forming factor in western Montana due to our exciting geologic past. Parent material is described by:

1. the dominant rock type - such as limestone
2. the deposit - such as glacial till
3. the landform - such as glacial moraine

IDENTIFYING ROCK TYPES

Most local rocks are Precambrian sedimentary rocks deposited as sandy and silty sediments in a shallow sea 1-3 billion years ago. You can usually see the individual layers of sediment in these rocks. Mud cracks, ripple marks and other signs of the sedimentary environment may also be observable.

Quartzite is simply very hard sandstone. Quartzite begins as sandy sediments deposited near shore (like you see at the beach). These sediments are buried under other layers and metamorphosed by heat and pressure into sandstone and then quartzite. The individual grains are fused together to form rock. Most local Precambrian quartzite is reddish, grayish or brownish in color.

Argillite is simply very hard mud. Argillite is deposited as mud, farther from shore than sandstone. Heat and pressure metamorphose the mud into shale or mudstone and then argillite. Most local Precambrian argillite is greenish or grayish in color. Other colors sometimes include brown and red.

Although we distinguish between quartzite and argillite, they most often occur together in the same rock formation on any given site. They can be seen as inter-bedded layers of coarser rock with visible grains (quartzite) and finer-textured, smoother rock where you cannot see the grains (argillite). Soils formed from these two rock types are usually grouped together since they have similar properties and management options.

Limestone is a sedimentary rock similar to argillite but containing significant amounts of calcium carbonate (lime). Local limestone is usually grayish or brownish in color and usually has white lime coatings on some rock fragments.

Limestone is deposited in shoreline environments where small marine creatures concentrate calcium carbonate from the water into shells and exoskeletons. These accumulate with other sediments and are hardened by heat and pressure into limestone rock. Solution and precipitation of the calcium carbonate also helps hold this rock together. Local Precambrian limestones have relatively low calcium carbonate contents (40-70%) and are often described as 'dirty limestones' or calcareous argillites'. Other limestone in Montana are relatively round and contain much higher concentrations of calcium carbonate (up to 99.9% in the Madison Limestone).

Granitic rocks, mainly dark granitics (granodiorite), occur as intrusions such as the Purcell sill. These rocks do not have the striped, layered appearance of sedimentary rocks. Most have a relatively uniform

coarse-grained appearance. Dark black, dark gray, or black and white(salt and pepper) are the most common colors and combinations. These rocks were intrude in molten form along cracks and fissures with the Precambrian sedimentary rocks.

Cretaceous rocks of Glacier Park occur along the eastern border and are mainly soft shales or sandstones. These are usually dark gray and were deposited in a cretaceous sea that occurred to the east of Glacier Park.

IDENTIFYING GEOLOGIC DEPOSITS

To identify major parent material types you simply need to remember what kind of deposit is left by several major geologic processes. Remember that you may find soils formed by several processes and these will have the characteristics of several different parent material types.

Wind usually leaves deposits that have very uniform silt or sand textures and no rocks. Silt may be carried on the wind for long distances. Wind may also deposit and redistribute sand-textured deposits over shorter distances. Wind deposits (aeolian or loess deposits) are recognized by their uniform silty or sandy, rock free-texture and sometimes by their dune appearance.

Running water sorts materials into relatively uniform particle sizes and smoothes the edges of rocks into spheres. The size of material which can be carried depends on the volume and velocity of the stream. Most streams and small rivers carry sand and gravel size material with occasional cobbles and stones. Large rivers and glacial outwash streams carry cobbles, gravels, and some stones. These deposits are recognized by the uniform size of very well-rounded rocks in each layer. Multiple layers of different size materials may be deposited on top of one another with sands and gravels alternating.

Lakes, ponds and other still water bodies also sort materials into different size classes. When streams carrying sediment reach a lake, the reduced velocity allows sediments to be deposited. The rocks are dumped immediately and together with most of the sand from a "delta" out into the lake. The silt and clay settle out more slowly in the deeper water.

Lake and pond deposits may have abundant organic matter accumulations. Lake deposits are usually recognized by their rock-free silty texture.

Small pond deposits are common in the fire area in glacial potholes and still have surface water and aquatic or wetland vegetation while others have filled in and are now forests or grasslands.

Ice-Rafting occurs when glacier flow into lakes and blocks of ice break off. The icebergs float out into the lake and drop the boulders, soils and other glacial till materials incorporated within the ice. Some large boulders (glacial erratics) and soil material in Glacier Park may have been transported by ice rafting.

Glaciers do not sort materials by size class but instead mix sand, silt, clay, gravels, cobbles, stones and occasional boulders into a heterogeneous mixture without apparent order. The rocks are usually semi-rounded by this process and may be very contrasting. Glacial till can be recognized by the presence of various sizes, shapes and compositions of rock in variable amounts imbedded in a matrix of finer soil materials. In some cases, you cannot tell if a deposit was left by a glacier, glacial outwash stream or ice-rafting. In other cases the soil is a mixture of all these deposits. These mixed deposits are often called Glacial Drift (includes till, outwash and ice-rafterd materials).

By keeping these processes in mind you can usually figure out the origin of various local soils.

IDENTIFYING LANDFORMS

WIND

Local surface soil deposits of wind are often silt-loam textures and may contain large amounts of volcanic ash. They are sometimes rock-free (since rocks don't blow on the wind) but often contain rocks from animal burrowing, frost action, windthrow or other processes.

RUNNING WATER STREAMS

Terraces are nearly level or flat-topped landforms that parallel current or past streams. Slope angle is usually a few percent. Usually are 1015 feet above the current water level. Terraces usually have steep edges with 25-50% slopes. Materials are usually sand and gravel.

Outwash Terraces are similar to regular stream terraces but usually were formed by larger streams that carried larger materials. Glacial outwash terraces usually have abundant cobble-sized rock (3-6") and occasional stones and boulders.

Kame Terraces are a special kind of glacial outwash terrace formed when a stream flows between the glacial ice and the adjacent mountain side. These leave sand and gravel stream terraces perched up on hillsides where no stream exists today. Kame terraces are difficult to see in forest landscapes but can be easily viewed in grasslands.

Eskers are long, narrow stream deposits that look like a small ridge snaking across the landscape. These landforms are created when streams flowing within glacier erode to the ice base and dump their sediment under the ice.

Alluvial fans are materials deposited by streams at the confluence of streams or streams and lakes. They usually have coarser textures than the surrounding deposits and better drainage.

GLACIAL ICE FEATURES

Ground Moraines are lumpy, rolling glacial till landscapes deposited beneath the flowing glacier. Material is referred to as "basal till" and is an unsorted deposit of all particle sizes from clay to boulders.

Lateral Moraines are landscape features of glacial till deposited along the sides of a flowing glacier. This material is both "bulldozed" up by the glacier and melted out of the adjacent ice. Usually forms a small ridge between the ice and the mountain slope. Most lateral moraines in Glacier Park have been erased or modified by slumping, soil creep or other erosional and depositional events since glaciation.

Terminal Moraines appear as a small lumpy ridge of glacial till deposited at the terminus of a flowing glacier. This material is both "bulldozed" up by the glacier and melted out of the adjacent ice. Terminal moraines usually form a horseshoe-shaped ridge around the front of the glacier.

Recessional Moraines from at spots where retreating glaciers remain stationary for short periods or make small re-advances. These moraines may appear as "terminal moraines" of minor ice advances. Recessional and terminal moraines impound many lakes in the park.

BEDROCK FEATURES

Residual Hillslopes are slopes where bedrock is weathering in place into soil materials. Usually very flat slopes (<15%) or near rock outcrops.

Colluvial Hillslopes are slopes where bedrock is weathering into soil materials and then moving downhill due to gravity.

IDENTIFYING SOIL FEATURES

DESCRIBING THE SOIL

While soil scientist may sometimes describe 20 individual layers in a 5 foot soil profile, foresters do not need such detail. Describe the 2 or 3 most obvious soil layers and any individual observations that seem appropriate. Soil texture, rock content, rock type and habitat type are especially important. The example profile description form on the following page can be copied for simple descriptions.

SOIL TEXTURE

Soil textures is often referred to as the single most important soil property. Classifications of soil texture date back 4000 years to the ancient Chinese. Soil texture is the particle distribution, the percentage of rocks, sand, silt and clay.

The USDA Soil Classification System identifies “rocks” as mineral particles over two millimeters (mm) in diameter. Rocks are subdivided into gravels (2 mm to 3 in dia), cobbles (3 l to 6 in), in stones (6 to 24 in) and boulders (>24 in). Rocky soils often have low nutrient and water retention capacities and rapid permeability. Rocky soils may provide a stable base for roads, landings and other construction activities.

ROCK CONTENT is difficult to estimate precisely and estimates may be off by 10-20% even after practice. Use the guide on the following page to make as precise an estimate as possible. Rock content as viewed in a roadcut may represent the soil due to erosion - clean off the surface to improve your estimate. Rock content can be seen to vary as you walk along a roadcut. Note size and angularity of rock fragments.

SAND is between 2mm and .04mm in diameter and will settle out of still water in 40 seconds or less. Individual sand particles do not bind together into “clods” as do clay particles. They may often occur as individual grains. Sand grains are easily dislodged and transported by water or wind. Sandy soils have low nutrient and water retention capacities. Wind transports sand particles by bouncing them along the ground eventually forming dunes. Sand is often deposited along with gravels and cobbles by running water. Sandy soils usually do not support steep streambanks and can form unstable roadbeds where they are on steep slopes. Extremely sandy soils require special construction techniques to overcome the looseness of the material and its tendency to “melt” away.

SILT particles are between .04 and .002mm in diameter and will settle out of still water in between 40 seconds and 2 hours. Silty soils have the highest nutrient and water holding capacities, as much as 10 times that of sandy soils. Silty soils have relatively slow permeability and high erosion hazards.

Silt particles are the most easily erode size for both water and wind. Slightly smaller than sand, silt can easily be carried in suspension by moving water. Silt is deposited where moving water slows significantly or empties into a calm water body (lake or pond). Most lake deposits are dominated by silt. Silt can also be deposited along the slower reaches of streams or across the entire floodplain during floods.

Silt is the most common size particle transported by wind. The ash which has reached Montana from west coast volcanoes is predominantly silt-sized. Heavier, sand-sized ash particles are deposited much closer to the source.

CLAY particles are less than .002 mm in diameter and take more than 2 hours to settle out of still water. Clay has a very high nutrient retention capacity. Clay also has a very high water holding capacity but it “holds” some of the water so tightly it cannot be extracted by plants. Clay particles are the “glue” which hold sand and silt together in most soils. These soils usually provide insufficient support for structures, road and other projects without special construction. These soils can be damaged by compaction and erosion but otherwise are quite productive.

Clay is not easily eroded since it binds tightly together into distinct “clods” which are difficult to dislodge, transport and dissolve. Clay is deposited in large bodies of still water such as large lakes and the cretaceous sea. Clay forms from other minerals over long periods of time. Local clay soils have high shrink-swell potential meaning they expand and contract upon wetting and drying. This forms the characteristic cracks you can view in roadcuts, root balls and other exposures.

DETERMINING SOIL TEXTURE

Soil texture is the relative amount of sand, silt and clay. Use the flow chart and textural triangle on the following pages to help you determine texture. Be sure to have enough soil, a hand full, not a teaspoon. Moisten the sample slowly, working the water into it and try to form a “ribbon” between your thumb and forefinger. The more clay, the better the ribbon will form. In short, sand feels gritty and you can hear the grains grating against each other. Silt feels smooth but doesn’t form a good ribbon and is not very sticky. Clay feels smooth, sticky and forms a good ribbon.

APPENDIX B. SIMILAR SOILS FROM SURROUNDING SOIL INVENTORIES

This project did not concentrate sufficient efforts along park borders to provide a formal correlation with adjacent soil inventories. The following table indicates similar soils and mapping units from surrounding inventories. These include the Lewis and Clark National Forest Landtype Report (1981), The Flathead National Forest Landtype Report (1983), The Glacier County Soil Survey (1972) and the Soil Survey of Waterton National Park (1975). A few of these soils and map units are very similar to those identified in Glacier park. However, most are only somewhat similar in properties and map unit composition. These other surveys were conducted between 14 and 25 years ago. The Glacier County survey shares the most common boundary with the park of all the surrounding soil inventories. However, there is a significant parent material, topographic, climatic and vegetation boundary near the eastern park border which limits the usefulness of data from that survey. In addition to reviewing adjacent inventories, we queried local soil scientists and the U. S. national soils database.

APPENDIX B. SIMILAR SOILS AND MAPPING UNITS FROM SURROUNDING SOIL INVENTORIES

MAP UNIT	MAP UNIT NAME	FLATHEAD COUNTRY AND LEWIS & CLARK FOREST LANDTYPES (USFS)	GLACIER OR MISSOULA COUNTY SOIL SURVEY (NRCS)	WATERTON SOIL SURVEY (PARKS CANADA) MAPPING UNIT NUMBER
	ALLUVIAL SOILS			
A1	FLOODED SOILS - FLOODPLAINS AND LOW TERRACES	10 - FLOODPLAINS	MIXED ALLUVIAL LANDS	11,20
A2	ROCKY/SANDY ALLUVIAL GRASSLAND SOILS - FANS AND HIGH TERRACES		BEARMOUTH SERIES	1,17,19,22
A3	ROCKY/SANDY ALLUVIAL FOREST SOILS - FANS AND HIGH TERRACES	17 - ALLUVIAL FANS	UPSATA SERIES	18,27,28
	WET FEATURES			
W1	WET SOILS - DEPRESSIONS, STREAMSIDES, TOESLOPES	12 - DEPRESSIONS		14.29,31,32,44,53,105
W	WATER			NO WATER MAPPED
	GLACIAL, LANDSLIDE AND MIXED SOILS			
G1	POORLY DEVELOPED SOILS - VERY RECENT GLACIAL MORAINES			54
G2	SILTY CLAY LOAM GLACIAL FOREST SOILS - WIDE VALLEY BOTTOMS	23 - GROUND MORRAINE	AUGGIE OR HOLLAND LAKE SERIES	
G2/G3	A COMPLEX OF G2 AND G3			
G3	LOAMY GLACIAL FOREST SOILS - VALLEYS			52,64
G3/C3	A COMPLEX OF G3 AND C3			
G4	CLAY-RICH CONIFER FOREST SOILS - MORAINES AND LANDSLIDES	25A - DRIFT PLASTERED SLOPES	LOBERG SERIES	46,57,103,106
G4/G5	A COMPLEX OF G4 AND G5	31 - BLOCK GLIDES ??		
G5	CLAY-RICH ASPEN FOREST SOILS - MORAINES AND LANDSLIDES		LIEBIG AND MORD SERIES	36,42,58,100,106
G6	CLAY-RICH GRASSLAND SOILS - MORAINES AND LANDSLIDES			100
G7	DEEP, ROCKY COLLUVIAL AND LANDSLIDE SOILS - THRUST FAULT ZONE			
G8	LOAMY LIMESTONE GLACIAL FOREST SOILS - VALLEYS	26A - GROUND MORRAINE - LIMESTONE	FELAN SERIES	
	BEDROCK SOILS - QUARTZITE AND ARGILLITE			
C1	ROCK OUTCROP - QUARTZITE AND ARGILLITE			ROCK
C1/C4	A COMPLEX OF C1 AND C4			90R
C2	TALUS - QA			TALUS, 141.142
C3	DEEP COLLUVIAL FOREST SOILS - LOWER MOUNTAIN SLOPES			49.64.150
C3/C5	A COMPLEX OF C3 AND C5			

Appendix B Table, Continued

MAP UNIT	MAP UNIT NAME	FLATHEAD COUNTRY AND LEWIS & CLARK FOREST LANDTYPES (USFS)	GLACIER OR MISSOULA COUNTY SOIL SURVEY (NRCS)	WATERTON SOIL SURVEY (PARKS CANADA) MAPPING UNIT NUMBER
C4	SHALLOW SOILS - SCOUR AREAS AND NEAR ROCK OUTCROPS		COEROCK SERIES	66
C4/C6	A COMPLEX OF C4 AND C6			
C5	MODERATELY DEEP SOILS - SCoured MOUNTAIN SLOPES			66,150
C5/C4	A COMPLEX OF C5 AND C4	21 - ALPINE GLACIATED BASINS OR 73 - GLACIAL TROUGHWALLS OR 57- GLACIALLY SCoured HILLSIEDS AND RIDGETOPS		
C6	ALPINE MEADOW SOILS - CIRQUE BASINS AND MOUNTAIN SLOPES			
C7	ICE-PATTERNED SOILS - PATTERNED GROUND ON MOUNTAINS			
C7/C1	A COMPLEX OF C7 AND C1			
C8	DEEP COLLUVIUAL GRASSLAND SOILS - LOWER MOUNTAIN SLOPES			
	BEDROCK SOILS - LIMESTONE			
LC1	ROCK OUTCROP - LIMESTONE			ROCK
LC1/LC4	A COMPLEX OF LC1 AND LC4			90R, 91R
LC2	TALUS - LIMESTONE			
LC3	DEEP COLLUVIAL FOREST SOILS ON LIMESTONE - LOWER MOUNTAIN SLOPES		WHITORE SERIES	
LC3/LC5	A COMPLEX OF LC3 AND LC5			
LC4	SHALLOW LIMESTONE SOILS - SCOUR AREAS AND NEAR ROCK OUTCROPS			
LC4/LC6	A COMPLEX OF LC4 AND LC6			
LC5	MODERATELY DEEP LIMESTONE SOILS - SCoured MOUNTAIN SLOPES			
LC5/LC4	A COMPLEX OF LC5 AND LC4			
LC6	ALPINE MEADOW LIMESTONE SOILS - CIRQUE BASINS AND MOUNTAINS			

APPENDIX C. HISTORY OF SOIL INVENTORY IN GLACIER

PREVIOUS SOIL INVENTORY

A Soil Survey of the Apgar Area, Glacier National Park by Thomas Nimlos

HISTORY OF SOIL INVENTORY IN GLACIER BY BARRY DUTTON OF LAND & WATER

Soils of Weed Management Areas - 1989

Soils of the Red Bench Fire Area - 1990

Soil, Vegetation and Wildlife Inventory of Granite Park and Sperry Chalets - 1994

Soil and Percolation Tests for Onsite Sewage Disposal at Granite Park Chalet -1994

Soil Inventory of Glacier National Park

- Soils of the McDonald Drainage - 1994

- Soils of the St. Mary, Many Glacier, Boulder and Kennedy Drainages - 1995

- Soils of the Waterton, Belly River, and Missouri River Drainages (Combined with 1995 mapping to produce a single document for the east side) -1996

- Soils of the North Fork, Flathead Drainage - 1997

- Soils of the Middle Fork, Flathead Drainage (Combined with 1997 mapping to produce a single document for the Middle and North Forks, Flathead Drainage) -1999

- Soils of Glacier National Park, Montana - 2001
(Compilation of the entire park)

APPENDIX D. EXAMPLE SOIL MAP SHEETS

A complete set of soil map sheets printed at 11 x 17 inches is available from the park GIS specialist. All soil maps are also available in digital form and can be compiled for any project area.

March 11, 2004

Richard Menicke
Science Center
Glacier National Park
West Glacier, MT 59936

RE: FINAL REPORT ON THE SOILS OF GLACIER PARK

Dear Richard:

Enclosed are five copies of the final soil report for the entire park. Michelle Arthur has already provided you with the soil layers in digital form. Note that I have included examples of the soil quad sheets at 11x17-inch size as Appendix D. I did not include copies of every quad with every report since there are 47 of them and they cost \$1.50 each. I have previously provided you with one complete set in a 3-ring binder so you can make quick copies as needed. I assume that for most projects, folks will contact you and you will print them the area they request.

I will also provide one complete copy to Pete Biggam and one to Chuck Gordon. I am sending you the report and metadata in electronic form as email attachments. Please contact Michelle or myself if you have any questions.

I also want to express my sincere thanks for all your efforts to make this project happen. If there were any justice in the world you would get a large reward for orchestrating the most cost effective soil inventory of any national park. Your professionalism, technical skills and extra efforts have made this project possible. It has been one of the great pleasures of my professional career to work with you and I hope to have the opportunity again in the future.

Sincerely,

Barry L. Dutton
Certified Professional Soil Scientist

Attachments